On Some Sedimentary Structures of Anhydrite within Miocene Evaporites in the Carpathian Foreland Area, Poland

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ABSTRACT

Within evaporites of the autochthonous Miocene, some typical sedimentary structures may be distinguished. In the southern zone, where evaporites belong to the Miocene thrust and folded in front of the Carpathians, majority of primary sedimentary structures were disturbed by tectonic movements. Among well preserved synsedimentary structures of anhydrite within evaporites of the IIIrd cyclothem, there occur numerous examples of flow structure. Origin of these structures may be explained by submarine flowage or slumping of unlithified sediment. Occurrences of flow structures are known within evaporites from the southern part of sedimentary basin only.

INTRODUCTION

In the Miocene salt-bearing formation of the Carpathian foreland in Poland two main units can be distinguished, namely an autochthonous unit and an overthrust one. The basic difference between evaporites within the autochthonous unit and these within the overthrust unit is that the latter were deposited on a flysch basement, in unstable sedimentation conditions. Primary extent of the Miocene evaporites, their distribution and facies changes have been presented in previous works (Garlicki, 1968, 1971, 1974, 1976). Among various sedimentological problems of evaporites, a special attention of the author has been turned to sedimentary structures of anhydritic rocks. Many years of author's field work made possible to distinguish typical structures of sulphate rocks from evaporites occurring in the autochthonous unit area and those characteristic for labile zones of sedimentation corresponding to deposits of contemporaneous overthrust unit.

SEDIMENTARY STRUCTURES OF SULPHATE ROCKS

In the area of the autochthonous Miocene the sulphate facies is the most extensive. It covers the Carpathian foreland from the eastern state boundary to the Kraków area and the major part of Upper Silesia. The average thickness of the sulphate facies in the mentioned area is 10 to 20 metres. Sediments of this facies are developed as anhydrite interbedded with claystones and siltstones. In the northern, marginal part of the Carpathian foreland sulphate facies is represented by gypsum which thickness exceeds 60 m. In this zone well known sulphur deposits of the Tarnobrzeg region occur. In numerous profiles from the central part of the Carpathian foreland one can observe bipartite development of anhydritic rocks. In lower part of each profile, there occurs fine laminated anhydrite composed of alternated light and dark laminae. Darker laminae display a considerable admixture of clay. In upper part of profiles nodular anhydrite is prevailing sediment. Anhydrite nodules of various size form regular layers or are irregularly dissipated within clayey matrix. In the field of the chloride facies anhydrite is associated with rock salt. Anhydrite also forms separate layers of nodular or fine-grained structure. Very conspicuous sedimentary structure displays fine-laminated anhydrite ("varvitic") consisting of alternated white and gray, very thin laminae of anhydrite. In some profiles from central part of the chloride facies there occur alternated thin layers of anhydrite and rock salt, so called anhydritic-salty shales. All structures mentioned above, due to their presence within the autochthonous Miocene, are considered to be the primary sedimentary structures.

Evaporites in the overthrust unit deposited on a flysch basement, during Late Miocene were folded in front of the Carpathian nappes and thrust from the south, over the autochthon. Intense structural deformation makes it difficult to distinguish the normal sequence of strata in the overthrust unit. Unstable conditions of sedimentation are indicated, among other data, by the frequent occurrence of flow (enterolithic) structure in banded anhydrites as well as the frequent presence of exotic, clastic flysch material within evaporites. Another typical feature of the evaporites within the overthrust unit is the occurrence of brecciated salt clays containing coarse salt crystals which reach a considerable thickness (Garlicki, 1968, 1974). Due to intense tectonic disturbances primary sedimentary structures and early diagenetic ones are inconspicuous. There is possible to distinguish them in few profiles only.

Flow structures of anhydrite caused by submarine slumping or flowage of unlithified sediment, are the subject of special interest of the present author.

FLOW OR ENTEROLITHIC STRUCTURES OF ANHYDRITE

This kind of structure was discussed and described by numerous authors, (von Gaertner, 1933; Herrmann and Richter-Bernburg, 1953; Richter-Bernburg, 1953; Riley and Byrne, 1961; Garlicki, 1968; Kwiatkowski, 1972; and Wardlaw, 1972). Besides the term "enterolithic structure" in geological literature one can find following terms: contorted structure, deformation structures, flexures, synsedimentary deformation etc. (German: Gekröselagen, Gekrösefalten, Gekrösestrukturen, Gleitfalten, Schlangengipse). Enterolithic structure is a more general term and may be applied both in anhydrytic and gypsum rocks, without precise explanation of origin of the structure. For those anhydrite occurrences which origin may be explained by submarine flowage or slumping of sediments soon after they were deposited, the author applies the term "flow structure."

Within the Miocene evaporites from the area of the overthrust unit, numerous examples of the flow structures were found, especially in underground galleries of the salt mines at Bochnia and Wieliczka. There has been stated, that occurrences of flow structure are mainly connected with one marker bed, belonging to the IIIrd cyclotherm of evaporites. These sediments are known at Wieliczka as "layered green salts interbedded with clay and anhydrite," in the Bochnia vicinity they are called "clayey-anhydrytic shales with layers of crystal salt."

An example illustrated in Figure 1 shows the effect of submarine slumping of clayey-anhydritic layers which primary thickness may be estimated as high as some 30 cm. This structure by no means may be explained as tectonically disturbed structure. Anhydrite layers themselves do not display any features of enterolithic or flow structure, too.

Various types of flow structures are exposed along several meters long section of gallery Maylath at Wieliczka salt mine (Fig. 2). Some bottom surfaces of anhydrite layers are flat and even, whereas their top surfaces are uneven and waved, as the result of partial flowage of unlithified sediment.

In some layers (Fig. 3) one can observe gradual decrease in thickness or even lack of anhydrite. In another part of the same layer (Fig. 4) there occurs a conspicuous flow structure.

In Figure 5 uppermost anhydrite layer increases in thickness from left to right displaying very distinct flow structures. Another flow structures occur on the top surface of laminated anhydrite layer below.

Typical flow structure is illustrated in Figure 6. Very thin laminae of dark clayey material built axial parts of small anhydrytic folds. Flowage direction is from right to left.

In specimen shown in Figure 7, above very fine laminated anhydritic claystone, during flowage of sediment three layers of nodular anhydrite were thrust over one another. A surface separating anhydrite layers is crimpled, resembling some ripple-marks. Above the uppermost anhydrite layer thin laminae of clayey sediment were deposited in conformity with the top surface of anhydrite.

A structure illustrated in Figure 8 seems to be rather the

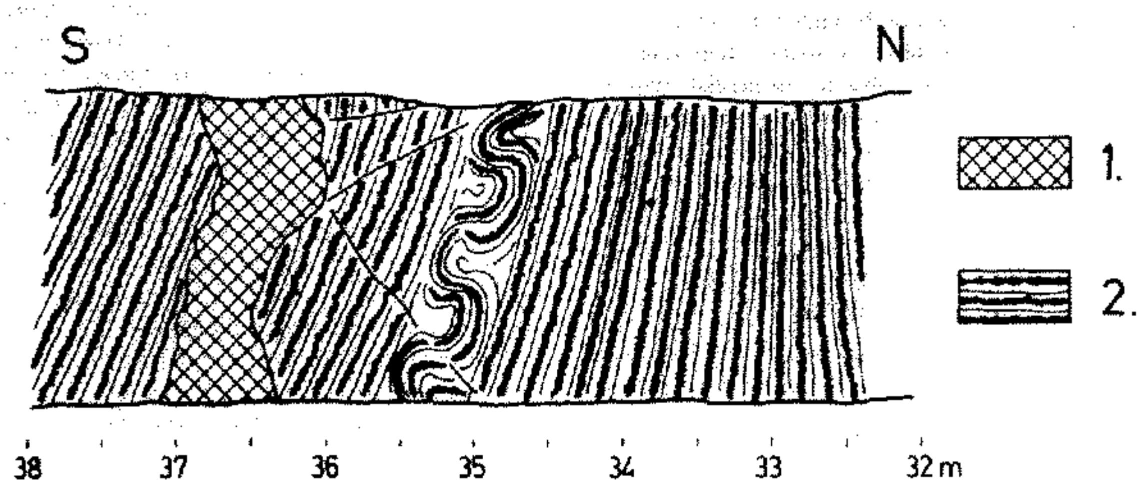

Figure 1. Bochnia salt mine, Level C-1, Gallery Wielopole (Courtesy of J. Poborski). 1—rock salt, 2—clayey-anhydritic shales.

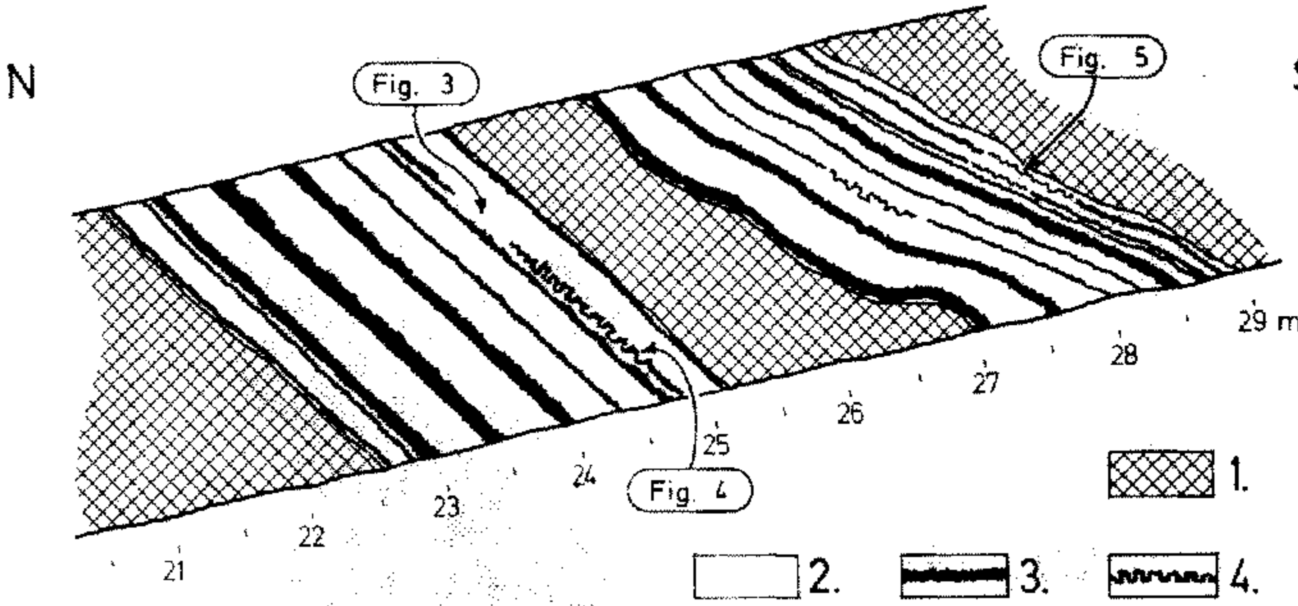

Figure 2. Wieliczka salt mine, Level 4. Gallery Maylath. 1—rock salt, 2—siltstone, 3—anhydrite, 4—flow structure.

Figure 3. Gallery Maylath, close up photo of layers.

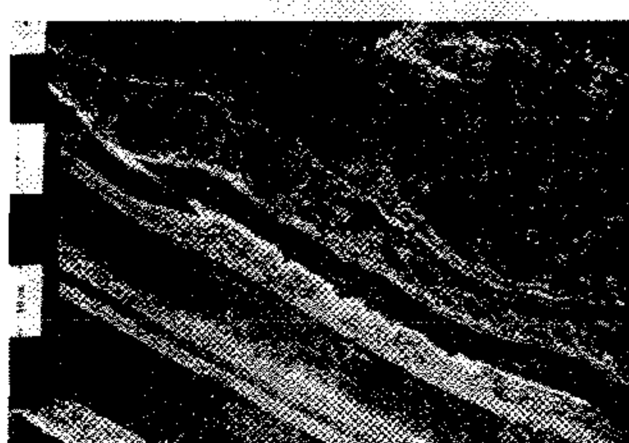

Figure 5. Gallery Maylath, close up photo of layers.

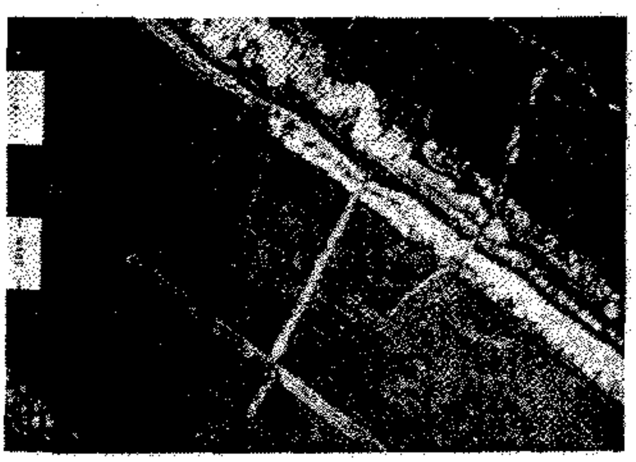

Figure 4. Gallery Maylath, close up photo of layers.

result of differential loading than due to flowage of unconsolidated anhydrite. Boundaries of laminae are vague and disturbances decrease downwards.

FINAL REMARKS

Examples presented above provide an evidence of synsedimentary origin of some deformational structures in anhydrite layers. Slumping and flowage of both sulphate and clayey deposits took place in plastic or semi-fluid state. This was possible along the southern zone of sedimentary basin, where uneven and unstable substratum of deposition underwent the most intense influence of the Carpathian movements.

Since enterolithic structure may be caused by various geologic agents, e.g. due to recrystallization of sulphate

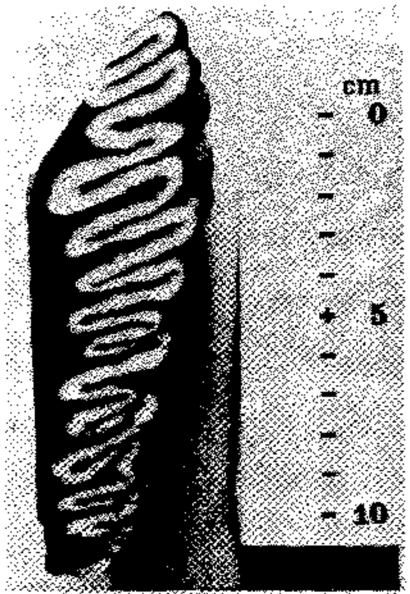

Figure 6. Bore-hole Lapczyca ML-3. Core depth 490.0 m.

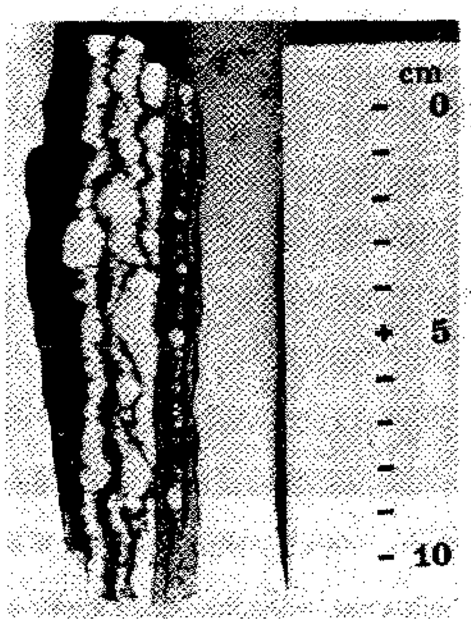

Figure 7. Wieliczka salt mine, Level 4. Chamber Grubenthal.

sediments, origin of the flow structure may only be explained by submarine slumping or flowage of unlithified sediment.

Detail study of anhydrite structures may be helpful in reconstruction of sedimentary environment of evaporites.

DISCUSSION

A. Whittaker:

Question. Could the author please say what type of carbonaceous material is present in the sulphate-rich (anhydrite) sequence and whether the fine-grained sediments are dolomitized at all? The

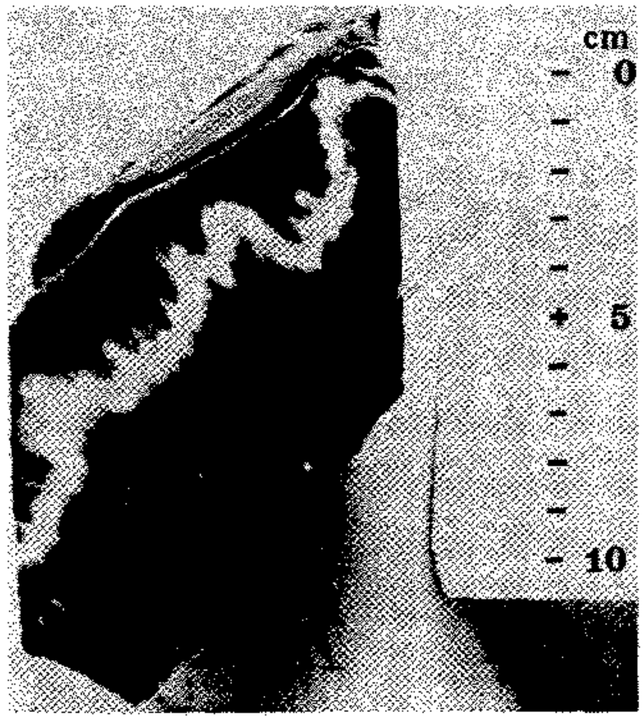

Figure 8. Bore-hole Lapczyca ML-3. Core depth 438.5 m.

sediments appear to have some of the features of a sabhka sequence, which implies relatively quiet (low energy), shallow water intertidal or supratidal deposition. Would the author care to comment on this, please?

Answer. Fine-grained sulphate rocks consists of pure anhydrite associated with clayey sediment. The latter is composed of clayey minerals with admixture of calcite. Dolomite is not present within discussed section. Sulphate deposits presented in this paper display many features of sedimentation which usually takes place within a widespread basin with restricted circulation. In the southern margin of the basin sedimentation of evaporites took place with considerable admixture (supply) of terragenic material from the Carpathians.

H. Borchert:

Questions. 1) Do you think that the differences in thickness of about 60 m of gypsum in the northern part of the Miocene Carpathian foreland basin and of 10–15–20 m of anhydrite have to be related to primary facies differentiations? 2) What is the calculation about the depth of the original transition of gypsum beds into anhydritic layers in the southern deeper parts nearer to the unstable conditions of the Carpathian orogenetic region?

Answers. 1) These differences in thickness for sure are of primary origin in the sedimentary basin. 2) Present position of this transition zone is estimated as deep as 100–200 m. During sedimentation it must have been situated not so deep, what is indicated by the thickness of later deposited clayey sediments overlaying evaporites. 3) The southern part of sedimentary basin of evaporites was situated upon the folded flysch sediments. After evaporites had been deposited, the whole set of sediments (including overlaying clayey sediments) underwent an intense tectonic disturbances and further erosion. This caused that sulphate sediments from the southern part of the basin was depleted almost entirely and the reconstruction of sedimentation is very difficult.

D. H. Kupfer:

Question. In your last slide of folded anhydrite I observed what appeared to be axial-plane cleavage on which shear folding occurred. Is this possible?

Answer. Each of small anhydrite folds displays a symmetrical patterns, i.e. inside the fold plastic deformations did not obscure the continuity of thin anhydritic and clayey layers. There is no cleavage.

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