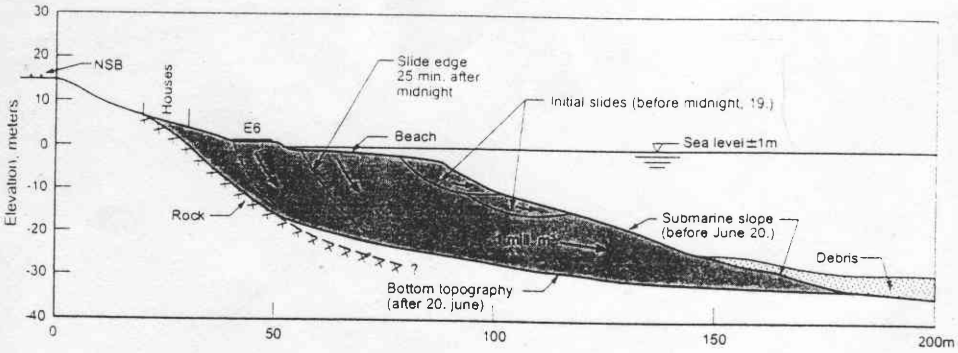


*Fig.2 Key sketch to illustrate the sliding mechanism*

surface cracks and into open slits between the steep rock face and the soil, and possibly water-main leakage, all of which could lead to seepage toward the unprotected submarine slope.

However, it is important to stress that stability analyses showed that the beach slope had a low margin of safety, perhaps less than 10% (i.e., F < 1.10). Thus any man-made activity, or nature-induced cause, amounting to a 10% safety reduction could have triggered the initial slides.

This fits neatly into almost all case records of quick-clay slides and submarine slope failures. They usually start without *a priori* warning, due to minor causes, and develop gradually to begin with, until the "main event" happens quickly, and often very dramatically.

The Finneidfjord landslide can justly be called a submarine slide-flow, as well as a submarine quick-clay slide.

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## Active Landslides on Slopes of Selbukhra Mountain, Southwestern Crimea, Ukraine

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### Geologic and Geomorphologic Setting

Selbukhra Mountain (elevation, 638.8 m), one of the highest mountains of the second Crimean ridge, is located in the southwestern part of the Crimea Peninsula, about 20 km northeast of Sevastopol (Fig.1). Landslides are found on the lower part of the northern 7–12° slope of the mountain. The upper stable slope segment consists of Cenomanian-Early Turonian marls, which are 40 m thick, and are underlain by a 10-m-thick layer of strong Late Albian sandstones. All strata have a gentle inclination of 10–12° to the northwest and are overlain by sub-horizontal Early Cretaceous marine clays. The total thickness of these clays is about 30 m, and they are underlain by folded and tectonically fissured Early Mesozoic ($T_3$-$J_1$) flysch. The slope is covered by late Pleistocene-Holocene diluvium up to 2 m thick. It has a concave form and gentle contours.

The climate here is comparatively dry, with an average precipitation of about 500 mm/year, but its distribution is non-uniform. Short heavy rains (30–40 mm in 1–2 hours) occur during hot, dry summers, and snowy winters are rare. These climatic characteristics influence landslide development.

Morphologically, the slope represents a broad ancient concave flow surface, conical in shape, widening toward the top of Selbukhra Mountain. This shape captures all precipitation along the northern slope of the mountain. Both margins of this surface are confined by ancient (Late Pleistocene) landslides, partly cut by erosion and thus not distinct in present relief under a cover of Holocene diluvium. These are relatively large blocks, quite stable now, but with minor active flow slides on their surface (area D of Fig. 2).

### Active Landslide

Three very active landslides threaten the stability of a single highway, connecting several settlements to the city of Simferopol. The most dangerous is the landslide shown in Figs. 3 and 4, the largest and longest-existing one. In its structure, several generations of movement can be separated. This landslide has a specific glacier-like shape. Its length from the tip to the crown (we are using nomenclature for landslides recommended by IAEG Commission on Landslides (1990)) is about 800 m, with a maximum width of 190 m. The most disastrous event took place during the spring of 1980, after a very snowy winter and rapid snow melting resulted in destruction of the highway. Parts of the highway were driven downslope for several tens of meters. This landslide has a complex structure and consists of three main parts (Figs.3, 4).

The major part is the landslide foot (area C), which makes up about 40% of the total landslide area. This is a stable portion consisting of several mostly ancient landslides, partly overlying each other. The boundaries between these ancient landslides coincide with bars several meters high, built of clays protruded from the frontal part of each succeeding generation of the landslide at the final stage of its movement. Mobile parts of the landslide consist of the two parts A and B.

The head (A) occupies an orchard area and its crown is located only a few meters from the new highway. The situation is critical because two minor, mobile landslides have recently appeared on both sides of the road here. A cross section of the landslide head was studied by excavation of a pit about 2 m deep; the section was composed of brown and brown-gray clays. Small half-rounded fragments of marl debris from Late Cretaceous rocks found in these deposits provided evidence of their diluvial origin.


*Fig. 1 Geographic location of the Crime Peninsula and the discussed landslide area.*

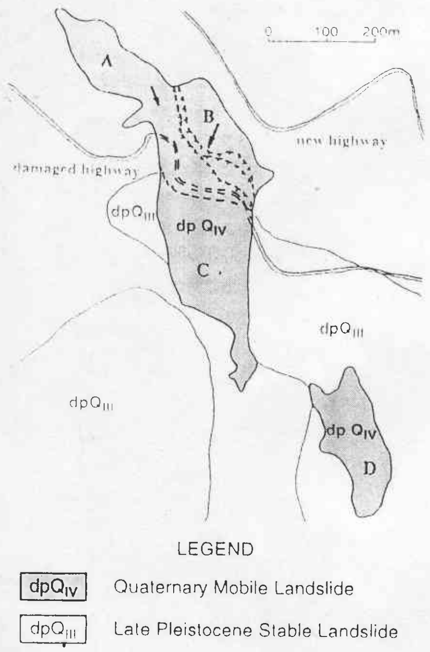


*Fig. 2 Schematic landslide map of the area: dpQIII - Late Pleistocene stable landslide, dpQIV - mobile landslides*

Careful study revealed that the zone of displacement at a depth of 0.8 m from the surface consisted of a layer of yellow-red ferruginous clay with numerous wide cracks. These cracks increased the permeability of the soil and allowed iron oxides and hydroxides to precipitate from the ground water. Clays capping this zone are cut by opened vertical tension cracks 3–5 cm wide, oriented along and across the slope. In general this situation has been interpreted as a result of creep rupture of clays at a depth of about 0.8–1 m.

But the most active portion of the landslide, that responsible for the highway damage, is part B. As can be seen from Fig. 4b this is a retrogressive slide. Rigid blocks of Late Albian sandstones are moving downslope, squeezing the underlying Aptian clays. The roof of these clays is moistened by ground water, draining at the base of relatively permeable sandstones. Thus, the main scarp is constantly "retreating" backward toward the new highway. Rows of these tilted blocks are separated by the concentric minor scarps shown in Fig. 2. This retrogressive part of the landslide moves at a sharp angle to the direction of head creep (shown in Fig. 2 by an arrow).

**Conclusion and Hazard Assessment**

The described landslide is a complex one, including two different active parts that move downslope in different directions. Creep

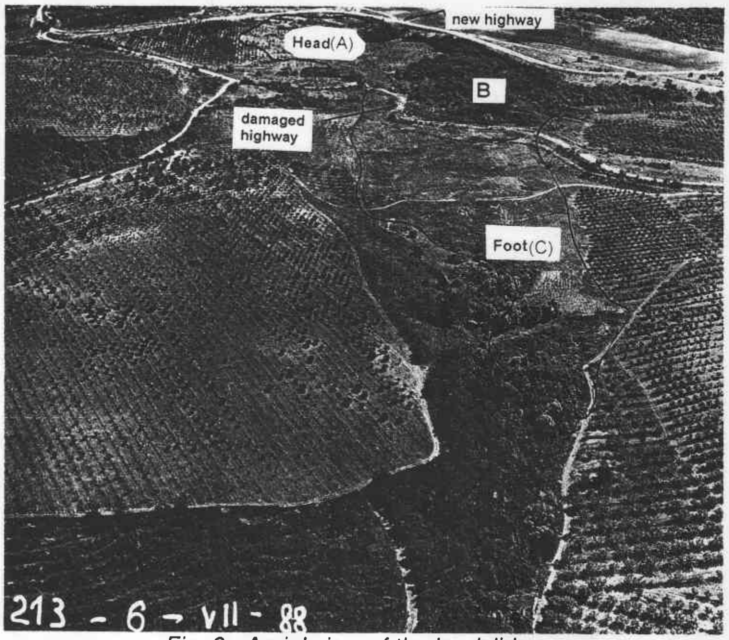


*Fig. 3 Aerial view of the landslide area.*

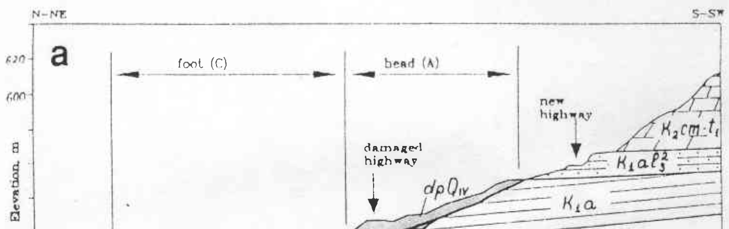


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*Fig. 4 Cross sections through mobile parts A and B of the landslide. a) Longitudinal section of parts A-C, b) Transverse section of parts B-C.*

rupture of clays is the mechanism controlling the slide development as a whole; however, rates of deformation and rock sliding volumes differ substantially between the two parts.

To evaluate the hazard and recommend means of mitigation, the following problems should be solved: 1) identification of the depth of the rupture zone (we believe this is not a distinct surface) under the retrogressive slide along its axis, and 2) evaluation of the probability of the stable part activation as a result of the accumulation of overlying mass.

**References**

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## Loess Landslides Triggered by Irrigation on the Slopes of the Terrace Edge in Heifangtai of Yongjing County, Gansu Province, China

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**Introduction**

Heifangtai terrace in Yongjing County is located 70 km west of Lanzhou, the capital of Gansu Province, China (Fig. 1). It belongs to the fourth terrace of the Yellow River valley. For construction of the Liujiaxia Hydro-Power Station, nearly 2,000 inhabitants in the reservoir area were moved to Heifangtai. In 1961, the government began to irrigate the terrace area for the new immigrants by pumping water from the Yellow River to 740 ha of arid land. However, this flood irrigation caused the ground-water level to rise sharply. As a result, a large area of the terrace subsided. By 1993, the maximum subsidence had reached 6m; the average was 1.86m. Landslides occurred frequently on the slopes of the terrace edge; by 1987, more than 20 landslide events had occurred. On 13 May, 1992, a disastrous landslide, with a volume of $1 \times 10^5$ m$^3$, took place in Jiaojia village (Fig. 2); two people were killed and two were seriously wounded; 10 ha of farmland and 65 m of ditch were buried; National Highway No.109 was blocked. The direct economic loss reached 260,000 Chinese yuan. At present, one factory, one power station, eight villages, three schools and 10 km of highway are threatened. Heifangtai consists of Heitai and Fangtai, two different terraces, with a total area of 13.44 km$^2$; the irrigated farmland consists of 740 ha., at the elevation of 1,710–1,760 m above sea level. The terraces are 150 m above the river. The average precipitation is 316.3 mm/year, and the mean temperature is 8.4°C. This region is sited in the Qilianshan Fold Belt and the Longxi Tectonic Belt. Tectonic and seismic activity is strong; six terraces have been developed along the valley since the Quaternary. The main strata are loess; secondary are loess, gravel, and Cretaceous sandstone and mudstone (Fig. 3).

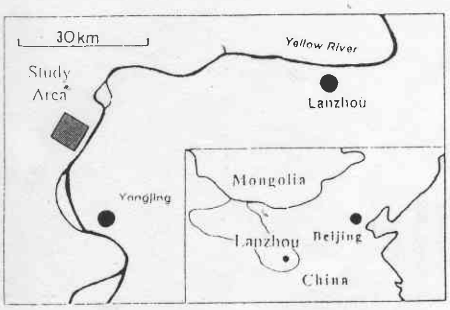


*Fig. 1 Index map showing location of the Heifangtai landslides in Gansu Province, China.*

**Distribution of Landslides on the Terrace Edge**

There are 40 various-sized landslides along the 10 km-long terrace edge. These landslides are connected to each other, and form a large-scale landslide group. Based on landform, the landslides can be divided into three zones from east to west (Fig. 2):

**Jiaojia Landslide Zone**

Landslides have frequently occurred in this zone. There are 18 landslides along 3 km-long terrace edge. Most recent landslides in this zone have been of the high-speed avalanche type. On 15 March, 1989, one $6 \times 10^4$ m$^3$ landslide slid from a 150-m-high steep slope in several minutes. The slide destroyed 50 m of irrigation ditch and 50 m of highway foundation. After that, the sliding mass moved into the Yellow River and caused huge waves, which submerged 2 ha of farmland on the opposite shore (Fig. 2). During 1992 and 1993, five landslides occurred in this zone (Fig. 4).

**Huangci Landslide Zone**

There are 12 landslides in this zone, most of which are old landslides. However in recent years, irrigation on the terrace surface, cutting by humans, and seepage from irrigation ditches have reactivated the

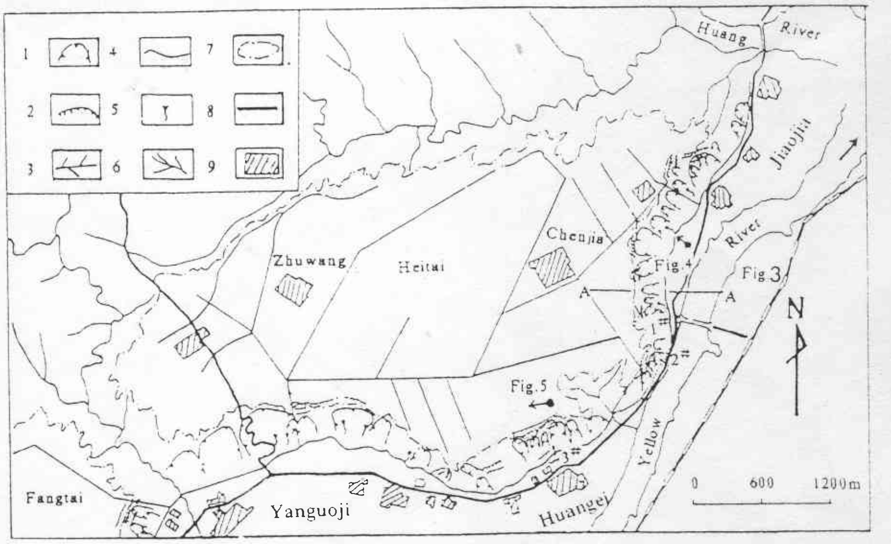


*Fig. 2 Distribution map of landslides at Haifangtai. Legend : 1. Landslide, 2. Fissure, 3. Ditch on terrace, 4. Ditch at foot of terrace, 5. Spring, 6. Gully, 7. Divide of terrace, 8. Highway, 9. Village.*