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Foraminiferal biostratigraphy of the uppermost Campanian-Maastrichtian in SW Crimea (Bakhchisaray and Chakhmakhly sections)

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Abstract

A detailed foraminiferal distribution, resulting from bed by bed collecting of the Beshkosh and Chakhmakhly sections in SW Crimea, is studied for the first time. Many of the taxa - planktonic and benthic - are illustrated. A biostratigraphical analysis of the units XIX to XXIII (Upper Campanian - Maastrichtian) and the correlation with other areas are discussed.

Key-words: Foraminifera - biostratigraphy - uppermost Cretaceous - Crimea.

Résumé

Une récolte banc par banc effectuée dans la partie Campanien-Maastrichtien des sections de Beshkosh et Chakhmakhly (sud-ouest de la Crimée), a permis de présenter la première distribution détaillée des foraminifères retrouvés dans cet interval. De nombreux taxa planctoniques et benthiques ont été figurés. Une analyse biostratigraphique des unités XIX à XXIII (Campanien supérieur-Maastrichtien) et une corrélation avec d'autres régions sont discutées.

Mots-clefs: Foraminifères - biostratigraphie - Crétacé sommital - Crimée.

Introduction

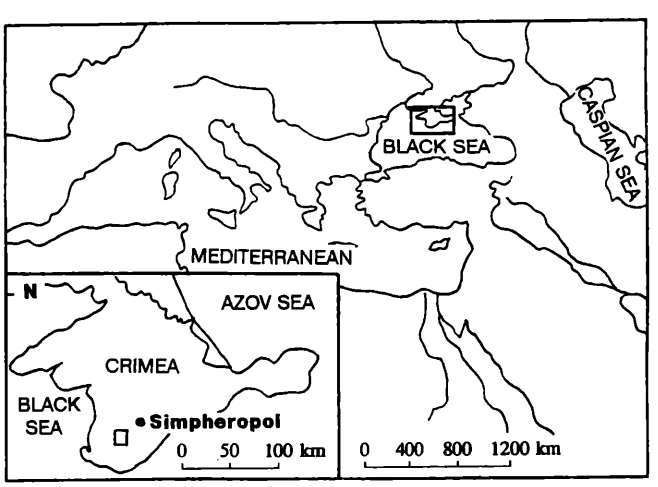
During the late Cretaceous the Crimean Peninsula was covered by a relatively shallow marine basin belonging to the northern Tethys margin. This basin had a wide connection with the boreal seas of the Russian platform (Figure 1). Because of the similarity in taxonomic composition of its marine fauna with those from northern Europe, it is generally included in the European palaeobiogeographic fauna (NAJDIN, 1969).

SW Crimea, and especially the area around Bakhchisaray, is a classic area for the study of the Upper Cretaceous in Crimea. The Cretaceous stratigraphy in this region has been studied since the middle of the last century (HUOT, 1842; STUCKENBERG, 1873; COQUAND, 1877; LANGE & MIRCHINK, 1910; SLOUDSKY, 1911; WEBER, 1923; WEBER & MALYCHEFF, 1924; MIKHAILOV, 1948). The most complete description of the sequence including its palaeontological characteristics was published by MASLAKOVA (1959 a, b, c, d; 1971), MASLAKOVA & VOLOSHINA (1969) and more recently by ALEKSEEV (1989).

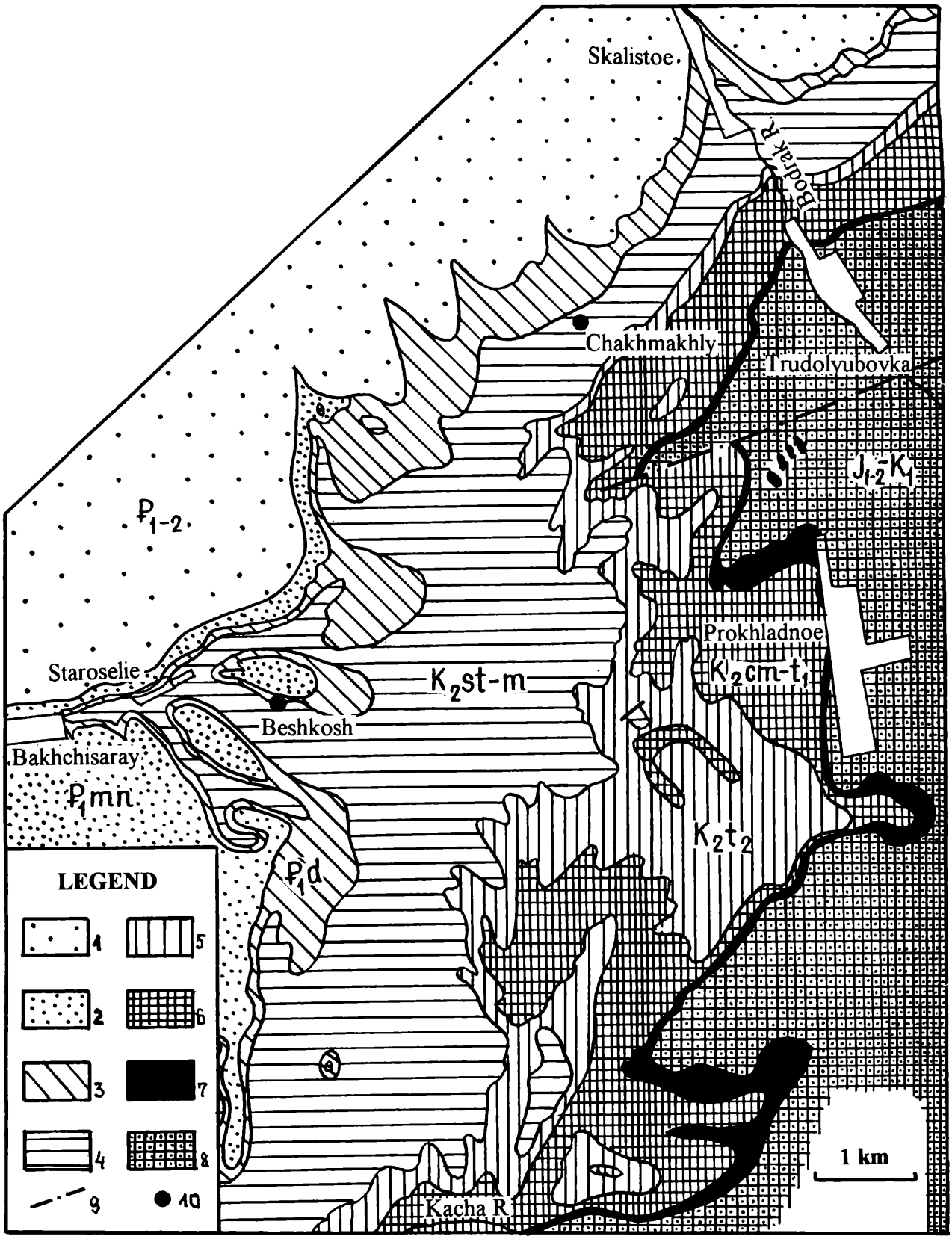
Campanian and Maastrichtian deposits in SW Crimea are very rich in Foraminifera. The first data on Foraminifera from the Campanian of Bakhchisaray were published by KELLER (1951). MASLAKOVA (1959 a) briefly described the Crimean late Cretaceous foraminiferal assemblages. MASLAKOVA & NGUYEN (1975) listed Maastrichtian and Danian Crimean benthic foraminifers. They used a zonal subdivision applicable to the southern part of the former USSR, which was later developed further for planktonic foraminifers by MASLAKOVA (1977, 1978). The most comprehensive foraminiferal data of Campanian and Maastrichtian age from the vicinity of Bakhchisaray (Beshkosh section) are found in MASLAKOVA, 1971.

However, despite the numerous existing publications, Foraminifera from this region were never illustrated, nor was their occurrence ever shown in a measured section, with a bed by bed distribution chart.

In this paper data are presented on the distribution and



Text-fig. 1. — Location of the area studied, situated in southern Crimea, The Ukraine.



Text-fig. 2. — Geological map of the studied area, abbreviations and legend: J_{1-2}-K_1 and 8: Lower - Middle Jurassic and Lower Cretaceous strata; 7: Lower Cretaceous (Upper Albian) strata; K_2cm-t_1 and 6: Upper Cretaceous (Cenomanian and Lower Turonian) strata; K_2t_2 and 5: Upper Cretaceous (Upper Turonian) strata; K_2 st-m and 4: Upper Cretaceous (Santonian to Maastrichtian strata); P_1d and 3: Palaeogene: Danian strata; P_1mn and 2: Palaeogene: Montian strata; P_{1-2} and 1: Palaeogene: Thanetian - Ypresian - Lutetian strata. Map compiled by D. P. Naidin from NIKISHIN *et al.*, 1933.

zonation of the Foraminifera from two important uppermost Campanian - Maastrichtian sections (Beshkosh and Chakhmakhly) situated near Bakhchisaray. Some correlations are also indicated.

Geological setting

Mountain Crimea is a folded Mesozoic structure (in western Crimea the main folding phase was during the Middle Jurassic, whereas in eastern Crimea it took place in early Cretaceous times), which was reactivated and uplifted in late Neogene-Quaternary times. During the early and middle Albian the tectonic rifting phase caused general subsidence of both Mountain and Plain Crimea. From the late Albian onwards and except brief interruptions shallow marine basins occupy these regions. In SW Crimea, Campanian and Maastrichtian outcrops are situated on the northern slope of the second chain of the Crimean mountains. These sediments are slowly dipping to the NW and the W, forming angles of 10 to 15°. Together with older Cretaceous rocks they form the NW wing of the Kacha Uplift (Figure 2). The central part of the same uplift consists of a strongly deformed early-middle Jurassic terrigenous flysch complex (Taurian Group) (MILEEV *et al.*, 1989).

The softer Campanian rocks are badly exposed and sometimes crop out in the bottom of valleys between Upper Turonian and Danian cuestas. The Maastrichtian can be studied in many sites along the steep southern scarp of the cuesta, which is capped by hard Danian limestones between the Kacha and Bodrak rivers, east of Bakhchisaray.

Material and methods

84 samples, taken at intervals of 2 to 5 m, were collected from the Beshkosh and Chakhmakhly sections. Sample weight varied from 100 to 200 g. The Foraminifera were extracted from the rock using standard washing techniques.

The planktonic/benthic ratio was calculated by counting more than 200 specimens in split part of the fraction above 50 l. In the Beshkosh section the insoluble residue was identified after its dissolution in 10 % H Cl.

Lithostratigraphy

For many years no lithostratigraphic subdivision existed for the Cretaceous Crimean strata and the geologists used only Western European stage and substage biostratigraphic units.

In 1984, Ukrainian geologists (PLOTNIKOVA *et al.*, 1984) proposed a few lithostratigraphic terms for Upper Cretaceous strata. For the interval under discussion they proposed f.i. the Beshkosh Formation (white chalky marls of late Campanian age) and the Staroselie Formation (siltic marls of Maastrichtian age). These units have not been generally used because their stratigraphic range is too wide and their lithology not sufficiently homogenous.

The generally used lithostratigraphic scale for the Upper Cretaceous strata of SW Crimea is that proposed by ALEKSEEV (1989). The scale includes 24 numbered units from the lowermost Cenomanian to the uppermost Maastrichtian. In the sections studied herein only the interval between units XIX and XXIII is visible. (The terminal Maastrichtian unit XXIV has only been found in the Belbek River section).

In the Beshkosh and the Chakhmakhly sections the lithology of all units is very similar and they are hereafter described together.

— **Unit XIX**: white chalky limestones with thin clayish films and rare inoceramids; carbonate content: 93 to 95 %; thickness: 27 m in the Beshkosh section, 10 m in the Chakhmakhly section (representing only the uppermost part of the unit).

— **Unit XX**: grey and light grey, mainly siltic marly limestones or marls; can be subdivided into three subunits.

subunit XXa: light grey spotted marls, with some siltic material; in weathered state these marls are blue-grey and thick-bedded; terrigenous material content increases from 7 % at the base of the subunit to 14 - 20 % at its top; thickness: 20 m in the Beshkosh section and 17 m in the Chakhmakhly section.

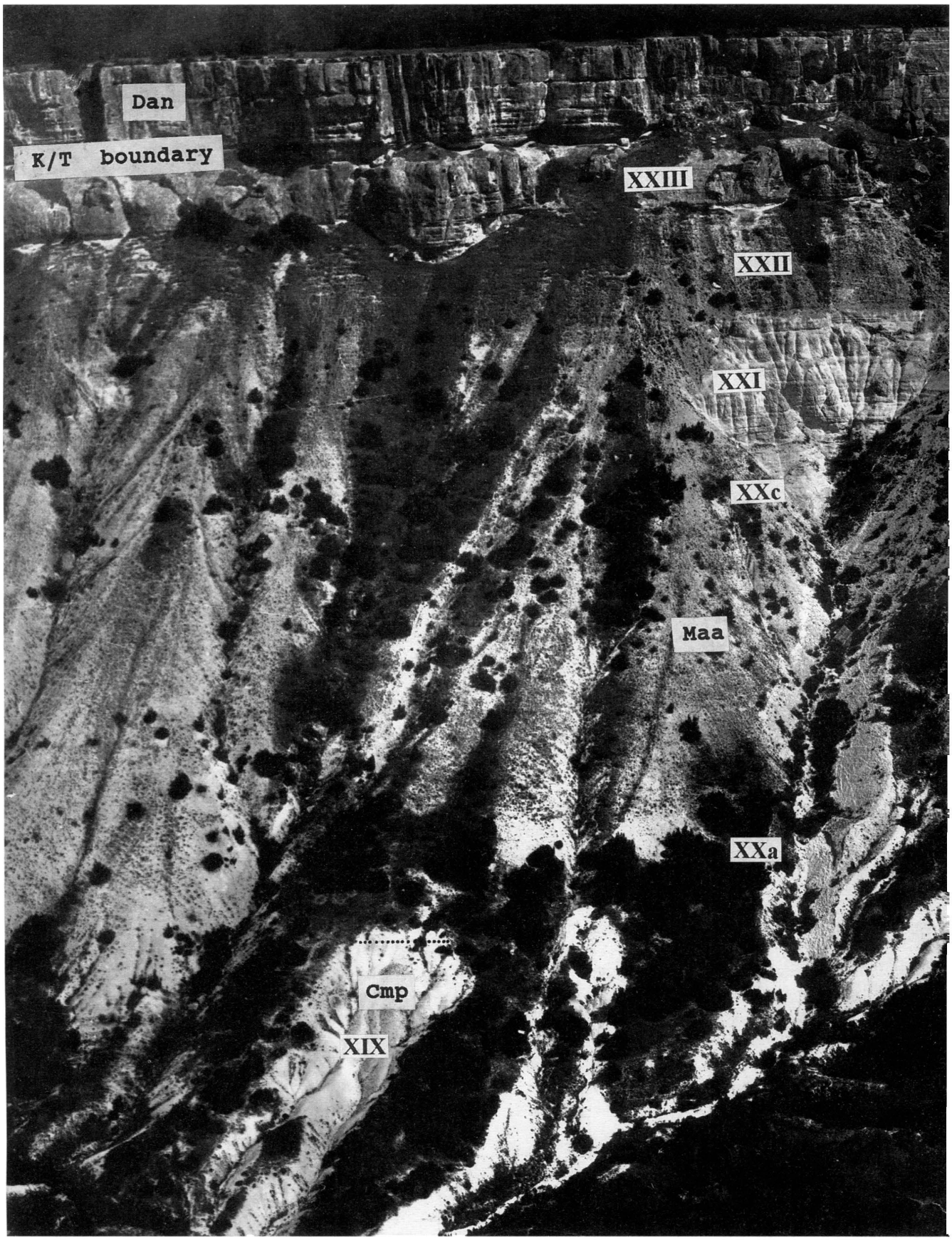
subunit XXb: light grey and yellowish siltic marly limestones with 20 to 28 % of insoluble residue; thickness: 23 m in the Beshkosh section.

subunit XXc: grey siltic marls with ferrugineous concretions (oxidized pyritic nodules; numerous silicified burrows and sponge fragments; content of terrigenous material is less than in subunit XXb and varies between 17 and 22 %; thickness: 23 m in the Beshkosh section.

In the Chakhmakhly section subunits XXb and XXc cannot be distinguished; their combined thickness is 43 m.

— **Unit XXI**: grey and light grey marls with ferruginous concretions; marls in the base of unit are enriched with glauconite; silicified burrows and sponge fragments are especially abundant; relief of the slope of this unit forms generally an almost vertical escarpment; in the Beshkosh section there is a prominent hardground in the middle part of this unit; content of terrigenous material can be more than 30 %; thickness: 28 m in the Beshkosh section and 33 m in the Chakhmakhly section.

— **Unit XXII**: grey and yellow-grey siltic marls with numerous silicified burrows and sponge fragments; soft marls which never produce steep surfaces on the slope, but a few layers are harder as a result of silification; content of terrigenous, mainly siltic material reaches 32 - 38 % (maximum values for the whole sequence); thickness: 26 m in the Beshkosh section and 23 m in the Chakhmakhly Section.



Text-fig. 3. — The Campanian-Maastrichtian in the Beshkosh section; abbreviations: Cmp: Campanian; Maa: Maastrichtian; Dan Danian.

— **Unit XXIII**: yellowish-grey, siltic, glauconitic limestones with numerous incipient hardgrounds and lens-like accumulations of oyster and pectinid shells; the top of the unit consists of green-grey glauconitic sandstones (carbonate content 63 %) with lumachelles. The rocks of this unit are harder than the marls of unit XXII. On the slope they form subvertical scarps uncovered by vegetation. Thickness: 22 m in the Beshkosh section, 7 m (only the lower part could be measured) in the Chakhmakhly section.

In both sections unit XXIII is overlain by Lower Palaeocene (Danian) glauconitic sandstones containing numerous oysters and pectinids, shark teeth and fragments of dinosaur bones. The Danian sandstones are very similar to those from the uppermost Maastrichtian, but are richer in glauconite. These sandstones are overlain by limestones, with a thickness of about 40 m in the Beshkosh section.

Description of the sections

The Beshkosh section is situated on the southern slope of the Beshkosh Mountain, 2.5 km to the E. of the city of Bakhchisaray (Figure 2). The characteristic feature of the section is a giant (more than 10 m across) block of Danian limestone, halfway up the slope (Figure 3). The Beshkosh section is very near the city of Bakhchisaray and has good exposures. The main part of the data used for the description of Upper Cretaceous stratigraphy in SW Crimea already in the last century were collected there (HUOT, 1842; STUCKENBERG, 1873). More recently, MASLAKOVA & LIPNIK (1971) gave a brief description of the Beshkosh section with the characteristics of its foraminiferal assemblages. ZAKLINSKAYA & NAIDIN (1985) gave a subdivision of the section based on macrofossils and described the palynofossil assemblage from the lower Upper Maastrichtian.

The Beshkosh section is highly fossiliferous; from this section DOBROV & PAVLOVA (1959) described new inoceramids, KUSMICHEVA (1987) octocorals, and RYABININ (1946) dinosaurs (reworked in basal Danian strata?).

The total thickness of the measured section on the Beshkosh Mountain is 159 m, including 27 m of the uppermost Campanian unit XIX (Beshkosh Formation) and 132 m of the Maastrichtian units XX - XXIII (Staroselie Formation). The Maastrichtian-Danian boundary is an erosional contact.

The Chakhmakhly section is situated in a ravine on the southern slope of the cuesta, capped by Danian limestones, on the left side of the Chakhmakhly Valley, about 2 km SW of the southern part of Skalistoe village, on the Bodrak River (Figure 2). This section has not been described in literature. Here, the thickness of the exposed uppermost Campanian unit XIX is 10 m, and that of the Maastrichtian units XX - XXIII is 121 m. Only the basal interval of unit XXIII was sampled because its upper part is an inaccessible vertical cliff.

Foraminiferal assemblages

The general taxonomic composition of the foraminiferal assemblages from both studied sections is very similar to those of northern Europe - Belgium (ROBASZYNSKI *et al.*, 1985; ROBASZYNSKI & CHRISTENSEN, 1989) and Northern Germany (SCHÖNFELD, 1989). The planktonic/benthic ratios (Figures 4 and 5) are not very high and vary from 0 to 50 %. In general they decrease sequence upwards in both sections. The lowest values are found in the Upper Maastrichtian unit XXIII where it changes from 1 to 5 %.

In both sections two levels of relative growth of P/B ratio are very clearly visible: one level coincides with the lower part of unit XX (30-40 % in the Beshkosh section and 40-70 % in the Chakhmakhly section). This first deepening episode reflects a sea level rise during the earliest Maastrichtian according to the macrofossil correlation by ZAKLINSKAYA & NAIDIN (1985). The second deepening episode is situated at the top of unit XXc and in the lower half of unit XXI in the Beshkosh section and in the lower part of unit XXI in the Chakhmakhly section. The P/B ratio grows at this level from 10-15 % to 50 %. This rise coincides with the *Belemnella sumensis* Zone in the upper Lower Maastrichtian. According to these data this depth interval could be described as middle and upper shelf.

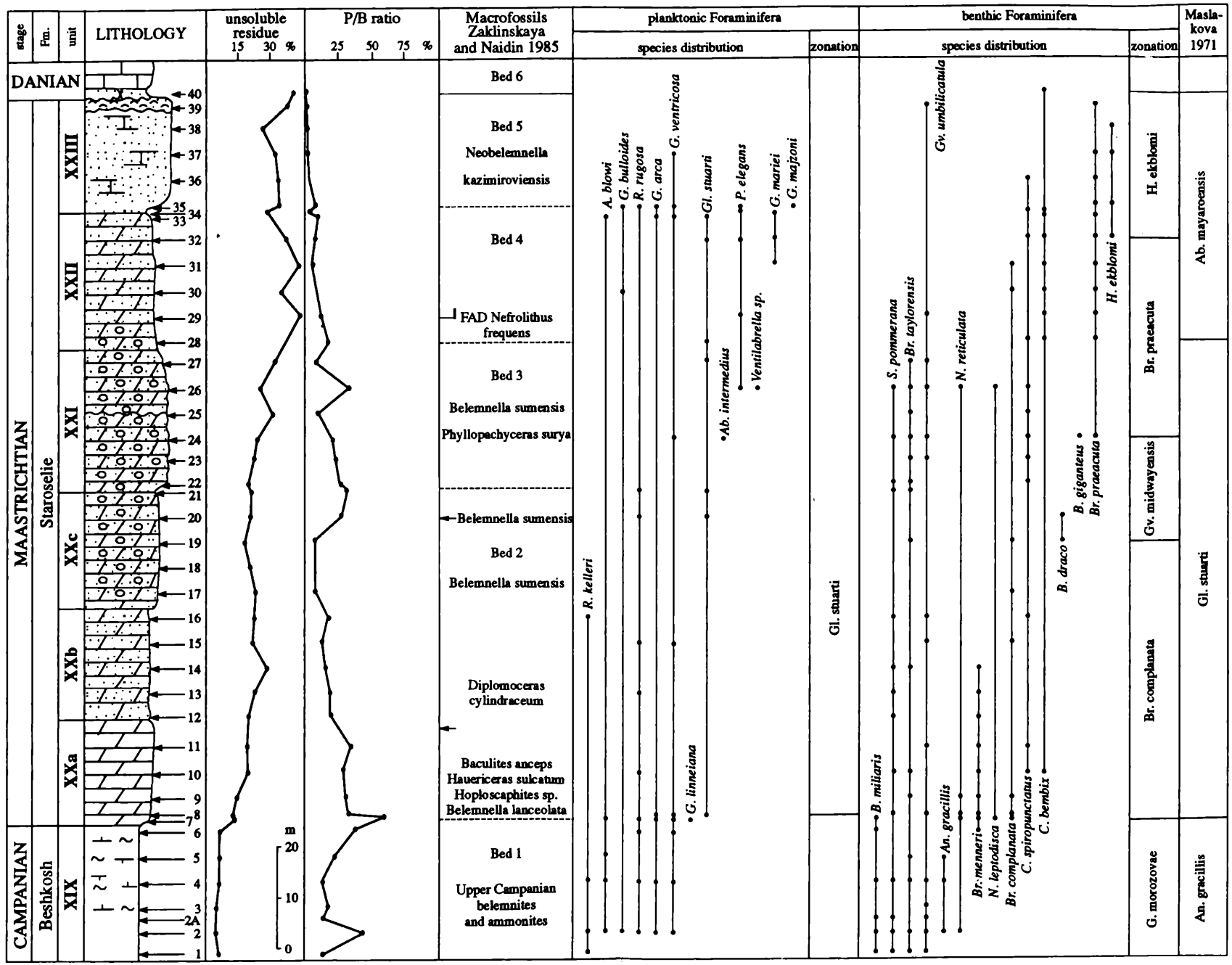
Most assemblages are dominated by calcareous benthic foraminifera. Agglutinated foraminifera comprise only a minor part of the assemblages (from 1 to 15 %), mainly 3-8 %. In this study the agglutinated foraminifera were not identified.

Foraminiferal biostratigraphy

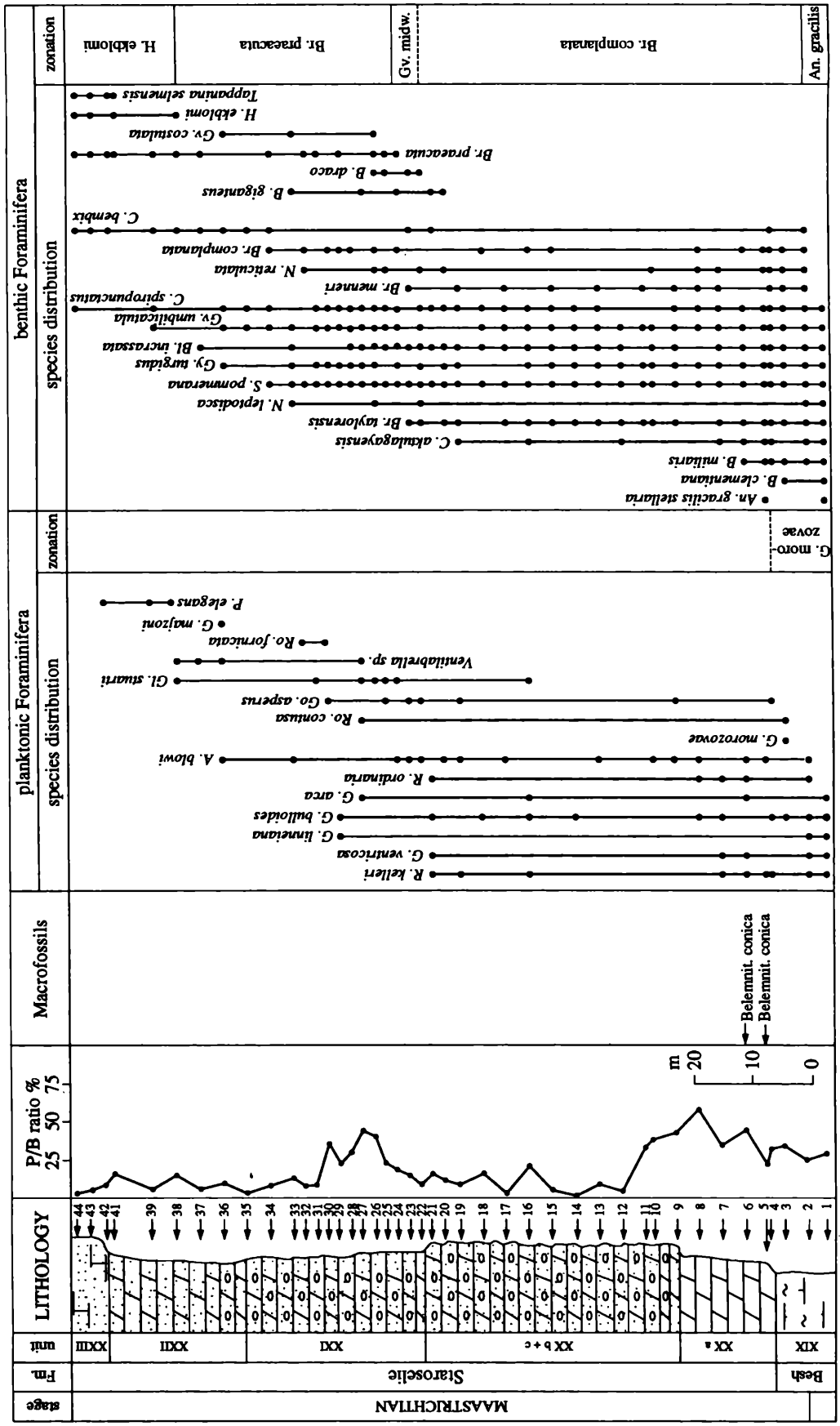
Planktonic zonation

Planktonic foraminiferal associations in the uppermost Campanian and Maastrichtian of SW Crimea have a low diversity. They are dominated by heterohelicids which comprise up to 80-90 % of the planktonic part of the oryctocoenoses. Globotruncanids are generally rare and their number increases only in intervals with higher P/B ratio. Among the globotruncanids shallow-water species of the genera *Globotruncana* and *Rugoglobigerina* are the most important.

The tropical planktonic zonation (CARON, 1986) cannot be used in SW Crimea. An alternative zonation was proposed by MASLAKOVA (1977, 1978) (Figure 6). In this scale the *Globotruncana morozovae* Zone (Upper Campanian), *Globotruncanita stuarti* Zone (Lower Maastrichtian) and *Abathomphalus mayaroensis* Zone (Upper Maastrichtian) were established. However, this zonation is also almost useless because of the rarity of its index forms. *Globotruncana morozovae* occurs only in one sample from the top part of unit XIX in the Chakhmakhly section and was not found in Beshkosh section. The F.O. of *Globotruncanita stuarti* is at the base of unit XXa and coincides with the probable macrofossil Cam-



Text-fig. 4. — Section at Beshkosh, indicating the position of the samples on the lithological column, the P/B (plankton/benthos) ratio in the samples, the most important planktonic and benthic foraminifera and their distribution in the samples. Abbreviations: A.: *Archeoglobergina*; Ab.: *Abathomphalus*; An.: *Angulogavelinella*; B.: *Bolivinoides*; Bl.: *Bolivina*; Br.: *Brotzenella*; G.: *Globotruncana*; Gl.: *Globotruncanita*; Go.: *Globigerinelloides*; Gv.: *Gavelinella*; R.: *Rugoglobigerina*; Ro.: *Rosita*.



Text-fig. 5. — Section at Chakhmakhly, indicating the position of the samples on the lithological column, the P/B ratio in the samples, the most important planktonic and benthic foraminifera and their distribution in the samples. Abbreviations: see text-fig. 4.

Planktonic zonation			Benthic zonation					
	Tropics Caron 1985	Crimea-Caucasus Maslakova 1977	East-European Platform Grigelis *et al.* 1980	Cis-Caspian Akimetz *et al.* 1983		European palaeobiogeographic province Naidin *et al.* 1984		
MAASTRICHTIAN	*Abathomphalus mayaroensis*	*Abathomphalus mayaroensis*	*Hanzawaia ekblomi*	MAASTRICHTIAN		*Hanzawaia ekblomi*	*Neobelemnella kazimiroviensis*	MAASTRICHTIAN
MAASTRICHTIAN	*Gansserina gansseri*	*Globotruncanita stuarti*	*Brotzenella complanata*	MAASTRICHTIAN	*Brotzenella praeacuta*	*Brotzenella praeacuta*	*Acanthoscaphites tridens* / *Belemnella sumensis*	MAASTRICHTIAN
MAASTRICHTIAN	*Globotruncana aegyptiaca*	*Globotruncanita stuarti*	*Brotzenella complanata*	MAASTRICHTIAN	*Gavelinella midwayensis*	*Gavelinella midwayensis*	*Acanthoscaphites tridens* / *Belemnella sumensis*	MAASTRICHTIAN
MAASTRICHTIAN	*Globotruncanella havanensis*	*Globotruncanita stuarti*	*Brotzenella complanata*	MAASTRICHTIAN	*Brotzenella complanata* / *Bolivinoides delicatulus*	*Brotzenella complanata*	*Acanthoscaphites tridens* / *Belemnella lanceolata*	MAASTRICHTIAN
CAMPANIAN	*Globotruncanita calcarata*	*Globotruncana morozovae*	*Globorotalites emdyensis*	MAASTRICHTIAN / CAMPANIAN	*Angulogavelinella gracilis*	*Angulogavelinella gracilis stellaria*	*Acanthoscaphites tridens* / *Belemnella licharewi*	MAASTRICHTIAN
CAMPANIAN	*Globotruncana ventricosa*	*Globotruncana morozovae*	*Brotzenella monterelensis*	CAMPANIAN	*Gem. orcinus* / *Brotzenella taylorensis*		*Belemnella langei* / *Belemnella langei najdini*	CAMPANIAN

Text-fig. 6. — Campanian-Maastrichtian planktonic and benthic foraminiferal zonation applicable in Crimea and comparison with similar zonations used in the tropics, in European Russia, in the Caucasus, and in the Cis-Caspian region Foraminiferal - belemnite zonation for the E.P.A. of NAIDIN *et al.*, 1984. Abbreviations as in text-fig. 4.

panian/Maastrichtian boundary. But in the Chakhmakhly section this species has a its F.O. only in the middle part of units XXb+c.

We have not found *Abathomphalus mayaroensis* in the Beshkosh section and this contradicts MASLAKOVA (1971).

Benthic zonation

Crimean benthic foraminifers allow the use of the zonation proposed by NAIDIN *et al.* (1984) for the European palaeobiographic province (Figure 6).

This scale is modified after the earlier introduced scales by GRIGELIS *et al.* (1980) and AKIMETZ *et al.* (1983). In both sections the base of *Brotzenella complanata* Zone is near to the bottom of unit XX. However, in the Chakhmakhly section it occurs slightly deeper in the sequence - in the topmost interval of unit XIX. The position of the younger *Gavelinella midwayensis* Zone is not so clear because this species occurs only in a few samples. It was possible to recognize the base of the *G. midwayensis* Zone only by the first appearance of *Bolivinoides draco* (which is an equally rare species!).

The uppermost Maastrichtian *Brotzenella praeacuta* and *Hanzawaia ekblomi* zones were recognized without any difficulties.

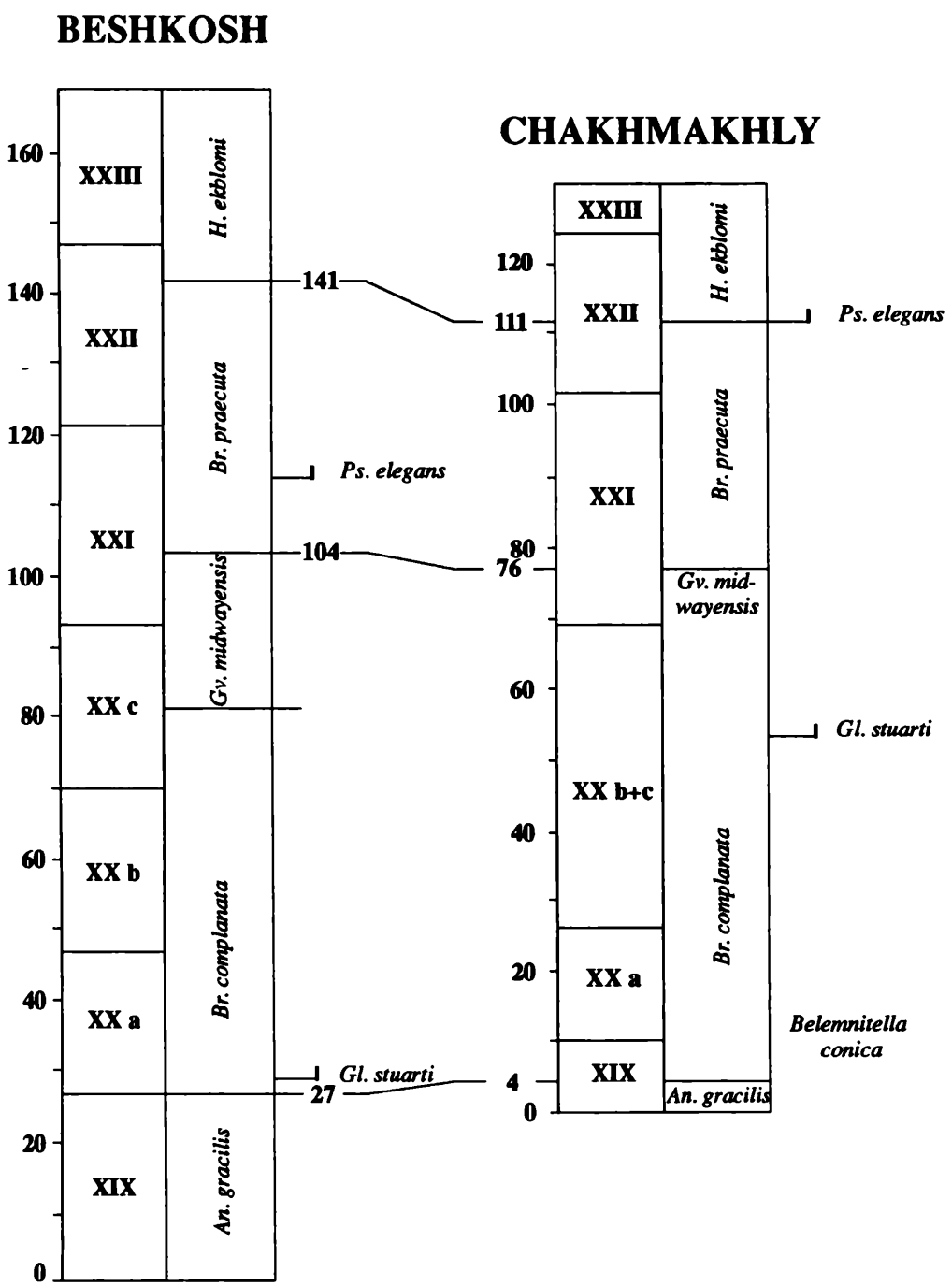
Correlations

SW Crimea

The correlation of the two studied sections, which are separated by a distance of about 7 km, on foraminiferal data is clear (Figure 7). It is possible to correlate the base of unit XX in the Beshkosh section (base of the *Brotzenella complanata* Zone, level 27 m) with level 4 m in the Chakhmakhly section (base of the *Br. complanata* Zone). The next correlatable levels are the base of *Br. praeacuta* Zone (level 104 m in the Beshkosh section and level 76 m in Chakhmakhly section; lower part of unit XXI) and the base of the *Hanzawaia ekblomi* Zone (level 141 m in the Beshkosh section and 111 m in the Chakhmakhly section; middle part of unit XXII). For other Crimean sections no such detailed data, which permit exact correlation, exist until now.

Western Europe

A very detailed zonation for the Campanian and Maastrichtian interval based on benthic Foraminifera was proposed by SCHÖNFELD (1988) for western Europe. Un-



Text-fig. 7. — Comparison of the Beshkosh and Chakhmakhly sections: assemblages and foraminiferal zonations.

fortunately, the ranges of most important benthic species in the SCHÖNFELD scale are not the same in SW Crimea and in North Germany. Moreover, the *Bolivinoides* species, which are important in the SCHÖNFELD scale, occur rarely in Crimea.

However, the first appearance of *Neoflabellina reticulata* in North Germany is inside the *decurrens* Zone, i.e in the lowermost Maastrichtian.

In the Beshkosh section, *N. reticulata* occurs in middle part of unit XIX andin the Chakhmakhly section in the uppermost part the same unit.

Campanian/Maastrichtian boundary

According to the macrofossil data the Campanian/Maastrichtian boundary coincides in SW Crimea with the base of unit XX (ZAKLINSKAYA & NAIDIN, 1985).

Our foraminiferal data support a correlation of the lower unit XIX with the *Angulogavelinella gracilis stellaria* Zone. In the belemnite scale the Maastrichtian base is at the bottom of the *Belemnella licharewi* Zone (NAIDIN *et al.*, 1984; Figure 6), i.e. in the middle *Angulogavelinella gracilis stellaria* Zone.

The base of Maastrichtian in North Germany (first appearance of *Belemnella lanceolata*) is in the *petersoni/hiltermanni* Zone (SCHÖNFELD,1988) and the first *Neoflabellina reticulata* occurs about 4 m higher in the sequence. In Crimea this last species was not found until the base of the *Brotzenella complanata* Zone, which is probably a few meters higher than the potential Campanian/Maastrichtian foraminiferal boundary.

This analysis shows that it is possible to recognize the Campanian/Maastrichtian boundary in the studied Crimean sections with a high precision.

Near to the Campanian/Maastrichtian boundary in Crimea, a very important correlative level exists with abundant rostra of the endemic belemnite *Belemnitella conica* Arkhangelsky. We found two rostra of this species in basal samples of unit XX. Consequently, in this area of Crimea the age of the *B. conica* level is Lower Maastrichtian, but not uppermost Campanian and Lower Maastrichtian (MIKHAILOV, 1948; NAIDIN, 1974). *Pachydiscus neubergicus*, marker taxon of the international Maastrichtian Stage proposed recently (ODIN, 1996) is not found in the basal Maastrichtian strata in SW Crimea, but ammonites have been described under this name from Upper Maastrichtian levels. They need to be revised.

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