 Worldwide ammonite correlation at the Pliensbachian Stage and Substage Boundaries (Lower Jurassic)

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INTRODUCTION

Since d’Orbigny introduced the notion of Stage and Oppel the concept of Zones near the middle of the 19th century (the subzone concept emerged more gradually during the 20th century), work has continued to refine and to define the succession of chronostratigraphic units so as to arrive at a reliable continuous time scale.

With this aim, the International Commission of Stratigraphy (ICS) indicates that boundaries must be formally defined by a stratotype; a standard Global Stratotype Section and Point (GSSP).

Despite radiometric dating and possibilities of correlations with magnetostratigraphy, stable isotopes and Milankovich cycles, biochronology remains of key importance due to its high precision and its resolution even if paleobiogeography and paleoecology sometimes restrict its potential.

The purpose of this paper is not to discuss again all the concepts of chronostratigraphy and biostratigraphy. For this, we refer to Dean et al. (1961), Salvador (1994), Callomon (1995) and Page (2003). Herein we just present a table to summarise my opinions concerning the smallest biostratigraphical and chronostratigraphical units: biohorizons and zonules (text-fig. I). Hedberg (1976 p. 49, 67) defined the concept of chronozones which is, for us, quite similar and can be integrated into the more precise concept of zonules well discussed by Phelps (1985) and Page (1995). The concept of zonules is discussed in detail by Callomon (1995) and Blau & Meister (2000). The definitions of biohorizon and zonules, as used herein, are briefly presented. A biohorizon is the smallest biostratigraphical unit that corresponds to a bed or a series of beds, characterized by a specified taxon or assemblage of time-diagnostic guide-fossils, within which no further stratigraphical differentiation of the fauna can be made. A biohorizon is locally recognizable and a standard horizon is reproducible at a large scale (ideally paleogeographic domain scale). A zonule is the smallest subdivision of a chronostratigraphical scale that should be defined at its base like a stage (see below). A potential zonule is still not defined.

The basic idea is to present guide ammonites or ammonite assemblages which characterize biohorizons in different localities of the Euroboreal, Tethyan and Pacific Domains and to correlate them.

Historically, the fossiliferous sequences of NW Europe are taken as reference to establish standard zonations, especially for the Jurassic, and the most effective standard zonation for this period is based on ammonites. This is the case for the Sinemurian-Pliensbachian and Lower-Upper Pliensbachian Boundaries.

This chronostratigraphical interval is a period of strong ammonite provincialism and the correlations between different paleobiogeographical domains (Euroboreal, Tethyan, Pacific Domains) remain difficult.

Two possible responses

1) The use of several regional zonations. If it is an absolute necessity first to describe and documents the succession in any region and to propose a biohorizon succession, it better, for us, at this stage of resolution to directly correlate with standard zonation without to establish regional biozones or subbiozones (see an example for ammonite succession in Mexico, Meister et al. 2009). Regional zonations raise more problems than they solve and increase the difficulties of correlations, at least for ammonites (see Meister et al. 2006). For hierarchical consistency it is necessary to select one scale as primary standard and to refer directly to it even it remains some uncertainties.

2) The second solution is to use the best zonation with the most accurate resolution - in this case the NW European zonation (reinforced by the choice of the Pliensbachian GSSP) as a reference to establish regional biostratigraphic boundaries. For hierarchical consistency it is necessary to select one scale as primary standard and to refer directly to it even it remains some uncertainties.
correlate with it. During recent years, several studies presenting very precise biostratigraphic frameworks have been published allowing the proposal of a more or less precise correlation between paleogeographical domains.

All the basic stratigraphical data have been published by the respective authors quoted in the figures and they have been critically reviewed for taxonomy and/or stratigraphy. The information came from range charts or from faunal lists based on bed by bed collections of ammonites. The references are given in each figure. These represent the successions of biohorizons across both boundaries throughout the world. Some significant ammonites are illustrated.

To identify precisely and to correlate the Sinemurian-Pliensbachian boundary is often very difficult because of sedimentological and tectonic problems which affect the fossil record. Moreover, the Lower-Middle Lias is a period of strong provincialism and/or endemism, and resulting in addition difficulties for ammonite correlations. Consequently, only one outcrop was deemed suitable to be selected for the GSSP of the Sinemurian-Pliensbachian boundary (see Meister et al. 2003) and formally defined in 2006 (Meister et al.) at Wine Haven (Yorkshire, UK).

For the Lower-Upper Pliensbachian Boundary several possible GSSP candidates can be selected to define the base of the Upper Pliensbachian. For this interval the proposed correlations remain informal but are quite precise because of the association of Euroboreal and Tethyan ammonite in some key regions such as the Austrian and Hungarian upper Austroalpine units.

Remark: In the following text the Sinemurian - Pliensbachian Boundary is abbreviated SPB and the Lower - Upper Pliensbachian Boundary to LUPB.

DISCUSSION

The Pliensbachian Stage

The Pliensbachian is the third Stage of the Jurassic System. Its name derives from Pliensbach, a small village in SW Germany not far from Holzmaden and the original definition of this stage dates back to Oppel (1858, p. 248-249, 256), previously d'Orbigny's Liasien (1849-1852).

The base of the Pliensbachian is located at a level of important faunal changes corresponding roughly to the disappearance of the Echioceratidae (Psiloceratoidea) and the subsequent full de-
development of the Eoderoceratoidea which underwent a significant radiation and increase in diversity. The Sinemurian-Pliensbachian ammonoid event is a good example of faunal renewal at a global scale.

The Pliensbachian is divided in two substages. The Carixian (see Lang 1913, p. 401) was an alternative to Lower Pliensbachian and the Domerian was proposed by Bonarelli (1894) for the Margaritatus and Spinatum Zones of Oppel (1856), corresponding now to the Upper Pliensbachian. Following the recommendation of the International Commission on Stratigraphy (ISC) that substages Carixian and Domerian should not be named, although widely used and should be replaced by Lower Pliensbachian and Upper Pliensbachian. (see for more details see Meister et al. 2003, 2006).

Around the Lower-Upper Pliensbachian Boundary (LUPB) contrary to the SPB, there is no major faunal change and this boundary is still not officially defined; the Pliensbachian Working Group of the Jurassic Subcommission is now focusing on this topic. At present, its definition is based on the gradual evolution of two ammonite superfamilies: the Eoderoceratoidea Spath 1929 for the Euroboreal and the Pacific paleobiogeographic Domains and the Hildoceratoidea Hyatt 1867 for the Tethyan Domain.

More precisely, in the Euroboreal Domain, the boundary is based on the evolution of the Liparoceratidae Hyatt 1867 emend. Dommergues & Meister (1999) with Oistoceras - Amaltheus. In the Pacific Domain it is based on the Dubariceratidae Dommergues & Meister 1999 with Andidiscus - Fanninoceras and in Tethys on Harpoceratinae (Neumayr 1875) within the lineage Fuciniceras (sensu Dommergues et al. 2002).

Based on ages in the recent versions of the Geologic Time Scale (Gradstein et al. 2004, International Commission on Stratigraphy 2009) compiled by Walker and Greissman (2009), the Sinemurian corresponds to an interval of 7 m.y. and the Pliensbachian of 7 m.y. too. So we can propose estimates for the durations of the ammonite succession based on the number of Chronozones/Subchronozones/zonules or standard horizons (Corna et al. 1997; Dommergues et al. 1997; Blau & Meister 2000; Meister et al. 2003, 2005; Geczy & Meister 2007) (text-fig. 2).

These numbers are estimates and averages of estimates. The durations of zones, subzones and biohorizons were certainly not all the same: On the basis of ammonite assemblages the European Pliensbachian presently comprises 5 Chronozones («Standard Zones»), further subdivided into 15 Subchronozones (Dean et al. 1961). Since 1997 (see Dommergues) the number of biohorizons recognised has increased for the Lower Pliensbachian from 22 to 25, even more for the Upper Sinemurian, from 14 to 40. Moreover the duration proposed in the literature for these two periods (U. Sin. and L. Pl.) has also changed in reliability. Consequently with the new ammonite data, the precision has increased and the estimated average for the duration of a biohorizon from 250,000 y. to about 87,500-58,000 y. for the Upper Sinemurian and from 220,000 y. to about 140,000-157,000 y. for the Lower Pliensbachian.

The base of the Pliensbachian Stage

One of the main problems for the Sinemurian-Pliensbachian Boundary is the rarity of «good» sections bearing ammonites. We are often confronted with obviously missing or condensed sediments, or sometimes simply poorly fossiliferous sediments (text-fig. 3).
The base of the Jamesoni Zone (more precisely the base of the Taylori Subzone) is traditionally used to identify the base of the Pliensbachian. The base of the first Pliensbachian Subzone (Taylori Subzone) was defined by Spath (1923) in the Dorset coast and later discussed by Dean et al. (1961) and other authors (for details see Meister et al. 2003, 2006). After the work of Dommergues & Meister (1990) and Schlatter (1990), it became apparent that the proposed definitions were inadequate to define the base of the Taylori Subchronzone (see Dommergues & Meister 1992) and the definition of the boundary had to be reconsidered and improved.

After intensive work by the Pliensbachian Working Group, the Global boundary Stratotype Section and Point (GSSP) for the base of the Pliensbachian Stage (Lower Jurassic) is now defined at the base of bed 73b at Wine Haven, Robin Hood’s Bay, Yorkshire Coast, UK. This level coincides with the ammonite association Bifuriceras donovani Dommergues and Meister and Apoderoceras sp. which define the base of the Taylori Subchronzone of the Jamesoni Chronzone. This fossil association overlies the last Upper Sinemurian Echioceratidae and precedes the first classic Lower Pliensbachian Apoderoceras associated with the acme of Phricodoceras taylori (Sowerby).

Nevertheless, this period of transition is usually poorly documented where Late Sinemurian and Early Pliensbachian strata are exposed. This boundary therefore is based on ammonites of Euroboreal affinities and we are faced with correlation problems with the Tethyan and Pacific regions. So it is important to propose correlations in terms of biohorizons around these stage (and substage) boundaries and to illustrate the characteristic ammonites of this period.

The Eoderoceratoidea Spath 1929 dominate the ammonite fauna during the Lower Pliensbachian. Among this superfamily, the Paramicroderoceratidae Venturi et al., 2004 (sensu Geczy & Meister 2007), the Liparoceratidae Hyatt 1867 (emend. Dommergues & Meister 1999) and the Eoderoceratidae Spath 1929 (emend. Dommergues & Meister 1999) already present in the Sinemurian survive and diversify in the Pliensbachian after the extinction of the Echioceratidae Buckman 1913. Moreover two new families the Coeloceratidae Haug 1910 (emend. Dommergues & Meister 1999) and the Tropidoceratidae Hyatt 1900 [= Acanthopeuroceratidae Arkell 1950 (emend. Dommergues & Meister 1999)] expand at this time.

A good element of correlation near to the Sinemurian-Pliensbachian Boundary is the presence of Paltechioceras tardescens (Hauer) and especially Paltechioceras romanicum (Uhlig) which indicate the topmost part of the Sinemurian. But a stage is defined by its base not its top. Indeed the base of a stage is defined by a taxon or an assemblage of taxa characterizing the lowest zonules of its lowest subchronozone of its lowest chronozone and so on, forming a continuous scale. The top being limited by the base of the overlying stage or chronozone or subchronozone or zonule.

A) NW Euroboreal Domain

In NW Europe (text-figs. 4-8) besides the Wine Haven section (GSSP), the presence of Apoderoceras nodogigas (Quenstedt) – leckebityi (Wright), Apoderoceras aculeatum (Simpson), Tetraspisoceras quadrarmatum (Dumontier) are close indicators of the boundary (text-fig. 4). This is the best approximation to the lowermost Pliensbachian and some homogeneity of the fauna throughout the domain allows good correlations with the GSSP. The superfamily Eoderoceratoidea dominated the NW European ammonite fauna of the Pliensbachian (about 7 m.y.) and, with the Dactylioceratidae, persisted through to the middle Toarcian.
TEXT-Figure 4

The black scale bar = 1 cm.
In UK, *Bifericeras donovani* Dommergues & Meister is, until now, restricted to the Yorkshire coast (text-fig. 5). In other regions, the position of the boundary can be identified by the presence of *Apoderoceras* gr. *leckenbyi* (Wright) associated (or not) with *Phricoceras* *taylori* (Sowerby). In Germany, *A. gr. nodogigas* (Quenstedt), *A. sparsinodum* (Quenstedt), *Tetraspidoceras quadratum* (Dumortier) are the index species close to the SPB (text-fig. 6). In France, the resolution is similar to that we have in Germany; only a strange form *Microderoceras* sp. is recorded from the Corbières (text-fig. 7). In the Lusitanian Basin, we have the presence of *Vicinitoceras* and *Apoderoceras* overlapping a biozone with *Gemmellaroceras* sp. (text-fig. 8). The position of SPB remains uncertain and now is in reinvestigation. In the Cordillera Ibérica, the SPB limit still cannot be placed very precisely; here also *Gemmellaroceras* sp. is present near to the boundary. The correlations with the Gemmellaroceras aenigmatic biozone of Subbeticas is not exactly known but *Gemmellaroceras* seems to be an important biostratigraphical marker in the Iberian peninsula.

**B) Tethyan Domain**

In the Tethyan Domain, the ammonite fauna is totally different already at the generic level and correlation with the GSSP is difficult. Although the Eoderoceratida remain conclusive for the base of the Pliensbachian, Hildoceratoidea started to play a major role for biostratigraphy since the Ibex Chronozone. Nevertheless, one genus *Catriceras* (*C. catriense* Venturi and *C. pannonicum* Meister & Geczy) seems to indicate very close to the base of the Pliensbachian (e.g. Apennine, Hungarian Upper Austroalpin) (text-figs. 9 and 10). The presentes of *Paraderoceras* in the Apennines and of *Bakonyceras* *evolutum* (Geczy) in the Hungarian Austroalpine can also be considered as approximate indicators of the SPB. In the Austrian Upper Austroalpine, in Tunisia and in the High Atlas where *Paramicroderoceras* is present, there remains a quite large uncertainty. For the Subbeticas and Pontides the position of the boundary is still uncertain (text-fig. 8).

**C) East Pacific Domain**

Here the boundary is still uncertain and cannot be accurately positioned with ammonites. The presence of *Patechioceras* *tardircrescens* (Hauer) and of *Paramicroderoceras* (=*Tetraspidoceras* nov. sp.) (maybe *Catriceras* (?) cf. *catriense* Venturi) may be close indicator in North Central and South America (text-fig. 11).

The strong endemism for the period and the important renewal of the ammonite faunas still increase the problems of correlation with Euroboreal and Tethyan Domains. Possibly systematic isotopes studies in some selected fossiliferous localities could supply ammonite data and provide better data to correlate with the GSSP of the Pliensbachian.

**The Lower-Upper Boundary of the Pliensbachian Stage (LUPB)**

If the duration of the Pliensbachian is about 7 m.y. and Lower and Upper Pliensbachian of the order of 3.5 m.y. each (see above). The LUPB may estimated at about 186.5 m.y.

The situation for the Lower-Upper Pliensbachian Boundary is different than for the Sinemurian-Pliensbachian Boundary because of the absence of a formal definition for this boundary (text-fig. 12). The Pliensbachian Working Group is currently focusing its efforts on this topic in order to propose a GSSP for this boundary (Meister 2007).

**Short historical background**

When Bonarelli (1894) used for the first time the name Domo- rian, he referred to the ammonite faunas of the Medolo of the Mt. Domaro (Southern Calcareous Alps, North Italy). Cita (1962) defined a type locality (*Domoñien-Type*) which is not a precise outcrop but rather the area of Mt. Domaro. Two main outcrops occur: Mt. Domaro-Colma di Domaro and Mt. Domar-Gardone. The first is a sequence of alternating marly limestones and marls called Medolo Deposits (see Bettoni 1900), very rich in macrofossils mainly cephalopods, brachiopods, gastropods, bivalves and echinoids. The second outcrop is situated on the northern part of Mt. Domaro and is mainly composed of limestones; fossils are much less abundant.

Throughout the whole area (see Cita 1962; Dommergues et al. 1997) the LUPB cannot be identified with precision either because it is not obvious in the sequence (Mt. Domaro-Gardone) or mainly because the alternatives of marls and marly limestones are now covered by fields or forests (Mt. Domaro-Colma di Domaro). Nevertheless, several other localities in western Tethys
and adjacents areas (NW Europe) and in Pacific regions are potentially good for defining this boundary. Therefore this section indicates the best areas for the definition of the boundary and their potential for correlations based on ammonites.

The strong faunal provincialism in the Pleniscbian (Meister and Stampfli 2000) makes correlation difficult. It is well expressed during the Davaoei Chronozone and specially in the Figulinium Subchronozone with a decrease of ammonite diversity (ibidem 2000, p. 258). On the contrary during the Stokesi Subchronozones (lower part of the Upper Pleniscbian) the diversity increases again and inter-domainal faunal exchanges occur even with Pacific regions, e.g. Fuciniceras (Matteiceras). Most probably the faunal exchanges are due to transgressive marine periods, so favouring correlations.

Only key areas like the Austroalpine units (Austria and Hungary) provide good information for correlations, indeed taxa of both paleogeographical affinities co-occur and reinforce the correlations (text-fig. 13).

A) NW Euroboreal Domain

For NW Europe several locations have potential: from the north (U.K., Yorkshire: Hawsker Bottoms or Staithes (see Howarth 1958, 1992) to the south the diversity of the ammonites increases progressively (e.g. Dorset), even more in the southern part of NW Europe Domain (e.g. France, Causses Basin (Riviere-sur-Tarn or Le Samonta (Bommergues & Meister 1985; Meister 1986, 1989) or Peniche in Portugal (Mouterde et al. 2007).

The definition of the Upper Pleniscbian is well known and is based on the association of Amaltheus bifurcus Howarth, Amaltheus stokesi (Sowerby) and P. (Matteiceras) occidentale Domergues. Correlations are easy and precise throughout this domain (text-fig. 14).

B) Tethyan Domain

In the Tethyan Domain the situation is also very good and two localities show a good potential [Italy, Central Apennine, Gola del Burano (Macchioni & Meister 2003) and Spain, Subbeticas, South Jaen (see Braga 1983)]. In this domain there remain some taxonomic problems and there is not complete agreement about species significance. The text-figure 13 shows my attempt to homogenize the taxonomy, making correlations throughout the Tethyan Domain easy and precise.

The boundary is also well defined by ammonites and is based on the presence of Fuciniceras laviniannum (Fucini) - portisi (Fucini) and most probably of Cetonicaceras psiloceroides (Fucini).

C) East Pacific Domain

In Pacific Domain, the potential is also high [e.g. Whiteaves Bay or Rennell Junction in Canada for the North Pacific (see Smith & Tipper 1996) and for Quebrada Chauchoquin and Quebrada Vaca Muerta in Chile for the South Pacific (Hillebrandt 2006)]. The appearance of Fanninoceras species with F. fannini McLean or F. leptodiscus (Behrendsen) is used for distinguishing the Lower and Upper Pleniscbian in this domain. It seems clear for these authors (Smith et al. 1988; Hillebrandt 2006) that the boundary is situated respectively near the base of the Kunae Biozone for the North Pacific and near the base of the Fannini Biozone for the South Pacific. If Fanninoceras leptodiscus (Behrendsen) (South Pacific) and F. fannini McLean (North Pacific) are situated around this line of correlation, its exact position is still to be determined (text-fig. 15). This problem of correlation with NW Europe and Tethyan Domains is still not resolved, at least by ammonites. In North America, the presence of Amaltheidae like Amaltheus stokesi (Sowerby) allow good correlations with the NW Euroboreal Domain Stokesi Subchronozone and the Kunae Biozone. But these Amaltheus, as shown by the range chart of Smith et al. (1988) are younger than the characteristic fauna around the Lower and Upper Pleniscbian Boundary and consequently do not help to precise the position of this boundary.

Between the NW Europe and Tethyan Domains (text-fig. 16) correlations are possible thanks to areas of mixed faunas areas such as the Upper Austroalpine units in Hungary and Austria. However, note that the correlation between these two domains is only
a proposition. Between the lower part of the Fuciniceras portisi-lavinianum Biohorizon and the upper part of the Fuciniceras costicillatum-detractum Biohorizon there are no NW European faunas to confirm the exact position. Nevertheless the interval of uncertainty for this correlation line is quite small: much less than for correlations with the Pacific areas (text-fig. 17).

In my opinion a locality with a diversified and rich ammonite fauna should be a better choice. The Southern NW European region (e.g. Causes Basin) seems provide this condition and also other fossils groups like brachiopods, proxies that remain to be studied.

CONCLUSION

Despite strong provincialism during the Early-Middle Lias, ammonites are a good tool for correlations throughout the oceans, at the Sinemurian - Pliensbachian and the Lower - Upper Pliensbachian Boundaries, given that the habitat and ecology of the ammonites impose restrictions (abundant in platform deposits and rare or absent in oceanic or proximal environments).

Bijericeras donovani Dommergues & Meister determines precisely the SPB. Nevertheless, Apoderoceras nodogigas (Quenstedt), A. leckenbyi (Wright), Tetraspidoceras quadrarmatum (Dumortier) for the Euroboreal Domain and Cariniceras carriense Venturi, C. pannonicum Meister & Geczy for the Tethyan Domain are also good proxies for this stage boundary.

For the LUPB, Amaltheus stokesi (Sowerby), A. bifurcus Howarth, P. (Matteiceras) occidentale Dommergues characterize well this substage boundary in the Euroboreal Domain. In the Tethyan Domain there are Fuciniceras lavinianum (Fucini) - portisi (Fucini) and probably Cetonoceras psiloceroides (Fucini). Although the boundary may be slightly shifted with the correlations, the presence of Fanninoceras leptodiscus (Behrendtsen) or F. latum McLear is a good proxy for Pacific areas. However, without formal definition with a GSSP for this boundary, all options remain open.

Besides direct correlations with ammonites which remain the primary marker for this period, the contribution of other fossil groups in developing parallel zonations as intermediaries and of other proxies like isotope stratigraphy and palaeomagnetism will certainly allow refining the correlations.

ACKNOWLEDGMENTS

I cordially thank Professor Nicol Morton (U.K.) and Dr. Joachim Blau (Germany) and two anonymous reviewers for their comments and the improvement of the English.

REFERENCES


BLAU, J., MEISTER, C., SCHLATTER, R. and SCHMIDT-EFFING, R., 2003. Ammonites from the Lower Jurassic (Sinemurian) of
## Text-Figure 8

Biohorizon successions in Portugal (Lusitanian Basin), in Morocco (High Atlas) and in Tunisia (Tunisian Dorsal) for the uppermost Sinemurian and the lowermost Pliensbachian and correlation with the chronostratigraphic framework. 1: *Apoderoceras* sp., 2: *Pseudophricodoceras dayiforme* Mouterde et al., 3: *Pseudophricodoceras caprariforme* Mouterde et al., 4: *Miltoceras taguendoufi* El Hariri et al., 5: *Pallechioceras* cf. *lardecrescens* (Hauer), 6: *Paramicroderoceras* sp., 7: *Phricodoceras* gr. (?) *bettonii* Geczy. The numbers in the table correspond to the ammonite illustrations. The black scale bar = 1 cm.

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<th>Sub-stages</th>
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<th>Uppermost Sinemurian</th>
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**BRAGA, J. C., COMAS RENGIFO, M. J., GOY, A. and RIVAS, P., 1982. Comparazione faunistiche e correlazioni in el Pliensbachiano de la Zona Subbética y Cordillera Ibérica. Bolletin de la Real Sociedad Española de Historia Natural, 80: 221-244.**
TEXT-Figure 9
Biohorizon successions in Italy (Apennines) and in Spain (Subbeticas) for the uppermost Sinemurian and the lowermost Pliensbachian and correlation with the chronostratigraphic framework. 1: Vicinitnomiceras gollingense (Rosenberg), 2: Paramicroderoceras sp., 3: Parosieroceras pehlombanone (Uhlgi), 4: Parosieroceras cf. tardecrescens (Hauer), 5: Catriceras catriense Venturi, 6: Catriceras catriense Venturi, 7: Parosieroceras sp., 8: Omodoceras sp., 9: Paramicroderoceras sp., 10: Milloceras sellae (Gemmellaro). The numbers in the table correspond to the ammonite illustrations and Fu 1, 2, 3 are the bioevents of Venturi et al. (2005, fig. 3). The black scale bar = 1 cm.
TEXT-Figure 10
Biohorizon successions in Austria (Alps), in Hungary (Bakony) and in Turkey (Pontides) for the uppermost Sinemurian and the lowermost Pliensbachian and correlation with the chronostratigraphic framework. 1: Bakomyceras evolutum (Gecz), 2: Eoderoceras gruenae (Blau), 3: Pallechioceras tardecrescens (Hauer), 4: Catriceras pannonicum Meister & Gecz, 5: Paramicroderoceras hungaricum (Gecz), 6: Paramicroderoceras aff. hungaricum (Gecz), 7: Paraderoceras sp., 8: Pseuduptonia suessi (Gugenberger), 9: Pallechioceras romanicum (Ubil), 10: Pseuduptonia suessi (Gugenberger), 11: Pallechioceras cf. tardecrescens (Hauer), 12: Epideroceras sp. The numbers in the table correspond to the ammonite illustrations. The black scale bar = 1 cm.


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<td>Jamesoni</td>
<td><em>Tropidoceras</em> ssp.</td>
<td><em>T. flandrini</em></td>
</tr>
<tr>
<td></td>
<td>Brevispina</td>
<td><em>Pseudoskirioceras</em> wiedenmayeri</td>
<td><em>P. laticostatum</em></td>
</tr>
<tr>
<td></td>
<td>Polymorphs</td>
<td><em>Pseudoskirioceras</em> imlayi</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Taylori</td>
<td><em>M. chicaense</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aplanatum</td>
<td><em>Catriceras</em> (?) cf. <em>tardecrescens</em></td>
<td><em>P. rothpletzi</em></td>
</tr>
<tr>
<td></td>
<td>Macdonelli</td>
<td><em>Orthechioceras</em> sp.</td>
<td><em>P. aff. boehmi</em></td>
</tr>
<tr>
<td></td>
<td>Raricostatum (partim)</td>
<td><em>Catriceras</em> (?) cf. <em>liciense</em></td>
<td></td>
</tr>
</tbody>
</table>

SOUTH AMERICA (Argentina, Chile, Peru)
Quinzio Sinn 1987, Riccardi et al. 1992

NORTH & CENTRAL AMERICA (USA, Canada, Mexico)

TEXT-Figure 11
TEXT-Figure 12
Biostratigraphic framework around the Lower - Upper Pliensbachian Boundary in Pacific areas and in western Tethys and correlation with the potential chronostratigraphic framework of NW Europe.


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TEXT-FIGURE 13
Detail of the biohorizon successions in Tethyan Domain (Apennines, Subbeticas, Bakony and Austrian Alps and correlation with the Lower - Upper Pliensbachian chronostratigraphic framework. C indicates the position of Cetonoceras psiloceroides (Fucini). The * means NW paleogeographical affinities.


TEXT-Figure 14
Significant ammonites from around the Lower - Upper Pliensbachian Boundary for Western Tethys and NW Europe. The black scale bar = 1 cm.


TEXT-Figure 15
Significant ammonites from around the Lower - Upper Pliensbachian Boundary for South and North America. The black scale bar = 1 cm.
Emerged land (non-deposition assumed and/or ascertained)
Shallow marine deposits mainly terrigene / carbonated
(Hemi)pelagic deposits of epicontinental basins
Deep preoceanic / oceanic basin deposits

TEXT-FIGURE 16
Detail of the locations in the Western Tethys and adjacent areas for the Sinemurian - Pliensbachian and the Lower - Upper Pliensbachian Boundaries. 1: Hebrides (UK), 2: Yorkshire (UK), 3: Dorset (UK), 4: NW Germany, 5: SW Germany, 6: Burgundy (France), 7: Subbriannonnais Alpine Unit (France, Switzerland), 8: Lusitian Basin (Portugal), 9: High Atlas (Morocco), 10: Subbeticas (Spain), 11: Cordiller Iberica (Spain), 12: Tunisian Dorsal, 13: Apennines (Italy), 14: Pyrenees and Bas-Languedoc (France), 15: Causses Basin (France), 16: Hungarian Upper Austroalpine, 17: Austrian Upper Austroalpine, 18: Pontides (Turkey).


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UPPER SINEMURIAN - PLIENSBACHIAN
(193 - 183 my)

Emerged areas  Continental Platforms  Deep sedimentary basins and oceanic crust

★ Sinemurian and Pliensbachian localities discussed herein  ○ Potential localities for the Lower-Upper Pliensbachian boundary

TEXT-Figure 17
Upper Sinemurian and Pliensbachian paleogeographical map with the main localities for the Sinemurian - Pliensbachian and the Lower - Upper Pliensbachian Boundaries.


