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Macropalaeontology and stratigraphy of lacustrine Miocene deposits at Crnika beach on the Island of Pag (Croatia)

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ABSTRACT

The sequence of Miocene fossiliferous marls of the Crnika beach, along the south west shore of Pag Bay, consists of an alternation of silty and clayey marls, sandstones, coaly clays, coal-bearing strata and sparse intercalations of bentonite in the older part, and of an alternation of calcitic marls and organogenic fossiliferous limestones with several coal strata in the younger part. Some of the strata are highly fossiliferous and rich in various species of freshwater gastropods of the genera *Melanopsis, Theodoxus, Pyrgula, Prososthenia, Orygoceras* and *Valvata* with the new species *V.* (*?Costovalvata*) *pagana.* Bivalves are represented by the genera *Congeria*, *Unio*, *Pisidium.* There is also, a rich ostracod assemblage, and remains of flora: twigs, leaves and seeds of higher and lower plants, and agglomerations of aquatic grasses and algae. Fish bones and teeth, as well as the crocodile tooth, are not particularly common, but they do help to complement the image of the diversity of the biological association that lived in the ancient lake and along its shores. According to facies analysis, the Miocene deposits of the Island of Pag, were deposited on the south-western edge of Paratethys, which has been moved more westward and south-westward within Croatian territory.

Keywords: marls, limestones, coal, bentonite, lacustrine bivalves and gastropods, crocodile tooth, plant remains, Early Miocene, Island of Pag, Croatia

1. INTRODUCTION AND PREVIOUS INVESTIGATIONS

Miocene fossiliferous deposits of the island of Pag, cropping out on Crnika beach are not known in other Adriatic islands or along the eastern Adriatic coastline. For this reason they are important and have a special value for lacustrine palaeontology and stratigraphy as well as for regional correlation.

This deposit transgressively overlies Upper Cretaceous limestones and Eocene flysch. The thickness is not constant and can be very variable. In Kolansko Polje, drilling revealed the greatest thickness of these deposits at 142 m. However, in the Crnika area, the thickness of the Miocene is much greater. With the assumption that the superposition relations have not been distorted by repetition, the total thickness of outcrops and deposits in the covered parts of the profile along the Crnika coastline is 265 m (Figs. 1a, 1b).

Apart from the outcrops that are seen immediately to the rear of the beach, the Miocene deposits in the Crnika area are on the whole covered with Quaternary sandy and gravely clays. Lithified coarse grained sandstones and breccias overlie the clay, making picturesque step sections that stand out on the edges of the Quaternary terrace for their individual appearance.

The coal layers alongside the beach of Crnika have been known since the end of the 19th century, but it is only recent palaeontological research that has revealed in these deposits rich finds of different kinds of molluscs, plant remains, and somewhat less often the teeth of fish and reptiles.

The discovery and collection of fossil remains of flora and fauna in the Miocene deposits on the island of Pag are closely connected with extractive and geological research into the coal beds in the Kolan area. There are historical data showing that the first research into the coal layers started as far back as 1757 (MARKOVIĆ, 2002). With shorter or longer interruptions, research into coal and other mining activities in Kolan lasted until 1951, when coal mining was halted, the mine was closed and abandoned. Although this was coal of good quality, it was estimated that the beds were too thin to make mining in Kolan economically viable.

The first data about the fossil flora and fauna in the coal bearing deposits of the island of Pag were recorded by RADIMSKY (1877a, 1877b). His collection of higher plant remains, such as *Taxodium distichum miocenicum*, *Glyptostrobus europaeus*, *Sequoia langsdorfi*, *Pinus holothana* and *Mirca lignitum* (ENGELHARDT, 1901), is of particular value. According to the findings of the genera *Congeria*, *Pisidium* and *Planorbis* (HÖRNES, 1898) these deposits are apportioned to the Sarmatian or the Congerian 'step'.

SCHUBERT & WAAGEN (1913) described the coal layers in Kolansko polje and provided the first complete palaeontological description of the fossil remains of flora and fauna, which were also the first scientific data on fossil remains in the coal-bearing deposits of Pag island. The authors promoted the opinion that the coal-bearing strata in Kolansko polje were deposited at the beginning of the Late Miocene, precisely in the Pannonian, which was earlier voiced by RADIMSKY (1877a, b) and by PÖSCH & HOFMANN (1909). MAMUŽIĆ et al. (1970) and MAMUŽIĆ & SOKAČ (1973) determined these deposits as being of Late Miocene and Early Pliocene age. According to KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ (1978) the bivalve *Congeria antecroatica* KATZER, discovered in Kolansko polje, implies a Karpatian or Badenian age.

Our investigation and systematic collection of fossil remains alongside Crnika beach took place in 2001 and later during 2004 and 2005. At that time new outcrops of Miocene deposits were found behind the Sv. Duh beach (Fig. 1a). These very fossiliferous organogenic limestones and marls with intercalations of coal, are for the moment, the youngest part of the Miocene sequence in the Crnika area.

2. GEOLOGICAL SETTING OF CRNIKA AREA

Crnika beach is on the island of Pag, part of the archipelago of the northern Adriatic (Fig. 1a). The island is sixty kilometres long in a NW–SE orientation, i.e. so Dinaric strike, and nearly ten kilometres wide. Pag Bay extends in the central part of the island, a drowned valley inundated by the sea. On the NE side the bay is linked to the Velebit channel.

With respect to geological composition and structural settings the island of Pag is a continuation of the northern Dalmatian mainland (Zadar hinterland). It is characterised by gentle and medium-steep folds, extending in the Dinaric direction (NW–SE). The wings of the folds are secondarily folded and faulted with longitudinal and lateral faults. As a rule, the anticlinal parts of the folds correspond to the elon-

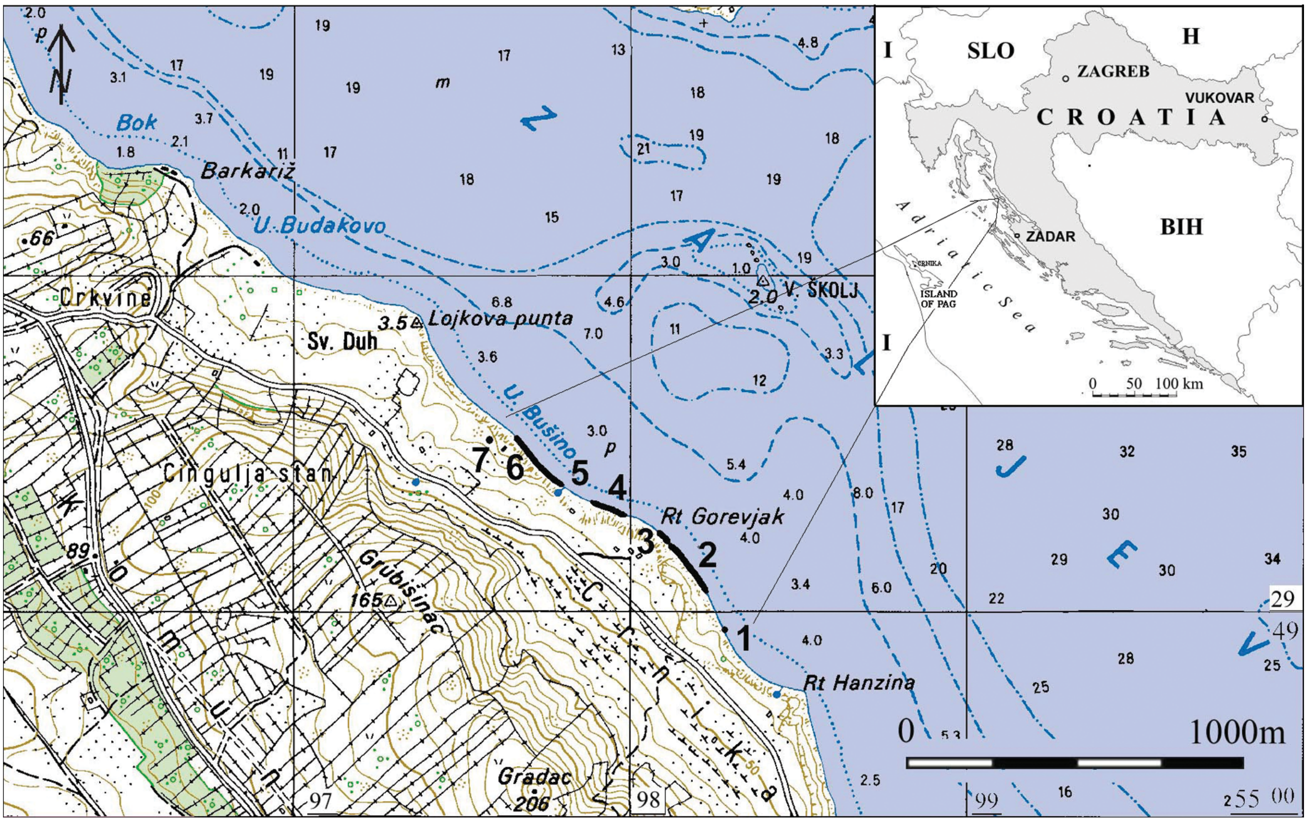

Figure 1a: Location map of Crnika beach with sampling points (1–7).

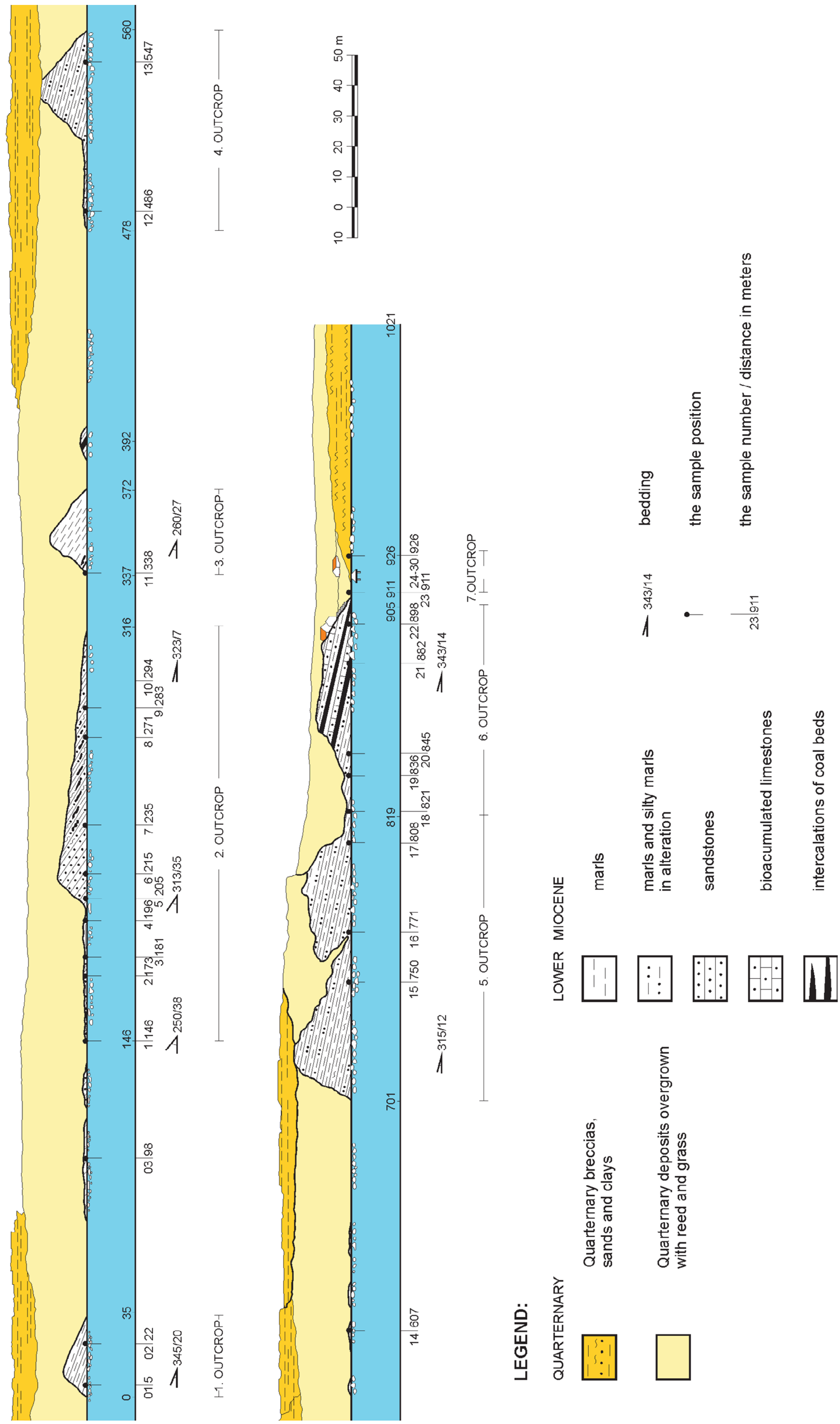

Figure 1b: Cross-section of the studied deposits in the seven outcrops.

gated upland ridges and highs, and the synclinal parts correspond with the narrow, shallow intermontane valleys. The anticlines are composed of Upper Cretaceous Rudist limestones and dolomites, and Palaeogene Foraminiferal limestones, while the synclines are filled with Palaeogene clastics significantly covered by Quaternary deposits (MAJCEN et al., 1970; MAMUŽIĆ et al., 1970; SOKAČ et al., 1974). Crnika beach stretches along the SW edge of Pag Bay, where over a distance of ca 900 m there are outcrops of Miocene marls, sandstones, clays, limestones, coals and very rare and thin strata of bentonite (Fig. 1b). These deposits slightly dip to the NW, with an inclination that on most of the outcrops ranges between 7 and 15 degrees.

Miocene deposits are rich in fossil remains of bivalves, gastropods, some higher and lower plants, as well as other organisms that populated the one-time lake and its shore. The following are particularly frequent; the bivalves *Congeria antecroatica, Unio* sp., then gastropods: two species of the genus *Delminiella,* a new species of the genus *Valvata*, *Melanopsis* sp., *Prososthenia* sp., *Thedoxus* sp., etc. and the remains of flora, for example leaves of sequoia, remains of rush, lacustrine grasses, algae and the seeds of land and water plants. In addition, rare remains of fish teeth and bones occur and a crocodile tooth was discovered.

Along with the indigenous fossil molluscs, lacustrine and land terrestrial plants there are numerous well preserved foraminiferal shells which were washed out and redeposited from the nearby marls of Middle Eocene flysch deposits.

3. LITHOLOGICAL SUCCESSION OF THE MIOCENE DEPOSITS

Alongside Crnika beach, over a distance of nearly one kilometre, seven outcrops were singled out in which the Miocene deposits are clearly exposed and accessible for investigation (Fig. 1a). Outcrops 5, 6 and 7 in the more recent part of the profile are continuous and constitute a unique and linked superposition sequence of deposits. The other outcrops are separated by Quaternary breccias, sandstones and clays, and overgrown with thick rush bushes and high grass. In total, the Crnika Miocene deposits form an outcrop thickness of 265 m (Fig. 1b).

It is possible that, in the hidden parts of the profile, because of tectonic shifts, the deposits are repeated several times, while giving the appearance of a normal superpositionary sequence. For these reason outcrops 1, 2, 3 and 4, which occur in the older part of the profile, cannot with certainty be placed in a normal superpositionary relationship. As shown in the composite stratigraphic column, this can only be postulated (Fig. 2).

The Miocene deposits in Crnika area are completely composed of fine-grained and muddy deposits: silty and clayey marls, coaly clays and fine-grained organogenic limestones. But there are differences in the lithological composition between the individual outcrops because of the proportion of siliciclastic and carbonate detritus in the deposits. The siliciclastic component decreases from the older to the younger deposits, while the proportion of carbonate components increases. Organic matter is equally represented in both the older and younger parts of the profile in the form of thinner and thicker intercalations and lenses of coal.

3.1. Deposits of outcrop 1

Deposits in this outcrop are composed of very calcitic, silty and fossiliferous marls of a yellowish brown colour. In the lower part of the outcrop the marls are variegated with very narrow layers and laminae of light grey fossiliferous limestones–biomicrites (Figs. 1b and 2). The well preserved shells of gastropods and congerians can sporadically be found over the whole surface of the outcrop, but are particularly frequent in the lower part of it. In the base of the outcrop there is a coal layer of unknown thickness (> 50 cm), of amorphous appearance, black with glossy breaks; it is easy to split into irregular small plates in which pyrite nests can be observed.

Between outcrops 1 and 2 in some places along the beach, below the Quaternary deposits and the shoreline gravel worn, grey-blueish, fine-grained, calcitic sandstones and siltstones can be observed. Sandstones are composed of fine grained detritus, comprising predominantly angular – half-rounded grains of quartz and rare grains of plagioclase, sheets of muscovite and particles of rock – including chert and quartzite.

3.2. Deposits of outcrop 2

The lower part of this sequence consists of thin strata of fine-grained dark-brown sandstones alternating with thin coaly marls and laminae of coal (Figs 1b and 2). In the strata alongside the beach, white sections and fragments of gastropods appear, together with a mass of their compacted shells mixed with black carbonised twigs and stems of wetland plants. In the sandy detritus, quartz grains are most abundant, alongside which small crystals of plagioclase, muscovite, grains of quartzite, chert and micrite could be seen. The matrix is sandy and clayey. The sandstones are overlain by very fossiliferous, dark-grey silty marls with a single layer of bentonite 5–7 cm thick (Fig. 3A) and light grey silty marls with concretions of limonite and red-brown and yellow nodules of limonitised marls. Congeria shells are frequent in the nodules of limonitised marls (Pl. IV).

The central and upper parts of the outcrop are characterised by very regular alternations of thin-layered, yellow-brown, fine-grained sandstones, coaly silty marls which gradually pass into olive-grey and dark-grey coaly marls with carbonised larger parts of trees – stumps and branches (Fig. 3B).

3.3. Deposits of outcrop 3

The lower part of the outcrop is composed of dark-grey silty marls with carbonised branches and stumps and coal layers (Figs 1b and 2). The central and upper part of the outcrop is composed of unstratified light grey and grey-red marls (Fig. 3C).

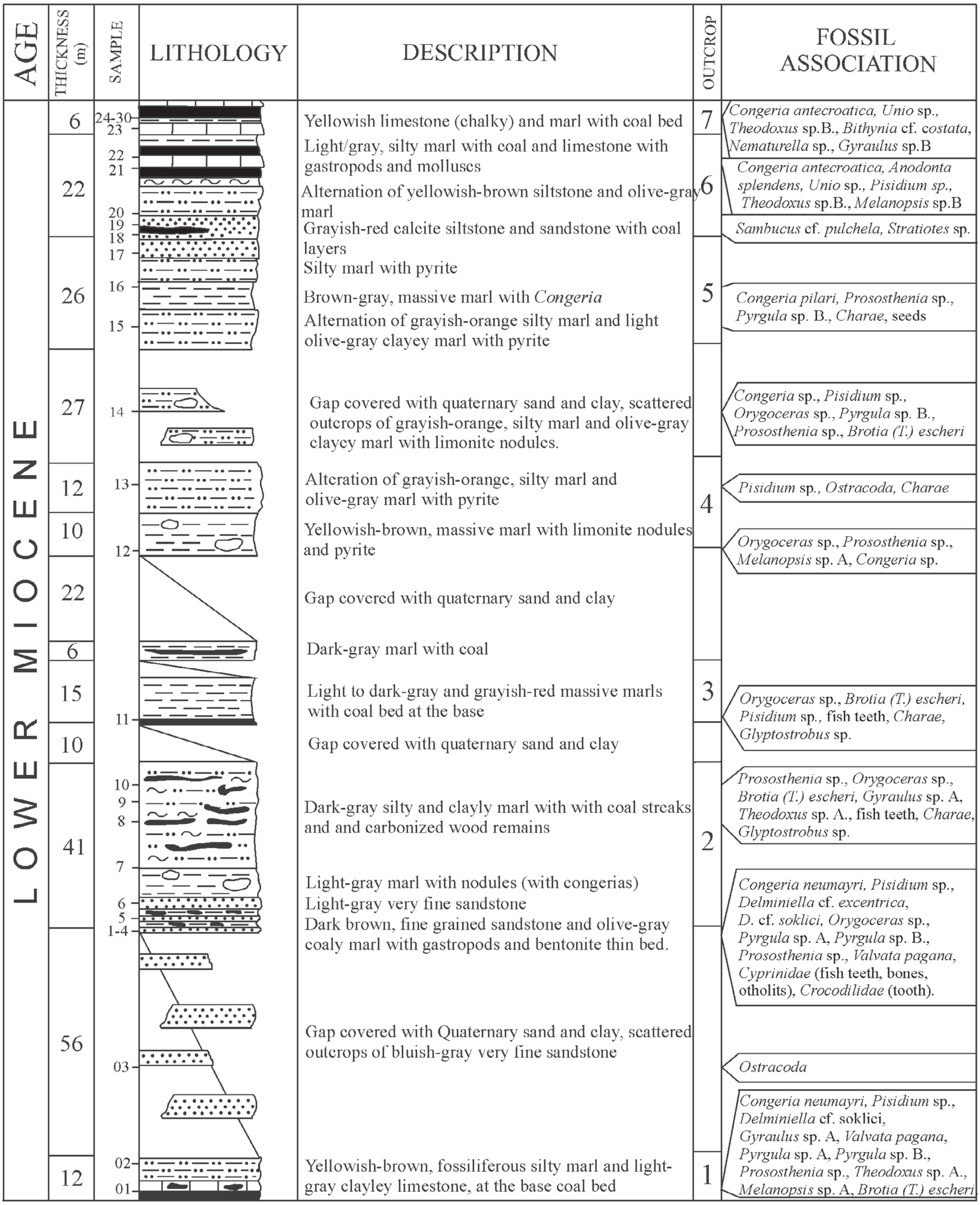

Figure 2: A composite stratigraphic column of the Lower Miocene beds at Crnika beach on the Island of Pag.

3.4. Deposits of the outcrop 4

These deposits crop out mid way between outcrops 3 and 5 (Figs 1b and 2). The outcrop is elevated above a spacious, low coastal zone behind the beach, covered with Quaternary sands and clays. In the lower part of the outcrop, a uniform sequence of unstratified yellowish brown marls with very particular yellow brown limonite nodules can be observed. In the muddy marl it is possible to find scattered very fine black fragments and debris of organic matter, of coal and small pyrite nests. The upper part of the outcrop is characterised by the alternation of calcitic silty marls and clayey marls. These deposits are characterized by a gradual change in colour. The silty marls are somewhat lighter, most often grey-orange in colour, and the clayey marls are darker, mainly of an olive-grey colour.

Figure 3: Outcrops of Miocene deposits along the beach Crnika. A – Detail of 2. outcrop with thin layered sandstones and coaly marls. B – Carbonised stumps and nodules of limonitic marls. C – Beach with marl outcrops and Quaternary breccias at the top of the slope. D – Thin layered siltstones and silty marls. E – Coal beds and marls with fossils at cap Fumić. F – Coal beds in the sea at cap Fumić.

At several places along the coast, between outcrops 4 and 5, there are smaller outcrops of silty and clayey marls, with characteristic brown-yellow limonite nodules.

3.5. Deposits of outcrop 5

The lithological composition of the fifth outcrop is similar to those of the fourth one and of the smaller outcrops in the covered part of the coastal zone, between the fourth and the fifth outcrops (Figs. 1b and 2). These are rocks with a muddy matrix composed of variable proportions of silt, micrite and clay. The matrix contains scattered dotted black organic matter debris, coal and globular agglomerations of pyrite as well as relatively well preserved shells of small gastropods and ostracods.

In the central part of the outcrop there is a massive marl bed, 1.5–2 m thick, with numerous moulds and whitish congerian shells (Fig. 3D).

3.6. Deposits of outcrop 6

The lower part of the outcrop is composed of greyish-red calcite siltstone and sandstone with coal beds (Fig. 3., E and F). They are overlain by an alternation of thin strata of yellow brown calcitic fine-grained siltstones, and olive grey marls and clayey siltstones, grey-red in colour, with intermittent and irregular narrow intercalations of coal (Figs. 1b and 2).

The upper part of the outcrop is composed of very fossiliferous light coloured limestones and thin strata of laminated calcitic marls, containing two coal beds of 60 and 50 cm in thickness. The limestones are recrystallised biomicrites. They are mostly composed of fine particles, of shattered and fragmented limestone shells of bivalves and gastropods containing a negligible proportion of quartz with the grain size of fine sand and silt.

3.7. Deposits of outcrop 7

This outcrop lies behind the beach, some twenty metres from the coast (Figs. 1a, 1b and 2). In the major part of the outcrop, and particularly in the lower part, there are fossiliferous limestones close to those of outcrop 6.

The limestones are pale yellow and white, with abundant bivalve shells and gastropods. In the upper part of the outcrop the limestones are thinner and gradually pass into grey laminated marls. The laminated coaly marls at the top of the outcrop merge into layers with coal. The coal is of amorphous appearance, black in colour, with thin intercalations of marl.

At the very top of the outcrop, the coal is directly overlain by light chalky biomicrites, which very probably continue into the youngest part of the profile, which remains uninvestigated.

4. PALAEONTOLOGICAL REVIEW

Foraminifera

Foraminifera are mainly planktonic species, seldom benthic. The shells are fairly damaged, broken, flattened, pyritized, or deformed. This suggests multiple resedimentation, and perhaps also fairly long transport. Taxa from several zones are mixed, which also suggests redeposition. The foraminiferal assemblage comprises: *Subbotina eocaena* GUEMBEL, *S. hagni* GOHRBANDT, *S. cryptomphaza* GLAESSNER, *Morozovella spinuloza* (CUSHMAN), *Acarinina bullbrooki* (BOLLI), *A. spinuloinflata* (BANDY), *Turborotalia frontosa* (SUBBOTINA), *T. pomeroli* (TOUMARKINE & BOLLI), *Globigerinatheca* sp. and is determined as Middle Eocene in age. They were probably washed out from Eocene flysch beds, and were redeposited in lacustrine deposits together with Miocene fossils.

Mollusca
Clivunellidae
***Delminiella* KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ, 1972**

The shell has preserved a much reduced part of the spiral at the tip, and the rest of the spiral is restricted to a very much expanded aperture. The lines of growth are prominent, divided by furrows, and pass into dense concentric ribs. It is differentiated from the genus *Clivunella* by the curved or spiral apex and the more remarked, denser and deeper sculpture. Because the part of the spiral has been preserved, this genus is more primitive than the genus *Clivunella.*

***Delminiella* cf. *soklici* KOCHANSKY-DEVIDÉ**
(Pl. I, Fig. 1)

1972 *Delminiella soklici* KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ, pl. III, figs. 3–7, pl. IV, fig. 9

Material: samples 01, 1, 3

The shell consists of 1–2 very small, spirally curved whorls, and the last half of an inflated coil expanded at the aperture.

Unfortunately the Pag specimens have no preserved spiral, but in the centre of the last whorl a convexity where the spiral starts can be seen. The apex that should be close to the upper edge is not preserved. The Pag specimens are mainly elliptical in shape, and in this they deviate from the type species. The spiral ribs that cover the last whorl in the Pag specimens are sparser and stronger.

The type specimens were found in Vučipolje and Mokronog in Duvanjsko polje, and in the area of Zenica, both in Bosnia and Hercegovina.

***Delminiella* cf. *excentrica* KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ**
(Pl. I, Fig. 2)

1972 *Delminiella excentrica* KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ, pl. IV, figs. 1–7, 10

Material: samples 01, 1, 2, 3

It has a small (approximately 1 cm), almost round shell with a flattened upper edge and an oblique, right-bent apex a little below the upper edge. The position of the apex in this species is far outside the centre of the flat shell, and in the type specimens the apex is bent slightly to the left. The specimen of this species from the Crnika site is the first occurrence in Croatia.

Type specimens were found in the Livanjsko, Duvansko and Roško polje in Bosnia and Hercegovina.

Planorbinae
***Gyraulus* sp. A**
(Pl. I, Figs. 5–6)

Material: Sample 1

A relatively large specimen of *Gyraulus* (8x6 mm), it is very deformed and damaged, but nevertheless the true shape can be discerned. On the upper edge the umbilicus is not seen, but there are probably several whorls judging from their width. The last whorl expands very much towards the aperture. Growth lines are visible, as well as the marked rib in the centre of the whorl. On the lower side the whorl seems completely involute, i.e., without an umbilicus.

***Gyraulus* sp. B,?n. sp.**
(Pl. I, Figs. 7–9)

Material: sample 28

Very tiny specimens, < 1.5mm in diameter. On the shell surface a uniform spiral rib is to be seen with a very marked single rib on the upper and one rib on the lower side (like the genus *Platyaphus*). The shell is partially involute, concave both on the upper and lower sides (Fig. 4).

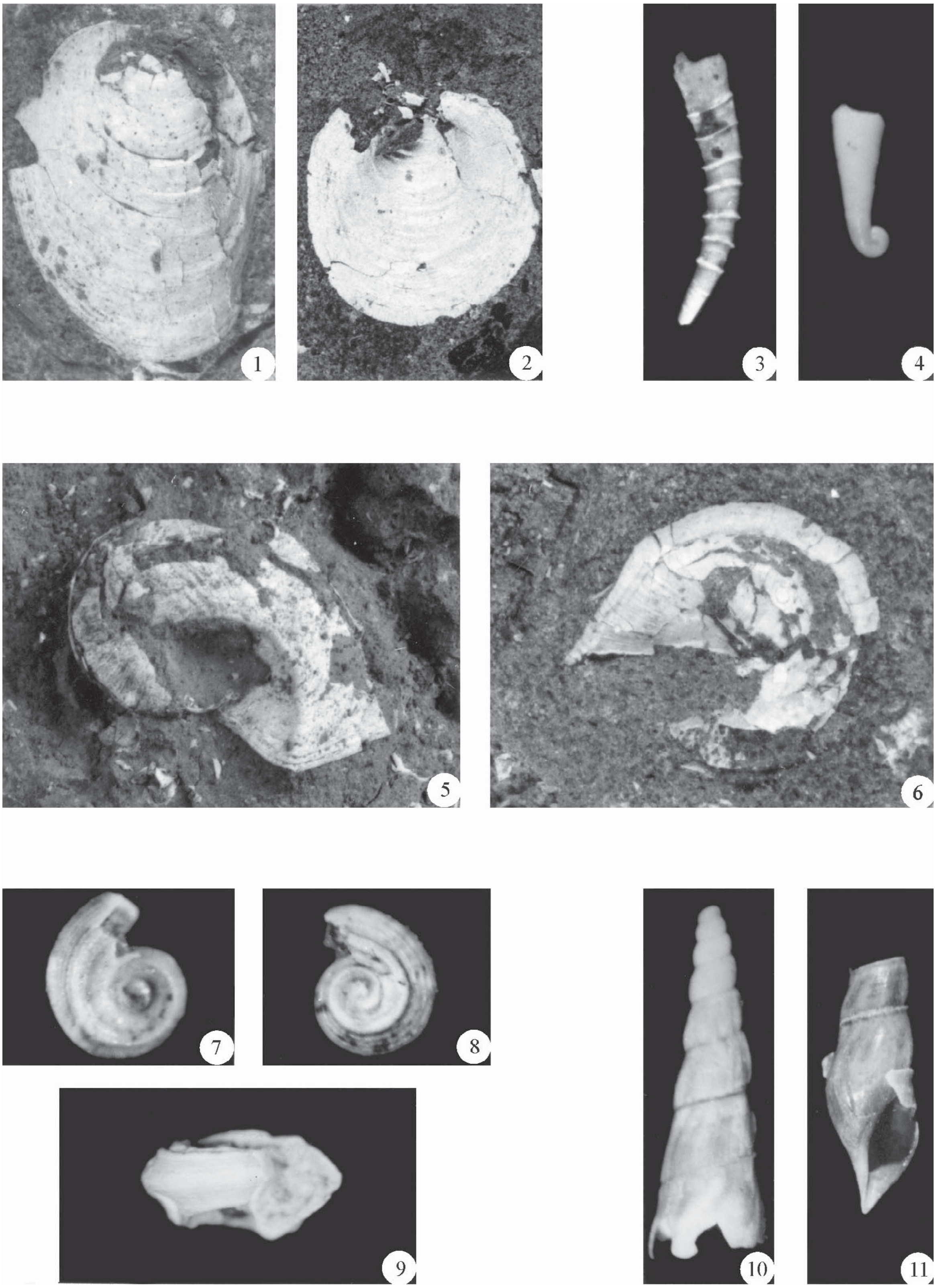

Plate I

1 *Delminiella* cf. *soklici* KOCHANSKY-DEVIDÉ. 4X. Sample 3.
2 *Delminiella* cf. *excentrica* KOCHANSKY-DEVIDÉ. 4X. Sample 1.
3 *Orygoceras* sp. 20X. Sample 11.
4 *Orygoceras sp*. 30X. Sample 14.
5–6 *Gyraulus* sp. A. Fig. 5 X4. Fig. 6 X7. Sample 1.
7–9 *Gyraulus* sp. B, Fig. 7–8 X25. Fig. 9 X20. Sample 28.
10–11 *Melanopsis* sp. A. 16X. Sample 9.

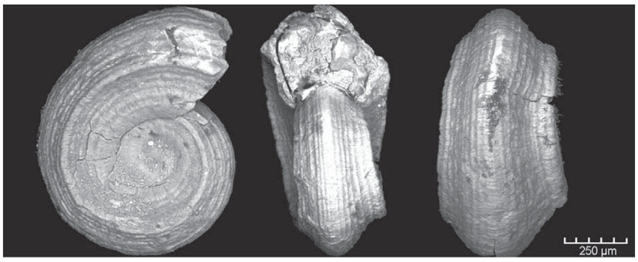

Figure 4: SEM BSE image of *Gyraulus* sp. B

This specimen is similar to the species *Gyraulus verticillus* BRUSINA in shape and to *Planorbis jukici* BRUSINA, both from the Markuševec locality, which has one spiral rib; but spiral ribs over the whole of the shell, as has the Pag gyraulus, are not present in a single one of the species mentioned. Identical forms were discovered by the authors in the Miocene deposits of Poljanska in Slavonia, North Croatian Basin (NCB).

Hydrobidae
***Prososthenia* sp.**
(Pl. II, Figs. 11–12)

Materials: samples 01, 1, 3, 8, 9, 10, 12, 14 and 22

A characteristic prososthenia with a thickened lip of the aperture, that expands to the outer side, 6–7 smooth rounded whorls, particularly in the juvenile phase, while at the sides of the last and penultimate they are straighter. These two whorls are also the highest, while the whorls of the third to the juvenile whorls grow more uniformly. They occur along the whole profile, and are very abundant at locations 8, 9 and 10.

Similar forms are found in Lohovo (Bihać basin; Bosnia and Hercegovina – BH), Strmen dolac, Košute, Brnaze and Peruča (Sinj basin, South Croatia).

?*Nematurella* sp.
(Pl. III, Figs 1–4)

Material: sample 28

Very small gastropods, about 2–3 mm high. Similar forms appear in great numbers in the Central European Molasse basins, in the Rzehakia or Oncophora deposits of the Ottnangian of Lower Bavaria (Germany), Ivančica in Moravia (Czech Republic) and so on (e.g. SCHLICKUM, 1964; ČTYROKÝ 1972). Our specimens recall the species *Nematurella klemmi* SCHLICKUM.

?*Pyrgula* sp. A
(Pl. II, Figs. 5–6)

Material: sample 2

On narrow shells (maximum height is 8 mm not including the last whorl, and the greatest width is 2 mm), consisting of about ten whorls. Decorated with a single rib immediately below the suture. No umbilicus. Narrow aperture, slightly thickened, and turned downwards.

In the form of the shell this pyrgula is similar to the genus *Micromelania*.

***Pyrgula* sp. B**
(Pl. II, Figs. 7–10)

Material: samples 2 (many pyrgulas with 2 strong ribs), 3 (fewer, but also with two strong ribs), 14 (pyrgula with a single wing-shaped rib – like a pagoda), 15 (pyrgula with one but not winged rib), samples 16, 17 and 19 contain little pyrgulas with 2 ribs.

Pag pyrgulas have strong shells, consisting of seven whorls. They have a thickened aperture. The surface of the shell is decorated with a single or two spiral ribs.

Comparing Pag pyrgula specimens with specimens of the species *Pyrgula carinata* from the Pontian Trilophos formation in Greece (RUST, 1997) it can be said that there is evidence of polymorphism, but there are not enough specimens for the development to be tracked. Still, evolution does not progress from smooth specimens here, but starts with shells with two strong ribs on the last two whorls, then,without any noted transitional forms, an elongated form of pyrgula with a single wing-shaped rib on each whorl (recall the shape of the pagoda) is observed. At later locations there are again pyrgulas with two ribs, but these are rare, and are not such marked forms.

Bulimidae
***Bithynia* cf. *multicostata* TCHERNOV**
(Pl. III, Figs. 5–8)

1975 *Bithynia multicostata* TCHERNOV, pl. II, fig. 3

Material: sample 28

A conical shell consists of five slightly rounded whorls. The last two whorls are covered with undulating radial ribs, with 15–16 of them on the last whorl. The aperture is rounded, with a slightly thickened edge. No umbilicus can be observed.

This species was defined in the Upper Pliocene deposits of the central Jordan valley in Israel.

In pre-Badenian deposits of Poljanska by Požega (NCB), identical specimens were found (by authors) overlying deposits with leaves.

Similarities and differences: Our specimens are very similar to ribbed bithynias from the Upper Pliocene deposits of the central Jordan valley in Israel. The Pag specimens also show a similarity with the recent species *Baikalia* (*Dybovskiola*) *ciliata* (DYBOWSKI) (see WENZ 1938–1944, p. 598). In form and sculpture they are practically identical specimens but the Baikal specimens have ciliae and they live at a depth of about 300–350 m, while the specimens from Crnika derive from a shallow water environment and could not have had ciliae.

Valvatidae
***Valvata* (?*Costovalvata*) *pagana*, n. sp.**
(Pl. III, Figs. 9–10)

POLINSKI (1931/32) described the subgenus *Costovalvata* from Lake Ohrid on the basis of a finding of the first species of this subgenus *Valvata (Costovalvata) hirsutecostata.* Cognate species live in Lake Baikal. Polinski points out that there are no fossil forms with such characteristics.

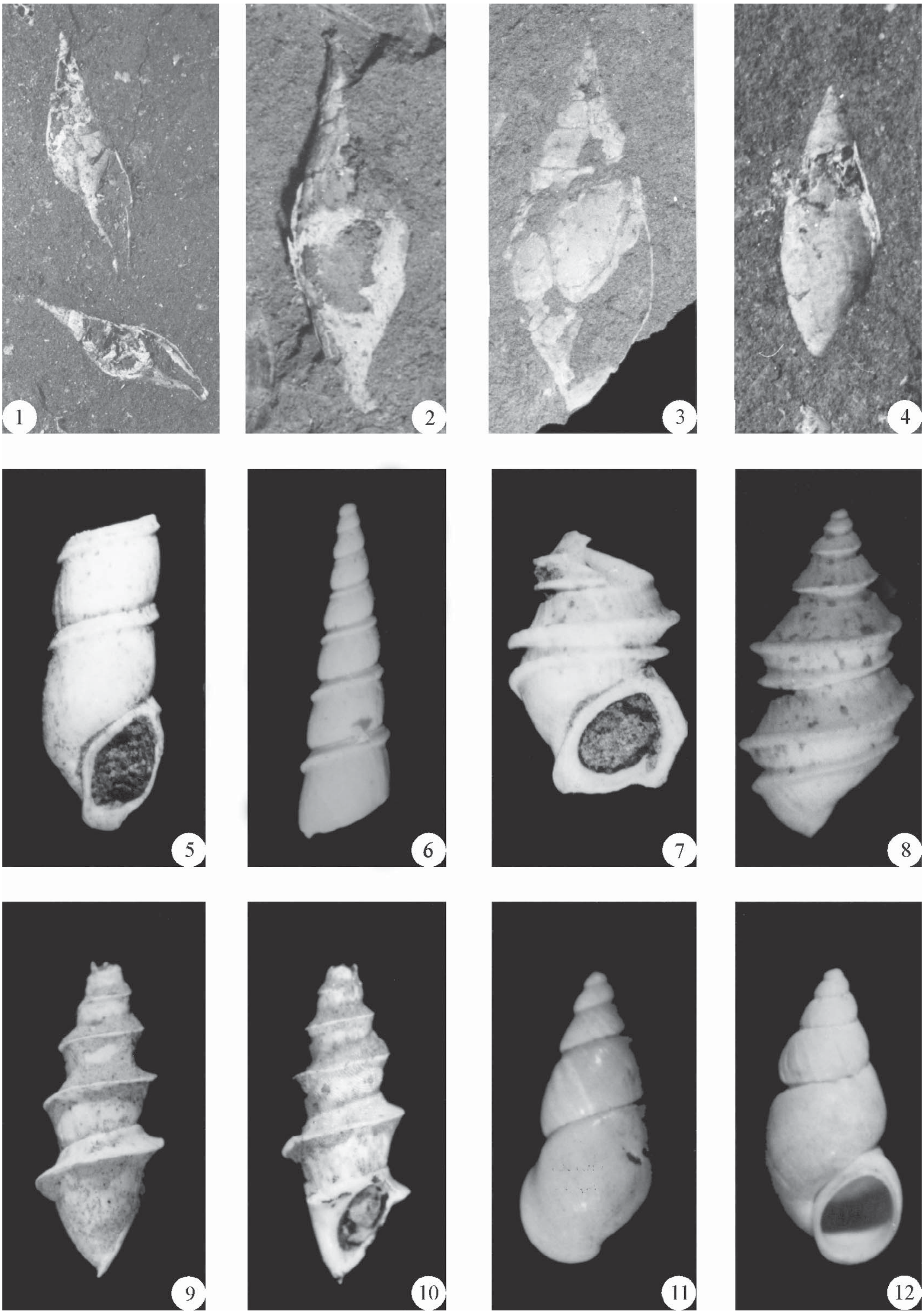

Plate II

1–4 *Melanopsis* sp. B. 2.5X Fig. 1, 5X Fig. 2–4. Sample 22.
5–6 *Pyrgula* sp. A. 9X. Sample 2.
7–8 *Pyrgula* sp. B. 9X. Sample 2.
9–10 *Pyrgula* sp. B. 9X. Sample 14.
11–12 *Prososthenia* sp. 12X. Sample 8.

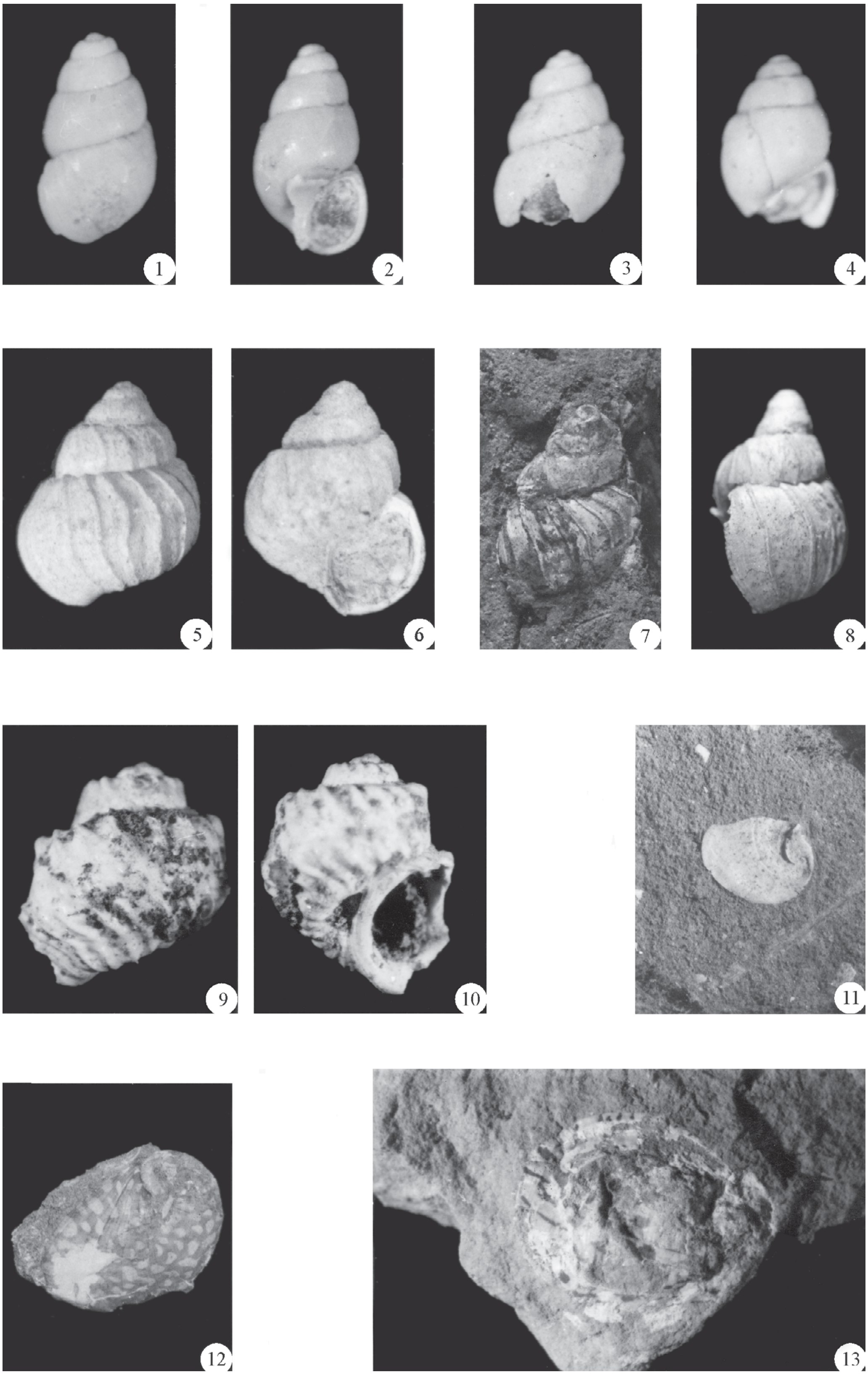

Plate III

1–4 ?*Nematurella* sp. 20 X. Sample 28.

5–8 *Bithynia* cf. *multicostata* TCHERNOV. 6 X. Sample 28.

9–10 *Valvata* (?*Costovalvata*) *pagana*, n. sp. 9 X. Sample 2.

11 *Theodoxus* sp., operculum. 4 X. Sample 22.

12 *Theodoxus* sp. A. 4 X. Sample 3.

13 *Theodoxus* sp. B. 2X. Sample 30.

WENZ (1938–1944, p. 505) described the subgenus in this way: Whorls with weak spiral lines and sharp radial ribs. Last whorl much enlarged, inflated downwards, broad umbilicus. Aperture is large, high rather than broad. Recent, Lake Ohrid, 1 species.

SCHŰTT (1962) described another species of the genus *Valvata* (*Costovalvata) klemmi*, deriving from Aetolia in Greece, (lakes Trigonis and Lysimachia). The strong shell consists of four and a half whorls. The whorl is raised with a blunt apex. The whorls are angular. Juvenile whorls are smooth, and then a combination of spiral and radial sculpture is developed. Radial sculpture consists of 20 or so slightly oblique rough ribs, additionally thickened with nodules. The aperture is large, circular, and polygonal. The edge of the aperture is sharp. Umbilicus is narrow and deep. Recent species.

The new species is named after the island of Pag, where it was found on the Crnika beach. This is the first fossil species of the genus *Costovalvata.*

The holotype (sample 2) is specimen inv. no. 10806 Department of Geology and Palaeontology of Croatian Natural History Museum, Zagreb.

48 specimens were found, for the most part only poorly preserved.

Material: samples 01, 2, 3, 5

Location: Crnika, island of Pag

Age: Lower Miocene

Diagnosis: Surface of the shell covered with 20 or so bent radial ribs, reinforced with nodules on the places where three rows of spiral ribs pass.

Description: the shell has four whorls, lying markedly gradually next to each other (shouldering). The dual sculpture is interesting: three pronounced spiral nodule sequences on spiral ribs, through which 20 or so rough radial ribs pass. The umbilicus is open, the aperture is thickened. It occurs in the oldest part of the profile, together with the clivunellas.

Dimensions: height 3 mm, width 4 mm.

Similarities and differences: This species is extremely similar to the recent species *Valvata* (*Costovalvata) klemmi* SCHŰTT from Greece in the form of the shell and the radial and spiral sculpture. But there are also differences. Here, the aperture is rounded and is not slightly polygonal, the aperture is thickened and not sharp. The upper spiral rib is immediately below the suture, and not distant from the suture. The whole sculpture is less regular than in *V. (C.) klemmi*.

***Orygoceras* sp.**
(Pl. I, Figs. 3–4)

Material: samples 1, 2, 3, 8, 9, 10, 11, 12, 13, 14, 16, 19, 22, 23 and 29

Specimens of this genus are found at practically all points of the profile. Ribbed and smooth forms often appear together, but only the smooth are more common.

Thiaridae
***Brotia (Tinnyea) escheri* (BRONGNIART)**

Material: samples 01, 3, 8

Several fragments found, with characteristic sculpture.

Melanopsis* sp. *A
(Pl. I, Figs. 10–11)

Material: sample 9

Only shell fragments are preserved, there are no complete specimens. Juvenile whorls start to curve in a single plane. The initial whorls are very rounded. The fourth whorl changes, the sides of the whorl becoming almost flat, lateral ribs appearing, and pigmentation is visible. The shell would seem to have some ten whorls. No whole specimen, but this little melanopsis might perhaps be about 1 cm long.

Melanopsis* sp. *B
(Pl. II, Figs. 1–4)

Material: sample 22

Very sharped-pointed melanopsid with elongated sipho. No specimen has been extracted from marl, so it could be said that the specimens are poorly preserved. Some 7 whorls were observed.

Neritidae
Theodoxus* sp. *A
(Pl. III, Fig. 12)

Material: samples 01, 2, 3, 5, 6, 8, 9 and 10

The typical pattern composed of irregular white spots on the dark surface of the shell is visible. But the pattern varies to spiral dark stripes filled with white reticular spots on the light surface of the shell, and some of the shells have light surfaces with no markings.

***Theodoxus* sp. B**
(Pl. III, Fig. 13)

Material: sample 30

The specimens are at least twice as big as the specimens at the beginning of the profile. They cannot be removed from the rock, but it would seem that the last whorl is very much enlarged, and the pattern consists of irregular triangular thin dark spots on the light surface of the shell.

Dreissenidae

NUTTALL (1990) introduced a new division of congerias on the basis of their mode of life, and stated that the genus *Congeria* is of Pontian age, and the previously Miocene congerias older than Pontian would be classified into the genus *Mytilopsis.* Because of the century-old tradition, we have retained the old name of the genus *Congeria* also for the older Miocene species. KÓKAY (2006) also uses the genus name *Congeria* for the Ottnangian species.

Congeria neumayri ANDRUSOV
(Pl. IV, Figs. 1, 4, 7)

1978 *Congeria neumayri*, KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ, p. 36, plate I, figs. 21–25

Material: sample 01, 1 and 3

Flat triangular shell of medium size (height about 1.5–2.5 cm). On some specimens brownish stripes can be seen along the growth lines. This species is found in the lower part of the profile.

According to KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ (1978) the species *C. neumayri* occurs in the Ottnangian of Gornja Planina in Medvednica, and in the Novo Brdo bore by Voloder (NCB).

Congeria pilari KOCHANSKY-DEVIDÉ
(Pl. IV, Figs. 5, 8)

1978 *Congeria pilari*, KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ, p. 44, pl. III, figs. 31–33; pl. IV, figs. 1–12

Material: samples 15, 16

A medium large congeria (height about 3 cm), with a protuberant and sharp edge, bent in the form of an S, anterior side steep and high. This species is common in the central part of the Crnika profile.

According to KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ (1978) this species occurs in the Karpatian of Glinsko Pokuplje (Kirin, Dugoselo, Lovča; NCB) and in northern Bosnia region.

Congeria antecroatica KATZER
(Pl. IV, Figs. 6, 9)

1978 *Congeria antecroatica*, KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ, p. 48, pl. IV, fig. 34; pl. V, figs. 16–21; pl. VI, figs. 1–18; pl. VII, figs. 1–13

Material: samples 21, 22, 26, 29, 30

A large congeria (up to 5 cm high), sharp-edged, with a posterior side drawn out wing-shaped. Very common in the most recent deposits of the profile.

According to KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ (1978) the typical deposits are lacustrine Karpatian and Badenian, and in addition to those at Drvar (the type location), there are occurrences at Duvno, Glamoč, Mostar and Rotimlja in Bosnia and Herzegowina, and also from Kolan on island of Pag.

Unionidae
Unio sp.
(Pl. V, Figs. 2, 3)

Material: samples 21, 29

Only the cores of fairly large shells are preserved (width about 6 cm, height about 3.5 cm). A hinge with strong teeth is visible. These are present mainly in the younger parts of the profile, together with the species *Anodonta splendens*, *Pisidium* sp. and *Congeria antecroatica*.

Anodonta splendens GOLDFUSS
(Pl. V, Fig. 1)

1972 *Anodonta splendens*, ČTYROKÝ, p. 126, pl. XXI, fig. 4

Material: sample 21

The genus *Anodonta* is kin to the genus *Unio*, but the shells are larger and thinner, and there are no teeth on the hinge. The shells are about 8 cm long.

This species was also found by authors at Jelenska near Kutina in northern Croatia. ČTYROKÝ (1972) states that there is well known occurrence of this species at the village of Ivančica in Moravia (Czech Republic).

Sphaeridae
Pisidium sp.
(Pl. V, Figs. 4, 5)

Material: samples 1, 3, 11, 13, 14, 15, 17, 19, 21, 22

Shells are rounded shape (up to 1 cm broad and about 0.7 cm high). This species was observed along the whole profile, but it is found most often in sample 21, i.e., at the younger part of the profile, and these specimens are bigger than elsewhere.

Vertebrata
Fam. _Cyprinidae_
(Pl. VI, Figs. 12–14)

Material: samples 1, 2, 3, 8, 11, 22, 28

Some dozen teeth of this group of fish have been found. Most specimens were found at sample 3. Otoliths were found at points 3 and 22.

This is a fresh to brackish water group of fish. Some species can be as long as 2.5 m, but many species are smaller than 5 cm, as was probably the case here, judging from the size of the little teeth discovered.

Fam. _Crocodylidae_

Material: sample 3

Only one tooth was found, probably belonging to a not very large specimen of crocodile. The length is 12 mm, the width 4 mm. It is conical, with a mildly curved shape, and has a rib on each side along the whole length of the tooth.

Crocodiles are semi-aquatic animals, live in the fresh water of rivers and lakes, but they can also be found in the brackish waters of shallow lagoons. They are limited to the warm and wet climate of the subtropical or tropical zones.

Flora
Potamogetonaceae
Limnocarpus sp.
(Pl. VI, Figs. 9–11)

1978 *Limnocarpus longepetiolatus,* BŮŽEK & HOLÝ, p. 164, pls. I–III

Material: sample 6

Recent genus *Ruppia* (there are also three species from the Miocene deposits) is a halophilous genus, connected to the

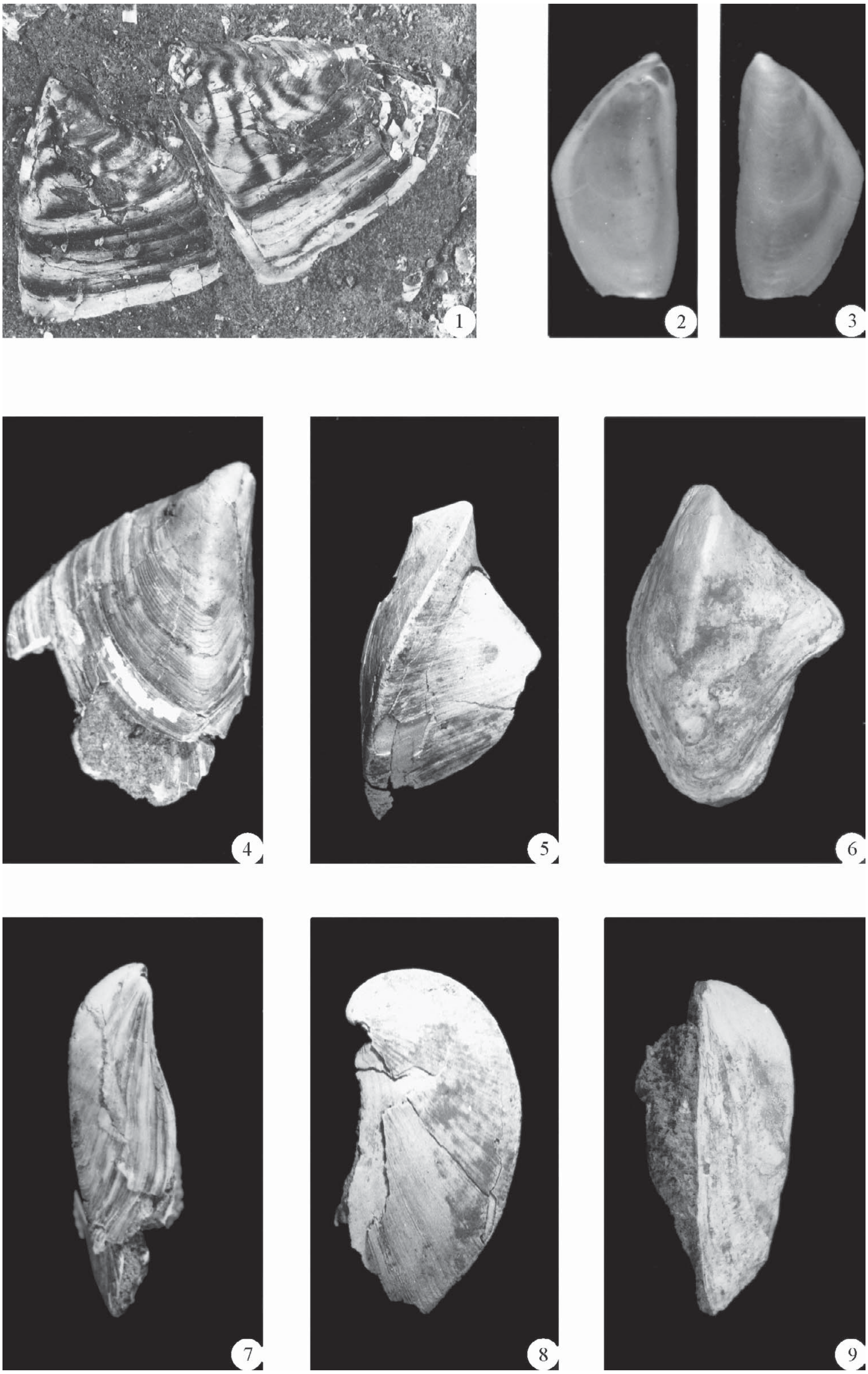

Plate IV

1 *Congeria neumayri* ANDRUSOV. 3X. Sample 3.
2, 3 *Congeria* sp. juv. 20X. Sample 8.
4, 7 *Congeria neumayri* ANDRUSOV. 5X. Sample 3.
5, 8 *Congeria pilari* KOCHANSKY-DEVIDÉ. 2X. Sample 15.
6, 9 *Congeria antecroatica* KATZER. 2X. Sample 21.

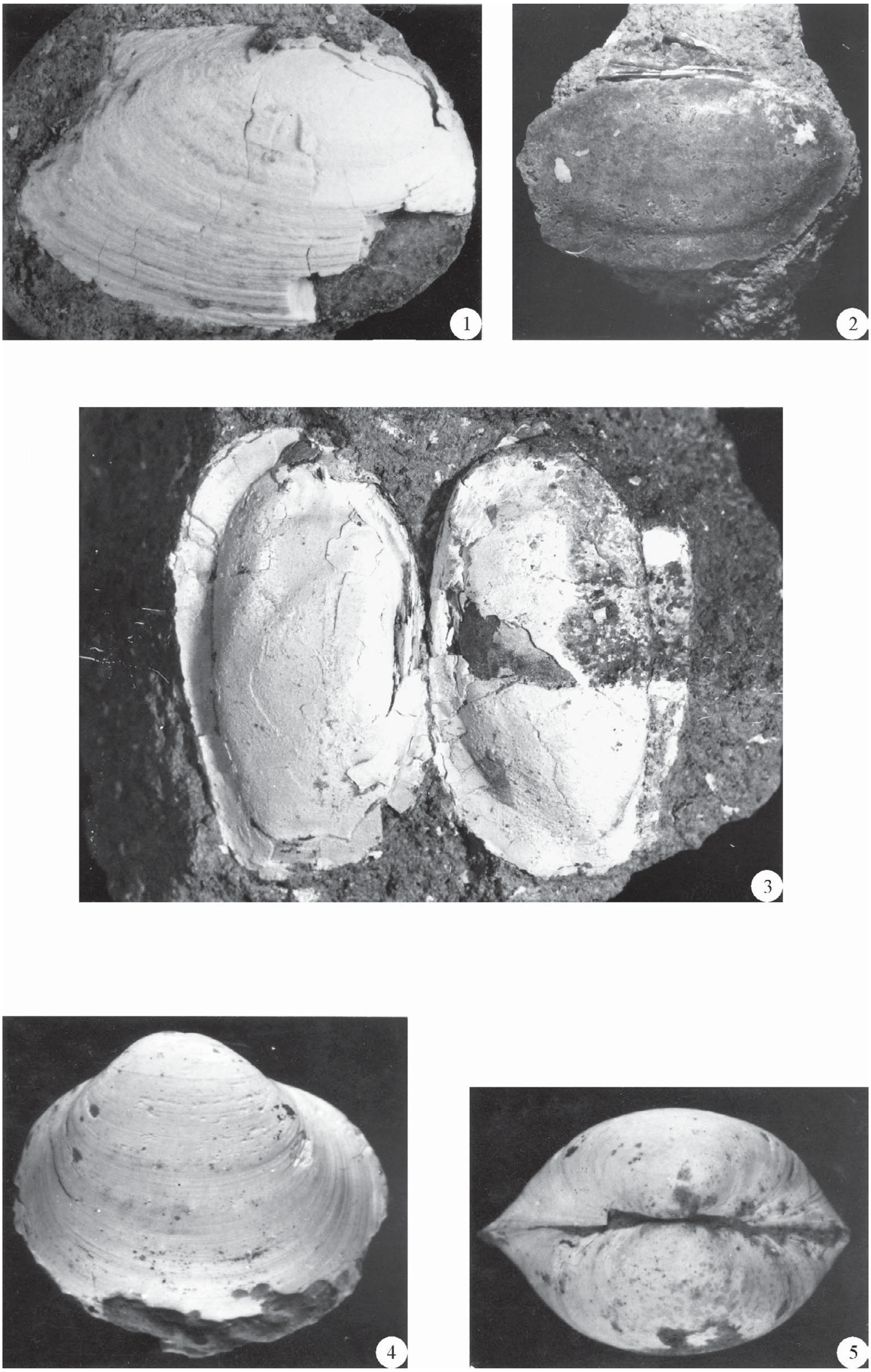

Plate V

1 *Anodonta splendens* GOLDFUSS. 1.5X. Sample 21.
2 *Unio* sp. 0.5X. Sample 21.
3 *Unio* sp. 1X. Sample 21.
4, 5 *Pisidium* sp. 7X. Sample 19.

sea coasts and slightly salty lakes. This is a species-poor underwater community that lives at a depth of 1 m. Today this grass is grazed by wild ducks, and in one 5000 seeds were found, and so it is called 'widgeongrass', or duck grass.

It is similar with fossil representatives kin to ruppia like the extinct genus *Limnocarpus* (Eocene to the upper Miocene between the Atlantic and Lake Baikal), which in addition to marine deposits is also found in fresh water, and thus makes up an ecological and taxonomic link with the limnetic genus *Potamogeton.*

Limnocarpus lived in brackish lagoons and stagnant water, but always close to the sea. Our specimens are reminiscent of *Limnocarpus* cf. *longepetiolatus* (ENGELHARDT) which occurs from the upper Ottnangian to the Karpatian of the Cheb and Sokolov basin in the Czech Republic (according to BŮŽEK & HOLÝ, 1981). This is the first discovery of *Ruppiaceae* seeds in Croatia. UNGER (1841–1847) described blades of the grass in the Sarmatian deposits of Radoboj, but seeds were not found there.

Capriofoliaceae

?Sambucus pulchela C. & E.M. REID

(Pl. VI, Figs. 3, 4)

Material: sample 18

1986 *Sambucus pulchela*, KNOBLOCH, p. 32, pl. I, fig. 2

KNOBLOCH (1986) mentioned an occurrence of this seed in the Lower Miocene of Moravia (Czech Republic), Slovakia and Austria, always connected with a swampy environment, or alongside deposits of brown coal. Our seed is a little narrower in form than that from Moravia.

?Hydrocharitaceae

?Stratiotes sp.

(Pl. VI, Figs. 1, 2)

Material: sample 19

Taxodiaceae

At the Crnika profile, fossilised twigs of these stemmed plants are close to coal deposits. At points 8 to 10 there were semi-carbonised stems at the primary site, and since these deposits were discovered alongside the present coastline, sometimes larger pieces of carbonised stems are discovered in the sea.

Species of *Taxodiaceae* are widespread in the Tertiary of Europe, and N. America too. They grew in coastal, wetland forests, particularly on the shores of stagnant waters. Sediments of brown coal from this period were derived mainly from stems of *Taxodiaceae*. This in particular relates to the genus *Sequoia* and the species *Glyptostrobus europaea* (BRONGNIART) UNGER, similar to the cypress. For example, in sands on the main Tertiary coal stratum of the Rhine coal basin in Germany many fossil twigs and cones were observed, of these two genera, among others (KILPPER, 1968). In the Upper Oligocene deposits of the northern edge of Saxony Lausitz remains of *Taxodiaceae* have also been found (MAI, 1997). Remains of leaves, fruits and seeds of *Taxodiaceae* have also been discovered in Upper Austria by Nieder Rudling, close to Eferding (KOVAR-EDER & BERGER, 1987). In Bosnian Miocene fresh water basins, it is common to find twigs and leaves of these genera (ENGELHARDT, 1901).

Glyptostrobus europaea (BRONGNIART) UNGER

(Pl. VI, Figs. 5, 7, 8)

Material: samples 3, 5, 8, 11, 20, 25, 30

1997 *Glyptostrobus europaea*, MAI, p. 15

Age: Oligocene to Pliocene in the whole of Europe.

Sequoia sp.

(Pl. VI, Fig. 6)

Material: sample 8

1968 *Sequoia langsdorfi*, KILPPER, p. 104, pl. 33, figs. 24, 31

1997 *Sequoia abietina*, MAI, p. 16

Palynology

According to Dr Koraljka Bakrač (personal comment), the most frequent occurrence in sporomorphs is the pollen of trees from mixed subtropical forests (*Quercus*, *Momipites*, *Engelhartioidites*), the pollen of coastal trees (*Carya*), bushes (*Ephedripites*, *Myrica*) evergreen trees (*Pinus*), swamp forests (*Taxodium*) and ferns (*Polypodium*).

The sporomorph composition is similar to that of the Lower Miocene deposits of Medvednica (the locality of Planina).

5. DISCUSSION

1. Similar fauna in the Lower Miocene Paratethys deposits of N. Croatia and the Lower Miocene lacustrine deposits of the Dinaric palaeodepressions Dinaride Lake System (DLS), JIMÉNEZ-MORENO et al. (2009), together with comparable sedimentation of marly carbonate deposits, with intercalations of coal, and lenses of pyroclastic material, confirm the proposition (ANIĆ 1951–1953, PAVELIĆ 2002) that the Dinaric lakes were also part of Paratethys. It is to this lake area that, in our opinion, the 'Pag Lake' also belongs. Although it is placed on the edge of the Mediterranean zone, the sea could not have had an essential influence on the sedimentation and living environment of Pag Lake, which is clear from the fossils observed. On the other hand, fresh water deposits with intercalations of coal layers and the flora and fauna from the Pag Lake show a great similarity with the freshwater Lower Miocene deposits of the NCB and of Bosnia and Herzegovina (ENGELHARDT, 1901).

Miocene lacustrine deposits and fossils have also been found in Krbavsko polje (JURIŠIĆ-POLŠAK et al., 1993); by Kosinj, where marls with freshwater fossils have been bored (FRITZ & PAVIČIĆ, 1975); by Žegar in open profiles of limestone marls, and in Bilišani in marly limestones where there are plant remains, congerians, unionids, and melanias (ŽAGAR-SAKAČ & SAKAČ, 1984). This, then, is not an isolated discovery; rather the Pag Miocene Lake is spatially connected with the hinterland. For this reason the border of

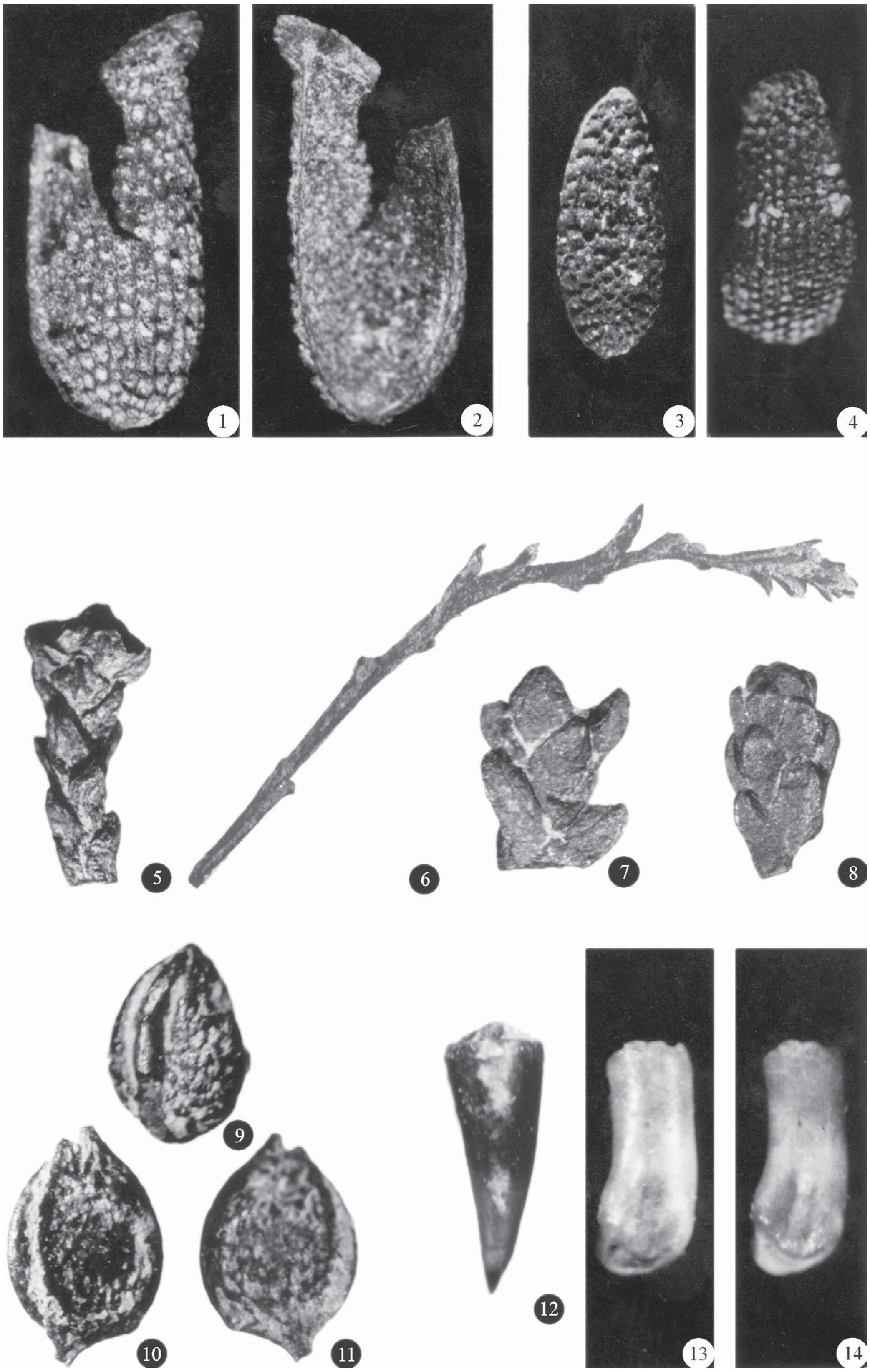

Plate VI

1, 2 *Stratiotes* sp. – seed, 15X. Sample 19.

3, 4 *Sambucus* cf. *pulchella* C. & E.M.REID seed, 16X. Sample 18.

5, 7, 8 *Glyptostrobus* sp. (Fig. 5. Sample 8, X10; Figs. 7, 8. Sample 11, X16)

6 *Sequoia* sp., 10X. Sample 8.

9, 10, 11 *Limnocarpus* cf. *longepetiolatus* (ENGELHARDT), seeds. 20X. Sample 6.

12, 13, 14 *Cyprinidae*. 30X (Fig. 12. Sample 28; Figs. 13, 14. Sample 2)

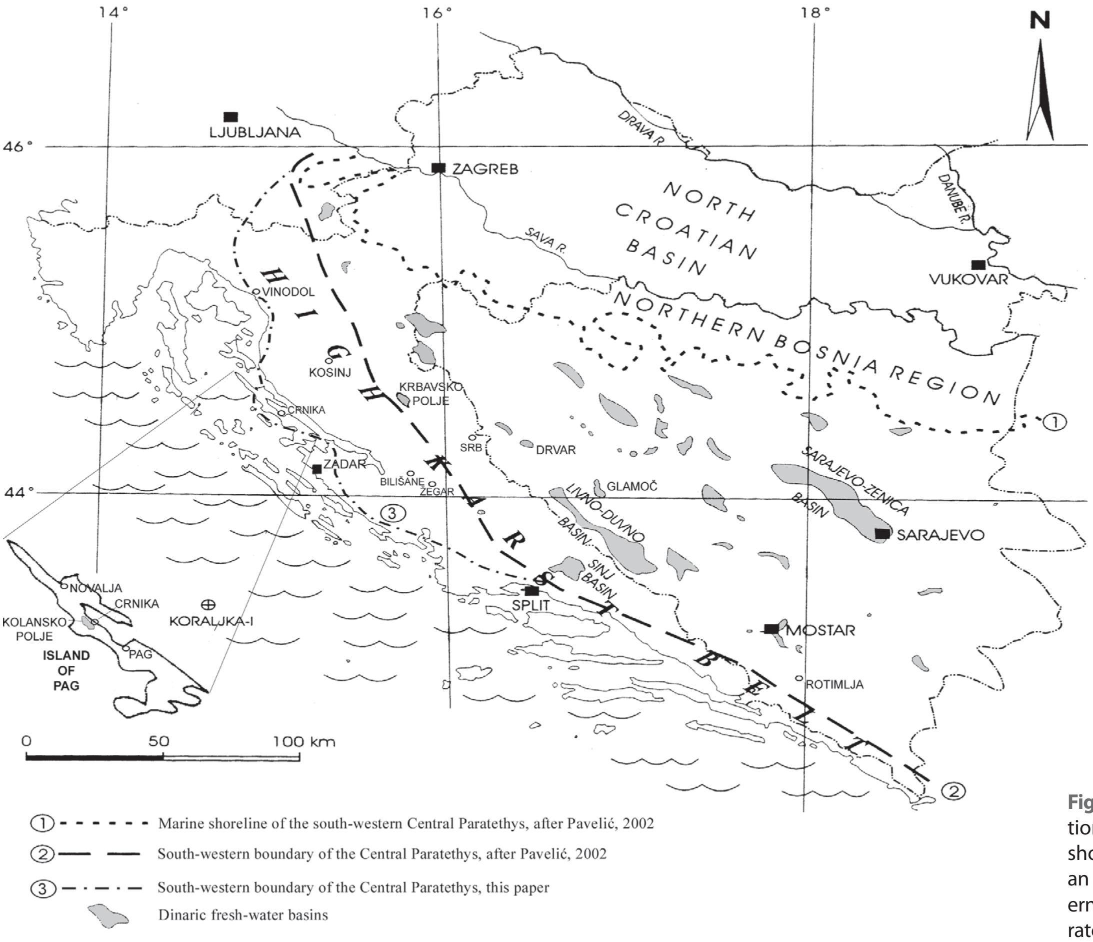

Figure 5: Approximate locations of the south-western shoreline of the Paratethyan Sea, and the south-western boundary of Central Paratethys.

Paratethys should be expected much further south-west than the line that ANIĆ (1951–53) and PAVELIĆ (2002) set in their studies (Fig. 5).

2. The migration of species from central Paratethys to the east has been known for some time, as has the population of Lake Baikal with many endemic species that derive from the Pannonian or Pontian, partially fresh, or entirely fresh water, of the inland Paratethys basin (HÖRNES, 1898, BRUSINA, 1874; 1887, DYBOWSKI, 1875). Similarly, some forms from the older Dinaric lakes are repeated in today's lakes as endemic or cognate species.

For example the species *Bithynia* cf. *costata* from Crnika, also discovered by the authors in Poljanska, has been determined in the Pliocene deposits of Israel, and it is cognate to recent endemic forms from Lake Baikal. The ribbed *Valvata*, here determined as subgenus *Costovalvata*, today lives in the Aetolia Lake in Greece (SCHŰTT, 1962) and Lake Ohrid in Macedonia (WENZ, 1938–1944).

Analogously, some endemic species from freshwater lakes migrated to brackish parts of the Pannonian basin during the Pannonian to Pliocene. The genera *Pyrgula*, *Fossarulus*, *Orygoceras*, *Prososthenia*, *Theodoxus* and so on that lived in the Miocene lakes were also alive later in the brackish Paratethys (BRUSINA, 1897, 1902). The species *Melanopsis defensa* from the Pontian deposits of Paratethys (Jagnjedovec, Podravina) has its own cognate in the younger lacustrine deposits of Livno and Duvno basins (JURIŠIĆ-POLŠAK & SLIŠKOVIĆ, 1988). However it is also necessary to take into consideration parallelism in the development of individual forms (KOCHANSKY-DÉVIDE, 1976).

3. Fresh water Miocene deposits of Sinjsko and Petrovo polje show a difference in floral and faunal composition than is the case in freshwater deposits along the Crnika beach on the island of Pag. In Sinjsko and Petrovo polje, together with some ten species of melanopsids and prososthenians, fossaruluses, congerians and unionids (BRUSINA, 1874, 1897, 1902; NEUMAYR, 1869) the fossilized fruits of swamp tree *Ceratostratiotes sinjanum* KERNER (BŮŽEK, 1982), so far not known from the Dinaric freshwater basins, have been found. But no clivunellas, no *Valvata pagana*, no common species of congerians, unionids, melanopsids from Pag have been found there, nor the remains of the big stemmed plants the taxodiaceans. We could speak here on difference in molluscs species sense, but not in generic sense. Still, the issue of the interrelation of these two basins remains unsolved for now.

4. Lacustrine development of the Lower Miocene is present in the whole of Croatia and also in western Bosnia and Herzegovina. Despite of previous/mentioned differences we are of opinion that the Dinaric Neogene lakes were probably occasionally linked with a watercourse network, which enabled the migration of plant and animal species from one lake to another. So we find examples of the mollusc *Congeria neumayri* from Crnika also in the N. Croatian locations

of Planina and Jelenska, the species *C. pilari* from Crnika also in Glinsko Pokuplje and in N. Bosnia, while *C. antecroatica* from Crnika was also found in N. Bosnia (Drvar) and in Duvanjsko and Mostarsko polje. Specimens of the genera *Bithynia* and *Gyraulus* identical to those of Pag were found by authors at Poljanska in Slavonia. While in northern Croatia this development was ended by marine transgression that happened everywhere during Badenian (ĆORIĆ et al., 2009), at the same time, in the Dinaric lakes, the freshwater regime went on until the lakes were filled and vanished, which largely depended on the sinking of the basins, in other words on tectonic movements. The last known lake was in Lika near the little town of Srb, where the fauna and flora has shown that the deposits are of Plio–Pleistocene age (JURIŠIĆ-POLŠAK et al., 1997).

5. The lacustrine development of the Lower Miocene is characterised by a specific facies of marly carbonate deposits with intercalations of coal and lenses of bentonite. As well as congerians of various species (*Congeria neumayri*, *C. pilari, C. antecroatica, C. socialis, C. zoisi, C. dalmatica, C. venusta, C. boeckhi*) there are also *Anodonta splendens*, *Unio* sp. and *Pisidium* sp., and the gastropod genera: *Brotia (Tinnyea) escheri*, plus several species of the genera *Melanopsis, Bithynia, Theodoxus, Pyrgula, Gyraulus, Valvata, Orygoceras*. There are frequent remains of flora and fish. As for vertebrates, along the Crnika profile, only a single crocodile tooth has been found. In Gornja Jelenska, the remains of the proboscideans *Prodeinotherium bavaricum* and *Gomphotherium angustidens*, as well as rhinocerotid *Brachypotherium brachypus* (RADOVČIĆ et al., 1998) have been found. At Lučane in Sinjsko polje (OLUJIĆ, 1999), where, together with evolutionary lineages of prososthenians and melanopsids, a new species *Conohyus olujici* has been determined (BERNOR et al., 2004), the proboscidean *Gomphotherium angustidens* and the rhinocerotid *Aceratherium incisivum* were also observed.

According to this vertebrate association, these deposits should correspond to the chronozones MN4 and MN5 (RÖGL & STEININGER, 1983). Using the radiometric method Ar/Ar the exact age of pyroclasts from the tuffs of the Sutina site at Lučane has been determined as 15.7 million years (Swisher – personal comment).

Because of the specific development we propose that these freshwater deposits shoud be called the *Illyric*. Illyric originated from Latin term Illyricum for the area on the Balkan peninsula, inhabited by Illyrians (group of tribes of the Indoeuropean origin) in the ancient time. The name derives from Greek mythology, after Illyrio, the son of Kadmo and Harmony.

6. In the Ottnangian of Central Europe (Slovakia, Upper Bavaria, Upper Austria) the Rzehakia or Oncophora brackish sediments were deposited (ČTYROKÝ, 1972). The following fossils are characteristic for these deposits: *Siliquia*, *Rzehakia*, *Limnopagetia*, *Ctyrokya*, several species of *Nematurella* while in the Croatian lacustrine Miocene deposits these fossils have not been found. Only the specimen Anodonta *splendens* and *Nematurella* sp. are common with the Crnika locality.

6. CONCLUSIONS

(1) Marls with strata of coal alongside Crnika beach and similar deposits with coal in Kolansko polje were created through deposition in a freshwater lake. For the most part these freshwater deposits are composed of muddy sludge; mainly of marls and coaly clays with intercalations of very fine-grained sandstones, organogenic limestones and frequent layers of coal.

In the lithological composition of the outcrops, no coarse grained clastites were observed, which might be ascribed to a lower intensity of erosion on the land areas with the gently expressed relief behind the lake, and the lower transportation power of the watercourses that drained this area.

It is assumed that these outcrops of Miocene deposits on Pag belonged to the same sedimentation area, i.e., a single freshwater lake, which in the Lower Miocene occupied the major part of today's Pag Bay, the Crnika beach and behind it, and a good part of Kolansko polje. The limestone ridge of Grubišinac, which today separates Crnika and Kolansko polje, was elevated later, probably as a result of post-Miocene tectonics.

(2) The representation of plant and animal communities in various parts of the Miocene sequence in Crnika area is not uniform, and shows that there were sudden changes of bioecological conditions during the sedimentation of these deposits.

Periods of typically lacustrine sedimentation in the area are marked by a very poor biological community, with few species, and few individuals; for example, the central part of the deposits on the profile.

Against this, in the oldest and youngest deposits of the profile, an explosive development of molluscs can be seen, particularly of gastropods and bivalves, and a lush development of plant communities, which can be ascribed to the shallowing of the lake in these periods, and the spread of marsh habitats (crocodiles, seeds of *Limnocarpus* grass and the stemmed vegetation *Taxodium* and *Sequoia*).

(3) At Crnika, examples of the *Clivunellidae* gastropods were observed for the first time in Croatia. They are otherwise known from a basement of coal in the Miocene lake deposits of Tušnica in the southern part of Livanjsko polje. After JIMÉNEZ-MORENO et al. (2009) Clivunellid gastropods appeared at the top of Ottnangian, before more than 17 Ma ago.

Three species of dreissenids have been determined, of which, *Congeria neumayri* occurs in the lowest part of the profile, C. *pilari* in the central part of the profile, and in the youngest deposits we find *C. antecroatica.* These congerias were found in several lacustrine deposits of North Croatia and Bosnia, as well as in Herzegovina. Disocvery of the species *Congeria pilari*, is particularly important, as this has previously been known from the freshwater deposits of Glinsko Pokuplje and North Bosnia, which lie below the Badenian marine deposits (KOCHANSKY-DÉVIDE & SLIŠKOVIĆ, 1978). Accordingly, the deposits in which these congerias are found are older than the Badenian. However, *Congeria neu-*

mayri suggests a possible Ottnangian age of the Crnika deposits, as well as for the Vukov dol on Medvednica Mt., where this species was previously found. But a Karpathian age for the Crnika locality is confirmed by the results of magnetostratigraphic investigations (JIMÉNEZ-MORENO et al., 2009).

Fish teeth and a crocodile tooth were also observed at Crnika, the latter being the first observation in Croatia.

(4) Although Pag Lake was settled at the edge of the Mediterranean zone, the sea did not have any essential effect on the sedimentation and living environment. Palaeontological data suggest the conclusion that Pag Lake belonged in a palaeogeographic sense to a unique Paratethys system of freshwater lakes that during the Lower Miocene covered large parts of the Pannonian basin and the neighbouring Dinaric area to the south.

(5) Freshwater lacustrine deposits of the Lower Miocene were developed over the whole of Croatia and in West Bosnia and Herzegovina. Because of their specific features, we propose that these deposits be called the Illyric.

In northern part of Croatia such lacustrine sedimentation lasted until the Lower Badenian when it was ended by a marine transgression (ĆORIĆ et al., 2009).

In the Dinaric lakes, such a fresh water regime existed for much longer, in some areas until the Pleistocene (JURIŠIĆ-POLŠAK et al., 1997.).

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