The structure of the gypsum-anhydrite dome at Alsótelekes

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Abstract. The Alsótelekes gypsum open pit works since 1987 and gives an insight to special features of evaporite tectonics in the Rudabánya Mountains. The evaporitic gypsum-anhydrite deposit was formed in the Upper Permian but the structure evolved during the Early Miocene movements of the Darnó sinistral strike-slip zone. The diapiric dome uplifted in an extension phase was overprinted by the imbrication of a later closure. These events produced a deposit in an advantageous thickness and position for the mining.

Keywords: evaporite tectonics, Darnó Zone, gypsum

Introduction

The Rudabánya Mountains is a SW-NE striking elongated chain of hills in the NE part of Hungary (Fig. 1). It lies in the Darnó Zone, a major tectonic boundary (Zelenka et al. 1983) which is about 4-5 km wide here. The metasomatic ores of the mountains, mainly copper and iron, were mined since the medieval times but nowadays all ore mining activities are stopped.

The evaporite complex was first found by drillings of an iron ore survey in 1950 in the outskirts of Alsótelekes. In 1952, the Perkupa-I. borehole explored a stack of anhydrite horses with imbricated serpentinized volcanic bodies in the Bódva Valley which was interpreted as a SE-verging overthrust structure (Mészáros 1957). Between 1957 and 1985, from the four-level underground mine of Perkupa anhydrite was exploited for melioration.

In 1968 the At-478 borehole at Alsótelekes (drilled for exploration of the tectonic structure) penetrated a gypsum-anhydrite body with more than 400 m thickness. When the Hungarian Geological and Geophysical Institutes (MÁFI and ELGI) examined the complex geological characteristics of the Aggtelek-Rudabánya Mountains (Less et al. 1988) from 1980 and made a gypsum-anhydrite prospect for the area (Grill & Szentpétery 1988), the shallow penetration high-frequency seismic profiles indicated the near-surface occurrence of the evaporitic complex eastwards from Alsótelekes (Albu et al. 1984). In 1986 the exploration drillings also confirmed the advantageous position of a gypsum body, covered by only few meters of other sediments in the Nagy Valley. After that, the area fit for open pit mining was explored by drilling along profiles and then in a network. Since then, 230 exploration boreholes, surface geoelectric (resistance, IP) surveys (Verő & Milánkovich 1983) and an open pit opened in 1987 explored the gypsum-anhydrite-shale-sandstone complex showing a diapiric evaporite tectonics in an area of 0,25 km^2 between the +160 and +205 m levels. Almost 2 million tons of raw materials were exploited. From the crystalline gypsum of better quality (>70% $CaSO_4 \times 2H_2O$) burnt gypsum (Paris plaster) and plaster boards are made. Gypsum of poorer quality and the anhydrite are used in the cement industry (Table 1).

So the pit (Fig. 2) offers a unique opportunity for studying the structural features of the evaporite. Our surveys covered the geological documentation of the drill cores (Kovács-Gál et al. 1987) and the pit walls with structural measurements. The aim was to get a picture about the structural details of the gypsum-anhydrite body and to build up a model for the formation of them with respect to the regional tectonics, first of all to the movements of the Darnó Zone.

Geological settings

The Darnó Zone consists of several individual fault blocks. The Telekes Valley itself indicates a fault parallel with the main strike of the zone (Fig. 1). On the SE side of this fault at Alsótelekes Gutenstein Dolomite crops out, the NW side is covered by neogene sediments. Surface geoelectronical (resistivity and IP) measurements proved the presence of the evaporite complex under 20-50 m cover next to the NW side of the Alsótelekes dolomite quarry (Verő & Milánkovich 1983). The gypsum open pit in the Nagy Valley lies some hundred meters away from that fault.

Stratigraphically the evaporitic formation can be considered the lowermost known unit of the Silicikum, named Perkupa Anhydrite Formation of Upper Permian age (Fülöp 1994). The Silica Nappes were detached from their basement in the incompetent material of this formation which acted as a décollement horizon (Less 2000). It is a typical lagoon facies sediment with sabkha-like conditions on the higher and reductive conditions on the deeper parts. There are three textural types of gypsum layers: brecciated, selenitic (coarse-grained) and laminitic. The lenticular, outwedging strata of the tidal zone

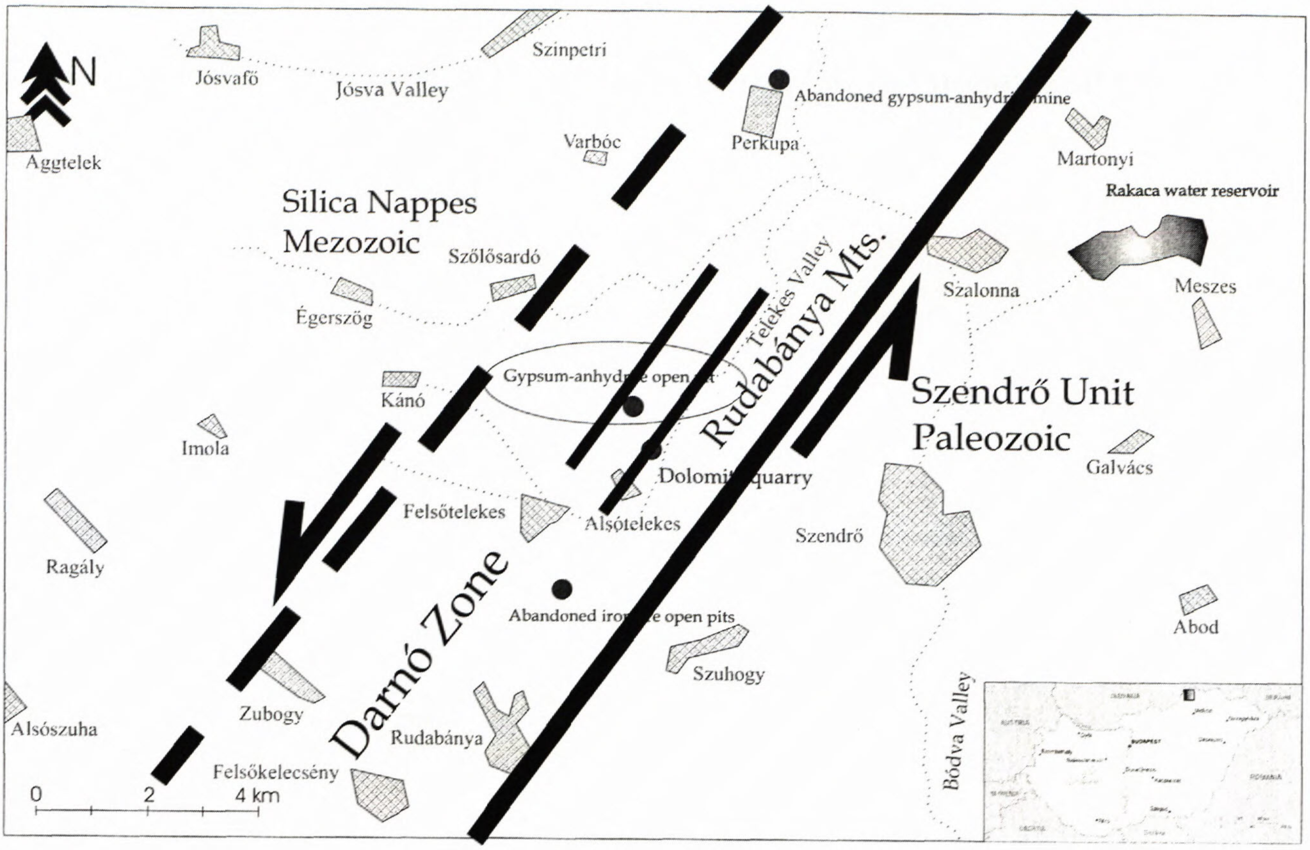

Fig. 1. Sketch map of the Rudabánya Mountains with the major tectonic elements.

Table 1. Chemical and mineralogical composition of the gypsum types at Alsótelekes. Chemical data measured in the Rudabánya laboratory, mineralogical data in the Eger laboratory of the OÉÁ (Hungarian Ore- and Mineral Mining Co) in 1987.

Chemical composition, %	**Laminitic gypsum**	**Selenitic gypsum**	**Brecciated gypsum**
SiO_2	1,2 – 8,6	2,2 – 3,55	4,05 – 10,05
Al_2O_3	0,1 – 0,52	0,12 – 0,26	0,12 – 1,01
CaO	26,63 – 31,54	28,7 – 32,53	25,23 – 29,44
MgO	1,61 – 2,72	0,4 – 2,81	1,92 – 6,35
CO_2	2,17 – 4,02	1,17 – 2,57	1,95 – 14,60
SO_3	36,70 – 43,50	40,3 – 44,05	30,39 – 40,13
Fe	0,2 – 1,0	0,2 – 0,8	0,20 – 1,10
Izz. veszt. 60°C	0,02 – 0,25	0,04 – 0,07	0,07 – 0,15
Izz. veszt. 225°C	15,18 – 18,71	16,98 – 18,38	12,43 – 16,79
K_2O water soluble	0,2 – 1,0	0,2 – 0,9	1,0 – 1,35
Na_2O water soluble	0,01 – 0,02	0,01 – 0,02	0,01 – 0,02
Mineralogical composition, %			
gypsum	77 – 92	85 – 93	64 – 85
anhydrite	0,5 – 6	0,5 – 5	1 – 7
carbonate	4	0,5	4 – 15
magnesite	4 – 5	3 – 4	5
muscovite	10	5 – 7	10 – 13
plagioclase	3	1 – 2	3
quartz	2	1 – 2	1 – 10
pyrite	-	-	1
serpentine	-	-	2 – 10

Fig. 2. SE-looking overwiev of the Alsótelekes gypsum-anhydrite open pit, 2004.

contain sand and cm-scale, slightly rounded, flat pebbles of anhydrite precipitated before and torn up by the wawes. On the highest parts elevated over the tide level lenses of red clay with iron oxides were formed. The strata formed beneath the tidal zone are dark, sometimes bituminous shales, sulphates and carbonates with fine scattered pyrite grains. Anhydrite occurs either with shale inclusions or with dolomite interlayering. The frequent alternation of the different rock types shows the undulation of the water level during the sedimentation. The microlayering of the dolomitic anhydrite indicates (probably seasonal) changes in temperature.

In the survey area and in the pit all contacts of the gypsum-anhydrite body are discordant. The direct cover is a continental red clayish sediment with debris and lenticular bodies of limestone breccia and resedimented black or purple clay of the evaporitic complex. The material often contains acicular gypsum crystals and veins. This sediment can be classified by its facies and material in the Lower Miocene Zagyvapálfalva Clay Formation, which is widely distributed in North Hungary. On the NW side of the pit large (10 m scale) blocks of dark and bright Steinalm Limestone are present, not directly on the gypsum but on the continental sediment and on black shale. This unmetamorphosed Steinalm Limestone is considered to belong to the succession of the Silica Nappes (Less 2000). There are also separate blocks of black shale, sandstone, dolomite and limestone of unidentified origin enclosed by the gypsum. Dark carbonates may have come from the Gutenstein Formation (underlying the Steinalm Limestone) but may be of Paleozoic origin as well. Black shale is most prevalent on the NW side not only in lateral contact with the gypsum but also with the continental sediment and between limestone blocks. Several blocks of black and bright limestone occur in a NE-SW striking zone on the SE side of the pit. This limestone is karstified and it contained considerable amount of water. The gypsum itself has become karstified on the top here too, with dolomite debris in the caverns (Fig. 3).

The uppermost beds are Pannonian fine-grained lacustric and limnic sediments with several lignite beds. The bedding is subhorizontal but seems to be inclined over the highest parts of the gypsum body.

Structure of the gypsum-anhydrite body

The present open pit explores the western side of a NE-SW elongated dome structure. In the upper 30-35 m of the evaporitic complex in the pit mainly gypsum with laminated black mudstone and anhydrite stripes can be found while under it there is a laminated dolomite-striped anhydrite. Several diapirs or mushroom-shaped intrusions of 10-20 m diametre with steep or vertical lamination are explored (Fig. 4). The laminated gypsum (which is the most prevalent type) shows at every part of the pit well-developed signs of ductile flow. Although the lamination may be an original sedimentary feature it is wholly transposed containing isoclinal or nearly isoclinal, dm-scale

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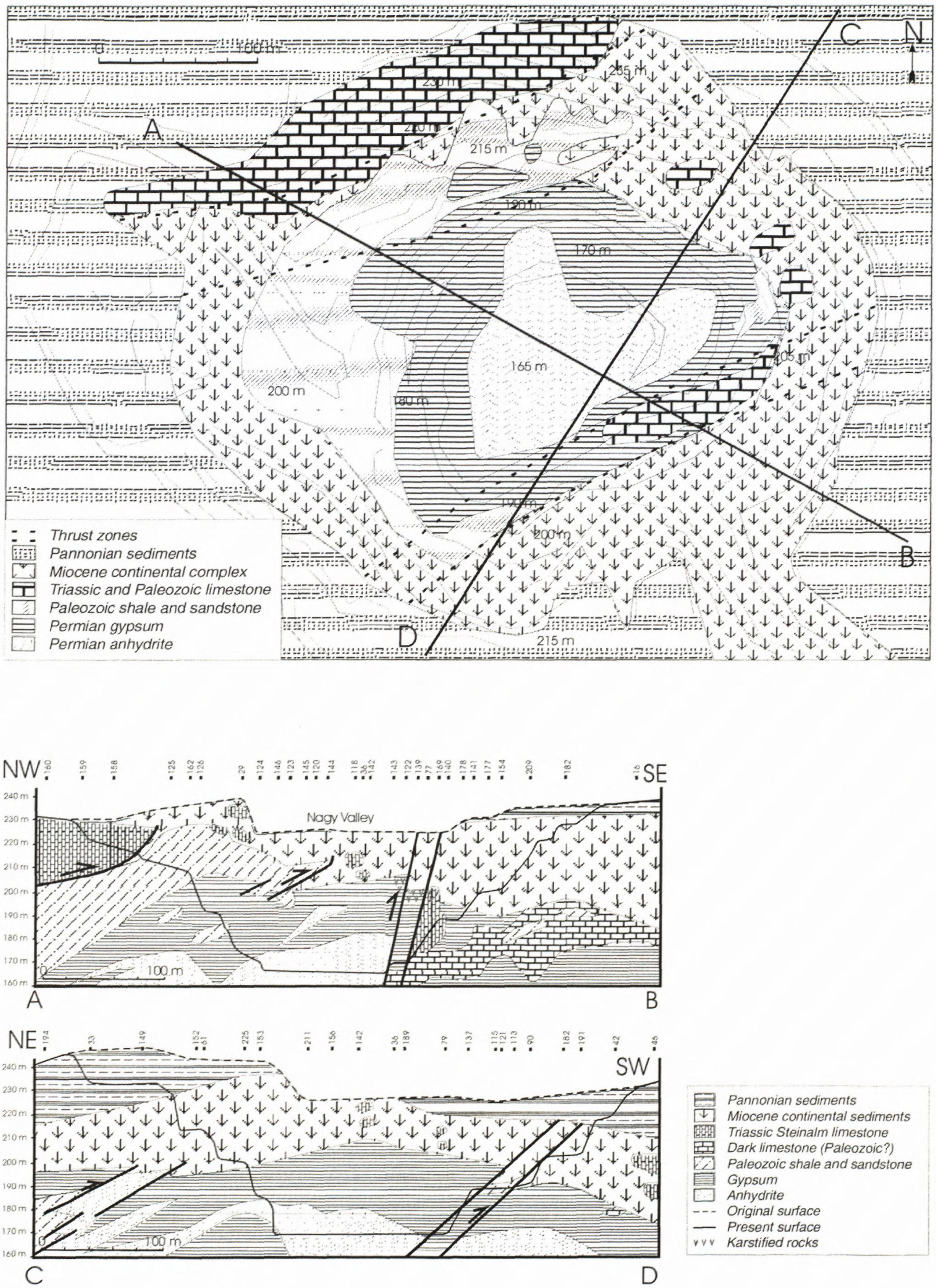

Fig. 3. Geological map (a) and profiles (b) across the Alsótelekes gypsum-anhydrite open pit.

Fig. 4. Diapir-structure in laminated gypsum.

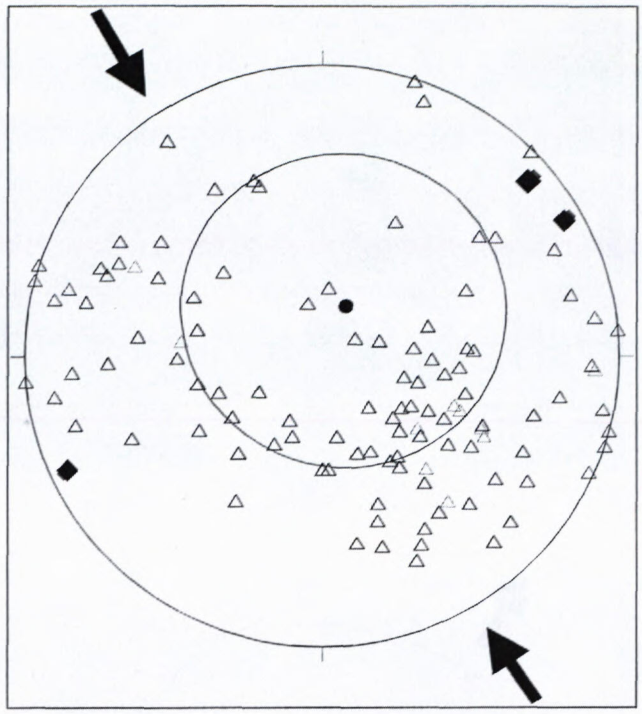

Fig. 6. Stereogram of the gypsum lamination dips. Triangles indicate lamination plane poles, qadrangles indicate second phase fold axes, best-fit small circle with dot indicates axis and folding angle of the dome (a conical fold), arrows show second phase compression.

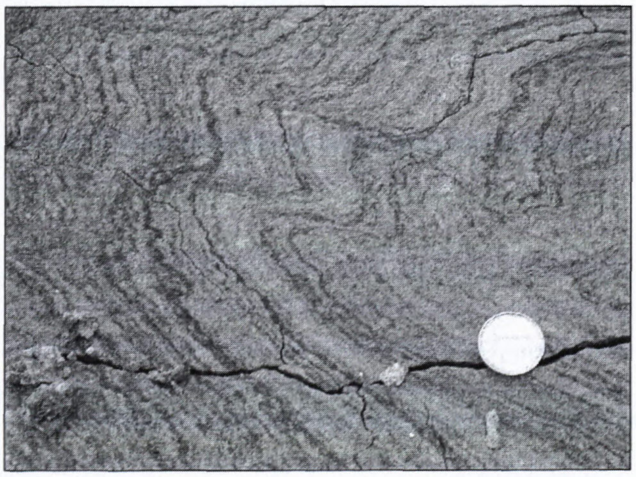

Fig. 5. Folding in laminated gypsum.

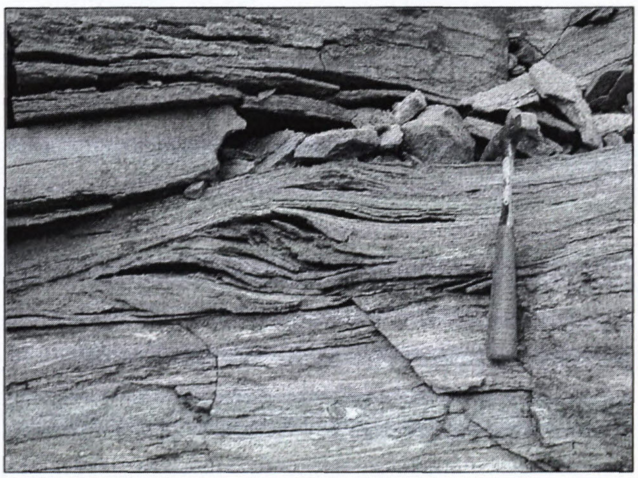

Fig. 7. Slightly bended anhydrite layers. The hammer is 28 cm long.

similar folds (this is the third-order folding here) (Fig. 5). These folds may seem to be cylindrical in their profiles but typically they are conical sheath folds. The laminae are continuous in general but truncated at enclosed limestone, sandstone or shale bodies. The dip angle has sudden changes from moderate to almost vertical in some zones. The pattern of the dips measured in the pit outlines a set of conical folds with subvertical axes (a diapiric structure) which corresponds to the second-order folding of a dome (Fig. 6). On the top of the diapirs the lamination is almost horizontal and bends over the top of the diapir like over a bootlast.

Anhydrite is also laminated but small-scale third-order folding is rare and of different style: the lamination bends with a gentle curvature, there are no sharp hinges (Fig 7). When it occurs together with gypsum, it acts as a competent material. Anhydrite pebbles in the laminated gypsum have in some cases δ-tails showing the direction of the tectonic transport (Fig. 8). Brecciated gypsum appears together with dark carbonate or sandstone clasts in the core of m-10m scale sheath folds (Fig. 9). It also seems to be competent in contrast to the laminated kind. Around these folds the laminated gypsum is jointed with curved surfaces reminding of onion

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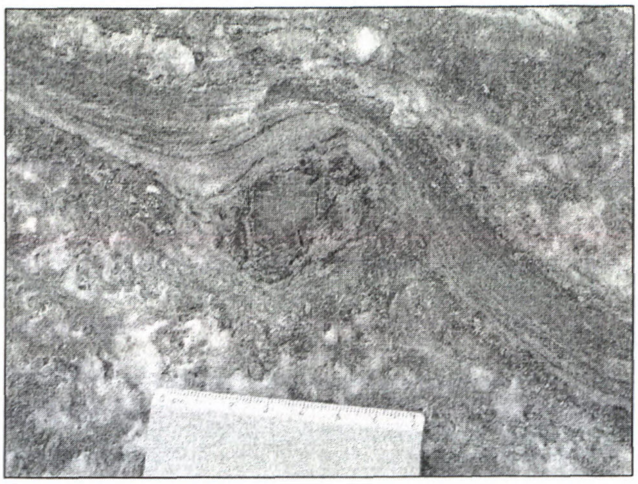

Fig. 8. Anhydrite clast with δ-tails in laminated gypsum.

Fig. 9. Sheath fold with limestone in the core.

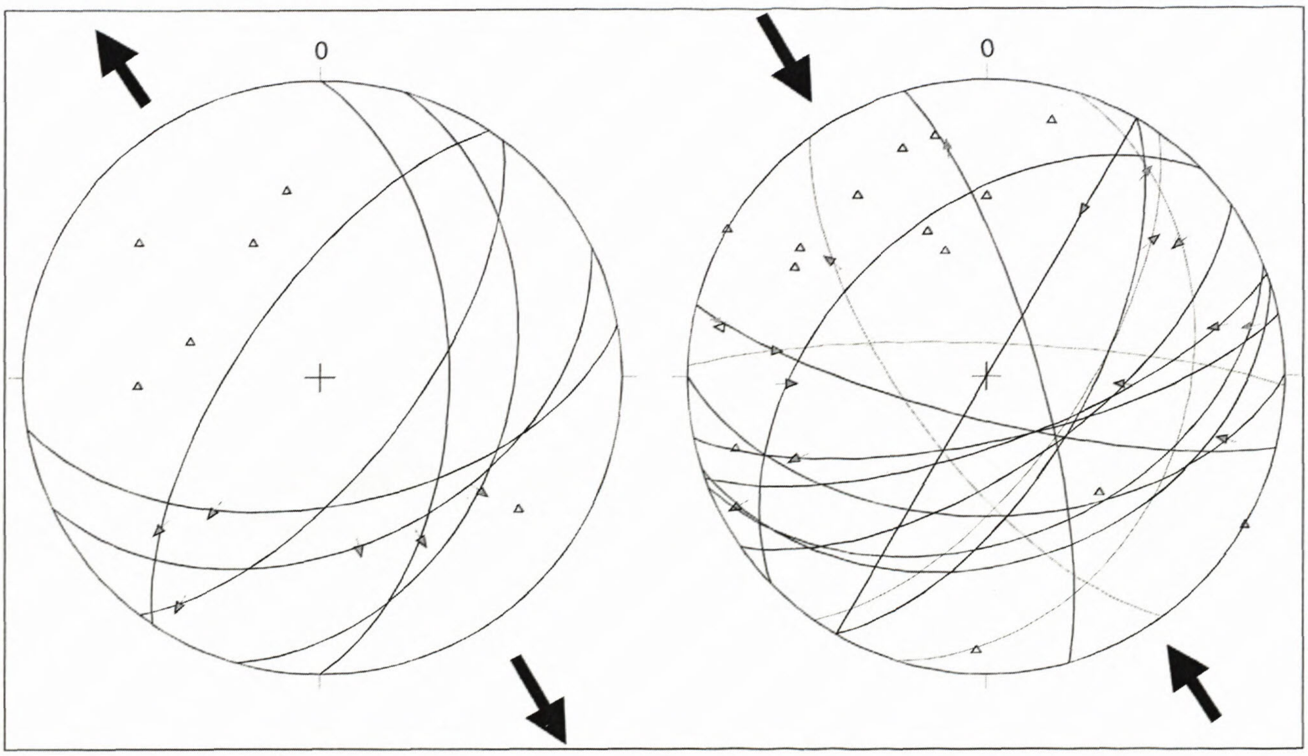

Fig. 10. Stereogram of the movements in the Steinalm limestone in the NW part of the pit. Major circles indicate planes, arrows indicate movement directions.

skin. The typical axis direction of these folds is horizontal around the 60°-240° strike corresponding to the elongation of the dome. When they occur together with vertical diapiric folds of the same scale, it causes a wavy interference pattern. The folding of the laminated gypsum is often associated with formation of brittle shear joints in the included or adjacent rock bodies.

In the S part of the pit there is a NNW-dipping fault zone with several blocks of dark limestone and with serpentinite-diabase clasts similar to the rocks reported from Perkupa (Mészáros 1957). Gypsum is brecciated at the contact and the movement planes on the limestone have slickenlines indicating a S-vergent overthrust. In the gypsum on the N side of this zone there is a 10 m-scale SSE-vergent antiform. In the core of this fold there is brecciated gypsum with several shear joints parallel with the axial plane of the fold and with slickenlines corresponding to the shear sense necessary to accommodate to the fold shape, forming an axial plane spatial cleavage with dm-scale domains. These joints are filled with acicular gypsum, and the fibres are perpendicular to the movement direction.

On the NW side the Steinalm limestone blocks are also in an overthrusted position and contain several movement planes with slickenlines. The older set of slickenlines indicates a NNW-SSE extension with normal faulting, while the younger set shows shortening in the same direction, corresponding to the present position of the blocks (Fig. 10).

Deformation history

The evaporitic diapirism at Alsótelekes is connected with the Miocene sinistral strike-slip dislocation of the Darnó Zone (Fig 1). The formation of the dome started with the opening of a zone-parallel elongated pull-apart basin along the NNE-SSW striking Telekes Valley fault in the Lower Miocene. The incompetent material of the evaporitic complex were moving toward this zone by ductile flow under the load of the overlying Mezozoic rocks and produced an anticline by its thickening. The remnants of the Mezozoic cover were uplifted and partly embedded in the evaporites while other blocks slipped aside. As the anhydrite became the outcropping layer on the surface, it was partly transformed into gypsum with karst features on the top. Meanwhile in the basin thick continental debris was accumulated, burying step by step the dome.

In a next phase, maybe still in the Lower Miocene the basin was inverted and closed by a NNW-SSE transpression. This phase is characterized by SSE-vergent thrusting of the competent blocks with folding of the gypsum, forming an uplifted, imbricated structure. The area took up a geographically high position as younger sediments are missing up to the Pannonian and these lie on an irregular sedimentation surface.

The Upper Pannonian lignite-bearing formation is unaffected by the evaporite tectonics, though its layers show slight bending above the gypsum diapir due to later extensions. In a cm-scale view, this bending is realized by several microfaults (Fig. 11). This subsidence can be derived either from solution processes or the slow ductile flow of the gypsum towards the Nagy Valley.

Conclusions

The Alsótelekes gypsum-anhydrite body is a diapiric dome structure intruded into a pull-apart basin of the Darnó Zone, overprinted by imbrication during the closure of this basin. The pit exposes the SW side of this anticline. The gypsum shows typical features of evaporite tectonics with structures of the ductile flow, while the deformation of other rocks was characteristically brittle. The most probable time of the main deformation events is Lower Miocene which is the supposed main period of activity of the Darnó sinistral strike-slip faulting.

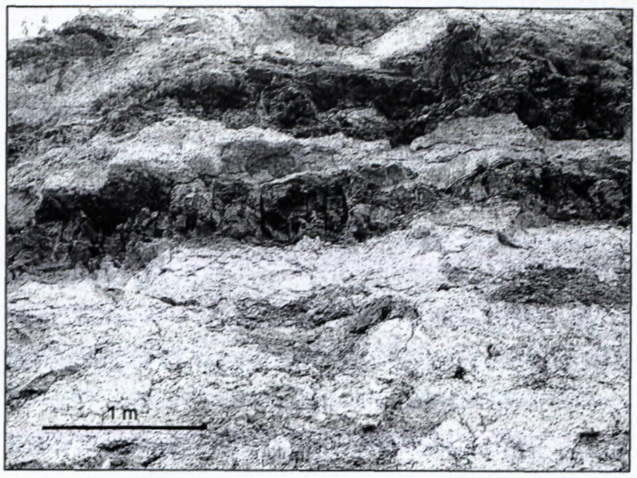

Fig. 11. Lignite beds with vertical joints.

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