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Stratigraphy and regional development of the mid-Cretaceous (Upper Albian through Coniacian) of the Mangyshlak Mountains, Western Kazakhstan

ABSTRACT: Dynamic stratigraphy and evolution of the Upper Albian through Coniacian of the Mangyshlak Mountains (Western Kazakhstan) is presented. The basic description, fossil content, and stratigraphic-sedimentary interpretation of selected sections covering the whole territory of the Central Mangyshlak Anticlinorium and the Tumgatchi Anticline are provided. From NW to SE the following sections are studied: Shakh-Bogota, Sulu-Kapy, Shyrkala-Airakty, Kush, Koksyrtau-Aksyrtau, Azhirektoy, and Besakty. With the exception of the Upper Albian the similarity of the fossil content permitted the application of the standard European zonation, including some of the bio-events (*A. plenus*, *C. waltersdorfensis*, *C. brongniarti*, and *M. striatoconcentricus*) of pan-European significance. The successive stages of the sedimentary development clearly show the dependence of the evolution of the area on the eustatic changes and the related paleogeography with only minor effects of the local tectonics. The studied macrofaunal elements (ammonites, belemnites, echinoids, and inoceramids) are invariably Boreal members of the North European Province.

INTRODUCTION

During the Cretaceous time Western Kazakhstan represented the marginal, south-easternmost part of the North European Paleobiogeographic Province, stretching from the Atlantic coasts in the west to the western tips of Central Asia. This position places it amongst very attractive areas for paleobiogeographic, paleontological as well as biostratigraphic studies, yielding possible record of the inter-regional links. Moreover, being a stable, epi-platform area close to the northern edge of the Alpine belt, it had great potential for recording the actual eustatic tendencies, as well as the whole series of bio-events recognized in the western and central European Cretaceous.

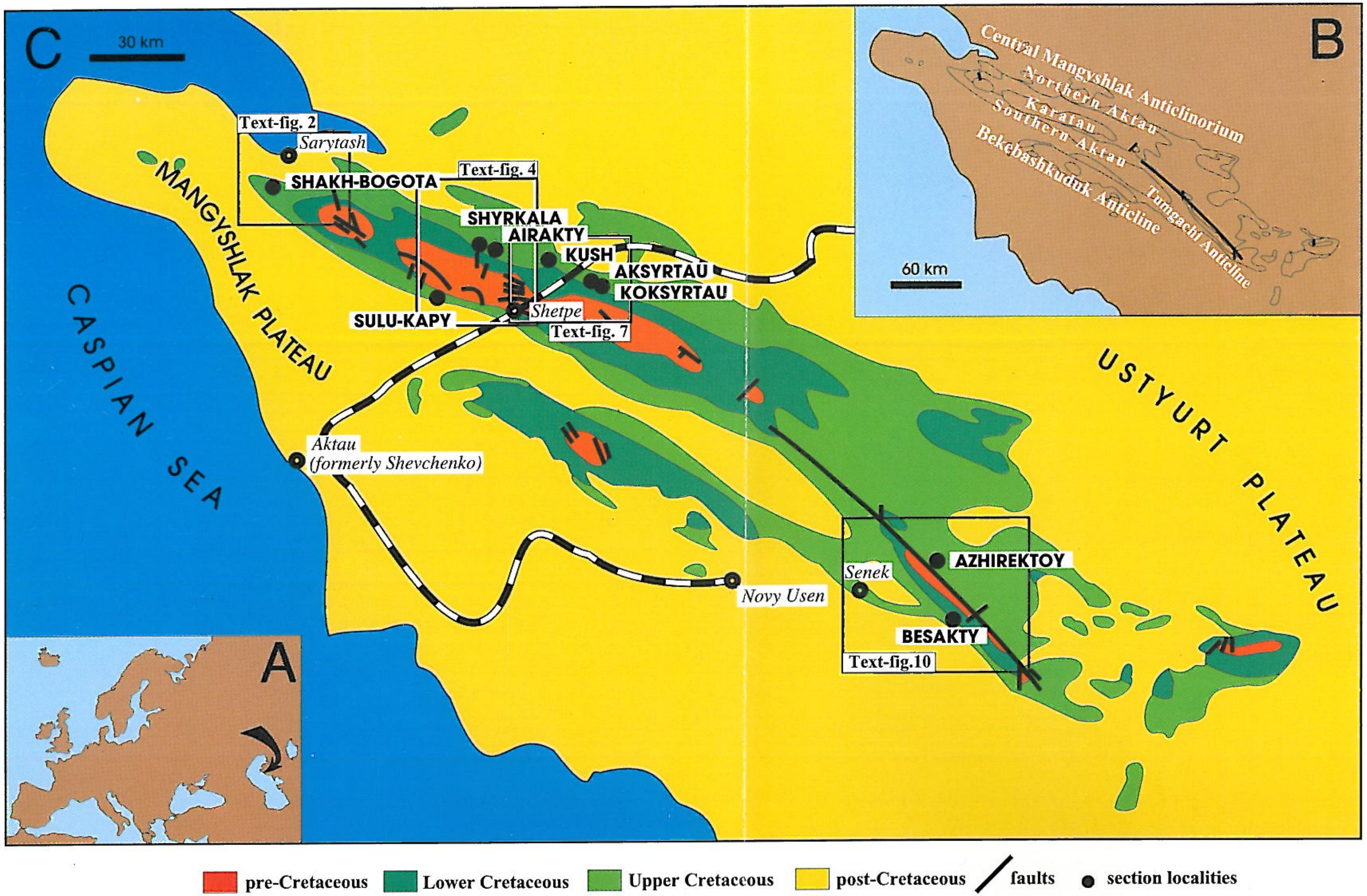
The mid-Cretaceous strata crop out in many parts of Western Kazakhstan, but it is in the Mangyshlak Mountains where the most extensive exposures are accessible for direct studies. Up to recently, however, because of political reasons, Mangyshlak was beyond the reach of foreign geologists, and only after the great political change in the former Soviet Union at the end of the 80ties work there became possible.

This paper provides a preliminary result of the work in the Mangyshlak Mountains carried in the year 1992, by a Polish expedition (sponsored by the National Committee of Scientific Research, *KBN*), organized and realized by the present authors. This expedition was preceded by a reconnaissance visit of one of us to selected areas of Mangyshlak (RM) in the year 1991; the results of this visit being an integral part of the present survey. The works embraced detailed studies of selected sections distributed all over the Mangyshlak Mountains, including also their rarely visited eastern parts, within the stratigraphic interval ranging from Upper Albian to Coniacian, including the Coniacian/Santonian boundary. This interval represents a particularly important time within the evolution of the Cretaceous Period as it is the time of a rapid acceleration of the pan-global transgression bearing a profound effect on the paleogeography, facies relations, and the evolution of the accompanying faunal assemblages. It starts with the first Late Albian major transgressive pulse at the base of the Leptohoplites cantabrigensis Zone, and lasts, at least in the studied area of Central Asia, to the very end of the Coniacian.

The above work allowed the detailed correlation and application of a uniform biostratigraphic scheme for the whole area, the recognition of some events known from Central and Western Europe, as well as inferences on the biogeography and the paleotectonic evolution of the area during this critical time for the Cretaceous evolution. Accounts are also given of selected faunal groups, particularly ammonites, belemnites, inoceramids, and echinoids (*see* Pls 11-19), whose systematic descriptions are to be published separately in the near future.

REGIONAL SETTING

The range of the Mangyshlak Mountains, occupying the Mangyshlak Peninsula and stretching further to SE into the Kazakhstan Plain (*see* Text-fig. 1), represents a structurally quite regular anticlinorium, traceable particularly well in its central and western parts. The anticlinorium is a part of



Geologic sketch-map of the investigated area in the Mangyshlak Mts (**C** – *after* V.F. BESPALOV & *al.* 1965; *simplified*), with main geotectonic and geomorphologic units of the area (**B**), and its location against the map of Europe and western Asia (**A**) the epi-Variscan (pre-Permian) Turan Platform, the northern boundary of which delimits the Pericaspian Depression (south-eastern part of the East-European Platform) while being bound to the south by the Transcaspian Alpine-Deformation Zone (*cf.* BOGDANOFF & KHAIN 1981). Within the Mangyshlak Anticlinorium the deposits of the three successive structural stages of the Turan Platform crop out: (1) the folded Permo-Triassic succession (over 6 km thick) representing the rifting stage in the Turan Platform evolution, and (2) the Jurassic–Paleogene and (3) Neogene successions (*c*. 2 km thick), with only slight disconformity inbetween, marking the following, downdropping stage of the Platform development (*see* TRIFONOV & BURAGO 1960, p. 179; SHVEDOV & DIMAKOV 1963, p. 142; MUROMTZEV 1973, p. 95, Figs 2-5; VOLTCHEGURSKYJ & PLESHEEV 1980, pp. 192-196).

The Mangyshlak Anticlinorium itself represents a very young, late Neogene structure (MUROMTZEV 1973, Figs 2-3). Up to the late Paleogene, and beginning as early as the Jurassic Period, the whole territory of Mangyshlak was the site of marine sedimentation, though with relatively low subsidence rate, particularly in its central part (Karatau Swell), and with a temporary emersion and erosion noted only at the Paleogene/Neogene boundary.

The axial part of the structure is composed of the Permo-Triassic and Jurassic deposits, forming the highest elevations of the area. Due to deep valleys separating it to NE and SW it forms distinct orographical unit within the Mangyshlak Mountains. Due to the dark colors of the deposits it is called the Karatau which in the local language means black mountains. To NE and to SW of deep valleys bordering the Karatau stretch steep faces of white-coloured ranges built predominantly of the white Upper Cretaceous and Tertiary carbonates, with the terrigenous clastics of the Lower and mid-Cretaceous at the bottom. These are called Northern and Southern Aktau (*Aktau* means white mountains) respectively. This morphological pattern is developed the best in the western and central part of the studied area but is also easily traceble within its eastern part, *i.e.* in the Tumgachi Anticline (*see* Text-fig. 1).

DESCRIPTION OF THE SECTIONS

The studies covered five sections distributed along the Northern and Southern Aktau, within the Central Mangyshlak Anticlinorium (Shakh-Bogota, Sulu-Kapy, Shyrkala-Airakty, Kush, and Koksyrtau-Aksyrtau) and two sections, *i.e.* Azhirektoy and Besakty, representing the northern and southern limbs respectively of the Tumgatchi Anticline in the SE part of

Mangyshlak (*see* Text-fig. 1). The detailed description of the sections and their faunal content comprises the Upper Albian (Semenovites michalskii Zone) through Coniacian strata including the Coniacian/Santonian boundary. Correlation of the studied sections was based mainly on biostratigraphic grounds. The high chronostratigraphic potential was shown, however, to be confined also to the main phosphatic horizons, traceable in the same position (though spanning different stratigraphic intervals) within the whole area studied, *i.e.* over a distance of about 250 km. These horizons, numbered here with Roman numerals (*I* to *V*) are shown, moreover, to represent the local expressions of the overregional phenomena, thus providing an excellent tool for the interregional correlations.

The particular sections are described in geographic order, starting from the NW situated Shakh-Bogota section and running subsequently to SE. The Arabic numerals denoting the particular lithologic units distinguished in particular sections refer only to individual sections and have no correlative meaning between the sections. In turn, chronostratigraphic significance is ascribed to the particular phosphatic horizons numbered here with Roman numerals. The graphs associated with the lithologic-stratigraphic column for the particular sections (Text-figs 3, 5, 6, 8-9, 11 and 12) show the vertical range of stratigraphically important groups, *i.e.* the ammonites, inoceramids, echinoids, and belemnites. Other faunal elements are mentioned in the descriptions.

All sections display the regional pattern of thickness and facies relations. The almost purely terrigenous facies of the Upper Albian through Middle Turonian change to a carbonate facies within the Upper Turonian – Coniacian. As concerns the thickness relations, the most to SE lying depocentre within the Late Albian through Cenomanian moves NW, with the boundary time spanning the Late Cenomanian through Middle Turonian characterized by very reduced deposition.

Crystals of secondary gypsum commonly occur in fine grained terrigenous facies. To secondary phenomena also belong the ferruginous cementations, though these are sometimes most probably of Cretaceous age.

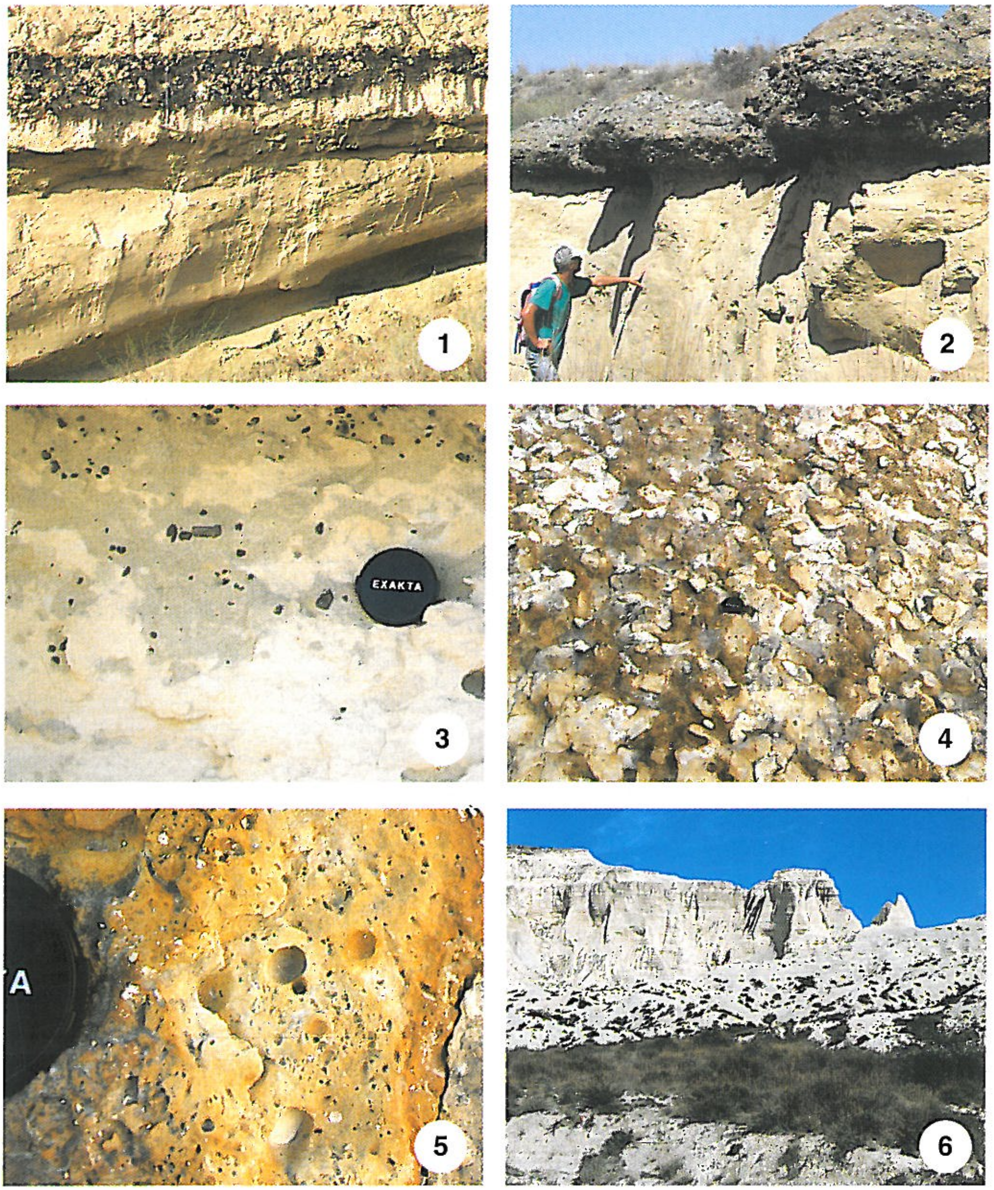
SHAKH-BOGOTA

The Cretaceous strata are exposed in the NW periclinal closure of the Karatautchik Anticline, the north-westernmost tectonic element of the Central Mangyshlak Anticlinorium (*see* Text-figs 1-2). The Upper Albian – Coniacian succession crops out on the steep sides of the eastern part of the large, subquadrate valley close to the Sarytash Bay of the Caspian Sea (*see* Text-fig. 2). The section was compiled on the basis of three study

Mid-Cretaceous succession of the Shakh-Bogota section

1 — Lower Turonian sandstones (Bed *10*) with the Upper Turonian hardgrounds at their top (Beds *12-13*) and the phosphatic bed (Phosphatic Horizon *IV* = Bed *9*) at the bottom; overlying are white limestones and marls of the Upper Turonian and, at the very top, pencordantly lying Miocene limestones; view to the north, in the eastern part of the Shakh-Bogota valley

2 — General view of the Upper Turonian – Santonian succession of the Shakh-Bogota section, as seen from the south, in the eastern tributary valley of Shakh-Bogota main valley; at the bottom, well seen is a couplet of the Upper Turonian hardgrounds placed at the top of the Lower Turonian sandstones building the bottom part of the slope



Mid-Cretaceous succession of the Shakh-Bogota section

1 — Phosphatic bed at the base of the Lower Turonian sandstones (Phosphatic Horizon *IV* = Bed *9*)

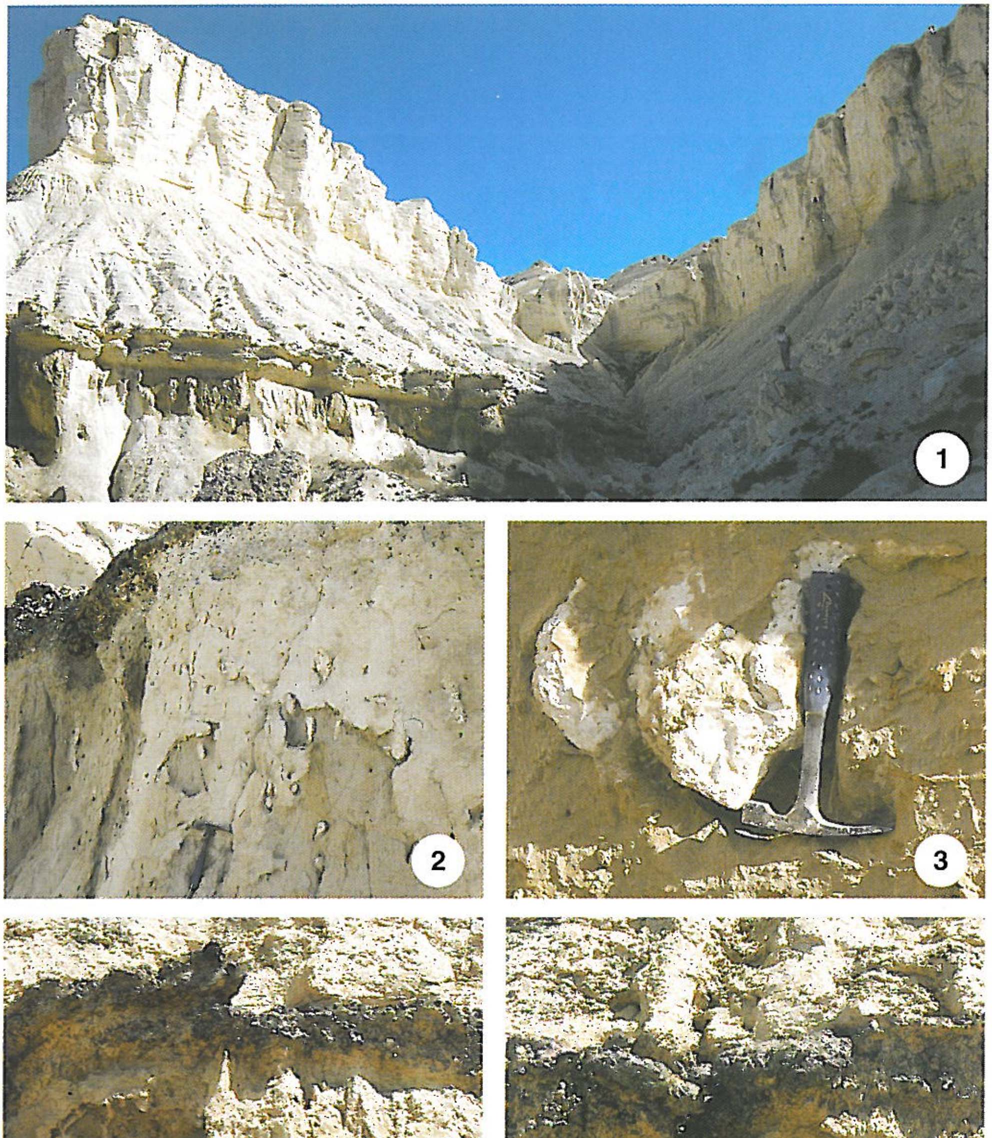
2 — Phosphatic bed at the Albian/Cenomanian boundary (Phosphatic Horizon *II* and *III* = Bed *6*), with the overgrown sandstone concretions (Bed *7*) above; hammer as a scale

3 — Distinct burrow infilled with a glauconitic sandstone and fine phosphatic concretions at the top of Bed *5*, and below the Phosphatic Horizon *II* and *III* (Bed *6*)

4 — Surface of the Upper Turonian (I. costellatus Zone) hardground (Bed *13*), with burrows, borings, and phosphatic and ferruginous mineralizations

5 — Close-up view of the hardground surface shown in Fig. 4

6 — Coniacian – Santonian marls and limestones in the southwestern border of the Shakh-Bogota Valley (*cf.* Text-fig. 2)



Mid-Cretaceous succession of the Shakh-Bogota section

1 — Lower Turonian sandstones (Bed *10*) capped by the hardground horizons (Beds *12-13*) and overlain by the Upper Turonian – Lower Santonian carbonates (Beds *14-17*)

2 — Phosphatic bed at the bottom part of the Lower Turonian sandstones (Phosphatic Horizon *IV* = Bed *9*) and the burrows with marly infillings below (ranging to about 1 m below the phosphatic bed) within the Cenomanian glauconitic sandstones (Bed *8*)

3 — Close-up view of the marly infilling of the burrow shown in Fig. 2

4-5 — Thickness doubling and breaking within the Phophatic Horizon *IV* (Bed *9*) due to collapsing and overriding of the cemented blocks of the phosphatic bed points in the eastern part of the valley (*see* Text-fig. 2 and Pl. 1, Figs 1-2; Pl. 3, Fig. 1).

The section displays a very reduced Upper Albian – Cenomanian part of the succession, due to erosion and condensation associated with the formation of phosphatic beds. In turn, it is the only section studied with an almost complete Upper Turonian – Lower Santonian succession; this latter being markedly reduced in the sections lying further to the SE (*see* Text-figs 3 and 14).

Upper Albian (part)

The 19.1 m thick succession of non-calcareous, fine-grained quartz sands with glauconite, interbedded with two phosphatic horizons.

Bed 1: The sands are yellow to yellow-brown in color, poorly cemented, grading in places into sandstones. Rare *Thalassinoides/Ophiomorpha* burrows. In the middle part of the bed there occurs a horizon of phosphatized-limonitized ammonite molds and, subordinately, of inoceramid bivalves; this fauna includes: *Semenovites michalskii* (SEMENOV), *S. uhligi* (SEMENOV) – common; more strongly ornamented morphotype of *S. uhligi* = *S. tenuis* (SAVELEEV); *S. pseudocoleonodus* (SEMENOV); *Hamites incurvatus* BROWN, and *Inoceramus anglicus* WOODS – very rare. Thickness 8 m.

Bed 2: Horizon of rare ellipsoidal concretions, 0.6–1.5 m in diameter, of calcareous sandstone with glauconite. Thickness 0.6 m.

Bed 3: The sands are interbedded by silty sands and light-gray mudstones. Thickness 5 m.

Bed 4: **Phosphatic Horizon I**

Horizon of light-brown phosphatic concretions, of the average diameter 2-3 cm, clustered in places; ?*Semenovites* sp. – very rare. Thickness 0.3 m.

Bed 5: Yellow-brown sands with an admixture of silty and muddy material. In the topmost part of the unit (to about 40cm below the top) there occur *Thalassinoides*-type burrows infilled with glauconitic sands and fine-sized, usually 1.5 cm in diameter, phosphatic concretions (Pl. 2, Fig. 3). Thickness 5.5 m.

Bed 6: **Phosphatic Horizon II & III**

Horizon of light-brown phosphatic concretions, of 3-4 cm diameter in average (max. 8 cm), within light-green, limy, fine-grained sandstones with glauconite (Pl. 2, Fig. 2). Thickness 0.3 m.

Cenomanian

Bed 7: Dome-shaped, closely spaced concretions of limy quartz sandstones with glauconite (Pl. 2, Fig. 2). The concretions are 0.5 to 1.0 m in diameter at the base and to 0.6 m in height, and yield rare *Inoceramus crippsi* MANTELL. Sometimes concretionary cementation embraces the underlying phosphatic horizon. Thickness 0.6 m.

Bed 8: Massive, light-green, poorly cemented quartz sandstones with glauconite and muscovite flakes. Numerous vertical *Thalassinoides*-type burrows of variable diameters occur throughout the bed, though particularly abundant in its topmost, 70 m thick part (just below the overlying phosphatic bed). The burrows, penetrating the bed without any preferred orientation, are infilled with material similar to the host rock, and dated for the Early Cenomanian. They are superimposed by much deeper (ranging down to about 1 m) burrows infilled with white, sandy marls (Pl. 3, Figs 2-3) and dated already for the Late Cenomanian (*see* NAIDIN & *al.* 1984). At the very top of the bed both generations are superimposed by fine burrows infilled with the quartz-glauconitc sands and dated for the latest Cenomanian or earliest Turonian. Thickness 8.5 m.

Lower Turonian

Bed 9: Phosphatic Horizon IV

Horizon with slightly varying thickness, bipartite (*see* Pl. 2, Fig. 1). Its lower part yields fine-sized, phosphatic concretions, singular or lumped irregularly, set in light-colored sandy marls. In the upper part of the unit the concretions are bound into solid phosphatic bed. The concretions obtain there maximum dimensions within the bed as well as within the whole studied area, ranging up to a dozen or so cm in diameter, with the average diameter about 5-6 cm. Sometimes the crushing and imbrication of the bed fragments up to 1 m long is observed (*see* Pl. 3, Figs 4-5). The host rock (sandy marls) yields Lower Turonian foraminifers (*see* NAIDIN & *al.* 1984), while stratigraphic range of the organic remains within the solid part of the bed range from the Early Cenomanian to probably the earliest Turonian. In the black and dark-red phosphorites were found: *Eutrephoceras* sp. – rare; *Sciponoceras baculoides* (MANTELL) – very rare; *Turrilites* (*Turrilites*) *scheuchzerianus* BOSC – frequent; *Hypoturrilites tuberculatus* (BOSC) – rare; *Mariella* (*Mariella*) *cenoma-*

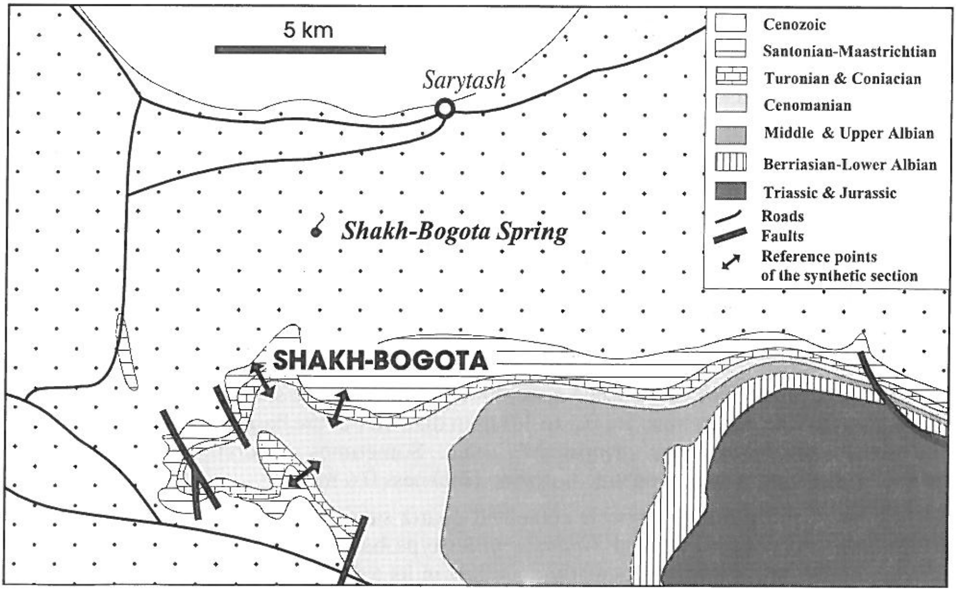
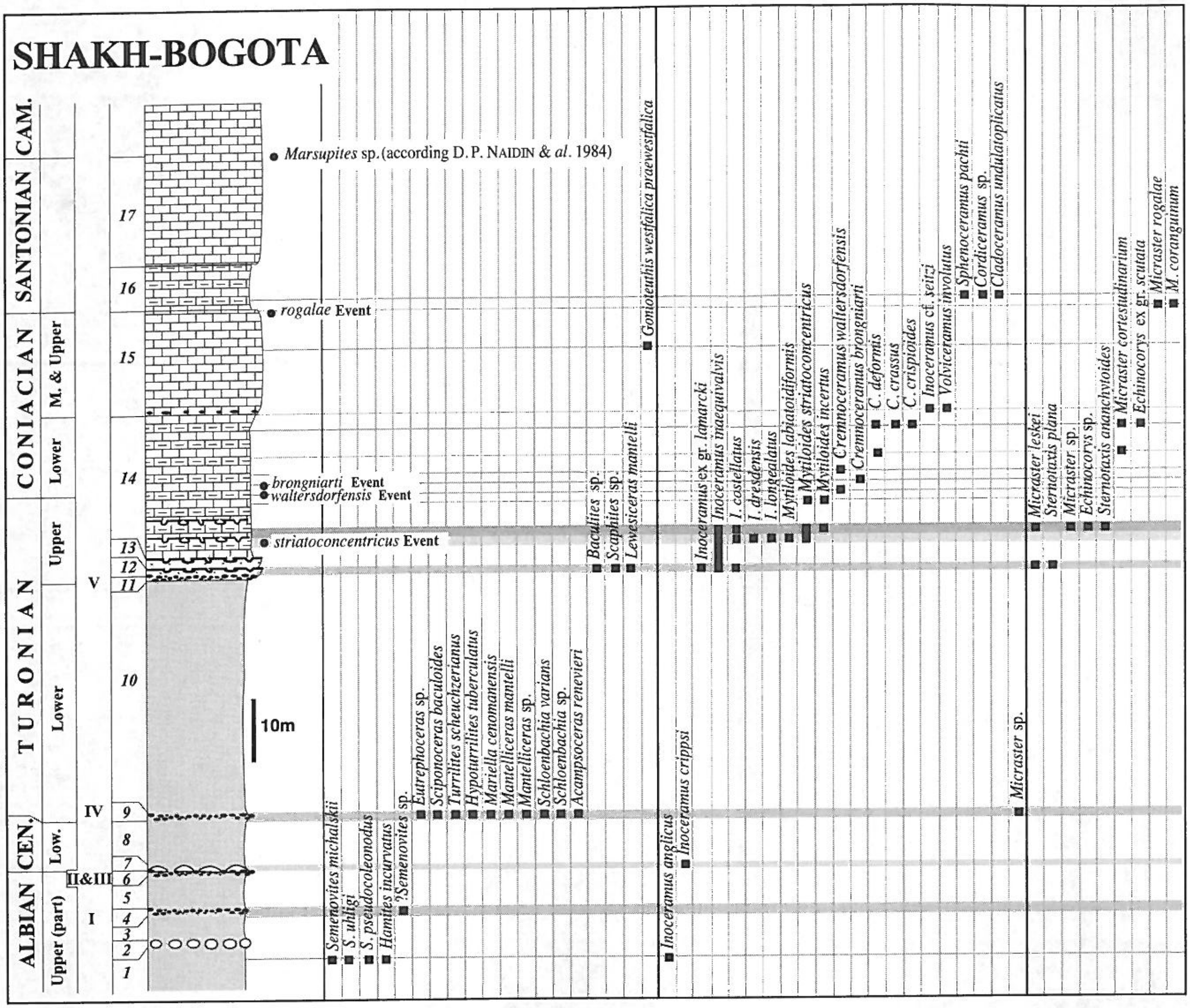


Fig. 2. Geologic sketch-map of the NW part of Mangyshlak with position of the Shakh-Bogota section (for location see Text-fig. 1); this Text-figure as well as Text-figs 4, 7 and 10 are simplified versions of the geologic map of Western Kazakhstan (scale 1 : 200000), published by the Geological Survey of the Soviet Union



Lithologic and stratigraphic column of the Shakh-Bogota section, with the vertical distribution of nautilids, ammonites, belemnites, inoceramids, echinoids, and crinoids
Lithology and faunal elements are described in the text (the same for Text-figs 5-6, 8-9, 11-12, 14)

nensis (SCHLÜTER) – common; undeterminable turrilitids – frequent; *Mantelliceras mantelli* (SOWERBY), *Mantelliceras* ssp. – frequent; *Schloenbachia varians* (SOWERBY) – common; *Schloenbachia* ssp. – frequent; *Acompsoceras renevieri* (SHARPE) – very rare; *Micraster* sp. – very rare; *Inoceramus* sp. – rare. Thickness 0.3-0.9 m.

Bed 10: Light-green, poorly cemented, fine-grained, quartz-glauconitic sandstones with an admixture of silty material and muscovite flakes (*see* Pl. 1, Fig. 1). Within the whole bed vertical *Thalassinoides*-type burrows particularly abundant in its topmost, 50 cm thick part, just below the overlying phosphatic bed. The unit displays high thickness differences, increasing from 20 up to 38 m in a distance of about 2 km. Thickness 20-38 m.

Upper Turonian – Middle Coniacian

Bed 11: **Phosphatic Horizon V**

Sandy-glauconitic marls with fine-sized (0.5 cm in diameter in average), irregularly-shaped phosphatic concretions particularly abundant in the bottom part of the bed. The basal part of the bed is characterized, moreover, by the high number of phosphatized fauna (mainly bivalves), often with oyster and/or serpulid encrustations. Thickness 0.8 m.

Bed 12: Firmground horizon developed within marls with numerous *Thalassinoides*-type burrows (*see* Pl. 1, Figs 1-2; Pl. 3, Fig. 1). In the bottom part there occur numerous, fine-sized phosphatic concretions and phosphatized fauna: *Inoceramus* ex gr. *lamarcki* PARKINSON – frequent; *I. costellatus* WOODS – rare; *I. inaequivalvis* SCHLÜTER – less frequent; other bivalves – frequent; *Baculites* sp. – very rare; *Scaphites* sp. – very rare; *Lewesiceras mantelli* WRIGHT & WRIGHT – frequent; *Micraster leskei* (DES MOULINS) [small forms] – relatively frequent; *Sternotaxis plana* (MANTELL) – rare. The lower part of the bed seems to be the result of reworking (due to bioturbation) of the topmost part of the underlying bed. Thickness 0.8 m.

Bed 13: Hardground horizon developed at the top of marly bed with ferruginous-phosphatic cementation at its top (*see* Pl. 1, Figs 1-2; Pl. 2, Figs 4-5; Pl. 3, Fig. 1). Well visible are *Thalassinoides*-type burrows and singular borings. Thickness 1.0 m.

Bed 14: Rhythmites with alternating, well-bedded marls and limestones, with the average thickness of rhythms about 50 cm, and with marls markedly dominating over the limestones. In the lower part of the bed there occur two omission surfaces represented by the initial hardgrounds. The lower one is overcrowded with inoceramids: *Mytiloides striatoconcentricus* (GÜMBEL) – very common; *M. labiatoidiformis* (TRÖGER) – frequent; *Inoceramus costellatus* WOODS – rare; *I. inaequivalvis* SCHLÜTER – rare, *I.* ex gr. *lamarcki* PARKINSON – rare. Toward the top of the unit inoceramids are similarly common with, moreover, some horizons with their mass occurrence (*C. waltersdorfensis* Event, *C. brongniarti* Event), dating the unit for the Late Turonian through Middle Coniacian (*see* Text-fig. 4): *Inoceramus inaequivalvis* SCHLÜTER, *I. longealatus* TRÖGER, *I. costellatus* WOODS, *I. dresdensis* TRÖGER, *I.* cf. *seitzi* ANDERT, *Mytiloides incertus* (JIMBO), *M. striatoconcentricus* (GÜMBEL), *M. herbichi* (ATABEKIAN), *Cremnoceramus waltersdorfensis* (ANDERT), *C. rotundatus* (*sensu* TRÖGER *non* FIEGE), *C. brongniarti* (MANTELL), *C. deformis* (MEEK), *C. crassus* (PETRASCHECK), *C. cripsioides* (ELBERT). Of other fossils there are echinoids which are relatively common: *Micraster leskei* (DES MOULINS) [median forms] – rare; *Sternotaxis ananchytoides* (ELBERT) – frequent; *Echinocorys gravesi* (DESOR) – frequent; *Micraster cortestudinarium* (GOLDFUSS) – rare. At the horizon with the mass occurrence of *Cremnoceramus waltersdorfensis* (ANDERT) singular specimens of bivalve genus *Didymotis* were found. Four meters below the top of the unit a horizon with frequent *C. crassus* (PETRASCHECK), echinoids, and rare large pachydiscids is observed. Thickness 23 m.

Upper Coniacian

Bed 15: White limestones, roughly bedded, massive on fresh walls, with the horizon of black, fine-sized phosphatic concretions and abundant inoceramid debris at the base. The identifiable inoceramids are represented by the large volviceramid, *Volviceramus involutus* (SOWERBY). Inoceramids are usually overgrown with small oysters. At the topmost part, there appears a horizon with common *Micraster rogalae* NOWAK [*M. rogalae* Event] and less frequent *Micraster coranguinum* (LESKE). Rare *Gonioteuthis westfalica praewestfalica* ERNST & SCHULZ was found in the middle part of the bed. Thickness 15 m.

Santonian

Bed 16: Light-gray, marly-limestone rhythmites. The base of the bed is marked by singular specimens of *Sphenoceramus* cf. *pachti* (ARKHANGELSKY) and *Cladoceramus undulatoplicatus* (ROEMER). Thickness 7 m.

SULU-KAPY

It is the only section representing the southern limb of the Central Mangyshlak Anticlinorium. In reference to the Shakh-Bogota succession it follows already the regional pattern, that is the marked, southeastward thickness increase of the terrigenous, Albian – low Turonian part of the section and simultaneous reduction of the succeeding, carbonate part of the succession (*see* Text-figs 1 and 14; *and* Pl. 4, Fig. 1). The section completed along the outcrops close to the Sulu-Kapy stream (*see* Text-Fig. 4), is characterized, particularly in the Cenomanian, by the exceptionally rich ammonite assemblages (*see* Text-fig. 5). Still relatively complete (in relation to the sections further to SE) Upper Turonian – Coniacian part of the succession is characterized by good record of the Turonian – Coniacian boundary beds with the complete inoceramid succession as well as with the co-occurring bivalve species *Didymotis*. The latter is the typical element of this boundary interval in the Central and Western Europe as well as in North America (*see* KAUFFMAN 1979, ERNST & *al.* 1983, WOOD & *al.* 1984, SZASZ 1985, CZECH 1989, WALASZCZYK 1992).

Upper Albian (part)

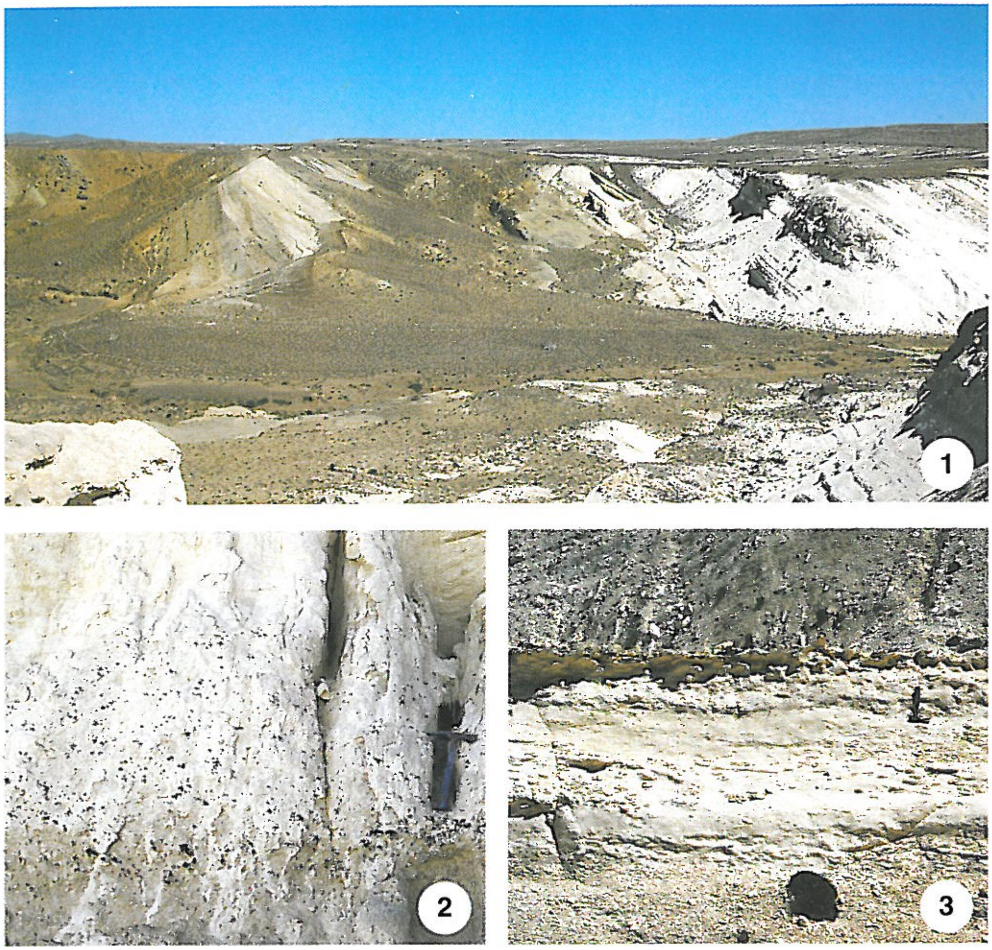
The succession of yellow- to gray-green in color, non-carbonate sandstones with glauconite and muscovite flakes, and with phosphatic horizon at the bottom.

Bed 1: Phosphatic Horizon II

Phosphatic conglomerate composed of dark-gray to black phosphatic concretions enclosed within brown-green, fine-grained limy sandstone with glauconite. The organic remains very rare; *Callihoplites* sp. Thickness 0.25 m.

Bed 2: The sands are yellow-green, moderately cemented. In their lower part there occur large (up to 1 m in diameter), oval sandstone concretions. Throughout the unit common *Thalassinoides*-type burrows and rare, fine-sized phosphatic concretions. Thickness 6.6 m.

Bed 3: The sands are gray-green, poorly cemented, with numerous, vertical *Thalassinoides*-type burrows, about 4 cm in



Upper Albian through Santonian of the Sulu-Kapy section

1 — General view of the exposures just west of the Sulu-Kapy stream; view to the east

2 — Upper Turonian phosphatic bed (Phosphatic Horizon *V* = Bed *17*)

3 — Upper Turonian firmground at the top of Bed *19* diameter in average. At the top of the unit the burrows are infilled with the fine phosphatic concretions identical to those occurring in the overlying phosphatic bed. Thickness 6.1 m.

Lower Cenomanian

Bed 4: **Phosphatic Horizon III & IVa**

Horizon with cherry-red, slightly carbonate, irregularly shaped phosphatic concretions, varying from 1 to 15 cm in diameter; numerous, bored and phosphatized wood fragments, and extremely rare *Schloenbachia varians* (SOWERBY) (the singular specimen of this species was found in the debris and is ascribed to this unit basing on the preservation habitus). Thickness 0.2 m.

Bed 5: Gray-green, poorly cemented, quartz sandstones with glauconite, and with frequent, rusty, irregularly shaped limonite concretions. Thickness 2 m.

Bed 6: Gray-green, non-carbonate, fine-grained quartz sands with glauconite. Thickness 2 m.

Bed 7: Yellow-green, fine-grained quartz sands with glauconite and muscovite flakes. Thickness 4 m.

Bed 8: Dark-gray, limy siltstones with dispersed rusty, ferruginous-siliceous concretions. Most of the concretions, occurring predominantly in the lower part of the unit, is represented by the ammonite internal molds. The ammonites are dominated by the representatives of the genera *Hyphoplites* SPATH and *Schloenbachia* NEUMAYR (mass occurrence), but many other forms, often with common occurrence were also identified: *Hamites duplicatus* PICTET & CAMPICHE, *H. simplex* D'ORBIGNY – frequent; *H.* aff. *simplex* D'ORBIGNY – less frequent (transitional form between *H. simplex* and *H. duplicatus*); *Sciponoceras roto* CIEŚLIŃSKI – frequent; *S. baculoides* (MANTELL) – rare; *Anisoceras auberti* (PERVINQUIÈRE) – frequent; *A. plicatile* (SOWERBY) – rare; *A.* aff. *exoticum* SPATH, *Neostlingoceras morrisiformis* (COLLIGNON) – very rare; *Hyphoplites falcatus* (MANTELL), *H. falcatus aurora* WRIGHT & WRIGHT – mass occurrence; *H. falcatus interpolatus* WRIGHT & WRIGHT – frequent; *H. campichei* SPATH – very frequent; *H. curvatus aurausionensis* (HERBERT & MUNIER-CHALMAS) – mass occurrence; *Schloenbachia varians* (SOWERBY) – very common/mass occurrence; *S. coupei* (BRONGNIART) – rare; *Karamaites mediasiaticum* (LUPPOV) – very rare; *K. grossouvrei* (SEMENOV) – very rare; *Mantelliceras mantelli* (SOWERBY) – frequent; *M. saxbii* (SHARPE) – frequent; "*Mantelliceras*" *aumalense* (COQUAND) – rare; "*M.*" *suzannae* (PERVINQUIÈRE) – rare. Thickness 2.5 m.

Bed 9: Gray-green, moderately cemented, sandy-limy mudstones. Thickness 0.8 m.

Bed 10: Light-colored, moderately cemented, well bedded sandy marls; shark teeth and *Inoceramus* sp. Thickness 0.3 m.

Bed 11: Gray-green, moderately cemented sandy-limy mudstones. Thickness 0.4 m.

Bed 12: Dark-gray marly clays with rusty, ferruginous-siliceous concretions. Many concretions represented by internal molds of small gastropods and non-inoceramid bivalves and, moreover: *Eutreophoceras* sp. – very rare; *Sciponoceras baculoides* (MANTELL) – very rare; *S. roto* CIEŚLIŃSKI – very rare; *Mariella cenomanensis* (SCHLÜTER) – very rare; *Schloenbachia varians* (SOWERBY) – rare; *Karamaites* sp. – very rare; *Inoceramus crippsi* MANTELL – very rare. Thickness 3 m.

Bed 13: Light-gray, sandy-limy mudstones with rusty ferruginous concretions, abundant particularly in the bottom part of the unit. Relatively rare fauna is represented by shark teeth, small gastropods, oysters, and very rare *Inoceramus crippsi* MANTELL. Thickness 3.4 m.

Middle Cenomanian

Bed 14: Gray-green siltstones with common ferruginous-siliceous, rusty-colored concretions. The concretions are mostly represented by internal moulds of ammonites, and are confined mainly to the upper part of the unit. At the topmost part of the unit occur large-sized ammonites of the genus *Karamaites*. The ammonite fauna is dominated by *Turrilites costatus* LAMARCK (mass occurrence) and representatives of the genera *Schloenbachia* NEUMAYR and *Scaphites* PARKINSON, but yielding, moreover, very diversified assemblage: *Worthoceras rochatinus* (D'ORBIGNY) – moderately frequent; *W. vermiculus* (SHUMARD) – less frequent; *Worthoceras* sp. – moderately frequent; *Hamites simplex* D'ORBIGNY – rare; *H. duplicatus* PICTET & CAMPICHE – rare; *Anisoceras plicatile* (SOWERBY) – moderately frequent; *Sciponoceras baculoides* (MANTELL) – moderately frequent; *S. roto* CIEŚLIŃSKI – very rare; *Turrilites costatus* LAMARCK – mass occurrence; *T. scheuchzerianus* BOSC – rare; *Scaphites basseae* COLLIGNON – very common; *S. evolutus* PERVINQUIÈRE – rare, *Schloenbachia varians* (SOWERBY) – very common; *S. coupei* (BRONGNIART) – very common; *Karamaites grossouvrei* (SEMENOV) – rare; *K. mediasiaticum* (LUPPOV) – more frequent. Thickness 4.1 m.

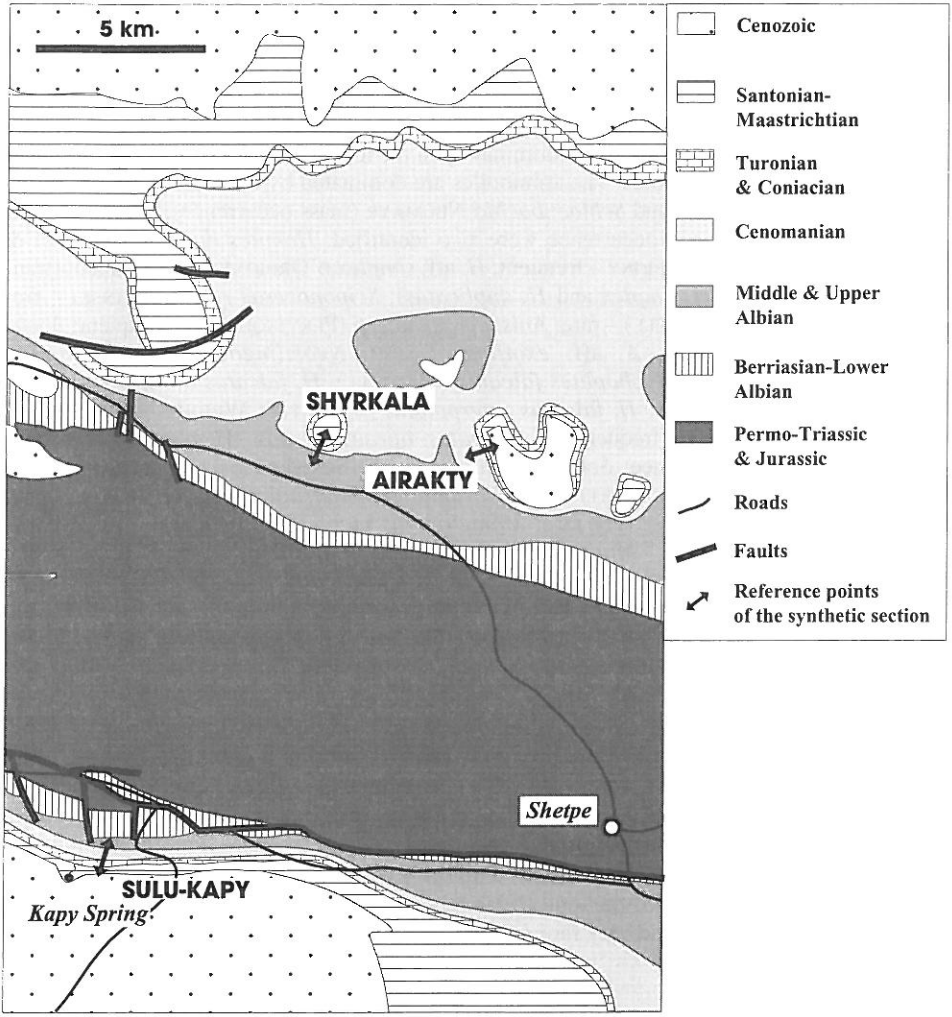
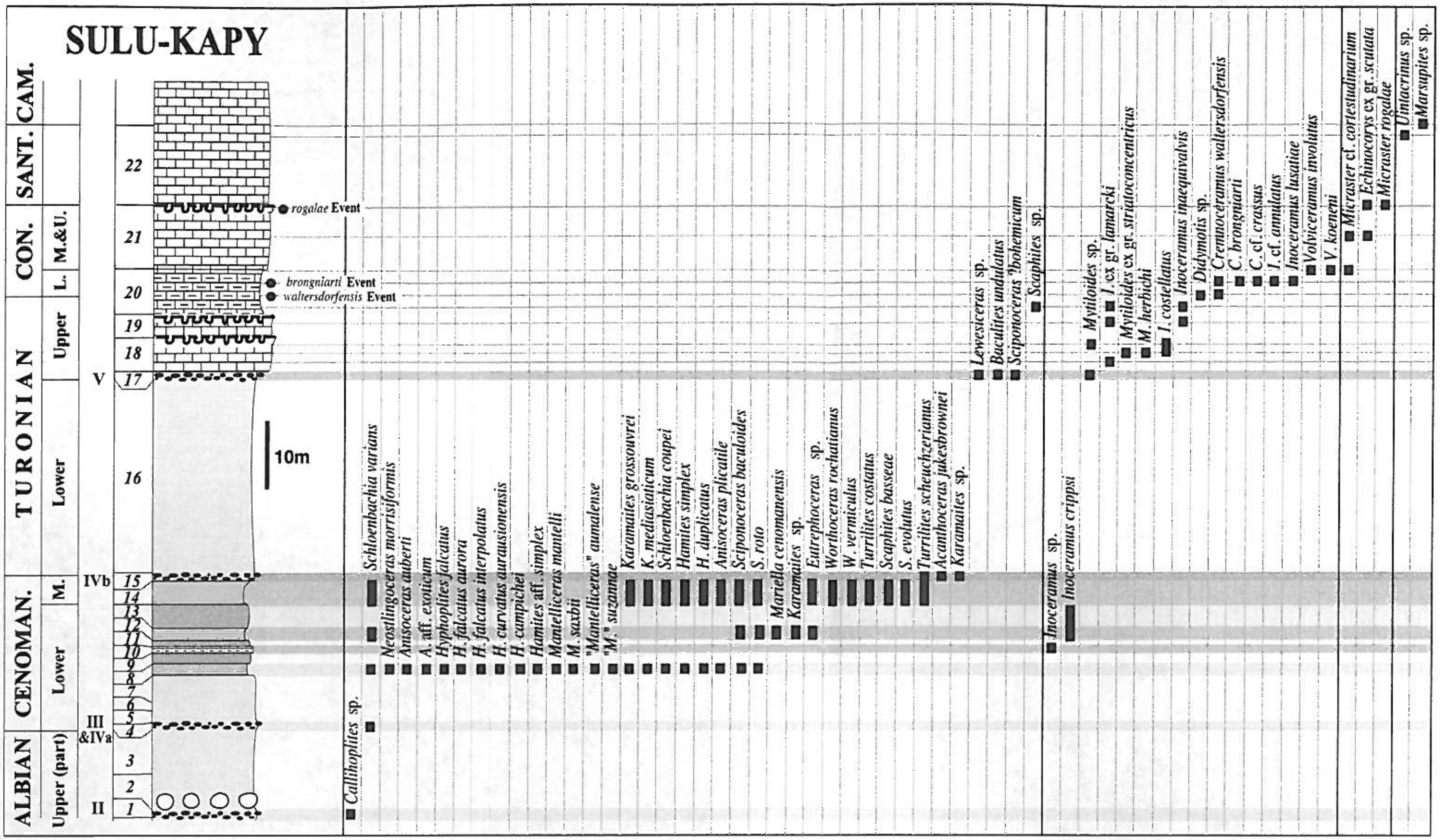


Fig. 4. Geologic sketch-map of the central part of the Mangyshlak Anticlinorium, with the position of the Sulu-Kapy and Shyrkala-Airakty sections (for location *see* Text-fig. 1)



Lithologic and stratigraphic column of the Sulu-Kapy section, with the vertical distribution of nautilids, ammonites, inoceramids, echinoids, and crinoids

Bed 15: Phosphatic Horizon IVb

Horizon with brown-colored, phosphatic concretions up to 4 cm in diameter, sometimes lumped irregularly. Rare fauna is represented by oysters, gastropods, and reworked, ammonites. These phosphatized, fragmented and corroded molds include moderately frequent *Turrilites scheuchzerianus* BOSC, *Acanthoceras jukesbrownei* (SPATH), and very rare, large-sized *Karamaites* sp. Thickness 5 m.

Lower Turonian

Bed 16: Gray-green, fine-grained, quartz-glauconitic sandstones with muscovite flakes, and with carbonate admixture, particularly high in the topmost, 3 m thick part of the unit. The sandstones are massive and poorly cemented. Within the whole unit vertical *Thalassinoides*-type burrows, with white envelopes. Scant fauna is represented by inoceramid (very bedly preserved), oysters, and brachiopods. Thickness 30 m.

Upper Turonian

Bed 17: Phosphatic Horizon V

Horizon of fine-sized phosphatic concretions, singular or irregularly lumped, set in pale-gray, sandy marls with glauconite (*see* Pl. 4, Fig. 2). The concretions are concentrated mostly within the lower, 10 cm thick part of the unit, and being much rarer higher in the bed. Relatively frequent phosphatized fauna is represented by gastropods, oysters, bivalves, ammonites, and rarely regular echinoids. Much scarcer unphosphatized forms include oysters, inoceramid shell debris, and some non-inoceramid bivalves (*e.g.* frequently occurring *Spondylus* sp.). Stratigraphically important elements are: *Baculites undulatus* D'ORBIGNY – very rare; *Sciponoceras ?bohemicum* (FRITSCH) – very rare; *Lewesiceras* sp. – very rare; *Mytiloides* sp. – very rare. Thickness 0.9 m.

Beds 18-19: White, bedded limestones with subregular occurrence of oyster shellbeds, and with the firmgrounds at tops of the units (Pl. 4, Fig. 3). In Bed *19* oyster shellbeds quite indistinct. Relatively frequent fauna is represented mostly by inoceramids: *Inoceramus costellatus* WOODS, *I.* ex gr. *lamarcki* PARKINSON (large forms), *Mytiloides* ex gr. *striatoconcentricus* (GÜMBEL), *M. herbichi* (ATABEKIAN). Thickness 7.7 m.

Upper Turonian – Coniacian

Bed 20: Pale-gray, slightly green marls, with the horizon of small phosphatic concretions and *Thalassinoides*-type burrows at the top of the unit. Numerous fauna, represented mostly by inoceramids, occur mostly within distinct horizons, corresponding to some event occurrences as noted in Central and Western Europe within the topmost Turonian – Lower Coniacian (*see* Text-fig. 5): *Scaphites* sp., *Inoceramus inaequivalvis* SCHLÜTER, *I.* ex gr. *lamarcki* PARKINSON [large forms]; *Cremnoceramus waltersdorfensis* (ANDERT) – mass occurrence; *Didymostis* sp. – rare; undeterminable ammonites; *Inoceramus lusatiae* ANDERT – rare; *Cremnoceramus brongniarti* (MANTELL) mass occurrence (*C. brongniarti* Event); *I.* cf. *annulatus* GOLDFUSS, *C.* cf. *crassus* (PETRASCHECK). At the top of the bed, within the horizon with phosphatic concretions there occur numerous shell fragments of large, Middle Coniacian volviceramids, usually overgrown with small oysters. Single *Micraster* cf. *cortestudinarium* (GOLDFUSS). Thickness 8.3 m.

Bed 21: White limestones, poorly bedded, with firmground at their top, and with ferruginous mineralization. In the middle part of the unit rare and poorly preserved *Micraster* cf. *cortestudinarium* (GOLDFUSS) and *Echinocorys* ex gr. *scutata* LESKE. At the top, horizon with *Micraster rogalae* NOWAK [*M. rogalae* Event] and frequent *Echinocorys* sp. Thickness 8.2 m.

Santonian

Bed 22: White, massive limestones with inoceramid shell debris at the bottom and with *Uintacrinus* and *Marsupites* horizons about 12 m above the bottom of the unit (*see also* NAIDIN & *al.* 1984). Thickness 12 m.

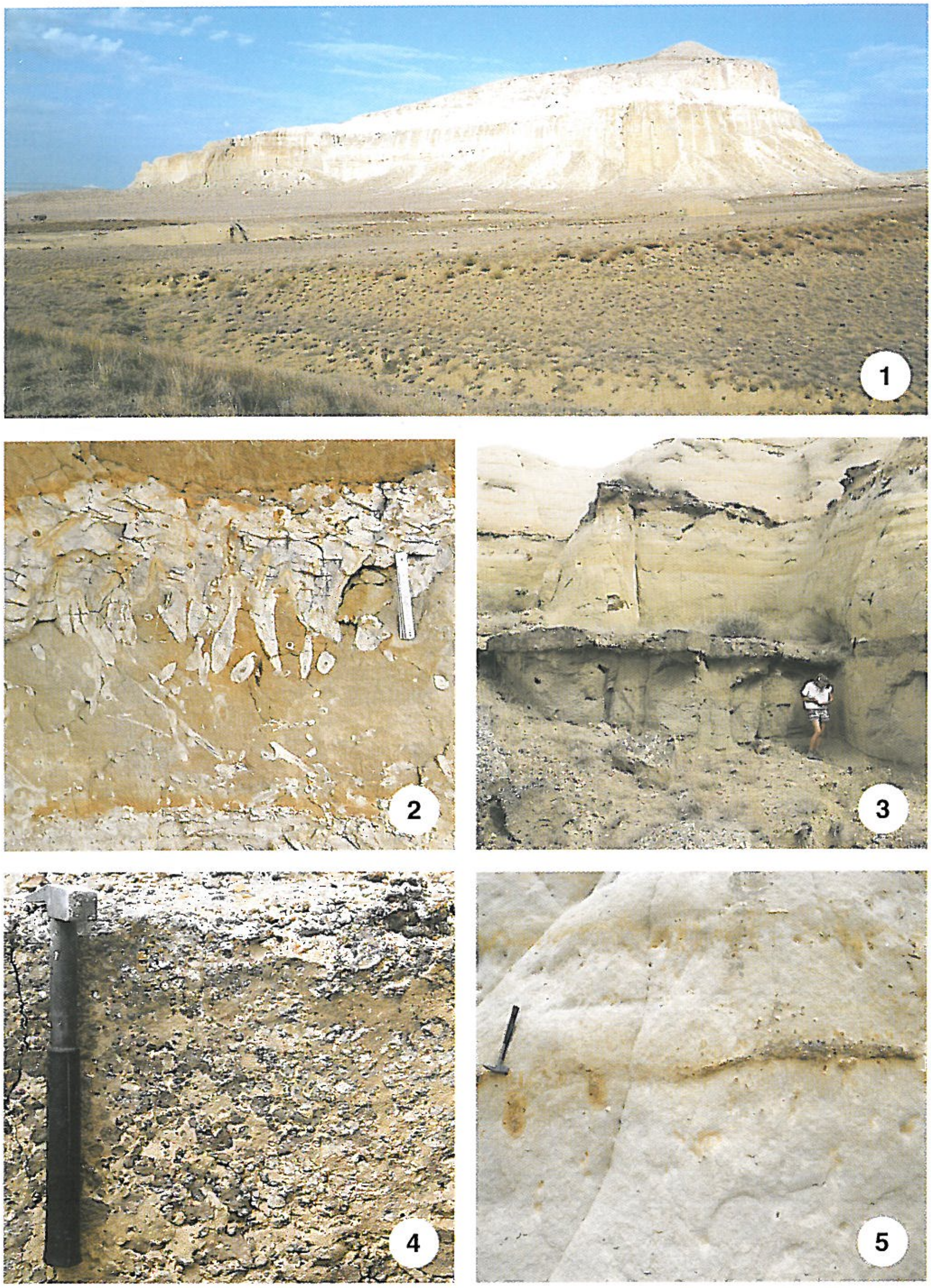
SHYRKALA – AIRAKTY

The succession was completed basing on the two erosional outliers, Shyrkala and Airakty Mounts (*see* Text-fig. 4 and Pl. 5, Fig. 1), located just opposite to the Sulu-Kapy section within the range of Northern Aktau (*see* Text-figs 1 and 4). Structurally it represents northern limb of the Central Mangyshlak Anticlinorium. Similarly as Sulu-Kapy, the Shyrkala-Airakty section (*see* Text-fig. 6) displays, in reference to the Shakh-Bogota section, gradual completing of the Albian – Lower Turonian terrigenous part of the succession with simultaneous reduction of the Upper Turonian – Santonian carbonate part of the succession (*see* Text-fig. 14). The topmost Turonian and the lowermost Coniacian is lacking. Similarly the upper part of the Coniacian is also cut through a set of discontinuity surfaces. In spite of the fact that no biostratigraphically dated gap is with them associated, they well mark the interrupted nature of the Late Turonian – Coniacian sedimentation in the area. The Coniacian/Santonian boundary was placed at the base of marls of the bed *28* by analogy to the Shakh-Bogota section.

Upper Albian

Bed 1: Light-yellow, poorly cemented, fine-grained quartz sandstones with glauconite and muscovite flakes. Present are *Thalassinoides*-type burrows. Lower part of the unit (Bed *1A* on the graph) yields large (up to 1 m in diameter), spherical concretions of limy sandstones, with abundant ammonite and bivalve fauna: *Callihoplites* sp. – very rare; *Semenovites uhligi* (SEMENOV) – common; more strongly ornamented morphotype of *S. uhligi* = *S. tenuis* (SAVELEEV) – frequent; *S. mangyshlakensis* (SAVELEEV) – rare; *Inoceramus anglicus* WOODS. The middle and upper part of the unit (*1B* on the graph – see Text-fig. 6) contains small concretions of limy sandstones with numerous limonitized ammonites (often clustered with clear imbrication – tempestites) and less frequent bivalves: *Pinna* sp., "*Pholadomya*" sp., and inoceramids. The occurring ammonites include: *Semenovites uhlighi* (SEMENOV) – mass occurrence; more strongly ornamented morphotype of *S. uhligi* – very common; *S. mangyshlakensis* (SAVELEEV) – rare; *S.* aff. *michalskii* (SEMENOV) – very rare; *S. pseudocoleonodus* (SEMENOV) – very rare; *Semenovites* ssp. – very common; ?*Anahoplites* sp. – very rare; *Inoceramus anglicus* WOODS – rare; *Inoceramus* sp. – rare. Thickness 5.5 m.

Bed 2: Horizon of large, oval concretions (max. diameter 2.5 m) of limy quartz sandstones with glauconite, often phosphatized to a different degree. The concretions are sometimes irregularly clusterd, and often preserve original sedimentary struc-



Mid-Cretaceous succession of the Shyrkala-Airakty section

1 — General view of the Shyrkala Mount as seen from the south-west; the lower two-thirds of the hill are composed of the Lower Turonian sandstones (Beds *22-24*), followed by the Upper Turonian – Coniacian – Lower Santonian carbonates (Beds *25-28*)

2 — *Rosselia socialis* DAHMER burrows infilled with the clays within the Upper Albian sandstones of Bed *9* (2.8 m above its bottom); the burrow has been kindly determined by Dr. A. UCHMAN (Jagiellonian University)

3 — Southern slope of the Shyrkala Mount with the Upper Albian sandstones interbedded through two phosphatic beds; the lower Phosphatic Horizon *I* (Bed *10*) and the upper Phosphatic Horizon *II* (Bed *12*)

4 — Close-up view of the Phosphatic Horizon *I* (= Bed *10*)

5 — Close-up view of the Phosphatic Horizon *II* (= Bed *12*) tures of the sands (most often cross bedding) and bioturbations. Extremely rare fauna includes *Semenovites* sp. (specimens with very poor shell ornamentation). Thickness 1 – 1.5 m.

Bed 3: Light-yellow, poorly cemented, non-carbonate, fine-grained quartz sandstone with glauconite. Throughout the bed fine-sized sandstone concretions containing rare, limonitized bivalve and ammonite molds (of the latter, one specimen of weakly ornamented body chamber of a large representative of the genus *Semenovites* was collected). Thickness 4 m.

Bed 4: Horizon of loosely packed light- to dark-brown sandstone concretions (up to 1.2 m in diameter) set in quartz sands with glauconite. Rare fauna, preserved exclusively within the concretions, is represented by *Semenovites* sp. Thickness 0.6 m.

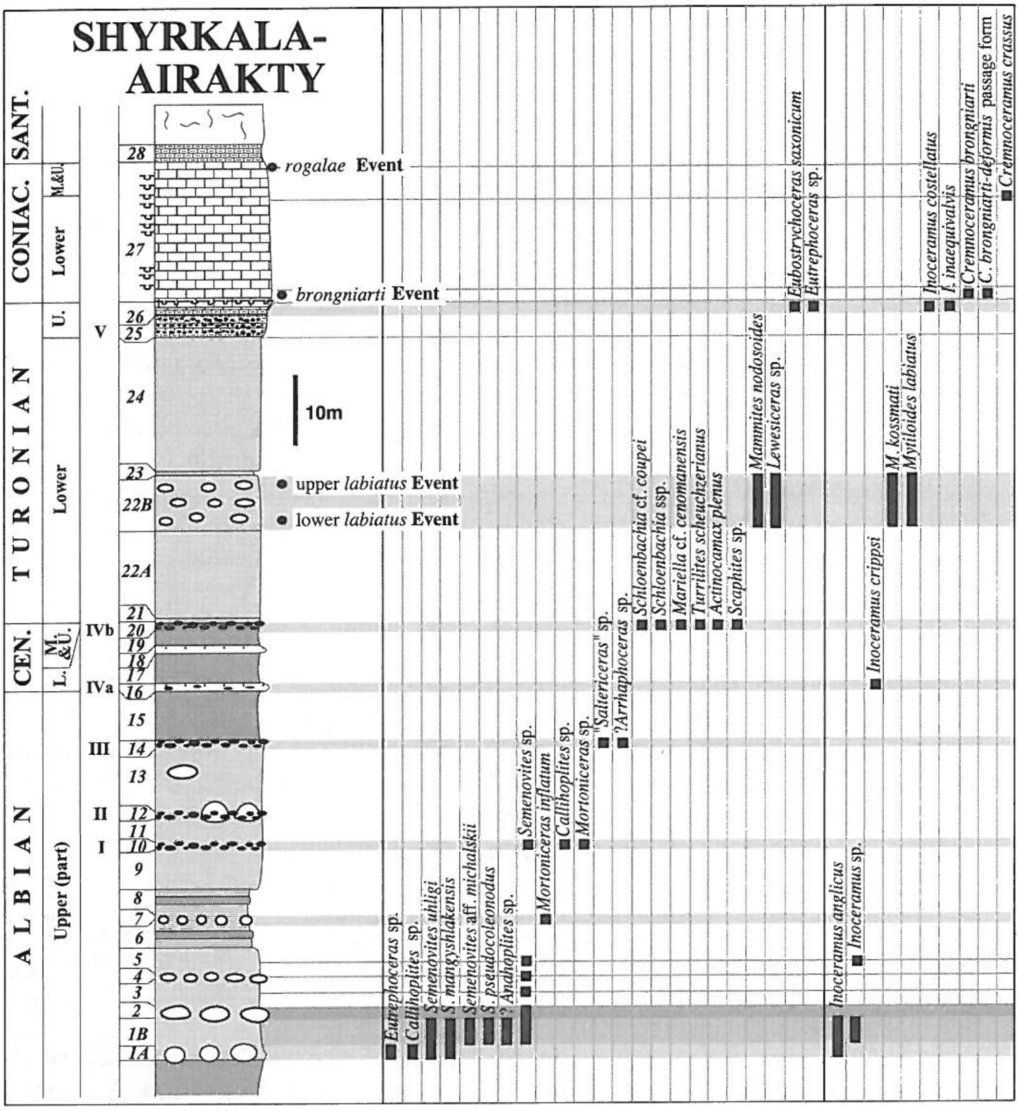


Fig. 6. Lithologic and stratigraphic column of the Shyrkala-Airakty section, with the vertical distribution of nautilids, ammonites, belemnites, and inoceramids

Bed 5: Yellow-green, poorly cemented, non-carbonate quartz sandstones with glauconite and muscovite flakes. The sands are partly limonitized and contain rare *Semenovites* sp., *Inoceramus* sp., and some other bivalves. Thickness 3.5 m.

Bed 6: Light-gray, non-carbonate silty clays with thin intercalations of mudstones. Thickness 4 m.

Bed 7: Horizon of light-green, spherical and oval sandstone concretions (with max. diameter up to 0.5 m) set in light-green non-carbonate sands, with marked glauconite content and rare muscovite flakes. In concretions rare *Mortoniceras inflatum* (SOWERBY). Thickness 0.5m.

Bed 8: Light-gray, silty clays with intercalations of mudstones. Thickness 3.5 m.

Bed 9: Light-green, poorly cemented, quartz-galuconitic sandstones with rare muscovite flakes. About 2.8 m above the bottom there occurs a clay horizon with the *Rosselia socialis* DAHMER burrows with clay infillings (*see* Pl. 5, Fig. 2). About 3.3 m and 5.3 m above the bottom of the bed there occur two minor phosphatic horizons with fine-sized (0.5 to 1 cm in diameter), rarely spaced phosphatic concretions. With these beds often associated are *Thalassinoides*-type burrows. Thickness 6.0 m.

Bed 10: Phosphatic Horizon I

Horizon of black, phosphatic concretions (up to 5 cm in diameter), and with brown, phosphatized sandstone fragments (up to 10 cm in diameter) embedded within the light-green, limy quartz sandstone with glauconite (*see* Pl. 5, Figs 3-4). Larger concretions and phosphatic lumps dominate the lower part of the bed, while in its upper part the concretions are smaller and rarely clustered into larger aggregates. At the bottom the *Thalssinoides*-type burrows infilled with sandstones with phosphatic concretions. Rare phosphatized fossils are represented by reptile bones and poorly preserved ammonite molds of the genera *Semenovites*, *Callihoplites* and *Mortoniceras*. Thickness 0.25-0.5 m.

Bed 11: Light-yellow, poorly preserved, fine-grained quartz sandstones with glauconite and small admixture of muscovite flakes. Within the whole unit rare, fine-sized phosphatic concretions. About 1 m above the bottom the horizon with small *Thalassinoides*-type burrows. Thickness 3.8 m.

Bed 12: Phosphatic Horizon II

Horizon with gray, fine-sized, phosphatic concretions with average diameter about 2 cm set in light-yellow, fine-grained quartz sandstones with glauconite (*see* Pl. 5, Figs 3 and 5). Sometimes the concretions are cemented into 1.5 m long and up to 7 cm thick lenses being the residue after the once existed here continuous phosphatic bed. The irregular accumulations of loose phosphatic concretions at the bottom part of the bed represent obviously infillings of large burrows. Thickness 0.4 m.

Bed 13: Light-green, poorly cemented, fine-grained quartz sandstones with glauconite and rare muscovite flakes. Rare limonitized concretions or lenses of more cemented sandstones with numerous *Pinna* sp. (in life position). East of Sharykala the spherical, up to 0.8 m in diameter, limy sandstone concretions start to occur. Throughout the unit numerous *Thalassinoides*-type burrows. Thickness 10 m.

Bed 14: Phosphatic Horizon III

Bipartite horizon with the lower part (about 15 cm thick) composed of black phosphatic concretions, with the average diameter 2 cm (max. 5 cm), set in the fine-grained quartz sandstones with glauconite. The upper part of the unit (20 cm thick), represented by the massiv phosphatic bed with rare black phosphatic concretions. In this part very rarely occur juvenile whorls of ammonites: "*Saltericeras*" sp. (transitional form between *Callihoplites* and *Schloenbachia* – *cf.* ATABEKYAN 1960, p. 187 and 1961, p. 35; MARCINOWSKI 1983, p. 165), ?*Arrhaphoceras* sp. Thickness 0.3-0.35 m.

Bed 15: Gray, non-carbonate mudstones with rare muscovite flakes. Thickness 8 m.

Lower Cenomanian

Bed 16: Phosphatic Horizon IVa

Light-gray, limy, fine-grained silty sandstones with very rare, black phosphatic concretions. *Inoceramus crippsi* MANTELL. Thickness 0.8 m.

Beds 17-19: Gray, non-carbonate, sandy mudstones with rare muscovite flakes. 4.5 m above the bottom thin interlayer (0.3 m) of light-gray, bioturbated, fine-grained, silty quartz sandstone (Bed *18*). Thickness 7.8 m.

Upper Cenomanian

Bed 20: Phosphatic Horizon IVb

Horizon with black phosphatic concretions (mostly gray-colored at the cross section), concentrated mostly at the bottom part of the unit with their number as well as sizes, markedly decreasing upward. In the lower part concretions are embedded within the marly, quartz-glauconitic sandstones, passing gradually upwards into sands. Relatively frequent fossil remains contain shark teeth, unphosphatized belemnite guards, inoceramid shell debris, and ammonite molds: *Turrilites scheuchzerianus* BOSC – rare; *Mariella* cf. *cenomanensis* (SCHLÜTER) – very rare; *Scaphites* sp. – very rare; *Schloenbachia* cf. *coupei* (BRONGNIART) – rare; *Schloenbachia* ssp. – relatively frequent; *Actinocamax plenus* (BLAINVILLE) – frequent; *Ptychodus* sp. – very rare. Thickness 0.6 m.

Lower Turonian

Bed 21A: White-gray, poorly cemented, limy silty clays with inoceramid prisms. Thickness 0.3 m.

Bed 21B: Light-green, partly yellow, poorly to moderately cemented, limy, fine-grained quartz sandstones with glauconite and muscovite flakes. Thickness 12.7 m.

Bed 22: Light-green, partly yellow, poorly to moderately cemented, limy, fine-grained quartz sandstones with glauconite and admixture of muscovite flakes. The unit contains poorly individualized horizons of hard sandstone concretions, with characteristic *Gyrolites* burrows and rare *Mytiloides labiatus* (SCHLOTHEIM); sporadically occur *Mammites nodosoides* (SCHLÜTER) (*see* Pl. 5, Fig. 4), and *Lewesiceras* sp. Thickness 8 m.

Bed 23: Silty clays, bioturbated. Thickness 0.1 m.

Bed 24: Light-green, partly yellow, poorly to moderately cemented, limy, fine-grained quartz sandstones with glauconite and admixture of muscovite flakes. Thickness 20 m.

Upper Turonian

Bed 25: Phosphatic Horizon V

Limy, quartz-glauconitic sandstones with three horizons (at the bottom, and 1 and 2 m above) of dark-brown, fine (0.5 cm in diameter) and sparce phosphatic concretions. Thickness 3 m.

Bed: 26: Sandy-glauconitic marls with shell fragments of large inoceramids in the bottom part of the unit, passing upward into pure limestones, with a hardground at their top. In the uppermost part occur: *Eutrephoceras* sp. – very rare; *Eubostrychoceras saxonicum*

(SCHLÜTER) – very rare; *Inoceramus costellatus* WOODS – rare; *I. inaequivalvis* SCHLÜTER – rare; and more frequent indeterminable echinoids. Thickness 2 m.

Coniacian

Bed 27: White limestones, marly at the bottom, with numerous firmground horizons, sometimes with ferruginous mineralization. Relatively frequent occur inoceramids, indicating the presence of all Coniacian substages: *Cremnoceramus brongniarti* (MANTELL) – mass occurrence (*C. brongniarti* Event); *C.* cf. *deformis* (MEEK) – rare; *C. crassus* (PETRASCHECK) – rare. In the topmost part of the unit (0.3 m below the top) the horizon with frequent *Micraster rogalae* NOWAK (*M. rogalae* Event). Thickness 21 m.

Santonian (part)

Bed 28: Green-gray marls, poorly bedded. Thickness 2 m.

KUSH

The section completed along the slopes of the Kush Mount, 10 km to SE of the Shyrkala-Airakty section, further along the northern limb of the Central Mangyshlak Anticlinorium (*see* Text-figs 1 and 7-8).

Upper Albian (part)

Not-numbered horizon (about 40 m below Bed *1*): horizon with frequent, limonitized ammonites: *Semenovites michalskii* (SEMENOV), *S. uhligi* (SEMENOV), *Semenovites* sp., rare inoceramid molds of *Inoceramus anglicus* WOODS, and rare *Birostrina sulcata* (PARKINSON).

Bed 1A: Horizon of giant (up to 5 m in diameter), oval sandstone concretions enclosed within non-carbonate, poorly cemented quartz sandstones with glauconite and muscovite flakes. Sandstone concretions often yield small, limonitic concretions and rare ammonites represented by *Semenovites michalskii* (SEMENOV) [its more robust and strongly ornamented variant described by SAVELEEV (1960) as a separate species *Anahoplites litschkovi*] and *Anahoplites* sp. Thickness 2 m.

Bed 1B: Light-yellow, rusty in places, non-carbonate, poorly cemented, fine-grained quartz sandstones with glauconite and muscovite flakes, cross-bedded, with numerous limonitized *Thalassinoides*-type burrows and rare, limonitized *Semenovites michalskii* (SEMENOV), *Anahoplites* sp., and *Birostrina sulcata* (PARKINSON). Thickness 5 m.

Bed 2: This bed is identical in lithology with preceding bed but numerous intercalations of light-colored mudstones. About 60 cm below the top of the unit there occurs the horizon with sparcely distributed, festoon-shaped bunches of phosphatic concretions, representing obviously infillings of the burrows descending from the overlying phosphatic horizon. This part of the unit is markedly enriched in glauconite. Thickness 17 m.

Bed 3: Phosphatic Horizon I

Light- to dark-brown phosphatic concretions up to 5cm in diameter (1 to 1.5 cm in average), clustered sometimes into irregular aggregates, enclosed within limy sandstones. Thickness 0.4 m.

Bed 4: Light-yellow, poorly cemented, non-carbonate, fine-grained quartz sandstones with small admixture of glauconite and muscovite flakes. Rare burrows. In the topmost part, the horizon of festoon-shaped bunches of phosphatic concretions; their origin is similar as the analogical horizon in Bed *2*, below the *Ist* Phosphatic horizon (see above). Thickness 10.5 m.

Bed 5: Phosphatic Horizon II

Light-brown, irregularly-shaped, up to 11 cm in diameter (5 cm in average), phosphatic concretions embedded within limy sandstones. In places phosphatic horizon is overcapped by large, up to 1 m in diameter, spherical sandstone concretions. In the latter, one specimen of *Mortoniceras inflatum* (SOWERBY) was found. Thickness 0.3 m.

Bed 6: Yellow-gray, poorly cemented, non-carbonate, fine-grained quartz sandstones with marked admixture of silty material. Just below the middle part of the unit the horizon with spherical sandstone concretions, up to 0.5 m in diameter. Thickness 11 m.

Bed 7: Yellow-green, poorly cemented, non-carbonate, fine-grained quartz sandstones with glauconite and muscovite flakes. Thickness 1.8 m.

Bed 8: Lenses (up to 1.5 m long and to 10 cm thick) of destroyed phosphatic bed embedded within a sandstone identical to that of Bed 7. Inbetween irregularly spaced, fine (1 cm in average) concretions, with festoon-shaped accumulations representing the burrow infillings. Thickness 0.1 m.

Bed 9: This bed is identical in lithology with Bed 8. It yields numerous *Thalassinoides*-type burrows with limonitized walls and, limited to its bottom part, rare, up to 0.5 cm in diameter, phosphatic concretions and, up to 50 cm in diameter, sandstone concretions. Thickness 3 m.

Bed 10: Phosphatic Horizon III

Light-brown, non-carbonate phosphatic concretions with the average diameter 1.5-2.0 cm (max. 4 cm), enclosed within poorly cemented quartz sandstones with glauconite and muscovite flakes. Whole bed is irregularly phosphatized, forming in parts massive, platy phophate. Fine-sized phosphatic concretions form also distint, festoon-shaped accumulations in the topmost part of underlying sandstones of Bed 9, representing obviously infillings of the burrows. Thickness 0.2 m.

Bed 11A: Light-yellow, non-carbonate, fine-grained quartz sands with glauconite and muscovite flakes. Thickness 0.6 m.

Bed 11B: Gray, mudstone/silty clay wih marly concretions up to 0.5 m in diameter. Thickness 13.9 m.

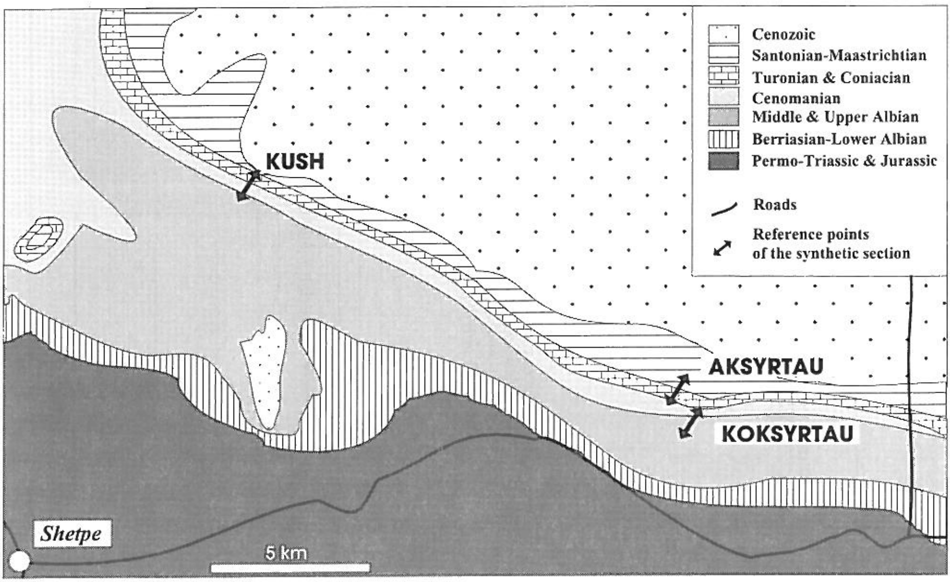


Fig. 7. Geologic sketch-map of the central part of the Mangyshlak Anticlinorium, with the position of the Kush and Koksyrtau-Aksyrtau sections (for location *see* Text-fig. 1)

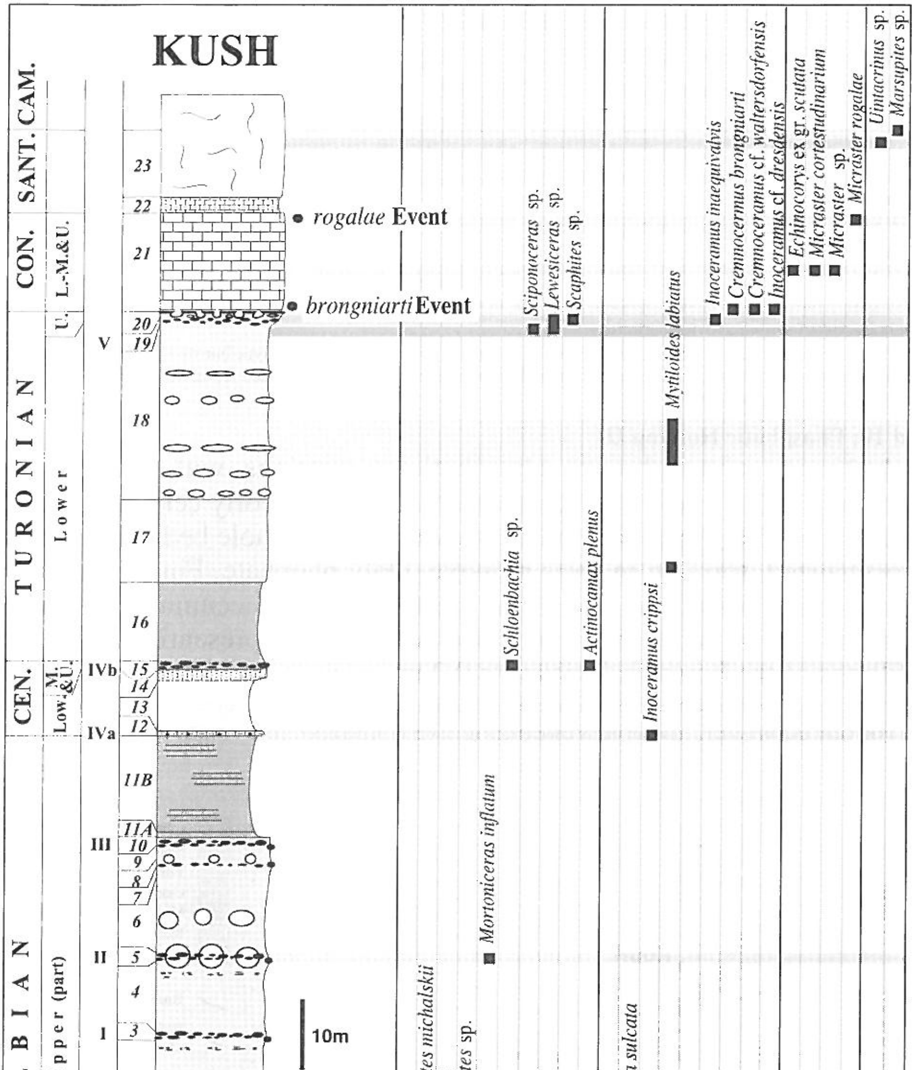


Fig. 8. Lithologic and stratigraphic column of the Kush section, with the vertical distribution of ammonites, belemnites, inoceramids, echinoids, and crinoids

Lower Cenomanian

Bed 12: Phosphatic Horizon IVa

Gray, well cemented, bedded sandy marls with rare, gray-brown to black phosphatic and limonitic concretions. Rare phosphatized ammonite and inoceramid molds: *Inoceramus crippsi* MANTELL. Thickness 0.8 m.

Bed 13: Gray clays with upward decrease of carbonate content. Rare small bivalves and gastropods. Thickness 7.2 m.

Bed 14: Light-gray, well cemented, thin bedded sandy marls. Thickness 1.2 m.

Middle - Upper Cenomanian

Bed 15: Phosphatic Horizon IVb

Horizon of black phosphatic concretions (gray at the cross section) enclosed within light-gray, well cemented marls. The amount and size of the concretions markedly decreasing upward. The fauna includes rare *Schloenbachia* sp., and frequent, fragmented guards of *Actinocamax plenus* (BLAINVILLE). Thickness 0.6 m.

Lower Turonian

Bed 16: Gray, limy mudstones with small admixture of sandy material. Thickness 12.0 m.

Bed 17: Dark-gray to grayish-green, poorly cemented, fine-grained quartz sandstones, limy, with muscovite flakes. Rare *Mytiloides labiatus* (SCHLOTHEIM) occurs in the lower part of the unit. Thickness 10.5 m.

Bed 18: Gray-green, poorly cemented, fine-grained, limy quartz sandstones, with glauconite. The bed contains some, 0.15-0.30 m thick horizons of variably shaped sandstone concretions. Throughout the unit there occur *Thalassinoides*-type burrows, 3-4 cm in diameter, with limonitized walls. These are particularly abundant in the topmost, 3.5 m thick part of the bed. The collected fauna includes single specimen of *Mytiloides labiatus* (SCHLOTHEIM) without precised location. Thickness 24.5 m.

Upper Turonian

Bed 19: Phosphorite horizon V

Brown, irregularly shaped phosphatic concretions with average diameter about 1 cm (max. 5-6 cm), set in sandy-glauconitic marls. The concretion accumulation and size is maximal at the bottom decreasing markedly upward. The phosphatized fauna includes rare ammonites of the genera *Sciponoceras* and *Lewesiceras*, and frequent gastropods, bivalves (*Spondylus* sp. and oysters), brachiopods, and fish teeth. Thickness 0.8 m.

Bed 20: Yellow-green, sandy-glauconitic marls, bioturbated, with hardground horizon at their top. The hardground bears ferruginous-phosphatic mineralizations. Relatively rich, though usually bedly preserved fauna includes: *Lewesiceras* sp., *Scaphites* sp., *Inoceramus inaequivalvis* SCHLÜTER, oysters and other bivalves, gastropods, and very rare regular echinoids. Thickness 0.7 m.

Coniacian

Bed 21: White-gray limestone rhythmites, marked by regular occurrence of nodular limestones and/or initial hardgrounds. Basal part of the horizon is fairly fossiliferous containing mass occurring *Cremnoceramus brongniarti* (MANTELL) and much rarer *C. waltersdorfensis* (ANDERT) [= *C. brongniarti* Event]. The other fauna of the bed includes rare *Inoceramus vistulensis* WALASZCZYK, *Echinocorys* ex gr. *scutata* LESKE, relatively frequent *Micraster coranguinum* (KLEIN), and very common *Micraster rogalae* NOWAK [*M. rogalae* Event]. Moreover there occur rare non-inoceramid bivalves and gastropods. Thickness 14.0 m.

Santonian

Bed 22: Green-gray, limy marls, thinly bedded. Thickness 1.5 m.

Bed 23: White, massive chalk with inoceramid prisms, small oysters, crinoids, and with *Uintacrinus* sp and *Marsupites* sp. at about 9 m above the bottom of the unit. Thickness 9.0 m.

KOKSYRTAU – AKSYRTAU

The Upper Albian through Santonian succession is accessible at the two, neighboring hills, Koksyrtau (in the south) and Aksyrtau (more to the north), built of the Albian-Cenomanian and the Turonian-Lower Campanian deposits, respectively (*see* Text-fig. 7 *and* Pl. 6, Figs 1-2) The hills are situated in the central part of the northern Aktau (*see* Text-Figs 1 and 7). The Koksyrtau-Aksyrtau section (*see* Text-fig. 9) is of particular interest for the Cenomanian/Turonian boundary interval, possesses a relatively complete record spanning the Upper Cenomanian (with only lowermost part of the substage lacking) and Lower Turonian. It is the only section with good record of the beds with *Actinocamax plenus* (BLAINVILLE) (*A. plenus* Event), as well as with the ammonite and inoceramid succession close to the Cenomanian-Turonian boundary.

In relation to Kush and Shyrkala-Airakty sections the stratigraphic gaps within the upper Upper Turonian – Lower Santonian part of the succession become more evident, The Turonian/Coniacian boundary interval is lacking (the gap comprises most probably the whole M. incertus Zone and ranges into the C. rotundatus Zone of the Lower Coniacian), and the evident gap, associated with the hardground horizon, markes the Coniacian/Santonian boundary (*seė* Pl. 7, Fig. 6).

Upper Albian (part)

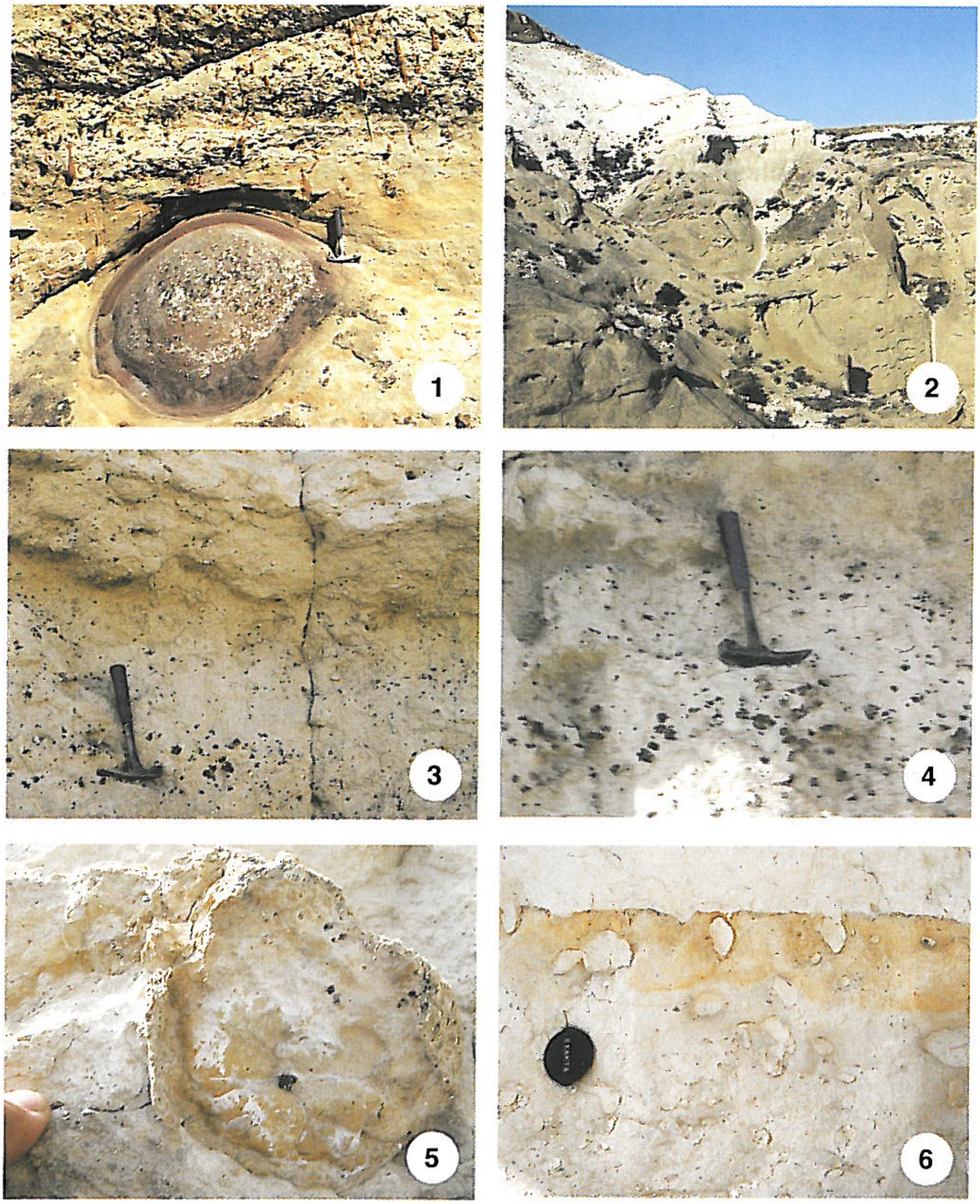
In the southern slope of the Koksyrtau Hill, about 40 m below the bottom bed (bed *A*) of the here described succession, there occur yellow, poorly cemented sandstones with mass occurring limonitized and/or phosphatized, molds of the ammonite species *Anahoplites rossicus* (SINZOW). This is the index taxon for the oldest ammonite zone of the Upper Albian in the area (SAVELEEV 1981, *see also* Table 1 and Text-fig. 1 in the present paper).

Bed A: Light-yellow, poorly cemented, fine-grained quartz sandstones with glauconite and muscovite flakes. The limonitized and slightly phosphatized fauna includes: *Semenovites*

Upper Albian through Santonian of the Koksyrtau-Aksyrtau section

1 — Southern slope of the Koksyrtau Hill, as seen from the west; at the bottom, visible is the surface of the Phosphatic Horizon *III* (= Bed *4*), with oval sandstone concretions, overlain by the topmost Albian and Cenomanian succession (Beds *5-23*)

2 — Southern slope of the Aksyrtau Hill, as seen from the south; at the bottom, visible are the Cenomanian/Turonian boundary sandy deposits (Beds *23-32*) followed by the Lower Turonian sandstones (Beds *33-35*) and by the carbonate succession of the Upper Turonian – Coniacian and Santonian; the very top of the Aksyrtau is built of the Campanian limestones



Upper Albian through Santonian succession of the Koksyrtau-Aksyrtau section

1 — Sandstone concretions in the Upper Albian sandstones with *Ophiomorpha* (Bed *2*)

2 — Lower/Upper Turonian boundary succession, as exposed at the southern slope of the Aksyrtau Hill; the bottom two-thirds of the slope are built of the Lower Turonian sandstones (Beds *33-35*) followed by the Upper Turonian phosphatic bed (Phosphatic Horizon *V* = Bed *36*) and hardground horizon (Bed *37*), and higher by the Coniacian carbonates (Bed *39*); at the very top (slightly darker) visible is the Santonian chalk

3 — Phosphatic Horizon *V* (Bed *36*) and the overlying hardground (Bed *37*), as exposed in the southern slope of the Aksyrtau Hill; at the bottom, exposed is the topmost part of the Lower Turonian sandstones (Bed *35E*) with numerous *Ophiomorpha* burrows

4-5 — Close-up views of the hardground and Phosphatic Horizon *V* as shown in Fig. 3

6 — Hardground at the Coniacian/Santonian boundary, seen at the southern slope of the Aksyrtau Hill; upper surface with distinct burrows, borings, and phosphatic and ferrginous mineralizations *uhligi* (SEMENOV) [*forma typica*, and probably more evolute and strongly ribbed variant described by SAVELEEV (1960, Pl. 41, Fig. 2, Text-figs 36-37) as the separate species, *S. tenuis*] – rare; *Inoceramus anglicus* WOODS – rare; other bivalves including trigoniids – very common. Thickness 11 m.

Bed B: Light-brown bivalve coquina with the matrix composed of fine-grained, limy quartz sandstones/sandy limestones. Toward the top and the bottom of the bed there occur concretions of limy sandstones, up to 0.5 m in diameter, and often lumped into large (up to 3 m) aggregates. Thickness 0.3 m.

Bed C: Yellow-green, poorly cemented, fine-grained quartz sandstones, with glauconite, muscovite flakes. Thickness 11 m.

Bed D: Light-green, fine-grained quartz-glauconitic sands. Thickness 6.5 m.

Bed E: Phosphatic Horizon I

Dark-brown, irregularly shaped phosphatic concretions set in poorly cemented (rarely poorly phosphatized) sandstones. The concretions range from very small up to 3-4 cm in diameter, with the average value 1.5 cm and are often lumped into irregular aggregates. The collected fauna includes single, corroded fragment of *Semenovites* sp. Thickness 0.25 m.

Bed F: Light-green, poorly cemented, fine-grained quartz-glauconitic sandstones with numerous spherical sandstone concretions, up to 1.5 m in diameter. Sometimes concretions are clustered into larger bodies. Thickness 13 m.

Bed 1: Phosphatic Horizon II

Horizon of dark-gray, irregularly shaped, limy phosphatic concretions, set in the glauconitic sandstone. The phosphatic concretions vary from 0.5 cm up to 9 cm in diameter. The phosphatized fauna includes very rare *Callihoplites* sp. Thickness 0.1 m.

Bed 2: Light-green, poorly cemented, fine-grained quartz sandstones with glauconite and muscovite flakes, and with large (up to 1.5 m in diameter) sandstone concretions, poorly phosphatized (*see* Pl. 7, Fig. 1). The concretions with numerous *Pinna* sp. In the whole unit there appear frequent, vertical *Ophiomorpha*-type burrows, up to 40 cm long and with 1.5 cm diameter. Rarely occur branching burrows referred to *Thalassinoides*-type. At the lower part, 80 cm above the bottom fine-sized, loosly packed phosphatic concretions. Thickness 5.5 m.

Bed 3: This bed is lithologically identical with Bed 2, but lacks the sandstone concretions. About 80 cm above the bottom there occur an indistinct horizon of phosphatic concretions. Thickness 6.0 m.

Bed 4: Phosphatic Horizon III

Horizon of dark-colored, phosphatic concretions set in the poorly cemented, fine-grained quartz sandstone with glauconite and muscovite flakes. The horizon is overgrown by large, oval sandstone concretions. The phosphatized fauna includes rare *Puzosia* sp., *Aucellina* sp., and relatively frequent oysters. Moreover there occur rare inoceramids and fish vertebrae. Thickness 0.5 m.

Bed 5: Yellow-gray, fine-grained silty sands. Thickness 4.4 m.

Bed 6: Dark-gray, sandy clays. Thickness 5.0 m.

Bed 7: Yellow, poorly cemented, fine-grained quartz sandstones with glauconite and muscovite flakes. Small-sized, limonitized burrows. Thickness 7.5m.

Lower Cenomanian

Bed 8: Horizon of oval concretions of limy, medium-grained sandstones with limonite and phosphatic impregnation. The concretions are usually 0.5 to 1.0 m, but reaching up to 2.5 m in diameter. Much rarer there occur spherical concretions not exceeding usually 1 m in diameter. The rare fauna was collected exclusively from the concretions and include: *I. crippsi* MANTELL, *Cucullaea* sp., gastropods. Thickness 0.6 m.

Bed 9: Light-yellow, poorly cemented, fine-grained quartz sandstones with limonitized, fine-sized *Ophiomorpha/Thalassinoides*-type burrows. Thickness 3.0 m.

Bed 10: Green, sandy siltstone, grading upward into fine-grained sandstone. At the topmost part ferruginous concretions, and *Ophiomorpha/Thalassinoides*-type burrows descending to about 0.5 m beneath, infilled with fine-sized, phosphatic concretions (firmground). Thickness 2.1 m.

Bed 11: Phosphatic Horizon IVa
Black, phosphatic concretions set in the light-gray, hard, sandy-glauconitic marl. The size and number of concretions markedly increases downward. The numerous phosphatized fauna includes: *Schloenbachia varians* (SOWERBY) – very common; *S. coupei* (BRONGNIART) – less common; *Mantelliceras mantelli* (SOWERBY) – very rare. Sporadically noted unphosphatized *Inoceramus crippsi* MANTELL. Thickness 0.5 m.

Bed 12: Light-gray, relatively hard sandy marls with glauconite, and with fine-sized, loosely packed, black-colored phosphatic concretions. Thickness 0.4 m.

Bed 13: Limonitized horizon; very rare *Sciponoceras roto* CIEŚLIŃSKI. Thickness 0.1 m.

Bed 14: Gray, limy, sandy clays. Thickness 2.5 m.

Bed 15: Red-yellow, limonitized, sandy clays, slightly porous. Thickness 0.15 m.

Bed 16: Gray, slightly calcareous clays, sandy in the middle part. In the sandy part very rare ammonites: *Sciponoceras* sp., *Schloenbachia* sp.; frequent thin-shelled bivalves. Thickness 4.6 m.

Bed 17: Light-gray, strongly calcareous clays/claystones with numerous sand-sized quartz and limonite concretions. Frequent thin-shelled, indeterminable bivalves. Thickness 1.7 m.

Bed 18: Gray, limy clays with relatively frequent fragments of large *Schloenbachia* sp. in the lower part of the unit. Thickness 1.7 m.

Bed 19: Yellow-brown, poorly cemented sandstones. Numerous, up to 5cm in diameter, horizontal *Thalassinoides*-type burrows with sandy infillings, descending down into the underlying clays. The limonitized, relatively frequent fauna includes *Turrilites costatus* LAMARCK and *Schloenbachia varians* (SOWERBY). Thickness 0.2 m.

Bed 20: Yellow-gray, non-carbonate clayey siltstones. Thickness 1.1 m.

Bed 21: Light-gray, marly, fine-grained quartz sandstones and/or sandy marls with glauconite and fine-sized phosphatic concretions. The rare, phosphatized fauna is represented by bivalves, gastropods and ammonites; *Mariella* sp., *Hypoturrilites tuberculatus* (BOSC), *Mantelliceras mantelli* (SOWERBY), *M. saxbii* (SHARPE), *Mantelliceras* sp., *Schloenbachia coupei* (BRONGNIART). Thickness 0.2 m.

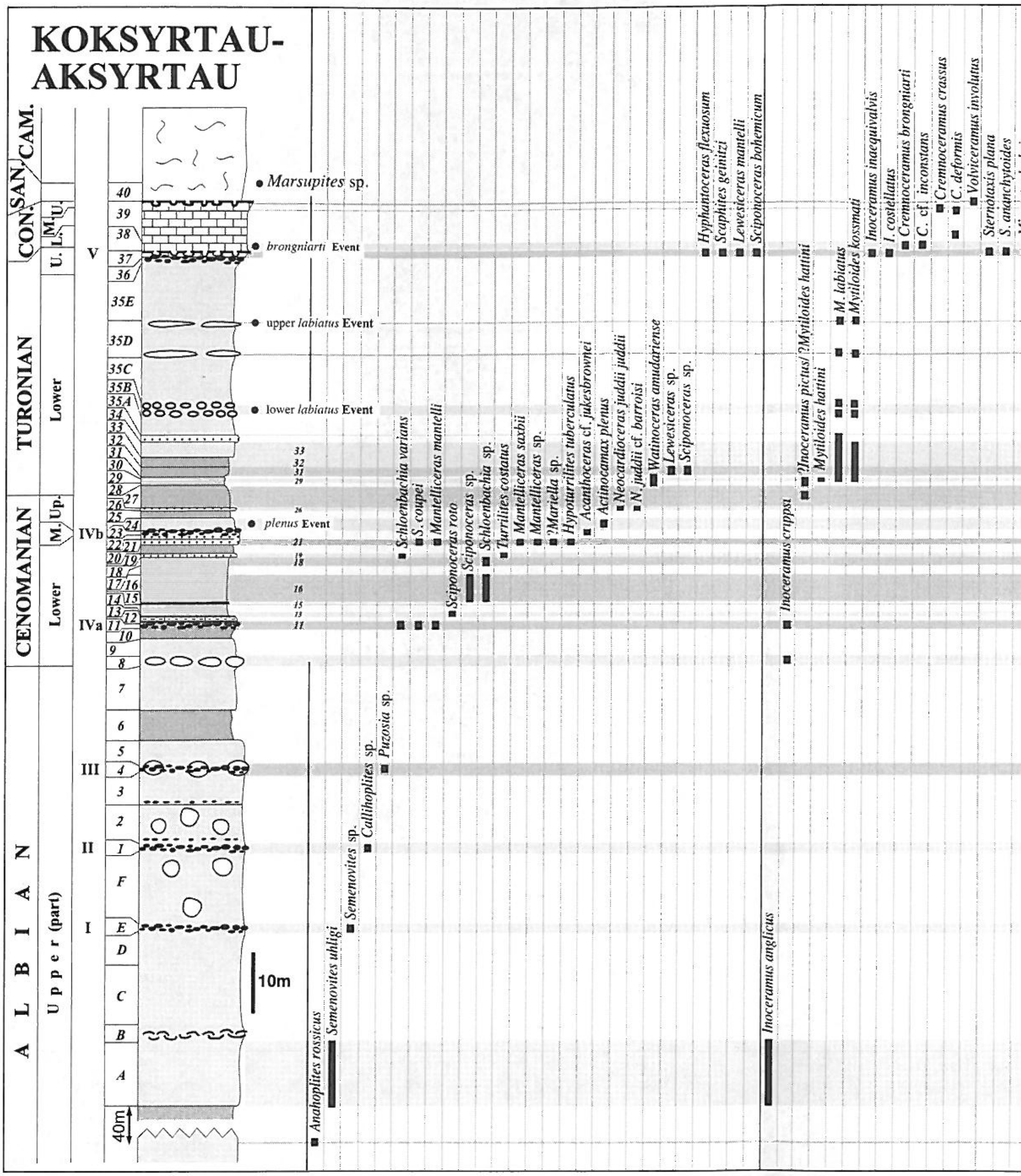
Bed 22: Yellow-gray, poorly cemented, marly, fine-grained quartz sandstones with glauconite and loosely packed, fine (up to 2 cm in diameter) phosphatic concretions. Throughout the bed occur patchily distributed oysters. Thickness 1.2 m.

Middle Cenomanian

Bed 23: Phosphatic Horizon IVb
Densly packed, medium-sized (usually 2-3 cm in diameter), brown-colored, phosphatic concretions set in light-yellow, moderately cemented quartz sandstones. The latter are fine-grained, marly. The very rare phosphatized and usually markedly corroded fauna includes single specimen of *Acanthoceras* cf. *jukesbrownei* (SPATH). Thickness 0.6 m.

Upper Cenomanian

Bed 24: Gray-green, poorly cemented, marly, fine-grained quartz sandstone with glauconite. About 1.5 m above the bottom there occur a horizon with limonitic concretions and mass occurring, well preserved *Actinocamax plenus* (BLAINVILLE). Thickness 2.7 m.



Lithologic and stratigraphic column of the Koksyrtau-Aksyrtau section, with the vertical distribution of ammonites, belemnites, inoceramids, echinoids, and crinoids

Bed 25: Gray, sandy siltstones, limy in places. Thickness 1.5 m.

Bed 26: Silty sandstones with ferruginous concretions. Very rare *Neocardioceras juddii juddii* (BARROIS & GUERNE), *N. juddii* cf. *barroisi* WRIGHT & KENNEDY, and oysters. Thickness 0.2 m.

Bed 27: Gray, sandy siltstones with muscovite; single specimen of *Inoceramus pictus* SOWERBY found in the upper part (1.5 m below the top) of the unit. Thickness 4.0 m.

Lower Turonian

Bed 28: Black clays with 20 cm thick bed of light-green siltstones about 30 cm above the bottom. In siltstones occur rare *Watinoceras amudariense* (ARKHANGELSKY) and ?*Inoceramus pictus* SOWERBY/?*M. hattini* ELDER. Thickness 0.6 m.

Bed 29: Green, limy clays; *Watinoceras amudariense* (ARKHANGELSKY) – common; ?*Inoceramus pictus* SOWERBY [in the lower part of the bed] – rare; *Mytiloides hattini* ELDER – frequent, *M. kossmati* (HEINZ) – frequent; *M.* ex gr. *labiatus* (SCHLOTHEIM) – frequent. Thickness 0.9 m.

Bed 30: Black clays with ferruginous horizon at the bottom and *Chondrites* burrows close to the top; *Watinoceras amudariense* (ARKHANGELSKY) – rare; *Mytiloides kossmati* (HEINZ) – rare; *M.* ex gr. *labiatus* (SCHLOTHEIM) – rare. Thickness 0.3 m.

Bed 31: Olive-green, limy siltstones with muscovite. In the lower part numerous *Chondrites* burrows, *Sciponoceras* sp., and *Lewesiceras* sp. (in the middle part of the bed) – very rare; *Mytiloides kossmati* (HEINZ) – common; *Mytiloides* ex gr. *labiatus* (SCHLOTHEIM) – common; and frequent small gastropods. Thickness 1.8 m.

Bed 32: Gray- to light-green, poorly cemented limy-sandy siltstones; *Mytioides kossmati* (HEINZ) – common; *M.* ex gr. *labiatus* (SCHLOTHEIM) – common; frequent oysters. Thickness 2.4 m.

Bed 33: Yellow-green, poorly cemented silty sandstones, with silt content gradually decreasing upward; *Mytiloides kossmati* (HEINZ) – common; *M.* ex gr. *labiatus* (SCHLOTHEIM) – common. Thickness 3.0 m.

Bed 34: Gray-green, cemented, marly, fine-grained quartz sandstones with numerous *Thalassinoides*-type burrows; common *Mytiloides* sp. Thickness 0.3 m.

Bed 35: Gray-green to yellow-green, poorly cemented, marly quartz sandstones with glauconite, muscovite flakes, and fine-sized, rare phosphatic concretions (*see* Pl. 7, Fig. 2). In the lower and the middle part of the bed there occur two pairs of horizons with sandstone concretions, characterized by common occurrence of inoceramids, represented by *Mytiloides kossmati* (HEINZ) and *M. labiatus* (SCHLOTHEIM); these horizons are distinguished here as beds *35B* and *35D* (*see* Text-fig. 9). At the top of the bed numerous vertical *Ophiomorpha*-type burrows, and unidentified burrows of much larger diameter with ferruginous mineralizations. Thickness 29.0 m.

Upper Turonian

Bed 36: Phosphatic Horizon V

Horizon with numerous, dark-brown phosphatic concretions, medium sized (with the average diameter not exceeding 1 cm), set in sandy marls with glauconite (*see* Pl. 7, Figs 3-4). The concretions are particularly abundant in the lower part of the horizon, and here they are the largest (3 - 4 cm in diameter). Numerous vertical *Ophiomorpha*-type burrows, and non-phosphatised shell detritus. Thickness 0.5 m.

Bed 37: Yellow, chalky limestones with fine-sized, light-brown phosphatic concretions and numerous *Thalassinoides/Ophiomorpha*-type burrows. The burrows not exceed 1 cm in diameter and are infilled with glauconitic marls. The unit represent the complex hardground horizon (*see* Pl. 7, Figs 3-5). The most cemented parts bear often with small-sized borings (*see also* NAIDIN & *al.* 1984). The numerous, usually slightly phosphatized fauna is represented by ammonites and echinoids and includes: *Sciponoceras bohemicum* (FRITSCH) – frequent; *Hyphantoceras flexuosum* (SCHLÜTER) – rare; *H.* sp. – rare; *Scaphites geinitzi* D'ORBIGNY – rare; *Lewesiceras mantelli* WRIGHT & WRIGHT – frequent; *Micraster leskei* (DES MOULINS) – rare; *Sternotaxis plana* (MANTELL) – rare; *S. ananchytoides* (ELBERT) – very rare. Thickness 0.5 m.

Lower Lower Coniacian

Bed 38: White limestones with sharp contact to the underlying hardground and with singular phosphatic conretions. The mass occuring fauna is dominated by the inoceramids of the *Cremnoceramus brongniarti* (MANTELL) – *C. rotundatus* (TRÖGER *non* FIEGE) lineage (= *C. brongniarti* Event). The sporadic occurrence of the representatives of the species *C. waltersdorfensis* (ANDERT), and the presence of rare *C.* cf. *inconstans* (WOODS) suggests the stratigraphic gap in the succession comprising the lowermost Lower Coniacian, comprising, most probably, the whole C. rotundatus Zone, as here defined (see the chapter on stratigraphy). Thickness 0.4 m.

Upper Lower – Middle ?Upper Coniacian

Bed 39: White limestones with large inoceramid prisms in the lower, 2.2 m thick part and the hardground horizon at its top. In this lower part there occur very rare *Cremnoceramus ?deformis* (MEEK). About 7 m and 7.8 m above the bottom there occur the horizon with *Cremnoceramus deformis* (MEEK) – *C. crassus* (PETRASCHECK) and the horizon with *Volviceramus involutus* (SOWERBY) respectively. Thickness 8.0 m.

Santonian

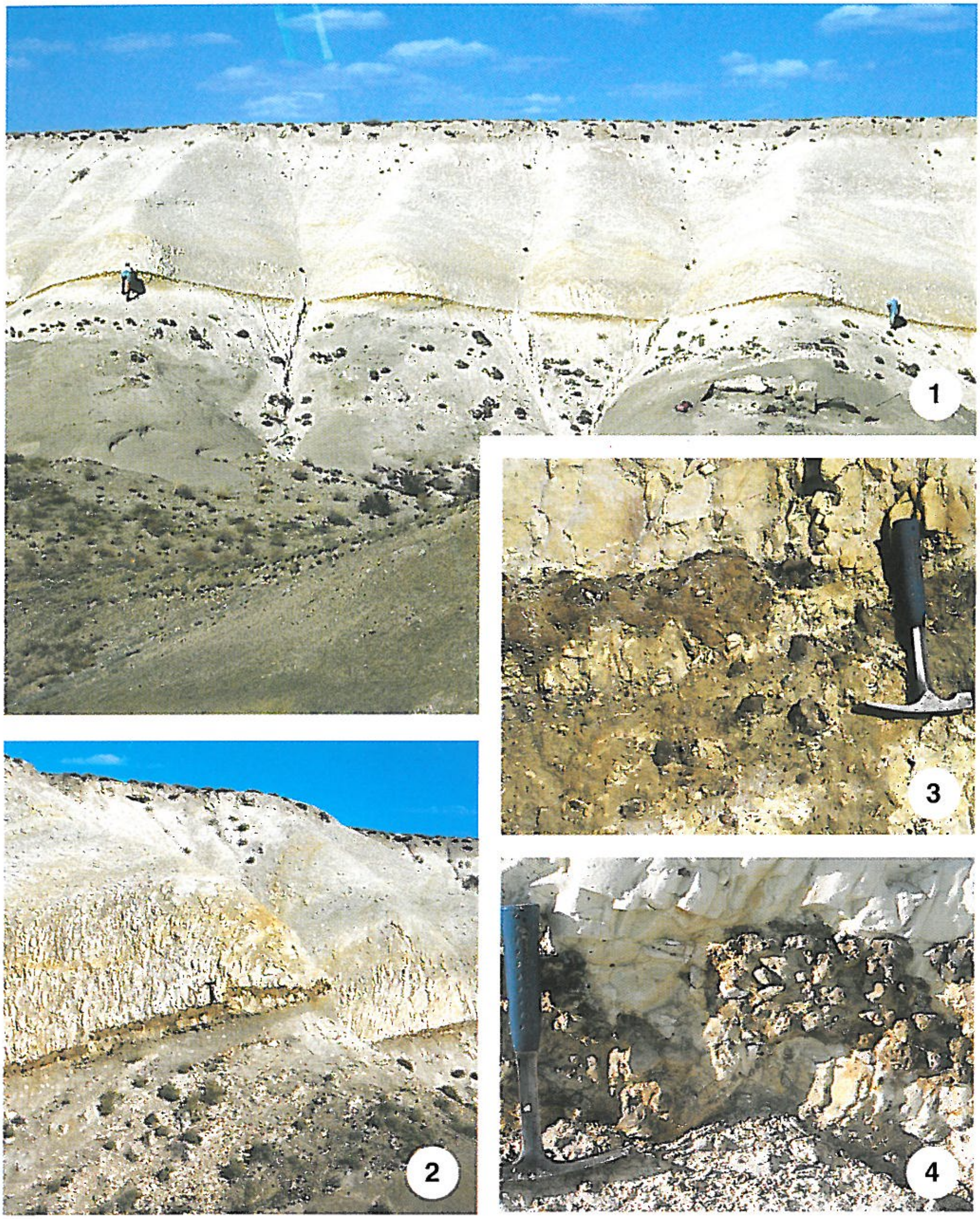
Bed 40: White, thick bedded, porous chalk. The single plates of the free-living crinoid *Marsupites testudinarium* SCHLOTHEIM form distinct horizon at about 2.8 m above the bottom of the bed, delimiting the upper boundary of the Santonian stage. Thickness 2.8 m.

AZHIREKTOY

The succession was completed in the environs of Azhirektoy, and represents the first of the two sections completed within the area of the Tumgachi Anticline (Text-figs 1, 10-11, and Pl. 8). The section possesses very thick and completely developed Upper Albian through Lower Cenomanian succession, but displays high reductions (and ?stratigraphic gaps) within the Middle Cenomanian through Lower Santonian part (*see* Text-figs 11 and 14-15). The whole Upper Turonian through Coniacian is enclosed within the phosphatic bed and closely associated hardground horizon (Bed *41*, *see also* Pl. 8, Figs 1-4).

Upper Albian

Bed 1: Gray-green, fine-grained quartz sands/silts with small admixture of glauconite and marked amount of muscovite flakes. The bottom part of the sands not exposed.



Mid-Cretaceous succession of the Azhirektoy section

1 — Lower Turonian through Santonian succession of the Azhirektoy section; at the bottom, visible is the Phosphatic Horizon *IVb*, followed by the Lower Turonian sandstones (Bed *39*) building the lower part of the slope, and capped by the Phosphatic Horizon *V* (Bed *40*) and hardground (Bed *41*); overlying is the Santonian and Campanian chalk

2 — Fault disturbances within the Phosphatic Horizon *V* at the top of the Lower Turonian sandstones (Bed *39*)

3-4 — Close-up views of the hardground (Bed *41*), strongly phosphatized with numerous echinoids

Bed 2: Light-brown, flat sandstone concretions (maximal dimensions 0.5 × 4.5 m) with ferruginous impregnations. Thickness 0.5 m.

Bed 3: Gray-green, fine-grained quartz sands with small admixture of glauconite and marked content of muscovite flakes. Thickness 7.0 m.

Bed 4: Gray-brown, flat concretions of medium-grained, marly, quartz sandstones with ferruginous impregnations, and with mass occurring small gastropods and bivalves. The sandstones contain glauconite and muscovite. Thickness 0.4 m.

Beds 5-7: Gray-green, limy, fine- to medium-grained quartz sands with glauconite and muscovite flakes. About 7.0 m and 12.5 m above the bottom there occur 0.5 m and 0.3 m thick, respectively horizons (Beds *6* and *8*) with gray-green, flat sandstone concretions (in Bed *6* very rare *Semenovites* sp.). Thickness 12.8 m.

Bed 9: Phosphatic Horizon II

Horizon with black, well rounded phosphatic concretions with the diameter ranging from 0.5 to 4.0 cm (2 cm in average). Thickness 0.1 m.

Bed 10: Gray-green, limy, fine-grained quartz sands with glauconite and muscovite flakes, and small admixture of silts and clays. Thickness 8.5 m.

Bed 11: Oval, limy sandstone concretions, with the diameter up to 1.5 m, and with numerous burrows. Thickness 1.5 m.

Beds 12-16: Gray-green, limy, fine-grained quartz sands with glauconite, muscovite flakes, and with small admixture of silty and clay material. About 2.0 m and 20 m above the bottom there occur horizons with spherical, up to 1.0 in diameter, sandstone concretions, with limy matrix (Beds *13* and *15* respectively). Thickness 29.0 m.

Bed 17: Phosphatic Horizon III

Horizon with black, well rounded phosphatic concretions, with 3-4 cm in diameter in average. Numerous phosphatized and relatively well preserved molds of trigoniids and other bivalves. Much rarer and poorer preserved phosphatic moulds of ammonites; *Callihoplites* sp. and *Karamaites* sp. Thickness 0.05 m.

Bed 18: Gray-green, limy, fine-grained quartz sands with glauconite and muscovite flakes, and with marked admixture of silty and clayey material. Thickness 19.0 m.

Bed 19: Horizon of spherical, sandstone, septarian concretions with the limy matrix, and with the diameter up to 0.8 m. Thickness 0.8 m.

Beds 20-22: Light-gray, fine-grained, marly quartz sands, silty-clayey in parts, with glauconite. About 29 m above the bottom the 0.6 m thick horizon of oval marly sandstone concretions, with numerous burrows (Bed *21*). Thickness 38.6 m.

Bed 23: Horizon with oval, marly sandstone septarian concretions with diameter up to 0.6 m, and with numerous burrows. Thickness 0.6 m.

Bed 24: Dark-gray, sandy-silty clays. Thickness 12.0 m.

Lower Cenomanian

Bed 25: Light-brown, limy quartz sandstones, phosphatized and limonitized in parts; rare *Schloenbachia varians* (SOWERBY). Thickness 0.4 m.

Bed 26: Dark-gray, plastic, silty clays. Thickness 5.0 m.

Bed 27: Light-gray to green-gray, fine-grained quartz sands with small glauconite admixture. Thickness 5.0 m.

Bed 28: Limy, medium-grained quartz sandstones with glauconite and muscovite flakes. In the lower part of the unit the sandstones are light-gray in color and unfossiliferous. Its upper part (20 cm) becomes almost brown, due to irregular limonitic and phosphatic mineralizations. In this part frequently occur gastropods, bivalves and ammonites: *Hyphoplites curvatus arausionensis* (HEBERT & MUNIER-CHALMAS) – very rare; *Schloenbachia varians* (SOWERBY) [up to 10 cm in diameter] – very common; *S. coupei* (BRONGNIART) – rare; *Karamaites mediasiaticum* (LUPPOV) – rare; *Mantelliceras mantelli* (SOWERBY) – very rare; *Inoceramus crippsi* MANTELL – common. Thickness 0.5 m.

Bed 29: Dark-gray, plastic, silty clays. Thickness 8.5 m.

Bed 30: Light-gray, fine-grained quartz sands with muscovite flakes. Thickness 8.0 m.

Bed 31: Light-brown, fine-grained quartz sands with glauconite and with phosphatic mineralization disappearing downward; frequent oysters, rare ammonite *Schloenbachia varians* (SOWERBY) and inoceramid bivalve *Inoceramus crippsi* MANTELL. Thickness 0.3 m.

Bed 32: Phosphatic Horizon IVa

Light-brown phosphatic concretions set in marly sandstones; *Schloenbachia varians* (SOWERBY) – rare, *Inoceramus crippsi* MANTELL – rare. Thickness 0.1 m.

Bed 33: Gray-green, clayey, fine-grained quartz sands with glauconite. Thickness 5.0 m.

Bed 34: Light-green, fine-grained quartz sands with glauconite and muscovite flakes. Thickness 3.0 m.

Bed 35: Light-brown, medium-grained, marly quartz sandstones, limonitized at their top,

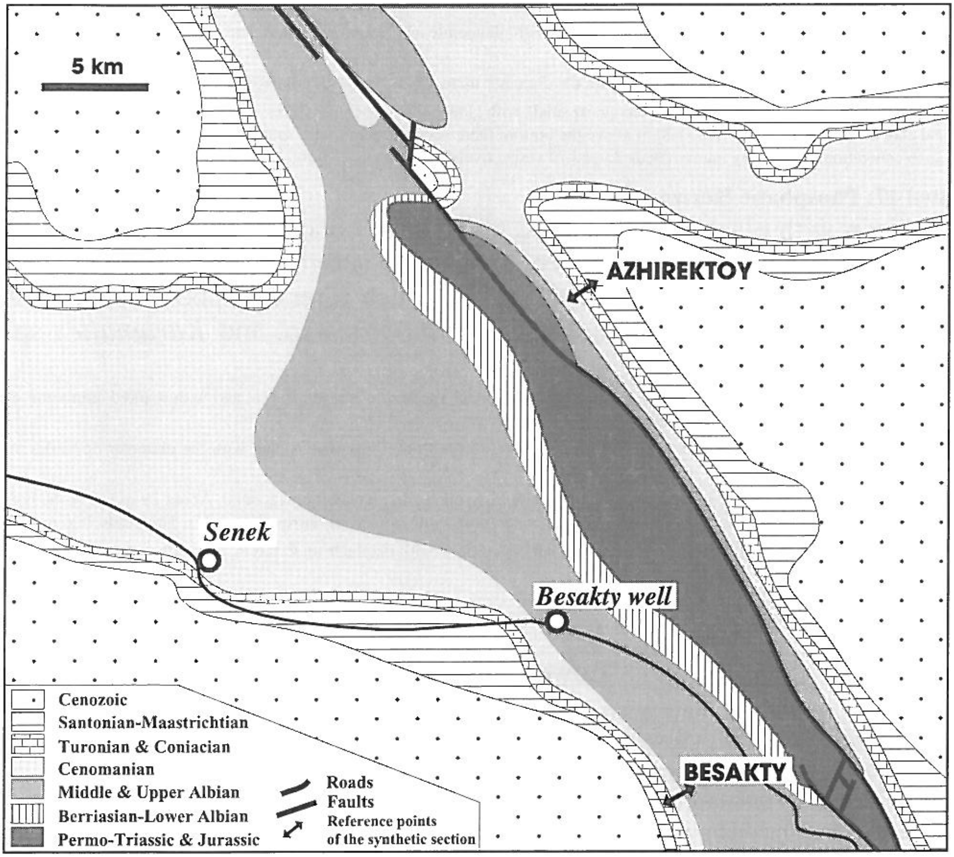


Fig. 10. Geologic sketch-map of the Tumgachi Anticline, with the position of the Azhirektoy and Besakty sections (for location *see* Text-fig. 1)

Fig. 11

Lithologic and stratigraphic column of the Azhirektoy section, with the vertical distribution of ammonites, inoceramids, and echinoids with numerous burrows; rare inoceramids and *Schloenbachia varians* (SOWERBY). Thickness 0.2 m.

Bed 36: Light-green, slightly calcareous, fine-grained quartz sands with glauconite and muscovite flakes, with 3.5 m thick horizon of sandy clays (Bed *36B*) 9.5 m above the bottom. Thickness 14.0 m.

Middle – ?Upper Cenomanian

Bed 37: Phosphatic Horizon IVb

Horizon of black phosphatic concretions (1*st* generation), up to 10 cm in diameter (3-5 cm most commonly). Rare fragments of phosphatized, light-green quartz sandstones (2*nd* phosphate generation) with glauconite (up to 10 cm in diameter) and black-colored phosphatic concretions. Phosphatized sandstone fragments represent the hiatus concretions from the destroyed phosphatic bed. The fossils are preserved exclusively within the black 1*st* generation phosphorites; very common gastropods, bivalves and diversified ammonite fauna: *Sciponoceras baculoides* (MANTELL) – rare; *Turrilites costatus* LAMARCK – rare; *T. scheuchzerianus* BOSC – very rare; *Schloenbachia varians* (SOWERBY) – relatively frequent; *S. coupei* (BRONGNIART) – relatively frequent; *Acanthoceras rhotomagense* (BRONGNIART) – relatively frequent; *A.* ssp. relatively frequent. Thickness 0.1 m.

Lower Turonian

Sandy deposits here described (the units 38-40) are below the unit with the first occurrence of the representatives of the Middle Turonian ammonite genus *Collignoniceras*, and are referred here to the Lower Turonian, only because of its position. It is noteworthy that in the neighboring Besakty section the deposits which are similar petrographically and which are in corresponding position in the section occur above the beds with collignoniceratids.

Bed 38: Flat concretions of light-green, fine-grained, limy sandstones with glauconite, and with fine (0.5-1.0 cm) phosphatic concretions. Thickness 0.2 m.

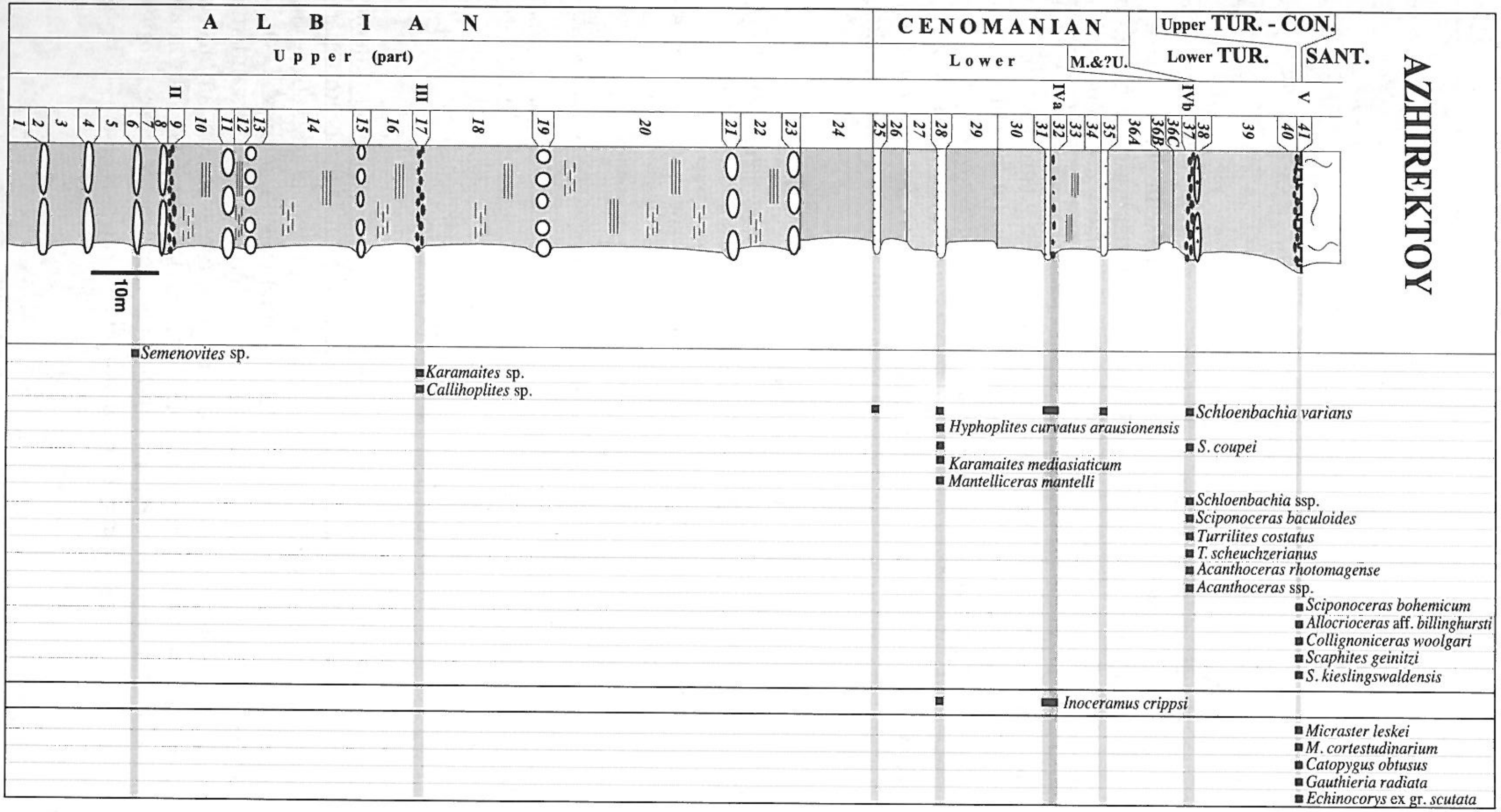
Bed 39: Light-green, poorly cemented, medium-grained limy quartz sandstones with glauconite and muscovite flakes and with rare limonitic concretions. The cementation increases upward. Thickness 14.0 m.

Bed 40: The sandstones identical to those in underlying unit but strongly bioturbated. Large *Thalassinoides*-type burrows descending from the overlying hardground are infilled with the white marls and range down to about 1 m down below the hardground. Thickness 1.0 m.

Middle Turonian – Coniacian

Bed 41: Phosphatic Horizon V

Horizon of light-brown phosphatic concretions, with maximum diameter up to 10 cm (most commonly 3-5 cm), concentrated at the bottom part of the unit. Also occur irregularly-shaped, brown-colored, phosphatized limestone/marlstone fragments (hiatus concretions) (*see* Pl. 7, Figs 1-4). The latter are represented often by molds of echinoids, bivalves, and much rarer of ammonites. In both mentioned above types of concretions very rich and diversified fauna was found, dated for the Late Turonian – Coniacian; *Allocrioceras billinghorsti* KLINGER – very rare; *Scaphites geinitzi* D'ORBIGNY – very rare; *S. kieslingswaldensis* LANGENHAN &



AZHIREKTOY
A L B I A N
Upper (part)
CENOMANIAN
Lower
M.&?U.
Upper TUR. - CON.
Lower TUR.
SANT.
II
III
IVa
IVb
V
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36A 36B 36C 37 38 39 40 41
10m
Semenovites sp.
Karamaites sp.
Callihoplites sp.
Schloenbachia varians
Hyphoplites curvatus arausionensis
S. coupei
Karamaites mediasiaticum
Mantelliceras mantelli
Schloenbachia ssp.
Sciponoceras baculoides
Turrilites costatus
T. scheuchzerianus
Acanthoceras rhotomagense
Acanthoceras ssp.
Sciponoceras bohemicum
Allocrioceras aff. billinghursti
Collignoniceras woolgari
Scaphites geinitzi
S. kieslingswaldensis
Inoceramus crippsi
Micraster leskei
M. cortestudinarium
Catopygus obtusus
Gauthieria radiata
Echinocorys ex gr. scutata

GRUNDEY – very rare; *Micraster leskei* (DES MOULINS) – very common; *M. cortestudinarium* (GOLDFUSS) – very common; *Echinocorys* ex gr. *scutata* LESKE – very common; *Catopygus obtusus* (DESOR) – rare; *Gauthieria radiata* (SORIGNET) – rare; *Cremnoceramus inconstans* (WOODS), *C. crassus* (PETRASCHECK), *Inoceramus* ex gr. *inaequivalvis* SCHLÜTER, *Volviceramus koeneni* (MÜLLER). Moreover, there also occur rare, black-colored phosphatic concretions often represented by phosphatized molds of bivalves, ammonites, and gastropods. These represent evidently the oldest generation of phosphatic concretions in the bed, and contain Middle Turonian fauna; *Sciponoceras bohemicum* (FRITSCH) – frequent; *Collignoniceras woollgari* (D'ORBIGNY) – very rare. Thickness 0.4 m.

Santonian

Bed 42: White chalk with rare and small-sized phosphatic concretions at the bottom.

BESAKTY

The Upper Cretaceous succession of the Besakty section is a part of the southern limb of the Tumgachi Anticline and crop out the best within the Upper Cretaceous questa, about 10 km south-east of Besakty well (*cf.* Text-figs 1, 10, 12; and Pl. 9, Figs 1-2). Similarly as the neighboring section Azhirektoy, lying at the northern limb of the Antlicline (*see* Text-fig. 10) the Besakty section possesses very reduced (condensed) record of the Middle Cenomanian through Coniacian succession. On the other way, it is characterized by a thick and seemingly complete Upper Albian through Lower Cenomanian record (*see* Text-figs 12, 14-15). Moreover, it is also the only section where, at least partially, the uncondensed Middle Turonian sandstones are preserved (Bed *41* – *see* Text-fig. 12). The Upper Turonian through Coniacian is enclosed within the composite hardground horizon (Bed *42* – *see* Text-fig. 12 and Pl. 10, Fig. 3), where this strong condensation (though the gaps spanning the singular intervals can not be excluded) is indicated by the exceptionally rich fauna of ammonites, echinoids, inoceramids, and belemnites (*see* Text-fig. 12).

Upper Albian

Bed 1: Phosphatic Horizon II

Horizon of black and dark-brown phosphatic concretions with the maximum diameter 5 cm (1-2 cm in average). Larger concretions irregularly shaped. Smaller are oval. The concretions are accumulated within a distinct bed, with a thickness about 10 cm, continuing across the oval, large (0.7 × 1.5 m) concretions of fine-grained, limy sandstones with glauconite and numerous burrows. Thickness 0.7 m.

Beds 2-5: The succession of soft, gray-colored, sandy-silty clays (Bed *2*), clayey quartz sands (Bed *3*), and sandy siltstones (Bed *5*). In the middle part 0.2 m thick bed of the flat concretions of the limy, fine-grained quartz sandstones (Bed *4*). Thickness 15.5 m.

Bed 6: Gray-green, fine-grained quartz sands with clay admixture. Present ellipsoid shaped concretions of the limy sandstones and interbeds of the sandy clays in the lower part of the unit. Thickness 10.7 m.

Bed 7: Phosphatic Horizon III

Gray-brown, fine-sized phosphatic concretions, with average diameter about 1 cm (maximum diameter 3-4 cm). The fine-sized concretions are oval- or spherical-shaped, the larger irregular. The concretions are set in sands, and are sometimes cemented into large (0.4 × 2.0 m), oval aggregates; "*Trigonia*" sp. – rare, *Eutrephoceras* sp. – rare. Thickness 0.4 m.

Bed 8: Gray-green, fine-grained quartz sands. Thickness 0.7 m.

Bed 9: Flat, large (0.6 × 5.0 m) concretions of fine-grained limy sandstones with glauconite and muscovite flakes. The sandstones contain large pectinids, and in the topmost part red-brown, limonite-phosphatic moulds of: *Karamaites kolbajense* SOKOLOV – very common; *Callihoplites vraconensis* (PICTET & CAMPICHE) – frequent; *C.* ssp. – very common; *Arrhaphoceras substuderi* SPATH – rare; *A.* ssp. – rare. Thickness 0.6 m.

Bed 10: Yellow-green, fine-grained quartz sands. Thickness 1.6 m.

Bed 11: Light-gray, silty-sandy clays. Thickness 13.1 m.

Bed 12: Horizon of oval- to spherically-shaped, medium-sized (up to 0.3 m in diameter) concretions of the fine-grained, limy quartz sandstones with glauconite. The concretions are widely spaced within the whole unit. Thickness 2.0 m.

Bed 13: Light-gray silty-sandy clays. Thickness 8.0 m.

Beds 14-16: Gray-green, fine-grained, clayey, silty quartz sandstones with glauconite and three indistinct horizons of septarian concretions (Beds *14-16*) of the limy sandstones. The latter are oval-shaped, and exceed 0.4 m in diameter. They contain slightly phosphatized fossils: *Karamaites kolbajense* SOKOLOV [large forms] – relatively frequent; *Arrhaphoceras* cf. *precoupei* SPATH [large forms] – rare; *Inoceramus* sp. – rare. Moreover, TRIFONOV & BURAGO (1960, p. 73) report from the concretions (their Bed *6*): *Cyprina* sp., *Cucullaea* sp., *Haustator* sp., *Placenticeras* sp. (=*Karamaites* sp.). Thickness 3.0 m.

Bed 17: Light-gray, sandy-silty clays with thin (up to 5 cm) siltstone interlayers. Thickness 8.1 m.

Beds 18-19: Clayey-silty quartz sands, red-yellow in the lower part (Bed *18*) and gray-green above (Bed *19*). Thickness 21.9 m.

Bed 20: Horizon of black and red-brown, small-sized ferruginous (?goethite)-phosphatic concretions, dispersed within light-green sands. Thickness 0.1 m.

Bed 21: Light-green clayey silty quartz sands. Thickness 13.0 m.

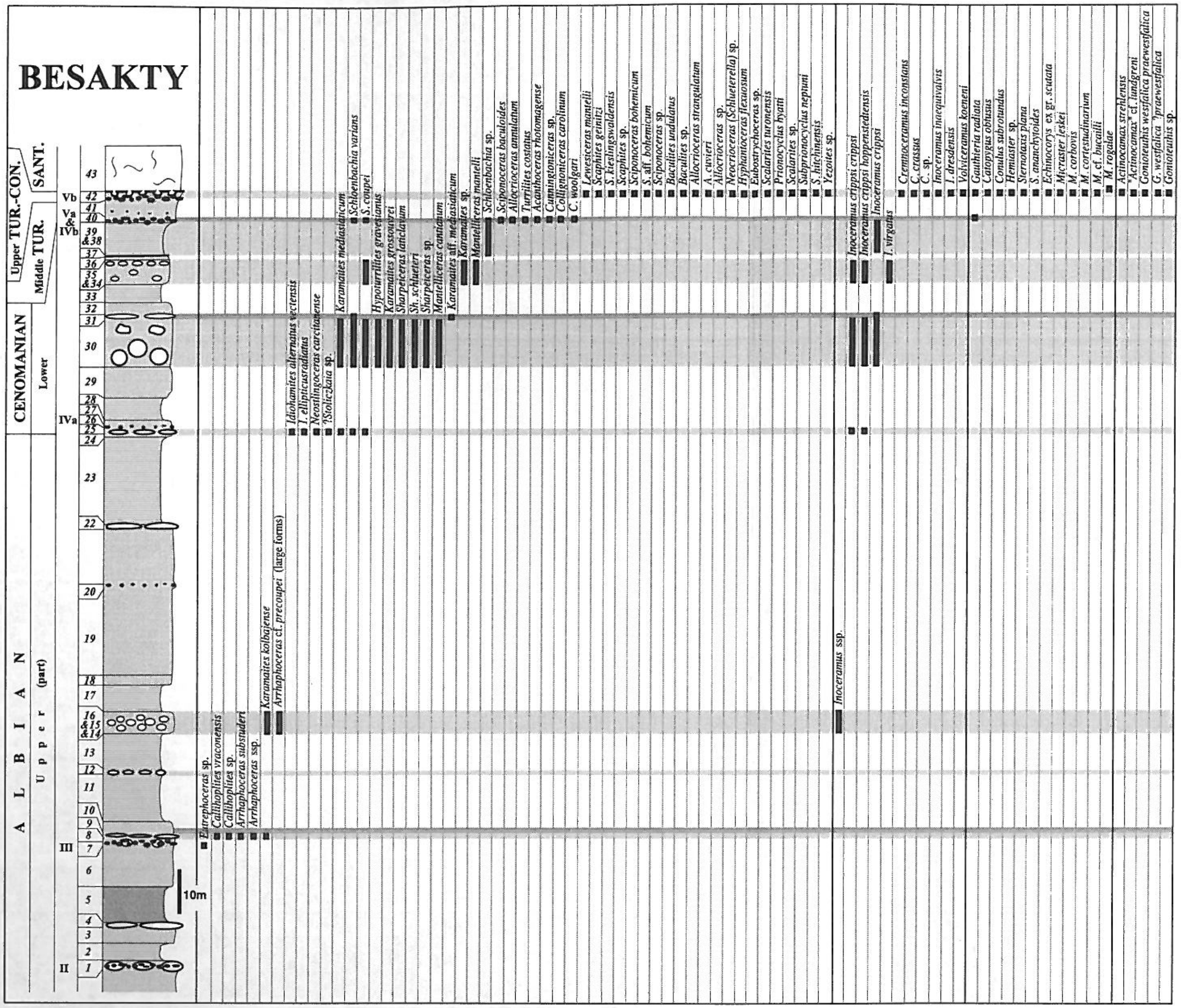
Bed 22: Horizon of large (0.6 × 5.0 m), discoid-shaped concretions of the gray-green, fine-grained limy quartz sandstones with glauconite and muscovite flakes. The concretions are slightly phosphatized at the surface, and contain: "*Solena*" sp., "*Exogyra*" sp., trigoniids, and piniids. Thickness 0.6 m.

Bed 23: Light-gray, silty sandy clays. Thickness 20.0 m.

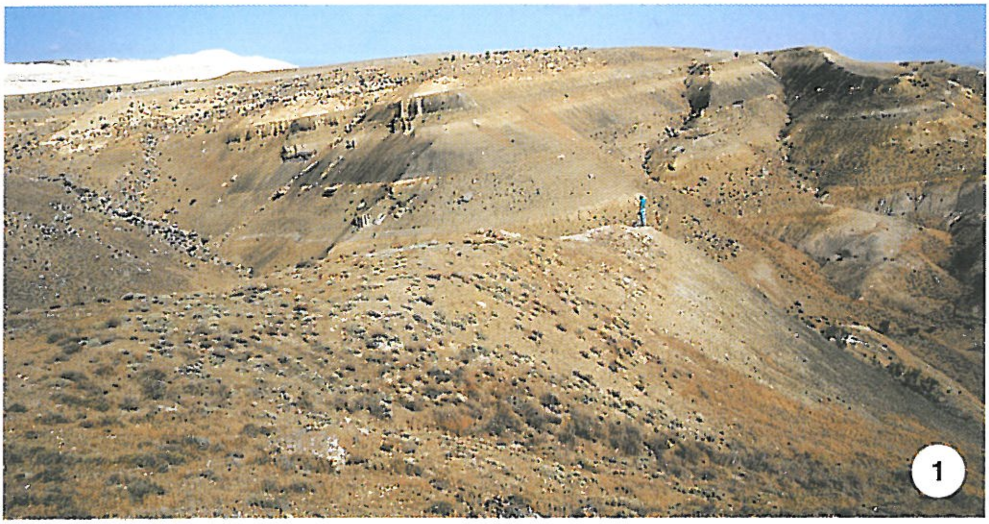
Bed 24: Gray-green, clayey-silty, fine-grained quartz sands. Thickness 0.8 m.

Lower Cenomanian

Bed 25: Horizon of moderately large (0.3 × 0.6 m), oval-shaped concretions of the gray-green limy sandstones, phosphatized in parts. The concretions are fullfilled with phosphatized fossils, dominated by bivalves, gastropods and ammonites, and often with preserved shell material. Within some concretions the imbrication of the placenticeratid ammonites is observed (tempestites); *Idiohamites alternatus vectensis* SPATH – rare; *I. ellipticus radiatus* SPATH – rare; *Neostlingoceras carcitanense* (MATHERON) – rare; *Karamaites mediasiaticum* (LUPPOV) – common (in some concretions very common); *Schloenbachia varians* (SOWERBY) – very common; *S. coupei* (BRONGNIART) – less common; ?*Stoliczkaia* sp. – very rare;



Lithologic and stratigraphic column of the Besakty section, with the vertical distribution of nautilids, ammonites, inoceramids, echinoids, and belemnites



Upper Albian through Santonian succession of the Besakty section

1 — General view of the section; **2** — Irregularly shaped, limy sandstone concretions within Bed *30* (Lower Cenomanian)

Upper Albian through Santonian succession of the Besakty section

1 — Large sandstone concretions (usually with numerous ammonites and inoceramids) within the soft sandstones of Bed *30* (Lower Cenomanian), as exposed in the NW part of the area

2 — Wood fragment with *Teredo* borings, Bed *34* (Lower Cenomanian)

3 — Phosphatic Horizon and hardground (Bed *42*) comprising the interval from the Upper Turonian up to the low-Upper Coniacian, with numerous phosphatized fauna

Inoceramus crippsi crippsi MANTELL – very common; *I. crippsi hoppenstedtensis* TRÖGER – very common. Thickness 0.4 m.

Bed 26: Phosphatic Horizon IVa

Fine-sized, red-brown to dark-brown ferruginous-phosphatic concretions, contained within the sands identical to that in unit 25. Thickness 0.1 m.

Beds 27-29: Gray-green, fine-grained quartz sands with glauconite and muscovite flakes. In the middle part 5.0 m thick succession of light-gray clays, silty in parts (Bed *28*). At the topmost, 1 m thick part of the unit numerous, large *Thalassinoides/Ophiomorpha*-type burrows (up to 4 cm in diameter). Thickness 14.3 m.

Bed 30: Light- and gray-green, poorly cemented, fine-grained quartz sandstones with glauconite and muscovite flakes. Throughout the bed occur irregularly shaped, relatively hard, sometimes slightly phosphatized concretions of the limy sandstones, up to 1.5 m in diameter. Although the concretions are dispersed thoughout the bed they are most abundant in its middle part. Moreover, they seem to be larger and more regular downward. The common fauna, except numerous serpulid patches from the soft sandstones, comes exclusively from the sandstone concretions: *Hypoturrilites gravesianus* (D'ORBIGNY) – very rare; *Karamaites mediasiaticum* (LUPPOV) – common; *K. grossouvrei* (SEMENOV) – rare; *K.* sp. frequent; *Sharpeiceras laticlavum* (SHARPE) – rare; *S. schlueteri* HYATT [large forms] – rare; *S.* aff. *schlueteri* HYATT [large forms] – rare; *S.* sp. – rare; *Mantelliceras cantianum* SPATH – very rare; *Schloenbachia varians* (SOWERBY) – very common; *S. coupei* (BRONGNIART) – less common; *Inoceramus crippsi crippsi* MANTELL – very common; *I. crippsi hoppenstedtensis* TRÖGER – very common; *I.* ex gr. *crippsi* MANTELL common; *I.* sp. – common. Thickness 10.8 m.

Beds 31-32: Gray-green, poorly cemented, limy quartz sandstones with glauconite, slightly coarser-grained when compared to the sandstones in the underlying unit. At the bottom (Bed *31*) commonly occurring *Schloenbachia varians* (SOWERBY) and rare *Karamaites* aff. *mediasiaticum* (LUPPOV), *Inoceramus crippsi* MANTELL, and "*Trigonia*" sp. The middle and upper parts (Bed *32*) yield numerous, vertical *Ophiomorpha*-type burrows. The burrows are up to 3 cm in diameter and possess relatively thick (up to 0.5 cm), slightly phosphatized walls. At the top of the bed there occur frequent, unphosphatized oysters. Thickness 3.3 m.

Bed 33: Light-gray silty clays. Thickness 4.5 m.

Beds 34-35: Light-green and light-yellow, fine-grained quartz sandstones with glauconite and medium sized (up to 0.3 m in diameter), oval-shaped concretions of the hard limy sandstones. The latter form horizon (Bed *35*) at the topmost part of the unit. Usually slightly phoshatized fossils are represented by bivalves (mostly inoceramids), rare gastropods and very rare ammonites: *Schloenbachia coupei* (BRONGNIART) – rare; *Karamaites* sp. – rare; *Mantelliceras mantelli* (SOWERBY) – very rare; *Inoceramus crippsi crippsi* MANTELL – very common; *I. crippsi hoppenstedtensis* TRÖGER – common; *I. virgatus* SCHLÜTER – rare; *I.* sp. – frequent; moreover numerous large wood fragments with boring bivalves (*see* Pl. 10, Fig. 2). Thickness 5.5 m.

Beds 36-37: Yellow-green, fine-grained, silty quartz sandstones. Thickness 1.05 m.

Beds 38-39: Light-gray, silty-sandy clays; rare fossils occurring in the form of limonitic molds: *Schloenbachia* sp. – rare; *Inoceramus crippsi* MANTELL – rare. Thickness 6.5 m.

Middle Turonian

Bed 40: Phosphatic Horizon IVb & Va

Horizon of dark- to light-brown and black phosphatic concretions, moderately large (up to 5 cm in diamter, with the average value 1-2 cm), cemented in parts into flat, tabular bodies (0.15 × 0.35 m). Sometimes the concretions form irregular aggregates up to 10 cm in diameter. The black concretions form evidently older, Middle – early Late Cenomanian generation, as indicated by the yielded ammonite fauna: *Sciponoceras baculoides* (MANTELL) – relatively common; *Turrilites costatus* LAMARCK – very common; *Schloenbachia varians* (SOWERBY) – rare; *S. coupei* (BRONGNIART) – more frequent; *S.* ssp. – frequent; *Acanthoceras rhotomagense* (BRONGNIART) [forma typica] – rare; *A. rhotomagense* (BRONGNIART) [morphotype *sussexiense* of MANTELL] – more frequent; *Cunningtoniceras* sp. – very rare. Dark- to light-brown concretions are younger, dated, with the help of ammonites and echinoids for the latest Cenomanian – Middle Turonian; *Allocrioceras annulatum* (SHUMARD) – very rare; *Collignoniceras woolgari* (MANTELL) – rare; *C. carolinum* (D'ORBIGNY) – more frequent; collignoniceratids (fragments) – relatively common; *Gauthieria radiata* (ORIGNET) – rare.The bed represents strongly condensed unit with two distinct periods of phosphatization and redeposition, in the Middle – early Late Cenomanian and Middle Turonian respectively.The Bed is characterized, moreover, by numerous gastropods, bivalves, shark and ray teeth and reptilian bony fragments (?mososaurids). Thickness 0.2 m.

Bed 41: Gray-green, poorly cemented, fine-grained, quartz limy sandstones with glauconite. About 30 cm above the bottom occurs the thin horizon of fine-sized phosphatic nodules. Similar nodules are noted also higher to about 1.5 m within the bed. The sandstones are gradually more limy and harder upward. The topmost, 30 cm thick part of the unit yeilds numerous *Spondylus spinosus* SOWERBY with well preserved spines. Thickness 4.5 m.

Upper Turonian – Coniacian

Bed 42: Phosphatic horizon (Bed *42A*) with the hardground (Bed *42B*) at its top. Thickness 1.6 m

Bed 42A: Phosphatic Horizon Vb

Horizon of light- and dark-brown, medium-sized (up to 4 cm and 1 cm in average in diameter) phosphatic concretions dispersed within green, fine-grained, limy quartz sandstones with glauconite. The concretions are most abundant in the bottom part of the unit, where they are, moreover, relatively large. The sandstones are strongly bioturbated and yield numerous *Ophiomorpha*-type burrows. Numerous fossils are represent by diverse invertebrate and vertebrate groups, as echinoids, ammonites, gastropods, bivalves, shark and ray teeth; *Sciponoceras bohemicum* (FRITSCH) – frequent; *S.* aff. *bohemicum* (FRITSCH) – more frequent; *S.* sp. – very rare, *Baculites undulatus* D'ORBIGNY – very common; *B.* ssp. – very common; *Allocrioceras strangulatum* WRIGHT – common; *A. cuvieri* (SCHLÜTER) – rare; *A.* ssp. – frequent; *Neocrioceras* (*Schlueterella*) sp. – rare; *Scalarites turonensis* (SCHLÜTER) – rare; *Scalarites* sp. – very rare; *Hyphantoceras flexuosum* (SCHLÜTER) – rare; *Eubostrychoceras* sp. – rare; *Yezoites* sp. – rare; *Scaphites geinitzi* D'ORBIGNY – very common; *S. kieslingswaldensis* LANGENHAN & GRUNDEY – frequent; *S. kieslingswaldensis doylei* WRIGHT – more frequent; *S.* ssp. –

common; *Lewesiceras mantelli* WRIGHT – frequent; large fragments (up to 40 cm in diameter) of lewesiceratids overgrown by serpulids – rare; *Subprionocyclus neptuni* (GEINITZ) – relatively frequent; *S. hitchinensis* (BILLINGHORST) – very rare; *Prionocyclus hyatti* (STANTON) [*gracile* forma *sensu* KENNEDY (1988)] – rare; *Actinocamax strehlensis* (FRITSCH & SCHLOENBACH) – very rare; *Gonioteuthis westfalica praewestfalica* ERNST & SCHULZ – relatively frequent; *G. westfalica ?praewestfalica* [transitional form to *G. westfalica westfalica*) – very rare; *G.* sp. – frequent; *Cremnoceramus inconstans* (WOODS) – rare; *C. crassus* (PETRASCHECK) – rare; *C.* ssp. frequent; *Inoceramus inaequivalvis* SCHLÜTER – common; *I. dresdensis* TRÖGER – rare; *Volviceramus koeneni* (MÜLLER) – rare; *Spondylus spinosus* SOWERBY (often preserved with spines) – common; *S.* sp. – common; *Micraster leskei* (DES MOULINS) – very common; *M. cortestudinarium* (GOLDFUSS) – very common; *M. corbovis* FORBES – rare; *M.* cf. *bucailli* PARENT – very rare; *Echinocorys* ex gr. *scutata* LESKE – very common; *Sternotaxis plana* (MANTELL) – frequent; *S. ananchytoides* (ELBERT) – rare; *Catopygus obtusus* DESOR – rare; *Conulus subrotundus* MANTELL – rare. Thickness 03-1.3 m.

Bed 42B: Lower part composed of white, sandy marls with glauconite (20 cm thick), fine-sized (up to 1 cm in diameter) and sparce phosphatic concretions, and common *Thalassinoides/Ophiomprpha*-type burrows. Topmost part characterized by the occurrence of hiatus concretions, with phosphatic and/or ferruginous mineralizations; the horizon is interpreted as erosional residue after the once existing here hardground horizon. Rare fossils are represented mostly by phosphatized molds: "*Actinocamax*" cf. *lundgreni* STOLLEY – rare; *Micraster* cf. *rogalae* NOWAK – rare; *Echinocorys* ex gr. *scutata* LESKE – rare.

Santonian

Bed 43: White chalk with rare, small, dark-brown phosphatic concretions occurring up to 10 cm above the base of the unit. The bottom part contains, moreover, numerous *Thalassinoides*-type burrows. According to foraminiferal dating the Santonian deposits are about 7 m thick (TRIFONOV & BURAGO 1960, p. 91).

BIOSTRATIGRAPHY

The biostratigraphic division of the studied succession (Text-fig. 13) is based on ammonites (Upper Albian through Cenomanian) and inoceramids (Turonian through Coniacian). The other groups, such as belemnites and echinoids, are either limited to narrow parts of the sections (as in the case of belemnites), or their stratigraphic value is much lower than that of the first two groups (as in the case of echinoids). Some representative forms of all these groups are herein presented, to illustrate their impressive content (Pls 11-19).

The ammonite division is based, to a large extent, on the standard division proposed by KENNEDY (1984a, b; 1985), OWEN (1984), and ERNST

stage	substage	standard ammonite zonation	compiled zonation as used in the present study
SAN.	Lower	Goniotetuthis westfaliea Texanites (Texanites)	Sphenoceramus pachti Cladoceramus undulatoplicatus
CONIACIAN	Upper	Paratexanites serratomarginatus	Magadiceramus subquadratus
	Middle	Gauthiericeras margae	Volviceramus involutus/V. koeneni
	Lower	Peroniceras tridorsatum	Cremnoceramus crassus/C. deformis
		Forresteria petrocoriensis	Cremnoceramus brongniarti
			Cremnoceramus rotundatus
TURONIAN	Upper	Subprionocyclus neptuni	Mytiloides incertus
			Inoceramus costellatus
	Middle	Collignoniceras woollgari	Inoceramus lamarcki
			Inoceramus apicalis
			Mytiloides hercynicus
	Lower	Mammites nodosoides	Mytiloides labiatus Mytiloides kossmati
		Watinoceras coloradoense	W. amudariense/M. hattini
CENOMANIAN	Upper	Neocardioceras juddii	Neocardioceras juddii
		Metoicoceras geslinianum	Actinocamax plenus
		Calycoceras guerangeri	
	Middle	Acanthoceras jukesbrownei	Acanthoceras jukesbrownei
		Acanthoceras rhotomagense	Acanthoceras rhotomagense
	Lower	Mantelliceras dixoni	Mantelliceras dixoni
		Mantelliceras mantelli	Mantelliceras mantelli
ALB.	Upper	Stoliczkaia dispar	Leptohoplites cantabrigensis
		Mortoniceras inflatum	Mortoniceras inflatum
		Dipoloceras cristatum	Semenovites michalskii

Fig. 13. The applied ammonite and inoceramid zonation to the mid-Cretaceous of Mangyshlak and its correlation with the standard European zonation, and the stage and substage division

(1966, 1974), and summarized by ERNST & SCHMID (1979) which, with slight modification concerning mainly the lowest part of the succession (Upper Albian), can also be applied to the Mangyshlak Cretaceous.

The inoceramid scheme is identical to that worked out in Central Europe (SEITZ 1956; TRÖGER 1981, 1989; ERNST & *al.* 1983; WOOD & *al.* 1984; WALASZCZYK 1992). The comments given in some intervals have a bearing not only on the studied succession, but in general on the European inoceramid zonation. Some peculiarities of the studied successsion which may potentially be used in the construction of a biostratigraphic zonation are also discussed.

UPPER ALBIAN

Above the beds with *Anahoplites rossicus* (SINZOV), indicative of the Middle Albian, three successive ammonite assemblages can be distinguished within the studied sections. The lower assemblage is characterized by representatives of the genus *Semenovites* GLAZUNOVA, 1960, accompanied higher by representatives of the species *Mortoniceras inflatum* (J. SOWERBY), which is characteristic of the second assemblage. The highest part is characterized by the occurrence of the genera *Leptohoplites* SPATH, 1925, *Arrhaphoceras* WHITEHOUSE, 1927, and the appearance of the genus *Karamaites* SOKOLOV, 1961. The latter genus represents the typical form of the latest Albian through Early Turonian of Middle Asia (*cf.* MARCINOWSKI 1980). This succession enables the three ammonite zones to be distinguished within the Upper Albian of Mangyshlak (*see* Text-fig. 13), *i.e.*: the Semenovites michalskii Zone, the Mortoniceras inflatum Zone, and the Leptohoplites cantabrigensis Zone. The Anahoplites rossicus Zone, distinguished by SAVELEEV (1981), within the lowermost Upper Albian of the region represents a lateral equivalent of the Anahoplites daviesi Zone, and thus must be lowered to the latest Middle Albian of the standard substage division (*see* OWEN 1984).

Semenovites michalskii Zone

The lower boundary of the Upper Albian in Mangyshlak marks the first appearance of representatives of the genus *Semenovites* GLAZUNOVA (*cf. also* AMEDRO & *al.* 1977). SAVELEEV (1981) who studied this genus at length, distinguished within it a series of new species, and subsequently constructed a very refined biostratigraphic zonation for the lower Upper Albian that comprises two superzones, three zones, and two subzones. This scheme, however, seems to be oversplit, as most of his new species appear to be synonymous with the earlier known forms and, moreover, many of his new forms regarded by him as stratigraphically successive were found to co-occur (*see e.g.* Shyrkala-Airakty and Kush sections – Text-figs 6 and 8).

The preliminary studies allow to distinguish two species groups with different ornamentation pattern within the genus *Semenovites*:

(1) Species with relatively strong ornamentation:

Semenovites michalskii (SEMENOV 1899, p. 120, Pl. 4, Fig. 5) = *S. pseudoauritus* (SEMENOV 1899, p. 119, Pl. 4, Fig. 4 – subjective synonym) = *S. litschkovi* (SAVELEEV 1960, Pl. 41, Fig. 1 and Text-fig. 32) = *S. laticostatus* (SAVELEEV 1960, Pl. 42, Fig.1 and Text-fig. 34);
Semenovites baisunensis (LUPPOV 1961, Pl. 6, Fig. 1 and Text-fig. 14);
Semenovites pseudocoleonodus (SEMENOV 1899, p. 122, Pl. 14, Fig. 4) = *S.* (*Planihoplites*) *pseudocoleonodus* (SEMENOV) [*see* SAVELEEV 1981, p. 45];

(2) Forms with relatively weak ornamentation pattern:

Semenovites uhligi (SEMENOV 1899, p. 124, Pl. 5, Fig. 1) = *S. pseudofittoni* (SEMENOV 1899, p. 125, Pl. 5, Fig. 2) = *S. tenuis* (SAVELEEV 1960, Pl. 41, Fig. 2 and Text-figs 36-37) = *S.* (*Planohoplites*) *tenuis* (SAVELEEV 1981, p. 45);
Semenovites mangyshlakensis (SAVELEEV 1960, pp. 182-183, Pl. 42, Fig. 2 and Text-fig. 35).

In the Semenovites michalskii Zone, moreover, there occur *Callihoplites* sp., *Anahoplites* sp., and *Hamites incurvatus* BROWN. The upper boundary of the zone is placed at the appearance level of representatives of the species *Mortoniceras inflatum* (J. SOWERBY). The so-defined S. michalskii Zone corresponds to the Dipoloceras cristatum Zone and to the lower part of the M. inflatum Zone in the standard division of the Albian stage (*i.e.* cristatum, orbignyi, and variscosum subzones *sensu* OWEN 1976, 1984).

Mortoniceras inflatum Zone

Besides the index taxon the zone is characterized by the occurrence of representatives of the genera *Semenovites* GLAZUNOVA, *Hysteroceras* HYATT, and *Callihoplites* SPATH. The zone is herein defined as the taxon range zone. It would thus correspond to the auritus Subzone of the M. inflatum Zone *sensu* OWEN (1976, 1984)[*cf. also* BREISTROFFER 1936, 1947; SPATH 1942; MARCINOWSKI & NAIDIN 1976; MARCINOWSKI & WIEDMANN 1990].

Leptohoplites cantabrigensis Zone

This Zone is a lateral equivalent of the Stoliczkaia dispar Zone in the ammonite Albian division of the Upper Albian (SAVELEEV 1981). SAVELEEV (1981; *cf. also* 1969) refers it to the Vraconian, a stratigraphic unit, which due to its imprecise definition, should be abandoned (*cf.*

MARCINOWSKI & NAIDIN 1976). The species *Stoliczkaia dispar* NEUMAYR was not reported from Mangyshlak, but the noted species, *i.e.* *Callihoplites vraconensis* (PICTET & CAMPICHE), *Callihoplites* sp., *Arrhaphoceras substuderi* SPATH, *A.* cf. *precoupei* SPATH, *Arrhaphoceras* sp., "*Saltericeras*" sp. [the passage forms between *Callihoplites* and *Schloenbachia* (*cf.* MARCINOWSKI 1983, pp. 165-166), with unclear generic affinity (*cf.* KENNEDY & JUIGNET 1984, p. 123)], *Karamaites kolbajense* (SOKOLOV), as well as *Anisoceras* sp., *Leptohoplites cantabrigensis* SPATH, *L.* aff. *cantabrigensis* SPATH, *Callihoplites tetragonus* (SEELEY), *C.* cf. *advena* SPATH, *Pleurohoplites renauxianus* (D'ORBIGNY), *Arrhaphoceras studeri* SPATH (*cf.* SOKOLOV 1966, SAVELEEV 1981) make up the typical assemblage of the S. dispar Zone and are known to occur in an identical stratigraphic position in Western Europe (*cf.* SPATH 1942; BREISTROFFER 1936, 1947; RENZ 1968; OWEN 1984; ROBASZYNSKI 1984).

In the studied area the lower boundary of the S. dispar Zone coincides with the III*rd* Phosphatic Horizon, and its upper boundary is marked by the appearance of representatives of such genera as *Idiohamites* SPATH, *Neostlingoceras* KLINGER & KENNEDY, *Schloenbachia* NEUMAYR, and *Mantelliceras* HYATT.

This zone reaches its maximum thickness in the studied area in the Besakty section (*see* Text-fig. 14). The ammonite fauna reported from there enable the division of the Zone into two well defined subzones (*see* SAVELEEV 1969, 1981).

Callihoplites vraconensis Subzone

Besides the nominative species the subzone comprises representatives of the species *Karamaites kolbajense* (SOKOLOV), *Callihoplites* sp., and *Arrhaphoceras substuderi* SPATH. All these ammonites were found 0.7 m above the III*rd* Phosphatic Horizon (Bed *9* in Text-fig. 12). Moreover, SAVELEEV (1981) mentioned *Callihoplites* cf. *advena* SPATH and *Leptohoplites cantabrigensis* SPATH from the same horizon.

Arrhaphoceras precoupei Subzone

The ammonites characterizing this subzone come from the level of septarian concretions (Beds *14-16* in Text-fig. 12) and are represented by *Karamaites kolbajense* (SOKOLOV) [large forms] and *Arrhaphoceras* cf. *precoupei* SPATH [large forms]. Furthermore, SAVELEEV (1981) reports from the same horizon, *Anisoceras* sp., *Leptohoplites cantabrigensis* SPATH, *Arrhaphoceras studeri* (PICTET & CAMPICHE), *Pleurohoplites renauxianus* (D'ORBIGNY) and *Callihoplites tetragonus* (SEELEY) establishing the new Arrhaphoceras studeri Subzone. While the index taxon of SAVELEEV's subzone was not found by the present authors, and the very close form, *A. substuderi* SPATH was found in the subzone below, the species *Arrhaphoceras precoupei* SPATH is herein proposed as the index taxon of the subzone. The Callihoplites vraconensis and Arrhaphoceras precoupei subzones distinguished within the

Albian of Mangyshlak correspond in the standard ammonite division (*cf.* OWEN 1984) to the Mortoniceras (Mortoniceras) rostratum and M. (Durnovarites) perinflatum subzones, respectively.

CENOMANIAN

In the studied area only the Lower Cenomanian is characterized by "normal" sedimentation with a relatively thick series occurring in most of the sections. The Middle and the Upper Cenomanian are strongly condensed (*e.g.* the IV*th* Phosphatic Horizon in Shyrkala-Airakty section comprises the whole Middle and Upper Cenomanian) or are simply absent.

LOWER CENOMANIAN

Mantelliceras mantelli Zone

The lower boundary of the zone is marked by the appearance of representatives of the genera *Idiohamites* SPATH, *Neostlingoceras* KLINGER & KENNEDY, and *Schloenbachia* NEUMAYR. In cases where ammonites are absent, the lower boundary of the zone (and consequently of the Cenomanian stage) is placed at the appearance level of the inoceramid species *Inoceramus crippsi* MANTELL which is regarded to have appeared almost simultaneously with the ammonites characterizing this zone (*see* TRÖGER 1981, 1989). Within the studied sections the index taxon is known only from the upper part of the zone, just below the unit comprising the Middle Cenomanian ammonites (*cf.* Text-figs 5, 9 and 12). The other ammonites occurring within the M. mantelli Zone represent typical forms of this interval; compare the lists in Text-figs 9 and 11-12 with the referenced data (KENNEDY 1971; JUIGNET & KENNEDY 1976; KENNEDY & HANCOCK 1978; KLINGER & KENNEDY 1978; KENNEDY & JUIGNET 1983, 1984; KENNEDY, JUIGNET & WRIGHT 1986; WRIGHT & KENNEDY 1984, 1987, 1990).

Mantelliceras dixoni Zone

The presence of the zone may be suggested indirectly by the occurrence of the species *Turrilites* (*Turrilites*) *costatus* LAMARCK still within the vertical range of the Lower Cenomanian representatives of the genera ?*Mariella* NOWAK, 1915, *Hypoturrilites* DUBOURDIEU, 1953, and *Mantelliceras* HYATT, 1900, in the Koksyrtau-Aksyrtau section (Beds *19* and *21*, respectively). The species *Turrilites* (*T.*) *costatus* LAMARCK represents a typical form of the lower part of the Middle Cenomanian; its first appearance, however, is already noted within the uppermost Lower

Cenomanian (*cf.* KENNEDY 1971, JUIGNET & KENNEDY 1976, KENNEDY & JUIGNET 1983). Thus, in the discussed section, beds *19-21* and probably also *22* may represent the Lower Cenomanian M. dixoni Zone. The upper boundary of this zone is erosional as it is the base of the Phosphatic Horizon *IVb* (Bed *23*). In the Sulu-Kapy section the M. dixoni Zone most probably represents Bed *13*, as directly below it there occurs *Mariella (Mariella) cenomanensis* (SCHLÜTER), the species confined to the lower two-thirds of the Lower Cenomanian (*see* KENNEDY & JUIGNET 1983, p. 64), and directly above it there is a level of mass occurrence of representatives of the species *Turrilites (Turrilites) costatus* LAMARCK and *T. (T.) scheuchzerianus* BOSC, as well as other forms, without, however, any typical Lower Cenomanian species (*cf.* Text-fig. 5). In other sections the presence of the Mantelliceras dixoni Zone is poorly documented, and conditionally one may refer to it the intervals between the last occurrences of the inevitably Lower Cenomanian representatives of the genera *Mantelliceras* and *Hypoturrilites* and the appearance level of the Middle Cenomanian acanthoceratids (*cf.* Text-figs 11-12).

MIDDLE CENOMANIAN

In the studied sections the Middle Cenomanian acanthoceratids were found only within the Phosphatic Horizon *IVb* and are represented by *Acanthoceras (Acanthoceras) rhotomagense* (BRONGNIART), *A. (A.) jukesbrownei* SPATH, *A. (A.)* sp., and *Calycoceras (Newboldiceras)* sp. Moreover, Horizon *IVb* also yields unquestionable Lower and Upper Cenomanian species (*cf.* Text-figs 6 and 8), thus indicating marked stratigraphic condensation, which makes it impossible to attempt any zonal subdivision of the Middle Cenomanian. The only exception is the Sulu-Kapy section where the presence of two Middle Cenomanian ammonite zones is proved.

Acanthoceras rhotomagense Zone

Turrilites costatus Subzone

This subzone is represented by unit *14* of the Sulu-Kapy section which is characterized by the mass occurrence of *Turrilites costatus* LAMARCK and absence of representatives of Lower Cenomanian genera such as *Neostlingoceras*, *Mariella*, *Hyphoplites*, or *Mantelliceras* which occur frequently in the beds below. It must be emphasized that no facies change is associated with the mass appearance of LAMARCK's species (*see* Text-fig. 5 and description of the section) thus excluding thus any facies controlled phenomena. ATABEKIAN (1985, Pl. 30, Figs 6-9) illustrates from that unit the forms referred by him to as *Turrilites* (*T.*) *acutus* PASSY. These forms seem, however, to represent the juvenile stages of the species *Turrilites costatus* LAMARCK (*cf.* MARCINOWSKI 1980, p. 259; Pl. 4, Figs 1-10). The overlying bed, *i.e.* the Phosphatic Horizon *IVb* already represents the A. jukesbrownei Zone. This suggests the lack here of the Turrilites acutus Subzone. This is similar in other Mangyshlak sections studied. Moreover, in some sections the A. jukesbrownei Zone contains the redeposited representatives of the species *T. costatus* LAMARCK (*e.g.* Azhirektoy and Besakty sections) whereas none of the forms characteristic of the T. acutus Subzone were found. It seems thus very probable that the regional stratigraphic gap, comprising the T. acutus Subzone which occurs in Mangyshlak, should be associated with the regressive mid-Cenomanian Event (*cf.* HART & TARLING 1974, ERNST & *al.* 1983).

Acanthoceras jukesbrownei Zone

The Phosphatic Horizon *IVb* from the Sulu-Kapy section contains, besides the index taxon, the representatives of the species *Turrilites scheuchzerianus* BOSC and *Karamaites* sp. (large forms). ATABEKIAN (1985, p. 12) reports, moreover, the species *Alternacanthoceras* cf. *nicensis* (THOMEL) which, however, seems to represent the juvenile stages of *Calycoceras* (*Newboldiceras*) [*cf.* WRIGHT & KENNEDY 1990, p. 292].

The overlying sandstones already belong to the Lower Turonian. In the Sulu-Kapy section the Upper Cenomanian fauna was not found; its presence however, based on the occurrence of the belemnite species *Actinocamax plenus* (BLAINVILLE) in the neighboring sections (Kush, Shyrkala-Airkaty, Koksyrtau-Aksyrtau), cannot be excluded.

UPPER CENOMANIAN

Actinocamax plenus Zone

This zone is well developed only in the Koksyrtau-Aksyrtau section where it is represented by Beds *24* and *25*. In two other sections, *i.e.* Kush and Sharkala-Airkaty, the index taxon was found within the Phosphatic Horizon *IVb* together with Middle Cenomanian ammonites, indicating that condensation spanned at least the Middle and the lower part of the Upper Cenomanian. In the Koksyrtau-Aksyrtau section, *Actinocamax plenus* (BLAINVILLE) appears distinctly higher, occurring in mass within Bed *24*. The species *A. plenus* (BLAINVILLE) is known exclusively from the Upper Cenomanian (*cf.* MARCINOWSKI 1972 and references therein; CHRISTENSEN 1974, WRIGHT & KENNEDY 1981), and its mass occurrence is dated as the middle part of the Upper Cenomanian, within the Metoicoceras geslinianum Zone (*see* ERNST & *al.* 1983). The upper boundary of the zone is marked by the appearance of the species *Neocardioceras juddii* (BARROIS & GUERNE), which is noted in Bed *26* of the Koksyrtau-Aksyrtau section.

Neocardioceras juddii Zone

The lower boundary of the zone is marked by the appearance of the forms *Neocardioceras juddii juddii* (BARROIS & GUERNE) and *N. juddii* cf. *barroisi* WRIGHT & KENNEDY, which are noted extremely rarely in Bed *26* of the Koksyrtau-Aksyrtau section. The upper boundary of the zone is placed at the appearance level of the ammonite species *Watinoceras amudariense* (ARKHANGELSKY).

TURONIAN

The Turonian stage is here divided mainly on the inoceramid fauna even though ammonites are still relatively common. Similarly, however, as in Central and Eastern Europe the inoceramids allow a more refined zonation to be compiled and, moreover, to be uniformly applied throughout the whole stage. The ammonites are confined almost exclusively to the phosphatic beds, and are thus limited to the very condensed horizons. The inoceramid fauna is well represented also within the uncondensed intervals.

LOWER TURONIAN

The lower boundary of the Turonian Stage is placed at the appearance level of the inoceramid species *Mytiloides hattini* ELDER and the first representatives of *Watinoceras amudariense* (ARKHANGELSKY). This level seems to approximate closely the appearance level of the ammonite marker of this boundary, *Watinoceras devonense*, as accepted during the II*nd* Symposium on the Cretaceous Stage Boundaries in Brussel, September, 1995 (*see also* KENNEDY & COBBAN 1991, KENNEDY & *al.* 1993, HARRIES & KAUFFMAN 1996). In the studied sections the Cenomanian/Turonian boundary interval with a relatively complete faunal record is present only in the Koksyrtau-Aksyrtau section (*see* Text-fig. 9), while in the others the corresponding stratigraphic gap spans the boundary interval between Cenomanian and Turonian stages (*see* Text-figs 14-15).

The Lower Turonian inoceramid zonation here applied comprises the three inoceramid zones, *i.e.* the M. hattini Zone, the M. kossmati Zone, and the M. labiatus Zone. The latter is used as defined by WALASZCZYK (1992), *i.e.* with the wide interpretation of the species *M. labiatus* (SCHLOTHEIM), and with *M. mytiloides* (MANTELL) as a synonym. While the interpretation of the species is still a matter of debate, the forms referred to as *M. labiatus* (SCHLOTHEIM) and to *M. mytiloides* (MANTELL) seem to co-occur in Mangyshlak. The only specimen of the ammonite species *Mammites nodosoides* (SCHLÜTER) was found in the middle part of the Mytiloides labiatus Zone in the Shyrkala-Airakty section (Bed *22A* – *see* Text-fig. 6 and Pl. 5, Fig. 4).

MIDDLE TURONIAN

The Lower/Middle Turonian boundary is marked by the appearance of the inoceramid species *Mytiloides hercynicus* (PETRASCHECK) which coincides with the appearance of *Collignoniceras woollgari* (MANTELL) in the ammonite division (*e.g.* KENNEDY 1984, 1985; KENNEDY & *al.* 1989; COBBAN 1984). The Middle Turonian is rather poorly represented in the studied sections and is only known from the condensed, phosphatic beds of the Azhirektoy section, where *Collignoniceras woollgari* was found in the Phosphatic Horizon *V*, together with Upper Turonian forms (*see* Text-fig. 11), and in the more complete Besakty sections (*see* Text-fig. 12). In the latter section representatives of the species *C. woollgari* (MANTELL) and *C. carolinum* (D'ORBIGNY) were found in the Phosphatic Horizon *IVb+Va*, occurring together with Middle and Upper Cenomanian ammonites, and within the Phosphatic Horizon *Vb*, together with Upper Turonian – Coniacian forms. Thus, the sandy unit inbetween (Bed *41*) must also be referred to the Middle Turonian. In other sections the massive sandstone unit of the Lower Turonian M. labiatus Zone is directly overlain by the Phosphatic Horizon *V*, already dated as Late Turonian.

The topmost parts of the Lower Turonian sandstones were dated directly with inoceramids only in two sections, *i.e.* in Sulu-Kapy and Koksyrtau-Aksyrtau, thus the possibility that this unit range into the lowermost Middle Turonian cannot be excluded. In general, however, besides the Besakty section the rest of the area is characterized by a stratigraphic gap comprising the whole Middle Turonian.

UPPER TURONIAN

The base of the Upper Turonian in the inoceramid standard division is placed at the first occurrence of *Inoceramus costellatus* WOODS, which is assumed to correspond to the appearance level of the ammonite marker of this boundary, i.e. *Subprionocyclus neptuni* (GEINITZ). Ammonites are relatively common in the Upper Turonian of Mangyshlak, however, they are almost completely confined to the basal phosphatic bed (Phosphatic Horizon *V*), and thus the inoceramids permit, similar as in Central Europe, a much better possibility for zonal subdivision of the substage. Two zones were distinguished herein, *i.e.* the Inoceramus costellatus Zone below and the M. incertus Zone above (*see* Text-fig. 13). The M. incertus Zone seems to be nearly the equivalent of the M. scupini Zone. The latter is a new name for the Inoceramus aff. frechi Zone of ERNST & *al.* (1983) and WOOD & *al.* (1984), because the form referred to as *I.* aff. *frechi* has recently been shown to actually represent the species *Mytiloides scupini* (HEINZ) (*see* discussion *in* WALASZCZYK & TRÖGER 1996).

CONIACIAN

Similar as in the case of the Turonian, the Coniacian stage is subdivided based on the inoceramid fauna. Ammonites are noted sporadically. Single specimens were found in the condensed bed *42* in the Besakty section. Here the representatives of the species *Scalarites turoniense* (SCHLÜTER) and of the genus *Neocrioceras* (*Schlueterella*) indicate the presence of the Lower and Middle Coniacian. The latter section also yields belemnites, which, besides the *A. plenus* Event, are really rare elements of the Mangyshlak mid-Cretaceous. Among the forms found in the Phosphatic Horizon *Vb*, the species *Actinocamax strehlensis* (FRITSCH & SCHLÖNBACH), "*A.*" cf. *lundgreni* STOLLEY, *Gonioteuthis westfalica praewestfalica* ERNST & SCHULZ, *G. westfalica ?praewestfalica* ERNST & SCHULZ [transitional form to *G. westfalica westfalica* (SCHLÜTER)] are indicative of the Coniacian stage.

The present substage division follows the inoceramid-based division as summarized by TRÖGER (1989; *see also* TRÖGER 1981, ERNST & *al.* 1983), which was generally accepted during the II*nd* Cretaceous Stage Boundary Symposium in Brussel, September 1995. The ammonite-based substage division of KENNEDY (1984, followed *e.g.* by WALASZCZYK 1992), due to a rather scant ammonite documentation within the Coniacian stratotype, does not allow for a precise correlation and it was not even considered during that Symposium.

LOWER CONIACIAN

The Turonian/Coniacian boundary is placed at the appearance level of the species *Cremnoceramus rotundatus* (*sensu* TRÖGER *non* FIEGE), This was the boundary definition agreed on during the Brussel Symposium, September 1995. This level is assumed to coincide with the appearance of the traditional ammonite marker of the boundary, that is

Forresteria petrocoriensis, but the real coincidence still has to be proved (*see* KAPLAN & KENNEDY 1993, and references therein).

In the proposed stratotype of the boundary, *i.e.* Saltzgitter-Salder section in Lower Saxony, Germany, this boundary is placed within the *Didymotis* II Event of ERNST & *al.* (1983), and WOOD & *al.* (1984). However, the inevitable representatives of the index taxon are found there only in the succeding *C. waltersdorfensis waltersdorfensis* Event. In the Vistula section in Central Poland, the first representatives of the species *C. rotundatus* (*sensu* TRÖGER *non* FIEGE) were found about 70 cm above the *C. waltersdorfensis* Event, being an equivalent of the *Didymotis* II Event of WOOD & *al.* (1984). It is possible that in this very boundary interval the proposed stratotype section is slightly condensed.

WALASZCZYK (1992) placed the Turonian/Coniacian boundary at the base of the Cremnoceramus waltersdorfensis Zone, placing the first appearance of this species at the *C. waltersdorfensis* Event, thus coinciding with the *Didymotis* Event II of ERNST & *al* (1983). Resentatives of the species *Cremnoceramus waltersdorfensis* (ANDERT) were shown, however, to appear markedly earlier, namely in the level of the *Didymotis* Event I of ERNST & *al.* (1983) [Prof. K.-A. TRÖGER, *personal communication*], and thus the appearance level of the species is inevitably within the range of typically Turonian ammonites.

The index taxon of the C. rotundatus Zone follows the interpretation of TRÖGER (1967), being referred here to as *C. rotundatus* (*sensu* TRÖGER *non* FIEGE), and it is different from *Cremnoceramus rotundatus* (FIEGE). The latter species is very close to *C. rotundatus* (*sensu* TRÖGER *non* FIEGE) but differs in surface ornamentation and, moreover, seems to occur stratigraphically higher, precisely in the upper Lower Coniacian C. crassus–C. deformis Zone. This form also seems to be similar to "*Inoceramus*" *stillei* HEINZ, and it is probable that both forms are synonymous, but the type of the latter cannot be found. WALASZCZYK (1992) included the species *C. rotundatus* (*sensu* TRÖGER *non* FIEGE) into the synonymy of *Cremnoceramus brongniarti* (MANTELL). Studies of other collections of the Early Coniacian cremnoceramids allow, however, to retain the former species separate (*see* WALASZCZYK 1996). Thus, the lower Lower Coniacian inoceramid zonation comprises two zones, *i.e.* the Cremnoceramus rotundatus Zone and the C. brongniarti Zone, both corresponding to the C. brongniarti Zone of WALASZCZYK (1992).

The inoceramid variability, succession, as well as the levels of their acme occurrences at the studied sections display exactly the same pattern as in Central Europe. It is clearly the best within the most westerly sections, *i.e.* Shakh-Bogota and Sulu-Kapy, where the complete Turonian/Coniacian boundary succession is present. East of the Sulu-Kapy section the boundary interval is usually absent with the stratigraphic gap spanning the topmost Turonian and the lowermost Coniacian (most probably the M. incertus Zone up to the C. rotundatus Zone).

The succeeding Cremnoceramus crassus–C. deformis Zone (representing the Middle Coniacian in the division of KENNEDY 1984) was earlier (WALASZCZYK 1992) divided into two separate zones, *i.e.* the C. deformis Zone below and the C. crassus Zone above. The vertical distribution of both species is, however, not clear and most probably they both appear simultaneously. The zone is well represented in almost all westerly and centrally located sections. In the easternmost sections, Azhirektoy and Besakty, this interval falls within the condensed level of the Bed *42* that is documented faunistically only in the Besakty section.

MIDDLE – UPPER CONIACIAN

Of the two succeeding Coniacian zones only the lower one, *i.e.* the Volviceramus involutus Zone, was faunistically documented, and it is relatively well represented in Shakh-Bogota and Koksyrtau-Aksyrtau sections, and possibly within the sections inbetween. The lower part of the zone was also documented within the condensed Bed *42* of the Besakty section, where the species *Volviceramus involutus* was found. The upper zone, *i.e.* the Magadiceramus subquadratus Zone was not reported. Its presence is assumed at least in the Shakh-Bogota section where above the level with volviceramids there occurs a carbonate unit with apparently continuous sedimentation, and with such lowermost Santonian inoceramids as *Cladoceramus undulatoplicatus* (ROEMER) and *Sphenoceramus pachti* (ARKHANGELSKY) at its top. The species *Magadiceramus subquadratus* (SCHLÜTER) is rarely reported east of Central Europe. It is well represented in the Western Ukraine (KOTSYUBINSKY 1968), and also reported from Kopet-Dag (ATABEKIAN 1961). The forms referred to this species by KHALAFOVA (1968) from the Minor Caucasus represent the species *Cremnoceramus rotundatus* (*sensu* TRÖGER *non* FIEGE).

SANTONIAN

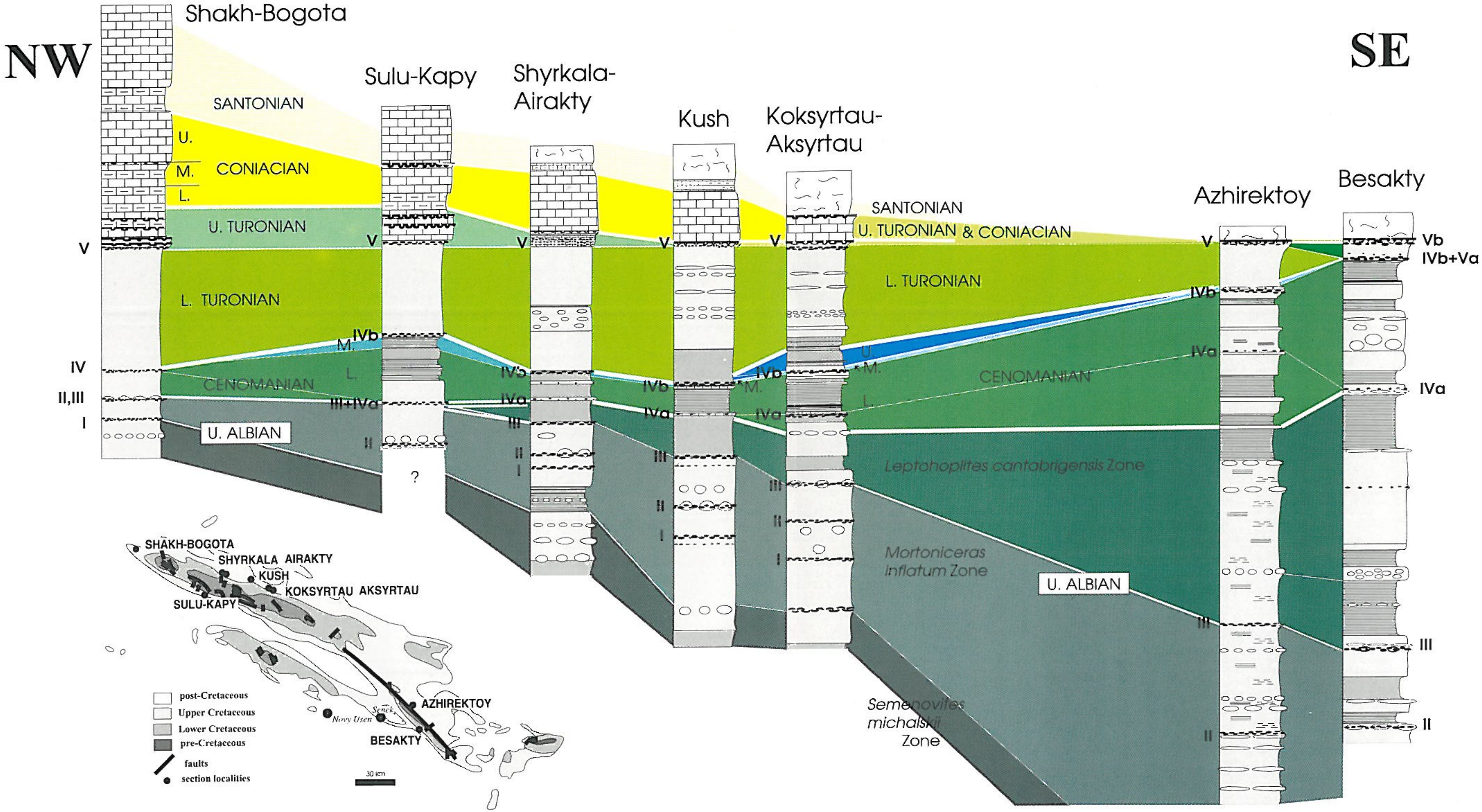
The lower boundary of the Santonian Stage is placed at the appearance level of the representatives of the species group *Sphenoceramus pachti* (ARKHANGELSKY) – *S. cardissoides* (GOLDFUSS) and/or *Cladoceramus undulatoplicatus* (ROEMER). In the studied area these forms were found only in the Sahkh-Bogota section. In other sections no macrofaunal elements indicating the basal part of the stage were noted, the

Coniacian/Santonian boundary having been often associated with a distinct discontinuity surface, and an assumed stratigraphic gap.

BASIN EVOLUTION AND FACIES DEVELOPMENT

It was already during the Jurassic when the sea transgressed onto the territory of Mangyshlak and lasted therein throughout the whole Cretaceous. During the Early Cretaceous the shallow sea was characterized by terrigenous clastic sedimentation. The mid-Cretaceous (Albian – Turonian) marks the acceleration of the Cretaceous transgression with the accompanying facies change, from terrigenous clastics to carbonates dominating over the area through the rest of the Cretaceous and persisting well into the lowermost Paleogene. This facies change is inevitably the most spectacular feature of the studied succession (*see* Text-fig. 14). The rapidity of this change is certainly exaggerated in the stratigraphic record, due to the associated very reduced or simply cessation of sedimentation, well expresed in the studied sections through the phosphatic horizon (number *V* in the present paper) and the accompanying hardground allover the area (*see* Text-figs 3, 5-6, 8-9, 14; and Pls 1-5). Apart from the Besakty section, the whole Middle Turonian is lacking in the most south-easternmost part of the area (*see* Text-figs 14-15). This is probably due partly to the primary omission, and partly to the erosion expressed by the formation of the phosphatic bed. The character of the evolutionary course, as well as the succession of the phenomena involved in this main facies turnover in the studied area (*see* Text-fig. 14) seem to correspond well to the general evolution of the Late Cretaceous sea, at least in the Euramerican region. The Middle Turonian transgressive peak (*see* HANCOCK 1989) caused shifting away of the source areas, wide cessation of the terrigenic infux, and corresponding condensation and/or gaps in the stratigraphic record. The sedimentation was limited to the marginal parts of the basins, being closer to the source areas. Such an area could be represented by the region of Besakty, the only section with a Middle Turonian record (*see* Text-fig. 14). These also allowed the appropriate conditions for the phosphatization processes to operate. The following fall of sea level, corresponding to the regressive trough of the Middle/Late Turonian boundary (HANCOCK 1975, 1989; HANCOCK & KAUFFMAN 1979; ERNST & *al.* 1983) led to erosion and to the formation of the horizon of nodular phosphates.

The regressive episode was either very short or it did not reach the level from the beginning of the Middle Turonian sea-level rise, as the terrigenous sedimentation did not return to the area, and carbonates started to dominate. The new rise of sea level, following the earliest Late Turonian



Stratigraphic correlation of the Upper Albian through Santonian deposits of Mangyshlak trough is well recorded in the basal part of the carbonate succession. It is characterized by a single, composite discontinuity surface (mostly hardground horizons), or a set of successive discontinuities clearly marking a very slow sedimentation rate, most probably with rather shallow-water conditions. At the central and eastern part of the area similar conditions seem to have survived still within the Coniacian and up to the Coniacian/Santonian boundary. In the western part (Shakh-Bogota, Sulu-Kapy) somewhere in the mid-Late Turonian a more continuous sedimentation commenced and lasted late into the Coniacian. Any signs of shallowing are identifiable only at the Early/Middle Coniacian boundary. The whole area thus displays the symmetric pattern with, from one side, a more deeper environment situated more to NW and, on the other hand, with the transgressive-regressive pulse spanning the Late Turonian – Late Coniacian interval with the maximum of the transgression positioned at latest Turonian – Early Coniacian time (*see* Text-fig. 15).

The Middle/Late Turonian boundary facies change is also accompanied by a regional shift of the depocenter. The zone of the maximum rate of sedimentation, located during the Late Albian and Cenomanian in the SE part of the area, moves to its north-westernmost tips in the Middle Turonian (*see* Text-fig. 14). This close association of the facies change and thickness relationships can be interpreted as the result of the different stratal geometry in a case of the terrigenous and carbonate sedimentation. While in the case of the terrigenous sedimentation it is the lateral transport and the general dependence of the thickness on the distance to the source area, it is the basin productivity with its intensity dependant positively on the basin depth, dropping to zero in a very shallow basin, in the case of the carbonate sedimentation. The observed regional pattern would be thus controlled largely by the original basin geometry and eustatic changes. The effects of local tectonics would be rather small, though in places, the stratal geometry could have been profoundly influenced by the synsedimentary tectonics, as *e.g.* observed in the Shakh-Bogota section where over a distance of 2 km the thickness of the Lower Turonian sandstones (Bed *10* – *see* Text-fig. 3) nearly doubles. Throughout the Late Albian – Coniacian the basin architecture could thus remain the same with the more deeper, or at least the more distal part situated more to the NW.

The presented scheme assumes that the area lying to the east or to ENE of the studied region was the source area, which is probable, but it is difficult to document now, as the data on the Cretaceous of the neighboring areas are insufficient to produce any reliable paleogeographic synthesis for the time interval discussed. Thus other interpretations, *e.g.* with the involved regional tectonic rearrangement of the area at the Middle Turonian, may appear equally possible.

The lower (Upper Albian – Middle Turonian) terrigenous part of the studied succession is sandwiched by a series of phosphatic horizons (numbered *I* to *V* – *see* Text-figs 14 and 15). The number of the horizons may vary from 4 to 6 between particular sections, though their actual number could primarily have been identical. The differences resulted from the secondary fusion of single horizons due to subsequent erosion of the intervening deposits accompanying the formation of the following phosphatic bed.

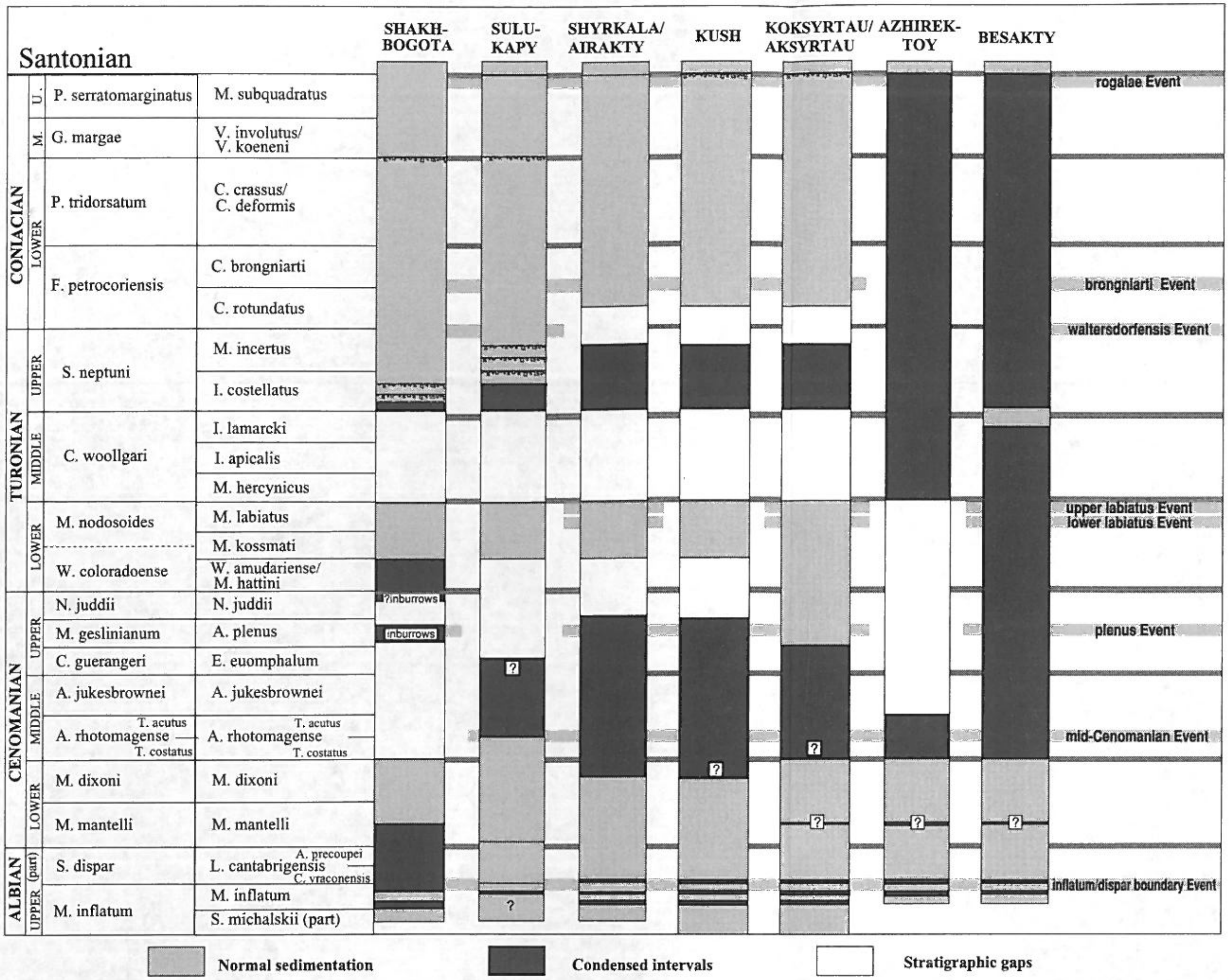
All phosphates are invariably nodular phosphates. The phosphatization process is assumed to operate during the intervals of relative rise of sea level (*see also* HANCOCK 1989) due to outward shifting of the source area and commencement of a period with non depositional conditions. The erosion of the phosphatized substrate and formation of the phosphatic bed correspond to the following regression and shallowing of the sea.

Dating of the particular periods of phosphatization and the following formation of the phosphatic horizons is difficult, as the associated erosion and condensation usually markedly widens the recorded stratigraphic extent in relation to the actual time of their origin. Moreover, the phosphatic beds are, together with early diagenetic sandstone concretions, the only diagenetic "traps" for fossils as in loose sands or poorly cemented sandstones fossils are preserved only sporadically.

Within the carbonate, Upper Turonian – Coniacian, succession the sea-level changes may be interpreted with a help of the distribution of the discontinuity surfaces (mainly hardgrounds), as it was presented by HANCOCK (1989). The hardgrounds would thus mark the shallowing periods, while the more complete sequences are limited to the more deeper environment.

The transgressive-regressive course of the mid-Cretaceous sea in the area, as based on the presented interpretation of the phosphatic beds and hardground horizons, displays a very similar patttern to the one based on the successions of Central and Western Europe and the Western Interior of the United States, as well as to the global one (*see* HANCOCK 1975, 1989; HANCOCK & KAUFFMAN 1979; ERNST & *al.* 1983; HAQ & *al.* 1988; TRÖGER & VOIGT 1995). The interval of the Cenomanian/Turonian boundary cannot be explained satisfactorily due to the very poor record of this interval. We can thus not offer any reliable interpretation.

The first well-dated regressive through is located at the boundary of the Mortoniceras inflatum and the Leptohoplites cantabrigensis zones (the level of the Phosphatic Horizon *III*). The preceeding period of sea level rise must have been somewhere at the end of the former zone. This regression with the following transgression at the beginning of the Stoliczkaia dispar Zone was noted also by HANCOCK (1989) and it coincides well with



Chronostratigraphic chart of the Upper Albian through Coniacian of Mangyshlak, with the position of the recognized events the discontinuity *1* of the Annopol section in Central Poland (WALASZCZYK 1987).

The following regressive course (marked by the Phosphatic Horizon *IVa*) is relatively well-dated in the Azhirektoy section for the lowermost part of the Cenomanian (*see* Text-figs 11 and 15). HANCOCK (1989) notes in this interval a marked transgressive pulse, and it similarly is the case with the data from northern Germany given by ERNST & *al.* (1983). The regressive event, the so-called *Schloenbachia/virgatus* Event, as interpreted by the latter authors, is markedly younger, being placed at the base of the Mantelliceras dixoni Zone.

The mid-Cenomanian regressive Event is well recorded, expressed by the Phosphatic Horizon *IVb* (*see* Text-fig. 15). This is a widespread phenomenon (*see* HART & TARLING 1974, MARCINOWSKI 1980, ERNST & *al.* 1983, HANCOCK 1989), following the dixoni/costatus transgressive period at the Early/Late Cenomanian boundary. In the Shakh-Bogota section the associated erosion reached down to embrace the Phosphatic Horizon *IVa* (*see* Text-figs 3 and 14).

The stratigraphic record following the Phosphatic Horizon *IVb* and underlying the Lower Turonian sandstones is very scant, corresponding most probably to the transgressive course and condensed or ceased sedimentation, but the record itself does not allow us to suggest any original interpretation.

The Lower Turonian sandstones, which form a relatively thick unit covering almost the whole area after the Late Cenomanian very reduced sedimentation, seem to clearly mark the regressive episode. In northern Germany this interval was suggested to be a trangressive pulse and the regression would follow later, within the Mytiloides hercynicus Zone. It is interesting that similar regressive trends within the Early Turonian Mammites nodosoides Zone are suggested by HANCOCK (1989) on data from England.

The Phosphatic Horizon *V*, usually overlying the Lower Turonian sandstones corresponds well to the widely documented regressive trough from the boundary interval of the Middle and Late Turonian (HANCOCK 1975, 1989; HANCOCK & KAUFFMAN 1979; ERNST & *al.* 1983; WALASZCZYK 1992). As the consequence of the preceding transgressive peak a regional stratigraphic gap spanning almost the whole Middle Turonian is assumed herein, with a definite record of the latter being limited to a single section (Besakty) at the marginal part of the region (*see* Text-figs 14-15).

The following transgression of the Late Turonian must have been relatively fast. The distribution of the hardground horizons indicates that already in the middle Late Turonian in the western part of the region the depth of the basin reached values where normal sedimentation could commence. At the eastern, and to a large extent also in the central part, the depth probably never exceeded any significant values, as the sections almost throughout the Upper Turonian and Coniacian are characterized by reduced rate of sedimentation (*see* Text-fig. 15). The next regressive event is here placed at the boundary level of the Early and Middle Coniacian (between C. crassus–C. deformis and V. involutus zones), where the hardgrounds start to appear again in the north-westernmost part of the region and are associated by phosphorites (*see* Text-fig. 15). This regression corresponds well to the Emscherian regression Event known from northern Germany (*see* ERNST & *al.* 1983).

The transgression/regression pattern of the mid-Cretaceous sea in the studied area displays, at least in the intervals with good stratigraphic record, a very similar course to that interpreted for other areas of Central and Western Europe as well as to the global eustatic curve of HAQ & *al.* (1988). Local tectonics had only a minor influence on the general architecture of the studied succession, though inevitably the synsedimentary activity of the particular blocks is well recorded and could have effected small-scale phenomena.

ECOLOGIC AND BIOGEOGRAPHIC SIGNIFICANCE OF THE FAUNAL CONTENT

Ammonites and **belemnites**

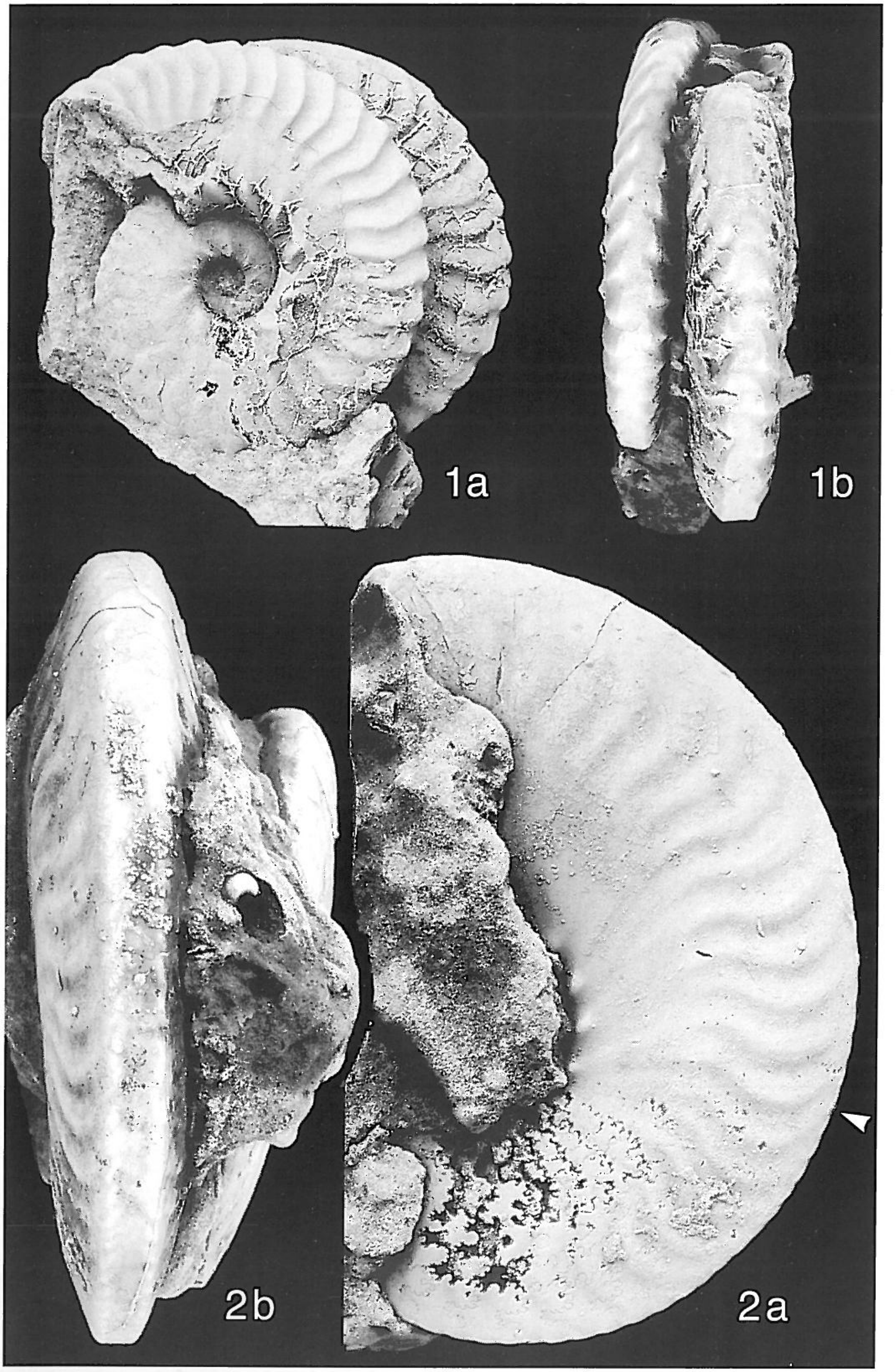
During the Late Albian through Coniacian the territory of Mangyshlak was a part of the European Zoogeographic Realm (NAIDIN 1959, 1969, 1981) or the North European Province (KAUFFMAN 1973, CHRISTENSEN 1990), the limits of which coincided during the Albian and Cenomanian with the Hoplitinid Faunal Province (OWEN 1971, 1976, 1979; MARCINOWSKI 1980, 1983; SAVELEEV 1981).

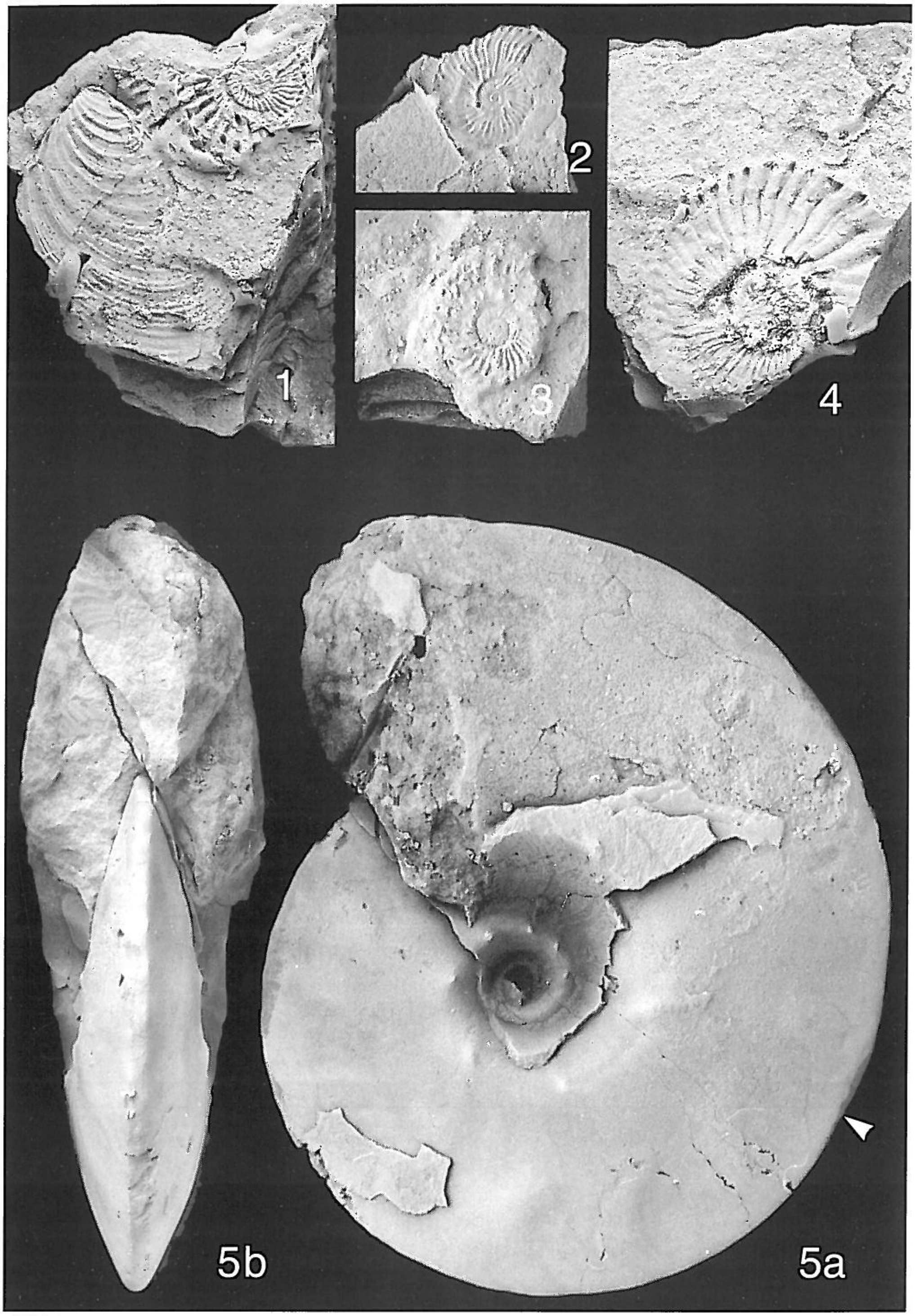
PLATE 11

1 — *Anahoplites rossicus* (SINZOW); A. rossicus Zone; Koksyrtau-Aksyrtau section, Koksyrtau Hill, 40 m below Bed *A*

2 — *Semenovites mangyschlakensis* (SAVELEEV); S. michalskii Zone; Shyrkala-Airakty section, Mount Shyrkala, Bed *1B*; arrowed is the beginning of the body chamber

All figures in natural size

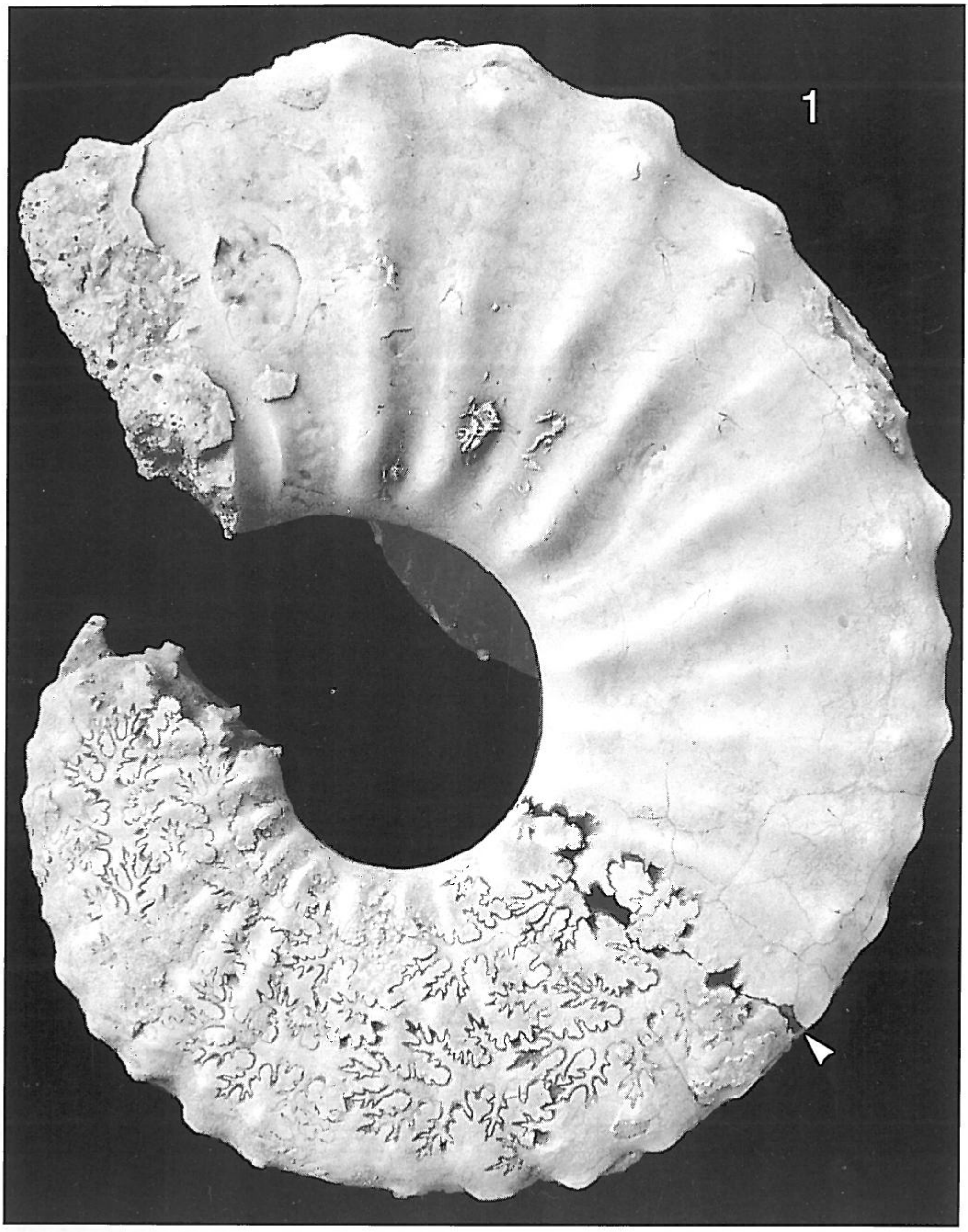

1a
1b
2b
2a



1-4 — *Watinoceras amudariense* (ARKHANGELSKY); W. amudariense/M. hattini Zone; Koksyrtau-Aksyrtau section, Aksyrtau Hill; all specimens from Bed *29*

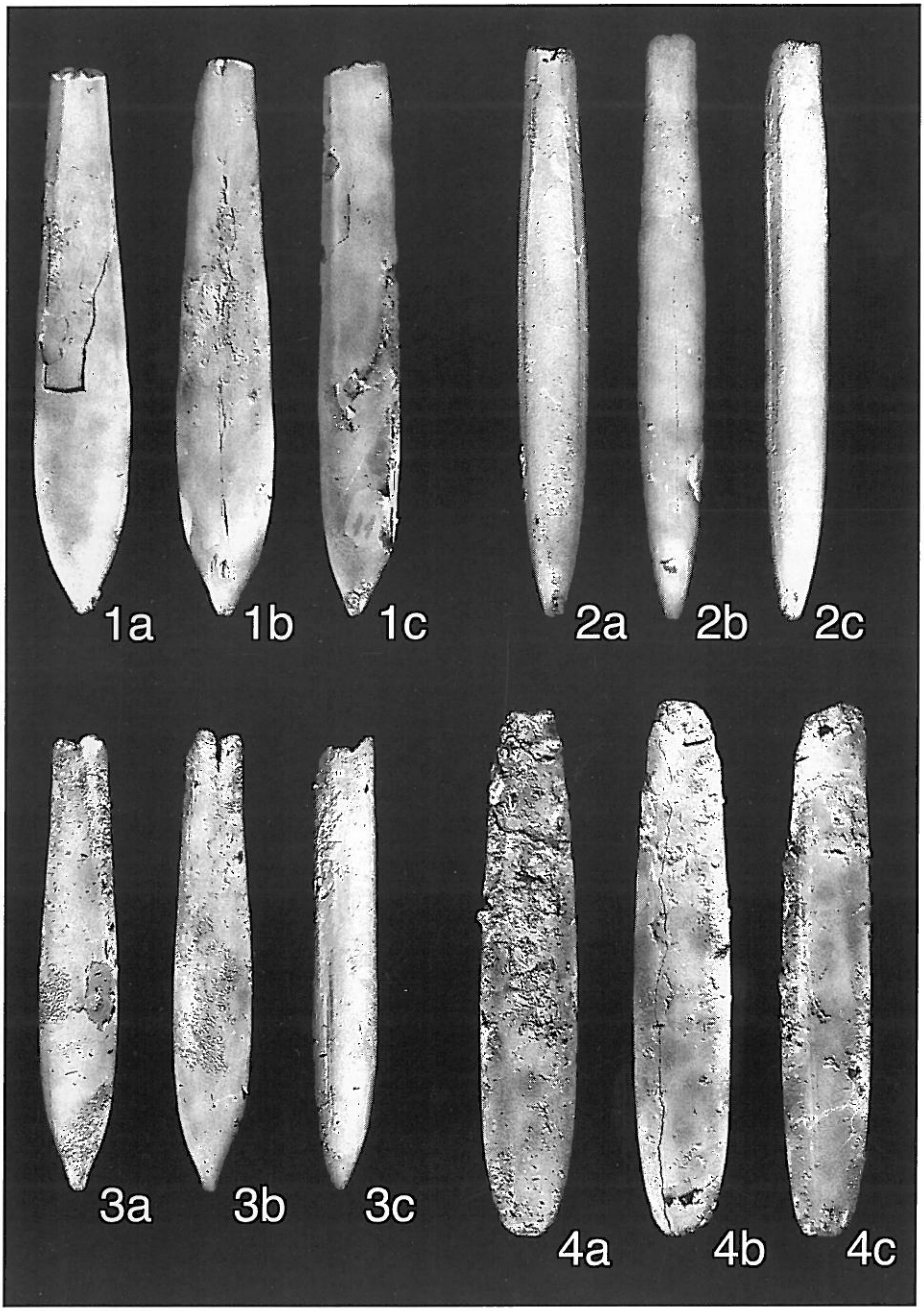
5 — *Karamaites mediasiaticum* (LUPPOV); M. mantelli Zone; Azhirektoy section, Bed *28*; arrowed is the beginning of the body chamber

All figures in natural size



1 — *Sharpeiceras laticlavium* (SHARPE); M. mantelli Zone; Besakty section, Bed *30*; arrowed is the beginning of the body chamber; nat. size

1 — *Schloenbachia varians* (J. SOWERBY); M. mantelli Zone; Besakty section, Bed *30*; arrowed is the beginning of the body chamber; nat. size



1-2 — *Actinocamax plenus* (BLAINVILLE); A. plenus Zone; Koksyrtau-Aksyrtau section, Koksyrtau Hill, Bed *24*; 1 – Senile specimen, 2 – adult specimen

3 — *Actinocamax strehlensis* (FRITSCH & SCHLÖNBACH); Lower Coniacian; Besakty section, Bed *42A* (Phosphatic Horizon *Vb*); adult specimen

4 — *Actinocamax* cf. *lundgreni* STOLLEY; Upper? Coniacian; Besakty section, Bed *42B*; senile specimen

All figures in natural size; **a** – dorsal, **b** – ventral, **c** – lateral views

During the Late Albian the ammonite faunas of Mangyshlak gradually lost their former endemic character. The ammonite assemblage of the lowermost Upper Albian, the Semenovites michalskii Zone, is dominated by representatives of the endemic genus *Semenovites* GLAZUNOVA, 1960, characteristic of Central Asia, as well as by the less abundant endemic species of the genera *Anahoplites* HYATT, 1900, and *Callihoplites* SPATH, 1925 (*cf. also* SAVELEEV 1981). The species *Hamites incurvatus* BROWN, also known from the cristatum through orbignyi subzones of England (SPATH 1941) as well as from the Upper Albian of the high-tatric series of the Tatra Mts, southern Poland (MARCINOWSKI & WIEDMANN 1990) really represents an accessory element among the Mangyshlak ammonites. The species *Semenovites michalskii* (SEMENOV) and *S. pseudocoleonodus* (SEMENOV) are known in the identical stratigraphic position in England and northern France (OWEN 1984, p. 339) while the species *Semenovites baisunensis* (LUPPOV) and *S.* cf. *michalskii* (SEMENOV) were reported from the Upper Albian of Central Iran (AMEDRO & *al.* 1977). These data indicate clearly the biogeographic contacts of the indicated regions and the Boreal character of the ammonite fauna.

Following the Late Albian transgression (M. inflatum Zone) immigrants from the west, representing the familiy Brancoceratidae SPATH, 1933 (*cf.* MARCINOWSKI & WIEDMANN 1990) appear in the record, markedly lowering the endemic character of the ammonite faunas in Central Asia. In Mangyshlak, besides the forms of the genus *Semenovites* there appear representatives of the species *Mortoniceras inflatum* (SOWERBY) and *Hysteroceras* sp. These phenomena are well readable also further to SE in the Upper Albian of Kopet-Dag (*cf.* GLAZUNOVA 1953, LUPPOV & *al.* 1960).

An evolutionary descendant of the genus *Semenovites* GLAZUNOVA, namely the genus *Karamaites* SOKOLOV, 1961 (=*Karamaiceras* SOKOLOV, 1966; *see* MIRZOEV 1967) appears in the latest Albian (Stoliczkaia dispar Zone). It is a typical form of Central Asia and it represents the early evolutionary stages of the placenticeratids during the latest Albian – earliest Turonian (MARCINOWSKI 1980). In the Mangyshlak Albian it is represented by the species *Karamaites kolbajense* (SOKOLOV), a form also known from northern France (*see* ROBASZYNSKI 1984, Fig. 2), co-occurring with the pandemic hoplitids, such as *Leptohoplites cantabrigensis* SPATH, *L.* aff. *cantabrigensis* SPATH, *Callihoplites vraconensis* (PICTET & CAMPICHE), *C. tetragonus* (SEELEY), *C.* cf. *advena* SPATH, *Pleurohoplites renauxianus* (D'ORBIGNY), *Arrhaphoceras studeri* (PICTET & CAMPICHE), *A. substuderi* (D'ORBIGNY), *A.* cf. *precoupei* SPATH. Worth noting is a lack of the Albian representatives of the genus *Stoliczkaia* NEUMAYR, 1875, which occur in the neighboring areas of

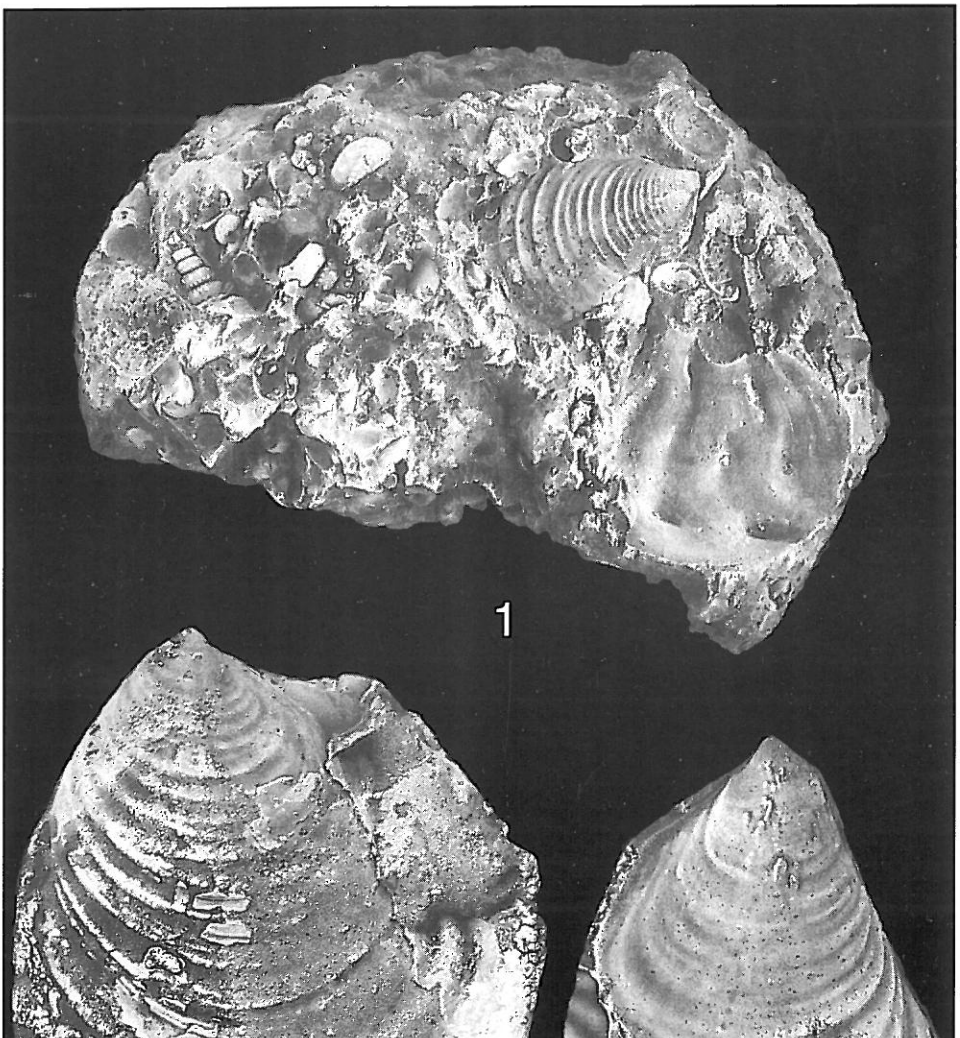
Tuarkyr, about 200 km to SE (*see* MARCINOWSKI 1983) as well as in western Kopet-Dag (ATABEKIAN 1960, 1992).

The Boreal affinity of the faunal assemblages of Mangyshlak is also retained during the Cenomanian. In the Early and Middle Cenomanian it is indicated by the hoplitids and schloenbachiids that dominate the ammonite assemblages (MARCINOWSKI 1980). In the Late Cenomanian it is marked by the belemnite species *Actinocamax plenus* (BLAINVILLE), the mass occurrence of which, as well as of other species of this genus delimits the southern boundary of the Boreal Province (*cf.* NAIDIN 1964, 1981; CHRISTENSEN 1990). This boundary within the Late Albian and during the Cenomanian was shifted even further to the south, ranging south of the present-day position of the Caucasus and Kopet-Dag. It supposedly reached the Zagros tectonic zone, which at present marks the northeastern limit of the Arabian Platform (MARCINOWSKI 1980).

The Turonian ammonite fauna is identical to that of Central and Western Europe leaving no doubt that it represents the same province, the North European Province. This is also the case in the Coniacian. Ammonites are noted here sporadicaly, but the reported belemnites of the genera *Actinocamax* MILLER, 1823, and *Gonioteuthis* BAYLE, 1879, are typical indices of the North European Province (*cf.* NAIDIN 1964, 1981; CHRISTENSEN 1990).

The Late Albian and Cenomanian ammonite assemblages of Mangyshlak are dominated by the massively ornamented hoplitids, placenticeratids, schloenbachiids, and acanthoceratids (group *A*), while the smooth or weakly ornate phylloceratids, lytoceratids, tetragonitids, gaudryceratids, and desmoceratids (group *C*) are completely absent, which indicates a nearshore environment (*cf.* TANABE & *al.* 1978, Fig. 10; MARCINOWSKI 1980). This is also suggested by the sedimentologic studies of analogous deposits in the neighboring area of Tuarkyr (*see* LIBROVICH 1960). In turn, the smooth and weakly ornate ammonites are noted together with Boreal forms in the more deeper, offshore environments of the northern Caucasus and Crimea (MARCINOWSKI 1980). Thus, the lack of these forms can be ascribed to some environmental conditions (bathymetry, facies) rather than to climatic ones, as the latter areas represented the Boreal regions. The environmental dependence is also indicated by the occurrence pattern of the heteromorph ammonites within the Cenomanian of the studied region. These, while being extremely rare in the sandy facies, occur frequently in clayey facies which inevitably originated in a quiet water basin, thus providing the optimum conditions for their development (*see* MARCINOWSKI & WIEDMANN 1990).

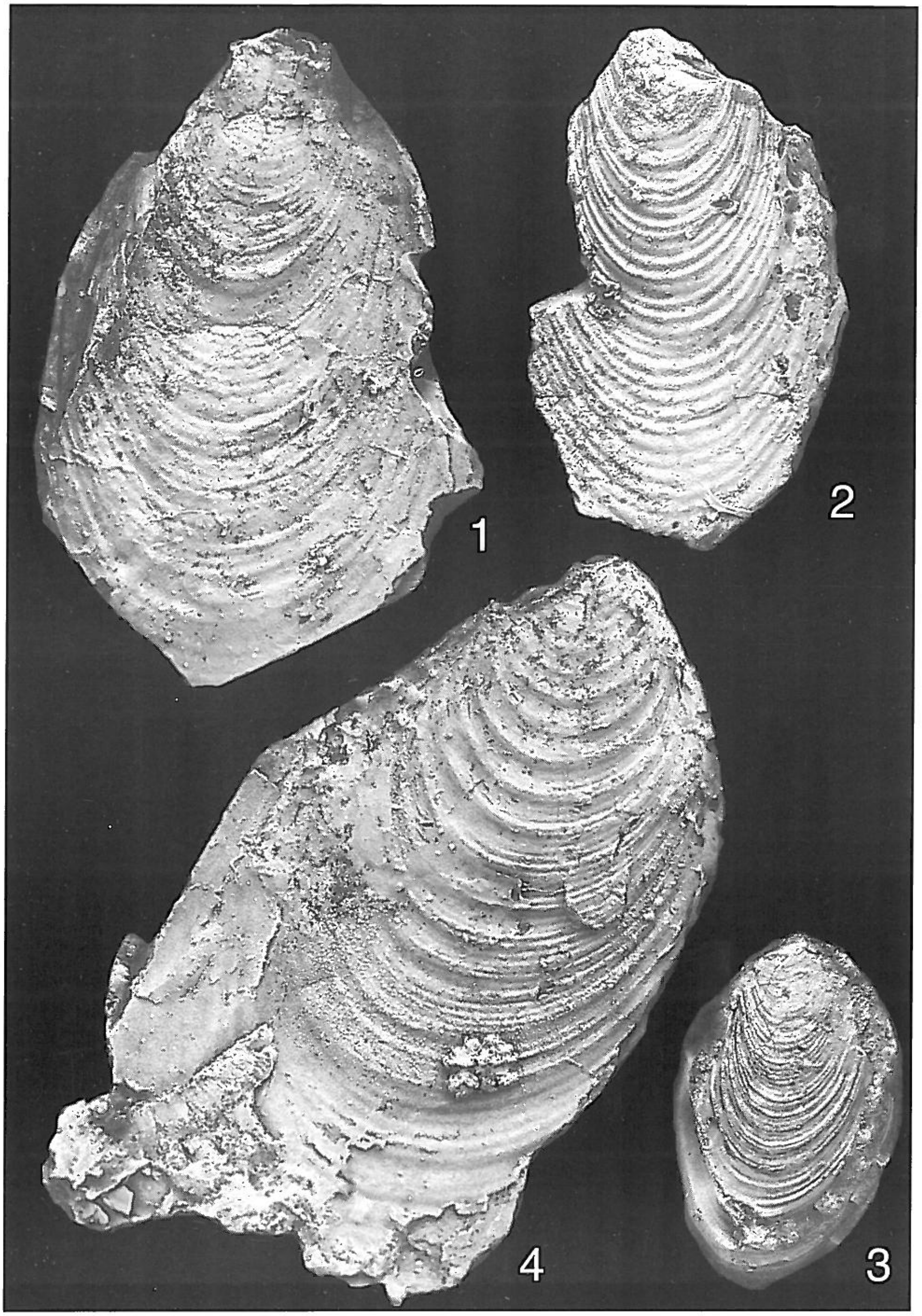
The massively ornamented forms are still noted within the Lower and Middle Turonian (*Watinoceras*, *Mammites* and *Collignoniceras*, respec-



1-2 — *Inoceramus crippsi* MANTELL; M. mantelli Zone; Besakty section; Fig. 1 – Specimen from limy sandstone concretion from Bed *25*, in which juvenile specimens of *Neostlingoceras carcitanense* (MATHERON) are also visible, Fig. 2 – specimen from Bed *30*

3 — *Inoceramus crippsi hoppenstedtensis* TRÖGER; M. mantelli Zone; Besakty section, Bed *30*

All figures in natural size



Inoceramid fauna of W. amudariense/M. hattini Zone in the Koksyrtau-Aksyrtau section of Aksyrtau Hill, Bed *29*

1 — ?*Inoceramus pictus* SOWERBY; **2-3** — *Mytiloides hattini* ELDER; **4** — *Mytiloides kossmati* (HEINZ)

All figures in natural size

tively). In the Late Turonian the massively ornamented collignoniceratids already represent the minority of the ammonite assemblages while these are dominated by the pachydiscids and heteromorphs indicating the nearshore to offshore environment of a moderate depth, the habitat characteristic of the groups *A* and *B* of TANABE & *al.* (1978, Fig. 10), or the lower neritic zone of the classic model of SCOTT (1940, p. 317, Fig. 8). The Late Turonian change of the ecomorphic characteristic of the ammonite assemblages reflects the relative deepening of the basin during the Late Turonian and with the associated facies change from terrigenous clastics during the Late Albian – Middle Turonian to carbonates starting in the Late Turonian and remaining here during the rest of the Late Cretaceous. This probably is also the reason for the lack of, in the discussed region, placenticeratids, which occur commonly within the Late Albian and Cenomanian, but favor more nearshore environments.

Inoceramids

The inoceramid bivalves, due to their relatively high dispersal potential, which makes them so useful in biostratigraphic divisions, are a rather secondary tool in biogeographic studies (KAUFFMAN 1973, 1977), at least on a scale of biogeographic provinces and short time intervals. These statements are well exemplified by the Late Albian – Coniacian inoceramid fauna from the Mangyshlak, being almost identical to that occurring in Central and Western Europe. In some parts, as in the case of the Turonian/Coniacian boundary interval, this similarity also embraces the very details of the range of variability (down to the subspecies level) as well as the vertical pattern of the specific frequency (including the acme horizons). This similarity was already underlain by TRÖGER (1978, 1981, 1989) who found only minor shifts in the specific frequency between Central and Eastern Europe, including the western tips of Asia. To these exceptional forms mentioned by TRÖGER, *i.e.* the species *Inoceramus wandereri* ANDERT, possessing much higher frequency in Eastern Europe, or the species "*Inoceramus*" *gradatus* EGOYAN, known exclusively from Eastern Europe, one may also add the very characteristic common occurrence of *Inoceramus inaequivalvis* SCHLÜTER within the Upper Turonian of Mangyshlak (though it is also well noted within the Upper Turonian of the northern Caucasus and Crimea). This form is naturally well known from Central and Western Europe, but there it never becomes the dominant element of the Later Turonian inoceramid assemblages, as it is a case in the studied area.

The inoceramid assemblages of Mangyshlak seem to be more similar to these from Central Europe as to those from the neighboring areas to the south (Kopet-Dag or the Minor Caucasus), though certainly the faunistic recognition of the latter areas is inadequate to allow for any final statement. The differences among inoceramid faunas between the North European Province and the Tethyan area, once assumed to be remarkable, actually do not seem to be so great. Particularly interesting are recent reports of sphenoceramids and volviceramids from Gosau in the Alps (TRÖGER & SUMMESBERGER 1994), groups generally believed to be absent in the Tethyan Realm. The latter were not found *e.g.* in northern Spain (LOPEZ & *al.* 1992) and they are also unknown from Tethyan Romania (Dr. SZASZ, *personal communication*). From Gosau, many forms common in the North European Province were reported also from the topmost Turonian – Middle Coniacian interval (KAUFFMAN *in* HERM & *al.* 1979).

Irregular echinoids

The irregular echinoids of the Turonian and Coniacian of Mangyshlak are dominated by representatives of the order Holasteroidea and Spatangoidea. Similarly it is the case with the very rarely reported Cenomanian forms. The former order is represented, first of all, by the genus *Echinocorys* (42% of the collected material) and much less frequent representatives of the genus *Sternotaxis* (5% of the material). The latter order comprises the most common representatives of the genus *Micraster* (51% of the material) and the sporadically noted genus *Hemiaster* (1% of the material). Representatives of the other genera, i.e. *Catopygus* and *Conulus*, appear very rarely (about 1% of the material). Such an assemblage forms a typical echinoid fauna of the Northern Realm and certainly of the North European Province, dominated by the genera *Echinocorys*, *Infulaster*, and *Micraster* (KÜCHLER & ERNST 1989). The genus *Infulaster* was noted from the Turonian of Mangyshlak by MOSKVIN & ENDELMAN (1972).

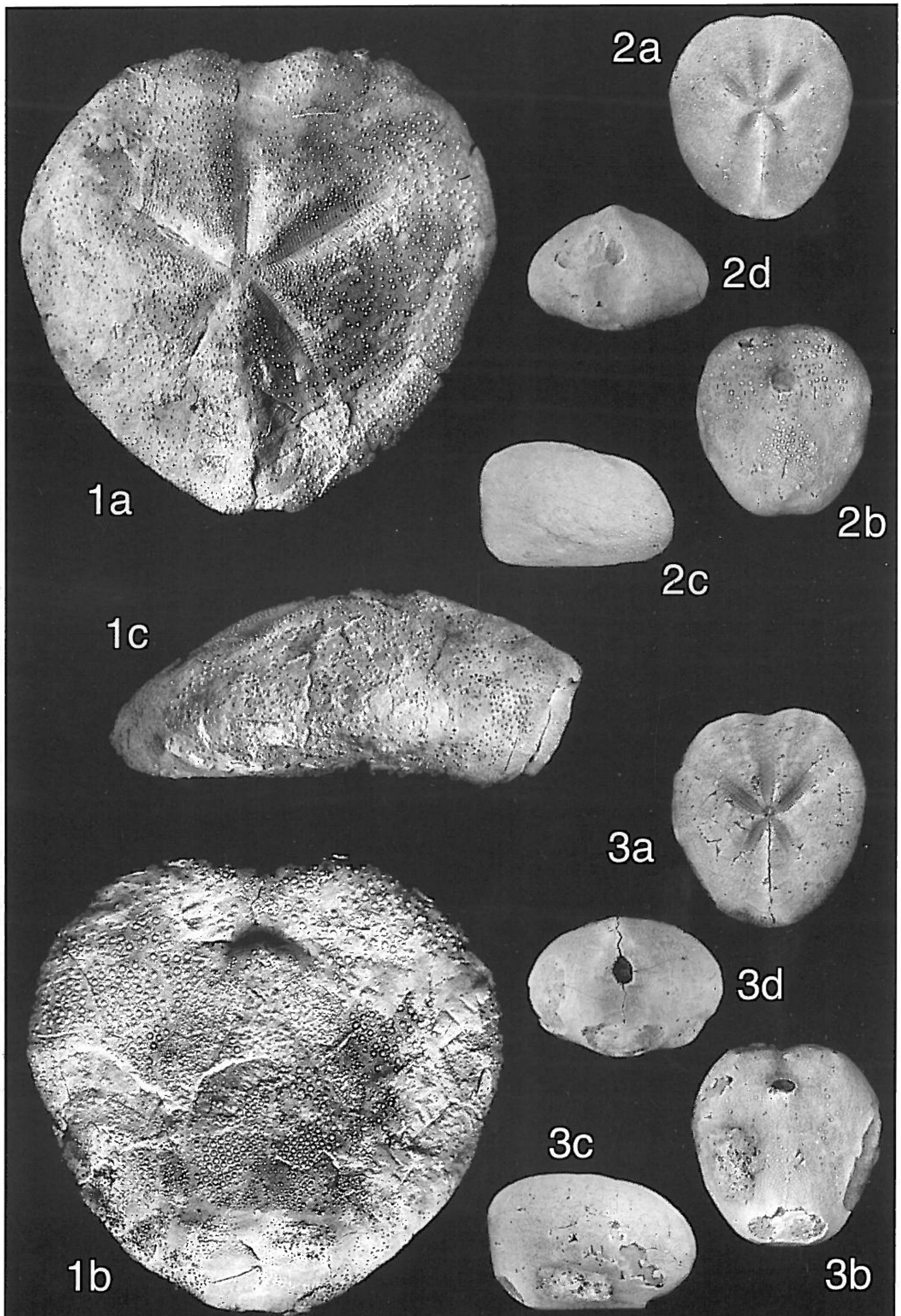
PLATE 18

1 — *Micraster rogalae* NOWAK; M. subquadratus Zone; Shakh-Bogota section, topmost part of Bed *15*

2 — *Micraster leskei* (DES MOULINS); I. costellatus Zone; Shakh-Bogota section, Bed *12*

3 — *Micraster leskei* (DES MOULINS); Upper Turonian; Besakty section, Bed *42A* (Phosphatic Horizon *Vb*)

All figures in natural size; **a** – aboral, **b** – adoral, **c** – lateral, **d** – posterior views


2a
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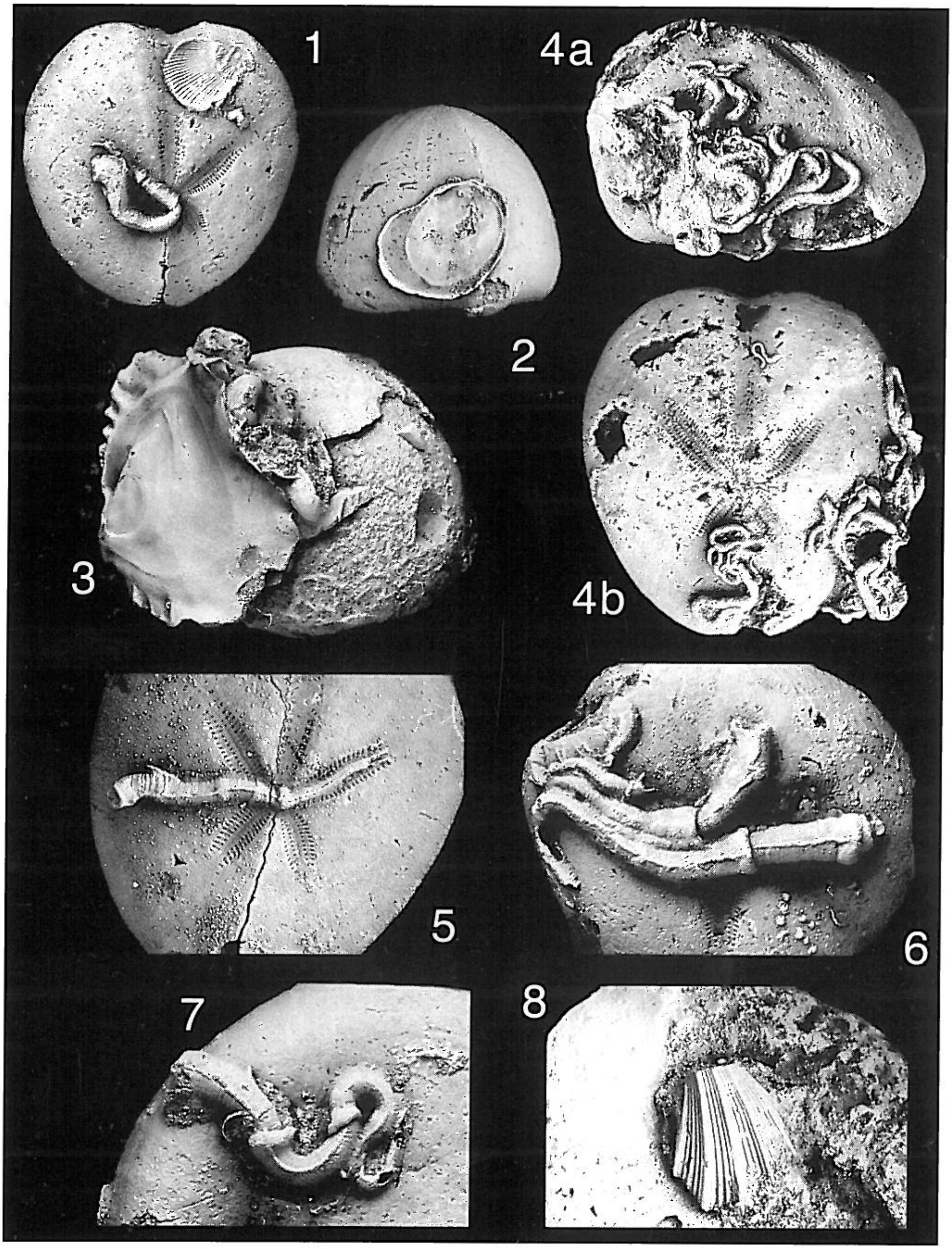

Associates of the echinoid tests; Besakty section, Bed *42A*
(Phosphatic Horizon *Vb*)

1 — *Proliserpula tumida* REGENHARDT and *Spondylus* sp. on the aboral side of *Micraster* sp.; nat. size

2 — *Pycnodonte* sp. on the postero-lateral side of *Echinocorys* ex gr. *scutata* LESKE; nat. size

3 — *Hyotissa semiplana* (SOWERBY) on the postero-lateral side of *Echinocorys* ex gr. *scutata* LESKE; nat. size

4 — *Cycloserpula gordialis* (SCHLOTHEIM) on *Micraster cortestudinarium* (GOLDFUSS); nat. size; 4a – view from lateral side, 4b – view from aboral side

5-6 — *Proliserpula tumida* REGENHARDT on the aboral side of *Micraster* sp.; both figures × 1.5

7 — *Proliserpula tumida* REGENHARDT on the adoral side of *Echinocorys* ex gr. *scutata* LESKE; × 2

8 — Non-epibiontic *Neithea* sp. on the lateral side of *Echinocorys* ex gr. *scutata* LESKE; × 2

The genus *Conulus* also represents a very common element of the North European Province, however, its distribution is strongly facially controlled, being limited to the areas of carbonate sands.

The most characteristic elements of the studied echinoid fauna are inevitably the representatives of the genus *Micraster*. They correspond well to the temporally equivalent fauna from Western Europe. KÜCHLER & ERNST (1989) mention the morphological plasticity of the genus with the development of many local forms, but they also underline the similaritiy and isochronity of the general philogenetic trends of the group within the Turonian and Coniacian of Western Europe (*see* FOURAY 1981, DRUMMOND 1983, DRUMMOND & FOUREY 1983). The same evolutionary trends may also be found within the *Micraster* fauna of Mangyshlak (OLSZEWSKA-NEJBERT 1996). Sometimes, however, very peculiar shifts are noted. For instance, with the species *Micraster rogalae* NOWAK, which appears in Mangyshlak at the latest Coniacian, marking a very distinct level of its acme occurrence (=*M. rogalae* Event). In Western Europe the species is noted, however, only from the upper part of the Lower Santonian and its acme is still higher within the Middle Santonian (ERNST 1966, ERNST & SCHULTZ 1974). These data as well as the occurrence in Mangyshlak of the species *Micraster praerogalae*, that is a transitional form between *M. rogalae* and *Micraster cortestudinarium*, indicate that the species *M. rogalae* NOWAK appeared markedly earlier in the eastern part and then migrated towards the west within the North European Province (*see* OLSZEWSKA-NEJBERT 1996).

The relatively rapid and somewhat explosive appearance character of the holasteroids and spatangoids in the Late Turonian of Mangyshlak was caused by the facies change from the generally terrigenous clastic in the Albian – Middle Turonian into carbonate from the Upper Turonian onward (*see* Text-figs 14-15). The fine-grained carbonates provided the required substrate conditions for such genera as *Echinocorys*, *Sternotaxis*, and *Micraster* (ERNST & SEIBERTZ 1977).

Acknowledgements

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