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ULTRASTRUCTURES OF UPPER JURASSIC MICRITES OF OUTER ZONE OF THE CARPATHIAN FOREDEEP

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УЛЬТРАСТРУКТУРИ ВЕРХНЬОЮРСЬКИХ КРИПТОКРИСТАЛІЧНИХ ВАПНЯКІВ ЗОВНІШНЬОЇ ЗОНИ ПЕРЕДКАРПАТСЬКОГО ПРОГИНУ

On the basis of the electron microscope investigation of Upper Jurassic micrites the morphological types of their cleavage surfaces were revealed and ultrastructures of rock-forming matter were identified. Obtained data allowed stating about biochemogenic genesis of investigated rocks.
Keywords: Upper Jurassic, Outer zone of the Carpathian Foredeep, micrite, cleavage surface, ultrastructure.

На основі електронномікроскопічного вивчення верхньоюрських криптокристалічних вапняків виявлено морфологічні типи поверхонь їх сколу та ідентифіковано ультраструктури породоутворюючої речовини. Одержані дані дали підстави стверджувати про біогемогенний генезис досліджених порід.
Ключові слова: верхня юра, Зовнішня зона Передкарпатського прогину, криптокристалічний вапняк, поверхня сколу, ультраструктура.

INTRODUCTION

Among lithological types of Upper Jurassic carbonate rocks of Outer zone of the Carpathian Foredeep (fig. 1) mikrites (cryptocrystalline limestones) are widespread in all three stages.

In genetic classifications of different authors rocks of this type are mainly reffered to clastic-chemogenic or chemogenic formations (Ushakova, 1974). At research of micrites under a polarizing microscope it is not possible to determine a morphological structure of carbonate grains. However, application of a method of fractography (Khvorova, Dmytryk, 1972), allows on the base of observation of cleavages' microreliefs to identify the ultrastructure of rock-forming substances. So, for example, with the help of the above mentioned method it is revealed, that marly-chalky rocks of Cretaceous age of the west of the East-European platform and Crimea are represented by fragments of coccoliths and have planctogenic genesis (Shumenko, 1970). The nature of carbonate deposits from the area of Bahama banks (Steiglitz, 1972) is discovered as organogenic too.

OBJECT, AIM AND METHOD OF RESEARCH

The ultrastructures of Oxfordian (Rudkivska series, well 1-Lanovychi, in-l 2151-2156 m) and Tithonian micrites (Nyzhnivska series, well 21-Kokhanivka, in-l 1234,4-1241,4 m, 22-Kokhanivka, in-l 1357,6-1359,2 m) of Outer zone of the Carpathian Foredeep have been studied using the scanning electron microscope (SEM) in a context of their genesis.

Electron microscopy investigations consisted of several successive stages. On fresh chip of the properly prepared debris of cryptocrystalline limestones, by vacuum sprayer of Jeol of mark JEE– 420, a carbon layer of about 300Å was sprayed. Carbon replicas have been studied under a scanning electronic microscope of Jeol of mark JSM - 6490 at a high-speed voltage 30kv and zoom from 1300 up to 6500 (analyst V.V.Permyakov, Institute of Geological Sciences of Ukraine). For individual samples the additional cleaning at which fresh fragments of rocks were bedded in a glass with water in ultrasonic camera of mark S100h ECmasonic for disintegration of the object (cleaning from mechanical admixtures and separation on the weakened zones) was carried out. After that the cleaned grains were sprayed by carbon. For interpretation of cleavage surfaces of Upper Jurassic micrites, classification of correlation of types of cleavage surfaces and microstructures by (Khvorova, Dmytryk, 1972) was used.

RESULTS OF RESEARCHES AND THEIR ANALYSIS

In the investigated rocks two morphological types of surfaces were determined: with a simple and a complex structure. On the data of fractography among the simple cleavage surfaces the following their types were revealed: blocky, irregularly blocky, stepped, smoothly - blocky, aggregatic smoothly blocky, blade-shaped. Blocky-stepped, blade-shaped-irregularly-blocky, drusoid-shaped-stepped types were established for complex cleavage surfaces.

Simple cleavage surfaces

Blocky type of a cleavage surface (fig. 2 A) is characterized by well expressed crystallomorphic ultrastructure. It is shown as well defined cleavage surfaces of calcite crystals surfaces, on which at the big magnifi-

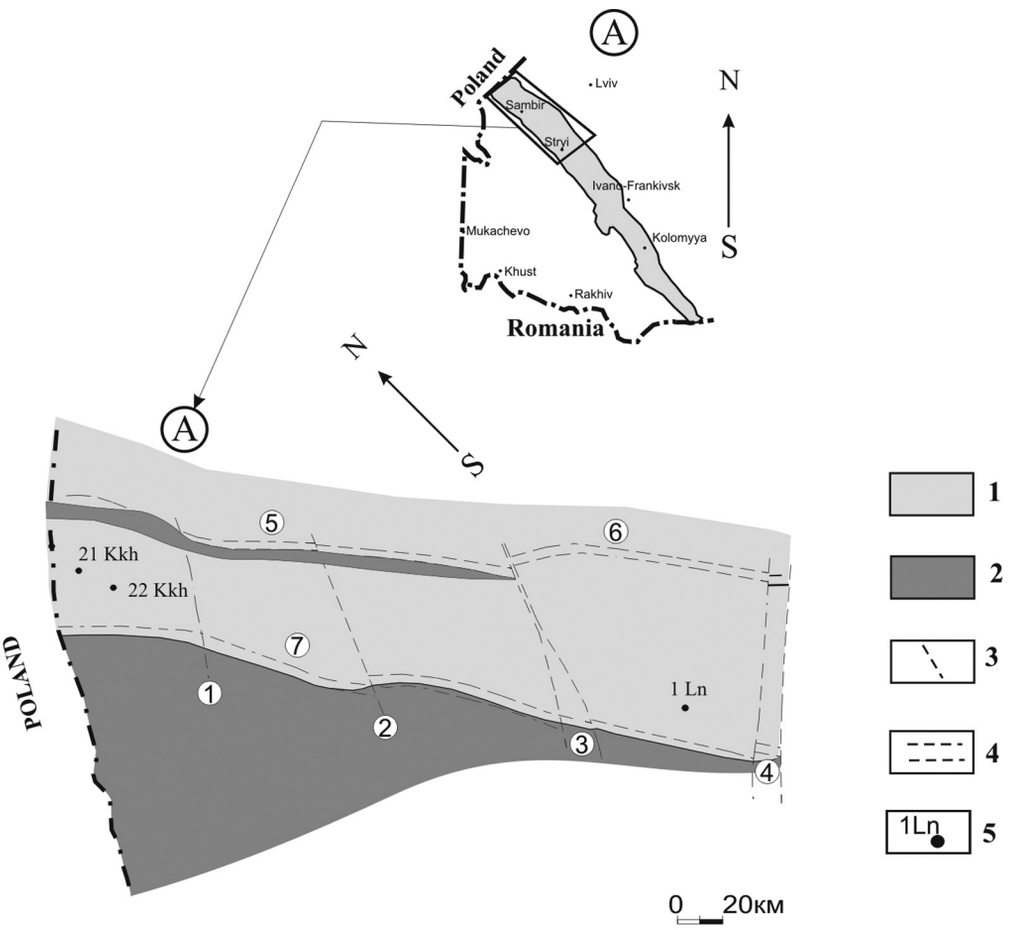


Fig. 1. Geological scheme of Upper Jurassic deposits occurence of the Outer zone of the Carpathian Foredeep (tectonic basement by I. V. Kilyn, A.S. Shcherba, 1999).

A – location of the sections studied; **1** – Upper Jurassic deposits; **2** – areas of absence of Upper Jurassic deposits; **3** – cross faults and their names (numbers in circles): 1 – Strvyazhskyi, 2 – Dnistrovsko-Monastyretskyi, 3 – Drogobytsko-Shchyretskyi, 4 – Stryiskyi; **4** – lengthwise faults and their names (numbers in circles): 5 – Gorodotskyi, 6 – Kaluskyi, 7 – Krakovetskyi; **5** – wells and their names, core samples of which were investigated by electron microscopy: 21, 22 Kh – 21, 22 – Kokhanivka, 1 Ln – 1–Lanovychi.

cations are visible the fine cracks and grooves, sometimes cavities in diameter from 1 to 5 μm, which is interpreted by authors as traces of dissolution. Sometimes blocky type of a cleavage surface is shown as mosaic ultrastructure. The latter is represented by the coarse-crystalline aggregates of calcite crystals compared with containing cryptocrystalline matrix. Under a scanning electron microscope the mosaic ultrastructure is characterized morphologically by well defined surfaces of large forms with conchoidal fracture. (fig. 2 B).

Irregularly–blocky type of a cleavage surface (fig. 2 C) consists of irregular-shaped blocks which sizes varying from 10 to 60 μm. The arrangement of blocks is chaotic, the surface of faces is frequently covered with fine cracks and cavities which were formed by dissolution of mineral grains. For rocks with irregularly - blocky type of a cleavage surface a subcrystallomorphic ultrastructure is inherent.

Stepped type of a cleavage surface (fig. 2 D) is typical for completely recrystallized rocks, it is formed at splitting of large calcite crystals on cleavage. Steps are parallel between themselves, from 2 to 3μm in height and have rectangular fracture. The stepped type of surface displays the crystallomorphic ultrastructure of rock.

Smoothly-blocky type of a cleavage surface (fig. 2 E) consists of calcite crystals with the smoothed edges of faces. Among them there are smaller crystals of irregular shape. Crystallomorphic ultrastructure, which is veiled as a result of gradual dissolution of crystals surface, develops into a subgranular version.

Aggregatic smoothly blocky type of a cleavage surface (fig. 2 F) is represented by accumulation of calcite grains with the smoothed edges of faces. The surface of faces is unequal, porous, covered with smoothed humps of elongated shape. The primary crystallomorphic calcite structure lost its outlines

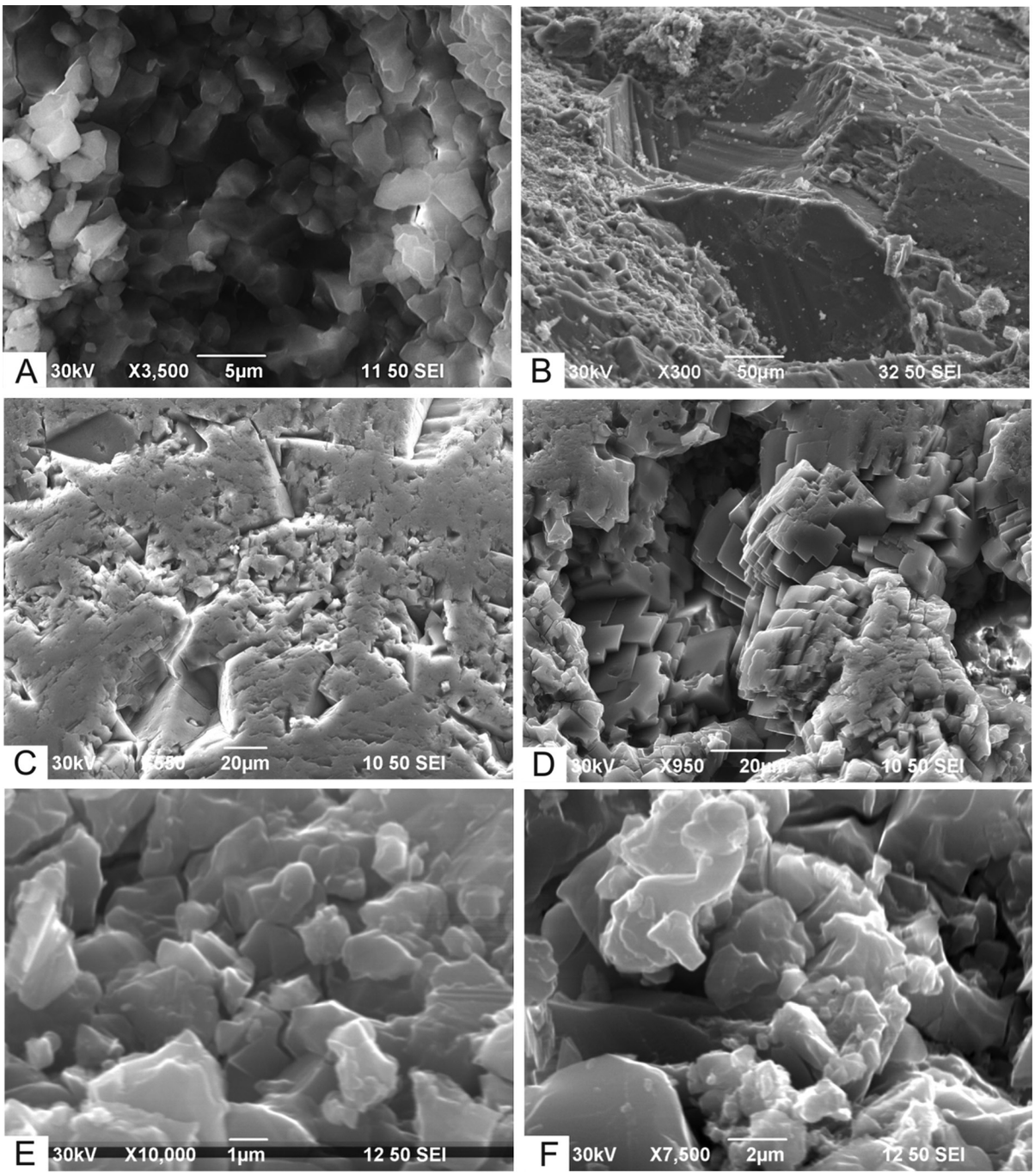


Fig. 2. Morphological types of surfaces of Upper Jurassic micrites of the Outer zone of the Carpathian Foredeep and corresponding ultrastructures:

A – block type of cleavage surface, crystallomorphic ultrastructure. Oxfordian.
W. 1 – Lanovychi (depth 2151-2156 m).

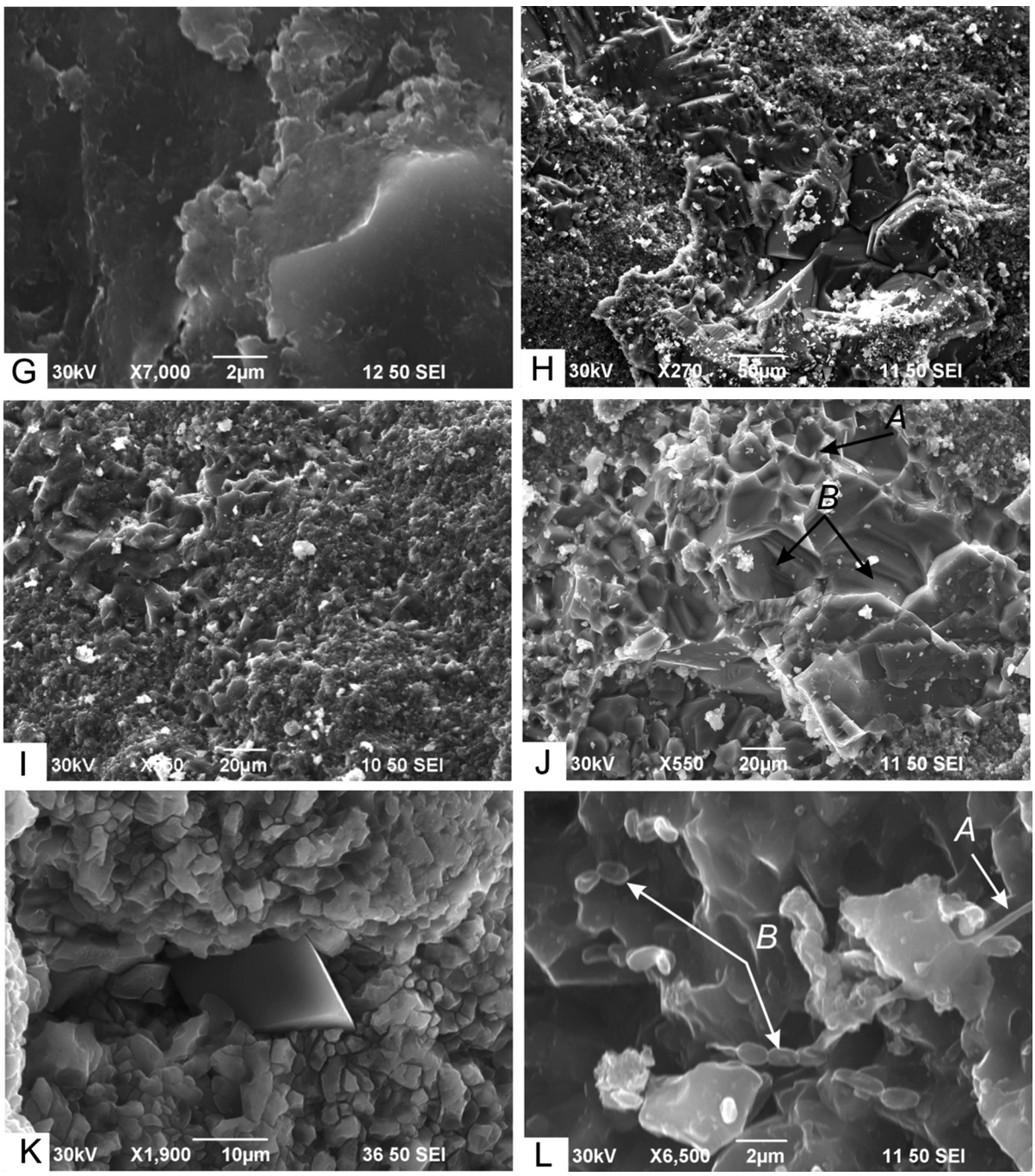
B – block type of cleavage surface, mosaic ultrastructure. Tithonian. W. 21- Kokhanivka (depth 1234,4-1241,4 m).

C – incorrectly- block type of cleavage surface, subcrystallomorphic ultrastructure. Oxfordian.
W. 1- Lanovychi (depth 2151-2156 m).

D – stepped type of cleavage surface, crystallomorphic ultrastructure. Oxfordian.
W. 1- Lanovychi (depth 2151-2156 m).

E – smoothly-block type of cleavage surface, subcrystallomorphic ultrastructure. Tithonian.
W. 21 – Kokhanivka (depth 1234,4-1241,4 m).

F – aggregatic-smoothly block type of cleavage surface, subgranullaric ultrastructure. Tithonian. W. 21- Kohanivka (depth 1234,4-1241,4 m).



G – blade-shaped type of cleavage surface, subcrystallomorphic ultrastructure. Tithonian.
W. 22 – Kokhanivka (depth 1357,6-1359,2 m).
H – block- stepped type of cleavage surface, subcrystallomorphic ultrastructure. Tithonian.
W. 22 – Kokhanivka (depth 1357,6-1359,2 m).
I – blade-shaped-incorrectly-block type of cleavage surface, subcrystallomorphic ultrastructure. Tithonian. W. 22 – Kokhanivka (depth 1357,6-1359,2 m).
J – druse-shape type of cleavage surface A with elements of stepped type B. Crystallomorphic ultrastructure with elements of mosaic. Tithonian. W. 21 – Kokhanivka (depth 1234,4- 1241,4 m).
K – incorrectly-block type of cleavage surface transforming to smoothly block type, subcrystallomorphic ultrastructure. Monocrystal of dolomite (size of edge 20 μm) in calcitic aggregation with middle-pelitic structure. Oxfordian. W. 1 – Lanovychi (depth 2151-2156 m).
L – aggregatic-smoothly block type of cleavage surface, subgranullaric ultrastructure:
A – jelly-like treads and B – necklace chains of cyanophycean algae. Oxfordian.
W. 1 – Lanovychi (depth 2151-2156 m).

and was showed as a subgranular ultrastructure as a result of transformation of mineral substance.

At fractographic investigation a *blade-shaped* type (fig. 2 G) is shown as rather even, slightly wavy surface. On this type of a cleavage chip surface the areas with strongly twisting contours with festoony outlines are allocated. The surface of separate blades is covered with a plenty of fine furrows. In the investigated samples the blade-shaped type develops as a result of change of blocky type of a cleavage surface and is characterized by a flake-shaped ultrastructure.

Complex cleavage surfaces

Occurrence of complex cleavage surfaces is obviously predetermined by a significant recrystallization of limestones. To the abovementioned cleavage surfaces correspond the complex types of ultrastructures.

Blocky-stepped type of a cleavage surface (fig. 2 H) is represented by large blocks (50-75 μm) which are orientated in different directions. Faces of blocks break up in steps on rombohedrons of cleavage. The size of steps makes 6-12 μm. The surface of faces is uneven, sometimes porous. For rocks with this type of a cleavage surface a crystallomorphic ultrastructure is characteristic.

Blade-shaped-irregularly-blocky type of a cleavage surface (fig. 2 I) is formed from irregular-shaped blocks whose characteristic feature are the serrated,»lacy»outlines. On the smoothed surface the fan-shaped blades are located. The surface of blades is covered with a plenty of fine scale-like furrows. Limestones with the abovementioned type of a cleavage surface is characterized by a flake-crystallomorphic ultrastructure.

Drusoid-stepped type of a cleavage surface (fig. 2 J) consists of crystals with well defined crystallographic forms. The size of blocks changes from 10 to 30 μm. Crystallographic ultrastructure, which corresponds to this type of a cleavage surface, is characterized by the aggregate of blocks with flat or convex – concave faces. Blocks do not adjoin to each other, between them the free space is visible. The surface of blocks is smooth. In the center the elements of step type of a cleavage surface are observed. For the investigated type of a cleavage surface the crystallomorphic ultrastructure is characteristic.

Some special mineral formations of cleavage surfaces

Studying under an electron microscope of the general picture of structure of carbonate substratum of different type of cleavage surfaces has shown, that sometimes on them are fixed the sporadically placed single authigenic mineral allocations of different «freakish» morphological outlines. So, by fractographic investigation of cleavage surfaces of Oxfordian micrites from well 1-Lanovychi (in-l 2151-2156m), after additional cleaning of the samples, separate minerals from group of carbonates have been revealed.

Rombohedrons (fig. 2 K). These forms are characteristic for crystals of dolomite (the size of an edge is 20 μm), which come forward on the background of calcite mass with medium-pelitic structure. Usually crystals of dolomite are idiomorphic, the surfaces of their faces are even. Calcite matrix with subcrystallomorphic ultrastructure is characterized by blocky type of a cleavage surface which in places develops into a smoothly - blocky type.

Fossilized filamentous forms probably represent the calcitic pseudomorphs on threads of cyanophycean algae. They are established in micrites with aggregatic smoothly blocky type of a cleavage surface (well 1-Lanovychi, Oxfordian) (fig. 2 L). Morphologically they are represented as differently orientated gelly threads or necklace-like chains, which consist of numerous oval-like forms of mineral formations. The latter are sporadically scattered in calcitic mass with subgranular ultrastructure.

CONCLUSIONS

Post-sedimentary processes of dissolution of primary carbonate aggregates of micrites of Rudkiwska (J_{3oxf}) and Nyzniwka (J_{3tth}) series were determined by fractographic investigations. The transformation of the blocky types of cleavage surfaces to smoothly blocky, aggregatic smoothly blocky, rarely blade-shaped types and accordingly changing over of ultrastructures from crystallomorphic to subcrystallomorphic, subgranullaric and, partly, to flake-shaped ultrastructure were caused by post-sedimentary dissolution of primary carbonate aggregates.

Crystallomorphic ultrastructures with blocky, irregularly-blocky and smoothly-blocky types of cleavage surfaces (well 21, 22-Kokhanivka), as it is known from (Ushakova, 1974; Perozyo et al., 1976; Zakrutkin and Shpitsgluz, 1981; Konyukhovetc., 1971), are inherent in rocks of chemogenic genesis.Blocky and drusoid types of cleavage surfaces with crystallomorphic ultrastructure are found out by SEM investigations of oolites of Nyzniwka (J_{3tth}) series from wells 21, 22-Kokhanivka. However, the presence in surrounding limestones of single shells of gastropods, pelecypods and foraminifers of Milliolidae range shows the biochemogenic sedimentation in an intertidal zone of the sea with normal salinity and moderately weak surf.

Fossilizated filamentous forms which are the calcite pseudomorphs on threads of cyanophycean algae in micrites of Rudkiwska series (J_{3oxf}) with aggregatic smoothly blocky type of a cleavage surface (well 1-Lanovychi) were revealed by fractographic investigations for the first time for the carbonate rocks of the mentioned region. As it is known, during their life the monocelled and multicellular cyanophycean algae form elastic gellylike covers and sticky gel coating around separate grains. Algal covers, that have evolved in the tidal zone of a shelf in environments of normal salinity of waters, usually are not preserved in a fossil form because of the presence of herbivorous organisms for which, according to (Sedymentology, 1980), the algal cover is a food. The establishment by the authors of the relicts of cyanophycean algae as gellylike filaments in Oxfordian limestones of Carpathian Foredeep testifies the biochemogenic sedimentation in environments of a shelf tidal shallows at high salinity of water. Under these conditions the algal covers of shelf basin, that existed at the territory of the Carpathian Foredeep during Oxfordian time, could develop without interferences, due to lack in a basin of benthonic and nektonic organisms that are nourished by phytobenthos. By the way, the presented data well agree with E. Flyugel's opinion (Ushakova, 1974), who among the ways of formation of modern micrites distinguished their biochemical sedimentation as a result of photosynthesis of cyanophycean algae in shallow water.

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