

mgr inż. Piotr Olchowy

ABSTRACT OF PhD THESIS

Depositional environments and characterization of stable carbon and oxygen isotopes in sulphur-bearing sediments from the Osiek-Baranów Sandomierski native sulphur deposit, Carpathian Foredeep

The PhD thesis presents sedimentological and stable carbon, and oxygen isotope characterization of Miocene (Upper Badenian) evaporitic complex from the area of the Osiek-Baranów Sandomierski native sulphur deposit. The deposit is located in the northeastern part of the Carpathian Foredeep, in the Sandomierz Depression. In this area, the evaporitic complex includes sulphur-bearing limestones, barren limestones, marls, claystones-mudstones, calcareous mudstones and sulphates (mostly gypsum). The research was based upon drill cores collected from both the deposit area and its vicinity, and comprised lithofacial observations of cores with special attention paid to sedimentary structures and rock textures. During the observations, samples were collected for thin sections preparation and for isotopic analyses of carbon and oxygen. Totally, 39 drill cores were studied from which 24 originated from deposit area and 15 from outside the deposit contour. Thickness of evaporite complex observed in studied drill cores varied from 4.2 to 50.1 m (average: 23.8 m). Sedimentological studies of evaporite complex were focused particularly on sulphur-bearing limestones, which form the bulk of the deposit and are essential for the research objectives. Studies included facial and microfacial development together with variability of sedimentary structures and rock textures (bedding, types and orientation of lamination), depositional discontinuities, grain size distribution, types and size of detrital fraction, deformational and flow structures, types and forms of porosity, sulphur abundance, forms of organic matter, other-than-sulphur mineralization of the framework, diagenetic transformations as well as the character of limestones/gypsum contacts.

In the studied sediments, three facial associations were distinguished: (1) calcareous, which includes: barren mudstones, sulphur-bearing mudstones, gypsum-ghost barren mudstones, gypsum-ghost sulphur-bearing mudstones, barren floatstones, sulphur-bearing floatstones, gypsum-ghost barren floatstones, gypsum-ghost sulphur-bearing floatstones, barren rudstones,

sulphur-bearing rudstones, gypsum-ghost barren rudstones, gypsum-ghost sulphur-bearing rudstones, gypsum-ghost coarse limestones, sulphur-bearing bindstones and pedogenic sediments (calcrets and vertisols), (2) clastic, including marls, calcareous muds and clayey mudstones, and (3) gypsum.

The observed facial features as well as the results of mineralogical examinations and isotopic analyses revealed that the marginal zone of evaporite basin dominated by calcareous sediments is facially inhomogenous, both horizontally and vertically. This indicates various depositional environments and paleogeographical diversity of study area. Basing upon facial features and mineral composition, three paleogeographical zones were distinguished: (i) barren limestones zone, (ii) limestone-gypsum, sulphur-bearing zone and (iii) gypsum zone, all arranged parallelly to each other and extending northwest-southeast.

Sedimentation of studied rocks proceeded in the marginal zone of evaporite basin dominated by carbonate deposition. This was the circum-evaporite, calcareous mud flat with diversified environments, which graded distally into salinary basin with gypsum deposition. The area of circum-evaporite deposition was morphologically diversified and included the relatively deeper areas of calm deposition connected with local, basin-floor, paleocurrent-bounded depressions and with local shoals, which were subjected to short, subaerial exposition. The marginal zone of (mostly calcareous) sedimentation with minor contribution of clastic and evaporitic (gypsum) facies developed in the close vicinity of islands surrounded by a large evaporite basin. The islands were the source of clastic and organic (plant-derived) material locally observed in studied sediments.

The facial distribution of studied sediments does not show any regularities in both the lateral and vertical successions, which points out to a high dynamics of depositional environment and, indirectly, to its shallow depth. Facies include numerous sedimentary structures and rock textures indicating diversified energy of the environment caused mostly by climatic features (storms, currents and waves) leading to erosion, transport and (re)deposition of diversified detrital material, karstification, recrystallization of calcareous fabric and cementation (mostly calcitic and calcitic-sulphuric).

The presence of disseminated native sulphur within the calcareous fabric, sulphur laminae and layers intercalated with sulphur-free calcareous laminae, common sulphur intraclasts and syngenetic deformations of native sulphur grains, all advocate the syngenetic character of

both minerals.

Sediments forming the evaporitic complex show diversity of isotopic compositions, both between the specific facies and within the facies. Such diversity was observed in facies of both the calcareous and the clastic associations. The evaporitic complex sediments show $\delta^{13}\text{C}$ values from -57‰ to 1.4‰ (average: -36,3‰) and $\delta^{18}\text{O}$ from -9.3‰ to 1‰ (average: -5‰). Both the isotopic compositions and the variability ranges of stable carbon and oxygen isotopes values indicate the open-system sedimentation in an environment with stratification of bacterial oxidation of organic matter. The variability ranges of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values suggest different sources of carbon and oxygen during deposition and diagenesis. Calcite precipitation took place under evaporitic, brackish and meteoric conditions, in the zones of methanogenesis and bacterial reduction of sulphates. Based upon facial and isotopic diversities of studied sediments, the following deposit zones were distinguished along the northwestern-southeastern strike of sulphur-bearing formation: Niekrasów, Osiek and Skopanie. These zones reflect various paleoenvironments and, generally, indicate the increasing influence of meteoric waters towards the southeast.

The character of limestone/gypsum contact precludes the influence of epigenetic transformations of gypsum beds. The limestone-gypsum interface shows features of submarine current washouts or dissolution caused by the changes in hydrochemical regime of waters. Gypsum crystals from the contact with limestones, when observed under the microscope, do not show structural and textural features indicative of metasomatic replacement. Taking into account presented facial, petrological and isotopic features of sulphur-bearing limestones, no evidence was found of epigenetic (metasomatic) transformations of gypsum beds.

The presented sedimentological and isotopic studies of sulphur-bearing limestones explain one of crucial aspects of the origin of Miocene native sulphur deposits in the marginal part of the Carpathian Foredeep - the formation conditions of sulphur-bearing limestones, which provide the framework for native sulphur accumulation. The results prove the sedimentary origin of limestones and the syngenetic genesis of native sulphur. The results extend our knowledge of depositional conditions and mechanisms operating in the sedimentary environments occupying the marginal zones of evaporate basin. The scheme of sedimentation development was presented in the facial-diagenetic model.