ГЕОЛОШКИ ЗАВОД УНИВЕРЗИТЕТА У БЕОГРАДУ
INSTITUT GÉOLOGIQUE DE L'UNIVERSITÉ A BELGRADE

ГЕОЛОШКИ АНАЛИ
БАЛКАНСКОГА ПОЛУОСТРВА

Година оснивања 1888.

КЊИГА LXXI

Уредник

ВЛАДАН РАДУЛОВИЋ

ANNALES GÉOLOGIQUES
DE LA PÉNINSULE BALKANIQUE

Fondée en 1888

TOME LXXI

Rédacteur

VLADAN RADULOVIĆ

БЕОГРАД 2010 BELGRADE

ISSN 0350-0608 UDC 55+56 (1-924.64)

Геолошки анали Балканскога полуострва
Annales Géologiques de la Péninsule Balkanique
Founded in 1888

For this volume, the following reviewers are gratefully acknowledged

Filippo BARRATOLLO (Napoli, Italy), Ion-Tudor BERZA (Bucharest, Romania), Nikita BRAGIN (Moscow, Russia), Nicolaos CARRAS (Athens, Greece), Marc CONRAD (Genève, Switzerland), Vladica CVETKOVIĆ (Belgrade, Serbia), Stijepan ĆORIĆ (Vienna, Austria), Christo DABOVSKI (Sofia, Bulgaria), Alan LORD (London, England), Jan VAN DER MADE (Madrid, Spain), Matevž NOVAK (Ljubljana, Slovenia), Alexey PAKHNEVICH (Moscow, Russia), Polina PAVLISHINA (Sofia, Bulgaria), Jerome PRIETO (München, Germany), Eric SIMON (Brussel, Belgium), Platon TCHOUMATCHENCO (Sofia, Bulgaria), Valentina VISHNEVSKAYA (Moscow, Russia), Ivan ZAGORCHEV (Sofia, Bulgaria), Henrique ZERFASS (Rio De Janeiro, Brazil), Svetlana ZORINA (Moscow, Russia)

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Published by
Department of Geology and Department of Palaeontology,
Faculty of Mining and Geology, University of Belgrade,
Kamenička 6, 11000 Belgrade, Serbia.

Abbreviation
Geol. an. Balk. poluos. / Ann. Géol. Pénins. Balk.

Printed at
“Excelsior”, Belgrade

Impression
500 exemplares

The editing of the journal is supported by the Ministry of Science and Technological Development of the Republic of Serbia and the Faculty of Mining and Geology, Belgrade

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: таркхански, 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

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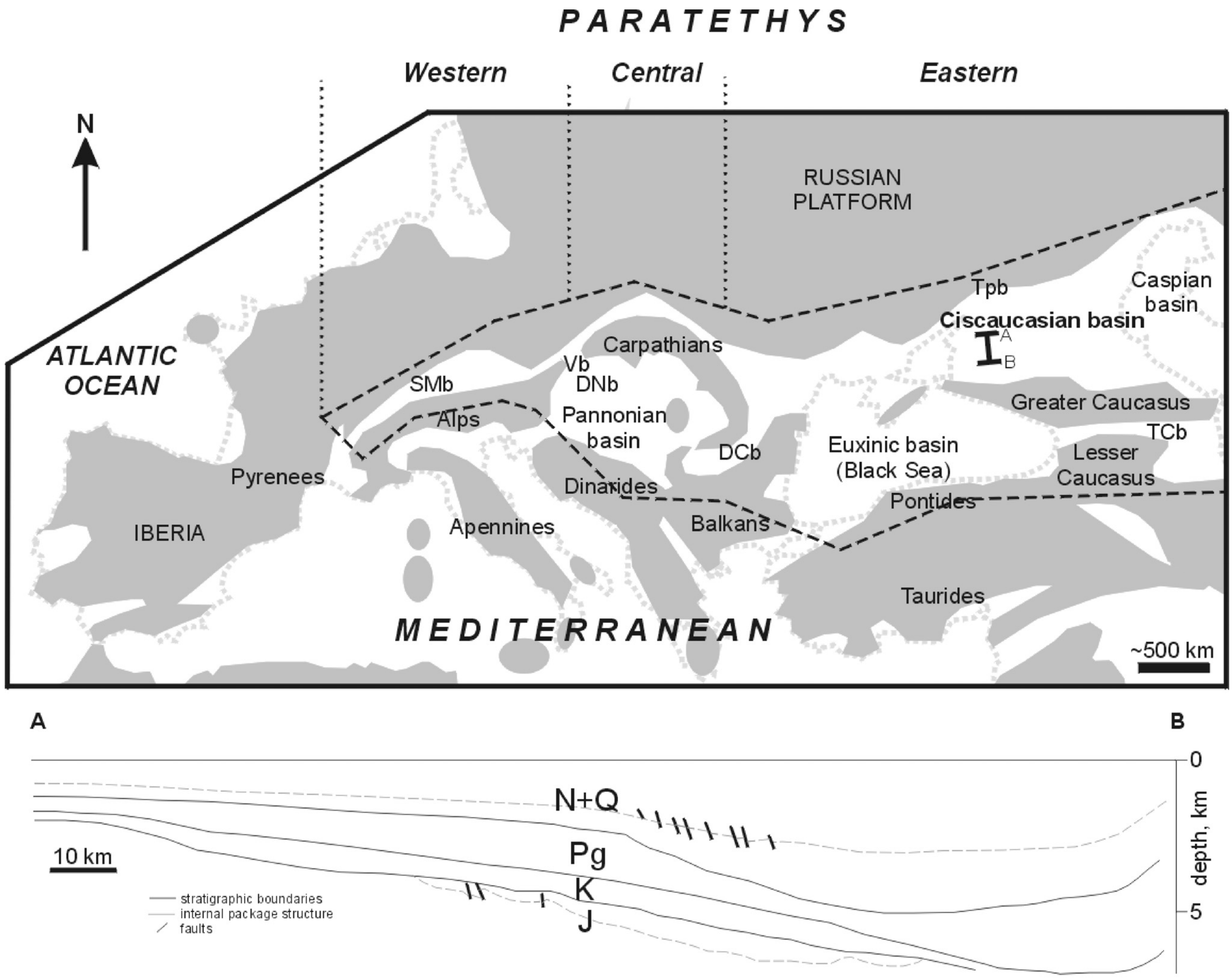

Fig. 1. Sedimentary basins of the Paratethys (modified after RÖGL & STEININGER 1983; STEINENGER & WESSELY 1999; GOLONKA 2004). Land masses are shown as grey. Abbreviations: **SMb,** Swiss Molasse basin; **Vb,** Vienna basin; **DNb,** Danube basin; **DCb,** Dacian basin; **Tpb,** Tanais palaeobay (Rostov 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

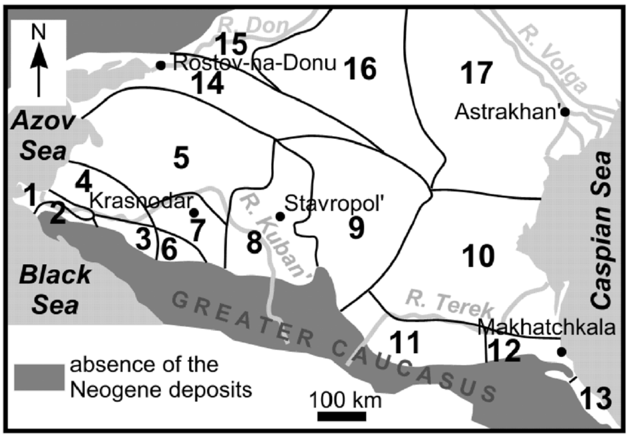

Fig. 2. Areas of the Ciscaucasian basin considered in this study. **1,** Taman'-Adagum; **2,** Anapa-Gladkovskaja; **3,** Afips-Pshekha; **4,** northern Western Kuban'; **5,** Western Ciscaucasus; **6,** Adygeja; **7,** northeastern Eastern Kuban'; **8,** western Central Ciscaucasus; **9,** eastern Central 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

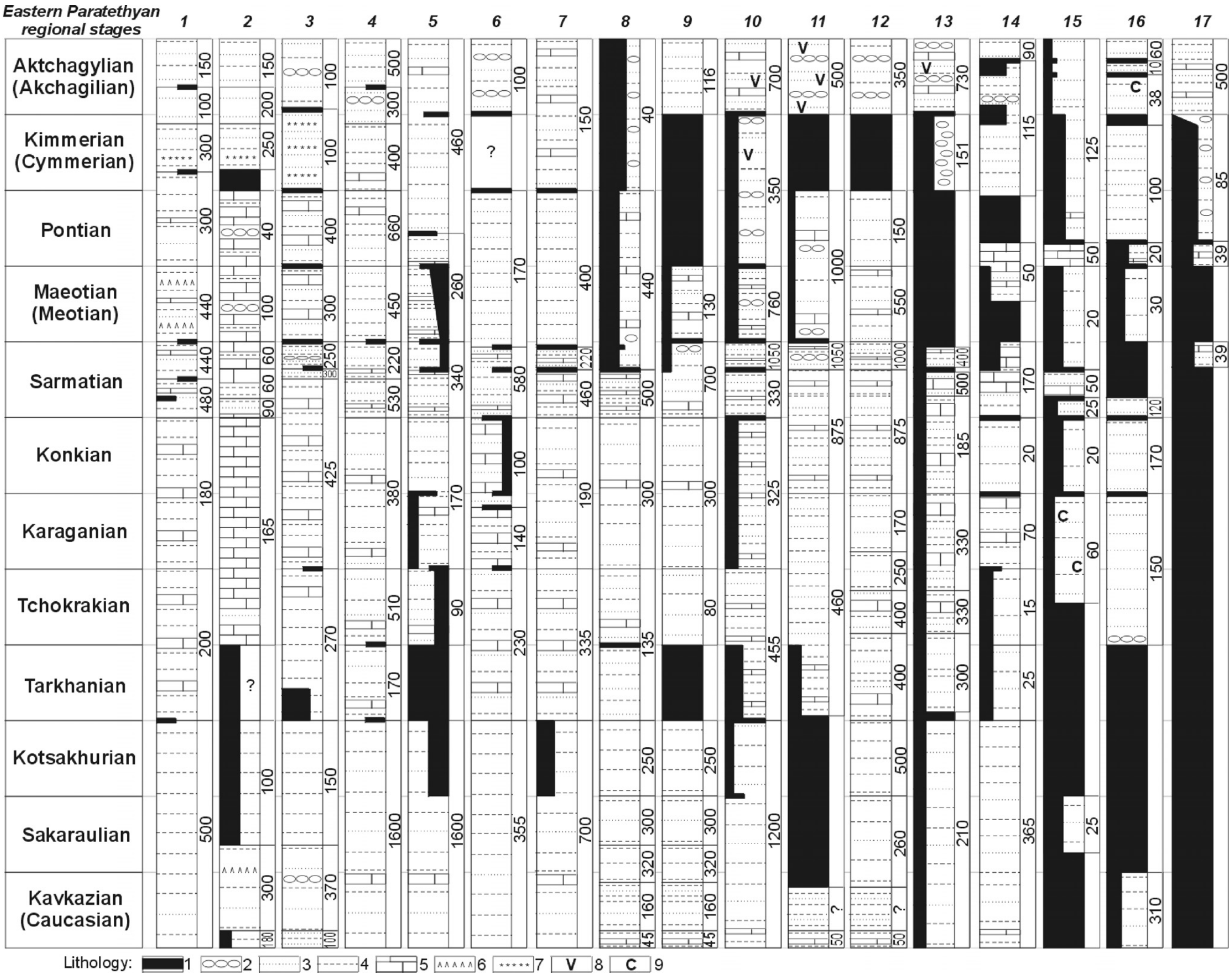

Fig. 3. Generalized composite sections of the Neogene deposits of the Ciscaucasian basin (data extracted from NEVESSKAJA *et al*. 2004). See Fig. 2 for explanation of area numbers. Maximum thickness (m) of the main stratigraphic units is given along each lithologic column. Lithology: **1,** hiatuses; **2,** conglomerates; **3,** sandstones and siltstones; **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-

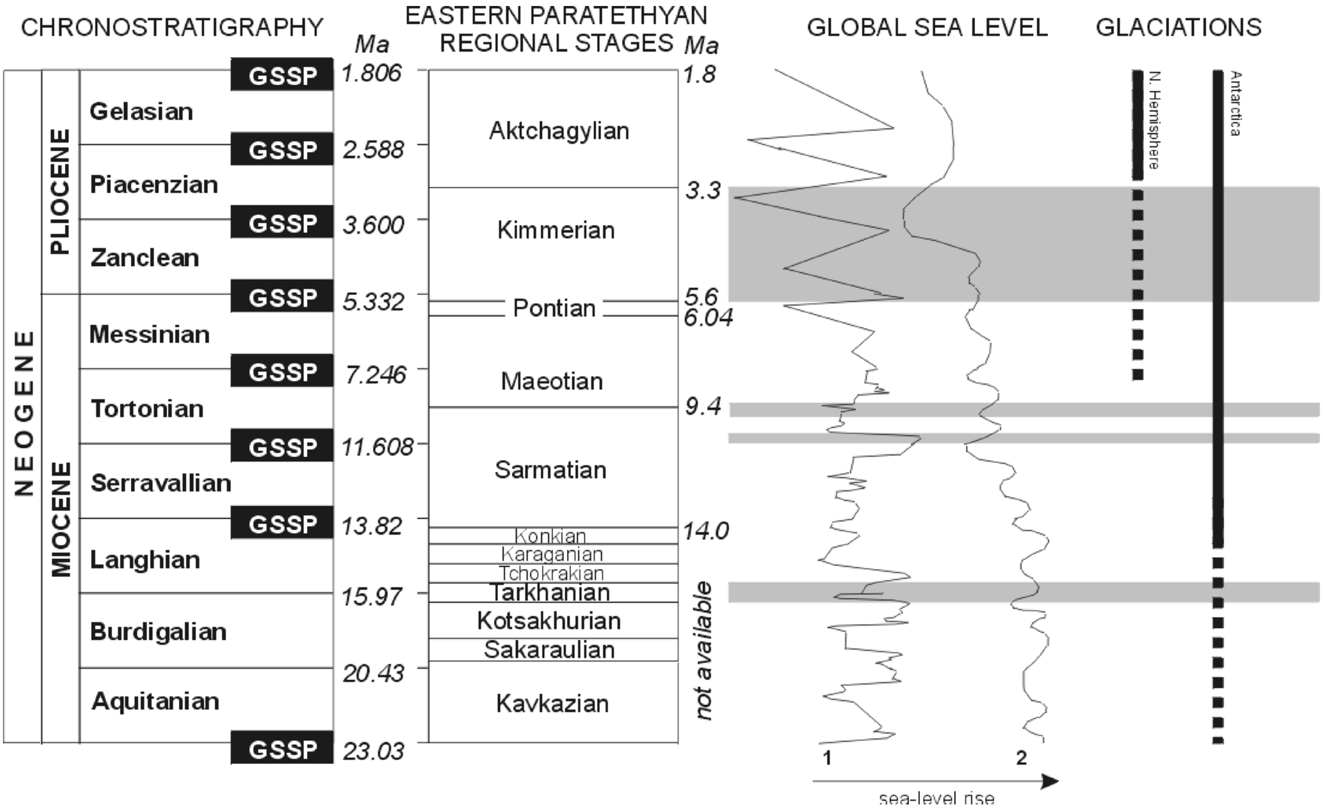

Fig. 4. Major hiatuses in the Ciscaucasian basin, eustatic changes (modified from 1 - MILLER *et al.* 2005 (Messinian-Gelasian curve is shown very schematically), 2 - HAQ & AL-QAHTANI 2005), and global glaciations (after ZACHOS *et al.*, 2001). Chronostratigraphy after OGG *et al.* (2008). Correlation 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., Maţenco, 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.

Геолошки анали Балканскога полуострва Annales Géologiques de la Péninsule Balkanique	71	13–22	Београд, децембар 2010 Belgrade, December 2010

DOI: 10.2298/GABP1071013B

Upper Cretaceous magmatic suites of the Timok Magmatic Complex

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Abstract. The Upper Cretaceous Timok Magmatic Complex (TMC) developed on a continental crust composed of different types of Proterozoic to Lower Cretaceous rocks. The TMC consists of the magmatic suites: Timok andesite (AT) – Turonian–Santonian, Metovnica epiclastite (EM) – Coniacian–Campanian, Osnić basaltic andesite (AO) and Ježevica andesite (AJ) – Santonian–Campanian, Valja Strž plutonite (PVS) – Campanian and Boljevac latite (LB). The sedimentary processes and volcanic activity of the TMC lasted nearly continuously throughout nearly the whole Late Cretaceous. The sedimentation lasted from the Albian to the Maastrichtian and the magmatism lasted for 10 million years, from the Upper Turonian to the Upper Campanian. The volcanic front migrated from East to West. The volcanic processes were characterized by the domination of extrusive volcanic facies, a great amount of volcanic material, a change in the depositional environment during the volcanic cycle, sharp facial transitions and a huge deposition of syn- and post-eruptive resedimented volcaniclastics.

Key words: Upper Cretaceous, magmatic suite, volcanism, volcanic facies, sediments.

Апстракт. Горњокредни Тимочки магматски комплекс (ТМК) развијен је на континенталној кори изграђеној од различитих стена протерозојске до доњокредне старости. У ТМК се могу издвојити следеће магматске свите: Андезити Тимока (AT) – турон–сантон, Епикластити Метовнице (ЕМ) – конијак–кампан, Андезитбазалти Оснића (АО) и Андезити Јежевице (AJ) – сантон–кампан, Плутонити Ваља Стрж (PVS) – кампан и Латити Бољевца (LB). Седиментни процеси и вулканизам у ТМК континуирано трају кроз целу горњу креду. Седиментација траје од алба до мастрихта, а магматизам континуирано 10 милиона година и то од горњег турона до горњег кампана. Вулкански фронт, у току вулканизма, мигрира од истока ка западу, а вулканизам карактерише доминација екструзивних вулканских фација у односу на експлозивне и интрузивне, велике количине емитованог вулканског материјала, честе промене средина депоновања, велике фацијалне разлике и огромне количине син- и пост-еруптивно реседиментованих вулканокластичних наслага.

Кључне речи: Горња креда, магматске свите, вулканизам, вулканске фације, седименти.

Introduction

The Upper Cretaceous volcano-sedimentary complex of the Carpatho–Balkanides belt spreads discontinuously from the northern parts of the Apuseni Mountains and Banat in Romania, over Timok Krajina in eastern Serbia, down to Srednogorie and the Black Sea in Bulgaria. This zone is 1500 km long and 70 km wide. Further on, this complex continues over the Pontides (Turkey) down to the northern parts of Iran. This is the most important active mining area in Europe, belonging to the Tethyan Eurasian Metallogenic Belt (Janković 1977). More recently, this entire province was named the Banatitic Magmatic and Metallogenic Belt (abbreviated as BMMB, Berza *et al.* 1998), or Apuseni-Banat-Timok-Srednogorie Magmatic and Metallogenic Belt (abbreviated as ABTS, Popov *et al.* 2002). Boccaletti *et al.* (1974) and Aiello *et al.* (1977) consider Srednogorie in Bulgaria as a back-arc rift. Geodynamic and tectonic models have also been provided (Hsu *et al.* 1977; Dabovski *et al.* 1991; Vlad 1997; Ciobanu *et al.* 2002 and von Quadt *et al.* 2004, 2005). Recent high precision U/Pb, $^{40}Ar/^{39}Ar$, Re/Os and geochemical data have improved and refined the tectonic models of this area and shed more light on its magmatic activity and metallogeny (Lilov & Chipchakova 1999; von Quadt *et al.* 2002, 2004, 2005; Clark & Ullrich 2004;

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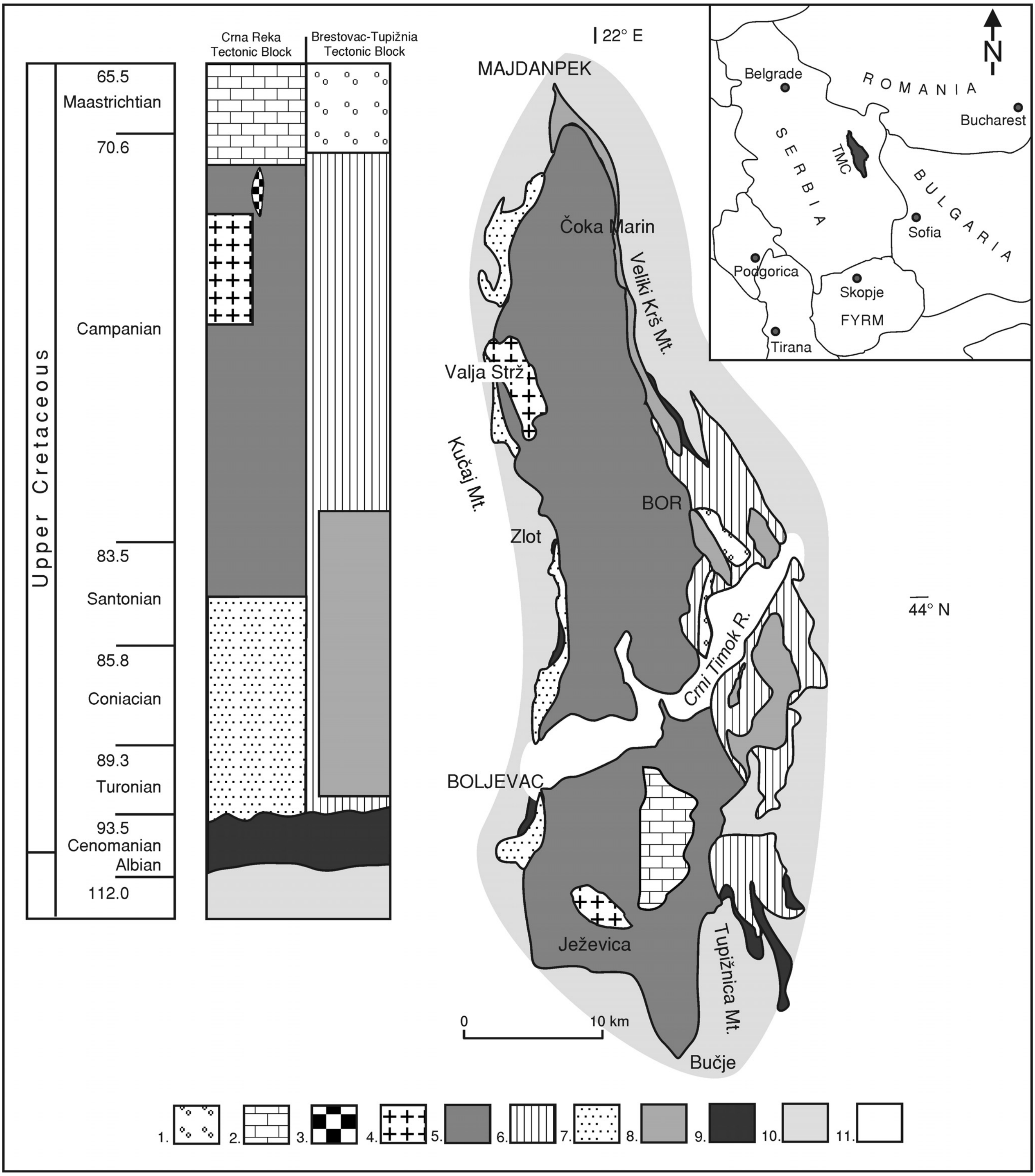

Fig. 1. Schematic geological map and column of the TMC. Legend: **1,** Campanian–Maastrichtian clastite; **2,** Campanian–Maastrichtian reef sediment; **3,** Boljevac latite; **4,** Valja Strž plutonite; **5,** Osnić basaltic andesite and Ježevica andesite; **6,** The epiclastite and the sediment in the BLTB; **7,** Turonian–Maastrichtian sediment in the CRTB; **8,** Timok andesite; **9,** Albian–Cenomanian clastite; **10,** Paleozoic to Lower Cretaceous rock; **11,** Alluvium of the Crni Timok Valley.

HANDLER *et al*. 2004; BANJEŠEVIĆ *et al*. 2006 and ZIMMERMAN *et al*. 2008).

The Upper Cretaceous magmatic activity in eastern Serbia occurred along two subparallel magmatic belts, namely: the Timok Magmatic Complex (TMC) and the Ridanj–Krepoljin belt in the East and West, respectively. The TMC is 85 km long and extends from Majdanpek in the North all the way to the Bučje

Village in the South. It developed on a continental crust composed of different types of Proterozoic to Lower Cretaceous rocks (ANTONIJEVIĆ *et al.* 1974). Geotectonically, it belongs to the Getic Nappe (GRUBIĆ 1983 and KRÄUTNER & KRSTIĆ 2003) or the Kučaj Terrane as part of the complex Carpathian–Balkan Terrane in eastern Serbia (KARAMATA & KRSTIĆ 1996). The Upper Cretaceous rocks of the TMC are overlain by Paleogene, Neogene and Quaternary deposits. Based on continuous geological mapping (ĐORĐEVIĆ & BANJEŠEVIĆ 1997; BANJEŠEVIĆ 2002 and BANJEŠEVIĆ *et al.* 2003) and new geological data (BANJEŠEVIĆ 2006 and LJUBOVIĆ-OBRADOVIĆ 2008), the TMC is interpreted as a succession of the following magmatic suites (Fig. 1): Timok andesite (AT) – Turonian–Santonian, Metovnica epiclastite (EM) – Coniacian–Campanian, Osnić basaltic andesite (AO) and Ježevica andesite (AJ) – Santonian–Campanian, Valja Strž plutonite (PVS) – Campanian and Boljevac latite (LB). This paper will show a synthesis of the data gathered through many years of geological investigations and a modified version of the TMC units. A first version of the formations was published in the Geological Map and Booklet of the southern part of the TMC (ĐORĐEVIĆ & BANJEŠEVIĆ 1997). The definition of the lithodemic hierarchy in this paper is made according to the recommendations of the North American Stratigraphic Code (by North American Commission on Stratigraphic Nomenclature) and International Stratigraphic Guide (SALVADOR 1994). In addition, it will provide a volcanological approach to the study of volcanic facies, including the implementation of modern volcanological terminology (*e.g.*, CAS & WRIGHT 1987; MCPHIE *et al.* 1993 and SCHMINCKE 2004).

Geological setting of the TMC

After continuous carbonate sedimentation from the Early Jurassic, a new sedimentation period commenced with the Albian transgression. The new sedimentation processes had clastic character and were related to oscillations of the depositional environment. The sedimentation proceeded with manifestations of Turonian volcanism in the TMC. These Albian–Cenomanian sediments are concentrated along the eastern boundary of the TMC (Fig. 1) and rarely in the central part of the western boundary of the TMC (near Zlot and Boljevac). The Albian clastites transgressively overlie Early Cretaceous rocks (Barremian–Aptian limestones or Aptian carbonate sandstones).

After a hiatus, the Turonian−Senonian evolution commenced with a new sedimentary cycle. The sediments overlie Albian−Cenomanian clastites (Figs. 4 and 6). The lowest part of the sediments contain microfauna (*Helvetoglobotruncana helvetica*), indicating Lower to Middle Turonian age (LJUBOVIĆ-OBRADOVIĆ 2008). During the Senonian, the whole TMC area shows a considerable difference in the evolution between the eastern (Bor-Lenovac tectonic block – BLTB) and the western (Crna reka tectonic block – CRTB) part (ĐORĐEVIĆ & BANJEŠEVIĆ 1997*,* Fig. 1). Until the Maastrichtian, the first sediments and the epiclastites developed in the BLTB, whereas from the Turonian to the Lower Campanian, andesites originated in this block. In the CRTB, the sediments developed until the Middle Santonian when andesitic and basaltic andesitic volcanism also started. When the volcanism ended, in the Early Campanian, plutonic rock was intruded and the sedimentation continued over a wider area. After the Upper Campanian to the Maastrichtian period, in the central part of the TMC, reef sedimentation commenced (Figs. 1 and 6). On the eastern part of the TMC, in the Upper Campanian, coarse-grained and regressive clastites were deposited (Figs. 1 and 2). This was the period when the TMC uplifted and its existence as an area of active volcanism and marine sedimentation terminated.

Timok andesite (AT)

Name: After the Timok River

Synonyms: “Timazit” – BREITHAUPT 1860.

“Andesites or volcanites of the I volcanic phase (Timocite)” – DROVENIK *et al.* 1962.

“Turonian andesites, Timok andesites, Subvolcanic-hypabyssal rocks of the Borska Reka” – ĐORĐEVIĆ & BANJEŠEVIĆ 1997.

“Banatite volcanites” – BERZA *et al.* 1998

“Biotite-hornblende andesite (Timocite)” – CLARK & ULLRICH 2004.

“Turonian-Campanian andesites” – BANJEŠEVIĆ 2006.

“Upper Cretaceous volcanics (Phase I)” – ZIMMERMAN *et al.* 2008.

Type locality (Type section): The Timok River locality from the Gamzigradska Banja to the Zvezdan Village. An a additional outcrops are exposed in the Krivelj Village area.

Location, boundaries, lithology and genesis: The AT occur in the eastern parts of the TMC (Fig. 1), where they overlie Cenomanian and Turonian sediments. They are covered by Senonian sediments (Fig. 2) and the EM. Amphibole andesites and trachyandesites of high potassium character predominate. They are light-grey to green-grey rocks, showing a holo- to hypo-crystalline porphyritic texture, sometimes characterized by cm-sized amphibole phenocrysts – Timazit (BREITHAUPT 1860). Andesine plagioclase, tschermakite amphibole (rarely Mg-hornblende), biotite and clinopyroxene are the main phenocryst phases (in decreasing order of abundance), whereas quartz phenocrysts are very rare. The amount of phenocrysts is usually around 50 % (rarely more than 60 %).

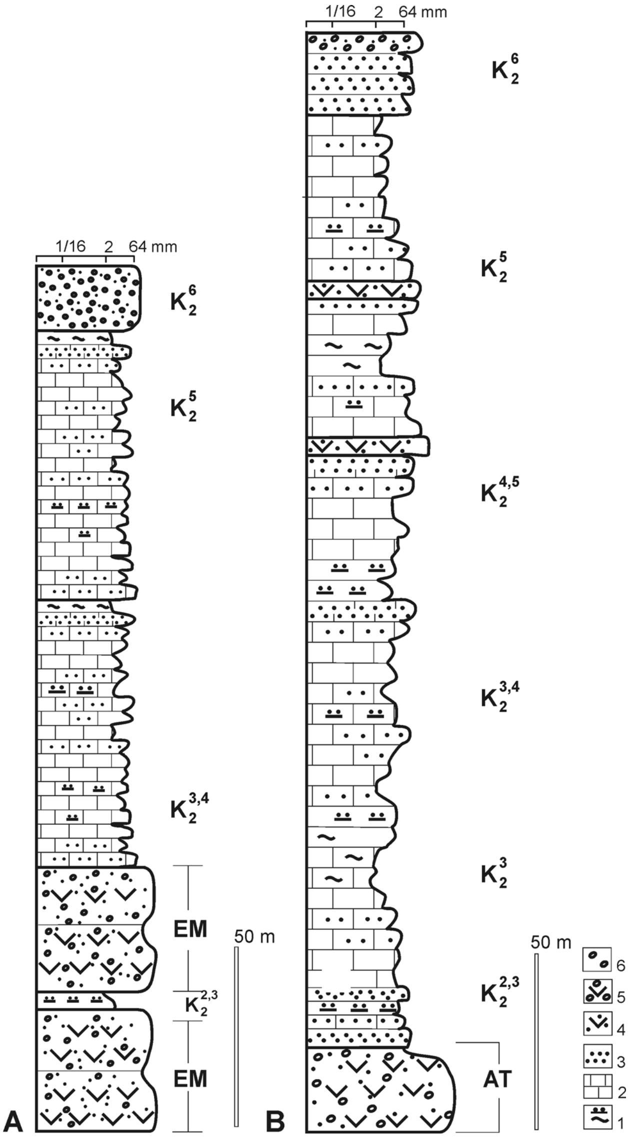

Fig. 2. Schematic geological columns Oštrelj (A) and Slatina (B) south of Bor, with a graphical lithology log. Legend: **AT,** Timok andesite; **EM**, Metovnica epiclastite; **1,** Marl and silty marl; **2,** Limestone; **3,** Sandstone; **4,** Fine-grained volcanoclastite; **5,** Coarse-grained volcanoclastite; **6,** Conglomerate.

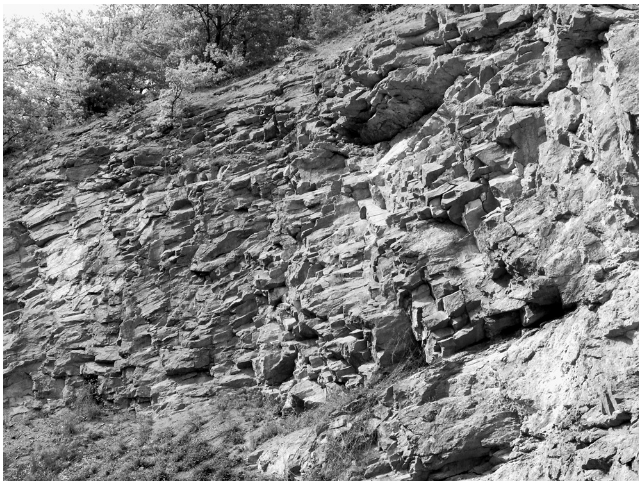

Fig. 3. The central parts of the coherent andesitic lava dome near the Krivelj Village, with columnar jointing.

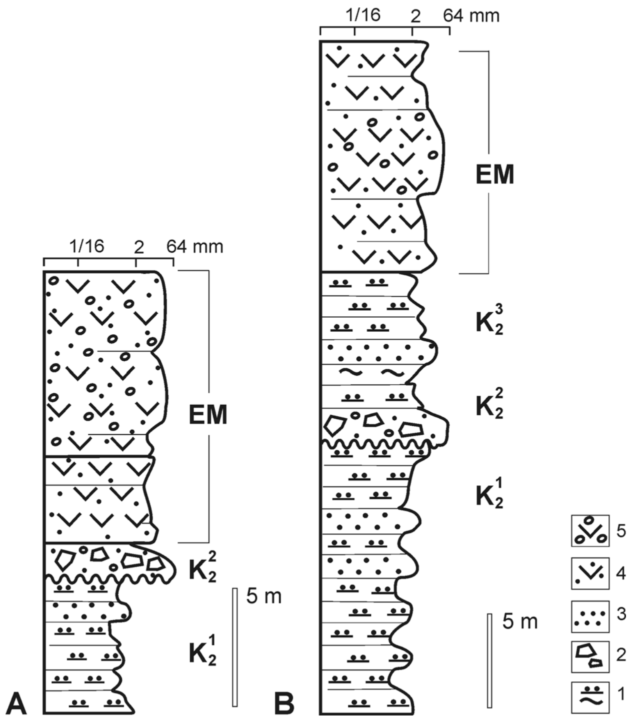

Fig. 4. Schematic geological columns Gamzigradska Banja (A) east of the Metovnica Village and Kravarnik (B) near the Lenovac Village, with a graphical lithology log. **EM,** Metovnica epiclastite; **1,** Marl and silty marl; **2,** Brecia; **3,** Sandstone; **4,** Fine-grained volcanoclastite; **5,** Coarse-grained volcanoclastite.

According to their lithological, volcanological and petrofabric characteristics, the andesites are distinguished into the following facies: lava flows (coherent and autoclastic), lava domes (Fig. 3), shallow intrusions and various volcaniclastic rocks. Completely or partially autobrecciated lava flow facies are predominant, while hyaloclastites are very rare. They have high aspect ratios having thicknesses that sometimes reach several tens of meters and a rather small aerial distribution, commonly < 100 m^2. The autobrecciated lava flows show a clast-supported volcaniclastic texture with subangular to angular clasts up to 30 cm in size, which show almost the same fabric and composition. The matrix is usually subordinated (up to a few vol. %). Lava dome or cryptodome facies are usually exposed on the surface in the range of several square kilometers. At several locations, the central parts of the lava domes are exposed as columnar and rectangular jointed volcanic rocks (Fig. 3). Dykes are usually up to 10 m wide and up to 50 m long. Syn-eruptive and post-eruptive redeposited volcaniclastic rocks have a great prevalence (here described as Metovnica epiclastite, see below).

Age: According to high precision U/Pb, $^{40}Ar/^{39}Ar$ age (von Quadt *et al*. 2002 and Clark & Ullrich 2004), the AT ranged from 89.0±0.6 to 84.26±0.67 Ma (Upper Turonian to Upper Santonian).

Metovnica epiclastite (EM)

Name: After the Metovnica Village, southern of Bor.

Synonyms: “Pyroclastites or volcanoclastites of the I volcanic phase” – Drovenik *et al*. 1962.

“Metovnica epiclastics” – Đorđević & Banješević 1997.

“Epiclastics of the Senonian” – Đorđević 2004–2005.

“Turonian-Senonian epiclastites” – Banješević 2006.

Type locality (Type section): The area from the Metovnica Village to the Nikoličevo Village. An a additional localities are near to the open pit in Bor and in the Lenovac-Leskovac Villages area.

Location, boundaries, lithology and genesis: The EM developed in the eastern part of the TMC (Fig. 1) in a shallow marine environment, infilling sharp volcanic bedrocks (Đorđević & Banješević 1997). The rocks are coarse- to fine-grained, massive, coarsely banded, sometimes even laminated (Fig. 5). They are composed of texturally and structurally different fragments deriving from different volcanic facies of the AT. The EM are often interlayed with the sediments (Figs. 2, 5 and 6).

Age: Sometimes, the rocks contain very well preserved Coniacian–Campanian microfauna (Đorđević & Banješević 1997 and Đorđević 2005).

Osnić basaltic andesite (AO) and Ježevica andesite (AJ)

Name: After the Osnić Village.

Synonyms: “Basaltic andesites or volcanites of the II volcanic phase” – Drovenik *et al*. 1962.

“Crna Reka andesite-basalt, Dumbrava andesite-basalt, Osnić andesite-basalt, Šarbanovac andesite” – Đorđević & Banješević 1997.

“Pyroxene andesitic and hornblende andesitic volcanic rocks” – Banješević *et al*. 2003.

“Hornblende-pyroxene and pyroxene andesite” – Clark & Ullrich 2004.

“Senonian basaltic andesite and andesite” – Banješević 2006.

“Upper Cretaceous volcanics (Phase II)” – Zimmerman *et al*. 2008.

Type locality (Type section): A section northern of the Osnić Village, from the Metovnica Village to the Šarbanovac Village. An a additional localities are in the area of the Ježevica Mt. and the Brestovačka Banja.

Fig. 5. Fine-grained, massive, banded and laminated epiclastites are interlayed with the sediments.

Location, boundaries, lithology and genesis: The rock suite corresponding to andesite – basaltic andesite of calc-alkaline to tholeiitic character can be distinguished among the Senonian volcanic rocks of the TMC. The first subsuite includes pyroxene basaltic andesite (AO), while the second subsuite comprises amphibole andesite (AJ). Both rock subsuites are located in the central and western parts of the TMC (Fig. 1) and are sometimes closely associated. The AO are predominant. These volcanic rocks are both underlain and overlain by sedimentary rocks (Fig. 6). Field and laboratory studies on several profiles showed that the underlying sediments contain Turonian–Santonian microfauna (Fig. 6), while the overlying sediments are composed of resedimented volcaniclastites, clastitic or reef sediments of Campanian–Maastrichtian age (Đorđević & Banješević 1997).

The pyroxene basaltic andesites are dark grey rocks (Fig. 7) of porphyritic texture, characterized by mm-sized phenocrysts. The structure is most commonly massive and sometimes vesicular. Plagioclase and clinopyroxene are the most abundant phenocrysts, while orthopyroxene and amphibole occur in small amounts or are completely subordinate. The plagioclase contains 42–93 % of An components, therefore these plagioclases are more basic than those occurring in the amphibole andesites and the AT. The amphiboles correspond to tschermakites, rarely to Mg hornblende, and show very primitive, more basic character than the amphiboles in the AT. The clinopyroxene corresponds to augites ($Wo_{40.3–50.2}$-$En_{36.3–45.2}$-$Fs_{11.1–18.1}$), while the rhombic pyroxene is enstatitic in character. The amount of phenocrysts in these rocks rarely reaches 50 vol. %. The groundmass is most often hypocrystalline, but rare holocrystalline varieties also occur.

The amphibole andesites are most frequently massive rocks, rarely with vesicular or banded structure, sometimes with very well exposed tabular or rectan-

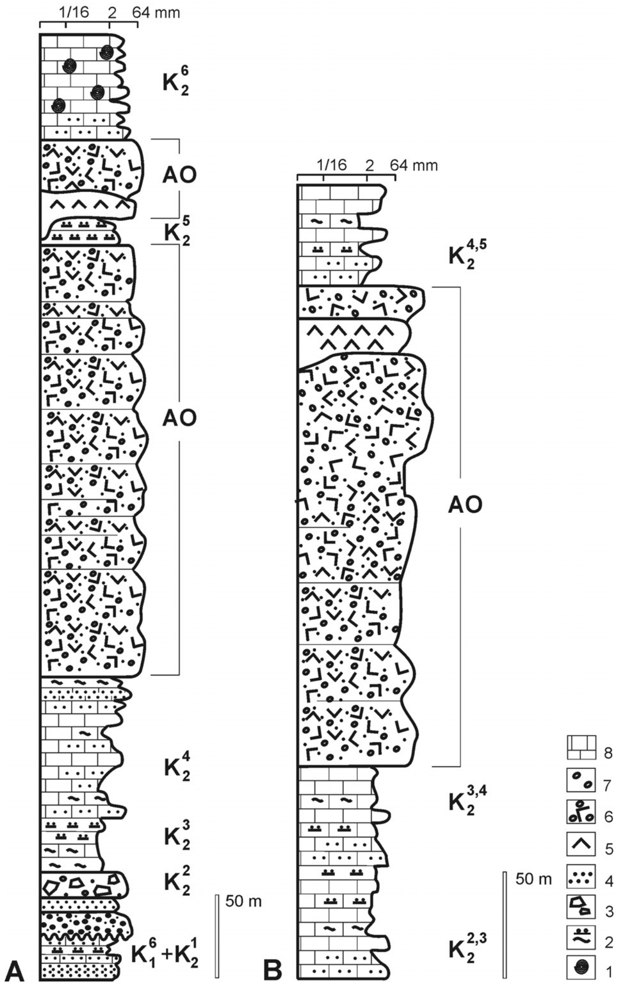

Fig. 6. Schematic geological columns Arnauta (A) northwest of the Osnić Village and Metovnica–Šarbanovac (B) north of the Osnić Village, with a graphical lithology log. **AO,** Osnić basaltic andesite; **1,** Reef fossil; **2,** Marl and silty marl; **3,** Brecia; **4,** Sandstone; **5,** Lava flow; **6,** Fine- to coarse-grained volcanite; **7,** Conglomerate; **8,** Limestone.

gular jointing. Their color varies from grey, pale-green to green-grey. The texture is hypo- to holocrystalline porphyritic, often with a fluidal groundmass. Amphibole and plagioclase phenocrysts are always present, clinopyroxene is subordinate, while orthopyroxene and biotite occur only rarely. The chemical composition of the minerals is very similar to the pyroxene-bearing varieties, except that the plagioclases are more basic in the latter.

The volcanic rocks predominantly occur as lava flow facies (autobreccias and hyaloclastic breccias) and resedimented volcaniclastic deposits. Lava flow facies are up to several meters thick, while their length reaches several hundred meters. The transitions from coherent to autobrecciated parts are usually very sharp (Fig. 7). The fragments are most often angular, rarely subangular, and have a very uniform composition and dimensions. They are rarely coarser than 10 cm in diameter. The hyaloclastites show gradual transitions toward coherent lava flow facies. They are unstratified, poorly sorted rocks, composed of semi-angular to angular fragments of different size – from 1 cm to up to 20 cm. The rock fragments show typical hyaloclastic characteristics, such as chilled margins, tiny normal joints and jig-saw-fit puzzle textures (YAMAGISHI 1991). In addition, there are numerous occurrences of lava lobes and pseudo-pillows (KANO *et al.* 1991). Shallow intrusion facies are represented by necks and dykes. Remnants of the pyroclastic rock deposits are very rare and exposed at only a few localities.

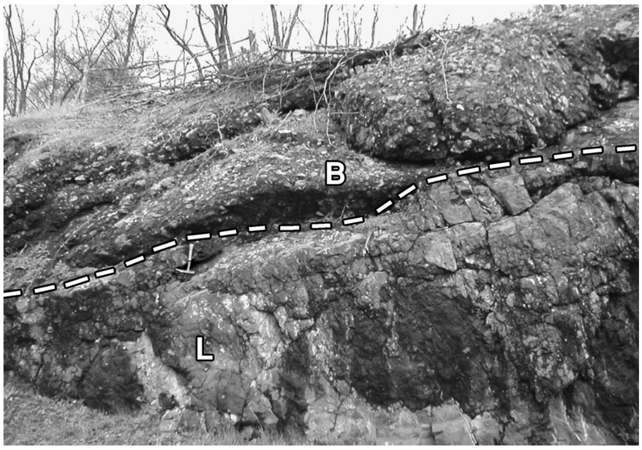

Fig. 7. The coherent pyroxene basaltic andesite lava flow (L) and autobreccia (B) in the upper part. The transitions from coherent to autobrecciated parts are very sharp. The dashed line marks the boundary lava flow and autobreccia.

The resedimented volcanoclastites are mostly stratified volcaniclastic rocks, psamitic to psephitic in grain-size of different origin and type of transport. The sedimentological and lithological characteristics of some deposits are very well exposed, clearly referring to sedimentary types of transportation (mostly debris flow or grain flow). However, for the other deposits, neither transportation type nor material source can be determined. The rock composition is heterogeneous, although there are some layers showing very similar fragment composition. The fragments are semi angular to rounded. The rocks are mostly semi- or well-sorted, but sometimes they can be very poorly sorted, showing typical sedimentary structures: normal and inversed gradation, parallel lamination, rarely also crossed or wave-like lamination.

Age: According U/Pb age zircon analysis, between 82.27±0.35 and 81.79±0.54 Ma. The age of the AO of the dyke from the Brestovac Village to the Brestovačka Banja area was confirmed as Santonian–Lower Campanian (BANJEŠEVIĆ *et al.* 2006).

Valja Strž plutonite (PVS)

Name: After the Valja Strž area.

Synonyms: “Laramian plutonite” – Drovenik *et al.* 1962.

“Subvolcanic-hypabyssal rocks of Ježevica” – Đorđević & Banješević 1997.

“Hypabyssal and abyssal rocks” – Banješević *et al.* 2003.

“Laramide intrusions” – Clark & Ullrich 2004.

“Campanian plutonite” – Banješević 2006.

“Upper Cretaceous plutons” – Zimmerman *et al.* 2008.

Type locality (Type section): The area of Valja Strž. An a additional locality is in the Ježevica Mountain.

Location, boundaries, lithology and genesis: The PVS occur at the western margin of the TMC (Fig. 1). They are grey to dark-grey rocks of hypidiomorphic granular texture and massive structure (Fig. 8), sometimes showing rectangular jointing. They range in composition from monzodiorite and monzonite to diorite, Q-diorite, granodiorite, syenite and rare gabbro. Generally, the plutonic rocks consist of plagioclase (10–58 vol. % their chemical composition varies from 20 to 46 % An component), potassium feldspar (15 – 37 vol. %), quartz (up to 10 vol. %), amphibole (up to 13 vol. %), biotite (about 11 vol. %), orthopyroxene (3–4 %, rarely around 23 vol. %, $Wo_{26.5–45.7}$-$En_{38.6–56.1}$-$Fs_{12.5–19.5}$), rare clinopyroxene (maximum 2 vol. %) and various accessory minerals (around 3 vol. %) (Majer 1953; Drovenik 1959; Đorđević & Banješević 1997 and Banješević 2006).

Fig. 8. Grey to dark-grey plutonic rock from Valja Strž with a hypidiomorphic granular texture and a massive structure.

Age: According to U/Pb age zircon analysis, the age of the Valja Strž plutonite is 78.62±0.44 Ma, Upper Campanian age of the PVS was confirmed (von Quadt *et al.* 2002).

Boljevac latite (LB)

Name: After Boljevac.

Synonyms: “Volcanite of the III volcanic phase” – Drovenik *et al.* 1962.

“Porphyroid biotite-augite mozonite” – Đorđević & Banješević 1997.

“Alkali basalt of Zlot” – Milovanović *et al.* 2005.

“Latite” – Banješević 2006.

“Upper Cretaceous volcanics (Phase III)” – Zimmerman *et al.* 2008.

Type locality (Type section): The outcrops near Boljevac.

Location, boundaries, lithology and genesis: Numerous latitic dykes occur along the western border of the TMC. These rocks crosscut the AO and the AJ. They appear in the form of shallow intrusions (dykes, sills and veins), seldom as lava flows. They are usually small masses, up to several tens of meters long and 3 to 4 meters thick. The rocks are dark-grey, showing very distinctive textures characterized by large, elongated phenocrysts of plagioclase and potassium feldspar, which sometimes exhibit fluidal orientations (Fig. 9). The texture is fine-grained, very fine-grained or hypocrystalline porphyrithic with a microcrystalline, intersertal and pilotaxitic groundmass. The latites consist of plagioclase (53–67 % An), potassium feldspar (61–69 % Or), clinopyroxene and various accessory minerals (Milovanović *et al.* 2005).

Fig. 9. The dark-grey latite south of Boljevac shows very distinctive textures characterized by large, elongated phenocrysts of plagioclase and potassium feldspar, which exhibit fluidal orientation.

Age: The latite crosscut the AO and AJ, however their age is poorly constrained.

Conclusions

Through long-term multidisciplinary and continuous geological investigations, as well as the employment of the volcanic facies concept in the textural and genetic classification of volcanic deposits, new geological data regarding the petrography and volcanic characteristics of the TMC magmatic and sedimentary rocks are available. The TMC consists of magmatic suites and sedimentary formations. After the Albian–Cenomanian sedimentary cycle, sedimentations lasted continuously from the Lower Turonian to the Maastrichtian. The available lithostratigraphic, paleontological and radiometric data indicate that the Upper Cretaceous magmatism in the TMC lasted more than 10 million years, from the Upper Turonian to the Upper Campanian. In this period, the volcanic front moved from East to West. The volcanic processes were subaerial to marine effusive, hypoabyssal and very rarely explosive in character. It commenced with andesitic to trachyandesitic volcanism (Timok andesite) in the present easternmost parts of the TMC. The volcanic rocks overlay Cenomanian or Lower Turonian sediments. When the volcanic processes ceased in the eastern parts, a new volcanic front opened in the central and western parts of the TMC. The Osnić basaltic andesite and Ježevica andesite overlay sediments containing Turonian–Coniacian microfauna and are overlain by Upper Campanian clastic and reef sediments. The magmatic activity finished with plutonic rocks (Valja Strž plutonite) and latitic dykes (Boljevac latite) in the western parts of the TMC. The termination of volcanic activity in the TMC was followed by subvolcanic processes in the Ridanj–Krepoljin Zone, which is situated more to the west. Deposition of reef sediments and coarse-grained sediments (conglomerates and sandstones) of Upper Campanian–Maastrichtian age certainly represent the end of continual marine development in the TMC area.

Acknowledgements

The author would like to thank CHRISTO DABOVSKI, IVAN ZAGORCHEV (Sofia), VLADICA CVETKOVIĆ (Belgrade) and ION-TUDOR BERZA (Bucharest) for their constructive reviews that significantly improved the paper. Thanks are due to the colleagues MARIJANA RADOVIĆ and DIVNA JOVANOVIĆ for critically reading the paper and correcting the figures. This work was supported by the Ministry for Science and Technical Development of the Republic of Serbia through Project No. 146013B.

References

AIELLO, E., BARTOLINI, C., BOCALETTI, M., GOCEV, P., KARAGJULEVA, J., KOSTADINOV, V. & MANETTI, P. 1977. Sedimentary features of the Srednogorie Zone (Bulgaria), an Upper Cretaceous Intra-arc Basin. *Sedimentary Geology*, 19: 39–68.

ANTONIJEVIĆ, I., GRUBIĆ, A. & ĐORĐEVIĆ, M. 1974. The Upper Cretaceous paleorift in eastern Serbia. *In:* KARAMATA, S. (ed.), *Metallogeny and Concept of the Geotectonic Development of Yugoslavia*, 315–339. Faculty of Mining and Geology, Belgrade.

BANJEŠEVIĆ, M. 2002. Geology of the area between eastern hillslope of the Crni Vrh Mt. and the Kriveljska Reka area – part of the Timok Magmatic Complex. *34th International October Conference, Journal of Mining and Metallurgy,* Special issue, 30–35, Bor.

BANJEŠEVIĆ, M., RADOVIĆ, M., JELIĆ, D. & COCIĆ, S. 2003. New data of geological composition westward of Veliki Krš – Timok Magmatic Complex. *35th International October Conference, Journal of Mining and Metallurgy*, 58–62, Bor.

BANJEŠEVIĆ, M. 2006. Upper Cretaceous magmatism of the Timok Magmatic Complex. Unpublished PhD dissertation., 184 pp. Faculty of Mining and Geology, Belgrade (in Serbian).

BANJEŠEVIĆ, M., CVETKOVIĆ, V., VON QUADT, A., PEYTCHEVA, I. & COCIĆ, S. 2006. Geodynamic reconstructions based on the magmatism in the Timok Magmatic Complex (East Serbia) – part of the Carpathian–Balkan Belt. *18th Congress of Carpathian-Balkan Geological Association*, 27–29, Belgrade.

BERZA, T., CONSTANTINESCU, E. & VLAD, S.-N. 1998. Upper Cretaceous Magmatic Series and Associated Mineralization in the Carpathian–Balkan Orogen. *Resource Geology*, 48 (4): 291–306.

BOCCALETTI, M., MANETTI, P. & PECCERILLO, A. 1974. The Balkanides as an instance of Back-arc Trust Belt: Possible relation with the Hellenides. *Geological Society American Bulletin,* 85: 1077–1088.

BREITHAUPT, A. 1861. Timazit, eine neue Gesteisart und Gamzigradit, ein neuer Amphibol. *Berg und Huttenmannische Zeitung*, 20: 51–54.

CIOBANU, C., COOK, N. & STEIN, H. 2002. Regional setting and geochronology of the Late Cretaceous Banatitic Magmatic and Metallogenetic Belt. *Mineralium Deposita*, 37: 341–567.

CLARK, H.A. & ULLRICH, D.T. 2004. $^{40}Ar/^{39}Ar$ age data for andesitic magmatism and hydrothermal activity in the Timok Massif, eastern Serbia: implications for metallogenetic relationships in the Bor copper-gold subprovince. *Mineralium Deposita*, 39: 256–262.

CAS, R.A.F. & WRIGHT, J.V. 1987. Volcanic successions, modern and ancient. A geological approach to processes products and succession. 528 pp. Unwin Hyman Inc., Oxford,

DABOVSKI, C., HARKOVSKA, A., KAMENOV, B., MAVRUDCHIEV, B., STANICHEVA-VASSILEVA, G. & YANEV, Y. 1991. A geodynamic model of the Alpine magmatism in Bulgaria. *Geologica Balcanica*, 21: 3–15.

DROVENIK, M. 1959. Complement to understanding the Timok Eruptive Massive rocks. *Rasprave in poročila, Geologija,* 5: 11–21 (in Slovenian).

DROVENIK, M., ANTONIJEVIĆ, I. & MIĆIĆ, I. 1962. New reference on magmatism and geological setting of the Timok Eruptive Area. *Vesnik Geozavoda, A*, 20: 67–79 (in Serbian).

ĐORĐEVIĆ, M. & BANJEŠEVIĆ, M. 1997. Geology of the southern part of the Timok Magmatic Complex, Booklet and Geological Map 1:50000. 171 pp. Federal Ministry of Economy FR Yugoslavia, Belgrade (in Serbian).

ĐORĐEVIĆ, M. 2005. Volcanogenic Turonian and epiclastics of the Senonian in the Timok Magmatic Complex between Bor and the Tupižnica Mountain, eastern Serbia. *Geološki anali Balkanskoga poluostrva (for 2004 – 2005),* 66: 63–71.

JANKOVIĆ, S. 1977. The Copper Deposits and Geotectonic Setting of the Tethyan Eurasian Metallogenetic Belt. *Mineralium Deposita*, 12: 37–47.

GRUBIĆ, A. 1983. Tectonic feature and Mesozoic-Cenozoic history of East Serbia (Yugoslavia). *12th Congress of the Carpatho–Balkan Geological Association*, 57–64, Bucharest.

HANDLER, R., VELICHKOVA, S.H., NEUBAUER, F. & IVANOV, Z. 2004. $^{40}Ar/^{39}Ar$ age constrains on the timing of the formation of Cu-Au deposits in the Panagyurishte region, Bulgaria. *Schweizerische Mineralogische und Petrographische Mitteilungen*, 84 (1): 119–132.

HSU, K., NACHEV, I. & VUCHEV, V. 1977. Geologic evolution of Bulgaria in light of plate tectonics. *Tectonophysics,* 40: 245–256.

KANO, K., TAKEUCHI, K., YAMAMOTO, T. & HOSHIZUMI, H. 1991. Subaqueous rhyolite block lavas in the Miocene Ushikiri Formation. Shimane Peninsula, SW Japan. *Journal Volcanological Geothermal Resources*, 46: 241–253.

KARAMATA, S. & KRSTIĆ, B. 1996. Terranes of Serbia and neighboring areas. *In:* KNEŽEVIĆ, V., ĐORĐEVIĆ, P. & KRSTIĆ, B. (eds.), *Terranes of Serbia*, 25–40. Belgrade University and Serbian Academy of Science and Art, Belgrade.

KRÄUTNER, H.G. & KRSTIĆ, B. 2003. Geological map of the Carpatho–Balkanides between Mehadita, Oravita, Niš and Sofia. Geoinstitute, Belgrade.

LILOV, P. & CHIPCHAKOVA, S. 1999. K-Ar dating of Upper Cretaceous magmatic rocks and hydrothermal metasomatic rocks from Central Sredna Gora. *Geochemistry, Mineralogy and Petrology*, 36: 77–91.

LJUBOVIĆ-OBRADOVIĆ, D. 2008. Paleontological and biostratigraphical characteristics of the Upper Cretaceous sediments of the Timok Magmatic Complex (eastern Serbia). Unpublished PhD dissertation, 134 pp. Faculty of Mining and Geology, Belgrade (in Serbian).

MAJER, V. 1953. Complement to of the understanding of monzonitic type rocks in eastern Serbia. *Vesnik Geozavoda*, 10: 135–147 (in Serbian).

MCPHIE, J., DOYLE, M. & ALLEN, R. 1993. Volcanic Textures. A guide to the interpretation of textures in Volcanic Rocks. 198 pp. Centre for Ore Deposit and Exploration Studies University of Tasmania.

MILOVANOVIĆ, D., KARAMATA, S. & BANJEŠEVIĆ, M. 2005. Petrology of the alkali basalts of Zlot, Timok Magmatic Complex (eastern Serbia). *Tectonophysics*, 410 (1–4): 501–509.

NORTH AMERICAN COMMISSION ON STRATIGRAPHIC NOMENCLATURE. 1983. North American Stratigraphic Code. *AAPG Bulletin*, 5 (67): 841–875.

POPOV, P., BERZA, T., GRUBIĆ, A. & IOANE, D. 2002. Late Cretaceous Apuseni–Banat–Timok–Srednogorie (ABTS) Magmatic and Metallogenic belt in the Carpathian–Balkan orogen. *Geologica Balcanica,* 32 (2–4): 145–163.

SALVADOR, A. (ed.) 1994. *International Stratigraphic Guide. A Guide to Stratigraphic Classification, Terminology and Procedure*. 214 pp. International Subcommision of Stratigraphic Classification of the International Union of Geological Science and Geological Society of America.

SCHMINCKE, H.-U. 2004. Volcanism. 324 pp. Springer Verlag, Berlin.

YAMAGISHI, H. 1991. Morphological features of Miocene submarine coherent lavas from the "Green Tuff" basins: examples from basaltic and andesitic rocks from the Shimokita Peninsula, northern Japan. *Bulletin of Volcanology,* 53: 173–181.

VLAD, S.-N. 1997. Calcic skarns and transversal zoning in the Banat Mountains, Romania: indicator of an Andean-type setting. *Mineralium Deposita,* 32: 446–451.

VON QUADT, A., PEYTCHEVA, I., CVETKOVIĆ, V., BANJEŠEVIĆ, M. & KOŽELJ, D. 2002. Geochronology, geochemistry and isotope tracing of the Cretaceous magmatism of East Serbia as part of the Apuseni–Timok–Srednogorie metallogenic belt. 17th Congress of Carpathian–Balkan Geological Association, *Geologica Carpathica,* Special issue, 175–177.

VON QUADT, A., DRIESNER, T. & HEINRICH, C.A. 2004. Geodynamic and ore deposit evolution of the Alpine–Carpathian–Balkan–Dinaride orogenic system. *Schweizerische Mineralogische und Petrographische Mitteilungen*, 84: 1–2.

VON QUADT, A., MORITZ, R., PEYTCHEVA, I. & HEINRICH, C.A. 2005. Geochronology and geodynamic of Late Cretaceous magmatism and Cu-Au mineralization in the Panagyurishte Region of the Apuseni–Banat–Timok–Srednogorie Belt, Bulgaria. *Ore Geological Revue*, 27: 95–126.

ZIMMERMAN, A., STEIN, H., HANNAN, J., KOŽELJ, D., BOGDANOV, K. & BERZA, T. 2008. Tectonic configuration of the Apuseni–Banat–Timok–Srednogorie belt, Balkans–South Carpathians, constrained by high precision Re-Os molybdenite ages. *Mineralium Deposita*, 43: 1–21.

Резиме

Горњокредна свита магматских стена Тимочког магматског комплекса

Рад пружа синтезу података о геолошкој грађи и свити магматских стена Тимочког магматског комплекса (ТМК), добијених дугогодишњим, мултидисциплинарним, континуираним геолошким истраживањима и допуњених савременим концептом вулканских и седиментних фација и генетском класификацијом вулканских наслага. ТМК лежи на континенталној кори изграђеној од

различитих стена протерозојске до доњокредне старости. После седиментног пакета карбонатног карактера који се континуирано таложи од доње јуре, нови седиментациони циклус почиње након албске трансгресије. Интензивно колебање депозиционе средине и знатан прилив теригене компоненте карактеристика је седиментних алб–ценоманских процеса који претходе појави вулканизма у ТМК. Турон–сенонски развој ТМК, после краћег хијатуса, почиње новим седиментационим циклусом. Новонастали седименти транзгресивно леже преко алб–ценоманских кластита и према нађеној микрофауни припадају доњем и средњем турону. Цели простор ТМК даље у сенону показује знатне разлике у развићу источних (борско–леновачки тектонски блок – БЛТБ) и западних (црноречки тектонски блок – ЦТБ) подручја.

У БЛТБ, одвија се таложење седимената и епикластита све до мастрихта и појава вулканизма. Вулканизам претежно андезитског састава (Андезита Тимока), траје од турона до горњег сантона. Вулканска активност је у највећој мери била копнена, субаерског, ефузивног до хипоабисалног карактера. Настају вулканске фације кохерентних и аутофрагментираних лавичних излива, плитке интрузије и реседиментоване вулканокластичне наслаге. Интрузивну фазу прате поствулкански процеси и циркулисања минерализованих раствора који стварају економски најзначајнија порфирска лежишта бакра. Вулканити се еродују и депонују даље од вулканских центара стварајући син- и пост-еруптивне вулканокластичне наслаге – епикластите (Епикластити Метовнице). Ове кластичне стене, псефитске до псамитске гранулације, изграђене су у високом проценту од фрагмената андезита из подлоге. Врло често су замењивани пирокластичним наслагама. На много места епикластити се прослојавају са седиментима. У њима се могу наћи фрагменти хидротермално измењених андезита и микрофауна конијак–кампанске старости .

У ЦТБ, односно у централним и западним деловима ТМК, таложење сенонских седимената у сантону прекида нова вулканска активност андезитског до андезитбазалтског састава. Овај вулканизам (Андезитбазалти Оснића), претежно линеарног ефузивног типа, првобитно се одвија у морским условима. Даљи развој вулканизма карактеришу ефузивне и експлозивне ерупције (Андезити Јежевице). Тада се одлажу велике количине вулканског материјала који највероватније почиње да формира вулканска острва. Вулканизам се одвија у копненим и морским условима. Самим тим издвајају се разноврсне вулканске фације: лавични изливи, аутобрече, хијалокластити, плитке интрузије – дајкови, некови, жице, реседиментовани вулканокластити и ретки пирокластити. У завршним фазама вулканизма у ТМК, утискују се плутонске стене (Плутонити Ваља Стрж) уз изражене поствулканске процесе који су разноврсни по трајању, интензитету и карактеру. Минерализациони и хидротермални процеси појављују се на широком простору. Након или у току ове интрузивне фазе вулкански фронт се помера даље на запад отварајући ново вулкански активно подручје, Ридањско–крепољинску зону. У централним и западним деловима ТМК јављају се и мања лавична тела или плитке интрузије латитског састава (Латити Бољевца), које пробијају андезитбазалте. Старост ових стена још није прецизно одређена.

У горњем кампану, у централним деловима ТМК, подлога од вулканита и велики прилив теригене компоненте у топлу, плитку, морску средину, погодује стварању спрудних седимената. Истовремено, у источним деловима ТМК, почиње таложење дебелог пакета регресивних грубокластичних седимената – ситнозрних пешчара до крупнозрних конгломерата и ретких алевролита. Таложење ових седимената указује на постепено издизање и оплићавање депозиционих простора, чиме се завршава континуирани морски развој у ТМК.

Геолошки анали Балканскога полуострва Annales Géologiques de la Péninsule Balkanique	71	23–35	Београд, децембар 2010 Belgrade, December 2010

DOI: 10.2298/GABP1071023C

Upper Permian ostracode assemblage from the Jadar Block (Vardar Zone, NW Serbia)

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Abstract. Ostracodes from the Changhsingian (latest Permian age) in the uppermost part of the "Bituminous Limestone" Formation of the Komirić Section in NW Serbia (Jadar Block, Vardar Zone) are described and illustrated. Three new species of ostracodes are introduced: *Basslerella jadarensis* n. sp., *Acratia serbianella* n. sp., and *Knoxiella vardarensis* n. sp. The ostracode assemblage, together with conodonts and foraminifers, is the first record of the youngest Late Permian age microfaunas from Serbia and from the central part of the Balkan Peninsula.

Key words: ostracodes, latest Permian (Changhsingian), taxonomy, stratigraphy, Vardar Zone, Jadar Block, NW Serbia.

Апстракт. У раду су приказани остракоди чангсјингског ката најгорњег перма из највиших делова формације „битуминозних кречњака" локалитета Комирић (СЗ Србија, Јадарски блок, Вардарска зона). Међу нађеним остракодима, утврђене су и описане три нове врсте: *Basslerella jadarensis* n. sp., *Acratia serbianella* n. sp. и *Knoxiella vardarensis* n. sp. Остракодска асоцијација, заједно са конодонтима и фораминиферима, представља први налаз микрофауне најмлађе горњопермске старости, како у Србији, тако и у централном делу Балканског полуострва.

Кључне речи: остракоди, највиши перм (чангсјингски кат), таксономија, стратиграфија, Вардарска зона, Јадарски блок, СЗ Србија.

Introduction

The Permian and Triassic deposits widely distributed in the Jadar Block area (NW Serbia) have been the subject of numerous geological investigations. Among these strata, sediments belonging to the Permian–Triassic (P–T) boundary interval, represented by shallow-water marine carbonates with different fossil associations and specific characteristics of the depositional environments, are unique in Serbia. They lack ammonoids, but diverse Upper Permian macro- and micro-assemblages (brachiopods, bivalves, gastropods, algae, foraminifers, *etc.*), and a poor Lower Triassic microfossil association (foraminifers, ostracodes) have been determined.

During long-term geological investigations, particularly in NW Serbia, the Serbian authors of this paper collected many samples for palaeontological and sedimentological analysis. The main interest was to confirm the presence of conodonts in Palaeozoic and Triassic sediments, especially in the P–T interval beds. Additionally, with these intensive geological studies of NW Serbia, the authors intended to document palaeontological, biostratigraphical, and sedimentological data in order to refine the existing lithostratigraphical definitions.

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These investigations resulted in several important papers on the Variscan and Early Alpine evolution of the Jadar Block (FILIPOVIĆ *et al*. 2003), Late Pennsylvanian conodont biostratigraphy and sedimentology (SUDAR *et al*. 2007b), Late Permian conodonts (SUDAR *et al*. 2007a), Late Permian foraminifers (NESTELL *et al*. 2009), and Early Viséan ammonoid fauna (KORN *et al*. 2010) during the last few years.

The current investigation represents a continuation of the above mentioned studies. In this paper, the Upper Permian ostracode fauna, not only from NW Serbia, but also from the whole of Serbia and the central part of the Balkan Peninsula is determined for the first time. From these regions, only PANTIĆ-PRODANOVIĆ (1979) mentioned "Campilian" ostracodes in the vicinity of Valjevo, and KRSTIĆ (1980) reported the ostracode fauna of the same age from the Gučevo Mt.

The ostracodes described and illustrated herein were found in samples taken from the Komirić section in the Vlašić Mt. region of NW Serbia. They occur together with conodonts and foraminifers in the uppermost part of the "Bituminous Limestone" Formation from the lower part of the section (SUDAR *et al*. 2007a, NESTELL *et al*. 2009).

Geological setting

The Jadar Block, situated at the southern margin of the Pannonian Basin, covers almost the whole area of NW Serbia and southern Srem (Vojvodina). Westwards, it extends beyond the Drina River to eastern Bosnia (Fig. 1A).

This tectonostratigraphic unit is today an exotic block terrane within the Vardar Zone. It is surrounded by the Vardar Zone Western Belt, except on the farthest south-eastern part where it is in direct contact with the Kopaonik Block and the Ridge Unit, which is also a part of the Vardar Zone (Fig. 1A). Unlike the Vardar Zone Western Belt, the absence of post-Early Jurassic sediments, ultramafites, ophiolitic mélange, and Cretaceous flysch development is evident in the Jadar Block (FILIPOVIĆ *et al.* 2003).

In the Jadar Block, the deposition occurred during the Variscan and Early Alpine evolution with a predomination of Dinaridic features. The later tectonic stage is characterized by sedimentation of Upper Permian and lowermost Triassic shallow-water marine carbonates, dolomites of Anisian age, "porphyrites" and pyroclastics of Ladinian age, platform-reefal limestones of Middle and Late Triassic age and their gradual transition into Lower Jurassic limestone.

Komirić Section

The Komirić Section is located on the north side of the Valjevo–Loznica road, in the Komirić Village, on the southern slope of the Vlašić Mt. (GPS coordinates x 4918588, y 7985697, Fig. 1). About 78 m of marine carbonates of Late Permian and Early Triassic age are exposed in this site, but only 19 m of the column were sampled for microfauna. The lower part of the outcrop consists of 7 m dark grey and black, massive to thick-bedded bituminous bioclastic limestones belonging to the "Bituminous Limestone" Formation (Fig. 2). Abundant

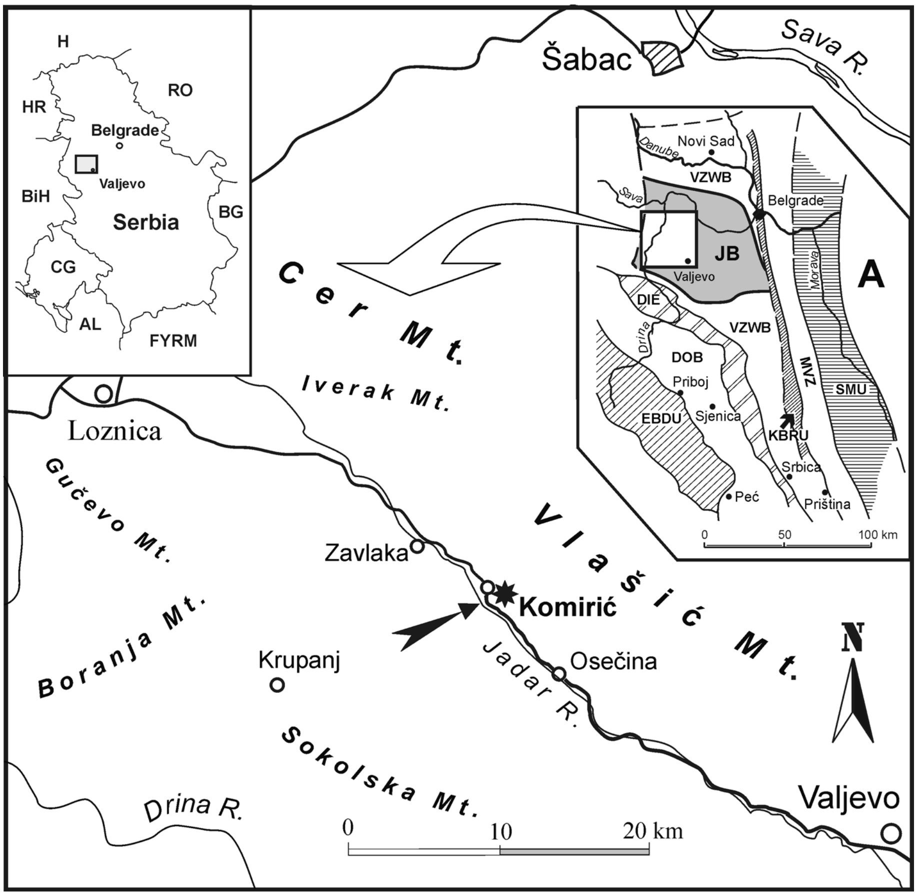

Fig. 1. Location maps of the Komirić Section in NW Serbia, Jadar Block, Vardar Zone (modified after SUDAR *et al*. 2007a). **A.** Terranes of a part of the Balkan Peninsula (KARAMATA *et al*. 2000; KARAMATA 2006): SMU – Serbian-Macedonian Unit; MVZ – Main Vardar Zone; KBRU – Kopaonik Block and Ridge Unit; VZWB – Vardar Zone Western Belt; JB – Jadar Block; DIE – Drina–Ivanjica Element; DOB – Dinaridic Ophiolite Belt; EBDU – East Bosnian–Durmitor Unit.

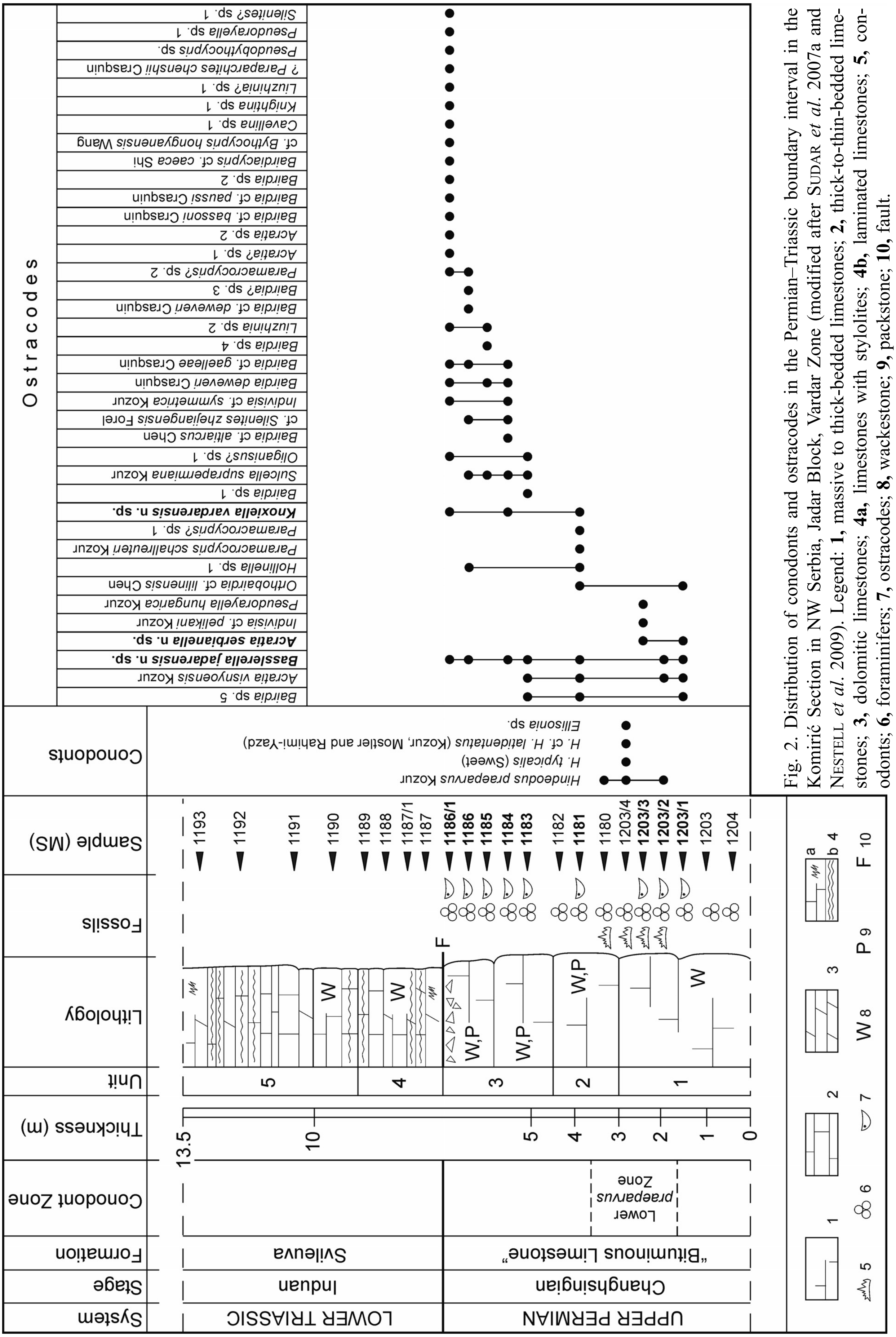

Fig. 2. Distribution of conodonts and ostracodes in the Permian–Triassic boundary interval in the Komirić Section in NW Serbia, Jadar Block, Vardar Zone (modified after SUDAR *et al.* 2007a and NESTELL *et al.* 2009). Legend: **1,** massive to thick-bedded limestones; **2,** thick-to-thin-bedded limestones; **3,** dolomitic limestones; **4a,** limestones with stylolites; **4b,** laminated limestones; **5,** conodonts; **6,** foraminifers; **7,** ostracodes; **8,** wackestone; **9,** packstone; **10,** fault.

foraminifers, algae, ostracodes, conodonts, holothurian sclerites, crinoids, echinoids, brachiopods, gastropods and ophiuroids occur. After a fault, marked with 15 cm-thick breccia, there are 12 m of the thick-to-thin bedded light grey and grey fine crystalline limestones (wackestones) with stylolites and laminae in certain levels. Occurrences of dolomitic limestones are less frequent. These latter limestones contain very rare indeterminable specimens of ostracodes, foraminifers and different parts of echinoids, and belong to the Svileuva Formation, which in Fig. 2 represent only 5.5 m of the column.

Ostracode fauna

Nine samples from the Changhsingian (Late Permian), processed for conodont study by 15–17 % acetic acid digestion, gave a poorly preserved ostracode fauna. However, it is the first time that ostracodes of this age have been discovered in Serbia and it is an important step in the knowledge of the distribution patterns of Upper Permian ostracodes.

Thirty eight species, including three new ones, belonging to 18 genera were distinguished: *Oliganisus*? sp. 1, *Knoxiella vardarensis* n. sp., *Indivisia* cf. *pelikani* KOZUR, 1985, *Indivisia* cf. *symmetrica* KOZUR, 1985, *Knightina* sp. 1, *Hollinella* sp. 1, ?*Paraparchites chenshii* CRASQUIN, 2010, *Bairdia deweveri* CRASQUIN, 2010, *Bairdia* cf *altiarcus* CHEN, 1958, *Bairdia* cf. *bassoni* CRASQUIN, 2010, *Bairdia* cf. *deweveri* CRASQUIN, 2010, *Bairdia* cf. *gaelleae* CRASQUIN, 2010, *Bairdia* cf. *paussi* CRASQUIN, 2010, *Bairdia* sp. 1, *Bairdia* sp. 2, *Bairdia*? sp. 3, *Bairdia* sp. 4, *Bairdia* sp. 5, *Orthobairdia* cf. *lilinensis* CHEN, 2002, cf. *Bythocypris hongyanensis* WANG, 1978, *Liuzhinia* sp. 2, *Liuzhinia*? sp. 1, *Paramacrocypris schallreuteri* KOZUR, 1985, *Paramacrocypris*? sp. 1, *Paramacrocypris*? sp. 2, *Pseudobythocypris* sp., *Bairdiacypris* cf. *caeca* SHI, 1987, *Pseudorayella hungarica* KOZUR, 1985, *Pseudorayella* sp. 1, cf. *Silenites zhejiangensis* FOREL, 2010, *Silenites*? sp. 1, *Acratia serbianella* n. sp., *Acratia visnyoensis* KOZUR, 1985, *Acratia*? sp. 1, *Acratia* sp. 2, *Basslerella jadarensis* n. sp., *Cavellina* sp. 1, and *Sulcella suprapermiana* KOZUR, 1985. Most are in open nomenclature due to their bad preservation and no internal features were observed. Only the new species are described. All the species are figured (Plates 1 and 2). The species distributions are given in Fig. 2.

The collection of ostracodes is deposited in Department of Palaeontology, Faculty of Mining and Geology, University of Belgrade, Belgrade, Serbia under the numbers from MS 1203/1.01 to MS 1186/1.61, corresponding to certain samples in the collection of MILAN SUDAR.

SEM photographs were prepared at the Pierre et Marie Curie University, Micropaleontology Laboratory (Paris).

Abbreviations: L2: median lobe; S2: median sulcus; L3: posterior lobe; DB: dorsal border; AB: anterior border; VB: ventral border; PB: posterior border.

Class Ostracoda LATREILLE, 1806
Subclass Podocopa MÜLLER, 1894
Order Palaeocopida HENNINGSMOEN, 1953
Suborder Kloedenellocopina SCOTT, 1961
Superfamily Kloedenelloidea ULRICH & BASSLER, 1908
Family Geisinidae SOHN, 1961

Genus ***Knoxiella*** EGEROV, 1950
Type species. *Knoxiella semilukiana* EGEROV, 1950

Knoxiella vardarensis n. sp.
Pl. 1, figs. 3–6

Derivation of the name. From the Vardar Zone, where the Jadar Block and the type locality are located.

Holotype. One complete male carapace figured on Pl. 1, fig. 3; collection number MS 1181.21.

Paratype. One complete male carapace figured on Pl. 1, fig. 4, collection number MS 1186/1.39.

Type locality. Komirić Section, Komirić Village, southern slope of the Vlašić Mt., NW Serbia.

Type level. Bed 2, sample MS 1181, 3.80 m at the base of the "Bituminous Limestone" Formation exposed in the Komirić Section, uppermost Permian, Changhsingian.

Material. 3 complete and 1 broken carapaces.

Diagnosis. A species of *Knoxiella* with a blade ridge on L3.

Description. Carapace subrectangular with straight DB; AB regularly rounded with maximum curvature located at mid height; VB regularly rounded; PB with medium radius of curvature and maximum convexity located at the upper third of height; ACA = 140–145°; PCA= 130–135°; free margins flattened; L2 poorly expressed; S2 deep, with lower part located between upper third and mid height; L3 large and clearly marked with a ridge in blade form on the dorsal part, its upper part extends beyond DB; maximum of height located between the anterior third and mid length; no secondary ornamentation observed. Sexual dimorphism expressed by a thickening of posterior part of the carapace in heteromorphs. RV overlaps slightly LV on free margins

Remarks. *Knoxiella vardarensis* n. sp. has the same outline as *Knoxiella infirma* SHI, 1982 from the Late Permian of South China and Turkey (CHEN & SHI 1982; CRASQUIN-SOLEAU *et al*. 2004). Here, the free margins are more flattened and there is a ridge on the dorsal part of L3. A similar ridge is present in some *Sargentina* species, such as *Sargentina pamucakensis* CRASQUIN-SOLEAU, 2004 or *Sargentina transita* (KOZUR, 1985), but the overlap, of course, differs completely between *Knoxiella* and *Sargentina*.

Size. L = 450–575 µm, H = 285–325 µm.

Occurrence. Latest Permian, Changhsingian, uppermost part of the "Bituminous Limestone" Formation; Komirić Section, Jadar Block, Vardar Zone, NW Serbia; samples MS 1181, MS 1184, and MS 1186/1 (see Fig. 2).

Order Podocopida MÜLLER, 1894
Suborder Podocopina SARS, 1866
Superfamily Bairdioidea SARS, 1887
Family Acratiidae GRÜNDEL, 1962

Genus ***Acratia*** DELO, 1930
Type species. *Acratia typica* DELO, 1930

Acratia serbianella n. sp.
Pl. 2, figs. 10–13

?2004 *Acratia* n. sp. 1. - CRASQUIN-SOLEAU, S., MARCOUX, J., ANGIOLINI, L., RICHOZ , S., NICORA, A., BAUD, A. & BERTHO, Y, p. 286, pl. 3, figs. 25–26.

Derivation of the name. From Serbia, where the type locality is located.

Holotype. One complete carapace figured on Pl. 2, fig. 10; collection number MS 1203/1.09.

Paratype. One complete carapace figured on Pl. 2, fig. 11, collection number MS 1203/1.10.

Type locality. Komirić Section, Komirić Village, southern slope of the Vlašić Mt., NW Serbia.

Type level. Bed 1, sample MS 1181, 1.5 m at the base of the "Bituminous Limestone" Formation exposed in the Komirić Section, uppermost Permian, Changhsingian.

Material. 4 carapaces.

Diagnosis. An elongated species of *Acratia* with a reversed overlap and a large radius of curvature at AB.

Description. Carapace elongated (H/L = 0.33–0.38); RV overlaps LV; overlap weak all around the carapace with the maximum at VB; AB with quite large radius of curvature for the genus; AVB straight and horizontal; acratian beak clear but not pronounced; VB slightly convex to straight on the RV, straight to gently concave on the LV; PB tapering; PDV and ADB straight on both valves; carapace thin, biconvex with a maximum of width at mid L.

Remarks. *Acratia symmetrica* HAO, 1992 and *Macrocypris* cf. *menardensis* HARLTON *sensu* SHI & CHEN, 1987 have the same reversed overlap but have a different outline. *Acratia oliverifera* CHEN *sensu* HAO, 1994 (the species figured by HAO (1994) is not *A. oliverifera* CHEN, 1958) has a similar outline but here the acratian beak is less pronounced. *Acratina goemoeryi* KOZUR, 1970 from the Upper Anisian is the closest species but has a straighter DB and a smaller radius of curvature at AB. *Acratia* n. sp. 1 *sensu* CRASQUIN *et al*. 2004 from the Upper Permian of Turkey (Western Taurus) is questionably included in the new species. The uncertainty comes from the fact that the Turkish specimens are not so well preserved.

Size. L = 660–730 µm, H = 260–280 µm.

Occurrence. ? Late Permian, Wuchiapingian, Pamucak Formation, Cürük dağ section, Western Taurus, Turkey; latest Permian, Changhsingian, uppermost part of the "Bituminous Limestone" Formation, Komirić Section; Jadar Block, Vardar Zone, NW Serbia; samples MS 1203/1 and MS 1203/3 (see Fig. 2).

Superfamily Cytheroidea BAIRD, 1850
Family Cytherideidae SARS, 1925

Genus ***Basslerella*** KELLETT, 1935
Type species. *Basslerella crassa* KELLETT, 1935

Basslerella jadarensis n. sp.
Pl. 2, figs. 20–24

Derivation of the name. From the Jadar Block (NW Serbia) where the type locality is located.

Holotype. One complete carapace figured on Pl. 2, fig. 20; collection number MS 1203/1.05.

Paratype. One complete carapace figured on Pl. 2, fig. 21, collection number MS 1203/2.13.

Type locality. Komirić Section, Komirić Village, southern slope of the Vlašić Mt., NW Serbia.

Type level. Bed 1, sample MS 1203/1, 1.5 m at the base of the "Bituminous Limestone" Formation exposed in the Komirić Section, uppermost Permian, Changhsingian.

Material. 12 complete carapaces and 1 broken one.

Diagnosis. A species of *Basslerella* with a relatively high carapace (H/L = 0.72), small radius of curvature at AB and straight DB.

Description. Carapace relatively high (H/L = 0.72); DB straight at RV and convex at LV; AB rounded with a quite small radius of curvature and a maximum convexity located at the lower third of H; VB nearly straight; PB relatively angular with postero-dorsal part quite vertical; maximum H located a little anterior of mid-L; LV overlaps RV all around the carapace; dorsal view biconvex with a maximum thickness located in the posterior part.

Remarks. *Basslerella annesophieae* CRASQUIN, 2010 from the Early–Late Permian of South China and South Alps is quite close to the new species but has an AB with a larger radius of curvature.

Basslerella firma KELLETT, 1935 and *B. obesa* KELLETT, 1935 from the Early Permian of Kansas (USA; KELLETT 1935) both have a more elongate carapace (H/L = 0.60) and a more narrowly rounded AB.

Size. L = 315–675 µm, H = 235–425 µm (Fig. 3).

Occurrence. Latest Permian, Changhsingian, uppermost part of the "Bituminous Limestone" Formation; Komirić Section, Jadar Block, Vardar Zone, NW Ser-

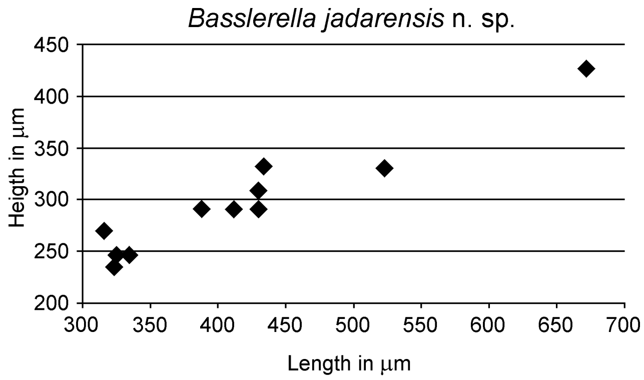

Fig. 3. Height/length diagram of *Basslerella jadarensis* n. sp.

bia; samples MS 1203/1, MS 1203/2, MS 1181, MS 1183, MS 1184, MS 1186/1 and MS 1203/3 (see Fig. 2).

Comments on the ostracode fauna

Three species present here are known in other areas. *Acratia visnyoensis* Kozur, 1985 is known in the Wuchiapingian, the late Permian of the Bükk Mountains in Hungary (Kozur 1985), in the Wordian–Wuchiapingian of western Taurus, Turkey, (Crasquin-Soleau *et al.* 2004) and in the Changhsingian, Late Permian of the Meishan Section, Zhejiang Province, South China.

Bairdia deweveri Crasquin, 2010 occurs in the late Changhsingian of the Dolomites, Italy (Crasquin *et al.* 2008) and of the Meishan Section, South China (Crasquin *et al.* 2010).

?*Paraparchites chenshii* Crasquin, 2010 is known from the latest Changhsingian of the Meishan Section in South China (Crasquin *et al.* 2010). The presence of these three common species demonstrates the palaeobiogeographical links between south-eastern, central and northern parts of the Palaeo–Tethys during the Late Permian.

Ostracodes are predominantly benthic inhabitants and, therefore, reflect sea-floor conditions. Different families had specific palaeoecological preferences. All the forms recognized here are characteristic of intertropical warm waters. Almost all specimens are represented by closed carapaces. This indicates limited transport and/or burial in a soft substratum (Oertli 1971). Such preferences of the Late Palaeozoic–Early Triassic ostracode families may be summarized as follow (Lethiers 1982; Melnyk & Maddocks 1988):

– internal zone with variations of palaeoenvironmental conditions (bathymetry, salinity), Kloedenelloidea, Kirkbyoidea, Hollinoidea (group 3 in Fig. 4);

– median zone with euryhaline environments in shallow to very shallow waters: Paraparchidoidea, Cytherideidae, Cavellinoinidae (group 2 in Fig. 4);

– external zone, open carbonate environments with normal salinity: Bairdioidea (group 1 in Fig. 4).

The respective percentages of the three groups are presented in Fig. 4. This representation shows that all the assemblages analysed here are, on the whole, typical of a platform environment with a depth of less than 50–100 m. Four levels contain ostracode assemblages that group three families, which testify to a more internal zone (samples MS 1203/1, MS 1181, MS 1184 and MS 1186/1).

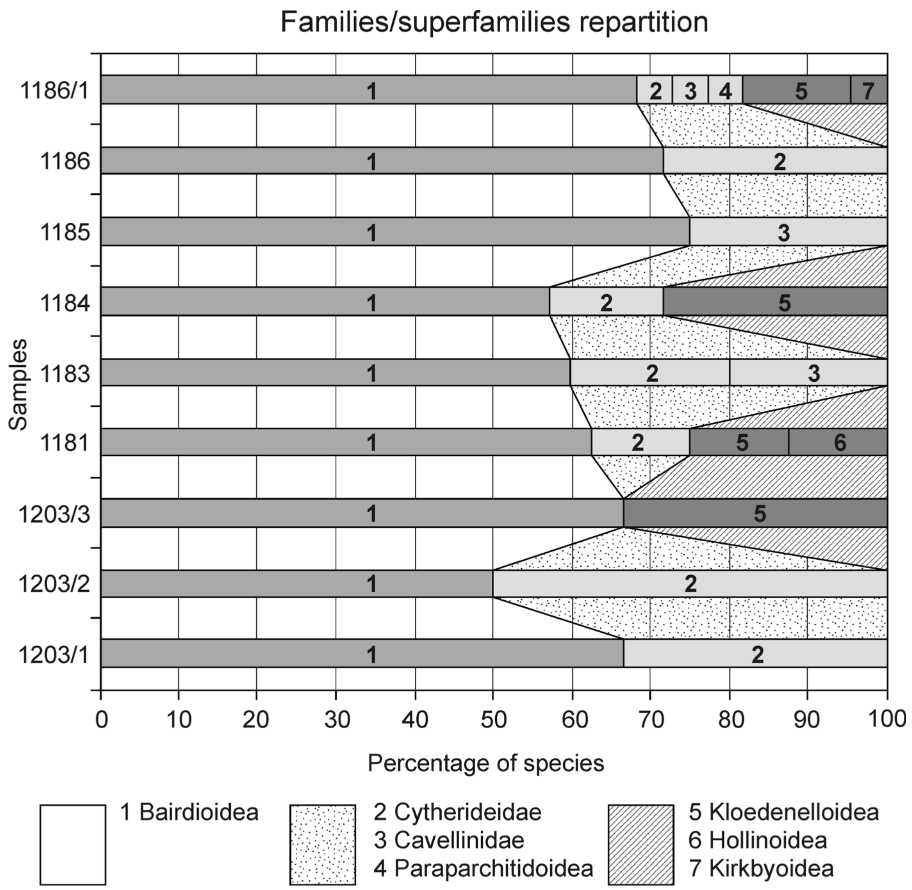

Fig. 4. Repartition of families and/or superfamilies in the samples. Three groups are distinguished, related to their palaeoecological affinities, from distal (1), median (2) and proximal (3) zones.

Acknowledgements

The research of Sylvie Crasquin is supported by CNRS

UMR 7207, CR2P. The investigations of DIVNA JOVANOVIĆ and MILAN SUDAR were supported by the Ministry of Science and Technological Development of the Republic of Serbia, Project No. 146009. The study of TEA KOLAR-JURKOVŠEK was financially supported by the Slovenian Research Agency (programme number P1-0011). This is a contribution to the IGCP-Project 572 ("Recovery of ecosystems after the Permian-Triassic mass extinction"). We thank ALEXANDRE LETHIERS (UPMC, Paris) for the preparation of some figures and the SEM microphotographs. Authors thank to reviewers ALAN FORD (Frankfurt) and MATEVŽ NOVAK (Ljubljana) for the critical and constructive comments.

References

BAIRD, W. 1850. The Natural History of the British Entomostraca. 364 pp. The Ray Society editor, London.

CHEN, D.-Q. & SHI, C.-G. 1982. Latest Permian ostracoda from Nantong, Jiangsu and from Miannyang, Hubei. *Bulletin of Nanjing Institute of Geology and Palaeontology, Academia Sinica,* 4: 105–152.

CHEN, T.C. 1958. Permian ostracods from the Chihsia limestone of Lungtan, Nanking. *Acta Palaeontologica Sinica,* 6 (2): 235–257.

CRASQUIN, S., FOREL, M.-B., FENG, Q., YUAN, A., BAUDIN, F. & COLLIN, P.Y. 2010. Ostracods (Crustacea) through Permian-Triassic boundary in South China: the Meishan stratotype (Zhejiang Province). *Journal of Systematic Palaeontology,* in press.

CRASQUIN-SOLEAU, S., MARCOUX, J., ANGIOLINI, L., RICHOZ, S., NICORA, A., BAUD, A. & BERTHO, Y. 2004. A new ostracode fauna from Permian–Triassic boundary in Turkey (Taurus, Antalya Nappes). *Micropaleontology,* 50: 281–295.

CRASQUIN, S., PERRI, M.C., NICORA, A. & DE WEVER, P. 2008. Ostracods across the Permian - Triassic boundary in Western Tethys: the Bulla parastratotype (Southern Alps, Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, 114 (2): 233–262.

DELO, D.M. 1930. Some Upper Carboniferous Ostracoda from the shale basin of Western Texas. *Journal of Paleontology* 4 (2): 152–178.

EGOROV, V.G. 1950. Frasnian ostracods from Russian platform. I. Kloedenellitidae. 175 pp. *VNIGRI (All Russia Petroleum Research Exploration Institut).*

FILIPOVIĆ, I., JOVANOVIĆ, D., SUDAR, M., PELIKÁN, P., KOVÁCS, S., LESS, GY. & HIPS, K. 2003: Comparison of the Variscan - Early Apline evolution of the Jadar Block (NW Serbia) and "Bükkium" (NE Hungary) terranes; some paleogeographic implications. *Slovak Geological Magazine*, 9 (1): 23–40.

GRÜNDEL, J. 1962. Zur Taxonomie der Ostracoden der Gattendorfia - Stufe Thüringens. *Freiberger Forschungshefte,* 151: 51–105.

HAO WEI CHENG. 1992. Early Triassic Ostracods from Guizhou. *Acta Micropalaeontologica Sinica,* 9(1): 37–44.

HAO WEI CHENG 1994. The development of the Late Permian – Early Triassic ostracod fauna in Guizhou Province. *Geological Review,* 40 (1): 87–93.

HENNIGNSMOEN, G. 1953. Classification of Paleozoic straight hinged Ostracoda. *Norsk Geologisk Tidsskrift,* 31: 185-288.

KARAMATA, S. 2006. The geological development of the Balkan Peninsula related to the approach, collision and compression of Gondwanan and Eurasian units. *In*: ROBERTSON, A.H.F. & MOUNTRAKIS, D., (eds.), *Tectonic Development of the Eastern Mediterranean Region*, Geological Society, London, Special Publications, 260**:** 155–178.

KARAMATA, S., OLUJIĆ, J., PROTIĆ, LJ., MILOVANOVIĆ, D., VUJNOVIĆ, L., POPEVIĆ, A., MEMOVIĆ, E., RADOVANOVIĆ, Z. & RESIMIĆ-ŠARIĆ K. 2000: The Western Belt of the Vardar Zone - the remnant of a marginal sea. *In*: KARAMATA, S. & JANKOVIĆ, S. (eds.), Proceedings of the International Symposium "Geology and Metallogeny of the Dinarides and the Vardar Zone", *Academy of Sciences and Arts of the Republic of Srpska, Collections and Monographs, I, Department of Natural, Mathematical and Technical Sciences,* 1: 131–135.

KELLETT, B. 1935. Ostracodes of the Upper Pennsylvanian and the Lower Permian strata of Kansas: 3. Bairdiidae (concluded), Cytherellidae, Cypridinidae, Entomoconchidae, Cytheridae and Cypridae. *Journal of Paleontology,* 9 (2): 132–166.

KORN, D., JOVANOVIĆ, D., NOVAK, M., SUDAR M.N. 2010. Early late Visean ammonoid faunas from the Jadar Block, NW Serbia. *Geologica Carpathica*, 61, 5, doi: 10.2478/v10096-.

KOZUR, H. 1970. Neue Ostracoden-Arten aus dem Obersten Anis des Bakonyhochlandes (Ungars). *Berichte Naturwissenschaftlich-Medizinischen Vereins in Innsbruck,* 58: 384–428.

KOZUR, H. 1985. Neue Ostracoden-Arten aus dem Oberen Mittelkarbon (Höberes Moskovian), Mittel- und Oberperm des Bükk-gebirges (N-Ungarn). *Geologish Paläontologische Mitteilungen Innsbruck,* 2: 1–145.

KRSTIĆ, N. 1980: The Lower Triassic ostracodes of Gučevo. *Zapisnici Srpskog geološkog društva za 1979. godinu (Vanredni zbor 24. I 1980)*, 203–208 (In Serbian, English summary).

LATREILLE, P.A. 1806. Genera crustaceorum et insectorum: secundum ordinem naturalem in familias disposita, iconibus exemplisque plurimis explicata. Parisiis et Argentorati: A. Koenig publisher, 1: 1–303.

LETHIERS, F. 1982. Les Ostracodes du Dévonien supérieur (Nord de la France, Belgique, Ouest du Canada). *Thése d'état*: 1–489 (unpublished).

MELNYK, D.H. & MADDOCKS, R.F. 1988. Ostracode biostratigraphy of the Permo-Carboniferous of Central and North-Central Texas, part I: Paleoenvironmental framework. *Micropaleontology,* 34 (1): 1–20.

MÜLLER, G.W. 1894. Die Ostracoden des Golfes von Neapel und der angrenzenden Meeres Abschnilte. *Fauna und Flora Neapel,* 21: 1–404.

NESTELL, G.P., SUDAR, M.N., JOVANOVIĆ, D., KOLAR-JURKOVŠEK, T. 2009: Latest Permian foraminifers from the

Vlašić Mountain area, northwestern Serbia. *Micropaleontology*, 55 (5): 495–513.

OERTLI, H.J. 1971. The aspect of Ostracode fauna - a possible new tool in petroleum sedimentology. *In*: OERTLI, H.J. (ed.), Paléoécologie des Ostracodes. *Bulletin du Centre de Recherche, SNPA, 5 supplement*, 137–151.

PANTIĆ-PRODANOVIĆ, S. 1979: Triassic of the Valjevo area. *Excursions quide, 7th International Symposium on Ostracodes, Serbian Geological Society*, 13–15.

SARS, G.O. 1866. Oversigt af marine Ostracoder. *Norske Videnskaps-Akademi, Förhandlingar (1865)*, 1–130.

SARS, G.O. 1887. Nye bidrag til kundskaben om middelhavets invertebrafauna: 4. Ostracods mediterranea (sydeuropaeiske ostracoder). *Archiv for Mathematik og Naturvidenskab,* 12: 173–324.

SARS, G.O. 1922-1928. An account of the Crustacea of Norway. Crustacea. *Bergen Museum*, 9: 1–277.

SCOTT, H.W. 1961. Suborder Beyrichicopina SCOTT, n.suborder. *In*: R.C. MOORE (ed), *Treatise of Invertebrate Paleontology. Part Q. Arthropoda 3, Crustacea, Ostracoda*: Q111. Geological Society of America and Kansas University Press, Lawrence.

SCOTT, H.W. 1961. Suborder Kloedenellocopina SCOTT, n.suborder. *In*: MOORE, R.C. (ed), *Treatise of Invertebrate Paleontology. Part Q. Arthropoda 3, Crustacea, Ostracoda*: Q180. Geological Society of America and Kansas University Press, Lawrence.

SHI, C.G. & CHEN, D.Q. 1987. The Changhsingian ostracodes from Meishan Changxing, Zhejiang. *Stratigraphy and Palaeontology of Systemic Boundaries in China; Permian and Triassic Boundary,* 5: 23–80.

SHI, C.G. & CHEN, D.Q. 2002. Late Permian ostracodes from Heshan and Yishan of Guangxi. *Bulletin of Nanjing Institute of Geology and Paleontology, Academia Sinica,* 15: 47–129.

SOHN, I.G. 1961. Family Geinisidae SOHN, n.fam. *In*: MOORE, R.C. (ed), *Treatise of Invertebrate Paleontology. Part Q. Arthropoda 3, Crustacea, Ostracoda*: Q182. Geological Society of America and University of Kansas Press.

SUDAR, M., JOVANOVIĆ, D., KOLAR-JURKOVŠEK, T., 2007a: Late Permian conodonts from Jadar Block (Vardar Zone, northwestern Serbia). *Geologica Carpathica,* 58 (2): 145–152.

SUDAR, M., JOVANOVIĆ, D., STOJANOVIĆ-KUZENKO, S., FILIPOVIĆ, I., GAJIĆ, R. 2007b: Late Pennsylvanian conodont biostratigraphy and sedimentology of the Kriva Reka Fm. from the Jadar Block, Vardar Zone (NW Serbia). *Journal of Alpine Geology*, 48: 101–115.

ULRICH, E.O. & BASSLER, R.S. 1908. New American Paleozoic Ostracoda. Preliminary revision of the Beyrichiidae, with description of new genera. *United State Natural Museum Paper,* 35: 277–340.

WANG, S.-Q. 1978. Late Permian and Early Triassic ostracods of Western Guizhou and Northeastern Yunnan. *Acta Palaeontologica Sinica,* 17 (3): 277–308.

Резиме

Горњопермски остракоди Јадарског блока (Вардарска зона, СЗ Србија)

Међу седиментима пермске и тријаске старости, веома распрострањеним у области Јадарског блока (СЗ Србија), нарочито су интересантни они који припадају граничном интервалу перм–тријас (P–T). Представљени су плитководним маринским карбонатима у којима су присутне специфичне асоцијације фосила јединствене у Србији. Амонити нису нађени, али стене обилују различитим горњопермским макро и микроасоцијацијама (брахиоподи, шкољке, пужеви, алге, фораминифери и др.), док су микрофосилне асоцијације доњотријаске старости сиромашне, и углавном су представљене фораминиферима и остракодима.

Један од локалитета на ком су опробовани и детаљно палеонтолошки, биостратиграфски и седиментолошки обрађени седименти P–T интервала је у селу Комирић. Стуб се налази на северној страни пута Ваљево–Лозница, на јужним падинама планине Влашић (x 4918588, y 7985697). Дебљине је око 78 m, али је само 19 m узорковано због микрофауне. У доњем делу стуба дебљине 7 m су тамно сиви и црни, дебело слојевити до масивни биокластични кречњаци формације „битуминозних кречњака“ горњег перма. Обилују фораминиферима, алгама, остракодима, конодонтима, криноидима, ехиноидима и др. Следи расед маркиран бречом дебљине 15 cm, па 12 m сивих дебело до танко услојених, спорадично ламинираних финокристаластих кречњака са стилолитима (wackestones) и са ретким неодредљивим остракодима као и фораминиферима доњотријаске старости формације Свилеуве.

Стуб је у почетној фази истраживан ради одређивања конодоната карактеристичних за P–T интервал. Каснијим изучавањима нађена је фораминиферска и остракодска фауна горњопермске старости. Налазак остракода, и других наведених микрофосила, из горњег перма на овим просторима је јединствен у целој Србији као и у централном делу Балканског полуострва.

Последњим истраживањима утврђено је 38 врста остракода (међу њима су 3 нове) које су сврстане у 18 родова. Како су детерминисани облици углавном лоше очувани, у раду су описане само нове врсте: *Knoxiella vardarensis* n. sp., *Acratia serbianella* n. sp. и *Basslerella jadarensis* n. sp. Три врсте: *Acratia visnyoensis* KOZUR, *Bairdia deweveri* CRASQUIN и ?*Paraparchites chenshii* CRASQUIN су познате и у другим областима а представљају палеобиогеографску везу са југоисточним, централним и северним деловима Палеотетиса током најмлађег перма. Испитивани остракоди су преовлађујуће бентоски организми, карактеристични

за међутропске топле воде, и представљени су примерцима са затвореним капцима. То упућује на закључак да су кратко транспортовани и/или су били похрањени у мекој подлози. Испитиване горњопермске-доњотријаске остракодске фамилије се могу сврстати у: *интерну зону* променљивих услова палеосредине (дубина, салинитет) којој припадају: Kloedenelloidea, Kirkbyoidea, Hollinoidea (група 3 на сл. 4), *средњу зону* еухалинске средине плитких до врло плитких вода (Paraparchitidea, Cytherideidae, Cavellinoidea, група 2 на сл. 4) и *екстерну зону* отворено карбонатне средине нормалног салинитета (Bairdiidae, група 1 на сл. 4). Анализирајући све три групе у целини сматра се да су типичне за платформну средину дубине мање од 50–100 m.

PLATE 1

Ostracodes from the Komirić Section, Jadar Block, Vardar Zone, NW Serbia; uppermost part of the "Bituminous Limestone" Formation, uppermost Permian, Changhsingian. Scale bars represent 100 µm.

Figs. 1, 2. *Oliganisus*? sp. 1. 1. Left lateral view of a complete carapace; MS 1183.25. 2. Right ateral view of a complete carapace; MS 1186/1.41.

Figs. 3–6. *Knoxiella vardarensis* n. sp. 3. Holotype, left lateral view of a complete carapace; MS 1181.21. 4. Paratype, left lateral view of a complete carapace; MS 1186/1.39. 5. Left lateral view of a complete carapace; MS 1184.27. 6. Left lateral view of a broken carapace; MS 1186/1.40.

Fig. 7. *Indivisia* cf. *symmetrica* KOZUR, 1985. Left lateral view of a complete carapace; MS 1186/1.42.

Fig. 8. *Indivisia* cf. *pelikani* KOZUR, 1985. Left lateral view of a complete carapace; MS 1203/3.14.

Fig. 9. *Knightina*. sp. 1. Left lateral view of a complete carapace; MS 1186/1.55.

Figs. 10, 11. *Hollinella* sp.10. Left lateral view of a damaged carapace; MS 1186.35. 11. Left lateral view of a damaged carapace; MS 1181.18.

Fig. 12. ?*Paraparchites chenshii* CRASQUIN, 2010. Left lateral view of a complete carapace; MS 1186/1.57.

Fig. 13. *Bairdia* cf. *altiarcus* CHEN, 1958. Right lateral view of a complete carapace; MS 1184.28.

Fig. 14. *Bairdia* cf. *bassoni* CRASQUIN, 2010. Right lateral view of a complete carapace; MS 1186/1.49.

Fig. 15. *Bairdia* cf. *deweveri* CRASQUIN, 2010. Right lateral view of a complete carapace; MS 1186.37.

Figs. 16, 17. *Bairdia* cf. *gaelleae* CRASQUIN, 2010. 16. Right lateral view of a complete carapace; MS 1186/1.45. 17. Right lateral view of a broken carapace; MS 1184.32.

Fig. 18. *Orthobairdia* cf. *lilinensis* CHEN, 2002 (in SHI & CHEN, 2002). Right lateral view of a damaged carapace; MS 1181.17.

Fig. 19. *Bairdia* cf. *paussi* CRASQUIN, 2010. Right lateral view of a complete carapace; MS 1186/1.50.

Figs. 20–22. *Bairdia deweveri* CRASQUIN, 2010. 20. Right lateral view of a quite complete carapace; MS 1186/1.43. 21. Right lateral view of a broken carapace; MS 1186/1.44. 22. Right lateral view of a complete carapace; MS 1184.31.

Fig. 23. *Bairdia* sp. 1. Right lateral view of a complete carapace; MS 1183.22.

Fig. 24. *Bairdia* sp. 2. Right lateral view of a complete carapace; MS 1186/1.51.

Fig. 25. *Bairdia*? sp. 3. Right lateral view of a complete carapace; MS 1186.38.

Fig. 26. *Bairdia* sp. 4. Right lateral view of a broken carapace; MS 1185.33.

Fig. 27. *Bairdia* sp. 5. Right lateral view of a complete carapace; MS 1181.16.

Fig. 28. cf. *Bythocypris hongyanensis* WANG, 1978. Right lateral view of a complete carapace; MS 1186/1.53.

Fig. 29. *Liuzhinia* sp. 2. Right lateral view of a complete carapace; MS 1185.34.

Fig. 30. *Liuzhinia*? sp. 1. Left lateral view of a complete carapace; MS 1186/1.56.

Fig. 31. *Paramacrocypris schallreuteri* KOZUR, 1985. Right lateral view of a damaged carapace; MS 1181.19.

Fig. 32. *Paramacrocypris*? sp. 1. Right lateral view of a complete carapace; MS 1181.20.

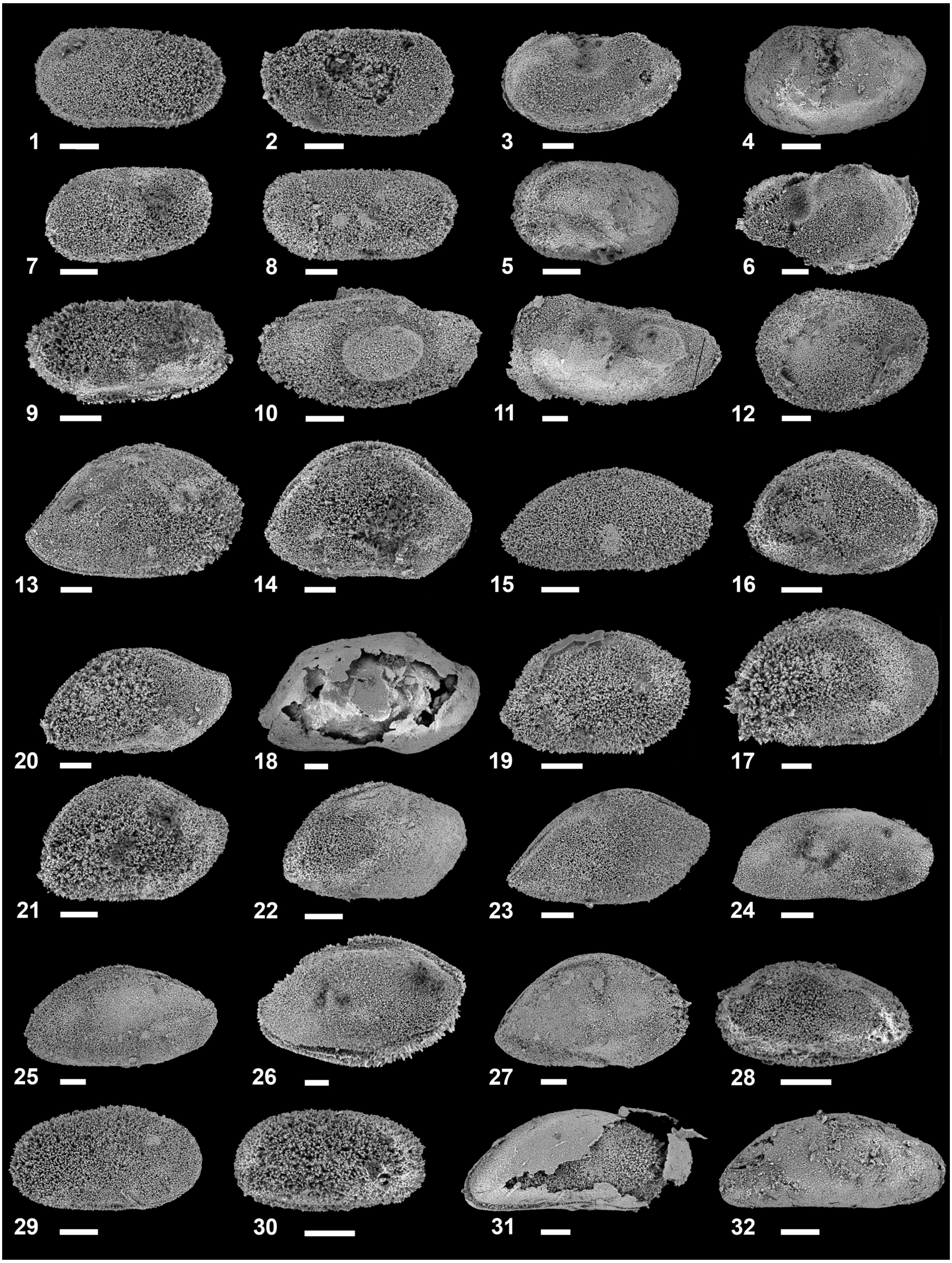
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PLATE 2

Ostracodes from the Komirić Section, Jadar Block, Vardar Zone, NW Serbia; uppermost part of the "Bituminous Limestone" Formation, uppermost Permian, Changhsingian. Scale bars represent 100 µm.

Fig. 1. *Paramacrocypris*? sp. 2. Right lateral view of a complete carapace; MS 1186/1.46.

Fig. 2. *Pseudobythocypris* sp. Right lateral view of a complete carapace; MS 1186/1.58.

Fig. 3. *Bairdiacypris* cf. *caeca* SHI, 1987. Right lateral view of a complete carapace; MS 1186/1.52.

Fig. 4. *Pseudorayella hungarica* KOZUR, 1985. Right lateral view of a complete carapace; MS 1203/3.15.

Figs. 5, 6. *Pseudorayella* sp. 1. 5. Right lateral view of a complete carapace; MS 1186/1.59. 6. Right lateral view of a complete carapace; MS 1186/1.60.

Figs. 7, 8. cf. *Silenites zhejiangensis* FOREL, 2010 (in CRASQUIN *et al*. 2010). 7. Right lateral view of a complete carapace; MS 1184.29. 8. Right lateral view of a complete carapace; MS 1184.30.

Fig. 9. *Silenites*? sp. 1. Right lateral view of a complete carapace; MS 1186/1.61.

Figs. 10–13. *Acratia serbianella* n. sp. 10. Holotype, left lateral view of a complete carapace; MS 1203/1.09. 11. Paratype, right lateral view of a complete carapace; MS 1203/1.10. 12. Right lateral view of a complete carapace; MS 1203/1.11. 13. Dorsal view of a complete carapace; MS 1203/1.12.

Figs. 14–17. *Acratia visnyoensis* KOZUR, 1985. 14. Left lateral view of a complete carapace; MS 1203/1.01. 15. Left lateral view of a complete carapace; MS 1203/1.02. 16. Dorsal view of a complete carapace; MS 1203/1.03. 17. Dorsal view of a complete carapace; MS 1203/1.04.

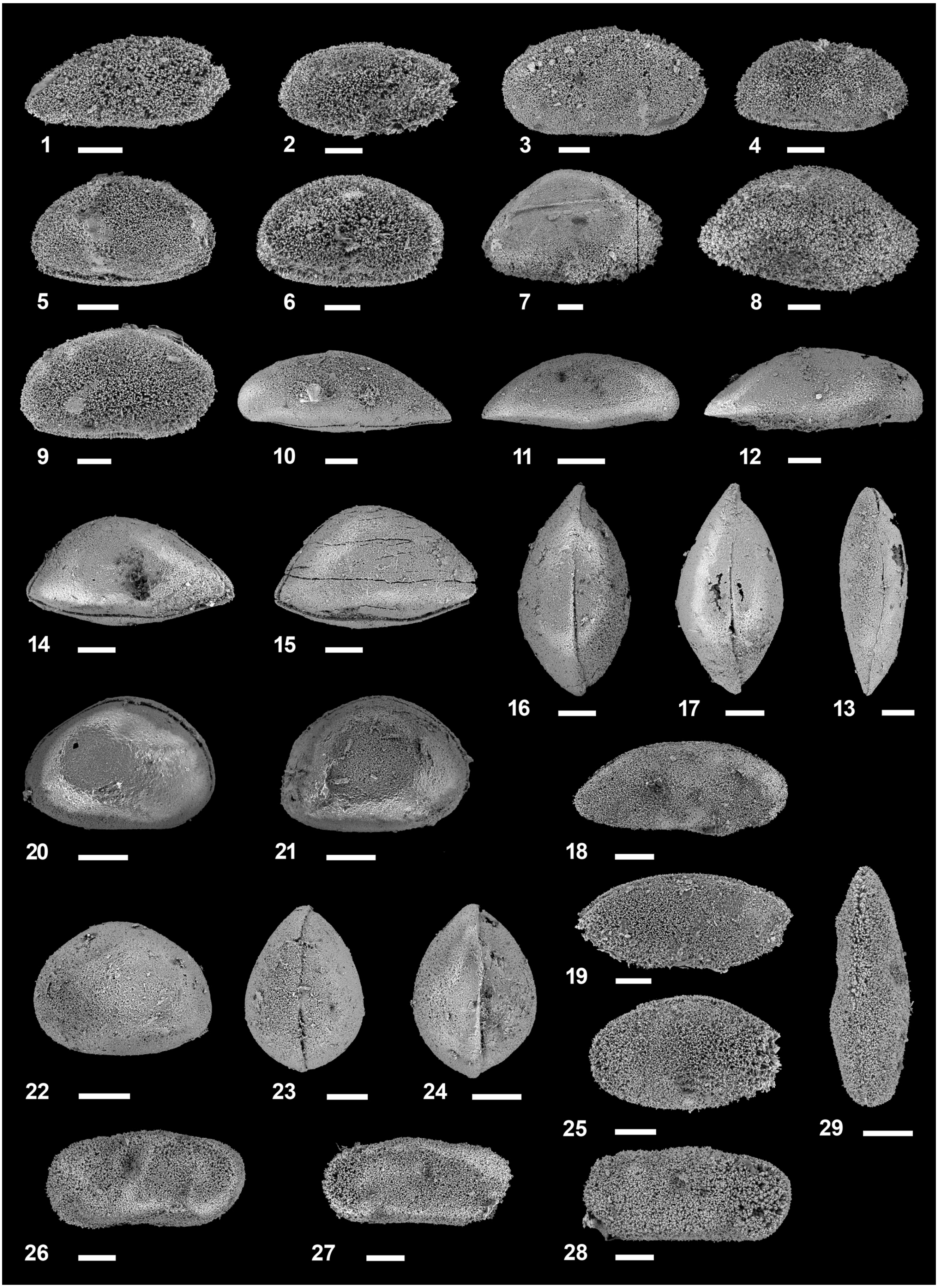
Fig. 18. *Acratia*? sp. 1. Right lateral view of a complete carapace; MS 1186/1.47.

Fig. 19. *Acratia* sp. 2. Right lateral view of a broken carapace; MS 1186/1.48.

Figs. 20–24. *Basslerella jadarensis* n. sp. 20. Holotype, right lateral view of a complete carapace; MS 1203/1.05. 21. Paratype, right lateral view of a complete carapace; MS 1203/2.13. 22. Left lateral view of a complete carapace; MS 1203/1.06. 23. Dorsal view of a complete carapace; MS 1203/1.07. 24. Dorsal view of a complete carapace; MS 1203/1.08.

Fig. 25. *Cavellina* sp. 1. Left lateral view of a complete carapace; MS 1186/1.54.

Figs. 26–29. *Sulcella suprapermiana* KOZUR, 1985. 26. Left lateral view of a complete carapace; MS 1184.26. 27. Left lateral view of a complete carapace; MS 1183.23. 28. Right lateral view of a complete carapace; MS 1186.36. 29. Dorsal view of a complete carapace; MS 1183.24.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Геолошки анали Балканскога полуострва Annales Géologiques de la Péninsule Balkanique	71	37–51	Београд, децембар 2010 Belgrade, December 2010

DOI: 10.2298/GABP1071037E

The age of the Dinaride Ophiolite Belt – derived olistostrome mélange at the northern slope of Moračka Kapa (Montenegro)

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Abstract. This paper presents the first results of a palynological investigation of the Dinaride Ophiolite Belt – derived olistostrome mélange at the northern slope of Moračka Kapa (Montenegro). The analysis of microfloral association provided a reconstruction of the Late Jurassic sedimentation conditions and depositional environment in the Morača Kapa Unit. The samples (8) collected from the different parts of ophiolite matrix yielded palynomorph assemblages (fossil spores, pollen grains and dinoflagellates) of the Upper Jurassic age. The uppermost part of the ophiolite suite on the presented palynomorphs could also indicate the lowermost Lower Cretaceous. These palynological results provide a very interesting framework of these widespread, but poorly stratigraphically understood sediments. The paleoecological results suggest humid and subtropical conditions in the hinterland.

Key words: palynomorphs, age, ophiolite mélange, Upper Jurassic, Moračka Kapa, Montenegro.

Апстракт: У раду се приказују први резултати палинолошких испитивања Динаридског офиолитског појаса на простору Морачке Капе (Црна Гора). Анализа микрофлористичке асоцијације омогућила је реконструкцију услова седиментације у горњој јури у јединици Морачка Капа. Узорци (8) потичу из различитих делова офиолитског меланжа садрже асоцијацију палиноморфи (фосилне споре, полен и динофлагелате) која указује на горњојурску старост. Највиши део офиолитског стуба на основу присутних палиноморфа могао би припадати и најнижим деловима доње креде. Судећи по карактеру микрофлоре може се закључити да је клима у време горње јуре била влажна и субтропска.

Кључне речи: палиноморфе, стратиграфија, офиолитски меланж, горња јура, Морачка Капа, Црна Гора.

Introduction

The Moračka Kapa Unit is located between the Mesozoic cover overlying the Adria-derived Dalmatian-Herzegovinian composite terrane and the East Bosnian–Durmitor terrane which continues towards the southeast to the Korab terrane. It is composed of fragments to blocks (up to few decameters is size) of limestones, sandstones, basalts and serpentinites, all set in a shaly and marly matrix. It is very similar to the Jurassic olistostrome mélange of the Dinaride Ophiolite Belt, formerly named the Diabase-chert formation. The Moračka Kapa unit represents an isolated part of the detrial subduction trench assemblage of the western margin of the Dinaride Ophiolite Belt (Karamata *et al*. 2010).

The purpose of this study is to present the microfloral characteristics of the Upper Jurassic sediments (ophiolite mélange) with special emphasis on their stratigraphic position, correlation with other similar palynological assemblages in Serbia and aboard and their geodinamic implications.

The Moračka Kapa Unit was first mentioned by Kalezić *et al*. (1966). Given that the position of the unit is absolutely strange in this surrounding, its geological properties and stratigraphic position deserve a special our attention. All the field work, petrographical investigation of selected samples, paleontological investigation and trace element analysis were coordinated by S. Karamata.

Experimental

Samples

The palynological studies (spores, pollen grains and dinoflagellates) were performed on 8 representative samples collected from an outcorp in the Mora-

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ča Kapa ophiolite mélange in the valley of the Morača River (Dragovića Polje, Velje Duboko, Montenegro; Fig. 1). The samples from the matrix in Morača ophiolite mélange were collected during earlier field works by S. KARAMATA and M. PAJOVIĆ, who studied these localities in great petrological and geological detail. Figure 1 shows the location of the exposed surface, which was discovered at Dragovići Polje and the position of the investigated samples.

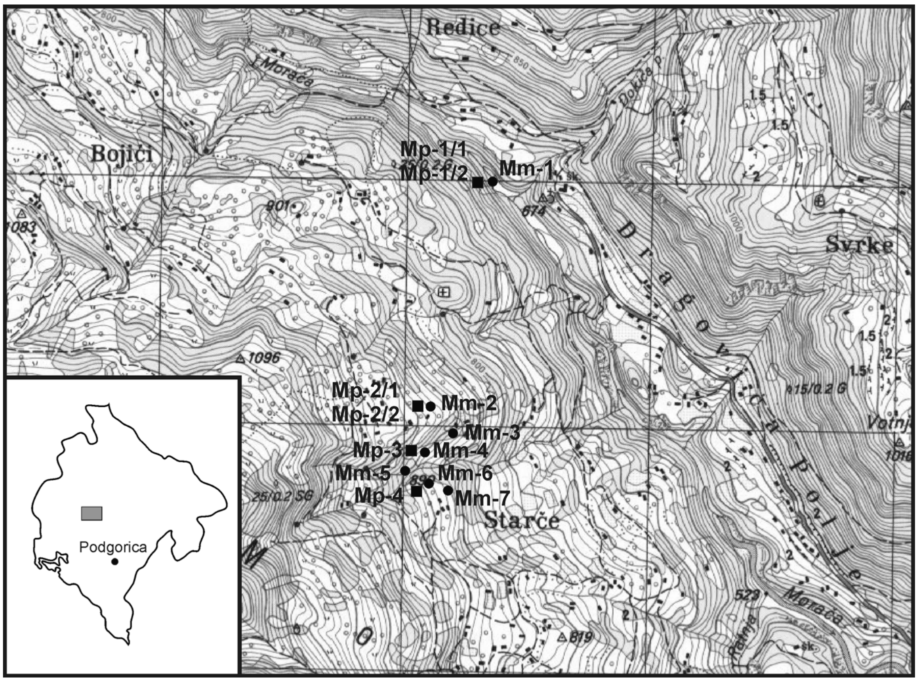

Fig. 1. The geographical position of the sampling points at Dragovići Polje.

Palynological investigations are performed on the samples that were taken from the sequences without any other microfossils. Due to the lack of ammonites and other macro-fossils, stratigraphic control was not possible for the investigated succession.

Details of the samples labeled with the numbers are as follows: 2347 (Mm-1: Morača, elevation 674, x–4 747 995, y – 6 607 355); 2348 (Mm-2: Starče, north from the elevation 890, x – 4 746 975, 6 607 180); 2349 (Mm-3: Starče, north from the elevation 890, x – 4 746 975, y – 6 607 180); 2350 (Mm-4: Starče, north from the elevation 890; x – 4 746 895, y – 6 607 095); 2351 (Mm-5: Starče, north from the elevation 890, x – 4 746 800, y – 6 607 030); 2352 (Mm-6: Starče, south from the elevation 890, x – 4 746 760, y – 6 607 130) and 2353 (Mm-7: Starče, south from the elevation 890; x – 4 746 750, y – 6 607 185, Fig. 1).

It also should be mentioned that samples for petrologic investigations, labeled as: Mp-1/1, Mp-1/2, Mp-2/1, Mp-2/2, Mp-3 and Mp-4, originated ftom the same localities. They are composed of fragments to blocks of limestones, cherts sandstones, basalts and serpentinites, all set in a shaly and matrix (KARAMATA *et al.* 2010).

Methods and aims

About 200 grams of each sample were taken for maceration. Palynomorphs were observed on isolated kerogen concentrates from different rock samples. The samples were initially treated with the classical 30 % HCL (removal of carbonate) and later with 40 % HF (3–5 days) to remove siliceous matter. Subsequently, the material was washed and submitted to separation ($ZnCl_2$; d = 1.9–2.0 g/cm³). Occasionally, the separated kerogen concentrate was also treated to conditional acetolysis and oxidation for about three days ($NaCl+HNO_3$; $KClO_3+HNO_3$; the staining efect on exines; ERCEGOVAC, 1996). Afterwards the material was again subjected to repeated washing to remove all traces of the acids. The macerated detritus was finally treated with 10 % KOH to dissolve the humic substances and clear the palynomorphs.

Some of the most significant and well preserved palynomorphs are illustrated on the Plates I–III. The prepared slides and the original rock samples are kept in the Palynological Laboratory of the Faculty of Mining and Geology, Belgrade.

Systematic palynology and biostratigraphic character of the palynomorph association

Spores, gymnosperm pollen grain and dinoflagellate types identified in the Upper Jurassic (Kimmeridgian; the Lowermost Cretaceous is not excluded) Morača ophiolite mélange (Fig. 1) are listed below. The spores and pollen grains reported in the present paper were treated under the morphographic system of R. POTONIÉ (1956, 1958, 1960).

Anteturma SPORITES H. POTONIÉ, 1893
Turma TRILETES (REINSCH) DETTMANN, 1963
Subturma AZONOTRILETES (LUBER) DETTMANN, 1963
Infraturma LAEVIGATI (BENNIE & KIDSTON) R. POTONIÉ, 1956

Genus *Cyathidites* COUPER, 1953

Cyathidites australis COUPER, 1953 (Pl. 1, Fig. 1)

Cyathidites minor COUPER, 1953 (Pl. 1, Fig. 2)

Cyathidites cf. *mesozoicus* (THIERGARTH) R. POTONIÉ, 1956 (Pl. 1, Fig. 3)
Cythidites hausmanoides COUPER, 1953 (Pl. 1, Fig. 12)
Genus *Todisporites* COUPER, 1958
Todisporites minor COUPER, 1958 (Pl. 1, Fig. 5)
Genus *Deltoidospora* (MINER) R. POTONIÉ, 1956
Deltoidospora cf. *mesozoica* (THIERGART) SCHURMAN, 1960 (Pl. 1, Fig. 4)
Genus *Biretisporites* DELCOURT, DETTMANN and HUGHES, 1963
Biretisporites potoniaei DELCOURT and SPRUMONT, 1955 (Pl. 1, Fig. 23)

Infraturma APICULATI (BENNIE & KIDSTON) R. POTONIÉ, 1956

Genus *Osmundacidites* COUPER, 1953
Osmundacidites cf. *wellmanii* COUPER, 1953 (Pl. 1, Fig. 6)
Osmundacidites parvus DE JERSEY, 1965 (Pl. 1, Fig. 24)
Genus *Acanthotriletes* (NAUMOVA) R. POTONIÉ and KREMP, 1955
Acanthotriletes cf. *varrispinosus* POCOCK, 1962 (Pl. 1, Fig. 22)
Genus *Neoraistrickia* R. POTONIÉ, 1956
Neoraistrickia cf. *taylorii* PLAYFORD and DETTMANN, 1970 (Pl. I, Fig.19)
Neoraistrickia sp. (Pl. 1, Fig. 20)
Genus *Apiculatisporites* R. POTONIÉ and KREMP, 1956
Apiculatisporites cf. *parvispinosus* (LESCHIK) E. SCHULZ, 1963 (Pl. 1, Fig. 18)

Infraturma MURORNATI R. POTONIÉ and KREMP, 1954

Genus *Lycopodiumsporites* (THIERGART) DELCOURT and SPRUMONT, 1955
Lycopodiumsporites cf. *gristhorpensis* COUPER, 1958 (Pl. 1, Fig. 19)
Lycopodiumsporites cf. *clavatoides* COUPER, 1958 (Pl. 1, Fig. 21)

Turma ZONALES (BENNIE and KIDSTON) R. POTONIÉ, 1956
Subturma AURITOTRILETES R. POTONIÉ and KRUTZCH, 1954
Infraturma AURICULATI (SCHOPF) DETTMANN, 1963

Genus *Trilites* (COOKSON) COUPER, 1953
Trilites cf. *distalgranulatus* COUPER, 1958 (Pl. 1, Fig. 13)
Trilites cf. *verrucatus* COUPER, 1958 (Pl. 1, Fig. 14)
Genus *Leptolepidites* COUPER, 1953
Leptolepidites verrucatus COUPER, 1958 (Pl. 1, Fig. 8)
Leptolepidites sp. (Pl. 1, Fig. 7)
Genus *Ischyosporites* BALME, 1957
Ischyosporites sp. (Pl. 1, Figs. 9, 10, 11)
Ischyosporites cf. *variegatus* (COUPER) SCHULZ, 1967 (Pl. 1, Fig. 26)

Subturma ZONOTRILETES WALTZ, 1935
Infraturma CINGULATI (R. POTONIÉ and KLAUS) DETTMANN, 1963

Genus *Cingutriletes* PIERCE, 1961
Cingutriletes sp. (*Pagyophyllum* cf. *connivens* KENDALL, 1952 (Pl. 1, Fig. 25)
Genus *Cingulatisporites* (THOMSON) R. POTONIÉ, 1956
Cingulatisporites cf. *rigidus* COUPER, 1958 (Pl. 1, Fig. 17)
Genus *Staplinisporites* COUPER, 1953
Staplinisporites cf. *pocookii* COUPER, 1953 (Pl. 1, Fig. 16)

Infraturma TRICRASSATI DETTMANN 1963

Genus *Gleicheniidites* (ROSS) DELCOURT and SPRUMONT, 1955
Gleicheniidites cf. *senonicus* ROSS, 1949 (Pl. 1, Fig. 15)
Gleicheniidites cercinidites (COOKSON) DETTMANN, 1963

Anteturma POLLENITES R. POTONIÉ, 1931
Turma SACCITES ERDTMAN, 1947
Subturma MONOSACCITES (CHTALEY) R. POTONIÉ and KREMP, 1954
Infraturma SACCIZONATI BHARDWAJ, 1957

Genus *Callialasporites* (SUKH DEV) R. POTONIÉ, 1966
Callialasporites dampieri (BALME) SUKH DEV, 1961 (Pl. 2, Fig. 5)
Callialasporites cf. *trilobatus* (BALME) SUKH DEV, 1961 (Pl. 2, Fig. 6)

Subturma DISACCITES COOKSON, 1947

Genus *Vitreisporites* LESCHIK, 1955
Vitreisporites cf. *pallidus* (REISSINGER) NILSSON, 1958 (Pl. 2, Fig. 7)
Genus *Alisporites* DAUGHERTY, 1941
Alisporites cf. *grandis* (COOKSON) DETTMANN, 1963 (Pl. 2, Fig. 1)
Genus *Abietinaepollenites* R. POTONIÉ, 1951
Abietinaepollenites microalatus R. POT., 1958 (Pl. 2, Fig. 2)
Genus *Podocarpidites* (COOKSON) R. POTONIÉ, 1958
Podocarpidites cf. *biformis* ROUSE, 1954 (Pl. 2, Fig. 4)

Turma ALETES IBRAHIM, 1933
Subturma AZONOLETES (LUBER) R. POTONIÉ and KREMP, 1954
Infraturma GRANULONAPITI COOKSON, 1947

Genus *Araucariacites* (COOKSON) COUPER, 1953
Araucariacites australis COOKSON, 1947 (Pl. 2, Fig. 8)
Araucariacites sp. (Pl. 2, Fig. 9)
Genus *Sphaeripollenites* (COUPER) JANSONIUS, 1962
Sphaeripollenites subgranulatus COUPER, 1958 (Pl. 2, Fig. 13, 14)

Subturma ZONALETES LUBER, 1935

Genus *Perinopollenites* COUPER, 1958
Perinopollenites elatoides COUPER, 1958 (Pl. 2, Fig. 12)

Turma PLICATES (NAUMOVA) R. POTONIÉ, 1958
Subturma PRAECOLPATES R. POTONIÉ and KREMP, 1954

Genus *Eucommiidites* (ERDTMAN) HUGHES, 1961
Eucommiidites cf. *troedssonii* ERDTMAN, 1948 (Pl. 2, Fig. 10)

Subturma MONOCOLPATES IVERSEN and TROALS-SMITH, 1950

Genus *Gingocycadophytus* (SAMOILOVITCH) DE JERSEY, 1962
Gyngocycadophytus sp. (Pl. 2, Fig.19)
Genus *Cycadopites* (WODEHOUSE) WILSON and WEBSTER, 1946
Cycadopites sp. (Pl. 2, Fig. 20)
Genus *Monosulcites* (COOKSON) COUPER, 1953
Monosulcites cf. *minimus* COOKSON, 1947 (Pl. 2, Fig. 18)

Turma POROSES (NAUMOVA) R. POTONIÉ, 1960
Subturma MONOPORINES NAUMOVA, 1939

Genus *Classopollenites* (PFLUG) POCOCK and JANSONIUS, 1961
Classopollenites cf. *classoides* (PFLUG) POCOCK and JANSONIUS, 1961 (Pl. 2, Fig. 10)

DINOFLAGELLATEAE
Division PIRRHOPHYTA PASCHER, 1914
Class DINOPHYCEAE FRITSCH, 1929
Order PERIDINIALES HAECKEL, 1894
Genus *Escharisphaeridia* ERKMEN and SARJEANT, 1980
?*Escharisphaerida* sp. (Pl. 3, Fig. 5)
Genus *Pareodinia* (DEFLANDRE) STOVER and EVITT, 1978
Pareodinia ceratophora var. *pachyceras* (DEFLANDRE) GOCHT, 1970 (Pl. 3, Fig. 2)
Pareodinia cf. *arctica* WIGGINS, 1975 (Pl. 3, Fig. 4)
?*Pareodinia* cf. *imbatodinesis* VOZHENNIKOVA, 1967 (Pl. 3, Fig. 14)
Genus *Apteodinium* EISENACK, 1958
Apteodinium sp. (Pl. 3, Fig. 3)
Genus *Lepdodinium* (KLEMENT) STOVER and EVITT, 1978
Leptodinium cf. *eumorphum* (COOKSON and EISENACK) SARJEANT, 1969 (Pl. 3, Fig. 8)
Genus *Nanoceratopsis* (DEFLANDRE) PIEL and EVITT, 1980
?*Nanoceratopsis* cf. *pelludica* (DEFLANDRE) EVITT, 1961 (Pl. 3, Fig. 9)
Genus *Indodinium* KUMAR, 1986
?*Indodinium* sp. (Pl. 3, Fig. 10)

INCERTAE SEDIS
Group ACRITARCHA EVITT, 1963
?*Epiplosphaera* sp. (Pl. 3, Fig. 7)
Tasmanites cf. *tardus* EISENACK, 1958 (Pl. 3, Fig. 15)
?Membranolimbus sp. (Pl. 3, Fig. 12)
Penetetrapiites cf. *mollis* HEDLUND and NORRIS, 1973 (Pl. 3, Fig. 13)
Acritarcha gen. et. sp. indet. (Pl. 3, Fig. 6)

Informal division: "PALYNOFORAMINIFERA"
Genus *Lagenammina* RHUMBLER, 1911
?Lagenammina sp. (Pl. 3, Fig. 11)

The palynomorph association from samples 2346, 2347, 2348, 2349 and 2353 are more or less similar in floral composition. They are presented as a integral assemblage of pteridophyte spores and conifer pollen, which was used for stratigraphic and paleoecological reconstructions. General characters of the presented palynomorph association can be described as follows:

Trilete pteridophytic spores of *Cyathidites australis, Deltoidospora minor, Trilites* cf. *verrucatus* and *Apiculatisporites* sp. are relative frequent in this association. The palynomorph assemblage of the Morača area is characterized by the abundant presence of the genus *Cyathidites*. These spores correspond to the plant species *Coniopteris*, or the families Cyatheaceae and Dicksoniaceae, which is a general characteristic of the Late Jurassic, partially of the Lowermost Cretaceous deposits in North America and Europe. The shallow depositional environment is characterized with dominant ferns (*Cyathidites, Ischyosporites, Deltoidospora*, etc.).

The species *Licopodiumsporites clavatoides* and other form with typical reticulum on the distal face is quite infrequent in the presented association. Its presence, however, has certain biostratigraphic importance. The common elements of the late Jurassic in this assemblage include *Ischyosporites variegatus*, *Perinopollenites elatoides* and *Leptolepidites verrucatus*.

The absence of typically Lower Cretaceous elements (*Trilobosporites*, *Appendicisporites*, *Cicatricosisporites, Schizosporis, Plicatella, Cooksonites* and others) in investigated samples is very characteristic. VAKHRAMEEV *et al.* (1973) believe that the transition from the Volgian (Tithonian) to the Berriasian (Lowermost Cretaceous) was characterized by the first occurrence of canaliculate spores of the type *Cicatricosisporites,* whereas in the Indo–European paleofloral province the genus *Appendicisporites* occurs in the Lower Cretaceous (Valanginian). The biostratigraphicaly significant presence of the Upper Jurassic taxa such as *Klukisporites*, *Callialasporites, Concavisporites, Perinopollenites* and *Araucariacites,* indicates to a Late Upper Jurassic, probably Kimmeridgian to Tithonian age for the Morača ophiolite mélange.

The coniferous miospores are represented by nonsaccate, monosacate and bisaccate elements viz., *Araucariacites*, *Classopollis*, *Callialasporites*, *Alisporites, Abietinaepollenites*, *Vitreisporites* and *Podocarpidites.* A quantitative analysis the forms of the microflora from the integral palynological association showed the different frequencies of the various taxa. It was concluded that *A*raucariaceae, Podocarpaceae and Calliala grains among the Gymnosperms, and Cyatheaceae, Gleicheniaceae, Lycopodiaceae and Osmundaceae among the Pteridophytes represent the most important families of the Morača microfloral assemblage. A vegetation of dominating conifers from the family Araucariaceae and Classopollis *group* existed in the land habitatus in the prominent places on islands, under a then warm climate. The species *Callialasporites dampieri* is a representative element for the middle–upper part of the Mesozoic in Europe, North America, Australia, China and India.

This assemblage is also characterized by gymnospermous pollen grain among which are the forms with two sacci, such as *Quadraeculina, Abietinaepollenites, Podocarpidites,* etc. Of lower abundance are the pollen grains of the monosaccate coniferales, such as *Araucariacites*, *Callialasporites*, *Classopollenites*, etc. In addition, there are some monosaccate coniferales, such as *Cerebropollenites*, together with a few monocolpate pollen grains of *Ginkgocycadophytus nittidus*.

The species *Eucommidites troedsonii* has been also recorded from the Morača assemblages, as a characteristic species of the young Mesozoic of the North Hemisphere; *Araucariacites australis* is distributed in the Upper Jurassic and Early Cretaceous in China, in limited numbers, but it is a characteristic species occurring in great abundance in the Middle Jurassic of England, Sweden and some others countries in Northwest Europe.

The Upper Jurassic (mostly Tithonian) in most of the localities over the world contain dinoflagellates (*Gonyaulax, Pareodinia, Apteodinium*, etc.; BERGER 1986; DAVEY 1982) and specific plankton remains (Acritarcha and *Incertae sedis*). The spore-pollen association of the Morača contain a low amount of marine microplankton. Late in the Tithonian, the phytoplankton content was much lower than in the Kimmeridgian, while spores and pollen grains of terrestrial plants are higher. The dynocyst assemblage reported the Upper Jurassic age of the investigated samples. The species *Gonyaulax jurassica* and *Pareodinia ceratophora* are scare in lowermost parts of the Lower Cretaceous Unit. The depositional environment is partially marked by the different plankton forms (Dinoflagellates, Acritarchs and Palynoforaminifers). The rare appearance of the low preserved genus *Sentusidinium* most probable point to the Upper Jurassic. On the whole the presence of the dynocyst assemblage predominantly reports the Upper Jurassic age of the investigated samples.

The microflora described from the ophiolite mélange of the Morača shows a remarkable analogies with the palynological assemblage of the bauxite deposits at Biočki Stan (north of Nikšićka Župa), which are located in the southern part of the Dinaric Carbonate Platform of Montenegro. The mentioned sedimentary rocks were formed during the Upper Jurassic–Lowermost Cretaceous (mainly late Kimmeridgian; ERCEGOVAC *et al.* 1996). The assemblages examinated near the Jurassic–Cretaceous boundary from the Biočki Stan are characterized by the following: *Gleicheniidites senonicus, Allisporites bilateralis, Vitreisporites pallidus, Cerebropollenites mesozoicus, Inaperturopollenites dubius, Araucariacites australis, Perinopollenites elatoides, Classopollenites torosus, Exesipollenites scabrosus, Podocarpidites* cf. *ellipticus* and *Eucommidites troedssonii.*

The present palynomorph assemblage of the Morača Region bears significant similarities to those of England (the Sycarham Beds in Yorkshire; COUPER 1958; NORRIS 1969), Germany (Regensburg–Passau area, Bavaria; LUND & ECKE 1987), the Netherlands (BURGER 1966; HERNGREEN *et al*. 1980), Normandy (SARJEANT 1968), Sweden (TRALAU 1968), Russia (Siberia; ILYNA 1986), Egypt (El Maghara, north-central Sinai; ABOUL & ALY 1988), Algero-Tunisian Sahara (REYRE 1973), North America (SARJEANT 1979), Canada (POCOCK 1967, 1970) and India (SRIVASTAVA 1966).

Some remarks about the palynological criteria for the recognition of the Jurassic–Cretaceous boundary in western Europe

Many references were originally demonstrated that significant palynologic differences exist between the major Jurassic–Cretaceous formations. NORRIS (1969, 1973), BATEN (1973), MORGAN (1980) for example, recognized three principal microflora assemblages close to the Jurassic–Cretaceous boundary, as follow:

The microflora of Lower–Middle Thithonian is very restricted in composition containing only the following species over and above the background species: *Cyathidites minor, C. australis, Coronatispora caldensis, Dyctiophydites equiexinus, D. harrisii, Deltoidospora psilostoma, Osmundacidites wellmanii, Lycopodiumsporites austroclavatoides, Klukisporites pseudoreticulatus, Rubinella major, Callialasporites dampieri, C. obrutus, Classopollis hammenii, Abietinaepollenites minimus, Cycadopites* sp., *C. nitidus, Eucommidites minor,* etc. Some of these species were of restricted diversity as a consequence of the offshore marine environment during the Late Jurassic.

The microflora of Upper Tithonian is characterized by the incoming of *Acanthotriletes varispinosus, Cicatricosisporites purbeckensis, Plicatella abaca, Deltoidospora rafaeli,Converrucosisporites sp., Lepdolepidites psarosus, Couperisporites complexus, Parrisaccites radiatus, Sphaeripollenites subgranulatus, Cycadopites carpentieri, Schzosporites spriggii, etc.*

The microflora of Berriasian – the following species first appear: *Concavisporites juriensis, Stereisporites antiquasporites, Leptolepidites epacrornatus, Baculatisporites comaumensis, Pilosisporites trichopapillosus, Pilosisporites delicatulus, Lycopodimsporites cerniidites, Cicatricosisporites brevilaesuratus, C. angicanalis, Tripartina* sp., *Foveosporites cannalis, Contignisporites dorsostriatus, Duplexisporites problematicus, Appendicisporites potomacensis, Trilobosporites bernissartensis, T. apiverrucatus, Densoisporites perinatus, Heliosporites* sp., *Aequtriradites spinulosus, Januasporites tumulosus, Callialasporites* cf. *trilobatus, Marattisporites scabratus, Monosulcites* cf. *minimus, Schizosporis reticulatus, Sch. parvus, Sigmopollis callosus, etc.*

Paleoecological reconstruction

The analysis of spores and pollen grains, also of dinoflagellate remains, provides for the reconstruction of land vegetation on the surrounding islands.

The younger Jurassic microflora from the Morača area is representative of a typical continental flora of island archipelagos in the tropical regions of the Tethys. From the palynological assemblage two main types of land vegetation were distinguished on the islands.

a. Wet coastal regions of islands with shallow water formations were characterized with vegetation of dominant ferns (Klukisporites, Deltoidospora and Lycopodiacidites) and some seed ferns (Cycadophytes).

b. Prominent areas on the islands had more xerophyte flora which is evidenced by the abundance of conifers (mostly pollen grains of Araucaria and Classopollis). Macrofloral remains of Bracyphyllum and Pagiophyllum were not recorded. The presence of Classopollis pollen indicates their xerophitic nature. However, the presence of Classopollis pollen can be related to both arid and humid climates of high littoral areas. Its occurrence in Mesozoic rocks indicates a warm climate (VAKHRAMEEV 1970). Similar climatic conditions are suitable also for plants producing pollen of *Araucariacites* and *Callialapollenites* types; in many examples, they are found together in Jurassic and Lower Cretaceous sedimentary rocks. The presence of the families Gleicheniaceae and Schizaceae in the Uppermost Jurassic and Lower Cretaceous indicates humid climate.

c. The depositional environment is also marked by a sparse form of dinoflagellatae, acritarchs and palynoforaminifers. As has already been mentioned, the occurrence of phytoplanktonic – algal remains is associated with an aquatic environment, which indicates a great influence of marine sedimentation conditions during the formation of these sediments.

The palynological assemblage could be used for consideration concerning the paleoclimate during the sedimentation of the investigated sequences in the Morača area. Transitional tropical–subtropical climatic belts during Upper Jurassic were concluded.

In the Upper Jurassic and Lowermost Cretaceous, in the stil large Tethys, continental flora of the Tethyan phytogeographic realm existed on many archipelagos situated between the south "Laurasian Phytogeographic Realm" ("Indo-European relm"; VAKHRAMEEV 1975) in the north and the north „Gondvana Realm" (African continent) in the south (BRENNER 1976). Continental floras on archipelagos in the realm of the west Tethyan intraoceanic carbonate platforms, at the time were much closer to the African continent, during the Jurassic and Lower Cretaceous („separate Tethyan phytogeographic realm"; PANTIĆ *et al*. 1983).

Conclusion

Based on the first palynological investigation of the Moračka Kapa ophiolite mélange (Montenegro), the conclusions are as follows:

From the possible affinity of the palynomorphs, it may be deduced that in the Upper Jurassic, the Morača area was not rich in floras, which include Pteridophytes belonging to families such as Lycopodiaceae, Selaginellaceae, Osmundaceae, Dicksoniaceae, Cyatheaceae, etc. Among the Gymnosperms, are those plants of Cycadaceae, Ginkgoaceae, Pinaceae, Podocarpaceae and Araucariaceae. From the ecological environment of the parent plants, it was inffered that this region at that time was under a warm and humid subtropic to temperate climate.

All these paleontological data contribute to an elucidation of the characteristic late Jurassic vegetation from the Tethyan phytogeographic province. The younger Jurassic microflora from Morača area is representative of a typical continental flora of island archipelagos (near shore environment) in the subtropical–tropical regions of the Tethys. The microflora described is of special paleo- and phytogeographical interest and shows remarkable analogies with mediterranean and south-alpine floras of the Tethys, but differs from the north-pennine flora, which may belong to the Laurasian floral realm.

Although the palynomorphs assemblage is not complete, the biostratigraphical analysis of the contained pteridophyte spores, conifer pollen and the remains of the monadophytic algae Peridineae, allows the conclusions that the mentioned unit was forming during the Upper Jurassic (most probably the Kimmeridgian). The presence of some taxons from the Lowermost Cretaceous is not excluded. Taking into account all the mentioned palynological data it was concluded that the Upper Jurassic age of the Moračka Kapa Unit coresponds to late phases of the Dinaride Ophiolite Belt foramation.

The microflora of the obtained palynological investigation on the Moračka Kapa ophiolite mélange allows a new consideration in relation to Upper Jurassic–Lowermost Cretaceous boundary.

The available data concerning the age of the Moračka Kapa Unit are very important for a new interpretation of palaeogeographic and geodynamic events in this part of Tethys during the Upper Jurassic (KARAMATA *et al*. 2010).

Acknowledgments

I wish to thank the reviewers POLINA PAVLISHINA (Sofia) and PLATON TCHOUMATCHENCO (Sofia) for useful discussions and comments that significantly improved the paper.

References

ABOUL ELA, N.M. & ALY, M.F. 1988. Jurassic microflora from the coal deposits El Maghara, north-central Sinai, Egypt. *Neues Jahrbuch Geologie Paläontologie, Monatheft*, 5: 263–277.

BALME, B.E. 1957. Spores and pollen grains from the Meesozoic of Western Australia. C.S.I.R.O. *Australian Coal Research Section. T.C.*, 25, 48 pp.

BATTEN, D.J. 1973. Use of palynologic assemblage-types in Wealden correlation. *Paleontology*, 16: 1–40.

BERGER, J.-P. 1986. Dinoflagellates of the Callovian-Oxfordian boundary of the „Liesberg-Dorf" quarry (Berner Jura, Switzerland). *Neues Jahrbuch Geologie Paläontologie Abhandlungen*, 172 (3): 331–355.

BURGER, D. 1966. Palynology of Uppermost Jurassic and Lowermost Cretaceous strata in the easter Netherlands. *Leidse Geologische Mededlingen*, 35: 209–276.

COUPER, R.A. 1958. Britisch Mesozoic microspores and pollen grains. *Palaeontographica Abt. B*, 103 (4–6): 75–179.

DAVEY, R.J. 1982. Dinocyst stratigraphy of the latest Jurassic to Early Cretaceous of the Haldager No. 1, Denmark. *Geological Survey Denmark*, Ser. B, 6: 1–56.

ERCEGOVAC, M., JEREMIĆ, M. & RADOIČIĆ, R. 1996. Stratigraphic column above bauxite at Biočki Stan, Montenegro. *Geološki anali Balkanskoga poluostrva*, 60 (2): 99–122.

FILATOFF, J. 1975. Jurassic palynology of the Perth Basin, Western Australia. *Palaeontographica*, (B), 154 (1–4): 1–113.

HERNGREEN, G.F.W., HOEKEN-KLINKENBERG, P.M.J. & VAN DER BOER, K.F. 1980. Some remarks on selected palynomorphs near the Jurassic-Cretaceous boundary in the Netherland. *IV. International Palynological Conference*, 2: 357–367, Lucknow.

ILYINA, V.I. 1986. Subdivision and correlation on the marine and non-marine jurassic sediments in Siberia based on palynological evidence. *Review of Palaeobotany and Palynology,* 46: 357–364.

KALEZIĆ, M., MIRKOVIĆ, M. & ŠKULETIĆ, D. 1966. Basic Geological Map 1:100000, sheet Šavnik. *Federal Geological Survey of SFRJ*, Belgrade.

KARAMATA, S., DIMITRIJEVIĆ M.N., DIMITRIJEVIĆ, M.D., ERCEGOVAC, M., KALEZIĆ M., MILOVANOVIĆ, D., MIRKOVIĆ, M., OLUJIĆ J., POPEVIĆ, A., PAJOVIĆ, M., RADUSINOVIĆ, S., STIJOVIĆ, V., SUDAR, M., CVETKOVIĆ, V., ŠARIĆ, K. & ZAHARIADZE, G. 2010. The Dinaride Ophiolithe Belt-derived olistostome mélange at the northern slope of Moračka Kapa (Montenegro): evidence of the emplacement of the southeast Bosnian-Durmitor terrane. *Bulletin Tome CXL de l'Académie serbe des sciences et des arts*, Sciences naturelles No 46.

LUND, J.J. & ECKE, H.-H. 1987. Dinoflagellate cyst stratigraphy applied to the Middle to Late Jurassic of the Regensburg-Passau area, Bavaria. *Bulletin des Centres de Recherches, Exploration-Production, Elf-Aquitaine*, 12 (1): 345–359.

MORGAN, R. 1980. Palynostratigraphy of the Australian Early and Middle Cretaceous. Memoits of the geological Survey of New South Wales. *Palaeontology*, 18: 1–153.

NORRIS, G. 1969. Miospores from the Purbeck Beds and marine Upper Jurassic of southern England. *Paleontology*, 12 (4): 574–620.

NORRIS, G. 1973. Palynologic criteria for recognition of the Jurassic-Cretaceous boundary in Western Europe: In "Palynology of Mesophyte", *Proceedings 3rd International Palynological Conference* Akademia Nauk SSSR, Sibir, Otdel. Geologičeskij, Geofizičeskij Institut, 97–100.

PANTIĆ, N. & BURGER, H. 1981. Palynologische Untersuchungen in der untersten Kreide des östlichen Helevikums. *Eclogae geologicae Helvetiae*, 74 (3): 661–672.

PANTIĆ, N., GRUBIĆ, A. & SLADIĆ-TRIFUNOVIĆ, M. 1983. The importance of mesozoic floras and faunas from intraoceanic carbonate platforms for interpretation of palaeogeographic and geodynamic events in the Tethys. *Bulletin Dela Societa Paleontologia Italiana*, 22 (1–2): 5–14.

POCOCK, S.A.J. 1967. The Jurassic-Cretaceous boundary in Northern Canada. *Review Paleobotany and Palynology*, 5: 129–136, Amsterdam.

POCOCK, S.A.J. 1970. Palynology of the Jurassic sediments of Western Canada. *Palaeontographica 130, B*, 12–72.

POCOCK, S.A.J. 1980. Palynology at the Jurassic-Cretaceous boundary in North Amerika. *IV. International Palynological Conference*, 2: 377–385, Lucknow.

POTONIÉ, R. 1956. Synopsis der Gattungen der sporae dispersae, I. Teil: Sporites. *Beihefte Geologischen Jahrbuch*, 23, 103 pp.

POTONIÉ, R. 1958. Synopsis der Gattungen der sporae dispersae, II. Teil: Sporites. (Nachträge), Saccites, Aletes, Precolpates, Polyplicates, Monocolpates. *Beihefte Geologischen Jahrbuch,* 31, 114 pp.

POTONIÉ, R. 1960. Synopsis der Gattungen der sporae dispersae. III. Teil: Nachträge Sporites, Fortsetzung Pollenites mit general Register zu Teil 1 bis 3. *Beihefte Geologischen Jahrbuch*, 39, 189 pp.

REYRE, Y. 1973. Palinologie du Mésozoique Saharien. *Mémoires du Muséum National d'Histoire Naturelle, C, XXVII,* 284 pp., Paris.

SARJEANT, W.A.S. 1962. Upper Jurassic microplankton from Dorset, England. *Micropaleontology*, 8: 255–268.

SARJEANT, W.A.S. 1968. Microplankton from the Upper Callovian and Lower Oxfordian of Normandy. *Revie Micropaléontologie*, 10: 221–242.

SARJEANT, W.A.S. 1979. Middle and Upper Jurassic dinoflagellate cysts: the world excluding North Amarica. *Proceedings AASP, seria 5, B,* 133–157.

SMELROR, M. 1988. Bathonian to early oxfordian dinoflagellate cysts and acritarchs from Kong Karls Land, Svalbard. *Review of Palaeobotany and Palynology*, 56: 275–304.

SRIVASTAVA, S.K. 1966. Jurassic microflora from Rajasthan, India. *Micropaleontology*, 12: 87–103.

TRALAU, H. 1968. Botanical investigations into the Fossil Flora of Eriksdal in Fyledalen, Scania, II., The Middle Jurassic microflora. *Sveriges Geologiska Undersökning,* C, 633, 62/4, 185 pp. Stockholm.

VAKHRAMEEV, V.A., BARKHANTNAJA, I.N., DOBRUTSKAJA, N.A., PAVLOV, V.V., ROVINA, L.V. & FOKINA, N.I. 1973. Paleobotanical data and the Jurassic-Cretaceous boundary. *Mémoires Du B. R. G. M. Coll. sur la limite Jurassique-Cretace,* Lyon, Neuchates.

VAKHRAMEEV, V. 1975. Main features of global phytogeography in the Jurassic and Early Cretaceous. *Paleontological Journal*, 2, 247-255.

Резиме

Старост Динаридског офиолитског појаса – меланж олистостроме на северној падини Морачке Капе (Црна Гора)

Јединица Морачка Капа налази се између мезозојског Далматинско-Херцеговачког терана и Источно Босанско-Дурмиторског терана. Овај олистостромски меланж састоји се од фрагмената и блокова кречњака, пешчара, базалта и серпентина уклопљених у глиновито-лапоровитом матриксу. Ова јединица је веома слична јурском олистостромском меланжу Динаридског офиолитског појаса, који је раније означаван као дијабаз-рожначка формација. Ова јединица представља изоловани део субдукционог рова на западној маргини Динаридског офиолитског појаса (KARAMATA *et al*. 2010)

Анализа микрофлористичког састава палиноморфа из офиолитског меланжа Морачке Капе показала је да доминира присуство спора петридофита које углавном припадају фамилијама *Lycopodiaceae, Selaginellaceae, Osmundaceae Dicksoniaceae, Cytheaceae* и друге. Полен гимносперми претежно припада фамилијама *Cycadaceae, Ginkgoaceae, Pinaceae, Podocarpaceae* и *Araucariaceae.* На основу еколошких карактеристика матичних биљака, закључено је да је овај простор у време стварања поменутих депоната био под утицајем топле и влажне субтропске до умерене климе.

Први палеонтолошки наласци доприносе упознавању карактеристика вегетације горње јуре у палеогеографској провинцији Тетиса. Млађа јурска микрофлора из Морачке Капе представља типичну континенталну флору острвских архипелага (средине близу обале) у субтропско-тропског региона Тетиса. Карактеристике ове микрофлоре показују да постоје запажене сличности са медитеранским и јужно-алписким флорама на простору Тетиса, али се разликују од северно-пенинских флора, које припадају Евроазијској флористичкој области.

Иако констатована палинолошка асоцијација није потпуна биостратиграфска анализа спора птеридофита, полена четинара и остатака монадофитних алги перидинеа омогућавају да се закључи да флористички састав ове асоцијације указује да је матрикс офиолитског меланжа настао за време горње јуре, највероватније у кимерицу. Неки присутни таксони упућују да би део испитиваних депоната могао припадати и деловима најниже креде. У сваком случају прочавања палиноморфа из офиолитског меланжа доприносе и прецизнијем утврђивању границе између горње јуре и доње креде на истраживаном простору.

Нови подаци о старости јединице Морачка Капа су веома значајни за нове интерпретације палео-

географских и геодинамичких догађаја у овом делу Тетиса за време горње јуре (KARAMATA *et al*. 2010).

Асоцијација палиноморфи из Морачке Капе показује знатне сличности са онима у Енглеској (Sycarham Beds, Yorkshire; COUPER 1958; NORRIS 1969), Немачкој (Regensburg-Passau, Bavaria; LUND & ECKE 1987), Холандији (BURGER 1966; HERNGREEN *et al*. 1980), Норвешкој (SARJEANT 1968), Шведској (TRALAU 1968), Русији (Siberia; ILYNA 1986), Египту (El Maghara, north-central Sinai; ABOUL & ALY 1988), Северној Америци (SARJEANT 1979), Канади (POCOCK 1967, 1970) и Индији (SRIVASTAVA 1966).

PLATE 1

Fig. 1. *Cyathidites australis* COUPER (sample 2347/5; 13-0/7).
Fig. 2. *Cyathidites minor* COUPER (sample 2347/4; 17-6/08).
Fig. 3. *Cyathidites* cf. *mesozoicus* (THIERGART) R. POTONIÉ (sample 2348/6; 46- 10/08).
Fig. 4. *Deltoidospora* cf. *mesozoica* (THIERGART) SCHURMAN (sample 2348/5; 39-8/08).
Fig. 5. *Todisporites major* COUPER (sample 2349/2; 3-8/08).
Fig. 6. *Osmundacidites wellmanii* COUPER (sample 2349/2; 11-0/8).
Fig. 7. *Leptolepidites* sp. (sample 2353/1; 49-8/08).
Fig. 8. *Lepdolepidites verrucatus* COUPER (sample 2353/1; 11-6/08).
Fig. 9. *Neochomotriletes* sp. (sample 2348/1; 53-6/08).
Fig. 10, 11. *Ischyosporites* sp. (sample 2348/3; 41-7/08 and 2348/6; 43-12/08).
Fig. 12. *Cyathidites* cf. *hausmanoides* COUPER (sample 2347/5; 23-6/08).
Fig. 13. *Trilites* cf. *distalgranulatus* COUPER (sample 2348/2; 15-7/08).
Fig. 14. *Trilites* cf. *verrucatus* COUPER (sample 2348/1; 35-6/08).
Fig. 15. *Gleicheniidites* cf. *senonicus* ROSS (sample 2348/1; 31-6/08).
Fig. 16. *Staplinisporites* cf. *pocookii* COUPER (sample 2348/4; 55-7/08).
Fig. 17. *Cingulastisporites* cf. *rigidus* COUPER (sample 2348/6; 50-10/08).
Fig. 18. *Apiculatisporites* cf. *parvispinosus* (LESCHIK) E. SCHULZ (sample 2348/1; 3-7/08).
Fig. 19. *Neoraistrickia* cf. *taylorii* PLAYFORD ET DETTMANN (sample 2348/1; 1-7/08).
Fig. 20. *Lycopodiumsporites* cf. *gristhorpensis* COUPER (sample 2348/2; 35-7/08).
Fig. 21. *Lycopodiumsporites clavatoides* COUPER (sample 2348/1; 45-6/08).
Fig. 22. *Acanthotriletes* cf. *varrispinosus* POCOCK (sample 2348/4; 59-7/08).
Fig. 23. *Biretisporites potoniaei* DELCOURT ET SPRUMONT (sample 2348/2; 23-12/08).
Fig. 24. *Osmundacidites parvus* DE JERSEY (sample 2348/6; 54-10/08).
Fig. 25. *Cingutriletes* sp.; *Pagiophyllum* cf. *connivens* KENDALL (sample 2348/6; 37-6/08).
Fig. 26. *Ischyosporites* cf. *variegatus* COUPER (sample 2348/5; 47-8/08).

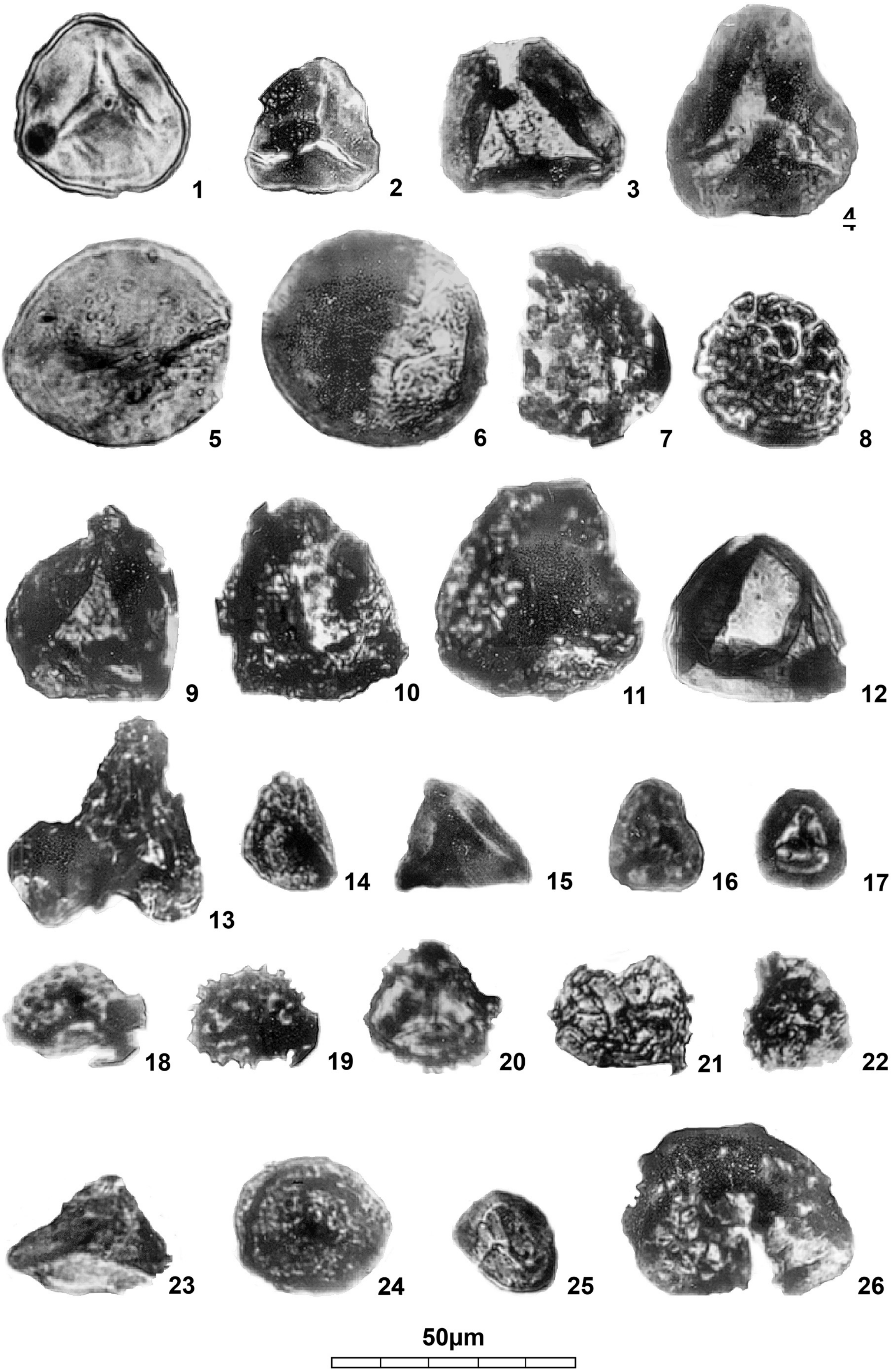
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PLATE 2

Fig. 1.	*Alisporites* sp. (sample 2347/7; 85-6/08).
Fig. 2.	*Abietinaepollenites microalatus* R. POTONIÉ (sample 2347/2; 5-6/08).
Fig. 3.	*Podocarpidites* sp. (sample 2348/1; 27-6/08).
Fig. 4.	*Podocarpidites* cf. *biformis* ROUSE (sample 2348/1; 55-6/08).
Fig. 5.	*Callialasporites dampieri* (BALME) SUKH DEV (sample 2348/2: 39-7/08).
Fig. 6.	*Callialasporites* cf. *trilobatus* (BALME) DEV (sample 2347/10; 58-10/08).
Fig. 7.	*Vitreisporites* cf. *pallidus* (REISSINGER) NILSSON (sample 2348/2; 9-7/08).
Fig. 8.	*Araucariacites australis* COOKSON (sample 2347/10; 56-10/08).
Fig. 9.	*Araucariacites* sp. (sample 2347/4; 15-6/08).
Fig. 10.	*Classopollenites* cf. *classoides* (PFLUG) POCOCK & JANSONIUS (sample 2347/1; 3-6/08).
Fig. 11.	? *Sequoiapollenites* sp. (sample 2348/1; 39-6/08).
Fig. 12.	*Perinopollenites* cf. *elatoides* COUPER (sample 2348/2; 25-7/08).
Fig. 13, 14.	*Sphaeripollenites subgranulatus* COUPER (sample 2348/1; 51, 61-6/08).
Fig. 15.	*Eucommidites* cf. *troedssonii* ERDTMAN (sample 2348/6; 66-10/08).
Fig. 16.	*Eucommidites* sp. (sample 2352/2; 55- 8/08).
Fig. 17.	*Quadraeculina* cf. *limbata* POCOOK (sample 2347/3; 9-6/08).
Fig. 18.	*Monosulcites carpentieri* DELCOURT & SPRUMONT (sample 2348/6; 64-10/08).
Fig. 19.	*Ginkgocycadophytus* cf. *nitidus* (BALME) DE JERSEY (sample 2348/1; 85-7/08).
Fig. 20.	*Cycadopites* cf. *follicularis* WILSON & WEBSTER (sample 2347/7; 19-6/08).

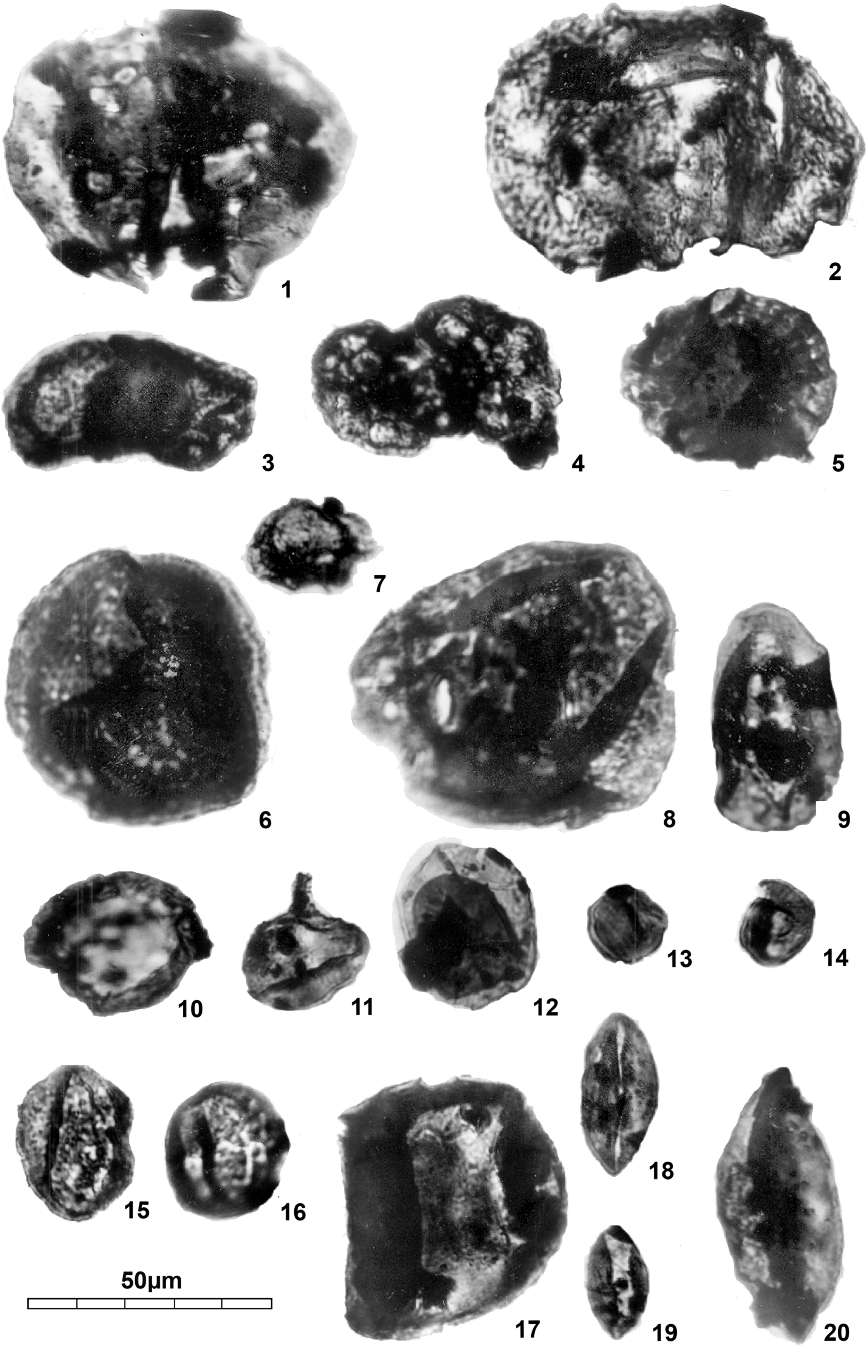
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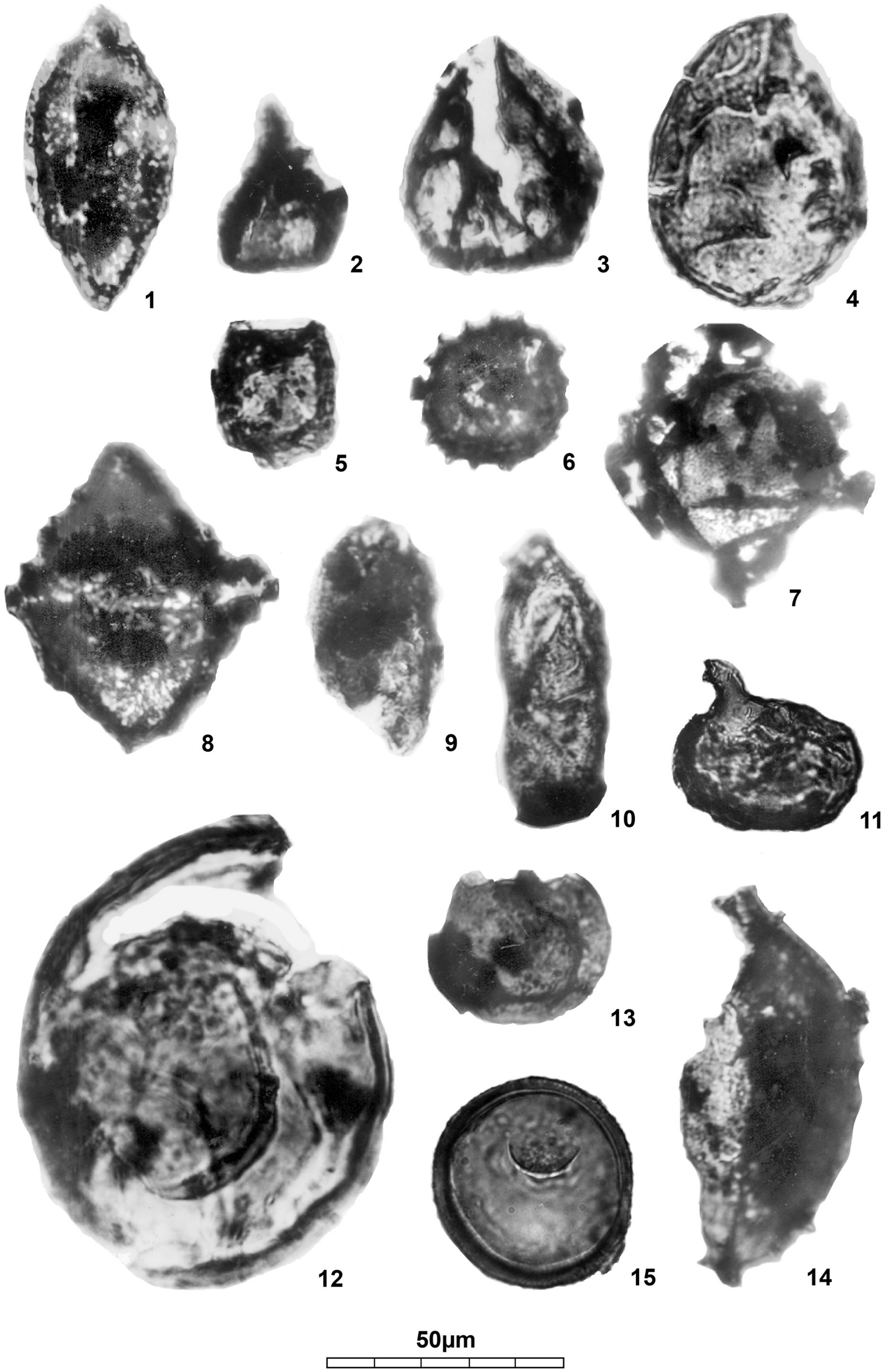
PLATE 3

Fig. 1. *?Steevesipollenites* sp. (?Bennettitales) (sample 2348/6; 37-10/08).
Fig. 2. *Pareodinia ceratophora var. pachyceras* SARJEANT (sample 2349/1; 1-8/08).
Fig. 3. *Apteodinium* sp. (sample 2348/4; 47-7/08).
Fig. 4. *Pareodinia* cf. *arctica* WIGGINS (sample 3248/4; 45-7/08).
Fig. 5. *Wallodinium* cf. *cilindricum* (HABIB) DUXBURY (sample 2348/1; 29-6/08).
Fig. 6. Acritarcha gen et sp. indet. (sample 2348/6; 48-10/08).
Fig. 7. ?*Epiplosphaera* sp. (sample 2348/4; 57-7/08).
Fig. 8. *Leptodinium* cf. *eumorphum* COOKSON & EISENACK (sample 2348/1; 49-6/08).
Fig. 9. ?*Nanoceratopsis* cf. *pellucida* (DEFLANDRE) EVIT (sample 2348/1; 63-6/08).
Fig. 10. *?Indodinium* sp. (sample 2347/1; 21-6/08).
Fig. 11. *Lagenamina* sp. (Palynoforaminiferae) (sample 234875; 45-6/08).
Fig. 12. ?*Membranolimbus* sp. (sample 2348/3; 45-7/08).
Fig. 13. *Penetetrapites* cf. *mollis* HEDLUND & NORRIS (sample 2348/6; 50-10/08).
Fig. 14. *?Pareodinia* cf. *imbatodinensis* (VOZHENNIKOVA) LENTIN & WILLIAMS (sample 2348/2; 29-7/08).
Fig. 15. *Tasmanites* cf. *tardus* EISENACK (sample 2346/6; 48-10/08).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Геолошки анали Балканскога полуострва Annales Géologiques de la Péninsule Balkanique	71	53–71	Београд, децембар 2010 Belgrade, December 2010

DOI: 10.2298/GABP1071053R

Observations on *Dissocladella annulata* (ELLIOTT, 1993) nov. comb. (Calcareous algae, Dasycladales) from the Cenomanian of west Serbia

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Abstract. Based on material from the type area at Tetrebovo in the Zlatibor massif of W Serbia, the Cenomanian dasycladalean alga originally described as *Harlanjohnsonella annulata* by ELLIOTT (1968, typified 1993 *in:* GRANIER & DELOFFRE), is emended and revisited as *Dissocladella annulata* (ELLIOTT) nov. comb. The evidence of tufts of short secondaries arising at the top of the drop-like primaries allows its transfer to the genus *Dissocladella* PIA, 1936. This species displays a different degree of skeleton calcification which is described in detail. The monospecific genus *Harlanjohnsonella* ELLIOTT becomes invalid, as being a junior synonym of *Dissocladella*.

Key words. Dasycladales, *Dissocladella annulata* (ELLIOTT) nov. comb., systematic taxonomy, Cenomanian, Serbia.

Апстракт. Дазикладацејску врсту из ценоманских слојева Тетребова (јужни Златибор) описао је ELLIOTT (1968, типификована 1993 *у*: GRANIER & DELOFFRE) као *Harlanjohnsonella annulata* nov. gen., nov. spec. Преиспитивањем узорака из типског локалитета добијени су детаљнији подаци о грађи ове врсте – документовано је постојање секундарних огранака. Овај податак указао је на њену припадност роду *Dissocladella* PIA, а на основу тога моноспецифични род *Harlanjohnsonella* је инвалидизиран. Дијагноза врсте *Dissocladella annulata* (ELIOTT, 1968) nov. comb. допуњена је уз детаљне илустрације о структури скелета.

Кључне речи: Dasycladales, *Dissocladella annulata* (ELLIOTT) nov. comb., систематска таксономија, ценоман, Србија.

Introduction

In 1968 ELLIOTT described a new dasycladalean genus and species as *Harlanjohnsonella annulata* from transgessive, basal Upper Cretaceous, possibly Cenomanian of "Tetrebovo, Dlaglica SE of Zlatibor massif, SW Serbia" with the following diagnosis of the genus *"Weakly calcified thin-walled tubular and annular dasyclad, with successive verticils showing numerous swollen primaries, the presumed secondaries not being calcified"*. The species is typified 1993 in GRANIER & DELOFFRE Discussing the relationships, ELLIOTT concluded *"that the form now described was, in fact, a dasyclad of very similar plant morphology to D.* (Dissocladella) *savitriae, but more weakly calcified"* and because *"there is no direct fossil evidence of secondary branch-structure the species cannot correctly be referred to Dissocladella."*

Based on material sampled at the type locality (RADOIČIĆ 1995), from which new thin sections have been prepared, it is documented that the genus *Harlanjohnsonella* ELLIOTT represents a younger synonym of *Dissocladella* PIA confirming ELLIOTT's presumption. The scope of the present paper is a taxonomic revision and detailed illustratation of *Dissocladella annulata* (ELLIOTT) nov. comb.

Geological setting

The Cretaceous deposits of the southern (Tetrebovo, Vis, Fig. 1) and of the central Zlatibor Mountains are rare remnants of a Cretaceous (Albian–?Lower Senonian) cover resting upon ultramaphic rocks. First data on the Cretaceous strata of southern Zlatibor were given by ELLIOTT (1968, "possibly Cenoma-

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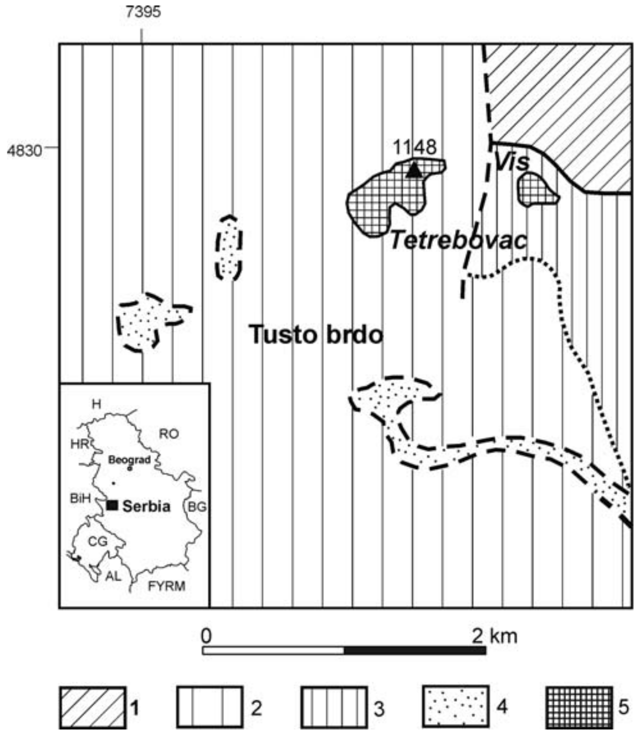

Fig. 1. Geological map of the Tetrebovo area, according to RAMPNOUX (1970, fig. 145), and Geological map sheet Prijepolje 1:100000, ĆIRIĆ *et al.* (1977). Legend: **1,** Upper Triassic limestones; **2,** Serpentinites; **3,** Habzburgites; **4,** Weathering crust, Lower Cretaceous; **5,** Upper Cretaceous limestones (?Albian–Cenomanian).

Fig. 2. Tetrebovo hill, northern view, Cretaceous deposit are covered by forest.

nian", based on RAMPNOUX's data and fossil material) and RAMPNOUX (1974). The presence of Turonian strata was documented by RADOIČIĆ (1995) at Vis (Fig. 1), in the central Zlatibor and Ravni area in the eastern part of Zlatibor. Regrettably, these data was ignored in the context of geological mapping for the Prijepolje sheet (ĆIRIĆ *et al*. 1977), and by subsequent researchers (e.g., DIMITRIJEVIĆ *et al*. 2002: Geology of Zlatibor).

The Tetrebovo succession (Figs. 1, 2), overlies peridotites. According to RAMPNOUX (1970, p. 275, fig. 145; 1974, p. 63), it starts with a Lower Cretaceous weathering crust. In detail the succession consists of:

– basal conglomerates,

– sandy limestones with gastropods, at places limestones with "*Harlanjohnsonella*" *annulata* ELLIOTT, and,

– limestones with *Chondrodonta joannae* CHOFAT, *Radiolites lusitanicus* PARONA and *R. peroni* DOUVILLE.

This succession was ascribed to the Turonian by RAMPNOUX in 1970, afterwards in 1974 to the Cenomanian–Turonian as being equal to that one at Ravni (East Zlatibor). In the meantime, the rudist limestones in the Ravni area, dated as Turonian by PEJOVIĆ & PASIĆ (1958) were revised as being Cenomanian in age (RADOIČIĆ 1995). It should be mentioned, that this does not correspond to the same Ravni succession dated as Turonian by RADOIČIĆ. Afterwards, these sparsely outcropping Tetrebovo Cretaceous deposits were sampled only at places (RADOIČIĆ 1995). One of the oldest observed beds is represented by a marly limestone containing gastropods and large specimens of *Dissocladella annulata* (ELLIOTT) nov. comb., which are well visible without lens. Upward in the section, the limestone contains rare benthic foraminifera, the dasycladalean algae *Heteroporella lepina* PRATURLON, *Terquemella* sp. and a few fragments of *Dissocladella annulata*. They are followed by limestones with frequent foraminifera, respectively *Marssonella turris* (D'ORBIGNY), *Rotalia mesogeensis* TRONCHETTI, *Pseudorhipidionia casertana* (DE CASTRO), *Pseudocyclammina rugosa* (D' ORBIGNY) and *Praealveolin*a cf. *iberica* REICHEL. Between these beds and youngest observeds skeletal calcarenites (middle-upper Cenomanian), the limestone with relatively frequent *Pseudorhapydionina dubia* DE CASTRO is sampled.

The limestone with *Dissocladella annulata* contains numerous large skeleton fragments, small and minute debris, different gastropods, molluscan shells and rare crustacean fragments, also mentioned by Elliott (1968). In the 25 thin sections studied, only one specimen of *Pseudorhipidionina casertana* and a few small foraminifera were observed. Clearly, *Dissocladella annulata* obviously populated shallow-water environments, probably of low salinity. At the type locality, the limestone with *Dissocladella annulata* can be ascribed to the lowermost Cenomanian.

Systematic taxonomy

Division Chlorophyta
Order Dasycladales Pascher
Family Triploporellaceae (Pia, 1920)
Tribus Dissocladelleae Elliott, 1977
Genus ***Dissocladella*** Pia, 1936 *in*: Rama Rao and Pia, 1936
(Synonym *Harlanjohnsonella* Elliott, 1968)

Dissocladella annulata (Elliott, 1968),
nov. comb., revisited
Pls. 1–5, Pl. 6, Figs. 1–16

1968 *Harlanjohnsonella annulata* nov. gen., nov. sp. – Elliott, p. 494, pl. 93, figs. 1-2, pl. 94, figs. 1-2.
1978 *Harlanjohnsonella annulata* Elliott – Bassoullet et al., p. 120, pl. 12, figs. 8-9.
non 1978 *Harlanjohnsonella annulata* Elliott – Lauverjat & Poignant, p. 123, pl. 2, figs. 1, 5-6.
1995 *Harlanjohnsonella annulata* Elliott – Radoičić, pl. 1, fig. 1.

Material. Twenty-five thin sections from the sample 022070, R. Radoičić collection RR4579 – 4584/9 deposited at the Geological Institute, Beograd.

Diagnosis. Elongated cylindrical thallus exhibiting a large central stem with moderately spaced horizontal whorls. The whorls consist of numerous laterals: drop-like primaries which, at the top, bear tufts of 5–6 thin phloiophorous secondaries. Primary calcification generally weak, stronger or only somewhat thicker around the proximal area of the primaries, becoming thinner outwards, especially at tip and around the secondaries. Possible presence of fertile and sterile individuals.

Description. Being rather variable in size, the skeleton of this species is rather thin with smooth inner surface. The primary calcification is diagenetically overgrown in variable degrees. Different degrees of recrystallization can be observed even within the same whorl. The weakly calcified distal part of the whorls, if not early diagenetically recrystallized, is more or less dissolved or abraded. Therefore, secondary laterals are preserved only in very rare cases, while poorly preserved secondaries are discernable as pores or open pores on the surface of many recrystallized skeletons (Pl. 1, Figs. 2, 4; Pl. 2, Figs. 3, 4; Pl. 3, Fig. 7; Pl. 4, Fig. 9; Pl. 5, Figs. 1–6). Only in some specimens, the membrane of the central stem can be recognized as a dark thin micritic line (Pl. 2, Figs. 1, 2, 5; Pl. 3, Fig. 7). The thin calcareous encrustation of the membrane is rarely preserved; it can be recognized only between two primaries of successive whorls, visible in some sections (Pl. 1, Fig. 4, arrows; Pl. 3, Fig. 4, left; Pl. 6, Figs. 4, 5). A thin-walled calcareous tube encloses the pores of primaries (Pl. 2. Fig. 1), Pl. 3, Fig. 6; Pl. 4, Fig. 1) or more frequently, the thin wall on the surface bears open pores of primaries (Pl. 1, Fig. 1; Pl. 2, Fig. 5; Pl. 3, Figs. 2–5). In rare specimens, the skeleton is dissolved so that it consists of a thin calcareous layer with irregular external surface, on which some parts of the basal calcification of the primaries can be recognized (Pl. 1, Fig. 3; Pl. 2, Figs. 6, 7).

The laterals are arranged in a plane; they are rarely slightly overlapping as shown in the specimen illustrated in Pl. 5, Fig. 8. In successive whorls, laterals do not alternate regularly, but occasionally alternation can be observed in a few successive whorls. In the proximal part the primaries display a regular funnel-like form; they communicate with the central stem by means of minute pores. In deep tangential sections, small basal pores can be seen gradually increasing from the center to the periphery (Pl. 4, Figs. 1). Transversal sections of primaries are circular in shape (Pl. 4, Figs. 1, 2; Pl. 5, Fig. 7, 8). In both, transversal and longitudinal sections of the skeleton, the pores are often secondarily enlarged or diminished and/or more or less deformed.

Besides more or less large specimens, the analyzed limestones of Tetrebovo contain numerous small and especially minute fragments of disintegrated skeletons. These have particular value for the recognition of the structure of this species and the processes of the skeleton alteration. Minute and small fragments as those shown in Pl. 1, Fig. 4 (arrows), Pl. 3, Fig. 3 (arrows), and Pl. 6, Figs. 1–7 indicate that some skeletons are characterized by a somewhat stronger primary calcification only of the shorter proximal part of the whorls, along with an especially thin calcification of the main axis membrane. Therefore, such a kind of calcification facilitated skeleton disintegration, more probably early post-mortem and becoming preserved as small or minute fragments. A further abiogenic stage of calcification resulted in the overgrowth of the primary calcification leading to irregular thallus coatings to variable degrees that is completely or partly coverage even within the same whorl.

Calcification and mode of preservation (Figs. 3 and 4) *Dissocladella annulata* is characterized by two types of primary calcification, shown in the drawings on Fig. 3/1 and 3/3; Figure 3/4 illustrates the relationship between these two types, on Fig. 4. are given different calcification types of the laterals and of the preservation of skeleton.

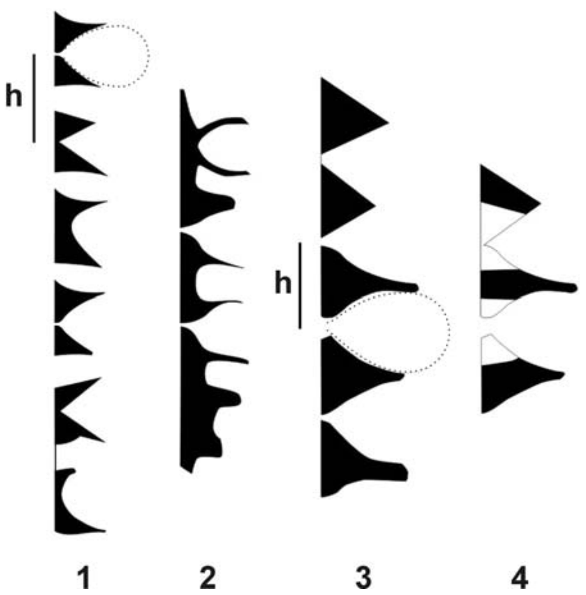

Fig. 3. Two types of calcification of *Dissocladella annulata* (longitudinal sections): **1, 2** – Skeleton A: relatively strong calcified proximal part of primaries which generally occur in the rock as dispersed elements of disintegrated skeleton; examples: Pl. 6, Fig. 1; Pl. 1, Fig. 4, arrows; Pl. 3, Fig. 3, arrows. **3** – B skeleton; example: Pl. 6, Fig. 9. **4** – Relation between A and B skeletons.

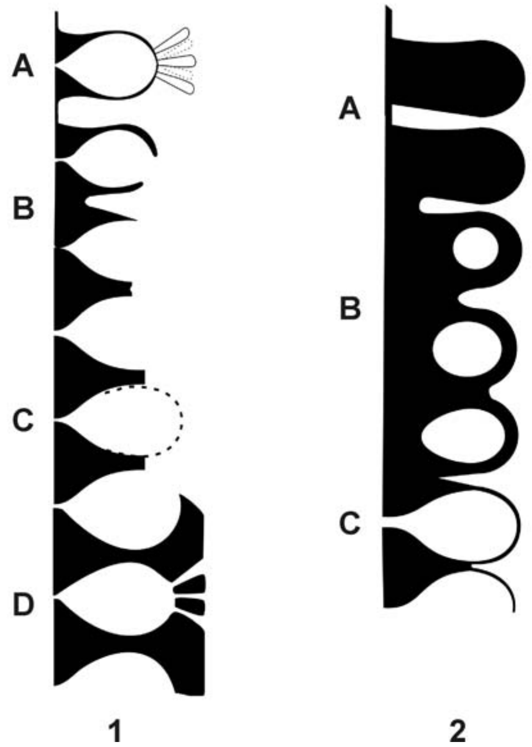

Fig. 4. *Dissocladella annulata* - different calcification types of the laterals and of the preservations of skeleton (longitudinal sections): **1A** – Skeleton A: primary calcification of primaries and secondaries with non-calcified space between the whorls; **1B** – More or less calcified distal part of primaries with advanced recrystallization in the space between the whorls; example: Pl. 4, Fig. 1 and 4, left; **1C** – Usual preservation of type B skeleton (collective calcified skeleton); example: Pl. 3, Figs. 2, 3, Pl. 6, Fig. 9. In the material studied, these parts of the skeleton are preserved as a mosaic trimmed by small calcite grains; **1D** – Recrystallized type B skeleton with only primary pores and with preserved secondaries, too; example: Pl. 2, Fig. 1 and Pl. 6, Fig. 13. **2A** – Completely recrystallized primaries in the annulated skeleton with encrusted stem membrane; example: Pl. 4, Fig. 3, right arrow. **2 A/B** – Different grades of recrystallized space between whorls, with or without preserved pores of primaries, type A skeleton; example: Pl. 4, Figs. 3, left arrow. **2C** – Calcification type of the primaries corresponding to the collective calcified skeleton sensu DE CASTRO (1997).

First type, skeletons of group A (A skeleton): relatively strong proximal calcification usually covering 1/3 of their length, and then distally gradually becoming thinner. Distally, delicate parts of the skeleton, including the secondaries (Fig. 4/1A), were not preserved in the studied material. The characteristic feature of the group A skeleton is that the specimens display a smaller size of the primary laterals (Fig. 3/1, Fig. 4/1A-B, and 2A), resulting in a primarily non-calcified space between the calcified whorls and an annulation of the skeleton (referring to the species name *annulata*). The best examples are illustrated in Pl. 4, Figs. 3, 5 also in Pl. 6, Figs. 1–7, 10 and 11, and also in Fig. 3/1, 4/1A and 2A.

Second type, skeletons of group B (B skeleton): this type is characterized by a) larger primary laterals which are, also in both transversal and longitudinal sections, in slight contact in the largest middle part of the lateral's length and b) by the stronger proximal calcification which, between successive whorls is compact - cf. collective calcified skeleton sensu DE CASTRO (1997, *"guaine calcificata collettiva"*). Secondarily altered, this skeleton part is formed by calcite mosaic trimmed by smaller grains. In the studied material the B skeleton is often preserved as non annulated relatively thin calcareous tubes (proximal area) with open pores of primaries (Pl. 3, Figs. 2–5). It has to be mentioned that in some recrystallized skeletons including secondaries, the "annulations" are reflected on the surface only as shallow feeble canals between the whorls (Pl. 4, Fig. 9; Pl. 5, Fig. 2). Therefore, the space between them is not calcified and as a consequence of this, the strong proximal primary calcification ends in this area (Fig. 5/3; Pl. 4, Figs. 3 left wall, and 4). Hence, this skeleton type is generally preserved as calcareous tubes mainly with open pores of the primaries at the surface.

Dimensions. The dimensions given by ELLIOTT (1968) are indicated between brackets.

Longest observed specimen (L): 12 mm

External diameter (excluding small form in Pl. 2, Fig. 5) (D): 1.18–3.10 mm (up to 2.25 mm)

Central stem diameter (d): 0.940–2.590 mm

d/D: 71% – 89.5% (about 74 %)

Thickness of the calcareous wall (e): 0.098–0.247 mm, maximum up to 0.330 mm (recrystallized – skeletons into secondaries) (0.26 mm)

Distance between successive whorls (h): 0.198–0.210 mm (0.19–0.25 mm)

Diameter of primary pores (p): 0.098–0.123 mm (0.13–0.14 mm)

Thickness of central stem membrane 0.015– 0.024 mm

Number of laterals in a whorl (w): 35–70 (48–50)

The distance between the whorls represents a fairly constant value, while the most variable biometric parameter is the main stem diameter.

Relationships As a consequence of the species emendation and new combination, *Dissocladella annulata* (ELLIOTT) is placed in the Tribus Dissocladelleae ELLIOTT, 1977. The genus *Harlanjohnsonella* ELLIOTT, 1968 (so far monospecific) becomes invalid as representing a synonym of *Dissocladella* PIA, 1936. Mention should be made, that the possible existence of secondary laterals was already assumed by ELLIOTT (1968) and integrated in the genus diagnosis. ELLIOTT anticipatorily remarked the similarity of "*Harlanjohnsonella*" *annulata* with *Dissocladella savitriae* PIA, 1936 (type-species of the genus) from the Maastrichtian–Danian of India showing some similar dimensional parameters (d, d/D, p) and both displaying typical thallus annulation. *Dissocladella annulata* (ELLIOTT) may show more variable and relatively larger external diameters and higher number of laterals per whorl (w about 40 in *D. savitriae*). Apart from this, the special type of calcification and different degree of preservation (due not only to diagenesis) seems to be a species-specific feature of *D. annulata*, not reported from *D. savitriae* with fully calcified ring-like elements enclosing both primaries and secondaries. Curiously, BASSOULLET *et al.* (1978, p. 92) mention an internal thallus undulation, though not mentioned in the original description. In any case, *D. annulata* lacks any internal undulation.

Remarks. In the generic discussion, ELLIOTT included the Carboniferous *Coelosporella*, the Permian *Epimastopora* and *Pseudoepimastopora*. From annular forms such as the Cretaceous *Neomeris cretacea* DELMAS & DELOFFRE non STEINMANN (DELMAS & DELOFFRE, 1962), *Dissocladella annulata "differs in the apparently simple branch-structure"*. Furthermore ELLIOTT concluded that "*a closer comparison can be made with Dissocladella*, *especially the Paleocene Dissocladella savitriae (PIA, 1936).*"

BASSOULLET *et al.* (1978, p. 120) essentialy refer to affinities with *Pseudoepimastopora*: "Le genre *Pseudoepimastopora* parait très voisin du genre *Harlanjohnsonella* et les differences n´apparaissent pas évidentes" and....... "cette espèce pourrait appartenir au genre *Pseudoepimastora*". BASSOULLET et al. (1978) furthermore express doubts on the existence of "annuli or rings" in *Harlanjohnsonella* (ELLIOTT 1968, p. 494). Also JAFFREZO *et al*. (1980) describing *Pseudoepimastopora pedunculata* were discussing affinities/differences to the genus *Harlanjohnsonella*. *Pseudoepimastpora*, however, cannot be considered in the discussion as it represents a nomen nudum (e.g. GRANIER & DELOFFRE 1993; GRANIER & GRGASOVIĆ 2000). In the "New taxonomy of Dasycladale Algae" presented by DELOFFRE (1988), *Harlanjohnsonella* ELLIOTT, 1968 is treated as a synonym of *Paraepimastopora* ROUX, 1979 although *Harlanjohnsonella* was established more than ten years earlier. *Paraepimastopora* is included by DELOFFRE (1988) in the Mastoporea PIA with aspondyle thalli, whereas in the original description ELLIOTT placed it in the tribus Thyrsoporelleae. DRAGASTAN (1975) reported *Harlanjohnsonella* sp. from the Lower Cretaceous of Romania, a form later included tentatively in the synonymy of *Anisoporella*? *cretacea* (DRAGASTAN 1967) by BUCUR (1995). From the Valanginian of Greece, DRAGASTAN & RICHTER (2003) described *Harlanjohnsonella fuechtbaueri* as a new species characterized by a head-and-peduncle thallus morphology: the peduncle bearing "*only primary vesiculiferous ramification with two shapes: a proximal tubular and the distal part globulous, like vesicle. The cylindrical peduncle is continued by a "head" made up of euspondyle verticils with vesiculiferous ramification"*. As shown in the present paper, *Harlanjohnsonella* represents a junior synonym of *Dissocladella*; therefore the generic position of the dasycladalean alga described by DRAGASTAN & RICHTER (2003) remains open. The authors also allege that *Dissocladella annulata* (ELLIOTT) should exhibit a head-and-peduncle type thallus, a view that must be rejected due to the studied abundant material. Concerning the section designated as holotype, in Pl. 4, Fig. 3, it has to be mentioned that the presence of a "head" is not sure (it may be the section of another specimen in a densely packed algal limestone).

Acknowledgements

We thank to reviewers FILIPPO BARATTOLO (Napoli) and MARC A. CONRAD (Genève) for comments and helpfull sugestions, to MARC A. CONRAD also for improvement english language.

References

BASSOULLET, J.P., BERNIER, P., CONRAD, M.A., DELOFFRE, R. & JAFFREZO, M. 1978. Les algues Dasycladales du Jurasique et du Crétacé. *Géobios, mém. spec,* 3: 1–333.

BUCUR, I.I. 1999. Lower Cretaceous Dasyclad algae from the Padurea Craiului Massif (Northern Apuseni Mountains, Romania). *Acta Paleontologica Romaniae*, 2: 53–72.

ĆIRIĆ, A., OBRADINOVIĆ, Z., NOVAKOVIĆ, D., POPEVIĆ, A., KARAJIČIĆ, L., JOVIĆ, B. & SERDAR , R. 1977. *Geological Map of sheet Prijepolje*, 1: 100 000, K34-16.

DE CASTRO, P. 1997. Introduzione allo studio in sezione sottile delle Dasicladali fossili (An Approch to thin-sections study of fossil Dasycladales). *Quaderni dell'Accademia Pontaniana*, 22: 1–261.

DIMITRIJEVIĆ, N.M., LJUBOVIĆ OBRADOVIĆ, D. & DIMITRIJEVIĆ, M.D. 2002. Upper Cretaceous of the Ravni domain. *In*: DIMITRIJEVIĆ, M.D. (ed.) *Geologija Zlatibora*, 75–85.

DRAGASTAN, O. 1975. Upper Jurassic and Lower Cretaceous Microfacies from the Bicaz Valley Basin (East Carpathians*). Institut de Geologie et de Geophysique, Memoires*, 21: 1–87.

DRAGASTAN, O. & RICHTER, D.K. 2003. Calcareous algae and foraminifers from Neocomian limestones of Methana Peninsula, Asprovouni Mts. (Greece) and from south Dobrogea (Romania). *Analele Universităţii Bucureþti*, *Geology, Special Publication,* 1: 57–128.

ELLIOTT, G.F. 1968. Three new Tethyan Dasycladaceae (Calcareous Algae*). Palaeontology,* 11 (4): 491–497.

GRANIER, B. & DELOFFRE, R. 1993. Inventaire critique des algues dasycladales fossiles II° Partie – les algues dasycladales du Jurassique et du Crétacé. *Revue de Paléobiologie*, 12 (1): 19–65.

GRANIER, B. & GRGASOVIĆ, T. 2000. Les algues Dasycladales du Permien et du Trias. Nouvelle tentative d´ inventaire bibliographique, géographique et stratigraphique. *Geologia Croatica*, 53 (1): 1–208.

JAFFREZO, M.A., POISSON, A. & AKBULUT, A. 1980. Les Algues au Crétacé inférieur des séries de type Bey Daglari (Taurides occidentales, Turquie). *Bulletin of the Mineral Research and Exploration Institute of Turkey*, 91 (1978): 76–88.

LAUVERJAT, J. & POIGNANT, A. 1978. Les algues de la série à Vascocératides du bassin occidental Portugais. *Cahiers de Micropaleontologie*, 3: 121–126.

PEJOVIĆ, D. & PAŠIĆ, M. 1958. Razviće turona u široj okolini sela Ravni i Sirogojna, zapadna Srbija. *Zbornik radova Geološkog instituta "Jovan Žujović"*, 10: 21–28.

RADOIČIĆ, R. 1995. Contribution to the study of Cretaceous biostratigraphy of Zlatibor Mountain. *Radovi Geoinstituta*, 31: 17–30 (in Serbian, English summary).

RAMPNOUX, J.P. 1970. Contribution à l'étude géologique des Dinarides: un secteur de la Serbie méridonale et du Montenegro orientale (Yougoslavie). *These,* Planche et Coupes, 176 pp.

RAMPNOUX, J.P. 1974. Contribution à l'étude des Dinarides: un secteur de la Serbie méridionale et du Montenegro orientale (Yougoslavie). *Mémoires de la Societé Géologique de France, Nouvelle serie*, 52 (1973), 119: 6–99.

Резиме

Опсервације о врсти *Dissocladella annulata* (ELLIOTT, 1993) nov. comb. (Dasycladales) из ценомана западне Србије

Кредне наслаге јужног (Тетребово, Вис, сл. 1) и централног Златибора остаци су кредног покрова (алб–?доњи сенон) на ултрамафитима. Први податак о креди на јужном Златибору дао је ELLIOTT (1968), а на основу података и материјала RAMPNOUX-а. Присуство туронских седимената документовано је знатно доцније на узвишењу Вис (сл. 2), на централном, и у области Равни на источном Златибору (RADOIČIĆ, 1995). Подаци о креди на јужном Златибору игнорисани су од стране тима који је радио гелошку карту листа Пријепоље 1:100 000 (ĆIRIĆ *et al*. 1978), као и од потоњих аутора студије о креди Златибора (DIMITRIJEVIĆ *et al.* 2002).

Систематика

Ред Dasyladales PACHER
Фамилија Triploporellaceae (PIA, 1920)
Триба Dissocladelleae ELLIOTT, 1977
Род ***Dissocladella*** PIA, 1936, in RAMA RAO and PIA, 1936
(Синоним *Harlanjohnsonella* ELLIOTT, 1968)

Dissocladella annulata (ELLOTT, 1968),
nov. comb., revisited
Табле 1–5; Таб. 6, сл. 1–16.

Дијагноза. Издужен цилиндричан талус са пространом централном стабљиком која носи раздвојене хоризонталне пршљенове. Пршљенови се састоје од бројних субсферичних примарних огранака који, на врху, носе 5–6 тањих флоиофорних секундарних огранака. Примарна калцификација је релативно слаба, јача или само нешто дебља у проксималном дијелу примарних огранака, отанчавајући дистално, особито у врху и око секундарних огранака. Могуће је постојање фертилних и стерилних индивидуа.

Врсту *Dissocladella annulata* карактерише знатна варијабилност димензија, скелет је релативно танак, глатке унутрашње површине. Примарна калцификација прекривена секундарно и прекристалисала у различитом степену, често неуједначено у истом пршљену. Секундарни огранци ријетко су очувани. Особеност ове врсте је различита калцификација – потојање два типа (тип А и Б, сл. 3). Скелет типа А има нешто ситније примарне огранке, те међу пршљеновима остаје примарно некалцифициран простор што је узрок анулације скелета али и склоности ка десинтеграцији. Скелет типа Б има нешто крупније примарне огранке, јаче калцифициран проксимални дио, те компакну калцификацију међу пршљеновима (тип "колективне калцификације скелета" у смислу DE CASTRO-а, 1997). Очуваност скелета овог типа је другачија – то су кречњачке цјевчице са порама примарних огранака или са отвореним порама уколико зид није потпуније очуван. У скелету рано прекристалисалих јединки изгубљени су елементи унутарње грађе, али са отисцима секундарних огранака на површини скелета.

Dissocladella annulata била је настањена у плитководном ареалу, највјероватније у условима смањеног салинитета. Кречњаци са *Dissocldella annulata* у типском локалитету приписани су најнижем ценоману.

PLATE 1

Dissocladella annulata (ELLIOTT, 1993) nov. comb., emended, aspects of different skeleton preservation.

Fig. 1. Relatively well preserved oblique section of type B skeleton with calcification reaching from the main stem to p.p. distal parts of the primary laterals; note, that in the topmost whorl, the primary laterals are in slight contact. Thin section RR4584/7.

Fig. 2. Oblique section of type B skeleton altered by endolithic activity; in parts of the wall secondaries are discernible. Thin section RR4583.

Fig. 3. Oblique section of a dissolved skeleton with only a very thin remnant of the proximal part being preserved. Note some primary pores in the upper part of the figure. Thin section RR4583/5.

Fig. 4. Slightly oblique transverse section of a completely recrystallized type B skeleton with denticulated outer (moulds of secondaries) and smooth inner surface. Arrows: minute fragments of primaries (type A skeleton), in two of which parts of the encrusted stem membrane are preserved. Thin section RR4583/2.

Scale bar for all figures = 0.50 mm

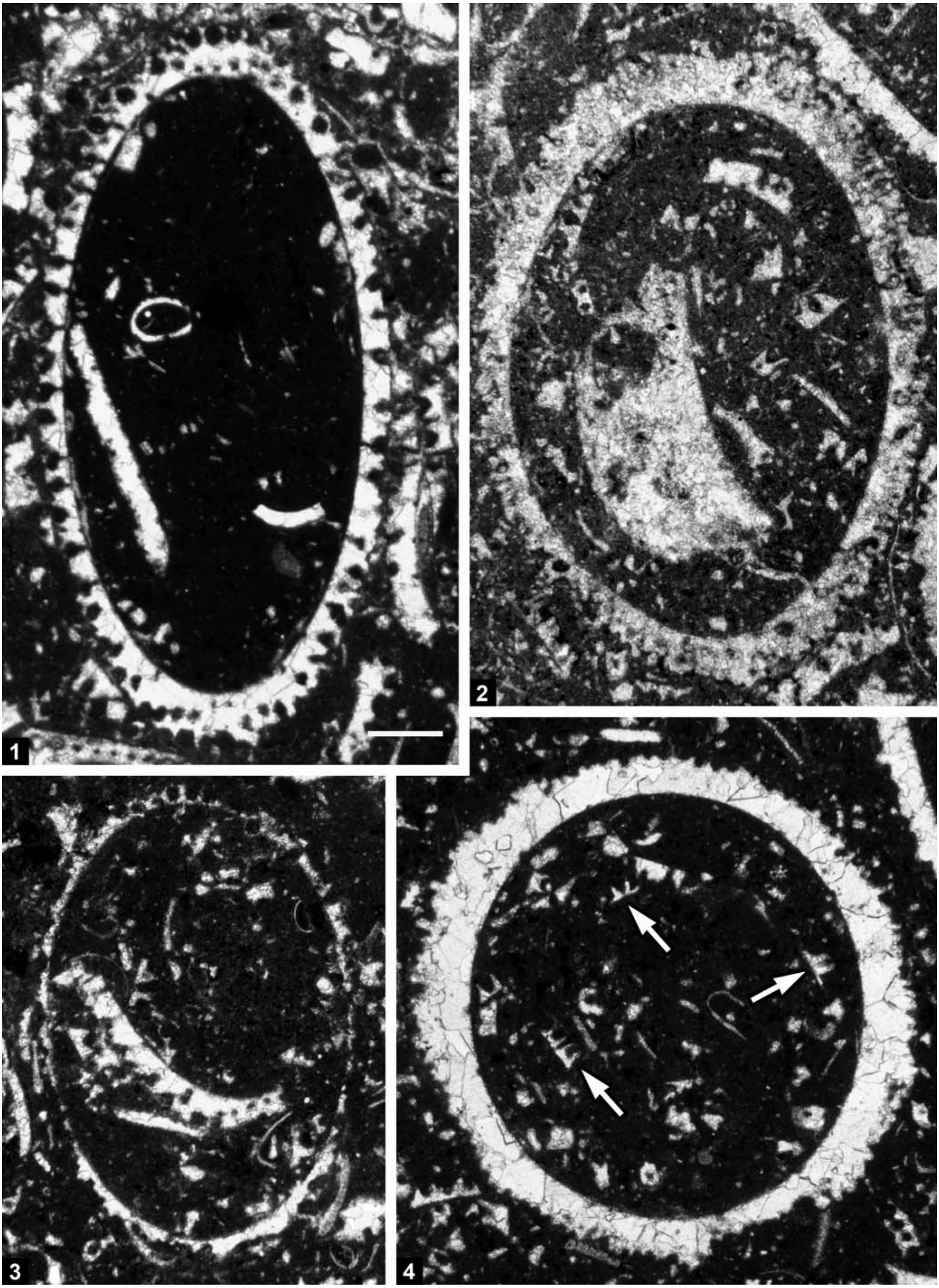
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PLATE 2

Dissocladella annulata (ELLIOTT, 1993) nov. comb., emended.

Fig. 1. Relatively well preserved, slightly oblique trnsverse section with main stem preserved as a thin micritic line; arrow: somewhat thicker part of the skeleton wall with a few poorly preserved open pores of secondaries. Thin section RR4584/8.

Figs. 2, 3. Transverse sections of poorly preserved, recrystallized and more or less dissolved skeletons with, in the upper part, slightly visible micritic main stem membrane. Thin sections RR4583/1 and 4583/7.

Fig. 3. Slightly oblique transverse section of a recrystallized type B skeleton, partly dissolved, with denticulate outer and smooth inner surface. Thin section RR4583/7.

Fig. 4. Oblique section of a large fragment, partly recrystallized, altered by endolithic activity and showing some relatively well visible open pores of secondary laterals. Thin section RR4583.

Fig. 5. Slightly oblique transverse section with only the proximal part of the skeleton and the main stem membrane as a thin micritic line being preserved. Thin section RR4583.

Figs. 6, 7. Transverse and longitudinal section of skeletons in nearly last stadium of dissolution; in both the inner surface is smooth. In Fig. 6, left, note the fragment of longitudinal wall section with three drop-like pores of primary laterals; Thin sections RR4584/8 and 4583/5.

Scale bar for all figures = 0.50 mm.

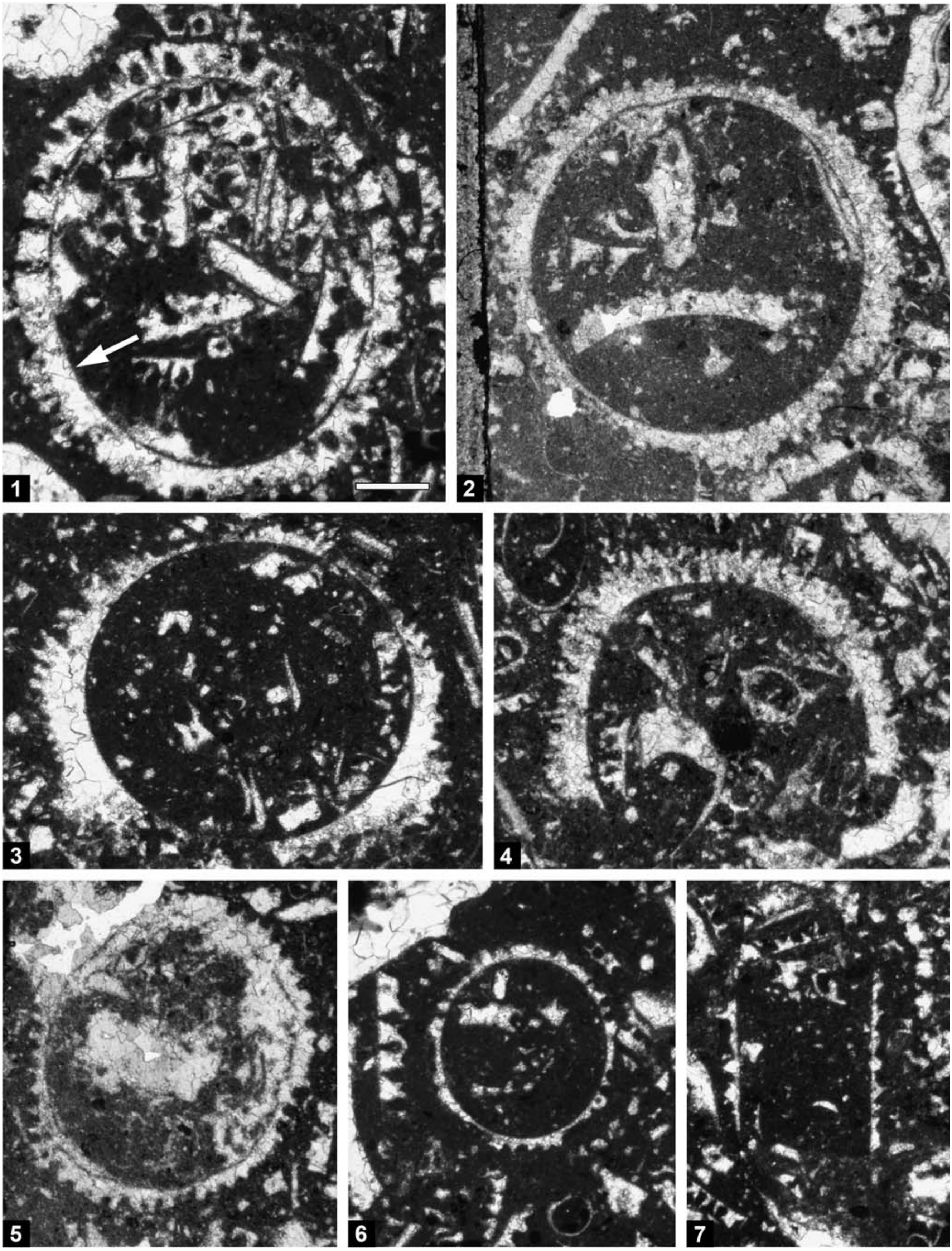
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PLATE 3

Dissocladella annulata (ELLIOTT, 1993) nov. comb., emended.

Fig. 1. Longitudinal section of a prevailing recrystallized calcareous tube (9 mm in length) in which some subsequently recrystallized pores of primaries are discernible. Thin section RR4584.

Figs. 2, 3. Longitudinal-oblique sections of thin type B skeleton's wall showing open pores of primaries on the surface. Arrows in Fig. 3: small fragments; note on the left: calcification of group A, *versus* those of group B skeletons; detail shown in Fig.4. Thin sections RR4584 /5 and 4584/1.

Fig. 4. Detail of the section in Fig. 3, A versus B type skeletons; note the white lines: the relationship of the distance between the whorls (c-c): in group A (left) and B (right). Thin section RR4584/1.

Fig. 5. Transverse section. Thin secttion RR4583/4.

Fig. 6. Oblique section of the smallest skeleton observed. Thin section RR4584/2.

Fig. 7. Recrystallized skeleton, note (arrow), two pores of primaries arising from the micrite main stem (micrite line) (lower arrow). In the upper part a few pores of secondaries are slightly discernible (upper arrow). Thin scetion RR4583/5.

Scale baar for all figures = 0.50 mm.

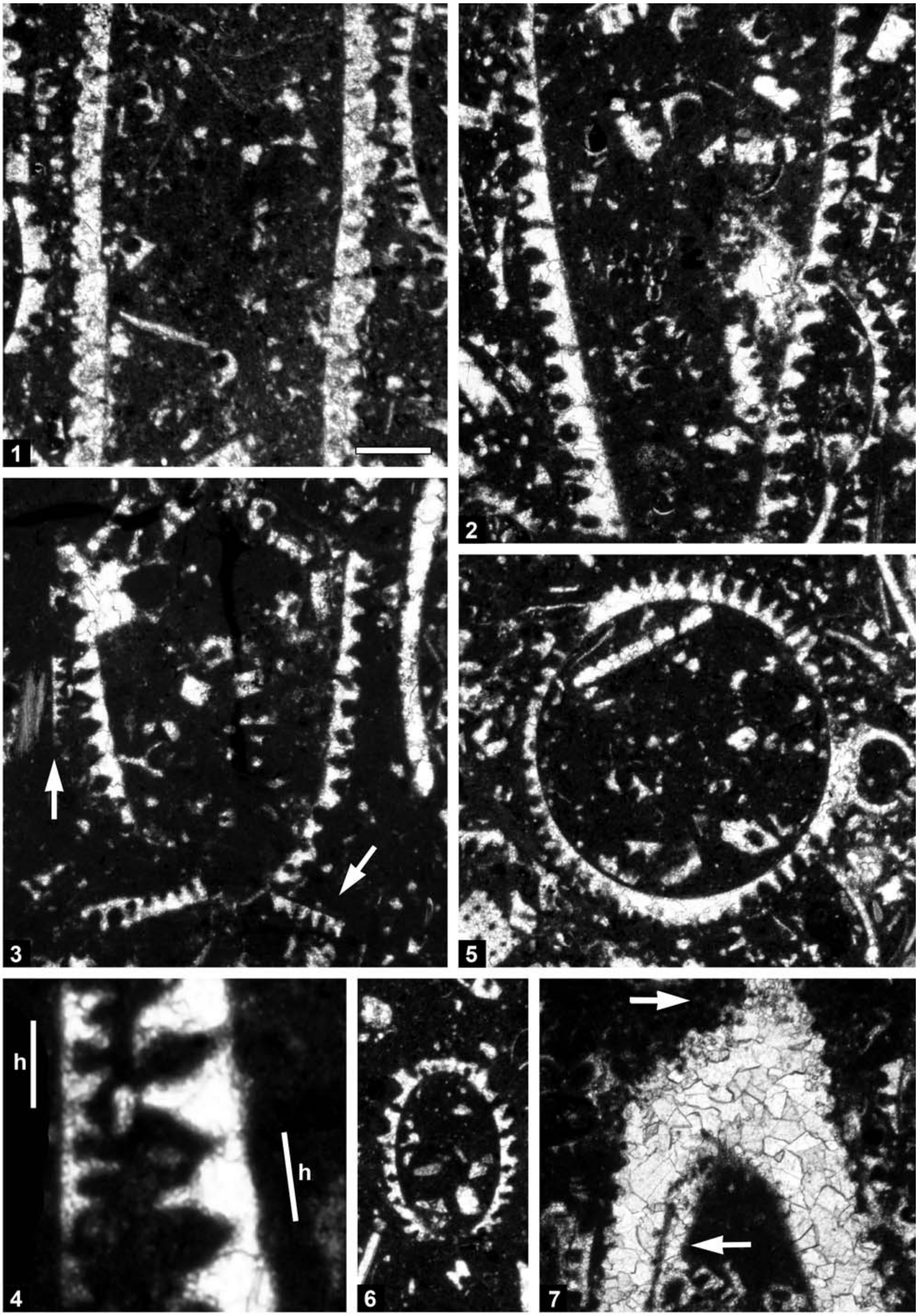
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PLATE 4

Dissocladella annulata (ELLIOTT, 1993) nov. comb., emended

Figs. 1, 4. Longitudinal-oblique sections of annulated, selectively altered skeletons. Only the space between the whorls in the proximal area is recrystallized, while the primary calcification is preserved in their distal parts (left in both figures). Thin sections RR4584/8 and 4584/5.

Fig. 2. Longitudinal-oblique section of type B skeleton. Thin section RR4584/1.

Fig. 3. Longitudinal-oblique section of an annulated skeleton in which, in contrast to that one in Fig. 2, the whorls with the primaries are completely recrystallized (Fig. 4/2A), while the space between the whorl is not filled; arrows: thin encrusted stem membrane (right) and (left) recrystallized basal part of the space between the whorls. Thin section RR4582.

Fig. 5. Tangential section corresponding to the skeleton shown in Fig. 2. Thin section RR4584/5.

Fig. 6. Slightly deformed longitudinal-oblique section of type A skeleton similar to that one shown in Fig. 3, poorly preserved and slightly deformed. Thin section RR4584/2.

Fig. 7. Fragment of a longitudinal-oblique section of a type A skeleton; note the encrusted main stem membrane on the right. Thin section RR4584.

Fig. 8. Oblique section of type A skeleton with encrusted stem membrane between the whorls. Thin section RR4584/6.

Fig. 9. Oblique section of a recrystallized skeleton altered by endolithic activity; secondaries discernible in the upper part (arrow). Thin section RR4583/3.

Scale bar for all figures = 0.50 mm.

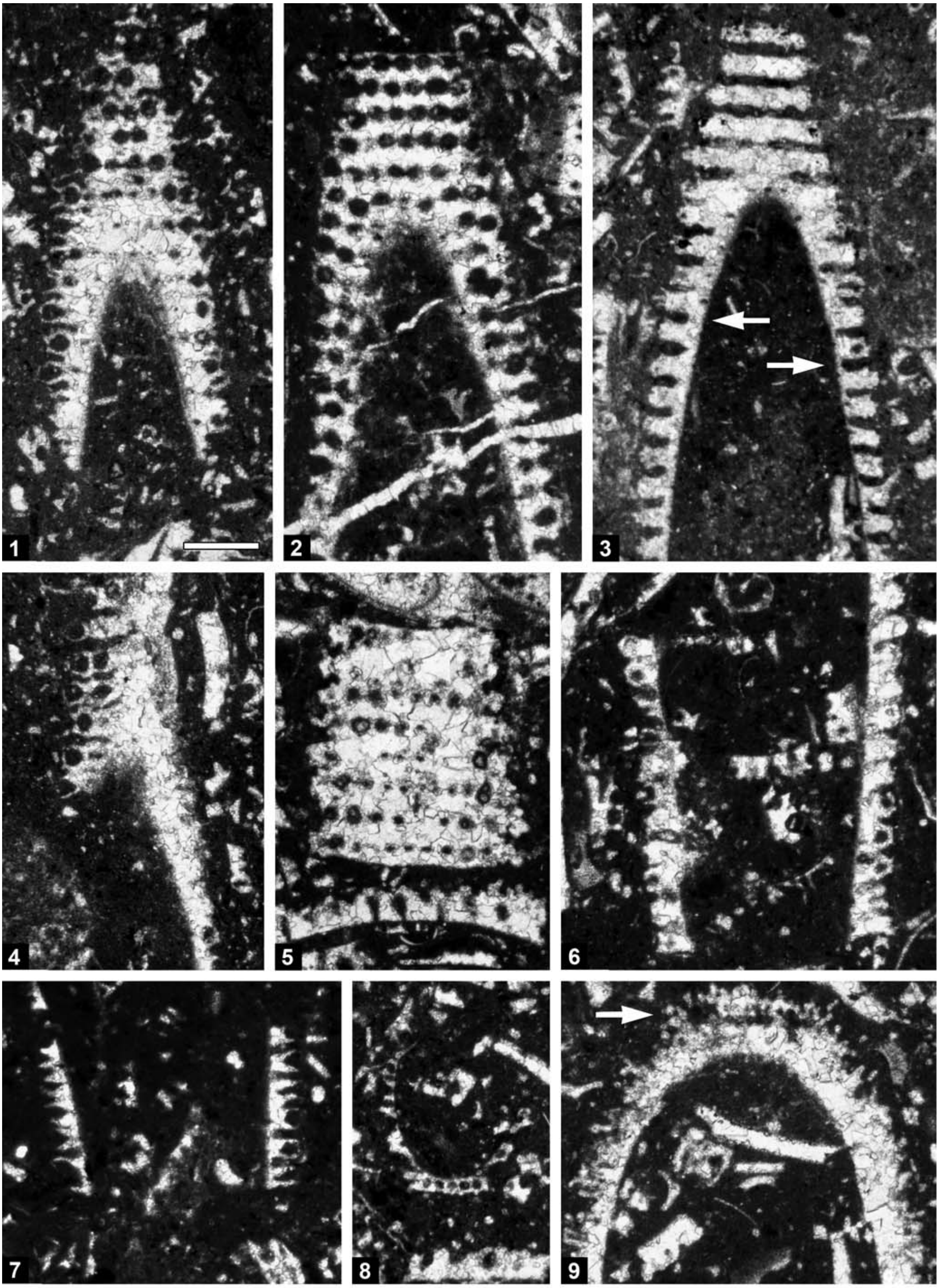

PLATE 5

Dissocladella annulata (ELLIOTT, 1993) nov. comb.

Fig. 1. Fragment of a tangential section with pores of secondaries in the upper part. Thin section RR4583/1.

Figs. 2–6. Poorly preserved recrystallized oblique sections and fragments with pores of secondaries on the surface. Thin sections RR4584/2, 4584/2, 4584/4, 4584/3 and 4584/9.

Figs. 7, 8. Tangential-oblique and shallow tangential section; "pores" between whorls in Fig. 7 are in fact pseudopores. Thin sections RR4584/2 and 4584/4.

Fig. 9. Oblique deep tangential section. Thin section RR4584/7.

Fig. 10. Tangential section with pseudopores (= not uniformly calcified space between whorls). Thin section RR4583/5.

Scale bar for all figures = 0.50 mm.

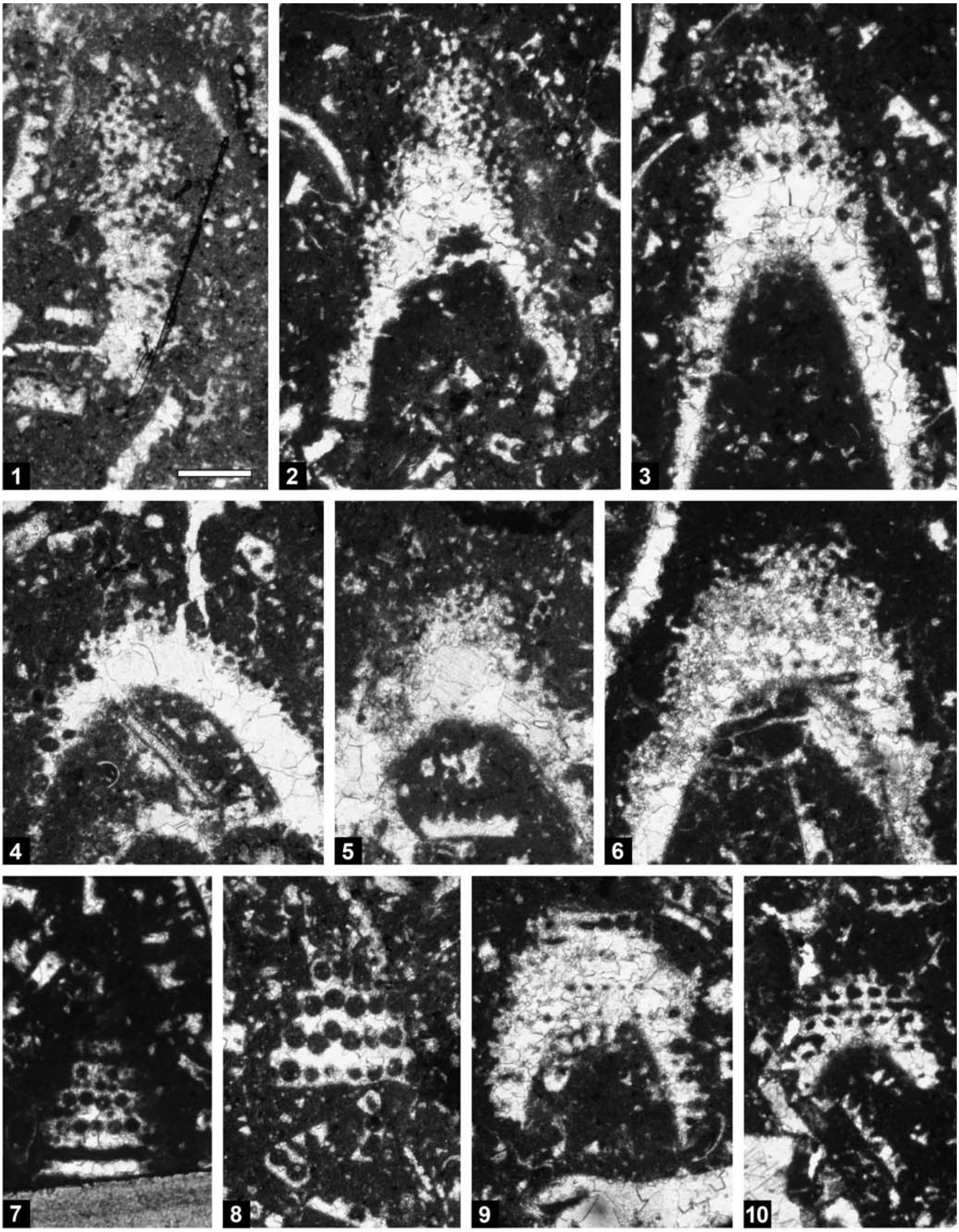

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PLATE 6

Dissocladella annulata (ELLIOTT, 1993) nov. comb., emended (Figs. 1–16), and associated organisms (Figs. 17–21).

Figs. 1–8, 10. Longitudinal and longitudinal-slightly oblique sections of different minute and small fragments of type A skeletons. Thin sections RR4584, 4583/2, 4584/5, 4584/2, 4581, 4584/8, 4584/7, 4584/1, 4583/2 and 4584.

Fig. 9. Longitudinal section, fragment of type B skeleton. Thin section RR4583/4.

Fig. 11. Tangential section of a type A skeleton, corresponding to longitudinal section of skeleton in Fig. 10. Thin section RR4583/2.

Fig. 12. Fragment, longitudinal section of a recrystallized type B skeleton with few open pores of secondaries. Thin section RR 4583/4.

Fig. 13. Fragment of a slightly oblique transverse section with three pores of secondaries. Thin section RR4583/5.

Fig. 14. Fragment of recrystallized transverse section with denticulate surface. Thin section RR4584/4.

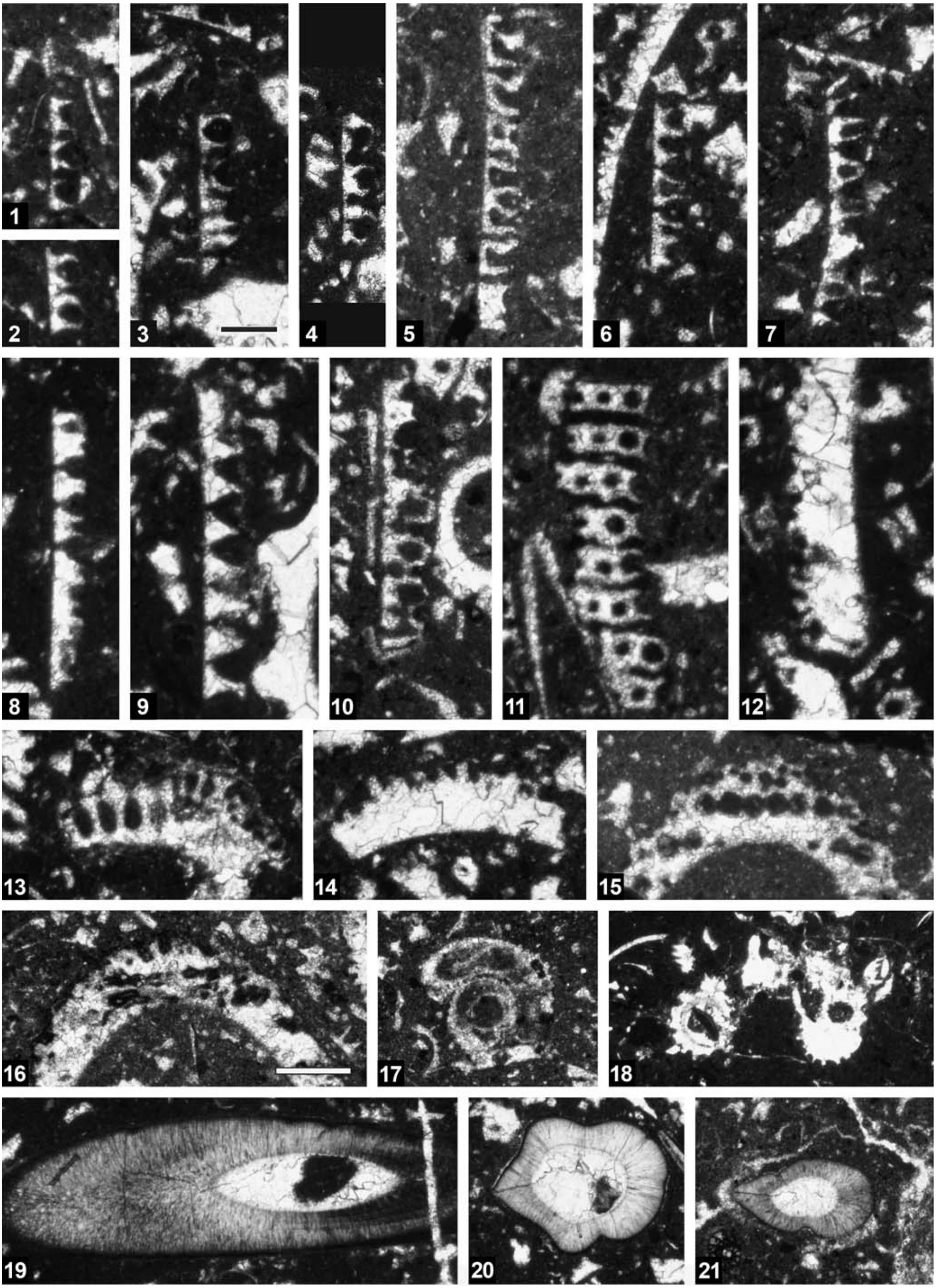
Fig. 15. Oblique section, note pores of secondaries . Thin section RR4586/5.

Figs. 16. Oblique section of a recrystallized skeleton affected by endolithic activity within the primaries. Thin section RR 4583.

Figs. 17, 18. Microgastropods. Thin section RR4583/6.

Figs. 19–21. Sections of crustaceans – *Carpathocancer* SCHLAGINTWEIT & GAWLICK (former *Carpathiella* MISIK, SOTAK & ZIEGLER). Thin sections RR4583/2, 4584/6 and 45 84/3.

Figures 1–15: scale bar = 0.25 mm; figures 16–21: scale bar = 0.50 mm.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Геолошки анали Балканскога полуострва Annales Géologiques de la Péninsule Balkanique	71	73–93	Београд, децембар 2010 Belgrade, December 2010

DOI: 10.2298/GABP1071073R

The age of the brachiopod limestones from Guča, western Serbia

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Dragoman Rabrenović[3] & Barbara Radulović[2]

Abstract. The asymmetric rhynchonellide brachiopod *Cyclothyris*? *globata* (Arnaud, 1877) has a large distribution in the Coniacian, Santonian and Campanian outcrops of the western Tethys. The species has also been identified in Guča, (Vardar Zone, western Serbia), where it occurs together with the capillate terebratuloid *"Terebratula"* sp. (gen. et sp. nov.). In addition to Serbia, this brachiopod association is found in many localities of northeastern Bulgaria (Shumen Formation). In older literature, in Romania and Bulgaria, *"Terebratula"* sp. (gen. et sp. nov.) was confused with the Late Maastrichtian *Terebratulina striata* (Wahlenberg, 1821). The present microfaunal study based on planktonic foraminifera showed that the age of the beds with *Cyclothyris*? *globata* and *"Terebratula"* sp. (gen. et sp. nov.) in Guča may be dated as Lowermost Campanian, *i.e.*, the Santonian/Campanian boundary.

Key words: brachiopods, *Cyclothyris*? *globata*, *"Terebratula"* sp. (gen. et sp. nov.), foraminifera, stratigraphy, Lowermost Campanian, Guča, Vardar Zone, western Serbia.

Апстракт. Асиметрични ринхонелид *Cyclothyris*? *globata* (Arnaud, 1877) има велико распрострањење у конијак–кампанским изданцима западног Тетиса. Врста је такође позната и из Гуче (Вардарска зона, западна Србија) где се појављује заједно са капилатним теребратулидом *"Terebratula"* sp. (gen. et sp. nov.). Изван Србије, ова брахиоподска асоцијација је пронађена у многим локалитетима северозападне Бугарске (Шумен формација). У старијој литератури, у Румунији и Бугарској, *"Terebratula"* sp. (gen. et sp. nov.) је одређивана као горњомастрихтска *Terebratulina striata* (Wahlenberg, 1821). Садашња микрофаунистичка проучавања заснована на планктонским фораминиферима су показала да је старост слојева из Гуче са *Cyclothyris*? *globata* и *"Terebratula"* sp. (gen. et sp. nov.) одређена као најранији кампан, тј. граница сантон/кампан.

Кључне речи: брахиоподи, *Cyclothyris*? *globata*, *"Terebratula"* sp. (gen. et sp. nov.), фораминифери, стратиграфија, најранијн кампан, Гуча, Вардарска зона, западна Србија.

Introduction

A brachiopod assemblage of two species, *i.e.*, *Cyclothyris*? *globata* (Arnaud) and "*Terebratula*" sp. (gen. et sp. nov.), was found in the Upper Cretaceous succession at the Dupljaj Stream, near Guča, in the Bjelica Belt of the Vardar Zone (western Serbia) (Fig. 1). The occurrences in ex-Yugoslavia of *Cyclothyris*? *globata*, which is common in several Coniacian––Campanian outcrops along the northern and southern Tethyan margins and in central Tethyan domains, were described and dated as Campanian by Radulović & Motchurova-Dekova (2002). In several localities of the Vardar Zone (Guča, western Serbia) and the Balkans (the Shumen Formation, northern Bulgaria), *C.*? *globata* was found in assemblages with the capillate "*Terebratula*" sp. (gen. et sp. nov.), which previously was misidentified with the Late Maastrichtian *Terebratulina striata* (Wahlenberg). The age of the brachiopod association from Guča, based on the

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abundance of microfossils, is updated herein. It is documented by the evidence of a rich association of benthic and planktonic foraminifera. The sequence of deposits bearing brachiopods evolved from a shallow marine environment weakly influenced by open sea into true hemipelagic calcisphere–globotruncanid deposits of the lower ramp-transition to a shallow basinal environment.

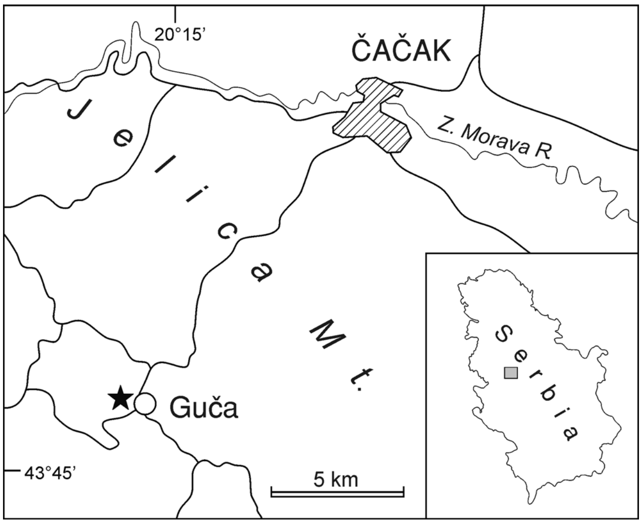

Fig. 1. Location map of the studied section (star).

Geological setting

The Cretaceous succession, according to ĆIRIĆ (1958), is formed of Senonian limestones and clastics transgressive and unconformable over different units of the Paleozoic complex. The author used abundant mollusks, mainly rudists, then corals and brachiopods, to document the Santonian, Campanian and Maastrichtian ages of the deposits; the latter also rich in large foraminifera – loftusiae and orbitoids.

Micropaleontological examinations and research of the rudist fauna during the geological mapping for the Sheet Čačak on the scale 1:100 000 documented the presence of the Coniacian and Turonian. Transgression in the present-day Dragačevo area started in the Albian, according to unpublished information (RR). Successive phases of the transgression evolved in the latest Cenomanian?–Early Turonian (following the Late Cenomanian event), in the Santonian and in Maastrichtian, when sea advanced over most of the area.

Albian deposits, precisely limestones bearing *Hemicyclammina sigali* MAYNC, are known only from the NE Kravarica Belt, under the Lower Cenomanian limestones with *Ovalveolina* sp, *Murgeina apula* (LUPERTO SINNI), *Pseudolituonella reicheli* MARIE, *Chrysalidina gradata* D'ORBIGNY, *Pseudorhipidionina casertana* (DE CASTRO) *etc*. A layer containing brachiopods, which is the subject of this note, was found in a minor exposure of the Bjelica Belt near Guča. The Cretaceous limestones and clastic preflysch succession of Bjelica were deposited during the Santonian, Campanian and Maastrichtian, whereas the age of the flysch (based on the nautilid *Hercoglossa* cf. *danica*) is Maastrichtian-Danian (ĆIRIĆ 1958). According to the authors of the geological map, massive marly limestones and partly marls in the Bjelica Belt are designated in the Middle Campanian only, while the flysch sedimentation in the belt, and in the entire Dragačevo expanse, excluding Jelica II, began (unsubstantiated!) much earlier, in the Late Campanian (BRKOVIĆ *et al*. 1978, Fig. 4). The presence of Maastrichtian limestones with rudists, loftusiae and orbitoids, well known from the publications on Dragačevo, has been unjustly and inexcusably neglected (first information on the Maastrichtian limestones was given by V. PETKOVIĆ 1909; in ĆIRIĆ 1958).

Observation on the Cretaceous of Jelica Mt. followed by an Explanatory Text for the Geological Map, Sheet Čačak on the Scale 1:100 000

The Cretaceous of Jelica Mt. is designated on the geological map in two belts of different developments: Jelica I (assigned to the Inner Dinarides) with a succession similar to the Bjelica Belt, and Jelica II (assigned to the Vardar Zone) with only a Middle Campanian Diabase-Chert Formation present (BRKOVIĆ *et al*. 1978, Fig. 4).

Why the (Jurassic) Diabase-Chert Formation was dated Campanian and what kind of deposits were developed there are the questions answered in the controversial text "Senonian of the Vardar Zone", as follows (translation from Serbian): "Senonian rocks in the Vardar Zone are represented by a particular Diabase-Chert Formation. They form a narrow, discontinuous belt along the Jelica Range, in a zone of intensive structural deformation, thereby in structural unconformity with adjacent units" "These rocks are rudistid in character (sic!) in a chaotic arrangement of units of ill-defined beds. The rock constituents are knots of different rocks chiefly in an arenite-silt matrix. Some areas in the breccioid mass differ in the composition and size of the knots and in the cementing material. The Jelica Range is built of breccia composed only of diabase fragments, with even the binder being fine-grained diabase breccia. The rocks in the western Jelica Range are sedimentary, subordinately mafite and ultramafite. In relation to the attitude of different units and their structures, these breccioids are likely an ophiolite mélange of olistostrome origin." (p. 36).

What the mapping researchers observed in the field was obviously tectonite, a chaotic unit or ophiolite mélange, by no means a Diabase-Chert Formation, which was only one component of a major tectonic event during the Campanian. Lamentably, the authors of the map uncritically accepted then the prevailing interpretation of M. N. DIMITRIJEVIĆ & M. D. DIMITRIJEVIĆ (1973, pp. 228, 230) that the Diabase-Chert Formation was a "typical olistostrome mélange", given "Cretaceous age" on Jelica.

Jelica II is a part of the known tectonic Rujevac–Veliki Majdan Zone in western Serbia (ĆIRIĆ 1996; RADOIČIĆ 1997). Based on planktonic foraminifera from some minor masses and blocks of the Jelica II Belt, the newest sediment is dated Early Campanian, the same as the Rujevac–Veliki Majdan ending in Kosovo.

Not infrequently, differentiation is not made between tectonites *s.str.*, particularly those of higher order of magnitude and post-tectonic sedimentation processes (there are, of course, specific relationships). Concerning the ophiolite mélange – tectonite, it depends on the mechanical properties of the rocks, crushed and broken in strong tectonic events, which were sufficiently plastic to include more compact components. In the given terrains, it is mostly the Diabase-Chert Formation.

Microbiostratigraphy

Upper Cretaceous rocks of the Bjelica Belt in the Dupljaj Potok near Guča are known from the finds of brchiopods. Basal terrigenous deposits of the Bjelica Belt pass into carbonate rocks (sandstone-calcareous sandstone-sandy to silty limestone) unexposed in the Dupljaj Potok. Neither of the oldest carbonate rocks is uncovered sufficiently for observation of the stratification. For detailed stratigraphical dating of the brachiopods, six samples (VR 101 through VR 106) were collected for micropaleontological examination from 10–12 meters of the stratigraphic column, *viz.*:

– The lowermost 2 m of the observed calcareous sandstone (sample VR 101) contains an abundance of coarse agglutinated foraminifer *Hemicyclammina chalmasi* (SCHLUMBERGER), few other benthic foraminifers: *Pararotalia minimalis* HOFKER, *Nummofallotia cretacea* (SCHLUMBERGER), *Goupillaudina* sp., miliolids and a few planktonic microfossils – *Heterochelix* sp. and calcispheres. Sparse fragments of corallinacean algae and mollusks are also found. (Pl. 1, Figs. 1–5; Pl. 3, Fig. 9; Pl. 6, Figs. 1, 11).

– Sandy limestone with brachiopods (sample VR 102), 1.5 m thick, contains cm-size fragments of corals, calcisponges and mollusks. In addition to some algal grains, the limestone contains quite rich benthic, dominantly varied rotaliform foraminifera, and planktonic microfossils. The microfossils are: *Hemicyclammina chalmasi* (very rare), *Pararotalia minimalis*, *Pararotalia* cf. *minimalis*, *Pararotalia* sp. G3, *Pararotalia*? sp. G4, *Rotalia* cf. *R. saxorum* D'ORBIGNY, *Goupillaudina* sp., *Sulcoperculina*? sp., rotaliacean foraminifera species G1 and species G2, *Nummofallotia cretacea, Vidalina* sp., miliolids and some undetermined forms. The planktonic foraminifera and other planktonics found in this limestone are: *Globotruncana linneiana* (D'ORBIGNY), *Globotruncana lapparenti* BROTZEN, *Globotruncana hilli* PESSAGNO, *Globotruncana* sp., *Globotruncanita* cf. *G. elevata* (BROTZEN), *Heterohelix* sp., *Pithonella multicava* BORZA, *Stomiosphaera* sp. and other calcispheres. Sparse algal grains are of *Terquemella*, fertile ampullae of *Neomeris* and corallinacean fragments.(Benthic: Pl. 2, Figs. 1–6; pl. 3, Figs. 1–6, 11; Pl. 4, Figs. 1–6; Pl. 6, Figs. 5–10; planktonic: Pl. 4, Fig. 11; Pl. 5, Figs. 1–7; Pl. 6, Fig. 2).

Upward follow 2–2.5 meters of hemipelagic silty calcispherulid limestones (samples VR 103 and 104):

– The planktonic microfossils from sample VR 103 are: *Pithonella ovalis* KAUFMAN, *Pithonella multicava* BORZA, *Cercidina supracretacea* VOGLER, *Stomiosphaera* sp., other calcispheres, than *Dicarinella asymetrica* (SIGAL), *Marginotruncana coronata* (BOLLI), *Globotruncana linnneiana* (D'ORBIGNY), *G. lapparenti* BROTZEN, *G. mariei* BANNER & BLOW, and very rare benthic foraminifera – *Navarella joaquini* CITY & RAT and G*oupillaudina* sp. (Pl. 5, Figs. 8, 9–11).

– The limestone of sample VR 104 bears: *Globotruncana linneiana, G. lapparenti, Globotruncananita stuartiformis* (DALBIEZ*), Heterohelix* sp., genus? (aff. *Gublerina–Schackoina*), frequent calcispheres and benthic foraminifera *Tekkeina anatoliensis* FARINACCI & YENIAY, *Navarella joaquini* (both large agglutinated species known from hemipelagic–pelagic deposits) and *Lenticulina* sp. (Benthic: Pl. 4, Figs. 7–11; planktonic: Pl. 5, Figs. 13, 14, 16; Pl. 6, Fig. 3).

– The some six meters of silty limestones of samples VR 105 and 106 contain *Marssonella* sp., then calcispheres and very few glogotruncanids – *Globotruncanita elevata* (BROTZEN), a transitional form between *Globotruncana arca* and *Contusotruncana patelliformis*. (Pl. 5, Figs. 15, 17).

Brachiopods

The brachiopod assemblage from the sandy limestones (sample VR 102) at Guča consists of two species: the asymmetric rhynchonellide *Cyclothyris*? *globata* and the capillate terebratulide *"Terebratula"* sp. (gen. et sp. nov.).

***Cyclothyris*? *globata* (ARNAUD, 1877)** (Figs. 2.1–5) – This species was recently described by RADULOVIĆ & MOTCHUROVA-DEKOVA (2002) from Slovenia, Croatia, Serbia and Bulgaria. Here follows the description based on the specimens from Guča.

Shell of medium size (L_{min} 17.7 mm; L_{max}, 26.7 mm), generally with subtriangular outline, or transversely-oval, always with a twisted asymmetrical anterior commissure. The dorsal valve is usually more convex than the ventral valve. Greatest width at the anterior

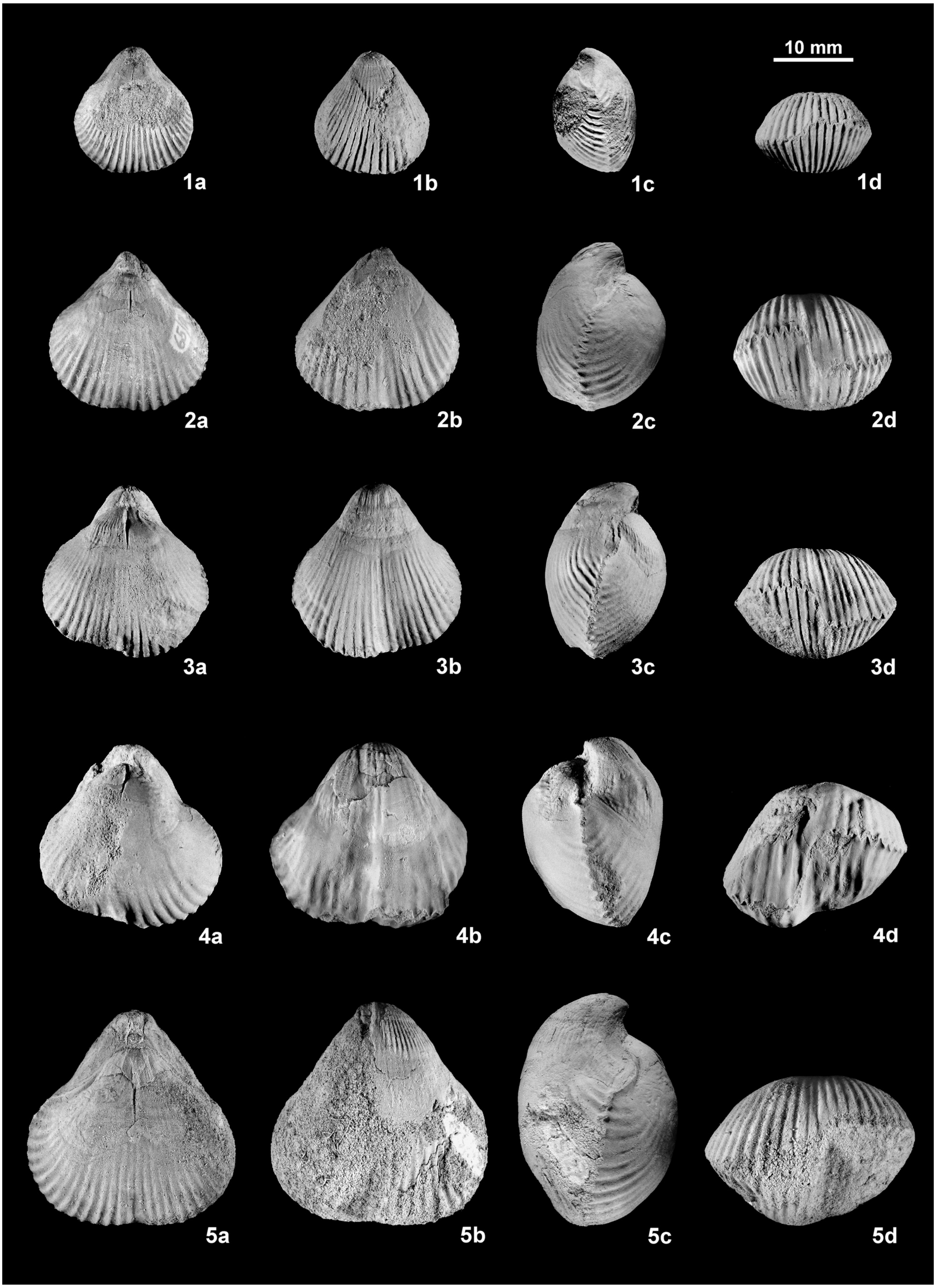

Fig. 2. *Cyclothyris*? *globata* (ARNAUD), Lowemost Campanian, Guča, western Serbia. **1** – RGF VR 62/4; **2** – RGF VR 65/14; **3** – RGF VR 62/6; **4 –** RGF VR 62/2; **5 –** RGF VR 65/27. The letters imply the view: **a**, dorsal; **b**, ventral; **c**, lateral; **d**, anterior.

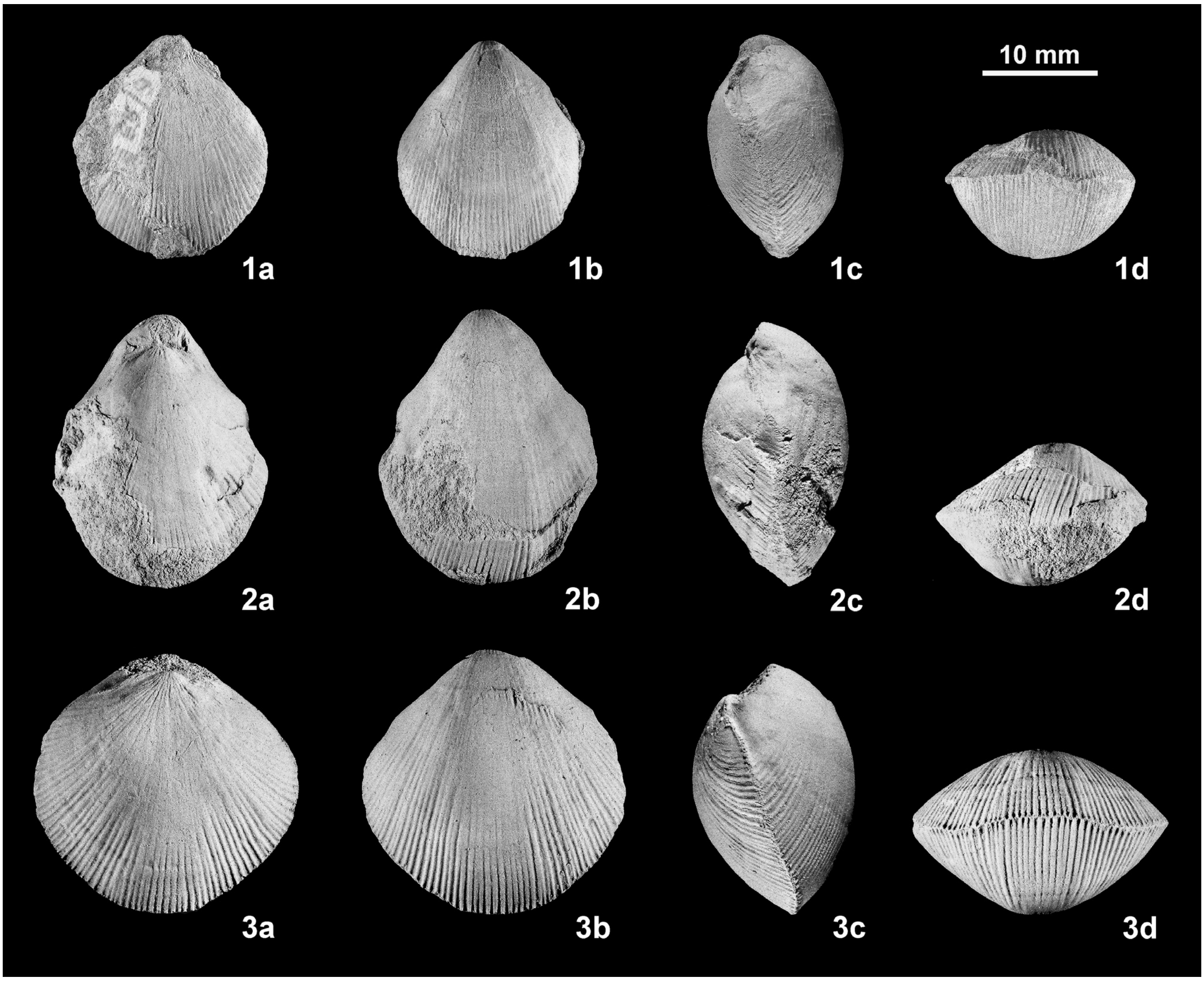

Fig. 3. "*Terebratula*" sp. (gen et sp. nov.), Lowermost Campanian, Guča, western Serbia. **1** – RGF VR 65/9; **2** – RGF VR 65/4; **3** – RGF VR 65/1. The letters imply the view: **a**, dorsal; **b**, ventral; **c**, lateral; **d**, anterior.

third, maximum thickness at midvalve. The lateral commissure straight. Beak massive, suberect to nearly straight with sharp and short beak ridges. Squama and glotta developed. The apical angle ranges between 72° and 96°. Foramen rounded, circular, relatively large, hypothyrid to submesothyrid, slightly labiate. The interarea small, concave. Each valve is ornamented with 24 to 36 simple ribs, which anteriorly become stronger and sharper.

Referring to the external features, such as asymmetric shell, the species is very similar to *Cyclothyris difformis* (VALENCIENNES *in* LAMARCK) and *C. contorta* (D'ORBIGNY) known from the Cenomanian of Europe, with which it was very often confused. *C. globata* differs from both latter species in having fewer costae, a more triangular outline, smaller foramen and a permanently asymmetric shell ("obligate asymmetry"), whereas *C. difformis* and *C. contorta* can develop both asymmetric and symmetric shells ("facultative asymmetry" *sensu* FÜRSICH & PALMER, 1984). (See RADULOVIĆ & MOTCHUROVA-DEKOVA 2002.)

The species frequently occurs in the Coniacian–Lower Campanian of the Pyrenees (MUÑOZ 1985, 1994), the Campanian of southwestern France (ARNAUD 1877; FAGE 1934; GASPARD 1983a, 1983b, 1991; GASPARD & ODIN 2001), the Late Campanian of Slovenia (PLENIČAR 1960), the Santonian of Croatia (PEJOVIĆ & RADOIČIĆ 1987), the Campanian of Serbia (RADULOVIĆ & MOTCHUROVA-DEKOVA 2002), the Latermost Santonian of Bulgaria (CANKOV 1930; TZANKOV 1947; ZACHARIEVA-KOVAČEVA 1947; JULKIČEV 1989; MOTCHUROVA-DEKOVA 1992a, 1992b, 1994, 1995, 1996b; RADULOVIĆ & MOTCHUROVA-DEKOVA 2002) and the Coniacian–Santonian of the southern Caucasus (ALIEV & TITOVA 1988).

***"Terebratula"* sp. (gen. et sp. nov.)** (Figs. 3.1–3) – Medium-size shell (L_{min} 19.5 mm; L_{max}, 26.7 mm), outline, independent of the size, can vary from ovally elongated to nearly circular. The valves are moderately and nearly equally biconvex or slightly dorsibiconvex. Maximum width at about mid-length; maximum thickness in the posterior third. The anterior commissure rectimarginate, in one large specimen slightly and widely uniplicate; the lateral commissure slightly curved towards the dorsal valve. Beak suberect to erect, with mesothyrid foramen. Under beak, very short and thickened ridges developed. Beak ridges rounded, poorly developed. The surface is covered by fine radiating capillae, increasing in number both by bifurcation and intercalation (about 2–3 capillae per mm near the anterior margin).

Remarks. Specimens of supposedly the same species from Romania and Bulgaria (northern margin of Tethys) were confused with *Terebratulina striata* (WAHLENBERG, 1821), known from the Late Maastrichtian of Sweden (Epicontinental Sea). A preliminary research of the internal morphology of this new form by V. RADULOVIĆ and N. MOTCHUROVA-DEKOVA on Bulgarian specimens reveals a terebratuloid loop. This feature clearly distinguishes this taxon from *T. striata* that has a ring-like loop; this feature places them in two different families. The capillate ornamentation of the shell of the new form makes it similar to *Capillithyris capillata* (D'ARCHIAC 1847), known from the Albian and Cenomanian of western Europe (Belgium, England, Poland and the Ukraine). However, the Serbian terebratuloid differs in having straight capillae (in *C. capillata* the capillae are waving and intersected by concentric growth lines. Internally, it is distinguished from the latter in having much reduced hinge plates.

This new capillate terebratuloid brachiopod will be officially described elsewhere by a different coauthorship board. Its preliminary description is proposed here with the kind permission of the colleagues N. MOTCHUROVA-DEKOVA and E. SIMON.

The species is known from the Santonian-Campanian of Romania (southern Dobrudja, Remus Opreanu; NEAGU & BĂRBULESCU 1979; BĂRBULESCU *et al.* 1979; BĂRBULESCU & NEAGU, 1988), the Latemost Santonian of northeastern Bulgaria (CANKOV 1930, ZACHARIEVA-KOVAČEVA 1947; JOLKIČEV 1989; MOTCHUROVA-DEKOVA 1996a), the Campanian and Maastrichtian of the Crimea and the Caucasus (ASTAF'EVA 1959).

Discussion

Hemicylammina chalmasi, a large agglutinated foraminifer, is known from the Coniacian–Late Santonian of the Spanish Pyrenees (CORNELLA 1977; CAUS *et al.* 1981), from the Late Turonian or Early Campanian of the Northern Calcareous Alps (SCHLAGINTWEIT & WAGREICH 2004) and from the Campanian of the Vardar Zone in Serbia. The Campanian age of *Hemicyclammina chalmas*i is based on planktonic foraminifera in the limestone with planktonic and benthic foraminifera (POLAVDER 2003). The abundance of *Hemicyclammina chalmasi* in bed VR101 is the acme of this species or, more probably the paracme, because extreme scarcity of specimens in the limestone with brachiopods (VR102) can be interpreted as their last occurrence. Other benthic foraminifera in bed VR102 have a larger stratigraphic distribution – the Coniacian to the Campanian.

Prevailing planktonic foraminifera in sample VR102 are two keeled species distributed in both the *asymetrica* and *elevata* zones, some of them earlier, in the *concavata* Zone. Species of the genus *Dicarinella* were not found in the five thin sections, whereas, in the overlying hemipelagic-pelagic silty limestone, *Dicarinella asymetrica* and *Marginotruncana coronata* were present in the sample VR103. Both species totally disappeared in the Lowermost/Lower Campanian (PREMOLI-SILVA & VERGA 2004, p.45). This leads to the conclusion that the layer containing brachiopods was the basal bed of the Campanian that marked the Santonian/Campanian boundary.

A few benthic macroforaminiferal specimens of *Navarella joaquini* were found in the samples VR103 and 104. This species is described by CIRY & RAT (1951) from the Maastrichtian of the Spanish Pyrenees, then cited also from the Maastrichtian of the Suisse Alps, from Scaglia rossa of the Veronese in Italy, in the Pyrenees and France (SAMPÒ 1972). In the Western Aquitaine, the species was found in the Campanian (RIBIS 1965 *fide* SAMPÒ 1972). The hemipelagic limestone of the sample VR104, beside *Navarella*, bears another macroforaminifer *Tekkeina anatoliensis* FARINACCI & YENIAY, a species described from the Santonian of Susus Dag in the Western Pontides, Turkey. The Santonian age was confirmed by the planktonic foraminiferal association with *Dicarinella concavata* (BROTZEN). In the type locality, the species ends at an unconformable boundary (a gap between the Santonian and Late Campanian), and is absent in the Upper Campanian (FARINACCI & YENAIY 1994).

Takkeina anatoliensis was known only from the Campanian in the Mur exposure near Novi Pazar, the Vardar Zone; the Campanian age is confirmed by planktonic foraminifera and nanofossils (POLAVDER 2003). A *Tekkeina anatoliensis* from the hemipelagic Campanian limestones of the Dol Formation on the Brač island, Adriatic Carbonate Platform, was illustrated as "large coarsely agglutinate foraminifer, similar (or akin) to *Navarella joaquini*" (GUŠIĆ & JELASKA 1990, pl. 11, fig. 2).

It follows from the above that *Tekkeina anatoliensis* is distributed in Santonian and Lower Campanian hemipelagic–pelagic deposits.

Conclusions

The researched stratigraphic sequences of Dupljaj Potok, based on micropaleontological contains, is dated as Latest Santonian and Early Campanian. The bed with brachiopods marks the boundary between the Santonian and the Campanian and is included in the basal Campanian.

Cyclothyris? *globata* is a species of large geographical distribution, known from the Northern and Southern Tethyan margins and the Central Tethys. The species occurs in the stratigraphic interval from Coniacian to Campanian. In western Serbia, it is found at Guča (Bjelica Belt, the Vardar Zone) in association with the capillate *"Terebratula"* sp. (gen. et sp. nov.). The association is also known from the uppermost Santonian of northeastern Bulgaria (Shumen Formation).

According to the obtained data, a part of the Bjelica Cretaceous Belt, during the Latest Santonian and Early Campanian, evolved gradually from a shallow marine environment weakly influenced by open sea (few planktonic foraminifera in *Hemicyclammina chalmasi* carbonate sandstone) to hemipelagic with mixed benthic and planktonic foraminifers and brachiopods into true hemipelagic calcisphere-globotruncanid deposits on a lower ramp-transition to shallow basinal environment. Information on the development of facies (ĆIRIĆ 1958; BRKOVIĆ *et al.* 1978) indicates subsidence of the Cretaceous Dragačevo Unit in the Bjelica Belt, which continued to the Maastrichtian or even into the Danian.

Acknowledgments

NICOLAOS CARRAS (IGME, Athens) and an anonymous reviewer are thanked for their constructive and very helpful comments on the earlier version of the manuscript. NENAD MALEŠEVIĆ (University of Belgrade) helped with computer processing part of the figures. The research was supported by the Ministry of Science and Technological Development of the Republic of Serbia, Project No. 146023 (grants to VR, DR and BR).

References

ALIEV O.V. & TITOVA M.V. 1988. Brachiopoda. Upper Cretaceous. *In* ALI-ZADE, Ak.A. et al. (eds.), *Cretaceous fauna of Azerbaidzhan*, 213–240. Elm, Baku (in Russian).

D'ARCHIAC, A. 1847. Rapport sur les fossiles du Tourtia. *Mémoires de la Societé géologique de France*, 2 (2): 291–351.

ARNAUD, M.H. 1877. Mémoire sur le terrain Crétacé du Sud–Ouest de la France. *Mémoires de la Société géologique de France* (*duexième série*), 10, 2 (4): 1–110.

ASTAF'EVA, K.A. 1959. Brahiopody. *In*: Moskvina M.M. (ed.), *Atlas verhnomelovj fauny severnogo Kavkaza i Kryma*, 221–236. Gostoptehizdat, Moskva.

BĂRBULESCU, A., NEAGU, T., PICEREA, I. & CIUPU, F. 1979. Contributions ă l'étude des brachiopodes Crétacés de la Dobrogea meridionale. *Revue Roumaine de Géologie, Géophysique et Géographie*, *Géologie*, 23 (2): 197–208.

BĂRBULESCU, A. & NEAGU, T. 1988. Brachiopodes Crétacés de la Dobrogea du sud. 4. Nouvelles contributions ă l'étude des Terebratulida Neocrétacés. *Analele Universitații Bucuresti*, *Geologie*, 37: 41–55.

BRKOVIĆ, T., MALEŠEVIĆ, M., UROŠEVIĆ, M., TRIFUNOVIĆ, S., RADOVANOVIĆ, Z., PAVLOVIĆ, Z. & RAKIĆ, M. 1978. *Explanatory booklet for sheet Čačak, Basic Geological Map 1:100 000,* Federeal Geological Survey, 64 pp., Belgrade (in Serbian, English and Russian summary).

CANKOV, V. 1930. Géologie du plateau de Shumen et ses environs immédiates. *Spisanie na Blgarsko Geologičesko Družestvo*, 2 (1): 1–74 (In Bulgarian, French summary).

CAUS, E., CORNELLA, A., GALLEMI, J., GILLI, E., MARTINEZ, R. & PONS, J.M. 1981. Field guide: Excursions to Campanian- Maastrichtian of South Central Pyrenees (WGCM – 3rd Working Session in Tremp). *Universitad Autónoma de Barcelona*, *Publicaciones de Geología*, 13: 1–70.

CIRY, P. & RAT, P. 1951. Un foraminifère nouveau du Crétacé supérieur de la Navarre Espagnole. *Bulletin Scientifique de Bourgogne*, 13 (for 1950–1951): 75–86.

CORNELLA, A. 1977. Foraminiferos Bentonicos del Santoniense del BCO. De la Front de la Plata. Mntsec de Rubies 8 Prov. De Lerida). *Universitad Autónoma de Barcelona*, *Publicaciones de Geología*, 8: 1–45.

ĆIRIĆ, B. 1958. Geologie des Gebietes fon Dragačevo (Westserbien). *Glasnik Prirodnjačkog muzeja, Serija A*, 9: 5–159 (In Serbian, Germany summary).

ĆIRIĆ, B. 1996. *Geology of Serbia*. 273 pp. Geokarta, Belgrade (in Serbian, English summary).

D'ARCHIAC, A. 1847. Rapport sur les fossiles du Tourtia. *Mémoires de la Societé géologique de France*, 2 (2): 291-351.

DIMITRIJEVIĆ, M.N. & DIMITRIJEVIĆ, M. D. 1973. Olistrostrome mélange in the Yugoslavian Dinarides and Late Mesozoic tectonics. *Journal of Geology*, 81: 328–340.

FAGE, G. 1934. Les Rhynchonelles du Crétacé supérieur des Charentes. *Bulletin de la Société Géologique de France*, 5 (4): 433–441.

FARINACCI, A. & YENIAY, G. 1994. *Tekkeina anatoliensis* n. gen., n. sp., a new foraminifer from Susuz Dað, Western Taurus, Turkey. *Paleopelagos*, 4 (4): 47–59.

FÜRSICH, F.T. & PALMER, T. 1984. Commissural asymmetry in Brachiopods. *Lathaia*, 17: 251–265.

GASPARD, D. 1983a. Brachiopodes. In Groupe A10: Le Sénonien Charentais du chantier de l'autoroute "L'Aquitaine". Apports biostratigraphiques. *Géologie Méditerranéenne*, 10 (3–4): 31–39.

GASPARD, D. 1983b. Distribution des Brachiopodes du Coniacien au Maastrichtien en France et pays limitrophes. *Géologie Méditerranéenne*, 10 (3–4): 229–238.

GASPARD, D. 1991. Les cas de non-symétrie chez les Rhynchonelles. Quelle(s) signification(s)? *Geobios, M.S*, 13: 33–44.

GASPARD, D. & ODIN, G.S. 2001. Brachiopodes du Campanien–Maastrichtien à Tercis les Bains (Landes, France). *In*: ODIN, G.S. (ed.), *The Campanian–Maastrichtian Stage Boundary, Characterisation at Tercis les Bains (France) and Correlation with Europe and other Continents*, 213-436. Developments in Palaeontology and stratigraphy, 19, Elsevier, Amsterdam–London––New York–Oxford–Paris–Shannon–Tokyo.

GUŠIĆ, I. & JELASKA, V. 1990. *Upper Cretaceous tratigraphy of the Island of Brač within the geodynamic evolution of the Adriatic Carbonate Platform*. Djela Jugoslavenske akademije znanosti i umjetnosti, Razred za prirodne znanosti, 69: 1–160 (in Crotian, English summary).

JOLKIČEV, N. 1989. *Stratigraphy of the epicontinental type Upper Cretaceous*. 184 pp. Kliment Ohridski University Press, Sofia.

MOTCHUROVA-DEKOVA N. 1992a. Peculiarities of the Shell Microstructure of Late Cretaceous Rhynchonellids (Brachiopoda) and their Early Diagenetic Alterations. *Godišnik na Minno-geoložkiâ universitet*, 38 (1), 19–33 (in Bulgarian, English abstract).

MOTCHUROVA-DEKOVA N. 1992b. Shell microstructure of *Cyclothyris globata* (ARNAUD), (Brachiopoda) from the Upper Santonian of Shumen region. *Spisanie na B"lgarskoto geologičesko družestvo*, 53 (3): 93–98.

MOTCHUROVA-DEKOVA N. 1994. New data about the evolution and phylogenetic relations of brachiopod families Basiliolidae and Cyclothyrididae on the basis of Late Cretaceous rhynchonellids from Bulgaria. *Geologica Balcanica*, 24 (4), 21–29.

MOTCHUROVA-DEKOVA N. 1995. Late Cretaceous Rhynchonellida (Brachiopoda) from Bulgaria. I. Genus *Cyclothyris* M'Coy. *Geologica Balcanica*, 25 (3–4): 35–74.

MOTCHUROVA-DEKOVA, N. 1996a. Late Cretaceous craniids (Brachiopoda) from Northeast Bulgaria. *Neues Jahrbuch für Paleontologie und Geologie, Abhandlugen*, 200 (3): 285–308.

MOTCHUROVA-DEKOVA, N. 1996b. Late Cretaceous Rhynchonellid assemblages of North Bulgaria. *In*: COPPER P. & JIN J. (eds.), *Brachiopods*, Proceedings of the Third International Brachiopod Congress, Sept. 1995, Sudbury, Canada, 185–189, Balkema, Rotterdam.

MUÑOZ J. 1985. Braquiopodos del Cretacico Superior de los Alrededores de St. Corneli (prov. Lleida). *Universitad Autónoma de Barcelona*, *Publicaciones de Geología*, 21: 1–124.

MUÑOZ J., 1994: *Estudio paleontológico y bioestratigráfico de los braquiópodos del Cretácico superior del Pirineo catalán*. Unpublished doctoral thesis, 413 pp., Universitad Autónoma de Barcelona.

NEAGU, T. & BĂRBULESCU, A. 1979. The paleoecologic and paleobiogeographic values of the Cretaceous Brachiopoda from Dobrudja. *Revue Roumaine de Géologie, Géophysique et Géographie*, *Géologie*, 23 (1): 69–75.

PEJOVIĆ, D. & RADOIČIĆ, R. 1987. Contribution to the study of Upper Cretaceous stratigraphy of Brač. *Geologija* 28/29: 121–150 (in Serbian, English summary).

PLENIČAR, M. 1960. The stratigraphic development of Cretaceous beds in Southern Primorska (Slovene Littoral) and Notranjska (Inner Carniola). *Geologija*, 6: 22–145 (in Slovenian, English summary).

POLAVDER, S. 2003. Upper Cretaceous integrated biostratigraphy in the western belt of the Vardar Zone. *Geologica Carpathica*, 54 (2): 81–92.

PREMOLI-SILVA, I. & VERGA, D. 2004. Practical manuel of Cretaceous Planktonic Foraminifera. *International school on Planktonic Foraminifera*, *3th Course*, 283 pp.

RADOIČIĆ. R. 1997. On the Rujevac–Veliki Majdan chaotic formation (Western Serbia). *Vesnik*, *Serija A*, *B*, 47: 53–61.

RADULOVIĆ, V. & MOTCHUROVA-DEKOVA, N. 2002. The rhynchonellide brachiopod *Cyclothyris*? *globata* (ARNAUD, 1877) from the Santonian–Campanian of Pannonides, Carpatho-Balkanides and Dinarides (southeastern Europe). *Geološki anali Balkanskoga poluostrva*, 64 (for 2001): 107–135.

SAMPÒ, M. 1972. Macroforaminiferi *Navarella joaquini* CIRY & RAT and *Lituonella grandis* (REUSS) nella Scaglia rossa (Maastrichtiano) del Veronese. *Bollettino della Società Paleontologica Italiana*, 2 (1): 100–117.

SCHLAGINTWEIT, F. & WAGREICH, M. 2004. *Hemicyclammina chalmasi* (SCHLUMBERGER, 1899) – Larger Benthic Foraminifera from the Upper Cretaceous Gosau Group of the Northern Calcareous Alps (Gossau, Austria). *Jahrbuch der Geologischen Bundesanstalt, B.–A.*, 144 (3–4): 367–372.

TZANKOV, V. 1947. Biostratigraphic and paleoecologic investigation of the geologic formations in Bulgaria. *In*: Osnovi na geologiata na Bulgaria. *Godishnik na direkciata za geolozhki i minni prouchvania, Otdel A*, 4 (for 1946): 239–334 (In Bulgarian).

WAHLENBERG, G. 1821. Petrificata telluris suecanae examinata. *Nova Acta Regiae Societatis Scientiarum Upsaliensis*, 8: 1–116.

ZACHARIEVA-KOVAČEVA, K. 1947. Les brachiopodes supracrétaciques da la Bulgarie. *Spisanie na Blgarsko Geologičesko Družestvo*, 15–19: 247–274 (In Bulgarian, French summary).

Резиме

Старост брахиоподских кречњака Гуче, западна Србија

Кредни седименти појаса Бјелице (Драгачево) у локалитету Дупљај поток код Гуче, познати су по наласку брахиопода (ĆIRIĆ 1958; RADULOVIĆ& MOTCHUROVA-DEKOVA 2002). Базални теригени седименти овог појаса поступно прелазе у карбонате (пјешчари–карбонатни пјешчари–пјесковити кречњаци–силтозни кречњаци). У Дупљај потоку базални теригени седименти нијесу откривени. Také, најстарији дио карбонатне сукцесије Бјелице овдје није добро откривен, те стога стратификација није јасно видљива. У циљу прецизнијег датирања брахиоподске фауне узорковано је 10–12 m стратиграфког стуба за микропалеотолошке анализе са 6 узорака (VR101–VR106).

Најстарији откивени слој је карбонатни пјешчар (око 2 m, VR101) са аглутинентним фораминифером *Hemicyclammina chalmasi*, понеким другим бентоским и веома ријетким планктонским микрофосилима.

Слиједећи, пјесковити кречњак са брахиоподима (око 1.5 m, VR102) у којем се запажају фрагменти корала, калциспонгија и мекушаца, садржи бројне бентоске, претежно роталиформне фораминифере, али такође и планктонске микрофосиле: *Hemicyclammina chalmasi* (веома ријетка), *Pararotalia minimalis*, *Goupillaudina* sp., *Sulcopeculina* sp., *Nummofalotia cretacea*, *Globotruncana lapparenti*, *Globotruncana hilli*, *Globotruncanita* cf. *Gl. elevata*, и др. Брахиоподску заједницу из пјесковитог кречњака (узорак VR 102) чине двије врсте: ринхонелид *Cyclothyris*? *globata* и капилатни теребратулид *“Terebratula”* sp. (gen. et sp. nov.).

Навише слиједе хемипелашки кречњаци (2–2.5 m, VR103, VR104; 5–6 m, VR105, VR106):

– са ситним роталиформним облицима, калцисферама и глоботрунканидама: *Dicarinella asymetrica*, *Marginotruncana coronate*, *Globotruncana marie, Globotruncana linneiana*, *Globotruncana lapparent,* и др.

– са калцисферама и глоботрунканидама – *Globotruncanita stuartiformis*, *Globotruncana linneiana*, *Globotruncana lapparenti* и крупним аглутинентним фораминиферима који су познати из хемипелашких седимената: *Navarella joaquini* Ciry & Rat и *Tekkeina anatoliensis* Farinacci & Yeniay.

– са калцисферама и ријетким глоботрунканидама *Globotruncana elevata*, прелазна форма *Globotruncana arca–Contusotruncana patelliformis* и др.

На основу микропалеонтолошких података, кредни седименати Дупљај потока су сантон–кампанске старости. Полазећи од податка да глоботрунканска врста *Dicarinella asymetrica* (нађена изнад слоја са брахиоподима) ишчезава у најнижем кампану, слој са брахиоподима приписан је најнижем кампану. Он овдје обиљежава границу између сантона и кампана, док се карбонатни пјешчар са *Hemicyclammina chalmasi* сматра горњосантонским (акма или параакма врсте, док је њено посљедње појављивање у раном кампану, у слоју са брахиоподима).

Према добијеним подацима седименти овог дијела кредног појаса Бјелице, током касног сантона и раног кампана поступно су еволуирали од плитководне маринске средине са јаким теригеним приносом и веома слабим утицајем отвореног мора, преко хемипелашких кречњака са мјешовитом бентоском и планктонском фауном, до чисто хемипелашких-пелашких седимената депонованих у предјелу доња рампа – прелаз у домен релативно плитководне басенске средине. На основу фацијалних карактеристика млађих седимената (Ćirić 1958; Brković *et al*. 1978) закључује се да је тоњење у дијелу кредне јединице Драгачева настављено у току мастрихта, са претпоставком до у данијен.

Plate 1

Figs. 1–5. *Hemicyclammina chalmasi* (SCHLUMBERGER), sample VR101, thin sections VR101a and 101b.

Scale bar = 0.5 mm for all figures.

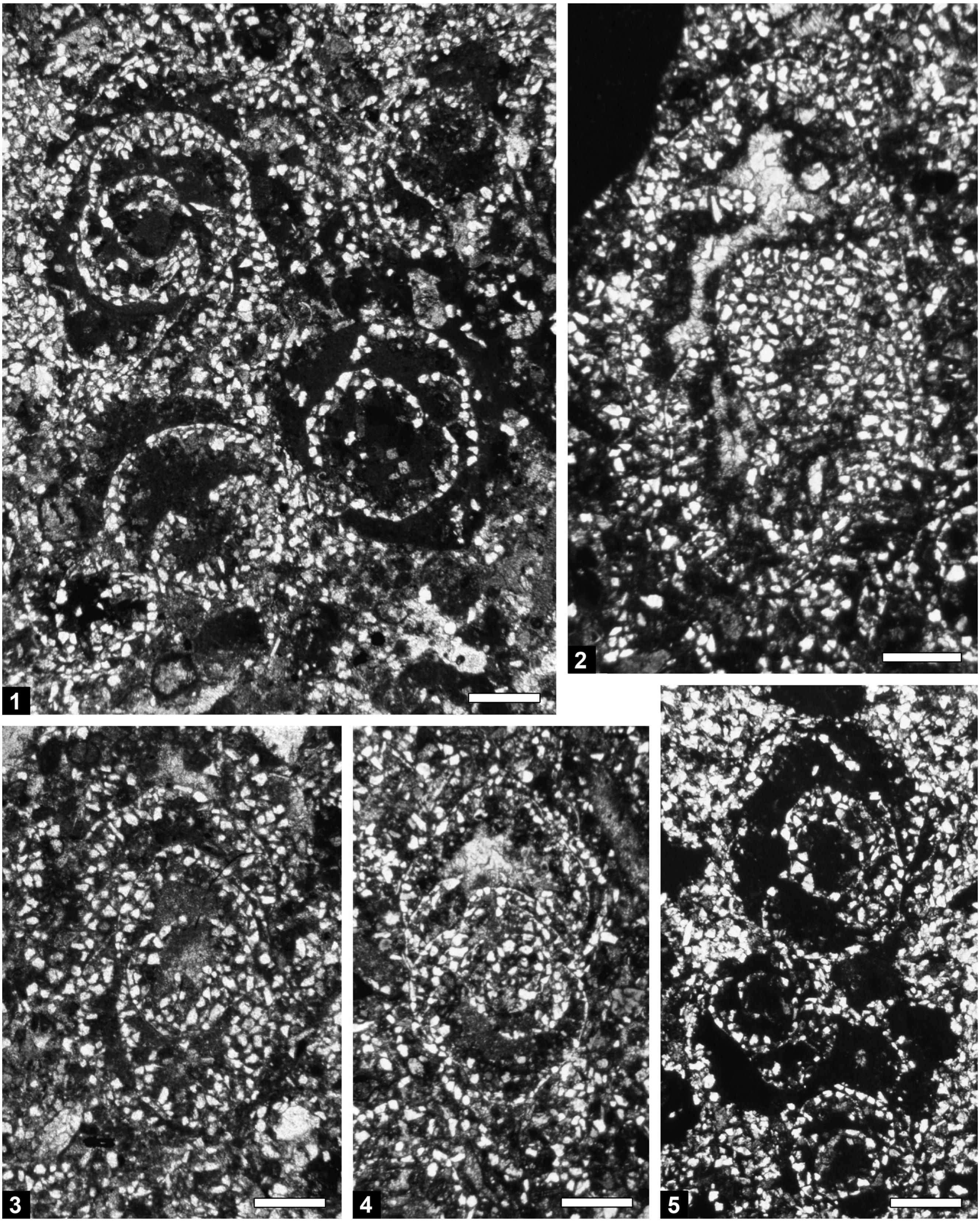
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Plate 2

Figs. 1–7. Rotaliform foraminifera from a bed with brachiopods, sample VR102.
1, 2. Rotalid – species G1, thin section VR102e, 102c.
3–6. Rotalid – species G2, thin section VR102c, 102d, 102d, 102.
7. Rotalid – species aff. G2, thin section VR102b.

Scale bar = 0.25 mm. for all figures.

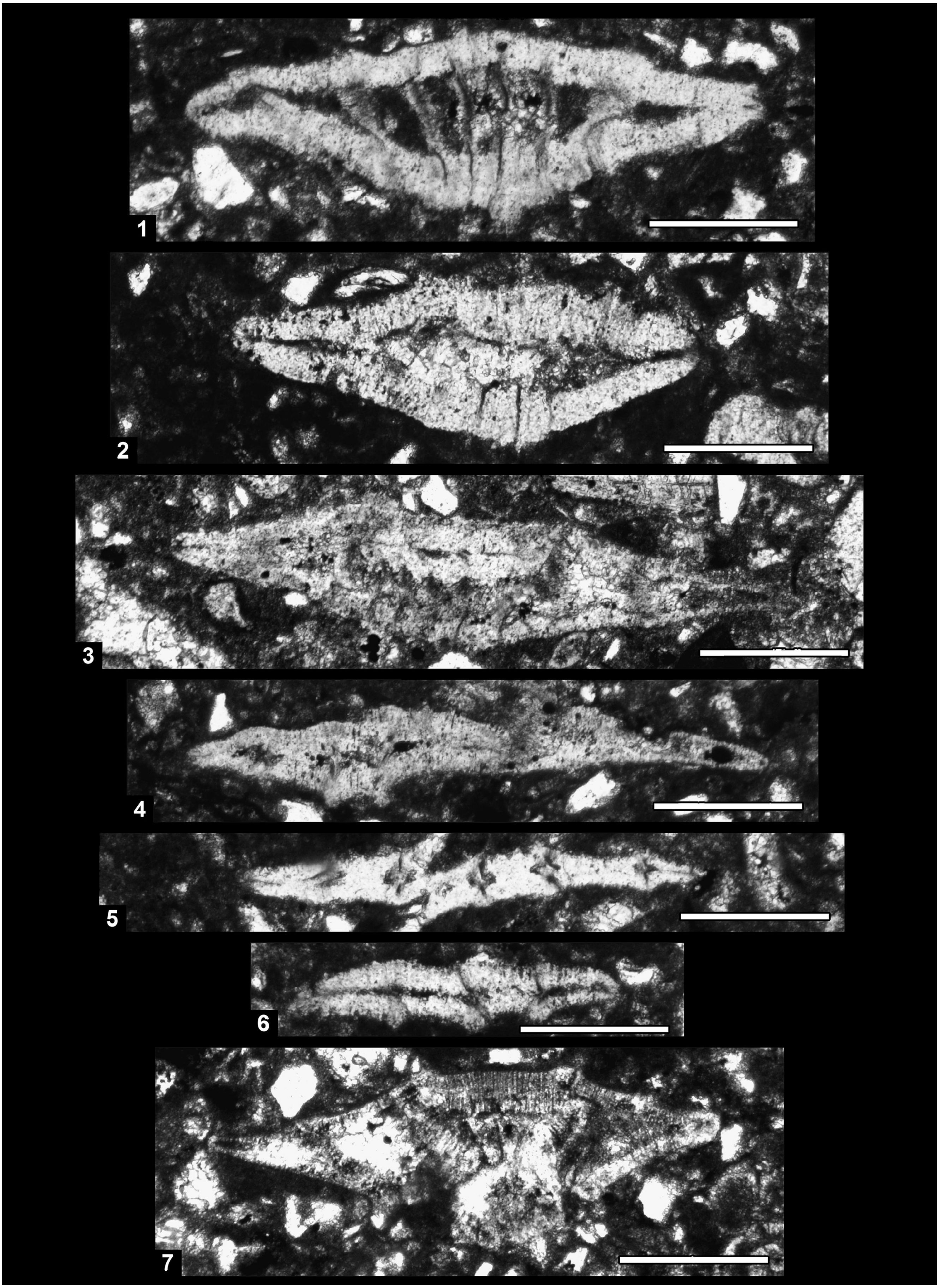
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Plate 3

Figs. 1–6, 11. Rotaliform foraminifera from a bed with brachiopods, sample VR102.
1–3. *Pararotalia* ? G3, thin sections VR102b, 102a, 102c.
4–6. *Sulcoperculina* sp., thin sections VR102, 102a, 102a, 102c.
11. *Rotalia* aff. *R. saxorum* D'ORBIGNY, thin section VR102e.

Figs. 7, 8. *Goupillaudina* sp., thin sections VR103a, 103b.

Fig. 9. *Goupillaudina* sp., thin section VR101a.

Fig. 10. Thin walled rotaliform foraminifera (aff. *Goupillaudina*), thin section VR103a

Scale bar = 0.2 mm for all figures.

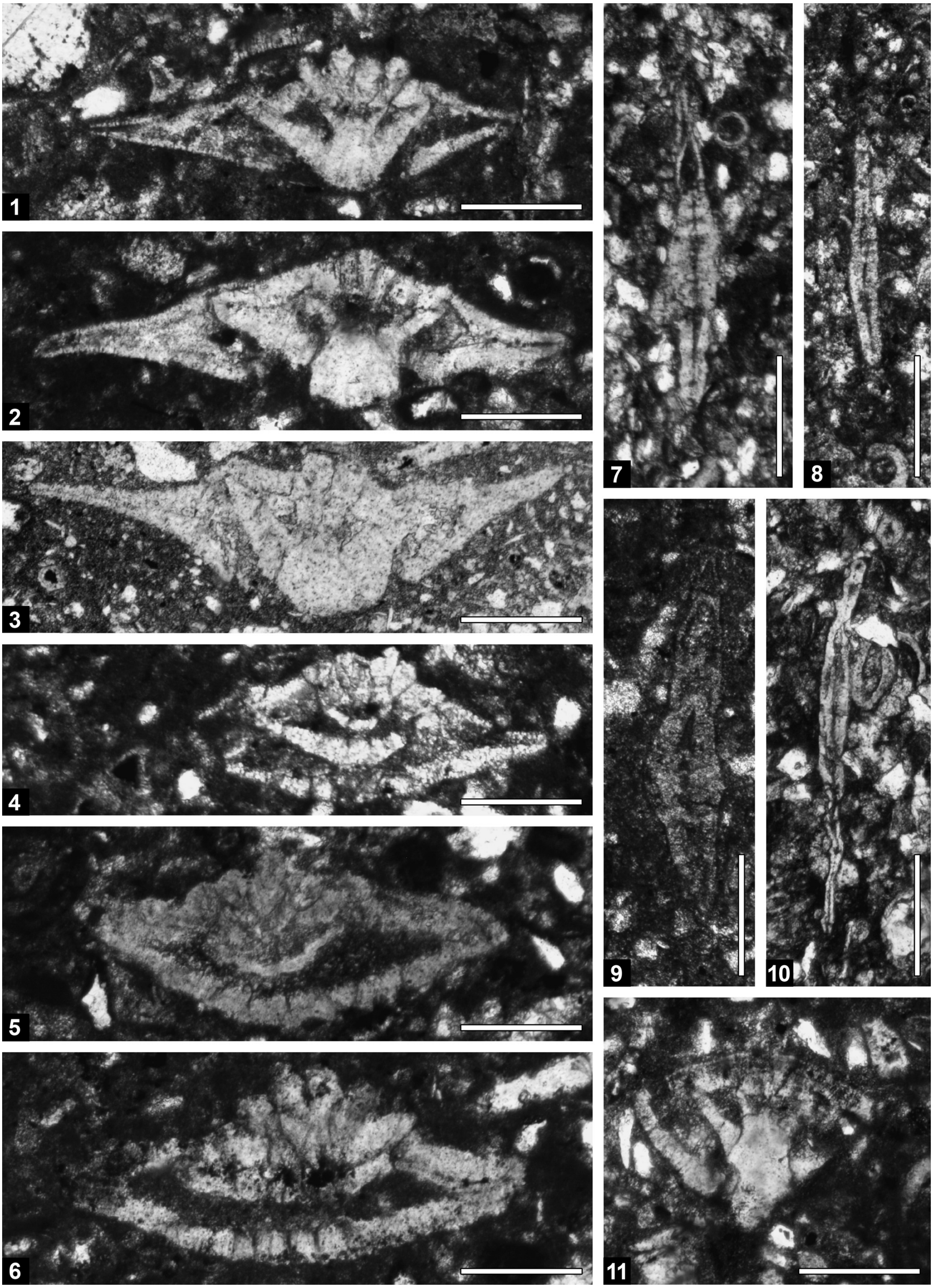
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Plate 4

Figs. 1–6. Benthic foraminifera from a bed with brachiopods, sample VR102.

1–4. *Nummofallotia creta*cea (SCHLUMBERGER), thin sections VR102c, 102c, 102b, 102b.

5. Lituolid, thin section VR102c

6. Rotaliform foraminifera and (upper) *Pithonella multicava* BORSA, thin section VR102c.

Scale bar = 0. 25 mm for all figures.

Figs. 7–11. Large *Lituolidae* from the hemipelagic limestone with planktonic microfossils, sample VR104.

7, 8. *Navarella joaquini* CIRY & RAT, thin section VR104a.

9–11. *Tekkeina anatoliensis* FARINACCI & YENIAY, thin section VR104b.

Scale bar = 0.5 mm for all figures.

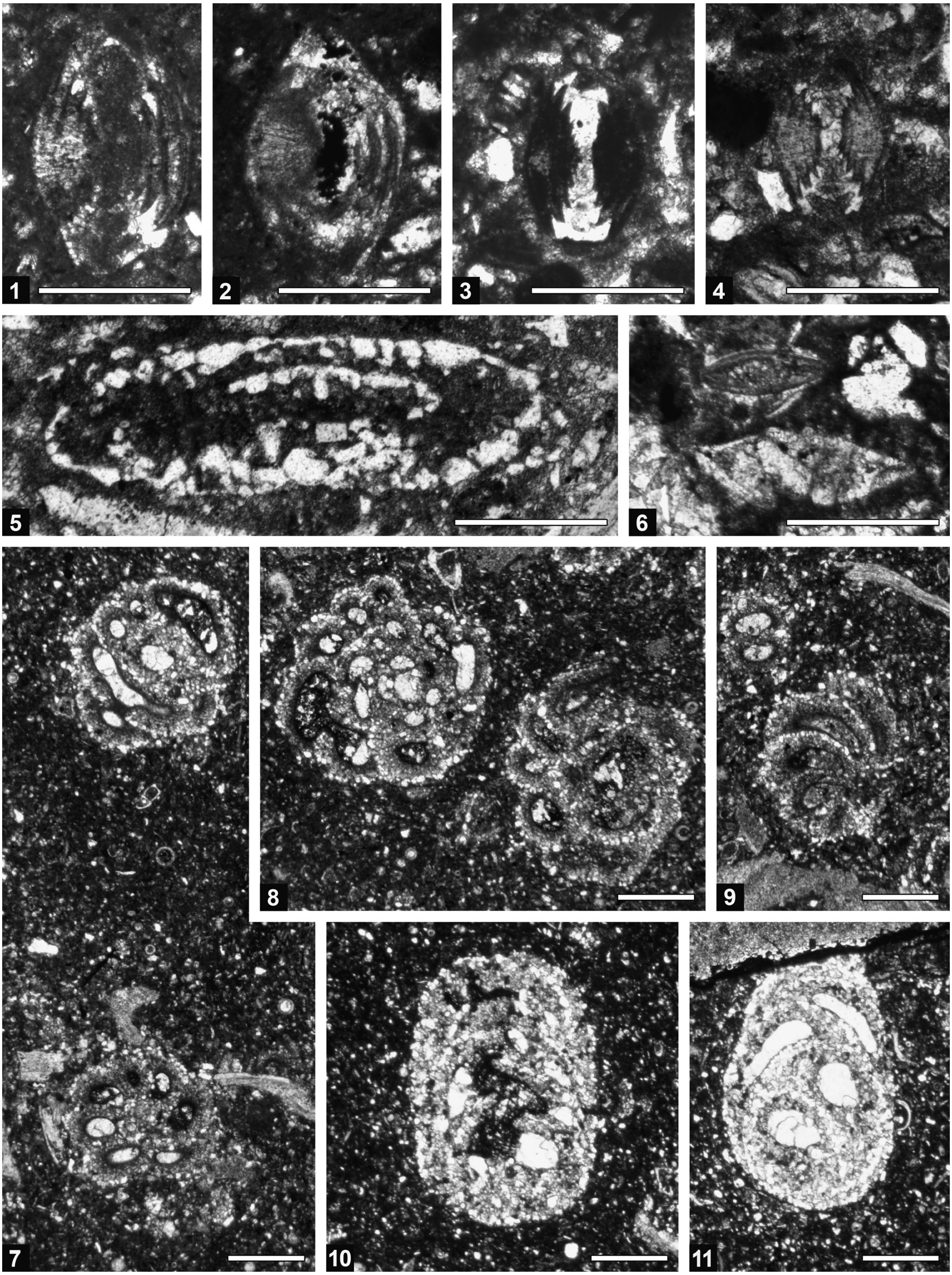
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Plate 5

Figs. 1–7. Planktonic foraminifera and *Pithonella* from a bed with brachiopods, sample VR102.
1–3. *Globotruncana linneiana*(D'ORBIGNY), thin section VR102a, D740 (= VR102), 102d
4. *Globotruncaanita* cf. *G. elevata* (BROTZEN), thin section D740.
5. ?*Muricohedbergella* sp., thin section VR102b.
6. *Globotrtuncana hilli* PESSAGNO, thin section VR102b.
7. *Pithonella multic*ava BORSA, thin section VR102b.

Figs. 8, 9. *Marginotruncana coronata* (BOLLI), thin section VR103b

Fig. 10. *Globotruncana lapparenti* BROTZEN, thin section, VR103a.

Fig. 11. *Dicarinella asymetrica* (SIGAL), thin section VR103b.

Fig. 12. *Globotruncana hilli* PESSAGNO, thin section VR103b.

Fig. 13. *Globotruncana linneana* (D'ORBIGNY), thin section VR104b.

Fig. 14. Genus? (the form aff. *Gublerina–Schackina*), thin section VR104a.

Fig. 15. The form between *Globotruncana arca* and *Contusotruncana patelliformis*, thin section VR106.

Fig. 16. *Globotruncanita stuartiformis* (DALBIEZ), thin section VR104b.

Fig. 17. *Globotruncanita elevata* (BROTZEN), thin section VR105.

Scale bar = 0.2 mm for all figures.

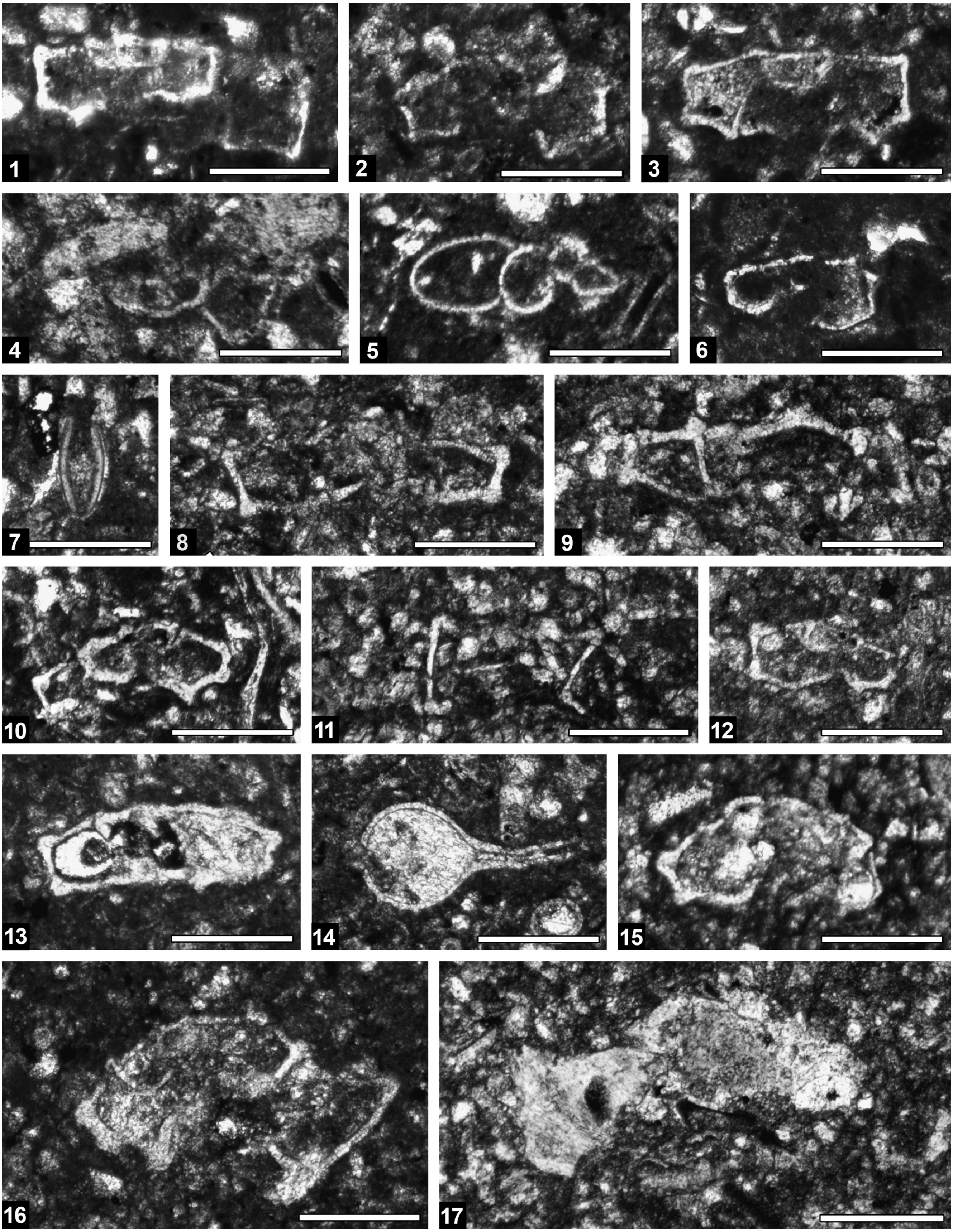
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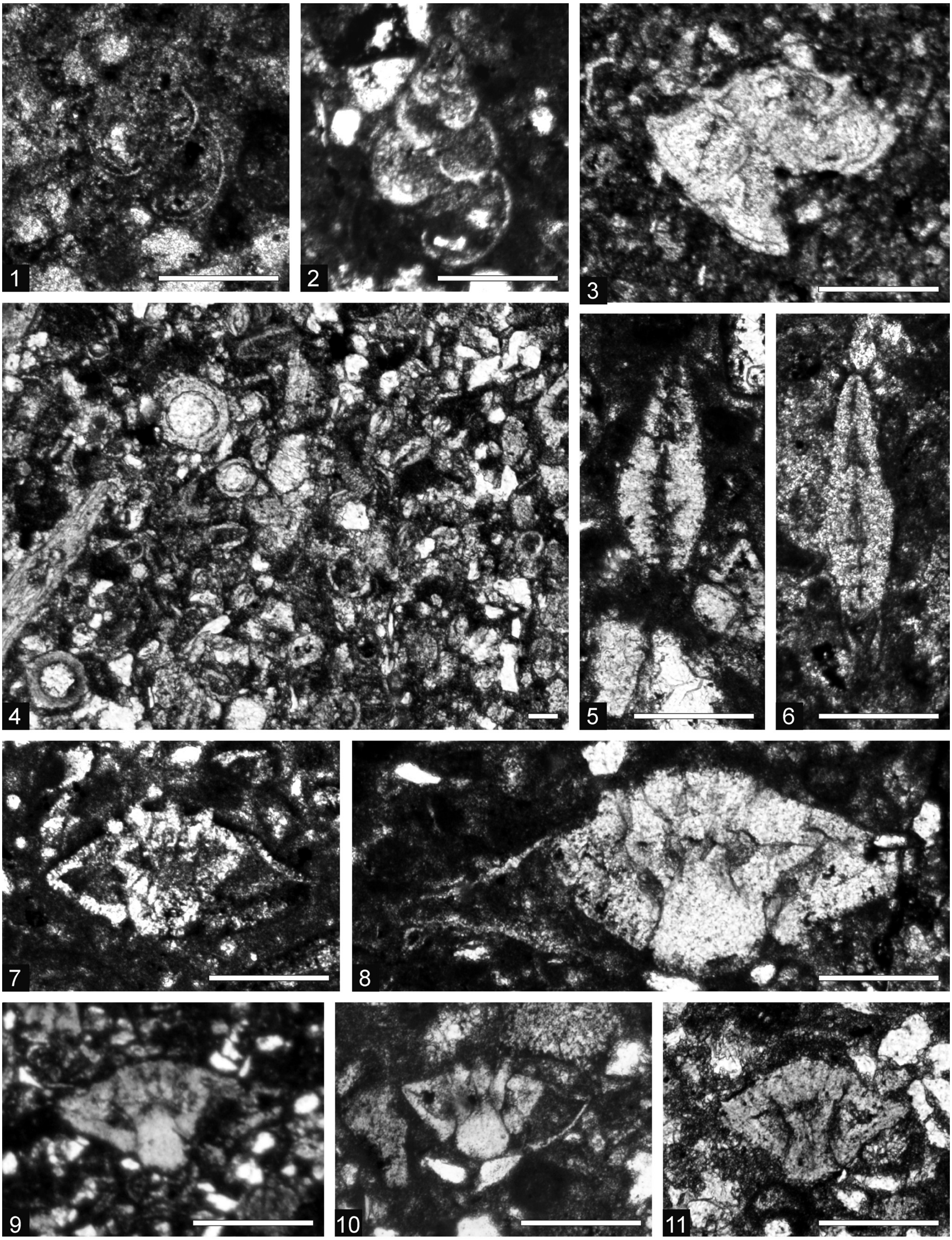
Plate 6

Fig. 1. *Heterohelix* sp., thin section VR101a.
Fig. 2. *Heterohelix* sp., thin section VR102a.
Fig. 3. *Globotruncanita stuartiformis* (DALBIEZ), thin section VR104c.
Fig. 4. *Pithonella ovalis* (KAUFMANN), *Stomiosphaera*, other calcispheres, thin section, VR103b.
Fig. 5. *Goupillaudina* sp. and *Pararotalia minimalis* HOFKER, thin section VR102a.
Fig. 6. *Goupillaudina* sp., thin section D740 (= VR102).
Figs. 7, 9, 10. *Pararotalia* cf. *P. minimalis* HOFKER, thin sections VR102c, 101a, 102e.
Fig. 8. *Pararotalia* sp. G4, thin section VR102c.
Fig. 11. *Pararotalia minimalis* HOFKER, thin sction VR102a.

Scale for = 0.2 mm for all figures.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Геолошки анали Балканскога полуострва Annales Géologiques de la Péninsule Balkanique	71	95–108	Београд, децембар 2010 Belgrade, December 2010

DOI: 10.2298/GABP1071095G

The Upper Miocene Lake Pannon marl from the Filijala Open Pit (Beočin, northern Serbia): new geological and paleomagnetic data

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Abstract: This work presents major lithological, structural, paleontological and paleomagnetic characteristics of the Upper Miocene Pannonian marl in the Filijala Open Pit of the La Farge Cement Plant near Beočin, northern Serbia. Pannonian marl lies between the underlying heterogeneous Sarmatian deposits and the overlying set of Pontian sand beds and Quaternary sediments. The open pit is located on the NE range of Fruška Gora, a horst structure with a core of Paleozoic, Mesozoic and Paleogene rocks in a complex structural pattern. Pannonian sediments, which are part of a younger structural stage, deposited on the horst limbs. The Pannonian marl strata dip at angles from 12° to 26° (to the NNW), forming a monocline. The strata deformations are a consequence of radial tectonics and are a potential source of landslides. The many mollusks (7 gastropod and 9 bivalve species) and ostracodes (27 species) and their biostratigraphical position indicate marl deposition throughout the Pannonian age. A paleomagnetic investigation established that the marl has inconsistent remanent magnetization (with bad statistical parameters), which originates from neoformed magnetite.

Key words: Upper Miocene, Lake Pannon, cement marls, lithology, stratigraphy, paleomagnetism, Beočin, Fruška Gora.

Апстракт: У раду су приказане главне литолошке, структурне, палеонтолошке и палеомагнетне карактеристике горњомиоценских, панонских лапораца са површинског копа Филијала у Беочину (северна Србија). У подини панонских лапораца су хетерогени сарматски седименти док им повлату чине понтски пескови и квартарне наслаге. Површински коп је лоциран на североисточним падинама Фрушке горе која представља једну хорст структуру изграђену од различитих палеозојских, мезозојских и палеогених творевина који се налазе у врло сложеним тектонским односима. Панонски седименти који представљају део млађе структурне етаже депоновани су по ободима хорста. Панонски лапорци граде једну моноклиналу у којој се падни угао креће од 12° до 26° (пад према С–СЗ). Такве деформације слојева су последица радијалне тектонике и често представљају извор потенцијалних клизишта на копу. Бројни мекушци (7 врста пужева и 9 врста шкољки) и 27 врста остракода као и њихов биостратиграфски положај, указују да се депозиција одиграла током целог панонског ката. Палеомагнетна истраживања су показала да лапорци имају неконзистентну реманентну магнетизацију која потиче од трансформације примарног магнетита у секундарни.

Кључне речи: горњи миоцен, језеро Панон, цементни лапорци, литологија, стратиграфија, палеомагнетизам, Беочин, Фрушка Гора.

Introduction

The area of the Fruška Gora Mountain represents an inselberg in the southern part of the Pannonian Basin, which extends between the Alps, Dinarides, and the Carpatho-Balkanides. The Pannonian Basin was formed as result of continental collision and subduction of the European Plate under the African Plate during the Late Early to Late Miocene (Fodor *et al.* 2005). Late Early Miocene subsidence and sedimentation was an effect of the syn-rift extension phase that resulted in the formation of various grabens filled by

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thin sin-rift marine and brackish deposits (HORVÁTH & ROYDEN 1981). The Pre-Pannonian (Late Miocene) unconformity is an effect of the first early post-rift phase of basin inversion that occurred during the Sarmatian (HORVÁTH & TARI 1999). Later, a quiet and slow thermal subsidence occurred combined with an uplift and erosion of the neighboring mountains (HORVÁTH & ROYDEN 1981; HORVÁTH *et al.* 2006; SCHMID *et al.* 2008). This post-rift sinking was compensated by intensive sedimentation in the caspibrackish Lake Pannon during the Late Miocene (FODOR *et al.* 2005; CLOETHING *et al.* 2006; HARZHAUSER & PILLER 2007). The tectonic events that formed the Pannonian Basin also affected the structure of the Neogene deposits on the northern range of Fruška Gora, which were deformed mainly by radial tectonics (MAROVIĆ *et al.* 2007). Still, deformations that are more complex have been noted in the Upper Miocene and Pliocene nearer to the Danube, in the influence zone of the regional fault that separated large blocks: the uplifted structures of the Fruška Gora horst from the southern Bačka depression (MAROVIĆ *et al.* 2007). Examples of strong deformations are located above the right bank of the Danube River and in the northern part of the Filijala Northern Field, which, at present, is the main worked deposit of the Beočin Cement Plant. This resource has been known since 1838 and worked from 1869. It is located on the northern Fruška Gora range near the piedmont, above the Danube. The marl deposit is worked in three fields unequal in size and degree of exhaustion: (1) the Northern Field, the largest, oldest and most exploited field, (2) the Middle Field or Interfield and (3) the Southern Field (Fig. 1).

The Fruška Gora Mountain was the focus of geological interest in the second half of the 19th century. Information on the initial geological prospecting of Fruška Gora was given by LENZ (1874), KOCH (1876, 1896 and 1902), who gave the first integral descrip-

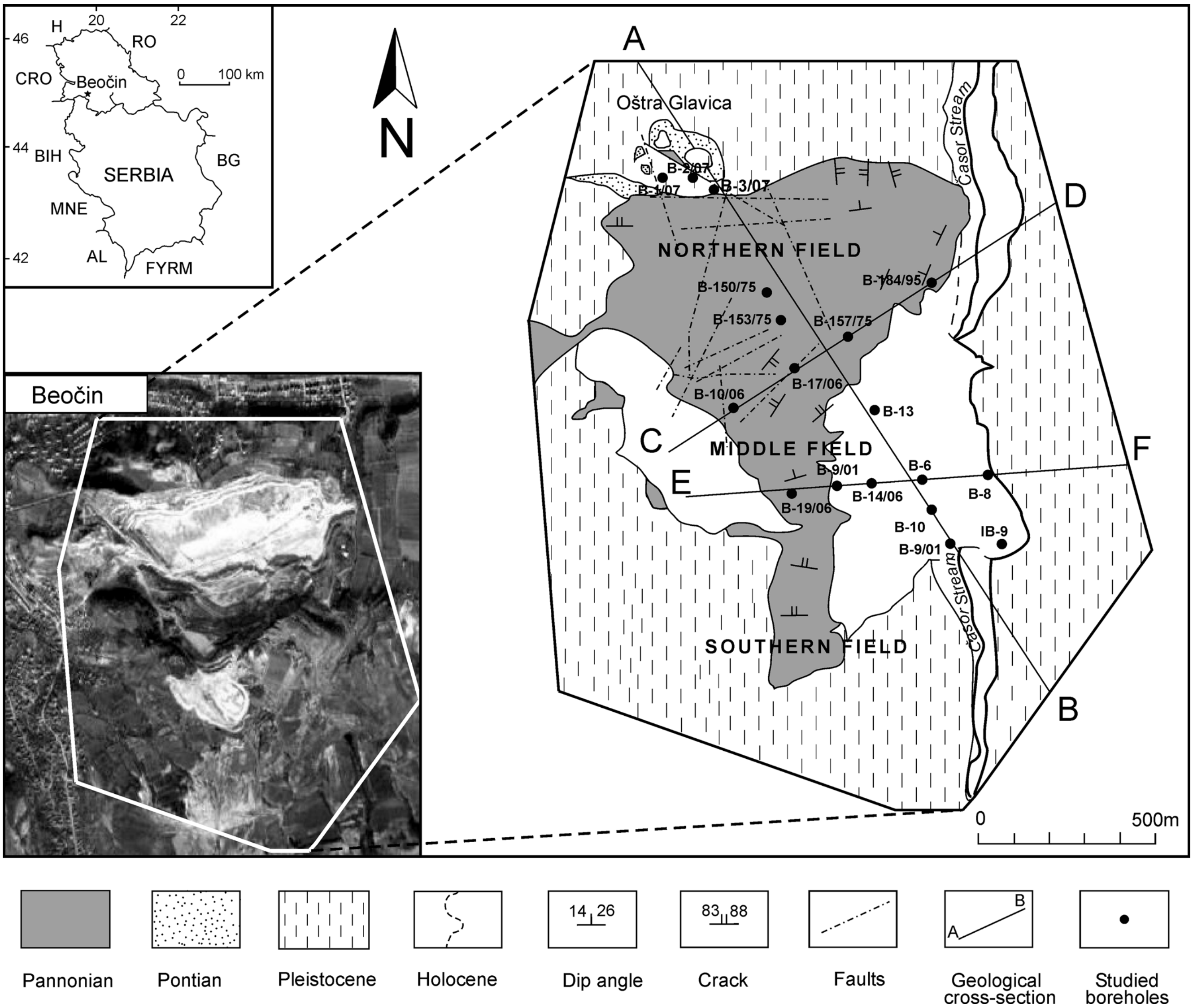

Fig. 1. The geological sketch map of the Beočin town area, with position of the geological cross-section and the studied boreholes.

tion of the geology of Fruška Gora and the first geological map on the scale 1:100000. R. Hörnes (1874) studied mollusks from cement marl near Beočin. Much later, Čičulić (1957, 1977), Čičulić-Trifunović & Rakić (1971), Petković *et al.* (1976), Stevanović & Papp (1985) wrote important contributions to the study of the stratigraphy of Fruška Gora. More recently, geology, stratigraphy, marl resource and quality of the Filijala property, and the chronostratigraphy of the Pannonian, were studied by Draško *et al.* (1998), Đurić (2005), Rundić *et al.* (2005), Simić (2005), Ganić *et al.* (2009) and Borgh *et al.* (2010).

This work presents new structural and stratigraphic–paleontological data for the Filijala property based on observations in the field and on drill-core analysis, as well as paleomagnetic measurements and interpretation.

Materials and methods

Data presented on the geological map and structural cross-sections were collected in all three fields of the Filijala Open Pit, where azimuths and dip angles, and fracture and fault positions were successively measured. Data from boreholes B-150/75, B-153/75, B-157/75, B-184/95, B-9/01, B-10/06, B-14/06, B-17/06, B-19/06, B-1/07, B-2/07, B-3/07, B-6, B-8, B-10, B-13 and IB-9 were used. Information was plotted on a geodetic plan on the scale 1:25 000, and cross-sections drawn, to be reduced to the scale and prepared for print.

Mollusks were identified from 18 samples and collected from the all three Filijala Pit fields, and from boreholes B-8 and IB-9. For a more precise stratigraphic position and biostratigraphic control, five marl samples were examined on ostracodes. Paleomagnetic measurements were conducted in Pannonian marls on the northern and southern margins of the Filijala Northern Field (BCP Lafarge, Beočin).

Twenty two fresh cores, light-grey in color, were drilled in four sections inclined about 10º to the north. The cores were oriented by means of a geological compass. Several samples cut from each core were examined in detail in the laboratory. For measurement of the initial magnetic susceptibility and the anisotropy of the susceptibility (AMS) in the low-intensity field (in fifteen positions) KLY-2 kappabridges was used with relevant software support. The line, direction and intensity of the remanent magnetization (RM) were measured using a JR-5 spinner magnetometer (in four positions) within the domain of the natural remanent magnetization (NRM) and after each step of demagnetization. A Schönstedt thermal demagnetizer was used for thermal demagnetization of the specimens, and an AFD300, Schönstedt AF and an LDA 3A demagnetizer were employed for the alternating field demagnetization. Magnetic minerals, the bearers of characteristic RM, were identified using KLY-2 kappabridges complete with a Curie temperature measuring device, pulse magnetizer and spinner magnetometers JR-4 and JR-5A. The demagnetization data were processed statistically following standard paleomagnetic procedures (Kirschvink 1980; Fisher 1953).

Geology of the Filijala Pit property

The area of the Filijala Pit property occupies a segment of the northern Fruška Gora horst. Paleozoic and Mesozoic rocks and Paleogene igneous rocks that form the basement constitute the horst body with Neogene sediments on its lateral sides. The basement rocks of Fruška Gora form a very complex structural pattern with features of most diverse folding and radial deformation.

Neogene sediments form a younger structural stage and are distributed on the slopes and piedmont of the Fruška Gora horst. In the Beočin area, the Neogene is part of a large range and foothill belt of northern Fruška Gora (Fig. 1). While the older Miocene beds are nearer to the Pre-Tertiary core of Fruška Gora in the south, younger stratigraphic members of the Neogene extend northward to the Danube River. Sarmatian sediments were identified in boreholes SE in the Filijala and exposed on a hill above the Filijala Southern Field in Beočin Village, in the Čerević Stream valley (between Veliki Komesarovac and Mali Komesarovac heights) and elsewhere (Fig. 2). The Sarmatian consists of het-

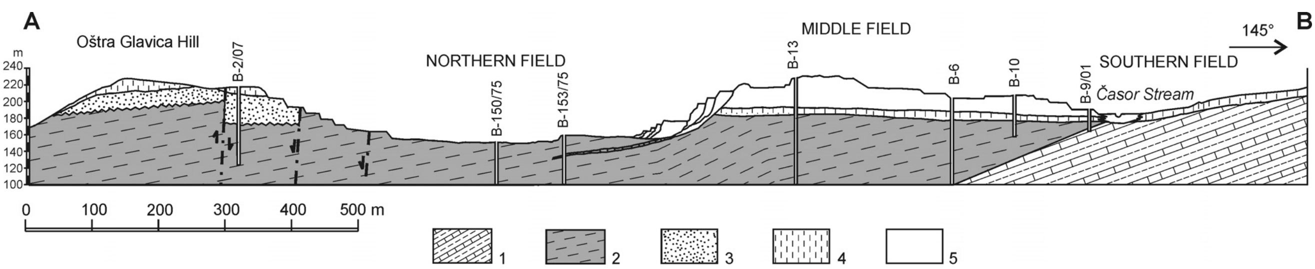

Fig. 2. Geological cross-section A–B through the Miocene sediments on the Filijala Open Pit near Beočin. Legend: **1,** Sarmatian (only in cross section) laminated marl, sandy marl, banded silty marl and siltstone, marly sandstone, stratified sandy limestone, lenses of conglomeratic marl, coaly clay, *etc.*; **2,** Pannonian marl; **3,** Pontian sand; **4,** Pleistocene loess; **5,** Holocene alluvial–prolluvial deposits, recent delluvial deposits and artificial deposits.

erogeneous strata, a succession of commonly laminated intrabasinal marl, banded marl, sand-conglomeratic marl, limestone and stratified sandy limestones.

Pannonian sediments are apparently conformable over the Sarmatian, developed in marly facies, associated with cement marl in the Filijala property (only at borehole B-9/01 in the Southern Field). At the contact, the Pannonian strata consist of compact sandy marl. Upward follows bedded or thick marl in a total thickness of 200 meters (Figs. 2 and 3).

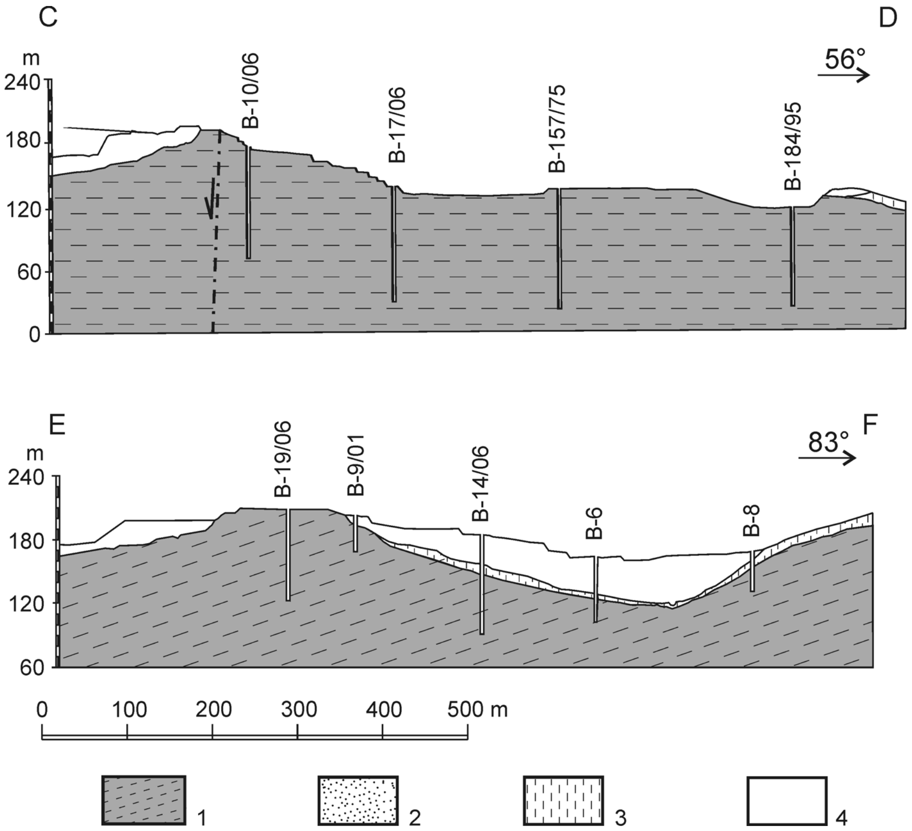

Fig. 3. Geological cross-sections C–D and E–F through the Miocene sediments on the Filijala Open Pit near Beočin. Legend: **1,** Pannonian marl; **2,** Pontian sand; **3,** Pleistocene loess; **4,** Holocene alluvial–prolluvial deposits, recent delluvial deposits and artificial deposits.

Near Beočin, the Pannonian marls are also located west of the Filijala. In addition, these deposits are present at the surface or under the Pontian on the local heights of Tancoš, Mali Komesarovac and Belo Brdo, designated as cement marl prospects.

Near Beočin, the Upper Pontian/Portaferrian beds unconformably and transgressively lie over the Upper Pannonian marls. They consist of sand, interbeds and lenses of sandy siltstone and gravelly sand, in small "oases" on the Filijala northern border (Figs. 1 and 2) and in larger areas on the Tancoš and Belo Brdo hills west of Beočin. The Pontian deposits are highly variable in thickness, more than fifty meters thick near Čerević, west of Beočin.

Lithostratigraphy

The whole Filijala Pit, all three worked fields, is formed of Upper Miocene and Quaternary deposits. Before the mining began, almost the entire terrain of the property had a Quaternary cover, but the long exploitation has uncovered the Neogene sediments, especially the units containing the mined raw material for the cement plant. The Sarmatian deposits under the productive strata, they themselves being gangue in the cement production, are not exposed on the surface anywhere within the borders of the property. They were found only in exploratory boreholes (IB-9 and B-9/01) located SE of the property, in the Časor Stream valley. It was inferred based on borehole sections, observations and mapping that the Sarmatian deposits underlie the Quaternary in a narrow tract on either side of the Časor Stream, SE of the delineated area. Further WNW, the Sarmatian sediments lie under the Pannonian marl. Beds of the Sarmatian and Lower Pannonian sediments, being provisionally conformable or without visible angular discordance, dip in almost the same direction (Fig. 2). As the Lower Pannonian exposures in the Southern Field have dip angles of about 20° to the NNW, the older Sarmatian layers presumably have the same dip direction. Tracing the inclination of the Neogene deposits, or the SSE-NNW azimuth, the Sarmatian layers dip in the same direction. Hence, even the deepest borehole did not enter Sarmatian rocks in the Northern Field. The measured section of borehole IB-9 and of the exposed deposits in the bordering areas indicated heterogeneous lithology of the Sarmatian (Fig. 4). Lithologically, it consists of laminated marl, sandy marl, banded silty marl and siltstone, marly sandstone, stratified sandy limestone, sand-gravelly marl lenses, coal clay, *etc*. The coal clay lies at the bottom of IB-9, between 14 m and 15 m deep, on the right bank of the Časor Stream (Fig. 4). The identified fossil fauna were *Pirenella picta* (DEFRANCE), *Ervilia* cf. *dissita* (EICHWALD), *Cerastoderma* sp.

Pannonian deposits have the largest distribution in the Filijala property, particularly in the largest mined

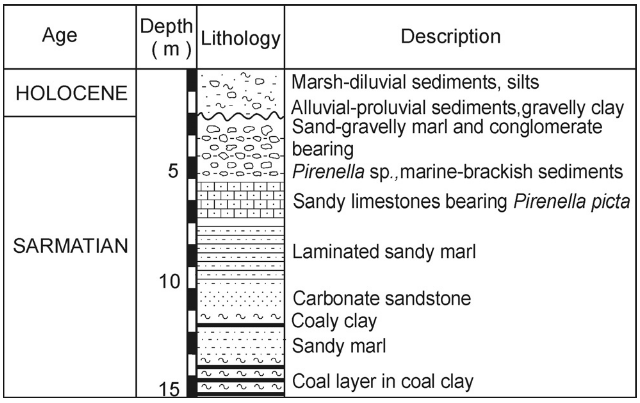

Fig. 4. Measured section of borehole IB 9 in the Časor Stream (near Southern Field of the Filijala Open Pit).

Northern Field. Unlike the heterogeneous Sarmatian sediments that frequently vary in both the horizontal and vertical directions, the Pannonian deposits are uniform in composition, represented by marl facies. They are sandy, hard at the boundary with the Sarmatian. The rest of the sequence consists of true marls to the boundary with the Pontian sandy beds.

The lower level of marls (Slavonian, sensu STEVANOVIĆ) is located in the mined Southern Field and probably is covered in the transitional area from the Southern Field to the Northern Field. It is marked by fossil fauna of scarce small gastropods, bivalves and ostracodes. These marls in the Southern Field are platy, then bedded and relatively hard, locally sandy with the occurrences of beds of indurated carbonate sandstone and marly siltstone. The average amount of $CaCO_3$ in the lower Pannonian marls of the Southern Field is 62.55 %.

The upper set of the Beočin marl beds (Serbian, sensu STEVANOVIĆ) is developed in the northern part of the Middle Field and in the Northern Field. The marl deposits of the Upper Pannonian form thick beds, or rather groups of beds, rarely partly massive and less indurated on average than the lower Pannonian marl. The average $CaCO_3$ in the Northern Field marls is 64.42 %. Upper Pannonian marls of the Northern Field include interbeds and lenses entirely different from the enclosing rocks. In exposures of the Northern Field, the interbeds of ferruginous silty sand are 10 cm or thinner, for example in observation points determined by the coordinates 45º12’12” N, 19º44’40” E and 45º12’08” N, 19º44’38” E (eastern border of the worked field). Sand or even gravel interbeds in massive marl deposit are found in some boreholes of the Northern Field. For example, a layer of sand-marl conglomerate, depth interval from 60 m to 61.1 m in borehole B-6, included pebbles of quartz, chert, serpentinite, Cretaceous sandstone, *etc.*; in borehole B-8 depth interval from 51.2 m to 53 m, a layer of marly sand succeeds gravelly-sandy marl. Note that these beds, as do the common Pannonian deposits, have a dip direction to the NNW. Minor local sand/gravel interbeds are wedges in marlstones, which deserve consideration because, being permeable, they may contain water and under certain conditions may disturb the stability of slopes. The landslide uncovered marl beds, which were the parting plane, with the dip elements 340/18 (45º11’51” N, 19º44’20” E, altitude 204 m).

In respect to granularity, sediments in the Filijala Open Pit property are classified as clay-silt deposits based on petrographic examination of samples from different parts of the marl deposit. The sand constituent is negligible, except in the mentioned lowest horizons and in small local interbeds and lenses. Consequently, Pannonian marl from the Filijala property should be taken for fine silt-clay material, micrite, or mudstone. Microcrystalline calcite is the essential mineral constituent varying between 60 % and 67 % on average. The non-carbonate proportion of the marl consists of quartz, hydromica, montmorillonite, feldspar kaolinite, limonite goethite and organic matter.

The Pannonian deposits generally have a dip direction from SSE to NNW at a gradually changing angle: about 20° in the Southern Field, 18° in the centre of the Interfield to 26° at the northern border of the Interfield. Following the azimuth, the marl dip angle in the Northern Field lessens to 12° or 14° in the northern pit slope. Within the confines of the marl deposit, Pannonian marls continuously dip to NNW from the southern border of the Southern Field, increasing in thickness to about 200 meters at the Oštra Glavica Hill. However, long excavation of marl in a large area of the Northern Field has reduced its natural thickness to the base bench level at an altitude of 110 m. The greatest thickness of about 109 m was measured in borehole B-19/06, which ended in Pannonian marl (Fig. 3).

While seemingly monotonous over a wide area, Pannonian marls vary upward in the lithostratigraphical section. Pontian sediments are the youngest Miocene stratigraphic unit in the Filijala property, which once covered it completely, but have naturally eroded and remained only in the north of the Northern Field. Through its mining history, however, most of Pontian deposits have been removed as mine waste, with only “oases” of Pontian left on the Oštra Glavica Hill and on the northernmost border of the property.

The Upper Pontian deposits of the Portaferrian substage (STEVANOVIĆ 1990) in the Filijala are transgressive and unconformable over the Upper Pannonian marl. These deposits have deep angle between 5° and 8°. The Upper Pontian strata consist entirely of sandy sediments, distinctly different in lithology from the older Pannonian marls. Pontian deposits begin with a layer of ferruginous silty sandstone, abounding in characteristic Portaferrian fossil fauna, over Pannonian marl. Upward follow cross-laminated grey-brown sand, lenses of gravelly sand and silty sand to the Quaternary loessoid (loess-like) deposits.

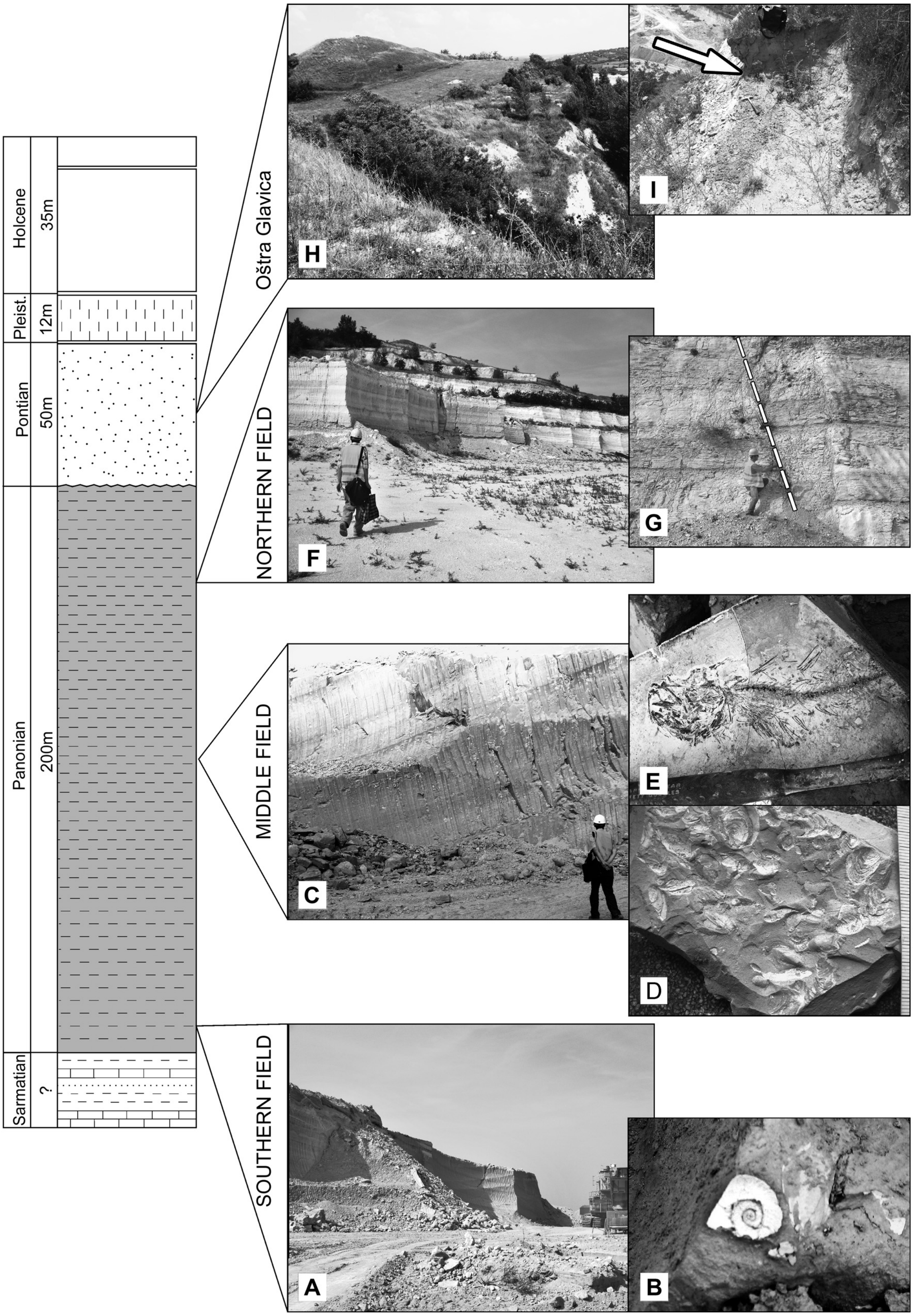

Fig. 5. Synthetic column of the Miocene sediments of the Filijala Open Pit. **A**, Outcrops at the Southern field; **B,** Lower Pannonian marls with *Gyraulus praeponticus;* **C**, Outcrops at the Middle field; **D,** Marls with *Congeria banatica;* **E**, Fossil fish at bedding surface; **F,** Outcrops at the Northern field of the Upper Pannonian marl; **G**, Fault in the Northern field; **H**, The peak Oštra glavica (Northern field) where there is a fault on the last layer that separates Pontian sand (left) and Pannonian marl (right); **I,** Contact between Pontian sand and Pannonian marl in the fault zone near the peak Oštra glavica – the Northern field.

The Pontian deposits lie over the Upper Pannonian marls on the Oštra Glavica Hill at altitudes over 175 m. Here, Pontian sands build up the last bench in the northern slope and continue upward to the Pleistocene boundary in a thickness of some 15 meters. In a small depression between the two tops of the hill, Pontian deposits fill a trench to the Pannonian marls (altitude 125 m) behind the highest bench above the northern pit slope.

The Northern Field has several identified faults that influence the morphostructural pattern. A fault in the strike direction ENE–WSW is at present in the base bench in the northern slope face and a similar minor fault in the northern slope (Fig. 5G). Open sections near the northern slope and in the new boreholes indicate a number of faults. A fault closes a small but relatively deep trough that is closed in the south by a fault of ENE–WSW trend (Fig. 6). The fault is located in a high bench where, along the same elevation, it separates the zone of Pannonian marl development in the south from the zone of the younger Pontian sand. The trough is closed by faults striking NNW–SSE (western) and ESE–WNW (eastern), which on the plan give the trough the shape of an elongated inequilateral triangle.

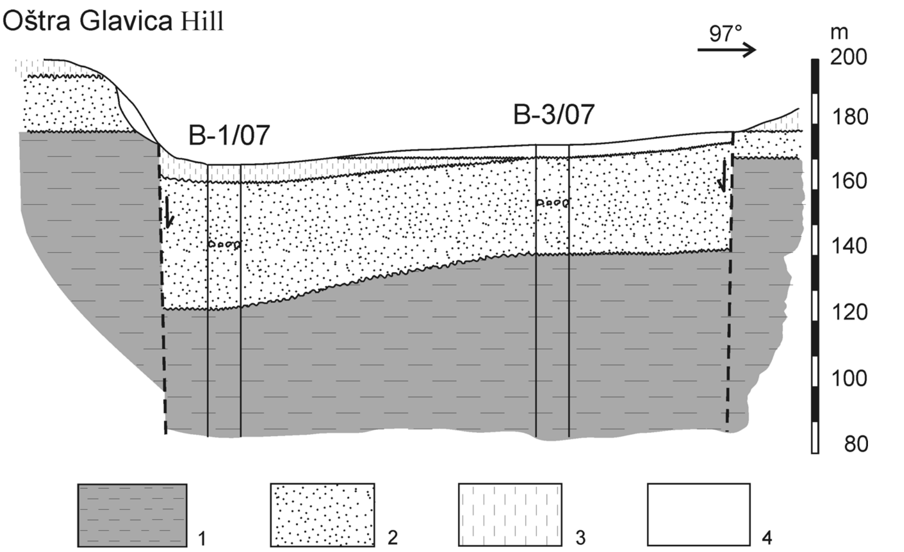

Fig. 6. Geological cross section in Oštra Glavica, northern border of the Filijala Open Pit. Legend: **1,** Pannonian marl; **2,** Pontian sand; **3,** Pleistocene loess; **4,** Holocene alluvial–prolluvial deposits, recent delluvial deposits and artificial deposits.

Fossils in cement marls

Marl samples collected for examination contained a relative abundance of mollusks (gastropods and bivalves), a few fish and floral remains and numerous ostracodes. Fossil fish and fossil turtle are known from previous excavations in the pit (ĐURIĆ 2005). The remains of a fossil proboscidean were excavated some years earlier, but, unfortunately, they have been lost. A very well-preserved fossil fish (Fig. 5E) was recently discovered in a landslide scar north in the Middle Field.

Fossil mollusks and ostracodes may be used in dating the Lower Pannonian, the so-called Slavonian substage (Slavonian, *sensu* STEVANOVIĆ), and the Upper Pannonian (Serbian, *sensu* STEVANOVIĆ).

The Lower Pannonian (Slavonian) is developed in the Southern Field. Its fossil content consists of scarce, small gastropods, notably of the Lymnaeidae family: *Radix croatica* (GORJANOVIĆ-KRAMBERGER) and *Radix kobelti* REUSS, then *Gyraulus praeponticus* (GORJANOVIĆ-KRAMBERGER) (Fig. 5B), *Limnocardium praeponticum* (GORJANOVIĆ-KRAMBERGER), *Paradacna cekusi* (GORJANOVIĆ-KRAMBERGER) etc. in the lower horizons, and *Undulotheca pancici* (GORJANOVIĆ-KRAMBERGER), *Undulotheca halavatsi* KOCH, *Gyraulus praeponticus* (GORJANOVIĆ-KRAMBERGER) and others in the upper horizons. The assemblage of ostracodes identified from the Southern Field includes *Amplocypris* ex gr. *acuta* KRSTIĆ, *Herpetocyprella auriculata* (REUSS), *Cypria* sp., *Candona* (*Candona*) sp., *Candona* (*Propontoniella*) sp., *Candona* (*Thaminocypris*) *improba* KRSTIĆ, *Candona* (*Typhlocypris*) *fossulata* (POKORNY) and *Loxoconcha* sp. Younger horizons of the Lower Pannonian are developed in the north of the Southern Field and probably also in the boundary area of the Southern and Middle Fields, presently under the embankment of the old waste dump.

The Upper Pannonian (Serbian) contains abundant mollusks with the specific dominance of *Congeria banatica* R. HÖRNES (Fig. 5D), *Congeria subdigitifera* STEVANOVIĆ, *Paradacna syrmiense* R. HÖRNES, *Provalenciennius pauli* R. HÖRNES, *Provalenciennius* sp. and *Gyraulus* cf. *praeponticus* (GORJANOVIĆ-KRAMBERGER). The ostracodes identified from the Northern Field are *Herpetocyprella hieroglyphica* (MÉHES), *Amplocypris acuta* KRSTIĆ, *A. major* KRSTIĆ, *Cypria* cf. *serbica* KRSTIĆ, *Cypria* sp., *Candona* (*Serbiella*) gr. *kolubarae* KRSTIĆ, *Candona* (*Zalanyiella*) *buchi* KRSTIĆ, *C.* (*Z.*) *rurica* KRSTIĆ, *Candona* (*Caspiolla*) *prebalcanica posterior* KRSTIĆ, *C.* (*C.*) *alasi beocini* KRSTIĆ, *Candona* (*Typhlocypris*) sp. 1, *Candona* (*Typhlocypris*) sp. 2, *Candona* (*Reticulocandona*) *reticulata* (MÉHES), *Candona* (*Typhlocyprella*) cf. *ankae* KRSTIĆ, *Candona* (*Lineocypris*) sp. and *Hemicytheria* sp. A similar association was identified from the Middle field, which additionally includes *Amplocypris sincera* ZALÁNYI and *A.* cf. *marginata* SOKAČ.

Paleomagnetic survey

Paleomagnetic measurements within the domain of the NRM indicate very low magnetic susceptibility and remanent magnetization of the Pannonian marls, a result of the low magnetic strength of minerals (Tab. 1). On a stereographic projection of ellipsoid AMS axes, the k_{min} axes are crowded near the centre of the equatorial projection, in the geographic and structural systems, which indicate a remanent magnetization induced through the process of compaction (Fig. 7, Tab. 2).

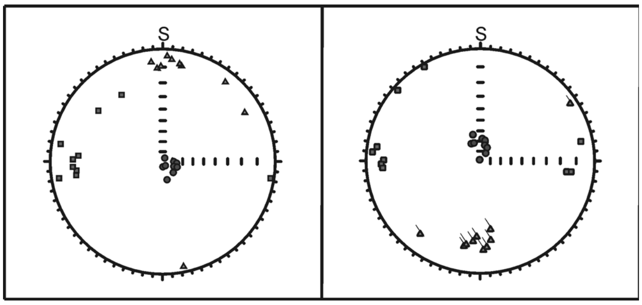

Fig. 7. Equatorial projection (on the lower hemisphere) k_{max} (square), k_{min} (triangle) and k_{int} (circle) of the AMS ellipsoid axes for individual marl samples from the Filijala Open Pit. Left: before correction for tectonics and right: after correction for tectonics.

Table 1. Initial magnetic susceptibility, remanent magnetization and polarity of the Pannonian marls after the process of demagnetization.

Filijala (YM 3044-065)					
Susceptibility (10^{-6} SI)			Intensity(10^{-5} A/m)		Polarity kRM
min	max	int	min	max	
38.07	53.18	44.88	7.32	58.7	N

Table 2. Magnetic properties of the Pannonian marls from the Filijala surface mine. Positions of the AMS ellipsoid axes (k_{max}, k_{int}, k_{min}) are expressed by declination (*D*) and inclination (*I*), anisotropy (*P*), lineation (*L*), foliation (*F*) and measurement reliability parameters (e_{12}, e_{23} and e_{13}).

Filijala (geographic orientation)											
k_{max}		k_{int}		k_{min}		*P*	*L*	*F*	*statistical stability*		
D°	*I*°	*D*°	*I*°	*D*°	*I*°	%	%	%	e_{12}(°)	e_{23}(°)	e_{13}(°)
97.6	–8.0	8.7	7.9	142.7	78.7	1.10	0.24	0.86	14.1	2.2	6.7
Filijala (tectonic orientation)											
k_{max}		k_{int}		k_{min}		*P*	*L*	*F*	*statistical stability*		
D°	*I*°	*D*°	*I*°	*D*°	*I*°	%	%	%	e_{12}(°)	e_{23}(°)	e_{13}(°)
97.7	1.5	8.0	–12.2	0.9	77.7	1.09	0.24	0.85	12.6	2.9	6.7

Hematite (Fe_2O_3), determined by mineralogical and petrological tests, was not confirmed by standard magnetic measurements, which was why special experiments for inducing isothermal remanent magnetization (IRM) and thermal demagnetization of the composite IRM were applied. The measured NRM and IRM values and the behavior of the magnetic susceptibility during heating indicated magnetite (Fe_3O_4), whereas the participation of hematite in the total RM of the marls was excluded (Fig. 8).

With the initial NRM measured, it was decided to demagnetize all samples from the southern and five samples from the northern pit borders by means of alternating magnetic field and/or heating. The demagnetization steps were small, 2–3 mT or by 10 °C (Fig. 9), due to the low initial RM intensity. Thermal demagnetization, at temperatures exceeding 400 ºC, caused pyrite oxidation and led to its transformation into magnetite. The newly formed magnetite grains induced chemical remanent magnetization during cooling along the ambient field (Fig. 8.C and Fig. 9).

Statistical processing of the demagnetization data did not give any RM direction sufficiently uniform for a definition of the primary RM. The heterogeneous directions of the RM independent of the cores are due to the transformation of a primary magnetic mineral into a secondary mineral.

Discussion

Pannonian marls on the northern ridges of Fruška Gora Mountain formed during the early phase of evolution of the Lake Pannon (MAGYAR *et al*. 1999; MAGYAR *et al*. 2007), in which a mesohaline/oligohaline lake formed related to the isolation of the Pannonian domain and fresh water inflow. Mollusks and ostracodes carried from the surrounding rivers and lakes into this lake modified to the slightly brackish environment and together with the few adapted marine species formed an endemic community (similar to that of the present-day Caspian Lake). The principal mass of calcium carbonate in the Beočin marl presumably formed through the chemical process of carbonate precipitation in the warm, mildly agitated aquatic environment saturated with bicarbonate solution. The chemogenetic carbonate mud mixed with inflown clay and clay-sand clastic materials (silicates)

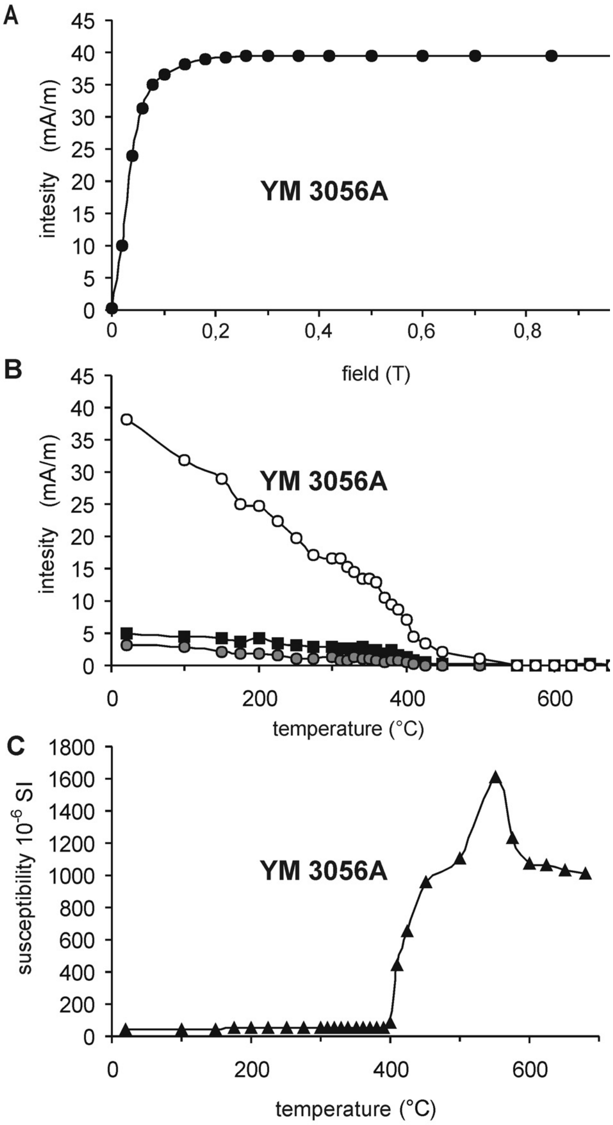

Fig. 8. Magnetic mineralogy. Diagrams of the magnetization-bearing mineral behavior during the magnetic field control and heating in the laboratory. Key: **A**, IRM acquisition behavior; **B**, The three-component IRM (Lowrie, 1990) behavior on thermal demagnetization. The hard (square), the medium hard (dots) and soft (circle) components of the composite IRM were acquired in fields of 1 T, 0.36 T and 0.2 T, respectively; **C**, Susceptibility variation with heating.

produced a carbonate-clay composite that later lithified into marl. The morphologic features of the fossil fauna give evidence of the depositional environment that produced the marls (MAGYAR *et al.* 1999; MAGYAR *et al.* 2007). Ostracodes and other fossils with mostly thin carapaces and their morphology indicate to their existence in calm water (RUNDIĆ 1998, 2006). There was an opinion that the uppermost marl at the contact with the Upper Pontian sand was transitional from the Upper Pannonian to the Lower Pontian (ČIČULIĆ 1977). It was explained that grey marl with *Valenciennius pauli* R. HÖRNES, *Congeria banatica* R. HÖRNES of the Upper Pannonian was succeeded by pale-yellow marl with *Congeria banatica* R. HÖRNES, *Limnocardium syrmiense* R. HÖRNES, *Paradacna lenzi* (R. Hörnes), *Plagiodacna* cf. *auingeri* (FUCHS), *Congeria* cf. *zagrabiensis* BRUSINA, which could have marked the boundary between the Upper Pannonian and the Lower Pontian. Above, there is a layer of ferruginous sand bearing Upper Pontian faunal fossils including the frequent *Melanopsis decollata* STOLICZKA, *Congeria zagrabiensis* BRUSINA, *Congeria* cf. *rhomboidea* M. HÖRNES and *Caladacna steindachneri* (BRUSINA). The fossil fauna and some lithological and structural characteristics were used to date the Early Pannonian (Slavonian, sensu STEVANOVIĆ) deposits in the Southern Field and the more widespread Late Pannonian (Serbian, sensu STEVANOVIĆ) in the Middle and Northern Fields. Generally, different characteristics of the investigated mollusk and ostracode species indicate stable conditions in a relatively deep-water environment. The common findings of *Congeria banatica* as well as *C. subdigitifera* point to deeper (basinal) development whilst the association with *Limnocardium*, *Valenciennessius* and *Paradacna* indicate a more shallow-water, sublittoral influence (MAGYAR *et al*., 1999). In addition, ostracode associations with smooth, thin and elongated forms of carapace suggest a calm deeper environment. Based on the results of stable isotope data from mollusk's shells, the climate in the Lake Pannon was changeable. The Early Pannonian was a period with an arid, subtropical climate that was followed by a more humid climate during the Middle ("Upper") Pannonian (HARZHAUSER *et al.* 2007). All the analyzed fossil assemblages indicate a mesohaline sublittoral environment of the Lake Pannon. The salinity of the lake water was estimated as 8–16 ‰. This is quite comparable to the recent sublittoral zones of the Black Sea and Caspian Sea (CZICZER *et al.* 2009).

Generally, the Pannonian deposits in the Filijala property have a dip direction to the NNW, only forming a gentle flexure (Fig. 2) at the Middle/Northern Field border. From the initial 20°, the deposits have a smaller dip angle in the central Interfield, again an increase in the inclination to the southern border of the Northern Field, and a lowering of the dip to the northern property border. Gentle flexures in the Pannonian marl may be explained by tectonic events that caused differential block faulting of the older geologic units under the marls. The molding of the marl probably evolved through the Lower Pontian, after the deposition of the Pannonian marl, when sedimentation ceased in the Beočin area due to an uplift of a part of Fruška Gora. Pannonian marl, still fresh and ductile sediments, possessed plasticity to form gentle flexures adjusting to the new underlying morphostructure without themselves being block faulted or displaced.

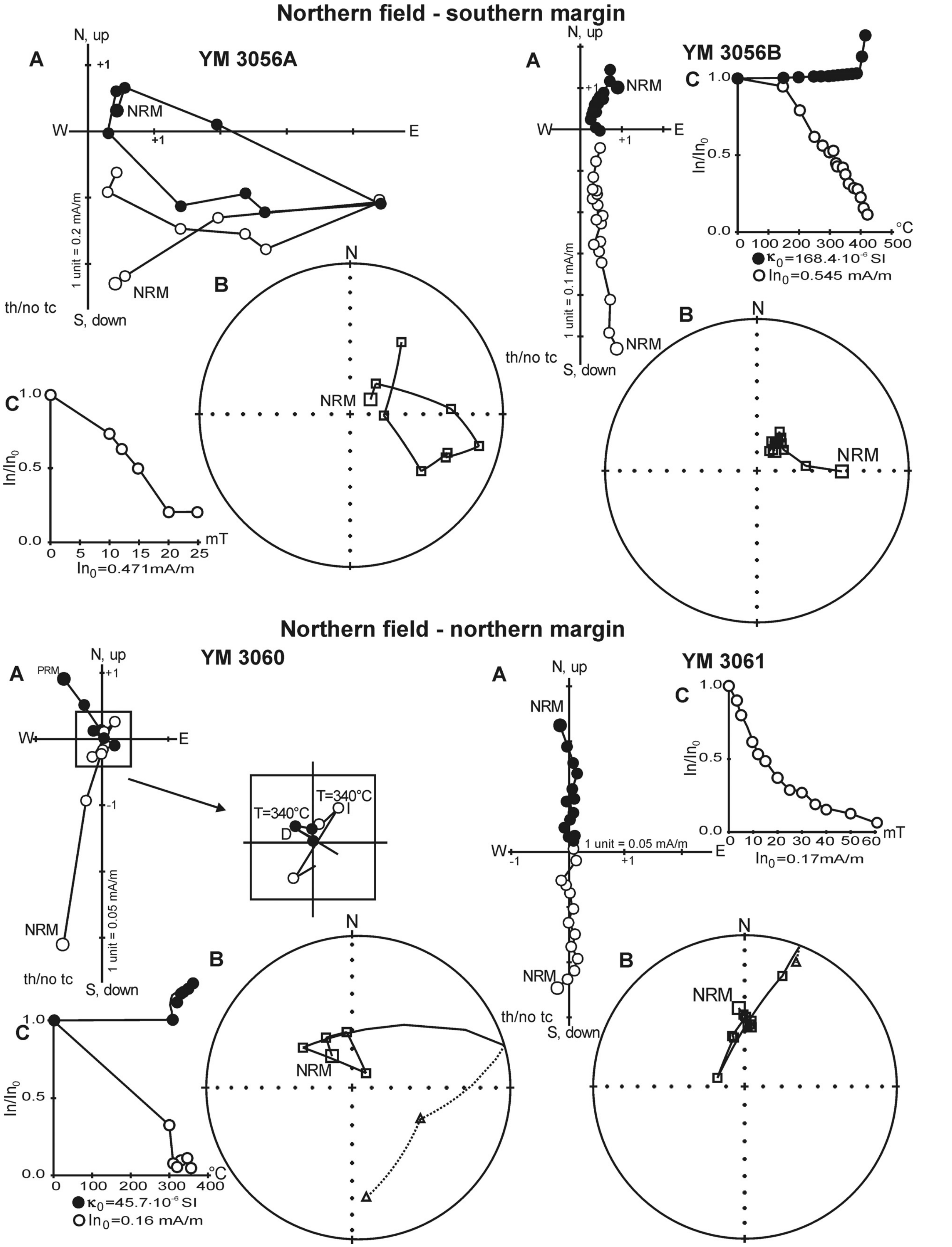

Fig. 9. Typical demagnetization curve: **A**, Zijderveld diagram (full/open circle: projection of the NRM in the horizontal/vertical plane); **B**, Schmidt diagram (square/triangle: projection on the lower/upper hemisphere, initial NRM position); and **C**, NRM intensity and susceptibility variations during demagnetization (In_o, initial intensity, k_o, initial susceptibility).

Another type of deformation features prevailing in the structural pattern of the Neogene deposits are different fractures and faults, the products of radial faulting (Fig. 5G). Fractures are visible everywhere in the exposed marl beds in the open pit. Interlacing fractures usually form two perpendicular systems: (a) one in the dip direction, SSE–WNW or slightly deviating from it and (b) the other transversal to the primary system of fractures. Diagonal fissures are present locally in more heavily crushed areas, which traverse the bedding planes at an angle.

There also are interstratal fissures along natural discontinuities between bedding planes, in the open pit easily filled with groundwater, the so-called fissure aquifers. A number of "springs" occur in the crosspoints of interstratal and longitudinal fractures, for example below the slide face in the southern part of the Northern Field, in the observation point determined by the coordinates 45º11'56" N and 19º44'19" E.

The areas of visible fractures and much crushed deposits are always potential landslides. Such an area is where fractures and small faults form networks (block faulting 1 m high) in the north of the Middle Field and the south of the Northern Field (Fig. 5G).

Potential gravity slides in the Filijala property are related to the structural pattern and dip to the NNW of the Neogene deposits, the nature of rocks and long uncontrolled exploitation in the northern part of the marl deposit. Two potential landslide areas are identified: (1) fault zone at the contact of the Pannonian marl and the Pontian sand at the base of the Oštra Glavica Hill (Fig. 5H, I) and (2) the steeper-sloping part of the flexure in the border area of the Middle and Northern fields (Fig. 5C). Slides develop in places of pressure relief of removed artificial deposits, which leads to relaxation of the rocks and to fracturing along naturally predisposed discontinuity surfaces. Slides of this type usually develop under the effect of abundant rain or melting snow, when water infiltrates along the fault. A newly developed slide in the north of the Middle Field has exposed how colluvial gravity materials broke and divided marl beds along the fracture surfaces into square or polygonal flat-faced sharp-edged blocks.

The most complex structural geology in the Filijala property is found above the northern slope of Oštra Glavica. Several faults near the unconformable Pannonian/Pontian contact and within the Pannonian marl controlled the formation of a particular structural pattern. It could be suggested as the phase of post-Sarmatian basin inversion and later, the post-rift subsidence combined with uplifting (HORVÁT *et al.* 2006).

Negative results of the paleomagnetic study of marls in the Filijala Northern Field was surprising considering the promising preconditions: known stratigraphic age, comparatively gentle slope of the beds, detailed petrological and mineralogical studies additionally based on the new exposure of the lower section and, finally, the suitable of marl for paleomagnetism. For this reason, Pannonian marls were "measured" once more west of the Filijala property under the magnetostratigraphic survey on the Belo Brdo Hill. The obtained results were practically the same. Low and isotropic magnetic susceptibility (10^{-5} SI), the intensity of the RM, which varied along the entire core (of 10^{-6} to 10^{-3} A/m), unstable directions of the characteristic RM and variable angle of inclination. These are all parameters that indicate an environment with variable physical-chemical conditions (oxidated water), during which constant transformation of magnetic mineral bearing the remanent magnetization occurs. An inference based on the correlation with the paleomagnetic data for the Pannonian–Pontian locations in Croatia (VASILIEV *et al.* 2007; BABINSZKI *et al.* 2007), Hungary (BABINSZKI *et al.* 2007) and Fruška Gora is that sediments with magnetite that bears remanent magnetization are not capable of "bearing" a coherent magnetic signal, because the RM was induced during the formation of secondary magnetite. If the bearer of the remanent magnetization is primary magnetite, it is low and, consequently, the "remanent signal" very weak, often additionally burdened by "magnetic disturbance" due to the presence of pyrite. Overall, the general paleomagnetic direction of Pannonian–Pontian deposits in the Pannonian domain coincides with the actual direction of the geomagnetic field, which indicates that the remanent magnetism is of a recent date. In contrast, fine-grained Pannonian–Pontian deposits with greigite, formed through the early diagenetic process, mostly possess a harmonized paleomagnetic signal, often of reversed polarity, with a declination deviating from the recent Earth's magnetic field due to the rock mass rotation around the vertical axis (MÁRTON *et al.* 2002a, b; MÁRTON & FODOR 2003).

The latest magnetostratigraphic prospecting of Pannonian marl in the Filijala property has been started (BORGH *et al.* 2010) and is expected to produce additional information on the marl chronostratigraphic position and the time of the isolation of the Lake Pannon.

Conclusions

The open pit Filijala is located on the NE ridges of Fruška Gora, near the Danube, over a surface area of 792563 m^2. It consists of three unequal in size worked fields (the Northern Field, the Middle Field or Interfield and the Southern Field). The entire marl deposit belongs to a belt of the late Neogene and Quaternary on the margin of the large horst morphostructure of the Fruška Gora Mountain.

Most widespread in the Filijala property are the Pannonian deposits of the Upper Miocene, which are apparently conformable over Sarmatian sediments (recently, more precise data concerning the nature of the Sarmatian/Pannonian boundary are missing). These deposits are present in the facies of marls, which are mined and used in the cement works. The distribution of the Pannonian marls is about 1.5 km long, and their assumed thickness is more than 200 meters. The marls dip in the Southern Field by about 20°, then 18° in the central Middle Field, slopes at 25° or 26° in the border area of the Middle and Northern Fields, and the dip continuously decreases across the Northern Field to some 12°. In the geological section, marl strata in the Filijala have the shape of a gentle flexure (monocline).

Elements of radial tectonics, dominantly systems of fractures and small faults (of very small throws), are recognized in the property. Major deformations by appreciable differential block faulting were formed on the Oštra Glavica Hill in the north of the property area. Surface landforms are related to these faults. There is a small but deep trough in the form of an elongated unequilateral triangle. The down-thrown block in the trough is formed of Pannonian marl and Pontian sand. The depth of the subsidence is not uniform, being the greatest in the B-1/07 area west in the depression. A correlation of Pannonian–Pontian strata from a borehole in the trough and from rises above the trough indicates differential faulting (heave and throw) of 35 to 50 meters. The folding structures, monoclines and flexures presumably formed at the time when the marl was still unsolidified (probably during the Early Pontian when sedimentation ceased as a result of uplifting). The widespread system of fractures and faults, and the trough in the Oštra Glavica Hill developed later in relation to the radial faulting during the Pliocene and early Quaternary (Pleistocene).

All analyzed fossil assemblages indicate a mesohaline, basinal development of the Lake Pannon. The salinity of the lake water was estimated as 8–16 ‰, which is quite comparable to the recent zones of the Black Sea and Caspian Sea.

By a paleomagnetic investigation, it was established that magnetite-bearing sediments deposited during the Pannonian mainly do not carry a coherent.

Acknowledgements

The authors wish to thank STJEPAN ĆORIĆ (GEOLOGICAL SURVEY, VIENNA) and the anonymous reviewer for the useful comments that significantly improved the paper. Also, many thanks go to the "HIDRO-GEO RAD" for unlimited access to the borehole cores. The study was supported by Ministry of Science and Technological Development of the Republic of Serbia, Project No. 146009 and 146023.

Reference

BABINSZKI, E., MÁRTON, E., MÁRTON, P.S. & KISS, L.F. 2007. Widespread occurence of gregite in the sediments of Lake Pannon: Implications for enviroment and magnetostratigraphy. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 252: 626–636.

BORGH, T. M., VASILIEV, I., STOICA, M., KNEŽEVIĆ, S., MATENCO, L., KRIJGSMAN, W. & CLOETINGH, S. 2010. Dating the isolation of the Central Paratethys: new constrains from magnetostratigraphy (Beocin section, Northern Serbia). *Geophysical Research Abstracts*, 12, EGU General Assembly.

CLOETINGH, S., BADA, G., MATENCO, L., LANKREIJER, A., HORVÁTH, F. & DINU, C. 2006. Modes of basin (de)formation, lithosheric strength and vertical motions in the Pannonian–Carpathian system: inferences from thermomechanical modeling. *Geological Society London Memoirs,* 32: 207–221.

CZICZER, I., MAGYAR, I., PIPIK, R., BOHME, M., ĆORIĆ, S., BAKRAČ, K., SUTO-SYENTAI, M., LANTOS, M., BABINSZKI, E. & MULLER, P. 2009. Life in the sublittoral zone of longlived Lake Pannon: paleontological analysis of the Upper Miocene Szak Formation, Hungary. *International Journal of Earth Sciences,* 98 (7): 1741–1766.

ČIČULIĆ-TRIFUNOVIĆ, M. & RAKIĆ, M. 1971. Basic geological map 1:100000, Sheet Novi Sad 1, with Explanatory book. *Savezni geološki zavod*, Beograd, 52 pp. (in Serbian).

ČIČULIĆ, M. 1977. Miocene of Fruška Gora. In: PETKOVIĆ, K. (ed.), Geologija Srbije, 2-3, stratigrafija, kenozoik, 286–294, Zavod za regionalnu geologiju i paleontologiju Rudarsko-geološkog fakulteta, Univerzitet u Beogradu, Beograd (in Serbien).

DRAŠKO, Z., BLEČIĆ, N. & KNEŽEVIĆ, S. 1998. Cement marl deposits- south field at Beocin. *Zbornik radova 13. Kongres geologa Jugoslavije*, Mineralne sirovine, 4: 641–648, Herceg Novi (in Serbian).

ĐURIĆ, D. 2005. Fossil Toroice from Fruška Gora. *The first International Workshop Neogene of Central and South-Eastern Europe, Abstract volume*, 50–51, Novi Sad.

FISHER, R. 1953. Dispersion on the sphere. *Proceedings of the Royal Society of London*, 217: 295–305.

FODOR. L., BADA G., CSILLAG G., HORVÁT, E., RUSZKICZAY-RÜDIGER, Z., PALOTÁS, K., SÍKHEGYI, F., TIMÁR, G., CLOETING S. & HORVÁT, F., 2005. An outline of neotectonic structures and morphotectonics of the western and central Pannonian Basin. *Tectonophysics,* 410: 15-41.

GANIĆ, M., RUNDIĆ, LJ., KNEŽEVIĆ, S., VASIĆ, N. & RADONJĆ, M. 2009. Northern slopes of Fruska Gora Mountain, Beočin vicinity (southern part of the Central Paratethys) – a representative example of the Neogene succession. *3rd International Workshop Neogene of Central and South-Eastern Europe, Abstract volume*, 33–34, Cluj-Napoca.

HARZHAUSER M., LATAL C. & PILLER W.E. 2007. The stable isotope archive of Lake Pannona as mirror of Late Miocene climate change. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 249: 335–350.

HARZHAUSER, M. & PILLER, W.E. 2007. Benchmark data of a changing sea – Palaeogeography, Palaeobiogeography and events in the Central Paratethys during the Miocene. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 253 (1–2): 8–31.

HÖRNES, R. 1874. Valenciennesia-Mergel von Beocsin. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt,* Tertiarstudien, 4, 24: 72–80.

HORVÁTH, F. & ROYDEN, L.H., 1981. Mechanism for the formation of the Intra-Carpathian Basins: A Review. *Earth Evolution Science*, 1: 307–316.

HORVÁTH, F., BADA, G., SZAFIÁN, P., TARI, G., ÁDÁM, A. & CLOETINGH, S. 2006. Formation and deformation of the Pannonian Basin. *In*: GEE, D.G. & STEPHENSON, R.A. (eds.), European lithosphere dynamics. *Geological Society of London,* 32: 191–207.

HORVÁTH, F. & TARI, G. 1999. IBS Pannonian Basin Project: a review of the main result and their bearings on hydrocarbon exploration. *In*: DURAND, B., JOLIVET, L., HORVÁTH, F. & SÉRANNE M. (eds.), The Mediterranean Basins: Tertiary Extension within the Alpine Orogene. Special Publication Geological Society, London, 156: 195–213.

KIRSCHVINK, J. L. 1980. The least-square line and plane and the analysis of paleomagnetic data. *Geophysical Journal of the Royal Astronomical Society*, 62: 699–718.

KOCH, A. 1876. Neue Beiträge zur Geologie der Fruška Gora in Ostslavonien. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt,* 26: 1–48.

KOCH, A. 1896. Geologie der Fruscagora. *Mathematic und Naturwissen Berichte aus Ungarn*, 13: 45–127.

KOCH, A. 1902. Beiträge zu den geo-paläontologischen Verhaltnissen des Beocsiner Cementmergels. *Földtani Közlöny*, 32: 311–322.

LENZ, O. 1874. Beitrage zur Geologie der Fruska Gora in Syrmien. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt,* 24: 325–332.

LOWRIE, W.1990. Identification of ferromagnetic minerals in a rock by coercivity and unblocking temperature properities. *Geophysical Research Letters,* 17 (2): 159–162.

MAGYAR, I., GEARY, D.H. & MÜLLER, P. 1999. Palaeogeographic evolution of the Late Miocene Lake Pannon in Central Paratethys. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 147: 151–167.

MAGYAR, I., LANTOS, M., UJSZÁSZI, K. & KORDOS, L. 2007. Magnetostratigraphic, seismic and biostratigraphic correlations of the Upper Miocene sediments in the northwestern Pannonian Basin System. *Geologica Carpathica,* 58: 277–290.

MAROVIĆ, M., TOLJIĆ, M., RUNDIĆ, LJ. & MILIVOJEVIĆ, J. 2007. Neoalpine tectonics of Serbia. *Serbian Geological Society*, Monograph of the Serbian Geological Society, 87 pp., Belgrade.

MÁRTON, E., FODOR, L., JELEN, B., MÁRTON, P., RIFELJ, H. & KERVIĆ, R. 2002a. Miocene to Quaternary deformation in NE Slovenia: complex paleomagnetic and structural study. *Journal of Geodynamics*, 34: 627–651.

MÁRTON, E., PAVELIĆ, D., TOMLJENOVIĆ, B., AVANIĆ, R., PAMIĆ, J. & MÁRTON, P. 2002b. In the wake of a counter clockwise rotating Adriatic microplate: Neogene paleomagnetic results from northen Croatia. *International Journal of Earth Sciences,* 91: 514–523.

MÁRTON, E. & FODOR, L. 2003. Tertiary paleomagnetic results and structural analysis from the Transdanubian Range (Hungary): Rotational disintegration of the Alcapa unit. *Tectonophysics*, 363: 201–224.

PETKOVIĆ, K., ČIČULIĆ-TRIFUNOVIĆ, M., PAŠIĆ, M. & RAKIĆ, M. 1976. Fruška gora - Monographic review of geological materials and tectonic assembly (eds.), *Matica srpska*, 267 pp., Novi Sad (in Serbian, French summary)

PILLER, W.E., HARZHAUSER, M. & MANDIC, O. 2007. Miocene Central Paratethys stratigraphy – current status and future directions. *Stratigraphy* 4 (2/3): 71–88.

RUNDIĆ, LJ. 1998. The carapace of fossil ostracods: paleoenvironmental indicators. *Geološki anali Balkanskoga poluostrva,* 62: 165–177.

RUNDIĆ LJ. 2006. Late Miocene ostracods of Serbia: morphologic and paleoenvironment considerations. *Geološki anali Balkanskoga poluostrva,* 67: 89–100.

RUNDIĆ, LJ., DULIĆ, I., KNEŽEVIĆ, S., BOGIĆEVIĆ, G., GAJIĆ, V. & CVIJIĆ, P. (eds.), 2005. The First International Workshop Neogene of Central and South-Eastern Europe, Field Guide, 31 pp., *Serbian Geological Society*, Novi Sad.

SCHMID, S., BERNOULLI, D., FÜGENSCHUH, B., MATENCO, L., SCHEFER, S., SCHUSTER, R., TISCHLER, M. & USTASZEWSKI, K., 2008. The Alpine-Carpathian-Dinaridic orogenic system: correlation and evolution of tectonic units. *Swiss Journal of Geosciences*, 101: 139–183.

STEVANOVIĆ, P. & PAPP, A. 1985. Beočin, Syrmien (Jugoslawien), 442–453, In: PAPP, A. *et al*. (eds.), *Chronostratigraphie und Neostratotypen,* Miozän, Pannonien 7, Akademiai Kiado, Budapest.

STEVANOVIĆ, P. 1990. Die pontische halbbrackische Molluskenfauna aus Serbien und Bosnien. *In*: MALEZ, M. & STEVANOVIĆ, P. (eds.), *Chronostratigraphie und Neostratotypen*, Pliozän, Pontien. 462–536, JAZU-SANU, Zagreb-Beograd. (in German).

SIMIĆ, V. 2005. Genetic types of the nonmetallic mineral deposites in the Fruška Gora area. *In*: RUNDIĆ, LJ., JOVANOVIĆ, G. & V. SIMIĆ (eds.), The First Internacional Workshop: Neogene of Central and South-Eastern Europe, Abstract volume, p. 48, *Serbian Geological Society*, Novi Sad.

VASILIEV, I. 2006. A new chronology for the Dacian Basin (Romania). Consequences for the kinematic and paleoenviromental evolution of the Patatethys region. *Geologica Ultraiectina,* 267: 1–193.

VASILIEV, I., BAKRAČ, K., KOVAČIĆ, M., ABDUL AZIZ, H. & KRIJGSMAN, W. 2007. Paleomagnetic Results from the Sarmatian/Pannonian Boundary in North-Eastern Croatia (Vranović Section, Našice Quarry). *Geologia Croatica*, 60 (2): 151–163.

VESELINOVIĆ-ČIČULIĆ, M. 1958. “Oligozän” und Miozän der Fruška Gora (Syrmien). *Bulletine Scientifiques*, 4 (2): 48–49 (in German)

Резиме

Горњомиоценски лапорци Панонског језера на површинском копу Филијала (Беочин, северна Србија): нови геолошки и палеомагнетни подаци

Површински коп Филијала у Беочину, налази се на североисточном ободу гребена Фрушке горе, у близини Дунава, на површини од око 792.563 m^2. Састоји се од три радна поља тј. ревира неједнаке величине: Северно поље, Средње поље или Међупоље и Јужно поље.

Панонски лапорци горњег миоцена представљају главни стратиграфски и продуктивни ниво на копу (основна цементна сировина) и леже преко старијих, сарматских слојева са којима граде јединствену структурну етажу. На основу идентификованих макро и микрофосила односно проучених структурно-стратиграфских карактеристика, цементни лапорци припадају доњем панону (славонијен) на Јужном пољу односно горњем панону (сербијен) на Средњем и Северном пољу. Протежу се у дужини од око 1,5 километара, док им укупна дебљина премашује 200 метара. На основу хемијских карактеристика седимента као и анализе фосилних остатака (доминантна врста *Congeria banatica* R. HÖRNES) сматра се да су поменути лапорци продукт седиментације у мирним, дубљим („басенским“) деловима јужног обода некадашњег Панонског језера.

На основу структурних особина, добро документованог падног угла (од 18°–20° у подручју Јужног и Средњег поља, 25°–26° у пограничном подручју Средњег и Северног поља, до само 12° на Северном пољу) утврђено је да панонски лапорци имају облик благе моноклинале (флексуре). Системи пукотина и малих разлома са слабим вертикалним кретањима су доминантне радијалне структуре на копу. У северном делу лежишта, на вису Оштра главица и у његовом подножју, присутни су и већи раседи са јачим диференцијалним кретањима раздвојених блокова. Ови раседи су утицали и на морфолошке карактеристике рељефа. Овде је утврђено постојање малог али дубоког тектонског рова облика издуженог разностраничног троугла у коме је спуштен блок изграђен од панонских лапораца и понтских пескова. Дубина спуштања је неједнака, а највећа је у локацији бушотине Б-1 на западној страни увале. Корелацијом панонско-понтских слојева из бушотине у рову, са истим седиментима на височовима изнад рова, утврђено је да су вертикална кретања 35–50 m.

У погледу датирања структурно-тектонских деформација, може се рећи да је моноклинала настала у млађој фази развоја Панонског језера, када су лапорци били још неконсолидоване стене (вероватно у доњем понту када је постојао прекид у седиментацији услед издизања дела Фрушке Горе). Поменути и распрострањени системи пукотина и раседа, као и тектонски ров на брду Оштра главица, настали су углавном касније, под утицајем радијалне тектонике током плиоцена и старијег квартара (плеистоцена).

За палеомагнетска испитивања узорковани су лапорци са северног и јужног обода Северног поља. Магнетска сусцептибилност лапораца је ниска и магнетски изотропна. Реманентна магнетизација је формирана током седиментације. Ниског је интензитета због мале концетрације магнетичних минерала. Доминатни носилац РМ је магнетит, праћен пиритом. Правци РМ издвојени након демагнетизације су хетерогени, са веома лошим статистичким параметрима сигурности (κ, α_{95}) на нивоу локалитета. Дисперзија праваца РМ независних узорака последица је трансформације примарних минерала носилаца магнетизације у секундарне. Панонски лапорци били су предмет и магнетостратиграфских испитивања на локалитету Бело Брдо (ББ-115),` западно од копа Филијала. Магнетска сусцептибилности, кохерентна по интензитету и магнетским својствима, поклапа се са вредностима измереним на лапорцима Филијале. Супротно магнетској сусцептибилност, интензитет и правац РМ варира са дубином испитивања, што указује на средину са нестабилним физичко-хемијским условима у којој је долазило до стицања реманентне магнетизације током вишеструко поновљених трансформација магнетичних минерала.

Уочено је да панонски седименти код којих је доминантан магнетични минерал, магнетит, не поседују примаран магнетски запис због: (а) мале концентрације примарног магнетита који носи слаб реманентни сигнал и (б) честе трансформације примарног магнетита у секундаран.

Геолошки анали Балканскога полуострва Annales Géologiques de la Péninsule Balkanique	71	109–117	Београд, децембар 2010 Belgrade, December 2010

DOI: 10.2298/GABP1071109M

Synchrotron radiation X-ray tomographic microscopy (SRXTM) of brachiopod shell interiors for taxonomy: preliminary report

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Abstract. Synchrotron radiation X-ray tomographic microscopy (SRXTM) is a non-destructive technique for the investigation and visualization of the internal features of solid opaque objects, which allows reconstruction of a complete three-dimensional image of internal structures by recording of the differences in the effects on the passage of waves of energy reacting with those structures. Contrary to X-rays, produced in a conventional X-ray tube, the intense synchrotron light beams are sharply focused like a laser beam. We report encouraging results from the use of SRXTM for purely taxonomic purposes in brachiopods: an attempt to find a non-destructive and more efficient alternative to serial sectioning and several other methods of dissection together with the non-destructive method of X-ray computerised micro-tomography. Two brachiopod samples were investigated using SRXTM. In "*Rhynchonella" flustracea* it was possible to visualise the 3D shape of the crura and dental plates. In *Terebratulina imbricata* it was possible to reveal the form of the brachidium. It is encouraging that we have obtained such promising results using SRXTM with our very first two fortuitous samples, which had respectively fine-grained limestone and marl as infilling sediment, in contrast to the discouraging results communicated to us by some colleagues who have tested specimens with such infillings using X-ray micro-tomography. In future the holotypes, rare museum specimens or delicate Recent material may be preferentially subjected to this mode of analysis.

Key words: brachiopods, internal morphology, non-destructive technique, SRXTM, tomographic reconstructions, holotypes.

Апстракт. Синхротронска Х-зрачна томографска микроскопија (SRXTM) је недеструктивна техника за проучавање и сагледавање унутрашњих особина кад чврстих и непрозрачних објеката. Она омогућава потпуну реконструкцију тродимензијалног изгледа унутрашњих структура на основу снимања разлика у ефекатима енергетских зракова као реакција на те структуре. Насупрот Х-зрацима, произведеним у уобичајној Х-зрачној цеви, јаки синхротронски светлосни снопови су јасно фокусирани као ласерски сноп. Приказани су охрабрујући резултати добијени употребом SRXTM за таксономске сврхе код брахиопода: начин да нађемо недеструктивну и ефикаснију замену серијским пресецима, неких других метода сечења као и Х-зрачној компјутеризованој микро-томографији. Две брахиоподске пробе су проучаване помоћу SRXTM. Код "*Rhynchonella" flustracea* је било могуће сагледи 3Д облик круре и зубних плочица, а код *Terebratulina imbricata* добили смо изглед брахидијума. Насупрот обесхрабрујућим резултатима употребом Х-зрачне микро-томографије саопштених од стране неких колега ми смо добили позитивне резултате употребом SRXTM код наше прве две насумичне пробе на примерцима запуњеним финозрним кречњаком и лапорцем. У будућности, холотипови, ретки музејски примерци или деликатан савремен материјал моћи ће се проучавати на овај начин.

Кључне речи: брахиоподи, унутрашња морфологија, недеструктивна техника, SRXTM, томографске реконструкције, холотипови.

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Introduction

Brachiopods are one of the prime examples among all animal phyla in which the morphology of the shell interior has proved crucial for the classification and understanding of their phylogeny. In order to reveal the internal structures of fossil brachiopods with a consolidated internal matrix, destructive serial sectioning has most commonly been applied. In several cases, this technique is the only way possible to reveal the critical internal morphological features of many fossil taxa. The advantage of such destructive techniques is that they are usually relatively inexpensive and efficient. However, they have several major disadvantages: (i) destruction of the specimen; (ii) providing a poor volumetric (3D) representation of the internal structures; (iii) time and labour consuming. Many of the new brachiopod taxa investigated with this technique were based on a very small number of specimens (sometimes only one), thus only parts of the internal morphology of some species have been sufficiently studied and variability was often neglected and/or open nomenclature was applied more often than necessary.

A modern variant of serial sectioning is the method used by SUTTON *et al*. (2005) where the morphology of a new Silurian brachiopod was reconstructed digitally by serial grinding at 20-μm intervals.

Here we report some pilot studies using a novel and relatively advanced method to reveal the internal morphology of fossil brachiopods. Synchrotron radiation X-ray tomographic microscopy (SRXTM) is a non-destructive technique for the investigation and visualization of the internal features of solid opaque objects, which allows reconstruction of a complete three-dimensional image of internal structures by recording of the differences in the effects on the passage of waves of energy reacting with those structures. It uses a synchrotron, a form of particle accelerator, as a bright monochromatic X-ray source. Contrary to X-rays, produced in a conventional X-ray tube, the intense synchrotron light beams are sharply focused like a laser beam. The wavelengths range from infrared to hard X-rays. SRXTM can produce tomographic data of exceptional resolution and clarity (SUTTON 2008).

Material and Methodology

The analyses were performed at the Swiss Light Source (SLS), Paul Scherrer Institute, Villigen, Switzerland. The SLS (Fig. 1) is a third-generation synchrotron light source. With energy of 2.4 GeV, it provides photon beams of high brightness for research in materials science, biology and chemistry.

We have applied SRXTM for three-dimensional reconstructions of the internal morphology of two pilot fossil brachiopod samples: (i) the rhynchonellide *"Rhynchonella" flustracea* Schlotheim from Faxe Quarry, Paleogene (Danian) of Denmark; (ii) the terebratulide *Terebratulina imbricata* Owen from the Cretaceous (Lower Cenomanian) in northern Bulgaria.

SRXTM in this study was performed at the TOMCAT beamline (Fig. 2) at SLS (STAMPANONI *et al*.

Fig. 1. Interior view of the experimental hall at the Swiss Light Source SLS (*Photo credit: H.R. Bramaz/PSI, source: http://www.psi.ch/media/MM20071121FrueheVerwandteDE/igp_1024x640%3E_MM071121_sls.jpg)*.

Fig. 2. The TOMCAT Beamline at the SLS, *source: http://www.panoramio.com/photo/10865922.*

Fig. 3. External dorsal view of the rhynchonellide brachiopod “*Rhynchonella” flustracea* from the Danian of Denmark.

2006). According to the absorption properties of the samples, monochromatic X-ray beams, respectively 20 keV (for “*Rhynchonella” flustracea*) and 33 keV (for *Terebratulina imbricata*) have been used. The magnification of the X-ray microscope was X4. A scintilator LAG: Ce 20 um was used. The number of projections for both specimens is 1501. Reconstruction was performed on a 32 node Linux PC farm using highly optimized filtered back projection routines.

Slice data derived from the scans were then analyzed and manipulated using Aviso 5.0 on a Dell Precision T 7400 PC with 64 GB DDR SDRAM at the Natural History Museum, Stockholm.

The specific investigative parameters for the two samples were: (i) for “*Rhynchonella” flustracea* the energy was 20 keV; objective - 4X; exposure time 300 ms; voxel size 1,85 µm; (ii) for *Terebratulina imbricata* on-chip binning (2X) was used; energy 33 keV; objective 4X; exposure time 400 ms; voxel size 3,7 µm.

Results

“*Rhynchonella” flustracea* Schlotheim (Fig. 3): The infilling sediment in this species was fine-grained limestone. Using SRXTM it was possible to visualise the 3D shape of the crura, the lack of hinge plates, the orientation and thickness of the dental plates (Figs. 4a, b) that helped to confirm our hypothesis that this species belongs to a new basiliolide genus (to be formally erected elsewhere).

Terebratulina imbricata Owen (Figs. 5, 6): The infilling sediment in *T. imbricata* was marl. It was possible to reveal the form of the brachidium in cross and longitudinal (Fig. 7) sections, especially the details of the tetebratulide loop forming a ring. Some traces of growth of shell material in the umbonal part were also observed (Fig. 5.4). Such growth structures are not usually revealed using X-ray computerised microtomography (Pakhnevich, pers. com. 2010).

Discussion

Non destructive techniques for the study of the brachiopod shell interior were applied for the first time by Hagadorn & Nealson (2001), Hagadorn *et al.* (2001) and later by Pakhnevich (2007; 2010a, b),

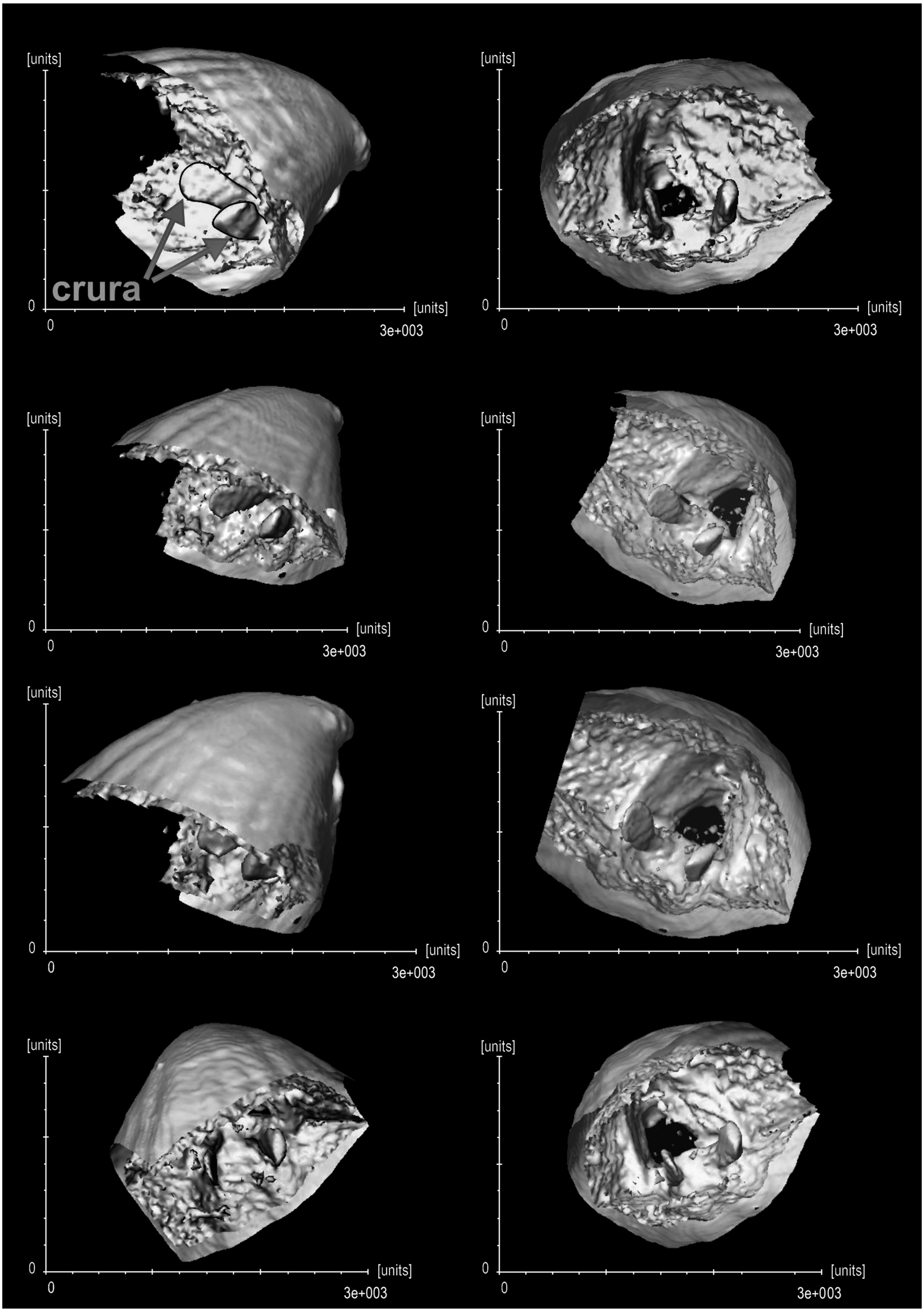

Fig. 4. Several views of tomographic reconstructions of the internal umbonal part of intact "*Rhynchonella*" *flustracea.* Anterior part of the shell virtually 'removed' to allow visual access to the interior of the umbonal part. Scale: one unit on ***x*** and ***y*** equal to 0.25 mm.

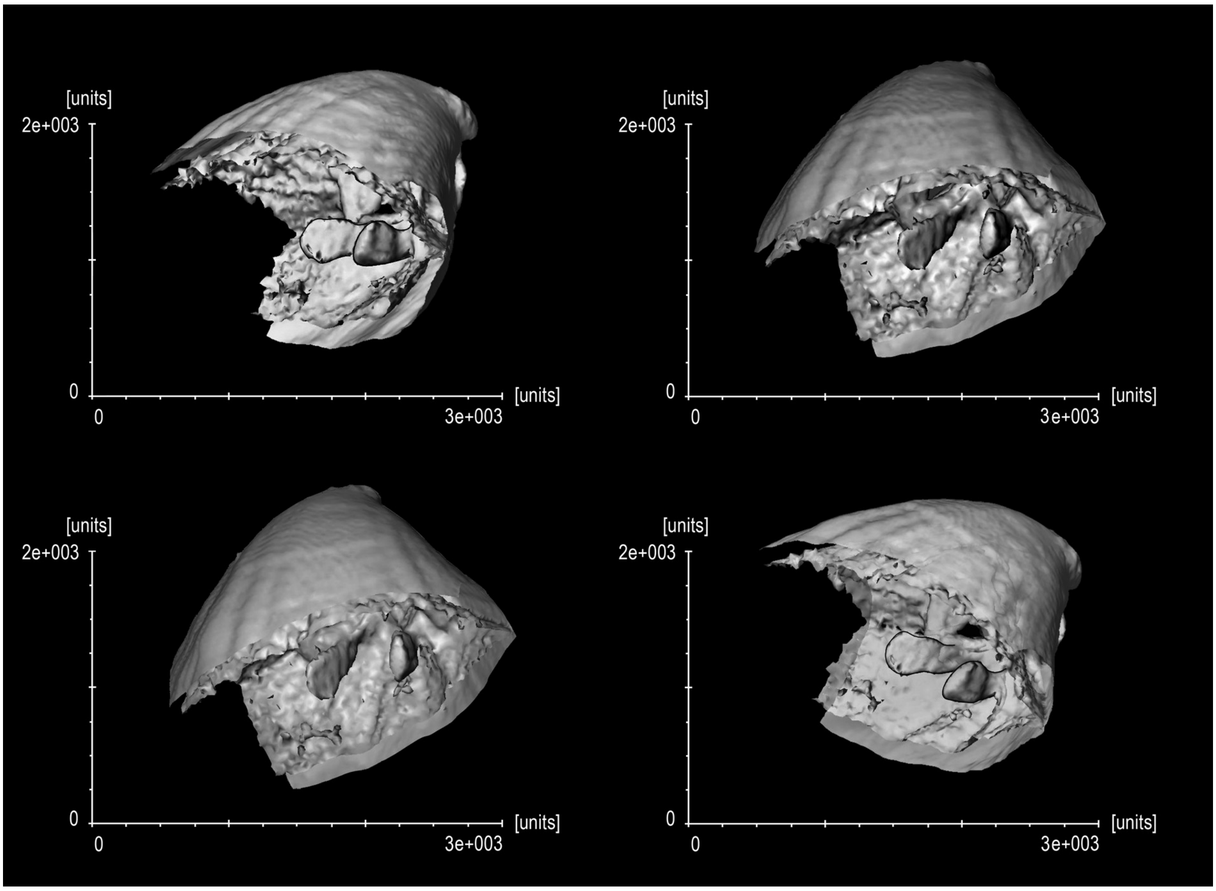

Fig. 4. Continued.

who reported successful experiments using X-radiographic computed axial tomography in a number of conference abstracts and papers but without providing any illustrations. Pakhnevich (2008, 2009a, b) illustrated for the first time some promising results using X-ray computerised microtomography (micro CT) on brachiopods interiors and shell structure. However, the effectiveness of the micro CT technique depends on the mineral composition of both brachiopod shells and host rock. Pakhnevich (2009a) performed extensive experiments to test the contrast of the 3D images depending on the mineral and rock compositions of different palaeontological specimens including brachiopods. He developed a scale of contrasts where he divided the studied minerals in 10 groups according to their contrast under micro CT Skyscan 1172. Recently, Angiolini *et al.* (2010) also reported that due to the intrinsic limit of this method based on density differences, only brachiopods filled with sandstone produced valuable CT images showing details of the cardinalia. Out of the many micritic limestone, bioclastic limestone and marlstone infilling the brachiopod interiors, in one case only satisfactory CT images were obtained by these authors due to the presence of a thin void layer (dark grey in the images) between the internal structures and the micritic matrix. The more extensive survey by Pakhnevich (2009a; 2010a) on the matrix showed that silicified, ferruginised, or pyritised shells demonstrate clear contrasts in a carbonate rock. Calcite shells in phosphorite rocks and dolomitised shells in carbonate rocks show insufficient contrasts.

In brachiopod research SRXTM was previously used to obtain three-dimensional information from Recent brachiopods to ascertain the function and growth of punctae in the shell and increase our understanding of the role of cell biology in the context of biomineralisation (Pérez-Huerta *et al.* 2009).

Here we report encouraging results from the use of SRXTM for purely taxonomic purposes: an attempt to find a non-destructive and more efficient alternative to serial sectioning and several other methods of dissection together with the non-destructive method of X-ray micro CT. The scans for our pilot attempts were carried out at the lowest available resolution, one that could be accomplished by more easily accessible X-ray micro-tomography scanners that are available at several institutions worldwide. X-ray tomographic microscopy is now a rather a routine method for several other groups of fossils (Sutton 2008), but not, to date, for brachiopods.

It is encouraging that we have obtained such promising results using SRXTM with our very first two fortuitous samples, which had respectively fine-

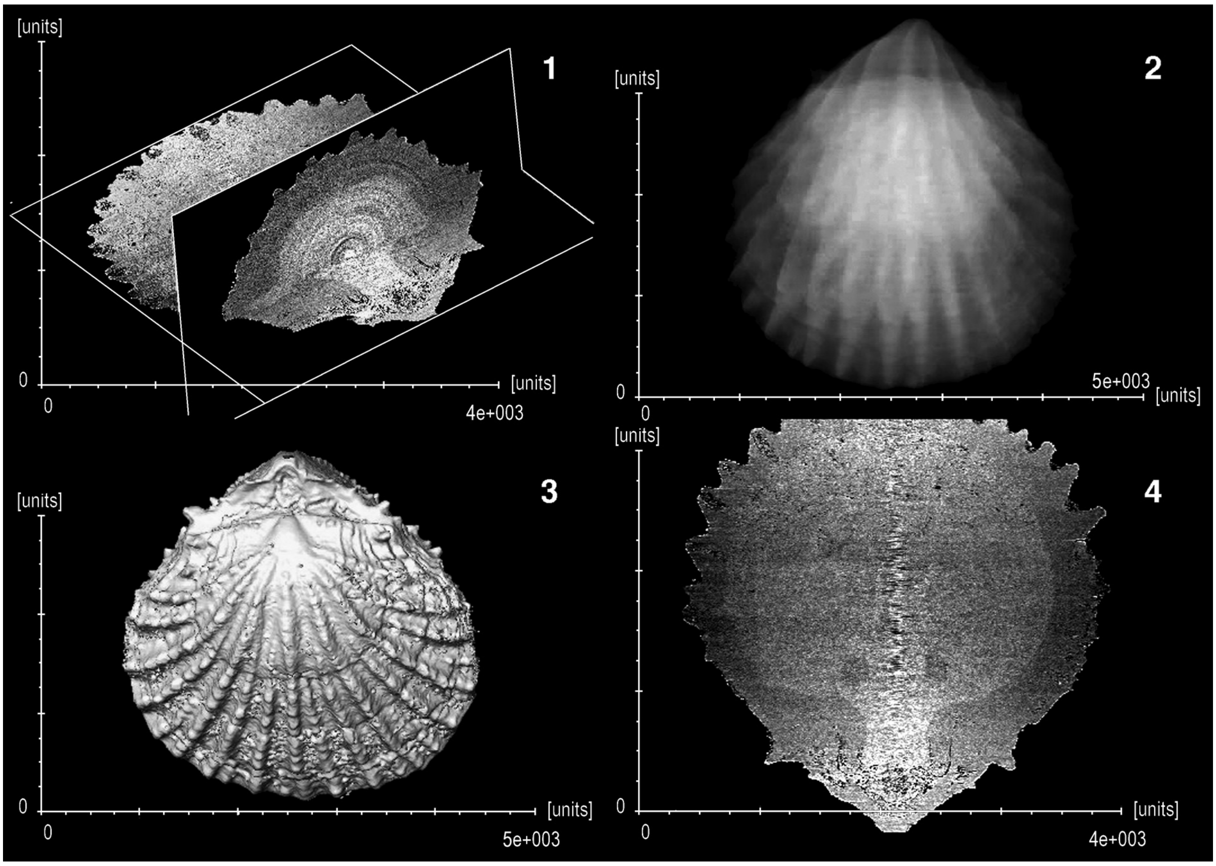

Fig. 5. Tomographic reconstructions of *Terebratulina imbricata*, 3.5 mm long. **1,** Orthogonal slices in *xy* and *xz* directions – general view; **2,** Volume rendering of the specimen (Voltex); **3,** Shape and external morphology of the specimen (isosurface) – dorsal view; **4,** Orthogonal slice in ***xz*** direction (longitudinal section). Note the traces of growth of shell material in the umbonal part.

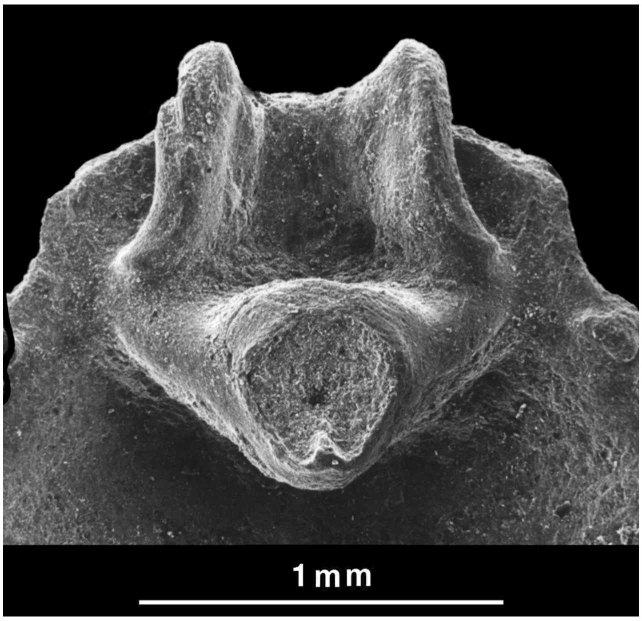

Fig. 6. A SEM micrograph of a prepared dorsal valve of another specimen of *Terebratulina imbricata* showing the shape of the cardinalium which can be revealed on the longitudinal sections obtained by the SRXTM (see Fig. 7). Courtesy M.A. BITNER.

grained limestone and marl as infilling sediment, in contrast to the discouraging results communicated to us by some colleagues who have tested specimens with such matrices using X-ray micro-tomography.

A major disadvantage of SRXTM, however, is that it is quite expensive and not readily accessible to taxonomists.

ALVAREZ & BRUNTON (2008) noted that very often, due to the scarcity of well-preserved specimens and the destructive nature of the technique, some authors chose the worst specimens for serial sectioning, keeping the best preserved (frequently only one) for the holotype. In future the holotypes may be preferentially subjected to this mode of analysis in order to check their conspecificity with the sectioned paratypes. Rare museum specimens or delicate Recent material can also be subjected to non destructive analyses (PAKHNEVICH, 2010). SRXTM and X-ray micro-tomography are also useful for the investigation of shell microstructure, microtexture and punctation (PÉREZ-HUERTA *et al.* 2009; PAKHNEVICH 2008, 2010a).

The X-ray tomographic microscopy and specifically SRXTM provides an opportunity to study the interiors of many taxa established only on exteriors, con-

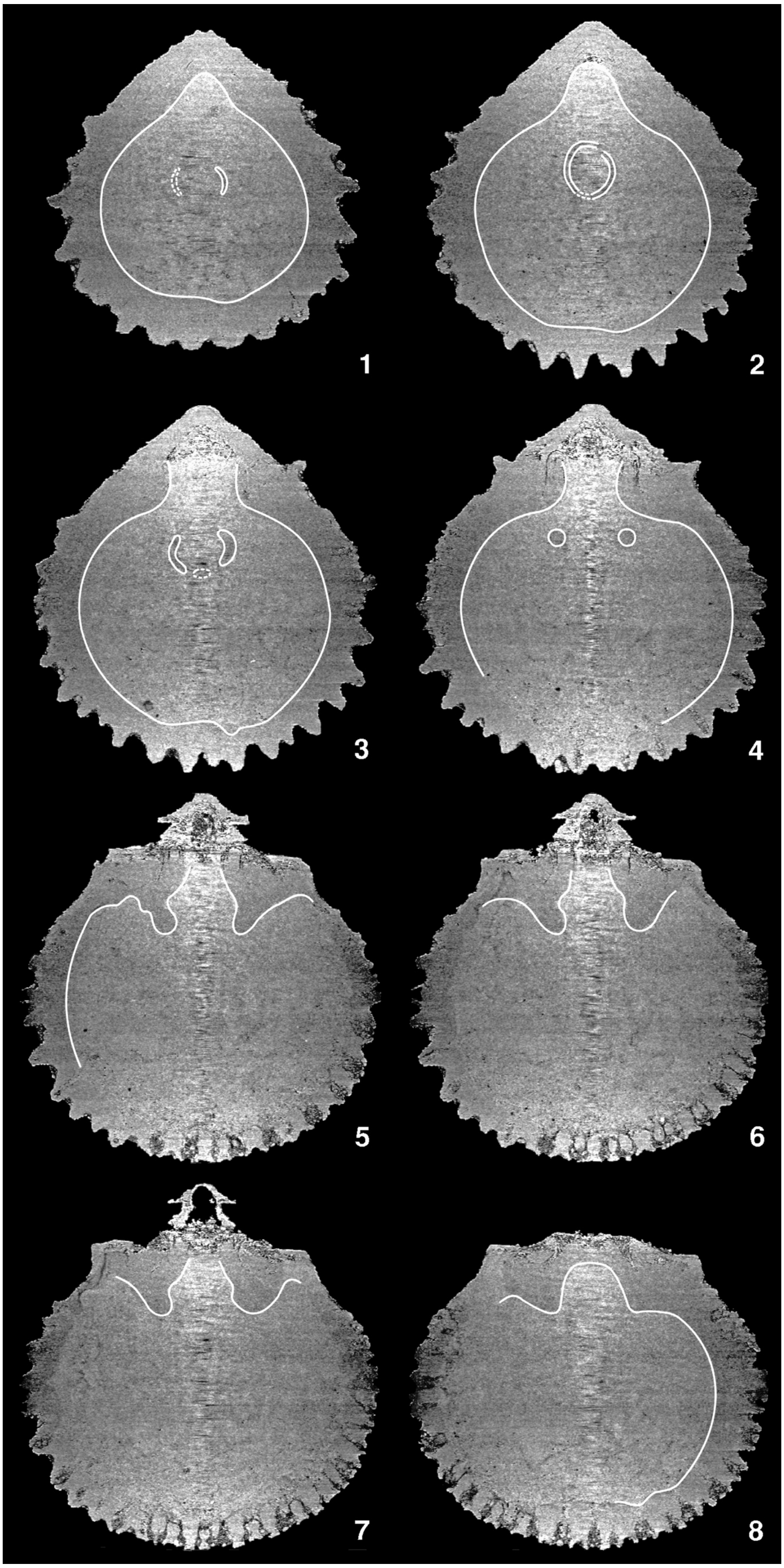

Fig. 7. Eight longitudinal sections of *Terebratulina imbricata* – tomographic reconstructions of the intact specimen on Fig. 5 obtained by the SRXTM (the most important outlines highlighted in white). Note the almost complete section of the ring in the second section.

firming or otherwise their taxonomic placement. We hope that this new methodology will also stimulate the study of intraspecific and intrageneric variability when enough material is available and help avoiding unjustified splitting or lumping in brachiopod taxonomy due to insufficient data on internal structures.

Acknowledgments

Our special thanks go to STEFAN BENGTSON and VENETA BELIVANOVA (Swedish Museum of Natural History, Stockholm) who generously performed all the analyses within the framework of their joint project with P.C.J. DONOGHUE (Bristol University). Kind help from M. STAMPANONI and F. MARONE at SLS is gratefully acknowledged. A. ILCHEVA (Sofia) provided technical assistance with processing the illustrations. NM-D was supported by three SYNTHESYS grants from the European Community Research Infrastructure Action under the FP6: DK-TAF-939 (2005), BE-TAF-4746 (2008) and major funding was received from the project SE-TAF-3928 (2008). DATH thanks the Carlsberg Foundation (Denmark) for support. Finally, we are grateful to the journal reviewers, A. PAKHNEVICH (Moscow) and E. SIMON (Brussels) for their useful comments.

References

ALVAREZ, F. & BRUNTON, C.H.C. 2008. On the reliability of reconstructing and comparing brachiopod interiors and their morphological variations based solely on serial sections. *Proceedings of the Royal Society of Victoria,* 120 (1): 58–74.

ANGIOLINI, L., BARBERINI, V., FUSI, N. & VILLA, A. 2010. The internal morphology of brachiopods under X-ray computerized tomography (CT). *6th International Brachiopod Congress, 1-5 February 2010, Abstracts*, 95: 7–8. Geological Society of Australia, Melbourne.

HAGADORN, J.W., WHITELEY, T. & NEALSON, K.H. 2001. 3D imaging of pyritized soft tissues in Paleozoic konservatlagerstätten. *Geological Society of America, Abstracts with Programs*, 33: 430–431.

HAGADORN, J.W. & NEALSON, K.H. 2001. X-radiographic computed axial tomography: New tool for astro/geo/paleobiology? *Journal of Conference Abstracts,* 6: 777, European Union of Geosciences.

PAKHNEVICH, A.V. 2007. Studying of fossil invertebrates for example brachiopods by using of the X-ray micro-CT Skyscan 1172. *SkyScan User Meeting*, p. 11, Brugge.

PAKHNEVICH, A.V. 2008. Micro-CT of geyserite, fossil wood and structure of brachiopod shells. *SkyScan User Meeting* (Antwerp, 16–17 June 2008): 4 p.

PAKHNEVICH, A.V. 2009a. On effectiveness of micro-CT research of paleontological objects. *Modern paleontology: classical and new methods*, 127–141 (in Russian, English summary).

PAKHNEVICH, A.V. 2009b. Reasons of micromorphism in modern or fossil brachiopods. *Paleontological Journal*, 43 (11): 1458–1468.

PAKHNEVICH, A.V. 2010a. Micro CT investigations of Recent and fossil brachiopods. *6th International Brachiopod Congress, 1-5 February 2010, Abstracts*, 95: 85, Geological Society of Australia, Melbourne.

PAKHNEVICH, A.V. 2010b. Using x-ray micro-ct for study of Devonian brachiopods ("lamp shells"). *SkyScan User Meeting*, 198–200, Mechelen.

PÉREZ-HUERTA, A., CUSACK, M., MCDONALD, S., MARONE, F., STAMPANONI, M. & MACKAY, S. 2009. Brachiopod punctae: A complexity in shell biomineralisation. *Journal of Structural Biology,* 167: 62–67.

STAMPANONI, M., GROSO, A., ISENEGGER, A., MIKULJAN, G., CHEN, Q., BERTRAND, A., HENEIN, S., BETEMPS, R., FROMMHERZ, U., BÖHLER, P., MEISTER, D., LANGE, M. & ABELA, R. 2006. Trends in synchrotron-based tomographic imaging: The SLS experience. *In*: *Developments in X-Ray Tomography, V Proc. SPIE* 6318, 63180M.

SUTTON, M.D. 2008. Tomographic techniques for the study of exceptionally preserved fossils. *Proceedings of the Royal Society, Series B,* 275: 1587–1593.

SUTTON, M.D, BRIGGS, D.E., SIVETER, D.J. & SIVETER, D.J. 2005. Silurian brachiopods with soft-tissue preservation. *Nature*, 436: 1013–1015.

Резиме

Синхротронска X-зрачна томографска микроскопија (SRXTM) унутрашњости брахиоподске љуштуре значајне за таксономију: прелиминарни извештај

Брахиоподи су један од најбољих примера у животињском царству у коме је унутрашња морфологија љуштуре од кључног значаја за класификацију и разумевање њихове филогеније. У циљу откривања унутрашњих структура фосилних брахиопода са консолидованим унутрашњим матриксом, најчешће се примењује деструктивна серија пресека. У неколика случајева ова техника је једини начин да откријемо веома важне унутрашње морфолошке особине фосилних таксона. Предност овакве деструктивне технике је у томе што је она обично релативно јефтина и ефикасна. Међутим она има неколико недостатака: (1) уништавање примерка, (2) дају лошу просторну слику унутрашњих карактеристика и (3) захтева време и рад. Многи до сада проучавани таксони са овом техником су засновани на веома малом броју примерака (понекад на само једном примерку), тако да је само делимично проучавана унутрашња морфологија, док је варијабилност често занемаривана, тако да је отворена номенклатура често примењивана.

Овом приликом, употребом нове и сасвим напредне методе, приказана је пробна студија за

проучавање кардиналијума фосилних брахиопода. Синхротронска X-зрачна томографска микроскопија (SRXTM) је недеструктивна техника за проучавање и сагледавање унутрашњих особина кад чврстих и непрозрачних објеката, која омогућава потпуну реконструкцију тродимензијалног изгледа унутрашних структура на основу снимања разлика у ефекатима енергетских зракова као реакција тих структура. Она користи синхротрон (врста акцелератора) као извор монохроматских X-зрака. SRXTM може да производи томографске податке изузетне резолуције и јасноће (SUTTON 2008). Употребом SRXTM добили смо тродимензионалне податке о унутрашњој морфологији два фосилна брахиоподска таксона: (1) ринхонелид "*Rhynchonella*" *flustracea* SCHLOTHEIM из палеогена Faxe Quarry у Данској и (2) теребратулид *Terebratulina imbricata* OWEN из доњег ценомана северне Бугарске. Ове анализе су обављене код Swiss Light Source (SLS), Институт Паул Шерер, Вилиген, Швајцарска. Код "*Rh.*" *flustracea* mogli смо да посматрамо облик крура (види стрелице код сл. 4) која је помогла да докажемо нашу предпоставку да ова врста припада новом басилиолидном роду (који ће бити ускоро уведен), док код *T. imbricata* било је могуће да добијемо детаље теребратулидске петље која формира прстен. SRXTM је раније била употребљивана за добијање тродимензионалних података, упознавање функције и раста пункти љуштуре и бољег разумевања улоге цитологије у контексту биоминерализације рецентних брахиопода (PÉREZ-HUERTA *et al.* 2009). Приказани су охрабрујући резултати употребом SRXTM за основне таксономске сврхе: покушај да се нађе замена за методе серијских пресека као и других метода сечења. Скенови су урађени у најнижој резолуцији тако да се ова метода може користити и са више прихваћеним X-зрачним микротомографским скенерима које поседују неколико институција у свету. X-зрачна томографска микроскопија је сада рутинска метода за неколико других фосилних група (SUTTON 2008).

Веома често, због недостатака добро очуваних примерака и деструктивне технике, неки аутори користе оштећене примерке за серије пресека, чувајући најбоље очуван примерак за холотип. У будуће холотипови могу бити приоритетни предмет оваквог начина проучавања у циљу провере њихове конспецифичности са сеченим паратиповима. X-зрачна томографска мокроскопија пружа могућност за проучавање унутрашњости многих таксона уведених само на основу спољашњости, потврђујући или оспоравајући њихову таксономску припадност.

Геолошки анали Балканскога полуострва Annales Géologiques de la Péninsule Balkanique	71	119–125	Београд, децембар 2010 Belgrade, December 2010

DOI: 10.2298/GABP1071119D

Middle Jurassic radiolarian assemblages from Zlatar Mt. (SW Serbia)

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Abstract. Detailed micropalaeontological research of Jurassic siliceous rocks was performed at the locality Komarani on the eastern flanks of the area of Mt. Zlatar in SW Serbia. According to the determined radiolarian associations, the investigated radiolarites are of Late Bajocian to Early Callovian age.

Key words: Middle Jurassic, radiolarians, Internal Dinarides, Komarani Village, SW Serbia.

Апстракт: На локалитету Комарани, на источним падинама планине Златар (ЈЗ Србија) извршена су детаљна микропалеонтолошка истраживања јурских силицијских седимената. На основу одређених радиоларијских асоцијасија утврђена је горњобајеска до доњокеловејска старост радиоларита локалитета Комарани.

Кључне речи: средња јура, радиоларије, Унутрашњи Динариди, село Комарани, ЈЗ Србија.

Introduction

The investigated area is situated in western Serbia, in an extremely complex geotectonic setting (Fig. 1). There are two belts of ophiolitic mélange in the territory of western Serbia. Petrographic and geochemical differences between the ophiolites of the two belts were used as evidence for the existence of two distinct oceanic basins, originally separated by one or several Adria-derived micro-continents (Robertson & Karamata 1994; Dimitrijević 1997 and Karamata 2006). The more external belt is known as the Dinaridic Ophiolite Belt (Pamić *et al*. 2002 and Karamata 2006) or the Central Dinaridic Ophiolite belt (Lugović *et al*. 1991), while the internal belt is known as the Vardar Zone Western Belt (Karamata 2006), Inner Dinaridic ophiolite belt (Lugović *et al.* 1991), External Vardar Subzone (Dimitrijević 1997, 2001) or simply the Vardar Zone (Pamić *et al*. 2002). This "two ocean" model contrasts with that of Pamić (1998), Pamić *et al*. (2000), Csontos *et al*. (2003) and Schmid *et al*. (2008), who suggested that both ophiolitic belts originated in a single ocean. Schmid *et al*. (2008) considered the two belts of ophiolites as relics of the same, formerly coherent ophiolitic sheet (their Western Vardar Ophiolitic Unit) that was obducted onto the Adriatic passive margin in the Late Jurassic. Parts of the Adriatic margin, which occur below the ophiolitic units in the form of windows, were interpreted as microcontinents by earlier authors.

The ophiolite belts in western Serbia are separated by the Drina–Ivanjica Unit. The majority of authors regarded the Drina–Ivanjica Unit as a continental terrane that was originally located between two separate oceanic basins (Dimitrijević & Dimitrijević 1973; Robertson & Karamata 1994; Dimitrijević 2001; Karamata 2006). Others were of the opinion that this element was formed by out-of-sequence thrusting from the European margin (Pamić *et al*. 1998; Pamić & Hrvatović 2003). According to Schmid *et al*. (2008), the Drina–Ivanjica is a thrust sheet which was probably emplaced on top of the East Bosnian–Durmitor thrust sheet in the Early to mid-Cretaceous times. Similar to the East Bosnian-Durmitor composite thrust sheet, the Drina–Ivanjica thrust sheet passively carried the previously obducted Western Vardar ophiolites (Zlatibor ophiolites).

Due to the tectonic position of the investigated area, this paper is an important contribution to a bet-

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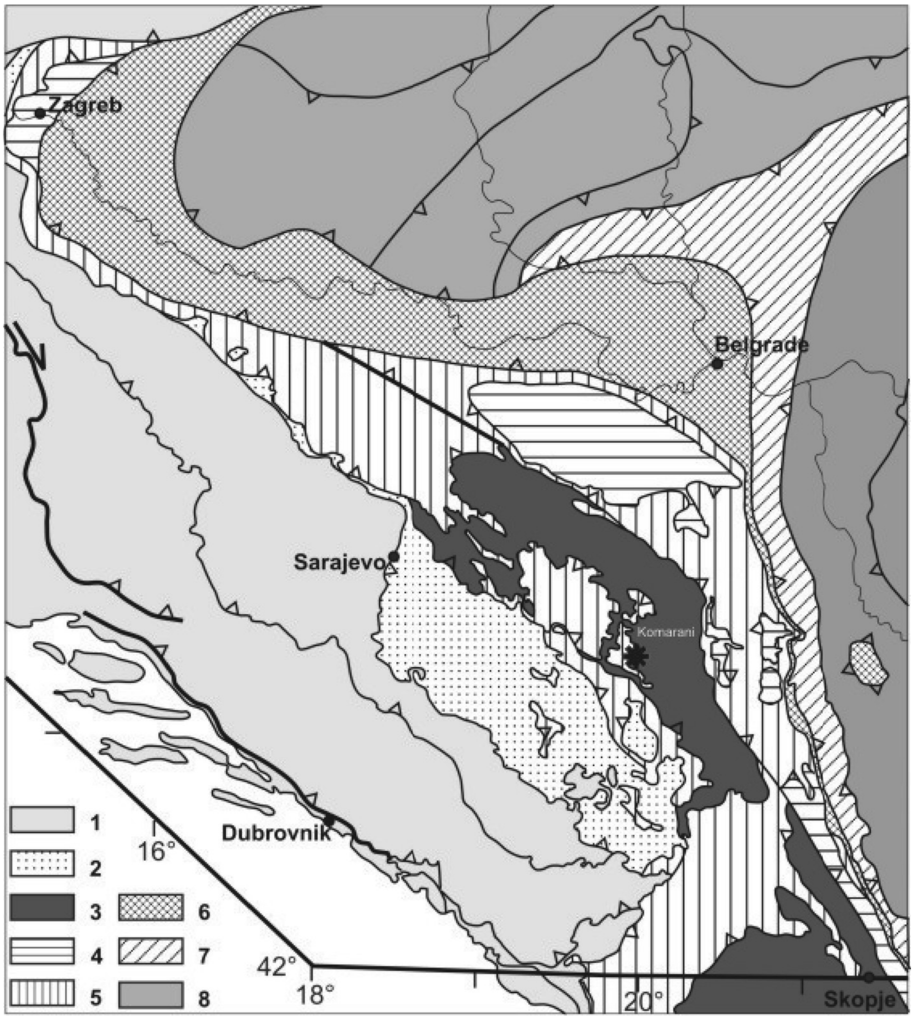


Fig. 1. Tectonic sketch of the Dinarides (after SCHMID *et al.* 2008), indicating the position of the studied locality. The units mapped are, from external to internal: **1,** External Dinarides (without subdivisions); **2,** East Bosnian–Durmitor Unit; **3,** Drina Ivanjica Unit (parallelized with the Korab Unit of Albania or the Pelagonian Massif of Greece, part of the Internal Dinarides); **4,** Jadar and Kopaonik blocks (part of the Internal Dinarides); **5,** Dinaridic and Western Vardar ophiolites (parallelized with the Mirdita ophiolites of Albania, obducted onto the internal Dinarides in Jurassic times); **6,** Sava Belt (Paleogene suture zone); **7,** Eastern Vardar Ophiolites; **8,** "European" units (Tisza-Dacia and Carpatho-Balkan).

ter understanding of the geological evolution of the area, which will enable comparison with similar rocks in the surrounding regions.

Geological setting

Very thick Jurassic radiolarite successions are typical for the area of the Zlatar Mt. A widely accepted opinion among Serbian geologists is that the association of siliceous rocks (cherts and radiolarites) that belong to the Zlatar Formation represents a sedimentary cover of an oceanic crust (RADOVANOVIĆ 1987, 2000). According to other opinions, Jurassic radiolarites are not necessarily a part of an *in situ* preserved stratigraphic cover of an ophiolitic sequence, but that they could also occur as gravitationally emplaced olistoliths or olistoplake (DIMITRIJEVIĆ 1997), or as tectonically incorporated slices torn off the Adriatic margin and incorporated into the mélange below the obducted ophiolite (DJERIĆ *et al*. 2007a; SCHMID *et al*. 2008). The third, largest group includes radiolarite strata deposited onto the drowning passive margin of the Adria (East Bosnian–Durmitor nappe and Drina–Ivanjica thrust sheet) (DJERIĆ *et al*. 2007a).

The radiolarites found at the locality Komarani could be a part of the ophiolitic mélange that structurally underlies the ophiolites of the Dinaridic Ophiolite Belt (KARAMATA *et al*. 1997). Alternatively, they could also represent the matrix (could also be a block in the mélange) of the mélange formation of the East Bosnian–Durmitor Unit (DJERIĆ *et al*. 2007b).

Material and Methods

The described radiolarian assemblages originated from one single section at the Komarani Village (Fig. 1). Four samples were taken from the radiolarites at the locality Komarani, but only two were positive. The chert samples were treated only with dilute 5–7 % hydrofluoric acid, following the method of PESSAGNO & NEWPORT (1972). In all samples, nassellarians were much more abundant than spumellarians. The residues of the acid treatment, which yielded well preserved faunas, were studied for biostratigraphic purposes. In order to establish the age of the radiolarian assemblages, the zonation schemes proposed by BAUMGARTNER *et al.* (1995) were used. An SEM microscope ISI-160 in GIN RAN (Moscow) was utilized for the precise identification and illustration of the radiolarians. These are illustrated in Plate 1. The micropaleontological material is housed at the Faculty of Mining and Geology in Belgrade (registration numbers NĐ 328 and NĐ 329).

Section description and biostratigraphy

The locality is, actually, an abandoned chert quarry in the Komarani Village, by the road Nova Varoš–Akmačići–Komarani–Pavlovića Brod (x = 7411117, y = 4811144). The investigated section is composed of alternating thin-bedded silicified siltstone and dark brown to black thin- to medium-bedded radiolarite. Siltstone is the predominating rock. The actual thickness of the radiolarite in this section can not be determined because the layers are extremely tectonically deformed. These radiolarites might belong to the ophiolitic mélange situated below the ophiolites of the Dinaridic Ophiolite Belt (KARAMATA *et al*. 1997). On the other hand, the radiolarites might be the matrix of the mélange in the East Bosnian–Durmitor Unit (DJERIĆ *et al*. 2007b).

Four samples were taken from the radiolarites in the quarry, but only two were positive.

Sample NĐ 328 was taken from dark brown, thin-bedded, partly clayey radiolarite. The fauna is sparse, poorly preserved, with mostly broken or deformed forms. The following species were identified: *Triversus hungaricus* (KOZUR), *Cinguloturris getsensis* O'DOGHERTY, GORIČAN & DUMITRICA, *Eucyrtidiellum* sp. cf. *E. semifactum* (NAGAI & MIZUTANI), *Unuma* sp. cf. *U. gordus* HULL, *Williriedellum* (?) sp. and *Hiscocapsa* sp. (Plate 1).

The uppermost Bajocian to Early Callovian (UAZs 5–7) age of the chert is based on the identified *Eucyrtidiellum* sp. cf. *E. semifactum*.

Sample NĐ 329 was taken from glassy, dark gray compact radiolarite. The radiolarian association is abundant and versatile. The following species were identified: *Dictyomitrella* ? *kamoensis* MIZUTANI & KIDO, *Eucyrtidiellum unumaense s.l.* YAO, *Williriedellum tetragona* (MATSUOKA), *Protunuma* ? *ochiensis* MATSUOKA, *Williriedellum* sp. aff. *W. yaoi* (KOZUR), *Williriedellum carpathicum* DUMITRICA, *Stichocapsa japonica* YAO, *Unuma gordus* HULL, *Unuma* sp. cf. *U. gordus*, *Triversus kasinzovae* VISHNEVSKAYA, *Stichocapsa* sp., *Protunuma* sp., *Unuma* sp., *Dictyomitrella* sp., *Xitus* (?) sp. i *Zhamoidellum* sp. (Plate 1).

Late Bathonian to Early Callovian age (UAZ 7) was established according to the presence of *Dictyomitrella* ? *kamoensis* (UAZs 3–7; BAUMGARTNER *et al*., 1995) and *Williriedellum carpathicum* (UAZs 7–11; BAUMGARTNER *et al*., 1995).

Final remarks

Siliceous deposits from the Komarani locality consist of radiolarian cherts with clay and silicified siltstone. Based on the radiolarians, the analyzed cherts were deposited between the Latest Bajocian and Early Callovian. The radiolarian association in the sample NĐ 329 is more abundant and versatile, thus it indicates a shorter time interval – Late Bathonian to Early Callovian. Radiolarites that represent the matrix (could also be a block in the mélange) were also observed in a nearby locality Abeško Brdo (area of Sjenica, SW Serbia). The age of the radiolarites from the locality Abeško Brdo is compatible with the age of the siliceous sediments in the locality Komarani (Callovian; GAWLICK *et al*. 2009). The radiolarian associations from the locality Komarani are correlatable with the radiolarian associations identified from sediments of the central Pontides in northern Turkey (BRAGIN *et al*. 2002), in the West Carpathians (RAKUŠ & OŽVOLDOVA 1999), as well as with the Upper Bajocian to Oxfordian associations from the sedimentary cover of ophiolites in Albania (MARCUCCI *et al.* 1994). Similar radiolarian associations are known from a locality on the Mangart Mt. in Slovenia (ŠMUC & GORIČAN 2004), the Medvednica Mt. in NW Croatia (HALAMIĆ *et al*. 1999), as well as from the Mirdita area in Albania (CHIARI *et al*. 1994; PRELA 1994).

Acknowledgments

The authors gratefully acknowledge the reviewers, VALENTINA VISHNEVSKAYA (Moscow) and NIKITA BRAGIN (Moscow), for their constructive comments on the manuscript. The work was supported by the Serbian Ministry of Science and Technological Development (Project No. 146009).

References

BAUMGARTNER, P.O., BARTOLINI, A., CARTER, E.S., CONTI, M., CORTESE, G., DANELIAN, T., DE WEVER, P., DUMITRICA, P., DUMITRICA-JUD, R., GORIČAN, Š., GUEX, J., HULL, D., KITO, N., MARCUCCI, M., MATSUOKA, A., MURCHEY, B., O'DOGHERTY, L., SAVARY, J., VISHNEVSKAYA, V., WIDZ, D., & YAO, A. 1995. Middle Jurassic to Early Cretaceous radiolarian biochronology of Tethys based on Unitary Associations. *In*: BAUMGARTNER, P.O., O'DOGHERTY, L., GORIČAN, Š., URQUHART, E., PILLEVUIT, A. & DE WEVER, P. (eds.), Middle Jurassic to Lower Cretaceous radiolaria of Tethys: Occurrences, Systematics, Biochronology. *Mémories de Géologie*, 23: 1013–1048.

BRAGIN, N.YU, TEKIN, U.K. & ÖZCELIK, Y. 2002. Middle Jurassic radiolarians from the Akgöl Formation, central Pontids, northern Turkey. *Neues Jahrbuch für Geologie und Paläontologie, Monatshefte*, 10: 609–628.

CHIARI, M., MARCUCCI, M. & PRELA, M. 1994. Mirdita ophiolites Project: 2. Radiolarian assemblages in the cherts at Fushe Arrez and Shebaj (Mirdita Area, Albania). *Ofioliti,* 19 (2a): 313–318.

CSONTOS, L., GERZINA, N., HRVATOVIĆ, H., SCHMID, S. & TOMLJENOVIĆ, B. 2003. Structure of the Dinarides: a working model. *Annales Universitatis Scientiarum*

Budapestinensis, Sectio geologica, 35: 143–144, Budapest.

DIMITRIJEVIĆ, M.D. 1997. *Geology of Yugoslavia*. 187 pp. Geological Institute GEMINI Special Publication, Belgrade.

DIMITRIJEVIĆ M.D. 2001. Dinarides and the Vardar Zone: a short review of the geology. *Acta Vulcanologica,* 13: 1–8.

DIMITRIJEVIĆ, M.D. & DIMITRIJEVIĆ, M.N. 1973. Olistostrome Mélange in the Yugoslavian Dinarides and Late Mesozoic Plate Tectonics. *Journal of Geol*ogy, 81: 328–340.

DJERIĆ, N., GERZINA, N. & SCHMID, M.S. 2007a. Age of the Juarassic radiolarian chert formation from the Zlatar Mountain (SW Serbia). *Ofioliti*, 32 (2): 101–108.

DJERIĆ, N., VISHNEVSKAYA, V. & SCHMID, M.S. 2007b. New data on radiolarians from the Dinarides (Bosnia and Serbia). *8th Workshop on Alpine Geological Studies*, *Davos/Switzerland, 10–12. October 2007*, Abstracts, 17–18.

GAWLICK, H.J., SUDAR, M., SUZUKI, H., DJERIĆ, N., MISSONI, S., LEIN, R. & JOVANOVIĆ D. 2009. Upper Triassic and Middle Jurassic radiolarians from the ophiolitic melange of the Dinaridic Ophiolite Belt, SW Serbia. *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen*, 53 (2–3): 293–311.

HALAMIĆ, J., GORIČAN, Š., SLOVENEC, D. & KOLAR-JURKOVŠEK, T. 1999. A Middle Jurassic Radiolarite-Clastic Sucession from the Medvednica Mt. (NW Croatia). *Geologia Croatica* 52 (1): 29–57.

KARAMATA, S. 2006. The geological development of the Balkan Peninsula related to the approach, collision and compression of Gondwana and Eurasian units. *In*: ROBERTSON, A.H.F. & MOUNTRAKIS, D. (eds.), *Tectonic Development of the Eastern Mediterranean Region*. Geological Society London Special Publications, 260: 155–178.

KARAMATA, S., KRSTIĆ, B., DIMITRIJEVIĆ, M. D., DIMITRIJEVIĆ, M. N., KNEŽEVIĆ, V., STOJANOV, R. & FILIPOVIĆ, I. 1997. Terranes between the Moesian Plate and the Adriatic Sea. *Annales Géologie Pays Hélleniques*, 1e, 37 (for 1996–1997): 429–477.

LUGOVIĆ, B., ALTHERR, R., RACZEK, I., HOFMANN, A.W., & MAJER, V. 1991. Geochemistry of peridotites and mafic igneous rocks from the Central Dinaric Ophiolite Belt, Yugoslavia. *Contributions to Mineralogy and Petrology*, 106: 201–216.

MARCUCCI, M., KODRA, A., PIRDENI, A. & GJATA, T. 1994. Radiolarian assemblages in the Triassic and Jurassic cherts of Albania. *Ofioliti*, 19 (1): 105–114.

PAMIĆ, J. 1998. North Dinaridic Late Cretaceous-Paleogene subduction-related tectonostratigraphic units of southern Tisia, Croatia. *Geologica Carpathica*, 49 (5): 341–350.

PAMIĆ, J., GUŠIĆ, I. & JELASKA, V. 1998. Geodynamic evolution of the Central Dinarides. *Tectonophysics*, 297: 251–268.

PAMIĆ, J., GUŠIĆ, I. & JELASKA, V. 2000. Basic geological features of the Dinarides and South Tisia. *In:* PAMIĆ, J. & TOMLJENOVIĆ, B. (Eds.), Pancardi 2000 Fieldtrip Guidebook. *Vijesti*, 37 (2): 9–18.

PAMIĆ, J., TOMLJENOVIĆ, B. & BALEN, D. 2002. Geodynamic and petrogenetic evolution of Alpine ophiolites from the central and NW Dinarides: an overview. *Lithos*, 65: 113–142.

PAMIĆ, J. & HRVATOVIĆ, H. 2003. Main large thrust structures in the Dinarides – a proposal for their classification. *Nafta*, 54 (12): 443–456.

PESSAGNO, E.A. & NEWPORT, R.L. 1972. A technique for extracting radiolaria from radiolarian cherts. *Micropaleontology*, 18 (2): 231–234.

PRELA, M. 1994. Mirdita ophiolites project: 1 Radiolarian biostratigraphy of the sedimentary cover of the ophiolites in the Mirdita area (Albania): initial data. *Ofioliti*, 19 (2a): 279–286.

RADOVANOVIĆ, Z. 1987. Report on investigations of the Diabase-Chert Formation in SW Serbia (Thematic Geologic Map – Project D2). *Geological documentation of the Geological Institute*, 1–76, Beograd (unpublished).

RADOVANOVIĆ, Z. (in press). Explanatory notes for the sheet Prijepolje, Geologic Map of FRY (1:50000). *Geološki zavod ¨Gemini¨*, Beograd.

RAKÚS, M. & OŽVOLDOVÁ, L. 1999. On the age of radiolarites from the Manín Unit (Butkov Klippe, Middle Váh valley, Western Carpathians). *Mineralia Slovaca*, 31 (2): 79–86.

ROBERTSON, A. & KARAMATA, S. 1994. The role of subduction-accretion processes in the tectonic evolution of the Mesozoic Tethys in Serbia. *Tectonophysics*, 234: 73–94.

SCHMID, M.S., BERNOULLI, D., FÜGENSCHUH, B., MATENCO, L., SCHEFER, S., SCHUSTER, R., TISCHLER, M. & USTASZEWSKI, K. 2008. The Alpine-Carpathian-Dinaridic orogenic system: correlation and evolution of tectonic units. *Swiss Journal of Geosciences*, 101 (1): 139–183.

ŠMUC, A. & GORIČAN, Š. 2005. Jurassic sedimentary evolution of a carbonate platform into a deep-water basin, Mt. Mangart (Slovenian–Italian border). *Rivista Italiana di Paleontologia e Stratigrafia*, 11 (1): 45–70.

Резиме

Средњојурске радиоларије планине Златар (ЈЗ Србија)

Силицијске седиментне стене, представљене рожнацима и радиоларитима, широко су распрострањене у Србији. Најчешће су присутне у унутрашњим деловима Динарида, у оквиру офиолитских појасева и/или са формацијама офиолитског меланжа, ређе у другим геолошким срединама. Рожнаци и радиоларити Србије формирани су у различитим условима, од подножја континенталне падине до абисалних делова, у дубокоморском рову и у континенталним рифтовима. Максимум акумулације рожнаци и радиоларити достижу у средњем и горњем тријасу, као и током средње и горње јуре.

На локалитету Комарани који се налази поред пута Нова Варош–Акмачићи–Комарани–Павловића Брод (x = 7411117, y = 4811144) откривен је профил танкоуслојених силификованих алевролита и тамнобраон до црних танко до средње услојених радиоларита. Стварна дебљина радиоларита и алевролита на овом профилу се не може установити јер су слојеви тектонски јако поремећени. Према Radovanović (1987) рожнаци и алевролити локалитета Комарани представљају члан Формације Златара Динаридског офиолитског појаса. Наведени аутор сматра да асоцијације силицијских стена са сливовима базалтних вулканита ове формације нису обухваћене процесом меланжирања. Према Djerić *et al*. (2007b) истраживани седименти највероватније представљају матрикс (блок?) меланжа Источнобосанско-дурмиторске јединице.

Из радиоларита Комарана узете су 4 пробе, али су само 2 дале позитивне резултате:

Проба НЂ 328 – Фауна је ретка, углавном слабо очувана и већина примерака је поломљена или деформисана. Старост рожнаца је горњи бајес (највиши делови) до доњи келовеј (UAZs 5-7) и одређена је на основу присуства врсте *Eucyrtidiellum* sp. cf. *E. semifactum* (Nagai & Mizutani).

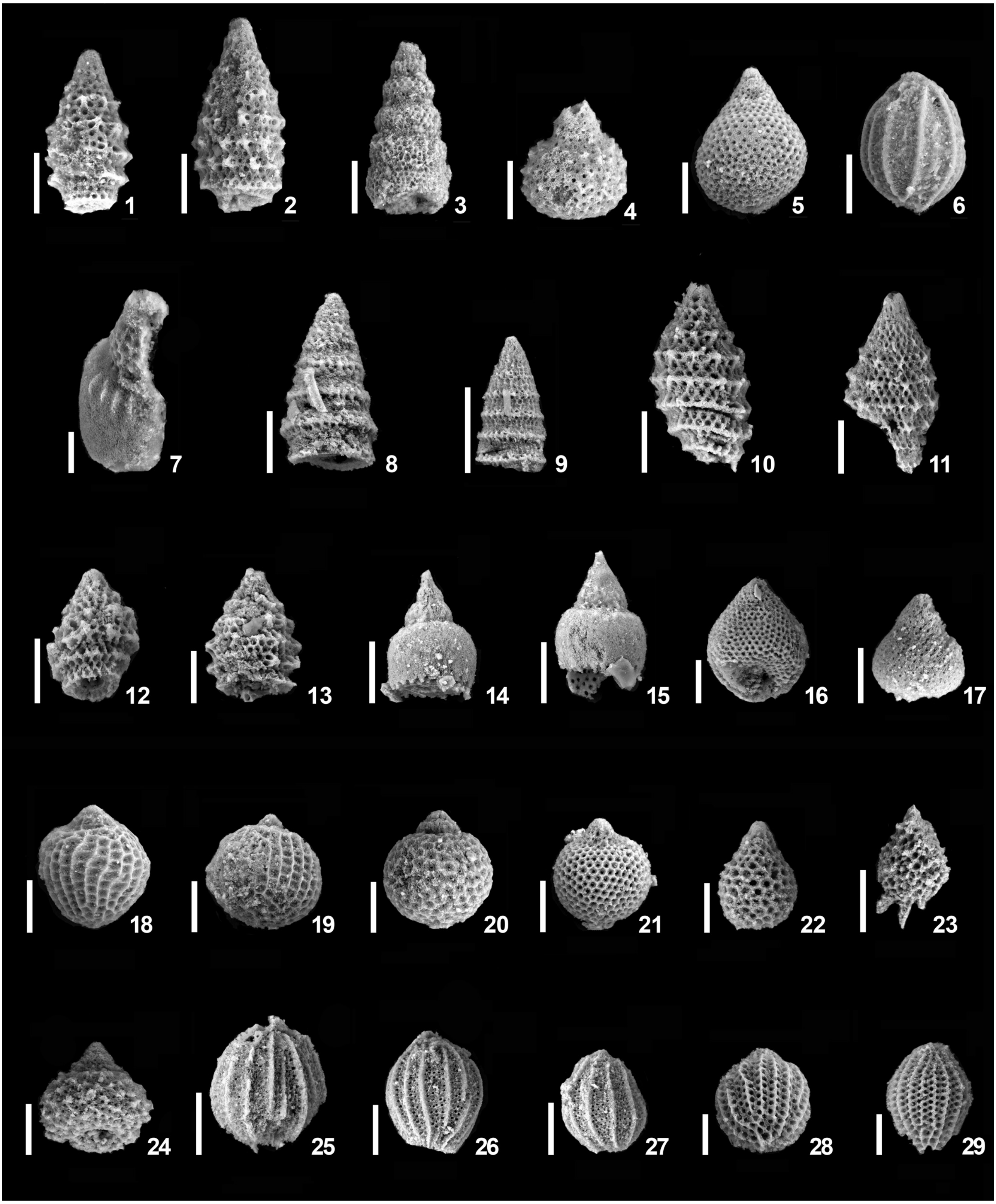
Проба НЂ 329 – Асоцијација радиоларија је бројна и разноврсна. Горњобатска до доњокеловејска старост (UAZ 7) одређена је на основу присуства *Dictyomitrella* ? *kamoensis* (UAZs 3-7; Baumgartner *et al*. 1995a) и *Williriedellum carpathicum* (UAZs 7-11; Baumgartner *et al*. 1995a).

Сличне средњојурске радиоларијске асоцијације познате су и из локалитета Абешко брдо, ЈЗ Србија (Gawlick *et al*. 2009), планине Мангарт, Словенија (Šmuc & Goričan 2004), планине Медведница, СЗ Хрватска (Halamić *et al.* 1999), Мирдита подручја у Албанији (Chiari *et al*. 1994; Prela 1994), као и западних Карпата (Rakuš & Ožvoldova 1999).

PLATE 1

Middle Jurassic radiolarians from the Komarani locality.
Scale bar = 50 µm (Figs. 1–6, 8, 10–22, 24–29); = 20 µm (Fig. 7); = 100 µm (Figs. 9, 23).

Figs. 1, 2.	*Triversus hungaricus* (KOZUR), sample NĐ 328.
Fig. 3.	*Cinguloturris getsensis* O'DOGHERTY, GORIČAN & DUMITRICA, sample NĐ 328.
Fig. 4.	*Williriedellum* (?) sp., sample NĐ 328.
Fig. 5.	*Hiscocapsa* sp., sample NĐ 328.
Fig. 6.	*Unuma* sp. cf. *U. gordus* HULL, sample NĐ 328.
Fig. 7.	*Eucyrtidiellum* sp. cf. *E. semifactum* (NAGI & MIZUTANI), sample NĐ 328.
Fig. 8.	*Dictyomitrella* sp. cf. *D. kamoensis* MIZUTANI & KIDO, sample NĐ 329.
Fig. 9.	*Dictyomitrella kamoensis* MIZUTANI & KIDO, sample NĐ 329.
Figs. 10, 11.	*Triversus kasinzovae* VISHNEVSKAYA, sample NĐ 329.
Figs. 12, 13.	*Xitus* sp., sample NĐ 329.
Figs. 14, 15.	*Eucyrtidiellum unumaense s. l.* (YAO), sample NĐ 329.
Fig. 16.	*Stichocapsa* sp., sample NĐ 329.
Fig. 17.	*Stichocapsa japonica* YAO, sample NĐ 329.
Fig. 18.	*Williriedellum* sp. cf. *W. tetragona* (MATSUOKA), sample NĐ 329.
Fig. 19.	*Williriedellum tetragona* (MATSUOKA), sample NĐ 329.
Fig. 20.	*Williriedellum* sp. aff. *W. yaoi* (KOZUR), sample NĐ 329.
Fig. 21.	*Williriedellum carpathicum* DUMITRICA, sample NĐ 329.
Fig. 22.	*Zhamoidellum* sp., sample NĐ 329.
Fig. 23.	*Arcanicapsa* (?) sp., sample NĐ 329.
Fig. 24.	*Hiscocapsa* (?) sp., sample NĐ 329.
Fig. 25.	*Unuma* sp., sample NĐ 329.
Fig. 26.	*Unuma* sp. cf. *U. gordus* HULL, sample NĐ 329.
Fig. 27.	*Unuma gordus* HULL, sample NĐ 329.
Fig. 28.	*Protunuma ochiensis* MATSUOKA, sample NĐ 329.
Fig. 29.	*Protunuma* sp., sample NĐ 329.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Геолошки анали Балканскога полуострва Annales Géologiques de la Péninsule Balkanique	71	127–137	Београд, децембар 2010 Belgrade, December 2010

DOI: 10.2298/GABP1071127S

Note on the first fossil remains of a whale from northern Bosnia

Ivan Stefanović[1]

Abstract. Herein, the first find of a fossil whale *Cethotherium* aff. *rathkei* is reported from the Middle Miocene sediments (Badenian) of the West Paratethys (the Štrbci village, east of Banja Luka and Prnjavor, northern Bosnia). Although mostly represented by vertebra, the well preserved remains of the single individual consist also of humeri, tympanicum, and some isolated fragments of the skull. The find is discussed in its paleogeographical context, and the importance of the discovery in an international context is shown.

Key words: Miocene, Badenian, whale, Paratethys, Bosnia.

Апстракт. Први примерак фосилног кита *Cethotherium* aff. *rathkei* пронађен је у средњомиоценским седиментима (баденске старости) Западног Паратетиса у селу Штрбци, источно од Бања Луке и Прњавора у северној Босни. Добро очувани остаци једне индивидуе углавном су представљени пршљеновима, остацима хумеруса, тумпаникума, као и фрагментима костију главе. Налаз је приказан и у палеогеографском контексту и представља други налазак ове врсте.

Кључне речи: миоцен, баден, кит, Паратетис, Босна.

Fossil whales of the Paratethys Sea

Although fossil finds of whales (Cetacea/Cetartiodactyla – depending on which classification is followed) are known from most of the regions of the world, their morphology and evolution is not well known (Fordyce & de Muizion 2001). In Europe, the Pliocene and Miocene species of whales seem to have been the most abundant and they were also present in Central Europe in the region that was once covered by the Paratethys Sea. During the Middle and Late Miocene, tectonics and a decreasing eustatic sea level gradually isolated the Paratethys Sea from the other seas, causing a decrease in salinity (Rögl 1998; Hámor 2001). This process resulted in the extinction of the marine fauna which was once present in the Paratethys. Cetacea became extinct during the final stages of the Miocene, when the Paratethys became a fresh water lacustrine environment. The presence of fossil whales is thus and indicator for higher salinity levels.

The Paratethys Sea was once present in extensive parts of Central Europe and fossil whales are found in Austria, Slovakia, Hungary, Croatia, Bosnia and Serbia. Most of the previously discovered specimens are attributed to the genus *Mesocethus*.

Mesocetus hungaricus Kadić, 1907 is known from several localities. Kadić (1907) based the species on a well-preserved complete skeleton from the Badenian of Borbolya in West Hungary. It is also known from the Middle Miocene (Late Badenian) locality Neudorf-Sandberg (Dvinska Nova Ves) on the border of Slovakia and Austria (Thenius 1952, Stabol & Holec 2001).

Mesocetus agrami van Beneden, 1880 is known from Sarmatian marls from Susjed in Zagreb (Agram was the former name of the city) and it was described by Van Beneden (1880) and Gorjanović-Kramberger (1892). The remains were recovered from the Sarmatian marls close to the border with the Badenian ("Sarmatian marls near to Mediterranean layers"; Gorjanović-Kramberger 1892) at Susjed and Vrbač in Zagreb (Croatia). This species seems to have been the most abundant in the region. Paunović (1993) published a paper on *Mesocetus* aff. *agrami* found in northern Bosnia and stated that it is found in several localities in Bosnia: Knežica, Šargovac, Lužani, Dažnica Ukrina and Kalenderovci. A Middle Miocene

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(Badenian) age was proposed for all these finds. Nevertheless, the remains described by PAUNOVIĆ (1993) consist only of fossil vertebra.

Mesocetus sp. is found in Slovakia in the Middle Miocene (Late Badenian) locality Glavica (SABOL & HOLEC 2002).

STEPANOVIĆ (1938) described lower jaws of a toothless whale found in Belgrade (Serbia). These jaws were atributed to *Cethotherium* sp. without any intention to attribute specimen to the genus *Cethotherium*, but to the Cetacea in general. The age of the sediments that yielded the fossil is Lower Sarmatian *s. str.* (Middle Miocene).

Locality Štrbci in northern Bosnia

The fossil was found in the village Štrbci east of Banja Luka and Prnjavor in northern Bosnia. It was recovered from a well at the depth of 26 m in a coat of marls.

The region of Štrbci was studied by EREMIJA (1970). Marls found in the area include remains of fauna represented by an association of *Vaginella austriaca* KITTL and rare finds of *Amussium* and *Natica milepunctata* LAMARCK with a long list of foraminifera. Eremija stated that the association of pelagic gastropods found in gray marls is characteristic for the region being well-connected to open sea. According to EREMIJA (1970), 214 species of foraminifera are found in strata of the same age in other parts of the basin and most numerous are representatives of the genera *Globigerinoides* and *Globigerina*, Lagenidae (*Robulus*, *Dentalina* and *Lagena*), *Spiroplectamina carinata* (D'ORBIGNY). The association suggests a Badenian age for the marls.

Northern Bosnia is geographically in contact with the Pannonian Lowlands that were the center of the Paratethys Sea, and in the late stages of the Miocene, northern Bosnia was a region of shallow waters.

Fig 1. Geographical position of Štrbci (triangle) and other localities of the Paratethys Sea: **1,** Borbolya; **2,** Neudorf-Sandberg; **3,** Zagreb (Susjed); **4,** Knežica; **5,** Šargovac; **6,** Kalenderovci; **7,** Dažnica; **8,** Lužani; **9,** Glavica; **10,** Belgrade.

Fossil remains

Order Cetacea BRISSON, 1762
Suborder Mysticeti FLOWER, 1864
Family Cethotheriidae CAMBERA, 1926
Genus *Cethotherium* VAN BENNEDEN, 1868–1880

Cethotherium aff. *rathkei* VAN BENNEDEN, 1868–1880

Material. *Cethotherium* aff. *rathkei* found in marls of Badenian age in Štrbci (N. Bosnia) represented by left and right tympanicum (RGFC1 and RGFC2), left and right humerus (RGFC6 and RGFC7), 4 well-preserved thoracic vertebra (RGFC11, RGFC12, RGFC13 and RGFC14), 4 well-preserved lumbal vertebra (RGFC15, RGFC16, RGFC17 and RGFC18), one caudal vertebra (RGFC19), 8 fragmented vertebra (RGFC29, RGFC30, RGFC31, RGFC32, RGFC33, RGFC34, RGFC35 and RGFC36), 5 vertebral epiphysis (RGFC25, RGFC26, RGFC27, RGFC28 and RGFC29), 8 skull fragments (RGFC3, RGFC4, RGFC5, RGFC8, RGFC9, RGFC10, RGFC34 and RGFC35) and other unidentified fragments.

The fossil is the property of the Gradiška Museum (Zavičajni muzej Gradiška) and it is kept at the Collection of the Faculty of Mining and Geology (University of Belgrade)

Description. The fossil whale found in Badenian (Middle Miocene) sediments in Štrbci (North Bosnia) east of Prnjavor is represented by a number of well-preserved bones and the skeleton was probably almost complete before it was excavated.

The auditory bulla is one of the most important bones. The auditory bulla was subject to notable changes during the evolution; thus it is important for distinguishing fossil and recent species (FORDYCE & DE MUIZON 2001). The tympanicum (Pl. 1, figs. 1–6, No. RGFC1 and No. RGFC2) show most resemblance to those of the fossil whale *Cethotherium rathkei* found on the Crimean Peninsula (VAN BENEDEN & GERVAIS 1868–1880, fig. 6, fig. 7, Tab VXII and BRANDT 1873, fig. 3b, fig. 4b, Tab XII). Figured here as Fig. 3 and Fig. 4. The size and shape of the tympnicum are almost the same and the dorsal surface of the bulla is without any texture, as in other *C. rathkei* specimens.

Both humeri are well preserved and are about 72.7 and 72.1 mm long (Plate 1, Figs. 13–20; RGFC6 and RGFC7).

Table 1. Measurements of bones given in millimeters.

No.	bone	length	proximal width	distal width		
RGFC6	humerus dex.	72.7	45.7	42.2		
RGFC7	humerus sin.	72.1	66.2	42.8		
No.	**bone**	**length**	**corpus cranial width**	**corpus caudal width**	**corpus cranial width**	**corpus caudal width**
RGFC11	thoratic vertebrata	24.5	46.8	44.1	34.7	36.1
RGFC12	thoratic vertebrata	25.0	47.2	46.6	36.1	37.6
RGFC13	thoratic vertebrata	23.9	47.8	45.2	34.3	40.0
RGFC14	thoratic vertebrata	30.7	47.8	45.7	37.1	37.8
RGFC15	lumbar vertebrata	31.6	50.2	–	41.8	–
RGFC16	lumbar vertebrata	33.1	49.4	–	41.6	–
RGFC17	lumbar vertebrata	27.8	–	–	40.2	–
RGFC18	lumbar vertebrata	33.8	–	–	–	–
RGFC19	caudal vertebrata	19.8	35.1	35.1	–	–
No.	**bone**	**length**				
RGFC1	tympanicum dex.	50.2				
RGFC2	tympanicum sin.	50.1				

A large part of the fossil material is represented by vertebrae (Pl. 1, Figs. 1–12; Pl. 2 and Pl. 3). Most of the vertebrae are incomplete but measurements of the preserved ones are given in Table 1. The manner in which the vertebrae were measured is indicated in Figure 2. The vertebrae of *Mesocetus* found in the region are much larger and the width of the lumbar falls into range of 12–14 cm (PAUNOVIĆ 1993).

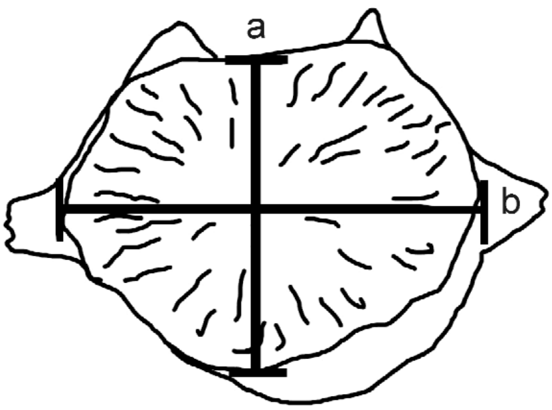

Fig. 2. Measurements of vertebra were restricted to the corpus of vertebra. **a,** height of corpus; **b,** width of corpus.

Among the other bones, some isolated fragments of the skull, and other unidentifiable fragments have to be noted.

Dimensions of the present specimen are in the range of that of *Cethotherium rathkei*. BRANDT (1873) gives an overall length of "6 to 7 feet" for this species. The vertebra of *Mesocetus* found in the region are much larger and width of lumbar falls into the range of 12–14 cm (PAUNOVIĆ 1993). Comparisons of the length of vertebra belonging to *Mesocetus* aff. *agrami* (PAUNOVIĆ 1993) and *Cethotherium* aff. *rathkei* from Štrbci is given on the Table 2. Although the present specimen is juvenile, the individual dimensions of the auditory bulla are identical to the dimensions of the Crimean specimen.

Table 2. Comparison of the length of vertebra belonging to *Mesocetus* aff. *agrami* (PAUNOVIĆ 1993) and *Cethotherium* aff. *rathkei.*

Cethotherium aff. *rathkei*		*Mesocetus* aff. *agrami*	
No.	length in mm	No.	length in mm
lumbar vertebra			
RGFC15	31.6	DAŽ-7	132
RGFC16	33.1	DAŽ-8	134
RGFC17	27.8	DAŽ-11	135
RGFC18	33.8	DAŽ-9	141
		DAŽ-10	148
thoracic vertebra			
RGFC11	24.5	KNEŽ-5	63
RGFC12	25.0		
RGFC13	23.9		
RGFC14	30.7		

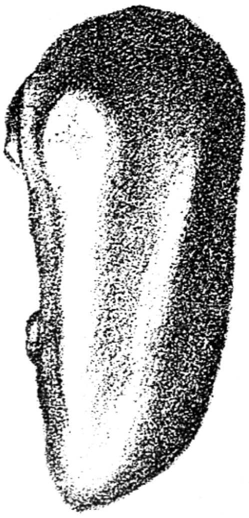

Fig. 3. Tympanicum of *Cethotherium rathkei*, Crimean Peninsula (original drawing from BRANDT 1873, pl. 12, fig. 3b).

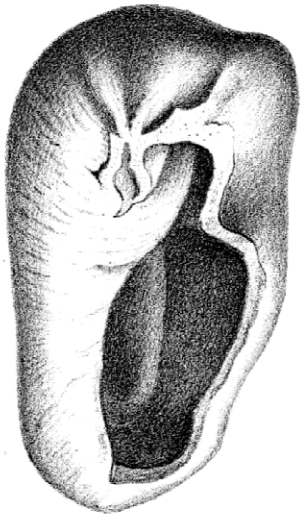

Fig. 4. Tympanicum of *Cethotherium rathkei*, Crimean Peninsula (original drawing from VAN BENEDEN & GERVAIS 1868–80, pl. 17, fig. 7).

Discussion. The genus *Cethotherium* includes only one Miocene species, i.e., *C. rathkei.* The holotype was recovered in the Crimean Peninsula by Prof. RATKE and described by VAN BENNEDEN (1868–1880) and later by BRANDT (1873). Unfortunately, no further details were given about the site and the stratigraphical position of the holotype.

The cethotheres belong to a separate group of Mystecete. The anatomy of mystecete resembles that of balenopterides but differs in the primitive structure of the frontal bone (FORDYCE & MUIZON 2001). Unfortunately, the studied specimen lacks the frontal bone

The geographical localities of the Paratethys Sea where remains of mystecete were found are shown in Fig. 1. They generally follow the borders of the Pannonian Lowlands which were once a part of Paratethys Sea. At the time, there was a connection with eastern provinces and the Black Sea (HÁMOR 2001, appendix VI). It might be concluded that whales belonging to this species were able to migrate through the basin and, hence, it is not surprising to find the representatives of the same species in two, apparently distant localities. According to KORETSKY (2001, fig. 58) and RÖGL (1998, pl. 9), there was a water corridor during the Badenian that allowed this connection. Probably *Cethotherium* migrated through this corridor.

While the Cethotheriidae systematics remain uncertain, they are probably represented by a few species and may be considered as probable ancestors of balaernopterids.

Conclusions

The remains of Middle Miocene whales are abundant in the Paratethys Region. Most of the species are attributed to *Mesocetus*, while a specimen from Štrbci (northern Bosnia) belongs to the genus *Cethotherium*. Bosnian localities numbered by PAUNOVIĆ (1993) yielded exclusively vertebra of fossil whales and it should be presumed that the remains of *Cethotherium* cf. *rathkei* from Štrbci are the best preserved whale fossil in the area.

There is a significant difference in size between *Mesocetus* remains and that of *Cethotherium rathkei*. The *Cethotherium* from Štrbci probably represents the only representative of the species found in this region and the first find of the species in the Western Parathetys. After the Badenian, (Middle Miocene), the salinity started to drop and influenced a general change of the flora and fauna. The climate was also affected during this process. This caused mass extinctions of marine fauna and whales in the area.

Representatives of the *C. rathkei* line are rare and not well-studied. Hopefully, this paper would fill the gap and allow future studies on this species.

Acknowledgements

I wish to thank the reviewers JAN VAN DER MADE (Museo Nacional de Ciencias Naturales, Madrid) and JEROME PRIETO (Ludwig-Maximilians-University, München) for useful discussions and comments that significantly improved the paper.

References

BENEDEN, P.J. VAN & GERVAIS, P. 1868–1880. Ostéographie des Cétacés Vivants et Fossiles, Comprenant la Description et l'Iconographie du Squelette et du Systéme

Dentaire de ces Animaux; ansu que des documents relatifs á leur histoire naturelle. 634 pp. Arthus Bertrand, Paris.

BRANDT, J.F. 1873. Untersuchungen die fossilen und subfossilen Cetaceen Europas. *Memoirs de l'Académie Impériale des Sciencies,* 7, 20 (1): 1–498.

EREMIJA, M. 1970. Biostratigraphic analysis of the Miocene deposits and fauna in the Prnjavor Basin. *Geološki anali Balkanskoga poluostrva*, 35: 25–108 (in Serbian, English summary).

FORDYCE, E. & MUIZON, DE C. 2001. Evolutionary history of cetaceans: a review. *In*: MAZIN, J.-M. & BUFFRÉNIL, De V. (eds.), *Secondary Adaptation of Tetrapodes to Life in Water,* 169–233. Verlag Dr. Friedrich Pfeil, München.

GORJANOVIĆ-KRAMBERGER, D. 1892. De fossilibus Cetaceis Croatiae et Carneolinae. *Rad Jugoslavenske akademije znanosti i umjetnosti*, 15: 1–22 (in Croatian).

HÁMOR, G. 2001. *Miocene palaeogeography of the Carpatian Basin*. In: BREZSNYÁNSZKY, K., (ed.), Explanatory Notes of the Geological Institute of Hungary, 71 pp.

KADIĆ, O. 1907. *Mesocetus hungaricus* KADIĆ eine neue Balaenopteridentart aus dem Miozän von Borbolya in Ungarn. *Jahrbuche der königlische Ungarischen geologischen Anstalt*, 16 (2): 23–91.

KORETSKY, I.A., 2001. Morphology and systemathics of Miocene Phocinae (Mammalia: Carnivora) from Paratethys and the North Atlantic region. *Fasciculi Instituti geologici Hungariaae ad illustrandam notionem geologicam et palæontologicam*, 54: 1–109.

PAUNOVIĆ, M. 1993. *Mesocetus* aff. *agrami* (Misticeti, Cetotheriidae) aus den mittelmiozänen Ablagerungen Nordbosniens. *Radovi Hrvatske akademije znanosti i umjetnosti*, 463: 1–9 (in Croatian, English summary).

RÖGL, F. 1998. Paleogeographic Considerations for Mediterranean and Parathethyc Seaways (Oligocene to Miocene). *Annalen des Naturhistorischen Museums in Wien*, 99A: 279–310.

SABOL, M. & HOLEC, P. 2002. Temporal and spatial distribution of Miocene mammals in the western Carpathians (Slovakia). *Geologica Carpatica*, 53 (4): 269–279.

STEPANOVIĆ, B. 1938 Über ein Fossilen Wall-Rest (*Cethotherium* sp.) in den untersarmatischen Schichten bei Bele Vode, Nahe Beograd. *Annales Géologiques de la Péninsule Balkanique,* 15: 268–273 (in Serbian, German summary).

THENIUS, E. 1952. Mammals of Tortonian from Neudorf an der March (ČSR) *Neues Jahrbuch für Geologie und Paläontologie*, 96 (1): 27–136 (in German).

Резиме

Кратак осврт на налаз фосилних остатака кита из северне Босне

Остаци средњомиоценских китова су чести у области Паратетиса. Већина до сада пронађених примерака су остаци *Mesocetus*-а, док остаци примерка из Штрбаца (северна Босна) припадају роду *Cethotherium*. Босански локалитети које наводи PAUNOVIĆ (1993) садрже искључиво остатке пршљенова *Mesocetus*-а, док остаци *Cethotherium* cf. *rathkei* из Штрбаца, описани овом приликом, представљају најбоље сачувани примерак фосилног кита у овој области.

Постоје значајне разлике између остатака представника *Mesocetus*-а и остатака *Cethotherium rathkei*. *Cethotherium* из Шрбаца вероватно представља јединог до сада нађеног представика у овој области и први је налазак врсте у западном Паратетису. По завршетку бадена (средњи миоцен) пад салинитета у Паратетису условио је општу промену флоре и фауне у том мору утицајући и на опште климатске промене. Ови процеси проузроковали су масовна изумирања морске фауне и китова у региону. Представници *C. rathkei* су ретки и недовољно познати. Циљ овог рада је да попуни празнину и омогући даља истраживања.

PLATE 1

Cethotherium aff. *rathkei* VAN BENEDEN, Middle Miocene (Badenian), Štrbci, northern Bosnia.

Fig. 1. Right tympanicum, RGFC1, medial view.
Fig. 2. Right tympanicum, RGFC1, lateral view.
Fig. 3. Right tympanicum, RGFC1, inferior view.
Fig. 4. Left tympanicum, RGFC2, medial view.
Fig. 5. Left tympanicum, RGFC2, lateral view.
Fig. 6. Left tympanicum, RGFC2, inferior view.
Fig. 7. Caudal vertebra, RGFC19, cranial view.
Fig. 8. Caudal vertebra, RGFC19, caudal view.
Fig. 9. Caudal vertebra, RGFC19, dorsal view.
Fig. 10. Caudal vertebra, RGFC19, ventral view.
Fig. 11. Caudal vertebra, RGFC19, view dex.
Fig. 12. Caudal vertebra, RGFC19, view sin.
Fig. 13. Right humerus, RGFC6, lateral view.
Fig. 14. Right humerus, RGFC6, proximal view.
Fig. 15. Right humerus, RGFC6, medial view.
Fig. 16. Right humerus, RGFC6, distal view.
Fig. 17. Left humerus, RGFC7, lateral view.
Fig. 18. Left humerus, RGFC7, proximal view.
Fig. 19. Left humerus, RGFC7, medial view.
Fig. 20. Left humerus, RGFC7, distal view.

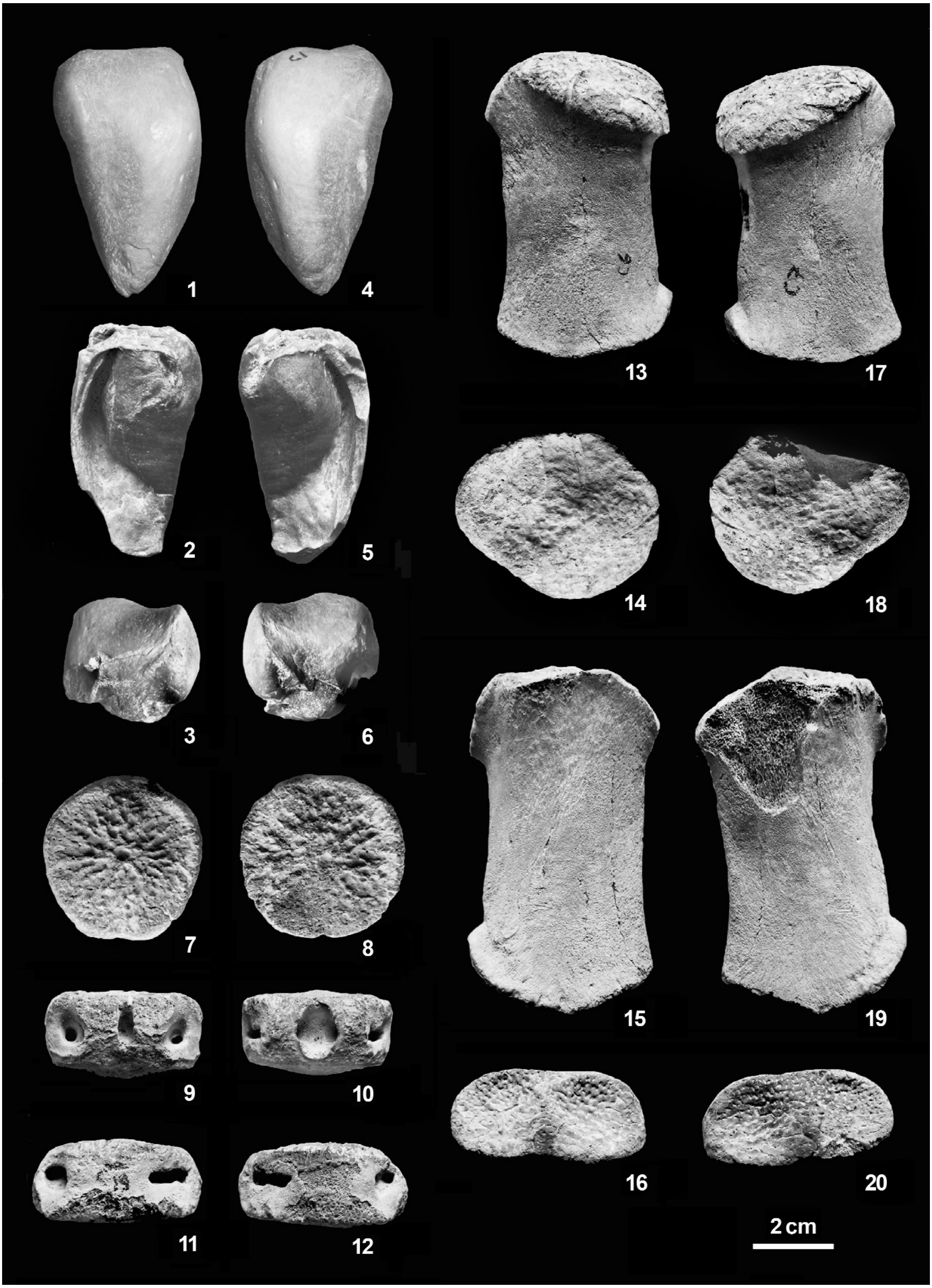
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PLATE 2

Cethotherium aff. *rathkei* VAN BENEDEN, Middle Miocene (Badenian), thoracic vertebrae, Štrbci, northern Bosnia.

Fig. 1. RGFC11, dorsal view.
Fig. 2. RGFC11, caudal view.
Fig. 3. RGFC11, ventral view.
Fig. 4. RGFC11, cranial view.
Fig. 5. RGFC12, dorsal view.
Fig. 6. RGFC12, caudal view (with epiphysis).
Fig. 7. RGFC12, ventral view.
Fig. 8. RGFC12, cranial view.
Fig. 9. RGFC13, dorsal view.
Fig. 10. RGFC13, caudal view (with epiphysis).
Fig. 11. RGFC13, ventral view.
Fig. 12. RGFC13, cranial view.
Fig. 13. RGFC14, dorsal view.
Fig. 14. RGFC14, caudal view.
Fig. 15. RGFC14, ventral view.
Fig. 16. RGFC14, cranial view.

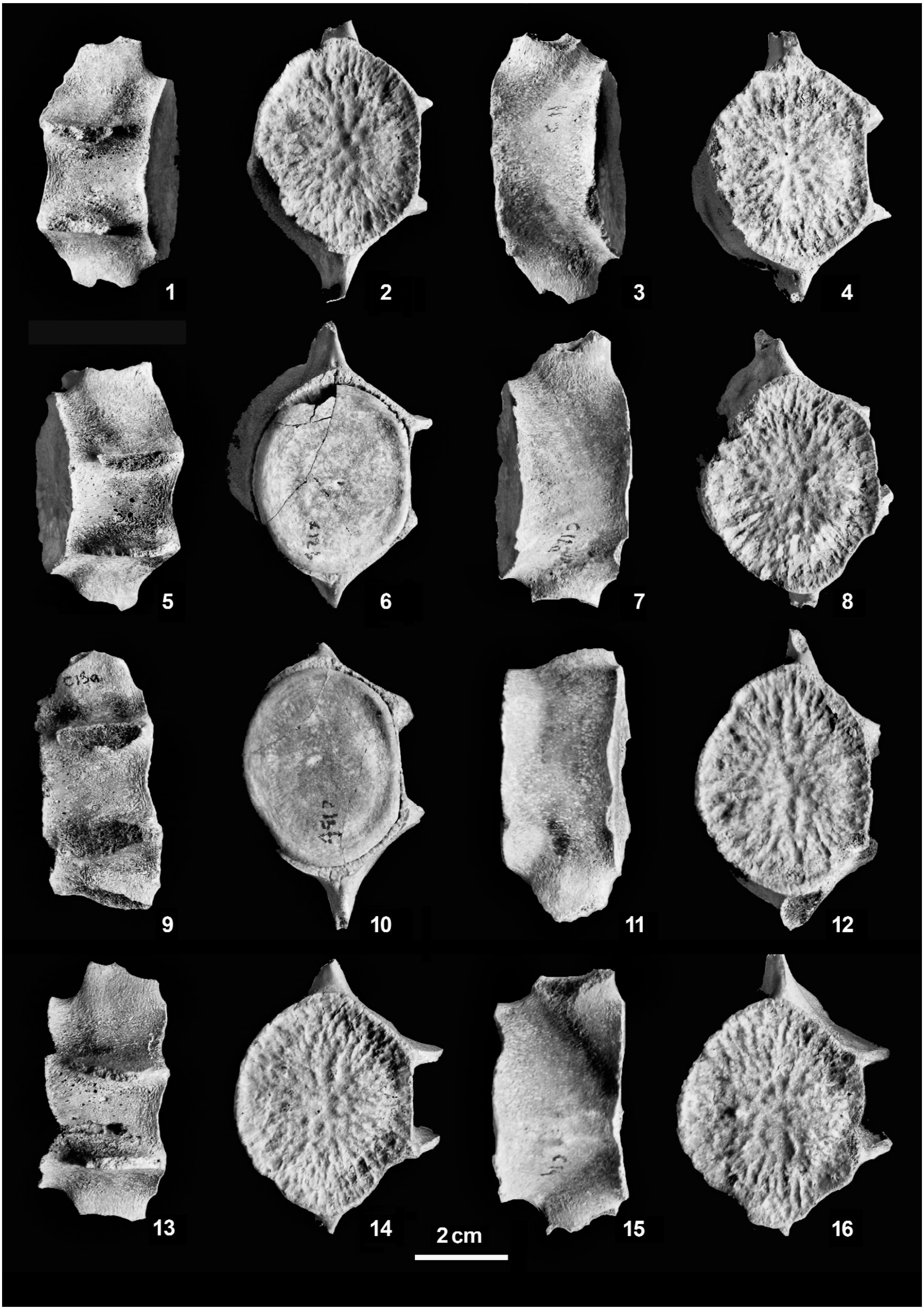
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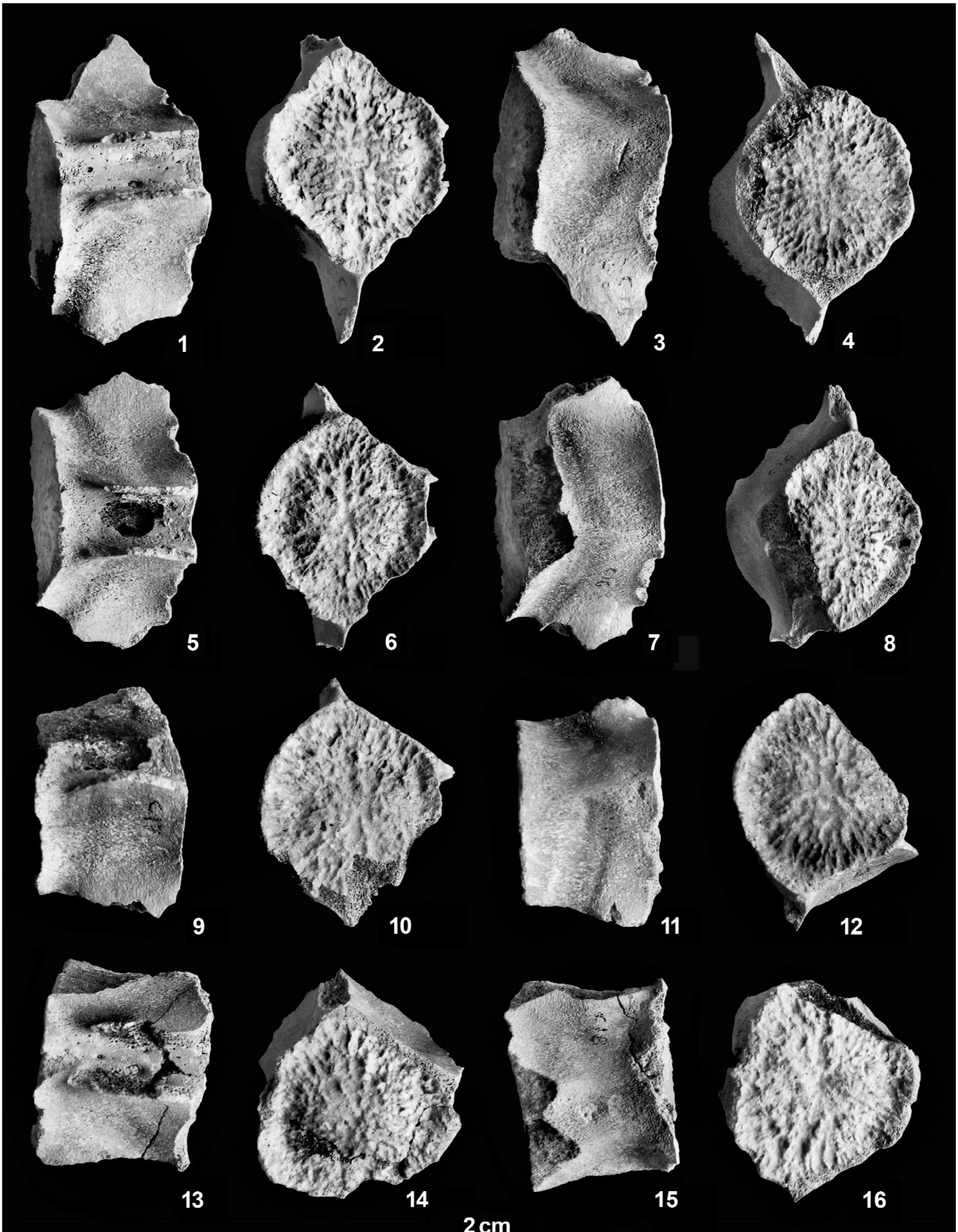
PLATE 3

Cethotherium aff. *rathkei* VAN BENEDEN, Middle Miocene (Badenian), lumbar vertebrae, Štrbci, northern Bosnia.

Fig. 1. RGF C15, dorsal view.
Fig. 2. RGFC15, caudal view.
Fig. 3. RGFC15, ventral view.
Fig. 4. RGFC15, proximal view.
Fig. 5. RGFC16, dorsal view.
Fig. 6. RGFC16, caudal view.
Fig. 7. RGFC16, ventral view.
Fig. 8. RGFC16, proximal view.
Fig. 9. RGFC17, dorsal view.
Fig. 10. RGFC17, caudal view.
Fig. 11. RGFC17, ventral view.
Fig. 12. RGFC17, proximal view.
Fig. 13. RGFC18, dorsal view.
Fig. 14. RGFC18, caudal view.
Fig. 15. RGFC18, ventral view.
Fig. 16. RGFC18, proximal view.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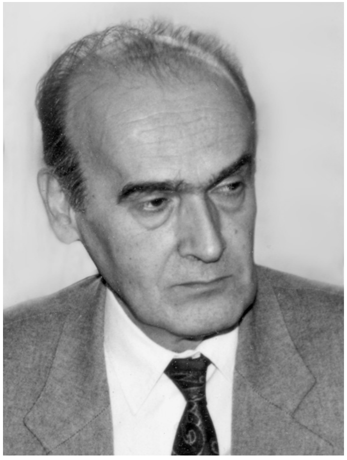
ГЕОЛОШКИ АНАЛИ БАЛКАНСКОГА ПОЛУОСТРВА ANNALES GÉOLOGIQUES DE LA PÉNINSULE BALKANIQUE	71	139–143	БЕОГРАД, децембар 2010 BELGRADE, December 2010

IN MEMORIAM

Др Ђорђе Михајловић, редовни професор (1946–2008)



Првог дана 2008. године, болно неочекивано, умро је Ђорђе Михајловић, доктор геолошких наука, редовни професор и Декан Рударско-геолошког факултета Универзитета у Београду (2000–2002).

Ђорђе Михајловић је отишао из наше средине предано и интензивно радећи за добробит геологије и рударства; од 2004. године био је на функцији заменика министра, односно државног секретара Министарства рударства и енергетике Владе Републике Србије, а од почетка 2007. године члан Скупштине Геолошког института Србије.

Професор Ђорђе Михајловић био је један од најзначајнијих европских палеоботаничара. Бројне генерације студената га памте као примерног, мирног и толерантног човека и доброг професора.

Рођен је 18. јула 1946. године у Београду где је завршио основну школу и гимназију. Рударско-геолошки факултет, Одсек за геологију, Смер за регионалну геологију и палеонтологију уписао је 1965., а дипломирао је 1970. године на усмерењу за палеонтологију. У периоду 1971–1974. године радио је у предузећу „Геосонда“, да би 1974. године био примљен за асистента-приправника на Рударско-геолошком факултету у Београду. На истом факултету је 1977. године магистрирао и био изабран за асистента, а 1983. године је и докторирао са темом „Фосилне флоре палеогена Србије“. За доцента за предмет „Палеоботаника“ изабран је 1983., а за ванредног професора 1989. године. Од 1995. године је редовни професор Рударско-геолошког факултета Универзитета у Београду.

У својству универзитетског наставника проф. Ђорђе Михајловић је држао предавања на следећим предметима основних и магистарских студија Рударско-геолошког факултета: „Палеоботаника“, „Палеоекологија“, „Еволуциона палеонтологија“, „Еволуција биљног света“ и „Методе палеоботаничких истраживања“. Био је ментор бројним дипломцима и последипломцима. Од 1996. до 2004. године био је шеф Катедре за Палеоботанику. Од 2000 до 2002. године био је декан Рударско-геолошког факултета, а 2004. године и члан Савета Универзитета у Београду. На Рударско-геолошком факултету у Штипу, Македонија, је у периоду од 1987. до 1990. године учествовао у извођењу наставе из предмета „Палеозоологија“.

У свом научно-истраживачком раду посебну пажњу посвећивао је истраживањима фосилне макрофлоре, кречњачког нанопланктона, као и проучавањима палеоекологије, биостратиграфије и палеоклиматологије кенозоика. Из наведеног широког научног опуса професора Михајловића посебно треба истаћи његове радове из области палеоботанике и стратиграфије неогена који су га учинили познатим у научним круговима не само наше земље, него и у европским оквирима. Године 1990. на Чехословачкој академији наука у Прагу специјализовао је примену кутикуларне анализе у палеоботаничким истраживањима.

Објавио је преко 90 научних и стручних радова од којих је десетак у међународно признатим часописима. Учествовао је у писању три међународне, и пет домаћих монографија. Учествовао је са рефератима у раду 19 међународних и 6 домаћих научних скупова. Био је уредник водича за екскурзије „Neogene of Eastern Serbia“ и „Lacustrine and Brackish Neogene of western part of Yugoslavia“ које су организоване у нашој земљи 1995. године у оквиру IUGS/UNESCO International Geological Correlation Programme – IGCP 329.

Посебно је значајно истаћи међународну сарадњу коју је професор Михајловић остваривао са бројним научним институцијама и колегама из

Пољске, Чешке, Немачке, Аустрије, Мађарске, Бугарске, Грчке, Хрватске, Босне, Македоније и других земаља.

У Србији је био члан следећих научних и стручних тела: Одбора за палеофлору и палеофауну Српске академије наука и уметности (од 1994. године), Српског геолошког друштва (од 1976. године, где је од 1977. до 1980. и од 1991. до 1993. године обављао дужност секретара). У периоду од 1992. до 1996. године био је руководилац Југословенске радне групе IUGS/UNESCO IGCP пројекта 329.

Био је члан почасног одбора 14. Конгреса геолога Србије и Црне Горе (2005. година), као и научног одбора 18th Congress of the Carpathian-Balkan Geological Association (2006. година). Такође је био члан уређивачких одбора водећих националних геолошких часописа „Геолошки анали Балканскога полуострва“ (од 1994. године до тренутка смрти) и „Записници Српског геолошког друштва“ (од 1978. до 1980. и од 1991. до 1992. године).

Добитник је следећих награда и признања: 1977. године награде „Милан Милићевић инжењер геологије“ за најбољи научно-истраживачки рад младог научника, повеље за рад у Српском геолошком друштву (1991. године поводом сто година постојања Друштва), и 1994. награде и плакете „Јован Жујовић“ за врхунски научни допринос из палеонтологије и регионалне геологије за 1993. годину.

Оовако кратак текст не може да обухвати целу каријеру и живот професора Михајловића. Био је декан Рударско-геолошког факултета, када је то било најтеже – одмах после демократских промена у Србији. Ми које смо га познавале, са њим радиле на истој катедри, свакодневно причале не само о палеонтологији, а током деведесетих заједно, много пута шетале Београдом, памтићемо га као благог и мирног човека увек спремног да саслуша и посаветује.

Са професором Михајловићем смо обишле велики део Србије, а уз његову подршку и подстрек пробиле лед у учествовању у међународним стручним конференцијама. У тим приликама смо упознале веселог и радозналог човека широког образовања и опште културе.

За нас које смо биле његови најближи сарадници, студенти и последипломци, овај текст нису само речи, већ и успомене. Памтићемо га као искреног и поузданог пријатеља, пријатног саговорника и цењеног ментора.

Зорица Лазаревић
Јелена Миливојевић

Докторска теза

Михајловић, Ђ. 1983. *Фосилне флоре палеогена Србије*. Докторска дисертација, Рударско-геолошки факултет, Београд, 152 стр.

публиковано:
1985. Фосилне флоре палеогена Србије. *Геолошки анали Балканског полуострва*, 49: 299–434.

Уџбеници и ауторизована скрипта

Спалић, О., Митровић, Ј., Судар, М. & Михајловић, Ђ. 1984. *Методе биостратиграфско палеонтолошких истраживања.* Универзитетски уџбеник. Рударско-геолошки факултет, Група за регионалну геологију и палеонтологију, Београд, 403 стр.

Михајловић, Ђ. 1998. *Палеоботаника*. Ауторизована скрипта, Рударско-геолошки факултет, Београд, 217 стр.

Михајловић, Ђ. 1999. *Палеоекологија. II Палеофитоекологија*, Ауторизована скрипта, Рударско-геолошки факултет, Београд, 103 стр.

Најзначајнији радови и саопштења

Михајловић, Ђ. 1969. Род *Conoclypeus* Agassiz из еоценских седимената Југославије. *Зборник радова студената Рударско-геолошког факултета*, 2: VI/1–VI/11.

Михајловић, Ђ. 1976. Горње олигоценска флора из околине Косаничке Раче. *Гласник природњачког музеја, А*, 31: 137–149.

Пантић, Н. и Михајловић, Ђ. 1976. Неогене флоре балканског копна и њихов значај за палеоклиматологију, палеобиогеографију и биостратиграфију (I). Панонска флора околине Сремске Каменице. *Геолошки анали Балканскога полуострва*, 41: 269–280.

Михајловић, Ђ. 1977. Прилози познавању терцијарних флора околине Београда. *Геолошки анали Балканскога полуострва*, 41: 269–280.

Пантић, Н. и Михајловић, Ђ. 1977. Неогене флоре балканског копна и њихов значај за палеоклиматологију, палеобиогеографију и биостратиграфију (II). Доње сарматска флора Београда (код моста на Дунаву). *Геолошки анали Балканскога полуострва*, 41: 159–175.

Михајловић, Ђ. 1978. Фосилна флора из села Вуковића (околина Голупца). *Геолошки анали Балканскога полуострва*, 42: 447–454.

Михајловић, Ђ. 1978. Фосилна флора из села Сланаца (околина Београда). *Гласник природњачког музеја, А*, 33: 199–207.

Михајловић, Ђ. 1978. Четрдесет термина. *У:* Пантић, Н. (уредник), *Геолошка терминологија и номенклатура II-2, Палеоботаника,* 130 стр. Завод за регионалну геологију и палеонтологију, Рударско-геолошки факултет.

Пантић, Н. и Михајловић, Ђ. 1979-1980. Неогене флоре балканског копна и њихов значај за палеоклиматологију, палеобиогеографију и биостратиграфију (III). Значај идентификације периода суве климе за стратиграфске корелације. *Геолошки анали Балканскога полуострва*, 43/44: 239–262.

Михајловић, Ђ. 1980. Миоценска флора из белих лапораца Јанчића (Добрињско-јежевички басен). *Записници Српског геолошког друштва за 1979. годину*, 159–164.

Михајловић, Ђ. 1981. Горње кредна кречњачка нанофлора из Љига и околине. *Записници Српског геолошког друштва за 1980. годину*, 81–86.

Павшић, Ј. и Михајловић, Ђ. 1981. Нанофлора баденијана ("тортона") Вишњице (околина Београда). *Глас Српске академије наука и уметности, Одељење природно-математичких наука*, 48: 1–16.

Stevanović, P. & Mihajović, Đ. 1981. Orešac on the Danube, near Grocka mouth of Požegovački potok creek. *In:* Stevanović, P. (ed.), *Excursion Guide: Marine and Brackish Neogene of Serbia,* 8-9, IGCP – Project 25, Beograd.

Михајловић, Ђ. 1983. Кречњачки нанопланктон из туронских наслага Миљаковца (околина Београда). *Геолошки анали Балканскога полуострва*, 47: 311–318.

Михајловић, Ђ. 1983. Кречњачки нанопланктон из мастрихтских седимената Тијањске реке (Драгачево, западна Србија). *Геолошки анали Балканскога полуострва*, 48: 185–191.

Маровић, М., Михајловић, Ђ. и Кнежевић, С. 1984. Прилог познавању старости Жагубичког неогеног басена. *Записници Српског геолошког друштва за 1983. годину*, 53–61.

Миловановић, Љ. и Михајловић, Ђ. 1984. Миоценска флора из Жагубичког басена. *Геолошки анали Балканскога полуострва*, 48: 201–213.

Пантић, Н. и Михајловић, Ђ. 1984. Проблеми еоцена у Србији и правци даљих истраживања. *Симпозијум "О догађајима на граници еоцена и олигоцена у Југославији". Апстракти,* стр. 3, Међународна подкомисија за стратиграфију палеогена, Мостар.

Пантић, Н. и Михајловић, Ђ. 1985. Проблеми еоцена у Србији и правци даљих истраживања. *Геолошки гласник,* 28 (2): 41–55.

Михајловић, Ђ. 1987. Доња креда (беријас-валендинотрив), макрофлора. *У:* Анђелковић, М. (редактор), *Геологија шире околине Београда 2. (Фосилна фауна и флора),* 93–94, Завод за регионалну геологију и палеонтологију, Рударско-геолошки факултет.

Михајловић, Ђ. 1987. Горња креда (кампан - мастрихт), кречњачки нанопланктон. *У:* Анђелковић, М. (редактор), *Геологија шире околине Београда 2. (Фосилна фауна и флора),* 147–151, Завод за регионалну геологију и палеонтологију, Рударско-геолошки факултет.

Михајловић, Ђ. 1987. Неоген, кречњачки нанопланктон. *У:* Анђелковић, М. (редактор), *Геологија шире околине Београда 2. (Фосилна фауна и флора),* 309–313, Завод за регионалну геологију и палеонтологију, Рударско-геолошки факултет.

Михајловић, Ђ. 1987. Неоген, макрофлора. *У:* Анђелковић, М. (редактор), *Геологија шире околине Београда 2. (Фосилна фауна и флора),* 313–330, Завод за регионалну геологију и палеонтологију, Рударско-геолошки факултет.

Пантић, Н. и Михајловић, Ђ. 1987. Кенозоик. Палеоген уопште. *У:* Анђелковић, М. (редактор), *Геологија шире околине Београда 1. (Геологија и геодинамика),* 138–140 Завод за регионалну геологију и палеонтологију, Рударско-геолошки факултет.

Михајловић, Ђ. 1987. Миоценска флора из левачког басена (село Калудра). *Записници српског геолошког друштва за 1985. и 1986. годину*, 143–149.

Mihajlović, Đ. & Jungwirth, E. 1988. Oligocene Aged Flora from Novi Dol (Slovenia, Yugoslavia). *Revue de Paléobiologie*, 7 (2): 435–447.

Михајловић, Ђ. и Рабреновић, Д. 1988. Кречњачки нанопланктон из доње-баремских наслага Гребена код Доњег Милановца (источна Србија). *Геолошки анали Балканскога полуострва*, 51: 335–339.

Пантић, Н., Михајловић, Ђ. и Врабац С. 1988. Фосилна флора баденијена из околине Тузле. *Геолошки анали Балканскога полуострва*, 51: 321–327.

Михајловић, Ђ. и Кнежевић, С. 1988. Кречњачки нанопланктон из сарматских наслага Београда. *Геолошки анали Балканскога полуострва*, 52: 317–332.

Миловановић, Љ. и Михајловић, Ђ. 1988. Палеогена флора из околине Кочана. *Геолошки анали Балканскога полуострва*, 52: 333-338.

Grubić, A., Sladić-Trifunović, M. & Mihajlović, Đ. 1988. Early Senonian biolithic complex at Leposavić (South-western Serbia). *First International Conference on Rudists, Guide book,* 31–34, Belgrade.

Pejović, D., Sladić-Trifunović, M. & Mihajlović, Đ. 1988. Early Senonian Rudist fauna of Svračija Stena (near Lešak). *First International Conference on Rudists, Guide book,* 35–39, Belgrade.

Sladić-Trifunović, M., Pantić, N. & Mihajlović, Đ. 1988. Transported faunas and floras in Cretaceous deepsea sediments (Inner Dinarides, Eastern Alps) and biostratigraphic implications. *Forth Symosium on Ecology and Paleoecology of Benthic Communities, Abstracts,* p. 28, Sorento.

Mihajlović, Đ. 1989. Paleogene flora of Yugoslavia (a rewiew). *Symposium Paleofloristic Changes in the Cretaceous and Tertiary, IGCP 216*, *Abstarcts,* 28–29, Prague.

Mihajlović, Đ. 1989. Some calcareous nannofosils from Pontian of Eastern Serbia. *14th Congress of the Carpathian-Balkan Geological Association, Abstracts,* p. 730, Sofia.

Михајловић, Ђ. и Кнежевић, С. 1989. Кречњачки нанопланктон из баденских и сарматских наслага Вишњице и Карабурме (Београд). *Геолошки анали Балканскога полуострва*, 53: 343–357.

Pantić, N. & Mihajlović, Đ. 1989. Tertiary Fixed floras in reconstruction of Paleoclimatological events and evolution of land vegetation. *Symposium Paleofloristic Changes in the Cretaceous and Tertiary, IGCP 216, Abstarcts,* p. 35, Prague.

Mihajlović, Đ. 1990. Pontian floras in Yugoslavia. *In:* Malez, M. & Stevanović, P. (eds.), *Chronostratigraphie Neostratotypen. Neogender Westlichen ("Zentrale") Paratethys*, *Pontian,* 8: 922–945, Zagreb–Beograd.

Pantić, N. & Mihajlović, Đ. 1990. Tertiary Fixed floras in reconstruction of Paleoclimatological events and evolution of land vegetation. *In:* Knobloch, E. & Kvaček, Z. (eds.), *Symposium Paleofloristic and Paleoclimatic Changes in the Cretaceous and Tertiary, Proceedings,* 105–122, Geological Survey Publications, Prague.

Mihajlović, Đ. 1990. Paleogene flora of Yugoslavia (a rewiew). *In:* Knobloch, E. & Kvaček, Z. (eds.), *Symposium Paleofloristic and Paleoclimatic Changes in the Cretaceous and Tertiary, Proceedings,* 141–146, Geological Survey Publications, Prague.

Сладић-Трифуновић, М., Пантић, Н., Михајловић, Ђ. и Дулић, И. 1990. О генетским карактеристикама и времену настанка мезозојског дубокоморског комплекса околине Београда. *Геолошки анали Балканскога полуострва*, 53 (1): 251–260.

Пантић, Н. Михајловић, Ђ. и Дулић, И. 1990. Значај терцијарних реперних флора за реконструкцију развоја вегетације и климе. *Геолошки анали Балканскога полуострва*, 53 (1): 343–357.

Сладић-Трифуновић, М., Пантић, Н. и Михајловић, Ђ. 1990. Дубокоморски кластични кречњаци из околине Београда и доњекредни кластични кречњаци код ушћа Беле реке у Топчидерску реку. *Геолошки анали Балканскога полуострва*, 54: 81–92.

Врабац, С. и Михајловић, Ђ. 1990. Палеонтолошке и биостратиграфске одлике кровинских седимената лежишта камене соли Тушањ у Тузли. *Геолошки анали Балканскога полуострва*, 53 (1): 293–303.

Mihajlović, Đ. 1991. Xerophytic plant forms in Paleogene floras of Yugoslavia. *Pan-European Paleobotanical Conference, Paleovegetional development in Europe, Abstracts,* p. 26, Wien.

Михајловић, Ђ. 1991. Фосилна флора Златокопа код Врања и њен значај за одређивање старости врањског миоценског комплекса. *Геолошки анали Балканскога полуострва*, 53 (2): 343–357.

Пантић, Н., Сладић-Трифуновић, М. и Михајловић, Ђ. 1991. Значај проучавања транспортованих и преталожених фосила у фанерозојским седиментима за стратиграфске интерпретације и тумачење геодинамичких догађаја. *Геолошки анали Балканскога полуострва*, 55 (1): 13–34.

Пантић, Н., Сладић-Трифуновић, М. и Михајловић, Ђ. 1991. Транспортовани и преталожени фосили и њихов значај за будуће реконструкције геолошке историје. *Записници Српског геолошког друштва за 1987., 1988., и 1989. годину,* 33–36.

Сладић-Трифуновић, М., Пантић, Н. и Михајловић, Ђ. 1991. О значају дубокоморских кластичних кречњака у стубу Бела река-Ресник, за стратиграфска рашчлањавања и реконструкције депозиционих средина горњејурско-доњекредног комплекса стена околине Београд. *Записници Српског геолошког друштва за 1987., 1988., и 1989. годину,* 361–367.

Пантић, Н., Дулић, И., Чановић, М. и Михајловић, Ђ. 1991. О значају проучавања кредних слојева у бушотини Шуј-1 (Банат) за тумачење пренеогене тектонике. *Геолошки анали Балканскога полуострва*, 55 (1): 95–116.

Mihajlović, Đ. 1992. Xerophytic plant forms in Paleogene floras of the western Balkan peninsula. *In:* Kovar-Eder, J. (ed.), *Procedings Pan-European Paleobotatnical Conference, Paleovegetational development in Europe and Regions relevant to its Paleofloristic evolution,* 189–196, Museum of Natural History Vienna, Vienna.

Mihajlović, Đ. 1993. *Praenoelaerhabdus*, a New Endemic Genus of Calcareous Nannoplankton from Pannonian Basin. *Geologica Carpathica*, 44 (1): 59–62.

Mihajlović, Đ. 1993. Importance of the Upper Eocene flora of the Pčinja - Ovče Polje Group for interregional correlations. *In:* Planderova, E. *et al.* (eds.), *Symposium Paleofloristic and Paleoclimatic changes during Cretaceous and Tertiary, Proceedings,* 99–104, Geolicesky ústav Dionyza Stúra, Bratislava.

Kvaček Z., Mihajlović Đ. & Vrabac, S. 1993. Early Miocene Flora of Miljevina (Eastern Bosnia). *Acta Paleobotanica*, 53–89.

Mihajlović, Đ. & Ljubotenski, T. 1994. Upper Eocene Flora of Ovče Polje, Macedonia. *Geologica Carpathica*, 45 (4): 203–210.

Kovar-Eder, J., Givulescu, R., Hably, L., Kvacek, Z., Mihajlović, Đ., Teslenko, J., Walther, H. & Zastawniak, E. 1994. Floristic Changes in the Area Surrounding the Paratethys During Neogene Time. *In:* Boulter, M. C. & Fisher, H. C. (eds.), *Cenozoic Plants and Climates of the Arctic*, NATO ASI Series, I 27: 347–369, Springer- Verlag, Berlin Heidelberg.

Mihajlović, Đ. & Krstić, N. 1995. Position of the Bessarabian (Middle Sarmatian) on global Biostratihraphic Scale Based on Calcareous Nannoplankton. *Записници Српског геолошког друштва за 1990., и 1991. годину,* 163–168.

Михајловић, Ђ. и Лазаревић, **З.** 1995. Горњобаденска флора Лешћа (околина Београда). *Геолошки анали Балканскога полуострва*, 59: 165–175.

Krstić, N., Dodiković, S., Mihajlović, Đ., Cvetković, D., Milićević, V., Gordanić, V. & Potkonjak, B. 1995. Properties of the Lower Pontian in the Srbovo bore-hole near Negotin Dacian Basin. *Geologica Carpathica*, 46 (6): 357–370.

Mihajlović, Đ. 1996-1997. Two fossil floras from Fruška Gora Mt. and their significance for stratigraphy of terrigenous-lacustrine deposits. *In:* Georgiades-Dikeoulia, E. (ed.), IGCP PROJECT No 329, *Annales Geologiques des Pays Helleniques*, 37: 75–81, Athens.

Михаjловић, Ђ. и Лазаревић, З. 1996. Понтска флора из колубарског угљеног басена (Србија). *Геолошки анали Балканскога полуострва*, 60 (1): 231–246.

Kovar-Eder, J., Kvaček, Z., Zastawniak, E., Givulescu, R., Hably, L., Mihajlović, Đ., Teslenko, J. & Walther, H. 1996. Floristic Trends in the Vegetation of the Paratethys Surroundings Areas During Neogene Time. *In:* Bernor, R. L., Fahlbuch, V. & Mittmann, H-V. (eds.), *Evolution of Western Eurasian Neogene Mammal Faunas*, 395–413, Columbia University Press, New York.

Mihajlović, Đ. 1997. Calcareous Nannofosilis of the Neogene Sediments in Serbia and Northeastern Bosnia. *In:* Mihajlović, Đ. & Krstić, N. (eds.), *Field Meetings in 1995 and 1996, IGCP - Project 329 - Paleogeographic and paleoecological evolution of Paratethys basins during Neogene and their correlation to the global scales, Proceedings, Geoinstitut-Beograd, Special edition,* 21: 49–55, Beograd.

Михаjловић, Ђ. и Лазаревић, З. 1997. О потреби примењивања савремених схватања о стратиграфском положају неогених катова Паратетиса. *Радови Геоинститута*, 34: 67–75.

Mihajlović, Đ., Mitrović, S., Rundić, L. & Jeremić M. 1997. Palaeoecological Characteristics of Miocene Microfossils of NE Bosnia and Serbia. *The First International Conference "Application of Micropaleontology in Environmental Sciences", Program & Abstracts,* 89–90, Tel Aviv.

Mihajlović, Đ., Rundić, Lj. & Mitrović, S. 1998. Miocene microfossils on NE Bosnia and Serbia: Biostratigraphical Characteristics and Palaeoenvironmental indicators. *Geologorum Conventus, Abstracts,* p. 383, Mente et Malleo, Societas Carpato-Balcanica, XVI, 1998, Austria.

Михаjловић, Ђ. и Лазаревић, З. 1998. Понтска флора из костолачког угљеног басена (Србија). *Геолошки анали Балканскога полуострва*, 62: 133–153.

Mihajlović, Đ. & Lazarević, Z. 1998. Three different Upper Pontian types of Flora from Northern Serbia. *5th European Paleobotanical and Palynological Conference, Abstracts,* 118, Krakow.

Mihajlović, Đ. & Lazarević, Z. 1999. Three Late Pontian leaf-floras from Northern Serbia reflecting different environments. *Acta Palaeobotanica, Supplements 2, 5th European Paleobotanical and Palynological Conference, Proceedings*, 341–347, Krakow.

Долић, Д., Михаjловић, Ђ. и Вулетовић, В. 2000. Језерски миоцен Радоиња код Нове Вароши у западноj Србиjи. *Геолошки анали Балканскога полуострва*, 63: 1–18, Београд.

Mihajlović, Đ. & Lazarević, Z. 2003. Early Miocene Flora from Snegotin-Vukovići basin. *Phytologia Balcanica*, 9 (2): 187–195.

Mihajlović, Đ. & Lazarević, Z. 2004. Fossil Flora from Late Neogene of Bitola Area, FYR Macedonia. *Bulletin de l' Academie serbe des sciences et des arts, CXXVIII, Classe des sciences mathematiques et naturelles, Science naturelles, Nouvelle serie* 42: 283–303.

Lazarević, Z. & Mihajlović, Đ. 2006. Paleoflora from Valjevo-Mionica Basin (Serbia). *7th European Paleobotanical and Palynological Conference, Abstracts,* p. 79, Prague.

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In memoriam

Др Бранислав Крстић, научни саветник (1933–2010)

Почетком лета, у време када геолози полазе на терен, на свој последњи пут кренуо је Бранко Крстић наш високо цењени стратиграф, уважени колега и изнад свега угледни стручњак. Савладан болешћу, отишао је као што је и живео, тихо, нечујно, али је иза себе оставио траг по коме ће га памтити генерације садашњих и будућих геолога.

Рођен је 10 августа 1933. год. у Књажевцу, као најмлађе од троје деце, у породици где је отац био рударски инжењер, а мајка учитељица. Строго васпитаван, од малена је стекао изванредне радне навике, што се огледало и у свим његовим каснијим активностима.

Тешке ратне године провео је као дете у окупираном Београду. Завршио је Шесту Београдску гимназију на Звездари, што је са поносом истицао. 1952. године отац га је одвео Кости Петковићу рекавши “Влада Петковић, Ваш отац, усмерио ме је, после Албаније и Волоса на рударство, а ја Вам доводим мог сина да буде геолог”. Тако се уписао на геолошки одсек Природно-математичког факултета. Од оца Добривоја је врло рано научио пуно тога о рудницима, али и о геологији, тако да му није било тешко да постане добар студент са деветкама и десеткама из свих важнијих предмета. Како је био вредан и жељан знања, то је инсистирао да му два професора (Коста Петковић и Петар Стевановић) формулишу тему за диопломски рад. Препоручили су му да уради геолошку карту околине Зворника. Карту је успешно урадио прикупивши при томе богату колекцију баденских мекушаца. Дипломирао је у априлу 1957. године, а своје резултате објавио је као рад под називом “Марински миоцен северно и северозападно од Зворника”, у *Веснику Завода за геолошка и геофизичка истраживања,* 1958. године, почевши тиме једну изузетно богату каријеру.

Цео свој радни век посветио је геологији, а резултати тога рада учинили су га једним од наших највише уважаваних стручњака. Највећи део тога времена провео је у *Заводу за геолошка и геофизичка истраживања,* где је био запослен од 1958. до 1985. године, скоро 30 година, врло активно радећи на разним задацима. Како је уз оца рударског инжењера постао добар познавалац рударства, на почетку свога рада у Геозаводу добио је задужење да скупља документацију из разних рудника. 1959. године прикључен је екипи која је картирала лист Бољевац. Већ првих дана свога рада на централном Кучају у усеку новог пута, код Кленцушког потока, нашао је у шкриљцима бројне отиске граптолита. Тај налазак одредио је његову будућу каријеру. Последипломске студије уписао је 1961. године, а завршио их 1965. године. Докторирао је 1983. одбранивши дисертацију под називом “Стратиграфија старијег палеозоика (ордовицијум-девон) између Ресаве и Нишаве (источна Србија)”. Због изузетног значаја, резултате тих истраживања објавио је као посебно издање *Завода за геолошка и геофизичка истраживања*, 1984. године.

Највећи део свога радног века посветио је изради Основне геолошке карте 1:100.000, тако да скоро сваки лист везан за терене источне Србије међу ауторима садржи и његово име. Током ових истраживања Бранко је радио само на основу факата, скупљајући чињенице, полазећи од конкретне теренске ситуације, праћењем границе формација, прикупљајући велики број података на изданку. Он се без устезања хватао у коштац са традиционалним стереотипима у нашој геологији, што се више оспоравало него што се полугласно одобравало. Међутим Бранко, строг према другима, али највише према себи, резултате својих истраживања је заснивао на чињеницама, а своја дела правио од најфинијег материјала, са јасним закључцима, истрајавши на својим стазама, којима „се ређе иде“. Остајао је стално на путу који је тежак и захтеван, али и плодотворан, на путу који доноси праве резултате. Све то, уз чињеницу да није имао унапред припремљене вештачке шаблоне, дало је његовим резултатима вредност која траје и данас. Врло често своја сазнања проверавао је учешћем на међународним скуповима, при чему је своја схватања модификовао, усавршавао и прилагођавао конкретним ситуацијама на терену. На томе је постигао свој реноме. Као такав Бранко Крстић је дао изванредан допринос геологији источне Србије успостављајући моделе на које се већ данас ослањају младе генерације при изради својих дипломских радова, магистарских теза и докторских дисертација. Тиме је Бранко Крстић себе уградио у делатност будућих генерација

Као врстан стратиграф обављао је за потребе Геозавода бројне послове у земљи, али и у иностранству. Захваљујући великом искуству на изради листова Основне геолошке карте, три месеца провео је са колегама у Нигеру као стручњак и саветник тамошње владе за израду основне геолошке карте. Према речима министра Кутубија, у то време задуженог за ресор геолошких истраживања, њихов тадашњи рад оставио је дубок траг и велики утицај на програме израде геолошких карата Нигера и других афричких замаља. У бројним приликама остваривао је контакте са страним колегама, откривајући им геолошке тајне изузетно комликованих терена источне Србије. Током своје каријере, зближио се и са геолозима Бугарске, Русије, Грузије, Аустрије, Чехословачке, Шпаније, Немачке, Румуније, активно суделујући у геолошким пројектима SEV-a, UNESCO-вом међународном програму геолошке корелације (IGCP) и другим пројектима. Обишао је многе терене: Стару Планину, Кавказ, западне Карпате, Алпе, Шпанску Сијеру, Харц, обилазећи њихова палеозојска језгра и често унапред указујући домаћим истраживачима на шта ће следеће наићи. Када је 1991. у Барцелони видео модел терана (управо креиран на Аљасци) постала су му јасна многа питања која је себи постављао радећи, са Кројтнером, на „Геолошкој карти Карпато-Балканида“. Интензивно је сарађивао са колегама из Аустрије, Мађарске, као и са простора бивше Југославије, који су такође примењивали најновије моделе, чиме су на нов начин тумачили геолошку историју целог циркумпанонског простора. О томе сведочи чињеница да је Бранко Крстић уврштен међу редакторе посебног издања Мађарског геолошког института “Tectonostratigraphic Terrane and Paleoenvironment Maps of the Circum-Pannonian Region”, као и то да је истовремено и коаутор две карте палеозоика у истој едицији. Слободно можемо да кажемо да је његов одлазак, велики губитак не само за нашу већ и за међународну геолошку заједницу.

Од 1985. године па све до пензионисања био је веома ангажован у геолошким истраживањима, али као сарадник Самоуправне заједнице за геолошка истраживања, а касније и Фонда за геолошка истраживања. Иако је овде био више везан за организацију геолошких истраживања, увек је налазио времена и за теренски рад, било да је учествовао у решавању одређених геолошких проблема, било да је млађе колеге упућивао у геолошку проблематику. Човек његове ерудиције и геолог таквог формата није се задовољавао тиме да седи у канцеларији, већ је у свакој прилици тражио могућности да обави неки теренски или лабораторијски рад. Таквим деловањем, а нарочито обилазећи терене источне Србије, у великој мери је проширио сазнања о геологији наше земље, оставивши резултате по којима ће га памтити генерације стручњака.

Научна активност др Бранислава Крстића била је превасходно усмерена на решавање проблема геолошке грађе источне Србије, али се бавио и појединим феноменима који нису уско везани за неки одређени простор. Написао је велики број научних радова, активно суделујући у UNESCO-вом међународном програму геолошке корелације (IGCP пројект 5: Грузија 1985., Шпанија 1991. итд.) и на скуповима организације SEV (нпр. Пољска 1977., Чехословачка 1985., Бугарска 1987., источна Немачка 1988.). Проучавао је опште карактеристике палеозојских турбидита и олистострома на Сувој Планини, Белави, у Кучајско-звоначком флишу, али се бавио и палеозоиком Праче, неогеном тектоником Карпатобалканида у целини, затим карактеристикама палеозоика између Нишаве и Руја, чиме је наставио рад који је започео одбраном своје докторске дисертације. На истраживању мезозоика сарађивао је са Д. Пејовић и А. Даниловом с којима је публиковао низ радова везаних за источну Србију. О теранима у нашој земљи, писао је са академиком С. Караматом, објашњавајући њихов развој и еволуцију од најстаријих периода. Поред тога заслужан је и за велики број карата које су изванредно значајне како за познавање геологије наших терена, тако и за популаризацију геологије на овим просторима, као што је нпр. серија од 15 карата у оквиру едиције „Геолошки атлас Србије“. Затим је уз сарадњу са колегом Кројтнером из Румуније објавио геолошку карту Карпато-балканида у размери 1:300.000 која представља један од најбољих приказа терена југозападне Румуније, источне Србије и северозападне Бугарске.

Бавио се и палеонтолошким проблемима, дајући заједно са другим колегама и сарадницима велики допринос познавању граптолита, кондоната, палиноморфи и постављајући темеље биостратиграфије палезоика у нас. Врло значајан тренутак у његовој каријери био је откриће граптолита у обновљеном усеку пута, у изворишном делу Кленцушког потока, такорећи првих дана рада на геолошком картирању. Ту су, у шкриљцима горњег силура, отисци граптолита веома бројни. Пре тога граптолити су констатовани једино код Звоначке бање, од стране бугарског геолога Зафирова који је ту радио током другог светског рата. Изузетно богат фосилни материјал Бранко Крстић је палеонтолошки обрадио током 1972. године у Хамбургу, као стипендиста фондације Alexander-von-Humboldt немачке владе. Тада је одредио граптолите не само из силура већ и из најмлађег ордовицијума (из Боговинске реке). Касније је уз помоћ колеге Јегера (Берлин) одредио, на профилима Звоначке бање, границу према девону па је ту установљен и доњи девон у фацији граптолитских шкриљаца. Заједно са колегом М. Сударом приказао је бројне конодонтске врсте из девона и карбона источне Србије.

Бранислав Крстић је на Малинику (Кучај), открио остатке трилобита *Dalmanitina* cf. *proeva*, што је један од најзначајнијих налазака фосила у нашем палеозоику. Колегу Албертија, свог домаћина у Хамбургу, као изузетног стручњака за трилобите одвео је на изданке кречњака на Сувој Планини, Алберти је, као палеонтолог са великим искуством из Харца и са Атласа, врло брзо нашао трилобите одредивши при томе нову врсту *Prantlia* (*Tetinia*) *krstići* Alberti, 1980 (штампано у Билтену САНУ), чији холотип је депонован у Природњачком Музеју у Београду. Нађене трилобите Алберти је ставио у доњи девон, и то *Tetinia krstići* у доњи локховиан, а другу форму, мало више, у прагиан, оба на основу пратећих тентакулита. Касније је Бранко Крстић са сталним сарадником седиментологом Љ. Маслaverевић, установио да доњодевонски кречњак није аутохтон, већ су његови комади током горњег девона или доњег карбона у виду олистолита склизнули у дубоку воду, а да су касније прекривени седиментима горњег карбона.

Као што је остварио велики допринос у струци, тако је био истакнут и у другим пољима. Врло активно учествовао је у раду Друштва инжењера и техничара, а генерације наших геолога упамтиће га као члана комисије за стручни испит. Његовим одласком Српско геолошко друштво, остало је без свог угледног и стално активног члана. Он није себи дозволио само пуко присуство и дискусију на зборовима. У више наврата био је предлаган и биран у органе Друштва, учествовао је и у припреми геолошких конгреса и других значајних скупова. У својим активностима није мимоилазио ни вечито актуелне проблеме наше геологије, о којима је говорио на тематским скуповима. Стицајем околности један део свога радног века провео је у Фонду за геолошка истраживања, где је био врло добро упознат са стањем у нашој геологији, па је успешно водио реализацију бројних истраживачких пројеката.

Овако богата геолошка каријера обележена је наградом “Јован Жујовић” коју је добио 2004. године за допринос развоју регионалне геологије и палеонтологије. Поред ове медаље специфично сведочанство о његовом раду представља и стипендија Немачке владе “Alexander-von-Humboldt” која је намењена само најбољима у струци.

Бранко Крстић је живео врло активно и урадио врло много. Све то је већ уграђено у српску геологију и сви смо од њега пуно научили. Покушавајући да схватимо колико смо изгубили, остајемо поносни што нам је био пријатељ, учитељ, човек чије ће нам особине бити “светло на крају тунела”, сваки пут када се ухватимо у коштац са бројним геолошким проблемима.

Овом приликом треба поменути и неке Бранкове карактеристике које нису везане за геологију. Као човек био је прави господин, увек насмејан, расположен и врло непосредан. Према младима се опходио са великим уважавањем. Захваљујући њему и помоћи коју је пружио многима, бројне магистратуре и докторати су урађени брже, лакше и квалитетније него што је то уобичајено. Никад надмен, увек спреман да помогне, био је ненаметљив, али и строг, чак бескомпромисан, јер је увек држао до свога става.

Обично се у оваквим приликама износи и нека лична црта, осврт, детаљ из богате каријере. Иако никада нисам радио са њим у истој организацији ипак су нам се стазе често укрштале. Почев од Комисије за државне испите, где је био строги испитивач, па преко мојих првих пројеката, где је био штедљиви финансијер, па до мога првог уџбеника где је био пажљиви рецензент. У свим тим приликама било је пуно дискусија о различитим проблемима. Иако ми никад није био професор, ипак сам од њега научио много. Бројне чињенице геолошке грађе сагледао сам у правом светлу тек после Бранкових објашњења, а неки детаљи наших разговора остаће заувек упамћени као сведочанство једног времена.

Желимо да верујемо да је Бранку постао тесан овај свет са својим геолошким формацијама, које је изузетно добро упознао и да је кренуо у истраживања неких виших формација у којима ће подједнако уживати. А нама остаје да га чувамо у тихом људском сећању.

Ненад Бањац

Др Бранислав Крстић објавио је велики број (преко 120) научних радова. У даљем тексту наведени су неки од радова у којима је Бранислав Крстић био аутор или коаутор. Прихватајући одговорно ризик да нешто и пропустимо, наводили смо само најзначајније радове који могу да осветле пут којим се Бранислав Крстић кретао током свог научноистраживачког рада. Радови су уређени хронолошки, према години настанка.

Докторска дисертација:

Крстић, Б. 1984. Стратиграфија старијег палеозоика (ордовицијум-девон) између Ресаве и Нишаве (источна Србија). *Расправе Завода за геолошка и геофизичка истраживања*, 22: 1–64, Београд.

Листови и тумачи Основне геолошке карте СФРЈ 1:100.000 у чијој изради је учествовао Бранислав Крстић:

Лист Жагубица Л 34-140: 1968.
Лист Бољевац К 34-8: 1968.
Лист Зајечар К 34-9: 1972.
Лист Пирот К 34-34: 1973.
Лист Брезник К 34-46: 1973.
Листови Књажевац К 34-21 и Белоградчик К 34-22: 1974.
Лист Бела Паланка К 34-33: 1978.
Лист Кучево К 33-128: 1978.
Лист Алексинац К 34-20: 1978.
Тумач за лист Жагубица Л 34-140: 1970.
Тумач за лист Бољевац К 34-8: 1970.
Тумач за лист Бор Л 34-141: 1976.
Тумач за листове Књажевац К 34-21 и Белоградчик К 34-22: 1976.
Тумач за листове Пирот К 34-34 и Брезник К 34-46: 1977.
Тумач за лист Алексинац К 34-20: 1980.
Тумач за лист Бела Паланка К 34-33: 69 стр., 1980.

Значајнији радови др Бранислава Крстића

Крстић, Б. и Еремија, М. 1958. Марински миоцен северно и северозападно од Зворника. *Весник Завода за геолошка и геофизичка истраживања,* 16: 29–39.

Крстић, Б. 1960. Старопалеозојске творевине централног Кучаја (ист. Србија). *Весник Завода за геолошка и геофизичка истраживања*, 18: 53–64.

Крстић, Б. 1962. Белешка о присуству пре-карадочке серије метаморфних стена на Кучају и Бељаници. *Геолошки анали Балканскога полуострва*, 29: 51–52.

Крстић, Б. 1963. О зони са *Monograptus testis* (*Barr.*) у силуру Кучаја. *Записници Српског геолошког друштва за 1960 и 1961 годину*, 179–182.

Крстић, Б. 1967. Ордовицијум-доњи девон. *VIII Конгрес Карпато-балканске геолошке ассоцијацје, Геолошки преглед Карпато-балканида источне Србије (стратиграфија, тектоника, магматизам)*: 14–18, Београд.

Крстић, Б., Каленић, М. и Данилова, А. 1968. Тупижничко-књажевачка синклинала. *Геологически институт БАН, Јубилеен геол. сборник*, 67–71.

Крстић, Б. и Масларевић, Љ. 1970. Вестфалска вулканогено-седиментна серија на Старој планини (источна Србија). *Весник Завода за геолошка и геофизичка истраживања*, *А,* 28: 431–436.

Pejović, D., Krstić, B. & Danilova, A. 1970. Rekonstruktion der reihenfolge der Maastrichter Gebilde im 'Senonischen' tektonischen Graben Ostserbiens zwieschen Boljevac und Dimitrovgrad. *Bulletin Scientifique du Conseil des Academies des Sciences et des arts de la RSF de Yugoslavie (Section A)*, 15 (9–10): 138.

Pejović, D., Krstić, B. и Danilova, A. 1971. Сеноманские и туронские отложениа в восточној Сербии. *Acta Geologica,* 15 (1–4): 257–263.

Krstić, B., Pejović, D., & Danilova, A. 1971. Die Mediterrane Phase im zentralen Karpathen – Balkan - Gürtel Ostserbiens. *Bulletin Scientifique du Conseil des Academies des Sciences et des arts de la RSF de Yugoslavie (Section A)*, 16 (9–10): 268.

Крстић, Б., Масларевић, Љ., Данилова, А. и Ракић, Б. 1972. Мезозојски седименти између Петруше и Кадибогаза у синклинали Новог Корита. *Весник Завода за геолошка и геофизичка истраживања, А,* 29/30: 129–136.

Пејовић, Д., Крстић, Б. и Данилова, А. 1972. Реконструкција редоследа мастрихтских творевина у "сенонском" тектонском рову источне Србије између Бољевца и Димитровграда. *Глас Српске академије наука и уметности, CCLXXXII, Одељење природно-математичких наука*, 34: 85–102.

Krstić, B. & Pajić, V. 1972. A contribution to the Knowledge of the Upper Devonian in Eastern Serbia. *Bulletin Scientifique du Conseil des Academies des Sciences et des arts de la RSF de Yugoslavie (Section A),* 17 (3–4): 70.

Krstić, B. & Dinić, J. 1972. Über die Erstreckungsrichtung der Antiklinale der Svrljiške planine in Ostserbien. *Bulletin Scientifique du Conseil des Academies des Sciences et des arts de la RSF de Yugoslavie (Section A),* 17 (3–4): 151.

Krstić, B. 1973. About some Associations of Graptolites from the Lower Silurian of Eastern Serbia. *Bulletin Scientifique du Conseil des Academies des Sciences et des arts de la RSF de Yugoslavie (Section A),* 18 (4–6): 69–70.

Krstić, B., Spasov, H., Stojanović-Kuzenko, S. & Pajić V, 1973. Contribution to the Study of the Lower and Middle Devonian in Eastern Serbia. *Весник Завода за геолошка и геофизичка истраживања,* А, 28: 347–367.

Krstić, B. & Maslarević, Lj. 1973. Westphalien volcanogenic sedimentary series on Stara planina (Eastern

Serbia). *Весник Завода за геолошка и геофизичка истраживања,* A, 28: 557–562.

VESELINOVIĆ, M. & KRSTIĆ, B. 1973. Zones of *Restrites Linnaei* and *Spirigraptus Turriculatus* in the Silurian of Kučaj. *Весник Завода за геолошка и геофизичка истраживања,* A, 28: 403–415.

MASLAREVIĆ, LJ., KALENIĆ, M. i KRSTIĆ, B. 1974. Staropaleozojski miogeosinklinalni sedimenti mezijske periplatformne zone u istočnoj Srbiji. *8. Jugoslovanski geološki kongres, Bled, 1.-5. oktobar 1974, Povzetki referatov*: 46–47.

КРСТИЋ, Б. 1976. Биостратиграфија силура и девона у источној Србији на основу граптолита и конодоната. *8. Jugoslovanski geološki kongres Bled, 1.-5. Oktober 1974, Paleontologija, sedimentologija, stratigrafija,* 2: 131–141.

МАСЛАРЕВИЋ, Љ., КАЛЕНИЋ, М. и КРСТИЋ, Б. 1976. Старопалеозојски миогеосинклинални седименти мезијске периплатформне зоне у источној Србији. *8. Jugoslovanski geološki kongres Bled, 1.-5. Oktober 1974, Paleontologija, sedimentologija, stratigrafija*, 2: 193–199.

KRSTIĆ, B. 1978. Some Silurian Graptolites from Eastern Serbia. *Bulletin de l'Academie serbe des Sciences et des Arts, LXI, Classe des sciences naturelles et mathématiques, Sciences naturelles, Nouvelle série,* 17: 25–47.

ПЕЈОВИЋ, Д. и КРСТИЋ, Б. 1980. Стратиграфски положај боксита у југословенском делу Карпато-Балканида. *Глас Српске академије наука и уметности, CCCXVII, Одељење природно-математичких наука*, 46: 79–85.

КРСТИЋ, Б., МАСЛАРЕВИЋ, Љ. и МИЛОВАНОВИЋ, Љ. 1981. Девонские осадки в југославскoj части Карпато-Балканид. *12th Congress of the Carpathian-Balkan Geological Association, Abstracts*: 78–79, Bucharest.

RAMOVŠ, A., HINTERLECHNER-RAVNIK, A., KALENIĆ, M., KARAMATA, S., KOCHANSKI-DEVIDE, V., KRSTIĆ, B., KULENOVIĆ, E., MIRKOVIĆ, M., PETKOVSKI, P. & TEMKOVA, V. 1984. Stratigraphic, correlation forms (SCF) of the Yugoslav Paleozoic.- *IGCP No 5, Newsletter*, 6: 81–109.

КРСТИЋ, Б. и МАСЛАРЕВИЋ, Љ. 1985. Доњокарбонски турбидити Белаве (горњи део Кучајско-звоначког флиша источне Србије). *Радови Геоинститута*, 18: 163–166.

КРСТИЋ, Б. и МАСЛАРЕВИЋ, Љ. 1985. Палеозојски турбидити на Сувој планини. *Весник Завода за геолошка и геофизичка истраживања, A*, 43: 29–33.

MASLAREVIĆ, LJ. & KRSTIĆ, B. 1987. The Kučaj-Zvonce Flisch. *The Turbiditic Basins of Serbia. Serbian Academy of Sciences and Arts Monographs, DLXXVI, Department of Natural and Mathematical Sciences,* 61: 210–237.

KRSTIĆ, B., GRUBIĆ, A., RAMOVŠ, A. & FILIPOVIĆ, I. 1988. The Devonian of Yugoslavia. Devonian of the World, *Proceedings of the Second International Symposium on the Devonian System, Vol. I,* 499–506, CSPG, Memoir 14, Calgary.

KRSTIĆ, B., FILIPOVIĆ, I. & MASLAREVIĆ LJ. 1988. Palaeozoic olistostromes of Prača area, SE Bosnia (Палеозојске олистостроме Праче (ЈИ Босна)). *Геолошки анали Балканскога полуострва,* 51: 223–229.

КРСТИЋ, Н., СИКОШЕК, Б. и КРСТИЋ, Б. 1988. Неогена тектоника југословенских Карпато-Балканида. *Радови Геоинститута*, 22: 75–85.

KRSTIĆ, B. & MASLAREVIĆ, LJ. 1989. Marine Paleozoic of Hercynid Kučaj Zone, Eastern Serbia. Depositional Environment. *14th Congress of the Carpathian-Balkan Geological Association, Abstracts*, 908–910, Sofia.

RAMOVŠ, A., FILIPOVIĆ, I., KRSTIĆ, B., PEŠIĆ, L. & SREMAC, J. 1989. Palaeogeographić, reconstruction of the Carboniferous in Yugoslavia. *XI Congres International de Stratigraphie et de Geologie du Carbonifere Beijing 1987, Compte rendu,* 4: 279–287, Beijing.

RAMOVŠ, A., HINTERLECHNER-RAVNIK, A., KALENIĆ, M., KARAMATA, S., KOCHANSKY-DEVIDE, V., KRSTIĆ, B., KULENOVIĆ, E., MIRKOVIĆ, M., PETKOVSKI, P., SREMAC, J. & TEMKOVA, V. 1990. Stratigraphic, correlation forms of the Yugoslav Paleozoic. *Rendiconti della Società Geologica Italiana,* 12: 359–383.

KRSTIĆ, B. & MASLAREVIĆ, LJ. 1990. Depositional environment of the marine Paleozoic, in the hercynid Kučaj Zone, Eastern Serbia. *Bulletin de l'Academie serbe des Sciences et des Arts, CII, Classe des sciences naturelles et mathématiques, Sciences naturelles, Nouvelle série,* 32: 29–37.

KARAMATA, S., KRSTIĆ, B. & STOJANOV, R. 1992. Terranes from the Adriatic, to Moesian massif in the central part of the Balkan Peninsula. *Alcapa – Geological evolution of the internal Eastern Alps, Carpathians and of the Pannonian basin. Terra Nova, Abstracts Supplement* 2 (4), communication no. 78.

PLANDEROVA, E., KRSTIĆ, B. & MASLAREVIĆ, LJ. 1992. Paleozoic, palynomorph assemblages from eastern Serbia. *Geologicke prace*, 94: 19–22.

KARAMATA, S., KRSTIĆ, B., DIMITRIJEVIĆ, M.N., KNEŽEVIĆ V., DIMITRIJEVIĆ M.D. & FILIPOVIĆ, I. 1994. Terranes between the Adriatic, and the Carpatho-Balkan arc. *Bulletin de l'Academie serbe des Sciences et des Arts, CVIII, Classe des sciences naturelles et mathématiques, Sciences naturelles, Nouvelle série,* 35: 47–68.

KRSTIĆ, B. & SUDAR, M. 1995. Paleozoic, conodonts of eastern Serbia, Yugoslavia. *XV Congress of the Carpathian-Balkan Geological Association,* 4 (1): 214–217, Athens.

KARAMATA, S., EBNER, F. & KRSTIĆ, B. 1996. Terranes - Definition of the Terrane, and Importance for Geologic Interpretations. *Terranes of Serbia - Symposium: The Formation of the Geologic Framework of Serbia and the Adjacent Region. University of Belgrade, Faculty of Mining and Geology, Committee for Geodynamics of Serbian Academy of Sciences and Arts*: 1–3, Belgrade.

KARAMATA, S. & KRSTIĆ, B. 1996. Pre neogene terranes in the central part of the Balkan Peninsula. *Mitteilungen der Gesellschaft der Geologie- und Bergbaustudenten in Österreich*, 41: 1–113.

KARAMATA, S., KRSTIĆ, B, DIMITRIJEVIĆ, M.N., KNEŽEVIĆ, V., DIMITRIJEVIĆ, M.D., STOJANOV, R. & FILIPOVIĆ, I. 1997. Terranes Between the Moesian Plate and the Adriatic Sea. *Annales géologiques des pays Helléniques*: 429–477.

Krstić, B. & Maslarević, Lj. 1997. The palaeozoic of Đerdap. *International Symposium Geology in the Danube Gorges, Geology of Đerdap Area, Geoinstitut-Beograd, Special edition,* 25: 25–28.

Maslarević, Lj. & Krstić, B. 1997. Paleozoic, continental slope deposits in the Stara Planina Mountains, Eastern Serbia. *Geologica Balcanica*, 27 (1–2): 7–18.

Карамата, С., Крстић, Б. и Димитријевић, М. 1998. Анализа терана, нов приступ објашњавању геолошког развоја. *13. Конгрес геолога Југославије,* 2: 125–132, Херцег Нови.

Krstić, B., Ercegovac, M., Maslarević, Lj., Đajic, S. & Milivojević, J. 1999. On the Age of the Marine Inovo Formation of Stara Planina, Eastern Serbia, dated on Palynomorphs. *Bulletin de l'Academie serbe des Sciences et des Arts, CXIX, Classe des sciences naturelles et mathématiques, Sciences naturelles, Nouvelle série,* 39: 91–97.

Krstić, B., Maslarević, Lj., Ercegovac, M. & Đajić, S. 1999. Ordovician of the East-Serbian South Carpathians. *Acta Universitatis Carolinae, Geologica,* 43 (1–2): 101–104.

Maslarević, Lj. & Krstić, B. 1999. Permian continental Redbeds of the Serbian South-Carpathian and Balkan (Stara Planina) Mountains. *International Congress "The continental Permian of Southern Alps and Sardinia (Italy)", Abstracts*, 62–64, Bresscia.

Димитријевић, М.Д. и Крстић, Б. 1999. Геолошки атлас Србије 1:2.000.000, Геотектоника. *Министарство рударства и енергетике републике Србије,* Београд.

Yanev, S., Maslarević, Lj. & Krstić, B. 2001. Outline of the permian paleogeography in the central and eastern part of the Balkan Peninsula. *Natura bresciana: Annuario del Museo Civico di Storia Naturale di Brescia, Monographia*, 25: 235–244.

Maslarević, Lj. & Krstić, B. 2001. Continental Permian and Lower Triassic, Red Beds of the Serbian Carpatho-Balkanides. *Natura bresciana: Annuario del Museo Civico di Storia Naturale di Brescia, Monographia*, 25: 245-252, Bresscia.

Kräutner, H.G. & Krstić, B. 2001. Corelation of Alpine and Pre-Alpine structural units within the Southern Carpathians and the Western Balkanides. *Pancardi 2001, Pannonian Basin, Carpathian and Dinaride system, Geol. Meeting on Dinamics of Ongoing Orogeny*, 2, Abstracts: CP 14, Sopron.

Kräutner, H.G. & Krstić, B. 2002. Alpine and Pre-Alpine structural units within the southern Carpathians and the western Balkanides. *17th Congress of the Carpathian-Balkan Geological Association, Proceedings*, Bratislava.

Karamata, S., Stefanović, D. & Krstić, B. 2002. Permian to Neogene Formation of the assemblage of geological units at the south of the Pannonian basin. *7th Congress of the Carpathian-Balkan Geological Association, Proceedings*, Bratislava.

Kräutner, H.G. & Krstić, B. 2003. Geological Map of the Carpatho-Balkanides beetwen Mehadia, Oravita, Niš and Sofia 1:300 000. *Geoinstitut-Beograd, Special edition*.

Karamata, S., Stefanović, D. & Krstić, B. 2003. Permian to Neogene accretion of the assemblage of geologic, units presently occuring to the south of Pannonian Basin – Development of the Vardar Composite Terrane and adjacent units. *Acta Geologica Hungarica*, 46 (1): 63–76.

Kovacs, S., Brezsnyansky, K., Haas, J., Szederkenyi, T., Ebner, F., Pamić, J., Gaetani, M., Gian-Batista, V., Kräutner, H.G., Vozar, J., Vozarova, A., Mioč, P., Karamata, S. & Krstić, B. 2003. Tectonostratigraphic, terrane and palaeoenvironment maps of the Circum-Pannonian Region. *Annales Universitatis Scientiarum Budapestinensis, Sectio Geologica*, 35: 65.

Karamata, S., Stefanović, D. & Krstić, B. 2003. Permian to Neogene accretion of the assemblage of geologic, units presently occuring to the south of the Pannonian Basin – Development of the Vardar Composite Terrane and adjacent units. *Acta Geologica Hungarica*, 46 (1): 63–71.

Krstić, B., Maslarević, Lj., Ercegovac, M., Sudar, M. & Đajić, S. 2004. Devonian in the Carpatho-Balkanides of Eastern Serbia. *Bulletin de l'Academie serbe des Sciences et des Arts, CXXVIII, Classe des sciences naturelles et mathématiques, Sciences naturelles, Nouvelle série,* 42: 7–16.

Kräutner, H.G & Krstić, B. 2004. Correlation of Alpine and Pre-Alpine structural units within the Southern Carpathians and the Western Balkanides. *Second Conference on Geological Heritage of Serbia, Guide for Excursion. European Assoc. for Conservation of the Geol. Heritage – ProGeo,* 8-11, Belgrade.

Ebner, F., Pamić J., Kovacs, S., Szederkenyi, T., Vai, G. B., Venturini, C., Kräutner, H.G., Karamata, S., Krstić, B., Sudar M., Vozar, J., Vozarova, A. & Mioč, P. 2004. Variscan preflysh (Devonian-Early Carboniferous) Environments. *Tectonostratigraphy, terrane and Paleoenvironment Maps of the Circum-Pannonian Region. Geological Institute of Hungary*, Budapest.

Vozarova, A., Vozar, J., Ebner, F., Pamić, J., Kovacs, S., Szederkenyi, T., Vai, G.B., Venturini, C., Kräutner, H.G., Karamata, S., Krstić, B., Sudar, M. & Mioč, P. 2004. Late Variscian (Latest Carboniferous to Early Permian) Environments. *Tectonostratigraphy, terrane and Paleoenvironment Maps of the Circum-Pannonian Region. Geological Institute of Hungary*, Budapest.

Ebner, F., Gawlick, H. J., Pamić, J., Kovacs, S., Haas, J., Gaetani, M., Kräutner, H.G., Karamata, S., Krstić, B., Sudar, M., Mello, J., Polak, M. & Mioč, P., 2004. Initial Neotethyan Riffting (Middle-Late Triassic) Environments 1:2 500 000. *Tectonostratigraphy, Terrane and Paleoenvironment maps of the Circum-Pannonian Region. Geological Institute of Hungary*, Budapest.

Ebner, F., Gawlick, H.J., Pamić, J., Kovacs, S., Haas, J., Gaetani, M., Castellarin, A., Kräutner, H.G., Karamata, S., Krstić, B., Sudar, M., Mello, J., Polak, M. & Mioč, P. 2004. Maximum Neotethyan Spreading (Middle Jurrasic) Environments. 1:2 500 000. *Tectonostratigraphy, Terrane and Paleoenvironment maps of the*

Circum-Pannonian Region. Geological Institute of Hungary, Budapest.

Ebner, F., Pamić, J., Kovacs, S., Szederkenyi, T., Vai G. B., Venturini, C., Kräutner, H.G., Karamata, S., Krstić, B., Sudar, M., Vozar, J., Vozarova, A. & Mioč, P. 2004. Variscan preflysh (Devonian-Early Carboniferous) Environments. *Tectonostratigraphy, Terrane and Paleoenvironment maps of the Circum-Pannonian Region. Geological Institute of Hungary*, Budapest.

Vozarova, A., Vozar, J., Ebner, F., Pamić J., Kovacs, S., Szederkenyi, T., Vai, G.B., Venturini, C., Kräutner, H.G., Karamata, S., Krstić, B., Sudar, M. & Mioč, P. 2004. Late Variscian (Latest Carboniferous to Early Permian) Environments. *Tectonostratigraphy, Terrane and Paleoenvironment maps of the Circum-Pannonian Region. Geological Institute of Hungary*, Budapest.

Krstić, B., Filipović, I., Maslarević, Lj., Sudar, M. & Ercegovac, M. 2005. Carboniferous of the Central Part of the Balkan Peninsula. *Bulletin de l'Academie serbe des Sciences et des Arts, CXXX, Classe des sciences naturelles et mathématiques, Sciences naturelles, Nouvelle série*, 43: 41–56.

Krstić, B., Maslarević, Lj. & Sudar, M. 2005. On the Graptolitic, Schists Formation (Silurian – Lower Devonian) in the Carpatho-Balkanides of Eastern Serbia. *Геолошки анали Балканског полуострва,* 66: 1–8.

Krstić, N., Krstić, B., Jovanović, G. & Savić, Lj. 2006. Paleolimnology of Serbian lakes (Carboniferous – Holocen). *18th Congress of the Carpathian-Balkan Geological Association, Proceedings*, 297–299, Belgrade.

Ebner, F., Vozarova, A., Kovacs, S., Krstić, B., Szederkenyi, T., Sremac, J., Tomljenović, B. & Trajanova, M. 2006. Devonian-Carboniferous pre-flysch and flysch environments in the Circum Pannonian region. *18th Congress of the Carpathian-Balkan Geological Association, Proceedings*, 114–117, Belgrade.

Vozarova, A., Ebner, F., Kovacs S., Krautner, H.G., Szederkenyi T., Krstić, B., Sremac, J., Tomljenović, B. & Novak M. 2006. Late Variscan (Latest Carboniferous – Early Pemian) late and post-orogenic, environments in the Circum Pannonian Region. *18th Congress of the Carpathian-Balkan Geological Association, Proceedings,* 651–654, Belgrade.

Krstić,B., Maslarević, Lj., Sudar, M. & Ercegovac, M. 2008. Paleozoić, and Lower Triassic, Formations in the SE part of East-Serbian Carpatho-Balkanides. *Bulletin de l'Academie serbe des Sciences et des Arts, CXXXV, Classe des sciences naturelles et mathématiques, Sciences naturelles, Nouvelle série*, 44: 9–28.

Ebner, F., Vozarova, A., Kovacs, S., Kräutner, H.G., Krstić, B., Szederkenyi, T., Jamičić, D., Balen, D., Belak, M & Trajanova, M. 2008. Devonian-Carboniferous pre-flysch and flysch environments in the Circum-Pannonian Region. *Geologica Carpathica*, 59 (2): 159–195.

Vozarova, A., Ebner, F., Kovacs, S., Kräutner, H.G., Szederkenyi, T., Krstić, B., Sremac, J., Aljinović, D., Matevž, N. & Skaberne, D. 2009. Late Variscan (Carboniferous to Permian) environments in the Circum-Pannonian Region. *Gelogica Carpathica*, 60 (1): 71–104.

Instructions for authors

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RABRENOVIĆ, D. & JANKIČEVIĆ, J. 1984. Contribution to the study of Albian near Topola. *Geološki anali Balkanskoga poluostrva*, 48: 69–74 (in Serbian, English summary).

SMIRNOVA, T.N. 1960. About a new subfamily of the Lower Cretaceous dallinoid. *Paleontologičeskii Žurnal*, 2: 116–120 (in Russian).

SULSER, H. 1996. Notes on the taxonomy of Mesozoic Rhynchonellida. *In*: COOPER, P. & JIN, J. (eds.), *Brachiopods*, 265–268. Balkema Press, Rotterdam.

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ГЕОЛОШКИ АНАЛИ БАЛКАНСКОГА ПОЛУОСТРВА
ANNALES GÉOLOGIQUES DE LA PÉNINSULE BALKANIQUE

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