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

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ABSTRACT:


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 pseudolineatiana, 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, Turkmen, 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-Dag 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 Tuarkyr and Kopetdag 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 (Stampfl 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, in the Aksyrtau-Koksyrtau section (see Marcinowski et al. 1999 expedition, see Marcinowski et al. 1999), 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. 1996, fig. 14). Consequently, the basic sections referred to herein are those from the latter area: Shakh-Bogota, Sulu-Kapy and Koksyrtau-Aksyrtau (Text-figs 2–4). Representative inoceramids are illustrated in Plates 1–10.

Lower and basal Middle Turonian

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 Cobbán, 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 kossmatai (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-Kappy 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.

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.
**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 inaequivalvis* 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. inaequivalvis* 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 labioidiformis* (Tröger, 1967), *Inoceramus longealatus* Tröger 1967 (PL 5, Figs A–D, F–H) and *I. inaequivalvis*. This horizon is known only from the Shahk-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 lusatiae* Andert, 1911 (PL 6, Fig. C; PL 7, Fig. B) similarly as in the Slupia Nadbrzeżna section, and possibly in the Sonnenberg section at Waltersdorf (see Wood et al. 2004) and then by (3) an almost monospecific assemblage of *Cremnoceramus waltersdorferiensis* waltersdorferiensis (Andert, 1911), accompanied by *Didymotis*. Immediately above the *C. walt. waltersdorferiensis* 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 waltersdorferiensis 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 Koskyrtau-Aktyrtau 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 waltersdorferiensis* lineage. The record was documented in the Shahk-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 seitzi* 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.
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* G. asper, G. bulboides, St. incongrua, N. gibbera
* S. ovum, S. yesujica, S. confluens, S. anschelica
* M. corona, A. praefactus, G. vombensis, S. anschelica
* M. pseudobulboides

Text-fig. 3. Geological log, chronostratigraphy, and inoceramid and foraminiferal ranges and zones in the Aksyrtau-Koksyrtau section, western Kazakhstan (geological log after Marcinowski et al. 1996).
Text-fig. 4. Cenozoic stratigraphy and mammalian and foraminiferal ranges and zones in the Sulu-Kapy section, western Kazakhstan (geological log after Marcinowski et al. 1996).

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- M. coronata
- M. pseudomelanea; G. moniliformis
- G. bulloides/tomicata
- G. asper; St. incondita; Hedistes gibbers
- A. blowi and St. exculpta
- C. concava; G. thalmanni / St. ernshera
- G. conbentis/St. ernshera
- A. cretaea
- Archaeogloborugosa boweni
- Archaeogloborugosa boweniana
- Archaeogloborugosa boweni
- Archaeogloborugosa boweni
- Archaeogloborugosa boweni
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 anomalous* 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 pachti* (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 NaHCO₃, and clayey samples were boiled with Na₂SO₄, and clayey samples were boiled and is presented in detail in Text-figs 2–4.

Shakh-Bogota, Aksyrtau-Koksyrtau and Sulu-Kapy sections. Other marginotruncanids appear in Bed 12 of the Sul-Kapy section, Late Turonian whiteinellids, hedbergellids and heterohelicids co-occur with Early Turonian *Dicarinella elata* Lamolda, *Praeglobotruncana oraviensis* (Scheibnerova) and *P. praechelverica* (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. paradoxa* (Sigal), *W. brittonensis* (Loeblich and Tappan). *W. portsdownensis* (Williams-Mitchell), *Hedbergella hoelzi* (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. pseudolimneiana* (Pessagno), *M. coronata* (Bolli), *M. renzi* (Gandolfi), *Dicarinella canalicularata* (Reuss) and *D. hagni* (Scheibnerova). The first *M. pseudolimneiana*, *M. marginata*, and *D. canalicularata* 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

**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. praechelverica* (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.

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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),
as well as in the Crimea-Caucasus area (Kopaevich 2009). C. concava 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 upper parts of the interval studied.

Aksyrtau-Koksyrtau section and with assemblages of flat marginotruncanids; A. blowi is rare to common; A. cretacea forms the middle/Late Coniacian boundary. The first appearances of the inoceramid and upper parts of the interval studied. The genus Archaeoglobigerina, represented by A. cretacea (d’Orbigny) 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 Aksyttau-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 macrobiorstratigraphic 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 Aksyttau-Koksyrtau section. This event is marked by the sudden appearance of forms characterizing the Hedbergella holzli / Whiteinella archaeocretacea 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 Dicarinalla 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 emshnerica Event and Archaeoglobigerina cretacea Event are known from the level of the first appearance of the inoceramid Cremnoceramus watersdorfiensis in the Shakh-Bogota section and that of Cremnoceramus deformis erectus in the Aksyttau-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 Volviceras 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 Spiroplectammina, 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 plano-convex, heavily ornamented planktonic foraminifera (see also Walaszczzyk and Peryt 1998; Walaszczzyk 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,
Traditionally, the two-fold subdivision of both the Turonian and Coniacian was applied in Mangystau, 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 Moskvin 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

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<td>L. (pars)</td>
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<td>*Inoceramus perplexus + <em>I. lamarcki</em></td>
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<td>UPPER</td>
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<td><em>Inoceramus woodsi</em></td>
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<td><em>Inoceramus apicalis</em></td>
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<td><em>Helvetoglobotruncana helvetica</em></td>
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<td><em>Inoceramus labiatus</em></td>
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Text-fig. 6. Inoceramid and foraminiferal zonations as applied in this paper and their correlations with previous zonations applied by various authors.
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 southeastern margin areas of the East European craton 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-Dagh (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* lamarki (in the Lower Coniacian), and the zones of *Inoceramus mantelli*, *Inoceramus involutus*, and the zone of *Inoceramus subquadратus* (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* Zone; and his *I. 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 *Concavatotruncana 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 the south-eastern margin of the East European Craton. 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 in 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 (Shupia Nadbrzeźna river cliff, see Walaszczyk and Peryt 1998; Salzgitte-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 wallersdorfiensis Zone in the Voronez high (central part of the East European Platform, 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 whitelinellids, archaeoglobigerinids, and double-keeled marginotruncanids, and are distinctly less diverse than the Tethyan assemblages. The typical Tethyan and biostratigraphically important umbilico-convex dicarninellids 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; Bieniaiski 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 the south-eastern margin of the East-European craton (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 Sullu-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 the south-eastern margin of the East-European Craton, none of the illustrated specimens actually represent Gümbel’s species. *I. striatoconcentricus* in Pavlova (1955, pl. 5, fig. 1; re-illustrated in Pl. 7, Fig. D) is *Cremnoceramus waltersdorfiensis 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 2–3), are *C. waltersdorfiensis*.

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

This morphology 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 south-eastern margin of the East-European craton, 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 woodsii* 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 woodsii* 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 longealatus* 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 longealatus* 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 lusatiae** Andert, 1911; Pl. 6, Fig. C; Pl. 7, Fig. B
This species definitely belongs to the *Inoceramus lamarki* 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). Kharitonov’s (1968, pl. 2, fig. 7 and pl. 3, figs 4, 5) *Inoceramus lusatiae* 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 lusatiae* of Pavlova (1955, pl. 4, fig. 5; re-illustrated herein in Text-fig. 11B) is *Cremnoceramus waltersdorfiensis 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 lusatiae* by Khalalova (1968) at least two (Khalalova 1968, pl. 1, figs 10, 11) represent early *Cremnoceramus deformis erectus* (Meek) and the other two (Khalalova 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 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 western south-eastern margin of the Russian Platform: Central Asia (Mangyshlak, Tuarkry, Kopet-Dagh; Atabekian and Likhacheva 1961; Aliev and Kharitonov 1981, 1988; Aliev et al. 1982), the Caucasus (Daghistan, Azerbaijan, Armenia; e.g., Pavlova 1955; Dobrov and Pavlova 1959; Khalalova 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 Moskvin 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* Boehm. 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 waltersdorfiensis waltersdorfiensis*).
Cremnoceramus 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 Cenomanian (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 lusatiae Andert (Pl. 6, Figs B, E from Pavlova 1955, pl. 4, fig. 5). See also discussion under I. lusatiae and M. striatoconcentricus.

Cremnoceramus crassus (Petrachev, 1903) (= Inoceramus schloenbachi Böhm, 1909); Plate 9

Conspecific with C. crassus crassus are specimens illustrated by Atabekian (1974, pl. 104, fig. 2 and pl. 104, fig. 3), Ivanikov (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 quasiminconstans 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. schloenbachii of authors) represent C. deformis erectus, as interpreted herein (see discussion under this latter taxon).

Volviceramus 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; Aksyrtau-Koksyrtau section, topmost part of unit 35D;
B – *Mytiloides goppelnensis* (Badillet and Sornay, 1980), ZI/45/3052, Aksyrtau-Koksyrtau section, unit 29;
D – *Mytiloides kossmati* (Heinz, 1930) and *Mytiloides mytiloides* (Mantell, 1822), ZI/45/3055, Aksyrtau-Koksyrtau section, topmost part of unit 35D;
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 stuemckeii* Heinz, 1926, ZI/45/3000, Shakh-Bogota section, bed 12
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;

All specimens are natural size
PLATE 4

_Mytiloides striatoconcentricus_ (Gumbel, 1868), bed 14b of the Shakh-Bogota section


All figures are natural size
PLATE 5

– *Inoceramus* ex gr. *inaequivalvis* Schlüter, 1877, ZI/45/3029, bed 12;
J – *Mytiloides costellatus* (Woods, 1912), ZI/45/3034, bed 12;
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 *Cremnoceramus waltersdorfenensis waltersdorfenensis* Event;

B, E – *Cremnoceramus waltersdorfenensis hannovrensis* (Heinz 1932) [= *Inoceramus lusatiae* in Pavlova 1955, pl. 4, fig. 5]; Rubas-Tchai section, Daghestan;

C – *Inoceramus lusatiae* Andert, 1911, ZI/45/3043, Sullu-Kapy section, bed 20, just below the *Cremnoceramus waltersdorfenensis waltersdorfenensis* Event, topmost Turonian;

D – *Cremnoceramus 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 – *Cremnoceramus deformis erectus* (Meek, 1877) [= *Inoceramus schloenbachi* Böhm in Dobrov and Pavlova 1959, pl. 8, fig. 2]; Sudahar section, Daghestan;

B – *Inoceramus lusatiae* Andert, 1911, ZI/45/3058, Sullu-Kapy section, bed 20, just below the *Cremnoceramus waltersdorvensis waltersdorvensis* 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.; Sullu-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, Dagestan [= 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 hannovensis (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
PLATE 9

*Cremnoceramus crassus crassus* (Petrascheck, 1903), ZI/45/3049, Shakh-Bogota section, bed 14h, *crassus* Horizon; the figure is $\times 0.5$
PLATE 10

_Volviceramus involutus_ (J. de C. Sowerby, 1829), ZI/45/3050, Shakh-Bogota section, unit 15, _involutus_ Horizon; the figures is $\times 0.5$
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 – Concavotruncana 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 globulus* (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 – *Concavatoruncana 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
A-C – *Stensioeina emsherica* Baryshnikova, 1959; Koksyrtau-Aksyrtau section, sample 9, Lower Coniacian;

D-F – *Stensioeina exculpata exculpata* (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 µm
PLATE 15

*Stensioeina*, Shakh-Bogota section

1-3 – *Stensioeina emscherica* Baryshnikova, 1959, middle part of unit 15, Middle-Upper Coniacian; Scale bar = 30 μm;

4-6 – *Stensioeina exsulcta exsulcta* (Reuss, 1860), middle part of unit 15, Middle-Upper Coniacian; Scale bar = 30 μm;

7-9 – *Stensioeina exsulcta cf. gracilis* Koch, 1977, Middle Santonian; Scale bar = 100 μm;

10-12 – *Stensioeina granulata incondita* Koch, 1977, Middle Santonian; Scale bar = 100 μm;

13-15 – *Stensioeina pommerana* Brotzen, 1936, uppermost Santonian; Scale bar = 100 μm.