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PROPERTIES OF THE LOWER PONTIAN IN THE SRBOVO BORE HOLE NEAR NEGOTIN, DACIAN BASIN

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Abstract: The hole was bored through the medium gray Lower Pontian silt with the yellowish sideritic intercalation and dark gray worm boring pack. Different sedimentary structures, like silt shadows and fish marks, are present. The chemical, radiometric and other obtained values are in the accordance with the composition of the Earth's crust or close to it. *Paradacna abichi, Carinatocongeria digitiferra, Valenciennius* and other macrofauna were observed paleoecologicaly. Micropaleontological analyses completed the sedimentological data. Paleoenvironment: sheltered part of basin, no islands, on the edge of steady currents coming from south-east.

Key words: North-eastern Serbia, sedimentology, paleoecology, magnetostratigraphy, sideritic silt.

Introduction

The presence of the Pontian in Negotinska Kraina was recorded by Pavlović (1937) and Stevanović (1951). During the mapping additional data were collected (Popović 1958; Stevanović 1955, 1977, 1978, 1990a, b; Stevanović & Dolić 1987; Dolić & Rakić 1976). Researches on microfossils (Krstić 1974, 1975, 1989, 1991a; Mihajlović 1989; Krstić & Stancheva 1990), magnetostratigraphy (Milićević et al. 1988; Krstić & Milićević 1990) with apparent sedimentation rates (Milićević & Krstić 1988), and ichnofossils (Krstić 1988) follow.

Overlain by 10-15 m thick Quaternary gravel, the Pontian sediments of Kobišnica Plateau (average height 60-70 m) crop out in a few places along the eastern part of the low plateau escarpment. They are mostly horizontally bedded clayey silt, beds distinguished by their yellow and yellowish-ochre colour. Among mollusks *Valenciennius (V. elliptica, V. suchovae,* cf. Taktakischvili 1967) and *Paradacna abichi* are most numerous. *Monodacna pseudocatilus, Limnocardium* cf. *riegeli, L.* cf. *zagrabiense, L. otiophorum orientale, L.* cf. *mayeri, Dreissena anisoconcha* are less abundant (Stevanović 1951, 1978, 1990b).

In the outcrop on a dirt road climbing up the SE escarpment of the plateau (in Krstić 1974: err. "plateau promontory"), among ostracodes *Leptocytheridae* are abundant (Lower Pontian Leptocytheridae Zone of Stancheva 1985) including some species from the Eastern Paratethys such as *Amnicythere palimpsesta, A. rosalinae, A. anormalis, A. (?) multituberculata, Maeotocythere praebaquana* (Krstić 1974, 1975). The assemblage represents a transition between the facies of silt and sandy silt. Most of the "key" fossils are facies bounded.

The bore hole E.VI-2 in Srbovo, east of Negotin, is situated on the eastern edge of the graben of Srbovo, nearly at the line where the graben starts dipping toward the north (Fig. 1). The

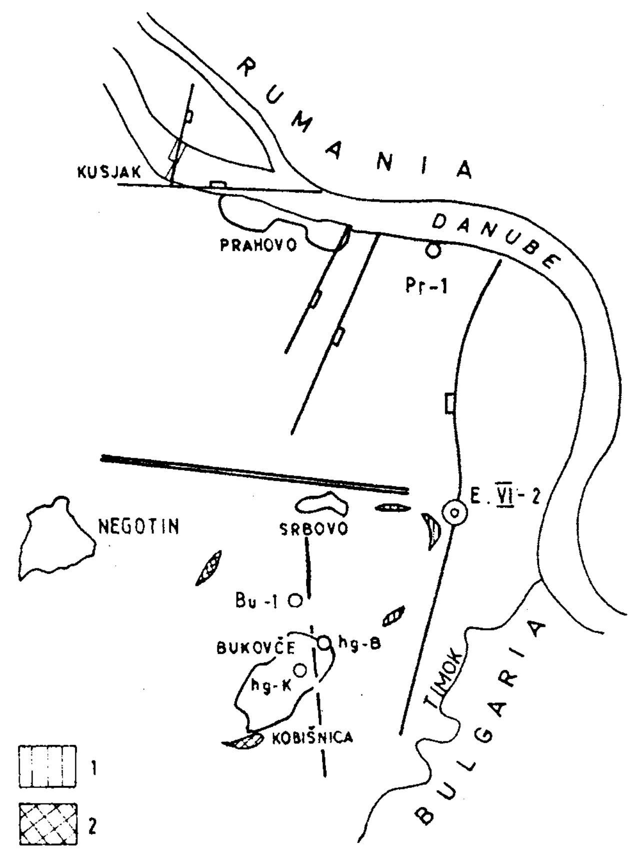
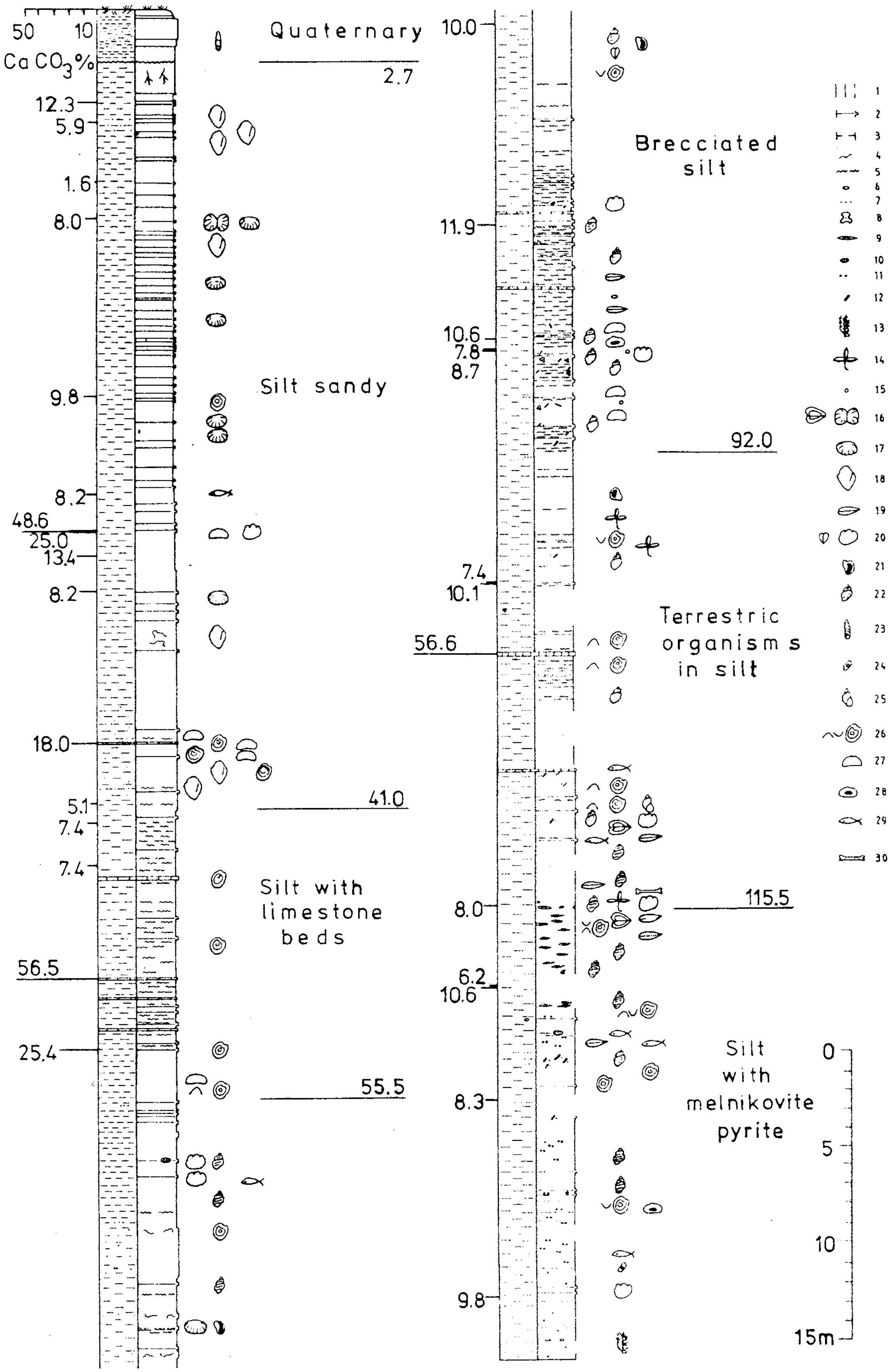


Fig. 1. The position of the Srbovo graben on a part of tectonic map of Negotinska Kraina (Mladenović & Krstić 1994) with bore holes and outcrops: 1 - Maeotian, 2 - Pontian.


50 10
Ca CO_3%
Quaternary
2.7
12.3
5.9
1.6
8.0
9.8
Silt sandy
8.2
48.6
25.0
13.4
8.2
18.0
41.0
5.1
7.4
7.4
Silt with limestone beds
56.5
25.4
55.5
10.0
Brecciated silt
11.9
10.6
7.8
8.7
92.0
7.4
10.1
56.6
Terrestric organisms in silt
8.0
115.5
6.2
10.6
8.3
Silt with melnikovite pyrite
9.8
0
5
10
15m
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

region belongs to the Dacian Basin or to the Getic Zone of Stevanović (1967: Fig. 11).

The bore hole, completely cored, penetrated the Pontian silt down to 138.5 m not reaching the Maeotian (Krstić 1991a; Krstić et al. 1992). In the other bore hole, Bu-1, studied mostly by geophysical methods, the semidiscordant boundary between the Pontian and Maeotian was laid down at the 103.0 m (Nafta-Gas). The bore hole Pr-1 penetrated the Pontian down to 600 m where, on the basis of the electro logging, the Pontian-Maeotian boundary was placed (Nafta-Gas; cf. Boškov-Štainer & Marinović 1971).

Bore hole E.VI-2

Within the work on Tertiary sediments of the Timok-Kraina area, (the Project E.VI of the New Geological Map 1:50,000), some holes were drilled. The bore hole E.VI-2 was placed east of the village Srbovo, close to the Bulgarian and Roumanian borders (Fig. 2). Thanks to the IGCP Project No. 329 the bore hole was correlated to the Taman Peninsula outcrops.

The bore hole is situated below the Kobišnica Plateau promontory (triangle 50.5 m). Its elevation point is 33.25 m and the depth 138.5 m.

The first 2.7 m of the hole cut through the Quaternary. It is represented mostly by the silty sand of the right bank of the Srbovo Stream containing *Valvata pulchella* and *Helicidae*.

The Lower Pontian silt is present from 2.7 m to the end of the bore hole at 138.5 m. The silt was sampled at the 5 m and the rest observed at each 3 cm intervals.

On the basis of the different sedimentological and paleoecological properties the silt could be divided into several units:

— 2.7-41.0 m. Silt, yellow and mixed yellow and gray with 5-10 % of the finest sand. This sand is presented as laminar or flaser structures on the bedding planes. *Arpadicardium* cf. *mayeri* and *Congeria rumana* appear in the more sandy parts while *Paradacna abichi, Carinatocongeria digitifera* and others (including *Valenciennius*) appear in the silty intervals.

— 41.0-55.5 m. Silt, medium gray with *Valenciennius* shells and four intercalations of marly limestone 5-10 cm thick and an additional one 15 cm thick (containing well inflated *Paradacna abichi*). Numerous dark gray and rare whitish beds.

— 55.5-92.0 m. Silt, medium gray, brecciated, with *Zagrabica* cf. *cyclostomopsis*, slightly sandy in places. Numerous silt shadows. *Valenciennius* only as fragments. Multitude of dark gray beds. Below 81.25 m plant detritus starts.

— 92.0-115.5 m. Silt, medium gray, in places brecciated. Complete *Valenciennius* shells are again present alternating with *Zagrabica* cf. *cyclostomopsis* levels. Plant detritus and leafimprints are rare. On 110 and 114 m remains of terrestrial organisms. Dark gray coloured beds are numerous in places.

— 115.5-138.5 m. Silt, medium gray with some melnikovite-pyrite and, in places, plant detritus. Fish remains not significantly commoner than previously. On 133 and 137 m remains of terrestrical organisms.

Fig. 2. The column of the Srbovo bore hole E.VI-2. 1 - disturbed by rotation, 2 - sideritic silt, 3 - the same, less clear, 4 - subrecent root marks, 5 - flaser structures(?), 6 - worm borings, 7 - pebble, 8 - sand intercalations, 9 - calcium carbonate concretions, 10 - melnikovite coatings, 11 - limonitic concretions, 12 - melnikovite globules, 13 - carbonised wood detritus, 14 - *Taxodium dubium*, 15 - leaf imprints, 16 - seeds, 17 - *Limnocardiidae* both valves, 18 - *Arpadicarium mayeri*, 19 - *Congeria rumana*, 20 - *Dreissensidae* closed valves, 21 - *Pisidium* (open & closed valves), 22 - *Lymnaea kobelti*, 23 - *Zagrabica* cf. *cyclostomopsis*, 24 - dry land gastropods, 25 - *Bithynia* operculum, 26 - *Succineid*, 27 - *Velenciennius* (stable & unstable), 28 - large ostracodes, 29 - otholithes, 30 - fish remains, 31 - bird bone.

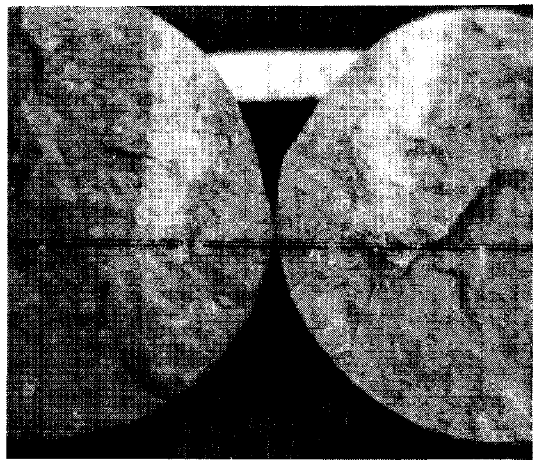


Fig. 3. The sand accumulation - flaser structure - showing the properties of the ripple mark. Depth 31.75 m. Magnification 0.71×.

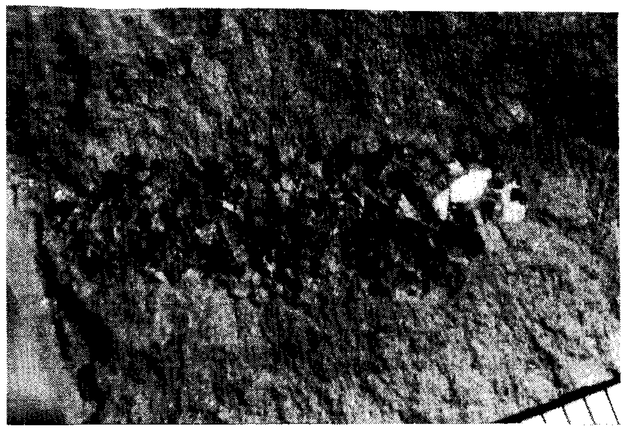


Fig. 4. The elliptical accumulation (a fish marks?) from 11.3 m with quartz grains and few mollusk debris on the lower core pice (above them plant remains are flotated). Magnification 3×.

Structures

Different structures observed in the Srbovo bore hole such as fish marks(?), ichnofossils and silt shadows are partially presented by the first author (Krstić 1988).

Bedding. Beds are distinguished on the basis of the grain size and colour. In the silt there are also some beds of marly limestones. The bedding planes in the silt are not present, except for the parts where sand laminae and the like occur. The small sand accumulations - flaser structures - are, maybe, the ripple marks (Fig. 3). The colour of the thin dark beds (1-10 cm) is due to the numerous worm borings filled by the dark gray silt; the worm borings could be tightly packed together (Pl. I: Figs. 1-2). The whitish beds of sideritic silt (from 2 to more than 15 cm thick) are present through-

Fig. 5. The irregular accumulation from 30.0 m: on the lower core piece shell fragments of *Valenciennius, Paradacna* etc. (on the upper side plant debris and mica). Magnification 3×.

Fig. 6. The perpendicular cut of the sand accumulation in a lodging or eating cast. Depth 32.35 m.

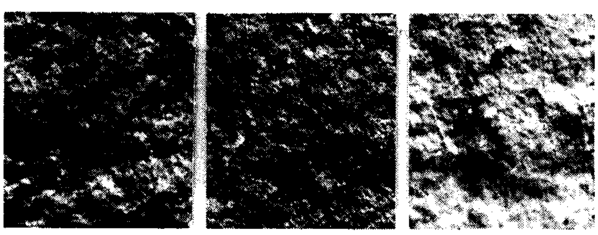


Fig. 7. A worm housing having the appearence of the whirl, filled by dark silt. Sample from 96 m. Magnification 3×.

out the whole column; but their frequency is quite different - from three beds in 15 cm to one in 100 cm.

Fish marks (?). Accumulations of coarser (arenite size) material a few cm-long on the bedding planes, are irregular or in the form of elongated ellipses (up to 3 × 1 cm in surface and less than 1 mm in height or thickness). In the sandy silt such accumulations, mostly of elliptical form, consist of coarse grained sand: quartz in lower and mica flotated on the upper half of the accumulation and sorted by their sizes from one side to the other as they were transported (Fig. 4). The bioclastic type of accumulations consists of mollusk shell fragments, juvenile *L. otiophorum*,

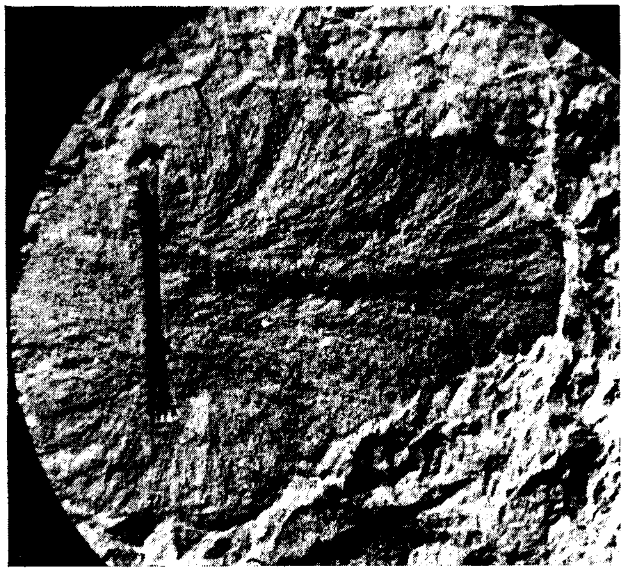


Fig. 8. Leg bone of the songbird as the core of the silt shadow. Upper side of the sample from 114.3 m. Magnification 1.17×.

large ostracode shells *(Camptocypria)* and small carbonized fragments of leaves flotated above heavier bioclasts (Fig. 5).

The origin of the accumulation is not explained. It is possible that they are marks of fish activity, turbulence caused by swimming first and type the remains of the fish meal later reworked (the fish vobla, a kind of roach from the Caspian, feed only on bivalves and in nutricient pure waters other fish, in Caspian Sea even sturgeon, could feed on mollusks - Zenkevich 1956).

Ichnofossils. The fine sand sometimes fills the resting - or eating-cast like forms. They are ca. 1 cm wide, more than 10 cm (the core diameter) long and a few mm deep (Fig. 6). On the bedding plane these casts cannot always be distinguished from small ripple marks.

There are two types of worm housing. Both are filled with dark gray silt (coloured by melnikovite?). Irregularly curved long boring worm, hausing 1-2 mm in diameter belongs to the first type. Its perpendiculars are roundish or elliptical due to the sag (Pl. I: Fig. 3). The second type of the blackish worm traces are 1 cm long and 1 mm wide conical structures wound like gastropods (Fig. 7). They are thinner than the biogliphes determined as *Hypania* and may belong to *Hypaniolla*. Both genera live today in the freshened parts of the Black Sea and in the Caspian Sea-Lake as Ponto-Caspian relics building a temporary conical tube made of cherty secretion and local clastic material. On one square meter up to 11,000 living specimens could be found (Marinov 1985). Such a biotope could be supposed for the Lower Pontian silt where, on the hardened ground, they lie horizontally.

Plate I: Fig. 1. Sideritic silt intercalation and a dark worm bored bed below it. Depth 79.3 m. **Fig. 2.** Sideritic silt containing dark worm borings and *Dreissena anisoconcha*. Depth 83.8 m. **Fig. 3.** Worm borings, one of them long, on the transition from whitish sideritic into medium gray silt. Depth 81.7 m. **Fig. 4.** Melnikovite coating and "rodochrosite". Depth 120.2 m. **Fig. 5.** Three intercalations of sideritic silt in the upper part of the drill hole. **Fig. 6.** *Valenciennius* in the medium gray silt with bioturbations. Natural (stable) position. Depth 73.8 m.

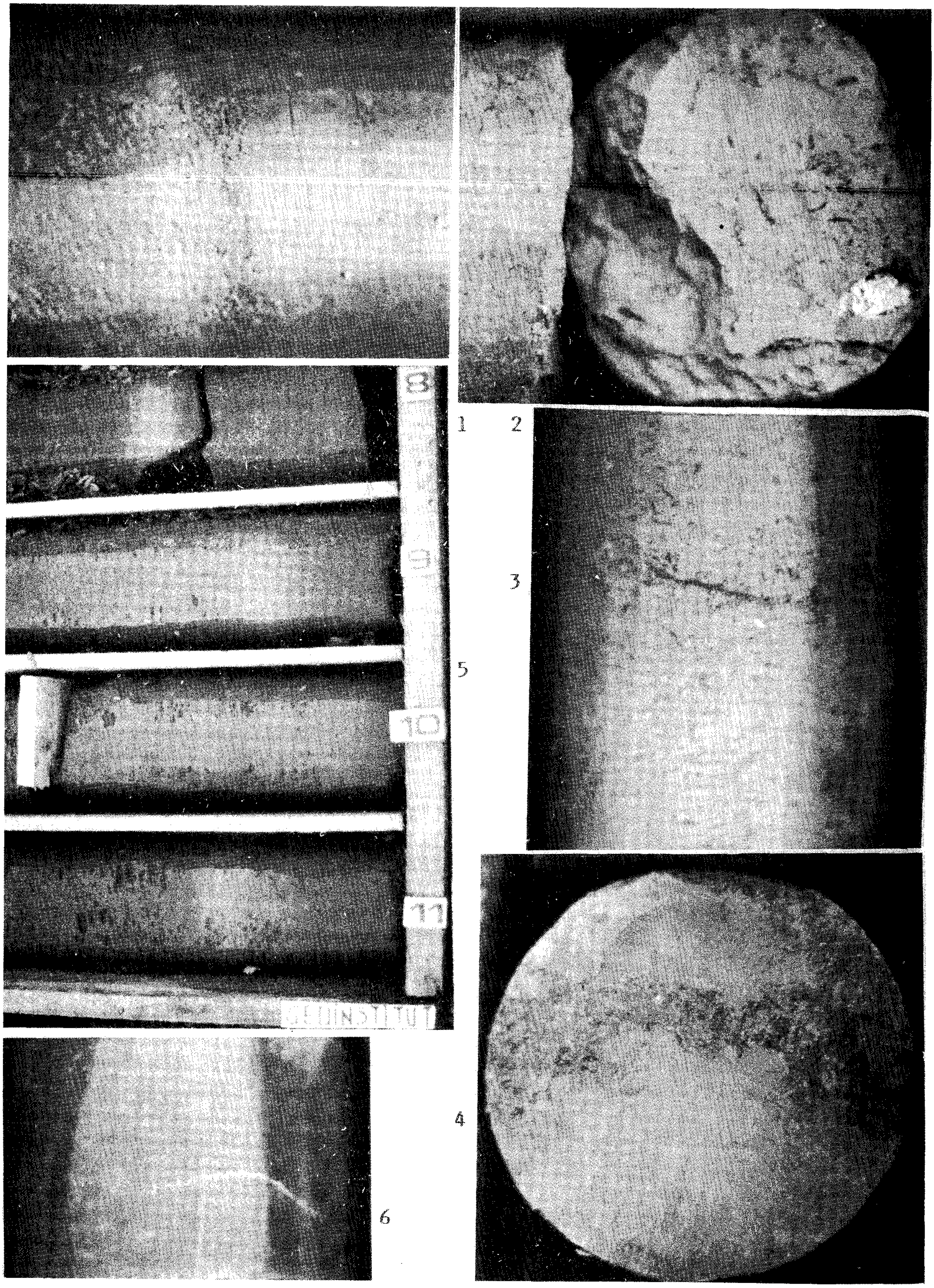

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Fig. 9. Silt shadow around a large sand grain. On the side an unstable *Carinatocongeria digitifera*. Sample from 114.9 m. Magnification 1.6×.

Fig. 10. Three silt shadows covering each other. Other side of the sample from Fig. 9. Magnification 2×.

Fig. 11. Calcium carbonate concretion of concentric structure. Sample from 87.8 m. Magnification 35×.

Silt shadows. From 55.5 m downwards some of silt beds are brecciated. At the beginning of brecciated silt unit *Zagrabica* cf. *cyclostomopsis* starts to appear often and there are no more complete shells of *Valenciennius*.

In the brecciated silt there are silt shadows (cf. Dimitrijević et al. 1967) around bioclasts and extraclasts (Figs. 8-10). The shadows could be explained only as accumulation of silt behind and in front of an semi-immobile object. The silt shadows are observed mostly in horizontal breakings. In a silt shadow the big clast (semi-immobile object) is not centrally placed. If the clast is roundish (*Zagrabica*, pebble) the shadow has a form of a "heart", with the big grain placed in its broader part. The height of the silt shadow depends on the height of the clast causing pilling up. Like a sand dune it is higher on one side. On the horizontal breaking of the silt shadow the directions of the stream lines of the water could be recognized (Fig. 8).

The brecciation and forming of the silt shadows are, most probably, a result of steady water currents. We could compare the Lower Pontian basin to the recent Caspian Sea-Lake (the same water chemistry/density) where speed of the currents "are very low and are not above 25 $cm.s^{-1}$, in most parts 10-15 $cm.s^{-1}$" (Apollov et al. 1969, p. 169). Given values depend on the depths down to 75 decibars (1 dbar in the Caspian is little less than 1 m). "Deeper than 170 dbars" (ca. 168 m) "in the middle and southern parts of the sea (...) water currents are very slow" (Kosarev 1969, p. 165). The currents are most intense in the upper water level of the Caspian Sea, down to 30 m.

Concretions. The term "concretions" is not fully justified because these are often unsufficiently consolidated. The calcium carbonate "concretions" are mostly concentrically built and only a millimeter in diameter (Fig. 11); they are situated in the silt with a low amount of calcium carbonate: 7.8 and 8.7 %, although there are beds with 50 % of $CaCO_3$. The melnikovite "concretions" vary in size from sub-mm globules (Figs. 17, 24) to the coatings (Fig. 18). Two limonitic concretions, a few cm in diameter, are ochre coloured.

Methodology and results

For the granulometric investigation mechanical sieving with 2 to 0.05 mm sieves was conducted; the fractions from 0.05 to

0.005 are determined by the pipette method. Differential thermal analysis was performed on ATD 67, Adamel Lhormargy with 0.1 mV susceptibility; for temperature a Pt-PtRh thermoelement was used. For the infra red absorption spectrum the gadget of Perkin-Elmer, model 883 in the spectrum area of 4000 to 200 cm^{-1} was applied; sample preparation was done in sodium bromide.

The following methods were used for the chemical analyses: for organic matter redox titration with potassium dichromate; pH and Eh potentiometry; for manganese and iron atomic absorption spectrophotometry; for calcium carbonate gas-volumetry. For spectrochemistry the spectrometer of the large dispersion of Hilger,

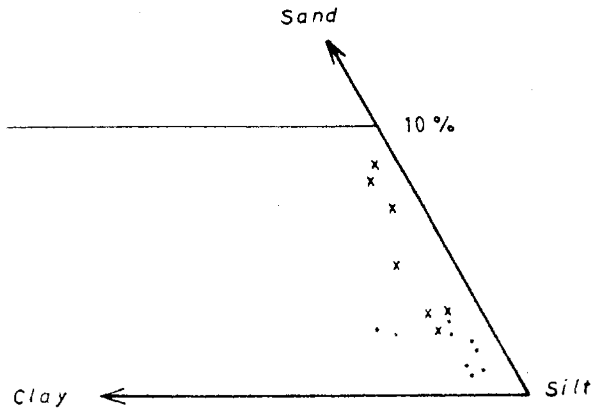

Fig. 12. The silt part of the triangular diagram, presenting the granulometry results above (x) and below (·) 41 m.

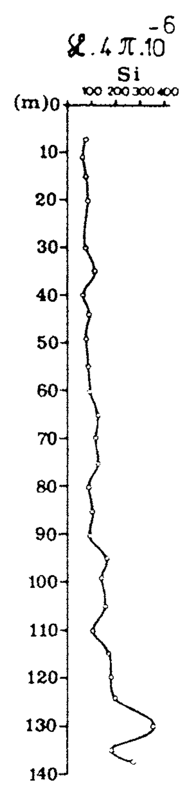

Fig. 13. Susceptibility curve of Srbovo bore hole (Milićević et al. 1988).

type Litior was applied. The sample combustion in Volta bow of 8 A. Radiometric analyses were performed on the detector Na I (TL), 100 × 100 mm, Bicron with the analyzer and computer Optec 7450, IN 90, using computer program <1, 2, 7, 8, 9>, <SSTE>.

Granulometry. According to granulometry the Lower Pontian belongs to the silt lithotype, with 91.35-98.57 % of silt, 2.7-8.9 % sand (last figures down to 41 m) and 0.4 to 1.3 percent of clay (Fig. 12). The granulometric curve is unimodal and belongs to the leptokurtic type. The grain sorting is variable: So = 1.44 to 1.82, i.e. it is well and medium sorted. The mode toward the median (Md 0.010-0.013) is on the side of smaller grains (Sk 1.16-1.45). In the fraction above 0.10 mm there are semiconsolidated silt lumps and, in the upper part, mica flakes, in the lower one Fe concretions.

Dynamic diagrams were used for environmental reconstruction. The Ruhin's diagram indicates shore deposits strongly disturbed by water movements. On the Kukal's diagram points are concentrated in the fields of river sand and river suspension. On the Passegas diagram the greater number of points fells into the pelagic suspension. The results do not oppose each other, but reflect the specific environment of the deposition of the Lower Pontian in Srbovo.

Chemical analyses. The content of calcium carbonate is shown in the column of the Srbovo bore hole (Fig. 2). In the greatest number of the medium gray silt samples the obtained values vary between 5.1 and 10.1 %, the average is 7.65 percent.

Another set of samples was taken from the whitish-yellowish beds of sideritic silt. The $CaCO_3$ content varies between 10.6 and 48.6 %. In four other samples it is determined by its colour (11.9 and 13.4 %). This means that except siderite in the light colored beds the calcium carbonate was precipitated and that in some of the pale gray ("unclear") beds only calcium carbonate is present.

The amount of iron was analysed, but because of the presence of organic matter it was not possible to determine its valence status (Tab. 1).

Table 1:

	Depth [m]	C_{org}	Fe%	Mn%
1	86.10	0.70	21.6	0.420
2	86.60	0.35	2.75	0.040
3	86.60	0.05	-	0.040
4	86.80	0.18	2.44	0.050
5	86.90	0.05	-	0.060
6	123.40	-	3.60	0.020
7	125.05	-	>5.00	0.025
8	125.05	0.27	2.62	0.060
9	126.35	-	2.50	0.090

The content of the Fe minerals was also studied by physical means. In the susceptibility analysis of the Srbovo bore hole, an increase of the content of magnetic minerals below 90 m was noticed (Milićević et al. 1988). The susceptibility curve varies, being most intense at 130 m of the dept (Fig. 13).

Semiquantitative analyses (by M. Dromnjak) give a content of Fe above 1 % as well as the content of Al, Mg and Ca. These contents lie inside the referent values for similar rocks.

An increase of the content was noticed for the Zr, Ti, Mn, Yb, Nb, La, Y as is given in Tab. 2:

Table 2:

	Content in Srbovo borehole [ppm]	Average content for sediments (Vinogradov 1962) [ppm]
Zr	180-260	200
Ti	3600-1%	4500
Mn	400-1500	670
Yb	to 4	3
Nb	to 35	20
La	23-54	40
Y	15-38	30

A relative content of some microelements (Ga, Pb, Y, Cu, Sr, Ni, Cr, V, Zr, Ba) is given in Fig. 14. The content of barium is relatively high and it could be connected with the salt water of the Lower Pontian sea-lake - the barium is correlative to the halite.

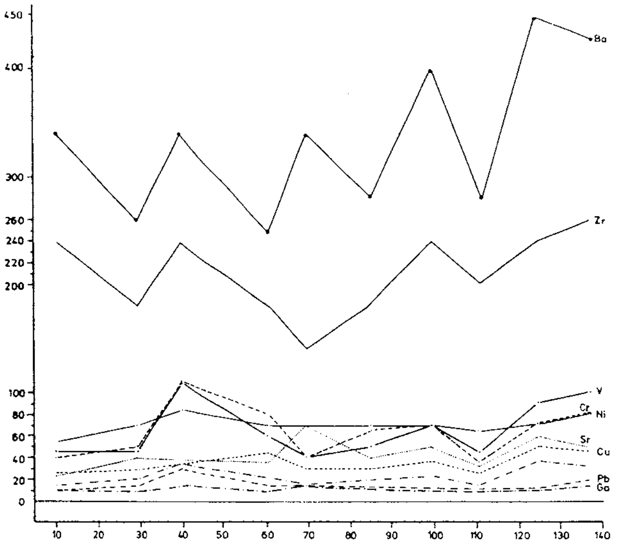

Fig. 14. Diagram of relative content of Ga, Pb, Y, Cu, Sr, Ni, Cr, V, Zr and Ba (in the order up the fig.).

Other analyses. The oxidation-reduction processes are of a low intensity with small variations of pH values in a low alkaline environment. The pH values vary from 6.8 to 7.8 with an average value of 7.4. Therefore there is no concentration of elements (such as uranium) dependant on oxidation-reductions processes. For Eh the potential lies between -20 and +20 mV.

The analyses of radioactive elements and their products (by R. Nedimović) in the Lower Pontian silt of the Srbovo bore hole were conducted on 10 samples. The uranium content is below the clark of similar rocks in the Earth crust (Vinogradov 1962). The thorium content is around the clark. The content of potassium is well below the clark. The given values (Tab. 3) could be taken as reference for the region of the westernmost part of the Dacian Basin (close to Kozlodui power plant).

Table 3:

	Content	Average	Clark	[ppm]
U	2.51-3.70	3.03	3.2	"
Th	7.60-13.15	10.16	11.0	"
K	1.38-2.16	1.74	2.28	"
Th/U	2.36-4.86	2.62	3.44	

Organopetrographic analysis (by Z. Popović) indicated a mostly coally type (intertinit) of kerogen, in very small amount between 0.5 and 3.5 %, average 1.3 %. A combined kerogen of sapropel or sapropel-coal type is rare and occurs in amounts of 0-1.0 %, average 0.41 %.

Paleomagnetic measurements give mostly reverse polarity of the Lower Pontian of the Srbovo bore hole. Few short intervals of the normal polarity were explained as the disturbance (breccation) of beds by sea currents (Milićević et al. 1988). Now a comparison of the polarity records from the drill hole Tiszapalkonya-1 (Elston et al. 1990) indicates a nearly good coincidence (Fig. 15). The polarity intervals from 35 to 125 m in the Srbovo hole is correlable to approximately 45 m of the column (between 900 and 1000 m) of the Tiszapalkonya-1 hole. Faster sedimentation in the marginal part of the Dacian Basin (Srbovo) has to be expected.

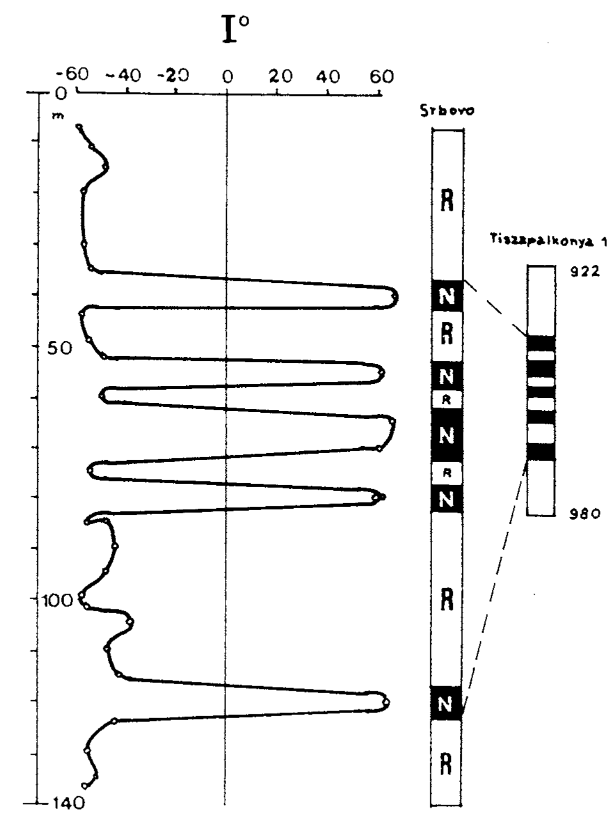

Fig. 15. The changes of inclination and polarity intervals of the Srbovo bore hole in comparison with Hungarian Tiszapalkonya-1 drilling (Elston et al. 1990).

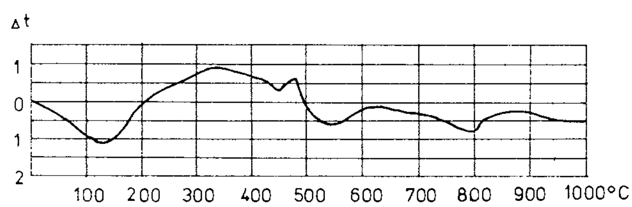

Fig. 16. The differential thermal analysis diagram bearing the siderite endoreaction pick. Sample from the depth 53.05-53.10 m.

Mineralogy and petrology

The main rock type is silt which is regularly interbeded with sideritic silt. Some cm-intercalations of marly limestone and sandy marlstone also occur.

The mineralogical analyses of the silt and sandy silt show the presence of feldspars (plagioclases), chlorite and pyrite (X-ray analyses); beside them clay minerals are determined (mostly montmorillonite, enough kaolinite), calcium carbonate, and small amount of quartz, sericite and organic matter (DTA, IR). The qualitative analysis of the sandy component from the upper part of the bore hole (by V. Jakovljević) corroborated the plagioclases and orthoclases, microcline, muscovite, biotite, chlorite, rare zirconium, garnets, amphiboles, staurolite, pyroxenes and zoisite; quartz is the main constituent of the fine sand, grains are angular or partially rounded; there are some chert, quartzite and occasionally volcanic glass.

Marly limestone and limy marlstone. In several of the thin (5-15 cm) well consolidated interbeds of muddy limestone of the micrite type and the limy-sandy marlstone (det. by V. Jakovljević) $CaCO_3$ appears in amounts of 18.0-56.6 percent. The terrigenous component varies from approximately 1 to 10 %, the size of grains is ca. 0.05 mm. In the terrigenous component quartz, always corroded (sometimes by the carbonate cement), and plagioclase intensively calcitised and corroded on its periphery are most frequent. The fossil content - *Limnocardiidae* - have their inflation excellently preserved but their shells are resorbed.

Sideritic silt. The thin (2-10 cm) beds of whitish-yellow colour are numerous (Pl. I: Figs. 1, 2, 5) but particular beds vary in colour. The colour is the result of siderite content and silt being present in the bed in a larger or smaller amount. The beds with a high content of siderite, being for a while open to the air, became limonitised and gained the dark ochre nuance.

Siderite grains are cryptocrystalline, probably precipitated from the sea-lake water, but it is also possible that they are deposited from the interstitial water. Siderite was spotted by differential thermal analysis (Fig. 16).

Siderite interbeds are found in the Lower Pontian of neigbouring Kusjak (Dodiković et al. 1992). The interbeds and concretions are known from Badenian in NW Bulgaria (Trašliev et al. 1962). There is a small content of the siderite in silt from the palustro-lacustrine Middle Miocene (Krstić et al. 1994). Some dm-layers of sideritic dolomitized carbonates are found in the marine Early Oligocene (Krhovský & Djurašinović 1993), also.

Melnikovite-pyrite. Melnikovite appears in three forms: 1 - sub-mm gelose black globules, 2 - coatings on the bedding plane, and 3 - replacements of organic matter (Figs. 17-19).

The thick coatings or thin intercalation of melnikovite contain some of framboidal pyrite (det. M. Stojanović). Some of these coatings on the fresh core, have the whitish-pink colour (Pl. I: Fig. 4) later turned dark. Such concretions often have elongated form as a few dead worms were rolled together. There could also be some other organic matter brought together by slow water movement. Around such "concretion" there were sometimes silt shadows.

Fig. 17. Numerous gelose black melnikovite globules and thin coatings on the brecciated silt with *Zagrabica* cf. *cyclostomopsis*. Sample from 130.9 m. Magnification 2×.

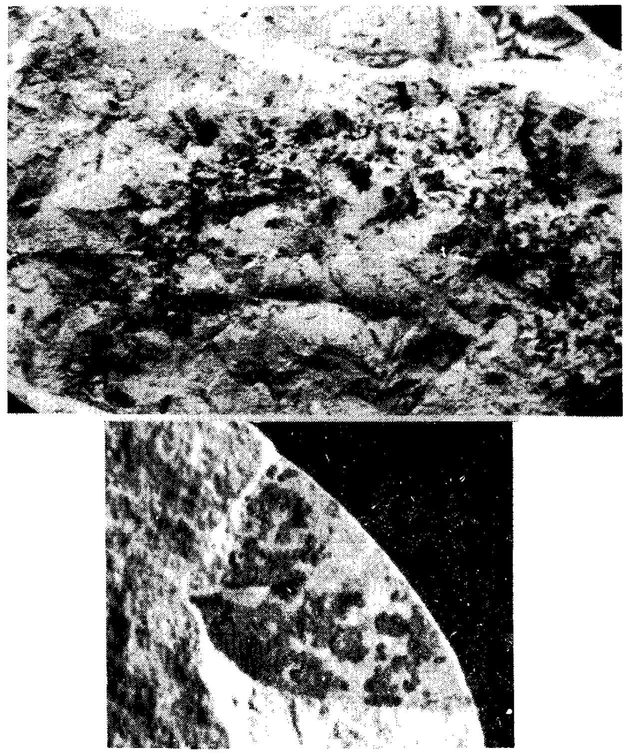

Fig. 18a, b. Melnikovite as coating (nuclei); *Labiatocandona* and *Camptocypria* differently oriented and broken due the sag. Lower side of the sample 86.6 m. Magnification 1.5×.

Fig. 19. Organic (plant?) remnants replaced by melnikovite. Sample from 87.8 m. Magnification 35×.

Fossils

On the basis of fossils it was possible to reconstruct the paleoenvironment. The age of the sediments was previously (Stevanović 1990, etc.) determined as the Lower Pontian.

Flora. Among floristic remains there are palynomorphs, some leaves and plenty of different fragments, mostly wood.

Out of 20 palynologicaly analysed samples only two contain microflora (det. Lj. Dimić) (Tab. 4):

Table 4:

	10.7	129.8
Lygodiosporites sp.	+	
Polypodiaceosporites sp.	+	
Pityosporites microalatus	+	+
Pitiosporites labdacus	+	
Pityosporites podocarpoides		+
Subtriporopollenites simplex	+	
Triatriopollenites myricoides		+
Polyporopollenites carpinoides		+
Monocotiledonae	·	+

The palynomorphs of the other samples are spilled basinwards, farther from the place where Srbovo lies now.

Rare findings of badly preserved leaves (*Dicotiledonae* det. Lj. Milovanovič) on 95.5–97.3 m have no environmental meaning. Some remnants of *Monocotyledonae* swampy flora were found at 108.95 and 125.05 m. The only determinable one was a twig of *Taxodium dubium* a swamp tree known from the whole Neogene.

Globular thick shelled seeds ornamented by pits, ca. 1.5 mm in diameter, were observed in short interval 84.45–89.5 m.

Microscopic plant debris are present throughout the column. Macroscopic plant fragments start from 79 m downwards. Some of them resemble the *Pinus* needle, other the small straight twigs (Fig. 24) and debris of branches.

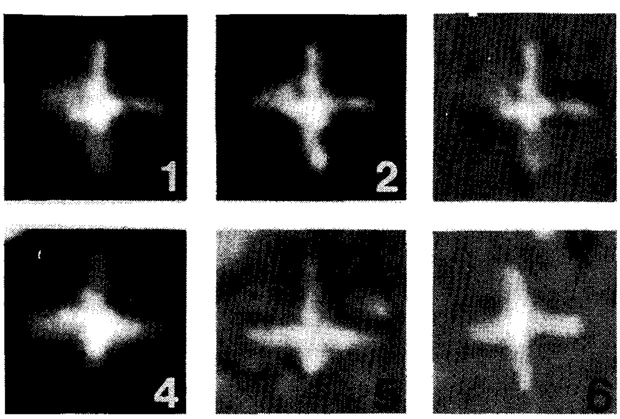

Fig. 20. Cross-shaped nannoliths. **1-2-4** - cross nicols; **3-5-6** - ordinary light (**1-3**, **4-6** are the same specimens). Bar 10 μm.

Calcareous nannofossils. In the Lower Pontian of the Srbovo bore hole rare calcareous nannofossils were found: cross-shaped nannoliths and nannoforaminifers(?). Apart from these there are extremely rare redeposited Neogene and Cretaceous nannofossils.

The cross-shaped nannoliths (Fig. 20) are small objects (ca. 5 μm). They have a prominent central knob and arms meeting at 90°. The knob is also cross-shaped. In appearance they resemble four arms discoasters (Eocene *D. cruciformis* and especially marine Pliocene *D. tamalis*) but because of small dimensions, different optical and ecological properties they must be separated from any taxon of calcareous nannoplankton.

The nannoforaminifers(?) from the Srbovo bore hole are exclusively globular - only one chamber of maximal diameter ca. 22 μm. They have a thick, unperforated shell-wall, indicating an inorganic origin (Fig. 21). The cross-shaped nannoliths and nannoforaminifers "might be the key fossils for Pontian" (Mihajlović 1989), the Lower(?) one.

Redeposited nannoplankton has been found in one third of the samples. It belongs to the Neogene and Mesozoic, a part of the latter being key fossils for the Maastrichtian (closest outcrops are in Bulgaria - Cheshitev et al. 1989).

Fauna. The most numerous species among mollusks (Stevanović 1990b) is *Limnocardium otiophorum orientale* often represented by juveniles (j). It was not possible to record every finding on the table; numbers are not specimens, but the fre-

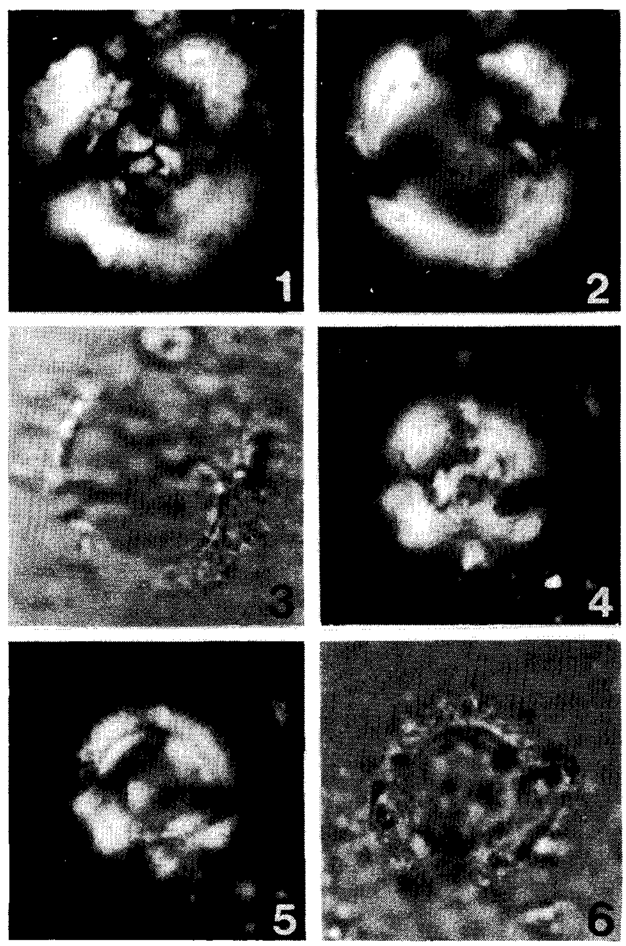

Fig. 21. Nannoforaminifers(?). **1-2-4** - cross nicols; **3-5-6** - ordinary light (**1-3**, **4-6** are the same specimens). Bar 10 μm.

Table 5:

Depth in m: / Species:	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140
Congeria rumana	3	1				1	2																				
Dreissena anisoconcha	2	3	4	2		1	4	1	1		2	1		1		1							2		1	4	
Carinatocon. digitifera	1	2					1	1				1	1	2		3	2	1		1		2	1	2	1	3	3
Paradacna abichi		3	1		2		3	2	1		2		1	2	2			2	1			2		1			
Limnocardium mayeri		2	1	2	?								1														
L. otiophorum orientale	1		1	1	1		1	4			4	1	1	1	1	1	4	3	2		2		1		2	4	2
Valenciennius elliptica			1		?		2				1	1								1	2			1			
Pseudocatillus simplex					1		1				1	1															
Zagrabica ampulancea	1				1				2															1	1		
Paradacna retowskii ossoinae							2		1			1															
Valenciennius suchovae							1	1	1	1		1				1				1	1	1	2	3	2		
Pisidium cf. *krambergeri*	j									4			1	?	?	j			j	?	j		j				j
Zagrabica cf. *cyclostomopsis*					1						3	2		5	6	3	5	2	2		3	2			1	1	1
Lymnaea (Radix) cf. *kobelti*													1	1				1									
Valvata sp.																	2					1					
Hydrobia vitrella																1	1										
Melanopsis esperoides																	1										
Succineid																					1						
Paradacna ex gr. *okrugici*																						2					1
Bithynia operculum																										1	

quency of findings (depths inside 5 m intervals). To prepare Tab. 5 the report of P. Stevanović was used.

Ostracodes of the Srbovo bore hole were determined by Krstić (in Krstić & Stancheva 1990: 753–754). The list of species of the uppermost and the lower part of the column is given in Tab. 6.

Fish bones are spread out along the whole column but they are scarce. Fish bones are a little more frequent below 108.2 m where pyrite is present hence the environment was poisoned. Fish vertebres, up to 2.5 mm in diameter, are most common. Rare scales belong to the cycloid type. Two elongated otoliths (86.95 and 130.9 m - Fig. 23) may belong to the genus *Lota* (Anjelković, in: Krstić 1991b). A single tooth with arrow like pick may belong to the genus *Lucioperca* (Simonović, in: ibid).

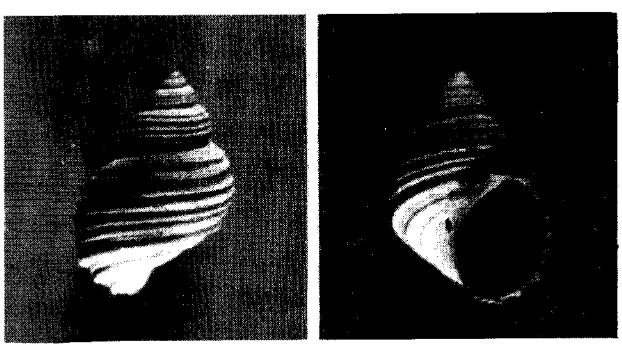

Fig. 22. *Zagrabica* cf. *cyclostomopsis* Brusina, juv. Sample from 80.25–80.35 m. Magnification 6×.

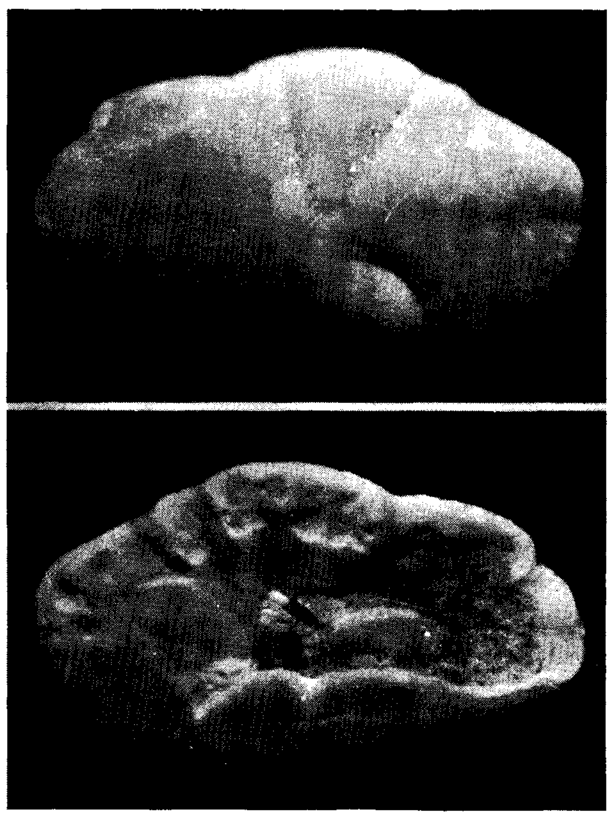

Fig. 23. Otolith inner and outher side. Sample from 86.95 m. Magnification 35×.

A small leg bone of the bird (Fig. 8) should belong to a songbird (Vesna Malez personal communication).

Facies fossils. The most contrasting facies fossils in the Srbovo bore hole are *Valenciennius* sp. *div.* and *Zagrabica* cf. *cyclostomopsis*. Nearly every mollusk is facies bounded, except for the *Limnocardium otiophorum* appearing both in silt and sandy silt.

The gastropod *Zagrabica* cf. *cyclostomopsis* (Stevanović 1990a) with a thick, round and ribbed shell, accommodated to the high energy environment is typical of brecciated intervals.

Table 6:

	4.45	5.6	115.4	116.1	118.2
Amnycythere cf. *alizadei*	+++	+	-	-	-
Camptocypria ossoinaensis	-	+	-	-	-
Typhlocypris gr. *selenae*	+	-	-	-	-
Amnicythere palimpsesta	+	+	+++	+++	+++
Loxocorniculina djafarovi	+	+++	-	+++	+++
Amnicythere sp. *(tuberculata)*	-	+	-	-	-
Euxinocythere visenda s. Olteanu	+	+	-	-	-
Chartocythere sp. (Krstić 1975)	juv	-	-	-	-
Loxocauda aff. *azeri*	-	+	-	-	-
Maeotocythere sp. I	-	+	-	-	-
Amnicythere lata s. Olteanu	+	-	-	-	-
Cypria tocorjescui	juv	+	+	+++	+
Labiatocandona sp. (nefrica)	+	+	+++	+	+
Amnicythere anormalis	-	+	+++	-	+
Bakunella cf. *guriana*	-	+	-	-	-
Amnicythere subcaspia	-	+	+	-	+++
Loxoconcha mokranjci	+	+	+	-	+++
Syrmiella arcuatoides	-	-	+++	-	-
Typhlocypris centropuncatata	juv	-	+	+	+
Amnicythere liticoides	+	+	+	+	-
Maeotocythere praebaquana	+	+	+	-	-
Amnicythere sinegubi	+	+	-	+	-
Pontoleberis pontica	+	-	-	-	-
Amnicythere crassa	-	-	-	+	-
Euxinocythere cf. *naca*	-	+	-	-	-
Amnicythere limbata s.Stancheva	+	-	+	-	-
Amnicythere polymorpha	-	-	-	+	-
Maeotocythere marijae	+++	+	-	-	+
Euxinocythere suzini	+++	-	+	-	-
Amnicythere rosalinae	-	-	-	-	+
Maeotocythere sp. II	+++	-	-	-	-
Zalanyiella gr. *rurica*	+	-	-	ind	-
Serbiella sinistritruncata	-	+	-	-	juv
Amnicythere costatella	+	-	-	-	-
Hastacandona sp. ind.	-	juv	+	-	-
Amnicythere sp. nov.	-	-	+	+	-

Signs means: +++ frequent, ++ not frequent, + rare, - not present

Sandy environment (i.e. sandy silt) is characterized by *Congeria rumana* and *Camptocypria ossoinensis*. *Limnocardium (Arpadicardium) mayeri* appears in less sandy environment. All these species were found in the upper part of the column down to 41.0 m and in 61.2-69.2 m interval.

Carinatocongeria digitifera (Fig. 24) and *Dreissena anisoconcha* (Pl. I: Fig. 2), which appear in many parts of the column, indicate higher water energy by anchoring themselves with byssus. In Srbovo they do not distinguish sandy from brecciated silt, but they are often transported, as can be seen from the silt shadows behind some valves. In most cases the valves were separated, but occasionally both valves are closed (see Fig. 2).

Fig. 24. *Dreissena anisoconcha* Andrusov, carbonized twig, *Zagrabica* cf. *cyclostomopsis* Brusina and melnikovite globules. Sample from 130.9 m. Magnification 1.5×.

Paradacna abichi, a low energy key fossil, was found with open valves, both together in stable position (Fig. 25), and only once with closed valves. Closed valves are also observed in some *L. otiophorum orientale*.

Valenciennius - a large and very wide open gastropod (Fig. 26) is quite common, demanding the quiet water "of the bottom of a slightly deeper part of the neritic zone" (Davitashvili 1941 : 201, 558; see also Taktakischvili 1967 : 176). The entire *Valenciennius* shells were found in undisturbed silt, while their fragments appear in brecciated intervals. Some shells have the natural position (Pl. I: Fig. 6), but some are unstable, turned in up side down position. Both cases are nearly equal in number, the stable a little more frequent. The cause of the reversed position of *Valenciennius* shells is not known. Wave action will brake its fragile carapace.

Candonid are the dwellers of the superficial part of the bottom mud.

Terrestrical fossils such as *Succineid*, bird bone, *Bithynia* operculum, and *Taxodium dubium* twig are concentrated between 110-115 (first two) and 133-138 m (other two). The leaf imprints (95.5-97.3 m) could be encounted here, but not the wood fragments, functioning as bioclasts.

Fig. 25. *Paradacna abichi* (R. Hoernes), the two middle valves belong to single individuum. Upper side of the sample from 11.0 m on which lower side, in sandy silt, *Limnocardium mayeri* M. Hoernes is placed. Natural size.

Fig. 26. *Valenciennius* cf. *suchovae* Taktakischvili from the middle of the paleomagnetic sample 124.5-124.6 m. Magnification 1.2×.

Conclusion

The environment belongs to the open basin (without islands) not far from the shore, in the area at the edge of the sea current. The numerous sideritic intercalations (without dinocist remains, but they could be spilled together with palynomorphs), not exactly measured, did not give any of Milanković curves (computed by M. Djurašinović); there is possibility that the siderite is connected to an unknown hydrothermal activity (suggested by A. Antonović). This nutrient pure basin has a small number of fish, some of which feed on mollusks.

The environmental (cf. Dimitrijević & Dimitrijević 1989) evolution is as follows:

The lowermost sediments were deposited in a quiet environment close to the shore. Some terrestrial organisms (*Bithynia, Succineid,* bird bone, plant leaves) were transported from the land. Redeposited nannoplankton (from undetermined Mesozoic, from Maastrichtian and Badenian) are the commonest here, due to the erosion of older sediments. The intercalations with the pyritic concretions indicate periods of stagnant water. Sea currents sometimes disturbed the water, brecciating the just deposited silt and oxygenating the water so that benthic organisms could again spread out. The brecciated intervals alternate with the ones bearing *Valenciennius,* belonging to the quiet water environment.

In the upper part of the column the influence of the sea currents diminishes. Gastropods *(Lymnaea kobelti)* could be turned up side down and the closed valves pelecipods placed vertical or buried in living position. This was the part of time with the deepest water - around 30 m. The dark worm boring beds are more frequent where they alternate with brecciated silt, maybe due to oxygen reaching into subsurface mud, enabling breeding of worms.

The quiet water sediments alternate with brecciated silt in the lower and with the sandy silt in the upper part of the sequence. *Valenciennius* as quiet water indicator is quite common here (Pl. I: Fig. 6). The transition to a slightly sandy environment started deep down in the column (69.2 m) but it is apparent above 41 m. Dark boring of worms, common in its middle part where limestone beds also occur, indicate oxygenating of mud holes before an early postsedimentary reductions process started. Limestone underwent diagenesis by deposition of calcite from interstitial water at an early stage.

The environment of higher water energy, close to the wave base, is represented by sandy silt in the uppermost column part, above 7 m where *Congeria rumana* is present. Fine sand laminae occur here and there, and sand was brought and spread out by waves.

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