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SEDIMENTOLOGICAL CHARACTERIZATION OF THE PLÁŠŤOVCE BEDS (SOUTHERN SLOVAKIA)

(Figs. 1—16)

Abstract: The Plášťovce Beds have peculiar lithofacies development in the Miocene of the West Carpathians. In this paper on the basis of foraminifers their stratigraphic position is briefly characterized, however, mainly some properties of conglomerate and sandstone textures and sedimentary structures are widely described with remarks clarifying their genesis, respectively the genesis of the Plášťovce Beds. Suitable structure elements are applied for considering paleocurrent directions and identification of the source area. Sedimentological characterization of the Plášťovce Beds results in statement that these beds are similar to fluxoturbidites. In the conclusion of this paper substantiation of their origin ot the border between the Ipeľsko-rimavská paňva Basin and the Danube Basin, respectively at the periphery of the region of Central Slovakian volcanics is presented.

Резюме: Плащтовские слои имеют редкое литофациальное развитие в западнокарпатском миоцене. В статье эти слои коротко характеризуются и дается их стратиграфическое положение на основании фораминифер. Но главным образом характеризуются некоторые структурные черты конгломератов и песчаников и детально описаны их седиментарные текстуры с примечаниями, объясняющими их генезис, или же генезис плащтовских слоев. Подходящие текстурные элементы используются для объяснения направлений палеотечения и нахождения области сноса. Седиментологическая характеристика плащтовских слоев приводит к констатированию, что эти слои похожи на флуксотурбидные слои. В заключении работы обосновывается их возникновение на границе Ипельско-римавской впадины и Подунайской низменности, или же на периферии вулканического ареала.

Introduction

The Plášťovce Beds extend at the SW margin of the upland of Krupinská vrchovina and the NE margin of the Danube Lowland (Small Danube Lowland). Typical profiles are found near the community of Plášťovce, N of the town Šahy in southern Slovakia.

The stratigraphic range of the Plášťovce Beds is the Lower Badenian up to the lower part of the Upper Badenian, i. e. corresponding to the *Orbulina* zone and reaching to the *Globigerina nepethes* zone. In the lower part of the Plášťovce Beds *Orbulina suturalis* Brönnimann and a rich assemblage of foraminifers with predominating representatives of the family Lagenidae are found: *Planularia antillea ostroviensis* Vašíček, *P. auris* Defrance, *P. dentata* (Karrer), *P. cassis* (*Fichtel* et Moll), *Vaginulina legumen* (Linne), *Lenticulina (Robulus) calcar* (Linne), *L. (R.) arcuatostriata* (Hantken). *L. (R.) arcuatostriata caroliniana* (Cushman) *L. (R.) cultrata* Montfort, *L. (R.) convergens* (Brönnimann), *L. (R.) melvilli* (Cushman), *L. (R.) clericii* (Former), *L. (R.) simplex* (Orbigny), *L. (R.) inornata* (Orbigny), *L. (R.) clypeiformis* (Orbigny), *Stilostomella verneuilli* (Orbigny), *S. pauperta* (Orbigny), *Nodosaria arcuata* Orbigny, *Globigerinoi-*

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des sacculifera (Brady), *Globorotalia scitula* (Brady) (V. Molčíková 1960. 1964).

In the uppermost parts of the Plášťovce Beds *Orbulina universa* is found, accompanied by benthonic foraminifers: *Martinotiella communis* (Orbigny), *Cibicides ungarianus* (Cushman), *C. lobatus* Walker et Jacob, *Sphaeroidina bulloides* (Orbigny), *Uvigerina hispidocostata* Cushman et Todd, *U. venusta* Franzenau, *U. semiornata* Orbigny (R. Lehotayová 1966).

The Plášťovce Beds have two fundamental lithological-petrographical characteristics: 1. Monomict composition — almost exclusively consisting of detrital andesite material. 2. Lithofacies variability — vertical partly also lateral alteration of layers of clastics of various granularity, various grain size sorting and degree of reworking. Generally from the east respectively NE ti the west respectively SW grain thickness decreases, also thicknesses of beds of coarse clastics are thinning. About 8 km SW of Plášťovce strata equivalent in age to the Plášťovce Beds predominantly consist of marly clays and silts.

Some Texture Properties of Conglomerates and Sandstones of the Plášťovce Beds

Conglomerates of the Plášťovce Beds are of two types:

1. Conglomerates with contact framework;
2. Conglomerates with pebbles submerged in the groundmass.

Conglomerates with contact framework: Conglomerate pebbles are contiguous with each other. Their average size is about 10 cm and they are predominantly reworked, relatively well sorted. In places, however, blocks exceeding by far average size are present. The groundmass of conglomerates is sandy. Average values of sphericity (Md_{sf})[1], index of rounding (Md_{Ro})[2] and coefficient of flatness (Mdp)[1] are mentioned in table 1, respectively 2.

Average values of sphericity of pebbles (exclusively andesite pebbles) agree with the values of rhyolite gravels on beaches of Lake Superior (Grogan 1945 ex F. J. Pettijohn 1957).

Average values of flatness coefficient are low also in spite of that pebbles with c axis considerably shorter than b axis were taken intentionally for measuring. Between flatness coefficients and indices of rounding relation of indirect dependence was found out in most cases (i. e. the greater the flatness, the lower the rounding — fig. 1). Such a relation was found out by Wentworth (1922 ex F. J. Pettijohn 1957) in pebbles of beach gravels.

Critical values of rounding, which may be applied in considering the environment of abrasion and rounding of pebbles according to J. Tricart (1960) are presented in table 2.[3]

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[1] Average values of sphericity and flatness coefficient cannot be considered as objective data, but only for orientation because measurements were not taken on representative sample but on pebble with measurable imbrication only.

[2] Average values of index of rounding were obtained by measurement of rounding of pebbles of size 4 to 6 cm.

[3] Critical values of rounding were derived from histograms, representing indices of rounding of 100 pebbles, size 4 to 6 cm. The individual indices of rounding were calculated according to the formula $Ro = \frac{2 r_1}{L}$, where r_1 is the smallest radius of rounding on plane ab, i. e. on the plane given by two longer axes of the pebble. The value Md_{Ro} was derived from cumulative curve.

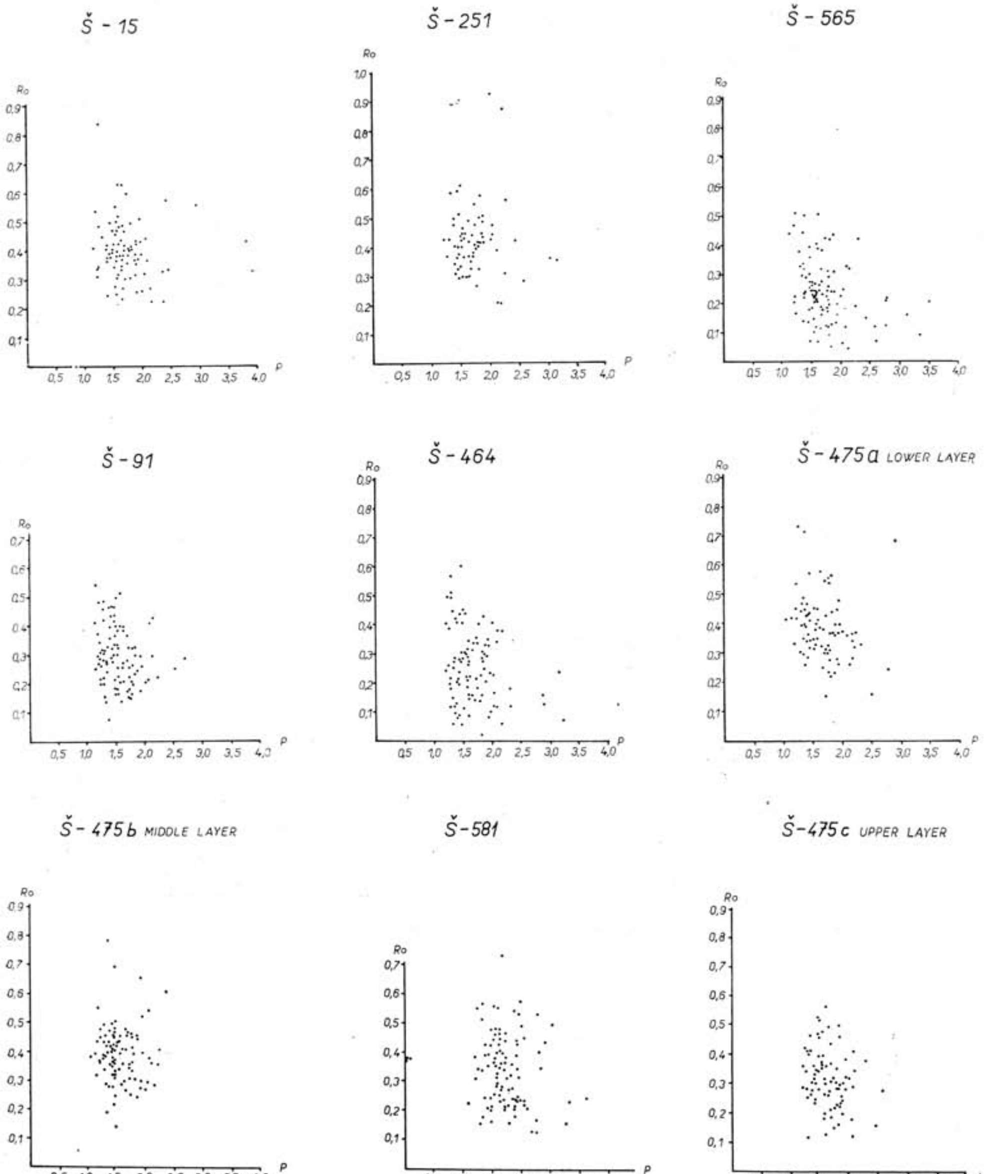

Fig. 1. Relation of rounding Ro and flatness P of pebbles.

All the average values were derived graphically from cumulative curves. The sphericity of the individual pebbles was derived by aid of Krumbein's curves on Zingg diagrams (W. C. K r u m b e i n 1941).

Table 1. Mean Values of Sphericity (Md_{Sf}), Flatness (Md_P) of Andesite Conglomerate Pebbles Applied in Imbrication Measurement

Outcrop	Md_{Sf}	Md_P
Š-15	0,56	1,70
Š-32	0,58	—
Š-91	0,58	1,50
Š-251	0,56	1,70
Š-464	0,56	1,60
Š-475a	0,56	1,60
Š-475b	0,59	1,45
Š-475c	0,57	1,65
Š-565	0,58	1,70
Š-581	0,56	1,75

Table 2. Critical Values of Rounding Indices Histograms of Conglomerate Pebbles (Ro)

Outcrop	Maximum Ro	Ro 500	Ro 100	Md_{Ro}
Š-15	300—500	12 %	0 %	385
Š-91	200—300	3 %	1 %	280
Š-251	300—500	15 %	0 %	410
Š-464	100—300	3 %	12 %	250
Š-475a	300—400	12 %	0 %	370
Š-475b	300—500	6 %	0 %	380
Š-475c	300—400	5 %	2 %	300
Š-565	200—300	1 %	9 %	230
Š-581	200—500	10 %	0 %	330

The coefficient of flatness of pebbles was calculated according to the formula $P = \frac{A + B,}{2C}$, where A, B, C are the longer, middle, shorter axis of pebbles.

The indices of rounding of pebbles from most localities correspond to rounding of beach gravel pebbles, only pebbles from the localities Š-464 and Š-565 show low Ro values similarly as pebbles of stream and terraces under semiarid climate.

Conglomerate of this kind are similar to sandstone conglomerates of the flysch series, deposited after slipping without clayey matrix or with slipping by combined turbidity current, which washed out clayey matrix (second type of flysch conglomerates of Ph. H. Kuenen l. c., 1959, p. 1017).

Conglomerates with pebbles embedded in the groundmass: The material of pebbles is imperfectly reworked, of chaotic sorting (fig. 2). Seldom indications of graded bedding are to be observed (fig. 3). The groundmass is of sandy-siltstone character. If siltstones are underlying the conglomerate layers, in this case fragments to blocks detached from the substratum are found in them.

Conglomerates of this kind are similar to sandstone conglomerates of the flysch series, respectively Wildflysch, which originated by deposition of subaqueous mudflows (first type of flysch conglomerates of Ph. H. Kuenen l. c.).

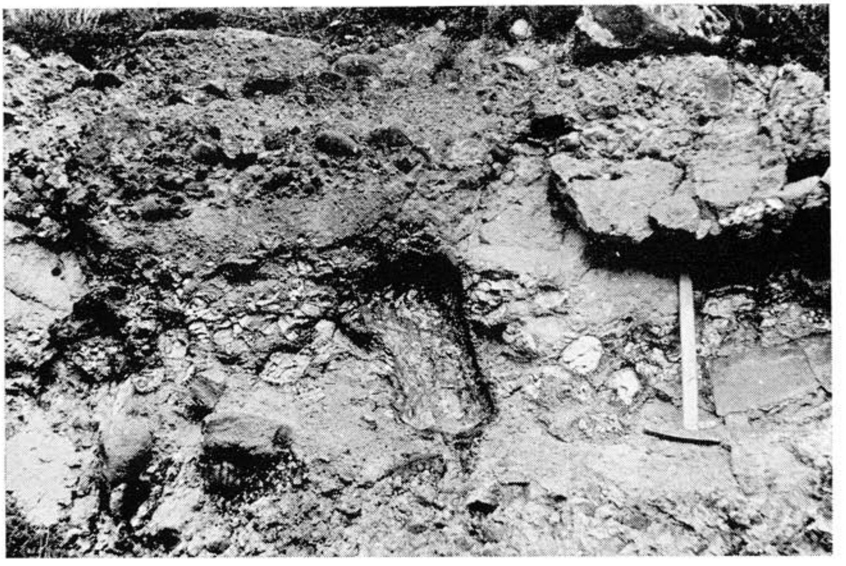

Fig. 2. Shreds and blocks of siltstone in chaotic conglomerates filling up the erosion channel. Kidney-shaped depression in the middle is an imprint after siltstone block, which fell out from the wall after weathering. In the upper part of the figure indications of graded bedding. W of Plášťovce.

Fig. 3. Erosion channel with indications of graded bedding of the filling.

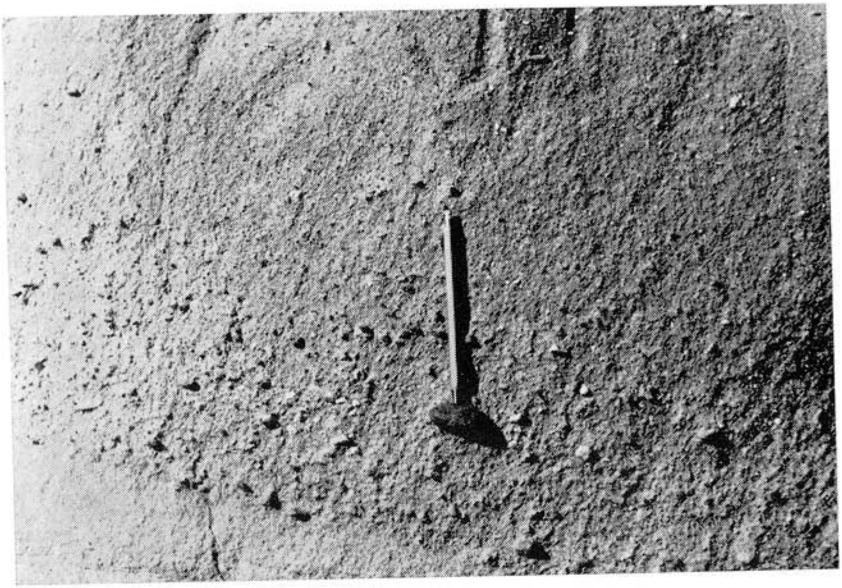

Fig. 4. Graded bedding of the filling of erosion channel trenched in sandstones. W of Plášťovce

Sandstones in 2nd and 3rd genetic subtype of stratification of the Plášťovce Beds show graded bedding. Gradation may be observed by the naked eye in some cases. For instance, in fig. 4 the base of the layer with graded bedding is of trough-shape — probably a wide wash-out bottom. The proper graded bed commences with fine conglomerates and gradually passes into sandstones. In most casses, however, graded bedding cannot be seen by the naked eye but positive gradation was found by microscope (by the method of measuring the 10 largest grains in thin section from the base, middle and top of the bed), average values of this measurement are mentioned in table 3. More detailed grain size analyses of sandstones of the Plášťovce Beds (M. Marková 1967) show two granulometric maxima in sandstones (especially the lower and middle part of the bed), one in the coarse and one in the finest fraction, simultaneously mechanical texture is getting finer from the base to top. Similar properties show experimental turbidites (Ph. H. Kuenen, C. I. Migliorini 1950).

Table 3. Mean Values of 10 Largest Greins in Thin Sections of Sandstones with Graded Bedding

	Š-52	Š-475	Š-468	Š-468
Top	0,07	0,08	0,06	0,08
Middle	0,14	0,09	—	0,11
Base	0,16	0,12	0,11	0,25

Sedimentary Structures of the Plášťovce Beds

Stratification

In the Plášťovce Beds three types of stratification may be distinguished according to morphology, development and thickness of beds.

1. Stratification with irregular development of beds.

2. Stratification with relatively regular development of beds and low index of stratification.

3. Stratification with regular development of beds and high index of stratification.

lst type of stratification is found in coarse clastic sediments. Mainly conglomerates are forming bodies of irregular shape, frequently to a considerable depth. Large lenticular layers of sands including streaks of conglomerates are found in them. Irregular stratification is sometimes to be seen also in sandstones with claystones. Sandstones usually form bodies tapering out sphenoidally amidst siltstones (fig. 5).

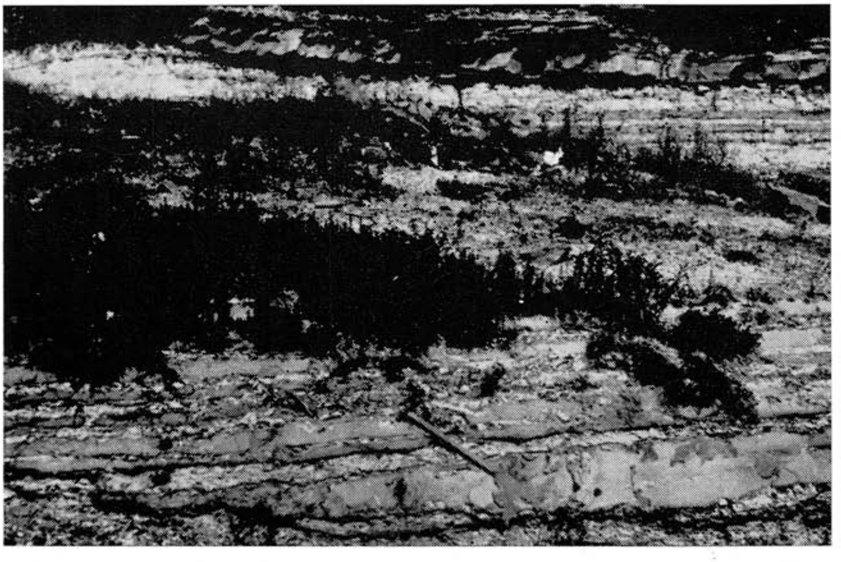

Fig. 5. Irregular stratification of sandstones and siltstones. In the lower part of the figure the sandstone bed is suddenly tapering out. W of Plášťovce.

2nd type of stratification shows more regular development of beds. Stratification bodies may be traced to a greater distance (50—100 m) if the extent of the outcrops permits it. Thickness of beds is relatively great, frequently exceeding 50 cm. In two typical outcrops average thickness of the bed attains 75 and 64 cm. Stratification index[4], which is a reciprocal value of average thickness of beds, is low (1,3 respectively

[4] Stratification index (V. C. Kelley 1956) is numerical expressing of the number of beds, which on an average fall to one square measure unit (foot, metre). Stratification index is calculated according to the formula $\frac{\text{thickness of complex}}{\text{number of beds}}$. In the Plášťovce Beds we are not finding any outcrop uncovering the whole complex, respectively one constinuous part of it, therefore we substituted the denominator in the above mentioned fraction by the heigh of outcrop. In that case stratification index characterized the exposed part of the complex only.

1,5 — table 1). In other outcrops thickness of the bed is greater than the height of the outcrop (2—3 m).

3rd type of stratification is the relatively least frequent. Thickness of beds in some cases exceeds 50 cm but beds thick up to 10 cm predominate. Average thickness varies from 5,8 to 15,1 cm, stratification indices from 6,6 to 17,2 cm (table 4, fig. 6).

Characterization of stratification with regular development of beds is completed with histograms, from which representation and frequency of the individual beds may be deduced (fig. 7). In the outcrop Š-468 the frequency of sandstone and siltstone beds is roughly the same (approximately 1:1) but sandstone beds are thicker, therefore sandstones predominate as to absolute representation. In outcrop Š-247 and Š-274 siltstone beds slightly predominate in number and also in absolute representation and that in outcrop Š-474 more distinctly than in outcrop Š-247.

Stratification of 1st and 2nd type is mainly found in the lower parts, that of the 3rd type mainly in upper parts of the Plášťovce Beds. Different stratification indices in 2nd and 3rd type prove various quality and amount of supplied and sedimented

Table 4. Stratification Indices Values and Bed Thickness

Outcrop	Height of measured outcrop in m	Number of beds	Ø Thickness of bed in m	Stratification index
Š-52	2,55	4	0,66	1,5
Š-91	2,26	3	0,75	1,3
Š-274	1,748	30	0,058	17,2
Š-474	3,326	22	0,151	6,6
Š-468	2,838	26	1,109	9,1

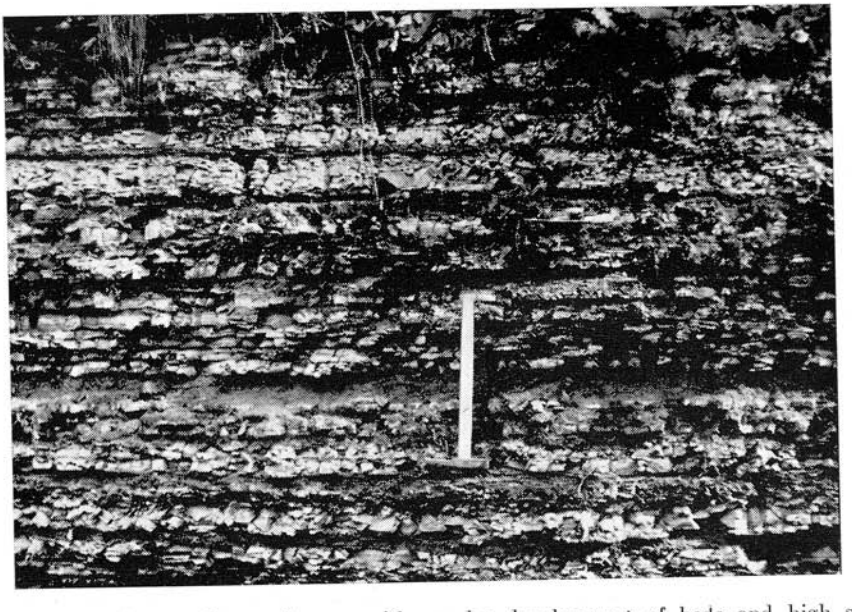

Fig. 6. Stratification sandstone-siltstone with regular development of beds and high stratification index. SE of Horné Túrovce.

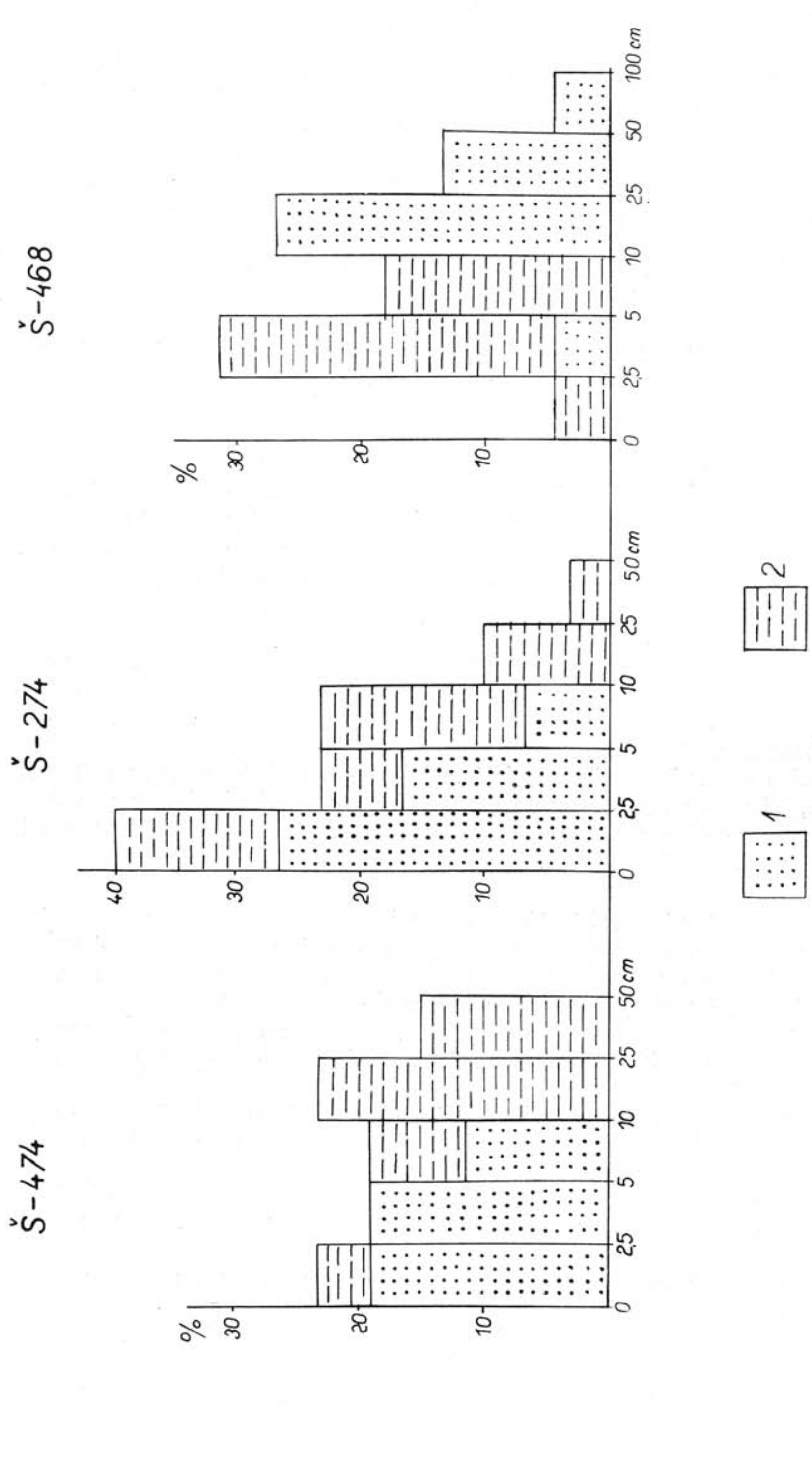

Fig. 7. Histogram showing frequency (in %) and thickness of beds (in cm) in stratification sandstone-silstone with high stratification index. 1 — sandstone, 2 — siltstone.

material. Since both types of stratification are confined to various parts of the vertical profile, it signifies that supply of material was changing with time.

Absolute representation and frequency of siltstone and sandstone beds in the 3rd type of stratification is changing in space. In absolute representation sandstones predominate in the north, to the south siltstones are getting more frequent and predominate in number of beds as well (see fig. 8, outcrop Š-468, respectively Š-474, Š-274). This fact is indicated by the direction of transportation from the north, respectively northeast. It may be also supposed that sandstones predominate in the zone relatively nearer to the source area.

All kinds of stratification of the Plášťovce Beds represent one genetic type of stratification according to Wortisch's classification (W. W o r t i s c h 1930 ex Z. K u k a l 1960, 1963)[5]:

Stratification conditioned by alteration of grain size of clastic material. This genetic type of stratification has three subtypes:

1. Stratification conglomerate-sandstone.
2. Stratification conglomerate-sandstone-siltstone.
3. Stratification sandstone-siltstone.

The first stratification is mainly found in the lower part, the second also in the upper part of the Plášťovce Beds. Conglomerate beds are of irregular shape and their contact with underlying beds is sharp and uneven — erosion channels (fig. 3, 10, 11), respectively load casts. Sandstone beds are usually more regular but also cases of sudden tapering out occur. Inside the sandstone bed sometimes wash-outs may be observed. At the contact with siltstones, which is usually uneven, are found unevennesses similar to load cast and such ones of organic origin (burrows). The burrows are tubular or sack-shaped, frequently bent (fig. 9). They are found near the top of sandstone beds and are filled in with siltstone material. Their cross sections show concentric structure.

Stratification of sandstone-siltstone is found in lower and upper parts of the Plášťovce Beds. The beds are of regular shape, with sharp delimitation from adjoining bed, usually uneven bases and frequently also top. The unevennesses represent load cast or phenomena similar to them.

S e q u e n c e o f t h e P l á š ť o v c e B e d s

Stratification of sandstones-siltstones forms sequences, i. e. regular vertical alteration of beds (members of the sequence, A. L o m b a r d 1956 ex Z. K u k a l 1963). These are predominantly interrupted sequences, i. e. with sharp boundary between the beds. They may be commonly designated as b-c-b-c. Rarely also positive sequences were found with gradual transitions between sandstone and siltstone, they may be commonly designated as bc-bc.

Indications of regular sequences can be also observed in stratification conglomerate sandstone. Stratification conglomerate-sandstone-siltstone shows irregural development of sequences.

Interrupted sequences mainly originate in shallow water environment (Z. K u k a l 1963), however, sediments of these sequences show also other signs of shallow water

[5] In the Plášťovce Beds also another genetic type of stratification is possibly present. This is indicated by the remark about the presence of organogenic limestone in primary documentation of borehole P-1 (westerly of Plášťovce). As the authors did not have the opportunity to see the complete drill core of this borehole, he cannot confirm this indication.

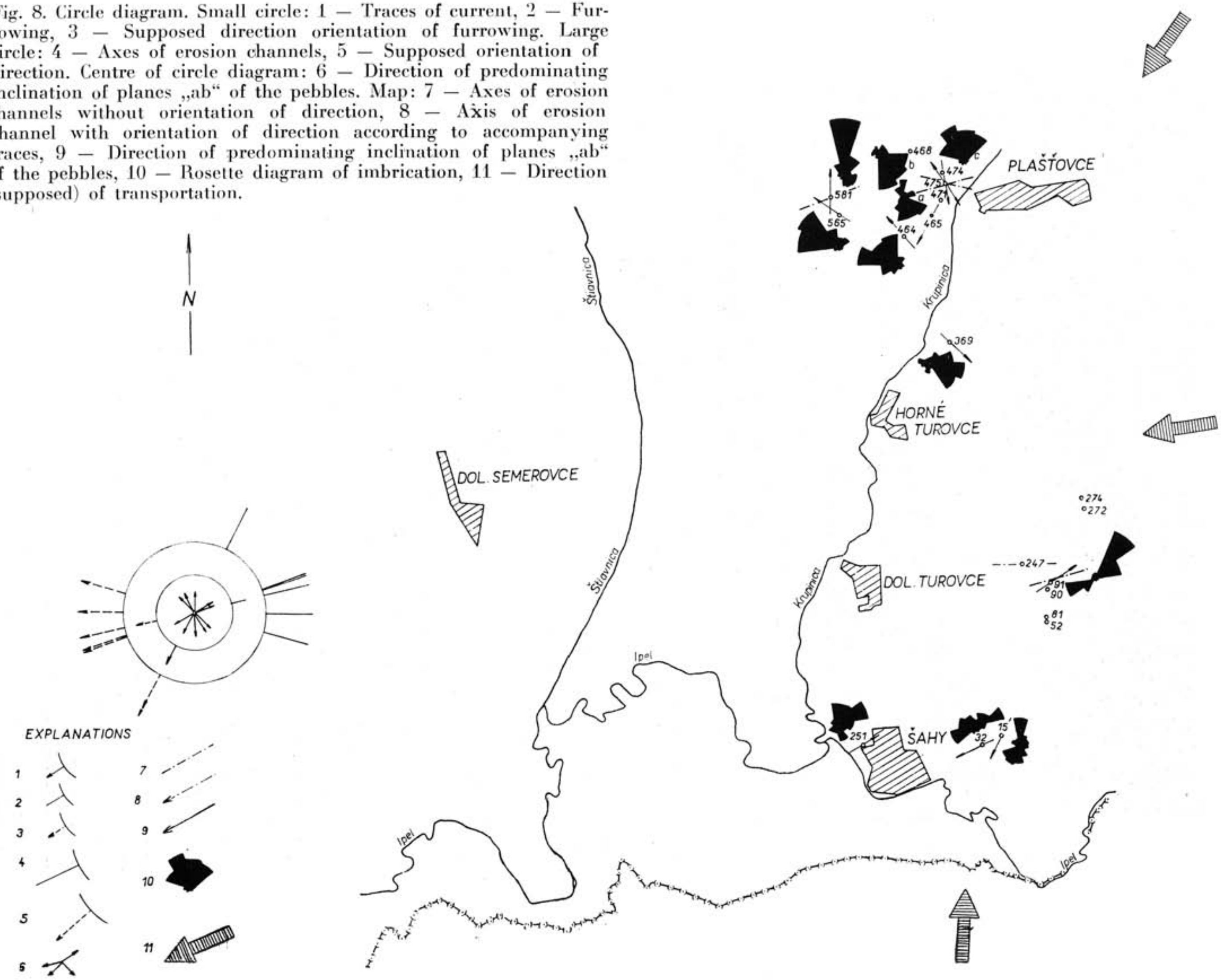

Fig. 8. Circle diagram. Small circle: 1 — Traces of current, 2 — Furrowing, 3 — Supposed direction orientation of furrowing. Large circle: 4 — Axes of erosion channels, 5 — Supposed orientation of direction. Centre of circle diagram: 6 — Direction of predominating inclination of planes „ab" of the pebbles. Map: 7 — Axes of erosion channels without orientation of direction, 8 — Axis of erosion channel with orientation of direction according to accompanying traces, 9 — Direction of predominating inclination of planes „ab" of the pebbles, 10 — Rosette diagram of imbrication, 11 — Direction (supposed) of transportation.

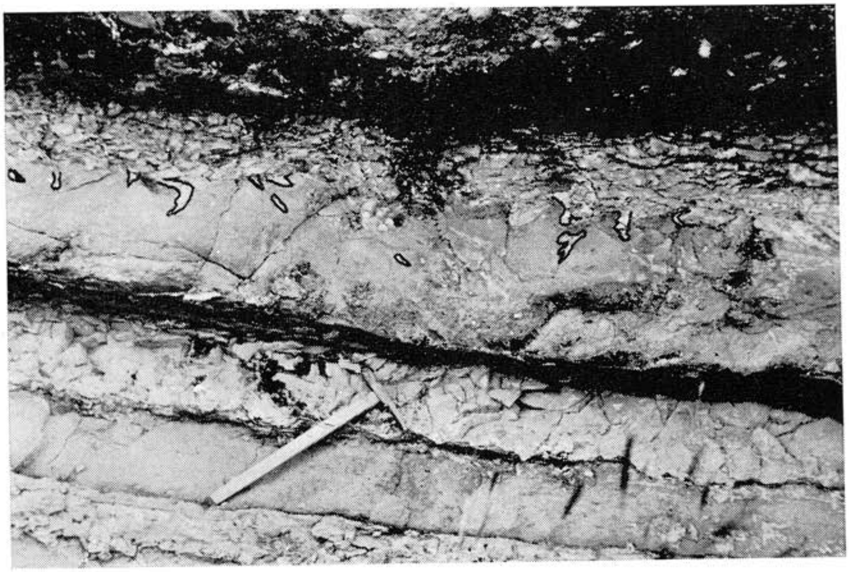

Fig. 9. Sequence sandstone-siltstone covered with conglomerates. In the upper part of the figure at the contact sandstone/siltstone traces after boring activity of benthonic organisms (burrows) are found. W of Plášťovce.

environment (large scale cross bedding, symmetric wave ripple marks, indications of emersion etc.). Sediments of interrupted sequences of the Plášťovce Beds are lacking in structures of shallow water environment, sandstone members of these sequences show graded bedding and together with siltstone form interrupted graded bedding (M. Ksiazkiewicz 1954) commonly found in flysch sediments; the opinion of the last named sediments generally prevails that they originated owing to turbidity currents.

Lamination

Lamination is found rarely (observable macroscopically), it is horizontal lamination of two types:

1. Laminae composing beds of the higher order. They are mainly found in upper parts of sandstones with graded bedding the laminae are 1—2 mm thick. They are often indistinct and can be recognized after desiccation or under light incident at certain angle.

2. Laminae occur independently. They are of two types:

a) Irregular laminae, tapering out at a short distance, with irregular changes of thickness. They are sandstone laminae in siltstone, frequently distinct by Fe hydroxides and sometimes of lenticular shape. They may be also irregular siltstone laminae in sandstones.

b) Laminae more or less regular amidst the bed of different mechanical texture (sandy laminae amidst siltstone bed), which do not wedge out and change thickness at a short distance. As the foregoing ones they are usually distinct by brown colouring caused by soaking in of Fe hydroxides.

Lamination may indicate shallow-water character of the environment in the time of formation of the sediment, but is also typical of turbidite (Ph. H. Kuenen,

C. J. Migliorini 1950 and others) and flexoturbidite sediments (S. Dzulyński, M. Ksiazkiewicz, PH. H. Kuenen 1959).

Linear Structures

In the Plášťovce Beds two types of linear structures are present: erosion channels and lineation at the undersurfaces (sole marks). From the last mentioned only two kinds have been found in the Plášťovce Beds: flute casts and groove casts.

Erosion Channels

They are the most common linear structures in the Plášťovce Beds. They are trenched in sandstones or siltstones. They are mainly filled up with coarse conglomerate material, frequently with shreds of rocks, into which the channel was eroded. The channels have the shape of a widely opened V in cross section (fig. 11). Sometimes epigenetic faults disturb the channel and deform its original shape (fig. 10). The dimensions of the channels and orientation of axes are presented in table 5. The dimensions of channels, big shreds of rocks cut by the channel, frequently found in the channel filling, thickness of conglomerates at the base of which the channels are situated, prove that the channels were trenched by vigorous submarine slumping.

Small forms similar to erosion channels in cross section (up to 50 cm wide), filled up with coarse- to medium-grained conglomerates may be really small channels but also great load casts may be concerned.

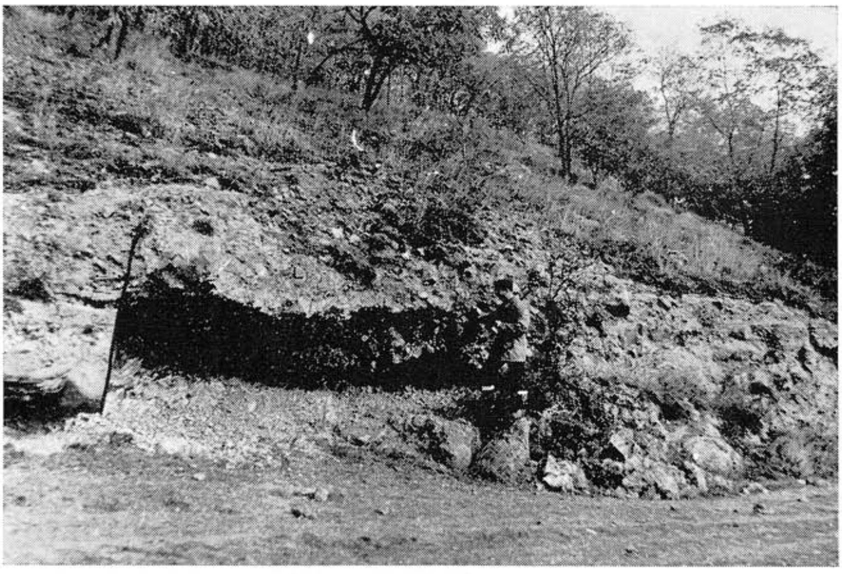

Fig. 10. Erosion channel trenched by mud-stone flow into thick siltstone bed. The left side of the channel is epigenetically disturbed by small fault.

Fig. 11. Erosion channel of the shape of widely opened V, filled up with conglomerates. NE of Šahy.

Table 5

Outcrop	Length	Depth	Direction of Channel Axis
Š-91	134 cm	12 cm	70° ?
Š-465	360 cm	51 cm	25°
Š-581	—	—	70°
Š-475a	—	ca 250 cm	75°
Š-475b	ca 400 cm	ca 50 cm	105°
Š-247	200 cm	25 cm	90° ?

Lineation at Undersurfaces

The way of uncovering the Plášťovce Beds does not make possible to study the undersurfaces. In spite of that flute casts and groove casts were found in two favourable outcrops and that at the bases of erosion channel fillings.

Flute casts are varied subconical forms of great dimensions. The longer axis is 15—20 cm long and the shape is bilateral symmetrical. The surface is smooth vithout sculpture. The pointed part is distinctly hollow. According to H. Rücklin 1938 (ex P. E. Potter, F. J. Pettijohn 1963) flute casts are fillings of small hollows, which originated by the effect of whirls of the current and are reliable indicator of the direction and sense of its movement. In the case given the direction of current agrees with the direction of erosion channel axis.

Groove casts in the Plášťovce Beds represent straight, smooth ramparts, 2—3 cm high. Groove casts must be considered as filling of furrows trenched into unconsolidated mud by various objects as fragments of rocks, bodies of organisms — plants or animal skeletons. These objects — tools of trenching were moved by the current and consequently groove casts are indicators of current direction, but not of the sense of movement. In the case given the direction of groove casts is parallel to the direction of erosion channel axis.

Deformational Structures

In the Plášťovce Beds three kinds of deformational structures are present: load cast, pull-apart structures and slipping structures.

Load Casts

Load casts are a phenomenon generally very frequent in sedimentary rocks, however especially in turbidites (P. E. Potter, F. J. Pettijohn 1963). They are unevennesses of various shape and size (pockets, hollows etc.), usually at the contact sandstone/claystone respectively siltstone (finer sediment in the substratum). According to R. R. Shrock 1948 (ex P. E. Potter, F. J. Pettijohn 1963) the main cause of the origin of load casts is the fact that on unconsolidated hydroplastic sediment (type of clay to silt) a bed of sand respectively gravel deposited, having evoked deformation of the plastic substratum by its load.

There are several kinds of load casts, respectively phenomena similar to load casts in the Plášťovce Beds.

1st type: normal load casts — impressing of sandstones into siltstones. The most common shape: flat irregular pockets 1—2 cm deep. There are cases of detachment of the impressed sandstone (detached shreds of sandstone, isolated from mother bed are „drowned" in the upper part of the siltstone bed. The siltstones also penetrate into the overlying sandstone in the form of vertical or oblique linguiform projections with relatively sharp points. In vertical dimensions they agree in order with the dimensions of sandstone pockets (1—2 cm), however, are narrower in cross section.

Particular load casts of this type were found at the bottom (on lateral side) of the erosion channel filled up with conglomerates. The load casts alone are formed by sandstone material, what agrees with the statement of P. E. Potter and F. J. Pettijohn (1963) that the filling of load casts uses to be finer-grained than the proper mass of impressing bed.

Shape of load casts: relatively regular hemispherical, half-loaf-like (in cross section).

Dimensions of individual load casts:

width:	depth:
35 cm	15 cm
35 cm	15 cm
45 cm	15 cm
50 cm	20 cm

Ratio between width and depth is 1:,3 to 1:3.

In the case of described great load casts an important diagnostic mark may be recognized: original stratification of siltstone, made distinct by stratification joints, is deformed and bent, not cut under the load casts.

In other load casts stratification and consequently ist deformation cannot be recognized in siltstones.

2nd type. Load case are not only at the base of sandstones but also of siltstones, i. e. siltstones, usually thin beds, have the upper and lower surface deformed by load casts. Into impressing sandstone siltstone tongues are injected (flame structure of E. K. Walton 1956 ex P. E. Potter and J. F. Pettijohn 1963), sometimes detached. Irregularities at the base of siltstone beds are rather of lobate shape and sandstones penetrate into overlying siltstone in the form of tongues. Similar impressing was described by T. Schibata 1962.

3rd type. Phenomena similar to load casts at the base of the siltstone bed (always coarser than in the foregoing case), which is uderlain by sandstones. They are of lobate, semicircular shape and cases of detachment of siltstone lobe occur (fig. 12).

Fig. 12. Structures similar to load casts at the contact siltstone (above) and sandstone (below). Right of the hammer under the uneven contact of both beds irregular shreds of siltstone are wrapped with sandstone. NE of Šahy.

Genesis of 1st type of load casts is known (see above mention). T. Schibata (1962) supposes load casts of 2nd type to have originated with rapid sedimentation when by the effect of the pressure of overlier not only overlying sands but also unconsolidated sands of the underlying bed were impressed into the plastic siltstone. 3rd type of load casts perhaps originated also as a consequence of differentiated pressure of the overlier rapidly deposited on unconsolidated sand bed soaked with water. In the origin of the load casts of 1st ad 2nd type earthquakes might have played some rôle because the area under consideration was the periphery of volcanoes in the time when the Plášťovce Beds were forming.

Pull-Apart Structures

Pull-apart structures are shreds of siltstone bed originally continuous amidst the sandy

Fig. 13. Pull-apart structure. Disrupted bed of siltstone amidst sandstone bed. W of Plášťovce.

matrix. The shape of shreds is in cross section irregular circular, elliptical, elongated, bent, with finger-like projections and hooked. A mark typical of all shreds is that they are wrapped with brown armour originated by impregnation of the circumference of shreds with Fe hydroxides. This armour is of secondary origin, not related to the origin of structure. They originated in two ways: 1. pull-apart structures with hooked, bent and irregular shreds were formed with disruption of siltstone bed during the movement — moderate slipping — of still unconsolidated sediments (Ph. H. Kuenen 1953 ex S. Dzulyński, K. M. Walton 1965, Ph. H. Kuenen, M. L. Notland 1951). 2. Pull-apart structures with shreds of silstone ordered parallelly to stratification and indications of uneennesses by impressing (fig. 13) originated as a consequence of extreme impressing (compare T. Schibata 1962). In table 6 values of longer and shorter axis of the shreds are presented and elongation is calculated from them (Z. Kukal 1963). Average elongations of shreds of the second type of pull-apart structures (locality Š-475-north) are somewhat greater than of 1st type. They cannot be compared with shreds described by Z. Kukal (l. c.) from the Barrandium Ordovician as „shreds of originally continuous bed desintegrated by overlying pressure". Z. Kukal mentions elongation of these shreds 10 and more. „Pull-apart" elongation, however, is probably dependent not only on the way of origin but also on mechanical properties of the desintegrated bed.

Slipping Structures

In the Plášťovce Beds two types of slipping structures are present: coherent slips and transitional forms between coherent and incoherent slips. (Terms applied occording to S. Dzulyński and E. K. Walton 1965.)

Transitional forms between incoherent and coherent slips are formed by irregular

Table 6. Dimensions and Elongations of Shreds

Locality	Longer axis in cm	Shorter axis in cm	Ø Elongation	Elongation
Š-475 (north)	12,8 4,0 5,0 11,0 5,8 7,3 4,3 9,5 3,0 4,2 8,2 7,0 4,0	5,5 3,4 2,7 4,7 2,6 2,0 1,0 2,6 0,8 1,1 2,0 4,5 2,0	2,3 1,2 1,9 2,4 2,2 3,6 4,3 3,7 3,7 3,9 4,1 1,5 2,0	2,9
Š-523 lower sandstone layer	4,2 5,0 6,0 12,5 7,0	2,4 4,2 3,5 6,0 3,5	1,8 1,2 1,7 2,0 2,0	1,7
Š-52 upper sandstone layer	8,0 6,0 10,0 7,5 21,0	3,0 2,5 7,0 4,0 10,0	2,7 2,4 1,4 1,9 2,1	2,1
Š-723 lower sandstone layer (shreds of two bands)	6,0 4,5 12,0 15,5 3,5 4,7 10,0 15,0 12,7 5,0	1,8 2,7 4,7 4,0 1,2 3,2 5,5 5,0 3,7 4,3	3,3 1,6 2,5 3,9 2,9 1,5 1,9 3,0 3,4 1,1	2,5
Š-723 upper sandstone layer	8,3 8,1 5,7 6,6 4,5 11,5 4,5 8,7	6,0 3,3 2,4 2,8 2,0 2,0 2,7 4,5	1,4 2,5 2,4 2,4 2,2 5,7 1,6 1,9	2,5
Š-465	11,0 9,0 14,0 13,0	7,5 6,5 7,0 12,5	1,4 1,4 2,0 1,0	1,4

bodies of siltstones (small fragments to blocks, 0,5 m on an average) amidst coarse-grained sandstones. They resemble pull-apart structures respectively slipping structures originated by movement penetrating the mass of slid sediment. Together with these shreds also elongated, bent, frequently hooked shreds (fig. 14) are found, common in coherent slips (type of „decollement" movement).

Typical coherent structure was found at one place (Š-468). It is formed by a fold of siltstone bed, in the core of which are sandstones. Thickness of structure is 1 m. The slip is not deforming underlying sandstones and the upper part of the structure is cut off and covered with undeformed sandstone bed (fig. 15). The described slip fold resembles in form a sedimentary fold from the locality of Radiša in the Bánovská kotlina Basin (West Slovakia), described and figured by R. Marschalko (1963) from the Flysch complex of the Central West Garpathians.

Another slip fold (?) is formed by siltstone layer 40—51 cm thick (locality Š-90). Its contact with underlying sandstone is unsharp — gradual transitions, with overlying sandstone it is sharp, uneven, with load casts (fig. 16). In the place, where the silstone bed is bent it is transversely injected with sandstone. The fact that the whole structure is not exposed in the outcrop makes its interpretation difficult. The structure may be considered in two ways: 1. as clastic vein, 2. as slip fold. For interpretation ad 1. speaks total appearance of the structure, i. e. conspicuously bent siltstone bed, which is as it would have intruded into sandy beds. The latter have no, at least not recognizable, marks of analogous bending. Detailed study of the structure, mainly indications of gradual transition from the underlier into the (bent) siltstone bed rather supports interpretation ad 2.

In coherent slips the sandstone bed is usually the bed deformed plastically (T. Schibata 1962, R. Marschalko 1963, S. Dźulyński and E. K. Walton 1965 and others). In Barrandium Ordovician (Bohemia), to the contrary, Z. Kukal (1963) established deformation of claystone beds. In our case the siltstone bed is the deformed one.

Fig. 14. Slipping structure: shreds of siltstone bed of various size and irregular shape. Typical are the hooked forms of shreds. SE of Horné Túrovce.

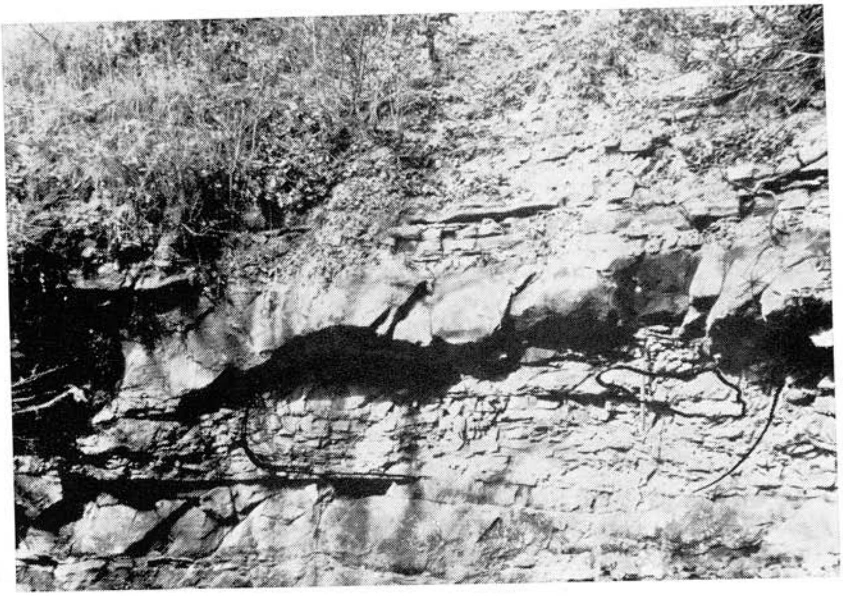

Fig. 15. Slip fold. The core of fold is formed by sandstone, the siltstone bed shows plastic bending. NW of Plášťovce.

Fig. 16. Bent bed of siltstone amidst sandstones (slip fold?). The upper surface of siltstone bed is uneven (load casts).

Slip structures originated for various causes. They originated in all places of accumulation of unstable sediments and with suitable inclination of the bottom. Direct impulses for the origin of slips in the Plášťovce Beds could have been: 1. volcanism and seismic activity, 2. tectonic unstability of the area in the time when the Plášťovce Beds were forming.

Remarks to the Paleogeography, Source Areas and Transportation Direction of the Plášťovce Beds

Petrographic composition of the Plášťovce Beds clearly indicates provenient rocks: andesites and andesite pyroclastics. Such rocks surround the area of extension of the Plášťovce Beds in a semicircle from the north, northeast and also partly from the south. There are the volcanic mountain ranges of the Krupinská vrchovina Upland and Börszöny, however, only the lower part of the volcanic complex of these ranges is coevat respectively somewhat older that the Plášťovce Beds. Sedimentological indications of transportation directions: sole marks and erosion channel axes confirm the supply respectively transportation of material from NNE, NE, E and ESE (circle diagram in fig. 8). Imbrication of conglomerates does not provide for unambiguous information of transportation direction. The difficulty lies in that we do not know what inclination of ab plane against transportation direction did the pebbles select falling out from the transported mass. In the case (locality Š—91) the direction of erosion channel axis and imbrication of conglomerates filling in the channel are almost identical and interpretation of the direction of the channel axis is opposite to imbrication, i. e. the majority of ab planes of pebbles is oriented against the supposed direction of transportation. In the other two cases imbrication of conglomerates is approximately perpendicular to the direction of erosion channel (Š-475, Š-581). Other measurements of imbrication cannot be confronted with erosion channel axis and also with other direction structures. If we admit that conglomerates at the locality Š-15 are inclined with plane ab against transportion direction (as it is the case at locality Š-91) then in near surroundings of Šahy we may suppose transportation from the south (from Börzsöny Mts., northern Hungary).

Genesis of the Plášťovce Beds

The Plášťovce Beds show structural and textural properties, which so far have not been found out in the sedimentary filling of the West Carpathian Neogene basins („inner molasse" of the West Carpathians). They are properties in which these beds resemble turbidites, respectively fluxoturbidites.

In the Plášťovce Beds these properties typical of turbidites were found out:

— graded bedding of sandstones and histogram with two peaks, slipping structures, load casts, rare occurrence respectively complete lack of macrofossils including leaf impressions, presence of traces of boring activity of organisms, presence of foraminifers with significant portion of planktonic constituent in siltstone beds, absence of structures of shallow-water sediments (mainly the absence of large scale cross bedding, reverse current bedding, symmetric wave ripple marks, indications of emersion, well sorted sandstones).

Other properties have also been established, which however, are not found generally in the Plášťovce Beds:

— regular alteration of beds (established in stratification sandstone-siltstone only), rare current structures at lower surfaces (found at the bases of erosion channel filling only).

Some marks of turbidite have not been found in the Plášťovce Beds:

— current lamination, convolute lamination.

The Plášťovce Beds have a series of properties and marks, which do not have turbidites but are found in so called fluxoturbidites:

— thick layers of conglomerates, irregular stratification (stratification conglomerate-sandstone-siltstone), lenticular and other irregular layers of coarser-grained material amidst finer-grained layer, absence of claystones, rare graded transitions from sandstone to siltstone, relatively small spatial extension.

In the study of the Plášťovce Beds we tried to find out nearer where from mainly the coarser-grained material (conglomerates) comes, where it originated and where it occurred formerly, before it was mobilized by slides and displaced into deeper zones of the basin of sedimentation. Considering sphericity, rounding and flatness coefficient of the pebbles, in the case of conglomerates with contact framework the material of pebbles was derived from near-shore accumulation of gravels, e. g. from shelf gravel terraces, where formerly it had undergone the process of abrasion on beach.

From the above mentioned the conclusion follows that the Plášťovce Beds are mostly similar to so called fluxoturbidites, i. e. sediments, in which properties and marks of turbidites as well as mighty slides are manifested (S. Dźułyński, M. Ksiazkiewicz, Ph. H. Kuenen 1959)[6]. Similar mechanism is attributed by I. V. Chvorova, M. N. Ilinskaja 1961 to the Irendyk tuffs, rocks similar to the Plášťovce Beds in their volcanoclastic character.

The conditions for the origin of the fluxoturbidite Plášťovce Beds were mainly formed by two circumstances: 1. synsedimentary tectonic regimen of the area. 2. volcanic activity.

The area where the Plášťovce Beds originated had its distinctive synsedimentary tectonic regimen owing to differential tectonic movements of two blocks, at the boundary of which the Plášťovce Beds originated. On the one hand it is the Ipeľsko-rimavská paňva Basin (E, SE) with subsidence fading out respectively indications of emersion, on the other hand (SW) the Danube Basin with growing tendency of subsidence (D. Vass 1964. D. Vass, M. Marková 1966, D. Vass, M. Marková, O. Fusán 1968). A zone active tectonically was thus concerned, with preconditions for tectonic bending up of the bottom and the origin of relatively steep slopes of the source area, near-shore zones respectively continental terrace. Along the slope steepened tectonically sliding of gravelous masses could have taken place and these then deposited in the form of flat cone at the foot of secondary inclination (i. e. steepened tectonically) and formed so called primary inclination or if the inclination was sufficient they kept on moving eroded the substratum, mobilized clastic material, which acquired the same degree of turbidity and this way conditioned the origin of fluxoturbidites (compare S. Dźułyński, M. Ksiazkiewicz, Ph. H. Kuenen 1959, R. Marschalko 1965, 1966).

Volcanic activity preceding respectively at least partly synchronnous with the origin of the Plášťovce Beds — the Plášťovce Beds originated in the more distant periphery of the volcanic region of Central Slovakia (the SW marginal part of which is the Krupinská vrchovina Upland) — had also an influence on the genesis of the Plášťovce Beds. Volcanism served as the main respectively only supplier of clastic material into the basin of sedimentation, this material was later mobilized by suspension currents (compare L. V. Chvorova, M. N. Ilinskaja 1961). It was possibly not direct

[6] Similar opinion of the origin of the Plášťovce Beds was expressed by M. Marková 1967.

supply of fresh ejected material but from young, steep, rapidly eroded relief, of which frequent slides are typical. Abundant supply of clastic volcanic materiaál dimished stability of primary accumulation, accelerated or induced the process of sliding, whereat a part of the slid material formed suspension currents.

Turbidite sedimentation typical of underlying sedimentary basins of the Central Paleogene and Outer Flysch of the Carpathians did not essentialy manifest in the Neogene basins of West Slovakia („inner molasse"). A rare exception are the above described Plášťovce Beds with properties and features of fluxoturbidites, mainly owing to particular tectonic regimen at the boundary between the subsiding Danube Basin and stabilized Ipeľsko-rimavská paňva Basin as well as volcanism and accompanying seismic activity of the volcanic region of Central Slovakia, at the periphery of which the Plášťovce Beds formed.

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