ROCZNIK POLSKIEGO TOWARZYSTWA GEOLOGICZNEGO
ANNALES DE LA SOCIÉTÉ GÉOLOGIQUE DE POLOGNE

Tom (Volume) XLI — 1971 Zeszyt (Fascicule) 3 Kraków 1971

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RECRYSTALLIZED AND DISAGGREGATED LIMESTONES IN THE TRIASSIC OF SILESIA

(Pl. XX—XXIII and 5 Figs.)

ZREKRYSTALIZOWANE I ROZSYPLIWE WAPIENIE W TRIASIE ŚLĄSKA OPOLSKIEGO

(Tabl. XX—XXIII i 5 fig.)

Abstract: The Middle Triassic Karchowice Beds of Silesia have been locally altered into a friable and porous aggregate of coarse calcite crystals. The alteration took place in two successive stages: 1) conversion of fine-grained calcium arbonate into a coarse calcite mosaic, 2) dissolution at the individual crystal boundaries, and subsequent disaggregation. The second change is largely the product of attack by meteoric waters, and is of recent origin. The recrystallization is regarded as a remote manifestation of changes which, further to the east, and at the close of Triassic time, resulted in dolomitization and emplacement of sulfide ores. Some specific karst features, which tend to develop in altered limestones, are briefly discussed.

INTRODUCTION

Dolomites and, to a much lesser extent, limestones are liable to disaggregate into a friable mass of crystals through recrystallization and dissolution at the individual crystal boundaries. The disaggregated or „sanded" dolomites, as they are often termed (see e. g. Heyl et al. 1959), are known to occur among wall-rock alterations at the contact with ore-bodies (see e. g. Lovering et al. 1949). In such cases the disaggregation is ascribed to the action of hydrothermal solutions. Outside the realm of mineralization, other processes, such as weathering, solvent action of meteoric water or bacterial activity, are called upon to explain the granular disaggregation, (see e. g. Andrusov 1955, Zgogović 1966, Caumartin 1963). In yet other instances the origin of „sanded" or „powdered" dolomites is sought in tectonic processes or in a combination of tectonic crushing and subsequent dissolution (Zalaffi 1969).

Very little work has been done on similar alterations in limestones, and geologic literature contains only brief references to their existence (Lovering et al. 1949, fide Heyl et al. 1959, Hrovat 1953, Zgogović 1964). The following report is largely devoted to this question and deals with extensive alterations observable in the Middle Triassic Karchowice

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Beds of Silesia. The end-product of these alterations is a friable or weakly cemented mass of recrystallized calcite crystals, which will be referred to as disaggregated or „sanded" limestone (in accordance with the term already applied to similarly altered dolomites). The altered limestones in the Karchowice Beds have been briefly mentioned by Assmann (1944), who attributed their crumbly appearance to the action of meteoric waters.

The aim of the present study is to provide more information on the origin of alterations in the Karchowice limestones. The examples cited are from the region of Kamień Śląski in Silesia (south-east of Opole). However, similar alterations occur in other places, and the ones described here may be regarded as representative for the Karchowice limestones.

GEOLOGIC SETTING

The Karchowice Beds belong to the upper part of the Lower Muschelkalk (Assmann 1944, Siedlecki 1948). They consist of medium bedded clastic limestones and rare plano-convex bioherms. The latter are made up of small colonial corals, crinoids and bryozoarians. Microscopic study of the unaltered limestones shows that they are chiefly composed of intraclasts of both, organic and inorganic derivation, cemented by micrite and sparry calcite. The rock as a whole is a relatively pure calcium carbonate with small amounts of MgO (up to 3 %), iron oxides and a negligible content of terrigenous material.

High porosity, chiefly of secondary origin, is one of the characteristic properties of the Karchowice limestones. Countless, small solution openings and spongework cavities give to the limestones a cavernous appearance. At present all these cavities are dry, and only during wet weather are some of them filled with percolating rain water.

The total maximum thickness of the Karchowice Beds is about 15 m. They are underlain by thin-bedded limestones and marls (the Terebratula Beds), which are practically impermeable to water.

PETROGRAPHICAL CHARACTERISTIC OF ALTERED LIMESTONES

An outstanding and unique feature of the Karchowice Beds is their display of recrystallized and disaggregated limestones. Megascopically such limestones exhibit a characteristic rusty coloration, succrose appearance and a highly increased porosity. Under the microscope they consist of a mosaic of anhedral and hypidiomorphic crystals with abundant solution voids at the crystal boundaries (Pl. XX, fig. 1—4). The grains are crystalographically randomly oriented, and are significantly larger than those of the unaltered rock. The latter, as seen in thin sections, is chiefly made up of micrite smaller than 0.005 mm in average size. Sporadically occurring sparry calcite varies in diameter entirely from 0.02 to 0.05 mm. In contrast, the altered or „sanded" limestone consists entirely of crystals varying in size from 0.02 to 0.5 mm.

The crystal mosaic of the altered limestones is entirely devoid of any traces of primary sedimentary structures. Only faint relics of earlier generations of calcite are still recognizable in some of the newly formed crystals, although in most of them the alteration is complete. The mosaic crystals may also contain small euhedral rhombs of calcite (Pl. XX, fig. 2).

The areas affected by recrystallization are not controlled by primary structures (pervasive recrystallization), and the crystals grew unselectively and simultanously from a great number of centers.

The development of secondary vug-porosity is an important modification imposed upon the mosaic calcite. The porosity, as seen in thin-sections, is present in the form of variously shaped vugs, which cover ca 20% of the area occupied by the calcite mosaic. The voids may occur both, within the crystals and between them (Pl. XX, fig. 3, 4). Small voids vary in size from 0.1 to 0.3 mm. There are also larger openings left after the dissolution of individual crystals or groups of crystals.

There is a notable concentration of iron oxides in the altered parts of the Karchowice limestones. The iron oxide coats the crystal surfaces, and may be so abundant locally, as to fill some of the vugs. It thus plays the role of both pigment and cement.

The sanded limestones contain clusters of drusy calcite crystals (Pl. XXI, fig. 1) which may be regarded as indicative of open-space crystallization. These nodular bodies, as well as the composing calcite crystals are large and some of them may measure several centimeters in diameter.

Apart from an increase in iron content, the chemical composition of the rock has been little affected by the alteration. The infra-red specturm of the altered limestones shows the presence of calcite (712 cm^{-1}) without any recognizable quantities of dolomite (Fig. 1).

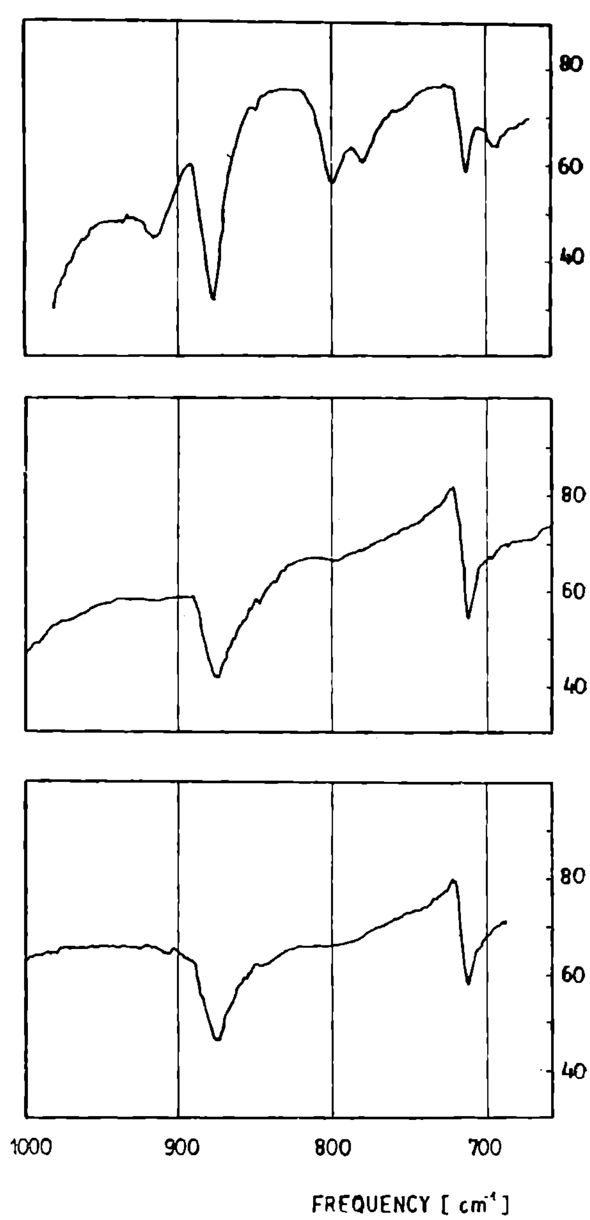

Fig. 1. Widma absorpcyjne w podczerwieni z przekrystalizowanych i rozsypliwych wapieni karchowickich z okolicy Kamienia Śląskiego

Fig. 1. Infrared spectrum of altered Karchowice limestones. Samples from Kamień Śląski

SPATIAL DISTRIBUTION AND THE SHAPE OF ALTERED LIMESTONES

Although certain parts of the Karchowice limestones are selectively altered in preference to others, the reason for this is not apparent from the lithological composition. Neither is the relation to joints conclusive in this respect. Sometimes the alteration affects the whole mass of the limestone,

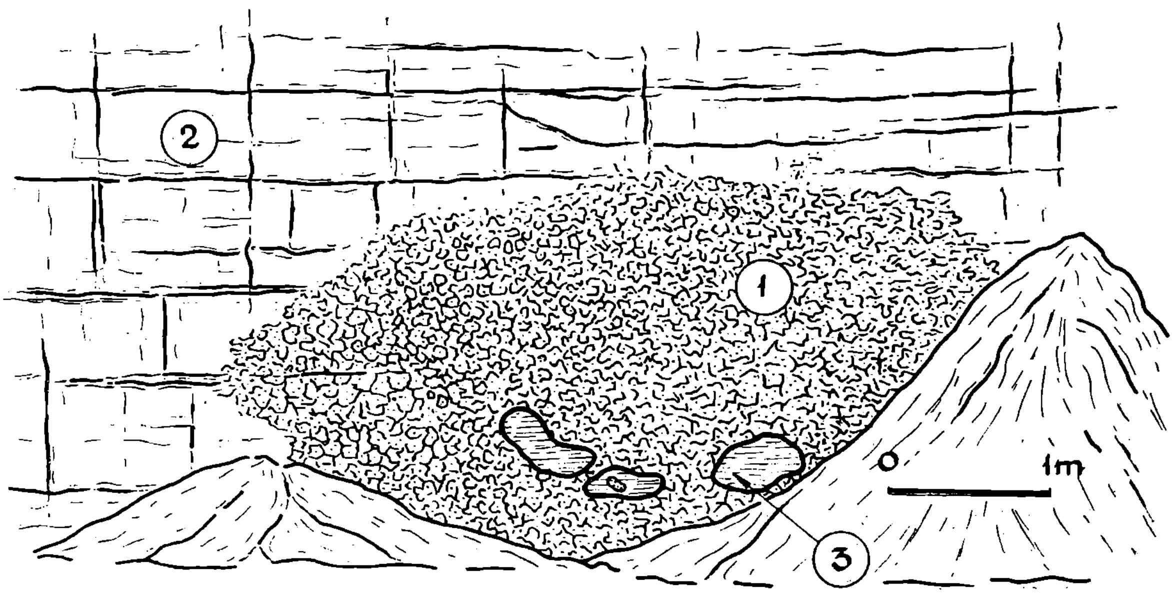

Fig. 2. Zmiany w wapieniach karchowickich. 1 — przekrystalizowane i rozsypliwe wapienie o strukturze reliktowej. Porównaj Tabl. XXI, fig. 1 i 2; 2 — wapienie nie zmienione; 3 — jamy krasowe wypełnione iłami. Kamień Śląski, kamieniołom we wsi

Fig. 2. Alterations in the Karchowice limestones. 1 — altered limestone with „sanded branchwork" structures. Compare with Pl. XXI, Fig. 1 and 2; 2 — unaltered limestone; 3 — clay filled karst cavities. Kamień Śląski

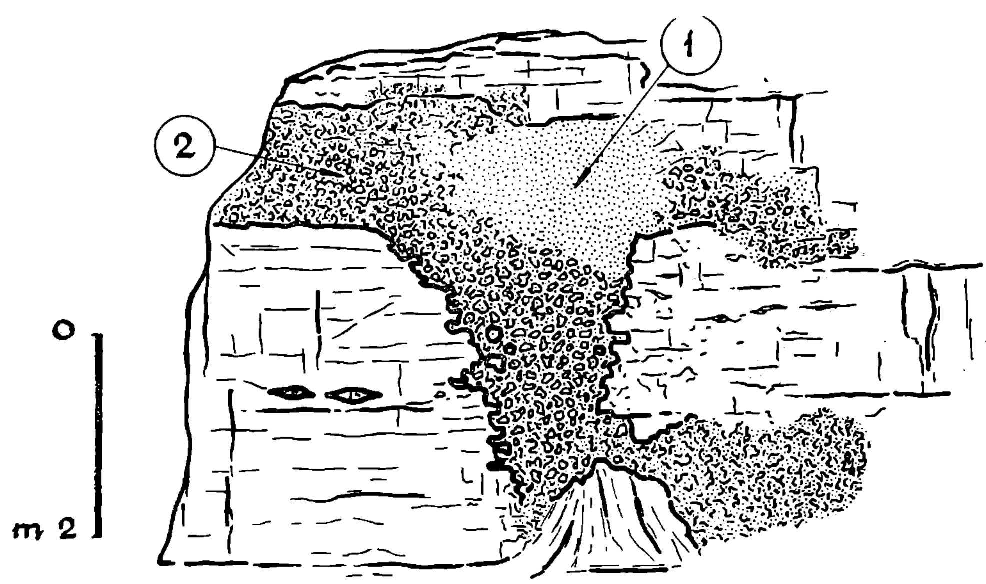

Fig. 3. Zmiany w wapieniach karchowickich. 1 — przekrystalizowany wapień zmieniony całkowicie w rozsypliwą masę kryształków kalcytu; 2 — wapień przekrystalizowany i rozsypliwy o strukturze reliktowej. Odsłonięcia na pd. od stacji kol. Kamień Śląski. Porównaj Tabl. XXIII, fig 1

Fig. 3. Alterations in the Karchowice limestones. 1 — sanded limestone; 2 — partly sanded limestone with sanded branchwork structure. Kamień Śląski. Compare with Pl. XXIII, Fig. 1

so that it is difficult to draw a separation line between the unaltered and altered rock. Often enough, however, such a line is recognizable, and the altered parts of the rocks take the form of more or less clearly delineated bodies. These bodies may have almost any shape. They may be rudely tabular, irregularly domed or chimney-like (Pl. XXIII, fig. 1, Fig. 3).

STRUCTURES RESULTING FROM PARTIAL ALTERATION

The degree of alteration expressed by volumetric proportion of altered to unaltered rock varies within the previously described bodies. It may be so small that much of the rock characteristics remain unaffected, or so profound that all relics of the primary limestone are obliterated. Between these two extremes there are all possible gradations.

The incipient alteration is marked by the appearance of isolated patches or spaces filled with porous calcite mosaic. These spaces are variously shaped and sized but volumetrically subordinate to the unaltered rock. In more advanced stages, the altered and unaltered limestones are present in more or less equal quantities. Under such conditions, the „sanded branchwork" is formed (Pl. XXII, fig. 1, 2). It resembles the pattern of spongework cavities in its complexity, close spacing and the irregular manner by which the altered parts of the rock are mutually interlocked. Where further developed, the altered limestone consists of disconnected relics of the unaltered rock floating in a mass of coarse calcite crystals. The relics exhibit surfaces etched by recrystallization, but retain most of their original petrologic characteristics. They are not surrounded by cockade structures and, as seen in thin sections, the contacts between the unaltered microcrystalline rock and the recrystallized mosaic calcite may be abrupt (Pl. XX, fig. 1).

It is of interest to note that individual relics may possess their own system of small open cracks. These cracks may be attributed to the stress redistribution consequent upon the solutional removal of calcium carbonate.

The ultimate development of disaggregation leads to total transformation of limestones into a weakly cemented mass of crystals. Not only does the original texture disappear but even relics and bedding surfaces are rendered obscure or altogether obliterated.

PROCESS OF ALTERATION

Field evidence shows that there is a close spatial coincidence between the recrystallized and sanded limestones. The „sanded" limestone is always the recrystallized one, and the recrystallization precedes the disaggregation. The latter is simply due to solutional widening of contacts between the crystals, faciliated by an increase in porosity which follows the recrystallization (see experimental investigations by O h l e 1955).

Near the ground surface, the solutional disaggregation is largely due to the action of meteoric soil waters (A s s m a n n 1944), aided by frost. The present incoherent character of the recrystallized Karchowice limestones is, thus, of recent age and, the altered rocks are often spoken of as weathered. The recent origin of disaggregation, however, does not debar the possibility that the vug-porosity might have been, at least partly, produced soon after recrystallization. It is known that slowly moving aqueous solution, which produces recrystallization, may in the course of time redissolve the recrystallized rock.

While the problem of solutional disaggregation is relatively simple, the origin of recrystallization, presents a difficult question. A troublesome barrier to its solution is the fact that, to date, the calcite-to--calcite conversion is „largely an unsolved enigma" (Chillingar et al. 1967, p. 217).

The recrystallization of the Karchowice limestones is undoubtedly epigenetic and later than all early diagenetic alterations. This is shown by the pervasive character of recrystallization and considerable size of the recrystallized bodies which may extend vertically through much of the whole stratigraphic unit.

Binocular microscopic examinations, of polished and etched surfaces, and the study of thin sections and acetate peels, disclose „tongues" or „fronts" of recrystallization extending along innumerable small diagenetic veinlets, stylolithic seams and minor secondary fractures which transect the limestone (Pl. XXI, fig. 1, 2). These primary and secondary discontinuities served as loci in themselves, and transmitted the process of recrystallization. Much of these discontinuities are very small on the scale of alterations and repeated at distances so small that they may be regarded as penetrative features in the meaning of Turner and Weiss (1963). This explains why the factors controlling the progress of recrystallization are not readily visible to the naked eye, and are not apparent from the shape of relics (Pl. XXII, fig. 1, 2).

Inadequate data make it impossible to determine with assurance the causes and time of recrystallization.

There are, however, certain indications which are relevant to this problem. These are:

1) the recrystallization in the Karchowice limestones is epigenetic

2) the recrystallization is chiefly localized in one lithostratigraphic unit, i.e. in the Karchowice Beds, while lithologically and petrographically similar beds, e.g. the Górażdże Beds are devoid of comparable alterations.

3) the occurrence of sanded limestones, in general, is a very rare phenomenon, hence their unusual abundance in the Karchowice Beds implies unusual causes and conditions, which are not commonly encountered.

Bearing these points in mind it is suggested that the recrystallization has been accomplished through the action of unusual ground and/or connate waters. This probably took place at the close of Triassic time, during the period of extensive dolomitization and ore-mineralization of the Triassic rocks situated further to the east (Cracov—Silesian ore—district). Although the available data neither substantiate nor disprove the above suggestion, these fit the above indicated points, and are consistent with the known facts concerning the zinc-lead mineralization in the Cracov—Silesian region. This mineralization was accompanied by a considerable horizontal transfer of hydrothermal solutions over some impermeable horizons (see Bogacz et al. 1970). It seems logical to assume that the introduction of such solutions may have initiated a widespread horizontal flow of ground and connate waters which caused the recrystallization. It may be appropriate at this point to indicate that, at the time of ore-emplacement and dolomitization, most of the faults which transect the Triassic rocks had not yet developed. Therefore the mobilized ground waters could easily migrate over considerable distances, taking advantage of porous limestones. The Karchowice Beds, being stratigraphically the highest permeable rocks within the

Triassic sequence of the region investigated, were most likely to invite the passage of ground waters working their way to the surface.

In attributing the recrystallization to the agency of ground waters at the close of Triassic time, it is realized that they differed in composition from the present-day ground waters. There is a good reason to suppose that these primary ground waters contained much of the connate brines entrapped during sedimentation. They also were enriched in Mg, as evidenced by the presence of primary dolostones. The ground waters having such a composition can convert limestones and primary dolomites into the epigenetic dolomites. This happens, in particular, when the waters are heated to an appropriate temperature (see L o v e r i n g 1969). In the present authors opinion, the late Triassic connate ground waters, heated by the introduction of hydrothermal solutions, were partly responsible for the formation of the so called „ore-bearing dolomite" in the Triassic of the Cracov-Silesian region. The origin of this dolomite is still a moot question; however, its epigentic character is evident (for references and discussion see Ś l i w i ń s k i 1969). Distally from the sources of the hydrothermal solutions, the mobilized connate waters caused extensive recrystallization of limestones. The recrystallized sanded Karchowice limestones, as seen from this point of view, are features characteristic of the outer limits of the ore-bearing dolomite. Their appearance reflects the alterations produced at low temperatures and higher Ca/Mg molar ratios. It also testifies to the epigenetic origin of dolomitization. It may be worth noting that very similar transformations, although on a much smaller scale, are known to occur as wall-rock alterations in limestones adjacent to ore-bodies (H a g n i and S a a d a l l a h 1965).

DEVELOPMENT OF CAVITIES IN DISAGGREGATED LIMESTONES

The altered parts of the Karchowice limestones offered an easier access to percolating water and became more affected by erosion than the unaltered rocks. This had an important bearing on the development of some karst feature in the Karchowice Beds.

It can be demonstrated that a part of the spongework cavities, which riddle the Karchowice limestones, evolved from the sanded branchwork previously described (P. XXII, fig. 1, 2). This is shown by the existence of all possible transitional stages between the sanded branchwork and spongework cavities. Moreover the walls of the spongework cavities coincide closely with the former boundaries between the sanded and unaltered parts of the rock (Pl. XXIII, fig. 2, Fig. 4). This pattern of coincidence is so consistent that it can scarcely be fortuitous. Therefore, the sanded branchwork may be regarded as an embryonic stage of some spongework cavities. No inference, however, of general applicability is here made, since even in the Karchowice limestones there are spongework cavities which do not show any apparent relation to the process of disaggregation.

With progressing enlargement of spongework cavities the supporting framework may be dissolved or collapse, resulting in larger openings (Fig. 5). The bottoms of such openings are littered with fragments of the disrupted framework and relics originally suspended in a mass of calcite crystals. The relics and fragments exhibit solutionally rounded edges, and their accumulation represents a specific type of cave filling which does not fit well into any accepted category of cave deposits. This accumulation can-not be equoted with the collapse breccia formed by mass failure nor with that resulting from progressive spalling and slabbing of rock fragments. It constitutes a specific residual product, although it is not that which most speleologists would have in mind when speaking about residual deposits.

Worth noting are openings formed along the upper boundaries of large sanded bodies (Fig. 5). A tentative explanation of the origin of such cavities is that they were initiated by the settling of sanded masses due to the solutional removal of calcium carbonate.

The cavities so far discussed are somewhat unusual, in that the mechanical removal of calcite crystals played an important role in their excavation. A considerable part of these crystals were then deposited within the cavities themselves and incorporated into the filling.

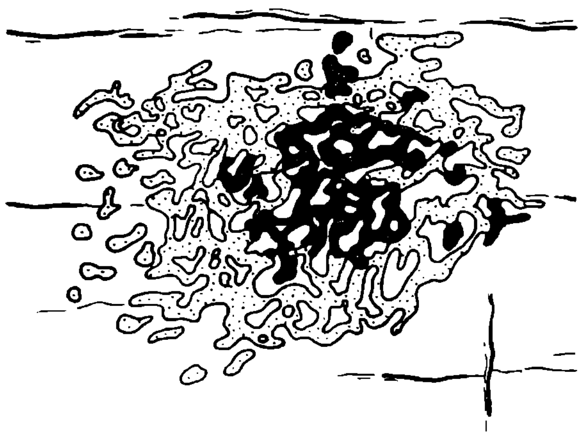

Fig. 4. Labiryntowe kanaliki krasowe rozwinięte w rozsypliwym wapieniu o strukturze reliktowej. Porównaj Tabl. XXIII, fig. 2

Fig. 4. Spongework cavities evolved from sanded branchwork. Compare Pl. XXIII, Fig. 2

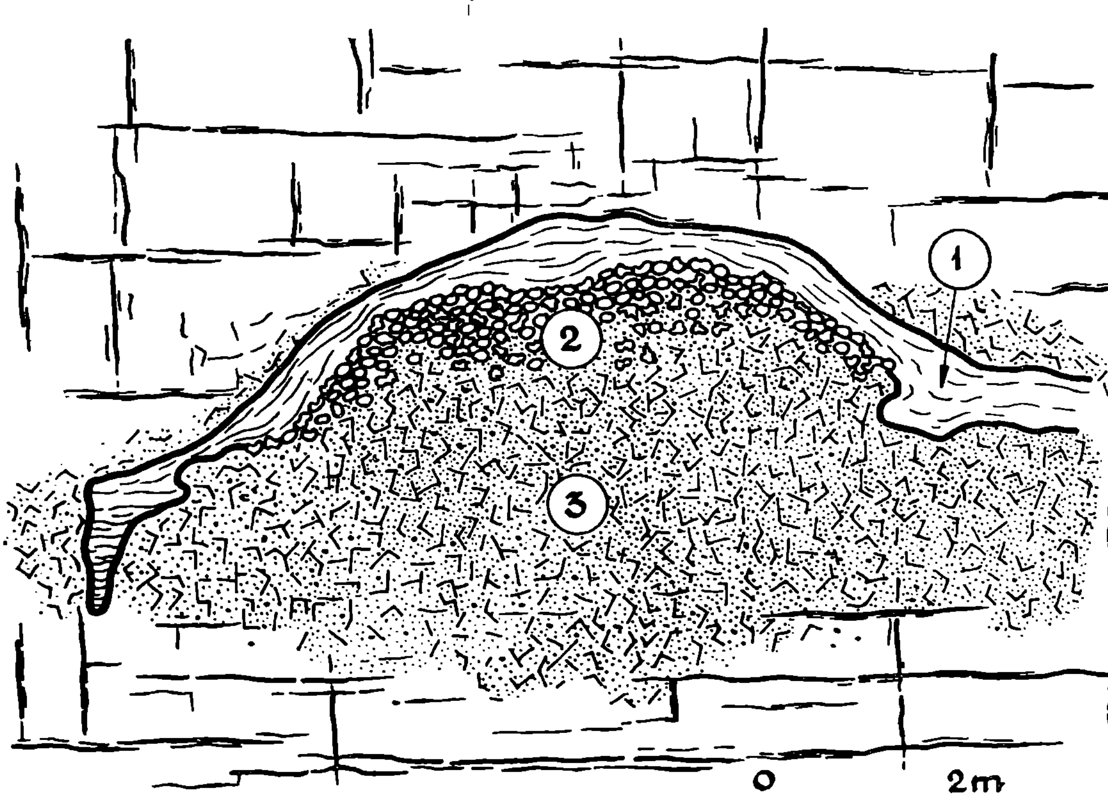

Fig. 5. Jama krasowa rozwinięta w stropie zmienionych wapieni. 1 — czwartorzędowe wypełnienie ilaste; 2 — nagromadzenie reliktów nie zmienionego wapienia; 3 — przekrystalizowany i rozsypliwy wapień z reliktami. Kamień Śląski, odsłonięcia na pd. od st. kolejowej

Fig. 5. Clay filled opening formed along the upper margin of a sanded body. 1 — clay fill (Pleistocene); 2 — accumulation of relics; 3 — sanded limestone with relics. Kamień Śląski

CONCLUSIONS

The foregoing remarks on karst features, although not of immediate consequence for the main subject of this article, were given to indicate some of the many implications which arise from the study of disaggregated and recrystallized limestones. The problem of sanded limestones leads also to the question of some ore-structures. The recrystallized limestones may serve not only as conduits inviting deeper penetrations of aqueous solutions but as superb host rock and receptacles for various ores. In this regard, the sanded branchwork and related structures are of interest for the light they may throw on some „breccia-like" ore-structures. The recrystallization of limestones, if envisaged as forerunning the front of dolomitization, may faciliate and clear the way for metasomatic replacement of calcium carbonate by dolomite. These as well as many other questions which arise in connection with sanded limestones constitute a promising field of inquiry for future investigations.

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STRESZCZENIE

Wapienie karchowickie podlegają przemianom, w których następstwie pierwotnie lity i spoisty wapień przeistacza się w rozsypliwą skałę o żółtawo-rdzawym zabarwieniu. Skała ta różni się zasadniczo od macierzystego wapienia. Składa się ona z mozaiki kryształków kalcytu o zarysach ksenomorficznych. Kryształki te swoimi rozmiarami (0,02—0,5 mm) wielokrotnie przewyższają ziarna, z których zbudowany jest nie zmieniony wapień karchowicki (por. Tabl. XX, fig. 1). Znamienną właściwością tej mozaiki jest wtórna szczelinowa porowatość. Powstała ona w wyniku rozpuszczania kalcytu, i to zarówno w obrębie powiększonych kryształów, jak również wzdłuż ich krawędzi (Tab. XX, fig. 3).

Przemiany, jakim podlegał wapień karchowicki, a które doprowadziły do jego obecnej rozsypliwości są zatem wynikiem: 1 — rekrystalizacji, 2 — osłabienia spoistości między nowo powstałymi kryształami w wyniku rozpuszczania przez krążące wody.

Wiek rekrystalizacji, która poprzedziła utworzenie się porowatości szczelinowej oraz rozpad wapienia jest trudny do ustalenia. Przypuszczalnie nastąpiła ona u schyłku triasu, równocześnie z dolomityzacją i okruszcowaniem skał triasowych w obszarze śląsko-krakowskim. Powodem rekrystalizacji mogła być migracja wód gruntowych, w których skład wchodziły głównie wody przychwycone w czasie sedymentacji.

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OBJAŚNIENIA TABLIC
EXPLANATION OF PLATES

Tablica — Plate XX

Fig. 1. Granica między wapieniem nie zmienionym (M) i zrekrystalizowanym (R). Nikole skrzyżowane
Fig. 1. Boundary between the unaltered (M) and recrystallized (R) limestone. Crossed nicols
Fig. 2. Wapień przekrystalizowany z silnie zrośniętymi ksenomorficznymi ziarnami kalcytu. Nikole równoległe
Fig. 2. Recrystallized limestone with interlocked texture. One nicol
Fig. 3. Pory rozwinięte na granicach i w obrębie kryształów kalcytu. Nikole skrzyżowane
Fig. 3. Typically developed vug-porosity within and between crystals. Crossed nicols
Fig. 4. Typowa struktura zmienionego wapienia karchowickiego. Nikole równoległe
Fig. 4. Typical texture of altered Karchowice limestone. One nicol

Tablica — Plate XXI

Fig. 1. Struktury rekrystalizacyjne odwzorowane na błonie acetonowej (negatyw), U — wapień nie zmieniony; R — wapień zrekrystalizowany; d — druzy kalcytowe; i — szczelinka wypełniona tlenkami żelaza. Część powierzchni zgładu przedstawionego na fig. 1, Tabl. XXII
Fig. 1. Partial recrystallization and disaggregation as seen in acetate peel (negative). U — unaltered limestone; R — recrystallized limestone; d — drusy calcite; i — crevices filled with iron oxides. Fragment of the surface shown in Fig. 1, Pl. XXII
Fig. 2. Struktury rekrystalizacyjne odwzorcowane na błonie acetonowanej, (negatyw). Oznaczenia jak na fig. 1. Widoczna ostra granica obszaru zrekrystalizowanego wzdłuż szczelinki kalcytowej — c
Fig. 2. Partial recrystallization as seen in acetate peel. Denominations as in Fig. 1. Note sharp boundary of recrystallized area along calcite vein — c

Tablica — Plate XXII

Fig. 1. Wygładzona powierzchnia wapienia o strukturze reliktowej. U — nie zmieniony wapień; R — wapień przekrystalizowany; d — druzy kalcytowe. Obszar objęty linią odwzorcowany jest na błonie acetonowanej na fig. 1, Tabl. XXI
Fig. 1. Polished surface of altered limestone. U — relics of unaltered rock; R — recrystallized and disaggregated limestone; d — drusy calcite. Area marked by lines is shown on acetate peel negative in Fig. 1, Pl. XXI
Fig. 2. Wygładzona powierzchnia wapienia o strukturze reliktowej. Oznaczenia jak na fig. 1
Fig. 2. Polished surface of altered limestone with typically developed branchwork. Denominations as in Fig. 1

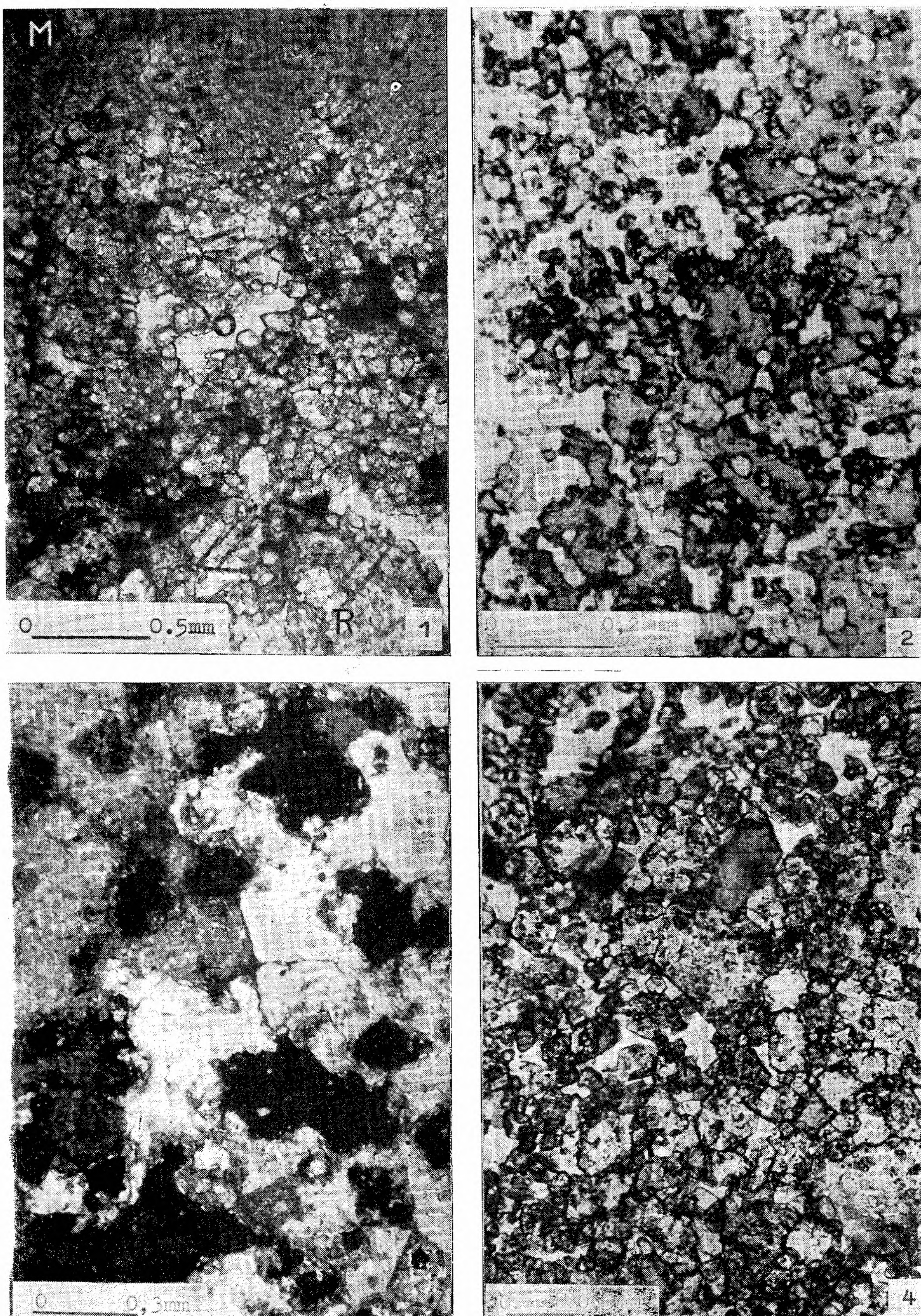
Tablica — Plate XXIII

Fig. 1. Zmiany w wapieniach karchowickich. 1 — całkowicie przekrystalizowany i rozsypliwy wapień; 2 — wapień częściowo przekrystalizowany z reliktami; 3 — wapień nie zmieniony

Fig. 1. Alterations in the Karchowice limestones. 1 — entirely recrystallized and sanded limestone; 2 — partly recrystallized limestone with relics; 3 — unaltered limestone. Exposure shown in Fig. 3. Kamień Śląski.

Fig. 2. Labiryntowe kanaliki krasowe rozwinięte w przekrystalizowanych wapieniach o strukturze reliktowej. Kamień Śląski

Fig. 2. Spingework cavities developed within the sanded branchwork. Karchowice limestones. Kamień Śląski.



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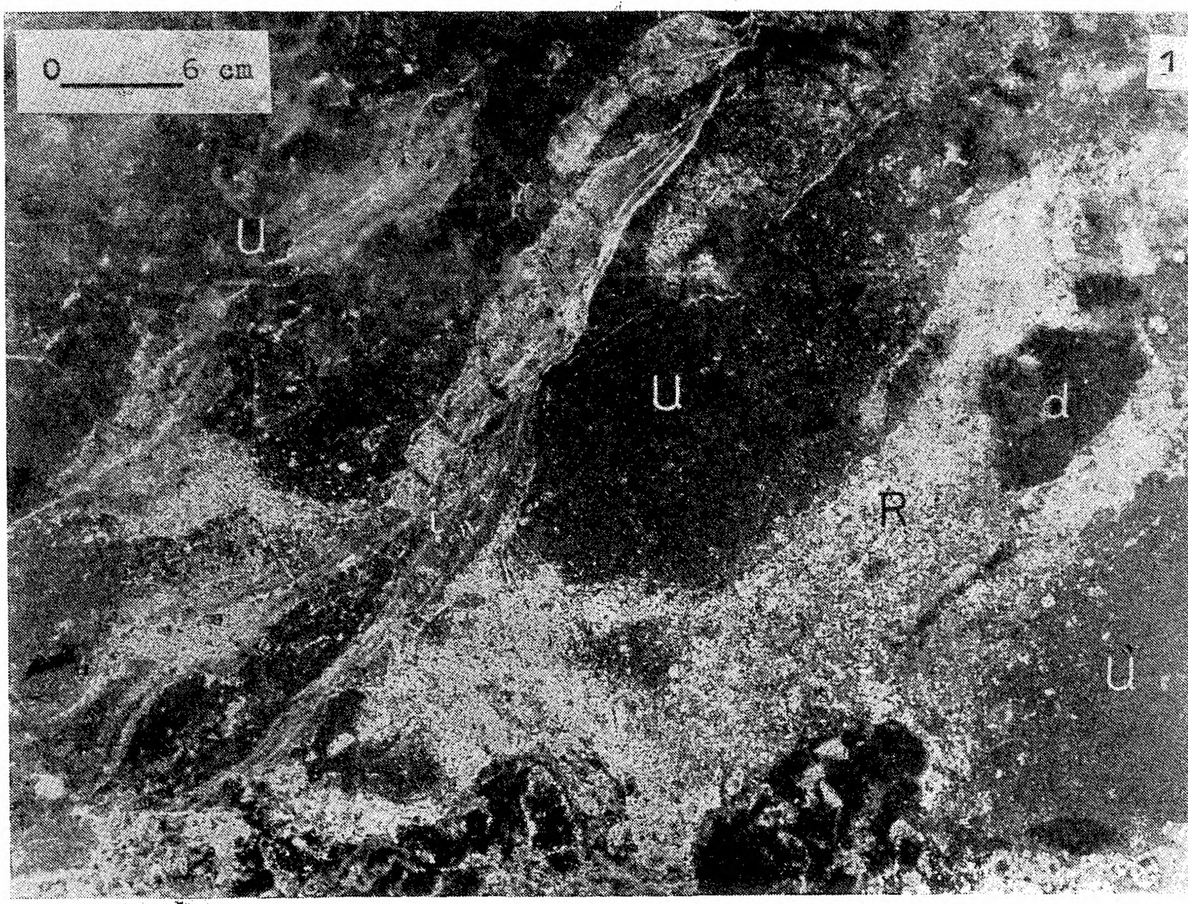

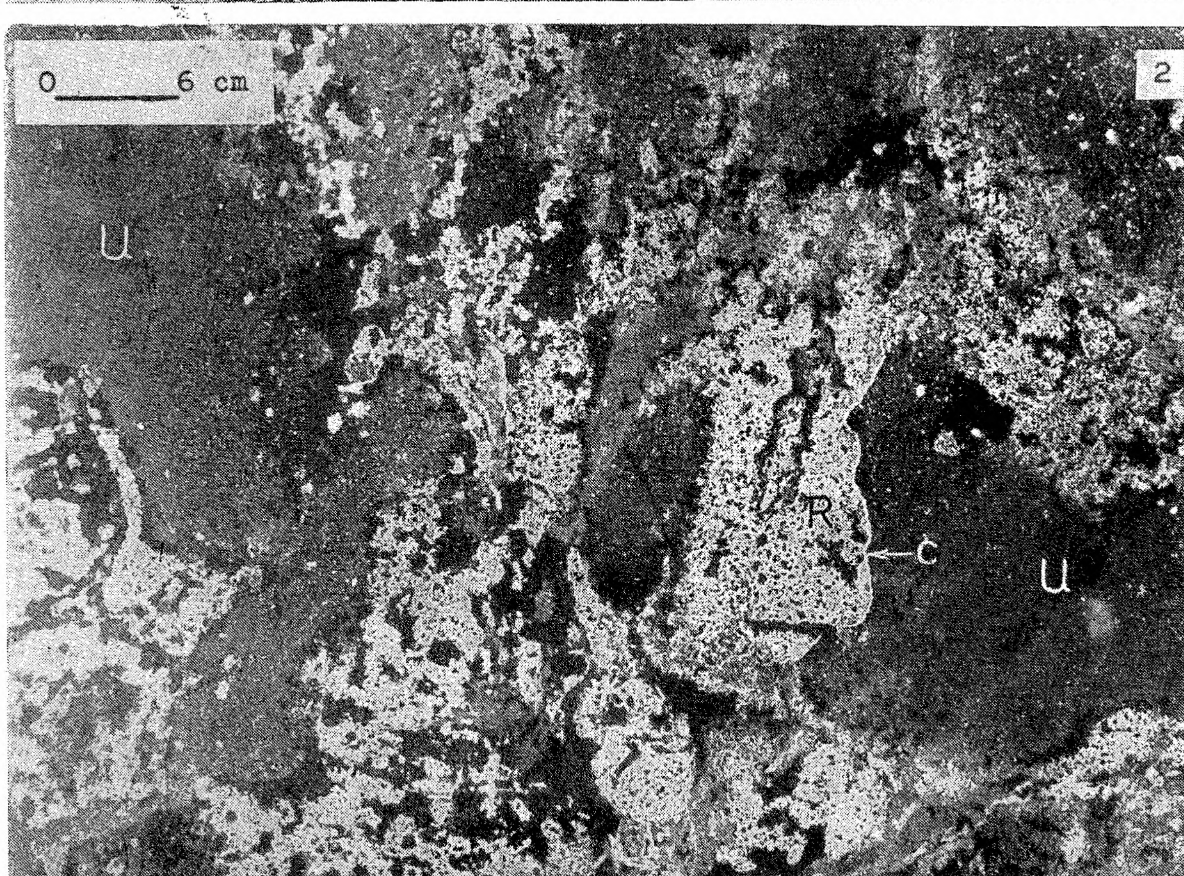

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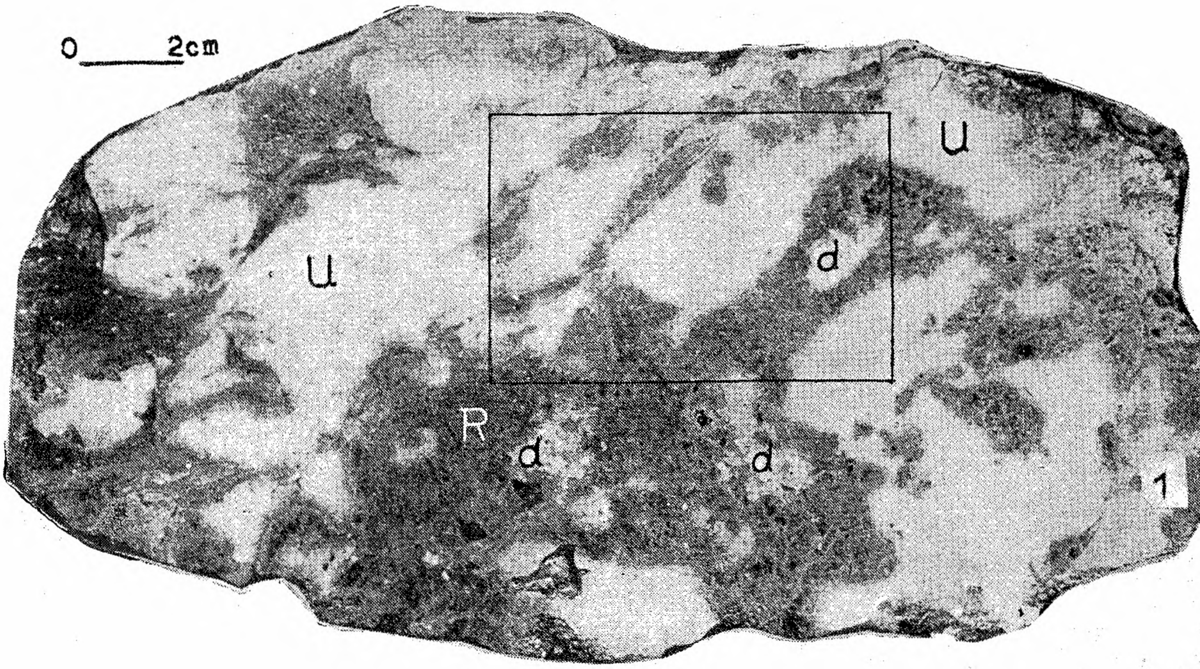
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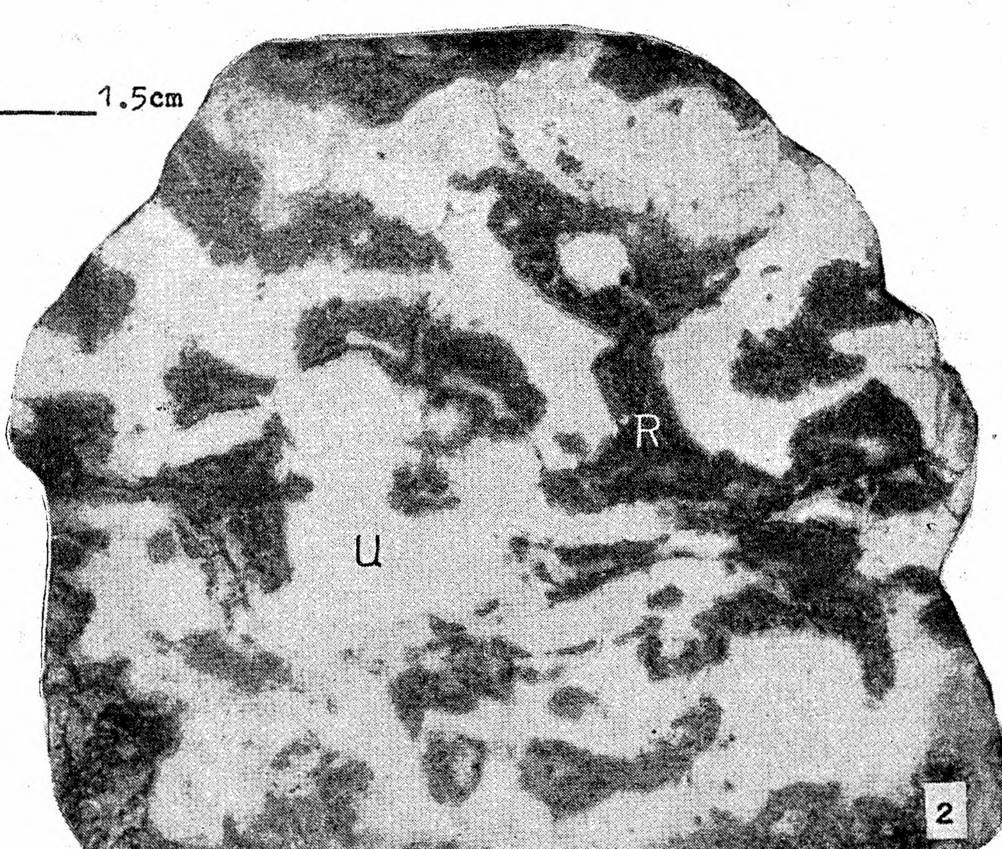
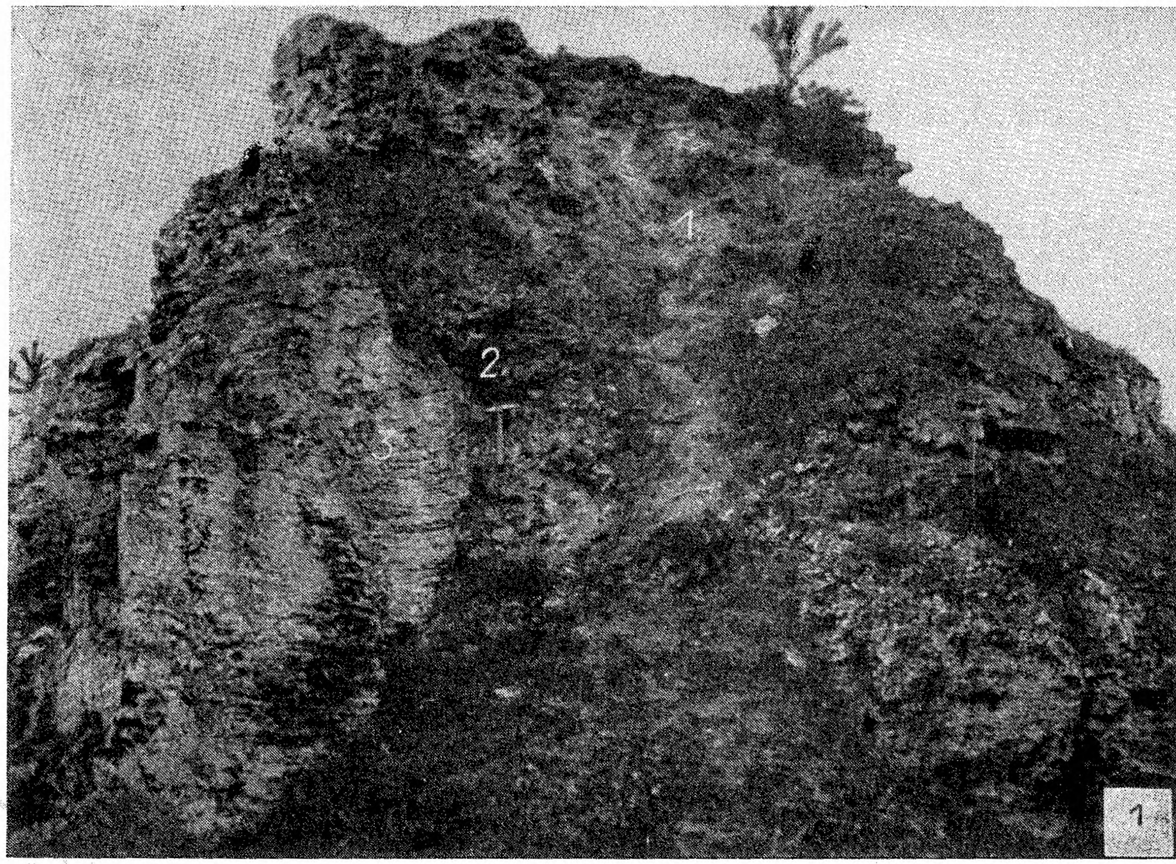
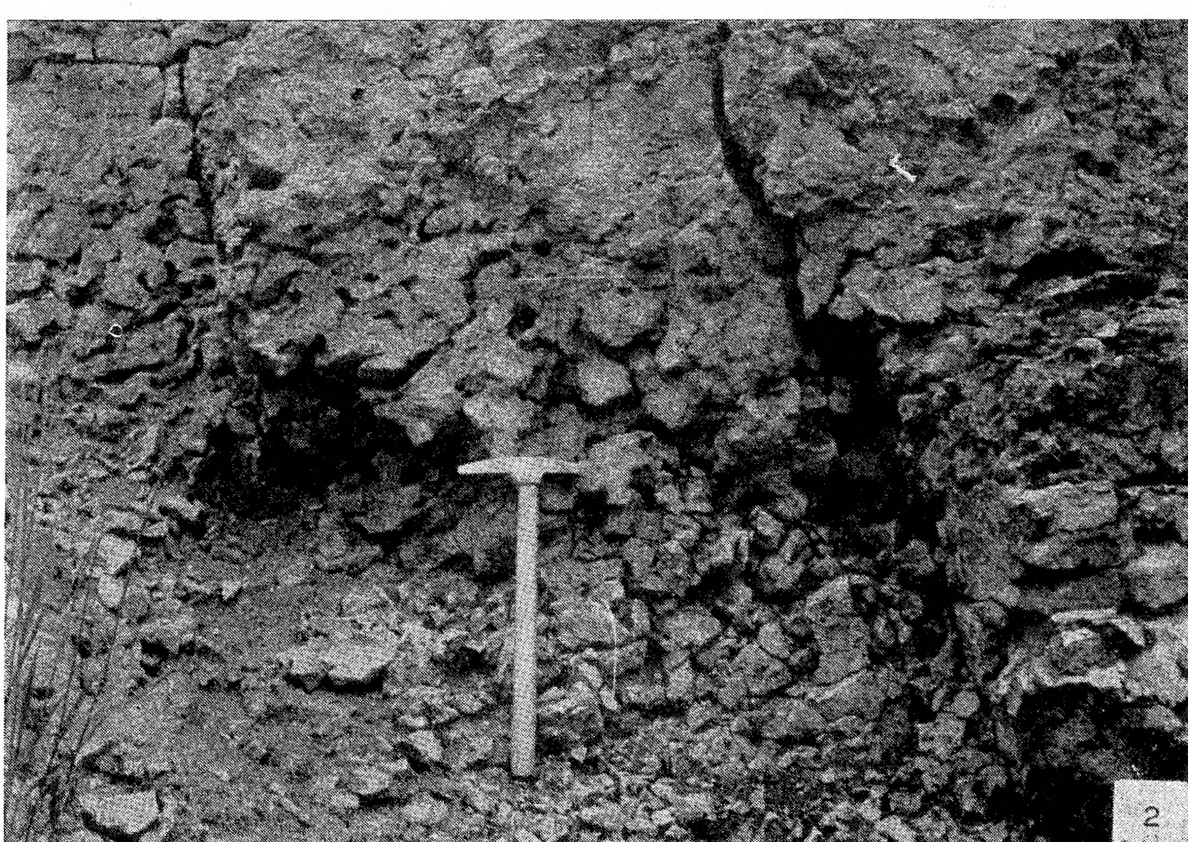
d
U
R
d
d
1


0 1.5cm
R
U
2





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