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MIOCENE CHAROPHYTA OF MAOČE, PLJEVLJA (NORTHERN MONTENEGRO)

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Abstract: The siliciclastic sediments of Maoče, with its sand beds and sand lenses of fluvial origin, as the clearly featured former shoreline, characterize this remote gulf of DS Lake. Its shallow water is corroborated by the frequent appearance of desiccation cracks. The lacustrine influence is mirrored in rare marly interbeds. Gyrogonites with mostly smooth spiral cells also indicate a low water mineralisation. An age is determined by *Rhabdochara langeri*, the key fossil for Burdigalian equivalents of W Europe, found both in Maoče and close laying Pljevlja. *Nitellopsis merianii* is an Euroasian Miocene species. A large mammal, from Pljevlja - *Chalicotherium grande*, a small morph - indicates the Lower Miocene. An entire herd of *Chalicotherium* was killed by a catastrophic earthquake catting forest they inhabit. The tuff of Maoče was destroyed by fluvial and vawe actions; in mineralized lakes, as Pljevlja is, tuff was transformed into siderite. Basaltic flows cannot support age because of the melting of the lower crust part. So, the biostratigraphic age is the upper part of Lower Miocene.

Key words. Early Miocene, a Balkan Land lake gulf, *Rhabdochara langeri*

1. Introduction

During the Early Miocene, the area of the Dinaric Alps was a large lacustrine environment named the Dinaride System of Lakes (Krstić et al. 2003). In order to understand its properties, it has been necessary to study its coastal fossil rich sites (Krstić et al., 2009; Jimenez-Moreno et al., 2009; Mandić et al., 2009), its sites in the center of the basin (Sokač, 1979), as well as its sites in remote gulfs that have freshwater tributaries (Žic et al., 1995). The remote gulf of Maoče, only 30 km SE from the already well-studied Plevlja mine (Krstić et al., 1994), with its ostracodes which indicate a saline lake environment (Krstić, 1987). As Maoče lies close to southeastern margin of the Dinaric System of Lakes, its properties are important.

The Maoče fluvio-denudation plateau (Žic et al. 1995), at an average altitude of 1400 m, was cut by the Ćehotina river into its Paleozoic and Mesozoic rocks. The plateau is tilted opposite to the direction of the river, cutting an epigenetic valley with numerous meanders incised in Middle Triassic limestone. The former lake coastline around Maoče, Pljevlja and all the way westwards to the Drina river has been mapped geomorphologically (Žic, 1991) and one of its erosion stages is featured by a caverne sediments of the early Pleistocene age (Dimitrijević, 1990) well above the recent Neogene surface.

The Maoče Neogene has also been studied due to its coal content.

2. Stratigraphy

The Neogene sediments of Maoče (Žic et al., 1995) are preserved at a surface of app. 10 km^2. In the central part of the plain, the Neogene thickness was greater than 300 m. Coal, at all, reach 35,5 m in the northeastern part of the plain. The sequence overlaying brown coal has an average thickness of 86 m.

Three superimposed parts are distinguishable in the Neogene column: the basal part lying below the brown coal, the coal part consisting of 3 seams, and the brown coal overburden. The youngest member contains a thin lignite bed close to the top.

The deposition of Neogene starts with a 30 m thick

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Fig. 1 Geomorphological map of Plevlja, Maoče (M) and its surroundings. The lake coastline was mapped in the field.

multicolored silt with cherty pebbles. The silt is grey-green, grey and whitish-grey; the green color should come from the tuff content.

The coal-bearing formation consists of two footwall seams and the main layer of coal above them. The oldest, second footwall seam is from 0.7 to 3.7 m thick; its composition is swampy clayey coal. The First Footwall Seam, of woody structures, has a thickness range of 0.4-6.8 m. The thickness of the main coal seam varies between 1 and 26 m following the shape of the bedrock. The marl below the main coal seam is laminated, porous and, sometimes has desiccation cracks; the $CaCO_3$ content varies from 58 to 68%; in sandy fraction quartz prevails, feldspars are rare, and there are mica flacks and gastropods. Some clay of illyte type is recignised.

The coal was formed by *Nyssa* and *Taxodium*. Among other plants there are subtropical ferns, palms, *Taxodium* and of temperate-climate genera *Cedrus, Myrica, Betula* etc. For a swampy ward *Nyssa* and *Taxodium* are characteristic.

Above the coal-bearing formation the column continues with laminated silt, often bedded (beds distinguished by the colors of reddish, pink, grey to blue-grey); also the sandy marl with meiofossils is 60 m thick. Following 40 m is of banded sandy silt, grey and bluish grey characterized by the lenses of quartz sand (80-90% SiO_2) often cross-bedded, up to 30 cm thick inside of thin-bedded sediments, otherwise the sand-beds are only up to 3 cm. Another 40 m is silt, grey, sandy with carbonate concretions, and many intercalations of coal in beds up to 10 cm. The youngest member of the overlaying sequence is the alternation of sandy clay with coaly clay and lignite coal of a humous and woody structure, in places up to 3 m, as numerous thin coal beds; it is characterized by its low $CaCO_3$ content and a granulation of the sediments transported and deposited from suspension uniformly and, rarely, graded. Sand lenses are seldom.

3. Paleontology

Only the bore hole BM-152 was subject to paleontological sampling, and only two samples have yielded meifossils. They are from 46.0-46.2 and from 41.0-41.1 m in depth. These are thicker grey beds containing halotolerant and halophilic fossils. The mollusks have included *Valvata* sp. with a longitudinal fold (carina), *Planorbis, Pisidium* and *Melanopsis?* fragments. The determined ostracodes have included the extinct genera *Moenocypris* ? *montenegrina* and *Brdacandona* cf. *bešići* and of recent genera halotolerant genera *Ilyocypris* sp. div., *Cypria, Pseudocandona, Neglecandona, Virgatocypris, Erpetocypris*. The endemic cando-

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ninae *Brdacandona* should be a halofile, as *Moenocypris*.

The **Charophyta** from samples with ostracodes includes:

Lychnothamnus barbatus antiquus Soulie-Marsche 1989 (Pl. I, Figs 10, 12-14). The sample of drilling BM-152 at 41.0-41.2 m contained large, well-calcified specimens (figs 12 and 14, on 13 is the basal plate) assigned to *Lychnothamnus barbatus* var. *antiquus* Soulie-Marsche 1989. The ridges bordering the sutures do not reach the basal pore (Fig. 10). These are the most numerous gyrogonites in the Maoče bed at 41 m and indicate a freshwater environment.

Rhabdochara cf. *langeri* (Ettings) Madler, L. Grambast, 1957 (Pl. I, Fig. 11) are from the same bore hole BM.152, but at a different depth (46.0-46.2 m), and are smaller in average from the related *Lichnotamnus* and have more concave spiral cells, corresponding to the morphology of *Rhabdochara*. The apex has no apical nodes in Maoče, whose specimens are characterised by the presence of poorly developed transverse ribs on the spiral cells corresponding to the morphology of *Rhabdochara langeri*. The Lower Miocene (Burdigalian) is characterised by this species and holds stratigraphic value.

The material from the locality Otilovići in the Plevlja area also contained *Rhabdochara* gyrogonites with specimens, which were shown as having well-developed and regularly distributed small transverse sticks on all spiral cells (Krstić *et al.* 2009: pl. II fig. 8). The apical nodes were present and sometimes developed short spines, while some of the small transverse ribs on the spiral cells were able to grow into a kind of elongated tubercle (ibid: pl. II fig. 9). They fit exactly into the morphology of *Rhabdochara langeri* (Ettingshausen 1872) Maedler 1955.

Chara molassica molassica Straub 1952 (Pl. I, Fig. 6) is known from the Auversien to "Tortonian" (Middle Miocene) of central and Western Europe, according to Madler, 1955 and Riveline, 1986.

It is doubtful if this species was found during the Pliocene in the Caspian Sea region (Kyrgyzstan, the northern Caucasuses, Turkmenistan). Maslov (1966) does not give any figures of *Ch. molassica*, only measurements during the establishing of a

new subspecies *kirgisensis*. According to Maslov, the *Ch. molassica molassica* from the Pliocene had

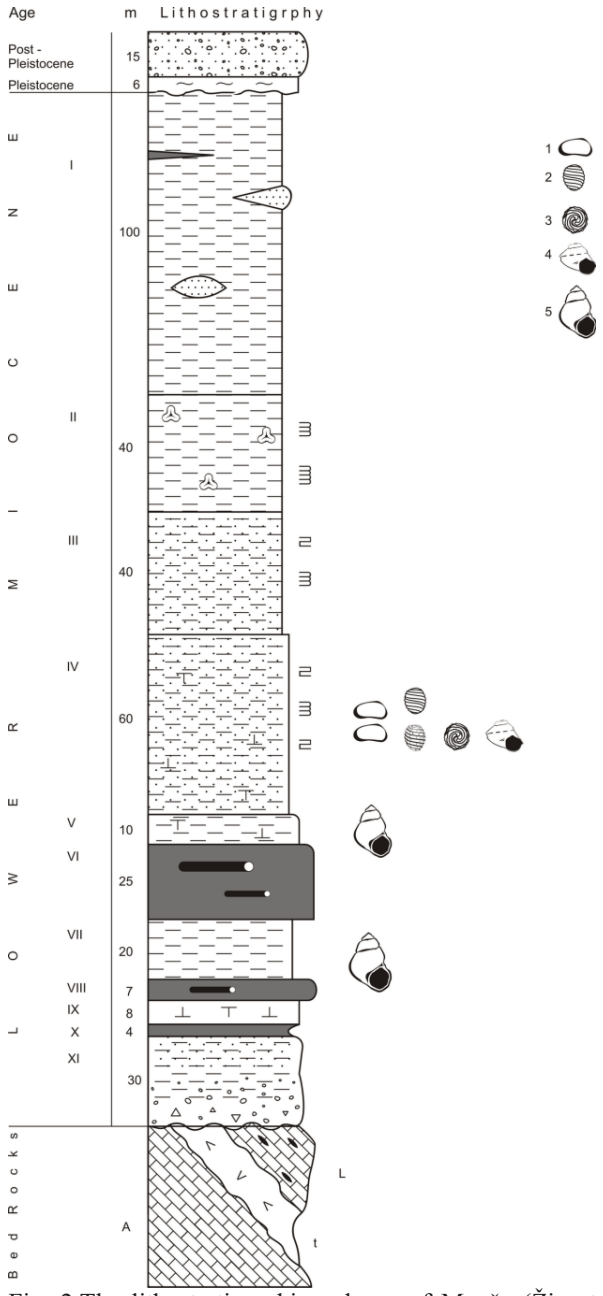

Fig. 2.The lithostratigraphic column of Maoče (Žic et al., 1995).Legend: 1. Ostracodes, 2. *Characea*, 3. *Nitellopsis*, 4. Carinate *Valvata,* 4. Mollusk remnants

a length of 0.547 mm, width of 0.370 mm, 11-12 whorls on its side, while the radius of the basal pore was 0.030 mm. Its subspecies *Ch. molassica kirgisensis* was larger: l-0.529-0.684, w-0.384-0.450, the number of whorls on its side was 11-14, basal pore 0.023 mm. It is highly possible that in the Pliocene population the smaller and stockier specimens **only** resemble *Ch. molassica molassica*.

The material from Maoče contains a single dwarf gyrogonite with only 4 spiral cells. SOULIE-

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Marsche (1989) showed that the populations are often a mixture of smooth and ornamented specimens (*Chara molassica notata)*, belonging to the same species.

Chara molassica notata Grambast and Paul, 1965 (Pl. I, figs 7-9). was distinguished by Straub, 1952, as *C. molassica forma a* (specimens ornamented "mit kleinen Knötchen"). Later, the ornamented form was separated as a different species: *Chara notata* by Grambast and Paul, 1965. Later Soulie-Marsche (1989) showed that many populations are an admixture of smooth and pustulated specimens, belonging to the same species but retained *notata*, only as a variety, thus joining the original opinion of Straub. It is also possible that in warm summers ornamented specimens developed together with the smooth ones. In the geological past, in a warm-temperate climate, such a possibility was often present as well.

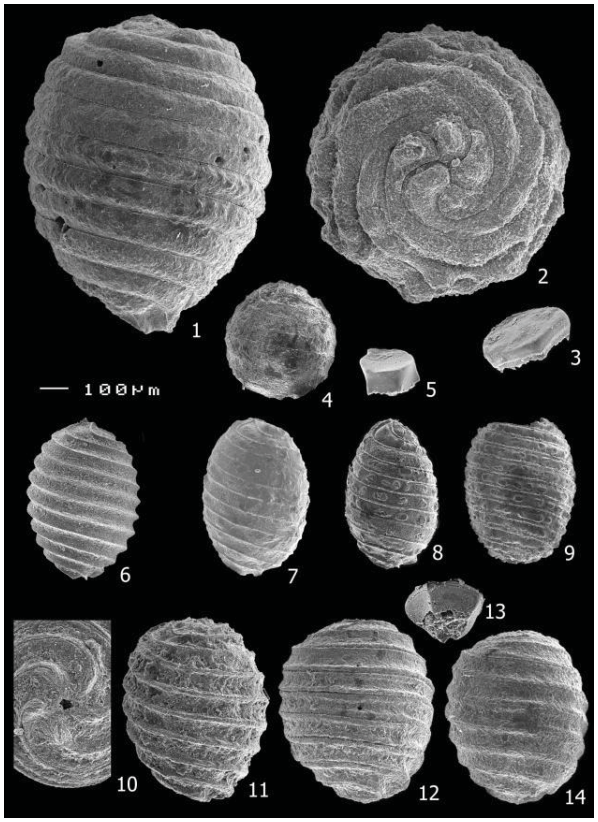

Plate I: 1-3. *Nitellopsis merianii* (A. Braun) Grambast & Soulie-Marsche 1972, BM-152 from 46.0-46.2 m, 4-5. *Spha-erochara sp.* ex gr. *S. parvula* Reid & Groves) Grambast, 1958, BM-152 from 46.0-46.2 m, 6. *Chara molassica molassica* Straub 1952, BM-152 from 46,0-46,2 m, BM-152 from 46.0-46.2 m, 7-9. *Chara molassica notata* Grambast and Paul 1965, BM-152 from 46.0-46.m, 11. *Rhabdochara langeri* (Ettings) Madler, L. Grambast, 1957, BM-152 from 46.0-46.2 m, 10, 12-14. *Lychnothamnus barbatus antiquus* Soulie-Marsche 1989, BM-152 from 41.0-41.1 m.

Nitellopsis merianii (A. Braun) Grambast & Soulie-Marsche 1972 (Pl. I, figs. 1-3) is the typical *N. merianii* with its regularly convex smooth spiral cells presented in fig. 1 on the plate. In the same plate, fig. 2 an aberrant specimen is shown, with uneven spiral cells, the beginning of tubercles growing (Pl. I, fig. 2), and has well visible roughness. The apical nodes of this specimen are more developed than in the first mentioned specimen. The thin basal plate (Pl. I, fig. 3) is typical for the genus *Nitellopsis*.

The presence of a nodose morph could mean that the water salinity had changed with seasons or over longer time intervals: with an influx of enough freshwater, in winter and spring, salinity would drops and the specimens would be normal, as in fig. 1. In a warmer summer, in this subtropic climate, the seasonal variability could produce aberrant specimens as in fig. 2. Both morphs were obtained from the sample depth (46.0-46.2 m) of the drill hole BM-152.

N. merianii is a very common species for the Miocene - found only in Europe and Asia, with one site in Morocco (Soulie-Marsche *et al.*, 2002).

Sphaerochara sp. ex gr. *Sph. parvula* Reid & Groves, Grambast) 1958 (Pl. I, Figs 4-5) is a little thicker than the one of *Sph. inconspicua* as given in Riveline, 1986. In Maoče, there were only a few specimens of this *Sphaerochara*.

The "stratigraphic range" of *Sphaerochara parvula* (in Riveline, 1986: 75) includes the "Lower Ludien to Upper Oligocene". A similar form is indicated for the "Tortonian' of "Switzerland and southern Germany (Madler, 1955 in Riveline 1986)".

4. Discussion

Most near to Maoče is Pljevlja, both plane and some other erosion remnants contain sediment of the former Neogene DS Lake gulf, as shown in fig. 1.

Geomorphologic mapping (see text-fig. 1) of the ancient lake shore (Žic, 1991) has been supported by structural analysis in the area of Prijepolje (Ilić & Neubauer, 2005), very close to Maoče. According to their paleostress study, it was obtained that the vertical movements are subordinate and overprinted by horizontal striae.

In Pljevlja the main coal, woody as in Maoče, is the product of a catastrophic earthquake, bringing

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tree trunks together with a whole herd of its large dwellers *Ungulata* with claws (Krstić *et al.*, 1994) into the lake. These tectonic movements caused the decomposition of the coal seam on the intermittent northern fault, which is still active (Krstić et al., 1994), tilting the whole plateau opposite to the direction of the Ćehotina river flow.

A comparison of the sedimentological reconstruction: In Pljevlja the main coal overburden is marl rich in calcium- and pure in magnesium-carbonates characterizing a hydrologically open lake; its water was well oxygenated (Krstić et al., 1994). In Maoče the fluvial sand of the coal overburden is cross-bedded and often accumulated as lenses. The exposition of quiet shallow parts of the lake in Maoče corroborate the desiccation cracks. The influence from Pljevlja, containing up to 84.65% $CaCO_3$, is mirrored in the marly beds of Maoče. It can therefore be supposed that there should be a sublacustrine threshold dividing shallow remote gulf part of Maoče from the wide and deep (below the wave base) lake part of Pljevlja. This threshold had been over-poured by highly mineralized and low saline water of the Pljevlja gulf part from time to time. In Maoče, there were not any spotted sideritic beds as there are in Pljevlja, where they do indicate some volcanic activity. In mineralized lakes, tuff changes into siderite, as it has been observed in Pontian sediments (while the "marine" Maeotian tuff could have been, by its wave actions, broken and rounded out and enveloped by a limonitic '"shell" but still have retained its structure and its biotite untucht - Krstić et al., 1995).

The water-salinity in Maoče has been inferred from the ornamented gastropods of the genus *Valvata* and the endemic ostracodes *Brdacandona* (Krstić et al., 1994) and *Moenocypris* described from the upper part of Lower Oligocene of W Germany (the lower part of Lower Oligocene is the marine - Triebel, 1963). All other fossils could be halotolerant, even *Chara molassica notata* and smooth and rough *T. merianii*.

Meiofossils from the two sites of Pljevlja, above the coal (Krstić, 1987) have yielded: the species *Moenocypris montenegrina* In white silt (lacustrine chalk) of Otilovići (4 m above the coal) where it is nearly a single ostracode, this is together with numerous characeans, one of which is the typical *Rhabdochara langeri*. From the gray silt of the site Rabitlje (55 m above the coal) *Brdacandona bešići* together with another extinct genera *Septocypris* sp*., Chinocythere* sp*., Clonocythere ćehotinae. Amplocypris* sp. and *Moenocypris montenegrina* were described. There are halotolerant to freshwater genera *Pseudocandona korjeni*, *Cypria sp., Paralimnocythere* sp. and a juvenile *Virgatocypris*, as well as *Metacypris sp,* having recent representatives living in freshwater (> 1.5 ‰ S).

Age: In the fluvio-deltaic milieu of Maoče, the tuff was eroded, while in Pljevlja, the mineralized lake had transformed it into sideritic layers. The biostratigraphic age was first determined to be MN5 (=NN5 of Mein, 1985, or Lower Langian= the Lower Miocene) for the species *Chalicotherium grande*, a smaller morph. For the DS Lakes and its congerian fauna Kochansky & Slišković (1978) the Ottnangian age along all Dinaric Alps valleys is proposed. The age of Sjenica terrestrial gastropods (Prysjažnjuk, 2008) corresponds to late Ottnangian-Carpathian. An absolute age of the analcimite basaltic rocks, directly overlaying the terrestrial gastropod bed is 22.95 + 1.25 Ma, but "the Serbian ultrapotasic rocks display many characteristics that are consistent with contamination of their mantle source by a subducted sediment component" (Cvetković et al., 2004: 179). Isotopic values in the lakes differ from the World Ocean, and they therefore cannot be applied (Frei, 2010) for DSLs. According to the characea, these are equivalents of Burdigalian. All these names are used for different formations of the upper half of the Lower Miocene.

5. Conclusion

The Neogene remnants of the Maoče valley originally belonged to a remote shallow gulf of DS Lakes where tributaries brought freshwater from the land. The hydrologically opened Pljevlja Lake, with its vertical coast, was boarded toward Maoče by a threshold, which was from time to time overpoured,by Pljevlja's mineralized water, immediately more or less diluted in Maoče. Subsidence in Maoče was slower than in the other parts of the DS Lakes, including the neighboring Pljevlja because of the firm land nearby. The movements of the Adriatic Plate caused a catastrophic earthquake which brought woody material into Maoče from the NE and not from S as it did so in Pljevlja. The slow movement that dismembers the northern part of Pljevlja's main coal is still active as well as with all DS Lakes and in Maoče.

The age of Maoče, as in all Dinaride System of Lakes, should be the Lower Miocene and, maybe, it could be pinpointed as being Ottnangian, the

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great freshwater period of Middle and southern Europe. The age cannot be measured by physical methods in the lake, with such an area that has a melting lower crust part, so it is only up to the fossils, *Rhabdochara langeri,* to give us the key: upper part of Lower Miocene.

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