GEOCHEMISTRY AND MINERAL ASSEMBLAGES OF THE MEDITERRANEAN EVAPORITE DEPOSITS. 3. SOME TEXTURAL CHARACTERISTICS OF EVAPORITE SEDIMENTS IN TUZLA SALT DEPOSIT

Vladimir Bermanec[1,3*], Marta Crnjakovic[2] and Goran Kniewald[3]

[1] Department of Mineralogy and Petrology, Faculty of Sciences, University of Zagreb, Zagreb, Croatia
[2] Natural History Museum, [3] Center for Marine and Environmental Research, Rudjer Boskovic Institute, Zagreb, Croatia

Keywords: basin formation, diagenesis, evaporites, mineralogy

Introduction

Evaporites in the Mediterranean region occur in a variety of environmental settings. Depositional milieus range from coastal intertidal and supratidal zones (sebkhas), over small costal or atoll-type lagoons, deeper marine basins and sub-sealevel basins with marine inflow, to non-marine interior freshwater and saline lakes. The paleogeographic and tectonic settings include continental margins and shelves, interior cratonic basins and rifted continental slopes. The passage from one evaporitic sub-environment to another is often not quite obvious, as in the case of the simpler and regular behaviour of carbonate formative zones or sedimentary facies in less dynamic regions. The inherent diversity of the evaporitic series is further complicated by active diagenetic processes. Moreover, some of the products of late diagenesis exhibit outward similarities to textures actually developed during sedimentation, including diagenetic features which developed from and may be superposed on any characteristic facies of the depositional environment. The evaporite deposite of Tuzla in Bosnia-Hercegovina is the largest rock salt deposit in the Balkans. Salts were deposited on tertiary dolomites and marls during the Styrian orogenetic phase (1). The geochemistry of coexisting brines and their saturation states imply that the formation environment may be interpreted in terms of the mixing-zone model, or the end-member type salt lake deposits (2,3). The mineral association of the Tuzla rock-salt series consists of halite, thenardite, tuzlaite, searlesite, northupite, glauberite, and anhydrite. The mineral assemblage have been studied in detail (2,4). In the paragenesis, a new mineral - named tuzlaite to honour the occurrence - with a pentaborate sheet structure has been discovered (5). However, up to now no systematic investigations of the sedimentary textures developed during the formation of the deposit have been done. In this study only the sediments from the IIIB salt series were investigated. These sediments contains varying amounts of dolomite, and may be classified as clay-calcitic dolomite to dolomitized limestones, and marls (6). All sediments are devoid of entrained fossil fragments, and are gray, grayish-brown or greenish-gray in colour A characteristic feature of the sediments is their fine lamination and interchanged with layers of homogeneous carbonate sediment or (more seldom) tuff up to a few centimeters in thickness. The laminae are parallel to each other and discontinuated. Usually light laminae replace darker ones marked with bituminous film. Both are built of micritic carbonate. Some thicker laminae show a vertical size fractionation. Secondary minerals in the assemblage - northupite, halite, searlesite, and pyrite crystallized as thin layers or lenses, but they can also be dispersed within the sediment. Fine mineral grains underline primary lamination sequences, while lenses and large crystals produce deformations of the laminae. Cracks filled with diagenetic calcite may be occasionaly found.

Experimental methods and results

Minerals were identified by X-ray powder diffraction. Sedimentary textures, appearance and shape of diagenetic minerals were investigated within polished and thin sections (including acetate folia pills). Carbonate minerals were distinguished by the staining method (7).

Northupite. Northupit is found to be developed within parallel layers up to 1-2 mm thick. Crystals vary from 0.07 to 0.45 mm in size and they can be closely packed or separated. Carbonate or clay mud is always placed between the crystals. Sometimes northupite crystals have rounded edges. Very often pyrite crystals are dispersed within northupite. Neighboring primary lamination is never disturbed.Bigger crystals up to 3 cm in size are usually developed alone. Sediment is deformed around them and there are cracks around the crystals which are filled with secondary calcite. Near these big hooper crystals organic matter is common. There are carbonate solid inclusions within the crystals of northupite. Such inclusions mark growth sectors. Near the rim of the crystals and around them very fine pyrite grains form the opaque zone (Fig. 1). There are also solid inclusions within the small crystals of northupite (up to 1 mm in size) which are determined just within thin sections to be a searlesite.

Halite. Halite is found to be crystallized as single crystals of hexahedral habit, sometimes with high concentration of micritic sedimentary inclusions and colored with dark organic material. There are also transparent, colorless halite crystals, often of tabular habit. Such tabular habit exhibit also hoopers. Halite is found within compact thick layers of coarse grains, within lenses, and as separate crystals forming more or less continous layers.

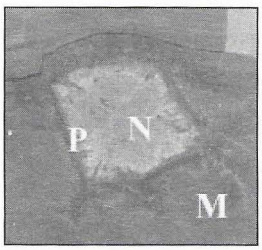

Fig.1. Big crystal of northupite, surrounded by hematite, after pyrite with in the marl with bended laminated texture

Pyrite. Pyrite is found as separate hexahedral crystals or as agglomerate. It is always connected with elevated concentration of organic matter. Within northupite it is found as solid inclusions and around giant northupite crystals it is found as cover. Sometimes it is oxidized to hematite and than northupite crystals are macroscopically red. These crystals are disintegrated to mixture of halite and magnesite (Fig. 1).

Searlesite. Searlesite is first boron mineral found in Tuzla salt deposit. It is found as small individual platy crystals dispersed within some layers, usually up to 2 mm thick. Sometimes it forms small sphaerulites, up to 1 mm in diameter, and sometimes it is found in big nests growing over the green (iron rich) northupite and before halite (Fig. 2). It is also found in Lopare near Tuzla in mixture with opal. Both of these minerals form sphaerical grains (8).

Fig. 2. Nodule of halite (H), searlesite (S), and northupite (N) which disturbed laminated sediment (it has about 3 cm in diameter).

Diagenesis

Occurrence of the dolomite is general characteristic of sediments developed in high salinity environment. Calcite-dolomite muds are typical for lake sediments and aragonite and Mg-calcite muds are typical for lagoons with permanent or temporary conection with the open sea (9). Very fine laminated textures typical for sediments in Tuzla deposit is similar to protodolomite developed in recent lakes where Mg-calcite (high-magnesian calcite) crystallize (10). During dolomitization grain size usually increase, but high Mg/Ca ratio prevent this process (6), what could be the explanation for such a fine lamination in this case. Pyrite is probably among the earliest diagenetic minerals growing in reductive conditions with the help of bacteria. It does not disturb sediments, because it is developed on the surface of the sediment or very early in very soft sediment. Northupite grew during few stages. Partly it crystallized within soft sediment and it included some carbonate grains and not disturbed sediments between small crystals. Some crystals with rounded edges, probably result of partial solving, also support early formation of this mineral. Later on bigger crystals grew and they bend the sediments around them. This sediments were still soft. At the end partly consolidated sediments were not so elastic to be banded, but small cracks around big crystals exist. The cracks were later on, filled with calcite cement. Northupite crystals grew very fast, because of high saturation of the brines. It is evident from the shape of the crystals (hoopers) and from growth sectors within most of the crystals. Such fast growth produced also many solid inclusions within the crystals. Halite also crystallized during few stages of consolidation of the sediment. Colorless hexahedral crystals were developed within the water on the surface of the sediment. The second type of crystals is full of inclusions, grew within the soft sediment. At the end halite grew within consolidated sediment which is highly disturbed by this process (halite together with searlesite and northupite remove the sediment and formed lenses or nodules). Organic matter colored such sediments and diagenetic minerals in brown or even black.

References

1. Kniewald, G., Bermanec, V. and Tibljas, D., 1998. Geochemistry and mineral assemblages of the Mediterranean evaporite deposits. 1. The Tuzla rock-salt deposit in Bosnia-Hercegovina. *Rapp. Comm. int. Mer Médit.*, 35, 78-79.
2. Bermanec V., Tibljas D., Crnjakovic M. and Kniewald G., 1992. Saline minerals of the Tuzla salt deposit as indicators of palaeooceanographic conditions. *Rapp. Comm. int Mer Médit.*, 33: 116.
3. Kniewald, G., Bermanec, V. and Tibljas, D., 1995. The depositional environment of the evaporite mineral series at Tuzla, Bosnia-Hercegovina. *Rapp. Comm. int. Mer Médit.*, 34, 105.
4. Kniewald, G., Bermanec, V. and Tibljas, D., 1986. On the origin and type of the Tuzla salt deposit in Yugoslavia. *Rapp. Comm.i nt. Mer Médit.*, 30/2, 72.
5. Bermanec, V., Armbruster, T., Tibljas, D., Sturman, D. and Kniewald, G., 1994. Tuzlaite - a new mineral with a pentaborate sheet structure from the Tuzla salt mine, Bosnia and Hercegovina. *American Mineralogist*, 79, 562-569.
6.Dickson, J. A. D., 1966. Carbonate identification and genesis as revealed by staining. Journal of sedimentary petrology, 36, 491-505.
7. Baric, Lj., 1966. Searlesit von Lopare in Nordostbosnien. Berichte der *deutschen Gesellschaft für geologische Wissenschaften, B. Mineralogie und Lagerstättenforschung, Bd.* 11, H. 4, 407-421, Berlin.
9. Bathurst, R.G.C., 1971. Carbonate sediments and their diagenesis. *Developments in sedimentology, 12. Elsevier Publ. Comp.*, XIX + 620, Amsterdam.
10. Müller, G., Irion, G. and Foerstner, U., 1972. Formation and diagenesis of inorganic Ca-Mg carbonates in the lacustrine environment. *Naturwissenschaften* 59, 158-164.

Acknowledgements. The authors thank the Ministry of Science and Technology of the Republic of Croatia for financial support of partial studies which have resulted in the present communication. Part of this work was facilitated by a research grant awarded to GK by the Alexander von Humboldt foundation, Bonn, Germany.