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On events of the Terminal Cenomanian in the eastern Central Asia

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Abstract. Changes of the foraminiferal assemblages in eastern Central Asia during a significant Mesozoic biotic crisis at the Cenomanian–Turonian boundary are discussed. The reported records are based on the study of the most complete section of the boundary Cenomanian–Turonian sediments in Asia that is located in southern Tajikistan, in the Koikitau Range. The ammonite *Sciponoceras gracile* Zone in this section contains extremely diverse and numerous benthic and planktonic foraminiferal assemblages. The flourishing of benthic foraminifers in this zone indicates the normal marine basin conditions. The changes in foraminiferal assemblages were not catastrophic and not accompanied by mass extinction of fauna, but resulted from the strengthened migration of foraminifers. The benthic and planktonic foraminifer flourishing in this interval was a global phenomenon manifested on shallow shelves not only in eastern Central Asia but also in the Western Interior Basin of North America and in Western Europe. At the same time in the oceans, on the contrary, anoxic conditions (AOE-II) were widespread. The reported materials also indicate the strengthening of lateral water mass circulation in the terminal Cenomanian, when moderately cold intermediate waters from the West European marine basins and warm surface waters from the southern tropical realm concurrently penetrated to Central Asia. It is suggested that one of the reasons for extinction of the characteristic planktonic foraminifer genus *Rotalipora* immediately prior to the events of the *Sciponoceras gracile* time, was a sharp restoration of normal marine basin conditions that occurred on the mid-latitude shelves in the Northern Hemisphere.

Introduction

According to present notion, a significant Mesozoic extinction of biota occurred at the Cenomanian–Turonian boundary. By the end of the Cenomanian 7% of invertebrate families and 27% of genera disappeared [*Sepkoski and Raup,* 1986]. The extinction particularly concerned mollusk genera and species, fish families, and ostracode species. The extinction of macrofauna began in the middle Cenomanian in the equatorial region and continued in the late Cenomanian in the temperate realm [*Kauffman and Hart,* 1996].

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In the Turonian the diversity of foraminifer genera slightly decreased compared to that of the Cenomanian [*Tappan and Loeblich,* 1988]. To our estimates, in the Cenomanian about 64 foraminifer genera were extinct, or approximately 27% of their total number in this period. However, they were extinct at different time during the middle–late Cenomanian and in various parts of the World. Their disappearance, like that of macrofauna, was stepwise and referred primarily to benthic inhabitants of warm-water regions and to planktonic forms. The Favusellidae planktonic family was extinct in the lowermost middle Cenomanian; the benthic family Orbitolinidae disappeared on the carbonate platforms in the mid-late Cenomanian; by the beginning of the *Sciponoceras gracile* time planktonic foraminifers *Rotalipora* were extinct; at the end of this period benthic members of *Merlingina* disappeared on the carbonate platforms; and planktonic foraminifers *Anaticinella* and Rotaliporidae were missing by the mid-early Turonian. However, in the Cenomanian the intense taxogenesis bursts and evolutionary events among planktonic foraminifers also occurred. For instance, in the early and mid-middle Cenomanian the genera *Asterohedbergella*, *Brittonella*, and *Badriella*, as well as the early member of Helvetoglobotruncaninae, the genus *Angulocarinella*, originated. In the terminal middle Cenomanian the first member of Concavatotruncaninae, the genus *Dicarinella*, appeared and was followed by the first members of *Helvetoglobotruncana*, *Whiteinella*, and the *Verotruncana imbricata* group and by *Costellagerina*. During the *Sciponoceras gracile* time or slightly later the double-keeled planoconvex foraminifers of the *Bollitruncana* genus originated [*Korchagin,* 2001]. The reported data differ from the viewpoint that considerable extinction and evolutionary events among planktonic foraminifers occurred precisely close to the Cenomanian–Turonian boundary or to the AOE-II event [*Hart,* 1999; *Leckie et al.,* 2002]. This conclusion partly results from the more detailed planktonic foraminifer classification assumed by the author [*Korchagin,* 2003]. However, one can hardly doubt about the age of such evolutionary events as the extinction of Favusellidae, the appearance of double-keeled planktonic foraminifers *Dicarinella* and Concavatotruncaninae, of single-keeled *Angulocarinella* tests with a complicated aperture and Helvetoglobotruncaninae, the origination of widely double-keeled members of *Verotruncana*, and the disappearance of *Anaticinella* and Rotaliporidae, which in no way occurred close to the AOE-II event.

Nevertheless, although the evolutionary changes in higher taxa – genera, subfamilies, and families – were not associated with the events nearby the Cenomanian–Turonian boundary, the species composition of foraminiferal assemblages in certain regions considerably varied during a short time span [*Eicher and Worstell,* 1970; *Jarvis et al.,* 1988; *Kaiho and Hasegawa,* 1994; *Keller et al.,* 2001]. In the uppermost Cenomanian in southern Tibet 34% of planktonic and 54% of benthic foraminiferal species were extinct; in the Pacific region, 28% of planktonic species; in Japan, 37% of benthic forms; in Poland, 50% of species; and in the Western Interior Basin of North America, 69% of species, respectively. The total number of extinct planktonic foraminiferal species constitutes 41% [*Wan et al.,* 2003b].

However, the cited estimates are considerably rough, whereas the changes in faunal assemblages at the Cenomanian–Turonian boundary were more thoroughly studied in the Western Interior Basin of North America. It was emphasized that the extinction of marine biota in this region was associated with the *Sciponoceras gracile* ammonite biozone and occurred against the background of extremely high taxonomic diversity of fauna [*Kauffman and Hart,* 1996]. Changes of the ammonite and bivalve mollusk composition took place in terms of the following pattern: interval of step-by-step extinction with several episodes of extinction and restoration of fauna from the disappearance of ammonite *Eucalycoceras pentagonum* to the first occurrence of ammonite *Pseudaspidoceras flexuosum* (equivalent to the appearance of ammonite *Watinoceras devonense* or to the Cenomanian–Turonian boundary GSSP), was followed by the survival period when only the survived taxa occurred, and subsequently by the recovery interval when the new taxa appeared [*Harries,* 1999].

In this region the extinction of ammonites and bivalve mollusks was characterized by an extremely high taxonomic diversity of assemblages and by a high degree of morphological divergence in ammonites [*Harries,* 1999].

During the extinction interval the faunal assemblages were marked by a predominance of oppressed dwarf forms. For instance, the decreased dimensions of ammonites, gastropods, corals, echinoids, and bivalves were recorded at this level in the Tajik depression [*Djialilov et al.,* 1986]. The similar dwarfing effect was described in other parts of the World and is now considered as a biotic event [*Keller et al.,* 2001]. It was emphasized that particularly strong changes during the extinction at AOE-II occurred in heterotrophic foraminifers and radiolarians and in autotrophic nannoplankton [*Leckie et al.,* 2002].

Apart from the changes of marine biota at the Cenomanian–Turonian boundary, the uncommon composition of sediments was recorded. The occurrence of black shales, a rock rich in organic matter, associated with the Anoxic oceanic event (AOE-II), is the most marked phenomenon at this boundary both on the shelves and in the ocean [*Kauffman and Hart,* 1996; *Schlanger and Jenkyns,* 1976]. In the Mediterranean region beds of black marls or clays are called "the Bonarelli beds" [*Premoli Silva et al.,* 1999]. The analogous layers occur in the Crimea and Caucasus as well. Beds of black sediments rich in C_{org} were recorded in the far south, on the Kergulen Plateau close to the Antarctic (ODP Site 1138A) and in the far north, on the northern slope of Alaska [*Holbourn and Kuhnt,* 2002]. It should be also emphasized that C_{org} rich black clays repeatedly accumulated in a great deal of shallow seas during the Cenomanian and Turonian [*Kauffman and Hart,* 1996].

However, the anomalies in isotope and trace element content that could have resulted from the global catastrophic changes in the oceans, endogenic activity, and climate, are recorded precisely in the black shales or Bonarelli beds at the Cenomanian–Turonian boundary.

Black shales/Bonarelli beds or their analogues are rich in Cd, Ag, Mo, Sb, Zn, V, Cu, Cr, and Ni both in the oceanic sediments (DSDP Site 367) and on continental shelves (Morocco) [*Brumsack,* 1986], as well as in Sc, Ti, Mn, and Ir on the Colorado shelf [*Orth et al.,* 1988]. These beds therewith considerably differ in composition and number of trace elements from the organic matter rich sequences that are now accumulated under upwelling conditions in the California Bay, and from the black-shale Toarcian sediments [*Brumsack,* 1986].

There is a great deal of evidence that one or two shifts of increased δ^{13}C and C_{org} were associated with the discussed stratigraphic interval or occurred close to it, during the *Sciponoceras gracile-plenus* time. The shift was recognized in both marine and continental sediments in England, Tunisia, Colorado, Tibet, and Japan [*Hart and Leary,* 1989; *Jenkyns et al.,* 1994; *Kaiho and Hasegawa,* 1994; *Keller et al.,* 2001; *Wan et al.,* 2003a]. On shallow shelves the beds with a high content of δ^{13}C and C_{org} are represented by marl, clay, and limestone. They are commonly considered as synchronous with black shales or Bonarelli beds. Nevertheless, one should take into account that the beds with a positive δ^{13}C and C_{org} anomaly in shallow-water sediments and black shales in the oceanic deposits could accumulate in a short time span but not simultaneously. Whereas the age of beds with a high δ^{13}C and C_{org} content on the shelves of England and Western Interior Basin in North America is exactly established with respect to the ammonite zonation, the age of black shales in the oceans and on the Mediterranean shelves of Italy and Morocco, was not strictly proved. It was estimated in reference to the moderately detailed planktonic foraminiferal zonation and to the *Whiteinella archaeocretacea* Zone that has a wide and uncertain range within the ammonite scale. The accumulation of black shales in the oceans could occur later than that of the beds rich in δ^{13}C and C_{org} on the shelves and therefore the mechanisms of their formation were different.

The δ^{13}C leap was short-term and occurred against a background of the extended, spanning the second half of the late Cenomanian and first half of the early Turonian, decrease of δ^{13}C [*Hasegawa,* 2003]. However, it was shown that the changes of the δ^{13}C and C_{org} content in the rocks during the Cenomanian and Turonian including the *gracile-plenus* time, correspond to the Milankovich climatic cycles [*Gale et al.,* 1993].

Paleotemperatures in the basins of that period are reconstructed from the δ^{18}O content. The δ^{18}O records of different benthic and planktonic groups and in various regions considerably differ. During the discussed period in the low-latitude area, for instance in Israel, temperature of surface marine water reached 32°–33°C [*Kolondy and Raab,* 1988]; in the western North Atlantic, 30°–31°C (Site 1052) and 33°–34°C (Core 144-4P-2) [*Huber et al.,* 1999; *Norris et al.,* 2002; *Wilson et al.,* 2002]; on the Blake Plateau the surface and bottom water temperatures were estimated at 22°–25°C and 16°–20°C, respectively [*Huber et al.,* 2002]. In mid-latitudes the paleotemperature of surface waters, according to planktonic foraminifers, was also high and in southern England reached 27°–28°C [*Jenkyns et al.,* 1994]; the bottom water paleotemperatures, according to brachiopods, reached in northern Spain 23.5°–27.8°C and in southern England, 16.9°–22.5°C [*Voigt et al.,* 2003].

The calculations showed that the temperature gradient was at that time similar to recent and constituted 0.7°C/1° [*Voigt et al.,* 2003]. It is noteworthy that in this interval in both low and middle latitudes the gradient between the bottom and surface waters decreased and the bottom waters became equally warm [*Norris et al.,* 2002].

Apart from the records indicating the climatic optimum at that time, other data, for example for southern England, point to a cooling [*Jeans et al.,* 1991]. In this region in the beds equivalent to the *gracile-plenus* Zone two or three positive and two negative shifts of δ^{18}O values were recorded [*Jeans et al.,* 1991]. The water paleotemperatures estimated from the belemnite *Praeactinocamax plenus* in Spain and southern England, constituted only 6°C (the so-called cool *plenus* effect) [*Voigt et al.,* 2003]. A slight positive shift of δ^{18}O values recorded in Tibet [*Wan et al.,* 2003a], may also indicate a climatic cooling. On our observations the paleobiogeographic data for this time interval are contradictory as well: the expanded distribution area of thermophilic clavate planktonic foraminifers (warm *Clavihedbergella effect*), that reached 60°N in the Western Interior Basin of North America, can be considered as the evidence for a warming in the Western Hemisphere, whereas the simultaneously expanded distribution area of belemnite *Praeactinocamax plenus* that penetrated far southeastward to the Tajik depression, indicates a cooling in the Eastern Hemisphere. These migrations can also be interpreted as a result of change of the global lateral water mass circulation [*Kuznetsova and Korchagin,* 2004].

It is considered that precisely at the Cenomanian–Turonian boundary a significant eustatic sea level rise with several minor lowering episodes, took place [*Hardenbol et al.,* 1998].

Despite the fact that considerable effort has been devoted to elucidation of the events at the Cenomanian–Turonian boundary, there is no unambiguous conclusion on the cause of the recorded changes. Most of researchers are agreed that an integrated destruction of the oceanic and climatic system took place, which resulted in the strengthened endogenic processes, submarine and land volcanism, and oceanic spreading; mid-oceanic ridges increased in length, the vertical and lateral water mass circulation in the oceans and on shelves changed and the climate significantly altered.

The possible mechanisms of the above-mentioned events are as follows. As suggested by certain researchers, the origination of beds enriched with C_{org} or δ^{13}C at the Cenomanian–Turonian boundary was associated with inner oceanic processes [*Brumsack,* 1986; *Damste and Koster,* 1998; *Schlanger and Jenkyns,* 1976]; according to other notion, the organic matter input from the continents played a leading role [*Jeans et al.,* 1991]. The processes in the oceans could be also various: the C_{org} or δ^{13}C rich beds could be formed either in response to the extension of the oxygen impoverished zone (anoxic event) [*Schlanger and Jenkyns,* 1976] or as a result of complete stagnation in the oceans and the enrichment of water with H_2S (euxinic event) [*Brumsack,* 1986]. The study of biomolecules from the black shales in the Atlantic provided evidence for a complete or partial contamination of water with H_2S in the area between the northeastern coast of South America and northwestern coast of Africa (DSDP/ODP Sites 144, 367, 368, Morocco) [*Damste and Koster,* 1998]. It is believed that waters were stratified during the Cenomanian–Turonian transition [*Huber et al.,* 1999; *Norris and Wilson,* 1998]. From our standpoint, the water stratification was weakened in the terminal Cenomanian subsequent to disappearance of *Rotalipora deeckei*, and was low in the *gracile* time and later on, up to the appearance of *Helvetoglobotruncana helvetica* [*Kuznetsova and Korchagin,* 2004].

At the end of the Cenomanian, nearby the AOE-II time the Sr^{87}/Sr^{86} ratio was also decreased [*Ingram et al.,* 1994]. Its reduction is explained by the growth of spreading and submarine volcanism that was the most intense in the Caribbean [*Ingram et al.,* 1994].

Since the δ^{13}C and C_{org} oscillations at the end of the Cenomanian–beginning of the Turonian correspond to the Milankovich cycles, the δ^{13}C and C_{org} positive anomaly during the *gracile-plenus* time has resulted from a climatic change [*Gale et al.,* 1993]. As the δ^{13}C positive shifts at that time were concurrently pronounced both in the ocean and on land, they were explained by the $p\mathrm{CO}_2$ drop in the atmosphere and by a short-term global cooling. However, it was marked that this cooling took place during an extended warm and humid period that occurred in the second half of the late Cenomanian and continued in the first half of the early Turonian [*Hasegawa,* 2003].

As the δ^{13}C and C_{org} shift in the *gracile-plenus* time was very sharp, it probably resulted not only from the climate but from other reasons. For instance, according to geochemical records, the major reason for the accumulation of C_{org} rich beds at the Cenomanian–Turonian boundary in the fore-arc basin of Japan, was the increased terrigenous input and intense acidic volcanism [*Zenya and Hirano,* 1996].

The rise of bottom temperatures in the oceans up to 16°–18°C in the terminal Cenomanian, composition and number of trace elements in the C_{org} rich beds, and the Sr^{87}/Sr^{86} decrease close to AOE-II were due to the strengthening of endogenic processes, penetration of hydrothermal solutions that followed the submarine volcanism, and their subsequent transportation to the shelves [*Larson,* 1991; *Leckie et al.,* 2002]. The formation of numerous bentonitic layers in the Western Interior Basin of North America is also considered as an indicator of increased volcanism at that time [*Leckie et al.,* 2002].

The increased endogenic activity and the superplume phenomenon are currently interpreted as the major mechanisms that caused the changes of the oceanic and climatic system in the terminal Cenomanian. The growth of intraplate oceanic volcanism, sea-floor spreading, and the increase in length of mid-oceanic ridges could be accompanied by the strengthening of hydrothermal activity, penetration of trace elements in the ocean and their transportation by tropical water during the transgression to the North American shelves. The increase of submarine volcanism could have led to the bottom water temperature elevation and the enhanced sea-floor spreading could be followed by an eustatic sea level rise. The active sea-floor spreading and/or the increase in length of mid-oceanic ridges, as well as the strengthening of the intraplate and continental marginal volcanism presumably have resulted in the rise of CO_2 content in the atmosphere, global climatic warming, lack of polar ice caps, decreased meridional temperature gradient, and in the enhanced water mass circulation. The ocean level rise could favour a good C_{org} preservation. At the same time the South and North Atlantic were separated by the stagnation zone and partially isolated. The increased water mass vertical circulation could facilitate the vertical advection of food resources and raise the initial bioproductivity. Thus a high productivity in the oceans during the AOE-II interval probably resulted from changes of water mass circulation or from the increase of the proper water mass productivity [*Leckie et al,* 2002]. A global warming that corresponded to the enhancement of submarine volcanism, could also strengthen the chemical weathering on land and food transportation to oceans, whereas the developed transgression provided a well preservation and burial of C_{org} [*Leckie et al.,* 2002].

Despite the fact that the described pattern is well justified, it should be taken into account that during the climatic optimum, which began in the mid-late Cenomanian *gracile-plenus* interval, a short cooling could take place that was followed not by strengthening but by destruction of water column stratification. At the time when in the equatorial Atlantic the euxinic zone was set in and water mass circulation slowed down, the shelf water masses in the mid- and high latitudes were slightly depleted of oxygen and their global lateral circulation increased.

All the recorded environmental changes were considerably sharp and could have affected the marine biota. For instance, the lowering of a temperature gradient and depletion of water column in oxygen near the thermocline, could lead to the extinction of the deep-water planktonic foraminifers *Rotalipora*; and the warming of bottom waters, to the disappearance of deep-water benthic forams [*Leckie et al.,* 2002]. However, the alteration in the bivalve mollusk and ammonite composition in the Western Interior Basin of North America that occurred almost concurrently with the climatic and oceanic changes, was most likely caused by biological reasons [*Harries,* 1999].

Initial Records

As indicated above, it was established that significant changes of foraminifers and other faunal groups, as well as drastic paleoclimatic and paleoecologic events were associated with the *gracile* biozone. Thus we should pay peculiar attention to the analysis of faunal assemblages in the corresponding interval in various regions including eastern Central Asia.

The records reported in this paper are based on the study of a shallow marginal basin. The basin lacked volcanism and the faunal assemblages distributed in the Cenomanian and Turonian sediments of eastern Central Asia were formed under the influence of both local environmental conditions that were greatly affected by land located to the north- and southeast, and the repeated penetration of boreal elements from the northwest and of tropical members from the southwest. In this region AOE-II was not pronounced in the black shale accumulation. The transgression developed there during the middle Cenomanian–middle Turonian. According to certain data, it reached maximum at the beginning of the middle Cenomanian and at the beginning of the middle Turonian but not in the terminal Cenomanian [*Korchagin,* 1988]; according to other records, at the end of the Cenomanian [*Korchagin,* 1998]. During the transgression a monotonous clay and marl sequence from 25 to 250-m thick was accumulated. In the middle of the sequence the exact equivalents or proper zonal units of ammonite and foraminiferal zonations for the boundary Cenomanian–Turonian sediments were recognized, including the *Sciponoceras gracile* biozone, which associates in other regions with the major extinction events. The boundary Cenomanian–Turonian sediments in this region are no less favorable for investigation than the synchronous sections, by the example of which the reference and standard zonations are developed and the events of the terminal Cenomanian–beginning of the Turonian are estimated [*Djialilov et al.,* 1985]. Among these are the sections in Western Europe [*Carter and Hart,* 1977; *Jenkyns et al.,* 1994; *Kennedy,* 1984; *Lamolda,* 1982; *Lamolda et al.,* 1997; *Porthault,* 1974; *Robaszynski and Amedro,* 1993; *Robaszynski* *et al.,* 1982], northern Africa, Tunisia [*Robaszynski et al.,* 1990], Western Interior Basin of North America [*Cobban,* 1984; *Eicher and Worstell,* 1970; *Kauffman et al.,* 1978], and in Alberta Province, Canada [*Stelck and Wall,* 1954, 1955].

Even *Arkhangel'skii* [1916], *Borneman* [1940], and *Simakov* [1952] in different regions of Central Asia recorded separate findings of ammonites *Vascoceras*, *Metoicoceras*, and *Watinoceras*. However, the significance of these findings for biostratigraphy was estimated subsequently, when a great deal of species of these and other genera were encountered, among which are *Sciponoceras gracile* (Schumard), *Kanabiceras septemseriatum* (Gragin), *Metoicoceras geslinianum* d'Orbigny, *Worthoceras diartianum* d'Orbigny, *Allocrioceras annulatum* (Schumard), and *Borrisiakoceras mirabile* Arkhangelsky [*Djialilov et al.,* 1986]. Along with ammonites the belemnite *Praeactinocamax plenus* (Blainville) was also found.

The ammonite zonation of eastern Central Asia in the transitional Cenomanian–Turonian interval includes the following zones upward the section: (1) *Eucalycoceras pentagonum*, (2) *Sciponoceras gracile*, (3) " barren of ammonites interval," and (4) *Watinoceras coloradoense* [*Khakimov,* 1998]. This part of the section was subdivided into zones by means of planktonic foraminifers as well [*Korchagin,* 2001].

The *Sciponoceras gracile* teilzone, which to a greater degree corresponds to the *gracile* biozone of North America, is the most clearly recognized there. The lower portion of this teilzone yielding *Kanabiceras septemseriatum* (Gragin), *Metoicoceras geslinianum* d'Orbigny, and *Praeactinocamax plenus* (Blainville), can be correlated with the *gracile* assemblage zone in North America and with the upper part of the belemnite *Praeactinocamax plenus* Zone or "plenus marls" in Western Europe.

In eastern Central Asia the most complete ammonite collections from the *Sciponoceras gracile* Zone were made in southern Tajikistan, in the Koikitau and Khodzhakazian sections. Just in these sections the above-mentioned rostra of the belemnite *Praeactinocamax plenus* (Blainville) were found.

The choosing of the Koikitau section as an example is due to the fact that precisely there the most complete collections of ammonites and belemnites were gathered and the representative foraminifer assemblages were recorded. However, the section is situated in one of the most distant parts of paleoshelf, which was closely connected with the open seas of northwestern Afghanistan, Mountainous Badkhyz, and Kopetdag, whereas the major territory of eastern Central Asia was occupied by the adjacent to land basins. The sediments that accumulated in the coastal areas differed from those of the open shelf in southern Tajik depression (Koikitau) and so did the faunal assemblages. As an example of marginal sediments and faunal assemblages we report the data on the Rovik section from southwestern Darvaz.

A certain disadvantage of the Koikitau and Rovik sections is the fact that the middle and upper Cenomanian sediments underlying the transitional Cenomanian–Turonian beds, have a reduced thickness though in other Tajik sections they are represented by a thick and rich in faunal remains clay sequence. The aforesaid therewith does not minimize the importance of the presented conclusions, which consider the records from other sections both in the Tajik depresion and in other regions.

This paper is based on materials collected and studied by the author.

Tajik Depression. Koikitau Section

At the Pistadara site to the south of the Koikitau Range massive limestones and sandstones of the lower middle Cenomanian Tagarian regional stage (the *Eoradiolites kugitangensis* Zone) are recovered in the core of anticline. At the top of limestones the hiatus is generally traced in the form of a hard ground. The limestones are overlain by dark grey clays of the Gazdaganian regional stage, in which the belemnite rostra identified as *Praeactinocamax plenus*, were previously found. The small, dwarf ammonites were also recorded there. Upward the section the clays are replaced by grey marls bearing *Mytiloides labiatus.* Both beds are marker levels and are traced throughout the studied area. It was established that the belemnite rostra and dwarf ammonite findings are associated with the phosphoritic bed that has separate outcrops in the Koikitau area. Owing to soil covering of the area, the complete description of the interval between the phosphoritic bed and *Mytiloides labiatus* marls in a single locality was impossible. However, the peculiarity of faunal assemblages and their successive alteration in the studied outcrops provide the assurance in a sufficient stratigraphic completeness of the discussed interval.

The characteristics and bed-by-bed description of the Koikitau [1] section was made previously [*Djialilov et al.,* 1986] and is given below. The stratigraphic distribution of planktonic and benthic foraminifers in the sediments is shown in Figures 1 and 2.

The sections are described upward from the base and in all cases, beginning from the top of the Tagara limestones.

Site V.

Bed 4283. Greenish-grey clay, partially hidden. Sample 4283 was taken 2.5 m above the top of the Tagara Horizon.....10 m.

Site IV.

Bed 3783. Hidden. Grey clay manifestations; evidently, the analogue of Bed 4283 at Site 5...................................10.2 m.

Bed 3883. Sediments bearing phosphoritic concretions up to 1 cm in diameter and phosphorized remains of corals *Microbacia coronula* Goldf. and *Trochocyatus* sp.; internal molds of bivalves; gastropod *Perissoptera* (?) sp. ind.; ammonites *Sciponoceras gracile* (Schumard); *Scaphites* sp., *Kanabiceras* (Gragin), *Worthoceras vermiculum* (Shumard), *Metoicoceras geslinianum* Orbigny, *Allocrioceras annulatum* (Schumard), *Anisoceras plicatule* Sow., and *Borrisiakoceras planum* Khakimov (in litt.); belemnite

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[1] The description of the Koikitau section reported above was made by V. I. Korchagin, A. A. Atabekyan, M. P. Djialilov, O. A. Korchagin, and F. Kh. Khakimov. Foraminifers were identified by O. A. Korchagin; corals, by E. I. Kuzmicheva; gastropods, by M. P. Djialilov; ammonites, by A. A. Atabekyan and F. Kh. Khakimov; belemnites, by D. P. Naidin; and echinoids, by L. G. Endelman.

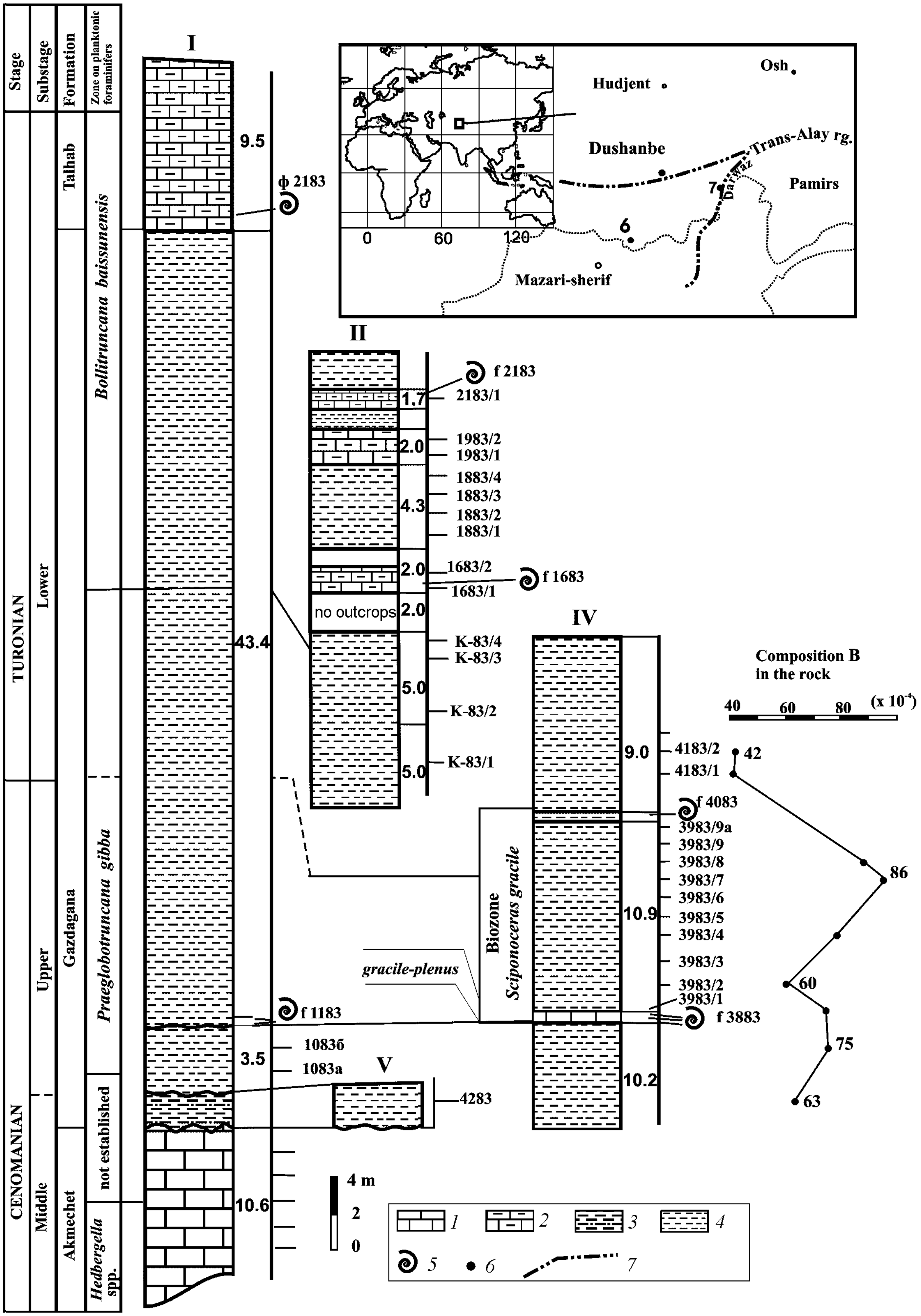
Stage
Substage
Formation
Zone on planktonic foraminifers
TURONIAN
CENOMANIAN
Lower
Upper
Middle
Talhab
Gazdagana
Akmechet
Bollitruncana baissunensis
Praeglobotruncana gibba
not established
Heđbergella spp.
I
9.5
ф 2183
43.4
f 1183
1083б
1083a
3.5
10.6
II
f 2183
1.7
2183/1
2.0
1983/2
1983/1
1883/4
1883/3
4.3
1883/2
1883/1
2.0
1683/2
f 1683
1683/1
no outcrops
2.0
K-83/4
K-83/3
5.0
K-83/2
5.0
K-83/1
IV
9.0
4183/2
4183/1
f 4083
3983/9a
3983/9
3983/8
3983/7
3983/6
10.9
3983/5
3983/4
3983/3
3983/2
3983/1
f 3883
10.2
Biozone Sciponoceras gracile
gracile-plenus
V
4283
Composition B in the rock
40 60 80 (x 10⁻⁴)
42
86
60
75
63
Hudjent
Osh
Dushanbe
Trans-Alay rg.
Darvaz
7
Pamirs
6
Mazari-sherif
0 60 120
4 m
2
0
1
2
3
4
5
6
7

Figure 1. Section of the boundary Cenomanian–Turonian beds in the Koikitau area. Notes: (1) limestone (clastic, organogenic, oolitic); (2) marl; (3) siltstone; (4) clay; (5) macrofauna locality (Sample F 1183: *Sciponoceras gracile* (Schumard), *Kanabiceras septemseriatum* (Gragin), *Metoicoceras geslinianum* d'Orbigny, *Borrisiacoceras mirabile* Arkh., *Wortoceras diarianum* d'Orbigny, *Allocrioceras annulatum* (Schumard), *Scaphites* sp., *Praeactinocamax* cf. *plenus* (Blainville), *Microbacia coronula* Goldf., *Trochocyatus* sp., *Perrisopteria* cf. *fragilis* Djialilov and Arustamov, *Semiinvoluta* sp.; Sample F 3883: *Sciponoceras gracile* (Schumard), *Wortoceras vermiculum* (Schumard), *Metoicoceras geslinianum* d'Orbigny, *Allocrioceras annulatum* (Schumard), *Anisoceras plicatule* Sow., *Borissiacoceras planum* Khakimov, *Praeactinocamax plenus* (Blainville); Sample F 4083: *Sciponoceras* cf. *gracile* (Schumard), *Semisolarium* (?) sp. ind.; Sample 1683: *Mytiloides labiatus* (Schloth.), ammonites; Sample F 2183/1: *Mytiloides* sp., *Gryphaea vesiculosa turkestanica* Bobkova; Sample F 2183: *Mytiloides* sp.; (6) Upper Cretaceous sections (6 – Koikitau section; 7 – Rovik section); I, II, IV, V – outcrop numbers; (7) northern and northeastern boundary of planktonic foraminifer distribution in the Cenomanian and Turonian.

Praeactinocamax plenus (Blainv.); echinoid *Discoides minimus* Ag...0.1 m.
Bed 3983. Greenish-grey, finely splinter, noncarbonate clay. Samples 3983/1-9..10.9 m.
Bed 4083. Numerous phosphoritic concretions with remains of gastropod *Semisolarium* (?) sp. ind. and ammonite *Sciponoceras* cf. *gracile* (Schumard). Sample 3983/9a...0.1 m.
Bed 4183. Greenish-grey, finely splinter, noncarbonate, partially limonitized clay. Upper part is hidden. Samples 4183/1-2...9.0 m.

Site II.
Bed 1383. Hidden...10.1 m.
Bed 1483. Greenish-grey, finely splinter, noncarbonate clay. Samples K183/1-4..5.0 m.
Bed 1583. Hidden...2.0 m.
Bed 1683. Bluish-grey, lumpy marl bearing pyrite concretions and impressions of *Mytiloides labiatus* (Schloth.). Sample 1683/1-2...1.1 m.
Bed 1783. Hidden...0.9 m.
Bed 1883. Bluish-grey, silty, lumpy clay bearing pyrite (?) concretions. Samples 1883/1-4....................................4.3 m.
Bed 1983. Bluish-grey, lumpy at the base and leafy at the top, marl. Samples 1983/1-2.................................2.0 m.
Bed 2083. Bluish-grey, splinter, noncarbonate clay......0.4 m.
Bed 2183. Bluish-grey, leafy marl bearing *Mytiloides* sp. and *Gryphaea vesiculosa turkestanica* Bobkova. Sample 2183/1...1.1 m.
Further upward the interbedded clay and marl are continued.

Site III is located 0.5 km east of Site 2. The lower Turonian sediments that are stratigraphically above the *Mytiloides labiatus* marls are recovered there, thus the description of the site is not reported.

Site I.
Bed 1083. Hidden. Separate manifestations of greenish-grey clays. Sample 1083 was taken at the top of the bed...5.6 m.
Bed 1183. Horizon with phosphoritic concretions, contains corals *Microbacia coronula* Goldf. and *Trochocyatus* sp., gastropods *Perissoptera* cf. *fragilis* Djialilov and Arustamov, *Semisolarium* sp. ind., ammonites *Sciponoceras gracile* (Schumard), *Kanabiceras septemseriatum* (Gragin), *Scaphites* sp., *Metoiceceras geslinianum* d'Orbigny, *Borrissiacoceras mirabile* Arkh., *Vascoceras diartianum* d'Orbigny, and *Allocrioceras annulatum* (Schumard), and belemnite *Praeactinocamus* cf. *plenus* (Blaivn.). The bed is the analogue to Bed 3883..0.1 m.
Bed 1283. Hidden. Separate manifestations of greenish-grey clays...43.4 m.
Bed 1283A. Bluish-grey, hard marl forming a distinct escarpment..3.7 m.

In this section foraminifers occur in both the *Sciponoceras gracile* Zone and overlying sediments. The foraminiferal assemblage from the underlying beds is impoverished and its composition can be estimated based on the middle and upper Cenomanian sediments from other regions of the Tajik depression where they are thicker and contain a well-preserved microfauna [*Djialilov et al.,* 1985]. It is characterized by the predominance of agglutinated foraminifers *Gaudryinopsis*, *Haplophragmoides*, *Ammobaculites*, *Ammobaculoides*, *Bykoviella*, *Buccicrenata*, *Verneuilinoides*, *Evolutinella*, *Baissunella*, and *Trochammina*, by rare planktonic forms, and monotonous species composition of calcareous benthic foraminifers represented by the numerous *Vaginulina* members and scarce *Gavelinella*.

The foraminiferal assemblage from the *Sciponoceras gracile* Zone differs greatly from that of the underlying sediments. The previously absent planktonic forms *Bollitruncana*, *Dicarinella*, *Helvetoglobotruncana*, and *Angulocarinella* appeared there and known from the older beds *Brittonella*, *Praeglobotruncana*, *Hedbergella*, *Heterohelix*, and *Guembelitria* sharply grew in number and diversity. Additionally, in this zone many above-mentioned genera of agglutinated foraminifers ceased to dominate in the assemblage. Among benthic forams the numerous calcareous forms appeared, particularly those of *Gavelinella*, and *Lingulogavelinella*.

The benthic foraminiferal assemblage includes *Saccammina complanata* (Franke), *Ammodiscus cretaceous* Reuss, *Haplophragmoides rota* Nauss, *Budashevaella* cf. *hendersonensis* (Stelck and Wall), *Loculorbis* aff. *darwini* (Dain), *Ammobaculites tyrelly* Nauss, *Ammobaculoides mosbyensis* Eicher, *A. suleymanovi* O. Korchagin, sp. nov., *Quasispiroplectammina longa* (Lalicker), *Gaudryinopsis*

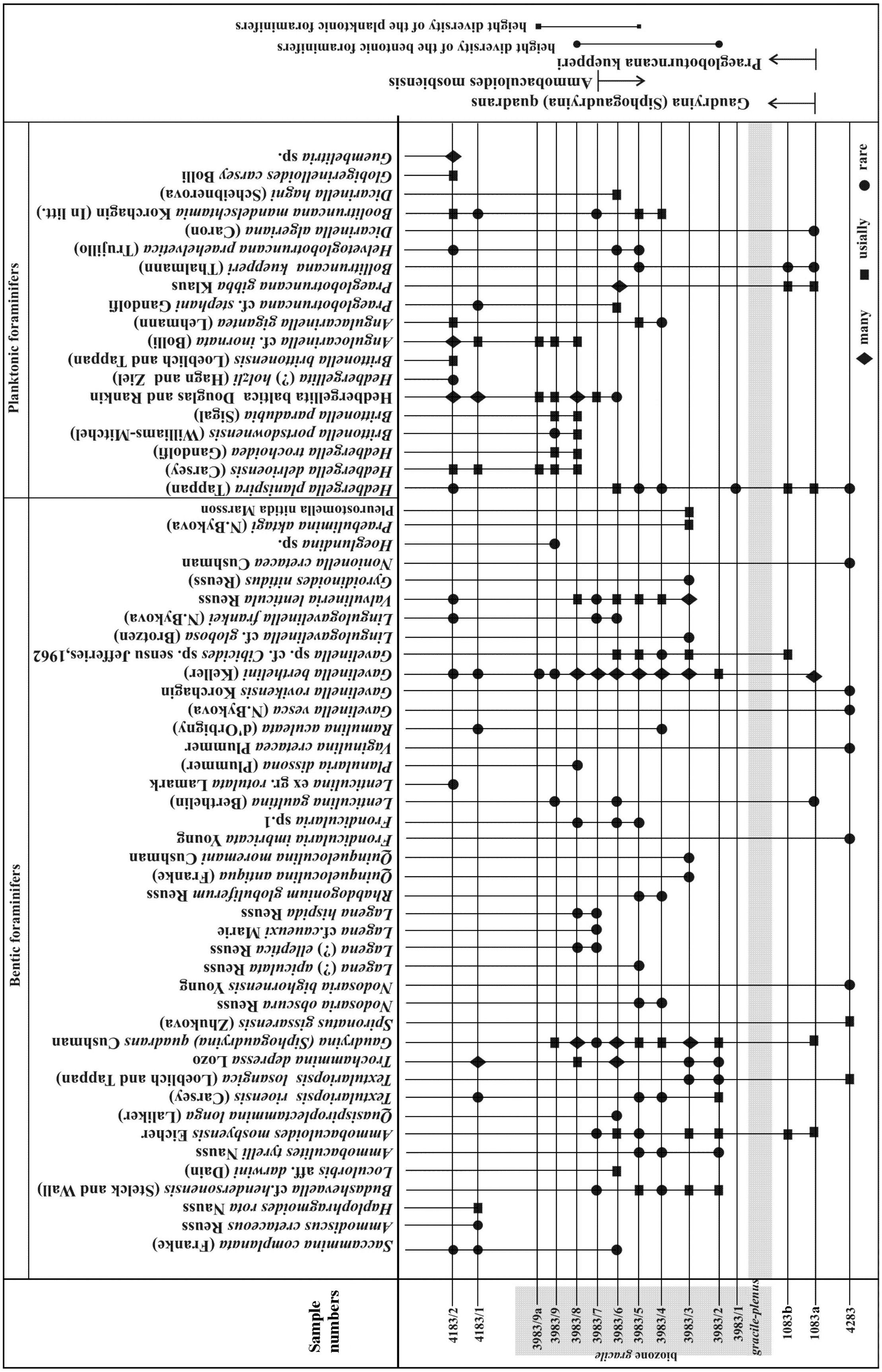

Figure 2. Foraminifers in the boundary Cenomanian–Turonian sediments in the Koikitau area. Notes: Abundance of foraminiferal specimens in samples: 1 – rare; 2 – common; 3 – abundant; 4 – the lowest findings of a species in the section; 5 – the highest findings of a species in the section.

costatus O. Korchagin, *Textulariopsis rioensis* (Carsey), *T. losangica* (Loeblich and Tappan), *Trochammina depressa* Lozo, *Gaudryina* (*Siphogaudryina*) *quadrans* Cushman, *Spironatus gissarensis* (Zhukova), *Nodosaria obscura* Reuss, *N. bighornensis* Young, *N. proboscidea* Reuss, *Lagena apiculata* Reuss, *L. elleptica* Reuss, *L.* cf. *caueuxi* Marie, *L. hispida* Reuss, *L.* sp., *Rhabdagonium globuliferum* Reuss, *Quinqueloculina antiqua* (Franke), *Q. moremani* Cushman, *Pleurostomella nitida* Marsson, *Frondicularia imbricata* Young, *Frondicularia* sp.1, *Lenticulina gaultina* (Berthelin), *L.* ex gr. *rotulata* Lamark, *Planularia dissona* (Plummer), *Vaginulina cretacea* Plummer, *Ramulina aculeata* (d'Orbigny), *Gavelinella vesca* (N. Bykova), *G. rovikensis* (O. Korchagin), *Gavelinella berthelini* (Keller), *G.* sp. cf. *Cibicides* sp. sensu Jefferies, *Lingulogavelinella* cf. *globosa* (Brotzen), *L. frankei* (N. Bykova), *Valvulineria lenticula* Reuss, *Gyroidinoides nitidus* (Reuss), *Nonionella cretacea* Cushman, *Hoeglundina* sp., and *Praebulimina aktagi* (N. Bykova).

Southwestern Darvaz. Rovik section

The section was described along the Rovik (Roika) Creek, the first from the Dashtidzhum Village right tributary of the Obi-Miniou River. The description is reported from the top of greenish- and light grey limestone bearing remains of rudists, echinoids, and gastropods of the middle Cenomanian Idzhudara Formation. The uneven, dissected by limivores, and ferruginated surface is overlain by the middle-upper Cenomanian–middle Turonian clay and marl sequence that is represented upwards by (Figure 3):

Middle-upper Cenomanian

Bed 15781. Dark grey, slightly carbonate, finely splinter clay..3.5 m.

Bed 15881. Greenish-grey, loose, clayey limestone bearing shells of *Rhynchostreon columbum* (Lam)....................1.1 m.

Upper Cenomanian

Bed 15981. Dark grey, slightly carbonate clay bearing numerous pyrite (limonite) concretions...........................6.1 m.

Lower Turonian

Bed 16081. Greenish-grey limestone-coquina admixed with a sandy detritus. Contains whole shells of *Mytiloides labiatus* (Schloth.), *Rhynchostreon columbum* (Lam.), and *Gryphaea vesiculosa turkestanica* Bob.

Bed 16181. Dark, greenish-grey, carbonate clay, bearing pyrite (limonite) concretions. Remains of bivalves *Mytiloides labiatus* (Schloth.) and *Mytiloides mutiloide* (Mant.) and ammonite *Thomasites* (*Koulabiceras*) *koulabicum* (Kler) were found In the upper part.....................................17.1 m.

Bed 16281. Hidden. Grey clay manifestations............9.8 m.

Bed 16381. Grey and greenish-grey, loose siltstone bearing shells of bivalve *Mytiloides* sp. ind. and ammonite *Proplacenticeras kharesmensis* (Lah.)..........................2.8 m.

Bed 16481. Hidden...1.1 m.

Bed 16581. Light grey marl admixed with sand...........8.0 m.

Middle Turonian

Bed 16681. Light grey, strongly carbonate siltstone interbedded with clay..13.0 m.

Bed 16781. Light and yellowish-grey, clayey limestone admixed with sand...6.0 m.

Bed 16881. Yellowish-grey, fine-grained, strongly carbonate sandstone..3.0 m.

Bed 16981. Yellowish-grey, sandy detrital, lumpy limestone, bearing echinoid *Hemiaster solignaci* Lamb. and ammonite *Collignoniceras woolgari* (Mant.)................................2.0 m.

Bed 17081. Light grey, sandy detrital limestone-coquina bearing numerous shells of pelecypods *Fatina* (*Costeina*) *costei* (Coq.) and *Pholadomya albina* Reich................5.5 m.

Grey and red-brown, fine- and medium-grained sandstones interbedded with gypsum in the upper part, which are referred to the middle-upper Turonian Garmak Formation, occur upward the section.

Thus the benthic foraminiferal assemblage of the discussed beds includes both agglutinated with carbonate and noncarbonate wall, and calcareous forms. The calcareous benthic foraminifers for the first time in this region became a dominant group. The appearance of numerous calcareous benthic foraminifers at this level is distinctly recorded in southwestern Darvaz, southern Tajik depression, and southwestern offsets of the Gissar Range. In the *Sciponoceras gracile* Zone the benthic foraminiferal assemblage as a whole is more taxonomically diverse and numerous with respect to both the underlying assemblage and that of the overlying beds.

The generalized curves of the benthic and planktonic foraminifer species and subspecies number in the Cenomanian and Turonian sediments of eastern Central Asia are shown in Figure 4. The curves summarize the records on several characteristic Cenomanian and Turonian sections from different regions: southwestern offsets of the Gissar Range, Tajik depression, southwestern Darvaz, Dushanbe trough, Alaskaya valley, and southeastern Fergana. The curves distinctly indicate the increase of the benthic foraminifer species diversity precisely in the *gracile* time.

I emphasize that in the central and southern parts of the shelf, for example, in the Koikitau region, the benthic foraminifer assemblage became sharply impoverished immediately on disappearance of *S. gracile* (Sample 4183/1-2), and the species diversity of planktonic foraminifers was also decreased. The benthic forms became again diverse in the beds equivalent to the *Watinoceras coloradoensis* unit. In the more open portions of the shelf – southwestern offsets of the Gissar Range (Tagara and Aktag sections) – the benthic foraminifers after the disappearance in the *Praebulimina aktagi* unit, remained considerably diverse up to the fading away of *Collignoniceras woolgari.* In the adjacent to land regions, for instance, in southwestern Darvaz (Rovik section), the foraminifer assemblage, subsequent to flourishing in the gracile Zone, became impoverished and remained poor up to the middle lower Turonian and *Mytiloides labiatus* beds (Figure 3).

Most of benthic foraminifer species encountered in the ammonite *Sciponoceras gracile* Zone, are transitional forms and have a wide stratigraphic range. At the same time the species that appear in this zone, are limited to it or disappear within the unit occur as well. Among them are the first occurred in the zone *Gaurdyina* (*Siphogaudryina*) *quadrans*

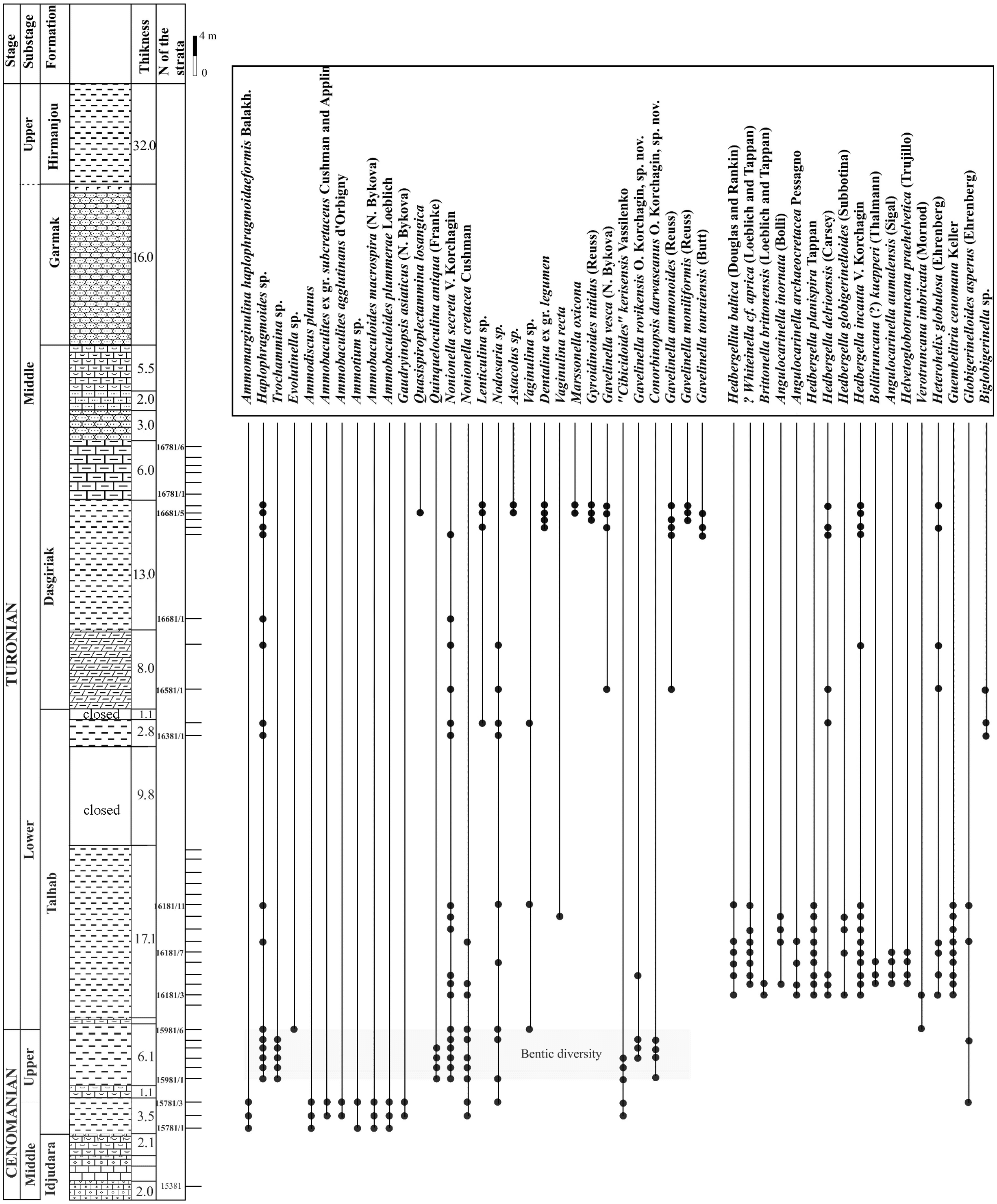

Figure 3. Foraminifers in the boundary Cenomanian–Turonian sediments in the Rovik section, southwestern Darvaz.

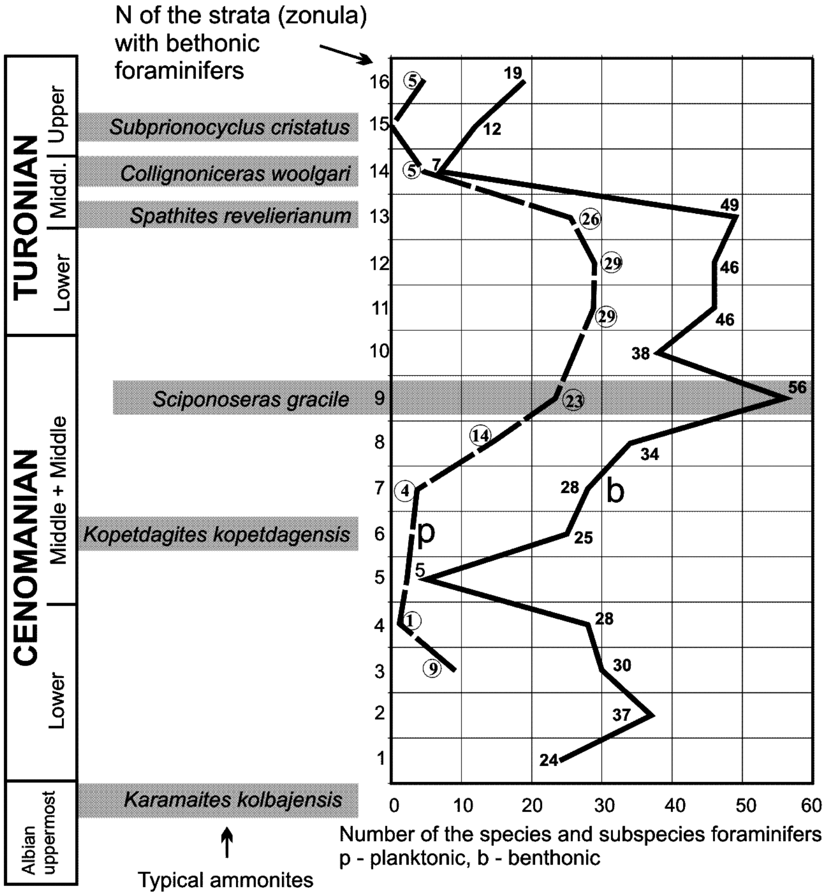

Figure 4. Number of foraminifer species and subspecies in the Cenomanian and Turonian sediments of eastern Central Asia.

Cushman and *Lingulogavelinella frankei* (N. Bykova); *Praebulimina aktagi* (N. Bykova) and probably *Gavelinella* sp. (=*Cibicides* sp. sensu Jefferies), which are limited to the zone; and *Ammobaculoides mosbyensis* Eicher and *A. suleymanovi* O. Korchagin, sp. nov. fading away in this unit. There are a lot of species that migrated in eastern Central Asia from other regions. Most of them inhabited the North European paleobiogeographic province. Such species as *Gavelinella berthelini* (Keller), *Lingulogavelinella frankei* (N. Bykova), and *Gavelinella vesca* (N. Bykova) are characterized by a great number of specimens and highly diverse subspecies. In these groups the intraspecific variability markedly increased. For instance, in certain specimens of *Gavelinella berhtelini*, *Gavelilnella vesca*, and *Gavelinella rovikensis* a test height and convexity from the spiral side increased, the outline changed from rounded to oval, and a knob from the spiral side appeared and grew.

The listed peculiarities of foraminiferal distribution in the *Sciponoceras gracile* Zone make them attractive for solving the problem of interprovincial and intercontinental correlation. In this connection the species *Gaudryina* (*Siphogaudryina*) *quadrans* Cushman, *Ammobaculoides mosbyensis* Eicher, *Praebulimina aktagi* (N. Bykova), *Gaudryinopsis acrabatensis* (Zhukova), *Gavelinella berthelini* (Keller), and *Lingulogavelinella frankei* (N. Bykova) should be marked first. Also important forms can be *Ammobaculoides suleymanovi* O. Korchagin sp. nov. and *Gaudryinopsis costatus* (O. Korchagin) that are excellent age indicators in the Tajik depression and northern Afghanistan where they were first described. It is likely that these new species will be encountered at that stratigraphic level in other regions of the World, as the previously known taxa cited above. For example, in quite separate regions – North America, Central Asia, and Western Europe – approximately at one level, near the base of the *Sciponoceras gracile* Zone, *Gaudryina* (*Siphogaudryina*) *quadrans* (Cushman) first occurred serving a good marker for correlation [*Amedro et al.,* 1978; *Frizzell,* 1954; *Korchagin,* 1989]. Its range in the studied sections – from the base of the upper Cenomanian *gracile* Zone up to the base of the middle Turonian – is roughly similar. The closely related forms referred to *Siphogaudryina* sp., were encountered in the *plenus* marls, i.e. at the same stratigraphic level in the Anglo-Parisien basin [*Jefferies,* 1962]. The species that I identified as *Ammobaculoides mosbyensis* (Eicher), rather common for the upper middle Cenomanian–upper Cenomanian clays in eastern Central Asia, has an analogous stratigraphic range in the Western Interior Basin of North America [*Kauffman et al.,* 1978]. In both regions this form disappeared in the *Sciponoceras gracile* Zone. One more peculiarity of the benthic foraminiferal assemblage from the ammonite *gracile* Zone is the occurrence of numerous specimens of *Praebulimina aktagi* (N. Bykova). This species does not continue outside the zone and is so much typical for the synchronous sediments of the Tajik depression, southwestern offsets of the Gissar Range, and northwestern Afghanistan, that was previously chosen as an index form of the corresponding assemblage zone [*Korchagin,* 1988].

Gavelinella berthelini (Keller) reached flourishing and extremely high intraspecific variability in the sediments of the *Sciponoceras gracile* Zone in eastern Central Asia and is considered as one of the species characteristic of the transitional Cenomanian–Turonian beds in other regions of the Northern Hemisphere, for example, in England [*Jarvis et al.,* 1988].

Among foraminifers peculiar for the discussed interval I point out several other species that in the future can be also important for correlation. Among them is *Lingulogavelinella frankei* (N. Bykova) that first occurred in the *Sciponoceras gracile* Zone in eastern Central Asia. The concurrent foraminifers closely related to the taxa from the *plenus* marls of the Anglo-Parisien basin where they were described as *Cibicides* sp. sensu Jefferies, 1962 [*Jefferies,* 1962], are noteworthy as well. *Gaudryinopsis acrabatensis* (Zhukova) that appeared in the beds overlying the *gracile* Zone in the Tajik depression, southwestern offsets of the Gissar Range, northern Afghanistan, and the Amudarya low reaches, can also serve as a significant stratigraphic marker.

It is remarkable that the *Praebulimina* and *Gavelinella* members occur and are numerous in synchronous sediments of many other regions of the World. *Praebulimina seabensis* was found on the northern slope of Alaska, whereas *Gavelinella dakotensis*, *Praebulimina nannina*, and *Praebulimina seeabensis* occur on the Kergulen Plateau, in the Western Interior Basin, in southern France, and Morocco [*Holbourn and Kuhnt,* 2002]. In addition to the listed taxa a great deal of other common genera, namely, *Lingulogavelinella*, *Pleurostomella*, *Valvulineria*, and *Gyroidinoides*, are included in the synchronous foraminiferal assemblages on the Kergulen Plateau, in the Western Interior Basin of North America, in northern Germany, and southern France [*Eicher and Worstell,* 1970; *Holbourn and Kuhnt,* 2002; *Korchagin,* 1988]. In so doing, on the Kergulen Plateau the diverse benthic foraminifers including the above-mentioned forms, occur in the black shales.

It is notable that some of the foraminifers listed here were very sensitive to the dissolved oxygen content [*Kaiho and Hasegawa,* 1994]. For instance, *Praebulimina aktagi* and *Pleurostomella nitida* serve as disoxic indices, the species of *Gavelinella* and *Cibicidoides* (?), as the indicators of oxygen saturated water, and the species of *Gyroidinoides* and *Hoeglundina* can inhabit waters slightly depleted of oxygen (the so-called species of Group B, intermediate indices). The sediments bearing *Praebulimina* and *Pleurostomella* (Sample 3983/3), as well as *Gavelinella*, *Gyroidinoides*, and somewhat impoverished benthic foraminiferal assemblage, were likely accumulated at a decreased oxygen content in bottom waters. The sediments with numerous *Gavelinella* and considerably diverse foraminiferal assemblage (Sample 3983/4-8) could be formed with a normal oxygen content, whereas that bearing *Hoeglundina* (Sample 3983/9) and impoverished assemblage, in conditions with a normal or slightly decreased oxygen content in bottom waters. The rise of calcareous benthos in the assemblage could also result from an increased $CaCO_3$ saturation of waters.

In the *Sciponoceras gracile* Zone in eastern Central Asia numerous and diverse planktonic foraminifers appeared (Figure 2). Among them are *Hedbergella planispira* (Tappan), *H. delrioensis* (Carsey), *H. trochoidea* (Gandolfi), *H. externa* V. Korchagin, *Brittonella portsdownensis* (Williams-Mitchel), *B. paradubia* (Sigal), *B. brittonensis* (Loeblich and Tappan), *Hedbergellita baltica* Douglas and Rankin, *H. holzli* (Hagn and Zeil), *W. aprica* (Loeblich and Tappan), *Angulocarinella gigantea* (Lehmann), *Praeglobotruncana* cf. *stephani* Gandolfi, *P. gibba* Klauss, *Bollitruncana kuepperi* (Thalmann) sensu Marianos and Zingula, 1966, *B. mandelshtamia* O. Korchagin and V. Korchagin, *Dicarinella algeriana* (Caron), *D. hagni* (Scheibnerova), *Helvetoglobotruncana praehelvetica* (Trujillo), *Globigerinelloides carsey* Bolli, and *Guembelitria* sp.

Many of the penetrated species occurred outside the studied region earlier. However, certain forms first occurred synchronously in the *Sciponoceras gracile* Zone both in the discussed region and beyond its boundaries. Among them are *Helvetoglobotruncana praehelvetica* (Trujillo), the first typical member of the genus, and *Dicarinella hagni* (Scheibnerova), *Angulocarinella gigantea* (Lehmann) and *Bollitruncana mandelshtamia* O. Korchagin, sp. nov. The zonal planktonic foraminiferal assemblage is characterized by the probably first occurrence and flourishing of the conic praeglobotruncan member, *Praeglobotruncana gibba* (Klaus) sensu Robaszynski, Caron, 1979 [*Robaszynski and Caron,* 1979], Plate 44, fig. 1, and by the flowering of the taxa from the so-called "large Hedbergella" group, *Brittonella brittonensis* (Loeblich et Tappan) and *B. paradubia* (Sigal). However, though the members of planoconvex *Bollitruncana* and *Helvetoglobotruncana* appeared in the studied assemblage, their share in the complex is moderate.

According to the ecological morphobathymetric models [*Hart,* 1999], two groups of species can be distinguished among the encountered planktonic foraminifers. The first group includes *Angulocarinella gigantea*, *Praeglobotruncana* cf. *stephani*, *P. gibba*, *Dicarinella hagni*, and *Helvetoglobotruncana praehelvetica*, which are attributed to the oligotrophic planktonic foraminifers that evolved by way of k-selection and inhabited middle and large depths in condition of a low (1–0.1 mg m^{-3}) chlorophyll content. The second group consists of eutrophic *Heterohelix moremani*, *Globigerinelloides carsey*, and *Guembelitria* sp., and the *Hedbergella* and *Brittonella* members, which experienced r-selection and inhabited surface waters rich in chlorophyll (1–100 mg m^{-3}). Oligotrophic species first penetrated in eastern Central Asia at the beginning of the *gracile* Zone but subsequently, by the end of the *gracile* time, were replaced by the eutrophic taxa that began dominating the assemblage.

In the *gracile* time in eastern Central Asia the peculiar environmental conditions were likely formed. They were characterized by waters enriched with food resources and (Ca^+)

and (HCO_3^-) ions, and by normal oxygen content with deviation towards a slight lowering of dissolved oxygen; surface waters were initially depleted of chlorophyll and later on its content raised. A slight boron decrease in the sediments indicates a certain short-term freshening of the basin bottom waters in the middle (Sample 3983/2) and immidiately after (Sample 4183/1-2) the *gracile* time.

These conditions appeared to be quite favorable for various benthic and planktonic foraminifers. They were therewith more favorable that those prior to the *gracile* appearance, stayed comfortable up to its extinction and drastically deteriorated after its disappearance.

Judging from the high diversity of benthic and planktonic forms in the *gracile* Zone, the initial water mass bioproductivity was very high. It is also probable that the oligotrophic and relatively deep-water planktonic foraminifers that were first to penetrate in eastern Central Asia, were transported to the shallows by warm tropical and moderately warm boreal waters, which elevated from middle and large depths. The water masses in the basin were also characterized by a high lateral and vertical circulation and weak stratification.

However, it should be noted that these conditions were not favorable for the obviously oppressed ammonites and bivalve mollusks.

From the overview of geographical distribution of the discussed taxa it is evident that the particularly diverse foraminiferal assemblages that included often predominant members of *Praebulimina*, *Gavelinella*, *Lingulogavelinella*, *Pleurostomella*, *Valvulineria*, *Gyroidinoides*, and *Hoeglundina*, inhabited shelves mainly in the middle and high latitudes of the Northern Hemisphere and the high-latitude oceans of the Southern Hemisphere nearby the Antarctica. At the same time in the equatorial realm, on the shelves outside the carbonate platforms and in the Atlantic Ocean, either extremely impoverished assemblages also including *Praebulimina* and *Gavelinella*, occurred or foraminifers were missing.

The benthic, as well as planktonic foraminiferal assemblages of the *gracile* Zone or their analogues, are extremely diverse not only in eastern Central Asia but in the Anglo-Parisien basin [*Jarvis et al.,* 1988; *Jenkyns et al.,* 1994] and the Western Interior Basin of North America, where the sediments enclosing such fauna were distinguished as the "benthic zone" [*Eicher and Worstell,* 1970; *Kauffman et al.,* 1978]. In all regions a great deal of common genera are recorded, among which there are both certain common species and the similar forms that may be recognized as common on closer examination. It is remarkable that the increased diversity of benthic foraminifer species and the alteration of dominant groups (agglutinated were replaced by calcareous), were most distinct in the marginal or semi-isolated basins in the middle latitudes of the Northern Hemisphere. The enhanced role of calcareous benthic foraminifers in the transitional Cenomanian-Turonian beds was also observed in more northern regions, for example, in Canada (Alberta) and northern Alaska, where scarce planktonic species occurred as well [*Stelck and Wall,* 1954, 1955]. In the assemblages from the above-mentioned regions the proportion of morphologically similar or vicarious species as *Ammobaculoides mosbyensis*, *Ammobaculoides suleymanovi*, *Siphogaudryina quadrans*, *Praebulimina aktagi*, *P. seeabensis*, *P. nannina*, *Gavelinella berthelini*, and *G. dakotensis* is great and the *Praebulimina*, *Pleurostomella* and *Gavelinella* members are of considerable importance.

In low latitudes in the Atlantic Ocean and on the Mediterranean shelves benthic foraminifers were substantially less diverse. In Morocco a rather poor assemblage including only *Praebulimina seabensis* and *Gavelinella dakotensis* was recorded. In the Crimea, on our observations, benthic foraminifers are almost absent in the black shales (Bonarelli beds), whereas planktonic taxa are scarce and are represented by *Hedbergella delrioensis* and *Hedbergella incauta.* In Turkey in the Tomolar Formation benthic foraminifers are also extremely scarce stratigraphically above the last specimens of *Rotalipora cushmani* and first Turonian radiolarians [*Bragin et al.,* 2001]. Evidently in other regions in the Bonarelli beds both benthic and planktonic foraminifers are equally rare.

It can be suggested that the impoverished benthic foraminifer assemblages in black shales were associated with the euxinic zone and H_2S contamination of water column in the central Atlantic. However, benthic and planktonic foraminifers were extremely scarce not only in the black shales of the Atlantic Ocean and in Bonarelli beds on the Mediterranean shelves, but also in the shallow strait through central Africa that connected the Guiana Bay and Mediterranean Sea. It seems likely that the formation of impoverished assemblages in the equatorial realm in both the Atlantic Ocean, where at that time the euxinic zone was formed, and shallows of central Africa, resulted not only from the increased submarine volcanism in the Caribbean.

Comparison of Records and Conclusions

Thus during the *gracile-plenus* time the diverse macrofaunal members, namely, ammonites, belemnites, corals, gastropods, and bivalves migrated to eastern central Asia. The migrants were considerably diverse but small-sized and were represented by distinctly oppressed forms. By the end of the *gracile-plenus* interval all of them were extinct. The migration was accompanied by the extension of cold-water area in the Eastern Hemisphere and likely reflected a global cooling or the so-called "cool plenus effect." Almost simultaneously the abundant planktonic foraminifers mainly represented by oligotrophic species, penetrated in the region. They were likely transported to shelf from intermediate depths of the moderately warm boreal or warm tropical realms. The diversity and abundance of benthic foraminifers concurrently increased.

In the mid-*gracile* time when the number of *Praebulimina aktagi* grew and *Pleurostomella nitida* appeared, the dissolved oxygen content decreased and, judging from the boron quantity, a short-term freshening of bottom water probably occurred. However, the benthic foraminifers remained as diverse as at the beginning of the interval.

At the end of the *gracile* Zone many agglutinated species with acid insoluble shells (*Ammobaculoides*, *Ammobaculites*) that dominated in the middle–late Cenomanian, disappeared, the share of calcareous benthos increased, and the *Gavelinella* species became abundant. The number and diversity of planktonic foraminifers grew but the eutrophic taxa began to dominate in the assemblage.

A high diversity of benthic and planktonic foraminifers was retained up to the end of *gracile*, but immediately after the *S. gracile* extinction the benthic foraminiferal assemblage was sharply impoverished along with the decrease of plankton diversity, among which the eutrophic species dominated with particularly common *Guembelitria*.

The beginning of the great ammonite and bivalve extinction in the Western Interior Basin of North America and eastern Central Asia coincides with a cooling (cool *plenus* effect) in the Eastern Hemisphere and flourishing of benthic and planktonic foraminifers.

However, if in eastern Central Asia the ammonites and belemnites were extinct at the end of the *gracile-plenus* time, in the Western Interior Basin this event occurred later, at the *gracile-flexuosum* boundary. This ultimate extinction coincided with the impoverishment of both benthic and planktonic foraminiferal assemblages and with a possible freshening of bottom waters. The black shales and equatorial euxinic zone were most likely formed in the *gracile-plenus* interval but it is probable that their formation began immediately after the *S. gracile* extinction.

The reported data permit to state that the *gracile* time in quite different regions including eastern Central Asia, was a greatly marked period in the evolution of not only ammonites and bivalves but of foraminifers as well. In several regions of the Northern Hemisphere the diversity of benthic foraminifer species and genera sharply increased, benthic calcareous foraminifers grew in number and replaced the previously dominated agglutinated forms. The intraspecific variability of *Gavelinella* and abundance of *Praebulimina* raised, the migration of benthic foraminifers was enhanced, the number of morphologically similar or vicarious species increased, and numerous and taxonomically diverse planktonic foraminifers appeared, among which the multichambered forms dominated.

However, judging from the studied sections from eastern Central Asia, all these events in evolution of foraminiferal biota were though significant but not catastrophic and were not followed by both mass and simply pronounced extinctions, even at a specific level. They were most likely associated with migrations caused by changes in water mass circulation. Accordingly, considerable evolutionary catastrophes did not take place at that level, except for the disappearance of one genus *Rotalipora*.

As noted above, in the *gracile* period benthic foraminifers inhabited shelves and oceans in mid- and high latitudes of the Northern and Southern Hemispheres and were almost absent on shelf portions beyond the carbonate platforms, and in the oceans nearby the equator. The strengthened lateral and vertical water mass circulation could smooth out the environmental conditions and result in a wide migration of benthic fauna to mid- and high latitudes. Migrants from different ecological niches and geographical regions began an intense invasion in favorable parts of shelves and oceans. This resulted in a rather even and extremely dense settling of both shelves and oceans except for the equatorial realm. According to a high initial diversity and abundance of species, there was enough food resources. Their growth could partially produce the rise of abundance and diversity of fauna. Concurrently the transgression reached its maximum and the accretion of areas suitable for settlement slowed down; possibly, these areas began to decrease owing to regression. This process could have led to overpopulation. In conditions of biological stress the fauna strongly mutated, the short-lived phylums appeared and were extinct. Evidently, with a high density of population any deterioration of environmental conditions could enhance the extinction in one groups and produce the decrease of abundance in others.

The reported observations also permit another explanation of one of the most pronounced event in the history of the Late Cretaceous plankton, the extinction of *Rotalipora*. The decline of the deep-water temperature gradient at the end of the Cenomanian and the drop in oxygen content near the thermocline could really be the important factors that influenced the planktonic foraminifers Rotaliporidae [*Leckie et al.,* 2002]. However, it should be noted that the family Rotaliporidae originated in the late Aptian and disappeared in the mid-early Turonian, i.e. occurred at the time when in the oceans the low oxygen content conditions were particularly common and oxygen declined six or seven times [*Kauffman and Hart,* 1996; *Leckie et al.,* 2002]. The last event was AOE-II at the end of the Cenomanian but its echoes were manifested on the shallows up to the mid-early Turonian [*Kauffman and Hart,* 1996]. It is not inconceivable that Rotaliporidae was a specialized group that originated, adapted itself, and occurred precisely in the water with a low oxygen content. Such adaptation in Rotaliporidae could be favored by additional sutural apertures that strengthened the organism–environment communication. The genus *Rotalipora* appeared during the AOE-1d anoxic event and was extinct in advance of the *gracile-plenus* time, whereas the last member of Rotaliporidae, the genus *Anaticinella* disappeared in the mid-early Turonian.

Accordingly, the extinction of *Rotalipora* could be affected by both the enhanced anoxic conditions and the isolation of northern and southern basins of the World Ocean owing to euxinization of near-equatorial area or a global decrease of anoxic regime. The occurrence of diverse benthic and planktonic fauna in the *gracile* Zone in mid- and high latitudes indicates that the oxygen content in water was though slightly lowered, but enough for the numerous inhabitants.

Appendix

As certain above-mentioned species are widely used for correlation of the discussed sediments in eastern Central Asia and can be applied for wider correlation, I present below the descriptions and illustrations (Plates 1–4) of the most characteristic species from the *Sciponoceras gracile* Zone and overlying sediments.

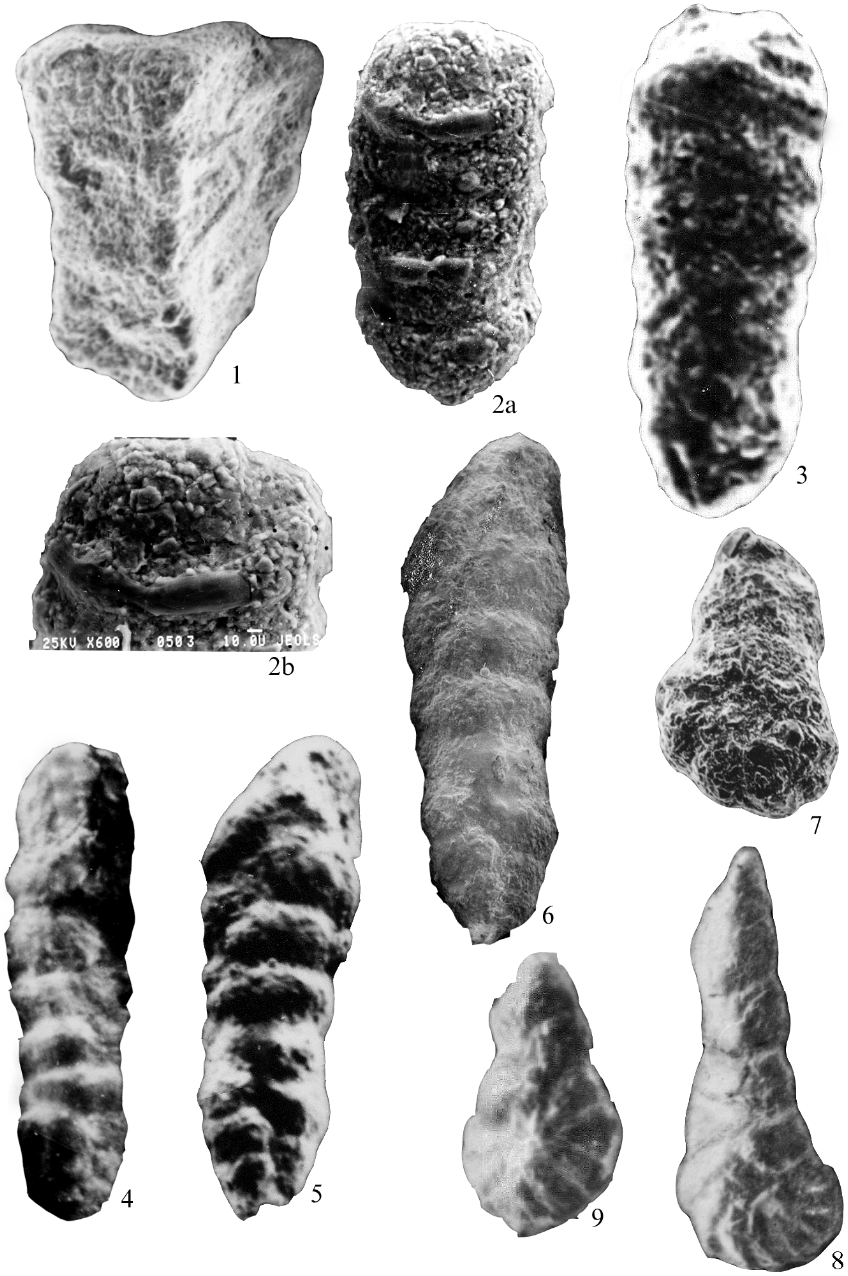

Plate 1. Fig. 1. *Gaudryina* (*Siphogaudryina*) *quadrans* Cushman. Hypotype No 66, Koikitau section, Sample 3983/3 (×160); Figs. 2a–b, 3. *Gaudryinopsis costatus* (O. Korchagin). Paratype No 92, Lower Turonian, Tajik depression, Vakhsh region, Bulgari section, Sample 25981/4, 2a – lateral view (×350), 2b – transverse rib fragment (×600); 3 – lateral view, paratype No 92-1, Koikitau section, Sample 3683/4 (×350); figs. 4, 5, 6. *Gaudryinopsis acrabatensis* (Zhukova). 4 – hypotype No 91, Koikitau section, Sample 3183/4 (×127); 5 – hypotype No 91-1, Koikitau section, Sample 3283/1 (×137); 6 – hypotype No 91-2, Koikitau section, Sample 3183/5 (×130); fig. 7. *Ammobaculoides mosbyensis* Eicher. Hypotype No 61-5, Koikitau section, Sample 3983/3, (×180); figs. 8, 9. *Ammobaculoides suleymanovi* O. Korchagin, sp. nov. 8 – Holotype No 61-1, Koikitau section, Sample 3983/3; 9 – paratype No 61, Koikitau section, Sample 3983/3, (×320).

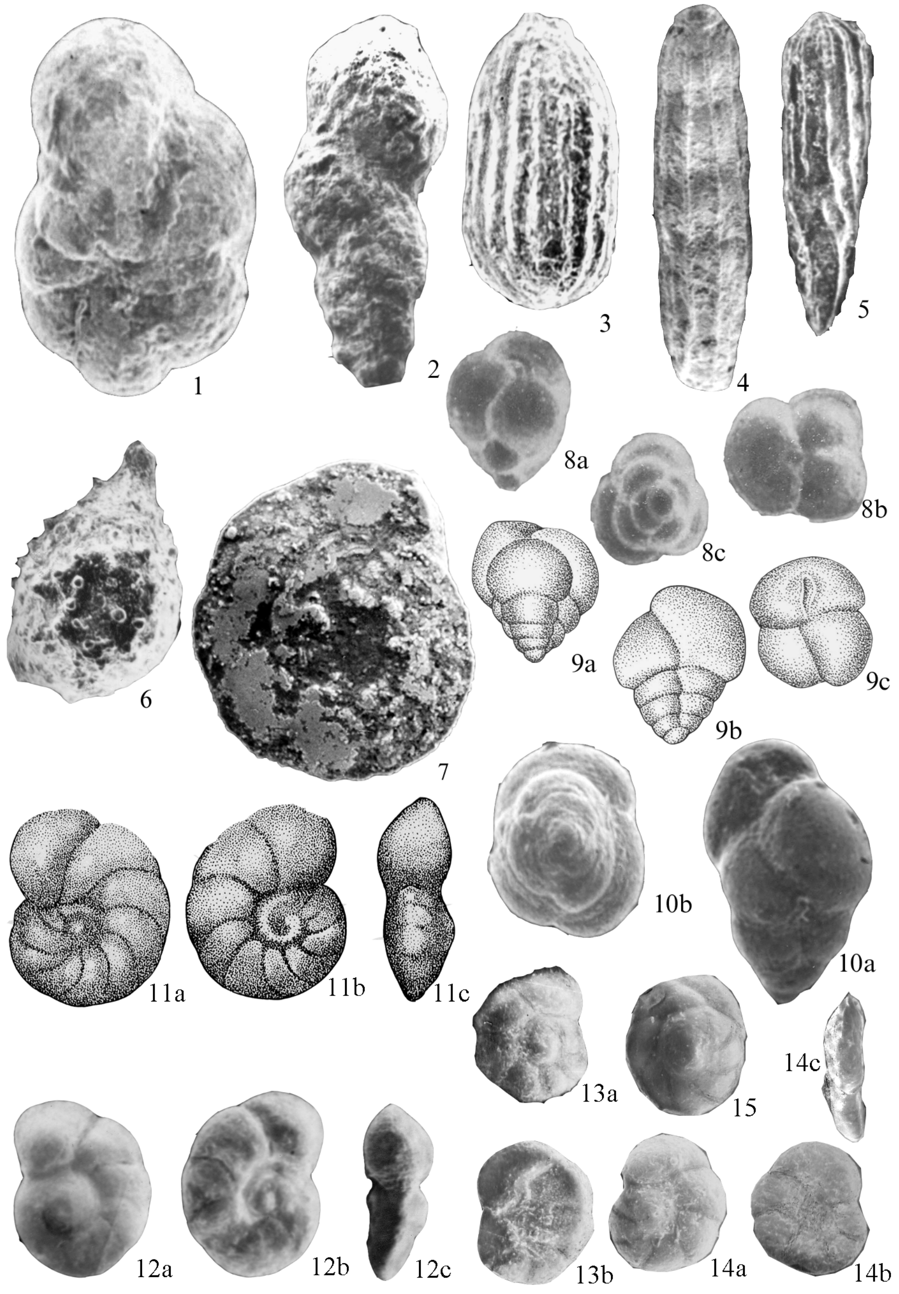

Plate 2. Fig. 1. *Lingulogavelinella frankei* (N. Bykova). Lectotype No 153, Koikitau section, Sample 3183/3 (×300); fig. 2. *Pleurostomella nitida* Marsson. Hypotype No 145, Koikitau section, Sample 3983/1 (×162); fig. 3. *Lagena* sp. Hypotype No 175, Koikitau section, Sample 3983/2 (×390); fig. 4. *Nodosaria obscura* Reuss. Hypotype No 95-1, Koikitau section, Sample 3283/1 (×88); fig. 5. *Nodosaria proboscidea* Reuss. Hypotype No 97, Koikitau section, Sample 3983/8 (×240); fig. 6. *Ramulina aculeata* (d'Orbigny). Hypotype No 135, Koikitau section, Samples 3083/4 (×400); fig. 7. *Hoeglundina* sp. cf. *Hoeglundina carinata* (N. Bykova). Koikitau section, Sample 3983/9, spiral view, (×105); figs. 8a–c, 9a–c, 10a–b. *Praebulimina aktagi* N. Bykova. 8a–c (picture). Picture from the manuscript by N. K. Bykova (1945) (pl. VII, fig. 12a–c) (a – lateral view, b – view from the aperture, c – view from chambers of the initial whorl), southwestern offsets of the Gissarskii Range, Shirabad section; 9a–c (picture), southwestern offsets of the Gissarskii Range, Tagara section; (a, b – lateral views, c – view from the aperture) (×150); 10a,b – lectotype No 159-3, Koikitau section, Sample 3983/3, (×220); fig. 11a–c. *Gavelinella berthelini* (Keller). Original after N. K. Bykova (picture) (Vassilenko, 1954, pl. XIV, fig. 4a–c) (a – spiral view, b – umbilical view, c – peripheral view), Central Asia, Bukhara region, (×75); fig. 12a–c. *Gavelinella*

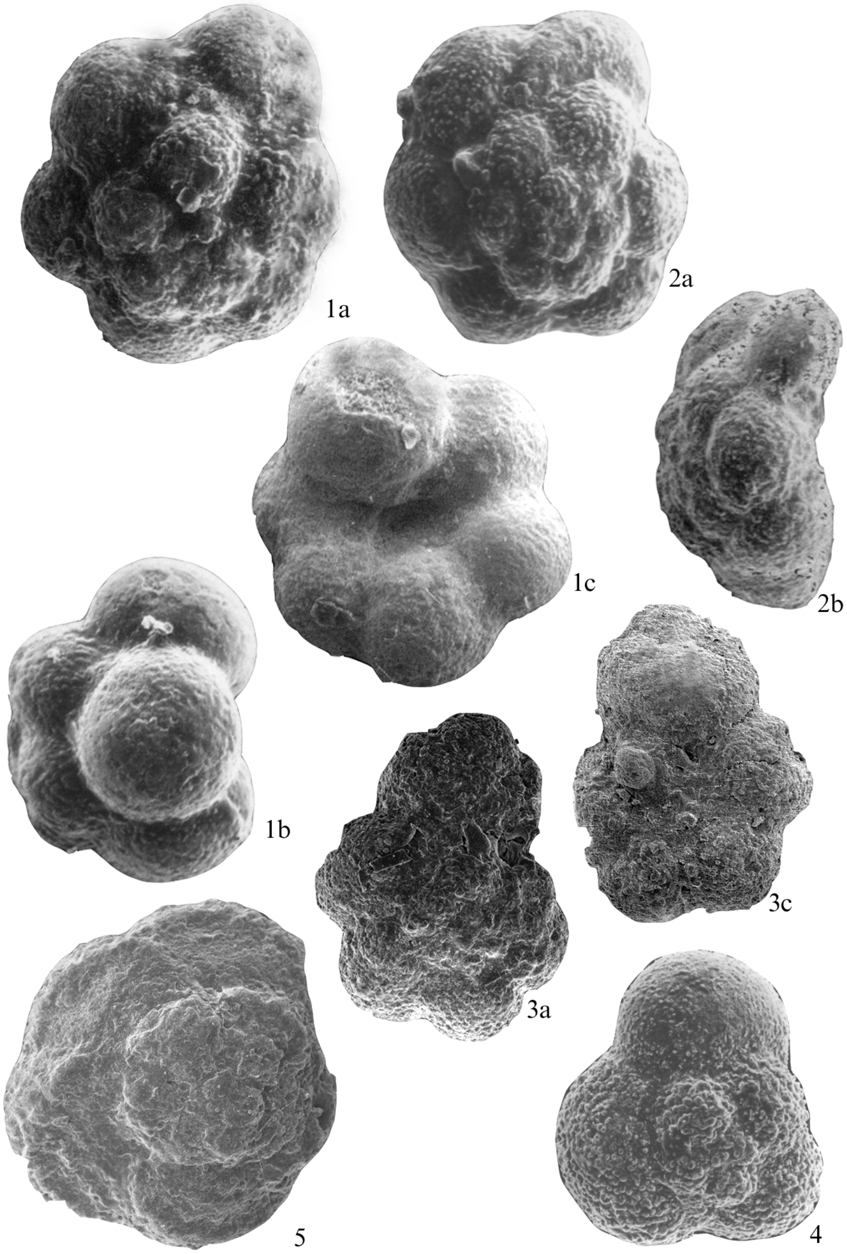

Plate 3. Fig. 1a–c. *Brittonella brittonensis* (Loeblich and Tappan). Hypotype No 178-2, Koikitau section, Talkhab Formation, lower Turonian, Sample 667; a – spiral view, b – peripheral view, c – umbilical view, (×120); fig. 2 a–b. *Brittonella paradubia* (Sigal). Hypotype No 179, Mountainous Badkhyz section, lower Turonian, Sample 55, a – spiral view, b – peripheral view, (×120); fig. 3a–b. *Hedbergellita holzli* (Hagn and Zeil). Hypotype No 162-3, Koikitau section, Gazdagana Formation, lower Turonian, Sample 4183/2; a – spiral view, b – umbilical view, (×150); fig. 4. *Hedbergella externa* V. Korchagin (spiral view), Koikitau section, Sample 1083a (×250); fig. 5. *Praeglobotruncana gibba* Klaus (spiral view), Koikitau section, lower Turonian, Gazdagana Formation, Sample 3983/6 (×166).

⇐ *berthelini* (Keller). Hypotype No 149, Koikitau section, Sample 3083/1, (a – spiral view, b – umbilical view, c – peripheral view), (×63); fig. 13a–b. *Gavelinella vesca* (N. Bykova). Lectotype No 143, Farkharchion section (1500 m south of Rovik), southwestern Darvaz, Sample 2281b (a – spiral view, b – umbilical view), (×65); figs. 14a–c, 15. *Gavelinella rovikensis* O. Korchagin, sp. nov. 14a–c – Holotype No 12, Khodzhafarang section (500 m north of Rovik), southwestern Darvaz, (a – spiral view, b – umbilical view, c – peripheral view), Sample 8981/a (×65); fig. 15 – paratype No 138 (spiral view), Khodzhafarang section, southwestern Darvaz, (×65).

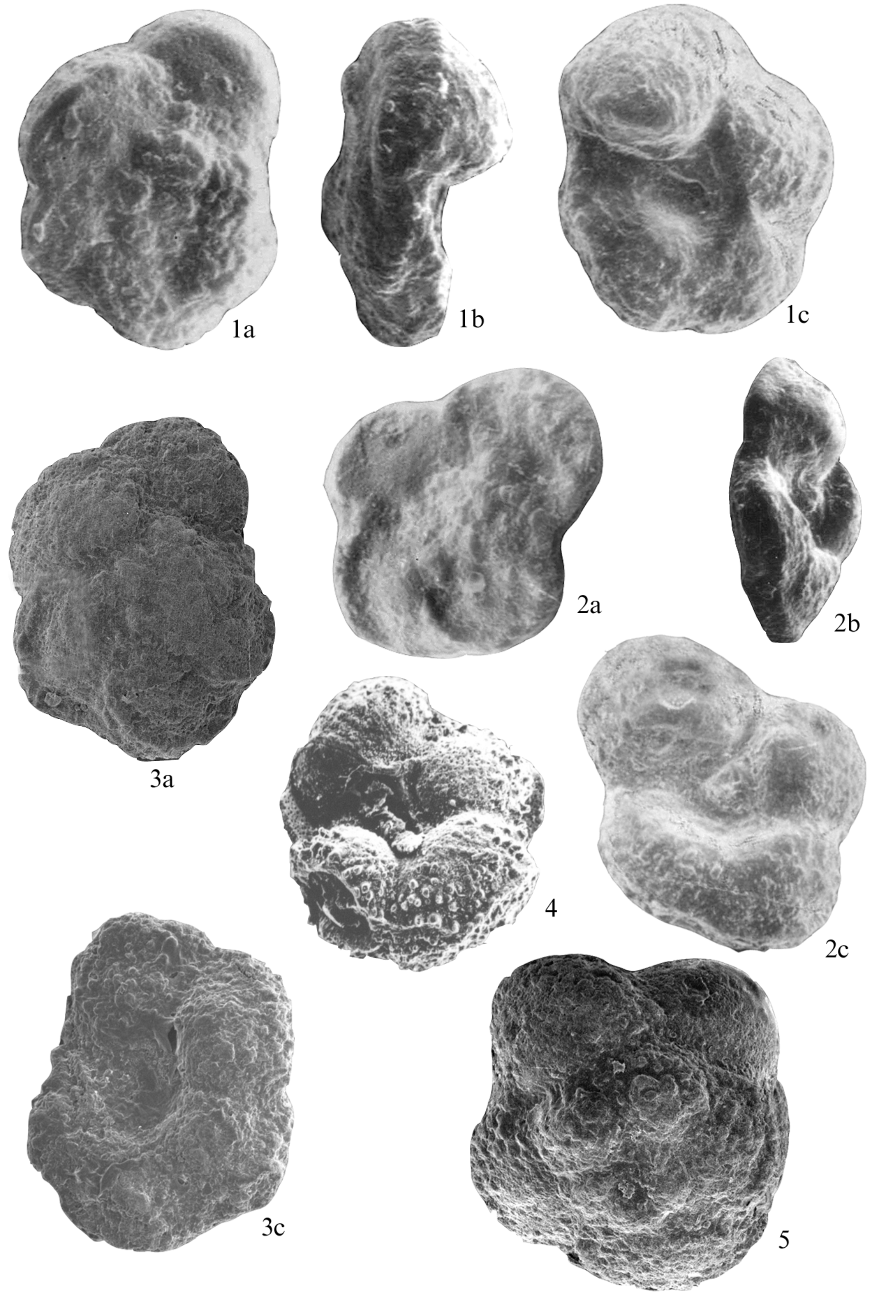

Plate 4. Fig. 1a–c. *Bollitruncana baissunensis* (V. Korchagin). Lectotype No 175, southwestern offsets of the Gissarskii Range, Aktag section, Talkhab Formation, lower Turonian, Sample 1611; a – spiral view, b – peripheral view, c – umbilical view (×117); fig. 2a–c. *Bollitruncana mandelshtamia* O. Korchagin and V. Korchagin, sp. nov. Holotype No 176, southwestern offsets of the Gissar Range, Aktag section, Talkhab Formation, lower Turonian, Sample 1116; a – spiral view, b – peripheral view, c – umbilical view (×117); figs. 3a,c, 4. *Dicarinella algeriana* (Caron). Koikitau section, Gazdagana Formation, upper Cenomanian, Sample 1083a; 3a – spiral view, 3c – umbilical view (×187); 4 – umbilical view (×189); fig. 5. *Bollitruncana* (?) *kuepperi* (Thalmann). Spiral view, Koikitau section, Gazdagana Formation, lower Turonian, Sample 3983/5 (×166).

Systematic Descriptions

Order Foraminiferida Eichwald, 1830
Suborder Textulariina Delage et Herouard, 1896

Superfamily Spiroplectamminacea Cushman, 1927
Family Spiroplectamminidae Cushman, 1927
Subfamily Spiroplectammininae Cushman, 1927

Genus *Ammobaculoides* Plummer, 1932

Ammobaculoides mosbyensis Eicher, 1965

Plate 1, fig. 7

Ammobaculoides mosbyensis Eicher: Eicher, 1965, p. 869, pl. 104, figs. 13–15; Eicher and Worstell, 1970, p. 281, pl. 1, figs. 8–10; Eicher in Kauffman et al., 1978, pl. 1, figs. 14a,b; O. Korchagin, 1989, p. 28, pl. IV, figs. 3–4, 8, 11. 17.

Remarks. Tests from the Tajik depression referred to this species are closely similar to those from the middle–upper Cenomanian of the Western Interior Basin of North America [*Eicher and Worstell,* 1970].

Occurrence and age. *A. mosbyensis* occurs universally in the clays of the middle–upper Cenomanian Gazdagana Formation and its analogues in the Tajik depression, southwestern offsets of the Gissar Range, northern Afghanistan, and Mountainous Badkhyz. In the Mountainous Badkhyz it occurs together with the marker middle-upper Cenomanian planktonic foraminifer *Rotalipora cushmani* (Morrow). The last findings of the species are associated with the *Sciponoceras gracile* Zone in the Koikitau section.

Ammobaculoides suleymanovi O. Korchagin, sp. nov.

Plate 1, figs. 8 and 9

Ammobaculoides mosbyensis Eicher, 1965 (partly): O. Korchagin, 1989, p. 28 [*Korchagin,* 1989].

Named for a noted geologist and micropaleontologist Dr. I. S. Suleymanov.

Holotype No 61-1, Lower Turonian, Koikitau section; paratype No 61, Koikitau section, Sample 3983/3.

Description. Test elongate; early coiled portion wider than subsequent biserial and uniserial portions; coil semi-involute, composed of 7 to 8 chambers in final whorl; outline smooth or slightly serrate, chambers in final whorl gradually increasing in size, trapezoidal; among last 4 or 5 chambers of the final whorl each subsequent chamber is slightly raised above the previous one; septal sutures straight, depressed, beveled; periphery angularly rounded; biserial portion symmetrical with respect to coil or slightly offset to one side of the test, consists of two rows of 2–4 weakly convex trapezoidal chambers; uniserial portion is less thick than biserial, composed of one or two chambers; aperture rounded, terminal on a low neck; wall hyalineous, finely grained, acid (HCl) insoluble.

Dimensions: Holotype (Plate 1, fig. 8): length is 0.37 mm, coil width is 0.14 mm; paratype (Plate 1, fig. 9): length is 0.14 mm, coil diameter is 0.10 mm.

Material. Several tests in the collection; the species is common in the samples from different regions of the Tajik depression.

Remarks. *A. suleymanovi* differs from *A. mosbyensis* in an angularly rounded periphery and in a serrate rather than smooth outline of planispiral portion of the test.

Occurrence and age. *A. suleymanovi* commonly occurs in the middle–upper Cenomanian clays; it disappeared in the lower Turonian *Sciponoceras gracile* Zone in the Tajik depression, intermontane depressions of southern Tien Shan, and in southwestern offsets of the Gissar Range.

Superfamily Verneuilinacea Cushman, 1911
Family Verneulinidae Cushman, 1911
Subfamily Verneuilinoidinae Suleymanov, 1973

Genus *Gaudryinopsis* Podobina, 1975

Gaudryinopsis costatus (O. Korchagin), 1989

Plate 1, figs. 2a–b, 3

Gaudryina costata O. Korchagin: O. Korchagin, 1989, p. 33, pl. IV, figs. 14 a, b [*Korchagin,* 1989].

Remarks. *G. costatus* is characterized by the presence of a distinct, small triserial portion and an elongate biserial one composed of tightly arranged, equal in size chambers with the surface covered by massive, yellowish, translucent, hyalineous transverse ribs; test is acid (HCl) insoluble.

Occurrence and age. *G. costatus* was found in northern Tajik depression in the middle Cenomanian; in southern Tajik depression and southwestern offsets of the Gissar Range, commonly in the *Sciponoceras gracile* Zone and overlying lower Turonian sediments.

Subfamily Gaudryininae Balakhmatova, 1973

Genus *Gaudryina* d'Orbigny, 1936

Gaudryina (*Siphogaudryina*) *quadrans* Cushman, 1936

Plate 1, fig. 1

Gaudryina quadrans Cushman: Cushman, 1936, p. 6, pl. 1, fig. 12; 1946, p. 35, pl. 8, figs. 2, 3 [*Cushman,* 1936]; Frizzell, 1954; p. 71, pl. 5, fig. 29 [*Frizzell,* 1954]; Tronchetti, 1981, pp. 53–54, pl. 12, figs. 7, 8 [*Tronchetti,* 1981]; O. Korchagin, 1989, p. 31–32, pl. V, fig. 2 [*Korchagin,* 1989]. *Gaudryina* cf. *Gaudryina quadrans* Cushman: Eicher, Worstell, 1970, p. 282, pl. 1, figs. 1–2 a, b [*Eicher and Worstell,* 1970].

Remarks. Specimens that we refer to *G.* (*Siphogaudryina*) *quadrans* Cushman from the Tajik depression, are identical to those described as *Gaudryina* cf. *Gaudryina quadrans* Cushman from the *Sciponoceras gracile* Zone and overlying lower Turonian sediments in the Western Interior Basin of North America [*Eicher and Worstell,* 1970].

Occurrence and age. *G.* (*Siphogaudryina*) *quadrans* is common in southern Tajik depression and southwestern offsets of the Gissar Range and are characteristic of the

Sciponoceras gracile Zone, overlying lower Turonian, and lower middle Turonian sediments.

Suborder Globigerinina Delage et Herouard, 1896

Superfamily Rotaliporacea Sigal, 1958
Family Hedbergellidae Loeblich et Tappan, 1961
Subfamily Concavatotruncaninae O. Korchagin and V. Korchagin, 2001

Genus *Bollitruncana* O. Korchagin, 2001

Bollitruncana baissunensis (V. Korchagin, 1967), 1998

Plate 4, figs 1a–c

Dicarinella baissunensis V. Korchagin, 1998: V. Korchagin, 1998, p. 31–32 [*Korchagin,* 1998].

Remarks. B. baissunensis (V. Korchagin) is characterized by sharply asymmetrical test, flattened from spiral side and angularly globularly convex from umbilical side, with 5–5.5 chambers in final whorl and two massive, offset to spiral side keels; as well as by raised supraumbilical and near-septal "bolsters" from the umbilical side of the test.

Dimensions (Plate 4, figs. 1a–c). Greater diameter: 0.47 mm; smaller diameter 0.35 mm; thickness: 0.26 mm.

Occurrence and age. B. baissunensis is an index species of the lower Turonian zone in the southern Tajik depression, southwestern offsets of the Gissar Range, and northern Afghanistan.

Bollitruncana mandelshtamia O. Korchagin and V. Korchagin, sp. nov.

Plate 4, fig. 2a–c

Named for a noted micropaleontologist Prof. M. I. Mandelshtam.
Holotype No 176, southwestern offsets of the Gissar Range, Aktag section, lower Turonian.

Description. Test low trochospiral consisting of two whorls, asymmetrical, strongly flattened from spiral side and convex from umbilical side; 4, rarely 4.5 chambers in final whorl; chambers flattened or slightly concave from spiral side, angularly globular from umbilical side, gradually increasing in size; sutures from spiral side beveled, elevated, curved, from umbilical side, depressed, straight, in last 3 chambers bordered by raised hyalineous "bolsters"; outline slightly lobate, oval quadrangular; along chambers' periphery two tightly arranged massive knobby parallel keels extend, offset to spiral side; surface of chambers from spiral side smooth, covered with scarce non-oriented spines, from umbilical side uniformly medium-spinose; umbilical area small, medium-sized; occupies from one-third of chamber diameter; aperture umbilical-extraumbilical, slitlike, screened by protruding, poorly preserved portici.

Dimensions (Plate 4, fig. 2a–c). Greater diameter: 0.46 mm; smaller diameter: 0.32 mm; thickness: 0.17 mm.

Remarks. B. mandelshtamia differs from *B. baissunensis* (V. Korchagin) in smaller test, less number of chambers in final whorl, and in oval quadrangular outline.

Material. About 10 tests.

Occurrence and age. B. mandelshtamia appeared in the *Sciponoceras gracile* Zone and occurs in the overlying lower Turonian sediments in the southern Tajik depression, southwestern offsets of the Gissar Range, and northern Afghanistan.

Suborder Rotaliina Delage et Herouard, 1896
Superfamily Anomalinacea Cushman, 1927
Family Gavelinellidae Hofker, 1956

Genus *Gavelinella* Brotzen, 1942

Gavelinella berthelini (Keller, 1935)

Plate 2, figs. 11a–c, 12a–c

Anomalina berthelini Keller: *Keller* [1935, p. 552, pl. 2, figs. 25–27];
Anomalina (*Pseudovalvulineria*) *berthelini* (Keller): *Vassilenko* [1954, pp. 105–106, pl. XIV, figs. 3a–c, 4a–c];
Gavelinella (*Berthelina*) *berthelini* (Keller, 1935): Gawor-Biedowa, 1982, pl. 20, figs. 7-9 (see synonymy).

Hypotype No 149, lower Turonian, *Praebulimina reussi* Zone, Koikitau section.

Remarks. The reported specimens of *G. berthelini* (Keller) are identical to those described by N. K. Bykova from the lower Turonian of the southwestern offsets of the Gissarskii Range [*Vassilenko,* 1954, pl. XIV, fig. 4a–c]. The studied specimens differ from that holotype in greater number of chambers, 9–11 instead of 8–9, in final whorl, and in more subacute periphery. It should be noted that the specimens referred to *G. berthelini* [*Keller,* 1939], differ greatly from the holotype and most likely should be assigned to different species.

Occurrence and age. G. berthelini is widespread in the lower Cenomanian–middle Turonian sediments in Western Europe (England), the Caucasus, Mangyshlak, and Central Asia. The flourishing of its members occurred in the late Cenomanian and early Turonian. In certain regions *G. berthelini* is used as the index species of the zone recognized in the upper Cenomanian. I emphasize that it may be wider distributed than is now considered. For instance, the illustrated specimens from the boundary Cenomanian–Turonian beds on the Kergulen Plateau near the Antarctica, which were referred to *Gavelinella dakotensis* [*Holbourn and Kuhnt,* 2002], in our opinion, are morphologically closer to the typical *G. berthelini* than to *G. dakotensis.*

Gavelinella rovikensis O. Korchagin, sp. nov.

Plate 2 , figs. 14a–c, 15

Name derived from the place where the species was first found: in the Rovik Creek valley in southwestern Darvaz.

Lectotype No 12, upper Cenomanian, *Gavelinella rovikensis* beds, southwestern Darvaz, Khodzhafarang section.

Description. Test hood-shaped; from umbilical side flattened or slightly concave, from spiral side convex with distinctly protruding conical hyalineous knob; widely rounded or slightly oval rounded; consisting of 2–2.5 whorls; early whorl constitutes one-fourth to one-fifth of chamber diameter; in final whorl 7–8 trapezoidal, gradually increasing chambers; septal sutures from spiral side straight, beveled, from umbilical side curved, beveled; early whorls are hidden under conical hyalineous knob; umbilical area wide, shallow, partly screened by supraumbilical flaps; periphery subacutely rounded; aperture interiomarginal slitlike with a short flap covering aperture and partly umbilical area; wall calcareous, smooth, finely perforate.

Dimensions. Diameter is 0.27 mm; thickness is 0.12 mm.

Variability. Variable characters of the species are a height of spiral hyalineous knob and sometimes a test outline, from rounded to oval rounded.

Remarks. G. rovikensis differs from *G. vesca* (N. Bykova) in a presence of well-pronounced hyalineous knob on spiral side; from *G. vesca* var. *senekensis* (Vassilenko) in less number of chambers in final whorl, a higher hyalineous knob on spiral side, and in a wider umbilical area.

Occurrence and age. G. rovikensis O. Korchagin, sp. nov. occurred in the upper Cenomanian; in a greater number it was found in southwestern Darvaz and somewhat rarer, in the Tajik depression and southwestern offsets of the Gissar Range.

Syperfamily Turrilinacea Cushman, 1927

Family Turrilinidae Cushman, 1927

Genus *Praebulimina* Hofker, 1953

Praebulimina aktagi (N. Bykova), 1945

Plate 2, figs. 8a–c; 9a–c; 10a,b

Bulimina aktagi N. Bykova, sp. nov.: Bykova, 1945 [*Upper Cretaceous stratigraphy and foraminifer fauna of the Bukhara region,* Part 1 (manuscript), pl. VII, fig. 12a–c].

Name derived from the Aktag section in the southwestern offsets of the Gissar Range where it was first found.

Lectotype No 159-3, lower Turonian, *Praebulimina aktagi* Zone (lower part of the *Gavelinella berthelini* beds); Koikitau section.

Description. Test small, oval subacute in early portion and strongly widening towards apertural margin; consisting of 4 whorls; chambers are tightly arranged, trapezoidal, low and wide; chambers of the last 2 whorls rapidly increasing and constituting two-thirds of test length; each whorl is composed of 3 chambers; septal sutures depressed, beveled; spiral suture distinctly depressed; septal surface of the last chamber oval convex; outline slightly lobate; in cross-section test oval rounded; aperture a high loop at the base of final chamber; wall calcareous, smooth, finely perforate.

Dimensions. Lectotype No 159-3 (Sample 3983/3) (Plate 2, fig. 10a,b): length 0.19 mm, width 0.15 mm.

Material. Several well-preserved tests.

Occurrence and age. P. aktagi is limited to the *Sciponoceras gracile* Zone in the Tajik depression, southwestern offsets of the Gissar Range, and northern Afghanistan.

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