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Structural and Tectonic Composition and Origins of the Magnesite Deposit within the Dúbravský Massif near Jelšava, based on studies at the 220 m elev. Level (Western Carpathians)

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Magnesite deposit Jelsava – Dubravsky Massif represents one of the foremost deposits in Europe, even in the world, in terms of its reserves size. A geological exploration and development of new blocks between the elevation levels of 220m and 320 m allowed more detailed studies of structural and tectonic development within the deposit, which yielded new results. As the mining continues deeper, it becomes essential to understand details of the youngest extension phase of the deposit deformation. This stage, combined with the earlier deformation stages, completes the deposit's complex structural development which significantly influences the distribution of mined raw materials, the stability of mine workings and the mining operations' safety. This paper summarizes individual structures studied and their characteristics. A special attention was devoted to youngest structures, which most likely developed during the Neo-Alpine stage. These structures completed the current block composition of the deposit and thus are the proof that even the oldest units within the Western Carpathians bear signs of the youngest deformation stages.

Key works: *Magnesite deposit, Jelsava, structural and tectonic, deformation phase.*

Introduction

The units within the Central and Inner Western Carpathians (Fig. 1) were significantly reworked by tectonic events during initial stages of Alpine orogeny in its Paleoalpine phase. This can be observed in conditions of the geology development between Gemericum and cover units of Veporicum (Hok et al., 2004). Based on results of studies of lithostratigraphy and radiometric dating, these tectonic processes were most intense during Upper Jurassic to Lower Cretaceous periods, which resulted in a significant structural and tectonic reworking of Meliaticum (Faryad S.W. and Henjes-Kunst, F., 1997). Plasienka, D. (2002) states that the structural composition of Veporicum, Hronicum, Fatricum and Tatricum within the Western Carpathians was formed gradually from the south during the time between the Jurassic and Cretaceous periods and from the north during Upper Cretaceous period. The crystallinicum complex was tectonically reactivated and moved during the time period between Upper Cretaceous and Paleocene (Plasienka, D. et al., 1999).

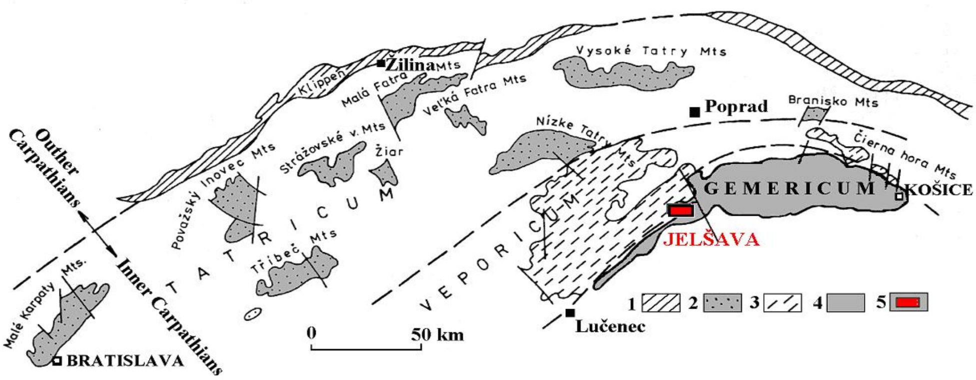

Fig. 1. Location of Jelsava deposit within the Western Carpathians (Grecula, 1995, edited). 1 – Bradlo Zone, 2 – Tatricum, 3 – Veporicum, 4 – Gemericum, 5 – Jelsava Deposit (2-4 – only pre-Triassic units)

The lower-Miocene sediment subduction of Outer Western Carpathians and European Platform is classified as one of the very important neo-Alpine tectonic processes. Subsequently within the Inner Carpathians, influenced by directional horizontal shifts, the disintegration of rock complexes occurred, followed by block rotations and horst-graben formations (Hok, J. at al., 2000). A compression

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of the subducted plate caused the formation of the outer-arc extension tectonic development within the Carpathian-Pannonian region (Lexa et al., 1993).

Doming of the asthenosphere during the Middle Miocene caused a maximum development of the outer-arc extension associated with the volcanic activity.

A final extension stage was observed within the rock environment of Paleozoic carbonates within the Jelsava magnesite deposit. This stage was represented by significant structures and tectonic zones, which segmented the deposit into several megablocks. These complete an already complex makeup of the entire carbonate body, characterized by the horst-graben formation.

Relationships among tectonic structures of individual deformation phases

Structural and tectonic studies were conducted at the Levels 482, 450, 400, 390, 323 and especially at the Level 220m elevation, studying structures, which segment the carbonate host rock with magnesite, dolomite and limestone sections. Studied were their inter-relations, filling and permeability. The current state of these structures is much more complex, influenced by a repeated development of secondary structures, which developed during every deformation stage AD_1, AD_2 a AD_3, containing deformation sub-phases generating deformation structures of mainly shearing characters. The spatial orientation of newly-formed shear structures depends on the orientation of dominant tension field, which was present during the development of the deformation sub-phases.

Tectonic structures (Fig. 2) are represented by following types:

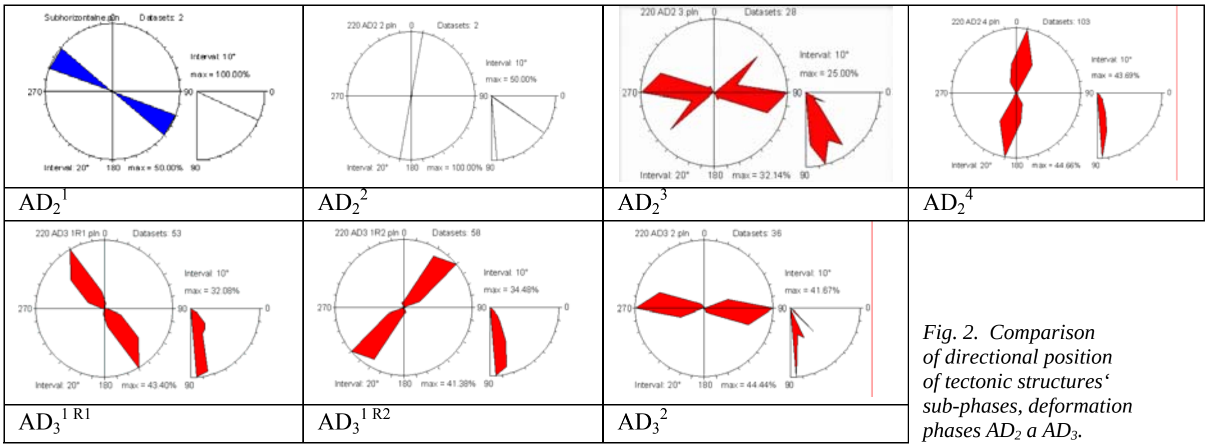

Fig. 2. Comparison of directional position of tectonic structures' sub-phases, deformation phases AD_2 a AD_3.

The spatial development of tectonic structures is mostly associated with following forced spatial structural directions of the slip-shear model during the deformation stage AD_1 and the simple shear deformation stage AD_2 (Fig. 3), while the release during the deformation stage AD_3 only re-activated already existing tectonic structures along their strikes and dips. Some re-activation of structures also took place within structures developed during the AD_2 deformation stage.

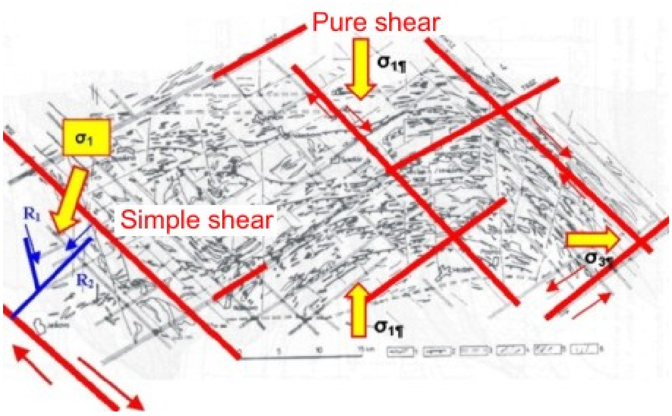

Fig. 3. Main Paleo-Alpine structures' model during the initial deveopment of slip-shear (AD_1) with subsequent development of simple-shear structures (AD_2) within Spišskogemerske Rudohorie. (Main trends of shear zones NW-SE and NE-SW are taken from Grecula (1995)).

The examinations of the relationships between the deformation sub-phases concluded that the above described intra-structural development cycles were also present during the older structural sub-phases. This could be attributed to changes of Paleo-tensions within individual deformation sub-phases, where representations of cyclical processes vary among individual structures.

The individual sub-phases of deformation phases display trends of N-S, E-W, NW-SE and NE-SW. They dip sub-vertically, steeply, in some cases also sub-horizontally. A re-activation is characteristic for tectonic structures. This causes occurrences of similar strike and dip values within younger deformation phases.

Block Shifts

At the Level 220 m elevation in the mine, in the area of crosscuts P-4-S, P-5-S, P-6-S, there is a presence of significant sub-horizontal and oblique shifts (Fig. 4). These shifts are associated with structures of different types of deformation phases. Some planes display markings of strong grooving or tearing, where structures of respective sub-phases are disturbed by structures of younger sub-phases. This suggests that the shifts occurred most likely as a result of inter-block shifts during deformation phases. Re-activation of structures due to changes of tension field took place during the re-balancing of tension forces. The studies of relative age of shifts and dips of blocks concluded that the dips were always of older age.

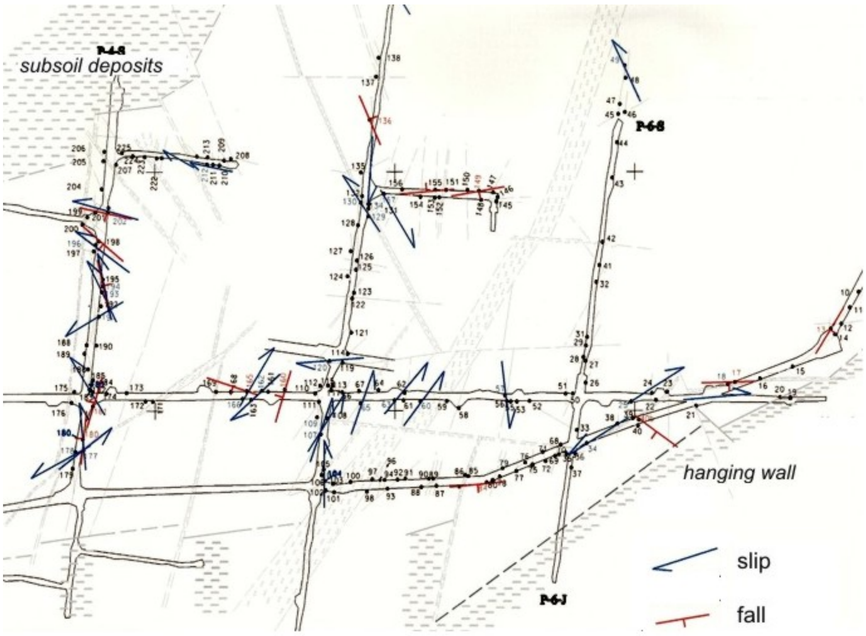

Fig. 4. Structural map of block shift lines and dips at the 220m elevation level.

Block Dips

Some block dips were detected in several locations in the eastern part of the 220 m elevation Level. Their distribution is relatively uniform (Fig. 4), suggesting a repeated dipping of individual structural blocks. Block dips can either be just dips or can be combined with shifts along the same plane. *The shifts are always of the older date.* This could be due to a younger extension process, predisposing conditions for structural dip formations.

Karst Structures

The analysis of tectonic structures related to individual deformation phases concluded that karst structures. A vast majority of karst structures is dry at the present time. The structures are closed. Their development is multi-stage and multi-event. They can be classified as the fossilized karst structures.

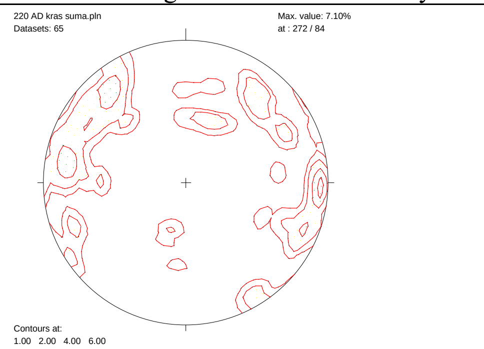

Fig. 5. Contoured pole tecktonogram of karst structures of deformation stage AD_3.

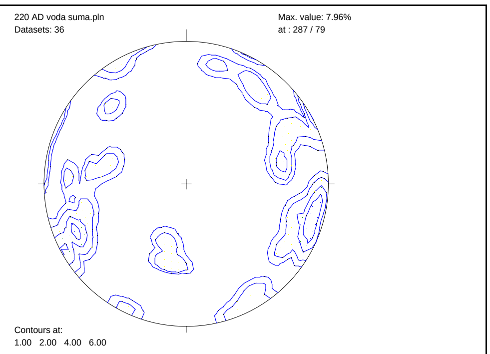

Fig. 6. Rosette tectonogram karst structures of deformation stage AD_3.

The most abundant and most prominent structures of the karst zone are associated with the structures of deformation sub-stages AD_2^4, $AD_3^{1\ R1}$ and $AD_3^{1\ R2}$. They populate trends of N-S, NE-SW and NW-SE. The most frequent trending zone of karst structures is 10°-50° (Fig. 5). Approximately 30 % of karst structures have steep - 75°to 85° dip angles. Most unstable are the structures trending NW-SE, which were re-activated several times. The structural analysis of disturbed zones had shown that the largest, best developed karst zones, several metres in size, are trending NE-SW. *These structures, under the criteria of massif disturbance, are the most unstable and prone to collapsing.*

Water-filled structures

A water presence is represented by wetness, water dripping or flowing from tectonic structures. Some open structures have outflow of up to 4l/sec.

The water presence within tectonic structures is associated with structures of individual deformation stages. Comparing structures of fossilized karst (Fig. 5) with recent open and water-bearing structures (Fig. 6), it appears that only an overlap exists in the N-S structures. All other trends are new, 105°-150°.

The analysis of karst structures and water-bearing structures concluded that, from the point of view of fossilized karst, the thickness of disturbed zones and recent water-bearing structures, the order of importance and stability of host rock have the following directions of weakening: the several-metres-thick zones of disturbance, the karst development of NNE-SSW trend, the coincidence of karst and the water-bearing structures of N-S trend and the smaller development of karst structures, the coincidence of water-bearing structures of NW-SE trend.

Structural relationship of Block "B" with the eastern part of the 220m elevation Level

The tectonic structures of Block "B" are defined by then Dúbravský fault in the western part and the Hradoviskový fault in the eastern part. This asymmetrical triangular space contains spread sub-vertical structures with a fan-like distribution of rock blocks A, B, C, D, E (Fig. 9). The sub-vertical connection zones of intra-block spaces define the fan-like block development.

A more intense disturbance of Block "B" due to tectonic structures can be observed in the vicinity of the Dúbravský fault. Detected were complex spatial rotations of rock blocks, sinistral rotations around sub-vertical axes and dextral rotations around sub-horizontal N-S and E-W axes. A negative influence on mining operations from the fan-like development of rock blocks can be expected. A strong tectonic block separation with very irregular fault directions and different fault infill may be the cause of the host rock instability in this part of the deposit.

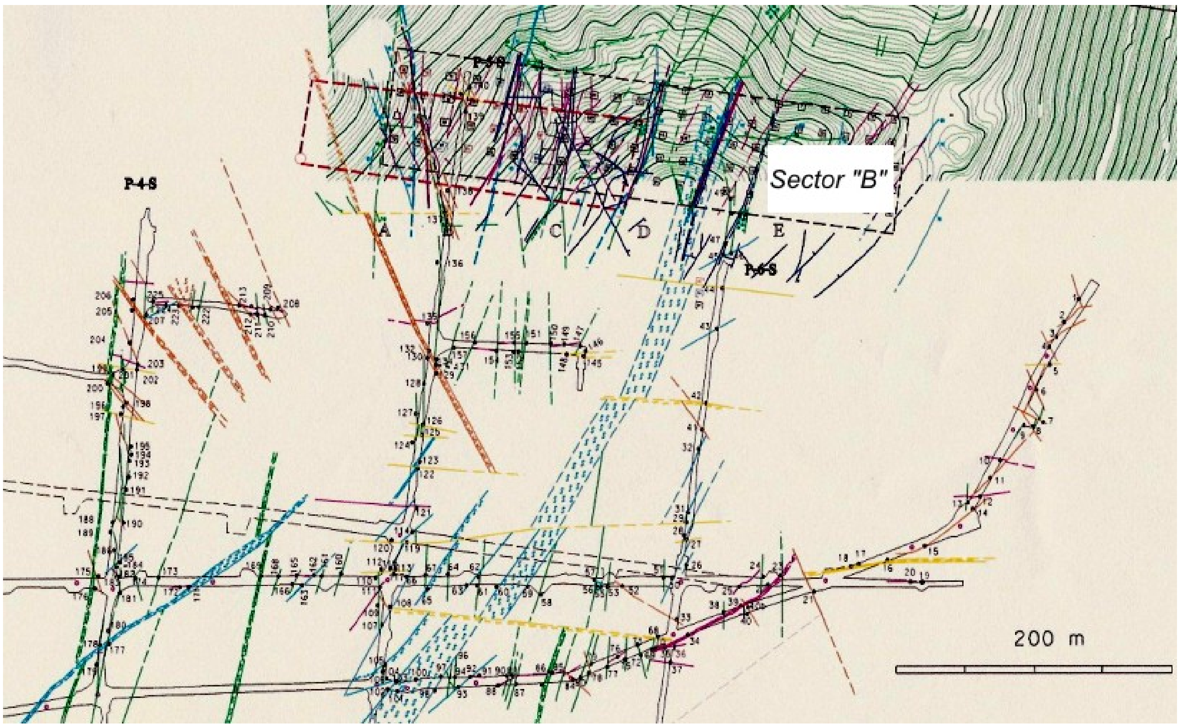

Fig. 7. Projections of tectonic structures in the area of Block "B" and eastern part of the 220 m elev. Level. Structures of deformation phases: purple-AD_2^3, green-AD_2^4, orange-brown-$AD_3^{1\ R1}$, blue-$AD_3^{1\ R2}$, yellow-AD_3^2.

The fan-like distribution of main structures is the northernmost continuation of the fan-like contact of Dúbravský and Hradoviskový faults at the 220 m elevation Level (Fig. 7). These structures resulted from the development of secondary structures of simple shear shift in the NW-SE direction of the regional shear structure of Spissko-Gemerske Rudohorie and the Jelsava-Revuca fault.

Conclusion

Three deformation phases, associated with geological-tectonic events of the Western Carpathians‘ development were identified within the magnesite deposit at Jelsava. It is assumed that in the area of Spissko-Gemerske Rudohorie, the deformation phase AD_1 is associated with the N-S trending Paleo-Alpine collision. The sub-horizontal compression-induced tension caused a development of slip shear within the regimen of deformations with a subsequent development of diagonal main shear zones NE-SW and NW-SE trends.

A reflection of intra-block movements along diagonal shear zones of the deformation stage AD_1 of NE-SW and SW-NE trends subsequently facilitated a development of tectonic structures within the simple shear deformation regimen. The system of simple shear secondary compression structures is characteristic by a development of tectonic breccia of different sizes. This deformation phase was classified as AD_2.

The period of tectonic relaxation within the extended tension field in Spissko-Gemerske Rudohorie is characteristic by the deformation phase AD_3 (Sasvári, T., Kondela, J., 2007). The extension released and opened structures of the previous deformation stage, which were then used as conduits for the epigenetic and hypergene mineralization. Developed were veins with several generations of quartz, dolomite, calcite and magnesite III. The mineralized structures were re-activated several times, which sometimes allowed for the formation of karst structures, disintegration of veins and the current water penetration.

The young Neo-Alpine development of Western Carpathians was the singlemost influence on the current development and morphology of not only the youngest units, but played a significant role influencing older units of Western Carpathians. While younger phases were associated with the contribution of volcanic activity and the development of new deposits within the Neogene volcanic environment, the older units were subjected to the destruction of deposits already present within them. One of the prime examples of this is actually one of our largest underground deposits – the actively mined deposit at Jelsava. The youngest most recent extension caused a development of karst even in relatively deep parts of the deposit, more than 400 m under the surface at the 220 m elevation Level. At the present time, these further disintegrate the already weakened host rock environment and complicate mining conditions of the deposit. All listed phenomena also significantly influence the distribution of mined minerals, mining safety and the stability of mine workings.

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