Геолошки анали Балканскога полуострва Annales Géologiques de la Péninsule Balkanique	71	1–12	Београд, децембар 2010 Belgrade, December 2010

DOI: 10.2298/GABP1071001R

Do major Neogene hiatuses in the Ciscaucasian semi-enclosed basin (Eastern Paratethys, southwestern Russia) record eustatic falls?

Dmitry A. Ruban[1], Michael Rogerson[2] & H. Martyn Pedley[2]

Abstract. Hiatuses in semi-enclosed basins can be caused by either eustatic falls or local tectonic uplifts. The Ciscaucasian basin is located in the south of European Russia. In the Neogene, it belonged to the Eastern Paratethys domain. On the basis of available stratigraphic data, four major hiatuses are traced in this basin as erosional surfaces or lengthy sedimentation breaks, namely the Tarkhanian, Middle/Upper Sarmatian, Sarmatian/Maeotian, and Kimmerian hiatuses. They are documented in most of the areas of the study basin. The three earlier hiatuses mark short-term and nearly isochronous, basinwide sedimentation breaks, whereas the latter hiatus is diachronous, embracing more than 2 myr. All reported hiatuses record the eustatic falls. Consequently, we argue that eustatic processes controlled sedimentation in the Ciscaucasian basin throughout the entire Neogene. This means the basin was connected to the open ocean throughout this period, with important consequences for our understanding of watermass history in the Mediterranean and Paratethyan basins further west and south.

Key words: hiatus, stratigraphic correlation, eustatic fall, glaciation, Neogene, Ciscaucasian basin, Eastern Paratethys.

Апстракт. Хијатуси код полузатворених базена могу настати еустатитичким падовима или тектонским издизањем. Предкавкаски базен се налази на југу европског дела Русије. У неогену базен је припадао Источном Тетису. На основу расположивих стратиграфских података четири главна хијатуса су уочена у овом базену, било као ерозионе површине или дужи седиментациони прекиди: тархански, средње/горње сарматски, сарматски/меотски и кимеријски. Они су доказани на више места проучаваног базена. Прва три хијатуса су означени кратким, приближно изохроним и широким седиментационим прекидима, док је задњи хијатус дијахрон, трајао је више од 2 милиона година. Сви поменути хијатуси указују на еустатичке падове. То је био разлог да докажемо да у Предкавкаском базену еустатички процеси контролишу седиментацију кроз цео неоген и да је базен био у вези са отвореним океаном за време тог периода. Ови подаци објашњавају распрострањење водених површина у западним и јужним деловима медитеранских и паратетиских базена за време неогена.

Кључне речи: хијатус, стратиграфска корелација, еустатички пад, глацијација, неоген, Предкавкаски басен, Источни Паратетис.

Introduction

The Paratethys was a major palaeogeographical domain, consisting of a constellation of small sedimentary basins. During the Cenozoic, it stretched from the Alps in the west to the Caspian Sea in the east. The basins were isolated partially from the Mediterranean by the tectonic uplift associated with the Alpine Orogeny, with important consequences for their watermass history and palaeoecology (Rögl & Steininger 1983; Rögl 1996, 1998, 1999; Steininger & Wessely 1999; Golonka 2004; Popov *et al*. 2006, 2010; Krijgsman *et al*. 2010). Traditionally, the Paratethys is subdivided into three parts; Western, Central and Eastern (Fig. 1). Due to their peripheral connection with the World Ocean and with the Mediterranean

[1] Division of Mineralogy and Petrography, Geology and Geography Faculty, Southern Federal University, Zorge Street 40, Rostov-na-Donu, 344090, Russian Federation. E-mails: ruban-d@mail.ru; ruban-d@rambler.ru

[2] Department of Geography, University of Hull, Cottingham Road, Hull, HU6 7RX, United Kingdom. E-mails: m.rogerson@hull.ac.uk; h.m.pedley@hull.ac.uk

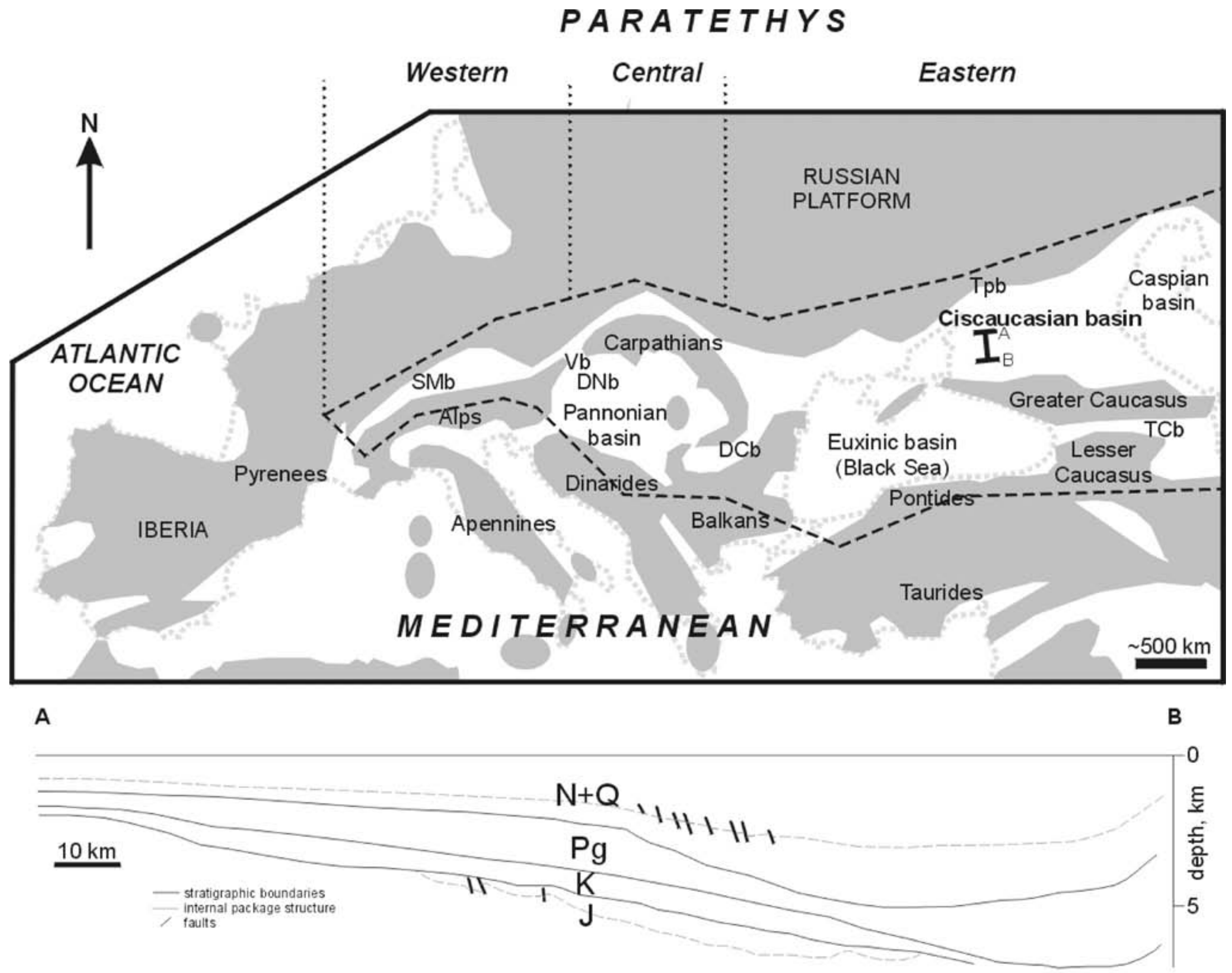

Fig. 1. Sedimentary basins of the Paratethys (modified after Rögl & Steininger 1983; Steinenger & Wessely 1999; Golonka 2004). Land masses are shown as grey. Abbreviations: **SMb,** Swiss Molasse basin; **Vb,** Vienna basin; **DNb,** Danube basin; **DCb,** Dacian basin; **Tpb,** Tanais palaeobay (Rostov Dome); **TCb,** Transcaucasian basin. The cross-section through the western part of the Ciscaucasian Basin is simplified strongly from Popov *et al.* (2010).

(e.g., Popov *et al.* 2006; Krijgsman *et al.* 2010), Paratethyan basins offered an environment in which eustatic signals, particularly those encompassing the onset and duration of the so-called "Messinian Salinity Crisis", may be amplified within sedimentary successions. However, these successions may also have been modified by local tectonic activity.

Despite decades of research, the Eastern Paratethys has remained relatively poorly-known within the international audience and reviews of Paratethyan basin evolution have been overwhelmingly concerned with the Western and Central parts (Sissingh 2001; Berger *et al.* 2005; Harzhauser & Mandic 2008; Harzhauser *et al.* 2008; Lirer *et al.* 2009). Publications by Ruban (2005), Popov *et al.* (2006), and Krijgsman *et al.* (2010) are amongst the minority of papers within the international scientific press specifically concerned with the Eastern sub-basins. Nevertheless, this region may provide some important clues to the understanding of basinwide environmental changes during the Neogene. For example, so long as the connection between the Mediterranean and Eastern Paratethys remained open, the net precipitative flux in the Caucasian region, which receives up to 3,000 mm precipitation per year today, is likely to have been large enough to alter the degree of salinification of Mediterranean water. Consequently, before the Messinian Salinity Crisis can be understood mechanistically, it is critical that the presence/absence and magnitude of freshwater supply from the Eastern Paratethys to the Mediterranean is established (Meijer & Krijgsman 2005; Krijgsman *et al.* 2010).

During the Neogene, the Earth experienced a series of glaciations and tectonic events (Kennett 1977; Zachos *et al.* 2001; Smith & Pickering 2003; Gornitz 2009), which resulted in a complicated chain of eustatic changes (Haq *et al.* 1987; Haq & Al-Qahtani 2005; Miller *et al.* 2005; Kominz *et al.* 2008).

Investigating evidence for the presence or absence of their signatures in the semi-enclosed Ciscaucasian basin therefore provides the empirical test for the connection of these basins to the World Ocean via the Mediterranean, and consequently the first direct indicator that these basins were a potential source of freshwater to the Mediterranean during the Messinian. This effort is in analogy to a previous study in Japan, where Hiroki (1995) and Hiroki & Matsumoto (1999, 2003) investigated eustatic signals within the Miocene sequence boundaries in central Honshu. Despite the complexity of the tectonic setting of Japan, which does drive some local differences between basins, a number of common surfaces were recognized as being traceable through the entire region, and positive shifts in $\delta^{18}O$ that occurred synchronously with these relative sea level falls suggesting a relation to the phases of growth of the Antarctic ice sheet, and consequently to eustasy. The accumulation of deposits of the Pleistocene Atsumi Group, which occurred in the tectonically-active region, was also controlled by the eustatic fluctuations (Hiroki & Kimiya 1990).

This paper is aimed at tracing major hiatuses in the Neogene sedimentary successions of the Ciscaucasian basin, which represents the central component basin of the Eastern Paratethys, with the intention of testing the degree of connectivity with the World Ocean. Eustasy and local tectonic activity are two important controls on the basinwide depositional settings (Catuneanu 2006). In the case of a basin positioned within the foreland of an active collisional zone, the local tectonics may reasonably be expected dominate the basin evolution. The main Caucasian orogeny started in the Greater Caucasu in the Paleogene, and accelerated from the mid-Sarmatian, i.e., early Tortonian (Ershov *et al*. 2003). Saintot *et al*. (2006) prescribes the Sarmatian tectonic pulse as the crucial event for the evolution of the entire region. This tectonic activity would definitely result in the development of major hiatuses spread across the entire Ciscaucasian basin or, at least in its southern areas. Should major changes in sedimentation coincide with major changes in eustatic sea level, this would confirm that the basin history is dominated by global (largely climatic) rather than local (largely tectonic) influences. If no coincidence can be shown, then the opposite conclusion may be drawn. The knowledge of hiatuses is therefore crucial to link regional sedimentation breaks with global environmental perturbations in this area.

Geologic setting

The Ciscaucasian basin is a typical foreland basin, which formed between the emergent Greater Caucasus in the south, which was probably rising during the period of interest of this study, and the stable Russian Platform in the north (Ershov *et al*. 2003; Saintot *et al*. 2006). As in the case of other Paratethyan basins, its origin and tectonic evolution were both related closely with the Alpine Orogeny (Golonka 2004). In the Neogene, the Ciscaucasian basin was wide and had an asymmetrical profile, with its deepest part located close to the island of the Greater Caucasus (i.e. in the south). The Ciscaucasus basin was connected with the Euxinic basin in the west and the Caspian basin in the east (Nevesskaja *et al*. 1984; Popov *et al*. 2006, 2010; Fig. 1).

The Neogene deposits vary in time and space within the Ciscaucasian basin. Sandstones, siltstones, and shales are dominating lithologies, whereas carbonates (including bioclastic limestones), conglomerates, diatomites, and other sedimentary rocks are also known. On the basis of lithology and facies, 17 areas are distinguished within this basin (Nevesskaja *et al*. 2004, 2005; Fig. 2). Each area represents a peculiar

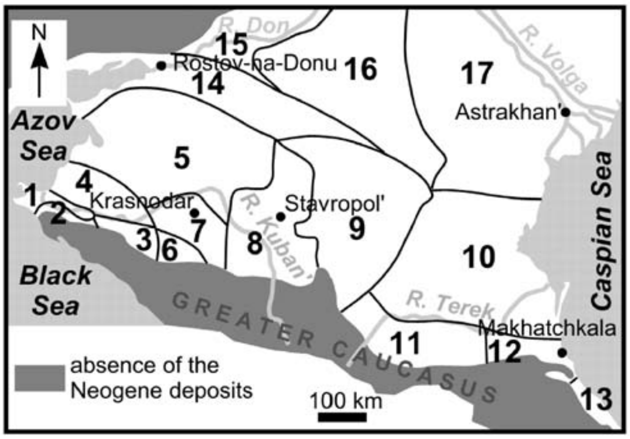

Fig. 2. Areas of the Ciscaucasian basin considered in this study. **1,** Taman'-Adagum; **2,** Anapa-Gladkovskaja; **3,** Afips-Pshekha; **4,** northern Western Kuban'; **5,** Western Ciscaucasus; **6,** Adygeja; **7,** northeastern Eastern Kuban'; **8,** western Central Ciscaucasus; **9,** eastern Central Ciscaucasus; **10,** Eastern Ciscaucasus; **11,** northeastern Eastern Caucasus; **12,** central Eastern Caucasus; **13,** southeastern Eastern Caucasus; **14,** Rostov Dome and Manytch; **15,** Nizhnij Don; **16,** Ergeni; **17,** Ciscaspian area (after Nevesskaja *et al*. 2004, 2005). Data on the Rostov Dome are taken from Ruban (2002, 2005).

Neogene sedimentary succession. The total thickness of Neogene deposits reaches up to 5700 m, and both short-term hiatuses (documented as erosional surfaces) and long-term hiatuses (represented by unconformities) occur within the succession (Fig. 3). The Neogene depositional environments in the Ciscaucasian basin did not remain constant. The position of the shoreline fluctuated significantly alongside the basin depth (Popov *et al*. 2010). Palaeoecological studies (Ilyina *et al*. 1976; Nevesskaja *et al*. 1984, 1986; Popov *et al*. 2006) also suggested significant changes in salinity of the Eastern Paratethys. Although these

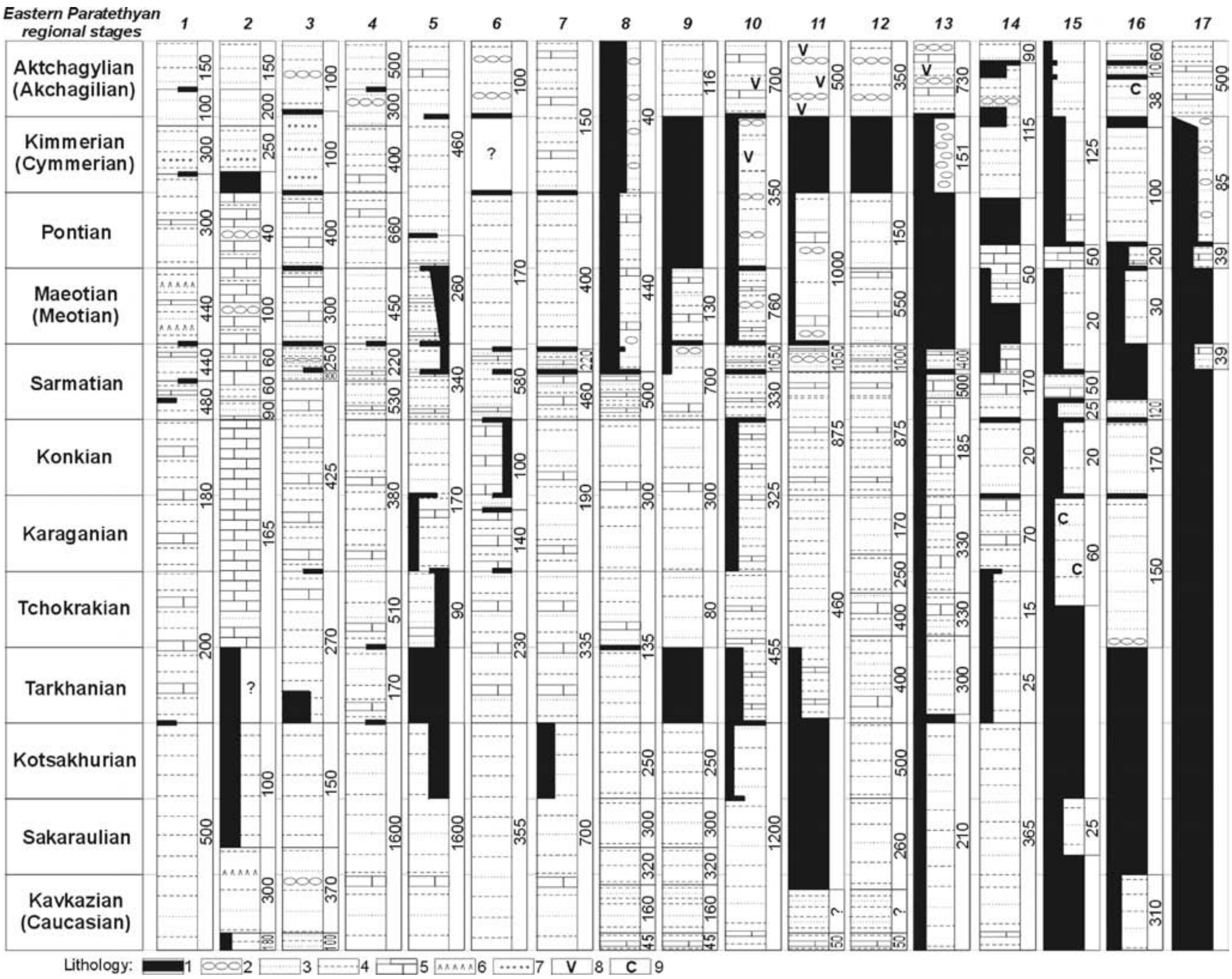

Fig. 3. Generalized composite sections of the Neogene deposits of the Ciscaucasian basin (data extracted from Nevesskaja *et al*. 2004). See Fig. 2 for explanation of area numbers. Maximum thickness (m) of the main stratigraphic units is given along each lithologic column. Lithology: **1,** hiatuses; **2,** conglomerates; **3,** sandstones and siltstone; **4,** shales; **5,** carbonates; **6,** siliceous rocks; **7,** iron-rich rocks; **8,** volcanics and volcaniclastics, **9,** coals.

changes occurred cyclically, a general trend towards a decrease in salinity can be traced. Undoubtedly, this is linked with a more or less gradual isolation of the Eastern Paratethys from both the Mediterranean and the other Paratethyan counterparts.

Neogene lithostratigraphy of the Ciscaucasian basin is summarized by Nevesskaja *et al*. (2004, 2005), who re-evaluated the available information, and defined or re-defined formations and groups. The ages of these lithostratigraphic units are established on the basis of bivalves, foraminifera, mammals, ostracods, calcareous nannoplankton, and other palaeontological data, and thus is based on published frameworks for the regional stages of the Eastern Paratethys (Rögl 1996; Steininger 1999; Nevesskaja *et al*. 2004, 2005; Popov *et al*. 2006; Ruban 2009). Correlation of regional and global stages remains uncertain, however, because of poor biostratigraphic control of the correlation between the Eastern Paratethyan region framework and global chronostratigraphy (see discussions in Krijgsman *et al*. 2010). Detailed correlation between global chronostratigraphic stages fixed by Gobal Stratotype Sections and Points (Gradstein *et al*. 2004; Ogg *et al*. 2008) and the Neogene succession of the Eastern Paratethys remains an objective for further studies. Meanwhile, absolute dating of regional stage boundaries Chumakov *et al*. (1992a, b) is the primary basis of correlation of existing regional and global stages (Ruban 2005, 2009; Fig. 4). New results obtained by Krijgsman *et al*. (2010) facilitate this correlation significantly.

Materials and methods

We use the dataset compiled by Nevesskaja *et al*. (2004) as the basis for tracing major hiatuses in the Neogene sedimentary successions of the Ciscaucasian basin. For the territory of the Rostov Dome (area 14 on Figs. 2, 3), previous constraints by Ruban & Yang (2004) and Ruban (2002, 2005) as well as results from new field investigations are used. Correlation between global and regional stages is based on the framework proposed by Ruban (2009), which takes into account recent chronostratigraphical developments (Steininger *et al*. 1997; Castradori *et al*. 1998; Rio *et al*. 1998; Hilgen *et al*. 2000a,b; 2003, 2005, 2006; Van Couvering *et al*. 2000; Kuiper 2003; Billups *et al*. 2004; Gradstein *et al*. 2004; Kuiper *et al*. 2005; Hüsing *et al*. 2007, 2010; Ogg *et al*. 2008), absolute dating of Upper Miocene regional stage boundaries (Chumakov *et al*. 1992a, b), and earlier constraints by Nevesskaja *et al*. (2005). New results presented by Krijgsman *et al*. (2010) are also accounted. Examples from the Swiss Molasse basin (Berger *et al*., 2005), the Dacian basin (Vasiliev *et al*. 2004), and the Central Paratethys (Lirer *et al*. 2009), provide great confidence in the efficacy of our approach.

Regional hiatuses are considered major if they can be traced in most of the areas of the Ciscaucasian basin. The next step is comparison of regionally-documented major hiatuses with global eustatic falls. For this purpose, we used two widely-accepted eustatic curves. Although the compilation by Miller *et al*. (2005) was updated by Kominz *et al*. (2008), these authors altered only the pre-Pliocene part of the dataset, so here we use the original data of Miller *et al.* (2005). The second eustatic curve considered in this paper is that proposed by Haq & Al-Qahtani (2005), who updated the earlier constraints by Haq *et al*. (1987). The correlation of basinwide major hiatuses and eustatic fluctuations is possible on the basis of the correlation between regional and global Neogene stages.

We assume that a coincidence of major basin-wide hiatuses and eustatic falls indicates a global sea-level control on regional sedimentation. Absence of this signal either indicates a lack of connectivity with the open ocean or complication derived from local tectonic activity. Basin subsidence larger than eustatic fall would prevent a hiatus from appearing, whereas uplift would produce additional hiatuses. Thus, finding a significant coincidence of hiatuses and eustatic falls is a good indication of a relatively stable tectonic regime and absence of significant activity within the given basin.

Results

Tracing the major hiatuses

Four major hiatuses can be documented within the Neogene deposits of the Ciscaucasian basin (Fig. 4). The lowest encompasses the entire Tarkhanian regional stage, and affects the succession in 14 of the 17 areas of the basin (Fig. 3). However, this hiatus is diachronous, appearing in some areas as erosional surfaces at the bottom and/or the top of the Tarkhanian, whereas in other areas it embraces the entire stage. An increase in the number and extent of sedimentation breaks occurred in the Kotsakhurian and remained until the Karaganian, indicating that this major hiatus was a culmination of sedimentation disruption, which embraced 3 regional stages. Despite some diachroneity of this hiatus, the absolute time-range encompassed was not so extensive, around 0.5 Ma, because the absolute duration of the Tarkhanian stage was probably short (Nevesskaja *et al*. 2004, 2005; Ruban 2009). The Tarkhanian hiatus corresponds to the Burdigalian/Langhian boundary of the global chronostratigraphic scale (Ruban 2009; Fig. 4).

The second major, but short-term hiatus, which modifies the succession in 13 of the 17 areas (Fig. 3), is observed within the Sarmatian regional stage (Fig. 4). This hiatus is a generally isochronous erosional surface with few exceptions. In the area 1, this surface appears to be diachronous (Fig. 3), whereas long-term hiatuses are registered in the areas 14, 16, 17, and, partly, in the area 15 (Fig. 3). According to data presented by Nevesskaja *et al*. (2004), this hiatus marks the boundary between the Middle Sarmatian and the Upper Sarmatian, for which an absolute age was established by Chumakov *et al*. (1992b) of 11.2 Ma, which lies just above the Serravallian/Tortonian boundary dated as 11.608 Ma (Ogg *et al*., 2008; Fig. 4).

The third major short-term hiatus is established at the top of the Sarmatian regional stage (Fig. 4). It is traced in 15 of the 17 areas of the Ciscaucasian basin (Fig. 3), and it is marked by a slightly diachronous erosional surface which is sometimes embraced by lengthy hiatuses. Diachroneity is evident from the areas 6, 7, and 8, where erosional surfaces are traced below the upper boundary of the Sarmatian (Nevesskaja *et al*., 2004; Fig. 3). The Sarmatian/Maeotian hiatus occurs within the middle interval of the Tortonian global stage (Ruban; 2009; Fig. 4).

The last major hiatus is pronounced in both its duration and spatial extent (Fig. 4). It encompasses the entire Kimmerian regional stage. Its signatures (erosional surfaces and lengthy hiatuses) are found in 15 of the 17 areas in the basin (Fig. 3). As in the case of the Tarkhanian hiatus, the concentration of hiatuses in the sedimentary successions appears to pre-date the major break in sedimentation since the upper Pontian, and continues up to the upper Aktchagylian with a culmination in the Kimmerian. Plotted against the global chronostratigraphic scale, this major hiatus started in the late Messinian (the Messinian/Zanclean boundary has an age of 5.332 Ma; Ogg *et al*. 2008) and ended in the early Piacenzian as one may judge by stage correlations attempted by Chumakov *et al*. (1992b) and Ruban (2009) and improved recently by Krijgsman *et al*. (2010). The time span of this hiatus exceeded 2 myr.

We can thus distinguish two kinds of Neogene major hiatuses in the Ciscaucasian basin. The Tarkhani-

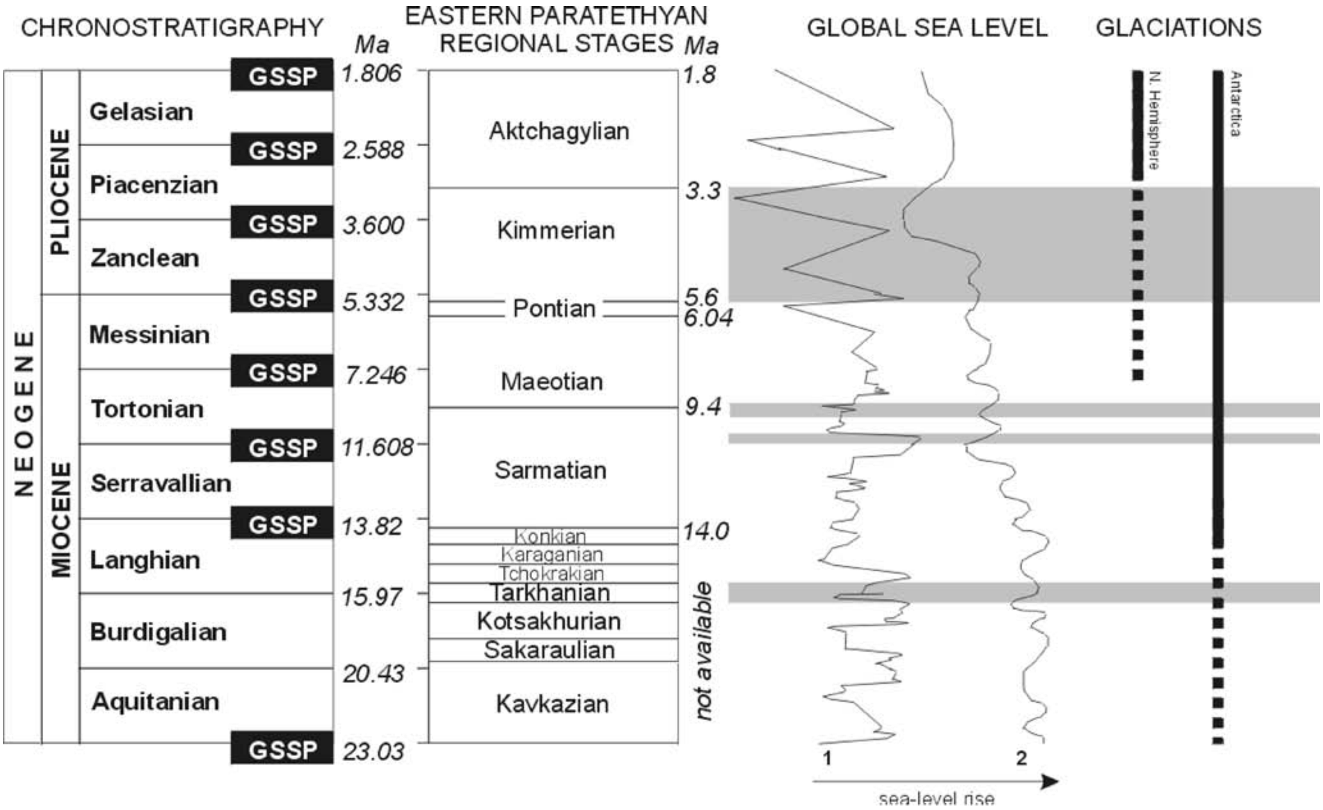

Fig. 4. Major hiatuses in the Ciscaucasian basin, eustatic changes (modified from 1 - MILLER *et al*. 2005 (Messinian-Gelasian curve is shown very schematically), 2 - HAQ & AL-QAHTANI 2005), and global glaciations (after ZACHOS *et al*., 2001). Chronostratigraphy after OGG *et al*. (2008). Correlation of the Eastern Paratethyan stages and the global stages of the Neogene according to RUBAN (2009) with improvements following by KRIJGSMAN *et al*. (2010). The latters concern the age of the Maeotian/Pontian and Pontian/Kimmerian boundaries.

an, Middle/Upper Sarmatian, and Sarmatian/Maeotian hiatuses, which were short-term and relatively isochronous, and the Kimmerian hiatus, which was long-term and diachronous.

Major hiatuses versus eustatic falls

Comparison of the timing of major Neogene hiatuses in the Ciscaucasian semi-enclosed basin with eustatic fluctuations through the same period (Fig. 4) indicates a high degree of coincidence, especially with the HAQ & AL-QAHTANI (2005) dataset. The Tarkhanian (Langhian/Burdigalian) hiatus corresponds to the pronounced global sea-level fall documented by MILLER *et al*. (2005) and is similar in timing (post-dates by no more than 0.5 myr) to a fall indicated by HAQ & AL-QAHTANI (2005). Additionally, the noted regional hiatus coincides some inversion of eustatic trends. The Middle/Upper Sarmatian (lower Tortonian) hiatus coincides with the onset of a very abrupt and strong eustatic fall on the curve of MILLER *et al*. (2005) and again post-dates (by no more than 0.5 myr) the fall indicated by HAQ & AL-QAHTANI (2005). The Sarmatian/Maeotian (mid-Tortonian) hiatus corresponds well to the global sea-level fall documented by both alternative curves (HAQ & AL-QAHTANI 2005; MILLER *et al*. 2005). Finally, the Kimmerian (late Messinian-early Piacenzian) hiatus formed at a time marked by a strong eustatic fall registered as by HAQ & AL-QAHTANI (2005) and a period of strong eustatic variability in the MILLER *et al*. (2005) dataset. If growth and fluctuation of Antarctic and then both Antarctic and Arctic ice sheets (KENNETT 1977; ZACHOS *et al*. 2001; SMITH & PICKERING 2003; GORNITZ 2009) is presumed as a main control on the global Neogene sea-level changes (MILLER *et al*. 2005; KOMINZ *et al*. 2008; GORNITZ 2009), we need to hypothesize a direct influence of the global climate perturbations on the regional sedimentation in the Ciscaucasian basin, because all major hiatuses from there coincide well with the global eustatic falls.

It is important to question whether there were significant eustatic falls, which did not leave an imprint in the Neogene stratigraphic record of the Ciscaucasian Basin. The falls of such kind occurred in the late Aquitanian, the mid-Burdigalian, the mid-Langhian, and probably in the early Gelasian (Fig. 4). Weak or no local evidence of these falls can be found (Fig. 3). It should be noted, however, that a lack of correspondence between some eustatic falls and the stratigraphic architecture of the Ciscaucasian Basin does not disprove an eustatic control on the basinwide depositional setting. This is likely to reflect that tectonic conditions in the basin masked the eustatic signal during some time intervals (Nevesskaja *et al.* 1984). We conclude that there is evidence of persistant, if punctuated, eustatic control on sedimentary rearrangments in the Ciscaucasian Basin throughout the entire Neogene.

Discussion

Major hiatuses and orogeny

The available data (Nevesskaja *et al.* 2004, 2005; Fig. 3) provide evidence that the four most significant hiatuses in the Ciscaucasian basin all coincide well with major eustatic falls (Fig. 4). Therefore, though intuitively it might be assumed that in a foreland semi-enclosed setting such as this tectonics would dominate over eustasy, this does not appear to be the case for the Ciscaucasian basin. In particular, we highlight the two major hiatuses reported from the Sarmatian, which were near-isochronous and short in duration, and so could not be produced by tectonic activity. The likely eustatic origin of these hiatuses provides a disproof of previous assumptions of a Sarmatian pulse or an acceleration in orogeny (Ershov *et al.* 2003; Saintot *et al.* 2006).

If even local tectonic activity in the Ciscaucasian Basin or in the neighbour Greater Caucasus explains a lack of regional signature of some eustatic falls (see above), this fact is not enough to hypothesize any significant tectonic pulses for at least two reasons. First, major regional hiatuses linked to global sea-level falls may be absent in only the case of increasing subsidence (e.g., this might have been the case during the pre-Tarkhanian interval), but not uplift. Second, there were eustatic falls with no major hiatuses in the Ciscaucasian Basin, but all major hiatuses have an appropriate eustatic explanation.

Other local hiatuses and local tectonics

We do not observe numerous local hiatuses in the lower-middle Miocene stratigraphic interval (Fig. 3). Their occurrence increases at the Kotsakhurian-Tchokrakian interval, which is linked to a series of prominent eustatic lowstands (Fig. 4). Many local (i.e., those registered in few areas only) Miocene hiatuses were short-term, and they are marked often by erosional surfaces or significant interruptions in the sedimentary record (Nevesskaja *et al.* 2004). These local events are unlikely to have been formed by tectonic pulses. There is some increase in both the quantity and the duration of local hiatuses in the latest Miocene and Pliocene (Fig. 3), but this coincides with the onset of higher frequency eustatic fluctuations (Haq & Al-Qahtani 2005; Miller *et al.* 2005) linked to the strengthening of Antarctic glaciation and then an appearance of ice sheets in the Arctic (Zachos *et al.* 2001; Gornitz 2009; Fig. 4).

The areas 1, 2, 3, 6, 7, 8, 9, 11, 12, and 13 located in the south of the basin, i.e., along the Greater Caucasus, are supposed to be most prone to tectonic influence (Fig. 2). However, these areas are not distinguished by a higher number of local hiatuses in comparison to other areas (Fig. 3). In contrast, areas located on the gentle northern slope of the Ciscaucasian basin (14–17 – see Fig. 2) are characterized by a higher number of local hiatuses, which is consistent with frequent interruption of sedimentation on the shallow basin periphery, where even small eustatically-driven fluctuations led to the emergence of large areas.

The clear regional signature of the global eustatic fluctuations in the Ciscaucasian basin implies a rather stable geodynamic regime, confirming an earlier assumption made by Efendiyeva & Ruban (2009). Our results do not imply an absence of tectonic activity in the Greater Caucasus or its influences on sedimentation in the Ciscaucasian basin. In fact, tectonism might have been responsible for some local hiatuses. However, it seems that eustatic control prevailed over local tectonic control within the Ciscaucasian basin during the Neogene. Further structual, fission-track, and isotope studies will allow testing of the exact timing of deformation phases and uplifts in the Caucasian region.

Connections of the Eastern Paratethys

One further inference must be made when documenting the evident eustatic control on the Neogene sedimentation in the Ciscaucasus. It has already been hypothesized, particularly by Rögl & Steininger (1983), Nevesskaja *et al.* (1984), Chepalyga (1995), Steininger & Wessely (1999), Popov *et al.* (2006), and Krijgsman *et al.* (2010), that the Eastern Paratethys retained at least ephemeral connections with the World Ocean via the Mediterranean Sea or the Indian Ocean until the end of the Neogene. Our results confirm this was present during the majority of the period studied. It therefore becomes crucial to consider whether this connection was via an Indian Ocean corridor or through an Euxine basin corridor. Given our knowledge of the palaeogeography of the time, the latter seems more likely and this has significant consequences for our understanding of the Messinian Salinity Crisis in the Mediterranean. The modern net freshwater flux from the Black Sea into the Mediterranean reducesthe total net freshwater export from the basin by 10% (Bethoux & Gentili, 1999) and the presence/absence of this flux is one of the most important unresolved issues in quantitative assessment of the Miocene Mediterranean (Meijer & Krijgsman 2005; Rohling *et al*. 2008; Krijgsman *et al*. 2010). Incorporation of the net freshwater flux from the Ciscaucasian and Caspian basins, which is the implication of the basin connectivity described in this paper, could mean that the Euxinic net freshwater flux was an even more important parameters in determining late Neogene Mediterranean palaeoceanography than it is in the late Quaternary. This connection is well reflected in the close relationships between Late Messinian Lago-Mare faunas from the Mediterranean and Ciscaucasian basins (Esü 2007) caused by a westwards faunal invasion from the Paratethyan basins into the Lago-Mare basins. Early Messinian links between the two regions can also be demonstrated on the basis of cardiid bivalve faunas common to both southern Italy and the Ciscaucasian regions (Pedley *et al*. 2008) and indicates an earlier global eustatic fall which encouraged ecological "leakage" from the Paratethys into the semi-isolated Mediterranean basins. Compelling evidence for earlier global eustatic control influencing water exchange between the two interconnected regions is demonstrated by the Tarkhanian event which correlates precisely with a major Burdigalian/Langhian lowstand within the Mediterranean (Grasso *et al*. 1994).

Further work on the location of the connections between the Eastern Paratethys and Mediterranean basins the watermass exchanges associated them should therefore be a priority for future research.

Conclusions

Four major Neogene hiatuses are traced in the Ciscaucasian semi-enclosed basin, which played a key role in the Eastern Paratethys domain. These include the Tarkhanian (Burdigalian/Langhian), Middle/Upper Sarmatian (lower Tortonian), Sarmatian/Maeotian (mid-Tortonian), and Kimmerian (late Messinian-early Piacenzian) hiatuses. The Ciscaucasian successions reflect well the eustatic falls recorded by global sea level datasets (Haq & Al-Qahtani 2005; Miller *et al*. 2005). Eustatic control on basinwide sedimentation breaks persisted througout the Neogene, which suggests a relatively "calm" tectonic regime and rather stable connections of the Eastern Paratethys and the World Ocean.

Further studies should be aimed at a precise reconstruction of the Neogene transgressions/regressions and depth changes in the Ciscaucasian basin. These may then be compared with known eustatic fluctuations and the position of the corridor connecting the Caucasian region with the World Ocean. Kominz *et al*. (2008) pointed out a broad interregional comparison of data on sea-level changes as the most desirable tool to reveal the true eustatic changes, but it is equally true that identification of known eustatic signals can be critical in understanding the history of poorly-known regions.

Acknowledgements

The authors acknowledge the "GABP" Editor-in-Chief V. Radulović (Serbia) for his help, H. Zerfass (Brazil) and S. O. Zorina (Russia) for their valuable improvements, and also N.M.M. Janssen (Netherlands), W. Krijgsman (Netherlands), Yu.V. Mosseichik (Russia), W. Riegraf (Germany), A.J. van Loon (Netherlands/Poland), and many other colleagues for literature support. This paper is dedicated to the memory of M. Bécaud, a distinguished French palaeontologist and a helpful colleague, whose enthusiasm in seeking out relevant literature helped to launch this project.

References

Berger, J.-P., Reichenbacher, B., Becker, D., Grimm, M., Grimm, K., Picot, L., Storni, A., Pirkenseer, C. & Schaefer, A. 2005. Eocene-Pliocene time scale and stratigraphy of the Upper Rhine Graben (URG) and the Swiss Molasse Basin (SMB). *International Journal of Earth Sciences*, 94: 711–731.

Bethoux, J. P. & Gentili, B. 1999. Functioning of the Mediterranean Sea: past and present changes related to freshwater input and climate changes. *Journal of Marine Systems*, 20: 33–47.

Billups K., Palike H., Channell J.E.T., Zachos J.C. & Shackleton N.J. 2004. Astronomic calibration of the late Oligocene through early Miocene geomagnetic polarity time scale. *Earth and Planetary Science Letters*, 224: 33–44.

Castradori, D., Rio, D., Hilgen, F.J. & Lourens, L.J. 1998. The Global Standard Stratotype-section and Point (GSSP) of the Piacenzian Stage (Middle Pliocene). *Episodes*, 21: 88–93.

Catuneanu, O. 2006. *Principles of sequence stratigraphy*. Elsevier, Amsterdam, 375 pp.

Chepalyga, A.L. 1995. East Paratethys-Tethys marine connections along Euphrat Passage during Neogene. *Romanian Journal of Stratigraphy*, 76 (suppl. 7): 149–150.

Chumakov, I.S., Byzova, S.L., Ganzey, S.S., Arias, C., Bigazzi, G., Bonadonna, F.P., Hadler-Neto, J.C. & Norelli, P. 1992a. Interlaboratory fission track dating of volcanic ash levels from eastern Paratethys: a Mediterranean-Paratethys correlation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 95: 285–287.

Chumakov, I.S., Byzova, S.L. & Ganzey, S.S. 1992b. *Geochronology and correlation of the Late Cenozoic of the Paratethys*. Nauka, Moskva, 95 pp. (in Russian)

Efendiyeva, M.A. & Ruban, D.A. 2009. The Caucasus in the Mesozoic and the Crnozoic - geodynamic analogs and new questions. *Azerbaihjan Oil Industry*, 2: 9–13. (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.

ESÜ, D. 2007. Latest Messinian "Largo-Mare" Lymnocardiinae from Italy: Close relations with the Pontian fauna from Dacic Basin. *Geobios*, 40: 291–302.

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

GORNITZ, V. (ed). 2009. *Encyclopedia of Paleoclimatology and Ancient Environments*. Springer, Dordrecht, 1049 pp.

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.

GRASSO, M., PEDLEY, H.M. & MANISCALCO, R. 1994. The application of a late Burdigalian-early Langhian highstand event in correlating complex Tertiary orogenic carbonate successions within the Central Mediterranean. *Geologie Mediterraneene*, 21: 69–83.

HAQ, B.U., HARDENBOL, J.& VAIL, P.R. 1987. Chronology of fluctuating sea levels since the Triassic. *Science,* 235: 1156–1167.

HAQ, B. U. & AL-QAHTANI, A.M. 2005. Phanerozoic cycles of sea-level change on the Arabian Platform. *GeoArabia,* 10: 127–160.

HARZHAUSER, M. & MANDIC, O. 2008. Neogene lake systems of Central and South-Eastern Europe: Faunal diversity, gradients and interrelations. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 260: 417–434.

HARZHAUSER, M., KERN, A., SOLIMAN, A., MINATI, K., PILLER, W.E., DANIELOPOL, D.L. & ZUSCHIN, M. 2008. Centennial- to decadal scale environmental shifts in and around Lake Pannon (Vienna Basin) related to a major Late Miocene lake level rise. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 270: 102–115.

HILGEN, F.J., IACCARINO, S., KRIJGSMAN, W., VILLA, G., LANGEREIS, C.G. & ZACHARIASSE, W.J. 2000a. The Global Boundary Stratotype Section and Point (GSSP) of the Messinian Stage (uppermost Miocene). *Episodes*, 23: 172–178.

HILGEN, F.J., BISSOLI, L., IACCARINO, S., KRIJGSMAN, W., MEIJER, R., NEGRI, A. & VILLA, G. 2000b. Integrated stratigraphy and astrochronology of the Messinian GSSP at Oued Akrech (Atlantic Morocco). *Earth and Planetary Science Letters*, 182: 237–251.

HILGEN, F.J., ABDUL AZIZ, H., KRIJGSMAN, W., RAFFI, I. & TURCO, E. 2003. Integrated stratigraphy and astronomical tuning of the Serravallian and lower Tortonian at Monte dei Corvi (Middle-Upper Miocene, northern Italy). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 199: 229–264.

HILGEN, F.J., ABDUL AZIZ, H., BICE, D., IACCARINO, S., KRIJGSMAN, W., KUIPER, K., MONTANARI, A., RAFFI, I., TURCO, E. & ZACHARIASSE, W.J. 2005. The Global Boundary Stratotype Section and Point (GSSP) of the Tortonian Stage (Upper Miocene) at Monte dei Corvi. *Episodes*, 28: 6–17.

HILGEN, F., BRINKHUIS, H. & ZACHARIASSE, W.-J. 2006. Unit stratotypes for global stages: The Neogene perspective. *Earth-Science Reviews*, 74: 113–125.

HIROKI, Y. 1995. Sea-level changes in the Early to early Middle Miocene series, Central Honshu, Japam. *Journal of the Faculty of Science, University of Tokyo*, 22: 251–284.

HIROKI, Y. & KIMIYA, K. 1990. The development of barrier-island and strand-plain systems with the glacio-eustatic sea-level change in the Pleistocene Atsumi Group, central Japan. *Journal of the Geological Society of Japan*, 96: 805–820 (in Japanese).

HIROKI, Y. & MATSUMOTO, R. 1999. Magnetostratigraphic correlation of Miocene regression-and-transgression boundaries in central Honshu, Japan. *Journal of the Geological Society of Japan*, 105: 87–107.

HIROKI, Y. & MATSUMOTO, R. 2003. Correlation of Miocene (18-12 Ma) sequence boundaries in central Japan to major Antarctic glaciation events. *Sedimentary Geology*, 157: 303–315.

HÜSING, S.K., HILGEN, F.J., ABDUL AZIZ, H. & KRIJGSMAN, W. 2007. Completing the Neogene geological time scale between 8.5 and 12.5 Ma. *Earth and Planetary Science Letters*, 253: 340–358.

HÜSING, S.K., CASCELLA, A., HILGEN, F.J., KRIJGSMAN, W., KUIPER, K.F., TURCO, E. & WINSON, D. 2010. Astrochronology of the Mediterranean Langhian between 15.29 and 14.17 Ma. *Earth and Planetary Science Letters*, 290: 254–269.

ILYINA, L.B., NEVESSKAJA, L.A. & PARAMONOVA, N.L. 1976. *Trends of molluscs development in the Neogene brackish basins of Eurasia (Late Miocene-Early Pliocene).* Nauka, Moskva, 288 pp. (in Russian).

KENNETT, J.P. 1977. Cenozoic evolution of Antarctic glaciation, the circum-Antarctic ocean, and their impact on global palaeogeography. *Journal of Geophysical Research*, 82: 3843–3860.

KOMINZ, M.A., BROWNING, J.W., MILLER, K.G., SUGARMAN, P.J., MIZINTSEVA, S. & SCOTESE, C.R. 2008. Late Cretaceous to Miocene sea-level estimates from the New Jersey and Delaware coastal plain coreholes: an error analysis. *Basin Research*, 20, 211–226.

KRIJGSMAN, W., STOICA, M., VASILIEV, I. & POPOV, V.V. 2010. Rise and fall of the Paratethys Sea during the Messinian Salinity Crisis. *Earth and Planetary Science Letters*, 290: 183–191.

KUIPER, K.F. 2003. Direct intercalibration of radio-isotopic and astronomical time in the Mediterranean Neogene. *Geologica Ultraiectina*, 235: 1–223.

KUIPER, K.F., WIJBRANS, J.R. & HILGEN, F.J. 2005. Radioisotopic dating of the Tortonian Global Stratotype Section and Point: implications for intercalibration of $^{40}Ar/^{39}Ar$ and astronomical dating methods. *Terra Nova*, 17: 385–398.

Lirer, F., Harzhauser, M., Pelosi, N., Piller, W.E., Schmid, H.P. & Sprovieri, M. 2009. Astronomically forced teleconnection between Paratethyan and Mediterranean sediments during the Middle and Late Miocene. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 275: 1–13.

Meijer, P.T. & Krijgsman, W. 2005. A quantitative analysis of the desiccation and re-filling of the Mediterranean during the Messinian Salinity Crisis. *Earth and Planetary Science Letters*, 240: 510–520.

Miller, K.G., Kominz, M.A., Browning, J.V., Wright, J.D., Mountain, G.S., Katz, M.E., Sugarman, P.J., Cramer, B.S., Christie-Blick, N. & Pekar, S.F. 2005. The Phanerozoic Record of Global Sea-Level Change. *Science,* 310: 1293–1298.

Nevesskaja, L.A., Voronina, A.A., Gontcharova, I.A., Ilyina, L.B., Paramonova, N.P., Popov, S.V., Tchepalyga, A.L. & Babak, E.V. 1984. History of the Paratethys. *In*: Lisitsin, A.P. (ed.), *Paleokeanologija*. 27 Mezhdunarodnyj Geologitcheskij Kongress, doklady, 3: 91–101. Nauka, Moskva (in Russian).

Nevesskaja, L.A., Gontcharova, I.A., Ilyina, L.B., Paramonova, N.P., Popov, S.V., Babak, E.V., Bagdasarjan, K.G. & Voronina, A.A. 1986. *History of the Neogene molluscs of the Paratethys*. Nauka, Moskva, 208 pp. (in Russian).

Nevesskaja, L.A., Kovalenko, E.I., Beluzhenko, E.V., Popov, S.V., Gontcharova, I.A, Danukalova, G.A., Zhidovinov, N.Ja., Zajtsev, A.V., Zastrozhnov, A.S., Ilyina, L.B., Paramonova, N.P., Pintchuk, T.N., Pis'mennaja, N.S., Agadzhanjan, A.K., Lopatin, A.V. & Trubikhin, V.M. 2004. Explanatary note to the unified regional stratigraphical chart of the Neogene deposits of the southern regions of the European part of Russia. Paleontologitcheskij institut RAN, Moskva, 83 pp. (in Russian).

Nevesskaja, L.A., Kovalenko, E.I., Beluzhenko, E.V., Popov, S.V., Gontcharova, I.A, Danukalova, G.A., Zhidovinov, N.Ja., Zajtsev, A.V., Zastrozhnov, A.S., Pintchuk, T.N., Ilyina, L.B., Paramonova, N.P., Pis'mennaja, N.S. & Khondkarian, S.O. 2005. Regional stratigraphical chart of the Neogene of the South of the European part of Russia. *Otetchestvennaja geologija*, 4: 47–59 (in Russian).

Ogg, J.G., Ogg, G. & Gradstein, F.M. 2008. *The Concise Geologic Time Scale*. Cambridge University Press, Cambridge, 177 pp.

Pedley, H.M., Grasso, M., Maniscalco, R. & Esü, D. 2007. The Monte Carrubba Formation (Messinian, Sicily) and its correlatives: New light on basin-wide processes controlling sediment and biota distributions during the Palaeomediterranean-Mediterranean transition. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 253: 363–384.

Popov, S.V., Shcherba, I.G., Ilyina, L.B., Nevesskaja, L.A., Paramonova, L.P., Khondkarian, S.O. & Magyar, I. 2006. Late Miocene to Pliocene palaeogeography of the Paratethys and its relation to the Mediterranean. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 238: 91–106.

Popov, S.V., Antipov, M.P., Zastrozhnov, A.S., Kurina, E.E. & Pintchuk, T.N. 2010. Sea-level fluctuations on the northern shelf of the Eastern Paratethys during the Oligocene-Neogene. *Stratigrafija. Geologitcheskaja korreljatsija*, 18: 99–124 (in Russian).

Rio, D., Sprovieri, R., Castradori, D. & Di Stefano, E. 1998. The Gelasian Stage (Upper Pliocene): a new unit of the global standard chronostratigraphic scale. *Episodes*, 21: 82–87.

Rögl, F. 1996. Stratigraphic correlation of the Paratethys Oligocene and Miocene. *Mitteilungen der Geselschaft Geologische Bergbaustudie Österreich*, 41: 65–73.

Rögl, F. 1998. Palaeogeographic Considerations for Mediterranean and Paratethys Seaways (Oligocene to Miocene). *Annalen des Naturhistorischen Museum in Wien*, 99A: 279–310.

Rögl, F. 1999. Mediterranean and Paratethys. Facts and hypotheses of an Oligocene to Miocene paleogeography: Short Overview. *Geologica Carpathica,* 50: 339–349.

Rögl, F. & Steinenger, F.F. 1983. Vom Zerfall der Tethys zu Mediterranean und Paratethys. *Annalen des Naturhistorischen Museum in Wien*, 85A: 135–163.

Rohling, E.J., Schiebel, R. & Siddall, M. 2008. Controls on Messinian Lower Evaporite cycles in the Mediterranean. *Earth and Planetary Science Letters*, 275: 165–171.

Ruban, D.A. 2002. Lithostratigraphy of the Upper Miocene deposits of the Rostov Dome. *Nautchnaja mysl' Kavkaza. Prilozhenije*, 14: 133–136 (in Russian).

Ruban, D.A. 2005. The Upper Miocene of the Rostov Dome (Eastern Paratethys): Implication of the chronostratigraphy and bivalvia-based biostratigraphy. *Geološki anali Balkanskoga poluostrva*, 66: 9–15.

Ruban, D.A. 2009. Regional Stages: Their Types and Chronostratigraphic Utility. *Cadernos do Laboratorio Xeolóxico de Laxe,* 34: 59–73.

Ruban, D.A. & Yang, W. 2004. Upper Miocene Sequence Stratigraphy of Rostov Dome, Russian Platform, Eastern Paratethys. *American Association of Petroleum Geologists. Annual Convention. Abstract Volume*, 121. Dallas.

Saintot, A., Brunet, M.-F., Yakovlev, F., Sébrier, M., Stephenson, R., Ershov, A., Chalot-Prat, F. & McCann, T. 2006. The Mesozoic-Cenozoic tectonic evolution of the Greater Caucasus. *In*: Gee, D.G. & Stephenson, R.A. (eds), *European Lithosphere Dynamics*. Geological Society, London, Memoirs, 32: 277–289.

Sissingh, W. 2001. Tectonostratigraphy of the West Alpine Foreland: correlation of Tertiary sedimentary sequences, changes in eustatic sea-level and stress regimes. *Tectonophysics*, 333: 361–400.

Smith, A.G. & Pickering, K.T. 2003. Oceanic gateways as a critical factor to initiate icehouse Earth. *Journal of the Geological Society, London*, 160: 337–340.

Steininger, F.F., Aubry, M.P., Berggren, W.A., Biolzi, M., Borsetti, A.M., Cartlidge, J.E., Cati, F., Corfield, R., Gelati, R., Iaccarino, S., Napoleone, C.,

OTTNER, F., RÖGL, F., ROETZEL, R., SPEZZAFERRI, S., TATEO, F., VILLA, G. & ZEVENBOOM, D. 1997. The Global Stratotype Section and Point (GSSP) for the base of the Neogene. *Episodes*, 20, 23–28.

STEININGER, F.F. 1999. Chronostratigraphy, Geochronology and Biochronology of the Miocene "European Land Mammal Mega-Zones" (ELMMZ) and the Miocene "Mammal-Zones (MN-Zones)". *In*: RÖSSNER, G.E. & HEISSEG, K. (eds.), *The Miocene Land Mammals of Europe*, 9–24. Dr. Friedrich Pfeil, Munich.

STEININGER, F.F. & WESSELY, G. 1999. From the Tethyan Ocean to the Paratethys Sea: Oligocene to Neogene Stratigraphy, Paleogeography and Paleobiogeography of the cirum-Mediterranean region and the Oligocene to Neogene basin evolution in Austria. *Mitteilungen Der Österreichischen Geologischen Gesellschaft*, 92: 95–116.

VAN COUVERING, J.A., CASTRADORI, D., CITA, M.B., HILGEN, F.J. & RIO, D. 2000. The base of the Zanclean Stage and of the Pliocene Series. *Episodes*, 23: 179–187.

VASILIEV, I., KRIJGSMAN, W., LANGEREIS, C.G., PANAIOTU, C.E., MAȚENCO, L. & BERTOTTI, G. 2004. Towards and atronomical framework for the eastern Paratethys Mio-Pliocene sedimentary sequences of the Focþani basin (Romania). *Earth and Planetary Science Letters*, 227: 231–247.

ZACHOS, J., PAGANI, M., SLOAN, L., THOMAS, E. & BILLUPS, K. 2001. Trends, Rhythms, and Aberrations in Global Climate 65 Ma to Present. *Science*, 292: 686–693.

Резиме

Да ли главни неогени хијатуси у Предкавкаском полузатвореном басену (Источни Паратетис, југозападна Русија) указују на еустатичке падове?

Паратетис је био простран палеогеографски акваторијум која се састојао од низа мањих седиментационих басена. За време кенозојика пружао се од Алпа на западу, па до Каспијског мора на истоку. Басени су били делимично изоловани од Медитеранског мора алпским орогеном који је условио значајне промене водених површина као и палеоеколошких услова. Насупрот више деценијским проучавањима Источни Паратетис је остао релативно слабо познат ширем аудиторијуму у односу на западне и централне делове. У овом раду приказани су главни хијатуси у неогеним седиментационим сукцесијама Предкаспијског басена, који представља главни басен Источног Паратетиса, као и његова веза са Светским океаном. Да ли се главне промене у седиментацији подударају са главним променама нивоа мора? У колико би ово било тачно то би био доказ да историја басена зависи од глобалних (углавном климатских), пре него локалних (углавном тектонских) утицаја. Уколико ова претпоставка није тачна тада се може повући сасвим супротан закључак. У Предкавкаскм басену неогени седименти се смењају у времену и простору. Од седимената доминирају пешчари, алевролити и шкриљци, док су у мањем степену присутни карбонати (укључујући биокластичне кречњаке), конгломерати, дијатомити и друге седиментне стене. На основу литологије и фација, у оквиру овог басена, могу се издвојити 17 области. Целокупна дебљина неогена досеже до 5700 m. Унутар сукцесије појављују се како кратки хијатуси (доказани као ерозионе површине), тако и дужи хијатуси (представљени дискорданцијама). У Предкавкаском полузатвореном басену могу се пратити четири главна неогена хијатуса. Ови хијатуси играју кључну улогу у области Источног Паратетиса. То су аркхански (бурдигал-лангиан), средње/горње сарматски (доњи тортон), сарматски/меотски (средњи тортон) и кимеријски (касни мезијан/рани пијачензијан) хијатуси. Упоређујући време главних неогених хијатуса у Предкавкаском полузатвореном бесену са еустатичким флуктацијама кроз исти период запажа се велики степен подударности. Раст и флуктација Антарктика, као и заједнички утицај Антарктских и Артичких ледених покривача могу се сматрати као главни чиниоци глобалних неогених промена нивоа мора, што се може сматрати као директни утицај глобалних климатских утицаја на регионалну седиментацију Предкавкаског басена. У предкопну полузатвореног басена тектоника би могла да доминира над еустатици, али највероватније да то није био случај са Предкавкаским басеном. Ми указујемо на два главна хијатуса у сармату, која су била приближно изохрона у трајању, и која нису могла бити последица тектонске активности. Вероватно еустатичко порекло ових хијатуса је доказ за оповргавање раније претпоставке о сарматском пулсирању у орогену. И ако чак локална тектонска активност у Предкавказком басену, или у суседном Великом Кавказу, објашњава одсуство регионалних знакова неких еустатичких падова, ова чињеница није довољна да се претпоставе било какви значајни тектонски пулсеви из најмање два разлога. Прво, главни регионани хијатуси повезани са глобалним падовима нивоа мора могу бити одсутни само у случају пораста спуштања, али не и код издизања. Друго, било је еустатичких падова и у другим хијатусима (без главних хијатуса) у Предкавказу, али сви главни хијатуси имају одговарајуће еустатичко објашњење. Овај аргумент не указује на јаку тектонску активност. Такође је претпостављено да је Источни Паратетис задржао привремене везе са Светским океаном (преко Медитеранског мора или Индијског океана) све до краја неогена. Наши резултати

доказују овакву дугу везу. Ово је последица регионалних манифестација глобалних промена нивоа мора. У овом раду се указује на могућност постојања стабилне морске везе Источног Паратетиса са његовим спољашњим окружењем. Будућа проучавања имала би за циљ детаљну реконструкцију неогених трансгресија/регресија као и промене дубина у Предкавкаском басену.