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PALEOCLIMATIC INTERPRETATIONS CONCERNING THE SALT-BEARING BADENIAN FROM PRAID-SOVATA AREA AND THE IMPACT OF THE SALT ON THE ENVIRONMENT

-Abstract of the PhD thesis-

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(Pages appears as the original thesis)

Key words: salt, Praid, Sovata, paleoclimate, Badenian, pollen, coexistence approach, clay minerals, Corund River, salinity.

Chapter I. Generalities

The Praid-Sovata hilly region is situated in the eastern part of Transylvanian Basin, and it represents a transition zone between Târnavelor Plateau and volcanic chain Călimani- Gurghiu-Harghita from the Eastern Carpathians. Praid Basin (including the small basins: Corund, Ocnelor, Praid, Sovata, Săcădate) has a longitudinal position relative to the axis of Gurghiu Mountains.

More detailed studies on the geology of the region were made by Bányai (1933), Oncescu (1952), Treiber (1953), Nagy (1956), Götz (1956), Zotta (1964). Within Salt Mine from Praid the deposit description was realized by Horváth (2002, 2004). Detailed geomorphological surveys were reported by Mac (1972) and Irimuş (1998). On Praid palynology analysis was performed by Petrescu and Bican-Brişan (2005). Stability solutions on mining works and prevent groundwater infiltration into Praid mine were provided by Deák et al. (2007, 2008).

Researches made in the region were focused mainly on studying the two deposits of salts from Sovata and Praid, and fewer studies have been made to postsalifer deposits. The existence of diapirs in eastern Transylvania were analyzed from a broader perspective (as a part of structural forms of salt from the Transylvanian Basin) and less attention was consacrated to the influence of the Eastern Carpathians, so the works of Krézsek and Bally (2006) and Szakács and Krézsek (2007) can be considered of an major importance, providing us a new theory about the causes of existence of an emphasized dipir in the region.

Chapter II. General geological aspects of the Transylvanian Basins

Were separated (Balintoni et al., 1998) seven sedimentary basins (four permo-mesozoics and three tertiary). As individual sedimentation basin Transylvania area begain his activity in late Cretaceous (Maastrichtian)-Paleocene. The cause of depression area formation was the extension due to circumscribed subduction phenomena (suction effect). At the end of this effect, the extension of basin area stopped too. During the Miocene the traction forces from the east are dominated and therefore over the thinned crust thick and variated sediments were deposited. When the front of subduction reached the edge of the Eastern Europe plate, very rigid, compressive forces in a westerly direction became predominant. (Bada şi Horváth, 1998).

Two stages can be distinguished in the evolution of the basin:

1. the first stage comprises Paleogene and Lower Miocene
2. the second phase held in Badenian-Pannonian, in the latter stage the subsidence being more active.

At the beginning of Paleogen partially- the northern and western parts- entered under marine waters, undergoing a gradual lowering and sedimentation under this waterbeds. In the Neogene -when along Transylvania's territory was installed Central Paratethys Sea- has been finalizing the Transylvanian Basin.

In Lower Badenian a strong transgression took place due to stirian movements. Commencement of subsequent magmatic activity in Eastern Carpathians and Apuseni Mountains led to the deposition of volcanic tuffs, wich form the Dej Formation. Dej tuff level is composed of dacite tuffs banks, it's spread throughout the Transylvanian Basin and is a good stratigraphic marker at surfaces and in boreholes. (Ciupagea et al., 1970).

The salt level –Ocna dej Formation- place over Dej tuff. The salt appears to surfaces in marginal areas because of diapiric anticlines from intensely folded area. There are two diapiric alignments: one in the west (Ocna Sibiu, Blaj, Ocna Mureş, Turda, Cojocna) and one in the east (Odorhei, Bențid, Praid, Sovata, Gurghiu, Sărățel) (Ciupagea et al., 1970). The age of the salt is estimated at 14 Ma (Badenian age). Over salt formation is the Radiolarian Scales Formation and Spirialis Marls Formation.

In the Sarmatian (ss), which includes Lower Bessarabian and Volhinian was a tendency of decrease salt content (up to 18-20 g/l). In that time a large volume of sediment have accumulated. Both in Badenian and Sarmatian there were favorable conditions for hydrocarbon formation.

In Pannonian continued the sweeten of the water. There was an extension of the surrounding area and an increase of water flow stream, which led to the transformation of marine waters in brackish water (in Sarmatian) and then to a lake (in Pannonian). The water of lake receded in the Bârsa- Borsec Depression behind Eastern Carpathians.

Chapter III. Geological characterization of the region Praid-Sovata.

Salt massif from Praid (called “The salt back”, “Salt Hill”, “Salt Mountain”) appears on the surface whit a quasi-circular shape. Outcrops in the salt block are located in the southern half and the two sides of Korond stream and a valley to the east. In outcrops are observed the presence of salt, clay and salt mass. Geological map of region is shown in figure 1.

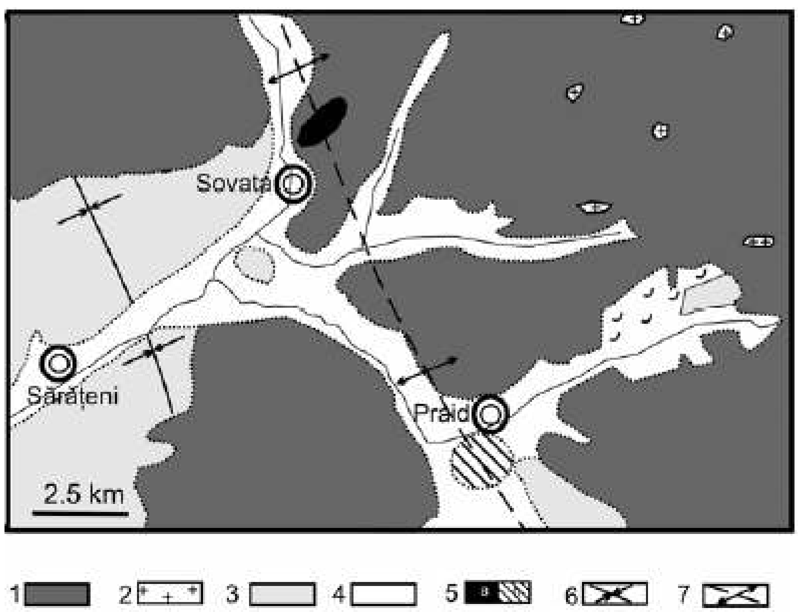


Fig. 1. Geological map of the region. (according to the geological map 1:200000 Odorhei) Legend: 1.- Neogene volcanic breccia and agglomerates; 2.- Pannonian amphibole andesite; 3.- Pannonian sands, clays and conglomerates; 4.- Quaternary deposits; 5.- Salt diapirs; 6.- Syncline; 7.- Anticline.

The salt massif from Sovata has an oval outline, elongated toward southwest-northeast. Most of its surface is covered by woods, infields and buildings belonging to Sovata . On the back of the salt massif there are a number of sinkholes, which resembles to the limestone karst phenomena.

Fig.2. Salt outcrop in Sovata

In addition to these two salt massifs, in the region are cropping out Pannonian deposits and volcanic breccias and agglomerates. Pannonian beds containing congerias, hydrobias, ostracods (Nagy, 1956). Microfaunistic research showed that based on the correlation of ostracods found here with those determined in Pannonian of Hungary, only Lower Pannonian is present (Zotta, 1964).

Nagy (1956) has separated here three horizons:

1. The lower horizon, composed of gray marls, with a thickness of 2-3 m
2. The middle horizon, with reddish and grey sandstones-sands layers. In some places it has diagonal bedding and can be found lens-like sandstones concretions (larger or smaller lens)
3. The upper orizon, in which thin layers of sandstone-sands and fine sandstones alternating with layers of marls, which have different thickness (1cm to 10 cm).

The Pannonian subsides eastward beneath the mass of volcanic breccias and agglomerates. They form a narrower strip along the Nagyvíz valley between Praid and Ocna de Sus, and appear in east too as larger or smaller patches. It consists of greenish-blue or gray clay, of yellowish or reddish sands, wich sometimes pass into gravel with elements of quartz or crystalline schists (Götz, 1956).

The volcanic breccias extend on most part of the region, exceeding 100 m in thickness. They differ from agglomerates to the area in their hardness and greater compactness, they are more homogeneous. They have diverse litology, but as the woods are covering large areas of where these rocks occur, for instance it is impossible to make sharp distinctions among the different types.

Götz (1956) separated the following breccia-types (in order of there position):

1. Andesitic volcano-breccia with hornblende
2. Andesitic volcano-breccia with hornblende and pyroxene

3. Andesitic volcano-breccia with pyroxene

4. Andesitic volcano-tuffs and breccia with hornblende

It was reported the presence of tuffites, dykes and andesite lava flows.

At Praid in 1965 and 1966 there were placed two boreholes (5MP Praid and 6MP Praid) and one in Ocna de Sus in 1965 (MP Ocna de Sus). They intercepted Pannonian, Sarmatian, Badenian beds and crystalline. Their limits are estabilished at the following depths.:

5MP Praid:

Pliocene(Pannonian)/Sarmatian……………………………494 m

Sarmatian/"Buglowian" (Lower Volhinian)………………..894 m

"Buglowian"(Lower Volhinian)/ Badenian………………...1088 m

6MP Praid:

Pliocene (Pannonian)/ Sarmatian……………………………1088 m.

Sarmatian/"Buglowian" (Lower Volhinian)…………………1624 m

"Buglowian"(Lower Volhinian)/ Badenian (salt)…………....1700 m

MP Ocna de Sus:

Pliocene (Pannonian)/Badenian……………………………..220 m

Badenian/crystalline………………………………………2800 m

Salt was intercepted between 1850m-2795m levels.

Note that some earlier work and documentations (especially in oil field) still use the term "Buglowian" as a transitional stage between the Badenian and Sarmatian, but in reality is Lower Volhinian. All drilling proved to be out of interest in terms of gas extraction.

The volcanic activity on Gurghiu Mountains has left its mark on the region's geological evolution. Volcanic rocks in these mountains are monotonous both in petrographic and chemical terms. The andesits are predominant and the most common types of rock are andesits with pyroxene. The magmatic activity in Gurghiu Mountains migrated too from north to south. (Seghedi et al., 2004).

Chapter IV. The Badenian salt

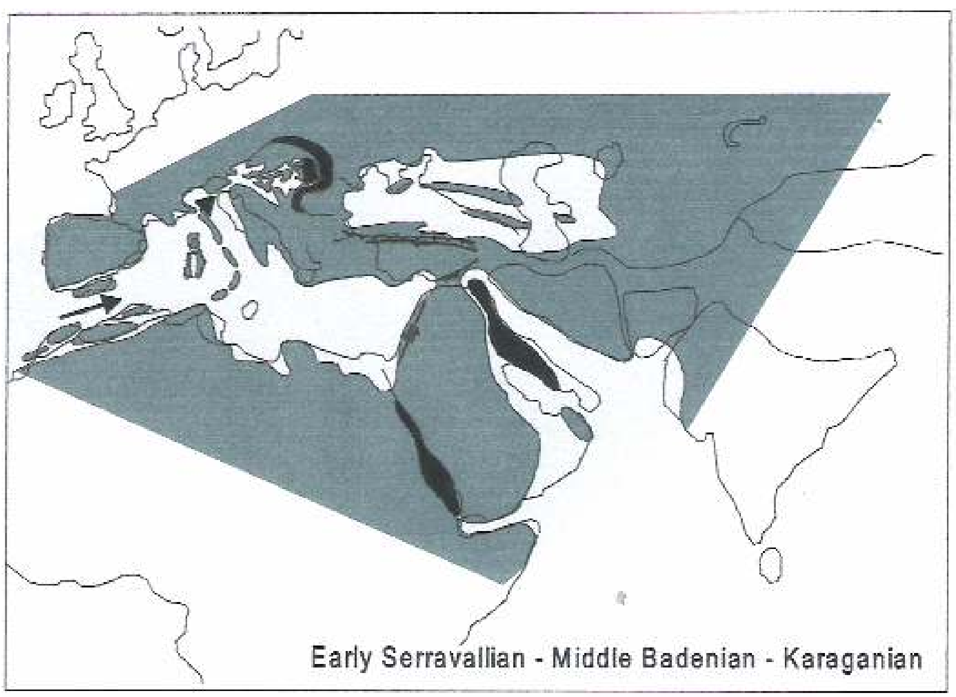


Fig.3. The salinity crisis in the Paratethys. Evaporites are marked with black (in Rögl 1999)

Salt deposition conditions in the Transylvanian Basin.

Over time, Paratethys seas (Oriental, Central, Occidental) had different sea conditions and there have been changes in the communication between them and the Mediterranean and the planetary ocean. The regression of Serravallian closed the seaway between the Mediterranean Sea and Indian Ocean (Fig.3). Central Paratethys, Carpathian Foredeep and the Transylvanian Basin became isolated with tick evaporitic deposition. (Rögl, 1999).

Climatic, tectonic and paleogeographic conditions most to be met for evaporitic deposition. Several factors control the accumulation of evaporits: temperatures, the concentration of solution, the relationship between concentrations of different salts with each other, etc. Theoretically a normal succession begins with carbonates and sulphates, than following NaCl, and ending with Ca and Mg salts.

Ciupagea et al. (1970) argues that there was a system of lagoons, with various sizes and reduced depths. Slow subsidence of the bottom of lagoons explains hundreds of meters thick deposit of salt. These lagoons communicated among themselves and with the sea.

Another theory (Dragoş, 1969) maintains that the Transylvanian Depression was not just a shallow lagoon but a marine basin. A slow subsidence of the basin allowed the evaporatating precipitation and an accelerate subsidence allowed the sedimentation of a deposit of over 3000 m that does not indicate that it would be a system of lagoons, but a veritable marine basin. Because salt is spread throughout the basin (inside too, not just at edges), lagoons theory becomes inadequate (Ilie, 1958)

Water communication between worldwide oceans at the outside of the Carpathians and the sea from Transylvanian Depression is controversial. A first hypothesis maintains that the Transylvanian Basin was related to the passage Mures with the Pannonian Basin, and possibly through the northwest, in the Apuseni Mountains. Lack of salt deposits in the Pannonian Basin is attributed to an intense water movement and does not allow water concentration and precipitation of salts. (eg. Dragoş,1969). The other hypothesis explains the presence of salt in the basin due to the communication with the sea outside Carpathians by a large seaway at Olt valley and west of it. After overcoming the region beyond the Eastern Carpathians, the concentrated seawater streams surrounding the Transilvanian lagoon, advancing first the Maramures Basin, and then the stream returned to south and cross the Olt valley. (Paucă, 1967; Balintoni and Petrescu, 2002). The thick of dacite tuff of Ocnele Mari region is explained by either the marine transport of volcanic ash from the Transylvanian Basin (followers of existence of an contact with extracarpatian sea) or by the existence of a volcanic apparatus in the region (if it did not exist a contact between Transylvanian Basin and extracarpatian sea).

A salt has termophilic or cryopholic character according to the presence in the complex solution, in certain proportions, of the other salts. The simple solution of NaCl or NaCl predominated solution is cryophil, so is cold precipited. If in NaCl occurs K, Cl, H and Mg, the character of NaCl is changed: if KCl exceeds a certain percentage, the solution becomes termophilic. The salt outside the Carpathians (with earlier age of Transilvania salt) , seawater has depleted in K and Mg ions, and the NaCl solution gained a cryophil character and precipitated at a lower temperature. (Dragoş, 1969).

A more recent study (Krézsek, Filipescu, 2005) of sequence stratigraphy (based on seismic profiles, well logs, cores and outcrops samples correlated by micropaleontologic based analysis) shows that the Miocene Transylvanian Depression evaporates were deposited in a tectonic stable basin, with a constant rate of subsidence in a deep-sea environment.

Mrazek (1907) released the tectonic of diapirism theory and the form of anticlines structures of salt, salt deformation is caused by tangential centripetal forces. Other explanations for the formation of diapiries in Transylvanian Basin: the mechanism of folding should be linked to molecular forces, namely increasing of the volume of salt masses, plastic flow of salt to areas of least resistance, folding due to the tangential forces within the basin (centrifugal forces). A new theory (Szakács and Krézsek, 2005) emphasizes the effect of volcanic activity in the Eastern Carpathians on the formation of salt diapirs from the eastern Transylvanian Depression. The tectonic aspects resulted from the volcano-basement interaction, which were combined with those related to regional tectonic processes involved in the evolution of the Carpathians and the Transylvanian Basin.

Visarion et al. (1976) separated seven main structural types in which salt is present in the Transylvanian Depression, one of these is a daipiric fold (one or more bundless of linear folds with salt cores, created due to tectonic forces and isostatic factors) In some areas salt passes through cover, in the others it remained in criptodiapir stage. (Fig.4). Association between anticlines-diapir dome was established in Ocna Mures and between Sărățel and Corund.

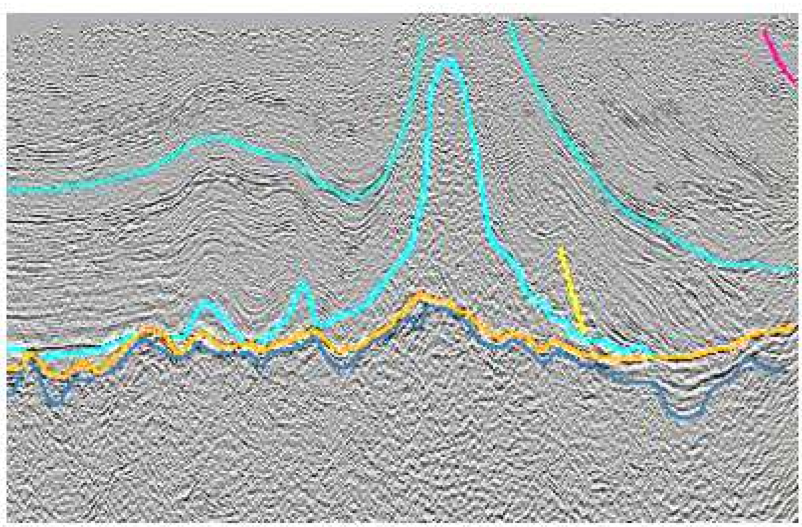


Fig.4. Dipair salt formations pass through over cover in eastern Transylvania (seismic profile). Colour key: : – crystalline, –Dej Tuff, – salt cap, –Sarmațian-Pannonian limit – fault (in Falk, 2007)

The Badenian salts from Carpathian region have in basement and are covered by deep-sea deposits. (Peryt). In Carpathian Foredeep the Badenian evaporites are placed at the bottom of the NN6 zone. During from Early to Middle Miocene evolution of the Carphatiam Foredeep, were identified two moments of salt formations: Early Burdigalian and Late Badenian (Ślączka şi Oszczypko, 2002). In the Northern Carpathians Foredeep the Badenian evaporites were precipitated in a salina type basin, which dynamic sedimentation was controlled more by the climate and less by the sea level fluctuations. (Bąbel, 2004).

Evaporites are chemical-formatted rocks, separated by hipersaline solutions with progressively increased concentration. Salt appears crystallized as cube in different size (crystallized in cubic system). It is colorless, glassy and white. The natural colors is white. Because of inclusions (penetration of allochromatic pigments in crystal lattice) it can get different colors. Stratification often has a rhythm in alternation of blackish-gray thin layers with dark gray open-white layers (Fig.5).

Fig.5 Rhythmic alternation of layers of salt (depending on purity in NaCl) at Salt Hill Praid

Mineralogical, XRD and EDX studies on salt in Sovata

Mineralogical studies that I performed on salt with microscopy revealed the existence of halite with the following minerals: clay minerals, carbonates, sulfates, quartz, silica, anhydrite, polihalit, biotite, chlorite, plagioclase feldspar. (Fig.6., 7., 8.)

In order to X-ray diffraction analysis, I collected 10 samples from "Salt Mountain" of Sovata. The analysis was realized between an interval of $2\theta = 3 - 90°$, with a Briker D8 Advance type diffractometer with geometry monochrome in θ - 2θ, equipped with a Cu-kα1 tube, with wavelength $\lambda = 1.5405$ nm. Data acquisition was performed with a step of 0.02° and 3 sec/step.

Each sample was subjected to record both after drying and after glycolation. (Fig.9). It has not been observed differences before and after glycolation (Fig.10), therefore the indexing was performed on the samples before glycolation. Database PDF-2, Match! program and EVA program (part of the diagrams) was used to identify minerals.

Fig.6.a. Anhydrit with cleavage at 90^o (N+, 45X)

Fig.6.b. Anhydrit with cleavage at 90^o (1N, 45X)

Fig.7.a. Tabular crystals of anhydrite, section S8, Sovata (N+, 35X)

Fig.7.b. Tabular crystals of anhydrite, section S8, Sovata (1N, 35X)

Fig.8.a. Tabular crystals of polihalit with good cleavage, section P7 Praid (N+, 35X)

Fig.8.b. Tabular crystals of polihalit with good cleavage, section P7 Praid (1N, 35X)

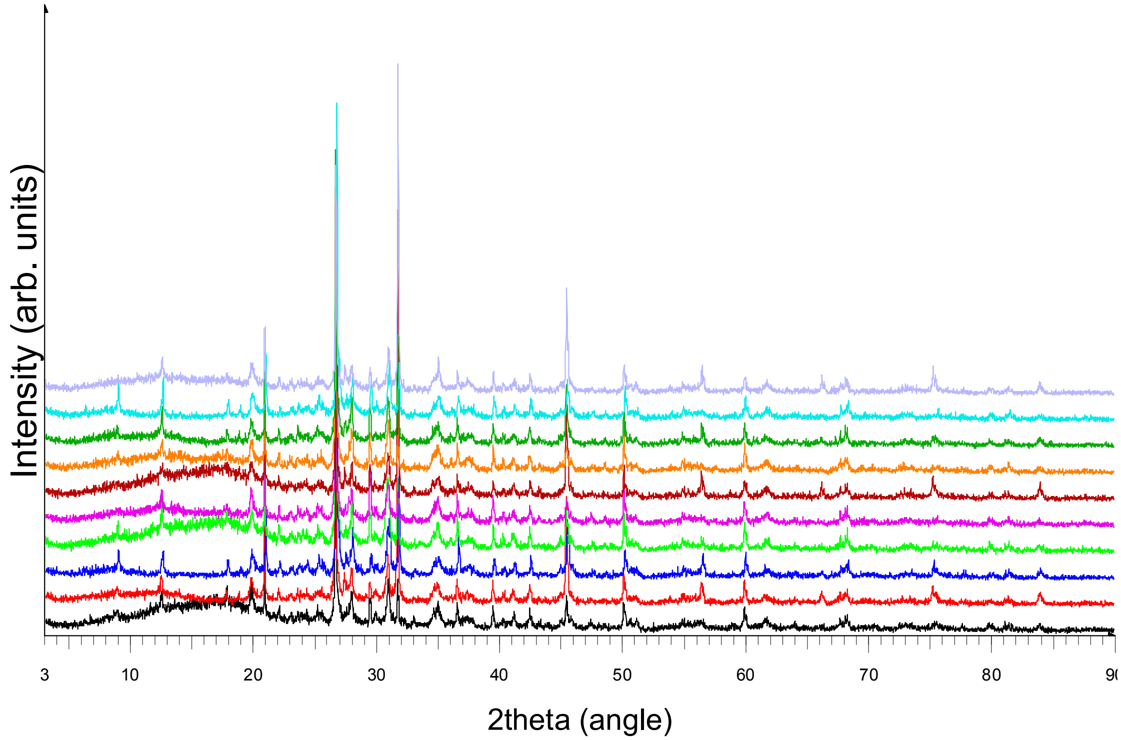


Fig.9. Overlapping samples Sovata1-Sovata 10 (neglycolated). Spectra are in ascending order from black (Sovata1) to purple (Sovata 10)

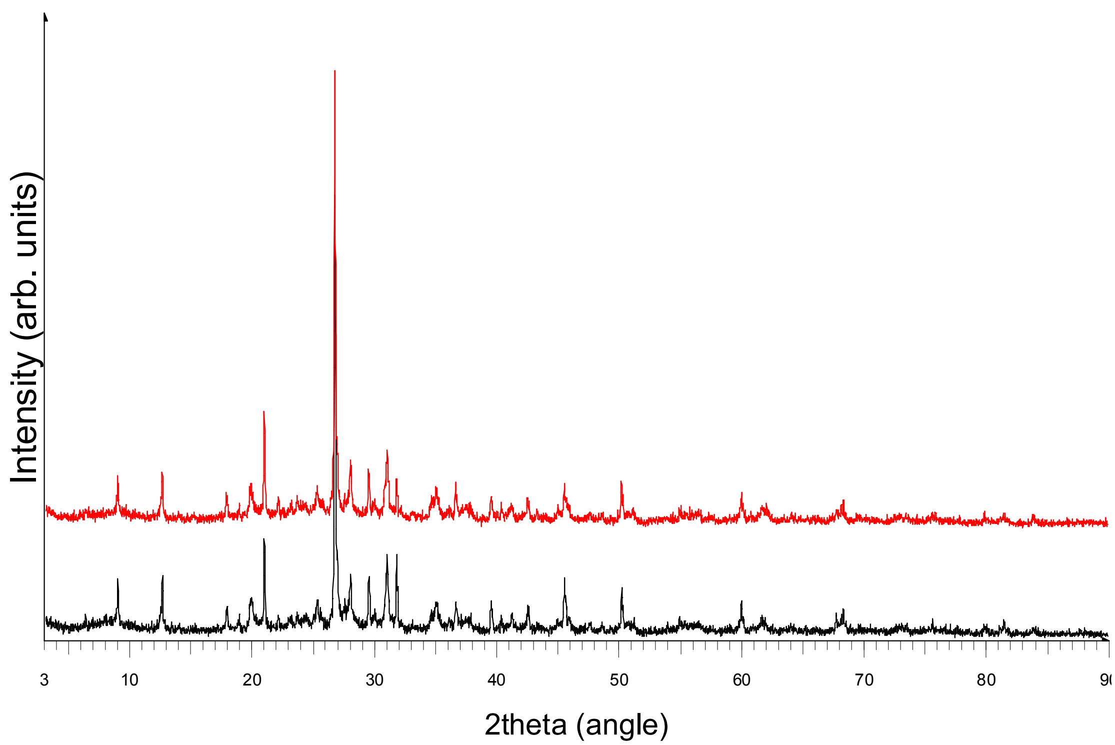


Fig.10. The similarity of diagrams obtained before (black) and after (red) glycolation for sample Sovata 9 (S9). Program EVA was used to obtain the graphics

The following minerals were identified: quartz, feldspar, carbonate (dolomite, calcite), muscovite, biotite, clay minerals (illite, kaolinite group: kaolinite, dickite, nackrite), potassium salts (polihalit, mirabilit), sulphates (gypsum, gorgheite). Predominantes detritic minerals. (Fig.11). The most important clay mineral is illite ($KAl_2\,[Si_3Al]O_{10}[OH]_2$), which is not affected by glycolation (Moore and Reynolds, 1997). Also appears chlorite ($Al_{4.5}(Al_{.8}Si_{3.2})O_{10}(OH)_8$ and kaolinitic groups minerals: kaolinite ($Al_2Si_2O_5[OH]_4$), dickite (Al2Si2O5[OH]4), nacrite (Al2Si2O5[OH]4),but these have a much lesser extent. Montmorillonite was not revealed. Generally,lack of peak amplification after glycolation excludes the presence of expandable clay minerals.

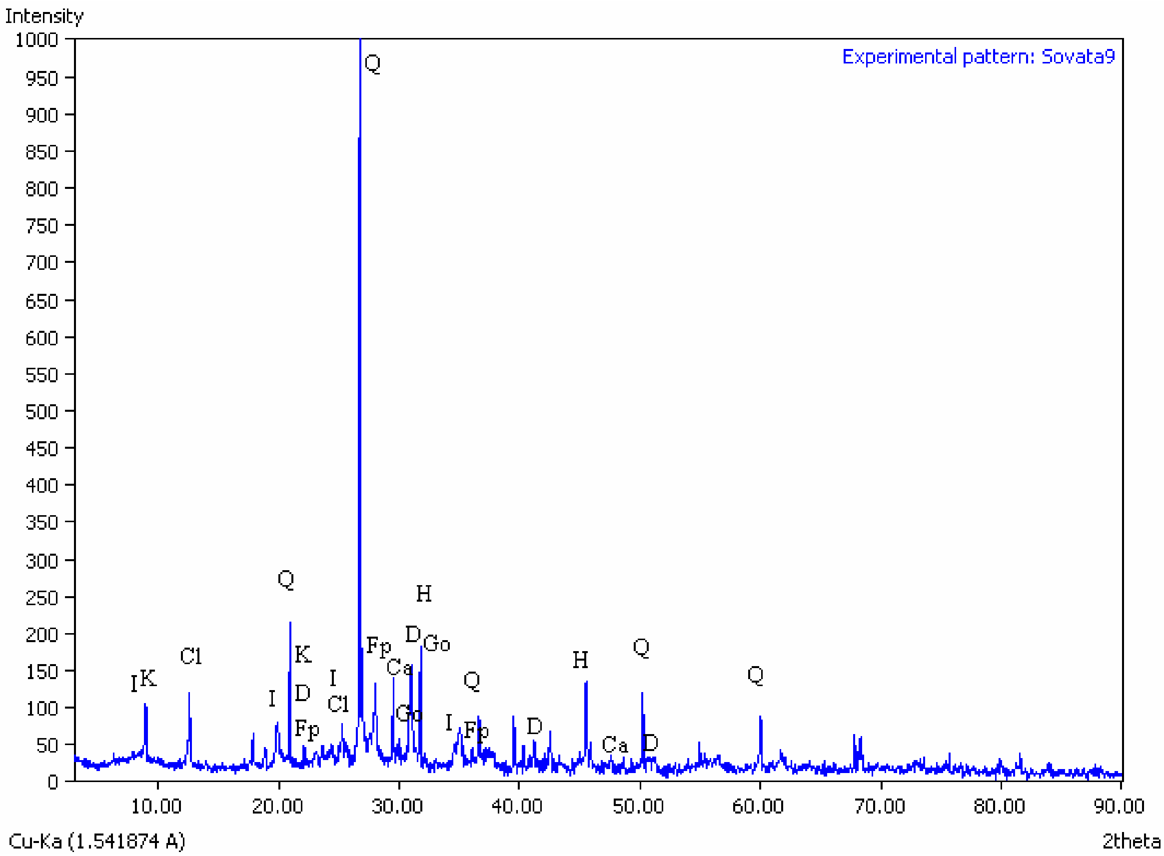


Fig.11. The diffractogram of sample Sovata 9 (Q- quartz, I- illite, Cl-chlorite, Fp- feldspar, D-dolomite, K-kaolinite, Ca- calcite, H- halite)

The evolution of the Transylvanian Basin is closely linked by the surrounding mountain development (Sanders et al., 2002). After a phase of extension in Early Badenian, the basin undergoes a rapid subsidence under a compressional regime because mountains uplift and loading pressure of molasses sediments. The Transylvanian Basin sediments accumulated during 17-15 Ma (Early Badenian) were deposited in an area much larger than today. After this period the rate of uplift and erosion of the Eastern Carpathians and Southern Carpathians show a close relationship with a rapid subsidence and an accelerated sedimentation in the molasses basin of Transylvania. The erosion of the mountains provided the clastic material deposited as molasses sediment.

The Match! program performs the semi-quantitative analysis using RiR (Refernce Intensity Ratio method). Table 1 and Fig. 12 show the results of these tests.

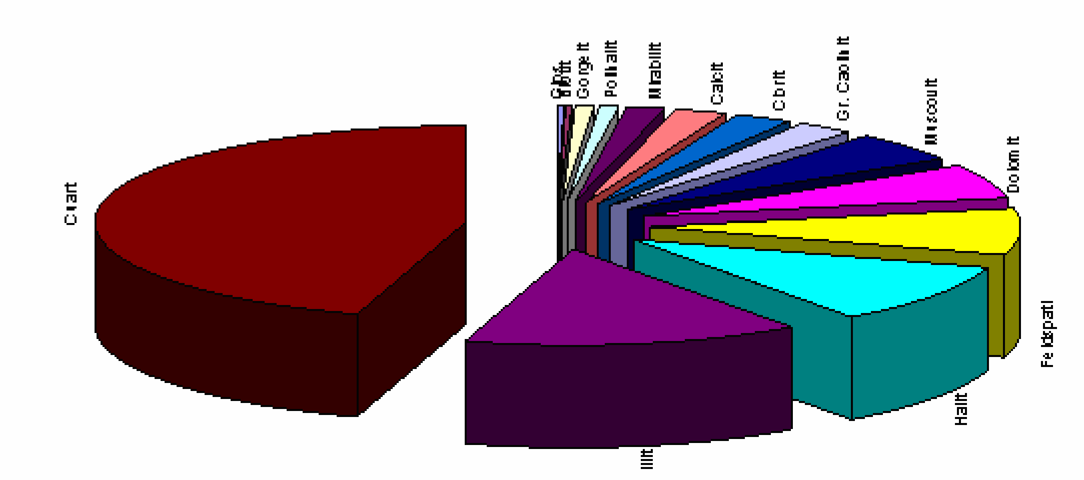


Fig.12. The quantity of minerals (%) in samples S1-S10.

	Cantitatea în procente (%) ale mineralelor din probele S1-S10 de la Sovata										TOTAL
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	
Biotit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.5
Calcit	0.0	0.0	0.0	4.4	8.0	3.1	4.8	2.1	0.0	0.0	2.2
Caolinit	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	6.4	0.0	1.1
Clorit	2.3	0.0	0.0	0.0	0.0	5.5	3.6	2.1	5.2	7.2	2.6
Cuart	76.3	40.6	75.8	5.8	33.9	22.3	44.5	75.2	38.4	39.1	45.2
Dickit	0.0	0.0	0.0	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Dolomit	2.7	5.7	3.9	9.3	7.3	4.2	6.9	2.9	8.2	7.0	5.8
Feldspati	8.2	8.9	2.3	8.3	7.7	3.7	9.5	4.2	11.7	11.8	7.6
Gips	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.2
Gorgeit	1.6	0.0	0.0	0.0	0.0	2.7	0.0	0.0	3.1	0.0	0.7
Halit	2.1	21.4	4.5	6.0	3.5	23.4	3.4	4.2	6.5	28.0	10.3
Illit	6.8	3.9	7.2	55.0	18.3	16.0	14.3	7.5	20.5	0.0	14.9
Mirabilit	0.0	0.0	0.0	4.5	5.1	6.8	0.0	0.0	0.0	0.0	1.6
Muscovit	0.0	13.8	2.6	0.0	14.0	8.6	8.7	0.0	0.0	2.4	5.0
Nacrit	0.0	5.6	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.8
Polihalit	0.0	0.0	3.8	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.8
	100	100	100	100	100	100	100	100	100	100	100.0

Table 1. The quantity of minerals from samples S1-S10 (Sovata)

It has been identified inclusions in halite crystals which are cubic or irregular in shape and most of them containing gas bubbles (Fig. 13)

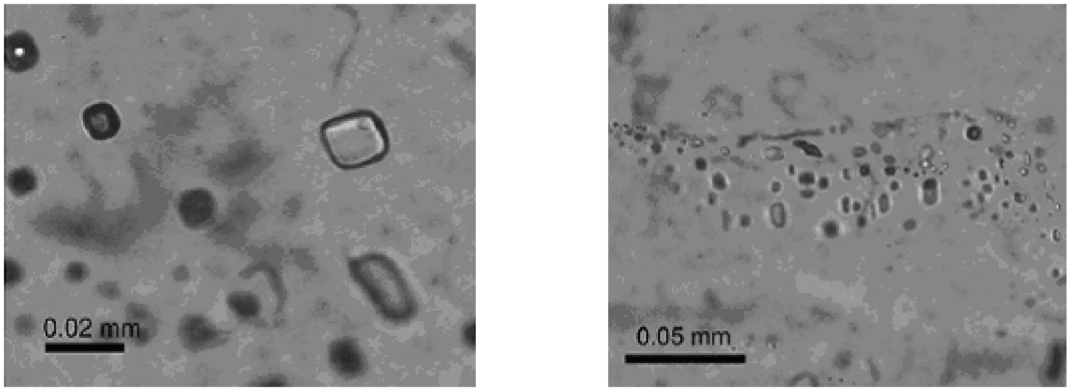


Fig.13. Inclusions in halite crystals (Har et al., 2010)

The EDX spectrum on a cubic crystal of halit had the following composition: Na=41.1%, Cl=58.9% (Fig.14). Using EDX investigations on the fine lamellar crystals were obtained 4 chemical spectrums, which indicated the presence of illite or some aggregate of clay minerals and possibly transitory compositions.

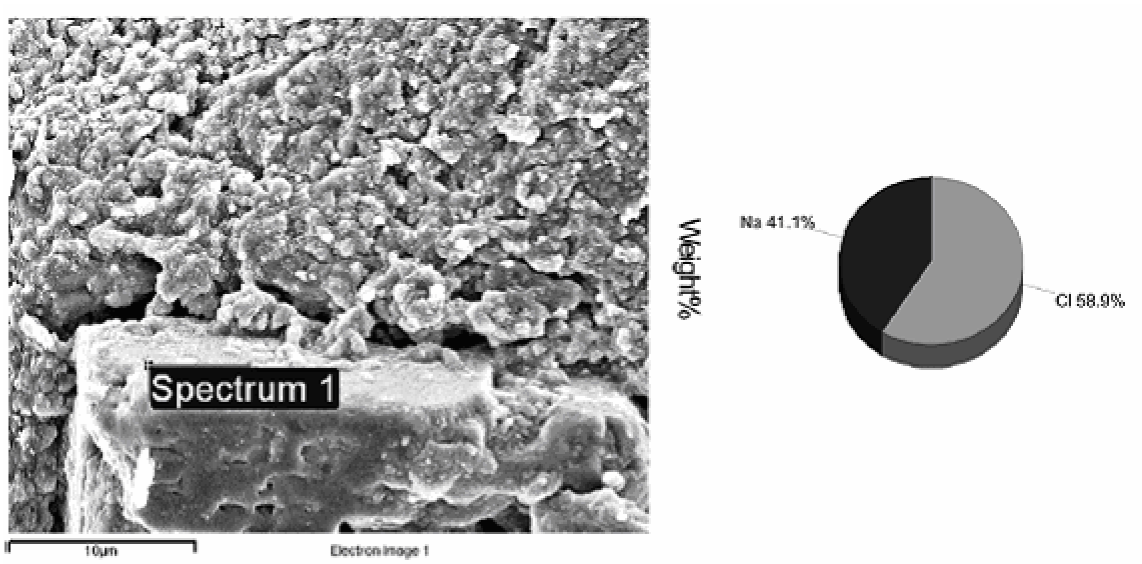


Fig. 14. SEM image and EDX chemical composition of a cubic crystal of halite (Har et al., 2010)

<u>Clay minerals as paleoclimatic indicators in salt formation of Sovata</u>

Clay minerals can be significant indicators of surface processes. Rate and type of alteration is controlled by several factors, such as mineralogy, climate and microbiological activity. Among these, the climate has a major role by temperature (a physical factor) and by precipitation (chemical factor).

It is generally accepted that illite and chlorite are detritic clay minerals and natural alteration and glacial erosion products, so they are typical of high altitude. The source of chlorite are metamorphic and basic rocks containing chlorite, but do not resist to chemical alteration and transport. Illite is a product of acidic rocks, and it is relatively resistant, typical for low temperatures. A hot but dry climate (which limited alteration) also may contribute to illite formation. Unlike chlorite and illite , kaolinite and montmorillonite are produced mainly by chemical alteration. Illite is a clay mineral present in considerable proportion in salt of Sovata. This predominance indicates the climatic conditions existing during the salt precipitation. But because in this time the Eastern Carpathians were in a phase of uplift and stronger erosion, started about 15 Ma (Sanders et al., 2002), the existence of cold climatic conditions is due to the altitudinal factor. On the other hand, illite can form at higher temperatures conditions, but lower precipitations (Weingarten et al., 1990). These could happen at mediterranean climatic conditions (meaning annual temperatures range from 12 to 19 ^{0}C, which is consistent with the temperatures around 16.6-17.0 determinated by the CA method from pollen assemblages of Praid). In mediterranean climate in the summer downward motion of air predominates , which is characteristic of deserts, and remaining 3-5 months. This involves high temperatures and aridity, and the relative humidity is low.

So probably illite of salt from Sovata has double source: one part would have been formatted under a cold climatic conditions, typical for mountains, and secondly could form under a hot and dry climatic conditions (Mediterranean climate).

Kaolinit- being present in a lower proportion that illite- also colud form under Mediterranean climate, but during the winter, with abundant rainfall.

Chlorite-present at low proportion- can form under the same conditions as illite.

Paleontological features of salt from the Transylvanian Depression

Badenian (16.4-13.0) began with transgression in both the Mediterranean and throughout the Paratethys. Invasion of tropical seas allowed the installation of an assemblages of *Candorbulina* (Filipescu, 1996). The most common planctonic forms are *Candorbulina glomerosa, C. universa, Globigerinoides triloba, Globorotalia mayeri, G. acrostoma, Globoquadrina altispira, G. advena*

.The salt horizon (Ocna Dej Formation) is poor in organic remains.

The deposition of salt from “Ocna Dej Formation” was realized within assemblage definited by *Pseudotriplasia* ex gr *minuta – Uvigerina asperula – Globigerina druryi şi Pavonitina styriaca – Globigerina grilli – Velapertina* (Filipescu, 1996).

Taxa *Globigerina bulloides* and *Globigerinoides trilobusare* are mentioned both in micropaleontological assemblages from Turda (Filipescu, 1994) , as in the salt mine from Praid, as well in cores samples from wells located in the mine . (Horváth, 2004). The taxa *Elphidium macellum*, *Orbulina suturalis*, *Pullenia bulloides*, *Quinqueloculina akneriana* occur in Turda and at Praid mine too.

<u>Nannoplankton study in the salt from Praid.</u>

Based on calcareous nannoplankton the salt from Turda and Ocna Dej was placed in the upper zone of NN5 and lower zone of NN6. (Chira, 2001). Wielician is defined as an interval beginning with the first appearance of *Discoaster brouweri* , indicating the top of zone NN5. On the other hand, NN5 zone is defined between the last occurrence of *Helicospaera ampliaperta* and the last occurrence of *Sphenolithus heteromorphus*.

I collected seven samples from the Praid mine for nannoplanktonic studies, from an intercalated clay bed found at level 402 m. The nannoplankton assemblages are characterized by the presence of taxa in situ, but there exists reworked taxa of olded formations (Cretaceous, Paleogene, Lower Miocene). They have a good degree of conservation, but they are quantitatively poor. Some of taxon that occur in almost all samples are:

Coccolithus miopelagicus (generally Miocene taxa))
Coccolithus pelagicus- (cosmopolitan taxon)
Cyclicargolithus floridanus (Upper Eocene –Middle Miocene)
Discoaster variabilis (Lower Miocene –Upper Miocene)
Helicosphaera kamptneri (NN2- NN21)

Helicosphaera walbersdorfensis (NN5-NN7, Wielician-Lower Sarmatian))
Reticulofenestra bisecta (Eocene-Lower Miocene)
Reticulofenestra pseudoumbilica (NN4-NN15)
Sphenolithus heteromorphus (NN5, Wielician species)
Syracosphaera histrica (NN6)
Reticulofenestra pseudoumbilica (NN4-NN15)
Syracosphaera histrica (NN6)
spores of fungi

The following observations can be made after the assemblages described in these seven samples:

- the 1-5 samples can be dated as Wielician, NN5
- the sample 6 age is possible Kossovian, NN6
- the samples 7 may be Lower Sarmatian.

Because the samples were taken from a salt inclusion, and because of dipairic structure, this ages are acceptable.

Chapter V. Paleoclimate of Middle Miocene

From geological points of view The Miocene Climatic Optimum (MCO) is the most recent warm period, with temperatures 3-5 ^{o}C higher than today but less than half the concentration of CO_2 than current values. So it seems that other factors played a major role in climate like vegetation, altitude, tectonic movements and other greenhouse gases.

<u>Miocene climatic models.</u>

A simple climate model was used to calculate the effects of continents-oceans distribution changing of the geological past at seasonal cycle of temperature in the last 100 million years. It was concluded that changes in sezonality may play a key role in the formation of ice caps. Warm summers are adjustments with cold winters, an Earth without ice is not necessarily a warm Earth. According to this hypothesis, there may be to types of non-glacial periods: cold non-glacials, when the presence of permanent ice is prevented by warm summers, warm non-glacials, in this case the mean annual temperatures are high. (Crowley et al., 1986). There were made five series of atmospheric general circulation models (AGCM) for Cenozoic.(55, 40, 33, 20, 14 Ma) Only on AGCM experiments can be concluded that continent position change had little impact on climate change in Cenozoic. Oceans configurations change within 44 and 44 Ma, and especially the opening and closing the straits probably have been changed significantly the termohalin circulation in oceans. (Bice et al., 2000). Both simulations show warmer than present conditions and the one of Miocene is warmer due to lower altitude. Ice sheet-climate coupled model (Langebroek et al., 2008) applied to the glaciations of Antarctica during Middle Miocene is controlled by mass-energy balance. It was concluded that it is highly unlikely that a constant pCO_2 forcing induced widely glaciations in Antarctica at Middle Miocene. The best evaluation of the Middle Miocene decline of pCO_2 is the scenario that went below 400 ppm 13.9 Ma, with a speed of about 150 ppm/30 ka.

<u>Middle Miocene paleoclimatic data obtained from deep sea drilling sample analysis (DSDP and ODP).</u>

Southern hemisphere oceans data from DSDP (Deep Sea Drilling Project) shown that ice have a different pattern in the two hemispheres in the last 38 Ma (Flohn, 1981). Antarctic ice sheet started to install from now on 38 Ma, at beginning of Oligocene. Here glaciers have increased there mean volume during the Miocene (14-12 Ma) and have a thickness greater than current during Messian (6-5 Ma). Carbon and oxygen isotope analyses on planktonic and bentonic foraminifera (from DSDP) showed an early Miocene heating, followed by a cooling and a second increase in mean temperature during the Miocene. Organic materials rich sediments were deposited at the

Pacific coast of North America, and conservated in Monterey Formation of California. These deposits are the bases of "Monterey hypothesis", which connects the cool of poles with termoclinic development. Changes in partial pressure of atmospheric CO_2 (pCO_2) are often invoked as the main factors led to the Miocene warm conditions and a rapid expansion of East Antarctica ice cap (EAIS) in Middle Miocene. A study made the reconstruction of pCO_2 from Late Oligocene to Late Miocene, based on carbon isotope analysis (from samples of DSDP and ODP) (Pagani et al., 1999). There is no evidence of high pCO_2 for climatic optimum of Miocene or a rapid drop in pCO_2 associate with EAIS growth. Paradoxically, pCO_2 increases simultaneously with the EAIS expansion, and reach pre-industrial values now 10 Ma. Record of carbon and oxygen isotopes (benthonic foraminifera) in pelagic sediments of Miocene age suggest that periods of cooling and/or ice cap developments have been associated with rapid burial of organic carbon and low atmospheric CO_2. In the southwestern Pacific have been made (Flower and Kennett, 1993) isotope studies for epi-benthic foraminifera (*Cibicidoides*), planktonic foraminifera (*Globigerinoides quadrilobatus, Globoquadrina dehiscens*) of Middle Miocene deposits (16-12 Ma). Total increase of benthonic oxygen isotope was performed in two stages: an initial increases of 0.8 ‰ in the interval 14.5-14.0 Ma and a second of 0.7 ‰ between 13.45-12.45 Ma, indicating a rapid growth of ice in east Antarctica and a deep-water cooling.

<u>Continental evolution of Middle Miocene paleoclimate</u>

The main tectonic and paleoclimatic events on the continents were the following: (after Behrensmeyer si Wing, 1992):

In North America, Sierra Nevada and Cascade Mountains lifting caused a non-seasonal and arid climate in the center of the continent. Increases of occurrences of droughts and overall decreases of rainfall promoted dry climates. The first migration of herbivores and carnivores between Siberia and Alaska via the Bering took place in the Middle Miocene and at Late Miocene the Isthmus of Panama formed between Central and South America. The uplift of Andes Mountains in South America has formed a rain shadow effect in the southeast part of the continent.

Climate in Australia has increased in aridity (due to the migration to the north of the continent) with more wet and dry periods. The number of tropical rainforests decreased being substituted by dry forests. Vegetation has changed from closed forests (with broader leaves) with more open forests, grasslands and deserts.

In Eurasia began to appear a steppe vegetation andgrasses have become predominants. In South Asia grasslands have expanded, creating miscellaneous habitats. In South Europe the grassland also has increased but wet forests still remain. However some regions, like Syria and Iran remained wet. The connection between the Mediterranean and the Pacific Ocean was reduced causing increased aridity in southern Europe. The barrier Paratethys that stopped the changes of flora and fauna in west of Europe was regularly interrupted, allowing periodic migration of animals.

In Africa occurs the east rift zone and the African-Arabian plateau is connected with Eurasia. Thus was created a barrier againsta the rainfall between the center of West Africa (humid) and East Africa (dry). The collision between the Eurasian and African continent led to disconnection and contraction of the Tethys sea, thereby reducing the primary source of atmospheric moisture in the area. Rainfall as well the sea temperature moderating effect has been significantly reduced on surrounding regions' climate.

In the Miocene Antarctica became isolated from other continents, which resulted in a circumpolar circulation model Global atmospheric and oceanic circulations also were affected by the circumpolar circulation model, which has restricted the north-south flow. This reduced the ocean hot tropical water mixing cold polar water, causing Antarctic ice formatting. This has accelerated the development of a global seasonality and aridity and intensified global cooling.

<u>Possible causes of climate change in Middle Miocene</u>

Miocene climate models and deep-sea drilling studies offer theories about the causes of climate change in the Miocene.

Cenozoic is a time of significant changes in climate. Middle Miocene is an important period in understanding the present climate setting. During the Miocene occurred changes in global circulation patterns due to insignificant changes in continents position and existence of warm climates on the Earth. It was also an increasing of aridity because mountain uplift, which favored the expansion off grasslands. Position of continents during the Miocene was very similar to the one currently occupies. From the point of view of the climate an important feature for Middle Miocene represents the climatic optimum, globally observed. Data from deep-sea drilling (based on isotope analysis δ^{18} O and δ^{13} C) have estimated that this warm period would be produced during period 17-15 Ma, and was followed by a gradual cooling and reestablishment of ice sheet on the Antarctica.

Some of the events that probably contributed to climate change in Miocene is the separation of Australia from Antarctica by deep water (38 Ma), opening Drake Strait between South America and Antarctica (23 Ma) that created a cold current around Antarctica and caused a subsequent accumulation of ice (Bassarova, 2005). Ocean models suggest that the effects of opening and closing straits between oceans on ocean heat transport and on climate can be dramatic.

A decrease in atmospheric CO_2 associated with a high dissolution rate and burial of organic material, could result in a global cooling and expansion of the Antarctic ice cap about 15 Ma. This scenario differs from the "Monterey hypothesis" by Vincent and Berger where the CO_2 reduction is done mainly by disaggregation of silicates and rather by organic carbon burial. However, warm climatic optimum of Miocene (14.5-17.0 Ma) is not associated with a high level of p CO_2, in contrast, found a low CO_2 concentration. While at cooling period that followed it (from 12.5 to 14 Ma) and East Antarctic ice expansion, there was a trend of increasing CO_2 in the atmosphere (Soon et al., 2001, Pagani et al., 1999). A combination of carbon ion concentration with the pH of the seas during Miocene climatic optimum period showed a lower p CO_2 as at present (Tyrell and Zeebe, 2004). On the other hand, stomatal frequency analysis of fossil leaves can be used to asses CO_2content (reverse relationship). Periods of low CO_2 are the same age with major glaciations, while high content of CO_2 (500 ppmv) coincides with the Miocene climatic optimum (Kürschner et al., 2008). Unlike geochemical data, these results show that climatic optimum was induced by high CO_2.

Chapter VI. Reconstruction of paleoclimate of Miocene from Europe based on palynological analysis

Botanical taxonomy of pollen grains helps to knowledge the paleovegetation, paleoecology, paleoclimate. It was applied to Pliocene and Miocene knowing that all kinds of present plants are represented starting with Eocene/

<u>Quantiataive methods used in paleoclimatic evaluations based on palynological analysis.</u>

In the past, for paleoclimatic estimations based on microfloristic analysis it was used the ratio between thermophilic:intermediate:temperate elements. In more recent works based on analysis of pollen in climate reconstructions, the used quantiative techniques are: „Coexistence Approach" (CA), elaborated by Mosbrugger and Utescher in 1997 and „Climatic Amplithude Method" (CAM) first time applied of Fauquette et al. in 1998.

Coexistence approach is based on the assumption that Cenozoic plants have the same climatic requirements as theirs current correspondents. The aim of the CA method is that for a given fossil flora and a given climatic parameter to find the climatic interval where all actual correspondants of fossil flora can coexist. CA uses only the presence of taxon in fosil flora and not their relative frequency. Although the relative frequency of taxon can provide additional climatic information (probability of occurence of a taxon varies with the taxon's geographical spread and becoming greater near synecological optimum of taxon), this parameter was not including because of taphonomic control. Fossilization processes also influence the composition of fossil flora (presence/absence of taxon), but this does not influence the applicability and the correctness of the method as long as fossil flora comes from a single eccosystem. Coexistence approach does not require that all taxa of the original vegetation should be preserved and known.

Coexistence approach is based only on several assumptions:

- the fossil taxa can be identified with actually existing correspondents with very close systematic affinities
- climatic requirements for a fossil taxon are similar to the present correspondent
- climatic conditions or tolerants of an actual correspondent (and implicitly for the fossil taxon) can be inferred from the distribution area. Also it is assumed that meteorological stations provide adequate and reliable data to describe the climate tolerances of a modern taxon, the used current climates data are reliable and of good quality.

All these assumptions may be wrong in some cases. For example, present correspondence with one fossil may be incorrect. Or actual weather conditions for a taxon may differ from the older correspondent, possibly because these plant distribution. Also weather conditions for an actual corresponding of a fossil taxon may be misleading, because the distribution of plant area shall not cover its climatic tolerances.

It is important that all such errors can be detected. For example, assuming that the database contains errors such as the first three listed, when applied CA for numerous fossil floras, these errors are quickly identified by the fact that it is always positioned outside the range of coexistence (outliers). Statistically significant are those intervals calculated in witch 88-100% of taxa can coexist.

"Climatic amplitude method" is as well a quantitative method of paleoclimatic reconstruction. It was assesed that climate reconstruction based on palynological analysis can not be made based on actual analogy conventional techniques, since Pliocene pollen spectrums contain taxa belonging to the temperate, warm temperate, subtropical plants, which are not together today. 8000 spectrums of present pollens were used. For each spectrum there were calculated the frequency of pollens comparing with totally pollens, but excluding water plants and spores. The present climatic amplitude tolerated of each taxon was determinated by representing the pollen frequency in actual pollen-spectrum in relation to each climatic parameter separately. For each graphic there were visually chosen one or two thresholds, first threshold corresponding to presence/absence under which the taxon probably is not present on site (pollen frequencies below this threshold reflects a long transportation by sea or air), the second is the threshold of abundance. All these thresholds vary from one taxon to another. If in a given pollen spectrum (fossil or actual) the frequency passes with 80% over the first threshold, then the climatic amplitude associated with this threshold is taken into account. If the pollen frequency is with 80% above the second threshold, then it is used the restricted climatic amplitude.

<u>Paleoclimatic evolution of Miocene (primarily Middle Miocene) in Europe based on palynological analysis.</u>

Miocene palynology of Europe reflects the existence of a diverse flora, indicating various weather conditions, controlled mainly by altitude and latitude. These Middle Miocene optimum climatic conditions were demonstrated on a global scale.

It is noticeable a climate conditions deterioration with high temperatures in the lower Miocene to lower temperatures of the Upper Miocene. Changes are demonstrated in vegetation due to altitude and latitude gradient and non-zonal vegetation. So for example, Çorum region and Sivas Basin (Turkey) after a tropical elements dominance in Lower Miocene, in Middle Miocene there was a gradual increase of temperate elements and tropical elements disappeared. (Kayseri şi

Akgün, 2008). Similarly, in Greece (Eastern Mediteranean) for Middle and Upper Miocene it can be observed a climatic deterioration in opposite to subtropical climate from Lower Miocene. (Ioakim et al., 2005). In northeastern Bulgaria at the end of Bessarabian the climate becomes variable and drier (mesophytic forests, vertical placement). in western Europe during Serravallian and Langhian it has been estabilished an overlap of very different environments (Jimenez-Moreno and Suc, 2007).

<u>Paleoclimate of Miocene (especially of Badenian) from central Paratethys based on palynological studies</u>

Miocene climatic characteristics of Paratethys area are similar to those established in Europe. Pollen analysis (Karpatian-Sarmatian) of core Tengelic (Hungary) indicates the existence of a vertical storied forests, a humid, temperate subtropical-warm climate (climatic optimum) with a decrease in temperature and rainfall during Late Badenian and Sarmatian, as same in core Hids-53 (Hungary) it has been observed a decrease of mesotermic and mega-mesotermic elements, many of them disappear, and there is an increase in meso-and meso-microtermic elements from badenian to sarmatian (Jimenez-Moreno, 2006). At Lăpugiu de Sus (Lower Badenian) it was revealed a subtropical climate with tropical elements, as evidenced by the dominance of thermophilic elements and subordination of temperate elements (reflecting the climatic optimum) (Petrescu et al., 1990), while pollen spectrum from Mereşti (Upper Badenian) is dominated by Arcto-Tertiary elements (Petrescu et al., 1988).

Chapter VII. The reconstruction of paleoclimate in Badenian salt formation of the Transylvanian Basin

Palynology and climate assessment of the Badenian salt from the Transylvanian basin has particular interest because this period coincides with the end of the Miocene climatic optimum. In the Transylvanian Depression there were made palynological analysis in salt for diapirs from Sărățel, Ocna Dej, Turda, Praid. In Ocna Sibiului it were not found sporomorphes. Microfloral studies reveal that assemblages of microflora of this period (Middle Badenian, Wielician) represent a transition from Lower Badenian to Upper Badenian, in the sense that there is a decrease in thermophilous elements and an increase in temperate elements since Lower Badenian to Upper Badenian.

Neogene evolution of the Transylvanian Depression is closely related to the development of the surrounding mountains. The period between 15-5 Ma (hence the period of salt deposition) corresponds to the uplifting phase, a so-called constructive stage. It was estimated a maximum elevation of 2500 m for the Eastern Carpathians. (Sanders et al., 2002). This explains the existence of altitude-elements in pollen spectrum of salt (the presence a large numbers of pollen Piceae). On the other hand the dominance of assemblage illite-chlorit in clay minerals, also suggests the existence of an altitude controlled sources area (Bican-Brișan şi Hossu, 2006).

The major marker taxa in climate assessments of salt:

A. Tropical-subtropical climate indicators (presence of macrotherm pollen): *Momipites punctatus* (Juglandaceae) , *Nyssapollenites kruschi* (Nyssaceae), *Monocolpopollenites* (Palmaceae), *Dicolpopollis kockeli* (Palmaceae), *Triatriopollenites myricoides şi T. bituitus* (Myricaceae), *Porocolpopollenites* (Symplocaceae), *Intratriporopollenites instructus* (Tiliaceae).

B. Warm temperate climate indicators (mesotherm pollen): *Caryapollenites simplex* (Juglandaceae), *Zelkovapollenites* (Ulmaceae), *Trivestibulopollenites betuloides* (Betulaceae), *Tricolporopollenites* (Fagaceae), *Cedripites* (Pinaceae)

C. Cold temperate climate indicators (microtherm pollen): *Pityosporites labdacus* (*Pinus sylvestris*), *Abiespollenites* (*Abies alba)*, *Zonalapollenites igniculus şi Z. maximus* (*Tsuga canadensis*), *Piceapollis (Piceae)*

D. The moisture-loving plants (hydrophilic plants, living in swamps or smoothly flowing waters and hygrophitic-plants living in places with excessive moisture, in valleys, along waters, near sources, in lowlands with swamps, just not in the swamps, but on their margins), the following types are present, some associated with wetlands: *Engelhardtia, Alnus, Ilex, Liquidambar, Nyssa, Taxodium, Cyrilla*, *Symplocos.*

E. Xerophytic plants (which leave in a seasonal or permanent deficiency of water in the soil or in the atmosphere) are present in small amount in salt: Chenopodiaceae, Eleagnacea.

Sequoia (*Sequoiapollenites polymorphosus şi S. gracilis)* is characteristic of dry climates. belonging to Taxodiaceae family.

The microfloras described in the salt from Praid, Turda, Ocna Dej are similar, with some slight differences, which are attributed to the local conditions and fossilization processes. (which may be more or less favorable for a good conservation).

<u>Pollen assemblage from Sovata.</u>

In Sovata there were not made palynological studies yet. The 18 samples were taken from "Salt Mountains" behind Lake Ursu.

Taxa	Frequency
PTERIDOPHYTA.FILICOPSIDA	
1. Polypodiaceoisporites sp	X
2. Laevigatisporites haardti	X
GYMNOSPERMATOPHYTA. CONIFEROPSIDA	
1. Abiespollenites cedroides	X
2. Pityosporites microalatus	XX
3. *Pityosporites macroinsignis*	X
4. Pityosporites labdacus	XXX
5. *Cedripites miocaenicus*	X
6. Cedripites crassiundulicristatus	XX
7. Podocarpidites libellus	X
8. *Zonalapollenites igniculus*	X
9. *Zonalapollenites maximus*	X
10. Cupressacites bockwitzensis	X
11. Sequoiapollenites polyformosus	X
12. Sequoiapollenites largus	X
ANGIOSPERMATOPHYTA. MONOCOTILEDONATEA	
1. Graminidites sp.	X
2. Moncolpopollenites sp.	X
3. Monocolpopollenites tranquillus	X
ANGIOSPERMATOPHYTA. DICOTYLEDONATEA	
1. *Triatriopollenites myricoides*	X
2. *Momipites punctatus*	XX
3. *Pterocaryapollenites stellatus*	XX
4. Caryapollenites simplex	X

5. *Ulmipollenites undulosus* X
6. *Intratriporopollenites insculptus* X
7. *Intratriporopollenites instructus* X
8. *Eucommiapollis eucommi* X
9. *Tricolporopollenites microhenrici* X
10. *Tricolporopollenites cingulum* XX
11. *Tricolporopollenites henrici* XX
12. *Nyssapollenites kruschi* X
13. *Ericipites baculatus* X
14. *Ericipites callidus* X
15. *Ericipites ericius* X
16. *Ephedripites treplinensis* X
17. *Trivestibulopollenites betuloides* X
18. *Capryfolipites andreansky* X
19. *Ilexpollenites iliacus* X
20. *Nymphaepollenites sp.* X
21. *Alnipollenites verus* X

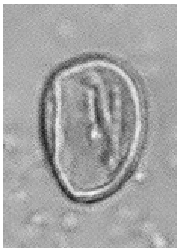
Legend: X very rarely (1-2 grains), XX rarely (3-9 grains), XXX frequently (10-12 grains)

<u>Characteristics and evolution of the Badenian paleoclimate.</u>

Classic concept is that salt is formed in higher temperatures and low rainfall climatic conditions. Thus, in the Transylvanian Basin the salt deposition from Badenian revealed a drying climate. Neverthless, analysis of the various flora deposited simultaneous with salt (Middle Badenian) or before (Lower Badenian) performed by Givulescu (1982) establishes that these observation does not allow the existence of a very hot and very dry climate during Lower and Middle Badenian in European continent but rather indicates more or less temperate warm climates. Recent reconstruction of Central Paratehyan paleoclimate and paleoenvironment demonstrated an initial warming of climate followed by a decline in mean annual temperature during the Middle Miocene. It is accepted that this warm period followed by a cooling correlates with the very well known global changes and deep-sea records. (Báldi, 2006). Paleogeographical reconstructions demonstrated that the Badenian Paratethys was formed by several large seas between the Mediterranean and Indo-Pacific Ocean. In early Badenian,Central Paratethys was connected with the Mediterranean sea by a narrow and deep strait. In Middle Badenian in theTransylvanian Depression salt was precipitated but in Pannonian Basin neither have been found evaporates nor fauna indicating an increase in salinity. The Mediterranean character of the early Badenian Central Paratethys is marked by several authors. The effect of East Antarctic ice expansion on Central Paratethys climate too is proved by stable isotopes records from the Styrian Basin from Austria. (Bojar et al., 2004).

From climatic points of view an important features for Middle Miocen is the climatic optimum, with global range. Data from deep-sea drilling (based on δ18 O şi δ13 C) have estimated that this warm period would be produced during the period 17-15 Ma, and was followed by a gradual cooling and restitution of ice shell in Antarctica (Zach et al., 2001). For Central Europe, the Miocene climatic optimum is estimated to have occurred between 18 and 14.0-13.5 million years ago (from Ottnangian until early/mid Badenian). Mean annual temperatures were between 17.4 and 20 to 22 ^{o}C. In this period (14.0-13.5 Ma) a rapid deterioration of climate occurred, with mean annual temperature of 15.4-14.8 ^{o}C against the cooling period from 15 to 14 Ma found in deep sea drillings is a shift from continental deposits. (Böhme, 2003).

PLANŞA I(1000X).



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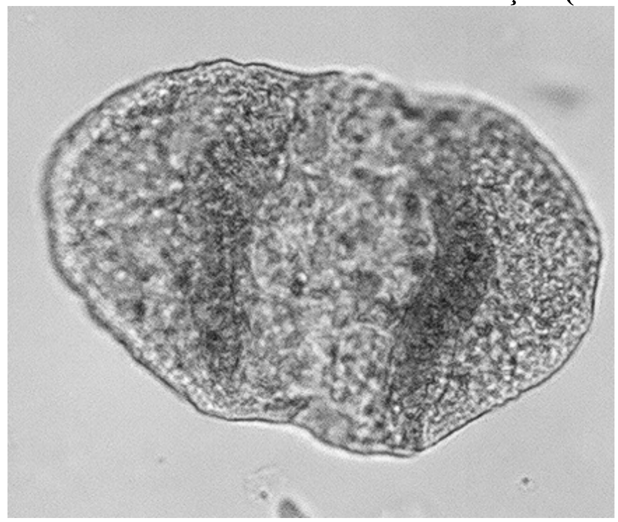

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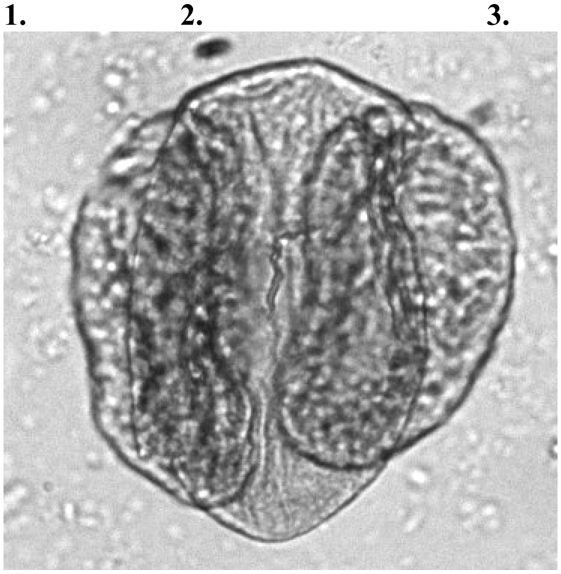

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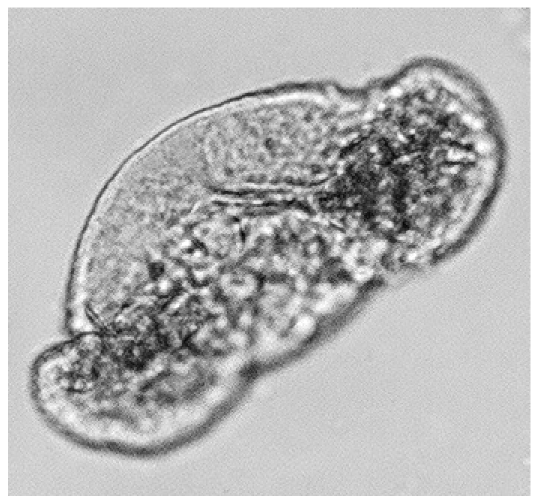

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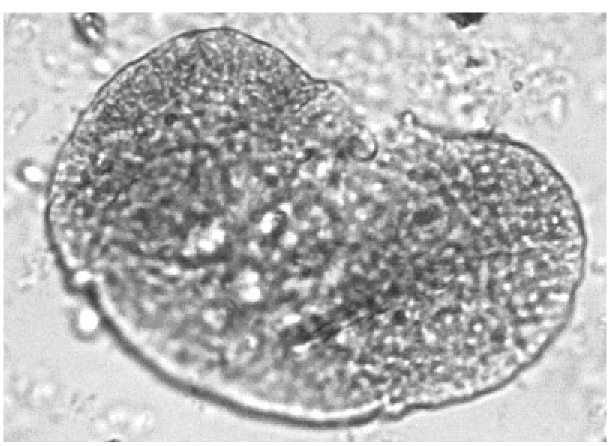

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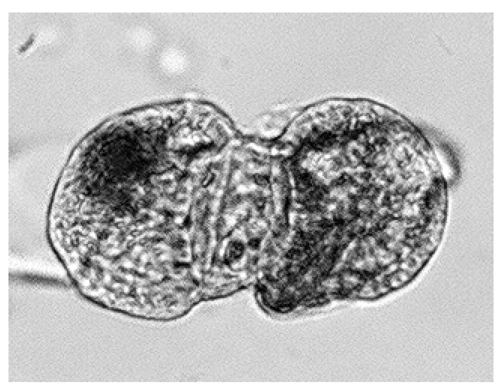
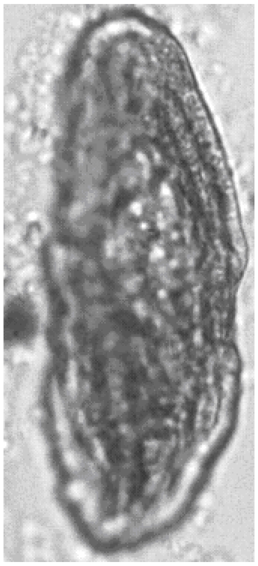


7.

PLANŞA I. 1. Laevigatisporites haardti, 2. Polypodiaceiosporites sp, 3. Pityosporites microalatus, 4., 5. Pityosporites labdacus, 6. Cedripites crassiundulicristatus, 7. Podocarpidites libellus

PLANŞA II(1000X).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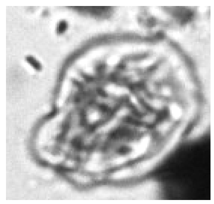
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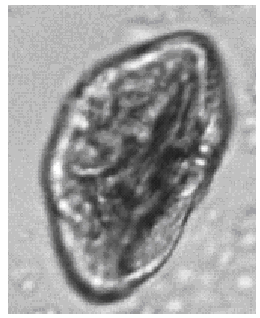
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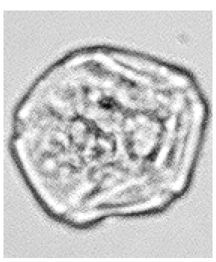
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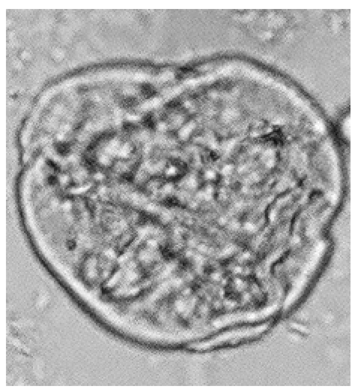
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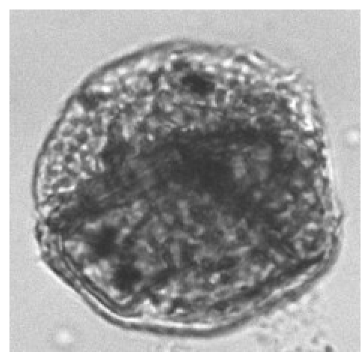
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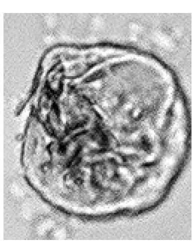
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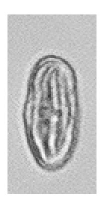
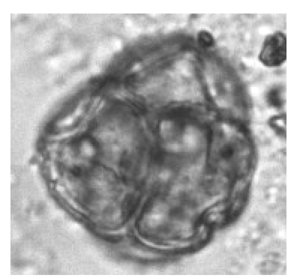

10.


11.


12.

PLANŞA II. 1. Ephedripites treplinensis, 2. Graminidites sp, 3. Monocolpopollenites tranquillus
4. Momipites puncatatus, 5. Pterocaryapollenites stellatus, 6. Caryapollenites simplex,
7. Ulmipollenites undulosus, 8. Eucommiapollis eucommi, 9. Tricolporopollenites henrici,
10. Tricolporopollenites cingulum, 11. . Ilexpollenites iliacus, 12. Ericipites callidus

It is known that oceans' water streams influence the climate of the surrounding lands (an example is the Atlantic Gulf Stream making the northwestern European climate to be more gentle, because warm transport). On the other hand, the climate induces the oceans' circulation. In a large inland-sea, connected with ocean, two types of circulations can be developed according to the equilibrium between water output and evaporation. (assuming a restricted water change by a deep strait). An antiestuarine (lagoonal) circulation is installed when the evaporation is intense. In Lower Badenian (NN5) an antiestuarine circulation was installed between the Mediterranian and Central Paratethys. Surface water from Mediterranean inflows in Paratethys and the deep water from Paratethys- with higher salinity- was inflown in the Mediterranean Sea. Evaporation increased into the continent, toward north. According to this model the heat was transported by surface currents from the Mediterranean to Paratethys. The first part of the Badenian (16.4-15 Ma) corresponds to a global warm period (Middle Miocene climatic optimum) (17-15 Ma). This warming in part is probably due to heat transport of the water surface at lower latitudes of the Mediterranean to the Central Paratethys.

Evaporation is controlled by climate and such high temperatures from the Middle Miocene climatic optimum created favorable conditions to deposition of evaporates. High temperatures were hold 17 to 15 Ma ago, followed by a decline 15 to 14 Ma ago, while in continental Europe's middle latitudes sediments cooling was delayed until 14 Ma ago, followed by a rapid cooling from 14 to 13.5 Ma.

This lagging of cooling may be the result of an antiestuarine circulation heat transport. The very short period of salt deposition (0.2 Ma) does not allow a precise stratigraphic positioning of salt, but they were formed under an antiesturiane circulation.(Báldi, 2006).

On the other hand exactly this lack of evaporites in the Pannonian Basin is given as argues of connection absence between this basin and theTransylvanain Basin during the deposition of salt (Petrescu and Balintoni, 2002). It is supposed that there was a contribution of preconcentrate solutions from the extracarpathic basin, carbonates and sulphates probably were deposited before reaching the Transylvanian Basin (in curvature zone- wherefrom water inflows in basin- there are large amounts of dolomite, gypsum, salt). In this case the main cause of salt deposition was not due to the climatic condition but to basin isolation (a mediterranean climate existing during salt precipitation).

The migration of Channidae (snakehead fishes) was used for reconstructing temperatures and precipitation patterns in Eurasian Neogene. (Böhme, 2004). These fish are sensitive indicators of summer precipitation maxima in subtropical and temperate regions. Expansion of snakehead fishes coincide with the beginning of the Miocene climatic optimum (18-17 Ma). In western Eurasia there was a zonal gradient of summer rainfall during the Miocene climatic optimum. North of paleolatitude 38^{o}N existing areas with wet summers, and dry areas between 30^{o}N and 38^{o}N paleolatitude. This zonality seems to have been interrupted in the Central and Eastern Paratethys region, where a drier climate existed, producing an additional meridional precipitation gradient in middle latitude of Europe, with a western wet and an eastern dry region. This zonality could be due to both orogenesis and atmospheric circulation. During this period the ITCZ (Intertropical Convergence Zone) was situated over North Africa. A high pressure, subtropical area was located over north-eastern and eastern Europe and produced a dry climate in the central and eastern Paratethys region. (this explains the large evaporitic deposits in Central Paratethys). Division of Miocene Europa into two different areas from rainfall points of view is supported by a synthesis of herbivorous mammals spread across Eurasia during the period 24-2 ma. After that in the early Miocene (24-15) it is observed only incipient dryness, Middle Miocene is dominated by the contrast between the western (wet) and eastern (dry) Europe. (Fortelius et al., 2002).

The climate of the Badenian can be correlated with Mediterranean (or subtropical dry) climate which is present actually in western parts of the continents (note that as in future there may be existing climates which have no corresponding climates among actual climates, as well as in the geological past there were total different climates from those of today). In the summer descending air masses (causing warm and dryness) are installed 3-5 months. In the other seasons western wind affects the climate, bringing oceanic air masses, these are rainy seasons. Length of seasons is not equal, the longest season is summer. The mean annual temperature varies between 12-19 ^{o}C. Warmest month mean annual temperature is between 22-26 ^{o}C. Winters are mild. The coldest month mean annual temperature is between 4-13 ^{o}C. Annual amplitude of temperature is higher in the Mediterranean area (15-20 ^{o}C). The mean annual precipitation is between 400-600 mm, but it may be higher because of orography. Annual precipitation regime is very regular: in the summer months it does not exist at all or just very small quantities. Other seasons, especially autumn and winter are characterised by high rainfall, when western winds bring a large amount of frontal precipitation. Relative humidity is low in summer, in winter it passes over 80%. Number of hours of sun is high (Futó et al., 1991).

Applying the "coexistence approach" method for determining the mean annual temperature based on the palinoflora of salt from Praid.

I applied the CA method as presented in the first part. I used www.palaeoflora.de website for determining the currents correspondents (NLRs, nearest living relatives) of Badenian taxa and temperatures (mean annual temperatures) intervals in which these plants occur. 28 taxa were used. Table 2 presents actually correspondents of some taxa from salt of Praid, and temperatures (MAT) intervals:

Fossil taxa	NLRs	MAT intervals
Polypodiaceoispori- tes torosus	*Pteris sp*	2.0- 21.7
Abiespollenites sp.	*Abies sp.*	-6.7- 27.4
Pityosporites microalatusPityosporites alatus	*Cathaya sp*	17.0- 22.2
Pityosporites labdacus pseudocristatus	*Pinus silvestris*	-9.2- 10.8
Piceapollis sp.	*Picea*	-8.9- 21.7
Cedripites miocaenicus	*Cedrus sp.*	11.6- 18.4
Podocarpidites libellus	Podocarpaceae	11.0- 27.7
Zonalapollenites igniculus *Zonalapollenites maximus*	*Tsuga sp.*	1.8- 21.9
Sciadopityspollenites sp.	*Sciadopitys verticillata*	7.4- 16.6
Cupressacites insulipapillatus	Cupressaceae (*Cupressus, Chamaecyparis*) Cupressaceae (*Austrocedrus, Libocedrus, Papuacedrus*)	1.8- 21.7 8.2- 26.5
Sequoiapollenites gracilis *Sequoiapollenites polymorfosus*	Taxodiaceae	9.1- 25.0

Sparganiaceaepollenites sparganioides	*Typha domingensis*	8.2- 25.7
Moncolpopollenites sp.	*Palmae*	13.3- 27.7
Arecipites sp.	*Arecoideae sp.*	13.5- 27.7
Triatriopollenites bituitus	*Myrica*	-6.9- 28.1
Momipites sp.	*Engelhardtia sp.*	15.6- 27.0
Caryapollenites simplex	*Carya cordiformis*	6.6- 21.3
Pterocaryapollenites stellatus	*Pterocarya sp.*	7.6- 24.2
Ulmaceae	Ulmaceae	3.4- 27.7
Alnipollenites verus	*Alnus sp.*	-13.3- 27.4
Intratriporopollenites instructus	*Tilia sp.*	2.5- 20.8
Chenopodipollis multiplex	Chenopodiaceae	-7,6-27,7
Tricolpopollenites liblarensis	Fagaceae	-1.1-27.9
Nyssapollenites sp.	*Nyssa sp.*	-1.1- 23.9
Cyrillaceaepollenites megaexactus	Cyrillaceae	13.6- 25.4
Ericipites baculatus *Ericipites callidus* *Ericipites ericius*	*Erica arborea* Ericaceae *Erica tetralix*	13.10- 18.60 4.6- 18.8

Table 2. Currents correspondents (NLRs) of pollens from Praid and mean annual temperature in which vegetae existing correspondents.

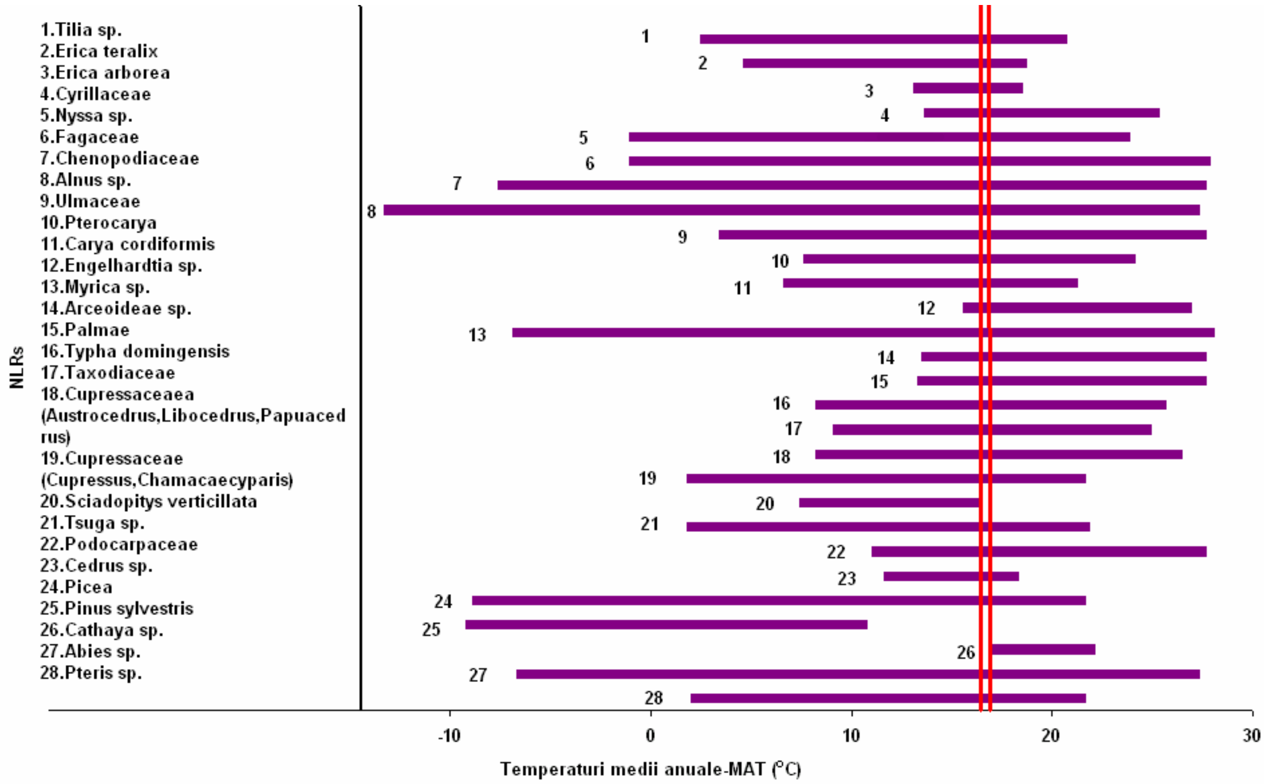


Fig.15. The coexistence interval for the MAT of the actual correspondents of the Badenian plant taxa in Praid. The MAT intervals for each taxon are represented in blue, and the coexistence interval is maked by the two horizontal black lines

In. Fig.15. there are the mean annual temperatures for actual taxa (purple) and coexistence interval (with two red lines). Coexistence interval for MAT for the microflora of Badenian salt from Praid is 16.6-17.0. One can observe an outlier, corresponding to MAT fitting with the actual *Pinus sylvestris.* The taxa which may coexist are representing 96% (statistically significant are the calculated coexistence intervals, where 88-100% of taxa could be in coexistence). For comparison, actually, the MAT measured in two meteorological stations (where the climatic measurements are running since over thirty years) located next to Praid, in Odorheiu- Secuiesc and Târgu- Mureş is of 8.0ºC and 8.6ºC (1961-2005).

In order to observe the evolution of MAT during Badenian, I applied the CA method to two assemblages, from Lăpugiu de Sus, Lower Badenain age (Petrescu et al., 1991) and from Mereşti, Upper Badenian age (Petrescu et al., 1988). In both cases taxa that can coexist is 100%. Coexistence intervals are presented in Fig.16 and 17.

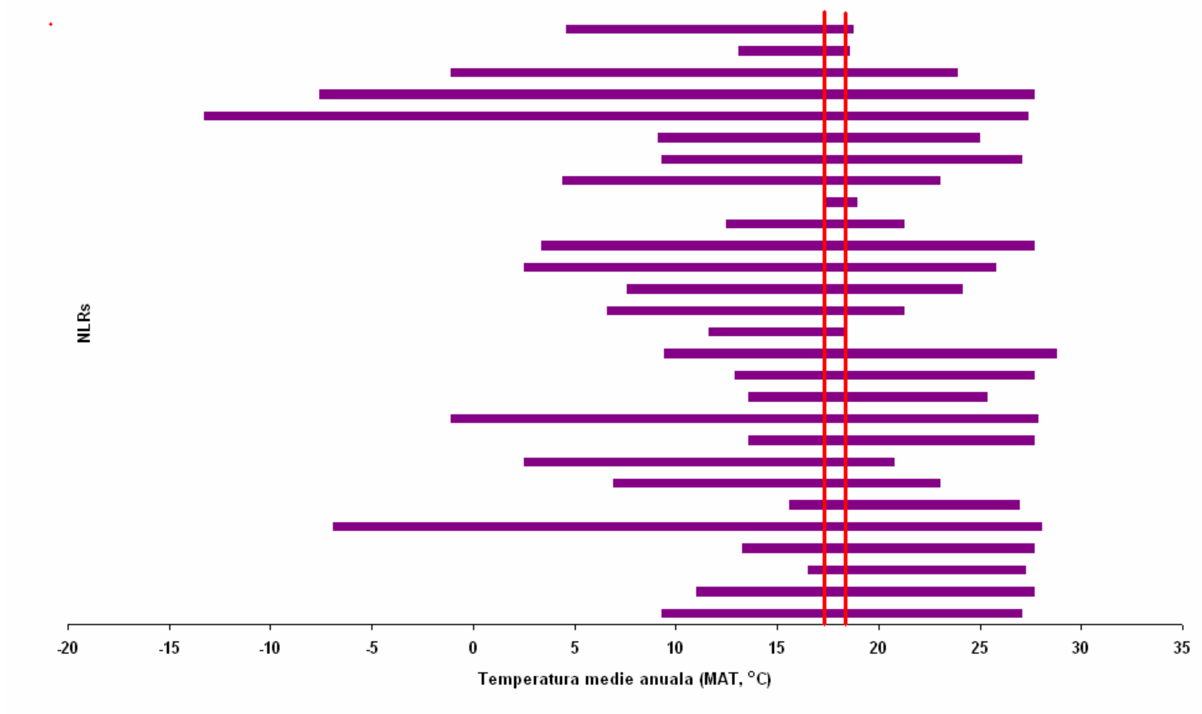


Fig.16. Coexistence interval for MAT from Lăpugiu de Sus (Lower Badenian). Legend as in Fig.15.

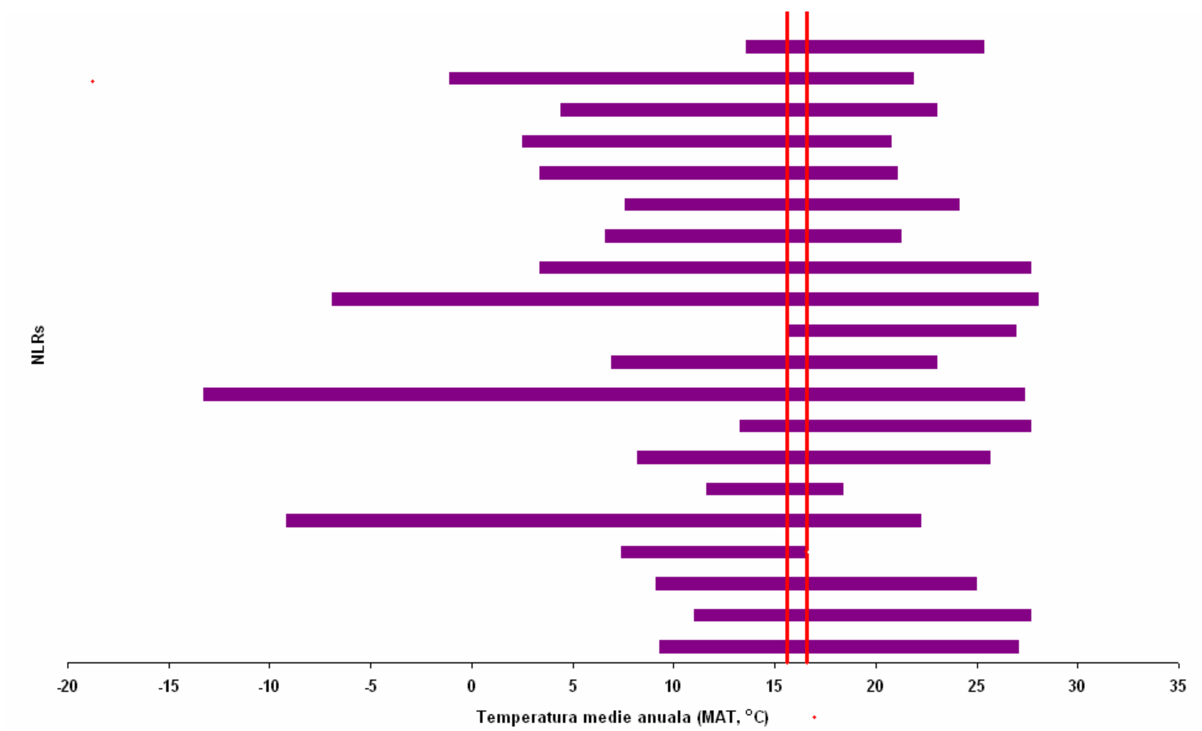


Fig.17. Coexistence interval for MAT from Meresti (UpperBadenian). Legend as in Fig.15.

For Lower Badenian resulting MAT is 17.3 to 18.4 ^{o}C, and for Upper Badenian 15.6 to 16.6 ^{o}C, once again it can be observed the downward trend of MAT during Middle Miocene, valid in Transylvanian depression for Badenian too. In table 3 I made a comparison for mean annual temperatures from Europe found for Miocene and mainly for Badenian. Are marked countries (or areas), type flora used, the authors, the method used. On can observe a decrease in MAT from Egerian to Sarmatian. Mean annual temperature determined for Praid resembling with the ones reported for the Central Paratethys and Easterm Paratethys (Petrescu & Nicorici, 1989, Petrescu & Fazecaş, 1989, Petrescu et al., 1990, Erdei et al., 2007, Böhme et al., 2007, Ivanov et al., 2002, 2007). Higher values (18-20 ^{o}C) are reported for Badenian of Hungary, due to "climatic amplitude method". (Jimenez-Moreno, 2006).

	Lăpugiu Polen (Petrescu et al.. 1990)	Bozovici Polen (Petrescu şi Nicorici, 1989)	Țebea Polen (Petrescu şi Fazecaş, 1989)	Ungaria Macrofloră (Erdei et al., 2007) CA	Ungaria Polen (Jimenez-Moreno et al., 2007) CAM	Germania Macrofloră (Böhme et al., 2007) CA	Praid (polen, CA)
Sarmațian				14.0- 16.5 °C	16.0 °C		
Badenian	17-18 °C		16-18.°C	14.5- 16.5 °C	18.0- 20.0 °C	15.7- 20.8 °C	**16.6- 17.0 ^{o}C**
Karpatian				15.6- 16.6 °C		15.7- 20.5 °C	
Ottnangi-an			> 16 °C			22.2- 24.2 °C	
Eggenbur-gian		16.-17 °C		16.5- 18.8 °C			
Egerian				13.3- 20.6 °C			

	Bulgaria, NV Polen (Ivanov et al., 2002) CA	Bulgaria, NE Polen (Ivanov et al., 2007) CA
Bessarabian	13.3- 17.0 °C	15.6- 16.6 °C
Tarkhanian Karaganian	16.0- 18.0 °C	14.0- 17.0 °C

Table.3. MAT (in °C) in some Miocene European localities, based on macro- and microflora and various methods.

Chapter VIII. Environmental impact of salt

Salt outcrop in Praid-Sovata area has several impacts on the environment. The presence of salt on the surface is evidenced not only by the existence of the two massifs from Praid and Sovata, but also by the salt lakes in the area, the salinity of rivers (eg. Corund river) crossing the salt massifs, the salt water springs, the halophitic vegetation, various forms of salt-karst from surfaces of massifs- exocarst (sinkholes, fissures, „salt-ponces") (Fig.18).

<u>Salt lakes from Sovata</u>

Surface waters had basic role in the formation of salt lakes in Sovata. For example, for Lake Ursu, withdraw of rivers Toplița (Köröstoplica) and Auriu (Aranybánya). Most of these lakes are carstosaline (Ursu Lake, Roşu Lake, Lake Aluniş, Lake Mierlei, Lake Şerpilor- eutrophic swamp, Lake Dulce- is clogged) and only one is antroposalted (Lake Negru). The depth of these lakes varies between 1m and 19m, the deepest is Lake Ursu.

Fig.18. Bizarre forms of karts (cauliflower) in salt of Praid.

Lake Ursu (fig.19) has its origin in sealing Toplița (Köröstoplica) river and territory landslide in 1875. Because a collapse the Auriu (Aranybánya) river was drained into the lake. Lake Ursu has heliotermic features. Because of erosion of the salt massif, the salinity of lake highly increased, and the freshwater input forms a distinct shallow layer above the high saline water. The surface freshwater impedes the emission of salt-water heat (warmed by sun) and hence at lake surface the temperatures are 20-24 ^{o}C, while at 2-3 m the water can reach 40-60 ^{o}C. Now, these temperatures are smaller, due to the degradation of water stratification (Horváth, 2004).

Since 1970 Lake Ursu from Sovata and surroundings stands have been declared nature reserves (surrounding aged forests have a protective role and in addition represent a biodiversity by the 23 species of woods). Since 2000 (Act 5) is a fourth category nature reserve of national interest, with an area of 79 hectares that contains both lakes (5.7 ha) and forest area (it is a case in point the mountain of salt).

Fig.19. Lake Ursu from Sovata

Fig.20. Lake Verde

Corund River and Salt hill from Praid

Corund valley (fig.21) which crosses the massif salt of Praid (getting a canyon aspect from few meters) is a anticline valley, being almost perfectly parallel to the folds orientation. Near diapire, its longitudinal profile has slight vertical oscillation. These reflect strong horizontally meanders and a slightly lifting of alluvial bed. The slopes show a build by flattening, the torrential valleys attack structure in a regressive way, developing small basins of local erosion. This action is combined with landslides and compaction at massif salt. (Irimuş, 1998; Irimuş, 2006)

Fig.21. Corund River upstream Salt Mountain

Corund flows into Târnava Mică after Praid, toward Sovata. The catchments basin of Târnava includes two major hydrographic arteries: Târnava Mică and Târnava Mare. The mean annual mineralization of the two rivers is increasing, generally from spring to influx, but differentiates along the two rivers. On Târnava Mică the increase of mineralization is more pronounced toward the sub-Carpathian area, with values of 575-629 mg/l. This shape is due to the outcrop of salt, or salt in underground, providing a permanent source of sodium chloride (Sorocovschi and Vigh, 2005).

Detailed measurements of salinity along Corund River were not made until now. I performed measurements using a digital electrical conductivitymeter (mS/cm), with automatic temperature compensation. (GLM 020). The coordinates of measuring points I have determinated with aGPS (Garmin 60 CSx).

<table>
<tr><th></th><th colspan="9">Cantități de precipitatii (mm=l/m^2)</th></tr>
<tr><th></th><th colspan="3">Septembrie 2009</th><th colspan="6">Octombrie 2009</th></tr>
<tr><th>Ziua</th><th>SM Odorheiu Secuiesc</th><th>SM Bucin</th><th>Postul pluvio Sovata</th><th>Ziua</th><th>SM Odorheiu Secuiesc</th><th>SM Bucin</th><th>Postul pluvio Sovata</th><th>Date radar (zona Corund-Praid)</th></tr>
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<tr><td>5</td><td>5,2</td><td>4</td><td>3,2</td><td>5</td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>0,2</td><td>1,2</td><td></td><td>6</td><td colspan="4">MASURATORI-prima serie (A)</td></tr>
<tr><td>7</td><td>0,2</td><td></td><td></td><td>7</td><td></td><td>0,3</td><td></td><td></td></tr>
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<tr><td>22</td><td></td><td></td><td></td><td>22</td><td colspan="4">MASURATORI-a doua serie (B)</td></tr>
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<tr><td>Suma lun.</td><td>10</td><td>15,6</td><td></td><td colspan="5"></td></tr>
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Table 4. Precipitation recorded before salinity measurements

Between salinity and electrical conductivity there is a very close correlation is. I acquired precipitation data from the nearest weather stations, from Odorheiu-Secuiesc and Bucin, and from Sovata's pluvio station. I have chosen the moments of measurements in order to have a series of measurements over a period of low rainfall and the second series of measurements over a period of abundant rainfall (table 4.)

Essential differences are observed between values obtained after the two set of measurements (fig.22, 23). In the first case (fig.22) after a period of drought (at Odorheiu Secuiesc meteorological station, when there were 10 consecutive days in which rainfall was less than 0.1 mm, or it did not rain at all), salinity values exceeded 2500 mg/l after the portion leaving the canyon of salt. The high values of the first portion of the trail indicate closeness to surface of salt diapire. It is interesting that the lowest values are recorded upstream of Salt Hill. This could be due to the existence of freshwater resources. The highest values were measured downstream of the Salt Mountain, they could be due to overflowing of water from the mine in that portion, which corresponds to the perimeter of old mines too.

In the second series of measurements (fig.23) salinity values obtained are more homogeneous and smaller, reaching the value of 1100 mg/l. So as the same, after Salt Hill, salinity somewhat has higher values than those recorded on the portion of canyon.

In both cases, at the junction with Târnava Mică values suddenly decrease, this ulterior has lower salinity levels (below 100 mg/l). After the Corund River flows into Târnava Mică the measured values approach those measured before penetrating portion of the salt massif. On fig.24 one can observe the place where Corund flows into Târnava Mică and two very different values of salinity only a few meters.

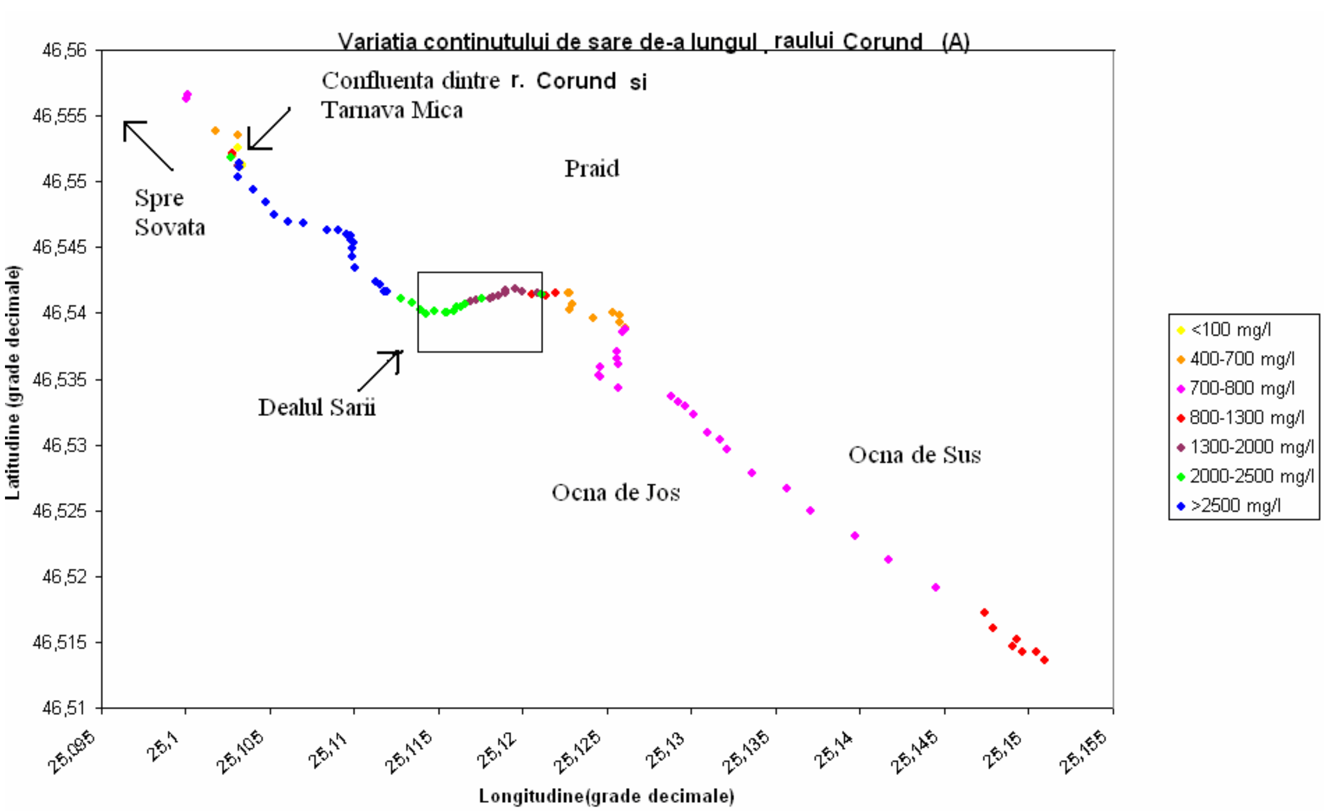

Fig.22. Salinity variation along Corund River after the first set of measurements

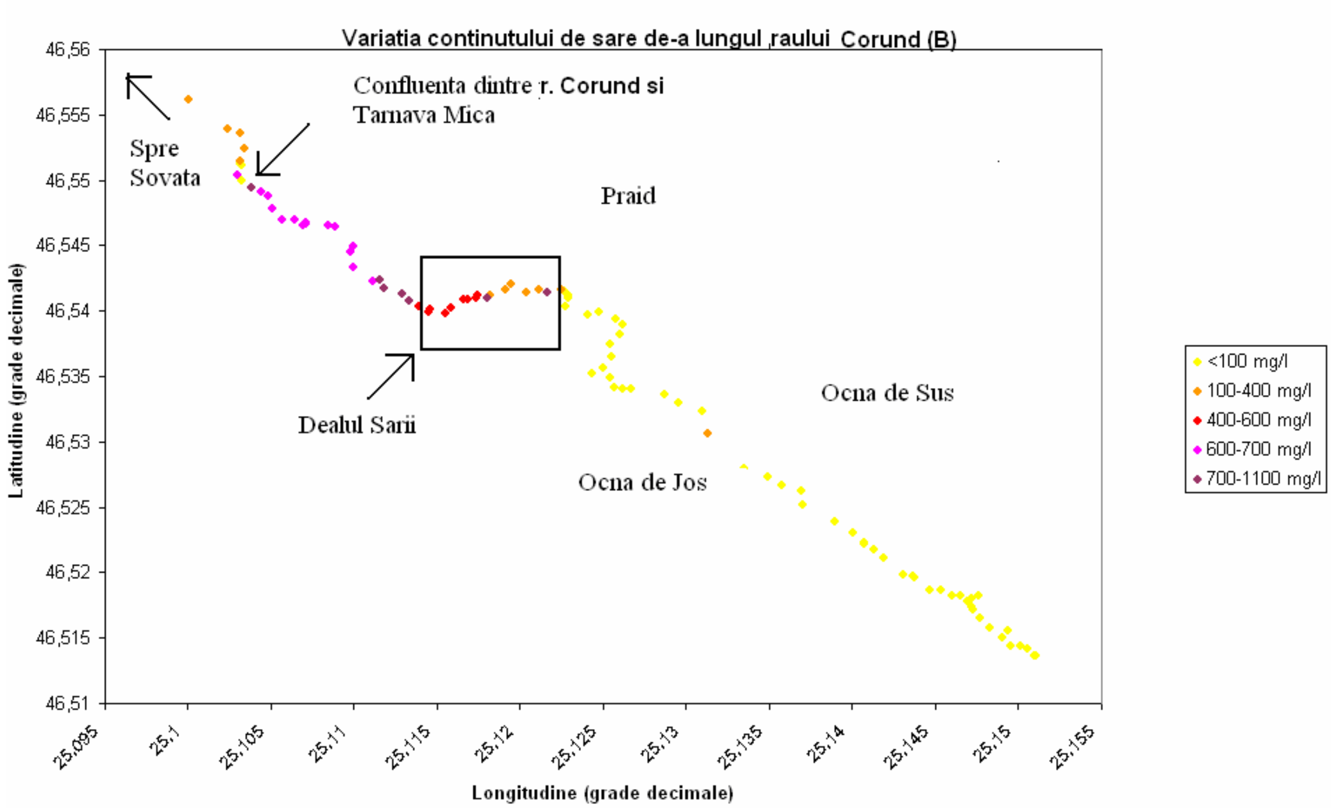

Fig.23. Salinity variation along Corund river after the second set of measurements

Fig.24. The confluence of Corund river and Târnava Mică and the very different values of salinity measured at a distance of only a few meters

Halophilic flora and fauna

At Sovata's salt lakes there were described forms adapted to high salinity conditions, as *Artemia*, a crustacean very resistant to unfavorable conditions (drought, frost). In addition to these forms it can be found *Culex annulipes, Stratiomys longicornis, Tabanus autumnalis, Berosus spinosus, Cibyster Roeselii, Hetochares dilutus, Ranatra linearis, Acilus Sulcatus,* etc. with which it have been described several species of Flagelata and Ciliata. (Alex et al., 2006).

Halophytic vegetation grows along springs and along Corund River in desert portions. *Limonium gmelini*, *Salicornea herbacea* (Fig. 25), *Aster tripolium*, *Spergularia salina*, *Salsola soda*, *Artemisia salina*, *Plantago maritima* şi *Statice gmelini*.

Plant species protected from the Salt Hill are: *Cephalantera longifolia* (L.) Fritsch, *Cypripedium calceolus* L., *Dactylorhiza sambucina* (L.) Soó, *Orchis militaris* L., *Orchis ustulata* L., *Traunsteinera globosa* (L.) Rchb.

Fig.25. Salicornea herbaceae on Corund river bank, at Salt Hill

The environmental impact of salt exploitation

Actual, the main extraction methods and preparation used in Praid salt-mine is „salt extraction method with small rooms and rectangular pillars" and „extraction method with small rooms and square pillars".

Systematic exploitation of the Praid mine was officially reported in 1787, when József mine was opened , it reached depts of 66 m. At present, salt mine works are conducted in two mining areas: the lower horizon sector (286 m, 266 m, 246 m, 230 m) and the Telegdy mining sector (488 m). To protect surface area and surface objects which are in the zone of influence of mine working, they are supplied with safety floors and pillars. (Horváth, 2002).

Surface waters near the massifs of salt have a negative impact on mining works. For monitoring and prevention of them at the perimeter of Praid mine, Corund water quality were analyzed, geoelectric tomography method and DKRControl method were applied (Deák et al., 2007). Solutions to prevent against flooding depend on the location of three hydrological and geomorphological monitoring stations at Corund River. In case of increasing risk with serious damage, the river diversion is required.

In 2002 it began the arranging of the old mines (fig.26) and stopping water drainage in airing pites.). (Horváth, 2004)

Fig.26. The old mines area at Praid.

A positive impact of the presence of salt mine at Praid it is used for therapeutic aims. The speleo-and climatotherapia is practiced at a left mining horizon, located at 402 m.

Chapter IX.Conclusions

The Transylvanian Depression salt formed in Middle Badenian (Wielician), in period 13.6-13.4 ma. (Petrescu and Balintoni, 2002) This corresponds with the upper part of NN5 zone, and lower part of NN6 zone. Nannoplancton studies that I have preformed in salt of Praid revealed assemblages belonging to NN5 zone (5 samples) and NN6 zone (one sample). For Carpathian Foredeep, evaporate deposition is placed in NN6 zone.

During the salt formation, Paratethys Sea was installed over the Transylvanian Depression, which consisted of a series of small basins, one of which was the Transylvanian Basin. During the Neogene, this sea had intermittent contacts with the Mediterranean Sea.

Carpathians uplift accompanied by volcanic activity had effect on salt tectonics of the Transylvanian depression. In the marginal parts of the basin, salt was thrusted and pushed to the surface (salt diapires). Salt diapires from Praid and Sovata belong to the diapiric fold area Şieu- Odorheiu Secuiesc- Brâncoveneşti- Sovata- Praid, with northwest-southeast orientation (Ciupagea et al., 1970). In these two localities salt crop out north of Lake Ursu, in Salt Mountain at Sovata, and south of Praid, in Salt Hill. Mineralogical studies that I have performed on salt with microscopy revealed the existence with halite the following minerals: clay minerals, carbonates, sulfates, quartz, anhydrite, polihalite, biotite, chlorite, plagioclase feldspars. Of clay minerals (determinated by X-ray diffraction analysis of 10 samples from Sovata) predominate illite, kaolinitic group is in a lower amount, and montmorillonite was not detected. At same, the EXD studies demonstrated the presence of illite.

Two major elements have left their mark on global Middle Miocene climatic changes: the climatic optimum has been followed by a cooling. They were revealed both in deep drillings and in paleoclimatic reconstructions of the continents. Some of the causes of the Middle Miocene cooling that led to the installation of permanent ice sheet in Antarctica, may be mentioned the opening and closing of straits, which led to the formation of Antarctic Circumpolar Current. Regarding to the changes in atmospheric CO_2 content during this period, there are contradictory establishments, they are attributed to different methods of research. Although geochemical studies have determinated low CO_2 concentrations in the atmosphere for the Miocene climatic optimum, and an increase during the cooling period that followed it (Soon et al., 2001; Pagani et al., 1999; Tyrrell şi Zeebe, 2004), stomatal analysis (Kürschner et al., 2008) and climatic models shows high pCO_2 levels for climatic optimum, and a decrease for the cooling period that followed. It was estimated that glaciations in Antarctica began when pCO_2 fell below 400 ppm (Langebroek et al., 2008).

High temperatures conditions in the period of climatic optimum can be followed both in deep-sea drilling data and the continents, although it has been occured not exactly at the same time. Permanent ice development in the Antarctic has had effects on Earth's climate, temperature decreases are reported across the globe. Their effects can be detected also in the climate evolution of Central Paratethys area during Middle Miocene.

Continents in Miocene were close to their current position, at same, climatic zones resembles to those of today. Middle Miocene is important from climatic point of view, because it was reported the last warm period of Earth history.

A method often used in the terrestrial climate reconstructions is that based on sporo-pollen analysis. Because all existing plants are known from Eocene, these studies can provide reliable results, knowing the sensitivity of vegetation on climatic conditions and one can get done analogies with existing plants. Lately increasingly are used quantitative methods to determine some climatic parameters of geological ages. The aim of coexistence approach method (Mosbrugger şi Utescher, 1997) is that for a given fossil flora and a given climatic parameter finding that interval for which all actual correspondents (NLRs) of fossil taxa can coexist in the same time. Miocene palynological studies performed in Europe were used for paleoclimatic reconstructions. Application of new methods for micro-or macroflora assemblages (coexistence approach, climatic amplitude method, CLAMP, etc.) evidences the extensive climatic changes from Middle Miocene.

Palynological analysis that I performed on salt from Sovata showed similarities with those previously effectuated from salt diapirs from Turda, Ocna Dej, Sărățel, Praid. In all sporo-pollen assemblages from salt predominate dicotyledonous angiosperms (eg. pollen of Ericaceae*, Carya, Engelhardtia, Alnipollenites, Ulmipollenites*), followed by conifers (*Pityosporites labdacus* a diploxilon-type Pinus is frequently encountered). Generally, pollen assemblages are characterized by the fact that there are together taxa which actual are not found together anywhere. The presence of large numbers of *Pityosporites labdacus* pollen in the pollen spectrum of Badenian salt can be explained by the fact that these pollens having auriferous bags can be transported far away. Also their presence indicates a vertical positioning of vegetation and implicitly of climate.

Climatic conditions during salt deposition show a transitional period from a warmer climate that existed since Lower Badenian to lower temperatures that followed this period. This was reported not only by palynological studies, but also by studies of clay minerals from salt or Wielician foraminifera studies in western Transylvanian Depression.

In order to determine the mean annual temperature during the deposition of salt from Praid, I applied the coexistence approach method for palynological assemblages described here (Petrescu and Bican-Brişan, 2005). 28 taxa were used, for each of them I allocated the actual correspondent and the mean annual temperature in which each taxon lives in part. It resulted a mean annual temperature of 16.6-17.0. This value is similar to other temperatures values evaluated for Middle

Miocene from Central and Eastern Paratethys. It assesses a cooler of climate around 8 ^{o}C within 14 Ma.

In order to follow the evolution of mean annual temperature during the Badenian in the Transylvanian Basin, I determined values of mean annual temperatures by means of two pollen assemblages from Lăpugiu de Sus (Lower Badenian) (Petrescu et al., 1990) and Mereşti (Upper Badenian) (Petrescu et al., 1988). In this case too it was revealed a temperature decrease from lower Badenian (17.3 to 18.4 ^{o}C) → Middle Badenian (16.6-17.0 ^{o}C) → Upper Badenian (15.6-16.6 ^{o}C).

Regarding to the rainfall, in Middle Miocene Europa was divided into two regions with different amounts of annual precipitation: a western area, more humid, and an eastern, more arid (based on the spread of Chaniidae and mammals). Existence of salt deposits in the Central Paratethys it is an argument in addition to the more dry conditions in the east.

In central Europe, the Miocene climatic optimum is estimated to have occurred between 18 and 14.0-13.5 Ma, the cooling began 14.0-13.5 Ma ago (Böhme, 2003). Accepting the salt age deposition between 13.6-13.4 ma, and the fact that the cooling period that followed higher temperature conditions of Miocene climatic optimum is placed 14.0-13.5 Ma, it seems that salt from the Transylvanian Depression deposition at a time when the climate began to deteriorate. Because of short duration of salt deposition can not be made an exactly stratigraphic position. Moreover the effects of climate heating-cooling at global scale manifests not exactly at the same time (or with same intensity) in all areas, can accept the fact that the evaporites from central Paratethys are deposited when there was an antiestuarien circulation(Báldi, 2006). The lack of salts in the Pannonian Basin can be explained by a single direction circulation from thePannonian basin to Carpathian Foredeep.

Badenian salt from the Transylvanian Depression was deposited under a transitional, cooling climate conditions. The cooling caused a fall of oceans and seas levels. But in this region there were still high temperatures enough due to an antiestuarien circulation that provided a heatflow, and thus were optimum conditions for salt precipitation. From performed studies and presented in this paper (coexistence approach, the study of clay minerals, compared with climatic conditions existing during this period in other parts of Europe) it can be concluded that during salt deposition in Praid-Sovata area, probably there was a climate similar to the actual mediterranean climate.

Salt has many impacts on the environment. The outcropping of salt contributed to salt lakes formation in Sovata, to the existence of a halophytic vegetation around salt massifs, to the formation of salt springs, etc. A major impact is on Corund River salinity (which crosses the Salt Hill from Praid), which is an affluent of Târnava Mică, contributes to a high level of salinity of that river. Measurements of salinity over a portion of around 8 km reveals both changes due to changes in river water discharges (depending on the rainfall) and variations before, during and after it crossed the salt massif. Higher values of salinity (2500 mg/l) were recorded after a period of drought and the salt massif sector and the sector where the river leaves the Salt Hill.

Chapter X. Selective Bibliography

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