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Pliocene deposits of Rišňovce Depression - Volkovce Formation

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Abstract. Sandy deposits of the Pliocene Volkov Formation in the Rišňovce Depression were studied at the localities of Dolné Otrokovice, Dolné Trhovište, Tepličky and Piesočnica near Behynce (Fig. 1). They probably represent sandy deposits of rivers entering a fresh-water lake. Palaeoflow direction, detected from vector measurements of cross lamination, is from NW to SE. Heavy mineral analysis suggests two possible source areas. Rutile, zircone, ilmenite and garnet suggest the crystalline source area, which according to the palaeoflow direction (from NW to SE) is located in the Považský Inovec Mts. The occurrence of β quartz suggests a source area with volcanic material which might have been delivered by tributaries from the Ruskovce Formation found in the Bánovce Depression.

Key words: Pliocene, Danube Basin, Rišňovce Depression, sedimentology, fluvial deposits, delta

Introduction

The sedimentary fill of the Rišňovce Depression consists of Neogene deposits transgressively and discordantly overlying pre-Neogene rocks. Regional geologic investigation supported by stratigraphic study of borehole profiles (Maglay et al., 1997) is being conducted in the study area.

The Pliocene Volkovce Formation and the Pontian deposits crop out at several localities in the study area. They are composed of variegated calcareous clay containing a variable sand admixture and variegated sand interlayers. Older authors refered to them as the variegated series. They were correlated with the G-H Zone of the Panonian, later with the Pontian and finally they were assigned to the Pliocene (Priechodská and Harčár, 1998).

Deposition prevailingly occurred in the river-dominated environment. We did petrographic, sedimentologic and grain-size analysis of the deposits.

Geologic background of the study area

According to the regional-geomorphologic division of the Slovakia the study area is a part of the Danube lowland. It occurs in the sub - units present in the Nitra Hills and the Nitra flood plain (Mazúr and Lukniš 1978). Following the regional geologic division of Slovakia the area is a part of the Rišňovce Depression belonging to the Danube Basin (Vass et al. 1988).

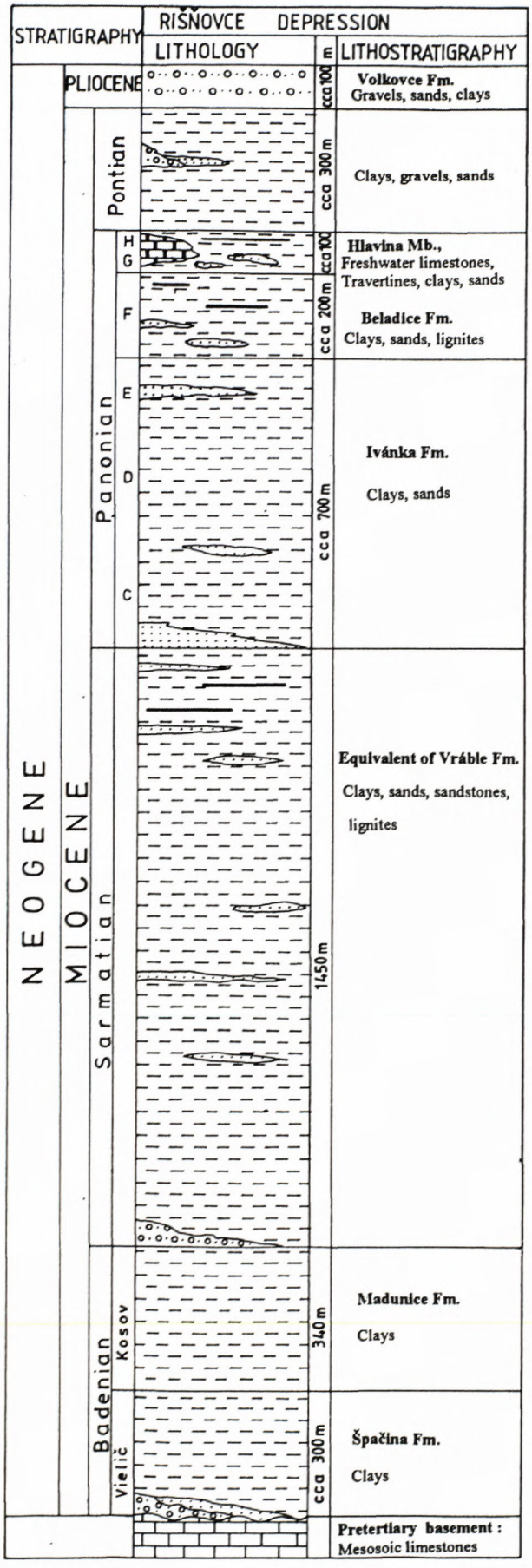
The Early to Middle Miocene represents an extensional synrift stage of the Danube Basin development (Kováč and Baráth 1995; Kováč et al., 1997). During the Middle Miocene the subsidence of the Rišňovce Depression was controlled by normal NE-SW trending faults. The sedimentary fill is mostly composed of sandy-clayey marine deposits commonly containing a tuff admixture. In the northern marginal area deltaic and brackish deposits occur (Vass et al., 1990). A sea-level fall connected with the erosion of older deposits is documented in the area of the Alpine-Carpathian junction (Hudáčková and Kováč 1993). Marine transgression during the Late Sarmatian resulted in formation of depocenters in the N and NW parts of the Danube Basin. The Rišňovce Depression, with prevailing deltaic deposition, represents one of these depocenters. The brackish development of the Sarmatian sea was caused by opening of the Badenian seaways to the Mediterranean area. The Panonian and Pontian subsidence, representing a postrift stage of the Danube Basin development, was still controlled by normal faults of the extensional regime along the northern margin of the basin. The deposition during the Late Miocene was influenced by a deltaic environment developing into a limnic estuary (Jiříček 1990).

The sedimentary fill of the Rišňovce Depression consists of the Badenian, Sarmatian, Panonian, Pontian and Dakian (Tab. 1), eventually also of Romanian deposits (Buday et al., 1962, Vass et al., 1990).

Badenian: Deposition in the Rišňovce Depression commenced by the Middle Badenian Špačina Formation (Jiříček 1985) transgressively and discordantly overlying the pre-Neogene deposits composed of the Mesozoic rocks of the Tatricum and Fatricum (Fusán et al. 1987). Špačina Formation consists of clayey-sand, sand and minor gravel deposits (Biela 1978).

The Late Badenian is represented by the Madunice Formation (Jiříček 1978), consisting of grey clay and calcareous clay with sand layers.

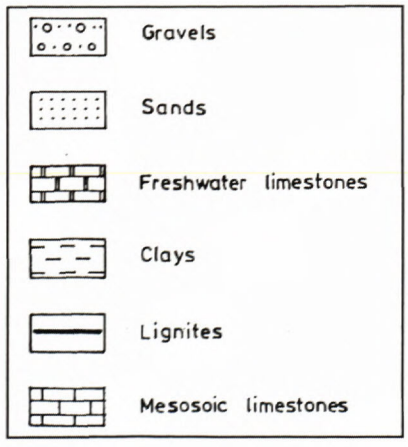
Sarmatian: The Sarmatian deposits represent the equivalent of the Vráble Formation (Harčár et al., 1988) and they can be divided into conglomerate-sandy, sandy-clayey and clayey development.



Panonian - Pontian: During the Panonian and Pontian deposition continued in a fresh-water environment. The Panonian (Zone A-E, Papp 1951) sediments are the analog of the Ivanka Formation (Harčár et al. 1988) and they are mainly known from the western part of the study area. They are mainly of a sandy-clayey character. Zone A, with *Miliamina subvelatina* and *Trochamina kobleri,* is several meters thick and is composed of clay with a sand admixture. Zone B, with *Hungarocypris auriculata - Amplocypris globosa,* is represented by grey calcareous pelites. Zone C is biostratigraphically documented in the Ripňany - 1 borehole (Gaža 1968) and consists of grey sandy clay with layers of calcareous sand. Besides the clay and sand, the formation also contains layers of dark grey and black clay. Microfaunally it is characterized by the ostracod genus *Pontionella acuminata* and *Cyprideis ventricea.* The Panonian zones C - D - E are documented by an abundant fauna of limnocardium - *Limnocardium conjugens* (PARTSCH), *Limnocardium brunense* (HOERNESS). Ostracoda are represented by *Pontionella acuminata* and *Cyprideis Ventricae.*

The Beladice Formation consists of deposits assigned to the Panonian Zone F (Papp 1951). They were assigned to the Pontian in the past. They are the analog of the beds commonly called coal series and they are characteristic by clayey-sandy layers containing lignite lenses. The Zone F is stratigraphically documented by boreholes Topoľčany 1 - 6 drilled east of the study area (Lunga 1965). Zone F is biostratigraphically documented by the occurrence of the macrofauna tests with preserved forms of *Limnocardium conjugens* (PARTSCH) and *Congeria czejiki.* Also, beds containing plant remnants *Glyptostrobus europaeus* (BGT) Hoer and fragments of oogonia characea. *Melanopsis bauei* (FER.) and fragments of *Bithynia tentaculata* (L.), *Congeria neumayrii* (ANDR.), *Planorbis sp.* were identified from the basal part of the Zone F. The plant remnants are represented by oogonia fragments of *Chara meriani* (UNGER).

The Hlavina Member (FORDINÁL and NAGY 1997) is assigned to the Panonian H Zone (PAPP 1951). The deposits are characterized by the occurrence of freshwater and limnic limestone associated with gravel, sand and clay deposits.



Tab. 1. Lithostratigraphic column of the neogene deposits of the Rišňovce Depression. (compiled by Fordinál 1997).

Former names of lithostratigraphic units	Dividing of the Pannonian into zones. The zones in the stages after different authors.								Lithostratigraphic units of the Danube basin	
	Papp, 1951		Jiříček – Švagrovský, 1975		Papp, 1986		Rögl et al., 1993		Pricchodská et al., 1988	Fordinál – Nagy, 1997
„variegated„ series	Pannonian	H	Pliocene	Dacian	Miocene	Pontian	Miocene	Pannonian	Volkovce Fm.	Hlavina Mb.
„blue„ series		G								
„coal„ series		F	Miocene	Pontian					Beladice Fm.	Beladice Fm.
		E		Pannonian		Pannonian			Ivánka Fm.	Ivánka Fm.
		D								
		C								
		B								
		A								

Tab. 2. Opinions of the different authors on subsumption zones into stages, an overwiev. (compiled by Fordinál & Nagy 1997).

Pontian: Deposits of commonly called clay series of the Zone F or Beladice Formation were assigned to the Pontian in the past (Priechodská & Harčár 1988). Because the deposits are assigned to the Panonian, sensu Fordinál and Nagy (1997), the up to now nameless freshwater deposits in the basin overlying the deposits of Hlavina Member, are assigned to the Pontian.

Dacian: The Pliocene is only represented by the Volkovce Formation in the study area. The deposits of the formation are mostly covered by the Quaternary sediments (Priechodská and Harčár 1988) and crop out only in scattered sites. They occur together with the Pontian deposits mainly in the western part of the area.

The deposits were only identified as the variegated series by the older authors and they were correlated to the Panonian Zones G - H, later to the Pontian and recently they were assigned to the Pliocene (Dacian). The deposition occurred in freshwater, either in a lacustrine or a fluvial environment. The deposits of the Volkovce Formation are represented by variegated calcareous clay with a variable admixture of sand grains. Layers of grey calcareous sand as much as 10 m thick and locally also layers of sandy gravel occur in the clay. Immediately beneath the Quaternary deposits grey fine- and coarse-grained calcareous, yellowish-gray and brownish-yellow sand with layers of weakly consolidated sand occur. This sand contains irregular layers of fine-grained gravel. According to Elečko (Pristaš et al., 1998) the deposits originated in alluvial fans and deltas.

Suggestions concerning the stratigraphic division of the Panonian or Pontian are summarized in Table 2. The lithostratigraphic division of the Panonian - Pliocene deposits, considering the latest suggestions (Fordinál and Nagy 1997) is following:

1. Ivánka Formation - Panonian (Zones A - E)
2. Beladice Formation - Panonian (Zone F)
3. marginal Hlaviná Member - Panonian (Zone H) and its equivalent in the basin
4. Volkovce Formation - Dacian

Methods

Sediment analyses in the study area are based on field processing represented by a detail sedimentologic documentation of the outcrops and samples. The samples were later processed in laboratories.

Methods of grain-size analysis, hydraulic methods for measurement of the smallest grain size fraction, heavy mineral analyses aided by X - ray and DT analysis were applied. The X - ray analyses from five samples taken from the clay rip-up clasts were done at the Geologic Survey of Slovak Republic. The RTG diffractograph DRON - 3 CuK alpha radiation, filter Ni associated with the program for powder analysis by the ZDS system were used for the RTG analysis of clay minerals.

The samples with a grain-size fraction below 0.002 mm were processed in the laboratory. The samples were diluted by distilled water and after addition of 15% HCL solution they were scrubbed 2 - 3 minutes by ultrasound. The mixture, homogenized by ultrasound, was dropped on a mount and thin sections were made. The samples were saturated by ethylenglycol.

Heavy minerals from the grain-size fraction in the 0.25 - 0.1 mm and the 0.1 - 0.05 mm ranges were separated in bromoform (gauge mass 2.88 kgm^{-3}). The separated heavy fraction was divided by a magnet in to a magnetic fraction and further, by an electromagnet, into a dia-magnetic fraction and para-magnetic fraction.

Lithology

The deposits of Volkovce Formation are well exposed near of Dolné Otrokovice, Dolné Trhovište, Tepličky and Piesočnica all near Behynce in the area of the Nitra Hills (Fig. 1).

The section of Dolné Otrokovice DO/1, DO/2, is shown in figures 2 and 3. It is exposed in a sand pit that lies 500 m NW of the village. The outcrop mainly consists of coarse-grained sand (the sand content in the sample is 69.93%), fine-grained sand and silt. The coarse-

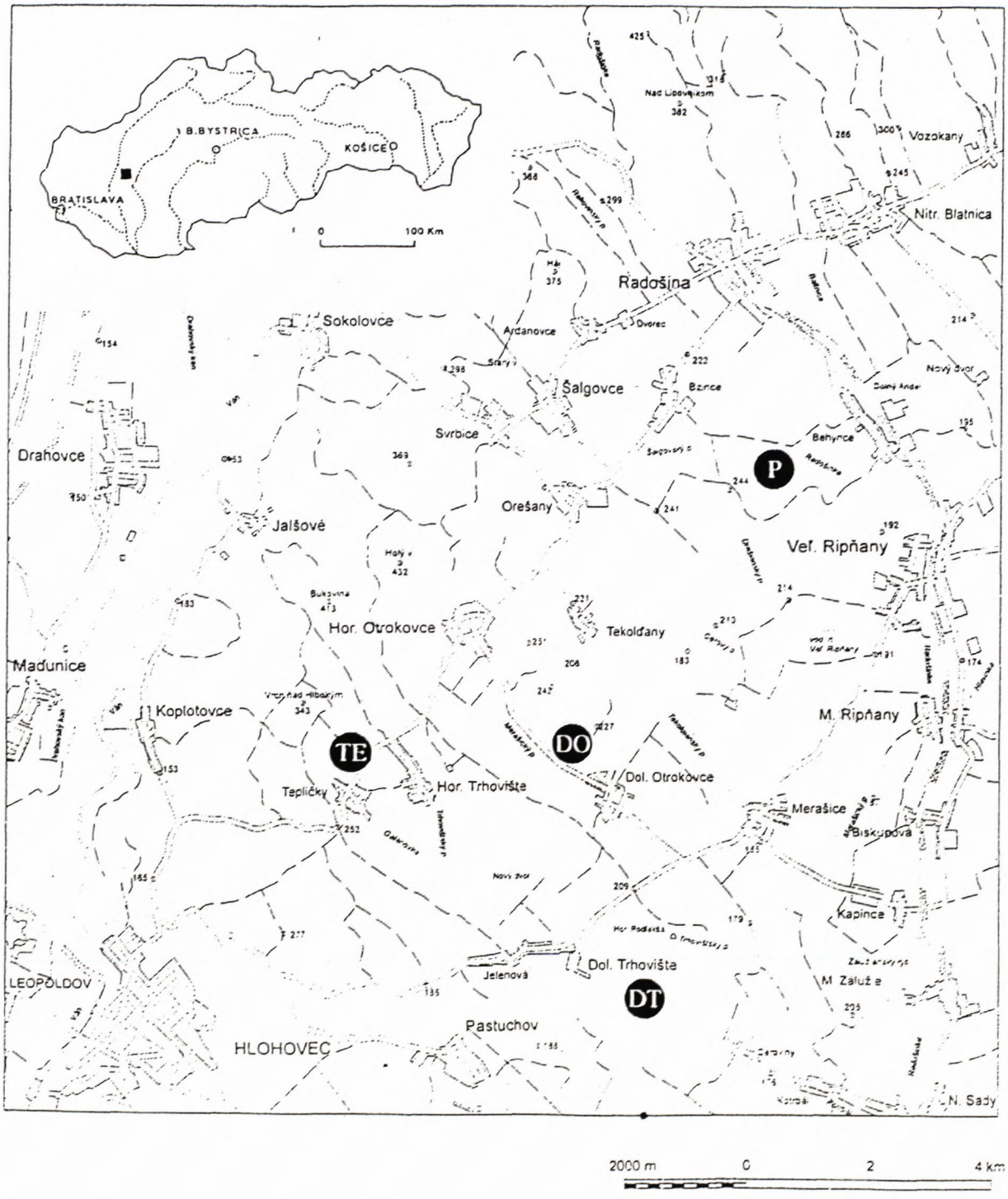
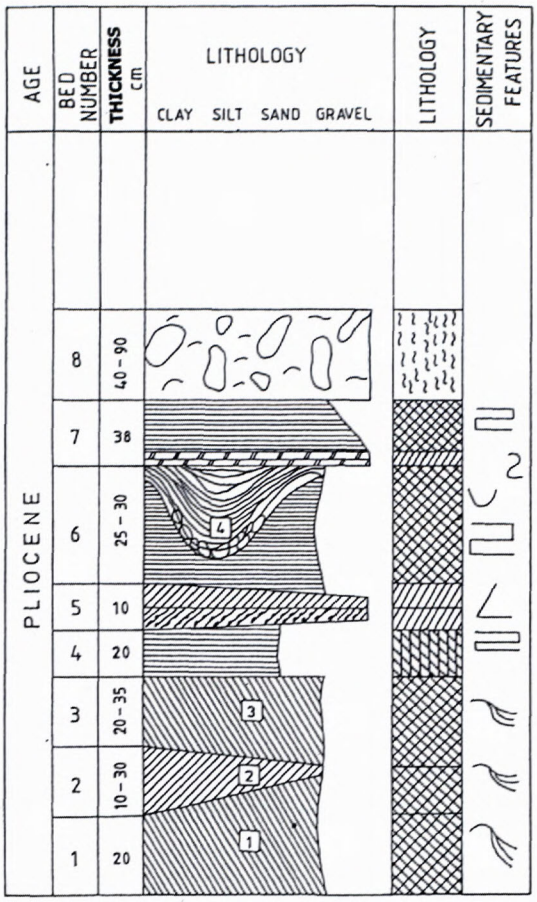


Fig. 1: Schematic map and location of the studied localities of Dolné Otrokovce (Do), Dolné Trhovište (DT), Tepličky (TE), Piesočnica near Behynce (P).

grained sand commonly contains an admixture of fine-grained gravel (11.96%) with clasts up to 1 cm. The admixture of fine-grained sand is 12.16% and silt admixture is 12.73%. The sand is yellow, ocherous-yellowish and brown. Sand grains are medium sorted.

The section of Dolné Trhovište DT/1 is shown on figure 4. It is situated on slope Dingov in the middle of the field about 1 km E of the village of Dolné Trhovište. It consists mainly of fine-grained sand (64.01 %). The medium-grained sand is present to 10.19%, the coarse-grained sand comprises 4.57 % and fine-grained gravel makes up 0.07 %. The mean silt content is 17.2 %. The sand is medium sorted and is grayish-white, white, dark-yellowish and rusty-brown.



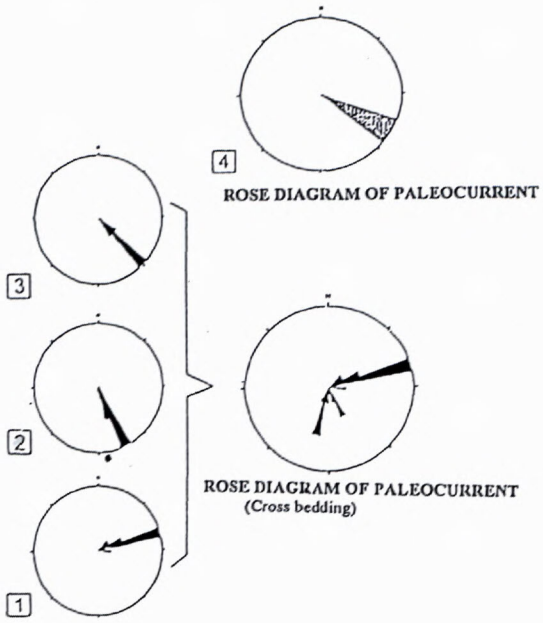
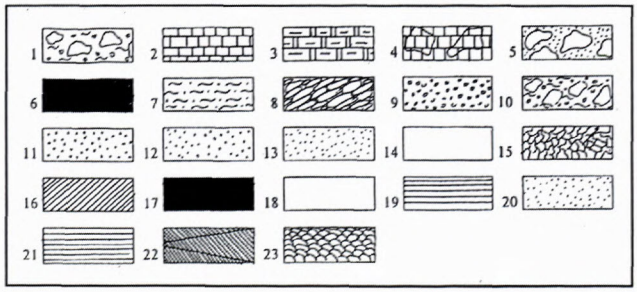


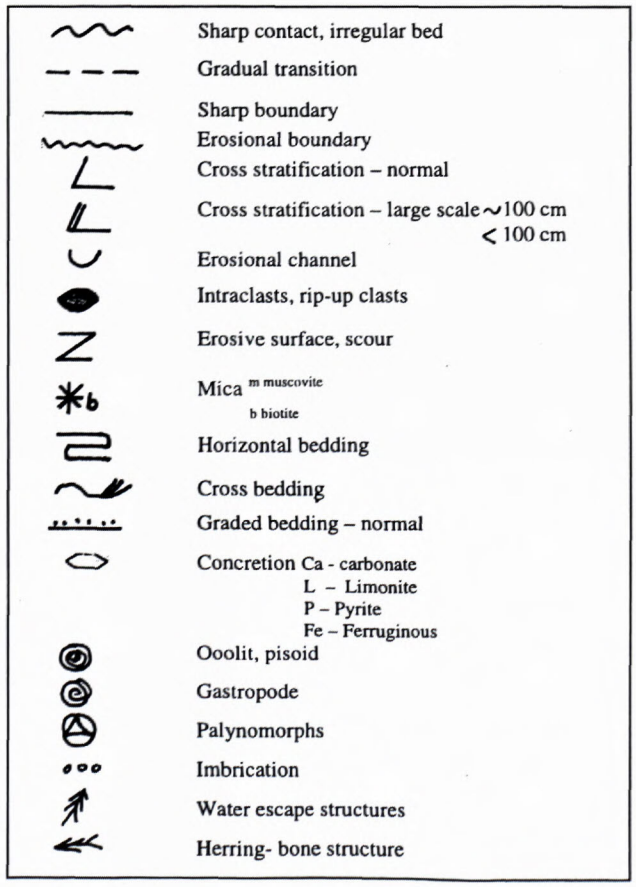
Fig. 2. Section of Dolné Otrokovce DO/1 (n = 30)



Legend to Fig. 2–6

1 – oolitic limestone, 2 – massive carbonate beds, 3 – porous carbonate, travertine, 4, 5 – fine-grained carbonate with calcareous matrix, 6 – greyish clay, 7 – lake marl, 8 – conglomerate, 9 – fine-grained conglomerate, 10 – gravelly loam containing occasional pebbles, 11 – coarse-grained sand, 12 – medium-grained sand, 13 – fine-grained sand, 14 – massive sand without lamination, 15 – calcareous crust, duricrust, 16 – $CaCO_3$ content, 17 – $MgCO_3$ content, 18 – calcite content, 19 – CaO content, 20 – MgO, 21 – horizontal bedding, 22 – cross bedding, 23 – ripple-cross lamination

Sedimentary features to the Fig. 2–6 ➡



The upper part of the outcrop consists of more consolidated calcareous deposits - duricrust, which probably originated during an arid climate.

The section of Tepličky (TE) is shown on figure 5. The section occurs west of the village in the valley about 500 m from the church. The outcrop consists of coarse-grained sand layers and fine-grained gravel. Pale-brown and brown coloured fine-grained gravel contains clasts up to - 1.5 cm. The sand contains interlayers of lithified conglomerate with carbonate clasts up to 5 cm in diameter, clay intraclasts of ocherous-yellowish colour and spheric concretion of Fe up to - 0.5 cm, too (Fig. 4).

At the base of the outcrop consolidated coarse-grained sandstone occurs. It consists of quartz and feldspar clasts lithified by calcite. Locally mica and calcite clasts also occur. Organic matter does not occur in the sandstone.

The section Piesočnica near Behynce (P) is shown figure. 6. The outcrop occurs about 1.5 km SW of the village of Behynce. It is the largest and most extensive outcrop in the area with coarse- to fine-grained sand beds. The sand is gray-white and ocherous-brown and is medium sorted. Black claystone intraclasts occur between the beds No. 10 and 11.

The upper part of the outcrop consists of fine-grained gravel containing quartz and carbonate clasts, kaolinized rocks and calcareous concretions (Photo 8).

Sedimentologic features, transport directions

The Volkovce Formation consists of gravelly and sandy fresh-water sediments deposited from suspension in lacustrine and fluvial environments. Sedimentary structures are mainly represented by cross bedding and less by trough bedding.

The deposits are conspicuously cross- and trough bedded at outcrops nearby Dolné Otrokovice (DO/1, DO/2, Figs. 2 and 3, Photos 2 and 3). The dip direction of inclined laminae in the cross-laminated deposits suggests transport direction from NW to SE. The laminae dip varies from 15° to 25°.

At the outcrop DO/1 in the bed No. 6 (Fig. 2), 30 cm deep and 1.10 m wide erosional channel was found (Photo 1). The channel axis has a 28° dip, the direction of the axis is from NW to SE. The channel is filled by medium-grained sand with occasional floating clasts (relict of lag deposits) passing in the upper part of the channel into fine-grained sand. The internal structure of the channel comprises conspicuous trough cross bedding. Loading is frequent on the lower bed planes of coarse-grained sand.

Hydroplastic deformation manifested by water-escape structures occurs on the right side of the sand pit. Most likely it reflects passive liquefaction in unconsolidated sediment which could be triggered by minor tectonic activity.

On the left side of the sand pit a layer consisting of medium-grained, weakly-consolidated sandstone overlies fine-grained gravel. At the base of the bed small clasts up to 1.5 cm in diameter and rip-up clasts of greyish claystone occur. The sandstone layer has an irregular channel form and it probably originated by erosional action of a stream on an at yet not consolidated underlying gravel, resulting in scour formation.

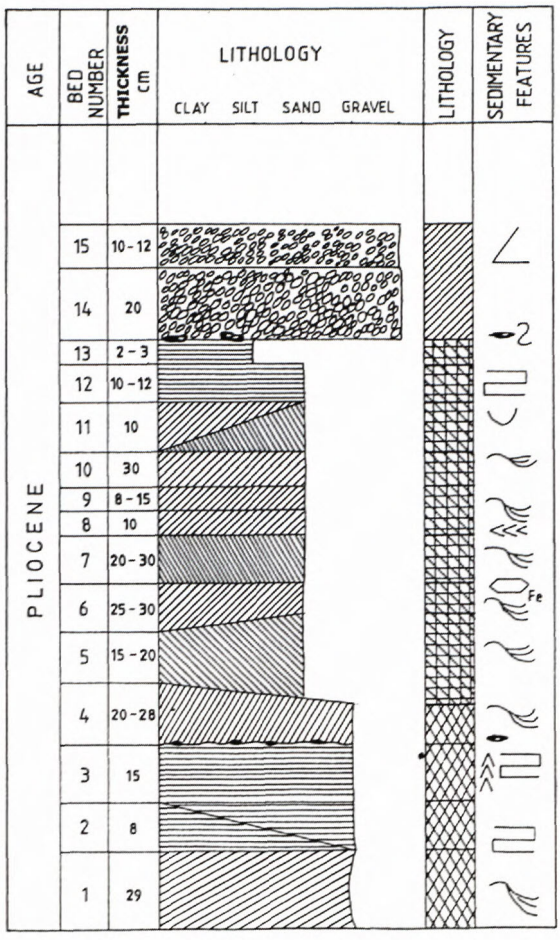


Fig. 3 Section of Dolné Otrokovice DO/2

The deposits occurring at the Tepličky (TE) outcrop are characterized by faint normal grading shown by a prevailing coarse-grained sand of light-brown colour in the upper part of the profile and a fine-grained gravel having the clasts up to - 1 cm in diameter in the lower part . The fine-grained gravel is matrix-supported. The matrix is composed of medium-grained sand. The deposits are horizontally and cross laminated (Photo 4).

According to the direction of the cross laminae, the palaeoflow direction was from NW to SE. The laminae dip varies from 12° to 22°.

A subtle normal gradation occurs in individual beds. Chaotically arranged calcareous concretions up to 5 cm in size (Photo 4), Fe concretions, clay intraclasts and rip-up clasts originating from thin layers torn by water flow occur throughout the entire outcrop.

At the base of the outcrop or beneath the outcrop well-rounded clasts of weakly consolidated coarse-grained sandstones up to 15 cm in diameter occur.

At the sand pit of Piesočnica sand is horizontally and planar cross bedded (Photo 5). In the thick layers of sand trough cross bedding is locally preserved. Herring-bone

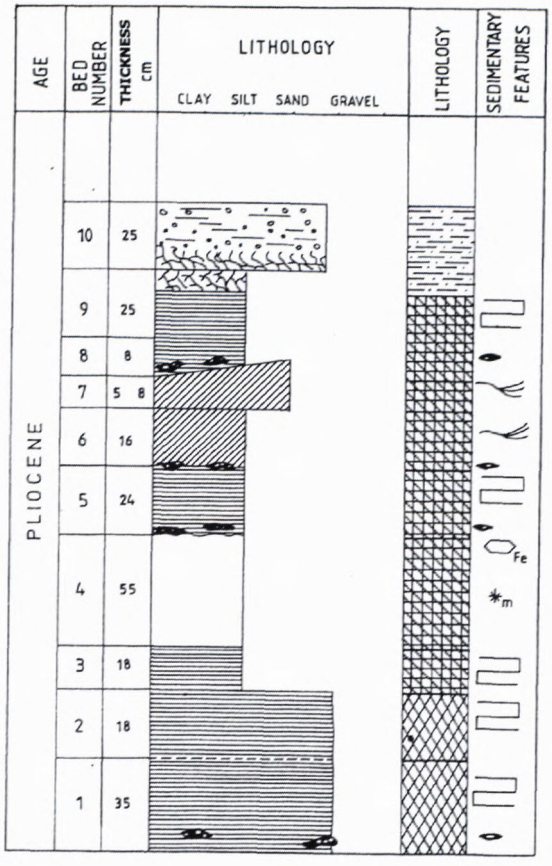


Fig.4. Section of Dolné Trhovište DT

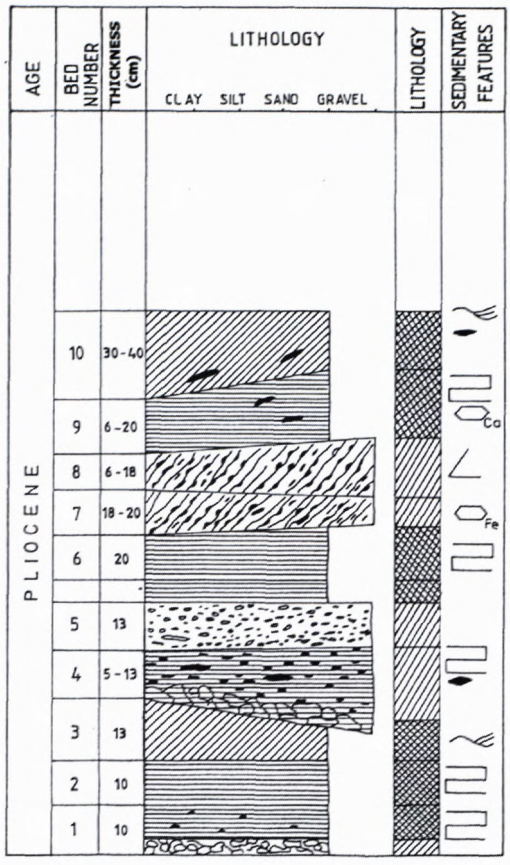


Fig. 5. Section of Tepličky Te (n = 27)

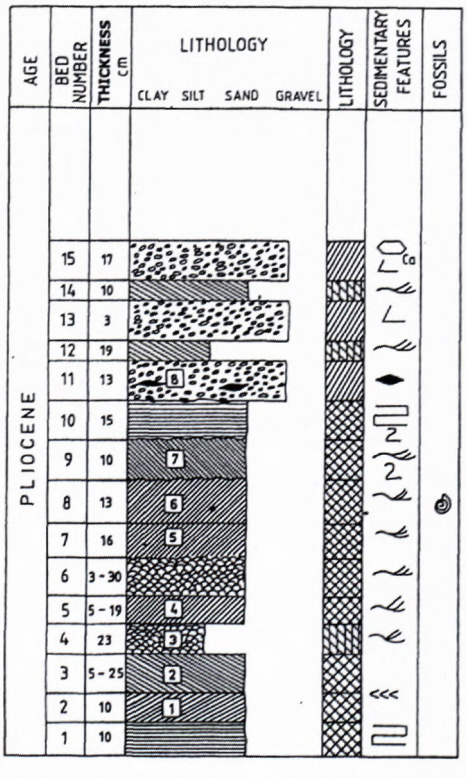
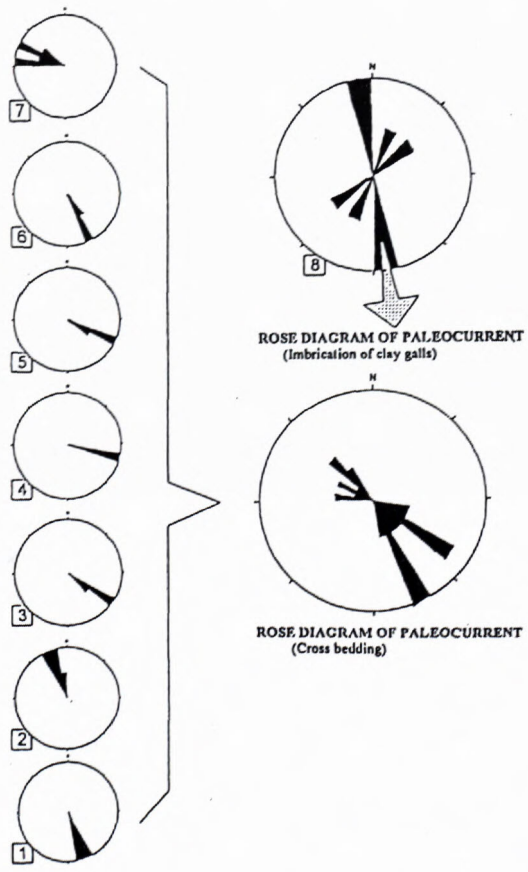


Fig. 6. Section at Piesočnica P (n = 35)



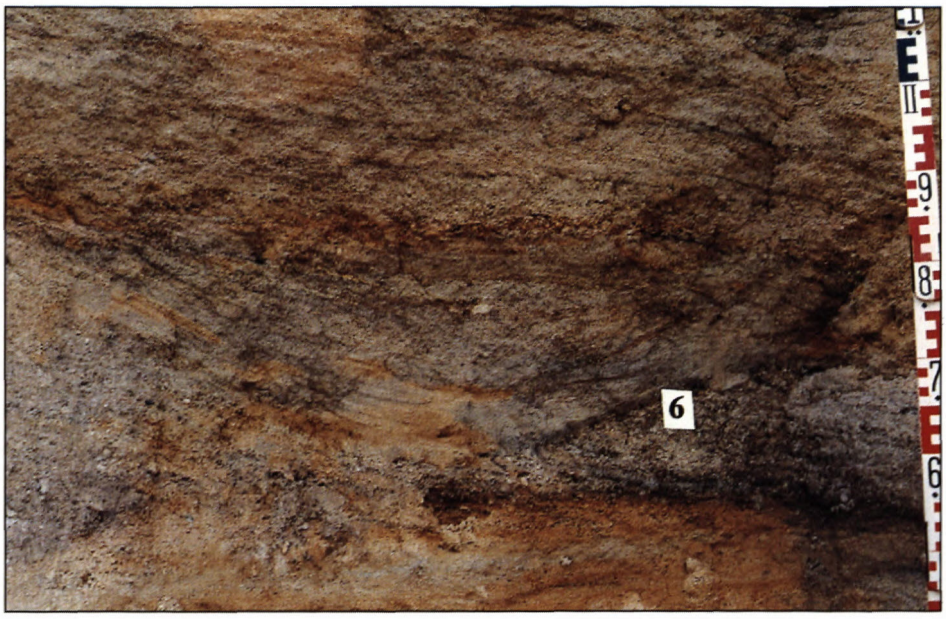


Photo. 1. Erosive channel. (profile DO/1, layer 6).

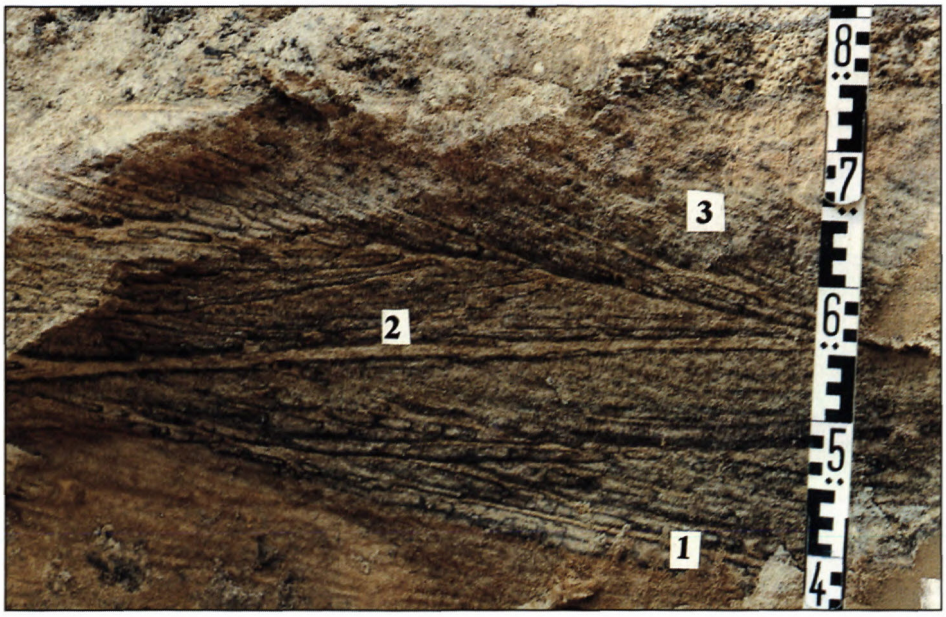


Photo 2. Cross - bedding. (profile DO/1 layer 1,2 and 3).

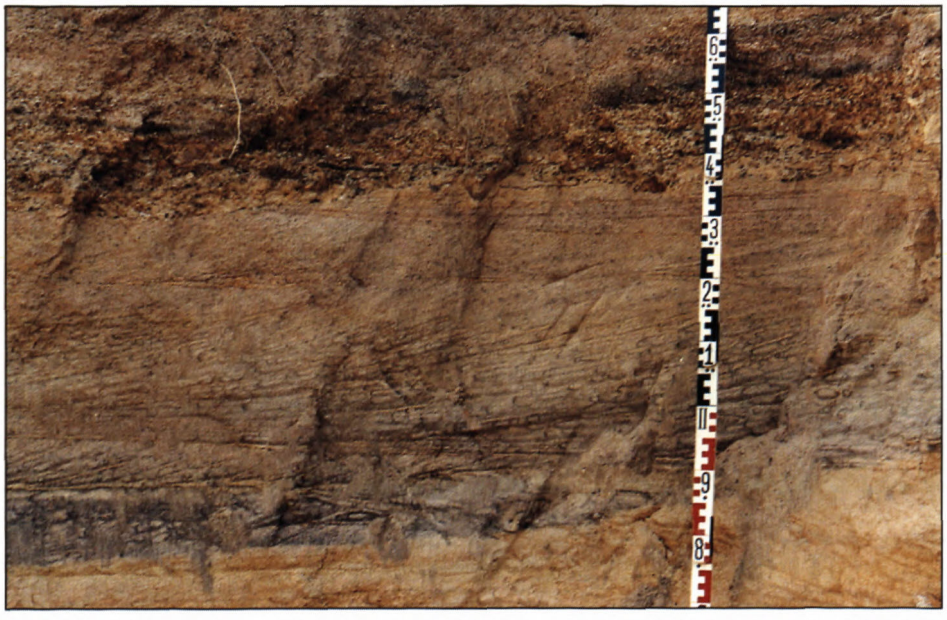


Photo.3. Planar cross – bedding. (profile DO/1 layer 5).

Photo. 4. Cross – bedding of sands. Carbonate nodules (Ř 1 – 3cm) are occurred in sands. (profile Te).

Photo. 5. Delta front characteristic of thick bodies of cross – bedded sands. (profile P, layer 6).

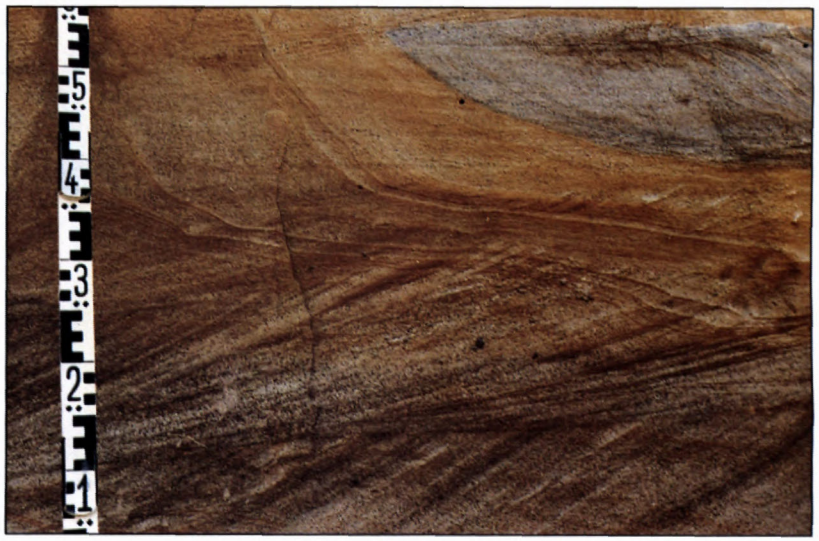


Photo. 6. Bimodal bedding of sands. (profile P, layer 2 – 3 and 8 - 9).

Photo. 7. Imbrication of clay galls. (profile P, layer 8).

Photo. 8. Fine – grained gravels interlaminated with sands. Rip – channel and synsedimentary tectonic are visible. (profile P, layers 11 – 15).

Photo. 9. Synsedimentary faults. (profile Dolné Trhovište).

cross bedding also occurs. It originated by flows with different orientation resulting in bidirectional appearance (Fig. 6, beds No. 2 – 3 and 8 - 9, Photo 6).

The transport direction is from NW to SE. The laminae dips vary from 12° to 20°. Imbricated clay intraclastsindicate transport consistent with the direction of cross laminae (Photo 7).

Interesting is the occurrence of liesegang rings over the entire outcrop. They originated during diagenetic processes by reduction of Fe oxides and they colour sand into ocherous-yellowish and brown colour. Clasts of black claystones containing organic plant remnants were found between the beds 10 and 11. In the left part of the outcrop the upper section is composed of fine-grained, clast-supported gravel alternating with layers of coarse-grained sand. The base of the sand beds is loaded with hydroplastic deformations resulted from water escape.

The section near Dolné Trhovište (DT/1) consists of prevailingly horizontally laminated deposits, only the sand in the beds No. 6 and 7 is cross-bedded (Fig. 4).

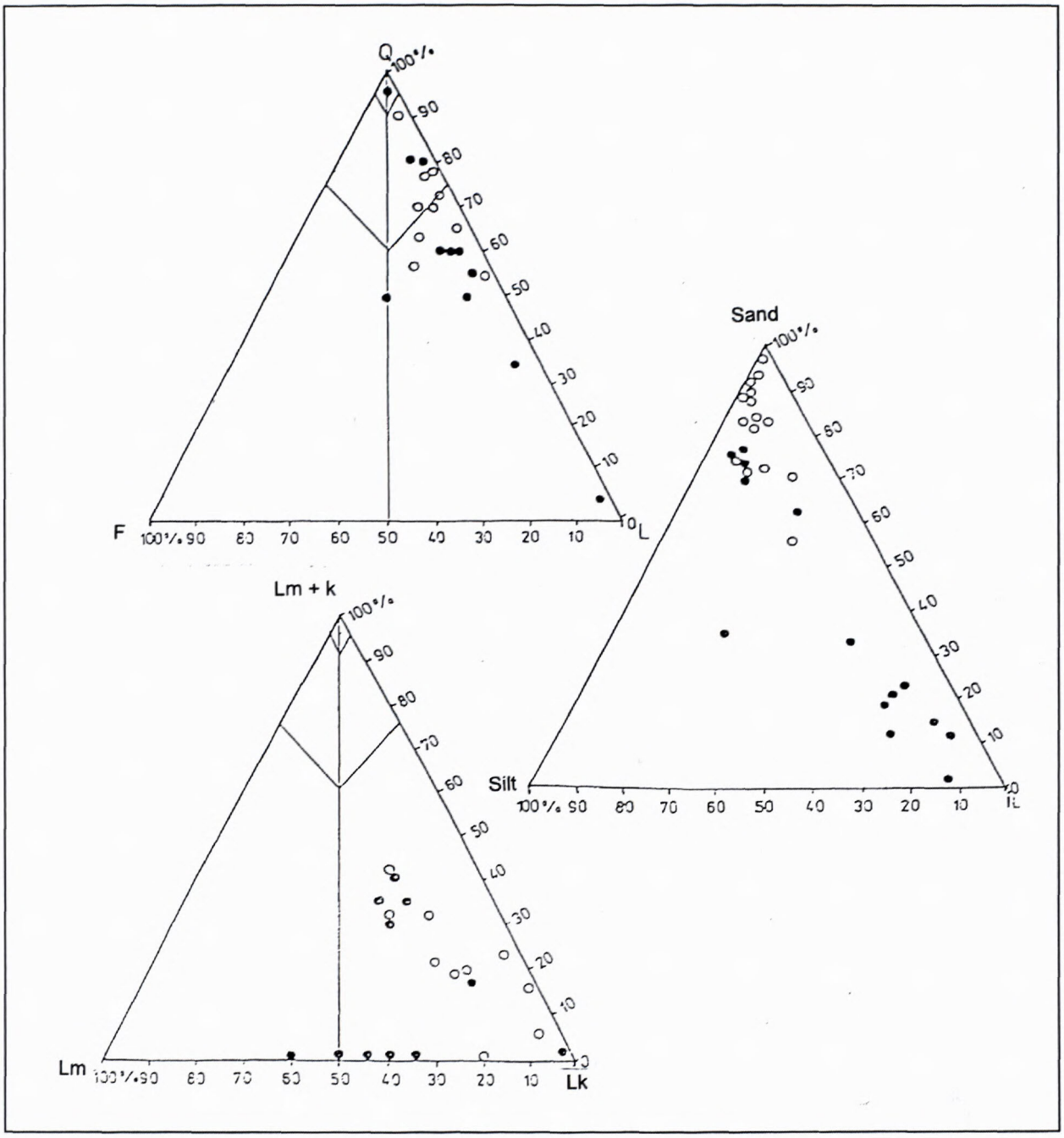


Fig. 7. QFL diagrams of minerals in sands. (after Pettijohn, Potter, Siever 1972).
Q – quartz, L – lithic grains (micas + carbonates), F – feldspar, Lm – lithic micas, Lk – lithic carbonates, L = Lk + Lm.

The dip direction of the cross laminae is toward the SE. At the base of the beds No. 5 and 6 rip-up clasts of ocherous-yellowish colour occur. The beds commonly contain small concretions (max. 0.3 cm) of Fe oxides colouring the sand to an ocherous-yellow. Horizontal lamination of sand is emphasized by an alternation of pale-brown, ocherous and grey coloured laminae. The colour is determined by the heavy mineral (ilmenite and limonite) content.

In the left part of the outcrop sand beds are deformed by synsedimentary faults with small throws suggesting minor tectonic activity (Photo 9).

Grain-size analysis of sand

Sand consists of fine- to coarse-grained fractions. The grain-size analyses showed occurrence of fine-grained gravel (0.07 - 23.28%) and coarse-grained sand (0.05 - 46.39%). The essential part of the sand is composed of medium-grained (1.02 - 74.83%) and fine-grained sand (7.41 - 72.16%). The silt content is 6.7 - 24.1%. Clay admixture is absent.

The grain size parameters (Mz, So, Sk, Kg) were calculated according Folk and Ward (1957). The median was calculated after Trask (1930).

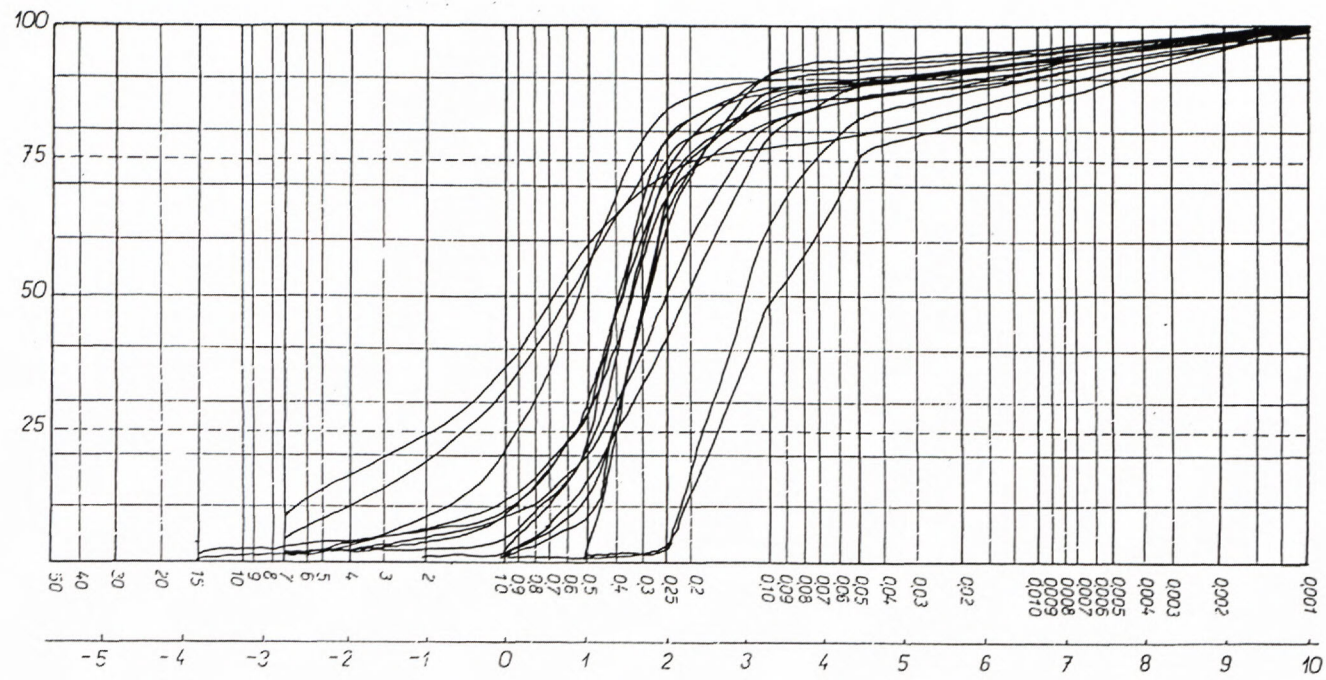


Fig. 8. Cumulative curver of sediments from localities at Dolné Otrokovce, Dolné Trhovište and Piesočnica.

The mean grain size (Mz) is 4.1 - 0.93 ϕ, the values in mm varies from 1.56 - .1 mm.

The median (Md) varies from 0.097 to 0.68 mm. The median shows mean grain size of deposits because the half of grains is smaller and the half of grains is larger than the grain size represented by median value. We infer it by reading of 50-percentile on cumulative curve.

The sorting coefficient (So) ranges from 1.1 to 2.08. According to cumulative curves the studied sand is of average sorting (Fig. 8).

Positive values of asymmetry (Sk) of the cumulative curve determine fine-grained and the negatively coarse-grained part of the sample. The positive values of the curve asymmetry range from 0.3 to 1.15 and they suggest fine-grained deposits. The curtisoity (Kg) of the curve, showing grain size distribution, is defined by the ratio between the spread in its central and marginal part. If the curve is steep (leptocurtic), fine grained clasts prevail in a coarse-grained fraction. On the contrary, if the curve is flat (platycurtic), fine-grained clasts prevail. The values of curtisoity range from 1.14 to 4.15, and they suggest leptocurtic to extremely leptocurtic curves. The higher degree of sorting may suggest an admixture of sandy deposits, which was already reworked before in a water environment somewhere.

Mineral content of sand

The sand clasts from the study localities are mainly surrounded to well rounded. Quartz prevails among the light minerals (55 - 90%). The quartz grains are coated yellow limonite. Abundant mica is also visible macroscopically. Feldspars abundance is 1.7 - 27.2%. The carbonate content varies from 0.02 - 20%. The mineral content suggest prevailing quartz and sublitic sand (Fig. 7) while in the sublitic sand carbonate and mica prevail. According to high content of quartz the quartoze sand represent a mature sediment.

The sand of the study localities also contain β quartz, indicating a volcanic origin. The closest occurrence of volcanic rocks is in the Middle Miocene Ruskovce Formation (Kováč et al., 1993) in the Bánovce depression located N of the study area. Taking into account the transport direction (from NW to SE), it is most probable that that formation was the source area for β quartz

Heavy minerals in sand

The association of heavy minerals was analysed from the samples taken from the localities of Dolné Otrokovce and Piesočná near Behynce.

The total heavy fraction content ranges from 0.2 - 0.92% (Tab. 3, Fig. 9). The mean values of heavy mineral content are shown in the table 4 and depicted in figure 10. The magnetic fraction with magnetite is totally absent. In the dia magnetic fraction rutile prevails from 7.1 - 23.4%. Zircon is abundant - from 2.06 to 9.6%. Apatite (0.5 - 7.9%), silimanite (0.1 - 2.6 %) and disten (1.3 - 8.6%) occur less frequently. In the para magnetic fraction ilmenite (5.3 - 90%) prevails. Tourmaline occurs in minor amount (7.3 - 17.6%).

At Piesočnica garnet (18.1 - 24.7%) and epidote (14 - 20.4%) prevail. At other localities the garnet content was lower (1.0 - 4.1%) and epidote was absent. Hematite was only found at Dolné Otrokovice (4.8%).

We calculated the ZTR index from the percentual content of zircon, tourmaline and rutile. The index shows a mineralogic maturity of the heavy mineral associations in sand. The ZTR index value is 42 - 96%, suggesting a mature sand.

Tab. 3. Content of heavy minerals in sands

Pattern	1/DO	2/DO	3/DO	4/DO	1/DO2	2/DO2	6a/DO	6b/DO	4/P	5/P
Fraction	0, 25 - 0, 1	0, 25 - 01	0, 25 - 0, 1	0, 25 - 01	0, 25 - 0, 1	0, 25 - 01	0, 25 - 0, 1	0, 25 - 01	0, 25 - 0, 1	0, 25 - 01
Cont. of HM %	0, 39	0, 31	0, 20	0, 39	0, 45	0, 23	0, 57	0, 48	0, 92	0, 63
rutile	23, 3	22	20	7, 1	10, 5	23, 4	22	23	18, 1	10, 9
zircon	18, 6	15	14	14, 4	9, 6	15, 8	18, 6	20, 6	12, 5	12, 3
apatite	4	3	7, 9	0, 5	1, 9	2	2, 6	1, 3	2, 1	1, 7
sillim.			2, 4	0, 1			2, 6	0, 6	0, 8	0, 7
distene	3	8, 6			2, 4	1, 3	4	2	3, 8	
zaphire										
gold										
ilmenite	30, 6	30	20	51, 2	48	20, 6	90	5, 3	11, 2	10, 9
limonite	10	4, 6	12, 1	3	7, 6	11	10	27, 3	9, 4	6
tourm.	16, 6	12	17, 6	16, 9	16, 8	16, 5		13, 3	8, 1	11, 3
garnet		2	3, 6	1	2, 8	4, 1		2, 6	18, 1	24, 7
epidote									15, 5	20, 4
hematite						4, 8				
ZTR index	89	78	81	96	83	88		90	49	42

Tab. 4

min	rutile	zircon	apatite	sillim.	distene	zaphire	gold	ilmenite	limonite	tourm.	garnet	epidote	hematite	magnetite	n
A	6, 07	11, 87	2, 3	5, 71	0, 53	0, 11	0, 04	41, 64	16, 3	3, 46	6, 9	3, 93	0, 41	4, 40	21
B	18, 3	15, 14	2, 7	0, 72	2, 51			31, 78	10, 1	12, 91	5, 89	3, 59	0, 48		10

The identified association of heavy minerals is typical for crystalline rocks. It is suggested by the occurrence of rutile, zircon, silimanite, disten and by the prevailing epidote and garnet in some samples. The increased content of ilmenite, similarly to β quartz, also may show that the source area had volcanic rocks.

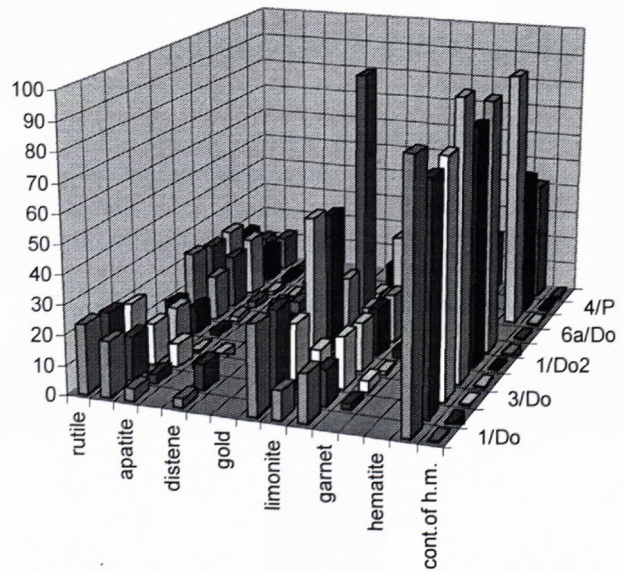


Fig. 9. Percentage histogram of heavy minerals in different localities

X - Ray analysis of clay

Clay rip-up clasts, which occurred between beds at localities Dolné Trhovište and Piesočnica, were RTG and DTA analysed. Smectite prevails in samples 1/DT from Dolné Trhovište and 6/P and 2/P from Piesočnica. The most abundant minerals are, then, illite and kaolinite. In the sample 3/P (Piesočnica) illite prevails; less frequent are smectite and chlorite. The sample 4/DT (Dolné Trhovište) contains smectite with an increased content of Na. However, the Na content was probably caused by natrium hexamethaphosphate added to the sample in order to prevent coagulation. Other minerals are illite and kaolinite.

Conclusion

The deposits of the Pliocene Volkovce Formation, represented by thick sand beds with a gravel admixture, were studied at several localities in the NW part of the Rišňovce Depression (Dolné Otrokovice, Dolné Trhovište, Teplička and Piesočnica).

The sand is mainly medium to fine-grained and it is well sorted (coefficient of sorting 1.1 to 2.08).

An imbrication of rip-up clasts occurs in the cross bedded sand. Vector measurements of clay imbrication support that the palaeoflow direction is from NW to SE.

Brown to ocherous coloured upper part of beds suggest that the influence of oxidation due to water level fall. Except for the rarely occurring redeposited clasts of black claystones with a high content of organic matter, which represent eroded swamp deposits, the deposits do not contain any organic matter.

Cross bedding and trough cross bedding is typical for the sand. Beds with horizontal lamination and scours also occur. The direction of cross laminae show transport direction from NW to SE. Locally found opposite orientation of herring bone cross laminae is caused by flows with different direction.

From the viewpoint of mineral composition, smectite prevails and kaolinite, illite and chlorite occur in lesser amounts. Based on the mineral composition the sands are

classified as quartz and sublitic sand with prevailing quartz and lithic rock fragments.

The heavy mineral associations with rutile, zircon, ilmenite, tourmaline, garnet, epidote, disten and silimanite suggest that the source area had crystalline rocks. According to the palaeoflow direction (from NW to SE) it probably is represented by crystalline rocks of Považský Inovec Mts. Most probably also rivers from Bánovce Depression, transporting β quartz and probably also illite from Ruskovce Formation, represented the path of sediment transport. High values of ZTR index suggest a relatively high sand maturity.

The continuing deposition, sufficient input of clastic material and probably also the absence of tectonic activity causing increased subsidence of the area of Rišňov Depression, show a progradational character of the delta. The delta probably joined south of the study area a lake occurring in the central part of the Danube Basin. The characteristics of the above described sandy deposits suggests their origin was in the delta plain represented by a wide channel.

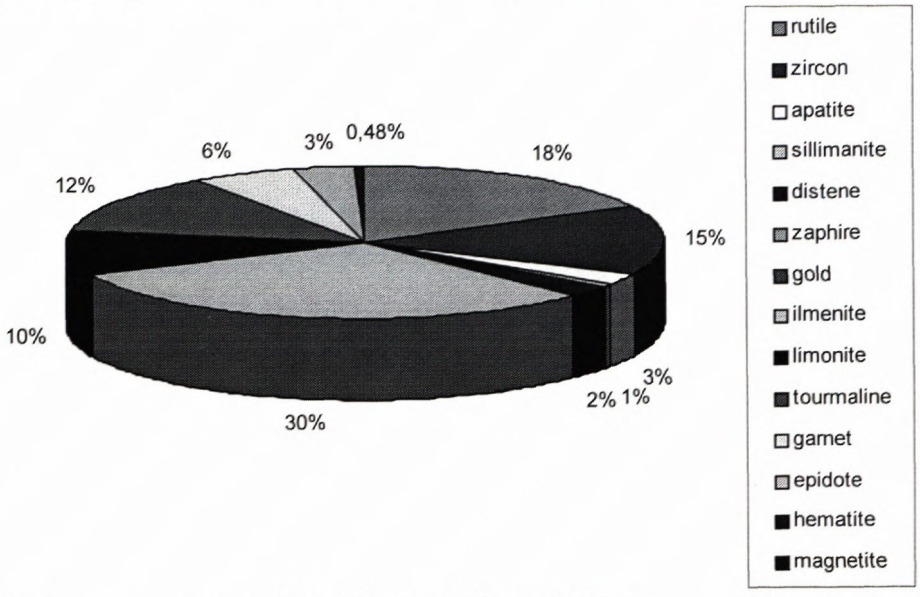


Fig. 10. Average contents of heavy minerals in different localities

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