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The Cretaceous history of the Bakhchisaray area, southern Crimea (Ukraine)

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Abstract

During the Cretaceous, the mountainous southern part of the Crimean Peninsula occupied a position which was transitional between the Boreal and Tethyan realms, best described as peri-Tethyan. The geodynamic evolution of this terrane was related to rifting, to the opening of the Black Sea Basin, as well as to tectonic processes in the Pontides. The Cretaceous history of the Bakhchisaray area can be subdivided into three stages, namely Valanginian-Aptian, early-middle Albian and late Albian-Maastrichtian. Stages are separated by intervals of regression, emergence or rifting.

Keywords: Chronostratigraphy, tectonostratigraphy, Cretaceous, mountainous Crimea, Ukraine.

Résumé

Pendant le Crétacé, la partie montagneuse de la Crimée du Sud se situe dans le Péritéthys, en étant une zone de transition entre les provinces boréale et téthyale. L'évolution géodynamique du terrain criméen a été façonnée par le rifting, par l'ouverture du bassin de la Mer Noire et par les processes tectoniques dans les Pontides. L'histoire du Crétacé du district de Bakhchisarai de la Crimée peut être subdivisée en trois étapes suivantes: Valanginien-Aptien, Albien inférieur-moyen et Albien supérieur-Maastrichtien, les étapes étant séparées les unes des autres par des intervaux de régression, émersion et rifting.

Mots-clefs: Chronostratigraphie, tectonostratigraphie, Crétacé, Crimée montagneuse, Ukraine.

Introduction

The Cretaceous of southern (mountainous) Crimea, along the north coast of the Black Sea (Fig. 1) has been attracting the attention of geologists on account of good exposures, richness in fossils and clarity of sequence, for over a century and a half. For more than 70 years, field campaigns for students of the geological disciplines at several Russian and Ukrainian universities have been conducted in the Bakhchisaray area, in the southwest of Crimea (Fig. 1).

In the present paper, we offer a brief overview of the geological history of the Bakhchisaray area during the Cretaceous Period, as based on chronostratigraphic and tectonostratigraphic interpretation of sections which have been studied in detail. More generalised data on the Cretaceous sequence can be found in some previous papers, such as the ones by MURATOV (1973), MAZAROVICH & MILEEV (1989a, b) and MILANOVSKY (1997).

Analysis of geological history

In the Cretaceous history of the Bakhchisaray area, three stages are recognised, namely the Valanginian-Aptian, the early-middle Albian and the late Albian-Maastrichtian. In turn, these stages can be subdivided into phases; the last interval did not end until Eocene time.

1. Valanginian-Aptian transgressive epoch

Strata of Valanginian to Aptian age are widely distributed in the study area, and within this sedimentary complex three phases are recognised, as follows: the Valanginian-

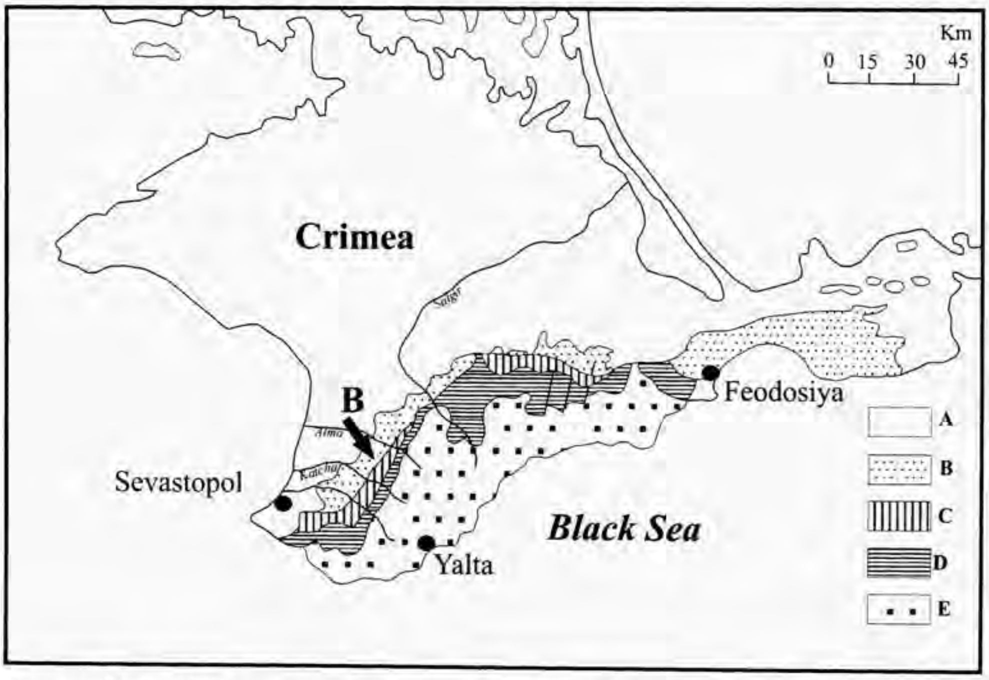

Fig. 1 — Geological map of the Bakhchisaray area (black arrow, marked B) in southern Crimea, Ukraine. Legend: A. Neogene; B. Paleogene; C. Upper Cretaceous; D. Lower Cretaceous; E. Upper Triassic-Jurassic.

early Hauterivian (Rezannaya Formation), late Hauterivian-late Barremian (Koyasdzhilga Formation) and late Barremian-Aptian (Biasala Formation). The entire complex represents a transgressive sedimentary cycle with a predominance of terrigenous sedimentation (BARABOSHKIN, 1997a).

The Valanginian is up to 40 m thick; to the north, this unit is cut by younger deposits. Strata reveal a complex facies composition, changing from north to south from bar-like cross-bedded sandstones and sandy limestones to sublittoral sandstones, siltstones and clays. This unit is characterised by the presence of tempestites as well as eluvial and erosional gaps. The Valanginian mainly represents an initial, shallow-marine, phase within the Cretaceous transgression.

The lower Hauterivian is up to 40 m thick in the south and totally pinches out towards the north; this being an excellent example of complexly composed polyfacies unit (BARABOSHKIN, 1997b). In the north, a coral reef limestone member (5 m thick) is developed, while in the south and west, these biohermal buildups transform into an area of reef apron (up to 11 m) with a predominance of clastic carbonates, generated by erosion of the reef massifs. Further to the south, bioclastic limestone facies turned into a more deep-water, marine unit of alternating sandy limestones and siltstones. Lower Hauterivian deposits formed within a minimum of three facies belts, namely: 1. shallow-marine biohermal buildups in the north, reflecting water depths of up to 30-40 m; 2. relatively deep-water, marine (up to 100-300 m) in the south, with a predominance of sandy material, and 3. an intermediate one.

The rapid deepening of the basin from north to south make the existence of a graben-like structure in the south likely during the Valanginian and Hauterivian stages.

A gap separates these strata from the overlying upper Hauterivian-lower Barremian rocks of the Koyasdzhilga Formation. This Formation comprises a widely distributed, condensed bed of cephalopod limestones with a total thickness up to 2 m. Within this unit, three beds can be distinguished: 1. brownish-yellow oolitic detrital limestones with abundant moulds of ammonites and bivalves, with associated brachiopod shells and echinoid tests; 2. red nodular detrital limestones with abundant ammonites, bivalves, brachiopods and echinoids; and 3. pink and grey micritic limestones and carbonate clays with fewer macrofossils. Generally, this unit is close to the pelagic 'Ammonitico Rossa' facies; it must have formed at a relatively large depth (about 200-400 m) under warm climatic conditions and in an offshore setting.

The contact between upper Barremian-Aptian rocks of the Biasala Formation and underlying strata of early late Barremian age is erosional; they comprise a monotonous succession of weakly calcareous clays, up to 100 m thick. Clays contain horizons with ankerite concretions. For the whole unit, benthic fauna is not typical (with the exclusion of the basal portion) and rare finds of nektic and planktonic fossils include foraminifera, belemnites, ammonites and cirriped plates. Clays accumulated in a relatively deep-water, marine environment (up to 500-600 m), under regionally consistent marine conditions. Clays correspond to a pelagic depression facies.

Water depth between the Valanginian and Aptian stages increased from 0 up to 400-600 m (BARABOSHKIN & ENSON, 2003). Such deepening cannot be explained solely by eustatic sea level rise; phase(s) of tectonic subsidence occurring mainly at the start of the late Hauterivian must be assumed. Tectonic subsidence may have been triggered by formation of grabens, but precise corresponding tectonic structures of that time are not preserved.

Attempts to present a palaeogeographic reconstruction for the whole of southern Crimea for Valanginian-Aptian time generally are fraught with difficulties, but, overall, the main phases are obvious. The first phase corresponds to the Valanginian-early Hauterivian, when a marine basin appeared along the northerly rim of mountainous Crimea with the depocentre situated in the Belogorsk Depression. To the north, cross-bedded sands and sandstones with subordinate conglomerates (including boulders) and clays (Mazanka Formation, a possible age analogue of the Rezannaya Formation) formed. These deposits originated in alluvial-deltaic and coastal marine environments. Thus, the Mazanka Formation marks the northern shoreline of the marine basin; however, the southern edge cannot be precisely defined. In the Tanas River Basin near the village of Kizilovka, an olistolith of Upper Jurassic limestones, about 1 km in diameter, is found within a unit of presumed Valanginian-early Hauterivian age. This most likely was transported from the south from the area of their modern distribution and the axis of the basin thus had to be located to the north from the strip of exposure of these olistoliths. Great differences in altitude in the relief, caused by tectonic movements, are needed to explain the origin of a such huge slide bodies. It is most likely that during the Valanginian-early Hauterivian a transversely asymmetric rift basin along the strip from Verkhorechie to Belogorsk was present. The southern shoulder of the rift was lifted up and mainly consists of Upper Jurassic limestones and older rocks. An accumulative alluvial-deltaic plain was situated in the area of the gently sloping northern shoulder. The Bakhchisaray area was located within the northern marginal part of this palaeorift. Levelling of sedimentary conditions occurred during the late Hauterivian-early Barremian within a relatively deep-water, marine shelf basin with an active sedimentary setting conducive to the existence of a rich biota, because of regional transgression as a result of post-rift subsidence. On a regional scale, the upper Barremian-Aptian deposits unconformably cover underlying rocks. For example, to the northeast of Balaklava, close to the village of Cherorechenskoye, these deposits fill ingressive depressions in Upper Jurassic limestones and at some localities they overlie pre-Upper Jurassic deposits. So a phase of vertically differentiated movements of presumed rift nature took place prior to a regional epoch of intensive clay accumulation. After the phase of tectonic movement, a rapidly differentiated submergence of the larger part of mountainous Crimea up to 200-500 m started. Possibly, this submergence was also accompanied by down-fault displacements, because in some places upper Barremian-Aptian clays contain olistostromes inclusive of huge boulders of Upper Jurassic limestones (for example, in the Krasnopestshernoye and Mramornoye areas of the Salgir Depression). Generally, for Valanginian-Aptian time two cycles of rifting have been documented, but reconstruction of details of palaeogeography of these palaeorifts is not possible. The axis of the main palaeorift possibly corresponded to the line Verkhorechie-Mazanka-Belogorsk. That is why we refer to this as the Verkhorechie-Belogorsk Basin. The Salgir Basin (or graben) may be a branch of this.

2. Early-middle Albian epoch of rising and rifting

In the Bakhchisaray area, as well as in most of mountainous Crimea, lower and middle Albian strata are missing. The town of Balaklava is the only place where upper middle Albian deposits have been recorded with certainty. Possibly these rocks could also be present in eastern Crimea (DRUSTCHITS & KUDRYAVTCEV, 1960).

The oldest upper Albian strata are referred to as the Mangush Formation and fill the erosional Mangush Depression, which primarily was a graben or semi-graben. Sandy limestones of late late Albian age, assigned to the Vysokiy Bugor Formation, rest transgressively and with a small angular unconformity (up to 5-10°) upon, and cut into, underlying rocks down to the folded basement. The Mangush Depression may have come into existence just at the start of the late Albian or even earlier. During its formation, about 100 m of Barremian-Aptian clays, *c.* 2 m of cephalopod limestones as well as up to 75 m of Valanginian-Hauterivian deposits were eroded. Taking this into account, we estimate the minimum erosion to equal 200 m. To produce a such palaeovalley, a highland relief with heights no less than 250-300 m is needed. If we take into account that in the Aptian sea was 500-600 m in depth, then during the early-middle Albian tectonic uplift of the area had to be about 400-800 m. At that time, a gentle monoclinal structure with inclination angles between 0 and 10 degrees within Neocomian-Aptian deposits was formed. Removing subsequent deformation, an inclination of beds within pre-Albian deposits from 0 to 10 degrees in an easterly direction can be reconstructed. Two types of deformation exist: 1. gentle folding, triggered by compression found in the Balkanides (Bulgaria), and 2. heterogeneous uplift of the area with a gentle rise of block surfaces, linked to a phase of extension (rifting) and a rise of the shoulders of palaeorifts (rifts of Aptian-Albian age are known in the central Pontides of Turkey and in the Belogorsk area of Crimea). Synrift volcanism started during the middle Albian (LESTCHUKH, 1992), traces of which have been documented from lowland Crimea – these provide indirect evidence for the latter hypothesis. The main volcanic centres were located in the Albian Karkinit rift.

In the regional background of the whole of southern Crimea it is difficult to reconstruct the palaeogeography of the early-middle Albian, because of limited distribution and poor exposure of rocks of this age. The main early-middle Albian basin has been detected within the Belogorsk foredeep, in which up to 500-700 m of clays, siltstones and sandstones accumulated. To the south, a region of highlands, which included the Bakhchisaray area, has been defined. It is most probable that the Belogorsk Basin was influenced by rift subsidence and that the main part of mountainous Crimea was a relatively raised shoulder of this rift. The second possible early-middle Albian graben may be the Salgir Depression.

Generally, the early-middle Albian interval was a period of regional rifting with the formation of several grabens in a strip from Sivash and the Odessa shelf in the north to the central Pontides (Turkey) in the south (Fig. 2).

3. Late Albian-Maastrichtian epoch of transgressions

Between the late Albian and the end of the Eocene, the Bakhchisaray area was influenced by transgressions which alternated with short regressional phases. It is possible to define the following cycles of cover formation at that time:

A. late Albian (Mangush time), with formation of an ingressive siliciclastic complex;
B. late Albian (Shara time), with short-time transgression and accumulation of shallow-marine carbonates;
C. late Albian (Vysokiy Bugor time), with regional transgression and accumulation of glauconitic sandstones and sandy limestones;
D. Cenomanian-Turonian-Coniacian with regional transgression and accumulation of mainly chalk-like rocks;
E. late Santonian-Campanian-Maastrichtian with regional transgression and accumulation of generally chalk-like rocks, capped by a regressive phase and strong shallowing of the basin;
F. Danian regional transgression with formation of calcarenites.

A - Late Albian Mangush ingressive phase

During Mangush time, the sea ingressed from the west into this palaeovalley which was 2-3 km in width, having formed a large estuarine. The valley was filled with siliciclastic material. Peri-tidal facies comprise poorly sorted sandstones with abundant reworked pebbles and clasts of Neocomian rocks from the adjacent highland. In sandstones, cross-bedded series can be seen. Sandstones of the Mangush Formation are the least mature because quartz content is only 35-55%. Some sandstone horizons contain boulders: in the sandy matrix, pebbles and boulders of different degrees of roundness and of different composition are represented. Boulders are up to 1 m in diameter or more. Among boulders and pebbles, rocks of Berriasian-Hauterivian and Barremian, Upper Jurassic limestones, sandstones of the Tavr Formation, rounded fragments of Middle Jurassic volcanic rocks, well-rounded quartz pebbles etc. have been identified. Among fragments, also rocks not found in Crimea are encountered, such as metamorphites, acid effusives and siliceous and siliceous-clayey shales (CHERNOV & YANIN, 1975). The composition of boulders and pebbles indicates the close proximity of the denudation area, not further than a few tens of kilometres. Part of the clastic material is situated within a clayey matrix. Poor sorting of sandstones and conglomerates indicates limited transport of the sedimentary material and its accumulation by rapid streams, mountain rivers and temporary streams such as mudflows. The central portions of the Mangush Depression were filled by clayish material. Clays are to a different extent silty and heterogenous with a large

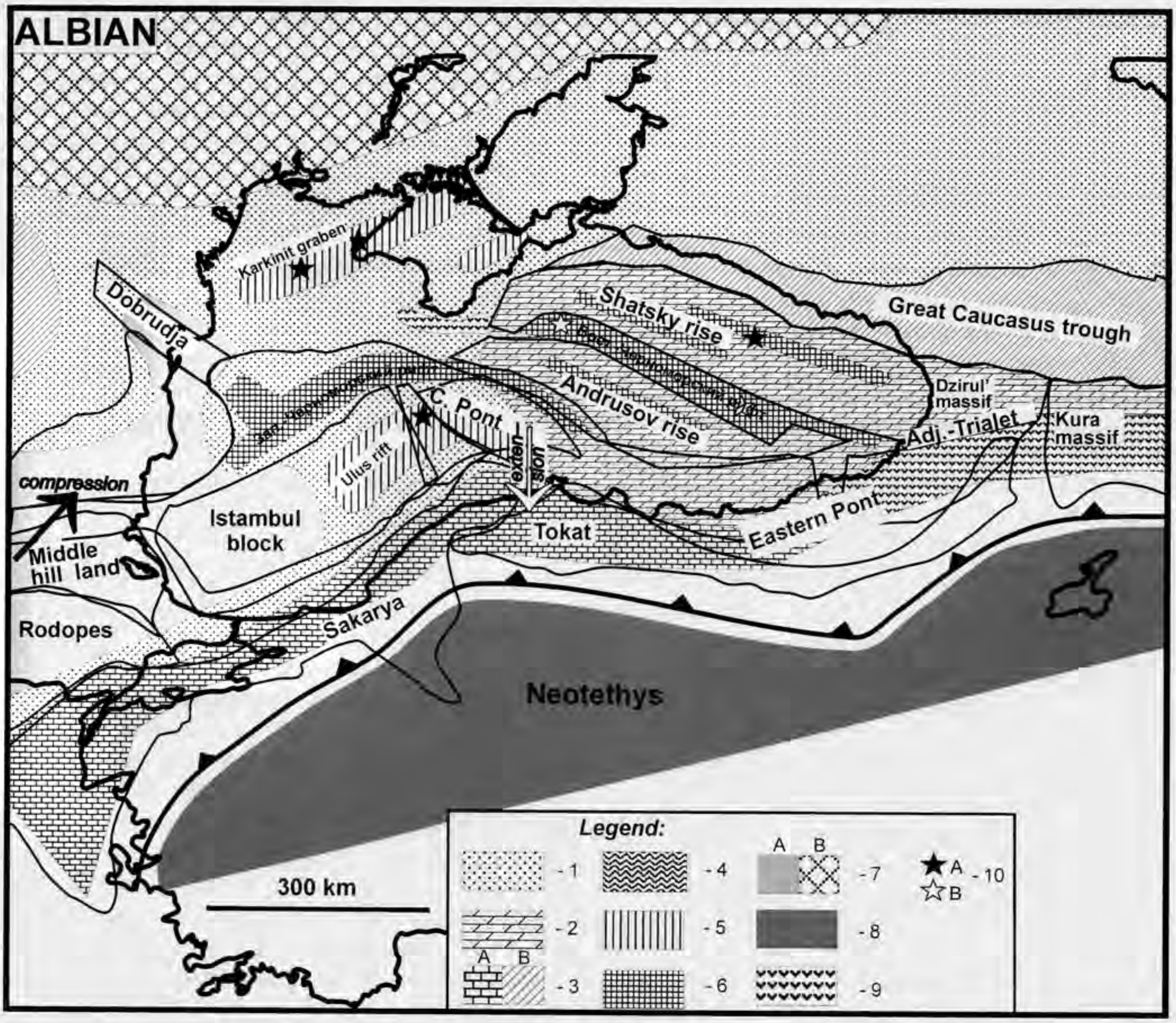

Fig. 2 — Palaeogeography of the Black Sea area for the Albian Stage (compiled by A.M. Nikishin; see also NIKISHIN *et al.*, 1997a-c, 2001, 2003). Legend: sediments (1-5): 1, shallow-marine, mainly terrigenous; 2, shallow-marine, mainly carbonate and presumed volcanic; 3, deep-water marine: carbonates (A) and turbidites (B); 4, ophiolites, accretional complex; 5, rifts, terrigenous deposits possibly with volcanics; 6, presumed rifts; 7, eroded land: highlands (A), plains (B); 8, oceanic crust; 9, volcanic arc; 10, rift volcanics: proved (A), assumed (B).

amount of plant debris. For the Mangush Formation, marine and brackish-water fauna is typical, indicating low salinity of the estuarine water column. The total thickness of this formation may reach 100 m.

B - Late Albian Shara Formation

This formation occurs only locally as isolated lenses in the area of the villages of Trudolyubovka and Prokhladnoye, and overlies the Mangush Formation, although the contact between these units has not been observed. Stratigraphically, it is positioned between the late Albian Mangush and Vysokiy Bugor formations. The unit is 1-3 m thick and comprises coarse bioclastic, brown limestones, rich in fragments of crinoid stems and gastropod and bivalve shells. In the limestones, pebbles of underlying rocks of basement, rounded to a variable extent, usually are present. It is assumed that after the Mangush transgression a short regression occurred and a shallow sea again filled the small valley along the Bodrak fault zone and north from it.

C - Late Albian Vysokiy Bugor Formation

This formation is of regional distribution, pinching out to the north. It is 20 m thick in the south. In the southern and central areas of distribution, three members have been distinguished within this unit. The lower member comprises quartz-polimiktic, poorly sorted sandstones with dispersed quartz pebbles; the middle member consists of calcareous quartz-glauconitic sandstone with nodular structure because of irregular distribution of carbonate cement, occasionally turning into detrital sandy limestones, while the upper unit is represented by strongly calcareous quartz-glauconitic sandstones. Sandstones are highly mature, the quartz content reaching 85-89%. Towards the north, the role of carbonate cement decreases and sandstones become weakly cemented sands. This formation is characterised by large-sized ammonite shells, brachiopods, bivalves, echinoids etc. Rocks of this formation formed in a shallow sea which deepened towards the southwest. In the upper part of the formation, eluvial and erosive gaps occur. In the top, in places where its upper part survived erosion, a horizon with reworked andesitic tuffaceous material is present. During the end of the Albian, there was active volcanism nearby. The assumed volcanic arc (referred to as the Lomonosov Massif) was located south of Sevastopol; in the Balaklava area, the thickness of upper Albian volcanic tuffs increased several times and from the Black Sea volcanics of probably Albian age have been dredged (SHNYUKOV et al., 1997). Upper Albian tuffstones are known from Kubalach Mountain in the Belogorsk Basin as well. Generally it is assumed that the Albian volcanic arc can be traced south of Crimea into the Adjaro-Trialeti zone (Georgia). The region of mountainous Crimea was within a back-arc environment, at least during the late Albian.

Within the regional background of southern Crimea, the upper Albian mainly comprises a transgressive series of sediments. For example, in the Belogorsk area upper Albian sediments show an erosional contact with Lower Cretaceous deposits of different ages (from Hauterivian to middle Albian). In the Bakhchisaray area, upper Albian overlies not only Lower Cretaceous, but also Lower-Middle Jurassic, rocks. Thus, to the end of the late Albian, a recession of tectonic activity in the region is documented, which is reflected in the petrographic composition of sandstones as well.

For the late Albian, volcanic activity is typical. In sandstones from the upper part of the Vysokiy Bugor Formation, weakly altered crystals of plagioclase, pyroxene and amphiboles sometimes making a thin beds of tuffites are typical. As mentioned above, in the Balaklava area late Albian volcanogenic-sedimentary rocks with reworked lapilli are known. Transportation of clastic matter proceeded from the south and southwest.

D - Cenomanian-Turonian-Coniacian regional transgression

An erosional contact is present between the Albian and Cenomanian. At the base of the Cenomanian, a bed rich in glauconite and containing quartz gravel has been documented; the sequence having a transgressive character: sandy-silty marls upwards change into clayey marls and then into pure and calcareous marls and limestones. The thickness of Cenomanian strata reaches 70-80 m. The lower part of the middle Cenomanian is missing as a result of a short, worldwide regression (GALE et al., 1999). For the upper middle Cenomanian a cyclic alternation of relatively dark- and light-coloured marls, interpreted as Milankovich cycles with an alternation of warm and colder epochs. Up section, in the Cenomanian sequence, the amount of benthic macrofauna decreases, which reflects the general deepening of the basin. Cenomanian carbonates contain large numbers of foraminifera, some radiolarians, but the calcareous nannofossils constitute the main rock-forming material, which indicates the chalk-like nature of primary sediments. Micro-downfaults are typical of the Cenomanian and this indicates a possible synsedimentary extension of the basin. In the lower and middle parts, thin bentonite beds, generated from volcanic ash falls, are present.

In the uppermost Cenomanian an inconstant dark bed, rich in organic matter (up to 7% of TOC), following with a gap on underlying rocks, is found (NAIDIN & KIYASHKO, 1994; FISHER et al., 2005). This bed, represented by different kinds of limestones occasionally with a notable portion of sandy and clayey material of mudstone and wackestone structures, was formed during OAE 2 conditions in the basin and is exposed at several outcrops (BADULINA & KOPAEVICH, 2007). In fact, the black bed consists of a few (usually two) thin beds that are between 20-140 cm thick. Geochemical research indicates the presence of kerogene of types II and III. An analysis of TOC/N ratio has documented the presence of marine and prevailing terrestrial organic matter. Rocks below and above the black bed accumulated under oxic conditions, while sediments of OAE 2 formed during warming of surface

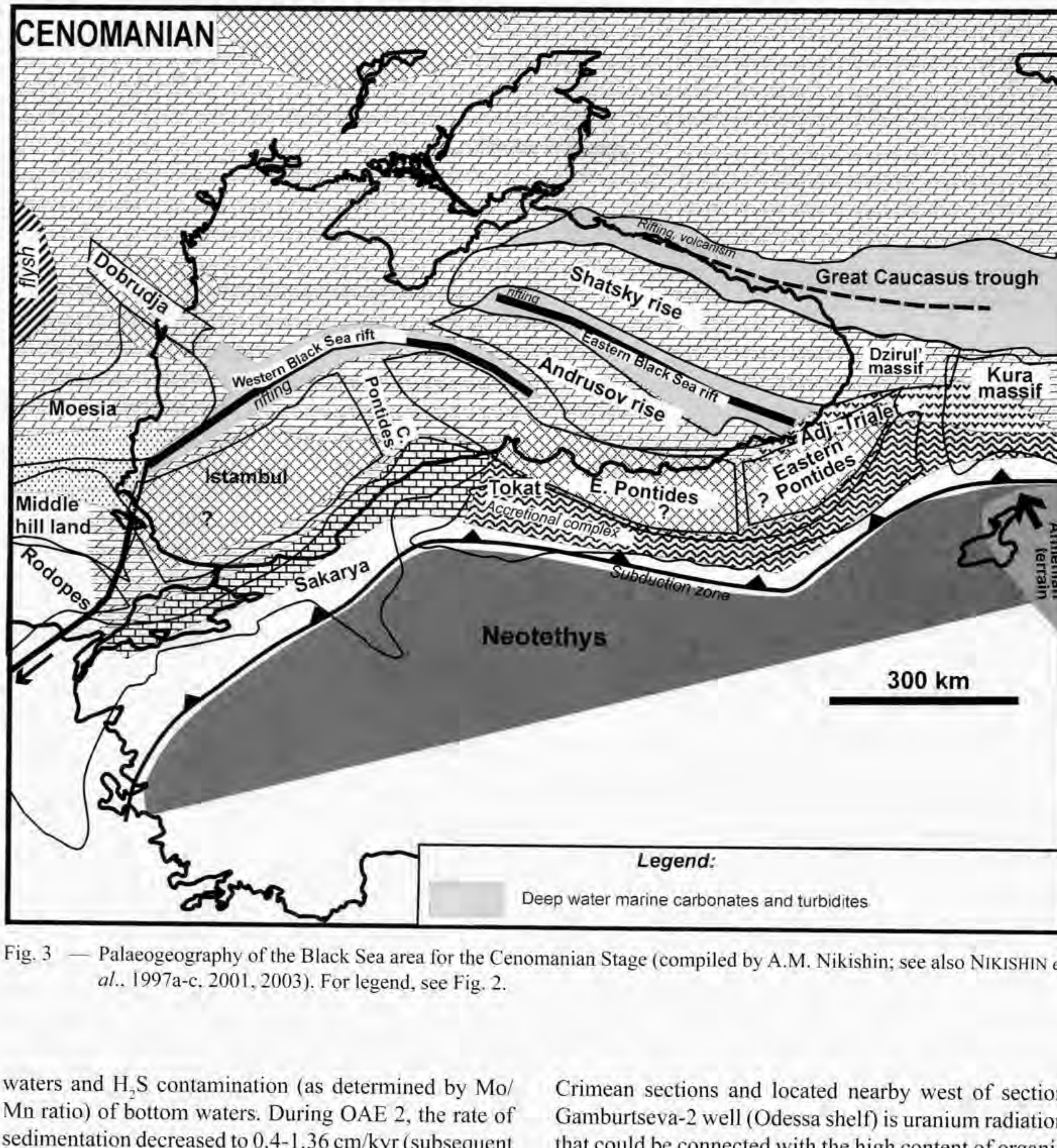

Fig. 3 — Palaeogeography of the Black Sea area for the Cenomanian Stage (compiled by A.M. Nikishin; see also NIKISHIN *et al.*, 1997a-c, 2001, 2003). For legend, see Fig. 2.

waters and H_2S contamination (as determined by Mo/Mn ratio) of bottom waters. During OAE 2, the rate of sedimentation decreased to 0.4-1.36 cm/kyr (subsequent to OAE 2, increasing to 1.11 cm/kyr) and a shallowing of the basin from 500 up to 450 m occurred.

Thus, the formation of OAE 2 sediments was controlled by a series of palaeogeographic events: climate change, transgression-regression-transgression, micro-upwelling with local predominance of radiolarians and active production of biogenic silica, blooms of dinocysts and algae with production and burial of organic matter, change in volume and rate of terrigenous input.

Increased radioactivity of OAE 2 sediments in Crimean sections and located nearby west of section Gamburtseva-2 well (Odessa shelf) is uranium radiation that could be connected with the high content of organic matter.

In sections that are most complete, Turonian rocks overlie Cenomanian ones, but in many outcrops an erosional boundary or bed, rich in glauconite, is observed at this level. In the Turonian sequence, two members are defined, the lower one being represented by chalk-like limestones and high calcareous marls with chert concretions (up to 30 m) and rare macrofauna. The upper member consists of pure limestones with stylolites and rare brachiopods, inoceramid bivalves and echinoids.

The Coniacian is lithologically analogous to the Turonian and comformably overlie this; in these limestones relatively more fragments of inoceramid shells and echinoids are present.

Generally, the Cenomanian-Coniacian series represents a single sedimentary sequence with depth maximum in the basin at the end of the Cenomanian or the start of the Turonian, reaching between 400 and 700 m. If so, not only eustatic sea level rise, but also regional tectonic processes must have led to the submergence of the basin (Fig. 3).

E - Late Santonian-Campanian-Maastrichtian transgressive-regressive cycle of sedimentation (Fig. 4)

Between the lower and upper Santonian, a time of submarine erosion of the sedimentary cover took place. In the north, sediments of Coniacian and part of Turonian were eroded, in the south the extent of erosion was less. Consequently, in the north, a new cycle of sedimentation started during the early Campanian, but in the south during the late Santonian. At the base of the new cycle of sediments, a distinctly expressed hardground is observed. Late Santonian deposits, clayey limestones with glauconite, are dated by uintacrinid crinoids of the genus *Marsupites*. Campanian deposits, with an erosional contact, cover upper Santonian and Turonian-Coniacian limestones and start with a horizon of silty marls. The greatest portion of the Campanian is represented by highly calcareous chalk-like marls and limestones with rare belemnites. Calcareous nannofossils formed the carbonate sediment. Chert concretions are encountered in the Campanian, the thickness of which amounts to c. 80-90 m in the northwest and up to 150-200 m in the southwest.

Maastrichtian strata conformably follow on Campanian and generally are an example of a regressive phase. In the Maastrichtian sequence, four members can be defined: 1. white limestones; 2. siliceous marls with silicified crustacean burrows and sponges; 3. siliceous silty marls with silicified crustacean burrows and rare sponges; and 4. calcareous sandstones with abundant fragments of molluscan shells and with oyster beds.

The thickness of Maastrichtian strata in the northwest is about 80 m, in the southwest c. 100 m. This sequence is an example of rapidly proceeding regression with a transition from sediments of the open shelf to coastal ones. This is proved not only by lithological composition, but also by faunal assemblages, i.e. the dominance of benthic foraminifera and shallow-marine bivalves (ALEKSEEV, 1989; ALEKSEEV & KOPAEVICH, 1997; DHONDT, 1999).

Thus, an abrupt shallowing is detected before late Santonian time, the maximum deepening of the basin occurring in the Campanian (up to 350-450 m), a phase of shallowing corresponding to the Maastrichtian.

At the base of the Campanian, a few horizons of montmorillonite (so-called 'kil') clays formed because of submarine weathering of andesitic ashes. Volcanic ash was supplied from the central-eastern Pontides (Turkey) which demonstrate the maximum of volcanic arc activity of andesitic composition during this time.

In regional aspect, between the Coniacian and late Santonian (or prior to the Campanian), an epoch of submarine erosion took place, exposing a number of territories. For example, this unconformity is distinctly expressed in the Novoselki Uplift of the Plain Crimea. Pre-Campanian (or intra-Santonian) vertical movements were caused by a brief interval of tectonic compression (Subhercynian phase of folding in western Europe).

Some tectonic events could also have occurred prior to the Maastrichtian. At least in eastern Crimea, near Koktebel on Klementieva Mountain, relatively deep-water marine limestones show an erosional contact with underlying Middle Jurassic volcanics.

F - Danian regional transgression

An erosional contact separates Danian (early Paleocene) deposits from underlying Maastrichtian rocks. At the top of Maastrichtian, a well-expressed hardground is ubiquitous and the overlying bed is rich in glauconite and contains remanié Maastrichtian fossils.

Conclusions

During the Cretaceous, southern (mountainous) Crimea subsided as a result of several impulses of rifting (*i.e.*, the first, or Early Cretaceous, tectonostratigraphic unit), but later a long period of post-rift subsidence coinciding with a global sea level rise followed (*i.e.*, second, or late Albian-Maastrichtian, tectonostratigraphic unit).

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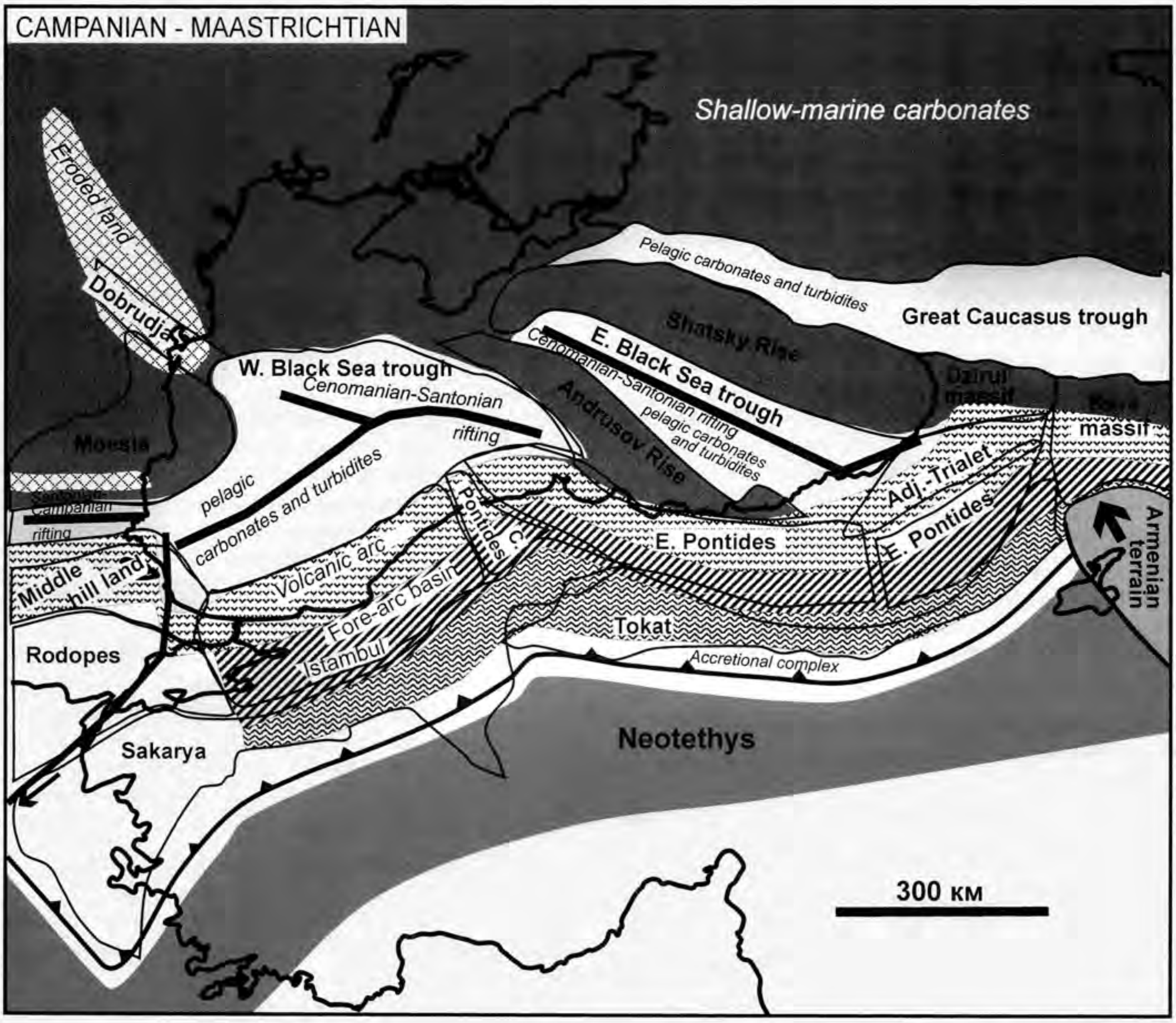

Fig. 4 — Palaeogeography of the Black Sea area for the Campanian-Maastrichtian stages (compiled by A.M. Nikishin; see also NIKISHIN *et al.*, 1997a-c, 2001, 2003). For legend, see Fig. 2.

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