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FIELD TRIP GUIDEBOOK

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NEOGENE STRATIGRAPHY OF THE SLAVONIAN MOUNTAINS

Marijan Kovačić & Davor Pavelić

The term Slavonian Mountains refers to the five, up to 1000 m high, hills of Papuk, Krndija, Psunj, Požeška and Dilj, located in the eastern Croatian region of Slavonija, along the southern margin of the Pannonian Basin System (PBS) (Fig. I.1). They represent large blocks composed of different, strongly tectonized pre-Miocene basement rocks, uncomfortably overlain by Miocene deposits and uplifted during the Pliocene and the Quaternary (Fig. I.2). The Pre-Miocene basements exposed on the surface in the central parts of Psunj, Papuk and Krndija are composed of metamorphic and igneous pre-Alpine rocks of the southern Tisia, and the Permian-Mesozoic sediments. The basement of the Miocene deposits on Mt. Požeška consists of Upper Cretaceous (ŠPARICA et al., 1979, 1980) and probably Palaeogene rocks (HALAMIĆ et al., 1993), while on Mt. Dilj pre-Miocene rocks are not exposed on the surface. The maximum depth of the pre-Miocene basement in the Požega Valley, situated between the Slavonian Mountains, is 2700 m. North of them, in the Drava depression, the maximum depth of the pre-Miocene basement is more than 7000 m, and to the south, in the Sava depression, about 5 km (SAFTIĆ et al., 2003).

The Slavonian Mountains are a part of the North Croatian Basin (NCB) situated in the south-western part of the Pannonian Basin System (PBS). Forming of the PBS commenced in the Early Miocene as a result of the continental collision and subduction of the European Plate and the African Plate. The development of PBS is divided into two successive phases: the syn-rift and post-rift phases. The syn-rift phase of the basin evolution was characterized by the tectonic thinning of the crust and isostatic subsidence, while the post-rift phase was marked by the basin subsidence due to the cooling of the lithosphere (ROYDEN, 1988). The development was complex and heterogenous which is reflected in the individual evolution of several subbasins. The PBS is surrounded by the Alps, the Carpathians and the Dinarides, and palaeogeographically it belongs to the Central Paratethys realm (RÖGL & STEININGER, 1983; POPOV et al., 2004; HARZHAUSER & PILLER, 2007).

The NCB is an elongated rift-type basin generated by the continental passive rifting that started in the Early Miocene. Its evolution was strongly controlled by external factors, such as tectonics, climate changes, volcanic activity and eustatic sea-level changes. The syn-rift phase of the basin evolution, which lasted from the Ottnangian until the Mid Badenian, was characterized by strong volcanism and depositional environments that changed from terrestrial into marine. The post-rift phase, which lasted from the Late Badenian to Quaternary, was characterized by a shift from marine and brackish to terrestrial environments, rapidly decreasing volcanism, and two compressional phases that caused the basin inversion and structural blocks rotation (JAMIČIĆ, 1995; MÁRTON et al., 1999, 2002;

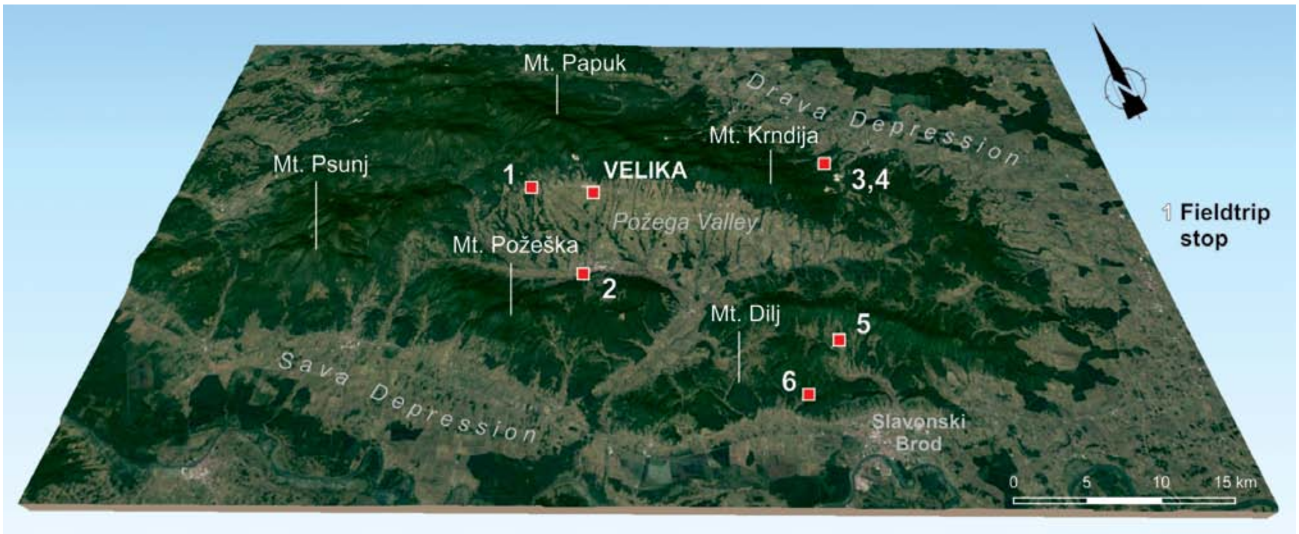

Fig. I.1 The position of the Slavonian Mountains in Eastern Croatia with field trip stops indicated.

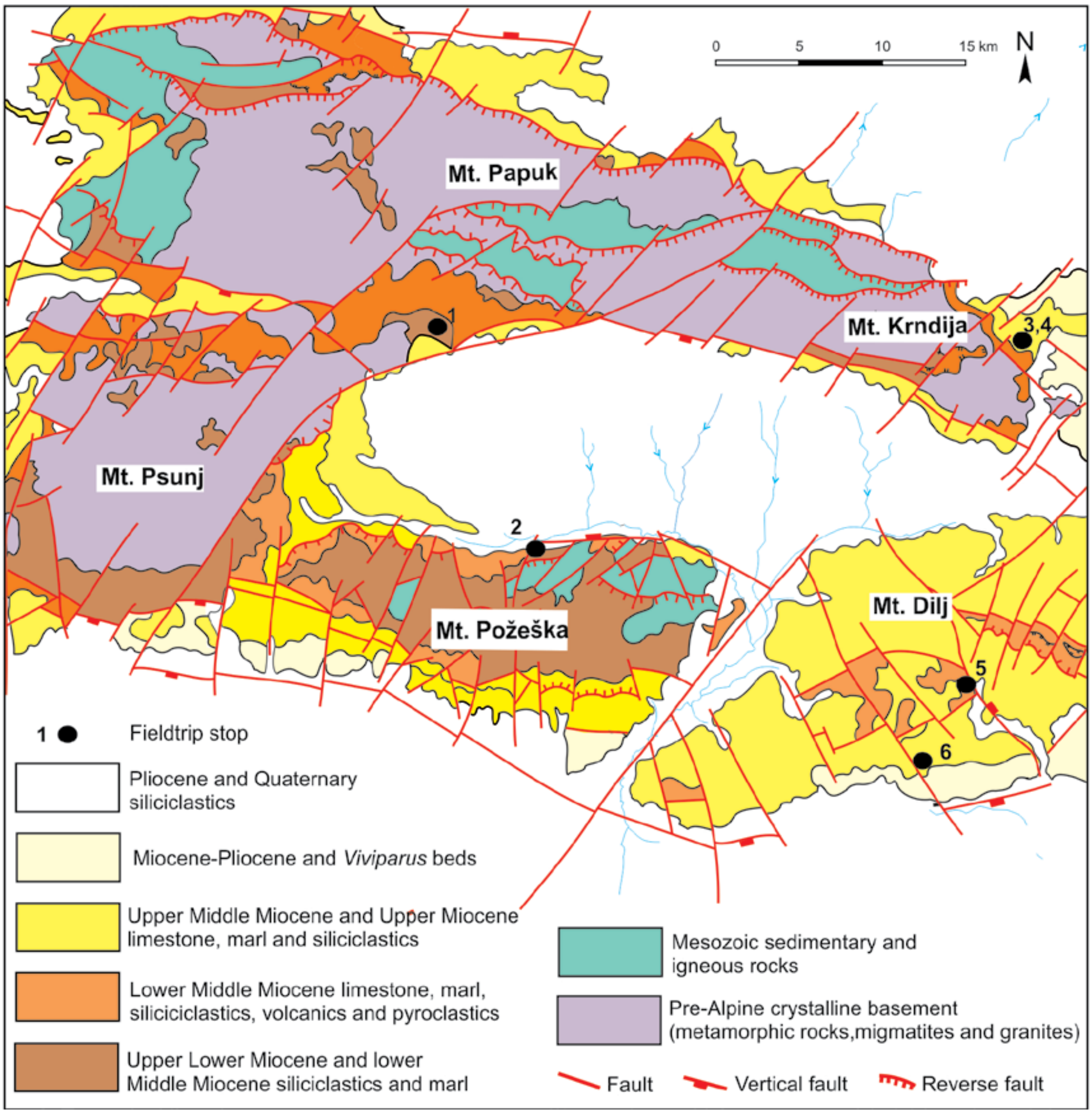

Fig. I.2 Geological sketch map of the Slavonian Mountains. Simplified after Geological Map of the Republic of Croatia 1:300 000 (CGS, 2009).

PAVELIĆ, 2001; TOMLJENOVIĆ & CSONTOS, 2001; PAVELIĆ et al., 2003; MALVIĆ, 2012). The consequence of the specific evolution is the modern structural pattern characterized by the WNW-ESE trending elongated and tectonically subsided zones of depressions with the maximum depth of basement rocks of about 7000 m separated by tectonically uplifted blocks with Palaeozoic-Mesozoic-Paleogene basement rocks on the surface.

The formation of the sedimentary basin in the Slavonian Mountains started in the Early Miocene, with terrestrial sedimentary environments that were strongly controlled by the climate characterized by cyclical alternations of arid and more humid periods (ŠĆAVNIČAR et al., 1983; PAVELIĆ et al., 2016). They are represented by rapid lateral and vertical facies alternations of coarse-grained and fine-grained deposits, with rare occurrences of red beds, laminated calcretes and pyroclastics (Fig. I.3). The coarse-grained deposits crop out in many places on Mts. Psunj, Papuk and Požeška, disconformably covering the pre-Neogene basement ("Daranovac unit"). They are characterized by rock-fall breccias and conglomerates interpreted as talus and alluvial fan deposits. Structureless silty units, intercalated with coarse-grained deposits, on the Mt. Požeška indicate aeolian deposition, (i.e. PAVELIĆ & KOVAČIĆ, 1999; PAVELIĆ, 2001; PAVELIĆ et al., 2016). However, on Mt. Papuk specific deposits represented by the predominance of well-bedded dolomites, pelite layers, sandstones, tuffs and tuffites with analcime ("Poljanska unit") occur, deposited in a salina-type lake (ŠĆAVNIČAR et al., 1983) (*Stop 1).* The stratigraphic position of Early Miocene deposits was problematic due to the lack of fossils, or their endemic characteristics. Early Ottnangian age of the oldest Miocene deposits based on superposition (PAVELIĆ, 2001) is confirmed by dating of pyroclastics intercalated with alluvial deposits on Mt. Kalnik, (MANDIC et al., 2012). As the Early Miocene alluvial and salina deposits are overlain by the Early Badenian lacustrine sediments the time span of their deposition is considered roughly from the beginning of the Ottnangian to the end of the Karpatian.

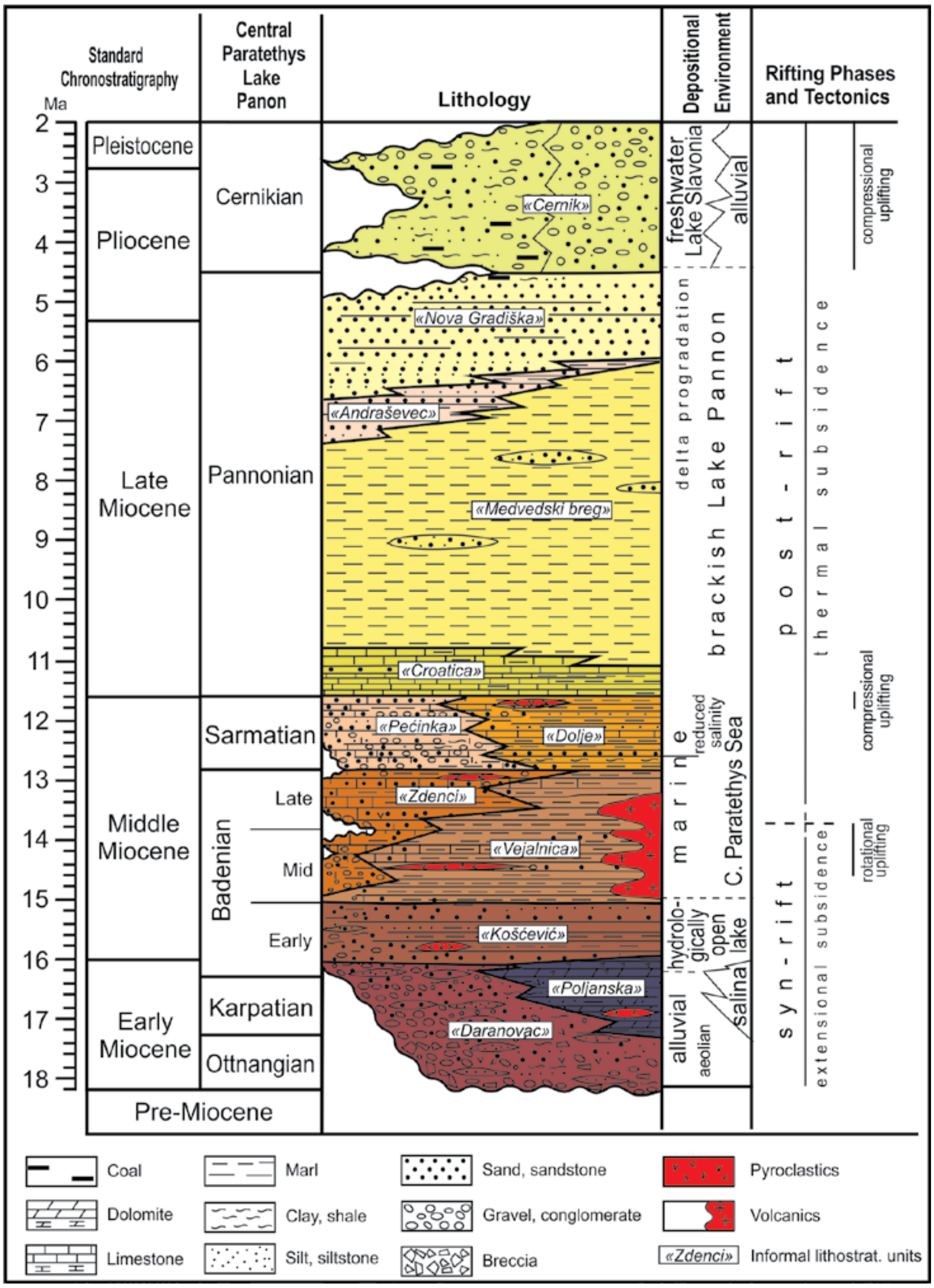

Fig. I.3 Sedimentological and stratigraphic scheme of the eastern part of the North Croatian Basin. The informal lithostratigraphic units are taken from the Basic geological map of the Republic of Croatia 1:50 000, sheets Požega 3 and 4 (FILJAK et al., 2016A, B). Rifting phases and tectonics after PAVELIĆ (2001).

The beginning of the Middle Miocene is characterised by the continuation of terrestrial deposition. Fresh-to-brackish water lacustrine deposits overlie the Early Miocene alluvial, aeolian and salina lake deposits ("Koščević unit") (Fig. I.3, *Stop 2*). In older studies, these deposits were regarded as belonging to Ottnangian and Karpatian (ŠIKIĆ, 1968; KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ, 1978; KOCHANSKY-DEVIDÉ, 1979; SOKAČ, 1987; SOKAČ & KRSTIĆ, 1987; JUNGWIRTH & ĐEREK, 2000; ŽAGAR-SAKAČ, 2004). However, recent results of integrative biostratigraphy of overlaying marine deposits (ĆORIĆ et al., 2009) and Ar-Ar dating of tuff horizons within lacustrine deposits in central Croatia, suggest their Early Badenian age (MANDIC et al., 2012, MARKOVIĆ, 2017).

The Lacustrine conditions were replaced by marine environments during the early Mid Badenian time (ĆORIĆ et al., 2009; MARKOVIĆ, 2017) (Fig. I.3). The Mid Badenian deposition is represented by two small-scale transgressive-regressive cycles and increased volcanism. They are characterized by a deposition of structureless offshore marl with rare intercalations of coarse-grained clastics ("Vejalnica unit") and a shallow water biocalcarenite and conglomerate ("Zdenci unit"), as well as tuff horizons and volcanic rocks (PAMIĆ, 1997; MARKOVIĆ, 2017). During the Late Badenian, i.e. in the beginning of the post-rift phase, the marine transgression definitely flooded even the peaks of the Papuk and Psunj Mountains, which formed isolated islands in the Early and Mid Badenian (JAMIČIĆ et al., 1987, 1989). The deposition is represented by a transgressive-regressive cycle where basal conglomerates are overlain by algal banks, reef limestones and offshore marls (*Stop 5*). The end of the Late Badenian (*Stop 3*) was characterized by general shallowing indicated by occurrences of biocalcarenites and conglomerates, and local emersions (ŠPARICA et al., 1988; BASSO et al., 2008; ZEČEVIĆ et al., 2010; SREMAC et al., 2016).

The Badenian/Sarmatian boundary is characterised by the extinction of most of the fully marine organisms which was the consequence of the beginning of the basin isolation and establishment of new restricted marine environment with a new and unique association of organisms adopted in different ecological conditions. Sarmatian deposits represent a transgressive-regressive cycle which started with mostly continuous deposition of shallow-water gravel, calcarenites and limestones with resedimented Badenian fully marine flora and fauna covering the Late Badenian deposits ("Pećinka unit"). Subsequent deepening caused the widening of the basin, and general dominance of deposition of fine-grained horizontally laminated sediments ("Dolje unit"). The latest Sarmatian is characterised by a general shallowing trend. Thin bentonite layer which occurs in the Late Sarmatian depositional succession at Krndija Mt. (*Stop 4*) indicates weak volcanic activity in the post-rift phase of the basin evolution (KOVAČIĆ et al., 2015; MARKOVIĆ, 2017).

The Late Miocene (Pannonian) deposits continuously overlie Sarmatian deposits and represent a transgressive-regressive cycle (Fig. I.3). They were deposited in Lake Pannon, a brackish lake formed after the isolation of the PBS from the sea that triggered intensive endemic molluscs radiation. On the basis of the superposition of the leading mollusc species, the Late Miocene sediments of Slavonian mountains were subdivided into early Pannonian *Croatica* beds (*Radix croatica*) and *Banatica* beds (*Congeria banatica*), and late Pannonian *Abichi* beds (*Paradacna abichi*) and *Rhomboidea* beds (*Congeria rhomboidea*). The oldest Pannonian deposits of the Slavonian Mountains, the so-called *Croatica* beds ("Croatica unit"), consist of thin-bedded limestones with marl intercalations (*Stop 4*). They were deposited in shallow-water, littoral parts of the lake and reflect lowstand deposition as a consequence of the regression at the end of the Sarmatian. The subsequent lake level rise caused deepening and deposition of structureless marls which belong to the Banatica and *Abichi* beds. In the regressive phase of deposition in the Late Pannonian, basinal succession is overlain by deltaic sandy deposits of *Rhomboidea* beds ("Andraševec unit" and "Nova Gradiška unit") as a consequence of the infilling and closing of the lake (KOVAČIĆ et al., 2011) (*Stop 6*). As the deltaic systems generally prograded from the north-west towards the east, the closing of the lake was diachronous. Hence, the uppermost brackish lake deposits (upper *Rhomboidea* beds) probably belong to early Pliocene (MANDIC et al., 2015).

Pliocene deposits of the Slavonian Mountains (the "Cernik unit") are known as *Viviparus* beds (previously *Paludina* beds). They conformably or transgresively overlie the Pannonian deposits. The deposition of the *Viviparus* beds was mostly in the freshwater Lake Slavonia, which formed after the infilling and closing of the brackish Lake Pannon. *Viviparus* beds are represented by different locally derived siliciclastic material with coal seams, and form two small-scale transgressive-regressive cycles. Pelites prevail in the older cycle, while sands and gravels are more common in the younger cycle. Based on recent studies of the evolution of the molluscs, a new regional stage named Cernikian was proposed (MANDIC et al., 2015). It comprises the time interval from the middle Pliocene to the early Pleistocene.

Quaternary deposition was similar to that during the Pliocene, with the exception of deposition of the large quantities of the aeolian material.

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STOP 1 POLJANSKA

EARLY-MIDDLE MIOCENE SALINA-TYPE AND OPEN LAKE DEPOSITS

Marijan Kovačić, Darko Tibljaš, Davor Pavelić, Valentina Hajek-Tadesse, Koraljka Bakrač, Oleg Mandic, Ines Galović, Lara Wacha, Radovan Filjak & Frane Marković

Locality: Poljanska
WGS84 coordinates:
the Main section: 45.454008 °N, 17.569245 °E; the Lower section: 45.453950 °N, 17.567397 °E
Age: Burdigalian-Langhian; (?) Ottnangian-Karpatian-(?)Early Badenian
Lithostratigraphy: "Poljanska unit"

INTRODUCTION

The investigated Poljanska section is situated on the south-western slopes of Mt. Papuk (Fig. I.1), near the eponymous village. In this area, according to the Basic Geological Map of the Republic of Croatia (CGS, 2009), Lower Miocene sediments are exposed on the surface. Their older part is composed of alluvial gravely-sandy deposits ("Daranovac unit"), while their upper part consists of lacustrine sediments and pyroclastites ("Poljanska unit"). The alluvial deposits of the "Daranovac unit" are widespread along the Slavonian mountains, especially on Mt. Požeška, while the key section of the "Poljanska unit" is described only on the south-western slopes of Mt. Papuk. The most representative outcrop of lacustrine sediments intercalated with pyroclastites is situated in an active quarry located west from the village of Poljanska. In this quarry ŠĆAVNIĆAR et al. (1983) described two layers of sediments rich in analcime and dolomite that alternate with tuffitic marls. As proposed by ŠĆAVNIĆAR et al. (1983) these layers deposited in a salty alkaline lake during arid climate conditions and in a freshwater lacustrine environment during more humid periods. Several representative outcrops of the "Poljanska unit" sediments are also exposed along the stream of Sokolovac.

DESCRIPTION

Two sections were described at Poljanska. The smaller, Lower section is located along the stream of Sokolovac. There, a 4 m thick sedimentary sequence is exposed. Based on the continuous layering of the sediments, this outcrop stratigraphically represents the basement of the Main section situated in the quarry. It consists of a 40 cm thick, green coloured acid vitroclastic tuff layer altered to smectite at the bottom of the section, and dark grey thin layered or horizontally laminated marls. The tuff layer contains 45% of fresh volcanic glass shards in the light mineral fraction and 94% of transparent heavy minerals. Among them garnet and pyroxenes predominate; amphibole, rutile and other transparent heavy minerals are present in a lesser amount. The marls are rich in fossil macroflora and intercalated with a few cm thick coal lenses and tuff layers.

The Main section is located in the active quarry (Fig. 1.1), where a more than 40 m thick sedimentary succession is exposed on the surface. The succession is divided in three parts. The lower part is characterised by the alternation of calcitic marls and tuffitic layers (Fig. 1.2). Calcitic marls are rich in fossil macro flora (Fig. 1.3 A,B) and contain analcime, a zeolite group mineral. The tuffite layers are 10-30 cm thick and greenish or grey in colour (Fig. 1.3 C,D). They consist of altered vitroclasts, feldspar crystaloclasts, analcime, carbonate minerals, and detrital grains of quartz, feldspar, amphibole and mica (Fig. 1.3 E,F). The thickest, middle part of the section is mostly composed of a few cm to several dm thick, massive, horizontally laminated or tectonically deformed carbonate-analcime sedimentary rocks (Fig. 1.3 G,H). Carbonate minerals are crypto- to

Fig. 1.1 Panorama photograph of the Poljanska quarry (photo by M. KOVAČIĆ)

microcrystalline, concentrated in some lamina or homogeneously dispersed in rock. Dolomite is the most abundant carbonate mineral, but hydrous Ca-bearing magnesium carbonate (HCMC) is also detected in almost all samples. The analcime is cryptocrystalline and homogeneously dispersed within the rock, or concentrated within the laminae in the form of up to 50 µm large isometric crystals (Fig. 1.3 I, J). The formation of analcime is a result of the alteration of tuff and/or clay minerals in an alkaline lake environment (ŠĆAVNIČAR et al., 1983). Minor natrolite, the other zeolite mineral characteristic for saline environment, is also present. The presence of HCMC, mineral characteristic for playa environments, also suggests extreme ecological conditions (QUERALT et al., 1997). In the middle part of the section, except for analcime-carbonate deposits, sandstone layers appear, with the thickness of several centimetres to two meters. The sandstone is poorly sorted with grains derived from the locally uplifted metamorphic and granitoid basement rocks of the Pannonian basin. The upper part of the section, which is exposed laterally in the quarry, consists of thin layered fossiliferous marls (Fig. 1.2).

FOSSIL CONTENT

The analcime bearing rocks are barren of fossils, while marls from the Lower section, as well as marls from the bottom and the top part of the Main section contain a relatively poor fossil assemblage of molluscs, ostracods, palynomorphs and calcareous nannofossils.

The mollusc fauna consists of one dreissenid bivalve *Illyricocongeria pikijai* and few hydrobiid and planorbid gastropod species (Fig. 1.4). The faunal composition relates the assemblage with the Illyrian bioprovince (MANDIC et al., 2011). The latter includes the Pannonian basin pre-Badenian continental deposits and the so called Dinaride Lake System (DLS), which are postorogenic late Burdigalian-Langhian intramontane basins situated in the Dinaride mountains and the Adriatic foreland. *Illyricocongeria pikijai* is exclusively known from the Požega region. There, it is restricted to lacustrine deposits predating the Middle Miocene marine transgression of the Paratethys Sea. The hydrobiids include *Prososthenia eburnea*, planorbids, and one newly discovered *Gyraulus* sp. (unpublished data) Such composition indicates long-living freshwater lacustrine settings and littoral conditions (MANDIC et al., 2011; NEUBAUER et al. 2015).

The ostracod fauna indicates a freshwater depositional environment. In the Lower section it consists of eight freshwater genera: *Cypridopsis, Potamocypris, Fabaeformicandona, Candona, Herpetocypris, Darwinula, Cypria* and *Pseudocypretta*. In the Main section, deposits did not yield ostracods, except marls from top of the section which contain rare poorly preserved carapaces of the genus *Cypridopsis* or *Potamocypris*. The palynomorph assemblage from both sections suggests the dominant role of wetland- and riparian-type vegetation. Conifer (*Pinus*) and riparian trees (*Carya*) pollen

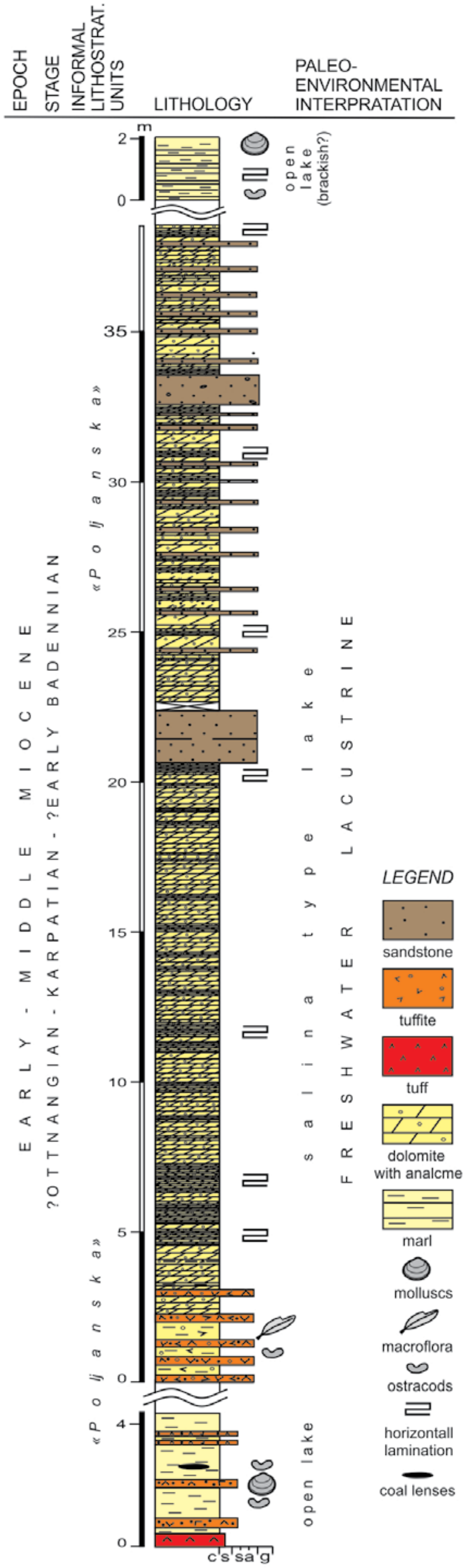

Fig. 1.2 Geological column of the Lower-Middle Miocene deposits at Poljanska.

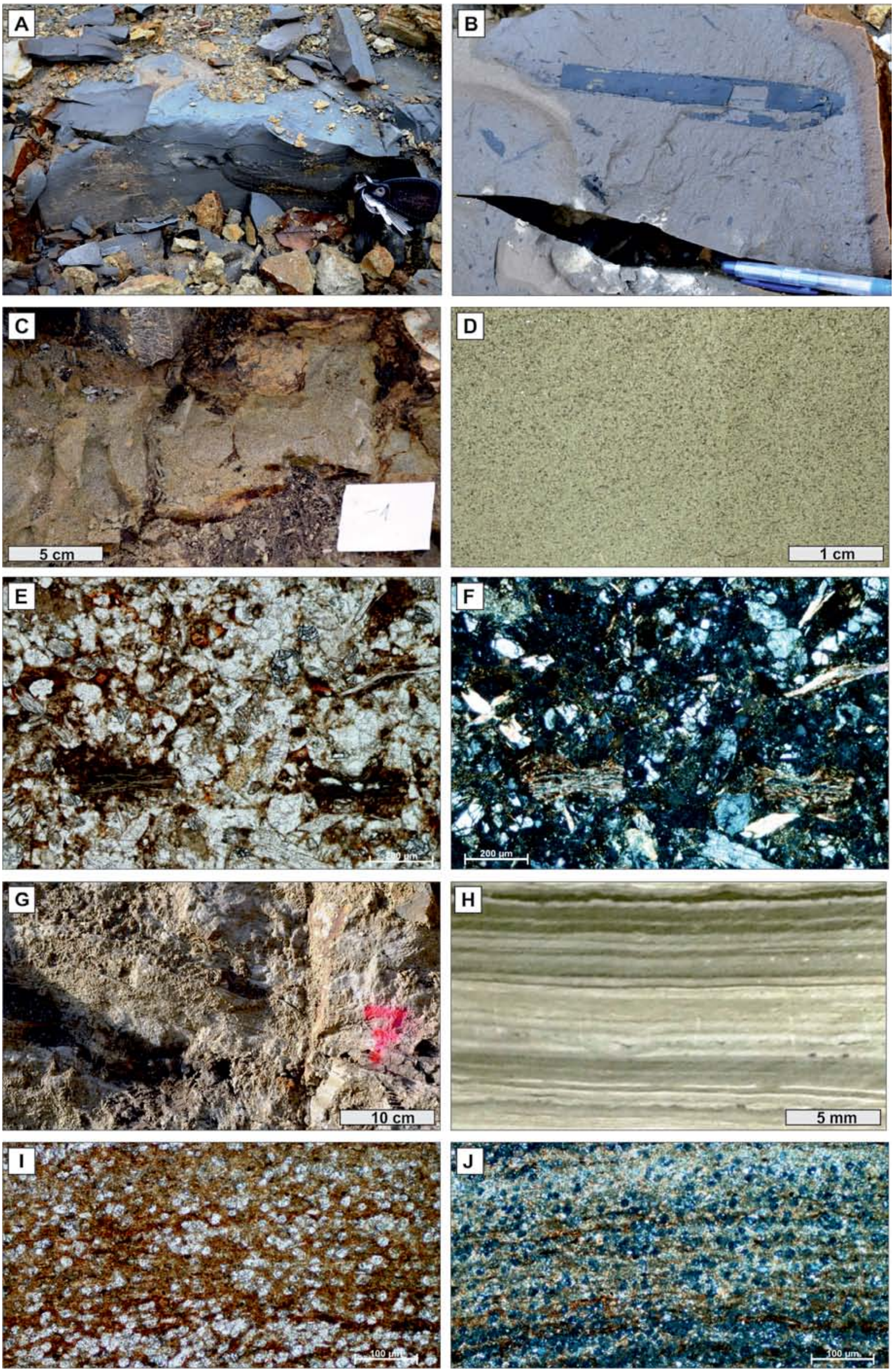

Fig. 1.3 Photographs and microphotographs of a typical lithofacies from the Main Poljanska section. A, B – dark grey marl with fossil macro flora from the lower part of the section. C, D – tuffite layer from the lower part of the section. E, F – Microphotograph of the same tuffite showing their composition dominated by clastic detritus of local origin, altered vitroclasts and analcime; G, H – horizontally laminated dolomite with analcime from the middle part of the section; I, J – microphotograph of dolomite with analcime. (E, I – An-; F, J – An+).

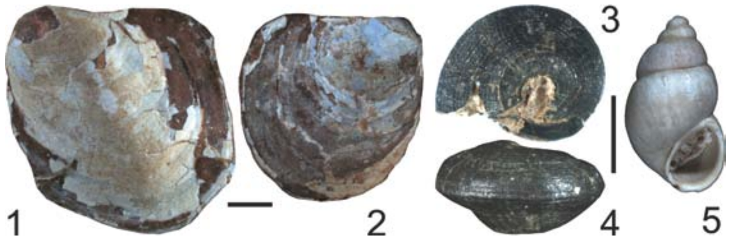

Fig. 1.4 Bivalves and gastropods from the Poljanska section. 1-2 *Illyricocongeria pikijai* (KOCHANSKY-DEVIDÉ) – left (1) and right (2) valve, upper part of the section; 3-4 *Gyraulus* sp. – top view (3) and side view (4) of the same specimen; 5 *Prososthenia eburnea* (BRUSINA), lower part of the section. Scale bars 1 mm.

dominates in the lowest part of the section, together with subtropical and tropical fern spores (e.g. *Echinatisporis, Mecsekisporites*, *Bifacialisporites)*. The *Mecsekisporites* and *Bifacialisporites* are Karpatian and Badenian marker fossils (NAGY, 2005). Furthermore, the warm-temperate forest composed of *Ulmus*, *Carpinus,* and *Quercus* sets up. Numerous pollen grains of conifers most probably were transported from the mountain area. All species of algae (*Botryococcus*, *Sigmopollis* and Zygnemataceae) generally live in freshwater environments (swamps, ponds, and lakes), though some of them tolerate changes in salinity. The abundance of subtropical ferns in the Poljanska section coincides with the Miocene Climate Optimum (17.0 – 14.7 Ma; HOLBOURN et al., 2014).

Samples from the marl of the Lower section comprise mostly crushed diatoms of cold water *Kurtkrammeria weilandii* (BAHLS) BAHLS 2015 with temperate *Encyonema minutum* (HILSE) MANN and *Fragilaria capucina* DESMAZIÈRES forms (DE WOLF, 1982). They are associated with sponge and ascidian spicules and a small endemic nannolith species *Isolithus semenenko* LYUL'EVA. Such assemblage suggests deposition in very unstable, small, shallow oligotrophic lake (pH ca. 7) with sporadic marine influxes and a temperate climate. In the lower part of the Main section *Rabdosphaera sicca* (STRADNER) FUCHS & STRADNER is recorded. It is calcareous nannofossil whose first appearance in the Paratethys is recorded in the NN4 zone (GALOVIĆ & YOUNG, 2012). Its scattered occurrence together with ascidian spicules characterises a shallow, alkaline oligohaline (1.7-4.5%) environment (BONA & GAL, 1985) with sporadic marine influxes that caused eutrophication (YOUNG & BOWN, 1991; GALOVIĆ, 2014). The monofloral assemblage with warm water *Isolithus* spp. (*I. semenenko* LYUL'EVA, *I. pavelici* ĆORIĆ & VRSALJKO) from the same part of the section defines a fluctuating and endemic environment, while the domination of ascidian spicules in the top part of the section suggests brackish conditions (ŁUKOWIAK et al., 2016).

INTERPRETATION

The rocks of the "Poljanska unit" exposed on Stop 1 Poljanska were deposited in shallow lacustrine environments which predate the Middle Miocene marine transgression of the Paratethys Sea. The lacustrine deposition most probably commences in the Early Miocene and continued during the Middle Miocene. These geological periods are characterised by the alternation of warm and wet subtropical periods and periods of hot and arid climate, as well as with strong volcanic activity. During the humid climate in fresh- or brackish-water lacustrine environments, pelites and marls were deposited and the coasts of this lake were covered with lush subtropical vegetation. In contrast, during arid climate periods dolomites and HCMC were deposited in a lake which had characteristics of an isolated salina-type lake. The presence of analcime is a result of high water alkalinity in the salina. Tuff and tuffite layers indicate volcanic activity at the end of the Early Miocene and the beginning of the Middle Miocene in the area of the SW PBS. Such activity produced large quantities of pyroclastic material which altered into smectite during humid periods or into analcime during more arid periods. Sandstone beds from the upper part of the succession indicate that metamorphic and granitoid basement rocks of the PBS, forming the core of the nearby mountains Papuk and Krndija, were already exposed on the surface and derived clastic material. The increased supply of the sandy material, along with the deposition of marly sediments, indicates a gradual establishment of more humid conditions and the formation of a large open lake in the Early Badenian ("Košćević unit"). Later on, during the Badenian, around 15 Ma ago (ĆORIĆ et al., 2009), the open lake was replaced by a marine settings.

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STOP 2 POŽEGA

LONG-LIVED BRACKISH WATER LAKE IN THE CENTRAL PARATETHYS BACKYARD*

Oleg Mandic, Valentina Hajek-Tadesse, Koraljka Bakrač, Bettina Reichenbacher, Anita Grizelj & Mirjana Miknić

Locality: Požega
WGS84 coordinates: 45.327591° N, 17.659389° E
Age: Burdigalian-Langhian (Early-Middle Miocene)
Lithostratigraphy: "Košćević unit"

INTRODUCTION

The Miocene continental deposits predating the Badenian marine transgression are currently still underexplored in the southern Pannonian basin. Many open questions exist considering their precise age, timing, depositional history, geochemistry, tectonic setting and paleogeographic extent (PAVELIĆ, 2001; PAVELIĆ et al., 1998; HAJEK-TADESSE et al., 2009; MANDIC

Fig. 2.1 Outcrop situation during the sampling and logging campaign (photo by V. HAJEK-TADESSE).

* The present text is an extract of a manuscript by Mandic et al. (submitted). Detailed documentation and discussion is presented therein.

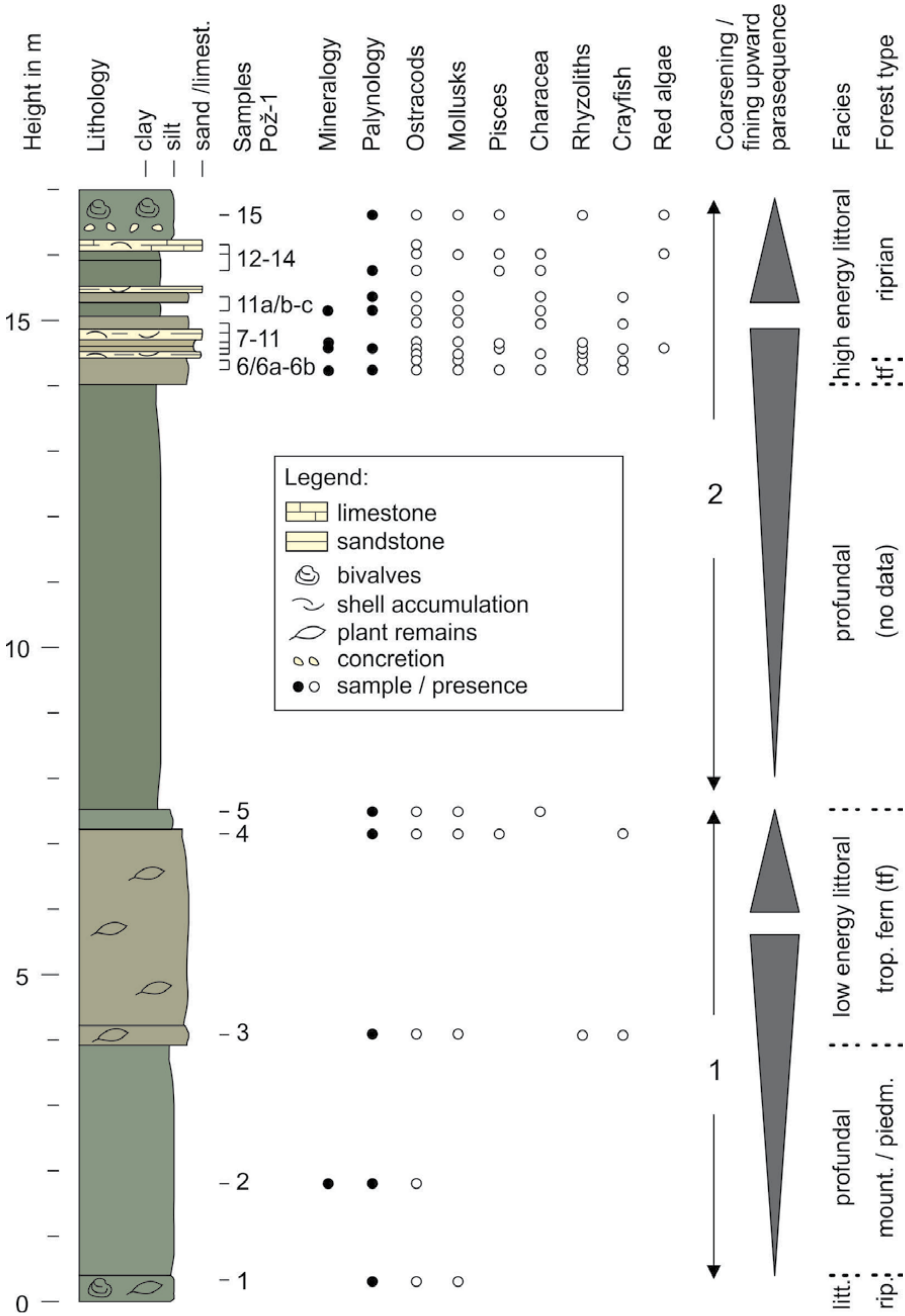

Fig. 2.2 Stratigraphical column showing the distribution of samples and fossil groups. To the right interpretations of depositional trends, sedimentary facies and floral data are added.

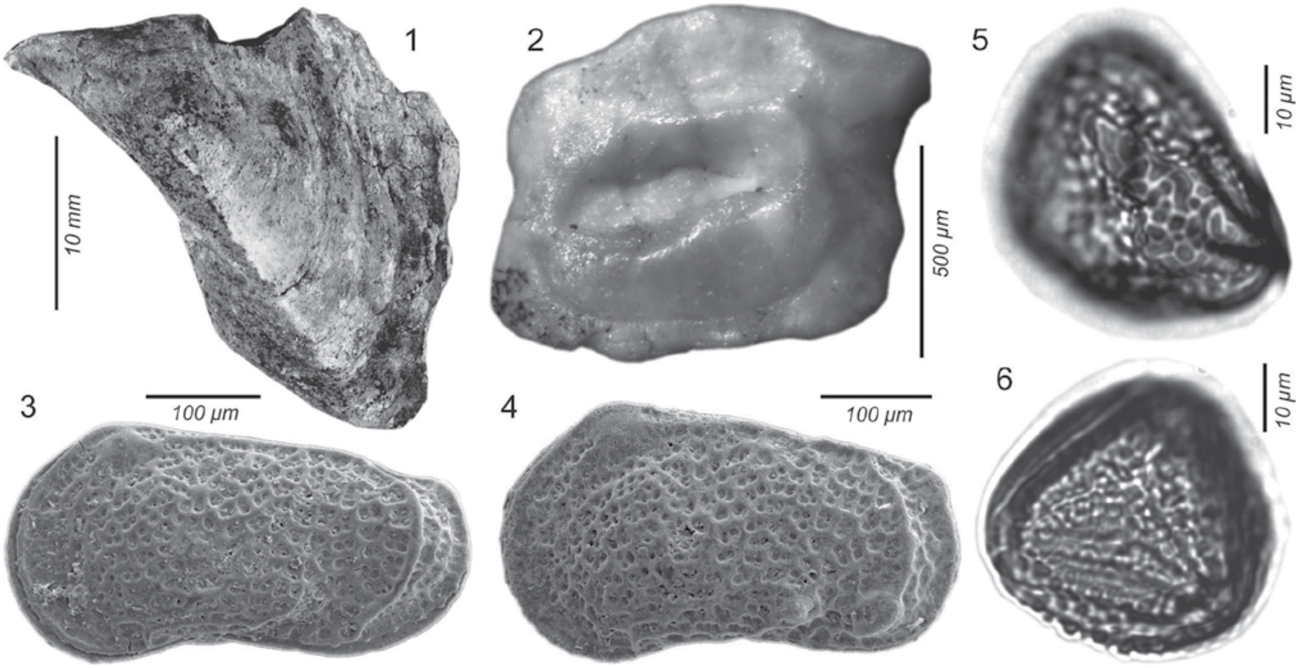

Fig. 2.3 Representative fossils found in the Požega section. Dreissenid bivalve – 1. *Trigonipraxis* cf. *zoisi*; Fish otolith – 2. *Eleogobius gaudanti*; Ostracods – 3. *Leptocythere* sp. and 4. *Amnicythere* sp.; Fern spores – 5. *Bifacialisporites medius* and 6. *Mecsekisporites mioceanicus.*

et al., 2012, 2016). Interpretations include reconstruction as isolated tectonic depressions filled by lakes, similar to the adjoining Dinaride Lake System, or the presence of only one large-sized lake extending across the Sava and Drava depressions.

Along Mt. Požeška, an inselberg in NE Croatia, the continental Lower to Middle Miocene deposits are widespread. These deposits are present in many outcrops, sections and boreholes, always underlying the Middle Miocene marine series. The present locality provides insight to fossil assemblages and depositional environments of the Mt. Požeška paleolake. Besides different fossil groups, such as ostracodes, fish otoliths, palynomorphs, coralline algae and mollusks, mineralogical and sedimentological data allow the reconstruction of depositional settings and contribute to the understanding of the history of the lacustrine succession in the Požega subdepression.

In addition, this locality is of special interest due to the occurrence of individual-rich, monotypic dreissenid bivalve accumulations. KOCHANSKY-DEVIDÉ (1979) mentioned the presence of such accumulations from the northern slope of Mt. Požeška. MANDIC et al. (2016) recorded them from a similar succession at Mt. Medvednica in NW Croatia. Such deposits are reported from an extended area striking about 650 km alongside the Pannonian Basin southern margin, from SE Austria, via N Croatia and S Hungary into Central Serbia. Together with Dinaride and Alpine orogenic belts, this region constituted a continental barrier between the Mediterranean and Central Paratethys Sea and encompassed numerous lake basins inhabited by endemic mollusks of the Illyrian Bioprovince (MANDIC et al., 2012).

DESCRIPTION

The studied section is situated 1.5 km WSW of the city of Požega, on the northern slope of Mt. Požeška and on the southern margin of the Požega valley (Fig. I.1). Požega section has the total thickness of ~17 m (Fig. 2.1) and displays two coarsening upward parasequences (PS) termed here as PS1 and PS2. (Fig. 2.2).

PS1 (~7 m) starts with one ~4 m thick clayey silt interval bearing in the lowermost 40 cm the accumulated bivalve and plant remains. Its upper part consists of sandy silt (~3 m) and likely bears common plant remains. One 30-cm-thick silt bed without macrofossils is present on top of the PS1.

PS2 (~10 m) starts with a thick package of monotonous clayey silt (~7 m) barren of macrofossil remains. Its upper part is 3 m thick and composed of alternating sandstone, fine grained sand, sandy silt, and very poorly sorted clayey silt beds. Dense accumulations of dreissenid bivalves are characteristic therein.

INTERPRETATION

The integration of data gained from the Požega section proves perennial lacustrine sedimentation with a large-scale fluctuation of the depositional depth. Two depositional intervals, termed here as PS1 and PS2, represent two coarsening and fining upward cycles with thicknesses of 7 m and 10 m. The profundal conditions are indicated by intervals of monotonous fossil poor muddy deposits; the littoral settings are marked by sandy deposits rich in fossils indicating the vicinity of a shore facies.

The deep water part of the section coincides with an increased abundance of mountain and piedmont tree pollen. Such dominance of the long-distance flying pollen might be interpreted by an increased lake surface suppressing the influence of the riparian forest. The very rare ostracods in this unit might reflect an oxygen poor setting at the lake bottom during the profundal phase. In contrast, the shallow water intervals show riparian and fern forest dominance and point to returning shore facies. The topmost interval shows phytal overproduction and possible lake eutrophication based on common fresh-water algae *Botryococcus*. Dense shell accumulations restricted to that interval indicate increased water energy and shallow littoral foreshore conditions.

The water of the lake must have been slightly brackish, as indicated by the presence of euhaline ostracods (*Leptocythere* sp. and *Amnicythere* sp.) and fish (*Eleogobius gaudanti*) species. The dominance of fresh-water taxa which tolerate brackish conditions still suggests a generally low salinity level. Warm water conditions are indicated by an abundant subtropical fern forest flora present in sandy parts of PS1 and PS2.

An integrative study based on mineralogical, sedimentological and paleontological data from ostracod, mollusk, pollen, spores and otoliths allowed the reconstruction of depositional, stratigraphic and paleobiogeographic settings of the Požega section.

The section shows two forced depositional cycles, possibly due to insolation. These mud-dominated coarsening-fining upward cycles reflect lake level fluctuations, between shallow littoral and profundal depositional settings.

Fauna (Fig. 2.3) is dominated by fresh-water species that tolerate increased salinity, bearing a few representatives of brackish water ostracod and fish taxa that can tolerate fresh water conditions (*Leptocythere* sp., *Amnicythere* sp., *Eleogobius gaudanti*). A part of that fauna migrated from the S-German Molasse Basin to the Pannonian Basin.

Therefore, we reconstruct the connectivity of the studied area with the Central Paratethys Sea controlling the salinity content of the present lacustrine environments. This, so-called S-Pannonian Basin Lake System, differs from the Dinaride Lake System with its hypothetical marine connection and consequent brackish water setting.

No direct stratigraphic inference is possible for the present section, because the marine plankton is missing. Yet, the presence of ferns *Bifacialisporites medius* and *Mecsekisporites mioceanicus* brackets the deposition to the Karpatian – Badenian interval. Finally, the regional correlation, based on literature data, suggests early Badenian as the most reliable age for the Požega section.

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STOP 3 BUKOVA GLAVA

A MIDDLE MIOCENE MARINE DEPOSITION WITH PYROCLASTICS

Marijan Kovačić, Davor Vrsaljko, Đurđica Pezelj, Vlasta Premec Fućek, Morana Hernitz-Kučenjak, Ines Galović, Stjepan Ćorić, Martina Zalović & Frane Marković

Locality: Našice
WGS84 coordinates: 45.448604° N, 18.032244° E
Age: Serravallian, Middle Miocene (Late Badenian-Sarmatian)
Lithostratigraphy: "Zdenci" and "Dolje" units

INTRODUCTION

On the northern slopes of Mt. Krndija, in the vicinity of the town of Našice, a large quarry is in use for cement production by "Našicecement d.d." (Fig. I.1) The quarry consists of two different sections; Bukova Glava and Vranović.

The Bukova Glava section is located in the southern part of the quarry. It is mostly composed of carbonate rocks of the Middle Miocene age which were described by PAVELIĆ et al. (2003) and ZEČEVIĆ et al. (2010). The recent prospecting research has also noted the presence of pyroclastic sediments in the transitional zone of Badenian and Sarmatian deposits. Due to intensive exploitation, the visage of the profile is constantly changing. Today, it is an approximately 300 meters wide and more than 120 meters high quarry (Fig. 3.1).

DESCRIPTION OF THE SEDIMENTS AND THE FOSSIL CONTENT

The Bukova Glava section is about 100 m thick. The lower half of the section belongs to the Badenian "Zdenci unit", while the upper half belongs to the Sarmatian "Dolje unit" (Fig. 3.2). The deposits are grouped in four main facies: algal limestones, biocalcarenites and biocalcirudites, marls and pyroclastics. The description of the section is partly taken from PAVELIĆ et al. (2003).

The algal limestones dominate in the lower part of the section where an about 20 m thick unit is located (Fig. 3.2). They are horizontally bedded and dominantly composed of whole or fragmented Corallinaceae. Other biogenetic particles include molluscs, bryozoans and benthic foraminifera. The faunal association suggests a shallow-water marine depositional environment and the existence of small reefs and banks growing in a shallow sea without any supply of terrestrial siliciclastic detritus.

Biocalcarenites and biocalcirudites are horizontally bedded to massive, mostly concentrated in the middle and upper parts of the section. They appear in a form of two, up to 20 m thick units and several thin layers intercalated with marls (Fig. 3.2). The thin layers usually show normal grading. Densely packed bioclasts mostly represent fragments of Corallinaceae, bryozoans and benthic foraminifera. They were very probably products of the erosion of algal banks and small reefs and of reworking of the material by waves and storms. Thick units of biocalcarenites and biocalcirudites, according to the foraminiferal assemblage, were deposited

Fig. 3.1 Panoramic view of the quarry at Bukova Glava hill. The Middle Miocene marine deposits are exposed on the surface (photo by M. KOVAČIĆ).

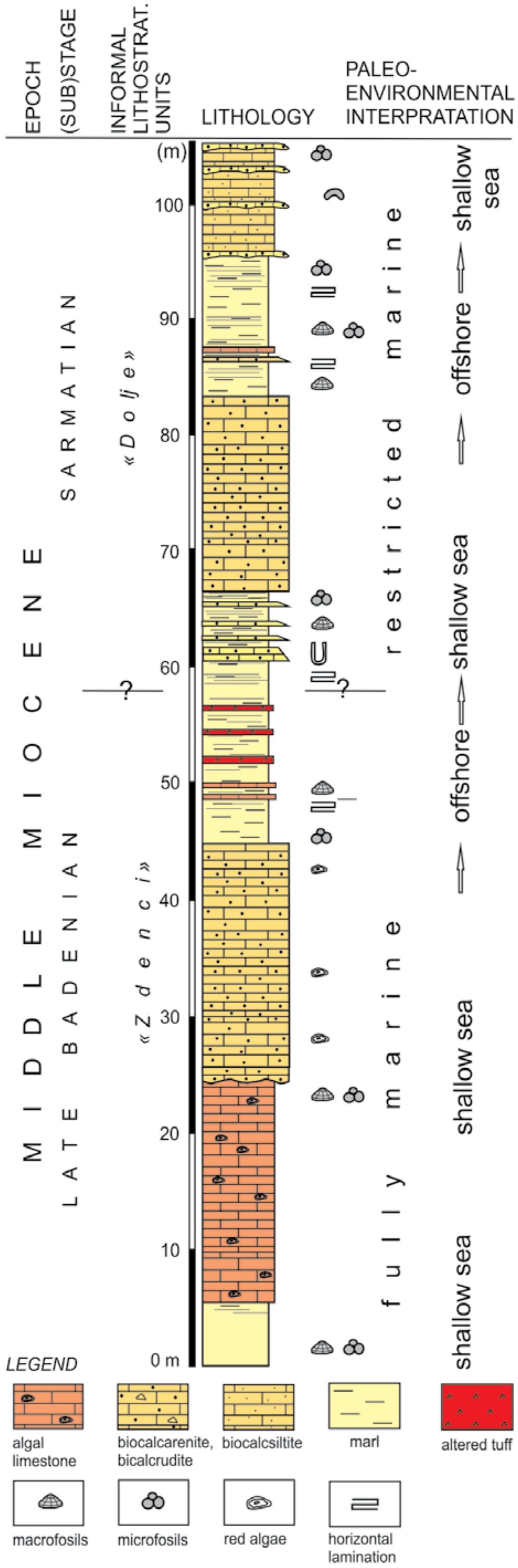

Fig. 3.2 Geological column of the Bukova Glava section (compiled after PAVELIĆ et al., 2003., ZEČEVIĆ et al., 2010., and partly modified).

in a shallow sea, while thin beds intercalated with marls could have been deposited by gravity flows in deeper, offshore environment. The position of the lower thick unit in the upper part of the Badenian lithostratigraphic unit "Zdenci", and the upper thick unit in the lower part of the Sarmatian lithostratigraphic unit "Dolje" suggests a sea-level fall at the end of the Late Badenian, subsequent erosion of the Upper Badenian shallow-water sediments, and redeposition in the Early Sarmatian (PAVELIĆ et al., 2003).

The marls form beds or units from a few dm up to 7 m thick. They have been detected in the bottom part of the section, but are mostly concentrated in the middle and upper parts (Fig. 3.2). In the bottom part, the marls are massive, rarely horizontally laminated, while in the middle and upper parts they are distinctly horizontally laminated. They were deposited from suspension in a calm environment.

Inside the marls, in the middle part of the section, three thin layers of altered tuff have recently been noted. The tuff layers are 2–10 cm thick (Fig. 3.3). Preliminary results showed that it was pure volcanic material, subsequently altered into bentonite clay.

According to their fossil assemblage, the marls from the lower half of the section are of the Late Badenian age, while those from the upper half belong to the lowest Sarmatian. In the Badenian part of the section, fully marine molluscs taxa like *Lucinoma, Corbula, Macoma*, *Linga* and *Amusium* have been discovered, while the Sarmatian part contains *Ervilia.*

Foraminiferal assemblage along the entire section is well preserved and rich with individuals and species. The marls from the lower half of the section contain planktonic formainifera assemblage consisting of *Globigerina bulloides* D'ORBIGNY, *Globigerina praebulloides* BLOW, *Globigerina diplostoma* REUSS, *Globigerina falconensis* (BLOW), *Globigerina tarchanensis* SUBBOTINA & CHUTZIEVA, *Globigerinella regularis* (D'ORBIGNY), *Tenuitella clemenciae* (BERMUDEZ), characteristic for the Late Badenian. The Late Badenian age of the lower half of the section has also been proven by the benthic foraminifera assemblage with index species *Pappina neudorfensis* (TOULA), *Bulimina insignis* ŁUCZKOWSKA and *Uvigerina brunnensis* KARRER that are characteristic for the *Bulimina–Bolivina* zone. However, in the upper part of the section, which overlies the three tuff layers (Fig. 3.2 and Fig. 3.4), bentic foraminiferal assemblage is characterised by low diversity and dominance of the species *Anomalinoides dividens* ŁUCZKOWSKA which indicate the lowest Sarmatian *Anomalinoides dividens* zone.

According to the foraminiferal assemblage, the marls from the bottom part of the section containing benthic taxa (*Elphidium, Cibicides)* that lived in a shallow marine environment. As indicated by the gradual increase of planktonic individuals of up to 90%, the marls from the middle part of the section in the zone below and between the tuff layers, have been deposited in a deeper shelf environment. Benthic foraminifera assemblage

Fig. 3.3 Altered tuff layer from the middle part of the Bukova Glava section (photo by M. KOVAČIĆ).

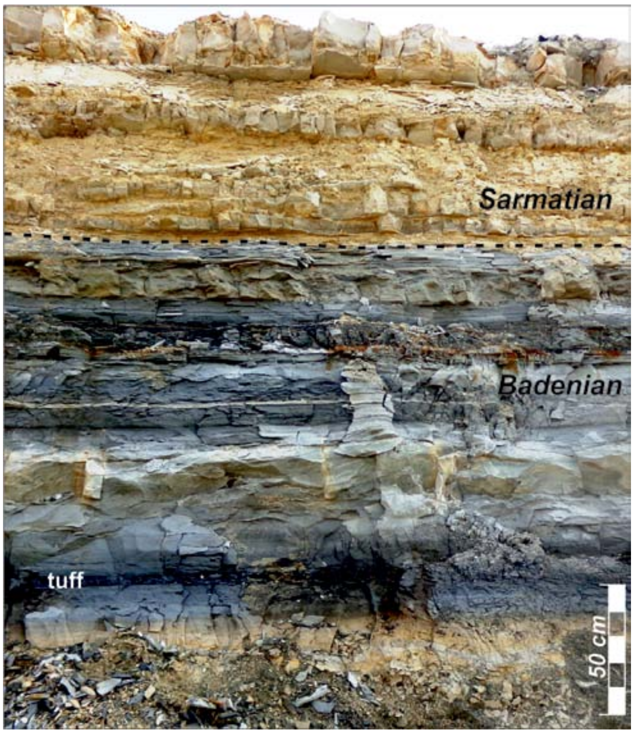

Fig. 3.4 The middle part of the Bukova Grava section. The position of the boundary between the Badenian and Sarmatian deposits is marked by the black line (photo by M. KOVAČIĆ).

also indicate deeper, middle-outer shelf environmental. The very low amount of planktonic foraminifera, in the marls which overlie the three tuff layers, indicate the shallowing trend at the end of the Badenian. The shallow environment was also present during the onset of the Sarmatian.

The calcareous nannoplankton assemblage along the entire section belongs to the NN6 zone of Late Badenian–Sarmatian. The presence of the species *Rhabdosphaera poculii* (BONA AND KERNERNE) MULLER in the marls below and between the tuff layers, in the middle part of the section, indicates the Late Badenian age. This part of the section is also characterised by predominance of *Coccolithus pelagicus* (WALLICH) SCHILLER which, in association with *Cyclicargolithus floridanus* (ROTH & HAY) BUKRY, *Helicosphaera carteri* (WALLICH) KAMPTNER, *Holodiscolithus macroporus* (DEFLANDRE) ROTH and *Pontosphaera multipora* (KAMPTNER) ROTH coccoliths, indicate a deeper hemipelagic environment. The predominance of species *Calcidiscus pataecus* (GARTNER) DE KAENEL & VILLA in the nannoplankton assemblage of the overlaying tuff horizons marks the NN6d subzone (CHIRA & MÂRUNTEANU, 2000) and suggests the onset of the lowest Sarmatian.

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STOP 4 VRANOVIĆ

DISINTEGRATION OF THE CENTRAL PARATETHYS AND ORIGIN OF THE LAKE PANNON

Marijan Kovačić, Frane Marković, Stjepan Ćorić, Đurđica Pezelj, Davor Vrsaljko, Koraljka Bakrač, Valentina Hajek-Tadesse, Anđelika Ritossa & Irena Tarnaj

Locality: Našice
WGS84 coordinates: 45.451760° N, 18.029569° E
Age: Serravallian-Tortonian; Middle-Late Miocene (Sarmatian-Early Pannonian)
Lithostratigraphy: "Dolje", "Croatica" and "Medvedski breg" units

INTRODUCTION

The Vranović section is situated on the northern slopes of Mt. Krndija, 200 m north of the Bukova Glava section (Fig. I.1). It is an active marl quarry and sandpit in use by the cement factory Našicecement d.d. Due to the intensive exploitation, the situation in the quarry is constantly changing. At present, at Vranović, around 100 meters thick section comprising the youngest middle Miocene and oldest Upper Miocene deposits is exposed (Fig. 4.1). Deposits at this location were described for the first time about 15 years ago by PAVELIĆ et. al. (2003), KOVAČIĆ (2004) and VASILIJEV et al. (2007). At that time, only the carbonate rocks and siliciclastic sediments of Late Miocene (Pannonian) age were exposed on the surface, while only recently the youngest Middle Miocene (Sarmatian) deposits have become visible as well.

SARMATIAN

The Sarmatian deposits exposed on the surface in the lower part of the section are 16 meter thick. They are represented by horizontally laminated fossiliferous marl, limestone, sand and clay, and belong to the "Dolje unit" (Fig. 4.2). The marls predominate in the succession. They consist of varve-like rhythmical alternations of dark and light laminae with thin lenses of carbonate sand (Fig. 4.3 A,B). The dark laminae contain an increased amount of organic matter, while the light laminae are rich in carbonates. The marls were deposited from suspension, while the varve-like lamination suggests seasonal changes in sedimentation. The fossil assemblage of molluscs, benthic foraminifera, ostracods, calcareous nannoplankton and palynomorphs points to the Sarmatian age and a shallow restricted marine depositional environment (Fig. 4.4). The limestone beds are 2–5 cm thick and consist of micrite and microsparite. A 10–20 cm thick layer of green coloured montmorillonite clay is detected 8 m below the abrupt lithological change from laminated marls to thin layered limestone (Fig. 4.3 C). This clay layer is an alteration product of neutral volcanic ash. According to the microelements content; it has a tephryphonolic composition (KOVAČIĆ et al., 2015a).

Fig. 4.1 Panoramic view of the Vranović section with marked Sarmatian-Pannonian boundary (Photo by M. KOVAČIĆ).

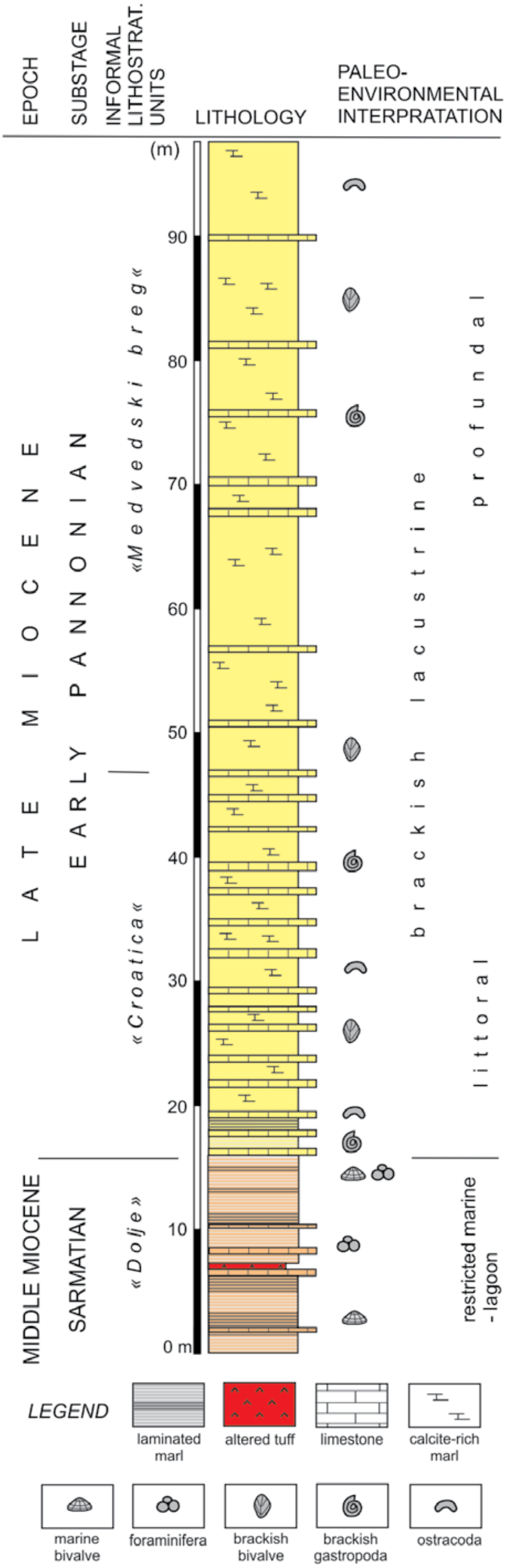

Fig. 4.2 The geological column of the Sarmatian and Pannonian deposits at the Vranović section (modified after KOVAČIĆ et al., 2015b).

It represents the first recorded evidence of volcanic activity close to the Sarmatian-Pannonian boundary in the Slavonian Mts.

SARMATIAN-PANNONIAN TRANSITION

The Sarmatian-Pannonian transition is characterised by a gradual change in the lithology and an abrupt change in the fossil assemblage. Namely, the five metres thick horizontally laminated marls characteristic for the Middle Miocene "Dolje unit", are intercalated with the platy limestone typical for the oldest Late Miocene "Croatica unit" (Fig 4.2). In contrast, between the marls with a typical Sarmatian fossil assemblage and limestones containing mollusc fauna of the early Pannonian age, only a few decimetres thick fossil-sterile layer can be seen (Fig. 4.3 D). Such abrupt change in the fossil assemblage points at the disintegration of the marine area of the Central Paratethys and the formation of the brackish Lake Panon.

PANNONIAN

The exposed succession of Pannonian deposits is about 80 m thick. The lower part of this succession belongs to the "Croatica unit", while the remaining upper part belongs to the "Medvedski breg unit" (Fig. 4.2). The "Croatica unit" consists of horizontally bedded marly limestones and massive calcite rich marls (Fig. 4.3 E). The thickness of the limestone beds varies between several and 30 cm, while the thickness of the marl layers varies from a few decimetres to a few metres (Fig. 4.3 F). The limestones and marls contain plant fragments and an association of endemic, lacustrine molluscs, ostracods, calcareous nannoplancton and palynomorphs (Fig. 4.5) that imply deposition at the littoral-sublittoral depth of Lake Pannon characterised by very low water salinity. The transition from the "Croatica unit" to the "Medvedski breg unit" is gradual and characterised by lithological transition from limestone into marls. The maximum thickness of the "Medvedski breg unit" is a few hundreds meters (KOVAČIĆ, 2004), but only the lowest 50 meters are exposed at the Vranović section. According to its fauna the "Medvedski breg unit" (Fig. 4.5 C) was deposited in sublittoral to profundal brackish-water, lacustrine environment.

The vertical succession and the replacement of the *Radix croatica* fossil assemblage typical for the "Croatica unit" with the *Congeria banatica* assemblage characteristic for the "Medvedski breg unit", indicates a deepening and salinity-increase upwards trend, from an almost freshwater littoral environment to a deeper-basin brackish-lacustrine environment.

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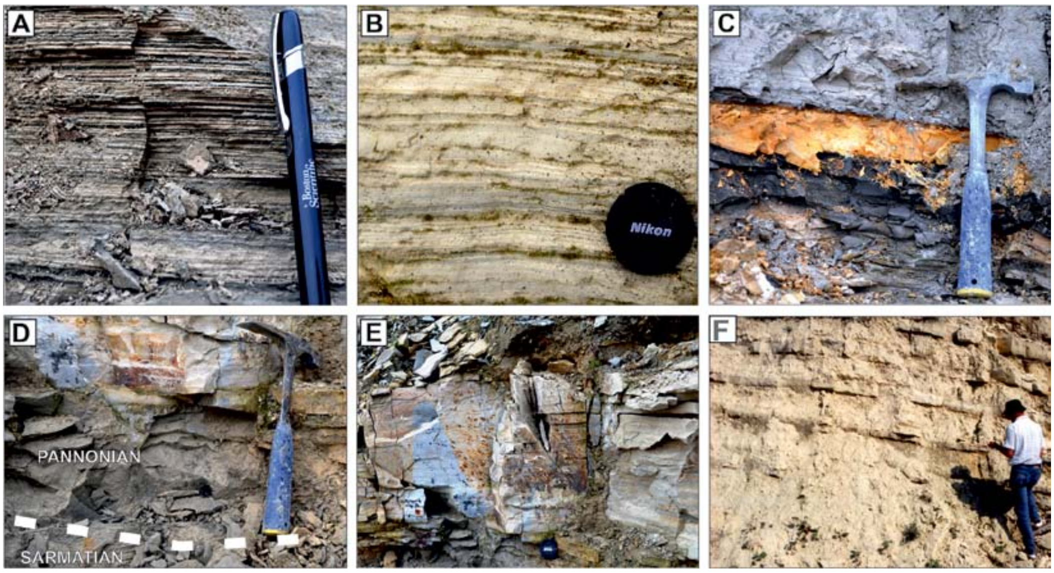

Fig. 4.3 Photographs showing details of different Sarmatian (A, B, C) and Pannonian (E, F, G) sedimentary facies of the Vranović section. A – Horizontally laminated marl with rhythmical alternation of dark, organic matter rich laminae and carbonate rich light laminae typical for the "Dolje unit". B – Horizontally laminated marls with a carbonate sand lens. C – altered tuff layer. D – The boundary between Central Paratethys marine deposits of Sarmatian age and the brackish Lake Pannon deposits of Pannonian age. E – Platy limestone from the lower part of the "Croatica unit". E – The intercalation of platy limestones and calcite rich marls characteristic for the transitional zone of "Croatica" and "Medvedski breg" units.

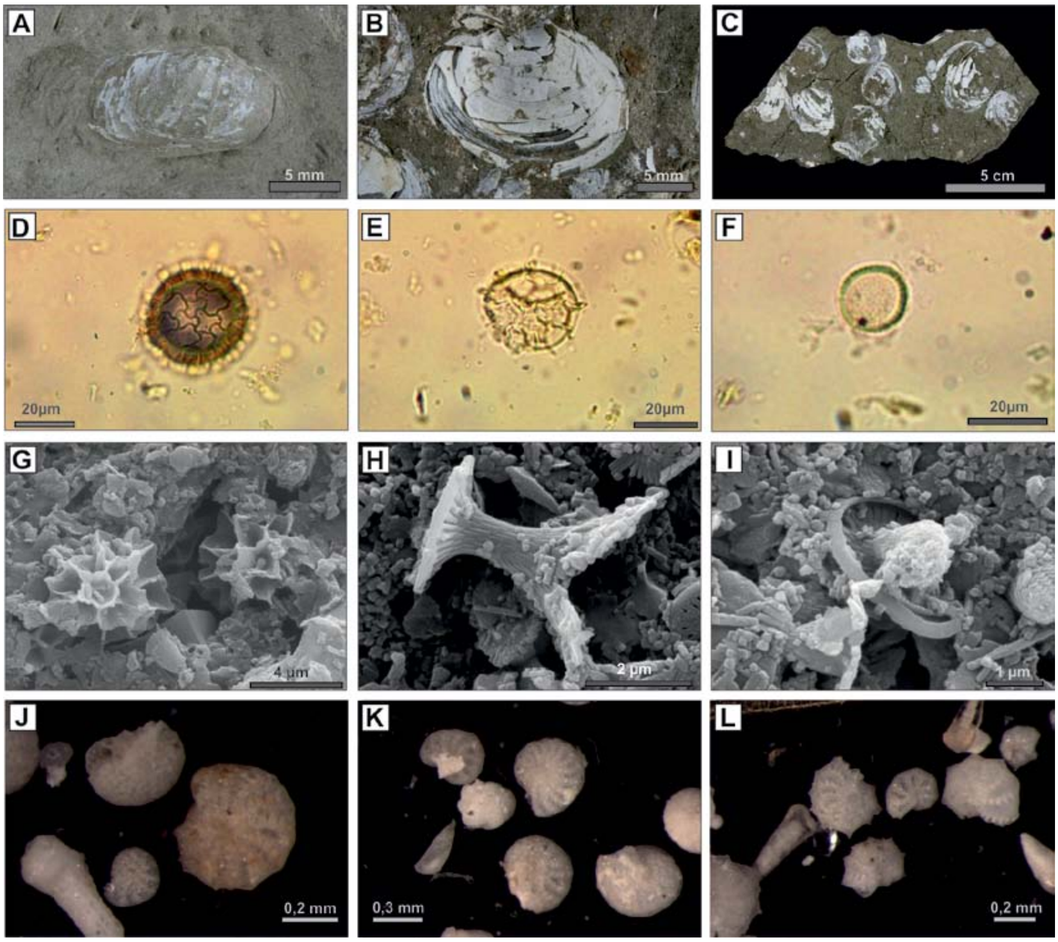

Fig. 4.4 The fossil assemblage from the lower part of the Vranović section which proves the Sarmatian age and a shallow, restricted marine depositional environment. A – *Cardium* (*Cerastoderma*) *gleichenbergense* (PAPP); B, C – *Ervilia dissita dissita* (EICHWALD); D – *Cymatiosphaera miocaenica* HAJÓS, 1966; E – *Cymatiosphaera undulata* HAJÓS, 1966; F – *Mecsekia spinosa* HAJÓS, 1966; G – *Sphenolithus moriformis* (BRONNIMANN & STRADNER, 1960) BRAMLETTE & WILCOXON, 1967; H – *Discoasphaera jerkovici* MÜLLER, 1974; I – *Acanthoica cohenii* (JERKOVIĆ 1971) AUBRY 1999; J, K, L – *Elphidium* foraminiferal assemblage (From KOVAČIĆ et al., 2015a).

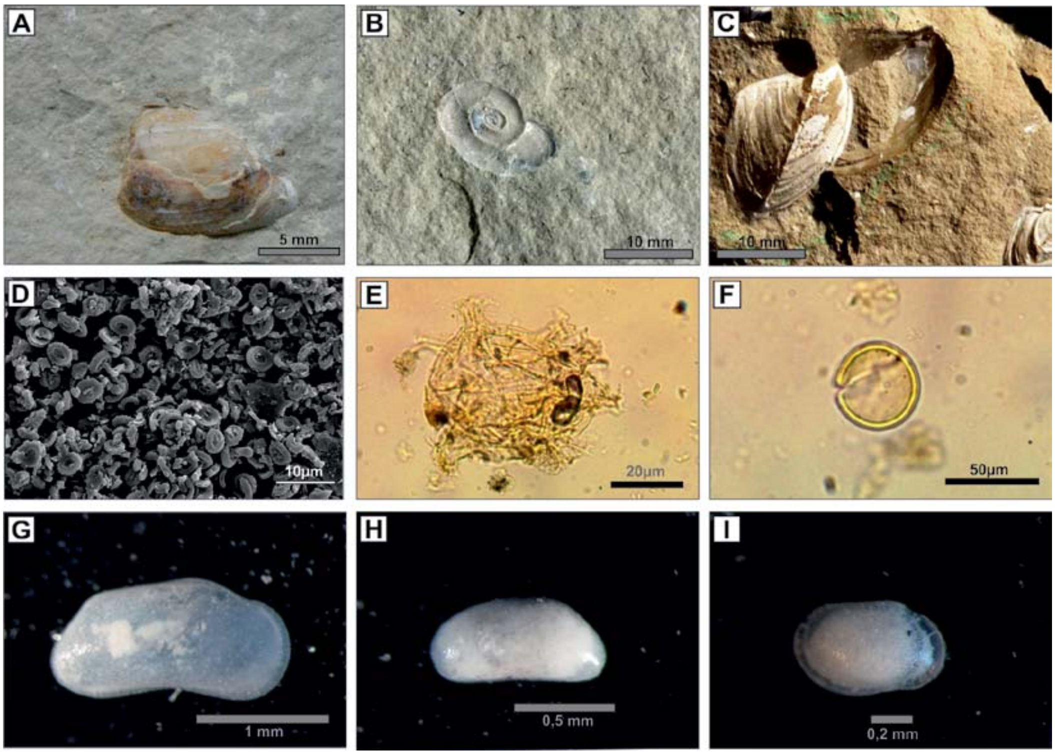

Fig. 4.5 The fossil assemblage of the middle and upper part of the Vranović section. A – *Radix (Radix) croatica* (GORJANOVIĆ-KRAMBERGER); B – *Gyraulus (g.) praeponticus* (GORJANOVIĆ-KRAMBERGER); C – *Congeria banatica* HÖRNES; D – monospheric assemblage of calcareous nanonplancton with *Noelaerhabdus* spp.; E – *Spiniferites bentorii* (ROSSIGNOL 1964) WALL & DALE, 1970; F – *Mecsekia ultima* SÜTŐ-SZENTAI, 1982; G – *Hungarocypris auriculata* (REUSS); H – *Candona postsarmatica* KRSTIĆ; I – *Loxoconcha porosa* (MEHES). *Congeria banatica* (C) found in the upper part of the section indicates a deep-water lacustrine environment and represents the "Medvedski breg unit". Other fossils are from the middle part of the section. They are typical for the oldest Late Miocene "Croatica unit" and indicate a shallow brackish to freshwater lacustrine depositional environment (from KOVAČIĆ et al., 2015a).

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BADENIAN FOSSILIFEROUS SHALLOW MARINE CARBONATES WITH FRAGMENTS OF RHYOLITE VOLCANIC ROCK

Monika Špišić, Mirjana Miknić, Marija Horvat & Marijan Kovačić

Locality: Brodski Zdenci
WGS84 coordinates: 45.247502° N, 17.928212° E
Age: Langhian-Serravallian (Badenian-Pannonian, Middle-Late Miocene)
Lithostratigraphy: "Zdenci", "Pećinka", "Croatica" units

The Zdenci quarry is situated in the vicinity of the village of Brodski Zdenci in the central part of Mt. Dilj (Fig. I.1). The quarry is still active, hence the exposure is constantly changing due to quarrying (Fig. 5.1). With the length of 200 meters and height of almost 50 meters, the sediments in the Zdenci quarry represent the growth of a patch reef in the shallow, tropical Badenian sea, interrupted a few times by volcanic activity from the surrounding area, and disconformly overlain, with Sarmatian and Pannonian sediments. The lithostratigraphic cross-section Zdenci has been studied for the purposes of the Basic Geological Map 1:50 000 and described in detail by ŠPARICA et al. (1988).

The carbonate complex is about 47 m thick and mainly composed of coralline algal limestones (Fig. 5.2). Scattered volcanic fragments are dispersed in the bioclastic limestones (bottom of the section) or sandstones (upper part of the section). The bioclastic limestone samples of the "Zdenci unit" (taken at the 3rd meter) are macroscopically determined as white bioclastic limestones containing fragments of volcanic rocks (Fig. 5.3 A,B). The quantity of psefitic and psammitic volcanic fragments varies from sandy bioclastic limestone, strongly conglomeratic limestone up to brecciated sandstone. Bioclasts are characterized by abundant coralline algae and corals, foraminifera and echino-

Fig. 5.1 The Zdenci quarry – present appearance, March 2017 (photo by M. ŠPIŠIĆ).

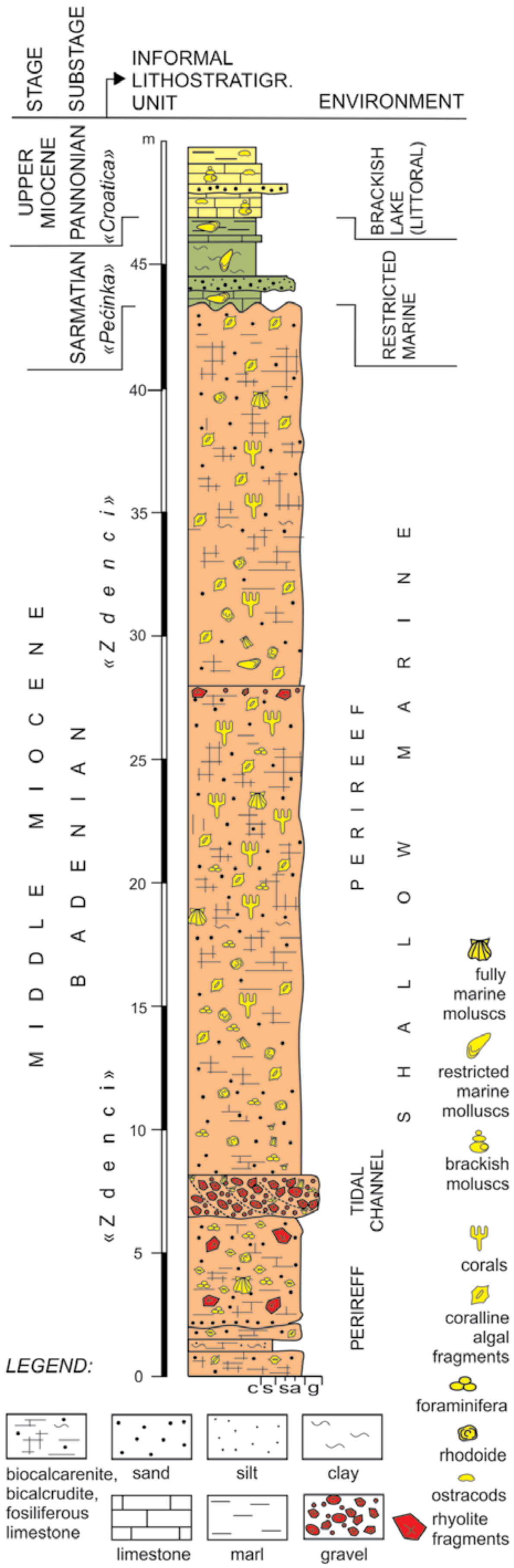

Fig. 5.2 The lithostratigraphic cross-section Zdenci; modified according to ŠPARICA et al. (1988). Tidal channel gravel composition is given in BELAK et al. (1991).

derms, subordinate bryozoans, ostracods and small gastropods. Coralline red algae are mainly represented by rhodolites with ingrown acervulinids and fragments of crustose forms (Fig. 5.4 A). Among foraminifera, oxyphilic shallow benthic forms like *Amphistegina* sp. (Fig. 5.4 C), *Elphidium crispum* (Fig. 5.4 D), *Lobatula lobatula* (WALTER & JACOB), *Eponides repandus* (Fig. 5.4 E) and *Sphaerogypsina* sp. are dominant. Rare textulariids and agglutinated sessile foraminifera *Hadonia* sp. (Fig. 5.4 B) also occur. Different cross-sections of corals are attributed to *Favia* sp. and *Porites* sp. (Fig. 5.4 F, G). Abundant and diverse *Ostrea* sp. (Fig. 5.5 B) are also present.

The matrix contains mostly micrite, but sparry calcite cement has also been found. Lithic fragments are all of rhyolitic composition. The chemical composition of the isolated volcanic parts of the sample gave 72.79 wt.% SiO_2. Microscopic investigation determined the volcanic fragments as spherulitic alkali-feldspar rhyolite (Fig. 5.3 C,E) with poorly preserved perlitic texture, aphyric alkali-feldspar rhyolite (Fig. 5.3 D,F) and slightly porphyritic alkali-feldspar rhyolite. The final stage of the patch reef growth is recorded around the 44th meter with increasing dissolution and recrystallization features together with the presence of *Microcodium* sp., which points to karstification during the phase of subareal exposure. Transgressive Sarmatian deposits of the "Pećinka unit" (Fig. 5.5 A) are characterized by sands in the base and clay with restricted marine mollusks (*Cerastoderma* cf. *lithopodolicum*, Fig. 5.5 C) in the top of the interval. The last few meters of the section are Pannonian marls ("Croatica unit"), rich in ostracods and brackish mollusks.

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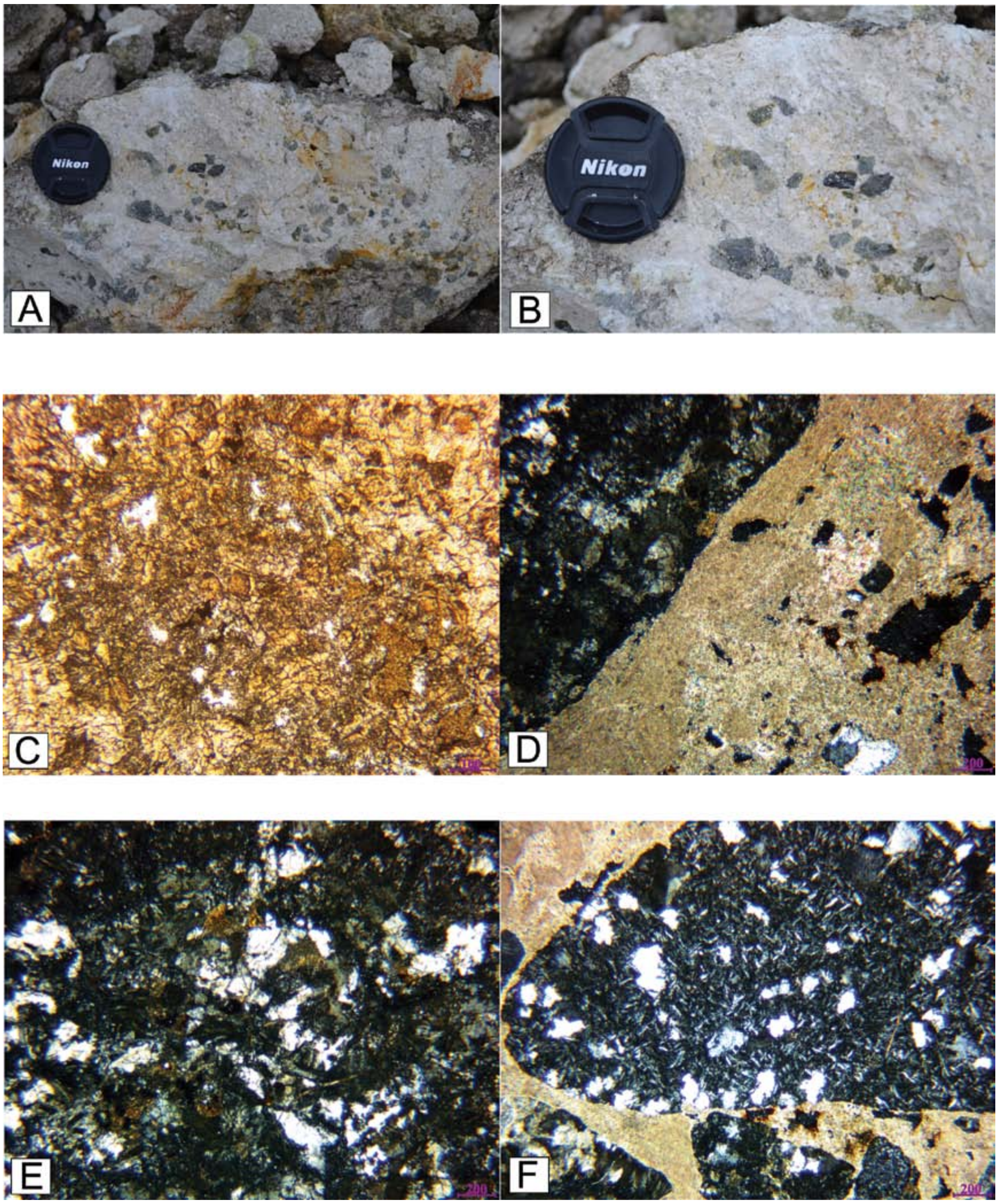

Fig. 5.3 Sedimentological characteristics of the bioclastic limestone: A – Bioclastic limestone sample with fragments of volcanic rocks (lens cap diameter 5 cm); B – the same sample – increased; C, E – Spherulitic alkali-feldspar rhyolite with poorly preserved perlitic texture; D, F – aphyric alkali-feldspar rhyolite fragments in the limestone. C, D, E, F scale in μm.

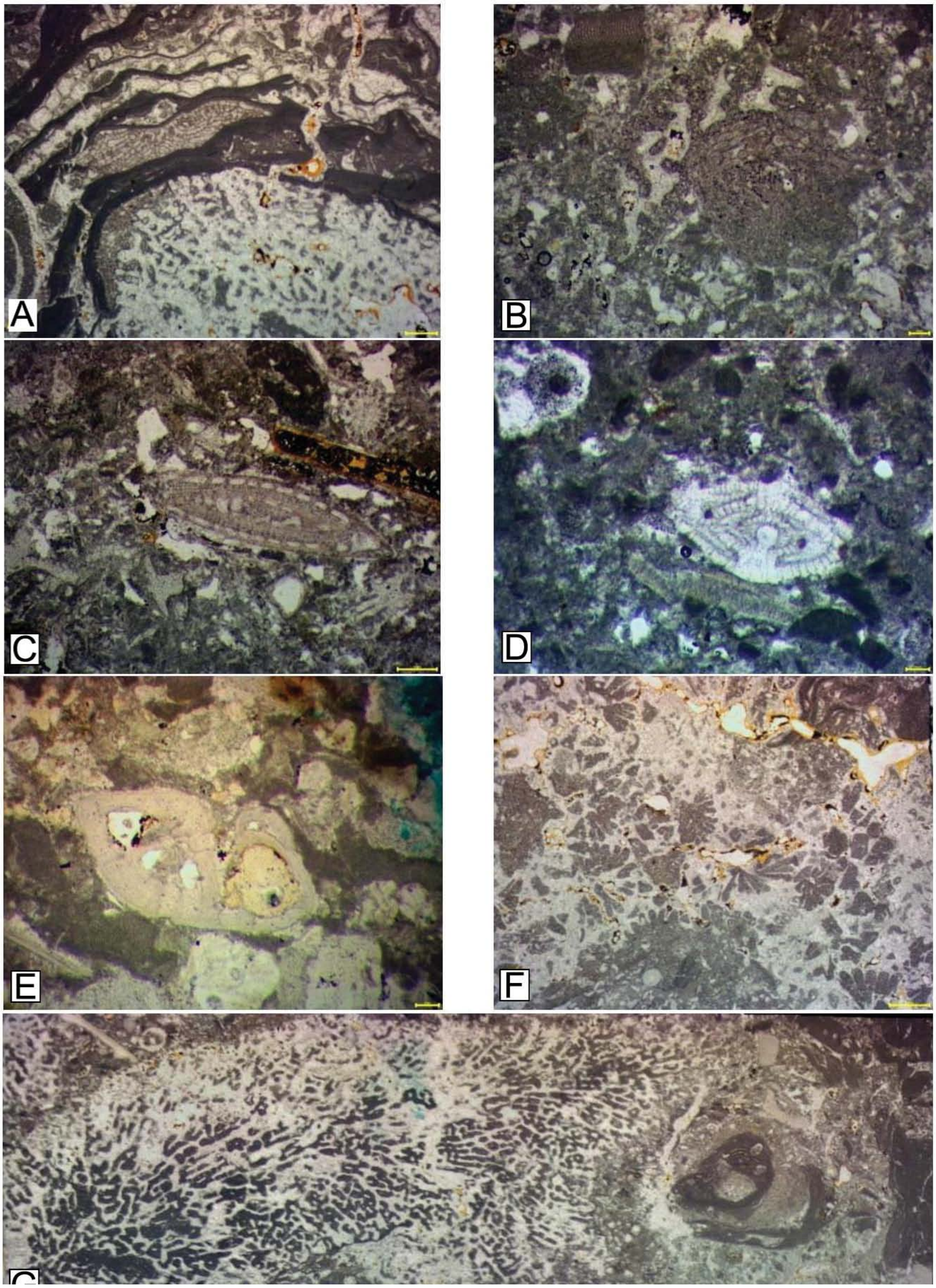

Fig. 5.4 Fossil assemblage in the bioclastic limestones: A – coral with overgrown crustose algae, bryozoan and acervulinid ingrowth; B – agglutinated sessile foraminifera *Hadonia* sp.; C – *Amphistegina* sp.; D – *Elphidium crispum* (LINNE); E – *Eponides repandus* (FICHTEL & MOLL); F – corals (*Favia* sp.); G – coral *Porites* sp. Scale bar A – 50 μm; B – 20 μm; C – 100 μm; D – 10 μm; E – 10 μm; G – 100 μm.

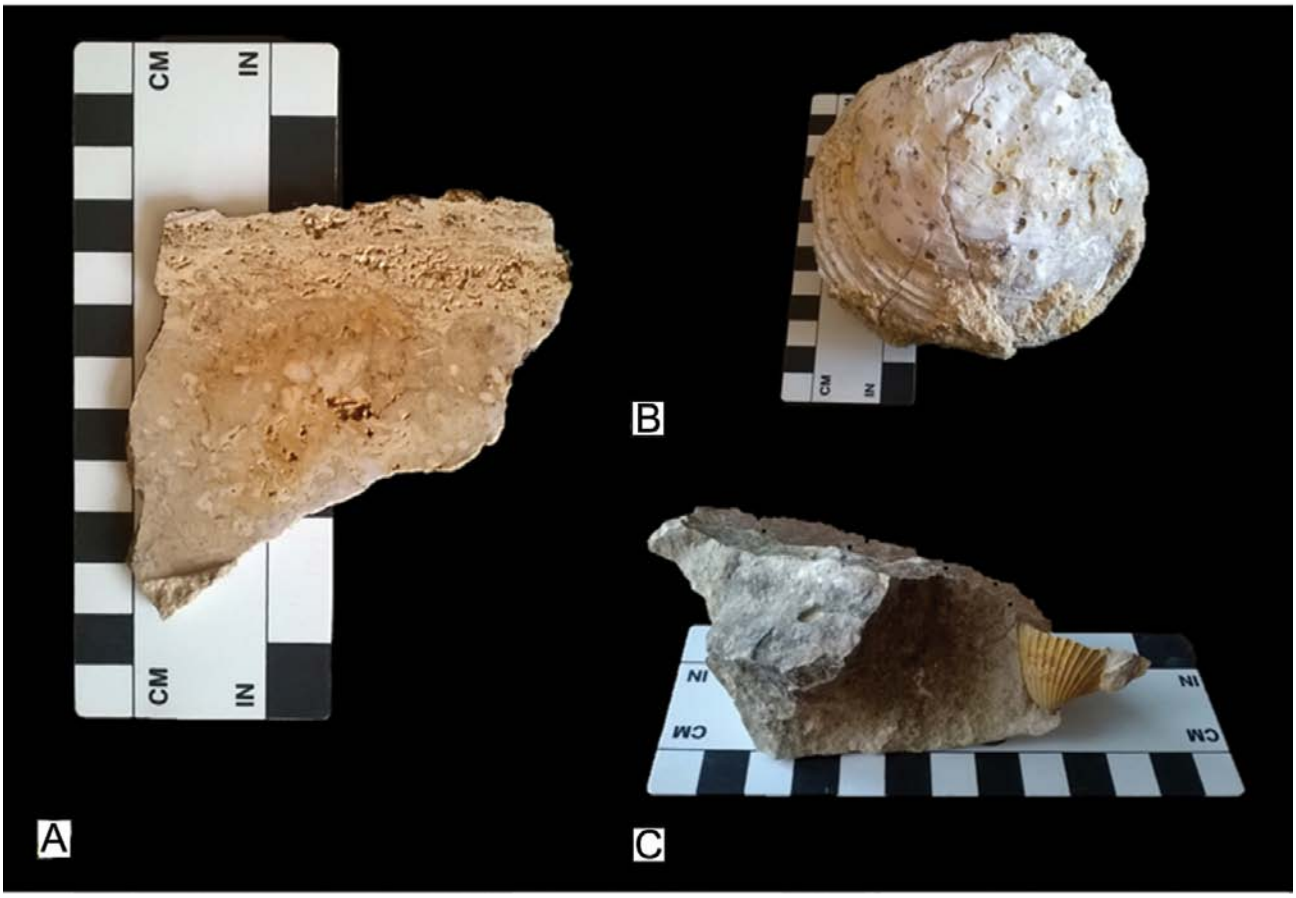

Fig. 5.5 A – Erossive Badenian (“Zdenci unit”) and Sarmatian (“Pećinka unit”) boundary; macrofossils from the Zdenci quarry: B – *Ostrea* sp.; C – *Cerastoderma* cf. *lithopodolicum* (DUBOIS) (D. VRSALJKO, personal comm.).

STOP 6 PETNJA

THE TERMINATION OF LAKE PANNON AND THE ORIGIN OF LAKE SLAVONIJA

Marijan Kovačić, Oleg Mandic, Marija Horvat & Tomislav Kurečić

Locality: Sibinj, Petnja
WGS84 coordinates: 45.204666° N, 17.942882° E
Age: Late Miocene-Pliocene (Late Pannonian-Cernikian)
Lithostratigraphy: "Nova Gradiška" and "Cernik" units

INTRODUCTION

The Petnja sandpit is situated on the southern slopes of Mt. Dilj, north of the village of Sibinj, near the road to the artificial Petnja lake (Fig. I.1). At present, it is mostly covered by debris and largely vegetated. The best profile is situated on the NW part of the sandpit, where a more than 80 m wide and about 20 meter high section is visible (Fig. 6.1). The lower part of the section belongs to the youngest Miocene unit – "Nova Gradiška unit", while the upper part of the section very likely represents deposits of the Pliocene "Cernik unit". This outcrop was studied by PAVELIĆ (2001) who interpreted the lower part of the section as a Gilbert type delta and the upper part as alluvial braided river deposits.

LITHOLOGY AND FOSSIL CONTENT

The partly exposed deposits in the sandpit can be divided into three different parts (Fig. 6.2).

The lower part of the section is 5–6 m thick. It consists of thin layered, well-sorted, fine-grained, dominantly massive sand and calcitic silt dipping towards S-SE by 20^0 (Fig. 6.2). Less represented are the horizontally or cross-laminated sands and silts. The position of the cross-laminae suggests the southeastward transport direction. Quartz and stabile lithic fragments dominate the modal composition of the sand, while the epidote group of minerals, garnets and amphiboles are the most abundant heavy minerals. The mollusc fauna is poorly preserved, mostly represented by fragmented individuals. Only brackish-water cardiid bivalve *Prosodacnomya vutskitsi* (BRUSINA) is determined in this part of the section.

The middle part of the section is 2–2.5 m thick, and gently dips towards the S-SE. It is composed of the sand with the same structural characteristics and modal composition as sands from the lower part of the section. In this part of the section, numerous lenses and channels are visible (Fig. 6.2) mostly filled by shells of fossil molluscs (Fig. 6.3). The channels are up to 60 cm deep and 3.5 m wide. The freshwater gastropod *Melanopsis decollata* (Fig. 6.4) predominates among the mollusc assemblage.

The upper part of the section is around 10 m thick, and, sharply separated from underlying deposits with a strong erosional boundary. It consists of alternating thin layers and lenses of gravel and sand (Fig. 6.5 A). The gravel is fine grained, medium sorted with subrounded pebbles (Fig. 6.5 B). Chert, radiolarian chert (Fig. 6.5 C, D), radiolarite and silicified limestone dominate in

Fig. 6.1 Panoramic view of the NW part of the Petnja sandpit (photo by M. KOVAČIĆ).

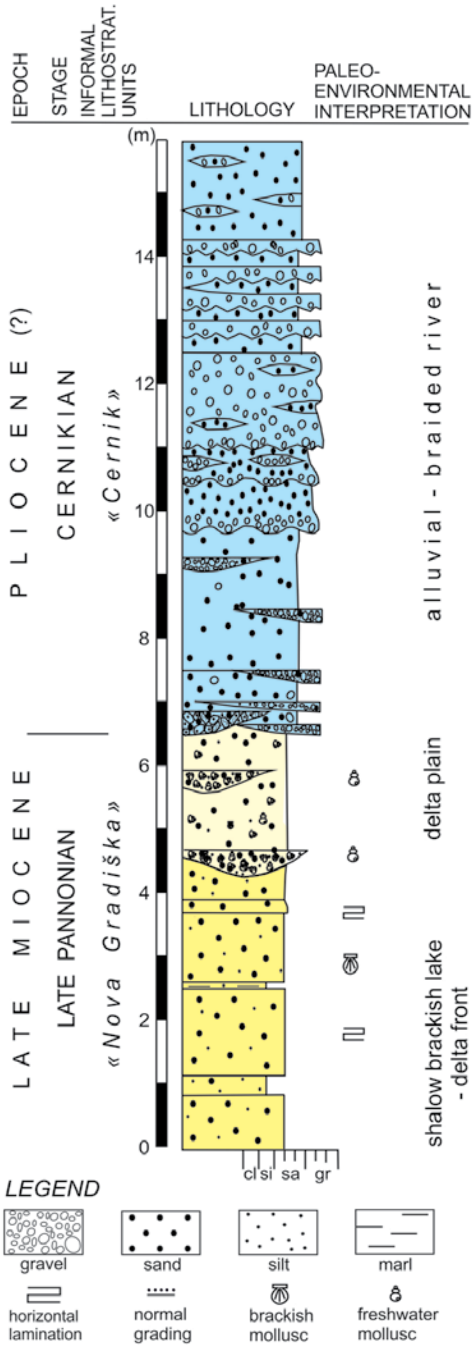

Fig. 6.2 Geological column of the Petnja section (modified after KOVAČIĆ et al., 2012).

their composition. The sand is coarse-grained, moderately or poorly sorted. Their modal composition is characterised by the presence of pyroxenes and chrome spinel (Fig. 6.5 E, F).

INTERPRETATION

Structurally and mineralogically mature sands and silts of the "Nova Gradiška unit" from the lower part of the section deposited on a delta front which prograded from the NW into the Lake Pannon. Fossil molluscs suggest that the lake was brackish and shallow. Furthermore, the molluscs also point to the time of deposition which was the latest Miocene (*Rhomboidea* beds, Potraferrian). The modal composition of detritus suggests their Alpine provenance (KOVAČIĆ et al., 2004, KOVAČIĆ & GRIZELJ, 2006; KOVAČIĆ et al., 2011).

The fossil-rich sands from the middle part of the section deposited on a delta plain, in distributary channels or formed sandy bars. The similarity of their modal composition with the composition of the underlying sand indicates their common provenance. The mollusc assemblage from the middle part of the section (Fig. 6.4) is composed of the species common in the latest Pannonian (Portaferrian) deposits of Lake Pannon (STEVANOVIĆ et al., 1989). The strong dominance of *Melanopsis decollata* by more than 95%, excellently reflects deltaic depositional settings (NEUBAUER et al., 2016). The presence of a diverse lymnocardiine assemblage is remarkable and strongly supports the biostratigraphic age, i.e. the Portaferrian (BASCH, 1990). Lymnocardiine species became entirely extinct at the Pannonian/Cernikian boundary. Viviparid gastropods, dominating the alluvial and lacustrine mollusc assemblages in the Cernikian are missing (MANDIC et al., 2015).

Structurally and mineralogically, immature gravely and sandy alluvial deposits from the upper part of the section disconformably deposited upon the Upper Miocene sediments. The dominance of chert pebbles in the modal composition of the gravel, as well as the presence of pyroxenes and chrome spinel in the heavy mineral association of the sands, point to ophiolites as source rocks. These ophiolites were located south of Petnja, in Central Bosnia, where ophiolites of the Inner Dinarides

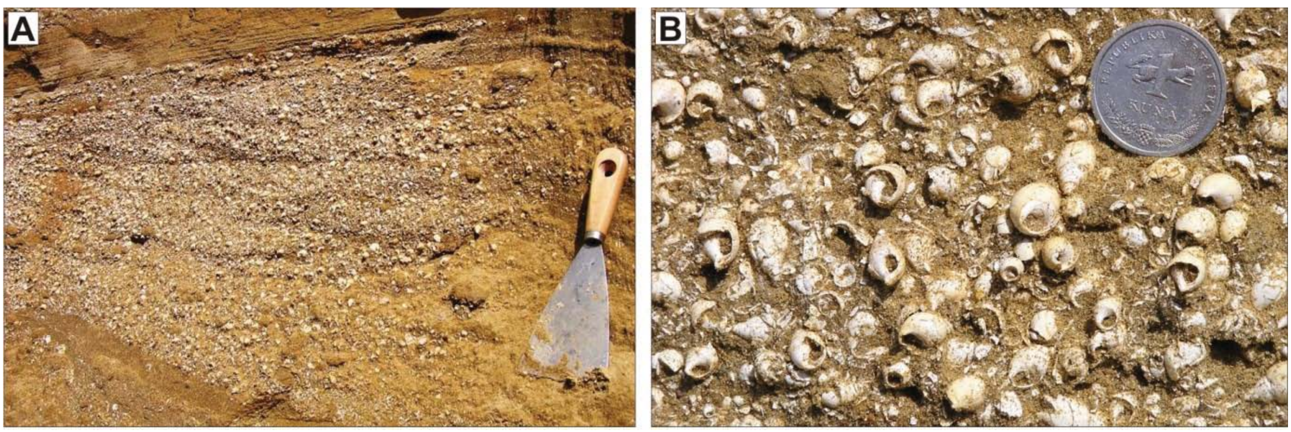

Fig. 6.3 The middle part of the Petnja section. A – Channel filled by fossil mollusc; B – detail of the channel (photo by M. KOVAČIĆ)

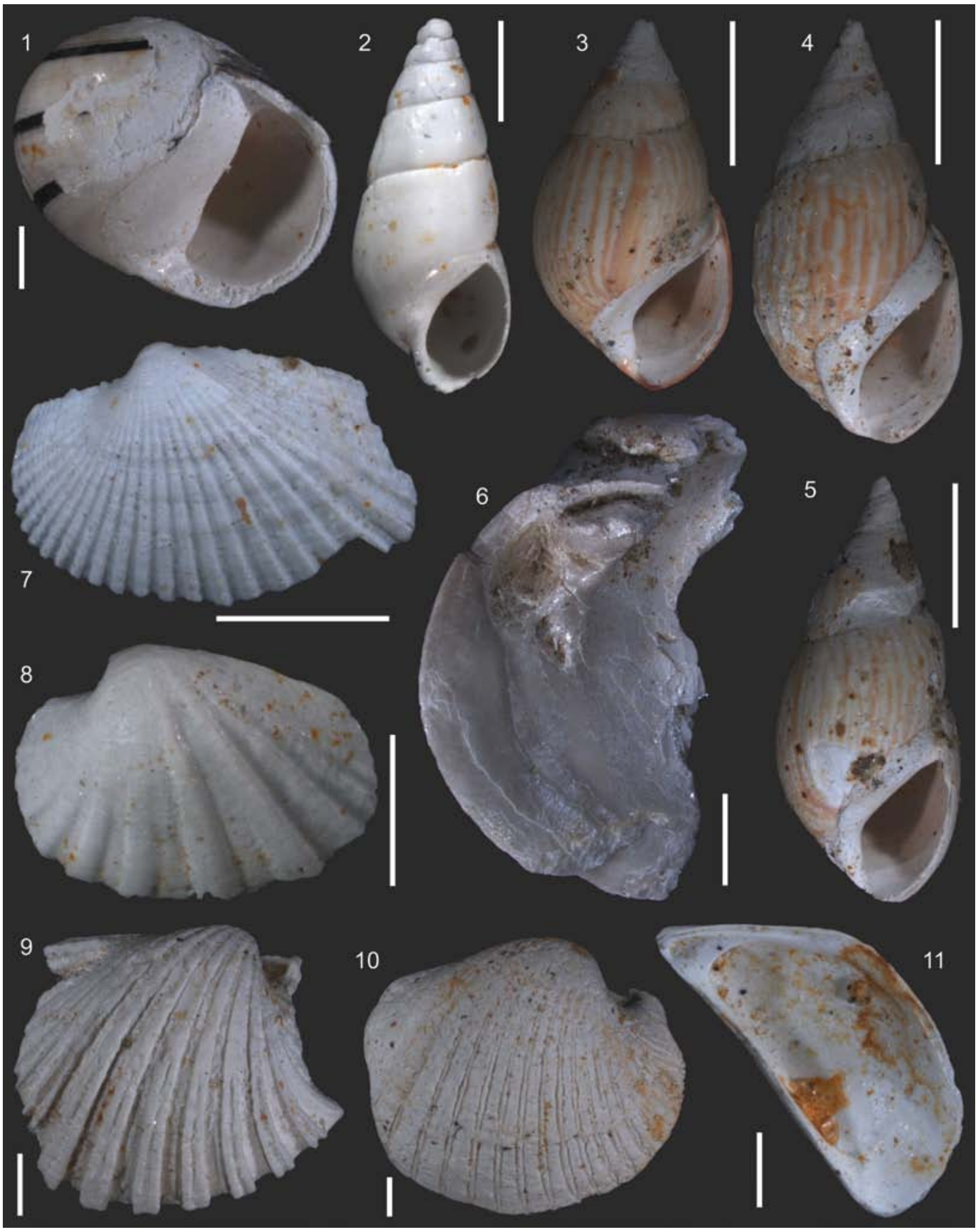

Fig. 6.4 Gastropods and bivalves from the Petnja section. 1. *Theodoxus xanthozona* BRUSINA – Smpl. 2 >2 mm; 2 *Prososthenia*? *praeslavonica* MANDIC, KUREČIĆ, NEUBAUER & HARZHAUSER – Smpl. 4 >2 mm; 3-5 *Melanopsis decollata* STOLICZKA – Smpl. 2 >2 mm (l); 6 *Unio kukuljevici* BRUSINA – Smpl. 3 >2 mm; 7 *Pseudocatillus simplex* (FUCHS) – Smpl. OM2016; 8 *Lymnocardium macropleurum* BRUSINA – Smpl. 4 >2 mm; 9 *Caladacna steindacheri* (BRUSINA) – Smpl. 2 >2 mm; 10 *Prosodacnomya vutskitsi* (BRUSINA) – Smpl. 2 >2 mm; 11 *Dreissena polymorpha* (PALLAS) – Smpl. 2 >2 mm (l). Scale bar 1 mm (figs. 1-2, 7-11) and 1 cm (figs. 3-6).

were exposed on the surface. The age of these deposits is not defined because they are fossil sterile, but according to the superposition they most probably belong to the Pliocene "Cernik unit".

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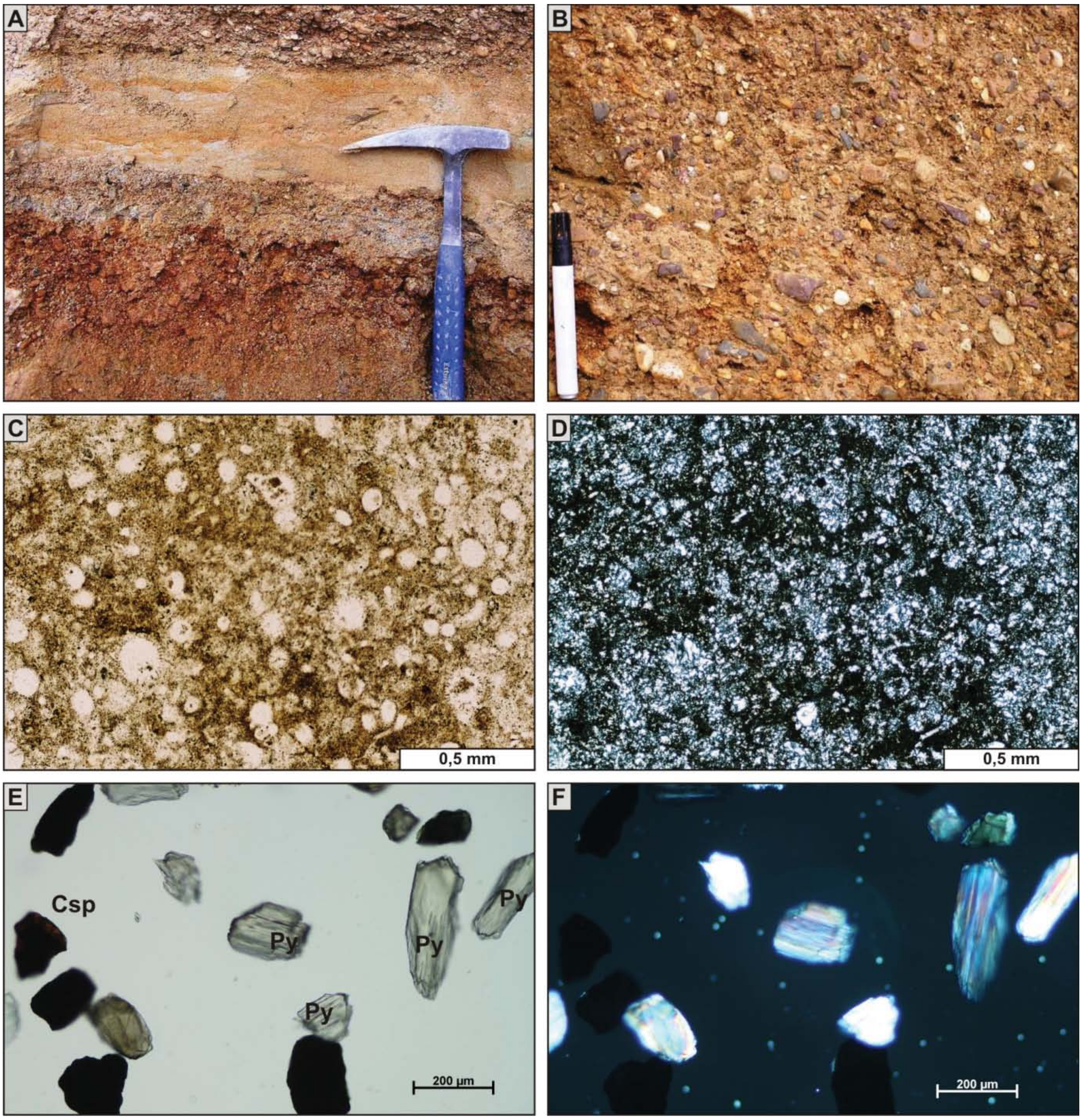

Fig. 6.5 Deposits from the upper part of the Petnja section. A – The intercalations of sandy and gravely beds; B – Fine-grained gravel with well-rounded different coloured pebbles; C, D – Microphotograph of radiolarian chert; E, F – Microphotograph of the heavy mineral fraction of sand characterised by the presence of pyroxenes (Py) and chrome spinel (Csp) (C, E – An-; D, F – An+).

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