gie de leurs versants méridionaux). — Prace P.I.G. (Trav. Serv. Géol. Pol.), t. 4. Warszawa.

— 1958. Tatry. Przekroje geologiczne przez Polskę. Wydawn. Geol. Warszawa.

— 1959. Zarys geologii Tatr (Outline of geology of the Tatra Mountains). W: Z badań geologicznych wykonanych w Tatrach i na Podhalu, t. 5 (*In:* From geological researches in the Tatra Mts. and in the Podhale Region, v. 5). — Biul. I.G. (Bull. Inst. Géol. Pol.) 149. Warszawa.

STOKES L. 1950. Some unusual ripple marks from the Triassic at Utals. — J. Geol., vol. 58, no. 2.

STRAATEN van L. M. J. U. 1953. Rhythmic patterns on Dutch North Sea beaches. — Geol. en Mijnbouw, 2.

— 1959. Minor structures of some recent littoral and neritic sediments. — Geol. en Mijnbouw, N.S., 21.

ŚWIDERSKI B. 1922. Korzenie leżącego fałdu Czerwonych Wierchów oraz nowe elementy budowy trzonu (Sur la géologie des monts Tatra. Les racines du grand pli couché de Czerwone Wierchy (Montagnes Rouges) et les nouveaux éléments tectoniques du massif autochtone des Tatra). — Rozpr. Wydz. Mat.-Przyr. Akad. Um., vol. 22, z. 3. Kraków.

THOMPSON W. 1937. Original structures of beach, bars and dunes. — Bull. Geol. Soc. Amer., vol. 48.

TURNAU-MORAWSKA M. 1947a. Prakarpaty w świetle analiz petrograficznych (Pracarpathian chain in light of petrographical analysis). — Ann. UMCS, ser. B, vol. 2. Lublin.

— 1947b. Permotrias lądowy Tatr i jego stosunek do trzonu krystalicznego (Permian and Triassic continental facies of Tatra and their relation to the crystalline mass). — Ibidem.

— 1948. Petrografia skał osadowych. Państw. Wydawn. Nauk. Warszawa.

— 1955. Uwagi o sedymentacji werfenu tatrzańskiego (Remarks concerning sedimentation of the Werfen beds in Tatra). — Rocz. P.T.Geol. (Ann. Soc. Géol. Pol.), t. 23. Kraków.

— 1957. Zagadnienie genetycznej klasyfikacji piaskowców (The problem of genetic classification of sandstones). — Arch. Miner., t. 20. Warszawa.

TURNAU-MORAWSKA M. & ŁYDKA K. 1954. Studia petrograficzne nad arkozą kwaczalską (Petrographic study of the arkose of Kwaczała). — Rocz. P.T.Geol. (Ann. Soc. Géol. Pol.), t. 22, z. 4. Kraków.

UHLIG V. 1897. Geologie des Tatragebirges. I Th. Einleitung und stratigraphischer Theil. — Anz. Akad. Wiss., math. nat. Kl., Bd. 64. Wien.

WESTERGÅRD A. H. 1931. Diplocraterion, Monocraterion and Scolithus from the Lower Cambrian of Sweden. — Sver. Geol. Unders., Årsbok 25, No. 1. Stockholm.

WÓJCIK Z. 1959. Serie wierchowe południowych zboczy Bobrowca (High-tatric series in the south side of Mt. Bobrowiec, Western Tatra Mts.). — Acta Geol. Pol., vol. 9, nr 2. Warszawa.

ZAPFE H. 1958. Die Fauna der Werfener Schichten vom Ulrichsberg bei Klagenfurt in Kärnten. — Verh. Geol. Bundesanst., H. 2. Wien.

ZOUBEK V. 1930. Geologické studie z kořenové oblasti subtatranské a zon sousedních jižně Podbrezové. (Études géologiques dans la partie nord-ouest de la Basse Tatra). — Věstn. Statn. Geol. Úst. ČSR, r. 6. Praha.

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LOWER WERFENIAN (SEISIAN) CLASTICS IN THE TATRA MTS.

(Summary)

ABSTRACT: The Lower Werfenian (Seisian) clastics in the Tatra Mts. occur within autochtonous and fold units, also in the lower sub-tatric (Križna) nappe units. Within autochtonous units the Seisian rests on the peneplained surface of the crystalline massif, in one of the exposures it overlies the Permian conglomerate of the Verrucano type. Seisian deposits begin with conglomerates or conglomeratic sandstones. Pebbles of siliceous, volcanic and milk-quartz rocks are exotic in character. They are overlain by arkose- and quartzitic sandstones displaying cross stratification, ripple marks and flutes. In the Upper Seisian there is a predominance of silt-clay deposits interbedded by quartz sandstones, in the uppermost part by yellow dolomites. The occurrence is noted of plant remains, and of slime-eaters. Illite is here the chief component of clay rocks. An analysis of the directional structures shows that the clastic material had been transported from the north southward. The petrographic composition suggests that the material had been brought from massifs built of crystalline, metamorphic and volcanic rocks which make up the Pra-Carpathian massif now completely covered by the Carpathian Flysch. The sedimentary structures and the character of the sediment, fairly uniform over large areas of the Central Carpathians, indicate that the sedimentation of the Lower Werfenian deposits took place in a water basin, most likely in a shallow-sea environment.

INTRODUCTION

The Lower Werfenian (Seisian) deposits formerly known as "Permo-Triassic" (Uhlig 1897, Limanowski 1903) have now, in the Polish literature, been referred to the Werfenian by S. Sokołowski (1948). By differentiating Campilian deposits which are palaeontologically documented and by comparing them with analogous sediments from the Central Carpathians of Slovakia, Z. Kotański (1956) used the term Seisian for these deposits. Thus in the Tatra Mts. the term Seisian is used exclusively with reference to the clastic sediments underlying the Campilian. Facially these deposits differ notably from the Seiser Schichten in the Eastern Alps. In the Central Carpathians, deposits of the Seiser Schichten type occur south of the Lower Tatras.

RELATION OF THE SEISIAN TO THE CRYSTALLINE SUBSTRATUM

Within autochtonous series (Mt. Szeroka Jaworzyńska, Skrajna Turnia and Żółta Turnia) Seisian deposits occur in sedimentary contact with granite of the crystalline massif. Pre-Triassic granite waste of the "sedentary arkose" type (Barton 1916) occurs below the contact. Casts of very small irregularities existing on the surface of the waste layer at the time of sedimentation of the lowermost Triassic are preserved on the underside of the lowermost Seisian layer. Poorly preserved current marks and clastic dykes (crevices infilled) are among those that have been described (Roniewicz 1963). Mt. Skrajna Turnia is the only site in the Tatras where fragments of granite from the substratum have been found in arkose sandstones of the lowermost Seisian.

Throughout the Tatra Mts. the contact surface is flat in result of strong pre-Triassic peneplenation of the whole area. Relics of the peneplain are seen best on the northern slopes of Mt. Żółta Turnia (pl. II). The pre-Triassic peneplain in the Massif of Belledonne (Gignoux & Moret 1952) is similarly preserved.

The contact surface is cut by a number of faults which shift either the

Seisian with the granite substratum or only the Seisian in relation to the substratum. Such disturbances are responsible for the local tectonic contacts of the Seisian with the substratum.

The best Seisian exposures are accessible within the autochtonous series. Observations resulting in the plotting of profiles (text-figs. 1—7) have been made in couloirs or on ridges where the most complete exposures may be reached. In high-tatric non-autochtonous series (i.e. folded ones) the only satisfactory Seisian exposure occurs within the fold unit of Mt. Giewont. Within the lower subtatric nappe there are some good outcrops in the Jaworzynka valley and in the Bielskie Tatra Mts.

The following sets of beds may be distinguished in the Lower Werfenian:

A. Sediments underlying the continuous conglomerate horizon only within some outcrops. They represent a differentiated sedimentary environment.

B. A set of beds beginning with a 2 m. thick layer of conglomerate that is not distinctly stratified. This is overlain by thick-bedded quartzitic sandstones and arkose sandstones. In profiles of Mt. Żółta Turnia and of Koszysta (central part of the Tatra) the arkose sandstones are lesss frequent than in the eastern or western margins of the Tatra Mts.

C. Quartzitic sandstones with moderately thick beds showing cross stratification, as under item 2, the surface of beds is often uneven owing to erosion.

D. Quartzitic, more thinly bedded sandstones, less often cross stratified, interbedded by argillaceous sandstones and shales in greater amounts than the lower sets. Carbonized plant remains are commonly encountered in the topside of this set.

E. A rock set where quartzitic sandstones grow subordinate while clay sandstones, mudstones and clay shales become predominant. Organic hieroglyphs are fairly frequent. Facially, both this and the next set approach the "Werfener Schichten" as is currently accepted by Slovakian geologists (Andrusov 1959).

F. Clay and mudstone rocks dominate here, but yellow dolomite intercalations and carbonate matrix in sandstones are also present. Obviously all the above differentiated sets very gradually pass one into the other without strict boundaries.

Sets A—D consist of rocks most resistant to erosion and forming very characteristic rocklets and ridges. All the major passes within the outcrop area of the high-tatric series occur in sets E—F.

LITHOLOGY

Conglomerates

Conglomerates or conglomeratic sandstones are encountered in the bottom of the Seisian (compare the profiles) and as thin intercalations in the top parts of sandstone layers. Chart 1 contains a representative illustration of the composition of the conglomerates.

Components of the conglomerates

Milk quartzes are the chief constituent. Inclusions of muscovite, apatite and zircon are observable in thin sections. Some pebbles are cut by ferruginous veinlets. All the quartz pebbles are better rounded than the other constituents.

Volcanic rocks — mainly rhyolites and trachites. The rhyolites are pink-coloured; pl. IX, fig. 3 shows the hexagonal quartz crystals and the variously decomposed crystals of K-felspars they contain. Acid plagioclases are encountered side by side with K-felspars. Fragments of trachites have a greenish tint. The rockmass in both types of pebbles consists of fine-crystalline quartz. Certain structures indicate that initially the matrix of some rocks was of a glassy texture, and that later on it was re-crystallized. The matrix is always strongly silicified.

Pyroclastic rocks (pl. IX, figs. 1—2). Angular quartz grains and strongly decomposed felspars are inserted among the rockmass consisting of quartz and chalcedony. Fragments of tuffites, similarly as other pebbles are always strongly silicified.

Black siliceous rocks. These are fragments and pebbles with quartzitic or fine-crystalline texture (pl. VII, fig. 2); in the latter case quartz and chalcedony are present. Their black colouration is due to graphite admixture (pl. VII, fig. 3) which agglomerate either as laminae or as rods (pl. VII, figs. 1—3). The graphite rods may represent some organic remains. The black colouration may also be due to dispersed pyrite. Small amounts of scale minerals whose properties approach those of sericite are occasionally found.

Red (jasper) and green siliceous rocks microscopically resemble the black rocks. Their red colouration is due to iron oxides. The black and greenish-coloured siliceous rocks contain poorly preserved sponge-spicule-like structures. Fragments of red-coloured quartzitic sandstones and banded cherts (pl. V, fig. 3) are encountered in the conglomerates together with the above named rock types. A fragment of silicified wood was also found by K. Borzá (1958).

The character and composition of the conglomerates suggest the following conclusions:

1. The material of the conglomerates is exotic in origin while rocks known from the Tatra Mts. are absent. The components of the conglomerate are resistant to the factors of transportation.

2. The presence of conglomerates in the bottom of the Werfenian suggests an increase in the transport energy at the beginning of sedimentation. The accumulation of fragments and pebbles near the surface of sandstone layers in the Upper Seisian indicates that their formation was due to outwashing of the sediment by weak currents which carried away sandy material and left on the spot only the coarser one.

3. The lithological composition of pebbles and fragments shows that within the source area of the clastic material there were acid magmatic, volcanic, and sedimentary rocks.

Sandstones

The following types may be distinguished in the sandstones:

Arkose sandstones. These are quartz sandstones with an up to 19 per cent content of K-felspars (chart 2, 1—3). In M. Turnau-Morawska's classification diagram they are placed in the margin of the arkose sandstone area. They display a haphazard texture. Two grain fractions are often encountered: larger better rounded grains and smaller more angular ones which fill in the spaces between the large grains (pl. X, fig. 1). Some specimens show parallel stratification. The potassium felspars vary in the degree of decomposition. The amount of scale minerals of the sericite type increases in the rock when the felspars are more decomposed. Arkose sandstones occur in the lower part of the Seisian; they are interbedded with quartzitic sandstones of greater resistance than they are, as it may be seen in their morphology (text-fig. 2).

Quartzitic sandstones. These are the rocks occurring in greatest amounts in the Seisian. Quartz is their chief component (comp. 4—8 in chart 2). The selection of grain size is not so good in the Lower Seisian as in the Upper Seisian, but still it is better than in the arkose sandstones. Subordinate amounts of K-felspars occur beside quartz, acid plagioclases being present in the fine-grained varieties of the Upper Seisian. The siliceous matrix is recrystallized around the quartz grains. In the brown varieties the original grain outlines are discernible owing to the ferruginous rims. In the light varieties the grain outlines vanish in places of stronger recrystallization. The quartzitic textures were formed both by way of recrystallization of silica supplied from outside and by autocementation. Quartzitic sandstones, as the most resistant Werfenian rocks, form bluffy rocklets typical for the Tatric landscape.

Quartz sandstones with clay or clay-ferruginous matrix

Their composition is shown in items 9—11 of chart 2. Beside quartz they contain K-felspars and acid plagioclases. The ferruginous varieties are red-coloured, the clay varieties are grey or greenish. Certain amounts of muscovite are present in the fine-grained varieties.

Siltstones

Siltstones occur in the uppermost Seisian. Among them may be differentiated quartz mudstones either with clay or carbonate matrix. Beside quartz they contain equal amounts of K-felspars and plagioclase. The siltstones accompany sandstones with a clay matrix and they grade one into the other.

Clay rocks

These are clay shales of a red, less often green colour. They are the main rock component in the uppermost Seisian but beginning from the bottom conglomerates they may also be encountered as thin intercalations. The chemical and DTA analyses (fig. 8 and chart 3) show illite as the main component of these rocks.

SEDIMENTARY STRUCTURES

Cross stratification. This type of stratification occurs most frequently in thick-bedded quartzitic sandstones of the Lower Seisian, also in arkose sandstones, clay sandstones and mudstones. The classification of stratification is based on geometrical characters and, in the main, it follows that of E. D. McKee & C. W. Weir (1953).

Planar cross stratification

This type of stratification occurs within light quartzitic sandstones. The sets of cross strata are up to 60 cm. in thickness. Two types may be distinguished on the shape of the cross laminae. One is the tangential type (pl. XI, fig. 2) in which the laminae tangentially reach the lower set while the top set is erosionally truncated. The other type is less common and usally grades into the first one. Complex stratification is also encountered. A number of variously oriented sets, separated by erosion surfaces, are superposed one on the other (pl. XI, fig. 2). The whole set of cross strata fills in a broad groove which brings this type of stratification closer to the trough cross stratification. No differences are, however, observable concerning the type of sediment within sets of cross strata or in relation to the underlying beds. The whole structure probably came into existence rather quickly as the effect of a current varying in direction. This stratification is referred to by the writer as polydirectional.

Trough cross stratification

Stratification representative of this type is observable in the lower part of the Seisian on Mt. Żółta Turnia. On the surface of layers of light quartzitic sandstones one can see there elongated grooves which are filled in by cross-bedded arkose sandstone. The sets of cross strata seen from the top have a fan-like shape, in cross section they are wedge-like or lenticular. Smaller dimensions of the cross sets are a characteristic feature of the upper part of the Seisian.

Structures due to outwatering of clay sediments

Mud cracks occur in two exposures within siltstones interbedded by clay shales. They are preserved on the bottom surfaces of sandstone layers, also on the topsides of siltstones (Roniewicz 1965, pl. XXII, fig. 1). Other forms have also been found (op. cit., pl. XXIII, fig. 1) whose origin may on the base of laboratory investigations be referred to cracks reworked owing to a subsequent inwatering after dessication, prior to the deposition of sediment on the dried up surface.

Slump structures

Underwater slumps are observable in mudstone-clay sediments of the Upper Seisian (pl. XX, fig. 1). Analogous structures have been noted by the writer in the Upper Seisian of Southern Slovakia and thus such structures are widely spread.

Organic traces and hieroglyphs

Organic traces discernible on the surface of beds, also organic hieroglyphs preserved on the lower surface of beds have been left by slime-eaters. This type of structures is encountered in various Seisian horizons, always in close proximity of beds with carbonized plant remains. The most characteristic structures are those of the type of *Monocraterion* sp. (Westergård 1931) which resemble *M. tentaculatum* described by Torell from the Cambrian of Sweden. A more detailed account of its characteristics cannot be attempted owing to the bad state of preservation, hence only the generic name is here stated.

The organic hieroglyphs are preserved as irregular elongated rolls detectable on the lower surface of the layer (pl. XVII and XIX, fig. 2).

Interpretation of directional structures

Directional structures such as cross stratification, asymmetric ripples and flutes were usefull in the plotting of transport direction diagrams (fig. 9). The transport followed a north-to-south direction which coincides with the earlier investigations by S. Dżułyński & R. Gradziński (1960). A deviation from the S-N trend is observable in the marginal parts of the Tatra, resulting in a slightly fan-like arrangement.

Ripple marks

Ripple marks occur in all types of Seisian deposits, the conglomerates excepted. The most common types are symmetric ripple marks and metaripple marks. The latter were initially symmetric and subsequently, under changed conditions of the action of waves, they were re-oriented and their crests became rounded. Asymmetric current ripple marks are relatively less frequent. Ripple marks from the upper part of the Seisian are, in the main, characterized by smaller dimensions.

The presence of symmetric ripple marks and metaripple marks in quartzitic sandstones with cross stratifications suggests the consecutively repeating periods of current action, intervened by periods of stagnant-water predominance. The various types of ripple marks encountered in the Seisian have their equivalents in structures described from other formations (Cambrian of the Holy Cross Mts. — Radwański & Roniewicz 1960; Moenkopi Triassic — McKee 1954, Stokes 1950, etc). If, however, the set of ripple marks from the Seisian be considered as one whole it will be seen to differ from those in the just cited deposits. Within the Triassic of Moenkopi there is a predominance of asymmetric ripple marks which are rather rare in the Seisian. In the Cambrian of the Holy Cross Mts. the ripple marks appear usually on numerous surfaces of layers in short segments of the profiles. In the Seisian ripple-covered surfaces of layers are rarer; moreover, the numerical ratio of the type of ripple marks as well as the set of other sedimentary structures associated with ripple marks, differ, too. The Seisian and the Bunter from the Holy Cross Mts. show the closest resemblance, though in the Seisian the ripple marks are rarer and in a poorer state of preservation. An analysis of the ripple marks alone shows that no complete analogies exist between the above mentioned sedimentary basins.

Flutes

On the surface of the quartzitic sandstone layers on Mt. Żółta Turnia there are elongated rounded V-shaped depressions, deeper in the narrow part and growing more shallow as they widen. The orientation of these depressions agrees with that of cross stratifications.

Plant remains

Carbonized fragmentary plant remains occur in several exposures in the high-tatric series, as well as in the subtatric Werfenian where they were found by M. Limanowski (1901). Strong disintegration of the remains and their position conformant with the stratification of clay shales and clay sandstones reasonably suggest their redeposition. The presence of symmetric ripple marks in a set of strata with plant remains indicates that they were deposited in a shallow stagnant-water environment. Plant remains displaying this state of preservation are a characteristic component of the Werfenian in the Eastern Alps (Zapfe 1958, Pirkel 1961).

SEDIMENTATION OF THE LOWER WERFENIAN (SEISIAN)

Sedimentation of Lower Werfenian deposits in the Tatra Mts. commenced on a surface that had been peneplained during the pre-Triassic period (in the high-tatric series it was the surface of the crystalline massif).

Sub-conglomeratic deposits underlie in some exposures the conglomerate horizon with exotic material. Among the most characteristic ones are a set of arkose sandstone beds containing granite fragments from the substratum of Mt. Skrajna Turnia. These sandstones display horizontal bedding (pl. XII, fig. 2). They represent a sediment that had been transported over a short distance and laid down in a water environment. This deposit contrasts with the underlying granite waste which is residual in character. Arkose sandstones formed owing to the erosion of the local granite waste which had been fed with an admixture of exotic material. The erosion and removal of the local waste could take place at the beginning of sedimentation before the material brought here from the north had covered the floor of the sedimentary basin.

On Mt. Ornak in the Western Tatras, below the conglomerate horizon, there are conglomeratic cross bedded deposits. This set may be regarded as relics of an allogenic gravel field whose deposition occurred perhaps under continental conditions. If such gravel fields did exist in other regions their material would have been incorporated into the Seisian deposits by means of erosion and redeposition in a sedimentary basin under uniform conditions. On Mt. Żółta Turnia, a thin set of fine-grained quartz sandstones underlies the conglomerates. This sediment was probably deposited in a rather small isolated basin being filled by finer material. The above examples show that the initial stages of Seisian sedimentation differed within the various regions of the Tatra Mts. The area of Mt. Skrajna Turnia must have represented an element with particularly exposed morphology, so much so that the granite waste material was outwashed. The conglomeratic deposits on Mt. Ornak have probably persisted in a more sheltered area. On Mt. Żółta Turnia a small basin was initially formed which was gradually filled with fine sandy material brought by weak currents. The proper Seisian sedimentation begins with the bottom conglomerate horizon. During the sedimentation of the bottom conglomerates the transport energy was locally checked, as is reasonably suggested by the shale intercalations in conglomerates in the profile of the Jagnięcy crest, and those of fine-grained sandstones on Mt. Ornak.

The conglomerates are overlain by a set of arkose sandstones and quartzitic thickbedded sandstones with sporadic clay shale interbeddings. The sedimentation here occurred in a water environment, the currents were intermittently rather strong so as to cause the formation of cross stratification and of flutes on the surface of layers. Other, somewhat weaker currents, were responsible for cross stratifications which fill in erosional grooves on the surface of quartzitic sandstone layers. The activity of the currents, however, did not continue throughout the process of sedimentation since most of the layers do not display the presence of any structures whose origin is referable to the work of currents. Shale intercalations and surfaces covered by symmetric ripple marks or metaripple marks indicate the intermittent dominance of stagnant-water environment. Locally the basin is filled in up to the water level and mud cracks are formed. Similar structures in an analogous position are known from the French Alps (Debelmas & Lemoine 1960).

In some regions (Mt. Ornak) one may observe a cyclic supply of material into the horizon here considered, resulting in the alternation of arkose-sandstone sets with sets of quartzitic sandstones (Roniewicz 1959b).

The upper sets of quartzitic sandstones are characterized by smaller thickness and more frequent presence of shale intercalations. This means a general decrease in the force of transport. The shale laminae in sandstones are overlaid by fragments of shale as a rule flatly arranged. The formation of the shale fragments was an effect of the rather weak erosion of the clay deposits where the process of synaeresis led to the development of polygonal partition. Along the zone of synaeresis cracks, fragments of shales were desintegrated and then transported over a small distance to be buried in sandy deposits. Within the profile of Mt. Mała Koszysta sets of mudstones and shales present as flat lenses within the sandstones are observable. The sandstones display cross stratification oriented towards the mudstone layers. The shales and mudstones sedimented in zones of small depressions which were supplied with the finest material. Sandy deposits were then laid down on the borders of these depressions.

The sedimentation of the uppermost parts of the Werfenian took place in stagnant-water environments where the role of currents was insignificant. Conditions there favoured the development of slime-eaters and the deposition of small plant remains. Carbonate sedimentation begins in the uppermost Seisian.

ENVIRONMENT OF THE LOWER WERFENIAN (SEISIAN) SEDIMENTATION

Opinions concerning the environment in which Seisian sedimentation took place were gradually modified with the progress of geological investigations. In 1897 V. Uhlig regarded all the Permo-Triassic deposits as marine in origin. M. Limanowski (1903), C. Kuźniar (1913) and M. Turnau-Morawska (1947b) accepted the view that these are desert sediments grading through the deltaic into marine deposits. E. Passendorfer (1950) and M. Turnau-Morawska (1955) recognised that the Lower Werfenian sedimentation occurred in fluvial environment which passed into a marine one during the Upper Seisian. K. Borzá (1958) and P. Roniewicz (1959b) postulated shallow-sea sedimentation while S. Dżułyński and R. Gradziński (1960) define the environment as "near shore lakes and flood plain sedimentation".

It might be interesting to note here analogies in the development of the Seisian deposits within large areas of the Central Carpathians, Eastern Alps and French Alps. Since the synchroneity of these deposits is currently recognised one can also accept analogies in the conditions of sedimentation. There is no sharp boundary in these deposits suggesting a change in sedimentary environment while in the Upper Seisian there is evidence of shallow-sea sedimentation. All the sedimentary structures described from the Lower Werfenian fit into shallow-water environment. The predominance of symmetric and metaripple marks over current ripple marks suggests that the environment was that of stagnant water rather than of flowing water. The lack of erosional grooves filled in by sediment indicates the absence here of deltaic environment or of a near-delta land zone which are characterized by such structures (comp. Potter 1963). Hence one can see that sedimentation took place in a large basin. The bulk of indirect evidence reasonably suggests a shallow-sea environment, among others — also the uniformity of the mineral composition of clay minerals in the Lower and Upper — undoubtedly marine — Seisian.

The terrigenic character of the Lower Seisian deposits is a result of violent supply of material from the adjacent land. With a decrease in the transport energy, most likely due to increasing sea transgression, the deposits gradually passed into marine ones.

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OBJAŚNIENIA DO PLANSZ I—XX

DESCRIPTION OF PLATES I—XX

PL. I

Widok na pokrywę dolnego werfenu na zboczu Żółtej Turni od strony doliny Pańszczycy. Zaznaczona granica z granitem i uskoki w obrębie werfenu

Fot. autor

View from Pańszczyca valley showing the Lower Werfenian mantle on the slope of Mt. Żółta Turnia; boundary of the Werfenian and the granite, as well as the faults in the Werfenian are shown *Phot. by the author*

PL. II

Widok na pokrywę dolnego werfenu na zboczu Żółtej Turni od strony Hali Gąsienicowej. Na pierwszym planie odsłonięcia na zboczu Łopaty zaznaczona granica z granitem i uskoki w werfenie. Na drugim planie widoczne dwa pasma werfenu na Dubrawiskach. Z prawej fragment płaskiego zbocza Żółtej Turni

Fot. K. Guzik

View from Hala Gąsienicowa showing the Lower Werfenian mantle on the slope of Mt. Żółta Turnia. In the foreground — the outcrops on the slope of Mt. Łopata with boundary of the Werfenian with the granite, also Werfenian faults. In the background — two Werfenian belts on Dubrawiska. To the right fragment of a flat slope on Mt. Żółta Turnia

PL. III

Kontakt piaskowców kwarcytycznych dolnego werfenu ze zwietrzałym granitem na Szerokiej Jaworzyńskiej. Na spągu werfenu widoczne odlewy nierówności powierzchni zwietrzeliny granitowej *Fot. autor*

Contact of quartzitic Lower Werfenian sandstones with granite waste on the Mt. Szeroka Jaworzyńska. The casts of irregularities of the granite waste visible in the bottom of the sandstone *Phot. by the author*

PL. IV

Odsłonięcie werfenu reglowego w dolinie Jaworzynki *Fot. K. Niemczynowicz*

1 czerwone piaskowce kwarcowe o spoiwie żelazistym z pojedynczymi otoczakami kwarcowymi, a także miejscami z warstewkami zlepieńców. Ku górze zanikają większe ziarna. Miejscami piaskowce mają charakter arkozowy, towarzyszą im wkładki czerwonych łupków ilastych. W całym zespole widoczne są warstwowania skośne w przekrojach prostopadłych do kierunku transportu. *2* piaskowce kwarcytyczne brunatne, zlewne, dość silnie strzaskane tworzą strome urwisko. Na powierzchniach warstw widoczne są nagromadzenia ziaren kwarcowych. Granica z 1 nierówna, głównie z przyczyn tektonicznych. W prawej części odsłonięcia zachowane są ławice czerwonych łupków ilastych *(łc)*. *3* jasne piaskowce, miejscami rozpadają się na kanciaste ziarna (zjawisko podobne jak w werfenie choczańskim w Podbrezowej). W spękaniach dość silna mineralizacja żelazista. W piaskowcach przewarstwienia zielonkawych łupków ilastych, szczególnie dobrze widoczne w prawym krańcu odsłonięcia *(łz)*. *4* piaskowce średnioziarniste, różowe, o oddzielności cienkopłytkowej z blaszkami miki widocznymi na powierzchniach warstw, wyżej czerwone mułowce i łupki piaszczyste. *5* białe piaskowce podobne do piaskowców z zespołu 3. *6* szaro-zielonkawe, cienkowarstwowe piaskowce i mułowce z fauną i ze zwęglonymi szczątkami flory. *7* czerwone mułowce, silnie spękane. Miejscami o zabarwieniu zielonym. *8* białe piaskowce kwarcytyczne silnie strzaskane. *9* czerwone mułowce z wkładkami równoziarnistych i drobnoziarnistych piaskowców. *10* żółtawe piaskowce, lekko wapniste i łupki piaszczyste z wkładkami żółtych dolomitów. *11* żółte dolomity, dolomity komórkowe

Exposure of the subtatric Werfenian in Jaworzynka valley

1 red quartz sandstones with ferruginous matrix containing isolated quartz pebbles, locally with conglomeratic laminae. Larger grains disappear towards the top. Locally the sandstones are arkose in character and are accompanied by intercalations of red clay shales. Throughout the set there are cross stratifications in sections vertical to direction of transportation. *2* brown quartzitic compact sandstones, moderately disrupted form steep crags. Concentrated quartz grains are observable on the surface of layers. The boundary with above sandstones is irregular, mainly owing to tectonic factors. Layers of red clay shales (*lc*) are preserved in the right hand of exposure. *3* light sandstones, locally disintegrated into angular grains (similarly as in the Chocz Werfenian from Podbrezowa). Rather strong ferruginous mineralisation observable within cracks. Intercalations with greenish clay shales are most readily discernible in the right periphery of the outcrop. *4* medium-grained pink sandstones, displaying thinbedded cleavage showing mica flakes on surface of layers; higher up red siltstones and sandy shales. *5* white sandstones similar to those in item 3, *6* grey-greenish, finebedded sandstones and siltstones containing fossils and carbonized plant remains. *7* red badly cracked siltstones. Locally green coloured. *8* white quartzitic sandstones strongly disrupted. *9* red siltstones with equigranular and fine-grained sandstone intercalations. *10* yellowish slightly calcareous sandstones and sandy shales intercalated by yellow dolomites. *11* yellow dolomites, cellular dolomites

PL. V

Fig. 1

Piaskowiec arkozowy ze spągu werfenu na Skrajnej Turni z zachowanymi okruchami granitu pochodzącymi z podłoża
w.n.
Fot. autor

Arkose sandstone of the Lower Werfenian — with fragments of granite from the bottom, Mt. Skrajna Turnia
nat. size
Phot. by the author

Fig. 2

Fragment zlepieńca ze spągu werfenu na Tomanowej. Widoczne słabo zaznaczone warstwowanie równoległe
w.n.
Fot. autor

Conglomerate from bottom of the Lower Werfenian in Mt. Tomanowa. Stratification is visible
nat. size
Phot. by the author

Fig. 3

Nadwietrzała powierzchnia zlepieńca ze spągu werfenu na Małej Koszystej. W centrum widoczny okruch krzemienia pasiastego
w.n.
Fot. J. Błaszyk

Bottom conglomerate surface, somewhat weathered, from Mt. Mała Koszysta. A banded chert fragment at center
nat. size

PL. VI

Fig. 1

Okruch skały wulkanicznej z piaskowca z Żółtej Turni
x ok. 20
Nikole skrzyżowane

Fragment of volcanic rock from sandstone in Mt. Żółta Turnia
x ca. 20
Crossed nicols

Fig. 2

Fragment otoczaka czarnej skały krzemionkowej z kryształkami pirytu. Żółta Turnia, zlepieniec spągowy
x ok. 20
Nikole skrzyżowane

Fragment of a pebble of black siliceous rock with pyrite crystals. Bottom conglomerate in Mt. Żółta Turnia
x ca. 20
Crossed nicols

Fig. 3

Fragment otoczaka zsylifikowanego riolitu ze zlepieńca spągowego z grani Jagnięcego
x ok. 7

Fragment of a silicified rhyolite pebble from bottom conglomerate in crest Jagnięcy
x ca. 7

PL. VII

Fig. 1

Skupienia grafitowe w czarnym otoczaku o strukturze kwarcytowej. Mała Koszysta
x ok. 20
Światło zwykłe

Agglomerations of graphite in black quartzitic pebble. Mt. Mała Koszysta x ca. 20
Ordinary light

Fig. 2

Ten sam preparat przy skrzyżowanych nikolach. Widoczna struktura kwarcytowa
x ok. 20

Ditto in crossed nicols showing quartzitic texture
x ca. 20

Fig. 3

Otoczak skały krzemionkowej zabarwiony substancją węglistą skupioną w cienkich laminach pociętych żyłkami kwarcowymi. Żółta Turnia, zlepieniec spągowy x ok. 20

Światło zwykłe

Fot. M. Siemiątkowska

Pebble of quartzitic rock coloured by coal substance agglomerated in thin laminae cut by quartz veinlets. Bottom conglomerate in Mt. Żółta Turnia x ca. 20

Ordinary light

Fig. 4

Fragment otoczaka czerwonej skały krzemionkowej (jaspis). Widoczne wciskanie się ziaren kwarcowych w otoczak x ok. 20

Nikole skrzyżowane

Fot. M. Siemiątkowska

Fragment of pebble of red-coloured siliceous rock (jasper) pitted by quartz grains x ca. 20

Crossed nicols

Fig. 5

Fragment otoczaka zsylifikowanej skały wylewnej x ok. 20

Nikole skrzyżowane

Fot. M. Siemiątkowska

Fragment of silicified volcanic rock x ca. 20

Crossed nicols

Fig. 6

Agregat chalcedonowy w obrębie zlepieńca z Żółtej Turni x ok. 20

Nikole skrzyżowane

Fot. M. Siemiątkowska

Aggregated chalcedony within the conglomerate. Bottom conglomerate of Mt. Żółta Turnia x ca. 20

Crossed nicols

PL. VIII

Fig. 1

Fragment niezwietrzałego skalenia potasowego ze zlepieńca spągowego z Żółtej Turni x ok. 20

Nikole skrzyżowane

Fot. M. Siemiątkowska

Fragment of not-weathered K-felspar from the bottom conglomerate in Mt. Żółta

Turnia

x ca. 20
Crossed nicols

Fig. 2

Fragment otoczaka skały krzemionkowej

x ok. 20
Nikole skrzyżowane
M. Siemiątkowska

Fragment of a siliceous rock pebble

x ca. 20
Crossed nicols

Fig. 3

Fragment zsylifikowanego otoczaka skały wylewnej. Widoczne automorficzne kwarce z wrostkami. Żółta Turnia

x ok. 20
Nikole skrzyżowane
Fot. M. Siemiątkowska

Fragment of silicified pebble of volcanic rock showing automorphic quartzes with inclusions. Mt. Żółta Turnia

x ca. 20
Crossed nicols

Fig. 4

Drobny okruch zsylifikowanej skały wulkanicznej ze zlepieńca z Żółtej Turni

x ok. 20
Nikole skrzyżowane
Fot. M. Siemiątkowska

Small fragment of silicified volcanic rock from conglomerate in Mt. Żółta Turnia

x ca. 20
Crossed nicols

PL. IX

Fig. 1 i 2

Fragmenty otoczaków zsylifikowanego tufu wulkanicznego z Żółtej Turni x ok. 20
Nikole skrzyżowane
Fot. M. Siemiątkowska

Fragment of silicified pebble of volcanic tuff. Mt. Żółta Turnia x ca. 20
Crossed nicols

Fig. 3

Fragment otoczaka zsylifikowanego riolitu ze zlepieńca spągowego w odsłonięciu w grani Jagnięcego

x ok. 25
Nikole skrzyżowane
Fot. autor

Fragment of a pebble of silicified rhyolite from bottom Werfenian conglomerate in crest Jagnięcy

x ca. 25
Crossed nicols
Phot. by the author

PL. X

Fig. 1

Piaskowiec arkozowy z niższego seisu — Ornak, Baniste. s skalenie potasowe

x ok. 30
Nikole skrzyżowane
Fot. M. Siemiątkowska

Sandstone; resembling in its composition an arkose sandstone — Mt. Ornak and Baniste. s grains of felspar

x ca. 30
Crossed nicols

Fig. 2

Kwarcytyczny piaskowiec kwarcowy z niższego seisu na Żółtej Turni. Widoczne warstwowanie równoległe

x ok. 20
Nikole skrzyżowane
Fot. M. Siemiątkowska

Quartzitic sandstone from Mt. Żółta Turnia. Parallel bedding visible

x ca. 20
Crossed nicols

Fig. 3

Kwarcytyczny piaskowiec kwarcowy z Żółtej Turni

x ok. 40
Nikole skrzyżowane
Fot. M. Siemiątkowska

Quartzitic sandstone from Mt. Żółta Turnia

x ca. 40
Crossed nicols

Fig. 4

Drobnoziarnisty piaskowiec kwarcowy o spoiwie ilastym z Żółtej Turni

x ok. 40
Nikole skrzyżowane
Fot. M. Siemiątkowska

Quartz sandstone with clay matrix from Mt. Żółta Turnia

x ca. 40
Crossed nicols

PL. XI

Fig. 1

Warstwowanie skośne, przekątne w białych piaskowcach kwarcytycznych na Małej Koszystej

Fot. autor

Cross stratification (diagonal) in white quartzitic sandstones in Mt. Mała Koszysta
Phot. by the author

Fig. 2

Warstwowanie skośne, tangencjalne, wielokierunkowe w brunatnych piaskowcach kwarcytycznych na Żółtej Turni *Fot. autor*

Cross stratification (tangential) in brown quartzitic sandstones in Mt. Żółta Turnia
Phot. by the author

PL. XII

Fig. 1

Warstwowanie skośne, przekątne w różowym piaskowcu z Żółtej Turni *Fot. autor*

Cross stratification (diagonal) in pink sandstone in Mt. Żółta Turnia
Phot. by the author

Fig. 2

Warstwowanie równoległe w rożowym piaskowcu żelazistym z Szerokiej Jaworzyńskiej *Fot. autor*

Parallel stratification in pink ferruginous sandstone in Mt. Szeroka Jaworzyńska
Phot. by the author

PL. XIII

Fig. 1

Warstwowanie skośne, tangencjalne podkreślone przez kliważ. Górna część zespołu skośnego ścięta erozyjnie. Brunatne piaskowce kwarcytyczne z Upłazków na Szerokiej Jaworzyńskiej *Fot. autor*

Cross stratification (tangential) pointed by cleavage. Upper part of cross stratification is truncated. Brown quartzitic sandstones from Mt. Szeroka Jaworzyńska
Phot. by the author

Fig. 2

Zmarszczki symetryczne o lekko spłaszczonych i zaokrąglonych grzbietach. Górna powierzchnia warstewki piaskowca z warstw ze szczątkami flory z Giewontu. Strzałka oznacza kierunek północy *Fot. autor*

Symmetric ripple marks with gently flattened and rounded crests. Upper surface of sandstone layer from plant-bearing beds in Mt. Giewont. Arrow points N
Phot. by the author

PL. XIV

Fig. 1

Zmarszczki na górnej powierzchni różowego piaskowca kwarcytycznego z Hali Gąsienicowej *Fot. autor*

Ripple marks on upper surface of pink quartzitic sandstone from Hala Gąsienicowa *Phot. by the author*

Fig. 2

Zmarszczki symetryczne na powierzchni warstwy białego piaskowca kwarcytycznego z Małej Koszystej *Fot. autor*

Ripple marks on upper surface of white quartzitic sandstone from Mt. Mała Koszysta *Phot. by the author*

PL. XV

Fig. 1

Zmarszczki na powierzchni brunatnego piaskowca kwarcytycznego z Szerokiej Jaworzyńskiej *Fot. autor*

Ripple marks on upper surface of quartzitic sandstone from Mt. Szeroka Jaworzyńska *Phot. by the author*

Fig. 2

Zmarszczki przetworzone na powierzchni czerwonego piaskowca kwarcytycznego z Żółtej Turni *Fot. autor*

Metaripples on upper surface of pink quartzitic sandstone from Mt. Żółta Turnia *Phot. by the author*

PL. XVI

Fig. 1

Silnie przetworzone zmarszczki na górnej powierzchni czerwonego piaskowca mulastego z fauną. Červena Skala (Słowacja) *Fot. autor*

Strongly reworked ripple marks on upper surface of red fossiliferous clay sandstone. Červena Skala (Slovakia *Phot. by the author*

Fig. 2

Słabo zachowane zmarszczki przetworzone na powierzchni piaskowca żelazistego z Szerokiej Jaworzyńskiej *Fot. autor*

Poorly preserved metaripples on upper surface of red ferruginous sandstone from Mt. Szeroka Jaworzyńska *Phot. by the author*

PL. XVII

Problematyczne hieroglify organiczne (mułojady?) na dolnej powierzchni czerwonego piaskowca ilastego z Suchej Doliny pod Osobitą *Fot. B. Mazek*

Problematic organic hieroglyphs (slime-eaters?) on lower surface of red clay sandstone from Sucha valley below Mt. Osobita

PL. XVIII

Ślady działalności organizmów mułożernych, *Monocraterion* sp.
Monocraterion sp. burrows of the slime-eaters

Fig. 1

Ślady widziane na górnej powierzchni mułowca — Sucha Dolina pod Osobitą *Fot. B. Mazek*

Burrows on the upper surface of siltstone from Sucha valley below Mt. Osobita

Fig. 2

Zachowany kanał wypełniony osadem piaszczystym przecina warstewkę piaskowca — dolina Jaworzynki *Fot. B. Mazek*

Sand-filled burrows cutting a sandstone layer — Jaworzynka valley

Fig. 3 i 4

Kanały widziane w przekroju prostopadłym do powierzchni warstwy z doliny Jaworzynki (3) i Małej Koszystej (4) *Fot. B. Mazek*

Section of burrows in silty sandstone layer in Jaworzynka valley and in Mt. Mała Koszysta

Fig. 5

Problematyczne kanały mułojadów widziane na przekroju piaskowca pasiastego z Małej Koszystej *Fot. B. Mazek*

Sections of problematic burrows of slime-eaters in banded sandstone in Mt. Mała Koszysta

PL. XIX

Fig. 1

Nagromadzenie okruchów łupków na spągu warstw piaskowca kwarcytycznego z Szerokiej Jaworzyńskiej *Fot. autor*

Agglomeration of red shale fragments in bottom of quartzitic sandstone layer, Mt. Szeroka Jaworzyńska *Phot. by the author*

Fig. 2

Hieroglify organiczne na spągowej powierzchni białego piaskowca kwarcytycznego. Dolina Stare Szałasiska *Fot. autor*

Organic hieroglyphs on lower surface of white quartzitic sandstone. Stare Szałasiska valley *Phot. by the author*

PL. XX

Fig. 1

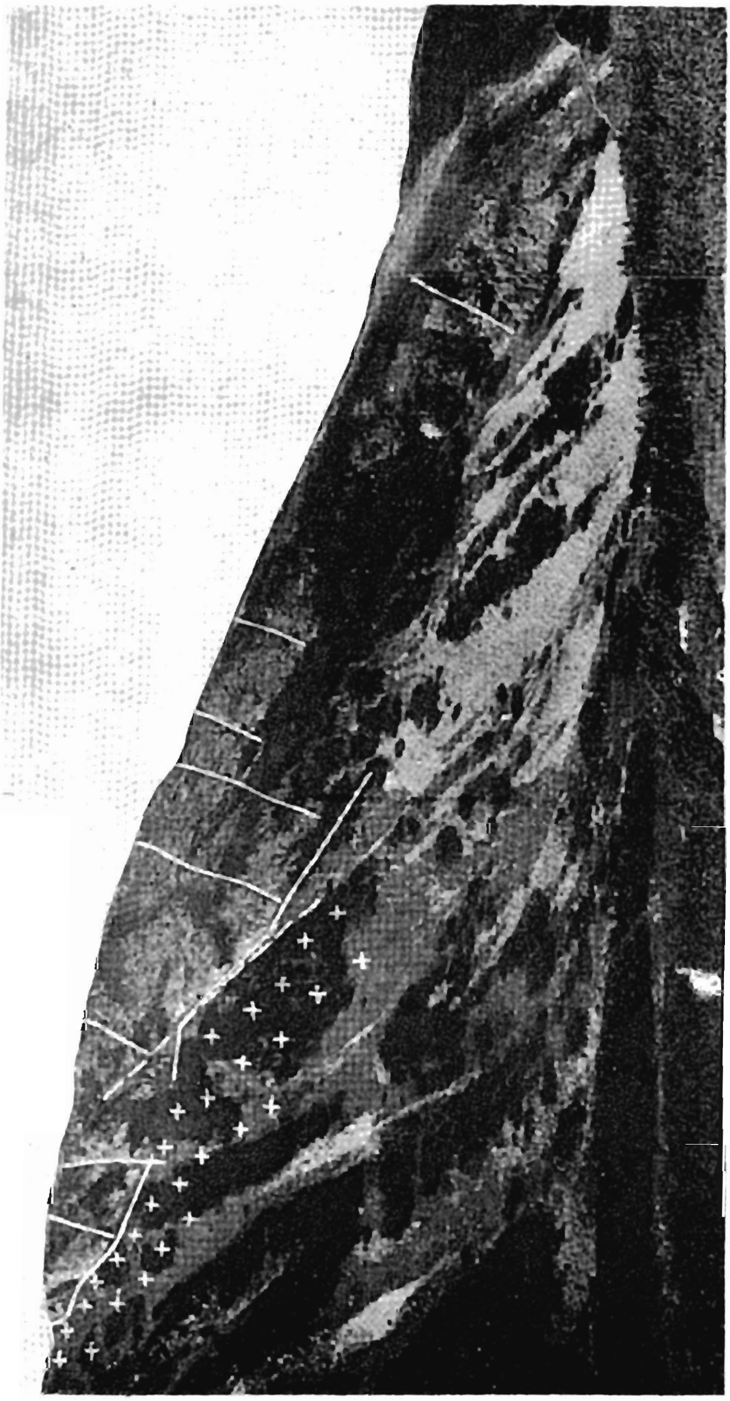
Fałdy osuwiskowe w mułowcu górnego seisu z Szerokiej Jaworzyńskiej *Fot. autor*

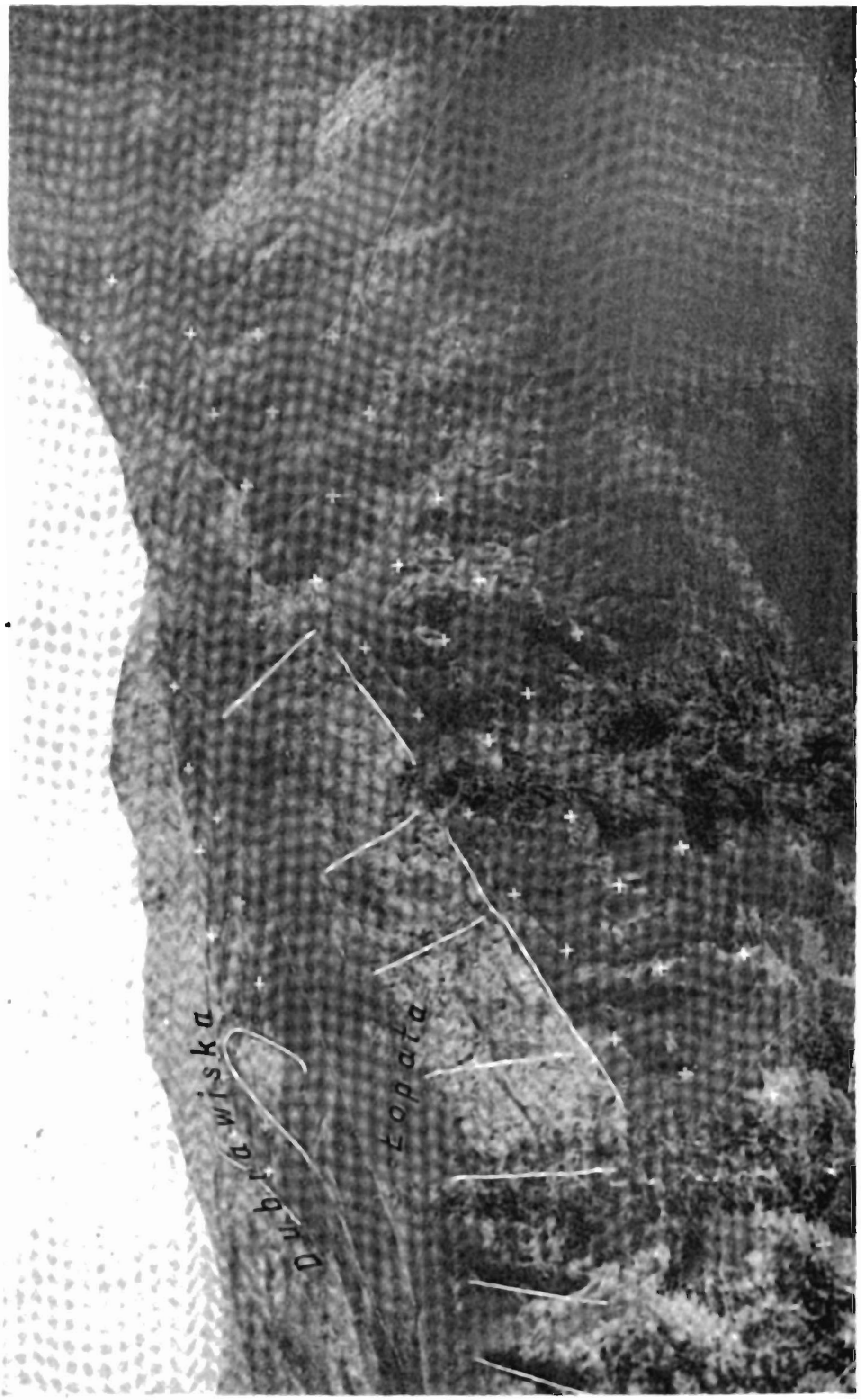
Slump folds in Upper Seisian siltstone from Mt. Szeroka Jaworzyńska *Phot. by the author*

Fig. 2

Kanały mułojadów z deformacjami spowodowanymi kompresją osadu ilastego. Żółta Turnia *Fot. autor*

Slime-eater burrows deformed by compression of the clay *Phot. by the author*

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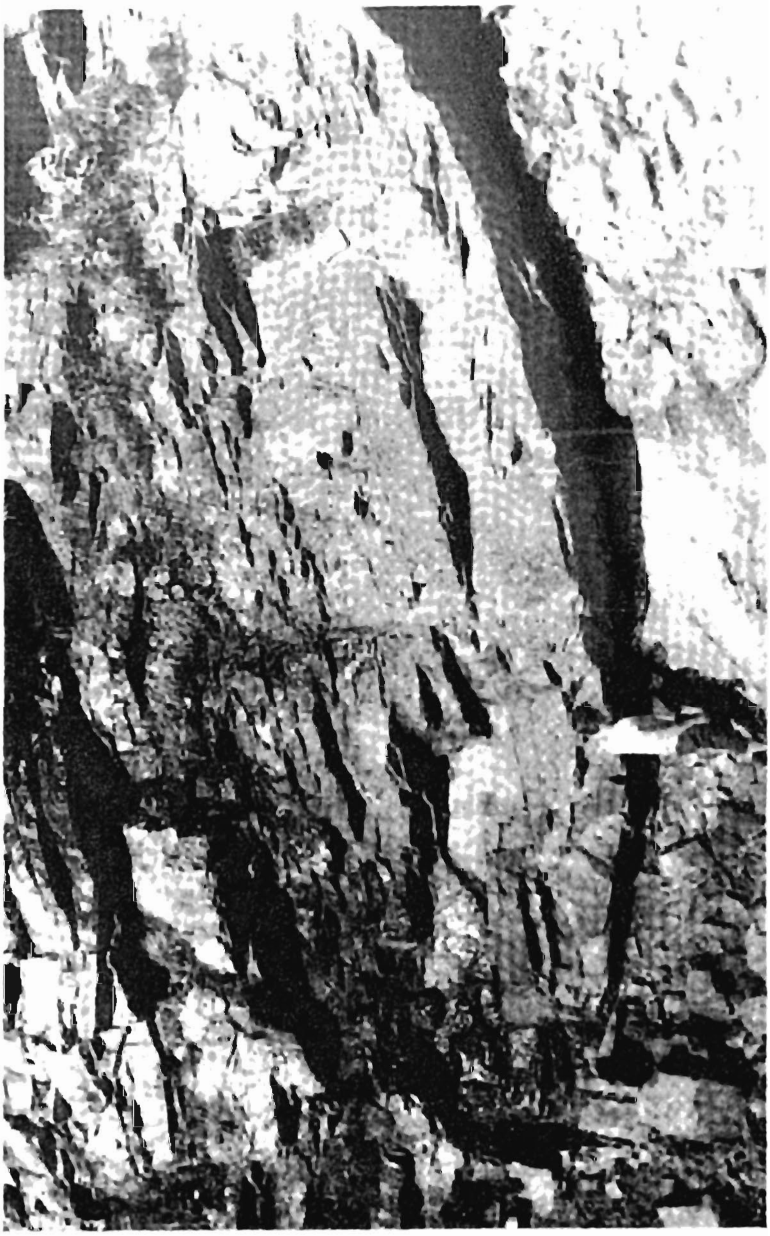

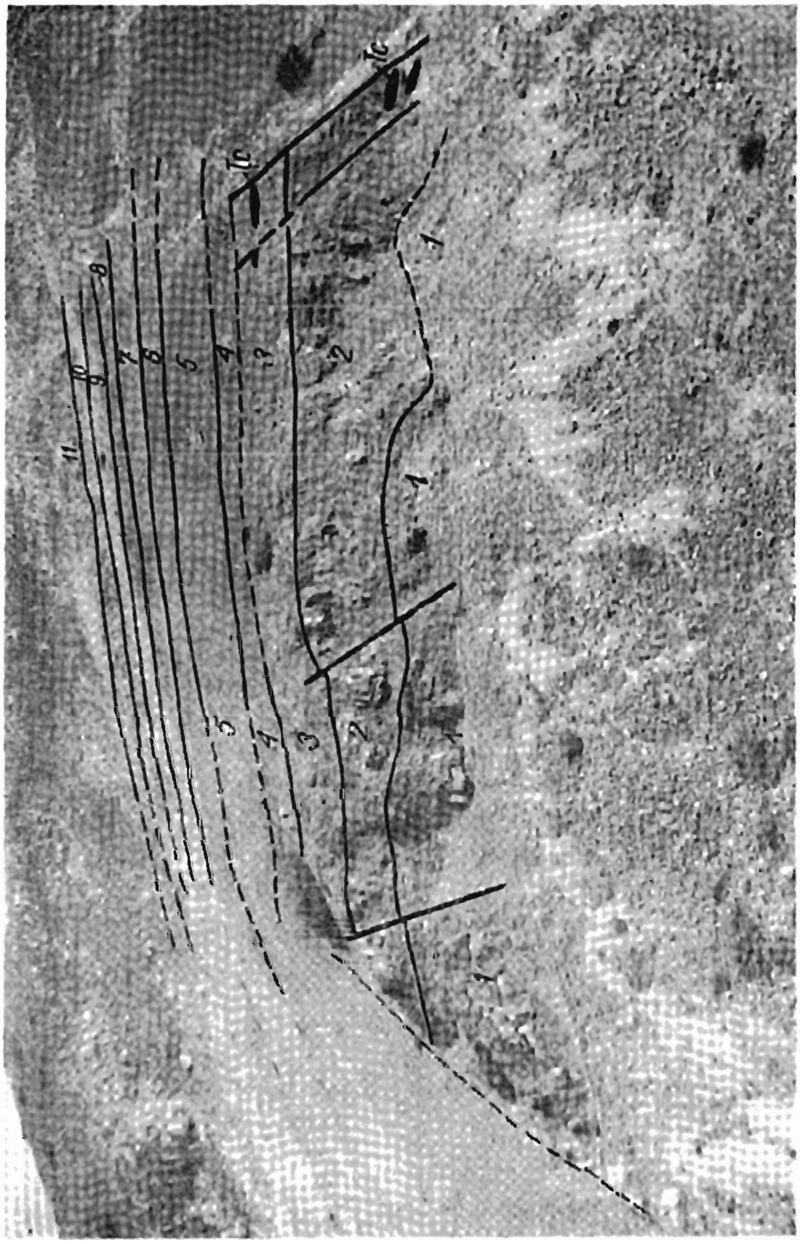

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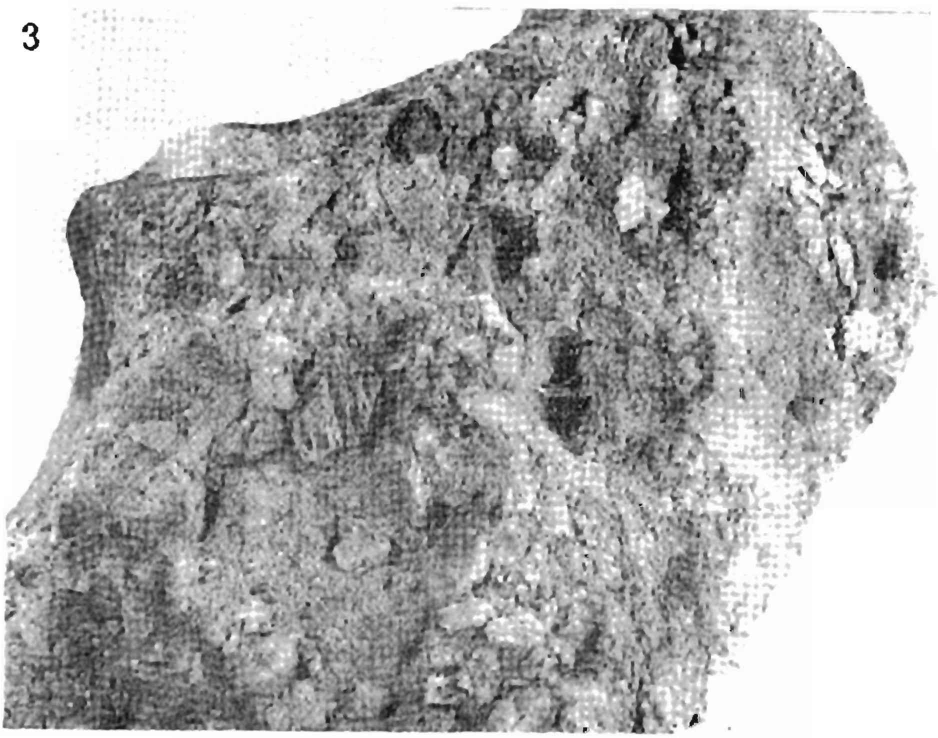

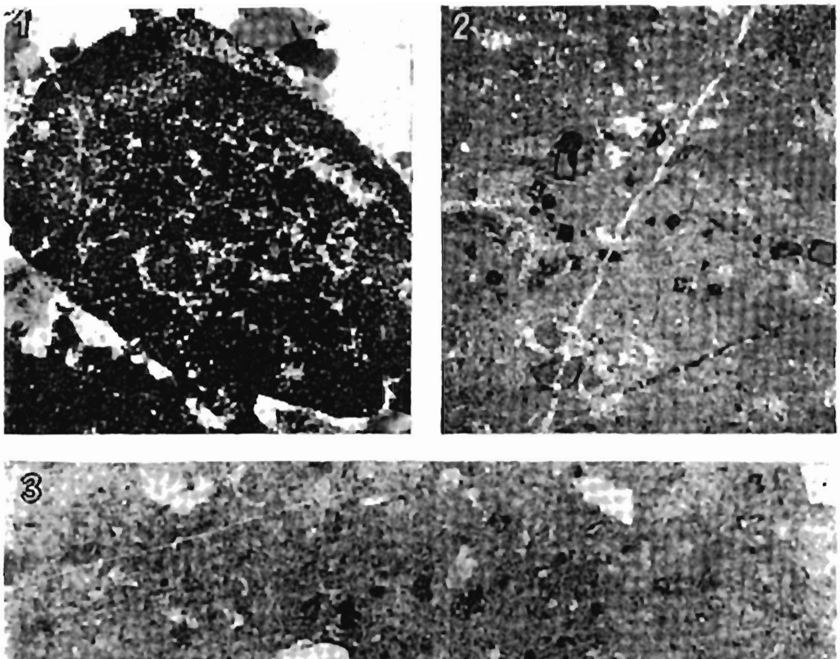
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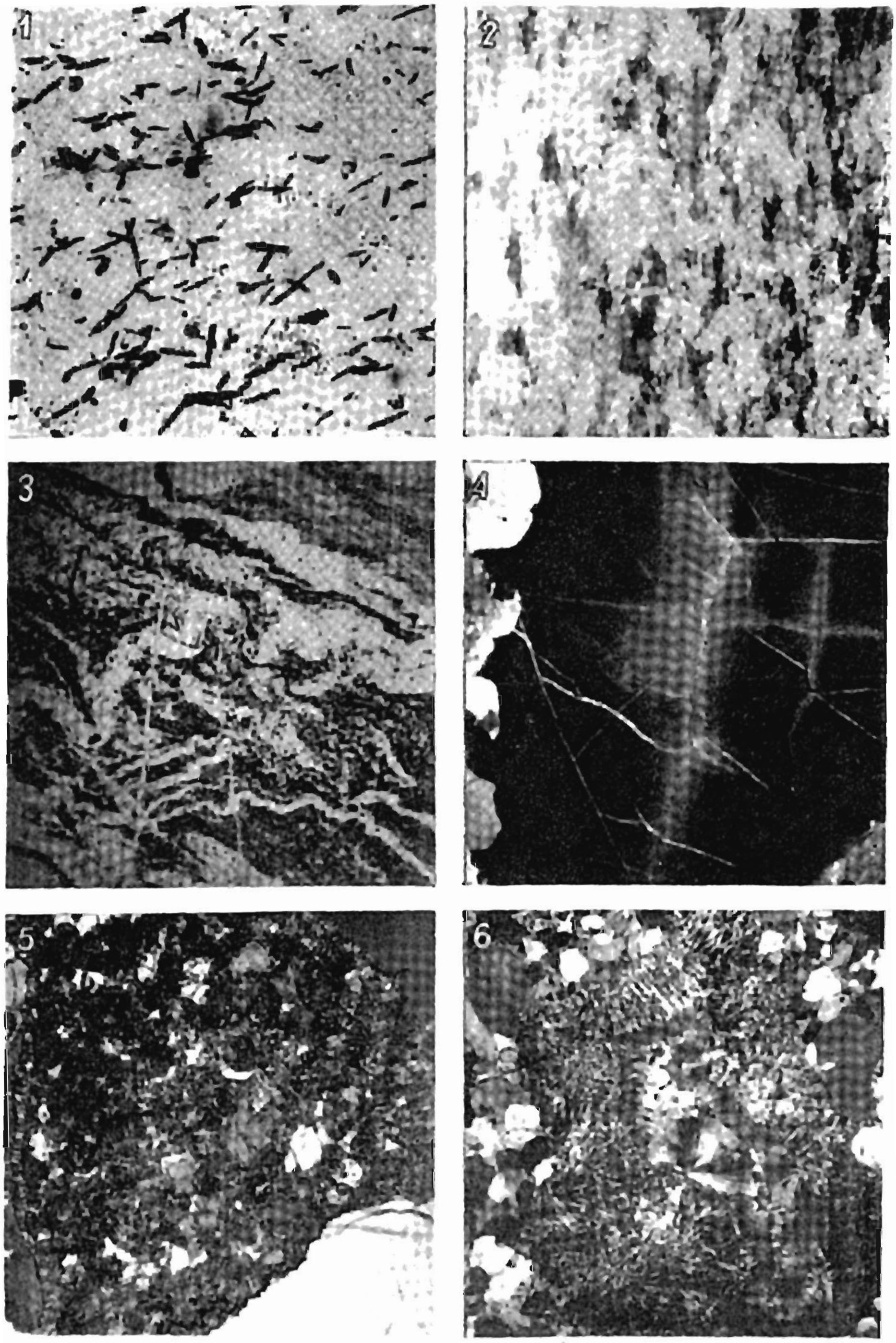
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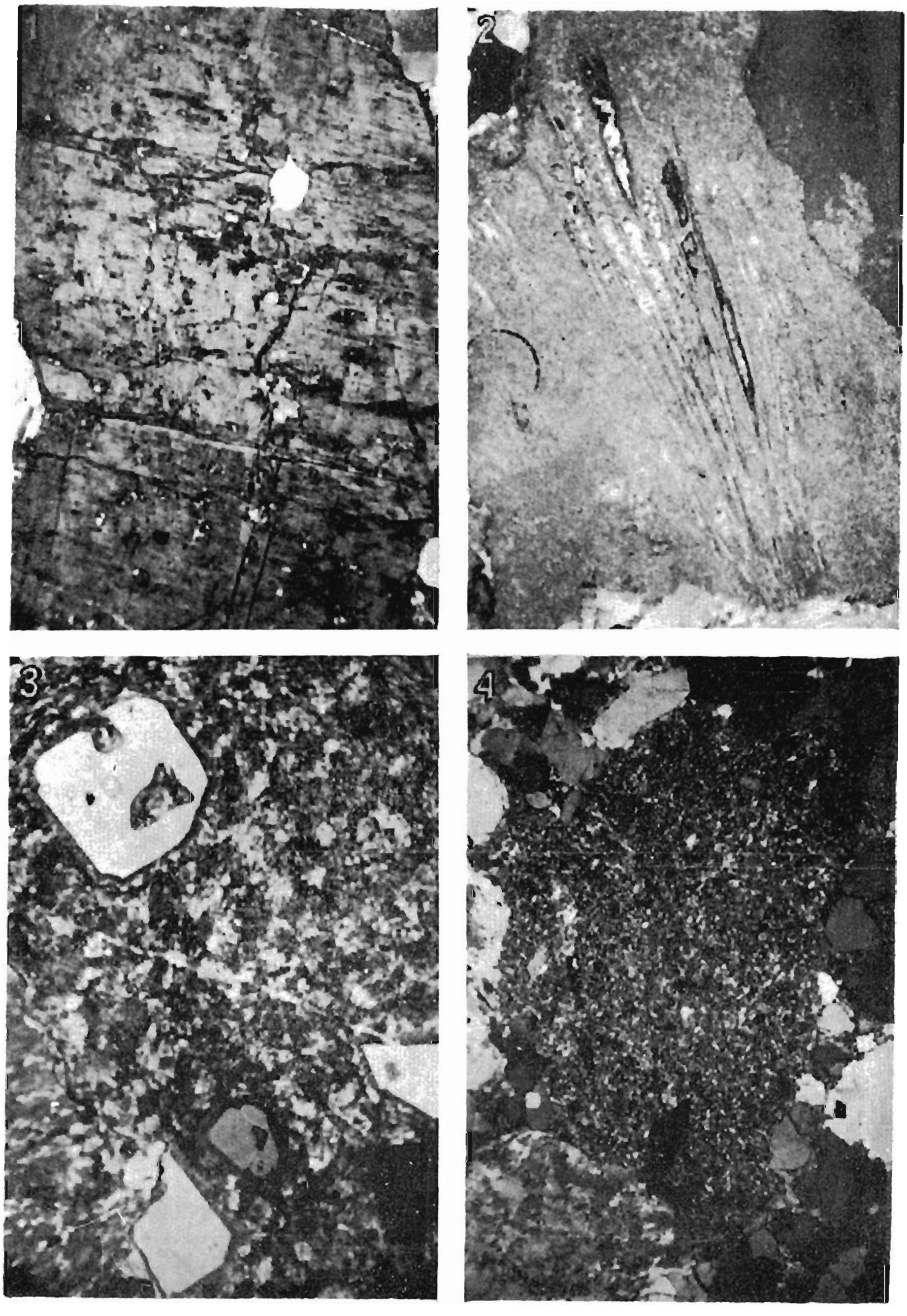
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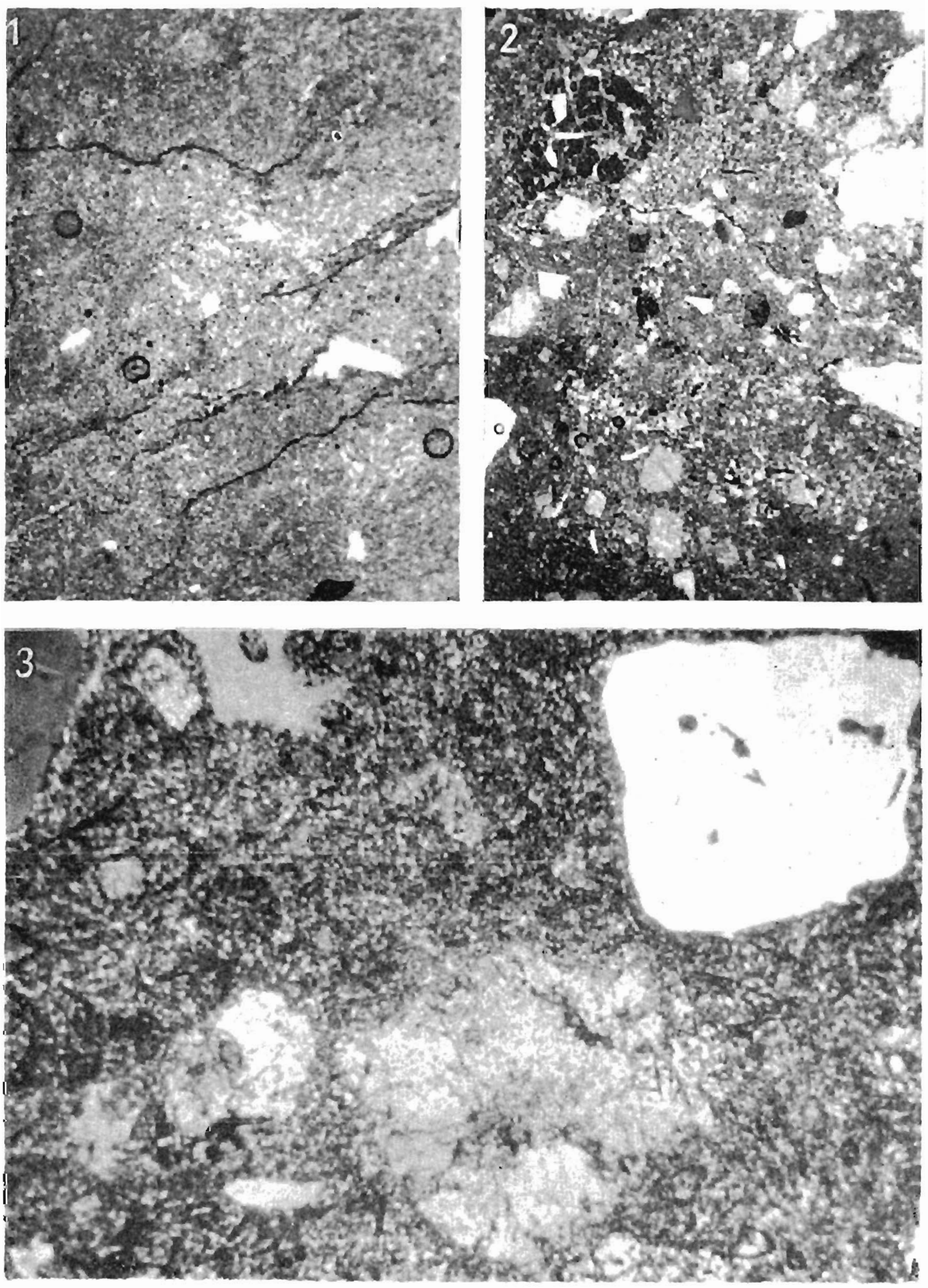
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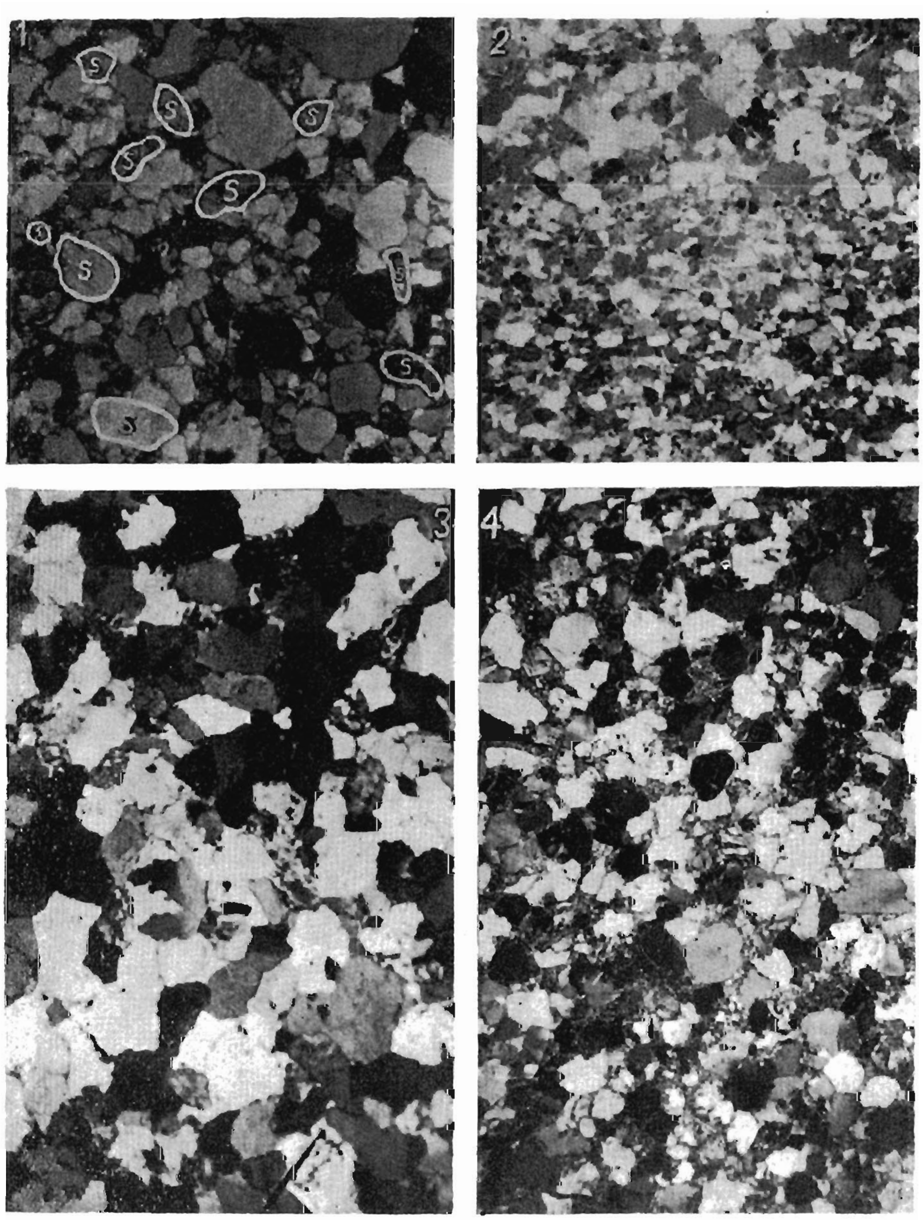
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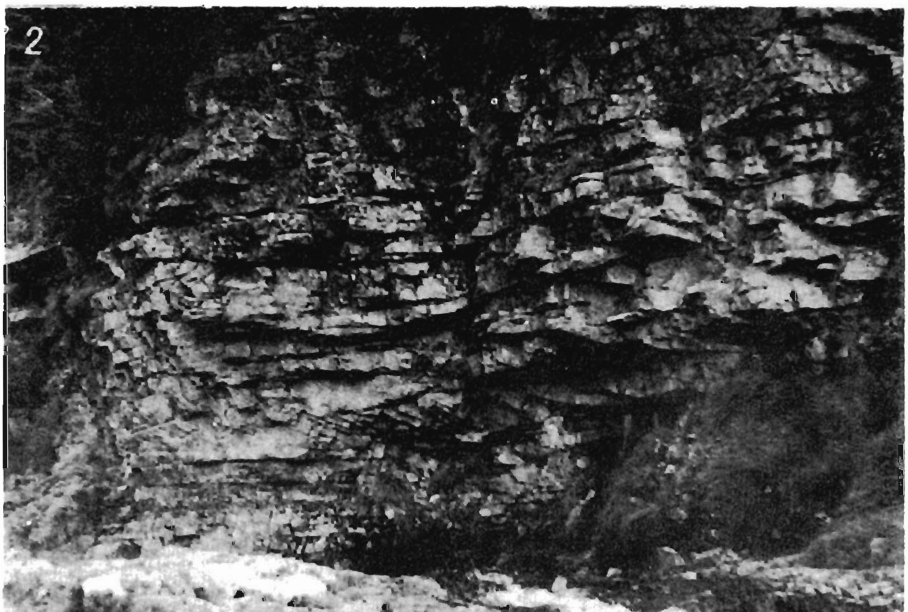

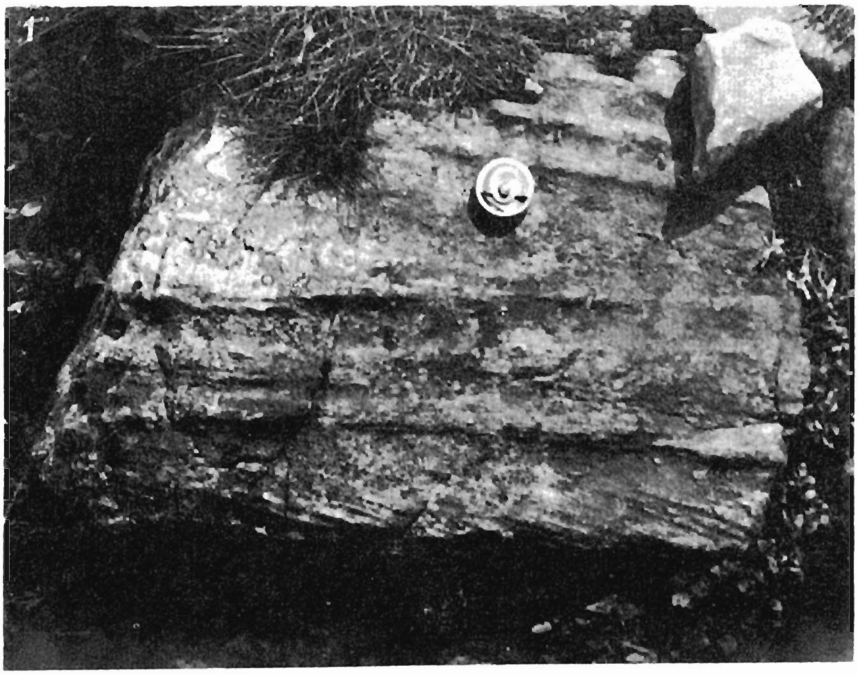

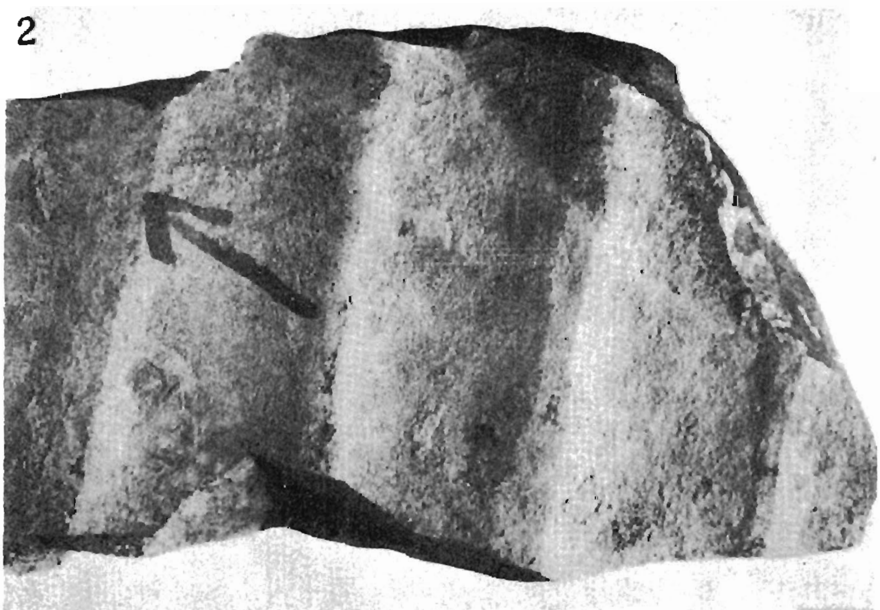

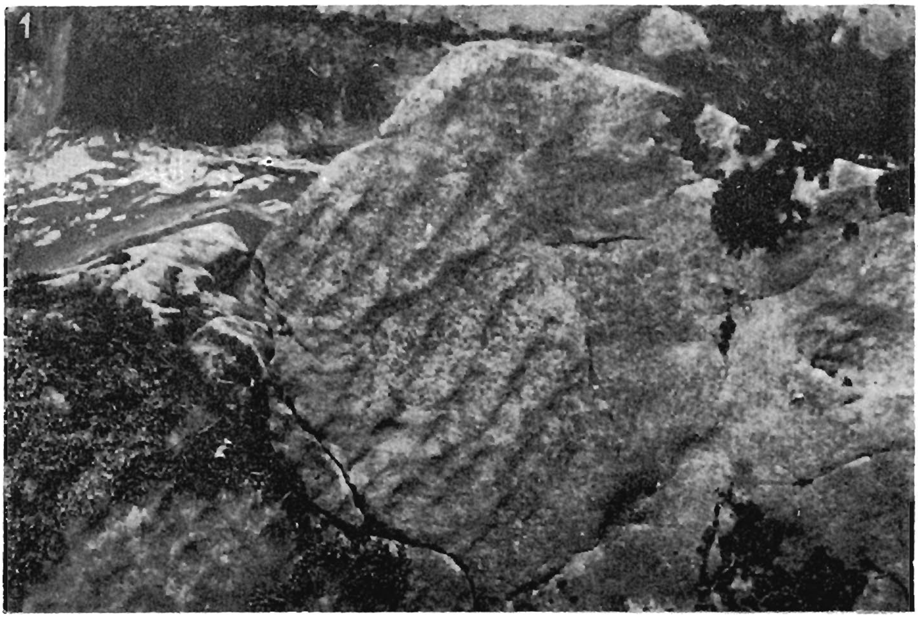
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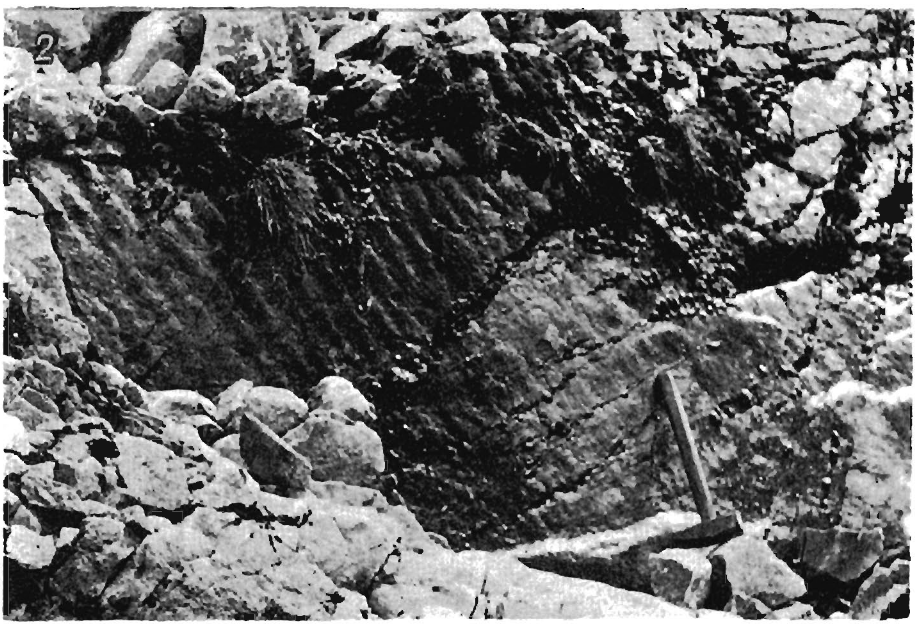
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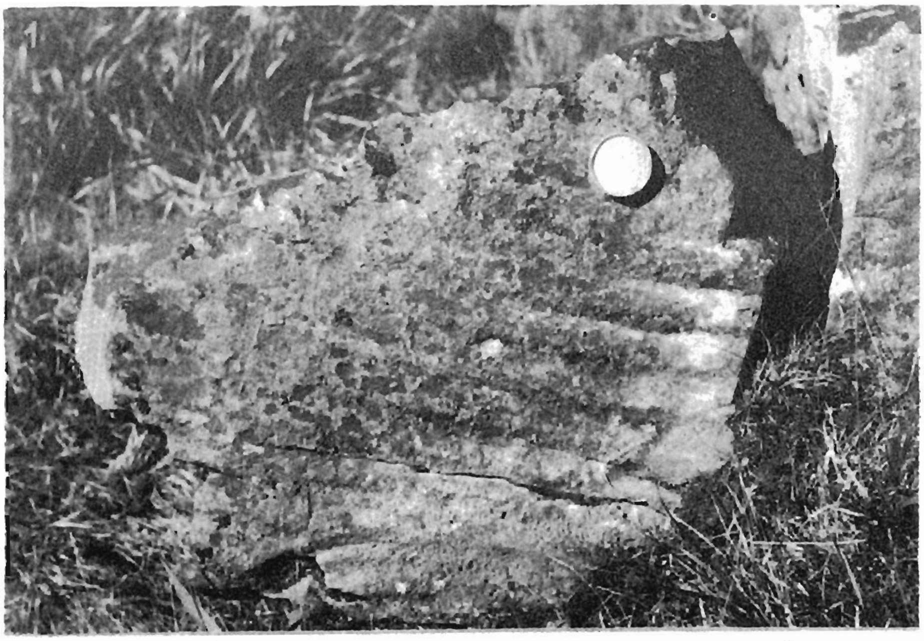

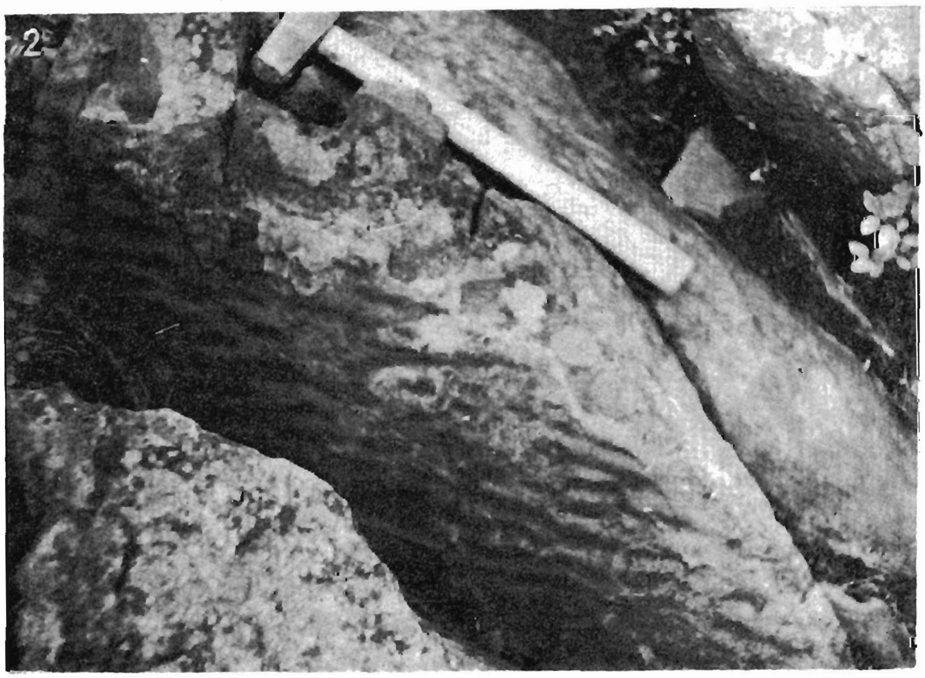


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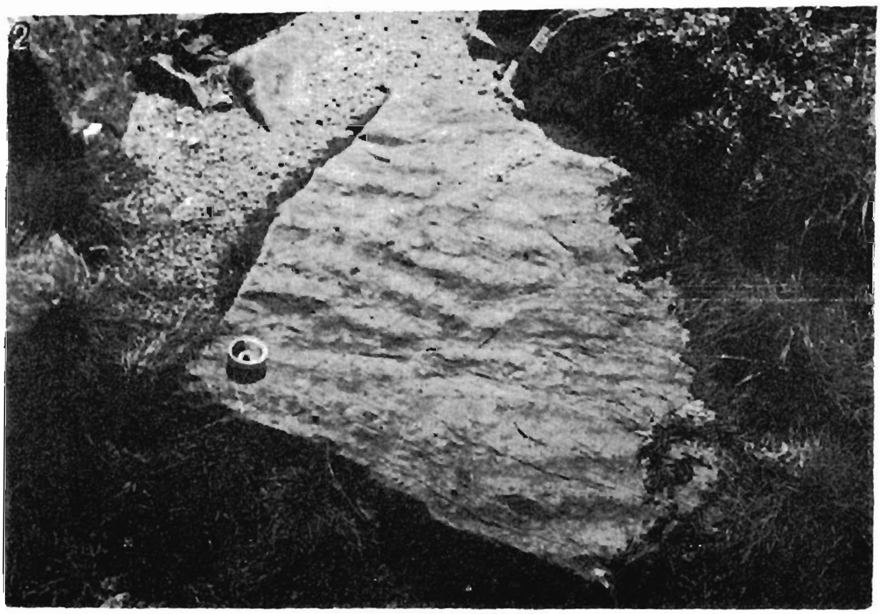
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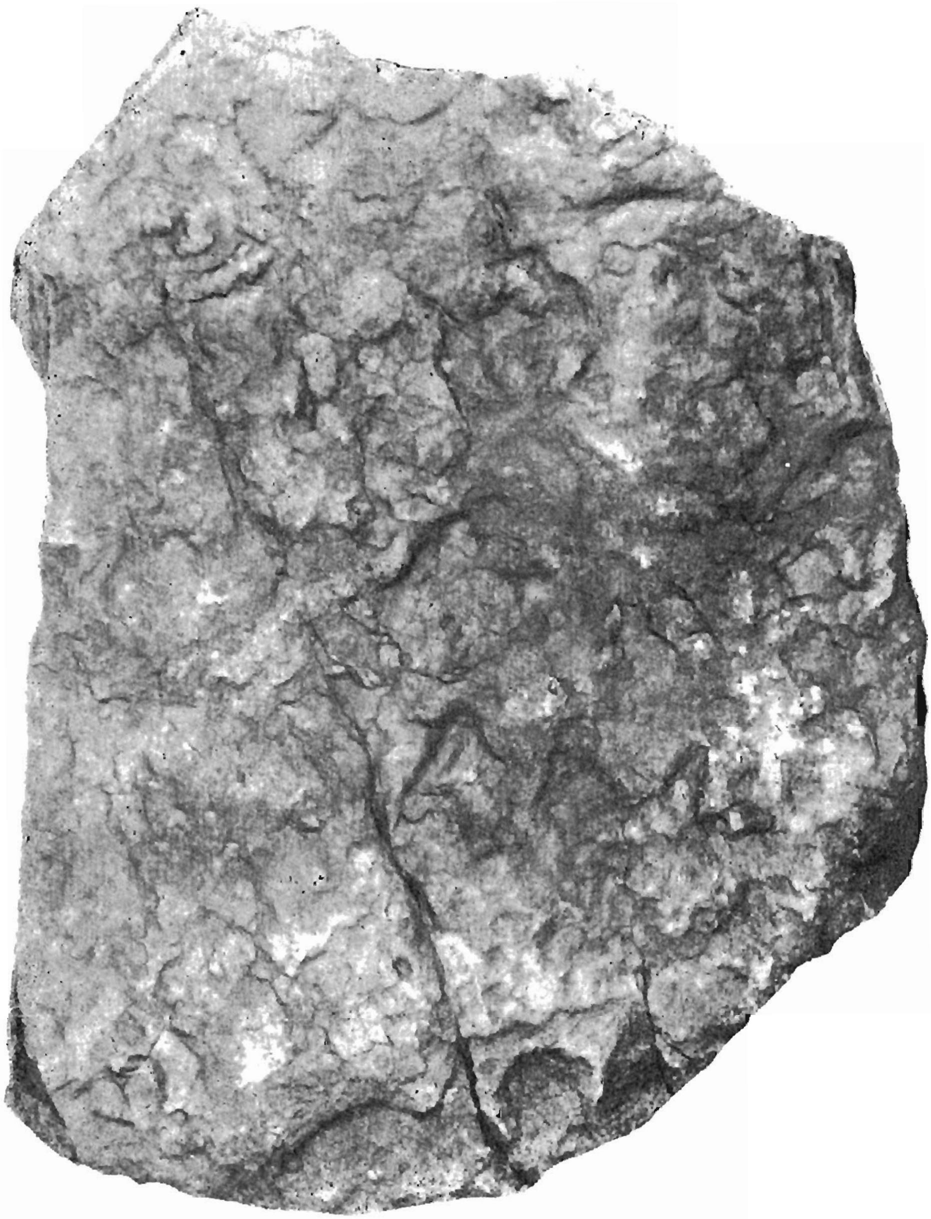

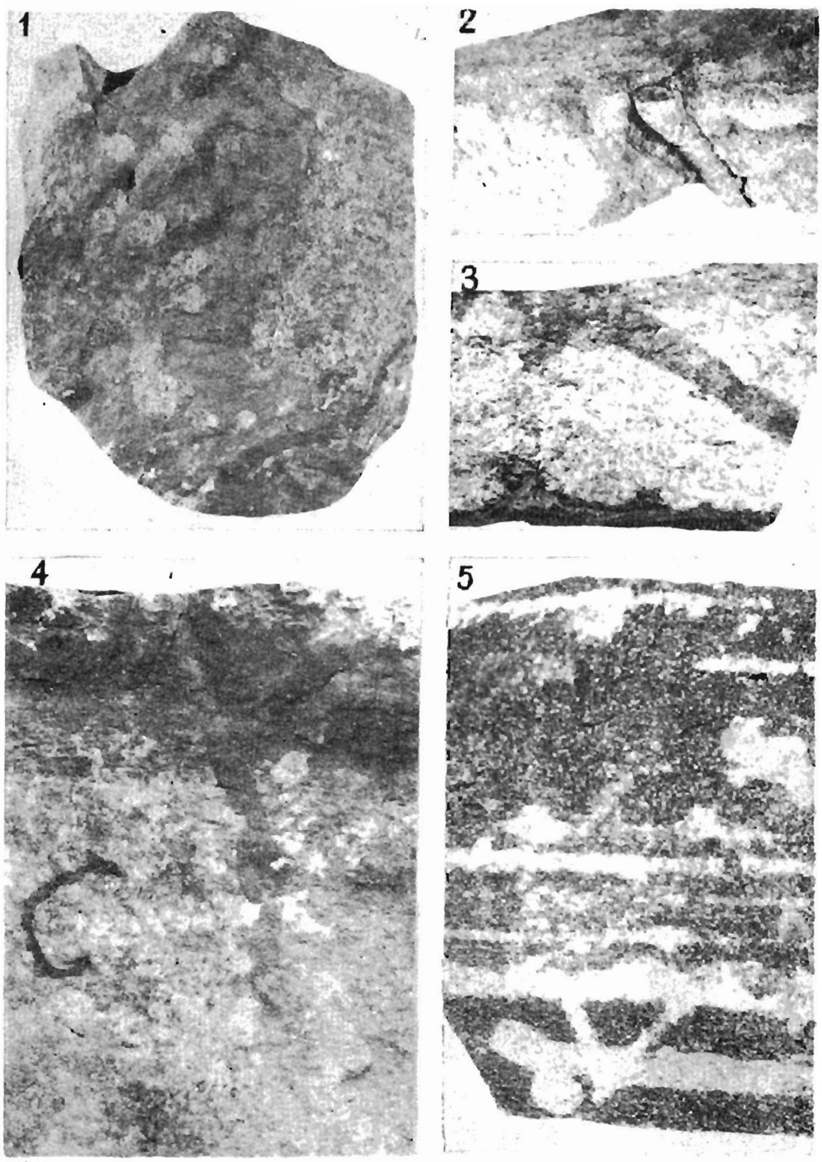
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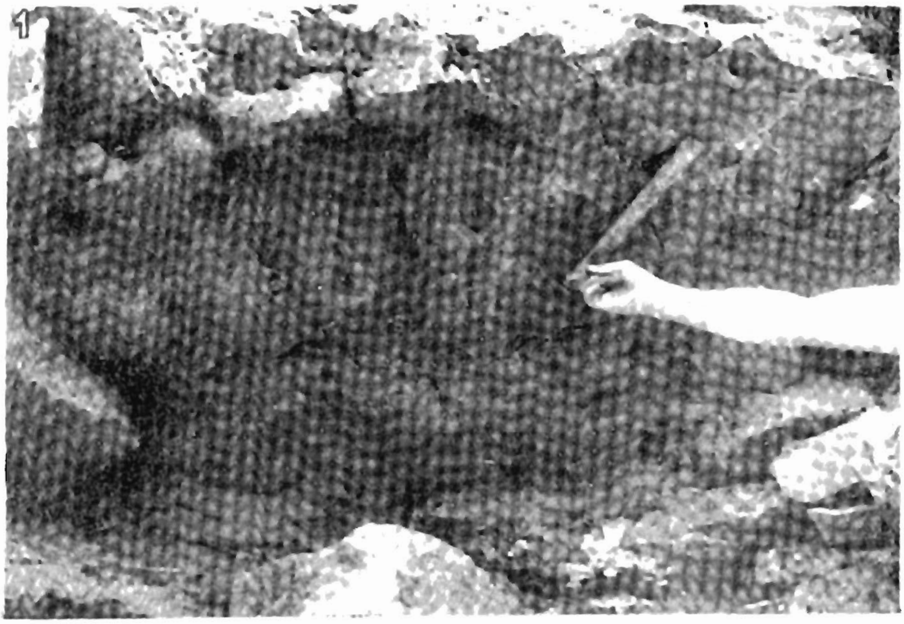

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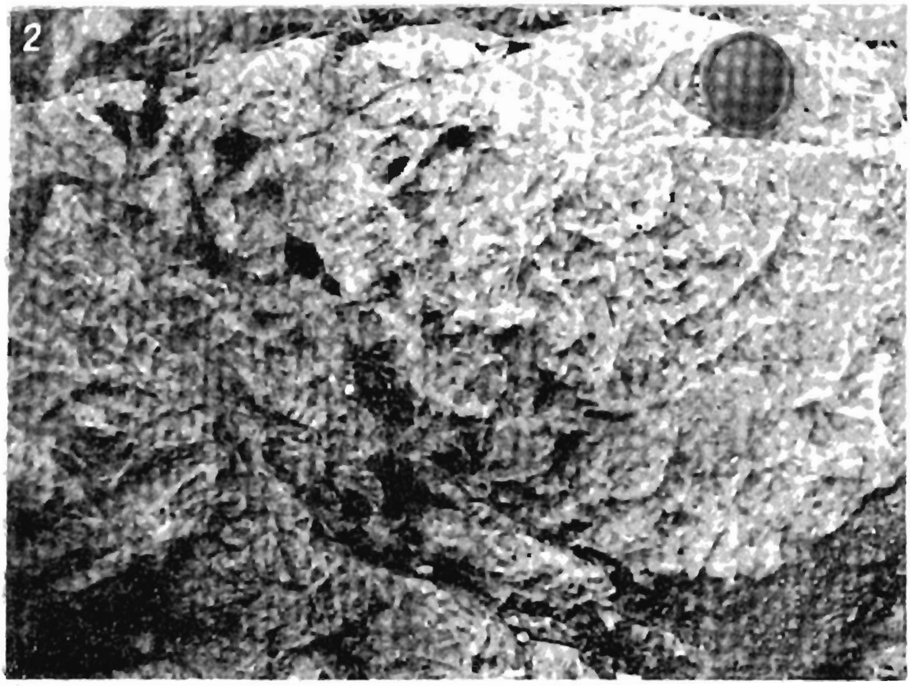

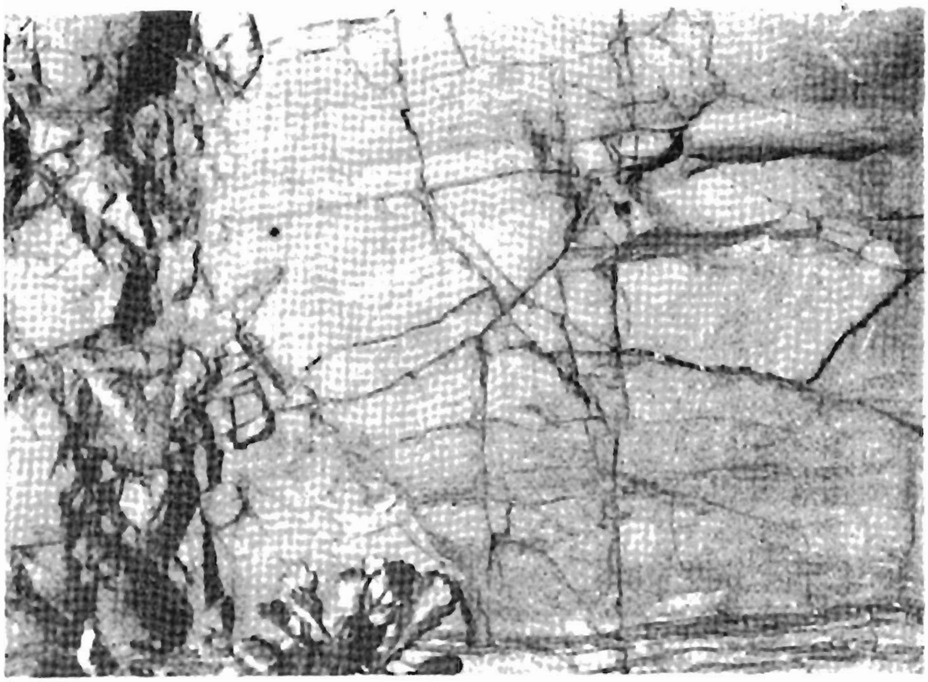

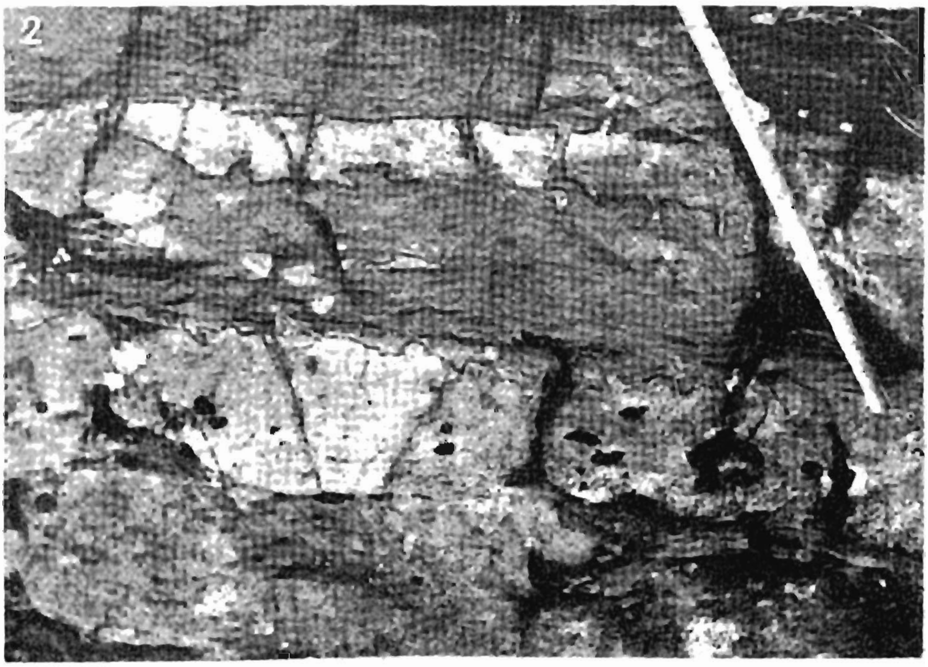
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