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# ON SOME SEDIMENTARY STRUCTURES OF THE CARPATHIAN FLYSCH

(Pl. I — V and 2 Fig.)

Abstract: Oriented tubes of bathysiphons, crescent casts caused by pebbles, wood fragments or sandstone fragments, laminated flute casts, flow-casted flute casts and contemporary flute marks are described.

## INTRODUCTION

During last few years Radomski (1958), Dżułyński and Ślączka (1959), and Birkenmajer (1958) have described many sedimentary structures developed on the surfaces of flysch sandstones. Their observations greatly increased the knowledge of these structures due to Grossheim (1946), Wassoevich (1951), Kuenen (1957) and others. To these descriptions I wish to add a few observations pertaining to some structures of the lower surfaces.

## 1. ORIENTATION OF BATHYSIPHONS

Oriented organic remnants have been noted from deposits of various type. Aligned graptolites were reported by Ruedemann (1894), orientation of pelecypods in deposits of flysch type was noted by Kuenen and Sanders (1956), and Natland (1957) observed aligned small foraminifera in deposits probably laid down by turbidity currents. Crowell (1955) described plants debris aligned in the current direction.

In the Carpathian flysch, beside plant detritus, organic remnants are very scarse, and so far no observations indicating an alignement of fossils have been made. Therefore it is worth while to note, that in some cases aligned *Bathysiphon* tubes may be observed. *Bathysiphons*[1] are not infrequent in Carpathian sediments; they quite often occur on the soles of sandstones. Usually they are stuck to the sole in an unoriented manner,

[1] Very much the same flattened tubes, with a longitudinal furrow, have been described under the name of *Jereminella* from deposits of Senonian age and regarded to be tubes of worms.

although it seems, that as they are as a rule fragmented, they must have been detached from the bottom on which they lived, and redeposited.

The oriented bathysiphons occur near Tabaszowa, on the western side of the Rożnow lake, in thin sandstones forming intercalations in the dark shales covering the Lower Istebna sandstones. From the same area, only from the other side of the lake, bathysiphons were reported by Bieda (1949) from the Lower Eocene Ciężkowice sandstone.

In this series the soles of the thin-bedded sandstones are often covered with small, on the whole poorly developed organic hieroglyphs, belonging to *Spiroraphe* and *„Helminthoida" appendiculata* Heer. If the sandstones are ripple-current-bedded, tubes of Bathysiphon are lying disorderly on the sole. If there is graded bedding, as a rule not conspicuous in these beds, because of the uniform grain size (the top is, however, always laminated), the fragments of tubes are aligned (Pl. I, fig. 1). *Bathysiphon* has one end of the tube pointed (cf. Bieda 1949, Avnimelech 1952). If the tubes of Bathysiphon are aligned, their pointed ends are directed in one direction. Most of the fragments are stuck to tiny, irregular ridges: these are elongated, parallel to each other, feebly linguoid, and can be regarded as small imperfect flute casts, filling little furrows eroded by the same current which carried the fragmented tubes. These were trapped in the furrows, at the same time under the influence of the current turning their pointed ends downcurrent. An alternative possibility is that the furrows were formed on the lee-side of the obstacle formed by the tubes if they stuck in the muddy bottom before the current arrived, or they were driven into the soft mud by the current, thus becoming an obstacle for it. The current flowing around the obstacle, concentrated on its lee-side and eroded below more strongly. In this case the tiny ridges would be the filling of „current marks" of Twenhofel (1932, p. 667, fig. 89) which are formed on the sea-shore below small obstacles. In the discussed case the tube fragments formed the obstacle; subsequently the tubes were overturned and trapped in the furrows. In both alternatives the pointed ends indicate current direction. In the same way according to Dapples and Rominger (1945) are aligned quartz grains, as in this position the resistance to flow is the smallest.

The length of the oriented tubes is up to 4 cm. If the tubes are longer, their arrangement is chaotic. Probably long tubes were not far transported, whilst broken tubes were transported farther away and aligned.

In several instances, particularly in the Inoceramian beds, the bathysiphons occur on the lower surfaces exhibiting well developed flute casts. In this instance the tubes are not placed on casts but accumulated between them; they are not aligned, often lying at right angle to the casts. It may be thought that if the current was strong enough to erode normal furrows, the vortex eroding furrows threw away the tubes and deposited them in more quiet places between the furrows.

In some cases when a lineation on the lower surface is marked by delicate lines, one may observe that smaller fragments of bathysiphons are parallel to the lineation, while larger fragments are lying obliquely.

Sometimes small, elongated ridges may be observed in the prolongation of the tubes. Possibly they are formed by dragging or by impact of the tubes with the sea-floor.

## 2. CRESCENT CASTS

Fossil structures corresponding with recent erosional furrows cut around some obstacles on the shore were first described by F i e g e (1937, Pl. VIII, fig. 3, 1942, p. 308, fig. 15). Later they were found in deposits of various type. D ż u ł y ń s k i and Ś l ą c z k a (1959), and R a d o m s k i (1958) found small crescentic hieroglyphs in the Carpathian flysch caused by small chips of shales. In a number of instances I found fairly large crescent casts provoked by fragments of wood, quartz pebbles and sandstone lumps.

Pl. II, fig. 2 represents a crescentic hieroglyph on the lower surface of a sandstone, (14 cm. thick, from the Podhale flysch). The cast is asymmetrical, one side being better developed than the other, a feature also frequent in the shore current marks. The cast has the form of a bent semi-cylindrical ridge. Similarly as at many flute casts, the main cast is accompanied by a small collateral cast. The length of the cast is 13 cm, its width 8 cm, in its center there is a piece of carbonized wood 8 cm. long and 3 cm. wide. The direction pointed out by the cast, nearly exactly eastward, corresponds with the directions of flute casts and current bedding as found by R a d o m s k i (1958) in the area.

Pl. I. fig. 2 represents crescent marks formed around quartz pebbles. The arms of the casts tend to join each other on the lee-side. It seems that in coarser types of the Carpathian flysch the crescent casts around pebbles are as much frequent as the crescent casts caused by shale fragments in fine-grained beds. Usually, however, the pebble falls out and the crescent cast remains with no obvious cause.

On Plate II, fig. 1 an exceptionally large crescent cast is shown. It occurs on the sole of a flaggy sandstone belonging to the complex of the Magura sandstone. Its width at the base is 8 cm, the length 25 cm, both arms are well developed and nearly of the same size. They do not unite with each other and gradually die out. A small flute cast appears among them. On the arms of the cast there are small ridges screwed toward the center; to be sure, they were formed by the filling of small secondary furrows eroded by horizontally moving vortices, created in the current when it was flowing around the obstacle. A formless lump of a sandstone, 8 cm. long was the obstacle. The sandstone is yellowish, micaceous, different from the sandstone on the sole of which it occurs, and also from other sandstones of the Magura complex. On the whole, reworked sandstones are rare in the Carpathian flysch, and redeposited pebbles (i. e. pebbles of the sandstones of nearly the same or the same age as the beds in which they occur) so far have not been described, although redeposited fragments of shales are quite numerous. In all probability turbidity currents moving along the clayey bottom, remove the soft clay, and when they reach more hardened clay resp. shale, erode it. Occasionally they may, on removing the shale, reach deeper and erode the sandy layer, more or less consolidated.

## 3. LAMINATED FLUTE CASTS

T e n H a a f (1959) under the name „terraced flute casts" described flute casts the surface of which is covered with small parallel steps. These steps are a reflection of the differences in hardness of the underlying laminated bed. Similar structures are also mentioned by K u e n e n (1957).

The hieroglyphs of this type occur in the Carpathian flysch apparently very infrequently, probably because the flute casts are usually cut into non-laminated shales. The most distinct terraced flute casts were observed by the present writer in the Albian flysch (internal flysch) in the valley of the Jalomitioara in the Roumanian Carpathians during an excursion in the company of Dr D. Patrulius and L. R. Contescu.

On the other hand, at Kamesznica (Żywiec area) in the main quarry there were exposed the casts, resembling the terraced casts, but probably of a different origin. They occur on the lower surface of a medium-bedded sandstone, belonging to the Krosno beds of the Pre-Magura scale.

These are large casts (Pl. III, fig. 1). corresponding in shape with the hieroglyphs of the neighbouring beds. They are cut into a mudstone with very indistinct, if any, lamination. The sandstone, on the other hand, is laminated throughout its whole thickness. Lamination inside the cast is hardly visible, whilst on the surface is well marked, in the same way as in the sandstone, in which it is visible on weathering. Therefore it may be surmised that the lamination of the casts is internal, and that it is not a reflection of the lamination of the underlying layer, as the case is with the terraced flute casts.

Lamination, according to all writers, is formed at small velocities. In flysch sandstones it is very often visible in the topmost part of the bed. There are cases, however, that the whole bed is laminated. This usually pertains to beds of small thickness:, such beds usually have no flute casts which were formed when the current was relatively fast, and had a corresponding turbulence, although according to Lamont (1957) turbulence may be active at low velocities. In the discussed case, the large furrows must have been eroded in the early stage of the current, and probably were filled with laminated sand some time after. There are known the cases that casts are filled with current-bedded sand (Kuenen 1953, fig. 11, p. 25), and Kuenen and Prentice (1957) note that a horizontal lamination may occur in flute casts. In the described case it is not possible to say whether the filling took place from the same current that eroded the furrows, or the furrows were filled by another current flowing along the furrowed bottom at a later date.

## 4. FLUTE CASTS DEFORMED BY SUBSIDENCE

Flute casts, similarly as other structures of lower surfaces, are in the Carpathian flysch usually not deformed. In some instances they exhibit deformations posterior to the time of their formation. Dżułyński and Radomski (1955) called attention to the possibility that sole casts may undergo compaction, and Kelling and Walton (1957) noted that sole structures may be load-casted.

A peculiar case of flute casts deformation may be observed at Struga (near Tęgoborze, Nowy Sącz area) on the western side of the Rożnów lake. Here fairly thick sandstone beds, occurring sparingly in a shaly series, show well developed flute casts. The sole of one bed (which is overturned) is covered with flute casts of various dimensions (Pl. III, fig. 2). The smaller and lower flute casts are normally developed, on the contrary the large casts have irregular shapes and are truncated to one flat common surface, 3 to 4 cm. above the sole of the bed. The truncated surface is granular and rough, while the surface of the sole and of the not truncated casts, as well as the surface of the not truncated parts of larger hieroglyphs is smooth.

The truncated casts are enlarged at a distance from their heads as if they were swollen sidewards. The sides below the truncated surface are bent outward, and at places at the edge of the truncating surface there are small overhangs and inclined ridges.

It follows from this description that all the casts that reached a certain depth, were truncated. This may be explained as follows:

The sandy bed was laid down on a soft clay; the deeper part of the clay was already hardened. After a certain time, but before the complete consolidation, the sandy bed subsided as a whole owing to the compaction of the underlying soft clay. During the subsidence the sole of the sandstone reached the hard layer of clay. This layer was so consolidated that it did not yield and bend under the load of the sandy bed, but conversely, the larger and deeper casts of the sole adapted their surfaces to the surface of hard clay. Under the load of the sandy bed these casts spread laterally and became enlarged sidewards, because the surplus of their mass in the confined space could only laterally be accomodated, in the direction where the clay was not yet entirely consolidated (Fig. 1).

As a matter of fact there exist some features indicating that below a certain depth clays were consolidated. T e n H a a f (1959) noted that load casts reach a certain limiting height, and explained this by the assumption that the deposited sand was sagged only to the depth at which it reached the hardened clay.

The described type of deformation is probably limited to thick-bedded sandstones as in the described case, and is probably rather rare. In the literature I have not found similar cases. Possibly the „hieroglyphs" of W i a ł o w (1955, fig. 3) from the Lower Paleozoic flysch of Turkestan, with flat surfaces, are the casts of ripple-marks on the lower surface, flattened by a wholesale subsidence of the bed, limited by the underlying hard clays.

## 5. FLOW-CASTED FLUTE CASTS

Describing the structures of the lower surfaces of the Carpathian sandstones I underlined that some bumps of the sole show a marked asymmetry and are bent in one direction (1954, p. 420, 446)[1]. Therefore I thought that F u c h s' explanation of some hieroglyphs as formed by the flowing of freshly deposited sand could be right. Similar views were held by Soviet workers (W a s s o e v i c h 1951) at that time, whilst in the Anglo-saxon literature a greater role was ascribed to vertical movements due to yielding of hydroplastic clay below the burden of sand. Soon, however, P r e n t i c e (1956) delimited the structures caused by a lateral flow from the structures formed by load-casting, a distinction already known in the Carpathian flysch.

Flow-casts may be formed in the moment of sand deposition, or at a slightly later time. In the first case the mechanism of transport and deposition must have been different (P r e n t i c e 1956) than in the

[1] In the same paper (p. 418) the presence of flow hieroglyphs on the upper surface was noted. Such structures were described from the Alpine flysch by K r a u s (1935).

instance when the current eroded and formed flute-marks. This is the reason why flute casts and flow-casts do not occur usually together on one and the same sole. This also probably is the reason why flow-casts occur much more frequently in very thick beds, and flute casts are more numerous in medium- and thin-bedded (although not very thin-bedded) sandstones.

Flute casts or groove casts deformed by a lateral flow of sediment seem to be much less frequent than flow-casts [1]. The flow must have been subsequent to the deposition and formation of casts, but certainly before the consolidation of the deposit. A few observations on deformed current structures are given below.

Pl. IV, fig. 1 presents a groove cast deformed by a lateral movement. A strong unilateral overhang (Fig. 2) points out that the deformation is not caused only by compaction. Just above the deformed part the bed is not internally contorted; this clearly indicates that the deformation was not caused by a slump movement of the whole bed. The flow movement was then limited to the sole, and to all appearance the groove cast itself was not translocated but the underlying clay dragged by the horizontal movement of the adjoining part of the sole was horizontally pushed into the sand above the cast.

Small impact casts (Radomski 1958, Dżułyński and Ślączka 1959) are associated with the groove cast and indicate the current direction. The flow deformation is nearly at right angle to the direction of the current.

Pl. IV, fig. 2 shows a much larger flow cast on the lower surface of the Magura sandstone. Here the deformation is also limited to the lowest part of the bed; upward no traces of flow or slump structure can be detected within the sandstone. Here the current hieroglyphs are deformed by flow or creep which formed flow casts in the form of overturned folds with axes parallel to the direction of the current hieroglyphs. In this case an influence of the current drag must be excluded, and it should be presumed that the slope induced the flow (Prentice 1956). The flow is again nearly at right angle to the current direction.

In the year 1956 during the Conference on Sedimentation of the Geological Society of Poland, after the lecture of Bukowy (1957, p. 153) I called attention to the fact that from the facts presented by that author the inference should be drawn that the direction of flow (in the meaning now used after Prentice) and the direction of current hieroglyphes (flutes) may differ, and that in the Magura beds I observed in some cases in the same bed the direction of flow at right angle to the current direction.

Similar features were in great detail described by Birkenmajer (1958) who found in the series examined by him that the direction of flute casts differs from the orientation of flow casts. Birkenmajer concluded that the currents could become independent from the slope under influence of various factors. It should be noted in this respect that Gross-

[1] To this cathegory belong according to Birkenmajer (1959, p. 60) „deltoidal" hieroglyphs. He regards them as groove casts converted by a lateral flow into „flow-load casts". Previously (1958, p. 125—126) he regarded them as a variety of flow casts, influenced by the presence of a erosional furrow. The present writer regards these hieroglyphs as a variety of flute casts (feather-like type, 1958, Pl. IV, fig. 1). Ten Haaf (1959) regards these structures, called „frondescent marks" by him, also as a variety of flute casts.

heim and Korotkova (1954, also Grossheim 1959) found in the Caucasus flysch that in individual beds the current direction marked by flute casts, had at first been parallel to the basin axis, but in the upper part of the bed the current directions marked by current bedding are variable and less markedly longitudinal. The Caucasian authors believe that the current had been strong at first, but subsequently it changed intensity and direction. Ten Haaf (1959) also gave an example of directional differences at the base (flute casts) and in the top (ripple-marks) of a bed. Similar facts were reported by Prentice (1960). This writer thinks that erosional structures such as flute marks, drag marks etc. are formed when the current has the greatest velocity and flows in the direction imparted to it in the initial phase, while the upper part of the bed was deposited by the slown down current, which had to adapt itself to the configuration of the sea-bottom. According to Prentice this could happen when the current changed its course from transversal to longitudinal (with regard to the axis of the basin).

The observed differences between flute casts and flow structures (Książkiewicz in Bukowy 1957, Birkenmajer 1958) and the difference between the initial and ultimate direction in the same current (Grossheim and Korotkova 1954, Ten Haaf 1959, Prentice 1960, (also some cases observed in the Carpathians, e. g. the Hauterivian-Barremian Grodischt beds south of Cracow) indicate that the currents did not always follow the maximal inclination of the bottom but in some instances they flowed obliquely to the maximal slope. This view is corroborated by fairly numerous instances that in one and the same area neighbouring beds exhibit different flute casts directions (Książkiewicz 1958, Dżułyński and Ślączka 1959)[1].

It seems that these facts may be referred to the hypothesis of the lateral filling of flysch basins (Książkiewicz 1956, p. 387). The turbidity currents, flowing down the slopes from cordilleras and reaching the central part of the basin, had to follow the resultant from the direction given to them on the submarine slope of the cordillera (i. e. approximately at right angle to the axis of the basin) and the longitudinal inclination of floor. It is possible that for this reason the oblique direction of current structures with regard to the facies boundaries and tectonic lines is so frequently observed. Oblique directions are at any rate more frequent in the Carpathians (Książkiewicz 1958, 1960) than longitudinal, although at first Wassoevich (1951, p. 70) presumed that the currents were directed along the trough, basing on the analogy with the Caucasus. Last data from the Caucasus seem to give a more complex picture of current directions. In the Polish part of the Carpathians recent

[1] Birkenmajer (1958, Polish text p. 136, also English text p. 146) referring to my paper published in 1954, says that I regarded the data resulting from the measurement of groove and flute casts as sufficient for determination of the slope of the basin-floor and for the location of the source of detrital material. It should be said that this problem is not even mentioned in my paper. In another paper, published in 1956 (perhaps this paper Birkenmajer had in mind) the location of the sources of the Carpathian flysch was reconstructed on the base of a facies analysis (p. 383—385) and not on transport directions, at that time very little known. In this paper I presumed that the laterally flowing currents turned with the inclination of the axial region of the trough, but this inclination was reconstructed not only on the ground of the flute casts orientation, but primarily again on the ground of the facies distribution.

research (Książkiewicz 1958, Dżułyński and Ślączka 1959, Książkiewicz 1960) shows that oblique and transversal directions are quite frequent. Oblique directions were reported from New Zeeland by Webby (1959), oblique and transversal directions in the Alps are reported by Crowell (1955) and Hsu (1960).

It is possible that a current on the sea-floor may flow not in the direction of the maximal slope, and even, if achieves a considerable velocity, it may be independent from the angle and direction of the slope (Birkenmajer 1958, p. 136), but it is doubtful whether in the comparatively narrow flysch basins this independence could be of greater importance. A turbidity current, even locally deflected, will in any case seek the direction of maximal slope for it moves primarily under the influence of gravity. The Coriolis force, if it really affects the turbidity currents which seems to be debatable (ten Haaf 1959), may be perhaps effective on a large, flat sea-floor, but its effect in the narrow flysch troughs is dubious. The facts known from the Carpathians do not confirm its influence. Both principal flysch troughs in all probability were filled from either sides (Książkiewicz 1960). In the northern trough the currents descending to the central part were deflected eastward, no matter whether they flowed from the northern or the southern coast. It they were under the influence of the Coriolis force, the currents flowing from the north should have been turned westward (to the right), and the currents flowing from the south should have been deflected eastward (to the right). Concurrently, in the southern trough the currents flowing from the southern border were deflected westward (to the left) and the currents coming from the north turned also westward (to the right). These facts imply that the morphology of the troughs and not the Coriolis force controlled the trend of the currents.

It should be pointed out, that the direction as read from flow casts does not necessarily indicate the actual slope of the sea-floor in the moment when the turbidity currents were flowing over it. Sand beds were laid down on a clayey layer, which under the load of the bed, especially of a thick bed (flow casts occur mainly in thick beds), undergoes compaction. In many instances the compaction could be differential, depending on the thickness of the underlying clay and other its properties. In this way a secondary unevenness could be formed, in some cases sloping at right angle to the original slope and current direction.

## 6. ON THE ORIGIN OF FLUTE MARKS

Since Grossheim (1946) and Rich (1950) published their papers on flute casts, these structures have become an important instrument of paleogeographical and paleosedimentological research. Erosional forms, corresponding to flute casts were obtained experimentally (Rücklin 1938), but very little observation has been made on recent formation of these marks. Erosional furrows cut in hard rocks were described by Maxson and Campbell (1935), while Wassoevich (1951, p. 51) observed their formation on soft river deposits. To his comments two photographs are added, presenting erosional furrows not quite exactly, as the author himself states, corresponding with flute marks. More similar furrows were obtained by him experimentally.

It seems, however, that contemporary flute marks are not very rare, and although from the sea-floor they are yet unknown, in rivers they are fairly often formed.

In the Carpathian stream-beds I observed several times asymmetrical hollows, with slightly overhanging and steep upstream wall, probably corresponding to anti-dunes. They may be observed shortly after overfloods.

In smaller streams on many occasions I could observe the furrows more or less similar to flute marks. They are usually formed during short showers when a stream is swollen for a few hours or so. In the silty stream--bed or on the floodplain aligned furrows, sometimes strongly resembling flute marks converted into casts in fossil beds, are formed.

It is worth while to note that the furrows are not entirely filled. In some cases larger grains or pebbles are trapped in them (Pl. V) but although turbid water flowed above them for some time, no material was deposited in the furrows. Thus the problem arizes, lately often discussed, whether the current can erode flute marks and not fill them immediately.

The problem was risen by C r o w e l l (1958) who in some instances observed in flute casts grain aggregates which could be coprolithes. According to him they had got into the furrow at a stage after erosion, and before the furrow was filled. A similar observation was made by the present writer (1954, p. 419): „Not all current hieroglyphs are connected with the origin of the sandy bed, on the surface of which they occur.... sometimes they have on their surface biogenic hieroglyphs, which means that after their formation but before the filling by sand, some organisms still crept on them" (transl. from the Polish text). Incidentally, traces of creeping organisms across empty furrows in stream-beds may occasionally be observed. C u m m i n s (1958) found that in some instances flute casts were cut by currents flowing from another direction than the currents that filled them.

Although, no doubt, the conditions in rivers are different from the conditions under which turbidity currents eroded and deposited, the presence of unfilled furrows indicates that a current can erode the mark but does not necessarily fill it.

In mountain streams one may observe that unfilled flute marks usually are formed at a certain distance below the knickpoint of the slope. Possibly in this zone the current has still a velocity (apparently not very great) and turbulence necessary for fluting, while the tail of the current is still swift enough to carry its load farther away. It may be presumed that above and below the furrows were instantly filled. Perhaps similar conditions may be visualized in the basins filled with turbidite deposits where also the flute marks in some zones could be left unfilled for a certain time.

The shape of erosional furrows in streams is very much the same as the shape which may be reconstructed for flute casts. The variability of shapes is also the same. Four types of R ü c k l i n (1938) may easily be found, e. g. the hoof-like (Pl. V, fig. 2 near the front), and also small accessory flute casts accompanying larger ones (Pl. V, fig. 2). It seems, however, that in rivers on one surface one encounters a greater variability of shapes as compared with flysch deposits, where usually one type of flute casts prevails on a sole. The spacing of furrows is in river deposits also not so regular as in the case of turbidite deposits in which as underlined by W o o d and S m i t h (1959) the spacing is very uniform. In rivers the furrows are not so parallel. This would confirm the view of Kuenen (1957, p. 241) that the flute casts in the beds deposited by turbidity currents are more straight and more parallel. My observations, however, pertain to small streams, where the influence of near river banks and the unevenness of the bottom are certainly an additional factor influencing the spacing of vortices in the river current. It is possible that in large rivers erosional furrows are of a more uniform type and more uniformly spaced.

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## EXPLANATION OF PLATES I — V

### Plate I

Fig. 1. Oriented tubes of *Bathysiphon*. Istebna beds, Senonian. Tabaszowa on the Rożnów lake.
Fig. 2. Crescent casts caused by pebbles. Inoceramian intercalation within the Istebna beds. Senonian. Czchów on the Dunajec

### Plate II

Fig. 1. Crescent cast caused by lumps of sandstones. Magura sandstone. Eocene. Polany near Grybów.
Fig. 2. Crescent cast caused by a piece of wood. Podhale flysch, Eocene. Krempachy.

### Plate III

Fig. 1. Laminated flute casts. Krosno beds. Upper Eocene. Kamesznica near Żywiec.
Fig. 2. Flute casts flattened by the subsidence of the sandy bed. Beds are inverted. Submagura beds, Eocene. Struga on the Rożnów lake.

### Plate IV

Fig. 1. Groove cast, deformed by flow. Lower Senonian flysch. Pieniny.
Fig. 2. Flow cast. Magura sandstone, Eocene. Zawoja.

### Plate V

Fig. 1 — 2. Erosional furrows (flute marks) in the Jalomitioara river near Fieni, Roumanian Carpathians.