ГЕОЛОШКИ АНАЛИ БАЛКАНСКОГА ПОЛУОСТРВА ANNALES GÉOLOGIQUES DE LA PÉNINSULE BALKANIQUE	67	1–11	БЕОГРАД, децембар 2006 BELGRADE, December 2006

The palaeogeographic outlines of the Caucasus in the Jurassic: The Caucasian Sea and the Neotethys Ocean

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Abstract. The Caucasian Sea, fringing the northern margin of the Jurassic Neotethys Ocean, largely covered the Caucasus. Continental, shallow-marine and deep-marine palaeoenvironments delineate palaeogeographic outlines for three significant time slices: the Late Toarcian, the Early Bajocian and the Middle Oxfordian. These new palaeogeographic outlines of the Caucasus and adjacent territories match the Neotethys Ocean reconstructions. In the Late Toarcian, the Caucasian Sea embraced the Greater Caucasus Basin and the Black Sea – Caspian Sea Basin, which were divided by the Northern Transcaucasian Arc; it opened to the Neotethys Ocean which covered the Exterior Caucasian Basin. In the Early Bajocian, the Caucasian Sea only embraced the Greater Caucasus Basin; it opened the epicontinental seas of the Russian Platform, connecting them with the Neotethys Ocean by straits between islands of the Transcaucasian Arc. In the Middle Oxfordian, the Caucasian Sea which further embraced the Greater Caucasus Basin had its outer shelf fringed by carbonate build-ups. The connection between the Russian Platform shallow sea and the Neotethys Ocean was maintained. In the course of the Jurassic, a seaway developed along the northern margin of the Neotethys, of which the Caucasian Sea became a significant part.

Key words: sea, seaway, basin, arc, Jurassic, Caucasus, Neotethys.

Апстракт. Кавкаско море захватало је северни обод јурског Неотетиског океана и великим делом је прекривало Кавказ. Континенталне, плитководне и дубоководне палеосредине оцртавају палеогеографске оквире три значајна временска раздобља: горњи тоар, доњи бајес и средњи оксфорд. Ове нове палеогеографске границе Кавказа и суседних области уклапају се у реконструкцију Неотетиског океана. У горњем тоару Кавкаско море је обухватало Велики Кавкаски басен и Црно море – Каспијски морски басен, који су били раздвојени Северним транскавкаским луком који се отварао према Неотетиском океану који је прекривао спољашњи Кавкаски басен. За време доњег бајеса, Кавкаско море је захватало само Велики Кавкаски басен; оно је било отворено према епиконтиненталном мору Руске платформе повезујући га са Неотетиским океаном земљоузима између острва Транскавкаског лука. Током средњег оксфорда стварале су се карбонатне наслаге по ободу спољашњег шелфа Кавкаског мора, које је и даље захватало Велики Кавкаски басен. Одржавала се веза између плитководне Руске платформе и Неотетиског океана. У току јуре постојао је морски пролаз дуж северног обода Неотетиса, где је Кавкаско море заузимало његов значајни део.

Кључне речи: море, морски пролаз, басен, лук, јура, Кавказ, Неотетис.

Introduction

The Caucasus stretches over about 1000 km between the Black and Caspian seas (Fig. 1). In the Jurassic, it was located on the northern margin of the Neotethys Ocean, forming a "key" transition between western and central parts of the Northern Neotethys (STAMPFLI & BOREL, 2002; GOLONKA, 2004). Not only palaeogeographically and palaeotectonically, but also palaeobiogeographically, the Caucasus was an important region. WESTERMANN (2000) after UHLIG (1911) have defined the Mediterran-Caucasian Subrealm of the Mesozoic Tethyan Realm.

In spite of its importance, the Caucasusian Jurassic palaeogeography is still poorly known. Previous publications are often only available in Russian and/or lack

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the incorporation of modern palaeogeographic and palaeotectonic concepts. Outdated "formation" analysis or geosynclinal theory are the basis of many studies. To date, plate-tectoinc and terrane analysis of the Caucasus still remains sporadic and schematic. In many Russian reconstructions, the Caucasus was viewed as an isolated region and its border often delineated by the boundaries of the former USSR. To avoid misunderstanding, which is inevitable when dealing with a high amount of the sufficiently reliable sources, in this paper only a few Russian works have been considered. The first one is a book by JASAMANOV (1978), who presented general palaeogeographic information on the Caucasus for each of the Jurassic stages, while the second is a review by LORDKIPANIDZE *et al*. (1984), who presented the most acceptable palaeotectonic reconstructions, based on palaeomagnetic data. Tectonic models proposed by ERSHOV *et al*. (2003) were also employed.

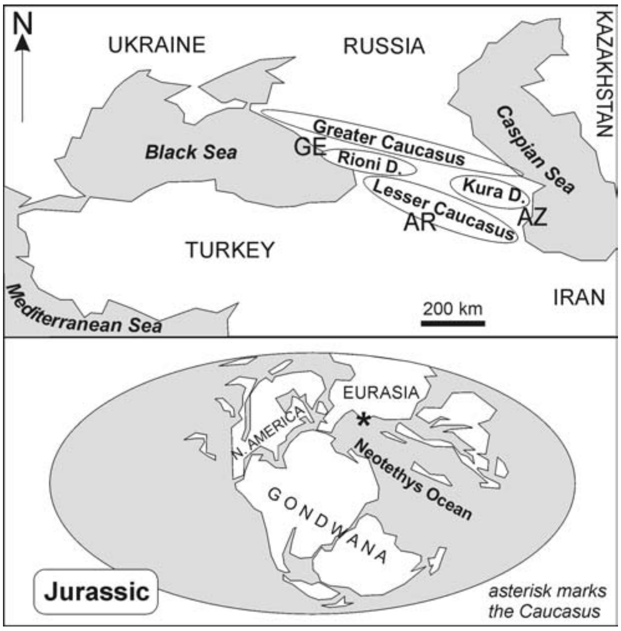

Fig. 1. Geographic location of the studied region. GE – Georgia, AR – Armenia, AZ – Azerbaijan. The position of the Caucasus in the Jurassic is shown on the palaeogeographic map, strongly simplified after SCOTESE (2004).

Thus, in any somewhat more detailed palaeogeographic reconstruction of a larger portion of the Jurassic Northern Neotethys, the Caucasus remained a blank space. The general target of this article is to initiate a discussion on the highlighted topic. Simplified Jurassic palaeogeographic outlines of the Caucasus are proposed and discussed. It should be emphasized that this attempt is based on personal field investigations, as well as a revision of the available and trustwarthy data from recent studies of the entire Jurassic Neothethys (STAMPFLI & BOREL, 2002; GOLONKA, 2004).

Geologic setting

The Caucasus consists of three main segments: (1) the Greater Caucasus, (2) the Lesser Caucasus (or the Transcaucasus) and (3) the Kura-Rioni Depression (or the Rioni Depression and the Kura Depression, also called the Transcaucasian Depressions) (Fig. 1). Their tectonic settings have been briefly overviewed by SAINTOT & ANGELIER (2002), ALLEN *et al*. (2003) and ERSHOV *et al*. (2003).

The Jurassic deposits, widely distributed within the Caucasus, vary in distinct areas. Their stratigraphy has been reviewed by ROSTOVTSEV *et al*. (1992). The stratigraphic scale used in the Caucasus was revised by the author according to new developments in the Jurassic chronostratigraphy, using ammonoids, brachiopods (for detail see RUBAN, 2003), foraminifers and marker horizons (Fig. 2). Stratigraphic suggestions from both International Commission on Stratigraphy and the Groupe Français d'Étude du Jurassique (CARIOU & HANTZPERGUE, 1997) were taken account in doing this. A correspondence between the chronstratigraphic stages and substages (after GRADSTEIN *et al.,* 2004) and stages in the regional sense (after ROSTOVTSEV *et al.,* 1992) was established. The precise revision of the regional ammonoid-based zonation is a task for further special studies. It is also necessary to note that traditionally the Callovian stage in the Caucasus is attached to the Upper Jurassic (ROSTOVTSEV *et al.,* 1992), in contrast to the present scale, recommended by the International Commission on Stratigraphy (GRADSTEIN *et al.,* 2004).

Jurassic lithostratigraphy of the Caucasus has been reviewed in detail by ROSTOVTSEV *et al*. (1992). In general, two major sedimentary complexes are identified. The Sinemurian-Bathonian complex comprises argillaceous and clastic deposits with a total thickness upto 10000 m. The Callovian-Tithonian complex is represented chiefly by carbonates (thickness up to 3000 m) and also evaporites in the upper part. The accumulation of the Late Jurassic deposits was connected with the evolution of a large carbonate platform rimmed by carbonate buildups (KUZNETSOV, 1993; AKHMEDOV *et al.,* 2003; RUBAN, 2005). In some areas (especially in the Lesser Caucasus), substantial amounts of volcanoclastic deposits are present. Two major regional hiatuses encompass the Hettangian-Early Sinemurian and the Bathonian.

In the Jurassic, the Caucasus was located in the central part of the northern margin of the Neotethys Ocean (Fig. 1) (STAMPFLI & BOREL, 2002; GOLONKA, 2004). Tectonic activity resulted from the dynamics between the terranes, which contacted with each other, and also with the larger Eurasian Plate. Several parallel subduction and spreading zones were located in this territory (LORDKIPANIDZE *et al.,* 1984; ERSHOV *et al.,* 2003), although a precise interpretation of the Jurassic geodynamics in this region has not been made yet and many questions remain open.

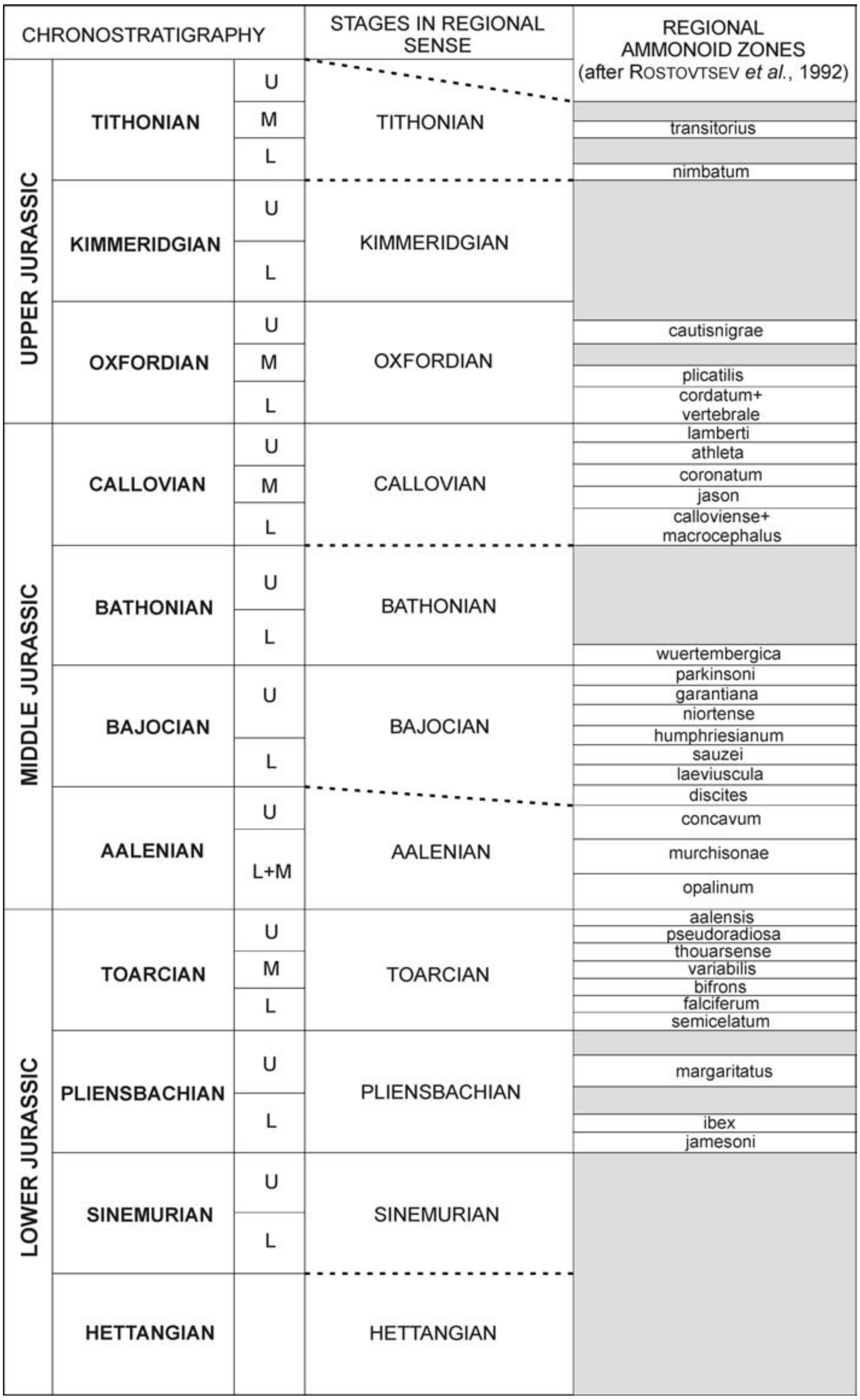

Fig. 2. Corrected stratigraphic scale of the Jurassic used in the Caucasus. Abbreviations: L – Lower, M – Middle, U – Upper. Unzoned intervals are shaded as gray. Dashed lines mark uncertainty in the boundary definition. Regional ammonoid zonation does not correspond on this scale to the shown chronostratigraphy (it seems to be impossible to correlate them at present), but only to the stages in a regional sense. The Callovian *macrocephalus* and calloviense regional zones, and the Oxfordian *vertebrale* and *cordatum* regional zones are evidently not separated in the regional ammonoid succession.

In the Early-Middle Jurassic, the Caucasus was located in a subtropical to moderate humid zone. The Toarcian palaeotemperatures are estimated as 15–20°C; in the Early Aalenian, they decreased to 5–15°C, but in the Late Aalenian, the temperatures increased again to 20–25°C, and apparently constant until the end of the Jurassic (JASAMANOV, 1978). After the beginning of the Callovian, the climate became subtropical to tropical and semi-humid. In the Late Kimmeridgian-Tithonian, evaporites were accumulated (JASAMANOV, 1978; ROSTOVTSEV *et al.,* 1992), which indicated arid conditions. In the Early-Middle Jurassic, dysoxic to anoxic palaeoenvironments were typical for the Caucasian basins (RUBAN, 2004; EFENDIYEVA & RUBAN, 2005; RUBAN & TYSZKA, 2005). The palaeobiogeographic position of the Caucasus is uncertain. While DOMMERGUES (1987) places it in the Euro-Boreal domain for the Early Jurassic, WESTERMANN (2000) includes it into the Tethyan Realm. An analysis of brachiopods suggests a rather transitional position (RUBAN, 2003).

Methods

Essentially, this study relies on palaeoenvironmental interpretation, realized in the same way as described by RUBAN (2006). The territory of the Caucasus is subdivided into several dozens of particular areas, which are traditionally called "zones". They are distinguished by the facies composition of the Jurassic succession. A total of 36 "zones" delineate the Hettangian-Bathonian interval (Fig. 3A), and 26 the Callovian-Tithonian interval (Fig. 3B) (ROSTOVTSEV *et al.,* 1992). A palaeoenvironmental interpretation for all formations in each "zone" was made. The comprehensive information of ROSTOVTSEV *et al.* (1992) and personal field observations in the Labino-Malkinskaya (see also EFENDIYEVA & RUBAN, 2005; RUBAN & TYSZKA, 2005), Lago-Nakskaja and Labinskaja "zones" were used.

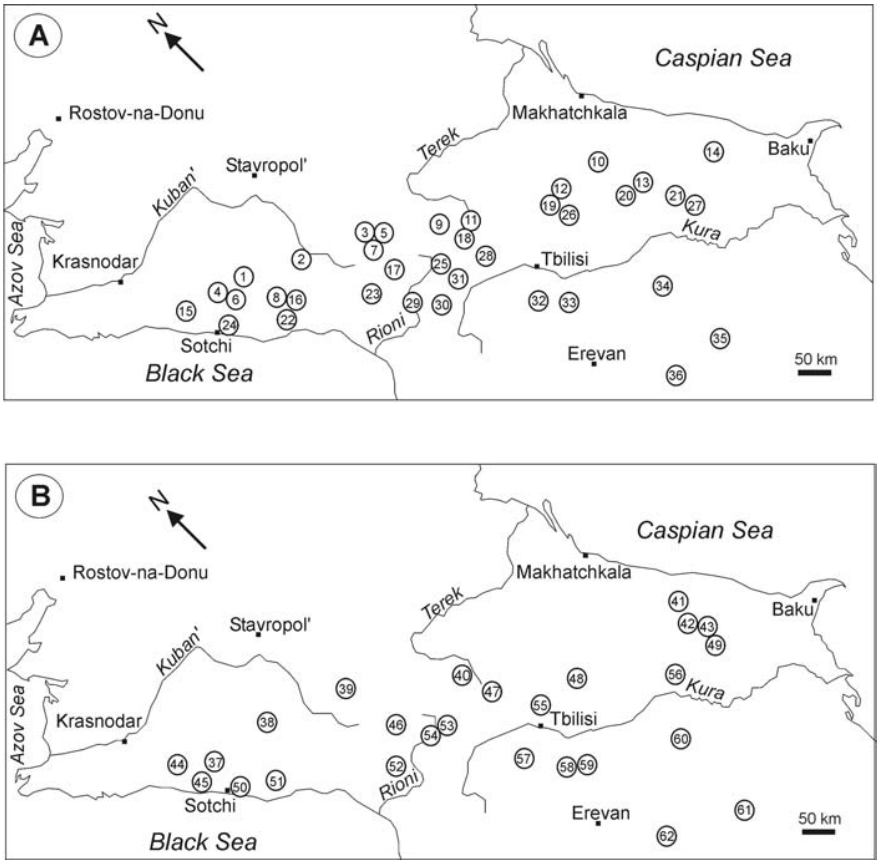

Fig. 3. Location of the Jurassic "zones" (marked by circles) in the Caucasus (after ROSTOVTSEV *et al.,* 1992). A, Hettangian-Bathonian "zones" (1–36); B, Callovian-Tithonian "zones" (37–62). "Zones" ("subzones" and regions of ROSTOVTSEV *et al.* (1992) are mentioned here as "zones"): 1, Western Labino-Malkinskaja; 2, Central Labino-Malkinskaja; 3, Eastern Labino-Malkinskaja; 4, Western Pshikish-Tyrnyauzskaja; 5, Eastern Pshikish-Tyrnyauzskaja; 6, Northern Arkhyz-Guzeripl'skaja; 7, Eastern Arkhyz-Guzeripl'skaja; 8, Southern Arkhyz-Guzeripl'skaja; 9, Digoro-Osetinskaja; 10, Agwali-Khivskaja; 11, Western Bokovogo Khrebta; 12, Central Bokovogo Khrebta; 13, Eastern Bokovogo Khrebta; 14, Southeastern Bokovogo Khrebta; 15, Gojtkhsko-Atchishkhinskaja; 16, Severoabkhazskaja; 17, Svanetskaja; 18, Western Glavnogo Khrebta; 19, Central Glavnogo Khrebta; 20, Tfanskaja; 21, Durudzhinskaja; 22, Western Gagra-Dzhavskaja; 23, Eastern Gagra-Dzhavskaja; 24, Amuksko-Lazarevskaja; 25, Sakaojskaja; 26, Shakrianskaja; 27, Vandamskaja; 28, Kakhetino-Letchkhumskaja; 29, Tskhenistskali-Okribskaja; 30, Southwestern Dzirul'skaja; 31, Northeastern Dzirul'skaja; 32, Loksko-Khramskaja; 33, Alaverdskaja; 34, Shamkhorsko-Karabakhskaja; 35, Kafanskaja; 36, Araksinskaja; 37, Lago-Nakskaja; 38, Labinskaja; 39, Malkinskaja; 40, Kabardino-Dagestanskaja; 41, Jugo-Vostotchnogo Dagestana; 42, Sudurskaja; 43, Shakhdagskaja; 44, Abino-Gunajskaja: 45, Novorossijsko-Lazarevskaja, 46, Svanetsko-Verkhneratchinskaja; 47, Liakhvi-Aragvinskaja; 48, Kakhetinskaja; 49, Dibrarskaja; 50, Akhtsu-Katsyrkha; 51, Dzhirkhva-Akhibokhskaja; 52, Tkvartcheli-Okribskaja; 53, Ratchinskaja; 54, Tsessi-Kortinskaja; 55, Iori-Tsitelitskarojskaja; 56, Vandamskaja; 57, Khramskaja; 58, Lalvarskaja; 59, Idzhevanskaja; 60, Dashkesano-Karabakhskaja; 61, Kafanskaja; 62, Nakhitchevanskaja.

Three main types of the palaeoenvironments were distinguished in general: continental, shallow-marine and deep-marine. Continental palaeoenvironments were usually documented by the hiatuses, while rarely by the subaeral deposits. Shallow-marine palaeoenvironments were interpreted by the presence of clastic or carbonate deposits, similar to those usually accumulated at a seashore or on a shelf. Deep-marine palaeoenvironments were traced mostly by the slope deposits (e.g., turbidites). In addition to lithology, also fossils, including plant remains, as well as sedimentological criteria, such as submarine slumps, concretions, etc., were used to determine the palaeoenvironments.

Special attention was paid to three time slices: the Late Toarcian, the Early Bajocian and the Middle Oxfordian, which all correspond to important phases in the evolution of the Caucasus. In the Late Toarcian, all the principal basins of the Caucasus were formed completely. The Early Bajocian and the Middle Oxfordian correspond to the time invervals after something like reorganizations of the Caucasian basins occurred, each following major regressions.

Maps showing the variety of the palaeoenvironments during these time slices were drawn for the Caucasus (Figs. 4A, 5A, 6A). They are attached to the present-day geography of the studied region. Therefore, the next step was to take into consideration the palaeotectonic reconstructions. In this paper, the reconstructions of LORDKIPANIDZE *et al.* (1984) were preferred, because they are based on reliable palaeomagnetic data. Additionally, the results of ERSHOV *et al.* (2003) were considered. Analyzing the composed maps of the palaeoenvironment distribution, attempt were made to recognize palaeogeographic elements (basins, arcs) highlighted by LORDKIPANIDZE *et al.* (1984), and, when necessary, correct their location. Then the verified and corrected information from the Caucasus was incorporated into the reconctructions for the entire Neotethys made by STAMPFLI & BOREL (2002) and GOLONKA (2004). Additionally, reconstructions made for the Pliensbachian by MEISTER & STAMPFLI (2000) became very helpful.

The final result, a set of the palaeogeographic sketches delineates what was the outline of the Caucasus at each of the studied time slices (Figs. 4B, 5B, 6B). They embrace the whole territory of the Caucasus and adjacent regions, including the Pontides, Moesia, Iranian terranes and the southern periphery of the Eurasia continent. Although these sketch-maps remain at a relatively low resolution and the position of landmasses (i.e., continents and islands) is schematic, they may help to fill the gap in our knowledge of the Jurassic palaeogeography of the Caucasus.

environments to the south of it correspond potentially to the Southern Transcaucasian Arc, i.e. another subduction zone. This arc is considered as the eastern edge of the Pontide structure (LORDKIPANIDZE *et al.,* 1984). In our palaeoenvironmental interpretation, there is no evidence to recognize the Lesser Caucasus Strait of the Tethys and the Nakhitchevan' Block, which were shown by LORDKIPANIDZE *et al*. (1984). Another basin, with the proposed name "the Exterior Caucasian Basin", might have been located between the Southern Transcaucasian Arc and the main subduction zone of the Northern Neotethys.

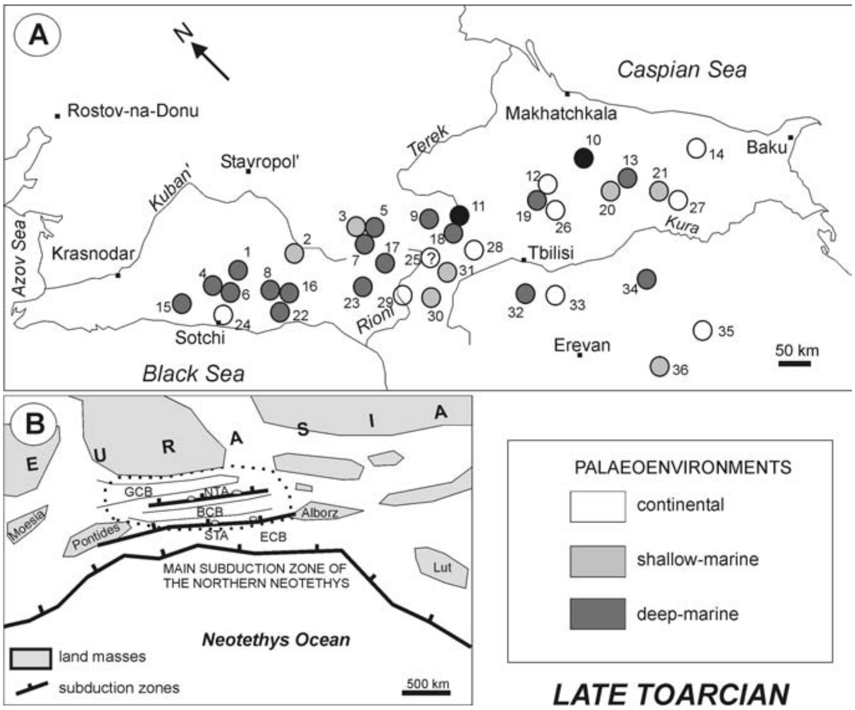

Fig. 4. The Late Toarcian palaeoenvironments (A) and the palaeogeographic outline (B) of the Caucasus (explanation of "zones" – Fig. 3A). "?" marks uncertainty in the interpretation of the continental palaeoenvironments, because of the doubtful establishment of hiatus. GCB, Greater Caucasus Basin, BCB, Black Sea – Caspian Sea Basin, ECB, Exterior Caucasian Basin, NTA, Northern Transcaucasian Arc, STA, Southern Caucasian Arc. The dotted line bounds the Caucasian Sea.

Reconstructions of the Jurassic outlines of the Caucasus

The Late Toarcian (~ 177 Ma)

Marine palaeoenvironments prevailed over most of the Caucasus in the Late Toarcian (Fig. 4A). In its northern part, dominating deep-marine environments trace the elongated basin, which may evidently correspond to the Greater Caucasus Basin of LORDKIPANIDZE *et al*. (1984). Perhaps its western part was the widest and deepest. Sporadic shallow-water environments to the south support the idea of the presence of the Northern Transcaucasian Arc (LORDKIPANIDZE *et al.,* 1984), related to the subduction zone. Moreover, there is no sound evidence for the presence of a large landmass there, as this is usually imagined (e.g., JASAMANOV, 1978). Presumably, only small islands might have been related to this arc.

Another deep basin is weakly delineated southwards, which may be related to the Black Sea – Caspian Sea Basin of LORDKIPANIDZE *et al*. (1984). Shallow-water

In the Late Toarcian outline of the Caucasus (Fig. 4B), a large sea, for which the name Caucasian Sea is proposed, opens towards the Neotethys Ocean. Wide straits between the landmasses to the west and east of this region entered this sea. The Caucasian Sea embraced two sedimentary basins, divided by a submarine mountain range, united perhaps to the west. Possibly, two archipelagoes consisting of very small islands which formed the Northern and Southern Transcaucasian Arcs characterized this sea. The boundary between the Caucasian Sea and the Neotethys Ocean stretched along the Southern Transcaucasian Arc. Our sketch-map suggests that the Exterior Caucasian Basin was embraced by the Neotethys Ocean.

The Early Bajocian (~ 171 Ma)

The Early Bajocian times were characterized by laterally variable palaeoenvironments within the Caucasus (Fig. 5A). Deep-marine environments trace the Greater Caucasus Basin, while shallow-water and continental

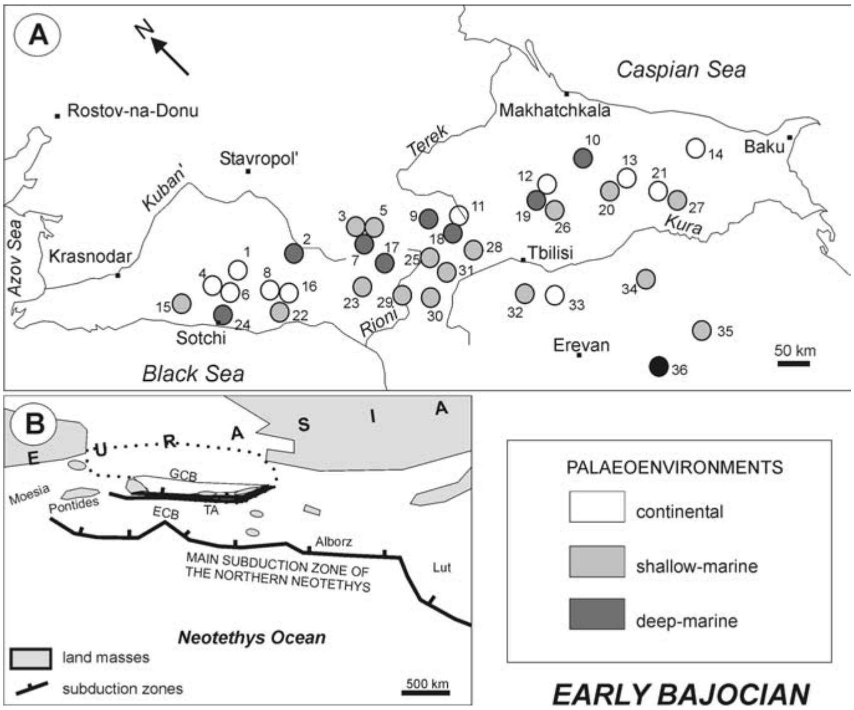

Fig. 5. The Early Bajocian palaeoenvironments (A) and the palaeogeographic outline (B) of the Caucasus (explanation of "zones" – Fig. 3A). GCB, Greater Caucasus Basin; ECB, Exterior Caucasian Basin; TA, Transcaucasian Arc. The dotted line bounds the Caucasian Sea.

environments delineate an island arc to the south, including relatively large islands. Intriguing was the landmass in the western part of the studied territory, where several continental deposits suggest large islands, which appeared as the result of the collision between Northern and Southern Transcaucasian Arcs, which closed the Black Sea – Caspian Sea Basin, generating a single Transcaucasian Arc. Palaeomagnetic data that highlight the presence of the Black Sea – Caspian Sea Basin in the Middle Jurassic appear doubtful (LORDKIPANIDZE *et al.* 1984). The Exterior Caucasian Basin was located between the Transcaucasian Arc and the main subduction zone of the Northern Neotethys. Some islands can be locally evidenced from continental palaeoenvironments.

The Early Bajocian outline of the Caucasus is presented in Fig. 5B. The studied territory was occupied by the Caucasian Sea. It was isolated from the Neotethys Ocean by the island archipelago of the Transcaucasian Arc. Connection between the sea and ocean was realized by straits between these islands, as well as landmasses, located to the west. From the north, the Caucasian Sea was opened to the large, but shallow interior sea, occuping a waste area of the Russian Platform. Only one sedimentary basin was embraced by this sea. The transgression resulted in the appearance of a very large shelf to the north of this basin, and the structure of the sea in the Early Bajocian was characterized by a strong asymmetry. The boundary between the Caucasian Sea and the Neotethys Ocean stretched along the Transcaucasian Arc. Our sketch-map suggests that the Exterior Caucasian Basin was embraced by the Neotethys Ocean. The islands occurring there might have been of volcanic origin and, therefore, related to the wide belt of intense magmatism to the north of the main subduction zone of the Northern Neotethys.

The Middle Oxfordian (~ 158 Ma)

During the Middle Oxfordian, the Caucasus was dominated by shallow-marine palaeoenvironments (Fig. 6A). Marine environments trace the Greater Caucasus Basin. The composed map does not permit the idea of LORDKIPANIDZE *et al.* (1984) about the complete separation of the Western and Eastern Subbasins and the presence of island between them, to be supported. We observed deep-marine environments in the western, central and eastern parts of the Greater Caucasus Basin. Nevertheless, the existence of islands at the western and eastern edges of the latter, hypothesized by LORKIPANIDZE *et al.* (1984) and also by GOLONKA (2004), is confirmed by our results, because continental palaeoenvironments were interpreted for those areas. Another island (or a chain of islands), delineated by the continental environments to the south, may be related to the Transcaucasian Arc. In contrast to LORDKIPANIDZE *et al.* (1984), no evidence for the presence of the Northern and Southern Transcaucasian Arcs, separated by the Black Sea – Caspian Sea Basin, was found. Therefore, it is hypothesized that in the Middle Oxfordian, a unique arc existed, as it was already in the Early Bajocian. However, this arc migrated southwards in comparison with the earlier time slices. Shallow-marine environments in the south of the studied territory are attributed to the Exterior Caucasian Basin.

The Middle Oxfordian outline of the Caucasus is presented in Fig. 6B. The studied territory was oc-

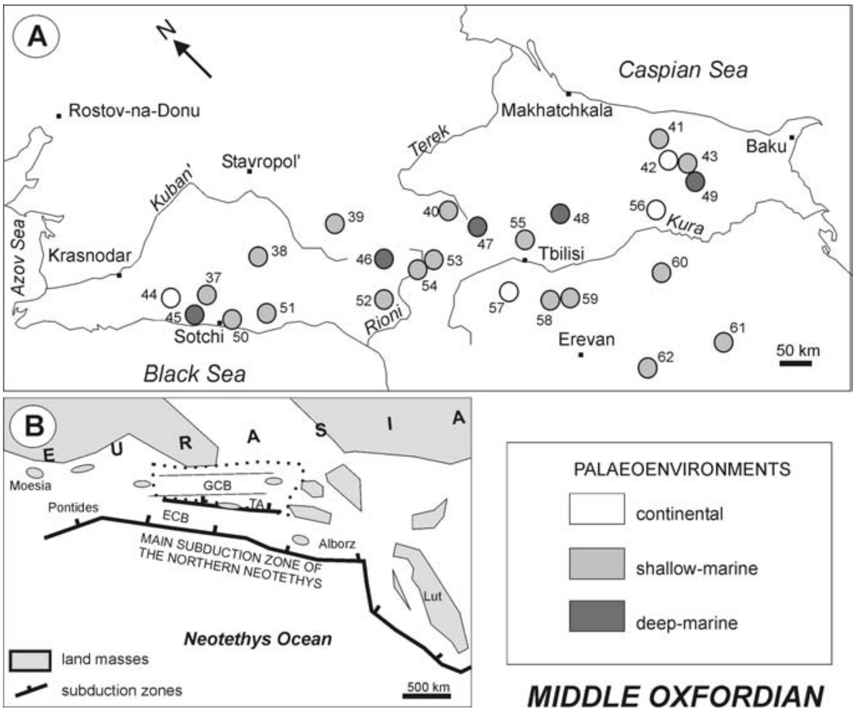

Fig. 6. The Middle Oxfordian palaeoenvironments (A) and the palaeogeographic outline (B) of the Caucasus (for an explanation of the "zones", see Fig. 3B). GCB, Greater Caucasus Basin; ECB, Exterior Caucasian Basin; TA, Transcaucasian Arc. Dotted line bounds the Caucasian Sea.

cupied by the Caucasian Sea. It was only a little isolated from the Neotethys Ocean by the above mentioned island and submarine mountain range of the Transcaucasian Arc. Straits between landmasses to the west and east of this sea also connected it with the Neotethys Ocean. From the north, the Caucasian Sea opened into the interior sea, as in the Early Bajocian, but its area was diminished. Only one sedimentary basin was embraced by this sea. A large shelf existed to the north-east of this basin. Thus, the sea basin in the Middle Oxfordian was characterized by strong asymmetry in its eastern part, but it was quite symmetric in its western part. The boundary between the Caucasian Sea and the Neotethys Ocean stretched along the Transcaucasian Arc. Our sketch-map suggests that the Exterior Caucasian Basin was embraced by the Neotethys Ocean.

A distinctive feature of the Late Jurassic of the Caucasian basins was the wide distribution of carbonate buildups (JASAMANOV, 1978; KHAIN, 1962; LORDKIPANIDZE *et al.,* 1984; KUZNETSOV, 1993; MARTIN-GARIN *et al.,* 2002; ROSTOVTSEV *et al.,* 1992; AKHMEDOV *et al.,* 2003; CECCA *et al.*, 2005; RUBAN, 2005). This coincided with the reef growth documented on the entire northern margin of the Neotethys Ocean (KIESSLING *et al.,* 1999; LEINFELDER *et al.,* 2002; MARTIN-GARIN *et al.,* 2002; OLIVIER *et al.,* 2004; CECCA *et al.,* 2005). The term "carbonate buildups" is preferred to that of "reefs", as they are traditionally called in Russian literature (e.g., JASAMANOV, 1978; KHAIN, 1962; ROSTOVTSEV *et al.,* 1992). SCHMID *et al.* (2001) mentioned the Caucasian buildups as mounds. The carbonate buildups are concentrated around the deepest parts of the Greater Caucasus Basin (Fig. 7). It is suggested that to the north, they developed on the outer shelf periphery, connected to the stable landmass of the Russian Platform, while in the south, they occupied the narrow outer shelf of the Transcaucasian Arc. However, some buildups were also found crossing the basin, suggesting atolls, isolated or in groups, characterizing the Late Jurassic Caucasian Sea and Exterior Caucasian Basin. In general, the distribution of the carbonate buildups was tectonically controlled (KHAIN, 1962; AKHMEDOV *et al.,* 2003).

Discussion

The presented palaeogeographic sketch maps suggest that during the Jurassic, the Caucasian Sea was located between the Eurasian landmass and large and little islands (Figs. 4B, 5B, 6B). A string of large islands located west- and eastwards were the result of accretion of small terranes along the subducted margin of the northern Neotethys. Straits between these small landmasses made a connection with the Caucasian Sea possible. Together they were able to form an important seaway that stretched along the southern periphery of Eurasia. The tectonic origin of this Exterior Caucasian seaway is very different from thopse of the well-known Hispanic Corridor and the Viking Corridor, the results of break-up of continents (HALLAM, 1983; SMITH & TIPPER, 1986; RICCARDI, 1991; WESTERMANN, 1993; ABERHAN, 2001). It also differed from the other seaways, lsuch as the Cretaceous Western Interior Seaway

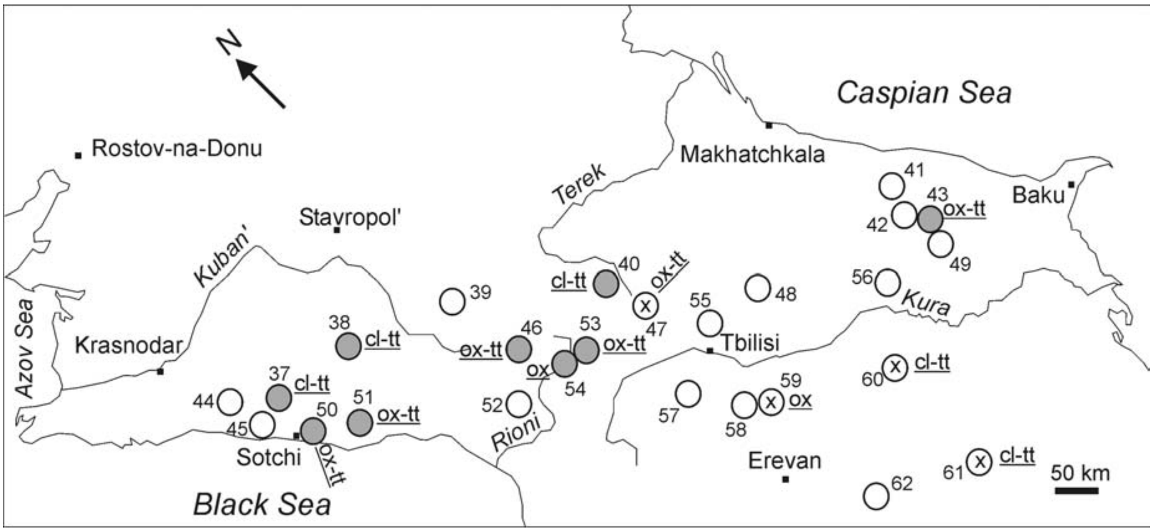

Fig. 7. The location of the Callovian-Tithonian carbonate buildups in the "zones" of the Caucasus (data was extracted from ROSTOVTSEV *et al.* (1992); for the western part of the Caucasus, it was supported by personal field observations) (for an explanation of the "zones", see Fig. 3B). "Zones" where carbonate buildups were evidently documents are highlighted as gray, while "zones" where only coral founds are known are marked by x. The age of buildup- or coral-bearing deposits is indicated.

in North America (REYNOLDS & DOLLY, 1983; SAGEMAN & ARTHUR, 1994; ROBERTS & KIRSCHBAUM, 1995; WHITE *et al.,* 2001, 2002).

The western branches of this seaway included the oceanic basins of the Western Neotethys, such as the Meliata, Maliac, Pindos and Vardar, as well as the Alpine Tethys which opened during the Jurassic (STAMPFLI & BOREL, 2002; BROWN & ROBERTSON, 2004; GOLONKA, 2004). The central part of the seaway consisted of straits separating the blocks of Moesia, Rhodope and Western Pontides. Further east, the seaway communicated with the small Izmir-Ankara Ocean (STAMPFLI & BOREL, 2002). It was directly connected with the Caucasian Sea. The eastern branches of the mentioned seaway extended as straits between the Alborz, South Caspian, Aghdarband, Herat and other terranes of the central part of the northern Neotethyan margin (GOLONKA, 2004). STAMPFLI & BOREL (2002) additionally placed the so-called South Caspian Ocean eastwards of the Caucasus, which seems to be a fragment of the seaway. The latter ended in two branches, as is suggested from the palaeoreconstructions of GOLONKA (2004). Northwards, the seaway connected the basin between the Turan, Herat and Pamirs landmasses, while southwards it led directly to the Neotethys Ocean.

Conclusions

This study of the Jurassic palaeogeography of the Caucasus allows the formulation of some important conclusions:

1) the Caucasian Sea occupied most, although not all, of the studied area during the entire Jurassic;

2) in the Late Toarcian, the Caucasian Sea embraced most of the Caucasus, including the Greater Caucasus Basin and the Black Sea – Caspian Sea Basin, and was opened to the Neotethys Ocean, which covered the Exterior Caucasian Basin;

3) in the Early Bajocian, the Caucasian Sea comprised the Greater Caucasus Basin, it opened to the epicontinental seas of the Russian Platform, and it was connected with the Neotethys Ocean by the straits between islands of the Transcaucasian Arc;

4) in the Middle Oxfordian, the Caucasian Sea also covered the Greater Caucasus Basin and was open to both the epicontinental sea of the Russian Platform and the Neotethys Ocean;

5) during the Jurassic, the Caucasus was included in the long seaway, which stretched along the northern margin of the Neotethys.

Further studies are necessary to verify and detalize the very simple palaeogeographic reconstructions proposed in this paper. A significant task is the collection of data on the carbonate buildups, which has already been made for the Azerbaijanian part of the Caucasus (AKHMEDOV *et al.*, 2003). These data will help to delineate the Late Jurassic carbonate platform. Special attention should also be paid to the high-resolution palaeotectonic interpretations.

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References

ABERHAN, M., 2001. Bivalve palaeobiogeography and the Hispanic Corridor: time of opening and effectiveness of a proto-Atlantic seaway. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 165: 375–394.

AKHMEDOV, A.K., BABAYEV, R.G. & MAMEDOV, I.I., 2003. Towards the distribution of the surficial and buried Mesozoic organogenous buildups in Azerbaijan. *Azerbaijan National Academy of Sciences. Proceedings. The Sciences of Earth,* 1: 71–77. (in Russian)

ALLEN, M.B., VINCENT, S.J., ALSOP, G.I., ISMAIL-ZADEH, A. & FLECKER, R., 2003. Late Cenozoic deformation in the South Caspian region: effects of a rigid basement block within a collision zone. *Tectonophysics,* 366: 223–239.

BROWN, S.A.M. & ROBERTSON, A H.F., 2004. Evidence for Neotethys rooted within the Vardar suture zone from the Voras Massif, northernmost Greece. *Tectonophysics,* 381: 143–173.

CARIOU, E. & HANTZPERGUE, P. (eds.), 1997. Biostratigraphie du Jrassique ouest-européen et méditerranéen: zonations parallèles et distribution des invertébrés et microfossiles. *Bulletin du Centre Recherche Elf Exploration et Production*, 17: 1–440.

CECCA, F., MARTIN GARIN, B., MARCHAND, D., LATHUILIERE, B. & BARTOLINI, A., 2005. Palaeoclimatic control of biogeography and sedimentary events in Tethyan and peri-Tethyan areas during the Oxfordian (Late Jurassic). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 222: 10–32.

DOMMERGUES, J.-L., 1987. L'evolution chez les Ammonitina du Lias moyen (Carixien, Domerien basal) en Europe occidental. *Documents du Laboratoire de Géologie de Lyon,* 98: 1–297.

EFENDIYEVA, M.A. & RUBAN, D.A., 2005. Anoxia, disoxia and euxinia in Mesozoic-Cenozoic basins of the Caucasus. *Azerbaijan Oil Industry*, 8: 7–14 (in Russian).

ERSHOV, A.V., BRUNET, M.-F., NIKISHIN, A.M., BOLOTOV, S.N., NAZAREVICH, B.P. & KOROTAEV, M.V., 2003. Northern Caucasus basin: thermal history and synthesis of subsidence models. *Sedimentary Geology*, 156: 95–118.

GOLONKA, J., 2004. Plate tectonic evolution of the southern margin of Eurasia in the Mesozoic and Cenozoic. *Tectonophysics*, 381: 235–273.

GRADSTEIN, F.M., OGG, J.G., SMITH, A.G., AGTERBERG, F.P., BLEEKER, W., COOPER, R.A., DAVYDOV, V., GIBBARD, P., HINNOV, L.A., HOUSE, M.R., LOURENS, L., LUTERBACHER, H.P., MCARTHUR, J., MELCHIN, M.J., ROBB, L.J., SHERGOLD, J., VILLENEUVE, M., WARDLAW, B.R., ALI, J., BRINKHUIS, H., HILGEN, F.J., HOOKER, J., HOWARTH, R.J., KNOLL, A.H., LASKAR, J., MONECHI, S., PLUMB, K.A., POWELL, J., RAFFI, I., ROHL, U., SADLER, P., SANFILIPPO, A., SCHMITZ, B., SHACKLETON, N.J., SHIELDS, G.A., STRAUSS, H., VAN DAM, J., VAN KOLFSCHOTEN, T., VEIZER, J. & WILSON, D., 2004. *A Geologic Time Scale 2004*. Cambridge University Press, Cambridge, 589 pp.

HALLAM, A., 1983. Early and mid-Jurassic molluscan biogeography and the establishment of the central Atlantic seaway. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 43: 181–193.

JASAMANOV, N.A., 1978. *Landscape and climatic conditions of the Jurassic, Cretaceous and Paleogene of the South USSR*. Nedra, Moskva, 224 pp. (in Russian).

KIESSLING, W., FLUEGEL, E. & GOLONKA, J., 1999. Paleoreef maps: evaluation of a comprehensive database on Phanerozoic reefs. *American Association of Petroleum Geologists, Bulletin*, 83: 1552–1587.

KHAIN, V.E., 1962. Rify i tektonika. *In*: OBUT, A.M. (ed.), *Znatchenije biosfery v geologitcheskikh protsessakh. Voprosy vzaimosvjazi paleontologii i tektoniki*, 162–170. Gosgeoltekhizdat, Moskva (in Russian).

KUZNETSOV, V.G. 1993. Late Jurassic – Early Cretaceous carbonate platform in the northern Caucasus and Precaucasus. *In*: SIMO, J.A.T., SCOTT, R.W. & MASSE, J.-P. (eds.), *Cretaceous Carbonate Platforms*. American Association of Petroleum Geology, Memoirs, 56: 455–463.

LEINFELDER, R.R., SCHMID, D.U., NOSE, M. & WERNER, W., 2002. Jurassic reef patterns: the expression of a changing globe. *In*: KIESSLING, W., FLUEGEL, E. & GOLONKA, J. (eds.), *Phanerozoic reef patterns*. SEPM Special Publication, 72: 465–520.

LORDKIPANIDZE, M.B., ADAMIA, SH.A. & ASANIDZE, B.Z., 1984. Evolution of the active margins of the Tethys Ocean. *In*: LISITSIN, A.P. (ed.), *Paleookeanologija. Doklady 27 Mezhdunarodnogo geologitcheskogo kongressa*, 72–83. Nauka, Moskva. (in Russian).

MARTIN-GARIN, B., LATHUILIERE, B. & GEISTER, J., 2002. Recifs, coraux et climats oxfordiens de la Tethys. *Documents du Laboratoire de Géologie de Lyon*, 156: 154–155.

MEISTER, C. & STAMPFLI, G., 2000. Les ammonites du Lias moyen (Pliensbachien) de la Néotéthys et des ses confins: compositions faunique, affinités paléogéographiques et biodiversité. *Revue de Paléobiologie,* 19: 227–292.

OLIVIER, N., CARPENTIER, C., MARTIN-GARIN, B., LATHUILIÈRE, B., GAILLARD, C., FERRY, S., HANTZPERGUE, P. & GEISTER, J., 2004. Coral-microbialite reefs in pure versus mixed carbonate–siliciclastic depositional environments: the example of the Pagny-sur-Meuse section (Upper Jurassic; northeastern France). *Facies*, 50: 229–255.

REYNOLDS, M.W. & DOLLEY, E.D. (eds.), 1983. *Mesozoic paleogeography of the west-central United States*. Rocky Mountain Section, Society for Sedimentary Geology, Denver, CO, 391 pp.

RICCARDI, A.C., 1991. Jurassic and Cretaceous marine connections between the southeast Pacific and Tethys. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 87: 155–189.

ROBERTS, L.N.R. & KIRSCHBAUM, L.A., 1995. Paleogeography of the Late Cretaceous of the Western Interior of Middle North America – Coal distribution and sediment accumulation. *United States Geological Survey, Professional Papers*, 1561: 1–115.

ROSTOVTSEV, K.O., AGAJEV, V.B., AZARJAN, N.R., BABAJEV, R.G., BEZNOSOV, N.V., GASANOV, N.A., ZASASCHVILI, V.I., LOMIZE, M.G., PAITCHADZE, T.A., PANOV, D.I., PROSOROVSKYA, E.L., SAKHAROV, A.S., TODRIA, V.A., TOPTCHISCHVILI, M.V., ABDULKASUNZADE, M.R., AVANESJAN, A.S., BELENKOVA, V.S., BENDUKIDZE, N.S., VUKS, V.JA., DOLUDENKO, M.P., KIRITCHKOVA, A.I., KLIKUSCHIN, V.G., KRYMHOLZ, G.JA., ROMANOV, G.M. & SCHEVTCHENKO, T.V., 1992. *Jurassic of the Caucasus*. Nauka, Sankt-Peterburg, 192 pp. (in Russian).

RUBAN, D.A., 2003. A correction of the Jurassic of the Northern Caucasus with brachiopods. *Izvestija Vysshikh Utchebnykh Zavedenij. Severo-Kavkazskij region. Estestvennyje nauki*, 4: 78–79 (in Russian).

RUBAN, D.A., 2004. Diversity dynamics of Early-Middle Jurassic brachiopods of Caucasus, and the Pliensbachian-Toarcian mass extinction. *Acta Palaeontologica Polonica,* 49: 275–282.

RUBAN, D.A., 2005. Rises of the macrobenthos diversity and the Paleozoic – Mesozoic rimmed shelves in the northern Caucasus. *The First International Scientific Conference of Young Scientists and Students: "New Directions of Investigations in Earth Sciences". Abstracts*. Baku.

RUBAN, D.A., 2006. Taxonomic diversity dynamics of the Jurassic bivalves in the Caucasus: regional trends and recognition of global patterns. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 239: 63–74..

RUBAN, D.A. & TYSZKA, J., 2005. Diversity dynamics and mass extinctions of the Early-Middle Jurassic foraminifers: A record from the Northwestern Caucasus. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 222: 329–343.

SAGEMAN, B.B. & ARTHUR, M.A., 1994. Early Turonian paleogeography/paleobathymetry of the Western Interior Seaway. *In*: CAPUTO, M.V., PETERSON, J.A. & FRANCZYK, K.J. (eds.), *Mesozoic Systems of the Rocky Mountain Region*, 460–469. Rocky Mountain Section, Society for Sedimentary Geology, Denver, CO.

SAINTOT, A. & ANGELIER, J., 2002. Tectonic paleostress fields and structural evolution of the NW-Caucasus fold-and-thrust belt from the Late Cretaceous to the Quaternary. *Tectonophysics,* 357: 1–31.

SCOTESE, C.R., 2004. A Continental Drift Flipbook. *Journal of Geology*, 112: 729–741.

SCHMID, D.U., LEINFELDER, R.R. & NOSE, M., 2001. Growth dynamics and ecology of Upper Jurassic mounds, with comparisons to Mid-Palaeozoic mounds. *Sedimentary Geology*, 145: 343–376.

SMITH, P.L. & TIPPER, H.W., 1986. Plate Tectonics and Paleobiogeography: Early Jurassic (Pliensbachian) Endemism and Diversity. *Palaios*, 1: 399–412.

STAMPFLI, G.M. & BOREL, G.D., 2002. A plate tectonic model for the Paleozoic and Mesozoic constrained by dynamic plate boundaries and restored synthetic oceanic isochrons. *Earth and Planetary Science Letters*, 196: 17–33.

UHLIG, W., 1911. Die marinen Reiche des Jura und der Unterkreide. *Mitteilungen der Geologischen Gesellschaft, Wien*, IV: 229–448.

WESTERMANN, G.E.G., 1993. Global bio-events in mid-Jurassic ammonites controlled by seaways. *In*: HOUSE, M.R. (ed.), The *Ammonoidea: Environment, Ecology and Evolutionary Change*. The Systematics Association, Special Volume, 47: 187–226.

WESTERMANN, G.E.G., 2000. Marine faunal realms of the Mesozoic: review and revision under the new guidelines for biogeographic classification and nomenclature. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 163: 49–68.

WHITE, T., GONZÁLEZ, L., LUDVIGSON, G. & POULSEN, C., 2001. Middle Cretaceous greenhouse hydrologic cycle of North America. *Geology,* 29: 363–366.

WHITE, T., FURLONG, K. & ARTHUR, M., 2002. Forebulge migration in the Cretaceous Western interior basin of the central United States. *Basin Research*, 24: 43–54.

Резиме

Палеогеографски оквири Кавказа у Јури: Кавкаско море и Неотетиски океан

Кавказ представља пространу издужену област између Црног мора и Каспијског језера, која обухвата југоисточну Русију и целу Грузију, Јерменију и Азербејџан. Ова област се за време јуре налазила на северном ободу Неотетиског океана и представљала је "главни" прелаз између западног и средњег дела северног Неотетиса. Ранија тумачења њене палеогеографије су застарела и често засснована на погрешним схватањима. Овај рад је покушај да се реконструишу палеогеографски оквири Кавказа у три временска раздобља – горњи тоар, доњи бајес и средњи оксфорд. Територија Кавказа је подељена на 62 посебне области, које се традиционално називају "зонама". За сваку зону је дато тумачење палеосредине свих формација и то континентална, плитководна и дубоководна палеосредина за поменута временска раздобља. Анализом карата распореда палеосредина утврђени су палеогеографски елементи података за Кавказ у реконструкције читавог Неотетиса. Као коначни резултат добијен је скуп палеогеографских скица које дају контуру Кавказа из свих проучаваних раздобља.

У горњем тоару (око 177 Ма), пространо море, за које се предлаже назив Кавкаско море, отварало се према Неотетиском океану. У ово море су залазили широки мореузи између копна са западне и источне стране ове области. Кавкаско море је обухватало два седиментациона басена, раздвојена подводним планинским ланцем, који су се можда спајали на западу. То море су вероватно карактерисала два архипелага врло малих острва која су образовала северни и јужни транскавкаски лук. Граница између Кавкаског мора и Неотетиског океана протезала се дуж јужног транскавкаског лука. Спољашњи, јужни кавкаски басен био је опкољен Неотетиским океаном.

У доњем бајесу (око 171 Ма) проучавану територију је заузимало Кавкаско море. Оно је било одвојено од Неотетиског океана архипелагом транскавкаског лука. Веза између мора и океана остваривала се мореузима између острва и копна на западу.

На северу се Кавкаско море отварало према великом али плитком унутрашњем мору које је заузимало пространу област руске платформе. То унутрашње море је обухватало само један седиментациони басен. Резултат трансгресије је формирање великог шелфа на северу басена, а структура мора се у доњем бајесу карактерисала великом асиметријом. Граница између Кавкаског мора и Неотетиског океана, као и у претходном случају, протезала се дуж транскавкаског лука. Спољни басен је био обухваћен Неотетиским океаном. Острва која су тамо постојала могла су бити вулканског порекла, па су према томе у вези са широким појасом интензивног магматизма северно од главне зоне подвлачења северног Неотетиса.

У средњем оксфорду (око 158 Ма) је проучавана територија још увек била под Кавкаским морем. Била је само мало изолована од Тетиског океана поменутим подморским планинским ланцем транскавкаског лука. Мореузи између копна западно и источно од овог мора такође су га повезивала са Неотетиским океаном. Са севера се Кавкаско море отварало према унутрашњем мору као и у доњем бајесу, али се његова површина смањила. Море је обухватало само један седиментациони басен. Велики шелф је постојао на североистоку басена. Тако се морски басен у средњем оксфорду карактерисао великом асиметријом у источном делу, али му је западни део био доста симетричан. Граница између Кавкаског мора и Неотетиског океана протезала се дуж транскавкаског лука. Схематска карта указује да је спољашњи кавкаски басен био обухваћен Неотетиским океаном.

Широка распрострањеност карбонатних наслага представља значајну карактеристику кавкаских басена горње јуре. Током јуре је створен морски пролаз дуж обода Неотетиса, а Кавкаско море је постало његов значајни део. Западни огранци овог морског пролаза обухватили су океанске басене западног Неотетиса као што су Мелиата, Малиак, Пинд и Вардар као и алпски Тетис. Средњи део морског пролаза састојао се од мореуза који су раздвајали блокове Мезије, Родопа и западних Понтида. Даље на исток морски пролаз је био у вези са малим Измирско-анкарским океаном, који је био директно повезан са Кавкаским морем. Источни огранци морског пролаза настављали су се у мореузе између Алборза, јужног Каспија, Агдарбанда, Херата и других терана средњег дела северног обода Неотетиса. Такозвани Јужни каспијски океан источно од Кавказа је по свој прилици представљао део басена између туранског, херaтског и памирског копна, док је на југу водио директно у Неотетиски океан.