ANN. INST. GEOL. PUBL. HUNG. | vol. LXX. | Budapestini, 1987

Proceedings of the VIIIth RCMNS Congress

# DEPOSITION ENVIRONMENTS OF THE WIELICZKA SALT DEPOSIT

by

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The Wieliczka salt deposit is part of a vast area of evaporites which developed during middle Badenian time on the Carpathian foreland. The stratigraphic position of the Wieliczka salt is based on foraminifers (LUCZKOWSKA, 1978). The salt deposits are underlain and made up by the zones with: *Candorbulina suturalis* (Moravian), *Uvigerina costai* (Lower Wielician) and are covered by the *Neobulimina longa* zone. The sedimentation of salt was preceded by marine fine-grained deposits with sporadic marine conglomeratic fans along the southern margin of the basin. The material of these fans derived from the Carpathians (ALEXANDROWICZ, 1965; DOKTOR, 1983).

The development of the evaporites was rendered possible by:

*1* partial cut off the western part of Paratethys from the eastern part—an open sea,

*2* constant influx of salty water from the East joined with intensive evaporation (GARLICZKI, 1979).

The salt accumulated in a narrow furrow situated in the southern part, the above mentioned evaporitic basin (Fig. 1). The depth of this furrow just before salt sedimen-

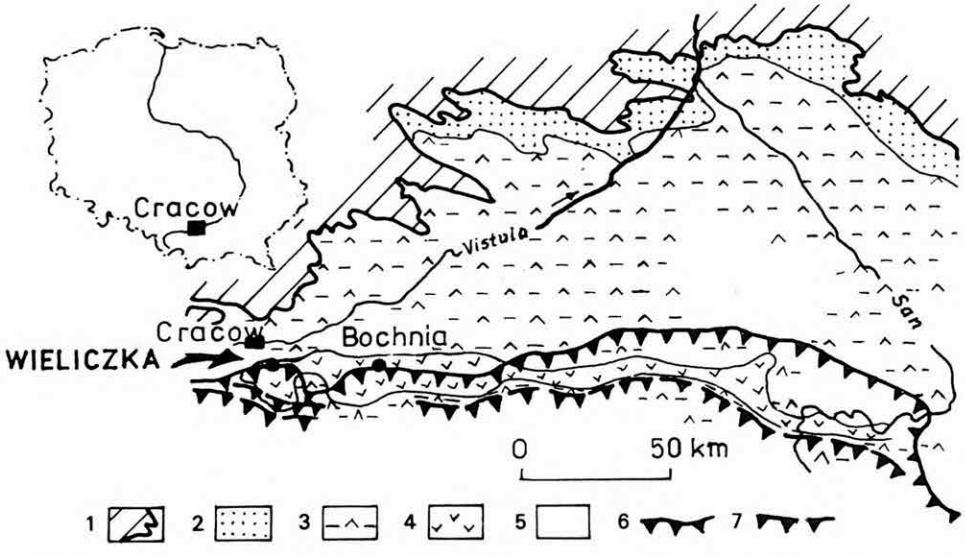


*Fig. 1.* Facies map of the Middle Miocene (Badenian) evaporites developed in the fore Carpathian depression (after GARLICKI, 1979; modified)

*1* Mesozoic and Palaeozoic substrate, *2* littoral facies, *3* sulphates, *4* chlorides, *5* region without evaporites, *6* present-day boundary of the Carpathian overthrust, *7* supposed boundary of the Carpathians at the Badenian time

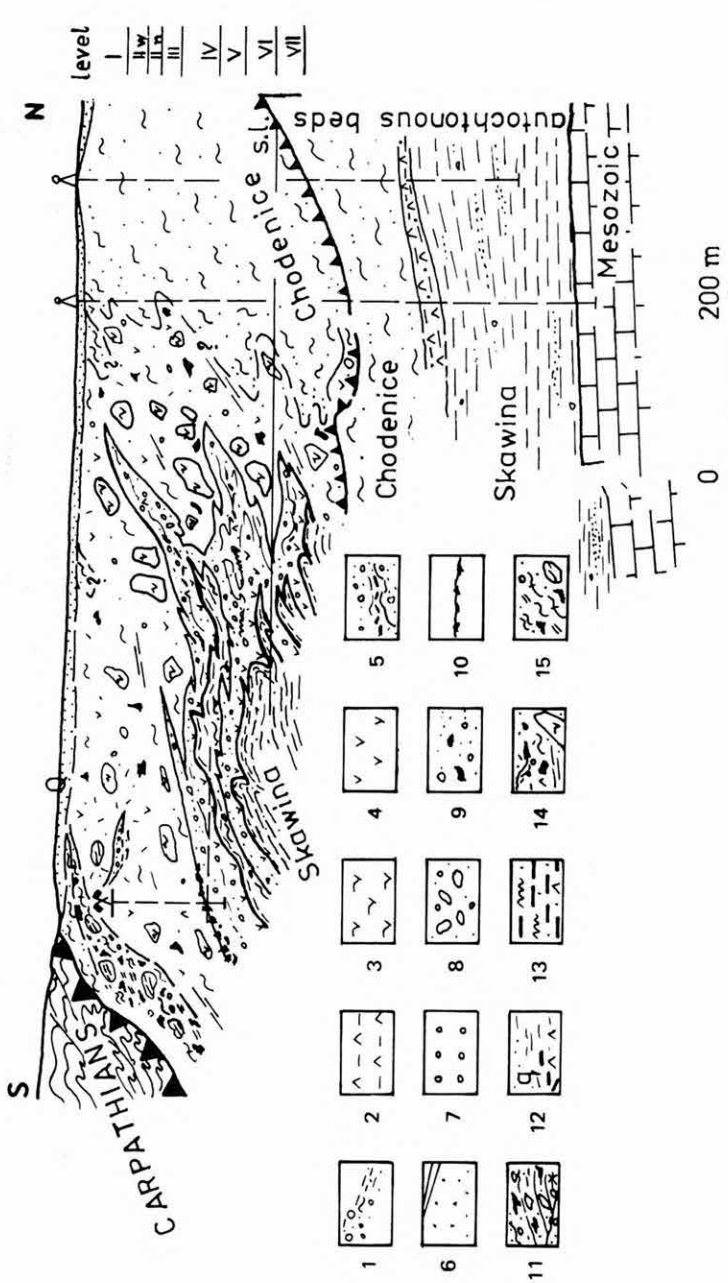


*Fig. 2.* Transverse section of the Wieliczka Salt Mine (after GAWEL, 1962; GARLICKI, 1968; modified)

*1 Stratified Member: 1* Littoral facies, *2* sulphates, *3* southern salt, *4* lower salt, *5* upper salt (Spisa); types of Spisa salt *6* pelitic laminated, *7* white (pure), *8* conglomerate, *9* gravelly saltstone, *10* breccia, *11* breccia and conglomerate with corals, *12* sand, clay, anhydrite, *13* mudy anhydrite intercalation. 11 *Chaotic Member* (olistostromes): *14* Zuber with huge salt boulders and lenses of redeposited salt, *15* upper breccia of Miocene and Carpathian rocks but without salt

tation was established on several hundred metres on the basis of foraminiferal assemblages (LUCZKOWSKA, 1978). There is no evidence of shallowing of the basin, the salt was deposited in a deep basin according to the model, proposed by SCHMALZ (1969). Moreover, in marly layers within the upper part of the salt sequence there were found pelagic foraminifers similar to those occurring beneath the salt. It shows also that in the upper part of the basin, salinity was, at least periodically, normal. On both sides of the chloride facies sulphate and littoral (fossiliferous) facies developed. These facies belts are more narrow on the southern margin then on the northern one. Along the uplifted part of the Carpathians there were probably subaerial cones of coarse material redeposited from the Carpathians. A problem which is still unsolved is the relation ship between the Wieliczka salt and the folded Carpathians. The main reason for it is a lack of preserved contact of the Wieliczka salt and the underlaying marls with their primary substratum. The whole sequence was striped off (Fig. 2). In our paper in the first place is presented idea that the Wieliczka salt basin was developed only on the Carpathian foreland (Fig. 3.). According to another idea the Wieliczka salt basin embraced also the marginal Carpathians part and Lower Badenian together with salt sediments was deposited not only on the platform but also on the Carpathians. This possibility is shown in Fig. 3a.

The Wieliczka salt sequence was deposited the central part of the furrow. It is composed of two units: the Stratified Salt Member, and the overlying Salt Breccia Member. The profile of the Stratified Salt Member begins with layers of coarse to finegrained salt originated from precipitation (Fig. 3, I). There are secondary intercalations of marls with anhydrite and layers of gravely mudstones with fragments of the Carpathian rocks (GAWEL, 1962; GARLICKI, 1979). The latter sediments can be an evidence of a tectonic movement within the area of the Carpathians. The next stage corresponds to a quiet period when several metres of pure coarse grained salt was precipitated. Higher in the profile together with salt also quartz grains and detritus of fauna have been deposited (lower part of Spisa salt). The salt displays often bands of dark and light colour and thin intercalations of mudstone with anhydrite. The layers are often strongly folded. These structures may be due to synsedimentary slumping as well as to tectonism. During this stage the first layers of redeposited salt with distinct gradation appear. The redeposited salt and slumping can be proofs of an another period of tectonic disturbances which embraced at that time not only the Carpathians but also the southern part of the salt basin. In this southern part during the fore-mentioned stages, mainly thick (up to 30 m) fairly pure laminated salt was deposited. As subordinate to this one there were e.g. stained-glass type salt, dolomitic salt, and coarse grained salt intercalated by marls. These salt deposits are known from redeposited boulders only and their primary pattern is unknown. This stage (lower Spisa salt) is terminated by a complex of mudstones, finegrained sandstones with anhydrite-halite cement and layers of anhydrite. There are fragments of carbonized flora. The clastic sediments contain a wide variety of primary structures (cross-bedding and ripplemarks) as a result of current action. Often they are disturbed by convolution. Current direction was approximately from the West to the East along the axis of the basin.

After the deposition of the clastic sediments once more salt precipitated but with a considerable amount of intercalations of redeposited salt lenses or layers (upper Spisa salt). Exclusively redeposited salt terminate the sequence. During that time the southern part of the salt basin was submitted to uplift, partial desintegration and salt clasts with barren rocks were deposited by density flows to the central part of the basin (Fig. 3, II). As an effect in the Wieliczka salt mine deposits similar to those of

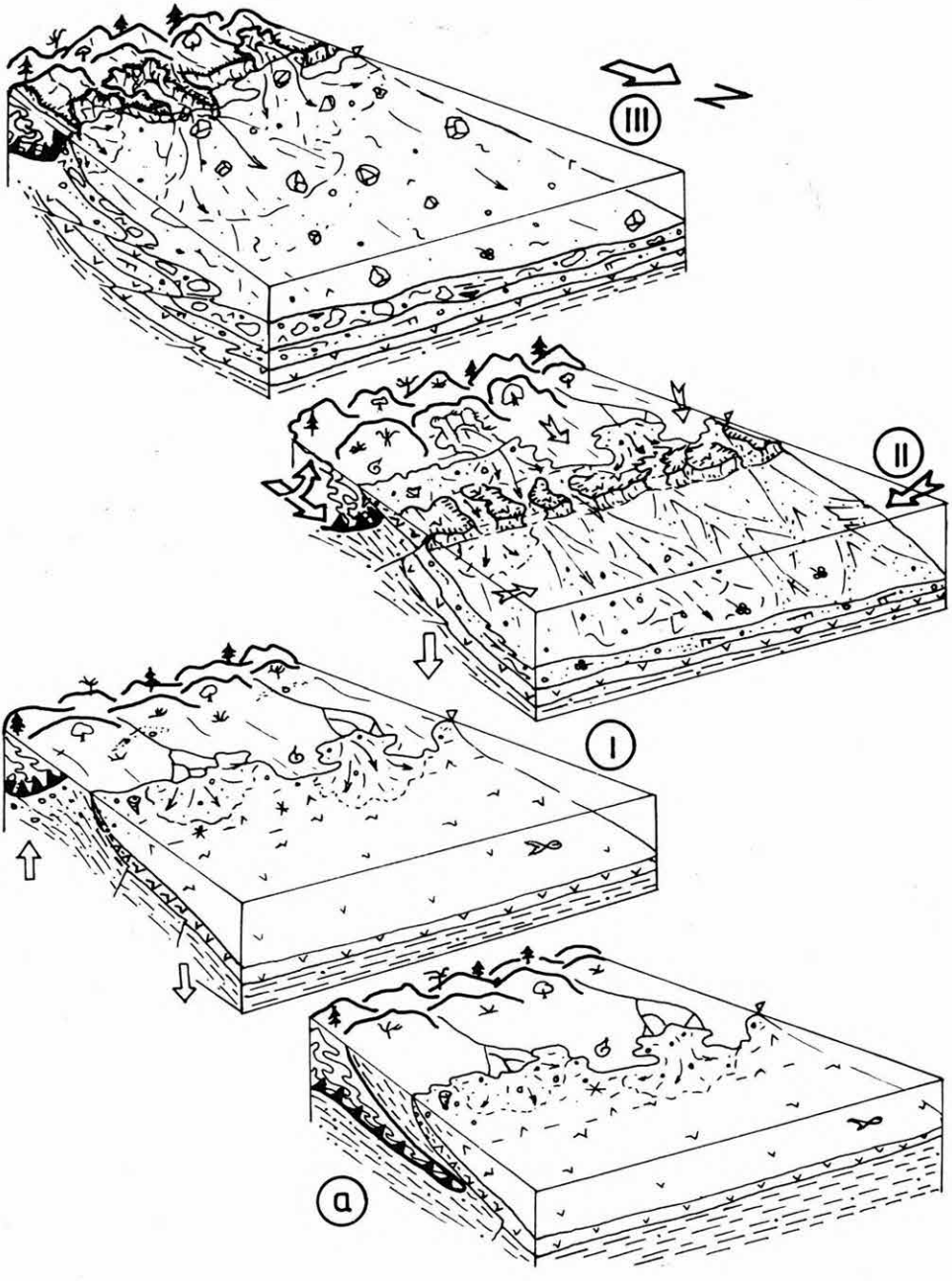


*Fig. 3.* Sedimentation model of Miocene salt formation at Wieliczka (for explanation see Fig. 2)

submarine fans can be distinguished with internal, middle and outer fan associations. The interfingering of these associations due to the lack of continous exposures are not always clear. The internal part of the fan situated in southernmost area of the mine consist of alternated gravelly saltstones, laminated sandstones and conglomerates deposited from various gravity flows (Fig. 4a). The sequence shows an overall coarsening upward tendency. These sediments are built up of redeposited salt fragments with subordinate amounts of pebbles of Miocene mudstones and marls, and also of Carpathian rocks (sandstones, shales, variegated marls, exotic rocks). Characteristic is the disappearance of the Carpathian rocks along current direction. Locally the whole sequence is terminated by cones of sedimentary breccia (Fig. 4a). This breccia is dominated by clast supported conglomerates which at places pass laterally into matrix supported ones. Those beds lack pronounced bedding plane separation and display overlapping contacts. The breccia is polimictic, composed of unsorted pebbles of rock salt and in smaller amount of the Miocene marls, anhydrite, Carpathian sandstones and shales. Very characteristic is the sporadic occurrence of coral fragments (Coenocyathus). The breccia might have be on deposited by avalanche grading into high density turbidity currents. The conglomeratic cone very rapidly wedges out as well in current direction as perpendicularly to it.

Sediments exposed in the central part of the Wieliczka Salt Mine are interpreted here as representing deposits of middle fan (Fig. 4b). The main differences are lack of rocks derived from the Carpathians, lack of sedimentary breccia and greater thickness of conglomerates. They are matrix-supported. Both matrix and clasts are made up by salt. The conglomerates usually grade upwards into laminated salt sandstones. These bodies are interpreted as deposits of high and low density turbidity currents. The conglomerates overlie crude laminated salt layers which do not show clear evidence of redeposition and a part of them may represent salt deposited by precipitation. The central part of the fan is remarkbaly aboundant in carbonized plant remnants although smaller amounts of these occurs in the whole sequence of the salt deposits. These plants belong to the so-called younger mastixioid floras known from the European Miocene, which comprise a number of plants of Mediterranean ecology (ŁAŃCUCKA—ŚRODONIOWA, 1984). Only one genus—Tetraclinis—associated with clearly arid biotope was found. The flora of Wieliczka consists of 136 taxons, with predominance of arboreal plants: dicotyledous and coniferous trees or shrubs, distinctly few herbs (Ceratonia, Myrtus, Olea, Nerium, Paliurus, Pinus, Pistacia, Vitis, Juniperus etc). A distinct predomination of plants from the higher elevations could be stated allochtonous fauna rich of phytophagous small land- and fresh-water gastropods (Helix, Pupa, Planorbis) extracted from the Spisa salt (KOWALEWSKI, 1933) indicate the conditions of the surrounding land area.

The distal part of the fan display generally decrease in clast size and in thickness of layers but increase in quantity of non-salt grains (quartz, cherts, fragments of fauna and glauconite). The salt fan sediments described above are covered by huge debris flow deposits (Salt Breccia Member) of olisthostrome type derived mainly from the southern part of the salt basin (KOLASA and ŚLĄCZKA, 1984; 1985), Fig . 3. III. The boundary is sharp and at places there are traces of synsedimentary erosion. Sometimes, however, on the top of the fan deposits there is preserved a thin layer of marl with poor planktonic foraminiferal assemblage. The debris flow deposits contain a poorly sorted collection of pebbles and boulders (salt, Badenian barren rocks, Karpatian rocks) embedded within finegrained matrix. The largest (up to thousend of cub. m.) and most common are salt boulders. The matrix is composed of marly of clayey mudstone with scattered small fragments of salt crystals (Zuber). In some places

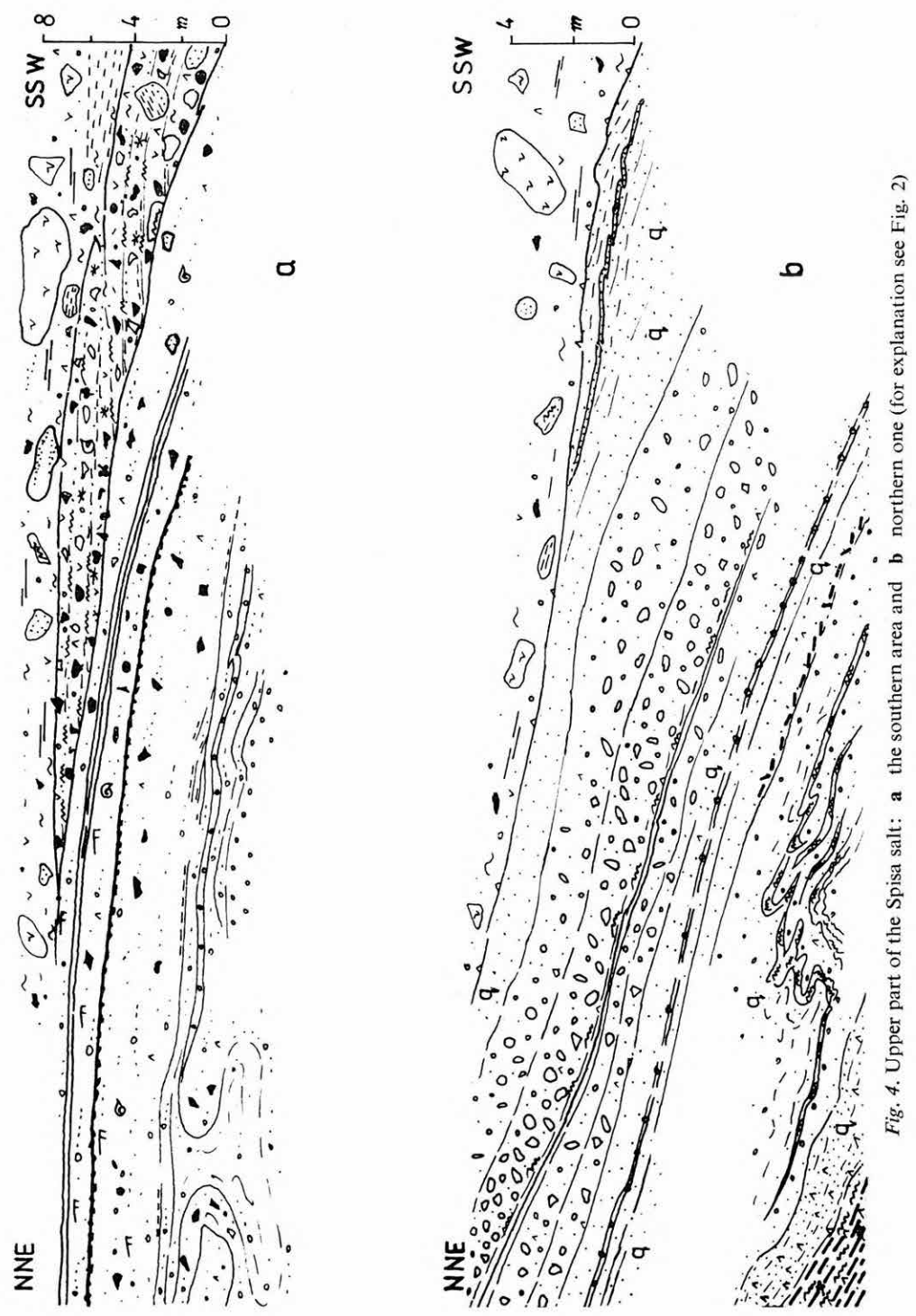


*Fig. 4.* Upper part of the Spisa salt: **a** the southern area and **b** northern one (for explanation see Fig. 2)

debris flow deposit pass upwards into clast-supported conglomerates and finally into laminated saltstones.

The Chaotic Member is terminated by another debris flow deposit with lack of rock salt but abounding in rocks derived from the Carpathians. The debris flow deposits are covered by marls shales, and sandstones of open basin with planktonic foraminifers (ŁUCZKOWSKA, 1978).

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