

Geological events at the Cretaceous — Paleogene boundary in Georgia (Caucasus)

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(Received and accepted 26 June 1992)

Ш. Адамия, Н. Салуквадзе, М. Назаров, Г. Гонгадзе, Т. Гвартадзе, Э. Киласония, Б. Асанидзе — Геологические события на границе мел-палеогена Грузии (Кавказ). В непрерывном разрезе мелкоморских карбонатных отложений Тетрицкаро (Южная Грузия), между палеонтологически хорошо датированными отложениями маастрихта и дания обнаружена пограничная глина (мощность 15—20 см) с аномально высоким содержанием Ir (3,46—5,34 нг/г), зернами ударно-метаморфического кварца, намагниченная обратно и соответствующая очевидно R-29 Международной палеомагнитной шкалы. К границе маастрихт-данний приурочено массовое вымирание ископаемой макро- и микрофауны морских бассейнов Грузии: 18 видов иноцерамов, 16 видов из 9 родов аммонитид, 5 видов беллемнитид, 25 видов из 12 родов ехиноидей, 6 видов из трех родов орбитонид, 9 видов из 4 рода планктонных фораминифер и 60 видов из 29 родов нанно-планктона.

Abstract. A continuous section at Tetricaro (South Georgia) of Maastrichtian-Danian shallow-marine paleontologically proved carbonate deposits is being described. Within the section, a boundary clay layer, 15-20 cm thick, has been established with anomalously high content of Ir (3,46-5,34 ng/g), with shock-quartz grains and reversed polarity corresponding to R-29 zone of the International Paleomagnetic Scale. Mass extinction of representatives of numerous marine macro- and microfossil groups has been established at the Maastrichtian-Danian boundary in Georgia. 18 species of inoceramids, 16 species from 9 genera of ammonitids, 5 species of bellemnitids, 25 species from 12 genera of echinoidea, 6 species from 3 genera of orbitoids, 9 species from 3 genera of planktonic foraminifers and 60 species from 29 genera of calcareous nannoplankton have disappeared at the end of Maastrichtian.

The Upper Cretaceous and Lower Paleogene deposits are of wide occurrence on the territory of Georgia, as well as in the whole Caucasus. Different types of facies occur (volcanites, carbonates, flysch-turbidites) characterized by abundant and diverse fossil faunas. From the viewpoint of studying the problem of the Cretaceous — Paleogene boundary, the most convenient are the sections exposed in the Transcaucasian region, within the Georgian and Artvin-Bolnissian blocks where shallow-marine fine grain carbonates (limestones and marls) were formed.

According to the palinspastic reconstruction for the late Cretaceous—early Paleogene based on geological, paleomagnetic and paleobiogeographical data the Caucasian region represented an active northern margin of the Tethyan Ocean of present-day West Pacific-type. Directly in the north of the ocean, in the hanging wall of the subduction zone two island-arc structures were situated — the South Caucasian and North Cau-

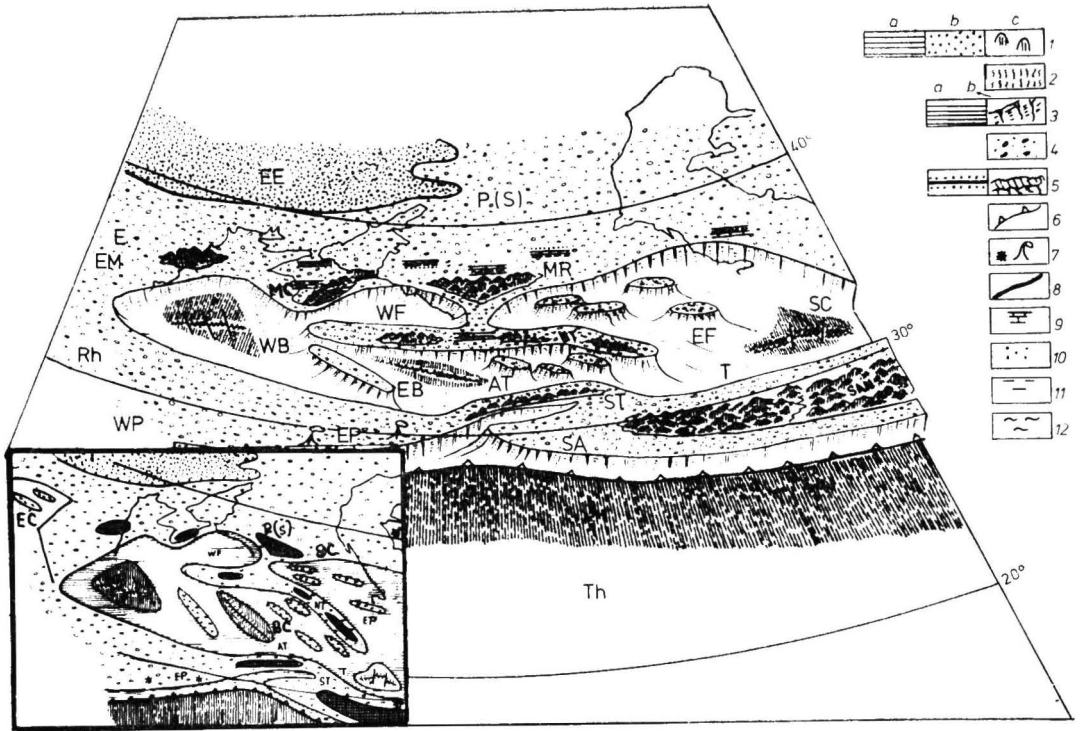


Fig. 1. Caucasian region — a palinspastic reconstruction for the Paleocene
 1 — thick continental crust (a, c — high dry land; b — low dry land); 2 — oceanic crust; 3 — thin continental crust (a — thin crust; b — continental slope); 4 — spreading zone; 5 — subduction zone; 6 — volcanoes; 7 — dislocations; 8 — carbonates; 9 — sandstones, gravelstones, conglomerates; 10 — clays; 11 — marls, calcareous clays. AT — Adjara-Trialeti; BC — Black Sea — Caspian Sea; EB — Eastern Black Sea; EC — Eastern Carpathians; EE — Eastern Europe; EM — Emine Flysch; EP — Eastern Pontides; GC — Great Caucasus; M — Moesia; MC — Mountainous Crimea; MR — Main Ridge; NT — Northern Transcaucasus; P(S) — Scythian Platform of the Precaucasus; RH — Rhodopes; SA — South Armenia; SAN — Sanandadj; SC — South Caspia; ST — Southern Transcaucasus; T — Tališ; Th — Tethys; WB — Western Black Sea; WF — Western Flysch; WP — Western Pontides

casian, which were separated by the Black Sea — South Caspian intra-arc rift (Fig. 1). In the north of the island-arc, the Great Caucasian small ocean occurred — a marginal sea on the southern periphery of the European continent. Within the Georgian and Artvin-Bolnissian zones situated in the uplifted parts of the North Caucasian and South Caucasian island-arcs respectively, shallow-marine carbonates rich in macro- and microfossils were deposited during Maastrichtian-Danian times (A d a m i a et al., 1991).

The Great Caucasian lithofacies unit occupies the Southern Slope of the Great Caucasus. It is divided into two parts: a western (Novorosijsk-Ricinsk) and an eastern (Liahvi-Iori) flysch troughs. In the Maastrichtian Age carbonate flysch deposits accumulated in the sedimentary basin corresponding to this unit. The sequence is built up mainly by grain clayey and sandy limestones, marls, calcareous sandstones and clays. These lithological types usually alternate, sometimes one of them dominating over the section. Packets and lenses of conglomerates and olistostromes occur locally.

Danian Stage is represented by an alternation of calcareous argillites, sandstones, siltstones, occasionally — by sandy and clayey limestones and marls; silicified rocks occur in the lower portion; the carbonate content decreases gradually upwards. The rest of the Paleocene sequence consists of non-calcareous argillites and sandstones. Faunal associations of relatively low diversity inhabited the Great Caucasian sea basins during the late Cretaceous and early Paleogene.

In the south of the flysch troughs, a marine basin occurred which corresponds to the Rioni-Kura lithofacies unit. This shallow sea covered the whole present-day Georgian block of the North Caucasian island-arc. Subplatform carbonates of relatively low thickness were here deposited. The Maastrichtian carbonate sequence includes mainly limestones, sometimes clayey or sandy limestones. During the Paleocene times, limestones and locally marls were formed in most parts of the basin. In numerous localities the limestones are of Danian age, whereas the marls are of younger age. In the latest Cretaceous and early Paleogene abundant and diverse floras and faunas lived in the basin which suggests existing of favorable environment.

The Minor Caucasian lithofacies unit is situated in the southern part of Caucasus. On the territory of Georgia it includes the Adjara-Trialetian intra-arc rift, the Artvin-Bolnissian zone (part of the South Caucasian island-arc) and the northern periphery of the Somhet-Karabah (Lok-Karabah) zone. The Maastrichtian Stage includes limestones, locally clayey or sandy. Layers of marls, calcareous clays, sandstones and conglomerates occur less commonly. In numerous localities, e. g. Hrami, Gumbatishkadi and Tusurebiskali, the highest part of the Cretaceous volcanogenic succession is exposed. It consists of tuffs, tuffites and calcareous tuffs. The intense Cretaceous sub-oceanic volcanic activity which was spatially related to the Minor Caucasian sedimentary basin, decreased gradually during the late Senonian and terminated completely at the end of the Maastrichtian. During the Paleocene variegated marls were formed in numerous localities, e. g. on the northern and southern slopes of the Trialetian Ridge, and locally — calcareous clays and clayey limestones. Within the intra-arc rift flysch sequence accumulated consisting of marls, clayey and sandy limestones, calcareous sandstones, clays and gravelstones. Lenses of olistostrome-like boulder breccias occur locally in the Upper Paleocene terrigenous-argillaceous sequence, some of the boulders being of limestones and Cretaceous volcanic rocks. The upper part of the sequence represents a volcanogenic series consisting of lavas, lavabreccias, tuffbreccias, tuffstones and tuffs of dacite-rhyolitic content. The latter are products of the initial phase of the Paleogene effusive volcanic activity.

The development of the Caucasian basin, including the Georgian basin, suggests that radical changes occurred at the late Cretaceous—early Paleogene time interval. They were probably caused by the Laramian tectonic phase clearly manifested by differentiated sea-floor motions.

Maastrichtian marine sedimentary basins of the Transcaucasian island-arcs represented relatively shallow seas with predominantly carbonate sedimentation. The sea-floor level was obviously not constant during that time. Maastrichtian deposits overlay locally transgressively older sediments. Sometimes coarse clastic materials occur in the sections of the Maastrichtian Stage. In some parts of the Maastrichtian basin such phenomena as shallowing, short-time break of sedimentation and washout have been established.

The Lower Paleocene, including Danian sediments, in numerous parts of the Adjara-Trialetian rift and Georgian block were formed probably in somewhat deeper-water conditions than the underlying sediments.

On most of the territory of the Georgian block and the adjacent areas of Gagra-Djava zone limestones were formed during the Paleocene. Relatively abundant and diverse bivalves (oysters) lived in the sea basin, part of them being of large size. They coexisted with corals and lithotamnians (shallow-marine plants). That evidence along with the lithological characters suggest that the Paleocene sediments in these regions were formed at little depths, perhaps in shallower water than the Maastrichtian.

The paleogeographical development of the late Cretaceous — early Paleogene sedimentary basins in Georgia evidently resulted in evolutionary changes of the faunal and floral associations. These changes were, however, so rapid and important that they could not be explained by paleogeographical reasons only.

In the Maastrichtian of Georgia molluscs are of wide occurrence (Ц а р е л и, 1954; Г а м б а ш и д з е, 1979). Together with ammonitids, the inocerams are of great importance in the Cretaceous biostratigraphy. Eighteen species of inocerams recorded in the Maastrichtian disappeared at the end of the Cretaceous.

Bivalves (oysters) are rather scarcely presented in the Maastrichtian sections by a couple of species only. Ten to twelve new species appeared in Danian Age belonging to the genera *Ostrea*, *Gryphaea* and *Exogyra*. The increasing of both diversity and abundance of the bivalves (the rocks are often crowded with them) is by no means an evidence that these animals were not affected by the change of the facies at the Cretaceous-Paleogene boundary. Most probably, they immigrated towards the optimal biotopes in the Danian sea basin of Georgia.

The cephalopod molluscs characterized by rapid evolutionary rates are of great importance in the Cretaceous stratigraphy of Georgia. The ammonitids (more than 15 species) in the Maastrichtian basins were represented by the genera *Pachydiscus*, *Parapachydiscus*, *Pseudokosmaticeras*, *Diplomoceras*, *Discoscaphites*, *Kosmaticeras*, *Acanthoscaphites*, *Helicoceras* and *Hauericeras*. At the end of the Maastrichtian they all disappeared.

The belemnites represented in the Maastrichtian by 5 species also reached their complete decline.

In Danian Age some nautiloids (cephalopod molluscs) appeared in Georgia, e. g. the genera *Eutrephoceras* and *Hercoglossa*.

It is to be noted that at the Maastrichtian-Danian boundary in Georgia six species of orbitoids disappeared belonging to the genera *Orbitoides*, *Simplorbites* and *Lepidorbitoides*. Larger foraminifers are not known from Danian Age in Georgia. In post-Danian times representatives of the genus *Discocyclina* appeared, whereas those of the nummulitids (the genera *Nummulites* and *Operculina*) appeared later on.

The smaller foraminifers, biostratigraphically important group for the Cretaceous and Paleogene, changed greatly at the end of the late Cretaceous. The Cretaceous planktonic foraminifers disappeared completely, as well as numerous species and genera of benthic foraminifers (the genera *Globotruncana*, *Praeglobotruncana*, *Rugoglobigerina* and *Pseudotextularia*). New taxa appeared in Paleocene time (the genera *Globorotalia*, *Globigerina*, *Globoconusa*, *Subbotina* and *Acarinina*) flourishing and becoming characteristic for the Paleogene (К а ч а р о в а, 1977).

The Maastrichtian, as well as Danian in Georgia have been divided into several nannofossil biozones. The Maastrichtian zonal associations bear a much closer resemblance to each other than to those of Danian nannofossil zones. The Maastrichtian-Danian boundary is the sharpest and most critical point in the evolution of Cretaceous-Paleogene nanoplankton. Among 29 genera and 65 species recorded from the Maastrichtian in Georgia 5 genera and 8 species only survived the Cretaceous-Paleogene boundary. During Danian Age 9 genera and 15 species of nannofossils appeared.

The echinids are one of the fossil groups of wide occurrence in the latest Cretaceous-early Paleocene sea basins in Georgia. Twelve genera of echinids have been recorded from the Maastrichtian: *Conulus*, *Cardiaster*, *Galerites*, *Echinocorys*, *Hemipneustes*, *Galeaster*, *Stegaster*, *Guettaria*, *Pseudoffaster*, *Micraster*, *Ovulaster* and *Homoaster*. Nine of them disappeared at the end of this stage and three genera only survived the Maastrichtian-Danian boundary (*Echinocorys*, *Galeaster* and *Homoaster*). It is to be stressed that two families belonging to the order Holotrypoida also disappeared completely at the end of Maastrichtian.

The data reviewed suggest that the biocoenotic changes at the Cretaceous-Paleogene boundary represent an animal and plant extinction of almost catastrophic character. This is as valid for the most diversified fossil groups (e. g. planktonic foraminifers, nanoplankton and echinids) as for those that fell into evolutionary decline (ammonitids, belemnites, inocerams).

Table 1

Distribution of the principal fossil groups in the Cretaceous-Paleogene boundary strata of Georgia

Fossil groups	Maastrichtian	Danian
1	2	3
Planktonic foraminifers		
genus <i>Globotruncana</i>	5 species	
" <i>Praeglobotruncana</i>	1 species	
" <i>Rugoglobigerina</i>	1 species	
" <i>Pseudotextularia</i>	2 species	
" <i>Globigerina</i>		2 species
" <i>Globorotalia</i>		6 species
" <i>Globoconusa</i>		1 species
" <i>Chilogumbelina</i>		2 species
" <i>Subbotina</i>		2 species
Orbotoids		
genus <i>Orbitoides</i>	3 species	
" <i>Simplorbites</i>	1 species	
" <i>Lepidorbitoides</i>	2 species	
Inocerams	18 species	
Ammonitids		
genus <i>Pachydiscus</i>	7 species	
" <i>Hayericeras</i>	1 species	
" <i>Diplomoceras</i>	1 species	
" <i>Discoscaphites</i>	1 species	
" <i>Acanthoscaphites</i>	1 species	
" <i>Kossmaticeras</i>	1 species	
" <i>Pseudokossmaticeras</i>	2 species	
" <i>Parapachydiscus</i>	1 species	
" <i>Helicoceras</i>	1 species	
Bellemitids	5 species	
Echinoidea		
genus <i>Comulus</i>	1 species	
" <i>Cardiaster</i>	1 species	
" <i>Galerites</i>	2 species	
" <i>Hemipneustes</i>	1 species	
" <i>Stegaster</i>	2 species	
" <i>Guettaria</i>	1 species	
" <i>Pseudofaster</i>	4 species	
" <i>Micraster</i>	1 species	
" <i>Ovulaster</i>	1 species	
" <i>Echinocorys</i>	11 species	2 sp., 8 n. sp.
" <i>Homoaster</i>	2 species	1 n. sp.
" <i>Galeaster</i>	1 species	2 n. sp.
Nannoplankton		
genus <i>Arkhangelskiella</i>	2 species	
" <i>Braarudosphaera</i>	4 species	4 sp., 1 n. sp.
" <i>Broinsonia</i>	3 species	
" <i>Ceratolithus</i>	1 species	
" <i>Chiastozygus</i>	2 species	
" <i>Crepidolithus</i>	3 species	
" <i>Cribrosphaerella</i>	1 species	
" <i>Cylindralithus</i>	3 species	
" <i>Cyclagellosphaera</i>	1 species	1 species
" <i>Deflandrius</i>	1 species	
" <i>Discorhabdus</i>	1 species	
" <i>Eiffellithus</i>	3 species	
" <i>Kamptnerius</i>	1 species	
Lithraphidites		
" <i>Lucianorhabdus</i>	3 species	
" <i>Manivitella</i>	1 species	
" <i>Markalius</i>	1 species	1 sp., 1 n. sp.

Table 1 (continued)

	1	2	3
„ <i>Microrhabdulus</i>		2 species	
„ <i>Micula</i>		4 species	
„ <i>Micrantholithus</i>		1 species	3 n. sp.
„ <i>Nephrolithus</i>		1 species	
„ <i>Parhabdolithus</i>		3 species	
„ <i>Praediscosphaera</i>		1 species	
„ <i>Reinhardtites</i>		1 species	
„ <i>Rucinolithus</i>		1 species	
„ <i>Tetralithus</i>		6 species	
„ <i>Thoracosphaera</i>		2 species	2 species
„ <i>Watznaueria</i>		3 species	
„ <i>Zygodiscus</i>		6 species	
„ <i>Biantholithus</i>			1 species
„ <i>Coccolithus</i>			3 species
„ <i>Cruciplacolithus</i>			2 species
„ <i>Chiasmolithus</i>			2 species
„ <i>Cyclococcolithus</i>			1 species
„ <i>Ellipsolithus</i>			1 species
„ <i>Neochastozygus</i>			1 species
„ <i>Placozygus</i>			1 species
„ <i>Prinsius</i>			3 species

Sudden mass extinction over an extremely short time interval at the Cretaceous-Paleogene boundary, as it is known, has been established in other countries, too. Numerous hypotheses have been proposed to explain this global biotical reconstruction. Biological evolution is thought to be affected by events of terrestrial and/ or extraterrestrial origin. The concept of iridium anomaly of impact origin which has been proposed by Walter and Luis Alvarez and their team is of greatest interest. Without discussing this well-known hypothesis, it is to be noted that in Georgia we have also obtained important data concerning the problem of Cretaceous-Paleogene boundary when studying the boundary interval strata in Tetrickaro region of Southeastern Georgia (the Artvin-Bolnissian zone).

During the studied time interval in Tetrickaro region a shallow-water sea basin of the Southern Caucasian island-arc existed. The lower part of the Upper Cretaceous (Upper Cenomanian — Lower Campanian) consists of shallow-water island-arc calc-alkaline volcanogenic series of basalt-andesite-dacite-rhyolitic content. The upper part of the Upper Cretaceous sequence (Upper Campanian — Maastrichtian) is composed of shallow-marine carbonate deposits — limestones and clayey limestones. All the stages of the Upper Cretaceous have been established based on inocerams, ammonitids and other fossil groups.

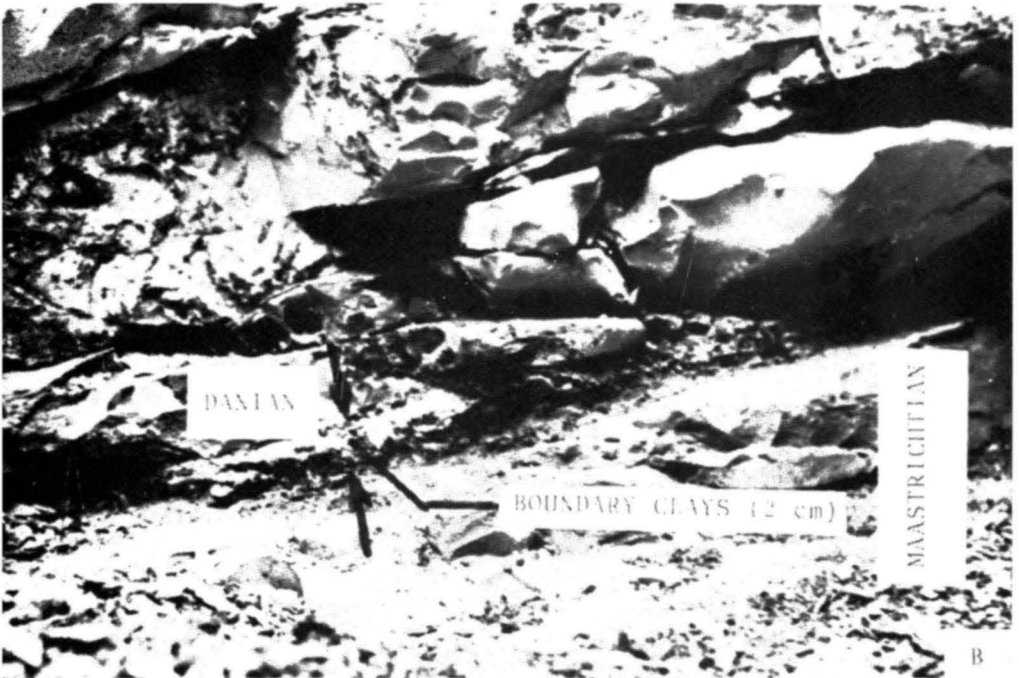
The Paleocene in the continuous sections is represented by shallow-water marls, clayey sandstones, calcareous conglomerates, clayey limestones, boulder breccias and volcanic rocks of dacite-rhyolitic content. Smaller and larger foraminifers occur, as well as nannoplankton. The oldest known nummulitids in Georgia, e. g. *Nummulites fraasi*, *N. solitarius* and *Discocyclina seunesi*, have been found in the Upper Paleocene deposits in this section.

The Cretaceous-Paleogene boundary interval Tetrickaro section is located in the northeast of the village of Tetrickaro at a ravine of a nameless tributary of the Hrami River (Fig. 2; Plate 1).

K₃m 1. (15 m)

Pale-grey clayey limestones. More calcareous beds occur in the upper part. The following zones have been established from the bottom to the top: *Lithraphidites quadratus* (0,0-3,10 m); *Micula murus* (3,10-11,40 m); *Micula prinsii*, the uppermost Maastrichtian zone (11,40 m — to the top) with the zonal associations *Watznaueria barnesae*, *W. britannica*, *Arkhangelskiella cymbiformis*, *Praediscosphaera cretacea*, *Broinsonia enormis*, *B. parca*, *Eiffelithus turriseiffelli*, *Zygodiscus spiralis*, *Chiastozygus anceps*,

PLATE I



The clay layer at the Maastrichtian-Danian boundary at Tetricaro section (A), greater magnification (B).

Geologica Balcanica, 23.3

Sh. Adamia, N. Salukadze — Geological events at the Cretaceous...

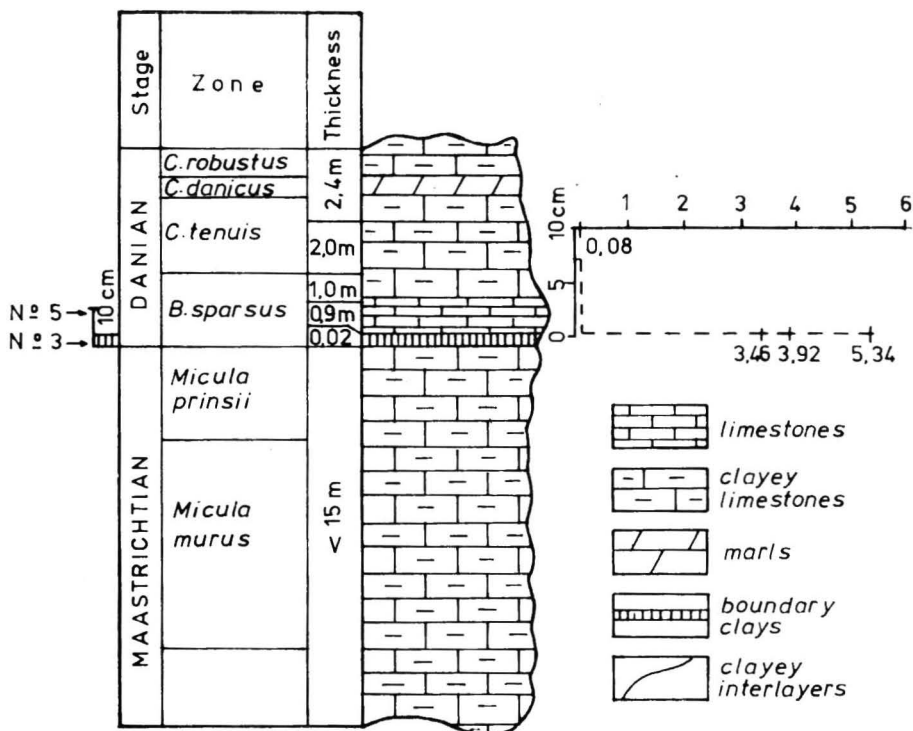


Fig. 2. Tetricaro section

Ir anomaly values in the boundary clay layer and the overlying limestones: N. 5 = 0,08 ± 0,01 ng/g, N. 3 = 3,46 ± 0,18 ng/g, N. 3 = 5,34 ± 0,16 ng/g, N. 3 = 3,92 ± 0,14 ng/g

Cribrosphaerella ehrenbergii, *Crepidolithus crenulatus*, *Parhabdolithus angustus*, *Micula murus*, *M. staurophora*, *M. prinsii*, *Markalius cyrkumradiatus*, *Tetralithus gothicus*, *Microrhabdulus decoratus*, *Lithraphidites carniolensis*, *L. quadratus*, *Lucianorhabdus cayeuxii*, *Nephrolithus frequens*, *Globotruncana confusa*, *Gl. stuarti*, etc. also occur (*Globotruncana confusa* zone).

2. (15-25 mm)

Thin clay layer, 15-25 mm thick, overlying directly the clayey limestones (Fig. 3). A thin layer of rust-coloured clay, 1-3 mm thick, occurs in the lower half. Shock-quartz grains and anomalously high content of Ir have been established in the clay layer (the samples have been examined at the Institute of Geochemistry and Analytical Chemistry, Moscow, and the University of Amsterdam). Locally, lenses and fragments of white limestone occur which are lithologically identical with the overlying rocks. They yielded a nannofossil assemblage characteristic of the lowest Danian *Biantholithus sparsus* zone: *Braarudosphaera bigelowii*, *B. turbinea*, *B. discula*, *B. africana*, *B. irregularis*, *Biantholithus sparsus*, *Thoracosphaera operculata*, *T. saxea*, *Biscutum parvulum*, *Placozygus sigmoides*, *Cyclagello-sphaera reinhardtii*, *Markalius inversus* and *M. apertus*. Thin layer of grey clay up to 10 mm thick overlies locally the carbonate fragments. Sometimes, an intrusion of clay into microdistributive fractures has been observed. We can not exclude the possibility that it might caused a contamination with iridium or shock-quartz grains of the strata overlying the boundary clay layer.

P₁d 3. (0,8-0,9 m)

Pale grey and white limestones. Thin layers and lenses of calcareous clay (0,5-2 mm thick, occasionally up to 10 mm) occur in the lower portion. Upwards the clayey beds decrease in number. The packet corresponds to the *Biantholithus sparsus* zone.

4. (0,8-1,0 m)

Pale grey and grey clayey limestones; *Biantholithus sparsus* zone.

5. (1,8-2,0 m)

Grey and pale-brownish-grey clayey limestones; *Cruciplacolithus tenuis* zone.

6. (2,4 m)

Brownish-grey, brick-grey and grey clayey limestones and marls. The following zones have been proved: *Cruciplacolithus tenuis* (0,0-1,0 m); *Chiasmolithus danicus* (1,0-2,1 m); *Cyclococcolithus robustus* (2,1 m — to the top).

In the purpose to determinate the magnetic polarity of the Cretaceous-Paleogene boundary section at Tetrickaro B. Asanidze and M. Zaališvili have collected 30 oriented samples from an interval of 29 m (Fig. 3). The sampling has been carried out according to A. N. Hramov and L. E. Solpo's method. The examination has been made at the Caucasian Institute of Mineral Resources. Six macroscopically different samples have been selected and examined in detail (at magnetic cleaning temperature step of 50°C) in order to reveal the natural remanent magnetic vector (I^n) and the magnetic cleaning regime. The stable component has been revealed at the temperature interval between 200 and 400°C. For this reason, the magnetic cleaning of the rest of samples has been undertaken at a temperature of 350°C. The stable component measurement on some samples has shown reversed polarity. All paleomagnetic data on Tetrickaro section are diagrammatically presented. It is seen that the lower and highest parts of the section are characterized by normal polarity (N), whereas the middle part — by reversed polarity (R). The boundary clay layer of anomalously high iridium content confronts the middle part of the reversed-polarity sequence. The comparison with the International Paleomagnetic Scale suggests that the reversed-polarity (R) sequence at Tetrickaro section corresponds to R-29 zone of the International Scale which coincides with the Cretaceous-Paleogene boundary.

There is no evidence to assess the rate of sedimentation of the boundary clay layer at Tetrickaro section. Approximate calculations, however, based on the ratio of joined thickness of the Maastrichtian and Danian sediments to duration of these ages (9 and 4,5 Ma respectively) suggest that the boundary clay layer of 15-20 mm thickness might be deposited during about 1000-2000 years.

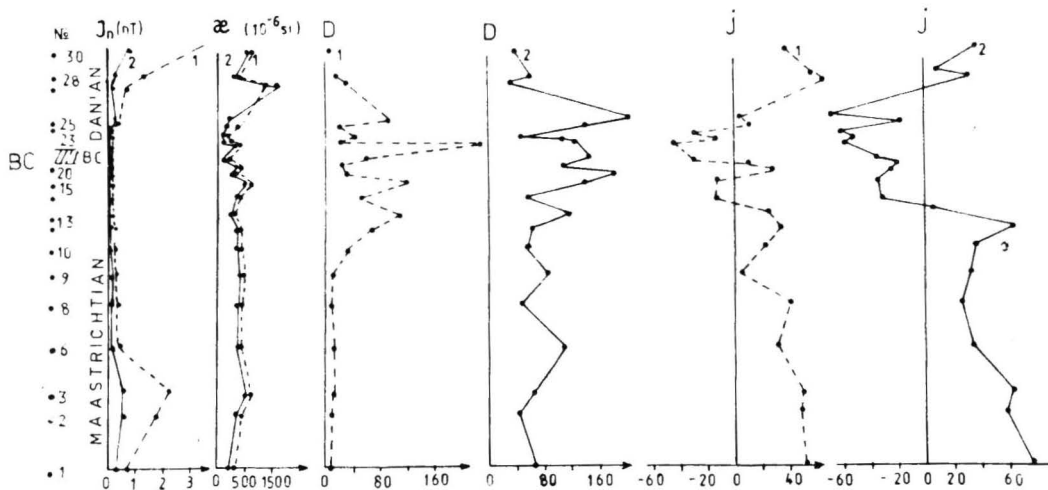


Fig. 3. Tetrickaro paleomagnetic section

I_n (nT) — moduli of the remanent magnetization vector; α — moduli of the magnetic susceptibility (10^{-6} SI); D, j — values of the magnetic declination and inclination of the vector I_n (in degrees); 1 and 2 — values of the magnetic characteristics before and after the temperature cleaning; BC — boundary clays (after Asanidze and Zaališvili)

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