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Freshwater Miocene of Krbavsko Polje in Lika (Croatia)

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Abstract

Ostracods and, for the first time, freshwater molluscs and microflora remains from Krbavsko polje have been investigated. The marls observed in this karst polje were deposited in a lacustrine environment. The lake was surrounded with swamps, flood plains lowland and hillside. The climate of this area was subtropical. The fossil fauna of the region is similar to the freshwater fauna of the Middle Miocene deposits from Dalmatia. On the basis of this study, and contrary to some previous studies the analysed sediments from Krbavsko polje are Miocene in age.

Sažetak

Iz lapora Krbavskog polja istraženi su ostrakodi, te po prvi puta, slatkovodni mekušci i mikroflora. Utvrđeno je da su naslage tog krškog polja taložene u jezeru okruženom močvarama, poplavnim ravnicama i brdima. Klima je bila prilično topla, suptropska. Fosilna fauna slična je slatkovodnoj fauni srednjomiocenskih naslaga Dalmacije. Pokazalo se da su, za razliku od prije uvriježenog mišljenja, naslage Krbavskog polja miocenske starosti.

1. INTRODUCTION

On the southeast side of Laudonov Gaj in the Krbavsko polje, in a two meters deep gully, ca. 30 m southwest of the benchmark 627 (Fig. 1), a few marl samples with visible macrofossils were collected for palaeontological analysis. Dissolution of the marls has revealed numerous faunal remains with ostracods being the most abundant and best preserved. The fossil gastropods have also been separated, as well as poorly preserved Dreissenidae and congerias, and abundant examples of well preserved gastropod opercula and Charophyta oogonia. The marl samples were treated by the normal palynological method of maceration. Three slides were made and analysed. Ostracods were determined by Valentina HAJEK-TADESSE, molluscs by Zlata JURIŠIĆ-POLŠAK and microflora remains by Krešimir KRIZMANIĆ.

2. PREVIOUS RESEARCH

Freshwater deposits from Krbavsko polje have been studied by ČUBRILOVIĆ (1940), who presumed that these were "congerian deposits and products of the younger Tertiary". This suggestion is corroborated by the following: "certain parts of these shells are similar to congerias, so the possibility that earlier Tertiary deposits are developed here could not be eliminated". The author himself did not find any fossil.

West of Krbavsko Polje, in the smaller Svračkovo Polje, IVANOVIĆ et al. (1967) found the limited outcrops of Neogene marls "which underneath Quaternary deposits come out to the surface". These marls lay transgressively on Late Palaeogene. The authors did not find any fossils during that occasion, so they shared ČUBRILOVIĆ's opinion about the age of the sediments.

MALEZ et al. (1975) investigated the Pleistocene sediments of Krbavsko polje.

SOKAČ (1975) determined the Pleistocene ostracod fauna from the area of Dinaric karst and from Krbavsko Polje.

SOKAČ et al. (1976) marked the sediments of Krbavsko and Svračkovo polje as Pliocene in age, based on a generically determined ostracod fauna. Some indeterminate small gastropods as well as many opercula and Charophyta oogonia were also mentioned. "Geophysical researches showed that the Quaternary and Pliocene sediments, in the central area of Krbavsko Polje, are 300 m thick, and there is no doubt that the deeper layers of the same region are Pliocene, maybe even Neogene in age" (SOKAČ et al., 1976).

3. LITHOLOGY

The calcareous marls are compact and exhibit conchoidal fracture. All are lightly colored, weathered on

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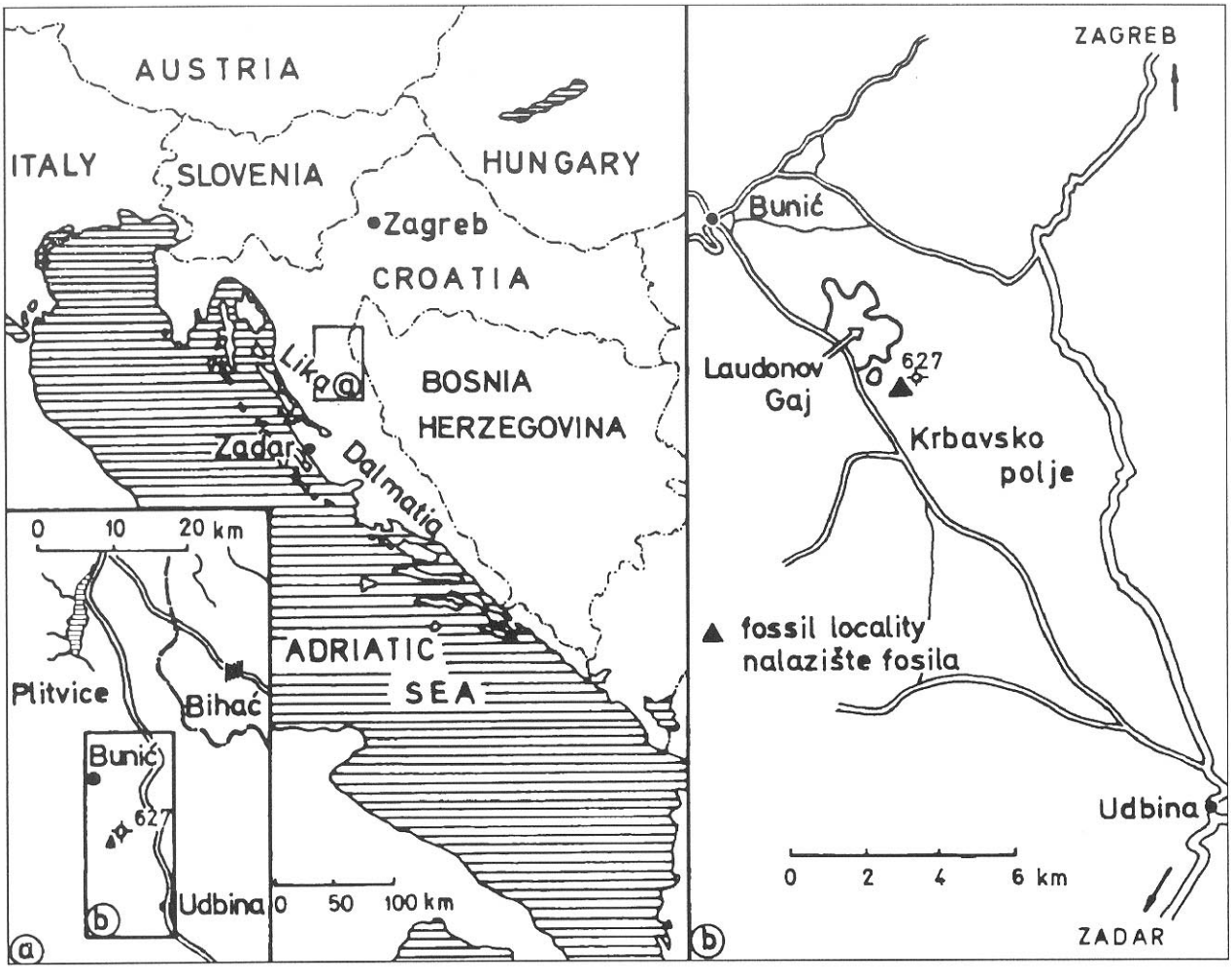

Fig. 1 Location map.
Sl. 1 Smještajna karta.

the surface, and bedding is poorly marked (SOKAČ et al., 1976).

4. BIOSTRATIGRAPHY AND PALAEOECOLOGY

The estimation of age and the palaeoecological environment of the sediments is based on data concerning the fossil association of ostracods, molluscs and microflora.

4.1. OSTRACODA

MALEZ et al. (1975), as well as SOKAČ (1975) listed in their papers the following ostracod species from Krbavsko Polje: *Cypridopsis vidua* (O.F. MULLER), *Potamocypris* sp., *Erpetocypris reptans* (BAIRD), *Candona albicans* BRADY, *C. improvisa* OSTERMAYER, *C.* ex. gr. *procera* STRAUB, *Candonopsis kingsleii* (BRADY & ROBERTSON), *Darwinula stevensoni* (BRADY & ROBERTSON), and *Paralimnocythere dalmatica* SOKAČ, which the authors dated as Pleistocene. MALEZ et al. (1975) presume that it is possible to find sediments even older than Pleistocene (i. e. Pliocene and older).

SOKAČ (1980) in her article on ostracods from Sinjsko Polje states that the species *Darwinula stevensoni* and *Potamocypris fulva,* as well as some of the species of *Paralimnocythere* and *Erpetocypris* occur in the Miocene assemblage, although they are extant. This occurence of *Darwinula stevensoni* and *Candonopsis kingsleii* is considered to be the first finding in sediments older than the Pleistocene. This is significant because this ostracod assemblage is similar to that of Krbavsko Polje.

The ostracod fossil fauna of Krbavsko Polje is relatively well preserved. The determined species are: *Cypridopsis biplanata* STRAUB (Pl. I, Figs. 10, 11), *Potamocypris fulva* (BRADY) (Pl. I, Figs. 7, 8), *Erpetocypris* sp. (Pl. I, Figs. 1, 6, 9, 12), *Candona praecox* STRAUB (Pl. I, Figs. 4, 5), *Candona luminosa* BODINA (Pl. I, Figs. 2, 3), *Candona* sp. (Pl. I, Figs. 13, 14), *Cypria* sp.

The species *Cypridopsis biplanata* STRAUB (Pl. I, Figs. 10, 11) is important as a stratigraphic marker, which indicates Miocene sediments exclusively in Europe (STRAUB, 1952; KLIE, 1938). In Croatia it was found in Miocene deposits of Sinjsko Polje (SOKAČ, 1980) and in freshwater Lower Miocene deposits of Medvednica (HAJEK-TADESSE, unpubl.).

Erpetocypris sp. (Pl. I, Figs. 1, 6, 9, 12) has dorsal and ventral ends almost parallel.

The occurence of the genus *Candona* is rare, but a few findings are significant: *Candona praecox* STRAUB (Pl. I, Figs. 4, 5) and *Candona luminosa* BODINA (Pl. I, Figs. 2, 3). The former was described from Miocene sediments of Germany (STRAUB, 1952), the latter from the Miocene of East Kazahstan (BODINA, 1961). Both were found in the Miocene of Sinjsko Polje (SOKAČ, 1980).

The ostracod assemblage from the site of Laudonov Gaj most resembles the Miocene ostracod assemblage of Sinjsko Polje (SOKAČ, 1980), so it is probably also Miocene in age. According to this fauna the environment was freshwater to oligohaline, rich in vegetation.

4.2. MOLLUSCA

The freshwater malacological fossil fauna from Krbavsko polje is poorly preserved. Five specimens of molluscs could be only generically determined: *Melanoides* sp., *Congeria* sp., *Dreissena* sp. A, *Dreissena* sp. B and *?Dreissenomya* sp. The only well preserved specimens are the opercula of the family Bithynidae (Pl. II, Fig. 11). Three of seven determined species are common with the Middle Miocene molluscs from Dalmatia: *Orygoceras dentaliforme* BRUSINA, *O. stenonema* BRUSINA and *Dreissena cymbula* BRUSINA. Another four species are similar to the Dalmatian molluscs: *Melanopsis* cf. *astrapaea* BRUSINA, *Pyrgula* cf. *dalmatina* BRUSINA, *Pseudoamnicola (Bania)* cf. *prototypica* (BRUSINA) and *Orygoceras* cf. *cornucopiae* BRUSINA. That is the reason why the fossil molluscs from Krbavsko polje are presumed to be Miocene in age.

Genus *Orygoceras* shows that the marl with fossils from Krbavsko polje could not be younger than the Late Pannonian, because this genus is not known from younger deposits in Europe.

On the other hand, the doubtful determination of the genus *Dreissenomya* perhaps shows the hypothesis that the mentioned deposits are not older than the Late Pannonian. Namely, this genus has not been found in the older deposits, till now. That is the reason why it is, at this moment, more correct to ascribe the marls with fossils from Krbavsko polje to Miocene.

4.2.1. Gastropoda

Prosobranchia. Mesogastropoda.
Familia: Hydrobiidae (after TAYLOR, 1974)
Genus: *Orygoceras* BRUSINA 1882

Orygoceras dentaliforme BRUSINA
Plate II, Figures 1-2

1882. *O. dentaliforme*, BRUSINA, p. 42, Pl. XI, Figs. 11-12.
1923-30. *O. dentaliforme*, WENZ, p. 2485-2486.

Material: 30 partially preserved specimens

Not a single specimen is preserved in its entire length; either the apex or aperture is lacking. The length of these specimens is about 3.5 mm. The shell is smooth, and near the aperture it sometimes has one ring-like lamella. Brusina's specimens are from Ribarić in the river Cetina valley and from the Župić stream near Sinj.

Orygoceras stenonema BRUSINA
Plate II, Figures 3-6

1882. *O. stenonemus*, BRUSINA, p. 43, Pl. XI, Figs. 4-8.
1923-30. *O. stenonema*, WENZ, p. 2490.

Material: 11 partially preserved specimens

On several specimens the entire shell is covered with sharp ring-like lamellae that are longer on the anterior side of the shell and shorter on the posterior side. The best-preserved specimen has 9 lamellae (Plate II, Figure 3). Brusina's specimens from Župić stream and Ribarić have 6-11 lamellae.

On some specimens from Krbavsko Polje (Plate II, Figures 5-6), after the third or fourth lamella there is a gap 2 to 3 lamellae wide, and afterwards they continue normally.

Without a single complete shell, it is impossible to state the total number of lamellae. Brusina's specimens come from Ribarić in the Cetina Valley and from the Župić stream near Sinj together with *O. dentaliforme*.

This species has also been identified from Kupreško Polje in Bosnia (JURIŠIĆ-POLŠAK & SLIŠKOVIĆ, 1988).

Orygoceras cf. *cornucopiae* BRUSINA
Plate II, Figures 7-8

1882. *O. cornucopiae*, BRUSINA, p. 45, Pl. XI, Figs. 1-3.
1923-30. *O. cornucopiae*, WENZ, p. 2485.
1938-44. *O. cornucopiae*, WENZ, p. 508, text figure p. 1330.

Material: 1 shell fragment

Only one fragment of a relatively large shell has been preserved. Nevertheless, it shows the typical characteristics of this species: dense, regular, ring-like lamellae that are separated by deep, incised interstices. In cross-section (Plate II, Figure 7) the shell appears to be approximately circular in shape. Brusina's holotype comes from Miočić in Petrovo Polje (Dalmatia). This species has also been identified in the fauna from Livanjsko and Duvanjsko Polje in Bosnia (JURIŠIĆ-POLŠAK & SLIŠKOVIĆ, 1988).

Familia: Truncatellidae
Genus: *Pyrgula* CHRISTOFORI & JAN 1832

Pyrgula cf. *dalmatina* BRUSINA
Plate II, Figures 12-14

1897. *P. dalmatina*, BRUSINA, p. 15, Pl. XI, Figs. 22-23.

1923-30. *P. dalmatina*, WENZ, p. 2099-2100.

Material: 4 partially preserved specimens

The first two juvenile whorls are smooth; on the third whorl appears the sculpture characteristic for the taxon: nodes on a strong spiral rib placed in the middle of the whorl. The sculpture is best expressed on the fourth and fifth whorl. On the last, seventh whorl, the nodes become lightly rounded. At this location the secondary spiral ridge also occurs.

Brusina's holotype comes from Miočić in Petrovo Polje (Dalmatia). In comparison with the holotype, the Krbavsko Polje specimens have more strongly expressed spiral ribs, while the nodes are less prominant than on the holotype.

Familia: Hydrobidae
Genus: *Pseudoamnicola* PAULUCCI 1878
Subgenus: *Bania* BRUSINA 1896

Pseudoamnicola (*Bania*) cf. *prototypica* BRUSINA
Plate II, Figures 9-10

1874. *Stalioa prototypica*, BRUSINA, p. 60, Pl. IV, Figs. 11-12.
1923-30. *Bania prototypica*, WENZ, p. 2093.
1938-44. *Pseudoamnicola* (*Bania*) *prototypica*, WENZ, p. 568, text fig. p. 1534.
1974. *Bania prototypica*, MILAN et al., p. 61, Pl. I, Figs. 4-5.

Material: 4 fragmentary preserved specimens

The shells are composed of 4-5 rounded whorls. The height of the shells is nearly 2 mm. The aperture is bordered by a ring-like thickening. Brusina's holotype is from Goručica near Sinj.

Familia: Thiaridae
Genus: *Melanopsis* FERUSSAC 1807

Melanopsis cf. *astrapaea* BRUSINA
Plate III, Figures 1-4

1897. *Melanopsis astrapaea*, BRUSINA, p. 9, Pl. IV, Figs. 1-2.
1909. *M.* (*Canthidomus*) *astrapaea*, COSSMANN, p. 178.
1929-1930. *Melanopsis astrapaea*, WENZ, p. 2664-2665.

Material: 23 fragmentary preserved specimens.

The shell is a low cone in shape and is formed of 7 whorls that are divided by shallow sutures. The last whorl is rounded and covered with yellowish zig-zag lines. The height of the last whorl is greater than half the height of the entire shell. The sculpture is composed of 12 to 20 axial ribs, each of which carries two nodes, which form two spiral rows of nodes. The upper row of nodes is located immediately below the suture. The upper row is followed by a depression, and then the next row of nodes, which is located above the mid-point of the last whorl. The inner lip is smooth, and in some specimens the columellar fold can be observed, although this feature may be strongly or weakly expressed. The dimensions of the best-preserved specimen are: height 8 mm, width 4.2 mm, height of the last whorl 6 mm.

The form and ornamentation of the Krbavsko Polje specimens is similar to the typical specimens of *M. astrapaea* from Dalmatia (Župića stream). On the other hand, the specimens from Dalmatia show no trace of a columellar fold and most of them are significantly larger. The feature of the columellar fold, which is otherwise significant for the genus *Melanoptychia*, likens this species to the Dalmatian species *Melanopsis cylindracea* BRUSINA from Ribarić (Middle Miocene), in which this feature sporadically appears. Having very sharp nodes on the ribs, the Krbava Polje specimens show a certain resemblance to the Dalmatian species *Melanopsis misera* BRUSINA from Lučane (Middle Miocene).

Genus: *Melanoides* OLIVIER 1804

?Melanoides sp.
Plate III, Figures 5-7

Material: 15 partially preserved specimens.

The longest shell fragment is 1 cm long. The first three juvenile whorls are smooth; the fourth whorl is covered with numerous axial ribs, while the remaining whorls have decreasingly fewer ribs. The ribs are particularly pronounced, with nodes on the last whorl. The aperture is not well preserved and that is the reason why the examples could not be generically determined with certainty.

4.2.2 Lamellibranchiata

Heterodonta
Familia: Dreissenidae
Genus: *Congeria* PARTSCH 1835

Congeria sp.
Plate IV, Figures 1, 4

Material: approx. 10 shell fragments.

Few apices are preserved, very narrow and sharpened. On some fragments a very sharp edge is visible, which points to the distinctive sharp angle between the dorsal and ventral area of shell.

Genus: *Dreissena* VAN BENEDEN 1835

Dreissena cymbula (BRUSINA)
Plate IV, Figures 2-3

1892. *Dreissensia cymbula*, BRUSINA, p. 199.
1897. *D. cymbula*, BRUSINA, p. 31, Pl. XVII, Figs. 16-18.
1964. *Congeria* (?) *cymbula*, ANDRUSOV, p. 144, Pl. III, Figs. 36, 39-40.

Material: 1 well preserved specimen and approx. 10

partially preserved specimens.

The best preserved specimen completely corresponds to Brusina's original specimen from Miočić in Petrovo Polje. Andrusov identified the species as *Congeria (?) cymbula*. Examining Brusina's specimens an apophysis has not been found, therefore the initial generic determination was correct (*Dreissensia* = *Dreissena*).

Dimensions: height 2 mm, length 1 mm.

Dreissena sp. A
Plate IV, Figures 7-8

Material: 1 partially preserved specimen

The incomplete right shell is about 2 mm high. Dorsal and ventral edges are approximately parallel. The growth lines are tightly curved towards the anal edge. Two muscle scars are visible on the septum.

Dreissena sp. B
Plate IV, Figures 9-10

Material: 1 partially preserved specimen

The fragment of the right shell is triangular in shape and it is about 2 mm high.

The growth lines are not as curved as those on the *Dreissena* sp. A specimen, and they gradually widen towards the shell edge. Muscle scars are not visible on the septum.

Genus: *Dreissenomya* FUCHS 1870

?Dreissenomya sp., juv.
Plate IV, Figures 5-6

Material: 1 partially preserved specimen

The left shell fragment has a streched circular shape and a hight of about 2 mm. The anterior edge is short and straight, and he forms a right angle with the ventral edge. The ventral edge is slightly convex and gradually continues into the anal edge, which is also probably convex in shape. On the interior surface it is visible that the muscle scar is separated from the rest of the shell. The specimen belongs probably to a juvenile individual. Similar specimens derive from the Early Maeotien of Rumania (MARINESCU, 1977, p. 79).

This would be the first finding of the genus *Dreissenomya* from freshwater Miocene sediments in the Dinarides.

4.3. MICROFLORA

The examined microflora is characterized by an abundance of the Angiosperm families. Most important are: Nymphaeaceae (*Nupharipollenites*), Myricaceae (*Myricipites, Momipites*), and Juglandaceae (*Caryapollenites*) as well as taxa of tricolpate and tricolporate pollen groups. The representatives of the Gymnospermae are less abundant, with the disaccate genus *Pinuspollenites* and bladderless genus *Taxodiaceaepollenites* prevailing. The most noticeable Pteridophyte genus is *Leiotriletes*.

According to PLANDEROVÁ (1990) and NAGY (1969, 1973), the palaeoecological and palaeoclimatological interpretation of the environmental conditions has been determined. The basis of this interpretation are identified fossil spores and pollen grains.

In the sample the subtropical pollen grains predominate with mediterranean floristic elements: *Engelhardtioidites microcoryphaeus* (Pl. V, Fig. 14), *Platycaryapollenites miocaenicus* (Pl. V, Fig. 9), *Magnoliae-pollenites simplex* (Pl. V, Fig. 2), *Myricipites rurensis* (Pl. V, Fig. 8), *Momipites punctatus* (Pl. V, Fig. 7), *Nyssapollenites* sp., *Taxodiaceaepollenites concedipites* (Pl. V, Fig. 3), *Sequoiapollenites* sp.

The occurrence of the spores *Leiotriletes* sp. suggests a subtropical palaeoclimate.

The identified vegetational elements of warm temperate conditions are: *Caryapollenites simplex* (Pl. V, Fig. 1), *Salixipollenites* sp., *Aceripollenites rotundus* (Pl.V, Fig.5), *Zelkovaepollenites thiergarti* (Pl. V, Fig. 15).

Only a few pollen grains of so called arctotertiary plants (PLANDEROVÁ, 1990) were found including, *Tsugaepollenites* sp., *Betulaepollenites betuloides, Ulmipollenites undulosus* and *Ericipites callidus* (Pl. V, Fig. 18). The above mentioned assemblage is usually present in the areas with a mild temperate climate, but phytocoenosis can also be indicative of higher relief.

The tanatocenosis of fossil spores and pollen grains consists of the taxa with different ecological values.

The water-plant assemblage of *Myriophyllumpollenites* sp. (Pl. V, Fig. 17) and *Nupharipollenites kedvesi* (Pl. V, Fig. 6) indicates a lacustrine, open freshwater environment (NAGY, 1969). The same conclusion is further proven by remnants of the alga *Botryococcus braunii*.

The bladderless coniferous pollen *Taxodiaceaepollenites* sp., *Taxodiaceaepollenites concedipites* (Pl. V, Fig. 3) and *Cupressacites bockwitzensis* (Pl. V, Fig. 4), as well as *Nyssapollenites* sp., *Myricipites intermedius* (Pl. V, Fig. 13), *Myricipites rurensis* (Pl. V, Fig. 8), and Bryophyta spores are characteristic of swamp-and-marsh forest environments.

The lakeshore forest assemblage (sporadically flooded plains) includes the following fossil pollen grains: *Caryapollenites simplex* (Pl. V, Fig. 1), *Pterocaryapollenites stellatus* (Pl. V, Fig. 16), *Platycaryapollenites miocaenicus* (Pl. V, Fig. 9), *Salixipollenites* sp., and spores *Leiotriletes* sp. and *Laevigatosporites* sp..

The mixed-deciduous-forest assemblage which covered the belt from the lakeshore forest to the piedmont zone (with a drier substratum) is represented by the sporomorphs *Ulmipollenites undulosus, Lycopodiumsporites* sp., *Zelkovaepollenites thiergarti* (Pl. V, Fig. 15), *Tsugaepollenites* sp., *Pinuspollenites* sp., *Sequoiapollenites* sp., *Quercopollenites* sp., *Ilexpollenites* sp., *Aceripollenites rotundus* (Pl. V, Fig. 5), *Engelhardtioidites microcoryphaeus* (Pl. V, Fig. 14) and *Ericipites callidus* (Pl. V, Fig. 18).

The possible existence of a higher mountain vegetation is indicated by *Abiespollenites* sp., *Pinuspollenites* sp., *Tsugaepollenites* sp.

Regarding the fact that the fossil spores and pollen are rather environmental parameters than stratigraphic indicators, the age of these strata could be determined in comparison with some stratigraphically well established floristic assemblages from other areas. The Neogene palaeoflora of Croatia, especially in the area of Krbavsko polje, is not completely and systematicaly studied as yet, so there is no valid model of the plant communities with precise palaeogeographic, palaeoecologic and stratigraphical information.

That is the reason why relevant papers from Hungary (NAGY, 1969, 1985), Slovakia (PLANDEROVÁ, 1990) and the northern part of Central Europe (KRUTZSCH, 1963-1971) were consulted as the main data source.

Thus, it seems appropriate, from the above analysed sample and determined floristic elements, that these strata could be attributed to the Miocene.

Furthermore, besides the knowledge about the temperature decrease in Europe from the Oligocene to the Pleistocene in general (GREGOR & VELITZELOS, 1987), and the knowledge of palaeotemperature and palaeofloral assemblages from various regions of European states (NAGY & PLANDEROVÁ, 1985; NAGY, 1969; PLANDEROVÁ, 1978, 1990; PLANDEROVÁ & PAPŠÍKOVÁ, 1989; PANTIĆ, 1960, 1989a, 1989b; ANIĆ, 1958; ZIEMBINSKA-TWORZYDLO, 1974; LEOPOLD, 1969) as well as the knowledge about these parameters from Croatian localities (ANIĆ, 1958; ERCEG, 1960; ŠPOLJARIĆ, 1952), we shoud be cautious in conclusion about the stratigraphy of Krbavsko polje. Also, this region might be explained as an isolated, restricted area, with a unique palaeomorphology, palaeoclimatology and palaeopedology.

Although the determined palynomorphs are known from the Eocene to the Pliocene, the general occurrence and maximum number of species appearing in the Paratethyan basins, e.g. *Zelkovaepollenites thiergarti* (Egerian-Sarmatian, Early to Middle Miocene), *Magnoliaepollenites simplex* (Egerian-Pannonian), *Plicatopollis plicatus* (Egerian-Pannonian), *Engelhardtioidites microcoryphaeus* (Egerian-Pannonian), *Platycaryapollenites miocaenicus* (Eocene-Miocene), *Momipitespunctatus* (Egerian-Pannonian) i *Myricipites rurensis* (Eocene-Late Miocene, Egerian-Pannonian), would also indicate that the analysed rock sample is Miocene in age.

The autochthonous fossil community of hydrophilous sporomorphs indicates the lake biotop surounded with swamps and flood plains. The xerophilous, allochthonous species from the entire drainage-basin area suggests the existence of the hills, and mountains with dryer soil. The climate was subtropical.

5. DISCUSSION

Most of the fossil malacological fauna (*Melanopsis*, *Pyrgula*, *Amnicola*, *Orygoceras*, *Dreissena*) shows a distinctive resemblance to the freshwater Middle Miocene fauna from Sinjsko and Petrovo Polje in Dalmatia, where, according to most authors (ANIĆ, 1951-1953; KÜHN, 1963; KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ, 1978), the sedimentation ends with the Sarmatian age.

Faunistical similarity may or may not mean also an absolute contemporanity with the fauna of the mentioned basins. In spite of this similarity, the fauna of Krbavsko Polje is somehow unique. The occurence of the genus ?*Dreissenomya* in Krbavsko Polje confirms this point of view because this genus has not yet been found in the freshwater fauna of Dalmatia. The first occurence of the genus *Dreissenomya* (MARINESCU, 1977) was described from the Late Pannonian deposits of the Paratethys, and up to now it has not been found in older sediments.

The genus *Orygoceras*, besides occuring in freshwater basins of Dalmatia, Krbavsko polje, as well as in Bosnia and Herzegovina, is common in Paratethys, but only in Pannonian sediments. It was found at several localities: Markuševec - Croatia (BRUSINA, 1892), Leobersdorf - Austria (PAPP, 1953), Tinnye - Hungary (LÖRENTHEY, 1902) and Soceni - Roumania (JEKELIUS, 1944). In younger sediments *Orygoceras* is not found anywhere in Europe. According to that, sediments of Krbavsko Polje can not be younger than Pannonian.

The ostracod fossil fauna also shows similarity to the Miocene ostracods from Dalmatia. The species *Cypridopsis biplanata*, *Candona preacox* and *Candona luminosa* are up to now found only in Miocene deposits in Europe (STRAUB, 1952; KLIE, 1938), Dalmatia (SOKAČ, 1980) and Medvednica (HAJEK-TADESSE, unpublished report).

Some authors (PLANDEROVÁ, 1990, 1978; THIELE-PFEIFFER, 1980; NAGY, 1969) have described subtropical vegetation with distinctive lake and swamp taxa from areas of Europe throughout the Miocene. But, only palynocenoses of Ottnangian, Badenian/Sarmatian boundary age and to a lesser degree Pannonian, correspond with any degree of similarity to the composition of fossil spores and pollen grains from Krbavsko Polje.

It could be assumed that the age of sediment is limited to the Miocene stages mentioned above.

6. CONCLUSION

Studying the ostracods, molluscs and microflora, the previous hypothesis of the existence of "also an older Neogene sediments" (SOKAČ et al., 1976) is confirmed for the first time.

Researching the abundant and rich microflora and fauna, the following conclusions are drawn:

- the studied sediment samples were deposited in lakes surrounded by swamps, flood plains and hill areas;
- the climate was subtropical;
- the fossil fauna of ostracods and molluscs from Krbavsko Polje is related to the freshwater Middle Miocene fauna from Dalmatia;
- the sediments belong to the Miocene (according to the correlative stratigraphic division by STEININGER, RÖGL & MÜLLER, from STEININGER et al., 1988).

It is obvious that it is necessary to carry out more detailed investigations of the fossil fauna and flora of Krbavsko Polje, to facilitate more precise dating of sediment, palaeogeographic reconstruction, interpretation of the relationships with surrounding Miocene basins, and determination of possible connections with Paratethys.

Acknowledgments

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Slatkovodni miocen Krbavskog polja u Lici (Hrvatska)

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Proučavanjem ostrakoda, te malakološkim i palinološkim istraživanjem po prvi puta je potvrđena već prije naznačena pretpostavka da postoje i neogenski sedimenti u Krbavskom polju (SOKAČ et al., 1976).

Makrofauna do sada nije bila podrobnije ispitivana. Iako bogata oblicima, veoma je slabo očuvana. Najveći dio malakološke faune (rodovi *Melanopsis*, *Pyrgula*, *Amnicola*, *Orygoceras*, *Dreissena*) pokazuju izrazitu sličnost s faunom slatkovodnoga srednjeg miocena Sinjskog i Petrova polja u Dalmaciji, gdje su prema većini autora (ANIĆ, 1951-1953, KÜHN, 1963, KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ, 1978 - sl. 1) sarmatske taložine završni član sedimentacije. Faunistička sličnost ukazuje na mogućnost postojanja određene povezanosti dalmatinskih bazena s krbavskim, ali ne mora značiti i apsolutnu istovremenost naslaga s faunom spomenutih bazena. Usprkos toj sličnosti fauna Krbavskog polja ima svojih posebnosti i ne može se poistovjetiti s dalmatinskom faunom. Tome u prilog govori i nalaz roda ?*Dreissenomya* u fauni Krbavskog polja, koji do sada nije nađen u dalmatinskoj fauni. S druge strane fragmentarni nalaz roda ?*Dreissenomya* također svjedoči o povezanosti s bazenom Paratethysa, gdje se taj rod prvi put pojavljuje u gornjem panonu (MARINESCU, 1977).

Rod *Orygoceras*, osim u slatkovodnim bazenima Dalmacije, Krbavskog polja, te Bosne i Hercegovine, čest je i u Paratethysu, ali samo u panonskom razdoblju. Nađen je kod Markuševca u Hrvatskoj (BRUSINA, 1892), kod Leobersdorfa u Austriji (PAPP, 1953), na nalazištu Tinnye u Mađarskoj (LÖRENTHEY, 1902), te Soceni u Rumunjskoj (JEKELIUS, 1944). Nakon panona origoceras nije poznat nigdje u Europi. Sudeći prema tome, naslage Krbavskog polja ne mogu biti mlađe od panona.

Dakle, fauna krbavskih naslaga bi prema sličnosti s dalmatinskom faunom mogla biti srednjomiocenske starosti, ali neki elementi, zajednički s faunom Paratethysa, upućuju na eventualnu gornjomiocensku starost.

Ostrakodna fauna također pokazuje sličnost s faunom ostrakoda iz dalmatinskog slatkovodnog miocena. Vrste *Cypridopsis biplanata, Candona praecox* i *Candona luminosa* iz Krbavskog polja dosad su nađene isključivo u miocenskim naslagama diljem Europe (STRAUB, 1952; KLIE, 1938), te kasnije Dalmacije (SOKAČ, 1980) i Medvednice (HAJEK-TADESSE, neobjavljeno). Neke ovdje nađene vrste (*Candonopsis kingsleii, Darwinula stevensoni*) poznate su iz miocenskih naslaga, iako žive i danas (SOKAČ, 1980). Ovdje određena zajednica ostrakoda ukazuje na slatkovodni do oligohalinski okoliš, bogat vegetacijom.

Mikroflora je znakovita dobrom zastupljenošću angiospermi familijâ Nymphaeaceae (*Nupharipollenites*), Myricaceae (*Myricipites, Momipites*), Juglandaceae (*Caryapollenites*) i taksonima iz skupine trikolpatnog i trikolporatnog peluda. Gimnospermi je manje, a najčešći su rodovi od bisakata *Pinuspollenites* i od bezsakata *Taxodiaceaepollenites*. Najzastupljeniji rod pteridofita je *Leiotriletes*. Prema prosudbama PLANDEROVÁ-e (1990) i NAGY-e (1969, 1973) načinjena je paleoekološka i paleoklimatološka odredba ondašnjih okolišnih uvjeta na temelju prepoznatih fosilnih spora i peluda.

Prevladava pelud suptropske vegetacije s mediteranskim florističkim elementima. Utvrđeni su i predstavnici vegetacije znakovite za toplu-umjerenu klimu, ali i oni koji nastanjuju područja s umjereno hladnijom klimom, odnosno područja s nešto povišenijim reljefom.

Tanatocenoza fosilnih spora i peluda sadrži taksone iz različitih okoliša. Prisutne su sporomorfe vodenih biljaka, koje ukazuju na jezersku sredinu, bezsakatni crnogorični pelud i spore briofita znakovite za šume močvarnih područja, taksoni zajednice obalne vegetacije (područje koje je svakako povremeno poplavljivano) i mješovite bjelogorične šume prijelaznog područja od obalnog do brdovitog okoliša s manje vlažnim tlom.

Budući da su fosilni pelud i spore mnogo bolji okolišni i klimatski nego provodni fosili, odredba starosti naslaga načelno se svodi na usporedbu s već prije stratigrafski određenim palinološkim zajednicama s istog lokaliteta.

Naime, neogenska paleoflora u Hrvatskoj, a poglavito iz ovim radom obuhvaćenog područja, nije do sada palinološki cjelovito i dovoljno sustavno istraživana, te ne postoje valjani opisi biljnih zajednica koje bi bile točno paleogeografski, paleoekološki i stratigrafski određene. Takvi su radovi za Mađarsku (NAGY, 1969, 1985), Slovačku (PLANDEROVÁ, 1990) i za sjeverni dio Srednje Europe (KRUTZSCH, 1963-1971) stoga korišteni kao glavni izvor podataka.Većina palinomorfi poznata je od eocena do pliocena. Ipak, sveopća provodnost i maksimumi pojavljivanja vrsta, primjerice, *Zelkovaepollenites thiergarti* (eger-sarmat, donji do srednji miocen), *Magnoliaepollenites simplex* (eger-panon), *Plicatopollis plicatus* (eger-panon), *Engelhardtioidites microcoryphaeus* (eger-panon), *Platycaryapollenites miocaenicus* (eocen-miocen), *Momipites punctatus* (eger-panon) i *Myricipites rurensis* (eocen-gornji miocen, eger-panon) dopuštaju pretpostavku o miocenskoj starosti analiziranog uzorka lapora.

Prema podacima dobivenim palinološkim analiza-

ma, uzorak stijene s Krbavskog polja je lakustrijski, miocenski sediment. Zajednica autohtonih hidrofilnih sporomorfa upućuje na jezerski biotop okružen močvarom i poplavnim ravnicama, a kserofilne, alohtone vrste iz nešto udaljenijeg slijevnog područja dokazuju postojanje brdovitih i suših predjela. Klima je bila topla, suptropska.

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PLATE - TABLA I

KRBAVSKO POLJE (near benchmark 627 - blizu kote 627)

1, 6, 9, 12 *Erpetocypris* sp., 50 X
- 1 Interior lateral view of female right valve - Unutarnja strana desne ljušture ženke.
- 6 Exterior lateral view of female right valve - Vanjska strana desne ljušture ženke.
- 9 Exterior lateral view of female left valve - Vanjska strana lijeve ljušture ženke.
- 12 Interior lateral view of male right valve - Unutarnja strana desne ljušture mužjaka.

2, 3 *Candona luminosa* BODINA, 50 X
- 2 Interior lateral view of female right valve - Unutarnja strana desne ljušture ženke.
- 3 Exterior lateral view of female right valve - Vanjska strana desne ljušture ženke.

4, 5 *Candona praecox* STRAUB, 50 X
- 4 Exterior lateral view of female left valve - Vanjska strana lijeve ljušture ženke.
- 5 Interior lateral view of female left valve - Unutarnja strana lijeve ljušture ženke

7, 8 *Potamocypris fulva* (BRADY), 50 X
- 7 Exterior lateral view of right valve - Vanjska strana desne ljušture.
- 8 Interior lateral view of right valve - Unutarnja strana desne ljušture.

10, 11 *Cypridopsis biplanata* STRAUB, 50 X
- 10 Exterior lateral view of left valve - Vanjska strana lijeve ljušture.
- 11 Interior lateral view of left valve - Unutarnja strana lijeve ljušture.

13, 14 *Candona* sp., 50 X
- 13 Interior lateral view of female right valve - Unutarnja strana desne ljušture ženke.
- 14 Exterior lateral view of female right valve - Vanjska strana desne ljušture ženke.

PLATE - TABLA II

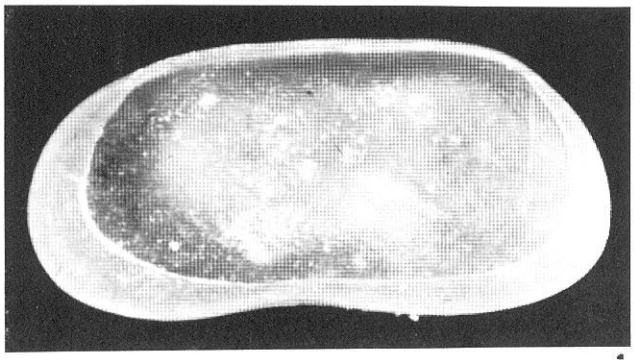
KRBAVSKO POLJE (near benchmark 627 - blizu kote 627)

- 1 - 2 *Orygoceras dentaliforme* BRUSINA, 20 X
- 3 - 6 *Orygoceras stenonema* BRUSINA, 20 X
- 7 - 8 *Orygoceras* cf. *cornucopiae* BRUSINA, 20 X
- 9 - 10 *Pseudoamnicola* (*Bania*) cf. *prototypica* (BRUSINA), 20 X
- 11 Operculum of the family Bithynidae - Operkul familije Bithynidae, 10 X
- 12 - 14 *Pyrgula* cf. *dalmatina* BRUSINA, 20 X

PLATE - TABLA III

KRBAVSKO POLJE (near benchmark 627 - blizu kote 627)

- 1 - 4 *Melanopsis* cf. *astrapaea* BRUSINA, 20 X
- 5 ?*Melanoides* sp., 10 X
- 6 - 7 ?*Melanoides* sp., 8 X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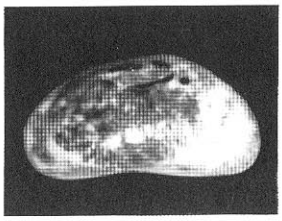
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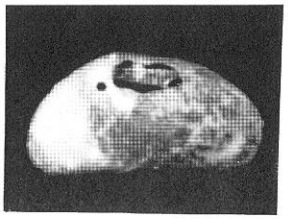
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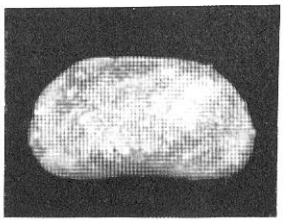
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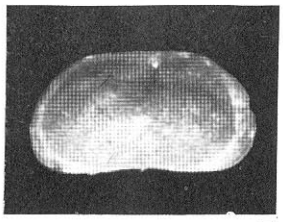
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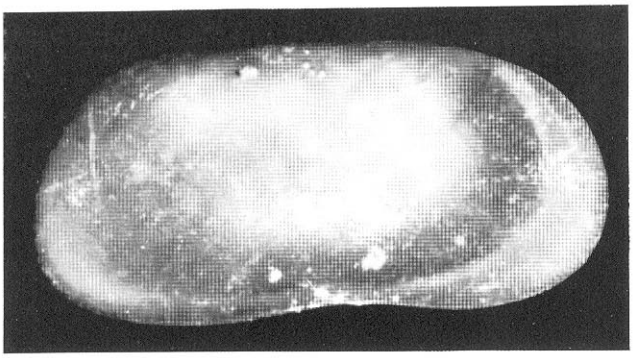
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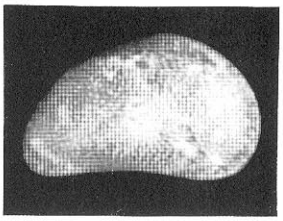
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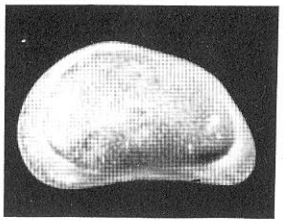
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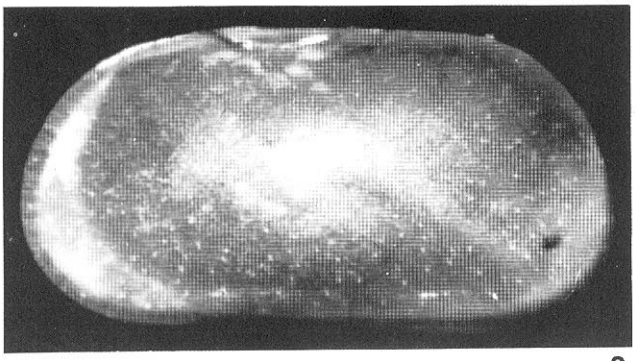
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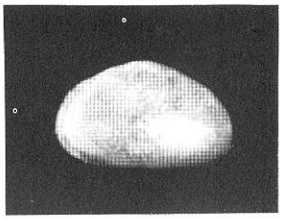
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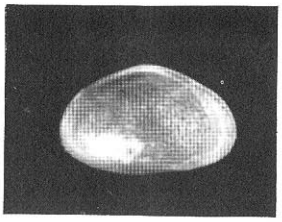
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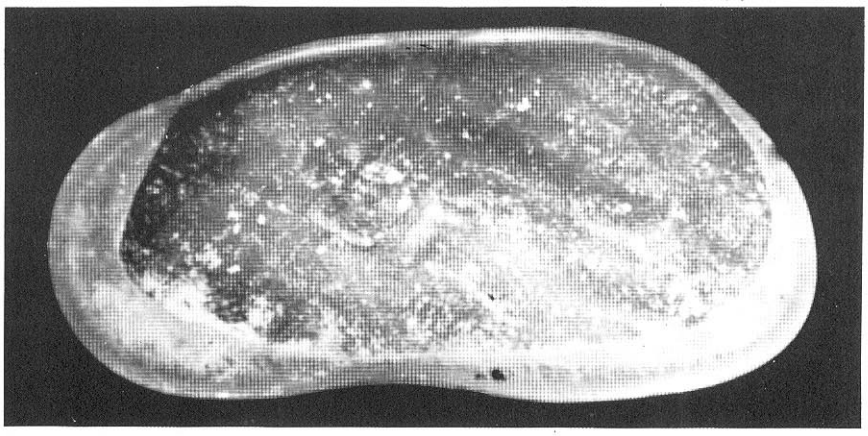
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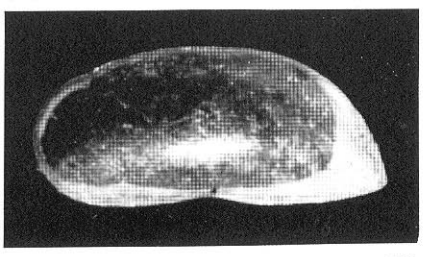
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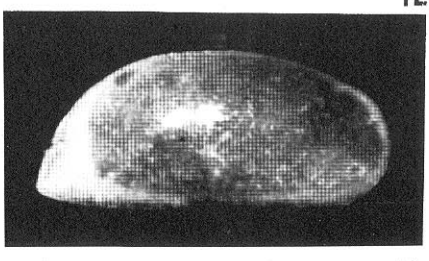
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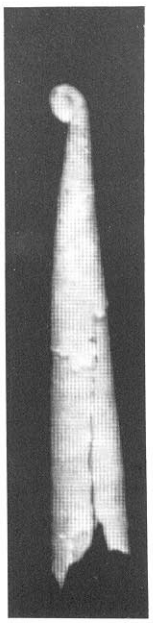

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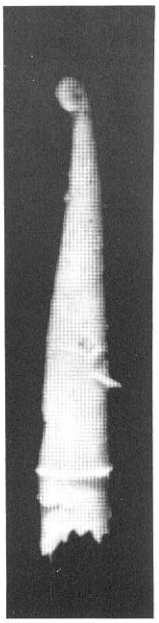

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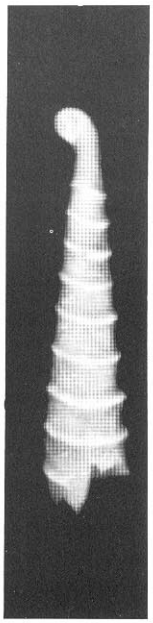

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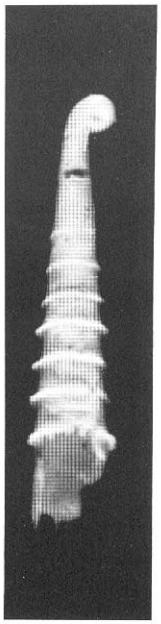

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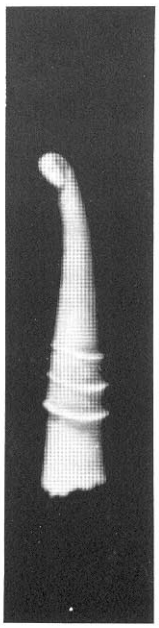

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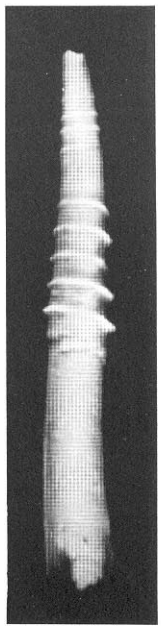

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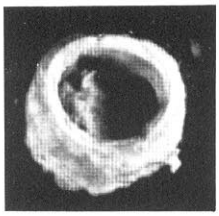

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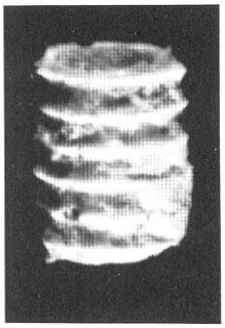

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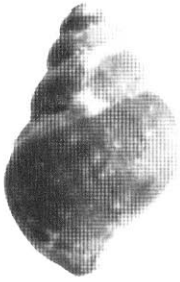

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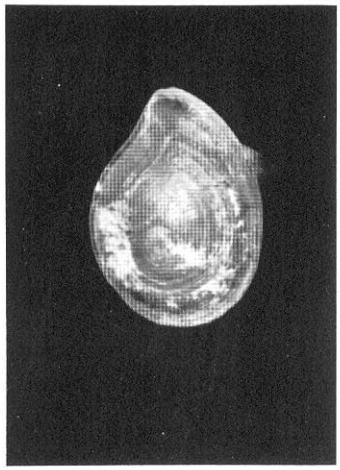

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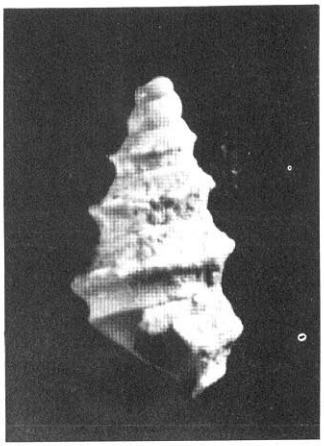

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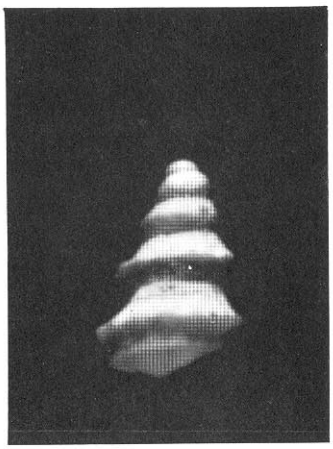

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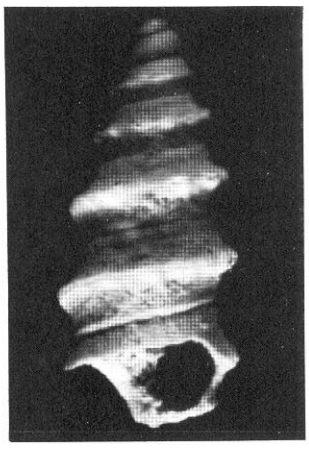

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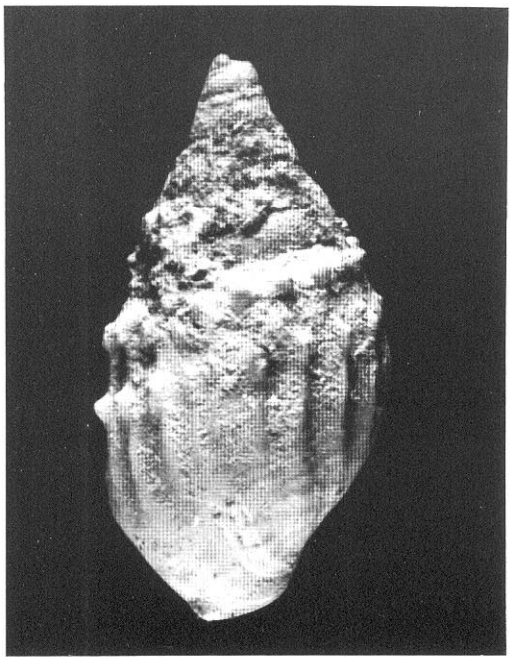
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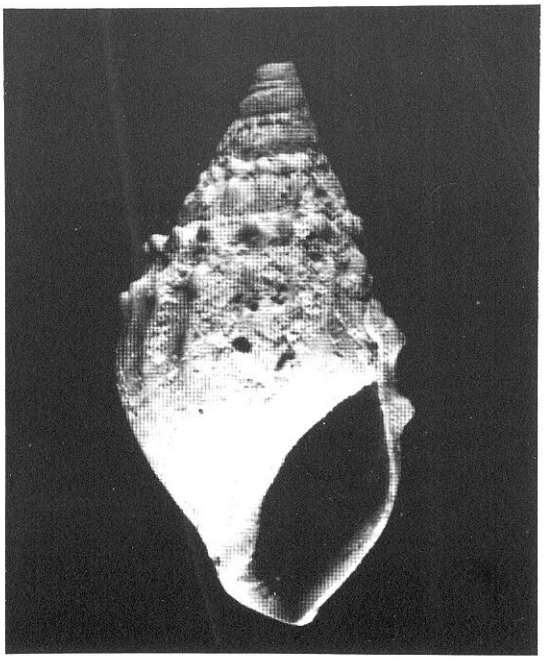
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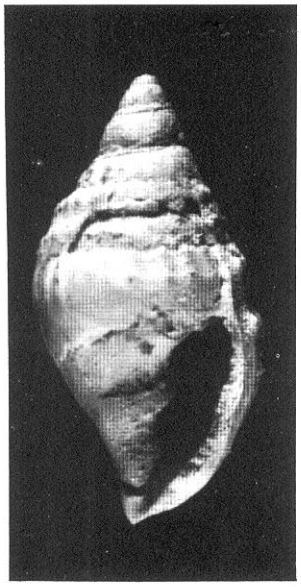
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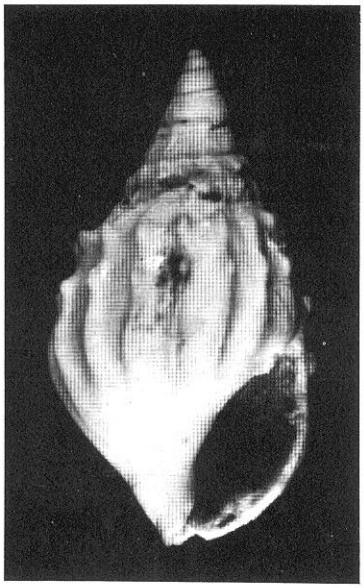
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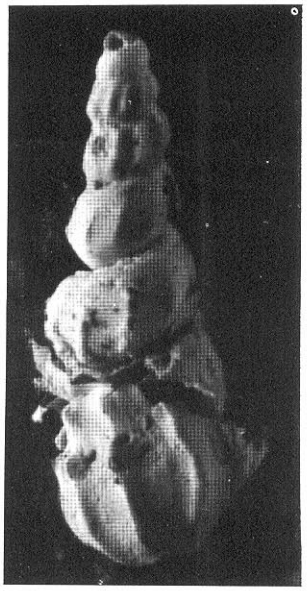
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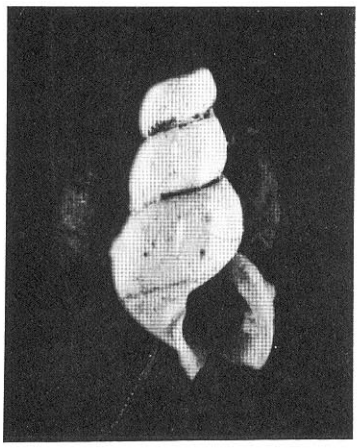
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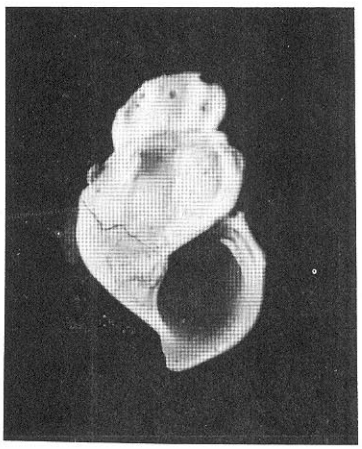
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PLATE - TABLA IV

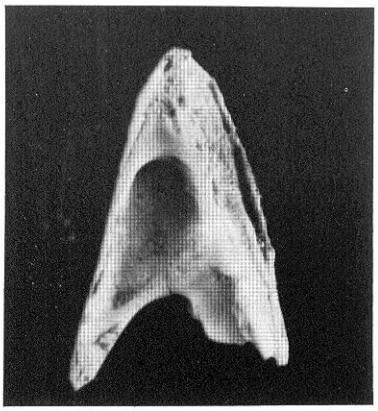
KRBAVSKO POLJE (near benchmark 627 - blizu kote 627)

1, 4 *Congeria* sp., 8 X
2 - 3 *Dreissena cymbula* (BRUSINA), 20 X
5 - 6 ?*Dreissenomya* sp., juv., 20 X
7 - 8 *Dreissena* sp. A, 15 X
9 - 10 *Dreissena* sp. B, 15 X

PLATE - TABLA V

KRBAVSKO POLJE (near benchmark 627 - blizu kote 627)
1000 X

1 *Caryapollenites simplex* (POTONIÉ) RAATZ 1937, Krbava 2 / 21.5 103.1
2 *Magnoliaepollenites simplex* NAGY 1969, Krbava 1 / 30.5 109.0
3 *Taxodiaceaepollenites concedipites* KRUTZSCH 1971, Krbava 3 / 27.6 103.6
4 *Cupressacites bockwitzensis* KRUTZSCH 1971, Krbava 3 / 32.6 111.7
5 *Aceripollenites rotundus* NAGY 1969, Krbava 1 / 27.2 106.9
6 *Nupharipollenites kedvesi* NAGY 1969, Krbava 2 / 36.1 112.1
7 *Momipites punctatus* (POTONIÉ) NAGY 1969, Krbava 1 / 35.9 108.1
8 *Myricipites rurensis* (PFLUG & THOMSON) NAGY 1969, Krbava 1 / 41.4 98.1
9 *Platycaryapollenites miocaenicus* NAGY 1969, Krbava 1 / 37.2 110.8
10 *Plicatopollis plicatus* (POTONIÉ) KRUTZSCH 1962, Krbava 1 / 35.7 109.5
11 *Tricolpopollenites* sp., Krbava 1 / 35.2 112.0
12 *Tricolporopollenites* sp., Krbava 2 / 28.2 103.2
13 *Myricipites intermedius* KEDVES 1974, Krbava 1 / 35.1 111.8
14 *Engelhardioidites microcoryphaeus* (POTONIÉ) POTONIÉ 1960, Krbava 1 / 35.0 102.2
15 *Zelkovaepollenites thiergarti* NAGY 1969, Krbava 1 / 27.6 110.0
16 *Pterocaryapollenites stellatus* (POTONIÉ) THIERGART 1937, Krbava 2 / 26.3 102.3
17 *Myriophyllumpollenites* sp., Krbava 2 / 26.5 102.3
18 *Ericipites callidus* (POTONIÉ) POTONIÉ 1960, Krbava 1 / 28.9 97.9



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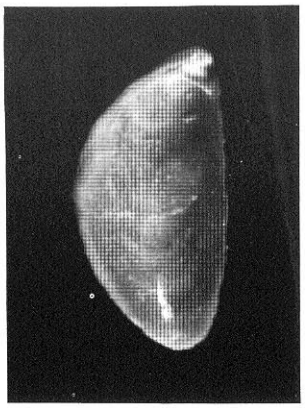

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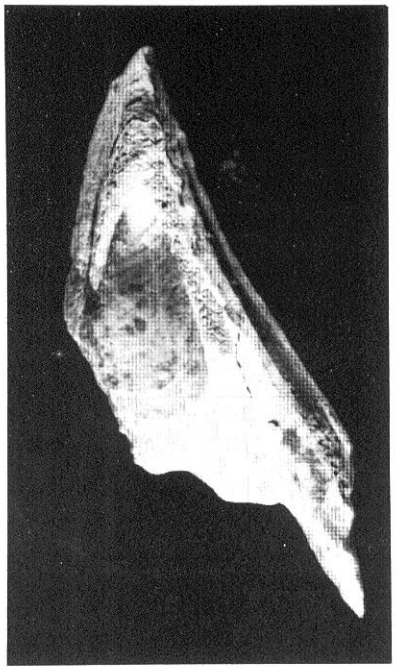

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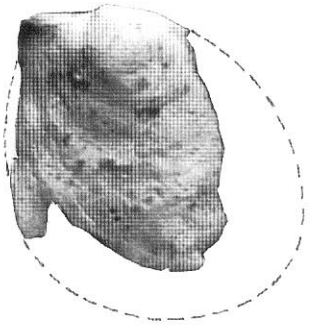

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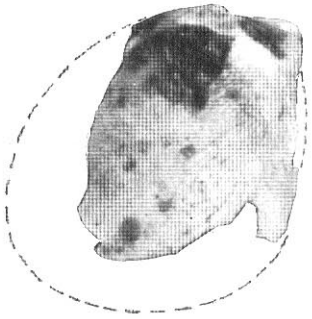

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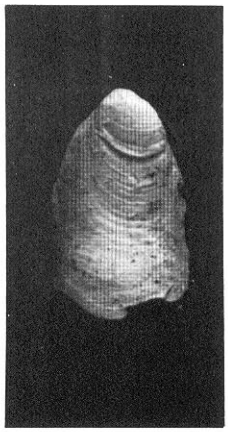

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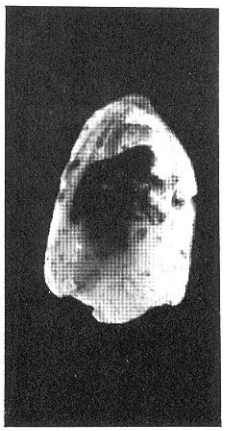

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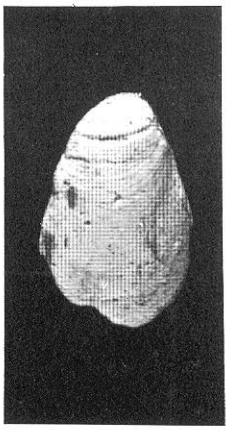

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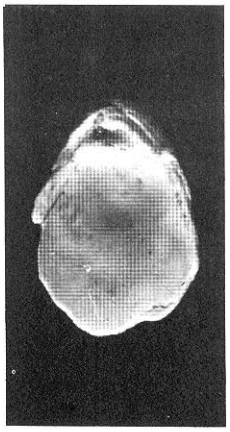

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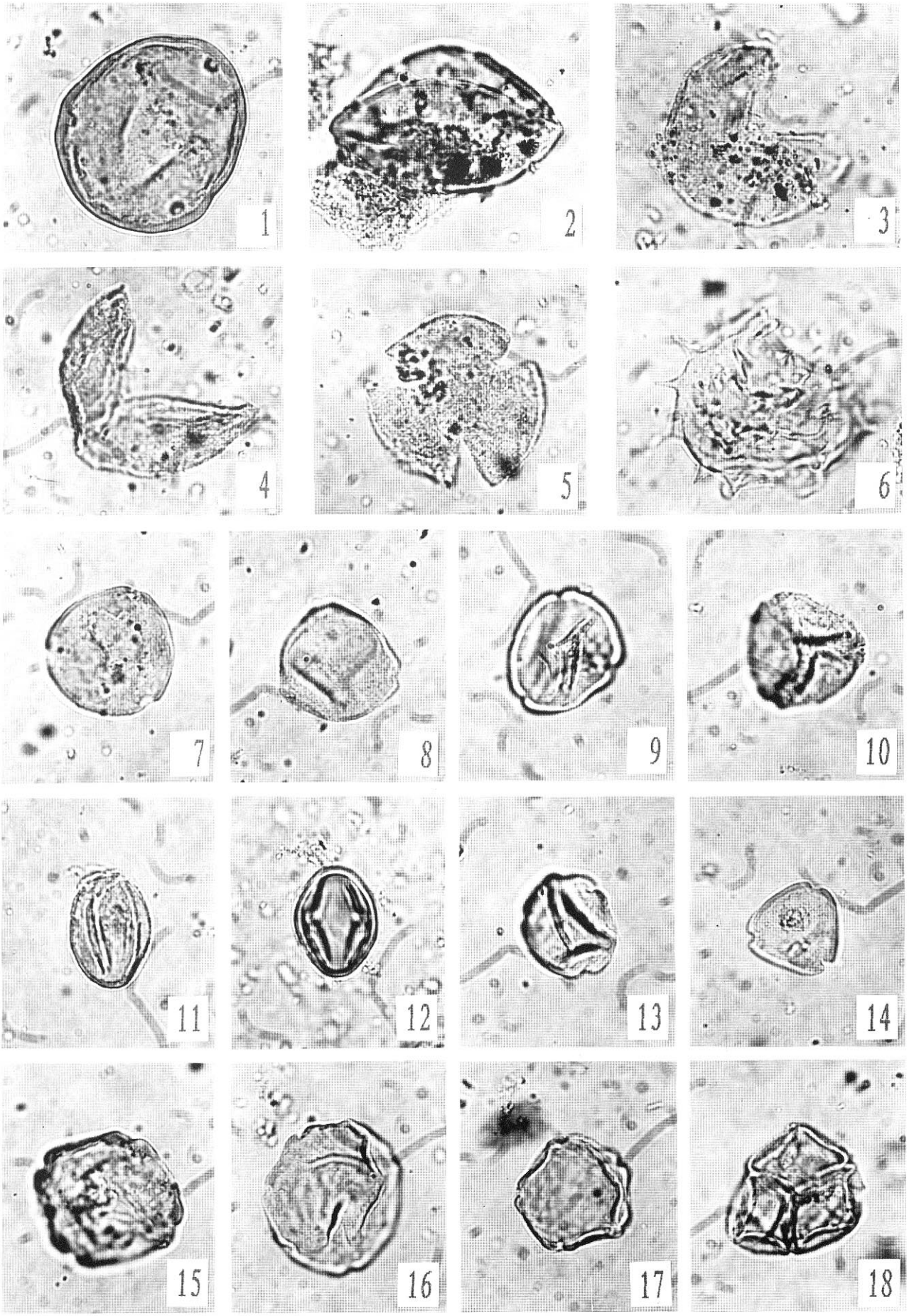
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