

# Inoceramid and foraminiferal record and biozonation of the Turonian and Coniacian (Upper Cretaceous) of the Mangyshlak Mts., western Kazakhstan

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## ABSTRACT:

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The Turonian and Coniacian (Upper Cretaceous) of the Mangyshlak Mts., western Kazakhstan, yielded a rich and relatively complete inoceramid bivalve record. The faunas and their succession correspond to those known from central and eastern Europe, allowing the zonation established in the latter areas to be applied in a virtually identical form. The gaps in the record of the group in Mangyshlak stem from the regional hiatuses in the geological record in the area and do not reflect any biogeographical differences between eastern and central-western Europe. Planktonic foraminifera are rare. Four successive interval range zones can be distinguished: in ascending stratigraphic order, the *Helvetoglobotruncana helvetica*, *Marginotruncana pseudolinneiana*, *Marginotruncana coronata*, and *Concavotruncana concavata* zones. Their correlation with the inoceramid zonation and, consequently, with the chronostratigraphic scheme, is demonstrated. The zonation and chronostratigraphic subdivision as applied in Mangyshlak may easily be applied to other areas of the peri-Caspian region (Caucasus, Tuarkyr, Kopet-Dagh, SE margin of the East-European Craton).

**Key words:** Cretaceous; Turonian; Coniacian; Mangyshlak; Biostratigraphy; Inoceramid bivalves; Foraminifers; Correlation; North European biogeographic Province.

## INTRODUCTION

The Cretaceous of western Central Asia, including Mangyshlak, has long been recognized to be a part of the European biogeographic Province (Naidin 1959) (= North European Province of Kauffman 1973) and, consequently, the successions of faunas in the rest of central and western Europe are expected to have thrived all over the region, at least during the Late Cretaceous

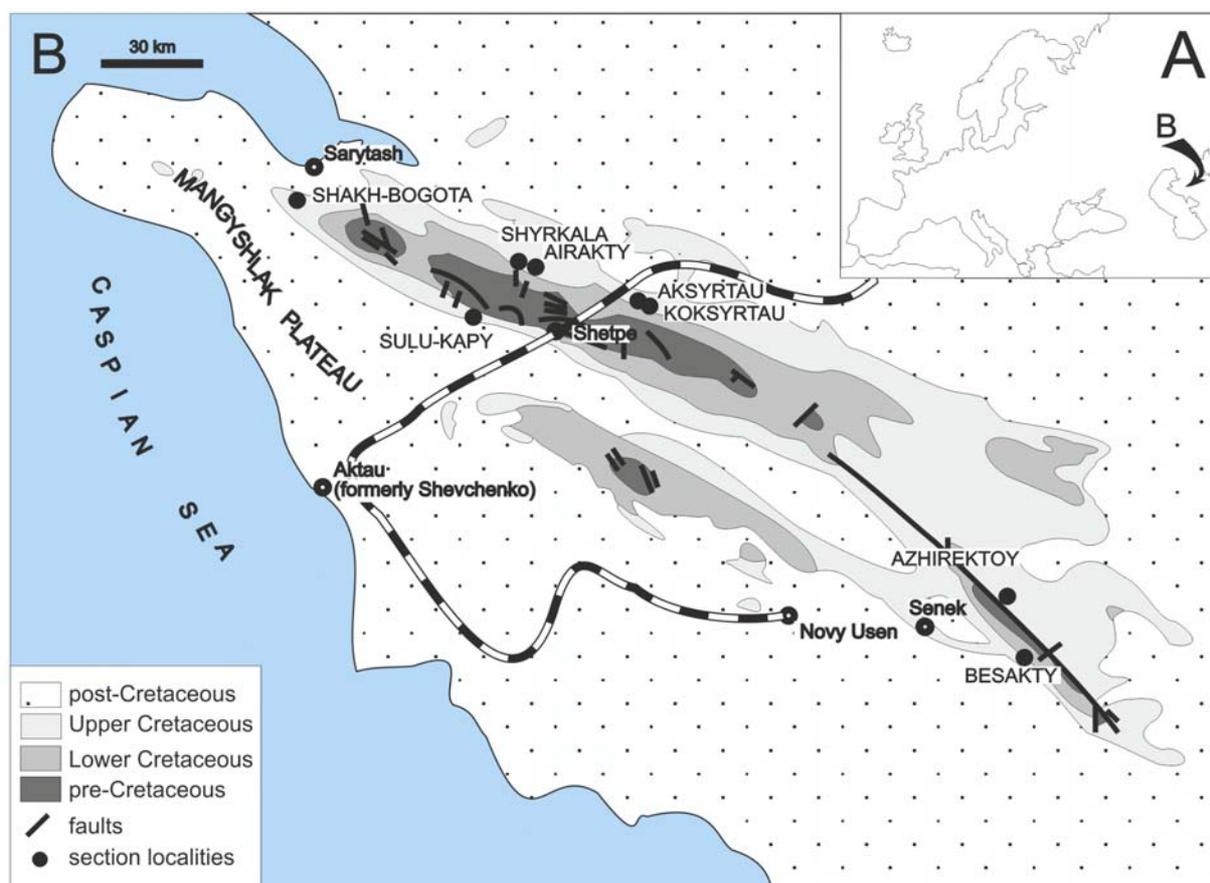
epoch. However, in comparing the reports, e.g., on the inoceramid bivalves, from various areas of the peri-Caspian region, as well as of the south-eastern margin of the Russian Platform, with those from regions farther to the west (central and western Europe), remarkable differences appear. For instance, the number of new, formally described inoceramid taxa [not to mention those that are only listed and never described] from the Caucasus or other peri-Caspian areas, but never reported

from central or western Europe, is remarkably long. Does this result simply from differences in the taxonomic approaches of the specialists working in these two regions, or is it really a reflection of actual biogeographic differences between the two parts of the North European province? This difference was explicitly interpreted as an actual phenomenon in a series of recently published reports (e.g., Kharitonov *et al.* 2003, 2007). The data provided, as well as their interpretation, are not convincing at all, hence we decided to provide the results of our study on sections from a single region, which clarifies at least part of the record.

Our paper provides a detailed description and discussion of the inoceramid and foraminiferal records of the Turonian and Coniacian (Upper Cretaceous) of the Mangyshlak Mountains, western Kazakhstan, one of the key areas for the biostratigraphy of the whole peri-Caspian regions (Caucasus, Mangyshlak, Turakyr, Kopet-Dagh and the south-eastern margin of the Russian Craton). The results are based on the collections and samples gathered by IW and LFK during the 1992 expedition to the area (led by Ryszard Marcinowski) and additional material collected by the senior author during the second Mangyshlak expedition

in 1999. The bed-by-bed inoceramid collections precisely tied to foraminiferal samples give the opportunity of tracing the detailed record of both groups in the area. References to other peri-Caspian areas are provided. Preliminary results of the study of the inoceramid material collected in 1992 were presented in the 1996 report of the first expedition (Marcinowski *et al.* 1996) and in an earlier report by Naidin *et al.* (1984); the reports on foraminifers are contained in Naidin *et al.* (1984), as well as in Kopaevich (1989); Naidin *et al.* (1994); Kopaevich (1996); Kopaevich *et al.* (1999); Baraboshkin *et al.* (2003); Alekseev *et al.* (2007); Kopaevich *et al.* (2007); Beniamovski (2008); and Kopaevich (2010, 2011)

Foraminiferal material illustrated herein is housed in the Department of Regional Geology and Earth History, of the Geological Faculty of the Lomonosov Moscow State University, collection numbers 2010 MSU/5, No2011MSU/6 (planktonic foraminifers), and in the Department of Micropalaeontology of the Geological Institute of the Russian Academy of Sciences, collection number 2007GINRAS/4 (benthic foraminifers); the inoceramid material is housed in the Museum of the Faculty of Geology of the University of Warsaw.



Text-fig. 1. Geological sketch-map of the Mangyshlak Anticlinorium with location of the referenced sections (after Marcinowski *et al.* 1996, changed)

## GEOLOGICAL SETTING AND LOCALITY DETAILS

The Mangyshlak Mountains (western Kazakhstan), apart from Tuarkeyr and Kopet Dag in western Turkmenistan, are one of the main areas in western Central Asia with well exposed and easily accessible Upper Cretaceous strata (Text-fig. 1). The Upper Cretaceous in Mangyshlak crops out along the flanks of the NW-SE running, late Neogene Central Mangyshlak Anticlinorium (e.g. Muromitzev 1973), composed of Jurassic, Cretaceous and Cenozoic strata. The Cretaceous represents part of the sedimentary cover of the Turan Platform, which ranges between the Pericaspian Depression in the north and the Transcaspian Alpine deformation zone in the south (Stampfli *et al.* 2001; Natalin and Sengör 2005).

The Turonian–Coniacian succession in Mangyshlak shows a distinct twofold facies development (Text-figs 2–4): a lower siliciclastic unit (composed mainly of sands and sandstones) of Early and earliest Middle Turonian age; and an upper carbonate unit of Late Turonian–Coniacian age. There is a marked unconformity between the two units, developed usually as a hardground, accompanied by a phosphatic horizon. A stratigraphic gap, comprising most of the Middle Turonian and ranging possibly into the lowermost Upper Turonian, is associated with the unconformity. The combined thickness of both units is relatively small. In the Shakh-Bogota section, where the Turonian–Coniacian succession is the most expanded, it reaches 80 m, but it decreases very fast eastward, and in the Aksyrtau-Koksyrtau section, which is only 60 km east of Shakh-Bogota, it is only 48 m, and in the Besakty section, in the eastern part of the Mangyshlak Mts., it does not exceed 2 m. Additionally, most of the succession throughout Mangyshlak is represented by the lower siliciclastic unit, which comprises the Lower Turonian and lowermost Middle Turonian, with both the Upper Turonian and Coniacian much thinner, rarely exceeding 20 m.

During the Cenomanian–Middle Turonian, the depocentre migrated gradually from SE to NW (Marcinowski *et al.* 1996), with the most complete record of the Turonian and Coniacian located in the NW part of the area, close to the Caspian sea (see Marcinowski *et al.* 1966, fig. 14). Consequently, the basic sections referred to herein are those from the latter area: Shakh-Bogota, Sulu-Kapy and Koksyrtau-Aksyrtau (Text-fig. 1). The sections from the SE part of the area (Azhirektoy and Besakty; Text-fig. 1; see also Marcinowski *et al.* 1966, fig. 14) are of lesser importance in the detailed study of the Turonian–Coniacian succession.

The details of particular sections are given in Marcinowski *et al.* (1996). What follows herein are the de-

tails of the inoceramid and foraminiferal successions in the Shakh-Bogota, Aksyrtau-Koksyrtau, and Sulu-Kapy sections (Text-figs 2–4).

## INOCERAMID SUCCESSION

Among the sections studied herein, the inoceramid succession of the Turonian and Coniacian is best represented in the Shakh-Bogota section. This is particularly the case in the Upper Turonian–Coniacian parts, which provide the most complete record in the whole area of Mangyshlak (Text-fig. 2). This section does not provide any information on the Lower Turonian record, the latter being based on the Shyrkala-Airakty, Aksyrtau-Koksyrtau and Sulu-Kapy sections (Text-figs 3, 4). Representative inoceramids are illustrated in Plates 1–10.

## Lower and basal Middle Turonian

In the Shakh-Bogota section, no Early Turonian inoceramids were found by the authors in either the 1992 or the 1999 expedition (see Marcinowski *et al.* 1996). This corresponds to the observations by Naidin *et al.* (1984, p. 14, fig. 2). However, early Turonian *Mytiloides* is well represented in all of the other sections studied in the western part of Mangyshlak (see Naidin *et al.* 1984; Marcinowski *et al.* 1996): the Shyrkala-Airakty, Aksyrtau-Koksyrtau and Sulu-Kapy sections.

The best record is known from the Aksyrtau-Koksyrtau section (see Marcinowski *et al.* 1996, text-fig. 9). The lowermost part of the succession (beds 29–31; see Text-fig. 3) is characterized by *Mytiloides goppelnensis* (Badillet and Sornay, 1980) (with forms transitional between *M. goppelnensis* and *Mytiloides puebloensis* Walaszczyk and Cobban, 2000) and *Mytiloides hattini* Elder 1991, indicating the very early Early Turonian (Pl. 1, Figs B, C, F). The main part of the succession is composed of *Mytiloides mytiloides* (Mantell, 1822), *Mytiloides kossmati* (Heinz, 1930) and/or *M. goppelnensis* (see Pl. 1, Figs A, D) the typical assemblage of the *Mytiloides mytiloides* Zone of Kennedy *et al.* (2000). In the 1999 expedition, specimens of the *subhercynicus-hercynicus* group (see Pl. 1, Figs E, G) were found in the topmost part of the Shyrkala-Airakty section. This confirms the earlier reports of Naidin *et al.* (1984) of this species group from both the Sulu-Kapy and Aksyrtau-Koksyrtau sections. The topmost part of the sandy unit throughout western Mangyshlak (bed 10 in the Shakh-Bogota section; bed 16 in the Sulu-Kapy section and beds 28–36 in the Aksyrtau-Koksyrtau sections; see Text-figs 2–4) is thus of early Middle Turonian age.

### Middle Turonian

The Middle Turonian, with the exception of its lowermost part (*M. subhercynicus* Zone) is missing in the area. This may to a large extent be interpreted by subsequent, pre-Late Turonian erosion, as recorded in the discontinuity surface at the base of the overlying carbonate unit (phosphatic horizon V of Marcinowski *et al.* 1996).

### Upper Turonian–Coniacian

The sandy unit of the Lower and basal Middle Turonian is overlain by the carbonate succession. The boundary is a composite discontinuity surface, with hardgrounds, omission surfaces, phosphatic horizons and reworking. Based on the inoceramid record, this boundary unconformity is associated with a stratigraphic gap spanning most of the Middle Turonian; only the lowermost part of the substage is present in the topmost part of the sandy unit below. The basal part of the carbonate unit is of Late Turonian age.

In the Shakh-Bogota section, the Upper Turonian–Coniacian succession is almost 40 m thick, and it is the most expanded and most complete succession of this age in the region. Consequently, the discussion which follows is based primarily on this record (Text-fig. 2). Supplementary data from other sections are indicated.

The succession starts with an assemblage composed of huge representatives of *Inoceramus* ex gr. *lamarcki* Parkinson, 1818 (Plate 2), representatives of the *Inoceramus inaequalis* Schlüter, 1877 group (Pl. 3, Figs F–J; Pl. 5, Fig. E), and small early ?*Mytiloides costellatus* (Woods, 1912) (Pl. 3, Fig. D; Pl. 5, Fig. J).

In Shakh-Bogota, this assemblage starts in bed 12, immediately above the phosphatic horizon capping the 38 m thick Early Turonian sandy unit (see (Text-fig. 2 and Marcinowski *et al.* 1966, fig. 3). Bed 13 is rather poor in inoceramids; a single *I. inaequalis* and a fragment possibly of *Mytiloides mytiloidiformis* (Tröger, 1967) were found. The same assemblage is known from the Sulu-Kapy section, from beds 18–19 (Text-fig. 3). In other sections this interval is missing.

This lowermost assemblage is followed by an horizon with a mass occurrence of *Mytiloides striatoconcentricus* (Gümbel, 1868) (Pl. 3, Fig. E; Plate 4). The index taxon is associated with *Mytiloides labiatoidiformis* (Tröger, 1967), *Inoceramus longevalatus* Tröger 1967 (Pl. 5, Figs A–D, F–H) and *I. inaequalis*. This horizon is known only from the Shakh-Bogota section, from bed 14b. It is evidently of secondary origin; associated with the hardground it possibly represents a series of (?storm-generated) redeposition events. Inoceramids of the *M. striatoconcentricus* horizon continue

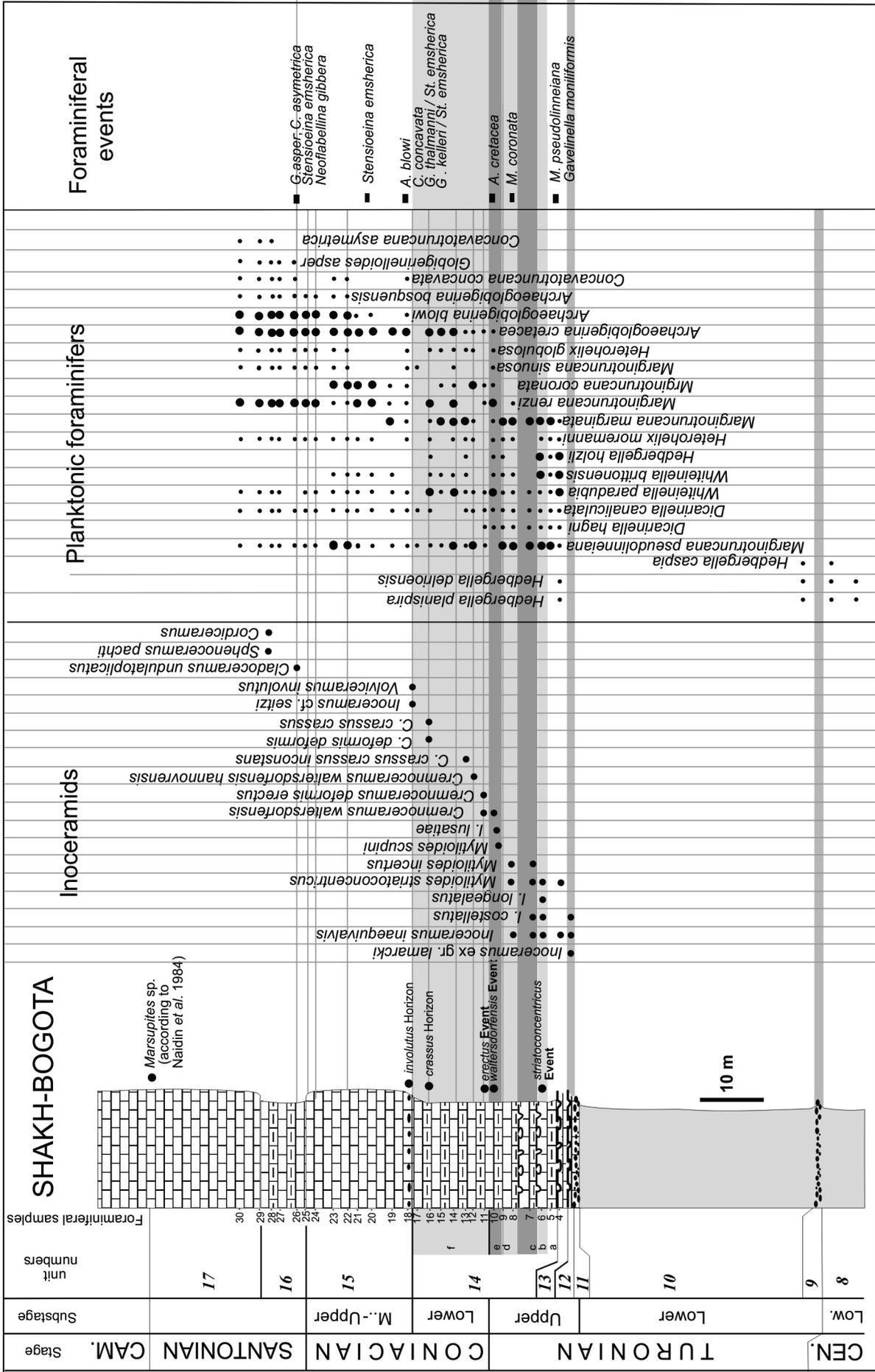
higher, in units 14c and d, where they are accompanied by *Mytiloides incertus* (Jimbo, 1894) (Text-fig. 2 and Pl. 3, Fig. 3). Again, this assemblage is known only from the Shakh-Bogota section.

After the succeeding interval in which inoceramids are rare, inoceramids re-appear in abundance in the Turonian/Coniacian boundary inoceramid succession. The succession is composed of a series of closely spaced horizons, with swiftly evolving assemblages, represented commonly by mass-occurrences. The succession (Text-fig. 2) starts with (1) an assemblage of *Mytiloides scupini* (Heinz, 1930) (Pl. 6, Fig. A) and *Mytiloides herbichi* (Atabekian, 1969), associated with common *Didymotis* (Pl. 8, Fig. A). It is followed by (2) an almost monospecific assemblage of *Inoceramus lusatae* Andert, 1911 (Pl. 6, Fig. C; Pl. 7, Fig. B) similarly as in the Słupia Nadbrzeźna section, and possibly in the Sonnenberg section at Waltersdorf (see Wood *et al.* 2004) and then by (3) an almost monospecific assemblage of *Cremnoceramus waltersdorfensis waltersdorfensis* (Andert, 1911), accompanied by *Didymotis*. Immediately above the *C. walt. waltersdorfensis* horizon appears the first *Cremnoceramus deformis erectus* (Meek, 1877) (Pl. 5, Figs O, P; Pl. 8, Figs B, F) which, slightly higher, forms an abundance horizon, which may be referred to (4) the *C. deformis erectus* Event (see Text-fig. 2). Still higher there is an horizon with common *Cremnoceramus waltersdorfensis hannovrensis* (Heinz 1932) (Pl. 5, Figs I, K–N), which seems to correspond to (5) the *hannovrensis* Event, known from western and central Europe. In the Sulu-Kapy, Shyrkala-Airakty, Kush and Koksyrtau-Akyrtau sections, the Turonian–Coniacian inoceramid succession is much less complete; still farther to the east, e.g., in the Besakty section, the whole boundary interval is contained within an expanded composite hardground horizon (bed 42 in Marcinowski *et al.* 1996, fig. 12).

The first *Cremnoceramus crassus inconstans* (Woods, 1912) appears distinctly higher, associated with forms of the *Cremnoceramus waltersdorfensis* lineage. The record was documented in the Shakh-Bogota section, where *C. crassus inconstans* appears c. 3 m above the *hannovrensis* Event.

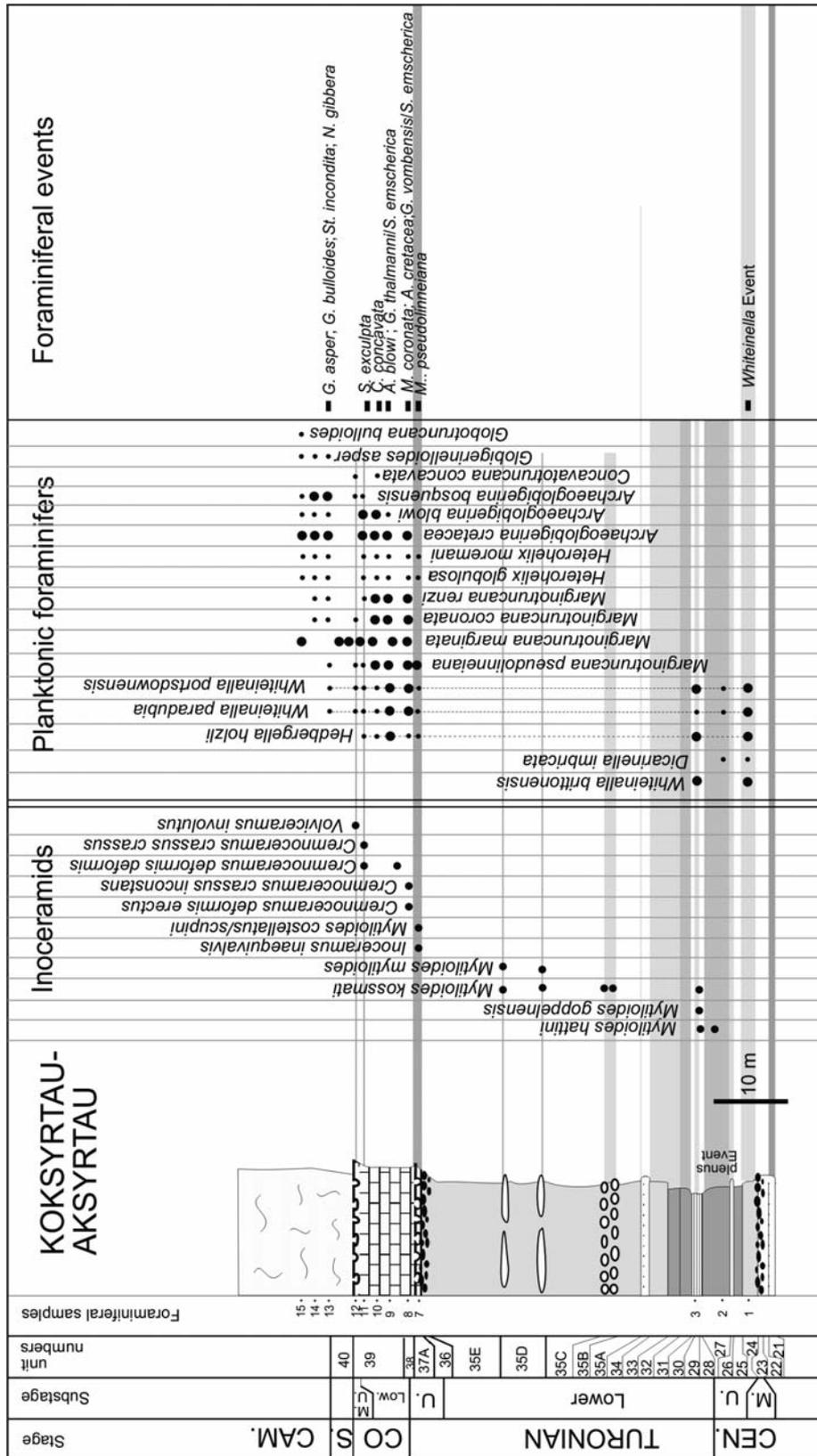
Another 10.5 m higher there is an horizon with common huge *Cremnoceramus deformis deformis* (Meek, 1877) and *Cremnoceramus crassus crassus* (Petrascheck, 1903) (Plate 9). Associated forms are *Inoceramus seitzii* Andert, 1934 and *Tethyoceramus* sp. (Pl. 8, Fig. C)

Higher up in the Coniacian inoceramids become rare. Above the *crassus* Horizon, there is a distinct erosion surface with phosphatic nodules and large inoceramids. Those identified are invariably volviceramids.

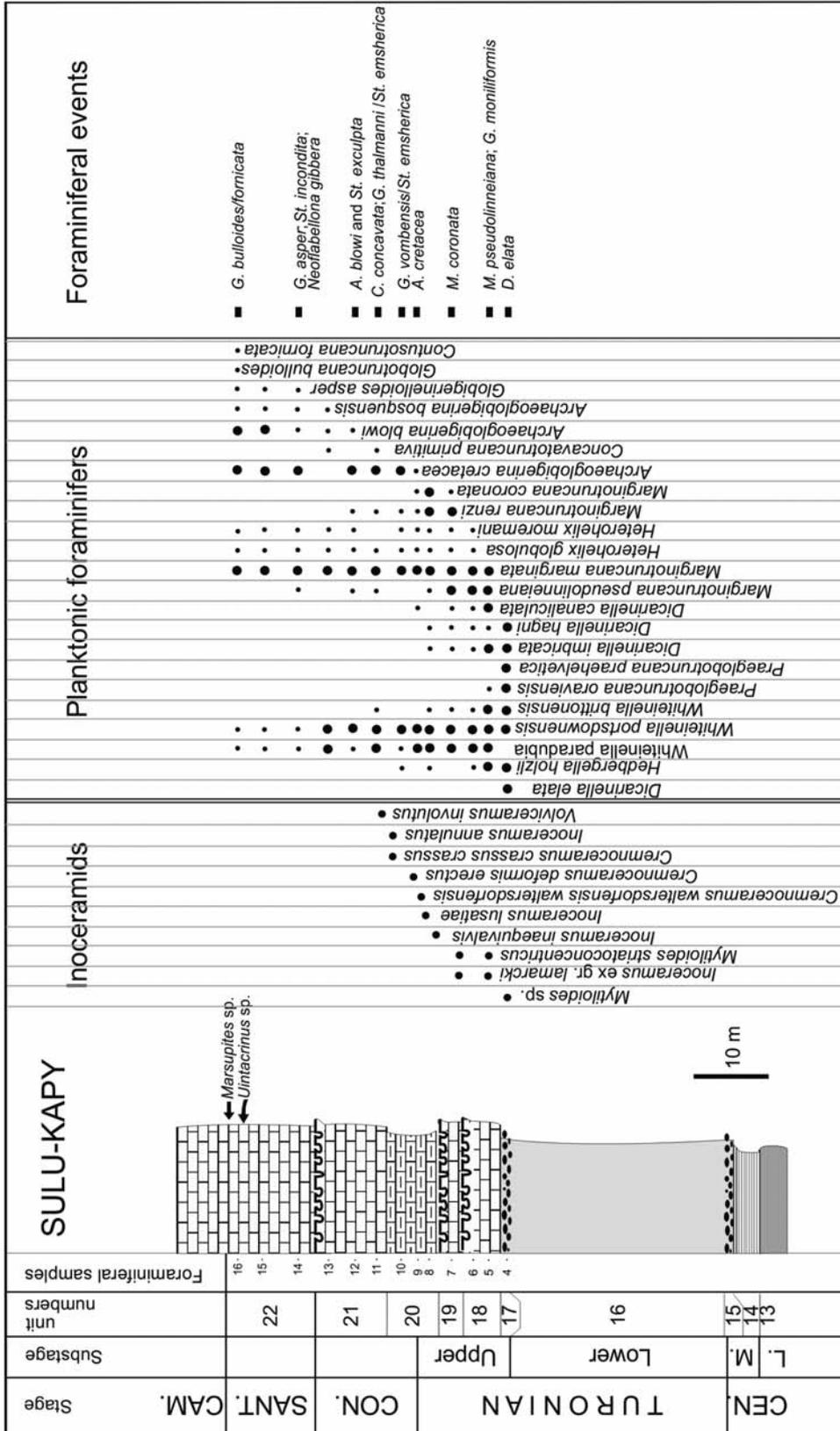


Text-fig. 2. Geological log, chronostratigraphy, and inoceramid and foraminiferal ranges and zonation in the Shakh-Bogota section, western Kazakhstan (geological log and lithological units after Marciniowski et al. 1996)

UPPER CRETACEOUS OF MANGYSHLAK, WESTERN KAZAKHSTAN



Text-fig. 3. Geological log, chronostratigraphy, inoceramid and foraminiferal ranges and zones in the Akysrtau-Koksyrtau section; western Kazakhstan (geological log after Marcinowski *et al.* 1996)



Text-fig. 4. Geological log, chronostratigraphy, inoceramid and foraminiferal ranges and zones in the Sulu-Kapy section; western Kazakhstan (geological log after Marciniowski et al. 1996)

## UPPER CRETACEOUS OF MANGYSHLAK, WESTERN KAZAKHSTAN

Identified to species level is *Volviceramus involutus* (J. de C. Sowerby) (Plate 10), represented by quite advanced forms, indicating the higher parts of its range (Text-fig. 2).

In the succeeding 17.0 m thick chalk unit (unit 15 – see Text-fig. 2) inoceramids are rare. No specimens were found *in situ*. Some loose specimens from the unit are *Volviceramus* sp., and a single form resembling the Late Coniacian *Inoceramus anomalus* Heine, 1929. Others are too poorly preserved to be identified.

In the overlying marly unit of bed 16, ca. 3.4 m above its base, there is an horizon with detritus of *Cladoceramus*, marking the base of the Santonian stage. In the topmost part of the bed an assemblage of Santonian forms, including *Cordiceramus* sp. and *Sphenoceramus pachtii* (Arkhangelsky), was found.

## FORAMINIFERAL RECORD

The best foraminiferal record comes from the Shakh-Bogota, Aksyrtau-Koksyrtau and Sulu-Kapy sections, and is presented in detail in Text-figs 2–4. Foraminiferal ranges are precisely tied to inoceramid occurrences, and the abundance data are given. In total, fifty-five samples were studied for planktonic and benthic foraminifera. Foraminifera were obtained by standard maceration procedure; rock samples were disaggregated with Na<sub>2</sub>SO<sub>4</sub>, and clayey samples were boiled with NaHCO<sub>3</sub>. Specimens larger than >150 µm were picked and all specimens identified; plankton/benthos ratios were calculated (Text-figs 2–4). Specimens of selected species are illustrated in Plates 11–15. The classification follows Robaszynski *et al.* (1979), Caron (1985), Loeblich and Tappan (1987), Korchagin (2003) and Premoli Silva and Verga (2004). All photographs were taken on the SEM in the Borissiak Paleontological Institute of the Russian Academy of Sciences, Moscow.

Foraminifera are present throughout the Cenomanian–Santonian succession in Mangyshlak, with remarkable fluctuations in their quantity and taxonomic richness from bed to bed. They are rare to absent in the siliciclastic Cenomanian–Lower Turonian sediments; abundant across the Turonian–Coniacian boundary (with a distinct increase in the P/B ratio), and common in the rest of the interval studied. The material is well preserved in the marlstones and moderately well preserved in the limestones. The assemblages are dominated by benthic forms, which provide the basis for the regional zonal scheme. The benthic foraminifera from Mangyshlak were widely discussed previously (Naidin *et al.* 1984; Kopaevich *et al.* 2007; Beniamovski 2008;

Beniamovski *et al.* 2013 and literature cited therein) and consequently the discussion herein is focused on planktonic forms. Of the benthic foraminifera only the biostratigraphically important genera, *Gavelinella*, *Stensioeina* and *Neoflabellina*, are documented in Plates 14 and 15.

## Planktonic foraminiferal assemblages

In the studied succession the planktonic foraminifera are of low to moderate diversity. In spite of this, twenty-five species are recorded (Text-figs 2–4). They are represented mainly by pandemic hedbergellids and whiteinellids and double-keeled, flat marginotruncanids (see Text-figs 11–13).

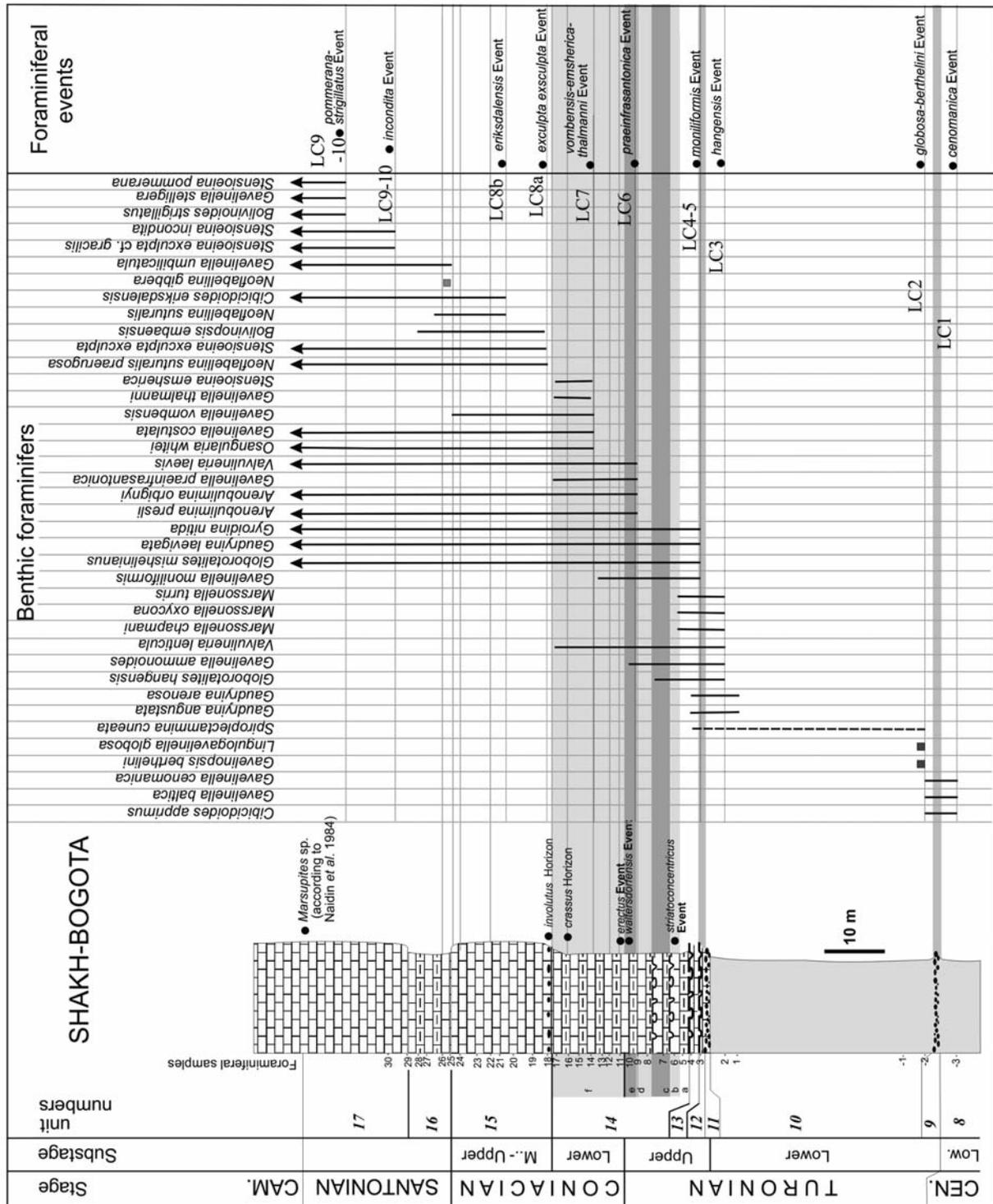
The Lower (and in places basal Middle) Turonian intervals of the sections studied are devoid of planktonic foraminifera. However, in Bed 17 of the Sula-Kapy section, Late Turonian whiteinellids, hedbergellids and heterohelicids co-occur with Early Turonian *Dicarinella elata* Lamolda, *Praeglobotruncana oraviensis* (Scheibnerova) and *P. praeheuverica* (Trujillo), which are clearly redeposited. This suggests that the absence of planktonic foraminifera in the Lower–lowermost Middle Turonian siliciclastics is due to taphonomic factors and does not reflect their original absence from the area during the Early Turonian.

Planktonic foraminifera are also common in the highest Cenomanian and lowermost Turonian. Due to the incomplete geological record, this interval is rarely represented in the area. Its foraminiferal record is known only from the Aksyrtau-Koksyrtau section. The samples from beds 24–27 of the section, corresponding to the *Praeactinocamax plenus* Zone, yielded *Whiteinella archaeocretacea* Pessagno, *W. paradubia* (Sigal), *W. brittonensis* (Loeblich and Tappan), *W. portsmouthensis* (Williams-Mitchell), *Hedbergella hoelzli* (Hagn and Zeil), rare *Heterohelix globulosa* (Ehrenberg), *H. moremani* (Cushman), and the keeled *Dicarinella hagni* (Scheibnerova) and *D. imbricata* (Mornod).

The Middle and Upper Turonian planktonic foraminiferal assemblages demonstrate an increase in diversity and quantity of keeled and unkeeled planktonic morphotypes. *Whiteinella* species are common to abundant throughout this interval. Keeled species are represented by *Marginotruncana marginata* (Reuss), *M. pseudolinneiana* (Pessagno), *M. coronata* (Bolli), *M. renzi* (Gandolfi), *Dicarinella canaliculata* (Reuss) and *D. hagni* (Scheibnerova). The first *M. pseudolinneiana*, *M. marginata*, and *D. canaliculata* appear in Bed 12 of the Shakh-Bogota section, and at the base of Bed 18 of the Sulu-Kapy section. Other marginotruncanids appear in Bed 13 of the Shakh-Bogota section and in Bed

19 of the Sulu-Kapy section. *Marginotruncana sinuosa* Porthault was found only in the Shakh-Bogota section. Rich marginotruncanids were identified from the base of Bed 38 of the Aksyrtau-Koksyrtau section. The most common is *M. marginata*; much less common are other

double-keeled species, and single-keeled forms were not recorded at all. *M. marginata* dominates in Beds 18–21 of the Sulu-Kapy section; *D. imbricata*, *D. hagni* and *D. canaliculata* occur in the same intervals but they appear earlier in the Aksyrtau-Koksyrtau section (Text-fig. 3),



Text-fig. 5. Geological log, chronostratigraphy, and benthic foraminiferal ranges in the Shakh-Bogota section; LC1 – LC11: Beniamovskii’s (2008) benthic foraminifera zonation for the East European Province of the European Paleobiogeographic Realm; western Kazakhstan (geological log and lithological units after Marcinowski *et al.* 1996)

as well as in the Crimea–Caucasus area (Kopaevich 2009). *C. concavata* occurs sporadically in the middle and upper parts of the interval studied. The genus *Archaeoglobigerina*, represented by *A. cretacea* (d'Orbigny), *A. blowi* Pessagno and *A. bosquensis* Pessagno, is rare to common; *A. cretacea* appears already together with assemblages of flat marginotruncanids; *A. blowi* and *A. bosquensis* are recorded from the middle and upper parts of the interval studied. *Globigerinelloides asper* (Ehrenberg) and *Concavatotruncana asymetrica* (Sigal) occur in the overlying intervals; Bed 16 of the Shakh-Bogota section and Bed 22 of the Sulu-Kapy section. *Globotruncana bulloides* (Vogler) and *Contusotruncana fornicata* (Plummer) were found in the upper part of Bed 22 of the Sulu-Kapy section and from Bed 40 of the Aksyrtau-Koksyrtau section.

### Foraminiferal events

The horizons characterized by mass and/or first occurrences of planktonic and / or benthic taxa are referred herein to as the foraminiferal events. They usually correspond well to critical chrono- and macrobiostratigraphic boundaries (see Text-figs 2–5).

The *Whiteinella* acme Event is noted at the Cenomanian/Turonian boundary and coincides with the [*Praeactinocamax plenus* belemnite Event. It is known only from the Aksyrtau-Koksyrtau section. This event is marked by the sudden appearance of forms characterizing the *Hedbergella holzli* / *Whiteinella archaeoretacea* Zone, above the Cenomanian interval dominated by benthic foraminifera. These taxa are widely distributed in space and time; they predominate in high latitudes and occupy shallower, near shore waters and unstable eutrophic environments. Whiteinellids are more abundant in horizons affected by an increased influx of organic carbon (Koksyrtau section). These intermediate morphotypes are inhabitants of mesotrophic environments.

The *Dicarinella elata* Event is known only from the Sulu-Kapy section, where it occurs close to the Middle/Upper Turonian boundary. The *Gavelinella moniliformis* and *Marginotruncana pseudolinneiana* events occur close to the base of the Upper Turonian.

The *Gavelinella kelleri*/*Stensioeina emsherica* Event and *Archaeoglobigerina cretacea* Event are known from the level of the first appearance of the inoceramid *Cremnoceramus waltersdorfensis* in the Shakh-Bogota section and that of *Cremnoceramus deformis erectus* in the Aksyrtau-Koksyrtau section.

The *Gavelinella thalmanni* / *Stensioeina granulata* Event and *Archaeoglobigerina blowi* Event are close to the Early/Middle Coniacian boundary (marked by the first appearance of *Volviceramus involutus* in the Shakh-Bogota and Sulu-Kapy sections).

The *Stensioeina exculpta* Event corresponds to the Middle/Late Coniacian boundary. The first appearances of the benthic species *Stensioeina incondita* and *Neoflabellina gibbera*, and of the planktonic species *Globigerinelloides asper*, *Globotruncana bulloides* and *Contusotruncana fornicata* are noted at the Coniacian/Santonian boundary.

### Plankton/Benthos ratio

Two peaks of a distinct increase in the Plankton/Benthos ratio (P/B) are noted in the Mangyshlak succession studied herein. The lower peak coincides with the *Whiteinella* Event (with *Hedbergella* and *Whiteinella* forming up to 92% of the foraminiferal assemblages) and is well recorded in the Koksyrtau section. The associated benthic forms, of the genera *Lenticulina*, *Nodosaria* and *Lingulogavelinella*, are rare and taxonomically of low diversity. (Kopaevich 1996). The higher peak is known from all of the sections studied, and spans the Turonian/Coniacian boundary interval (with P/B increasing up to 75%). Besides the dominating planktonic forms, this peak is characterized by taxonomically diverse benthic foraminifera, particularly the calcareous genera *Gavelinella*, *Stensioeina*, *Gavelinopsis* and *Reussella*, as well as the agglutinating genera *Spiroplectammia*, *Gaudryina*, and *Marssonella*.

Both peaks resulted apparently from the rise of sea level which extended favourable conditions up to the Mangyshlak area. The favourable and stable climate and available water depth had a significant effect on foraminiferal development and distribution. The intensity of sea water circulation favoured the development of selected benthic foraminifera, as well as that of the planoconvex, heavily ornamented planktonic foraminifera (see also Walaszczyk and Peryt 1998; Walaszczyk *et al.* 2010).

## DISCUSSION

### Inoceramid zonation

As demonstrated earlier (Marcinowski *et al.* 1996; but also Naidin *et al.* 1984), and further developed herein, the refined inoceramid zonation for the Turonian and Coniacian worked out in central Europe (Tröger 1989; Ernst *et al.* 1983; Wood *et al.* 1984,

2004; Walaszczyk and Wood 1998, 1999; Walaszczyk *et al.* 2010, 2012) can easily be applied to the succession in Mangyshlak and, consequently, to other regions of the peri-Caspian area. The apparent contradictions, as raised sometimes (e.g. Kharitonov *et al.* 2003, 2007), are the result of the incomplete nature of the Cretaceous successions of the region, and of differences in the taxonomic concepts applied to the inoceramid faunas. The latter point, discussed briefly below in the chapter 'Palaeontological Notes', cannot be resolved on the basis of the few and inadequate published records, and indicate the need of new studies, including both additional fieldwork and the re-study of existing material.

Traditionally, the two-fold subdivision of both the Turonian and Coniacian was applied in Mangyshlak, and similarly in all adjacent regions of western Central Asia and south-eastern Europe (e.g. Aliev and Pavlova 1983; Aliev and Kharitonov 1981; Aliev *et al.* 1982; various papers in Moskvina 1987). This two-fold subdivision was claimed by some authors (Kharitonov *et al.* 2003, 2007), as clearly reflecting better the actual changes in the biota living in the area during this time. Biostratigraphically (Text-fig. 6), the Lower Turonian was the equivalent of the *Inoceramus labiatus* Zone and the Upper Turonian embraced the zones of *Inoceramus apicalis*, *Inoceramus lamarcki* and *Inoceramus woodsi* [the index taxa changed sometimes (e.g. the *I. lamarcki* Zone was often

STAGES	SUBSTAGES	Inoceramid zonation (after Seitz 1970, Wood <i>et al.</i> 1984, Tröger 1989, Ernst <i>et al.</i> 1983, Walaszczyk and Wood 1998, 1999)	Stratigraphic ranges of the sections studied	Planktic foraminifera zonation	Benthic foraminifera zonation	Traditional inoceramid zonation and substage subdivision in south-eastern margin of the East-European craton		
SANT.	L. (pars)	<i>Cladoceramus undulatoplicatus</i>	Shakh-Bogota Sullu-Kapy Koksyttau-Aksyttau		LC8b	<i>Cladoceramus undulatoplicatus</i>	LOWER	SANT.
CONIACIAN	MIDDLE UPPER	<i>Sphenoceramus pachtii</i>		<i>Concavatotruncana concavata</i>	LC8a	<i>Sphenoceramus pachtii</i>	UPPER	CONIACIAN
		<i>Magadiceramus subquadratus</i>				<i>Inoceramus involutus</i>		
		<i>Volviceramus involutus</i>						
		<i>Volviceramus koeneni</i>						
CONIACIAN	LOWER	<i>Inoceramus gibbosus</i>		<i>Marginotruncana coronata</i>	LC7	<i>Inoceramus schloenbachi</i> (= <i>Inoceramus wandereri</i> )	LOWER	CONIACIAN
		<i>Cr. crassus crassus</i> + <i>C. def. def.</i>						
		<i>Cremonoceramus crassus inconstans</i>						
		<i>Cr. waltersdorfensis hannovrensis</i>						
		<i>Cremonoceramus deformis erectus</i>						
		<i>Cr. waltersdorfensis waltersdorfensis</i>						
TURONIAN	UPPER	<i>Mytiloides scupini</i>		<i>Marginotruncana pseudolinneiana</i>	LC4-5	<i>Inoceramus woodsi</i>	UPPER	TURONIAN
		<i>Mytiloides incertus</i>						
		<i>Mytiloides striatoconcentricus</i>						
		<i>Inoceramus perplexus</i> + <i>I. lamarcki</i>						
	MIDDLE	<i>Inoceramus lamarcki</i>		<i>Helvetoglobotruncana helvetica</i>	LC3	<i>Inoceramus apicalis</i>	UPPER	TURONIAN
		<i>Mytiloides hercynicus</i>						
		<i>Mytiloides subhercynicus</i>						
		<i>Mytiloides mytiloides</i>						
LOWER	<i>Mytiloides kossmati</i>		<i>Helvetoglobotruncana helvetica</i>	LC2	<i>Inoceramus labiatus</i>	LOWER	TURONIAN	
	<i>Mytiloides puebloensis</i>							
CEN.	U. (pars)	<i>Mytiloides hattini</i>			LC1			

Text-fig. 6. Inoceramid and foraminiferal zonations as applied in this paper and their correlations with previous zonations applied by various authors; benthic foraminifera zonation after Beniamovskii (2008)

referred to the *I. falcatus* Zone), but this has not influenced the basic concept of the zonation]. Similarly, the Lower Coniacian was regarded the equivalent of the *Inoceramus schloenbachi* Zone (or *Inoceramus wandereri* Zone), and the Upper Coniacian was regarded as the equivalent of the *Inoceramus involutus* Zone.

The applicable inoceramid zonation and its correlation with the 'traditional zonation' as used in the various regions of the per-Caspian area are shown in Text-fig. 6. The correlation is relatively straightforward. The *Inoceramus labiatus* (or *Mytiloides*) Zone in the traditional zonation may be understood as the range zone of the *Mytiloides labiatus* group, and ranges, consequently, from the base of the *Mytiloides hattini* Zone up to the *Mytiloides hercynicus* Zone. The most difficult to interpret is the traditional *Inoceramus apicalis* Zone. In comparisons with three-fold subdivision of the Turonian, this zone was usually understood as being equivalent to the *I. lamarcki* Zone, and would correspond thus, more or less, to the Middle Turonian, or at least it would be the zone below the *I. falcatus* Zone (which corresponds more or less to the range of *Inoceramus* ex gr. *inaequivalvis*). Unfortunately, the upper part of the Middle Turonian is missing in all of the sections studied in Mangyshlak, and the actual first appearance level of *I. inaequivalvis* in the area is unknown; it invariably starts at the base of the Upper Turonian in the sections. The Zone of *Inoceramus schloenbachi*, or of *Inoceramus wandereri*, commonly regarded as its strict equivalent, may quite safely be correlated with the series of zones, starting with the Zone of *Cremnoceramus deformis erectus* and extending up to the Zone of *Inoceramus gibbosus*. Most of the illustrated specimens of *I. schloenbachi* are actually *C. deformis erectus* (see discussion below). The zone of *Inoceramus involutus* spans an interval from the first appearance of volviceramids to the first appearance of sphenoceramids; consequently, the zone, in its traditional understanding in the area, should be correlated with an interval spanning the *Volviceramus koeneni* Zone up to the *Magadiceramus* zones in the Upper Coniacian. It should be noted that *Volviceramus*, as demonstrated e.g., in Tröger (1989) or Walaszczyk and Cobban (2006), may range very high in the Upper Coniacian, where it is accompanied by *Magadiceramus*. Although the latter genus was not recorded from Mangyshlak, it is reported from the western Kopet Dag (e.g. Arzumanova 1964) and Daghestan (e.g. Aliev *et al.* 1982), indicating its presence in the area.

It is worth noting that, at least in the case of the Coniacian, a quite refined zonation was proposed earlier by Kharitonov (first published in Aliev *et al.* 1982, but definitely worked out earlier; also repeated in Kharitonov

1993), based on successions in Daghestan. He recognized, in stratigraphic order, the zones of *Inoceramus schloenbachi*, *Inoceramus deformis*, *Inoceramus lamarcki lamarcki* (in the Lower Coniacian), and the zones of *Inoceramus mantelli*, *Inoceramus involutus*, and the zone of *Inoceramus subquadratus* (in, what is Middle and Upper Coniacian). His *I. schloenbachi* Zone comprises the *Cremnoceramus deformis erectus* Zone through to the *Cremnoceramus crassus inconstans* Zone; his *Inoceramus deformis* Zone corresponds precisely to the *Cremnoceramus crassus crassus*+*Cremnoceramus deformis deformis* Zone; and his *I. lamarcki lamarcki* Zone corresponds, more or less to the Zone of *Inoceramus gibbosus*. The three upper zones, correlate precisely with the zonation proposed herein. Unfortunately, for some reason this zonation was never developed further and never adopted as a standard.

#### Planktonic foraminiferal zonation

Four successive planktonic foraminiferal zones are potentially recognizable in the Turonian and Coniacian of Mangyshlak. These are (in stratigraphic order): the zones of *Helvetoglobotruncana helvetica*, *Marginotruncana pseudolinneiana*, *Marginotruncana coronata* and *Concavotruncana concavata*. The zone of *H. helvetica* was not documented, simply because of the lack of planktonic forms in the Lower Turonian siliciclastic successions, but the zone is known from other Cretaceous regions of peri-Caspian area. The *M. pseudolinneiana* Zone spans the lower Upper Turonian of all of the sections studied (see Text-figs 2–4); the precise chronostratigraphic location of the base of this zone is unknown but, based on other regions, this taxon first appears in the Middle Turonian. The middle Upper Turonian yielded the first *M. coronata* which, as may be observed in the most complete Shakh-Bogota section, first appears in the uppermost Turonian. Both taxa, *M. coronata* and *M. pseudolinneiana*, range higher, to at least the top of the Coniacian. The highest zone, that of *C. concavata*, is entirely Coniacian, and its base lies within the upper Lower Coniacian (see Text-fig. 2). The base of this zone may be diachronous, as in the lower latitudes, in the Tethys area, its index taxon seems to appear in the latest Turonian. The foraminiferal zonation as recognized herein is very close to that known from Central Europe (Słupia Nadbrzeżna river cliff, see Walaszczyk and Peryt 1998; Salzgitter-Salder Quarry, see Walaszczyk *et al.* 2010).

No planktonic species found in the Mangyshlak area can be used as a precise marker of the base of the Coniacian. Recently, this boundary is placed within the *C. concavata* Zone (Robaszynski *et al.* 1990; Premoli

Silva and Sliter 1994; Robaszynski and Caron 1995; Ogg *et al.* 2004). In Mangyshlak, *C. concavata* first appears, however, distinctly later, in the late Early Coniacian. *Marginotruncana sinuosa*, claimed as a good proxy for the base of the Coniacian (Walaszczyk and Peryt 1998) appears, e.g. in the northeastern Caucasus (Tur *et al.* 2001), already in the upper Upper Turonian. The FO of *Marginotruncana renzi* (Gandolfi) documented from the base of the *Cremnoceramus waltersdorfensis* Zone in the Voronez high (central part of the East European Platform, Walaszczyk *et al.* 2004) appears distinctly earlier in other regions (Walaszczyk and Peryt 1998; Walaszczyk *et al.* 2010).

Correlation of the foraminiferal scheme with the inoceramid zonation is shown in Text-fig. 6.

The planktonic foraminifera from the Upper Turonian and Lower Coniacian parts of the Mangyshlak sections represent faunas characteristic of the Cretaceous Transitional or Temperate Province (e.g. Hart and Bailey 1979; Pożaryska and Peryt 1979; Caron 1985). They comprise mainly whiteinellids, archaeoglobigerinids, and double-keeled marginotruncanids, and are distinctly less diverse than the Tethyan assemblages. The typical Tethyan and biostratigraphically important umbilico-convex dicarinellids and single-keeled marginotruncanids are either very rare or absent. High diversity planktonic foraminiferal assemblages appear only during distinct deepening intervals of the latest Cenomanian and of the Turonian/Coniacian boundary interval.

### Benthic foraminiferal zonation

The Upper Turonian–Coniacian benthic foraminifera are well preserved and abundant. Taxonomic differences between benthic foraminiferal assemblages enable the establishment of biostratigraphical zones and subzones for the territories of the Russian Platform and its southern margin (Kopaevich *et al.* 2007; Beniamovskii 2008). The distribution, zonation and the events recognized for benthic foraminifera are presented herein for the Shakh-Bogota section (Text-fig. 5) and its correlation with zonations based on planktonic foraminifera and inoceramids is shown in Text-fig. 6. The critical forms are illustrated in Plates 14 and 15.

### PALAEONTOLOGICAL NOTES ON SELECTED INOCERAMID TAXA

In the following notes, the critical species are briefly discussed in the context of the different taxonomic concepts applied to them by various authors. The material

illustrated was mostly collected by the authors from Mangyshlak; however, some forms from adjacent regions are herein re-illustrated and/or references to respective literature sources are made. As can be seen even from this short review, the concepts of particular species vary considerably among the different authors and, moreover, there is a long list of newly introduced inoceramid taxa in the Turonian and Coniacian, based on material from western Central Asia and the Caucasus. Many of these new forms are poorly documented, and a number of names were introduced without any description at all. Although formally these are *nomina nuda*, and can be forgotten, the question remains, may they simply be included in the synonymy of existing valid taxa, or do they actually document the real taxonomic richness of the inoceramid assemblages of the area. Consequently, a rigorous taxonomic treatment of the inoceramids of all these regions has to be undertaken. Unfortunately, this will have to be postponed for a while, until the restudy of all the original material of these taxa is completed.

### *Mytiloides labiatus* (Schlotheim, 1813) group; Plate 1

The group is best represented in the Koksyrtau-Aksyrtau section (Text-fig. 3 and Plate 1), where the succession starting from the Zone of *M. kossmati* through to the Zone of *M. subhercynicus* is well recorded. All of the morphotypes as recognized in the latest Cenomanian–early Middle Turonian *Mytiloides labiatus* lineage (see e.g., Kauffman and Powell in Kauffman *et al.* 1977; Walaszczyk and Cobban in Kennedy *et al.* 2000) are recognized in various regions of the peri-Caspian area (e.g. Arkhangelsky 1916; Pavlova 1955, pl. 3, figs 1–2; Dobrov and Pavlova 1959, pl. 2, figs 1 (sub *Inoceramus striatoconcentricus*) and 2; Aliev and Kharitonov 1988, pl. 5, figs 2, 3; Kharitonov *et al.* 2007, pl. 1). The claims about the co-occurrence of all forms of the group (lineage) result partly from the lack of precisely located collections, and partly from differences in taxonomic concepts.

*Inoceramus amudariensis* of Arkhangelsky, 1916, described based on material from the Turonian of the lower Amu-Daria River, Kazakhstan, most probably falls into the synonymy of *Mytiloides hercynicus* (Petrascheck, 1903).

### *Mytiloides incertus* (Jimbo, 1894); Pl. 3, Fig. A

This species is very rarely represented; just two specimens are known from the Shakh-Bogota section (Text-fig. 2 and Pl. 3, Fig. 9A). This seems, however, to result mostly from poor representation of this part of the Turonian. This species is widely distributed all over

the Northern Hemisphere (Tröger 1967; Noda 1984, Noda and Matsumoto 1998, Walaszczyk and Cobban 2000) but also Madagascar (Diebold *et al.* 2010) and is a good marker of the middle Upper Turonian. First reported from Mangyshlak by Naidin *et al.* (1984: determination by K.-A. Tröger).

***Mytiloides striatoconcentricus* (Gümbel, 1868);** Pl. 3, Fig. E; Pl. 4, Figs A-O

In the Shakh-Bogota section this species forms an accumulation horizon (Text-fig. 2, bed 14b). Also known from the Sulu-Kapy section; in other sections it does not occur. It is a mytiloid-shaped, small to moderate-sized, slightly to moderately inequivalve form, with fine, closely spaced, sometimes slightly lamellate growth lines. The left valve is more inflated; the right quite flat.

Although the species is commonly reported in the older literature from various regions of the peri-Caspian area, none of the illustrated specimens actually represent Gümbel's species. *I. striatoconcentricus* in Pavlova (1955, pl. 5, fig. 1; reillustrated later in Dobrov and Pavlova 1959, pl. 2, fig. 2; and re-illustrated herein in Pl. 7, Fig. D) is *Cremonoceramus waltersdorfensis hannovrensis*. The other specimen illustrated in Dobrov and Pavlova (1959, pl. 2, fig. 1) is probably the Early Turonian *Mytiloides hattini* (Elder, 1991). Similarly, two specimens from the Caucasus, illustrated by Aliev and Kharitonov (1988, pl. 8, figs 8, figs 2–3), are *C. waltersdorfensis*.

***Mytiloides* sp.;** Pl. 3, Fig. B, C; Pl. 5, Fig. Q

This morphotype is poorly represented, co-occurring with *M. striatoconcentricus*. It closely resembles *Mytiloides ratonensis* Walaszczyk and Cobban, 2000.

***Mytiloides scupini* (Heinz, 1930);** Pl. 6, Fig. A

Only three specimens of this species were found in the top (but not topmost) Turonian of the Shakh-Bogota section (Text-fig. 2). In the older literature from the whole area the species was most probably referred to *Inoceramus frechi*, as demonstrated by forms illustrated in Egoyan (1955, pl. 4, fig. 5) or Dobrov and Pavlova (1959, pl. 9, fig. 4) (see also discussion in Walaszczyk and Wood 1998).

***Inoceramus* ex gr. *lamarcki* Parkinson, 1819;** Plate 2

Forms referable to the group of *Inoceramus lamarcki* Parkinson, 1818, are relatively rare in the material studied. Rare specimens come from the basal Upper Turonian, where they co-occur with early *Mytiloides costellatus* (Woods, 1912). The large specimen seems to represent the subspecies *I. lamarcki stuemckeii* Heinz, as interpreted by Tröger, 1967.

The *I. lamarcki* group is inevitably the most, or at least one of the most perplexing forms of all of the Turonian–Coniacian inoceramid taxa. Its variability range, taxonomic structure and evolution and biogeographic pattern still await serious study.

***Inoceramus inaequivalvis* Schlüter, 1877;** Text-figs 9F–J; 11E

This is the other group that definitely needs further study. These are late Middle and early Late Turonian inequivalve forms, usually also referred to the *Inoceramus lamarcki* group (e.g. Tröger 1967). As the type of Schlüter's species is known from a single, fragmentarily preserved specimen (Goldfuss 1834–40, pl. 112, figs d, e), the differences between his *I. inaequivalvis* and other, apparently closely related (if not conspecific) species as described by Heinz (1928, 1932, and in Wolansky 1932) as *Inoceramus falcatus* and *Inoceramus modestus*, are unclear. In various regions of the peri-Caspian area, such forms were usually referred, seemingly correctly, to Heinz' species *Inoceramus falcatus* (e.g. Aliev and Kharitonov 1988), and the species has long been used as the index taxon of the eponymous (lower) Upper Turonian Zone.

***Inoceramus costellatus* Woods, 1912 (= *Inoceramus woods* Böhm, 1913);** Pl. 3, Fig. 5; Pl. 5, Fig. J

The Woods species concept was long used in central and western Europe for small-sized, erect, regularly rugate forms, characterizing the lower Upper Turonian. These forms were later referred to *Inoceramus perplexus* Whitfield (see Walaszczyk and Wood 1998 and Walaszczyk and Cobban 2000). The Woods species is a mytiloid form that closely resembles small-sized representatives of *Mytiloides scupini* (Heinz) and possibly is an earlier member of the *costellatus-scupini* lineage.

The species is commonly reported from the south-eastern margin of the East-European Craton, and is usually referred to *Inoceramus woods* Böhm, 1913, which is the replacement name for the Woods species, as the name *costellatus* was preoccupied by *Inoceramus costellatus* Conrad 1855–1858. The species was the index taxon of the eponymous highest Turonian inoceramid zone in the whole south-eastern margin of the Russian Craton.

***Inoceramus* sp. cf. *Inoceramus longevalatus* Tröger, 1967;** Pl. 5, Figs A–D, F–H

There are several small-sized specimens from the level of the *Mytiloides striatoconcentricus* Event, with subquadrate outline, fine to lamellate growth line and well extended posterior auricle, which closely resemble

*Inoceramus longelatus* Tröger, 1967. The species is poorly known as far as its origin as well as stratigraphic range is regarded. It is known from all over Europe and also from the US Western Interior (Tröger 1967; Walaszczyk and Cobban 2000).

***Inoceramus lusatae* Andert, 1911**; Pl. 6, Fig. C; Pl. 7, Fig. B

This species definitely belongs to the *Inoceramus lamarecki* group, but possesses a distinct *Mytiloides* outline. The species was commonly reported from the area; however, none of the illustrated specimens actually represents Andert's species (see also discussion in Walaszczyk and Wood 1998). The specimens in Aliev and Kharitonov (1988, pl. 8, fig. 4 and pl. 10, fig. 1) are *Mytiloides*, and the one in their pl. 10, is *Mytiloides scupini* (Heinz). Similarly, the specimens illustrated by Dobrov and Pavlova (1959, p. 151, pl. 4, figs 5, 6), are close to *Mytiloides scupini* (Heinz). Egoyan's (1955, pl. 2, fig. 7 and pl. 3, figs 4, 5) *Inoceramus lusatae* from Armenia are invariably Late Turonian *Mytiloides* species; the original of his pl. 2, fig. 7, referred by him to a new variety *grata*, is very much like *Mytiloides striatoconcentricus* (Gümbel) and the original of his pl. 3, fig. 4, is most probably *Mytiloides incertus* (Jimbo). *Inoceramus lusatae* of Pavlova (1955, pl. 4, fig. 5; re-illustrated herein in Text-fig. 11B) is *Cremnoceramus waltersdorfensis hannovrensis* (Andert), and the specimens illustrated by Aliev and Kharitonov (1988, pl. 8, fig. 4 and pl. 10, fig. 1) are definitely *Mytiloides* sp., the original of their pl. 10, fig. 1 being *Mytiloides scupini* (Heinz). Of the four different specimens referred to *Inoceramus lusatae* by Khalavova (1968) at least two (Khalavova 1968, pl. 1, figs 10, 11) represent early *Cremnoceramus deformis erectus* (Meek) and the other two (Khalavova 1968, pl. 1, figs 8, 9) may similarly represent either *C. deformis erectus* or some Late Turonian *Mytiloides*.

***Tethyoceramus wandereri* (Andert, 1911)**; Pl. 7, Figs C, D, E; Pl. 8, Fig. C

According to its original illustration in Andert (1911, pl. 5, figs 1a, b), it is a narrow, high morphotype, with the umbonal part projecting strongly above the hinge line, and with *Cremnoceramus*-type ornament. The type species comes from Dachsloch (Zittauergebirge), at the boundary between Bohemia (in the Czech Republic) and Saxony (in Germany), apparently from the level of the *Cremnoceramus crassus* Zone. The species is a representative of the genus *Tethyoceramus* (see discussion in Walaszczyk and Wood 1999).

The species is widely reported from various regions of the peri-Caspian area: Central Asia (Mangyshlak, Tuarkyr, Kopet Dag; Atabekian and Likhacheva 1961; Aliev and Kharitonov 1981, 1988; Aliev *et al.* 1982), the Caucasus (Daghestan, Azerbaijan, Armenia; e.g., Pavlova 1955; Dobrov and Pavlova 1959; Khalavova 1968; Pergament and Smirnov 1972; Aliev and Kharitonov 1988), Crimea (Atabekian 1997), Donbass (Kotsubinsky 1974; Ivanikov 1979) and western Ukraine (Kotsubinsky 1968). This is the index species of the eponymous Zone and corresponds in its range to the Lower Coniacian (e.g. Atabekian in Moskvina 1987). As may be judged from the illustrated reports, the species was interpreted very widely, and apparently all tethyoceramids were referred to this species, and even some cremnoceramids, but with elongated adult stage. In fact, forms that can safely be referred to *Tethyoceramus wandereri* in the sense of Andert (1911) are rare [Pavlova (1955, pl. 9, figs 1, 2; but not her pl. 9, figs 3–5, which is *Cremnoceramus inconstans*; possibly her pl. 8, figs 1, 2); none of the specimens illustrated by Dobrov and Pavlova (1959); or Aliev and Kharitonov (1988); possibly forms illustrated by Kotsubinsky (1968, 1974) from Donbass and the Lviv region]

***Cremnoceramus deformis erectus* (Meek, 1877)**; Pl. 6, Fig. D; Pl. 7, Fig. A; Pl. 8, Figs B, E, F

The species is well represented in most of the studied sections in western Mangyshlak. It forms a distinct zone at the base of the Coniacian, albeit the species ranges higher. The species was also widely illustrated from the Caucasus and peri-Caspian regions, albeit usually referred to *Inoceramus schloenbachi* Böhm. Good examples are: *I. schloenbachi* in Dobrov and Pavlova (1959, pl. 8, figs 1, 2) or in Aliev and Kharitonov (1988, pl. 9, figs 2, 3). Also most probably conspecific with *C. deformis erectus* are Kharitonov's (in various papers) 'early (or small) *Inoceramus schloenbachi*' but unfortunately these were never illustrated by him.

***Cremnoceramus inconstans* (Woods, 1912)**

Specimens illustrated and referred to this species represent various forms, with some only referable to *C. inconstans* in a narrow sense, as recently interpreted by Walaszczyk and Wood (1998). Usually these are various cremnoceramids with well-developed geniculation, irrespective of their juvenile stage. A number of these forms represent *C. deformis erectus*, as e.g. Dobrov and Pavlova (1959, pl. 5, fig. 1) or Aliev and Kharitonov (1988, pl. 7, fig. 3; but not fig. 4, which is *Cremnoceramus waltersdorfensis waltersdorfensis*).

***Cremonceramus waltersdorfensis hannovrensis* (Heinz, 1932)**; Pl. 5, Figs I, K–N; Pl. 6, Fig. B, E; Pl. 8, Fig. D

This subspecies of the *C. waltersdorfensis* lineage is well represented in the record, above the zone of *C. deformis erectus* of the basal Lower Coniacian (Text-figs 2 and Pl. 5, Figs I, K–N). This taxon was also reported from various adjacent areas, albeit usually referred to *Inoceramus striatoconcentricus* Gümbel (see Pl. 8, Fig. D from Pavlova 1955, pl. 5, fig. 1 and Dobrov and Pavlova 1959, pl. 2, fig. 2) or to *Inoceramus lusatie* Andert (Pl. 6, Figs B, E from Pavlova 1955, pl. 4, fig. 5). See also discussion under *I. lusatie* and *M. striatoconcentricus*.

***Cremonceramus crassus* (Petrascheck, 1903)** (= *Inoceramus schloenbachi* Böhm, 1909); Plate 9

Conspecific with *C. crassus crassus* are specimens illustrated by Atabekian (1974, pl. 103, fig. 2 and pl. 104, fig. 3), Ivannikov (1979, pl. 26, figs 1, 2), and possibly Kotsubinsky (1974, pl. 15, fig. 3), although the latter may represent *C. deformis deformis*. To this species also belong *Inoceramus inconstans achuraensis* subsp. nov. of Khalafova (1968, pp. 166–167, pl. 8, fig. 7; pl. 9, fig. 1), and her *Inoceramus quasiinconstans* sp. nov. (Khalafova 1968, pp. 168–170, pl. 9, figs 2–3), as well as *Inoceramus chosrovensis* of Atabekian (1974, pl. 106, fig. 1; pl. 107, fig. 1). A number of *C. crassus* (= *I. schloenbachi* of authors) represent *C. deformis erectus*, as interpreted herein (see discussion under this latter taxon)

***Volvicceramus involutus*** (J. de C. Sowerby, 1829); Text-fig. 10

The species is well represented in the *involutus* Horizon in the Shakh-Bogota section, but also in other sections studied herein (Text-figs 2–4). In all horizons occur large-sized forms typical of evolutionarily late members of the lineage. The older members seem to be lacking in the record.

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## PLATE 1

*Mytiloides labiatus* (Schlotheim, 1813) group

- A** – *Mytiloides mytiloides* (Mantell, 1822), ZI/45/3051; Shyrkala-Airakty section, bed 22 (see Marcinowski *et al.* 1996, text-fig. 6);
- B** – *Mytiloides goppelnensis* (Badillet and Sornay, 1980), ZI/45/3052, Aksyrtau-Koksyrtau section, unit 29;
- C, F** – *Mytiloides hattini* Elder, 1991; **C** – ZI/45/3053, **F** – ZI/45/3054; both from Aksyrtau-Koksyrtau section, unit 29;
- D** – *Mytiloides kossmati* (Heinz, 1930) and *Mytiloides mytiloides* (Mantell, 1822), ZI/45/3055, Shyrkala-Airakty section, bed 22 (see Marcinowski *et al.* 1996, text-fig. 6);
- E, G** – *Mytiloides* of the *subhercynicus-hercynicus* group Shyrkala-Airakty section, bed 22 (see Marcinowski *et al.* 1996, text-fig. 6); **E** – ZI/45/3056, **G** – ZI/45/3057.

All figures are natural size

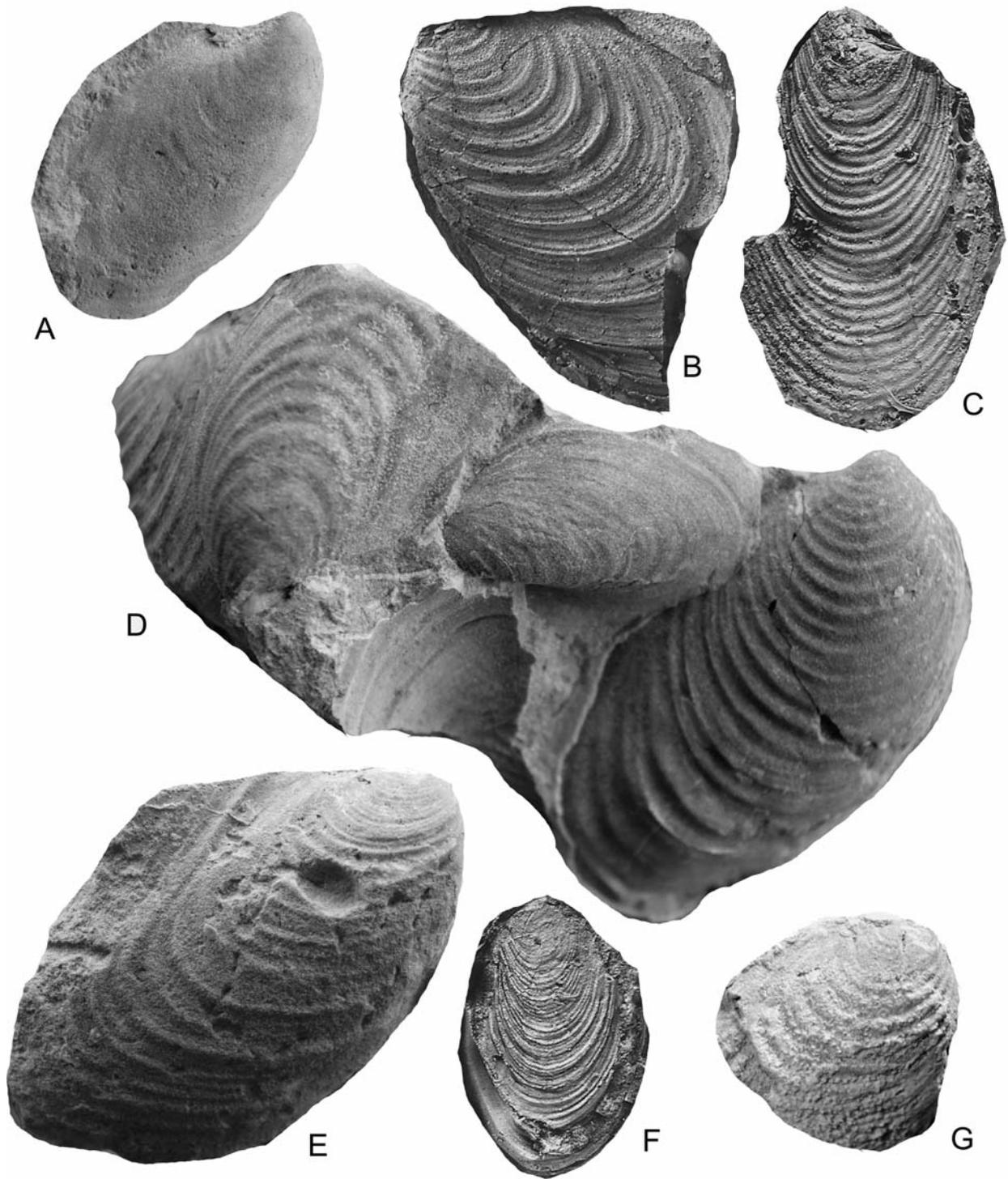


PLATE 2

*Inoceramus lamarcki stuemckei* Heinz, 1926, ZI/45/3000, Shakh-Bogota section, bed 12; × 0.9



## PLATE 3

Inoceramids from the Upper Turonian of the Shakh-Bogota section

- A** – *Mytiloides incertus* (Jimbo, 1894), bed 14d;  
**B, C** – *Mytiloides* sp., bed 14b, B – ZI/45/3002, C – ZI/45/3003;  
**D** – *Mytiloides costellatus* (Woods, 1912), ZI/45/3006, bed 12;  
**E** – *Mytiloides striatoconcentricus* (Gümbel, 1868), ZI/45/3004;  
**F-J** – *Inoceramus inaequalvis* Schlüter, F – UW.ZI/45/3005, G, I – UW.ZI/45/3007,  
H – UW.ZI/45/3008, J – UW.ZI/45/3009; F, J – bed 14b, G-I – bed 14c.

All specimens are natural size

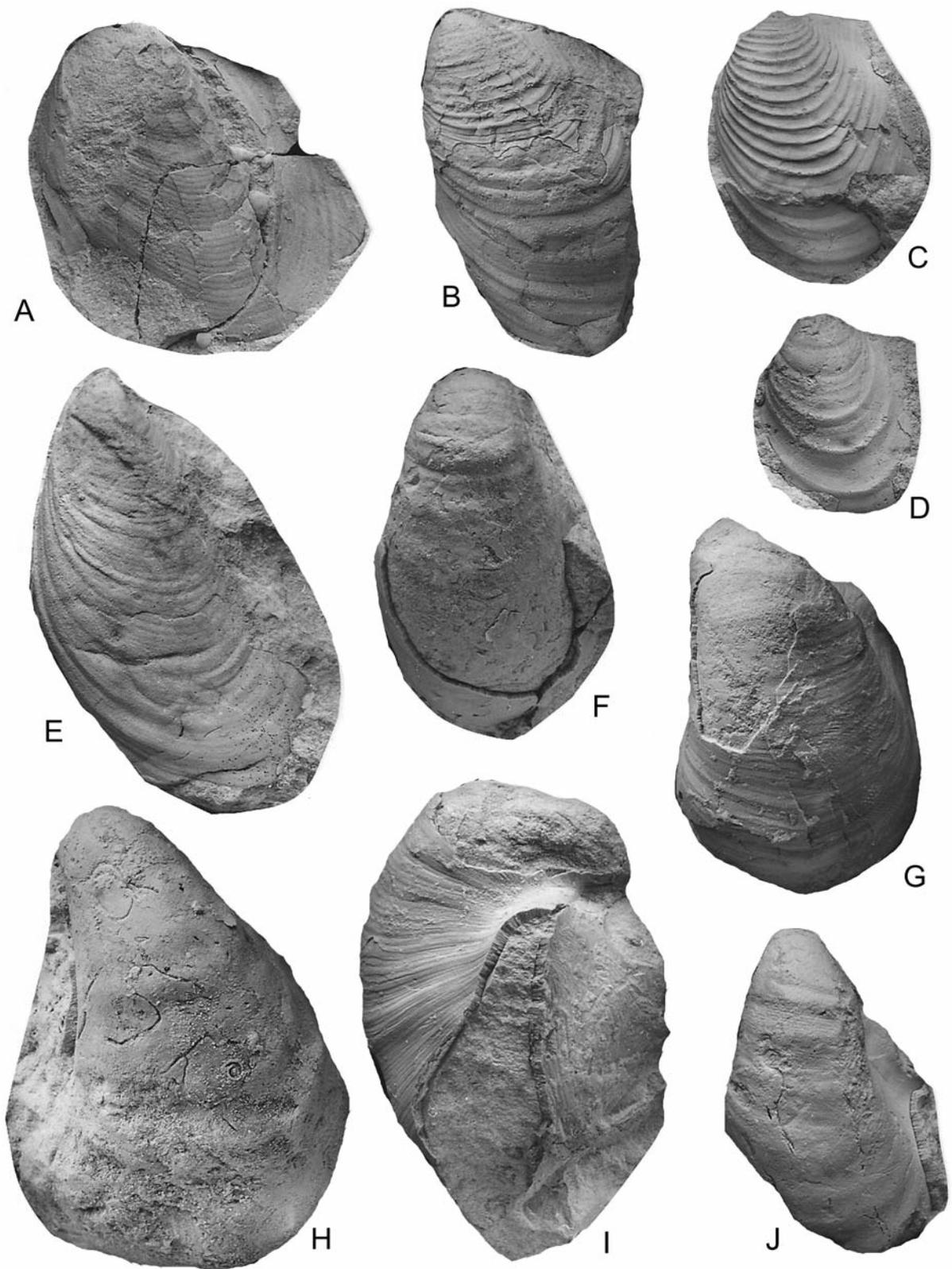
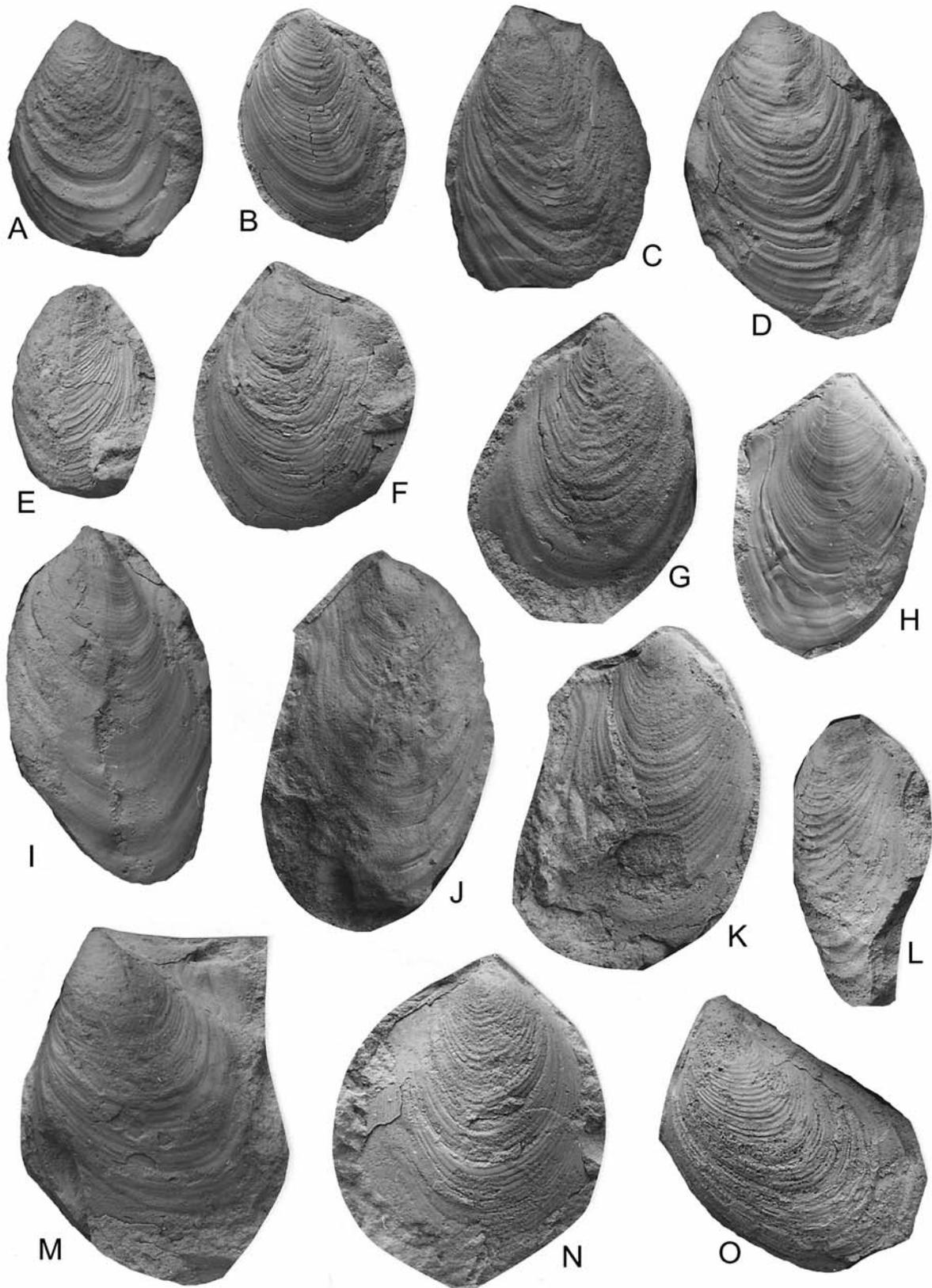


PLATE 4

*Mytiloides striatoconcentricus* (Gumbel, 1868), bed 14b of the Shakh-Bogota section

**A** – ZI/45/3010, **B** – ZI/45/3011, **C** – ZI/45/3012, **D** – ZI/45/3013, **E** – ZI/45/3014,  
**F** – ZI/45/3015, **G** – ZI/45/3016, **H** – ZI/45/3017, **I** – ZI/45/3018, **J** – ZI/45/3019,  
**K** – ZI/45/3020, **L** – ZI/45/3021, **M** – ZI/45/3022, **N** – ZI/45/3023, **O** – ZI/45/3024.

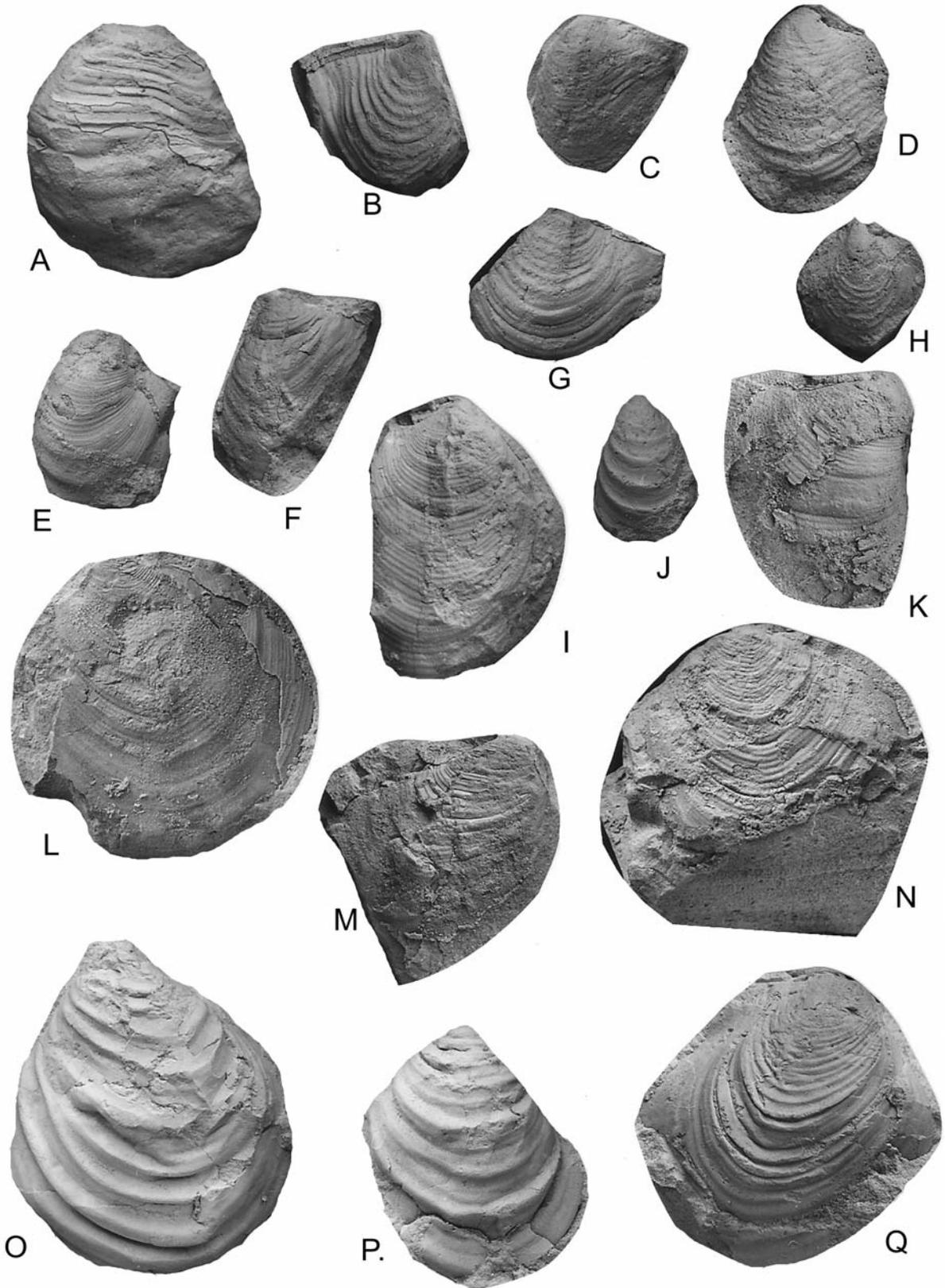
All figures are natural size



## PLATE 5

- A-D, F-H** – *Inoceramus* sp. cf. *Inoceramus longevalatus* Tröger, 1967; A – ZI/45/3025, B – ZI/45/3026, C – ZI/45/3027, D – ZI/45/3028, F – ZI/45/3030, G – ZI/45/3031, H – ZI/45/3032; all from bed 14b;  
– *Inoceramus* ex gr. *inaequivalvis* Schlüter, 1877, ZI/45/3029, bed 12;  
**J** – *Mytiloides costellatus* (Woods, 1912), ZI/45/3034, bed 12;
- I, K-N** – *Cremnoceramus waltersdorfensis hannovrensis* (Heinz, 1932), I – ZI/45/3033, K – ZI/45/3035, L – ZI/45/3036, M – ZI/45/3037, N – ZI/45/3038; all from *hannovrensis* Event, bed 14g;
- O, P** – *Cremnoceramus deformis erectus* (Meek, 1877), O – ZI/45/3039, P – ZI/45/3040, both from bed 14g, *erectus* Event;
- Q** – *Mytiloides* sp., ZI/45/3041; all specimens from Shakh-Bogota section.

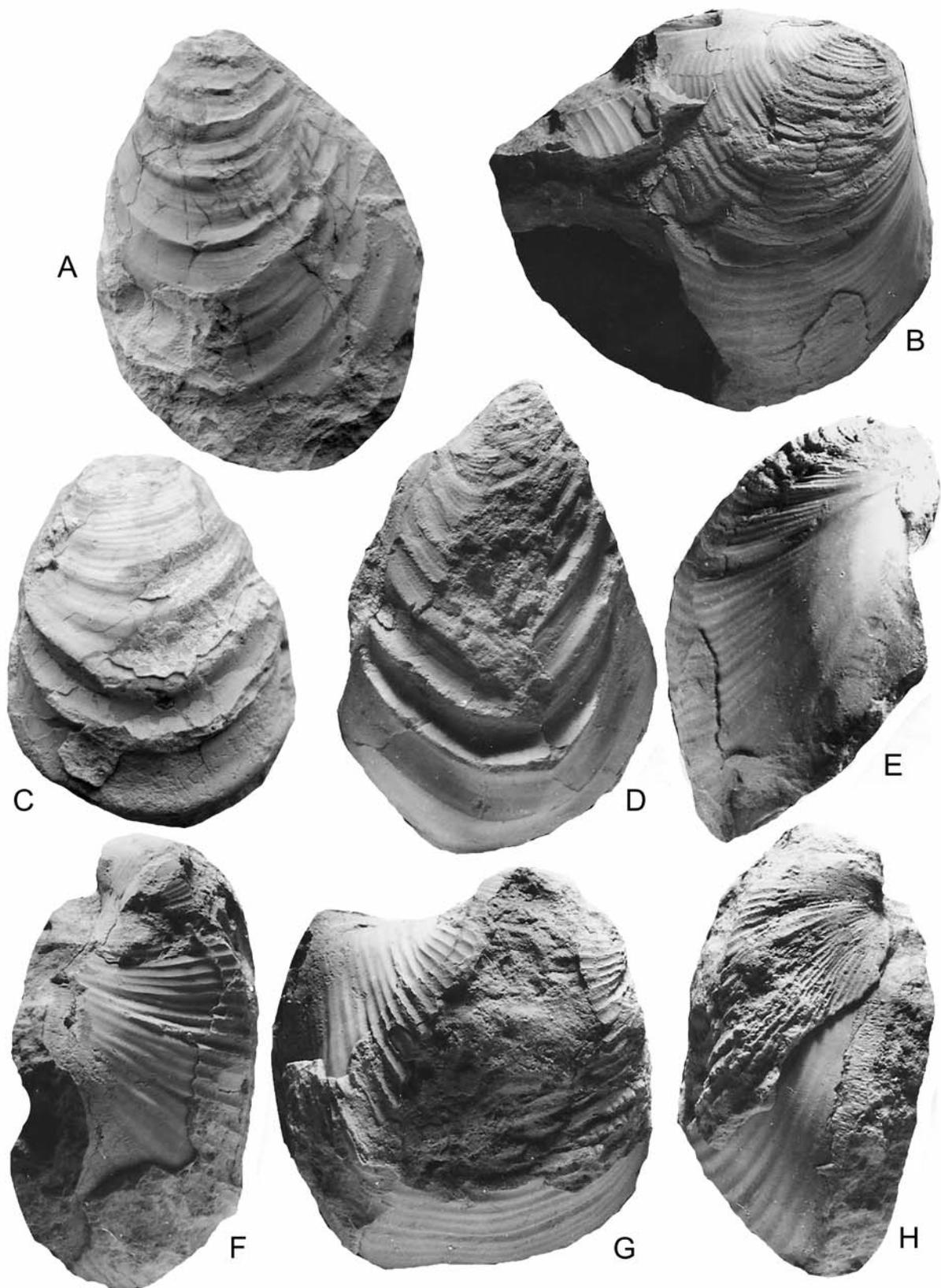
All figures are natural size



## PLATE 6

- A** – *Mytiloides scupini* (Heinz, 1930), ZI/45/3042, Shakh-Bogota, bed 14e, just below the *Cremonoceramus waltersdorfensis waltersdorfensis* Event;
- B, E** – *Cremonoceramus waltersdorfensis hannovrensis* (Heinz 1932) [= *Inoceramus lusatiae* in Pavlova 1955, pl. 4, fig. 5]; Rubas-Tchai section, Daghestan;
- C** – *Inoceramus lusatiae* Andert, 1911, ZI/45/3043, Sulu-Kapy section, bed 20, just below the *Cremonoceramus waltersdorfensis waltersdorfensis* Event, topmost Turonian;
- D** – *Cremonoceramus deformis erectus* (Meek, 1877) [= *Inoceramus inconstans* Woods in Dobrov and Pavlova, 1959, p. 137, pl. 5, fig. 1]; Tsmur-Tchai section, Daghestan;
- F-H** – *Inoceramus* sp., [= *Inoceramus lusatiae* Andert in Dobrov and Pavlova 1959, pl. 4, fig. 5]; Koarchag-Su, Daghestan.

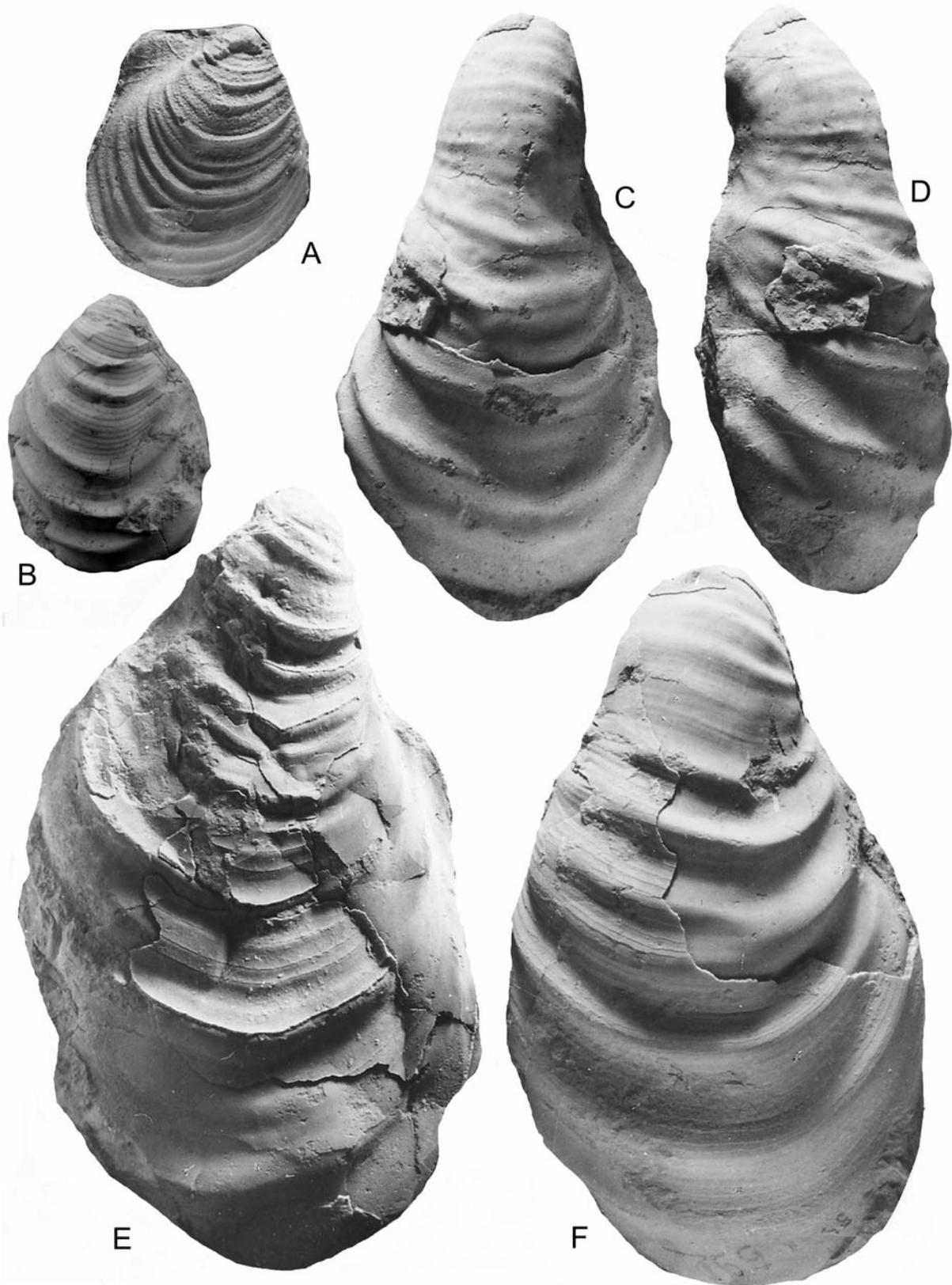
All figures are natural size



## PLATE 7

- A** – *Cremonoceramus deformis erectus* (Meek, 1877) [= *Inoceramus schloenbachi* Böhm in Dobrov and Pavlova 1959, pl. 8, fig. 2]; Sudahar section, Daghestan;
- B** – *Inoceramus lusatie* Andert, 1911, ZI/45/3058, Sulu-Kapy section, bed 20, just below the *Cremonoceramus waltersdorfensis waltersdorfensis* Event, topmost Turonian;
- C-E** – *Tethyoceramus wandereri* (Andert, 1911); C, D – from Pavlova 1955, pl. 9, fig. 1, Tsmur-Tchai section, Daghestan; E – from Pavlova 1955, pl. 9, fig. 2; Dzengutay section, Daghestan;
- F** – *Inoceramus* sp., [= *Inoceramus wandereri* Andert in Dobrov and Pavlova 1959, pl. 6, fig. 2]; Daghestan.

All figures are natural size



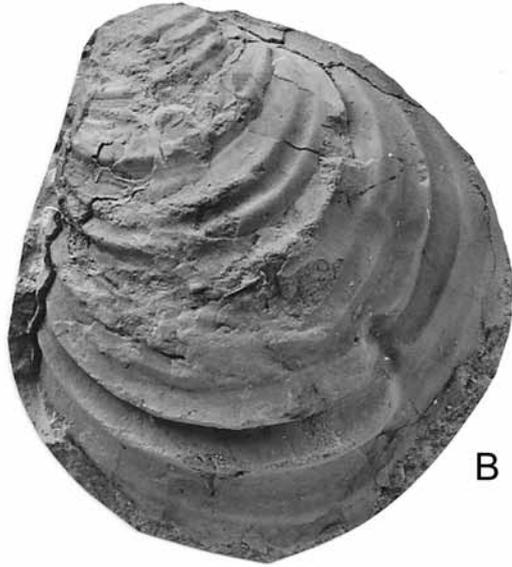
## PLATE 8

- A** – *Didymotis* sp.; Sulu-Kapy, ZI/45/3045;
- B, E, F** – *Cremnoceramus deformis erectus* (Meek, 1877); B - ZI/45/3046, Shakh-Bogota section, bed 14g, *erectus* Event; E – specimen from the Tsudahar section, Daghestan [= *Inoceramus schloenbachi* Boehm in Dobrov and Pavlova 1959, pl. 8, fig. 1]; F - ZI/45/3048, Shakh-Bogota section, bed 14g, *erectus* Event;
- C** – *Tethyoceramus* sp., ZI/45/3047, Shakh-Bogota section, *crassus* Horizon, bed 14h;
- D** – *Cremnoceramus waltersdorfensis hannovrensis* (Heinz, 1932) [= *Inoceramus striatoconcentricus* Gümbel in Pavlova 1955, pl. 5, fig. 1; in Dobrov and Pavlova 1959, pl. 2, fig. 2]; Kara-Koysu section; Daghestan.

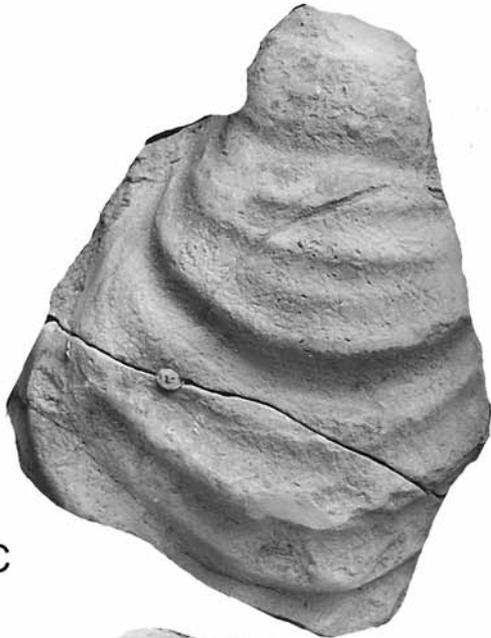
All figures are natural size



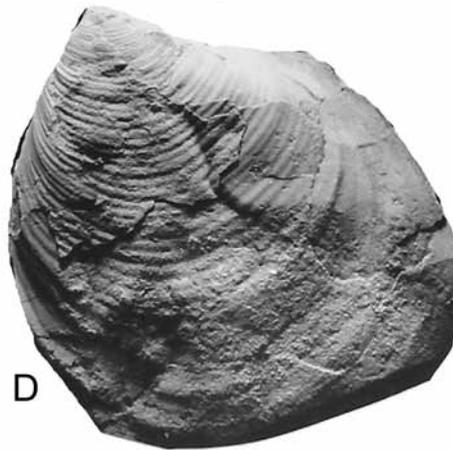
A



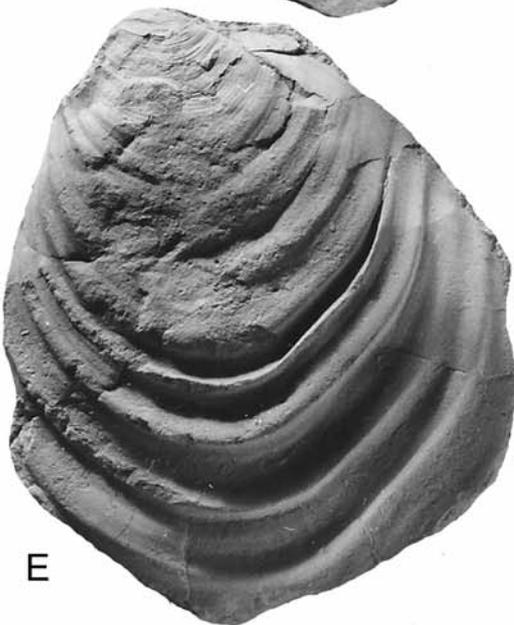
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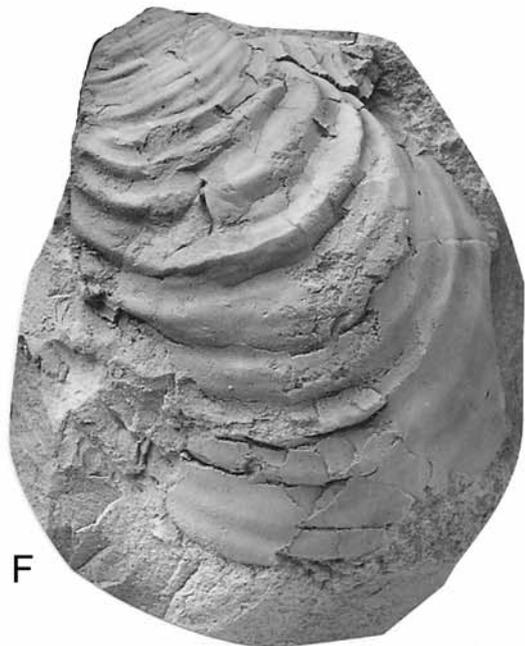
C



D



E



F

PLATE 9

*Cremnoceramus crassus crassus* (Petrascheck, 1903), ZI/45/3049, Shakh-Bogota section,  
bed 14h, *crassus* Horizon; the figure is  $\times 0.75$



PLATE 10

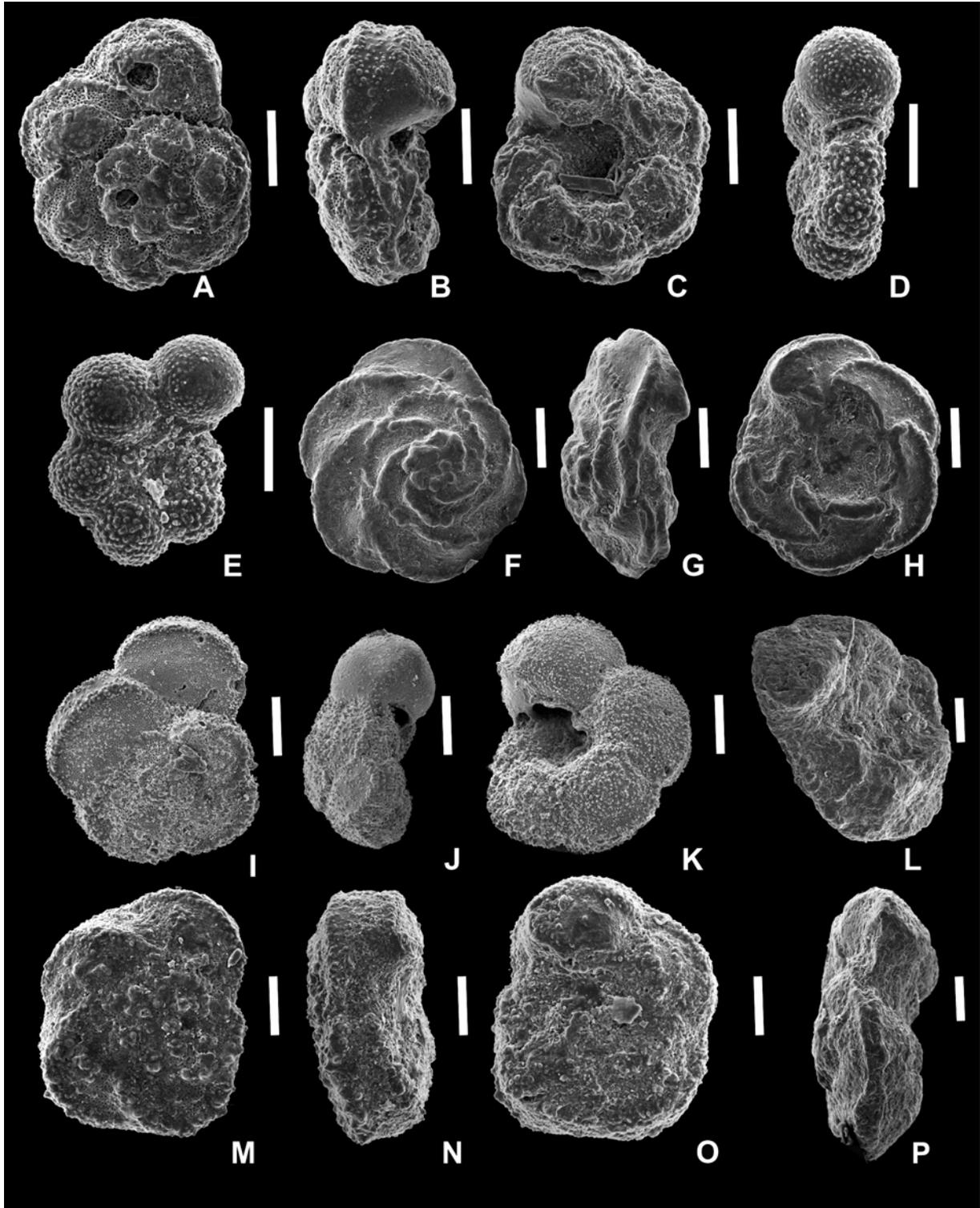
*Volviceras involutus* (J. de C. Sowerby, 1829), ZI/45/3050, Shakh-Bogota section, unit 15, *involutus* Horizon; the figures is  $\times 0.7$



## PLATE 11

- A-C** – *Marginotruncana marginata* (Reuss, 1845); Shakh-Bogota section, sample 5; Upper Turonian;
- D-E** – *Globigerinelloides asper* (Ehrenberg, 1854); Shakh-Bogota section, sample 28, Lower Santonian;
- F-H** – *Marginotruncana sinuosa* (Porthault, 1970); Shakh-Bogota section, sample 14, Lower Coniacian;
- I-K** – *Dicarinella hagni* (Scheibnerova, 1962); Shakh-Bogota section, sample 4, Upper Turonian;
- L, M** – *Concavatotruncana primitiva* (Dalbiez, 1955); Sulu-Kapy section, sample 13, Coniacian;
- N-P** – *Globotruncana bulloides* Vogler, 1941; Sulu-Kapy section, sample 16, Upper Santonian.

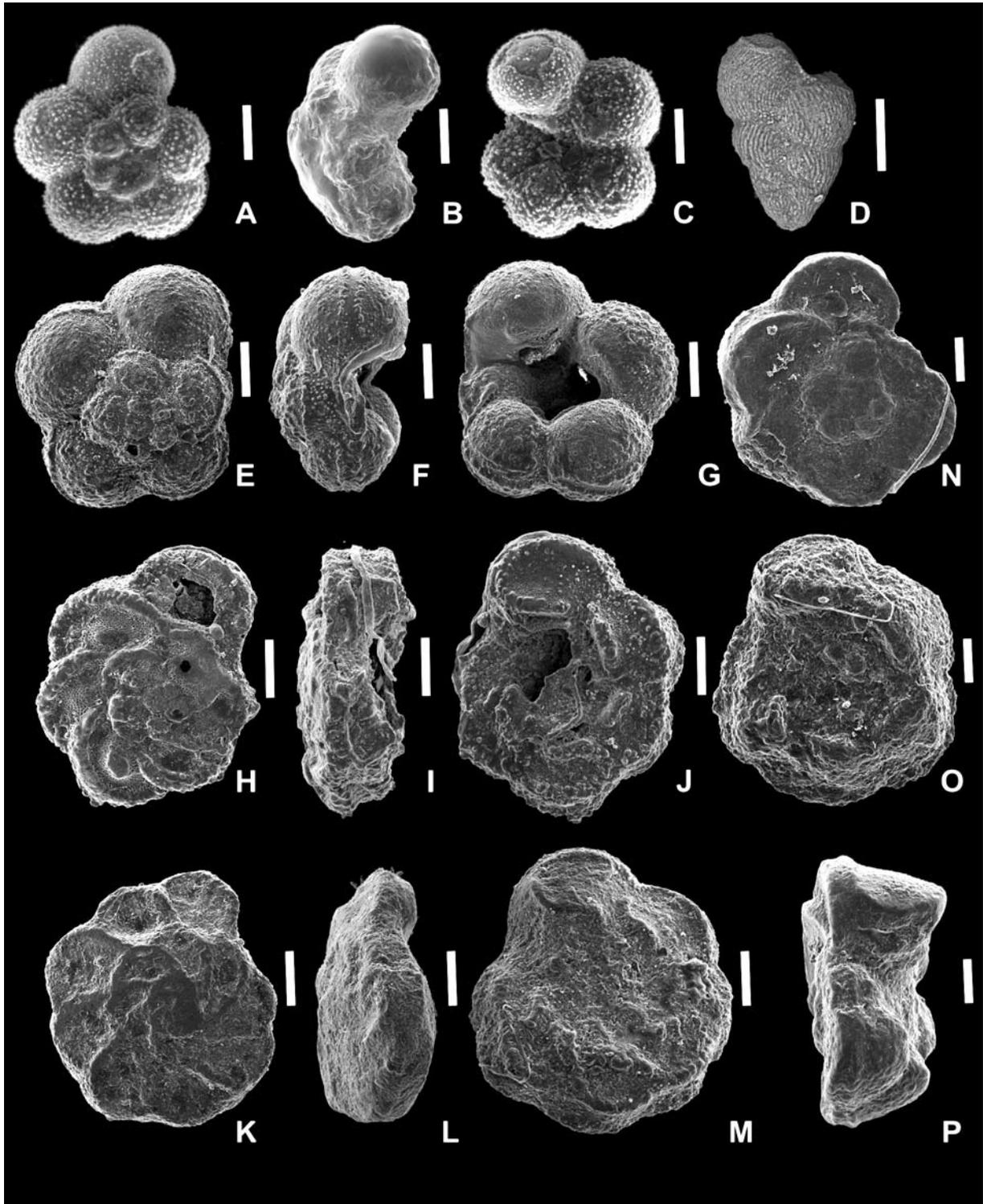
Scale bar – 100 µm



## PLATE 12

- A-C** – *Whiteinella brittonensis* (Loeblich and Tappan, 1961); Shakh-Bogota section, sample 5, Upper Turonian;
- D** – *Heterohelix globulosa* (Ehrenberg, 1840); Shakh-Bogota section, sample 14, Lower Coniacian;
- E-G** – *Archaeoglobigerina cretacea* (d’Orbigny, 1840); Shakh-Bogota section, sample 11, Lower Coniacian;
- H-J** – *Marginotruncana pseudolinneiana* Pessagno, 1967; Shakh-Bogota section, sample 11; Lower Coniacian; sample 14, Lower Coniacian;
- K-M** – *Marginotruncana coronata* (Bolli, 1945); Shakh-Bogota section, sample 12, Lower Coniacian;
- N-P** – *Concavotruncana concavata* (Brotzen, 1934); Shakh-Bogota section, sample 18, Middle Coniacian.

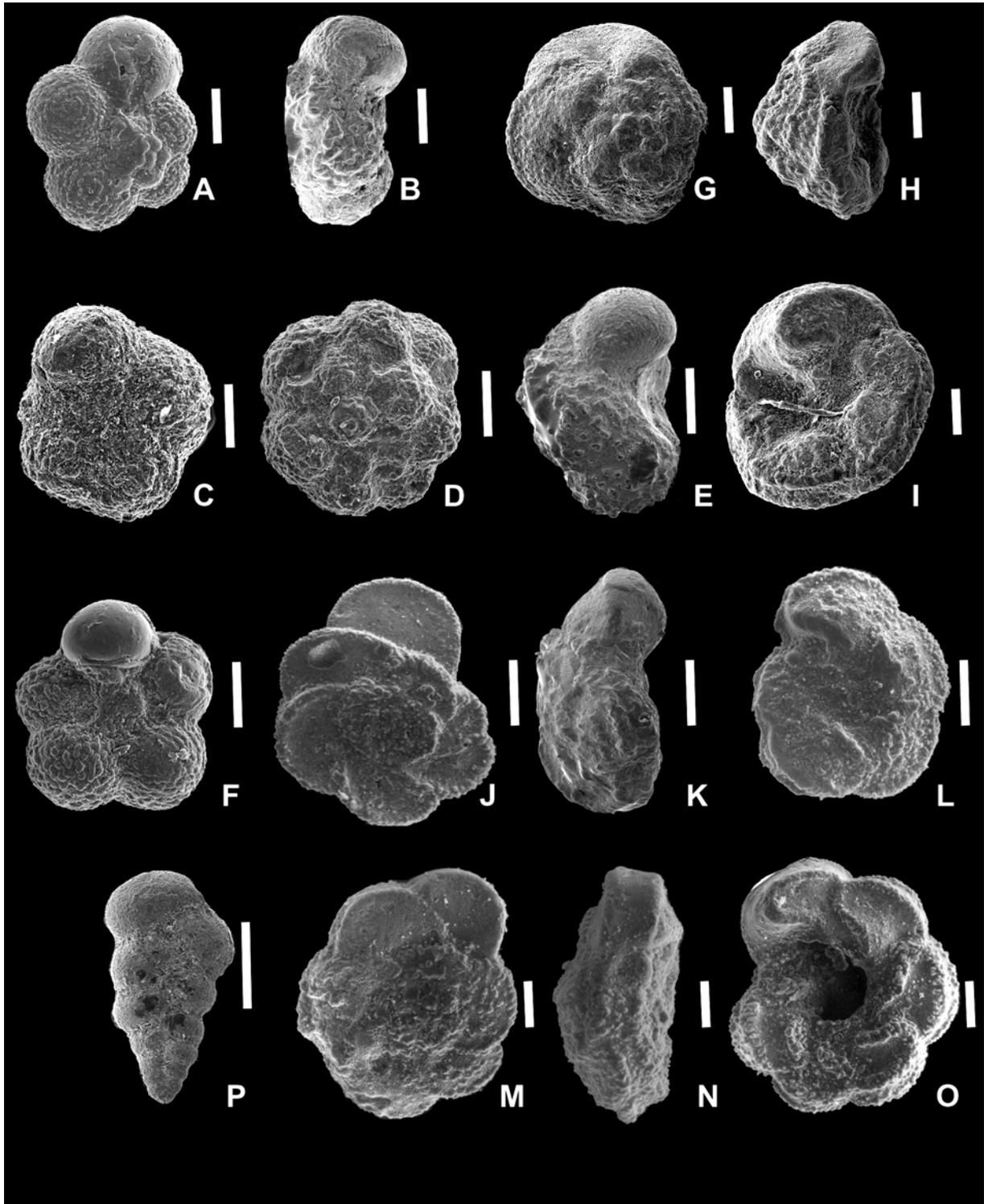
Scale bar – 100 µm



## PLATE 13

- A-C** – *Archaeoglobigerina blowi* Pessagno, 1967; Shakh-Bogota section, sample 18, Middle Coniacian;
- D-F** – *Archaeoglobigerina bosquensis* Pessagno, 1967; Shakh-Bogota section, sample 22, Upper Coniacian;
- G-I** – *Contusotruncana fornicata* (Plummer, 1931); Sulu-Kapy section, sample 16, Upper Santonian;
- J-L** – *Marginotruncana renzi* (Gandolfi, 1942); Shakh-Bogota section, sample 16, Lower Coniacian;
- M-O** – *Marginotruncana coronata* (Bolli, 1945); Koksyrtau-Aksyrtau section, sample 8, Lower Coniacian;
- P** – *Heterohelix moremani* (Cushman, 1938); Shakh-Bogota section, sample 20, Middle Coniacian.

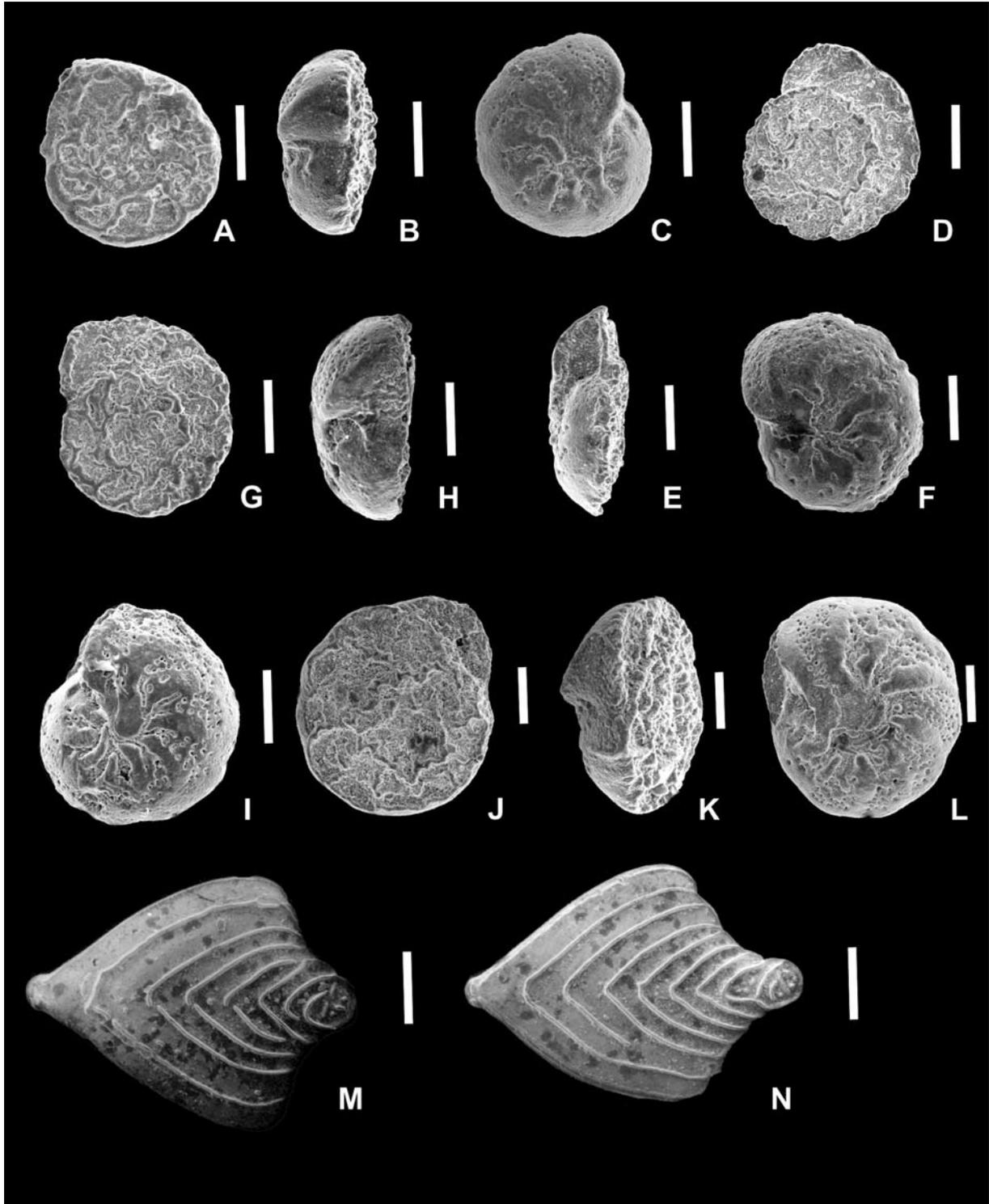
Scale bar – 100 µm



## PLATE 14

- A-C** – *Stensioeina emsherica* Baryshnikova, 1959; Koksyrtau-Aksyrtau section, sample 9, Lower Coniacian;
- D-F** – *Stensioeina exculpta exculpta* (Reuss, 1860); Koksyrtau-Aksyrtau section, sample 13, Lower Santonian;
- G-I** – *Stensioeina incondita* Koch, 1977; Koksyrtau-Aksyrtau section, Lower Santonian;
- J-L** – *Stensioeina pommerana* Brotzen, 1936; Sulu-Kapy section, sample 16, Upper Santonian;
- M, N** – *Neoflabellina suturalis* Cushman, 1936; Shakh-Bogota section, sample 29, Lower Santonian.

Scale bar – 100  $\mu\text{m}$



## PLATE 15

*Stensioeina*, Shakh-Bogota section

- A-C** – *Stensioeina emscherica* Baryshnikova, 1959, middle part of unit 15, Middle-Upper Coniacian; Scale bar = 30  $\mu\text{m}$ ;
- D-F** – *Stensioeina exsculpta exsculpta* (Reuss, 1860), middle part of unit 15, Middle-Upper Coniacian; Scale bar = 30  $\mu\text{m}$ ;
- G-I** – *Stensioeina exsculpta* cf. *gracilis* Koch, 1977, Middle Santonian; Scale bar = 100  $\mu\text{m}$ ;
- J-L** – *Stensioeina granulata incondita* Koch, 1977, Middle Santonian; Scale bar = 100  $\mu\text{m}$ ;
- M-O** – *Stensioeina pommerana* Brotzen, 1936, uppermost Santonian; Scale bar = 100  $\mu\text{m}$ .

