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# MINERAL COMPOSITION OF MIXED CLAYEY-SALT DEPOSITS (ZUBERS) FROM THE NEOGENE (UPPER BADENIAN) SUCCESSION OF THE POLISH CARPATHIAN FOREDEEP

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The Upper Badenian evaporitic deposits from the Polish part of the Carpathian Foredeep (Bochnia-Wieliczka area) contain units (several up to 70 m thick) of mixed salt-clay (15–85 % of clay) sediments (zubers), originated in deep marine (as chemical precipitates) to basin slope (redeposites) environs. Petrological and geochemical (XRF, TA, SEM) analyses indicated varied mineral composition of these rocks: evaporitic minerals (halite, sulphates: gypsum, anhydrite, rare celestine) are surrounded by detritical (quartz, feldspars, muscovite, biotite, glauconite, zircon, organic fragments) and pelitic (illite, smectite and rare chlorite) components. Frequently occur dolomite and calcite microlithes and microclasts, concentrations of organic matter (bitumens), pyrite phramboids accompanied by marcasite but only locally – ankerite and sphalerite concentrations suggesting possible volcanic provenience of Zn.

*Key words:* clayey-salt deposits, mineral, Badenian, Carpathian Foredeep.

**Geological setting.** Salt-bearing deposits of the Miocene (Upper Badenian) age [1, 4, 5] from the Polish Carpathian Foredeep include the specific chloride beds (so called "zubers"), with a significant content (15–85 %) of terrigenous material and dominant thickness of several-dozen meters, maximum – over 70 m (Łężkowice region). Studied zubers from the salt mines in Bochnia and Wieliczka and from the drills nearby Łężkowice (the area located between both mines, southward from Cracow) were defined as the older and the younger zuber horizons, distinguished in the whole salt-bearing succession [2]. Lithology of these units and observed sedimentary structures evidenced that discussed zubers originated at various depths in the saline basin [1]. Laminated zubers have accumulated on the bottom of open basin, in conditions of chlorides precipitation from bottom brines with fluctuating salinity. Deposits with chaotic or gradational distribution of salt clasts and terrigenous material were interpreted as the redeposited sediments (redeposites), corresponding to the proximal and the distal parts of giant submarine slumps, developed on the basin slope and initiated by seismic shocks and/or enormous floods and storm surges.

**Samples and methods.** 50 rocks samples were analysed, taken from both mentioned zuber horizons (older and younger ones) from the salt mines in Bochnia (20 samples) and Wieliczka (26 samples) and from the 2 well cores (4 samples), drilled in the Łężkowice area.

Mineral composition and petrological characteristics of zubers were defined after results of microscopic (polarizating and SEM) studies, X-ray (PW 1840 Philips diffractometer) and thermal (MOM derivatograph) analyses. Such studies were realised both on rock fragments (thin sections, powdered samples) and residua after rock dissolving in a water.

Concentrates of detritical and pelitic/clay material, required for the X-ray and thermal analyses, were obtained by a water dissolving of crushed zuber samples and drying residua composed of insolubles (detritical grains, clay and organic matter). 2 types of preparations were studied: *a*) preparations from residua, structureless; *b*) oriented (sedimented) preparations, analysed in conditions of a dried-air stage of clay matter; after saturation with glycol and after heating at 550°C to obtain data, enabling distinguishing clay minerals

**Results of microscopic studies/observations.** ***Polarising microscope.*** Study of thin sections evidenced occurrence of halite crystals up ton several mm with distinct cleavage, frequently including numerous inclusions emphases a zonal primary structure. The clay-detritic fragments of sections contain fine monocrystals or concentrations of anhydrite crystals, arranged as rosettes as well as infilling thin veins. Clasts composed of anhydrite or gypsum are also common but sporadically the whole sections represent fine crystalline, highly "folded" anhydrite.

Clay matter is developed as a "felt", composed of very fine slices of clay minerals, surrounding quartz and feldspar grains, both twinned and plagioclases, often highly sericitized. Size of quartz grains varies, up to 0,4 mm, and feldspars – up to 0,1 mm, they are medium sorted and variably rounded – from angular to well rounded grains. Few glauconite grains were noticed sporadically, they are fresh, up to 0,8 mm in diameter, but sometimes are chloritized. Muscovite is a common component of studied rocks, visible as plates up to 0,1 mm, accompanying quartz grains. Similarly pyrite is developed as a pigment, concentrations and pseudomorphs after organic remains. Some samples contain also heavy minerals, mainly zircon, and dispersed organic matter. Carbonates occur as crystals of varied size, concentrations of fine crystalline up cryptocrystalline clasts of algal origin and as foram tests.

***SEM microscope.*** SEM studies were realised on 7 selected samples, representing both Miocene zuber horizons [6].

Main rock component, *halite*, is developed as different forms in shape and size, some isolated ones are regular but are aggregates of idiomorphic microlithes with a granular structure. Surfaces of other forms exhibit irregular pores and holes, evidencing occurrence of inclusions, some grains have dissolution traces, registered as fragmentation of edges.

Sandy fraction occurred within *clay matter*, consists of dispersed angular to rounded *quartz* grains, angular *feldspars*, *glauconite* grains and seldom heavy minerals (zircon).

Other identified mineral components were as follow:

*organic matter*, occurred as single, brushed and laminar inclusions within halite, locally it also surrounds idiomorphic or rounded halite crystals. In some caverns analytical spectra with increased carbon content indicated *bitumen*;

*silica,* including a feather *chalcedony*, *quartz* and *crystobalite*. In all samples from Bochnia mine silica forms interfingers of authomorphic crystals or pseudoveins with wormy or handy shapes;

*sulphates*, represented by *gypsum* and *anhydrite*, occur within rounded clasts and characterise with densy, fine needelly structure, frequently fibrous-felty. Columnar or leather sulphate inclusions in halite are numerous and they compose laminae framing halite clasts. They resulted from 3-stage crystallisation (primary, synsedimentary and

post-sedimentary). Also microlithes of bar cystals of *celestine* are dispersed with dolomitic and clay matter;

*dolomite* is developed as a syngenetic (microlithes 0,5–1,0 μm in diameter, composed of oval but sometimes euhedral crystals situated within granular mass of syngenetic halite) and epigenetic (coexisted with a celestine as rounded dolomitic-celestine microclasts, located in fractures or between disrupted clasts of halite or within clay and silty parts of samples varieties). Dolomitic-celestine and halite-dolomitic-celestine microclasts are 200-800 μm in diameter. They are rounded and distinguish from a clay or a halite matrix, suggesting their redeposition;

*pyrite* forms fine, 10–20 μm in diameter, imprints of single crystals or spherical aggregates, called phramboids. They are probably biogenic and occur mainly in silty parts of samples;

*marcasite* was noticed nearby the clay "pocket" infilled with pyritic phramboids. Marcasite existed as a sintery interbed within clay matrix could be a postsyngenetic or an epigenetic mineral, generated be a secondary reduction of iron compounds in slightly acid conditions of consolidating sediments;

*sphalerite*, similarly as pyrite, builds aggregates up to 10–20 μm, visible as rosette twins dispersed in a clay-silty vein. Zinc source could be liberation of zinc ion during transformation of primary aragonite into calcite, the flysch deposits of adjacent Carpathians or volcanic phenomena active in this area during the Miocene.

Microprobe and SEM studies indicated that the clay-silty material, interbedded the zuber rocks, is composed of elastic plates of *illite*, *smectite* and seldom *chlorite* and it contains rounded grains of *quartz*, *albite*, *plagioclase*, crushed plates of *muscovite*, and rarely – of *biotite*, as well as few heavy minerals (*rutile* and *zircon*). These components came probably from erosion of leucocratic alkaline granites, alkaline ryolithes or alkaline volcanic tuffs.

**Results of X-ray analysis.** Results of X-ray analysis of Miocene zubers evidenced that common clay minerals are smectite, illite, chorite and a specific mineral with 7Å reflex (interpreted as a kaolin or one of leptochlorites – chamosite), and in most samples – also a mixed-packet mineral I/S (illite/smectite).

Studies of mineral composition of residual samples documented as principal minerals: quartz, anhydrite, feldspars and celestine and barite, also were noticed carbonates: dolomite and calcite but in few samples – iron dolomite, ankerite and magnesite. Sporadically observed bassanite is probably an artefact.

**Results of thermal analysis.** 92 thermal analyses of Miocene zubers indicated that the zuber samples from Bochnia mine contain significant amount of carbonates (content from 7 % to >17 %) and of organic matter (1,0–2,6 %). Characteristics of thermal curves at high temperatures documented occurrence of illite and locally – kaolinite. The main thermally non-active components are quartz and anhydrite, carbonates are represented by dolomite and calcite and in most samples also magnesite (up to 3,1 %.)

Composition of zubers from Wieliczka mine is more monotonous, dominant components are quartz and anhydrite, organic matter (to 2 %), carbonates (to 10 %) with prevailed calcite, magnesite was undetected.

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## МІНЕРАЛЬНИЙ СКЛАД ЗМІШАНИХ ГЛИНИСТО-СОЛЬОВИХ ВІДКЛАДІВ (ЗУБЕРУ) З НЕОГЕНОВИХ (ВЕРХНІЙ БАДЕНІЙ) РОЗРІЗІВ ПЕРЕДКАРПАТСЬКОГО ПРОГИНУ ПОЛЬЩІ

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Верхньобаденські евапоритові відклади польської частини Передкарпатського прогину (ділянка Бохня–Величка) містять змішані соляно-глинисті осадові породи (зубер), які утворилися в умовах від глибоководних морських (як хімічні осади) до басейнових на схилі (перевідкладення). За даними петрологічного, рентгенівського та інших видів аналізів виявлено коливання мінерального складу цих порід: евапоритові мінерали (галіт, сульфати) наявні серед уламкових (кварц, польові шпати, мусковіт тощо) та пелітових (гідрослюда, смектит, хлорит) компонентів. Часто трапляються доломітові й кальцитові мікроліти та мікрокласти, скупчення бітумів, піритові фрамбоїди, які асоціюють з марказитом та лише локально – з анкеритом і сфалеритом, що наводить на думку про можливе вулканічне джерело Zn.

*Ключові слова*: глинисто-сольові відклади, мінерал, баденій, Передкарпатський прогин.

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