SHORT PAPERS FOR THE 8TH INTERNATIONAL CONGRESS ON THE JURASSIC SYSTEM

Marine and non-marine Jurassic

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China University of Geosciences (Beijing); Peking University
INTRODUCTION TO THE 8TH INTERNATIONAL CONGRESS ON THE JURASSIC SYSTEM

The 8th International Congress on the Jurassic System will be held in Shehong County of Suining City, Sichuan Province, China, from August the 9th to the 13th, 2010. This congress follows the highly successful 7th International Congress on the Jurassic System held in September of 2006 in Krakow, Poland, and will center on a series of scientific sessions and symposia held to discuss new research findings all relating to the field of Jurassic studies. This is the first time for the Jurassic Congress to be held in Asia.

This congress is sponsored by the UNESCO-IUGS International Geoscience Program (IGCP), the International Subcommission on Jurassic Stratigraphy (ISJS), the Chinese Academy of Sciences (CAS), the Ministry of Land and Resources of the PRC, the National Natural Science Foundation of China (NSFC), and the People’s Government of Sichuan Province. The congress is organized by the Nanjing Institute of Geology and Palaeontology, CAS, the Department of Land and Resources of Sichuan Province, the Suining Municipal People’s Government, and Shehong County People’s Government of Sichuan Province.

The central theme of the congress is “Marine and non-marine Jurassic System.” A series of scientific topics and programs will be arranged covering topics such as Jurassic stratigraphy, palaeontology, palaeoclimate and palaeoenvironment, major geological events, mineral resources, as well as geological heritage protection and public education. In addition, the ISJS will have its general assembly and IGCP 506 will hold its business meeting during this congress.

About 250 participants from 30 countries will join this congress. In addition, several pre-, mid-, and post-congress excursions will be organized, providing opportunities for participants to visit classical marine and non-marine Jurassic (as well as Triassic and Cretaceous) deposits in China and adjacent regions in Thailand, and to visit famous Chinese cultural heritage sites and natural geoparks.

The venue of the 8th International Congress on the Jurassic System is Shehong County, which is administratively attached to Suining City in Sichuan Province. Shehong is well-known for its 1500-year-long history, strong cultural atmosphere, outstanding people, along with its rich and colorful folk culture and art. It is a charming city full of vitality and beautiful garden landscapes, and is surrounded by the outcrops of Upper Jurassic deposits.
THE 8TH INTERNATIONAL CONGRESS ON THE JURASSIC SYSTEM

August 9-13, 2010
Shehong of Suining, Sichuan, China
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International Geoscience Program of UNESCO-IUGS (IGCP)
International Subcommission on Jurassic Stratigraphy (ISJS)
Chinese Academy of Sciences (CAS)
Ministry of Land and Resources, People’s Republic of China
People’s Government of Sichuan Province
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PREFACE

—Short papers for the 8th International Congress on the Jurassic System—Marine and non-marine Jurassic

The International Congress on the Jurassic System, held once every four years, provides Jurassic experts, students, and amateurs from around the world a chance to present their recent achievements and research results to the international geosciences community. The Jurassic spans from 200 to 145 Ma, and topics dealt with at the congress include the geology, stratigraphy, palaeontology, palaeobiology, palaeogeography, palaeoecology, palaeoclimatology, sedimentology, geochemistry, palaeomagnetism, tectonics, astronomic geology, and mineral and energy resources of this geologic period. Participants contribute to science, technology, philosophy, geosciences education, and geoheritage protection. Research results presented at the congress have a bearing on the Earth’s future, and the international collaborations fostered by the congress will contribute to deepening our understanding of global change.

The 8th International Congress on the Jurassic System will take place in China in August of 2010. China is a country whose Jurassic lithology records Tethyan, subboreal, and Pacific events. To showcase major research achievements in global marine and non-marine Jurassic geosciences, in particular those of the last four years, we have compiled this special issue of Earth Science Frontiers (China University of Geosciences (Beijing) and Peking University), under the banner of “Short papers for the 8th International Congress on the Jurassic System—Marine and non-marine Jurassic”.

A total of 183 articles submitted, dealing with the following eight fields:
1) Marine and non-marine Jurassic boundaries and stratotypes;
2) Biostratigraphy, sequence stratigraphy, isotopic stratigraphy, magnetostratigraphy, and cyclostratigraphy of the Jurassic;
3) Biodiversity and evolution of Jurassic life;
4) Depositional facies, palaeogeography, palaeoenvironment and ecosystem reconstruction;
5) Jurassic palaeoclimate and palaeo-atmospheric CO2;
6) Major biological and geological events of the Jurassic;
7) Mineral and energy resources of Jurassic deposits;
8) Jurassic geoparks and museums: Their roles in geological heritage protection and public education.

This special issue is a contribution to the 8th International Congress on the Jurassic System and UNESCO-IUGS International Geoscience Program IGCP 506. Besides the sponsors, organizers and co-organizers, it was also made possible by support from the Ministry of Science and Technology, PRC, the National Natural Science Foundation of China, and the Knowledge Innovation Program of the Chinese Academy of Sciences (2006FY120400, 40632010, 40872013, 40872016, 40972008, KZCX2-YW-154). We heartily thank Dr. Noel J. Morris from the British Museum of Natural History, executive editor Prof. Wang Xiaolong and assistant editor Chen Siwei for their kind assistance in editing and compiling this issue. We would like to thank our graduate students, doctoral degree students Wang Yaqiong, Zhang Xiaolin, Tian Ning, and Jiang Zikun, and master degree student Peng Bo, all from the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, for their organization, compiling, and editing assistance, and Prof. Paul L. Smith from the University of British Columbia, Canada for generously undertaking a critical reading of the preface. We express our sincere thanks to all of the authors who contributed to this special issue.

Jingeng Sha (Chairman of the Organizing Committee)
EARTH SCIENCE FRONTIERS

Short papers for the 8th International Congress on the Jurassic System

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Position of the Triassic-Jurassic Boundary in the Newark Supergroup, Eastern North America

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For decades, the base of the Hettangian (the Triassic-Jurassic system boundary) in the terrestrial succession of the Newark Supergroup of eastern North America has been placed incorrectly at a stratigraphic level that coincides with a modest palynological turnover immediately beneath the lowest basalt flow of the Central Atlantic Magmatic Province (CAMP), e.g. the Orange Mt. Basalt in the Newark basin or the North Mountain Basalt in the Fundy basin (see review in Whiteside, et al., 2007). According to numerous studies (reviewed in Whiteside, et al., 2007), the system boundary can be defined on the basis of the following: (1) last appearances of certain Triassic species (Ovalipollis ovalis, Vallasporites ignacii, and Patina-sporites densus); (2) a dramatic increase in the abundance of Corollina spp. (= Classopollis and Gliscopollis); (3) and a bloom of trilete spores (fern spike), considered as the expression of a palynofloral recovery after the end-Triassic mass extinction. Consequently, all the strata overlying and interlayered with the CAMP lava flows have been assigned to the Jurassic, and the ages of the oldest CAMP basalts considered basal Jurassic. Calculations based on the cyclostratigraphy of the Newark basin strata suggest that the onset of CAMP volcanism should postdate the system boundary in the Newark basin by 20-40 ky and the entire basalt pile in these basins should have then been erupted during the Early Jurassic normal polarity chron E24n (e.g. Kent and Olsen, 2008).

Apparent validation for this definition of the system boundary came from the magnetostratigraphy of the Newark basin. Hounslow, et al. (2004) attempted to make a palaeomagnetic correlation to the Newark of the Upper Triassic-Lower Jurassic marine section at St. Audrie’s Bay, England, where the system boundary is in the upper part of the Penarth Group. They suggested that either their SA5r reversal, which is the stratigraphically highest short reversed interval, or one of the stratigraphically lower reversals, SA5n.3r or SA5n.2r, correlate to the E23r reversal that corresponds to the palynofloral turnover event in the Newark section. Notably, these correlations indicate that the E23r reversal is older than the currently proposed definition of the Hettangian base in the marine (lowest occurrence of Psiloceras spelae), and correlation of the E23r reversal to the two lower reversals at St. Audrie’s Bay would make E23r older than the stratigraphically highest conodonts. Whiteside, et al. (2007) similarly correlate the E23r reversal to one of the brief reversals (chrons SA5n.3r and SA5n.2r) of the St. Audrie’s Bay section (England).

Cirilli, et al. (2009) re-examined the palynology of the Newark succession in the Fundy basin. At Partridge Island the palynological content of the terrestrial Blomidon Formation, which lies below the North Mountain Basalt, is characterized by the dominance of circumpolles group species, represented in order of decreasing abundance by Gliscopollis meyeriana, Corollina murphyae, Classopollis torosus, and Corollina simplex. The total abundance of the circumpolles group varies slightly through the section, decreasing with the decrease of total organic matter due to poor preservation, but the sporomorph group crosses the putative boundary established previously (Whiteside, et al., 2007) without a marked change in content. P. densus is present from the lowest sampled level of the section up to the presumed system boundary. The presence of a group of trilete spores, such as Converrucosisporites cameroni, Dictyophyllidites harrisii and Dictyophyllidites sp., and other trilete spores below the presumed boundary is notable. Because in other Newark Supergroup basins, these fern spores have been found just above the presumed palynological
boundary and have been identified as a fern spike that represents the floral turnover following a mass-extinction. Most notably, the Scots Bay Member of the McCoy Brook Formation, which overlies the North Mountain Basalt in the Fundy basin, yielded a palynological assemblage dominated by bisaccate pollens (e.g., *Lunatissporites acutus*, *L. rhaeticus*, *Lueckisporites* sp., *A. parvus*, *Klausipollenites* sp., *Platysaccus* sp. and other bisaccates) in association with *Calamospora mesozoica* and minor specimens of *G. meyeriana* and *C. torosus*. The circumpolles group is less abundant than in the underlying Blomidon Formation. These data indicate unequivocally that strata of Late Triassic age overlie the North Mountain Basalt in the Fundy basin.

Whiteside et al. (2010) recently published composite carbon-isotope curves for terrestrial organic matter from the Newark and Hartford basins. They attempted to correlate these curves to the isotope data published for the St. Audrie’s Bay section by Hesselbo, et al. (2002) so that the first negative excursion above the E23r reversal in the Newark basin correlates with the SA3r reversal at St. Audrie’s Bay. Recognition that the base of the Hettangian is much higher in the Newark basin than previously believed demonstrates that these sections have been miscorrelated. It is more probable that the negative excursions that occur in the Newark and Hartford basin strata above the second CAMP flow correlate to the initial excursion at St. Audrie’s Bay. The E23r reversal in the Newark basin thus correlates to the SA5n.1r reversal at St. Audrie’s Bay. Although the proposed marker taxon for the base of the Hettangian (*P. spelae*) does not occur at St. Audrie’s Bay, correlation of the position of the system boundary from the proposed GSSP at Kuhjoch based on isotope stratigraphy (coinciding with the second negative excursion) allows an approximation of this horizon. Comparison with the curves of Whiteside, et al. (2010), and considering the now-established Triassic age of the inter-CAMP flow sediments, suggest that the optimal correlation places the base of the Hettangian in close proximity to (either above or below) the uppermost CAMP flow unit.

This new correlation is consistent with the results of other studies that have questioned the position of the Triassic-Jurassic boundary in the Newark Supergroup. Kozur and Weems (2007), for example, established a succession of conchostracan zones in the Newark basin and correlated this conchostracan succession to Upper Triassic strata of the Chinle Group in the southwestern USA and the German Keuper and to Jurassic strata in China. They placed the base of the Hettangian at the base of their *Bulbilimnadia sheni* zone, coinciding approximately with the base of the Towaco Formation, which lies above the second CAMP flow unit (the Preakness Basalt) in the Newark basin. Marzoli, et al. (2004) published a comprehensive set of isotopic ages, and magnetostratigraphic and palynostratigraphic data for the CAMP basalt interval in the High Atlas of Morocco. These authors found a Triassic palynomorph assemblage including *P. densus* that persisted up to the base of the CAMP basal sheet and thus concluded that the Triassic-Jurassic boundary must lie above the base of the CAMP in Morocco. In sum, continued claims that the end-Triassic floral extinction predates the CAMP zone in the Newark succession (cf. Whiteside, et al., 2010) thus run contrary to a diverse, extensive and growing database that places the system boundary well above the base of the CAMP extrusive zone.

**Key words:** Triassic-Jurassic boundary; Newark Supergroup; Fundy basin; Palynoflora

**References:**


Praecalpionellid and Calpionellid Distribution Across the Jurassic-Cretaceous Boundary in the Southern Tethys Maghrebian Margin. Updated Data and Correlations

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Praecalpionellids and calpionellids are considered as one of the excellent tools for biostratigraphy of Upper Jurassic-Lower Cretaceous series of the Tethyan area. Their high resolution biostratigraphy with wide geographic distribution make them of great interest in solid long distance correlation.

During the last two decades, wide biostratigraphic investigations based on bed-by-bed sampling were focused on the Jurassic-Cretaceous boundary interval successions in the Maghreb (Morocco, Algeria and Tunisia). The results provide new and/or complementary data to the distribution of preacalpionellid and calpionellid in the south-Tethyan margin, which are updated and synthetized herein.

Across the Lower-Upper Tithonian transition, previous studies of Chitinoidellid faunas from the south-Tethyan regions of Maghreb only dealt with scarce and unrevised taxa from the Prerif (Morocco) or sporadic representatives from disparate sections of Algeria and Tunisia. In a recently submitted work, we identified fifteen species from seven genera (Daciella Pop, Borziella Pop, Longicollaria Pop, Dobeniella Pop, Cubanella Pop, Popiella Reháková and Chitinoidella Doben), and all of them are first documented in Tunisia. In addition to revised forms from Morocco and Algeria, Chitinoidella carthagensis sp. nov., Ch. jedidensis sp. nov., Ch. Hegarati sp. nov. and Ch. popi sp. nov. are four new species that complete the enriched dataset of Praecalpionellid morphotypes from the Maghreb. All these faunas are compared to known taxa from the Carpathian Ranges where the chitinoidellid populations were revealed to be well diversified. The stratigraphic range of the Maghrebian associations fits easily the standards currently used in other Tethyan regions and allows the individualization of two new biostratigraphic horizons within each of the Dobeni and Boneti subzones.

Higher in the analysed sections, the lowermost Upper Tithonian Preatintinnopsella group, which is so far restricted to the unique P. andrusovi species, spans a small interval, just below and soon after the first occurrence (FO) of hyaline calpionellids. The H1 and H2 horizons, which are already identified by previous authors within the Remanei subzone (Crassicollaria zone) of the Moroccan Prerif and Mesorif successions, are also distinguished in northern Tunisia. They are characterized respectively by the co-occurrence of Chitinoidellids and hyaline calpionellids (H1), and by the same classic calpionellid morphotypes described for the whole A1 Remane subzone (H2). The top of this latter horizon is marked by the FO of big-sized, somewhat isometric Calpionella alpina representatives that also serve for placing the base of the Intermedia subzone (= A2 + A3 subzones of Remane). In Tunisia and Algeria, C. elliptica homeomorph specimens were observed at the top of the Intermedia subzone. Nevertheless, we were not able to separate the A2 and A3 calpionellid subzones of Remane as well as the two horizons identified within the upper A3 subzone in Morocco.

The base of the lowermost Berriasian Alpina subzone (calpionella zone) is easily traced considering the explosion of small to medium sized C. alpina specimens together with the abundance of Crassicollaria parvula. The FO of the genus Remaniella, together with –or just above– peculiar specimens assigned to Lorenziella, marks the Remaniella (or Ferasini) subzone. The base of the calpionellid Elliptica subzone is placed considering the FO of the index species the rapid increase of which indicates the Oblonga (or Calpionellopsis) zone (= C zone of Remane).

All the calpionellid zones and subzones identified in key sections from Morocco Algeria and Tunisia are correlated to the ammonite zones. The phylogeny pattern proposed herein mainly shows tight relationships between praecalpionellids and calpionellids, on one hand. And on the other hand, among calpionellid taxa, many chitinoidellid species are perfect homeomorphs of calpionellid ones and differ only in the lorica nature, and high morphological similarity degrees characterize successive species of distinguished calpionellid lineages.

Key words: Calpionellids; Biozonation; Phylogeny; Maghreb
Sedimentary Records of Environmental Change at T/J Boundary in Sichuan Basin, South China

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The Sichuan Basin is a typical fore-deep basin that has been developed by collision and amalgamation between the Song Pan Belt and South China Blocks. It records a long-term continental sedimentation from Late Triassic to Jurassic since the closing the Paleo-Tethys Sea, and documents a significant environmental change at Triassic-Jurassic boundary. This paper describes the nature of the T/J boundary, and examines changes in depositional facies, cycles and systems of the Upper Triassic and Lower Jurassic successions along the lower reach of Jialingjiang River, north of Chongqing (Beibei), Sichuan Province in South China.

The Upper Triassic Xujiahe Formation consists largely of deep- to shallow-lacustrine deposits with coal seams and overlies the Middle Triassic platform limestone (Leikoupo Formation) bounded by limestone olistostrome disconformably. It represents some coarsening-upward cycles that begin with off-lacustrine olistostrome mudstones (rhythmites) and end with lacustrine shore bars (cross-bedded sandstones). Very thick-bedded sandstones occur in the uppermost part and show an abrupt sedimentation accompanied with progradation of lacustrine delta toward the south.

The Lower Jurassic Ziliujing Formation, on the other hand, is divided lithologically into the Zhenzhuchong, Dongyuemiao, Ma’anshan, and Da’anzhai Members in ascending order (Li et al., 1996). Sequence-stratigraphic framework of the Ziliujing Formation could be established after adding a few revisions to the previous lithostratigraphic boundaries. Four depositional sequences (DSs) in the lower Jurassic were confined, herein, as lithologic units bounded by sharp transgressive surfaces in lacustrine setting, although they lack the transgressive lag beds. Sharp-based sandstones at base demonstrate an abrupt sedimentation. They show a wide variety of internal structures including parallel, sub-parallel, wave, low- to high-angle cross-stratification, climbing-rippled, massive, and inversely grading. All of these facies associations are comparable to mouth bar complex, in which the flood events might play an important role for transport process. The Zhenzhuchong DS shows a vertical facies change from pebbly sandstone of debris-flow origin at base, which passes into cross-bedded sandstone and silt/sand couplet of marginal to off-lacustrine facies, and ends with red-color siltstones of mudflat. The Dongyuemiao DS overlies the vari-color pedogenic siltstones of the Zhenzhuchong DS and includes some coquina and dinosaur beds in food-related sheet-like sandstones. The Ma’anshan DS is composed largely of calcareous sandstone with some yellow marls and anoxic blue clay beds rarely. Sandstones contain fresh-water molluscan remains commonly. Comparable sequence boundary as shown by debris-flowed base appears between the Ma’anshan and Da’anzhai DSs and suggests an unconformity along the basin margin.

The T/J boundary seems to be less noticeable apparently, but it could be confirmed as an important sequence boundary, the reason for which the sedimentary systems and provenances were changed fairly at the boundary. The Upper Triassic sandstones are of lithic arenites containing abundant mica and lithic fragments, whereas those of the Lower Jurassic are of well-sorted, highly matured, quartz arenites. Paleocurrent data also indicate that the source regions had changed drastically from the Longmenshan highland on the north in Triassic to certain desert region on the south in Jurassic.

The lower Jurassic depositional sequences represent cycles at less than 100 meters interval, and record a change in paleo-depth from shallow lacustrine above the storm wave-base to the dried-out condition. They seem to be controlled by both tectonic subsidence and paleoclimate. Periodic subsidence might correspond to the strengthening of coupling process between two continental blocks. The flood-related sedimentation into newly created accommodation space should take place, probably, under the monsoon circulation influenced by the new mountain belts in Early Jurassic time, such as Tianshan and Longmenshan highlands.

Key words: T/J Boundary; Non-marine sequence stratigraphy; South China

References:
Organic Geochemistry Across the Triassic-Jurassic Boundary in Southwest England

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The close of the Triassic period (~200 Ma ago) records a series of severe climatic crises. Across the Late Triassic and Early Jurassic, there is evidence for one of the largest mass extinctions of the Phanerozoic (Hallam and Wignall, 1997), a major perturbation to the global carbon cycle (e.g. Hesselbo, et al., 2002), the emplacement of the central Atlantic magmatic province (CAMP) (Marzoli, et al., 1999), and global warming associated with a four-fold increase in atmospheric CO2 (McElwain, et al., 1999).

St. Audrie’s Bay in southwest England preserves one of the most expanded and well-studied Triassic-Jurassic sections. Previous carbon-isotope measurements made on bulk organic matter across the uppermost Triassic and lowermost Jurassic at St. Audrie’s Bay have revealed evidence for two major excursions in bulk δ13Corg: a stratigraphically abrupt ‘initial’ ~5 per mil negative excursion, followed by a more protracted ‘main’ negative excursion of ~4 per mil (Hesselbo, et al., 2002). It is believed that these carbon-isotope changes, which have also been recognised in other sections distributed globally, reflect major perturbations to the global carbon cycle, perhaps associated with the release of 12C-enriched CO2 during rapid emplacement of CAMP basalts (e.g. Hesselbo, et al., 2002). In addition to these changes in carbon-isotope composition, changes in osmium and strontium-isotopes have been recognised that have been attributed to changes in global weathering influenced by the weathering of juvenile basalts associated with CAMP emplacement (Cohen and Coe, 2007). There is also evidence for a seismite deposit that has been linked with an extraterrestrial impact (Simms, 2003), and a marine biotic crisis that probably occurs just below the initial carbon-isotope excursion (Mander, et al., 2008).

In this study, we have applied organic geochemical techniques (i.e. GC-MS) to samples spanning a Norian to Hettangian interval at St. Audrie’s Bay in order to characterise the organic matter preserved across the Triassic-Jurassic boundary. We have allied these data with compound specific organic carbon-isotope measurements to discern changes in the isotopic composition of organic constituents. These data thus allow us to determine how changes in the type/input of organic matter preserved across the Triassic-Jurassic boundary at St. Audrie’s Bay relate to the known environmental changes that occurred during this important interval of time.

Preliminary results indicate that changes in the nature of organic matter are readily discernable through the studied interval, and that these changes in organic matter type/input are at least in part responsible for changes in the bulk organic carbon-isotope composition of the rocks. Based on these results, we suggest that parts of the Triassic-Jurassic carbon-isotope record of bulk organic matter can be best explained in terms of changing local environmental conditions (in particular sea-level) and care must therefore be taken when attempting to interpret such changes in the context of perturbations to the global carbon cycle.

Key words: Triassic-Jurassic; Organic geochemistry; Carbon-isotopes; Palaeoclimate

References:
Multidisciplinary Study on the Triassic-Jurassic Boundary Sequences from SW Japan

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The marine Triassic-Jurassic boundary sequences from SW Japan consist of rhythmically bedded cherts (1-10cm in thickness) and intercalated thin shales (<1-20mm in thickness), which are considered as typical pelagic sediments in deep-sea of Panthalassa (e.g., Matsuda and Isozaki, 1991). The sequences usually possess a good continuity spanning over 50m.y. because of their extremely slow sedimentation rates. Therefore, these bedded chert sequences are one of the suitable strata to examine continuous biostratigraphic record of microfossils and geochemical global trend escaping from endemic noise (e.g., Hori, et al., 2007). We present here a summarizing biostratigraphic and geochemical data performed on the chert sequences (Kurusu and Katsuyama sections) spanning the Upper Triassic and Lower Jurassic, Inuyama area, SW Japan.

Biostratigraphy: Upper Triassic conodont species, Misikella hernsteini, M. aff. hernsteini and M. posthernsteini, successively occurred in the Kurusu section, which associated with Upper Triassic radiolarian fauna such as Canoptum triassicum and Globolaxtorum tozeri. There is a Triassic-Jurassic boundary (TJB) zone above the final occurrence of conodont spanning 15-20cm interval in both pelagic sections, where rich spherical radiolarian fauna is recognized and characterized by a mixing occurrence of Triassic and Jurassic faunae. The faunal turnover of radiolarians clearly occurred in the TJB zone, and another bloom of spherical radiolarians is detected in Sinemurian.

REE and Trace elements: We have examined vertical change of REE pattern and compositions of major & trace elements in bedded cherts along the stratigraphic column. The REE pattern of bedded cherts is similar to that of average values of upper continental crust and/or loess. Although high REE contents of intercalated shales and low ones of chert parts of bedded chert sequence are observed, both show the same pattern in one chert-shale couplet. In the TJB zone, the REE pattern does not clearly change, and also there is no remarkable concentration of V (V/Al, V/Al2O3). On the other hand, distinctive concentration signals of V are detected in Sinemurian and Toarcian chert. These results may indicate that no anoxia around the TJB, but a weak anoxia in Sinemurian and a strong one in Toarcian recorded in the deep-sea sedimentary rocks in Panthalassa.

C-isotope: We have analyzed stable isotopic ratios of bulk organic carbon in bedded cherts. We observed a gradual decreasing of C-isotopic values (-25‰ to -29‰) in the whole Rhaetian interval, and a positive shift at the TJB zone from -29‰ to -24‰. There is no distinctive negative spike of C-isotopic ratios in the uppermost Triassic part, however a small fluctuation (c. 2‰) is observed occasionally in the Upper Rhaetian. Further high-resolution studies are required to clarify the precise excursion curve in TJB zone. While in the Lower Jurassic, remarkable negative and positive fluctuations are recognized in Sinemurian (Hori, et al. 2008) and Toarcian (Gröcke, et al. 2003) bedded cherts.

Os-isotope: The 187Os/188Os values of bedded cherts from the Kurusu Section (Kuroda, et al, submitted) show a remarkable negative peak about 70cm (c. 1m.y. estimated) below the TJB zone, and rapidly increases toward the TJB zone. The Os-isotopic ratios are stable in Hettangian, and then a positive peak probably occurred around the Hettangian-Sinemurian boundary. The minimum zone of the Os-isotopic ratios in the Upper Triassic reveals that deep-sea sediments of western Panthalassa recorded an effect of CAMP basalt.

There is no clear correlation between the minimum and maximum horizons of Os-isotopic ratio and faunal change of marine microfossils, however it seems that radiolarian faunal change occurred at the boundary between changing and stable phases of Os-isotopic values. On the contrary, the fluctuation of C-isotopic ratio seems to be correlated to radiolarian faunal change. In particular spherical spumellarian bloom synchronously occurred at the recovery interval from the large positive peak in C-isotopic excursion, which suggests changes of production rate and ecosystem in ocean at the TJB and Sinemurian.

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Key words: Triassic-Jurassic boundary; Radiolaria; Conodont; Isotopic stratigraphy
Fig. 1 An integrated biostratigraphy of conodont and radiolarian zones and simplified excursion profile of C-isotopic ratios in bedded chert sequences (Kurusu and Katsuyama sections) from Inuyama area, SW Japan.

References:
The Tilmanni Chronozone in NW Europe: Re-correlating the Base of the Jurassic System

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The recent discovery of the earliest known Jurassic-style ammonites faunas in Austria (Hillebrandt, et al., 2007) and the subsequently international agreement to define the Global Stratotype Section and Point (GSSP) for the base of the system at Kuhjoch in the Karwendel Mountains, at a level corresponding to the Pre-planorbis beds, has had significant implications for NW European Jurassic stratigraphy. Previously the base of the system had been drawn at the base of the later Planorbis Chronozone and eventually at the base of the Psiloceras erugatum Biohorizon – the first ammonite fauna in the UK sequence (Bloos and Page 2000). The earliest Jurassic faunas in Austria and their correlatives in North and South America have been assigned to a Tilmanni Chronozone (Index: Psiloceras tilmanni Lange), but have not been definitively recorded in North West Europe - the interval corresponding to the Psiloceras erugatum Biohorizon – the upper part of the ‘second CIE’, thus hinting at a potential means of correlating the base of the Tilmanni Chronozone faunas, even when specimens are crushed. Published carbon isotope data indicates that this level in the UK generally corresponds to the lowest part of the ‘second CIE’, thus hinting at a potential means of correlating the base of the Planorbis Chronozone where Neophyllites is currently unrecorded (or confirmed) (e.g. in north and south America).

Key words: Basal Jurassic; NW Europe; Zonation; GSSP; Ammonites; Carbon isotopes

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Terrestrial Carbon-isotope Stratigraphy of the Triassic-Jurassic Boundary and Early/Middle Jurassic from Tarim Basin in Xinjiang, NW China: Initial Results

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The Triassic-Jurassic (Tr-J) boundary extinction is one of the five major mass extinctions in Phanerozoic history and occurred synchronously (~200 Ma) with Central Atlantic magmatic eruption. Associated carbon-isotope anomalies have been reported from marine and terrestrial materials at various sites across the world, such as British Columbia (Ward, et al., 2001); Nevada (Guex, et al., 2003); England and Greenland (Hesselbo, et al., 2002); Austria (McRoberts, et al., 1997); and Hungary (Palfy, et al., 2001) at the Tr-J boundary.

However, there are few terrestrial carbon-isotope data from China, even though Mesozoic fluvial and lacustrine sediments occur widely in the provinces of the northwest and north. In this study, new organic carbon-isotope data are presented from Haojiagou in the Junggar Basin, Xinjiang, NW China. The data demonstrate that a long-term negative carbon-isotope excursion (Fig.1) occurs around the Tr-J boundary recognized on the basis of palynostratigraphy. This is broadly the same pattern reported from other locations, although the new data are not of sufficient resolution to confirm the presence of detailed features of these previously generated isotope profiles.

The isotopic composition of a thick lacustrine black shale in the Yangxia Formation from Tarim Basin, Xinjiang NW China has also been examined. These sediments are dated palynologically as late Early Jurassic or early Middle Jurassic. Our hypothesis was that the black shales are a terrestrial expression of the Toarcian Oceanic Anoxic Event (T-OAE). The T-OAE (about 183 Ma) in the Early Jurassic is associated with very large negative and positive carbon-isotope excursions (Hesselbo, et al., 2000; Hesselbo, et al., 2007; Jenkyns, 2003; Jenkyns, et al., 2001; Jenkyns, et al., 2002; Kemp, et al., 2005; McElwain, et al., 2005; van de Schootbrugge, et al., 2007). However, no anomaly is present in the new data, and it is concluded that the lacustrine shales are unlikely to have been associated with the T-OAE and are probably not of Early Toarcian age.

The new carbon isotope data obtained from terrestrial stratigraphy around the Tr-J boundary in Tarim Basin, Xinjiang, NW China are consistent in the global context, but the expression of the T-OAE has not yet been identified. We plan further study of the Early Jurassic successions of Xinjiang and to compare newly generated terrestrial carbon-isotope profiles with profiles generated from well-dated marine sections.

Key words: Carbon-isotope anomalies; Terrestrial stratigraphy; Triassic-Jurassic boundary; Toarcian

References:
Guex J., Bartolini A., Atudorei V., et al. Two negative


The Brodno Section–Stratotype of the Jurassic/Cretaceous Boundary in the Western Carpathians

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An abandoned quarry on the eastern side of narrow straits of the Kysuca River Valley (“Kysuca Gate”) north of the Žilina town yields a record of hemipelagic marine sedimentation in a marginal zone (the Pieniny Klippen Belt) of the Outer Western Carpathians. On the basis of an integrated biostratigraphic study using three microplankton groups (calpionellids, calcareous dinoflagellates and nannofossils), as well as stable isotope data (δ¹⁸O, δ¹³C) the Brodno section is proposed here as the candidate for a West Carpathian regional J/K boundary stratotype.

The high-resolution quantitative analysis of microfossils mentioned above indicates major variations in their abundance and composition. Correlation of the calcareous microplankton distribution and stable isotope analyses was used in the characterization of the J/K boundary interval as well as in the reconstruction of paleoceanography of this time. The biostratigraphical study based on the distribution of calpionellids allowed us to distinguish the Dobeni Subzone of the Chitinoidella Zone in the Brodno sequence for the first time. The J/K boundary interval can be characterized by several calpionellid events – the onset, diversification, and extinction of chitinoidellids (middle Tithonian); the onset, burst of diversification, and extinction of crassicollarians (late Tithonian); and the onset, diversification, and extinction of chitinoidellids (middle Tithonian); the onset, diversification, and extinction of chitinoidellids (middle Tithonian). Calcareous nannofossils show poorly diversified associations at the J/K boundary. The abundance of Watznaueria spp., Cyclagelosphaera spp., Conusphaera spp., and Polycostella spp. in the studied section is relatively high. Other nannofossils are rather rare. Conusphaera predominates in the Tithonian nannofossil assemblage (showing the middle Tithonian peak). Polycostella increased in abundance during the Boneti Subzone of the Chitinoidella Zone. On the basis of the appearance of the Polycostella beckmannii nannoliths, the early/middle Tithonian boundary was located in the Polycostella beckmannii Subzone. The middle/late Tithonian boundary was determined by the FO of Helenea chiastia coccolith accompanied by the first small nannoconids. Small nannoconids appeared during late Tithonian and increased in abundance during Berriasian. Polycostella group diminished in abundance towards the onset of the Crassicollaria Zone. The late Tithonian interval was dated more precisely by the appearance of Hexalithus noeliae and Litraphidites carniolensis within the frame of Microstaurus chiastius Zone. From the point of view of nannofossil stratigraphy, the Tithonian/Berriasian boundary interval should be limited considering the FO of Nannoconus wintereri together with small nannoconids at the base, and the FO of Nannoconus steinmanni minor to the top. Evolution of nannofossil, calpionellid and dinoflagellate genera coincided with assumed paleoceanographical changes across the J/K boundary interval.

Stable isotope (δ¹⁸O, δ¹³C) analyses indicated a relatively cold period occasionally disturbed by warming during the latest Tithonian accompanied by low contents of organic carbon. Oxygen isotope values indicate temperature and salinity changes connected with an invasion of warm water (or stagnancy of cold water input) into the basin resulting in nannoconid bloom episodes near the J/K boundary.

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Key words: Western Carpathians; Biostratigraphy; Chemostratigraphy; Jurassic/Cretaceous boundary
The Jurassic-Cretaceous Boundary Problem and the Myth on J/K Boundary Extinction

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Jurassic-Cretaceous boundary is the last system boundary within the Phanerozoic which is not fixed by GSSP. Moreover, key events as well as possible GSSP candidates still remain under discussion (Wimbledon, 2008; Zakharov, et al., 2009). Among the most important problems in the delimitation of this important boundary are the Tethyan-Boreal correlation controversies, absence of remarkable changes in fossil assemblages and poor corresponding of changes in assemblages belonging to the different fossil groups.

The latter reasons are strictly contradict with suggestion on J/K boundary extinction, postulating by many researchers since pioneering works by Raup & Sepkoski (1984 and later articles). Our analysis of changes in ammonite, bivalve and foraminiferal faunas (which thought to be most well-studied and widely ranged among marine faunas) through this boundary in the both Boreal and Tethyan areas has indicates absence of changes in extinction rate during the Tithonian and Berriasian (or Volgian and Ryazanian). From the other hand, Jurassic-Cretaceous transition is characterized by remarkable increase of faunal provinciality and oscillation in positions of province boundaries as well as high speciation rate, especially in non-leiostracan ammonoids. There are no remarkable changes at the J/K boundary in Tethyan section, while its analogues in the Panboreal Superrealm traced by means of paleomagnetics cannot be traced biostratigraphically, because it don’t marked by any biostratigraphical event. As could be shown on example of Boreal ammonite ranges through J/K boundary (fig. 1), small decrease of the diversity fixed through the Late Volgian, when Panboreal Superrealm lack connection with Tethys-Pantalassa Superrealm, while within Panboreal Superrealm provinciality decreased. Changes in the bivalve assemblages through the J/K boundary were much smaller. As has been shown by Zakharov and Yanine (1975), in the both Boreal and Tethyan bivalve faunas J/K transition marked by minor changes. Among the 61 Tithonian bivalve genera 59 are also known from the Berriasian.

Major sources for initial errors in determination of character of extinction rate through the J/K boundary were, in our opinion, the following:

Faunas of the interval under discussion (especially Boreal ones) were poorly known until recent time, especially in those time than Treatise, using as major source of data, were published.

Summaries of datasets from the whole stages/substages and all regions shaded increase of speciation rate and/or provinciality.

Wide development of regressive/terrestrial/freshwater facies around the J/K boundary in Europe, the
most intensively studied region provides the bulk of data used.

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Key words: J/K boundary; Mass extinction

References:
Identification of Jurassic Boundaries Based on Analysis of Wavelet Transformation Coefficients from Borehole Temperature Logs

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Introduction

Borehole temperature measurements are widely used in geophysical logging since the late 1950s. The well temperature distribution (thermogram) depends on the deep heat flow, thermal conductivity of rocks, the value and directions of the mass transfer in them, and other factors (Čermak and Rybach, 1979), and provides critical information on the thermal regime of the Earth including the structure and properties of the geologic section.

Up to the present day, thermogram features are interpreted using the simplest analytical techniques. The principal Earth’s thermal regime characteristics—temperature gradient and heat flow—may be easily obtained from the temperature curve slopes. In many cases this approach is adequate but visually imperceptible features will remain unnoticed, for instance, the periodic temperature variations with amplitudes of several tenths of a degree superimposed on the thermogram. These variations were not previously known, and will hereafter be referred to as spatial temperature waves.

It should be emphasized that temperature waves are spatial temperature variations in the rock mass. These waves have not yet been found to explicitly depend on time. Some minor time-dependent variations in their characteristics have been recorded, but these are difficult to explain clearly.

The experiment and data processing methods

In order to identify temperature waves the data bulk containing more than 300 borehole temperature distributions recorded by the authors on the East European Platform and in other regions of Russia and CIS states during several tens of years has been analysed.

Geothermal studies have been conducted in the wells with a steady thermal regime. Temperature measurements have been conducted in the depth range of 0 to 6000 m at 5 m to 10 cm intervals. The equipment and technique of these measurements have been described in published paper (Khristoforova, et al., 2000).

Some of the thermograms look like straight lines while the others are wave-like reflecting the complexity of the penetrated section and of the processes in it.

Fourier analysis of each thermogram permits the determination of amplitudes and wavelengths of the temperature variations. The more the thermogram deviates from the straight line, the higher the temperature waves’ amplitudes. Each thermogram has an individual Fourier spectrum consisting of a set of modes, i.e. waves of specific lengths, phases and amplitudes.

However, the Fourier analysis is unable to reveal local changes in the waves’ characteristics throughout the geological environment. That’s just the point of interest.

The wavelet analysis allows the identification of spatial temperature waves and tracing their characteristics throughout the geological environment as well. The wavelet analysis is the presentation of a signal as a generalised series or the Fourier integral taken over a system of basis functions constructed from the source wavelet through shifting and rescaling along the independent variable axis (Goswami, Chan., 1999). Wavelets are functions represented by short waves with the zero integral value that are localized along the independent variable axis. Rescaling permits the wavelet to reveal differences in the process characteristics on various scales. Wavelet shifting allows the analysis of local characteristics of the process at various points of the entire independent variable range. In this particular case, the process under review is the depth-dependent temperature variation in wells, and the independent variable is depth. The source wavelet used was the Morlet wavelet.

Wavelet spectra of the other thermograms may considerably differ from the one. However, the analysis of the repeated temperature measurements conducted in the same well at various time intervals only displayed the same spectra.

The authors have correlated the wavegrams with the well logging data acquired in several hundreds of wells to find out that spatial characteristics of these waves are defined by the geological structure. This can be illustrated as follows.

The association of wave phases with the geological structure

The most interesting feature is that the wave phases have been found to be associated with stratigraphic and lithologic boundaries in the rock sequence penetrated by the well. Certain phase values appeared to be tied to a certain depth or a boundary dividing rock strata of different thermal conductivities.

As shown by the analysis of the mass thermogram data overwhelming majority of critical points, i.e. extrema and inflection points, of the temperature waves
correspond to lithostratigraphic boundaries. This is not an accidental coincidence.

This work demonstrates temperature waves application for studying the sedimentary strata in which heat-transfer properties of the rock strata can significantly vary. On the other hand, temperature waves have also been recorded in the geological environments that are relatively homogeneous, for instance, in the 3.5 km thick salt-bearing mass in the borehole Sagis (Khristoforova, et al., 2000). Will the temperature waves be useful in that case as well?

For example, the Sagis well thermogram looks straight. It means that the crystalline basement is homogeneous, and thermal conductivity seems to be constant. It is difficult to get more detailed information in this case using conventional analytical techniques. However, the analysis of the temperature waves indicates that it is slightly inhomogeneous. The wave extrema and inflection points on the wavegrams are seen to correspond to the position of stratigraphic and petrographic boundaries are correlated to extrema and inflection points on the temperature waves.

This example demonstrates that, although in the homogeneous rock mass a thermogram is a straight line without any visible distinctive features, the corresponding wavegram provides much more detailed information on the thermal regime of the particular rock mass and on the geological structure.

All these features indicate that the position of the critical points on temperature waves can be used for the identification or more detailed location of Jurassic boundaries dividing rock strata, particularly, when other data are insufficient.

Temperature waves have been found both in the complex laminated structures and in the relatively homogeneous strata, irrespective of the composition, age or origin of the rocks.

Position of the critical points on temperature waves can be used for the identification or more detailed location of Jurassic boundaries dividing rock strata, particularly, when other data are insufficient.

Spatial temperature waves are a new feature of the Earth’s crust thermal regime, and their analysis provides a new instrument for the Earth’s interior studies.

Key words: Jurassic boundaries; Wavelet analysis; Borehole temperature measurements

References:
Microfacies and Nannofacies Analyses of Fine-carbonate Fraction at the GSSP Aalenian Stage of the Fuentelsaz Section (Iberian Range, Spain): Implication for the Palaeoenvironmental Evolution

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Here we present the synthesis of a multi-disciplinary approach that combines detailed micropalaeontological and sedimentological analyses in order to propose a refined palaeoenvironmental evolution for the Global Boundary Stratotype Section and Point (GSSP) for the Aalenian Stage of the Fuentelsaz section, Castilian Branch of the Iberian Range, Spain (Cresta, et al., 2001). Our results have been obtained comparing the microfacies (thin sections) of the upper Toarcian-lower Aalenian limestone and marl alternation with the nannofacies (ultra-thin sections) of the same time interval. The microfacies analyses allowed us to recognize five types (MF1-MF5) and the nannofacies study two types (NF1 and NF2), with four (NF1a, NF1b, NF2a and NF2b) subtypes (see Fig. 1).

The microfacies types are: (MF1) Bioclastic wackestone-packstone (lower part of the section): peloidal wackestone-packstone with large bioclasts embedded in a matrix affected by recrystallization; (MF2) Bioturbated wackestone (across the Toarcian-Aalenian boundary): bioclastic limestone dominated by Bosittra filaments (43.3%); (MF3) Bioclastic wackestone-packstone (mid-upper part of the section): wackestone to packstone limestones, and occasionally mudstone, with abundant and diverse fossil fragments; (MF4) Mudstone limestone: mudstone limestone with few allochems and dominance of Bosittra filaments (43.3%), and darker matrix, which is affected partially by recrystallization processes. The MF4 appears inserted in the MF3 microfacies type, denoting a minor pulse in facies development; (MF5) Bioturbated mudstone-wackestone (upper part of the section): mudstone to bioclastic wackestone with dominance of sponge spicules (51.3%) within a matrix showing recrystallization processes.

The fossil content includes abundant bivalves (Bosittra filaments) throughout the section and a noticeable progressive increase of sponge spicules from (7.7%) the Toarcian-Aalenian transition upwards (51.3%). In particular, the lower portion of the section is characterized by the dominance of Bosittra filaments, foraminifera tests and echinoderm plates together with the scattered and rare co-occurrence of gastropods and bryozoans. These last two fossil groups are absent in the upper portion of the section, which is characterized by the dominance of sponge spicules and Bosittra filaments. Ostracods, serpulids and brachiopods are always present with a low percentage, though in the lower part of the section they are more abundant.

Diversity and evenness are useful tools for evaluating the abundance changes of the allochems within the different microfacies throughout the section. The bioclastic wackestone-packstone of MF1 (Pseudoradiosa Sz. - lowermost Buckmani Sz.) is characterized by relative high diversity and evenness values (6.5 and 5.27 respectively), showing the coexistence of several fossil groups, neither of them dominating over the other. The onset of the bioturbated wackestone of MF2 (Buckmani Sz. - lowermost Comptum Sz.) shows a decrease in the number of fossil groups, indicated by an abrupt diminishment in diversity (4.75), whilst evenness values (3.41) indicate that some of them dominated over the others. This reveals that there were processes inhibiting the benthos development and displayed a change in the basin conditions.

A new event led to the increment of diversity and evenness values (6.64 and 4.46 respectively) shown by the onset of the bioclastic wackestone-packstone of MF3 (base of Comptum Sz.) denoting the re-establishment of less restricted palaeoecological conditions. This general trend is disrupted by a pulse of lower values of diversity and evenness (5.33 and 3.73 respectively) linked with the onset of the mudstone limestone of MF4 (Comptum Sz.), where palaeoecological conditions became a bit hostile, but after that returned to the average values of MF3. Finally, the bioturbated mudstone-wackestone of MF5 (Comptum Sz.), show diversity values (5.09) similar to those of the upper part of MF3, but the evenness decreases showing the lowest values within the section (2.75). That means that there where several fossil groups, but there was a big dominance of some of them among the others, indicating some kind of restriction in the basin.

Nannofacies have been studied using a polarizing light microscope at 1250x magnification. The evaluation of the carbonate fine fraction of the nannofacies was based on the percentage of the following groups: large carbonate fragments (>2μm) including calcite and dolomite (rhombic-shaped crystals), Schizospheraella tests and fragments of Schizospherella tests (“Schizospheraella-debris”); small carbonate fragments (<2μm), i.e., micarbs (nano-particles probably produced dur-
ing diagenesis by disaggregation of nannofossils and/or small foraminifers) and other grains: (detrital) quartz, iron-oxides and (rare) phosphates and phyllosilicates (chlorites).

Based on the abundance pattern of these constituents we can recognize: large-fragment-dominated nannofacies (NF1) with two subtypes: when large fragments \( \gg 50\% \) of the constituents (NF1a) and when they appear \( \approx 50\% \) (NF1b); and Schizosphaerella and micarbs bearing nannofacies (NF2), that due to the difficult to distinguishes into the wide continuous spectrum from “small fragments of Schizosphaerella” to “clouds of micarbs” could be subdivided into two subtypes based on the dominance of Schizosphaerella tests (NF2a), or by the dominance of “Schizosphaerella-debris” + micarbs (NF2b).

In summary, the integrated studies of microfacies and nannofacies reveal that: (1) there is a remarkable relationship between the percentage variation of the allochems and those of large fragments (mainly composed of broken skeletons of the allochems) and “Schizosphaerella-debris” + micarbs; (2) an interesting relationship between the percentage variation of “Schizosphaerella-debris” + micarbs and of Schizosphaerella tests is observed; (3) the variations of the micrite composition (i.e., the nannofacies established) seem to show a very close covariation with 3rd order sequences, whereas the microfacies succession is more related with 2nd order cyclicity.

Therefore, future studies dealing with the nature and abundance of the fine-carbonate components will be useful for improving the understanding of different palaeoenvironmental conditions. They also will be key factors to decipher the effect of diagenesis in the samples, studying the nature of micarbs in order to determine its origin, but also determining the abundance of Schizosphaerella and its conservation, in order to see the evolution of the porosity of the sample.

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Key words: Microfacies; Nannofacies; GSSP Aalenian Stage; Palaeoenvironmental evolution; Iberian Basin; Spain

References:
The Non-marine Triassic and Jurassic System in the Sichuan Basin, China: Stratigraphic Sequences, Biodiversity and Major Strato-boundaries

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Located in SW China and the eastern border of the Qinghai-Tibet plateau, the Sichuan Basin is one of the largest terrestrial basins in China with rich oil and gas resources being found in the Paleozoic and Mesozoic strata. The extensive distribution and development of the Early Mesozoic strata make the Sichuan Basin one of the best known areas for the Triassic-Jurassic studies in China. In particular, the Triassic and Jurassic sequences are continuously cropped out in this basin yielding diverse fossil organisms. The Lower and Middle Triassic strata in the basin are of marine origin, consisting of dolomites and limestones with a few gypsum and salt rocks, and are interpreted as a series of arid closed-plateform evaporite deposit. The Upper Triassic and the whole Jurassic strata represent the non-marine fluvial and lacustrine deposits bearing a variety of fossil plants and fauna. The well-developed sections of the Triassic and Lower, Middle and Upper Jurassic sequences are well developed in Hechuan, Beibei and Kaixian of Chongqing City, Guangyuan, Daxian, Shehong, Saitai and Suining of Sichuan Province, which are considered as typical profiles for investigating the Upper Triassic and Jurassic sequences in the basin (Fig.1 A).

The Jurassic sequences are widely distributed and extensively developed in the Sichuan Basin yielding diverse biota, making this basin one of the best known areas for the Jurassic of China. The Jurassic system in the central part of this basin is up to 2400-3700 m in total thickness and is represented by the red-color terrestrial clastic rocks, covering the majority area of the basin. The Zhenzhuchong and Ziliujing Formations are representatives of the Lower Jurassic sequence consist of shell limestones, purple red mudstone and limestones with sandstone or variegated bed. The former formation is the basal part of the sequence (ca. corresponding to the Hettangian), and it conformably overlies the Upper Triassic Xujiahe Formation; the Ziliujing Formation may roughly correspond to Sinemurian to Toracian. The fossils are abundant including bivalves, conchstracas, ostracodes, plants as well as spores and pollen grains (Fig.1 C).

The Middle Jurassic strata are well cropped out in the basin attaining a total thickness up to 1500 m. It’s a series of fluvial and lacustrine clastic rock deposit forming under the arid climatic condition. Three lithostratigraphical units are recognized, including the Xintiangou Fm. (ca. Aalenian to Bajocian), the Lower Shaximiao Fm. (ca. Bajocian to Bathonian) and the Upper Shaximiao Fm. (ca. Bathonian to Collovian). Fossil fauna are abundant in the Middle Jurassic including ostracodes, bivalves, dinosaur, turtles and conchstracas (Fig.1 D).

The Suining and the Penglaizhen formations form up the Upper Jurassic sequences, and are widely distributed in the central basin. They are characterized by the purple red mud stones, with intercalations of siltstone and sandstones. The Upper Jurassic is represented by the fluvial and lacustrine deposits that were formed under the arid and hot climatic conditions (Fig.1 E). The fossils are dominated by the conchstracas, ostracodes and charophytes. Abundant fossil petrified woods are the remarkable fossil plant remains which have been documented in recent years from the Penglaizhen Formation in Shehong region of the basin.
The Triassic/Jurassic boundary is defined in between the Upper Jurassic Xujiahe Formation and the base of Lower Jurassic Zhenzhuchong Formation (Fig.1 F). The boundary shows distinct lithological features and is distinguished by a scouring surface with feldspatic sandstones of the Upper Triassic and quartzose sandstones of the Lower Jurassic. Preliminary analysis shows that across the boundary the
biodiversity of fossil biota may display a pronounced change. Further analysis is undertaken focused on the vegetation, sedimentary facies, isotope variation as well as the ecosystem change. These aspects will be considered in the frame work of the non-marine T/J boundary geological and bio-events and their potential causes. The Jurassic/Cretaceous boundary is unconformity contacted in between the Penglaizhen Formation (Upper Jurassic) and the Lower Cretaceous Cangxi Formation in Saitai County of the Sichuan Basin (Fig.1 G). The Cangxi Formation is characterized by the pale yellowish grey sandstones and purplish red sandy mudstones, siltstones, and conglomerates. These two boundaries are distinct in the field by the lithological features.

Previous investigations have established diverse fossil remains and various assemblages for the Upper Triassic, Lower to Upper Jurassic, including bivalves, conchastracas, ostracodes, vertebrate fossils, spores-pollen and plant. These assemblages provide informative data for understanding the biodiversity and variation of the Jurassic biota, and are also helpful for defining the roughly geological ages. These supply further evidences for our understanding of the palaeotectonics, palaeoclimate, palaeoenvironmental and biodiversity aspects of the Sichuan Basin in the Jurassic period.

Acknowledgements: This work was jointly supported by the Knowledge Innovation Program of CAS (KZCX-2-YW-154), the National Key Basic Research Program of China (2006CB701401), National Natural Sciences Foundation of China (NSFC 40472004, 40972008) and the special grant of the Jurassic studies in the Sichuan Basin (No. 07D0020201). This is a contribution to UNESCO-IUGS project IGCP 506.

Key words: Upper Triassic; Jurassic; Triassic/Jurassic boundary; Jurassic/Cretaceous boundary; Fossil biota; The Sichuan Basin
Astronomical Calibrated Time Intervals for the Non-marine Badaowan Formation, Lower Jurassic in Haojiagou of Ürümqi City, Western China

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The thick coal-bearing sediments of Badaowan Formation (BF) accumulated at Haojiagou (about 50 km southwest of Ürümqi City), Northern Xinjiang, are very well exposed and structurally only slightly deformed. It is near 800 m thick, conformably resting on the Haojiagou Formation (Late Triassic) and disconformably underlying the Sangonghe Formation (Early Jurassic) (Zhang, et al., 2003; Lu and Deng, 2005; Huang, 2006; Sha, et al., 2010).

Lithologically the BF at Haojiagou section can be subdivided, from bottom to top, into three members, Lower Member (LM), Middle Member (MM) and Upper Member (UM). The LM and UM of BF are predominantly fluvial sediments, and the MM of BF is characterized by lacustrine deposits. On the basis of palynology, the Triassic−Jurassic boundary has been located between underlying Haojiagou Formation (HF) and BF (Lu and Deng, 2005; Sha, et al., 2010).

<table>
<thead>
<tr>
<th>Astron. Period/kyr</th>
<th>Dominant period</th>
<th>Deviation/kyr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thickness/m</td>
<td>Time/kyr</td>
</tr>
<tr>
<td>978(Ec 7)</td>
<td>81.9</td>
<td>973</td>
</tr>
<tr>
<td>405(Ec 1)</td>
<td>34.1</td>
<td>(405)</td>
</tr>
<tr>
<td>131(Ec 5)</td>
<td>10.2</td>
<td>121.1</td>
</tr>
<tr>
<td>124(Ec 3)</td>
<td>95(Ec 2)</td>
<td>95.4</td>
</tr>
<tr>
<td>99(Ec 4)</td>
<td>8.03</td>
<td>46.8</td>
</tr>
<tr>
<td>46.3(Ob 3)</td>
<td>3.94</td>
<td>36.0</td>
</tr>
<tr>
<td>36.5(Ob 1)</td>
<td>3.03</td>
<td></td>
</tr>
<tr>
<td>35.4(Ob 2)</td>
<td>2.09</td>
<td>24.8</td>
</tr>
<tr>
<td>26.6(Ob 4)</td>
<td>1.83</td>
<td>21.7</td>
</tr>
<tr>
<td>21.0(Pr 1)</td>
<td>1.72</td>
<td>20.4</td>
</tr>
<tr>
<td>17.9(Pr 3)</td>
<td>1.42</td>
<td>16.9</td>
</tr>
<tr>
<td>15.7(Pr 4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Ec-Eccentricity; Ob-Obliquity; Pr-Precession. The number followed after alphabet (1, 2, 3, ...7) indicates that the contribution of defined cycle in the spectrum decreases from larger to smaller.

The BF demonstrates a series of regular sedimentary cycles, which has been attributed to orbital climatic (Milankovitch) cycles. In this study, a cyclostratigraphic investigation, using lithologic variations in the Lower Jurassic terrestrial deposits of the BF and also upper part of HF based on the field investigations, spectral analysis and digital filter results, was employed to: (1) test for regular cycles; (2) establish an astronomically calibrated time intervals for Badaowan Formation; (3) independently determine microrhythmic (cyclic) comparison between LM of non-marine BF and marine Blue Lias deposits in south England.

As the period of 405 kyr (405EC) is the most stable of the orbital cycles over geological time (Olsen et al., 1996), and it is characterized by largest amplitude in the eccentricity, Laskar (2004) suggested it may be used for the calibration of the Mesozoic time scale. An average duration of BF is 6.07 Myr, and the duration of LM of BF is 3.03 Myr, which is very consistent with the current estimation of the duration of the Hettangian Stage (3.10±0.8 Myr).

There are 65 obliquity cycles which have been recognized from the LM of BF, and the obliquity cycles are also remarkable in LM of BF. Such obliquity cycles could be cyclically compared to the 65-67 micro-rhythms within three ammonite zones in Hettangian
Stage suggested by House (1985).

The highest peak is the cycle with period around 34.1 m/cycle for LM of BF and upper part of HF (Fig. 1), which is subjectively defined to match 405EC. The values listed in last column of Table 1 (see below) demonstrate small deviations of calculated values for LM of BF and upper part of HF to theoretical values of Milankovitch cycles. Except the value 34.1 m matching 405EC, among the other 11 dominant cycle values, there are 9 values (Table 1, column 3), which are nearly consistent with astronomical periods (a total of 13 periods, Table 1, column 1).

The difference between period of Ec7 (978 kyr) and the second largest peak (973 kyr) is only 5 kyr. Similar situations are shown for two other eccentricity cycles (Ec2 and Ec3), and also for three obliquity cycles (Ob1, Ob3, and Ob4) and three precession cycles (Pr1, Pr2, and Pr3) (Table 1).

The duration of various horizons of BF is illustrated by means of AR (accumulation rate) method or calculated cycle method, but they were not explained in this short article.

Acknowledgements: The spectral analysis and digital filter works mainly completed by Professor Daoyi Xu. This is a contribution to UNESCO-IUGS Project 506 financially supported by the National Committee of Stratigraphy of China and Special Basic Program of Ministry of Science and Technology of China (2006FY120300).

Key words: Cyclostratigraphy; Lower Jurassic; Non-marine deposit; Badaowan Formation

References:
Palaeoclimate Around Triassic-Jurassic Boundary of Junggar Basin

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The Haojiagou section, located in the southern margin of the Junggar basin, is of great significance in studying Triassic-Jurassic Boundary events. This paper deals with the climatic change during the transition period of Triassic and Jurassic.

The lower part of the Haojiagou section (bed 4 to bed 44) belongs to the Haojiagou Formation that is assigned to the Upper Triassic, and the underlying interval of bed 45 to 102 is the Badaowan Formation that is considered to be the Lower Jurassic (Deng, et al., 2000, 2003; Lu and Deng, 2005).

The palynological data show that the gymnosperm pollen grains dominate all the Haojiagou Formation (Fig.1), such as nonstriate bisaccate, monocolpate. On the contrary, fern spores have higher proportion than the gymnosperm pollen grains in the lower member of the Badaowan Formation (Fig.1). Among the fern spores, the genera *Asseretospora*, *Dictyophyllidites*, *Concavisporites*, *Densoisporites*, *Lycopodiacidites* and *Cyathidites* are prominent in quantity (Lu and Deng, 2009), most of them are related to the plants adapted to warm and humid climate. Therefore, we believe that it was warmer and more humid in the Early Jurassic than in the Late Triassic.

Organic carbon isotope data from the Haojiagou Section demonstrate that $\delta^{13}C$ curve has an obvious negative excursion (less than -24.5‰) in the interval of bed 44 to bed 68, while the underlying and overlying strata have similar $\delta^{13}C$ values (greater than -24.5‰) (Fig.1). Analyses of charcoal samples show a similar negative excursion in bed 44 to bed 59 (Fig.1). Ecological researches showed that sedimentary organic matter have lighter carbon isotope values when the climate is warm and humid (Yu, et al., 2001; Medina, et al., 1986; van der Merwen and Medina, 1989), and have heavier carbon isotope values when hot and dry (Ehleringer, 1993). Therefore, it is concluded that at the beginning of the Early Jurassic the climate is warmer and more humid than before and afterward.

The sudden creasing of fern spores and the distinct negative excursion of organic carbon isotope in the lowest member of Jurassic of the Haojiagou section are similar with some other sections. It may reflect a globally climatic change.

**Key words:** Junggar basin; Triassic-Jurassic boundary; Palaeoclimatic changes

**References:**


Fig. 1 The proportion of fern spores and organic carbon isotope curve across the T/J boundary of the Haojiagou section
Potential Marine and Non-marine Jurassic–Cretaceous Boundaries in China: A Review

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The Jurassic-Cretaceous boundary or the base of Berriasian Stage is estimated as 14.5±0.4 Ma age, and traditionally placed at the base of the ammonite Berriasella jacobi Zone. Although dozen international conferences and working groups dedicated to defining the base of the cretaceous system since 1974, the global Jurassic-Cretaceous boundary has yet not been established (http://www.stratigraphy.org). Such situation is mainly caused by the separation of the world into various biogeographic realms during the late Jurassic – early Cretaceous interval, particularly the Tethyan and Boreal realms, complicating the international correlation (Sha, et al., 2006).

In China, there are good Tethyan (in southern Tibet) and subboreal (in northeastern China) marine, and non-marine (in most part of China) Jurassic and Cretaceous deposits. The various previous works have implied that there potentially exist marine and non-marine boundaries which could be widely correlated.

1 Potential marine Jurassic-Cretaceous boundary
1.1 Tethyan type

There are sections spanning Jurassic–Cretaceous boundary in southern Tibet, particularly in Gyange–Nagarze and Menkadun–Gucuo areas. In Gyange–Nagarze area, the upper Jurassic is represented by the Weimei Formation, the lower Cretaceous includes Sangxiu and Jiabula Formations in Nagarze, and Jiabula Formation in Gyange. The Weimei Formation consists of lightly grey thick-bedded coarse- to fine-grained quartzose sandstone, yielding rare ammonite including Haplophyloceras and Himalayites. The Sangxiu formation is composed of black shale, an-desite and basalt. The Jiabula Formation comprises black shale, siliceous mudstone and shale, and sandy limestone (Wan, et al., 2005).

Both the lower Sangxiu Formation and Jiabula Formation yield ammonite Spiticeras, bivalve Inoceramus, and Berriasian and Valanginian nannofossil assemblages, i.e., Berriasian Nannoconus steinmannii–Nannoconus steinmannii minor–Watznaueria barnesae assemblage, and Valanginian Calci-calathina oblongata–Spoetienia colligate assemblage. The appearance of the ammonite Spiti-ceras and the nannofossil assemblage of Nannoconus steinmannii–Nannoconus steinmannii minor–Watznaueria barnesae is the indicators of the base of Cretaceous or Berriasian, which has been indirectly conformed by the radiometric age 136±3.0 Ma of the volcanic rock of the upper Sangxiu Formation (Wan, et al., 2010).

In Menkadun–Gucuo area, particularly in Gucuo, the Gucuo section used to be seen as a good Jurassic–Cretaceous boundary section because there were recordings of late Jurassic and early Cretaceous ammonites including Blanfordiceras (see Yin and Enay, 2004). Although, Yin and Enay (2004) have confirmed the existence of Tithonian ammonites in the area, they concluded that the Berriasian ammonites are remained to be examined.

1.2 Subboreal type

In eastern Heilongjiang of northeastern China, there also exist the potential Jurassic-Cretaceous boundary in Dong’An of Raohe country and Suibin of Suibin country.

In Dong’an area, the Jurassic–Cretaceous boundary strata is represented by the Dong’Anzheng Formation consisting of yellowish-green silty shale in the lower part, and dark grey and greyish-green muddy siltstone, silty mudstone and greywacke in the upper part. The lower part of the formation yields lower Berriasian (= upper Volgian) bivalve Buchiarus-siensis – Buchia fischeriana assemblage, and the upper Tithonian (= middle Volgian) Buchia fischeriana–Buchia unschensis assemblage. The upper part contains early Valanginian Buchia pacifica bed. The base Berriasian or the Jurassic-Cretaceous boundary is signed to the base of Buchia russiensis–Buchia fischeriana assemblage or between the Buchia fischeriana–Buchia unschensis and Buchia russiensis–Buchia fischeriana assemblages.

The Jurassic-Cretaceous boundary interval in Suibin area is represented by the Dongrong Formation from boreholes. It is mainly composed of dark fine-grained sandstone, siltstone and siliceous siltstone, intercalated with coarse- and medium-grained sandstones, microconglomerates, and greyish-green tufts. In ascending order, Dongrong Formation yields the uppermost Oxfordian–Kimmeridgian Buchia cf. concentrica assemblage and the Oxfordian–upper Kimmeridgian Gonyaulacysta jurassica dianoflagellate cyst assemblage in lower part; Tithonian (= lower and middle Volgian) Buchia cf. mosquensis–Buchia cf. rugosa assemblage including Buchia ex gr. tai-myrensis, and Kimmeridgian–lower Berriasian Am-

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Amphorala dilicata dinoflagellate cyst assemblage in the middle; Berriasian Buchia fischeriana bed and Berriasian–Valangian Oligosphaeridium pulcherrimum dinoflagellate cyst assemblage in upper. Consequently, there also probably exists a Jurassic–Cretaceous boundary interval between the middle and upper Dongrong Formation in Suibin area, indicated by the disappearance of Buchia cf. mosquensis - Buchia cf. rugosa bivalve assemblage and Amphorala dilicata dinoflagellate cyst assemblage, and the appearance of Buchia fischeriana bed and Oligosphaeridium pulcherrimum dinoflagellate cyst assemblage (Sha, 2007; Sha, et al., 2006, 2008, 2009).

2 Non-marine Jurassic-Cretaceous boundary

There are numerous articles on Chinese non-marine Jurassic-Cretaceous boundary which have been published, but they are mainly involved in northeastern China.

In northeastern China and Inner Mongolia, the terrestrial uppermost Jurassic and lower Lower Cretaceous, including Tithonian, Berriasian, Valangian and even part of Hauterivian are absent (Sha, 2007). However, judging from the radiometric age of 139.4 ± 0.19(ISD) ± 0.5(SE) Ma, corresponding to the Valangian obtained by Swisher, et al. (2002) from the Tuchengzi Formation of western Liaoning, Ji, et al. (2006) got a similar radiometric dating. The non-marine Jurassic-Cretaceous boundary is, therefore, probably within the Tuchengzi Formation in western Liaoning, though there is no fossil evidence (Sha, 2007; Zhou, et al., 2009).

3 Discussion

Due to the bio-provincialism separation caused by the pronounced latitudinal segregation, even the pelagic ammonites cannot play the international correlation role. Furthermore, ammonites are often absent or ill-preserved in the Jurassic-Cretaceous boundary interval. The non-ammonite fossils, including bivalves, belemnites, crinoids, calcareous nanofossils, calcipollinids, dinoflagellate cysts, foraminifers, radiolarians and ostracods become more and more useful in subdivision and correlation of stratigraphy, particularly when the ammonites are absent or ill-preserved.

The main approach to define the non-marine Jurassic–Cretaceous boundary interval is probably to correlate non-marine with marine strata, mainly on the basis of the biostratigraphy and radiometric dating obtained from the strata concerned. Through correct taxonomic identification of both marine and non-marine fossils in alternating marine and non-marine strata, the concerned marine and non-marine strata could be both correlated within the international chronostratigraphic chart (http://www.stratigraphy.org) and, therefore to determine or constrain the age of the non-marine strata/fossils (chronostratigraphy). The intervening volcanic rocks including tuffs, tuffaceous rocks and lavas can also be radiometrically dated (geochronology), providing a basis for accurate age determinations of the associated sedimentary rocks and the fossils they contain (Sha, 2007). Such correctly identified and dated (by marine fossils and non-marine fossils radiometric dating) non-marine fossils not only could be reliably date the widely distributed non-marine rocks, but also could correlate the terrestrial strata in the marine biostratigraphic framework.

The principles of “Strict phylogenetic closeness” of fossil taxa are very important and useful in biostratigraphic correlation and boundary definition in both marine and non-marine strata (Zhou, et al., 2009).

Key words: Marine and non-marine; Jurassic–Cretaceous boundary; China

References:


Ammonites of the Subboreal Province in Europe at the Turn of the Oxfordian and Kimmeridgian – Biostratigraphical and Palaeogeographical Implications

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The large biostratigraphical and palaeogeographical importance of the Subboreal Province in Europe, based, unfortunately, on purely historical grounds, results from the fact that “it is the area that has provided the zonal schemes that has been erected in the past and that have become deeply entrenched in the literature” (Sykes and Callomon, 1979, p. 840). This area is especially important for the Oxfordian and Kimmeridgian boundary beds as the two ammonites zones – the Pseudocordata Zone, and the Baylei Zone which define the boundary of these stages have been just founded here.

The Subboreal Province is characterized by occurrence of ammonites of the family Aulacostephanidae. These ammonites appeared already at the turn of the Middle Oxfordian and Upper Oxfordian [genus Decipia (M,m)] and occurred during the Late Oxfordian [genera Ringsteadia (M) – Microbiplices (m)], showing everywhere fairly uniform character within the Subboreal Province – from southern England, Normandy, the Boulonnais, through northern Germany, northern Poland and Lithuania, up to northern Russia west of Urals. These ammonites co-occurred with Boreal ammonites so far north as northern Scotland and eastern Greenland, as well as in northern Russia; representatives of the genera Ringsteadia-Microbiplices have been reported also as a minor element within the Submediterranean ammonite assemblages so far south as in central and southern Poland, and southern Germany.

The earliest Kimmeridgian revealed, however, a marked change in evolution of Aulacostephanidae which produced two separate lineages: one in NW Europe, and another in SE Europe. The first lineage is represented commonly in lowermost Kimmeridgian of southern England and northern France, but also in Scotland and eastern Greenland: it is represented by Pictonia (M), followed phylogenetically by Rasenia (M), and associated microconchs of both genera – referred to as Prorasenia (see e.g. Wright 2010 and earlier papers cited therein). These ammonites are typical of the NW part of the Subboreal province which is distinguished herein as NW European Subprovince.

The other lineage of Aulacostephanidae developed in the SE Europe including northern Poland, northern Germany, Lithuania, and northern part of European Russia. The lineage is represented by genera Vineta (M,m) and newly established genus Vielenia (M) – with the first Prorasenia as its microconchiate counterpart (Wierzbowski et al., 2010). These latter gave rise at slightly higher horizons to still more coarsely ribbed ammonites of the genus Pomerania (Pomerania, Pachypictonia). Moreover, there occur also ammonites attributed to the genus Pictonia – some of them, however, differ somewhat from typical representatives of the genus from NW Europe: their origin in not clear – they represent either local peripatric assemblage having their roots in migrants of NW European area and/or they derived independently of “true” Pictonia, as an offshoot off the SE European aulacostephanid stock. All these ammonites are indicative of the newly distinguished NE European Subprovince.

The development of the two parallel lineages of Aulacostephanidae was an effect of the allopatric speciation which has been related with formation of the land barrier separating the two areas of the Subboreal Province during earliest Kimmeridgian – possibly related with the uplift of the London-Brabant Massif and the Ringkøbing-Fyn High. The northeastern part of the Subboreal Province was opened towards southwest down to areas of Submediterranean central and southern Poland and southern Germany as indicated by records here of such Subboreal ammonites as Vineta, Vielenia and Pomerania. Such a distri- bution of the forms in question (as well as earlier Ringsteadia) strongly supports the existence of a marine flow from
northern regions towards south (from the so called Middle Russian Sea to the Submediterranean areas of the northern Tethyan margin) during latest Oxfordian-earliest Kimmeridgian, according to model of circulation in the epicontinental seas proposed by Bjerrum and Surlyk (1998).

**Key words:** Ammonites; Phylogeny; Palaeobiogeography; Correlations

**References:**
The Jurassic Carbonatic Formations Effects on Calcareous Soils of Iran

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Most of the Iranian soils contain different amounts of carbonate compounds from 0 to 90 percentage. These carbonates and lime have various origins, which has been outlined and surveyed by many scientists. Different geological formations have various biological and chemical origins of carbonate compounds in different geological eras. In Iran one of these geological eras is Jurassic with different types and amounts of carbonate compounds. These formations have outcropped tectonically and made the parent materials rocks of soils. By the weathering of these rocks and interflow of rain water they might gave their carbonates to soils and waters. The Jurassic calcareous formations surveyed by many geoscientists are entitled as: Alborz Mountains Jurassic Carbonate Formations, Cope-Dagh Mountains Jurassic Carbonate Formations, Central Iran Jurassic Carbonate Formations, and Zagross Mountains Jurassic Carbonate Formations.

Alborz Mountains Jurassic Carbonate Formations

In Alborz Mountains, the middle and upper Jurassic rocks are marine marly, calcareous sequences, which deposited between two geological formations and have a large deposition cycle characteristics. These rocks groups did not have equally distribution in all geographic parts of the Iran. In southern Alborz after middle Simerian, the marly and calcareous sediments covered the depostions of the marine sequences were not simultaneously. In some places the middle Jurassic sea started from Bazosian time, where the sedimentation of carbonates deposits in prime Jurassic continued at this time. But from the late Bostonian age the marine condition had dominated in the whole region of southern Alabors mountain ranges, and the marble calcareous sequences of late bottom Delichai at bottom) and Lar Formations deposited on the top.

Abnak Formation: A carbonate sequence of complex lithology composed of dark bituminous limestone, massive dark dolomite, and thick bedded light-grey lime stone. The unit is up to 600 m thick. It overlies conformably the Shemshak Formation. The lower part (“member A”) is dated as Callovian, and correlated to the upper part of the Dalichai Formation; the upper parts of Abnak (“members B, C and D”) with no fossils collected are correlated to the Lar limestone and therefore considered as Oxfordian-Kimmeridgian.

Dalchiah Formation: It is an ammonitiferous limestone, marly limestone and shales, more than 100m thick, and belongs to Late Bajocian to Late Callovian.

Lar Formation: The widespread, feature-forming unit of upper Jurassic limestone developing throughout the greater parts of Alborz Mountains overlies Dalichai Formation and Shemshak Formation. It is composed of light grey, compact, thin-bedded to massive limestone, with 250-350 meters thick and containing characteristic nodules and bands of white or violet chert. The limestone overlies the Dalchihai Formation conformably (Allenbach, 1966; Steiger, 1966; Stöcklin et al., 1965).

Cope-Dagh Mountains Jurassic Carbonate Formations

The most important limestone formations consist of: Chaman Bid Formation, a unit of dark, bituminous, pyritiferous, ammonite-bearing marl and thin bedded limestone with marly 2000 m thick, which belongs to middle-upper Jurassic. Khaneh-Zu Formation, sequences of thick rockiness limestone distributed in eastern Cope-Dagh. Mozduran Formation, a set of light colored, thick bedded to massive limestone, porous dolomitic and dolomite is also an important carbonate and limestone contents formation, which belongs to upper Jurassic.

Central Iran Jurassic Carbonate Formations

The most important limestone formations entitled as: Badamu formation yielding a fauna of ammonites, lamellibranches, belemnites, etc., located at Titu vilage, 17 km north to north-east of Zarand, north-western of Kerman. It is described through a number of sections in the wider Kerman area but statements of the formation at Badamu area is poor. Esfandiar Formation located in the Shotori Range, composed of the bulk of massive, dense, light-grey reef limestone with occasional oolitic beds content, 690 m thick. Its age is Late Middle Jurassic. Pectinid Limestone-Gypsum Facies developed in Ravar-Bahahbad area, with a thickness of several hundred meters and characterized by alternating light colored limestones, marls and Gypsum.

Zagross Mountains Jurassic Carbonate Formations

The most important Zagross mountains limestone formations entitled as: Surmeh Formation, dolomitic and argillaceous limestones containing Lithiots, the type section was measured on the north-western of Surmeh Mountain in Fars Province, with lowermost 91.4m and uppermost 507m thickness. It belongs to
early Jurassic. Neyriz Formation, the basal rubbly-weathering dolomites with a overlain of shale, more resistant thick-bedded dolomites and dolomitic limestones above which lies sandstone, and argillaceous dolomitic limestone. It belongs to Early Jurassic.

The other important limestone contents formations which belong to Jurassic are: Mus Formation, Alan Formation, Sargelu Formation, Najmeh Formation and Adaiah Formation which have various thicknesses and compositions.

**Key words:** Jurassic; Geological formations; Calcareous; Soils; Iran

**References:**
Sedimentology and Sr Isotopic Ages of the Bau Limestone Formation in Northwestern Borneo, Malaysia

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The Mid-Mesozoic era (from the Late Jurassic to the Early Cretaceous) was one of the periods in terms of the largest deposition of marine carbonate. In the eutrophied ocean, reef-builders were flourished under the circumstance of a relatively high CO₂ concentration and the warm ocean environment. Sedimentology and stratigraphy of the Mid-Mesozoic carbonate were well studied in Europe, the former territory of the Tethys Ocean. On the other hand, information on the Mid-Mesozoic carbonate of Asia and Pacific realm was limit. Hence, more information and more studies on them have been expected. Here, we present the sedimentology and Sr isotopic age of the Bau Limestone Formation (the Upper Jurassic to the Lower Cretaceous) in north-western Borneo of Malaysia, for the first time.

We surveyed at two quarries (Marup and SSF) of the Gunung Panga Area, located at 30km southwest of Kuching City (Fig. 1). The lithofacies are mainly massive limestone yielding mega fossils. The lithology of the Marup Quarry is subdivided into Bioclastic wacke-packstone including many cidaris spines and Bafflestone containing corals. The lithology of the SSF Quarry is subdivided to 5 facies: Oncoidal Packstone, Peloidal Packstone, Bioclastic Packstone, Bindstone, and Frame-Bafflestone. At Gunung Panga Area, mega fossils (especially Rudists and nerineoids) are yielded at all facies, and sparitic cements occupy the intergranular spaces.

We surveyed at Bunkit Akut Quarry near Kuching-Serian Road, which is located at 40km south-southeast of Kuching City (Fig.1). The limestone is clearly stratified and slumping fold is developed at the upper horizon of the surveyed section. Lithofacies are fine-grained limestone and subdivided into 3 facies: Calcarenite, Lime mudstone, and bioclastic wacke-stone. Additionally, mud beddings are intercalated with limestone at the middle to upper horizon of surveyed section.

Because of sparitic cements and hermatypic biota, the depositional environments of Gunung Panga are considered to be photic zone influenced by wave. On the other hand, because of absence of hermatypic biota and developing of slumping fold, the depositional environment of Bunkit Akut section is considered to be deeper than storm wave base, and environment where siliciclasts were intermittently supplied. Based on our description, it is concluded that the depositional environment of the Bau Limestone Formation is...
subdivided into two environments: shallow marine and hemipelagic at least.

Outer layers of rudist shells collected from Marup and SSF Quarries were powdered, and Sr was separated from them by a use of chromatography using Sr ion exchange resin and nitric acid. The $^{87}\text{Sr}/^{86}\text{Sr}$ isotopic ratios were measured by a thermal ionizing mass spectrometer (TIMS; Thermo Finnigan TORN). The Sr ratios were projected on the standard age-profile of Look-up Table (MacArthur, et al., 2001) in order to evaluate the depositional age.

The result shows the depositing age of Marup Quarry is from 156.40 to 153.10 million years ago, and that the depositing age of SSF Quarry is from 157.85 to 152.65 million years ago. It is obvious that $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of Marup and SSF are correlated to late Oxfordian to early Kimmeridgian of the Late Jurassic.

In previous studies, the age of Bau Limestone Formation was indefinitely considered to be later than the Late Jurassic by poor-preserved ammonoid fossils. But in this study, we are able to determine the depositing age of the specific horizon of the Bau Limestone Formation for the first time.

Additionally, this study suggests the age of Marup and SSF Quarries, where rudists are collected, is late Oxfordian to Kimmeridgian. These rudists are possibly one of the oldest rudist assemblages of the Far East.

**Key Words:** Bau Limestone Formation; Sr isotopic age; Jurassic; Malaysia

**References:**


Palaeontology and Biostratigraphy of Jurassic Clam Shrimps of the Sichuan Basin, China

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Clam shrimps are a common fossil group in the non-marine Mesozoic sequences. They are normally abundant and widely distributed in sediments that are accumulated in quiet, freshwater environment. Their rapid revolution makes them biostratigraphically useful for subdividing and classifying non-marine sequences (Chen et al., 2007). Abundant fossil clam shrimps have been recovered in the Sichuan Basin (Fig.1). The earliest fossil clam shrimps, reported by Chi Rongshen in 1931, were collected by Zhao Yazeng and Huang Jiqing from the Lower Shaximiao Formation. Since then, during geological mapping, geological prospecting in the Sichuan Basin, abundant clam shrimp fossils have been recovered, and taxonomically described (Zhang et al., 2004; Shen and Chen, 1982; Xu, 1982). Recently, through the using of scanning electron microscope, more detailed taxonomic research has been published (Li, 2004; Li et al., 2009). Here the author would introduce the five Jurassic characteristic clam shrimp faunas of the Sichuan Basin.

1. Palaeolimnadia baitianbaensis-Bulbilimnadia fauna

The Early Jurassic clam shrimp fauna has been first described from the Lower Jurassic Baitianba Formation in the Guanyuan area of northern Sichuan. The dominant taxon is Palaeolimnadia, with a few species of Euestheria. Palaeolimnadia is characterized by a big umbo, and has only several growth bands.

In south-eastern part of the Sichuan Basin, besides the above mentioned tow genera, this fauna contains another genus Bulbilimnadia, and has been recovered in the Ziliujing Formation. Bulbilimnadia differs from Palaeolimnadia by bearing elongated nodulous protuberance on big umbo. It occurs in the lower and middle part of the Ziliujing Formation of Wanxian, Shizhu, Tieshan, and also in the Ma’anshan Member of the Ziliujing Formation of Hechuan, Chongqing.

Althought Palaeolimnadia ranges from Late Permian through Middle Jurassic, but the fossil clam shrimp fauna dominated by this genus is normally occurred in Early Jurassic. This clam shrimp fauna consists of P. baitianbaensis, P. sichuanensis, P. longmenshanensis, P. chuan- beiensis, P. baoxingensis, P. lingguanensis, P. rhombica, P. subtrangularis, P. houjienis, P. pengxianensis, P. aff. dundugobica, P. cf. parva, P. oblonga, P. guangyuanensis, Euestheria? taniiformis, E.? elongate, Bulbilimnadia bullata, B. wanxianensis, Pseudolimnadia? weixinensis.

2. Shizhuestheria fauna

The Shizhuestheria fauna occurs in the Middle Jurassic Xintiangou Formation, and consists of S. truncata, and Euestheria spp. Shizhuestheria has relatively wider growth bands in the infancy stage, on which there are medium-sized reticulation, and several small reticulation (or puncta) occur within each lumina; the growth bands become narrower since the adult stage, and the reticulation become faint or disappeared, and only small reticulation (or puncta) remains (Li et al., 2009).

3. Euestheria ziliujingensis fauna

This Middle Jurassic fauna consists of Euestheria ziliujingensis, E. haiyanggouensis, E. yanjiawanensis, E. complanata, E. rotunda, Pseudolimnadia? shaxiensis. The carapace is normally small and rounded, ornamented with small-sized reticulation. And it occurs in the lowest member of the Guanyun Group in Guangyuan, northern Sichuan, and in the Lower Shaximiao Formation in southern part of the Sichuan Basin. It also occurs in the Zhanghe and Hepingxiang formations of Yunnan, the Haiyanggou Formation of western Liaoning, and in the contemporaneous deposits in Gansu Province and Xinjiang Autonomous District of north-western China.

4. Paleoleptestheria? chinensis fauna

This fauna occurs in the Middle Jurassic Upper Shaximiao Formation in Nanchuan and Shizhu Counties, south-eastern Sichuan Basin, and the Second Member of Guanyun Group in northern Sichuan Basin. Paleoleptestheria? chinensis is small or medium in size, with medium-sized cavernous reticulation, which shows as isolated rounded or elliptical nodules on external mould.

5. Eosestheriopsis dianzhongensis fauna

This fauna consists of Eosestheriopsis dianzhongensis, E. semiobrata, E. subovata, suiningestheria minor, Qinghaestheria Sichuanensis, Q. chuanzhongensis, Huilongestheria rotunda. It is widely distributed in the Sichuan Basin, and occurs in the Upper Jurassic Suining Formation of Leshan County, and in the Penglaizhen Formation of Daying, Zhongjiang and Shuangliu counties. This fauna has first been described from the Upper Jurassic Tuodian Formation of...
Chuxiong, Dayao, Shuangbai, Xiangyun and Yongren of Yunnan Province. *Eosestheria* is an important component of the wellknown Early Cretaceous *Eosestheria* fauna, which has occupied the whole drainage system of the ancient Heilong River in eastern Asia (Li et al., 2007). *Eosestheriopsis* has relatively smaller and thinner carapace, besides the large-sized reticulation and radial lirae ornament on lower parts of growth bands, the reticulation wall or radial lira forms a nodule when reaching the upper margin of each growth line. Thus, there is a row of nodules along the upper margin of each growth line of the carapace. Another important component of this fauna is *Qihaiestheria*, which have small carapace and have radial lirae and cross bars. There is a row of puncta along each radial lira and cross bars, and puncta occupy the upper part of the carapace and within the reticulation in the lower part of the carapace. The growth lines are serrated along its lower margins. This genus has first been described from the Upper Jurassic Hongshuigou Formation in the western Qaidam Basin of Qinghai Province (Wang, 1983). It associates with the Kimmeridgian ostracode *Cetacella*, which has also been reported occurring in the Suiying Formation in the Sichuan Basin. Thus, the Suiying and Penglaizhen formations should be Late Jurassic in age.

**Key words:** Jurassic; Biostratigraphy; Clam shrimp; Sichuan; China

![Fig.1 Fossil clam shrimp distribution in the Sichuan Basin](image)

**References:**


High-resolution Cyclostratigraphic Analysis of the Magnetic Susceptibility Record from the Upper Bajocian to Upper Bathonian of Central Poland and the Mineralogical Link Between Magnetic Susceptibility and Palaeoclimatic Changes

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The Middle Jurassic in Central Poland begins with sandy deposits representing the Koscielisko Beds that yield ammonites indicative of the lower Bajocian to lowermost part of the upper Bajocian (Kopik, 1998). They are overlain by an up to 180m thick, upper Bajocian to upper Bathonian sequence, comprising black clays and siltstones with ironstone concretions. These rocks are known as the Ore Bearing Czestochowa Clay Formation, famous due to the wealth of the extraordinarily preserved ammonites that are known since the nineteenth century and which are the basis for a very detailed chronostratigraphic interpretation (Matyja, et al., 2006). The Ore Bearing Czestochowa Clay Formation is currently well exposed in the Czestochowa Region in several clay pits.

![Image: Exemplification of the detrital grains of chromites identified in the Middle Bathonian black clays in the Ore Bearing Czestochowa Clay Formation](image)

To obtain a high-resolution magnetic susceptibility (MS) record we collected 2650 samples (taken with 2cm spacing) covering the entire accessible succession. All of the samples were taken as cores of standard palaeomagnetic dimensions (25.4×22 mm), and MS was measured with an Agico Kappabridge KLY-3 susceptometer.

The output MS signal was subjected to spectral analysis. Composite cycles have a frequency ratio that strongly corresponds to the ratio of orbital Milankovitch cycles.

All specimens have a mass MS between $3.5 \times 10^{-8}$ m$^3$·kg$^{-1}$ and $8 \times 10^{-8}$ m$^3$·kg$^{-1}$ suggesting a lack of or a very small amount of ferromagnetic minerals. We selected samples at MS extrema for further investigation. Rock magnetic (hysteresis parameters) and mineralogical (X-ray diffraction, scanning electron microscopy and energy dispersive spectroscopy) studies show the presence of a very few detrital grains of magnetite, Ti-magnetite and chromite in all test samples (Fig.1). The specimens with the highest MS values contain relatively more illite (paramagnetic mineral, mass MS = $15 \times 10^{-8}$ m$^3$·kg$^{-1}$) and less kaolinite (weak diamagnetic mineral, mass MS = $-2 \times 10^{-8}$ m$^3$·kg$^{-1}$). The specimens with the lowest MS values contain relatively less illite and more kaolinite. Hence, the changing proportions of illite (a product of weathering in cold and dry climate), and kaolinite (which formed in humid and warm climate) are responsible for the MS variations in the studied succession.

Key words: Cyclostratigraphy; Bajocian–Bathonian; Rock magnetism; Poland

References:


The Toarcian Stage in Asturias (North Spain): Ammonite Record, Stratigraphy and Correlations

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Although Toarcian sedimentary rocks of the Asturian coast (Spain) were studied by Suárez-Vega (1974), there are few papers that examine in detail ammonite successions and other stratigraphic aspects derived from its knowledge. We review in this work the available information and improve the knowledge of the ammonite record and biochronostratigraphy, as well as the sequence stratigraphy and chemostratigraphy.

Four sections have been studied along the Asturian coast: 1. El Puntal Section (Variabilis Zone to Aalensis Zone), 2. W-Rodiles Section (Tenuicostatum Zone to Variabilis Zone), 3. Santa Mera Section (Variabilis Zone to Aalensis Zone), and 4. Lastres Section (Tenuiscostatum and Serpentinum Zones). W-Rodiles and Santa Mera Sections have provided belemnites from numerous levels used for the isotopic analysis.

The Toarcian succession, 45 m thick, consists of an alternation of grey to black limestones and marly-limestones with marls, without relevant discontinuities. It corresponds to the upper part of the Santa Mera Member of the Rodiles Formation defined by Valenzuela et al. (1986), and it is organized in T-R cycles that show the transgressive maximums at the Tenuicostatum Zone (Semicelatum Subzone), Bifrons Zone (Bifrons Subzone) and Dispansum Zone (Gruneri Subzone). The first one is located within a black marls level very rich in organic matter; the second one is the most relevant as it represents the transgressive maximum for the Lower Jurassic; and the third one is situated within a marls level that can be recognized all over North and East Spain (Gómez et al., 2008). The deposit of the Toarcian succession takes place an external ramp within an epeiric platform below the storm wave base.

42 biohorizons have been identified by means of the ammonite assemblages, and 8 chrono zones, 20 subchrono zones and 32 of the 34 standard zonules (Elmi et al., 1997) have been characterized. The Pliensbachian-Toarcian boundary is situated at level 27 in the W-Rodiles Section, where the first appearance of Dactylioceras (Eodactylites) takes place. The uppermost Pliensbachian-lowermost Toarcian succession of ammonite in the Asturian Coast is: Pleuroceras followed by levels with Emaciaticeras and Canavaria, that characterize the Spinatum Zone, Hawskerense Subzone, and afterwards Dactylioceras (Eodactylites). This ammonite assemblages succession is similar to the one recorded in the proposed Toarcian GSSP (Peniche Section, Portugal, Elmi et al., 2007) and the proposed ASP (Almonacid de la Cuba Section, Spain, Comas-Rengifo et al., 2010). Hiatus and discontinuities are present in the Toarcian-Aalenian transition being frequent from Aalensis Zone (Mactra Subzone) upwards.

Stable isotope data, based on the analysis of belemnite calcite and bulk carbonates, allowed characterization of positive δ13C excursions in the Tenuicostatum Zone (Semicelatum Subzone), in the Serpentinum Zone (Falciferum Subzone) and in the Pseudoradiosa Zone (Levesquei Subzone), as well as negative δ13C excursions in the Bifrons Zone, (Bifrons Subzone) and in the Thouarsense-Dispansum zonal transition. Seawater temperatures have been calculated from the δ18O values. After a cool interval in the Spainatum Zone, a first increase in the seawater temperature of about 4 ºC was recorded around the Plienbachian-Toarcian boundary. At the Tenuicostatum-Serpentinum zonal transition, a new increase in temperature of more than 5ºC coincides with a mass extinction event which notably affects the ammonoids, brachiopods and other benthic and platonic organisms. Other thermal peaks occurred at the Bifrons Zone (Bifrons Subzone), Variabilis Zone (Illustris-Vitiosa subzones) and Dispansum Zone (Insigne Subzone), which unequally influenced to the represented taxonomical groups.

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Key words: Ammonoidea; Stratigraphy; Stable isotope; Correlations; Early Jurassic

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Comas-Rengifo M.J., Arias C., Gómez J.J., et al. A complementary section for the proposed Toarcian (Lower Jurassic) global stratotype: The Almo-
Sinemurian Oceanic Event Recorded in the Deep-sea Sediments from the Western Panthalassa

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Toarcian oceanic anoxic event (OAE) in Early Jurassic is one of the famous OAEs in Phanerozoic, however, there are few studies to examine environmental change of whole Early Jurassic time recorded in deep-sea sediments. Here we present a remarkable change of C-isotopic ratios in organic carbon and concentrations of trace elements of Lower Jurassic bedded cherts of SW Japan, which suggest the Sinemurian OAE that is predicted by Jenkyns (1988). The data indicates that a weak OAE probably occurred in panthalassian pelagic ocean and was recorded in deep-sea sediments.

The studied samples were obtained from a certain Sinemurian interval (c. 3 m in thickness) of the Katsuyama section consisting of red bedded chert sequence in the Inuyama area, SW Japan. The bedded chert of the Katsuyama section is considered as a pelagic sediment formed in deep-sea of the Panthalassa because of its extremely slow sedimentation rate (c. 1 m/m.y for Lower Jurassic part) and geological setting.

Radiolarian fossils obtained from the study part of the Katsuyama section represent characteristic taxa of the Subzone II of the Parahsuum simplum radiolarian zone of Hori (1990). Based on a faunal comparison with radiolarians from the Queen Charlotte Islands, Canada, and the sedimentation rate (1 m/m.y.) of this bedded chert, the study part is corresponded to a certain interval of the Sinemurian stage, and estimated as c. 3 m.y. duration. Abundance of spherical Spumellaria along the stratigraphic column was observed and a bloom period was detected in Sinemurian.

The bulk samples of shale parts in the bedded chert have been treated and C-isotopic ratios of organic matter have been examined at 57 horizons. The obtained $\delta^{13}$C$_{org}$ (‰ VS PDB) values indicate around -26‰ in average, and show remarkable excursions consisting of a positive shift from -26‰ to -23‰, and successively a negative spike from -23‰ to -28‰ in the middle part of the section (Fig. 1). In the upper part of the section, a small fluctuation (<3‰ range) and a negative spike are recognized, which is possibly correlated to around the Sinemurian-Pliensbachian boundary.

The variations of the trace elements normalized to Al contents are also examined through the interval of the stratigraphic column. The Rb/Al and Zr/Al ratios show no distinctive change along the column and posses stable values in whole interval. On the other hand, the V/Al ratios increase distinctively at the basal part, which almost simultaneously occurred in the first positive shift of $\delta^{13}$C$_{org}$ value, and then decrease rapidly in the middle part of the study section. After the peak of $\delta^{13}$C$_{org}$, the V/Al ratio shows low value and does not change remarkably. In general, Zr and Rb contents of deep-sea chert are mostly originated in materials derived from continental surface, therefore, the data suggests that environmental change did not occur on land during the study interval, but happened in pelagic sea, possibly concerning to redox condition.

Spherical Spumellaria, which is considered as an opportunistic taxon of Radiolaria, bloomed synchronously in the negative $\delta^{13}$C$_{org}$ spike after the maximum peak of V/Al ratio. Although there are no black sedimentary rocks in Sinemurian bedded cherts, the results reveal the possibility that a weak anoxic environment occurred in the Panthalassa at Sinemurian, and the bloom of spherical Spumellaria possibly concerned to this oceanic event. Summarizing all data and inference, we may propose a following tentative theory about this detected event: 1) High production rate of pelagic ocean caused the positive shift of $\delta^{13}$C$_{org}$ value, 2) some part of water column became anoxic,
and extra V was supplied into deep-sea floor, 3) a small extinction, 4) Spherical Spumellaria bloomed, and 5) a negative spike was recorded.

Our results seem to be one of the evidences that a Sinemurian OAE took place on a global scale, however further precise study must be required to verify it.

Key words: Sinemurian; Anoxic; Carbon isotope; Radiolaria

References:
Oxfordian Sea-Level Oscillations: 400-kyr Periodicity of Sequences in British (Subboreal) and French (Sub-Mediterranean) Reference Sections

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The combination of cycle stratigraphy, magnetostratigraphy and ammonite biostratigraphy of an array of sections within Europe has enabled construction of an integrated Oxfordian time scale with for the Boreal, Subboreal and Tethyan (Sub-Mediterranean) faunal provinces. The durations for the ammonite zones/subzones are derived from direct cycle-stratigraphy studies in French basinal successions or interpolated from calibration of spreading rates for the corresponding marine magnetic anomalies.

The dominant sedimentary cycle used for the scaling of French reference sections in basinal settings is the 405-kyr climatic oscillation caused by long-period variations in the eccentricity of Earth’s orbit. The Oxfordian of the Subboreal region spans 14.5 of these main cycles (implying a duration of 5.9 Myr).

In the lower to middle Oxfordian of SE France, these oscillations within Terres Noires formation are marked by relative changes in clay content. The correlative shallow-marine shelf successions of Dorset and Yorkshire, England, have quasi-periodic sedimentary hiatuses and facies shifts that are associated with low relative sea-level and erosion. These tops of these lowstand/hiatuses often correspond to boundingaries in the regional ammonite zonation. The lowstand system tracts or large stratal gaps that would encompass these systems tracts in Dorset that display this apparent 405-kyr periodicity are: (1) Nothe Grit Formation (and possible hiatus at Cardioceras cordatum / Card. vertebrale subzone boundary); (2) Bencliff Grit Member and possible hiatus at Card. vertebrale / Perisphinctes plicatis subzone boundary; (3) Shortlake Member and hiatus spanning upper Peri. antecedens Subzone; (4) Stratal gap between the Nodular Rubble Member and the Trigonia Clavellata Beds (hiatus spans upper part of Peri. parandieri Subzone and base of the Peri. nummintonense Subzone); (5) Stratal gap between the Sandsfoot Clay Member and the base of the Sandsfoot Grit Member, where there is a major hiatus that spans two entire 405-kyr cycles; and (6) Osmington Mills Ironstone Member and hiatus/condensation of the Ringsteadia evoluta / Pictonia baylei (base of Kimmeridgian) boundary.

In contrast to Dorset-Yorkshire, the French basinal sections appear to represent continuous sediment accumulation. A direct comparison of French cycle-stratigraphy to British sequences has been made for the Card. cordatum through Gregoryceras transversarium interval (French cycles C6 through C10). When lowstands occur in Dorset-Yorkshire, these French sections display marked influxes of carbonate and/or reduction in clay content.

A possible model for these synchronous changes in the two settings is that a minimum in long-term eccentricity corresponds to relatively cooler summers for Earth, hence a relative accumulation of ice in high-latitude or high-elevation settings. Shelf regions would experience a relative sea-level drawdown, and influx to basins in subtropical settings might have both a reduction in clay influx due to a lesser monsoonal rainfall intensity and an increase in carbonate influx as shallow-water carbonate production is shifted seaward. The current time scale framework can be applied to Oxfordian deposits in other regions to verify this periodicity and the possible orbital-climate-facies model.

Superimposed on these 405-kyr oscillations are longer-term trends in relative sea-level (e.g., a widespread baso-Oxfordian hiatus followed by slow accumulation of lowermost Oxfordian in many regions, and an extended lowstand or hiatus spanning most of the middle Upper Oxfordian of Dorset-Yorkshire) and in regional environment (e.g., the shift from clay-dominated Lower Oxfordian to carbonate-dominated Upper Oxfordian in the basins of SE France).

Acknowledgements: This summary incorporates data and concepts contributed by Slah Boulia, Linda Hinov, Piotr Przybylski, John Wright and other colleagues; although not all of them might agree with the full suite of interpretations and models.

Key words: Oxfordian; Dorset; Yorkshire; Sequence stratigraphy; Periodicity

References:


Marine Jurassic Black Rock Series: Litho- and Biostratigraphy (Qiangtang Basin, Tibet)

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Black rock series have become a hot topic of study. Their oil-producing potential and the link to anoxic events, however, have been long recognized. From the present investigation and analysis, there are two Jurassic black rock series in Qiangtang Basin, Tibet. One is in the Shuanghu-Sewa where the different lithological types develop such as mudstones, marls, oil shales and etc. The other is in the Bailongbinghe-Amdo as limestones, marls, shales and so on.

In the Shuanghu-Sewa area, many geologists have worked and got achievements. For example, Sun et al. found Harpoceratace ammonites in the Zamunaqu profile in 1979, which showed the marine Jurassic strata crop out. From 1972 to 1982, Lv et al. found a series of the dark gray to black mudstones and shales interbedded with limestones in the Quse, Baerza and Suobucha areas. From those fossils such as ammonites, brachiopod, the strata named Quse Formation are of Lower Jurassic. Wu et al. (1985) named them as Zesong Formation developing black mudstones, marls with abundance of ammonites. In a word, these strata are of Lower Jurassic in Sewa area. But in Shuanghu area, Bilong Co section is famous for the oil shales, high-organic carbon and ammonites. Wu and Hu (1985) named the oil shales strata Bilong Formation. Based on the petrology, the whole succession is divided into three intervals characterized by different lithological types. From lower to upper they are gypsums, oil shales interbedded with limestones and mudstones, and marls interbedded with mudstones. Our detailed field investigations show that the oil shales are brown to dark in color and occur as 0.2-2.0 m thick bituminous micro-laminated beds. In 1994, a research team of Chengdu University of Technology restudied the Bilong Co section and found abundant Jurassic bivalves but none of Triassic ones. At the same time, many ammonites were found at the top of the section. We suggested that these ammonites belong to a common species with excellent preservation, whose convolute shell, convolute rim and shell decoration coincide with early Toarcian Harapoceras sp. These ammonites thus may correspond to the Harapoceras falcifer Zone in the Paris Basin and may be associated with the Posidonian Shale of SW Germany, as well as with the early Toarcian black shales occurring extensively in European epicontinental seas and the Tethyan continental margins.

The Bilong Formation is particular of the lithologies and fossils, so it does not match the Yanshiping Group, which belongs to platform environment, but is similar to the Jurassic strata of Sewa area. On the basis of our study, we suggest these strata are of the same age in spite of Quse Formation, or Zesong Formation, or Bilong Formation. In other words, there are transition strata of deep water continental shelf, to slope, and to the deep water basin different from the Yanshiping Group of platform or Mugagangri Group of deep water flysch facies. Above-mentioned results showed it is wrong of only shallow water deposits in the Qiangtang basin.

According to the ammonites in Shuanghu-Sewa area, we draw a conclusion that there are three ammonite assemblages plus one horizon representing four stages of Lower Jurassic as follows: (1) Psiloceras-Schlothemica assemblage: mainly includes Psiloceras, Schlothemica etc., which are the index fossils of Hettangian stage in the southern Tibet; (2) Ariettites-Suiciferites assemblage: mainly includes Arnioceras, Ariettites, Baucautliceras, Geviceras and so on, which compares to the Arnioceras sericostatum zone and A. buckland zone of Sinemurian stage in Europe or Ridang Formation of southern Tibet; (3) Lyloceras cf. fimbriatum horizon: is paragenetic association of Productylioceras enodum in the Ridang Formation of Pliensbachian, and (4) Hildocers-Tiltonecercus assemblage: mainly includes Tiltoneceras, Eleganticeras, Maconiceras, Hildaites, Hildocerataceae, Oxynoticeratidae and so on of early Toarcian. So we suggested that the ammonites of the Bilong Co oil shales may be correspondent to the Hildocers-Tiltonecercus assemblage at top of the Quse Formation, or Harapoceras falcifer zone in the Paris Basin of France.

The other black rock series crop out in Bailongbinghe and Amdo areas. Zhang (1985) named Bailongbinghe Formation because of the Bailongbinghe section. From the lithologic characteristics, they are marls, mudstones, shales, limestones or oolite limestones with thickness of 2080 m. Ammonites are main ones, secondly the bivalvias. In especially, abundant ammonites are of Virgatosphincters minusculus, V. cf. pompeckii, V. cf. subfrequens, V. cf. kraffti, Autolacosphinctes and so on in the fourth stratum.

The Amdo 114 section is composed of sand-stone, limestone, biosparite, silty limestone and marls with
thickness of 90 m. Fossils include bivalves Buchia, Chlamys, Posidonia plus some significant ammonite fossils: the Virgatos-phinctinae subfamily (including Aulacosphinctes, Virgatosphinctes); the Berriasellinae subfamily (including Blanfordiceras); and the Spiti-ceratinae subfamily (including Spiticeras). These am-
monites are typical of Late Tithonian to Early Berrisian.
Xu et al., (1990) and Yin et al., (1996) worked in detail
about Late Jurassic ammonites including three horizons
from lower to upper: (1) Aulacosphinctoides-Virgato-
sphinctes: are of Early Tithonian; (2) Aulacosphinctes:
mainly include Aulacosphinctes hollandi, Haplophy-
loceras and Kossamatia belong to Middle Tithonian,
and (3) Blanfordiceras-Berriasella oppelii: are of Late
Tithonian. According to the above-mentioned am-
monites, we put forward the Amdo 114 strata are of
Middle to Late Tithonian and the contemporaneous
strata occur in the southern-eastern France, Denmark,
Madagascar, Indian, and Nepal.

The Jurassic Black rock series in Tibet have been a
focus of scientific interests and are still debated today
about many questions.

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Key words: Jurassic; Black rock series; Stratig-
raphy; Qiangtang Basin

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Jurassic rocks of Thailand consist of marine, brackish and non-marine aspects distributed throughout the country. Marine Jurassic rocks are well exposed in the Mae Sot, Umphang, and Phop Phra areas, less extensively near Mae Hong Son, Kanchanaburi, Chumphon, Nakhon Si Thammarat and Krabi. Generally, these rocks are unconformably underlain by Permian and Triassic rocks, and are overlain by Quaternary strata. Fourteen lithostratigraphic units are defined (in ascending order): Pa Lan, Mai Hung, Kong Mu Formations of the Huai Pong Group in the Mae Hong Son area; Khun Huai, Doi Yot, Pha De Formations of the Huai Fai Group, Mae Sot area; Klo Tho, Ta Sue Kho, Pu Khloe Khi, Lu Kloc Tu Formations of the Umphang Group, Umphang area; and Khlong Min Formation in the Chumphon, Nakhon Si Thammarat, and Krabi areas. Mudstones, siltstones, sandstones, and limestones are dominant lithologies in the Mae Sot, Phob Phra, Umphang, Kanchanaburi and Mae Hong Son areas; marls are found only in Mae Sot. Sequences are approximately 900m thick (Mae Sot), 450m thick (Umphang) and thinner elsewhere, especially the south. Based on ammonites, brackish to marine bivalves, and foraminifera, the beds are dated mainly as Toarcian–Early Bajocian.

A paleoecological analysis and depositional history of the marine Jurassic strata cropping out in the western part of Thailand are reported, based on bivalve assemblages with additional data from ammonites, brachiopods and microfossils. Generally, the benthic bivalve groups in most outcrops are rich in infaunal, semi-infaunal and epifaunal suspension-feeders. Of these, infaunal forms dominate. The diversity of the benthic assemblage was influenced by energy level, substrate, sedimentation rate and salinity. Low to intermediate energy levels and rather soft fine-grained siliciclastic substrate are proposed as factors governing faunal distribution and explaining the greater abundance and diversity of infaunal than epifaunal suspension-feeders. There were paleoenvironmental changes both in space and time, i.e. from north to south (Mae Sot to Umphang) and from Toarcian to Early Bajocian. In the Toarcian, most outcrops in Umphang are dominated by benthic bivalve groups (infaunal, semi-infaunal and epifaunal associations) implying warm, shallow water (inner neritic, 250-100m) and oxygenated conditions, except for the Mae Sot area where a deeper setting (outer neritic to possibly upper continental slope, 50-200m) with restricted basinal anoxic conditions is favoured as indicated by the presence of Bositra. After higher energy conditions in the Toarcian, lower energy conditions with low sediment supplies prevail in the Alenian, and the Mae Sot area was still a restricted basin. As a result of higher sea level, the oxygen content in the basin is increased, resulting in the presence of the ammonites. By the end of the Alenian–Early Bajocian, an ammonite-bivalve association (Mixed Facies A) and the presence of corals and microfauna (Mixed Facies B) are dominant but pass upwards to near-shore higher energy conditions in most area, except for restricted basin in Mae Sot. By the Middle Bajocian the environment in all areas had changed from marine to non-marine.

Based mainly on 5 measured sections in the Mae Sot area, marine Jurassic rocks of the Khun Huai, Doi Yot, and Pha De Formations have been selected for detailed study with the total thickness varying from 200-832m. The sedimentary sequences of the group are analyzed in terms of lithofacies association representing the shoreface, fan-deltas, protected lagoon, intertidal, subtidal and inner to outer ramp environments with occasional carbonate platform and reef flat. The Toarcian rocks were represented by transgressive-regressive (T-R) cycles and gradually changed to the highest sea level and water depth in the Aalenian. During late Aalenian to early Bajocian, sea level was still changing to transgressive phase. After early Bajocian, the sea level was retreated from this area. The eustatic curves in this study during Toarcian–early Bajocian correspond to the global curves, but differ significantly in the Late Jurassic–Cretaceous. In Late Jurassic–Cretaceous, T-R phases were conversely and probably caused by local tectonic movements.

The non-marine Jurassic rocks are widespread in the northeastern part (the Khorat Plateau), and partly in the northern, eastern, and southern portions of Thailand. In the Khorat Plateau, the rocks, more than 1,000 m thick, are represented by the Phu Kradung and Phra Wihan Formations of the Khorat Group. The rocks are less extensive in the north, east, and south, respectively. Reddish brown to greyish purple sandstones, siltstones, claystones, conglomeratic sandstones and conglomerates are the main lithological features; calcere nodules are also present in claystones only in the Phu Kradung Formation. The non-marine Jurassic rocks are interpreted as having been deposited mostly by the meandering and braided rivers in semi-arid and slightly humid conditions for the Phu Kradung and Phra Wihan Formations, respectively, except for the south where lacustrine deposits dominate. Age determinations are based mainly on vertebrates, bivalves and palynomorphs indicating that the rocks are reassigned to the Jurassic-possibly Early Cretaceous.

Key words: Jurassic; Marine; Non-marine; Thailand
Lithological and Palaeontological Characteristic of the Upper Bajocian to Lower Oxfordian Dalichay Formation in Emamzadeh Hashem Area, Central Alborz, North Iran

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The Alborz region in northern Iran extends from Azerbaijan in northwestern to Khorasan in northeastern Iran. The Middle and Upper Jurassic rocks (Upper Bajocian to Upper Tithonian) of northern Iran are of great importance due to their unique characteristics and extensive outcrops in Alborz region. These rocks were introduced as the Dalichay Formation by Steiger (1966) and the Lar Formation by Assereto (1966). The Dalichay Formation was deposited from deeper shelf to deeper open marine and its thickness increases from west to east Alborz and reaches its greatest thickness in the eastern Alborz.

In the northwest of Emamzadeh Hashem (File-Zamin section) in central Alborz, the Dalichay Formation with a thickness of 370 m is alternatively composed of green marl and limestone that can be divided into three informal members (Fig.1); including light-green marls (member 1), light-green marls with intercalations of brown, medium-bedded limestones (member 2) and red, medium-bedded cherty limestones with intercalations of light-green marls (member 3). This formation overlies the fluvial delta facies of Shemshak Formation (sandstone and shale) with Early Jurassic age and it is gradually covered by the thick-bedded shallow-water limestones of Lar Formation with Late Jurassic age. The gap between the Dalichay and Shemshak formations is related to Middle Cimmerian organic phase.

Ammonite fauna collected from different levels of the Dalichay Formation in studied section indicate a Late Bajocian to Early Oxfordian age for the formation. In this study, 132 ammonite fauna were collected and they belong to the families of Morphoceratidae, Stephanoceratidae, Oppeliidae, Perispincitidae, Parkinsonidae, Reinekeiidae and Aspidoceratidae. Paleobiogeographically, these ammonite fauna show approximately sub-Mediterranean bio-province and also show paleogeographic position of the Alborz region in the Northern Tethys Ocean during Middle to early Late Jurassic time.

Biogeographically, the Middle to Late Callovian ammonite fauna of the Dalichay Formation belong to the northern Tethys Ocean and show great similarity with those from Central and Western Europe (Schairer et al., 1992). The existence of similar rocks (with similar stratigraphy position) in northern Afghanistan, Turkmenistan, Tajikistan, and central Pamir shows that similar conditions and sedimentary environments existed along the northern margin of the Tethys ocean during Middle to early Late Jurassic time.

Key words: Jurassic; Ammonite; Dalichay Formation; Emamzadeh Hashem; Central Alborz

References:
Fig. 1 Lithological and palaeontological characteristic of the Dalichay Formation in northeast of Emamzadeh Hashem, Central Alborz, North Iran
The Ostracod Fauna of the Section Albstadt-Pfeffingen (Baden-Württemberg)

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The ostracod fauna from the Bathonian and lower Callovian of Albstadt-Pfeffingen (Baden-Württemberg, S Germany) has been studied. The Pfeffingen section is outstanding for its richness in ammonites and therefore has been proposed as Callovian GSSP by Callomon & Dietl (1990, 2000). The study of 13 samples yielded five faunal assemblages, reflecting the stratigraphic units of the section: the lower Bathonian (Zigzag zone), the middle Bathonian belonging to the Progracilis zone, the upper Bathonian of the Orbis zone (the Discus zone was not sampled) and the lower Callovian belonging to the Herveyi and Koenigi zones.

In general the Bathonian assemblages are more diverse than those from the Callovian. At the Bathonian/Callovian boundary a significant number of last occurrences of taxa are recorded. In the Keppleri subzone of the lower Callovian poor micro-faunal assemblages indicate infavourable benthic conditions. In the upper Herveyi and the lower Koenigi zones the number of individuals and the diversity both increase again.

The ostracod fauna of the Orbis zone is characterized by the first appearance of several species, e.g. Neurocythere plena, Cytherella limpida, Procytherura ovaliformis, Eucytherura parairregularis and Pleurocythere kurksensis. According to Franz et al., (2009) Neurocythere plena is the index species of the N. plena ostracod zone. 25 species were found only in the Orbis zone, 17 of which are represented by a single specimen (see above). 9 further species of the genera Blaszykina, Glyptocythere, Morkhovenicythereis and Oligocythereis have their last occurrence in the upper Bathonian.

Despite of the very poor fauna – a total of only 13 specimens was obtained from 3 samples – the keppleri horizon of the Herveyi zone can be characterized by its ostracod fauna: the most significant genus is Neurocythere (5 specimens), represented by three subspecies of N. cruciata. Neurocythere cruciata cruciata, which sharply characterizes the Bathonian/Callovian boundary (Buck et al., 1966: 43), appears in a thin marly layer immediately above the Bathonian/Callovian boundary at the base of the keppleri horizon, but is very scarce. Franz et al., (2009) recently defined a Neurocythere cruciata ostracod zone for the basal Callovian.

The assembly of the suevicum horizon of the Herveyi zone and the Koenigi zone is also dominated by the genus Neurocythere (31 specimens from a total of 77). The Bairdiidae play a subdominant role, represented by 11 specimens. N. cruciata alata, Terquemula flexicosta and Praeschuleridea subtrigona appear in the suevicum horizon for the first time in this section, Micropneumatocythere aff. convexa and Progonocythere polonica have their last occurrences. Neurocythere caesa caesa, Bythoceratina stimulea, Hutsonia sp. and Pontocyprrella atypica appear for the first time in the Koenigi zone.

In general the ostracod zonation shows a lower stratigraphical resolution than the ammonite zonation (see e.g. Bate, 2009, Brand & Mönnig, 2009, Bodergat, 1997, Franz et al., 2009, Wilkinson & Whatley, 2009). In Pfeffingen the most prominent boundary is lying at the transition upper Bathonian/lower Callovian. 22 species have their last occurrences in the Orbis zone – not including taxa, which are represented by single specimens. Neurocythere cruciata cruciata, N. cruciata francoonica, Praeschuleridea subtrigona and Terquemula flexicosta have their first occurrences in the Herveyi zone.

The ostracod assemblages of the Bathonian and lower Callovian in the section Albstadt-Pfeffingen are fully marine, but in general are made up of a small number of specimens. The scarcity of specimens in the samples might be due to unfavourable benthic conditions, but this needs further studies. Specimens of the family Progonocytheridae dominate all the studied samples. However, in the Bathonian they are accompanied by the subdominant families Cytheruridae, Trachyleberididae, Schulerideidae and, less important, Protocytheridae, all of which show a remarkable decrease at the Bathonian/Callovian boundary.

The ostracod zonation as established by Franz et al., (2009) – Connexa zone, Capreolata subzone, Plena zone and Cruciata zone – is recognizable in the Bathonian and the Callovian of Pfeffingen.

The highest number of last occurrences is concentrated in the upper Bathonian. This could probably represent a significant faunal turnover, which requires confirmation through the study of ostracod assemblages from the same time interval in other areas.
Key words: Callovian; GSSP; Ostracods; Biostratigraphy

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Moroccan Jurassic System: An Overview

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Jurassic Paleogeography of Morocco
Jurassic sedimentation is marked by a strong differentiation in the Atlas domain with a distinct development of two main regions:

Western area corresponding to a newly created basin open to the Atlantic but closed in the east along the length of the ancient mountain massif. This represents the coastal region (Essaouira, Agadir Basins).

Central and eastern part consisting of the intra-continental basins of the central High Atlas and Eastern or Sahara Atlas, separated by the Tamlelt sill. These basins together with the Middle Atlas Basin to the north constitute the western prolongation of the Tethys Ocean.

Atlas domain
The distribution of facies during the Jurassic is controlled by the structural framework inherited from the Hercynian orogeny, in particular by faults N60-70, N30-40 and E-W at N120. Episodes of rifting and expansion of the Tethys occurred during this period, and sedimentation became subjected to both eustatic and tectonic control.

In the Atlas region, Laville (1985) noted the following:

- A transgression in the early Lias, originating from the east and linked to the Tethys, reaching its maximum in the Pliensbachian.
- A regression in the Toarcian.
- A new transgression towards the end of the late Toarcian, which reached its peak in the Aalenian-Bajocian, when significant subsidence occurred.
- Basin infilling and regression in the Bajocian-Bathonian with widespread development of carbonate reefs, dolomite and deltaic facies.
- In the Callovian-Oxfordian, the regressive mega-sequence, which started in the previous cycle, kept on accumulating. Deltaic, coarse-grained, quartz dominated sediments were deposited within small subsiding basins.
- In the Kimmeridgian-Portlandian, this cycle registers the ongoing emergence of the High Atlas with the withdrawal of the Tethys to the east in the Sahara Basin.

Figures summarize the evolution of Jurassic deposits in the Atlas region, especially for the central Atlas. Du Dresnay (1979) identified:

- Early Lias: thin carbonate deposits on platforms with relatively rare reefs.
- Middle Lias: widespread development of reefs. Basinal facies are rich in ammonites. Carbonates become more marly towards the top.
- Late Lias and middle Jurassic (Toarcian to Bajocian/Bathonian) with intercalations of calcareous horizons within the marly facies rich in ammonites in the center of the basin. On the platform, the Toarcian is transgressive and the Bajocian/Bathonian is characterized by the development of carbonate ramps.
- End of middle Jurassic, marked by basin infilling and development of red beds containing the well known Moroccan dinosaur Cétiosaurus Moghrébiensis newly renamed Atlasaurus Imlaki.

Structural characteristics of Jurassic basins
In the Atlas region (High and Middle Atlas), the overall geometry of basins is characterized by two types of surrounding structures:

1-depocenters: forming large subsiding basins with clear “S”- or lozange-shape. This geometry is often prominently delineated by the contacts between individual Jurassic formations and by the sigmoid appearance of their cartographic axis.

2-furrows: consisting of narrow, synsedimentary anticlines, which are marked by thinning along their flanks with progressive discordance, intraformational breaks, gravitational structures and even local angular unconformities.

3-subvolcanic intrusions: In the center and a long the axis of basins, they are located in the central part of some furrows. They form a group of small subvolcanic massifs associated with dykes, sills, flows. Their mineralogical characteristics exhibit an alkaline affinity.

Laville (1985) noted in the Amouguer intrusions the presence of: doleritic dykes (d1), trochohilitic pluton (tc) recut by monzodiorite (mz), four networks of microfractures. To these intrusions (dyke and pluton) are associated concentric and radial joints, which recut previous formations.

Genesis model of Atlas basins
An examination of the geometry of Jurassic depocenters allows the following characters to be recognized: the Atlas basin consists of small basins that are more or less fitted together; their limits correspond to very narrow anticlinal furrows, which follow three directions related to late Hercynian events (N50-N60; N80-N90 et N120); these basins have an “S” or lozange-shape. In the center and along the axis of these basins, subvolcanic intrusions occupy the central part of some furrows. The overall characters of Atlas basins suggest an origin linked to displacements.

With the aim to better understand the importance of these displacements, we shall briefly describe the
following models:

a-Models of Crowell (1974): They invoked the notion of curvature that exists along a displacement or a non parallel alignment between two displacements. The play of the displacement initiates the curvature of rectilinear displacement, a large opening, which corresponds on a multikilometer scale to a “pull apart” basin.

b-Model of Haydin et Nurr (1982): In a simple model the shape of the “pull apart” basin generally depended on two parameters: on the width of the original separation of two faults “en échelons”, which controls the width of the basin; on the horizontal displacement of the fault, which increases the length of the basin when growing.

c-Models of Mann et al. (1983): These authors analyzed the geometrical shapes of several “pull apart” basins and proposed several stages in their development. They also demonstrated that the “S” or lozange-shape characterize basins generated from sinistral displacement and the “Z” shape basins included between dextral displacements.

d-Notions of “relai” of displacements: The “relai” designates the zone situated between two displacements “en échelons”. This zone is defined in terms of “recouvrement” and “separation”.

e-Model microtectonique of Rispoli (1981): It concerns the problem of disturbances at the ends of displacements. It shows that microstructures (slits, stylolites) take a different direction from their regional direction and indicate how the deformation is concentrated at both ends of a displacement.

f-“Pony tail” model of Granier (1985): In this model, the dampening of the horizontal movement in the early stages occurs at both ends of the displacement in the shape of a “pony tail”. Each component of this “pony tail” appears to correspond to a long, thin and parallel or sigmoid slit of tension.

g-Model of Riedel: When a displacement is active, it generates two openings: R (synthetic), which has the same direction as the main displacement and R’ (antithetic), which has an opposite direction to the main displacement.

Conclusions

The infilling of the Triassic rift by red beds is followed by the establishment of a carbonate platform in the early and middle Lias, which is characterized by the deposition of massive dolomites in the early Lias and of bedded carbonates in the middle Lias moyen (du Dresnay, 1979). Subsidence is controlled by accidents N70 à E-W, and shows a differential character between the platform and the border zones.

The middle and late Jurassic are characterized by the reactivation of basal faults and the start of the break up of the carbonate platform in the early and middle Lias. It coincides with the start of expansion of the central Atlantic dated as 180 Ma. The opening of the central Atlantic leads to the displacement of Africa towards the east with a sinistral displacement in relation to Europe.

Laville (1985) proposes a displacement tectonism and shows that this sinistral displacement generates in the High Atlas region the opening of sedimentary basins that are more or less fitted together within a “relai” system, which is distensive or compressive. These “relais” are limited to the south by the south Atlas accident.

Sabaoui (1987) proposes for the creation of the middle Atlas basin an opening of type R’ (antithetic) following the model of Riedel. This opening was generated by the activation of the mega-displacement formed to the north by the Gibalta-Açores accident and to the south by the south Atlas accident moving in a sinistral direction with a link to the opening of the central Atlantic.

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Non-marine Jurassic Ostracod Assemblages from Northern China

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Many non-marine ostracod fossils play an important role in stratigraphical subdivision and correlation of Jurassic rocks in the northern China. The Early and early Middle Jurassic ostracod is simple, but the ostracod diversity has tended to increase since the late Middle Jurassic. According to the previous ostracod researches, we established five ostracod assemblages in the northern China as following.

1. Darwinula sarytirmenensis–D. Magna–Timiriasevia Assemblage
   This ostracod assemblage has a very wide distribution in northern China. It has been recorded from the Toutunhe and Qiketai formations of northern Xinjiang and Qiackemake Formation of the Tarim Basin. It is also found from the Maao Formation of Henan province, Juilongshan Formation of Hebei province, Wangjiashan Formation of Gansu province, Caishiling Formation of Qinghai province, Zhihuo and Anding formations of Shanxi province, and Xiahuayuan Formation of Inner Mongolia. In southern China, it also presents in coeval horizons, such as Shangluofeng, Yaojie, and Hepingxiang formations in Yunnan province, Tongshan Formation in Zhejiang province, and Shaximiao Formation in Sichuan province.

   The representative forms of this ostracod assemblage are: Darwinula sarytirmenensis, D. impudica, D. magna, Timiriasevia epidermiformis, T. bella, T. catenularia, T. mackerrowi, etc.

   Of them, D. sarytirmenensis, D. impudica, T. epidermiformis, and T. catenularia were first discovered from the Jurassic coal-bearing strata of Saleitimian section which is located in the northern slope of the Karatan Mountain (Kaparaay) of eastern coast of Caspian Sea (Mangyshlak). According to Mandelstam (1947), this section was subdivided into 30 beds, the top 30th bed contains Callovian ammonite and bivalve fossils, and the 26th-16th beds contain ostracods as above. According to the age of overlying strata and comparison with adjacent areas, these ostracods are considered to be the Middle Jurassic in age (Ye et al., 1977). Neustrueva (1974) also found identical ostracods in the middle and upper part of Jurassic coal-bearing strata of Fergana Valley. Darwinula magna was first established by Jiang Xianting in 1963 (but published in 1977), thereafter it was widely found in the Middle Jurassic continental strata of China, it usually coexists with the first two Darwinula species, Darwinula sarytirmenensis and D. impudica mentioned above, and also was found in the Middle Jurassic strata of Fergana.

Furthermore, it should be noted that Timiriasevia epidermiformis has distinct features, particularly there is a lateral ridge near the ventral edge of both valves. In Kazakhstan, the assemblage is seen in continental strata below marine Bathonian of Middle Jurassic; in northwestern Sardinia, in Italy, it comes from Bajocian continental deposits with marine intercalation (Malz et al., 1985); in southern Tunisia, early Bajocian–early Bathonian (Mette, 1995), Oxfordshire in the UK, the Bathonian of the marine Sandwich is relatively stable (Bate, 1965). These ostracod fossils are generally from the continent intercalations of marine Bajocian-Bathonian deposit. This assemblage widely produced Shanxi-Gansu-Ningxia region Zhihuo Formation, Maao Formation in Henan province, Tarim Basin Qiackemake Formation, Turpan-Hami basin Qiketai Formation, and Lower Xiaximiao Formation Sichuan province.

Therefore, the age of this assemblage should be Bajocian–Bathonian, below Callovian.

2. Darwinula-Djunarica–Timiriasevia Assemblage
   The assemblage is distributed in Qigu Formation of northern Xinjiang, Taerga Formation of the Tarim Basin and Kushuixia Formation of Gansu province. The main members of the assemblage include: Djungarica yunnanensis, Dj. tracta, Dj. postiacuminata, Darwinula sarytirmenensis, D. paracontracta, Timiriasevia mackerrowi, Clinocythere wangjiashanensis ect.

   The composition of this assemblage is similar to that of Bazhulu Formation in Yunnan province (formerly upper part of this Hepingxiang Formation). Besides Darwinula and Timiriasevia which occurred in the first assemblage above, there are a lot of Djungarica fossils. The morphology and size of those Djungarica are similar to so-called Callovian marine Bythocypris? or Clinocypris and Paracypris? From a continental intercalation of marine Callovian beds (Mette, 1995) in southern Tunisia. Therefore this assemblage may be Callovian age.

3. Cetacella–Djunarica–Damonella Assemblage
   This assemblage has been recorded from the Hongshuigou Formation of Tsaidam Basin, Kuzinggu Formation of Tarim Basin and Siuning Formation of Sichuan province. Besides in China, Cetacella is the leading forms of the Kimmeridgian (Late Jurassic) ostracods in Germany, Spain, Portugal etc. A few species of Cetacella can be found from early Oxfordian
and Portlandian deposits (Schudack, 1989). This genus is also occurred in Morrison Formation in northern America. The age of this assemblage is considered to be as early as Kimmeridgian and as late as early Berriasian in age.

4. Luanpingella–Eoparacypris–Rhinocypris Assemblage

This assemblage is found from the Dabeigou Formation of northern Hebei province and Ershierzan Formation of northern Daxinganling area. The dominant forms are Luanpingella and Eoparacypris. They are distinctive in big size and smooth of surface of valves. Eoparacypris was firstly occurred in the Lower Purbeck bed of UK; Rhinocypris is a small ostracoda characterized by the spines ornament. It is ranging from Lower Jurassic to Lower Cretaceous and widely distributed in Europe and Asia; Luanpingella is an endemic genus with limited distribution. This assemblage doesn’t have Cypridea that was flourished in Cretaceous, so its age is later than Cypridea dunkeri zone of the Purbeck bed (Anderson, 1973, 1985; Horne, 1995) and may be Tithonian of Late Jurassic.

5. Minheella–Jingguella–Pinnocypridea Assemblage

The assemblage was found in Kapushaliang Formation of Tarim Basin, Datonghe Formation of Xining-Minghe basin, Jingxing Formation of Yunnan Province, Chengqiangyan Group of Sichuan province. It contains Minheella, Jingguella, Pinnocypridea, Cetacella, Prolimnocythere, Damonella etc., and has a few species of Djungarica, Ousocypris, Darwinula, Rhinocypris as well. Minheella and Jingguella are two endemic forms in the northern Tethys margin in southern China. They have a limited geographic distribution and restricted time range. Minheella and Jingguella must have a close relationship, but their convexities of posterior end of valves are different, the former is symmetrical, but the later is obviously asymmetric. Pinnocypridea has been widely recognized in UK, France, Germany, Spain from Portlandian (Late Jurassic) to Berriasian (Early Cretaceous), but they have been given different names, such as Cypris, Mantelliana etc., (Anderson, 1985). Cetacella can be collected from the Shushanhe Formation of Kapushaliang Group in Tarim Basin; its morphological feature is similar to the Hongshuigou Formation’s form. Although, the leading genera of this assemblage is most probably endemic, but the others are commonly appear from Late Jurassic to Early Cretaceous in Europe. Especially, Schudack (1989) argued that the genus Cetacella was found in Portlandian in Europe and Asia. We also found Cetacella in Shushanhe Formation. So, the age of this assemblage was considered to be Late Tithonian of Late Jurassic to Early Cretaceous.

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Key words: Jurassic; Ostracod assemblages; Northern China

References:
The Colorado Plateau Coring Project (CPCP): 100 Million Years of Earth System History


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Lasting over 100 million years, the early Mesozoic (252 to 145 Ma) is punctuated by two of the five major mass extinctions of the Phanerozoic (Permian-Triassic and Triassic-Jurassic) plus several smaller extinction events. It witnessed the evolutionary appearance of the modern terrestrial biota including frogs, salamanders, turtles, lizards, crocodilians, dinosaurs, birds, and mammals, and spans a time of dramatic climate changes on the continents. What is arguably the richest record of these events lies in the vast (~2.5 million km²) complex of epicontinental basins in the western part of Pangea, now largely preserved on the Colorado Plateau (Fig.1). Since the mid-19th century, classic studies of these basins, their strata, and their fossils have made this succession instrumental in framing our context of the early Mesozoic Earth system as reflected in the international literature. Despite this long and distinguished history of study of the Colorado Plateau region, striking ambiguities in surface sections over long geographic traverses. This problem is exemplified by the generally shallow bedding attitudes, lateral facies changes, and covered intervals compromise unambiguous superposition in surface sections over long geographic traverses. This problem is exemplified by the ambiguities in compiling a composite section even across small distances in the Late Triassic Chinle Formation outcropping in Petrified Forest National Park (Martz and Parker, 2010) in the state of Arizona, the area to be cored in Phase 1 of the CPCP. Furthermore, the most continuous sections in outcrop are either inaccessible in vertical cliffs or are intensely weathered and geochemically altered, making geological observations and sampling at the appropriate level of detail practically impossible. Despite the seemingly

A scientific coring program is essential because the generally shallow bedding attitudes, lateral facies changes, and covered intervals compromise unambiguous superposition in surface sections over long geographic traverses. This problem is exemplified by the ambiguities in compiling a composite section even across small distances in the Late Triassic Chinle Formation outcropping in Petrified Forest National Park (Martz and Parker, 2010) in the state of Arizona, the area to be cored in Phase 1 of the CPCP. Furthermore, the most continuous sections in outcrop are either inaccessible in vertical cliffs or are intensely weathered and geochemically altered, making geological observations and sampling at the appropriate level of detail practically impossible. Despite the seemingly
striking exposures and long history of study, by modern standards and the requirements of the scientific questions posed, the outcrops simply do not permit investigation of the physical, magnetic polarity, or chemical stratigraphy of the Plateau and environs at the appropriate levels of resolution or confidence.

![Fig. 1 Map of the Colorado Plateau (black enclosed line) and adjacent areas showing distribution of Triassic and Jurassic outcropping strata (from Olsen et al., 2008a)](image)

The overall coring strategy involves at least 6 cores taken in four phases: three long (~1000 m) cores and two shorter (300-600 m) cores intended to recover the full expression of the critical early Mesozoic transitions in clear superposition and with sufficient stratigraphic overlap to minimize gaps. In total the cores would minimally span the base of the Cedar Mountain Formation (~Early Cretaceous) through the base of the Moenkopi (~Middle and Early Triassic) with enough overlap between cores to firmly tie the sections together and to provide information on lateral facies and thickness changes and stratigraphic completeness. As planned, the CPCP will result in a major improvement in our ability to address outstanding issues of global importance, involving chronology, paleogeography, paleoclimatic, and biotic evolution in this sector of the Pangea supercontinent.

**Science questions**

The CPCP is stimulated by four compelling and intertwined, hypothesis-driven questions to address outstanding issues of Pangean biotic evolution, chronology, paleogeography, paleoclimate, and basin evolution.

1. How is the major biotic transition from the Paleozoic to essentially modern terrestrial ecosystems, including biotic events such as mass extinctions, linked to climatic and tectonic events, and what are the rates and magnitudes of these changes?

2. What are the trends in global or regional climate vs. those resulting simply from paleolatitudinal drift in “hot house” Pangea and Laurasia?

3. How did the largely fluvial systems and their biological communities respond to the climate changes?

4. How does the stratigraphy of the basin sections reflect the interplay between dynamic growth in accommodation space, uplift, and eustatic fluctuations in an intracontinental setting?

None of these questions can be addressed with the available data or, practically speaking, with the existing outcrops, and in fact virtually nothing remotely secure is known about these issues. Cases in point are illustrated in two recent papers: Rowe et al. (2007) and Lucas et al. (1998).

Rowe and others argue that the Early Jurassic age Navajo Sandstone, the product of the largest sand sea in Earth History, was deposited virtually at the equator based on comparison with a numerical climate model rather than in the subtropics as determined from apparent polar wander paths. If this model is correct, then the North American plate was virtually stationary over the entire Triassic through the Early Jurassic and the climate change expressed in the stratigraphic and paleontological records was due to true regional if not global climate change. Alternatively, North America drifted 25° northward during this time and thus the climate model is incorrect. Either way, the results are fairly shocking, but we will not know which hypothesis is more correct unless the needed temporal and stratigraphic contexts are much better developed.

Lucas and others (e.g., Lucas and Tanner, 2004, 2007; Tanner et al., 2004), using data from the Colorado Plateau, argue against the idea that the Triassic-Jurassic boundary marks a mass-extinction that literature compilations (e.g., Benton, 1995) suggest. In fact, based on such compilations, the Triassic-Jurassic extinction event is larger than the K-T boundary event and, by some metrics, even larger than the end-Permian event. The argument proffered by Lucas and others—that there is virtually no extinction event at this boundary—can be made solely because of the extremely poor constraints not only on the relative ages of the rich faunas relative to other parts of the world, but, even more importantly, relative to each other within and adjacent to the Colorado Plateau. This is because the geographically dispersed localities lack the criterion of superposition and are correlated to each other by lithostratigraphy and biostratigraphy, the same biostratigraphy that fails first-order quantitative correlation tests as witnessed by a 10 Ma change in the age strata inferred to be Carnian age to Norian age based on new U-Pb zircon ages (e.g., Mundil and Irmis, 2008) outlined below. This is most unfortunate, given that the Colorado Plateau has one of the richest Triassic-Jurassic vertebrate assemblages in the world. These
types of issues that permeate the entire early Mesozoic section will not be resolved until a proper temporal context is available, as we propose to develop in the CPCP.

There are apparent inconsistencies between predictions of climate models and paleogeography for the Colorado Plateau in the Permian to Jurassic (Rowe et al., 2007). These inconsistencies cannot be resolved with the existing data but are among the scientific issues that the CPCP is designed to address.

A useful model for the success of the CPCP is the NSF-funded Newark Basin Coring Project (NBCP: 1990-1994), which refocused Late Triassic chronostratigraphy by providing an astronomically calibrated geomagnetic polarity time scale for an interval of time as long and arguable at the same level of resolution as the entire Neogene. It is this magnetic polarity time scale that will serve as the template for correlation with the older part of the CPCP record, while the Late Jurassic marine magnetic anomaly record will serve a similar purpose in the younger part of the CPCP record.

As the longest continuous, high-resolution record of cyclical climate forcing on the planet it has been cited in arguments as far ranging as calibrating Solar System chaos (Pälike et al., 2004), human evolution (Lepre et al., 2007), the Paleocene-Eocene boundary (Cramer et al., 2003), and thermohaline circulation controls on modern climate (Broecker, 1999). Results of the NBCP have been described in 88 papers and 130 abstracts, the subject of 11 theses, and cited in 19 papers a year on average (Web of Science). The NBCP resolved the durations of Late Triassic stages, the role of precession-related Milankovitch forcing in the Pangean tropics, correlation of the Triassic-Jurassic of Eastern North American, Morocco, and Greenland, the duration of the largest igneous event in Earth History (CAMP), and constrained the chaotic Earth-Mars gravitational system for the Triassic and more down to earth, the qualitative pattern of rift basin growth. These points have withstood every quantitative challenge (e.g., Hinnov, 2000; Furin et al., 2006; Hames et al., 2000; Bailey and Smith, 2008). We think that the approach to chronostratigraphy exemplified by the NBCP has been at least mildly transformational, and we think the CPCP will be more so.

CPCP objectives and techniques

Chronostratigraphy

A basic foundation for all aspects of the CPCP will be the greatly increased reliability of early Mesozoic chronostratigraphy developed from the cores. Three suites of chronostratigraphic tools will form this foundation: magnetostratigraphy; radio-isotopic age determination; and cyclostratigraphy. These will be registered with other observables including biostratigraphic data, climate-sensitive lithofacies, and chemostratigraphies. The need for considerable refinements to the chronostratigraphy is illustrated by the following points:

1. Except in a nominal sense (at formation boundaries or unconformities), the stratigraphic position of the system boundaries (Permo-Triassic, Triassic-Jurassic, or Jurassic-Cretaceous) is unknown. In fact the system boundaries could be within formations (e.g., Moenave for the Triassic-Jurassic and Morrison or...
Cedar Mountain formations for the Jurassic-Cretaceous).

2. Ages, both relative and absolute at a stage level are practically unknown or based on uncritical and untested correlation schemes. A prime recent example is the previously mentioned inferred age of strata in the lower Chinle Group that was long assumed to be Carnian (ca. >230 Ma) even in the recently-published geologic time scales (GTS2004 and GTS2009), but turns out, on the basis of a high precision U-Pb zircon age (Mundil and Irmis, 2008), is 10 million years too old. Many more reliable age determinations are required to establish a robust chronostratigraphic framework; this example, however, forcefully underscores the urgent need for high-precision geochronological data using multiple state-of-the-art methods.

3. Even within a given formation, it is not yet possible to place biotic assemblages from different localities in a testable temporal sequence even though most of our “knowledge” of North American vertebrate biochronology for the early Mesozoic is based on observations from strata on or adjacent to the Colorado Plateau. Thus, the fact remains that the stratigraphic understanding is pretty much still in the 19th century and incapable of being applied to useful and exciting evolutionary, climatic, or geodynamical models that have relevance not just in a regional but also in a global context. This is not for lack of effort on the part of researchers, rather it is a direct consequence of the physical limitations of the outcrop itself.

The Colorado Plateau region has been a classic source of early Mesozoic paleomagnetic data for North America, including some of the earliest magnetostatigraphic records for the Triassic and Jurassic (e.g., Steiner and Helsley, 1972; Steiner and Helsley, 1974; Steiner and Helsley, 1975, Steiner, 1978; Steiner, 1980; Steiner and Lucas, 1992; Molina-Garza et al., 1991; Molina-Garza et al., 2003; Ekstrand and Butler, 1989; Bazar and Butler, 1991, 1992, 1994; Purucker et al., 1980). To date, the longest Colorado Plateau polarity sequence is derived from outcrops of middle Chinle Group strata in the Petrified Forest National Park (Steiner and Lucas, 2000) that allowed a correlation to the only Late Triassic polarity timescale with independent time control - the NBCP astronomically-calibrated geomagnetic polarity timescale (Kent et al., 1995; Kent and Olsen, 1999, Olsen and Kent, 1996; Kent and Olsen, 2000; Olsen and Kent, 1999).

The recent U-Pb single-zircon ages from the Chinle Group in the Petrified Forest (Dickinson and Gehrels, 2008) and Six Mile Canyon, near Fort Wingate, NM (Mundil and Irmis, 2008) suggest that the magnetostatigraphic correlation proposed by Steiner and Lucas (2000) is essentially correct. The implication is that a meaningful polarity sequence can be recovered from the Chinle Group in general, despite the low implied accumulation rate (150 m/10 Ma=0.015 m/1 ka) and largely fluvial facies. For the Chinle to be sampled at Newarkian temporal levels (~20 ka) to avoid aliasing, the sampling should be done at the 0.3 m level, which would be hardly feasible in the crumbly outcrops of the bentonitic Chinle Group (e.g., Fig. 2), as driven home by the experience of Zeigler et al., with the Chinle (Zeigler et al., 2008). In addition, although the new U-Pb-zircon ages provide a more encouraging framework than had previously existed, the Six Mile Canyon date is from a tuff located over 140 km east of Petrified Forest to which it has been correlated lithostratigraphically, a correlation that needs to be confirmed. Both of these objectives are further motivation for coring and obtaining the appropriate level of sampling resolution where superposition is unambiguous.

We are confident to find additional layers at many levels that are suitable for radio-isotopic dating. In this context it is important to recognize the need for the application of multiple dating methods (where feasible) to resolve any complications resulting from systematic and random bias. The core material is particularly suited to detect primary (or re-deposited) volcanic material containing datable minerals, and recent studies have demonstrated that even minute samples recovered from cores, containing very small numbers of datable crystals (on the order of 10s) are perfectly adequate for high-precision age determinations (e.g. Mundil et al., 2006). Radio-isotopic age data from different isotopic systems, of variable vintage and quality, are available from early Mesozoic age strata on the Colorado Plateau, but a recent focus on acquiring single-crystal U-Pb zircon ages using the CA-TIMS technique (Martinson, 2005) has begun to yield meaningful and precise preliminary results. However for these to be of utmost utility and maximally parsimonious they should be from the same place as other complementary data, which is typically and practically possible only in core. The cores themselves (in combination with samples from outcrops) will provide three kinds of age information: 1) depositional ages of ashes or tuffaceous sandstones providing penecontemporaneous ages (tephrochronology); 2) zircon data from re-deposited volcanic layers providing maximum ages; and 3) correlation by magnetic polarity zone boundaries to age information acquired elsewhere. In addition, the cores should provide a continuous record of detrital minerals, including zircons that will be a valuable asset to provenance studies (e.g., Rahl et al., 2003; Riggs et al., 1996; Dickson and Gehrels, 2003). We plan to use a combination of “reconnaissance” techniques (e.g. LA-ICP mass spectrometry, in order to screen the age spectrum of zircon populations within tuffaceous deposits: 41), followed by “high-resolution” techniques including CA-TIMS applied to zircons and $^{40}$Ar/$^{39}$Ar applied to K-bearing volcanic minerals.

The largely fluvial to paralic or eolian nature of most of the Colorado Plateau section, lacking independent assessments of accumulation rates, has
profoundly hindered cyclostratigraphic interpretations. Available data suggest relatively low accumulation rates, so that it is unlikely that the higher frequency orbital cycles will have a faithful record. However, the eccentricity cycles, especially the 405 ky and longer eccentricity cycles (Olsen and Kent, 1999), should leave a decipherable record of environmental change in the style of the fluvial systems, the distribution of eolianites, and in the biota from the cores (pollen, invertebrates) and outcrop (vertebrates: e.g., Van Dam et al., 2006) that can be tied to the cores by magnetic polarity stratigraphy. Correlation to the astronomically-calibrated Newark record will provide a check on the local environmental response to known cyclicity. We expect that the resulting chronostratigraphic framework will be closely tied to sedimentary archives from terrestrial and marine environments elsewhere.

Biotic history and events

CPCP cores will provide a framework for a detailed chronology of faunal and floral change for the early Mesozoic of western North America by linking the rich reservoir of surface information to the core chronostratigraphy. This will allow the recognition of the positions of major biotic events, such as the end Triassic, Toarcian, and possibly the Jurassic-Cretaceous transitions. In addition the pace of faunal and floral change can be quantified once there is a chronostratigraphy developed by the CPCP and tied to outcrop.

Crucial in this vein are correlations to continental and marine sequences from elsewhere. There are, for example, major differences in the first-order composition of continental vertebrate assemblages from different areas of the globe, despite the fact that during the Triassic and Early Jurassic the existence of Pangaea meant that terrestrial vertebrate could in principle walk from nearly the south pole to the north pole. Differences amongst these faunas have been attributed to differences in ages following a paradigm outlined nearly 40 years ago by Alfred Sherwood Romer (1970). However, this purely biostratigraphic argument masks the first-order pattern of real biogeographic provinciality as illustrated by the realization that Norian age assemblages from mid-paleolatitudes from both hemispheres are very distinct from tropical assemblages from the Colorado Plateau just now recognized as of contemporaneous Norian age on the basis of new U-Pb single-zircon ages (Irnis and Mundil, 2008). Similarly, continental vs. marine correlations are in limbo. The distinctive genera-level faunal turnover at the Sonsela Member of the Chinle Group of the Colorado Plateau thought to be correlate with the marine Carnian-Norian boundary extinction event, but instead is mid-Norian in age. Such obfuscation makes it impossible to even recognize what the major biological patterns are, let alone test existing hypothesis of biotic change and their origin. These actual patterns of biotic change can only be revealed if an accurate and precise chronostratigraphy is in place, such as will result form the CPCP.

Environmental history

Key to the CPCP will be a continuous record of environmental change in the cores. Environmental changes are largely recorded via sedimentary, pedogenic, and biotic processes, sensitive to climatic and drainage basin (e.g., tectonic) changes. The CPCP cores will be an unprecedented archive of these processes spanning 100 million years. Key environmental observations derived from the cores will include the detailed record of depositional conditions, a pedostratigraphy (soil types), stable isotope carbonate and molecular-level biomarker chemostratigraphies (pedogenic C and organic C, O, H, etc.), and palynologies (pollen, spores, dinoflagellates). Core and downhole logs will be able to provide cross-bedding orientation for wind and current direction.

Tectonostratigraphy and tectonic history

The position of sequence boundaries identified in outcrop can be tied to the CPCP cores, the chronostratigraphy of which will allow an assessment of the duration of associated hiatuses and proposed sequence boundaries and hence tests of their regional significance. The CPCP chronostratigraphy coupled with the temporal overlap between cores will allow quantification of accumulation rates, back stripping, and elucidation of the geographically and temporally evolving subsidence history. Coupled with the detrital provenance records this will allow a synoptic view of the dynamic evolution of epicontinental basins in this huge region.

CPCP phased coring plan

We propose the CPCP cores be acquired in three phases, roughly in stratigraphic order that includes the initial description and scientific results of the coring consistent with IODP practice. Each phase builds on the others, hence a vision and a program, but each phase actually has stand-alone science. Depending on funding rates, each phase could be accomplished in around 18 months.

Phase 1: Core 1-Petrified Forest, Arizona (PF: Figs. 1, 2), will be a roughly 500m long core in Petrified Forest National Park, Arizona. This core will span the Late Triassic uppermost Petrified Forest Formation and the underlying rest of the Chinle Group, and the local expression of the Early to Middle Triassic age Moenkopi Formation, bottoming in the Permian Kaibab Limestone. Working in conjunction with Petrified Forest park officials, we have identified a suitable coring site that is located on the north edge of the park. This core would tie directly to the CPCP cores, the chronostratigraphy coupled with the temporal overlap between cores will allow quantification of accumulation rates, back stripping, and elucidation of the geographically and temporally evolving subsidence history. Coupled with the detrital provenance records this will allow a synoptic view of the dynamic evolution of epicontinental basins in this huge region.
Group, conditions that will be experienced at often appreciably greater depths at other core sites; 2) test the lateral continuity of specific lithologically distinctive stratigraphic intervals and magnetic polarity zones; and 3) serve as an example of an environmentally responsible coring process for other phases of the project. We are encouraged that this phase of the project appears poised for funding.

**Phase 2:** Two complementary cores, one long, one short are designed to examine the Latest Triassic and Early Jurassic part of the record.

**Core 2:** Ward Terrace/Moenkopi Plateau, Arizona (WT: Figs. 1, 2), will be a 700-800m long core in the Ward Terrace/Moenkopi Plateau area in the Navajo Reservation in Arizona. This core will capture the thickest known development of the Late Triassic Chinle Group as well as a significant part of the overlying Jurassic Glen Canyon Group (Moenave and Kayenta formations at Ward Terrace/Moenkopi. This area has produced the bulk of the Early Jurassic faunal remains in the Western Hemisphere. The lower part of Core 2 nominally overlaps completely with Core 1, but will be separated by roughly ~160km and will test the lateral continuity of the physical and magnetic stratigraphy where the Chilie Formation is best developed.

**Core 3:** Rock Point/Lisbon Valley area in Arizona/Utah (RP: Figs. 1-2), will be a 600m long core that will capture the thickest known development of the Late Triassic Chinle Group as well as a significant part of the overlying Jurassic Glen Canyon Group (Wingate formation). This core would be adjacent to the faunally richest putative Triassic-Jurassic boundary sections.

**Phase 3:** At least 2 cores will span the Early through Late Jurassic age section

**Core 4:** St. George, Utah (SG: Figs. 1-2), will be a ~1100 m core that will recover the basal Early Jurassic Navajo Formation of the Glen Canyon Group through the base of the Moenkopi Formation. This core complements Phases 1 and 2, but differs in having an erosionally truncated Chinle Group and yet a greatly expanded section of Moenkopi, Moenave, and Kayenta strata. Both the Moenkopi and Moenave appear strikingly cyclical in these areas.

**Core 5:** San Rafael Swell area, Utah (SR: Figs. 1, 3), will minimally capture the basal Cedar Mountain Formation and entire Jurassic Morrison Formation, San Rafael Group, and Glen Canyon Group in a ~1500m core. This core will sample strata documenting the return to more humid conditions in the Colorado Plateau area, as well as the interval producing arguably one of the richest Late Jurassic continental biota in the world, exemplifying the culmination of dinosaur dominance. Planning for this part of the CPCP is still in its early stages. Furthermore, it seems likely that to fully encompass the full scope of the Morrison Formation, additional cores will be required.

**Conclusion**

The vision of the Colorado Plateau Coring Project (CPCP) (Olsen et al., 2008; Olsen et al., 2008; Olsen, 2009) is a complete cored section through the 100 million record of the early Mesozoic of the Colorado Plateau and its environs. These workshops identified the Petrified Forest core as the first phase of the CPCP that, along with other phases of the project, will result in tests of a series of globally significant hypotheses and serve as a basis for further research to a significant segment of the community. Furthermore, the results of the CPCP will allow for high-resolution correlation with other major early Mesozoic sequences, notably those in Asia, particularly China (Zhou and Dean, 1996; Sha, 2009; Smith, 1990). Because this area has such extensive lacustrine sequences broadly coeval with the younger parts of the CPCP sections such correlations ultimately may allow the development of astrochronology for the Jurassic that would link with the Newark Basin astrochronology and time scale (Olsen and Kent, 1999). This will open the door for a truly Earth Systems approach to understand the key events of the Triassic and Jurassic and potentially result in a far more detailed knowledge of environmental forcing especially evolution of Milankovitch climatic cyclicity coupled to the uncharted deep time chaotic diffusion of the behavior of the solar system (Laskar, 2008).

**Key words:** Colorado Plateau; Early Mesozoic; Continental strata; Environmental change
Fig. 2 Generalized Colorado Plateau section (Glen Canyon/ Kaiparowits Plateau, with the tentative sections proposed for coring, as discussed by the St. George workshop participants and a very generalized evaporation – precipitation (E-P) curve loosely based on climate sensitive facies. See caption to Fig. 1 for core area abbreviations. Note that the relative thicknesses of tentative drilling intervals through stratigraphic units are in general different than what is shown in the color section and not the same among different coring target areas (from Olsen et al., 2008a).

References:


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The Non-marine Jurassic and Ostracod Biostratigraphy in the Central Yunnan Province, China

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Owing to the influence of the north-south tending tectonic zone and Tethys Sea shrunk to west, the Jurassic strata in Yunnan Province, China, from west to east, is generally composed of three sedimentary types: marine facies, continental-oceanic facies and non-marine facies. Especially the red strata of non-marine Jurassic was widely distributed in the central area of Yunnan and now has became an important part of the “Sichuan-Yunnan Red Bed”. The non-marine Jurassic red strata mainly appear in basins of various sizes in central Yunnan, of which is best developed in the Chuxiong and Kunming area. The non-marine Jurassic of the two areas are different in terms of sedimentary environments and characteristics. Therefore, two different sets of lithostratigraphic unit names are applied.

1. Lithostratigraphy

1.1. The sequence of lithostratigraphic unit in Chuxiong area (from up to bottom as follows):

Tuodian Formation (J1t), Shedian Formation (J1zh), Zhanghe Formation (J1zh), Fengjiahe Formation (J1zh) and Yubacun Formation (J1yz).

1.2. The sequence of lithostratigraphic unit in Kunming area (from up to bottom as follows):

Anning Formation (J1zh), Madishan Formation (J1zh), Laoluocun Formation (J1zh), Chuanjie Formation (J1zh), Lufeng Formation (J1zh) and Yubacun Formation (J1yz). Abundant fossils were found, such as vertebrates, ostracoda, insect, conchostracans, bivalves, fish and fish coprolites.

1.3. The sequence of lithostratigraphic unit in the Chuanjie Basin (from new to old as follows):

Anning Formation (J1zh), Madishan Formation (J1zh), Laoluocun Formation (J1zh), Chuanjie Formation (J1zh), Lufeng Formation (J1zh) and Yubacun Formation (J1yz).

2. Ostracod biostratigraphy

2.1. The sequence of lithostratigraphic unit in Chuanjie Basin (from up to bottom as follows):

Shawan Member, is composed of dark purplish red sandstone while the upper member, named Zhangjiaao Member, is a deposit of deep-red sandstone and mudstone. The characteristic production is the sauropod dinosaur Chuanjiesaurus Fauna. While others are fossils of turtles, fish, ostracoda, chareae, etc.

2.2. The sequence of lithostratigraphic unit in the Yubacun Basin (from new to old as follows):

Yubacun Formation (J1yz).

This lowest stratum of Lower Jurassic in central Yunnan is the transitional deposit from Upper Triassic to Jurassic. Sporadically distributed over the Kunming area, it is composed of mottled argillaceous siltstone and silty mudstone. The few productions are fossils of spores and pollens, and of plants. A few ostracoda is found in the Yubacun section of Lufeng Basin

2.3. The sequence of lithostratigraphic unit in the Lufeng Basin (from new to old as follows):

Lufeng Formation (J1zh).

It is lithostratigraphic unit of Lower Jurassic Series. This widely distributed formation is generally divided into two members. The lower member, named Shawan Member, is composed of dark purplish red sandstone while the upper member, named Zhangjiaao Member, is a deposit of deep-red sandstone and mudstone. The characteristic production is Lufengosaurus Fauna, the early dinosaurs are principally paleopoda but a small amount of real sauropod dinosaurs appeared during the later stage of the formation. The ostracoda is also found in the Zhangjiaao Member.

Yubacun Formation (J1yz)

This lowest stratum of Lower Jurassic in central Yunnan is the transitional deposit from Upper Triassic to Jurassic. Sporadically distributed over the Kunming area, it is composed of mottled argillaceous siltstone and silty mudstone. The few productions are fossils of spores and pollens, and of plants. A few ostracoda is found in the Yubacun section of Lufeng Basin

2. Ostracod biostratigraphy

The very abundant ostracoda fossils were found at the Chuanjie Basin in 1999-2003 and comprises: 5 family 9 genus 43 species and may be subdivided 4
assemblage zones (from old to new as follows):

2.1. The first assemblage zone: Darwinula liulingchuanensis–Metacypris menglaensis–Gauricythere? chuanjieensis assemblage zone

The fossils of the assemblage zone consist of 4 genus 10 species: Darwinula liulingchuanensis Zhong, D. giganimpudica Wang et Ye, D. huaiqiaoeensis Fang et Xu, D. magna Jiang, D. aff. incurva Bate, Metacypria menglaensis Ye, Fatocythere? lunfgensis Pang and Gauricythere? chuanjieensis Pang, and they are distributed in the Zhangjiaao Member of Lufeng Formation. This assemblage zone reveals the Lower Jurassic characteristics of the Menkoushan and Guanyintan formations in Hunan Province, the Zilijuqing Formation in Sichuan Province, the Lufeng Formation (original Lower Lufeng Formation) in Lufeng Basin, the Fengjiahe Formation in Chuxiong area, Yunnan Province. They should belong to the late stage of the Lower Jurassic in the age.

2.2. The second assemblage zone: Darwinula sarytirmenensis–D. impudia–D. lunfgensis assemblage zone

This assemblage zone was found in the Chuanjie and Laolucun formations of the Chuanjie Basin and Daguantian section of Yangjiazhuang town in Lufeng Basin. The fossils of the assemblage zone contain 2 genus 10 species: Darwinula sarytirmenensis Sharapova, D. incurva Bate, D. giganimpudica Wang et Ye, D. magna Jiang, D. lunfgensis Wang et Ye, D. changxianensis Ye, D. impudia Sharapova, D. yibinensis Su et Li, D. xiaofanzhangziensis Pang and Djungarica similis Jiang. The assemblage zone reveals evidently the Middle Jurassic characteristics in China and Russia, such as the Zanghe and Hepingxiang formations in Yunnan Province, the Xincun, Liangaoshan, and Xiashaximiao formations of Sichuan Province, the Toudunhe to Qigu formations of Xinjiang Autonomous Region, the Yaojie Formation of Gansu and Qinghai provinces, the Jiulongshan Formation of Hebei Province, the Yushanjian Formation of Zhejiang Province etc. Therefore, the second assemblage zone and the strata (Chuanjie and Laolucun formations) undoubtedly belong to the Middle Jurassic in the age.

2.3. The Third assemblage zone: Darwinula neosarytirmenensis–Damonella depressa assemblage zone

The fossils of this assemblage zone are distributed the Madishan Formation (original “wine-red bed”) in the Chuanjie Basin and the Daguantian section of Yangjiazhuang town in Lufeng Basin and comprise 2 genus 13 species: Darwinula neosarytirmenensis Li, D. henanensis Sun, D. postitruncata Ye, D. paracressa Ye, D. paracratonta Ye, D. subparallel Ye, D. piona Jiang, D. magna Jiang, D. changxianensis Ye, Damonella depressa Gou, D. subovata Gou, D. obvata (Li), D. scalaris Wei in the Chuanjie Basin, and 2 genus 10 species: Darwinula incurva Bate, D. changxianensis Ye, D. paracressa Ye, D. lunfgensis Wang et Ye, D. jinhuensis Li, D. submuricata Hou et Ye, D. yaozhanensis Pang, Damonella depressa Gou, D. scalaris Wei, D. huobashanensis Liu distributed in the Daguantian section of Yangjiazhuang town in Lufeng Basin. The three assemblages zone reveal to start with the Late Jurassic characteristics of the Suining and Penglaizheng formations in Sichuan Province, the Seidian and Tuodian formations in Yunnan Province. So, it should belong to the early stage of Late Jurassic in the age.

2.4. The fourth assemblage zone: Darwinula bapanxiaensis–Eolimnocythere rongxianensis–Man telliana hepingxianensis assemblage zone

This assemblage zone was found in the Anning Formation of Chuanjie Basin, and consist of 4 genus 19 species: Darwinula bapanxiaensis Song, D.sarytirmenensis Sharapova, D. magna Jiang D. incurva Bate, D. subparallel Ye, D. paracressa Ye, D. postitruncata Ye, D. neosarytirmenensis Li, D. henanensis Sun, D. submuricata Hou et Ye, D. piona Jiang, Eolimnocythere rongxianensis Li et Wei, E. alta Li, E.chuangjieensis Pang, Mantelliana hepingxianensis Gou, M. purbeckensis (Forbes), M. obliquovata Pang, M.wuzhuanshanensis Pang, Eoparacypris penglaizhenensis Geng.

The fossils of the assemblage reveals clearly the Late Jurassic characteristic of the Shedian and Tuodian formations in Chuxiong area, Yunnan Province, the Penglaizhen Formation of Sichuan Province, the Xiangtan and Datonghe formations of Minhe Basin, Qinghai Province, the Kushuixia Formation in Gansu Province and the Tuchengzi (Houcheng) Formation in Hebei Province, the Yushanjian Formation of Zhejiang Province etc. Therefore, the fourth assemblage zone and the Anning Formation undoubtedly belong to the Late Jurassic in the age. There are both Late Jurassic species and also some the Early Cretaceous species, although also with some Middle Jurassic species, yet it is very a few in the assemblage zone. Therefore, the Anning Formation and the fourth assemblage zone should belong to the late stage of the Late Jurassic in the age. 

Key Word: Non-marine Jurassic; Ostrooda; Biostrtigraphy; Central Yunnan
Progress in Defining Jurassic Stages – A Learning Process

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In Jurassic stratigraphy we have a long and influential heritage. By the end of the 18th Century Jurassic successions in several countries had been divided into small named units that we now call lithostratigraphy. These were shown on early geological maps such as that of William Smith. It was also known that stratigraphical units could be recognised by the fossils they contained.

By the middle of the 19th Century the fossil content was used to recognise the same unit in different areas, despite changes in lithology, implying correlation in time—what we now call chronostratigraphy. The pioneers in the Jurassic, Alcide D’Orbigny (1850) and Albert Oppel (1856–58), established, respectively, the concepts of stages and zones much as these are used today in Jurassic stratigraphy.

During the latter half of the 19th Century and into the 20th Century many new stage names were introduced into Jurassic stratigraphy, to the extent that W.J. Arkell (1930) listed 120; others have been added since! Clearly, there were too many, with too many partial overlaps and synonyms, to be useful for international correlation and communication. Fortunately we had in Jurassic stratigraphy the widely respected authority of W.J. Arkell (1956) who was able to convince most to use a simplified scheme of only eleven stages as the basis for a global time-scale. This has stood the test of time, with only two modifications—international agreement at Luxembourg in 1962 and 1967 to reintroduce the Aalenian Stage in the Middle Jurassic and by ISJS vote in 1984 to use Tithonian as the international standard top Jurassic stage in place of Portlandian and Purbeckian or Volgian.

The Stages were defined in terms of the ammonite zones they contained, but it became evident in the 1960s that more precise and unambiguous definitions were required. During the 1962 1st International Jurassic Colloquium in Luxembourg organised by P.L. Maubeuge, it became clear that the traditional stratotypes were of limited value. To establish a sequence of stages that did not overlap or leave gaps only the base of each stage should be defined. At the 1967 2nd International Jurassic Colloquium also organised in Luxembourg by P.L. Maubeuge, specific levels (at zone, subzone or horizon) were proposed with suggestions as to where a stratotype section and point could be selected to define the basal boundary of each stage. There was even one stage (Bathonian) for which a specific bed and section were proposed—10 years before the first formal GSSP definition (base Devonian)!

Unfortunately the then Jurassic Subcommission became inactive.

With the re-establishment of a Jurassic Subcommission (first Chair Arnold Zeiss, Secretary Olaf Michelsen) a new series of International Jurassic Symposia/Colloquia was initiated. During the first at Erlangen in 1984, Working Groups with a Convenor and a flexible number of members, were established for each of the standard Jurassic stages. Their primary responsibility was to research alternatives and propose the level for recognizing the base of the stage and a specific point and section (the Global Stratotype Section and Point, GSSP) to define the boundary (see Morton, 2008). After approval by majority vote (at least 60%) within the Working Group membership, the proposal should be submitted to the Executive (Chair, Vice-Chair, Secretary) and Voting Members (20) of the International Subcommission on Jurassic Stratigraphy (ISJS) for comment and approval (again 60% YES votes required). After revision, if required in the light of comments received, the proposal should then be submitted by ISJS to the International Commission on Stratigraphy (ICS) for comment and approval, and finally by ICS to the Executive Committee of IUGS for ratification.

To date six of the eleven Jurassic stages have been ratified (see Morton, 2008 for details). These will be discussed briefly, in the order in which they were ratified by IUGS, with my comments based on personal experience with most as to what could be learned from each.

Bajocian: at base of the Hyperlioceras mundum Horizon, Discites Zone, with GSSP at the base of bed AB11, Murtinheira, Cabo Mondego, Portugal and Auxiliary Stratotype Point (ASP) at the base of bed U10, Beareraig, Isle of Skye, Scotland. Ratified by IUGS 1996 (Pavia & Enay, 1997).

Aalenian (also Middle Jurassic): at base of the Leioceras opalinum Horizon, Opalinum Zone, at the base of bed FZ197, Fuentelsaz, Iberian Chain, Spain. Ratified by IUGS January 2000 (Cresta et al., 2001).

Sinemurian: at the base of the Vermiceras quantoxense Horizon, Bucklandi Zone, 0.9m above the base of bed 145, East Quantoxhead section, Kilve, Somerset, England. Ratified by IUGS August 2000 (Bloos & Page, 2002).


Bathonian: at base of Bigotites diniensis Horizon, Convergens Zone, base of bed RB071, Ravin du Bès
section, Bas-Auran, Alpes du Haute-Provence, France. Ratified by IUGS July 2008 (Fernandez Lopez et al., 2009).

**Hettangian (also Lower Jurassic and Jurassic System):** at base of *Psiloceras spelae* Horizon, Tilmanni Zone, 5.80 m above base of Tiefengraben Member, Kendelbach Fm., Kuhjoch section, Karwendel Mts., Austria. Ratified by IUGS April 2010.

Of the remaining stages:

**Toarcian:** Details of this have been agreed, but the untimely illness and death of the Convenor Serge Elmi delayed preparation and submission of a formal proposal, now being prepared by Rogerio Rocha.

**Kimmeridgian:** The section has been selected but there is not yet agreement on the precise level at which to define the boundary; Convenor Andrzej Wierzbowski.

**Oxfordian:** Two sections have been proposed but documentation for both is not yet complete to enable fully informed selection; Convenor Guillermo Melendez.

**Callovian:** The precise point and section were proposed in 2000 but a fully documented proposal has not been submitted – a situation exacerbated by the surprise death of the Convenor John Callomon.

**Tithonian:** Further thought and discussion will be required.

**Key words:** Jurassic Stages Definition; GSSPs

**References:**
Lower Jurassic of the Wulong Area, Tingri County, Tibet

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In June and July 1999 I was invited by Prof. Xiaoying SHI to participate in an expedition to study the Mesozoic sequence stratigraphy of the northern slopes of Mount Qomolangma (Mt. Everest) in southern Tibet, funded by a National Natural Science Foundation of China grant to Prof. Shi and by a Royal Society grant for my travel to China. The group from China University of Geosciences, Beijing (Shi Xiaoying, Sun Keqin, Hue) and myself visited Tingri, Nyalam and Gamba Counties, with seven working days in the Wulong area. Information on the sequence stratigraphy are given by Shi (2001); this contribution summarises my observations on the Lower Jurassic sections around Wulong village in Tingri County, within the Mount Qomolangma National Park, and will discuss ammonites found.

The main sections studied were in the valley leading to Omalung village to the west of Wulong village and, for the upper part, the valley north of Yongjia where the road from Shegar to Everest Base Camp crosses the stream. The lithostratigraphical scheme of formations used here is based on Shi, Yin & Jia (1996) because this seems more appropriate to these sections than the generalized one in Shi, Sha & Deng (2006); subdivision into members is suggested. Thicknesses are mostly estimated rather than measured in detail.

**TOP**

Section north of Yongjia:

[higher beds not measured]

**Yongjia Formation [Toarcian-?Aalenian]**

**Yongjia Formation, Member 2**

Pale-coloured sandstones with bidirectional cross-bedding, patches of fossils, thin silty or shaly layers, sandy limestone and two *Lithiotis* limestone beds towards base.

43.1 m

**Yongjia Formation, Member 1**

Massive to thinly-bedded fine-grained to bioclastic limestones with bivalve fragments or intraclasts, marly partings.

182.5 m

Section continued downstream from ford:

sharp facies change

**Kangdui Formation [Sinemurian-Pliensbachian]**

Total thickness approx. 800 m

**Kangdui Formation, Member 9**

Interbedded sandstones, calcareous sandstones, siltstones and limestones; one sandstone bed near top carbonaceous with rootlets, limestone in lower part with thick-shelled trigoniids.

87.5 m

**Kangdui Formation, Member 8**

Dark grey mudstones with siltstone beds and some sandstone beds; some thicker sandstone beds greenish and appear volcaniclastic; plant fragments.

Seen 40.0 m

**Stream section north of Omalung:**

Vertical wall of fault breccia, trend 032-042 degrees;

**Kangdui Formation, Member 9**

Thinly-bedded calcareous shales, limestones, siltstones and sandstones with large calcareous and small marcasite nodules; belemnite ca. 20 m above base and ammonites (*J1 k*) ca. 10 and ca. 40 m above base.

90.0 m

**Kangdui Formation, Member 8**

Greenish sandstones, volcaniclastic, some black shales; trace fossils and ammonites (*J1 k*)

52.6 m

**Kangdui Formation, Member 7**

Black shales with nodules

60.0 m

**Kangdui Formation, Member 6**

Grey harder sandstones, channel bases with pebbles

50.0 m

**Kangdui Formation, Member 5**

Black shales and siltstones, plant fragments

40.0 m

**Kangdui Formation, Member 4**

Pale sandstones with dark grains, trace fossils and bivalves, channel sandstones and siltstones; structurally complex zone near base and base faulted.

113.5 m

**Kangdui Formation, Member 3**

Black shales with siltstones and sandstones, ammonites c20 m (*J1 k*) and c45 m (*J1 k*) above base.

88.0 m

**Kangdui Formation, Member 2**

Hard calcareous sandstone with bivalves and brachiopods (15.0 m)

Section along track to and through Omalung village:

Interbedded sandstones, some with channel base, siltstones and black shales, faulted.

208.5 m

**Kangdui Formation, Member 1**

Dark grey shales with scattered large calcareous
nodules (occasionally fossiliferous).

est. 90-100 m

Wulong Formation [Hettangian-Sinemurian?]
total thickness approx. 380 m

Wulong Formation, Member C
Massive to bedded coarse to medium-grained sandstones, calcareous with lenses of fossils, inter-bedded with siltstones and shales; ammonite (J1w') near top, bivalves and plant fragments also lower.

140.0 m

Wulong Formation, Member B
Interbedded limestones, siltstones and shales with occasional thin greenish sandstones.

126.9 m

Wulong Formation, Member A
Thickly-bedded shelly limestones with brachiopods at top underlain by mixed limestone and sandstone beds.

112.5 m

Zhamure Formation [?Rhaetian – Hettangian] thickness over 170 m

Upper part interbedded sandstones, siltstones and limestones, strongly folded and structural relations not clear, separated by major fault zone from lower part of red-coloured sandstones, siltstones and shales.

>170 m

Derirong Formation [Rhaetian] thickness over 120 m

Quartzitic sandstones, white to red-weathering, thickly- to thinly bedded with cross-bedding and vertical burrows; some calcareous beds with bivalves near base.

>120 m

Norian and Carnian strata crop out towards main track and to south.

The ammonites found will be presented and discussed

Key words: Lower Jurassic; Stratigraphy; Wu-long; Tibet

References:
Aragonitic Foraminifera (Robertinina) from the Triassic-Jurassic Boundary Interval of the Northern Calcareous Alps

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In the Northern Calcareous Alps, three west-east directed basins with a continuous sedimentation from the upper Rhaetian to the Hettangian are found from North to South: The Allgäu Basin in the North, the Eiberg Basin in the middle and the Hallstatt-Zlambach Basin in the South. The Allgäu Basin was influenced biogeographically by the Northwest European Province, the Hallstatt-Zlambach Basin from the Tethyan Realm and the Eiberg Basin was transitional in between. Sedimentation was similar in the Allgäu and Eiberg Basins. The Rhaetian of these basins is characterized by limestones and marls of the Koessen Formation and ends with a finely bedded layer of a bituminous shale with the last Triassic ammonites (Choristoceras marshii). Above are followed by some decimetres of greyish to yellowish marls which pass over to predominant reddish, clayey marls which are called Schattwald Beds and which are at least in part finely bedded. Above are followed by marls, in part clayey, or marls alternating with limestone beds (Tiefengraben Members). The first Jurassic ammonite (Psiloceras speleae tirolicum), marking the Triassic-Jurassic boundary, is found in the eastern part of the Eiberg Basin (Karwendel Syncline) and occurs in the lower part of these marls. Up to now, no outcrop with a continuous Triassic-Jurassic section was found in the Hallstatt-Zlambach Basin. The Rhaetian Zlambach marls with the last Triassic ammonites (mainly Choristoceras) are followed by mm-bedded, silty marls which are several meters thick and probably can be compared with the Schattwald Beds. Above is followed by a series of clayey marls which are at least 20 m thick and contain in the uppermost part protoconchs of ammonites and up to now only the innermost whorls of a poorly preserved ammonite (?Psiloceras). The upper part of the Early Hettangian and the Middle Hettangian are only known from moraine boulders.

The Robertinina are represented in the Late Triassic by the families Duostominidae with the large sized genera Variostoma, Duostomina and Diplotremina and the Oberhauserellidae (Fuchs, 1967) with the small sized genus Oberhauserella. The Duostominidae are found in shallower water and a better oxidized sea floor than Oberhauserella which probably was living in greater water depth under less oxidic or disoxic conditions. Duostominidae and Oberhauserellidae are rarely found in marls of the Rhaetian Koessen Beds. Both families occur more or less frequently in the Rhaetian Zlambach marls and clays. Often they are preserved with their original aragonitic shell. No Robertinina are found in the bituminous layer at the top of the Koessen Beds, the marls immediately above, the red Schattwald Beds and the corresponding, finely bedded, silty marls above the Zlambach beds. The microfauna of these beds is impoverished. Ecologically unpretentious foraminfera predominate. The Schattwald beds of the Eiberg Basin are characterized by the siliceous genus Hippocrepina. No foraminfera or other marine microfossils are found in the Schattwals Beds of the Allgäu Basin.

The greyish marls above the Schattwald Beds of the Eiberg Basin (Tiefengraben Members) and the clayey marls above the finely bedded, silty marls of the Zlambach Basin are yielding a microfauna increasing in genera and species from bottom to top and small sized Robertinina are returning. The Schattwald Beds of the Allgäu Basin are thicker than those of the Eiberg Basin and the transition to greyish marls probably takes place biostratigraphically later. The Robertinina must have survived in the more central part of the Tethyan Realm and returned in the latest Rhaetian gradually to the peripheral parts of this Realm and Northwestern Europe, as also found in other fossil groups like ostracods or ammonites.

In the lower part of these marls are found in the Eiberg- and Zlambach Basins the last specimens of small Diplotremina. Oberhauserella are common. Especially clayey marls are yielding specimens with their originally aragonitic shells. An evolution of Oberhauserella to Praegubkinella takes place in these beds and the latter appears around the T/J-boundary. Further species of Oberhauserellidae evolved. The species are characterized by different chambers forms, chambers per whorl, umbilical width and height of the spiral side. From bottom to top is increasing the size of the test. It starts with a diameter of ~ 0.06 to 0.12 mm in Oberhauserella and attains a size of ~ 0.15 to 0.2 mm in Praegubkinella. About one meter above the T-J boundary appear transitional forms from Praegubkinella to Reinholdella with an edged periphery. Closely higher up is found a new species of Reinholdella (? new genus) which is characterized on the umbilical side by chambers which are lengthened and curved towards the centre thus forming a central boss (umbo). They are distinguished from Reinholdella s. str. by a less developed tooth plate. This new species can be very frequent...
in some samples and reaches a diameter up to 0.3 mm. The range of variation is very high. Specimens with a high spiral side are found together with specimens with a relatively low spiral side. At the end of growth the ultimate chambers are decreasing and the umbilical side increases or decreases with an erected last chamber.

The evolution of *Praegubkinella* continues parallel and leads to species with a low spiral side and an open umbilicus and a less rounded periphery. Specimens of Oberhauserellidae (Ø 0.2 to 3 mm) with a high or low spiral side are found in moraine boulders of upper Early Hettangian and middle Hettangian age. The youngest Oberhauserellidae were described by Wernli (1988) from the Early Toarcian. The Oberhauserellidae are said (Fuchs, 1967; Wernli, 1988; Hart, et al., 2003) to be the ancestors of the Middle Jurassic Globuligerinidae and the earliest planktic foraminifera. Well preserved specimens of both families are mainly distinguished by different apertures, a secondary foramen, and the shell surface and the form of the chambers.

The evolution of *Praegubkinella* continues parallel and leads to species with a low spiral side and an open umbilicus and a less rounded periphery. Specimens of Oberhauserellidae (Ø 0.2 to 3 mm) with a high or low spiral side are found in moraine boulders of upper Early Hettangian and middle Hettangian age. The youngest Oberhauserellidae were described by Wernli (1988) from the Early Toarcian. The Oberhauserellidae are said (Fuchs, 1967; Wernli, 1988; Hart, et al., 2003) to be the ancestors of the Middle Jurassic Globuligerinidae and the earliest planktic foraminifera. Well preserved specimens of both families are mainly distinguished by different apertures, a secondary foramen, and the shell surface and the form of the chambers.
Species of the Globuligeneridae often are forming packstones which can be compared with the today’s foraminiferal ooze of planktic foraminifera. Similar packstones were described by Wernli (1988) from the Toarcian of Turkey (western Taurus). Oberhauerefellidae mostly are found in more or less bituminous shales or marls.

**Key words:** Aragonitic foraminifera (Robertinina); T-J boundary; Northern Calcareous Alps

**References:**
First Circum-Pacific Record of *Dimorphinites* (Ammonoidea, Upper Bajocian) in the Precordillera of Northern Chile

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New ammonite fossil-assemblages containing morphoceratids have been discovered in the Quebrada San Pedro area, northern Chile, Region de Antofagasta, Comuna Sierra Gorda, approximately 40 km ESE of Sierra Gorda town and 75 km south of Calama city. The outcrop is located 1 km north of the composite section described as Quebrada de San Pedro and 10 km south of the classical localities of Caracoles Mining District previously studied by diverse authors (Gottsche, 1878; Steinmann, 1881; Mörck, 1894; Westermann, 1967, 1981; Hillebrandt, 1970, 1973, 1977, 2001; Westermann and Riccardi, 1979, 1980; Jensen and Quinzio, 1979, 1981; Gröschke and Hillebrandt, 1985; Hillebrandt et al., 1986; Gröschke et al., 1988; Riccardi et al., 1990a, b; Riccardi and Westermann, 1991a, b; Fernandez-Lopez et al., 1994; Gröschke and Hillebrandt, 1994).

In the Caracoles-Quebrada de San Pedro area, overlying unconformably Triassic volcanic and metamorphic rocks, there is a succession of Jurassic, fossiliferous deposits belonging to the Caracoles Group (Harrington, 1961; Garcia, 1967; Montaño, 1976; Marinovic and Garcia, 1999; Ardill et al., 1998). The lowest marine deposits are brown, calcareous sandstones and fine-grained conglomerates belonging to the Coronado Formation. This lithostratigraphic unit is followed by yellow and brown shales with intercalations of limestones and calcareous sandstones, of the Torcazas Formation, developed in shallow marine settings. In overlying levels, there are yellow and green shales with intercalations of limestones, belonging to the Mina Chica Formation, developed in offshore settings. The lithostratigraphic position of the new ammonite fossil-assemblages is the top of the Torcazas Formation, below the Mina Chica Formation. In this locality, the last beds of the Torcazas Formation correspond to a centimetric interval of grey wackestone to packstone limestones containing re-sedimented specimens of Upper Bajocian ammonites, without traces of re-elaboration. These ammonites have been collected by one of the authors (F.L.) during several field studies, between 2006 and 2010.

![Fig. 1 Lithostratigraphy and lithology of study area](image_url)

Among the ammonoids of these fossil-assemblages, Sphaeroceratidae are dominant, being *Megasphaeroceras* [M+m] the most common ammonite genus. Stephanoceratidae, Persipinctidae and Oppeliidae are scarce, but *Cadomites* [M]-Polyplectites [m], *Ferrispinctes* [m]-Prorsispinctes [M] and *Oxycerites* [M]-Parococotraustes [m] are well represented. Morphoceratidae, Lissoceratidae and Strigoceratidae are very scarce, respectively represented by *Dimorphinites* [M]-Vigoriceras [m], *Lissoceras* [M]-Microlissoceras [m] and *Strigoceras* [M]. Besides Ammonitina, Phylloceratina and Lytoceratina are extremely scarce, but they occur. Among the morphoceratids of this stratigraphical interval, macroconchs of *Dimorphinites dimorphus* (D’Orbigny) and microconchs of *Vigoriceras defrancii* (D’Orbigny) have been identified. Since *Dimorphinites dimorphus* (D’Orbigny) [M+m] has only been known from the...
Parkinsoni Zone, Upper Bajocian, of Europe, North Africa and south part of the Transcaucus (cf. Dietze and Bernt, 2009), this standard zone is now extended to the SE Pacific. Some associated taxa, such as *Vernisphinctes* [m]-*Prorsisphinctes* [M], *Strigoceras* [M] and *Oxycerites* [M]-*Parococotraustes* [m] also indicate the uppermost Bajocian age and Tethyan affinities.

**Key words:** Jurassic; Marine stratigraphy; Palaeobiogeography; South America

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Tithonian Ammonites Fauna from Koppeh Dagh, Northeastern Iran

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In contrast to the 1722 m measured by Afshar Harb (1994) 1556 m were measured here. The Chaman Bid Formation mostly consists of alternations of grey limestone, grey marly limestone (mudstone to packstone) with pyrite, shale, argillaceous shale, and a few levels of sandstones. According to the ammonite fauna, the Chaman Bid Formation ranges from the ?Bathonian to the Tithonian. At the type locality, the formation has been subdivided, from base to top, into seven members.

Some of the ammonite genera and species are recorded from Iran for the first time, including Phanerostephanus subsenex, Nothostephanus sp., Nannostephanus cf. subcomitus, Richterella richteri, Pseudolissoceras zitteli, Glochiceras sp., Oxytenticeras cf. lepidum.

Based on ammonites, the Chaman Bid Formation ranges from the ?Bathonian to Lower Tithonian in Chaman Bid section.

Open-marine environments of the Chaman Bid Formation was separated from the extensive shelf lagoon by a rimmed platform margin. Their sediments were deposited on the slope of the carbonate platform and in the adjacent basin.

Introduction

Jurassic rocks are widely distributed and superbly exposed in the Koppeh Dagh (northeastern Iran). Some parts of the Middle Jurassic are characterized by a thick siliciclastic succession (Kashafrud and Bashkalateh formations), whereas the Upper Bathonian to Tithonian rocks are predominantly carbonates, which represent a platform, slope and basin system. The Chaman Bid Formation in the Koppeh Dagh, is the scope of this research.

In the last decades, many authors studied the Middle and Upper Jurassic succession of Iran with respect to micro- and macrofossils (e.g. Madani, 1977; Afshar Harb, 1979, 1994; Seyed-Emami et al., 1994, 1996; Schairer et al., 1999; Hossonion, 1996).

The Middle and Upper Jurassic sedimentary successions of Koppeh Dagh in northeastern Iran comprise four formations; Kashafrud, Bashkalateh, Chaman Bid and Mozduran.

Biostratigraphy and lithostratigraphy

Kashafrud Formation

This formation consists of a sequence of dark coloured turbiditic siliciclastics containing turbidites. They mainly comprise shales, siliceous shales and sandstones. This unit is widespread in the south-eastern region of Koppeh Dagh (Madani, 1977; Afshar Harb, 1994, 1979; Hossonion, 1996). In the southwestern Koppeh Dagh the Kashafrud Formation is not developed; its time-equivalent rock units are the Bashkalateh and Chaman Bid formations. The lower part of the formation overlies with angular unconformity or locally with a coarse-grained conglomerate of the Triassic Aghdarband Group, Upper Permian ophiolites, or the Mashhad Granite of Mid-Cimmerian origin. The upper boundary of the formation is either a disconformity, a tectonic contact, or a conformable contact with the Chaman Bid and Mozduran formations (Hossonion, 1996). The Kashafrud Formation represents a turbidite facies forming at the suture of the Iran Plate with the Turan Plate (Seyed-Emami et al., 1994).

Bashkalateh Formation

The formation occurs mainly in the western Koppeh Dagh (Afshar Harb, 1979, 1994). According to Seyed-Emami et al., (2001), it is a fine-grained lateral equivalent of the Kashafrud Formation.

Chaman Bid Formation

The Chaman Bid Formation consists of grey to bluish, thin- to medium-bedded limestone with intercalations of marly shale and marl (Afshar Harb, 1979, 1994). At the type section (north of Chaman Bid village), the formation attains a thickness of 1722 m. The thickness varies and increases from east of Koppeh Dagh towards the west. The Chaman Bid Formation conformably overlies the Bashkalateh Formation. Its upper boundary with the Mozduran Formation is sharp. Main sedimentary environments of the formation are basin and continental slope. Afshar Harb (1994) assigned a Late Bajocian to Oxfordian age to the formation, but recent studies (Schairer et al., 1999) show that the formation may continue up to the Tithonian.

Mozduran Formation

At the type section, the Mozduran Formation consists of light-coloured thick-bedded limestones to massive, porous dolomitic limestones and dolomite. According to Afshar Harb (1979) the thickness of the formation at the type section is about 420 m, but towards the northeast, at Sirzar village, it reaches 1400 m (Stöcklin, 1972). At the type locality, the Mozduran Formation conformably overlies the Kashafrud Formation. According to Afshar Harb (1979) however, the contact is a weathered surface. At some localities of the Koppeh Dagh region, the Mozduran Formation has a conformable contact with the Chaman Bid Formation. The upper boundary of the Mozduran Formation with...
Shorijeh Formation is erosional. However no detailed information is available to reach any final conclusions (see chapter 3). Nabavieh (1995) believed the boundary between the Mozduran Formation and the Shorijeh Formation to be transitional. At many localities, the age of the Mozduran Formation, based on foraminifera, was found to be Oxfordian-Kimmeridgian, at others Neocomian (Afshar Harb, 1994). Lasemi (1995) divided the environment of the Mozduran Formation to in four sub-environments, i.e. tidal flat/beam, lagoonal, platform margin, and open marine.

In the following, the lithology of the four measured sections is briefly described and their faunal content, in particular ammonites, is given. The latter are used to biostratigraphically subdivide the successions.

**Locality of section**

Chaman Bid section: The section is located 3.5 km NW of Chaman Bid village in the Kourkhod Mountains. The distance from the section point to the Bojnourd – Gonbad road (60 km W of Bojnourd) is almost 1 km (co-ordinates: N 37°26´00´´, E 56°30´50´´; Fig. 1.1).

**Chaman Bid section**

The Chaman Bid Formation mostly consists of alternations of grey limestone, grey marly limestone (mudstone to packstone) with pyrite, shale, argillaceous shale, and a few levels of sandstones. According to the ammonite fauna, the Chaman Bid Formation ranges from the ?Bathonian to the Tithonian. At the type locality, the formation has been subdivided, from base to top, into seven members.

**Bashkalateh Formation**

This formation is characterized by thinly bedded siltstone and dark grey silt with intercalations of medium-bedded, dark-grey sandstones interpreted as turbidites. Fossils include the trace fossils *Paleodictyon*, reworked plant remains, and in the upper part small pyritized ammonites and belemnites (*Cadomites* sp.) the latter indicating a Late Bajocian age. The transition to the overlying Chaman Bid Formation is gradual.

**Member 1 (30 m):** Alternations of grey shales and thin-bedded, sandy limestones (grainstone) with bryozoans, sponge spicules, bivalves (filaments), echinoderm debris, belemnites and radiolarians.

**Member 2 (408 m):** The member contains the following ammonites: *Hecticoceras* sp., *Reineckeia* sp., and *Rehmannia* sp., which indicate a Callovian age. All ammonites have been obtained from the upper part of the member. For the lower part, which lacks index ammonites, a ?Bathonian age is inferred based on its stratigraphic position, as Upper Bajocian ammonites have been recorded from the top of the Bashkalateh Formation.

**Member 3 (33 m):** Trace fossils include *Thalasinosoides*, *Planolites*, and *Gyrochorte*.

**Member 4 (357 m):** the member contains a rich ammonite fauna, indicative of the Oxfordian-Lower Tithonian. Based on these ammonites, three assemblage zones can be distinguished:

Biozone A (Oxfordian) comprises the ammonites *Taramelliceras* cf. *costatum* (Binammatum and planula zones), *Dichotomoceras* sp., *Glochiceras* sp., and *Subdiscosphinctes* sp.
Biozone B: This biozone is represented by abundant ammonites, which occur in the upper part of the member and which are similar to the ammonites described by Spath (1970) from northern Iraq. According to Spath (1970), these ammonites indicate the upper part of the Lower Tithonian and the lower part of the Upper Tithonian. However, at top of this member Richterella richteri is common, which indicates Lower Tithonian (Cecca, 1986). Therefore, the age of this assemblage is older than that of Richterella. The assemblage comprises the following taxa:

Pseudolissoceras zitteli, Glochiceras sp., Oxytenticeras cf. lepidum, Phanerostephanus subsenex, Nothostephanus sp., Phanerostephanus sp., and Nanostephanus cf. subcornutus.

Biozone C: This biozone is indicative of the Lower Tithonian Fallauxi Zone and is characterized by abundant Richterella richteri and Richterella sp. Sublithacoceras sp. is rare.

Member 5 (78 m): Trace fossils include Gyrochorte.

Member 6 (42 m): No index fossils were recorded.

Member 7 (658 m): Based on its stratigraphic position, a Tithonian-Neocomian age of the member is assumed, although no index fossils were recorded.

Mozduran Formation: Massive, light-grey limestones (wackestone to grainstone), which overlie the Chaman Bid Formation with conformable but sharp contact.

Key words: Tithonian; Ammonites; Chaman Bid; Koppeh Dagh

References:
Cylindroteuthid Belemnite Correlation of the Jurassic/Cretaceous Boundary Strata in Northern Siberia and Northern California

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In the Northern hemisphere there are some sections of the Jurassic/Cretaceous (J/K) boundary strata where Boreal and Tethyan molluscan fauna can be found together. They are all located on the Pacific margins, in northeast Asia (Far East of Russia, Northeast China) and on the western coast of North America (Western British Columbia in Canada, Northern California and Southwest Oregon in the USA). Cephalopods are quite rare here, and age determinations are based on Boreal bivalve Buchia records. Tethyan ammonites on separate levels make it possible to determine the age of rocks in accordance with the standard Tethyan zonal scheme. The greatest abundance of belemnites (Boreal Cylindroteuthididae and Tethyan Mesohibolitidae) is found in Northern California (Stanton, 1895; Anderson, 1945).

The Northern Siberia buchiid succession correlates with that of Northern California through British Columbia. The absence of common Buchia zones in all three regions in the Tithonian and most of the Berriasian gives rise to a variety of interpretations of the correlation relationships (e.g., Zakharov, 1981, 2004; Jeletzky, 1984; Hoedemaeker, 1987). In this case it is rather difficult to compare J/K boundary strata based only on Buchia. Certain progress has been made in solving this problem following the investigation of a new collection of belemnites from the Nordvik Peninsula (Northern Siberia, Russia) where one of the most complete Boreal sections of the J/K boundary interval is located.

In the Volgian and Ryazanian of Nordvik Peninsula a number of Cylindroteuthididae species known in Northern California have been determined such as Cylindroteuthis (Cylindroteuthis) knoxvillensis, C. (C.) cf. newvillensis, C. (Arctoteuthis) porrectiformis, C. (A.) tehamaensis, Lagonibelus (Lagonibelus) napaensis. Most of them are index-species of the belemnites beds and zones in Siberia (Fig.1). In the J/K boundary interval two parallel continuous sequences of cylindroteuthid biostratons have been established: 1)Russiensis Zone, Gustomesovi–Porrectiformis Beds; 2)Napaensis Beds, Tehamaensis Zone, Knoxvillensis Zone. The two latter zones can be traced to Northern California in the belemnites beds rank.

Lagonibelus (Lagonibelus) californicus and L.(L.) tomsensis finds in the lower part of the Buchia elderensis Subzone in Northern California make it possible to compare this stratigraphic interval with lower part of the Boreal Variabilis ammonite Zone. This is evident from the fact that the L.(L.) californicus is closest to the Middle Volgian Lagonibelus forms and in particular to L.(L.) parvulus. There were certain
speculations as to the identity of \(L(L.)\) \textit{tomsensis} and \(L(L.)\) \textit{napaensis} (Dzyuba, 2004). Species \(L(L.)\) \textit{parvulus} has been found together with \(L(L.)\) \textit{napaensis} only in the lower part of the Variabilis Zone where they are known in Siberia. It is noteworthy that the section interval in the upper part of the \textit{Buchia elderensis} Subzone in Northern California containing Kossmatia and Durangites? ammonites correlates with the lower part of the Tethyan Durangites Zone (e.g., Hoedemaeker, 1987). Stratigraphically its location is above the Californic–Tomsensis Beds corresponding to the Variabilis Zone that concurs with paleomagnetic data for the Middle Volgian deposits (Houša et al., 2007).

Tehamaensis belemnite Beds provide a correlation of the upper part of the Californian \textit{Buchia fischeriana} Subzone with the interval within the Siberian \textit{B. unschensis} Zone corresponding to the upper part of the Taimyrensis Zone, Chetae Zone and basal part of Sibiricus Zone in ammonite scale. In spite of the fact that belemnites have not been discovered in bottomset deposits, the \(C(C.)\) \textit{newvillensis} found in Northern California in the uppermost part of the Tehamaensis Beds suggests their near full release, since \(C(C.)\) cf. \textit{newvillensis} appears in the Nordvik Peninsula in the base of the Chetae ammonite Zone.

Knoxvillensis belemnite Beds in Northern California have been released in the volume of the \textit{Buchia} aff. \textit{Okensis} Zone. In accordance with various correlation models with the Siberian Buchia scale this zone corresponds to: (1) the \textit{B. okensis} Zone (Zakharov, 1981); (2) the \textit{B. unschensis} Zone (e.g., Jeletzky, 1984; Hoedemaeker, 1987); (3) the small interval within the \textit{B. unschensis} Zone (Sey and Kalacheva, 1993); (4) the uppermost part of the \textit{B. unschensis} Zone–\textit{B. Okensis} Zone (Zakharov, 2004). By referring to the data obtained it can be concluded that the lowermost part of the Siberian \textit{B. unschensis} Zone comprising the Taimyrensis and Chetae ammonite zones, cannot be correlated to the Californian \textit{B. aff. Okensis} Zone since the Knoxvillensis belemnite Zone in Siberia contains ammonite zones placed stratigraphically above (Fig.1). Belemnites testify to the correspondence of the \textit{B. aff. Okensis} Zone to, at the very least, the Sibiricus ammonite Zone of the Ryazanian Stage. Since no belemnites have been found in the base of the superjacent \textit{Bunctoides} Zone in California we cannot determine the stratigraphic content of Knoxvillensis Beds released here. It is not improbable that the Knoxvillensis Beds and \textit{B. aff. Okensis} Zone respectively contain more recent deposits, which is shown by the find in this interval of the ammonite \textit{Bochianites glennensis}, recently cf.-marked, in the base of the Kochi ammonite Zone on the Nordvik Peninsula (Rogov and Igolnikov, 2009).

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**Key words:** J/K boundary; Belemnites; Siberia; California

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Late Jurassic Time Scale: Integration of Ammonite Zones, Magnetostratigraphy, Astronomical Tuning and Sequence Interpretation for Tethyan, Sub-Boreal and Boreal Realms

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Several inter-disciplinary teams have enabled the assembly of a composite Late Jurassic time scale (an excerpt is shown in Figure 1), which includes the following syntheses and implications:

**Intercalibration of the Boreal, Sub-Boreal and Tethyan faunal realms.** Ammonite biostratigraphers have improved the standardization of zonal definitions for each faunal realm and identified inter-regional incursions of marker taxa. The detailed polarity sequences enhance the correlation of subzones among faunal realms.

**Absolute durations for each ammonite zone and most subzones.** Expanded sections of clay-rich sediments or alternations of marl to limestone in basal settings display a signature of superimposed cyclic oscillations. The distinctive 405kyr long-term eccentricity signal enables estimates of durations for ammonite zones/subzones in Oxfordian, Kimmeridgian, Volgian, and portions of the Berriasian.

**Correlation to the M-sequence of marine magnetic anomalies, thereby enabling determination of spreading rates.** The cycle-scaled magnetic polarity pattern of the Oxfordian through Berriasian can be matched to the “M-Sequence” derived from Pacific marine magnetic anomalies. Spreading rates for the Hawaiian spreading center gradually slowed from an early Oxfordian rate of 29 km/myr to the middle Berriasian with 26 km/myr.

**Quantifying offsets of regional usage of “base-Kimmeridgian” and other stage/substage boundaries.** The combined ammonite-magnetic time scale indicates that the proposed base-Kimmeridgian GSSP (coinciding with base of the *Pictonia baylei* Zone of Sub-Boreal ammonite province) is equivalent to a level within the middle of the *E. bimammatum* Zone) in the Sub-Mediterranean standard zonation, or 1.3 myr older than its traditional placement in that Sub-Mediterranean zonation.

Many of the sedimentary sequences correspond to 405-kyr eccentricity cycles. The Oxfordian shelf successions of the Dorset and Yorkshire regions in England have pronounced facies changes and recognized hiatuses within its ammonite biostratigraphy. The interpreted sequences display a consistent relationship to the shifts in clay/carbonate content in SE France. The cycle stratigraphy of these French sections implies that the major control on the minor Oxfordian sequences is a 405-kyr long-eccentricity orbital-climate oscillation.

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**Key words:** Oxfordian; Kimmeridgian; Tithonian; Timescale; Cycles; Magnetostratigraphy
Fig. 1 Integrated time scale for the Late Jurassic
Callovian Ammonites of North Iran

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The Dalichai Formation ranges from 97 to 567m of light-grey to bluish-grey limestone with thin intercalations of marl. The lower boundary of the Dalichai Formation is an unconformity due to the Midd-Cimmerian tectonic event (the marine transgression of the Dalichai Formation over the Shemshak Formation is diachronous). In many areas theupper boundary of the Dalichai Formation is, however, gradational. In a few areas it is continuous but sharp and followed by the Lar Formation. The sedimentary environments, in which this formation was deposited, are the lower shelf to continental slope. The Dalichai Formation is rich in ammonites (Upper Bajocian to Lower Tithonian).

Callovian ammonites are described from the Dalichai Formation of the Alborz (northern Iran). The ammonites belong to the following genera and sub-genera respectively:

Phylloceras sp., Holcophylloceras sp., Calliphylloceras sp., Ptychophylloceras sp., Sowerbyceras sp., Bulimatimorphites (Sphaeroptychius) sp., Macrolephalites (M.) jacquoti, Macrocephalites (Kamptophycus) sp., Hubertoceras sp., cf. Holcophylloceras sp., ct. Pseudopunctatum, Hecticoceras (Brightia) aff. Solinophorum, Pachyceras lalandei, Reineckeia (Tyranmites) convex, Reineckeia (Tyranmites) sp., Reineckeia (Reineckeia) anceps, Rehmanna (Loczyeceras) segestana, Rehmanna (Loczyeceras) cf. hungarica, Rehmanna (Loczyeceras) intermedia, Rehmanna (Loczyeceras) sequanica densicostata, Indosphinctes (Elatmites) cf. revile, Indosphinctes (Elatmites) sp., Flabellisphinctes (Flabellia) tsiytovitchae, Binatisphinctes (Okaites) cf. mosquensis, Choffatia (Grossouvria) kontkiewiczii, Homoeoplanulites (Homoeoplanulites) sp. Grossouvria (Alligaticeras) sp., cf. Hubertoceras sp.

Introduction

Jurassic rocks are widely distributed and superbly exposed in the Alborz Mts. (northern Iran). The Lower Jurassic and large parts of the Middle Jurassic are characterized by a thick siliciclastic succession (Shemshak Formation), whereas the Upper Bajocian to Tithonian rocks are predominantly carbonates, which represent a platform, slope and basin system. The Callovian ammonites in the Dalichai Formation are the scope of this research.

In the last decades, many authors studied the Middle and Upper Jurassic succession of Iran with respect to micro- and macrofossils (e.g., Erni, 1931; Arkell, 1956; Assereto, 1966; Assereto et al., 1968; Davis et al., 1972; Stampfli, 1978; Seyed-Emami et al., 1985, 1987, 1989, 1991, 1995, 1997; Seyed-Emami & Nabavi, 1985; Keshani, 1988; Schairer et al., 1992; Schweitzer & Kirchner, 1995,1996).

Biostratigraphy and lithostratigraphy

Dalichai Formation

The type section of this formation consists of 107 m of light-grey to bluish-grey limestone with thin intercalations of marl. According to Steiger (1966), the thickness of the formation is about 50 to 120 m (average: 100 m, reaching more than 300 m in the eastern Alborz). The lower boundary of the Dalichai Formation is an unconformity due to the Midd-Cimmerian tectonic event (the marine transgression of the Dalichai Formation over the Shemshak Formation is diachronous). In many areas the upper boundary of the Dalichai Formation is, however, gradational. In a few areas it is continuous but sharp and followed by the Lar Formation. The sedimentary environments, in which this formation was deposited, are the lower shelf to continental slope. The Dalichai Formation is rich in ammonites, which were studied by Erni (1931), Arkell (1956), Assereto et al., (1968), Seyed-Emami et al., (1985, 1989, 1991, 1994, 1995, 1996, 1997), and Schairer et al., (1992).

Shal Formation

The Shal Formation is restricted to the Talesh Mountains in the north-western Alborz and is Middle to Late Jurassic in age (Davis et al., 1972). At the type section, the thickness is about 61 m. The sediments consist of green, glauconitic and calcareous sandstones grading upward into medium-to thick-bedded glauconitic limestones. The lower part of the formation rests with a sharp boundary on siliciclastic rocks of the Shemshak Formation, whereas at top it grades into yellow marls of the Neocomian Kolur Formation. The Shal Formation contains abundant ammonites, but no detailed studies have been carried out so far. Ammonites of the lower part are thought to be Callovian or even Bathonian in age (Seyed-Emami, et al., 2001), whereas those from the top belong to the Tithonian.

There is a similarity with respect to stratigraphy and facies between this formation and the Dalichai Formation.

Farsian Formation

The Farsian Formation occurs in the northeastern
Alborz, close to Azadshahr. For the main part, it consists of red and yellow limestone, silt and marl. Stampfli (1978), who erected the formation, considered the red sediments to be a transitional unit sandwiched between the Shemshak Formation and the Lar Formation. Despite tectonic activity, the boundary between the Farsian and Shemshak Formations, is conformable but the upper boundary with the Lar Formation is gradual. The boundary has been drawn where the red limestone of the Farsian Formation changes to the yellowish to cream-coloured Lar Formation. Based on ammonites and foraminifers the age of the formation is late Middle Jurassic. According to Stampfli (1978) the Farsian Formation was deposited in infra-littoral to circa-littoral environments. According to him there is a similarity with respect to stratigraphy and facies between this formation and the Dalichai Formation.

Key words: Callovain; Ammonites; Dalichai; Mid-Cimmerian; Unconformity

References:
British Columbia and the Jurassic Time Scale: Contributions and Applications

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Understanding the Jurassic geology of western Canada has proved challenging. The combination of rapid lateral variations in facies and tectonic complexity made mapping difficult but, as a consequence, the importance of fossils for correlation was well appreciated from the early days of geological exploration. More recently, the need has been for well-documented, multi-taxial, regional zonations calibrated with a geochronological time scale. Only on this foundation can we build an understanding of the interplay between terrane accretion, intrusive activity and sedimentation. In such a plate tectonically active setting, sequences tend to be thick (often more than order of magnitude thicker than in Europe) and dominated by volcanic and volcanioclastic rocks. Consequently, condensing is rare and the interbedding of fossiliferous sediments and ash beds, from which U-Pb dates can be obtained, is common. This creates an ideal situation for time scale development and calibration. In addition, the common mixture of Tethyan, Boreal and endemic taxa has been particularly useful for global correlation. For North America, a well tested ammonite zonation now exists for much of the Lower and Middle Jurassic (Hall and Westermann, 1980; Jakobs et al., 1994; Longridge et al., 2006; Pálfy et al., 2000; Poulton and Tipper, 1991; Smith et al., 1988; Taylor et al., 2001). In this presentation, we will review the current status of the Jurassic of British Columbia and show how the time scale is being used to address a variety of geological and paleontological questions. In particular, we will explore the history of the Stikine terrane (or Stikinia) as it interacted with adjacent terranes during the Jurassic.

Fig. 1 Variation of conglomerate clasts as a function of age showing strong shifts in provenance for the Lower and Middle Jurassic rocks of the Lisadele Lake area, northwestern British Columbia

On Stikinia, there is an outlier of the Whitehorse Trough basinal strata occurring in the vicinity of Lisadele Lake in the central part of the Tulsequah map area (northwestern British Columbia). It includes conglomerates and interbedded fossiliferous finer clastic rocks of the Lower to Middle Jurassic Takwahoni Formation (Laberge Group) which unconformably overly Upper Triassic limestone of the Sinwa Formation. Ammonite collections record the Pliensbachian, Toarcian and Bajocian stages. We refine the age and provenance of several episodes of coarse clastic input and document the character of the dominant clasts in the conglomerates (Fig. 1). Immediately above the Triassic–Jurassic unconformity, sedimentary clasts derived from the Sinwa Formation predominate. The dominant rock-type of clasts in the overlying conglomerates changes up-section from volcanic near the base, to plutonic in Pliensbachian–Toarcian strata, metamorphic in uppermost Toarcian rocks, and to chert in the Middle Jurassic strata of Early Bajocian age. The Bajocian chert-pebble
conglomerate and the immediately underlying thick-bedded black mudstone are correlated with the Bowser Lake Group. The implication of the clast composition and regional correlation is that the basal part of the Bowser Lake Group (Ashman Formation) is diachronous, younging southwards towards the central Stikine terrane and suggesting that obduction of the Cache Creek terrane source area occurred first in the north (Fig. 2). Comparison of the isotopic ages of the zircons and granite clasts with the biochronologically constrained ages of the enclosing strata suggests that Early Jurassic intrusion, uplift, unroofing, and deposition probably occurred within five million years. Petrographic studies and biochronological and isotopic age control of sandstone petrofacies indicate a complex arc-basin evolution. The trends indicate a rapid change from transitional to dissected arc and finally to recycled orogen source area affinities in northern Stikine terrane in Early and Middle Jurassic time.

Key words: Time scales; Stikinia; Tectonics; Canada

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Pálfy J., Smith P.L., Mortensen J.K. A U-Pb and $^{40}$Ar/$^{39}$Ar time scale for the Jurassic. Canadian Journal of Earth Sciences, 2000, 37: 923-44.
The Mikhalenino Section of the Russian Platform: A Key Section for Palaeobiogeography and Ammonite Correlation of the Middle Oxfordian to Lowermost Kimmeridgian in Europe

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The Oxfordian and lowermost Kimmeridgian deposits which crop out along the Unzha River of the Kostroma District, about 500 km north-east of Moscow, although generally of small thickness, are stratigraphically among the most complete of the Russian Platform, and thus are especially important for wider correlations and palaeobiogeography. The Mikhalenino section located close to the town of Makariev is one of the best sections of the area. It yielded numerous ammonites of the Middle Oxfordian to lowermost Kimmeridgian carefully collected bed by bed by all the authors. The ammonites belong mostly to the Boreal family Cardioceratidae, but also to the Subboreal ammonite zones of the Upper Oxfordian: the Decipiens Zone (Cautisnigrae Zone), and the Pseudocordata Zone – which is the topmost zone of the Subboreal Province. Younger aulacostephanids in the Mikhalenino section are represented by genera Vineta, Pomerania(Pachyptictonia), and a special Pictonia species, all of them differing from aulacostephanids known in coeval deposits of the lowermost Kimmeridgian of the NW European part of the Subboreal Province. Their occurrence is thus typical of the lowermost Kimmeridgian of the NE part of the Subboreal Province which embraces the northern Germany, northern Poland (including Pomerania) and Lithuania, and as shown in the material studied – a large part of the Russian Platform. Some ammonites of the NE European Subboreal assembly in question are moreover known also to occur in the lowermost Kimmeridgian of the Submediterranean Province in Poland and Germany. The data given enables the recognition of the Oxfordian/Kimmeridgian boundary as recognized in the Flodigarry section, Isle of Skye, Scotland, also using the NE European Subboreal ammonites.

The Submediterranean ammonites in the Mikhalenino section occur mostly in the Middle Oxfordian, and lowermost part of the Upper Oxfordian – proving the presence of the Plicatilis Zone, the Transversarium Zone, and the Bifurcatus Zone of the Submediterranean zonal scheme. A well defined assemblage typical of the Elisabethae Subzone of the Transversarium Zone has been found together with Boreal ammonites of the Ilovaiskii Subzone of the Glosense Zone, as well as the Subboreal ammonites of the genus Decipia indicative of the Decipiens (Cautisnigrae) Zone. The youngest representatives of the genus Perisphinctes indicative of the Bifurcatus Zone, has been found together with Boreal Amoeboceras of the Regulare Zone, and the first Subboreal Ringsteadia of the lower part of the Subboreal Pseudocordata Zone.
Key words: Ammonites; Biostratigraphy; Correlation; Zonal schemes

References:
Problems of the Correlation of the Middle-Upper Jurassic of Caucasus

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Caucasus is very important region for understanding of migration of the Jurassic biota between different parts of Tethys and from Tethys to the Boreal paleobasins (East European Platform) and back. Caucasus is the key area for correlation of the Jurassic deposits from the Carpathians to Asia. During Jurassic time Caucasus had two stages of development: first–Early-Middle Jurassic, second–Middle-Late Jurassic. In the first stage the difference of the biota and lithofacies for different parts of this region is not so much, but in second one–difference is higher. On the whole the terrigenous deposits are dominated in the first stage and carbonate rocks–for the second one. Moreover, in the Middle-Late Jurassic time there are more diverse deposits–flysches, evaporites, reefs and other.

The official stratigraphical schemes of the Jurassic of Caucasus were published in 1984 (Rostovtsev and Krymholz, 1984), which were accepted by Interdepartmental Stratigraphic Committee of the USSR. The last stratigraphical schemes of the Jurassic of Caucasus were published in 1992 by international group of geologists from different countries (Rostovtsev et al., 1992). After that stratigraphical schemes were produced by the local geological survey from the North Caucasus in the unpublished reports or published by person. So, there are very old official stratigraphical schemes and we needs new schemes, because there are a lot of new data and some non official versions of such schemes.

In this report some above mentioned schemes and a new personal version of stratigraphical scheme of the Middle-Upper Jurassic of the Russian part of Caucasus are discussed. The considered territory consists of several paleotectonical zones which are included in Scythian plate, the Great Caucasus and Transcaucasus massive. Each paleotectonical zone has typical number of formations. In the considered stratigraphical scheme of the Middle-Upper Jurassic of the Russian part of Caucasus, there are a lot of formations and groups. In the Middle-Upper Jurassic of Caucasus, there are a lot of fauna groups, but only two–ammonites and foraminifers are used for biostratigraphical zonation. There is only one ammonite zonation, and there are several foraminiferal zonations. In the last century there was only one region of the Russian part of Caucasus–Kabarda-Dagestan paleotectonic zone (central and eastern part of the Northern Caucasus), which has the schemes of the foraminiferal zonation for dividing the Middle-Upper Jurassic (Makar’eva and Mazieva, 1985). Several years ago the foraminiferal zonation for the Upper Jurassic of the eastern part of the Lagonaki zone (Western Caucasus) was proposed, which consists of two local foraminiferal zones: Aníospirocyclina jaccardi local foraminiferal zone (Oxfordian-Kimmeridgian) and Melathrokerion spiralis local foraminiferal zone (Tithonian) (Vuks, 2002). Besides, analysis of the foraminiferal distribution in the Upper Jurassic of the Western Caucasus allows us to suggest the name (typical species) for each association and new zonation. In general, Alveosepta ukrainica (?) local foraminiferal zone is characteristic for Oxfordian–Kimmeridgian of the southern part of the Novorossijsko-Lazarevskaya zone, eastern part of the Abino-Gunajskaya zone and western part of the Lagonaki zone. Anchispirocyclina jurassica–Lenticulina ponderosa local foraminiferal zone is typical for Tithonian of the northern part of the Novorossijsko-Lazarevskaya zone, eastern part of the Abino-Gunajskaya zone and western part of the Lagonaki zone. Thus, in the Upper Jurassic of the Western Caucasus there is a preliminary biostratigraphitical scheme, where there are two successions of the local foraminiferal zones: Alveosepta ukrainica (?) local foraminiferal zone (Oxfordian–Kimmeridgian) and Anchispirocyclina jurassica–Lenticulina ponderosa local foraminiferal zone (Tithonian) for the most part of the Western Caucasus, Alveosepta jaccardi local foraminiferal zone (Oxfordian–Kimmeridgian) and Melathrokerion spiralis local foraminiferal zone (Tithonian) for the eastern part of the Lagonaki zone (Vuks, 2007). On the most part of the Western Caucasus, there are very similar assemblages and they are good correlated, but in the Lagonaki barrier reef zone and Abino-Gunajskaya zone, there are very specific facies and foraminiferal communities. Thus, the successions of the foraminiferal assemblages of the above-mentioned regions of Caucasus are not the same, because foraminifers in each part of this territory developed with different rates and their successions of events were not coeval. The preliminary foraminiferal zonation schemes are the first step toward to create the detailed foraminiferal zonation schemes for each paleotectonic zone of the Western Caucasus and correlate to such schemes from the others regions of Caucasus and world. Unfortunately foraminiferal zonation is not in the some paleotectonical zones of the Russian part of Caucasus (especially eastern part). This is the main problem for correlation of Jurassic by foraminifers. There is one ammonite zonation for the Russian part of Caucasus, but the findings of ammonites are very rarely and this zonation is very old. So,
there are zonations by ammonites and foraminifers, but other groups of fauna are not used.

There are problems for correlation concerned with special facieses (especially with reefs, and evaporites). Foraminifers and ammonites are very difficult to collect from these rocks or there are fauna (algae, gastropods), which are not studied in this area.

Some new formations were not used, because the descriptions of these formations were not published or were published without key data. According to “Stratigraphic Code of Russia” there is no possibility to use the formation in the official work, which was published without key data.

Thus, the main problem for correlation of the Middle-Upper Jurassic of the Russian part of Caucasus is concerned with two points. The modern paleontological researches are different and specific groups of fauna for carbonate rocks on Caucasus are absent. There is necessity to progress the investigation of the main group for Jurassic–ammonites and foraminifers.

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Key words: Middle-Upper Jurassic; Caucasus; Biostratigraphy; Correlation

References:
Nomenclature Problems of Ammonite Biohorizons (Faunal Horizons) in Jurassic and Cretaceous Stratigraphy

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Most detailed correlatable units using in the Jurassic and Cretaceous biostratigraphy are ammonite biohorizons (or faunal horizons). Most important features of biohorizons are the following: (1) potential indivisibility to those taxonomic criteria on which they are established, (2) determinacy as lower and upper boundary of biohorizons in a geological section, (3) identification from recognition of the single (unique) index-taxon (usually species or subspecies) (Callomon, 1984, 1985; Page, 1995; Gulyaev, 2001, 2002; Rogov et al., 2009, among the others). Paleobiological nature of biohorizons could be connected primarily with phylogenetic or immigration events (Zakharov et al., 2007); their geological nature controlled by different sedimentary and post-sedimentary processes.

For optimization of the decision of major aims of stratigraphy, which are subdivision and correlation, within the single area several parallel scales of biohorizons based on the different lineages of the key-taxa could be present. Also at a composite scale “intercalated” biohorizons based on the invasions of the immigrant species could be present (Fig. 1).

Taking into account a geological structure and an investigation level of a concrete regional section presence of gaps between successive biohorizons is allowed as well as noncoincidence of their boundaries with zonal and subzonal boundaries.

For the first time in the Jurassic such detailed geochronological ammonite-based units (“hemerae”) were used at the end of the XIX century (Buckman, 1893), but active application of biohorizons in the Jurassic and Cretaceous biostratigraphy began since 80th of the XX century.

Rapid development of the infrazonal approach during the last three decades has lead to the certain anarchy in establishing of new biohorizons and other infrazonal units. Proposed index-taxa of newly established units in many cases were given in open nomenclature, and many chronospecies were marked by non-linnean characters (greek letters, digits etc). All such examples are responsible for ambiguity in the understanding of the established units and should be considered only as provisional and require for revision. In other cases biohorizons are erected without any References to bed(s) in the studied sections and even within the heterogeneously condensed deposits. It is expedient to consider all such units as unavailable. If ones unable to present in publication detailed data about the position of new units within sections, better to use terms “faunal assemblage” or “fauna” instead the term “biohorizon”. Biohorizons are also sometimes recognized by acme-level of the index-species or by concurrent ranges of some taxa. In our opinion using of relative abundance of index-taxon for recognition of biohorizons as well as several index-taxa is undesirable, because nature of such units not always unambiguous and their correlative potential is small. Such units could not be considered as true biohorizons, and should be used as acme-horizons/zones and as concurrent range horizons/zones.

The current nomenclature uncertainty creates the necessity to develop a set of basic rules for establishing, recognizing and describing of biohorizons, because further use of biohorizons without such rules could lead to discredit of the whole infrazonal approach. Below brief review of the proposed rules are given (Gulyaev, 2002).

Most important nomenclatural characteristics are availability and validity.

Availability of biohorizon determined by (1) presence of name, which is consist from-word “biohorizon” or its synonym, available name of the index-species, name of author and year of publication of biohorizon; (2) presence of the stratotype; (3) accordance to publishing criteria accepted by ICZN and ICBN.

Validity of the biohorizon determined by principle of triple priority, including subordinate principles: (1) minuteness: the biohorizon having a smaller stratigraphical range has priority over a biohorizon having the larger stratigraphical range; (2) continuity: the biohorizon based on a species of the same lineage as contiguous biohorizons has a priority over a biohorizon based on a species of other lineage if it does not contradict with minuteness (3) seniority: the oldest of the available names of biohorizon has priority to the later, if it does not contradict the principles of minuteness and continuity.

Nomenclature of biohorizons in some extent depends on the nomenclature of the index taxa: (1) if the name of the index-species change on the basis of objective synonymy or homonymy (nomenclature type remains), the name of biohorizon also automatically changed, but the author remains the same, and his name is placed in brackets; (2) if the name of the index-species is recognized invalid due to the subjective synonymy, also becomes invalid and the name of the
biohorizon. In the latter case, the author of the new name of the biohorizon will be the first who revised it.

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Key words: Infrazonal biostratigraphy; Ammonites; Biohorizons; Faunal horizons; Nomenclature

References:


Page K.N. Biohorizons and zonules: Intra-subzonal
New Data on the Kimmeridgian Ammonite Biostratigraphy of Spitsbergen

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Recent progress in the Kimmeridgian ammonite-based biostratigraphy and discussions concerning the Kimmeridgian GSSP leads to the more detailed studying of the Kimmeridgian ammonites over the world. Among the other questions it is applicability of the proposed criteria of the Kimmeridgian GSSP level for wide correlations. Here new information about the basal portion of the Kimmeridgian of Spitsbergen is presented, along the revision of the ammonite succession for the whole stage based upon recent field works and, partially, on the re-interpretation of ammonite collections collected before.

The bulk of the data is based on the results of the field works (years 2006 and 2007) held at the famous Festningen and Myclegradfjellet sections, which were studied previously by many scientists (Frebold, 1928; Sokolov and Bodylevski, 1931; Birkenmajer et al., 1982; Erschova, 1983, among the others). As has been shown recently, Kimmeridgian ammonite succession permits to recognize some widely ranged faunal horizons (Wierzbowski, 1989), but its basal portion was little-studied.

Ammonite succession with preliminary zonal scheme could be summarized below (Table 1). Rarity of aulacostephanid ammonites and abundance of cardioceratid-based zonal and infrazonal scales (Wierzbowski and Smelror, 1993):

- **Lower Kimmeridgian**
  - **Bauhini Zone:** recognized at the Festningen section by appearance of *Plasmatites* (*P. cf. bauhini, P. cf. lineatum*)
  - **Kitchini Zone**
    - **Bayi horizon:** *Amoebites bayi* has been recognized at Festningen from level slightly above the Plasmatites.
    - **Subkitchini horizon:** well-defined at Janusfjellet section (Wierzbowski, 1989) as well as at Myclegradfjellet; at Festningen *Amoebites cf. subkitchini* are uncommon.
    - **Mesezhnikovi horizon:** recognized at Janusfjellet by Wierzbowski (1989), characterized by *Amoebites mesezhnikovi*.
    - **Amoebites pingueforme horizon:** firstly recognized at Janusfjellet (Wierzbowski, 1989) as *Rasenia cymodoce–Amoebites pingueforme* horizon it also could be traced at Festningen by presence of its characteristic taxa as well as microconchaulacoce Stephanids *Prorasenia*. Birkenmajer et al. (1982) also figured *Rasenia cymodoce* from the Myclegradfjellet section, but not *Amoebites pingueforme* nor *Rasenia* were found during the studies of the same section undertaken by the author.

- **Amoebites cf. beaugrandi** horizon perhaps could be fixed at Myclegradfjellet, where single specimen of *A. cf. beaugrandi* occurs few beds above the level with numerous *A. subkitchini*, but its preservation is far from good. Precise position of *Xenostephanus (= Zenoste-phanus, corrected)* horizon proposed by Wierzbowski (1989) is still unrecognized, because albeit *Zenoste-phanus* (including species *Z. sachsi*, which is widely ranged in Arctic) are known from Spitsbergen, and these ammonites were collected by our precursors during the geological survey and lacking data about precise level of their records within the succession.

- **Kochi Zone**
  - **Norvegicum horizon:** *Amoebites norvegicum* has been chosen as marker of the separate faunal horizon of the Barents Sea Kimmeridgian (Wierzbowski and Smelror, 1993). This remarkable species is characterized by weakly ribbed inner whorls which became strongly ribbed later. Presence of this horizon at Spitsbergen could be proposed at the base of record of *A. norvegicum* at the Myclegradfjellet section.

- **Sokolovi horizon:** *Amoebites sokolovi*, which is could be the recent synonym of the *A. kochi* (see Birkelund and Callomon, 1985), is a very characteristic ammonite for the Spitsbergen. Few specimens of this species have been collected at the Festningen section.

- **Elegans Zone**
  - Previously Wierzbowski (1989) based on his observations at Janusfjellet and suggested that in Spitsbergen decipiens and elegans horizons, which are recognized in East Greenland, cannot be separated. Upper part of the Kimmeridgian of the Festningen is very poor in ammonites, only one small nucleus resembling *Amoebites elegans* or *A. kochi* has been found. But at the Myclegradfjellet section late *A. elegans* (= *A. bodylevskii* Shulgina) occurs at the uppermost fossiliferous horizon within the Kimmeridgian ammonite succession and clearly separated from band with *Amoebites decipiens* which is located some 3.5 m below.

- **Taimyrensis Zone (?)**
  - *Suboxydiscites taimyrensis*, the Boreal oppelidi ammonite, is restricted at the Arctic by uppermost zone of the Kimmeridgian. But genus *Suboxydiscites*, as has been shown recently (Rogov and Wierzbowski, 2009), ranged through the whole Kimmeridgian Stage and its successive species are very poorly studied.
the collection by Erschova revealed presence of few *Suboxydiscites cf. taimyrensis*, but their precise position within the succession remains unclear.

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Key words: Kimmeridgian; Spitsbergen; Ammonites; Biostratigraphy

Table 1 Kimmeridgian ammonite zonation of Spitsbergen (preliminary) and East Greenland

<table>
<thead>
<tr>
<th>Subboreal zonation</th>
<th>East Greenland horizons (cardioceratid horizons were chosen when possible succession after Birkeland, Callomon, 1985)</th>
<th>Spitsbergen horizons (letters indicates sections: M - Myklegardfjellet, F - Fenningen, J - Janusfjellet (Wierzbowski, 1989))</th>
<th>Boreal zonation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aulacostephanus autissiodorensis</td>
<td>Aulacostephanus autissiodorensis</td>
<td>?</td>
<td>Suboxydiscites taimyrensis</td>
</tr>
<tr>
<td>Aulacostephanus eudoxus</td>
<td>Amoebites elegans</td>
<td>Amoebites elegans</td>
<td>M</td>
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<td></td>
<td>Amoebites decipiens</td>
<td>Amoebites decipiens</td>
<td>M</td>
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<tr>
<td></td>
<td>Amoebites kochi</td>
<td>Amoebites sokolovi</td>
<td>F-J</td>
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<td></td>
<td>Aulacostephanoides mutabilis</td>
<td>Amoebites norvegicum</td>
<td>M</td>
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<tr>
<td></td>
<td>Amoebites cf. beaugrandi</td>
<td>?</td>
<td>Suboxydiscites taimyrensis</td>
</tr>
<tr>
<td>Rasenia cymodoce</td>
<td>Amoebites aff. rasenense</td>
<td>Amoebites pingueformae</td>
<td>F-J</td>
</tr>
<tr>
<td></td>
<td>Amoebites aff. subkitchini</td>
<td>Amoebites meszchinkovi</td>
<td>J</td>
</tr>
<tr>
<td></td>
<td>“Pachyptictonia”</td>
<td>Amoebites subkitchini</td>
<td>F-M-J</td>
</tr>
<tr>
<td></td>
<td>Amoebites subkitchini</td>
<td>Amoebites bayi</td>
<td>F</td>
</tr>
<tr>
<td>Pictonia baylei</td>
<td>Amoebites bayi</td>
<td>Amoebites bayi</td>
<td>F</td>
</tr>
</tbody>
</table>

References:
Late Jurassic paleotectonic development was characterized by the start of a tensional decay of sialic crust (Vašíček et al., 1994). Carbonate platforms rimmed by barrier reefs evolved along the continental shelf margins which formed the substrate of the present Outer Carpathians. In shallow marine environments oosparites, pelbiosparites and biomicrosparites with grainstone to wackestone structures of Hrušovany, Novosedly and Pasohlavky formations were deposited. Tensioal basins situated inside the shelf were filled by detrital Vranovice, Klentnice, Kurdjuk and Novosedly and Pasohlavky formations. Biodetrital fragments were derived from shallows in Tatric and Hronic Units and they dominated also basinal bottoms in the Alpine-Carpathian basin. The basinal sedimentation in the areas adjacent to the Penninic Ocean was represented by Czajakowa Radiolarite Formation or by Ruhpolding Formation occupying also basinal bottoms in the Alpine-Carpathian basin. Elevations in the Central Carpathian zones (Tatric, marginal Fatric and Hronic) were also characterized by “Ammonitico Rosso” sedimentation (Tegernsee Formation). During Kimmeridgian and Tithonian, the Zliechov Basin was filled by argillaceous Jasenina Formation, while shallow Tatric and Hronic blocks. Elevations in pelagic environments were characterized by condensed sedimentation of the “Ammonitico Rosso” facies (Niedzica, Czorsztyn, and Tegernsee formations). The basinal sedimentation in the areas adjacent to the Penninic Ocean was represented by Czajakowa Radiolarite Formation or by Ruhpolding Formation occupying also basinal bottoms in the Alpine-Carpathian basin. Elevations in the Central Carpathian zones (Tatric, marginal Fatric and Hronic) were also characterized by “Ammonitico Rosso” sedimentation (Tegernsee Formation). During Kimmeridgian and Tithonian, the Zliechov Basin was filled by argillaceous Jasenina Formation, while shallow Tatric Ridge was covered by neritic limestones of Rapawicka Turnia Formation. Bioclastite fragments were derived from shallows in Tatric and Hronic Units and they deposited in the frame of turbidite cycles (Barmstein Formation) within the basinal micritic limestone (Oberalm Formation).

During the Early Cretaceous the Penninic Ocean evolved in oblique rifting and pull-apart spreading regime. This activity was controlled by facies variability of the subsiding basins of the Alpine-Carpathian microcontinent. Mass development of the calcareous microplankton, as well as differentiated current system, and a stabilized geodynamic regime in the Mediterranean Tethys resulted in the origin of the widely distributed “Neocomian facies”. “Biancone” and “Maiolicia” (Pieniny, Ladce, Osnica, Padlā Voda, Oberalm formations, Vašíček et al., 1994) dominated at the beginning of the Cretaceous.

The Upper Jurassic and lowermost Cretaceous pelagic sediments of the Western Carpathians are poor in ammonite fauna. Their stratigraphy is supported by the successive bioevents observed in planktonic associations (calpionellids, calcareous dinoflagellates and calcareous nannofossils). Calpionellid remnants rarely dominate over the phytoplankton being eliminated in environments in which radiolarians prevailed. The distribution of these planktonic groups emphasizes not only their biostratigraphical potential but shows them as the proxies in palaeoecology and palaeoceanography. Correlation of the calcareous microplankton and stable isotope analyses was used in the characterization of the J/K boundary interval (Michalík et al., 2009). Four calpionellid zones (Chitinoidella, Praetintinnopsella, Crassicollaria and Calpionella) with six subzones (Dobeni, Boneti, Intermedia, Brevis, Colomi and Alpina) and two nannofossils zones (Conusphaera mexicana mexicana, Microstaurus chiastus) with five subzones (Hexapodorhabdud cuvilieri NJ-20A, Polycostella beckmanni NJ-20B, Hexalithus noeliae NJK-A, NJK-b, NJK-c) are based on calpionellid and nannofossil distribution. Twelve calcareous dinoflagellate bioevent zones (Parvula, Fibrata Acme, Parvula Acme, Moluccana, Borzai, Pulla, Tithonica, Malmica, Semiradiata, Tenuis, Fortis, Proxima) were identified. Thus, parallel calpionellid, nannofossils and dinocyst zonation provide a more precise tool for the stratification of deposits investigated as well as for better understanding and reconstructing of the palaeoceanographical and palaeoecological conditions of the ancient marine environments.

Acknowledgments: This is a contribution to the 506 IGCP UNESCO Project and projects of Slovakian Grant Agency: APVV-0280-07, APVV-0248-07, APVV-0465-06, LPP 0120-09 and VEGA 0198.

Key words: Western Carpathians; Jurassic; J/K boundary; Biostratigraphy; Lithostratigraphy; Paleogeography

References:
Late Jurassic to Early Cretaceous Stratigraphy in Gyangze-Nagarze Area, Southern Tibet

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Three sections of uppermost Jurassic and Lower Cretaceous have been studied in the Gyangze-Nagarze area, southern Tibet. They are the Jiabula and Jiabula-goukou sections near Gyangze, and the Kadong section at Kadong village, Nagarze. The Jurassic Weimei Formation is composed mostly of sandstone and siltstone. The overlying Cretaceous Sangxiu Formation is a thick group of sedimentary-volcanic strata. In Gyangze, however, the Cretaceous strata above the Weimei Formation is named as Jiabula Formation and is mostly composed of black shale and muddy siltstone (Fig. 1). Many fossils have been found, including calcareous nannofossils, bivalves, belemnites, ammonites, and gastropods.

The J-K boundary succession is normally constrained by ammonites, and biostratigraphically between Haploghylloceras strigile and Spiticeras in the Gyangze-Nagarze area. Unfortunately ammonites are mostly domestic elements and calcareous nannofossils have become a key biostratigraphic tool. The calcareous nannofossils in this area comprise the Nannoceras st. steinmannii–N. st. minor–Watznaueria barnesae assemblage and the Calcicalathina oblongata–Spettonia colligata assemblage. The former assemblage can be correlated to NJK-D and NK-1 of the Tethys zonation, and the latter assemblage to NK-3 (Hardenbol et al., 1998). The two assemblages are also comparable with the Boreal biostratigraphy (Mutterlose and Kessels, 2000). Compared with the corresponding fossil zones in other areas in the world, the calcareous nannofossils have been integrated by graphic correlation with magnetochrons, ammonites, and calpionellids from twenty-three published reference sections. This dataset was composed with the MIDK45CS range data (Scott, 2009), which results in a database that spans the entire Cretaceous System, CRET1. The fossil ranges in the Gyangze section were compared to this mainly Tethyan data set and plotted on an X/Y graph. Two correlation segments project the base of the Berriasian Stage into the Gyangze section at 44 m above the base of the exposure, the base Valanginian at 100 m, and the base of the Hauterivian Stage as defined by the FO of Acanthodiscus radiatus (Reboulet et al., 2008) at 134.28 Ma into the section at 314 m. The tuff bed in the Kadong section yielding the radiometric is projected into the Gyangze section at 190 m by measuring section thickness from the contact between the Weimei and Sangxiu formations to the dated bed. The age of this level is projected by the upper LOC (line of correlation) at 137.61 Ma, well within the 136±3 Ma range. On the graph the error box spans the 6 myr error range of the radiometric date and is extended up section to the intersection of 136 Ma on the LOC. This box outlines the thickness range in the tuff bed in the Kadong section up to the Gyangze section. Also the FO of Inoceramus everesti Oppel is projected from the Kadong section to a position between the FO of Cretaceous nannofossils and Jurassic ammonites. The estimated rates of sediment accumulation are 22.6 m/Myr in the lower interval and 28.2 m/Myr in the upper part.

Numerical ages for the Gyangze section can be interpolated by comparing the fossil ranges with ages calibrated in other sections. The objective is to identify which species ranges in the Gyangze section approximate the maximum known global ranges so that their ages can be interpolated into the Gyangze section. Two different datasets are available to test this hypothesis. First, ages of some nannofossil species have been integrated with Lower Cretaceous magnetochrons (Hardenbol et al., 1998; Ogg et al., 2004). Second, the ranges of Lower Cretaceous nannofossils have been integrated by graphic correlation with magnetochrons, ammonites, and calpionellids from twenty-three published reference sections. This dataset was composed with the MIDK45CS range data (Scott, 2009), which results in a database that spans the entire Cretaceous System, CRET1. The fossil ranges in the Gyangze section were compared to this mainly Tethyan data set and plotted on an X/Y graph. Two correlation segments project the base of the Berriasian Stage into the Gyangze section at 44 m above the base of the exposure, the base Valanginian at 100 m, and the base of the Hauterivian Stage as defined by the FO of Acanthodiscus radiatus (Reboulet et al., 2008) at 134.28 Ma into the section at 314 m. The tuff bed in the Kadong section yielding the radiometric is projected into the Gyangze section at 190 m by measuring section thickness from the contact between the Weimei and Sangxiu formations to the dated bed. The age of this level is projected by the upper LOC (line of correlation) at 137.61 Ma, well within the 136±3 Ma range. On the graph the error box spans the 6 myr error range of the radiometric date and is extended up section to the intersection of 136 Ma on the LOC. This box outlines the thickness range in the tuff bed in the Kadong section up to the Gyangze section. Also the FO of Inoceramus everesti Oppel is projected from the Kadong section to a position between the FO of Cretaceous nannofossils and Jurassic ammonites. The estimated rates of sediment accumulation are 22.6 m/Myr in the lower interval and 28.2 m/Myr in the upper part.

The rhyolite samples were collected from the upper unit of the Sangxiu Formation, and 15 zircon grains of the rhyolite sample were tested. The test results in an age for magmatic zircons of 136±3.0 Ma, which constrains the age of rhyolitic volcanism in the Sangxiu Formation. However more detailed dating by utilizing zircon SHRIMP for the basalt in the lower part of the Sangxiu Formation should be conducted. The
The sedimentary sequence was deposited rapidly and is characterized by coarse and fine clastics after the basaltic volcanism. Deposition was followed by the rhyolite extrusion with columnar jointing and dissilient fabrics of partial quartz phenocrysts. These features indicate that volcanism in the Sangxiu Formation was a short period, and the basaltic magmatism was only slightly earlier than the eruption of rhyolite. Both the rhyolite and the basalt in the Sangxiu Formation were formed in an extensional tectonic setting. The zircon SHRIMP age of rhyolite, therefore, is the age of volcanism in the Sangxiu Formation during the Valanginian Stage following deposition of the \textit{Calcicalathina oblongata–Speetonia colligata} assemblage.

![Fig.1 Lower Cretaceous stratigraphic correlation of Gyangze and Nagarze sections, southern Tibet](image)

<table>
<thead>
<tr>
<th>Gyangze</th>
<th>Nagarze</th>
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<tr>
<td><strong>J3</strong></td>
<td><strong>J3</strong></td>
</tr>
<tr>
<td><strong>Berriasian</strong></td>
<td><strong>Berriasian</strong></td>
</tr>
<tr>
<td><strong>Wetzmann sp.</strong></td>
<td><strong>Wetzmann sp.</strong></td>
</tr>
<tr>
<td><strong>Jiabula Formation</strong></td>
<td><strong>Jiabula Formation</strong></td>
</tr>
<tr>
<td><strong>Calcitalithina oblongata</strong></td>
<td><strong>Calcitalithina oblongata</strong></td>
</tr>
<tr>
<td><strong>Speetonia colligata</strong></td>
<td><strong>Speetonia colligata</strong></td>
</tr>
<tr>
<td><strong>W. fossicincta</strong></td>
<td><strong>W. fossicincta</strong></td>
</tr>
<tr>
<td><strong>Spiticeras</strong></td>
<td><strong>Spiticeras</strong></td>
</tr>
<tr>
<td><strong>Haploglyloceras striige</strong></td>
<td><strong>Haploglyloceras striige</strong></td>
</tr>
<tr>
<td><strong>Nannoconus steinmannii</strong></td>
<td><strong>Nannoconus steinmannii</strong></td>
</tr>
<tr>
<td><strong>Watznaueria barnesae</strong></td>
<td><strong>Watznaueria barnesae</strong></td>
</tr>
<tr>
<td><strong>Inoceramus everesti</strong></td>
<td><strong>Inoceramus everesti</strong></td>
</tr>
<tr>
<td><strong>Corongoceras</strong></td>
<td><strong>Corongoceras</strong></td>
</tr>
<tr>
<td><strong>Himalayites</strong></td>
<td><strong>Himalayites</strong></td>
</tr>
</tbody>
</table>

Ammonites of these two assemblages are also found in shale and siltstone of the lower part of the Nagarze section. In addition the Berriasian genera \textit{Spiticeras} and \textit{Berriasella} have been found. More indicative data are the nannofossils reported herein. The globally distributed \textit{Nannoconus steinmannii–N. st. minor–Watznaueria barnesae} Assemblage indicates Berriasian age, and the \textit{Calcitalithina oblongata–Speetonia colligata} Assemblage correlates with the Valanginian. The first appearance of the Berriasian nanofossil assemblage in the Gyangze-Nagarze area is about 3 to 5 m above the base of the Sangxiu and Jiabula formations (Fig. 1). Therefore the J/K boundary is placed near the bottom of the Jiabula Formation at Gyangze, and at the base part of the Sangxiu Formation at Nagarze. The boundary is marked by the first appearance of the ammonite \textit{Spiticeras} and the nannofossil \textit{Nannoconus st. steinmannii–N. st. minor–Watznaueria barnesae} Assemblage.

The present SHRIMP U-Pb analysis on the rhyolite sample dates the volcanic rocks in the upper unit of the Sangxiu Formation at 136±3.0 Ma. Therefore, the Berriasian-Valanginian fossil assemblages in the lower unit of the Sangxiu Formation are older, which is consistent with ages in Gradstein et al. (2004) and Ogg et al. (2004). The rhyolite sample dated by the SHRIMP U-Pb analyses is 190 m above the J/K biostratigraphic boundary. As estimated above, the sedimentary accumulation rate of the lower Sangxiu Formation is 22.6 m/myr. By consideration of underlying sedimentary deposits, the J/K boundary in the Gyangze-Nagarze area is approximately 145 Ma as suggested by the new International Stratigraphic Chart (2008).
Acknowledgments: Financial support was provided by the National Natural Science Foundation of China (Project NO. 40872016).

Key words: Southern Tibet; Jurassic/Cretaceous boundary; Graphic plot; Nannofossil

References:
Finds of a Unique Upper Toarcian Fauna from the SW Crimea (Ukraine)

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Field works, held in 2007-2009 in quarry “Lozovoe” (south to Simferopol, right bank of Salgir river), resulted in a rich collection of macrofauna, collected from a large block of cherry red limestones buried in dark grey mudstones. Collection includes numerous belemnite rostra, ammonites, bivalves, brachiopods, crinoids, several nautiluses and aulacoceratids. Belemnites, bivalves and crinoid remains are the most common for the complex. Limestones are represented by shallow-water limestone conglomerate and crinoid limestones; the mudstones are flysh-like and do not reveal any macrofauna. Previous researchers indicated finds of Upper Triassic fauna in grey mudstones, but the tectonic structure here is extremely confusing and difficult for understanding. There are at least three independent models of geological interpretation and dating of these deposits, also known as “block horizon” in literature.

Our study of cephalopod fauna here showed that the collection comes from a condensed horizon in a block, including elements of all four upper Toarcian Mediterranean ammonite zones (Thouarsense, Dispansum, Pseudoradiosa, Aalenensis). Most fauna represents terminal Aalenensis Zone, other ones are represented by only several specimens. During the recent field works one specimen of the Catacoeloceras cf. crassum (Young et Bird) has been collected, thus indicating possible presence of the uppermost middle Toarcian (Crassum Subzone of the Bifrons Zone). Ammonites are quite typical for the Mediterranean Realm and show strong affinity with upper Toarcian ammonite fauna of other Mediterranean successions (Hungary, Italy). Almost a half of all retrieved ammonites are the oceanic Phyllo- and Lytoceratidae. Other ones show high diversity and include representatives of Grammoceratinae, Dumortieriinae, Hammato-ceratidae, Erycitidae. They are represented by only several specimens. During the recent field works one specimen of the Catacoeloceras cf. crassum (Young et Bird) has been collected, thus indicating possible presence of the uppermost middle Toarcian (Crassum Subzone of the Bifrons Zone). Ammonites are quite typical for the Mediterranean Realm and show strong affinity with upper Toarcian ammonite fauna of other Mediterranean successions (Hungary, Italy). Almost a half of all retrieved ammonites are the oceanic Phyllo- and Lytoceratidae. Other ones show high diversity and include representatives of Grammoceratinae, Dumortieriinae, Hammato-ceratidae, Erycitidae. They are Pseudogrammoceras fallaciosum (Bayle), Bredya brancoi (Benecke), Pley-dellia (Cotteswoldia) paucicostata (Buckm.), Pley-dellia spp., Crestaites cf. victorii (Bon.), Pseudam-matoceras clocheri (Rulleau et Elmi) and Erycites barodiscus (Gennm.).

Belemnites also indicate upper Toarcian age, by the presence of several forms, very typical for Aalenensis Zone – Rhabdobelus spp., which have an acme in terminal Toarcian, and also such characteristic species like A. (A.) subgracilis Kolb., A. (O.) ernsti (Schleg.), A. (O.) curtus (d’Orb.), which are characteristics of Aalenensis Zone in Germany. Other ammonite zones (see above) are not represented by any belemnite markers. Comparison with belemnite scales of Southern Germany and France confirms this age determination. No trace of Aalenian fauna was found. Totally belemnite fauna shows very high biodiversity and counts 25 species attributed to 10 genera and subgenera. The most common are Acrocoelites s.str., A. (Odontoabela), Megateuthis, Rhabdobelus, “Catateuthis” and Holco-belus. A taxonomic revision shown that 11 species are new to science. In Crimea few Toarcian belemnites previously had been found only in deep-water sediments, and complexes of adjacent regions (Caucus, Carpathians) are studied more purely. The fauna of Lozovoe shows several peculiarities, which make it remarkable among all upper Toarcian belemnite locations of the world. First of all, there is the highest known diversity of genus Rhabdobelus – 4 species (2 of them are new). Furthermore, the fauna is characterized by numerous species with elongated rostra (Acro-coelites s.str., Catat euthis spp., Megateuthis sp., Holobelus sp.); both mentioned traits probably indicate open-sea environment for the upper Toarcian for this locality. There are also representatives of the most ancient undoubtable Holobelus and Megateuthis species in the complex. As a whole, belemnite fauna is very close to those described from Southern France (described by Lissajous), Slovenia (numerous papers by E. Cincurova) and Carpathians.

The fossil complex also includes several finds, principally new for the territory of the former USSR. Among them are:

1. Unique serpulid community on sponge substrate. Although all specimens are indeterminable to the specific level, four morphotypes can be recognized, and this evokes some paleoecological interpretations;
2. First finds of Jurassic Nautiloidea from the territory Crimea;
3. First finds of aulacoceratid rests from the Toarcian (described by Ippolitov et al., 2009);
4. Two new species of Lower Jurassic cyrtocrinids, previously unknown for this age (Anekeeva, pers. comm.).

After analyzing the fauna and lithological characteristics of the rocks, we managed to find several brief mentions of the same type of rocks in literature, in several cases the age was determined erroneously as Lower Cretaceous on the basis of misidentification of
Rhabdobelus rostra as Pseudobelus bipartitus, leading some authors to very geodynamical reconstructions of the history of region. This scarce data of different authors let us discover several more localities of the same age, achievable at present: one is situated in Petropavlovski quarry, the other on the northern slope of Kermen mountain (Bodrak river basin)—but both of them are comparatively poor in macrofauna, except for bivalves.

Blocks limestones of different age, from Carboniferous to Lower Jurassic, are very common for the “block horizon”, whose matrix is usually dated by Middle Triassic–Lower–Middle Jurassic. These blocks are interpreted as shallow-water olistolites buried in deep-water terrigenous sediments. There are several hypotheses in literature on genesis of shallow-water blocks, some are really fantastic ones and two deserve serious attentions. First model based on widely spread idea that to the north there was a margin of carbonate platform existing at least from Carboniferous to Lower Jurassic, and the second model implies that Lower Jurassic shallow water limestones, most numerous in the “block horizon”, formed at flat tops of guyots–eroded Triassic volcanic buildings.

Our material supports second hypothesis: Jurassic limestones are pure of terrigenous material, but often contain limestone conglomerates and cephalopod fauna (ammonites and belemnites) can be characterized as oceanic, not epicontinental. Anyway, our finds widen the stratigraphic range of blocks (and of a probable carbonate platform/guyot sequence) to the very end of Lower Jurassic: previously the youngest dated blocks had Pliensbachian age. It is also worth to be mentioned that the lithotype of limestones is very similar to red limestones in Carpathians and Caucasus (Georgia) of the same age, and this can be explained from the point of view of geodynamics.

The studied community is unique for the territory of Crimea and also allows, in comparison with adjacent regions, to retrieve some biogeographical conclusions.

Acknowledgements: The investigation was supported by RFBR grant № 09-05-00456.

Key words: Toarcian; Crimea; Belemnites; Ammonites; Unique fauna

References:
A Review of the Jurassic Stratigraphy of the Jaisalmer Basin, Western Rajasthan, India: An Implication on Biostratigraphy

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Jurassic sequence of the Jaisalmer Basin – a pericratonic shelf basin on the western part of the Indian craton, enjoys a unique position in the world stratigraphy because of its diverse facies variations, rich and high diverse faunal contents and very easy accessibility (Fig.1).

Lithostratigraphically, the Jurassic sediments have been grouped into Lathi, Jaisalmer, Baisakhi and Bha-dasar formations. These sediments range in age from Lower Jurassic to Tithonian (Table 1). The facies consist of (i) high-angle cross-bedded calcareous to ferruginous medium- to coarse-grained sandstones, (ii) low-angle cross-bedded to thinly laminated calcareous to ferruginous silt to fine-grain sandstone, (iii) silty marls, (iv) calcareous mud- to wake- to pack- to grain- to sandy/gritty rudstones, (v) thinly laminated carbonaceous or argillaceous shales and (vi) conglomerates. These represent fluvialite, floodplain, lacustrine, protected marginal marine, open nearshore shore face to shelf environment of deposition. If not all, some of the lithostratigraphic units begin with non-marine sediments. There are some sequences of marker beds, which make intrabasinal correlation very easy. These marker beds are either characterized by sequence boundaries, hardground surfaces, condense sequences, conglomerate beds, biotic assemblages, stratigraphic disposition of facies or cyclicity in sedimentation (Fürsich et al., 1992; Pandey & Choudhary, 2007; Pandey et al., 2009a, 2010).

The siliciclastic sediments are barely fossiliferous, however, baring a few, most of the calcareous beds are richly fossiliferous. The commonly recorded body fossil groups in order of abundance are bivalves (lamellibranches), ammonoids, nautiloids, belemnites, brachiopods, gastropods, echinoderms, corals, foraminifers, ostracods, calcareous nannoplankton, pollen grains and spores, leaf fossils, wood fossils and vertebrate fossils (e.g., Sahni, 1955; Sahni and Bhatnagar,
The trace-fossils also are abounding in number and diversity (Fürsich et al., 2006). In the lower part of the Jurassic successions (Lathi Formation) the sandstones are so much diagnostically changed that it has become impossible to separate them from the concretions, however, there are impressions of trace fossils such as, *Thalassinoidea, Ophiomorpha, Planolites*, etc., whereas in the upper part of the Jurassic successions Jaisalmer, Baisakhi & Bhadasar formations, which consist more of calcareous sediments, well preserved trace fossils of alternating *Crusiana* ichnofacies and *Skolithos* ichnofacies have been recorded (Pandey & Uchman, 2010).

Sequence stratigraphically, the sediments represent either transgressive systems tracts (TST) or highstand systems tracts (HST). The sediments deposited in TST are generally not very thick (maximum up to 1.0m) characterized by either cross-bedded rudstones or calcareous sandstones with erosional surfaces, whereas, sediments deposited in HST are thicker (minimum up to 1.0m) and characterized by a bioturbated unit followed by either cross-bedded coarsening upward calcareous sandstones/packstones beds, or alternate bioturbated and cross-bedded units or shell beds (storm influenced) within silty marl unit. At times small scale TST – HST cycles of well cemented and poorly to moderately cemented units have also been recorded (Pandey et al., 2010).

**Key words:** Jurassic; Stratigraphy; Jaisalmer Basin, India
Table 2 Temporal distribution of ammonites recorded by workers from the Jurassic Sediments of the Jaisalmer Basin

<table>
<thead>
<tr>
<th>Fm.</th>
<th>Member</th>
<th>Age</th>
<th>Chatterjee, 1990</th>
<th>Pandey and Jaikrishna, 1996; Jaikrishna, 1987</th>
<th>Pandey and Krishna, 2002</th>
<th>Prasad, 2006; Prasad et al., 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhadasar</td>
<td>Mokal</td>
<td>Late T.</td>
<td>Aulacosphinctoides, Virgatosphinctes, Virgatosphinctes meridionali</td>
<td>Virgatosphinctes densiplicatus Zone (Bhadasar) with Himalayitinae</td>
<td>Virgatosphinctes communis Zone (Rupsi &amp; Bhadasar)</td>
<td>Aulacosphinctoides natricoides Zone (Rupsi) Virgatosphinctes Zone (Rupsi)</td>
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<tr>
<td></td>
<td></td>
<td>Cretaceous</td>
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<tr>
<td>Kala Dungar</td>
<td></td>
<td>Middle Tithonian</td>
<td>Haploceras eliatum, Aulacosphinctoides</td>
<td>Virgatosphinctes-Pachysphinctes ass. (1987) Aulacosphinctoides, Virgatosphinctes Hildoglociceras, Holcophyloceras, Haploceras (Rupsi)</td>
<td>Virgatosphinctes communis Zone (Rupsi &amp; Bhadasar)</td>
<td>Aulacosphinctoides natricoides Zone (Rupsi)</td>
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<tr>
<td></td>
<td></td>
<td>Early</td>
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<tr>
<td>Lanela</td>
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<td>Late Kimmerid.</td>
<td>Katrolceras depressum, Lithacoceras indicum</td>
<td>Torquatisphinctes alterniplicatus (Rupsi)</td>
<td>JODHAWAT 1984</td>
<td>Katrolceras and Torquatisphictes</td>
</tr>
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<td></td>
<td></td>
<td>Middle</td>
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<td></td>
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</tr>
<tr>
<td>Rupsi*</td>
<td></td>
<td>Early P. bathyplocus</td>
<td>Pachysphinctes major</td>
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<td>Baisakhi</td>
<td>Jaiya</td>
<td>Late Oxford.</td>
<td>Dhosaites ass. zone Epimayaite's ass. Zone (Rupsi)</td>
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<td>Early</td>
<td>Sivaciceras congener (may come from Late Bathonian)</td>
<td>Subkossmatia opis ass. (first appearance)</td>
<td>Macrocephalites transitorius, M. chariensis, M. semilaevis</td>
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Comment in bold after fossils are of present authors. * seems to be time transgressive from Mid. Oxfordian to Lr. Tithonian.

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Ammonite Faunas from the Middle Jurassic-Lowest Cretaceous Somanakamura Group in Fukushima Prefecture, Northeast Japan

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The Somanakamura Group, distributed in the eastern part of the Abukuma Mountains in northeast Japan, is shallow marine and non-marine sequences ranging from Callovian to Valanginian in age. The group is composed of the Awazu, Yamagami, Tochikubo, Nakanosawa, Tomizawa and Koyamada formations in ascending order (Yanagisawa et al., 1996). Marine biota-bearing formations are the Awazu, Yamagami, Nakanosawa and Koyamada formations.

A rich marine fauna composed of ammonite, bivalve, gastropod, crinoid, coral and others was obtained from a new outcrop of the upper part of the Nakanosawa Formation excavated in connection with a construction of the Jyoban Highway at Ishigami of Minamisoma City, Fukushima Prefecture. The fossiliferous bed is calcareous mudstone and is about 5 m in thickness. The ammonite fauna includes Aulacosphinctoides tairai Sato & Taketani, Subdichotomoceras chisatoi Sato & Taketani, Pseudowaagenia sp., Taramelliceras sp. and so on (Sato et al., 2010). The faunal association in the newly discovered site is similar to those reported from other localities of the Nakanosawa Formation by Sato and Taketani (2008). The ammonite-bearing horizon corresponds to Level 3 of Sato (1962) and Sato and Taketani (2008). A few well-preserved specimens of Taramelliceras show that the horizon is of Kimmeridgian age.

Another ammonite fauna was recovered from the lowest part of the Koyamada Formation. This fauna was also discovered at a construction site of the Joban Highway in Koyamada, Minamisoma City. The ammonite rich bed is tuffaceous mudstone and is about 0.5 m in thickness. The Koyamada Formation in the Umazawa area, 1 km north of the newly found locality, yielded Berriasella akiyamae Sato, Dalmasiceras munoei Sato & Taketani, Parakilianella umazawensis Sato (Sato, 1961; Sato et al., 2005; Sato and Taketani, 2008). This faunal composition indicates Berriasian in age. The newly found specimens are similar to the Umazawa assemblage in faunal composition and their taxonomic study is now in progress. The ammonite-bearing horizon corresponds to Level 5 of Sato (1962) and Sato and Taketani (2008).

These newly found ammonite faunas from the Somanakamura Group will give us important data sets not only for age determination and paleobiogeographic setting of Late Jurassic–lowest Cretaceous marine sequences in northeast Japan but also for taxonomic and phylogenetic studies on ammonite species including endemic ones.

Key words: Ammonite; Late Jurassic; Earliest Cretaceous; Somanakamura group; Northeast Japan

References:
Astronomical Calibration of the Jurassic Time Scale

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Astronomically forced cyclostratigraphy has become an important tool in defining Jurassic geologic time and establishing ‘floating’ astronomical time scales. Astronomical time scales have a resolving power of 0.4 Myr in the Jurassic Period, compared with the Geologic Time Scale 2004 at ±0.6 to ±4.0 Myr. Research has shown that orbital eccentricity dominates much of Jurassic cyclostratigraphy; this is the result of climate rectification of precession index forcing that was captured in the sedimentary record. Obliquity (~37-kyr period) forcing had a lesser, although still important role. Presently, astronomically calibrated stratigraphy for the Jurassic Period is as follows:

• **Hettangian.** The duration of the Hettangian is a minimum of 1.29 Myr interpreted from the Blue Lias Formation (UK) (Weedon, 1985); lacustrine sequences in eastern North America suggest a 2 Myr duration (Kent & Olsen, 2008).

• **Sinemurian.** The Sinemurian is partially calibrated, 0.342 Myr for the *bucklandi* zone in the Blue Lias Formation (UK) (Weedon et al., 1999); a new evaluation suggests 0.73 Myr for the zone. Borehole data from the Subalpine Basin (France) (Razin et al., 1996) may provide additional coverage.

• **Pliensbachian.** The duration of the Pliensbachian is 4.82 Myr, from the Belemnite Marls (UK) (Weedon & Jenkyns, 1999) and Morbio Formation (Switzerland) (Weedon, 1989).

• **Toarcian.** The Sancerre core, Paris Basin (France) indicates a 405-kyr calibrated duration of 9.6 Myr for the Toarcian (Huret et al., 2008a).

• **Aalenian.** The 405-kyr calibrated duration of the Aalenian Sogno Formation (Italy) is 3.85 Myr (Huret et al., 2008a).

• **Bajocian-Callovian.** Astronomical stratigraphy has not yet been assembled for the Bajocian-Callovian stages. Several key cyclostratigraphies are under investigation: the Bathonian Czestochowa Clay Formation (Poland) (Ziółkowski & Hinnov, 2009), and Callovian marly formations of the Paris Basin (France) (Huret et al., 2008b).

• **Oxfordian.** Cyclostratigraphy of the Lower to Middle Oxfordian Terres Noires Formation in the Vocontian Basin (SE France) has a 405-kyr calibrated duration of 4.1 Myr (Boulila et al., 2010). The Late Oxfordian remains uncalibrated.

• **Kimmeridgian.** The 405-kyr calibrated duration of the Lower Kimmeridgian Clay (UK) is 3.63 Myr (Huang et al., 2010a). Multiple gaps occur in the lowermost three ammonite zones; cyclostratigraphy at La Méouge (France) (Boulila et al., 2008) adds 1 Myr to these zones.

• **Tithonian.** The lower part of the Volgian Hekkingen Formation (Greenland-Norwegian Seaway) (Swientek, 2002) correlates with the Lower Tithonian of the astronomically forced Kimmeridgian Clay. The two formations together indicate 6.03 Myr duration for the Tithonian (Huang et al., 2010b).

• **Jurassic-Cretaceous transition.** Orbital eccentricity cycles predominate in Volgian petroleum source rocks of the Greenland-Norwegian Seaway. Interpreted 405-kyr cycles in lightness data from the Hekkingen Formation indicates 11.74 Myr for the Volgian Stage (Tithonian to early Berriasian) (Huang et al., 2010b).

**Key words:** Jurassic; Time scale; Astronomical calibration; Orbital eccentricity cycle

**References:**


C-isotope and Climatic Correlation of the Terrestrial and Shallow Marine Sequences around the Triassic-Jurassic Boundary (West Carpathians)

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Sedimentation on Central Western Carpathian part of the northern Tethyan shelf was controlled by local terrestrial input from the hinterland. In emerged areas, lacustrine to palustrine black silty shales and quartz sandstones of Rhaetian Tomanová Formation with dinosaur footprints and iron ores cover Carpathian Keuper terrigenous deposits Pollen-dominated association (Classopollis, Glisocopollis) is accompanied by sporomorphs (Taeniasporites, Protohaploxypinus) and fern macroflora, supplemented by few Jurassic-type elements (Michalík et al., 1988). In the Červený Úplaz section, quartz forms 25%-44% of the rock, the kaolinite prevails (34%-44%) in clay mineral spectrum (11%-23% consists of illite/mica) as indicated by qualitative and quantitative r.tg-diffraction analyses of whole rock. Clay-size fraction of claystones frames 58%-65% of kaolinite, sandstones 56%-57%. Content of kaolinite decreases upwards of the section (≈40%) being substituted by increasing illite (28 to 48%). The shape and size distribution of kaolinite crystals indicates their detritic origin. Iron-bearing minerals (siderite, chamosite and goethite) occur in beds in the uppermost part of the section. Clay-size fraction of samples contains 3% to 10% of chamosite. Generally clay minerals documented low diagenetic overprint (Šrodoň et al., 2006). Weathering in Rhaetian humid and warm climate formed kaolinite crust on granite hinterland. These kaolinite-rich products were transported into lowlands. Occurrence of (pelo) siderite and chamosite indicates temporary reduced condition in lacustrine mud generated by organic matter accumulation and decomposition. Although the content of residual organic matter is generally relative low (Corg 0.1%-1.5%) it locally increases (2.5% or 8.12%) which could document more humid periods with water table level rise, increased input of plant debris and higher bioproduction (dinosaur traces). δ13Corg data (-27% to -25‰ V-PDB) indicate that organic matter is derived mostly from terrigenous plants debris, probably mixed with aquatic (limnic, probable algal) organic matter.

Adjacent area farther to the south was inundated by a shallow sea. Neritic carbonates of Rhaetian Fatra Formation are overlain by shales of Hettangian Kopienec Formation. The Fatra Formation consists of bioclastic limestones and marls deposited in a proximal marine setting (Furkaska, Kardolina and Široký žlab sections; Gaždicki et al., 1979; Michalík et al., 2007). Its benthic fauna comprises index foraminifers (Triasina hantkeni), bivalves (Rhaetavicula contorta), corals (Rettiphyllia paraclathrata) and brachiopods (Austrirhynchia cornigera). A diversity decrease at the base of the uppermost member of the Fatra Formation indicates freshwater input. The palynomorph assemblage of the Fatra Formation is characterized by numerous specimens of Ricciisporites tuberculatus. The marine fraction contained in the lower part of the section is dominated by dinoflagellate cysts Dapcodinium priscum and Rhaetogonyaulax rhaetica (Ruckwied and Götz, 2009; Michalík et al., 2010). The palynomorph assemblage of the Kopienec Formation is characterized by a significant increase of trilete laevigate spores, mainly Deltodiospora spp. and Concavi-sportes spp. The dinoflagellate cyst Dapcodinium priscum replaces Rhaetogonyaulax rhaetica in the marine fraction. The overlying Lower Jurassic sequence consists of shallow marine sandy limestones. The Široký žlab section represents the marginal part of the basin affected by fluvial influx and it was probably emerged during the T/J time. The T/J boundary interval was recognized in the Furkaska and the Kardolina sections as the proximal basin setting. Based on micro-facies analyses and a negative δ13Ccarb excursion, the boundary interval is placed near to the lithological boundary (Michalík, 2003; Michalík et al., 2007). The δ13Corg values of marly sediments of the Furkaska section range between -24.78‰ and -29.36‰ PDB. In the upper Triassic part, data are close to -27‰. At first δ13Corg positive excursion (-25‰) appears in the uppermost part of the so called “transitional beds”, where striking negative δ13Ccarb excursion in carbonate bed was documented (Michalík et al., 2007, 2010). The second, major negative δ13Corg excursion (up to -29.36‰, occurs higher up, in the Boundary Clay. The basal member of the Hettangian Kopienec Formation is characterized by a slightly positive trend of the δ13Corg curve, but the δ13Corg values around -28‰ fit with a typical Hettangian negative excursion documented. Sections studied reveal a strikingly similar distribution of kaolinite, without connection to their marginality. Less than 10% of kaolinite in clay-size
fraction of the Boundary Claystone samples was identified while underlying strata were free of kaolinite. Mixed-layer illite-smectite minerals dominated in analysed clay-size fraction of both Rhaetian and Hettangian samples at the expense of discrete illite, which indicated relative high diagenetic overprint (Biron in Michalík et al., 2010), typical to the Fatric unit (Sredoň et al., 2006). Prevalent IS in clay-size fractions most probably originated from a smectitic precursor formed during weathering in seasonally wet and dry climate of the hinterland.

High kaolinite content of the Tomanová Formation indicates an earlier Rhaetian humid event than was this, indicated in the Boundary Claystone. Carbon isotope data of organic matter from the limnic Tomanová Fm environment are more-or-less comparable with data from marginal/proximal marine zones which is indicated by mixed terrigeneous and aquatic (marine /limnic) organic matter composition.

Key words: Organic carbon; Clay mineral; Kaolinite; Tatra Monuntains

References:


Long-period Astronomical Cycles from the Upper Triassic to Lower Jurassic Bedded Chert Sequence: Implications for Jurassic Cyclostratigraphy

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Astronomical timescales provide the highest resolution robust timescales over the tens of thousands to millions of year timescales. Milankovitch forcing is one of the main drivers of climate change, and Milankovitch cyclicity recorded in sediments provides a high-resolution and high-precision age model that is critical to the understanding of dynamics of global geological events. Bedded cherts consist of rhythmical alternations of chert and shale beds and Milankovitch cycle origin of bedded chert was demonstrated based on the hierarchal cyclicity of chert bed thickness variations in Triassic bedded chert sequence (Ikeda et al., in review). However, the chaotic evolution of the Solar system prevents a precise determination of the Earth’s motion over Mesozoic (Laskar et al., 2004). Cyclostratigraphic studies of middle Triassic bedded chert sequence and upper Triassic lacustrine sequence suggested that Earth-Mars secular resonance during Triassic had been in a different librational state from the present state (Olsen and Kent, 1999; Ikeda et al., in review).

To examine the Jurassic astronomical timescale and the chaotic behavior of Earth-Mars secular resonance, we extend cyclostratigraphy for the upper Triassic (Rhaetian) to lower Jurassic (Toarcian) bedded chert in the Inuyama area, central Japan (e.g. Hori, 1990). Cyclostratigraphic studies of middle Triassic bedded chert sequence and upper Triassic lacustrine sequence suggested that Earth-Mars secular resonance during Triassic had been in a different librational state from the present state (Olsen and Kent, 1999; Ikeda et al., in review).

The section is comprised bedded chert sequence in the Jurassic accretionary complex of Mino-Tamba terrane (Kimura and Hori, 1993), which is representative of deep-sea sedimentary rocks deposited below carbonate compensation depth (CCD; Matsuda and Isozaki, 1991). The bedded chert is mostly red-brown to green in color, except for the dusty red bedded chert near the Triassic/Jurassic boundary and black bedded chert near the Toarcian oceanic anoxic event interval (Carter and Hori, 2005; Hori, 1997). We measured thickness of approximately 800 chert and shale beds, respectively. The estimated average duration of a chert-shale couplet based on the radiolarian biostratigraphy (Carter and Hori, 2005; Hori, 1990) were about 20-kry, confirming the possibility of its precession cycle origin. By further assuming approximately 20 beds cycle as representing 405-kry eccentricity cycle of constant and stable periodicity, we converted the bed number series to the time series. Spectral analysis of the time series detected distinct periodicities of ca. 2400- and 105-kry in addition to 405-kry above 99% confidence level, which agree well with the periodicities for eccentricity cycles. Moreover, we detected amplitude modulation of 405-kry cycle of time series with approximately 2400-kry periodicity, which would correspond to the amplitude modulation of 405-kry eccentricity cycle by 2400-kry eccentricity cycle. 2400-kry cycles would be related to the present librational state of Earth-Mars secular resonance.

Our results suggested that the chaotic transition of Earth-Mars secular resonance would have occurred near Triassic/Jurassic boundary. Further investigation in continuous late Mesozoic cyclostratigraphy by continuous pelagic bedded chert sequence will be necessary to reconstruct the chaotic evolution of Solar system and astronomical timescale for Mesozoic era.

**Key words:** Cyclostratigraphy; Chaos; Toarcian; Raetian

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Lower Kimmeridgian Biostratigraphy and Correlation in the NE Iberian Chain (Spain) Based on Ataxioceratinae Ammonites

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The sections analyzed in the eastern Iberian Chain correspond to neritic sites within a large epicontinental shelf system that occupied eastern and southern Iberia during the Late Jurassic (e.g., Aurell et al., 2002 for an overview). The palaeogeographic setting resulted in environmental conditions related to distance and/or relative poor connection to open waters belonging to outer shelves adjacent to the northwest-Tethyan oceanic fringe (e.g., Moliner and Olóriz, 1999). Thus, water masses during the early Kimmeridgian were inner than those covering typical continental, structured slopes not underpinned by oceanic crust in Tethyan margins, and identified as epi-oceanic environments (e.g., Olóriz, 1997 and 2000 for extended treatment). A low-energy, mixed carbonate-siliciclastic ramp covered by turbid, nutrient-rich water masses and depths in the range of 30-80m, which was commonly supplied with shedding of fine clastics and carbonates from inner-shelf areas, well adapts sedimentary conditions as interpreted from stratigraphic sections in which the Loriguilla Fm. crops out (e.g., Moliner and Olóriz, 1999; Olóriz, 2000; Bädenas and Aurell, 2001; Aurell et al., 2002, and References therein). Shallower environments located northwards and westwards, and locally eastwards, and bottom irregularity was locally conspicuous revealing tectonic instability also determining tectono-eustatic interactions (e.g., Pérez-Urresti and Delvene, 1998; Salas et al., 2001; Benito and Mas, 2006; Delvene et al., 2007; Climent-Domenech et al., 2009). In such an environmental context, ecological pressure on ammonite populations occurred and resulted in common endemism.

More than two decades of improving knowledge on ataxioceratins gathered bed-by-bed from lower Kimmeridgian deposits in the eastern Iberian Chain, E–NE Spain (e.g., from to Moliner and Olóriz, 1984 to 2009a,b and Moliner 2009, and References therein), allow to propose a biostratigraphic chart based on their precise ranges and to evaluate its correlation potential with respect to the Secondary Standard for the Submediterranean Province (e.g., Hantzpergue et al., 1997).

Lower Kimmeridgian biostratigraphy has been approached favouring delimitation of biostratigraphic units based on first appearance data (FAD), and three ranges of biostratigraphic divisions have been identified to refine biostratigraphic resolution to the upmost: the biozone, subbiozone and biohorizon (or faunal horizon s. Callomon, 1984) levels. Due to meager ammonite record in marly deposits below the Loriguilla Fm. in lower-to-lowermost horizons of the Sutneria platynota biozone, no precise data about the lowermost Kimmeridgian have been available.

The Sutneria platynota biozone has been subdivided, from bottom to top, in the “Orthosphinctes”, Ardescia desmoides, and Schneidia guilherendense subbiozones. No subbiozone subdivision was possible within the “Orthosphinctes” subbiozone, but the Ardescia enayi and Ard. desmoides biohorizons were identified within the Ard. desmoides subbiozone, and the Olorizia olorizi and Scneidia guilherendense biohorizons within the Schneidia guilherendense subbiozone. Based on reinterpreted systematics, endemism among ataxioceratins, as it is identified in taxonomic terms, is close to 30% in the Sutneria platynota biozone.

The Ataxioceras lothari biozone has been subdivided in the lower Atax. hippolytense and the upper Atax. lothari subbiozones. Within the Atax. lothari subbiozone, the Atax. lothari biohorizon below and the Geyericeras aragoniense biohorizon above have been recognized. Based on reinterpreted systematics, taxonomically expressed endemism among ataxioceratins is close to 50% in the Ataxioceras lothari biozone.

The Crussoliceras divisum biozone embraces the upper Lower Kimmeridgian in the area and has been subdivided in the lower C. divisum subbiozone and the upper subbiozone of Orthaspidoceras uhlandi/Garnierisphinctes virgatocostatum. Within the Crussoliceras divisum biozone, and therefore within the stratigraphic range of the index species, no records of Idoceras balderum have been obtained, hence non formal identification of the corresponding and widespread recognized subbiozone and/or biohorizon has been realized. Based on reinterpreted systematics, the endemism expressed in taxonomic terms is close to 17% among ataxioceratins in this biozone.

FAD based biostratigraphy provides high correlation potential at the biozone and subbiozone levels, and determines the reinterpretation of the lower boundary of the Crussoliceras divisum biozone as well as local subbiozone division. Local biohorizons show their highest correlation potential in the Sutneria platynota Biozone. Higher correlation potential has
been proved with epicontinental than with epioceanic sections.

Ammonitina abundance is highest in the *Sutneria platynota* biozone, as well as it is the relative abundance of ataxioceratins, which show their lowest value in the *Ataxioceras lothari* biozone. In contrast, the registered trend in taxonomically expressed endemism at the biozone level indicates maximal values for ataxioceratins in the *Ataxioceras lothari* biozone. Hence, no direct relationships have been recognized between Ammonitina abundance and the degree of taxonomically expressed endemism in Ataxioceratinae. In two cases endemic taxa serve to characterize biostratigraphic units at the lowest level – i.e., biohorizons.

Table 1 Recognized biostratigraphic units for lower Kimmeridgian deposits in NE Iberian Chain and Maestrazgo, prov. Teruel, Spain (based on Moliner, 2009; Moliner and Olóriz, 2009a, b)

<table>
<thead>
<tr>
<th>BIOZONE</th>
<th>SUBBIOZONE &amp; BIOHORIZON</th>
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<tr>
<td>Lower KIMMERIDGIAN</td>
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<tr>
<td>Crussoliceras divisum</td>
<td><strong>Orthaspidoceras uhlandi / Garnierisphinctes virgatocostatum</strong> Crussoliceras divisum</td>
</tr>
<tr>
<td>Ataxioceras lothari</td>
<td><strong>Ataxioceras lothari</strong></td>
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<tr>
<td>Ataxioceras hippocylytense</td>
<td><em>Schneidia guilherandense</em></td>
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<tr>
<td>Sutneria platynota</td>
<td><strong>Schneidia guilherandense</strong> <strong>Olorizia oloriz</strong> <strong>Ardescia desmoides</strong> <strong>Ardescia Enayi</strong> <strong>“Orthosphinctes”</strong></td>
</tr>
</tbody>
</table>

**Key words:** Ammonites; Ataxioceratinae; Biostratigraphy; Kimmeridgian; Spain

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On the Systematic of the Ammonite Genus *Kepplerites* and Its Occurrence in the Koenigi Zone (Callovian, Middle Jurassic) of Central Europe and England

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The Callovian Stage (Middle Jurassic) is accurately subdivided in the marine facies by means of ammonites. In the first instance in each of the different faunal provinces six or seven standard zones were defined or described, and it is possible to correlate them over long distances in spite of the occurrence of different species (Cariou, 1985). Within the standard zones it also possible to distinguish up to seven biohorizons or faunal horizons. These can also be followed quite well, but a precise correlation may be difficult (see Dietze et al., Fig. 13). A great help should be a comprehensive systematic examination of the ammonites.

In the Lower Callovian, the Subboreal Province extends from England over northern France to Central Europe and from the Callovien Zone in Russia too. In this area occurs a dozen of ammonite genera, but only a few of them are good guide fossils. Some species are either rare (e.g. in *Cadomites, Subgrossoverwia, Chamoussetia*) or difficult to distinguish (e.g. in *Homoeoplanulites, Proplanulites, Macrocephalites, Cadoceras*). The best guide fossils are species of *Kepplerites* and its successor *Sigaloceras*.

In England the Koenigi Standard Zone of the Subboreal Province comprise eight or nine faunal horizons, all named after species of *Kepplerites* (Callomon et al. 1989, Dietze et al., 2007). Within the genus *Kepplerites* it is comparatively easy to differentiate between the several species. A provisional determination results from shape and size of the shell, but this is not sufficient because of the intra specific variability. A precise determination is only possible by counting the ribs, because every species has a characteristic rib curve (number of the ribs against the diameter). Those of the lower Koenigi Zone have only few ribs on the last whorl of the phragmocon (*toricellii, metorchus, gowerianus*), but many on the body chamber, but in higher Koenigi Zone it is the other way around (*trichophorus, galliae, copernici* n.sp. MS). In between the number of the ribs is approximately constant (*curtilobus* sensu Page, *indigustus* sensu Page).

As well as in England *Kepplerites* occurs in NE France and in Germany, but not frequent and only as a concomitant fauna of *Macrocephalites* and diverse *Perispinctidae*. An exception is the horizon with *Kepplerites toricellii*, in which this species suddenly emerges with 70%-90% of the fauna. Above follows *K. metorchus*, also occurring in England, and with a compressed variant in Russia too. Then, England and Central Europe disperse. At the beginning of the Koenigi Zone there was a sea level lowstand and the marine basins were not connected, and so new species evolved by isolation. Although the rib curves remain similar, the German and French species are more depressed and bigger than the English forms. So it is probably necessary to establish some new species among *K. densicostatus* Tintant 1963. In the course of the Koenigi Zone was a sea level rise, and starting from the horizon with *K. galilaei* we have in the whole Subboreale Province the same species.

The sequence of the of the ammonite faunal horizons of the Koenigi Standard Zone (Lower Callovian) in Northern Germany (from the bottom up, localities after Mönnig 1989, 1991, 1995):

- **toricellii horizon**: *Kepplerites toricellii* (Oppel) and its corresponding microconch *K. uhligi/hexagonus* are very abundant (80%-90%), the genus Macrocephalites is representated by its inflated variant *Platystomatoceras. Pseudocadoceras, Homoeoplanulites, Parapatoceras, Hecticoceras* are common. The first *Proplanulites* appears. Localities: Steinbergen, Hannover (Linden, Tönniesberg, Mühlenberg), Hildesheim (Temme Clay Pit), Lechstedt.

- **metorchus horizon**: *Kepplerites* is still common (10%), but *Macrocephalites, Homoeoplanulites and Proplanulites* become more frequent. Locality: Porta Westfalica (Jacobsberg).

- **aff. gowerianus horizon**: A variety of *Kepplerites gowerianus*, very densely ribbed on the last quarter of the body chamber. Locality: Hannover (train station Linden-Fischerhof).

**halleyi horizon:** K. halley n.sp. (MS) is very close to K. besseli, but smaller and less inflated. *Macrocephalites* and Pseudoperisphinctides are abundant. In contrast *Chamussetia, Cadoceras, Hecticoceras* und *Bullatimorphites* are very rare: *Macrocephalites macrocephalus* (Schlotheim), M. (Platystomaceras) sp., M. (Pleurocephalites) sp. (m), H. (Parachoffatia) cf./aff. mandani Spath, H. (*Homoeoplanulites* furculus (Neumayr), H. (*Homoeoplanulites* cf. lobatus (Buckman), Proplanulites sp. (m), Proplanulites (*Crassiplanulites*) sp.. Locality: Häverstädt (Porta mine), bed 6c.

**densicostatus horizon:** The fauna is dominated by *Macrocephalites* (40%) and *Pseudoperisphinctides* (45%). *Kepplerites* (10%) is frequent. *Cadoceras* and *Proplanulites* are rare: *Macrocephalites macrocephalus* (Schlotheim), M. (Platystomaceras) sp., M. (Pleurocephalites) sp., H. (Parachoffatia) funatus (Oppel), H. (*Homoeoplanulites* cf. furculus (Neumayr), Choffatia (*Subgrossouvria*) sp., Proplanulites sp., *Cadoceras* sp.. Localities: Hildesheim (Temme Clay Pit, top of the Macrocephalen Beds); Luttern (Porta mine).

**hubblei horizon:** *Kepplerites* hubblei n.sp. (MS) is small and densely ribbed (N > 33) on the last whorl. The *Kepplerites* are only 5 % of the fauna, other ammonites are *Macrocephalites* (Platystomaceras) *jacobi* Corroy, *Macrocephalites* cf. macrocephalus (Schl.), *Cadomites* westfalicus Mönnig & Beginski, *Cadoceras* aff. tolype Buckman, *Homoeoplanulites* (Parachoffatia) ssp., H. (*Homoeoplanulites*) ssp., *Indosphinctes* (Indosphinctes) ssp., *Choffatia* (Choffatia) sp., *Choffatia* (*Subgrossouvria*) sp., *Proplanulites* ssp., *Proplanulites* (*Crassiplanulites*) sp., *Bullatimorphites* (Bombrurites) bombrur (Oppel), Reineckeia quenstedti (Callomon et al.). Locality: Häverstädt (Porta mine), bed 6d.


**Key words:** Ammonites; Middle Jurassic; *Kepplerites*; Central Europe
References:
Zonal Subdivision of Lower and Middle Jurassic of Siberia on the Bivalves, Foraminifers & Ostracodes: Concept of Construction and Resolution

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Stratigraphic scales of Siberian Jurassic are based on zonal ammonite scale. But ammonites findings in sections are rare and zones defined by ammonites often do not have common boundaries. In this case, findings of ammonites are used for dating of zones defined using other groups of fossils (Nikitenko, Shurygin, 1994; Zakharov et al., 1997; Shurygin et al., 2000). As a rule scales defined by benthos groups (bivalves, foraminifers, ostracodes, palynomorphs) are the most effective tools for prompt sections dissection and correlation particularly at sections made in the form of well. All varieties of parallel biostratigraphic zones are regarded as operational scales combination of bio-eventful origin. It is used for identification of reference levels of different kinds (benchmarks) at dissection of well cuts on well logging, at intraregional and interregional correlations of Siberian Jurassic (Shurygin et al., 2000; Shurygin, 2005; Nikitenko, 2009). At that all varieties of independent methods of dissection and correlation of sections are used as well for cross check (feedback).

The basis of biostratons identification on parastratigraphic groups is the revelation of fossil complexes succession, specifics of assemblages structural features (with similar taxonomic composition) and inimitable succession of these assemblages change in the course of time. Biostratons revealed using parastratigraphic groups are regarded as concurrent-range zones, tail-zones, acme-zones, ecozones or as a complex of parallel phylolozones (Shurygin, 2005; Nikitenko, 2009). Zonal scales on parastratigraphic groups were created by means of tracing of reference levels of different kinds (corresponding to the boreal biota levelling moments) and comparison of the zones between these levels (Shurygin et al., 2000). Content of zones revealed by parastratigraphic groups is mostly corresponds to ecozones: sequence interval characterized by definite association of facies recurrence and associations recurrence (Fig.1). Generally full palaeontolology characterisation of such zones is included in elemental circle or in half cycle. The zones boundaries (usually the lower ones) are defined if new assemblages or new taxons (due to either phylogenesis or immigration) are found and at the boundaries of epiboles coincidence areas of typical spices (from the paleo-community cores) etc. (Shurygin, 2005; Nikitenko, 2009).

In practice, in sections, not surfaces of change of taxonomic composition of assemblages are taken into account but the succession of layers (thickness) with the different taxonomic composition of assemblages, with the different structure of fossil assemblages and (or) with the different law of change of assemblages in recurrent facies (Fig.1). In succession, the boundaries between adjacent biostratons always have some range of uncertainty, in a more or less degree (depending of facies recurring). In fact, a succession and combination of the results of events of different origin (horological - migrants penetration, ecosystem - communities reorganization, dominants change, rapid growth of some taxon or life-form, phylogenetic - autochthon origin of new taxon) are used for zones size definition (Shurygin et al., 2000).

At the same time narrow- and wideband zones were defined with different assemblage characterization for different facies (Fig. 1). In Lower and Middle (without Callovian) Jurassic of Siberia, 27 zones can be traced on the bivalves, 25 zones - on foraminifers and 15 zones - on ostracodes. Zonal scales by benthos can be regarded as 'bioeventful' scales (for interregional correlations) in which the reference intervals are characterized by inimitable succession of results of combinations of biological events of different nature (independent from each other) (phylogenetic, horological and ecosystem). This is the fixed succession of events of different nature (independent from each other) that has apparently the highest isochronism probability at identification in different regions. Developed set of scales (together with ammonite one) is used as a Boreal zonal standard of Jurassic (Zakharov et al., 1997; Shurygin et al., 2000); it provides a circumpolar correlations of sections.

Boundaries defined by different biostratons fossils groups often do not coincide with each other. At dissection and correlation of sections, if entire complex of parallel zonal scales is used the zone boundaries discrepancy makes it possible to identify and trace very narrow intrazonal intervals (intervals of overlapping for zones defined on different scales - co-intervals) (Shurygin et al., 2000; Shurygin, 2005; Nikitenko, 2009).

Acknowledgements: This job was supported by RFFI (Russian Foundation for Basic Research) (project № 09-05-00136) and RAS (Russian Academy of the Sciences), programs 15 and 17.

Key words: Jurassic; Stratigraphy; Benthos; Siberia
Fig. 1 Principles of definition of zones on benthos in different facies (A), fragment of combination of parallel zonal scales of Boreal Jurassic (B) and the territories of their use (C).

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The Vertebrate Assemblage from Shaximiao Formation of Sichuan Basin, China and Discussions on Its Age

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The Shaximiao Formation, a continental Mesozoic stratum in Sichuan Basin with a thickness of 650 to 2500 meters, is in much advance of others at its large distributing area and abundant fossils. It has a conformable contact with underlying strata (The Xintiangou Formation or The Qianfoya Formation) and overlying strata (The Suining Formation). And there also exists a parallel unconformity between the Shaximiao Formation and the underlying Ziliujin Formation. Usually, the Shaximiao Formation is divided into two members by “Shale Containing Conchostracans”, which is located in the middle of the Shaximiao Formation and contains a lot of conchostracans.

The aubergine mudstones and silty mudstones compose the Lower member of the Shaximiao Formation, and also less fine sandstones and siltstones are mixed. At the bottom of this lower member, a bed of medium grain sandstone (Guankou Sandstone) with large oblique bedding has a conformable contact with the Xintiangou Formation (or The Qianfoya Formation). As to the Lower member of the Shaximiao Formation, there is a prominent feature of being thin in the west and thick in the east. Fossils are mainly from the “Shale Containing Conchostracans”, including bivalves, ostracods, a few plants and abundant of conchostracans. The famous *Shunosaurus-Omeisaurus* Fauna is located in Dashanpu of Zigong and Jinji of Kajjiang, which includes *Shunosaurus lii*, *Omeisaurus tianjuiensis*, and additionally with fishes, amphibians, chelonians, crocodilians, plesiosaurs, pterosaurs and mammal-like reptiles.

The Upper member of the Shaximiao Formation consists of rhythmic layers, composed of dark-aubergine mudstones and grey-green, aubergine feldspar-quartz sandstones. The Upper member of the Shaximiao Formation has prominent features, such as dark colour of rocks, mudstones being rich of calcareous concretion, sandstones varying significantly, rhythmicity of the sandstones and mudstones, and so on. The fossils include ostracods, bivalves, conchostracans, gastropods, chara and the famous *Mamenchisaurus* Fauna. The *Mamenchisaurus* Fauna contains abundant vertebrates such as fishes, amphibians, chelonians, crocodilians, plesiosaurs, mass of dinosaurs and a few mammals.

For a long time, the age of the Upper member of the Shaximiao Formation has been in dispute. Invertebrate paleontologists advocated that the total Shaximiao Formation belonged to the Middle Jurassic, whereas vertebrate paleontologists suggested that the Upper member of the Shaximiao Formation belonged to the Late Jurassic. The vertebrate paleontologists also considered the age of *Mamenchisaurus* Fauna to be Late Jurassic.

Here the age of Shaximiao Formation would be discussed in three aspects as follows.

Firstly, vertebrate fossil assemblage of both Upper and Lower Shaximiao Formation have been analysed and compared, and the result shows: the age of some vertebrates such as fishes in *Mamenchisaurus* Fauna belongs to the Middle Jurassic; the Upper and Lower members of the Shaximiao Formation have the same composition of main vertebrate fossils, coelurosaurians, carnivores, sauropods, ornithopods, stegosaurs, plesiosaurs, crocodilians, chelonians, chondrichthians, lung-fishes, actinopterygians and so on; the dinosaurs are different in the Upper and Lower members of the Shaximiao Formation, and both primitive sauropods as *Shunosaurus* and progressive sauropods as *Omeisaurus* occurred in the *Shunosaurus-Omeisaurus* Fauna of the Lower member of the Shaximiao Formation, whereas *Mamenchisaurus*, a kind of progressive dinosaurs with long neck, are the primary sauropods in *Mamenchisaurus* Fauna of the Upper member of the Shaximiao Formation. *Omeisaurus* are considered to be the ancestor of *Mamenchisaurus*. So it is thought that the *Mamenchisaurus* Fauna inherits and develops from the *Shunosaurus-Omeisaurus* Fauna.

Secondly, the Shaximiao Formation is compared with the Middle Jurassic stratum of the Chuanjie Basin in Yunnan province. They have similar lithological features, and both are composed of the rhythmic layers of yellow, purplish-grey feldspar-quartz sandstones and aubergine, purplish-grey mudstones/shales. The Upper member of the Shaximiao Formation has the similar vertebrate assemblage to the Chuanjie Formation, especially *Chuanjiesaurus* and *Mamenchisaurus* have resembled skeletons which are totally in the same evolutionary level. Therefore, it is thought that the *Chuanjiesaurus* Fauna of the Chuanjie Basin in Yunnan province is coetaneous or at least close to the *Mamenchisaurus* Fauna of the Sichuan Basin.

In the third, a contrastive analysis between *Mamenchisaurus* Fauna and abroad vertebrate fauna of Late Jurassic has been carried out. There are two
important formations containing the Late Jurassic dinosaurs, the Morrison Formation in western North America and the Tendagura Formation in Eastern Africa. Those two abroad vertebrate faunas have much difference with the *Mamenchisaurus* Fauna. The former are superior in the vertebrate diversity and quantity to the latter. They have no genus and species in common, the former contains many sauropods with nail-liking tooth, whereas the sauropods from the latter have scoop-liking tooth without exception. Thirdly, the former have higher evolutionary level than the latter. As a result, the age of the *Mamenchisaurus* Fauna is earlier than the vertebrate fauna of the Morrison Formation and the Tendagura Formation.

In sum, our results suggest the *Mamenchisaurus* Fauna in the upper member of the Shaximiao Formation should be aged in Mid-Late Jurassic. Nevertheless, some deleted species of this fauna can last to the late stage of Late Jurassic. The upper member of the Shaximiao Formation belongs to the late Middle Jurassic, which might be aged in Bathonian - Callovian; the age of the Shaximiao Formation, which correlated to the Chuanjie Formation and the Laoluocun Formation in Chuanjie area of Lufeng in Yunnan province, belongs to the middle-late Middle Jurassic, and might be Bajocian – Callovian. This result is consistent with the viewpoint of the invertebrate paleontologists, and also coincides with the age data of ESR (Electron Spin Resonance), which shows that the Shaximiao Formation is in 165-178 Ma.

**Key words:** Sichuan Basin; Jurassic; Shaximiao Formation; Vertebrate fossil; Age
Biodiversity, Reproductive Structures and Palaeoecology of Fossil Ferns from the Early Jurassic Hsiangchi Flora in Western Hubei, China

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During the past decades, increased progress has been made for systematic and phylogenetic analysis of ferns and allied plants based upon morphology and molecular data leading towards a full understanding of the fern tree of life. However, fossil records of ferns in deep time provide unequivocal and indispensable evidence for exploring the diversity variation, evolutionary radiation and phylogeny of this plant group.

The Lower Jurassic Hsiangchi Formation in western Hubei, China is well known for its abundant and diverse fossil ferns, including five families such as Marattiaceae, Osmundaceae, Matoniaceae, Dipteridaceae and Dicksoniaceae as well as 25 species referred to 11 genera (Table 1).

Recent investigations on fossil ferns based on well preserved specimens of Hsiangchi Formation, have revealed detailed fertile structures of a diverse fossil ferns, including Marattia asiatica, Phlebopteris polypodioideis, Dictyophyllum nilssonii, Coniopteris cf. bella and Coniopteris sp. (Wang, 1999; Wang and Mei, 1999; Wang, 2002; Wang et al., 2001, 2009; Guignard et al., 2009). In situ spore ultrastructures of Marattia asiatica and Dictyophyllum nilssonii provide palaeobotanical evidence and positive support for the phylogeny and evolution of both fossil and living ferns. Available data show that the filicopsid exospore ultrastructure gradually became simplified from the primitive groups to the derived groups. The spore ultrastructure of fossil Marattia is simpler than that in Ophioglossaceae and Osmundaceae, but is more simplified in Gleicheniaceae than in Marattiaceae. From Gleicheniaceae (Oligocarpia), Matoniaceae (Phlebopteris), Dipteridaceae (Dictyophyllum), to advanced fern groups, the spore ultrastructures display a reduction trend from complex to simple. It is therefore significant that the fossil and living fern spore ultrastructures are stable characters that endured a long history, providing unequivocal evidence for the evolutionary relationships of fern lineages.

A remarkable fern community from the upper part of the Hsiangchi Formation in western Hubei has been established, which is dominated by matoniaceous and dipteridaceous groups, and is associated with Marattiaceae, Osmundaceae and slender herbaceous Dicksoniaceae (Wang, 2002). The nature of the preservation and the associated sedimentary conditions suggest that ferns from this horizon represent an autochthonous or hypautochthonous fluviatile peat-forming community dominated by Phlebopteris of the Matoniaceae. This fern community indicates a warm and humid, tropical to subtropical climate. It is a remarkable and representative fern community recognized for the late Early Jurassic in the Southern Floristic Province of China.

Acknowledgements: This work was jointly supported by the Knowledge Innovation Program of CAS (KZCX-2-YW-154), the National Key Basic Research Program of China (2006CB701401), National Natural Sciences Foundation of China (NSFC40472004, 40972008). This is a contribution to UNESCO-IUGS project IGCP 506.

Key words: Fossil ferns; Biodiversity; In situ spores; Jurassic; Palaeoecology; Western Hubei; China
Table 1 List of fossil ferns from the Early Jurassic Hsiangchi Formation, western Hubei
(after Wang, 2002; Wang et al., 2009 with modifications)

<table>
<thead>
<tr>
<th>Sub-class</th>
<th>Family</th>
<th>Taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eusporangiate</td>
<td>Marattiaceae</td>
<td><em>Marattia asiatica</em> (Kawasaki) Harris</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Todites princeps</em> (Presl) Gothan</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Todites leei</em> Wu</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Todites williamsonii</em> (Brongniart) Seward</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cf. <em>Osmundopsis sturii</em> (Raciborski) Harris</td>
</tr>
<tr>
<td></td>
<td>Osmundaceae</td>
<td><em>Cladophlebis denticulata</em> (Brongniart) Fountaine</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Cladophlebis asiatica</em> Chow and Yeh</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Phlebopteris ziguensis</em> Meng</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Phlebopteris muensteri</em> (Schenk) Hirmer and Hoehhammer</td>
</tr>
<tr>
<td></td>
<td>Matoniaceae</td>
<td><em>Phlebopteris polypodioides</em> Brongniart</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Dictyophyllum nilssonii</em> (Brongniart) Goeppert</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Dictyophyllum nathorstii</em> Zeiller</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Dictyophyllum rugosum</em> Lindley and Hotton</td>
</tr>
<tr>
<td></td>
<td>Lepto-</td>
<td><em>Clathropteris obovata</em> Oishi</td>
</tr>
<tr>
<td>sporangiate</td>
<td>Dipteridaceae</td>
<td><em>Clathropteris platyphylla</em> (Goeppert) Nathorst</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Hausmannia ussuriensis</em> Kryshtofovich</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Hausmannia buchii</em> Andrae</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Thaumatopteris remauryi</em> (Zeiller)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Thaumatopteris schenki</em> Nathorst</td>
</tr>
<tr>
<td></td>
<td>Dicksoniaceae</td>
<td><em>Coniopteris hymenophylloides</em> (Brongniart) Seward</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Coniopteris cf. bella</em> Harris</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Coniopteris murrayana</em> (Brongniart) Brongniart</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Coniopteris chenyuanensis</em> Meng</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Coniopteris</em> sp.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Eboracia lobifolia</em> (Phillips) Thomas</td>
</tr>
</tbody>
</table>

References:
The Late Triassic to Early Jurassic palynological investigation was carried out in the Kuqa Depression in the Tarim Basin, Xinjiang, northwestern China. The following assemblages are recognized covering the terrestrial Upper Triassic and Lower Jurassic deposits in this region.

The Dictyophyllidites-Atartrisporites-Parataeniaesporites Assemblage

It occurs in the Upper Triassic Huangshanjie and Tariqike Formations. It is characterized by the dominant gymnosperm pollen (averaging 67.1%), especially Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, China

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The increase of gymnosperm pollen (averaging 70.1%) and the first appearance of Bactrosporites ovatus, Quadraeculina limbata, and Alisporites toralis. Among the gymnosperm pollen, the non-striate bisaccate type ranks the first (averaging 51.8%). Chasmatosporites (12.6%) reaches its maximum percentage in the Triassic assemblages of the studied area. The striate bisaccate pollen becomes less frequent (2.1%). Fern spores constitute 24.6% of the to the total, decrease obviously compared with the previous subassemblage (44.8%). Dictyophyllidites, Convicavsporites and Cyathidites slightly increase (4%).

2. Disacciatrileti-Cyathidites Assemblage: occurs in the early Early Jurassic Ahe Formation

This assemblage is characterized by the predominance of gymnospermous pollen with a percentage of 81.2% of the total, being the highest in the Jurassic assemblages in the study area. The conifer bisaccate pollen grains occur in extraordinary abundance (averaging 69.5%). Chasmatosporites (7.1%), Cycadopites and Ginkgocecdophyton are frequent. Fern spores reach 16.7% of the total, among them Cyathidites minor increase its percentage up to 6.8%.

3. Cyathidites-Cibotiumspora-Disacciatrileti Assemblage: occurs in the late Early Jurassic Yangxia Formation

Gymnosperm pollen grains decrease to 56.7% in the present assemblage. Bisaccate grains dominates the gymnosperm pollen with an average percentage of 44.7%. Ginkgocecdophytus and Ceratopollinates are common, other pollen grains are rare. Fern spores increase up to 43% which are dominated by Cyathidites minor (up to 38%).

This investigation provides further evidences for exploring the terrestrial Triassic and Jurassic boundary on the northern margin of the Tarim Basin. It is interesting that the important Triassic elements, Ara-trisporites, Zebrasporites, Parataeniaeasporites and Chordasporites are present in the Upper Subassemblage (Tariqike Fm.); but are absent in early Early Jurassic Ahe Formation (Disacciatrileti-Cyathidites Assemblage). Dictyophyllidites, Convicavsporites are slightly higher in abundance than in the Lower Subassemblage (Huangshanjie Fm.). Cyathidites are rare in the Lower Subassemblage, also slightly in- creases in the Ahe Formation. Our palynological data suggest that the age of the Tariqike Formation may be assigned to late Late Triassic, and the Ahe
Formation be assigned to early Early Jurassic. The Triassic and Jurassic boundary on the northern margin of the Tarim Basin is proposed to be placed in between the transition of the Tariqike Formation and Ahe Formation in this region.

Acknowledgements: This work was jointly supported by the Knowledge Innovation Program of CAS (KZCX-2-YW-154), the National Key Basic Research Program of China (2006CB701401), National Natural Sciences Foundation of China (NSFC 40472004, 40972008). This is a contribution to UNESCO-IUGS project IGCP 506.

Key words: Palynology; The Tariqike Formation; The Ahe Formation; Triassic and Jurassic boundary; The Tarim Basin; Xinjiang
An Oxfordian Ammonite Fauna from the Northern Margin of the Lhasa Block, and its Geological Significance

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The Qinghai-Tibet Plateau today is composed of Mesozoic geological blocks, namely Himalayan, the Lhasa and Qiangtang blocks. It was suggested that the Qiangtang block was separated from the Lhasa block by the Bangonghu-Nujiang oceanic basin during the Jurassic times. However, because of few ammonite-biostratigraphic evidence available in both Qiangtang and Lhasa blocks, it is controversial about the closure time of the Bangonghu-Nujiang oceans.

Table 1 Ammonite biostratigraphical evidence in north Europe, south Europe, and on the Lhasa block during the Middle and Upper Oxfordian

<table>
<thead>
<tr>
<th>European ammonite zone</th>
<th>Lhasa block</th>
</tr>
</thead>
<tbody>
<tr>
<td>north Europe (Poland)</td>
<td>Euaspidoceras hypselus, periphiinetid</td>
</tr>
<tr>
<td>south Europe (Swiss)</td>
<td>E cf varicosatum E. lhasense n. sp.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Upper Oxfordian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone</td>
</tr>
<tr>
<td>Bimammatus</td>
</tr>
<tr>
<td>Bifurcatum</td>
</tr>
<tr>
<td>Wartel</td>
</tr>
<tr>
<td>Transversarium</td>
</tr>
<tr>
<td>Plicatilis</td>
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<td></td>
</tr>
</tbody>
</table>

With recent geological mapping work carrying out in Qiangtang, new ammonite specimens were collected there in the last decade, and ammonite fauna ranging from the late Bathonian to early Callovian was found in the Chinbuzhang area, north Qiangtang for the first time, including Homoeoplanulites sp., and Neuqueniceras cf. yokoyamae Kobayashi & Fukada. In the other hand, several ammonite localities in south Qiangtang indicating the age from the Toarcian to Early Callovian, including Harpoceras sp. Ptychophylloceras cf. hatricum (Pusch, 1837), Lycoceras cf. rasile Vacek, 1886, Lycoceras cf. penicillatum (Quenstedt, 1886), ?Pseudapetoceras cf. amplexeter (Buckman, 1920), Euhoploceras cf. marginata Buckman 1892, Euhoploceras cf. modesta Buckman 1892, Haplopleuroceras mundum Buckman 1892, Haplopleuroceras cf. subsinatum (Buckman 1881), and Stephanoceras cf. telegidirothi Geczy 1967. In addition, Oxycerites orbis (Giebel), Oxycerites cf. subcostarius (Oppel), Homoeoplanulites cf. acutus (Roemer), Homoeoplanulites cf. homoeorrhaphus (Buckman), Homoeoplanulites cf. furcatus (Neumayr), and Neuqueniceras cf. yokoyamae Kobayashi & Fukada, ranging from the Discus Zone of the Upper Bathonian to the Koenigii Zone of the Lower Callovian. It is noted that none of the late Jurassic ammonites has been confirmed in Qiangtang block up to now. However, Oxfordian fauna, represented most by Radulopecten and Gryphaea, was distributed widely over the Qiangtang region, suggesting that shallow-water carbonate plateform was well established at that time. Both depositional and bivalve successions of the north Qiangtang exhibit a regression sequence with brackish and freshwater bivalve faunas ranging from Kimmeridgian to Tithonian. While the Himalayan ocean which separated Lhasa from Himalayan blocks was well established during the Late Jurassic times, an epihayatid-fauna dispersal reached the Nyalam area, south Tibet, and the depth of Himalayan oceans might reached its maximum by the early Tithonian time with appearances of various forms of Virgatosphinctes and Hplaphylloceras.

With regards to the Lhasa block, it is very poorly known about Jurassic ammonites before. This paper is to describe an Oxfordian ammonite collection which was sampled in the Biru area of the northern margin of the Lhasa Block. This fauna is dominated by aspidoceratids, including Euaspidoceras hypselus (Oppel, 1863), Euaspidoceras cf. varicosatum (Dorn, 1931), exhibiting a close affinity with west Tethyan faunas, although two new forms appear which are Euaspidoceras lhasense n. sp., and Ataxioceras biruense n. sp. The ammonite fauna, particularly the appearances of an
index fossil of the Hypselum subzone, *Euaspidoceras hypselus* (Oppel, 1863) allows to establish a biochrono-
logic correlation at zonal level between fauna of the
Lhasa block and European standard.

In the Biru area the Upper Jurassic is represented
by Hala and Nongmo Formations. The Hala Formation
is mainly composed of siltstones and shales, aspido-
ceratid-fauna was yielded from the top of the Hala
Formation. The Nongmo Formation is unconformably
overlying on the Hala Formation, yielding bivalves,
gastropods, plant debris, as well as ripples. Therefore, it
is proposed that the dispersal of aspidoceratid-fauna to
the Lhasa block might be corresponding to the sea-level
rise taking place in the late Late Oxfordian. The
changes of depositional environments in both Qiang-
tang and north Lhasa blocks are probably caused by the
northward movement of the Lhasa block resulting from
the spreading of Himalayan oceans induced by the
collision between the Lhasa and Qiangtang beginning
in the late Oxfordian.

**Key words**: Lhasa Block; Jurassic; Oxfordian; Aspidoceratids

Fig. 1-2 *Euaspidoceras hypselus* (Oppel, 1863), X1/2; Fig. 3 *Euaspidoceras lhasense* n. sp., X1/2; Fig. 4 *Euaspidoceras cf. varicornatum* (Dorn, 1931), X1/2
Finding Spores of *Coniopteris* and Pollens of *Classopollis* in Hon Gai Formation at Dong pagoda, Yen Tu, Quang Ninh Province, Vietnam

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5. Institute of Geosciences, Vietnamese Academy of Sciences and Technology, Hanoi, Vietnam (E-mail: lethi.nghinh@yahoo.com)

At Yen Tu, a palynological assemblage of *Coniopteris* and *Classopollis* aged Jurassic was found in the coal-bearing sediments of Hon Gai Formation, which was once considered as Late Triassic Norian–Rhaetian.

The palyniferous sediments are thin siltstone layers intercalated with coarse grained sediments mainly composed of conglomerate with a thickness of about 300 m, and they spread from Bao Sai pagoda to Dong pagoda (Chua Dong), on the top of Yen Tu mountain.

This conglomerate belongs to the uppermost part of the coal-bearing sediments here. It is the "Chua Dong conglomerate" aged Early Jurassic (J₁). Thus, the Hon Gai Formation at Yen Tu has a thickness of 1,150-1,300 m and is aged Late Triassic (Norian)–Early Jurassic (T₃n-T₁h₁).

The "Chua Dong conglomerate" in the paper is the name for the conglomerates in the uppermost part of the coal-bearing sediments of Hon Gai Formation, currently aged Late Triassic Norian–Rhaetian (T₃n-T₁h₁), occurring at Yen Tu.

This formation also crops out in many places such as in Bao Dai, forming Bao Dai–Yen Tu mountain range. At Con Son, behind the Nguyen Trai Temple there is a small stream where crop out a conglomerate which is similar to the Chua Dong conglomerate.

The section of Hon Gai Formation crop out along the trail from Giai Oan stream to Hoa Yen pagoda, at the elevation of +800 m. The thickness of the middle part is 550-700 m. Some plant fossils, including *Neocalamites* sp., *Equisetites* sp., *Podozamites* sp. (determined by Nghiem Nhat Mai) were found behind the Hoa Yen pagoda along the trail to Mot Mai pagoda. These fossils belong to the "Hon Gai flora" aged Late Triassic Norian–Rhaetian.

Upper part: extends from Bao Sai pagoda to the top of Yen Tu mountain, in the “Chua Dong conglomerate section”.

Four palynological samples were collected in the section from Hoa Yen pagoda to Bao Sai pagoda. Sample YT1 behind the Hoa Yen pagoda, contains no spores and pollens. Sample YT2, in claystone below the Chua Bao Sai conglomerate, contains *Granulatisporites* sp., *Lycopodium macroreticulatum*, *Classopollis* sp., *Lycoglossum echinacum*, many fungus spores. Sample YT3, in Chua Bao Sai coaly shale, contains *Granulatisporites* sp., *Coniopteris* sp., *Leiotriletes* sp., *Anemina* sp. Sample YT4, at the building site of Tran Nhan Tong monument, about 80 m south of Dong pagoda, contains *Inaperturopollis* sp., *Araucariacites* sp. and many fungus spores.

Nguyen Duc Tung made the palynological determination remarks:
- The three samples (YT2, YT3, YT4) do not contain many spores. The species found here are often seen in Jurassic–Cretaceous sediments.
- The two samples (YT2, YT4) contain many pollens. This shows that sample YT4 is the weathering product of sample YT2.
- All the samples contain many contemporary and Quaternary spores and pollens. But these species have been excluded from the study results.
- The minor presence of gymnosperm pollens, especially the absence of angiosperm pollens indicates the possibility that the sediments represented by samples YT2, YT3, YT4, i.e. the “Chua Dong conglomerate” are aged Jurassic (Fig.1).

In summary, the section of coal-bearing sediments...
at Yen Tu is divided into three parts. No fossils have been found in the lower part, but based on the plant fossils from the middle part, the middle and lower parts are placed together to Late Triassic Norian–Rhaetian. The upper part, composed of coarse grained sediments, mainly “Chua Dong conglomerate”, which has a thickness of about 300 m, is placed to Early Jurassic (J1).

Thus, the section of the Hon Gai Formation here is 1150–1300 m thick and is aged Late Triassic (Norian) - Early Jurassic (Tnn-J1hg).

**Correlation with coal-bearing sediments of Nong Son Formation**

Many geoscientists have proposed the similarities between the Upper Triassic coal-bearing sediments in two areas: Yen Tu (in Uong Bi town, Quang Ninh Province, NE of Bac Bo) and Nong Son (Que Son and Dai Loc districts, Quang Nam Province, North of Trung Bo). Both of them are continental sediments, and contain the same plant fossil assemblage belonging to the “Hon Gai flora” aged Late Triassic (Norian–Rhaetian). Both of them contain anthracite.

The section of coal-bearing sediments from Thach My to Ngoc Kinh coal mine in Nong Son has been described (Nguyen Chi Huong, 1983; Bui Phu My and Hoang Dinh Kham, 1999). With the new data and cognition, the section of the Nong Son Formation can be divided into three parts.

Lower part can be divided into two members: Member 1, overlying unconformably the Paleozoic limestone of Thach My Formation, is basal pebble conglomerate, with the pebbles mainly composed of quartz, quartzite, some of granite which is similar to the granite of Dai Loc complex, poorly rounded, with cement of light brown sandstone, with thickness 10-15 m. Further upward are light brown thick-bedded sandstone and siltstone intercalated with gravelite, with thickness of 550 m. In some thin intercalated layers of siltstone are met poorly preserved plant remains which are hard to do identification. Member 2 composed of pebble conglomerate, cobble conglomerate intercalated with some layers of thick and medium-bedded fine-grained sandstone, siltstone with light brown color, with thickness of 205 m. In this part no fossils have been found. The common thickness of the lower part is about 360 m.

Middle part: It consists of thin to medium bedded, in some places cross-bedded medium to coarse grained sandstone of light gray color, intercalated with siltstone, clay shale of dark gray color, few lenses of pebble conglomerate of coarse quartz pebbles. This part contains 3-5 industrially minable coal seams, and in some places the coal seams are up to 30m thick. The coal layer is placed near the coal seams contain some plant fossils belonging to the "Hon Gai flora", including Clathropteris obovata, Dictyophyllum nathorstii, Podozamites distans, P. lanceolatus, Ptilozamites vennis, Goepperiella vietnammica, Cycladocarpidium erdmanni, Cladophlebis raciborski aged Late Triassic (Norian–Rhaetian) collected and determined by Nguyen Chi Huong, 1983). At the bank of Khe Tre stream, 150 m from the mouth of the stream, the clay layers intercalated with conglomerate and coarse sandstone between thin coal seams yields many plant fossils: *Thaumatopteris remauryi*, *Neocalamites hoerensis*, *Clathropteris mongaica*, *Cladophlebis (To dithe*) *shensiensis*, *Equisetites sarrani*, *Squamiofolium dictyonomerum*, *Palissya brunnii*, *Yuccites vietnammensis*, *Taeiopterus cf. ensis* (collected by Bui Phu My, Hoang Dinh Kham, 1999, determined by Nguyen Chi Huong). At the same locality, Nguyen Chi Huong (1983) collected and determined plant imprints of *Neocalamites carrerei*, *Clathroteria longilobata*, *Dictyophyllum*, *nathorstii*, *D. muensteri*, *Thaumatopteris remauryi*, *Podozamites lanceolatus*, *P. reini*, *Pterophyllum bavieri*, *P. sp.*, *Hausmania sp.*, *Ferganiella sp* and Bui Duc Thang (1981) found pollens of gymnosperm plant *Classopoliss* sp. The thickness of the middle part as it is exposed along the road in the area of Ngoc Kinh coal mine is 350 m and along the Khe Tre stream from its mouth upstream is 150 m; the common thickness is 500 m.

In summary, the section of the coal-bearing sediments in Nong Son is also divided into 3 parts as the section in Yen Tu. But as no fossils have been found in the lower part, the middle and lower parts are placed in Late Triassic (Norian–Rhaetian) based on the plant fossils from the middle part.

Upper part: The upper part changes transitionally from the middle part, composed of coarser grained sediments, mainly conglomerate, containing fossils of *Classopoliss* sp etc., extending from the outcrop on the bank of Khe Tre stream, 150 m from its mouth to the water divide, with a thickness of 360 m.

Bui Phu My once compared the Khe Tre conglomerate with the Bao Dai–Yen Tu conglomerate (which is now called Chua Dong conglomerate). In this part of the section there are no fossils, but on the top of Ban Co mountain, the similar conglomerate yield plant fossils belong to the “Hon Gai flora”. The new finding of *Coniopterus*, *Classopoliss* in the Chua Dong conglomerate at Yen Tu, and especially the presence of *Classopoliss* in the Nong Son coal-bearing sediments agree with Bui Duc Thang’s remarks (1981) “Although the number of analyzed samples has been very small (3 samples), the large amount *Classopoliss* pollens allows to initially think about the Liassic element (J1) in the uppermost part of the Nong Son coal-bearing sediments”. Further detailed studies will surely give more data to clarify this issue.

**Correlation with suoi bang coal-bearing sediments**

The Suoi Lao key section (Vu Khuc and Nguyen Vinh, 1967) can be divided into 3 parts.

Lower part consists of 2 members: Member 1 composed of siltstone, bedded gray shale, with intercalations of gray marl, shell limestone, shelly calcareous sandstone, intercalated calcareous sandstone,
containing fossils of Pelecypoda *Halobia distincta*, *Zittelihalobia sublaevis*, *Gervilla shaniorum*, *Anomia napengensis*, *Palaeocardita singularis*, *Mezoneilo fromagetii* and *Ammonoida Discaropites noricus*. The thickness is 212 m. Member 2 composed of medium bedded fine grained sandstone, quartz sandstone, with mica, with intercalations of gray siltstone, followed upward by light color polymictic sandstone, containing plant detritus, further by sandstone intercalated with sandstone with coarse pebbles, pebble conglomerate, cobble conglomerate, containing fossils of *Zittelihalobia teniscostata*, *Burnesialirata singularis*, *Praclaria sollasi*, *Dentilucina mona*, *Triapsurus angularus*, *Discaropites noricus*, *Burmesialirata singularis*, *Prafromageti noptensis*, *Palaeocardita singularis*, *Mezoneilo Gervillia*

Gervillia brackish water species were collected in this part: mainly to sandstone. Animal fossils mainly marine and coaly shale and some lean coal seams, passing upwards sandstone, some intercalations of black gray claystone, usually containing plant detritus, intercalated with gray siltstone, thin-bedded sandstone, containing *Pterophyllum aff. contigum*, *P. sp.*, *Cladophlebis sp.*, *Ottozamites ef. indosinensis*, *Nucula coccinea*, *Phyllocladus* sp., etc. The thickness is 90 m.

3. Bedded claystone intercalated with gray, thin-bedded siltstone, gray sandstone. In the sandstone, the following animal fossils are found: *Cardinia ef. nachamensis*, *Anodontophora damdunensis*, *Estheria sp.*, *Thracia sp.* 130 m thick.

4. Gray, bedded fine claystone with nodular structure, intercalated with gray siltstone, brown claystone. In the claystone, the following animal fossils are found: *Cardinia ovoidae* *Anodontophora damdunensis*. The thickness is 90 m.

5. Sandstone intercalated with gravelite, banded siltstone, red claystone, occasionally with conglomerate layers. In the claystone, the following fossils are found: *Anodontophora convexa*, *Estheria sp.* The thickness is 170 m.

The common thickness of this part is 550 m. Nguyen Ba Nguyen suggested the plant fossil collection including *Coniopteris clavipes*, *C. sp.*, is aged Liassic (*J1*).

In general, the red sediments contain a probable Jurassic fossil assemblage. But Vu Khuc reminds the presence of local small size species such as *Anodontophora damdunensis*, *A. convexa*, which often occurred in the Late Triassic coal-bearing sediments.

In spite of this, some large size species such as *Cardinia ovoidae*, *N. nachamensis* with a common shape similar to *Cardia philea* and *C. gigantea* are aged Liassic (*J1*).

There are many fresh water fossils such as *Estheria sp.*, but in the section their occurrence is above the *Coniopteris* and intercalated with the fossil assemblage which bears many Jurassic factors, therefore we propose that the uppermost 550 m of the Suoi Bang section, which had previously been placed to a subdivision of *J1* (Bui Phu My, 1971), is the upper part of Suoi Bang Formation (*J1*).

The thickness of this section is much less than that of Suoi Lao section.

Upper part: As in Yen Tu and Nong Son, the coal-bearing sequence occurs as following:

1. Black gray bedded claystone intercalated with fine grained sandstone; crushed claystone intercalated with thin coal seams, the claystone contains plant fossils: *Coniopteris clavipes*, *C. sp.*, *Equisetites sp.*, *E. ef. arenaceus*, *Clathropteris meniscoides*, and animal fossils: *Anodontophora damdunensis*; black gray, yellow gray, thin-banded fine claystone intercalated with thick-bedded sandstone, containing *Anodontophora convexa*, 60 m thick.

2. Thick-bedded, medium to fine grained micaeous sandstone and nodular claystone intercalated with sandstone, containing plant remains: *Pterophyllum aff. contigum*, *P. sp.*, *Cladophlebis sp.*, *Ottozamites ef. indosinensis*, *Nucula coccinea*, *Phyllocladus* sp., *Glossopteris* sp., but in the section their occurrence is above

3. Sandstone intercalated with gravelite, banded siltstone, red claystone, occasionally with conglomerate layers. In the claystone, the following fossils are found: *Cardinia ovoidae* *Anodontophora damdunensis*. The thickness is 90 m.

4. Gray, bedded fine claystone with nodular structure, intercalated with gray siltstone, brown claystone. In the claystone, the following animal fossils are found: *Anodontophora convexa*, *Estheria sp.* The thickness is 170 m.

5. Sandstone intercalated with gravelite, banded siltstone, red claystone, occasionally with conglomerate layers. In the claystone, the following fossils are found: *Anodontophora convexa*, *Estheria sp.* The thickness is 170 m.

The common thickness of this part is 550 m. Nguyen Ba Nguyen suggested the plant fossil collection including *Coniopteris clavipes*, *C. sp.*, is aged Liassic (*J1*).

In general, the red sediments contain a probable Jurassic fossil assemblage. But Vu Khuc reminds the presence of local small size species such as *Anodontophora damdunensis*, *A. convexa*, which often occurred in the Late Triassic coal-bearing sediments.

In spite of this, some large size species such as *Cardinia ovoidae*, *N. nachamensis* with a common shape similar to *Cardia philea* and *C. gigantea* are aged Liassic (*J1*).

There are many fresh water fossils such as *Estheria sp.*, but in the section their occurrence is above the *Coniopteris* and intercalated with the fossil assemblage which bears many Jurassic factors, therefore we propose that the uppermost 550 m of the Suoi Bang section, which had previously been placed to a subdivision of *J1* (Bui Phu My, 1971), is the upper part of Suoi Bang Formation (*J1*).

The section of Suoi Bang Formation according to this paper has a thickness of about 1,500 m and is aged Late Triassic (Norian)–Early Jurassic (*T1n*- *J1sb*).

**Remarks and recommendations**

The finding of Jurassic spores and pollens in the Chua Dong conglomerate in Yen Tu and the correlation with Nong Son and Suoi Bang formations show that: all three sections of Suoi Bang, Nong Son and Yen Tu, which are typical coal-bearing sediments in these areas, were once placed to Late Triassic. The Jurassic fossils found in their upper part indicate that part of them may
be of Lower Jurassic (J1).

However, there are still too little data to confirm the age of Early Jurassic. Moreover, this is the matter of boundary between Triassic and Jurassic in Vietnam, which is in general difficult.

Therefore, additional detailed investigation should be carried out for verification.

- Another new problem is to find out the relationship between the Jurassic spores and pollens and the "Hon Gai flora" in terms of geological time and space.
- The attribution of coal-bearing sediments to Rhaetian in Suoi Bang Formation may be appropriate, but this still depends on the results of studying the Nong Son and Yen Tu sections together with the study of the Hon Gai flora.
- In 1995, Cat Nguyen Hung et al. divided the Suoi Bang Formation, and upgraded the Nong Son Formation aged Norian–Rhaetian to Nong Son series and divided it into two formations:
  - The upper part containing coal, plant fossils, is called Suon Giua Formation, aged Rhaetian.
  - The lower part with neither fossils nor coal found is called An Diem Formation, aged Norian.

To be persuasive, it is necessary to find fossils in the lower part of the Nong Son section — i.e. An Diem Formation and in the lower part of Yen Tu section as well (currently placed in Norian–Rhaetian by the authors).

More detailed studies of the Nong Son coal-bearing sediments would not only serve scientific purposes, but also serve the prospecting of mineral resources, including coal and associated uranium ore, which are also very important.

The Nong Son coal deposit has been mined for a long time, but uranium-radioactive anomalies were newly discovered only after the reunification of the country (by the Geological Subdivision No. 501 of Geological Division No. 5, Hoang Dinh Kham, 1978 and Subdivision No. 500, Geological Mapping Division, Huynh Trung, 1979). Both mineral and environmental researches are necessary here.

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References:
Progress on the Study of the Terrestrial Jurassic in Western Liaoning, NE China

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The Lower and Middle Jurassic in western Liaoning consist of two volcanic- or volcanioclastic-dominated rocks and a coal bearing deposits in between, containing all kinds of fossils, such as plants, sporo-pollen, bivalves, conchostracans. The lower volcanic- or volcanioclastic-dominated rocks, the Xinglonggou Formation, are sporadically outcropped in western Liaoning. The coal-bearing Beipiaoj Formation contains mainly megaplants and sporo-pollen. The megaplants of the Beipiaoj Formation belong to the Early-Middle Jurassic Coniopterus – Phoenicopsis flora of northern China (Si and Zhou, 1962). The sporo-pollen of Beipiaoj Formation belongs to late Early Jurassic Cyathidites – Cycadoptites – Paleocoeniferus assemblage of north China (Song and Shang, 2000). The upper volcanic- or volcanioclastic-dorminated rocks are much more widely exposed in western Liaoning, including the Haifanggou and Lanqi formations. The Haifanggou and Lanqi formations contain the Untio–Ferganoconcha bivalve assemblage, which belongs to the Early-Middle Jurassic Lamprotula (Eolamprotula) cremeri – Kija (= Pseudocardinidina) kweichouensis fauna of northern China (Gu, 1982). The megaplants belong to the early Middle Jurassic (Haifanggou Formation) and the late Middle Jurassic (Lanqi Formation) assemblages of the Coniopterus – Phoenicopsis flora. Sporo-pollen of the Haifanggou and Lanqi formations belong to the Middle Jurassic Cyathidites – Cycadoptites – Classopolis assemblage of north China (Song and Shang, 2000).

The recently discovered volcanic Daohugou Bed, which located at the joint area of Liaoning, Hebei and Inner Mongolia, contains insects, conchostracans, plants, vertebrates, and other invertebrates fossils. The Daohugou Bed was once erroneously considered as belonging to the Yixian formation by Wang et al., (2000) and Wang (2000). Conchostracans include Nestoria reticulate (Chernyshev), N. orbita (chen), and Mesolimnadia jinlingsiensis Chen, which belong to the Pseudograptapla fauna of China. Pseudograptapla are commonly co-occurred with Nestoria and both of them are characterized by huge reticulate ornamentation, reflecting a Late Jurassic age (Zhang et al., 1976). Sporo-pollen of the Tuchengzi Formation is called the Classopolis assemblage, which also indicates a Late Jurassic age (Song and Shang, 2000).

Recently achieved, high-precised radiometric datings give strong support for subdivision of the terrestrial Jurassic in not only western Liaoning, but also the whole eastern Asia. Yang and Li (2008) reported radiometric ages of the Xinglonggou Formation from the Xinglonggou village of Beipiao city, the Haifanggou Formation from the Daohugou village (Daohugou Bed) of Ningcheng county, and the Lanqi Formation from the Haifanggou village of Beipiao city respectively. The results showed that age of Xinglonggou Formation is 176.7±3.5 Ma, belonging to late Early Jurassic (Toarcian); the ages of Haifanggou Formation and Lanqi Formation are ranging from 165 Ma to 156 Ma, belonging to the Bathonian of the Middle Jurassic to the Oxfordian of the Late Jurassic, but mainly the Callovian of the Middle
Jurassic. Two $^{40}\text{Ar}/^{39}\text{Ar}$ ages of tuffs from the top of the Tuchengzi Formation in Beipiao were reported by Swisher et al. (2002) and Chang (2009) respectively. 139.4±0.19 and 138.8±0.3 Ma indicate age of the top of the Tuchengzi is already the Valangian of Early Cretaceous.

**Key words**: Progress; Terrestrial Jurassic; Western Liaoning

**References**:


Update on the Jurassic Stratigraphy of the Indian Subcontinent with Focus on the Tectonically Controlled Regional Transgressive-Regressive Couplets

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We here for the first time endeavour integration of the otherwise highly variable spatio-temporal Indian subcontinent (from Madagascar in the west through Pakistan, Jaisalmer and High Himalayan belt of India, Nepal and S.Tibet in the east) Jurassic ammonoid record (Arkell, 1956; Shah, 1978; Fatmi, 1986, Bassoullet et al., 1986; Krishna and Pathak, 1994: Pandey and Krishna, 2002; Geiger and Schweigert, 2006; Krishna et al., 2008 and References there in) to develop a composite scale of about 40 plus ammonoid zones in a regional perspective in comparison to 66 formal ammonoid zones on the European Tethyan margin (ETM) (Cariou and Hantzpergue, 1997). The salient results include two large regional stratigraphic gaps of varying duration: (1) Hettangian – Pliensbachian subaerial stratigraphic gap increasing in duration from basin to margin at the start of the Jurassic; (2) Bathonian – Tithonian submarine gap increasing in duration from margin to basin which amply well testify their over all net tectonic origin. We apply basic sequence stratigraphic concepts (Haq et al., 1987) to satisfactorily explain the highly varied and disjunct ammonoid data in-turn organized into major and inferior order regionally spread succession of 9 transgressive/regressive couplets (Fig. 1). We also piece together our several other recent and not so recent research initiatives towards a synthetic tectono-igneo-sedimento-ammonoid-radio-magneto-sequence stratigraphic regional comprehension (Krishna, 2002, 2005).

The Indian subcontinent Jurassic thus includes a c.25 my long early Early Toarcian to late Middle Oxfordian major transgressive regime followed-up by c 12 my long latest Late Middle Oxfordian to late Late Tithonian early part of the major regressive regime. On the lower side the c 17 my long pre-Toarcian early Jurassic marks the terminal part of the major regressive regime of the preceeding depositional sequence. The inferior order couplets (Fig. 1) are: 1. Hettangian–Pliensbachian, 2. Toarcian – Aalenian, 3. Bajocian – early Middle Bathonian, 4. Late Middle Bathonian – early Middle Callovian, 5.Late Middle Callovian – latest Late Callovian, 6. Basal Oxfordian – latest Late Oxfordian, 7. Early Early Kimmeridgian – mid-Early Kimmeridgian, 8. Late Early Kimmeridgian to latest Kimmeridgian, 9 Early Early Tithonian – mid-Early Tithonian and late Early Tithonian – latest Tithonian inferior order transgressive regime. Each of the T/R couplets marks extinction of at least one significant ammonoid subfamily/lineage.

Among other significant ammonoid paleontological observations are:

The relatively less shallower superfamily Stephanocerataceae dominates in the major intra-Jurassic transgressive regime from early Early Toarcian to late Middle Oxfordian, and more significantly so has nearly the same stratigraphic range (Arkell et al., 1957; Donovan et al., 1981) as that of the said major transgressive regime. The two ranges appear to be strongly influenced by some phenomenon common to both.

There is observed successive extinction of ammonoid subfamilies almost in each inferior order sequence, that too, at or near close of either MFS or SB. It again suggests genetic linkage of ammonoid evolution and sequence surfaces through their common driving vehicles.

Until Bajocian, the successive Jurassic ammonoid faunas undisputedly maintain their Tethyan character, while thereafter from Bathonian the faunas acquire regional character on account of climatic/latitudinal bio-provincial differentiation.

During Toarcian there is relative dominance of the relatively shallower superfamily Hildocerataceae.

During Bathonian there is shared influence of the regional, yet less shallower, Macrocephalitinae over relatively shallower Tethyan perisphinctids.

During Callovian – Middle Oxfordian there is dominance of relatively less shallower Stephanocerataceae possibly on account of the realization of rapid hike in sea levels to maximum of the Jurassic in late Middle Oxfordian intra-Jurassic major MFS.

During late Middle Oxfordian – Late Tithonian interval there is greater proportionate representation of perisphinctids over others in view of relatively lesser bathymetry in the terminal Jurassic in the early part of the major regressive regime.

**Key words:** Jurassic; Maximum flooding surface; Sequence boundary; Indian subcontinent; European Tethyan Margin; Ammonoid

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Fig. 1 European and Indian Jurassic ammonoid zones composite scales in comparison.
Ammonite Faunas and Biostratigraphy of the Spiti Shales Formation (Late Callovian – Tithonian) from the Thakkhola Area, Central Nepal

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The Spiti Shales Formation, of which the type area is the Spiti Valley in the Indian Tethys Himalaya, is well developed in central Nepal where the name Nupra Formation was also used. Ammonite faunas and biostratigraphy in the Spiti area were studied by Uhlig and just 100 years later his monograph (Uhlig, 1903-1910) is still the reference for the Indo-SW Pacific Province (or Sub-Realm).

Ammonite faunas from the Spiti Shales Formation of the Thakkhola area in central Nepal, proceed from new samplings with the most stratigraphical control as possible. Outcropping conditions and tectonics were the major problems for the field investigation, during four field journeys which enabled to establish the faunal succession. New data gathered in Nepal modify the traditional scheme inherited from V. Uhlig and established for the type-area of Spiti. More recent studies, as well in Indian Himalaya as in Nepal, use Uhlig’s scheme just as it is or slightly modified, often on uncertain data. But facies monotony and outcropping conditions result in stratigraphical accuracy far from reaching the one which serves as an example in Europe and other areas studied since a long time. Spiti Shales Formation in Nepal is cut at top by terrigenous arrivals of the Chuck Formation (or Unit) which is referred to Lower Cretaceous; so the sequence of faunas is not so complete as in Spiti where the Spiti Shales reach up probably lowermost Hauterivian.

Facies of the Spiti Shales is relatively monotonous, black shales with more or less plentiful nodules, very hard, and silica and pyrites rich. Published papers on deposition conditions from facies and microfaunas studies suggest environment with limited oxygen supply on a deep shelf or upper slope. Depositional environment of the Spiti Shales can explain why the organic carbon was preserved on an anoxic sea bottom associated with high planktonic productivity and high oxygen consumption, such conditions being connected with deep waters upwelling as those modelized on the southern Tethyan margin. The lack of a rich planktonic fauna in the sediments resulted probably of unfavourable embedding and fossilization conditions. Scarcity or nearly lack of benthonic fauna agrees with depositional conditions of the Spiti Shales, as well as the ammonite faunas components. Referring to Ziegler model and more recent somewhat different readings, the very subordinate part of the “Leiostraca” agrees with marine open sea environment on the distal platform and/or the upper slope, about 300 meters deep. No complete sequence exists and so the exact thickness is difficult to determine from scattered outcrops, but a good estimate will be about 150/200 meters.

The result is a biostratigraphical sequence of nine faunal assemblages, each dominated by one single genus or a limited number of related genera, other associated forms being always subordinated to the dominating genus (or genera), whatever they are indigenous or episodic stragglers of exotic origin. The endemic character of the Indo-SW Pacific forms reduce possibilities for correlation and dating referring to the zonal standard scale established for Mediterranean Tethys and adjacent areas. A few and rare forms from European origin or relationship are the only supporting data for the ages hereafter assumed, which revised the ones assumed in previous papers (Enay and Cariou, 1997, 1999).

To the Oxfordian Stage are ascribed the Mayaitid Beds and Faunas. Rare Peltoceratids found not in situ prove the Lower Oxfordian is present but not identified in the field. Lower Mayaitid fauna with European Submediterranean Tethyan Perisphinctids (Perisphinctes s. st. Arispincthes, Dichotomosphinctes) and indigenous Perisphinctids (Praekossmatia n. gen., Zeissia n. gen.), is dated as Middle Oxfordian. Upper Mayaitid fauna is dominated by Indo-SW Pacific Perisphinctids (Sulaites, Praekossmatia), likely of Late Oxfordian age. The exact position of the Oxfordian-Kimmeridgian boundary remains uncertain because any succession is known displaying the passage beds with the next faunal assemblage.

Kimmeridgian Stage. The Paraboliceras Beds and Fauna were assumed to be Kimmeridgian in age in a previous paper. The Lower Paraboliceras Beds yields the last Mayaitids together with the index genus which is dominating in the Upper Paraboliceras Beds. Associated fauna includes the new genus Stevensia, Uhligites and Glochiceras, with species looking very near the European dimorphic pair Streblites-Creniceras, and East Africa-Indo-Malagasian Perisphinctids (Toriuqtisphinctes, Pachysphinctes, and Katroliceras). The finding of Hybonoticeras in the uppermost Paraboliceras Beds is a major datum for situate the Kimmeridgian-Tithonian boundary.

Early Tithonian Substage begins with the Kossmatia Beds and Fauna, with a strict acceptance of the genus (excluding the so-called “Kossmatia”) from North and South America. Kossmatia shows here a wide range of forms without any equivalent outside...
Nepal and almost exclusive of other taxa (very few Pseudowaagenia, Physodoceras, Nebrodites, and Mesosimoceras). Of Early Tithonian age are also beds and faunas previously dated as Late Tithonian. First, the Virgatosphinctes and Aulacosphinctoides Beds and Fauna, a homogeneous fauna, the more so as there is some doubt that some elements belong to that fauna, because they are known in upperlying beds and fauna. Then, the Malagasites and Hildoglochiceras Beds and Faunas, of which the new genus Malagasites (= "Virgatosphinctes" gr. denseplicatus) is well-known in the Indo-Malagasian embayment and Antarctica. Hildoglochiceras perhaps would be characteristic of a peculiar fauna (and horizon) with numerous Oppeliids (Hildoglochiceras, Metauhligites). Although there is some doubt on the genus assignment, "Semiformiceras" aenigmaticum n. sp. is a clue datum for dating the fauna as uppermost Early Tithonian.

Late Tithonian (pars). Ammonite bearing-beds of Late Tithonian age are not well developed in Nepal, being cut at top by terrigenous arrivals of the Chuck Formation (or Unit). The Blanfordiceras Beds and faunas are characterized by an almost exclusively monogeneric fauna, with supposition that a few other genera (Physodoceras, Corongoceras, Himalayites) belong to that fauna. The last ammonite assemblage, the Blanfordiceras and Umiaites Fauna, is known in only one outcrop, in the uppermost ammonite-bearing deposits, already invaded by silty arrival.

Some dubiousness remains and proposed equivalences with the European Tethyan zonal standard are close estimates, already at the stage level, still more concerning zones. The faunal succession achieved in Nepal is the reference used to revise correlations, first with the Himalayan belt, in Pakistan, Indian Himalaya (Spiti, Kumaon) and southern Tibet; then towards east and more widely along the Indo-SW Pacific Province, Australasia (Sula Islands, Misol and Buru, Irian-Jaya and Papua-New Guinea), New Zealand, Antarctica and Magallanes Basin; at last towards west in the Indo-Malagasian embayment, in Kachchh (India), Malagasy, eastern Africa (Tanzania, Kenya, Ethiopia, Somaliland) and Yemen.

Studied faunas are often dominated by one single genus or little number of genera within a same taxonomic group. Those point out some endemism of the Himalayan faunas which is also traced in the Indo-SW Pacific faunas along the perigondwanan margin (Sula Islands, Papua-New Guinea, New Zealand) as far as Antarctica and Magallanes Basin. These faunas strongly contrast with the faunas which inhabited the Indo-Malagasian embayment (Kachchh, Malagasy, eastern Africa, Yemen) more diverse, including a greater frequency of forms identified or closely related to Submediterranean Tethyan taxa.

It is assumed that the Indo-Malagasy faunas were related to relatively shallower environmental conditions on the proximal platform, a picture which is consistent with evidences of shallowing of the Spiti Shales in the Malagasites Beds and the uppermost Blanfordiceras and Umiaites Beds. The low diversity of the Indo-SW Pacific Province was already interpreted as resulting from origination of an Austral fauna and Realm (or Subrealm) during Late Jurassic time.

Key words: Ammonite, Late Jurassic, Biostratigraphy, Nepal Himalaya.
A larger part of Gansu, the west of Innermongolia and the northeast of Qinghai, in the centre part of northwestern China, consists of Alashan, Beiqilian-Hexizoulan, Zhongqilian and Qaidam stratigraphical divisions. In this region the widely well-developed Jurassic sediments are rich in coal and oil natural resources. Based on fully studied Jurassic spores and pollen in this area, with preceding achievement, seven spora-pollen assemblages have been established. The low Jurassic includes three assemblages: Protoconiferus-Taeniaesporites, Osmundacidades-Chasmatosporites-Disaccites and Classopollis-Cyathidites-Cycadopites. The middle Jurassic includes three assemblages: Cyathidites-Quadraeculina-Cycadopites, Cyathidites-Callialasporites-Pinuspollenites and Classopollis-Cyathidites-Inaperturopllenites. The upper Jurassic is only represented by Classopollis assemblage.

(1) Protoconiferus-Taeniaesporites assemblage: This spora-pollen assemblage is from lower Huxishan formation in Qaidam basin. Gymnosperm pollen (66.4%-100%, averaged 93.3%) are dominant and Pteridophytic spores (0-33.6%, averaged 6.4%) are much less. Among Gymnosperm pollen, nonstriata bisaccate pollen are dominant, consist of Paleoconiferus, Protoconiferus, Pseudopicea, Pseudopinus, Piceites, Piceaepollenites, Abietineae pollen, Pinuspollenites, Podocarpidites etc, with a small amount of noncoloplate pollen Cycadopites Chasmatosporites. In addition, there are some other elements such as Taeniaesporites of the striate and ridged bisaccate pollen and Chordasporites, Riccisporites convolutae, Rhaetipollis germanicus, Ovalipollis breviformis in small quantities which usually appear in the Triassic. Among pteridophytic spores, apiculati azonotriletes spores are dominant, such as Baculatisporites, Osmundacidades, Lophotriletes, Apiculatisporites, Granulatisporites. A small quantity of the laevigati azonotrites spores occurs. This assemblage is Early Jurassic, may be Hettangian stage.

(2) Osmundacidades-Chasmatosporites-Disaccites assemblage: This spora-pollen assemblage is from upper Huxishan to the first member of Dameigou formation in Qaidam basin, the lower-middle Tandonggou formatin in Yaojie, Daxigou formatin in Aganzheng, Jijigou formation in Chaoshui and Yabulai basin. Gymnosperm pollen (averaged 88.5%) are dominant and pteridophytic spores are few. Among Gymnosperm pollen, bisaccate pollen are very abundant. The second is the monocolpate pollen mainly containing Cycadopites, Chasmatosporites. In addition, there are a little Chordasporites, Taeniaesporites, Luekisporites. Among the Pterodophytic spores, the genus Osmundacidades is of the highest percentage. Dictyophyllidites, Calamospora, Asseretospora, Concavisporites, Crassitudisporites are common. This assemblage is Early Jurassic, may be Pliensbachian stage.

(3) Classopollis-Cyathidites-Cycadopites assemblage: This spora-pollen assemblage is from the second-third member of Dameigou formation, upper Tandonggou formatin in Yaojie. The Gymnosperm pollen are much more abundant than pterodophytic spores. Among the Gymnosperm pollen, the quantity of Classopollis (13.7%-44.8%) overwhelms the bisaccate pollen of the Osmundacidades-Chasmatosporites-Disaccites assemblage, with higher content of Cycadopites, and few bisaccate pollen. Among the pteridophytic spores, Cyathidites, Deltoidaspora appear commonly. In addition, there are some genera in small quantities such as Dictyophyllidites, Calamospora, Asseretospora, Concavisporites, Crassitudisporites, Chordasporites, Taeniaesporites, Luekisporites. This assemblage is referred to Early Jurassic, may be Toarcian stage.

(4) Cyathidites-Quadraeculina-Cycadopites assemblage: This spora-pollen assemblage is from Longfengshan formation in Jinyuan, Yaojie formation in Minhe basin, Qintuqing formation in Chaoshui and Yabulai basins, the fourth and fifth member of Dameigou formation in Qaidam basin. Among the pteridophytic spores, Cyathidites (13%-23%) and Deltoidaspora appear in a large quantity, with familiar species Neoraistrickia, Punctatisporites, Lycopodiumspores, Cibotiumspora, Undulatisporites, Beretisporites, Klukisporites, Lycopodiacdites, Converrucosporites, Crassitudispora, Asseretospora, Gleichendites, Osmundacidades, Todsipores, Stereospores. Gymnosperm pollen mainly consist of Cycadopites (7.3%-38.3%) and Quadraeculina (4%-8.3%), a few other elements such as Callialasporites, Cerebropollenites, Perinopollenites, Piceaepollenites, Eucoc ммидites, Piceites, Pinuspollenites, Podocarpidites appear. This assemblage is Middle Jurassic, may be Aalenian-Bajocian stage.

(5) Cyathidites-Callialasporites-Pinuspollenites assemblage: This spora-pollen assemblage is from lower Wangjiaoshan formation in Jinyuan, lower
Hongshuigou formation in Yaojie, the sixth member of Dameigou formation in Qaidam basin. The pteridophytic spores are dominant by *Cyathidites* (11.2%-21.3%), along with *Deltoidospora, Punctatisporites, Cyclogranisporites, Osmundacidites, Undulatisporites, Asseretospora, Crassitudispora*. Among Gennosperm pollen, the content of *Cycadopites* and *Quadraeculina* are high. In addition, there are *Callialasporites, Cerebropollenites, Pinuspollenites, Podocarpidites, Abietinaperturopollenites, Cycadopites, Asseretospora, Crassitudispora*. Among *Gemnosperm* pollen, the content of *Cycadopites* and *Quadraeculina* are high. In addition, there are *Callialasporites, Cerebropollenites, Pinuspollenites, Podocarpidites, Abietinaperturopollenites, Eucommiidites, Classopollis*. This assemblage is referred to Middle Jurassic, may be Bathonian stage.

(6) *Classopollis-Cyathidites-Inaperturopollenites* assemblage: This spora-pollen assemblage is from upper Wangjiashan formation in Jinyuan, upper Hongshuigou formation in Yaojie, Xinhe formation in Chaoshui and Yabulai basins, the seventh member of Dameigou formation in Qaidam basin. The gymnosperm pollen (averaged 93.3%) are dominant. Among them, *Classopollis* (39%-59%) and *Inaperturopollenites* (10.5%-42.9%) are leading elements, Bisaccate and *Cycadopites* are the second dominant elements. The mainly pollen genera are *Psophosphaera, Verrucosisporites, Klukisporites, Punctatisporites, Eucommiidites, Callialasporites, Cerebropollenites, Quadraeculina, Podocarpidites*. Among pteridophytic spores, *Cyathidites* and *Deltoidospora* are less than that of *Cyathidites-Callialasporites- Pinuspollenites* assemblage in amount. This assemblage is referred to Middle Jurassic, may be Callovian stage.

(7) *Classopollis* assemblage: This spora-pollen assemblage is from Shazaohe formation in Caoshui basin, Kushuixia formation in Jinyuan, Xiangtang formation in Youjie, *Classopollis* (more than 90%) is dominant. The other spora-pollen are very scarce, e.g., *Cycadopites, Quadraeculina, Pseudopinus, Podocarpidites, Cyathidites, Deltoidospora, Densoisporites Concavissimisporite*. This assemblage is Late Jurassic, maybe Oxfordian stage.

Based on the paleoecology analysis on the mother plant of spores and pollen, combined the range of paleoclimate indicating rocks in strata, the Jurassic climate has been reconstructed. The Jurassic climatic evolution shows cyclicity and zoning features. There is a fluctuated temperature-rising and humidity-falling event in the late Early Jurassic (Toarcian). The late Middle Jurassic climate is comparatively hot and arid. It is revealed that the paleo-temperature is higher in Qaidam basin and Middle-Qilian area than that of other places during the early-middle Early Jurassic. The paleo-humidity in Yabulai basin is lower than that of other places in the early Middle Jurassic, but it is higher than that of other place in the late middle Jurassic in Qaidam basin. The paleoclimate is hot and arid during Late Jurassic in whole of the study area. It is concluded that during the Early and Middle Jurassic, the paleoclimate is rather warm and humid in Innermongolia, Gansu, Qinghai, which is in favor of developing of coal, oil shale and dark mudstone, helpful to form rich oil and gas sag, and favorable for oil and gas exploration.

**Key words:** Spora-pollen assemblage; Palaeoclimate; Jurassic; Innermongolia, Gansu, Qinghai area of China
A Preliminary Study on Jurassic Fossil Elateroids of China
(Insecta: Coleoptera: Elateroidea)

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Chinese Mesozoic elaterids have been widely reported from Middle Jurassic to Lower Cretaceous. The Jurassic click beetles have been described from the Middle Jurassic Shiti Formation of Guangxi Province (Lin 1986; considered as the Lower Jurassic in the original paper), the Middle Jurassic Haifanggou Formation in Beipiao of Liaoning Province (Dong and Huang 2009), and the Middle Jurassic Jiulongshan Formation at Daohugou Village in Ningcheng County, Inner Mongolia (Chang et al., 2009a, b). However, the diversity of Mesozoic elaterids was still poorly revealed. Recently, hundreds of well-preserved fossil elateroids (Family Elateridae and Cerophytidae) were collected from the Middle Jurassic Jiulongshan Formation at localities near the Daohugou Village, Ningcheng County, Inner Mongolia. In addition, some other materials were collected from the Middle Jurassic Jiulongshan Formation at localities near the Daohugou Village, Ningcheng County, Inner Mongolia. In addition, some other materials were collected from the Middle Jurassic Haifanggou Formation and the Lower Cretaceous Yixian Formation in Beipiao of Liaoning Province, the Lower Cretaceous Lushangfen Formation of Beijing, and the Lower Cretaceous Laiyang Formation in Laiyang of Shandong Province. These fossils from Daohugou (nearly 200 specimens of elaterids and 100 specimens of cerophytids) may provide many new data on early evolution of Elateroidea, but most of them are still undescribed.

The position of some Chinese Jurassic beetles should be re-considered. Five species of \textit{Ovivagina} (Zhang 1997) described from the Lower to Middle Jurassic of Xinjiang are probably not elaterids (Dong and Huang 2009). \textit{Artinama qinghuoensis} described from the Lower Jurassic \textit{Zhaocheng Formation} at Shijiaba, Liuyang, Hunan Province was formerly placed into Acanthocuemidae Crowson, 1964 with a questionable mark (Lin 1986). We suggest that it is more likely an elaterid beetle based on re-observation of the holotype. Thus, it is one of the earliest elaterids. \textit{Mercata festira} and \textit{Gripecolous enallus} described by Lin (1986) from the Middle Jurassic Shiti Formation at Zhongshan, Guangxi Province, was assigned into the Family Silphidae, but they are in fact elaterid beetles after our reexamination.

Fossil cerophytids were also reported from the Upper Cretaceous amber of Russia (Zherikhin 1977) and the Lower Cretaceous Lebanase amber (Kirejtshuk and Azar 2008). However, both of them are strongly doubted. The closely related group is the Lower Jurassic Praelateridae (Dolin 1973), which armed cross-shaped prosternal process and well-developed metacoxal plates. Recently diverse cerophytids are examined from Daohugou biota. They strongly display remarkable similarities to the recent forms. However, recent cerophytids' distribution is extremely limited, only dozens of species described, which is called ‘living fossil’. Our Middle Jurassic cerophytids showing some features different from extant forms provide valuable evidences to the origin and early evolution of Cerophytidae and the evolutionary relationships among different families of Elateroidea.

The new material of elaterids from Daohugou indicates a relatively close evolutionary relationship with those from the Upper Jurassic Karabastau Formation in Karatau, Kazakhstan (e.g. Martynov 1926; Dolin 1975, 1976, 1980). We suggest that Jurassic is a very important era for elateroid evolution. A distinct radiation of elaterids occurred in the Middle Jurassic. The Early Cretaceous elateroids of China (mainly from Jehol Biota) displayed larger body size but both diversity and quantity were reduced. The Early Cretaceous elateroids exhibit a great difference from those Mid-Late Jurassic ones, but some relicts of Protaerypninae remained.

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**Key words:** Elateroidea; Elateridae; Cerophytidae; Middle Jurassic; Daohugou biota

Table 1 A list of the Jurassic elateroids from China

<table>
<thead>
<tr>
<th>Species</th>
<th>Age</th>
<th>Strata</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Archaeolus funestus</td>
<td>Mid-Jurassic</td>
<td>Shiti Fm.</td>
<td>Zhongshan, Guangxi</td>
</tr>
<tr>
<td>Paradesmus baiae Chang,</td>
<td>Mid-Jurassic</td>
<td>Jiulongshan Fm.</td>
<td>Ningcheng, Inner Mongolia</td>
</tr>
<tr>
<td>Kirejtshuk and Ren, 2009</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paradesmus ponomarenkoi</td>
<td>Mid-Jurassic</td>
<td>Jiulongshan Fm.</td>
<td>Ningcheng, Inner Mongolia</td>
</tr>
<tr>
<td>Chang, Kirejtshuk and Ren, 2009</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protagrypnus robustus</td>
<td>Mid-Jurassic</td>
<td>Jiulongshan Fm.</td>
<td>Ningcheng, Inner Mongolia</td>
</tr>
<tr>
<td>Chang, Kirejtshuk and Ren, 2009</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paraprotagrypnus superbus</td>
<td>Mid-Jurassic</td>
<td>Jiulongshan Fm.</td>
<td>Ningcheng, Inner Mongolia</td>
</tr>
<tr>
<td>Chang, Zhao and Ren, 2009</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sinolithomerus dolini</td>
<td>Mid-Jurassic</td>
<td>Haifanggou Fm.</td>
<td>Beipiao, Liaoning</td>
</tr>
<tr>
<td>Dong and Huang, 2009</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artinama qinghuoensis</td>
<td>Early Jurassic</td>
<td>Zaoshang Fm.</td>
<td>Luyang, Hunan</td>
</tr>
<tr>
<td>Lin, 1986</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercata festiva Lin, 1986</td>
<td>Mid-Jurassic</td>
<td>Shiti Fm.</td>
<td>Zhongshan, Guangxi</td>
</tr>
<tr>
<td>Gripecolous enallus</td>
<td>Mid-Jurassic</td>
<td>Shiti Fm.</td>
<td>Zhongshan, Guangxi</td>
</tr>
</tbody>
</table>

**References:**


Cyrtocrinid Crinoids (Echinodermata, Crinoidea) from the Late Jurassic Štramberk-type Limestones of Southern and Eastern Poland

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Hohenegger (1849) was the first, who defined the Štramberk-type limestones, but failed to designate a stratotype for such a rock unit. These limestones are represented primarily by carbonate blocks, conglomerates and breccias that crop out near the original site of Štramberk (Czech Republic). According to Menčík et al., (1983) the Štramberk-type limestones are blocks derived tectonically from a carbonate platform during the slip of the so-called Silesian Platform (for definition see Golonka et al., 2008), and they were formed through disintegration of the Silesian Platform and re-deposition of its fragments into younger basinal sediments adjacent to the Baška elevation. However, this hypothesis does not explain the chaotic distribution of sediments with limestones near Štramberk (Golonka et al., 2008). Picha et al., (2006) stated that the truth lies somewhere in the middle. The carbonate platform of Štramberk, surrounded by coral reefs, probably was the source of small blocks and debris. Submarine flows and suspension currents transported these pieces of rock from the platform margin to the adjacent basin, at the base of the slope. However, during subsequent tectonically induced transportation, larger pieces of platform were derived from the unconsolidated and loose sediments situated along the platform margins. As a result, the melange was formed. Smaller blocks and debris are linked to sediments which formed during the Early and early Late Cretaceous.

The quarries near Štramberk in Czech Republic contain the most diverse and richest cyrtocrinid faunules, with approximately 50 taxa. These were described in detail by Jaekel (1891) and in a number of subsequent papers (e.g. Arendt 1974; Žítt 1983 and the literature cited therein). In Poland, the Štramberk-type limestones occur in a few localities (see Salamon and Gorzelak 2010). The most famous is Roczyny locality (fig. 2 in Salamon and Gorzelak 2010), exposed within so-called “Andrychów Rocks”, which are represented by isolated blocks of limestones of Jurassic-Paleocene age.

A systematic account of highly diverse cyrtocrinid faunules from Upper Jurassic strata of Štramberk-type (Oxfordian-Tithonian) from Roczyny is presented. Fourteen taxa (Phyllocrinus malbosianus, Ph. stellaris, Ph. sp., Psalidocrinus armatus, Sclerocrinus compressus, S. polonicus n. sp., Hemicrinus aff. kabanovi, Ancepsicrinus parvus n. gen., n. sp., Tetracrinus baumilleri n. sp., Eugeniacrinites alexandrowiczii, E. cf. moravicus, E. sp., Eudesicrinus glucowiskii n. sp. and Hemibrachicrinus tithonicus n. sp. are recorded for the first time. Representatives of the genus Eudesicrinus, were previously known only from the Lower Jurassic, thus, the present find constitutes the youngest record of this genus to date. Other cyrtocrinids considered are common in Jurassic-Cretaceous strata across Europe. In the present faunules, isocrinid (Isocrinida), comatulid (Comatulida) and roveacrinid (Roveacrinida sensu Rasmussen, inclusive of Saccocoma) crinoids have been also documented.

The discovery of a new genus Ancepsicrinus is the most important. The only species, Ancepsicrinus parvus, is characterized by ‘spoon-like’ and rosette-like cups and bilateral symmetry. Their cups are elongated, covered by rounded tubercles in upper portion. Two irregular radial facets situated on opposite side of axis of symmetry are well-visible. All representatives of Hemicrinus, the genus most closely similar to Ancepsicrinus, differ significantly from the type species of the latter. However, some features (e.g. presence and shape of tubercles) compare to the Early Cretaceous H. angulatus Žítt, 1983, but in that species the pentaradial cup has five large radial facets (Žítt 1983, pl. 3, figs. 1-3). Occasionally, radials in H. angulatus may be unequal and be arranged bilaterally, in which case they differ markedly in size and shape.

Similar crinoid assemblage has been recently documented in eastern Poland (Kruhel Wielki locality of Tithonian-Berriasian age; details in Morycowa 1964). In this locality, a new genus Ascidicrinus was proposed (paper in review).

Co-occurrence of abraded ossicles with very well-preserved, articulated pluricolumns and cups indicates that crinoid faunules from both localities may represent a mixture of organisms from different environments (i.e. an allochthonous assemblage). In the material studied, only a small percentage (6%) of ossicles reveal epibionts. Similarly, a minority of ossicles (12%) show evidence of bio-erosion by encrusters or borers, in the form of irregular and relatively tiny cavities.

Key words: Jurassic; Cretaceous; Crinoids; Cyrtocrinids; Southern Poland
References:
Salamon M.A., Przemysław G. Cyrtocrinid crinoids (Echinodermata, Crinoidea) from the Late Jurassic Štramberk-type limestones of southern Poland reveal hidden diversity. Palaeontology, 2010, in press.
Diversity of Jurassic Insects – Exemplified by Daohugou Fauna

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The Jurassic was the time of drastic tectonic differentiation of the land masses. Some high ranking taxa originated during the Jurassic such as moth, snake-flies, and advanced dragonflies (Rasnitsyn and Quicke, 2002). Many famous entomofaunae have been reported from the Jurassic such as the Early Jurassic Upper Liassic entomofauna, German and UK, the Middle Jurassic Yanliao entomofauna, China, the Late Jurassic Karatau entomofauna, Kazakhstan, and the Late Jurassic Solnhofen fauna, German. However, the Jurassic was still considered as the probably poorest sampled period for fossil insects (Grimaldi and Engel 2005). Our knowledge of the Jurassic insect diversity may be greatly updated since the discovery of Daohugou fauna at the end of last century (Ren et al., 2002), including very abundant well-preserved vertebrates, invertebrates, plants, and especially outstanding fossil insects.

The fossils from Daohugou Beds (Middle Jurassic Jiuulongshan Formation; ca. 165 Ma) preserved in gray to brownish volcanic tuff layers with very fine grains near the Daohugou Village, Wuhua Township, Ningcheng County, Chifeng City, Inner Mongolia, NE China. The palaeoenvironmental studies of Daohugou Beds indicated as seasonal lakes. These insect fossils are always completely preserved with fine details (e.g. setae) and only a few specimens slightly decayed that indicate a rapid burial condition. Therefore, Daohugou Beds display an exceptional preservation for animals. Some soft-bodied invertebrates may be preserved such as arachnids, branchiopods, and worms. The vertebrates from Daohugou always preserved with soft tissues. For insects, some very soft (e.g. larvae) and tiny (e.g. thrips) forms can be fossilized here that provide a great chance to understand the diversity of a Jurassic entomofauna. There are 18 insect orders have been hitherto described from Daohugou. These are: Ephemeroptera, Odonata, Plecoptera, Embioptera, Orthoptera, Dermaptera, Grylloblattodea, Mantophasmatodea, Blattodea, Psocoptera, Hemiptera, Raphidioptera, Neuroptera, Coleoptera, Hymenoptera, Mecoptera, Diptera, and Trichoptera. Other 7 orders have been distinguished from our collections as followed: Archeognatha, Zygentoma(?), Phasmatomata, Thysanoptera, Megaloptera, Siphonaptera, and Lepidoptera. It represents the earliest fossil records of Embioptera (Huang and Nel, 2009), Mantophasmatodea (Huang et al., 2008), and Siphonaptera (Huang et al., in progress). A large specimen of Diplura has been also discovered from Daohuhou as the second Mesozoic record. Moreover, some problematic insects also exist in Daohugou fauna such as Strashila originally described from the Upper Jurassic Bada Formation, Russia (Rasnitsyn, 1992). Thus, the Middle Jurassic Daohugou fauna probably exhibit the most diverse (in order level) entomofauna so far known in the Mesozoic.

Daohugou entomofauna is dominated by Neuroptera, Diptera, and with lesser Orthoptera in quantity and diversity (Huang et al., 2006). Hemiptera also contains some very common groups such as corixids and proccercopids. Coleoptera and Hymenoptera are very diverse in Daohugou Beds but they are not very abundant like those mentioned above. Additionally, earwigs (Dermaptera) displayed special importance in Daohugou that represented by circa 5,000 specimens in our collection. Some advanced earwig forms appeared already unlike the former understanding that only Aechidermaptera was discovered (Huang et al., 2006).

The aquatic insects of Daohugou mainly were represented by mayfly nymphs (e.g. Mesoneta) and aquatic bugs (e.g. Yanliacorixa). The secondary important aquatic representatives are some larvae (nymphs) of Plecoptera and Coleoptera. Odonata displayed remarkable diversity on imagines but nymphs are relatively rare. Plenty of dipteran larvae only found in a few layers. Caddis larvae (cases) are rare by contrast to their rather common adults. The larvae of Megaloptera remarkably present in Daohugou but the adults are extremely rare. Nevertheless, most aquatic ecosystems of Daohugou fauna were respectively dominated by different branchiopods such as conchostracan, anostracan, or cladoceran.

Daohugou entomofauna may be considered as a local assemblage of Yanliao entomofauna. Yanliao entomofauna erected by Hong (1983) that contents a wildly distributed Middle Jurassic insect fauna mainly represented by those from the Haifanggou and Jiu-longshan Formations. A plenty of publications indicate a close relationship of insects from Daohugou and Karatau. Furthermore, some similarities between Daohugou and Lias should not be ignored, for example the appearance of Aphidium (Protopsyliidiidae; Ansorge, 1996). These data confirm that the geological age of Daohugou fauna is between that of Lias and Karatau.

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**Key words:** Middle Jurassic; Insects; Daohugou; China

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Huang D.Y., Nel A. Oldest webspiders from the Middle Jurassic of Inner Mongolia, China (Insecta: Embioida). Zoological Journal of Linnean Society, 2009, 156: 889-895.
Current Knowledge on Jurassic Staphylinids of China
(Insecta, Coleoptera)

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Staphylinidae is one of the largest families of Coleoptera with more than 55,000 described species and circa 3700 genera placed into 32 subfamilies. The earliest reported staphylinid is from the Late Triassic (ca. 220-230 Ma) of Virginia, USA (Fraser et al., 1996). A variety of Mesozoic staphylinids have been known from the Jurassic to Cretaceous. While the Jurassic staphylinids are more poorly understood compare to the Cretaceous ones. The described Jurassic staphylinids are mainly from the Upper Jurassic Karabastau Formation of Karatau, Kazakhstan, with 18 species assigned into 10 genera (Tichomirova, 1968). Besides, 3 species separately belong to 3 genera are from the Early or Middle Jurassic of Novospasskoye and Kubekovo in Siberia (Ryvkin, 1985). Some Jurassic staphylinids are from China: 1) a new genus and species named Prostaphylinus mirus has been described from the Middle Jurassic Haifanggou Formation of Beipiao, western Liaoning Province (Lin, 1976); 2) another specimen found in the Middle Jurassic Jialongshan Formation of the Zhouyingzi Village, Luanping County, northern Hebei Province was considered the same species as P. mirus (Hong, 1983, 1984); 3) Zhang (2002) mentioned an unnamed new specimen of Globoides from the Middle Jurassic Jialongshan Formation at Daohugou, Ningcheng County, Inner Mongolia. However, some formerly described as Jurassic or Early Cretaceous such as those from Laiyang Formation of Shandong Province (e.g. Zhang, 1988), Jiuda Formation of Jilin Province (Hong, 1992), and Yixian Formation of Liaoning Province (e.g. Yue et al., 2010). These real Jurassic staphylinids are placed into some Recent subfamilies such as Oxytelinae, Omaliinae, Piestinae and Tachyporinae, or sometimes into uncertain subfamily position (Herman, 2001).

We have collected abundant fossil insects in the Middle Jurassic Jialongshan Formation from Daohugou (ca. 165 Ma) in recent years. More than two hundreds of staphylinid specimens have been examined in our collection. These materials help us to understand the early evolution and diversity of Staphylinidae. The 3 Chinese Jurassic staphylinids are discussed.

The holotype of Prostaphylinus mirus collected from the Middle Jurassic Haifanggou Formation near the Haifanggou Village, Beipiao, Liaoning Province (Fig.1 a). Its generic characters described by Lin (1976) as follows: antenna 11 segmented, first 3 segments rather long, last 5 segments gradually dilate, last segment remarkable dilate and elongate, other segments moniliform; head rather triangle shaped, posterior edge narrower, conspicuous; mandible not protrudent; eyes located at posterior-laterally of head; prothorax larger than head, width as twice as length, pronotum smooth; elytra short, smooth; 5 abdominal segments visible, with straight later margin, last two segments smaller. The comparison with other Mesozoic forms has not stated. Its general morphology, some details (e.g. antenna, pronotum) and small size resemble Globoides from Karatau. Globoides has been assigned into the Recent subfamily Omaliinae (Herman 2001). A few new specimens from Daohugou strongly display similarities to P. mirus (Fig.2 a). They are probably represents a same species. The holotype is lost, thus the detailed comparison is difficult.

Hong (1983, 1984) described a staphylinid fossil from the Middle Jurassic Jiulongshan Formation at the Zhouyingzi Village, Luanping County, northern of Hebei Province (Fig.1 b, c). He attributed this specimen to Prostaphylinus mirus. Some morphological differences to holotype were listed: distal antennal segments unremarkable dilate, elytra shorter, 6 abdominal segments exposed, and a larger size that considered as intra-specific variation (Hong, 1983, 1984). Moreover, the pronotum of Hong’s specimen shows trapezoid shape that clearly differs from the more or less traverse rectangular pronotum of the holotype of P. mirus. Therefore, we suggest that ‘Prostaphylinus mirus’ from Zhouyingzi represent a new species even a different genus. A few new specimens from Daohugou extremely resemble Hong’s material (Fig.2 b) including the body shape and size, even some details such as antenna, pronotum, elytra, and abdomen. We herein tentatively consider that it is the same species as Hong’s specimen. The conchostracans from Daohugou and Zhouyingzi are congeneric indicates these two areas could be biostratigraphic correlated (Shen et al., 2003). Thus, our study gives another evidences to the biostratigraphic correlation of Daohugou and Zhouyingzi.

Zhang (2002) reported an unnamed new specimen of Globoides from Daohugou (Fig.1 d) as an evidence to correlate the strata of Daohugou to Karabastau Formation, Kazakhstan. However, Zhang’s specimen is remarkably different from both two species of Globoides from Karatau in several features: 1) the antenna of the latter is longer and thinner unlike the relatively short antenna with clear distal segments clubbed in...
Zhang’s specimen; 2) the elytra of the latter is obviously shorter than that of Zhang’s; 3) the abdomen of the latter is oval shape different from the tapering shaped abdomen of Zhang’s specimen; 4) the size of two known species of *Globoides* are relatively small as 2.2 to 4.5 mm long, but Zhang’s specimen is more than 10 mm long. Thus, Zhang’s specimen is probably not a *Globoides*. Such kind of staphylinids represented by several species (Fig.2 c, d) are very common in Daohugou. Nevertheless, we suggest *Prostaphylinus mirus* and our new specimen (Fig.2 a) are more similar to *Globoides*.

![Fig.1 The formerly reported Jurassic staphylinids from China](image1)

Only 22 staphylinid species hitherto described from the Jurassic. Based on the large collection of staphylinids from Daohugou, our knowledge on early evolution and diversity of Staphylinidae should be consumedly updated in future.

![Fig. 2 Some new staphylinids from the Middle Jurassic Jiulongshan Formation at Daohugou, Inner Mongolia](image2)

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**Key words:** Jurassic; Staphylinidae; Diversity; China; Daohugou

**References:**


Jurassic Crinoids: Can Their Skeletons Be Used as Palaeoenvironmental Proxies?

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Extant echinoderms usually produce high-magnesium calcite skeletons (e.g. Weber, 1969, 1973). It has been argued, however, that Mg²⁺/Ca²⁺ ratio in skeletons of fossil echinoderms has varied significantly over the Phanerozoic due to variations of Mg²⁺/Ca²⁺ ratio of seawater that, in turn, is thought to be a function of the rate of ocean-crust formation (Dickson, 1995, 2002, 2004; Hardie, 1996; Stanley and Hardie, 1998; Lowenstein et al., 2001). For example, well-preserved (diagenetically unaltered) echinoderms from the Cambrian and from the Carboniferous to the Triassic are preserved as Mg calcite with high, 9-12 mole% MgCO₃ content, whereas echinoderms from the Jurassic to the Cretaceous have low, 4-6 mole% MgCO₃ content (Dickson 2002, 2004). These differences perfectly match change between high Mg⁴⁺/Ca²⁺ ratio of “aragonitic seas” and low Mg⁴⁺/Ca²⁺ ratio of the “calcitic seas”. It has been suggested, therefore, that the skeletal Mg⁴⁺/Ca²⁺ ratio of well-preserved fossil echinoderms can be used to reconstruct past Mg⁴⁺/Ca²⁺ ratio in seawater up to the Phanerozoic.

Crinoid (Crinoidea) ossicles from the Middle Jurassic (Bathonian and Callovian) clays in Gnaszyn and Łuków (central and eastern Poland), which co-occur with originally aragonitic (metastable CaCO₃ polymorph) fossils (such as ammonites, gastropods; e.g. Gedl et al., 2003, 2006; Manecki and Tarkowski 1987), seems to be diagenetically unaltered as suggested by nanoscale structural and biogeochemical features of the stereom (Stolarski et al., 2009) identical to those observed in present-day crinoids (Gorzelak et al., 2009). In contrast with high−Mg calcite skeletons of modern, tropical echinoderms, however, the fossil crinoid ossicles from Poland contain only ca. 5.0 mole% of MgCO₃. This low Mg⁴⁺ content suggests that these crinoids preserve a record of low Mg⁴⁺/Ca²⁺ seawater ratio of Jurassic “calcitic seas”, which is consistent with the hypothesis concerning that seawater composition can change the skeletal mineralogy of echinoderms (Ries, 2004).

On the other hand, it is also known that Mg⁴⁺ content in the skeletons of extant echinoderms varies significantly (5-19 mol% MgCO₃) with physiological/environmental factors. For different echinoderm taxa these content may vary significantly and overall Mg⁴⁺ content in their skeletons seems to be correlated with sea−water temperature and salinity (e.g. Chave, 1954; Weber, 1973; Borremans et al., 2009). Interestingly, geochemical spot analysis of deep-sea skeletons of extant stalked crinoids collected from the subtropical environments revealed an unexpectedly high degree of variability in Mg⁴⁺/Ca²⁺ at many levels (within a single stereom trabeculae, within a single ossicle, within a skeleton of a single animal, within a single population and within different populations). Given that the specimens were collected from the subtropical and deep-sea environments, where no significant temperature and salinity changes are recorded, such variations suggest that physiological factors play important role in controlling the Mg⁴⁺/Ca²⁺ ratio in the crinoid skeletons. These data suggest that the fractionation system of Mg⁴⁺/Ca²⁺ in echinoderms is very complex and it is dependent on both environmental and genetic (vital) factors making a reliable reconstruction of elemental contents of past oceans based on fossil echinoderm skeletons exceedingly difficult.

**Key words:** Echinoderms; Crinoids; Skeletons; Mg⁴⁺/Ca²⁺

**References:**


Diversity of Jurassic Caddis Cases (Insecta, Trichoptera)

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The larvae of Trichoptera, or caddis worms, generally lived in different fresh water environments. Some of them (e.g. Integripalpia) constructed cases probably mainly for protection from predators. These cases were always built with particles of minerals, sand grains, shells of mollusks, carapaces of arthropods, or even pure secretion. These materials were easier to fossilize than the chitinous ex-skeleton. For this reason, there were many caddis cases preserved as ichnofossils in geological times. Although the special remains in ancient deposits always ignored by collectors, they attracted attention of some researchers. Vyalov and Sukatsheva (1976) proposed an artificial classification system for fossil caddis case. Many papers described new fossil caddis cases based on this system. Sukatsheva (1982), Ivanov and Sukatsheva (2002) and Ponomorenko et al. (2009) summarized the evolutionary history of caddis cases. They pointed that the caddis cases became abundant in Late Jurassic, and reached the highest diversity in Early Cretaceous. The earliest caddis cases were found in the lower Middle Jurassic in Transbaikalia, they were made of silk with additional sand grains. The grains were chaotic in size and arrangement (Sukatsheva, 1985). These cases were considered as the pupative larval cases of hydroptilids. Sukatsheva (1994) found some Middle and Late Jurassic caddis cases in Mongolia made by Integripalpia, a suborder of caddisflies, which build potable cases. These Middle Jurassic cases displayed relatively higher complexities and diversities. Their building materials included sand grains and plant fragments. Some of them displayed special building behaviors, for example the cutting of building materials, organization of the materials in rows or transverse. All Late Jurassic Cases were found in Eurasia (Sukatsheva, 1994, 2000), except for some in USA (Hasiotis, 1997). The knowledge on the age of several formations in Transbaikalia and Mongolia changed from Early Cretaceous to Late Jurassic. Thus, some caddis cases once considered as Cretaceous forms were Late Jurassic forms. The diversity of caddis cases was relatively high in Late Jurassic. They were built with various materials such as pure sands, pure ostracod shell, pure conifer needles. Ponomorenko et al. (2009) concluded that highly sophisticated cases already appeared at the end of Jurassic.

There were more than 20 insect orders discovered from the Middle Jurassic Daohugou fauna (ca. 165 Ma) at Ningsheng County, Inner Mongolia, NE China. Dozens of trichopteran imagines with a few caddis cases (e.g. Philopotamidae, Necrotauliidae) had been examined in our collections (Huang et al., 2009). These cases from Daohugou displayed different types. Most of them were small and straight tube and tapering toward posterior end built with sand grains (Fig.1 b, d). A few cases consisted of transverse arranged plant fragments. The pure plant fragments seemed well selected or cut, showing relatively uniform size and shape in one case (Fig.1 a). It displayed remarkably tapering shape. Another case (Fig.1 e) consisted of mainly plant fragments but mixed with some sand grains. Its plant material looked stochastic selected. This case showed a short tube shape with parallel margins that clearly differs from the former one. One case consisted of both sands (anterior part) and silk (posterior part) material with a clear boundary (Fig.1 c). The described caddisflies from Daohugou were not able to build portable cases (Wang et al., 2009; Wu and Huang, 2010 in press). Thus, the discovery of the above caddis cases from Daohugou showed the diversity of Trichoptera in family level in Middle Jurassic. Some possible case-makers found in our collections (e.g. Dysoneuridae), thus further studies on the relationships between cases and imagines could be done. The diverse and complex caddis cases found in Daohugou indicated the highly sophisticated cases appeared earlier than our former understanding.

Only a few cases with caddis larvae were preserved. Ivanov (2006) reported some well-preserved caddis larvae in the Lower Cretaceous of Baissa. A part of caddis larva exposed at the posterior end of a case (Fig.1 a). It is hitherto the earliest known caddis larva.

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Key words: Jurassic; Trichoptera; Caddis case; Daohugou
Fig. 1 The caddis case from the Middle Jurassic Jiulongshan Formation at Daohugou, Inner Mongolia
a, A caddis case (NIGP 152185) built with transverse arranged plant fragments that shows a caddis larva in posterior end. b, A straight sands tube caddis case (NIGP 152186). c, A caddis case (NIGP 152187) built with sands and silk. d, A caddis case (NIGP 152188) preserved with a bivalve, *Ferganoconcha sibilica*. e, A caddis case (NIGP 152189) build by transverse arranged plant fragments. Scale bars represent 2 mm.

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Sukacheva I.D. New fossil caddis flies (Trichoptera)
Palaeontinidae is an extinct family of Hemiptera existed from the Triassic to the Middle Cretaceous. Until now, it includes 44 genera and 110 species, and have a distribution in Kyrgyzstan (Triassic of Issyk-kue and Sulucta, Jurassic of Sai-Sagul), Turkmenistan (Jurassic of Karabas-Tau), China (Jurassic of Xinjiang, Hebei, Gansu and Inner Mongolia; Late Jurassic to Early Cretaceous of Liaoning), Russia (Jurassic of Iya, Ust-Baley and Irkutsk, Early Cretaceous of Transbaikalia), Tadzhikistan (Jurassic of Shurab), Kazakhstan (Jurassic of Turgay), Australian (Triassic of Ipswich), South Africa (Triassic of Bird’s River), Brazil (Cretaceous) and Spain (Late Jurassic to Early Cretaceous) (Wang Y. et al., 2007a). The extinct family Palaeontinidae had the first appearance in the Middle Triassic of Australian (Evans, 1956). It was abundant in the Jurassic and became extinct by the Mid-Cretaceous (Menon et al., 2005). The distribution of Palaeontinidae is correlated with the abundance of Ginkgoales (Zherikhin and Kalugina, 1985). It is highly improbable that they may feed on phloem of rather thick stems of Ginkgoales.

Mesozoic volcanic activity in eastern China commenced in the Late Triassic, gradually increased in intensity during the Early and Middle Jurassic. During the Late Jurassic the volcanism was very strong, while in the Early Cretaceous it was weaker and nearly terminated in the Late Cretaceous (Xu, 1990). The Northeast China, especially Jiulongshan Formation of Middle Jurassic and Yixian Formation of Late Jurassic, Terminated in the Late Cretaceous (Xu, 1990). The paleoenvironment reconstructed for this locality is a volcanic region with mountain streams and lakes. The age of Daohugou fossil-bearing beds is Middle Jurassic. With recent discoveries of the fossil genera Daohugoucossus (Wang et al., 2005a), Eocassus (Wang et al., 2006b), Cladocassus (Wang and Ren, 2009) and Bricocassus (Wang and Ren, 2009), Daohugou area has proven to be one of the most important site for studying past diversity of the Palaeontinidae. By comparison, the Middle Jurassic palaeontinids diversity is greater than those in any other epoch, suggesting that the family probably went into its most prosperous stage in the Middle Jurassic. Their high taxonomic and morphological diversity suggests a high complexity of niche structure and a high level of specialization within the guild.

Key words: Palaeontinidae; Taxonomy; Mesozoic; China

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A Jurassic Angiosperm and Its Implications for Seed Plant Systematics

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Among the current ecosystem seed plants are the structure defining group. Among seed plants angiosperms are the dominating ones. However, the origin of such an important group and its phylogenetic relationships with other peers have been mysterious for long time. The current widely accepted angiosperm fossils are restricted to the Early Cretaceous and younger strata while their peer gymnosperms are dated back to the Devonian. How did the plants evolve the angiospermy? From which group did angiosperms arise? How do the earliest angiosperms look? These have been lasting and vexing problems for botanists. With more and more discoveries of early angiosperms, the general pattern of early angiosperm evolution is now emerging. In this talk I will focus on one of the recent discoveries: Xingxueanthus sinensis, which potentially undermines the foundation for the traditional perspective on angiosperms. The fossil was found in the stratum of the Haifanggou Formation (160 Ma, Middle Jurassic) in western Liaoning, China. The fossil is a catkin-like female inflorescence, about 23 mm long, with more than 20 flowers. Bracts are helically arranged alone the inflorescence axis, each subtending a pistil in its axil. The pistil is composed of a sub-spherical ovary and an apical style. There is a vertical column bearing numerous ovules in the ovary. This kind of ovule arrangement and enclosure are hard to be distinguished from free central placation in living angiosperms. Apparently, the occurrence of Xingxueanthus in the Jurassic contradicts the current doctrines on origin and evolution of angiosperms. However, this new fossil evidence and evidence from other fields converge to the same conclusion. First, the developmental genetics of model plant, Arabidopsis, indicates that carpel and placenta are controlled by different sets of genes, suggesting that they are two separate organs, namely, the carpel is, like other lateral floral parts, equivalent to a leaf while the placenta is equivalent to a shoot bearing ovules. Second, floral morphology, development and anatomy indicate that many ovules in Caryophyllales are borne on the periphery of the floral axis, subtended and enclosed by carpels from bottom up, and that sometimes the ovules are completely independent of the carpels. These phenomena suggest that early ovules in angiosperms may be borne on shoot and independent of the carpels. Third, vascular anatomy proves that the distribution of vascular bundles, which is thought more conservative, may provide implications on the history of the organs. The comparative floral anatomy indicates that carpel and ovules have independent vascular supplies in flowers, implying that ovule/placenta is independent from carpel in early angiosperms. Fourth, the evolutionary trend in Cactaceae suggests that the highly specialized inferior ovary in Cactaceae, in which carpels have little to do with ovules but covering the latter, is derived from ovary with protruding basal placenta, implying that earlier ovules are borne on a shoot, and carpels are foliar accessories covering the ovules. Fifth, outgroup comparison based on molecular systematics confirms the conclusion in the above implications. Protulaccaceae, the closest sister of Cactaceae, has the ovules clustered on a basal protrusion on the ovary bottom, very similar to the above inferred primitive ovary in Cactaceae. All these evidences concurringly suggest that carpels in angiosperms are foliar accessories, and placenta are ovule-bearing shoots independent of carpels. This conclusion based on comparative morphology, development and anatomy of living angiosperms, which are from the same time level and thus bears only weak historic hints, is further confirmed by the information residing in Xingxueanthus, a fossil angiosperm from the Middle Jurassic. Following this guidance, searching for archetype angiosperms suggests that Cordaitales or its close relatives in the Palaeozoic are very informative worthy of further studying because their ovules and megasporophylls are borne on the secondary shoots in axils of bracts. Interestingly, this hypothesis is supported by cladistics, and when Caryophyllales is taken as the representative of angiosperms, the systematics for seed plants becomes well-resolved and stable.

Key words: Angiosperms; Jurassic; Systematics; Flowers

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First Overview on the Nautiloids from the Pliensbachian and the
Toarcian of the Iberian Peninsula (Portugal and Spain)

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During the Early Jurassic, the current Iberian Peninsula was a relatively independent tectonic unit, named Iberian Subplate. Its particular structural layout and its privileged palaeogeographical location enabled that the eustatic cycles were registered in several epicontinental flooded regions of the Iberian Subplate (e.g. the Basque-Cantabrian and the Iberian basins, Spain; and the Lusitanian Basin, Portugal), containing both Boreal fauna, coming from the Protoatlantic Ocean, and Meridional fauna, arrived from the Tethys Sea. Likewise, as these basins constituted relatively confined environments, endemic fauna arose in their waters as well. Among this rich and diverse fauna, numerous nautiloids from the Pliensbachian and the Toarcian of the Iberian Peninsula have been collected and studied.

Historically, the nautiloids arisen during the radiation of the Early Jurassic that followed the mass extinction of the end-Triassic have been notably difficult to classify and to group. Most of them have been assigned initially to the genus Nautilus Linneo, 1758, and subsequently to the genus Cenoceras Hyatt, 1883. This genus, originally considered as a unity (e.g. Kummel, 1956), has been subsequently divided into several subgenera (e.g. Tintant, 1984). At present, a tendency to rehabilitate other genera or to describe new ones predominates among the few authors who try to classify and to group in a logical and practical system these controversial cephalopods (e.g. Chirat, 1997; Rulleau, 2008) of other close countries (e.g. Tintant, 1990; Martínez and Rábano, 1999), of Portugal (e.g. Tintant and Courbouleix, 1974; Mouterde and Rocha, 1981), or both countries (e.g. Barroso-Barcenilla et al., 2010), most of these taxa have never been previously clearly described or illustrated, and their stratigraphic distribution has not been determined accurately for the Iberian Peninsula. Some others of the species identified already have been cited in the Pliensbachian (e.g. Tintant and Courbouleix, 1974; Cenoceras cubaynesi, Tintant, 1990) or the Toarcian (e.g. Nautilus austriacus, Hauer, 1856; Nautilus semistratiatus, d’Orbigny, 1843; Cenoceras ciryi, Rulleau, 2008) of other close countries (e.g. Tintant, 1990; Chirot, 1997; Rulleau, 2008), have not been mentioned for this geographical region of south-western Europe by the first time in the present work.

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Key words: Nautiloidea; Taxonomy; Pliensbachian; Toarcian; Spain; Portugal

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Jurassic Organic Reef in Northern Tibet and Its Significance

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The organic reefs reported in this thesis are discovered by authors in northern Tibet during 1995 to 1997. It is distributed in the following three areas: Dongqiao area of Anduo County, Maru of Baqing County and Suo County. The reef-building organisms are mainly composed of stromatopora, hexacorals and bivalve, which form characteristic of their own in this area.

1 Type and Characteristic of the Reefs

The main reefs of Jurassic System in this area are similar to the reefs of Early Ordovician in Middle Yangtze. Both of them have the characteristics such as small to medium thickness, big quantities and wide distribution. The reefs identified are distributed over two horizons, namely, the Mid-Jurassic System and Late Jurassic System. The geographical range of the organic reefs distribution is over 300 km from east to west. The Jurassic organic reefs can be divided into five types combined with the types of reef-building organisms and their forms of developing in this area.

1.1 Dendritic Stromatoporids Baffling Reefs

The reefs preserved in the Shamulu Formation of the Upper Jurassic System, Dongqiao area of Anduo County are 3-3.5 m in thickness, 60 m in visible exposed width, extending length about 10 km in the region. They are moundy or bread-like in shape. The dendritic stromatopora Cladocoropsis is the main reef-building organisms, which partly accounts for 40%-60% or 60%-70%. They are mostly preserved in place to barricade or catch plaster. That both reef-base and reef cap are spararenite shows that reef development is limited by shallowing of the seawater.

1.2 Cylindric Stromatopora–Massive Stromatoporids Baffling Reefs

The reefs also preserved in the Shamulu Formation of the Upper Jurassic System, Dongqiao area, Anduo County are 2.5-3.0 m in thickness, 30-40 m in visible exposed width of the section, extending to 10 km in the region. They are bread-like or bed-like in shape. The main reef-building organisms are massive stromatopora, cylindric stromatopora and dendritic stromatopora. The massive one composes the framework of the reefs, accounting for 25%-35%. The cylindric one accounting for 15%-20% and the dendritic one accounting for 10%-15% build up the barrier of the reefs which are mainly used to barricade or catch plaster and a small number of dust and bioclast. Both the reef-base and reef cap are spararenite, which reflects the reefs declination are caused by shallowing of the seawater.

1.3 Cylindric Stromatopora–Hexacoralla Baffling Reefs

This kind of reefs occur in Liuwan Formation, Mid-Jurassic System of Suo County and Shamulu Formation, Upper Jurassic System of Dongqiao area, Anduo County. The reefs which are moundy or bread-like in shape are 1.5-2.0 m in thickness, 30 m in visible exposed width of the section, extending to 10 km regionally. The main reef-building organisms are hexacoralla and cylindric stromatopora. The former preserved in place composes the framework of the reefs, accounting for about 20%-30%, which are characterized by Schizosmilia rollieri in Suo County and Actinastrea in Dongqiao area of Anduo County. The latter preserved in vertical status are baffling organisms, accounting for 15%-20%, which are characterized by Para-stromatopora membranacea in Suo County and Milleporidium cylindricum in Dongqiao area of Anduo County. The reef-base is spararenite, while the reef cap is micrite, reflecting that the reefs declination are caused by seawater deepening.

1.4 Hexacoralla Baffling Reefs

This kind of reefs kept in Liuwan Formation, the Mid-Jurassic System of Suo County are bread-like or moundy in shape. They are 2-2.5 m in thickness, about 20 m in visible exposed width of the section, tracing to 5 km in the region. The reef-building organisms are characterized by the flue-like composed hexacoralla Schizosmilia rollieri, accounting for 35%-40%. They arranged radially from center to around in a macroscopic view. The diameter of the radial ring is 25-30 cm. They are preserved in place to compose the framework of the reefs. The associated organism is rare, while a small number of bivalves can be seen. The main fillings between the reef frameworks are plaster with little of dust, bioclast. That the reef-base is spararenite and the reef cap is micritic limestone shows the reefs declination was caused by water deepening.

1.5 Liostrea Baffling Reefs

This kind of reefs are only scattered in the Baqu Formation of the Jurassic system, Maru area of Baqing County, which are bed-like or bedded in shape. Every single reef is 5-8 m in thickness, with a cumulative thickness of 15-20 m of the section. The reef rock which is 100 m in visible exposed width, stretching to 100 km regionally is distinguished from the normal sedimentary formation. Liostrea birmanica is the main reef-building organisms which accounts for 70%-80% and is preserved in place intactly with the left and protruding valve down, the right flat valve shell up. Its
main function is to grow fixedly to barricade plaster and resist wave. Other organisms rare can be found in the reefs except Camptonectes riches, Protocardia stricklandia etc. The main fillings in the reefs is plaster, accounting for about 20%-30%. The phenomenon of oil cutting often can be seen in this kind of reef. Both reef-base and reef cap are spararenite reflecting the reefs declination caused by water shallowing.

2 The Existing Significance of Organic Reefs

It is of great significance to discover the Jurassic organic reefs in northern Tibet. Firstly, it not only supplies a gap of research area on Jurassic organic reefs in northern Tibet, but also enriches the types of them. Secondly, the authors hold that the ocean crust subduction of the middle part of Ban Gongcuo-Nujiang should be at the end of Middle Jurassic or before formation of Shamulu Formation. The existing of Late Jurassic Reef-building communities demonstrates that the research area may be one part of shallow marine shelf of rudimental back-arc basin after the ocean crust of Ban Gongcuo-Nujiang subducted.

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Key words: Organic reefs; Ban Gongcuo-Nujiang Suture Belt; Jurassic; Tibet
Jurassic Pollen and Spore Floras of the Qinghai-Xizang (Tibet) Plateau

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Pollen and spores are ideal for marine and non-marine stratigraphic division and correlation and are also useful for studying the plate tectonics from a palaeofloristic point of view. Up till now, knowledge of the Jurassic palynofloras of the Qinghai-Xizang Plateau is poor. It was just until recent years that a few papers were published (Li and Batten, 2004, 2010). Although it is still very far away from fully knowing the palynofloras of this tectonically complicated region, some interesting results have been achieved.

The Early Jurassic palynoflora is only known from the Jialapu Formation at Linzhou County, Gandise-Lhasa Terrain with a probable Rhaetian–Lias age (Wang et al., 1983). It comprises spores Calamospora, Todisporites, Retusotriletes, Riccisporites and Verrrucosisporites and pollen Rhaetipollis, Ovalipollis, Alisporites, Vitreisporites, Classopollis, Chasmato-sporites, Quadraeculina, Cycadopites and Inaperturo-pollenites. The assemblage seems to imply a similarity to that of the southwestern China but it is hard for us at present to say more on the floristic affinity as the authors only supplied a taxa list.

In Qiangtang Terrain, a Middle to Late Jurassic palynoflora is yielded from the Yanshiping Group in southern Xizang Province (Li and Batten, 2004). It is low in diversity with the most abundant components being Cyathidites and Classopollis, which together often amount to 70%-90% of the specimens recorded. Cycadopites is also an important element, occurring relatively more consistently and often in larger numbers than other taxa. The other constituents are always low in percentage. This palynoflora shows a closer affinity to North Gondwana Province than to Laurasia Province in that Classopollis occurs abundant and bisaccates are very rare.

In southern Xizang, knowledge of the Jurassic vegetation is from a Himalayan succession, i.e. the Puna Formation in Dingri County (Li and Batten, 2010). The most common components of the assemblage are Alisporites, Araucariacidites, Callialaspites, Contignisporites and Classopollis. Other elements are rare and/or only occasionally common but comprise a relatively diverse assemblage of spores that includes species of the genera Annulatisporis, Apiculatisporis, Asseretosporites, Baculatisporites, Biretisporites, Cyathydites, Deltoidospora, Densoisporites, Dictyophyllidites, ?Foraminisporis, Foveospores, Gliechenidites and Striatella, and a smaller association of gymnosperm pollen grains including Chasmato-sporites, Cycadopites, Exesipollenites, ?Protoconiferus, Pristi-

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Key words: Pollen; Spores; Jurassic; Xizang (Tibet); Tectonic evolution

References:
New Finds of Dinosaur Tracks in the Morrison Formation of Moab Area, Utah, USA

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Four new Late Jurassic dinosaur track discoveries are herein reported from the Morrison Formation of Moab area, Utah. Between 2004 and 2009, new Morrison tracksites were found north of Moab. These sites yield a large theropod footprint of *Megalosauripus* (Fig.1 A) and *Stegopodus*, a possible stegosaurian track (Fig.1 B). In addition, a small *Deltapodus* track of possible ankylosaurian affinity (Fig.1 C), was also discovered for the first time in this area. These three finds came from the area near the junction of the Primary Highway 191 and the Secondary Highway 313. Further to the north another site with tracks of small tridactyl bipeds was found in association with a crocodilean track and tail trace (Lockley and Foster, 2010, in press).

All sites appear to be in the Salt Wash Member of the Morrison Formation which is dominated by channel sandstones.

The large theropod footprint was found at GPS coordinates: N 38°40.341' and W 109°41.438'. This is 53 cm long, elongate, tridactyl, right pedal print. Digit II is slightly narrower and considerably shorter than digits III and IV. The ratio of the footprint length to length of digit III is 1.8. Metatarsophalangeal pad of digit IV is located far posteriorly from the base of digit III. Discrete phalangeal pads are distinguishable. These features strongly resemble those of *Megalosauripus*, according to the concept of this ichnogenus presented by Lockley et al. (1998).

The stegosaurian track is located at GPS coordinates: N 38°40.224' and W 109°41.299'. This moderately sized print of a right tridactyl, digitigrade pes. Footprint is 25 cm wide and 22 cm long, width > length.. The pes is asymmetrical, with the large proximal pad located posterolaterally. A single phalangeal pad occurs on each pedal digit, but the swollen pad of digit II is wider than those on digits III and IV. Pedal digit IV is the longest, but barely projecting beyond the hypex. Digits II and III are relatively shorter but more projecting beyond the hypex than digit IV. These fit directly the diagnosis of *Stegopodus sensu* Gierlinski and Sabath (2008). Thus, this is a second record of that type of track in the Moab area, since the discovery reported by Lockley and Hunt (1998).

The probable Ankylosaurian pedal print was found at GPS coordinates: N 38°40.366' and W 109°41.527'.

The footprint is 12 cm wide and 15 cm long, length > width. It is distinguished by very large triangular heel area and thick, extremely short three digits. In contrast to many dinosaur footprints its fourth toe is slightly larger than others. When this kind of tracks were first described and named as *Deltapodus* by Whyte and Romano (1994), authors thought they are sauropod prints. Later, Whyte and Romano (2001) have suggested their stegosaurian origin. However, several features discussed by McRea et al. (2001) support rather the ankylosaurian affinity of *Deltapodus* trackmaker. The typical *Deltapodus* configuration of pedal digits, which increase in length in the sequence of II, III and IV, evidently miss the stegosaurian formula IV, III and II.

Track and traces found at the northern locality include an assemblage of small bipedal tracks, one of theropodan origin and another of possible ornithopod affinity. They are associated with a tetractyl crocodylian track (cf. *Hatcherichnus*; Foster and Lockley, 1999) and various tail traces presumably made while swimming.
Acknowledgements: This study was conducted under BLM permit UT09-006S.

Key words: Dinosaur footprints; Theropoda; Stegosauria; Ankylosauria; Jurassic; Morrison Formation; Utah

References:
New Haglidae (Insecta: Orthoptera: Hagloidea) from the Jurassic of China and Their Implications for the Early Evolution of Acoustic Communication

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The orthopteran superfamily Hagloidea is a crown group of Ensifera which existed from the Triassic to recent (Sharov, 1968; Gorochov, 1995; Yuan, 2006). The fossil record of this group is very rich and diverse during Jurassic times. It intensively diversified in the Middle Jurassic and Early Cretaceous, and then quickly declined. There are two small extant subfamilies: Prophalangopsinae, with 5 species in 3 genera from China and northeastern India; and Cyphoderrinae, with 4 species in 2 genera from western North America (Zeuner, 1939; Carpenter, 1992; Liu et al., 2009). The Hagloidea was possibly originated from the Carboniferous to Permian Oedischioidea, which is also the ancestor of two large recent superfamilies: Tettigonioidea and Stenopelmatoida (Gorochov, 1995).

The extinct family Haglidae is the second largest group of Hagloidea, and contains about 56 genera from the Lower Triassic to Cretaceous of Europe and Asia. However, most known fossils are just wing impressions, and some of them need re-consideration. So far, few comprehensive phylogenetic analyses have been attempted. The family Haglidae appears to be a paraphyletic group, and the relationships between major lineages are still poorly understood (Béthoux, 2002).

The phenomenon of sexual dimorphism is widespread in fore wings of Jurassic Haglidae, of which most males have acoustic mating system. These insects produce calling and courtship sounds through friction between specialized veins of fore wings, and received these signals primarily via auditory tympana on the front tibiae of both sexes (Jost and Shaw, 2006). This kind of acoustic structures and communication is considered to be the most primitive of all tegminally stridulating Ensifera. Tegminal stridulatory morphology and tibial tympana of Ensifera have evolved more than once in this suborder (Zeuner, 1939; Sharov, 1968; Jost and Shaw, 2006), and the Middle Jurassic is an important period of the evolution of stridulatory apparatus in Haglidae. The venation of fore wings related to making song changed distinctly in the Middle Jurassic, and two opposite trends occur in the evolution of stridulatory apparatus of this group (Gorochov, 2003).

The detailed research on the Jurassic Haglidae is very important not only for understanding the early evolution of acoustic communication, but also for investigating the phylogenetic relationships among recent lineages of Tettigonioidea and Stenopelmatoida. Very recently, abundant Haglidae were discovered from the Middle Jurassic of China (Fang et al., 2007, 2009; Gu et al., 2009). A new genus with two species of Haglidae, was identified based on well-preserved fossils from the Middle Jurassic Daohugou Biota (Inner Mongolia, China). The diagnostic characters and systematic position of genera Mongolovoliopus (Gorochov, 1986), Bacharovololiopus (Gorochov, 1986) Bacharaboilus (Gorochov, 1988) and Tettaboilus (Gorochov, 1988) are discussed in detail. The terminal diagnostic characters of Haglidae are discussed, and subfamilies, genera, and species are keyed. The newly described genus is characteristic by the long arched ScA, oblique vein between RP and MA, and stridulatory on fore wings fairly strong and plumbed to posterior margin. The new genera shares some features with basal Haglids. The absence of the oblique vein between RP and MA and strengthen of CuP indicate the transform of orientation of stridulatory vein and reduction of middle part of fore wings. These characters reflect the improvement of stridulatory apparatus of tegmina probably due to the appearance of new predatory vertebrates with good visual analyser in the Jurassic.

Key words: Haglidae; Orthoptera; Jurassic; China

References:
sian).


Conodonts are one of the most significant groups that disappeared during the Triassic-Jurassic extinction event. After a biodiversity and abundance maximum in the Ordovician, in the Silurian the biodiversity decreased, but recovered during the Devonian. The decadence of the group started in early-middle Carboniferous, with a long-term diversity reduction that continued along the Permian. But after the Upper Permian mass extinction the conodonts recovered during the Early and Middle Triassic, with a biodiversity comparable to the early Carboniferous one. A series of extinction and recovery episodes, taking place in the Upper Triassic (Carnian), produced the total disappearance of the group, with only two species, Zieglericonus rhaeticus and Misikella ultima, reaching the late Rhaetian (Rigo et al., 2005).

Interestingly, the conodonts exceed the largest extinction event known, at the end of the Permian, but were extinguished at the end of the Triassic, not exceeding the limit of the Triassic-Jurassic (TJB). In this work we are going to compare both events and discuss about some paleobiological aspects of the extinction of conodonts. Our study is based on a database of species of Triassic conodonts from a revision of the literature and the study of scientific collections. With this data, we have calculated the origination, extinction and radiation rates of conodonts in the interval from the Changhsingian (Upper Permian) to Rhaetian (De Renzi et al., 1996; Plasencia and Márquez-Aliaga, 2005; Plasencia, 2009). In summary, this work analyzes the conodont diversity between the Permian/Triassic and Triassic/Jurassic extinction events.

In reference to the Permian-Triassic Boundary (PTB) we considered the last Permian stage, the Changhsingian (2.8 m.y.). Only 9 species of 5 genera and 3 families overpass the Wuchiapingian limit. Despite the crisis, the conodonts evolved in 26 different taxa during this period, with an origination rate of 1.03 and an extinction rate of 0.75. The PTB is overpassed by 13 species of 3 genera and 3 families (Gondolellidae, Ellisonidae and Spathognathodontidae). The origination rate during the Induan (1.5 m.y.) is 1.69 and the extinction rate of 1.89, with a radiation rate of 0.28. Two of the families (Ellisonidae and Spathognathodontidae) disappeared during early Triassic.

Despite of the total extinction in the Rhaetian, the really extinction of the conodonts happened during Carnian. The forms that dominated the Middle Triassic (Neogondolella, Paragondolella or Gladigondolella) and other that evolved during Carnian (i.e. Carnie-pigondolella) disappeared during the Carnian-Norian boundary. Norian was a period of recovery, but the boundary with the Rhaetian marks the beginning of a diversity reduction. Despite of some gondolellids forms, like Mockina, the Rhaetian conodonts were forms with reduced size and complexity. This can be observed in the platform-less Misikella or in the P1 element of Zieglericonus, which was a coniform element, similar to the primitive conodonts and very rare in the post-Ordovician ones.

For the TJB, we studied the Rhaetian (4 m.y.). The species that overpass the Norian-Rhaetian boundary were 7, with 3 genera and only 1 family (Gondolellidae). This number is quite similar to the Changhsingian, and even superior to the species that surpassed other Triassic stage boundaries, like the Olenekian-Anisian or Carnian-Norian. The main difference with the PTB is that we have only 5 species during the Rhaetian that means an origination rate of 0.17 and an extinction rate of 0.42, which is not particularly high, but represents more than double than the first one, so the radiation rate is -0.25, the lowest of all the studied period. Thus, the extinction of conodonts can be interpreted, instead of a sudden mass extinction, as a progressive one due to the reduction of diversity during the whole Upper Triassic that concluded with the total extinction of the group just before the beginning of the Jurassic (Hallam, 2002).

To explain the biological crisis of the TJB have been pointed out several environmental causes that include sea-level changes, long-term climate changes and others (i.e. Tanner et al., 2004). However, about the conodont extinction we point out a biological evolutive answer of this Palaeozoic group, with less capable forms to get adaptation in both the stress environmental conditions and to the new Mesozoic biota competition that produced the definitive extinction of the group.

**Key words:** Evolutionary Rates; Conodonta; Extinction; Triassic-Jurassic boundary

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The Palynofloras at the Jurassic-Cretaceous Boundary
(Russian Far East)

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The palynofloras were studied from the Upper Jurassic to Lower Cretaceous terrestrial deposits of the Bureya Basin and terrestrial and marine beds of Primorye region.

In Bureya Basin the Upper Jurassic is represented by Talyndzhan Formation, the Lower Cretaceous - by Urgal Formation. Talyndzhan Fm. is composed of gravels, sandstones, shales, mudstones, tuffs, tuffites and coals (more than 20 seams). The thickness of this stratigraphic unit is 500 m. The Urgal Formation overlies the Talyndzhan Formation conformally or with local unconformity and consists of conglomerates, gravels, sandstones, shales, mudstones and coals (about 50 seams). Thickness is about 600 m. The Urgal Formation is divided into Dublikan and Soloni Sub-formations, some geologists range these stratigraphic units into Formations (Vachrameev and Doludenko, 1961; Krassilov, 1972, 1973). The deposits of these formations were sampled in detail with special emphasis on coals. Abundant and well-preserved palynomorphs were obtained.

The Upper Jurassic strata were deposited in brackish coastal environments. Horsetails, bryophytes, ferns, ginkgoaleans, czekanowskialeans and conifers made up plant communities of this age (Vachrameev and Doludenko, 1961; Krassilov, 1972, 1973). The burials are dominated by ginkgoaleans and czekanowskialeans, the role of ferns and cycadophytes is high.

The Late Jurassic palynoflora is characterized by predominance of fern spores, mainly have been assigned to osmundaceous and cyatheaceous ferns (up to 90%). The participation of diverse mosses is considerable. Gymnosperms are dominated by pollen close to Pinaceae and Ginkgocycadophyta.

Palynological assemblages from middle and upper parts of Talyndzhan Formation are similar to assemblages of Chonok Formation containing the Volgian Buchias (Vilyui synclise), Sytogen Formation (Priverkhoyansky depression), the upper Volgian deposits of Kheta River basin and Paks Peninsula (Eastern Siberia).

In the Cretaceous the sea retreats from this area and the accumulation of sediments took place on swampy seaside plains.

The Berriasian palynoflora is dominated by ferns, mainly belonging to Cyatheaceae, Dicksoniaceae, Duplexisporites (up to 84%). The palynomorphs Stereisporites bujargiensis, Neorastriickia roundiformis, Contignisporites dorsiostriatus, Appendicispores tri-costatus, Concavissimisporites asper appeared. Among gymnosperms Classopolis and Pinaceae prevail (Markevich, 1995).

The Valanginian palynoflora is dominated by conifers (up to 60%) and Ginkgocycadophyta. Ferns reduce up to 50%. The osmundaceous ferns lost their significance, gleicheniaceous and schizaeaceous replaced them.

The cyatheaceous ferns, ginkgoaleans, cycadophytes, cheirolepidiaceous plants and conifers provided a basis for the Early Cretaceous plant communities. Essential features of these plant communities are inherited from the Jurassic vegetation. Their conservatism is related to similar environments.

The Berriasian palynoflora in Primorye region is known from Tauhe Formation of marine origin and from Ustinovka Formation with the Berriasian fossil plants (Primorye region, Coastal Uplift). Tauhe Formation contains ammonites Neocomites ex gr. neocomiensis (Orb.), Dalmasiceras sp. and bivalves Buchia cf. volgensis (Lah.), Nucula sp., Myopoharella (Myopoharella) nottica Konov., Stolmorhynchia sp., Cyclothyris acuticoalis Smirn. (Markevich et al., 2000). This palynoflora is dominated by gymnosperms, mainly by Classopolis. Among spores Cyathidites predominates. The peculiarity of palynological assemblage is the appearance of costate spores Appendicisporites (Markevich, 1980, 1995). The Berriasian palynoflora from marine Tauhe Formation has a similarity with palynoflora from Dublikan Formation.

The Berriasian flora from localities of Tauhe Formation comprises ferns, cycadophytes, and conifers (Krassilov, 1967).

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Key words: Jurassic-Cretaceous non-marine stratigraphy; Palynology; Russian Far East

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Roles of Insects in the Mesozoic Ecosystems of Northeastern China

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Insects have been existed for at least 400 million years. These relatively small-sized terrestrial arthropods, along with their durable cuticle, have allowed them to be preserved in compression fossils and ambers. Insect fossils have been collected in many fossil sites which are listed in Grimaldi and Engle (2005). Based on insect fossils collected in northeastern China (e.g. Liaoning, Inner Mongolia and Hebei), fossil insect researches in China have made significant progress in recent years. However, most of the researches devoted to the insect taxonomy, and only a few to the ecology (Liu et al., 2009a, 2009b). However, insects have played important roles in their eco-systems and must have made significant impact on others at the community level. In this presentation, we will discuss roles of insect in the Mesozoic ecosystems, as represented by the Yanliao Biota during the Middle Jurassic and the Jehol Biota during the Late Jurassic to Early Cretaceous.

Fossil records show that both the Yanliao and Jehol Biota have a high diversity of insects. Some insects are indicators of paleoenvironment, providing some evidences for us to reconstruct their Mesozoic environment. For example, all Siphlonuridae nymphs are aquatic, preferring cool-water habitats and their adults do not move far from water. Multiramificans ovalis and freshwater conchostracans were found from the Yanliao Biota in Daohugou, Inner Mongolia, indicating presence of the lakes or swamps with appropriate aquatic environment (Huang et al., 2007). Another example is that the Siberoioperlidae prefers to live in cool, well-oxygenated waters of the mountain lakes. A representative of this family, Sinosharaperla zhaoi from the Yanliao Biota, for example, the nymphs of mayflies and damselflies which were at the third trophic level. In addition, there were some necrophagous insects serving as decomposers in the Mesozoic ecosystems. Some phytophagous insects were at the primary trophic level. Bees and ants played important roles in the ecosystems of Jehol Biota were comparatively stable and mature. Compared to the Yanliao Biota, Jehol Biota had more coexisting vertebrates and plants, especially aquatic angiosperms. Although the environment and rich flora were advantageous to insects, the pressure from natural enemies for insects was higher. The food web of Jehol Biota was more complicated than that of Yanliao Biota. The average sizes of some insects from the Jehol Biota were larger than those from the Yanliao Biota, for example, the nymphs of mayflies (Liu et al., 2009b).

Many insects have interactions with plants. Some Mesozoic insects either visited flowers or served as pollinators. For example, Mirimordella gracilirostris of the family Mordellidae (Liu et al., 2007), Anthoxyela orientalis of the family Xyelidae (Gao & Ren, 2008) and Archaeopelecinus tebbei of the Family Pelecinidae (Shih et al., 2009) might have visited flowers or served as pollinators. Recently, a probable pollination mode before angiosperms was proposed based on the eurasian, long-proboscid fossil scorpionflies from the Middle Jurassic to the Early Cretaceous. These ancient long-proboscid scorpionflies fed on ovular secretions of extinct gymnosperms and engaged in pollination mutualisms with gymnosperms (Ren et al., 2009). Other insects also had long tubular mouthpart, like Protoneustes jurassicus (Ren, 1998). Long tube-like rostrum indicates its flower visiting habits, which is important for the study of the origin of angiosperms (Ren, 1998).

According to the insect habitats, the Mesozoic ecosystem community was divided into four types: forest insect community, aquatic insect community, soil insect community and alpine insect community (Ren et al., 1999). We compared four communities of the Yanliao Biota and Jehol Biota at family, genus and species levels respectively. In both Yanliao Biota and Jehol Biota, the forest insects had the highest counts, thus, constituting the main body of ecological landscape at that time, while alpine insects were the lowest. In the Yanliao Biota, the number counts of soil-inhabiting insects were the second, followed by aquatic insects. But, in the Jehol Biota, the number counts of aquatic insects were the second, followed by soil-inhabiting insects. Insect fossil records show that the Yanliao Biota had greater diversity than Jehol Biota. We presume that ecosystems of the Yanliao Biota were unstable, possibly in the early development stage. Ecosystems of Yanliao Biota were abundant in plants and less predators for insects, hence, more beneficial for insects’ survival and reproduction. On the contrary, the ecosystems of Jehol Biota were comparatively stable and mature. Compared to the Yanliao Biota, Jehol Biota had more coexisting vertebrates and plants, especially aquatic angiosperms. Although the environment and rich flora were advantageous to insects, the pressure from natural enemies for insects was higher. The food web of Jehol Biota was more complicated than that of Yanliao Biota. The average sizes of some insects from the Jehol Biota were larger than those from the Yanliao Biota, for example, the nymphs of mayflies (Liu et al., 2009b).

Based on the coexisting plants and other animals, we established a structure of the ecosystems of the Yanliao Biota (Fig.1) and Jehol Biota respectively. There were five trophic levels in the ecosystems. Most insects served as the primary, secondary and tertiary consumers in the Mesozoic food chain. Some phytophagous insects were at the primary trophic level. Besides Odonata, which were at the third trophic level, most predaceous insects were at the second trophic level. In addition, there were some necrophagous insects serving as decomposers in the Mesozoic ecosystems. Insects connected the producers and the fourth trophic level. They played important roles in
maintaining food chains and ecological successions, in circulation of substances and global flow of energy.

**Key words:** Insects; Fossils; Ecosystem; China

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Liu Y.S., Sinitshenkova N.D., Ren D. A new genus and
Paleobiogeographical Changes of Late Early Jurassic Ammonite Assemblage from East Asia

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The Early Jurassic period is especially attracted by the analyses of the Early Toarcian Oceanic Anoxic Event (OAE), and transitions of marine biota affected by this paleoecological event have also been discussed in many taxa. On the other hand, worldwide paleobiogeographical change of the Jurassic ammonites was analyzed by Page (2008). However, detailed transitional pattern of late Early Jurassic ammonite assemblages from Japan have not been analyzed, and the lack of these data have disturbed the discussions of Asian ammonite paleobiogeography of this period. The aim of this study is to analyze the chronological changes of the late Early Jurassic ammonite faunal compositions from Japan by using the assemblages from the Toyora Group and the Kuruma Group and to discuss the paleobiogeographical positions of the each time assemblages by comparing with fauna from outside Japan, for example, NW European, Mediterranean, northern Tibetan (Yin et al., 2006), Northeast Russian, and Fareast Russian provinces. These discussions are carried out on the basis of the ammonite zonal scheme reexamined in the Toyora Group (Nakada and Matsuoka, 2007).

The Toyora Group exposed in southwest Japan is the Lower to Middle Jurassic continental shelf sediments and is divided into the Higashinagano Formation, the Nishinakayama Formation, and the Utano Formation in ascending order. The Nishinakayama Formation, mainly composed of black mudstone, is known as the most major source of the latest Pliensbachian-Early Toarcian ammonoids (e.g. Hirano, 1973; Nakada and Matsuoka, 2010). The Kuruma Group is the Lower Jurassic epicontinental deposits distributed in central Japan. This group is divided into six formations, the Jogodani Formation, the Kitamatadani Formation, the Negoya Formation, the Teradani Formation, the Shinadani Formation, and the Otakidani Formation in ascending order, and some Late Pliensbachian ammonites were recognized in the Teradani Formation (Sato, 1955). This formation is mainly consisted of muddy-mudstone.

The Late Pliensbachian ammonoid assemblage from the Stokesi Subzone (Margaritatus Zone) to the Apyrenum Subzone (Spinatum Zone) recognized in the Teradani Formation is mainly consisted of the genus Amaltheus, typical in Boreal Realm faunas in this period. This assemblage contains the Russian endemic species of this genus, and the faunal composition is similar to that of the Northeast Russian assemblage. However, the genus Amaltheus is absent in latest Pliensbachian (Hawkskeren Subzone, Spinatum Zone), and the assemblage of this period is dominated by a variety of Arieticeratinae, typical in the Tethyan Realm faunas. A same transition is also detectable in almost coeval (Apyrenum Subzone) assemblage from the Nishinakayama Formation, whereas this turnover recognized in Japanese assemblages is earlier than the similar faunal changes common in NW European assemblages, chronologically corresponded with Pliensbachian/Toarcian boundary. The main composition of the assemblage from Toyora Group is replaced by Harpoceratinae, dominant in Tethyan Realm faunas, in Hawkskerene Subzone. These latest Pliensbachian fauna show strong affinities with those of the Mediterranean province.

The earliest Toarcian ammonite assemblage from the Toyora Group is dominated by Dactylioceratidae and high-diversity Harpoceratinae. This Tethyan-derived fauna continues during the Tenuicostatum Zone (earliest Toarcian) and has the generic similarities with that of the Mediterranean province. However, the fauna of the Serpentinum Zone (middle Early Toarcian) is characterized by the occurrence of Cleviceras exaratum (YOUNG and BIRD). During the middle Early Toarcian, Boreal Realm faunas are dominated by the genus Cleviceras. Therefore the association of this assemblage suggests the mixing of Tethyan and Boreal faunas in East Asia. This mixed fauna is similar to that of the Fareast Russian province rather than the coeval northern Tibetan fauna, mainly consisting by the genus Cleviceras and Dactylioceratidae.

The late Early Jurassic ammonite assemblages from Japan is characterized by the transition from Boreal fauna to Tethyan fauna at latest Pliensbachian (Hawkskeren Subzone) and the mixing of Boreal genus with Tethyan-dominated fauna at middle Early Toarcian (Serpentinum Zone). These transitional patterns are broadly similar to those of the Fareast Russian faunas. The elucidation of the late Early Jurassic ammonite transition in East Asia is important for analyzing the worldwide ammonite paleobiogeography.
of this period.

**Key words:** Ammonite paleobiogeography; Late Early Jurassic; Faunal transition; Southwest Japan

**References:**
Fossils of *Elatides* from the Lower Cretaceous Bantou Formation, Fujian Province, Southeast China

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The Bantou Formation developed in Yong’an Basin, Fujian Province, southeast China, which consists mainly of white, gray and brownish shales and sandstones. It is overlain by the red-beds mostly of sandstones and rests on a volcanic lava flow known as red rhyolite. Abundant fossil remains were discovered from the Bantou Formation (Sze, 1945). According to the fossil assembles and stratigraphic correlation, an Early Cretaceous age is supported for the Formation (Sze, 1945). Jishan section, the typical section of the Bantou Formation, is well exposed in the Jishan village, southwest Yong’an City. In Feb. of 2009, we collected many fossils from the Jishan section, including Cupressiocladus elegans Chow, Sphenolepis sp., Pagophyllum gracile Sze, Brachyphyllum obesum Heer, Elatides sp., Ptilophyllum boreale (Heer) Sewerd, Zamophyllum sp. and Cladophlebis browniana (Dunker) Seward and so on. In addition to the plant fossils, several fish remains have also been found. Here, some leafy shoots and cones of a conifer fossil Elatides sp. is described. The extinct genus Elatides is known from the Middle Jurassic of Yorkshire (Harris, 1943) and from the Lower Cretaceous of Liaoning, China (Zhou, 1987).

Vegetative organs: Vegetative branches of at least two orders (incomplete). Ultimate branches 0.4 to 1.2 mm wide, probably oriented in one plane. Leaves helically arranged. In some cases, leaves are adpressed to the axis for about half their length and then curve outward at angles of 40° to 80° (most commonly 50°–60°). Leaves are opposite and whorled on the lateral shoot, and the successional pair often forms a right angle with the former pair (Fig.1 1). Although the leaves are helically arranged, they spread as two lateral ranks in one plane by twisting at the base. The free part of the leaves is straight or slightly falcate, more details of leaves are not visible because of the preservation.

Pollen cones: Young cones are found attached to leafy shoots (Fig.1 2, 3). They are not well preserved, appearing to be rounded to elliptical. Elongated cones of mature or near mature stages are mostly preserved as detached organs (Fig.1 4, 6). The mature pollen cone is up to 7 mm long and 2.1–4.5 mm wide, with acute apex. The microsporophylls occur in a minimum number of 16, they are helically arranged on a 0.6–1.0 mm thick axis and emerge at right angles. The microsporophylls head expands nearly horizontally, with acute apex. Near the base of the microsporophyll head, pollen sacs are borne abaxially.

Ovulate cones: They are preserved as detached organs. Megasporangiate cones are elliptical, 10 mm long and 3.0–5.5 mm wide. Bract-scale complexes are helically borne on a stout axis up to 1.5 mm in diameter (Fig.1 5, 7). The bracts are composed of a stalk-like basal portion and an expanded flattened head with an acute apex. The basal stalk is perpendicular to the cone axis on the basal complexes, while the bracts near the cone apex are inserted in an acute angle. The bract head is rhomboidal in outline (Fig.1 8), up to 3.2 mm long and 1.7 mm wide. The abaxial surface of the bracts shows a distinctive keel. Normally one, rarely two, oval inverted ovules occur on the proximal part of the adaxial bract surface (Fig.1 7).

Escapa et al. (2008) assigned a new genus of Austrohamia (Cupressaceae) from the Jurassic of Patagonia. The new genus shows similarity to Elatides morphologically. However, the evolutionary history of the genus Elatides was not well known for paleobotanists. Only williamsonii and Elatides harrisii were well studied by other authors (Zhou, 1987; Kurmann, 2003). The present fossils are available to reconstruct the genus. Unfortunately, the specimens are preserved detached and it is difficult to identify a specific name at present. However, a further detailed study will be done for the fossils since the morphological and evolutionary significance for the extinct Elatides.

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Key words: Elatides; Lower Cretaceous; Morphology; Fujian Province

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Fig.1 Fossil remains of *Elatides* sp.
1-Terminal vegetative shoot, scale bar =10 mm; 2-Leafy shoots of at least two orders, scale bar =10 mm;
3-Terminal shoot with a pollen cone, scale bar =5 mm; 4-A detached pollen cone, scale bar =5 mm; 5-A detached ovulate cone, showing cone axis, scale bar =2 mm; 6-A detached pollen cone, scale bar =2 mm; 7,8-Detail of ovulate cone, showing bracts and ovule, scale bar =2 mm
The Late Jurassic-Early Cretaceous Coal-forming Plants (Russian Far East)

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The coal-bearing deposits of Transbaikalia (Goose Lake, Chita-Ingoda, Bukachacha, Turga-Kharanor basins), Amur River region (Bureya basin) and Primorye region (Razdolnensky and Partizansky basins) were studied. On this territory the Tithonian-Valanginian, and Barremian-Albian stages of coal formation can be distinguished. During this time favorable conditions for existence of mire vegetation occurred. The abundant plant material was feedstock for peat accumulation and coal origin. Coal-forming plants were buried in close proximity to their habitats. We tried to reveal their composition, processing coal from the thick and thin coal seams. The very thin cuticles of ferns do not remain after chemical maceration of coal, but their spores, having exine resistant to acids and alkali, can evidence about existence of ferns in mire vegetation. Both palaeobotanical and palynological data revealed plants contributed in coal formation.

The Bureya Basin located in upper part of the Bureya River has been the best subject of study of the Upper Jurassic to Lower Cretaceous coal-bearing deposits, because the sequence of this tectonic structure includes productive coals of the Tithonian, Berriasian, Barremian, and Aptian ages. The coals of other ages are thinly and do not have commercial significance. The Upper Jurassic strata were deposited in brackish coastal environments. Characteristic of the Late Jurassic epoch are homogeneous composition, not clearly defined differentiation, low diversity and smoothed zonation of vegetation. The main coal-forming plants were cyatheaceous ferns, ginkgoaleans, and conifers. This stage is most conspicuous in Bureya basin. The coal-bearing Upper Jurassic (Talyndzhan Formation) to Lower Cretaceous (Dublikan, Soloni, Chegdomyn, and Chemchukin formations) deposits have thickness about 200-3000 m.

Palynological assemblage from middle part of the Talyndzhan Formation characterized by predominance of fern spores, mainly have been assigned to osmundaceous and cyatheaceous ferns (up to 90%). The participation of diverse mosses is considerable. Gymnosperms are dominated by pollen close to Pinaceae and Ginkgocycadophytus. In palynological assemblages from upper part of Talyndzhan Formation fern spores decreases in abundance with increase of taxonomical diversity. Amount of gymnosperms rises. Their pollen is represented by close to Pinaceae (up to 70%) and Ginkgocycadophytus (up to 40%).

Horsetails, bryophytes, ferns, cycadophytes, ginkgoaleans, czekanowskialeans, and conifers made up plant communities of this age (Vachrameev, Doludenko, 1961; Krassilov, 1972, 1973, 1978). The burials are dominated by ginkgoaleans and czekanowskialeans, the role of ferns and cycadophytes is high. The representative of ginkgoaleans (Pseuadotorellia angustifolia Dolud.) sometimes forms monospecific burials; their cuticle remains are common in coals. Perhaps, this arboreal plant prevailed in mire vegetation, osmundaceous and cyatheaceous ferns were in understory. Sphenobaiera huangii (Sze) Krassil. and S. umaltensis Krassil. are of considerable importance in the Late Jurassic swamp vegetation of Bureya Basin. Cycadophytes are often abundant in the clastic beds, but coals entirely lack remains of these plants. Consequently, cycadophytes were not constituent of mire vegetation.

The Lower Cretaceous (the Berriasian-Valanginian) strata accumulated in vast swampy lowland. The peculiarity of palynological assemblage from Dublikan Formation (the Berriasian) is considerable amount of fern spores (up to 84%). Among gymnosperms as well as Classopollis prevails in parallel with conifers. The floristic changes at the Jurassic-Cretaceous boundary have consisted in the increase of ferns and cheirolepidiaceous gymnosperms, which might be related to the marginal uplift and drier climate (Markevich, 1981, 1995; Markevich and Bugdaeva, 2008). Palynological assemblage of Soloni Formation (the Valanginian) is dominated by conifers (up to 60%) and Ginkgocycadophytus. Ferns reduce up to 50%. The gleichenia- ceous and schizaeaceous ferns have assumed great importance.

In the middle Cretaceous the sea retreats from this area and the coal are accumulated in the interior depressions. The Chegdomyn Formation (the Barremian) is typified by dominance mainly of spores Cyathidites. Ginkgocycadophytus and conifers prevail among gymnosperms. The diversity and amounts of ferns are high in palynological assemblage of Chemchukin Formation (the Aptian); they are represented by cyatheaceous, gleichenia- ceous and osmundaceous ferns. The Pinaceae and Taxodiaceae predominate among gymnosperms. The involvement of Ginkgocycadophytus remains rather high.
The cyatheaceous ferns, ginkgoaleans (Pseudotorellia angustifolia Dolud., P. longifolia Dolud., Sphenobaiera urgalica Krassil., S. ikorfatensis (Sew.) Florin), cheirolepidiaceous plants, and conifers provided a basis for the Early Cretaceous mire plant communities. The osmundaceous ferns lost their significance and gleicheniaceous and schizaeaceous replaced them. Essential features of these plant communities are inherited from the Jurassic vegetation.

Based on a number of criteria, such as the abundance of bryophytes, cycadophytes index and replacement of ecological dominance, V.A. Krassilov has suggested a warming trend during the Talyndzhan and Dublikan time, followed by a cooling trend in Soloni and Chegdomyn time. The czekanowskialeans are reduced whereas cheirolepidiaceous plants increase during the Chemchukin climatic warming (Krassilov, 1973).

The Barremian-Albian stage was in a great part. Coal accumulation was manifested on vast areas of Siberia and Far East. During the Barremian-Aptian main coal-forming plants varied in composition depending on environments: in sea-side marshy plains they were represented by cyatheaceous and gleicheniaceous ferns, Miroviaceae and taxodialeans, in intracontinental basins — ginkgoaleans (mainly Pseudotorellia and Sphenobaiera), czekanowskialeans, Pinaceae, and Cheirolepidiaceae.

The Jurassic mire plant communities significantly consisted of cyatheaceous and osmundaceous ferns, ginkgoaleans, conifers, as well mosses. We emphasize that considerable distinctions between taxonomical composition of palynospectra from coal seams and terrigenous sediments between coals were not revealed, which is meant that vegetation occupied both lowland and upland was similar. On the contrary, the palynological spectra from the Early Cretaceous coals and elastic sediments diverged substantially. It seems reasonable to say that since the Cretaceous period the differentiation of lowland and upland vegetation begin to form. Perhaps it resulted from increase of contrast of climatic conditions.

The conservatism of taxonomic composition of mire plant communities is related to similar environments. It is well known that coal accumulation is controlled by tectonics, climatic conditions, and the structures of ecosystems that provided the organic material for the coal.

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Key words: Late Jurassic; Early Cretaceous; Coals; Russian Far East

References:
The Lower Jurassic Boreal Bivalve Assemblage from the Higuchi Group, Shimane Prefecture, Southwest Japan

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Lower Jurassic Sinemurian? to Pliensbachian shallow marine fossiliferous deposits are distributed in southwestern and central Japan. The ammonoid and bivalve assemblages are composed of Tethyan and/or Boreal species. Representatives of the Tethyan ammonoid family Hildoceratidae (Fontanelliceras, Canavaria, and Arieticeras) and the Boreal ammonoid family Amaltheidae (Amaltheus) occur commonly in the Toyora Group in southwestern Japan and the Kuruma Group in central Japan (Sato, 1956; Hirano, 1971, 1973a, b). Tethyan and Boreal species of bivalves are abundant in the Higashinagano Formation, Toyora Group (Hayami, 1962), although benthic marine fossils are rare in the Kuruma Group.

The Higuchi Group is distributed in the Toyora and Kuruma areas of southwestern Japan (Naka et al., 1985). Hirano et al. (1978) reported the Tethyan ammonoids Fontanelliceras and Canavaria in this group. We found these Tethyan ammonoids, the Boreal ammonoid Amaltheus, and abundant shallow marine bivalves in the Higuchidani Formation. In this paper, we report on the Boreal bivalves from the Higuchidani Formation and discuss the palaeobiogeographic significance of the Lower Jurassic benthic fauna.

The Higuchi Group, consisting mainly of siliciclastic sedimentary rocks, is exposed in the Muikaichi area in southwestern Shimane Prefecture and comprises the Orojidani and Higuchidani formations. The Orojidani Formation (180-400 m thick) unconformably overlies the Permian Nishiki Group and consists of increasingly fine repeating units (5-30 m thick), beginning with conglomerate and coarse sandstone, passing through sandstone, and ending with mudstone at the top. This formation commonly contains marine bivalves such as Oxytoma cf. inequivalve and Pleuromya sp. In the Higuchidani Formation (60-120 m thick), which is predominantly dark gray mudstone intercalated with sandstone, Hirano et al. (1978) reported a Late Pliensbachian ammonoid assemblage consisting of Fontanelliceras cf. fontanellense, Arieticeras sp., and Canavaria.
sp. We found some molluscan fossils (the bivalves *Kolymonectes mongkensis*, *Ryderia textulata*, *Palmoxytoma cygnipes*, *Pleuromya* sp., and *Goniomya* sp., and the ammonoids *Fontanellliceras* sp. and *Amaltheus?* sp.) in the lower part of the Higuchi-dani Formation.

*Kolymonectes*, *Palmoxytoma*, *Radulonectites*, and *Agerchlamys* were bipolar in distribution during the Early Jurassic, and did not extend to low palaeolatitudes (Damborenea, 1993, 1998, 2002). Specifically, *Kolymonectes* was common in the northern polar region (= Boreal region; northeastern Russia and northern Canada), though *Kolymonectes weaveri* was exceptionally found in western Argentina (Damborenea, 1998). The Lower Jurassic Sinemurian? to Pliensbachian Higashinagano Formation, Toyora Group, contains abundant corals (*Chomatoseris cyclolitoides*, *Hispaniastraea* cf. *ramosa*, and *Actinastrea* sp.) in calcareous sandstone. The bivalve assemblages of this formation contain Tethyan and Boreal species, including *Tutcheria itoi*, *Prosogyrotrigonia inouyei*, *Sphaeriola nipponica*, *Cardinia toriyamai*, *Plagiostoma* matsumotoi, *Chlamys textoria*, *Oxytoma inequivalve*, *Entolium* cf. *calvum*, *Entolium* cf. *lunare*, *Plagiostoma kobayashii*, *Lopha sazanami*, *Liostrea toyorensis*, *Ctenosteron japonicum*, and *Palmoxytoma* cf. *cygnipes* (Hayami, 1962). Therefore, the bivalve assemblage of the Higuchi Group is typical of the Boreal biotic realm, and the benthic assemblages of the Toyora Group are probably a transitional fauna between the Tethyan and Boreal biotic realms.

**Key words:** Bivalves; Boreal fauna; Southwest Japan; Lower Jurassic

**References:**
The Major Diversification of Cicadomorpha in the Jurassic (Insecta: Hemiptera)

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Representatives of the suborder Cicadomorpha (Insecta: Hemiptera) are among the most common insects nowadays. This ancient group was originated in the Permian and prevailing in the Mesozoic. However, our knowledge and understanding of its early evolution are far from complete. The number, status, and phylogenetic relationships of their superfamilies are also in debate (Evans, 1964; Hamilton, 1992; Blocker, 1996; Dietrich, 2002). The studies of fossils are very important for reconstructing the evolution of Cicadomorpha, because they contribute significantly in valuable information to the time of origins and extinctions, provide a means to estimate the palaeodiversity and reveal trends in the evolution of the morphological disparity. The Jurassic is a period when the rapid evolution and diversification occurred in the major Cicadomorpha lineage (Clypeata). Recently discovered fossils provide new insight into the early evolution of Cicadomorpha in the Jurassic.

In the Jurassic, Cicadomorpha were represented by superfamilies: Prosboloidea (Dysmorphoptilidae), Palaeontinoidea (Palaeontinidae), and Clypeata: Hyli-celloidea (Hylicellidae), Cicadoidea (Tettigarctidae), Cicadoptera (Proceropidae and a new family) and Membrocoidea (Karajassidae and probably the earliest Cicadellidae). Dysmorphoptilidae, prevailing in the Triassic, is a rare group in the Jurassic, while other groups are rich during this period.

Palaeontinae were common large arboreal insects, often found in the Jurassic deposits. This family was derived from Dunstanidae in the Late Triassic, and went into its most prosperous stage in the Middle Jurassic, and became extinct in the mid-Cretaceous (Wang et al., 2009). The latest Jurassic Palaeontinae from Solnhofen and most of Creta-ceous Palaeontinae form a monophyletic group. A rapid diversification from ancient to more derived Palaeontinae took place during the Late Jurassic times. Early Palaeontinae declined sharply in the Late Jurassic, probably owing to the rise of newly evolved insectivorous animals like small pterosaurs, early birds and mammals. Late Palaeontinae with better flight ability survived and became a dominant insect group during latest Jurassic times.

Hylicellidae is a family weakly known in terms of taxonomic diversity and morphological disparity, with fossil record from Triassic to mid-Cretaceous. This group consists of three subfamilies: Hylicellinae, Archijassinae (its systematic position is under debate) and Vietocyclinae. The first subfamily is just reported from the Triassic. Archijassinae are relatively rich in the Early Jurassic deposits of Eurasia, while Vietocy-linae are abundant in the Eurasian Jurassic deposits. The superfamily Hylicelloidea (including Hylicellidae and Triassic Chiliodyclidae) is clearly a paraphyletic group, and requires detailed revisions. It is believed to be an ancestral unit for Cerco-poidea, Cicadoidea, Myerslopioidea and Membrocoidea (Shcherbakov, 1996; Szwedo et al., 2004). This superfamily and all four derived groups are grouped into Clypeata. Clypeata are characteristic, among other features, of strong development of frontoclypeus, containing strong salivary pump muscles. In contrast to phloem-feeding Fulgoromorpha, ancestral Clypeata were xylem-feeders, presenting numerous particular morphological and physiological (as their recent descendants) adaptations to such kind of food. They also retained the median ocellus and primary segmentation of the antennal flagellum, which were present in earliest representatives of recent Clypeata. Besides the modification of head, ancestral Clypeata probably possessed simple tymbals and good jumping ability (Hoch et al., 2006).

Tettigarctidae is the earliest representative of Cicadoidea, with the earliest record from the latest Triassic. They were continuously diversifying during Jurassic times, and were ancestors of extant Tetti-garcidae (two relic species in Australia and Tasmania) and Cicadidae. Most of Jurassic Tettigarctidae presented an elliptical forewing with broad costal area and clavus; whereas extant Tettigarctidae have elliptical forewing with narrow costal area and reduced clavus. This evolutionary trend is similar to that of Mesozoic Palaeontinae, and probably is related to an improvement of flight ability. Tettigarctids could not sing like extant singing cicadas because of the absence of opercula and tympana. The short hind legs of Jura-sassic Tettigarctidae suggest that they lost the jumping ability, and the unmodified forelegs of adults indicate that their nymphs probably were not hypogoeic.

Proceropidae is very weakly known group, which is believed to be ancestral of extant families of...
Cercopoidea (Shcherbakov, 1996). Although Procer-
ycopidae is evidently the dominating cicadomorphan
group in terms of specimen abundance, but its
taxonomic diversity remains unclear due to the lack of
detailed studies. Early Cercopoidea were subject of
diversification in the Jurassic, however the recent
families are reported since the Palaeogene. Another
unit is identified among Middle Jurassic fossils. It
seems to be related to Procerycopidae, but shares some
plesiomorphies with hylilcellids and early procerycopids.
Some Jurassic froghoppers, possessing well-developed
meral lobe in hind legs, evolved the novel locking
mechanism. They were good jumpers, like their extant
descendants.

Karajassidae is believed to be ancestral for recent,
extremely diversified morphologically and taxono-
mically Cicadellidae (Shcherbakov, 1992). It appeared
in the Early Jurassic. So far, just few specimens were
reported from the Jurassic and all described fossils are
restricted to the Central Asia fossil sites. Karajassidae
had transversely enlarged hind coxae, suggesting them
as good jumpers, hind tibiae with rows of macroseatae
and homologous with derived Cicadellidae at least
partial fusion of M3+4 and CuA1 on tegmina and hind
wings.

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Key words: Jurassic; Cicadomorpha; Insecta;
Diversification

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ntinidae from China and the higher systematics of
Palaeontinoidea (Insecta: Hemiptera: Cicado-
Trace Fossils as Microfossils Preserver: A Case of Burrows Containing Late Jurassic Radiolarians and other Microbial Remains from the Upper Mesozoic Tetori Group, Central Japan

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Burrow infill is an interesting subject in the light of not only ichnology but also other geological aspects. For example, it is pointed out tube material filled inverted-conveyor feeding are available as a kind of “sediment trap” (Nara, 2000). Here, we report burrows containing microfossils form the Upper Mesozoic Tetori Group, central Japan. Lower part of the strata is Callovian-Kimmeridgian marine sediments deposited eastern margin of the Laurasian continent, and thus, provides us important information for Middle to Late Jurassic non-pelagic paleoecology.

The Oxfordian-Kimmeridgian Arimine and Kiritani formations are shallow marine deposits of the Higashisakamori Subgroup distributed southeastern Toyama Prefecture, which is a basal part of the Tetori Group (Maeda, 1961). Both beds mainly consist of black sandy siltstone intercalated with very fine- to medium-grained sandstone layers. Sandy siltstone is generally suffered moderate to intense bioturbation and yields many trace fossils such as Phycosiphon, Planolites-, Schaubcylindrichnus-, and Skolithos-like burrows. These ichnofossils co-occur from the same horizons. It is revealed that microfossils are quite rear in the host rock but commonly in the pipe material of Skolithos- and Planolites-like burrows, by detail observations on thin sections and residues obtained from hydrofluoric acid (HF) treatment. Phycosiphon and Schaubcylindrichnus-like tubes, however, do not intend to contain microbial remains.

Skolithos-like burrows are predominantly observed in the Arimine Formation (Fig.1 a). The traces are simple unbranched tube with steady diameter or somewhat downward thinning spindle shaped, slightly curving and vertical to the bedding plane. The burrows are nearly circular in transverse section. They have smooth surface and no internal structures, such as lining. Each pipe dose not cut or cross one another. Length of the tubes is more than 15 cm and diameter ranges from 1 to 2 cm. Total length of the tube is 1 cm at least. Internal diameter is about 0.5 cm and the lining is approximately 0.3 cm in maximum thickness.

Boundary between the microfossils-containing burrow traces and surrounding sandy siltstone are distinctive in general, because the tube fill are considerably different lithology with the host deposit. Infilling material is characterized by microbial remains in black clay-rich matrix with organic detritus, fewer sand-sized particles in comparison with the host rock. In Skolithos-like burrows fill, grading structure is not observed. The tube material is well-sorted, only finer particles than host sediment from top to bottom of the pipes (Fig.1 b). Planolites-like burrows material shows no sedimentary structures, relatively poorly-sorted and rich in sand-size grains compared to those of Skolithos-like tubes (Fig.2 b). While infill of Phycosiphon is muddy, organic-rich sediment similar to Skolithos-like burrows, however, there is no intention to contain microfossils. Schaubcylindrichnus-like pipes fill, which is recognized no microbial remains, exhibits the same lithology as surrounding sandy siltstone.

Microfossils are extracted from the burrow fills treated with diluted hydrofluoric acid (HF; 5 v/v%) for approximately 24 hours. Skolithos-like burrows from the Arimine Formation bear radiolarians (spumellarians and nassellarians), sponge spicules, echinoid spines and so on (Fig.1 c). The microfossil assemblage from Planolites-like tubes fill of the Kiritani For-
mation is more various than those of Skolithos-type burrows yielded the Arimine Formation. It contains radiolarians (spumellarians and nassellarians), rhaxellid sponge microscleres, juvenile bivalves, charophyte gyrogonite of charales and planktonic foraminifera (Fig. 2c). In Skolithos- and Planolites-like burrows fill, radiolarians are major component and sponge remains next to the microfauna. It is notable both siliceous and calcareous tests are preserved in pipe materials.

Trace makers of Skolithos and Planolites are considered to be suspension and deposit feeders, respectively (Häntzschel, 1981). According to Bromley (1990), many organisms that feed at the bottom surface deposit their excrement at depth within the sediment. Skolithos-like burrows fill might result from inverted-conveyor activity, that is, the suspension feeder selectively ingests suspended dust with microfossils and excretes them in the substrate. As the reason for that, the tube material dose not show grading and is composed of only fine particles with microbial and organic matter. Planolites-like burrows sediment is also massive organic-rich muddy material containing microfossils. It may suggest that detrial matter on the bottom is transported beneath the surface by inverted-conveyor surface deposit feeder. In addition, fecal matter delivered into the bottom substrate has high preservation potential because of escaping the hazards of physical and biogenic reworking and oxygenation (Bromley, 1990). This is perhaps one of the causes that siliceous and calcareous microfossils are preserved in the burrows infill.

The discovery of microfossils from the Higashisakamori Subgroup introduces new members into paleo-fauna of the Tetori Group, for no microbial remains have been known from the marine strata since Geyler (1877). Until our study, the marine Jurassic Tetori Group is principally correlated on the basis of ammonoids. Co-occurrence of radiolarians and charophyte gyrogonite (Fig. 2c, 1-3) may enable us to establish multiple biostratigraphic time scale for the group. Planktonic foraminifera (Fig. 2c, 5) from the Kiritani Formation is probably the first record from the East Asian Jurassic system (Hasegawa per. comm.). This case mentioned above shows certain forms of burrow traces can be used as “microfossils preserver”. So, marine burrowing trace fossils are important target, from microfaunal or biostratigraphical point of view.

Key words: Burrow fill; Central Japan; Late Jurassic microfossils; Tetori Group

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Jurassic Spiders

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The first fossil spiders (Araneae) ever described from rocks of Mesozoic age were from the Jurassic period. Eskov (1984) erected the new family Juraraneeidae, based on Juraraneeus rasnitsyni, a single adult male from the Jurassic of Transbaikalia, Siberia, and Eskov (1987) described an arachnid spider, Jurarchaea zherikhini, from the Jurassic of Kazakhstan.

Since then, most newly reported Mesozoic spiders have come from Cretaceous strata. These include: indeterminate Araneae from Koonwarra, South Australia; mygalomorphs from Transbaikalia and Mongolia; orbicularian araneomorphs from the Sierra de Montsech and Las Hoyas localities, Spain; an unnamed lycosoid from Orapa, Botswana; a poorly preserved specimen from Mexico; many new spider specimens reported from the Crato Formation of Brazil, of which just a few have been described so far; and many also are now being collected from the Lower Cretaceous of China. Spiders are known from Cretaceous amber from Canada, the Caucasus and Siberia, France, Lebanon, Myanmar, New Jersey (USA), Álava and Asturias (Spain), Jordan, Ethiopia, and the Isle of Wight (England). References to these can be found in Selden et al. (2009). Triassic fossils are rarer still; these are also reviewed in Selden et al. (2009).

In this talk I shall give an overview of the known records of Jurassic spiders. In addition to those described by Eskov (1984, 1987), a large number of new forms from the Middle Jurassic Jiulongshan
Formation of Daohugou, Inner Mongolia, are being described by the author in collaboration with Dr D.Y. Huang of the Nanjing Institute. A few of these have already been published (Selden and Huang, 2010; Selden et al., 2008). As yet undescribed specimens are known from the Lower Jurassic of Grimmen, Germany, and the Upper Jurassic Talbragar Fish Bed of Australia. Note that the identifications of spiders from the Jehol Biota by Chang (2004) are erroneous, and the age of the Yixian Formation which bears the Jehol Biota is Cretaceous. Jurassic spiders belong to modern families and superfamilies. Though few in number, the geographic spread of these finds throws up interesting palaeogeographic hypotheses.

Fig. 1 shows the phylogenetic tree of spiders and their supposed outgroup (Uraraneida) on the geological column. The four published descriptions (asterisks) are responsible for the range extensions into the Jurassic of three major groups of spiders: the Haplogynae, the Palpimanoidea (Archaeidae and allies) and the Araneoidea. Future finds of Jurassic spiders are expected to have a similar, dramatic impact on our knowledge of the geological history of the Araneae.

Key words: Jurassic; Araneae

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Early Jurassic Sauropod Footprints of the Southern Carpathians, Romania: Palaeobiological and Palaeogeographical Significance

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Relatively very few unequivocal examples of sauropod tracks are known in Early Jurassic strata worldwide (Lockley et al., 1994b), even though true sauropods (Eusauroidea – Upchurch, 1993, 1994) bones are known from this epoch, such as Vulcanodon karihaensis Raath 1972 from Africa (Raath, 1972; Cruickshank, 1975; Cooper, 1984) and fragmentary preserved remains from other continents, including Sanpasaurus, Zizhongosaurus and Kunningosaurus from China (Dong et al., 1983; Dong, 1992), Othmndenosaurus from Germany (Wild, 1978), and Barapasaurus from India (Jain et al., 1979). The most important sites with Early Jurassic sauropod footprints comprise Hettangian sites in northern Italy (Leonardi and Lanzinger, 1992; Dalla Vecchia, 1994; Avanzini and Petti, 2008; Avanzini et al., 2008) and central Poland (Gierliński, 1997; Gierliński and Sawicki, 1998; Gierliński and Pieńkowski, 1999; Gierliński et al., 2004; Pieńkowski, 2004). Besides Hettangian strata, sauropod tracks have been also found in Pliensbachian strata of Morocco (Ishigaki, 1988; Farlow, 1992). Finds of both body and trace fossils, scattered around the globe, suggest that Early Jurassic sauropods were geographically widespread. However, true sauropod (Eusauroidea) footprints and body fossils are absent from Early Jurassic deposits in North America (Hunt et al., 1994; Olsen et al., 2002), suggesting the existence of a barrier situated along the Central Atlantic rift, which prevented migration of dinosaurs to North America from the rest of Pangaea.

We present the new find of dinosaur footprints cf. Parabrontopodus isp. Lockley, Farlow et Meyer, 1994, attributed to sauropods (Lockley et al., 1994a), which have been found in Hettangian (earliest Jurassic) alluvial deposits in Anina (Colonia Cehă quarry, Reşiţa Basin), belonging to the Getic Nappe in the Southern Carpathians, western Romania (Popa, 2005; Popa and Kędzior 2006, 2008; Pieńkowski et al., 2009). Heteropodous pes-manus sets and one short, narrow-gauge trackway have been recognized on a large sandstone surface trampled by sauropods.

The track-bearing sandstone surface at the base of the Valea Tereziei Member is densely trampled by sauropods, which makes indentification of individual tracks and trackways difficult. However, in two places (Fig.1 A, B) the last generation of tracks allow one to recognize two probable pes-manus sets (A) and a narrow-gauge trackway (B). Particularly, one pes footprint with digit imprints is diagnostic (Fig.1 A). The pronounced heteropody may also be diagnostic of Parabrontopodus sp. Lockley, Farlow et Meyer, 1994 – here tentatively labelled cf. Parabrontopodus (Lockley et al., 1994a). The best preserved pes no. 2 (Fig.1 A) shows other characteristic features. A robust digit I is typical for Eusauroidea, which can also point to a large first ungual (Wilson and Sereno, 1998). Moreover, Wilson and Sereno (1998) mentioned that the asymmetrical robustness of pedal digits must be related to the unequal weight distribution across the sub-plantigrade pes in Eusauroidea. Indeed, in the presented specimen (Fig.1 A), digit I is the dominant digit of the pes and the medial (inner) side of the pes is deeper, and the heel pad is substantial. These features are also observed in trackways produced by Eusauroidea (Pittman and Gilette, 1989) and may reflect how a greater load was carried by the inner digits of the pes of sauropods. The significance of these features is that the collapse from digitigrade to a sub-plantigrade (or gravipodal) posture was an important turnover in the evolution of sauropods as the Eusauroidea evolved from basal Sauropoda in the Early Jurassic times (Wilson and Sereno, 1998). Early and middle Hettangian sauropod footprints from Poland (Gierliński, 1997; Gierliński and Sawicki, 1998, 1999; Gierliński et al., 2004; Pieńkowski, 2004) show substantial heel pad and a conspicuous traces of pes digit I. Also a difference in depth between the deeper medial and shallower lateral parts of pedal imprints in several tracks. Consequently, these features indicate that a greater load was carried by the inner digits of the pes, particularly digit I, and the heel pad is deeply imprinted, which points to a sub-plantigrade pes and gravipodal posture, typical for Eusauroidea. A pentadactyl manus imprint (Fig.1 B) suggests that manus digits of early sauropods might have been separate and perhaps more functional when supporting walking on unstable, sticky ground.
Fig.1 Early Jurassic sauropod footprints of the Southern Carpathians, Romania

A, Isolated sauropod tracks (last track generation on the heavily trampled surface), deeper parts of the footprints shadowed, note the pes-manus set (p2–m2), pes with four digits imprinted, and prominent digit I; medial (inner) part of the pes is significantly deeper, as in all pes tracks on the surface, and were produced by different sauropod individuals. B, Short, one-step (two manus-pes sets) trackway with inferred midline, distorted in the soft, saturated sediment. Note bent midline, changing stride and divergence angle (probably resulting from progression on an unstable surface) and deeply impressed footprints with high sediment displacement rims.

Pentadactyl manus of the second set (m2) shown in the insert photo – similar to *Eosauropus* sp. (Lockley et al., 2006).

Although relatively few unequivocal narrow-gauge sauropods trackways are recorded from Early Jurassic strata worldwide (Hettangian: Leonardi and Lanzinger, 1992; Dalla Vecchia, 1994; Gierliński, 1997; Gierliński and Sawicki, 1998; Gierliński and Pieńkowski, 1999; Avanzini and Petti, 2008; Avanzini et al., 2008, and Pliensbachian strata of Morocco: Ishigaki, 1988; Farlow, 1992; see also Lockley et al., 1994b), it is clear that sauropods roamed this region, in both the Pangaean (African, Eurasian) mainland and supposed island/peninsula areas within the western/northern Tethys domain (Fig.1). The palaeogeographic reconstructions of Blackley (2009), Golonka (2004) and Golonka et al. (2005) show that the area which is now the Romanian Carpathians included large islands, embracing both Hungarian and Romanian coal-bearing formations (Fig.1). A palaeogeographic map of Scotese (2002) shows a rather peninsular area, but this map is much more generalized. As mentioned above, in the Early Jurassic, the Getic Unit would belong, together with the Danubian Units, to the larger Moesian Platform, including the “Moesian Island” of Golonka (2004). Such an island could provide a habitat for lush subtropical flora and animals, but this hypothetical island must have been at least temporarily connected to mainland Pangaea to allow migration of sauropods. Migration routes of sauropods would cross the western and northern frames of Western Tethys, including Africa and Eurasia (Fig.1). Moreover, the size of sauropod cf. *Parabrontopodus* sp. footprints from Romania is typical for the Early Jurassic sauropods and does not differ from those from Poland (mainland Pangaea-Eurasia) and Italy (Tethyan carbonate platform/sea shore). Thus, the size of Romanian footprints would speak against insular dwarfism, with the latter condition expected in the case of long-lasting island conditions. This is contrary to the finds of Maastrichtian dinosaurs of the “Hațeg Island” in Romania, where dinosaur bone remains clearly point to the insular dwarfism (Bojar et al., 2005; Csiki and Grigorescu, 2008). Polish and Romanian Early Jurassic sauropod footprints come from the continental alluvial environment, whereas Italian and Moroccan ones come from carbonate tidal flat facies. This suggests a wide spectrum of environments roamed by early sauropods and a great mobility of these animals. Assuming this mobility and the varied environments, one can suppose that the absence of sauropods in North America in the earliest Jurassic times was rather caused by a permanent obstacle (rift) between this part and other parts (Africa, Eurasia) of the fragmenting Pangaecean landmass.

**Key words:** *Parabrontopodus*; Sauropods; Romania; Hettangian; Graviopodal posture; Palaeobiogeography; Western Tethys domain

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Ammonoid Morphology Changes Across the Triassic-Jurassic Boundary

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The end-Triassic mass extinction was the last severe bottleneck in ammonoid evolution before their final demise at the end of the Cretaceous (e.g. Raup and Sepkoski, 1982; Dommergues et al., 1996). The ammonoid diversity collapse was prolonged in the Late Triassic and only one earliest Hettangian genus served as the ‘root stock’ for the spectacular adaptive radiation that followed (Guex, 2001, 2006). We use bivariate and simple multivariate techniques to examine changes in shell geometry and suture style from the Carnian to the Bajocian. Based on simple shell geometry, this interval has three phases: 1) the Late Triassic pre-extinction phase which includes diverse shell shapes and heteromorph genera with four types of shell geometry (Figs.1, 2.1); 2) the Hettangian through Aalenian post-extinction phase, where expansion rate is negatively correlated with volution and involute, slowly expanding forms are lacking (Figs.1, 2.2); and 3) the Bajocian recovery phase in which shell shape diversity increases and heteromorphs of a single shell geometry reappear (Figs.1, 2.3). Correlations between umbilical width and expansion rate versus whorl shape vary from negligible to moderately strong. The most depressed shells are usually located in slowly expanding or evolute regions of morphospace. In ammonoids with nearly equidimensional whorls, there is a trend towards greater hydrodynamic efficiency with time. In the Late Triassic, ammonoids with the simplest suture style tend to be evolute whereas ammonoids with the most complex suture style are usually more involute. In nearly all cases, Hettangian ammonoids are characterized by complex sutures and more evolute morphologies.

Key words: Morphospace; Ammonoids; Triassic-Jurassic; Extinction

References:

Fig.1 Schematic of shell morphology of ammonoids in W-U morphospace

\[ W = \frac{1}{U} \]

where \( W \) is expansion rate and \( U \) is umbilical ratio (Smith, 1986). The line indicated on the figure is the off-lap line (Raup, 1967), which separates coiled forms where consecutive whorls are in contact from those where whorls are uncoiled. Modified from Raup (1967)
Fig. 2 W-U density contour plots (points indicate individual genera) showing shell expansion rate and looseness of coil morphospace for ammonoids from the pre-extinction (Carnian through Rhaetian), post-extinction (Hettangian through Aalenian) and recovery (Bajocian) intervals. The W=1/U lines indicated on the figure are the off-lap lines (Raup, 1967)
Conifer Diversity in Sehora, Jabalpur Formation, Satpura Basin, India

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Sedimentary deposits of Jabalpur Formation are exposed along the Narbada River in Satpura Basin. These outliers mainly occur between Mahadevas and Lametas at Mahadeva Hill and extend laterally to Bairam and Belkher areas in the western part of central India. These sedimentary deposits represents highest Gondwana strata, embody significant floral assemblage. The highly diversified plant fossils are preserved in the vicinity of Sher River near Sehora, in compressed state, usually found in blackish-grey carbonaceous shale. The high diversity of conifer macrofossils are represented by number of species of *Brachyphyllum*, *Pagiophyllum*, *Araucarites*, *Elatocladus* and *Coniferocaulon*, displaying wide range of foliar morphology and cuticular variations.

Podocarpaceae is the predominant family of conifers in the Southern Hemisphere, is well represented by sterile and fertile twigs of genus *Elatocladus*, exhibit helically arranged leaves that ranges from scale to linear or broad leaves. Thickness of cuticles show variations in upper (thin) and lower cuticles as they are comparatively thick. Stomata are sunken and arranged in stomatal bands. Araucariaceae is mainly represented by detached leafy twigs of genus *Brachyphyllum*, *Pagiophyllum* and cone scales of *Araucarites*. Here leaves are closely ad-pressed, conical or hexagonal to short falcate or lanceolate types and cone scales are typically wedge shaped, minute to large sized. The cuticles of genus *Pagiophyllum* and *Brachyphyllum* exhibit both upper (thin) and lower thick cuticles with sunken stomata arranged within the stomatal bands. Sometimes stomatal hairs are also observed in stomatal pit suggesting its thermophyllous nature. Both the families are cosmopolitan in southern hemisphere, but they grew and evolved simultaneously in northern hemisphere (Krassilov, 1974).

Conifers first appeared in early to late Triassic, thrived well during Jurassic and steadily diversified till Early Cretaceous period. The flora of Jabalpur (Sehora) is one of the richest floras among Indian Gondwana representing 49% conifers, 22% pteridophytes, 17% bennettitales, 1% ginkgo and pteridosperms (Prakash, 2008). Among these conifers are floristically dominant and considered as a significant components of Gondwana vegetation comprising plants of families Podocarpaceae, Araucariaceae along with incertae sedis elements. The assemblage is coeval to Rajmahal type-2 flora of Nipania which also embody Araucarian and Podocarpian fossil remains, but differ in presence of Pentoxyleae group. The plant fossils of East-Coast occur in isolated patches of Early Cretaceous deposits characterized by broad-leaved cycadophytic leaves; however, floral assemblage of Gollapalle is comparatively closer to present floral assemblage, where conifers are dominant over the cycadophytes and pteridophytes (Pandya and Sukh-Dev, 1990) with common occurrence of *Elatocladus*, *Pagiophyllum*, *Brachyphyllum* and *Araucarites*. The flora of Bluff
Formation, Alexander Island, Antarctica (Jefferson, 1983) show dominant conifers, but differs from Jabalpur flora due to absence of bennettites. The flora of Mirihiku forearc basin, New Zealand (Pole, 2009) is also dominated by conifers over the other plant groups representing with common foliage types of Pagio-phyllum, Brachyphyllum, Araucarites, henceforth resembling with present flora. The Baquero’ flora of Patagonia resembles with Jabalpur flora due to common occurrence of similar podocarpacean and araucarian elements, while Brachyphyllum leaves are significantly reported from flora of Kachaike Formation, Argentina but differ by advent of angiospermous leaves (Passalia, 2007). Therefore, presence of common elements in eastern Gondwana indicate that the Antarctic peninsula might have acted as biotic gateway for South America and India during Cretaceous period before breaking of Gondwanaland. Thus, the united Gondwana was a best dispersal corridor for spreading and filtering of these conifers ensuing to its maximum diversity in these regions.

**Key words:** Conifers; Diversity; Jabalpur (Sehora) Flora; Upper Gondwana; India

**References:**
Pole M. Vegetation and climate of the New Zealand Jurassic. GFF volume, 2009, 131: 105-111.
Fig. 2 Conifer diversity in Sehora, Jabalpur Formation, Satpura Basin, India
1-Brachyphyllum sehoraensis Maheshwari & Kumaran; 2-Elatocladus kasatii sp nov.; 3-Pagiophyllum satpuraensis Maheshwari & Kumaran; 4-Brachyphyllum elkaistomum Sukh-Dev and Zeba –Bano; 5-Coniferocaulon rajmahalense Gupta; 6-Satpuria sehoraensis Sukh-dev & Zeba Bano; 7-Enlarged SEM photograph of stomata of B.sehoraensis; 8-Pagiophyllum sherensis Maheshwari & Kumaran; 9-Enlarged SEM photograph of stomata of P.satpuraensis; 10-SEM photograph of E. sherensis showing stomata arranged in rows; 11-Araucarites pantiana Bose & maheshwari; 12-Araucarites sehoraensis Bose & Maheshwari; 13-Araucarites cuthensis (Feistmantel) Bose & Maheshwari; 14-Pagiophyllum satpuraensis, stomata arranged in rows.
The Sonniniidae (Ammonitina) from the Laeviuscula Zone (Lower Bajocian, Middle Jurassic) of Moroccan Central High Atlas

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In the central High Atlas of Morocco, the Laeviuscula Zone (ovalis and Laeviuscula subzones) of the Lower Bajocian contains rich ammonite fauna dominated quantitatively (Fig.1) by a family of Sonniniidae (up to 58%).

![Graph of ammonite family distribution](image)

**Fig.1** Share (%) of family of ammonites in the Upper Aalenian and the Lower Bajocian of Moroccan Central High Atlas

The present study is concerned with the analysis of Sonniniidae of Laeviuscula zone (Ovalis subzone and Laviuscula subzone) of the Moroccan Central High Atlas. A taxonomic revision is presented and several species of this family are revised. These are among the following Genera: Euhoploceras, Fissilobiceras, Shirbiurnia, Witchellia, Papilliceras and Sonninia. The chronostratigraphical position and the distribution of the various species are discussed; a comparison with forms from other regions is established.

**Key words:** Sonniniidae; Ammonites; Laeviuscula Zone; Lower Bajocian; Central High Atlas; Morocco
Fig. 2 Distribution of genera of the family of Sonniniidae in the Upper Aalenian and Lower Bajocian of Moroccan Central High Atlas

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The Eligminae, Symbiotic Oysters of the Middle Jurassic

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The Eligminae are preserved in limestone platform facies of the Middle Jurassic. Initially they were recognized in the Bathonian of Northern France and southern Poland, then in the Bathonian and Callovian of more southerly parts of France. Their oyster-like morphology, but lack of any conspicuous area of cementation, has convinced palaeontologists from Eudes-Deslongchamps onwards that they lived symbiotically within soft-bodied organisms, comparable to soft-bodied sponges of the class Demospongiae. The extant bivalve genus *Vulsella* and the oyster *Cryptostrea permollis* (G.B. Sowerby !!) live in this manner today.

The detailed morphology and shell structure associate the Eligminae with the oysters rather than *Vulsella*. The shell is calcitic except apparently except for the muscle scars and the surface of the ligament area.

We have found no evidence of an outer shell layer of prismatic calcite which occurs in at least some Gryphaeidae.

The outer shell layer is formed of cross-foliated calcite in common with other Jurassic ribbed or plicate oysters.

The inner shell layer consists of thin folia of calcite with hollow interspaces, infilling the shell but retaining its relatively light weight. This in some species gives a blistered appearance to the inner surface of the shell.

In our well preserved material we have found no evidence which Douville considered that he had observed and led him to link *Eligmus* taxonomically with *Vulsella*. Although we now know that such a nacreous inner layer occurs in several Triassic oysters.

The ribbing pattern of the earliest species, *Eligmus integer*, from the Late Bajocian, is practically identical to that of typical *Actinostreon*, to which we consider it is most closely related.

Although there is little evidence of any cementation in early growth stages the initial growth produced backward pointing umbones, typical only of the oysters and the Inoceramidae. *Vulsella* on the other hand, beneath a thick and scaley peristracum, has an outer shell layer of prismatic calcite and an inner layer of nacreous aragonite; a combination which is normally considered to be a more primitive shell structure combination within the Pteriomorpha.

Oyster-like chomata are presenting “*Eligmus* australites” and *Gryphaelegmus* but have not been observed in *Eligmus sensu stricto*.

Apart from the notable exception of *Gryphaeligmus*, the early growth stages are sometimes inaequivalved, with a more convex left valve but approach a more equivalent condition in later life. Most species have a noticeable gape between the posterior of the hinge and the Branchytellum. In most species this is in the form of a slightly curved shell margin but in *Eligmus polytypus* the margins are in the form of irregular sinusoidal curves which form an extensive irregular gape. The form and position of these posterior “dorsal” gapes is consistent with ease of rejection of waste particles from the mantle cavity in a position with the normal ventral margin pointing upwards as occurs in living *Vulsella* and the giant clams.

The group is widespread across the Middle East during the Middle Jurassic and in spite of the difficulty of dating the rocks in which they occur. They seem to have originated from an ancestor resembling *Actinostreon* in the Late Bajocian, evolved into at least five species in the Bathonian, and with at least three species remaining towards the end of the Callovian.

By re-examining the morphology of this group we suggest the possibility that the different contemporary species occurred within different host species as is understood for living *Vulsella*. The group apparently became extinct at the end of the Callovian, possibly reflecting the demise of their host species.

We consider that the comparable symbioses of oysters have happened on at least three separate occasions since Jurassic times.

**Key words:** Jurassic Symbiotic Oysters; Faunal Change

**References:**


The Early to Middle Jurassic Flora from Primorye Region
(Russian Far East)

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The Early and Middle Jurassic floras are known from Partizansk and Razdol’naya Rivers Basins in South Primorye (Krassilov and Shorokhova, 1975; Volynets, 1999, 2008).

The Early Jurassic flora (the Hettangian) is collected from the Shituke Formation. This flora includes 39 taxa. The Shituke floral assemblage consists of horsetails (Equisetum, Neocalamites), ferns (Cladophlebis, Marratiopsis, Phlebopteris, Clathropteris, Hausmannia, and Todites), caytonialeans (Sagenopteris), cycadophytes (Pterophyllum, Ctenis, Nilssonia, and Taeniopteris), conifers (Podozamites, Cycadocarpidium, Pityophyllum, and Elatocladus), ginkgoalleans (Ginkgoites, Baiera, and Sphenobaiera), and plants of unclear affinity (Linguirofillum, Carpobites). Fems are dominants, and they are accompanied by cycadophytes and conifers.

Cladophlebis (5 taxa) are most diverse among ferns; C. ex gr. haihurnensis (L. et H.) Brong., C. ex gr. denticulata (Brong.) Font. and Cladophlebis sp. are common; C. scoresbienisiis Harris is rare. Marratiopsis hoerensis (Schimp.) Thomas and Phlebopteris angustiloba (Presl) Hirm. et Hoeram. are abundant; Clathropteris elegans Oishi, Hausmannia sp., Todites sp. are single.

Pterophyllum cf. subaequale Harts, Ctenis sulcicaulis (Phill.) Ward and Nilssonia acuminata (Presl) Goeppert are abundant among cycadophytes; Taeniopteris lanceolata Oishi is typical; Ctenis cf. yokoyamae Krysh., Nilssonia spinosa Krassil. and Taeniopteris sp. are rare.

Pityophyllum ex gr. nordenskioldii Heer is abundant among conifers; and Podozamites is most diverse (P. schenkii Heer, P. latifolius (Schenk) Krysh. et Pryn., P. lanceolatus (L. et H.) Schenk).

Marratiopsis hoerensis (Schimp.) Thomas, Phlebopteris angustiloba (Presl) Hirrn. et Hoeram., Cladophlebis scoresbienisiis Harris, Ctenis sulcicaulis (Phill.) Ward are guide fossil plants for the Lower Jurassic deposits.

The plants of Shituke assemblage such as Clathropteris, Phlebopteris, Marratiopsis evidence about the humid subtropical climate during the Hettangian.

The Middle Jurassic (the Bathonian) plant remains have been found in the Ananyevka (Razdol’naya River Basin) and Monakino (Partizansk River Basin) formations. The floral assemblage is represented by 81 taxa (Volynets, 2008): bryophytes (Thallites), horsetails (Equisetum), ferns (Sphenopteris, Cladophlebis, Klukia, Cyathea, Osmundopsis, Phlebopteris, Ruffordia, Dicksonia, Coniopteris, Onychiopsis, Adiantopteris, and Acrocladophyllum), conifers (Podozamites, Araucarites, Cunninghamia, Pityophyllum, Brachyphyllum, Elatocladus, Coniferites, and Conites), cycadophytes (Otozamites, Dictyozamites, Cycadolepis, ANozamites, Pittophyllum, Zamites, Nilssonia, and Pseudocenis), pteridosperms (Thinfnfeldia), caytonialeans (Caytonia, Sagenopteris), ginkgoalleans (Baiera and Pseudoporellia), czechanowskialeans (Czechanowska and Phoenicopsis) and plants of unclear affinity (Linguirofillum, Carpobites). Fems are dominants, and they are accompanied by conifers and cycadophytes.


Among conifers Podozamites ex gr. lanceolatus (L. et H.) Schimp., P. angustifolius (Eichw.) Heer, Elatocladus subzamyoides (Moell.) Tur.-Ket. are most numerous in burials; Elatocladus (2 taxa) is common. Brachyphyllum cf. toyroraensis Takah., Brachyphyllum sp., Conites sp. and Coniferites (C. marchaensis Vachr., Coniferites sp.) are rare; Cunninghamia and Araucarites are single.

Nilssonia (6 taxa) and Dictyozamites (5 taxa) are most diverse among cycadophytes. Dictyozamites nevolinae Volynets and D. tateiwae Oishi are abundant; D. doledunkoae Volynets is rare; D. cf. reinformis Kimura et Ohana and Dictyozamites sp. are single. Zamites, Pittophyllum, Otozamites, Anozamites, Ps-
eudocenis and Cycadolepis occur rarely in the localities of these formations.

Among the caytonialeans it was revealed three species of Sagenopteris (S. mantellii (Dunk.) Schenk, S. phillipsii (Brong.) Presl., S. cf. petiolata Oishi).

Ginkgoioleans, czekanowskialeans, bryophytes, horsetails, pteridosperms and plants of unclear affinity are rare.

The taxa Coniopteris bella Harris, Cladophlebis toyoraensis Oishi and Dictyozaamites nevolinae Volynets have been found only in beds of these two formations.

These floral assemblages strengthen the case for a warm and moderately humid climate.

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Key words: Jurassic; Flora; Floral assemblage; Primorye region; Russian Far East

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Serpulid (Annelida, Polychaeta) Evolution and Ecological Diversification Patterns During Middle-Late Jurassic

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Tube-dwelling polychaetes of families Serpulidae, Spirorbidae and Sabellidae are extremely widespread, but poorly studied group of Mesozoic fossils. The main problems with serpulid study are:

1) Unclear and complicated systematics on tube features, which can not be easily coordinated and correlated with modern systematics based on soft body features;

2) Punctuated stratigraphical distribution, in most sections numerous serpulids occur only at one specific level;

3) Unequal palaeontological study of the group at different territories, absence of any knowledge/systematic descriptions for some areas.

For the last decade the group attracts much attention of the researchers, and numerous papers are published not only in taxonomy, but also in tube microstructures. Thus, the study of serpulids gradually comes to a new level, and first aspects of evolution and paleoecology can be drawn by coarse dabs at the moment.

The fact is that total biodiversity rapidly grows during the Mesozoic (there are about only 15 nominal species described from the Triassic, about 150 – from the Jurassic, and more than 200 – from Cretaceous deposits), and the most remarkable radiation took place during Middle-Late Jurassic. The author has studied about 70 locations with Jurassic and Berriasian serpulids in Central Russia and Crimea. It was shown, that the main abiotic factor, which defines the serpulids in Central Russia and Crimea. It was shown, about 70 locations with Jurassic and Berriasian during Middle-Late Jurassic. The author has studied deposits), and the most remarkable radiation took place during the Jurassic, and more than 200 – from Cretaceous deposits. During the Mesozoic (there are about only 15 nominal species described from the Triassic, about 150 – from the Jurassic, and more than 200 – from Cretaceous deposits), and the most remarkable radiation took place during Middle-Late Jurassic. The most important factor that defines the serpulids in Central Russia and Crimea. It was shown, about 70 locations with Jurassic and Berriasian during Middle-Late Jurassic. The author has studied deposits, and the most remarkable radiation took place during the Jurassic, and more than 200 – from Cretaceous deposits.

The diversification during Middle-Late Jurassic, anyway, is marked by the first appearance of Conorca morphotype and most ancient of spirorbids – representatives of Neomicrocrbis – on live substrates (sponges). Recently it was shown by Taylor and Vinn (2007) that Paleozoic spiral spirorbis-like tubes are not relatives of modern Spirorbidae, which appeared
somewhere around Jurassic-Cretaceous boundary. Our investigation shows that first Spirorbids were already small and compact. This group derived from Serpulidae (for the last years it is proven also from molecular phylogenetics), probably as an attempt to make tube small, which makes possible attachment to 1) flexible substrates like algae in the upper sub-littoral zone; 2) small free areas in densely inhabited biotopes and live substrates. This makes possible to effectively live in high-energy and rich in food shallow-water environment. It is interesting that *Conorca*-like tubes have the same basic morphological characteristics as spirorbids and can be considered as adapted to the similar environment, thus there were a parallel evolution of two independent and concurrent braches of tubicolous polychaetes.

**Key words:** Serpulidae; Spirorbidae; Jurassic; Evolution; Adaptation

**References:**
Origin and Early Evolution of Jurassic Planktic Foraminifera

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Following extensive studies of the Oberhauser (1960) and Fuchs (1967) collections of Triassic foraminifera in Vienna, it is unlikely that any of these taxa exhibited a planktic mode of life. In the basal Hettangian of the Karwendel Syncline (Austria) and in the Hettangian clays at Hernstein (Austria) only species of Oberhauserella and Praegubkinella are recorded (von Hillebrandt et al., 2006; Fuchs, 1970) with no sign of planktic morphotypes. This means that the earliest Conoglobigerina are derived from the Oberhauserella–Praegubkinella lineage in the mid-Toarcian, in association with the post-extinction event recovery (Wernli, 1988, 1995). Diversity remains low in the Aalenian, although there are only a few recorded localities at which one can study the planktic assemblage. In the Bajocian there is evidence (from the Carpathians in Poland and the Bakony Mountains in Hungary) of the first “foraminiferal ooze” in red limestone facies (Wernli and Görög, 1999; Hudson et al., 2005). In these successions there is a 99:1 planktic:benthic ratio and the rocks can be foraminiferal packstones. Many of these assemblages appear almost mono-specific, although there is some variation in spire height and rate of expansion of the chambers. As much of this work has been done on thin-sections, the aperture is rarely (if ever) visible and it is impossible to determine these as Conoglobigerina or Globuligerina. In some exceptionally preserved material from the Bathonian of Southern Poland (Pazdrowa, 1969) it is noted that there is a great deal of variation in spire height (though the majority are high-spired and quite ‘pointed’) but only rare specimens exhibit the loop-shaped aperture required for the determination of Globuligerina. All other characters appear to be identical.

Fig.1 Origin and early evolution of Jurassic planktic foraminifera

Arising in the Aragonite ll Ocean, these early planktic foraminifera had aragonite tests and their distribution informs us about the Aragonite Compensation Depth (ACD) but not the Calcite Compensation Depth (CCD), which must have been created by the (also) developing calcareous nannoflora. There is a significant expansion of numbers, diversity and the palaeobiogeographical distribution of planktic foraminifera in the Callovian-Oxfordian (Hudson et al., 2009). At this time species of Conoglobigerina or Globuligerina are recorded in the North Atlantic Ocean as far south as the Gulf of Mexico. In glauconitic mudstones of latest Callovian and earliest Oxfordian age at Ogradzieniec (Poland) large numbers of glauconitic steinkerns are found which represent an abundant assemblage of planktic foraminifera. Fuchs (1973) used material from this locality to generate a complete range of new genera and species, all of which
have been studied in the collections of the Geologisches Bundesanstalt in Vienna. Several of these new species are mineral artefacts, while others are benthic foraminifera. There are, however, many high-spired specimens of Conoglobigerina in the assemblage. The abundance of planktic foraminifera in the latest Callovian and earliest Oxfordian may be indicative of a ‘cool’ phase (associated with southward ammonite migrations) in which the aragonite assemblage is preferentially preserved. There is evidence for a reduction in both numbers and diversity of planktic foraminifera in the latest Jurassic and across the Jurassic-Cretaceous boundary. At this time there was a change in the calcification of the tests from aragonite in the Jurassic to calcite in the Cretaceous. After remaining a low diversity assemblage in the earliest Cretaceous, there is an expansion in numbers, diversity and palaeobiogeographical distribution as the continents fragmented in the post-Barremian and Aptian. With the temperature increases in the mid-Cretaceous (especially Cenomanian and Turonian) there was a cross-latitudinal migration and warm-water assemblages are known from many, relatively high latitude locations (e.g. North Sea Basin, western Interior Seaway). Fluctuations in distribution occurred throughout the Late Cretaceous until a final warming pulse in the latest Maastrichtian was followed by evidence of cooling immediately before the K/Pg boundary.

**Key words:** Planktic Foraminifera; Evolution; Toarcian; Aragonite II Ocean; Preservation

**References:**


Microfossil Evidence for A Possible Mid-Jurassic Squid Egg-laying Area in Association with the Christian Malford Lagerstätte

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In the shell-rich, laminated clays of the Phaeinum Subzone (Athleta Zone) of the Peterborough Member of the Oxford Clay Formation we have found an abundance of statoliths indicative of a mass mortality of “squid”. As this exceptional rate of mortality extends over some 3 m of strata, this has been interpreted as a record of mass egg-laying (and subsequent death) of “squid” over an extended period of time rather than one catastrophic event.

In the 1840s, during the construction of the Great Western Railway west of Swindon, a number of beautifully preserved coleoids (belemnites and squid-like cephalopods) were found (Pearce, 1841). These famous specimens of Belemnoteuthis and Mastigophora, as well as a number of fish, are recently described as a fossil lagerstätte under the name of the “Christian Malford Squid Bed”. Many of these specimens, which come from the Phaeinum Subzone (Athleta Zone, Callovian) of the Oxford Clay Formation, contain soft tissue, muscle fibres and the content of their ink sacs.

In October 2007 the British Geological Survey funded an excavation of the site some ~100 m from the original borrow pits alongside the railway. This pit provided some new coleoid specimens as well as many ammonites, bivalves and gastropods, all of which are exquisitely preserved (Wilby et al., 2008). Some of the bedding surfaces recovered are plastered with monospecific assemblages of foraminifera (Epistomina spp.). Our work (ADJ/MBH) on borehole core No. 10 (from the same location) has recovered exceptionally large numbers of statoliths, otoliths (fish ‘ear’ bones), squid hooks and foraminifera. Statoliths are the small, paired, aragonitic stones found in the fluid-filled cavities (or statocysts) within the cartilaginous heads of all modern and probably all fossil coleoids. Jurassic statoliths have yet to be described in any detail as there are only two References to them in the literature (Clarke, 2003; Clarke and Maddock, 1988). Otoliths, which are of similar appearance, are the aragonitic, stato-acoustic organs of bony (teleost) fish. They are more familiar to micropalaeontologists and have a better known, though limited, fossil record.

The exceptional abundance of statoliths and squid hooks recorded in the samples from the core is thought to represent a Jurassic squid-breeding ground which existed for an interval of late Callovian time. The annual spawning of female squids massively enlarges their ovaries and this breaks down the body wall leaving spent individuals to die. The lack of fossil belemnites in the same strata suggests that the animals involved (unknown at present) did not possess a calcified “guard” or phragmacone. The highest numbers of statoliths occur over a 3 m thickness of strata with the greatest abundance ~1 m below the Christian Malford Squid Bed (which is now thought to be of greater stratigraphical range than initially thought). The numbers recorded in this part of the Phaeinum Subzone are well above background levels in the rest of the Jurassic in the UK (Malcolm Clarke, pers. comm.) where one has to wash several kg of sediment to recover < 200 statoliths. Indeed, the average figure quoted by Clarke (2003, p. 43) is 0.1 statoliths per kg of sediment while our average in this core is 0.4 statoliths per gram (= 400 per kg). In core 10, the elevated levels of statolith abundance extend from 4.25 m down-core to 0.25 m down-core, with the highest levels of abundance at 2.70 m down-core. This peak abundance is approximately 1.0 m below the originally-defined, Christian Malford Squid Bed. Otoliths show a similar pattern, although their numbers are always below that of the statoliths: a reversal of the normal situation where otoliths normally dominate (Hart et al., 2009).

Statoliths from a number of samples have been measured and compared in a simple bivariate analysis. While there is a clear scatter along a presumed growth curve, there is a concentration within certain limits. This would be expected if all the squid were of the same age, and sexual maturity, when they laid their eggs. However, it is known from studies of modern faunas that reproductive behaviour within cephalopods, which involves courtship, copulation, fertilization and spawning, is incredibly variable. The majority do, however, share certain characteristics.

Concentrations of belemnites (especially in the Jurassic) have been described as belemnite battlefields and ascribed to a number formative mechanism, including breeding areas (Doyle and MacDonald, 1993). In some locations a number of such battlefields have been described in the succession, but there is no sug-
gestion of the continued concentration demonstrated by our statolith abundances.

The occurrence of abundant, though low diversity, foraminiferal assemblages in the same samples point to an oxic, though possibly stressed, environment. The significant proportion of deformed foraminifera in the assemblages appears to confirm that the environment was less than optimal but still able to support a relatively diverse and abundant fauna.

**Key Words:** Lagerstätte; Statoliths; Otoliths; Squid ecology; Wiltshire (UK)

**References:**
Gastropod Faunas of the Lower Lias of Dorset, Southern England

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The Lower Lias (Hettangian, Sinemurian and Lower Pliensbachian) of the Devon and Dorset coast is exposed between The Slabs, near Corbin Rocks, Devon in the west and Seatown (Dorset) in the east and is exposed in the world famous Pinhay Bay, Lyme Regis to Charmouth sections. These form an integral part of the Jurassic Coast World Heritage Site. The Lias of the Dorset coast is a rich source of fossil vertebrates and macrofossils. Gastropods, despite being amongst the most commonly occurring and species-rich macrofossils in the British Early Jurassic are poorly known. They are less conspicuous than the abundant ammonites and belemnites, however; a brief search of the limestone layers can soon reveal their presence. Besides gastropods, the benthic fauna includes bivalves, typically Plagiostoma spp. and brachiopods most commonly rhynchonellids, epifauna is uncommon. Remains of crinoids are abundant, much less commonly echioids and rarer still crustaceans occur. Some layers retain signs of bioturbation indicating a rich benthos at those times.

The Lower Lias comprises the alternating limestones and mudstones of the Blue Lias Formation, succeeded by the massive mudstones of the Charmouth Mudstone Formation which comprises the Shales-with-Beef, Black Ven Marl, Belemnite Marl and Green Ammonite Mudstone members. Gastropods are most commonly found within the Belemnite Marl and the Green Ammonite Mudstone members (Lower Pliensbachian), however, they also occur albeit far less frequently in lower horizons such as the Blue Lias Formation (Hettangian). Recent analysis of the Blue Lias Formation by Paul et al. (2008) concluded that it was deposited as a rhythmic sedimentary unit and that deposition was episodic rather than continuous.

Preliminary results of a re-evaluation of the Lower Lias gastropod fauna based upon specimens at The Natural History Museum (London) were found to include representatives of the Orthogastropoda, such as Discohelix, Eucycloscala, Ptychomphalus and Pleurotomaria, Caenogastropoda including Cryptaulax and Procerithium, Hypsogastropoda including Katosira, and Coelodiscus Heterobranchia including Ovactaeonina and Tricarida, and limpet-like adherent forms of uncertain taxonomic affinity. These collections include specimens collected by W.D. Lang as part of his detailed stratigraphical study of the Lias (Lang, 1928, 1936) subsequently studied and described by Cox (1928, 1936) and therefore most of the material included in this study has good stratigraphic resolution.

Larger gastropods are found preserved in three dimensions in limestone horizons or nodules, such as the large specimens of Pleurotomaria seen in the Blue Lias Formation. However, specimens are crushed in the intervening mudstones and distorted in horizons such as the Belemnite Stone (Belemnite Marl Member). Though generally less distorted, smaller taxa may be re-crystallized and poorly preserved, with the fine details of apex and aperture necessary for correct taxonomic assignment obscured by sugary diagenetic calcite. However, well preserved three-dimensional material of smaller taxa such as cerithioids and zygopleurids can also be found such as in the Green Ammonite Member and Belemnite Stone at Seatown. There does however, remain enormous potential for recovering important material and for making new discoveries, particularly the smaller species as well as the systematically informative larval shells of larger taxa.

Over the past few decades there has been a revival of interest in the diversity and systematics of European Lower and Middle Jurassic gastropods. Resultantly, knowledge of these gastropods has advanced considerably, with new families, and many new genera and species having been discovered and described. Despite this, British Liassic gastropods have remained largely unstudied since the late nineteenth and early twentieth centuries when most species were described or last revised. Wilson (1887) estimated that as many as 438 species of Liassic gastropods had been found in Britain. However, this includes more diverse gastropod faunas found away from coastal sections in south-west England and the Midlands. Our study indicates that the fauna is far less diverse from the Devon to Dorset coast sections. Some of the taxa included in this study require detailed systematic work to re-determine their affinities and have been left in open nomenclature pending further study or discovery of more complete specimens.

Key words: Lias; Gastropoda; Dorset; England

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Early to Late Jurassic Palynofossils from South Rewa Gondwana Basin, Madhya Pradesh, India

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The marine Jurassic sequences in Indian Gondwana are well defined in western India and Himalayan region; however, there is no definite record of non-marine Jurassic sequence in Peninsular India. The Early Jurassic sequences are widely distributed and known from Lathi Formation (Rajasthan), Kota Formation (Andhra Pradesh), Mochu Formation (Bhutan), upper part of Dubrajpur Formation, lower part of the Rajmahal Formation in Rajmahal Hills, and in some part of the Dorma Basin, West Bengal in India. In Rajmahal Hill, the Late Triassic sequence are conformably associated with ‘Ptilophyllum flora’ bearing upper part of the Dubrajpur Formation, suggesting no break between Triassic and Jurassic sequence in Peninsular Indian Gondwana. In South Rewa Basin, the post-Barakar sequences are classified into Pali-Tiki-Parsora and Bandhogarh/Hartala formations (Mitra, 1993; Tarafdar et al., 1993). The petrological characters, palynomorphs, plant megafossils study and contact relationship of Pali and Tiki formations, have been established and suggested that Upper Pali Member (Early to Middle Triassic in age) is conformably overlain by the Carnian-Norian Tiki Formation (Kundu et al., 1993). The palynoflora recorded from Parsora Formation by Ram-Awatar (2000) revealed the presence of Callialasporites trilobatus, C. segmentatus, Cicatricosisporites ludbrookae and Aequitriradites spinulosus, suggesting Jurassic age of the Parsora Formation without any hiatus in Rewa Basin. Some workers suggested that Parsora Formation is older than Hartala/Bandhavgarh Formation. The plant megafossils – Pagiophyllum, Brachypodium and Desmiophyllum recorded from Bandhavgarh/Hartala formations is assigned Rhaetic-Liassic age (Pal, 1984). Therefore, it is quite plausible that Parsora is a part of Hartala/ Bandhogarh formations.

In the present communication, an Early to Late Jurassic palynofossils have been recorded for the first time in South Rewa Basin, Madhya Pradesh. A 5-m thick bed consisting of carbonaceous shale, silicified carbonaceous shale and coarse grained compact sandstone is exposed along the tributaries of Mahanadi River around the Jhala village (80°45’ 25” N, 23°42’ 25” E), District Umaria, M.P. India. The carbonaceous shale and clay beds embody rich palynofloral assemblages. The palynoflora reveal LADs of certain key taxa viz., Klausipollenites schaubergeri, Falcisporites minutosaccus, Densoisporites mesozicicus, Alisporites landianus, Striatopodocarpites decorus and Satsangisaccites triassicus in the basal part of strata. Besides these, occurrence of Podocarpidities grandis, Calliasporites microvelatus, C. turbarus, C. barragaonensis, C. jaisalmeriensis, C. segmentatus, C. dampieri, C. trileatus, C. monoalasporus, C. microvelatus, C. lenticularis and Classopollis minor shows a definite record of Early Jurassic palynofossils in the assemblage.

The various species of Callialasporites (C. dampieri, C. trilobatus and C. turbarus) are dominating taxa, followed by Araucarites ghunarensis, Microcachrydites antarcticus, Podosporites rarus, Alisporites grandis and Murospora floria, which support an Early to Late Jurassic age of the assemblage. The palynoassemblage is compared with Callialasporites dampieri Super Zone (Hettangian to Tithonian) described by Helby et al. (1987) from Australia and other known Jurassic successions of India. The composition of palynoassemblage enables to correlate with other Gondwanic continents like Australia (Walloon Series), Africa (Drakensberg Volcanic) and Antarctica (Ferrar Group), showing a close association of India with Gondwanaland and their biogeographic distribution in the southern hemisphere. The present study help us to understand the existence of non-marine Jurassic sequence in India as well as bridging the gap, so far...
unknown from the South Rewa Basin, M.P., India.

**Key worlds:** Jurassic; Palynology; Non-marine; South Rewa; Madhya Pradesh; India

Fig. 2 (A) Photograph showing exposed section along Umrar River, (B) lithocolumn showing position of samples

**References:**


Determining Morphotypes of Fossil Clam Shrimps by Fourier Shape Analysis: Possible Implications and Limitations Tested on Middle Jurassic Specimens from Gansu, China

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During the Middle Jurassic, the Eurasian continent comprised two conchostracan biogeographic provinces (Chen and Hudson, 1991). They are the Skyestheria fauna from northern Scotland and the Euestheria ziliujingensis fauna that was widely distributed in East Asia. The first one includes eight species within six genera, the latter no less than 31 species also assigned to six genera. Chen et al. (2007) speculated that this number might be significantly reduced when sexual dimorphism is taken into account and the material is further investigated under the scanning electron microscope (SEM). Unfortunately, the specific ornamentation of the carapace is not always well preserved, which especially applies to younger individuals. The only diagnostic properties that are left for such individuals are morphometric characteristics of the carapace, which can well be used for a determination of lower taxonomic ranks (Zierold, 2007). This study proposes an approach that involves morphometric outline analysis using Fourier shape analysis in combination with a thorough examination of the carapace micro-ornamentation under the SEM. That way, both genetic and environmental factors determining the morphology are accounted for.

Stratigraphically, the study area is located within the Ordos Province that belongs to the almost exclusively inland continental North China Domain (Chen, 2003). During the Early and Middle Jurassic coal-bearing, fluvial-lacustrine siliciclastic sediments accumulated within the Ordos inland basin under a warm and humid climate. In the course of the late Middle Jurassic, the climate changed to hot and arid, which persisted throughout the Late Jurassic (Yan et al., 2006). Biostatigraphic correlation within these terrestrial deposits is mainly based on plant-fossils, charophytes, fishes, dinosaurs, bivalves, ostracods, and conchostracans. The taxonomic record of the latter group is far from clear due to the variability of carapace characteristics, ontogenetic changes, and compactional deformation, which probably led to misclassifications.

A standardised classification for the Euestheria ziliujingensis fauna is a prerequisite for a finer biostratigraphic resolution. In order to achieve this, an objective description of outline characteristics of the conchostracan carapace is needed, for which statistical methods are well suited.

This approach has been tested on material from Middle Jurassic strata at two localities in Gansu, about 370 km apart, which yielded rich conchostracan faunas. The first locality (1) belongs to the Oil-shale Member of the Wangjiashan Formation. It is situated in the Baiyin prefecture, about 127 km northeast of Lanzhou. The second locality (2) is part of the Wangjiawan section that crops out about 18 km southeast of Shandan, Zhangye prefecture. Detailed sedimentological and palaeoecological analyses have been carried out.

At both localities lacustrine deposits are intercalated between fluvial sediments. However, they differ markedly in thickness and sedimentological properties. (1) The thickness of the lake sediments that had accumulated as part of the Wangjiashan Formation is 80.5 m, beginning with a palaeosol horizon that is overlain by mostly laminated, medium-grey clay and silt with few intercalations of fine-grained sandstone. (2) The thickness of the lacustrine deposits of the Wangjiawan section is distinctly smaller (about 2.5 m) and its infill controlled by coarser siliciclastics, although finely bedded.

The conchostracans have been allocated to the genus Euestheria Dépèret and Mazeron (1912). In some horizons, which show traces of bioturbation, they are associated with other invertebrates of low diversity (darwinulid ostracods and freshwater gastropods). Fish remains occur scattered throughout both sections.

Analyses have been carried out for a number of specimens of the genus Euestheria to test their variability with regard to biotic and abiotic influences. The carapaces have been analysed using ornamentation and traditional morphometric characteristics in combination with outline analysis in the form of Fourier shape analysis. Only outlines of conchostracans of exceptional preservation have been considered in order to avoid misclassifications, which easily arise as most of the conchostracan specimens are deformed (Goretzki, 2003). Morphotypes have been erected and variability is discussed with respect to environment, ontogenesis and deformation.

On the basis of Fourier shape analysis, conchostracan outlines can be roughly correlated with each locality, but a proper separation of all conchostracans from the two localities is not possible. The reason for this might be because morphospace occupation is also...
strongly influenced by ontogenetic changes, since conchostracans exhibit a pronounced allometric growth. To account for that, growth bands of selected individuals have been traced. Fourier shape analysis of these supports a line of correlation between the outlines of several growth stages of single individuals. The recognition and definition of allometric morphospaces of conchostracan taxa facilitates the identification of less well preserved individuals, giving an indication of which morphotype or species the conchostracan specimen in question might belong to.

Combining the analyses of outlines with investigations of micro-ornamentation based on SEM-observations, the number of taxa within the *Euestheria ziliujingensis* fauna can be revised in further studies through the assignment of morphospaces.

**Key words:** Middle Jurassic; Gansu; Fourier shape analysis; Spinicaudata; Conchostracans

**References:**
Jurassic Arctic Associations of Molluscs and Microfauna: Phases of Development, Biotic and Abiotic Events

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There are well defined specific phases of Jurassic history development of the Arctic macro- and microfauna, and their limits are marked with the change of predominant taxa. Gradual increase in the diversity of Arctic sea molluscs, foraminifera and ostracodes during the Jurassic period had been regularly interrupted by relatively rapidly reorganizations of their associations, related to the sharp cut in taxonomic diversity and simplification of community structure. Such reorganizations we consider to be critical. In the Arctic paleobasins there were recorded the most notable two Jurassic crises: In the Early Toarcian and Early Bajocian (Nikitenko, Shurygin, 1994; Shurygin et al., 2000; Nikitenko, Mickey, 2004; Shurygin, 2005; Zakharov et al., 2006). Both crises have significantly affected the restructuring in taxonomic structure of associations of Arctic ammonites, belemnites, bivalves, microfauna and microphytofossils. Less expressed associations of Arctic ammonites, belemnites, bivalves, microfauna and microphytofossils. Less expressed restructuring of biota at the end of Bathonian and the end of Oxfordian are associated with common boreal transgression, large introduction of migrant species to communities and with sharp increase in taxonomic diversity of associations. The discussed periods of biotic crises are noticed in many regions, including those outside the Arctic, and may be considered as reference. Lateral length of reference “crisis” intervals is rather different, and the possibility of their use for interregional correlation is not the same.

One of the most dramatic biotic events of the Early and Middle Jurassic is the crisis in the Early Toarcian (Fig. 1). This crisis of macro- and microfauna is well recorded in the Western European seas, it is sharply expressed in the Arctic sections, and can be traced in a number of Tethyan regions (for example, in South America and the Caucasus). Generic and familial composition of ostracods in the Arctic seas was renewed completely, species and generic composition of bivalves and foraminifera was changed significantly, representatives of many families disappeared. Arctic ammonites after Pliensbachian/Toarcian boundary completely changed the taxonomic composition. At the end of the crisis phase belemnites appeared in the communities of Arctic molluscs, and their high days were in post-crisis time. The early Bajocian crisis and specific widespread “Ammodiscus” facies are well traced in the regions of Boreal-Atlantic and Arctic realms, closed to critical ecotonic area (north of Great Britain, North Sea, Barents Sea, Northern Siberia, Priverhoyane).

With a similar global nature of these crises their fixing in biota was substantially different. Transfer of biota through critical phases was different. In the Early Toarcian there was noticed a sharp reduction in diversity without appearance of new taxa, the structure of benthic communities became simplified, whereas in the Early Bajocian there took place a wavy falling in diversity with appearance of new forms, the structure of catena became simplified, the predominant groups changed. Accordingly, these crises have been identified as the crises of the first (Early Toarcian) and second (Early Bajocian) types (Shurygin, Nikitenko, 2005).

The mechanism of initiation of these crises differs. To the east of the Arctic basin (junction with Paleo Pacific) there always was a wide ecotone zone, where the taxonomic diversity in benthic communities and number of representatives of low Boreal and Tethyan fauna gradually decreased to the west direction. To the west of Arctic (the North Sea, Greenland and Svalbard), Tethyan and Boreal fauna often contacted without formation of wide ecotone areas. During Early and Middle Jurassic the ecotone zone in the east constantly brought immigrants to the Arctic biota. Ecotone zone in the west only occasionally took part in supply of immigrants, but was a key region (critical zone of Paleoarctic) in the crises initiation of the Arctic biota.

Early Toarcian crisis was due to global causes. In the Late Pliensbachian there was noted eustatic fall, resulted in change of water circulation system, increase of climatic effect of continents, growth of seasonal contrast of temperatures, and cooling. At the beginning of Early Toarcian there took place a major eustatic sea-level rise, global warming, change in configuration of underwater landscapes resulted in change of currents circulation and extensive development of stagnant environments. Due to alternation in this set of abiotic stress factors a sharp decrease of biota diversity happened in a relatively short time.

The crisis of the second type (Early Bajocian) (Fig.1) was initiated by local palaeographical (or tectonic) factors, but in the critical western ecotone zone of Paleoarctic. Beginning from the late Early Jurassic and in early Middle Jurassic in the North Sea takes place an overheating of the lithosphere and rise of molten substance, the so-called Middle Jurassic plume (Nielsen et al., 2003). These phenomena might contribute to the formation of series of geographic barriers in region of the North Sea. In many parts of the Northern Hemisphere at the Aalenian/Bajocian boun-
During this time, there is noted a significant drop in sea level. At the same time, both in marine basins, and in terrestrial ecosystems in different regions of the Northern Hemisphere, there is noted a negative shift in the isotopic composition of organic and carbonate carbon, which is usually associated to the cooling and low content of CO₂ in the atmosphere. This is also evidenced by numerous finds of glendonites in the Lower Bajocian of Siberia. Close down of Viking Corridor in the Aalenian-Early Bajocian resulted in limited ingress of Paleoatlantic waters to Arctic, changing of water circulation system, cooling, changing in emigration and immigration directions and in relatively rapid restructuring of communities. At the same time, the eastern ecotone zone functioned in the normal for the Jurassic period mode.

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Fig. 1 Phases of development of benthos and nekton in Siberian Jurassic paleobasins and main abiotic events
Key words: Jurassic events; Molluscs; Microfauna; Siberia

References:
Jurassic Fulgoridiidae and Roots of Fulgoroidea
(Insecta: Hemiptera: Fulgoromorpha)

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The Fulgoromorpha (Insecta: Hemiptera) is an ancient suborder of the hemipterans. It comprises three superfamilies: Coleoscytoidea with Coleoscytiidae Martynov, 1935 (Permian) and Surijkokocixioidea with Surijokocixiiidae Shcherbakov, 2000 (Permian–Triassic). These widespread plant-sucking hoppers comprise 21 extant and 7 extinct families. Descending from Surijokocixiidae, ancestors Fulgoroidea lead to prolonged prosperity since the Jurassic. Extinct families of Fulgoroidea Latreille, 1807 are: Jurassic Fulgoridiidae Handlirsch, 1939 and Cretaceous ones – Lalacidae Hamilton, 1990, Neazoniidae Szwedo, 2007, Perforissidae Shcherbakov, 2007 and Mimarchnidae Shcherbakov, 2007 (Hamilton, 1990; Szwedo, 2007, 2008, 2009; Shcherbakov, 2007a, b). The monophylly, relationships, range and content of several families (both extant and extinct) is under discussion.

The extinct family Fulgoridiidae Handlirsch, 1939 needs a full revision as numerous taxa described by Geinitz (1880), Handlirsch (1906, 1939), Bode (1907, 1953), Martynov (1927, 1939) and Becker-Migidisova (1962), as well as more recently described by Lin (1986) and Zhang et al. (2004) must be re-analyzed and the characters of genera and species redefined. It has to be seen now as a paraphyletic assemblage (Bourgoin and Szwedo, 2008). There are a number of genera and over 150 species placed in ‘Fulgoridiidae’ and vast majority of them need to be revised (Szwedo, et al. 2004, Szwedo and Żyla, 2009). Most of the species reported are based on the tegmen imprints, the hind wings or body structures are rarely preserved and available for examination. ‘True’ Fulgoridiidae share a long basal vein RP and a short stem of CuA due to its early double forking (= long cell C5) before the nodal line level. As example, Fulgoridium Handlirsch, 1906 and Eofulgoridium Martynov, 1939 (which differs from the former by numerous crosseveins in the basicostal area and a multibranched vein RP) have a long cell C1 and an uncommon early forking of stem CuA2. In reverse, Fulgoridulum Handlirsch, 1939 exemplifies a long ScP+R stem (= short cell C1), closed cells C2, C3 and C4 short, less than twice as long as wide and an unforked CuA2. The features of species within other genera must be revised, and taxonomic placement of species remains doubtful.

Despite taxonomic uncertainties and problems ‘Fulgoridiidae’ comprises ancestral forms to the fossil and recent families of Fulgoroidea (Bourgoin and Szwedo, 2008). ‘Fulgoridiidae’ had body structure resembling the recent representatives of Cixiidae; this general pattern is also retained in most of the extinct families. However, the venation pattern of ‘Fulgoridiidae’ is variable, but some tendencies are observed also in other extinct and recent units are to be found. Two main trends observed is reduction/development of basicostal area. In most ‘Fulgoridiidae’ this area is narrow, provided with a few transverse veinlets. In some others this part is reduced and veins Pc+CP and CA are fused at least at base. In comparison, veins of costal complex are completely fused in vast majority of recent ‘basal’ or cixiidae-like planthoppers, while in numerous so-called ‘higher’ Fulgoroidea basicostal area is enlarged, well developed and provided with numerous transverse veinlets. In the Cretaceous Lalacidae the costal margin is thickened, while in another family known from the Lower Cretaceous of northern China the costal margin is weakened at stigmatic area, similarly as in some recent Kinnaridae. In most Cixiidae the extravenal pterostigma is developed in various degree (absent in ‘Fulgoridiidae’), other modifications in stigmatic area are known in fossil and recent cixiidae-like planthoppers. Also basal cell is modified in various degree (in most cases narrowed) in the descendants of ‘Fulgoridiidae’. The patterns of forking of stems Sc+R, M and CuA present enormous variability. The most clear evolutionary tendency to be observed is the reduction of number of branches of CuA; usually there are four main branches of CuA in ‘Fulgoridiidae’, the condition retained in Lalacidae, but in most descending forms there are two main branches of CuA (sometimes one secondarily polymerized). Also clavus could be modified – in ‘Fulgoridiidae’ clavus is usually of closed type. In the descending families Achilidae+ Achilixiidae+ Derbidae, believed to be one of the most ancient lineages of Fulgoroidea, known since the Lower Cretaceous, the clavus is open; open clavus is known also in the Lower Cretaceous families, highly derivative Perfosissidae, and Mimarchnidae.

Trying to explore the early evolution of the tegmen characters in the Fulgoroidea and Fulgoromorpha is quite challenging. The most crucial for this is the analysis of some ‘anchor points’ or ‘landmarks’ in the tegmina and wings of ‘Fulgoridiidae’, ‘cixiid-like’ and ‘higher’ planthoppers. There are several areas
which must be examined in detail: costal area, stigmal area, basal cell, external and internal surface of tegmina in both extinct and extant representatives of the group. As already pointed out (Bourgoin and Szwedo, 2008) for such a comparative approach, the best set of characters shared by both extinct and extant families are the tegminal characters which are best preserved and often the only trace we have of these fossil taxa.

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Key words: Planthoppers; Fossil; Evolution; Jurassic

References:
New Froghoppers from the Jurassic of China and Their Phylogenetic Significance (Insecta: Hemiptera: Cercopoidea)

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The hemipteran superfamily Cercopoidea (commonly called froghoppers) is the second largest group of Cicadomorpha (Insecta: Hemiptera). The fossil record of this group is extremely fragmentary, and most known fossils are just wing impressions.

Some Triassic forms (e.g. Triassocixius and Trifidella) were attributed to Cercopoidea (Evans, 1956; Hamilton, 1992), the superfamily was believed to arise in Late Permian or Early Triassic times (Evans, 1964; Blocker, 1996). However, Sheherbakov (1996) excluded these Triassic fossils from Cercopoidea, and suggested that Cercopoidea was derived from Triassic Hylicelloidea.

The earliest Cercopoidea appear in the Early Jurassic times with the family Procercopidae. The group is treated as sister-taxon of Cicadoidea (etymology). The fossil record of this group is extremely fragmentary, and most known fossils are just wing impressions.

The newly described family is characteristic among fossils from the Middle Jurassic Daohugou Biota (Inner Mongolia, China). Two new genera with three new species could be erected so far, based on well-preserved whole-bodied specimens. The morphological characters of Procercopidae and the new family are presented, and families, genera and species are keyedy. The genera Luanpingia Hong, 1983 and Sinotettigarcta Hong, 1986 are considered to be junior synonyms of Anthoscytina Hong, 1983.

The newly described family is characteristic among other features, of enlarged hind coxae and long hind tibia with a row of apical teeth. This suggests them as the good jumpers. The hind coxae are medially contiguous, and may be coupled to each other by microtrichia fields to move together synchronously during jumping, like in the recent froghoppers (Gorb, 2004). The hind tibia is provided with an apical row of smaller teeth close to the articulation with the tarsus, and the two most proximal tarsal joints also have a row of apical teeth. These teeth, only occurring on hind legs, increase traction as thrust is applied through the tibia and tarsus to the ground at take-off in a jump (Burrows, 2006). Extant froghoppers are the best jumpers amongst the insects, because of presence of a locking mechanism between the femur and meral lobe (coxal protrusion) that allows force stored before the jump to be released rapidly (Burrows, 2003). In extant froghoppers, a protrusion on the dorsal, proximal surface of a hind femur engages with a protrusion from the ventral and lateral part of a coxa, and both protrusions are covered with some microtrichia that both increase the surface area and may interlock with each other (Burrows, 2006). If the hind leg of a dead froghopper is forcibly elevated, it will lock in its cocked position. The meral lobe is distinct in hind legs of the new fossil family and the locked position is also observed in a fossil. Therefore, froghoppers evolved the novel locking mechanism at least in Middle Jurassic times.

The new family from the Daohugou strata shares some general characters (plesiomorphic conditions) with majority of Clypeata: Postclypeus distinctly swollen, transversely wrinkled; antenna with a flagellum of a few elongate segments; presence of median ocellus; partly punctate tegmina; tegmen with stem M branching based of stem CuA branching.
However the unique characters are also present: Discs of crown and pronotum punctuate; pattern of M branching on tegmina; lack of peripheric membrane on hind wings; two rows of very scarce lateral setae on hind tibia. This lineage seems to be a transitional unit between some extinct Hylicelloidea and derived Cercopoidea. Its discovery indicates that early Cercopoidea were undergoing considerable evolutionary divergence during the Jurassic.

The detailed analyses, comparisons and relationships reconstruction are very difficult at present stage of knowledge on ancient Clypeata. Hylicelloidea is a paraphyletic group, containing all ancestors of recent Clypeata and some other extinct groups. The Triassic Chilioscyclidae is an enigmatic group of debatable position. The status of Archijassidae is still under debate; it is treated as synonym of Karajassidae and placed in Membracoidea (Ansorge, 1996), placed as a distinct family in Cercopoidea (Hamilton, 1992), or placed as a subfamily in Hylicellidae (Shcherbakov, 1996). Another family, Ligavenidae described by Hamilton (1992) from the Lower Cretaceous of Koonwarra, Australia was synonymized under Hylicellidae by Shcherbakov (1996), but its taxonomic placement remains unclear.

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Key words: Froghopper; Fossil; Jurassic; China

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Anzorge J. Insekten aus dem oberen Lias von Grimmen (Vorpommern, Norddeutschland). Neue Paläon-
Phylogeny of some Oxytomidae and the Lower/Middle Jurassic Boundary in the North of Russian Asia

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Representatives of the bivalve family Oxytomidae Ichikawa, 1958 are widely distributed in the Jurassic and the Cretaceous sediments of Russia, North America, Europe, Asia, Australia, and New Zealand. They include species of the genera Oxytoma Meek, 1864, Meleagrinella Whitfield, 1885, and Arctotis Bodylevsky, 1960.

The hinge morphogenesis of the Oxitomidae and the phylogeny of select representatives of the family were discussed in detail elsewhere (Lutikov, Shurygin, 2010; Lutikov, Temkin, Shurygin, 2010). Our analysis of the ontogeny and phylogeny of the ligamental and byssal character complexes allowed for a taxonomic revision of some oxytomids, that included redefining the concepts of the genera Meleagrinella Whitfield, 1885 and Arctotis Bodylevsky, 1960, and recognizing two new subgenera, Meleagrinella (Praemeleagrinella) subgen. nov. (Hettangian-Aalenian) and Arctotis (Praearctotis) subgen. nov. (Toarcian-Aalenian).

The phylogenetic consideration regarding Meleagrinella and Arctotis were based on the comparative analysis of the ligament ontogeny in the Hettangian-Sinemurian, Pliensbachian, Toarcian, Aalenian, Bajocian, Callovian, Oxfordian, Kimmeridgian, Volgian and Valanginian forms. Phylogenetic reconstruction of the supraspecific groups of the Oxytomidae were based on the combination of the cladistic analysis and stratigraphic considerations (Fig.1 A).

The direction of the evolutionary transformation of the ligamental and byssal character complexes in the Oxytomidae was reconstructed according to the results of the cladistic analysis (Fig.1 B, C). In the phyletic lineage Praemeleagrinella-Arctotis, the change in the morphogenesis of the ligamental complex led to the origin of a complex, spoon-like resilifer. In the Bajocian- Toarcian s.str., the evolution of the morphogenesis of the byssal complex resulted in the progressive closure of the byssal notch (from the opened byssal notch in the Hettangian Praemeleagrinella to closed (overgrown and fused)). The outline of the auricle of the right valve has shifted from subquadrangular to subtriangular (Fig.1 D).

The appearance of new phenes in large and geographically widespread populations was critical for the segregation of Arctotis. The oblique resilifer of Praearctotis was the precursor of the developed spoon-like resilifer of Arctotis. This type of the resilifer was recorded in multiple individuals from the regions corresponding to the Vilui (Siberia, temperate) and Nordvick (Siberia, north temperate) epicontinental seas in the Late Toarcian (Pseudolioceras wurttenbergeri phase) (Knyazev et al., 2003). The spoon-like resilifer in Praearctotis evolved somewhat later on the territory of the Zhigansk (Siberia, temperate) and East-Taimyr (Siberia, north temperate) epicontinental seas.

We recorded the appearance of the developed spoon-like resilifer in Arctotis s.str. on the territory of the Zhigansk Sea in the Middle Jurassic sediments (Pseudolioceras maclintocki phase, Early Aalenian).

The evolution of the new genus-group taxon did not involve an abrupt adaptive change. The transition from the exclusively byssal attachment (Praemeleagrinella) to the attachment by the byssus-anchor complex (Arctotis s.str.) progressed from the Early Toarcian to the Bajocian. In the Late Toarcian, the representatives of the genus Praearctotis characterized by the transitional states of the genus-level characters were dominant. The integration of several phenes during the evolution of the adaptive morphological structures ensured the definitive formation of the supraspecific taxon Arctotis and its diversification during the general regression in the Aalenian.

Consequently, the presence of Arctotis s.str. with a well-developed spoon-like resilifer marks the stratigraphic boundary between the lower- and middle Jurassic strata on the wide territory of Central Siberia.

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Key words: Jurassic; Bivalvia; Taxonomy; Biostratigraphy
Fig.1 Hypothetical relationships between some supraspecific groups of the family Oxytomidae based on cladistic analysis and corresponding distribution of characters of the ligament and byssal blocks. A-cladogram superimposed with the distribution of apomorphic characters. Mapped apomorphies are unambiguously optimized nonhomoplastic (black squares) and homoplastic (white squares) character states. The numbers above and below the squares denote characters and corresponding character state changes according to Appendices 1 and 2 in Lutikov et al. (2010); B-diagrammatic view of the left valve hinge; C-diagrammatic view of the right valve hinge; D-diagrammatic view of the byssal complex of the right valve. The areas in black (in B and C) indicate the resilifer. The arrow shows the denticle, a – auricle shape in early Praearctotis (Early Toarcian), b-auricle shape in late Praearctotis (Pseudolioceras wurttenbergeri phase, Late Toarcian), c-resilifer in late Praearctotis (Pseudolioceras wurttenbergeri phase, Late Toarcian), resilifer in Arctotis (Pseudolioceras maclintocki phase, Early Aalenian).

References:
A Early Jurassic Flora from Southern Jilin, China

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A diversity Early Jurassic flora was preserved in the fine-grained sandstone and siltstone beds from the middle-upper part of the Yihe Formation in the Yihe Basin, southern Jilin, China. The Yihe Formation is represented by fluvial and swamp sediments, consisting of conglomerates, sandstones, siltstones, and thin coal layers.


The flora is dominated by cycads and ferns. Among cycads, the most of genera have been found from the Early Jurassic floras of the North and South China except for Siberia and the northern part of Northeastern China. Based on comparisons with subtropic or tropic floras from the southern China, some typical genera of cycads, for instance Pitrophyllum, Otozamites, are absent in the present flora. Ferns possess a higher percentage in the present flora, especially the occurrence of Clathropteris seems to indicate a warm and humid climate, but compared with the those of the subtropic and tropic floras the components of Dipteridaceae are not abundant. Ginkgos and Czechanowskiales with a low-diversity showing seasonal change of climate also occur in the present flora. The more abundant Neocalamites of horsetail shows relatively complete fragmentation suggesting it grew close to the depositional site. Sedimentological characteristics and the composition of the flora significantly indicate a relatively warm and humid palaeoclimate for the Yihe Basin Early Jurassic.

The age of the Yihe flora has been generally accepted as Early Jurassic (Liu and Mi, 1981, Bureau of geology and mineral resources of Jilin, 1982). Although the Yihe flora contains some taxa that are long ranging through Late Triassic to the Jurassic in Eurasia, the occurrence and low-diversity of Coniopteris offers an evidence supporting a late Early Jurassic age. This genus is long ranging (late Early Jurassic to Late Cretaceous) in the Northern Hemisphere, but it begin to occur in the late Early Jurassic and diverse in the Middle Jurassic, absent in the early Early Jurassic. Only two incomplete specimens of Coniopteris were collected from this flora. It is a significant component for us to regard the age of the present flora as late Early Jurassic.

The present flora is similar to the those of Early Jurassic floras distributed in the North China and Middle Asia, such as Fuxian flora from Northern Shanxi, Yongdingzhuang flora from Datong, Shanxi, Wudanggou flora from Inner Mongolia, The flora of the upper number of Beipiao Formation from Western Liaoning, Tianshungou flora from Northeastern border of Qaidam Basin, Qinghai and Aksaisk flora from Issy-kul Basin, Sandjia flora from Gissar, Kokkijila flora from Eastern Fergana, Sarikamish flora from Northern Fergana, Dzhil flora from Northern Kirgizija.

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Key words: Southern Jilin; Early Jurassic; Flora

References:
Genkina R.Z. Older Mesozoic flora and stratigraphy
A series of footprints of sauropods from Zhaojue area of Xichang in Sichuan are described and palaeoenvironmental analysis is also carried out.

In February 2006, large scale dinosaur footprints fossils were discovered in Sanbiluoga Village of Sanshahe in Jiefanggou Area of Zhaojue County of Xichang City. There are about 1000 footprints were preserved on the exposed surface of thick red muddy siltstones developing oblique beddings, which is about 1500 square kilometers. It is the largest dinosaur footprints fossil group discovered in Sichuan up to now. The morphological features of the large foot prints point to typical sauropods, like length>width ellipse-shape hindfoot, and width>length hemicycle-shape forefoot, and forefoot is smaller than hindfoot.

Preliminary studies on the shapes and movement patterns of these footprints suggest there were sauropods, pterosaurs and theropods living together in this area at that time. Most of the footprints belong to sauropods, some are pterosaurs’, and few theropods footprints were discovered not far from the main fossil area.

Sichuan Basin is one of the regions with relatively complete and well developing Mesozoic strata exposed in China. Rivers and lakes were everywhere in the warm and humid Sichuan Basin during the Mesozoic dinosaur era.

The earliest dinosaur footprints in Sichuan Basin were discovered by Yang (1941) in Guanyuan County. More and more dinosaur footprints fossils have been reported in Yibin County since 1949, but they were usually sporadic distributed with a small number, and never formed a trace line.

Before the discovery in Zhaojue County, most of dinosaur footprints from Sichuan Basin are produced by bipedal dinosaurs, except the ones found in Jurassic and Early Cretaceous strata. Quadruped stegosaurus and sauropods are commonly occurred in the Late Jurassic strata of Sichuan Basin, such as Mamenchisaurus hechuanensis, Huayangosaurus taihaii etc., but few footprints of sauropods were found. So such a large group of fossilized dinosaur tracks discovered in Zhaojue County has undoubtedly added new materials to the research on sauropods of Sichuan Basin.

The sauropod footprints in Zhaojue County are similar to those from Chuxiong of Yunnan, with narrow step spacing. Chen and Huang (1993) researched the large sauropod footprints in Chuxiong of Yunnan, named Canglingchuxiong Footprints and suggested the age of these footprints could be Cretaceous. But Lockley et al. (2002) restudied the specimens from Chuxiong, and put them into Brachiosaurus. Most of the dinosaur footprints from Chuxiong belong to sauropod, some are theropod’s, but no ornithopod tracks. Chen et al. (2006) reviewed the ages of strata with dinosaur footprints of China, and the dinosaur footprints from Chuxiong should be Cretaceous in their opinion.

It is also the first time of pterosaurs footprints discovered in Sichuan Basin.

It was a set of lacustrine sediments yielding dinosaur footprints in Zhaojue, and at that time the water level changed many times. According to the 1:200,000 scale geological mapping in the Xichang area of Geological Bureau of Sichuan Province in 1977, this area belongs to the Feitianshan Formation, and the age of Feitianshan Formation is Late Jurassic.

The discovery of dinosaur footprints in Zhaojue Area of Xichang is of great significance to study the dinosaur habits and related paleoclimatic environment.

Key Words: Zhaojue; Dinosaur footprints; Sauropods; Pterosaurs; Feitianshan Formation

References:
Zhen S.N., Li J.J., Han Z.K., et al. The Study of...
The Evolvement of Long-necked Sauropods of Sichuan Basin

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Lots of sauropod fossils, including long-necked type and short-necked type, had been discovered in the Jurassic of Sichuan Basin. There are three genera of long-necked sauropods: Tonganosaurus from the Early Jurassic, Omeisaurus from the Middle Jurassic, Mamenchisaurus from the Middle and Late Jurassic.

The Early Jurassic sauropod Tonganosaurus from Yimen Formation in Huili (in the south of Sichuan Province) is among the earliest known long-necked sauropod dinosaur in the Sichuan Basin. Tonganosaurus hei Li et al., 2010 is the only species of this genus. According to the original description by Li et al. (2010), Tonganosaurus is a moderate sauropod (its length is approximately 12 m), Pleurocoels are developed in all presacral vertebrae, and the bone texture is solid. Cervical centra are slender. A ventral keel is present on each cervical centrum. Posterior cervical centra have well developed laminae and cavities. Both laminae and pleurocoels are well developed in the dorsal vertebrae. Cervical and anterior dorsal centra are opisthocoelous, middle dorsal centra are platycoelous, posterior dorsal and anterior caudal centra are amphicoelous. Centra lack a cancellous structure. Forelimb length is 80% of hindlimb length. Humerus is straight and robust, and deltopectoral crest is well developed. Femur is straight and robust with a well developed 4th trochanter (Li et al., 2010).

The Middle Jurassic sauropod Omeisaurus have six species, they are Omeisaurus junghsiensis Young, 1939 (Young, 1939) from Rongxian County, Omeisaurus fuxiensis Dong et al., 1983 (Dong et al., 1983) from Zigong County, Omeisaurus tianfuensis He et al., 1984 (He et al., 1984) from Dashanpu of Zigong County, Omeisaurus luquanensis Li, 1988 (He et al., 1988) from Luoquan of Zizhong County, Omeisaurus changshouensis Young, 1958 (Young, 1958) from Changshou County of Chongqing Municipality, Omeisaurus maoianus Tang et al., 2001 (Tang et al., 2001) from Huangshikang of Jingyan County. Above all six species of Omeisaurus have been discovered in the Shaximiao Formation. Their geographic positions extend from south to east of Sichuan Basin. Omeisaurus are middle, 18-20 m-long sauropods, their skull moderately high. Teeth spatulate and robust. The denticles well developed on the anterior edge of the teeth, poor or absent on its posterior edgdr. The vertebral formula: 17 cervicals, 12 dorsals.

Posterior cervical and anterior dorsal spine simple and not bifurcated, anterior caudals slightly amphicoelous; first caudal rib more less fan-shaped (He et al., 1984).

Genus Mamenchisaurus had been established in 1954 on the basis of sauropod fossils from the Shaximiao Formation of Yibin County. Mamenchisaurus constructus Young, 1954 is the type species (Yang, 1954). Beside, there are four species of Mamenchisaurus had been found in Sichuan Basin, they are: Mamenchisaurus hochuanensis (Young and Zhao, 1972) from the Shaximiao Formation of Taihe Town of Hechuan County (Yang and Zhao, 1972), Mamenchisaurus anyuenensis (He et al., 1996) from the Penglai- zhen Formation (Late Jurassic) of Longqiao Town, Anyue county (He et al., 1996), Mamenchisaurus youngi (Pi et al., 1996) from the Shaximiao Formation of Zigong County, Mamenchisaurus jingyanensis (Zhang et al., 1998) from the Shaximiao Formation of Jingyan County (Zhang et al., 1998). Mamenchisaurus are large size sauropods (their length approximately 24m long) with extremely small skull. Occipital crest is well developed. Mandible slender with a hight symphyseal region. External mandibular foramen is present. Teeth arranged closely. The wear facets of teeth prominent, and denticles on the posterior carinae degenerate. Vertebral formula: 18-19 cervicals, 12 dorsals, 4-5 sacrals and more than 50 caudals. Presacral are opisthocoelous with cancellous structure in varying degree. Posterior cervical and anterior dorsal spine bifurcated, Cervicals elongated with long cervical ribs. Anterior caudals are procoelous, the middle-posterior ones amphicoelous, and distal caudals fused and expanded. There are typical diplodocoid forked chevrons in the middle tail region. Scapula is longer than femur with a expanded distal blade. Sternum small and subcircular. The length ratio of forelimb and handlimb about 0.75 to 0.80 (Ouyang and Ye, 2002).

Those three long-necked sauropods bear many homology characteristics: 1) their cervical centra are slender, the ratio of centrum length to posterior width in the 3rd cervical are more than 2.90; They have or more 15 cervical centra; 2) Anterior dorsal centra, in which both laminae and pleurocoels are well developed, are opisthocoelous; 3) Forelimb length is 0.75–0.80 of hindlimb length. Owing to the above resemble characteristic, we considered that Tonganosaurus,
Omeisaurus and Mamenchisaurus have close relationships with each other. In other words, Tonganosaurus may be Omeisaurus, ancestor, and Mamenchisaurus may be Omeisaurus’ descendant and developmental offspring, they bear clear phylogenetic evolution.

The evolutionary direction of those three long-necked sauropods shows as fellows: Firstly, the bodily form becomes more and more big; Secondly, centra structure become more and more complex. We take pleurocoels of the presacral centra as example. Tonganosaurus’ pleurocoels are large and deep, but simple in structure; Every pleurocoel of Omeisaurus is divided into many parts by clapboards; There are too many ridges or clapboards in pleurocoel of Mamenchisaurus to find the pleurocoel’ shape; Third, the bone texture of centra become poriferous from solid.

Key words: Sichuan Basin; Long-necked sauropod; Evolvement

References:
Brief Report on a New Material of *Ashicaulis* (Osmundaceae, Filicales) from the Middle Jurassic of Western Liaoning, NE China

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The Osmundaceae is a primitive family of Filicales which receives much concern of palaeobotanists because of its peculiar characters of sporangia, phylogenetic relationships and extensive fossil records. The Osmundaceae contains only 21 extant species distributed among the genera *Osmunda*, *Todea* and *Leptopteris* (Hewitson, 1962). The osmundaceous ferns were diverse and widespread in the geological time, more than 180 fossil species have been described so far represented by compressed foliage, isolated spores and sporangia and permineralized stems (Tidwell and Ash, 1994); among them, over 80 species are based on permineralized rhizomes or stems. The earliest fossil evidence of the Osmundaceae can be traced back to the Early Permian (Rößler and Galtier, 2002). Molecular and morphological data of living species suggest that the origin of this family is the Late Carboniferous (Pryer et al., 2004). This group has been regarded by many authors as intermediate between the eusporangiate and leptosporangiate ferns, while the latest molecular studies place the Osmundaceae as sister group to the rest of the leptosporangiate ferns (Pryer et al., 2004).

During the past decades, some well preserved petrified osmundaceous rhizomes have been described from the Middle Jurassic of western Liaoning and northern Hebei Provinces, NE China. It is considered this region to be one of the most significant petrified osmundaceous fossil localities in Northern Hemisphere. To date, 3 species of *Ashicaulis* and 2 species of *Milleroaulis* have been described from northeastern China (Wang, 1983; Zhang and Zheng, 1991; Matsumoto et al., 2006; Cheng and Li, 2007; Cheng et al., 2007). The present paper is to briefly report a new species referred to *Ashicaulis* by comparison with living and fossil fern rhizomes in the subfamily Osmundoideae.

The specimen is collected from the Middle Jurassic Tiaojishan (Lanqi) Formation in Beipiao County, western Liaoning Province. It is about 4-4.5 mm in diameter, and is composed of pith, xylem cylinder, a two-layered cortex, adventitious roots and numerous petiole bases. In cross section, the stem shows an ectophloic-dictyoxylic siphonostele consisting of 24-32 xylem strands; Xylem cylinder consists of 11-13 xylem strands, and is about 0.8-1.2 mm (12 to 15 tracheids) in thickness. Most of xylem segments are separated by complete leaf gaps and rare incomplete leaf gaps; Leaf gaps are mostly delayed type. The pith is with an ill preservation, 1.5-3.5 mm in diameter. Inner cortex is poorly preserved, and the outer cortex is sclerenchymatous; the whole cortex consists of about 22-25 leaf traces. Leaf traces are mostly adaxially concave with endarch single protoxylem cluster which bifurcates when entering into the outer cortex.

Petiole bases are spirally arranged surrounding the stele, and each one bears two lateral wings. The petiole bases consist of a parenchymatous outer cortex, a homogeneous sclerotic ring, a C-shaped vascular bundle, a sclerenchyma mass at the concavity of the vascular bundle. The shapes and composition of the petiole base change in different position; Immediately proximal to the junction of the stele, the petiole base bears relatively short stipular wings (5 mm wide and 3.5 mm high), and the sclerenchyma mass in the stipular wings and concavity of the vascular bundle are absent. Distally, the stipular wings become longer (8.0 mm wide and 2.5 mm high), and the sclerenchyma mass is present in the vascular bundle concavity, and nearly oval in shape. In the most distal levels, the length of the lateral wings are much more longer (10.0 mm wide and 3.5 mm high), and sclerenchyma masses in the stipular wings and concavity of the vascular bundle can all be observed, sclerenchyma masses in the vascular bundle concavity ranged from oval to kidney in shape. In addition, at such levels of the petiole bases, some thick-walled fibers also exist in stipular wings irregularly. Of interest, adventitious root traces are well developed in the new species. Typically, they mostly diverge from the leaf trace or petiole bases, merely minority of them are directly from vascular strands of the stele. Xylem of these root are diarch.

Depend on the diagnostic combination of characters (ectophloic dictyoxylic siphonostele, complete leaf gaps, oval sclerotic ring), the present specimen exhibit more similarity with the genus of *Ashicaulis*. Since it differs from the *Osmunda*, *Milleroaulis* and *Aurealcaulis* in stele type; additionally, it is also distinct from the Palaeosmunda in bearing oval sclerotic ring. In the classification of the different species of the osmundaceous genera, the arrangement of sclerenchyma in the stem and petiole bases is considered a key feature (Hewitson, 1962; Miller, 1967, 1971; Cheng and Li, 2007; Tian et al., 2008). Some other features,
such as the stem diameter, stele diameter, pith diameter, xylem cylinder, cortex thickness and trace number are also important distinguishing characters at species level. This species is characterized by the presence of a crescent-shaped sclerenchyma mass in the concavity of petiolar vascular strands, one large mass and several small sclerenchymatous in each stipular wing, and homogeneous sclerenchyma ring in the petiole bases. When comparing with other known species of the Ashicaulis in these identification features, our specimen is considered to be distinct from all the previously reported Ashicaulis species, hence the authors prefer to regard it as a new taxon referred to Ashicaulis.

As the sixth described osmundaceous rhizome from the Middle Jurassic of northeastern China, the new material helps to further understand the radiation of the family Osmundaceae in the Northern Hemisphere. The new species seems to show many similarities in anatomical characters with the A. liaoningensis from the same locality and A. woolfiei from North America. Furthermore, anatomical similarities in the distribution of sclerenchyma tissues of the petiole base between the new taxon and the modern species Osmunda pluma indicates that the new species be a possible precursor of the subgenus Osmunda.

Our new species may provide valuable information for understanding the developing trace and geological occurrences of the osmundaceous rhizomes in the northern hemisphere. It is noted when compared with the species referred to the extant genus Osmunda, the new material shares a great similarity with the O. shimokawaensis from the Middle Miocene of Hokkaido, Japan. Though the O. shimokawaensis is with a distinct bigger size in shape (20 cm long and 4-7 cm in diameter), the stele characters (thickness and xylem strand number of the xylem cylinder, homogeneous sclerotic ring, as well as leaf trace number in the inner and outer cortex) really approach our new specimen. Particularly, sclerenchyma tissue distribution pattern in petiole base of the new taxa is extremely comparable with the earlier stages of that in O. shimokawaensis (Matsumoto and Nishida, 2003). Of interest, this may indicate the two species are closely related with each other, and the O. shimokawaensis may be derived form the present species. Additionally, it also provides a clue for interpreting the Miocene osmundaceous rhizome species of Japan may not immigrated from North American, but from northeast China. The new hypothesis is more easily understandable in the the view of palaeo-geography. O. shimokawaensis is assigned to the sub-genus Osmunda; hence the authors may propose that the new material from China be a close relative of the living species of subgenus Osmunda and O. shimokawaensis be an important intermediate in the evolution from Ashicaulis to subgenus Osmunda.

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Key words: Ashicaulis; Osmundaceae; Tiaojishan Formation; Middle Jurassic; Liaoning Province

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Ginkgoales and Czekanowskiales from the Middle Jurassic in Western Junggar Basin of Xinjing, China

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Middle Jurassic strata are well exposed in western Junggar Basin of Xinjiang, yielding abundant fossils of Ginkgoales and Czekanowskiales (Miao, 2009). The earliest known study of the Middle Jurassic plants from the Junggar Basin was made by A.C. Seward in 1911, in which the taxa Ginkgo obrutschewii Seward and Raphaelia diamensis Seward were first reported (Seward, 1911). Since 2001, the authors have carried out a new-cyclic study of the Middle Jurassic flora from the Xishanyao Formation of the western Junggar Basin, and over 50 species of 26 genera have been identified, including horsetails, ferns, seed ferns, ben- nettitales, ginkgoales, czekanowskiales, conifers, etc. Generally, the flora is represented by the assemblage of Coniopteris-Phoenicopsis, implying a warm-temperate and some humid climate favorable for the coal-forming in large scale during the early Middle Jurassic time (Seward, 1911; Zhou, 1995; Miao, 2003; Sun et al., 2004; Miao, 2005; Sun et al., 2006; Zhou, 2003). At present, the authors have collected about 400 pieces of specimens of Ginkgoales and Czekanowskiales preserved in compression or impression from the Xishanyao Fm. of the Baiyang River valley of the southwestern Junggar Basin. The well-preserved cuticle material brings a favor to the anato-mic study of the fossil plant taxonomy.

The taxa of Ginkgoales consist of Ginkgo obrutschewii Seward, G. cf. sibirica Heer, G. coriacea Florin, Baiera fuscata (L. et H.) Harris et Millington, Sphenobaiera junggarensis Sun, Miao et Chen, S. cf. huangi (Sze) Hsü, Desmiophyllum sp., Stenorachis cf. lepida (Heer) Seward, etc. Among them Sphenobaiera junggarensis was first reported in the Junggar Basin in 2006 (Sun et al., 2006). The cuticular characters of Sphenobaiera junggarensis indicate some new data for reconstruction of the paleoclimate of the Junggar Basin.

The taxa of Czekanowskiales include Czekanowskia rigida Heer, C. cf. setacea Heer, Phoenicopsis (P.) angustifolia Heer, P. speciosa Heer, Leptostrobus laxiflora Heer, and Ixostrbus sp. The cuticle study of Phoenicopsis helps us in the taxonomy of this genus, while the reproductive organs Leptostrobus and Ixostrbus bring us more fresh knowledge on the evolution of Czekanowskiales.

Since Ginkgoales and Czekanowskiales both are deciduous in nature, their abundance in the strata from the Junggar Basin implies a warm-temperate and some humid paleoclimate with seasonal changes during the Middle Jurassic (Miao, 2005; Zhou, 2003; Deng, 2007).

Key words: Ginkgoales; Czekanowskiales; Middle Jurassic; Junggar Basin

References
In Situ Spores of Two Dipteridaceous Ferns from the Jurassic of China and Their Evolutionary Implications

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The Dipteridaceae is a representative leptosporangiate fern family with a single extant genus Dipteris, and is currently restricted to Indo-Malaysian region. During the Mesozoic, the family was globally distributed with more up to 6 genera and 60 species. They form a significant element of many Northern Hemisphere Mesozoic floras, from Middle Triassic to Early Cretaceous. Among them, Dictyophyllum and Hausmannia are two representative genera of the family. So far only four species of Dictyophyllum have been described for their in situ spores from the Triassic and Jurassic. All of the previously described species of Hausmannia are based on compression/impression fossils, and little is known about the fertile structures including sporangia and in situ spores of this genus. In this note the in situ spores of two dipteridaceous ferns Dictyophyllum and Hausmannia from the Jurassic of China are reported based on recent studies on the material from western Hubei and Inner Mongolia, China.

Well-preserved compression specimens of Dictyophyllum nilssonii (Brongniart) Goeppert were investigated from the Lower Jurassic Hsiangchi Formation in Western Hubei, Southern China. The reproductive characters including sporangia and in situ spores are examined using LM and SEM (Guignard, Wang et al., 2009). The sporangia are rounded with oblique annulus, each being 300-450 µm in diameter. Each sporangium produces 220-280 trilete spores that are triangular to subtriangular in outline with smooth exines as well as interradial thickenings along the laesura in proximal surface (Fig.1). The in situ spores are average 40 µm in diameter and comparable to the dispersed trilete spore genus Dictyophyllidites.

A new species of Hausmannia (H. sinensis Wang and Zhang) was reported from the Middle Jurassic of Nei Mongol (Inner Mongolia), Northern China (After Wang and Zhang, 2009). Laminae are broadly fan-shaped with almost entire margin. Primary and lateral veins dichotomously branch to form square or polygonal meshes. Each ultimate mesh bears one to two circular sori of 0.4 mm in diameter. The sori are
exindusiate and circular, densely distributed in the lower surface of the lamina. Each sorus consists of 3 to 6 round to oval sporangia with oblique annulus. Each sporangium produces about 64 to 128 spores which are trilete and circular to oval in outline. Both proximal and distal surfaces are covered with baculate to subverrucate sculptures (Fig.2). Spore size ranges from 20 to 30 µm in diameter (average 28 µm). This spore is comparable with dispersed types Apiculatisporites Potonie and Kremp and Baculatisporites Thomas and Pflug.

It is emphasized that Dictyophyllum nilsonii from western Hubei of China represents the first in situ spores of fossil genus Dictyophyllum described in Asia. Hausmannia sinensis represents the first compression species of Hausmannia and the first species of the genus in Eurasia continent that shows the combination of well preserved fertile organs, including sori, sporangia, annuli and in situ spore characters, and is therefore helpful for further understanding the diversity and evolution of the Dipteridaceae fern lineage through time. Recent phylogenetic investigations based on molecular and morphological data suggest that family Dipteridaceae is considered as systematically a monophyletic clade of gleichenioid (including Dipteridaceae, Gleicheniaceae and Matoniaceae), showing great importance for exploring the phylogeny and evolution of leptosporangiate ferns. The current study on fertile organs and in situ spores of Dictyophyllum and Hausmannia from the Jurassic of China provides further evidence for comparisons with fossil and living records of the Dipteridaceae, and is hence helpful for exploring the diversity and evolution of this important leptosporangiate fern lineage through time.

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Key words: Fossil ferns; In situ spores; Dipteridaceae; Jurassic; China

References:
Preliminary Analysis on the High Petrified Ratio of the Osmundaceous Fossils Based on Materials from the Jurassic of Western Liaoning, China

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The family Osmundaceae is among the most primitive ferns of the Filicales with extensive fossil records. Over 180 fossil species have been documented worldwide for this family (Tian et al., 2008), with about 20 species represented by isolated spores and sporangia (Miller, 1971) and more than 80 species based on compressed foliages (Tidwell and Ash, 1994). In particular, numerous fossil osmundaceous rhizomes have been documented in the geological history, reaching a high proportion in preservation (Miller, 1971; Tidwell and Ash, 1994; Tian et al., 2008). Till date, about 83 species referred to 14 genera have been reported globally based on permineralized rhizomes or stems, namely that the petrified taxa occupy over 40% of the whole family. Most information about the evolutionary history of the order Osmundales and family Osmundaceae comes from structurally preserved rhizomatic stem segments (Taylor et al., 2009). This makes the Osmundaceae unique among all ferns, since such a high petrified ratio have never been documented from other fern taxa.

In China, about six unequivocal species of petrified rhizomes or stems of the Osmundaceae assigned to three genera (Palaeosmunda, Ashicaulis and Milleroicaulis) have been so far described. It is noted that well preserved petrified osmundaceous rhizomes have been reported from the Middle Jurassic Tiaojishan Formation of western Liaoning Province during the past decades, i.e. M. sinica, M. preosmunda, A. liaoensis (Zhang and Zheng, 1991; Cheng and Li, 2007; Cheng et al., 2007). In addition, our recent field survey in the Middle Jurassic of western Liaoning shows that more well preserved osmundaceous rhizomes are found in this region, with a potential high structural and species diversity. The western Liaoning region is supposed to be one of the most significant petrified osmundaceous fossil localities in Northern Hemisphere. Consequently, the materials from there are typical and representative. It might indicate that this region is one of the important activity centers of Northern Hemisphere for osmundaceous plants. Here we provide a primary analysis on the petrified mechanism and high petrified ratio of the osmundaceous plants, based on the investigation and discussion on the materials from western Liaoning. Four major conclusions are made in multiple views, such as the floral constitution, permineralizing condition, ecological environment and peculiar structures of osmundaceous rhizomes.

1) In the forming progress of the petrified wood, ample minerals resolution is absolutely necessary. During the Middle Jurassic, western Liaoning region located in the core regions of the circum pacific volcanic belt, hence crustal and volcanic activities are always frequent, the thick volcanic tuff deposits are the appropriate proof. Frequent volcanic activities provide sufficient minerals (i.e. SiO2) for the permineralization; additionally, the crustal activities are also helpful for the quick bury of plants, which helps to isolated plants from oxygen;

2) Abundant plant fossils have been documented from the Tiaojishan Formation; about 91 species referred to 49 genera have been reported so far (Zheng and Zhang, 1982; Zhang and Zheng, 1987). In this flora, ferns run the second in diversity with about 20 species of 14 genera, the family Osmundaceae with 12 species is the most significant among all the pteridophyte plants, represented by Todites, Ashicaulis, Milleroicaulis as well as Cladophlebis and Raphaelia. The flourishing of the osmundaceous plants provides more primary raw materials for permineralization than other fern groups;

3) The peculiar anatomical structure is also considered to be of great help for the high petrified ratio of the Osmundaceae. The osmundaceous rhizome specimen is commonly composed of pith, xylem cylinder, a two-layered cortex, adventitious roots and numerous petiole bases. It is noted that the outline of the osmundaceous rhizomes are always covered by a mantle comprising of spirally arranged petiole bases and adventitious roots, there is much interspaces between these petiole bases. This unique structure is suitable for absorbing mineral resolution, and may be the most valuable factor for the high petrified ratio of osmundaceous fossils;

4) The ecological characters of the Osmundaceae, such as the thriving environment (swamp, river or lake banks) provide them an appropriate buried depth, which are also help for the rapid embedding.

The four major factors are integral, the combined action of them help the Osmundaceae to realize a high...
petrified ratio. On the contrary, it is noted that the cycadophytes is the dominant group among the Tiaojishan flora with over 40 species of 6 genera, however only with 3 petrified species (i.e. *Lioxylon liaoningense*, *Williamsoniella sinensis*, *Williamsoniella ? exiliforma*) are ascribed to them. This may be attributed to the lack of peculiar structure like Osmundaceae.

In conclusion, the high petrified ratio preservation of the Osmundaceae in western Liaoning is of high significances. Firstly, it provides good opportunity for anatomical studies of the family; then it is helpful for understanding the ecological and environmental features of the western Liaoning regions in the Jurassic. Finally, it helps to improve the fossil diversity of the petrified osmundaceous rhizome in the Jurassic of Northern Hemisphere, and provides rules for understanding the evolution and migration of the Osmundaceae.

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**Key words:** Osmundaceae; Petrified mechanism; Beipiao; Middle Jurassic; Tiaojishan Formation

**References:**


The Jurassic Palynofloral Provinces of China

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The Jurassic strata widely distributed in China are rich in fossil plants and fauna. Biotic and sedimentary features show that there are two stages in the Jurassic paleoclimate evolution, namely the early and late stages. The early stage ranges from Early to early Middle Jurassic; and the late stage from late Middle Jurassic to Late Jurassic. Obvious differences exist in the Jurassic sporopollen floras between South and North China Subprovinces. The boundary between the southern and northern paleogeographic units of China extends basically along a line of the Kunlun – Qinling – Dabieshan Mountains. According to Vakhrameev (1988), the Jurassic flora of South China Subprovince is an important part of the East Asia Province in the Europe-China Region. The flora of North China falls into the Siberia Region. A preliminary study on the sporopollen fossils from Kuqa Depression of northern Tarim Basin and from the southwestern border area of the Tarim Basin shows that the sporopollen floras from the Kuqa Depression are similar to those of North China Subprovince, while those from the southwestern border of the Tarim Basin resemble to those of South China Subprovince. Therefore the western edge of the boundary between the South and North China Subprovinces should be shifted northward to almost the central of the Tarim Basin, extending in a northwest-southeast direction.

The Jurassic sporopollen floras in China can be divided into two different subprovinces, including the North China palynoflora Subprovince and the South China palynoflora Subprovince.

(1) North China Subprovince

It covers the extensive area in the northern China and is represented by the Jurassic sporopollen assemblages from the Junggar Basin and the Shaanxi-Gansu-Ningxia Basin. The sporopollen assemblage sequences and their corresponding ages are listed as follows in ascending order:

A. Disacciatrileti-Cadargasporites-Cyathidites Assemblage: early Early Jurassic (Hettangian-Sinemurian).
B. Cyathidites-Cibotiumspora-Disacciatrileti Assemblage: late Early Jurassic (Pliensbachian-Toarcian).
C. Cyathidites-Neoraistrickia-Disacciatrileti Assemblage: early Middle Jurassic (Aalenian-Bajocian).
D. Cyathidites-Classopollis-Quadraeculina Assemblage: late Middle Jurassic (Bathonian-Callovian).
E. Classopollis-Cyathidites-Concauvissimisporites Assemblage: early Late Jurassic (Oxfordian).
F. Piceites-Podocarpidites-Schizaeoisporites Assemblage: late Late Jurassic in age.

(2) South China Subprovince

This subprovince includes the extensive area in south China. Based on the Jurassic palynological data from Jiangxi, Hunan, Hubei, Sichuan, Yunnan, Xizang and other areas, five Jurassic sporopollen assemblages are recognized as follows:

A. Dictyophyllidites-Classopollis-Cycadopites Assemblage: early Early Jurassic (Hettangian-Sinemurian).
B. Dictyophyllidites-Cyathidites-Classopollis Assemblage: late Early Jurassic (Pliensbachian-Toarcian).
C. Cyathidites-Callialasporites-Classopollis Assemblage: early Middle Jurassic (Aalenian-Bajocian).
D. Cyathidites-Classopollis-Neoraistrickia Assemblage: late Middle Jurassic (Bathonian-Callovian).
E. Couperisporites-Classopollis Assemblage: Late Jurassic (Kimmeridgian-Tithonian).

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Key words: Jurassic; Palynological assemblages; Northern China Subprovince; Southern China Subprovince; China
The Spatial and Temporal Distribution of *Waagenoperna* and Its Biostratigraphy Significance

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*Waagenoperna* was first proposed by Tokuyama (1959) based on the Japanese specimens and restudied “*Edentula*” specimens of Waagen (1907), “*Edentula* lateplanata Waagen, 1907” as the type species. Hayami (1975) gave a clear definition on *Waagenoperna*: “Shell subequivalve, mytiliform or cuneiform, compressed; both wings not clearly delimited; umbo prosogyrous, subterminal; ligament area elongated along dorsal margin but becoming somewhat obscure near posterior end, provided with several subquadrature pits of Isognomon-type; anterior and posterior teeth obsolete already in early stage; no radial ribs.” For many years, this genus was only found in Europe and Asian, ranging from Middle or Upper Permian to Upper Triassic (Tokuyama, 1959; Cox, 1969; Hayami, 1975; Gu et al., 1976; Gu et al., 1980; Liu and Li, 1980; Xu, 1984). Chen and Zhang (2000) reported three species of *Waagenoperna* collected from Jurassic Badaowan Formation in northern Xinjiang Junggar Basin, and suggested that some Chinese *Waagenoperna* specimens once known as Triassic should be Jurassic (e.g. Zhang et al., 1977; Chen and Xu, 1980).

All the European and Japanese specimens of *Waagenoperna* were collected from Triassic strata with quite a limited distribution (Waagen, 1907; Tokuyama, 1959; Hayami, 1975), except for *W. hayamii* (Nakazawa and Newell, 1968) from Lower and Middle Permian. According to Fang (1982, 1987), these Permian *W. hayamii* are not real *Waagenoperna*. But this genus displays a wider distribution in China from south to north: upper triassic strata in Yunnan Xiangyunmiao (Gu et al., 1980; Reed, 1927), the second member of Banan formation in Guizhou Zhenfeng (Gu et al., 1976; Gu et al., 1980), anyuan formation in Hunan Liling (Zhang et al., 1977; Gu et al., 1980), the middle and lower part (Tabakou member and Paitjachong member) of guanyintan formation in western Hunan (Chen and Xu, 1980), anyuan formation in Hubei Yuanan (Zhang et al., 1977; Gu et al., 1980), the upper most part of xujiahe formation in Sichuan Basin (Xu, 1984), ermaying formation in Shanganning Basin (Liu and Li, 1980), and Badaowan Formation in northern Xinjiang Junggar Basin (Chen and Zhang, 2000).

Except for the specimens from Guanyintan formation in western Hunan and Badaowan formation in northern Xinjiang Junggar Basin, others are all collected from Triassic sediments. It has been a long debating on the age of Guanyintan formation in western Hunan. Some researchers believed that guanyintan formation could be correlated to Lower Jurassic Jinji Group with the evidences from palaeobotany (e.g. Chen and Xu, 1980; Chen and Zhang, 2000). But others disagreed based on other invertebrate fossils, and suggested to be correlated to Upper Triassic anyuan formation (Gu et al., 1980). For the Badaowan Formation in northern Xinjiang Junggar Basin yielding *W. mytiloides*, *W. lilingensis*, *W. pernoformis*, it has been accepted as Lower Jurassic, after many years’ studies on the T/J boundary in Junggar Basin (Deng et al., 2003; Lu and Deng, 2005 etc.). Thus, considering Chinese materials, the genus *Waagenoperna* ranges from Triassic to Upper Jurassic with the occurrences in Europe, Japan and China.

Most of the *Waagenoperna* specimens were collected from alternative marine and terrigenous facies, such as Japanese Nariwa Group in Nariwa area and Mine Group in Mine area, Xujiahe Formation in Sichuan Basin, Anyuan Formation in Hunan and Hubei, Guanyintan Formation in western Hunan, Ermaying Formation in Shanganning Basin, and Badaowan Formation in northern Xinjiang Junggar Basin etc. Especially in Badaowan Formation of Junggar Basin, *Waagenoperna* is usually co-occurred with typical fresh water bivalves *Unio, Margaritifera, Yananoconcha* etc. One possible explanation would be *Waagenoperna* is not a strict marine genus, it prefers to coast or lagoon brackish environments, or lacustrine environment which is sometimes affected by sea water.

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Key words: *Waagenoperna*; Jurassic; Spatial and temporal distribution; Biostratigraphy

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The Discovery and Preliminary Study of Middle Jurassic Silicified Wood in Qijiang, Chongqing

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The study of silicified wood in China has several decades, many different authors have researched the wood fossils from various geological ages in many provinces (Si, 1951, 1953, 1962; Si et al., 1963; Xu, 1953; Cheng et al., 1980; Wang et al., 1994; Feng et al., 1998; Duan, 1986,2000; Duan et al., 1998, 2002; Dong et al., 2002; Nian et al., 2003; Zhu et al., 2003; Yang et al., 2004; Wang et al, 2006). There is a long history of wood record in Chongqing, while the beginning of research on them is marked by the preliminary study of Qijiang silicified wood flora.

The flora was discovered in 2005 and the excavation and research work were made by Chongqing museum of natural history. The buried site is Masangyuan quarry of Wenlong village, Gunan town, Qijiang county. More than 20 wood specimens were found in approximate 1000 square meters, but none was exposed completely. Among them the largest one is over 25 meters in length, with the top and root of the fossil still unseen. The diameter of two trees is about 1 meter.

There are many places of wood fossils in Chongqing, and Qijiang flora is the typical one of the most concentric buried and best preserved. The field investigation showed that the buried area of wood fossils is probably over one square kilometer. The surface of wood is deeply coalfield, while its internal wood fiber part is various mineralized including silified and limonitized etc. The forming mechanism is distinct from those of other fossils. Qijiang silicified wood flora is the direct evidence of large trees at that time in this area, and has important significances not only in paleobotany, but also in stratigraphy, paleo-environment, paleontology, paleoecology of Chongqing as well as adjacent areas.

The Qijiang county is located in the joint of Sichuan basin and southeast Yungui plateau. The Indo-China orogenesis at the end of Triassic caused the margin of Sichuan basin to uplift as mountains. The original sea basin turned into a terrestrial one, and the ‘Bashu Lake’ was formed which almost occupied the whole basin area. In middle Jurassic a tectonic movement changed the sedimentary background of basin. As a result, the period of lacustrine facies developed into that of terrestrial fluvial facies, producing a large distribution of thick-bedded sandstone. Silicified wood have been for the first time discovered from Middle Jurassic Upper Shaximiao Formation in Masangyan as referred above. The wood fossils were buried in middle medium coarse grained lithic feldspar quartz sandstone. In this area, Jurassic is represented by a terrestrial facies red fragment rock series in river and lake sedimentary environment. In addition, Middle Jurassic Suining formation, Upper Jurassic Penglaizhen formation as well as Early Cretaceous Jiaguan formation are also exposed in this area.

The wood fossils are relatively completely preserved, with large and small branches. Their features of morphology are similar to the type of Araucaria cunninghamia (needs a further study on cell structures). Most wood is buried parallel to the plane of strata. Fossils lie in the excavated area of 1000 square meters, and are distributed vertically along the surface of rock bed because the dip of strata is basically consistent with the slope direction, some woods’ direction are perpendicular or oblique to the dip. All woods underwent mineralization, with dark black or brown yellow appearance, hard and heavy, emit sparks when hit by a hammer. Some structures such as the external scars of bark, annual rings and even wood fiber structure can be observed in their sections.

The trunk of trees is round or oval, the diameters are usually 50-60 cm, and the large one is more than 100 cm. The bark are morphologically clear, the surface is as black as coal. The interior color is mainly black with some dark black. The largest wood is more 25 meters long, with the top and root could unseen, so its whole length is estimated more than 30 meters. The branches are round; the diameter is 10-20 cm, usually incomplete. The exterior surface is cinnamon-like, 0.5 cm in thickness, and very easy to drop off. Parts of the wood surface are brown yellow as a result of limonitization.

According to the observation of micro-structure of thin sections under the microscope, some part of cell tissue structures are still well preserved. The discovery of Qijiang wood flora shows that a large forest composed of high trees existed in Chongqing as well as neighbouring region during Middle Jurassic.

The horizon of Qijiang wood fossils is the Middle Jurassic Upper Shaximiao formation. Araucarioxylon zigongensis has ever been founded in Lianggao mountain, Zigong, which is near to the famous Dashanpu buried site of dinosaurs, the distance is only 3.5 kilometers, the horizon is Lower Shaximiao formation, so the age of Qijiang wood fossils are later than that of Zigong wood.

In Yibing, Sichuan, Jiangan wood flora was
found in east part of Dashanpo syncline which is symmetrical and extends 5 kilometers. The wood fossils lie mainly in grey yellow calcareous feldspar sandstone of the lower part of Upper Jurassic Penglaizhen formation, which shows that it is younger than Qijiang flora.

There were a lot of petrified woods concentrated in Shenhong National Geological Park, Sichuan. It was extremely rare that the petrified woods appeared together with the dinosaur fossils. It has been proved that its age is Upper Jurassic Penglaizhen formation, later than that of Qijiang flora.

In north China, many Middle Jurassic wood fossils have been found in some provinces including Liaoning, Henan, Jilin and Xinjiang, the strata bearing wood fossils are Tijishan formation, Yima formation, Sukang formation and Yingshugou formation (Wang et al., 2006). But in south China the middle Jurassic wood fossil record is rare. This discovery of Qijiang flora increases the distribution range of Silicified woods, and provides the new materials for the large plant fossils in Middle Jurassic.

Usually the general law is that during the process of diagenesis, deposits under the same geological background and diagenetic conditions should get the consistent sedimentary result. The bark of Qijiang wood was coalified, the wood was silicified and limonitized. Coalification represents reductive environment, and limonitization is oxide environment, how this two opposite environment appeared in the wood together? How to explain the inconsistence? The answer lies in the natural and geological action. The coalification was probably due to a big forest fire which caused the bark of trees to become coal. The silicification and limonitization was the result of wood’s being immersed by solution of SiO₂ and FeO. This two opposite genetic environment occurred successively in the same wood, and therefore appeared in the preserved condition simultaneously.

The coalification of Qijiang wood fossils shows as discussed above that the trees were probably burned by a forest fire, suggesting a dry climate at that time. This judgment can be proved from previous conclusions. Qijiang wood fossils were primarily concluded a kind of Araucaria cunninghamii. Duan et al. (1998, 2000) A. cunninghamii had a wide distribution in China during late Mesozoic (Late Jurassic to Early cretaceous). According to some related information (Wang, 1992), oceanic climate dominated from Jurassic to cretaceous, forming a universal wet and humid climate on the globe. While in middle and East Asia, the dry climate which began at the end of Middle Jurassic or Late Jurassic lasted to Cretaceous. On the other hand, Wang et al. (2008) inferred that the climate in this area was subtropical semi-humid and semi-arid in early Middle Jurassic, but was subtropical semi-arid–arid in late Jurassic (the period of Upper and Lower Shaximiao formation) based on his research on spore and pollen fossils.

Qijiang wood flora is important silicified wood fossils in many respects and deserves a further systemic study. Firstly more detailed study should be made on strata, including biostratigraphy, petrology and chemical stratigraphy. High-resolution event stratigraphy will be applied to Upper Shaximiao formation with fossils to precisely confirm the horizon and age of wood fossils, and to look for the evidence of forest fire. Secondly, to make a detailed study of biological features on wood fossils, and observe the microstructure by experimental methods to ensure its taxonomic position and to make an identification of species level and find out the characters of plant combination. Thirdly, through the analysis of lithofacies paleogeography, spore and pollen fossils, isotopic geology to know paleogeography environment, the character of palaeo-climate and water condition (hydrodynamic condition, elements, Ph values, Eh values and water temperature and so on). It is noteworthy that some big sauropod dinosaurs sites have been found near the wood sites, so the wood fossils will also provide valuable materials for the study of dinosaurs food chains.

Key words: Silified wood; Qijiang; New materials; Further study

References:
A New Rhamphorhynchoid Pterosaur from the Late Jurassic of Northeastern China

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As primitive pterosaurs, non-pterodactyloids are characterized by a short neck, abbreviated and massive metacarpus, long and stiff tail, and a well-developed pedal digit V. Although non-pterodactyloids appear to be worldwide distributed, their fossils have been found rarely in the Jurassic deposits outside Europe, especially in terrestrial deposits. Recent discoveries of non-pterodactyloids in the Late Jurassic lacustrine deposits of Liaoning, Inner Mongolia, and Hebei Provinces, such as Jeholopterus ningchengensis, Pterorhynchus wellnhoferi and the recently-erected Changchengopterus pani, Darwinopterus modularis, Wukongopterus lii and Fenghuangopterus lii (e.g. Czerkas and Ji, 2002; Wang et al., 2002; Lü et al., 2010), exhibit a significant pterosaur assemblage in the Jurassic terrestrial ecosystems.

Herein a new non-pterodactyloid pterosaur was collected from the Late Jurassic Tiaojishan Formation in Linglongta, Jianchang County, western Liaoning, China, with an articulated skull and fragmentary postcranial skeleton. The specimen (Fig.1) is characterized by a convex dorsal margin of the skull, antorbital fenestra posterior to naris, a caudoventral process of the premaxilla beneath the naris, posterior process of the jugal short, jaw articulation above the half level of the mandible, angular slightly smaller than surangular, a strongly reduced and evenly spaced dentition, and the fifth upper tooth at the level of the anterior margin of the naris. A preliminary phylogenetic analysis shows that Sordes pilosus, Scaphognathus crassirostris, the new pterosaur and Pterorhynchus wellnhoferi as the successive taxa occupy the basal positions of the family Rhamphorhynchidae clade. This discovery further enriches the taxonomic diversity of non-pterodactyloids in the Late Jurassic lacustrine deposits of northeastern China.

During the Late Jurassic of Laurasia, the non-pterodactyloid fossils are mainly known in the Solnhofen Limestone, Germany, and in Karatau lacustrine deposits, Kazakhstan. In the Solnhofen Limestone (a coastal environment), there are over three hundred non-pterodactyloid materials have been found, but representing a low taxonomic diversity with only three taxa, such as the rhamphorhynchid Rhamphorhynchus muensteri, the anurognathid Anurognathus ammoni, and the scaphognathine Scaphognathus crassirostris (e.g. Wellnhofer, 1991; Unwin and Bakhurina, 2000). In contrast, two non-pterodactyloid taxa are known in the Karatau lacustrine deposits of Kazakhstan, Central Asia with ten specimens, such as the anurognathid Batrachognathus volans and the scaphognathine Sordes pilosus (Unwin and Bakhurina, 2000). Furthermore, recent pterosaur discoveries from Inner Mongolia, Hebei and Liaoning, northeastern China, show a high diversity pterosaur assemblage in the Late Jurassic terrestrial ecosystem, with seven taxa and 15 specimens. Consequently, in the Late Jurassic Laurasia, the non-pterodactyloids seem to be more diverse in the inland regions than in the coastal areas. This non-pterodactyloid assemblage in the Late Jurassic terrestrial ecosystem of northeastern China provides important insights into the evolution and the biogeography of the non-pterodactyloids.

Key words: Non-pterodactyloids; Late Jurassic; Biodiversity and biogeography; Northeastern China

Fig.1 Reconstruction of the new pterosaur skull
Scale bar equals to 20 mm.

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Froghoppers, Leafhoppers, Planthoppers and Their Allies from the Mesozoic of Northeastern China
(Hemiptera: Cicadomorpha and Fulgoromorpha)

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The northeastern China, especially Jiulongshan Formation of Middle Jurassic and Yixian Formation of Late Jurassic to Early Cretaceous, yield a mass of notable fossils including abunded froghoppers, leafhoppers, planthoppers and their relatives (hoppers), which provide important evidence for study of the origin and early evolution. The published report of fossil records included at least representatives of nearly 50 species placed in 20 genera (Wang et al., 2006), but this number vastly increased since then. Representatives of various families are present in northeastern China deposits, both extinct and extant.

The most abundant group present in both Jurassic and Cretaceous strata is Procercopidae (Cercopoidea), which covered about 40% of all specimens collected. However, the known taxonomic diversity of these froghoppers must be recognized again and future systematic revisions are needed.

Tettigarctidae (Cicadoidea) is the most ancient lineage still present in recent fauna, and the fossil records can date back to terminal Triassic (Shcherbakov, 2009). Ancient tettigarctids are ancestors of recent singing cicadas (Cicadidae), known in fossil record since the Late Triassic. Tettigarctidae were morphologically diverse and quite abundant in the Jurassic and Cretaceous, like Cicadidae in the Cenozoic and nowadays. The pronotum concealing major of mesonotum seems to be an autapomorphy of Tettigarctinae (Wang and Zhang, 2009). 23% of the fossil materials from the northeastern China belong to Tettigarctidae, but so far, only 4 definitive species of Tettigarctidae are known.

Representatives of extinct lineage Palaeontinoidea, i.e. Palaeontinidae were huge, moth-like insects, resembling a little, but not related to singing cicadas, which witnessed the rise and fall of dinosaurs. Their wing span ranges 10-36 mm; wings are very often disruptive patterned (Wang and Ren, 2009), and body is often covered with scales or dense hairs. A combination of cryptic coloration and disruptive marking enhanced their camouflage. Palaeontinids existed from the Triassic to the Mid Cretaceous. They make up 14% of fossil specimens from northeastern China.

Hylicellidea, the common ancestors of the living Cicadomorpha, evolved from Prosboloidea by the Middle Triassic. The extinct family Hylicellidae had the first appearance in the Middle Triassic (Anisian) of Vosges, France. It was abundant in the Jurassic and became extinct by the Mid-Cretaceous (Shcherbakov and Popov, 2002). Hylicellidae are quite common in the insectiferous deposits from the northeastern China, often very well preserved and presenting distinct morphological disparity. They constitute at least 7% of the known specimens, but their taxonomic diversity is still weakly recognised and needs further investigations.

The knowledge on the other groups is virtually rear; a few weakly preserved specimens could be ascribed to Karajassidae or their descendants Cicadelidae. Some others seem to be related to Archijassidae, however the taxonomic status of this family is still under debate.

The 2% remaining include some uncertain taxa and only a few Fulgoromorpha. The study of fossil Fulgoroidea from China is still at the debut stage, but the number of new outcrops and specimens is increasing. Single specimen ascribed to the paraphyletic ‘Fulgoridiidae’ was identified in the late Middle Jurassic deposits of Daohugou. However, it clearly differs from all forms known from Europe and Asia.

Another planthoppers group of taxa including genera Lapicixius Ren, Yin et Dou, 1998, Yanducixius Ren, Lu et Ji, 1995 and another not yet described genus superficially resembles Cixiidae, but in details of venation pattern, head capsule and leg structures clearly differs from it and deserve familial placement.

The increment of number of specimens collected and examined is bringing a number of new taxa described. The known taxa are under revisionary studies as well. These allow further comparisons. By analyzing the record of animals and associated plants fossil, palaeoclimatic data and palaeoecological data the processes of evolution of Cicadomorpha and Fulgoromorpha could be traced and analyzed. Concurrent changes in both plants and flourish of predators during
the Middle Jurassic to Early Cretaceous, limited a series of the hoppers fauna developed and radiation.

**Key words:** Hemiptera; Cicadomorpha; Fulgoromorpha; Northeastern of China

**References:**
Vertebrate Assemblages from the Middle-Late Jurassic Yanliao Biota in Northeast China

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Introduction

In the last twenty years, many exceptional fossils have been recovered from the Early Cretaceous Jehol Biota (131-120 Ma) in western Liaoning, northern Hebei and southeastern Inner Mongolia, Northeast China, including early birds, feathered dinosaurs, mammals, pterosaurs, amphibians, fishes, insects and flowering plants (Zhou, 2006; Zhou and Wang, 2010). Relatively less known from almost the same region are many equally important Middle-Late Jurassic fossils belonging to the Yanliao Biota, including the oldest known feathered dinosaurs (Hu et al., 2009), swimming and flying mammals (Meng et al., 2006), pterosaurs with hair-like integuments, lizards, fishes, and abundant salamanders and insects. The recent fossil discoveries of the Yanliao Biota have extended the temporal distribution of feathered dinosaurs and helped to resolve the so-called “temporal paradox” that perplexed paleontologists studying the origin of birds. Despite its relatively lower vertebrate diversity, the Yanliao Biota is no less important evolutionarily than the more famous Jehol Biota. This short paper aims to provide a brief introduction to the vertebrate components of the Yanliao Biota as compared to that of the Jehol Biota, and to clarify the current debate on the age of the Yanliao Biota and the correlation of its fossil-bearing deposits.

Distribution and Age

Hong (1983) first used Yanliao to refer to an insect fauna from northern China, and it was later adopted by Ren et al. (1995) to refer to the Middle Jurassic fauna from mainly northern Hebei and western Liaoning. The Yanliao Biota is well known for including hundreds of insect species and many plants, conchostracans, ostracods and bivalves. It was, however, little known to vertebrate paleontologists due to the limited vertebrate fossil record. Important vertebrate fossils have now been reported from the Lanqi Formation at the Daohugou locality in Ningcheng, Inner Mongolia (sometimes referred to as the Daohugou Biota) and more recently from the Linglongta area in Jianchang, western Liaoning (Duan et al., 2009). In this paper, we regard the Daohugou Biota as equivalent to Yanliao Biota and adopt the latter as a more commonly accepted name for this Jurassic terrestrial biota.

Like the Jehol Biota, the Yanliao Biota is mainly distributed in western Liaoning, southeastern Inner Mongolia and northern Hebei, but some elements of the biota have a broader distribution in Central Asia and East Asia. The Yanliao fossil-bearing horizons mainly include the Haifanggou Formation (or Julongshan Formation in Hebei) and the overlying Lanqi Formation (or Tiaojishan Formation in Hebei).

The age of the Yanliao Biota was traditionally considered to be Middle Jurassic (Ji and Yuan, 2008), but recent dating indicates that it actually ranges from Middle to Late Jurassic. A recent dating of the Lanqi Formation resulted in an age estimate of 166-153 Ma for this formation (Yang and Li, 2008; Ma and Zheng, 2009), consistent with an earlier estimate of 168-152 Ma (Liu et al., 2006). Furthermore, recent published dating (161 and 158 Ma) for the basal Lanqi Formation by Chang et al. (2009) even led to the proposal that the Lanqi Formation belonged completely to the Late Jurassic. This would imply that the major Yanliao fossil-bearing horizon (Lanqi Formation) is mostly Upper Jurassic, with only the earliest elements of the biota from the Haifanggou Formation (Ji and Yuan, 2008) being of Middle Jurassic age.

Composition of the Yanliao Vertebrate Assemblage

In the past, the only vertebrate fossils known from the Yanliao Biota were the reptile Yabeinosaurus tenuis (Young, 1958), the mammal Liaotherium gracilis (Zhou et al., 1991) and the acipenseriform fish Liaosteus hongi (Lu, 1994) from the Haifanggou Formation in Liaoning. In recent years more vertebrates, including fishes, amphibians, lizards, pterosaurs, dinosaurs and mammals, have been discovered and described from the Lanqi Formation at various localities in Inner Mongolia, western Liaoning and northern Hebei (Wang, 2004; Ji and Yuan, 2008; Zhang et al., 2008; Evans et al., 2009; Hu et al., 2009).

The vertebrates from both the Haifanggou and Lanqi formations include: Liaosteus hongi and an undescribed palaenisciform fish (personal observation by F.J.); four genera and species of salamanders, Chuenerpeton tianyiensis, Jeholotriton paradoxus, Liaoxiuriton daohugouensis and Pangerpeton sinensis, and an unnamed juvenile anuran (Wang et al., 2010); “Yabeinosaurus tenuis” (Young, 1958) and two other unnamed lizards (Evans and Wang, 2009); five genera and species of pterosaurs, Changchengopterus pani, Darwinopterus modularis, Jeholopterus ningchen-
genera, *Pterorhynchus wellhoferi*, and *Wukongopterus li* (Wang et al., 2009; Lü et al., 2010); four genera and species of theropod dinosaurs, *Anchiornis huaxi* (Hu et al., 2009) *Epipodophus ningchengensis* (=*Scanoripteryx heilinmanni*), *Epipodophus hui*, and *Pedopenna daohugouensis*; and four genera and species of mammals, *Castorocauda lutrasimilis*, *Liaotherium gracile*, *Pseudotribos robustus* (Ji and Yuan, 2008) and *Volaticotherium antiquum*.

**Comparison and Discussion**

The Yanliao Biota and the Jehol Biota represent the two most important late Mesozoic lagerstätten in Northeast China. They shared a similar paleo-geographic distribution. The vertebrate assemblage from the Jehol Biota in western Liaoning, northern Hebei, and southeastern Inner Mongolia currently comprises, at generic level, approximately 31 birds, 30 dinosaurs, 16 pterosaurs, 13 mammals, five lizards, five choristoderes, two turtles, eight amphibians, and seven fishes as well as one agnathan, a total of 118 genera (Zhou and Wang, 2010). The Yanliao vertebrate assemblage currently comprises a much lower generic diversity with one fish, four salamanders, one lizard, five pterosaurs, four dinosaurs, and four mammals, as well as several unnamed taxa of fishes, frogs and lizards. Compared to the Jehol Biota, the Yanliao Biota lacks any record of teleost fishes, birds, choristoderes or turtles. Its relatively much lower vertebrate diversity can be at least partly explained by preservational and sampling bias. On the other hand, the great vertebrate diversity of the Jehol Biota also reflects the evolutionary radiation of major groups such as birds, dinosaurs, pterosaurs and mammals in the Early Cretaceous, a radiation that continued into the Late Cretaceous.

The Yanliao Biota and the Jehol Biota share some faunal components: the squamate *Yabeinosaurus* is reported from both biotas, though the identification of the older specimen is uncertain; the acipenseriform *Liaosteus* from the Yanliao Biota is referred to the same subfamily, Spherosteiinae, as *Yanosteus* from the Jehol Biota (Jin, 1999); the pterosaurs *Jeholopterus* from the Yanliao Biota and *Dendrorhynchoides* from the Jehol Biota both belong to the family Anurognathidae (Wang et al., 2002); and two species of the salamander *Liaoxiatrix* have been reported from the Yanliao and Jehol biotas, respectively (Wang, 2004). These similarities have led to the proposal that the Yanliao Biota represented a “Pre-Jehol Biota” (Zhang, 2002; Meng et al., 2006). However, there appears to be a clear interval between the Yanliao and Jehol biotas spanning the latest Jurassic and the earliest Cretaceous. The thick deposits laid down during this interval are generally referred to the Tuchengzi Formation (or Houcheng Formation in Hebei), previously considered Late Jurassic in age but currently dated as approximately 139-156 Ma (Zhou et al., 2009). Vertebrate fossils are rare and include palaeciosiform fishes and the ceratopsian dinosaurs *Chaoyangosaurus* and *Xuanhuaceratops* (Zhao et al., 2006). Despite the lasting controversy over the continental Jurassic-Cretaceous boundary in China (Zhou et al., 2009), we consider that the J-K boundary probably lies within the Tuchengzi Formation.

Many of the Yanliao vertebrates bear some resemblance to those of other localities in Central and East Asia, and also Europe. The pterosaur *Jeholopterus* from Inner Mongolia belongs to the same rhamphorhynchoid family, Anurognathidae, as *Anurognathus* from Solnhofen, Germany (Upper Jurassic) and *Batrachognathus* from Karatau, Kazakhstan (Upper Jurassic). Among mammals, *Liaotherium* is related to *Amphilestes* from the Middle Jurassic of Europe (Ji and Yuan, 2008); *Castorocauda* is a member of the Docodonta, also known from the Middle-Upper Jurassic of Europe and Xinjiang; and *Pseudotribos* is related to *Shuotherium* from the Upper Jurassic of Sichuan, Southwest China (Wang et al., 2006). The Yanliao palaeciosiform fishes closely resemble *Pteroniscus* from Karatau, Kazakhstan, and *Jeholotriton* and *Pangerpeton* are stem caudates as is the Karatau genus *Karaurus*.

Some paleobiogeographic barriers (e.g., Okhotsk Sea and Bering Sea) may have limited faunal exchange from the Middle Jurassic onward, but the fauna in Asia was probably never completely isolated from that of Europe in the Middle and Late Jurassic. By the Early Cretaceous, the disappearance of paleogeographic barriers had resulted in a more global distribution of vertebrate groups with the exception of freshwater fishes.

From the Middle Jurassic to Early Cretaceous, Northeast China underwent a period of tectonic activity with frequent volcanic eruptions. Ash beds are often interbedded with fossil-bearing fluvial or lacustrine deposits due to the Yanshan Orogeny and the destruction of the North China Craton. We consider that the evolutionary period between the Yanliao Biota and the Jehol Biota was punctuated by a long interval of dry climate, during the deposition of the Tuchengzi Formation. More fossil discoveries from this formation should help to clarify the transition between the two major terrestrial biotas of this region.

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**Key words:** Yanliao Biota; Jurassic; Vertebrate assemblage; Northeast China

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Late Early Jurassic Floras in the North of China and Their Palaeoclimate Implications

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The terrestrial upper Lower Jurassic strata are extremely developed in China, of which those in the South of China are chiefly composed of red beds, usually without plant fossils; while the other in the North of China are consist of coal-bearing or no-coal sediments containing abundant plant fossils (Deng et al., 2003). These strata include the Sangonghe Formation of the Junggar and Turpan-Hami Basins of Xinjiang (Deng et al., 2000; 2010), the Tianshuigou and Yinma-guo Formations of the Qidam Basin (Li et al., 1988), Qinghai Province, the Fuxian Formation of the Ordos Basin of Shaanxi Province (Huang et al., 1980), the Jiashan Formation of Northern Hebei Province (Wang, 1984), Alatanheli and Nansuletu Formations of Inner Mongolia (Wang, 1984), and the Beipiao Formation of Liaoning Province (Mi et al., 1996), which all yield abundant plant fossils.

Based on the fossils from the above formations, the main characteristics of late Early Jurassic floras in the North of China are summarized. The florae are of less abundance and lower diversity compared with the earlier or later ones in every locality, generally consisting of one or two dozen species, and only in a few localities over 50 species. The florae are usually dominated by ferns and Ginkgopsida, with many Cycadopsida, some sphenopsids and conifers. It is noticeable that the florae are obviously different from the ones of both the underlying and overlying strata in having more thermophilous or arid-tolerant elements, which include ferns belonging to the Dipteridaceae, Matoniaceae, Marattiaceae, Schizaceaeae and Glei-cheniaceae; Otozamites, Zamites and Ptilophyllum of the Bennettitalean, Hirmeriellae, Brachyphyllum and Pagiophyllum of the Cheirolepidiaceae (conifer) and also some Gnetalean plants, such as Ephedrites and Cadmisega ephedroides.

The high content of these thermophilous and arid-tolerant plants indicate that the climate in the North of China during the late Early Jurassic is hotter and more arid than that of the earlier and latter periods, which is possibly linked with the Toarcian palaeoenvironment event (Vakhrameev, 1991).

Additionally, palynological analysis has also indicated sharp content peaks (usually 50%-70%) of the cheirolepidiaceous pollen Classopolis, which is considered as a good hot and arid climate indicator (Vakhrameev, 1991), appear in the plant fossil-bearing beds. This supports the palaeoclimate changing during the late of the Early Jurassic in the North of China.

Key words: Upper of the Lower Jurassic; Flora; Toarcian; Palaeoclimate; North of China

References:
Jurassic Fossil Vertebrate Fauna in North Xinjiang

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North Xinjiang not only contains rich oil resources, such as Junggar basin and Turpan-Hami Basin, but also has yielded many vertebrate fossils. There are widely developed Jurassic strata in north Xinjiang area. Abundant fossil vertebrates have been discovered in the area. Therefore the area has attracted general attention by stratigraphy paleontologists over a long period of time.

The first research on paleovertebrate in this area commenced in early 19th century until new China is founded. Many Chinese and overseas geologists participated in the job, such as the Sino-Swedish scientific Expedition to the North-Western Province of China (1927-1935) joined by the founder of Chinese paleo-vertebrate Yang Zhongjian, Yuan Fuli etc. The initial description and taxonomy toward the early fossil vertebrate in the Junggar Basin had been made during this period. When new China is founded, with large-scale petroleum expedition and geology investigation, systematic stratigraphy paleontology researches have been made in the Junggar Basin in 1960s and 1990s, respectively. And a series of fruits and monographs (Zhao, 1980; Eberth et al., 2001; Deng et al., 2003) have been published. Especially the Sino-Canadian dinosaur expedition plan performed in the late 1980s, abundant and significant discoveries have been made in north Xinjiang (Currie and Zhao, 1993; Zhao and Currie, 1993); with the constant endeavor of paleontologists, a series of important fossil vertebrates in-cluding dinosaurs, crocodiles and mammalians have in succeSSION been discovered at the south border of the Junggar Basin, Wucaiwan and Jiangjunmiao.

With nearly hundred years of researches, systematic biology framework and evolution sequence of paleovertebrate in north Xinjiang area have been erected. As the introduction of cladistic systematics and bone histology, the research methods for paleo-vertebrate have been developed from qualitative characteristic description to quantification. These new methods have greatly improved the research on Jurassic paleovertebrate in north Xinjiang area, not only provide convinced evidence for stratigraphic comparison but also more precise information for biological evolution and taxonomy are provided.

Vertebrate fossils at the Junggar Basin are abundant with a long research history. Fossil vertebrate in the Lower Jurassic Junggar Basin is rare. No determined genus or species of fossil vertebrate in the basin is discovered with the exception of some occasionally discovered scales of Ganoid. Whereas fossil vertebrates are frequently discovered in the Middle-Upper Jurassic strata. Among which the fossil vertebrates of the Middle Jurassic are mainly distributed in the lower Shishugou Group at Jiangjunmiao, eastern basin. The stratum was named as Wucaiwan formation by Zhao Xijin et al. Currently known species include fish, amphibian, terrapin, saurian, crocodile, dinosaur, Mammal-like reptile and mammalian. Furthermore, dinosaur tracks were discovered at the Xishanyao Formation of the southern basin, while Ankylosauria were yielded from the Toutunhe Formation; the fossil vertebrates in the Upper Jurassic are even richer both in species and quantity, mainly discovered at the Qigu Formation of the southern border of the basin and the upper Shishugou group (Shishugou formation as its another term) of the eastern basin. The majority fossils yielded from the Qigu Formation are fish, crocodile and dinosaur; the remains from the Shishugou Formation include amphibian, terrapin, crocodile and dinosaur. In addition, some scattered fossil remains were recently discovered in the Toutunhe Formation of the southern border of the basin in succession (Maisch et al., 2003a, b).

Few researches has been performed on the vertebrate fossils at the Turpan-Hami Basin, the distribution of fossil vertebrates in the Turpan-Hami Basin is similar to that of the Junggar Basin, which is mainly distributed in the Middle-Upper Jurassic strata. For instance, fish scales were discovered at the Middle Jurassic middle Qiketai Formation, fragmentary limb...
bones of basal carnivorous dinosaur were yielded from the Upper Jurassic Qigu Formation at Yingzuishigou, Qiketai, Shanshan county, abundant limb bones and vertebrae of terrapin and Coeluridae were discovered at the upper Qigu Formation. Partial dinosaur fossils were discovered at the interlayer of grey-green sandstone and dust-colour mudstone at the lower Kalazha Formation. In addition, a few fragmentary terrapin, fragmentary remains of Sauropoda and other phylum of dinosaurs plus crocodile remains were discovered at Kalazha formation as well.

The fossil records suggest, the general feature of vertebrate fauna in the Middle-Upper Jurassic at north Xinjiang is predominated by reptiles, especially featured by gradually flourishing of dinosaurs accompanied by a few fishes. Mammalian was in starting stage in the Jurassic period, whereas amphibian, which flourished in Paleozoic was significantly reduced in quantity, only the survived genus and species of labyrinthodont Amphibians were discovered. Therefore, both mammalian and amphibian are not predominated either in variety or in quantity. In the last decade, with profound research on paleovertebrate fauna in north Xinjiang, a series of important fossils were obtained. Not only do these discoveries contribute to the variety degree of regional fauna, but also reveal and improve the major evolution sequence for many phyla and the fauna feature in partial stratigraphy.

Recent works on the North Xinjiang have increased the number and biodiversity of animal genera; it is predictable that, with further development of the research, more evidences for the biodiversity of evolution will be provided, that would exert positive action on the division and correlation of stratigraphy, or confirming the geology age. The prospect is brightening.

**Key words:** Jurassic; Junggar Basin; Vertebrate fossil; North Xinjiang

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Evidences of Vertebrate Activity Recorded in the Lower Jurassic Continental Deposits of the Steierdorf Formation, SW Romania

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The Steierdorf Formation, Hettangian-Sinemurian in age is known from the south-western part of Romania within Resita Basin. The fully developed and best exposed strata have been recognized at the Anina town, where the deep coal mine operated since XVIII century. The continental deposits of the Steierdorf Formation are composed with two distinctive members i.e. Dealul Budinic and Valea Tereziei. The boundary between them have been appointed at the pyroclastic layer, which is traceable along the whole quarry at distance about 3 km.

The Dealul Budinic Member is mainly composed of matrix supported conglomerates and very coarse-grained sandstones with subordinate amount finer deposits like medium- to fine-grained sandstones and mudstones. The deposits are usually massive, only in a few cases the clasts’ imbrication or large-scale cross bedding have been observed. The typical sequence starts with conglomeratic layers up to 5 m thick, containing chaotically dispersed pebbles ranging even 15 cm in diameter. At the base of that layers the erosional surfaces have been found. At the top of several sandstone bodies the oval blocks with secondary ferroxide crust are visible. The lithofacies associations and other sedimentary features of the Dealul Budinic Member are indicative for alluvial fan environment. The red colorization of the sediments was connected with oxidation of detrital hematite under warm moist climate. Lack of plant remains and red colorization of the sediments confirm highly oxidative conditions. The periodic drying out of the sediments with high content of clay mineral produced desiccation cracks, now visible as coated oval blocks. The presence of the matrix supported conglomerates and very coarse grained sandstones with dispersed pebbles suggest high viscosity flows and deposition without any hydrodynamic fractionation. The finer sediments, including bounding pyroclastic layer, were accumulated in areas of coalescing individual lobes or central depressions developed at the top of the alluvial fan. Heavy rainfalls causing extreme runoff, washed down weathered sediments from the source areas. All these features are indicative for monsoonal climate with clearly established wet and dry periods.

The Valea Tereziei Member at the lower part show similar sedimentary features, however the content of the coarsest sediments decreases. The deposits are mainly composed of coarse- and medium-grained sandstones with subordinate amount of mudstones. Among red facies occur first gray layers, containing coalified plant remains. It is transition between alluvial fan deposits and truly fluvial environment. This part represents a braided channels developed at the top of alluvial fan. Above, the coal-bearing succession is observed. The succession contains up to 7 coal-seams of the variable thickness, nowhere exceeding several dozens of centimeters. The typical in-channel sedimentary sequence starts with erosional surface, above which rest clast supported conglomerates passing into coarse-, medium- and fine-grained sandstones followed by mudstones and coals or coaly shales. Fully developed sequences are relatively rare and reduced sequences predominate ending with coarse- and medium-grained sandstones. The conglomerates are usually massive, whereas sandstones show large-scale cross bedding and ripple lamination. In the proximity of coals the primary sedimentary structures have been destroyed by dense root systems. Those parts, which are composed of fine-grained sandstones interbedded with mudstones and phytogenic sediments are interpreted as repre-
sented overbank areas as natural levee, crevasse channels and crevasse splays. The content of the clastic fines is relatively small, rarely exceeding 25% and in-channel deposits predominate. The shape of the channel bodies, high interconnectedness ratio, overall in-channel deposits structure suggest deposition within active channel tracts constructed by braided river system.

The first evidences of the vertebrates activity have been noted just below of the pyroclastic layer within underlying red-colored mudstones. These trace fossils can be divided into two groups: linear and spiral (Popa and Kędzior, 2006). The linear type is represented by cast structures up to 150 cm long and 40 cm wide. The shape is strongly elongated, sometimes dichotomously divided. In one place a sharp with lateral striation trace fossil has been found suggesting digging with claws. The rest is rather evidences for digging of the burrows used for example as a hiding place against high insoluation, similarly to recent crocodiles, which dig holes in river’ banks. The second type of the trace fossils have been found as an isolated occurrence. The spiral shape is perpendicular to the bedding surface, with a ferroxide crust at the contact between trace infill and surrounding deposits, resembling also seleridic concretions as well.

With the transitional zone between alluvial fan and fluvial environments are connected another trace fossils related to vertebrates (see Pietkowsk et al., 2009). These troves have been found several meters above bounding pyroclastic layer and represented by sauropods tracks and trackway are evidences of the earliest vertebrate findings in Romania. The features of the trace fossils are indicative for heteropodous animals, and points out a sub-plantigrade pes and gravipodal posture, typical for Eusaropoda. A pentadactyl manus imprint suggests that manus digits of early sauropods might have been separate and perhaps more functional when supporting walking on unstable, sticky ground (Pietkowsk et al., 2009). The climatic conditions during accumulation sediments of the Valea Tereziei Member were probably the same like in the older unit, what was demonstrated by Popa and Van Konijnenbrug-Van Cittert (2006). These authors interpreted the palaeolatitude of the Resita Basin as between 20° and 30° north.

The youngest vertebrate trace fossils have been found within the coal-bearing succession, at its lower part (Popa, 1999). The foot-prints have been left by small tetrapods belonging to Batrachopus cf. deweyi an crocodylomorph ichnogenus (Olsen and Padian, 1986). It is not excluded that the same type of animals made the burrows, which have been found at the top of the Dealul Budinic Member.

The Resita Basis, which nowadays is located in the Southern Carpathians, during the Lower Jurassic Series probably constituted a part of the Moesian Plate. Several papers demonstrate that the Moesian plate was an island located southward of Eurasia (Blackley, 2009; Golonka, 2004., Golonka et al., 2005). The current observations do not confirm such thesis that are in opposition to the opinions expressed by Romanian geologists. The presence of the sauropods implicate a stable connection between Eurasia landmass and Moesia to allow migration of sauropods. Moreover, the size of the sauropod cf. Parabrontopodus isp. foot prints from Romania is typical of Early Jurassic sauropods and does not differ from those from Poland and Italy and do not prove insular dwarfism, what would be expected in the case of long-lasting island conditions (Pietkowsk et al., 2009).

**Key words:** Lower Jurassic; Romania; Continental deposits; Vertebrate trace fossils

**References:**


Middle Callovian-Upper Oxfordian Corals from Middle Shale Member of Qaleh Dokhtar Formation-Tabas Area (Central Iran)

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The east-central sea had its greatest extent in the late Middle Jurassic and early Late Jurassic time. In the Shotori Range and in the Tabas area (East Iran), the Baghamshah Formation (marly shale with some salt and gypsum) follows conformably above the Badamu Limestone. The Baghamshah Formation is conformably overlain by the Esfandiar Formation or, in the NE part of the Shotori Range, by the western Qaleh Dokhtar Formation. In the W part of the Shirgesht area the formation becomes increasingly sandy (Ruttner, Navabi and Hajian, 1968). It resembles the well-known sandy facies of the Middle Jurassic in the Kerman area (Hojedk Formation). Upper Jurassic rocks of Callovian-Oxfordian-Kimmeridgian age conformably overlay the Baghamshah Formation. Two different facies are to be distinguished: a massive reef limestone (Esfandiar Formation), and sandstone and shale together with thick-bedded detrital and oolitic limestones (Qaleh Dokhtar Formation). Both formations represent nearly the same stratigraphic interval and interfinger in the northern part of the Shotori Range. The upper limit of the Qaleh Dokhtar Formation is an erosional surface unconformably overlain by Cretaceous and/or Tertiary formations. The Qaleh Dokhtar is considered to be a kind of back reef facies developed in the East of the district. The upper limit of the Esfandiar Limestone is an erosional surface unconformably covered by Tertiary or, in some places, by Cretaceous rocks.

The Qaleh Dokhtar Formation with up to 900 meter thickness is divided to 3 members with an underlying Baghamshah Formation. The contact is covered by terrace deposits, but the typical pale-green marly and silty shales of the Baghamshah are well exposed in a row of shafts starting only a few meters away from the lowest exposed sandstone bed of the Qaleh Dokhtar and indicate a sharp lithological break but no visible unconformity. These three members are:

The Lower Sandy Member, composed of alternating grey quartzitic sandstone and brown calcareous sandstone.

The Middle Shale Member, composed of marly, sandy and silty shales with thin intercalations of limestone and fine-grained sandstone; yellow-green to brown-green to dull green-grey colors; with conspicuous dark-grey coral bed in the middle part.

Upper Calcareous Member, consisting of thin bedded limestones and calcareous shales. The limestones are partly dense, argillaceous, and partly sandy-detrital, including also some oolitic beds; light-blue color predominates, locally with irregular, brown, dolomitized patches.

This Formation is truncated and unconformably overlain by Cretaceous rocks.

Jurassic rocks are widely distributed and superbly exposed in the Shotori Range (Tabas area) of east-central Iran. The corals of Qaleh Dokhtar Formation are the scope of this paper.

The corals of Middle Shale Member of the Formation were studied. This study resulted in the recognition of 12 genera and 16 species that are as follows:

*Amphaistrea piriformis* Gregory, *Heliocoenia variabilis* Etallon, *Microphyllia contorta* (Koby),
Ovalastrea sp. A, Pseudocoenia slovenica Yurnsek, Pseudocoenia sp., Stylina girodi Etallon, Stylina sp., Trigerastraea serialis (Milne-Edwards and Haime), Thecosmilia longi Koby, Dimorpharaea iranensis Dhirendra K. Pandey, Dimorpharaea sp., Montlivaltia decipiens (Goldfuss), Actinastrea sp.

Previous studies (e.g. Stocklin et al., 1965; Ruttner et al., 1968) of Jurassic strata of the Sholori Range were mainly concerned with mapping. These authors broadly characterized the Qaleh Dokhtar Limestone Formation as back reef sediments. Stratigraphical studies show that sedimentation occurred in a shoreline environment. The sedimentation was controlled by changing depth within the littoral zone. Probably orogenic activity and climatic changes were responsible for shale and marl sediments in cold waters and limestones were deposited in a warm climate. The corals studied belong to a hermatypic fauna which developed in natural and suitable conditions. The assemblage of corals evolved in the back reef of Middle Callovian-Upper Oxfordian age in the Tabas area.

Key words: Paleoenvironment; Middle Callovian-Upper Oxfordian; Corals; Qaleh Dokhtar Formation

References:
Mineralogical and Geochemical Evidence of Sea Level Changes and Diagenesis of the Middle Jurassic Golden Oolitic Grainstones, Kachchh Basin, Western India

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The Kachchh sedimentary basin filled up with 5000 to 8000 ft. of Mesozoic sediments and 1800 ft. of Tertiary sediments which are covered by Recent sediments of the Rann and Banni. The Mesozoic sediments deposited during the Middle Jurassic to Lower Cretaceous are exposed in six highland area, these are the “Kachchh Mainland” near the depocentre; Pachham Island in the northern part of the basin and the Khadir, Bela, and Chorar Islands and Wagad, in eastern Kachchh. Each highland area has its distinctive facies related to its place within the basin.

The basin framework, palaeoenvironment and depositional history of the Mesozoic sediments of Kachchh have been described in detail by Biswas (1981). Biswas (1977) has classified the Jurassic succession exposed in the Kachchh Mainland into four formations, namely the Jhurio, Jumara, Jhuran and Bhuj Formations respectively.

In its type section in Jhura Dome, the Jhurio Formation is exposed as thick sequences of limestones and shales with bands of golden oolites which form the lower part of the Mainland stratigraphy. The formation is exposed as small inliers in the three hills which are large domal structures, along the northern margin of Mainland - Habo, Jhurio and Jumara from east to west (Fig. 1). In the Jhura Dome the entire hill is composed of the Jhurio Formation and numerous good sections is exposed in radial streams. The Jhurio Formation dates back to Bathonian times as indicated by the ammonite faunal association of Macrocephalites (first occurrence) and Sivajiceras congener (Callomon, 1993; Khadkikar, 1996).

Previous researchers have not carried out any mineralogical or geochemical studies on the Middle Jurassic deposits of the Kachchh Sedimentary basin. The present study therefore focuses on the mineralogy and composition of the Golden Oolitic limestones, thereby establishing the sea-level changes and diagenetic pathways of the Middle Jurassic of the Kachchh Basin (western India). The Golden Oolitic Grainstone Facies deposited during Middle to Late Jurassic Period shows remarkable condensed horizons within the Golden Oolitic Limestone-Grey limestone Lithofacies, (association (LFA-1)), in its type section.

The field evidence of cyclic sedimentation, as well as the fossil content, original aragonitic mineralogy, presence of low-magnesian calcitic (LMC) mineralogy and the golden yellow to dark brown laminae over the ooidal grains are the evidence, meticulously collected with the detailed petrographic studies, which suggest a peritidal shoaling environment for these facies. X-ray Diffractometer (XRD) results show predominant LMC-mineralogy along with secondarily dominant goethite mineralogy of the individual golden ooids, and equally dominant LMC and goethite mineralogy of the golden coloured cement matrix. The geochemical analysis of representative samples of Golden oolitic grainstones also support the original aragonitic mineralogy. The textural maturity of coated ooids and bioclasts, the mineralogical composition of oolitic grainstones and the geochemical results confirm the shoaling peritidal environment of the facies developed during a Highstand System Tract (HST) within a major third order Transgressive System Tract (TST) across the Kachchh Sedimentary Basin. The source of the iron coating of the ooids and bioclasts, is evidenced by the short lived episodes of magmatic activity during the genesis of mid-oceanic system between greater India and Africa. Low Magnesian Calcite (LMC) mineralogy is contributed by burial and followed by the fresh water diagenesis in the near surface conditions. The iron oxide changed to goethite, with a tarnished golden oolitic colour due to oxidation while exposed to a warm and humid climate at the surface that occurred in the basin area during the latter stages of uplift and exposure to chemical weathering dominated by surface water percolation and oxidation.

Key words: Jurassic; Golden oolitic facies; Kachchh Basin; India
Fig. 1 Location map of Kachchh

References:
Evolution of a Carbonate-Platform-Complex in Response to Plate-Tectonic Forcing (Jurassic, Western Neotethys, Evvoia, Greece)

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The tectono-sedimentary interplay between ancient carbonate platforms and ocean basins is not always recognisable as the oceans involved are only rarely preserved. This study investigates the evolution of a carbonate-platform-complex of mainly Jurassic age and its adjacent ocean through a succession of different plate tectonic episodes. Time-lapse views can be reconstructed of a plate polarity change from divergence to convergence that took place during the Early Jurassic and ended with inter-plate collision and ophiolite obduction at the end of the Jurassic. The effects of ocean-floor spreading, convergence, pending collision and obduction are stratigraphically documented, showing that carbonate platforms are sensitive recorders of changing tectonic environments. This integrated approach also takes into consideration the tectono-sedimentary evolution of the study area in a regional context.

The area under investigation is in the Pelagonian zone of the Hellenides where Late Triassic and Jurassic platform formations have been overthrust by nappes of a well known oceanic ophiolite complex. The early history of this region began during the Triassic with the break-up of Pangaea which resulted in the creation of micro-continental plates, having granitic basements and passive margins adjacent to newly forming oceanic lithosphere. The closure of the Meliata-Maliac-Vardar branch of the Neotethys during the Jurassic culminated with the obduction of oceanic crust onto the Pelagonian micro-continent. The present theme concerns the interplay of sedimentation and plate-tectonics and it focuses on well preserved remnants of the Vardar ophiolite that were emplaced over the carbonate successions of the Pelagonian platform.

Platform Evolution and Plate-tectonic episodes a–e are depicted in Figure

Platform Evolution and Plate-tectonic episodes a–e

a. Ocean spreading during Late Triassic and Early Jurassic, as confirmed by radiolarian biostratigraphy, shows that ocean spreading was underway during the Middle to Late Triassic. During the same time period, the Pelagonian platform was a subsiding passive margin where a long-persisting, Norian to Sinemurian, peritidal carbonate platform evolved.

a-b. Plate polarity changed from divergence to convergence about the late Sinemurian to Pliensbachian and coincided with the onset of incipient platform...
drowning.

c. Intra-oceanic supra-subduction intrusions of sub-volcanic dolerite occurred during the Middle Jurassic and formed a primitive arc, covered by pillow basalts and radiolarites. The Pelagonian platform was the site of deeper water carbonate deposition during early plate convergence.

d-e. Initial inter-plate collision took place about late Middle Jurassic between the oceanic arc and the Pelagonian platform. This event correlates with the uplift of the oceanic arc-formations above the carbonate compensation depth (CCD) and, in the course of its obduction, this volcanic pedestal became a so-called piggy-back platform. The collision apparently caused thrust-faulting on the Pelagonian platform, where uplifted areas became the sites of erosion and later, during the Late Jurassic, pedestals for reefs. In the regional context, Middle Jurassic disconformities also occurred throughout the western Tethys.

e. As the ophiolite became emplaced, during the late Tithonian to Valanginian, nappe-loading forced the drowning of the entire Pelagonian carbonate-platform-complex below the CCD. Platform thrust-packages in front of the ophiolite nappes were transported over a décollement and thus escaped subduction metamorphism.

The timing of tectonic forcing in a regional context

An important question concerns the polarity change that occurred during the Early Jurassic: What caused the spreading to stop and convergence to begin? A second question concerns the late Middle Jurassic emergent surfaces observed not only in the study area but throughout the western Neotethys. Although the emergent surfaces of the study area can be directly attributed to the inter-plate collision of the Vardar ophiolite with the leading edge of the Pelagonian plate, this collision alone can hardly have been the fundamental cause of the Middle to Late Jurassic gaps observed across the western Neotethys, for example, in the Dinarides, in western Greece, in the NW-Sicilian Panormide block and extensively in SW-European platforms. In addition, the stratigraphic depth to which erosion extended differs greatly from place to place, suggesting that tectonic movements of different intensities were involved. Both of the above posed questions can be resolved, however, by considering the far-reaching plate-tectonic processes that are reported to have started around the late Sinemurian: the Atlantic Ocean and the Alpine Tethys became the new active centres of spreading. They were being supplied with enormous amounts of sub-lithospheric mantle material - enough to construct oceanic lithosphere over 100 km thick. It is postulated here that sub-lithospheric mantle material was being removed laterally, by processes of convection, viscous flow and dislocation creep, from beneath the western Neotethys towards the new spreading centres. This fundamental process is thought to have caused horizontal compression in the lithosphere across the entire region, forcing the cessation of spreading of the Vardar Ocean and initiating conversion that led to intra-oceanic subduction, followed by collisions and widespread epeirogenic movements across the western Neotethys.

Key words: Carbonate platforms; Oceanic lithosphere; Plate collision; Obduction

Reference:
Paleogeography of the Bathonian Basins of Georgia

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In the history of the geological development of Georgia, the Bathonian period appears particularly interesting as it was the time of considerable transformations in the tectonic as well as the paleozoogeographic sphere. The Bathonian formations on the territory of Georgia (Fig.1) are represented by flysch, flysch-like, epicontinental and lake-lagoon deposits and are bound with the Fold system of the Greater Caucasus (I), South Caucasian intermontane area (II) and the Fold system of the Lesser Caucasus (III).

There are many works giving a detailed description of the geological conditions of the Bathonian basins formation process as well as the paleogeographical issues (Dzotsenidze and Skhirtladz, 1961; Rostovtsev, 1978; Topchischvili et al., 2006).

A.Tsagareli and M.Eristavi (1977) were among the first researchers studying the paleogeography and paleozoogeography of the Caucasus in the Mesozoic period. On the bases of the paleontological material analysis the authors came to the conclusion that during the Mesozoic period the migration routes and the fauna composition in the Caucasus were considerably changing and that the Caucasus should be researched as an independent paleo-geographical area. Later on Rostovtsev K. (1978) made a zoogeographical division of the Caucasian seas and singled out the North Caucasian, South Caucasian, Lesser Caucasian and Nakhitchevanian zoogeographical provinces in the Middle Jurassic period. According to the author’s data, in the Late Bajocian period the representatives of the Middle European and Mediterranean ammonites were commonly occurred in the Caucasian province. As to the Bathonian fauna, only the ammonite fauna of the Lesser Caucasus is discussed there. In that work the Bathonian zoogeographical situation and the corresponding fauna of the ammonites of the South Caucasian province were not discussed. Most probably the author was not acquainted with the description of representatives of families *Oecotraustes*, *Cadomites*, *Sphaeroceras*, *Morphoceras*, *Ebrayiceras* from the Lesser Caucasian province (Zesashvili et al., 1977).

New paleontological materials accumulated in recent years allows for bringing some alternations into existing image of paleozoogeography of the Caucasus in the Bathonian period.

The strong Bajocian – Bathonian regression in the South Caucasus resulted in the emergence of a vast land mass with small sea basins. They connected to the neighbouring seas but it is difficult to trace the connection precisely.

On the territory of Georgia four separate sea basins were formed (Fig.1): 1. Flysch-like (Novo-rossiysk-Toapse Zone), 2. Flysch (Chkhalta-Laila, Mectia-Tianeti and Kazbegi-Lagodekhi Zones), 3. Epicontinental (Gagra-Java Zone: in Abkhasia - the basin of Bitaga, Gega and others; in Racha – the basin of the Rioni-Kvirila rivers) and in South-East Georgia (the Lesser Caucasus – Locki-Karabakh Zone) and 4. Lake–lagoon (the southern periphery of the Gagra-Java Zone of the Fold system of the Greater Caucasus - Bzibi, Magana, Tkvarcheli) and in the Central Zone of the uplift of the South Caucasian intermontane area: the coal-bearing basins of Kutaisi, Gelati, Tkibuli.

Fig.1 Outlines of the Bathonian basins of Georgia
The sea fauna found in the flysh-like and epicontinental basins of Abkhasia and the Lesser Caucasus is of Early Bathonian age while that of Racha is of Middle and Late Bathonian age (Table 1).

The analysis of the paleontological materials has brought us to a well-grounded conclusion that the territory of Georgia during Bathonian belonged to the Submediterranean paleozoogeographic Province of the Mediterranean Realm (Pan-Tethyan Superrealm).

Thus, on the basis of examining new geological materials and the analysis of the already existing paleogeographic maps, we managed to retrace changes in the configuration of the Bathonian sea and lake-lagoon basins on the territory of Georgia and present new paleogeographic maps.

**Key words:** Paleogeography; Georgia; Bathonian; Submediterranean province

**Table 1** Stratigraphic distribution of the South Caucasus Bathonian Ammonites

<table>
<thead>
<tr>
<th>Genera</th>
<th>South slope of GC</th>
<th>Lesser Caucasus</th>
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<tbody>
<tr>
<td></td>
<td>Abkhasia</td>
<td>Racha-Kudaro</td>
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<tr>
<td>1. <em>Adabofoloceras</em></td>
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<tr>
<td>3. <em>Pseudophylloceras</em></td>
<td>L -</td>
<td>-</td>
</tr>
<tr>
<td>4. <em>Calliphylloceras</em></td>
<td>L M U</td>
<td>-</td>
</tr>
<tr>
<td>5. <em>Eurystomiceras</em></td>
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<td>-</td>
</tr>
<tr>
<td>6. <em>Dinolytoceras</em></td>
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</tr>
<tr>
<td>7. <em>Nannolytoceras</em></td>
<td>L -</td>
<td>-</td>
</tr>
<tr>
<td>8. <em>Thysanolytoceras</em></td>
<td>M U</td>
<td>-</td>
</tr>
<tr>
<td>9. <em>Lissoceras</em></td>
<td>M U</td>
<td>U</td>
</tr>
<tr>
<td>10. <em>Oxycerites</em></td>
<td>L M U</td>
<td>U</td>
</tr>
<tr>
<td>11. <em>Oecotraustes</em></td>
<td>L M U</td>
<td>-</td>
</tr>
<tr>
<td>15. <em>Hemigarantia</em></td>
<td>- -</td>
<td>-</td>
</tr>
<tr>
<td>16. <em>Homoeoplanulites</em></td>
<td>M U</td>
<td>-</td>
</tr>
<tr>
<td>17. <em>Flabellisphinctes</em></td>
<td>M U</td>
<td>-</td>
</tr>
<tr>
<td>18. <em>Planisphinctes</em></td>
<td>- -</td>
<td>-</td>
</tr>
<tr>
<td>19. <em>Siemiradzkia</em></td>
<td>M U</td>
<td>-</td>
</tr>
<tr>
<td>20. <em>Morphoceras</em></td>
<td>- -</td>
<td>U</td>
</tr>
<tr>
<td>21. <em>Ebrayiceras</em></td>
<td>- -</td>
<td>U</td>
</tr>
<tr>
<td>22. <em>Bucegia</em></td>
<td>- -</td>
<td>-</td>
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</tbody>
</table>

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The Palaeogeographical Evolution of the Iberian Plate during the Jurassic Comparison of Iberian Palaeomagnetic Data with Data from the African, Eurasian and North American plates


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During the Mesozoic, the Iberian microplate occupied a tectonic key position between the African, Eurasian and North American plates and its evolution was related to the movement of these major plates, the opening of the Atlantic and the kinematics of the Tethys. However, the Apparent Polar Wander Path (APWP) of Iberia is still poorly defined and previous attempts to use palaeomagnetic data to test geodynamic models proposed for the Iberian evolution failed, because the reliable palaeomagnetic information was not resolution enough. To investigate the consistency between the palaeomagnetic information and the tectonic models proposed for the western Mediterranean, a revision of Jurassic palaeomagnetic data from Iberia has been carried out. Due to the presence of a widespread (but partial) remagnetization which affected most Jurassic sediments in Iberia, selection criteria have been designed to avoid completely remagnetized sites. A total of 72 sites have been considered for the palaeomagnetic discussion (35 sites from the Messejana–Plasencia dolerite dyke, 14 sedimentary sites from the Iberian Range and 23 sites from the Betic Cordillera). Three palaeopoles for Iberia have been selected (from the Iberian Massif and from the Iberian Range) for the period around 200 Ma (Triassic–Jurassic boundary), the Toarcian–Aalenian and the Oxfordian. Data from the Subbetic Zone (Betic Cordillera) are used to constrain the palaeolatitude of the Iberian microplate.

Iberian data are in general agreement with the Besse and Courtillot (2002) Master Curve and the reconstruction parameters used to transfer the Iberian data to Europe. However, lower palaeolatitudes are observed in Iberia for the Late Jurassic. Tectonic reference models for the Western Mediterranean (Stampfl i and Borel, 2002, 2004) (SB02) do not fit the Iberian declinations at the Hettangian–Sinemurian nor the Eurasian and African APWPs. Differences in palaeolatitudes have also been observed. New palaeogeographic reconstructions are proposed for the Hettangian–Sinemurian, the Toarcian–Aalenian and the Oxfordian which are in agreement with the new palaeomagnetic information.

Differences are observed between the trend of the Iberian palaeolatitude variation during the Jurassic proposed by the SB02 model, the BC02 master curve translate to Iberia and the Iberian palaeomagnetic information. According to the SB02 model and the BC02 curve, Iberia moved towards higher palaeolatitudes from the Hettangian up to the Toarcian (in agreement with the Iberian palaeomagnetic data), and constant palaeolatitudes are proposed for the Toarcian–Oxfordian interval. In contrast, decreasing palaeolatitudes are observed in the Iberian palaeomagnetic data for this time interval. The SB02 model does not fit the Iberian declinations. An angular discrepancy of about 16 has been observed. To fit the new palaeomagnetic information the position of the Iberian plate in the SB02 palaeogeographic reconstructions has been modified.

In addition, the Jurassic poles positions considered by SB02 for Europe have been modified according to the most recent palaeomagnetic compilations.

Referring to the contradictory published data from the North American Plate, our data from Iberia transferred to the North American plate favours the proposal of a high palaeolatitudeal APW path segment during the Early–Middle Jurassic. It is followed by a swing to low palaeolatitudes by the Latest Jurassic which is not well described in the too smoothed global compilations (e.g. BC02).

Key words: Palaeomagnetism; Iberian Plate; Palaeogeographic reconstructions; Western Tethys

References:
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The Central Atlantic Magmatic Province (CAMP) and Birth Ksour Basin (Saharan Atlas, Algeria)

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The Saharan Atlas is a Meso-Cenozoic intracratonic chains formed during the orogeny Atlas from subsiding basins. In the Ksour mountains (Western Saharan Atlas, Algeria), the structuring of the basin is due to the Triassic-Liassic rifting. During upper Triassic, it was filled with sedimentary series generally capped by a volcanic pile (Aït Ouali and Delfaud, 1995; Yelles-Chaouche et al., 2001). These outcrops are associated with Triassic diapirs controlled by NE-SW anticlines (Galmier, 1972). We investigate the volcanism of the Ksour Mountains, based on a detailed mapping, in order to reconstitute the Triassic-Liassic volcano-evaporitic sequence (Meddah et al., 2006; Meddah et al., 2007). Three volcanic units, of basaltic composition, have been recognized: the lower unit (B1) is 4 to 6 m thick and is associated with red oligist argillites; the intermediate basaltic unit (B2), 2.5 m thick, overlies 10 m of variegated gypseous argillites and is associated with 2 m of argillites and greystromatolitic limestones; the upper unit (B3), 5 m thick, is overlain by black stromatolitic limestones (1.5 m thick) covered by evaporitic argillites and halite and, upwards, by dolomites. In Djebel Melah Rhaetian-Hettangian has been attributed to the black stromatolitic limestones by a lamellibranches Gervillia praecursor QUENSTEDT (Flamand, 1911; Bassoulet, 1973). In Ain-Ouarka Hettangian has been attributed to the top of these dolomites by an ammonite Caloceras sp. of the Planorbis Zone (Mékahli, 1995). In El-Hendjir, Chellahta Daharia, and Tiout, the upper unit is directly overlain by bluish-grey stromatolitic dolomitic limestones. This formation is considered of Rhaetian (Aït Ouali and Delfaud, 1995) or Rhaetian-Hettangian on the basis of lamellibranches (Bassoulet, 1973). The middle and upper limestones show Hummocky Cross Stratification (HCS), synsedimentary folding and emersion surfaces, indicating a continental lagoon to supratidal environment preceding the setting up of the Liassic carbonated platform. The synsedimentary basaltic lava-flows locally flooded wet sediments, as attested by the silicified basis of carbonated and argillaceous layers. This sequence describes the syn-rift volcano-sedimentary filling and the transition from an evaporitic cycle to the first open marine incursions heralding the post-rift installation of the Liassic carbonate platform, in the Ksour basin. In this context, the volcanic units witness the different stages of the birth Ksour basin. In these volcanic units, the primary paragenesis, represented by olivine, plagioclase, clinopyroxene and Ti-magnetite, is homogeneous and typical of the continental tholeiites forming the CAMP province, particularly in Morocco (Bertrand, 1991). The olivine occurs as microphenocrysts in the lower unit, more occasionally in the intermediate unit and is absent in the upper unit: This represents a good stratigraphic marker. A granophyre interstitial phase has been observed once in the lower unit (Tiout locality). The volcanic rocks of Ksour Mountains are basalts and basaltic andesite, poorly differentiated basalts ([Mg] = Mg/(Mg + Fe)) from 0.57 to 0.71) in accordance with the hydrothermal phases observed. The alkaline elements are highly mobilized (K₂O up to 7.55%) and cannot be used as magmatic markers. Nevertheless, the tholeiitic nature of the three volcanic units is clearly attested by immobile elements: low Ti (TiO₂: 1.13-1.63 wt%), P (P₂O₅: 0.1-0.2 wt%) and Zr (87 ppm < Zr < 151 ppm) contents, Y/Nb and Zr/P₂O₅*10⁴ ratios varying from 1.7-4.6 and 0.07-0.09, respectively (Bassoulet, 1973). Trace element patterns, enriched in light rare-earth (La/Yb(n) = 2.5-5.9) and other incompatible elements (Th(n) = 57-124), displaying an anomaly negative Nb, are characteristics of continental tholeiites. These chemical characteristics, along with the stratigraphic position of the lava pile, allow to assign this volcanism to the Central Atlantic Magmatic Province (CAMP). Moreover, a decreasing of incompatible elements is observed from the base to the top of the lava pile: Average values TiO₂: 1.46 wt%, 1.34 wt%, 1.18 wt%; P₂O₅: 0.17 wt%, 0.16 wt%, 0.12 wt%; La/Yb(n): 5.24, 3.96, 2.52, in accordance with the hydrothermal phases observed. The alkaline elements are highly mobilized (K₂O up to 7.55%) and cannot be used as magmatic markers. Nevertheless, the tholeiitic nature of the three volcanic units is clearly attested by immobile elements: low Ti (TiO₂: 1.13-1.63 wt%), P (P₂O₅: 0.1-0.2 wt%) and Zr (87 ppm < Zr < 151 ppm) contents, Y/Nb and Zr/P₂O₅*10⁴ ratios varying from 1.7-4.6 and 0.07-0.09, respectively (Bassoulet, 1973). Trace element patterns, enriched in light rare-earth (La/Yb(n) = 2.5-5.9) and other incompatible elements (Th(n) = 57-124), displaying an anomaly negative Nb, are characteristics of continental tholeiites. These chemical characteristics, along with the stratigraphic position of the lava pile, allow to assign this volcanism to the Central Atlantic Magmatic Province (CAMP). 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Key words: Tholeiitic basalt; CAMP; T-J boundary; Saharan Atlas; Algeria
References:
Growth History and Its Paleoenvironmental Significance of Ferromanganese Crusts from Magellan Seamounts in the Western Pacific Since the Cretaceous

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Two ferromanganese crusts M1-1 (recovered at a water depth of 2600 m at 17.4442°N 150.2861°E) and M2-1 (recovered at a water depth of 2700 m at 17.2022°N 152.2583°E) were collected from Magellan Seamounts in West Pacific. The two crusts were both divided into four layers (including basement) (Fig. 1).

The preparing methods are as follows: (i) First carve crusts vertically to the growth layer to get a vertical section; (ii) Sample in this section parallel the growth layer (sampling with pin); (iii) Scratch the surface of the sample to avoid contamination; (iv) Scratch sample powder on fresh face. When the sample powder is ready, put it on a slide and spread using distilled water, then fix with neutral balsam and cover glass after drying of water. Foram identification is undertaken after amplifying 1000 times with ZAISS polarizing microscope. The results are shown in Table 1 and Fig.1 for some fossils which are significant in chronologic age and a few common fossils.

<table>
<thead>
<tr>
<th>Epoch</th>
<th>Nannofossil zone</th>
<th>Calcareous nannofossil event</th>
<th>Age (Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleistocene</td>
<td>NN21</td>
<td>Emiliania huxleyi Acme</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Helicosphaera inversa</td>
<td>0.16</td>
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<tr>
<td></td>
<td></td>
<td>Emiliania huxleyi</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>LO</td>
<td>Pseudoemiliania lacunosa</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>FO</td>
<td>Gephyrocapsa oceanica</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>NN19</td>
<td>Calcisculus. macintyre</td>
<td>1.58</td>
</tr>
<tr>
<td></td>
<td>LO</td>
<td>Gephyrocapsa (medium) spp.</td>
<td>1.69</td>
</tr>
<tr>
<td>Pliocene</td>
<td>NN18</td>
<td>Discoaster brouweri</td>
<td>1.96</td>
</tr>
<tr>
<td></td>
<td>NN16</td>
<td>Sphenolithus spp.</td>
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<td>Miocene</td>
<td>NN4</td>
<td>Helicosphaera ampliaperta</td>
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<td>NN2</td>
<td>Discoaster druggii</td>
<td>23.20</td>
</tr>
<tr>
<td>Oligocene</td>
<td>NP22</td>
<td>Reticulofenestra umbilicus</td>
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<td></td>
<td>NP21</td>
<td>Ericsonia formosa</td>
<td>32.80</td>
</tr>
<tr>
<td>Eocene</td>
<td>NP20</td>
<td>Discoaster saipanensis</td>
<td>34.20</td>
</tr>
<tr>
<td></td>
<td>NP15-16</td>
<td>Birklandia staurion</td>
<td>40.4-49.7</td>
</tr>
<tr>
<td>Paleocene</td>
<td>NP9</td>
<td>Fasciculithus tympaniformis</td>
<td>55.30</td>
</tr>
<tr>
<td></td>
<td>NP4</td>
<td>Fasciculithus tympaniformis</td>
<td>59.70</td>
</tr>
</tbody>
</table>

Based on the study of nannofossils in ferromanganese crusts, the nannofossil species H. carteri, C. leptoporos and G. oceanica with ages younger than Miocene were identified in layers II and III of ferromanganese crusts M1-1 and M2-1 from Magellan Seamount in West Pacific, so layers II and III are developed in the Third Formation Period - the Miocene-Pleistocene period which corresponds to the Younger Time Layer proposed by Halbach et al. (1986).

Based on rapid uplift of carbonate compensation depth (CCD) Berger (1972) proposed a new theory to explain the apparent dissolution at C/T interface. At C/T interface the fact that calcareous nannoplankton dissolve selectively is consistent with stage dissolution pattern widely spreading in the ocean. The extinction of calcareous foraminifera and nannoplankton in the late Cretaceous can be the immediate consequence of CaCO3 unsaturated water appearing in sea surface.
The absence of calcareous nannofossils in layer I may be related to the abrupt changes of carbonate compensation depth (CCD) in the late Cretaceous. The cold and oxygen-rich Antarctic Bottom Water not only provided favorable oxidation environment for the formation of crusts, but also brought about an extensive sedimentation hiatus to permit the growth of the crusts in the whole region.

Fig.1 The Photos and sketches of fossil sampling points of ferromanganese crust (a: M2-1; b: M2-1)

Acknowledgements: This work was supported by the program “Explaining crusts growth period, growth rate and growth environment with microfossil and nanofossil (Grant No. DY105-01-04-08)”, “oreforming system and some metallogenic provinces estimated of deep sea ferromanganese ore deposit (Grant No. DY105-01-04-02)” and the national public welfare project of China — in situ measument, sampling and measurment system in the abyssal bottom (Grant No. 200905025-2).

Key words: Magellan Seamounts; Ferromanganese crusts; Nannofossil; Growth history

References:
Paleogeographical Conditions of Formation of Upper-Jurassic Oil-producing Deposits of Northern Slope of Surgut Arch (Western Siberia)

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Surgut arch is one of the main structures of Western-Siberian oil-producing province. There are a great number of hydrocarbon deposits. Formation of this structure occurred in an oscillatory mode that has caused accurately expressed rhythm of Jurassic sediments of this region. These deposits are characterized as multiplaten productive horizons. Oscillatory mode of development of this structure has caused transgressive-regressive character of sediments. It has led to their rhythmical structure and accordingly, to alternation of certain sequences of rocks complexes (Berthault et al., 2008a).

Distinctive feature of these deposits is the raised shaliness of transgressive adjournment that is connected with periodically arising conditions of avalanche sedimentation of pedigree complexes poorly differentiated on granulometry.

As the evolution indicator of paleogeographical conditions we considered structure of cement weight of sandstones of productive horizons of Upper-Jurassic adjournment. Based on structure of cement weight inside of wedge-form deposit bodies are allocated southern, central, northern parts. Within the Southern area of a deposit, the structure of clay substance of cement weight is almost homogeneous for all cut of horizon. Except for rare lenses within horizon the structure of its clay component is presented by a complex of finely dispersed minerals concerning to hydromica-kaolinite association (Berthault et al., 2008b).

Within the central square, the bottom part of horizon dominates chloride-hydromica-kaolinite association, upwards on a horizon cut replaced hydromica-kaolinite association with inclusion of lenses chloride-kaolinite, kaolinite and chloride-hydromica-kaolinite associations. Sedimentation conditions and transformations of cement weight were the most changeable in the central square of the Tevlinskoye deposit. According to the data of research of mineral structure of rocks in transparent petrographic sections in cement of sandstones of studied horizon of the central square, carbonaceous (calcite) component has wide development. It confirms the fact of more shallow mode of sedimentation.

Within northern part of a deposit the parity of clay minerals becomes simpler, the association starts to prevail chloride-hydromica-kaolinite association, and prevalence of hydromica-kaolinite association is considerably reduced.

As a whole on the basis of distribution of the allocated associations of clay minerals within the studied areas, it is possible to draw a conclusion on gradual loss of kaolinite cement components in northern direction on the area of deposits of the Tevlinsko-Russkinskoe deposit and role increase hydromica-chlorite phases.

Besides, the certain indicator of sedimentation conditions are carbonaceous (calcite) phase in cement of sandstones. The role of this phase is most expressed within the central square (wide development of calcite in cement of sandstones) and reduced within Southern and northern areas of the Tevlinsko-Russkinskoe deposit.

The carried out researches of correlation of finely dispersed phases in cement of sandstones of horizon J1 representing a complex of wedge-form bodies allow to assert that these changes are connected with facial-paleogeographical conditions of formation of the deposit localized on northern slope regionally expressed arch (Maslov and Alekseev, 2003).

Within the southern area of the Tevlinsko-Russkinskoe deposit in Upper-Jurassic time there were rather deep-water conditions of a high shelf with active drift of kaolinite material and to a lesser degree a hydromicaceous material.

Within the central square there were more shallow conditions that conducive to reduction of a clay component with its indemnification carbonaceous material in studied breeds. With what the wide circulation in cement both finely dispersed and crystals of calcite is connected more. It is possible to assume that within a central square of the Tevlinsko-Russkinskoe deposit in paleogeographical plan there was original “saddle” - the shallow zone dividing the area of a deposit on more deep-water northern and southern area.

Further, more deep-water mode begins to dominate in Northern part of the Tevlinsko-Russkinskoe deposit. However thus hydromica-chlorite phases of finely dispersed component receive wider development. Presence of hydromica-chlorite phases in cement of sandstones testifies to restriction of drift of kalinite material.

Presence of hydromica-chlorite phases in cement
of sandstones is the evidence of development of more stagnant deep-water sedimentation conditions of sedimentary material, and in further and development difficult diagenetic processes in the conditions of the regenerative environment. With it raised pyritization of sandstones within this area is connected. Occurrence of finely dispersed particles and crystals of pyrite is connected with development of sulphate-producing bacterial forms in the conditions of hydrosulphuric infection that confirms presence of more stagnant concerning deep-water conditions.

The carried out analysis of litological-facial conditions of sedimentation and postsedimentational transformations of sandstones of horizon J1 within the Tevlinsko-Russkinskoe deposit is a basis for drawing up of the litological-technological scheme of this deposit as features accumulation and diagenetical transformations of breeds of studied horizon directly define its filtration-capacitor properties and their dynamics in the course of the subsequent working out.

Key words: Upper Jurassic oil-producing deposits; Northern slope of Surgut Arch; Paleogeographical conditions

References:
The Impact of Calcareous Nannofossils on the Pelagic Carbonate Deposition from Late Tithonian (Jurassic)-Early Berriasian (Cretaceous) Boundary

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Calcareous nannofossils were important producers of pelagic carbonates in Mesozoic. The carbonate deposition in pre-Jurassic time mainly occurred in epicontinental seas. Substantial amounts of deep-sea carbonate are unknown from the Palaeozoic and the early Mesozoic. The Jurassic-Cretaceous boundary interval is characterized by a wide spread increase of the pelagic carbonate production and major changes in the palaeoenvironmental conditions. In late Tithonian and early Berriasian times, before planktonic foraminifera occurred in rock-formation proportions, calcareous nannofossils were the most important carbonate contributors to deep-sea sediments.

In Amdo 114 section of the Qiangtang Basin, northern Tibet, the lower part of this section is composed of sandstone, sandy gravel and siltstone, whereas the middle part is limestone, biosparite, and silty limestone. The lower and middle parts are ~295 m thick with abundant bivalves (Pectinidae, Ostreidae, etc.) and brachiopods (Burmihrhyenia sp.). The upper part of the section was divided into two members: the lower member (~90 m thick) consists of well developed grey-green siltstone, calcareous fine-grained sandstone with a few intercalated argillaceous siltstone and silty mudstone, and the upper member consists of grey-dark, medium-heavy layer microcrystalline limestone, medium-thin layer marls and biosparite interbeds, partly as argillaceous and/or silty limestone with bivalves Buchia, Chlamys, Posidonia plus some significant ammonite fossils. These ammonites mostly pertain to Virgatosphinctinae subfamily (including Aulacosphinctes, Virgatosphinctes), Berriasellinae subfamily (including Blanfordiceras), and Spiticeterinae subfamily (including Spiticeras). Above-described ammonite fossils are some typical molecules of late Tithonian to early Berriasian.

Except for abundant ammonites, calcareous nannofossils were found in the Amdo 114 section. Employing microscope work, the first discovery of the family Watznaueriaceae has been made, Watznaueria fossicincta is distinguished from Watznaueria britannica. From the biostratigraphy and chemostratigraphy, the sediments are characterized by paucity of assemblages, prevalence of coccospheres, and a relatively high organic content. There are two classes of preservation: poorly and moderately preserved assemblages. Total nannofossil abundance and species diversity show lower values within calcareous beds, compared to the argillaceous. Assemblage composition appears quite different in the marls and argillaceous rocks compared with the limestones. Fossil abundance and preservation are partly determined by diagenesis, selective dissolution and sedimentary environment.

Various authors have inferred the lithogenetic importance of calcareous nannofossils of the Early Jurassic. Limestone-marl alternations have been interpreted as the result of productivity cycles of schizospheres and coccolithophorids producing fluxes of biogenic carbonates to the sedimentary reservoir. However, it remains difficult to find a mechanism to explain why both coccoliths and Schizosphereella spp. are systematically found in higher quantities in marls than limestone. Our work concerns the quantification of pelagic carbonate production in late Tithonian-early Berriasian, and the comprehension of the main factors controlling production and transfer of pelagic carbonates to the sedimentary reservoir.

According to Price (1999), the latest Jurassic was an episode of cold and subfreezing polar conditions with possible polar ice sheets approximately about one-third of the size of those at the present day. During the Late Jurassic to earliest Cretaceous interval the eustatic sea level reached its maximum in the early Tithonian, probably caused by increased seafloor spreading and rifting of the Pangaea continent. Both Haq et al. (1987) and Hallam (1988) agree that the Tithonian was marked by a sea-level high followed by a drop across the Jurassic-Cretaceous boundary. This long-term sea-level fall was probably initiated by decreasing spreading rates causing numerous semi-restricted epicontinental seas, which in turn favored the evolution of endemic taxa. Provincialism in Tithonian-Berriasian times has been proposed for many marine floral and faunal groups on a global scale, e.g. belemnites and ammonites, with endemisms peaking in the Berriasian. Similar patterns are also reflected by calcareous nannofossils, which exhibit a distinctive latitudinal distribution.

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Key Words: Jurassic-Cretaceous; Carbonates; Calcareous nannofossils; Northern Tibet

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The Jurassic-Cretaceous Continental Red Beds of Peninsular Malaysia

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After the closure of the Bentong-Raub Suture that brought together Sibumasu and Indochina, a large part of the newly formed landmass of Peninsular Malaysia was uplifted and remained subaerially exposed at the beginning of the Mesozoic Era. Lower Triassic marine sedimentation was centered in the northwestern Kodiang–Semanggol Depocenter and the Gua Musang–Semantan Depocenter in the central belt (Fig. 1). The former was developed on the Upper Palaeozoic Sibumasu landmass as the only remnant of what was once an extensive area of marine deposition in Late Palaeozoic times. The Gua Musang–Semantan Depocenter was more extensive and was developed on Upper Palaeozoic shelf deposits of the Eastern Province made up of a central belt and an eastern belt. The extensive occurrences of tuffs and associated lavas, tuffaceous siliciclastics and conglomerates in the Gua Musang–Semantan Depocenter during Triassic times indicate that volcanic activities and basal instability were active during the life-span of the basin. Thick accumulations of turbidite flysch deposits are found in the deeper southern parts of the Gua Musang–Semantan Depocenter.

As the Triassic period drew to an end, a new regional pattern of sedimentation was established in the aftermath of tectonic disturbances and widespread plutonism that formed the main range, central belt and the eastern belt granitic plutons. Voluminous sediments eroding from the newly emergent mountain ranges to the west were deposited in these basins in various settings ranging from alluvial fans, braided streams, flood plains and lakes. In general, the sedimentary successions show a fining-upwards trend ac companied by increasing maturity of the sandstones. Sedimentary successions show a fining-upwards trend for the Siong Beds and southeastward and eastward directed palaeocurrents for the western edge of the Gua Musang-Semantan deposits with some westward directed currents for those to the south in Johore.

Most of these red beds were confined to the eastern margin of the central belt graben in Peninsular Malaysia with only a small patch named the Siong Beds in the Kodiang–Semanggol Depocenter in northeast Kedah in the western belt that extends into Thailand. The red beds of the central belt are made up of those belonging to the Tembling Group (consisting of the Kerum Formation, Lanis Conglomerate, Mangking Sandstone and Termus Shale from oldest to youngest respectively) and Koh Formation in the northern sector and Bertangga Sandstone, Ma’Okil Formation, and Paloh Formation in the southern sector. Red beds of the Eastern Belt include those of the Gagau Group (made up of the Badong Conglomerate overlain by the Lotong Sandstone), Lesong Sandstone, Ulu Endau Beds, Panti Sandstone and Tebak Formation from north to south.

Most of these sedimentary successions are of red to grey polymict conglomerate with up to cobble-sized clasts of quartz, chert, sandstone, shale, quartzite and volcanic rock embedded in sand and sandy clay matrix with lesser beds of sandstone, mudstone and shale developed unconformably on Palaeozoic or Triassic rocks. Estimated thicknesses of the various formations range from 1200 m for the Siong Beds to over 6500 m for the Tembling Group sequence. Most were continental deposits laid down by westward palaeocurrents for the Siong Beds and southeastward and eastward directed palaeocurrents for the western edge of the Gua Musang-Semantan deposits with some westward directed currents for those to the south in Johore.

The most abundant fossils found in the red beds are plant fossils of Late Jurassic-Early Cretaceous age. Some palynomorphs indicate a warm and dry climate during the Early Cretaceous. The plant fossils recovered include Gleichenoides gagauensis, Sagenopteris sp., Neocalamites, Classopolis classoides, Circulina sp., Exesipollenites sp., Ephepidites sp., Cycadoptites sp., Clavatipollenites sp., Ptilophyllum cf. pterophylloides, Gleichenites (Gleichenoides) gagauensis, Gleichenites (Gleichenoides) pantiensis, Cicatricissporites australiensis, Cicatricissporites ludbrooki, Reticulatisporites pudens, Podozamites pahagensis, Otozamites gagauensis, Araucarioxylen telentangensis, Gleichenites (Gleichenoides) pantiensis, Frenelopsis malaiana, Frenelopsis malaiana parvifolia, Aequitriradites inornamentus, Ischyosporites scaberis and Ischyosporites variegates.

Floral and palynomorph assemblages indicate that in general, the youngest of the post-Triassic sediments were deposited during Early Cretaceous. Unfortunately, the Lanis Conglomerate, Badong Conglomerate and other conglomerates could not be dated due to the absence of well-preserved fossils. A Late Jurassic age is often assumed for these deposits. In the Koh and the Kerum formations, Late Triassic bivalves were documented from the basal part of these units. Thus, it appears that the deposition of terrestrial sedimentary rocks in the Koh–Temblinging basins was nearly continuous from Late Triassic to Early Cretaceous. Subsequent to Early Cretaceous times, the Jurassic–Cretaceous basins became inverted and were subjected to erosion that continued to the present day.
Key words: Jurassic-Cretaceous; Red beds; Peninsular Malaysia

Fig. 1 Distribution of Jurassic-Cretaceous basins in Peninsular Malaysia (modified after Tjia, 2000; Nuraiteng, 2009)

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Conservation lagerstätten such as plattenkalks, laminated limestones and stratified lacustrine siliciclastics with their characteristically exceptional fossil preservation offer a unique view of former communities. Analysis of exceptionally preserved fossils from laminated lagerstätten started shortly after the discovery of such lagerstätten. So far, however, most attention was paid to taxonomic, sedimentological and palaeoenvironmental aspects.

Taphonomic studies were mainly limited to qualitative analyses of fossil assemblages or to particularly famous single specimens such as Archaeopteryx or Juravenator. This is the more striking, because quantitative taphonomic data can provide us not only with a new way of understanding the formation of individual conservation lagerstätten and the exceptional preservation of their fauna and flora, but also offer tools for comparing similar modes of preservation and fossilisation in laminated sediments with different sedimentological and palaeoenvironmental aspects.

For this purpose one needs hierarchically arranged, comparable taphonomic patterns related to similar genetic processes. The upper Kimmeridgian Wattendorf Plattenkalk, the oldest of the Solnhofen-type plattenkalks of southern Germany, allows such investigations because with an average thickness of 20 cm every bedding plane along which the laminated rocks split has been equally thoroughly searched for fossils. Moreover, despite the small thickness of these plattenkalks, they contain an unusually high number of fossils, many exhibiting the exceptional preservation of fishes, reptiles, cephalopods and arthropods commonly known also from other plattenkalk deposits (Fürsich et al., 2007; Mäuser, 2008).

For establishing the basis for a quantitative taphonomic analysis of the Wattendorf lagerstätte, a number of different taphofacies was established with the help of a euclidean cluster analysis using Ward’s method. For this, taphonomic features of the most abundant group of fishes, primarily of the genus Tharsis, were recorded, which provide information on the quality of preservation. Percentages of the occurrence of these features per layer were determined and clustered into groups of similar patterns.

Fishes were chosen because they were collected quantitatively during six phases of excavations and they occur scattered throughout all layers of the plattenkalk. Furthermore, fishes exhibit a relatively high number of taphonomically quantifiable features, both with respect to hard parts and soft tissues.

In the preliminary cluster analysis presented herein, taphonomic features utilized were bending of the spinal column, dissociation of articulated extremities from the trunk and overall skeletal articulation.

Four different taphofacies, representing various combinations of these preservational features could be identified.

Taphofacies A consists of only a small number of complete specimens with their heads and caudal fins. Half of the complete specimens are slightly bent. There is a very high amount of separate heads and of all the fish remnants over 90% are articulated.

In taphofacies B, one third of all specimens are complete. Of these, over 90% are slightly bent. The rest of the individuals have a straight spinal column. There is an equal amount (ca. 20%) of separate heads and caudal fins which corresponds well with headless and/or tailless specimens. Approximately, 15% of the fishes are disarticulated.

In taphofacies C, over 50% of the fish specimens are complete with heads and caudal fins. Three thirds of these are strongly bent. The amount of separate caudal fins matches well with individuals missing their tails but there are five times more separate heads than headless fish. Three thirds of the specimens are articulated.

Taphofacies D is represented by only a small number of complete specimens. A relatively high amount of individuals has a broken spinal column (over 50% of measurable specimens). Although the amount of separate caudal fins and tailless fish correspond well, there are 10 times more separate heads than specimens lacking their head. Nearly 90% of the specimens in this taphofacies are disarticulated, 54% of these strongly.

In future analyses it will have to be established, whether these taphofacies, deduced by means of fish taphonomy can also be reproduced by the taphonomic analysis of other taxonomic groups (such as molluscs and echinoderms). A next possible step would then be to use the quantitative data of cosmopolitan taxa from Wattendorf, and compare them with similar occurrences in other plattenkalks and laminated sediments in order to establish general taphonomic models for these biota.
Key words: Jurassic; Taphonomy; Plattenkalk; Wattendorf

References:

Microphytoplankton and Facies of Lower and Middle Jurassic of Siberia

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During the last decades the multi-proxy palynological analysis became very useful not only in biostratigraphy, but also for the facies and paleosetting reconstructions. Facies analysis is especially important for the investigation of Siberian Jurassic sediments of great oil and gaz potential. Paleoeological interpretations of phytoplankton are based on the comparison (if possible) with modern microphytoplanktons and on the analysis of combined lithological, geochemical and paleontological data. Quantitative analysis of phytoplankton associations as well as ratio marine/continental palynomorphs through the section allows to recognize transgressive-regressive trends and to reconstruct sea-level fluctuations.

Here we present our quantitative palynological results and facies analysis from a several of Siberian lower-middle Jurassic sections (boreholes Middle-Nakyn 360 and Yigyatto-Tung-1, eastern Siberia; borehole Tulai-Kiryaka 1, eastern region of Taymyr Peninsular; borehole Lul-Yach 5P, West-Tymskaya 1 and North-Pravdinskaya 521, central West Siberia; borehole Vostok 4 and Zolotoi Kitat outcrops, South-East of western Siberia;). On the base of taxonomic composition and quantitative fluctuations in phytoplankton assemblages, 9 associations have been recognized in studied sections.

Thus, palynological results from Eastern Siberia (borehole Middle-Nakyn 360) suggest a most complete facies transition reflecting the transgression trend during Upper Sinemurian-Toarcian. Our data from the borehole Yigatto-Tung 1 (presence of dinocysts, prasinophytes, green algae and colonial green algae) specify on the shallow marine conditions with gradual transition to coastal fresh water settings characterized this region during Sinemurian-Pliensbachian (Goryacheva, 2005, 2006). Facial analysis of borehole Tulai-Kiryaka 1 shows gradual change of from transgression (Pliensbachian-Toarcian) to regression (Aalenian-Bathonian) of conditions (Goryacheva, 2009b). Palynological data from central West Siberia (borehole Lul-Yach 5P) indicate an abrupt transition from continental to marine conditions during Upper Bathonian-Lower Callovian (Goryacheva, 2005b).

In the borehole West-Tymskaya 1 and North-Pravdinskaya 521 are revealed acritarchs (Micrhystridiurn sp.), prasinophytes (Tasmanites sp.), green algae (Schisosporis sp., Ovoidites sp.) and colonial green algae (Botryococcus sp.), that probably notes on coastal-sea conditions in the Lower Toarcian of central West Siberia (Goryacheva, 2008). In the borehole Vostok 4 saltish-water conditions have been certain (Upper Pliensbachian-Bajocian) with transgression in the Lower Toarcian (greatest quantity of dinocysts in the section) (Goryacheva, 2009). Palynological results from south-eastern West Siberia (Zolotoi Kitat outcrops) suggest a condition from fresh water to shallow marine (Goryacheva, 2006b).

Obtained new data are very important for paleogeographic reconstruction of West and East Siberian in the Jurassic time.

Key words: Jurassic; Stratigraphy; Palynology; Facies; Siberia

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Jurassic Evolution of the Oravic Crustal Segment (Pieniny Klippen Belt, Western Carpathians) and Its Importance for the Tethyan Paleogeography

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Pieniny Klippen Belt (PKB) is a strongly compressed mélangé zone between the Inner and Outer Western Carpathians. The mélangé consists of Jurassic and Cretaceous sediments. Paleogeographic reconstruction of this zone (summarized by Birkenmajer, 1977) showed that most of the mélangé components came from the paleogeographic zone called Oravicum (formerly known as Pieninicum); smaller part was of the Inner Carpathian origin. The Oravic segment represented a segment of the continental crust with crystalline basement and Mesozoic sedimentary cover. Only Jurassic and Cretaceous sediments were preserved as tectonic blocks and matrix of the mélangé; the basement with Triassic part of the sedimentary cover was detached and probably underthrust below the Inner Western Carpathians. The known sedimentary record of the Oravic successions is mostly with Aalenian black shales, which served as a detachment horizon during the deformation. Jurassic evolution can be then reconstructed solely on the basis of Middle to Upper Jurassic sedimentary record (Liassic sediments are present but were individualized in the Middle Jurassic is problematic). It is supposed that the Oravic segment prior to the Middle Jurassic rifting was a part of the North European Platform shelf. The exact position of the segment is difficult to reconstruct as the older rocks were not preserved. However, heavy mineral analysis of the clastic admixture in the Jurassic sediments showed predominance of pyrope-almandine garnets from granulitic and eclogitic source rocks. As the best matching position for the Oravic crustal segment, the Moldanubian Zone of the Bohemian Massif was inferred (Aubrecht and Méres, 2000). However, recent research in the Bathonian–lower Callovian clastics in the Cracow-Wieluń Upland (Polish Platform) showed predominance of similar garnets from an unknown source (Aubrecht et al., 2009). This stretched the possible provenance of the Oravic segment as far as the Polish Platform. The rifting caused block tilting which resulted in rising of the central part is called Czorsztyn Ridge, which became a site of shallow-marine deposition (Czorsztyn Succession). The first signs of the ridge uplift are visible already in the Aalenian sediments, otherwise dominated by black shales, in form of local olistoliths (Aubrecht et al., 2004), intercalations of crinoidal limestones (Schlögl et al., 2004), local turbidites, passing to siliciclastic flysch (Szlachtowa Formation – Birkenmajer, 1977). In the west Ukrainian part of the PKB sandy to coarse-clastics dominate the Aalenian sediments of the Czorsztyn Succession. In Bajocian, sedimentation of shallow-marine crinoidal limestones started (Krolicki and Wierzbowski, 2004), locally preceded by coral limestones in the western part of the PKB (Schlögl et al., 2006). In deeper parts of the Oravic Zone (Kysuca-Pieniny Succession), deposition of spotted limestones occurred, with distant crinoidal calciturbidites coming from the Czorsztyn Ridge. Extensional synsedimentary tectonic on the Czorsztyn Ridge is expressed by presence of breccias to megabreccias (Krasin Breccia – Aubrecht and Szulc, 2006). At the Bajocian/Bathonian boundary, a sea-level rise caused deepening of the sedimentary area which resulted in deposition Ammonitico Rosso facies on the Czorsztyn Ridge and radiolarites in the Kysuca-Pieniny Trough. The continuing synrift extension is expressed by numerous neptunian dykes in the Czorsztyn Succession (Aubrecht and Túnyi, 2001) with predominantly NE-SW orientation (indicating NW-SE extension). Paleomagnetic investigations showed that the oceanic spreading increased rapidly during Callovian, when the Oravic crustal segment was shifted rapidly towards south for almost 1000 km (Lewandowski et al., 2004). In Oxfordian, the spreading stopped and the segment slowly returned to higher latitudes. At the end of the Jurassic (after Kimmeridgian), the Ammonitico Rosso facies was replaced by Calpionella limestones in the trough, with organodetritic admixture on the Czorsztyn Ridge forming even various sorts of coquinas.

The Callovian rapid oceanic spreading registered in the PKB should also concern other Tethyan crustal segments but their sediments are often remagnetized. Moreover, the time span of the event is relatively short and the corresponding facies are often condensed which makes paleomagnetic detection very difficult.

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Key words: Western Carpathians; Pieniny Klippen Belt; Jurassic; Paleogeography

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Evaluating Palaeoecological Response in Condensed Aalenian-Bajocian Deposits from western Tethys (Iberian Range, Spain)

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The relationship of fossil assemblages, lithofacies and stratigraphic sequences within the uppermost Toarcian-lowermost Bajocian deposits of the North-western Iberian Range (Spain) has been studied in order to distinguish ecozones and ecostratigraphic sequences. The condensed carbonate deposits display specific features related with the depositional architecture of the studied area. A detailed study and comprehension of the timing of the sedimentation in this area, is reflected in the establishment of type sequences, which show the lithofacies changes and the temporal distribution of fossils based in accurate biostratigraphic data. The combined analysis of stratigraphic sequences and palaeontological data (macro- and microfacies analyses of the fossil content, including ichnofacies) allow to detect changes in the record of fossil assemblages, and to establish ecozones and ecostratigraphic sequences (Fig.1).

The condensed deposits located in the San Leonardo, Madero-Moncayo and Demanda areas exhibit five discontinuity bounded sequences (Garcia-Frank, 2007; Garcia-Frank et al., 2006, 2008) in which five ecozones are observed. These ecozones are organized into three ecostratigraphic sequences. However, in the more expanded deposits of the Cameros area a remarkable distinctive style of sedimentation is recorded.
(García-Frank et al., 2006, 2008), which is consistent with a different ecostratigraphical development.

Despite the slow sedimentary rate that characterise these deposits, changes in the state of substrate have been detected, showing progressive lithification from loose to firm, and even, to hardground formation. The ichnites related with (stiff)/firm sediment are found within the Glossifungites ichnofacies, whereas the ichnites associated with lithified sediments and development of hardgrounds, correspond to the Trypanites ichnofacies. Some ichnotaxa such as Chondrites and Zoophycos are recorded in the Zoophycos ichnofacies.

The changes or breaks in colonization or ichnofacies development are revealed at key stratal surfaces, where they are extremely important in order to detect environmental shifts, which would be underestimated or missed in condensed deposits.

The substrate-controlled ichnofacies are linked with key stratal surfaces such non-depositional discontinuity surfaces: the Glossifungites ichnofacies is related with omission surfaces and the Trypanites ichnofacies related with hardgrounds.

Specific ecostratigraphic events are detected within the ecostratigraphic sequences. Productivity (a notable increase of the abundance and diversity of fossil populations) and colonization events occurred at the lower (I) and intermedium (II) ecostratigraphic sequences respectively; some other colonization events (by pioneer organisms) took place above some barren or poorly fossiliferous beds in the upper ecostratigraphic sequence (III). The first colonization event was developed within the Madero-Moncayo area (M-M); whereas the second one occurred westwards, in the San Leonardo area (S-L).

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**Key words:** Palaeoecology; Condensed deposits; Early-Middle Jurassic; Iberian Basin; Spain

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Eastern Arctic in Jurassic: Paleogeography and Paleoclimatology

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Eastern part of Arctic region in Jurassic spread into both halves of modern Arctic Ocean: to the east from Taymyr and Lena river mouth in Asia, to the west from Mackenzie river mouth and Alaska in Northern America, and also to the Bering sea region.

This territory is interpreted as a part of Pacific geodynamic system (Mesozoic folding belt of Northeastern Asia and North America). Sedimentary basins of this geosystem have been interpreted as geosynclinals in former times and were characterized by very contrasting bathymetry and widely spread volcanism. From the point of view of plate tectonics, this geosystem has been formed as a result of the collision of Eurasian and North American plates with numerous microplates (terranes), which were accreting during the Jurassic to the margin of the Siberian platform.

According to the geodynamic interpretation, significant area between continental plates was occupied by a deep sea (or a gulf) of northern Paleopacific, penetrating to the modern Arctic ocean area, and called the same name as its ophiolitic suture Anyui “paleoocean” (Zonenshain and Kuz’min, 1992; see Fig. 1a). During the Triassic and Jurassic this “ocean” was steadily decreasing, moving in the direction of Pacific, and finally was closed in the Early Cretaceous, probably in Barremian. A connection between Northern Paleopacific and Arctic Ocean from this moment has been lost. Both scenarios described above implicate there was the connection between Arctic and North Pacific basins in the Early Jurassic, and the reduction of water mass exchange to the end of Jurassic.

The comparative analysis of mollusk paleobiogeography data in Arctic and North Pacific basins allows us to make more precise reconstruction of paleobiogeography changes and climatic fluctuations of this region during the Jurassic. Structure and biodiversity of marine biota let us suppose that on the territory of modern Arctic Ocean there was a large water area (possibly an oceanic basin) in Mesozoic as well as in Jurassic. This means that most principal factors of environment – salinity and temperature – were relatively stable in time.

There were open connections between North Pacific and Arctic basins, and during the Jurassic these connections were gradually reducing. Final separation of basins took place in Early Cretaceous, as a result of Alaska-Chukotka plate moving. According to W. Hay et al. (1999) this plate occupied large area between North America and northern Asia, and the connection was completely closed as a result of central Alaska terranes movement. Paleobiogeographic analysis allowed us to reject the hypothesis of terrane movement from tropic zone of Paleopacific to the Eastern Siberia craton. Taxonomic diversity of marine fauna of the Early Jurassic decreases to the west, Middle Jurassic is characterized by low diversity, and during the Late Jurassic the diversity grows in all taxonomic groups of marine invertebrates, due to the influence of Central Russian Sea biota (Zakharov and Rogov, 2007). The passage between Arctic and North Pacific was closed, most probably, in the Barremian: there is strong evidence that deep-water troughs near Novosibirsk islands, extending from North Pacific oceanic gulf, were still existing in Early Valanginian (Kuzmichev et al., 2009, Fig. 1A).

To the east of Urals the diversity of low-boreal ammonites slightly decreases: in North Siberia sections of Upper Jurassic, at Kheta river basin, peritethyan and many low-boreal taxa are not found. 500 km to the east, on the shore sections of Laptev sea, only high-boreal (arctic) ammonite taxa can be found, represented by several genera of Cardioceratidae and Boreal Opellidae (Oxfordian-Kimmeridgian), Dorosplanitidae and Craspeditidae (Volgian, Ryazanian and Valanginian). Bivalves show very similar pattern of distribution: among shallow-water taxa, widely spread in central Russian Sea during the Oxfordian, Gryphaea and Plicatula disappear in Pechora basin sections, and low-boreal Neoacrassina (Astartidae), distributed in late Oxfordian Timano-Pechora sea, can not be found in Khatanga sea.

Oxfordian and Kimmeridgian deposits of Volga river basin in central Russia contain little number of Buchia, which are abundant to the north-east, in Pechora basin sections, and which are the major element of Late Jurassic fauna in northern Siberia. In the north-eastern Asia, around the northern paleo-pole, monogenetic accumulations of Buchia are common for the Upper Jurassic sections. A very similar situation in Jurassic can be seen along the Pacific coast of northern Asia. Episodes of Boreal-Tethyan immigrations, as a rule, were caused by sensible fluctuations of water mass temperature (Fig. 1B), which, in turn, were caused by eustatic events. In the sections of Upper Jurassic of Novosibirsk islands, Chukotka, Koryakia and Okhotsk sea region cold-water buchias predominate in bivalve complexes.

This confirms that geographic Northern pole in Jurassic was located around modern Bering strait (Sellwood and Valdes, 2008). This fact is also indicated
by the sedimentological data: along western Pacific coast the share of carbonate rocks is gradually decreasing to zero from South Primorje to Bering sea, being replaced by terrigenous and volcanogenic rocks. There is no data on paleotemperatures of water mass for the north of eastern Siberia. Late Jurassic seas in the North Siberia average annual water paleotemperatures were about 12 to 15°C (Berlin et al., 1970).

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Key words: Arctic; Jurassic; Paleogeography; Paleoclimatology

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Depositional Events and Climatic Signals Recorded in the Condensed Oxfordian Dhosa Oolite of the Kachchh Basin, Western India

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The Kachchh Basin in western India formed following rifting between Africa and India in the Late Triassic (Biswas, 1982, 1991). An E-W oriented chain of domal structures lies on the Kachchh Mainland between the salt marches of the Great Rann of Kachchh to the north and the Arabian Sea to the south. These domes offer outcrops from Bajocian to Tithonian in age.

The top of the Chari Formation (Callovian-Oxfordian) is formed by the Dhosa Oolite member, which received considerable attention (e.g. Singh, 1989; Fürsich et al., 1992) due to its highly complex top unit, the Dhosa Conglomerate Bed. This marker bed which can be traced for over 100 km is highly condensed and contains gaps with several million years of apparent non-deposition.

A detailed sedimentological analysis led to a model of the events that took place during these times of non-deposition. Ammonites allowed the establishment of a chronostratigraphic framework, while palaeo-climatic reconstruction based on oxygen isotopes and clay mineralogy support the model.

**Genesis of the Dhosa Oolite**

During the Late Callovian the relative sea level in the Kachchh Basin fell. This is highlighted by a coarsening of the grain size from silt to sand, as well as by the appearance of sedimentary structures such as cross-bedding. The ferruginous ooids of the Dhosa Oolite member are allogenic and were transported from their near-shore place of origin into the basin.

During the Early Oxfordian formation of the Dhosa Conglomerate Bed started (Fig. 1). Large conglomerates formed in the substrate, which had been bioturbated by crustaceans constructing large Thalas-sinoïdes networks (A). During an erosional phase (B) the soft sediment was removed and the conglomerates were left exposed on the sea floor forming a discontinuous hardground surface with traces of Thalas-sinoïdes preserved as negative epireliefs on their upper surfaces. The sea level fell further until the sea floor was subaerially exposed (C). Erosion by meteoric waters produced highly irregular, pitted upper surfaces on the conglomerates. During a transgressive phase the sea once again covered the basin floor and smaller slabs, pebbles, and ammonites were reworked (D). The fine matrix of the resulting highly fossiliferous conglomerate points to relatively deep water conditions below wave base. Bioturbation led to the incorporation of this matrix into deeper sediment layers. During very high-energy events large concretionary slabs were lifted to swim in the matrix (E). The nature of these events has not been satisfactorily determined yet, but earthquakes in the fault-bordered basin and resulting tsunamis are a reasonable explanation. Signs of synsedimentary tectonics are a common feature. As sediment input remained very low, concentration of fossil remains and re-working, especially of ammonites, continued. During quiet conditions oncoids and microbial-stromatolitic crusts formed in some areas of the basin (F). Finally, the whole unit hardened and locally a thin layer of Fe-oolithic fine sand was deposited on top. Subsequently, the sea level in the Kachchh Basin fell again and the sea floor became once more subaerially exposed (G). Erosion by meteoric waters led to the formation of dissolution cavities which later on were filled with sparitic calcite. The fine-grained sandstone layer present at a few localities developed a pitted, irregular surface similar to that of the concretions formed earlier on (C). After this second phase of subaerial exposure the unit was drowned again (H).

**Palaeoclimatic signals**

The recorded sea-level changes in the Kachchh Basin could have been caused either by local (tectonic) or global (climatic) phenomena. To evaluate climatic conditions during the deposition of the Dhosa Oolite member isotope analyses of belemnite rostra have been carried out. Calculated temperatures from the Dhosa Conglomerate Bed are lowest and range between 10.3°C and 11.5°C, which is around 6°C less than published data from Early Callovian belemnites and even around 10°C less than values from Bathonian brachiopods of the Kachchh Basin (Fürsich et al., 2005; all temperatures calculated with the equation given by Anderson and Arthur, 1983, and with $\delta^{18}O_{sea} = -1‰$ V-SMOW). This decrease in sea-water temperatures towards the Oxfordian may well be connected to the global climatic change leading to glaciation and a fall in sea-level as proposed by Dromart et al. (2003a, b). While the latter authors suggest the peak of glaciation around the stage boundary, the two subaerial phases of the Dhosa Conglomerate Bed are clearly Oxfordian in age as is shown by ammonite data. Offsets in sea-level changes between the Kachchh Basin and global trends can be explained by tectonics in the basin and the rate of...
subsidence. Palaeoclimatic reconstructions will be completed by isotope analyses of benthic organisms such as brachiopods and oysters as well as by clay mineralogy. These results will allow the evaluation of climatic changes from the Callovian to Kimmeridgian in the Kachchh Basin and will provide insights into the exact development of the global sea-level curve, which is still under debate. While Dromart et al. (2003b), for example, propose a sea-level minimum in the latest Callovian, Wierzbowski et al. (2009) suggest maximum flooding.

Key words: Jurassic; India; Palaeoenvironment; Palaeoclimate

Fig. 1 Simplified model illustrating the formation of, and sequence of events recorded by, the Dhosa Conglomerate Bed in the Kachchh Basin

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Bajocian Patch Reefs Architecture of High Atlas, North Errachidia (Morocco)

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In the Moroccan High Atlas mountains, along the geotraverse Midelt Errachidia, thick sequences of Jurassic rocks can be studied. These marine carbonate series were deposited in the short-lived Atlasic basin upon underlying continental Triassic and Liassic rocks. The Middle Jurassic carbonate rocks belong to the Agoudim and Taziazaout formations in the central basin area (Ait Addi, 1994, 2002) and to the adjacent, age-equivalent “formations 1 and 2” of the Bin El Ouidane Group in the southern, eastern and northern platform areas. The carbonate buildups (reef knolls, mud-mounds, bioherms, patch-reefs etc.) are frequently observed within the Liassic and Dogger series. Bajocian carbonate buildups are often organized as a patch reefs or as a bioherms and biostroms but rarely as a limited extent barrier. They are developed in marine environments like platform or carbonate ramp and formed particularly by polyps and some calcareous sponges (Ait Addi, 2002, 2006). In the distal area (basin axis), buildup horizons form the upper parts of two “shallowing-upward” transgressive/regressive cycles corresponding to Agoudim and Taziazaout formations (Ait Addi, 2006). Biohermals structures present usually a flat base and a convex top (plano-convex lens) with variations in height and width. But the highest level never exceeds fifteen meters on an extension of about one hundred meters. These can be nested together or coalescing with flat and horizontal bases (Ait Addi et al., 1998). Vertically, lower level mounds are generally rare, small (0.5 to 1.5 m /1 m), lenticular and domal shaped. On the top of regressive cycles, patch reefs become more frequent, more diverse and larger (up to 15 m /100 m, Ait Addi, 2002). The buildup horizons are generally tough but not very hard and shows a variable lithology: undulating and bioclastic limestones (enriched beds in brachipods and bivalves), bioclastic limestones and oolitic .... These can be compared to the Acropora? genus. The thanmasteriod and colonial meandroid shapes are good indicators of zooxanthellae character. Types of coral colonies suggest a relatively moderate deep environment. The assemblage shows a Tethyan affinity and recalling the biodiversity of the Caribbean coral reefs (Warme, 1988; eg. Acropora cervicornis). The massive forms appear to be most affected by bio-erosion generated by lithophagous molluscs. The micritisation processes by micro-perforation are widespread. The corals skeletons are often broken and fragmented by turbulent currents (storms). Buildup horizons reveal frequent instability of bajocian sea level in the area. This instability is imposed by the combined effects of tectonic, climatic and eustatic.

Key words: Morocco; High Atlas; Bajocian; Patch reefs

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Biomarkers for A Widespread Tethyan Flooding on Mexican Shelves During the Early Tithonian

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Mexican areas showing marine Upper Jurassic outcrops belonged to neritic shelves accommodating more or less fine terrigenous deposits and secondary carbonates during the Late Jurassic, including the Early Tithonian. The interpretation of fluctuations in relative sea level during the Late Jurassic has been proposed for long time ago in the area (e.g. Burckhardt, 1930). The Late Jurassic in Mexican epicontinental shelves was a time for their main biogeographic role as reception centers for cephalopods, as well as areas pro-moting common but variable endemism among these animals (e.g. Olóriz, 1992; Olóriz, 1992; Olóriz and Villaseñor, 2006). Fossil assemblages composed of megainvertebrates dominated by mollusks, especially ammonites and bivalves, have been usually reported together with the occurrence of wood and plants remains, and more recently obtained from the bed-by-bed sampling of Upper Jurassic sections (e.g. Burckhardt, 1930; Olóriz et al., 1999). Other groups of fossil macroinvertebrates and/or vertebrate remains are secondary, except for particular horizons (e.g. Burckhardt, 1930; Michalzik and Schumann, 1994). Factors determining skeletal accumulations, and their areal and stratigraphic distribution, as well as their preservation, have been approached taking into account eco-sedimentary conditions (e.g. Schumann, 1988; Michalzik and Schumann, 1994; Olóriz et al., 1997; De La Mora et al., 2000).

Within a context of widely separate areas and highly distinct depositional conditions, ammonite records support the correlation of sedimentary packages and the assumed relative sea-level dynamics. Interpretations of Upper Jurassic (Lower Tithonian) deposits at the so-called third-order cycles of relative sea level are in agreement with effects of relative sea-level highs within the Lower Tithonian, Semiforme/Verruciferum Zone in the Secondary Standard for Tethyan areas (e.g. Geyssant, 1997) at both the global (e.g. Hardenbol et al., 1998) and regional levels. Consistent interpretations have been proposed for comparatively inland seas (e.g. Badenas et al., 2004 and References therein for the Iberian subplate), but the identification of local/ regional deviations forced by tectonics is widespread even within areas subdued to marine Tethyan influence (e.g. Benzzagah and Atrops, 1997; Krishna et al., 2000; and Ruban, 2007 for different ranges of deviation).

Selected records of Mexican ammonites indicate Tethyan influence during the late-Early Tithonian, a time when a relative sea-level pulse favored the widespread distribution of Tethyan-derived ammonites throughout distant areas (e.g. Myczyński, 1994; Cecca, 1999; Olóriz et al., 1999; Parent, 2001; Villaseñor and Olóriz, 2001; Villaseñor et al., 2003; Ruban, 2007). Mexican records of genera Simocosmoceras, Pseudovolanoaceras and Pseudhimalayites, support biostatigraphic correlation at the standard biochronozone level, thus favoring the possibility for long-distance correlation with the Americas and other areas subdued to Tethyan influence in Europe. Hence, Lower Tithonian deposits composed of claystone, siltstone, fine-grained and more or less calcareous sandstone, silty limestone and phosphorites belonging to the Semiforme/ Verruciferum Chron are evidenced and correlated in Mexico, and their relationships to relative sea levels discussed. In such a context, the underlying biogeographical dynamics for interpreting Mexican records of Simocosmoceras, Pseudovolanoaceras and Pseudhimalayites is approached.

Key words: Ammonites; Correlation; Sea level; Upper Jurassic; Lower Tithonian; Mexico
Fig.1 Elevations, sediment types, and biomarkers for widespread flooding on Mexican Shelves in the early Tithonian

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Geochemical data from four different types of carbonate materials are presented: micrite matrix from two sections (Cardador and Alamedilla), carbonate cements, neomorphic ammonite shells and belemnite rostra.

Analysed materials belong to Lower Tithonian deposits, Semiforme/Verruciferum Zone, registered as Ammonitico Rosso facies in an epi-oceanic high (Cardador section), and a coeval cephalopod limestone deposited closer to the mid-Subbetic volcanic ridge (Alamedilla section).

The Cardador section shows more and less calcareous, red-to-grey AR horizons with variable nodularity. Wackstones dominate containing radiolaria, calcisphaeres, calcareous dinoflagellates, plantik crinoids (Saccocoma), unidentifiable benthic forams, ostracods, cephalopods (rare ammonitella or embryonic shell of ammonoids; aptychi), and fragments of juvenile and adult ammonite carcasses along with broken mollusks, echinoderms (plates and spines), sponge spicules and pelagic bivalves, among others; backstone horizons mainly composed by filaments also occur.

The Alamedilla section shows reddish-brownish-to-pale-grey limestone and marls. Limestones are locally rich in ammonites (cephalopod limestones) which preserve neomorphic shells and within-bed orientation related to shell size, although horizontal settling is dominant. Wackstones dominate containing rare radiolaria, common to abundant calcareous dinoflagellates, lesser amount of planctik crinoids (Saccocoma), benthic forams (most probably Lenticulina), ostracods, cephalopods (common ammonitella or embryonic shell of ammonoids), and fragments of juvenile and adult ammonite carcasses and rare aptychi, along with broken mollusks, lesser amount of small gastropods, rare brachiopods and echinoderms (plates), and variable amount of filaments (pelagic bivalves).

Hand specimens were collected under precise stratigraphic control and two slabs were produced for each sample: one for thin section preparation (micro-facies and cathodoluminescence) and the other for geochemical studies. Cathodoluminescence inspection was carried out in order to access the degree of diageneric imprint. Stable isotope composition analyses were performed on their Ca, Mg, Mn, Fe and Sr elemental concentrations using inductively coupled plasma-atomic emission spectrometry (ICP-AES).

Cathodoluminescence imaging of matrix micrite presents distinct degrees of luminescence (Fig.1 B, F): brighter for micrite matrix from the Alamedilla section, attributed to an environmental enrichment in Mn²⁺, in agreement with elemental data. A latter carbonate cement phase is identified as secondary blocky calcite (Fig.1 F) with alternating pattern between intrinsic and yellow luminescence (zonation), providing evidence for shallow marine burial (Bruckschen and Richter, 1994). Skeletal material shows overall intrinsic dark luminescence (Fig.1 B, D), suggesting a fair preservation of both neomorphic ammonite shells and belemnite rostra.

Carbon isotope values for matrix micrite from the studied section at Cardador and the rock block from Alamedilla section, neomorphic ammonite shells and secondary blocky calcite plot within the same range of values, from 1.5‰ to 2.1‰. The obtained values are comparable to published data from other former Tethyan margin locations (Jenkyns, 1996; Weissert and Mohr, 1996; Bartolini et al., 1999) that reflect Upper Jurassic seawater carbon isotope composition. Belemnite rostra carbon isotope values differ from this trend, showing δ¹³C values depleted as much as 3.8‰ relative to the encasing matrix micrite (Alamedilla section). A likely lighter carbon source is metabolic carbon, that fails to be in equilibrium with seawater carbon due to the internal position of belemnite rostra (Price and Page, 2008; Price et al., 2009).

Oxygen isotope composition presents a higher variability. Matrix micrite from the Cardador section and neomorphic ammonite shells are the least depleted materials, ranging from 0.1‰ to 0.9‰, followed by matrix micrite from Alamedilla and encased belemnite rostra. As most depleted, carbonate cements range from -2.7‰ to -0.3‰. Oxygen isotope composition is here considered to reflect marine bottom water paleo-temperature, except for carbonate cements, that indicate higher temperature of circulating fluids during marine burial diagenesis, supported by the observed zonation under cathodoluminescence.

Elemental composition revealed an exceptional Mn enrichment on micrite matrix from Alamedilla (up to 4000 ppm), only present at the Cardador section on
the base of the Tithonian. Such enrichment can be attributed to hydrothermal/volcanic activity (Kickmaier and Peters, 1990; Corbin et al., 2000) during phases of local physiographic readjustment. Neomorphic ammonite shells do not reflect this enrichment, suggesting that aragonite inversion into neomorphic calcite occurred in a very early diagenetic stage, prior to micritization. Belemnite rostra present Mn and Fe and Sr concentrations below “cut-off values” published by several authors (Voigt et al., 2003; Price, 2010) and are therefore considered as well preserved and useful for comparison with data obtained from the remaining carbonate materials.

**Key words**: Geochemistry; Skeletals; Tithonian; Betic Cordillera

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**Fig.1** Cathodoluminescence images of matrix micrite, carbonate cements, and skeletals

A) Neomorph ammonite shell and matrix micrite from Alamedilla; B) Same area under cathodoluminescence; C) Belemnite rostrum, note growth increments; D) Under cathodoluminescence (note bright orange fine veining); E) Carbonate cement filled void in matrix micrite from the Cardador section; F) Under cathodoluminescence, note the zonation pattern on secondary blocky calcite and duller matrix micrite.

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High-Stress Aquatic Ecosystems in the Jurassic and Early Cretaceous: The Macrobenthos Aspect

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Quantitative palaeosynecological analyses, such as cluster analysis, and various diversity analyses have become well established tools to define and characterize remnants of communities (i.e. associations) in the fossil record. On one hand, these associations provide us with an idea of how life in the past had been organised in communities and how these communities, and with them the ecosystem, changed through time. On the other hand, as modern and ancient communities are strongly related to the environment, associations can be used to reconstruct aspects of the palaeoenvironment. This is particularly true of benthic organisms, which are generally more closely tied to particular environmental settings than nektonic and planktonic organisms. Generally, the shelly macrobenthos of marine shallow-water ecosystems is dominated by bivalves followed by gastropods, brachiopods, crinooids, echinoids, corals, and sponges. Common encrusters include bryozoans and serpulids, whereas the endolith is characterized by bivalves, a variety of worm-like organisms (polychaetes, phoronids), and sponges. In fully marine environments, these taxa occupy a wide variety of niches with respect to substrate and food. In non-marine, lacustrine environments the shelly macrobenthos is dominated by bivalves and gastropods. Conchostracans, crustaceans, and aquatic insects may also be common, but due to their organic skeleton they require special conditions for their preservation.

In high-stress environments one or several environmental parameters such as salinity, oxygen, substrate, and water energy exceed the tolerance level of most species. Thus the species composition of such environments consists of generalists and opportunistic species, which are characterized by a rapid population turnover. As a result, they may occur in great abundance. Communities living under high stress typically have a simple structure, expressed by a low species diversity, and are strongly dominated by one or two species. Moreover the taxa may show morphological adaptations to cope with high stress levels, especially when stress levels remain constant long enough for evolutionary novelties to become established. These features can be used to identify stress-controlled community relicts and to recognize high-stress environments in the fossil record. However, diversity of fossil community relicts may have been strongly modified by taphonomic processes. Chemical and mechanical sorting leads to a decrease in species diversity, whereas time-averaging is increasing diversity values. A thorough taphonomic analysis should therefore precede any palaeoecological analysis, especially when diversity values are used as a major line of evidence to deduce environmental conditions.

Jurassic ecosystems in which salinity was a major stress factor are dominated by infaunal bivalves. They commonly belong to families, which occupy salinity-controlled environments at present-day such as members of the Neomiodontidae, Corbulidae, and Corbiculidae (Fürsich, 1984). However, the byssate bivalves Praemytilus, Arcoemytilus and Isognomon and oysters such as Praeexogyra and Nanoeryga may also be locally abundant, forming clusters, banks and small patch reefs, and are commonly associated with the terquemid Placunopsis and the anomiid Juranomia. Characteristic adaptations are largely physiological in nature e.g. the ability to regulate the osmotic pressure. Morphological features include reduction in size and shell thickness and the progressive loss of ornamentation towards lowered salinities. These bivalves are accompanied, in some cases, by gastropods belonging to a variety of families. At the lower end of the salinity range these consist partly of euryhaline freshwater forms.

One of the commonest stress factors in aquatic environments is the limited availability of oxygen, often documented in the rock record as black shales. Apart from physiological adaptations, macrobenthic organisms exhibit certain morphological adaptations (e.g. flat clams) and may react by adjusting their life cycle to seasonally fluctuating oxygen levels.Jurassic oxygen-controlled ecosystems are characterized by several members of the Posidoniidae (e.g. Basitra, Posidonotis, Aulacomyella), Inoceramidae (e.g. Pseudomytiloides) and Lucinidae, but a number of other bivalves were apparently also able to tolerate somewhat reduced oxygen conditions in the sediment or in the bottom water (e.g. corbulids, Protocardia, Parvamissium, Nicaniella; Aberhan, 1994).

High water energy is another common stress factor, but evidence of organisms able to flourish under such conditions is difficult to find in the fossil record, as post-mortem reworking, transport and destruction of such organisms is the rule. Generally speaking, favourable adaptations for life on or in unconsolidated high energy substrates include the ability to burrow fast (e.g. some bivalves with smooth, compressed valves)
and to have a mobile mode of life as is true of most gastropods. On hard substrates, a cemented mode of life and skeletons, which are thick and sturdy (e.g. some bryozoans, oysters) or flexible (as in the case of crinoids), are adaptations to high-energy conditions that are likely preserved in the fossil record.

Many benthic organisms are substrate-controlled, but it is the substrate consistency, in particular the presence of soupgrounds that exerts considerable stress on the benthic fauna. Jurassic communities inhabiting such substrates are characterized by a strong dominance of infaunal forms, which are usually quite small (e.g. the bivalves Nicaniella, Protocardia, Corbulomina). Epifaunal taxa are present in form of specialised, small or large recliners such as Nanogryra virgula and Gryphaea. Encrusting taxa are restricted to large “benthic islands”, provided, for example, by the mud-sticking bivalve Stegoconcha.

High environmental stress in lacustrine ecosystems is usually caused by lack of oxygen. In particular eutrophic lakes are, at least seasonally, stratified. Under such conditions no complex benthic ecosystem can become established, as mass mortality regularly wipes out the benthic fauna. Therefore, in Mesozoic oxygen-controlled lacustrine ecosystems organisms prevail that have a rapid population turnover such as larvae of aquatic insects (e.g. ephemerids) and conchostracans. The latter often occur in great abundance as the time between consecutive mass mortalities is too short for populations of their natural predators (e.g. fishes) to become re-established.

Although high environmental stress can be identified relatively easily in the fossil record, its cause may be more difficult to decipher, especially when more than a single stress factor is involved. This case is illustrated by the pauci- to monospecific benthic fauna of the Kimmeridgian Tereñes Formation of Asturias (northern Spain). The formation consists of metre- to decametre-scale coarsening-upward cycles (García-Ramos et al., 2008). Generally, these cycles start with a thin shell bed of the free living oyster Nanogryra virgula, which is followed by dark-grey marly silt with numerous shell beds and pavements of the small, shallow infaunal bivalve Corbulomina. The cycles are commonly topped by sandstones with abundant dinosaur tracks, or else by marly fine sandy siltstone and fine-grained sandstone, bioturbated by Rhizocorallium irregularare and Thalassinoides. These successions represent asymmetric deepening-shallowing cycles and are best explained as resulting from the progradation of delta lobes in a protected environment (?shelf lagoon).

The presence of thin gypsum layers, calcite pseudomorphs after gypsum crystals, and associated thin stromatolitic layers around 4 and 9 m above the base of a cycle, which has been investigated in great detail, indicate inter- to shallow subtidal conditions and an arid climatic regime with reduced siliciclastic influx. Thus different climate states are recorded by the sediments: humid (documented by progradation of delta lobes) and arid (documented by sabkha-type to shallow brine-pool sediments). The abundant shell concentrations and the intervening more or less unfossiliferous sediments are thought to document high-frequency climatic oscillations of the sub-Milankovitch band. Taphonomic analysis shows that the abundant mono- to paucispecific Corbulomina concentrations are autochthonous and that the low species diversity reflects high stress conditions rather than selective transport or chemical sorting. The fine-grained substrate, high pyrite and Corg content, and the presence of evaporate minerals suggest that three environmental parameters contributed to the stress level i.e. a soupy substrate, dysoxic conditions at the sediment-water interface, and salinity values deviating from fully marine conditions. This assumption is corroborated by what is known about the ecology of modern corbulid bivalves, which commonly are extremely eurytopic. Moreover, the occurrence of Corbulomina in other Jurassic strata, which exhibit signs of brackish-water conditions, a soupy substrate, and possibly lowered oxygen conditions, also supports the conclusions.

Key words: Jurassic; Macrobenthos; Palaeoecology; Environmental stress

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Lower Callovian-Middle Oxfordian Facies from the La Manga Formation Carbonate Ramp: A Forced Regression. Atuel Depocenter, Neuquén Basin, Mendoza Province, Argentina

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The Neuquén Basin was a Mesozoic-Cenozoic retro-arc foreland basin that generated eastwards of the main Andean Cordillera between 36° S and 39° S, at the western margin of the South American platform, bounded by the magmatic arc to the west and by a tectonic foreland to the east. The foreland consisted of the Sierra Pintada belt to the northeast and the North Patagonia massif to the south (Fig.1 a). Four tectonic episodes of this basin development are described by Legarreta and Guliisano, (1989): 1- rifting (Upper Triassic-Lower Jurassic), 2- thermal subsidence (Lower Jurassic-Upper Cretaceous), 3- subsidence due to magmatic and loading (Upper Cretaceous-Lower Cenozoic) and 4- Andean tectonism (Lower Cenozoic-Early Quaternary). Much work has been conducted to regional knowledge of the Neuquén Basin (e.g. Legarreta and Guliisano, 1989; Legarreta and Uliana, 1996; among others). The Jurassic succession is part of the lower supersequence of Legarreta and Guliisano (1989) and includes the Precuyo, Cuyo and Lotena mesosequences. The Lotena Mesosequence, developed from Middle Callovian to Upper Oxfordian-Kimmeridgian times, consists of five depositional sequences and includes marine and continental siliciclastic facies (Lotena Fm.), marine carbonate deposits (La Manga Fm.), and evaporites (Auquilco Fm.) (Fig.1 b). According to the new data the Lotena Mesosequence is extended to the Lower Callovian. From these, La Manga Formation reflects a widespread carbonate deposition through the basin during the Lower Callovian-Middle Oxfordian interval, in both shallow water mosaic-like environments, and the adjacent deeper-water settings. The unit records sea-level fluctuations and changes in the regional marine hydrographic regime (Palma et al., 2007).

In this study, La Manga Formation is analyzed at the so-called Atuel depocenter, where is 53 m thick and consists of two informal units (1 and 2), that respectively represent outer ramp (1), and intertidal to supratidal facies (2) (Fig. 1 c). The Unit 1 is 46 m thick and consists of peloidal-bioclastic wackestone-packstone with an abundant fauna of ammonites, some gryphaeids, echinoderm fragments, and oncolites, commonly interbedded with thinly laminated dark green marls and shales rich in organic matter (Palma et al., 2010). These outer-ramp facies are arranged in meter-scale sedimentary cycles. According to the lack of storm or wave generated structures, the Unit 1 represents a low energy open marine setting. Lamination and organic matter content in the marls suggest that deposition was mainly below storm wave base in outer ramp environment (e.g. Burchette and Wright, 1992). A new biostratigraphy study includes ammonites, in the Unit 1, from the Lower Callovian to Middle Oxfordian (Riccardi, pers. comm.). Near the base of Unit 1, a 11 cm thick condensed interval has been recognized. It consists of bioclastic wackestone and shows Thalassinoides-type burrows on the top. It has yielded Rehmannia cf. pauccostata (Tornq.) Homoeoplanulites sp., Rursicerias sp. (Upper Callovian-Lower Oxfordian) and Peltoce-ratooides sp. (Upper Callovian-Lower Oxfordian Peltoce-ratooides-Parawedekindia Zone). That level is overlaid by a Middle Oxfordian succession characterized by Perisphinctes (Arispinctes) sp., Perispinctes (Kranaoosphinctes) sp., Mirospinches sp. (Bifurcatus Zone), Perispinctes (?Antilloceras) cf. prophaetae Gygi and Hill, and Perispinctes (Dichotomoceras) sp., Perispinctes (?Subdisccosphinctes) sp., and Perispinctes (Kranaoosphinctes) cf. Decurrens (Buck.) (Perispinctes Araucanites Zone).

The Unit 2 (7-12 m in thickness) consists of microbial stromatolites, intraformational breccias and discrete beds of flat-pebbles. Stromatolites are characterized by wavy- wrinkled laminations. Subaerial exposure features including tepee structures, bird’s eyes, mud-cracks and sheet-cracks are common. Pala-lekarst surfaces are also present. Usually, microbial stromatolites are overlaid by breccia facies defining small-scale cycles. Breccia clasts show orientation from bedding – parallel to random, and imbrications also occur. Facies from Unit 2 are interpreted as deposited in upper intertidal-supratidal facies of Unit 2 with domi- nance of subaerial exposure.

The transition between the outer ramp facies of Unit 1 and the overlying intertidal-supratidal facies of Unit 2 is sharp and reflect an interval of rapid decrease in accommodation causing forced regression. This can be interpreted to represent an abrupt fall in the relative sea-level during the end of the Middle Oxfordian in the Neuquén Basin, which probably precluded the deposi-
tion of Auquilco evaporites.

Key words: Jurassic; Carbonate ramp; Forced regression; Neuquén Basin; Argentina

Fig. 1  a, Location map of the Neuquén Basin with indication of the Atuel depocenter; b, Jurassic stratigraphic framework of the Neuquén Basin at Atuel depocenter; c, simplified lithological log of the La Manga Formation at La Manga creek

References:
Microfacies Analysis and Paleoenvironment Interpretation of Upper Jurassic Carbonates of Jajarm Area, N-NE Iran

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This research is focused on the Upper Jurassic (Oxfordian-Kimmeridgian) carbonates in Jajarm area, north-northeast Iran. These deposits have very good and wide exposure in this area. Five stratigraphic sections that are studied in Jajarm area is shown in Fig.1.

Upper Jurassic sediments have transitionally overlain by Middle Jurassic deep water carbonates and unconformable underlain with fluvial siliciclastic deposits of Early Cretaceous. Thickness increases to the west part of study area and ranges from about 300 to 700 m. These deposits mostly consist of gray to light gray and pink to red calcilutite to calcarenite and calcirudite with big ammonites, pelecypods, gastropods and brachiopods in coarser rocks. Interbedded fine and coarse crystalline dolomite are also present. Since Upper Jurassic carbonate rocks (Mozduran Formation) in Kopet-Dagh Basin (NE Iran) are a major gas reservoir, the objective of this study is comparison of lithofacies and depositional history of these formations. Based on five measured stratigraphic sections, field observations, detailed petrographic considerations on more than 500 thin sections, microfacies are analyzed and depositional environment are interpreted.

Microfacies petrographically are mainly consist of skeletal grains such as bivalve, foraminifer, gastropod, brachiopod, echinoderm, bryozoan, coral and non-skeletal carbonate grains such as ooid, intraclast and peloid.

Mudstone, dolomudstone, pelloid wackestone/packstone, pelloid ooid grainstone and bioclast wackestone/packstone are the most important microfacies that mainly deposited in intertidal-subtidal subenvironment in a carbonate platform (Flugel, 2004; Hips and Haas, 2009). The lacking reef constructers in the shallow water microfacies of study area and decreasing carbonate production led to ramp development. Transitional relation between microfacies in study area is supported carbonate sedimentation in a carbonate ramp (e.g. Brachert et al., 2001). Present of various bioclasts in these sediments also show all subenvironments are connected together.

Foraminiferal and pelloid wackestone/packstones are deposited in lagoon environment, ooid grainstone are formed in high energy conditions (Cadjenovic et al., 2008; Hofmann and Keller, 2006), bioclast (echinoderm, brachiopod) grainstone/packstone/wackestones deposited in open marine and finally radiolaria and pelagic pelecypods wackestone are deposited in deeper parts of depositional environment. Type of skeletal carbonates and increasing of non-skeletal carbonate grains especially ooids revealed that Upper Jurassic carbonate may have been precipitated in warm, tropical and supersaturated waters (e.g. Pomar et al., 2004; Hips and Haas, 2009).

Based on size and shape, dolomites of study area in general divided into two groups including fine to very fine and coarse crystalline. Fine dolomites are mainly associated with silt to very fine sand quarts as well as interbeded with non fossiliferous mudstone and show these rocks may have been deposited in tidal flat condition, while coarse crystals are diagenetic dolomite and have formed in shallow to deep burial diagenetic environments.

Microfacies comparison of studied sediments with Upper Jurassic deposits in Kopet-Dagh basin as well as paleogeography construction show a relative similarity in some aspects between two location, but lack of siliciclastic and evaporate deposits indicate that the carbonates of Jajarm area are deposited in a relatively deeper water condition.

Key words: Jurassic; Carbonate rocks; Microfacies analysis; Iran
Fig.1 Location map of study area

References:
Cadjenovic D., Kilibarda Z., Radulloic N. Late Triassic to Late Jurassic evolution of the Adriatic carbonate platform and Budva Basin, southern Montenegro. Sedimentary Geology, 2008, 204: 1-17.
Microfacies and Nannofacies Analyses in Aalenian Deposits from Western Tethys (Iberian Range, Spain)

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This report addresses new data regarding the contribution of calcite microparticles to the input of carbonate sediments. The study of the fine-fraction of limestones and marls in Muro de Aguas, a relatively expanded Aalenian section at the NW Iberian Range (northern Spain), has shown that a combined analysis of nannofacies in ultra-thin sections and smear slides using the classical microfacies approach increases notably the information about the origin of this fine-fraction. It has been revealed as a good tool in order to improve inferences made by field (facies) observations in monotonous sections, that can overlook factors concerning carbonate sedimentology, because allows to distinguish provenance tendencies and paleoenviromental changes. Previous studies of this section (García-Frank, 2007; García-Frank et al., 2008) displayed a quite monotonous alternation of micrite-rich microfacies within the calcareous sediments, organized in twelve coarsening-upwards stratigraphic sequences (s1 to s12), where three major tectonic pulses were distinguished. Unfortunately, the microfacies alternation does not seem to show special connexion to the main tectonic pulses inferred for the area (Fig.1). Since the last decades the use of nannofacies analysis as a tool to elucidate the origin of the fine-carbonate fraction or to reconstrcut paleoenviromental changes has been reported in several studies (e.g. Minolleti et al., 2005; Bour et al., 2007; Beltran et al., 2009; Giraud, 2009; Carcel et al., 2010).

The first studies concerning nannofacies (term defined by Nöel, 1969) used SEM in order to identify the nannofossil contribution to micrite (Nöel and Melgen, 1978). More recent works (e.g. Bour et al., 2007) have also been carried under SEM, to investigate nannofacies but since this is technique that involves more time and expenses, and can only be applied to small samples and to very restricted areas, we decided to use the same methodology as in the microfacies, with the difference of scale (10x-40x vs. 1000x-1500x). The entire set of characters (fossil and mineral abundance and textures) observed on different samples by the microfacies approach was used to define the nannofacies, studying not only the limestone levels, but also the marly ones, with the combination of ultra-thin section and smear slide observations. As aforementioned, the use of ultra-thin sections, allows to see fabric relationships (fossil and mineral abundance and textures), but medium- to small-sized and rare to very rare calcareous nannofossil taxa could be difficult to identify. As this is not a biostratigraphic study, we have selected some taxa that are easily recognizable in the petrographic microscopy, i.e. Schizosphaeraella spp. In contrast, due to their preparation, the smear slides lack of textures and original fossil abundance, but are very useful for isolating the fine fraction and recognizing all the calcareous nannofossil taxa and mineralogies that can be scattered in the thin/ultrathin sections (such as quartz, phyllosilicates and zircon).

The nannofacies analysis reveals that Muro de Aguas micrite contains a mixture of abraded skeletal components that were deposited with larger skeletons and hence is an allomicrite (Wolf, 1965). The allomicrite (senso Flügel, 2004) can be subdivided into bioclastic micrites, formed by disintegration of benthic invertebrate skeletons, and nannomicrites, formed by the disintegration of pelagic biota (accumulation of calcareous plankton, i.e. foraminifers, pteropods and calcareous nannofossils). The bioclastic micrites include mainly what we have referred as carbonate large fragments, that consists of broken fragments >2 μm of easily recognizable benthic foraminifera tests and other invertebrate groups (mainly Bositra and echinodermes). The nannomicrites includes specimens of Schizosphaeraella, “Schizosphaeraella-debris” (i.e. tiny broken fragments of Schizosphaeraella shells), specimens of coccoliths (e.g. Crepidolithaceae, Watznaueriacae) and of nannoliths (e.g. Hexalithus), as well as indeterminate micarb. Micarb are calcite crystals <2 μm, probably produced during dia genesis by disaggregation of nannofossils and/or small foraminifers (for other hypothesis about their origin see Beltran et al., 2009, and reference therein). Other mineralogies also observed in the nannofacies are detrital grains of quartz or zircon, masses of iron-oxides and phyllosilicates (clorites), but they are less frequent.

The bioclastic micrite is usually the main component of the allomicrite, but there are several levels where the proportion of “Schizosphaeraella-debris” + micarb increases and even overtakes the other (i.e. maximum values during the Murchisonae Biochron), or where the nannomicrite is significantly composed of Schizosphaeraella (i.e. peak across the Gigantea-Concavum Subbiochrons boundary). At the base of the section and during the first tectonic pulse (Comptum
Subbiochron), the decrease of the bioclastic micrite is correlated to the increase of “Schizosphaerella-debris” + micarb, though the contribution of Schizosphaerella is also recognizable. Within the Murchisonae Biochron, nannomicrites are dominant, and mainly composed of “Schizosphaerella-debris” + micarb. This event is related to the prevailing marly levels (s4 and s5 sequences) and coincides with an increase of the percentage of hialine foraminifera in the microfacies. The subsequent decrease in the bioclastic micrite content (Gigantea-Concavum Subbiochrones) is related to the sharp increase of nannomicrite which also shows a significant contribution of Schizosphaerella. This episode also coincides with the maximum flooding of the basin during the Aalenian. Dominance of nannomicrites could be related with several causes, e.g. 1) tectonics: restructure of the basin after the “mid-Cimmerian” Unconformity event (García-Frank et al., 2008) related with the first tectonic pulse (chance for Schizosphaerella to fill empty niches formed during the palaeogeographic changes) or the run out of other allomicrites in nearby areas after the tectonic pulses; 2) palaeoecology: the planktonic rain (proliferation of nannoplankton, i.e. dominance of Schizosphaerella) was the most effective source at these moments. More detailed works about the calcareous nannofossil assemblages are needed in order to see the real impact of palaeoecology.

Another remarkably fact, when comparing micro- and nannofacies, is the higher accuracy of the fluctuations of the different detrital fractions behaviour, which in both cases are a minor components of the nannofacies. Though quartz values in the microfacies shown the same general trend as in the nannofacies, with this new approach the general knowledge improves, due to a more complete record of different sized particles and also new levels sampled. Besides, the nanno-zircon crystals abundance display similarities with quartz, whereas the phyllosilicates shown opposite behaviour: They generally peak when quartz and zircon decrease, and although all of them are within the silt-sized particles range, they settled differently (flocculation vs. disperse grain deposition). So the provenance factors are clearly enhanced, and show a neat correlation with the sedimentological evolution of the basin, linked both with eustatic and tectonic controls determining the accommodation space.

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Key words: Microfacies; Nannofacies; Limestone-marl alternations; Early-Middle Jurassic; Iberian Basin; Spain
References:


Structure of Pyrite in the Limb Fragment of Fossil Plesiosaurus

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The study of vital activity tracks of organisms and their remains allows determining habitat conditions of “living” taxa, processes of mineralization and also composition of substitution minerals and digenetic changes in sedimentogenesis. To study the details of fossilization for complex faunas (ammonites, tetrapods and others) we investigated the structural organization of pyrite formed at ferritization of bone bioapatite in the fragment of skeleton of fossil plesiosaurus.

The object of study was the bone remain of plesiosaurus from Middle Jurassic (Lower Callovian) deposits that was found at the Oka River (Elatma, Ryazan region, Russia) and represents fragment of hind limb (Fig.1).

Fig.1 General view of limb fragment

Visually it was determined that order located pores and relics of skin fibers imparted marked roughness to the outer surface of bone. On the cross section the pyrite forms massive oval structure with linear dimension 3 cm. Bone apatite, well preserved on the peripheral part of the fragment, has a spongy structure. The similar structure is characteristic for bone tissue of modern mammals.

It was determined by structural methods that the bone apatite, not substituted, consists of well crystallized carbonated apatite-(CaOH) with unit cell parameters \( A=9.40\pm0.04 \) and \( C=6.87\pm0.04\) Å. Maintenance \( \text{CO}_2 \) makes \( 2.80\% \).

It should be noted that fluorine content was not determined. The analysis of isotope composition of carbon and oxygen of one sample of carbonate-apatite at mass-spectrometer (Delta V Advantage) showed \( \delta^{13}\text{C} \) equal to 11.5‰ (related to RDB) and \( \delta^{18}\text{O} \) — +21.6‰ SMOW.

Microscopic study determined that pyrite formed masses substituting soft tissues in channels and simultaneously preserving structure of crystalline apatite of bone tissue. This mineral is the most often represented at REM images as roundish framboids – “colonies” with diameter from 10 to 100 mm (Fig.2 a, b). Crystals with size 0.5 mm or more often 1 mm are seen in each of them. As a rule crystals of each framboid are well sorted. Octahedrons are surrounded by gel-like film, which look like a “cocoon”, from which crystal tips are seen. It is interesting that gel-like substance can also surround the framboids formed both in pyrite mass, and apatite mass. Sometimes crystal scatterings include oval-like forms, which we regard as pyritized relics of bacteria, as well as framboids of later generation.

<table>
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<tr>
<th>Chemical compound (%) of apatite of a bone fabric</th>
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<tr>
<td>CaO</td>
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<td>34.85</td>
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REM images of polished sections, made from fossil bone remain and chip, showed a number of single crystals with octahedron form, scattered on the surface of bone apatite or in its channels. Separate crystals have hatched faces. Besides, rare individuals of pyrite with cubic habitus are found. It is interesting that massive structure of pyrite on microimages represents homogeneous mass of pyritized bacterial mat.

Thus, on the basis of the study of structural details of pyrite forms we can prove the existence of bilayered biogenic cover supporting origin, growth of crystals and further preservation of framboid. The studied pyrite forms indicate the role of microbiological processes at fossilization of bone remain, though chemical variants of its resementation during diagenesis are not excluded.

**Key words:** Plesiosaurus; Pyrite; Framboid; Apatite
Early Callovian (Middle Jurassic) Ostracods from the Kursk Region (Central Russia) as Paleodepth Indicators

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Studying of early Callovian ostracods from the two boreholes (no. 4 and no. 7) drilled in Kursk region, Central Russia (derived from A.V. Chereschinsky, Voronezh University), have revealed existence of two different ostracod associations in the both successions (Fig.1).

Noteworthy both associations were found in both boreholes only in clays. In the siltstones (borehole no. 7) there were no ostracods at all. Therefore the ostracods analysis of reconstruction of palaeoenvironment is more detailed than facial one, for it can differentiate two biofacies in one lithofacies. The first biofacies (A) comprises ca. 20 species, while the second one (biofacies B) is twice poor in species contents (ca. 10 species), while the ostracods in the same biofacies practically are identically in both boreholes.

In the borehole no. 4 the first biofacies lies below the second, which becomes very poor in species upwards: 4 species were found in its upper part and only 2 species in the top (Fig.1a). Analysis of the relations between abundance and diversity of ostracods has shown that in the first biofacies changes in the both ones (abundance and diversity) are parallel or, in the background of little diversity high abundance of ostracod appearance. At the second biofacies continuous rise of ostracod abundance coincides with gradual reduction of species diversity and afterwards both diversity and abundance decreases. This situation could be explained by existence of the first biofacies in much more favorable environments comparing the second ones. Sandy and silty facies becomes more abundant upwards and these environmental changes seem to be connected with shallowing.

In the well no. 7 both these biofacies were found
two times, i.e. first biofacies follows upwards by
second, and upwards cycle repeats again (Fig.1 b).
Abundance and diversity of ostracods in this borehole
are the same. It is noteworthy that anytime when
biofacies B changes A the ostracods diversity
diminishes and abundance increases. This is a usual
reaction of community on the changes of environments
for the worse, when its taxonomical structure
simplifies and its biomass rises in the same time (the
buffer mass). The sandy facies of the upper part of
succession of the well no. 7 rises, too (the siltstones
appear). We can connect the changes of environments
for the worse in the biofacies B with shallowing of the
basin and approaching of costal line. It confirms the
previous conclusion.

These cycles could be considered as two trans-
gressive-regressive cycles which are finished by strong
shallowing of the basin. Each biofacies of ostracods is
characteristic of specific depth, and species typical for
one biofacies could be called ecological antipodes of
the species from the other one and thus could be used
as paleodepth indicators. The ostracod species, most
typical of the first biofacies (A) are the following:
Lophocythere scabra Triebel, 1951; Fuhrbergiella
archangelskyi (Mandelstam in Lyubimova, 1955),
Fastigatocythere interrupta directa Wienholz, 1969,
Parariscus octoporalis Blaszyk, 1967; Pleurocythere
kurskensis Tesakova in Tesakova, Gulyaev et Štrež,
2009; Glabellacythere nuda Wienholz, 1969; Pro-
cytherura teniicostata Whatley, 1970; Eucytherura?
sokolovy (Lyubimova, 1955); Paracypris sp., Nodop-
ymphalmocythere sp. They are typical of relatively
deep environments, possibly 30-50 m. The ostracods,
typical of second biofacies (B), are the following:
Cytherella fullonica Jones et Sherborn, 1888; Aequa-
cytheridea legitima (Lyubimova, 1955); Palaeo-
cytheridea parabakirovi Malz, 1962; Fastigatocythere
interrupta interrupta Triebel, 1951; F. interrupta ssp.
A Lutze, 1960; F. interrupta ssp. nov., Neurocythere
cruciatu francaconica (Triebel, 1951); N. flexicosta
flexicosta (Triebel, 1951); Bythoceratina cf. scro-
biculata (Triebel et Bartenstein, 1938); Sabacythere ex
gr. rubra (Mandelstam in Lyubimova, 1955). They
inhabited more shallow water with probable depth
5-20 m. Two species, which occurred with high
abundance in the both associations, Praeschuleridea
wartae Blaszyk, 1967 and Lophocythere karpinskyi
(Mandelstam in Lyubimova, 1955), considered as
eurybions in relation to water depth and cannot be
used for paleobathymetry reconstructions.

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ported by RFBR grant 09-05-00456.

Key words: Ostracods; Early Callovian; Kursk
region (Russia); Paleodepth
Sedimentary Facies of the Upper Jurassic Suining and Penglaizhen Formations in the Central Sichuan Basin, SW China

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The Sichuan basin extends for 1000 km E-W and 500 km N-S, and is mainly filled with Mesozoic continental redbeds. The upper Jurassic strata are of terrestrial origin and extensively distributed in the Sichuan Basin, which are subdivided into the Suining and the Penglaizhen Formations, ascendingly (Xia et al., 1982). The Suining Formation deposits are mainly of brownish-red mud and brownish-red siltstones, whereas the Penglaizhen Formation consists of sandstones and mudstones. Both of these two formations are conformably contacted (Fig.1). The Penglaizhen Formation disconformably underlies the Lower Cretaceous Cangxi Formation (Fig.2), and is assigned to the Late Jurassic on the basis of abundant ostracods such as Darwinula oblonga and Darwinula leguminella (Bureau of Geology and Mineral Resources of Sichuan Province, 1982, 1991).

Fig.1 The boundary between Suining and Penglaizhen formations cropped out near Suining City, Sichuan Province

Fig.2 The boundary between the Upper Jurassic Penglaizhen Formation and the Lower Cretaceous Cangxi Formation in Santai County, Sichuan Province

The sedimentary facies features and sedimentary structures are synthetically analyzed in order to clarify the sedimentary environment and evolution of the central Shichuan Basin during the Later Jurassic episode. Our study results show that the basin is widely covered with a set of lacustrine grayish to reddish, purple-red mudstone or shale interbedded with feldspathic fine-grained sandstone, and these deposited beds are nearly horizontal occurrence. The sedimentary particles are relatively fine-grained both in the Suining and Penglaizhen Formations, showing that the tectogenesis is relatively stable during the Late Jurassic Epoch (Wu et al., 2003; Wang et al., 2001). However, in the Late Jurassic of Penglaizhen stage, the basin is characterized by widely-spread varigrained and vari-colored thick sandstone, mudstone and fine conglomerate of river or alluvial fan subfacies, and there are usually sediments and coarse sedimentary particles of relatively large thickness in the Upper Jurassic, reflecting rapid uplift of the mountains around the basin. According to the study of sedimentary structure, sediment particles and colors, the central Sichuan Basin should have undergone a warm climate during the Suining stage and hot climate from the beginning of the Penglaizhen stage.

The sedimentary environment of the Suining Formation in early Late Jurassic epoch in this area is mainly considered as permanent lake, marsh and floodplain, however, the sedimentary environment of the Penglaizhen Formation in late Late Jurassic epoch is mainly considered as a floodplain, seasonal lake and intermittent lake (Fig.3).

Fig.3 Sketch map of paleogeography of the Late Jurassic in the Sichuan Basin, China
From Middle Jurassic on, the mountain ranges around the basin were in stable, the sediments transported to the basin were fine-grained, mainly characterized by reddish mud and silt and fine sand, as well as popular in mud crack; in some beds, very thin gypsum layers are occurred. It is therefore implied that during this period, the area of the lake was very large with shallow water level. In some time, the lake maybe dried up, or turned to a strong oxygenous seasonal lake and intermittent lake. During Penglaizhen stage, because of the Yanshan orogeny movement, the Longmen Mt. in the west and northwest and Qinling Mt. belts in the north and northeast were strongly uplift, the sediments transported from the mountainous rivers were mainly coarse deposits (Wang, 2001). The sedimentary environment during this period was mainly branched out into lake delta system and fluvial and floodplain subfacies, there were seasonal or intermittent lake between the wide rivers and abandoned channels, maybe some of the lake were oxbow lake subfacies. The sedimentary environment and facies are analyzed based on the field outcrops and embedding petrified wood features. The petrified wood widely distributed in the Upper Penglaizhen Formation, maybe caused by flood events during the Late Jurassic.

**Key words:** Central Sichuan Basin; Upper Jurassic, Suining Formation; Penglaizhen Formation; Sedimentary facies

**References:**


Palaeoecologic and Palaeobiogeographic Analysis of the Jurassic Bivalves in Tibet

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Tibet was formed from a complex assembly of allochthonous plates surrounding a series of ocean basins which opened and closed during the Palaeozoic to the Cenozoic period. The Jurassic is a key period for the northward drifting of the Lhasa block, and the Meso-Tethys’ closing (Metcalfe, 2006; Sengor, 1984).

Bivalves are one kind of the most abundant Jurassic fossils in Tibet. This paper discusses palaeogeographic evolution of Tibet based on the palaeoecologic and quantitative palaeobiogeographic analysis of the Jurassic bivalves.

114 fossil records are collected for the database. These records are put into certain faunas based on their spatial and temporal distribution during the Jurassic. Stratigraphic framework is adopted from Sun et al. (2000). There are totally 4 faunas (the Tsada-Nyalam, Lhasa, Rutok-Nima and Qamdo faunas) including 56 genera of the Early Jurassic, 10 faunas (the Tsada, Nyalam and Nakartse faunas of the Himalaya block, the Lhasa and Tsochen-Gertse faunas of the Lhasa block, the Rutok, Nima and Mengchen faunas of the Qiangtang block, and the Amo and Qamdo faunas of the Qamdo block) including 106 genera of the Middle Jurassic; and 7 faunas (the Tsada, Nyalam and Nakartse faunas of the Himalaya block, the Lhasa fauna of the Lhasa block, the Rutok and Mengchen faunas of the Qiangtang block, the Amo fauna of the Qamdo block) including 76 genera of the Late Jurassic (Fig.1).

Three types of environments are differentiated, based mainly on the \( \frac{R_{ECS}}{EFS} \) gradient. They are:

- **Coastal environments**: the most abundant bivalve guilds, high value of ECS diversity, and the \( R_{ECS/EFS} \) is between 0.52-1.15;
- **Shelf environments**: the diversity value of total diversity, abundant EFS but scarce or even absent of ECS, and the \( R_{ECS/EFS} \) is between 0-0.13;
- **Bathyal environments**: only EFS guild, lowest value of diversity.

Cluster analysis is employed for shelf environments faunas from the Early to the Late Jurassic and coastal environments of Middle Jurassic. Fauna-genus (present or absent) tables are used to calculate the DICE similarity – the percentage similarity between districts (Cecca, 2002). No genus is eliminated and no interpolation of taxa made. The SPSS 10.0 for WINDOWS is used to calculate a minimum spanning tree from the similarity matrix and produce an average link (Between group) cluster analysis in the form of a dendrogram (Fig.1).

DISCUSS AND CONCLUSION

Results of cluster analysis show that four faunas of the Early Jurassic fall into two groups: the Tsada-Nyalam with the Qamdo, and the Lhasa with the Rutok-Nima (Fig.1). The similarity between the Lhasa and Rutok-Nima faunas indicates the biotic communication or short distance between the Lhasa and Qiangtang blocks. Cluster together of the Tsada-Nyalam and Qando faunas seems unreliable according to currently widely accepted palaeogeographic framework. The Qamdo block was closer to Lhasa than the Himalaya block during the Early Jurassic, with the Meso-Tethys in between the Lhasa and Qiangtang blocks. Cluster together of the Tsada-Nyalam and Qando faunas seems unreliable according to currently widely accepted palaeogeographic framework.

Cluster analysis of the Middle Jurassic faunas reflects that the similarity between the northern edge of Lhasa block and the southern Qiangtang or the Qamdo blocks lies not only in the A-B type environment faunas (Tsado-Nyalam and Qamdo) but also in A type environment faunas (Techeng and Qamdo). The

Three types of environments are differentiated, based mainly on the \( \frac{R_{ECS}}{EFS} \) (the species number ratio of ECS to EFS) gradient. They are:
Tsochen-Gertse fauna in the northern edge of Lhasa block is more similar to the Nima fauna of the Qiangtang block than the Lhasa fauna in the southern part of Lhasa block. This suggests the fauna communication between northern Lhasa and Qiangtang blocks is easier than that between the northern and southern parts of the Lhasa block, i.e. the Mesotethys was no longer a significant isolation for bivalve immigration during the Middle Jurassic. Moreover, formation of coastal environments (A type) in the northern edge of Lhasa block (the Tengchen fauna) and the southern edge of the Qamdo block (the Qamdo fauna) (Fig.1) might result from the northward drifting of Lhasa block and the subsequent uplifting due to the collision between the Lhasa and Qamdo blocks.

The Amdo, Tengchen and Lhasa faunas are grouped together in the dendrogram of the Late Jurassic faunas, which indicates consistent bivalve faunas in the remnant ocean basin between Lhasa and Qiangtang-Qamdo blocks. The former coastal environments between the Lhasa and Qamdo blocks disappeared and non-marine bivalves occurred during the late Jurassic may result from uplift in Qamdo.

Key words: Bivalve; Palaeoecology, Palaeobiogeography; Jurassic; Tibet

References:


Facial Characteristics and Forming Conditions of Jurassic Sediments in the Ha Coi Depression, Quang Ninh Province

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The Jurassic Ha Coi basin is situated in the Quang Ninh Anticline structure (Tran Van Tri et al., 1977). It has the form of a rectangular channel of NE-SW direction, extending from Cua Ong - Tien Yen to Mong Cai - Ngoc Son with a width of 20-25 km and a length of over 100 km, enlarging northward. This basin is filled up with continental sediments, mainly composed of red, polymictic conglomerate, sandstone, siltstone, claystone interbedded with thin beds or lenses of coal, coaly shale, marl and, more rarely, limestone of the Ha Coi Formation determined as of Early-Middle Jurassic age on the basis of fossils collected in the basal part of the formation.

Based on the analysis of lithological facies and material composition of sediments of samples collected from 39 exposures situated in 6 survey lines, the mineral association, as well as facial association, sedimentary systems and forming conditions of Jurassic sediments of the Ha Coi Formation have been clarified.

Continental sediments of the Ha Coi Formation, basically, belong to the quartz association, from monomineral quartz, oligomictic quartz to polymictic quartz associations, in which usually occur mica and rock fragments. A small quantity belongs to the grauwacke association, mainly of quartz and quartz-feldspar grauwacke. The change in material composition of sediments from terrigenous, lime-bearing terrigenous, calcareous terrigenous to limestone is rather conformable with the rule of facial change from lacustrine shoreface to shallow-water and deep-water sedimentary associations.

17 lithological facies have been determined, distributed into 5 facial associations, belonging to 2 main sedimentary systems, alluvial and lacustrine systems with the main amount of lacustrine sediments. Based on the distribution rule of facial association and sedimentary system, in the lower part of the Ha Coi Formation there is the change from coarse- to fine-grained sediments that shows clearly the change of depositional environment from near-bank zone of river to lake intercalated with estuarine and deltaic facies, then lacustrine shallow-water faci al associations. The middle part of the formation is mainly composed of fine-grained sediments of lacustrine environment, from zone of shoreface, shallow-water to lacustrine deep-water zones. The upper part consists of an intercalation of shallow-water to shorefaces sediments. The relative stability of lacustrine facies in the middle and upper parts of the formation expresses the rather stable syn-depositional tectonic regime. During the Jurassic period, in the Ha Coi Basin, the continental climate became semi-dry hot; the high thermal background was intercalated with humid cycles which gradually shortened in time.

I. Introduction

The Ha Coi sedimentary basin is situated in the Duyen Hai Structural Zone (Dovzhikov et al., 1965) or in the Quang Ninh Anticlinorium (Tran Van Tri et al., 1977). Lying in the extreme Northeast Bac Bo Region, the Quang Ninh Zone has the form of a crescent moon embracing the An Chau Superimposed Depression in the north-northwest with the northwest end near the Vinh Yen Town and the northeast end in the East Sea (fig.1). In the topographical side, it belongs to a hilly and low-mountainous area with the average altitude of from hundred to some hundreds metres. Its topographic surface inclining south-southeast ward is strongly eroded and dissected.

The Quang Ninh Zone is composed of formations of volcanic clastic, terrigenous-carbonate and carbonate sediments of Late Ordovician to Late Paleozoic ages. Their total thickness is about 6000-7000 m. Apart from these there are still Mesozoic and Cenozoic coal-bearing and mixed continental red beds filling up grabens and basins with the thickness of some hundreds to some thousands metres. During all the Paleozoic era, the Quang Ninh Zone subsided, creating the conditions of accumulating Paleozoic formations, as for during Mesozoic and Cenozoic its Paleozoic basement was feebly folded, but many times fractured by faults. Lying upon Paleozoic formations, Mesozoic sediments (T2-J1-2) were formed in a narrow graben extending from Vinh Yen - Dong Trieu to Hon Gai - Mong Cai with a length of about 250 km and a width varying from 6 to 20 km.

The Ha Coi superimposed basin has the form of a rectangular trough of northeast direction extending from Cua Ong - Tien Yen to Mong Cai - Ngoc Son with a width of 20-25 km and a length of over 100 km enlarging northward. It is filled up with continental sediments, composed mainly of red polymictic conglomerate, sandstone, siltstone and claystone with some interbeds or lenses of coaly shale, coal, marl and limestone of the Ha Coi Formation. They are exposed in the form of very gradual isoclinal beds (10°-20°) in the margin of the depression like a centripetal binding
ribbon. The centre of the depression is covered by Quaternary deposits and contemporaneous sea water. In the northwest limb and on the Cai Chien, Vinh Thuc Islands, the Ha Coi Formation covers with angular unconformity the Tan Mai Formation (O2-Si), while in the southwest and south it rests unconformably upon or has tectonic contact with Upper Triassic coal-bearing formation.

The Ha Coi Formation (Zhamoida A.I., 1962) was named in accordance to the geographic name of the centre of the area and the Ha Coi Bay in Mong Cai. Based on Liassic fossils collected in its lower part it was firstly dated as Undifferentiated Jurassic. In the geological mapping at medium scale (1:200,000) and in thematic studies, it has been subdivided into two (Nguyen Cong Luong et al., 2001; Fir.1) or even three (Nguyen Xuan Khien et al., 2003) subformations. New collections of fossils have allowed geologists to date the formation more precisely as Early-Middle Jurassic.

Geological and stratigraphic characteristics of these continental red beds have been described by some works (Zhamoida A.I., 1962; Vu Khuc and Bui Phu My, 1988; Bui Cong Luong et al., 2000; Nguyen Xuan Khien et al., 2003; etc.), but there are still lots of unclear problems related to characteristics of lithological facies, forming conditions and sedimentary composition. Our study is aimed to contribute in the clarification of these problems, then to establish paleogeographic characteristics of the basin, where there are the famous World Natural Heritage Ha Long Bay.

II. Stratigraphic characteristics of the Ha Coi Formation

The most sufficient section of the Ha Coi Formation has been observed on the Ban Chat - Ban Thin Road and on the talus of the Tan Mai - Ha Coi Car Road. It is composed of 3 following parts (Nguyen Xuan Khien et al., 2003, with supplementation and adjustment of the authors):

(1) Lower part: including mainly coarse-grained sediments, which were formerly described by French geologists as “Continental Sandstone” or “Upper Sandstone”. It is composed of 4 members:

Member 1: Thick-bedded quartz sandstone with some interbeds of white-pink sandstone and violetish siltstone; 50 m thick.

Member 2: White-grey medium- to coarse-grained quartz sandstone with some interbeds of fine sandstone, red-brown siltstone and claystone; 200 m thick.

Member 3: Red-brown siltstone with some dark grey beds due to the content of black or black-brown coaly shale, lenses of coaly shale, marl and calcareous siltstone; 30 m thick. Yielding leaf imprints of Anomozamites sp., Equisetites sp., and Neoecalimites sp.

Member 4: White-grey quartz sandstone containing poorly preserved gastropod fossils with some interbeds of red-brown siltstone and calcareous siltstone; 110 m thick.

The total thickness of the lower part is about 390 m.

(2) Middle part: mainly of the intercalation fine-grained sediments (siltstone, claystone, calcareous clayey siltstone) with some interbeds of sandstone with 4 members:

Member 1: Red-brown siltstone interbedded with fine- to medium-grained sandstone and some lenses of yellow-greenish marl; 10 m thick.

Member 2: Red-brown siltstone and calcareous siltstone with some interbeds of cross-bedded fine sandy siltstone; 82 m thick.

Member 3: Brown-violetish, cross-bedded siltstone and calcareous silty claystone interbedded with lighter coloured fine-grained sandstone; 120 m thick.

Member 4: Brown-violetish siltstone interbedded with reddish sandstone; 160 m thick.

The total thickness of the middle part is 372 m. Near the Cai Lam Village, leaf imprints have been collected in this part, such as: Coniopteris sp., Equisetum sp., Podozamites sp. together with the phyllopods Amussia sp., Baidestheria sp. and spores and pollens Ginkgo sp., Benettites sp., Protoconiferus sp., Chomotiletes sp., and Laevigatosporites sp.. Among these fossils, Coniopteris sp. is usually considered as characterizing Liassic.

(3) Upper part: consisting of an intercalation of fine- and coarse-grained sediments with 2 members:

Member 1: Quartz sandstone containing small calcareous concretions, light violet-brown calcareous sandstone interbedded with thin-banded silty sandstone of the same colour, 116 m thick.

Member 2: Light red-brown calcareous siltstone with some interbeds of thin-banded fine-grained sandstone, 190 m thick.

The total thickness of the upper part is 306 m, and the total thickness of the Ha Coi Formation in this section reaches 1068 m.

In the foot of the Trang Vinh Dam (Mong Cai, Quang Ninh Province) and in the Ban Chat - Po Hang earth road (Dinh Lap, Lang Son Province), Nguyen Xuan Khien et al. (2004) have discovered in violetish-brown calcareous gritty gravelstone of the lower part of the formation an abundant collection of bivalves with Cuneopsis sp., Eocuneopsis dehuaensis Guo (sample MD.140/2). Similar fossils have been found in the Zhangkezhai Formation (J1,2) in Yunnan (China). Apart from these, there still is Pseudocardinia sp. (samples MD.140, MD.140/1). Based on collected fossils and the unconformable relation of the Ha Coi Formation upon older sediments, this formation have been dated as Early-Middle Jurassic.

III. Material composition of sediments of the Ha Coi Formation

(1) Composition of sediments

a. Conglomerate: Not widespread. It occurs only at the base of the formation, distributed mainly in the northwest of the basin. Pebbles have the dimension from small to medium; coarse pebbles are rare. They have the composition of monomineral, oligomictic and
polymictic quartz. In the basal conglomerate bed, there are still in-situ pebble fragments, such as in the Tan Mai area there are pebbles from quartzitic sandstone, mica-bearing sandstone and phyllite of the Tan Mai Formation; in the Cai Chien Village conglomerate has pebbles from Paleozoic limestone. Besides, in many places there are pebbles from chert, siltstone and sandstone.

b. Sandstone: Sandstone is of different grain sizes. Fine-grained sandstone is widespread, then comes medium-grained sandstone. They are distributed mainly in the lower and upper parts of the formation with polymorphous bedding, isoclinal cross-bedding, trough cross-bedding, horizontal gravitational bedding to wavy cross-bedding and very gradual wavy cross-bedding.

The dominant composition of clasts consists of quartz, but it is also very polymorphous, varying in dependence to the common clast composition and other accompanying minerals. Medium-grained sandstone belongs to the association of river branch-bed facies; it often has the monomineral quartz composition or oligomictic quartz containing mica scales and rich in heavy minerals, such as tourmaline, zircon, zoisite, rutile, leucoxene, etc.. However, in large rivers emptying into lakes forming estuarine delta, sand has the monomineral quartz composition grading upward into polymictic composition with the increase of rock fragments (Quang Ha, Quang Ninh Province).

Sandstone, siltstone of the lake shore zone have the structure of trough cross-bedding, lenticular bedding interbedded with wavy cross-bedding, discontinuous wavy horizontal bedding with a polymorphous composition. In the most part of investigated points, they have the composition of siliclyte quartz, polymictic quartz; specifically in the Cai Bau Island area there is the grauwacke-quartz composition and in Tien Yen – the grauwacke composition. Intercalated with these formations there are silt-sand, calcareous clay-silt with the content varying from 15% to 28%.

c. Siltstone: This is the main component in the formation, occupying up to 40%-60% of the common amount. It is of different grain sizes and rarely forms beds of great thickness, but usually interbedded with sandstone, and more commonly, with claystone and marl. Just siltstone sometimes contains limes of different level, from 5% to 25%, in dependence to forming conditions. The bedding of siltstone is polymorphous, including banded horizontal bedding, small cross-bedding, opposite small cross-bedding, small wavy bedding, wavy bedding intercalated with lenses, etc.. Together with fine-grained sand and clay, silt forms wavy surface in large areas (Cam Y, Mong Duong, Quang Ninh Province). Siltstone exists in almost all facial zones, from alluvial to lacustrine. Its composition consists mainly of polymictic quartz, rich in rock fragments and usually belonging to the quartz siliclyte form. Siltstone of this form is usually met in the shallow-water and deep-water lake facial zone. Siltstone of polymictic, grauwacke-quartz, arkose-grauwacke composition is observed in the near-shore lacustrine facial zone.

d. Claystone: Claystone usually forms thin beds intercalated with siltstone, marl, microcrystalline limestone and even, sandstone. Occupying great amount in the middle and upper parts of the formation, it is mainly of allothigenic origin. In its composition, a great amount belongs to redeposited clay, which was washed from old metamorphic formations. Especially, the occurrence of redeposited sericite has been often observed with large amount in almost all sediment types.

e. Marl, calcareous siltstone: This group is rather widespread in the middle and upper parts of the formation. It can form great members with the thickness varying several to tens of metres, or interbeds between claystone, siltstone and sandstone. The carbonate content oscillates from 20%-30% to 45%-50% or greater. Terrigenous components have the composition varying from oligomictic to polymictic quartz, frequently very rich in schist and shale fragments. Marl and calcareous siltstone are usually met in the association of shallow-water and deep-water lacustrine facies.

f. Limestone: This component is mainly composed of very thin-, wavy horizontally bedded microcrystalline limestone of the deep- and shallow-water lacustrine facies. Besides, there still occurs red-brown coarse-clastic limestone of the deltaic estuarine facial zone or shore zone. Recently discovered fossils with the dominant role of bivalves occur just in this facial zone. In near-shore zones, there are mixed sediments including clay colloid, iron colloid mixed with oolitic calcareous concretions lying within calcareous clayey siltstone. Microcrystalline limestone of great lense form usually occurs in the basal part of the formation together with bioclastic limestone. At the same time, the intercalation of limestone micro-beds with claystone and siltstone is widespread in the middle and upper parts.

(2) Terrigenous mineral association of sandstone-siltstone of the Ha Coi Formation

Preliminary results of the study on terrigenous associations of the Ha Coi Formation have shown following basic characteristics.

Basically, terrigenous sediments of the Ha Coi Formation belong to the quartz sedimentary association consisting of monomineral quartz, oligomictic quartz and polymictic quartz among them the existence of mica and rock fragments plays the dominant role. The smaller amount belongs to the grauwacke association, mainly with quartz grauwacke and quartz-feldspar grauwacke.

The association of terrigenous sediments of monomineral and oligomictic quartz composition is more widespread in the lower and upper parts of the
formation, while polymictic quartz composition (mainly of silicilyte quartz) is largely and regularly distributed in the formation. The monomineral and polymictic quartz associations occur mainly in sediments of alluvial, shore lacustrine, and more rarely, shallow-water lacustrine facies.

The association of terrigenous sediments of quartz grauwacke and quartz-feldspar grauwacke composition is rarely met. It occurs in sediments of near-shore zone grauwacke and quartz-feldspar grauwacke composition material composition of the Jurassic lacustrine basin. The association of terrigenous sediments of quartz grauwacke and quartz-feldspar grauwacke composition – to the association of shallow-water lacustrine facies, and siltstone, claystone interbedded with microcrystalline limestone – to the association of deep-water lacustrine facies.

The formation and distribution limestone-bearing terrigenous, calcareo-terrigenous or carbonate containing terrigenous components conform the law of facial distribution and the evolution of the referred material composition of the Jurassic lacustrine basin.

IV. Characteristics of lithological facies and their forming conditions

On the basis of facial analysis of samples collected, the formation consists of an intercalation of shallow-water to deep-water zone. The upper part of the formation has the change in grain size from coarse- to fine-grained sediments that indicates the change in sedimentary environment from alluvial to lacustrine - shore zone intercalated with estuarine-deltaic, then shallow-water lacustrine facies associations. The middle part of the formation is composed mainly of fine-grained sediments of the lacustrine environment, from near-shore zone, shallow-water to deep-water zone. The upper part of the formation consists of an intercalation of shallow-water lacustrine and near-shore sediments.

The facies of undirectionally cross-bedded conglomerate and pebble-bearing sandstone interbedded with or without sandstone of the river-bed facies association, sandstone and siltstone of the alluvial bank facies association are distributed in the topography of hills and low mountains, situated in the northwest margin of the depression. They belong to systems of main and secondary streams emptying into lacustrine basins situated in the centre of the structural zone at the beginning of the Jurassic period. Main rivers formed the estuarine deltaic system (typically in the Trang Vinh area) with the thickness of each rhythm reaching up to 10 m, and the elongated system of estuarine sand dykes. Sediments of the bank zone are rather polymorphous with 4 facial types including mainly fine sand, sandy silt, silty clay without or containing carbonate, coarse to medium sand, sometimes bearing grit and limestone pebble. In some places, river mouth area of this zone became swampy forming beds of coaly shale and thin lenses of coal. Intercalated with bank zone sediments, there are shallow-water lacustrine formation including calcareous silty sandstone interbedded with sandstone rich in carbonate-clay concretions, discontinuously wavy-bedded to horizontally wavy thin-bedded fine sandstone, interbedded silty sandstone, etc. At present, lacustrine sediments of these two facial associations mainly form ranges of turned-bowl hills surrounding the Ha Coi Bay and lying in some islands.

Lacustrine sediments of the deep-water association include fine-banded, fine sandstone containing calcareous concretions interbedded with thin-, parallel-banded, silty sandstone, marl and thin-, micro-bedded microcrystalline limestone. The typical section has been observed in the Cai Chien, Vinh Thuc Islands. They are distributed in centripetal form oriented to the basin centre.

On the basis of distributive rule of facial associations and sedimentary systems, we can see that the lower part of the formation has the change in grain size from coarse- to fine-grained sediments that indicates the change in sedimentary environment from alluvial to lacustrine - shore zone intercalated with estuarine-deltaic, then shallow-water lacustrine facies associations. The middle part of the formation is composed mainly of fine-grained sediments of the lacustrine environment, from near-shore zone, shallow-water to deep-water zone. The upper part of the formation consists of an intercalation of shallow-water lacustrine and near-shore sediments.

The forming process of the Lower-Middle Jurassic Ha Coi Formation expresses a cycle of sedimentary accumulation from very coarse- to fine-grained beds in the lower part, an intercalation of medium- and fine-grained beds with interbeds of microcrystalline limestone in the middle part and from fine- to coarse-grained in the upper part. This indicates that the depositional basin passed through a gradual subsidence since the beginning of the forming process; it reached the maximum depth during the forming time of the middle part. The upper part marked the gradual uplift of the depositional basin by the intercalation of coarse- and fine-grained beds of the shallow-water lacustrine facies. The distribution of facial zones obeys the common law of depositional basins of continental lake type: shallow-water facial zone grades upward into deep-water one with the orientation toward the centre of the basin. As for near-shore zone, it is distributed in the topographic part lying between the basin and the eroded area with gradual slope. At present, alluvial sediments have been only observed in the northwest margin of the depression.

The relative stability of lacustrine facies in the middle and upper parts of the Ha Coi Formation shows a rather stable syn-depositional tectonic regime. The elongated distribution form of facial zones as well as features of ripples on the wavy surface remained in sediments of the shore zone allow us to predict on the rather large scale of the Jurassic continental lake in the studied area.

V. Paleoclimate

At the end of the Triassic period, the hot-humid climate created good conditions for the development of an abundant vegetation cover to the Hon Gai Coal Basin in the Norian-Rhaetian time. However, at the
beginning of the Jurassic period the climate turned into semi-dry-hot with a high thermal background intercalated with humid cycles which became shorter and shorter in time; all that marked the formation of the Ha Coi Continental Red Beds. Features of accumulation environment, associations of authigenic minerals, couples of indicator elements together with characteristics of distribution of the biological world in this time show that the climate became dryer and dryer.

At the beginning of Jurassic, in the Quang Ninh Zone humid cycles were rather long, creating the conditions of development of marshes in the shore zone to form coaly shale beds and thin lenses of coal in the lower part of the Ha Coi Formation. Apart from this, in this part there are cycles of formation of grey to greenish-grey sediments interbedded with beds of reddish and red-brown colours. Basically, the biological world was developed and widespread in just this time that was showed by many fossil occurrences. Further, the climate became more and more dry and hot, leading to the development of the weathering crust upon acidic effusives largely distributed in the area. This formed favourable conditions for the formation of thick members of ferric oxide-rich sediments which are of red colour, very rare in fossil remains with the increase of carbonate content in the middle and upper part of the formation.

Key words: Jurassic sediments; Ha Coi formation; lacustrine deposits; Quang Ninh Province; Viet Nam

References:
Revised Phosphate-water Fractionation Equation: Implications for Jurassic Paleotemperature Reconstructions from Biogenic Apatite

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The oxygen isotope composition (δ¹⁸O) of biogenic apatite has become increasingly used to reassess anomalous temperatures inferred from biogenic calcite, more prone to diagenetic alteration (e.g. Pucéat et al., 2007; Trotter et al., 2008; Joachimski et al., 2009). However, recent studies have shown that significant differences arise in apatite oxygen isotope composition acquired using the different techniques in current use (Vennemann et al., 2002; Chenery et al., 2009). Yet all authors in the field use phosphate-water fractionation equations that have been acquired over 25 years with analytical techniques that are not applied any more (Longinelli and Nuti, 1973; Kolodny et al., 1983). The differences in apatite δ¹⁸O induced by analytical techniques question the applicability of these fractionation equations to more recently acquired data.

In this work, we generated a phosphate-water fractionation equation using apatite from fish of a single species (Sparus aurata) raised in controlled environment (temperature and water δ¹⁸O), using the most recent techniques analyses. The new phosphate-water fractionation equation we establish presents a similar slope but an offset of about 2‰ with the earlier published fractionation equations. Our results have major repercussions on paleotemperature reconstructions from biogenic apatite δ¹⁸O in all studies since the work of Crowson et al. (1991) and O’Neil et al. (1994) have been underestimated and need to be consequently revised.

For the Jurassic period, fish tooth δ¹⁸O data have been acquired using two different analytical techniques, and have been standardized using a value of either 21.7‰ or 22.6‰ for NBS120c (Lécuyer et al., 2003; Dera et al., 2009). As a result, differences of about 4 °C exist between the paleotemperatures inferred from the two data sets, which are due to data standardization only. Applying our new fractionation equation to the published data sets increases the reconstructed temperatures by about 8 °C for the Early Jurassic, and by about 4 °C for the Middle and Late Jurassic.

Key words: Paleotemperature; Oxygen isotopes; Apatite; Jurassic

References:

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During the last two decades, works applying oxygen and carbon isotope analyses (respectively $\delta^{18}O$ and $\delta^{13}C$) to marine fossils have highlighted major changes in seawater temperature, polar ice volume, and carbon cycle during the Phanerozoic (e.g. Zachos et al., 2001). On this score, recent $\delta^{18}O$ data measured on well-dated bivalves, belemnites, brachiopods, ammonites, or fish teeth from European domains have importantly contrasted the former ideas about the Jurassic climate (200 to 145 Ma) (Brigaud et al., 2008; Dera et al., 2009; Dromart et al., 2003; Lécuyer et al., 2003; Price, 2010; Suan et al., 2010; van de Schootbrugge et al., 2005; Wierzowski and Joachimski, 2007), which was for a long time suggested as warm, with low latitudinal gradients (Frakes et al., 1992). Though the effectiveness of Jurassic climatic events may be seriously questioned, because: (1) in spite of noisy $\delta^{18}O$ time series, the geochemical trends are never statistically tested on exhaustive data sets; (2) the past evolution of the oxygen isotope composition of seawater remains unknown; and (3) signals based on organisms with different ecologies or isotopic fractionation mechanisms may be discordant. In addition, studies embracing the whole Jurassic interval are scarce, although they are necessary to point out the processes responsible to the long-term $\delta^{18}O$ variations during this period marked by major continental break-ups and volcanic events.

In order to address these questions, we present an extensive $\delta^{18}O$ database covering the whole Jurassic period, which includes 2741 published and 127 new $\delta^{18}O$ values measured on well-dated belemnites and bivalves from the NW Tethyan domain. In order to compare the patterns of both organisms and to detect significant climatic trends standing out from the background noise, the SiZer approach (Significant ZERO crossings of the derivatives) was used (Marron and Chaudhuri, 1998). This multiscale method is based on the construction of curves fitting time series using different levels of smoothing (h). The first derivatives of each curve are simultaneously computed with their 95% confidence intervals, allowing the signs of derivative estimates to be statistically tested. The results of multiple tests are then reported under the form of slope SiZer maps with different colours, which enables us to identify significant features at different time scales simultaneously.

Whatever the smoothing resolution, the SiZer maps based on both fossil organisms depict numerous significant features, in spite of differences in the absolute $\delta^{18}O$ values and in the amplitude of variations, which are concordant during the overlap intervals. This similarity in SiZer results relative to organisms with distinct ecologies (i.e. life depth or temperature) validates the robustness and the paleoenvironmental (not biotic) origin of geochemical trends over the whole Jurassic interval. Both fossil organisms confounded, 14 significant rapid $\delta^{18}O$ changes (0.5 to 1 My) with different amplitudes are statistically validated by the SiZer method and related to paleoclimatic events. In addition, our analysis depicts long-term $\delta^{18}O$ trends characterized by two low $\delta^{18}O$ plateaus during the Toarcian and the Kimmeridgian, and a progressive increase during the Middle Jurassic. Once a clear paleoclimatic framework is statistically validated for the whole Jurassic period, the $\delta^{18}O$ changes are ultimately compared to a synthesis of carbon cycle disturbances, volcanic and palaeoeoceanographic events potentially responsible to short- and long-term paleoclimatic variations.

**Key words:** Jurassic; Palaeoclimate; Oxygen isotopes; SiZer approach

**References:**


Upper Jurassic Paleoclimatic Reconstructions Based on Clay Mineral Distribution in Deposits of the Russian Platform: Possibilities and Restrictions

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The Upper Jurassic reference “Gorodishchii” section (Middle Volga River region; Russian Platform) was repeatedly becoming an object for paleoclimatic reconstructions. Recently clay mineral distribution analysis, paleoecological study of calcareous nannofossils, registration of boreal-tethyan ammonites migration, and isotopic variations of 13C and 18O in belemnite rostra enabled recognition of main Volgian (Tithonian) trends, which were interpreted as an evidence of significant regional and/or global climatic fluctuations (Price and Rogov, 2009; Riboulleau et al., 2003; Ruffell et al., 2002). However, the trends obtained from different methods show no correlation. In such a situation the reliability of paleoclimatic indicators has to be revised.

So, an episode of climatic acidization was assumed on the basis of changes in the clay mineral distribution, i.e. decrease of kaolinite (~ from 50% to 10%) and simultaneous increase (~ from 10% to 50%) of smectite in Middle Volgian deposits in ‘Gorodishchii’ section (Riboulleau et al., 2003; Ruffell et al., 2002). It covered interval of Panderi ammonite Zone, during which OM-rich shale (5%-30% TOC) accumulated. The sporadic presence of palygorskite in Panderi Zone sediments was an additional argument of climatic warming and aridization. It should be emphasized that new model of OM-rich shale formation was based on idea of climate acidization (Rengarten and Kuznetsova, 1967). The enrichment of sediments with OM was connected with specific sedimentary processes and mechanisms of arid environments such as eolian input of nutrients (Fe) into the basin as a part of atmospheric dust (resulted in dramatic increase in bioproductivity) and development of thermohaline stratification in the water column (i.e. conditions protecting the OM oxidation).

Upper Jurassic marine deposits cover a large area on the central and western part of the Russian Platform (from Caspian to Barents Sea).

Our research has shown that authigenic formation of clay minerals at the early diagenesis stage and redeposition (recycling) of clay minerals from earlier accumulated (under different climatic conditions) sediments and their involving into new sedimentation cycles negatively affected the preservation of initial “climatic memory” of the clay minerals in the Upper Jurassic sediments of the Russian Platform.

An X-ray analysis of the clay fraction (<0.001 mm in size) of sediments (29 samples) made from Kimmeridgian/Volgian sediments of the “Gorodishchii” section (J2km, Eudoxus zone – J3vlg2 Virgatus zone) revealed four types of mineral associations successively changing each other up the section.

I. Smectite-illite-kaolinite (low smectite content) association with nearly equal volumes of each mineral phase (sometimes with a small prevalence of kaolinite over illite and smectite) is common within the lower part of the section, which cover the broadest stratigraphic range (J2km, Eudoxus zone – J3vlg2, Panderi zone, 18.0 m) including the bottom of OM-rich shale unit (~1.0 m).

II. Illite-kaolinite-smectite association characterized by an appreciable prevalence of smectite over kaolinite and illite corresponds to the lower part of the OM-rich shale unit (without lower ~1.0 m).

III. Illite-kaolinite-smectite association (with clinoptilolite) is close to association II in ratio of basic components, but is distinguished by the presence of clinoptilolite. This association represents an intermediate features to association IV and is found in the bottom of the upper half of the OM-rich shale unit (Panderi Zone).

IV. The illite-clinoptilolite-smectite (high smectite content) association with kaolinite losing its rock-forming role and present in the form of a tributary impurity is common at upper part of the OM-rich shale unit (Panderi Zone) and overlying silt/sand deposits (Virgatus Zone).

The clay mineral chlorite was presented in all associations as insignificant admixture.

Clay mineral associations show the tendency to decrease of the relative quantity of kaolinite and increase of smectite content is closely connected with occurrence of the clinoptilolite in the sediments. This mineral is a calcium version of high-silica zeolites of the heulandite group and is formed via a synthetic way under the presence of a reactive siliceous material (pyroclastic or biogenic one) in an alkaline condition, which is rich in calcium cations. Clinoptilolite was only formed in the immediate proximity to a silica source, as it became destroyed during transportation. Therefore, this mineral may only can be of authigenic origin in the Panderi Zone deposits. In clinoptilolite formation from pyroclasts in the Middle Volgian sediments of Russian Platform was proposed (Rengarten and Kuznetsova, 1967), however ash particles were not found in this interval. At the same time numerous evidence of broad presence of the authigenic mineral association clinoptilolite – montmorillonite – silica minerals (opal-CT, cristobalite) in biogenic silicites (for example, Upper...
Creataceous and Paleogene of the Russian Platform) is documented (Muravyov, 1983).

The presence of biogenic siliceous remnants (radiolarian shells and silicon sponge spiculas) in Panderi Zone deposits was reported in (Vishnevskaya and Baraboshkin, 2001). According to our data radiolarian shells are presented mainly in the upper part of OM-rich shale unit. Both in diffuse condition and in the form of mass accumulations on individual narrow interval. They are present in much more appreciable quantities in the overlying silty deposits of the Virgatus Zone. The initial siliceous substance typically does not remain in shells, and they usually are filled by autigenic phosphates or glauconite-like fine clay aggregates, however lighter ones – greenish, grayish and yellowish shades of color. These formations are closer to smectites than micas (actually glauconites) in their optical properties.

As well as the previous researchers (Riboulleau et al., 2003; Ruffell et al., 2002), we consider that clay mineral association I (with low smectite content) has terrigenous detrital origin in Upper Jurassic sediments under the study. However, clay mineral associations II, III and IV (with high smectite content) occurred at the Panderi Zone time interval should be connected, in the first place, with more or less intensive processes clay mineral neoformation (i.e. specific smectite-clinoptilolite mineral association, apparently with a tributary quantity of silica minerals) during early diagenesis stage, not with paleoclimatic changes.

Generally similar relationship between decreasing of kaolinite-smectite ratio, on one hand, and enrichment in siliceous fauna remnants, on the other hand, was observed in other Upper Jurassic sections, particularly in the Northern part of the Russian Platform (in Syssola River region) and evidently displays the common regularity. At the same time, constancy of the ratio kaolinite, illite and smectite is a characteristic feature of Upper Jurassic sediments from Kostroma Region, i.e. Lower Kimmeridgian and Middle Volgian (Panderi Zone) deposits containing no biogenic silica remnants (and authigenic minerals developed on them) (Gavrilov et al., 2008).

Also it should note that clay mineral palygorskite is common in Upper and Middle Carbon sediments in the central part of the Russian Platform (Rateev, 1985) as well as in Famennian deposits of the Upper Devonian of Voronezh syncline where it is one of the main minerals (Karpova, 2004). Since Devonian and Carbon deposits closely contact Upper Jurassic deposits (sometimes Middle Volgian deposits) in many places of the central part of the Russian Platform, there exist all grounds to connect the presence palygorskite, which is sporadically found in the form of traces on different stratigraphic levels of Upper Jurassic, with its redeposition (recycling) from more ancient sedimentary units. In particular, Panderi Zone episodes were apparently connected with the lowering of the erosion basis in the course of general Late Jurassic marine regression, which affected the relatively raised central part of the Russian Platform, in the first place.

Thus, the paleogeographic reconstructions based on clay mineral distribution in Upper Jurassic deposits of the Russian Platform should be careful. Factors distorting the initial “climatic memory” of clay minerals, such as: a) early diagenetic neoformation of clay minerals; b) redeposition (recycling) of clay minerals from more ancient sediments should be taken into consideration.

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Key words: Upper Jurassic; Clay minerals; Paleoclimatic reconstructions; Russian Platform

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Toward the Stratigraphic Correlation and Reconstruction of Atmospheric pCO2 in Terms of Stable Carbon Isotope in the Terrestrial Jurassic Carbonates, China

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We have been studying the non-marine middle and late Mesozoic in China from the bio-, stable carbon isotope-, and sequence stratigraphic points of view. In 2009, we collected samples from the lower to upper Jurassic in and around Hebei, Chongqing, Sichuan Provinces for the international correlation by using the fluctuation curve of the stable carbon isotope as well as for the reconstruction of atmospheric pCO2 by calcareous concretions in paleosols.

The non-marine lower Jurassic Ziliujing, Middle Jurassic Xintiangou, Lower Shaximao, and upper Jurassic Upper Shaximao Formations (Liet al., 1997) distributed in the studying area. This age correlation is based on dinosaurs (ditto). For the stable carbon isotope stratigraphy, we collected samples from the Daanzhai Member of the Ziliujing Formation. The member is lacustrine beds composed of quartz grains with carbonate matrix.

We have tried high resolution correlation by using stable carbon isotope curves for the non-marine lower Cretaceous which is correlated with the Jehol Group in Heilongjiang, Jilin, Liaoning, and Hebei Provinces. We obtained δ13C from the terrestrial organic matter in visual kerogen contained in mud stones of those beds. This method is based on the successful results which we conducted for the marine Cretaceous Yezo Group distributed in Hokkaido, Japan.

Ninety-nine percent of visual kerogen is composed of terrestrial organic matter in the marine Cretaceous Yezo Group (e.g. Uramoto et al., 2007, 2009). Therefore, it is not always difficult to obtain the δ13C of terrestrial organic matter in the Group for the stratigraphic correlation. However, in the non-marine lower Cretaceous of northern China often the ratio of terrestrial organic matter is low and there is much amount of algae (e.g. the Jiufotang Formation, δ13C values range from -29 per mil to -23 per mil; in some levels the amorphous organic matter occupies 98% of TOC). Algae show different δ13C values from terrestrial organic matter. Therefore, it is often impossible to make stratigraphic correlation by using the stable carbon isotope fluctuation. It is necessary to develop the method to remove algae from the visual kerogen by using specific gravity separation, which we are trying. Additionally, the lower Cretaceous which is famous by well preserved fossils like feathered dinosaurs contains too much amount of tuff and the total organic carbon contents are relatively smaller amount. It is also difficult to obtain δ13C from such beds.

It is desirable to make cross checks for the obtained correlation by stable carbon isotope from various aspects. In the case of the Yezo Group, ammonoids, inoceramid bivalves, planktic foraminifers, radiolarians, sporopollen, dinoflagellates and radiometric method were used for the cross checks and the validity was confirmed (e.g. Uramoto et al., 2007, 2009). In the case of the Chinese non-marine beds, the validity of the obtained excursion curve of stable carbon isotope would be checked by some marine organisms which are sometimes found in the marine invasions.

The analytical results of the terrestrial lower Jurassic Daanzhai Member (carbonate matrix) do not show the negative spike of the early Toarcian anoxic event (Jenkyns, 1988) which continued for 500,000 years. The analytical values are different from the expected values. We are now considering it.

We also began to reconstruct the atmospheric pCO2 of Jurassic and Cretaceous by using calcareous concretions obtained from the paleosols. For Jurassic, we have studied the pCO2 by samples from the above mentioned Jurassic in and around Beibei district. The analytical results are fairly concordant from various data obtained in the world. At present, we are analyzing concretions and calculating the raw data. We would like to show you the results at the time of the symposium.

Key words: Stable carbon isotope stratigraphy; International Correlation; Atmospheric pCO2; Terrestrial Jurassic

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Component Analysis of Organic Matter between Extant and Fossil *Ginkgo* and Wall Rock from the Jurassic in Lanzhou, Northwest China and Paleoclimatic Significance

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Organic matters in the sediments are admixtures of many kinds of matrices. Although these substances have been changed during the lithification, they also remain framework of carbon, organic components and carbon isotopic composition, which can provide the paleoenvironmental information. On the other hand, terrestrial plants are sensitive to environment, and they recorded various information of the environment under which they grew and developed at that time. Especially there is obvious correlation among the carbon isotopic composition of plants and CO\(_2\) concentration, rainfall and temperature.

Carbon isotopic composition of organic matter and inorganic carbonate in lake sediments, paleosoil, loess-paleosoil sequences have been widely used to study Quaternary environmental change as the substituted index of paleoclimate and paleoenvironment (Wang et al., 1998; Hatte et al., 1998). However, it is concluded that the discrepancy occurs in the carbon isotopic composition of plants, which belong to the same genus but different species and live in the same condition.

Carbon isotopic composition of extant and fossil *Ginkgo* cuticles was studied in this paper. The fossil was identified to *Ginkgo huttonii*, which is lower than that of fossil *Ginkgo* cuticles. The fossil was identified to *Ginkgo huttonii*, which has well-preserved cuticles. The fossil cuticles can be separated from the samples with dissection pin. Extant leaves of *Ginkgo biloba* were collected from Lanzhou. The rock samples were collected from the Yaojie coalfield and were crushed, then dealt with the 5% HCl to take out carbonate completely, and then the samples were burnt into CO\(_2\) in the oxygen condition, after following the purification, finally they were studied by the mass spectrum analysis.

Cuticles of fossil and extant *Ginkgo* were dipped in C\(_2\)H\(_2\)Cl\(_2\) solution for 72 hours. The dissolved organic components were extracted with ultrasonic concussion, and then were concentrated under rotary evaporation at 25 °C. Separate the saturated hydrocarbon with ligarine, then separate the aromatic hydrocarbon with benzene, finally wash the nonhydrocarbon with ethanol from the dissolved organic component in the silica gel-alumina column chromatogram. Measure the content of total hydrocarbon and components after the rotary evaporation concentration of separated component. A GC-MS analysis was carried out to study the organic component of saturated hydrocarbon and aromatic hydrocarbon with HP6890-Micromass Platform series II at the State Key Laboratory of Organic Geochemistry (SKLOG), Guangzhou Institute of Geochemistry, Chinese Academy of Sciences. Chromatogram procedure: Heating from 80°C (5 min isotherm) to 290 °C (40 min isotherm) at a rate of 4 °C/min. Helium was used as carrier gas at 1 ml/min. The chromatogram column is quartz capillary (50 m X 0.32 i.d).

The study shows that the content of organic components of *Ginkgo cuticle* is much higher than that of fossil *Ginkgo*. The carbon isotope composition of extant *Ginkgo cuticle* is lower than that of fossil *Ginkgo*. On one hand, it might be the result of thermal action, which caused the organic isotope fractionation. On the other hand, without thermal abnormality, the difference...
of carbon isotopic composition of parent material might result in the difference of carbon isotopic composition of fossil *Ginkgo cuticle*. It is obvious that we could make use of carbon isotope composition of fossil *Ginkgo cuticle* to reconstruct paleoenvironment.

In a word, the carbon isotope composition of organic matter from strata has good correspondence to sedimentary environment. The different sedimentary environments with different substance sources are in control of carbon isotope change. It shows that the effect of higher plant is very important in continental sediments, which is proved by studying biomarker in strata. The present analysis result shows that the paleoclimate of Lanzhou was warm and wet in the early period of the Middle Jurassic, and became gradually arid and little rain in the middle and late period of the Middle Jurassic.

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**Key words:** *Ginkgo*; Organic matter; Carbon isotope; Paleoclimate

**References:**
Carbon Isotopes and Stomatal Characters Reconstructing the Middle Jurassic Paleoenvironment Based on Fossil Ginkgo from Huating Coalfield in Northwest China

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The fossil cuticle containing stomata may be regarded as a skeletal record of environmental change. Stomatal characters of fossil cuticles can provide information of paleo-CO2 levels, and the stable carbon isotope values of fossil cuticles record interactions between fossil plants and their paleoenvironment (Beerling and Royer, 2002). Since Woodward (1987) suggested that it is an inverse relationship between the partial pressure of atmospheric CO2 and the stomatal frequency, the stomatic parameters of fossil plants have been widely used in the reconstruction of paleo-CO2 for different geological ages. Ginkgo L., with wide geological distributions, is considered as one of the most reliable agents to reconstruct the paleo-environment.

The cuticles of fossil plants from the Middle Jurassic Yan’an Formation at Huating coal-mine in Gansu Province, China have not been studied previously. In 2008 and 2009, lots of fossil plant specimens were collected from Yan’an Formation by the authors and their colleagues, which provided valuable material for the paleoenvironment reconstruction. In present article, seven specimens were identified as Ginkgo obrutschewi Seward with well-preserved cuticles are studied in detail. They are characterized by: leaf typically fan-shaped with slender petiole in 8 mm long by 1 mm wide, basal angle 110°-130°, with radius of lamina 35-55 mm, divided by a deep median sinus into two lobed parts; each part shallowly lobing once again and forming 4 ovate lobes for the whole leaf; lobes rounded or obtuse in apex, about 50 mm long by 8-13 mm wide; veins parallel, about 9-14 per cm half-way up lamina, branching in lower parts of lobes only (Fig.1 1, 2). Cuticle hypostomatic. The upper cuticle composed of 3-7 rows of longitudinally elongated rectangular cells, 60-150μm × 14-30 μm in size; periclinal walls flat or with irregular, uneven papilla or shallow domes, anticlinal walls slightly undulate. Between veins epidermal cells usually irregular both in arrangement and shape, 40-125 μm × 25-80 μm in size. In lower cuticles, the non-stomatal zone consisting of 8-10 rows of longitudinally elongated rectangular cells, 80-190μm × 20-45 μm in size, the stomatal zone 302-450 μm wide, consisting of isodiametric or polygonal epidermal cells arranged randomly, with shallow domes or ridges on periclinal walls. Stomatal apparatus are haplocheilic and round-oval in shape with irregularly orientation, 50-65 μm long and 32-42 μm wide. 4-5 subsidiary cells for per stoma, lateral ones often strongly cutinized, inconspicuous on outline; one or two polar ones often present in short rectangular or wedge-shaped. Most of the subsidiary cells more or less thickened. The stomata density is 30.2 per mm2 in stomatal zones (Fig.1 3, 4).

The present specimens are consistent with the type specimens described from Xishanyao Formation of Xinjiang in the Middle Jurassic (Seward, 1911; Sze, 1963). Morphologically, the present specimens are similar to G. sibirica (Heer) Seward from Xishanyao Formation (Sze, 1963; Miao, 2005), but the present specimen has denser and more distinct veins in leaves than those of G. sibirica. The specimens of G. yimanensis from Henan (Zhou and Zhang, 1989) are similar to the present specimens on the shape of leaves, but the cuticle of G. yimanensis is amphistomatic.

Leaves of Ginkgo are sensitive to atmospheric CO2 concentration, so paleo-CO2 levels can be evaluated through investigating the stomatal parameters of Ginkgo fossil leaves. Stomatal ratio (SR) is defined as the ratio of the stomatal index (SI) of the Nearest Living Relative (NLR) to that of the fossil plant under investigation. SR can be translated into estimates of RCO2 in GEOCARB III (Berner and Kothavala, 2001), the Carboniferous standardization (ISR equivalents to 2 RCO2) was employed for the reconstruction of Jurassic CO2 levels in this article. Seven specimens of G. obrutschewi are used for paleo-CO2 reconstruction, the SI of G. obrutschewi is 4.8 and of the extant G. biloba L. is 12.1. Therefore, the paleo-CO2 in the Middle Jurassic of Huating is calculated about 1513 ppm, which is closer to the mean estimated value of GEOCARB III, and is also coincided with the results from the adjacent Yaojie area and most Jurassic estimates of paleo-CO2 based on stomatal ratios of Ginkgo.

The carbon isotope composition of the plants leaves has a close relationship with their living environments. The mean δ13C value of G. obrutschewi from the Yan’an Formation is -25.5‰, and we can calculate the carbon isotope composition (δ13C) of G. obrutschewi is 19.9‰ based on the carbon isotopic discrimination model of C3 plants (Farquhar et al., 1982). By using the formulation of WUE (Farquhar and Richards, 1984), the WUE of G. obrutschewi is calculated as 208.3 mmolCO2/molH2O. Correspondingly, the δ13C of the extant G. biloba from the Northwest China is about -28.4‰, and the δ13 C is 22.6‰.
that the WUE is 52.6 mmolCO$_2$/molH$_2$O. Our results indicate that the leaves of *G. obrutschewi* from the Middle Jurassic in Huating had lower carbon isotope discrimination and higher WUE than those of its NLR, *G. biloba*. It is appear that the trees of fossil *Ginkgo* in the “greenhouse” world in the Jurassic can regulate theirs carbon isotopic discrimination and WUE to obtain an ideal physiologic state, which probably assisted the radiation and diversity of the fossil *Ginkgo* in the Mesozoic.

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**Key words**: Jurassic; Fossil *Ginkgo*; Paleo-environment; Huating coalfield.

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Carbon and Oxygen Isotope Composition of Upper Callovian-Lower Kimmeridgian (Middle-Upper Jurassic) Cephalopod Shells from the Russian Platform: A Proxy for A Global Climate Change?

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We present the carbon and oxygen isotope data derived from well-stratigraphically dated belemnite rostra and ammonite shells from two sections (Dubki near Saratov and Mikhailenino in the Kostroma district) in the Russian Platform. Studied samples were screened for diagenetic alteration using cathodoluminescence, trace element analysis, X-ray analysis and scanning electron microscopy (SEM) and were found to be well preserved. Belemnite rostra and ammonite shells were carefully separated from surrounding sediment with a microdrill and ground. Samples were analysed for carbon and oxygen isotopes using an automated carbonate reaction device (Kiel IV) connected to a Finnigan Mat Delta Plus mass spectrometer at the Institute of Geological Sciences and the Institute of Palaeobiology, Polish Academy of Sciences in Warsaw.

The belemnite $\delta^{13}$C values are high and scattered (from 1.5‰ to 3.8‰ VPDB) in the uppermost Callovian and the lowermost Oxfordian and decrease slightly in the uppermost Middle Oxfordian-lowermost Kimmeridgian part of the studied interval, where they range from 1.0‰ to 3.2‰ VPDB. The new carbon isotope record is consistent with previously presented data from the Russian Platform (see Price and Rogov, 2009). The carbon isotope record of the Russian Platform with high belemnite $\delta^{13}$C values differs significantly from the record of the Submediterranean ammonite province of Poland and Germany (cf. Wierzbowski 2002, 2004; Wierzbowski et al., 2009) being similar to the record of the Isle of Skye in Scotland (Nunn et al., 2009). Higher (than Submediterranean) $\delta^{13}$C values of Russian belemnite rostra are likely related to high biologic productivity and/or high organic matter burial in semi-isolated Boreal marine basins. Further studies are, however, necessary to precisely document carbon isotope variations in the uppermost Lower and the lowermost Middle Oxfordian of the Russian Platform.

The temperatures calculated from the oxygen isotope compositions of belemnite rostra are low in the uppermost Callovian and the lowermost Oxfordian (averages of 5 ºC and 8 ºC for cylindroteuthids and belemnopseids, respectively; Fig.1). The trend to lower belemnite $\delta^{18}$O values and higher temperatures is seen in the new dataset through the Middle-Upper Oxfordian and the Lower Kimmeridgian. The temperatures calculated for cylindroteuthid belemnites are highest in the Kitchini Zone of the Lower Kimmeridgian ranging from 14 ºC to 18 ºC (Fig.1). The decrease in belemnite $\delta^{18}$O values was already reported from the Russian Platform (cf. Price and Rogov, 2009) and interpreted as a result of global warming (Dromart et al., 2003). It is, however, not clear whether the observed decrease should be related to changing water temperature or chemistry as an apparent increase in calculated temperatures may be caused by a decline in seawater $\delta^{18}$O value owing to the enhanced freshwater influx (Wierzbowski et al., 2009). Some observed facts like moderate temperatures calculated from well-preserved uppermost Callovian and lowermost Oxfordian ammonite shells (average 13 ºC) and the retreat of Mediterranean-Submediterranean ammonite fauna in the Upper Oxfordian of the Mikhailenino section seem to be not compatible with the inferred warming. On the other hand, the discordance between ammonite spectra oscillations and stable isotope data of belemnite rostra has recently been shown for the Late Kimmeridgian-Volgian of a central part of the Russian Platform (Price and Rogov, 2009). Ammonite associations were thought, in this case, to be influenced not only by changes in palaeotemperatures but also by palaeography changes in connections between the Volga Basin and the Tethys (Price and Rogov, 2009). It is also worth noting that belemnites are considered to be nektobenthic, while ammonites are thought to have inhabited an upper part of the water column (Wierzbowski and Joachimski, 2007; Price and Page, 2008), therefore, differences between belemnite and ammonite isotope records may be linked to different palaeotemperatures of bottom and surface waters.

Further studies are planned in order to present more detailed oxygen and carbon isotope record of the Russian Platform. We hope that the collected data will contribute to the better understanding of perturbations in the Middle-Late Jurassic climate and the global carbon cycle.

Key words: Stable isotopes; Belemnites; Ammonites; Palaeoclimates
Fig. 1 Stratigraphy, $\delta^{18}O$ values and palaeotemperatures calculated from $\delta^{18}O$ values of well-preserved belemnite rostra from the Russian Platform using equation given by O’Neil et al. (1969) and modified by Friedman and O’Neil (1977)
Open circles = cylindroteuthid belemnites. Filled diamonds = belemnopseid belemnites.

References:
The Early Toarcian Oceanic Anoxic Event in Western Canada

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The Early Toarcian Oceanic Anoxic Event OAE is marked by a brief (~200 ky to ~1 my) period of severe disruption in ocean water geochemistry that is related to intense climate change and marine anoxia in the Early Jurassic (Hesselbo et al., 2000; McArthur et al., 2000; Hesselbo et al., 2007 and References therein). Geochemical data from the Queen Charlotte Islands (QCIs), British Columbia Canada are presented herein as a test of two specific hypotheses concerning global (Hesselbo et al., 2000; Pálfy and Smith, 2000; Kemp et al., 2005) vs. regional (McArthur et al., 2008 and References therein) controls for this event. Toarcian lithostratigraphy in the QCIs consists, in ascending stratigraphic order, of the Fannin, Whiteaves, and Phantom Creek formations representing continuous deposition along a terrane margin from the late Early Jurassic into Middle Jurassic time. The ~100 m thick Whiteaves Formation makes up the majority of Toarcian strata and consists largely of grey/green medium to fine grained siltstone with calcareous nodules, medium to coarse grained sandstone interbeds, and zircon-bearing ash beds interspersed throughout. The Whiteaves Formation is widely distributed throughout the QCIs but a section located along the Yakoun River in central Graham Island (Fig.1 c) is the most complete and fossiliferous.

Carbon-isotope data from the Yakoun River section show an abrupt negative shift in $\delta^{13}$C$_{org}$ (7‰) that averages ~30.94‰ for ~11 m, which also coincides with increasing Total Organic Carbon (from 0.3% to 1.9%) from 32 m to 43 m in the section. A negative excursion in fossil wood is also evident in this interval, recording a ~8.5‰ shift in $\delta^{13}$C$_{wood}$ value with a maximum of ~29.94‰ at 33 m in the section. Stratigraphically above the excursion interval, $\delta^{13}$C$_{org}$ values have a steady negative trend from ~25‰ to ~29‰ with low TOC (~0.5%) from 43 m to 104 m in the section. New and previously recorded biostratigraphic and geochemical data indicate that the large negative carbon-isotope excursion occurs in the Kanense Zone of the Early Toarcian and is therefore interpreted as evidence of the OAE in western North America. In the late Early Jurassic the Queen Charlotte Islands were part of the Wrangellia terrane located in the northeast paleo-Pacific Ocean (Fig.1b) near the present Canada/US border at an unknown distance west of the North American margin. Our results show that perturbation of the atmospheric/marine carbon reservoir was widespread in the Early Toarcian and was evident in the open ocean environment of the northeast paleo-Pacific. This argues that the OAE was the result of global rather than regional controls.

Key words: Toarcian; Carbon-isotope excursion; Anoxia; Canada

References:


Fig. 1. a, Ammonite zonal schemes for the Early and Middle Toarcian of western North America, northwestern Europe and the Mediterranean. Absolute dates are based on U–Pb data and schematic isotope profiles are those documented for the Tethys Ocean area. Stratigraphic position of the OAE interval is shaded. Middle Toar. = Middle Toarcian, pos (+) = positive excursion, neg (−) = negative excursion, rise (+) = rising values; b, Paleogeographic map of Pangaea showing positions of the Wrangellia terrane, Tethys Ocean, and Karoo–Ferrar Igneous Province during the Toarcian; c, Modern map of the Queen Charlotte Islands showing location of the Yakoun River section in central Graham Island.
Strontium Isotope Variations in Middle Jurassic (Late Bajocian – Callovian) Seawater

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The seawater strontium isotope curve is characterized by a broad and deep minimum at the Middle-Late Jurassic transition. Precise data were, however, missing for the Bathonian-Callovian interval (cf. Jones et al., 1994, Jenkyns et al., 2002).

We analysed well-stratigraphically dated and well-preserved belemnite rostra (non-luminescent, C Fe <150 ppm, C Mn <50 ppm, C Sr >990 ppm) and ammonite shells (≥99% aragonite, well-preserved microstructure) derived from clay and carbonate sediments of the Polish Jura Chain in central Poland. Belemnite rostra and ammonite shells were carefully separated from surrounding sediment with microdrill, ground and dissolved in 2.5M HCl. The leachates were evaporated to dryness. Strontium separation was performed in two steps: with cation exchange resin Bio-Rad 50W-X8 using 1M HCl as an eluent and with Sr resin 50-100 μm using 3M HNO₃ as an eluent. Total blank of chemical procedures was less than 20 pg compared to >20 μg strontium in the samples. Isotope analyses of strontium were performed by a MC ICP-MS Neptune Thermoelectron Finningan at the Institute of Geological Sciences, Polish Academy of Sciences in Cracow. All isotope ratios were corrected for fractionation effect using the ⁸⁷Sr/⁸⁶Sr value of 0.1194 and normalized to SRM 987 ⁸⁷Sr/⁸⁶Sr ratio of 0.710248.

The belemnite ⁸⁷Sr/⁸⁶Sr ratios from the Polish Jura Chain show a narrow range of values (Fig.1). A high-resolution seawater ⁸⁷Sr/⁸⁶Sr curve for the Middle Jurassic (Late Bajocian-Callovian) is produced from the obtained analyses of belemnite samples. The measured seawater ⁸⁷Sr/⁸⁶Sr ratio decreases gradually starting from the Late Bajocian to the early Late Bathonian (from ca. 0.707060 to ca. 0.707012), a relatively abrupt decrease of seawater ⁸⁷Sr/⁸⁶Sr ratio is noted at the Bathonian-Callovian transition (from ca.0.707012 to ca. 0.706915) although some data are missing from this interval. A further decrease of seawater ⁸⁷Sr/⁸⁶Sr ratio up to ca. 0.706850 is observed in the course of the Early and the Middle Callovian. Lowest ⁸⁷Sr/⁸⁶Sr ratios have been measured from uppermost Middle and Upper Callovian belemnite rostra derived from the Coronatum and the Lamberti ammonite zones. The presented belemnite temporal ⁸⁷Sr/⁸⁶Sr trends are entirely consistent with several data reported from the studied stratigraphic interval by Jones et al. (1994), Podlaha et al. (1998), Callomon and Dietl (2000) and Page et al. (2009; see Fig.1). The ⁸⁷Sr/⁸⁶Sr ratios measured from ammonite shells of the Late Bajocian-Bathonian age range from 0.707080 to 0.707275. The ammonite ⁸⁷Sr/⁸⁶Sr ratios are 0.000025 to 0.000120 higher than the ratios of coeval belemnite rostra.
The Middle-Late Jurassic minimum of the seawater $^{87}\text{Sr}/^{86}\text{Sr}$ ratio might have been linked to the enhanced hydrothermal activity of the seafloor, which resulted in the influx of isotopically light strontium to the oceans (cf. Jones and Jenkyns, 2002). The magnitude of the minimum (lowest $^{87}\text{Sr}/^{86}\text{Sr}$ ratio in the Phanerozoic) and its long time-span (ca. 30 my) are, however, unusual. The relatively rapid fall in the seawater $^{87}\text{Sr}/^{86}\text{Sr}$ ratio observed at the Bathonian-Callovian transition as well as during the Early Callovian (in contrast to the Late Bajocian-Late Bathonian interval) may result from the disparate duration of ammonite subchronozones used for the construction of the time-scale of the diagram (see Fig. 1). The decrease of the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio at the Bathonian-Callovian transition correlates, nevertheless, with a warming and a change in facies distribution across Europe (Brigaud et al., 2009; Wierzbowski et al., 2009). This may prove that acceleration of the volcanic activity of the seafloor and an increase in atmospheric CO2 level occurred at the Bathonian-Callovian transition. The plateau of the seawater $^{87}\text{Sr}/^{86}\text{Sr}$ curve in the Middle-Late Callovian correlates, on the other hand, with a global transgression (cf. Norris and Hallam, 1995, Wierzbowksi et al., 2009). The Middle-Upper Callovian sediments of European Tethyan and peri-Tethyan areas show abundant condensations and omission surfaces. The Middle-Late Callovian is additionally marked by the waning of the production of marine carbonates (Bartolini et al., 1996; Morettini et al., 2002; Dromart et al., 2003; Cecca et al., 2005). All the data show a link between palaeoceanography and the tectonic activity of the Earth during the Jurassic. The presented isotope data from belemnite rostra may be used to obtain a best fit of the strontium isotope curve in the Late Bajocian-Callovian.

Studied ammonite shells are characterized by lower $\delta^{18}\text{O}$ values when compared to coeval belemnites and bivalves (Wierzbowski and Joachimski, 2007). This fact together with sedimentologic and faunistic proxies allowed Wierzbowski and Joachimski (2007) to assume that the ammonites lived (contrary to belemnites) in surface or shallow near-coastal waters of the basin affected by freshwater influx from neighbouring land areas. The slight enrichment of ammonite shells in $^{87}\text{Sr}$ isotope may be hence linked to a change in strontium isotope composition of the brackish water owing to the riverine strontium input. Alternative...
explanation may be the diagenetic alteration of fragile ammonite shells as primary strontium isotope composition may be affected by the contribution of isotopically heavier strontium transported by diagenetic fluids derived from weathered land areas. This scenario seems, however, to be controversial as studied ammonite shells were found to be well-preserved based on careful screening of aragonite contents and the preservation of the microstructure.

**Key words:** Strontium isotope stratigraphy; Middle Jurassic; Belemnites; Ammonites

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Stepwise Atmospheric Carbon Isotope Excursion During the Early Jurassic Oceanic Anoxic Event

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During the Mesozoic (250-64 Myr ago) geologically short intervals of about 0.5 Myr were subject to particularly severe environmental changes, including high sea-surface temperature and very low oxygen content of marine water. These so-called Oceanic Anoxic Events, or OAEs, occurred simultaneously with profound disturbance to the carbon cycle. A giant Early Toarcian (~182 Myr ago) negative carbon-isotope excursion, possibly the largest such anomaly in whole Phanerozoic, has been described from marine materials, and high-resolution datasets in marine sections have shown that the shift to light carbon-isotope values occurs as a series of stratigraphically abrupt steps towards lighter isotopic values. (Hermoso et al., 2009; Jenkyns et al., 2001; Kemp et al., 2005). However, what is still poorly known about this event is its manifestation in non-marine and marginal marine environments. Although the prominent negative carbon-isotope anomaly, has been described from terrestrial organic matter in fully marine deposits (Hesselbo et al., 2000; Hesselbo et al., 2007), the same excursion towards light isotopic values has until now been documented from only a single marginal marine site, on the island of Bornholm, Denmark (Hesselbo et al., 2000; Hesselbo et al., 2007; McElwain et al., 2005) and, furthermore, the stepwise character of the excursion has not hitherto be identified from non-marine materials.

Here we present new carbon-isotope data from terrestrial organic matter (phytoclast separates), collected from 5 fully cored boreholes (Fig. 1) and one outcrop through a Toarcian coastal and marginal marine sedimentary succession (Ciechocinek Formation) in the Polish Basin, a setting where hinterland climate and sea-level change are particularly well recorded. A comprehensive sequence stratigraphy and inferred relative sea-level history has previously been developed for the Early Jurassic succession in the Polish Basin, based on sedimentological and palaeontological study of boreholes and outcrops (Pieńkowski, 2004). Early Toarcian strata are assigned to a single unconformity-bounded depositional sequence, which has been objectively subdivided into five para-sequences (Pieńkowski, 2004). The principal new dataset constitutes >400 carbon-isotope analyses of phytoclasts separated manually from palynological preparations. The organic content consists mainly of phytoclasts (wood fragments, cuticle) and spores and is thus made up of material that originates almost entirely in the terrestrial environment. All profiles analyzed show the same well-developed excursion towards exceptionally light isotopic values through the Early Toarcian. The results show that the shift to light carbon-isotope values in atmospheric carbon dioxide also occurred in a series of major steps that match those identified from marine materials, where they have previously been identified with 100 kyr eccentricity forcing of climate change. The new data are particularly

Fig. 1 Parkoszowice core, showing Lower Toarcian Ciechocinek Formation (mudstones, heteroliths and subordinate sandstones) and major sedimentary and geochemical events
significant in this regard because they demonstrate that the stepped pattern was characteristic not just of surface seawater, but also the contemporaneous atmosphere and terrestrial biosphere, where localized systematic anomalies matching those in the ocean are inconceivable.

The Polish Basin succession contains further independent evidence for palaeoclimatic conditions prior to, during, and after the OAE. The new and old data combined suggest that each 100-kyr cycle in carbon-isotope values was characterized by increasingly severe palaeoclimatic change, culminating in extremely hot and humid conditions co-incident with the peak of the final most negative carbon-isotope excursion.

Additionally, the results demonstrate a powerful new tool for a high-resolution stratigraphy of the Late Pliensbachian – Early Toarcian strata, important in this case for proving stratigraphic integrity of one of most important seal rock formations for future CO₂ sequestration systems in Poland.

**Key words:** Toarcian; Atmospheric carbon isotope excursion; Stepped pattern; Palaeoclimate; Orbital forcing

**References:**


Jurassic and Lower Cretaceous Glendonite Occurrences and Their Implication for Arctic Paleoclimate Reconstructions and Stratigraphy

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Since the pioneering articles by Kaplan (1978) and Kemper and Schmitz (1981) idea on using glendonites as paleotermometers became useful for investigation of rocks of the different origin (shallow and deep-marine as well as terrestrial) and age (from Neoproterozoic to Quaternary). There are no doubts that origin of these pseudomorphoses and their precursor ikaite should be restricted by very narrow temperature range (Swainson and Hammond, 2001; Selleck et al., 2007) and even highest estimated temperatures slightly above 7º C (Stein and Smith, 1986) reflect existence of such low paleotemperatures during the predominantly greenhouse Mesozoic Era. Ikaite precipitation is favored by elevated alkalinity and dissolved phosphate, and in many cases their formation is associated with organic-rich marine sediments where methane oxidation is occurring (Selleck et al., 2007). Glendonites, as a rule, occur within terrigenous members (mudstones, siltstones or sandstones), in many cases associated with other carbonate concretions or limestone bands.

There are many papers considered stable isotope value of glendonites or their occurrences in some regions or sections, but most full review of their occurrences in Arctic Mesozoic has been published at the dawn of such studies (Kaplan, 1978). Here we are presenting some additional data, received from recent field works held in Spitsbergen and Northern Siberia, which permit to date paleoclimate oscillations more precisely and revealing differences of influence of climate/current changes between the shallow and deep-water environments.

1. Stratigraphical and geographical distribution of glendonites in Arctic Jurassic and Lower Cretaceous

Glendonite concretions, especially more or less big ones, usually attracted attention of geologists due to their strange outline, and in spite of rarity of mentioning of “glendonites” such concretions well recognized through References under the names “stellate concretions” or “antraconite concretions”. Nevertheless their precise dating frequently met some difficulties because fossils are not numerous and diverse at the glendonite-bearing members.

Oldest Jurassic records of such concretions are known from the Upper Pliensbachian above the Stokesi Zone and perhaps restricted to uppermost Pliensbachian Amaltheus viligiaensis Zone of the Northern Siberia and lower Lena river flow. Upper Pliensbachian glendonites, discovered recently at the Northern Germany (Teichert and Luppold, 2009) also belongs to the uppermost zone of this stage. At the top of the Pliensbachian glendonites disappeared drastically, which is well corresponding with remarkable warming at the beginning of the Toarcian (Zakharov et al., 2006, among the others). Again glendonites appears at the Early Aalenian, but in this time their occurrences restricted by the western board of the Khatanga Sea. Late Aalenian glendonite distribution is close to those of the Early Aalenian, and such concretions are also mentioned from the Vilyui and Kolyma basins.

Peak of the glendonite abundance and diversity falls to the Bajocian (including also bulk of the Bathonian of the early authors). Bajocian glendonites are known from numerous localities of the Northern Siberia, Jakutia, North-East of the Russia. Bathonian glendonites are less widely ranged, and at the Lena lower flow they became smaller are disappeared at the lower part of the Bathonian. Callovian glendonites are known only from the restricted area at the Anabar Bay and Bolshoi Begitchev Island. They are known from the lowermost Callovian and from the Middle-Upper Callovian boundary beds. Precise age of the glendonites form the Kolyma basin, mentioned by Chumakov and Frakes (1997) as Callovian-Early Oxfordian, is unknown, because Middle-Upper Jurassic ammonites in this area are very rare and never been figured or described. Most probably age of their Koster Fm, as follow from the “macrocephalitids” mentioned from this formation, which should be ammonoids from the Arctrocephalites — Arcticoceras lineage seems to be Bathonian and, perhaps, partially Early Callovian. Upper Jurassic glendonite records from the Arctic are unknown except mentioning of the “stellate concretion” from the Upper Oxfordian of the North-East of the Russia (Paraketsov and Paraketsova, 1988). Glendonites of the Oxfordian age also were reported from the Khabeyskay-a-2 well near Yenisei mouth (Zlobina, 2007), but their precise age is unknown.

Wide distribution of the glendonites began again at the Valanginian. Lower Valanginian glendonites are known from the Northern Siberia (Kaplan, 1978) and Sverdrup Basin (Kemper, 1987). Record of Lower Cretaceous (Valanginian or Hauterivian) glendonites was also reported recently from the Western Siberia (Potapaov, 2006). Glendonites are also present at the uppermost Valanginian (Homolosomites bojarkensis Zone) of the Northern Siberia and Upper Valanginian age is also supposed for some glendonites from the
Partially in could be connected with changes of facies stratigraphical range of shallow-water glendonites. Deep and shallow facies showing smaller size, smaller and Bathonian glendonite occurrences in relatively bottom of the Jurassic sea. Comparison of the Bajocian with peculiarities of methane seeps location at the such distributional patterns could be partially connected connected with influence of currents. Alternatively mainly by western part of the Khatanga Sea and did not facies. During the Aalenian glendonites were restricted are more numerous at the more or less deep-water of the sites (deep or shallow water): usually glendonites distribution has been influenced by facies and position very far from each other has revealed that glendonite of the Upper Jurassic and Lower Cretaceous deposits of Eastern Siberia. Aptian-Albian glendonite occurrences are known from the Arctic Canada (Upper Aptian to Lower Albian of Sverdrup Basin, studied by Kemper (1987)). At Spitsbergen Aptian glendonite concretions presence at the shaly member containing *Tropaeum arcticum* (Stolley) and thus they are Middle Aptian in age. Possible Aptian glendonites (“stellate concretions”) are also known from the NE Russia (Efimova et al., 1970). Age of the Lower Albian glendonites (?) from Spitsbergen, reported as “anraconites” (Pëčelina, 1965), should be corrected to Aptian due to re-determination of some ammonites (Ershova, 1983).

2. Some peculiarities of geographical distributional of glendonites in the Jurassic of the Siberia: paleoclimates, environmental control and implication for correlation

In all studied cases beds containing glendonites are relatively poor in fossils, which showing high endemism and mainly represented by Arctic bivalves and ammonites. This is well corresponding with suggested cooling events. As a rule glendonites occur at thin bands and don’t scattered through the relatively thick members. Such patch distribution of glendonites through the sections could reflect high-frequency climate oscillations. Comparison of the more or less well-dated sections of Northern Siberia situated not very far from each other has revealed that glendonite distribution has been influenced by facies and position of the sites (deep or shallow water): usually glendonites are more numerous at the more or less deep-water facies. During the Aalenian glendonites were restricted mainly by western part of the Khatauga Sea and did not occur in its eastern part. Such distribution could be connected with influence of currents. Alternatively such distributional patterns could be partially connected with peculiarities of methane seeps location at the bottom of the Jurassic sea. Comparison of the Bajocian and Bathonian glendonite occurrences in relatively deep and shallow facies showing smaller size, smaller amount of bands with these concretions and narrower stratigraphical range of shallow-water glendonites. Partially in could be connected with changes of facies from mudstones to sandstones, but also reflect higher water temperature in the shallow-water environments. Thus rare bands with glendonites at the shallow-water facies possibly could reflect most prominent cooling events. Nevertheless rarity of fossils at the Bajocian-Bathonian of the Northern Siberia still doesn’t permits to test such suggestion.

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Key words: Mesozoic paleoclimate; Glendonite; Integrate stratigraphy; Arctic

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Assemblages and Paleoclimate Implications of the Middle and Late Jurassic Floras in Western Liaoning, China

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The Jurassic system is well developed and exposed in vast areas of western Liaoning, China, and is characterized by a series of terrestrial pyroclastic rocks, yielding diverse fossil organisms such as plants, spores and pollen, bivalves, insects, and vertebrate fauna (e.g. birds and dinosaurs). The Middle Jurassic system in this region includes two formations from the ascending order, i.e. the Haifanggou Formation and the Tiaojishan Formation (=Laqian Formation). The Tiaojishan Formation is represented by intermediate extrusive and pyroclastic rocks, with intercalations of basic volcanic and sedimentary rocks. The Upper Jurassic system is represented by the Tuchengzi Formation, which consists of gray purple, purple-red shales, sandstones with large cross-beddings. It is disconformably underlain by the Tiaojishan Formation and unconformably overlain by the Lower Cretaceous Yixian Formation. Recent isotope analysis of oxygen shows that the geological age of these formations are debated, i.e. the Late Jurassic to Early Cretaceous for the Tiaojishan Formation and the Late Jurassic to Early Cretaceous for the Tuchengzi Formation (Zheng et al., 2001; Swisher et al., 2002; Wang et al., 2004; Zhang et al., 2008). The investigations of our recent collection reveal more new wood taxa in this flora assemblage. Besides the fossil wood, impression and compression plant foliage specimens suggest that the flora in this formation is characterized by the dominance of cycads and ferns (which are systematically ascribed to the families of Marattiaceae, Osmundaceae, Dicksoniaceae and Filicales Insertae Sedis), followed by ginkgophytes; conifers and sphenopsids are less frequent. Lots of permineralized rhizome materials have been reported in this formation showing anatomically preserved and diverse taxa belonging to fern families such as Osmundaceae and Cyatheaceae. In the Tuchengzi Formation, the plant fossils are rare, except for few fossil wood, megafossils and dinosaur footprints. The fossil wood taxa include Protophylicladoxylon francoanum Vogellehner and Xenoxyllon ellipticum Schultze-Motel; and some fossil plants associated with them, such as: fruit cluster of Czekanowskia: Leptostrobus marginatus Samylyna; reproductive organs of Pinaceae: Pityolepis sphenoides Zheng, P. pachyrachis Zheng, P. laxiformis Wang, P. pinquanensis Wang, Elatides leptolepis Zheng, Schizolepis beipiaensis Zheng, S. shangyuanensis Zheng, the seed of gymnosperm: Carpolithus fabiformis Zheng et Zhang; and plant foliage, e.g. Podozamites sp., Brachyphyllum sp., Pagiophyllum sp. Sporo-pollen assemblage mainly consists of Classopollis, as up to 86.2%, other type such as fern spores are less than 5%, which indicate arid or semi-arid climate (Zheng et al., 2001).

Flora aspects of the Tiaojishan Formation indicate that the subtropical to temperate warm and humid climate prevailed during the late Middle Jurassic in Beipiao area (Wang et al., 2006). Growth ring pattern analysis of the fossil conifer wood demonstrates wood growing in a temperate climatic condition with distinct seasonal variation. In addition, the mean sensitivity (MS) index of growth rings shows the variation condition of the environment and the climate tolerance. In the Tuchengzi Formation, the floral assemblage is totally different from that of the Tiaojishan Formation, i.e. fossil plants are rare in the former formation. In the Tuchengzi floral assemblage, the cycads, ferns and ginkgophytes which show warm and humid environment almost disappeared, reflects a dry climate with small desert forests in it. The growth ring of the Tuchengzi Formation has a very wide early wood and very narrow late wood, which indicate a hot long summer and a cold short winter with seasonal climatic variation. The present floral assemblages in the Middle to Late Jurassic Tiaojishan and Tuchengzi Formations provide palaeobotanical evidences for further exploring the palaeoclimate change and the evolutionary process of the terrestrial ecosystem across the Middle to Upper Jurassic in NE China.

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Key words: Middle to Late Jurassic; The Tiaojishan Formation; The Tuchengzi formation; Flora assemblage; Palaeoclimate

References:
Mesozoic Structural Deformation and Tectonic Evolution in Central and Eastern Sichuan Basin

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The Sichuan Basin in southwestern China underwent significant Mesozoic shortening due to the collision between the North China Block (NCB) and South China block (SCB). It is an important tectonic element of the SCB during Mesozoic age. The basin is bounded on all edges by fold and thrust belts (FTB), including the Longmen Shan FTB on the northwest, Micang Shan and Daba Shan FTB on the northeast, and east Sichuan FTB on the east, and southwest Sichuan FTB on the south (Fig.1). Large-scale Mesozoic contractional deformation and shortening were quite strong in front of these FTBs. Thick sedimentary sequences of Triassic through Cretaceous ages record a relatively complete history of their tectonic evolution. Previous studies discussed Mesozoic structural deformation and tectonic evolution of Sichuan Basin in a quite general way, and some detailed work was mainly concentrated on Mesozoic and Cenozoic tectonics of the Longmen Shan FTB, western Sichuan Basin, Micang Shan and Daba Shan. Few studies dealt with structural deformation and tectonic evolution of the central and eastern Sichuan Basin. Based on the analyses of satellite remote sensing images and seismic reflection profiles combined with the field investigations, we document the Mesozoic structural deformation pattern in the central and eastern Sichuan Basin.

Mesozoic structural deformations are quite complicated in central and eastern Sichuan Basin and the two belts are separated by the Huaying Shan fault. The surface structural pattern in central Sichuan is characterized by the low-relief and gentle folds with a few of surface faults. In contrast, the surface geological structures in eastern Sichuan are characterized by the Jura-type (ejective) folding structures in which they appear tight anticlines, open synclines and asymmetry of limbs. The structural pattern in the study area can be explained by multi-detachment faulting along various weak sedimentary layers. Seismic profiles reveal that detachment faults are certainly to be in existence beneath these folds. Evaporite, shale and argillite layers within Lower to Middle Cambrian, Silurian and Lower Triassic sequences provided weak plastic layers for detachment folding. Mesozoic deformations in central and eastern Sichuan basin had undergone at least two-stage development which was the earlier thrusting caused by collision from southeast to northwest between the South and North China blocks since the late Middle Triassic and ended with detachment folding due to progressively basinward intracontinental convergence from the Middle Jurassic to Late Cretaceous times.

Key words: Jura-type fold; Detachment folding; Tectonic evolution; Mesozoic; Sichuan Basin
Fig.1 Simplified tectonic map of the Sichuan Basin, derived from interpretation of satellite images and geological map (SBGMR, 1991)
Fossil *Baiera cf. concinna* from Middle Jurassic Qiaoerjian Formation in Yuxian County, Hebei Province, North China and Their Paleoclimate Significances

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Several compressed fossils of *Baiera cf. concinna* were found from the Middle Jurassic Qiaoerjian Formation in Yuxian County, Hebei Province. The coal bearing stratum is a series of continental detrital deposits consisting of fluvial or lakeshore, estuarine delta facies, lacustrine facies and slough facies (Wu and Li, 1992; Zhang, 2009). The lithologic units are mainly white-gray, gray, and black-gray sandstone, silty sandstone and clay stone interbedded with each other including many coal beds. The fossils were all collected from the white-gray sandstone or silty sandstone beds.

More than 10 compressed fossil leaves were identified as *Baiera cf. concinna* based on their morphological and epidermal characteristics (Si et al., 1963) as their cuticles were preserved well. Leaves are generally fan shaped with a distinct petiole which is 1 to 1.5 cm in length and ca. 1 mm in width (Fig.1 1). Leaf size varies from 3.5 to 9 (or more) cm long, and >2.5 to >9 cm wide. The leaves are 3 to 4 times dichotomously branched into nearly equal lobes. Each lobe is (1) 3 to 5 mm wide and (2) 5 to 8 (or more) cm long. The apices of the lobes are blunt or rounded. The venation is parallel in the lobes and each lobe has 3 to 5 veins. Leaf cuticular structure is important for identification. A light microscopy is used (Fig.1 2, 3). Leaves are amphistomatic. Strips of stomatal and non-stomatal zones are well defined in the lower cuticle. The stomatal zone is 70 to 210 µm wide, consisting of 1 to 5 rows of isodiametric, polygonal to rectangular epidermal cells whose size are ranging from 15-42×40-98 µm. The cell size of vein area is ranging from 10-80×25-242 µm and normally polygonal or rectangular in shape. The anticlinal wall is mainly straight rarely slightly sinuate. The periclinal wall of the cuticle is smooth. Stomata are irregularly distributed between vein courses. Stomata complex is oval to round in shape, up to 22-45 µm in diameter (average 34 µm). Guard cells are sunken with some papillae arching over stomatal aperture and guard cells. There are 4-7 subsidiary cells, typically 6, per stomata with regular shape and size. The epidermal cells in the upper cuticle are similar with the lower ones in both shape and size. They are also well defined as veinal and interveinal areas. But the central part of periclinal wall in nearly every cell of the cuticle is thickened. The stomata complexes (including shape, guard cells and subsidiary cells) are all similar to the lower epidermis ones. But stomata are sparsely distributed in the interveinal area with a very low stomata density (SD) ranging from 1-4 (average 2) stomata/mm². However, SD in the lower cuticle is much higher than the upper one, up to 29-42 (average 36) stomata/mm².

| Table 1. Stomatal parameters of *Baiera cf. concinna* and *Ginkgo biloba* |
|-----------------|-------|--------|-------|
| Species         | Age (Ma) | SD (s.d.) | ED (s.d.) | SI (s.d.) |
| *Baiera cf. concinna* | 161-175 | 36.2±4.4 | 616±75 | 5.6±0.6 |
| *Ginkgo biloba* (Sun) | 0 | 99.5±5.9 | 667±59 | 13.1±1.4 |
| *Ginkgo biloba* (Shade) | 0 | 74.1±10.3 | 663±72 | 10.3±1.3 |
| *Ginkgo biloba* (Mix) | 0 | 87.4±15.3 | 665±64 | 11.7±2.0 |

Fig.1 Gross morphologic and cuticular characteristics of a selected fossil *Baiera cf. concinna*
1. Gross morphology of a selected fossil *Baiera cf. concinna*. Scale bar=1 cm; 2. Upper cuticular characteristics of *Baiera cf. concinna*. Scale bar=200 µm. Arrows point out the stomata; 3. Lower cuticular characteristics of *Baiera cf. concinna*. Scale bar=200 µm
Since Woodward (1987) observed the significant inverse relationship existed between plant somatal density and atmospheric CO$_2$ concentration. The subsequent studies found that the stomatal index (SI) is a better indicator for paleo-CO$_2$ as it is primarily sensitive to the partial pressure of CO$_2$ not other environmental factors. SI is calculated as (Salisbury, 1927): SI (%) $= \frac{SD}{SD+ ED}$, where SD is stomatal density, and ED is non-stomatal epidermal cell density. However, stomatal responses to CO$_2$ are generally species-specific (Royer, 2001). The ideal material is a single species, the so called living fossil, whose extant, subfossil and fossil SI versus CO$_2$ relationships can be studied; then a regression function can be got to calculate the paleo-CO$_2$ concentration. But it is hard to find such a single species which can live from the Jurassic to now. McElwain et Chaloner (1995) found another way to get the CO$_2$ value earlier than the Cretaceous with terrestrial plant stomatal parameters: the stomatal ratio (SR) method for the fossil species and its nearest living equivalent (NLE) species (details see McElwain and Chaloner, 1995). Stomatal ratio is defined as the SI of a nearest living morphological or ecological equivalent (or both) to the fossil plant under consideration, divided by SI of the fossil plants. SR values are related to the ratio of atmospheric CO$_2$ in the past relative to the preindustrial (or the time when the nearest living equivalent materials were collected) (RCO$_2$) (McElwain and Chaloner, 1995; McElwain, 1998; Beerling and Royer, 2002). There are two calibrations for this method. The first one is the ‘Carboniferous standardization’ introduced by Chaloner and McElwain (1997), which is one stomatal ratio unit being equal to two RCO$_2$ units. A second standard, the ‘Recent standardization’ introduced by McElwain (1998), which is one stomatal ratio unit being equal to one RCO$_2$ unit. Here, we selected *Ginkgo biloba* as the NLE species for *Baiera cf. concinna* due to their morphological similarity. Extant leaves of *G. biloba* were collected in June 2010, at the campus of Lanzhou University and divided into sun and shade leaf groups. The modern atmospheric CO$_2$ concentration was get from the mean value of the first five months’ measurements of 2010 in Mauna Loa Observatory, which is ca. 390 parts per million by volume (ppmV) (www.esrl.noaa.gov/gmd/ccgg/trends). So the two equations we used to calculate the paleo-CO$_2$ concentration are: 

\[ Ca=SI(\text{extant})/SI(\text{fossil}) \times 390 \] (eq. 1)

\[ Ca=2 \times SI(\text{extant})/SI(\text{fossil}) \div 390 \] (eq. 2).

Leaf cuticles were sampled and prepared from the fossil and extant leaves and stomatal counts were made following the standard procedures (Kerp and Krings, 1999; Beerling, 1999), with all the data given in Table 1. Because the SD in the upper cuticles of the fossil is very low and without statistical insignificant, we only focused on the stomatal parameters of the lower cuticles. The results got from equation (1) are 913±96, 706±74 and 815±86 ppmV for the extant sun leaf group, shade group and mix group respectively. And the results from equation (2) are 1827±191, 1412±148 and 1629±171 ppmV for the extant sun leaf group, shade group and mix group respectively. The results show that the ‘Carboniferous standardization’ gives a good agreement with the long-term geochemical model, GEOCARB III (Berner and Kothavala, 2001) in 161-175 Ma.

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**Key words:** Middle Jurassic; *Baiera cf. concinna*; Paleo-CO$_2$; Hebei Province

**References:**


The Evolution of the Jurassic Climate in China
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The major data used in palaeoclimatic analysis include: i, Sedimentology: the climatic sensitive minerals and sedimentary rocks; ii, Palaeontology: the abundance, diversity and distribution of climate sensitive organism remains, including plants (spore and pollen also) (Deng, 2007), bivalves, ostracods, as well as their morphology and structure; iii, Geochemistry: the contents or ratios of the relevant trace elements, carbon and oxygen isotope values and their variations in rocks or fossils; iv, ancient atmospheric concentrations of carbon dioxide based on organic carbon isotopic values and stomata parameters of plant epidermis.

As indicated by the four types data mentioned above, the evolution of the Jurassic climate in China can be roughly divided into 5 stages, namely the early-middle Early Jurassic, late Early Jurassic, early Middle Jurassic, late Middle Jurassic and Late Jurassic.

1. Early-middle Early Jurassic (about Hettangian-Pliensbachian)
   There are 5 climatic regions in China during the Jurassic (Fig.1 A): i, The Wusuli cool temperate region, a small area of Eastern Heilongjiang Province located at high latitude in the Jurassic. The climate type is indicated by cool water faunas (Zhong et al., 2003). ii, The North China warm temperate region with warm-humid climate. It is bounded by the Kunlun-Qinling-Dabie Mountains at the south, including Northwest, North and Northeast China except the east part of Heilongjiang Province. iii, South China subtropic-tropic region, characterized by hot and humid climate, including Southeast and Middle-South China. Its west boundary is near the line of Chengdu-Yongchuan-Zunyi-Guilin-Wuzhou-Zhanjiang. iv, Southwest subtropic-tropic arid or semi-arid climatic region, joined with the South subtropic-tropic hot-humid region on the east, and bounded by the Lomuco-Shuanghu-Lancang River suture zone (north Tibet and west Yunnan Provinces) on the west, including west and south of Sichuan Province, middle-east of Yunnan Province, west parts of Guizhou Province and Guangxi Province. The north and east of Tibet and south of Xinjiang and Qinghai Province are also included in this region temporarily due to lack of effective data. v, Tibet-west Yunnan tropic arid region, including the major of the Tibet and western Yunnan Province (Fig.1 B).

2. Late Early Jurassic (mainly the Toarcian)
   There are five climatic regions in China as the former stage. But due to the obvious temperature rise, the south boundary of the warm temperate region moves distinctly northward to the Altai-Longshou-Yinsha-Yansha Mountains, and its area is markedly reduced, which meets the global Toarcian temperature rising and arid event (Vakhrameev, 1991).

3. Early Middle Jurassic (Aalian-Bajocian)
   The temperature obviously decreases in this stage and the south boundary of the North temperate region moves southward to the position almost equivalent to the early Early Jurassic stage (Fig.1 C).

4. Late Middle Jurassic (Bathonian-Callovian)
   The temperature rises in this stage, which results the south boundary of the north warm temperate region moving northward greatly to close to the Yanshan Mountain of North China (Fig.1 D). The major of north, northwest China belong to subtropic semiarid and semihumid climate, and the south and southwest of China are attributed to tropic-subtropic arid climatic region.

5. Late Jurassic
   The temperature rises greatly during the Late Jurassic. It is generally arid in China, from which the temperate humid climatic region disappears. The subtropic humid climatic region is just confined in the northeast of China, and almost all the other areas of China belong to hot and arid climate region, and deserts are even existed in North China (Zhang et al., 2008).

Key words: Jurassic; Climate; Evolution; China
Fig. 1 Jurassic climatic regions of China
A, Early-middle of the Early Jurassic: I. Cool temperate region; II. Warm temperate region with warm-humid climate; III. Subtropic-tropic hot-humid region; IV: Subtropic-tropic semi-arid and semi-humid region; V. Tropic arid region;
B, Late Early of the Jurassic: I. Cool temperate region; II. Warm temperate with warm-humid climate; III. Subtropic-tropic semi-arid and semi-humid region; IV: Subtropic-tropic arid region; V. Tropic arid region;
C, Early of the Middle Jurassic: I. Cool temperate region; II. Warm temperate region with warm-humid climate; III. Subtropic-warm temperate semi-arid and semi-humid region; IV: Subtropic-tropic arid region; V. Tropic arid region;
D, Late of the Middle Jurassic: I. Cool temperate region; II. Warm temperate region with warm-humid climate; III. Subtropic semi-arid and semi-humid region; IV: Tropic-subtropic arid region; V. Tropic arid region;
E, Late Jurassic: I. Cool temperate region; II. Subtropic humid region; III. Tropic-subtropic arid region; IV: Tropic arid region.

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During the Early Toarcian (Early Jurassic), a second ordered OAE prevailed in the world oceans which led to a prominent turnover of marine biota in both shallow and deep water settings. The Early Toarcian OAE event is characterized by deposition of bituminous black muddy sediments that lacks apparent remains of benthic organisms in association with negative stable carbon isotope excursion (e.g. Jenkyns, 1988). The Early Toarcian OAE deposits in the Northwest Europe standard and Tethys regions have been studied extensively from the viewpoints of geochemistry, sedimentology and palaeontology, but little was investigated for the contemporaneous strata deposited in the eastern Tethys margin and the Panthalassa.

The Nishinakayama Formation distributed in the Toyora area, Yamaguchi Prefecture, West Japan is correlated to the Upper Pliensbachian to Lower Toarcian by ammonite biostratigraphy (Hirano, 1973). This formation represents a shallow marine sequence deposited at the Northeastern margin of the Tethys Sea that was connected with the Panthalassa. It contains fine-laminated, bituminous black shales with sedimentary pyrite, in the middle part, which are contemporaneous with and similar in lito- and biofacies to the Early Toarcian OAE strata in Northwest Europe. The biostratigraphical, palaeoecological and taphonomical aspects of the molluscan fauna of Nishinakayama Formation have been extensively investigated and their relationship to the Early Toarcian OAE has been suggested (Tanabe, 1991). Nevertheless, little was known for the activity of benthic organisms in relation to the OAE event.

In this study, we investigated the activity of the benthic organisms recorded in the sediments as trace fossils and/or bioturbation for the Upper Pliensbachian to the Lower Toarcian succession exposed in the Sakuraguchi-dani Valley. For this purpose, rock samples and ammonite fossils were successively obtained from the sequence, making a detailed geologic column. In the field, laminae and trace fossils which were visible to the naked eye were observed elaborately, and lamina preservation index was given to all rock samples. In addition, soft X-ray images of 17 rock samples that were cut in vertical to the bedding plane were taken in the laboratory in order to distinguish the degree of bioturbation and types of trace fossils which were invisible to the naked eye.

As some studies (e.g. Rohl et al., 2001) discussed oxygen level of bottom water using various biofacies and sedimentary facies scheme, redox condition of the Lower Jurassic succession exposed in the Sakuraguchi-dani Valley was estimated by lamina preservation index in this study.

As a result, OAE sediments were identified in the Sakuraguchi-dani Valley. However, beds accompanying trace fossils and bioturbation were episodically intercalated at several horizons in the OAE sequence which lacks trace fossils and/or bioturbations. This fact strongly suggests that the Early Toarcian OAE event recorded in the Sakuraguchi-dani Valley section was not a single event but was interrupted by short-term oxygenation events during the interval.

Furthermore, international correlation between Toyora area (Northeastern margin of the Tethys realm) and European Tethys regions by means of ammonite biostratigraphy suggests that the interval of the Early Toarcian OAE in the shallow setting differed between the western and eastern parts of the Tethys Sea.

Key words: Toarcian; OAE; Nishinakayama Formation; Lamina preservation index

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Simultaneous Formation of Trench-slope Basin Deposits in the Southern Chichibu Terrane During Oxfordian, Outer Zone of Southwest Japan

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In the Outer zone of Southwest Japan, distribution of the Upper Mesozoic strata including terrigenous shallow-marine carbonates (Torinosu-type limestone) is well known. This study focuses on the sedimentary and tectonic evolution of the Upper Jurassic Torinosu-type limestone bearing strata (TLBS) in the Southern Chichibu Terrane, a Jurassic to Early Cretaceous accretional complex. Although TLBS are common in this terrane, the presence of shallow-marine carbonates in accretion-related deep-marine siliciclastics with accreted ocean-floor and seamount fragments remains unexplained.

This study addresses the Miyazono Formation, an Upper Jurassic TLBS in the Southern Chichibu Terrane, western Kyushu. The formation, established by Ishida (2009), is subdivided into three members: the Kurekogawa Mudstone Member, the Nakamichidani Sandstone Member and the Kamiarachi Mudstone Member, in ascending order. Total thickness of the formation is approximately 2,600 m. Conglomerates in the Nakamichidani Sandstone Member contain clasts of terrigenous limestone and marl. The formation overlies the Momigi Complex, which is considered to be an ancient accretionary prism.

In the Miyazono Formation, radiolarian zones from the upper part of Kilinora spiralis Zone to the Pseudodictyomitra carpathica Zone (lower Upper Jurassic to upper Upper Jurassic; Oxfordian to upper Tithonian) are recognized (Ishida, 2009). The underlying Momigi Complex also includes the Kilinora spiralis Zone, no significant depositional hiatus is present between the Momigi Complex and the Miyazono Formation.

The Miyazono Formation conformably overlies the ancient accretionary prism, the Nakamichidani Sandstone Member is dominated by coarse-grained sediment, and the thickness of the formation is unusual for a trench-slope apron sediment. These characteristics indicate that the main part of the Miyazono Formation was deposited in a trench-slope basin rather than a trench-slope apron. These features of the Miyazono Formation are strikingly similar to those of the Nias beds in the forearc of Sunda Trench, which are considered to be the ‘typical example’ of trench-slope basin deposits (Underwood and Moore, 1995).

Based on studies of modern and ancient examples (e.g. Moore et al., 1980; Underwood et al., 2003), trench-slope basin deposits are divided into two lithofacies that reflect basin evolution; lower immature basin facies and upper mature basin facies (Underwood and Moore, 1995). In the case of the Miyazono Formation, immature facies correspond to the Kurekogawa Mudstone Member and mature facies correspond to the Nakamichidani Sandstone Member. The uppermost Kamiarachi Mudstone Member consists of trench-slope apron facies.

Upper Jurassic TLBS are present over 900 km of strike-length in the Southern Chichibu Terrane. These TLBS have certain characteristics in common: proxy-mity to basement, simultaneous initiation of sedimentation, and similar sedimentary facies. The basal parts of most of the Upper Jurassic TLBS in the terrane belong to the Kilinora spiralis Zone, indicating that initiation of TLBS deposition in the Oxfordian was probably both simultaneous and widespread. All TLBS exhibit fine-grained immature basin facies in their lower parts, and comparatively thick TLBS contain mature coarse-grained sediments in their upper parts.

The Upper Jurassic TLBS contain Middle Jurassic Torinosu-type limestone bodies as exotic clasts. The Torinosu-type limestone bodies are presumed to have been originally deposited in shallow-marine environments on accretionary prisms, such as trench-slope breaks, during the Middle Jurassic. They were later broken and/or eroded, and their fragments were displaced into deeper trench-slope basins in the Late Jurassic.

The tectonic and sedimentary evolution of TLBS of the Southern Chichibu Terrane started in the early Late Jurassic (Oxfordian). On the accretionary prisms, which were formed by the frontal delamination during the Middle Jurassic (Matsuoka, 1992), several trench-slope basins were formed in the forearc regions along the eastern margin of Asia. Initially, fine-grained sediment and fragments of accreted elements were transported into the basins from surrounding unstable slopes. During the Late Jurassic, these trench-slope basins were filled by terrigenous siliciclastics, which were supplied through conduits that cross-cut older sedimentary bodies including shallow-marine carbonates on the trench-slope breaks. Filling of the basins was completed in the late Late Jurassic (Tithonian), after which large volumes of seamount-type limestone (Sanbosan limestone) accreted from the latest Jurassic to the Early Cretaceous.

One plausible cause for the simultaneous...
formation of numerous trench-slope basins is an abrupt change in the motion of the Izanagi Plate, an oceanic plate that was subducting under the Asian continent. This Oxfordian deformation event in the forearc may, therefore, records a major change in circum-Pacific plate tectonic behavior.

**Key words**: Oxfordian; Trench-slope basin deposit; Southern Chichibu Terrane; Southwest Japan

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Palaeoceanographic Events Prior to the Negative Carbon-isotope Excursion During the Early Toarcian in the Paris Basin: A Volcanic Trigger?

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The Early Toarcian (ca. 183 million years ago) was characterized by two large perturbations to the carbon cycle: a positive trend associated with increased organic matter burial and ocean anoxia, and a pronounced negative carbon-isotope excursion (CIE). The first one corresponds to an Oceanic Anoxic Event (OAE; Jenkyns, 1988, 2010) and is evidenced by widespread deposition of organic-rich sediments that led to a positive trend in the carbon-isotope profile. The second one, recorded during a relatively short period of ~ 100kyr (Kemp et al., 2005), consists of a pronounced negative carbon-isotope excursion (Hesselbo et al., 2000). The record of a ~ –6‰ negative CIE in carbonate, marine organic matter and wood fragments across Europe (Hesselbo et al., 2000, 2007; Kemp et al., 2005; Hermoso et al., 2009a) and provides compelling evidence for a pronounced isotopic perturbation of the whole ocean-atmosphere system during this period. The stepwise descent of carbon-isotope values that defines negative-trending limb of the CIE has been ascribed to the release, in discrete pulses, of isotopically light carbon from the dissociation of methane hydrates (Hesselbo et al., 2000; Kemp et al., 2005).

Our high-resolution results from a core drilled in Sancerre-Couy (Southern Paris Basin) show a substantial drop in the carbonate content preceding the first step of the CIE. This change in the carbonate content primarily corresponds with diminished calcareous nannofossil (coccoliths and calcareous dinoflagellate calcispheres of Schizosphaerella sp.) in the sediment. We interpret this progressive dissolution of carbonate as due to acidification of seawater in the interval preceding the negative CIE in relatively shallow environments (~ 100 m) such as the Paris Basin. This sequence of progressive acidification culminated in a "pelagic carbonate blackout" during which even the most resistant carbonate particles of the assemblage, such as the blocky Crepidolithus sp. coccoliths, were dissolved.

We speculate that substantial seawater acidification immediately prior to the onset of the negative carbon-isotope excursion may have been caused by the Early Toarcian phase of the subaerial Karoo–Ferrar volcanism (Pálfy et al., 2000). This initial perturbation to the carbon cycle, accompanied by a slight (~ –0.5‰) decrease in the carbon-isotope profile, may have been the trigger to the subsequent dissociation of methane hydrates, amplification of ocean acidification and reinforcement of anoxia.

Key words: Toarcian; Seawater acidification; Carbon-isotope excursion; Oceanic Anoxic Event.

References:
Jurassic black shales occur in northern Tibet, which are the subjects for many geologists. We carried out detailed field investigations of the Shuanghu oil shales section in the southeastern Bilong Co area, which is about 45 km away from the Shuanghu special district. The whole succession is divided into three intervals characterized by different lithological types. From lower to upper they are gypsiums, oil shales interbedded with limestones and mudstones, and marls interbedded with mudstones. Yi et al. (2003) surveyed the section again and recognized ammonites at the top of the section and suggested that these ammonites are principally of early Toarcian age, roughly within the Harpoceras falciferum Zone in the Paris Basin and may be associated with the Posidonian Shale of SW Germany, as well as with the Early Toarcian black shales occurring extensively in Europe.

Organic geochemistry supplies powerful tools for the analysis of organic-rich sedimentary rocks. Rock Eval pyrolysis is a method to evaluate the thermal maturity of rocks, quality and origin of organic matter. Hydrogen index (HI) values provide information about the type and preservation of organic matter. HI values higher than 277 mg HC/g TOC generally indicate preservation of marine organic matter (kerogen type II) dominated by bacteria and phytoplankton with only a minor contribution of terrestrial organic compounds. Sedimentary organic matter of laminated shale anomalously rich in organic carbon across the Shuanghu area is characterized by high organic carbon contents, ranging between 1.8% and 26.1%. The carbon isotope curve displays the δ13C values of the kerogen (δ13Ckerogen) fluctuating from −26.22‰ to −23.53‰ PDB with a positive excursion close to 2.17‰, which, albeit significantly smaller, may also have been associated with other Early Toarcian Oceanic Anoxic Events (OAEs) in Europe. The organic atomic C/N ratios range between 6 and 43, and the curve of C/N ratios is consistent with that of the δ13Ckerogen values. Abundant biomarkers, including n-alkanes, isoprenoids, steranes and terpanes from the black shales, have been detected by GC and GC-MS. The n-alkanes are composed of nC15-nC31 with nC15, nC16 and/or nC17 as the main peaks, and characteristic of single peak distribution. The nC17/nC31 ratios of 5.51 to 30.00 show the predominance of light hydrocarbons in the n-alkanes. OEP values vary from 0.90 to 1.01, and CPI from 0.93 to 1.13, close to equilibrium value of 1.0, indicating no obvious odd-even carbon number predominance. Pr/Ph values range between 0.77 and 1.59, and they fluctuate in the vertical section. In the m/z191 GC-MS, C30 hopane is the most abundant in the terpanes. According to the relative abundance, pentacyclopteranes are characterized by highest abundances, tricyclic terpanes by the second, and then tetracyclic terpanes. Minor gammacerane is presented. In the m/z217 GC-MS, the regular steranes C27-C28-C29 distributed with “V” shape, and Σ(C27+28)-ΣC29 with varying ratios between 1.25 and 1.99, whereas steranes ΣC37/ΣC29 from 0.51 to 3.65 and rearranged steranes C27/regular steranes C27 from 0.21 to 0.47. 4-methyl stearane have been detected, but its abundance is relatively lower. Series of C27 and C29-C35 hopanes, maximizing at C30 and C31, are present in all samples. The 22S/(22S+22R) ratios of the 17α,21β(H)-hopanes are near equilibrium values (0.58-0.60), while the C29aa20S/(20S+20R) ratios and C29αββ/(αββ+αaa) of the steranes are by 0.35-0.43 and 0.43-0.54, respectively, which indicate maturity or over maturity conditions during deposition of the rocks.

The biological assemblage was characterized by scarcity of benthic organisms and bloom of calcareous nannofossils (coccoliths) by means of optical polarizing microscope and scanning electron microscope. Watznaueriaceae family was firstly discovered pertaining to watznaueria fossacincta with a central pore and watznaueria britannica with a bar, which reveals high biological productivity in the surface water and an unfavorable environment for the benthic fauna in the bottom water during the Oceanic Anoxic Event (Chen et al., 2003).

During the lower Toarcian, coincident with the peak of the Lower Jurassic transgression (De Graciansky et al., 1998), highly bituminous shales were deposited extensively in the European epicontinental seas and the Tethyan continental margins (Farrimond et al., 1994; Jenkyns and Clayton, 1997). In addition, contemporaneous black shales occur in western Canada, Japan, Madagascar and Argentina, and on the Arctic slope (Schouten et al., 2000). The most organic carbon-rich facies of the Lower Toarcian in Germany, the Posidonian Shale, has long been known for its excellent preserved fossils, the high amount of organic matter (up to 16%) and positive excursion of carbon isotope (Röhl et al., 2001). Jenkyns (1988) demonstrated that the global occurrence of the synchronous black shale facies occurring in the upper part of the tenuicostatum Zone.
and the lower part of the *falciferum* Zone led to the hypothesis that organic matter deposition in the Lower Jurassic was due to an Oceanic Anoxic Event. Its striking features include enrichment in $^{13}$C and a positive excursion of $\delta^{13}$C isotope, from 2‰ to 4.5‰, during anoxic periods (Schlanger and Jenkyns, 1976; Jenkyns, 1985, 1988). Discussion is still open as to what mechanisms were responsible for the most organic carbon-rich black shales and caused oceanic anoxic events. Many geologists explained the phenomenon as a result of tectonic movement of the crust, change of sea level, palaeoclimate, palaeoproductivity and so on (Jenkyns and Clayton, 1986). On the basis of organic geochemistry and characteristics of the biological assemblage, this study suggests that the carbon-isotope excursion is caused by the changes of sea level and productivity, and that the black shale deposition, especially oil shales, is related to the bloom and high productivity of coccoliths (Chen et al., 2005).

In addition, well attention is paid to this section about event stratigraphy. This section is characterized by thicker gypsums in the lower parts, representing terrigenous moisture-free environment, while the oil shales interbedded with limestones and mudstones are overlying on the gypsum, representing marine transgressive environment. It seems to be contradictory and interesting. At present, Early Toarcian OAE and bloom event have been discussed and got some information, but other event stratigraphy is still unknown.

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**Key words:** Early Jurassic; Organic chemistry; Oceanic anoxic event; Northern Tibet

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Upper Jurassic Explosive Volcanic Events from Tethyan and Boreal Domains: Geodynamic and Stratigraphic Consequences

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A systematic search for pyroclastic deposits preserved as bentonite has been undertaken during the last decade in various Jurassic sedimentary basins from European tethyan and North Sea domains (Pellenard et al., 2003; Pellenard et al., 2008). These bentonites correspond to primary or weakly reworked ash fall deposits from major paroxysmal ultraplinian or co-ignimbrite dynamic eruption. Their recognition in sedimentary series are essential 1) to better understand the past volcanic activity and its interaction with paleoenvironmental changes, more particularly those in relation to the carbon cycle; 2) to improve the knowledge of the palaeogeography by integrating active volcanic source locations; 3) to use reliable key stratigraphic marker-bed for intrabasinal correlations, and possibly 4) to obtain precise and robust radiometric ages well constrained biostratigraphically, in order to refine the Jurassic Time Scale where only few radiometric data are available for the Middle and Upper Jurassic (Palfy et al., 2000; Gradstein et al., 2008).

The studied sites are the Paris and Subalpine basins in France, the Hebrides basin in Scotland (Skye Island) and the Rosso Ammonitico Veronese (RAV) in northeastern Italy. Studied stages include the Callovian and the Oxfordian, which are characterized by an abundant ammonite fauna allowing a detailed biostratigraphy (i.e biohorizon scale) to be defined. Petrographical and mineralogical data from ash layers, now altered into bentonites, are relatively common: pure smectite (>99%) or, in the case of burial diagenesis, a mixture of kaolinite and smectite/I-S mixed-layers and smectite (>99%) or, in the case of burial diagenesis, a mixture of kaolinite and smectite/I-S mixed-layers and smectite (>99%), or, in the case of burial diagenesis, a mixture of kaolinite and smectite/I-S mixed-layers and smectite (>99%) or, in the case of burial diagenesis, a mixture of kaolinite and smectite/I-S mixed-layers and smectite (>99%).

Therefore, it is inferred that volcanism described here, constitutes the most realistic source. We suggest that volcanic events evidenced by the occurrence of bentonite are the expression of the most powerful eruptions, but a perennial aerial explosive volcanic activity probably also occurred during the entire Upper Jurassic, what could explain in part the high content of smectites in sediments from the Tethyan realm. The Upper Jurassic is thus characterized at the West-european scale by a period of volcanic crisis (North Sea and Tethys) which may have climatic consequence together with volcanism known in other parts of the World (i.e. Patagonia, Asia).

Radiometric measurements (monograin 40Ar/39Ar method) of preserved sanidine are in progress. Such data are fundamental to add new radiometric landmarks to the Jurassic Time Scale, where precise radiometric data are scarce, and estimation of time is based on other calibration methods.

Key words: Palaeovolcanism; Bentonites; Long-range correlations; Oxfordian

Reference:
The Triassic of the Iberian Micro-Plate: The Early Mesozoic Pre-Jurassic Tethys Hinge

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The Triassic represents the short (51.4 my) transition between the end of Palaeozoic life and the ascent of Mesozoic life. It is important for me to point out that in my opinion; this recovery is also the time when the modern life on Earth began. It was a time when the huge continent of Pangaea still existed, a land mass that was altering global climate and ocean circulation. During the Permian-Triassic transition, one of the most important climatic and biological crises of Earth history took place. As a result of extinctions, almost 95% of marine species disappeared; amongst them whole groups like trilobites and fusulinids. Others lost the greater part of their representatives like the brachiopods. Goniatites were replaced by ceratites, tabulates and rugosa by scleractinia. The benthonic fauna, dominated in the Palaeozoic by brachiopods, sessile crinoids, echinoderms and bryozoans, consists in the Triassic mostly of bivalves. The Triassic is also a time when the survivors of the P/T extinction event spread and newly colonized the environments lost to low sea levels. The most important floral and faunal renewal of phanerozoic times occurred in a relatively short time.

Alberti (1864) was the first to formally describe and name “Trias” the well-differentiated trilogy of clastic, evaporitic and carbonatic formations that followed the underlying Permian “Dia” of Zechstein and Rothliegendes between the North Sea and the Alps. At base, red conglomerates, sandstones and clays form the “Buntsandstein”, followed by the characteristic carbonate formations with marine fauna of the Muschelkalk, while the upper unit is a series of evaporites, clays, marls and sandstone, the Keuper. These facies-units are present in the Triassic of Spain. After painstaking investigations, these units were correlated between two large landmasses: Laurasia to the north and Gondwana to the south, as illustrated by Stampfli et al. (2001). Simultaneously two processes that directly affected the Iberian Peninsula began: the complex evolution of the Tethys and the opening of the Atlantic. Therefore, knowledge of the palaeontology of the Iberian Peninsula, located on the western end of Tethys, plays an important role in understanding of Triassic-Jurassic palaeogeographic developments.

The palaeontology of the Triassic of Spain counts a limited number of authors. This is due to the very scarce fossil record and their bad preservation in general that renders it is very difficult to reach any taxonomic determination. Schmidt (1935) was first in studying the marine fauna of the Muschelkalk of the Central-Eastern area of Spain, comparing it with the Muschelkalk of the Germanic Basin. To Virgili (1958), we owe a first faunal synthesis (mainly of molluscs) and most important, the unraveling of the stratigraphic succession that with more than one carbonatic and evaporitic units, and thus counting more than the original trilogy, had in the early days been erroneously interpreted as tectonic repetitions. Márquez-Aliaga (1985) and Ros (2009) gave a modern revision of the Triassic bivalves, Goy (1995) and Perez Valera (2005) of the ammonoids. Hirsch (1966) found the first conodonts, studied further by Budurov et al. (1993) and most recently Plasencia (2009). Márquez (1994) investigated foraminifera. All members of the Spanish Working Group of the IGCP 506 have improved this research line.

The first marine transgression is that of the Spanish upper Muschelkalk facies (Márquez-Aliaga and Martínez, 1996) that took place in Anisian times. In the Iberian Ranges, the “Serra-Association” contains the bivalves Hoernesia socialis, Myophoria vulgaris, Unionites fassaensis, and Neoschizodus laevigatus, forming an assemblage, similar to that of the upper Muschelkalk facies of the German basin. In the Catalan Coastal Ranges, this Spanish lower Muschelkalk facies yields the conodonts Paragonodoella bulgarica, P. hanbologi, P. bifurcata, Neogondolella constricta, N. cornuta, N. excentrica and N. basisymetrica. These represent the P. bulgarica and N. constricta zones and indicate middle-upper Pelsonian to upper Illyrian ages (Márquez-Aliaga et al., 2000), in good correlation with the Bulgarian assemblage of the Tethys.

The second marine transgression is that of the Spanish upper Muschelkalk facies that took place in Ladinian times. The bivalve assemblage have Tethyan nektonic elements as Daonella and Bositra, the bentonic and cosmopolitan “Enantiostreon” diforme, Pseudocorbula gregaria, Bakevillia costata, and numerically abundant “Spanish” Pseudoplacunopsis teruelensis, P. flabelllum, Gervillia joleaudi and Costatoria kiliani. The conodonts Pseudofurnishius murcianus and Sephardiella mungoensis (Plasencia,
2009) occur with fish-remains (Botella et al., 2009). The distribution of these species defines the Sephardic bio-province. This realm extends from Iberia to Arabia (Hirsch 1987, Márquez-Aliaga and Hirsch, 1988) and was located on the Gondwanian margin of the Tethys.

The Upper Triassic - Lower Jurassic formations are largely of siliciclastic, carbonatic and evaporitic facies.

The third and last Triassic marine transgression took place in the Rhaetian Imón Formation that in the Iberian Ranges and the Catalanian Coastal Ranges is made of Upper Triassic carbonates. The bivalves Laternula cf. amici, Neoschizodas rezae, Protocardia cf. rhaetica and Pseudocorbulina alpina are recorded pp in the “layers with Avicula contorta” of Lombardy (Goy and Márquez-Aliaga, 1998, Arnal et al, 2002). The Triassic-Jurassic transition in the Asturian ranges and the western Basque-Cantabrian Basin (Palencia Province) of Northern Spain, encompasses the Rhaetian bivalves Isocyprina concentrica, Bakevillia praecursor, Isocyprina cf. ewaldi, Pteromya cf. crowcombeia, Pseudoplacunopsis alpina, which belong to an assemblage similar to that found in the Westbury and Lilstock formations (Penarth Group) in the late Rhaetian of southern England. Hettangian forms are Isocyprina (Eotrapezium) germari, Cuneigerbillia rhombica and Pteromya cf. tatei. No relationship of these Rhaetian–Hettangian bivalves exists with the Tethyan open-marine faunas, but they are similar to those of northwestern Europe and northern Africa instead (Márquez-Aliaga et al, 2010).

In Spain, a close marine relationship may be established with the Paleoethys in the Anisian. In the Ladinian, the typical elements of the Sephardic domain belong to the meridional area of the Neoethys. During the Rhaetian in Eastern Spain, some scarce bivalves correlate with the Tethys. Finally, let me emphasize that in the north of Spain, the bivalve record in the Triassic - Jurassic transition beds shows the opening of seaways as the beginning of the break-up of Pangea that took place during the Rhaetian.

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Key words: Anisian; Ladinian; Rhaetian; Hettangian; Palaeontology; Bivalves; Conodonts; Spain

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The Early Jurassic was a time of rapidly rising sea level associated with the extensive spread of anoxic bottom waters (Kemp et al., 2005; de Schootbrugge et al., 2005; Cohen et al., 2007). Sea level, in particular, rose across the Pliensbachian-Toarcian boundary, culminating in the Falciferum Zone of the Toarcian. The associated period of sea floor anoxia coincides with a notable period of mass extinction of the marine fauna (Hallam and Wignall, 1997). High resolution sampling and study of the microfaunas through several sequences in the United Kingdom (and elsewhere) confirm that benthic foraminiferal assemblages were similarly affected by an Early Toarcian Falciferum Zone event (Hylton, 2000; Hylton and Hart, 2000).

Evidence for the foraminiferal extinction event in the Pliensbachian-Toarcian interval includes the eliminatuuon of the important Lower Jurassic Lingulina tenera, Frondicularia terquemi and Marginulina prima plexus groups, initiating a significant period of turnover. A marked change also occurred in the character of associated nodosariid assemblages: the uniserial forms of Nodosaria, Frondicularia and Lingulina, which dominate the Pliensbachian assemblages, were largely replaced by coiled Lenticulina in the Early Toarcian. A reduction in test size (Lilliput Effect?) and a decline in species diversity, compared with Hettangian to Sinemurian assemblages, reflect the development of low oxygen conditions followed by the subsequent renewal of the microfauna in the middle Toarcian.

Little’s (1996) detailed biostratigraphic sampling of invertebrate macrofaunas through complete, expanded sequences in North Yorkshire, England and in southwest Germany shows that a species level event occurs in the early Toarcian. During the late Pliensbachian there was a diverse range of benthic species including infaunal and epifaunal bivalves, brachiopods and crinoids. The equally diverse nekton included Marginulina prima, Marginulina tenuicostatum and Lingulina tenera, Frondicularia terquemi and Marginulina prima plexi were eliminated; these seem to have been relatively shallow-water mid-shelf forms which were replaced by the very tolerant Lenticulina. The generic diversity of the Lagenina continued to increase through the Mesozoic and showed no signs of decrease through the early Toarcian events. Elevated, interconnected continents and restricted seaways in the Lower Jurassic resulted in the expansion of cosmopolitan smaller foraminifera. Common in the shales of the Jurassic (and Cretaceous), the flattened and elongate tests of the Lagenina were probably an adaption to burrowing in the upper few centimetres of organic-rich substrates, as detrital or bacterial scavengers. In contrast to these larger foraminifera of shallow water, the relatively small nodosariid Lingulina tenera, Frondicularia terquemi and Marginulina prima plexi were unaffected by anoxia and included ammonites and belemnites. In addition, epifaunal taxa adapted to low-oxygen conditions such as the posidoniids and inoceramids, flourished in the post-extinction environment during the survival interval. As conditions ameliorated, the biota became more diverse and gradually began to resemble the pre-extinction biota.

This pattern was not reflected in the response of the microfauna and especially not in the case of benthic foraminifera. The post-extinction faunas were of a completely different character compared to the pre-extinction biotas and have greater affinities with Middle Jurassic foraminiferal faunas. The evidence from the North Yorkshire Coast, and other northwest European sections, confirmed the Hallam (1986) model that the main species extinctions during the late Pliensbachian–early Toarcian time interval occurred, not at the end of the Pliensbachian, but near the top of the early Toarcian tenuicostatum Zone. However, this event is only significant at species level; it cannot be recognised at genus level or at family level. This study shows a species extinction event with a 19% (9 from 47 species) reduction in diversity at the top of the tenuicostatum Zone. This was followed by an 8% (3 from 38 species) reduction at during the falciferum Zone. The loss of foraminiferal species is low compared to the figures of Little (1996) who records a significant macro-species extinction event at the top of the tenuicostatum Zone with a 77% (17 from 22 species) reduction in diversity. The benthos was most severely affected, with an 88% species drop including the disappearance of the total infauna.

No major foraminiferal group suffered extinction over this interval but the important Lower Jurassic lageniids Lingulina tenera, Frondicularia terquemi and Marginulina prima plexi were eliminated; these seem to have been relatively shallow-water mid-shelf forms which were replaced by the very tolerant Lenticulina. The generic diversity of the Lagenina continued to increase through the Mesozoic and showed no signs of decrease through the early Toarcian events. Elevated, interconnected continents and restricted seaways in the Lower Jurassic resulted in the expansion of cosmopolitan smaller foraminifera. Common in the shales of the Jurassic (and Cretaceous), the flattened and elongate tests of the Lagenina were probably an adaption to burrowing in the upper few centimetres of organic-rich substrates, as detrital or bacterial scavengers. In contrast to these larger foraminifera of shallow water, the relatively small nodosariid Vaginulinidae, Vaginulinidae, as well as smaller Robertinina, thrived in the fine clastic sediments deposited in deeper waters. These foraminifera with flattened, lenticular, or low trochoid tests probably fed on bacteria or other protozoans, or were infaunal detrital feeders.

As a result, the Lagenina were not greatly affected by the environmental changes and resulting extinctions during the early Toarcian, but continued to show a slow and steady increase in diversity.
Community replacement, involving gradual abrupt substitution of one benthic community for another as a result of subtle to sharp changes in habitats over sub-evolutionary time, could also explain the changes seen in the foraminiferal faunas during the Pliensbachian–Toarcian interval. The environments during this period changed quite rapidly, featuring a type of community replacement involving species turnover, where environmental tolerance limits of certain species of foraminifera were closely approached or exceeded. It is notable that the origination rate during this period was quite low.

The replacement of (possibly extinct) species in the foraminiferal faunas is borne out by the low rates of origination and the dominance of species like Lenticulina muensteri after the falciferum Zone events. The assemblages in the mid-upper Toarcian are composed of species that, while contributing to earlier assemblages, now have a greater dominance and have presumably taken over the niches previously occupied members of the Lingulina tenera and Marginulina prima plexus groups and to a certain extent species of Nodosaria.

One beneficiary of the changes in the mid-Toarcian was within the members of the Oberhauserellidae with Praegubkinella giving rise to the ancestral Conoglobigerina and the lineage leading to the planktic foraminifera (Wernli, 1988, 1995; Hudson et al., 2009).

Key Words: Foraminifera; Toarcian; Anoxic Event; Sea level rise; Palaeoecology

Reference:
A Novel Integrated Modeling Approach, Using Tectonic, Climatic, Environmental, and Stratigraphic Data of the Late Jurassic in the Southern North Sea Area (NW Europe)

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The Late Jurassic-Early Cretaceous strata are a target for oil and gas exploration in the Netherlands (Herngreen and Wong, 1989). In the early days of the Dutch offshore exploration history various oil and gas fields were discovered. Several fields were not economic due to complex reservoir architecture predicting low recovery. Basin-fill of rift related basins, such as the Upper Jurassic Central Graben, usually occurs in an active tectonic non-marine to shallow marine setting and is therefore complicated (Van Adrichem Boogaert and Kouwe, 1993-1997). Rapid lateral facies transitions, repeating log and facies patterns over time and space and strong salt movements make a reliable seismic interpretation and log correlation very difficult (Wong, 2007).

Recently however, novel biostratigraphical techniques, like the Sporomorph EcoGroup (SEG) model which has been developed to combine quantitative palynological techniques with expert knowledge in the field of paleobotany, and newly acquired stratigraphical data have led to the identification of a series of events which can be related to the tectonic, climatic, environmental and stratigraphic development of the Late Jurassic in the Dutch North Sea basin. The better understanding of the complex geology led to renewed interest in this play.

The age interpretations are based on palynology. The palynostratigraphy is according to Riding and Thomas (1992), Abbink (1998), Duxbury et al. (1999) and Herngreen et al. (2000).

Applying the SEG technique enables the user to recognize sea-level changes (even in non-marine settings close to the coast) and furthermore to separate sea-level and climate signals for independent interpretation and correlation. This powerful new technique has been tested on various hydrocarbon plays in the Carboniferous, Jurassic and Cretaceous from the southern North Sea area (NW Europe) and in the Triassic from the Middle East.

The basic principle, on which this technique is founded (Abbink, 1998), is the existence of a relationship between a pollen or spore taxon, its botanical affinity, and, with that, its inferred habitat and ecological preference. With the SEG technique, botanical affinities are established (or have been established in the past) by extracting pollen and spores from reproductive organs of plant fossils. Because these fossils are derived from outcrops, the depositional environment and paleolatitudinal setting is usually known. In the ideal case, all occurring pollen and spores can be classified in groups, the so-called Sporomorph Eco-groups, such as River, Lowland, Coastal, Upland etc. In a non-marine setting close to the sea (not in an intra-montane setting), the aerial extent of particular the Lowland and Coastal groups will shrink or expand when sea level rises and falls. Likewise, the changes in the composition of the climate dependant types reflect changes in climate changes. The sea-level and climate signal can be separated and interpreted independently, when the warm-cool curves are based on a single group only. For instance, a curve can be constructed from the Coastal Group, in which a Coastal Warm and Coastal Cool Group are represented. In that way, the sea-level signal can be differentiated from the climate signal.

The present contribution shows how these results have improved modeling of the Late Jurassic in the southern North Sea area (see Fig.1). Based on these data, three stratigraphical sequences can be recognized (Abbink et al., 2006):

Sequence 1 (Middle Callovian-earliest Kimmeridgian) coincides with the inception of the Dutch Central Graben. The top of this sequence is marked by an unconformity in the early Kimmeridgian (mutabilis Ammonite Zone).

Sequence 2 (early Kimmeridgian-early Portlandian) shows the initiation of the Terschelling Basin. The top is dated as early Early Portlandian (anguiformis Ammonite Zone).
Fig. 1 Schematic diagram of the Late Jurassic sequences with key lithostratigraphic units of the northern Dutch offshore.
During Sequence 3 (late Portlandian-Ryazanian) the Dutch offshore is characterized by a regional transgression. The top is dated as basal Valanginian.

These sequences are punctuated by at least two significant Maximum Flooding Surfaces (Partington et al., 1993). Each sequence has its own, relatively unique, geological history. The sequences can be correlated with major changes in sea-level and climate and are bounded by well defined dis- and unconformities caused by regional tectonics. The integrated approach with the use of high resolution biostratigraphic, sedimentological, lithological, paleoenvironmental and paleoclimatic data enables the reconstruction of the geological history. In particular, the integration of all tools to reconstruct the Late Jurassic has significant impact on the exploration models.

Key words: Late Jurassic; Dutch offshore; Palynology; Stratigraphy

References:
Early Toarcian (Early Jurassic) Mass Extinction Linked to Warming in Northern and Central Spain Comparison with Other Sections of Western Europe

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The Early Toarcian (Early Jurassic) mass extinction is one of the most important biotic crises of the Mesozoic. However, causes are controversial. Most papers hypothesized that this important floral and faunal loss of biodiversity is caused by widespread anoxia in the oceans, as a consequence of a postulated major Early Toarcian Oceanic Anoxic Event (ETOAE). This event is supposedly synchronous and global in extent. Another group of papers links the mass extinction with a major climate change that occurred synchronously with the mass extinction.

Five sections of the uppermost Pliensbachian and the Lower–Middle Toarcian deposits, located in northern and central Spain, have been studied. Detailed ammonite-based biostratigraphy, coupled with stable isotope analysis of diagenetically screened belemnite calcite and bulk carbonates, as well as total organic carbon (TOC) analyses have been performed in all sections. Carbonate deposits are bioturbated, indicating oxygenated environments, except for a 1m thick intercalation of laminated organic deposits found in the West Rodiles section. In four of the studied sections, the records of the vertical distribution of mainly benthic fossils have been compiled, allowing delineation of the distribution of the extinction interval, the extinction boundary and the population interval. The results obtained in the Spanish outcrops have been compared and correlated with other time-equivalent European sections.

Seawater palaeotemperatures, calculated from the oxygen isotope values obtained in belemnite calcite, reveals that the uppermost Pliensbachian represented a cool interval, on which average seawater palaeotemperatures in the Spanish platform system were around 13 °C. This palaeotemperatures were lower than expected for a palaeolatitude of central Spain of 30°N. The first step of warming started at the onset of the Lower Toarcian Tenuicostatum Zone. A progressive ΔT of about 3 °C has been recorded in most European localities, reaching seawater palaeotemperatures of around 16 °C. This progressive increase in temperature is coupled with a progressive and substantial drawdown in the number of species of nektonic, planktonic and benthic organisms, representing the extinction interval. Up to 88% of the species of ammonites disappear, the crises severely affected to nanofossils, the brachiopods completely disappear in most Europe, and up to 85% of the species of ostracods were extinct. Progressive loss of species was also recorded in many other groups such as belemnites, bivalves, gastropods and foraminifers. In Northern Morocco, up to 89% of the foraminifers species did not surpass the extinction boundary. Migration of the benthic organisms towards northern cooler waters was impeded by the predominant southward currents through the Laurasian Seaway and the European Epicontinental Sea. The excellent correlation between the patterns of the Early Toarcian progressive warming and the concomitant progressive mass extinction evidences a cause-and-effect relationship between the increase of temperature and the severe biotic crises. A rapid and prominent increase in the seawater temperature occurred around the Lower Toarcian Tenuicostatum–Serpentinum zonal boundary. Average temperatures at the Serpentinum Zone rose to 23 °C, representing an average ΔT of about 7 °C. This sharply accelerated increase in seawater temperature conditioned maxima extinction rates, marking the extinction boundary. Coinciding with this boundary, a minimum in diversity was recorded in most groups. The high temperatures of seawater continued during the Middle Toarcian Bifrons Chronozone, where average temperatures of 22.5 °C have been calculated for the European sections. The number of taxa as well as the number of new appearances increased, representing the population interval. Nevertheless, repopulation was uneven in the different fossil groups. Ammonites rapidly increased their diversity, and by the Middle Toarcian Bifrons Zone the number of species even surpassed the pre-extinction values in some areas. Recovery of most of the groups was relatively rapid in the well oxygenated environments of central Spain, with many species of immigrants from the warmer waters of the Mediterranean. After total extinction of brachiopods, the Spanish platform system was colonized in about 0.5 Myrs by opportunistic species of Tethyan brachiopods better adapted to warmer environments.

The anoxia linked to the postulated ETOAE cannot be the responsible for the mass extinction, because of mass extinction occurs synchronously in the
well oxygenated environments of many European and Northern African platforms. Deposition of laminated organic-rich black shale facies, above 5 wt.% TOC indicating anoxic environments, was mostly geographically confined to the Western Europe Euxinic Basin, and mainly deposited after the extinction event, during the interval of faunal recovery.

**Key words:** Palaeoclimate; Mass extinction; Oxygen isotope; Anoxia
Evidences of Widespread Wildfires in Laurasia and Gondwana During the Middle Jurassic

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Wildfires play a key role in Recent and ancient terrestrial ecosystem modeling but their geological history after higher plants colonization is still not well-recorded. We used the charcoals (Fig.1) and pyrolytic polycyclic aromatic hydrocarbons (PAHs) co-occurrence as proxies of Middle Jurassic wildfires on both the Laurasia and Gondwana continents. The Laurasian evidence comes from the Lower Callovian terrigenous deposits of the eastern part of the Central European Basin. We have detected the charcoal fragments co-occurring with unsubstituted polycyclic aromatic hydrocarbons in the Lower Callovian, Papilė Formation of Lithuania, indicating that forest fires took place at this time. The sum of concentrations of the pyrolytic polycyclic aromatic hydrocarbons, including fluoranthene, pyrene, benzo[ghi]perylenes, benzo[e]pyrene, benzo[ghi]perylene and coronene (Finkelstein et al., 2005) ranged from 4.66 and 6.57 μg/g TOC for charcoal-bearing clay and sand samples, respectively, while for the rest of the samples, the obtained values are below 0.5 μg/g TOC. Concentrations of PAHs are significantly lower than those from the Hettangian samples of Soltyków and similar to those from the Podole and Lower Gromadzice localities in central Poland (Marynowski and Simoneit, 2009). Besides of pyrogenic PAHs, the charcoal-bearing horizons are characterized by the occurrence of oxygen-containing aromatic compounds. The most common are benzo[ghi]naphthofuran, dinaphthofuran, and benzo[b]naphthofuran. As far as we know, this is the first evidence of wildfires during Callovian, as based on multi-proxy documentation (Marynowski and Zatoń, 2010). The Gondwanan record of wildfires comes from the Neuquén province in Argentina, where the Upper Aalenian/Lower Bajocian to Bathonian terrigenous sequences are characterized by the occurrence of charcoal and PAHs, a distribution of which suggests their pyrolytic origin. This is the first multi-proxy evidence of Jurassic wildfires from the Gondwana continent and generally one of a very few records of wildfires in Gondwana during the Mesozoic.

Fig. 1 Scanning electron photomicrographs of: (a) relatively well preserved small charcoal fragment from the Lower Callovian clays of the Karpenai exposure, Lithuania. (b) tangential section of excellently preserved charcoal from the Upper Aalenian-Lower Bajocian of the Rincón del Agüila exposure, Argentina.

Temperature interpretations, derived from inertinite reflectance data, show that in all cases the Middle Jurassic charcoals formed at low temperature surface fires that, in the case of Aalenian/Bajocian wildfires, sporadically reached the higher temperature crown fires. The occurrence of charcoals in the investigated deposits of the both continents confirms the recent results that the atmospheric oxygen level reached at least 15% during the Middle Jurassic times (Belcher and McElwain 2008; Berner, 2009).

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Key words: Wildfires; Charcoal; PAHs; Middle Jurassic

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The Jurassic comprises some 55 million years of Earth history. However, within the Jurassic, only one major environmental change event is really well known — the Early Toarcian Oceanic Anoxic Event (OAE) at ~183 Ma — and even in this case the extent to which the accompanying environmental changes was global has been strongly debated over recent years (e.g. Wignall et al., 2006). Nevertheless, partly as a result of the international effort to define GSSPs, much more is now being discovered about environmental changes taking place at and around the Age (Stage) boundaries, to the extent that meaningful comparisons between these events can begin to be made (e.g. Wignall and Bond, 2008). In the case of the Pliensbachian-Toarcian transition, the Early Toarcian OAE, and the Triassic-Jurassic boundary chemostatigraphy has been key to improved knowledge (Jenkyns et al., 2002). In particular carbon-isotope stratigraphy has delivered: 1) an unprecedented, ultra-high-resolution chronological framework (Hermoso et al., this volume); 2) marine to non-marine correlations (Hesselbo and Pienkowski, this volume); 3) demonstration of global impact (Al-Suwaidi et al., 2010), and 4) a means to gauge changes in the carbon-cycle and parallel changes in palaeotemperature (e.g. Suan et al., 2010).

Other events have appeared at least superficially similar to the Early Toarcian in a number of ways, and striking amongst these is the Sinemurian-Pliensbachian boundary (~190 Ma) which is also marked by a carbon-cycle perturbation, a black shale event, and an association with major sea-level rise of at least regional extent. With regard to sea-level change the Sinemurian-Pliensbachian boundary black shale occupies the same position within a ‘second-order’ depositional sequence as does the OAE black shale (Hesselbo and Jenkyns, 1998; Hesselbo, 2008). Recent work on both carbon and oxygen isotopes from bivalves and carbon-isotopes from organic matter (work with Chris Korte, University of Copenhagen, in preparation) is shedding new light on both similarities and differences between these events. Nevertheless, what both events have in common is a global expression, at least in terms of carbon-cycle perturbation, and this implies that the second order sea-level change, as an associated phenomenon is also global.

Many other events in the Jurassic are still very poorly known or even unknown, and may or may not be of more than regional significance, but will undoubtedly repay more vigorous study using an integrated approach. Primary amongst the known but poorly understood events are those in the Mid-Oxfordian (transversarium zone), at about the Aalenian-Bajocian boundary, and within the late Pliensbachian. Study of such events, especially in conjunction with the fast improving astrochronological timescale, which hints at correlation from cyclic sedimentary sequences directly to a calibrated astronomical model (Huang et al., 2010), promises a step change in our understanding of Jurassic Earth history and the relationships between physical and biotic evolution (e.g. Belcher et al., 2010; Ruhl et al., 2010).

**Key words:** Carbon and oxygen isotopes; Sea-level change; Oceanic Anoxic Event

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Causes and Timing of the Triassic-Jurassic Mass Extinction and Subsequent Early Jurassic Recovery

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The Triassic-Jurassic transition (~201.5 Ma) is regarded as one of the five major mass extinction events of the Phanerozoic, with a terrestrial ecosystem turnover and 50% loss in marine biodiversity. This event is further marked by a negative excursion in δ13CTOC records. It closely coincides with a period of extensive volcanism in the Central Atlantic Magmatic Province (CAMP), associated with the initial break-up of Pangaea. A causal relationship is however still debated. Here we present a concise chronostratigraphic framework for the T–J boundary interval and establish detailed trans-Atlantic and marine–continental correlations, by integrating astrochronology, paleomagnetism, basalt geochemistry and geobiology, in which the end-Triassic mass extinction in the marine realm is directly related to the onset of CAMP basalt deposition in continental basins (Fig.1). Our results support the hypotheses of Phanerozoic mass extinctions resulting from emplacement of Large Igneous Provinces (LIPs) and provide crucial time constraints for numerical modelling of Triassic–Jurassic climate change and global carbon-cycle perturbations.

We show that the negative carbon isotope excursion (CIE) in marine δ13CTOC records represents a global carbon perturbation. This interpretation is based on compound specific C-isotope data of long-chain n-alkanes derived from waxes of land plants. It shows a ~8.5‰ negative excursion coincident with the extinction interval, indicating a strong 13C depletion of the end-Triassic atmosphere, within 5-10 kyr. Magnitude and rate of this C-cycle disruption can only be explained by the injection of ~12x103 Gt of isotopically depleted carbon from the methane-hydrate reservoir. Concurrent vegetation changes reflect strong warming and an enhanced hydrological cycle. Hence the mass extinction event at the T–J transition is, for the first time, mechanistically linked to massive carbon release and associated climate change.

Strongly reduced biodiversity during the end-Triassic mass extinction in the marine realm is succeeded by early Jurassic recovery, with origination of ammonite species throughout the Hettangian, the first stage of the Jurassic. Accurate timing of events is however still poorly constrained. We present combined field observations and physical and chemical proxy records, covering the uppermost Triassic and lower Jurassic marine successions of St Audrie’s Bay and East Quantoxhead (UK). These data have been used to construct a floating astronomical time-scale of ~2.5 Myr in length. This time-scale is based on the recognition of meters thick cycles in limestone and (black) shale predominance and concurrent variability in physical and chemical proxy records. Three to five individual black-shale beds occur within these meters-scale sedimentary bundles and are interpreted to reflect precession-controlled changes in monsoon intensity, while the bundles are interpreted as ~100-kyr eccentricity cycles. On the basis of these findings, we propose an astronomically constrained duration of the Hettangian stage of 1.8 Myr in the UK and unequal duration of Hettangian ammonite zones (P. planorbis zone: ~250 kyr; A. liasicus zone: ~750 kyr; S. angulata zone: ~800 kyr). Within this astronomical framework, the extinction interval and coinciding negative CIE represent 1 to 2 precession cycles (~20-40 kyr). The amount of time succeeding the end-Triassic negative Carbon Isotope Excursion (CIE) and preceding the first Jurassic ammonite occurrence (in the UK) is constrained to 6 climatic precession cycles (~120 kyr). Cyclostratigraphic correlation to the astronomically-tuned sedimentary record of the continental Newark basin (USA) allows to locate the stratigraphic position of the marine defined Triassic-Jurassic and Hettangian-Sinemurian boundary in the continental realm.

Key words: Triassic-Jurassic mass extinction; Early Jurassic recovery; Causes and timing

References:

Fig.1 Stratigraphic framework correlating the marine and terrestrial realm across the Triassic-Jurassic transition
Structure Features of Void Space of Hydrocarbon Reservoirs of Upper-Jurassic Oil-Producing Complex of Middle-Ob Group of Fields (Western Siberia)

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Features of localisation of void space of rocks-collectors define the most important characteristics of the oil-saturated horizon. They are potential capacitor properties and degree of fluid phases recovery from reservoirs. Active methods are used to increase the extraction of oil. Thus it is necessary to consider influence of these methods not only on a fluid phase of a layer, but also on a mineral phase of system oil-collector. The basic types of structures of void spaces of rocks-collectors, upper-Jurassic horizon of the Tevlinsko-Russkinskoe oil deposit which is located within Western-Siberian oil-and-gas bearing provinces (the Surgut arch) have been studied.

Studies have shown that it is necessary to consider structure, features of geological structures of pots of hydrocarbon deposits and also features of a structure of void spaces of collectors and its mineral composition.

In order to study structure of void space elektron-microscopic research of a structure of Jurassic horizon rocks had been carried out, with additional X-ray diffraction analysis of fine dispersed component, and filtration-capacitor properties were also studied. Elektron-microscopic researches were carried out by a scanning electronic microscope of system Philips XL-30 in a mode reflected electrons, using sample microshears with their preliminary dressing by gold. Studying of reservoirs of upper-Jurassic horizon of the Tevlinsko-Russkinskoe deposit was based on a number of chinks.

The carried out researches allowed to study the features of a structure of reservoirs and the mineral individuals forming void spaces of upper-Jurassic oil-bearing complex (Izotov et al., 2008; Sitdikova et al., 2009). Features of a structure and the detail of morphology of void space are defined by following lithological-geochemical factors:

1. Character of packing (distribution of clastic-sandy fraction minerals in rock).
2. Morphological features of rock constituent clastic minerals.
3. The mutual relation of clastic minerals forming a skeleton of rock and cement-porous masses.
5. Studying of these factors allows to analyse lithological-geochemical balance in an oil-collector system and also to predict its evolution (shift) during depositing. Especially it is important when using active methods of influence on a layer.

The carried out researches allowed to establish different types of rocks cementation: basal, interstitial and the mixed type. Processes of clusterization – partial accretion of clastic grains of collector and its' regeneration - are characteristics for the studied reservoirs. Cluster is a set or joints of several grains at the expense of processes of their regeneration. Regeneration process of clastic grains is understood as the process of crystal-chemical morphology restoration and growth of clastic grains in a course of diagenetic and catagenetic rock transformation.

It is important to notice that clastic grains regeneration processes lead to the growth of their sizes and further to their accretion and even formation of dense, impenetrable sites (clusters). The arrangement of clusters essentially changes primary void space structure of collector. It is expressed in change (fall) of their capacitive characteristics. Change of filtrational features of rocks is especially important.

Clusterization processes (regenerations) of clastic grains of rocks is usually accompanied by corrosion processes – destructions of grains of other minerals or cement rock. Mineral components (field spars, biotite, quartz) are unstable during diagenetic processes. Liberated at corrosion of minerals oxide of silicon goes...
on reclaiming processes or on formation of fine dispersed quartz grains in rock cement. Thus transformations of clay minerals of cement can occur. Other elements liberated at corrosion of clastic grains (for example, iron ions) promote formation of hydroxide cement of rocks. In case of the regenerative environment it promotes formation of diagenetic pyrite. Occurrence of the pyrite leads to change of filtrational characteristics of a collector as crystals and crystals joints of pyrite clog porous space of rocks (Izotov and Sitdikova, 2008).

Thus, accretion of several grains at the expense of regeneration processes leads to the general change of volume of mineral component of rock. Intercluster pores and intercluster porous channels arise. Somewhere corrosion processes lead to almost full dissolution of clastic grains and to the occurrence of so-called "skeleton" minerals.

Owing to unstable thermodynamic conditions during diagenesis there is an "mosaic" chemical balance effect (on D.S.Korzinsky). Within one grain processes of corrosion and regeneration are observed. Often corrosion processes lead to almost full decomposition of grains. It promotes (in microsites) to increase in volume of void space. Sometimes regeneration processes lead to occurrence of complex, sometimes drusy joints – clusters of quartz or zeolite grains. These minerals often block primary porous channels and create new (diagenetic) filtrational network in collector structure.

Thus, as a result of corrosion-regeneration processes there is a reorganisation of collector structure. The basic laws of accumulation processes – migrations of fluids in system of porous channels - vary. The reconstructed structure of rock is characterised by its own features of a structure. Mutual relations between a recycled clastic skeleton of rock and the reconstructed cement mass lead to new type of a collector (Izotov et al., 2008).

The carried out researches by a complex of methods allowed to make a conclusion that features of processes of migration-accumulation of fluids are defined by structure, structure of porous spaces, features of localisation of cement mass of collectors of deposits of the Western-Siberian Province. In collectors of Jurassic petrolierous horizons the greatest development has basal, porous and pellicular- intergranular cement. Practically there is no visually distinguishable microscopic porosity, except for separate, in most cases isolated, pores.

The carried out researches of features of structure of collectors cement indicate that cement of rocks of collectors should be considered from following positions:

1. Structure of cement and void space of rock are based on character of distribution of minerals of cement mass of a collector. As a part of cement the clay minerals which are belonging to the class of layered silicates have the most part and, hence, cement-forming lamellar individuals depending on their mutual position create cement mass of various degree of competence. Ordered-lamellar, modular-randomly lamellar, diverse columnar, and drusy cement mass are allocated.

2. Degree of intensity of packing fine dispersed minerals of cement. It is necessary to notice that besides micropores having the size more 0.01mm, meso- and nanopores are allocated.

3. Features of localisation of clay minerals of a diagenetic complex of minerals (pyrite, quartz, calcite, zeolites) in structure of cement mass. For example, pyrite has thin impregnations of automorphic crystals that frequent trace a way of migration of regenerative fluids in cement mass.

Authigenous quartz is a characteristic mineral of cement, which is described in insignificant quantities. It is shown in two forms: opaline quartz in close accretion with a clay complex of cement and in the form of separate microcrystals in cement mass. Authigenous quartz plays an essential role in of fluids filtration processes.

Minerals of zeolite group are presented by a clinoptilolite. Zeolites have the greatest development in the Central part of the deposit.

The carried out researches demonstrate that reservoirs of oil fields of Midle-Ob group of deposits are combined with upper-Jurassic formations. They differ at a difficult structure, a variety of the mineral individuals forming void space. In the course of working out of these deposits, it is necessary to give particular attention to these features which define filtrational-capacitor properties.

Key words: Hydrocarbon reservoirs; Upper-jurassic oil-producing complex; Western Siberia

References:
Showings of Oil in Jurassic Section of Laptev Sea Coast
(Siberian Arctic)

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Bitumen-bearing deposits on the southern shore of Laptev Sea (Northern Siberia) are known for a long time. Drilling at Urung-Tumus Peninsula during the 1940s revealed small, shallow oil pockets in connection with salt structures (Urvantsev, 1978). We analyzed oils and bitumens from natural shows on the eastern edge of Urung-Tumus Peninsula from the Lower–Middle Jurassic section. Detailed litho- and biostratigraphy of this section was given by Meledina et al. (1987). Samples were collected from two localities: vicinity of the Cape Neftyanoi, GPS coordinates 74°00′26″N, 111°34′34″E (Lower Toarcian); vicinity of the mouth of Neftyanoi Creek, GPS coordinates 74°02′3″N, 111°34′54″E (Lower Bajocian).

Jurassic sandstones and siltstones have good reservoir properties. The character of distribution of bituminous matter in rocks suggests that the considered reservoirs are assigned to the group of intergranular, cement-porous ones. The bitumen content is up to 5.3 wt. %.

Judging from data on analyses of elemental and group hydrocarbon (HC) composition of oils and bitumens, all of them, based on V.A. Uspensky’s classification (1964), are attributed to classes of crude oil, malthas, asphalts, and asphaltites.

Gas chromatography-mass spectrometry investigations of fraction saturated HC have been carried out for samples collected at the outcrops of the Urung-Tumus Peninsula and compared with crude oils from Nordvik (Triassic) and South Tigyan (Permian) oil fields (Fig.1).

As it follows from the total ion current chromatograms, the oil and bitumens are characterized from moderate to significant concentrations of C_{23}–C_{25} normal alkanes and isoprenoid alkanes as well as mono- and C_{15}–C_{16} bicyclic sesquiterpanes. Pristane/phytane ratio is 0.60–0.75.

The distinctive feature of distribution of pentacyclic HC is relatively high concentration of adiantane (h_{29}) which exceeds that of regular hopane (h_{30}). But the most essential distinction of bitumens oil is very high concentration of gammacerane (Fig.1). The ratio of gammacerane to regular hopane amount to 0.30 in comparison to the values of 0.08-0.16 of this parameter in Precambrian oils of the Siberian Platform (Kashirtsev, 2003).

Most of the available geochemical parameters (low value of the Pr/Ph ratio, high concentrations of squalane and gammacerane, predominance of adiantane over hopane, C_{24} tetracyclic hydrocarbon) suggest that the source rocks have formed under conditions of highly saline lagoon basin. In the considered region, the salt strata are related to Devonian deposits (e.g. Kashirtsev, 2003). They form a series of diapirc structures, in some of which oil shows and small oil pools are known to occur (Nordvik and others).

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Key words: Jurassic; Bitumen; Oil; Arctic
Fig. 1 Mass-Chromatograms (m/z 191) with distribution of hydrocarbon-biomarkers in the crude oils and natural bitumens from Arctic coast of Laptev Sea

References:
Upper Jurassic Oil Shale Deposits of Aiyuva Shale-Bearing Basin

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Three lithological strata were determined in the section. For the first time the deposits from the Aiyuva outcrop are characterized by miospores and dinocysts. Aiyuva-1 outcrop is located 3 km downstream from the village of Kerka on the left bank of the Aiyuva river (Fig.1). Samples on microfauna and palynological analysis were taken to determine the age of deposits.

Fig.1 Map of the study area

Three lithological strata were determined in the section. The description of the outcrop is given from bottom to top.

The first stratum is represented by aleuritic, grey, light grey with greenish hue, carbonate non-plastic clay with shell detritus, belemnite and bivalve fauna and undetermined pyritized nuclei of ammonite shells.

Innumerable foraminifers (stratum base) include: Astacolus aff. suprajurassicus (Mjatl.), A. sp., Lenticulina aff. nedulosa Jak., L. sp., Citharina aff. lepida (Schwag.), Marginulina cf. robusta Reuss, Guttulina (?) sp. The forms are characteristic for the Late Jurassic Early Kimeridgian (J3km1).

Fern spores are found: Cyathidites australis Coup., C. triangularis Rom., Gleicheniidites laetus (Bolch.), G. senonicus Ross, and also conifer pollen: Pinus-pollenites pernobilis (Bolch.), Podocarpidites major (Naum.), P. multesusimus (Bolch.), Sciadopityspollenites mesozoicus Coup., Classopollis clausoides Pflug, C. minor Coup.

Apart from the miospores, Jurassic dinoflagellate cysts (dinocysts) are abundant: Gonyaulacysta jurassica (Defl.) Norris et Sar. subsp. adecta Sarj., G. jurassica (Defl.) Nor. et Sarj. subsp. jurassica, G. jurassica (Defl.) Nor. et Sarj. subsp. adecta Sarj. var. longicornis (Defl.) Sarj., Gonyaulacysta sp., Leptodontium sp., Ctenidodium ornatum (Eis.) Defl., Rynchodiniopsis cladophora (Defl.), Fromea amphora Cook. et Eis., Pareodinea sp., P. ceratophora Defl., Chytroeisphaeridia sp., Olygosphaeridium sp., Hystrichosphaeridium sp. The organic remains of very small foraminifers are found - Microforaminifera sp.

On the top the following foraminifers are determined: Lenticulina infravolgaensis (Furss. et Pol.), L. aff. kaschpurica (Mjatl.), L. media (Furss. et Pol.), L. sp., Saracenaria pravoslavievi Furss. et Pol., S. ex gr. alta K. Kuzn., Planularia polynovae K. Kuzn., Astacolus obliteratus (Furss.), Marginulina robusta Reuss, Vaginulinosis embensis (Furss. et Pol.), Citharina raricostata (Furss. et Pol.), Dentalina sp.

Miospores and dinocysts are represented by the same taxa.

The second stratum is represented by intercalation of dark grey, carbonate clays with numerous fragments of rostra of belemnites, fragments and unbroken shells of bivalves and grey-brown oil shales. The shales contain many prints of ammonites and bivalves. Foraminifers include here: Evolutionella aff. emeljanzevi Schleif., Kutsevella cf. labythangensis (Dain).

Single fern spores are found: Foveosporites pseudoalveolatus Coup., Osmundacities jurassicus (K.-M.), and also pollen grains: Piceapollenites variabiliformis (Mal.), Classopollis sp., Sciadopolyssollenites mesozoicus Coup. Dinocysts are present: Gonyaulacysta jurassica (Defl.) Nor. et Sarj. subsp. adecta Sarj., G. jurassica (Defl.) Nor. et Sarj. subsp. jurassica, G. jurassica (Defl.) Nor. et Sarj. subsp. adecta Sarj., Cribroperidinium sp., Pareodinea prolangeata Sarj., Chytroeisphaeridia sp., Plerosperma sp.

The third stratum – intercalation of grey, light grey, low plastic, carbonate clays with abundant fauna...

Miospores are rare - *Gleicheniidites senonicus* Ross, conifer pollen – *Piceapollenites exilioides* (Bolch.), *Podocarpidites major* (Naum.), *P. multesimus* (Bolch.), *Classopolis* sp. Algae are represented by *Gonyaulacysta jurassica* (Defl.) Nor. et Sarj. subsp. *adecta* Sarj., *G. jurassica* (Defl.) Nor. et Sarj. subsp. *jurassica*, *Pareodinea prolongata* Sarj., *Tubotuberella* sp., *Chytroeisphaeridia* sp., *Chlamidophorella* sp.

Judging by the presence of foraminifers, miospores and dinocysts, the deposits of the given outcrop can be related to the middle substage of Volzhsky stage of Upper Jurassic (zone *Dorsoplanites panderi* (J3v2)), which corresponds to Upper Tithonian in ISC.

The exclusion is the base of stratum 1 – this seems to be Upper Jurassic Kimmeridgian (J1km). For the first time the deposits from the Aiyuva outcrop are characterized by miospores and dinocysts. The studies revealed that dinocysts are developed in the section irregularly. The greatest number and diversity is observed in the samples from the first stratum. Perhaps it is connected with more favorable conditions for dinoflagellates.

**Key words**: Upper Jurassic; Foraminifers; Miospores; Dinocysts
Facies Analysis, Reservoir Characterization and Hydrocarbon Habitat of the Upper Jurassic Arab “C”, Qatar, Arabian Gulf

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The Arab C is a member of the Arab Formation, the main host of the huge Jurassic reserve in the Arabian Basin. The Arab “C” member in Qatar has similar lithologic characteristics throughout the country, and to that of the type locality in Saudi Arabia. The Arab “C” member consists of a sequence of limestone and dolomite limestone with numerous stylolites. Anhydrite occurs as nodules and in thin streaks as well as forming the reservoir cap rock.

Detailed petrographic analysis of core materials and thin sections from selected wells from the onshore Dukhan Oilfield indicates that the unit represents a transgressive system tract and made up of oolitic peloidal grainstone, algal boundstone, bioclastic grainstone and packstone with dolomite of different textures and sizes. Petrographic analysis of the Arab “C” suggests that its microfacies are similar to that of Upper Jurassic sediments in other parts of the Arabian Gulf. The Arab “C” member consists mainly of repeated small cycles of micritised grainstone- packstone with some dolomites at the base, which gradually pass upwards to wackestone-packstone with local coral-algal boundstones at the middle part and ended with fossiliferous grainstones-packstone that gradually change to anhydritic dolomites and anhydrites which capped the Arab “C” member.

The upper boundary of the Arab “C” was picked from positive gamma-ray deflection. At the base, the gamma-ray change across the boundary is very gradational.

During the Early Jurassic, the Arabian Gulf was a vast carbonate-evaporite platform (Murriss,1980). In this time, evaporitic conditions were limited to the north-western of this platform. By the end of the Early Jurassic, humid conditions predominated and evaporite deposits gave the way to carbonates. During the Middle Jurassic, a carbonate deposits covered most of the Arabian Gulf region (Murriss, 1980). Mixed clastic-carbonate was deposited toward north and north-west of the region. By the end of the Middle Jurassic, major flooding of the platform led to deposit relatively deep carbonates facies under euxinic conditions. These facies are believed to be the source rocks of much of the oil reservoirs in the Arabian Gulf. In the Late Jurassic, an intra-shelf basin extended over most of the platform and siliciclastics were totally absent.

Most of the studied rocks had undergone extensive diagenetic processes that modified their original features and their petrophysical properties. Dissolution created a considerable amount of moldic porosity and with the intercrystalline porosity resulted from dolomitization are the main types of porosity. Petrophysical analysis of well logs and core data indicate that high porosity (up to 30%) and permeability (up to 450 kmd) were found in the lower part of the unit. The widespread distribution of the unit, its lithologic features and reservoir characteristics make it an important exploration target.

From the nature of the recognized facies and the values of porosity and permeability, the Arab C is an important reservoir rocks and more attention should be directed to explore for it. Exploration should be directed to areas where there is extensive leaching by meteoric water or where dolomite forms the larger part of the succession.

Key words: Qatar; Arab C; Upper Jurassic; Hydrocarbon

References:
Oil Shales from Timan-Northern Ural Region (Russia): New Results of Investigations and Prospects of Development


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Oil shales are widely developed in the Timan-Northern Ural Region (Oil shales, They are included in the vast Volga-Pechora shale-bearing province and confined to the Upper Jurassic, namely to the Upper Jurassic Volgian stage Middle Volgian substage (J3v2 zone Dorsoplanites panderi) and correspond to the Upper Tithonian (J3t3) (Lyurov, 1996). In 2008-2009 field works were carried out at Aiyuva and Chim-Loptyugskoe deposits of the Timan-Northern Ural region. The authors took a task to study the deposits and to evaluate prospects of their development taking new data into consideration.

The Upper Jurassic section is composed of clays and oil shales. Between these rocks there are gradual transitions to carbonaceous clays and argillaceous oil shales.

The section is predominated by dark grey, grey and green-grey clays. Their composition includes illite, smectite, kaolinite, chlorite and mixed-layered minerals. Most samples show heulandite, sometimes its content reaches 20%. Generally clays are calcareous with inclusions of quartz grains and feldspars of silt sizes.

Oil shales are isolated in three strata with thickness from 0.4 to 3.2 m. The organic matter of the oil shales includes highly hyrolyzed compounds including amino acids, humic acid, chloroform A bitumen, alcohol-benzol mixture and insoluble organic matter (OM) – kerogen. These data testify to multicomponent composition of OM of Jurassic oil shales, as well as considerable participation of humic matter. On the basis of pyrolytic and elemental analyses, microscopic study and semicoking methods, four OM types are determined: 1) predominantly algal (alginate) (type I, Tissot and Welte, 1982; 2) alginate-inertinite (types I-IV); 3) resinite-alginite (types I-II) and 4) predominantly humic (types III-IV).

Total thickness of shale-bearing interval varies from 1.2 to 17 m.

The Upper Jurassic deposits include remains of various groups of marine fauna and flora from protozoa to highly organized organisms. Macrobenthos includes remains of bivalves, mud-eaters and urchins. Inarticulate brachiopods are found. Microbenthos population is represented by rare remains of ostracodes and foraminifers, pelagic nektan – by cephalopods (ammonites, belemnites) and perhaps by fish (phosphate biogenic remains are found). Zooplankton is represented by rare shells of radiolarians, and phytoplankton – by green and golden algae. Dominating remains testify to normal marine salt content of waters and boreal basin.

New lithological markers are determined, and new strata correlation of oil shales is done. The lower part of the Upper Jurassic shale-bearing section, corresponding to the lower bed (III) is characterized by small cyclitic structure. New data on mineralogy and geochemistry of oil shales and enclosing strata are obtained. Maximal Mo – 0.001%-0.002% and V – 0.060%-0.080% contents are correlated to oil shales development in the section and distinctly concentrated in semicoking products. It is determined that increased content of Ni – 0.050%-0.060% and Co – 0.001%-0.003% in underlying clays are related to authigenic vaesite microcrystals on the surfaces of various mineral grains.

The technological characteristics of oil shales depend on the composition and type of organic matter. The conducted technological studies prove high quality of oil shales: combustion heat 7.5–30 MJ/kg; resin yield –8 %–30 %; sulphur content in resin –2%-7%.

Taking into account the considerable contrast of enclosing clays and oil shales on radioactivity and specific atomic density it is recommended to apply the preliminary sorting and separation of mineable rock mass – to separate shales from clays and to increase raw quality for processing. This technology allows to mine both standard shales and lower thin layers.

Mining works may be conducted by Wirtgen Surface Miner. It will allow working out thin layers with minimal loss of oil shales.

The processing of oil shales results in four basic industrial products: shale oil, energy, fuel gas, shale ashes. The further prospects are connected to both enhancement of processing in each listed product, and creation of new branches of industrial production.

Key words: Upper Jurassic deposits; Tithonian; oil shales; Timan-Northern Ural; Clays; Organic matter; Technology

References:
Late Jurassic Radiolaria of Hydrocarbon-rich Mesozoic Basins Developed Along the Russian Arctic and Pacific Rims

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Owing to high interest to questions of the elaborating of radiolarian biostratigraphy of hydrocarbon-rich sedimentary basins the title of the special issue of Micropaleontology, which included proceeding of the INTERRAD meeting, which took place in 1988 in Marburg (Germany) is “Radiolaria of giant and subgiant fields in Asia” (Radiolaria., 1993). So far as major attention was paid to Asia part of Eurasian continent the main oil and gas provinces of the Europeans North have not been recorded in the proceeding. Unfortunately text-figure of generalized map of selected Eurasian Basins (Blueford and Gonzales, 1993) did not show any giant or subgiant fields in the area of the Russian Arctic, excluding West Siberia sedimentary basin, which is predominantly located in Siberia, but not in Arctic. North Sea, Norway Sea and Barents Sea areas also do not present on this text-figure.

Application of radiolarian data to petroleum exploration is pertinent, as radiolarians may be the only truly abundant and diverse microfossils available for constraining the ages of core samples from holes drilling into hydrocarbon-rich sedimentary successions. Recently, Upper Jurassic-Lower Cretaceous Bazhenov oil productive horizon of the West Siberia and the Kimeridgian and Volgian bituminous beds of the Northern Russia attracted a special attention (Hantzpergue et al., 1998; Zakharov, 2006). Similar high-bituminous deposits are well known along the Barents Sea margin and Volga-pre-Ural basin, Kara, Laptevs Sea margin and also from the Norway and North Seas. Of a great interest is a problem of the origin of the Volgian combustible shale sequence, as well as problem of stratigraphic correlations within the North Boreal Province.

The investigations of radiolarians allow the elaboration of provincial zonal schemes and correlation with other regions.

The Volgian (Kimmeridgian-Tithonian) radiolarian faunas of the Russian Arctic Margin are characterized by low diversity and high abundance of typical boreal Genus Parvingcula and spongy spumellarians and nassellarians. The complete absence of tethyan species and genera like Tritrabs sp., Acanthocircus dicranacanthos (Squinabol), Archaeodicyomitra apiara (Rust), Podocapsa amphitreptera, Andromeda, Mirifusus, Podobursa, Tethysetata was recorded among collected radiolarian faunas of the Russian Arctic Margin, while a lot of representatives of typical Tethyan genera Pantanellium, Tethyseta, Mirifusus, Podobursa were found among coeval radiolarian faunas of the Russian Pacific Margin.

It is necessary to emphasize that an endemism of radiolarian faunas of the Russian Arctic Margin increases from Kimmeridgian up to Middle-Late Volgian time, while diversity decreases.

In contrast to Californian coeval radiolarian assemblages the comprehensive analysis allowed to document the wide distribution of the Family Pantanelliidae within the North Boreal Province.

The change of Parvingcula rich assemblage into Stichocapsa and Spinicingula rich association at the Jurassic-Cretaceous boundary is observed. The Lower-Middle Volgian (Kimmeridgian-Tithonian) fauna is dominated by Parvingcula, whereas among Upper Volgian (Berriasian) fauna Stichocapsa and Spinicingula are prevailed. The Stichocapsa devorata arctica Vishnevskaya et Murchey is very characteristic species of Berriasian assemblages of North Arctic Basins of Russia.

The presence of similar radiolarian associations with boreal affinities in the terranes of the Bering and Okhotsk regions allows us to suppose the opportunity to find the synchronous bituminous radiolarian-bearing facies at the shelf of the Russian North-East and may be within the Canadian sector.

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Key words: Parvingcula; Boreal; Tethyan; Russia

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Vishnevskaya V.S. Evolution of Species Diversity of

The Departmental Nature Reserve of La Boissine, La Voulte-sur-Rhone, France: A Middle Jurassic Lagerstätten

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Location

La Voulte-sur-Rhone is situated in south-east France, 120 km south of Lyon, on the right bank of the Rhone. Here, in a locality called La Boissine, there are the remains of an ancient mine, where exceptionally rich iron was excavated in the 19th Century. Very important fossil remains have been found in marls intercalated between the ironstone beds.

The outcrops are 800 m west of the town, beside the La Voulte-sur-Rhone fault over an east-west distance of about 1600 m. The beds are strongly tilted and the total thickness seen is less than 12 m, consisting of blackish, brownish-red or sometimes multicoloured fissile marls rich in limonitic concretions, with some discontinuous limestone beds and horizons of fossiliferous nodules.

History

Mining of iron in the La Voulte-sur-Rhone area dates back to gallo-roman times. In 1777 the naturalist De Gensanne, of the Montpellier Academy, sent by the Languedoc authorities into the region with a mission to make an inventory of sites, informed the local authorities of the discovery of an important vein of haematite that could be mined. In 1788 Faujas de Saint Fond, inspector general of coal mines, took charge of this deposit, considered one of the richest iron mines in France and in 1794 an official concession was signed to open the iron mine of La Voulte-sur-Rhone. From 1860 to 1880 up to 60,000 tons per year (20% of national production) was excavated. Subsequently, production declined due to difficulties of excavation and a metallurgical crisis. The mines were closed in 1892 and the concession was given up in 1904.

Because of the important mining activity in the 19th Century, the first detailed geological studies appeared. As a result of a meeting of the Société Géologique de France in Valence in 1854 the deposit was correlated to the base of the lower Oxfordian, based on ammonite identifications by d’Orbigny. Elmi (1967) described the outcrops at La Voulte-sur-Rhone and compared them with other deposits in Ardeche, dating them as Lower Callovian.

In 1970 Bernard Riou restudied the deposits, and in 1982 made the remarkable discovery of the oldest known octopod, Proteroctopus ribeti (Fischer and Riou, 1982). Subsequently the special character and palaeontological interest of this site has been demonstrated by several scientific publications.

The deposits at La Boissine are of international importance as one of the rare examples, if not the only one, of a site yielding fauna of the deep marine Jurassic environment and giving also unpublished key information on the biodiversity at great sea depths of the Jurassic Period.

The Fossils

The fossils of the Lagerstätte of La Voulte-sur-Rhone make up a special population very similar to that of the present day relatively deep marine environment. Thus siliceous sponges, cirrate octopods, vampyromorphs, large pycnogonids and asteroids all indicate the bathyal zone. Many others found represent the ancestors of present-day relict forms.

More than 60 fossil species have already been described: especially arthropods – 50% of the fauna with 13 crustacean species, 4 thylacocephalans species (“bivalved” arthropods with hypertrophic eyes) and 3 pycnogonid species. Cephalopods represent over 11% of the fauna with 7 coleoid species (octopods, vampyromorphs and teuthoids) and several ammonite species. Marine worms are diverse, with 7 species described. Of echinoderms, ophiurids are very abundant with one species dominant – Ophiupinna elegans (Heller, 1858). Echinoderms represent about 10% of the fauna, with equally comatulids, sea urchins and starfish. Bivalves
and brachiopods are each represented by 2 species. Among vertebrates, numerous difficult to identify sharks, and fish including 2 coelacanths and 1 crocodilian skull are found.

The sedimentary rocks of the area of La Voulte-sur-Rhone to Rompon form a monoclinal structure. The various fossiliferous deposits are aligned along a fault that could lie at the origin of these deposits: submarine oozing similar to hydrothermal events could explain the presence of such a concentration of fossils in this site. The extraordinary environment with soft parts preserved, according to Wilby, Briggs and Riou (1996), Wilby and Briggs (1997), seems directly related to the action of bacteria causing mineralisation of soft tissues molecule by molecule.

Site Protection and Projected Development

The palaeontological site of La Voulte-sur-Rhone (La Boissine) was acquired by the Department of Ardeche in 2005, under legislation for the protection of vulnerable natural sites (Espaces Naturels Sensibles – ENS). It is one of 14 such sites in Ardeche, six of which have significant geological interest. By its great palaeodiversity and exceptional preservation of marine organisms, the fossiliferous site of La Boissine is a deposit of national and international importance. It is classified among the 20 most remarkable sites for preservation of fossils.

The Conseil General of Ardeche has given as objectives the protection of this unique geological heritage, improved scientific knowledge of the site and plan to open it to the public in a supervised manner (guided visits, teaching workshops). The Nature Reserve of La Boissine should become a window into the politics of vulnerable natural sites, with implications that are scientific, patrimonial, ecological, pedagogic and social.

This project is part of a plan to develop the tourist attraction of the area. The creation of a teaching and tourism tool (green tourism) that is at the same time a Nature Park of international repute and a museum structure can strengthen central Ardeche by proposing a centre of excellence. One can also hope to improve the image of this area and develop economic activity creating sustainable employment calling on its heritage values.

Opening to the public of the first part of the project (teaching activities and geological trail) is planned for 2011. The second phase, in close collaboration with the commune of La Voulte-sur-Rhone, is the renovation of a building for the site where the exceptional discoveries at the site can be displayed and a 3D presentation of the geological heritage (opening planned for the end of 2012).

Key words: Callovian; Lagerstätten; La Boissine; France

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World Heritage on Sale in England: State Supported Trade in Global Palaeonto-Logical Heritage and Its Consequences

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The Dorset and East Devon World Heritage Site was listed by UNESCO in 1999, one of its primary features being a remarkably complete Jurassic sequence, well exposed in coastal cliff and foreshore exposures. The area has been important in the development of Jurassic science and includes the historical types locality of the Kimmeridgian Stage, the historical type area of the Portlandian, Stage ‘now assigned to the Tithonian) and a potential GSSP for the Oxfrodian Stage. The area also has a long history of recreational and commercial fossil collecting, which at times significantly conflicts with its scientific use (Page and Wimbledon 2009).

Rather than attempt to manage this potential conflict within existing legal and administrative frameworks, the site administrators (local government authority Dorset County Council and the then national conservation agency for England, English Nature, adopted a voluntary Code of Conduct for fossil collectors – with no enforceable legal status. A key feature of this Code is a voluntary reporting scheme, which allows fossil collectors to record certain categories of find, and in the process be given legal title to the find. The collector then has the right to sell the specimen nationally or internationally, should a UK public museum fail to raise any asking price. Virtually the only mechanism invoked, therefore, to help retain some of the collected specimens for display or as part of a national heritage is financial, where public museums in the UK are assumed to be willing and able to bid against private and foreign individuals and institutions in an international market place, to purchase key specimens. The recovery of specimens under the ‘West Dorset Fossil Collecting Code of Conduct’, however, has been very poor and a scientific analysis over the first 3 years of implementation suggested that although at least 1300 scientifically important specimens might have been expected to have been found, the Code recorded only 36 - and later results are not much better (Page and Wimbledon 2008). Not surprisingly, the Code is very popular amongst the commercial fossil collectors that exploit the area to supply an international market place, as it allows them to pursue their business interests with the minimum of state intervention.

The Code is promoted through a close -collaboration between Dorset County Council administrators and commercial fossil collectors and dealers. Both have argued that that real issue is the failure of public institutions to provide the same resources for purchasing geological materials as they do, for instance, for works of art. Unfortunately this argument is deeply flawed, as the works of art in question are general already in private ownership, whereas the fossils from the coast are often owned by national heritage organisations. This approach creates a bizarre scenario in which the state is expected to buy back what it has, in effect, given away. In 2008 this is exactly what happened, when the UK’s, national state lottery awarded Dorset County Council’s museum service around £250,000 to purchase some of the fossils that its own World Heritage management group had ‘given away’ to fossil collectors and commercial traders.

It is perhaps understandable that a local government body should seek to promote the local economy in whatever way it can. But when this policy has the potential to conflict with national legal and policies – in this case in the field of nature conservation – surely the state should intervene? In West Dorset and East Devon, however, rather than invoking national legislation to protect geological heritage, the governmental conservation administrator – now Natural England – has participated in this process. The most striking example concerns the discovery of a rare plesiosaur skeleton within its own Axmouth-Lyme Regis National Nature Reserve in 2008. Rather than initiating a scientific excavation and placing the specimen in a public museum, Natural England permitted it to be removed and ’gave’ the specimen to the finder, the proprietor of a fossil shop in Lyme Regis – presumably now a candidate for ’buy back’ using state lottery money.

This direct participation by a state conservation organisation in the commercial exploitation of a World Heritage site is a very worrying development – especially when supported by the provision of state money to buy specimens collected. Does UNESCO really appreciate what is happening in the Jurassic Coast World Heritage site and what are the implications for other World heritage sites globally and indeed many other key Jurassic palaeontological localities? Could this undermine some of the hard work carried out elsewhere in the raising of public awareness of the scientific and heritage value of fossils, as opposed to their commercial? Or do we simply have to accept that our research material is simply another commodity to trade in, along with stocks, shares and equity and in addition to raising grants for research, will we also have...
to raise purchase funds, rather than collect specimens ourselves. And if global market prices for fossils are applied – sometimes 1000s of dollars, even millions – could this lead to a virtual ’extinction’ of much of scientific palaeontological activity, especially on certain groups of macrofossils? The dangers are there, and if scientists and conservationists do not make their views known, the glint of money and economic, revival could persuade other government decision makers to follow Dorset County Council and Natural England to adopt a similar approach. What then would be the future of our science?

**Key words:** Jurassic; World Heritage; England; Palaeontological heritage; Fossil collecting

**References:**
Prospects for Establishing An International Database of Key Jurassic Sites and Stratotypes to Aid National and International Research

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As the few remaining stage stratotypes (i.e. GSSPs) for the Jurassic are established over the next few years, the primary function of the International Subcommission for Jurassic Stratigraphy (ISJS) will have been fulfilled. This consequently poses a question – what future roles could the Subcommission fulfill? As GSSPs establish globally applicable bases for all Jurassic stages, what level of international applicability should their component ammonite-correlated chronozones have? If these zonations should really be considered to be ‘standards’, surely some form of international agreement is required to stabilize their usage and ensure that every time a new review is published zonal boundaries do not move around? (if they do then the zonation is certainly not a ‘standard’). Inevitably, due to faunal provincialism, regional standard schemes may be necessary, but all must now ‘fit’ within the defined GSSP isochrons. Commonly, however, some faunas are shared between adjacent provinces and these can provide the basis for establishing formal divisions at the chronozone and subchronozone level. Any regional or local (i.e. single basin) variations can be accommodated at the level of ‘horizon’ or ‘biohorizon’, thus providing a degree of ‘flexibility’ to accommodate new discoveries.

Deciding on what ‘standard’ schemes are applicable would be an ideal role for established stage working groups within the ISJS, whose multi-disciplinary expertise has already led to the establishment of stage GSSPs. Indeed, the formalization of true Standard Zonations would be a natural extension of this work, and key review papers and volumes such as Cariou and Hantzpergue (1997), Westermann (1992) and Page (1992), can provide a basis on which to build. Crucially, although ammonites are likely to remain as the primary stratigraphic indicators – i.e. because they can be readily identified in the field by appropriate specialists without the need for expensive sample processing - the value of establishing defined stratotypes for each chronozone and subchronozone as is required by chronostratigraphical method, allows a range of other ‘proxies’ to be used to correlate each unit. Examples which have been used at this level include brachiopods, a range of microfossil groups and even carbon isotopes – as will be apparent from every GSSP definition. Every definition of every standard chronozone and subchronozone requires a stratotype – a defined point in a designated section at a geographically identified location. Just like GSSPs, such sections are ‘reference sections’ and should, therefore, remain open and accessible for study and sampling by a global scientific community. Unfortunately, national conservation and related heritage management frameworks and perspectives can often either inappropriate restrict this use or permit unregulated use of which can, literally, erode its scientific value. Knowledge of such frameworks and issues is essential for any scientists planning any future work at any established stratotype.

Basic information of this type has been provided for all established and proposed Jurassic GSSPs by Page, Meléndez and Henriques (2009) and the it is proposed here that a database is established to provide similar information for all other Jurassic chronostratigraphic stratotypes (following the agreement on internationally applicable ‘standard’ zonal schemes by each stage-focused working group of the ISJS). Such a database should ideally be accessible – and updatable – online, thus providing a global resource for Jurassic science (although some thought may need to be given as to whether open or ‘controlled’ access is appropriate, to reduce the risk of any misuse of the included information, e.g. by commercial fossil collectors). Key information for each site could include: Name, Geographical referencing (including map), Status (e.g. chronozone stratotype), Nature of site (e.g. natural coastal cliff), Conservation status (e.g. legal designations), Access and Ownership, Key References, Contacts (e.g. email, website, etc., including of conservation authorities, key researchers, etc). Ultimately, this information could also be published as a series of printed, individual stage-focused volumes. There is clearly a strong link in such a project between science and conservation, as the needs of science require an appropriate conservation process to take place to ensure that the ‘reference’ localities remain open and available for study. The establishment of the international value of the suite of stratotypes recognized and described could also inform international conservation projects, such as the global geosites initiative, initially established through the International Union of Geological Sciences (IUGS; Wimbledon et al., 2000) which also, ultimately, of course, oversees the core work of the ISJS selecting GSSPs.
Key words: Jurassic; Stratotypes; Database; Conservation; Geosites; ISJS

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