ROCZNIK POLSKIEGO TOWARZYSTWA GEOLOGICZNEGO
ANNALES DE LA SOCIÉTÉ GÉOLOGIQUE DE POLOGNE

Tom (Volume) XLIII — 1973 Zeszyt (Fascicule) 2 Kraków 1973

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SOME REMARKS CONCERNING SYNTAXIAL OVERGROWTH ON ECHINODERM FRAGMENTS IN MIDDLE TRIASSIC LIMESTONES

(Pl. XIX—XXII and 1 Fig.)

Uwagi na temat wzrostu kalcytu w ciągłości optycznej z fragmentami szkarłupni

(Tabl. XIX—XXII i 1 fig.)

Abstract. The author gives some new data concerning the problem of syntaxial overgrowth on echinoderm fragments. These data are as follows:

1) Growth of rim cement around echinoderm plate covered with micrite envelope;
2) Growth of rim cement in intergranular pore spaces and within pelecypod mould infilled with cement crystals;
3) Development of syntaxial rim or rim cement resulting in mammillary appearence;

Moreover, growth of neomorphic spar in optical contiunity with echinoderm plate and its rim cement is confirmed. Furthermore, pseudopleochroism of echinoderm plates is briefly described.

The paper deals with some interesting features concerning the growth of calcite in lattice continuity with echinoderm fragments. Echinoderms (mainly crinoids, ophiuroids, echinoid spines etc.) are important rock-forming components of limestones belonging to the Wolica Beds, Wellenkalk Beds and Łukowa Beds of the Lower Muschelkalk (H. Senkowiczowa, 1957) of the Holy Cross Mts. They occur abundantly in biosparites and biomicrosparites; in microsparites (terminology after Folk, 1959) appearing as rarely scattered elements.

The growth of substance in optical continuity around a nucleus of the same material was known for many years (Sorby, 1879 in Folk, 1965). Pettijohn (1949) has called such a growth "secondary enlargement". Bathurst (1958 in Orme and Brown, 1963) used the term "rim cement" for calcite cement growing in lattice continuity with a single calcite host of, e.g. echinoderm plate, and "syntaxial rim" for calcite of neomorphic origin (Folk, 1965). Orme and Brown (1963) modified these terms as "syntaxial cement rim" and "syntaxial replacement rim", respectively.

The purpose of this paper is to give some additional data, concerning the problem. These data are as follows:

1. Growth of rim cement around echinoderm plate covered with micrite envelope (see B a t h u r s t, 1964, 1966);
2. Growth of neomorphic spar in optical continuity with rim cement;
3. Growth of rim cement in intergranular pore spaces and within pelecypod mould infilled with cement crystals;
4. Development of syntaxial rim or rim cement resulting in mammillary appearence;
5. Moreover, pseudopleochroism of echinoderm skeletons is described.

The earlier described and interpreted features concerning growth of calcite in lattice continuity with echinoderms (L u c i a, 1962, E v a m y and S h e a r m a n, 1965) and with prismatic structure of some pelecypods, ostracods (see B a t h u r s t, 1971) and nodosariids are confirmed.

GROWTH OF RIM CEMENT AROUND ECHINODERM PLATES COVERED WITH MICRITE ENVELOPE

(Pl. XIX, Figs. 1a, b, Pl. XX, Figs. 1a, b, 2a, b)

Echinoderm fragments are one of the main rock-forming components of biosparites. They are rounded and coated frequently with a micrite envelope. The echinoderm plates are accompanied by rounded foraminifers and peloids, some broken and rounded molluscan shell fragments and casts. All these grains are well sorted (their diameters are from about 0,5 to 1,0 mm), cemented with calcite showing drusy appearence. The rock is cross-bedded.

If echinoderm fragments are free of micrite, rim cement infilling neighboring intergranular pores is developed. If micrite envelope is thick and continuous — the rim cement is lacking and the grain surface is covered with drusy calcite. However, if micrite envelope is thick but discontinuous, the rim cement may be developed around the echinoderm fragment also in these places where micrite envelope is present (Pl. XIX, Figs. 1a, b, Pl. XX, Figs. 1a, b, 2a, b). According to Lucia (1962) and Evamy and Shearman (1965) the growth of rim cement or syntaxial rim is prevented where the surface of echinoderm is coated with micrite envelope or where the superficial pores in skeleton are filled with micrite. In the light of studies presented here, there arises a question: is the development of rim cement really inhibited by micrite? If so, how to explain its occurence?

It seems that the explanation of this phenomenon may be dual: a) In three dimensions the rim cement grew from the echinoderm surface free of micrite, at the same time drusy cement developed on the other part of the same skeleton coated with micrite envelope. Theoretically it is possible that in the plane of thin section we can see the intersection line between micrite and rim cement developed close to one another (Fig.-text 1). But such sections appear to be exceptional. In every thin

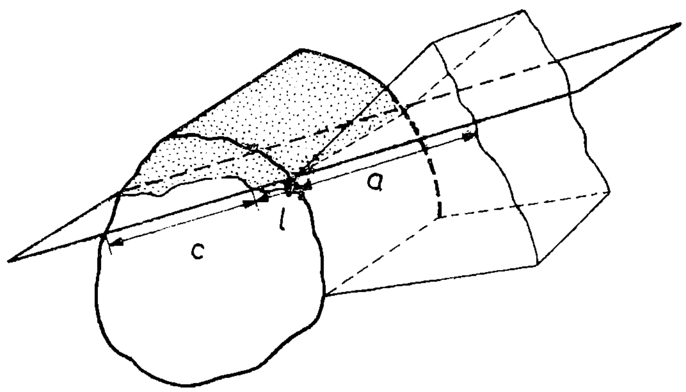

Fig. 1. View of echinoderm fragment in three dimensions. This fragment (c) has discontinuous micrite envelope (1) and calcite crystal as rim cement (a). In the plane of thin section there are visible: rim cement (a), micrite envelope (1) and echinoderm plate (c)

Fig. 1. Widok przestrzenny fragmentu szkarłupnia (c) otoczonego nieciągłą powłoką mikrytową (1) z narastającym cementem kalcytowym (a) w ciągłości optycznej z fragmentem. W płaszczyźnie płytki cienkiej widać kolejno: cement kalcytowy (a), powłokę mikrytową (1) i fragment szkarłupnia (c)

section examined there were up to 10 echinoderm fragments coated with micrite and with rim cement. It would be rather surprising that so numerous particles were cut in such a peculiar plane, b) It seems to be more probable that rim cement has grown from the surface free of micrite and then it behave like calcite crystal of echinoderm plate. The further growth of the rim was independent of skeletal particle and quicker than that of drusy cement (P r a y, 1969 in B a t h u r s t, 1971); in consequence the rim cement could occupy still free volume of porosity (Pl. XIX, Figs. 1a, b, Pl. XX, Figs 1a, b, 2a, b).

GROWTH OF NEOMORPHIC SPAR IN OPTICAL CONTINUITY WITH RIM CEMENT

(Pl. XIX, Figs. 2a, b)

Some examples of this phenomenon were found in biosparites described above. Nearby the echinoderm plates there are, in places, peloids showing evident neomorphism. Their inner parts are occupied by large poikilotopic spar with relics of microspar embedded within it (Pl. XIX, Figs. 2a, b). The spar is in lattice continuity with the echinoderm plate or with its rim cement, then overgrowth on cement crystals must be assumed. This is in agreement with statement made by B a t h u r s t (1959) and others (see B a t h u r s t, 1971).

GROWTH OF RIM CEMENT IN THE INTERGRANULAR PORE SPACES AND WITHIN THE PELECYPOD MOULD INFILLED WITH CEMENT CRYSTALS

(Pl. XIX, Figs. 1a, b, Pl. XX, Figs. 1a, b)

In biosparites some examples of the pelecypod moulds filled with cement being in optical continuity with rim cement of echinoderm grains were observed. Such a cast is normally coated with discontinuous micrite envelope. It must be presumed that dissolution — precipitation has taken place as there is no shell-wall fabric. Moreover, two generations of calcite cement are observed here, first of them being scalenohedral in habit (Pl. XIX, Figs. 1a, b, Pl. XX, Figs. 1a, b). One calcite crystal of the second generation is now in optical continuity with rim cement of echinoderm fragment (Pl. XIX, Fig. 1b, Pl. XX, Fig. 1b). It has been stated that c — axis of the second generation calcite crystal and that of echinoderm have the same orientation. It seems that rim cement of echinoderm grain reached far from nucleus and began to occupy still empty portion of a pelecypod cast, the remaining open space being filled with cement of the second generation. Of course, such a coincidence may be fortuitous but there are too much examples to regard them as casual. Probably, the time interval between the first and the second generation of calcite cement has been rather short as no characteristics of compaction are visible.

DEVELOPMENT OF SYNTAXIAL RIM OR RIM CEMENT RESULTING IN MAMMILLARY APPEARENCE

(Pl. XXI, Figs. 1a, b, 2a, b)

The next observations concern the echinoderm fragments in microsparites, biomicrosparites and laminated limestones. In these rocks the echinoderm plates have syntaxial rim (?) developed in peculiar way: close to the skeleton or in short distance from it there are forms circular in plane. These forms are filled with calcite in optical continuity with the echinoderm grain (Pl. XXI, Figs. 1b, 2b), so that, presumably, in three dimensions the surface of the echinoderm looks as it were covered with mammillae.

Similar circular, rarely ovoid forms are also numerous in some microsparites and biomicrosparites, independently of echinoderm skeletons. Their diameters are from about 30 to 80 microns. Some of them are filled with single calcite crystals, some are empty thus creating pore spaces, and some are partly filled with fine, clear calcite (Pl. XXI, Figs. 1a, b). Their origin is enigmatic and further examinations must be continued to solve the problem. It seems, that if echinoderm skeleton was nearby these forms then, within them, calcite in optical continuity with echinoderm developed, whether as cement or neomorphic spar.

In laminated limestones echinoderm fragments show the same phenomenon. The limestone is built of alternating light and dark laminae. The light ones consist of microspar (?) with diameters between 10 and 20 microns. The fauna is poor: some echinoderm plates and ostracod valves accompanied by peloids are rarely scattered throughout the matrix. The intriguing feature of these laminae are numerous pore spaces circular or ovoid in plane, disposed in highly regular pattern (Pl. XXII, Figs. 3a, b). If the quantity of voids decrease then peloids appear to be more frequent (Pl. XXII, Figs. 1, 2). The shape and size of peloids and those of pores are nearly the same, ranging about 25 to 80 microns, also the disposition pattern of peloids closely resemble that of pores. Some voids are filled with single calcite crystals.

It seems that fabric selective solution has taken place here, resulting in micromolding porosity after peloids (Choquette and Pray, 1970). Later on, some micro-openings were filled with calcite cement (?). Those which are close to the echinoderm skeletons reveal calcite crystals in optical continuity with the skeleton. Unfortunately, in the rock under consideration much difficulties arise when distinction between microspar and cement is attempted. The author has no possibilities to make her observations under the electron microscope.

PSEUDOPLEOCHROISM OF ECHINODERM SKELETONS

(Pl. XXII, Figs. 4a, b)

In thin sections the majority of echinoderms show brown-coloured calcite. Under plane polarized light calcite appears pleochroic in shades of brown. The pleochroism is confined mainly to calcite building the skeletons, but in some weathered rocks the rim cement may also be brown and pleochroic. It has been stated that the intensity of pleochroism depends on quantity of tiny dark-brown inclusions involved (the more inclusions the darker colour and stronger pleochroism), and on the optical orientation of echinoderm calcite. Maximum colour in all cases coincides with an extinction position of calcite and with maximum refractive index. In e direction brown colour is weakly visible (Pl. XXII, Fig. 4b), in o direction it is dark brown (Pl. XXII, Fig. 4a). Simultaneously, in c — axis direction of echinoderm plate rim cement or syntaxial rim is the best developed (Evamy and Shearman, 1965, 1969).

Cases of pseudopleochroism in neomorphic calcite of some molluscan shells have been described by P. R. Brown (1961 in Bathurst, 1971) and Hudson (1962). The latter author has found that the colour and pleochroism are related probably to inclusions of conchiolin.

In the opinion of the present writer brown inclusions responsible for pseudopleochroism of echinoderm calcite are iron oxides as this phenomenon is observed in rim cement too, chiefly in weathered rocks. In limestone where pyrite crystals have been observed, echinoderm fragments are slightly coloured and their syntaxial rim or rim cement is clear. On the other hand, however, it has been found that only rim cement infilling intergranular pore spaces in biosparites may be brown coloured, whereas neomorphic spar in lattice continuity with it is always colourless, independently whether the rock is weathered or not. It is surprising that cement crystals within pelecypod casts being epitaxial with echinoderm plates also do not show pleochroism. This problem is not clear and examinations will be continued.

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STRESZCZENIE

Z dotychczasowych badań wynika, że powłoka mikrytowa otaczająca fragmenty szkarłupni uniemożliwia narastanie cementu kalcytowego w optycznej ciągłości z tymi fragmentami (Lucia, 1962, Evamy and Shearman, 1965). Autorka stwierdziła, że w przypadku, gdy powłoka ta jest nieciągła, cement kalcytowy optycznie zgodny z fragmentem szkieletu rozwija się również w miejscach pokrytych mikrytem (Pl. XIX, fig. 1b, Pl. XX, fig. 1b, 2b). Zjawisko to można tłumaczyć dwojako:

1) jako pozorne, wywołane szczególnym przecięciem przez płytkę cienką kontaktu między cementem narastającym na wolnej od mikrytu powierzchni a tą częścią szkarłupnia na której znajduje się powłoka mikrytowa (fig. 1); przypadek ten zdaje się jednak być bardzo rzadki;

2) cement narasta na powierzchniach pozbawionych mikrytu, a następnie rozwija się dalej, już niezależnie od fragmentu szkarłupnia.

Potwierdzone zostały obserwacje niektórych badaczy (patrz Bathurst, 1971), że neomorficzny kalcyt (neomorphic spar) może narastać w ciągłości optycznej z cementem kalcytowym otaczającym elementy szkieletowe szkarłupni lub z samymi elementami (Pl. XIX, fig. 2a, b,).

Stwierdzono, że cement kalcytowy pozostający w ciągłości optycznej z elementem szkieletowym szkarłupnia może również częściowo wypełniać próżnie powstałe po rozpuszczeniu skorupki małża, otulonej nieciągłą powłoką mikrytową (Pl. XIX, fig. 1a, b, Pl. XX, fig. 1a, b). Proces ten przebiegał w kilku etapach:

1) rozpuszczenie skorupki i powstanie na jej miejscu próżni;
2) wzrost od ścianek próżni do wewnątrz skalenoedrycznego kalcytu pierwszej generacji;
3) wypełnienie pozostałej wolnej przestrzeni przez cement kalcytowy drugiej generacji. Niektóre kryształy cementu drugiej generacji narastały w ciągłości optycznej z znajdującym się w pobliżu elementem szkieletowym szkarłupnia (Pl. XIX, fig. 1a, b, Pl. XX, fig. 1a, b).

W niektórych biomikrosparytach i mikrosparytach występują kuliste lub owalne formy (średnica od około 30 do 80 mikronów) wypełnione pojedynczymi kryształami kalcytu. W przypadku gdy formy te znajdują się w pobliżu fragmentu szkarłupnia lub do niego przylegają, wypełniający je kalcyt posiada orientację optyczną zgodną z kalcytem budującym dany fragment. Formy te narastając na powierzchniach elementów szkieletowych szkarłupni nadają im brodawkowy wygląd (Pl. XXI, fig. 1a, b, 2a, b).

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Szczątki szkarłupni wykazują bardzo często wyraźny pseudopleochroizm od blado brunatnego do brunatnego. Najbardziej intensywna barwa brunatna jest zgodna z kierunkiem promienia zwyczajnego (Pl. XXII, fig. 4a); blado brunatne zabarwienie jest zgodne z promieniem nadzwyczajnym (Pl. XXII, fig. 4b). Autorka przypuszcza, że przyczyną pseudopleochroizmu są bardzo drobne wrostki, będące prawdopodobnie tlenkami żelaza.

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EXPLANATIONS OF PLATES
OBJAŚNIENIA TABLIC

Plate — Tablica XIX

Fig. 1a. Dark and pleochroic echinoderm fragment with thick and discontinuous micrite envelope. To the right side molluscan mould infilled with calcite of two generations. Biosparite, 1 nicol

Fig. 1a. Fragment szkarłupnia otoczony grubą, lecz nieciągłą powłoką mikrytową. Na prawo próżnia po skorupie małża wypełniona kalcytem dwu generacji. Biosparyt. 1 nikol

Fig. 1b. The same as in Fig. 1a. Rim cement is visible. Within the molluscan cast, calcite crystal of the second generation is in optical continuity with the echinoderm plate. Crossed nicols

Fig. 1b. Jak na fig. 1a. Widoczny cement w optycznej ciągłości z fragmentem szkarłupnia. W obrębie odlewu skorupy małża jeden z kryształów kalcytu drugiej generacji jest w ciągłości optycznej z fragmentem szkarłupnia. Nikole skrzyżowane

Fig. 2a. Echinoderm fragment with patches of micrite and with micrite envelope. Peloid (white) built of neomorphic spar (left center). Biosparite, 1 nicol

Fig. 2a. Fragment szkarłupnia ze skupieniami mikrytu i cienką powłoką mikrytową. Na lewo peloid (biały) zbudowany z neomorficznego kalcytu. Biosparyt, 1 nikol.

Fig. 2b. The same as in Fig. 2a. Neomorphic spar within the peloid is in optical continuity with the echinoderm plate. Crossed nicols

Fig. 2b. Jak na fig. 2a. Neomorficzny kalcyt wewnątrz peloida jest w ciągłości optycznej z fragmentem szkarłupnia. Nikole skrzyżowane

Plate — Tablica XX

Fig. 1a. Echinoderm plate (dark) and fragment of the molluscan cast above. Biosparite, 1 nicol

Fig. 1a. Fragment szkarłupnia (ciemno zabarwiony), powyżej odlew skorupki małża. Biosparyt, 1 nikol

Fig. 1b. The same as in Fig. 1a. Around the echinoderm plate rim cement. Within the molluscan cast calcite crystal of the second generation is in lattice continuity with rim cement. Crossed nicols

Fig. 1b. Jak na fig. 1a. Wokół fragmentu szkarłupnia cement zgodny z nim optycznie. W obrębie odlewu skorupy małża jeden z kryształów drugiej generacji w ciągłości optycznej z ziarnem szkarłupnia. Nikole skrzyżowane

Fig. 2a. Echinoderm plate with thin and discontinuous micrite envelope. The envelope covered with tiny drusy cement. Biosparite, 1 nicol

Fig. 2a. Fragment szkarłupnia z cienką i nieciągłą powłoką mikrytową, pokrytą druzowym cementem kalcytowym. Biosparyt, 1 nikol

Fig. 2b. The same as in Fig. 2a. Drusy cement and rim cement around the echinoderm plate are visible. Crossed nicols

Fig. 2b. Jak na fig. 2a. Widoczny cement druzowy, intergranularne pory wypełnione cementem kalcytowym w ciągłości optycznej z fragmentem szkarłupnia. Nikole skrzyżowane

Plate — Tablica XXI

Fig. 1a. Microsparite with numerous circular forms (white), and the echinoderm plate in the center. 1 nicol

Fig. 1a. Mikrosparyt z licznymi kulistymi formami (białe). W środku fragment szkarłupnia. 1 nikol

Fig. 1b. The same as in Fig. 1a. Some of the circular forms are empty (black), some are filled with calcite. Around the echinoderm plate "mammillae" built of calcite being epitaxial with the plate. Crossed nicols

Fig. 1b. Jak na fig. 1a. Niektóre z kulistych form są porami (czarne), inne wypełnione kalcytem. Dokoła fragmentu szkarłupnia formy „brodawkowe" wypełnione kalcytem w ciągłości optycznej z tym fragmentem. Nikole skrzyżowane

Fig. 2a. Echinoderm plate with „mammillae" in matrix of microspar (?). Circular and ovoid forms (white) are pore spaces. Laminated limestone, 1 nicol

Fig. 2a. Fragment szkarłupnia z formami „brodawkowymi" w mikrosparytowym tle skalnym. Kuliste i owalne formy (białe) są głównie próżniami. Wapień laminowany, 1 nikol

Fig. 2b. The same as in Fig. 2a. Calcite of „mammillae" is in lattice continuity with the echinoderm plate. Pore spaces are black. Crossed nicols

Fig. 2b. Jak na fig. 2a. Kalcyt wypełniający formy „brodawkowe" jest w ciągłości optycznej z fragmentem szkarłupnia. Próżnie zabarwione na czarno. Nikole skrzyżowane

Plate — Tablica XXII

Fig. 1. Numerous fine peloids (dark gray) in microspar (?). Laminated limestone, 1 nicol

Fig. 1. Liczne drobne peloidy (ciemnoszare) w mikrosparytowym (?) tle skalnym. Wapień laminowany, 1 nikol

Fig. 2. Fine peloids (dark grey) and pore spaces (white). Some pore spaces are visible as to develope at the expance of peloids. Laminated limestone, 1 nicol

Fig. 2. Drobne peloidy (ciemnoszare) i próżnie (białe). W kilku przypadkach widoczne tworzenie się próżni kosztem peloidów. Wapień laminowany. 1 nikol

Fig. 3a. Some peloids (dark grey) and abundant pore spaces (white). Laminated limestone. 1 nicol

Fig. 3a. Kilka peloidów (ciemnoszare) i dość liczne próżnie (białe). Wapień laminowany, 1 nikol

Fig. 3b. The same as in Fig. 3a. Pore spaces are black. Crossed nicols

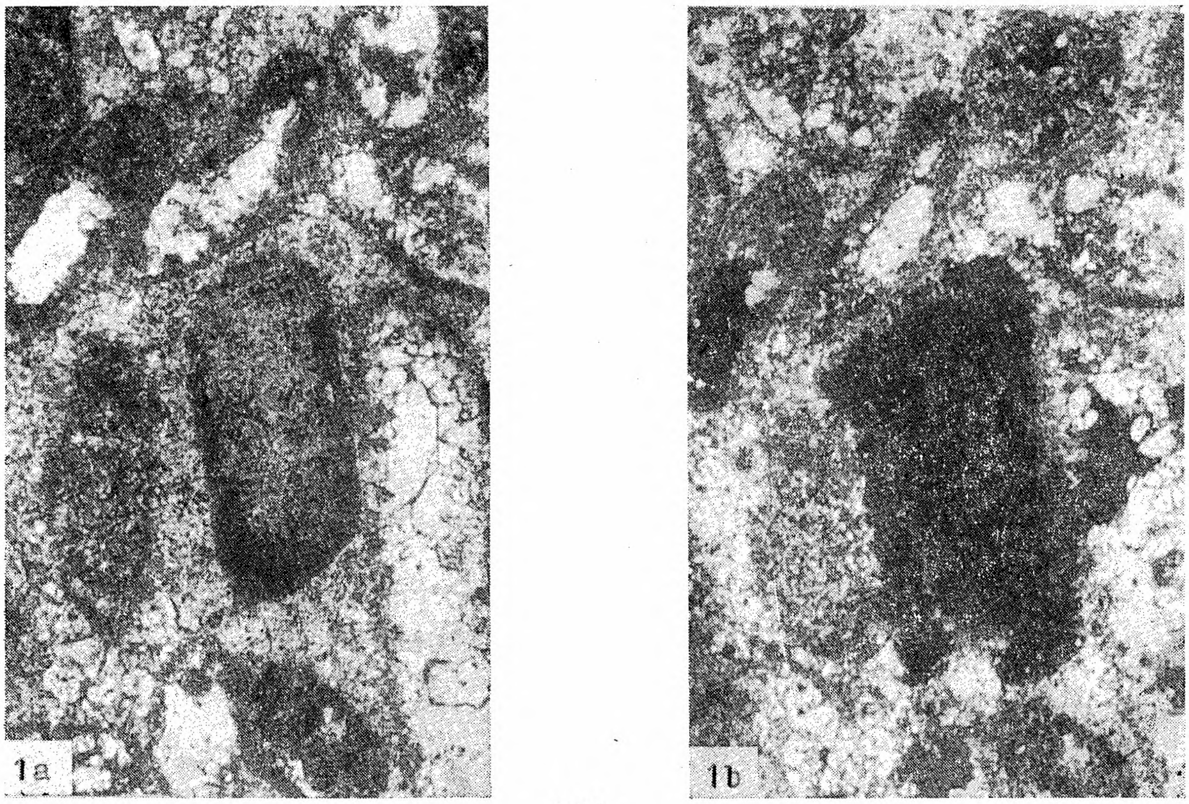
Fig. 3b. Jak na fig. 3a. Próżnie są czarne, peloidy ciemnoszare. Nikole skrzyżowane

Fig. 4a. Dark coloured pseudopleochroic crinoid plate in *o* direction. Biomicrosparite, 1 nicol

Fig. 4a. Pseudopleochroism fragmentu krynoida. Brunatne zabarwienie zgodne z kierunkiem promienia zwyczajnego. Biomikrosparyt, 1 nikol

Fig. 4b. The same (as in Fig. 4a) light coloured plate in *e* direction. 1 nicol

Fig. 4b. Ten sam fragment szkarłupnia jak na fig. 4a. Blado brunatnawe zabarwienie zgodne z kierunkiem promienia nadzwyczajnego. 1 nikol



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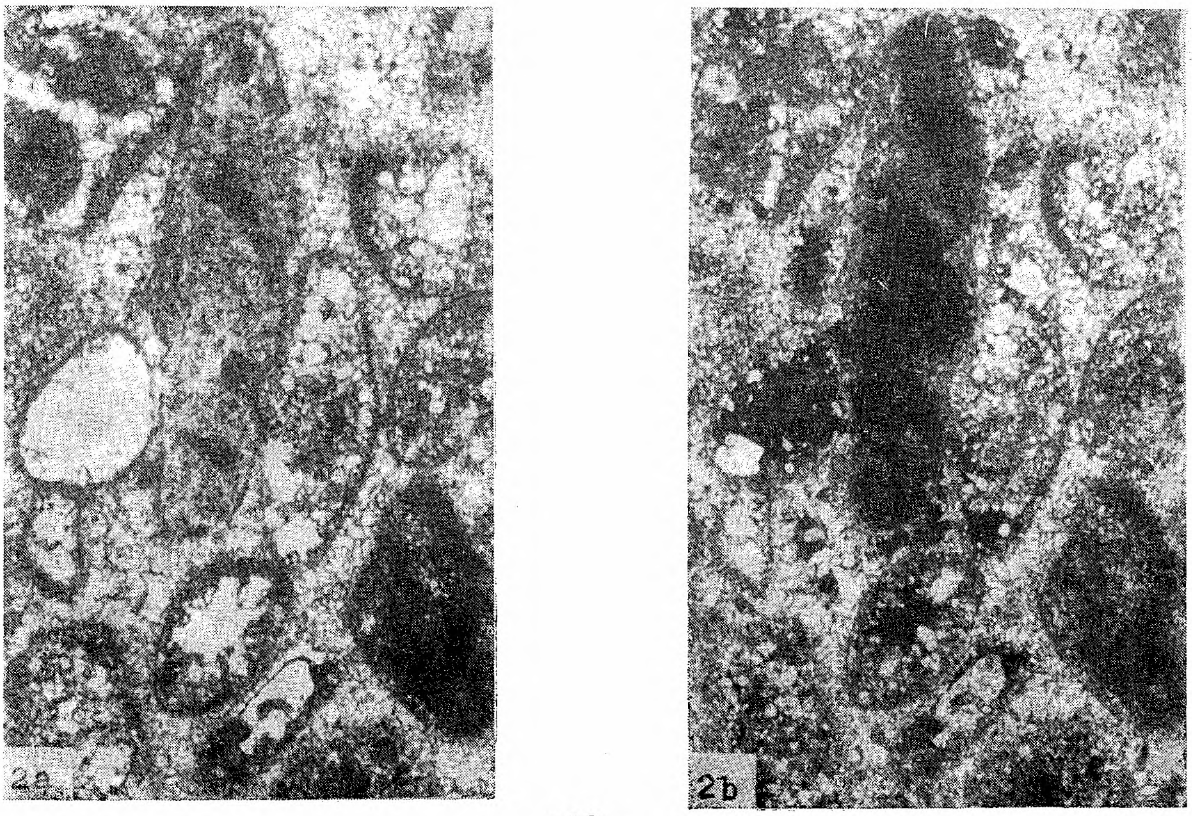

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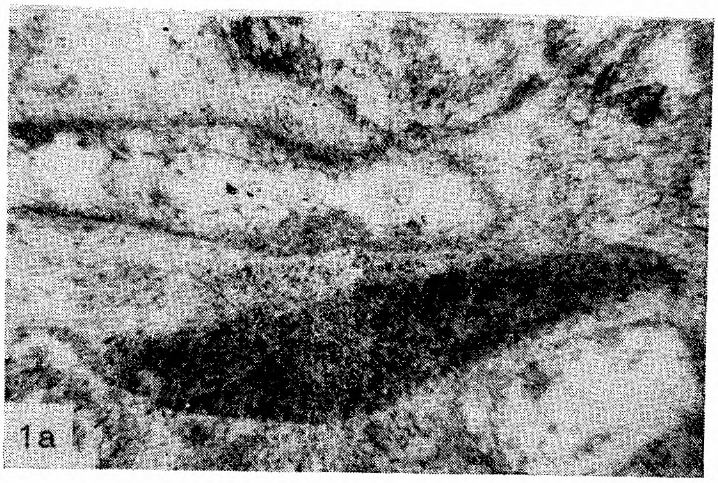

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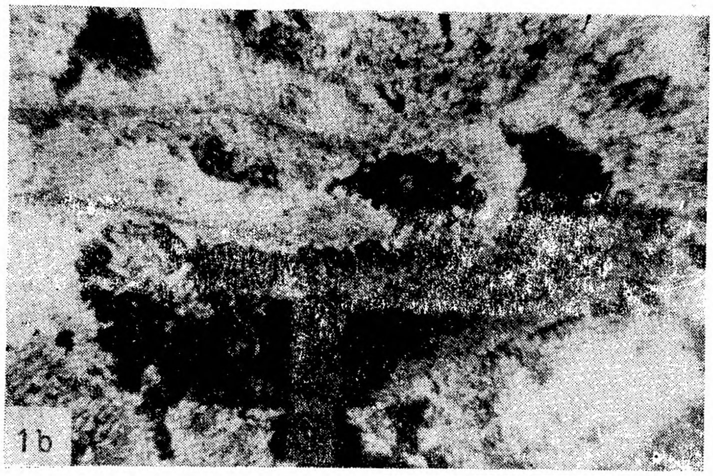

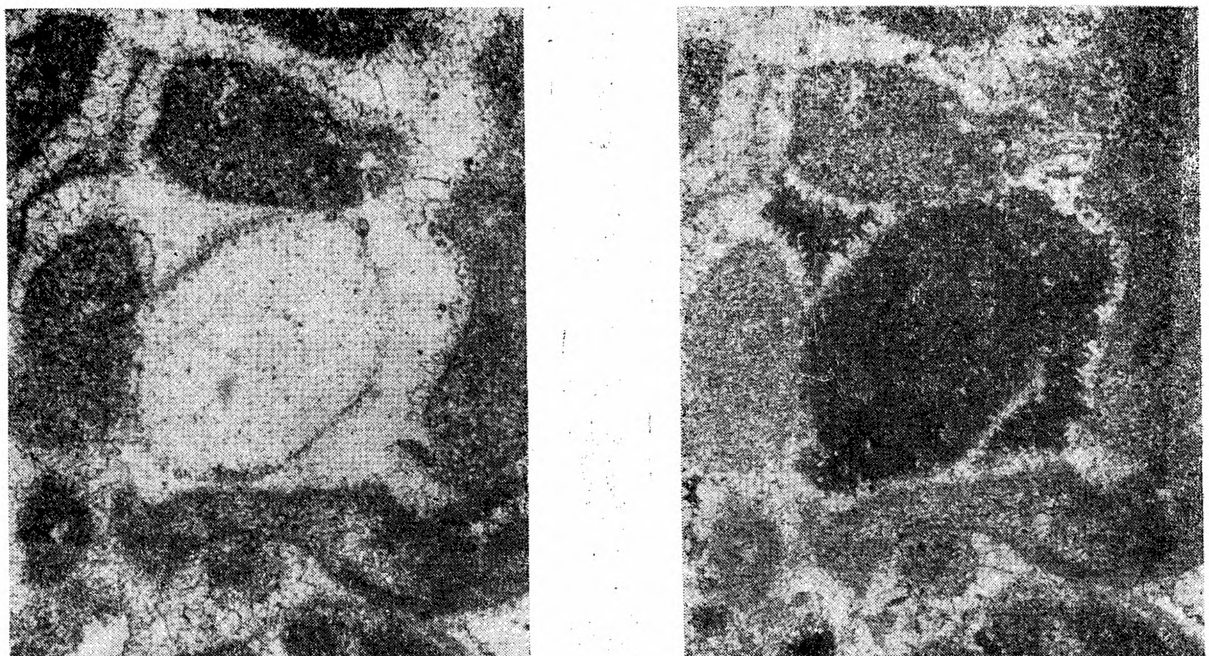

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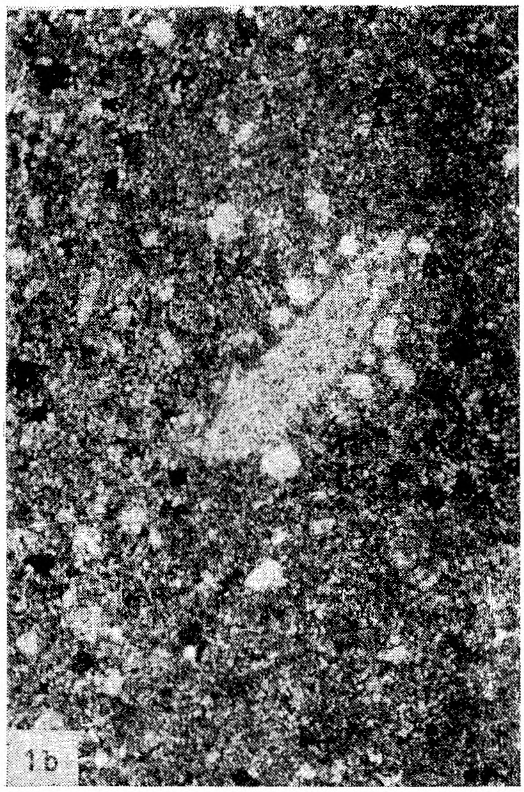

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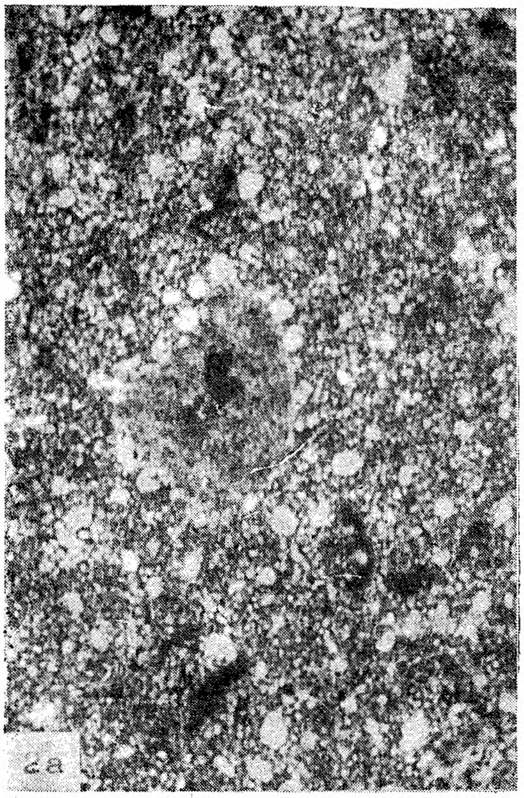

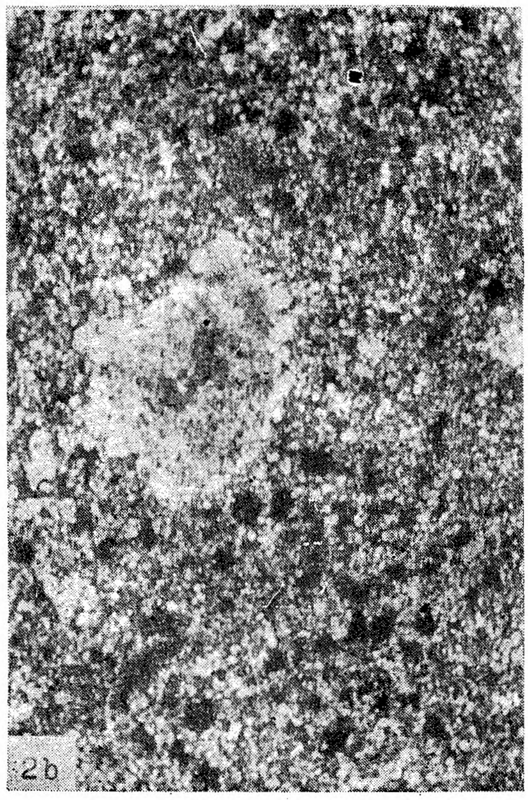

250μ

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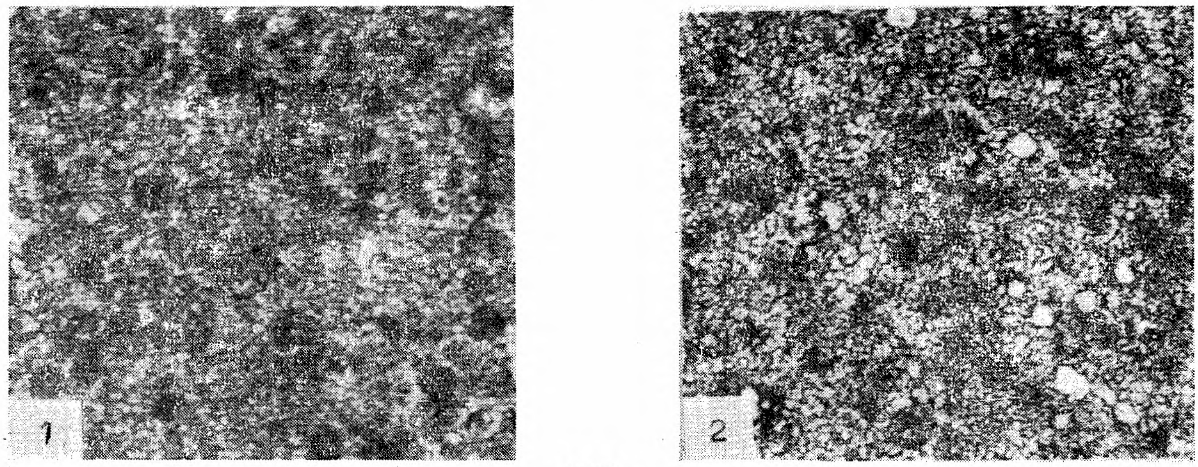
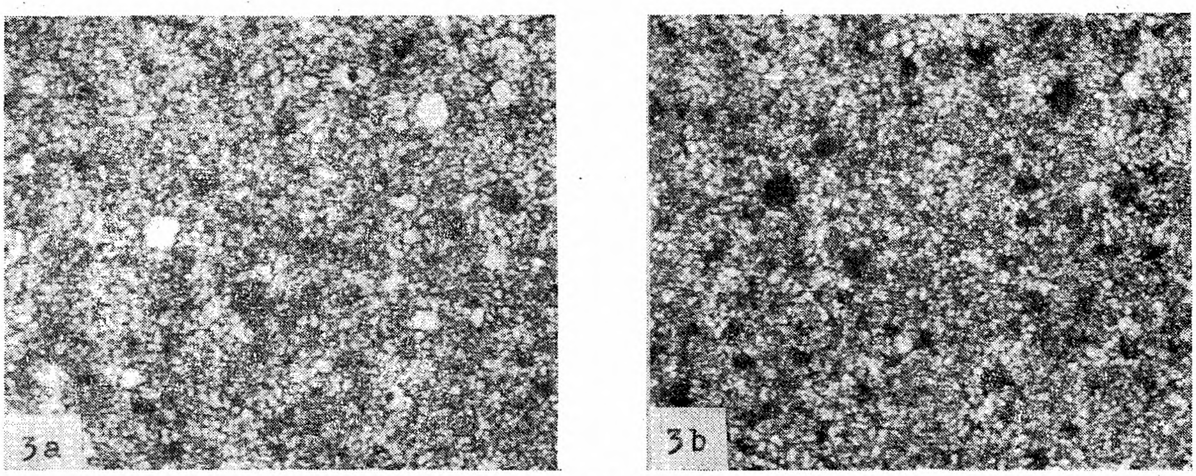
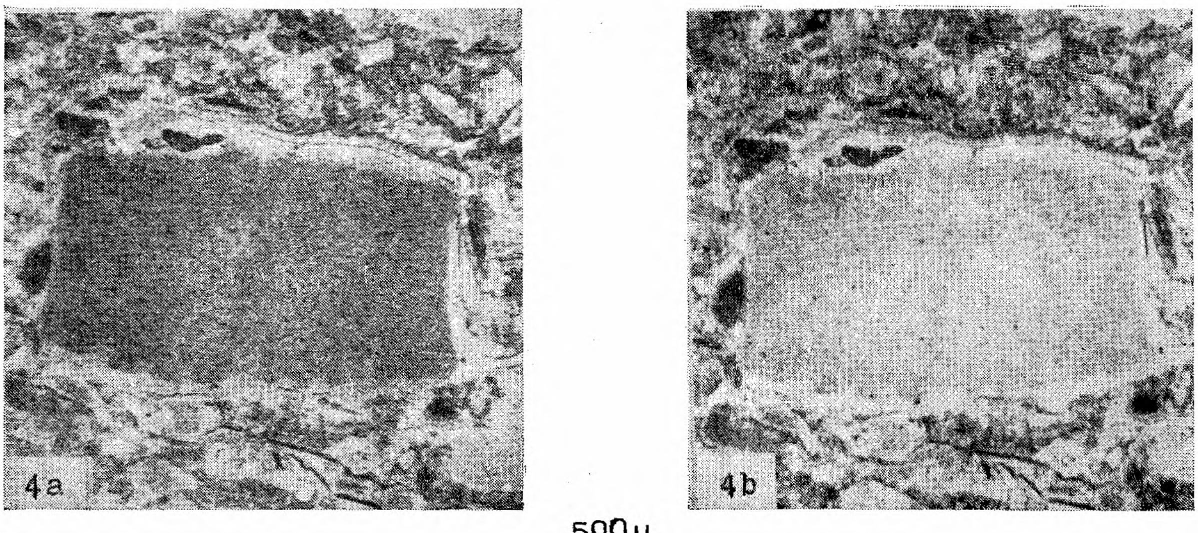


250μ



250μ



500μ

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