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SEDIMENTOLOGY OF THE LUNZ BEDS

(Fig. 1—8, Pl. XXII—XXIV)

Abstract: In this work the analysis of the paleocurrent system and composition of the clastics of the Lunz beds in the West Carpathians (the lower part of the Upper Triassic) is presented. It has been found that the paleocurrent analysis may contribute not only to the reconstruction of the sedimentary basin, but also to the solving of paleotectonic problems concerning mountain ranges with nappes structures.

The Lunz beds are present in the Triassic of the two main West Carpathian units: the Krížna and the Choč units. The study of sedimentation, the paleocurrent investigation and the reconstruction of the basin are closely connected with the problem of allochthonity of these tectonic units. The fact, that the Krížna and the Choč tectonic units are the original sedimentary mantles completely separated from their original crystalline substratum, and overthrust to the North upon the Tatrides in the form of extensive overthrust mass, while their crystalline substratum remained on the south where it was resorbed and in dependently folded. — then this fact was generally affirmed by the earlier works by A. Matějka, D. Andrusov (1931), J. Koutek (1931), V. Zoubek (1931) and R. Kettner (1931) as well as by the later investigations of D. Andrusov (1959—1964), A. Biely, O. Fusán (1965), J. Bystrický, A. Biely (1964), M. Maheľ (1965, 1967). The sedimentation area of the Krížna tectonic unit lay farther to the North of the Choč area of sedimentation in the Triassic, and — according to the later opinions of A. Biely, O. Fusán (1965), M. Maheľ (1967) — it was separated by the submarine rise of the Vepor crystalline. The disproportion between the widths of the areas of sedimentation of both the units (50+50 km in common) and the width of the crystalline substratum overlapped by the former, led to completely different interpretations of the original tectonic scars. Although the present shape of the overthrust masses shows distinct traces of the post-Paleogene tectonic movement, still the formation of the overthrust masses is pre-Senonian. The erosional effects upon the Choč nappe formed mostly of the Triassic, were caused by the post-Paleogene movements. Therefore now the Choč nappe has the outlook of tectonic outliers resting on the Cretaceous of the lower Krížna nappe. In the structure of the nappes simple folds and digitations with their axes more or less parallel to the course of the axis of the West Carpathians may be observed. This act was considered in the rotation of the measured azimuths of the oriented sedimentary structures to get the picture existing before the tectonic deformation. The systematic deviation of the paleomagmatic declination in the Choč nappe was determined by the last paleomagmatic studies by J. Kotásek, M. Krs (1965) in the Upper Permian and the Lower Triassic of the West Carpathians. Thus it may be stated that the alpine tectonic movements in the Choč nappe had a rotational effect reaching 45° from the near pole of declination derived statistically for the Triassic from the published data concerning the Euro-Asiatic continent. The fact cannot be affected by the paleomagnetic data of the Choč nappe collected from the southernmost marginal zone nearer to the tectonic scars. Rotation of the nappe round the vertical

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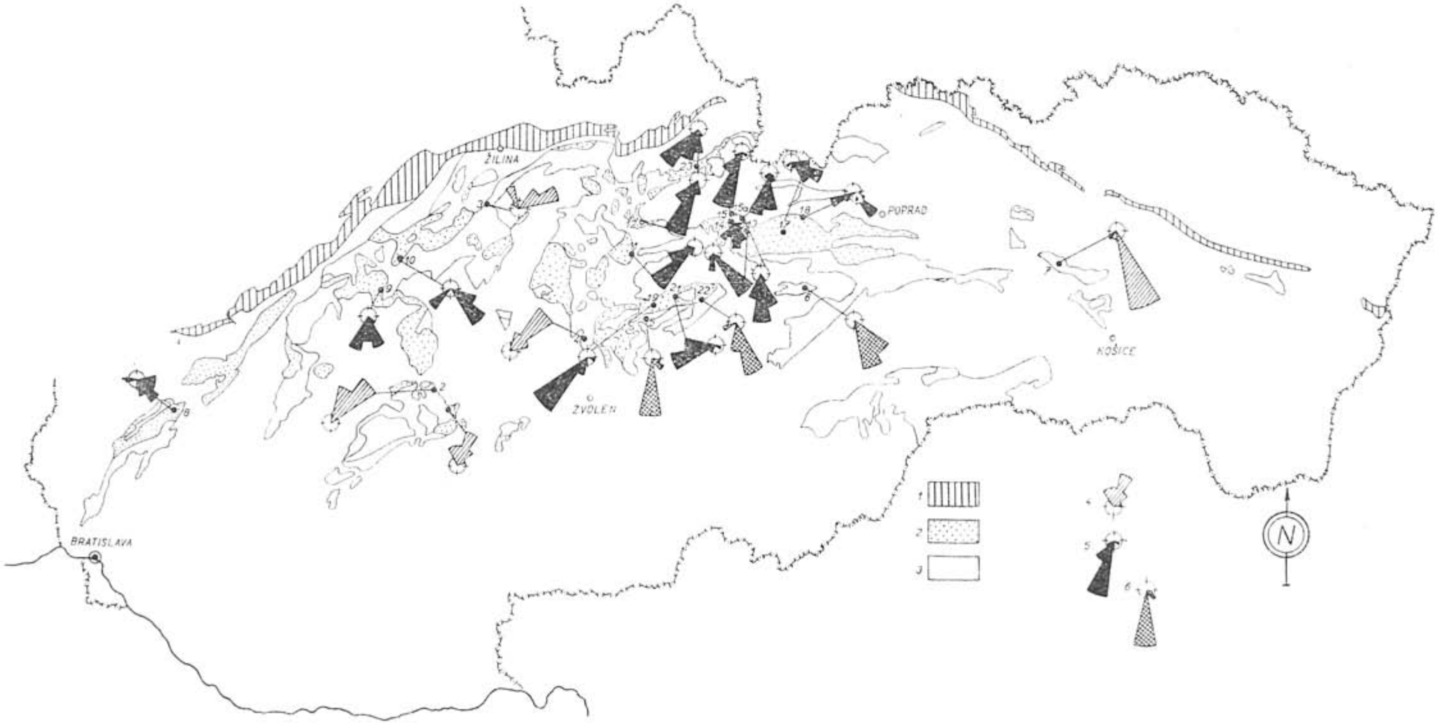


Fig. 1. Paleocurrent map of the Lunz beds. 1 — Klippen lineament. Line of the northern limitation of the Krížna and Choč units. 2 — Choč tectonic unit. 3 — Krížna tectonic unit including the Gemer Mesozoic. 4 — Current rose diagram. Paleocurrent pattern in these Krížna unit. 5 — Paleocurrent pattern in the Choč unit. 6 — Paleocurrent pattern in the southernmost part of the Krížna unit (the series of Veľký Bok). Numbers of localities: 1 — Veľké pole (the mill). 2 — Tribeč Müller. 3 — Kunerad. 4 — Podlavice, 5 — The Ľubietová quarry. 6 — Heľpa. 7 — Čierna hora. 8 — Balunky. 9 — Šípkov. 10 — Homolka. 11 — Liptovská Lužná. 12 — Ludrová. 13 — Liptovská Porúbka. 14 — Podtureň — cut of the Váh river. 15 — The Podtureň quarry. 15a — Liptovský Hrádok. 16 — Malužiná. 17 — Svarín. 18 — Východná. 19 — Brusno. 20 — Ráztoka. 21 — Predajná. 22 — Podbrezová. 23 — Kvačany Prosečnô.

axis caused the rotation of all the current data in a given value, therefore it ought to be considered in their interpretation.

Stratigraphical and Facial Relations

The Lunz beds consisting of darkgrey to black claystones and greygreen sandstones represent the abrupt interruption of the thick predominantly carbonatic formation of the Middle Triassic of the Krížna and Choč units. On the base of the Lunz beds in the Krížna unit there are finegrained to microcrystalline dolomites, light to black in colours, 200—400 m thick. They originated from the marine carbonatic oolites, coral limestones and muds. In the Choč unit, the dolomites contain abundant remains of algae, indicating their Middle-Triassic (Ladinian) age. Above the zone of dolomites in this unit there are local occurrences of cryptocrystalline darkgrey limestones with cherts (50—70 m thick) including the *Globochaeta alpina* Lombard association. In D. Andrusov's (1958) and M. Mišík's (1966) opinions they represent pelagic sediments neritic, shallow bathyal, usually developed in the substratum of thicker Lunz beds. The Aonian limestones (Aonschiefer), 2—30 m thick, found in the nearest substratum of the Lunz beds correlated with the Aonian beds of the Eastern Alps, contain fauna (*Trachyceras aonides*) typical of the Lower Carnian. The Lunz beds and their Lower-Carnian age were determined by D. Štúr (1868) in the West Carpathians. The detail paleontological and lithological investigations by M. Pulec (1965) proved that the forms *Leda defneri* Oppel, *Entolium discites* Schloth., *Halobia rugosa* Gümbel, *Carnites floridus* Wulfen belonged to the upper zone of the Lower Julian. The faunistic association were found exclusively in the clayey-sandy to siltstone beds on the basis of the sequence (10—20 m). According to J. Seneš (oral communication) this association is typical of the deeper parts of the neritic to shallow bathyal, having lived in the sea of normal salinity. In the upper horizons there is no macrofauna present, except benthonic and planktonic foraminiferal association. There are exceptional finds of plant remains in sandstones. In the overlier of the Lunz beds there sharply rest masses of bedded and massive dolomites and limestones of the Triassic, that reach even 200—300 m in the Choč unit and 50 m in the Krížna unit, as far as their thickness is concerned. They contain the marine fauna including *Megalodon triqueter*.

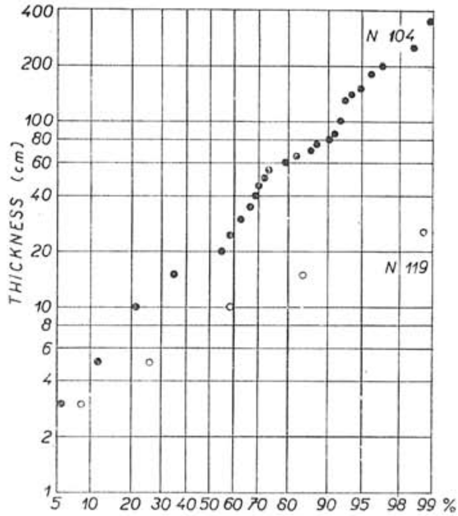
The continuous and uninterrupted development of the marine faunistic associations from the Middle to the Upper Triassic proves that the cause of the abrupt facial changes from the carbonatic sedimentation to the clastic sedimentation of the Lunz should be sought in the paleogeographical changes that took place in areas unavailable for the study. The Lunz beds are nowhere replaced with the underlying or overlying facies in the finger-like manner. This phenomenon proves that they arose in the course of the subsidence of the basement in the whole area of the West Carpathians.

The analysis of thicknesses showed that the subsidence in the Choč unit passed from the NW to the SE and S, the maximum thicknesses (fig. 1, locality Kvačany 23, loc. Lipt. Hrádok 14—15, loc. Lipt. Lužná 11, loc. Balunky 8, loc. Šípkov 9, loc. Homolka 10) 100—300 m decreasing to the SE and S in agreement with the transport direction. In the Krížna unit the mean values are 10—50 m, in the maximum 80 m, and subsidence in the separated zones is not so distinct. In the mantle series of the Tatrides to the N of the Krížna area of sedimentation, there are no Lunz beds, their equivalent — the Carpathian Keuper — being considered a lagoon marine formation.

Opinions about the genesis are different. D. Andrusov (1959) and M. Mahel (1967) considered the Lunz beds as a Flyschoid formation connected with the phase of tectonic processes. M. P u l e c (1959) partly explained the rise of the Lunz beds by the activities of the turbidity currents. The facts that the beds did not rise in the culmination stage of the main orogene but at its commencement, that they do not contain any coarse clastics nor do they transgrende upon the older crystalline substratum as well as their extension in the West Carpathians and in the Alps — all this makes the study of the Lunz beds quite urgent.

Bed Thickness and Shape

The distribution of bed thickness of sandstones in two sections of the Choč unit shows irregular course (fig. 2), indicating thus rather the tendency to the normal distribution only in the beds with medium thickness (up to 20 cm). Suchs were (fig. 2. N 119, the profile Brusno) predominantly in the section situated 40 km to the SW of the preceding one. The thick beds of sandstones were sharply alternating with the thin claystones in the series 20—50 m thick, especially in the middle and upper parts of the formation, in the northernmost zones of the Choč unit. The decrease of the thickness of sandstones to the SE and S, and the comparative increase of claystones are in an agreement with the fading out of the current system. Instances of the sharp wedging out of beds are known (pl. XXI, fig. 1) in the upper part of the formation. No erosive channels of the types as detaily described by B. F r e y b e r g (1965) from the German Keuper, were observed there. The sandstone beds are distinctly defined in black claystones, the rhythmical alternation indicating the obviously Flysch character of the formation (pl. XXI, fig. 2).



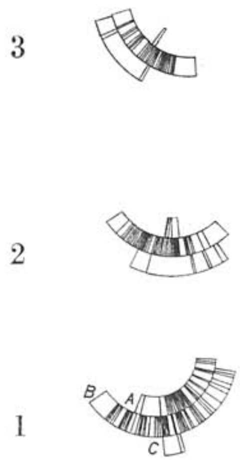


Fig. 2. Logarithmic probability plots of thickness of sandtone beds. The upper row — profile Liptovský Hrádok (fig. 1, loc. 14—15). The lower row — profile Brusno (fig. 1, loc. 19).

Fig. 3. Current rose diagram. Observations plotted: A. Scours marks (Flute marks). B. Current ripple lamination. C. Direction of movement of slump deformations calculated from the orientation of the long axes of slump folds. Profile Liptovský Hrádok. 1 — The lower part of the Lunz beds. 2 — Middle part of the profile. 3 — Upper part of the profile Podtureň (quarry).

Types of Bedding and Their Origin

Massive bedding (not graded bedding) was most frequent in the thick beds. There are completely homogenously distributed grains without any signs of gradation. The grain size analyses (of thin sections) of the two samples from the base and the top of the massive bedded strata showed slight lessening of the coarse grains in direction from the bottom to the top with the tendency to better sorting, beginning at the base. In 75 per. cent of cases the massive bedding passed up into the lower interval of parallel lamination (B) (pl. XXI, fig. 3) and current ripple lamination (C), and represented thus only the lower part of the beds. In smaller number of cases (20 per. cent) the massive bedding covered the whole thickness of sandstones sharply limited up and down. The presence of the massive bedding and the absence of the graded bedding need not exclude the classification of these deposits as turbidites, since in most studied beds (75 per. cent) there is regular sequence of sedimentary structures as described by Ph. H. Kuenen (1953), M. Ksiażkiewicz (1954), and in the last years by A. H. Bouma (1962, 1964) in the facies model of turbites.

The interval of the lower parallel lamination (2—7 cm thick) and of the current ripple lamination (5—11 cm, pl. XXI, fig. 4) rest above each other in the upper part of the beds, or they form separate bed units. The investigations showed that the process of the formation of these laminations took place in the course of the main depositional stage of the current. Together with the massive bedding they represent one closed sedimentary unit. It is proved especially by rather characteristic gradation features of the parallel lamines (pl. XXII, fig. 1) and the typical development of the non-truncated superimposed current ripple lamination (pl. XXII, fig. 2), which — according to J. E. Sanders (1963), R. G. Walker (1965) — may arise only under the conditions of the traction shifting of sand in ripples during the continuous fall-out of grains from the current. Sets of climbing ripples showed rather low angles of climb indicating the slower fall-out of grains and quicker forward movement of the ripples (R. G. Walker 1963). The direction of the dip of current lamination was equally oriented in several sets of one bed, and it was measured and estimated on a map (fig. 1). Current ripples were often preserved on the top surfaces of beds with parallel straight crest (pl. XXII, fig. 3) or of linguoid shapes. Regular symmetrical dipples of the wave origin (oscillation ripple marks R. R. Shrock 1948) have not been found. The ripples were not covered by traces of the crawling of animals, this indicating the unsuitable living conditions in the basin — together with the complete absence of macrofauna.

The complete sequence of intervals in the Lunz beds is extended by rather rare convolute lamination developing within one bed. It was found mainly in the interval of the lower parallel lamination, having been formed of the former by the shearing of currents flowing over the cohesive hydroplastic bottom surface (J. E. Sanders 1960).

As there were some stages during the transport in the current, so the sequences of sedimentary structures above each other were preserved, too. Usually the sequence consists of the massive bedding (A), lower parallel lamination (B), current ripple lamination (C) or combinations AC, BC, AB. Force and velocity of the current at the rise of the massive bedding must have been greater than with the parallel lamination and ripples, since the clay fragments were up to 14 cm long, accumulated in various levels, frequently irregularly, and only in this bedding (pl. XXIII, fig. 3). Abundant scour marks (pl. XXIII, fig. 1, 2) of various shapes, present on the bottom surface of beds must have required high speeds of currents and their accompanying turbulent character (S. Dżułyński, J. E. Sanders 1962, S. Dżułyński, E. K. Walton 1965). There are some indications that the traction carpet either did not exist in the current or lasted only for a short time, and the coarser grains kept dispersed in the current. The presence of the tool marks is just slight, representing only 20 per. cent of the whole amount in the studied profiles. This may indicate that the deposition from the current took place before the formation of the turbidity current with the typical traction carpet. Therefore the rise of the massive non-graded bedding may be ascribed to the semi-mature turbidity currents. In fact, descriptions of this type of bedding from the turbidity formations are not rare (A. Wood, A. J. Smith 1959, R. Marschalko 1961, R. G. Walker 1965) and the opinions are in agreement concerning the most suitable conditions of deposition from these currents in shorter distance from the source, in the so-called marginal or proximal facies of the Flysch.

Deformational Sedimentary Structures and Paleoslope

Different varieties of deformational structures are accompanied by series with the increased share of thick beds of sandstones and siltstones. Mudflows containing completely stirred fragments of the original beds and sand lamines, are rather rare (pl. XXIII, fig. 4), indicating that the replacement along the slope proceeded on large distances. More frequent are sandflows with clay fragments, often in chaotic position.

Subaqueous slumps with distinct deformations of beds (pl. XXIV, fig. 1) into more or less symmetrical folds — separated or accumulated above each other — formed a group of coherent slumps (S. Dżułyński 1963). Movements of these slumps were gravitationally controlled. In case the angle of slope along that they were moving, was high (R. Marschalko 1963), the axes of the deformed folds were oriented perpendicularly to the direction of movement. The study of these deformations in the profile Liptovský Hrádok—Podtureň (fig. 1, loc. 13—15, fig. 3) showed that the dip of the slope conditioning the movements of the deformations, caused also the movements of currents, i. e. the movement medium was in an agreement with gravitation forces. The gravitation control of deformations is possible and it has been documented from the turbidite formations adjacent to the uplifted source zones.

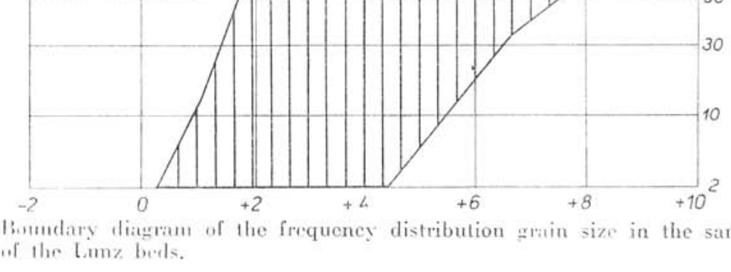


Fig. 4. Boundary diagram of the frequency distribution grain size in the sandstones and siltstones of the Lunz beds.

Other Types of Sedimentary Structures

The exception from the general picture is represented by the uppermost part of the Lunz beds on their passage to dolomites. There are sets of megaripples (pl. XXIV, fig. 2), lens-like shapes of beds and sedimentary deformations of the type of flow rolls rising because of the vertical sinking of the lenticular sand bodies into the underlying clay without horizontal replacement (J. E. Sorauf 1965). Interbedded claystones become strongly sandy and calcareous, characterized by light colours. In the Krížna unit the development of the current ripple lamination in greater thickness was found, yet it could not be determined whether it was a complex of several sedimentary units. The thickness of the units was 50—170 cm.

Mutual Granulometric Relations of Clastics and Their Composition

In order to determine the source rocks and the provenience of the Lunz beds, their composition and grain size were analyzed. The modal analysis was carried out from thin sections by the planimetric method. Grain size distribution was studied by the method of C. W. Krumbein (1935), in more than 400 long axes of grains in each thin section. From the cumulative curves by D. L. Inman (1952) schemes the parametres Median (Mo), sorting coefficient (So), Skewness (Sk) were gained that — according to the present state of the study of the granulometric composition of turbidites — may be best compared reflecting the genesis of the former (Z. Kukal 1958, 1964, G. Kelling 1962, T. Ďurkovič 1961, R. Unrug 1963, H. Okada 1966, S. Dżułyński, E. K. Walton 1965).

Although it was determined that sediments of the turbidity currents were not characterized by any special grain size distribution, the majority of the sediments (Z. Kukal 1964) had the Md ∅ of the silt and fine-sandy grain size with the So ∅ koefficient 0,5—1,0. The Median (∅) of the Lunz sandstones falls to the pole of. mediumgrained sandstones to siltstones (fig. 4, table 1), their So (∅) showing the maxima (82 %) within 0,6—1,2 corresponding to the medium well and medium sorted sandstones and siltstones. The research showed that the sorting of the Lunz clastics depended upon the grain size (fig. 5). Decrease of sorting occurs within 2,5—5,0 Md ∅. Similar relation was described by G. Kelling (1962), R. Unrug (1963) from the fluxoturbidite formations. The values of the Sk were mostly positive (73 %) indicating that fractions coarser than Md were less sorted. This result did not correspond to the C=M diagram by R. Passega (1964), according to which there was no change in the sorting of the coarser fraction since distribution was symmetrical with the C=M pattern (fig. 6).

On the base of the comparison of the parametres gained it may be supposed that the sediments were not deposited on beaches, since they had substantially higher koefficient of sorting (So). The sandy and silt fractions are in relative equilibrium as well as in sediments deposited from the unidirectional current. These data are well illustrated by the petrographic composition of the clastics (fig. 7, table 1). On the ground of the high content of irresistent feldspars and igneous fragments of rocks (granites) (2,9—59 %) they may be arranged to immature arcoses (72 %) and subarcoses, according to the classification by R. L. Folk (1961) and E. F. McBride (1963). It is probable, that the quick transport of the feldspathic sand was supported by topography, the selective abrasion of the feldspar grains being of small importance. The increasing share of feldspars with the grain size affirm this supposition (fig. 8) (cf. H.

Table 1

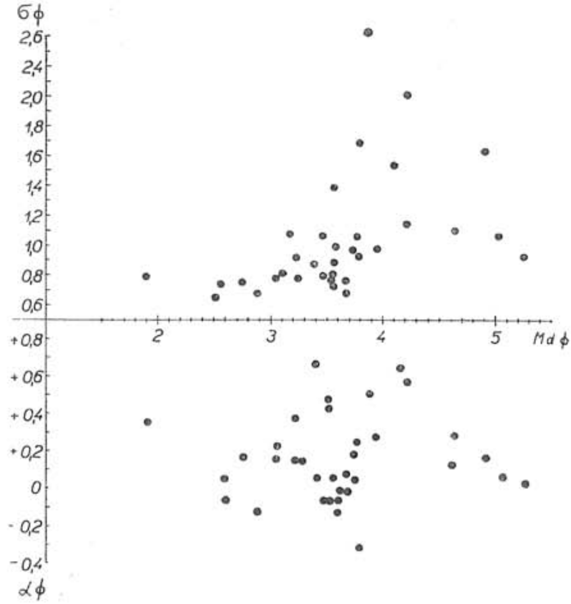
	1	S_o	M_z	S_k	Md	Q	M	F
1	1	2,48	5,12	0,50	3,87	86,5	1,2	12,3
1A	2	0,68	3,72	0,07	3,67	52,6	6,0	41,4
3		—	—	—	0,15	56,2	40,0	3,8
5		0,72	3,58	0,056	3,54	61,8	3,7	34,5
5A		0,68	2,78	0,132	2,87	—	—	—
6		—	—	—	1,90	82,0	7,0	11,0
6A		0,80	2,20	0,375	1,90	—	—	—
7		0,96	4,18	0,271	3,94	86,0	3,3	10,7
8A		0,92	3,35	0,141	3,22	69,5	1,7	28,8
8B		0.77	3,49	0,079	3,55	—	—	—
8C		1,05	5,10	0,048	5,05	—	—	—
9A		1,11	4 86	0,59	4,20	—	—	—
9B		3,30	5,60	0,67	3,42	—	—	—
9C		1,40	4.15	0,46	3,55	71,0	6,5	22,5
9D		1,63	5,17	0,167	4,90	—	—	—
11		—	—	—	7,25	59,0	3,0	32,0
12		—	—	—	6,15	89,0	3,3	7,7
13		0,88	3,44	0,057	3,39	—	—	—
13A		0,97	3,92	0,195	3,73	47,4	2,7	49,9
14		1,06	3,60	0,395	3,18	48,8	4,0	47,2
14A		0,8	3,41	0,062	3,46	—	—	—
14B		0,88	3,43	0,136	3,55	53,5	1,4	45,1
15		0,75	2,85	0,16	2,73	56,2	5,2	38,6
15A		0,88	5,28	0,034	5,25	95,4	2,5	2,1
15B		0,78	3.22	0,22	3,05	48,0	5,7	46,3
16		0,92	3,97	0,24	3,75	38,5	3,1	58,4
17A		1,04	3,79	0,036	3,74	41,5	4,0	54,5
17B		0,99	3,56	0,011	3,57	—	—	—
17C		0,74	3,52	0,012	3,61	—	—	—
17D		1,06	3,38	0,074	3,46	—	—	—
18		0,74	2,49	0,067	2,54	68,5	2,5	29,0
18A		0,76	3,34	0,145	3,23	59,4	4,0	37,0
18B		1,10	4,95	0,29	4,63	49,0	7,5	43,5
19		—	—	—	6,17	83,5	1,8	14,7
21		1,77	3,18	0,325	3,76	58,0	1,6	40,4
22		2,04	5,57	0,655	4,14	41,4	1,5	57,1
23		0,80	3,84	0,425	3,50	—	—	—
24		0,81	3,19	0,148	3 07	40,0	1,0	59,0
25		0,65	2,60	0,047	2,57	57,5	12,1	30,4

Notes: Q — quartz, quartzite, sillicite; M — metamorphic fragments of rock, mica; F — feldspars, igneous fragments of rocks; 1—7 — Krížna unit; 8A—25 — Choč unit.

O k a d a 1966) and the preceding opinion about the movement medium in agreement with the gravitation forces causing the quick transport of the clastic material into the basin.

The origin of sandstones may be best indicated by the feldspars. They form an important component in sandstones. In about 20 % of the samples studied, feldspars predominate over quartz. Mostly they are strongly decomposed, rarely solid. Transitions from slinghtly to strongly decomposed up to completely alternated feldspars may be observed. The most frequent type of metamorphosis is either sericization, kaolinisation

Fig. 5. Grainsize parametres of the Lunz clastics. Relation between the median (in the Ø units), So (Ø) and Sk (Ø).



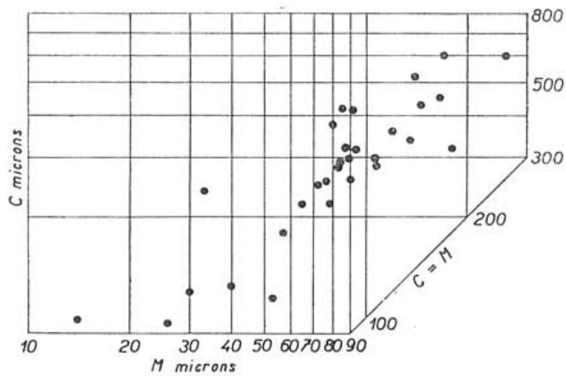


Fig. 6. Diagram of the changes of C and M.

or carbonatization. Most intense is carbonatization. In some cases complete calcification of feldspars may be observed. No differences in the spacial distribution of the ratio plagioclase: orthoclase have been observed. Generally orthoclase predominates over the acid plagioclase (oligoclase) in 9:1.

Quartz (40—95 %) is usually slinghtly undulose. On the locality Svarín (fig. 1. loc. 17), Podbrezová (loc. 22), Kunerad (loc. 3) there is the quartz with undulose extinction. Grains are angular, subrounded, rarely rounded. Spindle-like shape of grains may be found, too. Inclusions of indetermined minerals (chlorite, rutile?) are present. In many grains there were gas and liquid enclosures. Calcite cement caused slight corosion in some quartz grains.

From among rock fragments quartzite and cristalline schists are most frequent. Intraclasts of claystones are quite frequent. Fragments of basis rocks are very rare. Neither micas have high representation (0,2—3,2 %). Biotite was baueritized. As for the accessories, zirkon is most abundant, then tourmaline with brown pleochrosm. Corundum occured on the localities Liptovský Hrádok (fig. 1, Nr. 14, 15) and Čierna Hora (Nr. 7), and rutile and titanite on the locality Svarín (Nr. 17).

Glauconite belonge to the rare minerals, too. There are no more than 5 grains in a thin section. Its shape is irregular, colour lightgreen and green. Rare darkgreen glauconites are there, too. The glauconite is not component part of the cement among grains, it is supposed to have been resedimented. Higher concentrations were there on the localities Liptovský Hrádok (fig. 1, Nr. 13, 15, 17, 18).

It was difficult to differenciate the matrix of sandstones from the products of the desintegration of feldspars. In the thicker beds matrix was only slightly present, while in thin beds (2—15 cm) its content was quite a high one, especially in lamines (pl. XXII, fig. 1). Chemical cement is carbonatic, rarely chalcedonic. Feldspars are often replaced by carbonatic cement. The chalcedonic cement rose by recrystallization of the opal, most probably.

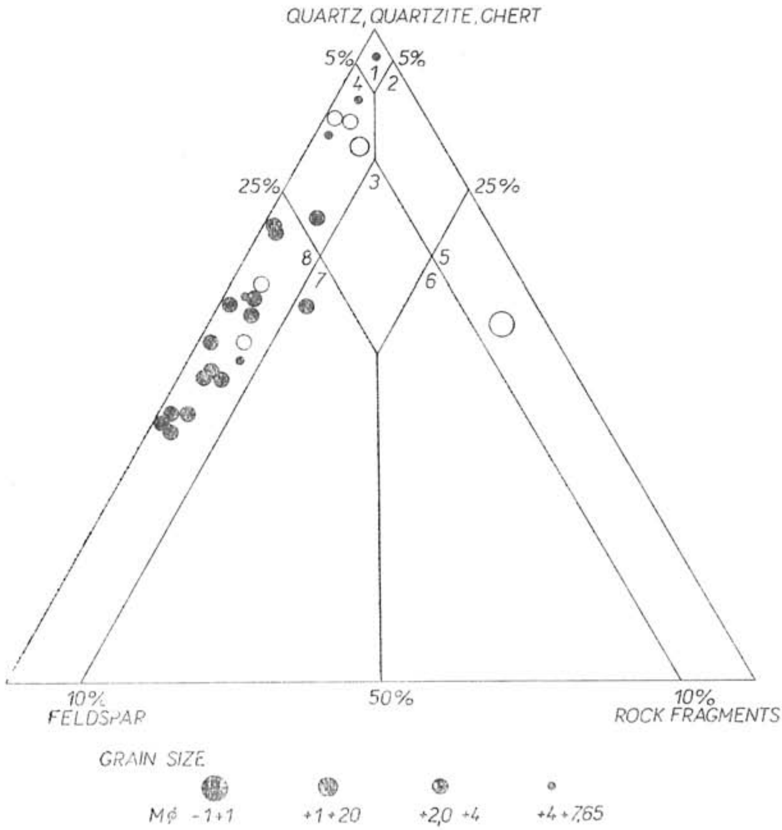


Fig. 7. Mineral composition of primary clastic components of the Lunz beds. Classification types according to R. L. Folk (1961). 1 — Orthoquartzite. 2 — Subgraywacke. 3 — Feldspathic subgraywacke. 4 — Subarkose. 5 — Graywacke. 6 — Feldspathic graywacke. 7 — Impure arkose. 8 — Arkose.

According to the mineral composition and granulometric parameters it may be supposed that the immature arkoses and subarkoses were slightly modified during their transport into the basin. High content of orthoclase and feldspars in general indicates their origin in the acid igneous rocks (granites) or partly in arkoses. R. Kettner and J. Koutek (1927) supposed the origin of sandstones in the basic rocks of the Lower Triassic melaphyre series, on the ground of the occurrences of chalcedony and serpentine. D. Andrusov (1958) considered resedimentation of clastics from the Carpathian Keuper and saw their origin in an extra geosynclinal source. Still the feldspar content in the Keuper does not exceed 19 % (D. Andrusov 1958), and the frequent carbonate fragments present in the Keuper do not occur in the Lunz clastics at all. Granulometric data indicated that arkoses had not been modified during the transport by the quick turbidity currents.

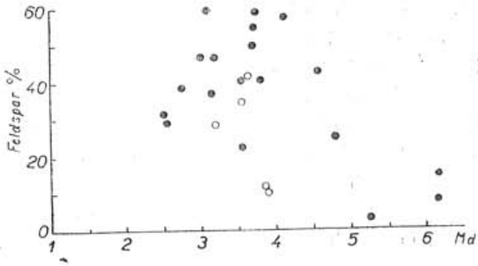


Fig. 8. Relation between the feldspar content and median (Ø).

Paleocurrent Investigation and Paleogeographic Considerations

The investigations proved that sediments in one limited bed had been deposited over the bottom from one current, therefore the sedimentary structures were oriented in the direction of the current activity. Determination of the current direction and the dip of the bottom are presented on current rose diagrams on the map in the observation points and profiles (azimuths are in intervals of 22.5 °). The current rose diagram shows the per. cent amout of observations in each class as well as the modal class interval suitable for the graphical interpretation. Simultaneously variability of current data may be determined, which may be very important in the determination of the current gradient (P. E. Potter, F. J. Pettijohn 1963), especially in the cross bedding (in this case current ripple lamination studied and presented here).

On the map several different current systems may be observed.

I. In the Krížna unit (the northern zone) the direction of the current system corresponds to the tectonic axis of the West Carpathians running from the SW to the NE and E, turning at the end near Košice to the SE, the variability of currents forming the current ripple lamination, fluctuating within 40—120°. In the southern zone of the Krížna unit (the series of Veľký Bok, cf. the squared raster on the fig. 1) the course of currents turns from the NNW to the SSE and SE. with just a low variability.

II. In the Choč unit the directional homogenity is stable enough, still the precise measurings in the sequence near Liptovský Hrádok (fig. 3) showed the turn of the current field from the base upwards in 80° in direction of the watch hands. The turning of the currents observed especially in the northern part of the Choč unit is reflected either by the bimodal distribution in current rose diagram (fig. 1, loc. 8, 9, 10, 18) or partly by gradual variability of modes (loc. 19, 21, 22). The current variability does not exceed the limits below 40° and over 130° in the separate profiles: **Polar alternation of currents has not been followed.**

The definite interpretation of the paleocurrent data in the Choč unit has to include the rotation of the unit around the vertical axis in 45° as a result of the alpine orogenesis. Then if the measured current direction, evaluated in the map is turned in this value (i. e. 45° opposite the direction of the watch hands — cf. J. Kotásek. M. Krs 1965), the dispersion of currents has the following course: in the lower series the current direction from W—E. NWW—SSE is parallel or oblique to the tectonic axis of the mountain range, while the distinct direction from NNW to SSE and S is perpendicular to the axis.

The margins of the basin were supposed in places where the maxima of the submarine slope failures had been localized, and the thick deposits of the slopes along that the turbidity currents were running down — accumulated. Thus the preferred NWW—SSE and S current directions and slump movements in the Choč unit represent the direction of the paleoslope and sedimentation. The source zone might have been localized to the N of this direction, i. e. to the N of the area of sedimentation of the Choč unit. This zone of uplift modified the transport of clastics by the turbidity currents into the basin resting in the S, where the greatest depths occured. On the base of the Upper Triassic the Choč unit represented an independent basin filled first from the intrageosynclinal source — longitudinally, and later on — laterally. Actually there exist only few indications of the existence of this source zone. Now here in the West Carpathians any transgression of the Lunz beds upon the underlying granites may be observed, and even the decisive amount of gravels typical of the Flysch facies near cordilleras (Ph. H. Kuenen 1958), is missing. The only find of granite pebbles in the mudflow near Východná signalizes that the source zone offered the coarse clastics. too.

One of the possible explanations is that the considerable part of these facies was reduced in the course of the tectonic overthrusts and the original source zones remained resorbed deep in the crystalline below the overthrust plains. If the width of the source zone with the proximal facies was 15—20 km, then the width of this zone has to be calculated in estimation of the horizontal shortening of the geosyncline. This supposition is supported mainly by the facial changes, increase in the thickness of sandstones, localization of the slope failures distict in the northern marginal part of the Choč unit — in its frontal part. Thus the original intrageosynclinal zone might represent the primary lines of weakening, along which the separation of nappes took place in the course of horizontal overthrusts. Although the experience from the Flysch Carpathians (M. Ksiażkiewicz 1960, Z. Roth 1961) could lead to such a conclusion, yet the rough comparison of the Lunz formation with very thick Flysch facies of the outer units of the West Carpathians would not be right. The lasting of the clastic sedimentation of the Lunz is chronologically limited and the uplift of sources must have been abrupt and short as to time. Therefore the absence of coarse clastics is surprising, strongly contradicting to the previously formed opinion about their origin in the intrageosynclinal source. Yet the high content of feldspars, low roundness of grains point to the origin of clastics being not in the distanced areas and the granite or arkose source not supplying too coarse grained detritus.

Lateral transport of clastics by the turbidity currents deposition and wedging out of the beds outwards from the centre of the geosyncline to its margins (cf. A. Tollmann 1963, W. Medwenitsch, W. Schlager 1964), and especially the euxine type of facies lead to the ordering of the clastic sediments of the Lunz to the Flysch formation that arose at the commencement of the development of the Alpine-Carpathian geosyncline. Still there is a bad need to verify these finds on the Alpine material.

Translated by E. Jassingerová.

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EXPLICATIONS OF THE PLATES

Plate XXI

Fig. 1. Wedging out of the sandstone bed in claystones. Cut of the Váh r. — Podtureň. — Fig. 2. Rhythmical alternation of sandstone and claystone beds. The Podtureň quarry. — Fig. 3. Massive bedding with the interval of the lower parallel lamination. Cut of the Váh r. — Podtureň. — Fig. 4. Massive bedding with the interval of the superimposed current ripple lamination. Liptovský Hrádok. Photo R. Marschalko.

Plate XXII

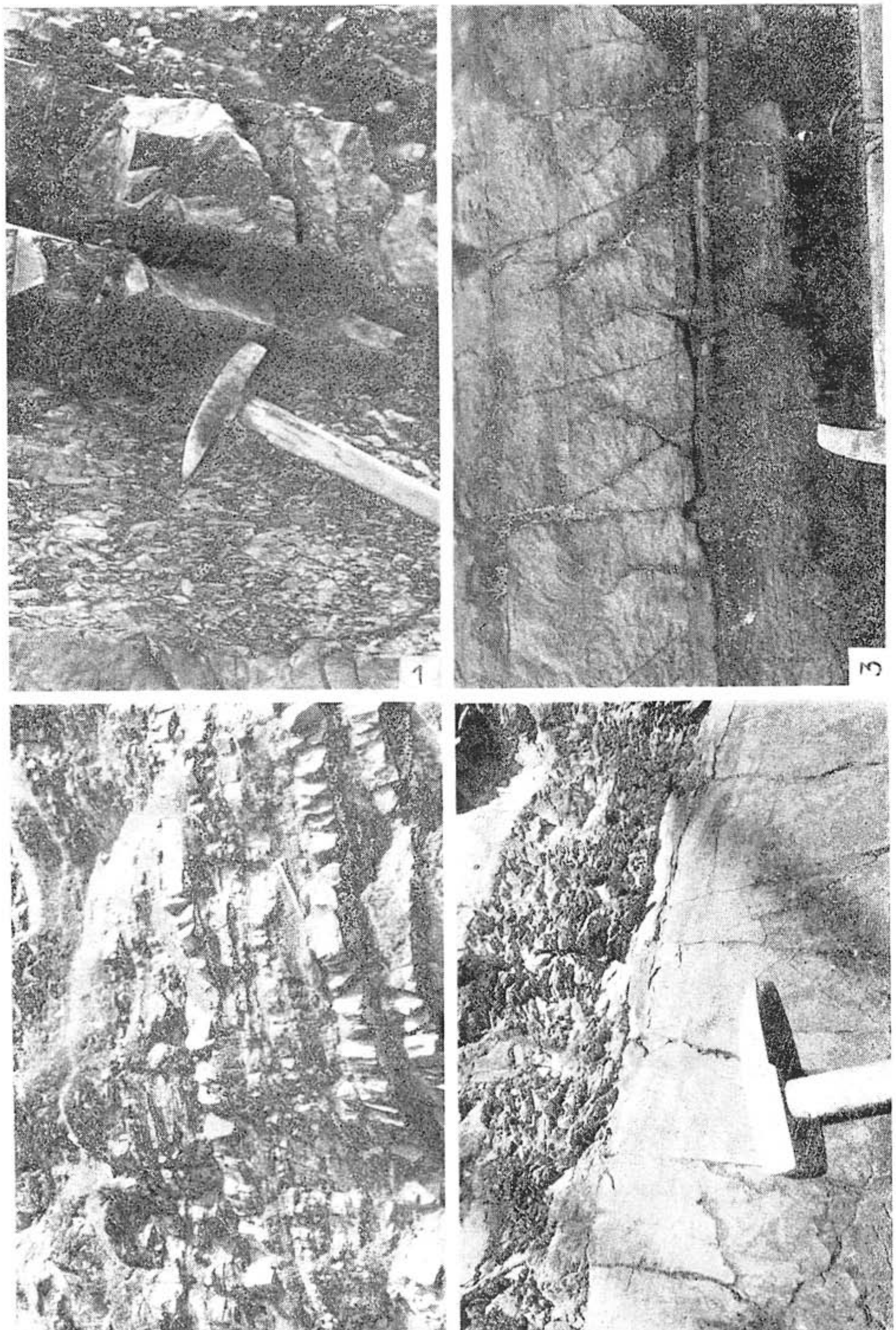
Fig. 1. Graded bedded lamines of the lower parallel lamination. Magnified 24×. Photo M. Pulec. — Fig. 2. Superimposed current ripple lamination. Scale (in cm) in the top right corner. Liptovský Hrádok. Photo M. Pulec. — Fig. 3. Asymmetrical current ripples with parallel course of crests. Upper surface. Size 22×15 cm. Malužiná. Photo L. Osvald. — Fig. 4. Asymmetrical current ripples in parallel rows (lower bed) and linguoid ripples (upper bed). Podtureň quarry. Photo R. Marschalko.

Plate XXIII

Fig. 1. Flute casts. Size 22× 15 cm. Svarín. Photo L. Osvald. — Fig. 2. Longitudinal furrows and ridges. Size 30×18 cm. Východná. Photo L. Osvald. — Fig. 3. Rounded claystone fragments (pebbles), their impressions in the bed. Pebbles oriented along the long axis. Cut of the Váh r. — Podtureň. Photo R. Marschalko. — Fig. 4. Mudflow with destroyed and mixed beds of sandstone. Cut of the Váh r. — Podtureň. Photo R. Marschalko

Plate XXIV

Fig. 1. Slump fold with lamines bended downwards. The Podtureň quarry. — Fig. 2. Megarippels. The Podtureň quarry. Photo R. Marschalko.



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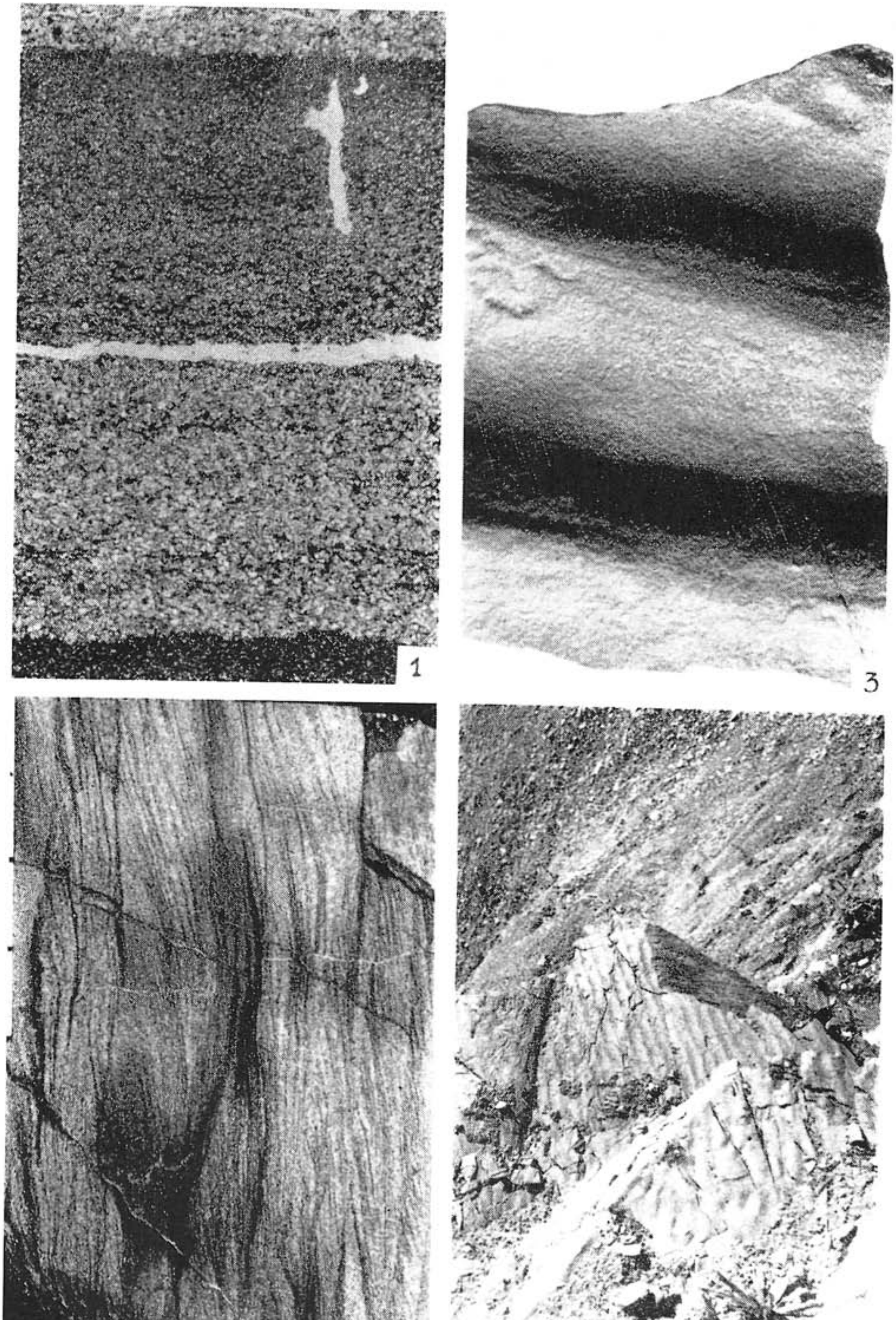

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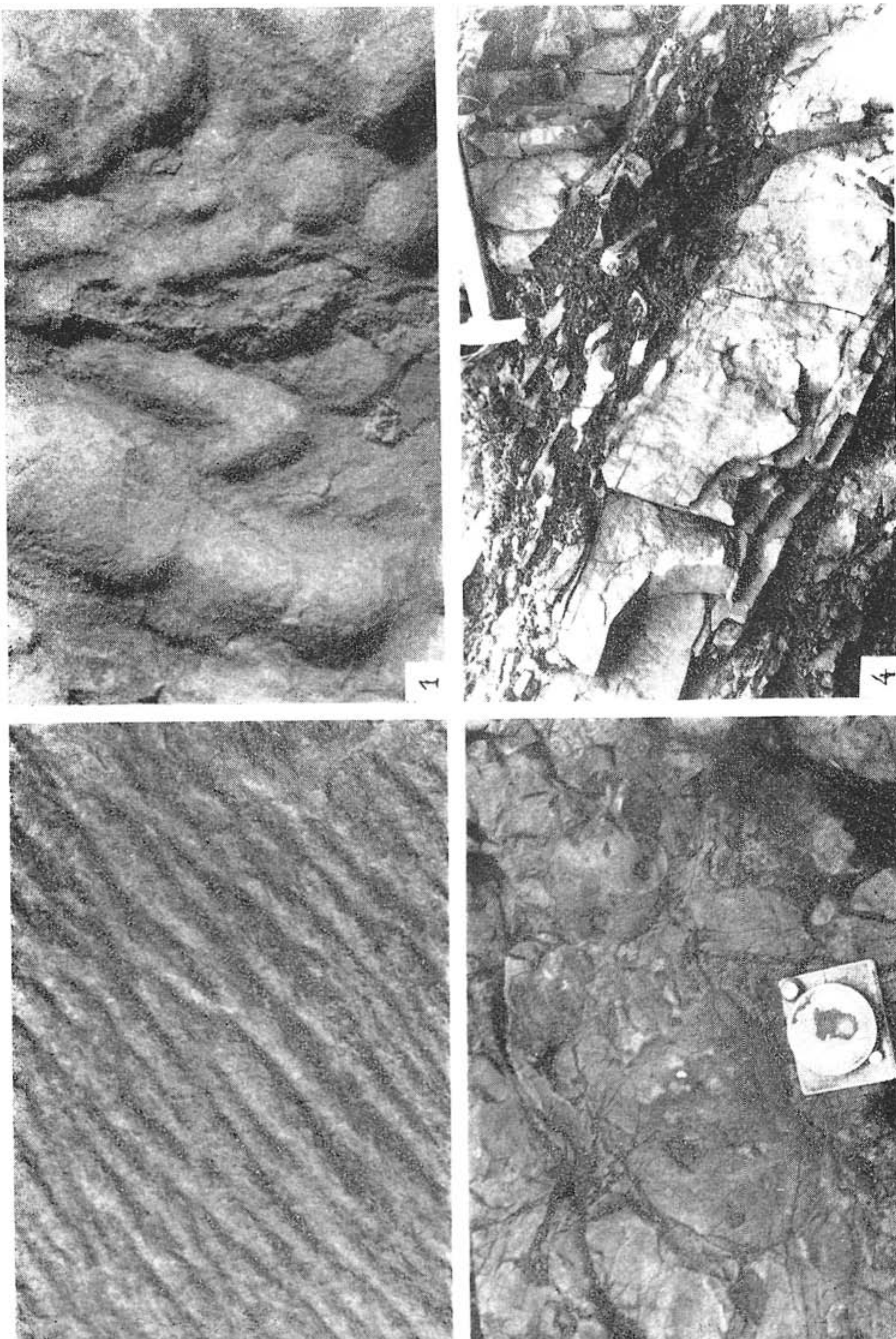

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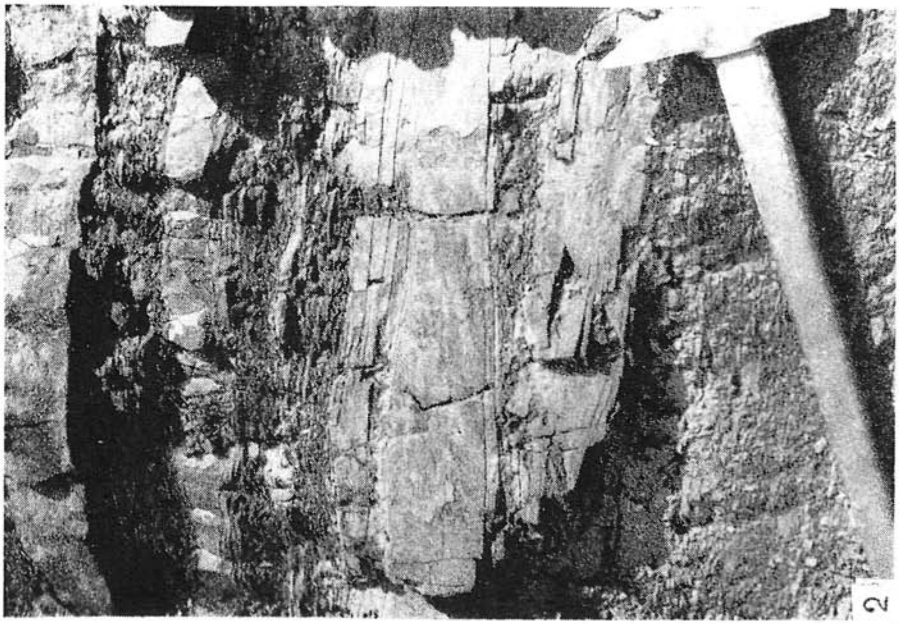

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