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Slump structures and turbidites in Upper Devonian limestones of the Holy Cross Mts.

ABSTRACT: The structures and deposits associated with subaqueous mass movements in the Upper Devonian of the Holy Cross Mts. are described. Slumpings, mud flows and turbidity currents were important factors during exclusively calcareous sedimentation. A considerable part of the resedimented calcareous Frasnian deposits is connected with contemporaneous reefs. They had a bearing on the sedimentation of the basin facies (the Kostomłoty Beds) and the Frasnian sedimentation of the southern part of the Kielce region within the reach of turbidity currents. The resedimented deposits come partly from the carbonate shelf lying most likely NW of the Holy Cross Mts. Resedimentation also took place in the pelagic facies.

INTRODUCTION

The Upper Devonian of the Holy Cross Mts. is developed as calcareous deposits. Facially they are strongly differentiated and contain sediments, from skeletal limestones (bioherms, biostromes) and detrital reef-deposits to pelagic sediments. The present paper deals with some selected problems of Upper Devonian sedimentation, but only concerning subaqueous mass movements and their results. The connection of these problems with the Famennian has been previously discussed by Radwański and Roniewicz (1962). Other authors have also reported similar structures (Kotański 1959, Czermiński 1960, Pajchlowa 1962). Those discussed here may prove of essential importance in the reconstruction of the paleogeography and sedimentary history of the Upper Devonian in the Holy Cross Mts. These questions cannot, however, be more thoroughly discussed until the exact stratigraphic division has been settled. The Upper Devonian sedimentation of the Holy Cross Mts. is being investigated by the writer, the present paper being of a preliminary character.

GENERAL STRATIGRAPHY AND PALEOGEOGRAPHY

The Paleozoic deposits in the Holy Cross Mts. may be divided into two chief facies (fig. 1): the southern facies of Kielce and the northern facies of the Łysogóry Mts. This facial division also exists in the Upper Devonian (Czarnocki 1950). In the Łysogóry facies the Frasnian is believed to be geosynclinal, while contemporaneous deposits in the Kielce facies are mainly reef or detrital deposits (Czarnocki 1948, 1950; Pajchlowa & Stasińska 1965). Czarnocki (1950) divided the Frasnian of the Łysogóry facies into three successive members: the Pokrzywianka Beds,

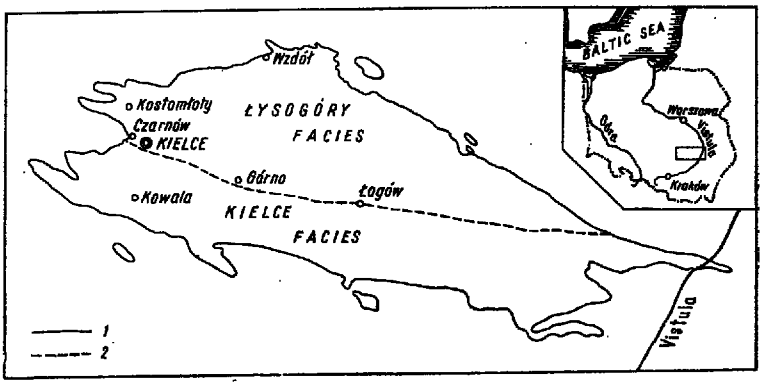

Fig. 1

Sketch map of the Holy Cross Mts. (Central Poland) showing localities mentioned in the text

1 contours of Palaeozoic deposits, 2 boundary between the Łysogóry facies and Kielce facies during the Famennian (after Czarnocki 1950)

the Nieczulice Beds and the Kostomłoty Beds. Czarnocki also supposed that all these members had their equivalents in the tripartite Frasnian of Kadzielnia and Wietrznia (Kielce facies). Later investigations (Pajchlowa 1957) have, however, shown that out of the above members only the Kostomłoty Beds are of Frasnian age. Their Frasnian age has recently been confirmed by conodonts (Kościelniakowska 1966). Some doubts arise, however with regard to more detailed conclusions about the age of the Kostomłoty Beds.

These were divided by Kościelniakowska (1966) into four stratigraphic units (the *a*, *b*, *c*, *d* sets). She supposed them to comprise only the *I*β/γ zone. Other conclusions are, however, suggested by the stratigraphic range of the conodonts (cf. Ziegler 1962, Glenister & Klapper 1966) described from the above sets. Namely, among the conodonts listed by Kościelniakowska (1966), ***Polygnathus dubius*** is recorded only from the Polygnathus asymmetrica zone (to Iα — to Iβ), ***Ancyrognathus triangularis*** ranges from the A. triangularis to the Palmatolepis gigas zone (to Iγ — to Iδ), ***Ancyrognathus asymmetrica*** and ***Palmatolepis linguiformis*** indicate the Palmatolepis gigas zone (to Iδ), while the same occurrence of ***Polygnathus glabra*** is in the Palmatolepis crepida zone (to IIα). Additionally, the list of conodonts presented by Kościelniakowska (1966) offers a rather improbable succession of these fossils. Thus the stratigraphic position of the Kostomłoty Beds and their exact correlation with the Frasnian deposits of the Kielce region still remains an open question.

Facial differentiation of the deeper-water Łysogóry facies from the shallower Kielce facies continues during the Famennian (Czarnocki 1950). In the Kielce facies the Famennian is characterised by calcareous sedimentation; stratigraphic condensation, stratigraphic gaps and the abundance of cephalopods are the common features of most deposits. The Łysogóry facies is characterised by marly-calcareous sedimentation and greater thickness of deposits. The latest investigations, however, show that Famennian rocks resembling the Łysogóry facies may also occur in the Kielce region (Freyer & Żakowa 1967). In some outcrops e.g. at Kowala, the Frasnian-Famennian boundary has not, so far, been established. In such doubtful cases only the general assignment to the Upper Devonian will be used here.

SEDIMENTARY STRUCTURES

The structural and depositional types resulting from subaqueous mass movements in the Upper Devonian of the Holy Cross Mts. display strong differentiation and contain the plastic deformations of bedding as well as the disintegration and redeposition of sediments. The most common types in the Upper Devonian are: a) slump folds, b) slump sheets, c) intraformational conglomerates and breccias, d) turbidites. Reef breccias which will not be discussed here are also of common occurrence there.

Slump folds

The presence of slump folds in the Famennian at Łagów has been reported by Radwański & Roniewicz (1962). Slump structures of this type have also been found in the Frasnian at Kowala (fig. 2; pl. I, fig 2).

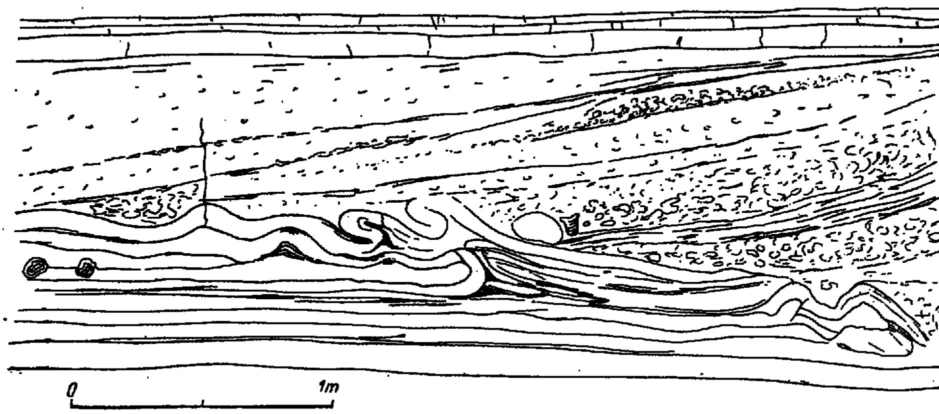

Fig. 2

Slump folds in thin-bedded limestones overlaid by cross-bedded detrital reef, deposits. Frasnian at Kowala (set *E*)

Slump folds occur there in the lower part of a complex of thin-bedded planar limestones with regular stratification. These folds involve several limestone layers but each particular fold includes only some of the layers. On the left of fig. 2 the folds are shown involving more and more of the higher layers while the lower layers, involved by the preceding folds, are uncontorted. The slump folds may be vertical folds, inclined folds or asymmetrical recumbent folds. They may be twinned and the continuity of layers is only sporadically broken. The dragging of the upper layers involves the fold pattern in the layers beneath. Anticlinal inclined folds dragged the underneath layers bending them in a direction opposite to that of the slumping (as shown by Spreng 1967, fig. 13B). In fact the direction of the movement is pointed out by the anticlinal folds, in this case to the south.

The upper part of the above complex, overlying the folds, is a cross-bedded limestone breccia built up of limestone fragments and abundant fossils, i.a. massive stromatoporoids. The cross-bedding direction suggests that the transport direction was the same as that of slumping. The upper surface of the breccia is flat and parallel to the bedding of limestones underlying the slump-fold-bearing layers.

The slump structure shown in fig. 3 (see also pl. I, fig. 1) differs in character. The slump folds here occur as independent synclinal folds, ruptured one from the other and lacking the anticlinal crests. The synclinal folds are accompanied by isolated limestone blocks embedded in marly shales. The slump structure contains a 1 m thick complex of layers. The glide surface corresponds to the top surface of one of the

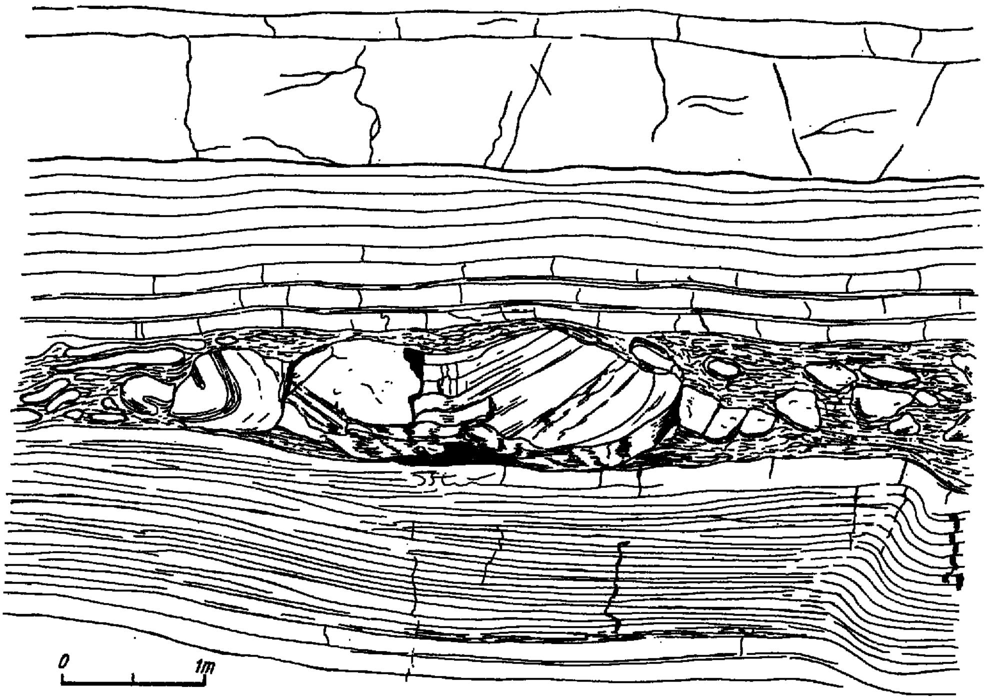

Fig. 3

Slump folds in a set of thin-bedded limestones and shaly marls. Frasnian at Kowala (set *F*)

thin-bedded limestone layers and does not bear an erosional character. The underlying beds are undisturbed. The above slump structure closely resembles a submarine slumping from the Devonian Unnenberg-Sandstone described by Jux (1960, Abt. 4, Taf. 10, Fig. 1, Taf. 11, Fig. 1).

Slump sheets

Besides slump folds, representing the plastic deformation of layers by slumping, slump sheets containing large slip blocks also occur in the Upper Devonian of the Holy Cross Mts. The slip blocks occur as big slabs which had been only slightly affected and had not been folded. The slabs were torn out of the substratum conformably with bedding, as it is suggested by their shape and lamination. The slump sheets contain several overlapping slabs (fig. 4). The bottom boundary of the slump sheets shown in fig. 4 has an erosional character. The slabs are embedded in the intraformational conglomerate composed mainly of flat pebbles. They may also be associated with reef detritus. The top of the slump sheets

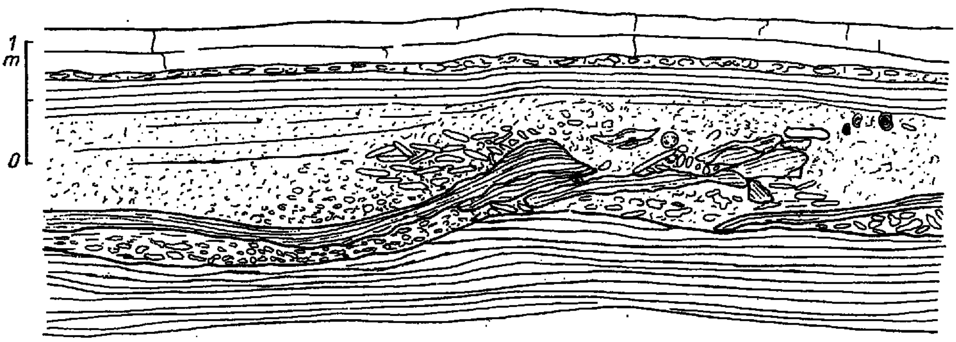

Fig. 4

Slump sheet consisting of flat pebbles and bigger slabs. Frasnian at Czarnów

is indistinct as the sheets grade into laminated limestone. A slump sheet containing slabs of some metres (fig. 4) occurs in the Frasnian at Czarnów (in the bibliography also known as Śluchowice). Quite lately it was also observable in the Frasnian at Kowala (railroad cut).

Intraformational conglomerates and breccias

The presence of intraformational breccias in the Famennian at Psie Górki (Kielce) was reported by Kotański (1959). The breccias were also observed by Czermiński (1960) in the Givetian and Frasnian at Kowala, while Pajchlowa (1962) mentions intercalations of „sedimentary breccia" in the Frasnian at Kostomłoty.

Intraformational calcirudites are very common in the Upper Devonian of the Holy Cross Mts. They occur in the Frasnian as well as in the Famennian of both the Kielce and the Łysogóry regions. They are exceptionally abundant in the Kostomłoty Beds (Kostomłoty, Czarnów, Górno). Two kinds of deposits may be distinguished among the Upper Devonian calcirudites, viz. flat pebble conglomerates and irregular pebble breccias.

The flat pebble conglomerates (pl. II, figs. 1, 2; pl. III) always occur in regular layers up to 190 cm thick, but mostly half a metre thick.

The bottom surface of the layer is usually flat and smooth. The bottom surface of the layer is obviously erosional (fig. 5) only in two instances (Górno, Czarnów). The top surface of the layer is usually indistinct.

The intraclasts composing the conglomerate are flat and highly discoidal, up to 40 cm in size. The intraclasts are made up of pelitic limestones, such as those most common in all the Upper Devonian of the Holy Cross Mts. Intraclasts are chiefly subangular. Many intraclasts are fractured or broken (pl. III). Bended intraclasts, i.e. those affected by plastic deformations, are also encountered.

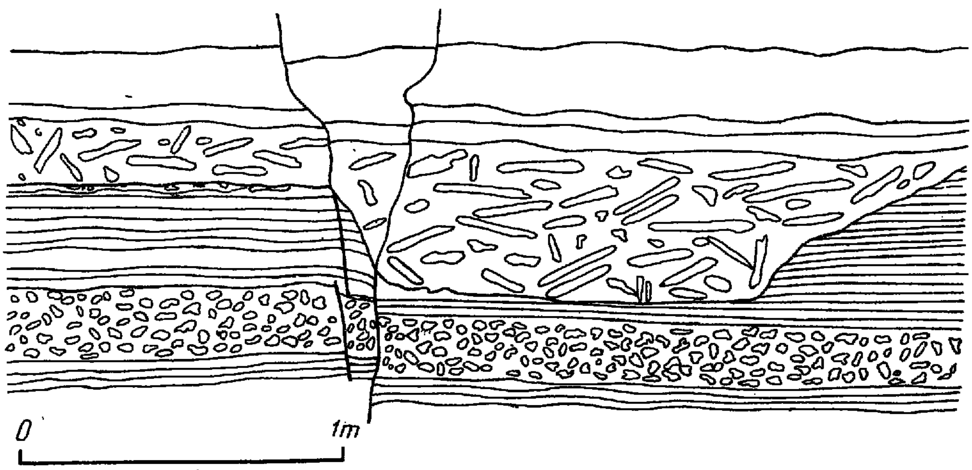

Fig. 5

Layer of flat pebble conglomerate showing distinct erosion at bottom. Frasnian at Górno

The matrix of the flat pebble conglomerates is of the calcarenite type. Organic detritus, mainly crinoidal, is one of the chief components. The intraclasts are usually haphazardly arranged. All possible patterns may be observed from that parallel resembling „flat pebble breccias" of Fenton & Fenton (1937) to the „edgewise breccias" of the Fentons and of Hadding (1931). In the latter case the intraclasts are at sharp angles to the surface of layers (fig. 6). Imbrication of pebbles is occasionally encountered, too. Besides intraclasts the matrix of flat pebble conglomerates also contains embedded fragments of shallow-water animals (massive stromatoporoids and anthozoans, crinoid stems, brachiopods). These fossils are often broken up and never in life positions. In some profiles (Czarnów, Górno) the flat pebble conglomerates are the only deposits containing an assemblage of shallow-water benthonic organisms (massive stromatoporoids, anthozoans). Thin-bedded limestones and marly shales, among which few intercalations of flat pebble conglomerates occur, are slightly fossiliferous. They contain a distinctly different fauna of tentaculitoids, ramose stromatoporoids, few brachiopods. In the scarp of the road leading to the quarry at Kowala flat pebble conglomerates contain numerous silicified fossils.

Fig. 6

„Edgewise" texture in intraformational deposits intermediate between a flat pebble conglomerate and an irregular pebble breccia. Frasnian at Górno

Irregular pebble breccias (pl. IV, figs. 1, 2; pl. V, fig. 3) occur in the Frasnian of the Łysogóry facies (the Kostomłoty Beds). Their presence is noted throughout the exposed profile in the quarries at Górno and Czarnów, as well as in the lower part of the Frasnian profile at Kostomłoty. They are, however, absent from the region of the Łysogóry facies in the Frasnian borehole Masłów II (Żakowa & Pawłowska 1966). Intraformational breccias of this type also occur among deposits at Wzdół, by Kościelniakowska (1966) regarded as Famennian. The occurrence frequency of the intraformational breccias in the Kostomłoty Beds is remarkable. In the Czarnów quarry there are 40 intercalations of irregular pebble breccias within a 27 m Frasnian profile, while at Górno a 10 m profile of the Frasnian contains 25 of these intercalations.

The irregular pebble breccias consist of irregular intraclasts, often very intricate in outline (pl. IV, figs. 1, 2; pl. V, fig. 3). The intraclasts often bear circular or ovate holes which, however, are not of lithophag origin. Usually the intraclasts are 2—3 cm in size but sporadically they may be up to 15 cm. The irregular pebble conglomerates contain only calcareous material. They are built almost exclusively of unfossiliferous pelitic limestone and but rarely contain calcarenite intraclasts. The lithology of the intraclasts agrees with the nature of limestones directly underlying the intraformational breccias. The bottom surface of the breccias is mostly uneven (pl. IV, fig. 2; pl. V, fig. 3), shaped into crests and furrows. These are due to the scouring of the substratum also resulting in the deposition of intraclasts over the erosional surface. The crests and furrows of the bottom surface range from 2 to 3 centimetres.

The irregular pebble breccias may be individualized layers where the intraclasts occur from the bottom to the top of the layer. Small amounts of such irregular pebbles may, however, also occur in the calcarenitic layers. The intraclasts are then strictly confined to the lowermost part of the calcarenitic layer (pl. V, fig. 2). Occasionally, however, the intraformational breccia may laterally pass into pure calcarenite. The matrix of the breccia is always a calcarenite built up mainly of crinoidal detritus and often containing long fragments of crinoidal stems. Anthozoan debris which are never in life position and bear traces of mechanical wear are much rarer in the intraformational breccias. The thickness of the beds of the intraformational breccias may be up to 2.5 m (Kostomłoty), but in most cases it does not exceed 35 cm and sometimes it is hardly a few centimetres.

Flat pebble conglomerates and irregular pebble breccias have many features in common: 1) they always occur in layers, 2) they are monogenetic rocks devoid of any non-calcareous material, 3) their matrix always consists of calcarenite built up mainly of organic detritus, 4) they contain fossils redeposited from shallow-water environments. Nevertheless the shape of the intraclasts and the nature of the bottom surface of layers suggest that the formation of irregular pebbles resulted from the reworking of penecontemporaneous deposits within the deposition area. The disintegration of the deposits supplying the material for the flat pebble conglomerates took place farther from the area of deposition. The intraformational deposits of these two kinds of calcirudites do not represent the successive stages of disintegration of deposits being intraformationally reworked, but they differ greatly in origin.

The considerable size and the discoidal shape of the intraclasts in the flat pebble conglomerates suggest that their formation is due to the reworking of consolidated or semi-consolidated bedded calcareous deposits. Slabs torn out in conformity with original bedding cannot be due directly to the erosional action of currents or of littoral agents. The general facial character of the Upper Devonian in the Holy Cross Mts. does not reasonably suggest the dessication of littoral deposits at it was currently believed in the case of some similar deposits (Walcott 1896, Richter 1926 fide Fenton & Fenton 1937). Neither is it possible that such conglomerates in this case could develop in result of subaqueous synaeresis cracks as is suggested by some authors (Fenton & Fenton 1937). The morphology and size of the intraclasts indicate an abrupt reworking of the deposits and their slight rounding by transport. The deposits moved along a broad front line, hence, the layers of flat pebble conglomerates stretch out widely. They originated from subaqueous sliding, hence, genetically, they are slide conglomerates. The edgewise texture of conglomerates frequently encountered here, indicates according to Hadding (1931) this mode of formation. The material mobilised by underwater sliding subsequently passed into a mud flow moving into the deeper parts of the basin. The passage of slump structures into intraformational conglomerates has also been observed (fig. 4; see also Crowell 1957, figs. 5, 10; Jux 1963, fig. 1).

Many features of the irregular pebble conglomerates suggest that they formed owing to the strong erosion of the superficial parts of semi-consolidated sediment, caused by currents carrying skeletal remains into a pelitic limestone environment. These currents, or at least a part of them — as is shown in the next chapter — were the turbidity currents. The lack of lithological conformity between the intraclasts and the immediate substratum of some breccias (pl. IV, fig. 1), the textural passages of irregular pebble breccias into flat pebble conglomerates, and the „edgewise breccia" texture associated with these passages, all suggest that a part of the breccias, too, might have been transported as mud flows.

Turbidites

The turbidites occur in the Frasnian of the Łysogóry facies (lower part of the Kostomłoty Beds at Kostomłoty, Czarnów, Górno) and of the Kielce facies at Kowala and Wietrznia (Kielce). They are represented by detrital calcareous deposits, devoid of terrigenous material. The material of which they are built comes from the intraformational reworking or it is the detritus of shallow-water benthonic organisms. The detrital material grades from calcirudite to calcilutite but most frequently it consists of fine calcarenite and calcilutite. Turbidites occur as beds, 1—75 cm thick (Czarnów). Most of them are graded (pl. V, figs. 1, 2; pl. VI, figs. 1, 2, 3). All the turbidites here considered show normal graded bedding. In the particular beds it is single and complete bedding, single and incomplete bedding or multiple and incomplete bedding. In most beds graded bedding contains calcerenite and calcilutite material but the bottom part of some beds may contain calcirudite up to several centimetres thick (pl. VI, fig. 3). Laminated bedding occurs at the top of graded beds (pl. V, figs. 1, 2; pl. VI, figs. 1, 3). Horizontal, cross and wavy laminae are of the three types (cf. Unrug 1959) encountered here. Contorted lamination may occur, too, resulting in „pseudo-ripples" (pl. VI, fig. 1). Turbidites form frequent intercalations within the thin-bedded pelagic sequences of limestones and marly shales. The turbidite layers rest either on limestones or on shales (pl. VI, figs. 1, 2). The lower contact with the underlying bed is always sharp and distinct, often erosional (pl. V, figs. 1, 2; pl. VI, figs. 1, 2). The turbidites differ from the alternating deposits not only in structural and textural features, but also in their fauna and its biostratonomical characters. The organo-detrital particles dominate in the turbidites, while autochthonous deposits occurring in alternation with the turbidites are slightly fossiliferous or unfossiliferous. The autochthonous deposits contain chiefly tentaculitoids, ramose stromatoporoids and lingulids. The coarse fractions of the turbidites contain massive and ramose stromatoporoids, anthozoans, brachiopods, while crinoids predominate in the fine fractions. The benthonic fossils are often broken up, never in life position, and sorted according to the grain size.

The turbidite origin of the deposits described above is plainly suggested by the following features:

1. They are all detrital and in this they differ from the pelagic, calcareous and marly deposits alternating with them.

2. The lower margin is always clean-cut, often erosional, while the top merges imperceptibly into the covering pelitic or marly deposits.

3. Graded bedding is frequent.

4. The upper, fine-grained part of beds shows lamination; cross or wavy laminae have often been found.

5. The detritus of benthonic fossils, absent from the pelitic or marly deposits alternating with the turbidites, represent the bulk of the material. These fossils come from facies shallower (partly reef-complexes) than the facies of the autochthonous deposits in the area of deposition.

The features of the above deposits agree in all essential points with the „allodapic limestones" of Meischner (1964) recognized as lime turbidites. This applies particularly to the turbidites of Kowala. The turbidites from the Frasnian of the Łysogóry facies (Kostomłoty, Czarnów, Górno) exhibit certain features in which they differ from the typical allodapic limestones, i.a. from the turbidites of Kowala. One of the particular characters of turbidites in the Łysogóry facies is the exceptional intensity of intraformational erosion resulting in a great number of intraformational breccias and erosional surfaces. The lower contacts with the underlying bed are strongly irregular (pl. V, figs. 1, 2) and do not in any respect differ from the lower erosional contacts of the irregular pebble breccias (pl. V, fig. 3). Parts of the detrital limestones are graded and represent typical turbidites (pl. V, fig. 1). If they contain a coarse fraction it consists of skeletal debris, mainly reef-building organisms. More often, however, we can observe false graded-bedding: the lower part of the bed consists of calcareous intraclasts which are not derived from the littoral parts of the basin fed by organic detritus, but they have been reworked from within the deposition area and within the same formation (pl. V, fig. 2). This is reasonably suggested not only by the erosional character of the bottom surfaces of layers but also by the lithological analogies of the intraclasts with the underlying eroded beds. A wide scale of the passages of deposits may be observed, from typical turbidites without any coarse detrital material, due to intraformational reworking (pl. V, fig. 1), to intraformational breccias where calcarenite or calcilutite only play the role of matrix (pl. V, fig. 3). In the intermediate types coarse intraclasts occur in the lower part of the layer while fine-grained fractions of graded bedding are encountered in the upper part of the layer, and lamination occurs in the uppermost part (pl. V, fig. 2). Lateral passages of turbidites into intraformational breccias occur, too.

Currents which laid down the deposits described above originally carried only fine fractions of the material which represented but a small volume of the deposit. These were high energy currents expressed in the strong erosion of the substratum. Most likely the density of the current was not sufficient for the coarse-grained material to be raised in suspension. Eroded intraclasts could probably move in a watery slide along the base. This, rather probable, type of movement may correspond to one of the modes of the formation of fluxoturbidites (Dżułyński, Książkiewicz & Kuenen 1959), though the effect of these processes here would bear a specific character, differing from the so-far observed fluxoturbidites.

It is quite possible that a strong erosion of the substratum took place closely to the alimentary area of turbidity currents (cf. Kuenen & Carozzi 1953). In fact, the distance from the shallow-water areas is rather small here. Strong intraformational reworking is exceptionally associated with calcareous turbidites. It is common only in a Jurassic turbidite formation described by Bernoulli (1967).

SIGNIFICANCE OF RESEDIMENTATION IN THE UPPER DEVONIAN OF THE HOLY CROSS MTS.

Kielce facies

The frequent occurrence of skeletal limestones seems to be the most characteristic feature of the Upper Devonian in the Holy Cross Mts. Czarnocki (1948) observed that the reef facies is closely associated with the Kielce elevation, and that further on in the Kielce region it passes laterally into detrital, brachiopod-coral or cephalopod deposits. The Frasnian bioherms on the Kielce elevation (Kadzielnia hill at Kielce) have been described by Pajchlowa & Stasińska (1965). The skeletal limestones also occur in the Frasnian at Kowala. The profile at Kowala (fig. 7) clearly shows the relation of the redeposited sediments to the skeletal limestones. The terms „reef", „biostrome" and „bioherm" defining

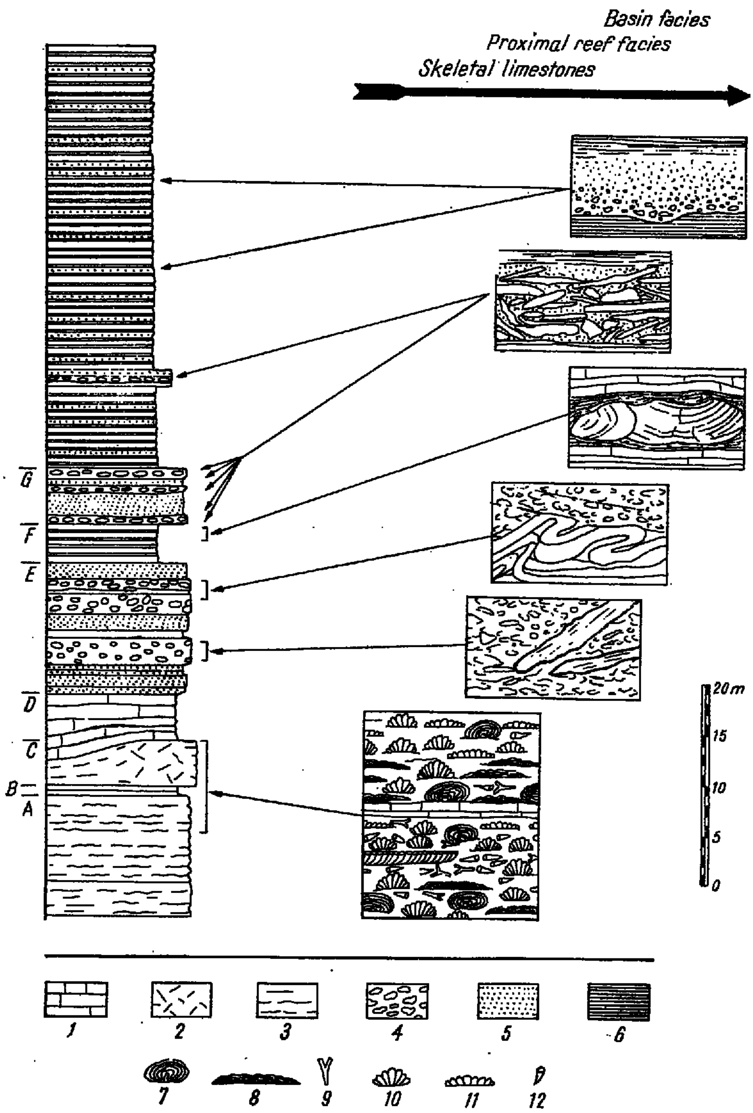

Fig. 7

Slump structures and turbidites in the Upper Devonian profile along the railroad cut at Kowala

1 distinctly bedded, pelitic limestones, 2 biohermal limestones, 3 biostromal limestones, 4 coarse detrital limestones, 5 fine-grained detrital limestones, 6 marly shales, 7 massive stromatoporoids, 8 lamellar stromatoporoids, 9 ramose *Thamnopora*, 10 massive *Alveolites*, 11 lamellar *Alveolites*, 12 branching Rugosa

the type of skeletal limestones will be used here after Nelson et al. (1962) and following the concept of Cummings (1932) and Lowenstam (1950). Thus the terms „bioherm" and „biostrome" refer to the shape of skeletal limestones while the term „reef" refers to an assemblage of organisms building wave-resistant structures.

Set „*A*" at Kowala (fig. 7) consists of biostromes while set „*C*" is a bioherm. These deposits do not substantially differ in the assemblage of the rock-building organisms. They are very fossiliferous; massive and lamellar stromatoporoids, also massive and lamellar *Alveolites* being the chief rock-building organisms of these skeletal limestones. The above fossils occur in association with numerous ramose *Thamnopora* and branching Rugosa, in places also with brachiopods, gastropods, crinoids and *Aulopora*. In the two above types of deposits most fossil organisms occur in the position of growth. This applies to large-sized organisms, i.a. to the lichen-shaped ones.

Skeletal limestones supply the material for most of the redeposited sediments. A lateral passage of skeletal limestones into derivative detrital deposits has never been observed. Nevertheless detrital deposits containing large amounts of organisms that occur in bioherms and biostromes are very common in the Upper Devonian of the Holy Cross Mts. Coarse detrital limestones consisting chiefly of stromatoporoids and anthozoans are produced by the wearing away of the reefs. They are reef breccias associated with fine-grained detrital limestones built of the fine detritus of similar organisms. In the profile of Kowala (fig. 7) the detrital, fore-reef deposits intercalate with well bedded pelitic limestones (*D*, *F*, *H*). This reasonably suggests an interfingering of the reef facies with the facies of chemical calcareous sedimentation, as well as changes in the expansion of reef sedimentation over the adjoining areas. The bedded chemical limestones contain a distinctly different faunal assemblage than that in the detrital, reef-deposits. The platy limestones (*D*) contain numerous brachiopods, while the rhythmically stratified thin-bedded limestones, alternating with marly shales (*F*, *H*, *J*) contain tentaculitoids, brachiopods with a predominance of lingulids, and branching stromatoporoids. These deposits had already formed in the basin facies which was also affected by reef environment. This is expressed by the presence of numerous turbidite beds, consisting of reef-building debris (*J*). The decreasing thickness of the successive proximal sets of detrital, reef-deposits, and, finally, the limitation of detrital, reef-deposits to turbidites testify to the recession of the reef facies during the Upper Devonian.

Slump structures are not confined to detrital, reef-deposits. They occur both in deposits of the basin facies and in the proximal detrital, reef-deposits (fig. 7). Flat pebble conglomerates are an instance of slump deposits containing material from the two above facies, although the predominant material is that from the basin facies.

Łysogóry facies

As is currently accepted, the Frasnian in the Łysogóry facies is developed as the Kostomłoty Beds (see p. 304). The Kostomłoty Beds in their stratotype are, however, divided into two, lithologically quite distinct members. The lower member, Kościelniakowska's (1966) set „*a*", is built of alternating nodular limestones, pelitic or marly limestones, also

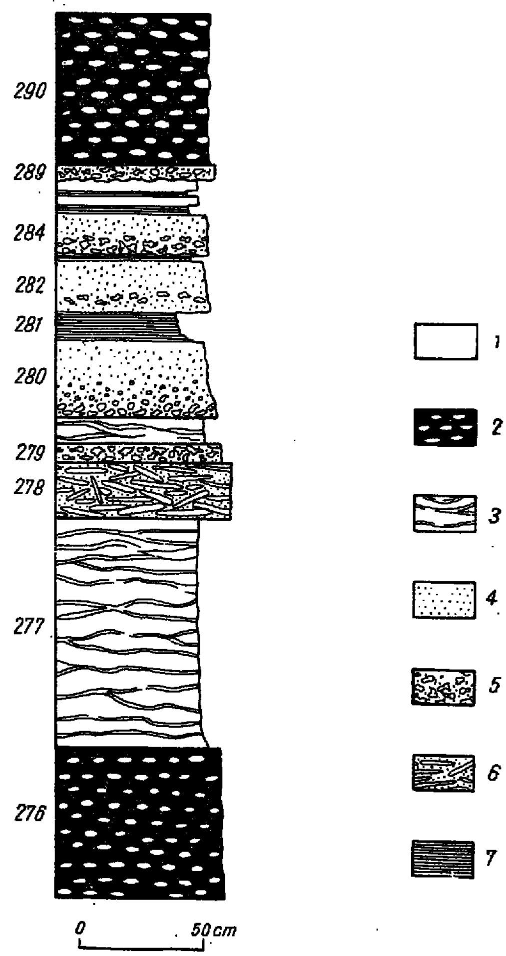

Fig. 8

Fragment of profile of the Kostomłoty Beds. Frasnian at Czarnów

1 pelitic limestones, 2 nodular limestones, 3 wavy bedded limestones, 4 fine-grained detrital limestones, 5 irregular pebble intraformational breccia, 6 flat pebble intraformational conglomerates, 7 marly shales

of calcarenites and intraformational breccias. Irregular pebble breccias predominate in the latter deposits, though flat pebble conglomerates are also encountered.

The higher member (set „*b*" of Kościelniakowska, 1966) consists of calcarenites with intercalations of crinoidal limestones. Intercalations of black cherts, absent from the lower member, are frequent and strongly characteristic here. The Frasnian at Górno and Czarnów (fig. 8) in lithology closely resembles only the lower member of the Frasnian at Kostomłoty. The Frasnian at Czarnów differs from the Frasnian at Górno and from the lower member of the Frasnian at Kostomłoty in that it contains numerous marly shale intercalations (fig. 8).

In the Frasnian sequence of the type of the lower Kostomłoty member the autochthonous deposits are represented by pelitic, nodular and wavy-bedded limestones, also by marly shales. The redeposited sediments are represented by calcarenites, intraformational breccias and slump sheets. The resedimented deposits bear traces of transport by slumping (slump sheets, slide conglomerates) and by diluted turbidity currents (graded beds). A part of the calcarenites forming the thicker beds and showing cross lamination was deposited by bottom traction currents. The autochthonous deposits are slightly fossiliferous and their fauna resembles the fossil assemblage in the basin facies at Kowala. The turbidites with coarse material, and slump sheets contain massive stromatoporoids, anthozoans and numerous brachiopods. The calcarenites consist chiefly of organodetritic material with the predominance of crinoids. Both at Górno and at Czarnów the autochthonous deposits make up 2/3 of the thickness of the profile, the remaining 1/3 of thickness being represented by resedimented deposits. In the lowermost part of the Kostomłoty Beds at Kostomłoty the resedimented deposits make up nearly one half of the total thickness of beds. At Górno the frequency of redeposition (slides, mud flows, density currents) is four times per 1 metre of the thickness of deposits, and in some parts of the profile it is even up to 12 per 1 metre.

The top part of the Kostomłoty Beds in their stratotype is not turbidite-like. In spite of the presence of numerous cherts the deposits there are not deep-water sediments. The limestones are calcarenites, and contain crinoidal intercalations indicating the shelf character of the sediments. The material of which they are built was not supplied by biohermal deposits but comes from the carbonate shelf crowded by crinoids. Perhaps, this area lay more to the north or the north-west of the Kostomłoty facies. This might be suggested by the absence of similar sediments in Upper Devonian profiles lying farther south (Czarnów, Górno). Quite likely, some parts of the redeposited sediments with a crinoidal matrix in the bottom of the Kostomłoty Beds, come also from the north. These influences may have reached further south (Czarnów, Górno).

The Kostomłoty Beds, are not, however, the only type of Frasnian deposits within the Łysogóry area. Near Czarnów (cote 868 m), below the Kostomłoty Beds there is a more than 10 m thick set of reef breccias, calcarenites and flat pebble conglomerates. Both, the reef breccias and the slide conglomerates, contain numerous massive stromatoporoids and *Alveolites*, branching Rugosa and *Thamnopora*, brachiopods and crinoids. Hence, these are proximal reef-deposits, closely resembling the deposits of set „G" at Kowala (fig. 7) as well as certain links of the Frasnian profile on the Wietrznia hill (Kielce). Therefore, this is the „Kielce" type of the Frasnian facies.

Flat pebble conglomerates are the most common type of slump structures in the Famennian of the Holy Cross Mts. Genetically they are slide conglomerates. Slump folds and flow rolls (slump balls) described by Radwański & Roniewicz (1962) are also encountered in the Famennian. The origin of the latter structures will be discussed in greater detail in a separate work.

FINAL REMARKS

Though the Upper Devonian of the Holy Cross Mts. developed as calcareous deposits, a great part of these deposits was resedimented and mechanically transported. The movement of deposits in the Upper Devonian sea took on the form of subaqueous slumping or sliding, mud flows and turbidity currents, thus representing a wide scale of subaqueous mass movements (see Dott 1963). The complete absence in the redeposited sediments of terrigenous or non-calcareous deposits suggests that the dynamics of the subaqueous gravity depositional processes were controlled only by processes within the basin itself and not by littoral processes. Resedimented deposits contain a great amount of the debris of organisms which have the ecological potential to build wave-resistant structures. Stromatoporoid-anthozoan reefs were the most common types of the latter structures in the Upper Devonian sedimentation in the Holy Cross Mts. They influenced not only the adjacent areas but also the relatively distant basin facies which they occasionally supplied with derivative detrital deposits (fig. 7). The proximal detrital, reef-deposits are of the type of reef breccias and fine-grained detrital limestones. These deposits interfinger with the basin facies suggesting an intermittent effect of the reef environment on the surrounding facies. The proximal, reef-deposits are widely distributed. In the south they reach to Kowala (fig. 7) but they also invade the Łysogóry facies (cf. fig. 1) where they underlie the Kostomłoty Beds (Czarnów). The limits and the influence of the reef facies on the adjacent basin gradually decrease. This is connected with the disappearance of the reef formation within the Holy Cross region. The range of the proximal, reef-deposits gradually decreases while that of the turbidites and the associated slump deposits, invading the basin facies and supplying it with reef detritus, gains in importance. If, originally, the detrital, reef-deposits of the „Kielce" type had encroached the area of the Łysogóry facies, later on the facial development in some regions of the Kielce facies (Kowala) rather resembles the Łysogóry type. At the close of the Frasnian the waning reef zone separates the two basins which are symmetrically supplied with detrital material by turbidity currents and sliding. Stromatoporoid-anthozoan reefs were not, however, the only source of material transported by gravity processes. As was shown above, a part of the resedimented deposits probably come from the shelf area, inhabited by crinoids and supposedly situated to the NW of the Holy Cross region. A part of redeposited sediments comes partly or entirely from the basin facies (flat pebble conglomerates, slump folds, slump sheets). Such types of sediments still continued during the Famennian when the reefs had disappeared in the Holy Cross region. It may be also stated that the mass movement dynamics were associated not only with the mechanical wear of reefs but also with earthquake activities in the early phase of Variscan movements (Radwański & Roniewicz 1962).

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M. SZULCZEWSKI

OSUWISKA I PRĄDY ZAWIESINOWE W SEDYMENTACJI WAPIENI GÓRNEGO DEWONU GÓR ŚWIĘTOKRZYSKICH

(Streszczenie)

W wapiennych osadach górnego dewonu w Górach Świętokrzyskich pospolicie występują utwory redeponowane lub zdeformowane przez podmorskie ruchy masowe. Wśród nich największe znaczenie mają fałdy osuwiskowe, powłoki osuwiskowe (ang. slump sheets), zlepieńce i brekcje śródformacyjne oraz osady prądów zawiesinowych (ang. turbidites).

Fałdy osuwiskowe mają dwojaką postać: są to albo zespoły przechodzących w siebie, nieporozrywanych fałdów (fig. 2 i pl. I, fig. 2), albo oderwane od siebie fałdy synklinalne, nie posiadające partii antyklinalnych (fig. 3 i pl. I, fig. 1). Powłoki osuwiskowe (fig. 4) mają charakter regularnych warstw złożonych z materiału poddanego przede wszystkim deformacjom sztywnym; w masie złożonej z fragmentów wapienia pelitowego oraz z detrytusu płytkowodnych organizmów bentonicznych pływają wtedy kilkumetrowe „kry", wyrwane z podłoża wzdłuż powierzchni warstwowania. Pospolitsze od nich są warstwy zlepieńców śródformacyjnych złożone z dużych, płaskich intraklastów (fig. 5 i 6; pl. II, fig. 1 i 2; pl. III), będące produktem osuwisk podmorskich i spływów błotnych. Znacznie różnią się od nich brekcje śródformacyjne złożone z nieregularnych intraklastów (pl. IV, fig. 1 i 2; pl. V, fig. 3), które powstawały w wyniku erozji powierzchniowej partii osadów przez prądy niosące detrytus organiczny. Prądy te, a przynajmniej ich część, miały charakter prądów zawiesinowych i spływów błotnych. Część osadów franu została osadzona przez prądy zawiesinowe. Osady te, czyli turbidyty, złożone są z materiału czysto wapiennego: z intraklastów i detrytusu organicznego. Turbidyty wyraźnie różnią się detrytycznym charakterem i zawartością płytkowodnych organizmów bentonicznych od rytmicznie warstwowanych, ubogich w skamieniałości osadów wapiennych i marglistych, z którymi się przewarstwiają. Turbidyty zazwyczaj są warstwowane frakcjonalnie (pl. V, fig. 1 i 2; pl. VI, fig. 1—3). Spągowe ich granice są natomiast zawsze ostre i często erozyjne (pl. V, fig. 1 i 2; pl. VII, fig. 1 i 2).

Osady redeponowane występują powszechnie zarówno w facji kieleckiej, jak i łysogórskiej górnego dewonu (fig. 1). W sedymentacji górnego dewonu Gór Świętokrzyskich wielkie znaczenie miały rafy stromatoporoidowo-koralowcowe usytuowane w północnej części facji kieleckiej. Produktem ich niszczenia są gruboderytyczne osady rafowe typu proksymalnego, występujące zwłaszcza w facji kieleckiej (fig. 7), a w niższym franie sięgające również na obszar facji łysogórskiej (Czarnów — Śluchowice). W południowej części obszaru kieleckiego (Kowala) detrytyczne osady rafowe niższej części franu zazębiają się z osadami pelagicznymi (fig. 7). Wyższe, pelagiczne osady franu w facji łysogórskiej (warstwy kostomłockie, Czarnocki 1950) również pozostają pod wpływem facji rafowej, z której osuwiska i prądy zawiesinowe przynosiły materiał organodetrytyczny (fig. 8). Turbidyty są także obecne w wyższym franie (?) Kowali (fig. 7). Tak więc prądy zawiesinowe spływały z obszaru rafowego zarówno na północ, jak i na południe. Strefa sedymentacji warstw kostomłockich pozostawała prawdopodobnie nie tylko pod wpływem znajdującej się na południu facji rafowej, ale także pod wpływem rozciągającego się dalej na północny zachód od facji łysogórskiej szelfu wapiennego, zasiedlonego głównie przez liliowce. Pochodzący stamtąd materiał wchodzi w skład najwyższego

ogniwa franu w Kostomłotach (warstwy *b* Kościelniakowskiej, 1966), a prawdopodobnie był on także redeponowany dalej na południe i południowy wschód (Czarnów, Górno). Wskazać należy ponadto, że osady niektórych osuwisk podmorskich zawierają niemal wyłącznie materiał pochodzący z osadów facji pelagicznej, a więc podmorskim ruchom masowym podlegały w górnym dewonie Gór Świętokrzyskich nie tylko osady rafowe.

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DESCRIPTION OF PLATES I—VI

PL. I

Fig. 1

Slump folds in a set of thin-bedded limestones and marly shales. Frasnian at Kowala (set *F*)

Fig. 2

Slump folds in thin-bedded limestones overlaid by cross-bedded detrital, reef deposits. Frasnian at Kowala (set *E*)

PL. II

Fig. 1

Flat pebble intraformational conglomerate of slump origin. Frasnian at Kowala (set *G*)

Fig. 2

Flat pebble conglomerate of slump origin. Frasnian at Kowala (set *G*)

PL. III

Flat pebble intraformational conglomerate showing broken intraclasts at bottom and centre. Frasnian at Czarnów slightly magn.

PL. IV

Fig. 1

Intraformational breccia consisting of irregular limestone intraclasts underlaid and overlaid by marly shales. Bottom surface of erosional origin. Frasnian at Czarnów
nat. size

Fig. 2

Intraformational breccia consisting of irregular pelitic limestone intraclasts and, subordinately, of calcarenite. Calcarenite and calcilulite matrix. Irregular contact with underlying pelitic limestone. The bottom part of the pelitic limestone shows load deformation with calcarenite pockets sunk in the sediment. Frasnian at Górno
nat. size

PL. V

1 — Lime turbidite. Graded calcarenite and calcilutite overlying the erosional surface of pelitic limestone; wavy laminae at the top of the graded bed. Upper Devonian at Kowala (set *J*) nat. size

2 — Lime turbidite. Graded calcarenite and calcilutite containing in its lowermost part numerous rudite intraclasts caused by erosion of the underlying pelitic limestone. Erosional bottom of turbidite in contact with pelitic limestone. Cross lamination in the top part of turbidite. Frasnian at Górno nat. size

3 — Intraformational breccia overlying the erosional surface of pelitic limestone, and consisting chiefly of pelitic limestone intraclasts. Frasnian at Górno nat. size

PL. VI

1 — Lime turbidite. Graded calcirudite, calcarenite and calcilutite. Erosional bottom surface; contorted lamination and pseudoripples in the top. Upper Devonian at Kowala (set *J*) nat. size

2 — Lime turbidite. The erosional surface of marly shales overlaid by cross-bedded calcarenite and calcilutite, towards the top passing into marly shale. Frasnian at Wietrznia (Kielce) nat. size

3 — Lime turbidite. Multiple graded limestone consisting of calcirudite, calcarenite and calcilutite. The laminae occur at top of the graded bed. Upper Devonian at Kowala (set *J*) slightly reduced

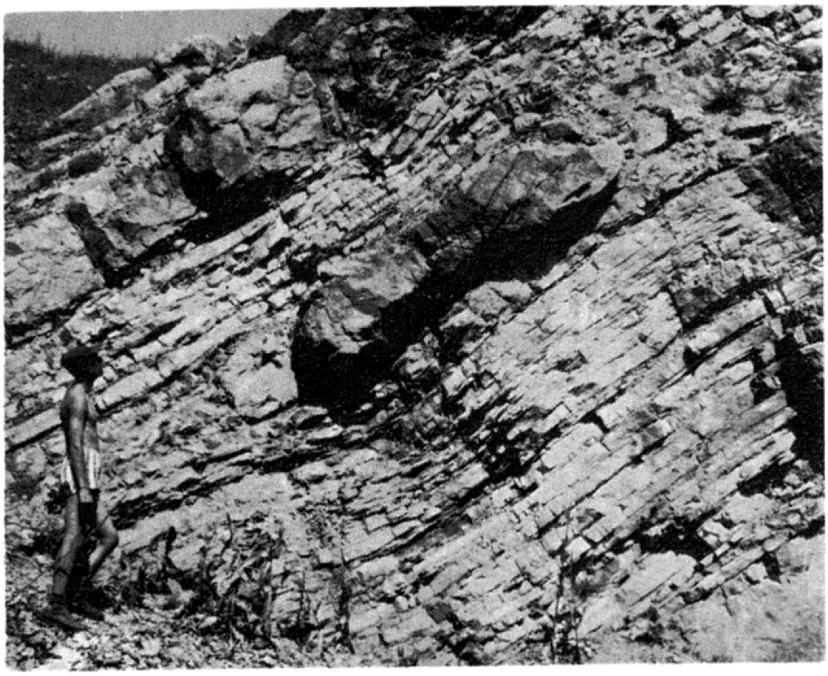


Fig. 1

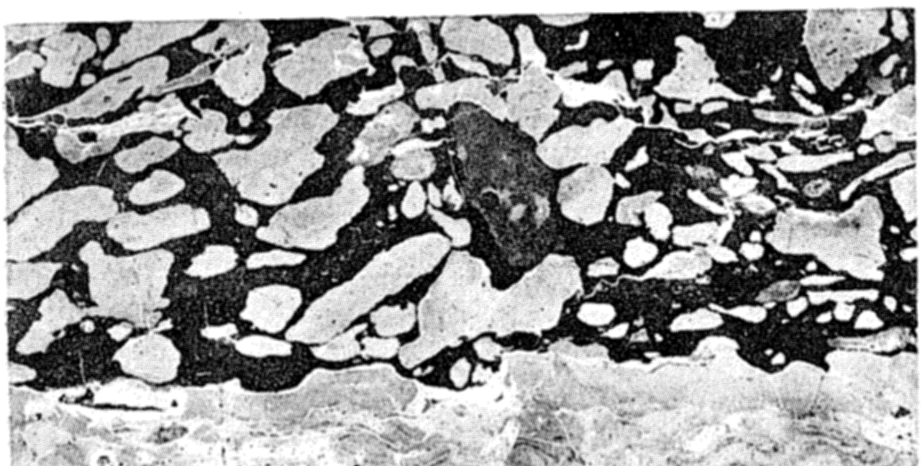
Fig. 2

Fig. 1

Fig. 2

Fig. 1

Fig. 2

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2


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