ISSN 0543-5846
METABK 46 (2) 117-122 (2007)
UDC - UDK 553.3(437.6):622.368=111

DEMONSTRATION OF ALPINE STRUCTURAL PHENOMENA AT THE STRUCTURE OF MAGNESITE DEPOSIT JELŠAVA - DÚBRAVA MASSIF

Received - Primljeno: 2005-06-10
Accepted - Prihvaćeno: 2006-05-05
Review Paper - Pregledni rad

Magnesite deposits in the Central Western Carpathians belong among the biggest deposits in the Europe. Their today's structure is mainly the result of the Alpine orogenesis. During this period several deformation stages were active, which deformed the deposit body. This resulted in today's complicated structure of the deposit. The genesis of deposit is still ambiguous; however, the importance of the Alpine orogen is clear at least from structural point of view. The presented individual deformation stages show multiple compressional and extensional phases. Identification of properties of individual structures directly helps at exploitation of individual parts of the deposit.

Key words: *magnesite deposits, deformation stages, exploitation*

Prikaz fenomena alpskih struktura u strukturi magnezitnog ležišta Jelšava u masivu Dubrava. Magnezitna ležišta u centralnom dijelu Zapadnih Karpata ubrajaju se među najveća ležišta u Europi. Njihova današnja struktura je uglavnom rezultat orogeneze Alpi. Tijekom toga peroida bilo je aktivno više faza pomjeranja koje su deformirale tijelo ležišta. To je dovelo do današnje komplicirane strukture ležišta. Geneza ležišta je još uvijek nejasna. Međutim važnost alpskog orogena je jasna, barem s točke gledišta strukture. Prikazane pojedinačne faze deformacije pokazuju faze višestrukog tlačenja i istezanja. Određivanje svojstava pojedinih konstrukcija izravno pomaže eksploataciji pojedinih dijelova ležišta.

Ključne riječi: *magnezitno ležište, faze pomjeranja, eksploatacija*

INTRODUCTION

Damping of ore mining after 1990 resulted in dominant position of magnesite deposits in relation to underground exploitation of ore deposits in Slovakia. Among the most important magnesite exploitation organizations belongs Slovak Magnesite Company, Inc. Jelšava, which produces loose alkaline heat-resistant materials with its own ore-material base. The deposit is assigned to the largest magnesite deposits all over the world (Figure 1.).

With its specific mineralogy it represents a unique source of ferrous magnesium used for production of the best quality basic monolithic matters for steelworks (www.smjelsava.sk). It produces products for metallurgy, ceramic and chemistry industry as well as for agriculture and building industry. For metallurgy and ceramic industry it produces brick magnesite, basic monolithic heat-resistant ramming, repairing, feed and spraying matters. For chemical industry it produces row magnesite and brick meal, for agriculture components for synthetic fertilizers and for building industry magnesite gravels and sands of various fractions.

The prevailing part of magnesite deposits, including deposit parts of Dúbrava, Miková and Jedlovec in the Dúbrava Massif belongs to the upper part of Ochtiná Formation of the northern Gemericum. The Ochtiná Formation has a flysch-like development with an intensive alkaline volcanism in its lower part. In the area of Dúbrava Mas-

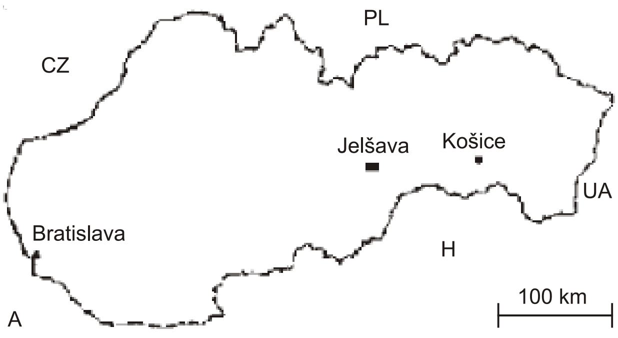

Figure 1. **Geographical position of the magnesite deposit Dúbrava massif**
Slika 1. **Zemljopisni položaj magnezitnog ležišta masiva Dubrava**

T. Sasvári, J. Kondela, Faculty of Mining, Ecology and Geotechnology, Technical University of Košice, Košice, Slovakia

sif this lithostratigraphic sequence is 150 - 200 m thick. It gradually passes into 60 m thick interval of sericitic gray and black phyllites with small amount of psamitic material. In the higher position a gradual transition from pelitic to carbonate deposition is preserved. The thin- and thick-layered dolomite passes into overlying deposit bodies of magnesite and dolomite (Figure 2.).

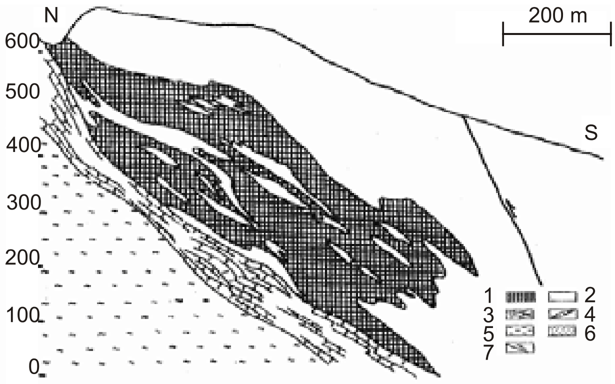

Figure 2. **Geological profile (direction N-S) through the magnesite deposit Dúbrava massif (Čapo, 1992)**
Slika 2. **Geološki profil (smjer S-J) kroz magnezitno ležište masiva Dubrave (Čapo, 1992)**

The strike direction of the magnesite horizon in the Dúbrava Massif is 4500 m in E-W direction. It dips 55 - 60° southward and has maximum thickness about 600 m. The magnesite comprises irregular bodies in the dolomite.

The age of the magnesite horizon in the Ochtiná Formation, based on paleontology, is Upper Visean - Serpuchov [1]. The genesis of the magnesite was interpreted by [2] as sedimentary - exhalation deposit. [3] it interprets as metamorphous-metasomatic, [4] as hydrosomatic and [5] as sedimentary with multiple tectono-metamorphic reworking. Metamorphous origin of magnesite deposits is also suggested by Grecula et al. [6].

STRUCTURES IN THE FIELD OF DÚBRAVA MASSIF

Tectonic picture of Gemericum [7] was importantly affected by regional shear zones, which are a part of the entire Carpathian belt shear zones. Their activity is polyphase and lasted from the Createaceous as long as Neogene. The represent a system of parallel faults with simple-shear character and a clear discontinuity at individual structures. As to kinematics, they have character of horizontal translations with sinestral translation on NE-SW shear zones and dextral translation on NW-SE zones.

The NE-SW and NW-SE shear zones suggest initial north-south shortening of the fundament, which at the same time generates fundament nappe and superficial nappes [8].

In Jurrasic and Early Cretaceous in N-S compressional regime it came to the tectonic arrangement of the Gemericum rock complexes with contemporaneous products of several metamorphic events [9].

The primary stress of deformation phase AD_1, resulted due to N-S subduction, provided origin of NW-SE and NE-SW shear structures and origin of E-W fold structures with subhorizontal axis of regional folding.

An important activization of shear zones belongs to the Early and Middle Cretaceous because all granites in the Gemericum occur in the shear zones. This is suggested by data yielded by separated biotites from the granite, which assume the age of 100 - 140 My [10]. The subhorizontal translations in direction of evolving shear zones of the deformation stage AD_2 provided conditions for reactivization of N-S and NNE-SSW, E-W structures and origin of secondary structures in simple-shear conditions.

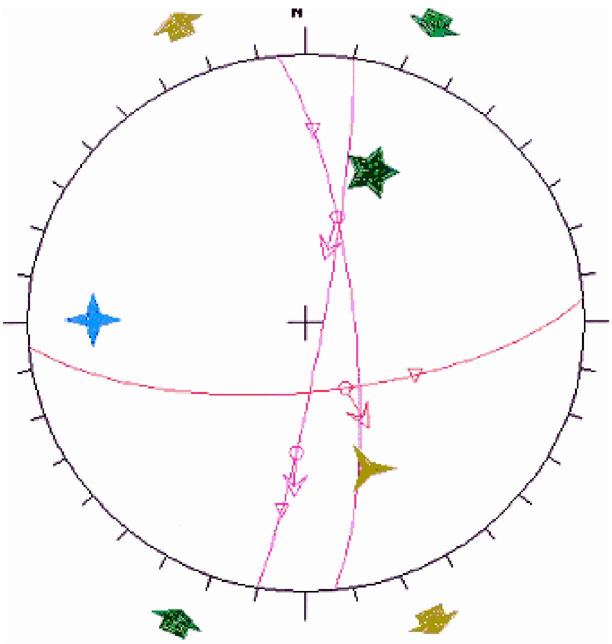

Figure 3. **Paleostress tectonogram showing stress $\sigma_{1\text{-}3}$ distribution. Thrusts and normal faults originated in transtensional regime and are related to old, N-S fault structures. σ_1 = 23/39°, σ_2 = 271°/25°, σ_3 = 158/41°**
Slika 3. **Tektonogram paleonaprezanja pokazuje rasprostiranje naprezanja $\sigma_{1\text{-}3}$. Potiskivanja i normalne greške nastale u transtenzionalnom režimu odnose se na greške u starim strukturama S-J. σ_1 = 23/39°, σ_2 = 271°/25°, σ_3 = 158/41°**

In the Miková part of the magnesite deposit of Dúbrava Massif deformation phase AD_2 is subdivided into several substages [11]. In this phase it came to the intratectonic mineralization of various dolomite and calcite generations and it also came to the intramineralization tectonics. As to succession, it is possible to characterize four substages AD_2^1, AD_2^2, AD_2^3, AD_2^4. The individual substages are characterized by various paleostress fields. Older primary and secondary structures were reactivated, which mutual relative intensity is various. They resulted from translation subhorizontal motions, thrusts and normal faults. Typical attendant phenomenon is the origin of tectonic breccias of dolomites and magnezite in secondary fault structures of R_{1-2} types (synthetic and antithetic horizontal translations), *P* (secondary synthetic horizontal translations, *T* (tensile fractures), *Y* (horizontal translations parallel to the zone of main translation), elongation of tectonic breccias into pull sigmoidal shapes in compressional fault structures, block rotations, block rotations in thrust conditions, sinistral and dextral translations.

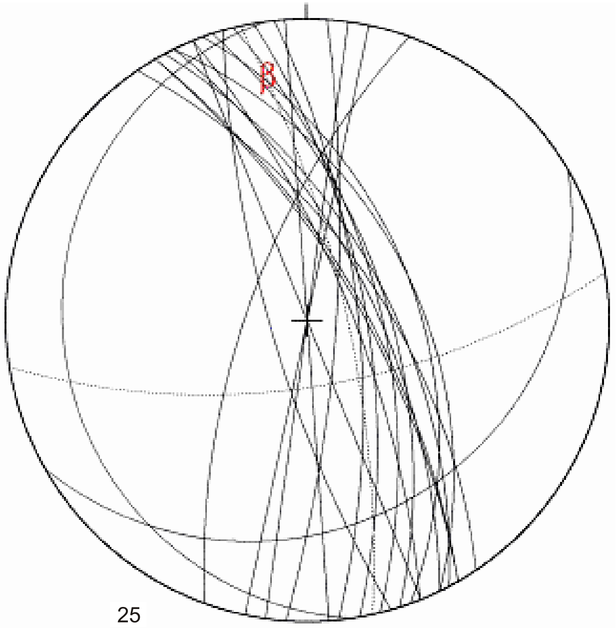

Figure 4. **Great circles of dislocation planes AD_2^2. Calculated mean of intersections of great circles is $\beta \equiv \pi$ poles of rotation axis of dislocation planes**
Slika 4. **Velike kružnice dislokacija AD_2^2. Izračunata sredina presijecanja velikih kružnica je $\beta \equiv \pi$ polova osi rotacije dislokacije ravnina**

Post-Cretaceous evolution of tectonic structures of the deformation stage AD_3 has regionally, and also locally extensive, subsiding character. It generates block rotational movements, block subsidence and opening of deformations in extensive regime. The attendant phenomenon is tectonic breccias in subsided dislocations, where mostly intensive infiltrations of surface, rain water occur.

DEFORMATION STAGE AD_2

Deformation stage AD_2 is subdivided on the base of succession relationships of dislocation structures filled by several generations of dolomites, into four substages AD_2^{1-4}. The measured structures are characterized by dislocation fault plane, lineation reflecting relative motion between two mutually moving blocks or lineation of β-axis of dislocation planes undulation. The substages AD_2^{1-4} contain calculated stress fields with stress tensors σ_{1-3}.

Deformation substage AD_2^1

It is characterized by subvertical faults of NNE-SSW with motion lineation of oblique dextral translation. It is developed in the fine-grained magnesite and it is crossed by dislocation structure of substaged AD_2^2. The field stress (Figure 3.) shows asymmetric distribution of σ_{1-3}, which generated oblique dextral translations in relatively higher compression regime with the coefficient $\phi = 0{,}37$.

Deformation substage AD_2^2

It is characterized by older subvertical dislocation structures of N-S direction. The structure thickness is 20 - 40 cm and they contain tectonic breccias repaired by 3 generations of dolomites, which are represented by milky-white, pink, red and gray dolomites. System of older, N-S

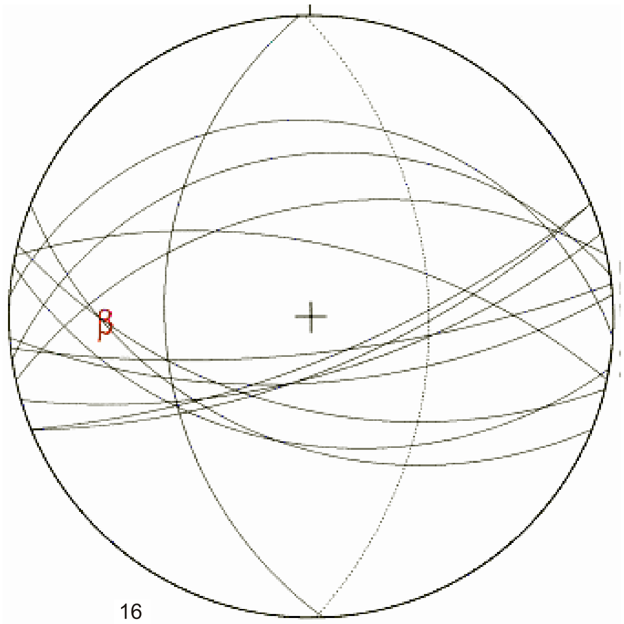

Figure 5. **Summary tectonogram showing dislocation structures of the sector "B". The mean value of β-axis = 269/32° determines cross-section of diagonal subvertical E-W dislocation planes**
Slika 5. **Sažetak tektonograma prikazuje dislokaciju strukture sektora "B". Srednja vrijednost osi β = 269/32° određuje presjek dijagonalne subvertikale I-Z dislokacije ravnina**

structures of deformation substages AD_2^2 is crossed and translated by younger E-W structures of deformation substage AD_2^3. AD_2^2 structures originated as shear structures, as documented by secondary Riedl planes R_1 and destruction shapes of brittle deformation of shear zones.

AD_2^2 stress field is asymmetric. The σ_{1-3} stress distribution (Figure 3.) induced in the following extension regime of NNW-SSE direction normal faults origin. Compressional subphase with horizontal oblique thrusts enabled rotation of subvertical dislocation structures around mean β = 351/18° (Figure 4.).

Deformation substage AD_2^3

It is characterized by striking E-W structures with subvertical dip and thrusts dipping northward. The E-W structures are locally oblique with dip toward south (Figure 5.). Subvertical dislocation structures are 5 - 20 cm thick and locally discontinuously filled by dolomite. E-W structures cross older N-S structures and at the same time are crossed by younger N-S structures. Along the younger N-S structures E-W structures are translated in 1 - 2,5 m. It suggests direction of block restricted by younger N-S and E-W structures. Subvertical E-W structures moved vertically and also horizontally. It is documented by subvertical lineations of translations as well as by subhorizontal sinistral translation lineations.

Important dislocation structures are E-W thrust structures dipping 30 - 40° southward. They occur in the central part of exploitation field of the sector "B".

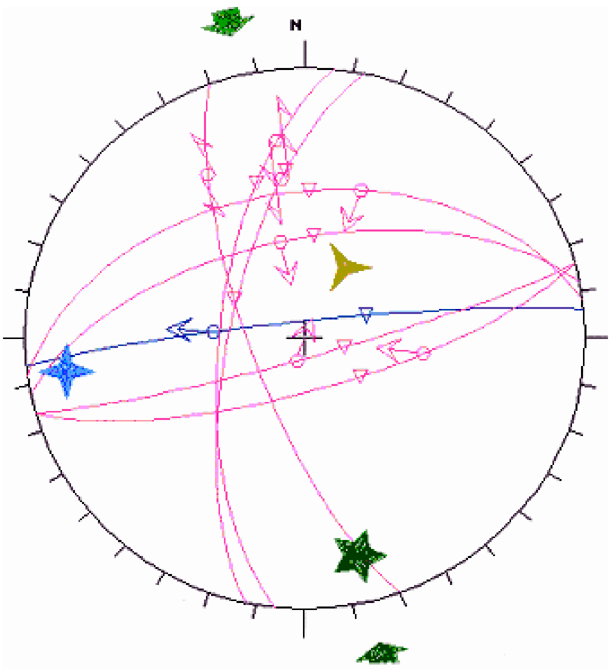

Figure 6. **Tectonogram of paleostress AD_1^3. The stresses σ_1 = 180/22°, σ_2 = 273/7°, σ_3 = 21/67°**

Slika 6. **Tektonogram paleonaprezanja AD_1^3. Naprezanje σ_1 = 180/22°, σ_2 = 273/7°, σ_3 = 21/67°**

The paleostress tectonogram (Figure 6.) containing thrusts and dextral translations suggest by subhorizontal stress σ_1 a striking N-S compression while subhorizontal stress σ_2 provides possible origin o E-W translations. The distribution of paleostresses σ_{1-3} favours origin of primary subvertical dislocation structures of E-W direction, which occur in the northern and southern part of the "B" sector.

Deformation substage AD_2^4

AD_2^4 substage is characterized by younger dislocation N-S structures. It is mostly represented by striking reactivization of older N-S dislocation structures. The younger N-S dislocations intersect E-W structures of deformation substages AD_2^3. In the areas, where E-W structures were not intersected by N-S dislocations, the N-S AD_2^2 structures occur.

The younger N-S dislocations have various thicknesses from 20 to 80 cm. They are filled by dolomite and brown ochre of several generations. It indicates changing stress field which generated subhorizontal and also oblique sinistral translations. The fill of dislocation is various. In the wider zones (40 - 80 cm) the tectonic breccias are cemented by dolomite. It shows activity of NNE-SSW maximum

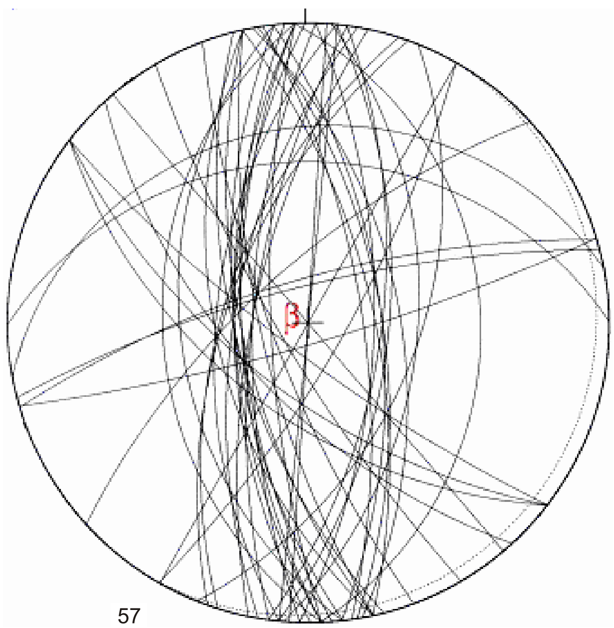

Figure 7. **Tectonogram of great circles of younger N-S dislocation planes of deformation substage AD_2^4.**

Slika 7. **Tektonogram velikih kružnica mlađih ravnina dislokacije deformacijske subfaze AD_2^4.**

subhorizontal compressional component σ_1, which enabled origin of dextral and sinistral subhorizontal and oblique translations and thrusts.

Dislocation structures are often conjugated (paired). The intersections of β-axis of dislocation planes are uniformly distributed in the northern and southern part of the tectonogram (Figure 7.). Their calculated mean is 300/85°. The dip of N-S dislocations is steep but quite variable. The transtlation lineations most frequently dip southward.

The paleostress tectonogram (Figure 8.) shows a huge subhorizontal stress σ_1 and in the space rotated stress σ_2 and σ_3. According to the coeficient ϕ = 0,38 the total stress field is compressional. In this field conjugated dextral and sinistral translations were generated and also diagonal thrusts. The stress fields provided conditions for regional dextral transpression from which NW-SE primary transpressional shear zone may be deduced.

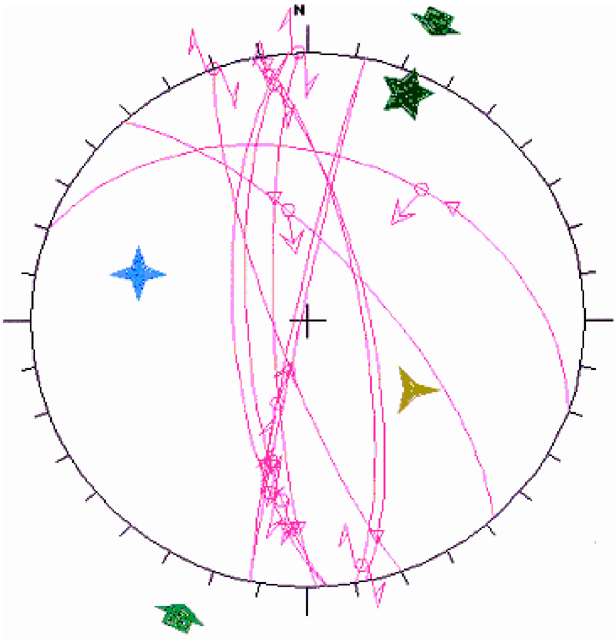

Figure 8. **Paleostress tectonogram of deformation substage AD_2^4. σ_1 = 23/9°, σ_2 = 286/36°, σ_3 = 124/52°. Coefficient ϕ = 0,38**

Slika 8. **Tektonogram paleonaprezanja subfaze AD_2^4. σ_1 = 23/9°, σ_2 = 286/36°, σ_3 = 124/52°. Koeficijent ϕ = 0,38**

Reactivization of younger N-S dislocation zones induced generation of intradislocation blocks and relative motions among them. This is manifested by several motion lineations. Transpressional regime of interblock motions is also suggested by many b-axes of undulation on younger N-S dislocation planes. They dip diagonally from north to south. It suggests primary transpressional phase along N-S subhorizontal translations providing semiductile deformation and origin of β-axis of undulations.

Origin of younger N-S shear zones is also due to reactivation of older N-S structures AD_2^2. Dynamics of younger N-S shear zones in conditions of simple-shear affected origin of secondary structures of R_{1-2} type and *P* shears, *T* fractures and *Y* shears.

DEFORMATION STAGE AD_3 (EXTENSION)

It contains change of transtension into normal fault - extensional system of dislocation, above all N-S and NNW-SSE structures. The paleostress orientation of σ_1 is subvertical and σ_2, σ_3 are subhorizontal. The structures represent right, extensional subsiding system. It is mostly demonstrated by block subsidence and by opening of deformations in extensional regime, origin of tectonic breccias in subsiding deformations, infiltration of surface and ground-water along extensional dislocation structures and origin of block rotational movements.

Characteristic feature of AD_3 deformation stage reactivated younger N-S structures in extensional - tensile regime. Dislocation structures are open to 10 - 20 cm and filled by ochreous material. Locally it is possible to observe karst chimneys and caverns originated in N-S structures and locally filled by crystalline dolomite and, prevailingly, by brownish-red ochre.

The paleostress diagram of AD_3 deformation stage (Figure 9.) mostly contains sinistral subhorizontal and oblique translations as well as subvertical and oblique normal faults. Stress tensor σ_1 = 350/75° is subhorizontal and stress tensors σ_2 = 119/9° and σ_3 = 211/11° are subhorizontal what provides an ideal stress field for extension conditions.

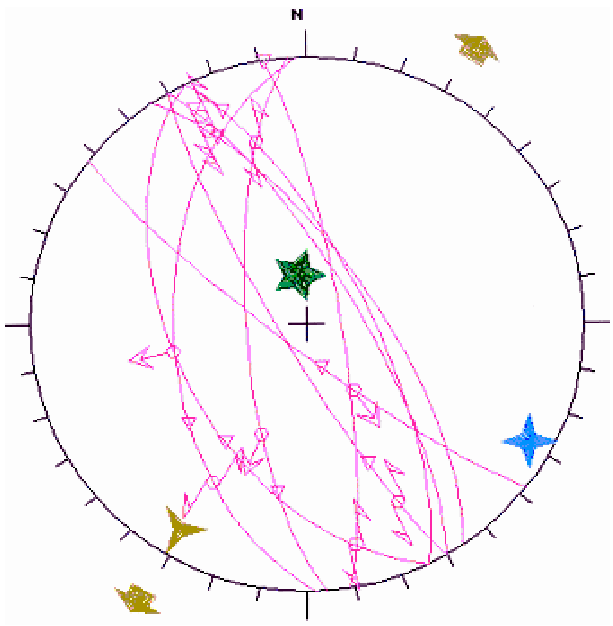

Figure 9. **Paleostress tectonogram of deformation stage AD_3. The stress σ_1 = 350/75°, σ_2 = 119/9°, σ_3 = 211/11°. Coefficient 0,71 shows striking extension**

Slika 9. **Tektonogram paleonaprezanja subfaze AD_3. Naprezanje σ_1 = 350/75°, σ_2 = 119/9°, σ_3 = 211/11°. Koeficijent 0,71 prikazuje izražajno istezanja**

It mainly shows opening of younger, N-S structures and reviving of infiltration of surface rain water and groundwater. It results into corrosion of dolomites and origin of weakly soluble rests of chemical corrosion and their accumulation in deformations in the form of ochreous sediments.

GEOLOGICAL - STRUCTURAL CONDITIONS OF STABILITY OF MINING WORKS AT THE MINE MIKOVÁ IN JELŠAVA - DISCUSSION

Deformation phases AD_1, AD_2^{1-4}, AD_3 are affected by long-term geologic evolution of the Alpine orogen. The phase AD_1 of paleo-Alpine stage is related to transpressional regime of thrust structures, which generated sinistral horizontal translations of NE oriented faults in brittle-ductile conditions. For deformation stage AD_2 it is characteristic transtensional regime with reactivization of NW-SE and activization of NNE-SSE and NW-SE faults. In the Dúbrava Massif the transtensional evolution is found in four substages AD_2^{1-4}.

The subsequent predominancy of subhorizontal stress tensors σ_2 and σ_3 induced extension in horizontal direction (AD_3), which provided in conditions of brittle deformation origin of horst (Dúbrava part of the deposit) and graben (Miková part of the deposit).

It was found that successive tectonic regime of AD_{1-3} deformation phases activated and reactivated dislocation structures in individual paleostress regimes. It came to the alternation of compresional and extensional paleostress fields. It was demonstrated by gradual evolution of dextral and sinistral translations, subhorizontal, subvertical, oblique thrusts and normal faults. Reactivation of compressional structures induced brittle-ductile conditions what is manifested by slightly undulated dislocation planes while β-axes of these undulations are parallel to the direction of tensile stress tensor of secondary regional and local shear zones. The thrusts and mainly dextral translations developed markers of lineation translations mainly in the form of grooves and identations. It provides to define direction of movement of two mutually moving tectonic blocks.

Compressional regime of brittle-ductile deformation was several times changed by extensional regime. It induced spatial release of dislocation structures and good infiltration and circulation of surface water and groundwater. It provided generation of several (3-5?) generations of dolomites. Higher intensity of ground water circulation through the extensional structures enabled chemical corrosion of primary and also secondary dolomite and origin and accumulation of weakly-soluble rests in the form of ochre. This is most characteristic for deformation stage AD_3, where sediments of various type of ochre show jumping - abrupt motions in extensional regime. It is probably related to change of block stresses in the framework of existing regional paleostress. Such originated structures may have, mostly in upper horizons, several meters width.

The above mentioned facts influence stability of open mining spaces which are stabilized by regular system of stabilization pillars. The biggest problem rests in inhomogeneous deformation of rock massif by tectonic structures - dislocation deformations. Existence of sericitic gray and black phyllites with high amount of psamitic material, which underlies the carbonate bodies, deteriorates the stability conditions. The mean thickness of this layer is about 60 m. The mean dip is 15 - 30°. From the geomechanical point of view this layer is much more ductile and plastic as the overlying rigid layers of dolomites and magnesites.

The paleostress field of extensional regime provides origin and acting of maximum tensor σ_1 in subvertical direction. It means mostly pressure of carbonate rock blocks of brittle deformation on underlying, obliquely dipping layer of ductile phyllitic rocks. It results possible widening of dislocation structures of carbonate massif, origin of rock blocks, their subsidence, rotation and translation. The result is continual and from the viewpoint of the stress various dynamics of interblock systems. Integration or disintegration of stress energies in the deformed rock massif in dependence on time has usually jumping - abrupt character.

CONCLUSION

Several deformation etapes resulted in disintegration of magnesite deposit body into smaller blocks. This requires higher demands on preservation of stability of mining works during the exploitation and suitable method for exploitation of magnesite ore.

REFERENCES

[1] H. Kozur, R. Mock, H. Mostler: Stratigraphische Neueinstufung der Karbonatgesteine der unteren Schichtenfolge von Ochtiná in das oberste Vise derpukhovian (Namur A). Geol. Paläont. Mitt., Insbruck 6 (1976) 1, 1 - 29.

[2] V. Zorkovský: Kotázke vzniku magnezitov. Geol. Zbor. Slov. Akad. Vied 6 (1955), 131 - 140.

[3] J. Ilavský: Geológia rudných ložísk Spiš.-gem. rudohoria. Geol. Práce, Zoš. 46 (1957), 51 - 95.

[4] A. Abonyi, M. Abonyiová: Magnezitové ložiská Slovenska. Monografia, Miner. Sl. 1981, 125.

[5] L. Turan, L. Vančová: Ďaľšie výskyty magnezitu v s.z. časti gelnickej série gemeríd. Západ. Karpaty, Ser. Mineral., Petrogr., Geochem., Metalogen. 6 (1979), 157 - 202.

[6] P. Grecula, et al.: Ložiská nerastných surovín Slovenského rudohoria. Zv. 1., Monogr.-Min. Slov., Bratislava 1995, p. 829.

[7] P. Grecula: Domovská oblasť gemerika a jeho metalogenéza. Mineralia slov. 5 (1973), 221-245.

[8] P. Grecula: Gemerikum - segment riftogénneho bazénu Paleotetýdy. Min. Slov. - Monogr., Bratislava, Alfa 1982, p. 263.

[9] Z. Nemeth, W. Prochaska, M. Radvanec, M. Kovacik, J. Madaras, P. Kodera, L. Hrasko: Magnesite and talc origin in the sequence of geodynamic events in Veporicum (Inner Western Carpathians, Slovakia). *Acta Petrol Sinica, 2004, in print.*

[10] A. Kovách, E. Svingor, P. Grecula: Rb/Sr isotopic ages of granitoide rocks from the Spiš-Gemer metalliferous Mts., West Carpathians, Eastern Slovakia. Mineralia slov. 18, 1-14. (Namur A). Geol. Paläont. Mitt., Insbruck 6 (1986) 1, 1 - 29.

[11] T. Sasvári, J. Kondela: The influence of tectonical structures on the stability rock massif in the area of the magnesite deposit Jelšava of the Dubrava massif. Acta Montanistica Slovaca 4 (2002), 219 - 222.