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MINERALIA SLOVACA
Ročník 33 – 2001
OBSAH

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COVER: "Earth's skin" (traditional designation used by Slovak miners) palygorskite (MgAl)$_2$Si$_4$O$_{10}$OH.2H$_2$O+2H$_2$O in cavern of magnesite deposit Jelšava. Dúbrava massif, Slovakia. Palygorskite crystallized on dolomite and magnesite crystals. Photo: Z. Németh and W. Prochaska.

OBÁLKA: „Zemská koža" (tradičné označenie používané baníkmi) palygorskit (MgAl)$_2$Si$_4$O$_{10}$OH.2H$_2$O+2H$_2$O v dutine magnezitového ložiska Jelšava. Dúbravský masív, Slovensko. Palygorskit kryštalizoval na kryštáloch dolomitu a magnezitu. Foto: Z. Németh a W. Prochaska.

Geovestník

Mineralia Slovaca, 33 (2001), 517–525

Successive replacement of Upper Carboniferous calcite to dolomite and magnesite in Dúbrava magnesite deposit (Western Carpathians, Slovakia)

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Abstract

In Dúbrava magnesite deposit, being a part of the Dúbrava massif in Slovakia, the successive replacement of the Upper Carboniferous limestone to dolomite and magnesite was studied using the relationship between minerals, inclusion fluid chemistry and petrology. The host rock of the magnesite body, the black schist, contains the mineral assemblage: graphite(?)-organic matter, quartz, chlorite 1 (ripidolite), muscovite–illite, Fe-chloritoid, pyrite, kaolinite, rutile, monazite, zircon, xenotime and sphalerite. The Mg-carbonate body mostly supplies the magnesite and the first generation of dolomite 1. The second generation of dolomite 2, two generations of calcite, Fe-magnesite, talc, chlorite 2 (clinochlore), graphite(?)–organic matter, apatite, quartz and pyrite occur in small amounts. According to the successive crystallization of minerals, the progressive two (a, b) steps and one separated step (c) of the replacement were distinguished:

a) The first stage of the replacement reequilibrated relict of the sedimentary calcite 1 and formed dolomite 1 + calcite 2 in the range of the temperature T = 370–400 °C. It was calculated using the carbonate geothermometry between dolomite 1 and calcite 2.

b) The second and major stage of the successive replacement formed magnesite with reduced amount of dolomite 1 at the beginning of the retrograde metamorphism.

c) The third stage of the replacement formed the younger mineral assemblage: dolomite 2 + talc + chlorite + quartz + Fe-magnesite, which occurred as the tiny veins of XX-cm thickness and vugs crosscutting the magnesite body. This stage is representing a time-separated later metamorphic and a sourcely different fluid flow event.

The successive replacement, being classified to the metamorphism in greenschist facies, formed chloritoid and chlorite 1 in the host black schists. Results on magnesite and dolomite 1 show very high Br/Cl ratios of the inclusion fluids. The minerals forming fluids are plotted at the end of the evaporation trend. Dolomite 1 bordering the magnesite shows the same fluid composition ratios in the Na-Cl-Br diagram as the magnesite, indicating the same fluid source and a consanguineous genesis with the magnesite. The chemical composition of the inclusion fluids from magnesite and dolomite 1 is consistent with an evaporitic brine source for the mineralizing fluids generated by fractionation of large amounts of halite during intense evaporative processes. Large amounts of evaporitic brines in the Gemericum realm had been generated only during the Upper Permian including the Permian boundary with Lower Triassic. The Permian extensional tectonics and high heat flow facilitated the generation of a hydrothermal system. It is unlikely that the mobilization of the fluid and the dewatering of the Variscan basins occurred as late as the eoalpine event in the Cretaceous. Younger dolomite 2 exhibits different compositions of the fluid chemistry. Most likely the late stage surface waters (seawater?) percolated into the magnesite and caused secondary "dolomitization".

Key words: magnesite, successive replacement, petrology, fluid inclusions chemistry, evaporation trend, seawater, Dúbrava massif, Slovakia

Introduction

In Slovakia, 3.5 km to NE of Jelšava town, the large and tectonically separated carbonate body, frequently named Dúbrava massif, includes three, Dúbrava, Miková and Jedľovec, more or less separated magnesite deposits (Fig. 1). The Dúbrava massif has the directional length of 4,500 m, the strike is NE–SW, and dips 55–60° to SE. The maximal thickness is 600 m (Abonyi and Abonyiová, 1981; Grecula et al., 2000).

In the western part of the massif the Dúbrava magnesite body exhibits average thickness of 70–80 m. It is proved in the inclined length of 1,500 m and is usually assembled in the lower part of the carbonate body. Several

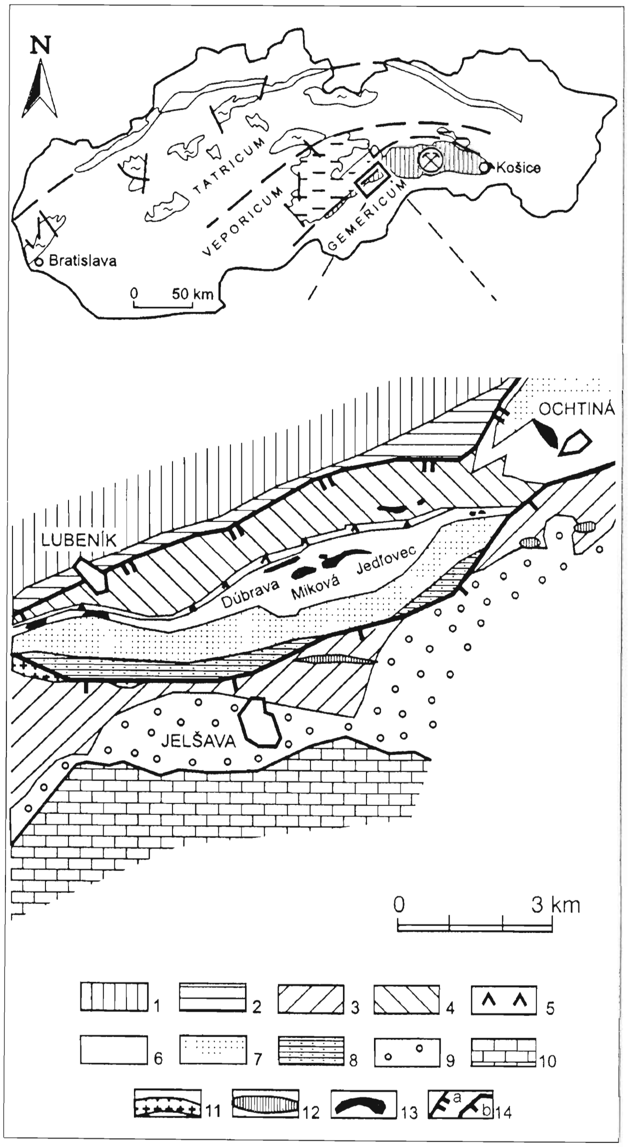

Fig. 1. Magnesite deposits between Jelšava, Lubeník and Ochtiná – western part of Gemericum (modified after Abonyi and Abonyiová, 1981). 1 – Veporicum undivided, 2 – Permian cover of Veporicum, 3 – Gelnica Group, 4 – Rakovec Group, 3–4 – Lower Paleozoic of Gemericum, 5 – greenstones, 6 – black schists ± basalt pyroclastics, magnesite-bearing horizon, 7 – black schists, 8 – pelitic schists with psammitic and psephitic intercalations, 5–8 – Carboniferous Ochtiná Group, 9 – Gočaltovo Group, 5–9 – Upper Paleozoic of Gemericum, 10 – nappe of Mesozoic carbonates and shales, 11 – Turčok granite, 12 – ankerite deposits and occurrences, 13 – magnesite deposits and occurrences, 14 – overthrusts: a – Lubeník-Margecany line, b – Hrádok-Železník line.

magnesite bodies in the middle – Miková part reach a thickness of 100–180 m. This deposit is explored over a length of 1,300 m. The eastern – Jedľovec part consists of small magnesite bodies of variable thickness of 5–50 m. Along dip it is explored in a distance of approximately 1,300 m. The magnesite deposits have an average content of MgO = 42.53 % wt. and harmful components CaO = 2.5 %, SiO_2 = 0.55 %, and FeO = 3.74 %. According to CS module magnesite belongs to calcitic technological type. In 1967 the calculation indicated above 500 million kt of the magnesite resources for Dúbrava massif and after modification of conditional parameters this sum reached near 536 million kt in year 2000.

In the following, the successive replacement of the Upper Carboniferous limestone to dolomite and magnesite is presented using the relationship between minerals, inclusion fluid chemistry, petrology and the metamorphic evidences in Dúbrava part of the Dúbrava massif.

Geological setting

In Dúbrava massif the magnesite deposits are located in black schists of the Upper Carboniferous Ochtiná Formation (Abonyi and Abonyiová, 1981; Grecula et al., 1995, 2000, Fig. 1). The stratigraphic classification of the Ochtiná Formation is based on fossil records. Found fossils comprise of corals (Heritsch, 1934; Mišík, 1953; Soták, 2000), brachiopods (Mišík, 1953; Macko, 1992), trilobites (Bouček and Přibyl, 1960), lamellibranchiates (Macko, 1992), cephalopods (Turek and Prokop, 1981), bryozoans (Zágoršek and Macko, 1994), echinoderms, crinoids, algospongies and foraminifers (Plašienka and Soták, 2001). The most precise stratigraphic data resulted from conodont study (Kozur et al., 1976), providing the uppermost Viséan – Serpuchovian (Namurian A) age of the Ochtiná Formation. In the Dúbrava magnesite deposits, there are the carbonates with pellets, intraclasts, echinoderms, crinoids, lamellibranchiates, foraminifers and ostracods (Vozárová and Vozár, 1988). Fossils are predominately well-distinguished in dolomite but the constituent of the primary calcareous sediment occurred calcite (limestone) that originated at the continental Carboniferous shelf. Well-preserved relicts of the hermatypic corals had produced the limestone layers; no dolomite was present in the shelf. The calcareous $CaCO_3$ dominated sediments or limestone were a real protolith of magnesite deposits in Dúbrava massif.

Previous mineralogical study

Systematic survey of magnesite deposits Dúbrava, Miková and Jelšava started in 1957. Using the optical methods, RTG and the bulk chemical composition of the optically separated minerals, the successive stages and generations of minerals were studied by Trdlička (1959), Varga (1965) and Abonyi and Abonyiová (1981). Minerals were generally described for all Carboniferous magnesite deposits where Varga (1965) and Abonyi and Abonyiová (1981) distinguished the magnesite as the major mineral occurring in three successive stages. In all deposits, the second important mineral was dolomite being formed in five stages and the third calcite formed in three stages. Other well-distinguished minerals are quartz, palygorskite, limonite, pyrite, chalcopyrite, tetrahedrite, pyrrhotite, sphalerite, galena, chlorite, talc and muscovite – sericite (Abonyi and Abonyiová, 1981).

Sample, locality, petrography and mineral investigation

In the Dúbrava part of the magnesite deposit, the representative samples of the host black schist and the major magnesite and dolomite body were collected. Samples investigated so far are coarse-grained sparry magnesite of typical "Veitsch type" (Prochaska, 2000), usually exhibiting pinolitic structures (samples Nos. 1, 2, 4, 7a, 5a, 26; Tab. 4).

Other sets of samples are fine-grained dolomites (Dol1) usually occurring as "alteration haloes" around the magnesite bodies and the late stage dolomites (Dol2) occurring in veins, fissures and vugs (samples Nos. 7b, 27). Samples from dolomite represent filled veins and vugs (Dol2) clearly related to late structures cutting the magnesite. In the core of the vugs idiomorphic crystals of dolomite occur (sample 5c). This core-zone is rimmed by pseudomorphs of dolomite after magnesite still exhibiting pinolitic structures (sample 5b). Both dolomite zones are hosted by the original, unaltered magnesite (sample 5a; Tab. 4).

The polished thin sections have been studied by the optical methods and by the chemical compositions of the optically distinguished minerals determined by the microprobe as well. The JEOL microprobe equipped with a Kevex analytical system, Kevex using 8000 + Quantum detector, was used. To the analyses of carbonate data acquisition was performed for 40–100 second (Tabs. 2 and 3).

The identical samples were used for the mineralogical, petrological and for solute chemistry studies of inclusion fluids. The results from the inclusion fluids are used to decipher the origin of the dissolved salt content of the fluids that precipitated the magnesite, and further constrain the timing and origin of the hydrothermal event.

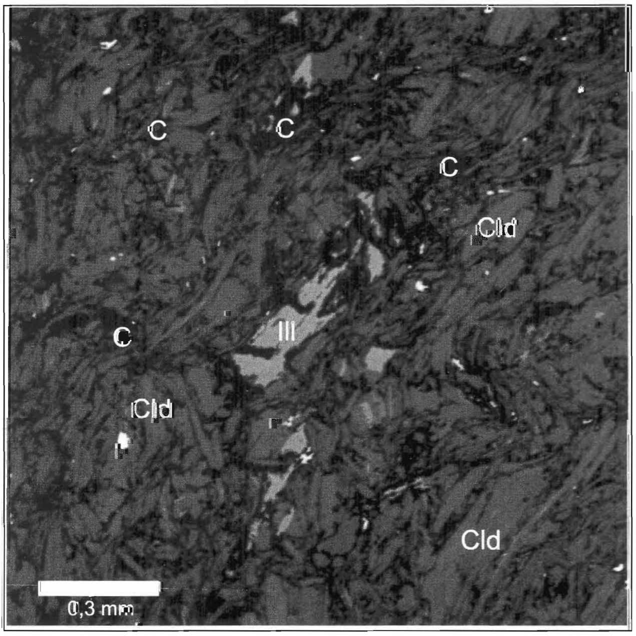

Fig. 2. Mineral assemblage of the host black schists. C – organic matter (graphite?); Cld – chloritoid; Ill – muscovite–illite. Back-scattered electron images (BEI). Analyses are in Tab. 2.

Tab. 1
Mineral composition of the carbonate body and host black schists in Dúbrava magnesite deposit

Mineral		Black shists	Carbonate body
Quartz	Qtz	------------------	....
Graphite?	C	------------------	....
Fe-chloritoid	Cld	------------------	
Chlorite	Chl	------------------	------------------
Muscovite-illite	Ill	------------------	
Kaolinite	Kln	------------------	
Magnesite	Mgs		------------------
Dolomite	Dol		------------------
Calcite	Cal		....
Talc	Tlc		------------------
Apatite	Ap		------------------
Rutile	Rt	------------------	
Monazite	Mo	------------------	
Zircon	Zr	------------------	
Xenotime	Xe	------------------	.
Pyrite	Py	------------------	------------------
Sphalerite	Sp	....	

Explanations: .... - Rare occurring mineral

The chemical composition of paleofluids can be used as "geochemical tracer" to investigate the original signature and origin of different kinds of inclusion fluids. The analytical work on the chemistry of the inclusion fluids (F, Cl, Br, I, Na, K, Ca, Pb, Zn, Cu, etc.) can contribute substantially to the solution and help to solve the genetic model of the magnesite mineralization (Tab. 4).

Tab. 2
Representative analytical data of silicates in host black schists Dúbrava part of the magnesite deposit

Mineral Place Comment	Cld matrix black schist	Chl1 matrix black schist	Ms-Ill matrix black schist	Ms-Ill matrix black schist	Tlc matrix magnes body	Chl2 crack magnes body
SiO_2	24.92	25.43	47.26	47.12	62.86	29.82
TiO_2	0	0	0.21	0.14	0	0
Al_2O_3	42.65	23.95	37.26	38.63	0.42	21.35
FeO*	21.01	23.02	1.67	0.27	1.24	2.34
MnO	0.14	0	0	0	0	0
MgO	4.12	16.04	0.85	0.81	30.28	33.37
CaO	0	0	0	0	0.14	0.22
Na_2O	0	0	0.89	0.91	0.43	0
K_2O	0.06	0	8.74	8.56	0	0
H_2O*	7.28	11.34	3.92	3.75	4.72	12.79
Total	100.18	99.78	100.80	100.19	100.09	99.89
O=	14	36	24	24	24	36
Si	2.012	5.256	6.213	6.178	7.987	5.592
Al	3.000	2.744	1.787	1.822	0.015	2.408
Al	1.055	3.085	3.981	4.143	0.047	2.307
Ti	0	0	0.021	0.014	0	0
Fe^{2+}	1.419	3.979	0.139	0.030	0.131	0.367
Mn	0.010	0	0	0	0	0
Mg	0.496	4.942	0.166	0.158	5.737	9.326
Ca	0	0	0	0	0.019	0.044
Na	0	0	0.227	0.231	0.105	0
K	0.006	0	1.465	1.432	0	0
Total	7.998	20.006	13.999	14.008	14.036	20.044
OH	3.92	15.63	3.44	3.28	4.00	16

Mineral assemblage in host black schists

The major constituents of the black schist are graphite(?)–organic matter, quartz, chlorite 1 (ripidolite; Mg/(Fe+Mg) = Mg* = 0.54), muscovite–illite (Mg* = 0.34–0.75). Locally coarse and hypidiomorphic Fe-chloritoid (Mg* = 0.26) occurs as well as pyrite grains (Figs. 2 and 9). Kaolinite, rutile, monazite, zircon, xenotime and sphalerite are the rare occurring minerals in black schists (Tab. 1). The chemical composition of the major minerals is listed in Tab. 2.

Mineral assemblage in Mg-carbonate body and evidences of the successive replacement

The Mg-carbonate body mostly supplies the magnesite and the first generation of dolomite (Dol1). The second generations of dolomite (Dol2), two generations of calcite (Cal1, Cal2), Fe-magnesite, talc (Mg* = 0.98), chlorite 2 (clinochlore; Mg* = 0.96), graphite(?)–organic matter, apatite, quartz and pyrite occur in small amounts (Tab. 1). According to the successive crystallization of minerals, the progressive two (a, b) steps and one separated step (c) of the replacement were distinguished.

a) Relationships between reequilibrated calcite 1 and dolomite 1 and relationship between calcite 2 and dolomite 1

Only relicts of the protolithic limestone as the calcite 1 (Cal1) have been distinguished by the back-scattered electron images (BEI) in samples. In the most parts, the dolomite 1 (Dol1) replaced calcite 1 generating irregular rim at the boundary between relict of the calcite 1 and the first generation of dolomite 1 (Fig. 3). Calcite 1 contains more $MgCO_3$ = 11.90 % comparing the younger and second generation of calcite 2 ($MgCO_3$ = 2.40 %). Calcite 2 is disseminated as an irregular to rounded small grains occurring obviously in dolomite 1 but also in magnesite respectively (Fig. 4). The crystalline mixture of two carbonates (Dol1 + Cal2) is interpreted as an exsolution product, formed by reequilibrium of Mg-rich primary calcite 1 with Mg + CO_2 rich fluid, forming dolomite 1 and calcite 2 in the first stage of the replacement where

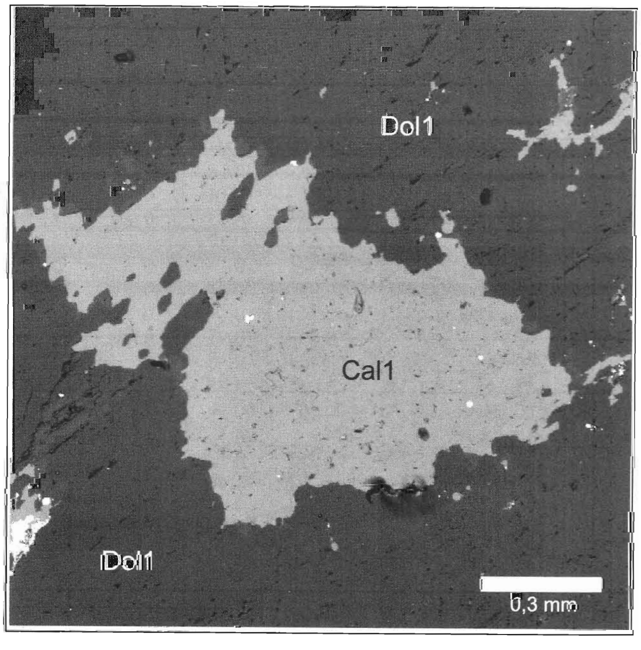

Fig. 3. Relict of calcite 1 (Cal1) occurs mostly in the host dolomite 1 (Dol1). Calcite 1 is the constituent of the primary calcareous sediment (limestone) that originated at the continental Upper Carboniferous shelf. Back-scattered electron images (BEI). Analyses are in Tab. 3.

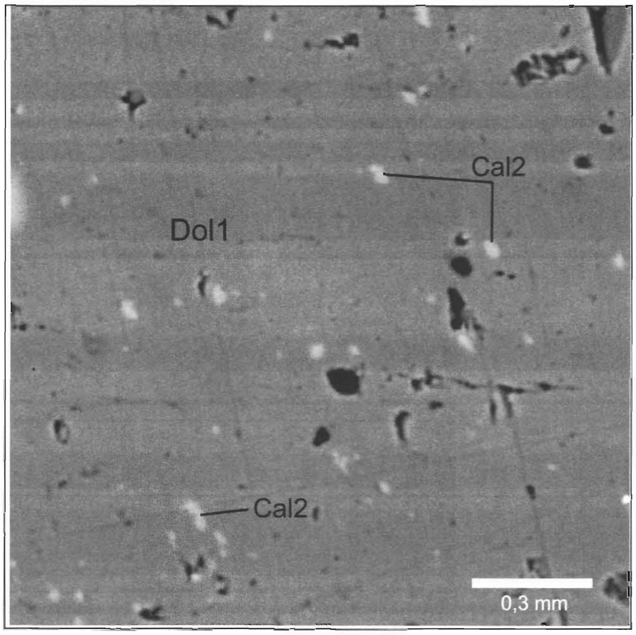

Fig. 4. The small rounded inclusions of calcite (Cal2) distributed in dolomite (Dol1). Back-scattered electron images (BEI). For chemical compositions of carbonates see Tab. 3.

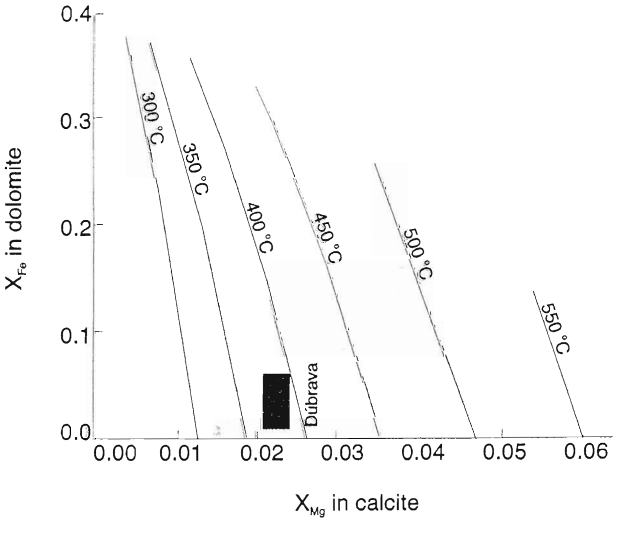

Fig. 5. Diagram of X_{Fe}–dolomite versus X_{Mg}–calcite comparing chemical composition of calcite inclusions in host dolomite (Fig. 4) using the carbonate geothermometry of Powell et al. (1984).

Tab. 3
Representative analytical data of carbonates in Dúbrava part of the magnesite deposit

Mineral Place Comment	Cal1 relict in Dol1	Dol1 matrix	Cal2 inclusion in Dol1	Mgs matrix minim.	Mgs matrix maxim.	FeMgs rim Mgs minim.	FeMgs rim Mgs maxim.	Dol2 crack in Mgs
FeO	0	1.19	0	0	5.39	7.58	10.77	1.04
MnO	0.22	0	0	0	0	0	0.37	0.11
MgO	4.89	21.96	0.98	47.58	43.81	41.85	39.10	22.57
CaO	50.39	29.46	54.80	0.11	0	0.19	0	29.00
CO_2*	44.89	47.70	44.09	52.14	51.00	50.50	49.53	47.97
Total	100.39	100.31	99.87	99.83	100.20	100.12	99.78	100.67
Fe	0	0.030	0	0	0.065	0.092	0.133	0.026
Mn	0.003	0	0	0	0	0	0.005	0.002
Mg	0.119	1.002	0.024	0.998	0.935	0.905	0.862	1.024
Ca	0.878	0.966	0.976	0.002	0	0.003	0	0.946
Total	1.000	1.998	1.000	1.000	1.000	1.000	1.000	1.998
Sd	0	1.50	0	0	6.50	9.20	13.30	1.30
Rds	0.30	0	0	0	0	0	0.50	0.10
Mgs	11.90	50.10	2.40	99.80	93.50	90.50	86.20	51.20
Cc	87.80	48.30	97.60	0.20	0	0.30	0	47.30

CO_2* is calculated on stoichiometry

primary calcite 1 was replaced to dolomite 1 + calcite 2 (Fig. 4, Tab. 3). According to the chemical composition X_{Fe} = Fe/(Fe+Mg+Ca+Mn) in dolomite 1 versus X_{Mg} = Mg/(Fe+Mg+Ca+Mn) in calcite 2, the temperature of the replacement was calculated using the carbonate geothermometry of Powell et al. (1994) and established as the essential temperature T = 370–400 °C (Fig. 5, Tab. 3). This temperature had controlled the first stage of the successive replacement where the mineral assemblage Cal2 + Dol1 ± Mgs was formed and the estimated temperature is the temperature peak of the replacement or metamorphism as well (Fig. 6).

b) Relationship between magnesite and dolomite 1

The second and major stage of the successive replacement formed magnesite with reduced amount of dolomite 1 at the beginning of the retrograde metamorphism. In matrix the irregular to tabular inclusions of older dolomite 1 are frequently enclosed inside largely dominated

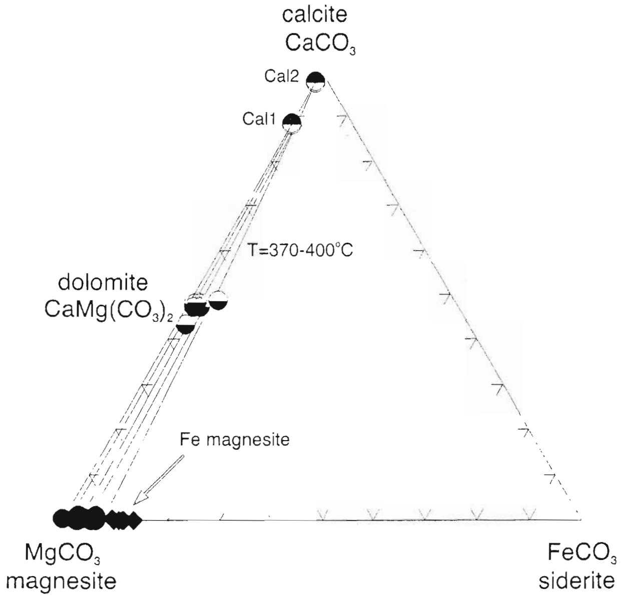

Fig. 6. The nomenclature of carbonates and solid solution in system $CaCO_3$ – $MgCO_3$ – $FeCO_3$ at estimated temperature T = 380–400 °C according to Powell et al (1984). Estimated temperature calculated between Cal2 and Dol1 Calcite 1 (Cal1) is the relict of the primary calcareous sediment (limestone). The chemical compositions of carbonates see Tab. 3.

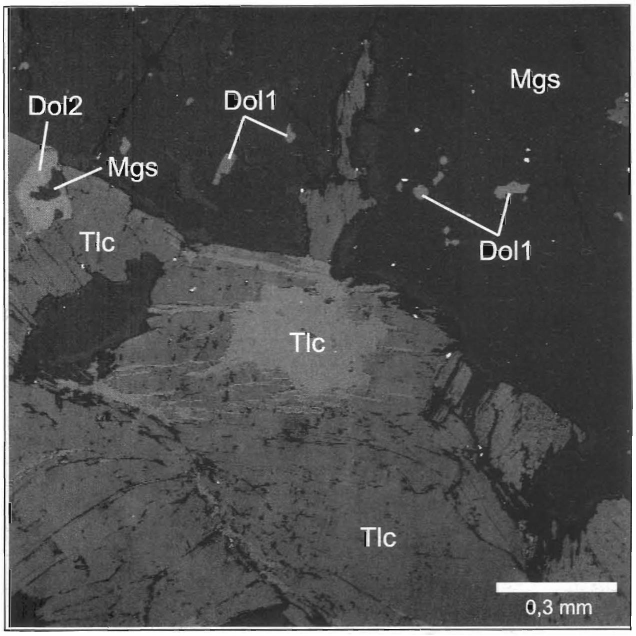

Fig. 7. Inclusions of dolomite 1 (Dol1) occurred in host magnesite. Talc (Tlc) enclosing second generation of dolomite 2 (Dol2) with inclusions of magnesite (Mgs). Back-scattered electron images (BEI). Analyses are in Tab. 3.

and chemically homogeneous magnesite. In this case the occurrence of the dolomite 1- inclusions are interpreted as a relict of the first stage. The second stage is characterized by the crystallization of the dominant amount of magnesite and the stage is recognized by inclusions of dolomite 1 in the host magnesite (Fig. 7).

c) Relationship between magnesite + dolomite 1 and younger mineral assemblage dolomite 2 + talc + chlorite + quartz + Fe-magnesite

The third stage of the replacement formed the idiomorphic or hypidiomorphic dolomite 2 usually enclosing small and irregular grains of older magnesite. The dolomite 2 also occurs in tiny veins of XX-cm thickness and vugs crosscutting the magnesite structures, respectively. This stage of replacement locally forms talc and chlorite 2 replacing magnesite along cracks (Figs. 8 and 9). Dolomite 2 with inclusions of magnesite is well recognized in the youngest talc (Fig. 7). Inside the magnesite body, the dolomite 2 + chlorite (Chl2 – clinochlore) + pyrite filled cracks and small faults (Fig. 8). In the matrix, the third stage forms Fe-magnesite ($FeCO_3$ = 9.20–13.30 %) at the rim of the individual grains of magnesite ($FeCO_3$ = 0–6.5 %, Fig. 10, Tab. 3). Fe-magnesite is usually accompanied with pyrite. The third stage of the replacement represents a time-separated metamorphic or a later and a sourcely different fluid flow event in the Dúbrava magnesite body.

Inclusion fluid chemistry

The characterization of TDS (total dissolved solids) chemistry of inclusion fluids was first and most widely applied to the study of Mississippi Valley type Pb-Zn mineralizations to obtain information on the source of solutes in the ore-forming brines and to explore genetic linkages among deposits. The utility of the technique was first demonstrated by Hall and Friedman (1963) in the Upper Mississippi Valley Pb-Zn district. More recently, Viets and Leach (1990) characterized the fluids from a number of Mississippi Valley type deposits worldwide, showing that in general the salinity of the ore-forming fluid was acquired in an evaporitic environment and is oc-

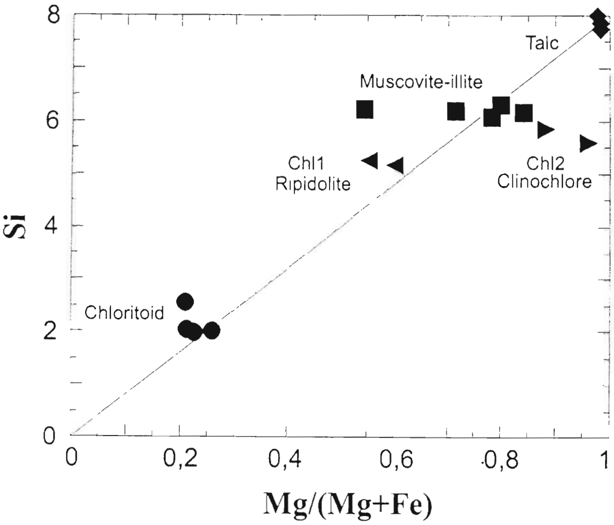

Fig. 9. Chemical classification Mg/(Mg+Fe) versus Si according to the stoichiometry of chloritoid, Chl1-ripidollite and muscovite-illite in host black schists. Talc and Chl2-clinochlore occurs in magnesite body Analyses are in Tab. 2.

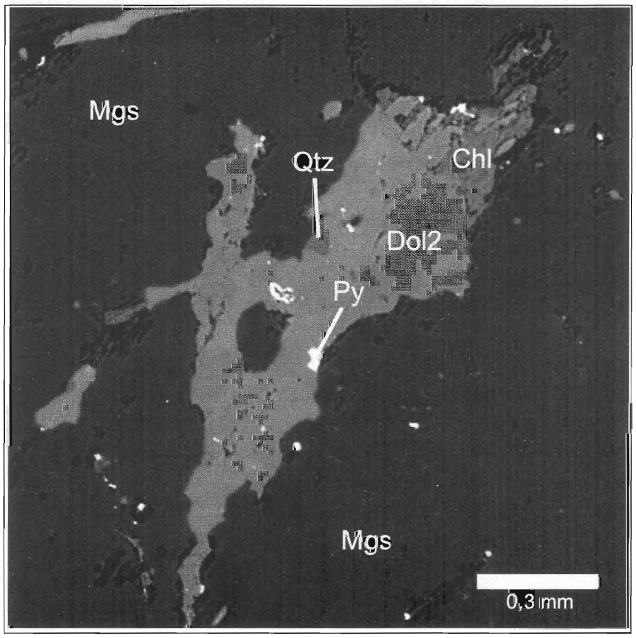

Fig. 8. Crack in magnesite (Mgs) is filled with dolomite (Dol2) + chlorite-clinochlore (Chl2) + pyrite (Py) and quartz (Qtz). Back-scattered electron images (BEI). Analyses are in Tabs. 2 and 3.

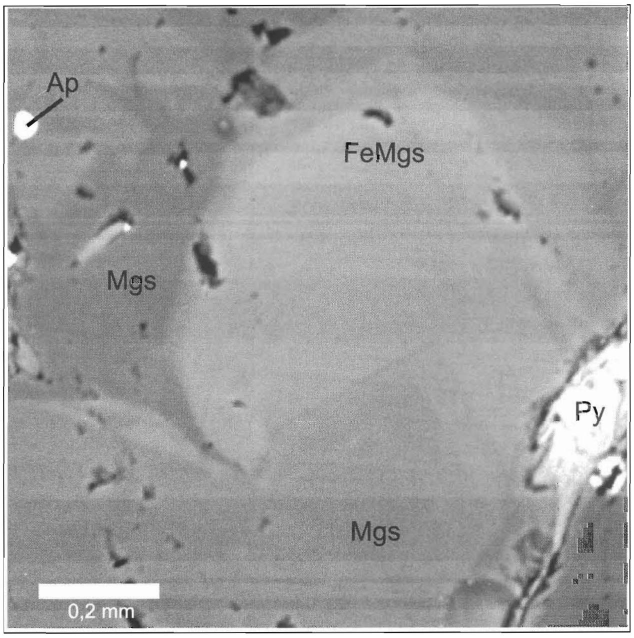

Fig. 10. Relationship between magnesite (Mgs) and younger Fe-rich magnesite (Fe-Mgs). Crystallization of Fe-magnesite occurred as the last event in the successive replacement. Py – pyrite, Ap – apatite. Back-scattered electron images (BEI). Analyses are in Tab. 3.

Tab. 4.
Chemical composition of fluid inclusions in Dúbrava part of magnesite deposit

Sample Magnesite	Li	Na	K	Mg	Ca	F	Cl	Br	SO_4	Na/Br mol	Cl/Br mol
PR-JEL-1	20	5616	559	19 204	1837	95	16 008	353	396	55	102
PR-JEL-2	8	2377	591	20 143	1556	116	5712	104	250	79	124
PR-JEL-4	18	4278	583	20 451	9344	68	10 747	295	639	50	82
PR-JEL-5a	31	7477	608	25 791	12 586	58	19 807	345	352	75	129
PR-JEL-7a	12	11 024	840	19 427	1215	17	26 660	507	296	76	119
PR-JEL-26	21	7898	562	18 700	2461	65	23 278	468	501	59	112
Dolomite 1, alteration											
PR-JEL-7b	8	3269	292	23 662	10 922	49	9741	285	287	40	77
PR-JEL-27	64	10 261	1037	19 384	15 016	81	33 328	834	453	43	90
Dolomite 2, vugs or veins											
PR-JEL-5b	2	4492	197	22 336	9468	60	6957	26	1044	600	603
PR-JEL-5c	3	6365	182	20 777	5582	63	11 984	33	1125	670	818
PR-JEL-6 (dolomite vein)	1	8071	412	20 220	10 945	57	16 529	44	970	642	853

All concentrations are in ppb

casionally augmented by halite dissolution. Kesler et al. (1996) used Na/Br and Cl/Br ratios of inclusion fluids to document two regionally extensive hydrothermal events responsible for Mississippi Valley type ore formation in the Appalachian Basin. A more general application of the use of Br/Cl and I/Cl ratios from inclusion fluids was presented by Böhlke and Irwin (1992), who conducted extensive characterizations of these ratios from inclusion fluids from a variety of ore deposit types.

In an initial stage of evaporation in a hypersaline environment Na, Cl, and Br are concentrated in the residual brine, and their ratios do not change. At an evaporation index of > 10, halite is precipitated. Br has a very conservative behaviour and is not incorporated into the halite lattice. At an evaporation index of approx. 70, Mg-salts start to precipitate and Br is still concentrated in the residual brines. The cation systematics changed from an original Na preponderance to Mg and K dominated systems (McCafferey et al., 1987). In a Cl/Br and Na/Br molar ratio diagram the composition of evaporitic, bittern brine is shifting along the "evaporation trend" when halite starts to precipitate at an evaporation index of about 10. On the other hand fluids percolating through the crust acquiring salinity by dissolution of halite, are expected to plot towards higher Cl/Br and Na/Br molar ratios.

Results on magnesite and dolomite 1 from the Dúbrava massif show very high Br/Cl ratios of the inclusion fluids (Tab. 4). On a Cl/Br and Na/Br molar ratio diagram (Fig. 11), it is demonstrated that the composition of the magnesite and dolomite (Dol1) fluids plots at the end of the evaporation trend. This position of the plots at the end of the evaporation trend and the extent of fractionation suggest evaporitic bittern brines to be the original fluid source, although other mechanisms for Br-enrichment have to be considered. No indications of halite dissolution whatsoever are observed with the fluids forming the Dúbrava magnesite.

The fine-grained dolomite 1 usually bordering the sparry magnesite basically shows the same fluid composition ratios in the Na-Cl-Br diagram as the magnesite thus indicating the same fluid source and a consanguineous genesis with the magnesite. Younger dolomite 2 occurring as veins and vugs crosscutting the magnesite structures exhibit totally different compositions. Most likely late stage surface waters (seawater?) percolated into the magnesite caused this late stage secondary "dolomitization" (Fig. 11).

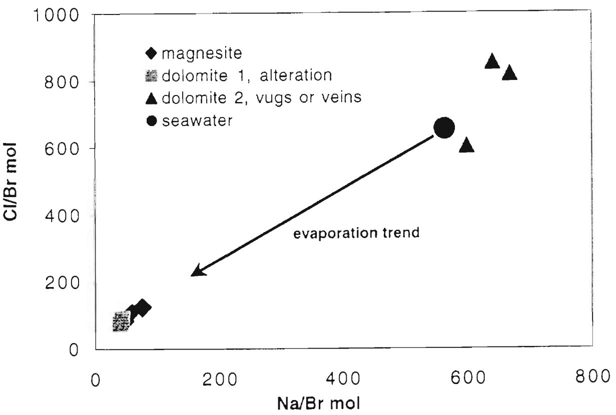

Fig. 11. Diagram of Na/Br versus Cl/Br comparing chemical composition of fluid inclusions in two different source fluids. The main hydrothermal event represents evaporation trend and formed magnesite and dolomite 1 The later and separated hydrothermal event represents seawater that probably formed dolomite 2 distributed in vugs or veins. Analyses are in Tab. 4.

Discussion of the genetic model

The magnesite deposits originated by a "metasomatic" alternation of originally shelf Upper Carboniferous limestone bodes that had been tectonically embedded in surrounding black schists (Abonyi and Abonyiová, 1981). This genetic model generally holds in Dúbrava deposit as well. Geological, mineralogical and petrological evidences show that magnesite of Dúbrava deposit was not formed during sedimentation. Hydrothermal structures are ubiquitous and the "metasomatic" magnesite bodies generally exhibit alteration haloes of hydrothermal dolomite (Dol1). The "saddle texture" of the magnesite is another strong argument for the hydrothermal nature, indicating a brine of high salinity at elevated temperatures to be responsible for the mineralization. Petrological studies well explained the relationship between host and relict of the calcite 1, dolomite 1 and magnesite group of carbonates, finally forming magnesite bodies in the successive replacement. The temperature T = 370–400 °C controlled crystallization of carbonates in this successive replacement indicating the metamorphism in the greenschist facies forming chloritoid and chlorite 1 in the host black schists. The time-separation and younger replacement formed dolomite 2 + talc + quartz + chlorite 2 + pyrite that filled vugs, cracks and veins in the magnesite body.

The chemical composition of the inclusion fluids from magnesite and hydrothermal dolomite 1 are consistent with an evaporitic brine source for the mineralizing fluids generated by fractionation of large amounts of halite during intense evaporative processes. Large amounts of evaporitic brines in the Gemericum realm had been generated only during the Upper Permian including the Permian boundary with Lower Triassic. The corresponding evaporitic sediments are still exposed in the triangle Spišská Nová Ves – Markušovce – Matejovce and near Šankovce village.

Unaltered hostrock usually are fossiliferous marine limestones thus indicating a diagenetic formation of the mineralization either by seepage reflux of evaporitic bittern brines or by expulsion of connate fluids during later tectonic activity. Maybe Permian extensional tectonics and high heat flow facilitated the generation of a hydrothermal system. It is unlikely that the mobilization of the fluid and the dewatering of the Variscan basins occurred as late as the eoalpine event in the Cretaceous.

The late stage forming of dolomite 2 in vugs and veins clearly shows a totally different fluid signature (Fig. 11). No mixing trend can be observed thus indicating that these late stage carbonates are due to a separate event. These late fluids exhibit the signatures of the surface fluids, most likely seawater (Tab. 4).

Conclusions

The successive replacement of the Upper Carboniferous limestone to dolomite and magnesite was studied using the relationship between minerals, inclusion fluid chemistry, petrology and the metamorphic evidences in Dúbrava part of the Dúbrava massif.

In the western part of the Dúbrava massif, the Dúbrava magnesite body exhibit average thickness of 70–80 m. The magnesite deposits are located in black schists of the Upper Carboniferous Ochtiná Formation. The stratigraphic classification is based on fossil records. Findings of fossils comprise of corals, brachiopods, trilobites, lamellibranchiates, echinoderms, crinoides, algospongies, foraminifers and conodonts, providing the uppermost Viséan–Serpuchovian (Namurian A) age of the Ochtiná Formation. In the Dúbrava magnesite deposits, there are the carbonates with pellets, intraclasts, echinoderms, crinoids, lamellibranchiates, foraminifers and ostracods. Fossils are predominately well-distinguished in dolomite but are the constituent of the primary calcareous sediment – calcite (limestone) – originating at the continental Carboniferous shelf. Well-preserved relicts of the hermatypic corals produced the limestone layers, but no dolomite in the shelf. The calcareous $CaCO_3$ dominated sediments or limestone were a real protolith of magnesite deposits in Dúbrava massif.

In the Dúbrava magnesite deposit, the representative samples of the host black schist and the major magnesite and dolomite bodies were collected. Samples contained coarse-grained sparry magnesite usually exhibiting pinolitic structures. Other sets of samples are fine-grained dolomite 1 usually occurring as "alteration haloes" around the magnesite bodies and the late stage dolomite 2 occurring in veins, fissures and vugs. Samples from dolomite are from filled veins and vugs (Dol2), clearly related to late structures, cutting the magnesite.

The host rock of the magnesite body, the black schist, contains the mineral assemblage: graphite(?)–organic matter, quartz, chlorite 1 (ripidolite), muscovite–illite, Fe-chloritoid, pyrite, kaolinite, rutile, monazite, zircon, xenotime and sphalerite.

The Mg-carbonate body mostly supplies the magnesite and the first generation of dolomite 1. The second generation of dolomite 2, two generations of calcite (Cal1, Cal2), Fe-magnesite, talc, chlorite 2 (clinochlore), graphite(?)–organic matter, apatite, quartz and pyrite occur in small amounts. According to the successive crystallization of minerals, the progressive two (a, b) steps and one separated step (c) of the replacement were distinguished:

a) The first stage of the replacement reequilibrated relict of the sedimentary calcite 1 and formed dolomite 1 + calcite 2. The relict of calcite 1 contains more $MgCO_3$ comparing younger and second generation of calcite 2. Calcite 2 is disseminated as an irregular to rounded small grains occurring obviously in dolomite 1 but also in magnesite, respectively. This crystalline mixture of carbonates (Dol1 + Cal2) is interpreted as an exsolution product, formed by the reequilibrium of Mg-rich primary calcite 1 with Mg + CO_2 rich fluid. Dolomite 1 and calcite 2 formed in the first stage of the replacement where primary calcite 1 was replaced to dolomite 1 + calcite 2. According to the chemical composition X_{Fe} in dolomite 1 versus X_{Mg} in calcite 2, the temperature T = 370–400 °C of the replacement was calculated using the carbonate geothermometry. This temperature had controlled crystallization of carbonates in the successive replacement indicating the metamorphism in the greenschist facies, forming chloritoid and chlorite 1 in the host black schists.

b) The second and major stage of the successive replacement formed magnesite with reduced amount of dolomite 1 at the beginning of the retrograde metamorphism.

c) The third stage of the replacement formed the younger mineral assemblage. Dolomite 2 + talc + chlorite + quartz + Fe-magnesite and pyrite occurred in the form of the tiny veins reaching XX-cm thickness, as well as the vugs crosscutting the magnesite body. This stage of replacement locally forms talc and chlorite 2 replacing magnesite along cracks. Dolomite 2 with inclusions of magnesite is well recognized in the youngest talc. In the matrix, the third stage forms Fe-magnesite at the rim of the individual grains of magnesite. The third stage of the replacement represents a time-separated metamorphic or a later and a sourcely different fluid flow event.

Results on magnesite and dolomite 1 from the Dúbrava massif show very high Br/Cl ratios of the inclusion fluids. The composition of the magnesite and dolomite 1 forming fluids plots at the end of the evaporation trend. This position at the end of the evaporation trend and the extent of fractionation suggest evaporitic bittern brines to be the original fluid source, although also other mechanisms for Br-enrichment have to be considered. No indications of halite dissolution whatsoever are observed with the fluids forming the Dúbrava magnesite. The fine-grained dolomite 1, usually bordering the sparry magnesite, basically shows the same fluid composition ratios in the Na-Cl-Br diagram as the magnesite thus indicating the same fluid source and a consanguineous genesis with the magnesite.

Geological, mineralogical and petrological evidences show that Dúbrava magnesite was not formed during sedimentation. Hydrothermal structures are ubiquitous and the "metasomatic" magnesite bodies generally exhibit alteration haloes of hydrothermal dolomite 1. The "saddle texture" of the magnesite is another strong argument for the hydrothermal nature, indicating a brine of high salinity at elevated temperatures to be responsible for the mineralization. The petrological studies well explained the relationship between host and relict of the calcite 1, dolomite 1 and magnesite group of carbonates, finally forming magnesite bodies in the successive replacement.

The chemical composition of the inclusion fluids from magnesite and hydrothermal dolomite 1 are consistent with an evaporitic brine source for the mineralizing fluids generated by fractionation of large amounts of halite during intense evaporative processes. Large amounts of evaporitic brines in the Gemericum realm had been generated only during the Upper Permian including the Permian boundary with Lower Triassic.

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The late stage forming the dolomite 2 in vugs and veins crosscutting the magnesite structures clearly show a totally different fluid signature. No mixing trend can be observed thus indicating that these late stage carbonates are due to a separate event. Fluids exhibit the signatures of the surface fluids, most likely seawater percolated into the magnesite caused this late stage of secondary "dolomitization".

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Economic assessment of magnesite and talc deposits in the Slovak Republic

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Abstract

Every mineral deposit has its own specific geological-deposit dependencies of reserves [Z], average grade [x] and cut-off grade $[x_0]$, which are determining factors for actual technical-technological parameters (recovery, ore contamination, processing recovery factor a. o.) and economic parameters (utility value, initial and operation costs, total price of deposit). Process of economic assessment must respect these relations. Price of deposit is directly dependent on reserves volume and quality of raw material and for correct and optimal economic assessment, it is necessary to define relations between reserves, average grade and cut-off grade, as the first step of valuation process.

Key words: mineral deposit, reserves/resources, variant reserves computation, economic assessment, cut-off grade, deposit price

Introduction

Considerable progress of mineral deposit economic assessment was recorded during the last decade in Slovakia. Economic estimation became necessary standard operation after every phase of geological prospecting and exploration. Concerning the incompleteness of exploration data, especially in beginning phases of geological survey, the help of following studies usually uses three-step process of feasibility assessment:

- Geological, or opportunity study,
- Pre-feasibility study,
- Feasibility study.

This complies with UN-ECE Classification for reserves/resources of minerals and solid fuels from 1997.

Geological study, realized after prospecting or preliminary exploration, calculates operation costs based on statistical estimates. Pre-feasibility and feasibility study calculate operating costs by the medium of direct technical-economical computation.

Decision criteria for resumption or abortion of exploration works is usually profit ratio expected from deposit exploitation and risk rate of mining business. After this manner, selection of optimal alternative of deposit exploitation is designated.

Destiny of prospected and measured mineral deposits depends on result of technical-economical assessment and classification of every deposit body.

For example: after phase of drilling exploration the deposit of magnesite or talc was discovered and measured. After statistical processing of sample analyses and alternative (variant) reserves calculation, rich average and poor parts of deposit were detected. Economic geologist must answer following four questions:

1. What is the deposit size (big deposit, medium deposit, small deposit or deposit occurrence)?
2. Are measured reserves economic or uneconomic (potentially economic)? What part of total reserves/resources could be classified as economic or potentially economic (according to the UN-ECE Classification for reserves/resources)?
3. Where are borders between economic reserves (economically usable) and potentially economic resources (uneconomic at present)? Where are borders between potentially economic resources and sterile rocks?
4. What is the value (price) of this measured deposit?

Resultant answers have determining impact on deposit fate and exploration or exploitation continues only on significant deposit objects with economic reserves and positive balance (price).

Theoretical and methodological questions of economic assessment and classification for reserves/resources of mineral deposits

The keystone of mineral deposit economic assessment consists in comparison of returns from mining and beneficiation of raw material [r] and costs [c], necessary for these operations. For economic reserves must be satisfied condition:

$$r > c.$$

In the case of $r < c$, there are only potentially economic resources present on deposit.

Values of returns [r] and costs [c] are gained through geological-economical modelling of exploitation and beneficiation process, by means of technical-economical assessment of calculated (estimated) deposit reserves.

Every mineral deposit has its own specific geological-deposit dependencies of reserves [Z], average grade [x] and cut-off grade [x_0], which are determining factors for actual technical-technological parameters (recovery, ore contamination, processing recovery factor a. o.) and economical parameters (utility value, initial and operation costs, total price of deposit). Process of economic assessment must respect these relations and assessment of mineral deposit, based only on one variant of reserves computation, is not correct. Price of deposit is directly dependent on reserves volume and quality of raw material. For correct and optimal economic assessment it is necessary to define relations of reserves [Z], average grade [x] and cut-off grade [x_0], as the first step of each valuation process. After graphical and mathematical definition of listed relations, technical-economical assessment of each calculated variant of reserves computation determines price of deposits and contours of economic reserves, or potentially economic resources of the deposit.

Definition of relations among reserves [Z], average grade [x] and cut-off grade [x_0] has remarkable meaning for optimal classification of measured reserves into economic reserves and potentially economic resources. Generally, relations among [Z], [x] and [x_0] are reached through the variant reserves computation for different cut-off grades [x_0]. For most of mineral deposits, volume of reserves and their average grade depends on accepted cut-off grade. Low cut-off grade results to large reserves, but of low average grade and on the other hand, high cut-off grade secures high average grade, but low quantity of reserves. The reserves/cut-off grade curve changes depending on the ore mineralization variability and type of mineral/ore distribution (lognormal, normal, left-asymmetrical, right-asymmetrical, bimodal, composite). Mostly, relation between [Z] and [x_0] is polynomial function of higher grade. For normal distribution, it is mainly linear dependence, for right-asymmetrical distribution has dependence between [Z] and [x_0] parabolic character (Fig. 1).

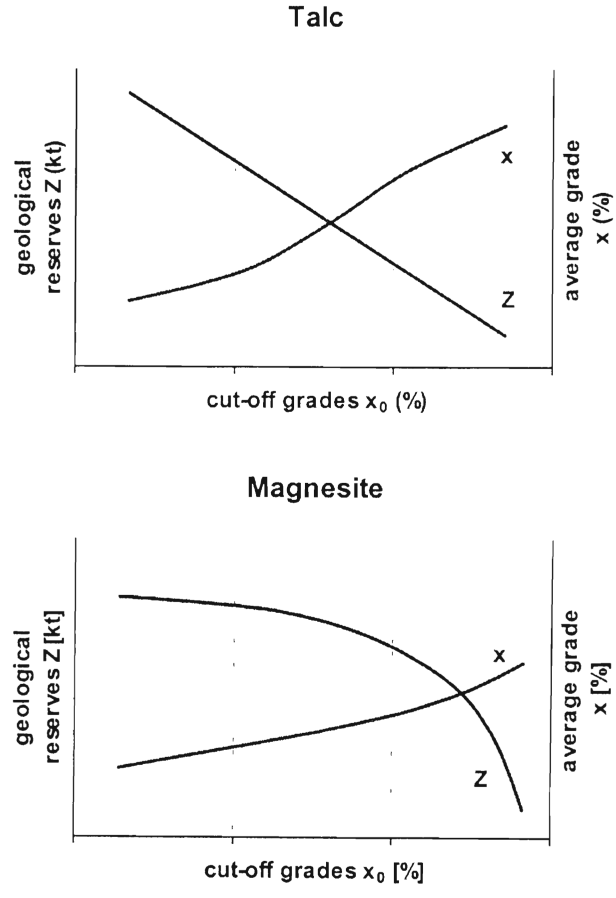

Fig. 1. Function dependency of geological reserves [Z], average grades [x] and cut-off grades [x_0]

Hence it follows that each mineral deposit, as non-repetitive natural object, has its specific dependences [Z], [x] and [x_0], which are necessary to be graphed and mathematically described for optimal economic assessment, outgoing from variant reserves computation for various cut-off grades.

Necessity of graphic and mathematical description of every measured mineral deposit, connected with definition of function dependency of [Z], [x] and [x_0], results from the need for determination of economic or potentially economic reserves/resources contours, and also from need for determination of optimal [Z], [x] and [x_0], corresponding to maximal deposit price for changing economic and technical-technological parameters (mineral price, production costs, ore contamination, recovery, processing recovery factor a. o.).

Function dependences between deposit price and so-called "static" geological-deposit parameters ([Z], [x], [x_0]) are visible in Fig. 2.

From Fig. 2 results, that increase of world market price (WP) of mineral commodity ($WP_1 \geq WP_2 \geq WP_3$), under constant production costs and technical-technological parameters, causes not only the growth of deposit price, but moves optimal geological-deposit parameters ([Z], [x], [x_0]), corresponding with maximum deposit price:

– Reserves Z_1 of average grade x_1 over cut-off grade x_{01} respond to maximum deposit price P_1 for world mineral price WP_1

– Reserves Z_2 of average grade x_2 over cut-off grade x_{02} respond to maximum deposit price P_2 for world mineral price WP_2

– For following decrease of world price WP_3, reserves Z_3 of average grade x_3 over cut-off grade x_{03} respond to maximum deposit price P_3

– Further decrease of world mineral price WP could imply to minus value of the deposit price, i. e. resources could be classified only as potentially economic.

Similar function dependencies between deposit price and "static" geological-deposit parameters ([Z], [x], [x_0]) stand in the case of substantial changes of production costs and technical-technological parameters, too. From above mentioned, we can suppose, that deposit price [P] (economic value of measured reserves) depends not only on mineral market price [mp], production costs [c], technical-technological parameters [tp], but it also depends on geological-deposit parameters ([Z], [x], [x_0]), which es-

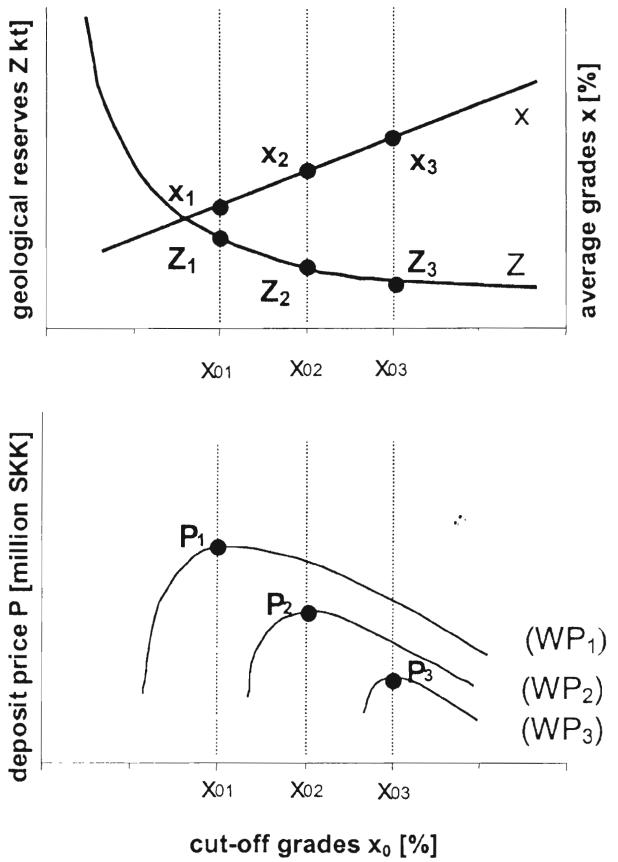

Fig. 2. Relation between maximal deposit price |P| and geological-deposit parameters |Z|, |x| and $|x_0|$ in the course of world mineral price change |WP|

sentially affect so-called "dynamic" economical and technical-technological parameters:

$$P \rightarrow f(Z, x, x_0, c, mp, tp)$$

From mutual function dependencies between "static" (geological-deposit) and "dynamic" (economic and technical-technological) parameters of mineral deposits issue:

1. Exactly assigned volume of reserves, defined by cut-off grade and average grade, responds to maximum deposit price, for constant mineral price, production costs and technical-technological parameters.

2. Significant changes of mineral price, production costs or technical-technological parameters result in changes of cut-off grades, average grades and geological reserves, defining maximal deposit price.

3. Under certain relation of production costs and value of returns ($c \geq r$), economic reserves vanish and only potentially economic resources are classified on mineral deposit. Volume of resources and their average grade respond to reserves over the contour for potentially economic resources.

Despite the fact, that mineral deposits are of various genetic type, age, morphology and mineral composition, it is liable, that application of this methodology of mineral deposit economical assessment (economic feasibility of reserves/resources) will by applicable for majority of mineral deposits, with some modifications for different morphological and geological-technological types. Another assumption is, that proposed methodology will be suitable not only for phases of preliminary or detailed exploration of deposit, but for economic assessment of exploited deposits, too.

General methodology of mineral deposit assessment, based on variant reserves computation (Fig. 3) indicates necessity to define relation of |Z|, |x| and $|x_0|$ (static deposit characteristics) before technical-economical evaluation (definition of dynamic deposit characteristics). Concerning proved dependence between static geological-deposit parameters and dynamic technical-technological and economic parameters from measured mineral deposits, optimal methodology for economic assessment of deposits is following:

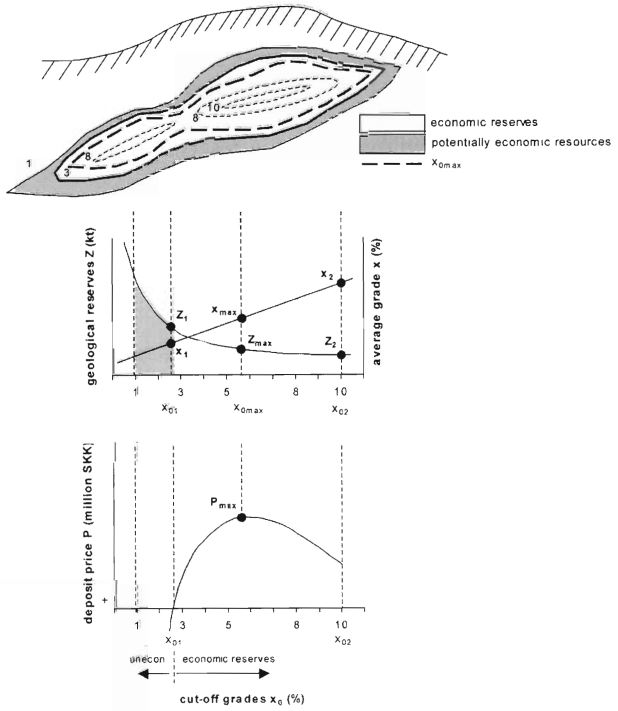

Fig. 3. Methodology for determination of economic and potentially economic reserves/resources.

1. Geological-deposit parameters (reserves, average grades, cut-off grades, thickness, number of deposit bodies a. o.) enter to the process of economic assessment.

2. Assessment process starts with variant reserves computation, which enable solid modelling and contouring of reserves of various average grade, responding to particular cut-off grade, covering whole interval of grades, measured over the limit for potentially economic resources. Variant computation of deposit reserves enables graph and mathematical description of relations between reserves, cut-off grade and average grade. For some deposits, it is advisable to realize computation after cut-off thickness $|m_0|$.

3. Each variant of reserves estimation is then economically assessed and deposit price is calculated through the utility value per 1 metric ton, production costs per 1 metric ton and extractable reserves, by NNP (Nominal Net Profit) or Cash-flow, NPV (Net Present Value) methodology.

4. After technical-economical assessment of variant reserves computation, following parameters can be classified:

For economic reserves:

a) Cut-off grade for economic reserves
b) Average grade for economic reserves
c) Quantity (volume) of economic reserves
d) Cut-off grade for economic reserves, equivalent to maximum deposit price
e) Average grade for economic reserves, equivalent to maximum deposit price
f) Quantity (volume) of reserves, equivalent to maximal deposit price

Note: Conditions for economic reserves issue from request for 10 % profit ratio.

For potentially economic resources:

a) Cut-off grade for potentially economic resources
b) Average grade for potentially economic resources
c) Quantity (volume) for potentially economic resources.

Advantages of economic and potentially economic reserves/resources defined by this way are following:

– Proved reserves of deposit are assessed in financial formulation (deposit price), based on valid prices, production costs and technical-technological parameters. This allows owner of deposit (state) negotiate with mining company about royalties payment.

– Variant reserves computation and its results, determining rich and poor parts of deposit, i.e. reserves (economic) and resources (potentially economic), represent fixed information formula, from which next revaluation of reserves balance is simply feasible by changing of entry economic data (prices, production costs).

Application of assessment methodology on talc and magnesite deposits

Economic assessment of Gemerská Poloma talc deposit

Talc deposit Gemerská Poloma represents large and meaningful object, which serve the purpose as proper model for application of economic assessment methodology (variant reserves computation and their next technical-economical valuation).

The deposit is situated in the Early Paleozoic rock complexes between villages Gemerská Poloma and Henclová, about 18 km to the south from Spišská Nová Ves town. Geological composition is visible in Fig. 4. Deposit of talc-magnesite raw material lies in the depth of 250 to 800 metres, between granite bedrock and volcano-sedimentary rock complexes of the Early Paleozoic (hanging wall). Deposit length reaches 2,700 metres, thickness varies from 2 to 400 metres, and width varies from 150 to 400 metres. Deposit bedding is sub-horizontal, with moderate dip (10–15°) to the east. North and south demarcation of deposit is not definitely solved, likewise its eastern continuation.

Talc content fluctuates from several % to 95 %. The best quality talc bearings are of 1 to 28 metres thickness with talc content of 50–70 %. Medium quality bearings contain 30–50 % of talc and poor quality material (magnesite with talc) only up to 30 % of talc. Distribution of talc is bimodal.

Example of so-called *global economic assessment*, which consists in technical-economical evaluation of reserves of whole deposit (i. e. evaluation of each variant of reserves estimation), is in Fig. 5. Dependence of deposit reserves [Z], average grade [x] and cut-off grade [x_0] is presented here. Conclusions resultant from the graph are that the deposit contains:

– 103 Mt of reserves with average grade 36 % of talc, or

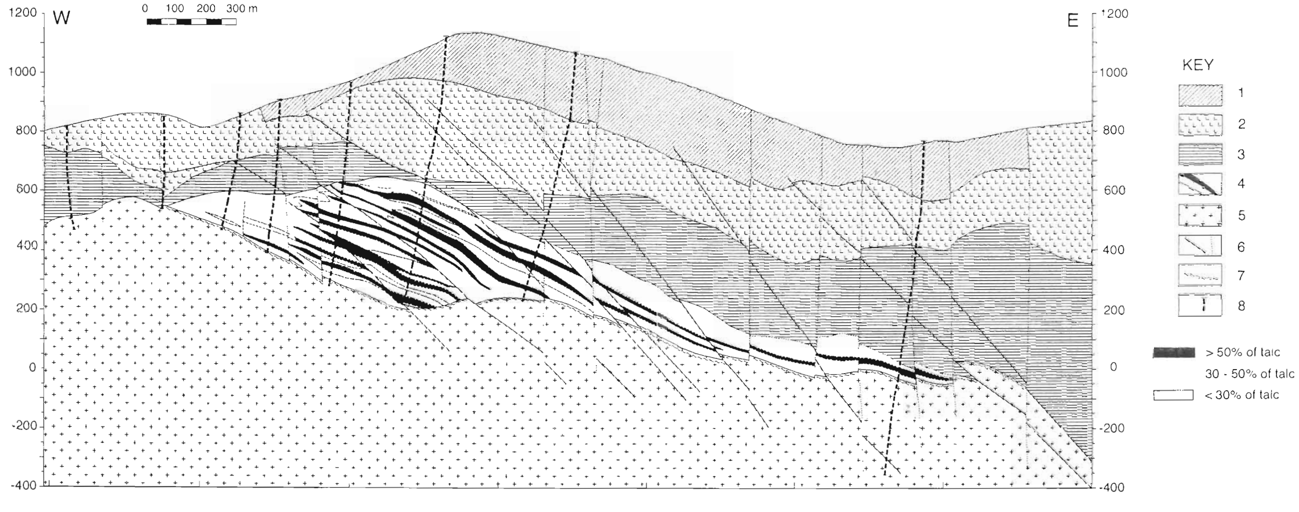

Fig. 4. Geological setting of Gemerská Poloma talc deposit (Gelnica Group, Vlachovo Formation: 1 – metamorphosed psammitic and pelitic sediments, 2 – metarhyolite and metakeratophyre tuffs, 3 – laminated clastic sediments, 4 – steatitized carbonate body, 5 – Hercynian granites, 6 – faults, 7 – overthrust lines, 8 – realized boreholes.

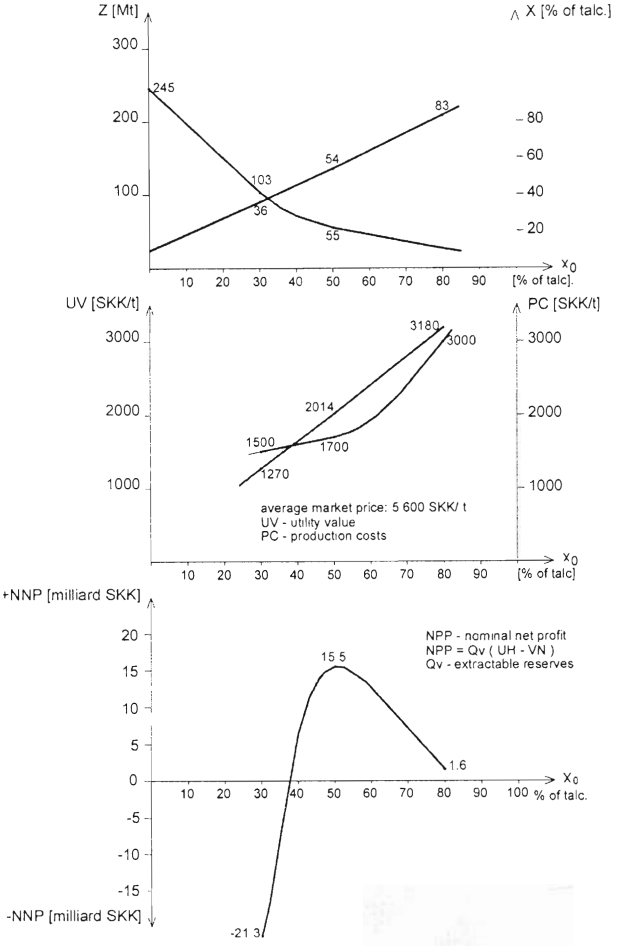

Fig. 5. Global economic assessment of Gemerská Poloma talc deposit applied on whole deposit reserves.

– 55 Mt with average grade 54 % of talc, or
– 25 Mt with average grade 83 % of talc.

Questions from the introduction (what is size of deposit, what are borders between economic reserves and uneconomic resources, what is deposit price) are solved by the next technical-economical assessment of each variant of reserves computation.

The first step of technical-economical valuation is calculation of utility values per 1 metric ton of reserves of given quality (grade) and construction of function dependence curve, representing relation between utility values [UV] and cut-off grades [x_0]. For this case was applied average price of talc 5,600 SKK (47 SKK correspond approximately to 1 USD) per metric ton and determined mining and processing parameters, relative to the current exploration phase of deposit.

The second, very important and difficult step is estimation of capital and production costs [PC] for each variant of reserves computation and construction of dependence curve between costs [PC] and cut-off grades [x_0].

Analysis of relative position of curves UV/x_0 and PC/x_0 suggests to qualitative intervals, in which occur economic reserves and potentially economic resources. Cut-off grade interval 10–40 % of talc content allocates potentially economic resources. Cut-off grade interval 40–80 % of talc content, where UV/x_0 curve is over the curve PC/x_0, refers to economic reserves (according to UN Classification, 1997).

The third step of assessment process is price [P] estimation for each variant of reserves computation and construction of price-cut off grade curve (P/x_0). Deposit price (Nominal Net Profit), realized after geological (opportunity) study is calculated by following formula:

$$NNP = Q_E(UV-PC),$$

where: NNP – Nominal Net Profit [million SKK]
Q_E – extractable reserves [metric ton]
UV – utility value [SKK/t]
PC – capital and production costs [SKK/t]

i. e. without time factor regarding and discounting.

Analysis of P/x_0 curve shows, that maximal price of deposit (by NNP method) reaches 15.5 milliard SKK for cut-off grade 50–55 % of talc content. For cut-off grade 40 % of talc, deposit reaches zero value price and for 80 % cut-off grade of talc, deposit price would be only 1.6 milliard SKK, concerning low reserves of the best quality

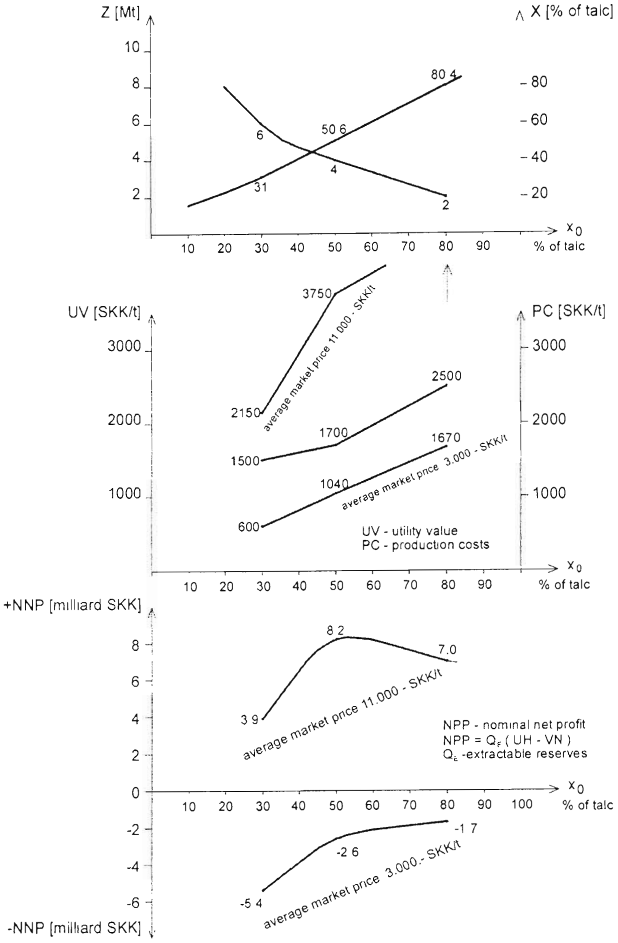

Fig. 6. Local economic assessment applied on selected part of Gemerská Poloma talc deposit.

talc (25 Mt). This example of global economic assessment of talc deposit clearly shows importance of function dependence definition for cut-off grade [x_0], reserves [Z], average grade [x], utility value [UV], capital and production costs [PC] and deposit price [P]. For present mineral price (5,600 SKK/t), technical-technological parameters and defined production costs, exists only one cut-off grade [x_{0max}], for which deposit price will be maximal.

Replies to questions from introduction are following:

1. Gemerská Poloma deposit could be classified as a large deposit with geological reserves over 10 Mt of talc (20.7–29.7 Mt).
2. Economic reserves are determined by cut-off grade over 50 % of talc content, i. e. 55 Mt of average grade 54 % of talc. Other resources, for 10–40 % cut-off grade interval, are classified as potentially economic at present.
3. Border between economic reserves and potentially economic resources ranges in cut-off grade interval 40–50 % of talc, depending on desired production profitability. Mining of the best quality talc (cut-off grade over 70–80 %) is not recommended, concerning considerable decrease of reserves and lifetime of deposit. Border between potentially economic resources and low-mineralized (sterile) rocks was estimated to 10 % of talc content, following actual technological and economical parameters (processing recovery factor, quality of concentrates, mineral prices).
4. The price of Gemerská Poloma talc deposit reaches maximum of 15.5 milliard SKK, for optimal cut-off grade 50 % of talc.

Besides global economic assessment of whole mineral deposit, for large deposits of long lifetime, thanks to volume of estimated reserves, so-called *local economic assessment* could be realized. The local economic assessment concerns with that part of deposit, which will be prepared for exploitation in the next 3–10 years, after detailed exploration campaign. Example of local economic assessment for part of talc deposit with reserves 2–8 Mt and cut-off grade range from 20 to 80 % of talc is visible in Fig. 6. In the case of talc market price reaching 11,000 SKK/t during the exploitation, reserves will be classified as economic, with maximum price (NNP) 8.2 milliard SKK for cut-off grade 50–60 % of talc. In the case of market price decrease to about 3,000 SKK/t, no variant of reserves computation will secure profitable exploitation and all resources in this part of deposit would be classified as potentially economic.

Economic appraisal of Gemerská Poloma deposit after mono-variant reserves computation with predetermined cut-off grade 20 % of talc (initially stated condition for reserves computation) could imply to stagnancy of deposit survey and eventual exploitation of this big deposit. Mono-variant reserves computation (for the only one cut-off grade) cannot secure complex deposit evaluation.

Economic assessment of Jelšava – Dúbrava massif magnesite deposit

Magnesite deposit Jelšava – Dúbrava massif occurs in rock complexes of Carboniferous age and belongs to large, economically important, metasomatic deposits. Geological reserves reach 535 Mt and yearly production is about 900 kt within the last years. Average content of MgO utility component is about 41.5 % and content of impurities is following: CaO 3.58 %, SiO_2 0.64% and Fe_2O_3 3.76 %. Production value reaches 1.8–2 milliard SKK.

Chemically pure magnesite ($MgCO_3$) contains 47.6 % MgO and 52.4 % CO_2. Mg^{2+} cations are partially replaced by Fe^{2+} and Ca^{2+} cations. FeO content in magnesite ranges from 1.4 to 7.0 %, CaO content ranges from 1.2 to 4.0 %. Moreover, magnesite contains admixtures of SiO_2, Al_2O_3, Fe_2O_3 a. o., with important influence to raw material quality. Mineral commodity is usually marked as magnesite, if MgO content is at least 40 %, together with CaO content max. 4 %. Utility component MgO is bounded mostly in magnesite, lesser in dolomite and marginally in chlorite and talc. Basic impurity – CaO – is bounded mostly in dolomite, less calcite. Other impurities (SiO_2 and Al_2O_3) are bounded in mica, chlorite, talc and quartz. SiO_2 and Fe_2O_3 contents lower refractoriness, therefore they must be delimited.

In 1995, reserves of depth and east continuation of deposit (Dúbrava massif – depth and Jedľovec) were revaluated.

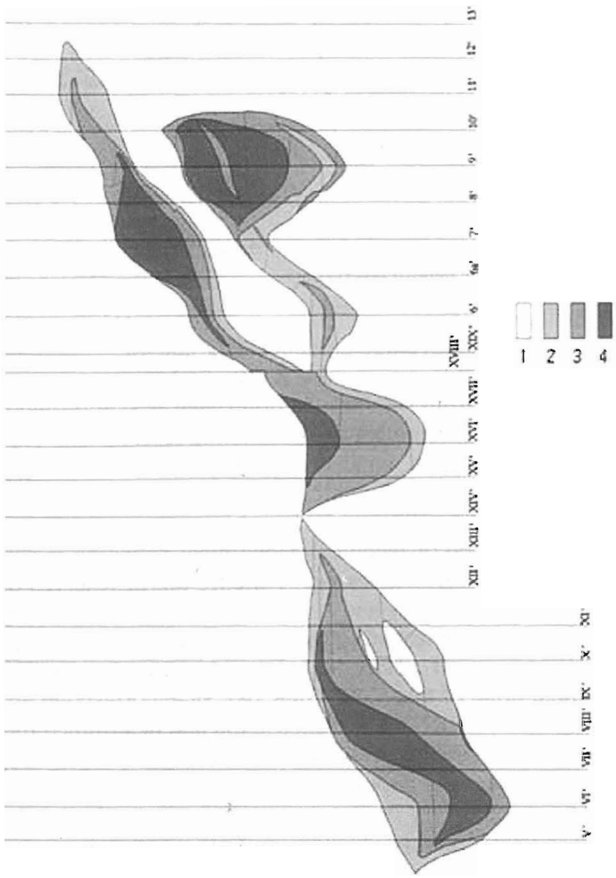

Fig. 7. Spatial position of qualitative classes of magnesite in horizontal cross-section on the level 0 metres above the sea level. 1 – dolomite, 2 – >35 % MgO (magnesite + dolomite), 3 – >41 % MgO (magnesite), 4 – >43 % MgO (magnesite).

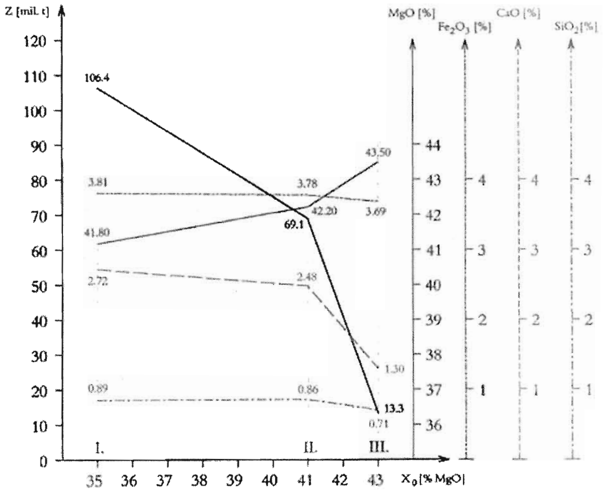

Fig. 8. Dúbrava massif – Jedľovec: dependence between MgO cut-off grade (x_0), reserves (Z), MgO average grade (x) and impurities content (CaO, Fe_2O_3, SiO_2).

A new variant reserves computation in this part of deposit was realized, being followed by technical-economical assessment that essentially amended viewing angle on economical meaning of reserves estimated in the past. Until 1995, reserves computation was realized after conditions from 1979, in which cut-off grade was determined for both economic and potentially economic reserves/resources at 35 % of MgO.

Spatial position of qualitative classes of magnesite in horizontal cross-section (on the level 0 metres above the sea level) is illustrated in Fig. 7, based on variant reserves computation, realized for cut-off grades 35 % MgO, 41 % MgO and 43 % MgO.

It is evident (see Fig. 7), that magnesite-dolomite mixture of quality 35–40 % MgO is concentrated mostly in marginal parts of deposit bodies, on transition from metasomatic magnesites to metasomatic dolomites. These poor, marginal parts of deposit, reach thickness up to 50 metres. After conditions from 1979, reserves computation included all parts over 35 % of MgO content, what resulted in increase of geological reserves and decrease of average grade (MgO content). In some parts of deposit, for example in the eastern part of Dúbrava massif–Jedľovec, extremely low cut-off grade 35 % of MgO (common for economic reserves and potentially economic resources) caused that all calculated reserves were classified (after mono-variant conditions) as uneconomic, concerning present technological and economic conditions.

In 1995, new variant reserves computation was realized for three different cut-off grades: 35 % MgO, 41 % MgO and 43 % MgO.

Results of this reserves estimation are figured in Fig. 8, from which issue:

– Increase of MgO cut-off grade from 35 % to 41 % and 43 % causes decrease of reserves volume from 106.4 Mt to 69.1 Mt and 13.3 Mt.

– Increase of MgO cut-of grade causes growth of average grade from 41.8 % to 42.2 % and 43.5 %; on the other hand, content of impurities (CaO, SiO_2 and Al_2O_3) decreases.

Quality analysis of the second variant of reserves computation showed, that 69.1 Mt of reserves of average quality 42.28 % MgO, 2.38 % CaO, 0.79 SiO_2 and 3.72 % Fe_2O_3 fully satisfies conditions for economic reserves. Only 37.3 Mt of geological reserves are classified as potentially economic resources.

Qualitative difference between mono-variant (after given conditions) and variant reserves computation is evident. Variant reserves computation (estimation) allows classification of some reserves as economic (69.1 Mt), i. e. usable reserves under present technical-technological and economic conditions.

From the point of view of methodology, the shortness and non-complexity of mono-variant reserves computation were proved. For potentially economic reserves, it is possible to accept cut-off grade 35 % of MgO, for economic reserves must be MgO content at least 38–41 %

Statistical parameters of data files and following realities were taken into consideration for average grade calculation:

– Right asymmetrical to normal distribution of MgO and Fe_2O_3 contents (with low variability 3–10 %).

– Left asymmetrical to lognormal distribution of CaO and SiO_2 contents (with higher variability 68–83 %).

– High minus correlation (-0.94) of MgO and CaO contents.

Conclusion

Variant reserves computation, including economic assessment of each selected variant, results in determining of rich and poor parts of deposit, i. e. reserves (economic) and resources (potentially economic), and represent fixed information formula, from which next revaluation of reserves/resources balance is simply feasible by changing of entry economical data (market prices, production costs).

Mono-variant reserves computation (for the only one cut-off grade) cannot secure complex deposit evaluation and could cause stagnancy of deposit survey and restrain eventual exploitation of mineral deposit.

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Influence of Slovak magnesite processing on the environment

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Abstract

Slovak magnesite industry has at its prosperous economic activity by the exploitation of domestic raw-material resources also unfavourable influences on the basic components of the environment, i. e. soil, water, surrounding air and biot. These unfavourable influences are caused by the emissions, above all from thermal technologies at the processing of magnesite raw-material The air is polluted by solid particles, composed of Mg-bearing minerals. At present time an amount of emissions is significantly eliminated in consequence of the new dust collecting devices installation. Emitted solid particles, represented by mineral phases such as periclase, caustic MgO, magnesite, dolomite, calcite, etc., create the hydrates of Mg-minerals in immission position after their contact with air humidity and in that way they strongly alkalize the soil horizons, water and biosphere.

Key words: emissions, immissions, magnesium mineral forms, soil horizon

Introduction

Slovak Republic is one of the most important producers of refractories in the world. The production is based on domestic magnesite reserves, which constitute about 8 % of total world reserves. As to magnesite exploitation Slovakia is the 4th in the world. Deposits of the crystalline magnesite in the Western Carpathians belong to giant and the most important in Europe. In addition to prosperous economic activities of magnesite industry, its processing technologies unfavourably influence on all components of the environment, i. e. land, water and biot. The industrial, mining and processing activities result in physical changes of surrounding landscape, especially in pits or craters after surface mining, dumps, waste banks as well as in a dustiness of wider surroundings caused by the emissions of solids from thermal technologies. Naturally, high dust deposition is connected with the contamination of soils and water by alkalinous components and this fact consequently results in a damage of biot. For a long time, during operation of thermal technologies of magnesite processing in shaft and also in rotary furnaces, the facilities were equipped by dust collectors with low efficiency and in many cases no collectors were applied. Thus, a large amount of solids in the form of emissions leaks out into surrounding air, where they influence as strongly alkaline substances.

For several years the dust deposit at the surroundings of magnesite processing plants exceeded the values of maximum allowable concentration (MAC), i. e. 150 $t.km^{-2}$, or 12,5 $g.m^{-2}$. $(30 \text{ days})^{-1}$ and at its composition and MgO content of 30–40 % it contaminated wider area of the plants. In 1970s, in the area of the most concentrated production, i. e. the belt of Lubeník-Jelšava the MAC was exceeded in the area of 32 km^2 (Leško, 1987). Recently, after installation of new dust collecting devices and technologies the situation in plants surroundings is stabilized and even improved. But up to present time there are visible the localities of dust deposits there as a result of plants operation in the past. The crusts, that achieve the thickness from several millimetres to 3–5 cm, were formed. They contain minerals and metals which were emitted from point and plane sources of plants. These areas covered and contaminated by dust under "favourable" weather condition become the secondary source of dust and in such way the dust may get into a long distance from primary source. The soil has a high content of Mg and alkalinity is also high. Endothermic decomposition of magnesite liberates a large amount of CO_2. During decarbonization a strength of material falls down, MgO originates, but the structure of carbonate conserves itself (Fig. 1) and the crystallization of periclase directly from caustic MgO is very rare (Fig. 2).

Average chemical composition of solid dust outlets from rotary furnaces of operating magnesite plants is presented in Tab. 1.

The elements introduced in Tab. 1 contaminate the soil through the air in the form of mineral phases-containing dust. The dominant minerals in dust outlets represent periclase and caustic MgO, that are accompanied by magnesite, calcite as well as by dolomite. The occurrence of quartz is rare. Naturally, mentioned minerals also participate on the composition of soils and/or crusts, respectively, which were formed in the precincts of magnesite plants.

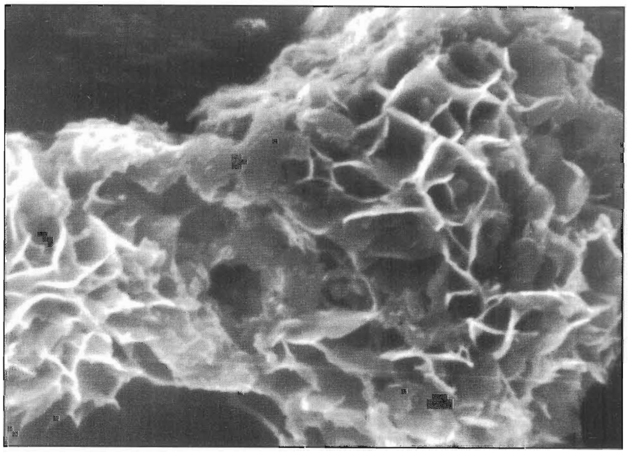

Fig. 1. Creation of the cubic forms inside of decarbonatized particle, magn. 5000x.

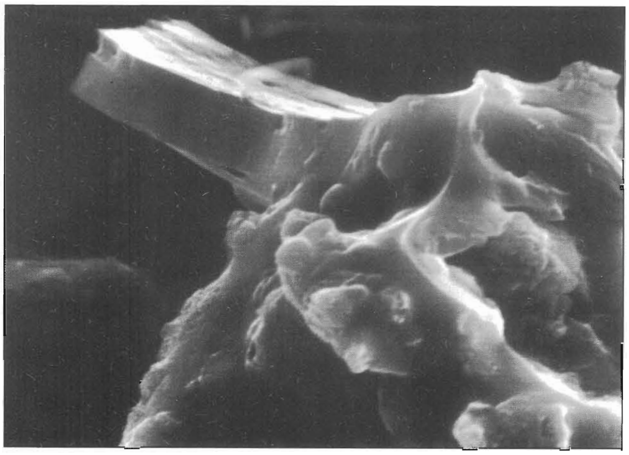

Fig. 2. Amorphous particle of caustic and phenocryst of periclase magn. 5000x.

Tab. 1
Content of elements in dust outlets from rotary furnaces of magnesite processing plants in $mg.kg^{-1}$ (ppm)

Plant	Mg	Ca	Fe	Mn	Cu	Pb	Zr	Co	Cr	Ni	As	Hg	Cd	Sb
Jelšava	332.600	9,730	46,250	2,270	20	14	47	4	21	22	87	0.6	7	6
Lubeník	267.000	11,400	15,800	1,222	17	10	40	26	33	54	27	0.4	1	89
Bočiar	422,300	10,400	38,300	2,800	55	19	95	14	98	64	6	0.8	2	99

Magnesite production and related environmental protection in Slovakia

Mineral composition of contaminated areas, where magnesite deposits occur and processing facilities were and are in operation, with their history and influences on the environment, from the west towards the east, is as follows:

Podrečany – Lovinobaňa deposit

On the deposit of Podrečany-Lovinobaňa firstly, an iron ore has been exploited and during prospecting works in 1952 the deposit of magnesite was discovered. Magnesite was processed in shaft furnaces. A favourable localization of plant with regard to the morphology of surrounding terrain, where valley widens towards the south and prevailing air current is in the direction of NNW–SSE, did not create any conditions enabling the contamination of wider surroundings. The soils were contaminated in the direction of prevailing wind to the distance of about 2 km. Except for plant area the crusts were not observed anywhere. The following minerals were determined in the crusts: periclase, magnesite, dolomite, calcite, hydromagnesite, brucite and hydrocalcite. The dominant mineral was caustic MgO, from which secondary minerals originated. These minerals are soluble in weak acids and this fact results in the movement of their dissolved components into deeper parts of soil horizon. Recently, thermal technological centres of the plant do not operate and thus, favourable condition are for environment regeneration.

Mútnik and Hačava deposits

In 1871, during the construction of railway Hnúšťa-Tisovec in the Rimava river entrance area, magnesite was discovered near the calcite quarry of Mútnik. On the threshold of the 20th century the raw-material began to be processed in shaft furnaces in Hačava and in the 1960s a rotary furnace was put into operation. Unfavourable morphology of surrounding terrain, technologies without a dedusting and the other operating plants in vicinity, namely a chemical one in Hnúšťa, a blast furnace in Tisovec and talc grinding plant in Mútnik caused an intensive devastation of landscape. A coherent crust with the area of several tens hectares without vegetative cover was formed. The crust is composed of primary dust particles, that are cemented by secondary minerals. The caustic MgO and periclase are present as the dominant minerals. The secondary minerals represent brucite, hydromagnesite, nesquehonite and hydrocalcite. Later, these minerals with water in their structure crystallized into calcite and dolomite. That caused that the crust is stony and resistant. The content of MgO in the crust attains of 55–60 %. Recently, the crusts slowly desintegrate also by means of unpretending plants.

Jelšava and Lubeník deposits

In the area of Jelšava-Lubeník the processing of magnesite from surrounding deposits in Ratková, Ochtiná, etc., began in 1894–1895. Firstly, magnesite was processed in the shaft furnaces, later in the annular ones and finally, for the last 30 years in the rotary ones. Recently, five shaft and one rotary furnaces are working in Lubeník and three rotary and four shaft furnaces are operating in Jelšava-Teplá voda. In this area the processing of magnesite has tradition for more than 100 years and during this period a wide surrounding of these plants was contaminated by the immissions of solid particles. Dedusting devices were imperfect and for this reason the crusts on strongly alkalized soils, with similar mineralogical composition as above mentioned, was created. Lastly, a high dust deposition was caused by the application of rotary kilns, designed for the burning of lime. Thus, dedusting devices designed for lime dust outlets was not suitable for the magnesite ones and this fact resulted in an intensive contamination of wide surroundings. The forest stand was strongly damaged and for instance in the locality of Hradovisko nad Jelšavou the forest stand have been petrified. The dominant minerals are represented by calcite and dolomite that crystallize in wood mass from their hydrates. The area, where two magnesite processing plants operate, can be characterized as a narrow valley in the direction of NW–SE, closed on its sides by mountain massifs. Thus, prevailing wind is also in the direction of valley. For this reason, the crust composed from Mg salts, i. e. primary and secondary minerals of dust outlets, with the thickness up to 5 cm have been created on the soils in the surroundings of the plants.

Generally, it is given, that crusts originate in the case if dust deposition with Mg content over 50 % exceeds the amount of 600 $t.km^{-2}.year^{-1}$. Such soils contain a minimal amount of organic substances. The following minerals are present: periclase, caustic MgO, magnesite, dolomite, calcite and also hydrates of these minerals occur. Minerals were identified by means of DTA and X-ray analyses (Bobro, 2000). Currently, ecological situation improves as a result of new high effective dust collecting devices installation, namely *Amertherm.* Thus, for instance, in 1970–1980 the emission of solids attained the amounts about 4,800 $t.year^{-1}$, but in 1990 it was 500 $t.year^{-1}$ and finally, in 2000 it was 170 $t.year^{-1}$ in Jelšava and 85 $t.year^{-1}$ in Lubeník. This view is very optimistic and situation incessantly improves by serious approach of the plants management to questions of the environment in this damaged area (Hančuľák, 2000, 2001).

Bankov deposit

The eastern part of Slovak magnesite deposits belt is represented by the Bankov deposit. The production of caustic magnesite began there in 1911. Firstly, two shaft furnaces were in operation. In 1950s, the magnesite processing plant was removed to Ťahanovce, where in 1980s and 1990s a severe development of housing caused that plant found itself in an urban settlement. Till 1990, four rotary furnaces have operated there, later only two ones that were equipped by dust collecting system *Amertherm.* Because the plant is located in the northern part of densely populated area, in the mouth of the Hornád river to an alluvial plain, that widens in the direction of E–W and prevailing air current is in the direction of N–S, all agglomeration has been contaminated. The highest pollution was in the central air corridor along the river plain, where the largest amounts of polluted air have been moved. After the installation of effective dust collecting devices the Mg content in dust deposition fell down from 35–40 % to 8–10 % and in aerosol, i. e. in dust ambient it decreased from 20 % to 1–3 %. Today, the plant is not in operation, but all area of plant and spoil areas in its precincts are and will be for a long time a plane source of mineral dusts. In this place the laminas of mineral dust in the form of periclase, magnesite, calcite and the hydrates of the other carbonates still occur and during stronger winds they pollute the wide area of agglomeration. Mg-bearing dusts deposited in town area for a long time and effectively neutralize acid rain. During the magnesite processing plant operation the neutralization carried out in the air, most effectively in the immission position. After cutting-off of thermal technological centres the alkalinity of rains and snow in the town area fell down from pH 8–9 to pH 5.5–6.5. In dusts and spoil areas similar minerals have occurred as in the other localities. The higher portion of dolomite was observed that may come from the localities of dolomite quarries in entrance area of the Hornád river, several km to the north from magnesite plant. Currently, the magnesite processing plant is moved to the Bočiar locality near at the iron and steel works factory, where applied technologies of dust elimination are almost wasteless.

Discussion

In the world an abundance of magnesium in soil horizons is rare. On the contrary, majority of literary sources deals with a deficiency of this significant biogenetic element. In Slovakia, in the localities with magnesite industry, the soils and their dynamic components, such as soil reaction, nutrients regime, biological activity, organic substances quality and structural status of plough layer are still influenced by Mg immissions. The high occurrence of Mg immission, above all of amorphous caustic MgO results in a high alkalinity of soils. According to agrochemical criteria the suitable amount of Mg received by soil is up to 200 $mg.kg^{-1}$. But in the localities with magnesite industry this value is exceeded by 4–100 fold. Under natural conditions the annual loss of magnesium per one hectare of soil by crops, leaching and migration achieves of 26–34 kg (Hronec, 1996). Thus, it is possible to decrease the Mg content in soil during a determinate period, under consideration that its input will be stopped. But currently, in the surroundings of magnesite plants the input of Mg-bearing into soil still exists. For instance, dust outlets from Lubeník contain 44.5 % of MgO, in Jelšava it is 55.4 % of MgO and in former magnesite processing plant in Košice it was 77 % of MgO.

Animal organisms have some magnesium resistance, better than plants. Metabolic disorders under influence of magnesium abundance were identified only in experiments with animals, for which a high doses of magnesium components have been fed. But differences between exposed and checking files were not significant. On the basis of the epidemiological investigations of exposed and non-exposed workers the following knowledge have been obtained in exposed group: enhanced excretion of Mg by urine, hypertension, defects of embryonal development, abortions, lower birth-rate and length of newborns. Observed differences between the investigated groups were on the border of significance. Also in the case of workers operating under high dust exposure any disorders of breathing system was not directly proven (Groch, 1985).

An occurrence and movement of heavy metals is connected with the movement of magnesium solid immissions. The heavy metals are directly bonded on emitted dust or on particles of various form, i. e. ions, molecules and their aggregates, that adhesively react with solid particles and together with them contaminate soils and other components of the environment. The following elements are considered as contaminants: Zn, Cu, Cd and mainly Mn. A transition of these elements from soils into biomass and by food chain along was not statistically significant (Mičura, 1995).

Conclusion

Conclusively, above mentioned facts mean that enhanced Mg contents in the air, soil, water and consequently unsignificantly in biomass is a special Slovak problem in the small areas with magnesite industry. More advanced technologies and feasible management with these valuable raw-materials give an expectation for the future that input of magnesium into natural and municipal surroundings will constantly decrease. Wasteless technologies are planned in this branch of industry, but it is long-term vision. Visible damages as a result of previous operating technologies will endure and spoil, generally improving situation.

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Emission from magnesite production as a source of excessive magnesium intake in ruminants

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Abstract

Nowadays the interest about magnesium metabolism is increasing due to its clinical, biological and ecological importance. The results of our studies proved that an excess magnesium supply is mostly the problem of those regions, where magnesium-processing industries are present in Slovakia. Ruminants including the wild ones are the most sensitive animals to the excessive supply of magnesium, where the magnesium toxicity is manifested by the decrease of production and diarrhea. First of all in most cases, the digestive system is affected. During the study of an excessive supply of magnesium, the decrease of the digestion of solid feeds was investigated. This is caused by the decreasing of the fermentative processes in the forestomach together with the decrease of the feed intake and the increase of the water intake. It was also confirmed that an excess intake of magnesium has negative influences on the content of the total protein, alpha and beta globulin fractions, as well as on the activities of AST and ALT This paper presents the review of the up-to-date theoretical and experimental knowledge about the influences of an excessive load of magnesium in the digestion process, metabolism, production and health of ruminants.

Key words: magnesium, magnesium emission, ruminants, metabolism and rumen digestion

Absorption, metabolism and magnesium excretion

Magnesium is evaluated as a multifactor cation, which in a high extent influences the life processes of animals. The significance, which is given to researches and practices of magnesium, is increasing. This fact is emphasized in the international magazine "Magnesium" and the establishment of the "World society for magnesium research" and the "IX Symposium of ecology in chosen agglomeration in Jelšava – Lubeník and Middle Spiš" (Vrzgula, 1999). The importance of magnesium, according to the amount in the sequence of the fourth cation, is after calcium, sodium and potassium, and helps also the activation of approximately 300 enzymes. It influences the characteristics of the cell membrane and neuromuscular sensitivity. It has anti-stress, anti-toxic and anti-allergic factors. Magnesium is in high measure interfering the metabolism of other elements, such as proteins, saccharides, fats and insulin. It has an irretrievable task in the bone metabolism. Mainly absorbing it from the digestive system but also re-absorbing it in the kidney and mobilization from the bones are influencing the magnesium efficiency. Magnesium together with Ca and P is present 70 % in bones, 28 % in cells and 1 % in extra-cellular fluid. Magnesium is present in the blood plasma as well as in the blood cells. It is partly bind to the protein (non-diffusible) and part of it is free (ionized) in the blood plasma. In bones of young animals there is approximately one third and in adult animal one fourth of magnesium that is mobilized. The level of magnesium in the blood serum of the farm animal is moving from 0.70–1.20 mmol.l. The digestion process of magnesium is decreasing to 20–30 %, when the animal is getting older, but also the volume of the mobilized magnesium is decreasing and the speed of the mobilization is decreasing. In the process of magnesium re-absorption mostly other mineral substances are applying in the feed dose, mainly Ca and P. The higher the content of the Ca in the feed intake, the lower the storage of the magnesium in the bones. During magnesium excretion via the feces, it is the vice versa, the older the animal the more volume of magnesium is secreted. The excretion of magnesium from the feed intake via the feces is as follows: three-week-old calf 32 %, but from 16-week-old calf is up to 86 % (Vrzgula, 1999). Magnesium, which is excreted via the feces, contains magnesium, which was not absorbed from the feed, and also from the endogen magnesium, which entered into the digestive system via saliva and other secretions. Some portion of the endogen magnesium is reabsorbed again.

Magnesium excretion depends on the form of its supply to the organism and on its level in the blood. Magnesium excretion via the urine by the hypomagnesium process is decreasing to the minimum, but after parenteral application of the magnesium salt, it is excreted via the urine up to 90 % (Vrzgula, 1999).

Absorbability of magnesium in the ruminant fore-stomachs is influenced by:

– The content of other mineral elements in the feed dose, mainly Ca and P. The negative influence of a high content of magnesium in the feed dose on the magnesium re-absorption can be explained by the fact that the volume of the non-dissolved cadmium phosphate that raised in the digestive system, can absorb into its surface also the magnesium ions and by this way it hinders the re-absorption. The antagonism of Ca and Mg probably depends also on the individual compounds, on which such elements are presented. After the per-oral application of chlorine-hydroxide and cadmium-phosphate they positively influence the cadmium re-absorption, but magnesium-sulfate is influencing its balance negatively.

– High level of fat in feed dose decreases the magnesium absorption. Fatty acids with magnesium in the stomach fluid create dissolved soap. It is reflecting in the decreasing of the absorption and by this way also the magnesium level in the blood serum.

– High content of nitrogen elements and low concentration of energy in the feed dose causes the decreasing of the magnesium absorption during increasing of the NH_3 level and decreasing of the volatile fatty acid (VFA) in the rumen. Decreasing the production of VFA and CO_2 leads to the decreasing of the blood flowing in the wall of the rumen and this decreases the magnesium absorption. The increasing of the NH_3 level in the rumen, which is accompanied by the pH increasing, decreases the amount of magnesium dissolved in the rumen fluid. Magnesium is precipitated as magnesium-ammonium-phosphate and such complex is not possible to be absorbed in the rumen.

– Transaconite acid, which is highly presented in young plants during spring, is also negatively influencing the magnesium absorption (Vajda et al., 1994b).

The influence of an excessive magnesium supply on the fermentation and digestion processes

Magnesium in excess amount exists very rarely. We can only see an excess of magnesium in areas with the deposit of the natural magnesium ore and where industrial processing are taking place. The usual problem is caused when the dust filtering process in the industries is not well functioning. The excess magnesite load mostly damages the digestive system. During long-term excessive magnesium supply (500 mg/kg/h) in the calf feed dose (Vendrák et al., 1992) was proved the decreasing of the digestion of the solid feeds in the rumen that is caused by the decreased fermentative processes. There were not recorded discrepancies in concentration of the total VFA, as well as the individual VFA before the animal has been fed. The discrepancies were evident only after 3 hour after feeding, when significantly lower value of VFA was recorded for animals with a high magnesium supply. During the increased magnesium supply there was recorded the amount of the increasing of the ammonium nitrate and the pH. Jenčík et al. (1998) have in their experiments investigated the similar tendency.

The influence of the increased magnesium supply (203.8 mg/kg live weight) in the fermentation processes in the rumen of the fattening bull calves has been studied by Chrenková et al. (1998). The authors did not find any differences among animals, in molar rate of the acetic acid and its molar rate in both feed doses presented approximately 71 %. Similar tendency was seen in the propionic acid, but essentially lower concentration was in animals with increased magnesium supply. Opposite effect was recorded for butyric acid. In total volume of VFA there were not recorded significant discrepancies. Different influence to the fermentative process in the rumen of the ruminants in the presented experiments is possible to explain by the different concentration of the magnesium in the diets, in the experiments of Vendrak the result of the value was 2.5 times higher (Vendrák et al., 1992).

Bíreš et al. (1996) in their experiment on ewes observed the clinical picture by the supply of the industrial emission with high content of magnesium in the diets (500 mg/kg live weight). The supply of hay and concentrate feed mixture with the content of the industrial emission was not changed until the 12th day of experiment. The intake of the feed mixture decreased about one-third between the 12th and 20th days, but the hay intake was not changed. The water consumption has been drastically increased. Between the 20th and 26th days of observation the concentrate feed mixture intake comparing to the volume at the beginning of the experiment has decreased to one third. The intake was minimal or completely null between the 26th and 32nd days. The lose of appetite to the concentrate feed mixture was up to the 20th day accompanied by the decrease of the hay intake on the 32nd day from beginning 2 kg to its half. The increased water consumption has also persisted.

The feces started to change its consistency from compact form to the sleazy form since the 12th day of observation. Between the 15th and 20th days of experiment there was observed watery consistency feces in all animals. The color of the feces was dark green. Persistence of diarrhea was alternately in all experimental animals. It was alternatively accompanied by the hypermotoric of the forestomach and hyperperistaltics of the intestines. A little merely apathy was observed in all experimental sheep since the 20th day of experiment. Similar negative influences from high magnesium dosage to the digestive system, has been manifested as a persistent diarrhea have been observed (Jenčík et al., 1993). The mechanism of the diarrhea formation after the magnesium burden was explained by the effect of the magnesite cation on the increasing motility of the digestive tract, their influence on the creation of the metabolic alkalosis, gastroenteritis and dyspepsia (Reichrtová et al., 1985).

The influence of an excessive magnesium intake on the metabolism, productivity and health

Evaluating the biochemical markers in the internal environment is very important to observe the influence of the high magnesium intake on the metabolism of the ruminants. Sommer et al. (1996, 1997) followed the influence of the magnesite load on the balance of Mg, Ca and P in bull calves. An excessive magnesium supply in feed dose caused an increased excretion of the P via the urine and feces. High dosage of Mg had not any influence on the balance of Ca, but it caused the increased excretion of P in the urine and feces. It is connected with the antagonism of P and Mg. Therefore it is very important for ruminants to respect the ratio (Mg + Ca): P. Bíreš et al. (1996) have followed changes in mineral metabolism of sheep at an excessive magnesium supply of 500 mg/kg live weight. Feeding magnesite exhalants has significantly increased the secretion of magnesite in the feces and urine of the experimental sheep. This shows to the regulative mechanism during inadequate magnesium supply (Khorasani and Armstrong, 1992). Despite of the existed interactive relationships in the level of resorption of the intermediary metabolism and secretion of the Mg to Ca and P in ruminants (Waterman et al., 1991), the increased intake of magnesite from the sources of the magnesite emission, there have not been manifested any negative influence on the dynamics of the Ca and P in the feces and urine. The evidence was the significant increase of the serum concentration of both elements and the decrease of the excretion of Ca and P in the feces and urine. The known metabolic interactions of Mg to K and Na was not unambiguously proved in this experiment (Fisher et al., 1994; Dewes, 1995), because feeding the industry magnesite emission has not significantly changed the content of K in blood serum. At the end of the experiment, there has been observed the decreased excretion of K and Na comparing to the original values despite of the persisting diarrhea.

Bíreš et al. (1994) have observed the significant metabolical dependency of Ca, P, K, Na, Fe and Cu to Mg intake from the diet of heifers. The different reactions of the sheep and heifer on the magnesite burden is explained by the decrease of the intake of the tested emission in the sheep since the 12th day of experiment, in difference to the heifers, where the appetite was good during the whole experimental period. The dynamics of the analyzed microelements in the blood serum, feces and urine have been changed during the experiment in relation to their content in the tested emission and changes of the intake. Fe excretion in the feces and Cu excretion in the urine have significantly increased during the magnesite burden.

Jenčík et al. (1999) followed the influence of the excessive magnesium (500 mg/kg live weight) on the protein and fat metabolism in the fattening bull calves. From the results of the observed values of the metabolic markers on the level of protein metabolism – total protein and urine, fat metabolism – total lipids and cholesterol, is possible to state, that they were moving in the range of the physiological margins, except the value of the total protein, which was below the level of the referential physiological range.

Lower levels of the total protein, alpha and beta globulin fractions in the bull calves in the area of magnesite burden have been followed by Mariščáková et al. (1999). The lower level of the total protein, as well as alpha and beta globulin fractions indicate the liver damage, the organ where their synthesis is going on. By evaluating the hepatic profile during magnesite burden in heifer Bíreš et al. (1994) found out, that the most sensitive reaction during the intake of magnesite emission was reflected by the activity of AST and ALT. The significant increase of both enzymes was marked on the 30th resp. 50th days of experiment. At this time the values exceeded the upper physiological boundary. The negative value of correlative coefficient, which was determined during the evaluation of the serum IgC, indicates the heifer's defense mechanism destruction during the excessive magnesite intake. In a similar experiment on sheep was observes the increase of ALT only. But damage excludes the activity of the other enzyme ability in the liver (AST, GMT, ALP) and the concentration of the total bilirubin was in the physiological limits during the whole time of the magnesite burden (Bíreš et al., 1996). Differences between the hepatic profile markers of the previous experiments were possibly evoked by age (heifer – young, growth, ewe – adults) as well as the decrease of the magnesium intake of the ewe by mal appetite.

Magnesite burden deteriorates the health states, the production and reproduction (lower milking rate about 430 kg, with an interval of 3 to 7 days, service period about 20 days, inter-period about 16 days. Such markers are worse than the average values (Jenčík et al., 1997).

For eliminating the negative influences of the magnesite emission, mostly was used feeding dicalcium-phosphate, unprotected fats and urea (Jenčík et al., 1996; Pajtáš et al., 1997; Pavlík et al., 1997 and others).

The effect of an antidote was verified on the milk cows, fattening cattle and sheep on the basis of farm and semi-farm experiments. The suggested steps of care have partially or totally eliminated the negative influences of the magnesite burden and showed the improvement of the health status and increased production.

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Development of the magnesite exploitation and elaboration in Slovakia

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Abstract

This paper intends to be a short information guide about the development of mining and treating of magnesite in Slovakia and an information about history of the magnesite industry The history of magnesite deposit of Košice is a topic of following separate article.

The year 1900 is considered as the beginning of the industrial treatment of magnesite. Each deposit in Slovakia was opened by the surficial way using the wall or pit quarry method. The hammers were used to obtain drilling sticks by manual work. Discharging has been made by dynamite. The deliberated big pieces of raw material were broken with 15 kg heavy hammers. Discharged raw material at the wall quarry has been transported by the self-fall to the storage area. At the pit quarry it falled to the bottom of the profile. Later the elaborated slopes with wodden leakage were used in the wall quarry

At the stocks, the raw material was manually separated. Then it was transported to the shaft furnaces by horse carriages or by railway trucks. The first ropeway was constructed in 1903 in Hačava plant. The first shaft furnace for magnesite burning was constructed in Jelšava in 1894.

Owing to the scientific and technical progress the level of mining mechanization as well as the level of magnesite treating increased. There were introduced various improvements of technology, mainly for magnesite concentrates treating. Therefore also processing of the building materials production in Lovinobaňa and Lubeník plants has been improved.

Used equipments are described in the areas of Jelšava, Lubeník, Lovinobaňa and Hačava magnesite plants in the period of 1919–1944, than during 1945–1948, 1949–1970, 1971–1985 and finally during 1986–2000.

Key words: magnesite exploitation, magnesite elaboration, history of magnesite industry

Introduction

We are living in a period that is underlined by the strong competitive environment, where the success or unsuccessfullness of the firms depend on the firms' ability to identify its position on the market. Each demand of the market has raised and developed as well as declined in certain conditions.

To serve the reader an information about the amount of investments to magnesite mining and elaboration, we state their known costs in Czechoslovak/Slovak crowns. Though the exchange ratio of this currency to US Dollar in the past changed, recently 1 USD is an approximate equivalent to 47 Slovak crowns.

Magnesite mining and elaboration in Slovakia till 1919

The beginnings of the industrial elaboration of the magnesite in Slovakia we can date back to 1900, when the construction of two plants Hačava and in Jelšava-Teplá Voda started.

The magnesite bearing Carboniferous layer was firstly opened by superficial way using the wall or ditch stonepit exploitation. (Geological setting and location of Slovak magnesite deposits with maps and cross-sections is available in contribution by Grecula et al., 2000, published in IGCP 443 Introductory Newsletter.)

The Hačava plant was supplied by magnesite from deposits at Burda and additional one in Sušiany. Magnesite for the need of the old plant in Jelšava was exploited in various places of Dúbrava hill. The lower magnesite plant in Hnúšťa was constructed directly at the Mútnik deposit, since 1910 it owned mining rights also for the

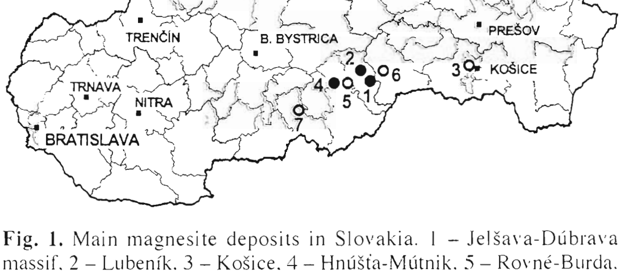

Fig. 1. Main magnesite deposits in Slovakia. 1 – Jelšava-Dúbrava massif, 2 – Lubeník, 3 – Košice, 4 – Hnúšťa-Mútnik, 5 – Rovné-Burda, 6 – Ochtiná, 7 – Podrečany. Full circle – exploited mineral deposit, empty circle – non-exploited mineral deposit.

Ružiná deposit. Stone-pit Kopáň (later AMAG) plant Lubeník Chyžná Voda exploited magnesite in three horizons, each one 15 m high. The horizons were connected with inclined shaft to the level of surrounding country, designated as the 4th horizon. At the level of 3rd horizon the tunnel Alexander has been constructed and tunnel Bartolomeus led to the 4th horizon. The 3rd and 4th horizons were connected with a tunnel, through which raw material has been transported by the gravity to the Bartolomeus tunnel.

Drilling works were done manually by stroking the drilling bar with a hammer. Dynamite has been used for shots. Hard work during drilling has been completed with the mechanical crushing of the stones with hammers weighting 15 kilograms. Shoted muck has been transported by gravity to the stone-pit's wall foot, where the stock was situated. At the ditch stone-pit it was transported by the leakage.

Raw material was manually selected at the stock piles, then it was transported by horse carriages to the plants, either to the railway feeder, or directly to the filling hole of the shaft furnace. The first ropeway was built in 1903. It was 6,630 m long and connected the Burda deposit with the Hačava plant. In 1906 an additional 1 km long ropeway was built and it connected the deposit at Sušiany hill with the final station of the big ropeway in Burda. In 1913 the ropeway long 3 km from Ružiná to Lovinobaňa started to work. The discharge station of the ropeway and railway station were connected with a railway feeder. A narrow-gauge railway from Dúbrava to Teplá Voda with 2.5 km in length was constructed during 1917–1918. Magnesite in the plants was manually loaded into the mining wagons, that were pulled up to the filling hole of the furnace (Bandurová, 2000).

The old plant in Jelšava – Teplá Voda was attached to the "upper and lower" furnaces, being constructed already in 1894–1897. Equipment for the crushing and selection of the burnt magnesite has been constructed at the upper furnaces for their more effective use. Lower furnaces were shutted down in 1911. In 1913 a single-stool shaft furnace was constructed at the upper furnaces. The plant was without production between the 1st World War and 1922.

The lower magnesite plant in Hnúšťa was constructed in 1902 directly at the Mútnik deposit. It consisted from two bothside shaft furnaces that were heated with generator gass. These were the first press furnaces in Slovakia. Burnt magnesite was extracted from the slanting exit of the furnaces and selected manunally.

In 1904 in the old upper-plant of Hačava the construction of four single-side stool shaft furnaces was finished. They were heated directly by the coal from the grates. In 1908 construction of the new plant started. In its frame in 1909 the first rotary furnace on the world for magnesite clinking with performance 20,000 tonnes was installed. In 1910 the magnetic separation of the burnt magnesite as well as a transformator for alternating current started to be examined. In 1913 the electromagnetic dressing with roller separators was built. The former shaft furnace from 1905 was rebuilt in 1915 for the vertical one with automatic extraction. The generator gass was used as a fuel. Production of the upper magnesite plant in Hačava, owing to the technical development of the plant, was increasing till 1913, reaching of 33,951 tonnes of produced magnesite, then there was a temporary decrease, but in 1916 it raised to 24,152 tonnes, and in following years it again lowered.

The Lubeník Chyžná Voda plant started to be constructed in 1906. It consisted of 6 double stool shaft furnaces, heated with generator gass. For further enrichment of the clinker, burnt in shaft furnaces the electromagnetic dressing was installed – and by this way the complexe technological chain for magnesite clinker production originated (Gulyás and Frák, 1986).

Exploitation and elaboration of the magnesite in 1919–1944

In August 1923 the first quarry of the post-war period was opened in the Ploské locality in the altitude 650 m. The deposit Lubeník Studená was known since 1927, but exploitation there started only in 1934. This deposit was the biggest and richest from the new deposits. The deposit was opened in 376 m altitude. Magnesite started to be exploited superficially and later also by underground mining.

In 1923 the new ropeway Ploské-Burda was constructed as well as another ropeway from Ružiná quarry to the Lovinobaňa plant. In 1924 the pneumatic hammer started to be used in the Dúbrava quarry, magnesite was exploited exhaustingly in the high quarry walls.

In 1919 the plant Lubeník Chyžná Voda started to work among the first ones of post-war period. In the same year the upper magnesite plant Hačava started to produce again. In 1925 it was neccessary to build the electromagnetic dust-collector due to the extreme pollution of the surrounding areas. In 1938 there were produced 3,314 tonnes of magnesite, in 1939 it raised to 6,717 tonnes and in 1941–1943 production did not decrease below 7,000 tonnes.

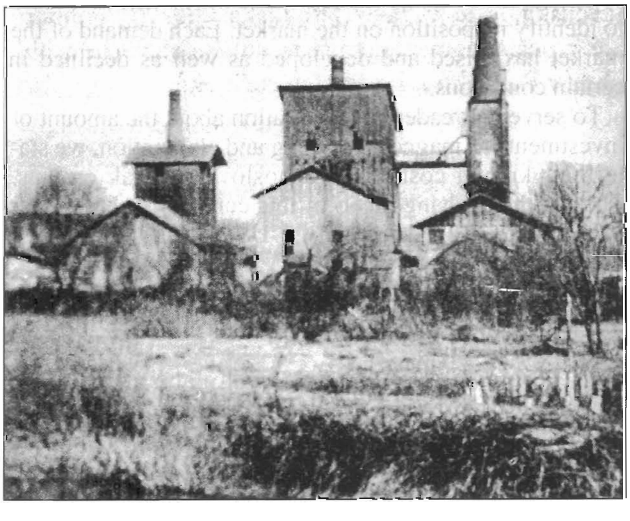

Fig. 2. First furnace for magnesite burring built in Jelšava in 1894. Taken from the book Slovak Magnesite Works, national enterprise, Košice.

The lower plant Hnúšťa started production in 1920. In 1923 there was decision to build a new plant in Lovinobaňa and later to move production of the burnt magnesite from the lower plant to new one. The lower plant in Hnúšťa in 1930 stopped to serve to its original purpose – elaboration of the magnesite and it was never renewed. Its production equipment (2 pressers, roler mixer, some elaboration machines) and also experts were transferred to the plant Lovinobaňa.

The old plant Jelšava Teplá Voda started to work again in 1922. In 1920 a new plant in Jelšava started to be built in the northwestern slope of the Kohútik hill. There were constructed 8 stool shaft furnaces, 2 generators for gass, dressing for electromagnetical separation of the burnt magnesite, 3 iron-cement silos to store the burnt magnesite and 12 small storage places for elaborated magnesite.

In 1923 a plant at Lovinobaňa started to be built. The plant at Lovinobaňa become the only plant in Slovakia with closed production cycle. Production of the burnt magnesite in 1939 presented 28,800 tonnes, in 1940–1943 it decreased to 24,712 tonnes. Demand for magnesite products was a reason of new investments. In 1942 the further shaft furnace started to be built, it was the ninth one (Markovič and Balog, 1967).

Exploitation and elaboration of magnesite in 1945–1948

The plant in Lovinobaňa was the biggest magnesite plant in Slovakia and also the only plant with a closed productional program. Reconstruction began in January 1945 and production started on 4 September 1945. In 1947 production of burnt magnesite reached the amount of 9,617 tonnes and in 1948 14,198 tonnes. The Lubeník (Studená) mine belonged to the Lovinobaňa plant and the quarry Mútnik belonged to the Hnúšťa – Likier plant, but it was not exploited.

After reconstruction the production in the Hačava rotary furnace started on 17 October 1945. The Hačava plant had the worst situation with raw material, therefore in 1946 there was prepared opening of the former magnesite quarry at Burda, having overflowed three horizons from 1919. The production in Hačava plant was 13,499 tonnes of burnt magnesite in 1947, and in 1948 it was 21,648 tonnes.

The plant in Jelšava began to work after the reconstruction. Its production reached 21,408 tonnes in 1947 and 34,811 tonnes of burnt magnesite in 1948.

After the national decree number 100/1945 and after the Ministry of Industry's promulgation about nationalization of individual entrepreneurial companies there was established the Slovak Magnesite Works (SMZ), national enterprise, with residence in Bratislava. It was established according promulgation of the Ministry of Industry in Praque from 7 March 1946, number 1127/1946. Activity of the SMZ enterprise was given by the ministry of industry through the promulgation about the national enterprise: "mining, elaboration, production, distribution of magnesite, dolomite, other materials, products, semiproducts, where the principal raw material is magnesite and also performance of other enterprises, that where connected with national enterprise." SMZ enterprise was subordinated to the central organ for industry of building materials and ceramics in Praque and also to the regional organ for industry of building materials and ceramics in Bratislava.

The national enterprise SMZ had at the moment of its origin the following plants and production capacities: production unit in Lovinobaňa with plants – Lovinobaňa, Ružiná, Kalinovo (with mines Jelačič a Poltár), production unit in Hačava with plants – Hačava, Ploské, Sirk, Hnúšťa, Ratkovská Suchá and production unit in Košice with plants – Košice and Košice mine, production unit in Jelšava with plants – Teplá Voda, Dúbrava, Lubeník and Ochtiná.

By establishing of the national enterprise SMZ all magnesite plants came under joint management. The strength of this economic unit was magnified by the fact that it included also plants for production of refractories.

In 1946 SMZ started the preparation of investments for a new plant that would produce the dinas building materials in Banská Belá. Construction of the Dinaska Banská Belá factory began in 1947 with costs 60 million crowns.

According to the law No. 114/1948 about nationalization of several other enterprises and plants, 14 objects were added to the SMZ. The deposit of magnesite in Košice, belonging to the Vietscher magnesitwerke A. g. in Wien, was nationalized in 1955, together with another one in the area of Podrečany in 1956. The majority of objects remained in SMZ, but some of them were separated, for example the plant Hnúšťa was added to the enterprise Rudné Bane Banská Bystrica (Gulyas and Frák, 1986; Markovič and Bulog, 1967).

Mining and elaboration of the magnesite in 1949–1970

In 1949–1970 magnesite was mined mainly superficially. For underground mining only one mining method was implemented – bank mining with gobbing. In 1953 for Ružiná, Dúbrava and Lubeník mines there was recommended mining methods with interhorizon gobbing, mining for stocks and mining with open chamber. At the Burda deposit the method of interhorizon gobbing was examined and 20 % higher performance was achieved. In 1961 the implementation of mining method with open chamber started in the Lubeník plant. Variant of this method was elaborated for Miková deposit and introduced in 1967–1968. By this method there were reached good results and the method was introduced also in Jelšava, Košice and later also in the Podrečany deposit.

The SMZ enterprise was reorganized in 1951–1952 and three individual enterprises were established. As the first of them, the enterprise Middle-Slovakian ceramics (SKZ) was established on 1 January 1951. National enterprise Banská Belá included the plants Banská Belá and Kalinovo. On 1 January 1952 the residence of the enterprise changed from Banská Belá to Kalinovo plant and the plant became to be principal one.

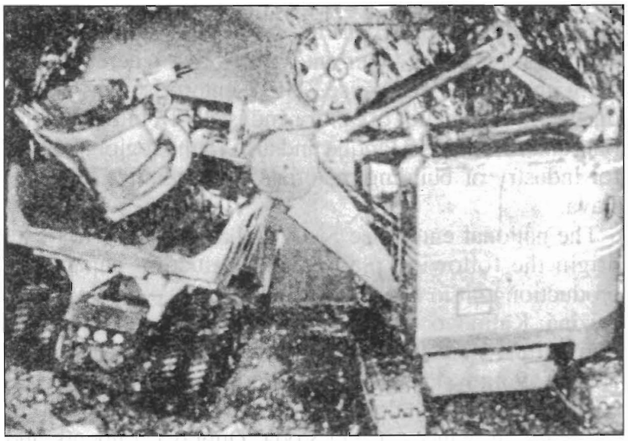

Fig. 3. Filler KL-260 in Mikivá mine Taken from the book Slovak Magnesite Works, national enterprise, Košice.

Fig. 4. Entry tunnel in altitude 450 – Miková with Kiruna transporter. Taken from the book Slovak Magnesite Works, national enterprise, Košice.

On 1 July 1952 the Magnesite mine and works (MHB), national enterprise, Jelšava was established, to which the plant Jelšava, Košice (old and new plant) and constructed plant in Lubeník were added. Residence of enterprise MHB was changed in 1953 from Jelšava to Lubeník and Lubeník plant became the base plant of the enterprise.

The SMZ enterprise did not change its residence and name. The plants Lovinobaňa and Hačava belonged to it, the principal one was Lovinobaňa. These three enterprises existed till 31 March 1958. After 1 April 1958 they were connected to one enterprise with former name SMZ, national enterprise in Lovinobaňa. At the same time residence of the enterprise changed to Košice. On 1 January 1962 there was added to SMZ an engineering plant at Kunová Teplica. This state was maintained till 1992.

In the period of 1949–1970 owing to the extensive investments for construction of the national enterprise SMZ, new plants were built and existing plants were reconstructed. This was period of *extensive development.*

In Jelšava plant the new shaft furnaces started to be built at the beginning of 1949. The shaft furnace No. 9 was constructed as first one with the cost of 2.8 million crowns. It reached production capacity of 5,000 tonnes of clinker in 1949–1950. In 1954–1955 the semiautomatic shaft furnace No. 10 was constructed in Jelšava with total cost 5.6 million crowns and production capacity 12,000 tonnes of clinker. It was the test furnace with mechanical transport of the burnt clinker. At the same time there was constructed the mechanical coke shaft furnace No. 11 for the burning of basisfrit, with cost of 4.6 million crowns and capacity of 12,000 tonnes. In 1959 the semiautomatic shaft furnace No. 12 was constructed in Jelšava with capacity 7,500 tonnes of clinker with cost 1.2 million crowns. It had an advantage, since burnt clinker was transported from the furnace by a moving cylindrical grid directly to the railway wagons without help of men. Construction of the furnace demanded extension of the generator station and boiler service, that started to work together with the furnace. The shaft furnace No. 13 with cost of 5.3 million crowns started to be built in 1956. Production started at the end of 1967. In 1972 it was reconstructed for heating by natural gass and used for burning of pieces of magnesite.

Big investments in construction of the Jelšava plant began in 1960. It was series of big buildings – mine Dúbrava, Miková, three big rotary furnaces and auxiliary objects. The construction of the Dúbrava mine provided materials for shaft furnaces, while Miková mine was prepared for mining. After several considerations about the way of mining, it was decided to mine the deposit using the underground method with planned capacity of exploitation of 590,000 tonnes. The construction that costed 112.3 million crowns was made simultaneously with production in 1962–1971.

Obtaining of magnesite for old shaft furnaces as well as for building of the high performance rotary furnaces de-

Tab. 1

Development of the mining and production (Augustínová, 2000)

Product	1948	1955	1960	1965	1970
Mining of ore (t)	230.7	410.7	1,142.7	1,840.8	2,929.5
Production of the clinker (t)	109.1	191.4	328.5	484.4	631.2
Production of alkaline building material (t)	26.1	38.7	117.0	164.7	208.5
Production of chamotte (t) building material	6.5	13.8	27.7	31.5	29.2
Production of dinas building material (t)	–	13.5	25.0	31.5	28.4
Gross production (million crowns)	69.1	189.0	310.9	408.4	842.7

manded quick realization of next investment – the opening of Miková mine. The decision followed after successful finishing of the geological research in 1961–1963, when calculation of reserves proved, that it would be the biggest deposit in Slovakia.

Construction of the new plant in Lubeník (LuNZ) began in 1951 near the quarry Studená. It was projected for production of the magnesite building materials. The major target of the construction, consisting of 45 objects, was press service containing 11 pressers, then there were finished 2 tunnel furnaces, both with capacity 22,500 tonnes of burnt building materials. Production in the new plant began in 1956 with elaboration of clinker transported from Jelšava and Hačava plants. Lubeník plant had its own raw materials basis and already in 1954–1955 the construction of the clinker technological link called LuNZII started to be prepared. Construction began in 1956 with the cost of 37.9 million crowns and capacity of 44,000 tonnes of clinker.

At the Hačava plant in 1950, the construction of the rotary furnace No. 2 began with costs of 3.5 million crowns and production capacity of 24,000 tonnes of clinker. It was implemented to the service in 1951 and reached projected capacity in 1953 after extension of the capacity of the coal mill service (Rudášová, 1999).

Development of the mining and production of the SMZ in 1948–1970 is presented in Tab. 1.

Mining and elaboration of the magnesite in 1971–1985

The years of 1971–1975 represented a period of *intensive development*. Investments were used for modernization of the production, for innovation, with emphasis on production quality, saving of fuel, metal and energy.

Raw material in Jelšava and Lubeník plants has been obtained by mining with open chamber, bank mining, liquidation of the pillars and from preparation works. In Lovinobaňa (Podrečany) plant mining has been done to 90 m altitude by open chamber and in lower parts by bank mining. At the Burda-Poproč deposit at the 3th and 5th horizons there was used bank mining with gobbing.

In plant Jelšava an intention to elaborate emission, caught during the rotary furnace services as a material of high quality, caused in 1972–1978 building of the Mill and bricket services with budgeted cost of 52.4 million crowns. Atypical facilities for magnesite industry were firstly used in this construction, that later demanded various improvements. Liquidation of the exhalations was constructed in 1979–1984 with cost of 108.2 million crowns and with capacity of 120,000 tonnes of reductions. Construction had two main parts. Firstly the rotary and shaft furnaces were reconstructed for the use of gass. By this way there originated a double-fuel system (natural gass and mazut) in 1981. Secondly the antidust problem of the rotary furnaces was solved by building of the fibre filtre. Caught emissions were elaborated to brickets. Construction "Opening of the deposit Miková", realized in 1981–1985 with cost of 131.1 million crowns, secured extension of the mining capacity of the deposit Miková by the new horizon at 400 m altitude.

Opening of the mine Lubeník below the 4th horizon in 1972–1980 with cost of 55.1 million crowns secured reproduction of the mining in Lubeník mine. Antidust process of the shaft furnaces in Lubeník was firstly not very effective. Reducing dust from the rotary furnaces costed 20.4 million crowns and started in 1975 with the construction of the antidust equipment *Amertherm*. In the enterprise there were not proper technological conditions for burning of the complicated and big shaped products. Therefore in 1971–1972 the construction of "Flap furnace" was prepared, being realized in 1973–1974 with cost of 10.4 million crowns, in the frame of which there was constructed the *Bickely* flap furnace with capacity of 3,000 tonnes of building materials. It served for burning

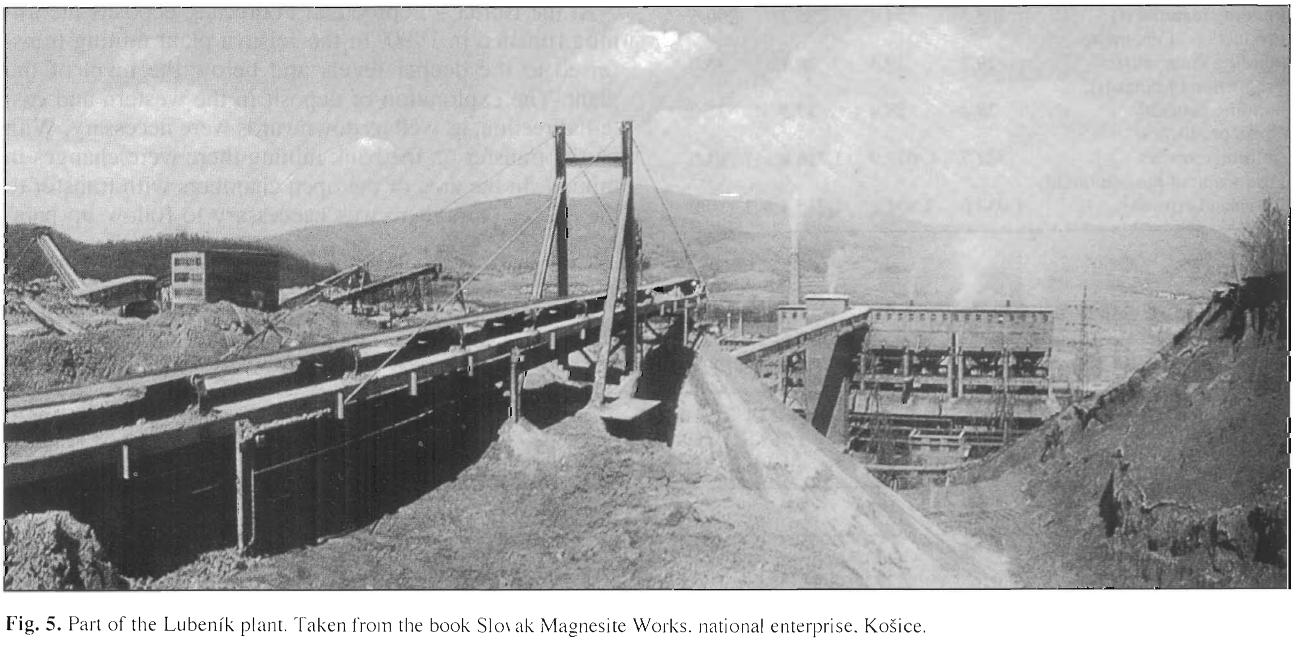

Fig. 5. Part of the Lubeník plant. Taken from the book Slovak Magnesite Works, national enterprise, Košice.

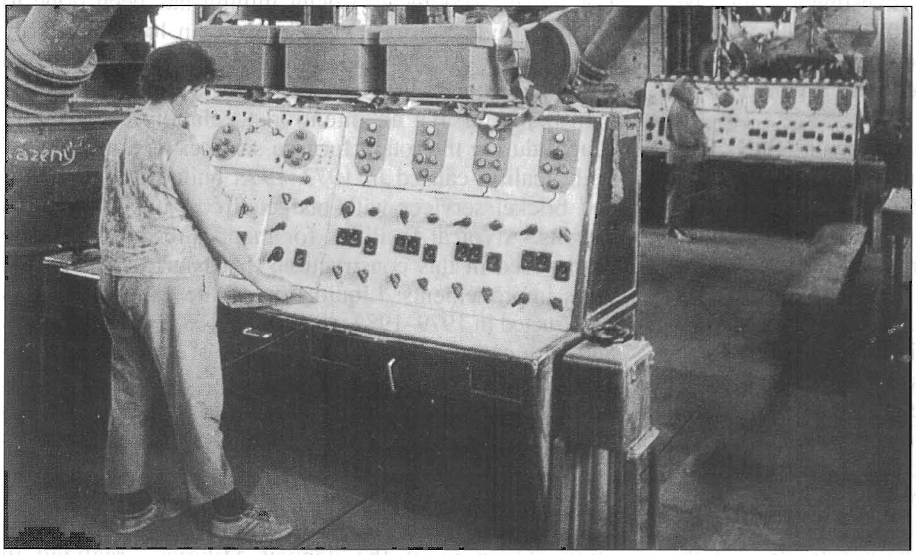

Fig. 6. One of workstations in Lovinobaňa plant. Taken from the book Slovak Magnesite Works, national enterprise, Košice.

of the basic building materials and shaped products of large dimensions, for products of uncommon shapes according to technological mode for ceramics.

Government in resolution No. 2 from 12 January 1984 approved the obligatory task of the development for 1985–1989 in plant Hačava named "Production of the clinker without iron" with the cost of 837 million crowns.

Tab. 2
Development of the mining and production in SMZ during 1970–1985 (Gulyas and Frák, 1986)

Product	1970	1975	1980	1985
Mining of ore (t)	2,929.5	2,864.8	3,069.4	3,080.0
Production of the clinker (t)	631.2	657.7	661.6	657.0
Production of alkaline building material (t)	208.5	254.4	285.3	290.5
Production of chamotte building material(t)	29.2	29.3	28.1	25.0
Production of dinas (t) building material	28.4	28.4	27.5	22.0
Gross production (million crowns)	842.7	1, 011.9	1.716.8	1.783.0
Production of the commodity (thousand crowns)	1,034.6	1,402.1	1,715.4	2,210.0

Mining and elaboration of the magnezite from 1986

Slovakia is ranked in the first place in Europe concerning geological reserves of magnesite, and in fourth place in the world. From the perspective of 2000, according to the volume of the mining stocks, the most important deposits are – Dúbrava massif, Jelšava, Košice – Bankov and Lubeník. Magnesite industry focussed its intentions during the development to the more effective use of the ore, for concentration of exploitation in individual deposits, that secured capacity of the production with raw material. Former mining and elaboration of the magnesite were more or less unilaterally orientated to the mass production, that coresponded to the demand of the consumers in domestic and also foreign markets. Tables 4 and 5 show development of the mining and production of the concentrates.

At the Burda – Poproč and Podrečany deposits the mining finished in 1990. In the Jelšava plant mining transferred to the deeper levels and below the level of the plant. The exploration of deposit in the western and eastern direction, as well as downwards were necessary. With partial transfer on the bank mining there were changes in mining. In the area of the open chambers with transfer to the deeper parts there was neccessary to follow up para-

Tab. 3
Development of decisive indexes of SMZ enterprise in 1971–1984 (in million crowns)

index	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
profit	67.1	95.5	152.3	322.1	311.3	425.4	255.3	237.7	267.8	262.8	185.8
yield	1,190.2	1,269.5	1.257.7	1.362.8	1.483.7	1.602	1.662	1.683.8	1.707.4	1.771.4	1.928.6
cost	1,131.5	1,185.4	1.123.7	1.154	1.191.4	1.178	1.407.8	1.426.7	1.439.7	1,508.9	1.744

index	1982	1983	1984
profit	114.1	88	133.7
yield	1,997.2	2,016.7	2,274.9
cost	1,884.2	1.929.7	2,141.2

Tab. 4
Mining of the magnesite ore (%)

Plant	1985	1990	1995	2000
Hačava	4.0	–	–	–
Jelšava	51.1	55.3	64.8	62.4
Lovinobaňa	7.5	8.0	–	–
Lubeník	18.7	18.6	19.3	20.6

Tab. 5
Production of the concentrate (%)

Plant	1985	1990	1995	2000
Hačava	6	–	–	–
Jelšava	46.3	49.5	61.3	58.6
Lovinobaňa	10	11.4	–	–
Lubeník	18.1	20.4	22.4	24

metres of the mining and of the pillar system, as well as of the overlying massif. In Lubeník there was verified continuation of the deposit downwards at the eastern and western parts.

The deposit according present exploration losses its thickness and changes its dip. It affects technology of the mining. From the new facility for production of the ironless clinker, built in Hačava in 1985–1989 with the cost of 837 million crowns, it should be obtained the capacity of 26,000 tonnes in 1990, but in reality it was obtained only 13,000 tonnes. Finalization of the ironless clinkers production from Hačava would be realized by new facility for Special Ceramics Service in Lovinobaňa in 1986–1990 with capacity 35,800 tonnes of building materials. In 1990 the capacity was 13,000 tonnes of the new types of the basic building materials and 2,500 tonnes of the basic monolithic materials.

In 1987–1998 the new shaft furnace No. 1 in Jelšava was built with capacity 45,000 tonnes of brick clinker. In 1995 in Jelšava construction of the new shaft furnace No. 2 was realized with capacity of 45,000 tonnes of clinker of spinelitical type. The opening of the mine Miková below level 323 m, planned for 1992–1997, due to the various reasons was not realized. Also opening of the deposit Lubeník below 9th horizon in period of 1991–1995 was not accomplished. These activities had to guarantee the development activities of the Slovak magnesite plant. As a consequence of the changes in 1989 there was transformation of the enterprise to the state enterprise and consequently the enterprise was closed in 1 January 1993. The enterprise was separated to 8 individual enterprises (Košice, Banská Belá, Hačava, Jelšava, Kalinovo, Lubeník, Lovinobaňa, Kunová Teplica). From these enterprises individual companies were established – Košice magnesite, state enterprise, Slovmag, joint stock company (a. s.), Lubeník, Magnatech Slovakia, Ltd., Hačava, Lovinit, joint stock company (a. s.), Lovinobaňa and SMZ, joint stock company (a. s.), Jelšava. New subjects had to orientate to the new situations. The situation on the markets of refractory material demanded a change in supply, that needed also to increase in a very decisive way the quality of the produced sortiment and to extend the supply with new materials and products on the market.

Conclusion

Presented paper deals with mining and elaboration of the magnesite according to historical periods. It also demonstrates the development of the magnesite elaboration from the viewpoint of available technical equipment. At the same time it describes the development of the magnesite industry from its beginning to the present time.

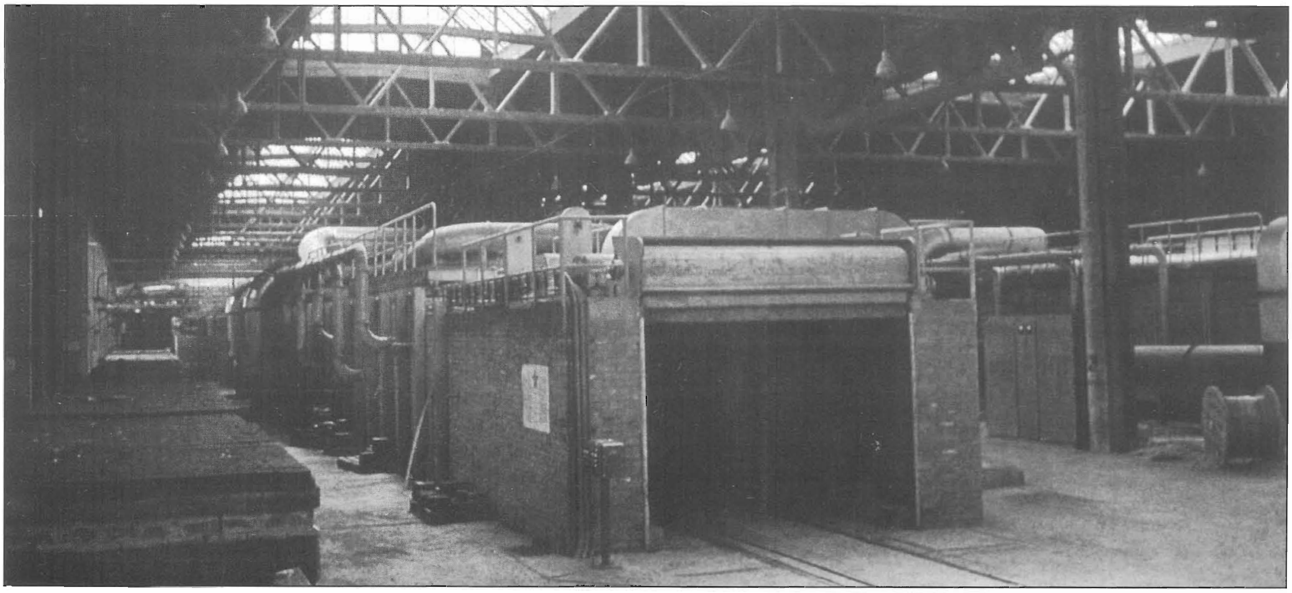

Fig. 7. Tunnel furnaces in Lubeník plant. Taken from the book Slovak Magnesite Works, national enterprise, Košice.

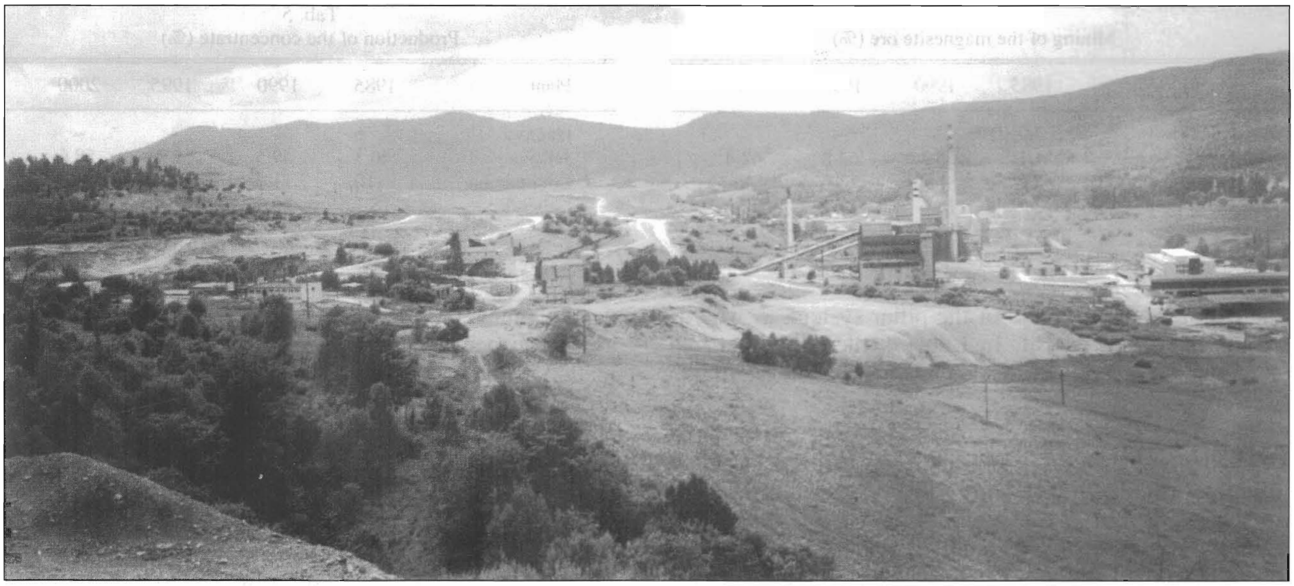

Fig. 8. Slovak Magnesite Works (SMZ, a. s.), joint stock company, Jelšava. Taken from Annual report 1999 of SMZ, a. s., Jelšava.

Presented article can serve together with the title "Historical development of the magnezite plant in Košice" as a tool for obtaining basic and brief information about the development of mining and elaboration of magnesite in Slovakia as well as about history of the magnesite industry.

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Historical development of the magnesite plant in Košice

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Abstract

Beginnings of magnesite mining in Košice are dated back to 1901. Construction of the magnesite plant began in 1909 with support from the German-Hungary magnesite company. The plant had two shaft furnaces and electromagnetic separation. The furnaces were heated by oil. A mill for crushing of burnt magnesite was a part of the plant, too. The plant was connected to a railway station by railway feeder. Raw magnesite was transported from Bankov through the city by horse carriages. The production was 17–18 kilotonnes of burnt magnesite per year.

Despite several changes in ownership – Dr Weiser and Bayern, magnesite company Hercules plants, and West Czech clay and chamotte plants in Praque, construction began in all three parts, the Bankov, Banisko and Medvedza deposits, in concord with decision about the plant extension. In 1955 there was a decision to build in the vicinity of the new shaft furnaces in Ťahanovce village two and then additional two rotary furnaces with capacity 120.000 tonnes of clinker per year. Electrical excavator (2.5 m^3) as well as truck cars (with capacity 11 t and 25 t) were used for mining of raw material and recovering of the rubbish. Gravity treating service was constructed for 400–533 kilotonnes of raw material. A new technology appeared for production of the flotation magnesite and its heating elaboration in shaft furnace in Bočiar. Antidust protection for heating elaboration in Ťahanovce plant was constructed in 1981–1984 by applying of the fibre filter technology.

Later problems in plant existence were solved by the change of ownership from state to KOMAG firm (VSŽ Košice and VÚB bank) and next to the SMZ Jelšava, joint stock company and TELESERVIS, Ltd. in Bratislava. The title of the firm was changed to SMZ Jelšava, Division plant Bočiar.

Tradition, quality of raw material, quality of technological discipline and abilities of production managers, as well as flexibility of the employees are and will be useful for new owner of the plant and will secure its future perspective existence.

Key words: magnesite exploitation, magnesite elaboration, historical development

Introduction

Subjective abilities of the producer together with technical and technological equipment and with the objective conditions of the deposits of profitable raw material in Košice are the reason of long-term existence and effectiveness of the mining, elaboration, heating and granulometrical treatments of the clinkers, including the implementation of the separators for magnesite emissions and its elaboration in the mill and following briquetation and burning process to the clinker.

To serve the reader an information about the amount of investments to magnesite mining and elaboration, we state their known costs in Czechoslovak/Slovak crowns. Though the exchange ratio of this currency to US Dollar in the past changed, recently 47 Slovak crowns are an approximate equivalent to 1 USD.

The old plant in Košice

Magnesite mining in Košice began in 1901, when the town council allowed Mr. Frigyes Bródy to open the Bankov deposit by the agreement from 29 March. Construction of the magnesite plant began in 1909 with the support of the German-Hungary magnesite company. Production began in 1911. The old plant consisted of two shaft furnaces with electromagnetic separation. The first shaft furnace began to work in January 1911, the second furnace three years later. The furnaces were the only ones heated by oil in Slovakia. The plant had also a mill for the crushing of burnt magnesite. The plant was connected to a railway station by railway feeder. Raw magnesite from Bankov was transported through the city by horse carriages from the former Kalvary street to the plant. The Košice plant elaborated material from the so-called "main" locality of the Bankov hill (today it is Medvedza). Production presented 17–18 kilotonnes of the burnt magnesite per year.

After beginning of 1st World War the Košice plant fell to the financial difficulties and then to bankruptcy. During the war the plant did not produce. After the war in 1919 domestic businessmen Dr. Weiser and Bayern purchased the plant (Košice plant and its "main" locality at Bankov), and they established a new company "Herkules plants". Reconstruction of the Košice plant was realized in 1920–1921. There were performed general repairs of two shaft furnaces and other technological equipment. Naphtha was used again as a fuel. The plant reached full production capacity in 1925. Share capital of the Herkules plants was increased by the entering of the firm Mining and metallurgical company, joint stock company Brno. The plant yet had a loss in 1926, and only from 1927 it showed production growth.

In 1928 the West-Czech plant of kaolin and chamotte in Praque purchased the Košice plant. That brought more intensive mining in the "eastern" locality, today called Medvedza. At the south-eastern part of the former quarry a mine adit was built for exploitation of the so-called iron magnesite, that served for production of the special clinker, being exported mainly to France. From 1928 pneumatic hammers started to be used in quarry. In 1930 a compressor was installed and later a second compressor and third in 1934. To the inventory of the plant belonged also 15 drilling hammers, 1 drilling machine, 1 machine for drill sharpening, and 2 air cisterns. Company has been looking for a way to reduce the expenses of the service in the Košice plant and a possible way how to decrease the costs for heating of the shaft furnaces. Therefore from 1932 the shaft furnaces in Košice magnesite plant were heated by the cheaper brown coal tar. In the same year there was installed one stationary steam boiler. In 1935 the machinery service was constructed with installed shed for the plant locomotive, stock piles, the forging service and one administrative office. Two years later in the plant a new stock for three cisterns of the liquid fuel and a new steam boiler was installed. In 1937 the plant had been connected with the city sewage system. The transport of raw material from the quarry to the shaft furnaces was very complicated. Raw material was transported from the quarry wall and from the mine adit by mining wagons to the separation service, where magnesite was separated manually from waste rocks using visual control. Then the industrial narrow-gauge railway with petrol locomotives transported material to the shoots and then by horse carriage through the city to the dressing plant. Due to the linking of Košice to Hungary after Wien arbitrage in 1938 the plant received a new name – Košice magnesite plants, and became the branch of the West-Czech company. There are not preserved any records about magnesite mining that time. After 1941 the plant had been submitted to the army's supervision. The objects of the plant were destroyed, the quarry overflowed with water and for several months it did not work. By the resolution of the Slovak National Council, the Košice plant, being one of the first industrial plants in Slovakia, was given under the forced administration. Electric power was the key problem, therefore everything was concentrated on the reparation of the electric power station. In April 1945 the electric power station was already working and water from the quarry started to be drawn off. Works continued very quickly, so the beginning of the magnesite mining in Bankov was in June 1945. An important acceleration in the process of the reconstruction was after the ending of the war in May 1945, when from Horní Bříza all equipments and machinery returned to the Košice plant and they were quickly installed. That enabled the first shaft furnace to burn in august 1945 and second one in 1 January 1946. After the beginning of the service the main mine adit Vavro was excavated from Bankov to the Banisko deposit and already in 1945 there started mining. The Košice plant, concerning technical facilities, was the most stagnant from all plants in Slovakia producing cohesionless materials. Therefore reconstruction of the plant was necessary, but it did not happen. In 1946 the old plant was gradually put out of function (it hindered the construction of the city) and a new plant started to be built at the new locality – Ťahanovce (Rudášová, 1997; Gulyás et al., 1986).

Košice new plant

Construction of the new plant in Košice began in 1947. In 1948 the shaft furnaces and other objects were constructed. These three modern two-sided shaft furnaces of the type "Veitsch" represented the newest type used in Austria. At the same time the ropeway was constructed from Bankov to the new plant and raw material was not longer transported by trucks. In 5 May 1951 the reduced production facilities were tested, the projected capacity of the furnaces of 23,000 tonnes was reached in 1952, with the output of 23,165 tonnes.

Simultaneously with the plant's construction the extensive geological researches were performed at all three magnesite deposits (Bankov, Banisko, Medvedza). These confirmed the perspective magnesite reserves. According this fact the plant started to be extended. Moreover, the raw material from the Košice locality consisted of the magnesite type with medium content of iron, siliceous and low-calcareous, being used for production of the most qualitative basic building materials. In 1955 two rotary furnaces Nos. 1 and 2 with diameter 2.6 m, length 22 m and annual capacity for 60,000 tonnes of clinker were constructed in Ťahanovce with the cost of 35.2 million crowns. The produced clinker should be elaborated in the existing magnetic dressing service, that was constructed for the shaft furnaces. Technological fuel of the rotary furnaces was black dust coal, that was prepared in three Fuller's mills. Electrostatic filters were used for antidust protection, and Fuller's coolers for cooling of the clinker. Smoke gases driven to electrostatic filter were cooled in long cooling pipeline and antistream scrubbers were installed in front of the filters. The facility had 21 parts, but the question of removal of dust, caugtht in electrostatic filters has not been solved. The first rotary furnace with minimal complex was introduced to the service in 16 March 1960, second furnace in 14 April 1960.

To supply the rotary furnaces with raw material, in the period from 1957 to 1966, the magnesite quarry was upgraded for capacity 250,000 tonnes of the raw material with investments of 32.3 million crowns. Because exploitation of the magnesite as well as waste rocks would be done by the electric excavators, the transformation station and communications were set up firstly. Gravity dre-

Fig. 1. Open-pit mine Bankov at Košice. Taken from the book Slovak Magnesite Works, national enterprise, Košice

ssing service with capacity of 200–250 kilotonnes of the raw material would be constructed together with the mine. The dressing service built at the western part of the former quarry would supply two new rotary furnaces with concentrate. For the shaft furnaces the pieces of magnesite would henceforth be separated by hand and they would be transported to the old and to the new plants by trucks. Before the beginning of the construction of the gravity dressing service a principal change occurred in the end of 1957. It was decided to build other rotary furnaces Nos. 3 and 4 with cost 65.5 million crowns and capacity for 70,000 tonnes of clinker in 1959–1967. This solution caused preparation of new dressing equipment, the gravity dressing service with capacity for 533 kilotonnes of batch, while fraction 3–60 mm would be elaborated in heavy liquid. This solution required to build crushing and separating link with capacity 700–850 kilotonnes.

The construction of the rotary furnace Nos. 3 and 4 began in January 1959. Construction was divided into three periods. The first period included construction of the rotary

Fig. 2. Machineman on drilling facility Uralec in Bankov open pit mine. Taken from the book Slovak Magnesite Works, national enterprise, Košice

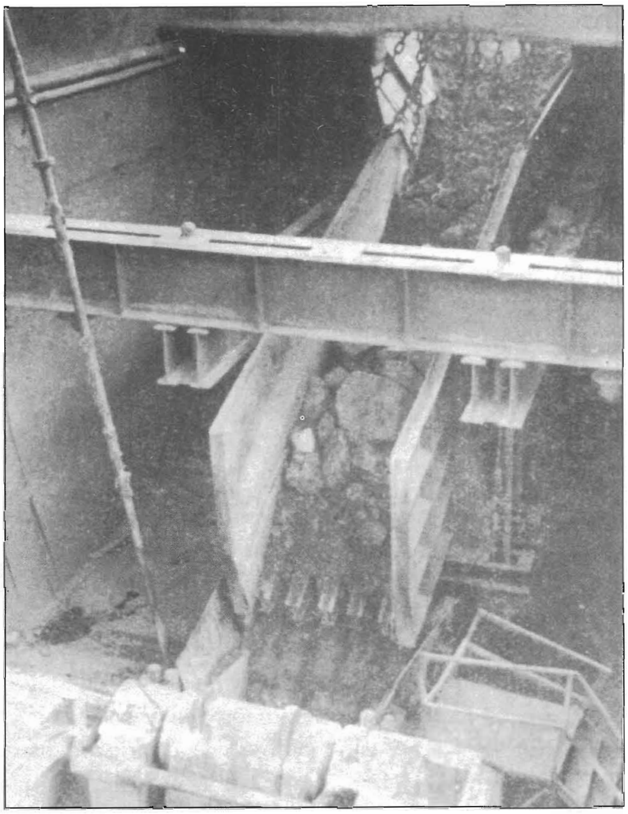

Fig. 3. Grating feeder in Bankov open pit mine. Taken from the book Slovak Magnesite Works, national enterprise, Košice

furnaces, their loading, antidusting, oil economy, electromagnetic separation, and transformation station with cable distribution, together with the reconstruction of some other objects – ropeway, boiler station, railway feeder, garage, road. The second period consisted of the concentration and removal of the dust from the electrostatic filter dust chambers by pneumatic transport to the stacker. Then the caught dust was transported by highpress pneumatic transport to the provisory stocks at the river Hornád, where it was stocked and drenched. This period finished in January 1967 and during its construction the rotary furnaces Nos. 3 and 4 had problems witch concentration and removal of the dust. During the third period of the plant construction the problem of the dust emissions was solved by the way of balling. The semi-operation balling link was constructed for verification of the technology. In the third period of the construction a definitive balling link was equipped with three balling plates with diameter 4.2 m in April 1967. Neither clinker, obtained from the balling procedure, nor clinker obtained by the direct dust burning reached required volume weight (instead of 3 g/cm^3 it was only 2 g/cm^3). Therefore it was again necessary to solve the problem of dust removal from the clinker link by constructing two electrostatic vertical filters. Construction began in 1961 and was finished in 1966.

After the powerful clinker service had started to operate, but the mining service was not able to supply sufficiently rotary furnaces with newly exploited magnesite. Therefore in 1961–1962 there were solved the questions of the enlargement of superficial mining and pumping water from the quarry, of interplant handling, reconstruction of the magnesite manual separation, of dressing and other questions.

A complex investment for beginning of the underground mining was divided into three individual constructions. During the first period with the cost of 52.3 million crowns the shaft with drawing machine was deepened. In the second period with the investment of 90.4 million crowns the horizontal workings were mined and in the third period superficial objects were constructed with the most important flotation dressing service having capacity for 101,500 tonnes of the flotation concentrate per year. The opening of the Medvedza deposit in 1978–1981 with the cost of 54.9 million crowns had to guarantee reproducibility of the magnesite mining in the horizon 50 m above sea level. Dust removal from the rotary furnaces, constructed in 1971–1972 with the cost of 101.1 million crowns and capacity for 10,000 tonnes of the emissions, was not sufficiently effective. In 1976–1980 a new project "Dust removal from the plant" was prepared and in 1981–1985 the fibre filters were added. In January 1978 the plant in Ťahanovce terminated its function (Rudášová, 1997). In 1981–1984 the transfer of clinker service from the area of Ťahanovce for new locality Bočiar was planned. Building of dressing plant in Košice – Bočiar together with enlargement of former mine was accredited by the Ministry on 10 May 1984 as a centralized construction. It should be finished in 1985–1989 with the cost of 574.4 million crowns. The capacity of the clinker service was 50,000 tonnes of the flotated clinker. Finalization of the clinker to basic building materials should be done in Lubeník and in Lovinobaňa. By this construction the heating service of the Košice plant has been gradually transferred from Ťahanovce to the Bočiar area. Continually the next enlargement of the magnesite mine as well as dressing service Košice – Bočiar II were successfully constructed in 1986–1990 with total transferring of the heating service from Ťahanovce, where production activity finished. Construction consisted from the extension of the flotation dressing service and expansion of the capacity for the other 50,000 tonnes of the clinker in Bočiar with the cost of 584.4 million crowns. Realization of this expansion of production capacity in Košice plant should be extended to 410,000 tonnes, production of the flotate concentrate to 203,000 tonnes, production of the flotate clinker to 100,000 tonnes. The beginning of the construction was interrupted, that means additional increasing of the investment costs, increasing of the foreign exchange liabilities and loss in the performance for the second period in total volume of 246 million crowns. Financing of the construction would be covered from their own sources and from bank credit, but the firm did not have its own financial means. Therefore construction stopped due to the financial difficulties from November 1992 to November 1996 (Bandurová, 2000; Gulyás et al., 1986; Rudášová, 1997).

Košický Magnesit, state enterprise, Košice

Košický Magnesit, Košice state enterprise, was established in 1 January 1993 as a successor of the former Košice Slovak Magnesite Works. It consisted of two plants named Mining activities and Production plant of the cohesionless materials. It was located in three areas. In the first locality – the Mining activities plant, were concentrated underground mining, elaboration of the ores for rotary furnaces, flotation dressing service and service workstations. The second locality, Production plant of the cohesionless materials in Ťahanovce, secured work of rotary furnaces, elaboration, briquets production and service workstations. The third locality, plant in Bočiar, suplied calcination process, mill service, briquet service, shaft furnace, dressing service and service workstations.

The deposit in Košice, being the second biggest deposit in Slovakia, belongs, according to quality of magnesite, to the first place. The mining space of the deposit is 353.1 ha total. The carbonate bodies of the Košice deposit are located in three deposit parts – Bankov, Banisko and Medvedza. (Geological setting with map and cross-section is available in contribution by Grecula et al., 2000, published in IGCP 443 Introductory Newsletter.) According to the content of CaO and SiO_2, that influences technological characteristics of the magnesite material, there are presented magnesite reserves of the silicium and calcium types. The amount of geological balance free reserves to the level of the 6th horizon is 25,659 kilotonnes. Volume of the possibly exploitable stocks is 8,426 kilotonnes. During exploitation of the deposit the following mining methods were used: mining with open chamber from inter-horizon adits with use of drills of medium-length and bench mining with stowing of the mining space.

After exploitation and transport to the surface, the ores proceed to the magnesite dressing plant. Elaboration consists of a gross crushing process, middle crushing process, hydrocyclone link, static link and flotation link. Material with granularity between 0 and 0.2 mm is transported on already elaborated clinker. Products of this elaboration are brick and steel clinkers of various granularities and of various qualities, then powder and material for maintenance. Producted brick clinker consists of SiO_2 = 3.0–5.0 %, CaO = 1.7–2.5 %, steel clinker with SiO_2 = 3.5–6.0 %, CaO = 4.0–5.0 %. Caustic magnesite is produced with granularity between 0 and 0.5 mm, 0.5 and 2 mm, 0 and 2 mm, according to the level of caustification in quality of the aktimag type K, KA, KF.

KOMAG, joint stock company, Košice

The joint stock company KOMAG, Košice, was established on 1 January 1996. It became the new owner of the Košice magnesite plant and immediately started its own activity. KOMAG company, Košice, received Košický Magnesit, the state enterprise, from the Ministry of the Industry in Slovakia for symbolic 4 Slovak crowns. It did not receive the liabilities of the former state enterprise. VSŽ, joint stock company in Košice is owner of 49 % of the equity of the magnesite company, further 49 % is in the hands of the Bank VÚB, Bratislava, and rest 2 % are owned by company Ferrimex. Basic equity of the company presents 100 million crowns.

The main tasks of the new company were to maintain mining and elaboration of the magnesite in Košice, to finish the elaboration plant in Bočiar and to decrease ecological pollution on the Košice city, continually to begin production of the projected capacities and to maintain, and later to increase, employment in the region. The plan for the 1997 production presented 60,000 tonnes of raw material. Plan for production of clinker and caustic magnesite presented 15,500 tonnes. KOMAG company is planning to increase production in the next years to 300 kt and production of the magnesite to 70,000 tonnes per year. Beginning of the production was planned for the second half of 1997 after finishing of the furnace aggregates in Bočiar. At the same time there were running reparations of the vertical and horizontal transports, as well as the crusher and dressing services. The aim of the company in the mentioned period was: to finish flotation facility in the mine, finish engineering net in Bočiar, as well as calcination, shaft furnace and dressing service. Magnesite is main entering raw material. Aside from the traditional caustic burnt magnesite, classical and flotated clinker and matter, a new product – FLOTMAG (flotated clinker) – spinellitical clinker with characteristics of the flotmag started to be produced in Bočiar. Also there were plans to extend the sortiment of the production of basic refractory monolithic materials using new types of clinkers. During the next extension of heat processing in Bočiar plant the use of magnesite raw material for refractories is planned.

The Bočiar dressing plant was finished and installed for permanent service in 1997. The production link began with stocking the flotation concentrate in banks 4 x 550 m^3, calcination with performance of 7 t/h, drilling in mills and it finished with the burning in the shaft furnace with projected output of 7t/h of clinker. Magnesite clinkers have granularity elaborated in dressing service that enables in two individual links crushing, separation, and stocking according to fraction and expedition. Each elaboration link enables to fulfil the capacity of the shaft furnace. Maintenance service of the plant is situated in the area with the possibility to extend directly any given object with minimal influence to the other projected objects. Total area of the dressing plant is 14.7 ha. The reached parameters during service in 1998 did not reach the projected ones mainly in performance of the shaft furnace, that reached maximum 3.5 t/h, next in the norm consumption of the heat as well as clinker quality, which was affected mainly by quality of the entering raw material.

Business activities of the company in 1998 were focussed to 6 main areas:

1. sale of the caustic magnesite
2. sale of the flotate magnesite clinker
3. sale of the briquet clinker
4. sale of the refractory materials
5. sale of the magnesite sand
6. services

Gradually the building of the following services was finished, including individual and complex testing: the elaboration plant in Bočiar, flotation in Bankov mine, shaft furnace and calcination. In February 1998 was built whole technological unit. In December 1998 the pilot testing of the whole link finished. Running and improvement of all activities were in great measure influenced by the unfavourable financial situation, and late influx of credit sources. Therefore the company fell to the paying disability. Such unsuccess during securing of the financial sources forced the company to stop the production in 1 January 1999. In 7 May 1999 company applied for bankruptcy. Bankruptcy for KOMAG, joint stock company Košice, has been declared by the Regional Court in Košice in 26 June 1999.

In 15 January 2001 at the Regional Court in Košice the envelopes with price suggestions were opened and in 23 January 2001 the Court declared covenant of the sale (to 15 days) with two subjects. They were presented with company SMZ, joint stock company, Jelšava and Teleservis, Ltd. Bratislava. Change of the firm's owner brought also the change of the name from the Košice production plant to the Bočiar Division plant, SMZ Jelšava (Augustínová, 2000; Rudášová, 1997).

Conclusion

The magnesite plant in Košice is working and producing. It will be surely successful owing to magnesite need in Europe as well as in the world. Tradition, quality of the raw material, quality of the technological discipline and abilities of the managers and technologists in the production, as well as the flexibility of all employees in magnesite deposit and plant at Košice are well known. They are and also will be useful for the new owner, the SMZ Jelšava.

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Chlorite-talc mineralizations in central Sardinia, Italy

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Abstract

The discovery of important albitite deposits near the already known talc-chlorite deposits in Central Sardinia (Italy) reopened the discussion about the genesis of these deposits. In fact it was commonly agreed that Mg had been supplied by limestones, even though these rocks are not abundant in this area. However, taking into account the volume of albitized rocks, their mean Mg content and the distribution of the newly formed silicates, it appears that the Mg displaced by Na-metasomatism could produce the assessed quantity of Mg-silicates.

Key words: albite-chlorite-talc, metasomatism, Paleozoic, Sardinia

Introduction

In the mining district of Barbagia (Central Sardinia, Italy), dominated by Hercynian granitoids and their Paleozoic roof-pendants partially covered by Tertiary volcanics, several Na-feldspar deposits and talc-chlorite deposits occur along a NE–SW strip (Fig. 1).

The earliest record about exploration activity on talc-chlorite bodies dates back to 1915, and concerns the area of Sa Matta. Mining activity reached its complete development in the 1930s. All really important properties gradually passed in the hands of two companies, Valchisone and SOIM.

The peak of activity was reached in the fifties and sixties, with an overall manpower exceeding 200 units. The products were talc (also of cosmetic grade) and chlorite. The mean output from each mine was in order of a few thousands of tonnes per year, with a maximum of about 25,000 tonnes at Sa Matta (talc-chlorite) (Fig. 2).

Valchisone continued operating up to 1989, when stopped its activity and released its mines for Ente Minerario Sardo (E.M.Sa.). In 1995 the German company Hoechst acquired 70 % share of the E.M.Sa Company Talco Sardinia, then in 1997 released this share for the Luzenac group, which is today the only owner.

The later discovered Na-feldspar deposits are mined since 1986 (Bornioli et al., 1996); their overall annual production is about 150,000 tonnes of material grading 6–7 wt. % Na_2O (Fig. 3). This last discovery reopened the debate about the genesis of the deposits (Garbarino et al., 1993; Fiori et al., 1993; Fiori et al., 1994).

Geological setting

The area is dominated by Hercynian granitoids and their Paleozoic roof-pendants, partially covered by Tertiary volcanics, located along a NE–SW strip (Fig. 1).

These geological and structural characteristics rule the spatial array of the economic occurrences. In fact they are related to granite emplacement, which is controlled by regional structures. The NE–SW structure was already active and prominent here during the Hercynian cycle.

The huge Hercynian intrusive activity in Sardinia actually includes several emplacement phases, pre- to post-tectonic, with gradually more acidic intrusive bodies and different intrusion levels. Particularly, in the studied area, pre- to late-tectonic plutons occur (Ghezzo and Orsini, 1982), mainly granodiorites, monzogranites and intermediate terms.

The metamorphic host rocks mainly include terms deriving from terrigenous sediments, arenaceous to clayey, while the carbonatic lenses are of lesser importance, reaching a fairly significant development only at Monte Gonare (south-eastern corner of the area). The metamorphic facies range from shales to micaschists for the originally terrigenous sediments, while the metalimestones vary from marble to garnet-rich skarns. The metasomatic processes that caused origin of the bodies of economic relevance will be characterized later. Now we only add that the control by NE–SW structures appears of primary importance for their distribution.

The same structural control, still active in Tertiary time, is responsible for the effusion of the Oligocene calc-

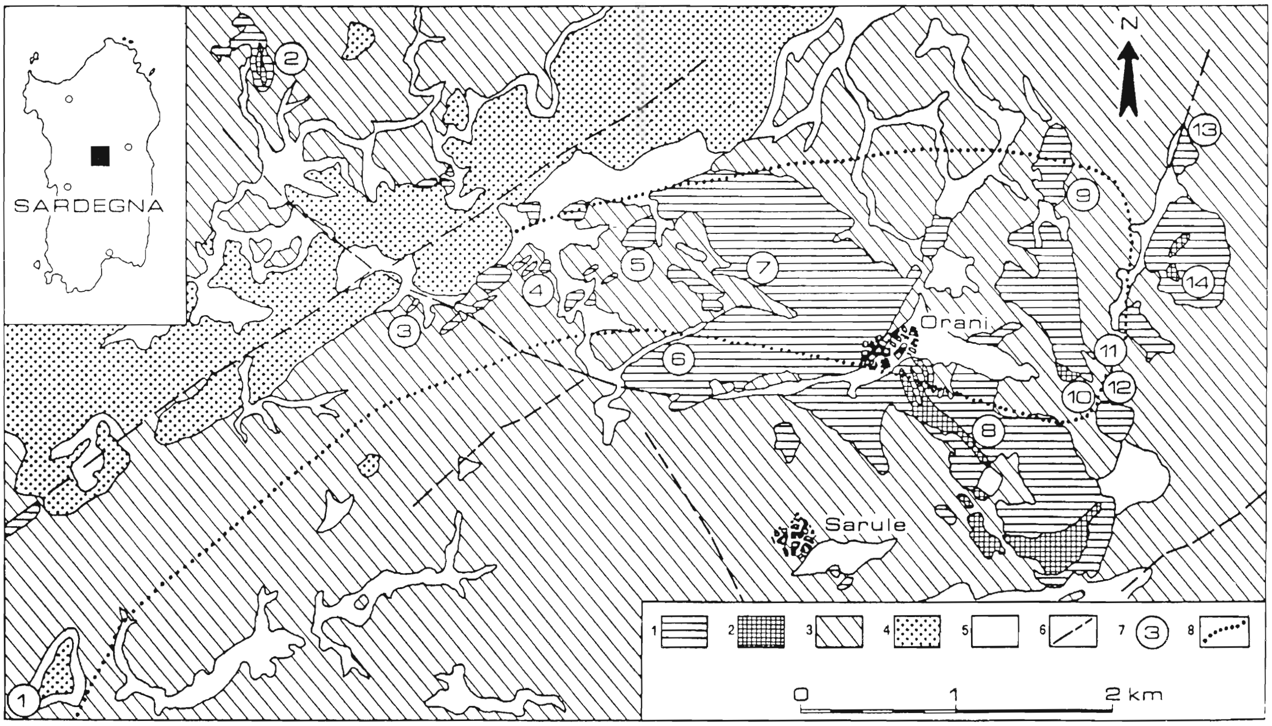

Fig. 1. Geological sketch map, with the main occurrences and mining sites. The only albitite (Ab) domain lies just left of the represented area. The dotted line separates the domain of contemporaneous Na- and Mg-silicate occurrences (inside) from the predominantly chlorite-talc (Chl, Ta) occurrences outside. Geology: 1 – Pre-granitic metamorphic rocks, mostly of terrigenous origin, 2 – Paleozoic metalimestone lenses, 3 – Paleozoic granitoids, 4 – Tertiary volcanics and sediments, 5 – Quaternary cover, 6 – main faults, 7 – mineralization of individual sites: 1 – Ab; 2 – Ta, Chl, 3 – Ab, Chl, Ta; 4 – Ab, Chl, 5 – Ab, Chl, 6 – Ta, Chl, 7 – Ab, Chl-Ta; 8 – Chl, Ta, Ab; 9 – Chl, Ab; 10 – Chl, Ab; 11 – Chl, Ab; 12 – Chl, Ab; 13 – Chl; 14 – Chl.

alkaline volcanics, which covered wide areas of the crystalline basement. Besides relatively small remnants still forming the tabular tops of some hills (e. g. Sa Planedda, south-western corner of the map), these volcanics fill in an important NE–SW trough, which crosses the area in its north-western part and is a branch of the main Tirso trough, that lies just northwestwards of the mapped area.

Distribution of occurrences

The already noted spatial array of economic occurrences along a NE–SW structure also displays an internal distribution of the mineral assemblages (Fig. 1). An elongated "core zone" is characterized by predominant albitites, but a gradual increase of chloritization from SW to NE (as chloritization of albite, or appearance of chlorite bodies, or both) is clearly perceptible (Fig. 4). Inside this zone all the exploitable albitite bodies occur (Nos. 1, 5 and 7 in the map), but also old chlorite (-talc) exploitations (Nos. 4, 5, 7, 9 and 11) and prospects (Nos. 3 and 10) are present. The most important talc occurrences (Nos. 12, 13 and 14), where the albitization phenomena are strongly obliterated or negligible, occur outside the "core zone", mostly around the northeastern side (Fig. 5).

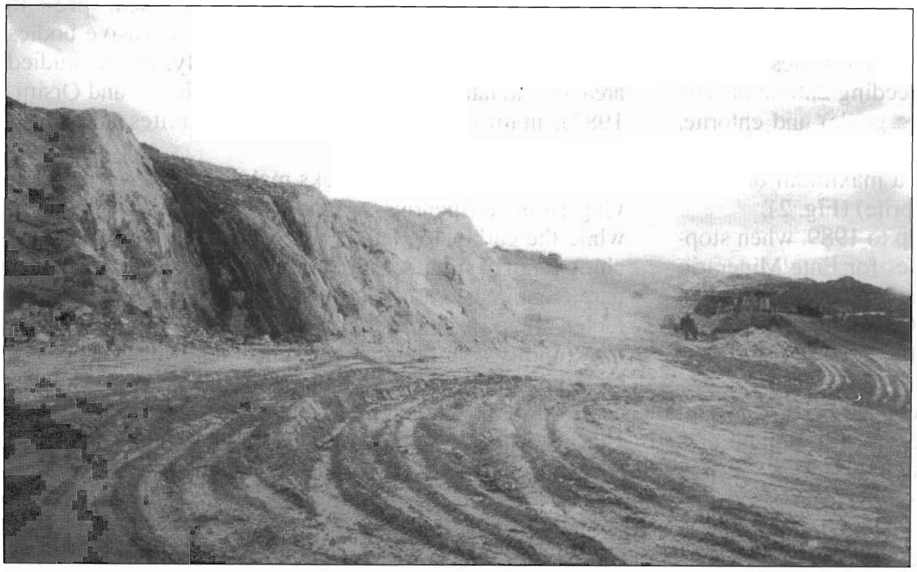

Fig. 2. Talc body, Sa Matta mine.

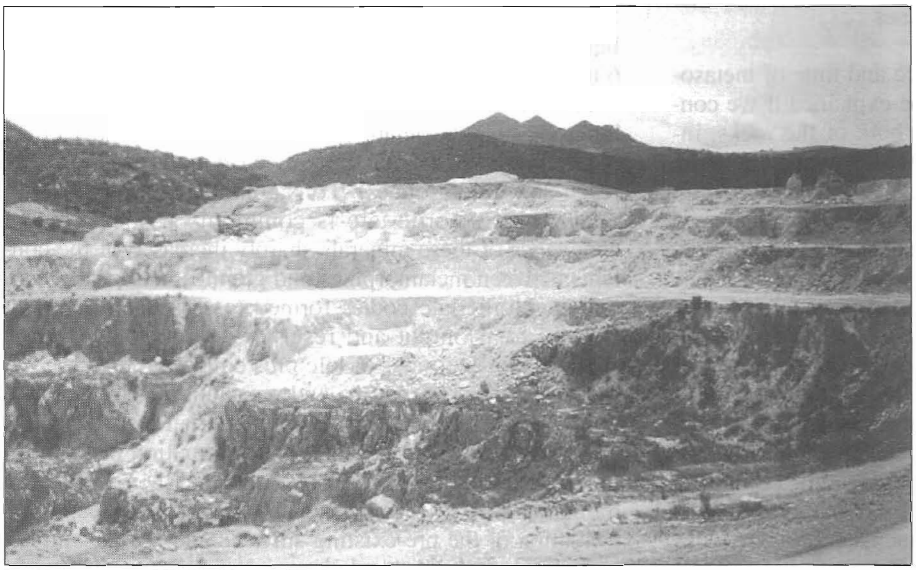

Fig. 3. Massive albitite. Ispaduleddas mine

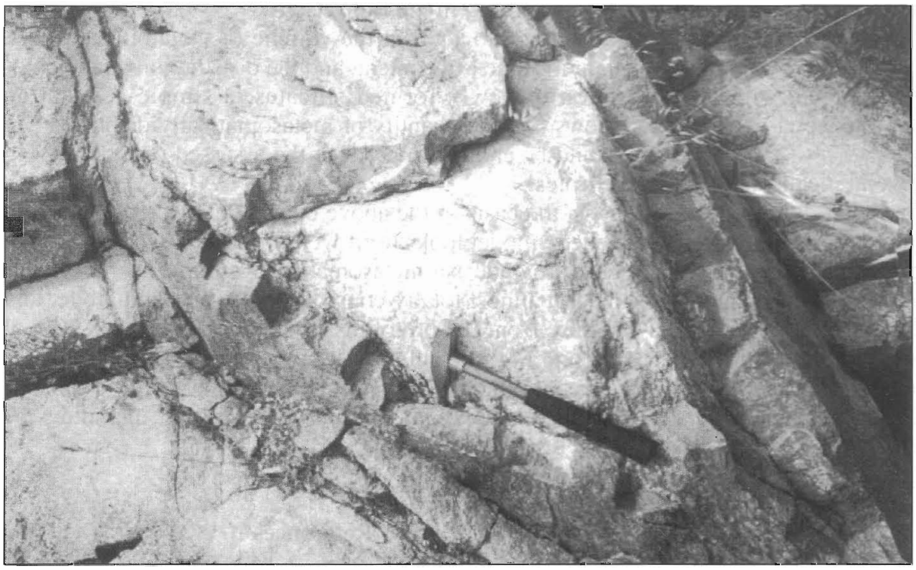

Fig. 4. Chloritization along fracture in albitite Predas Biancas mine

Fig. 5. Talc (greyish white)-quartz (white) veinlets in massive chlorite Predas Biancas mine

Genetic hypotheses

The observed distribution in space and time of metasomatic phenomena in the area can be explained if we consider the different steps. Since the bulk of the rocks, involved in the albitization, are granitoids, we shall develop most of considerations on these rocks. On the other hand, the bulk of chemical and mineralogical characteristics of the micaschist sensibly approaches those of granitoids. The development of Na-metasomatism in the western part of the area mainly involved the feldspars, biotite and muscovite, which, along with quartz, form the bulk of the local granitoids and micaschist. Given the predominance of Na as reactant, and the huge quantities of fluids that circulated, this metasomatism was pervasive on enormous rock volumes. As a consequence huge quantities of metals not entering the albite composition, or being present in exceeding quantity in the pre-existing silicates, where released. This group of elements mostly includes K, Ca, Mg, Al, and Fe (Fiori and Grillo, 1991; Fiori et al., 1994). Of the first three, the most soluble one, K, did not apparently reprecipitate in the study area, at least in significant quantities, Ca and Mg, particularly the latter, gradually reached sufficient activity to react with both the surrounding metamorphics and the newly formed albitites.

Then, the albitization displaced several metals, in particular K, Ca and Mg. While the first metal did not apparently reprecipitate, at least in significant quantities, the other two, particularly Mg, gradually reached sufficient activity to metasomatize both – the already formed albitites and the metamorphics.

In fact, no other source of Mg is available for the formation of Mg-silicates, since the absence of mafic rocks is complete and mean Mg content of the carbonatic metasediments is low, quite similar to that of the terrigenous metasediments (1.5 wt. % in average).

Flowing eastwards, these fluids reached the conditions favourable for Mg-metasomatism of pre-existing silicates, both feldspars and micas of the original granitoids and micaschist and albite of the albitized rocks.

The proposed scheme of phenomena has been verified on the basis of known reserves of albite and Mg-silicates in the studied area and of a rough assessment of abundance of other important minerals, such as quartz and epidotes.

In the albitite properties some 25 million tonnes of exploitable material have been recognized so far. Despite this it should be taken into account that the exploration is not yet exhaustive, the material is considered economically recoverable only in open pit operations, with comparatively low waste/albitite ratio; the Na_2O cut-off is high (around 6 wt. %). Thus the deeper parts of the bodies, the low-grade bodies (including the partially albitized rocks) and the innumerable small occurrences are not calculated in this assessment.

For the Mg-silicates, which are much better known, starting from 2 million tonnes of measured resources (including the already exploited parts), adding a similar quantity for the unknown resources, and again the same number for the uneconomic occurrences, a total figure of 6 million tonnes looks reasonable.

The action of late fluids in the study area determined an intense Na–metasomatism on the granitoids and formed huge albitite–rich bodies (assessed commercial reserves reach 25 million tonnes). To Na–mineralization a certain quantity of chlorite-talc is commonly associated; the abundance of these minerals sharply increased of the contents between metamorphics and granites and locally economic chlorite-talc bodies formed (assessed reserves, including total output and reserves, still in place, reach some 2 million tonnes of talc plus chlorite).

The peculiar distribution and association of two kind of mineralization leads to the hypothesis that a single circulating fluid was responsible for the formation of the albitite bodies during the prograde phase, and then, during the retrograde phase, it would induce chemical-physical transformation of the pre-existing silicates and produce albite, with consequent Na depletion and enrichment in K, Ca, Al, Fe and Mg in the fluid itself.

Taking into account the volume of the albitized rocks, their average Mg content, and the distribution and composition of newly formed silicates, a simple calculation shows that the quantity of metasomatically displaced Mg would be enough to produce the assessed quantity of Mg silicates.

On the basis of the above considerations, the following genetic model looks to fit well to the observed situation:

1. prograde Na-metasomatism resulting in a rock formation almost totally consisting of quartz and albite, and release from the protoliths of elements such as K, Ca, al Fe, and Mg into sulution.
2. retrograde Mg–metasomatism, due to the chemical-physical changes in the fluid, particularly including the Mg enrichment.

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Talc-magnesite deposits in Finland

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Abstract

The talc-magnesite occurrences and deposits in Finland are located in Eastern Finland in the Archean and Proterozoic formations. This contribution provides geological descriptions of significant talc-magnesite deposits and summarizes their use for talc and soapstone production.

Key words: talc, soapstone, production, Finland

Introduction

With the exception of a few occurrences in Northern Finland, the talc-magnesite occurrences are mainly located in Eastern Finland. Over 100 occurrences of talc schist and soapstone are reported in Finland (Vesasalo, 1965). Most of them are situated in the Archean greenstone belts or the Proterozoic schist belts.

For centuries, the talc-magnesite occurrences have been used for making of soapstone fireplaces. At present, soapstone is used on a large scale as a raw material for heat reserving ovens and fireplaces. Talc-magnesite deposits began to be utilized for the production of talc for the needs of paper industry in 1969 when Suomen Talkki Oy started the talc production by flotation in Lahnaslampi. In 2000, the overall volume of talc production was approximately 500,000 tonnes while the production of soapstone for use as dimension stone totalled 135,000 tonnes.

Finnish bedrock in brief

Finland is situated geologically in the central part of the Precambrian Fennoscandian (Baltic) Shield. Approximately one third of Finnish bedrock is composed of Archean rocks (3100–2500 Ma) situated in Eastern and Northern Finland (Fig. 1). They are mainly polydeformed and polymetamorphosed tonalitic-trondhjemitic-granodioritic gneisses with minor greenstone belts (Gaál and Gorbatsev, 1987; Lundqvist et al., 2000).

The main part of the Finnish bedrock was formed during the Paleoproterozoic era 2500–1800 Ma ago (Fig. 1). The sedimentary and volcanic rocks of the Karelian Domain in Eastern and Northern Finland are comprised mainly of epicratonic, shallow marine and fluvial formations deposited 2500–2000 Ma ago on the Archean basement (Gaál and Gorbatsev, 1987). At present, these rocks are metamorphosed to conglomerates, quartzites, mica schists, black schists, dolomites and amphibolites. The Lapland Granulite Belt in the northernmost Finland represents a major allochthonous unit of high-grade metasedimentary and igneous metavolcanic and plutonic rocks.

The Svecofennian Domain (1930–1820 Ma) in Southern and Western Finland is believed to represent a collage of accreted 2060–1900 Ma island arcs which collided 1910–1885 Ma ago to the margin of the Archean basement (Gaál and Gorbatsev, 1987). The main supracrustal lithologies in the Svecofennian Domain are deep-seated metaturbiditic wacke sands-shales and various metavolcanic rocks of island arc affinity. The supracrustal units were intruded 1890–1850 Ma ago by a huge volume of syn- to late orogenic, mainly granitoid plutonic rocks. Rapakivi granites (Fig. 1) were emplaced 1650–1540 Ma ago after the main phase of the Svecofennian orogeny. The Jotnian (1400–1200 Ma) sandstones and dolerite sills in the west along the Bothnian Bay represent the youngest Proterozoic units preserved in Finland.

Minor remnants of Paleozoic cover sequences (570–250 Ma) comprising conglomerates, sandstones, shales and limestones are preserved in some places in the southern part of Finland. A small part of Caledonian (450–400 Ma) thrust belt exists in the northwesternmost part of Finland (Fig. 1). Kimberlite and lamproite pipes and dikes (570–430 Ma) occur in Eastern Finland within the Karelian Domain. There are a few carbonatite and alkaline plutonic intrusions approximately 370 Ma of age in the eastern and northern part of Finland.

By the beginning of the Paleozoic era, the Svecofennian mountain chain was completely cratonized and peneplanized close to the present erosion level. During the Pleistocene, the Fennoscandian Shield was affected by several glaciations the last of which took place approximately 8000–11 000 years ago. The glaciations have left distinct marks on the geomorphology. Ice-polished outcrops, moraine landscapes, eskers, glaciofluvial erosion forms and thousands of lakes have created a landscape of changing character and special beauty (Simonen, 1980).

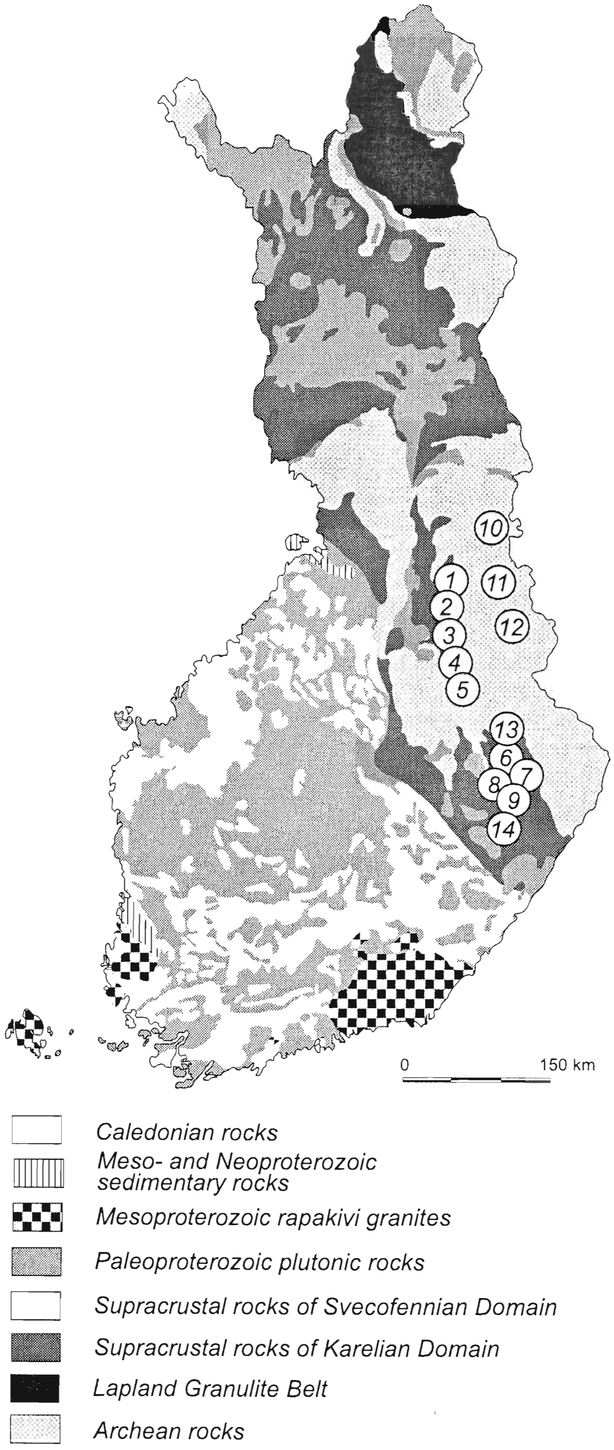

Fig. 1. Location of talc-magnesite deposits on the bedrock map of Finland (simplified from Korsman et al., 1997). 1 – Mieslahti, 2 – Jormua, 3 – Lahnaslampi, 4 – Uutela, 5 – Alanen, 6 – Lipasvaara, 7 – Vasarakangas, 8 – Horsmanaho, 9 – Sola, 10 – Kivikangas, 11 – Hyrynsalmi, 12 – Verikallio, 13 - Nunnanlahti, 14 – Savonranta.

Deposits in Proterozoic formations

Lahnaslampi deposit

Lahnaslampi talc-magnesite deposit is situated within the black schists and mica schists of the Paleoproterozoic Kainuu Schist Belt in the axial culmination of an antiform. The deposit continues as a thinner unit to the south while its north end plunges below the country rock (Tuokko, 1992). Over 600 m long and 250 m wide, the talc-magnesite deposit is surrounded by black schists with an amphibole skarn in the contact. There is no massive serpentinite typical for metamorphic ultramafites in the deposit. The use of the Lahnaslampi talc deposit began at the end of the 1960s. Today, the annual production totals over 500,000 tonnes of ore. At present, over 1,000,000 tonnes of country rock is quarried due to the extension of the open pit (Fig. 2). The ore is processed at a nearby processing plant. Processing methods are discussed later.

The Lahnaslampi deposit consists of talc-magnesite rocks with minor serpentine breccias. Serpentine breccias consist of carbonate, talc and serpentine with minor chlorite, olivine and ore minerals. Chlorite schists and a graphite vein cut the deposit. The 2–5 m wide chlorite schists represent mafic dikes and fault zones. Comprising of graphite, chlorite, talc and sulphides, the graphite vein is only a few dozen centimetres wide.

The Lahnaslampi deposit is composed of talc (40–60 %) and magnesite – breunnerite (40–60 %). Dolomite is the dominant carbonate at the margins of talc-magnesite rock. As a rule, the amount of dolomite, as well as the amount of chlorite and sulphides increases towards the margins of the deposit. The chlorite content is approximately 5 % and the ore mineral content is a few percent. The sulphide minerals comprise pyrrhotite, pentlandite, pyrite and chalcopyrite while the oxide minerals include ferrichromite and magnetite. The chemical composition of Lahnaslampi talc-magnesite rock is presented in Tab. 1.

Tab. 1
Chemical compositions of Finnish talc-magnesite rocks

	Lahna-slampi 1)	Horsma-naho 2)	Uutela 2)	Nunnan-lahti 3)
SiO_2	33.69	34.60	34.40	30.10
Al_2O_3	0.98	0.48	0.64	1.47
Fe_2O_3 (tot)	6.20	5.91	5.74	7.88
MgO	35.48	36.00	36.40	33.06
CaO	0.29	0.07	0.06	2.02
CO_2	20.45	24.03	24.51	21.05

1) Average of 11 analyses (Kuronen, 1995)
2) Geological Survey of Finland (Kontinen, unpublished data)
3) Wiik (1953)

The talc-magnesite rock has gone through a multiphase deformation and metamorphism during the Svecokarelic orogeny approximately 1900–1800 Ma ago. Steatitiza-

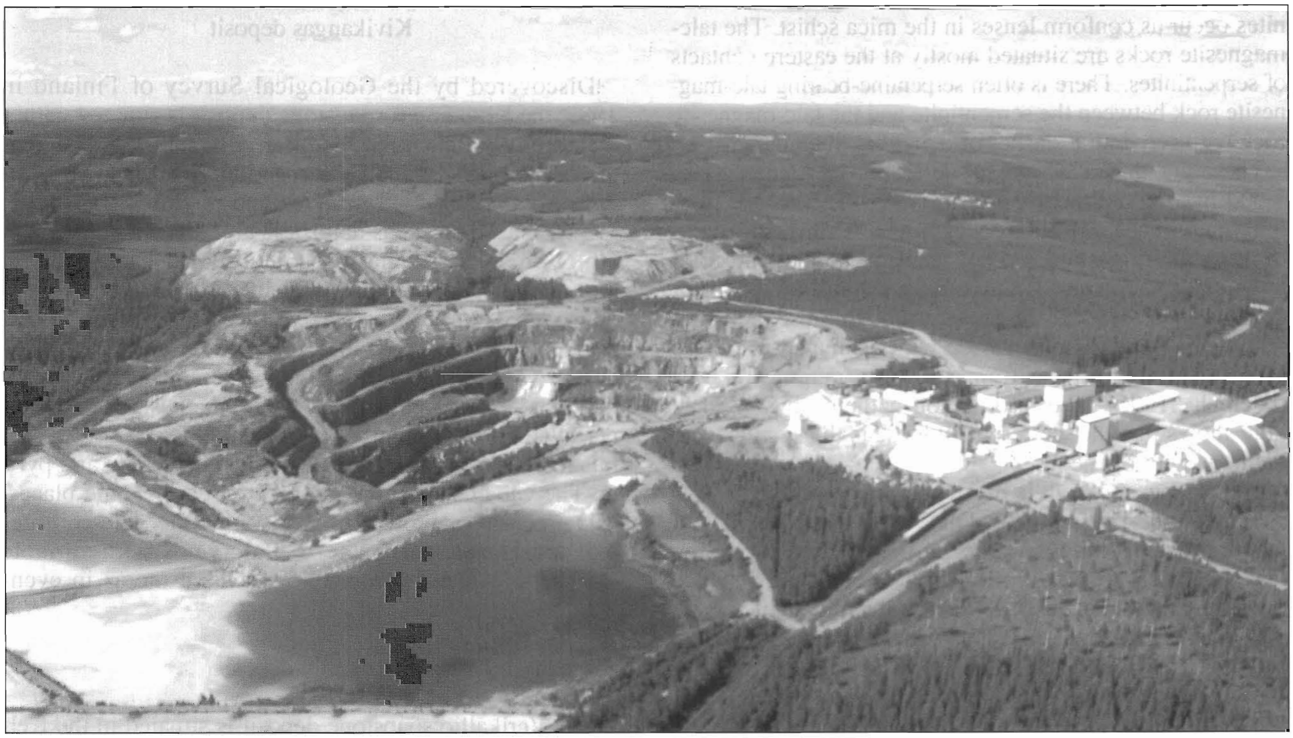

Fig. 2. Overview of the Lahnaslampi talc mine

tion has taken place in two stages. The first stage was before the metamorphic peak when primary ultramafite was serpentinized and partly transformed into talc by H_2O-dominated solutions. Metamorphic olivine met in serpentine breccias originates from the dehydration of altered ultramafite at the peak of metamorphism. The main steatitization took place at a declining pressure and temperature and was caused by the influence of CO_2-bearing liquids. Suitable structural location and size have created an almost perfect talc-carbonate alteration and high-quality talc ore (Kuronen, 1995).

Horsmanaho and Pehmytkivi deposits

The Horsmanaho talc-magnesite deposit is situated within the Outokumpu association. The general sequence of lithologies proceeding from serpentinite to regional wall rock is as follows: serpentinite – talc-magnesite rock – talc schist – skarn – quartz rock – black schist – micaceous schist (Kuronen and Tuokko, 1997). The Horsmanaho talc-magnesite rocks are closely associated with a lense of massive serpentinite. The main talc deposit is situated towards its west and south-west margin. The position of the deposit is also controlled by a lineation dipping towards the southwest at about 30 degrees; both the ore body and the adjacent skarn and quartz rocks are elongated downwards in this direction.

The main deposit is about 500 m long. The contact between the serpentinite and the soapstone is typically steeply dipping and generally transitional. The thickness of the transition zone varies from a few dozen centimetres to a few metres owing to the progressive decrease in the proportion of talc and magnesite and the contemporary increase in the amount of serpentine minerals.

The deposit contains up to 50–70 % talc with the remainder consisting mostly of magnesite and dolomite. The latter can comprise up to 40 % of the rock at the margins of the deposit and 3–10 % elsewhere. Dolomite typically occurs as veins, whereas magnesite occurs as discrete grains or grain aggregates. The amount of chlorite varies from 5–10 %. The sulphide content is 1–2 % while the oxide content (chromite and magnetite) is less than 1 %. The chemical composition of Horsmanaho talc-magnesite rock is presented in Tab. 1.

Quarrying operations commenced in Horsmanaho in the 1980s when the deposit was owned by Oy Lohja Ab. Today, the owner of the deposit is Mondo Minerals Oy and the production totals approximately 450,000 tonnes of ore and 600,000 tonnes of country rock per year. The ore is processed in plants located in Vuonos and Kaavi.

The Pehmytkivi quarry is situated about one kilometre to the north of Horsmanaho. Surrounded by black schists, the ore is 250 m long and 30–50 m wide. Production started in 2001.

Alanen deposits

The Alanen talc-magnesite deposits were discovered in 1981–1984 by the Geological Survey of Finland (Vanne, 1988). The deposits are situated in the southernmost part of the Kainuu Schist Belt. The part of the schist belt where the deposits are located is 500–1,300 m wide and consists of mica schists with serpentinites, talc-magnesite rocks, skarns, quartz rocks and black schists. The serpentinites occur as conform lenses in the mica schist. The talc-magnesite rocks are situated mostly at the eastern contacts of serpentinites. There is often serpentine-bearing talc-magnesite rock between the serpentinite and the talc-magnesite rock with serpentine slashes of 0.5–4 cm in diameter.

There are three talc-magnesite lenses in Alanen. Over 1,000 m long and nearly 100 m wide, the SW–NE trending main lense dips 40–65 degrees to northwest. According to drillings and gravity measurements, the total amount of resources is approximately 9 million tonnes of talc-magnesite rock. The easternmost lense is about 800 m long and 20–50 m wide with estimated resources of less than 1 million tonnes of talc-magnesite rock (Niemelä, 1996). The information gathered by one drill hole shows that the westernmost lense is the smallest and the most heterogeneous.

Talc-magnesite rock is mostly light grey, homogenous and massive. The amount of talc equals the amount of magnesite. Dolomite, chlorite, serpentine and ore minerals occur as accessory minerals. The ore minerals include pyrrhotite, pentlandite, pyrite, chromite and magnetite.

Over the last few years, the French company Talc de Luzenac has conducted test mining of the deposit. The mining concession process is currently underway.

Deposits in Archean formations

Nunnanlahti deposits

The Nunnanlahti soapstone deposits are situated in a 10 km long and 1 km wide NW–SE trending zone. The age and origin of the soapstone deposits are yet poorly known. Apparently, the Nunnanlahti soapstones lie within an allochtonous Archean greenstone belt sandwiched between Paleoproterozoic formations (Sorjonen-Ward, 1997). The industrial use of Nunnanlahti soapstone started on a small scale at the end of 19th century. Kärenvaara, Mustanvaara and Korpisaari were the most important quarrying places. At present, two prominent companies, Tulikivi Oyj and Nunnanlahden Uuni Oy, are quarrying in Kärenvaara which is also the location of the processing plants for the manufacturing of soapstone products.

In Kärenvaara, the soapstone deposit is situated between mafic amphibolites and granite-gneiss. Chlorite dikes are found inside the soapstone parallel to the schistosity. There is often a biotite-chlorite blackwall at the contact between the soapstone and country rock. Tremolite-bearing schists are also met in the contact zones of the soapstone and serpentinite (Kojonen, 1986).

The Kärenvaara soapstone is fine-grained and generally schistose. The colour is grey in different shades with vividness brought about by light-coloured carbonate clusters and light green chlorite dykes. The soapstone contains 40–50 % talc, 40–50 % magnesite, 5–8 % chlorite, as well as dolomite and ore minerals as accessory minerals. The ore minerals consist mainly of magnetite but pyrrhotite, pentlandite, pyrite and chromite are also found. The chemical composition of Kärenvaara (Nunnanlahti) soapstone is presented in Tab. 1.

Kivikangas deposit

Discovered by the Geological Survey of Finland in 1989, the Kivikangas soapstone deposit is situated within the Suomussalmi Greenstone Belt. The north-west side of the deposit is bordered by serpentinite while the other sides are bordered by volcanites and phyllites (Leinonen, 1992). The Kivikangas deposit is at least 250 m long and 60–110 m wide. Kiantastone Oy (a subsidiary of Tulikivi Group) has quarried the deposit since 1999.

The Kivikangas soapstone is either even-grained or veined soapstone. Even-grained soapstone is dark grey, massive or variably veined. The talc content is over 50 % and the carbonate content is over 30 %. Magnesite and breunnerite comprise the carbonate minerals. Accessory minerals include chlorite, dolomite, serpentine, rutile and pyrite. The veined soapstone is mostly grey; in some places, it is greenish or brownish. Veins are either talc-chlorite-magnetite-, talc-carbonate- or talc-veins with variable thickness. Mineral composition is the same as in even-grained soapstone.

Verikallio deposit

The Verikallio soapstone deposit is situated in the Kellojärvi ultramafic formation within the Kuhmo Greenstone Belt. The formation is layered metacumulate consisting mainly of different ultramafic and mafic cumulates (Tulenheimo, 1999). Verikallio soapstone is surrounded by serpentinites. The Verikallio soapstone deposit is 200–250 m long and 30–100 m wide. Kivia Oy started the quarrying and processing of the soapstone in 1998.

The soapstone is dark grey, grey or greenish grey, massive or spotted. Light 0.5–5 mm wide carbonate veins cut the soapstone. The talc content is approximately 45 % and the magnesite content is 40 %. The serpentine and chlorite content is a few percent and the ore mineral content (mainly magnetite and limonite) is approximately 12 %. In addition to this, there are single grains of pyrrhotite and pyrite.

Use of talc-magnesite deposits

Talc production in Finland

In the beginning of the 20th century, small amounts of talc were produced from Nunnanlahti soapstone for use as a pigment mineral. The first mine solely for the production of talc was opened in Jormua. It was operated in 1952–1971 by Suomen Mineraali Oy. The talc-magnesite rock was simply crashed, milled and separated by screen and air-suction. The coarse-grained fraction was used for asphalt roofing while the fine-grained talc was used mainly in insecticides and nitrogen fertilizers to prevent the material from getting lumpy (Aurola and Nieminen, 1954).

The actual use of talc started in late 1960s when Suomen Talkki Oy opened the Lahnaslampi mine. Nowadays, Mondo Minerals Oy (previously Finnminerals Oy) has four talc mines (Lahnaslampi, Horsmanaho, Pehmytkivi and Lipasvaara) and three plants which are located in Sotkamo, Outokumpu and Kaavi. Recently, the production in Lipasvaara mine has been at its minimum. In addition to this, talc was produced on the Sola and Vasarakangas deposits in the 1980s. Finnminerals Oy has conducted test mining of the Mieslahti and Uutela deposits (Fig. 1). The French company Talc de Luzenac is exploring the possibilities of the use of the Alanen talc deposit. The talc production in Finland is presented in Fig. 3.

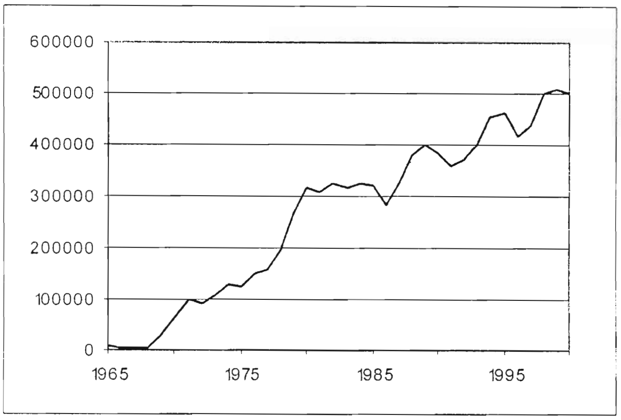

Fig. 3. Talc production in Finland 1965–2000. Source: Ministry of Trade and Industry

Mondo Minerals Oy (part of the Omya Group) is nowadays the sole talc producer in Finland. In the plants of Mondo Minerals Oy, the talc is concentrated through flotation in which the ore containing 60 % talc is transformed by means of a sophisticated multi-stage process into a 97 % talc concentrate, the brightness of which is 75–81 %. This concentrate is then processed into final products using various grinding and classification methods. Depending on the customer's requirements, talc is supplied either as a dry powder, moist pellets or an aqueous slurry. Talc is used in paper industry as a filler and a coating pigment. In pulp and paper mills, it is used to eliminate problems caused by pitch. In addition to this, talc is used in paint and varnish industry and plastic industry, as well as in fertilizer industry to prevent caking.

Soapstone production in Finland

As early as the Stone Age, soapstone was used for making decorative articles and tools. An example of such an article is the elk's head which is the oldest sculpture made of soapstone in Finland. Casting moulds made of Juuka soapstone in the Bronze Age have been found as far as central Europe. In Eastern Finland, soapstone has been used for centuries for making fireplaces.

The industrial use of soapstone started in Nunnanlahti at the end of the 19th century. In 1893, a company called Finska Täljsten Ab was established to quarry the Nunnanlahti soapstone for the manufacturing of decorative facades to public buildings and ovens. In the beginning of 20th century, the main products were fireproof coating stone for soda recovery boilers and talc which was used as a filler in paper industry. A company called Suomen Vuolukivi Oy was established in 1925 to continue the production. After the Second World War, fireplaces again became the most important product. During the 1950s, the production slowly decreased and ceased entirely in the early 1970s. The interest in soapstone picked up again, and in 1980, Suomen Vuolukivi Oy (now Tulikivi Oyj) started manufacturing heat reserving ovens and fireplaces in Nunnanlahti.

Other manufactures are Nunnanlahden Uuni Oy which is also quarrying in Nunnanlahti, Kiantastone Oy (a subsidiary of Tulikivi Oyj) quarrying in Kivikangas and Kivia Oy quarrying in Verikallio. In addition to this, soapstone has been quarried and processed on a small scale in Hyrynsalmi by Kainuun Uuni Oy and Savonranta by Top Stone Oy and Uunikivi Oy. In the 1980s, Suomussalmen Vuolukivi Oy conducted test mining of the Portti soapstone deposit located at approximately 2 km south of the Kivikangas deposit. The amount of quarried soapstone is presented in Fig. 4.

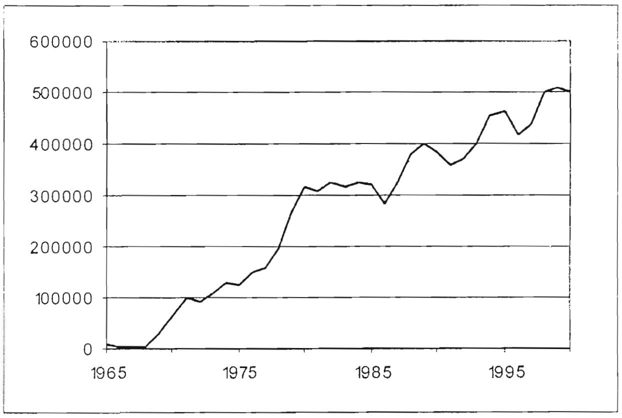

Fig. 4. Amount of soapstone quarried in Finland 1985–2000. Source: Ministry of Trade and Industry

In addition to soapstone ovens (Fig. 5) and fireplaces, significant export products include tiling stones for covering metallic stoves. There is also a wide variety of other products made of soapstone, for example, pots, cooking and grill stones, different kinds of mugs for hot and cold drinks, wine coolers, high quality speaker housings, snooker tables and even ice stones. In addition to this, soapstone is used as building stone on floors and facades.

On a global scale, Finnish companies specialized in soapstone production are among the largest producers of processed natural stone and as to the production of soapstone they are the world market leaders (Pekkala and Niemelä, 1997). Today, the three leading soapstone producers, Tulikivi Group (Tulikivi Oy, Mittakivi Oy and Kiantastone Oy), Nunnanlahden Uuni Oy and Kivia Oy employ over 700 people. The total turnover of these three soapstone producers is over 70 million € over 50 % of

Fig. 5. Soapstone fireplace produced by Tulikivi Oyj.

which comes from export. The most important countries to which soapstone is exported are Germany, Sweden, Denmark, Switzerland and Austria.

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The comparison of amorphous (cryptocrystalline) and crystalline magnesites

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Abstract

Magnesite deposits of different genetic types have been compared. It has been shown that comparative analysis of so-called "amorphous magnesites", connected with ultrabasites, and crystalline magnesites of carbonate series could give the information for understanding the physico-chemical conditions of $MgCO_3$ formation and peculiarities of Mg^{2+}-removing ions in different geochemical environments.

The data on mineralogy of poorly understood magnesite deposits of East Iran are also presented. It has been shown that cryptocrystalline (amorphous) magnesite could pass into fibrous magnesite rims and then in magnesite crystals of rhombic habit. Crystalline magnesites are associated with minerals of characteristic facies of metamorphism. The size, form and quantity of admixture minerals depends on the conditions of formation. These parameters determine the technology of the processing.

Key words: magnesite, amorphous, crystalline, ultrabasics, carbonate series

Introduction

The magnesite deposits are divided into 3 main genetic types: 1) deposits connected with ultrabasics, 2) deposits connected with magnesite-carbonate formations and 3) deposits connected with evaporite salt-bearing complexes. In this paper, we will consider the first two of them.

Magnesites of carbonate formations are presented by large beds up to 5–6 km long and 20–80 m thick. This type of deposits is the most important for commercial using. Recently, the majority of investigators follows the opinion that during the formation of large magnesite deposits the primary sedimentary Mg-bearing terrains were the main source of Mg.

The study of magnesite deposits, spatially connected with ultrabasics, gives an additional material to understand the behavior of Mg in different physico-chemical conditions during disintegration of magnesian rocks and subsequent removal and sedimentation. The magnesite can occur not only in parent ultrabasics, but in surrounding rocks near ultrabasic massif. The surrounding rocks can be represented by flysch or volcano-sedimentary terrains. Magnesites of this genetic type have cryptocrystalline structure: magnesite crystals of tiny size are seen only through electron microscope. The aggregates of these crystals form white quite homogeneous mass, so the "amorphous" term should not be the exactly correct name. There are two diametrically different opinions on the origin of amorphous magnesite. The Russian geologists traditionally consider amorphous magnesites as the product of ultrabasic rocks weathering (Tatarinov, 1969). However, another large group of investigators considers amorphous magnesites to be typical for hydrothermal formations (Maksimovic and Dangic, 1974).

The goal of this work is to show some similarities and differences between amorphous and crystalline magnesites. In addition, we would like to call attention to magnesite deposits of East Iran, which have not been adequately studied to date.

Methods

X-ray diffraction analysis was conducted by DRON Diffractometre (Cu K_α radiation, Ni–filter) in interval 2–65° 2θ. The oriented specimens were prepared by sedimentation of the suspension on glass slides. They were analysed in dry state and after saturation with glycerin (saturated overnight at 60° C).

Electron micrographs were taken using transmission electron microscope (TEM) JEM-100C with the dispersion attachment of KEVEX and scanning electron microscope (SEM). The specimens for TEM were prepared by drying of the suspension on a carbon foil. For SEM the rock chips coated with carbon were used. The micro-diffraction pictures and energy dispersion spectra were taken from separate particles in range from Na to U. The basal reflexes (001), characterizing phylosilicates, were obtained for turn up or down edges of particles.

The samples were chemically analysed using a Philips Analytical PW 2400 automatic XRF Spectrometer. For

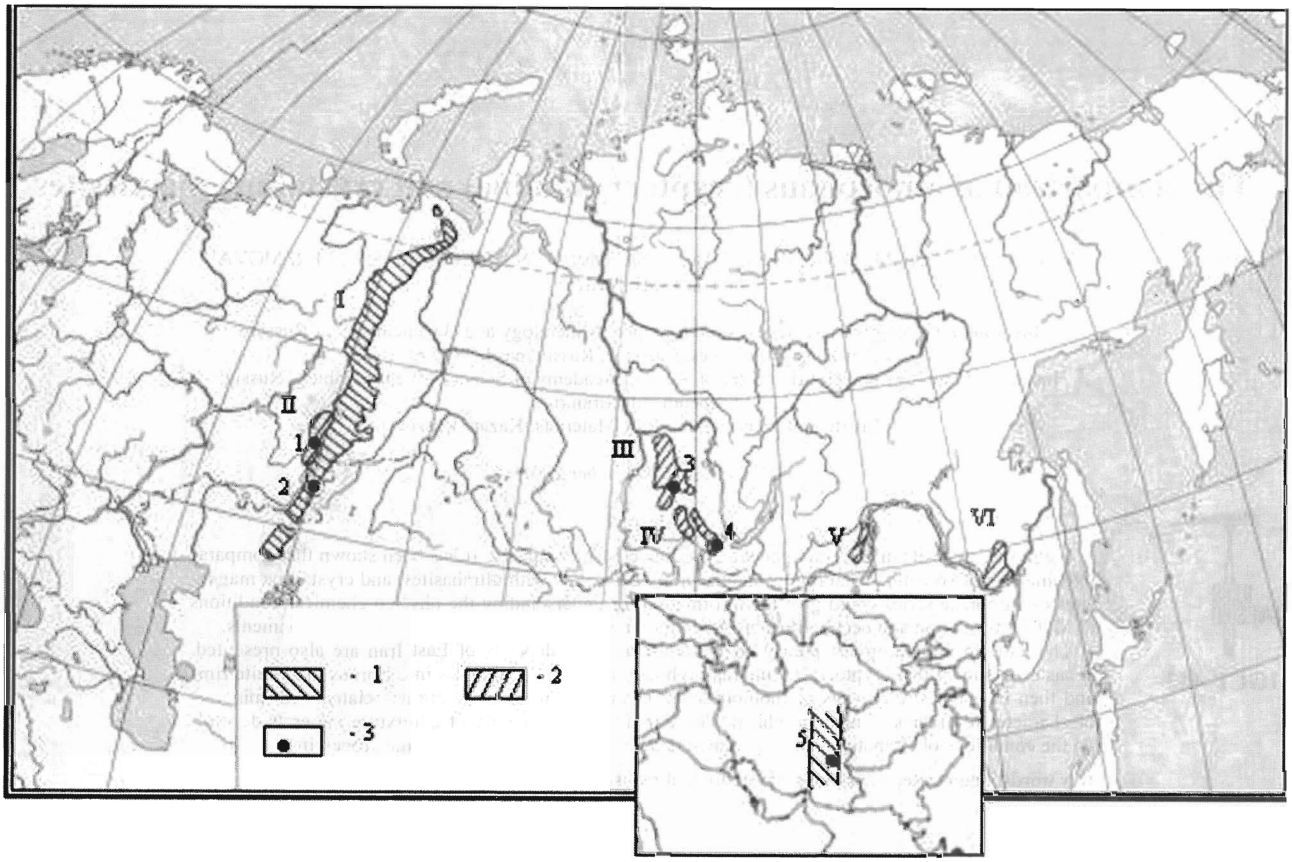

Fig. 1. Schematic map of distribution of magnesite provinces in Russia and East Iran 1 – ultrabasic belts, 2 – carbonate series, 3 – deposits. Arabic numerals on map – deposits 1 – Satkinskoe, 2 – Halilovskoe, 3 - Talskoe, 4 – Savinskoe, 5 - Torshak and other; Roman numerals – provinces I – ultrabasic belt of Urals, II – South Uralskaya, III – Udereiskaya, IV – East Sayanskaya, V – East-Transbaikalskaya, VI – Malochinganskaya.

X-ray fluorescence analyses, the reference standards ANRT, ASK, CCRMR, NIM and USGS were used to check the accuracy of analytical data.

Some analyses were made on "Camebax SX-50" electron microprobe, using an accelerating voltage of 20 kilovolts for all elements with a sample current of 20 nanoamps.

Geological setting

As noticed above, only two types of magnesite deposits are considered in this paper: deposits of amorphous magnesite associated with ultrabasics and the ones of crystalline magnesite in carbonate units (Fig. 1).

Amorphous magnesites associated with ultrabasics. Ultrabasic bodies are usually located along large faults and form ophiolitic belts. Magnesite deposits occur in serpentinite and another ultrabasic rocks of these belts.

In the Urals there are magnesite deposits located in Orenburg, Sverdlovskaya province and Bashkir Republic. Halilovskoe deposit is the largest deposit studied here.

The Halilovskoe magnesite deposit is located near railway station Halilovo, 60 km west from the city Orsk. This deposit is situated inside the grate serpentinite massif, which is formed as a result of serpentinization of peridotite. Magnesite containing serpentinite are vertically divided into two horizons: the upper and lower (Tatarinov, 1969).

The upper horizon is presented by magnesite breccia, which consists of fine angular magnesite fragments with inclusions of serpentinite breccia. Serpentinite breccia is schistose and has slickensides. The thickness of the upper horizon is 5–6 m.

The lower horizon consists of dark-green serpentinites with chrysotile veinlets. Magnesite occurs here as veins and lenses (Fig. 2a). The veins cross between each other,

Tab. 1
Main magnesite provinces of Russia

Magnesite-bearing province	Dimensions of bodies, m		Estimated resources, kilotonnes
	Length	Thickness	
South-Uralskaya	100–5,600	10–80	250,000
Udereiskaya (West Siberia)	10–1,200	2–200	200,000
East-Sayanskaya	50–5,500	10–200	2,145,000

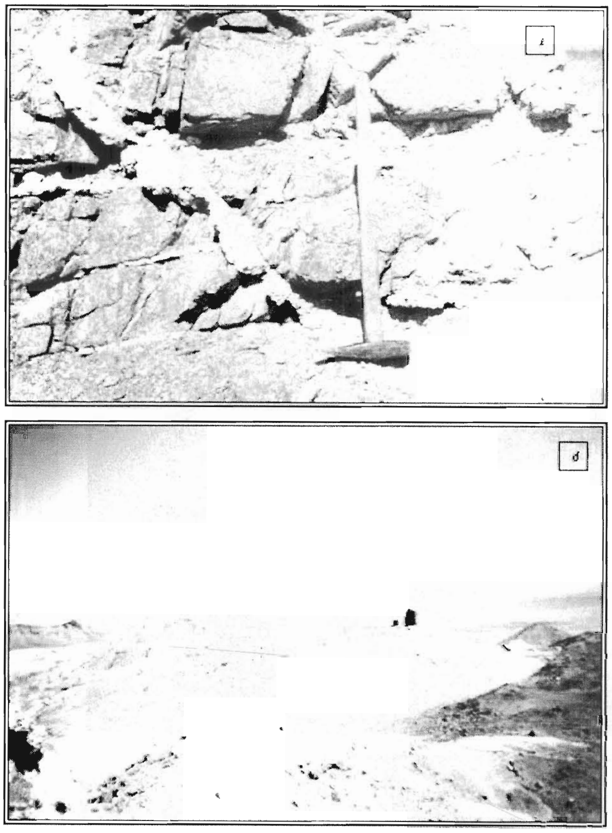

Fig. 2. Deposits of cryptocrystalline magnesite. a – magnesite veins in serpentinite (Halilovskoe deposit). b – magnesite bodies located along contacts of serpentinite massif (Northern Khunik deposit, East Iran).

forming stockwork. The magnesite veins have nearly 0.8–1.3 m in thickness. Total explored and estimated reserves are about 4-4.5 million tonnes.

The Halilovskoe deposit was mined before 2nd World War, but at present time it is practically closed. The mining does not exceed 100–200 tonnes per year.

In Iran there are magnesite deposits located in eastern provinces – Khorosan, Sistan and Baluchestan. In total, there are about 20 deposits. Approximately, 80 % of the deposits are located in the Khorosan and 20 % are in the Sistan and Baluchestan provinces. Magnesite from these deposits is presented by so-called amorphous or cryptocrystalline varieties (Fig. 2b).

Total reserves are about 3.5 million tonnes. About 2.5 million tonnes of this amount are related to low-grade magnesite (16 deposits from 20). At present, only two deposits are being mined. As noticed above magnesite bodies can occur not only in ultrabasics but in surrounding rocks, too. One of them, the Torshak deposit, has been studied in detail. The magnesite body is nearly 300 m long and 80–100 m wide. The enclosing rocks are presented by flysch consisting of thin beds of sandstones and argillites. The magnesite body consists of massive and brecciated magnesite ores. The central parts of magnesite body are represented by massive amorphous magnesite with the high content of MgO up to 87–90 %. Brecciated magnesites occur near contact with enclosing rocks. The MgO content is no more than 75–85 %.

Crystalline magnesites in dolomites. Magnesite of carbonate complexes occurs as beds and lenses. We have considered 3 main magnesite-bearing provinces: South-Uralskaya, Udereiskaya, East-Sayanskaya (Fig. 1).

The main commercial mineral of magnesite ore is the crystalline magnesite. Additional minerals are talc, quartz, chlorite, and dolomite.

Mineralogy

Cryptocrystalline (amorphous) magnesites. Magnesite ores are divided into 3 varieties: massive, banded and brecciated (Fig. 3). Each of the named magnesite varieties is located in specific places of the geologic section or is typical for individual deposits.

Massive amorphous magnesite. Magnesite is a mineral of white colour. The individual crystals are not seen in the polarized light under the optical microscope. The aggregates of magnesite crystals are practically opaque in crossed nicols. The size of individual grains is 1-5 microns. The massive variety is characterized by the high MgO content up to 87–90 % and in some cases represents slightly marked porous structure. The pore content is 5–6 unit per cm^2, the size of them is 0.02–0.08 mm. The pore walls are incrusted by fine magnesite and dolomite crystals (Fig. 3a). Besides magnesite the following minerals were identified by different methods: Fe-hydrooxides, amorphous silica, quartz, serpentine, dolomite, talc.

Amorphous silica. Amorphous SiO_2 represents clusters of very fine particles; some of them are 1–5 micrometers in diameter. The size of these local clusters varies from 5 to 50 microns. The magnesite ore, enriched by amorphous SiO_2, has relatively high SiO_2 content (Tab. 2, Fig. 4a).

Talc is present as aggregation of poorly crystalline minute flakes and individual particles (Tab. 2). The association of talc and ultra-fine particles of amorphous SiO_2 is typical.

Tab. 2
Average chemical composition of magnesite ore and some minerals

Oxide	1	2	3	4	5
MgO*)	91.9	42.40	59.30	59.22	85.64
SiO_2	3.4	56.83	33.30	40.51	3.27
Al_2O_3	1.36	0.07	3.23	–	0.7
FeO	0.37	0.04	0.70	–	2.23
CaO	2.30	0.52	3.0	0.27	7.52
Na_2O	0.38	0.11	0.07	–	–
K_2O	0.29	0.03	0.40	–	–
SO_3	–	–	–	–	0.18
Total	100.00	100.0	100.0	100.0	99.54

1 – an average magnesite ore composition (Torshak deposit, central part), 2 – the fragment of the sample with high content of SiO_2, 3 – the fragment of the sample with increased content of SiO_2 and CaO, 4 – talc, 5 – magnesite ore of Halilovskoe deposit, Russia. Analyses 1–4 – Torshak deposit, East Iran.

Note: MgO*) in scaling on dead burned $MgCO_3$

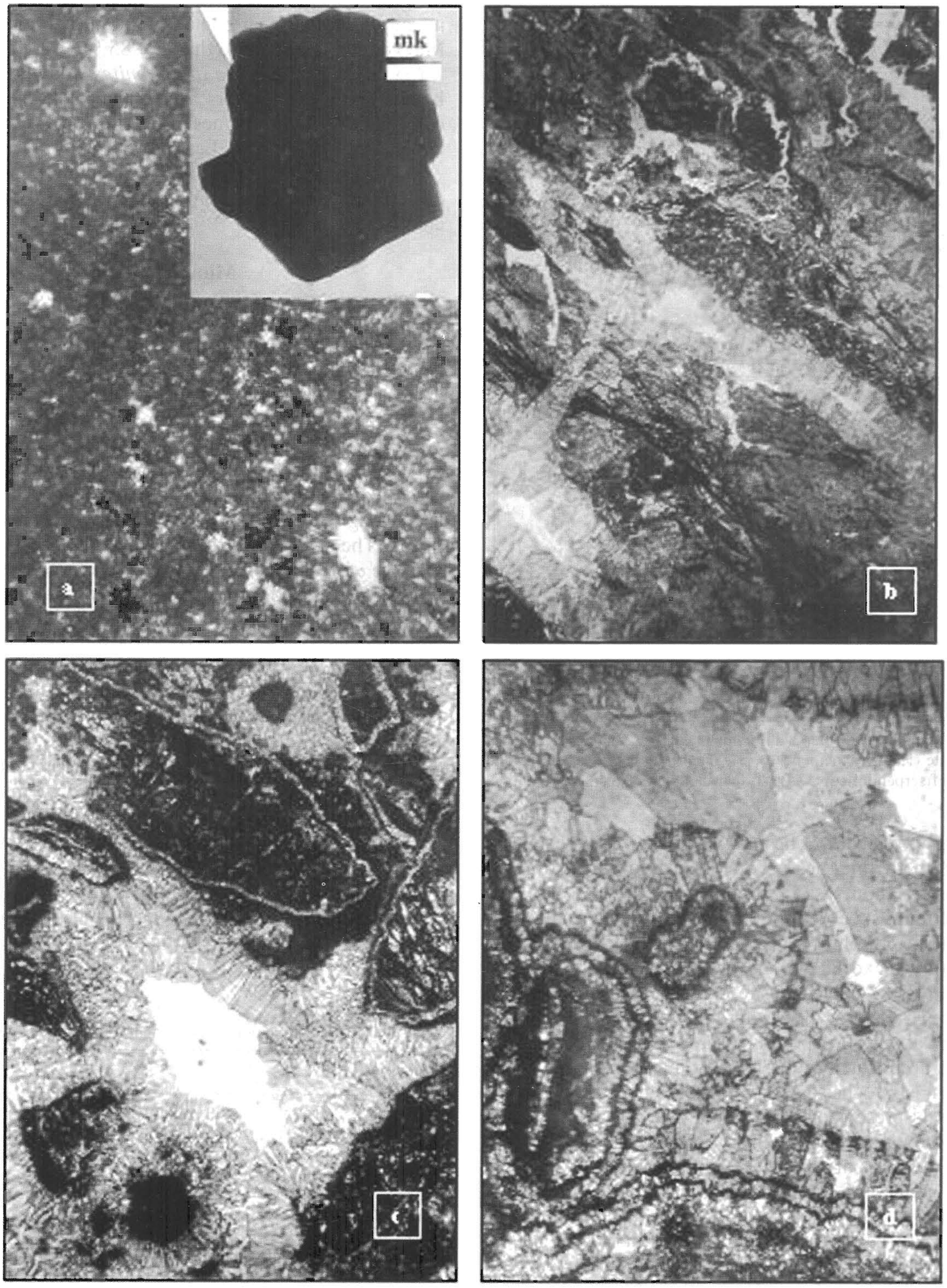

Fig. 3. The varieties of cryptocrystalline (amorphous) magnesite. a – Close-grained magnesite. The individual crystals are not seen in polarized light under optical microscope, magn. 12x. The form and size of individual crystals, obtained by TEM (suspension preparation, magn. 8500x) are shown on the electron micrograph in the right upper corner of the picture. b – Banded magnesite ore. Banding is due to position alternating of highly sheared harzburgite beds (dark) with parallel oriented magnesite veinlets of fibrous habit, magn. 12x. c – Brecciated magnesite. This magnesite variety consists of the fragments of different sizes from 1–2 to 10–15 mm. The cementing mass is characterized by a coarse-crystalline structure. The free space between individual fragments is filled up by aggregates of prismatic magnesite crystals. Sometimes, these crystals form the rows of successive rims, magn. 24x. d – The inner filling of a cavity between fragments in brecciated magnesite. The coarse crystals are presented by dolomite, magn. 36x.

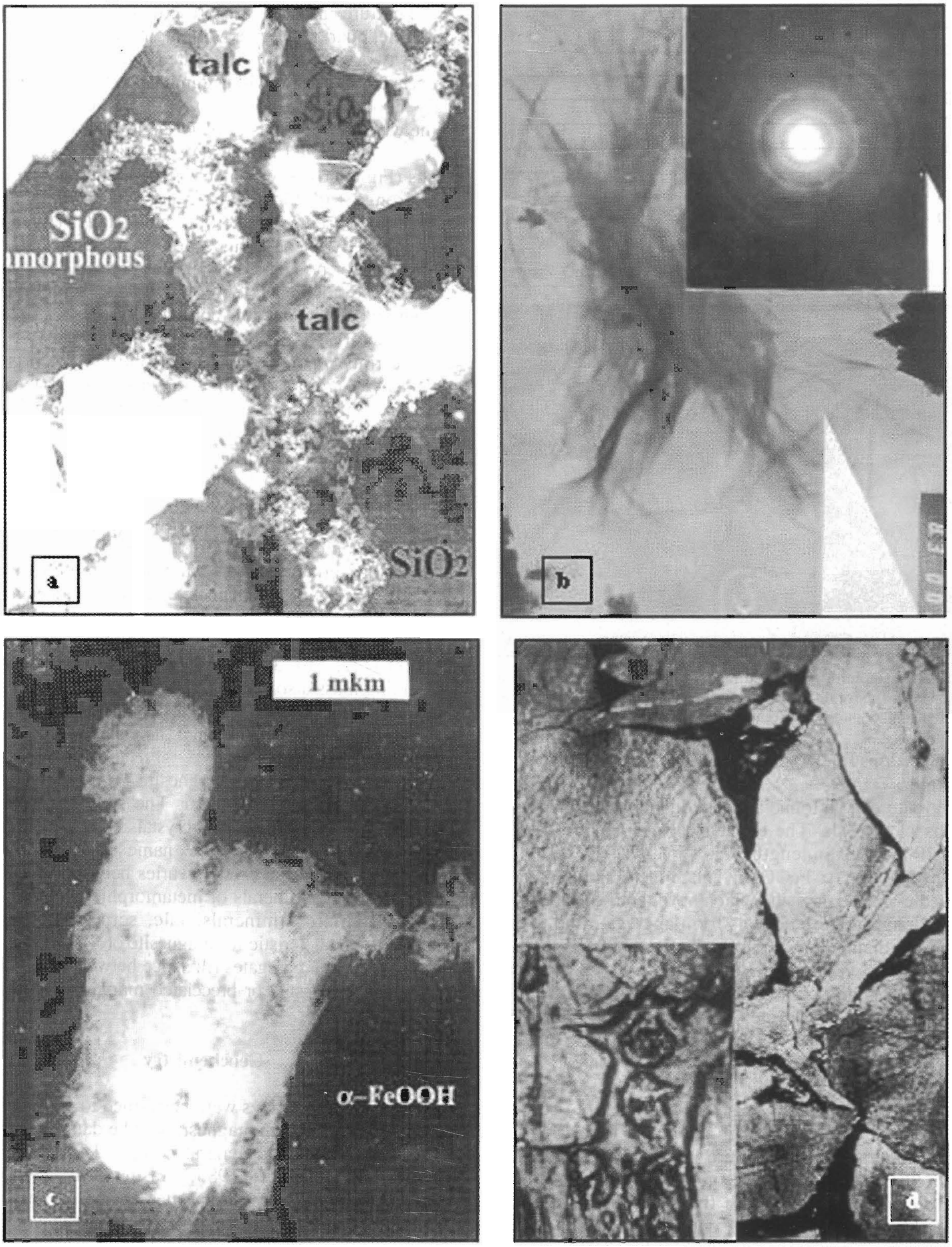

Fig. 4. The individual minerals of cryptocrystalline magnesite ore. a – The transmission electron micrograph of the suspension showing admixture minerals: clusters of amorphous SiO_2 with very fine grains, deformed particles of talc and faceted quartz grains (magn. 5000x). b – Sepiolite aggregate, the electron diffraction pattern of pure sepiolite at the right upper corner of the picture (magn. 16 000x). c – An aggregate of Fe-hydrooxide (α-FeOOH). This mineral is represented by needle-shaped crystals which have the tenth share of microns in length. d – Coarse-grained magnesite of Satkinskoe deposit, magn. 36x. Liquid inclusions at the down left corner of the picture (magn. 100x).

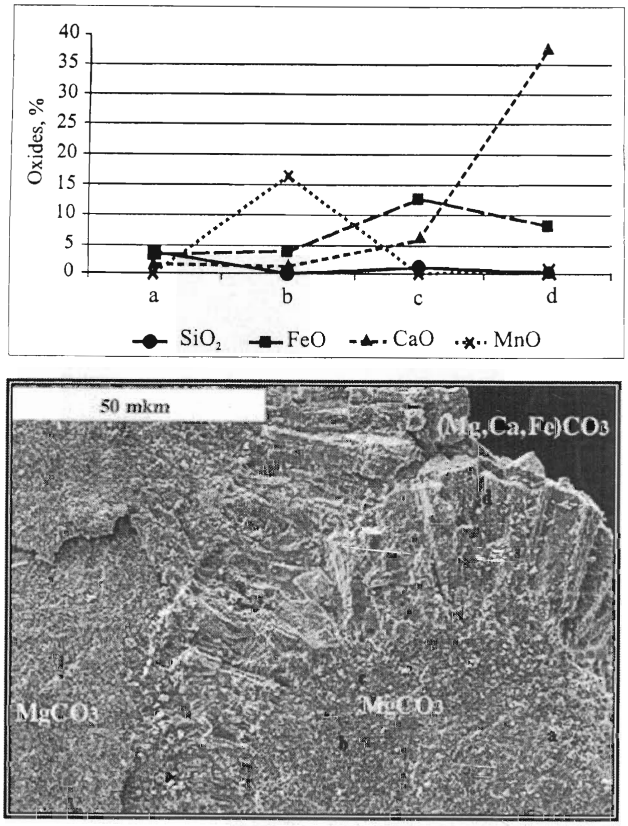

Fig. 5. The sample of brecciated magnesite with a zonal structure. The zones (a-d) have different chemical composition that is shown on plots in the upper part of the figure; see text for explanations.

Quartz forms fine grains, in average up to 10–20 microns in length.

Dolomite can be found as individual crystals and segregations of crystals. The crystals have prismatic habitus up to 20 microns in length.

Fe-hydrooxide (α-FeOOH). This mineral is represented by needle-shaped crystals, which have tenth share of microns in length. These crystals form aggregates up to 3–5 microns in diameter (Fig. 3c).

Banded magnesite ore. Banding is due to position alternating of highly sheared harzburgite beds with parallel oriented magnesite veinlets. Harzburgite is altered by weathering up to opal-kerolite aggregate (Fig. 3b). The banded magnesite ore has the low MgO content, below 60–70 %.

Brecciated magnesite. This magnesite variety consists of fragments of different size from 1–2 to 10–15 mm. Sometimes these fragments are poorly seen with naked eye. In this case the magnesite ore has more heterogeneous structure in comparison with the massive sample (Fig. 3c-d). The parts of samples containing admixtures of SiO_2 and CaO stand out on general background of magnesite with a relatively high MgO content (85–90 %). The size of these parts reaches 0.05–0.3 mm. The average MgO content in such ore decreases to 68–70 %. Some varieties of brecciated magnesite are characterized by a relatively high Mn content up to 25 %.

Admixture minerals are presented by Fe-hydrooxide, dolomite, quartz, siderite, Mn-magnesite, sepiolite.

The two varieties of brecciated magnesite are: a) the brecciated magnesite with fragments of foreign rocks (totally serpentinous olivine, pyroxene and cerolite), b) the same without fragments of heterogeneous rocks.

a) The brecciated magnesite with fragments of foreign rocks (Fig. 3c-d). The content of fragments may be different from 10 to 20–40 %. As noticed above, the fragments are presented by cerolite and totally serpentinous olivine and pyroxene. Magnesite occurs as linings and radial groups of prismatic and fibrous crystals in open spaces between fragments of brecciated rock. Sometimes, the serpentinite fragments are bordered by rims of prismatic magnesite crystals. These crystals form the rows of successive rims. Along the outward outline, the prismatic crystals pass into the magnesite rhombohedra enriched with Fe, Ca and Mn. A free space between fragments may be filled by crystals of dolomite, siderite or Mn-magnesite.

b) Brecciated ore without fragments of heterogeneous rocks consists of fragments and cement. The fragments are characterized by white colour. Their size is 10–50 mm. The MgO content is high, up to 90–92 %. The cement is yellow, light brown due to occurrence of minute flakes of goethite placed among magnesite crystals. The cementing mass is characterized by a coarse-crystalline structure. The magnesite crystals have a columnar habit and radial arrangement (Fig. 5b). As in the first case the crystals of cementing mass also are enriched by Ca, Fe and Mn. The apexes of these magnesite crystals contain dolomite, ankerite and kutnahorite component. The fibrous sepiolite is present (Fig. 4b).

Crystalline magnesite. Magnesite is presented by minerals of white or grey colour. The structure is usually coarse-grained. The individual crystals have a good pronounced cleavage, hence – the rock name is sparry magnesite. The size of magnesite crystals varies between 0.5–20 mm (rarely 5–6 cm). Minerals of metamorphic genesis usually present admixture minerals: talc, serpentine, chlorite. Chlorite is characteristic for magnesite of Satkinskoe deposit. The chlorite aggregates fill space between the grains or fragments in massive or brecciated magnesites correspondingly (Fig. 4d).

Geochemistry

The chemical analyses were performed to compare crystalline and amorphous magnesites. The data for crystalline magnesite were in general compiled from literature (Shevelev and Urasina, 1983; Urasina et al., 1993). The analyses of amorphous magnesites are based on original materials. The Satka magnesites have homogeneous composition along the whole stratum over ~ 6000 m. The MgO content varies from 92 to 93 % (average from 130 analyses). The CaO content does not exceed 1.5 %, SiO_2 is below 1.25 % and Fe_2O_3 is below the tenth share of percent (Fig. 6). Magnesite of Savinskoe deposit is chemically near magnesite of Satkinskoe deposit but has

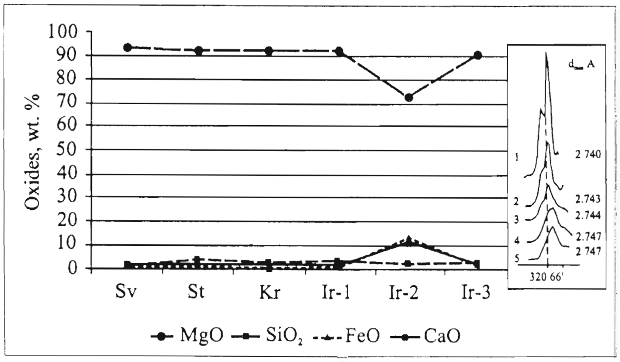

Fig. 6. The comparison of the chemical composition and X-ray features (small figure right) of amorphous (cryptocrystalline) and crystalline magnesites. Crystalline magnesites have more stable composition and more ordered structure then cryptocrystalline magnesites. Deposits: Sv – Savinskoe, St – Satkinskoe, Kr – Kirgiteiskoe, Ir-1 – Torshak (central part), Ir-2 – Torshak (marginal part, on an average), Ir-3 – Subzshirino; X-ray features – the samples: 1 – giant-grained magnesite, Karagai open pit, Satkinskoe deposit, 2 – cryptocrystalline magnesite, Halilovskoe deposit, 3 – cryptocrystalline magnesite ("cabbage stone"), Habaminskyi occurrence, 4 – the same, with hydrooxides Mn, 5 – cryptocrystalline magnesite ("cabbage stone"), Halilovskoe deposit.

higher SiO_2 content reaching 2.5 %. MgO is partly chemically connected with Mg-silicates. It is also characterized by the enhanced average amount of 0.24 % Mn. Many magnesite grains contain liquid inclusions (Fig. 4d) with 150–200 °C temperature of homogenization (Urasina et. al., 1993).

Kirgiteiskoe deposit is characterized by magnesite with the high content of MgO up to 90–92 % and a relatively high SiO_2 content. Present are magnesite blocks with higher MgO content in comparison with magnesite of Satkinskoe deposit.

The coarse crystalline and the cryptocrystalline (amorphous) magnesites have different X-ray characteristics. The main reflection of crystalline magnesite (Satkinskoe deposit) showed double sharp peak at 2.74 and 2.70 A, whereas the same reflection of cryptocrystalline magnesite has broader peak at 2.74 A with weak shoulder at 2.70 A (Halilovskoe deposit) (Fig. 6).

Amorphous magnesites are more heterogeneous in comparison with crystalline magnesites. The deposits can be separated into the blocks with different content of MgO and admixture components. For example, Torshak deposit consists of two parts: the central part and the marginal one. In the central part, the MgO content is 91–92 %; in the marginal one it is 78–87 %. The main admixture minerals are dolomite, amorphous silica, Mn–magnesite (possible kutnahorite?).

The heterogeneity of chemical composition we can see even in one sample. The Mn to Mg substitution can vary from 16.0 % in the central part of the sample to about 0.2 in crystals of breccia cavities. The analogous composition change in this sample is characterized for some other components, for example SiO_2 and CaO (Fig. 5a).

The wide changes of chemical composition are found in the sample collected on Subzshirino deposit (Tab. 3, Fig 5). The sample has brecciated structure. Vesicles are on contact of some fragments. A sufficiently high Mn and low Fe, Si and Ca contents characterize magnesite from the central part of sample. The magnesite crystals near of cavities pass into fibrous magnesite rims and then in magnesite crystals of rhombic habit with a relatively high Ca and Fe content.

Conclusion

In nature, magnesite is found in two forms: as cryptocrystalline (amorphous) and crystalline. The first one is formed by weathering of ultrabasics, the second – by recrystallization of primary sedimentary hypothetical substance. It may be cryptocrystalline magnesite sediment saturated with H_2O.

In studied deposits, cryptocrystalline magnesite can be found not only directly in ultrabasics, but also in surrounding rocks (flysch, pyroclastic volcanic rocks and others). However, in all cases these magnesites are in close proximity to ultrabasic massifs. Magnesite bodies occurring outside ultrabasics could be formed as the result of lateral infiltration of Mg-containing carbonic-acid waters. Another opinion is widely spread among some Iranian

Tab. 3
Chemical composition of magnesites

Oxide	1	2	3	4	5	6	7	8	9	10
MgO	93.2	92.1	92.1	91.9	72.45	90.1	91.71	78.2	80.4	53.7
SiO_2	1.2	3.9	2.5	3.4	2.1	2.5	3.56	0.1	1.1	0.3
Al_2O_3	0.6	0.8	–	1.36	0.05	2.1	–	–	–	–
FeO	1.6	1.2	0.61	0.9	13.4	2.2	3.1	3.9	12.5	8.1
CaO	2.3	1.95	1.62	2.3	11.6	2.3	1.63	1.2	5.9	37.7
MnO	0.00	0.0	0.34	0.3	0.1	0.35	0.1	16.6	0.1	0.2
Na_2O	0.05	–	–	0.05	0.1	0.25	–	–	–	–
K_2O	0.05	–	–	0.02	0.07	0.1	–	–	–	–
SO_3	–	–	0.02	0.07	0.13	0.1	–	–	–	–
Total	100.0	100.0	100.0	100.0	100.00	100.0	100.0	100.0	100.0	100.0

Deposits: 1 – Satkinskoe (average of 130), 2 – Kirgiteiskoe (average of 165), 3 – Savinskoe (average of 118), 4 –Torshak, central part (sample Ir-1), 5 – Torshak, margin part (Ir-2), 6 – Subzshirino, central part (Ir-3), 7, 8, 9, 10 – Subzshirino, zonal sample (7 – central part, 8 – first intermediate part, 9 – second intermediate part, 10 – marginal part). Analyses 1–3 (Urasina et al., 1993).

commercial geologists (verbal communication). According this, the deposits of this type are formed in 2 stages. The first stage is the leaching of Mg^{2+} from Mg-ferrous silicates and previously deposited $MgCO_3$ during weathering and removing down of carbonic-acid waters, containing Mg ions in a zone of increased temperature (related to former volcanic activity). The second stage is the deposition of $MgCO_3$ from ascending warm waters in the upper levels of the lithological column.

Relatively low average MgO content (75–88 %) is characteristic for cryptocrystalline magnesites. The most widespread admixture minerals and rocks in cryptocrystalline magnesites are the fragments of altered ultrabasics, amorphous SiO_2, dolomite, Fe-hydrooxides and other minerals. The heterogeneous fragments and particles, larger than 10 mm can be separated by benefication using the heavy suspension. The flotation is necessary to separate amorphous silica, dolomite, and Fe-hydrooxides.

Magnesite of carbonate complexes occurs among crystalline rocks of different degree of metamorphism. Minerals of amphibolite facies are characteristic for the East-Sayanskaya province deposits, talc and chlorite for the Udereiskaya province deposits and chlorite for the Satkinskoe deposit. The chlorite is found directly in magnesite ore of this deposit. The high MgO content is characteristic for crystalline magnesite deposits. However, dolomite beds are constantly present in magnesite series. The size of fragments after crushing of magnesite ore is 20–50 mm that is why the enrichment in heavy suspension is possible.

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Exploration of talc deposits in Paraná State, Brazil

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Abstract

The Paraná talc district is located in southern Brazil and contributes with 50 % of the Brazilian production of this commodity. The host rocks of its talc deposits are dolomite marbles which belong to a metavolcanosedimentary sequence of the Itaiacoca Group, Late Proterozoic. This sequence suffered a strong ductile and ruptile deformation with nappe structures. The region, during late tectonic process, was affected by great transcurrent faults. The talc bodies are veins and irregular pockets. The talc minerals are sparry and micro-crystalline ones forming massive and disseminated ore deposits. The genesis of the deposits is metamorphic and hydrothermal There are lithostratigraphic, lithologic, structural and morphologic deposit controls that are used for prospecting in Paraná talc district. The contrast of electrical properties between talc bodies and carbonatic host rocks, makes possible and recommendable the application of Spectral Induced Polarization (SIP) and Resistivity methods for geophysical prospecting for talc deposits in Paraná. In the past, mining in this district had caused various environmental impacts, but in recent years, this problem has been overcome.

Key words: talc, genesis, control, exploration, environmental impacts, Paraná, Brazil

Introduction

In Paraná State, Brazil, the main deposits of talc are situated in Castro and Ponta Grossa regions. These deposits belong to the Paraná talc district which is constituted by approximately 40 talc deposits. The Paraná talc district is located in southern Brazil (Fig. 1). The talc deposits in Paraná State contribute with 50 % of the Brazilian production (Gondim, 2000b).

Geological setting

The host rocks of the deposits in Paraná talc district are dolomite marbles of the Itaiacoca Group, Late Proterozoic (Figs. 2 and 3). This lithostratigraphic unit was described for the first time as Itaiacoca Formation by Almeida (1956) that focuses mainly dolomite marbles with the presence of stromatolitic features and diverse interposing quartzite layers. Hasui et al. (1984) elevated the Itaiacoca Formation to group category. Souza (1990) defined four formations of this group, one of them the Bairro dos Campos Formation that correspond to Tanque Grande Formation of Lima et al. (1993). This formation is composed by dolomite marbles (host of talc deposits), quartzites, metacherts, phyllites, and acid to basic metavolcanic rocks (tuffs and pyroclastics) described by Reis Neto (1994).

The metavolcanosedimentary sequence suffered a strong ductile and ruptile tectonic deformation with nappe structures. The region, during the end of tectonic process, was affected by great transcurrent faults of NE direction.

The metavolcanosedimentary sequence was intruded by two batholitic granite bodies: the Cunhaporanga and Três Córregos granite complexes, situated respectively to NW and SE of the talc deposits area. These bodies are polydiapiric granites, mainly syntectonic, dated on 550 Ma.

The region presents several dolerite dykes of thickness from 5 to 30 meters, vertical to sub-vertical dip, intruded during the Cretaceous.

In the south of the region, the Proterozoic sequences and the granite bodies are overlaid by horizontal sandstone layers of Furnas Formation from the Devonian. These sandstones belong to the Phanerozoic Paraná basin.

Characteristics and genesis of talc deposits

The deposits of Paraná talc district have vein and irregular pocket forms. The talc minerals are sparry and microcrystalline, forming massive and disseminated ore deposits hosted by dolomite marbles.

The talc is generally *in situ,* but there are some deposits that present allochthonous concentration. This kind of talc mineralization is remobilized by karstic dissolution or by colluvionar process.

The metamorphic talc bodies are concordant with the regional NE trend of the sedimentary and metamorphic structures. The hydrothermal talc deposits are also concordant, but some discordant veins are found.

The talc mineralization is pervasive in dolomite marbles forming deposits elongated in NE–SW direction, along the layers (S_0) and faults. These deposits present se-

Fig. 1. The Paraná talc district located in Southern Brazil.

veral hundred meters in length (NE) and up to one hundred meters in width and depth.

The talc minerals are mainly white, but they are also light green, light yellow and pink. The common impurities are dolomite, chlorite, tremolite, sericite, quartz and pyrites. The secondary Fe-oxides are common impurities in talc deposits of the Paraná district.

All deposits in this district are mined by open pit methods. The dolomite marbles with disseminated talc minerals are mined to ceramic use. The production in the region could be classified in three kinds of talc: pure, middle pure and impure.

There are two kinds of mineralization processes of talc in the deposits of the Paraná talc district:

1. Regional dynamothermal metamorphism (orogenic metamorphism).
2. Hydrothermalism.

There are three types of talc deposits in this district:

1. Talc deposits constituted by metamorphic mineralization.
2. Talc deposits constituted by hydrothermal mineralization.
3. Talc deposits with both kinds of mineralizations.

The talc mineralization was mainly formed by the reaction:

$$3\ CaMg(CO_3)_2 + 4\ SiO_2 + H_2O = Mg_3(OH)_2Si_4O_{10} + 3CaCO_3 + 3CO_2$$

This reaction occurred in dolostone during the regional metamorphism. It also occurred in the dolomite marbles during the action of hydrothermal systems associated to the intrusion of the granites.

Prochaska (2000) suggested a similar genetic model of hydrothermal transport to talc deposits in Austria.

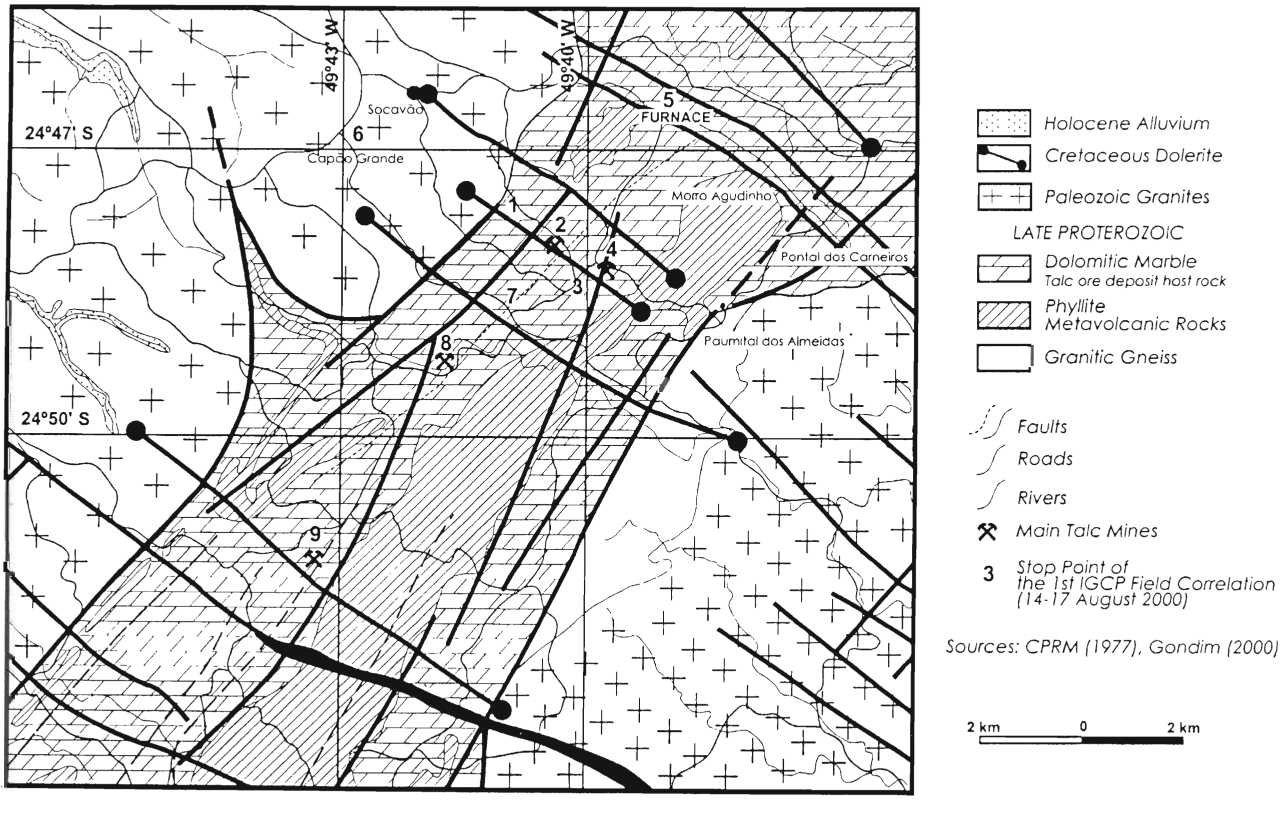
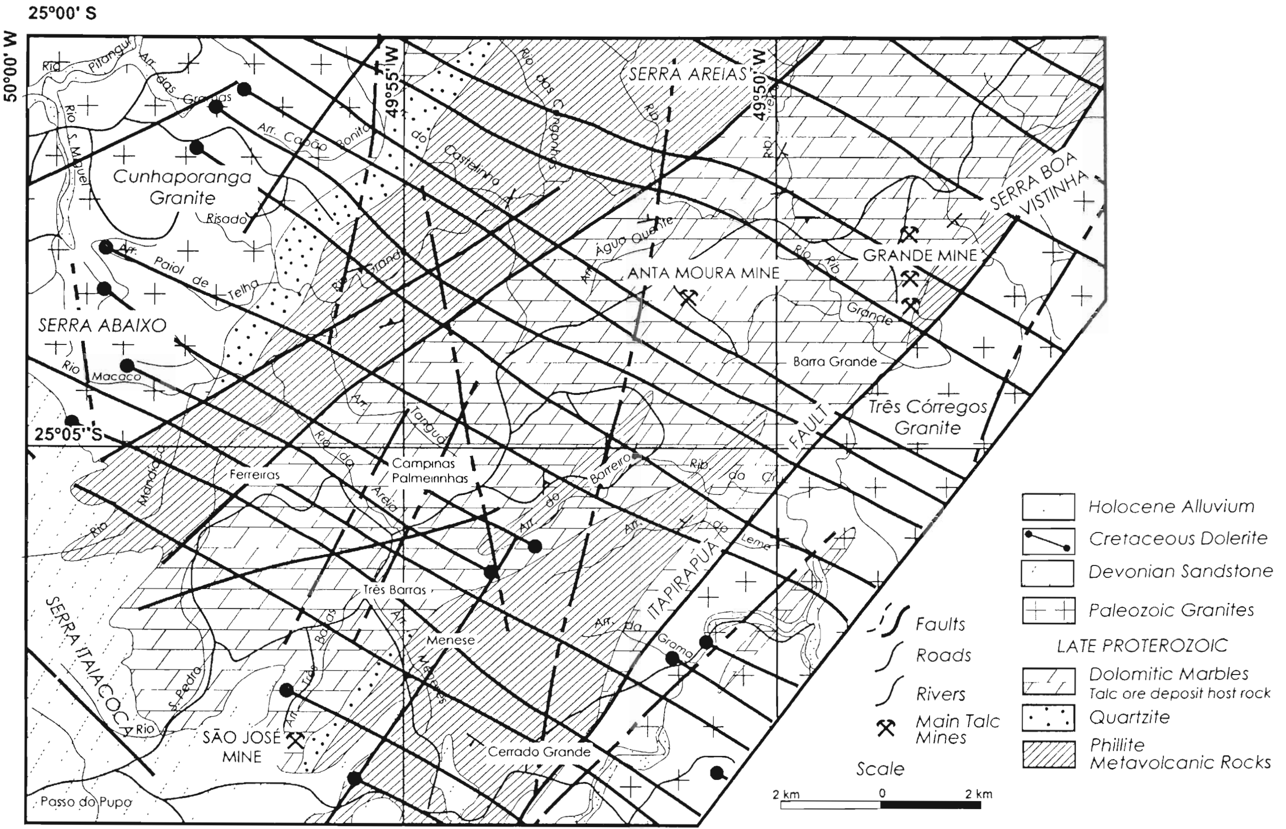


Fig. 2. Geological map of the Paraná talc district – Castro/Socavão region.



Sources: CPRM (1977) Gondim 2000

Fig. 3. Geological map of the Paraná talc district – Ponta Grossa Region.

Now the IGCP 443 project is searching characteristics that would be evidence to construct a genetic model with more precision in formation temperature, source of elements and solution that formed the talc mineralization. The research is focused on fluid inclusion studies and stable isotopes determination on talc minerals and their host rocks.

Deposit controls and exploration

There are several controls of talc deposits in talc Paraná district:

1. Lithostratigraphic control: Itaiacoca Group (Late Proterozoic).
2. Lithologic control: dolomite marbles.
3. Structural control: fault systems.
4. Morphologic control: dolerite dykes (direction NW, vertical dip) and quartzites (direction NE, subvertical dip). These rocks are more weathering resistant than the host dolomite marbles, protecting the talc bodies against the erosion (Fig. 4).

The exploration of talc in Paraná considers these various controls. The structural and morphologic controls are determined by aerial photos and satellite images, sometimes geophysical magnetic methods are used to detect dolerite dykes configuration. The contrast of electric properties between talc bodies and carbonatic host rocks, makes possible and recommendable the application of Spectral Induced Polarization (SIP) and Resistivity methods for geophysical prospecting of the talc deposits in Paraná district.

Environmental conditions

The First Paraná Plateau, where the talc ore deposits are situated, is a subtropical region, with annual rainfalls up to 1,400 mm and average temperature around 16 °C. This humid environment was covered with huge *araucaria* trees that were exploited during two centuries for wood and firewood. Acid soils restricted the agricultural activities to small subsistence crops and impoverished pasture for cattle, so that only familiar dispersed farmers lived in this area.

The talc mining activities based in small open pits require a multiplicity of mines, in order to maintain the production. The life span of each mine is very short, therefore it is common to find abandoned dirt roads and a profusion of mined areas that are subjected to erosion, landslides and sedimentation. Nevertheless in the last decade, according to the new laws and environment regulation agencies, mining companies have started to recuperate degraded areas.

In order to dry the various kinds of talc extracted, it is necessary to employ several furnaces. Gas or wood with continuous reforestation are good choices as combustible.

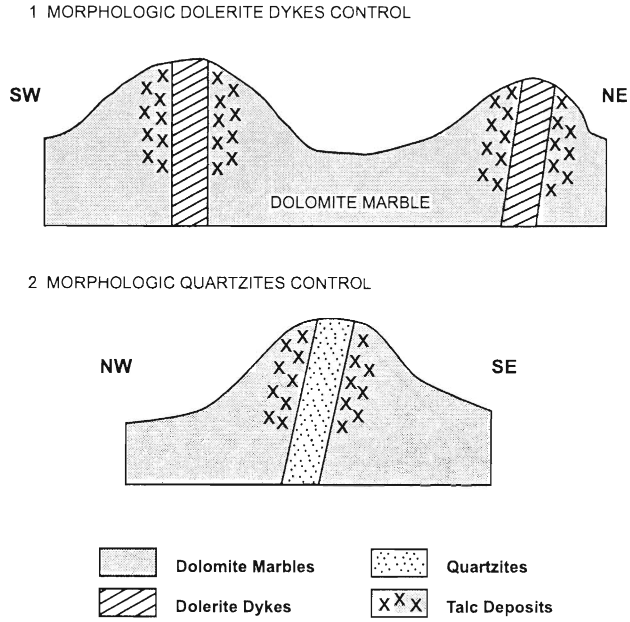


Fig. 4. Morphologic control of the talc deposits, Castro and Ponta Grossa region Paraná State – Brazil.

Then, it is possible to avoid the use of native vegetation that commonly happened in the past and caused enlarging of the surface of clear cuts and depletion of the riparian forest.

Economic aspects and use of the talc commodities of Paraná

The State of Paraná produce 50 % of the talc produced in Brazil. The annual production is approximately 145,000 tonnes. In Paraná there are not economic reserves of pyrophyllite, so this mineral is not producted here.

The talc of Paraná, in its different purity grades, has found a steadily increasing number of uses:

1. Pure talc: used in paint, paper filler, food industries, special rubbers, pharmacy products, cosmetics and colour pencils.
2. Middle pure talc: used in rubbers, refractory industry and electrical and domestic ceramics.
3. Impure talc: used in ceramic to civil construction (flooring and roof materials).

The production of the talc district of Paraná has been commercialized mainly in São Paulo and the states of Brazilian southern region: Paraná, Santa Catarina and Rio Grande do Sul.

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The talc-magnesite deposits of Serra das Eguas, Bahia State, Brazil

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Abstract

The metavolcanosedimentary complexes that occur in the central belt of the São Francisco Craton in the State of Bahia, Brazil, are depicted by the presence of Pb-Zn sulphides, BIF, banded Fe-Mn, dolomite-magnesite, and talc deposits. They represent the products of the subaqueous chemical depositions in specialized evaporitic basins that took place during the Paleoproterozoic times. The Serra das Eguas in the Brumado region is the main producer area of magnesite of Brazil and its ore reserves are up to 150 millions tonnes. The main lithologies of the Serra das Eguas are those related to the Ibitira-Brumado metavolcanosedimentary complex and they include lithotypes derived from volcanic flows and tuffs, chemical and, in minor proportion, clastic sediments. In this complex the magnesite-rich horizons are set between the silicate facies, at the stratigraphic footwall and orthoquartzites or dolomitic quartzites, at the stratigraphic hanging wall. They constitute continuous strata up to 700 m in thickness and over 1,300 m in length and lens-like bodies from facies variation in the siliceous-dolomitic strata. More than 75 % of the ore reserves is made up of high quality crystalline magnesite that is classified into three types with the basis on the MgO content of the sintered produced magnesia.

Key words: Brazil, São Francisco Craton, Paleoproterozoic, metavolcanosedimentary terranes, Ibitira-Brumado complex, magnesite deposits, Serra das Eguas

Introduction

The Serra das Eguas is located northwest of the town of Brumado in the southern portion of the central belt of the São Francisco craton in the State of Bahia (Fig. 1). It is the main producer of magnesite and it ranks second in the Brazilian talc production (DNPM, 2000). Although some records on the existence of sparry magnesite crystals in the Brumado area go back to the end of the 19th century, this industrial raw material is assumed to be discovered there in 1938 by emerald prospectors and that soon motivated some geologists to carry out a series of study in the area (e. g. Barbosa, 1943; Leonardos, 1943; Melo Jr., 1943; Gama, 1946). Its rational exploration started in 1945 when was made the first technical work on the reserves and quality of the ore, whose data were later published in the USGS Bulletin (Bodenlos, 1954). The Serra das Eguas is a NNE elongated canoe shaped topographic feature, formed by a series of hills (hills means "serra" in Portuguese). These are made up by metamorphosed chemical sediments that stand up a brachysynclinal structure flanked by Archean high grade schists (gneisses) in the eastern border, and by migmatites in the western border (Fig. 2). During the Transamazonian cycle (2.6 to 1.8 Ga) a tectonothermal episode occurred in this portion of the São Francisco Craton and it was marked by migmatization and granitization that culminated with granite emplacements. Pinto et al. (1998) presented good evidences that these granites are the product of crustal recycling processes that took place from 1.8 to 2.2 Ga. Among the four mining companies that operate in the area the biggest one has an installed capacity located in the Catiboaba industrial village of 330,000 tonnes/year of sintered magnesia. Talc is commonly associated to the magnesite and in places it may constitute economical deposits. Its proven reserves that subordinately include those talc which is associated to the basal silicate facies amount nearly 12 million tonnes (Carvalho, 2000a). The distribution of the most important talc and magnesite deposits is shown in the Fig. 2. These deposits are quoted in Tab. 1 with the respective number.

Geological framework

The main lithologies of the metavolcanosedimentary complexes that occur in the central belt of the São Francisco craton in the State of Bahia were previously considered by the author (Carvalho, 2000b). They comprise lithotypes derived from volcanic flows and tuffs, chemical and, in small proportion, clastic sediments. The volcanism was alkaline to perialkaline and the volcanic rocks were almost entirely altered by the granitization-migmatization

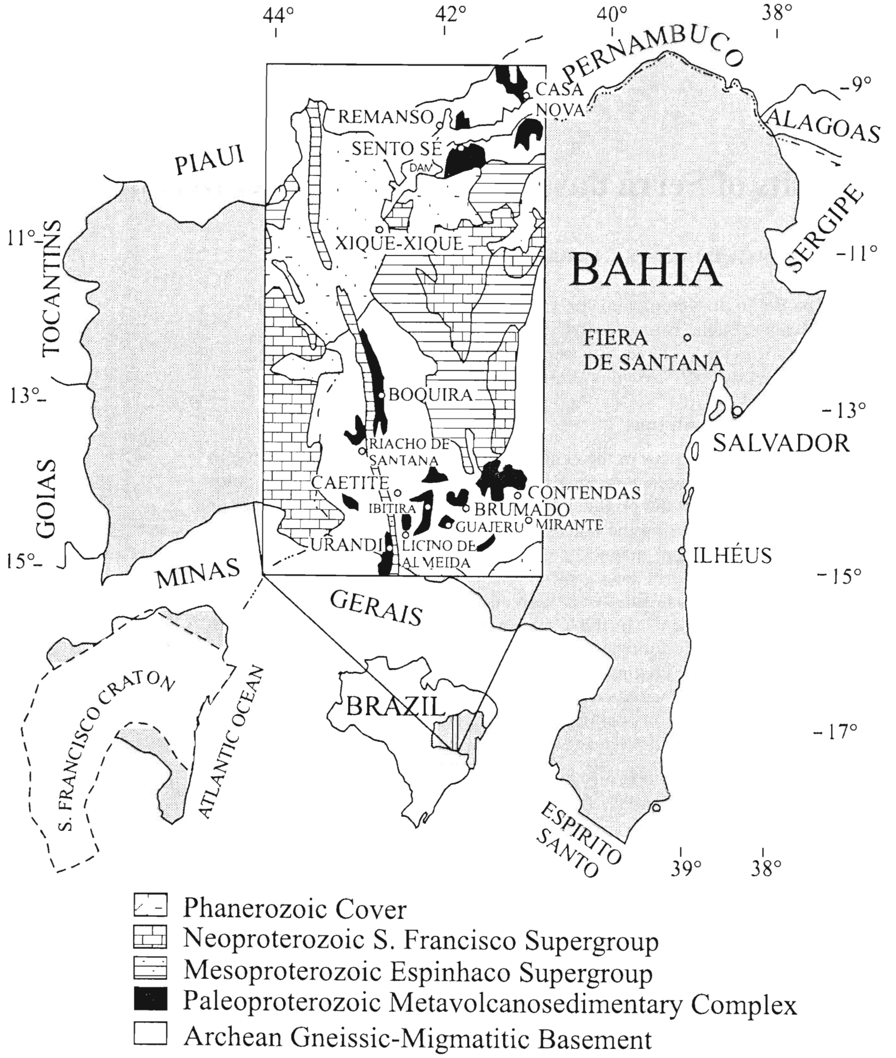

Fig. 1. Location of the metavolcanosedimentary complexes including the general geology of Central Bahia.

processes into schistose materials, including quartz-mica, quartz-sericite, quartz-chlorite, quartz-biotite, muscovite, chlorite and garnet schists. Carvalho (2000b) and Carvalho and Albuquerque (1996) described the facies variation of the chemical deposition and the rocks that were derived from it. From the shallow oxidizing to the deep reducing depositional zone these rocks include: itabirite (oxide facies of BIF), metachert, ferrugineous quartzites and orthoquartzites, banded carbonates-amphiboles-martite (carbonate facies of BIF) and amphiboles-magnetite lithotypes (silicate facies of BIF). Sulphide facies which is mineralized in lead and zinc is only reported in the Boquira complex (Carvalho et al., 1982, 1997). Banded iron-manganese and manganese formations are only reported in the southwestern portion of this central belt, more precisely in the Urandí, Jacarací-Licinio de Almeida, and Caculé-Caetité complexes (Fig. 1) where they may be in association with BIF and they constitute the major important source of manganese ore in the State of Bahia. Magnesite occurs as continuous strata as well as lens-like bodies that are formed by facies variation in the iron poor dolomitic or siliceous dolomitic layers that lay on the amphibole-rich lithotypes that represent the base of the chemical deposits in the Barreiro-Colomí (Sento Sé area), Boquira (Contendas area) and Ibitira-Brumado (Serra das Eguas area) complexes.

The Serra das Eguas is formed by an isolated series of hills that stand up 600 meters over the surrounding Archean gneiss-migmatitic complex. It constitutes an elongated synclinorium structure formed by a deformed narrow synclinal whose the main axis strikes in the N20°E and its western border was faulted perpendicularly to the compressive stresses and it was tilted to give the local present day appearance of an inverted stratigraphy. This NE–SW overthrust basculating fault system is disrupted by a set of faults that strick nearly parallel to the N45°W direction and that also affected both Paleoproterozoic sequence and Archean basement.

From the base to the top the chemical metasediments which are present in the Serra das Eguas (Fig. 3) are classified into the following groups of rock suites: amphiboles-rich layers of the silicate facies, calc silicate rocks plus iron-poor magnesian-rich carbonate formation (IPMRCF), siliceous dolostones and dolomitic quartzites, ferrugineous metachert and itabirite (oxide facies of BIF).

The silicate facies unconformably lies on the old basement and locally on the undifferentiated schists which are made up by schistose rocks derived from volcanic flows and tuffs. It corresponds to amphiboles-rich strata in which alternations of amphiboles-rich and magnetite-rich bands may be noticeable. The commonest types of amphiboles are those of the tremolite-actinolite and hornblende series. Subordinately occur amphiboles of the cummingtonite-grunerite series. Four talc occurrences (18, 19, 20, and 21) from those listed in Table 1 are typically related to this facies where talc occurs in association with amphiboles of tremolite-actinolite and hornblende compositions. The presence of amphiboles is not restricted to this facies. They are also present as sub-banding in the calc-silicate rocks and they may be locally reported in the magnesitic and dolomitic marbles of the IPMRCF as well as in the amphibolites derived from mafic flows and that occur in the not differentiated schists at the interface between the chemical sediments and the gneissic basement.

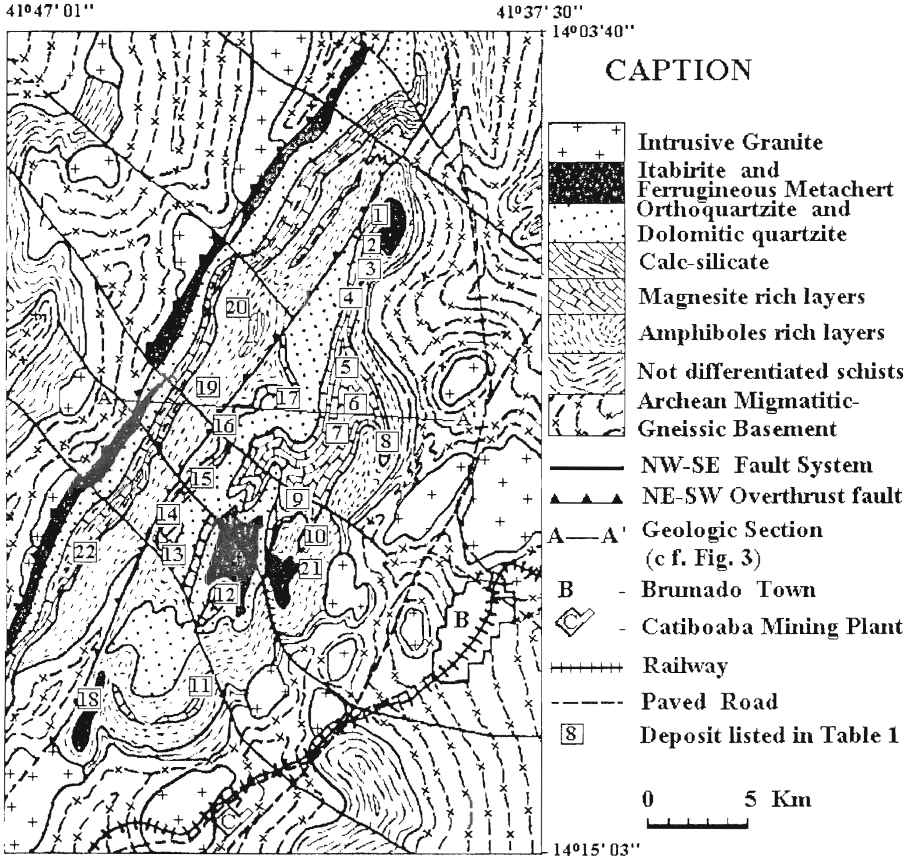

Fig. 2. Geology of the Serra das Eguas and distribution of the major magnesite and talc deposits.

The iron-poor magnesian-rich carbonate formation (IPMRCF) overlays the amphiboles-rich lithotypes of the silicate facies. It is economically important because of the presence of the thick magnesitic horizons and deposits of talc of good quality. It must be noted that in the Serra das Eguas the stratigraphical position of this magnesitic layers which may be in subordinate association with dolomitic levels corresponds to that one positioned by the carbonate facies of a normal worldwide BIF sequence. However, in the Serra das Eguas the FeO content in these carbonates rarely exceeds 2 %. So it is much lower than that one of 19.3 % suggested by James (1954) for the lower limit of iron content to define the BIF's facies, and by this reason the

Tab. 1
The major ocurrences of talc and magnesite of Serra das Éguas referenced as in Fig. 2

Reference (cf Fig. 2)	Name	Type of Ore	Host Lithology
1	Morro Grande	Magnesite and talc	IPMRCF
2	Campo de Dentro I	Magnesite	IPMRCF
3	Campo de Dentro II	Magnesite and talc	IPMRCF and silicate facies
4	Pedra Rolada	Talc and magnesite	IPMRCF and silicate facies
5	Pedra Pedra	Magnesite (and talc)	IPMRCF
6	Jatobá	Magnesite and talc	IPMRCF
7	Pomba	Magnesite	IPMRCF
8	Salgada	Talc	IPMRCF and silicate facies
9	Bate Pé	Magnesite	IPMRCF
10	Boa Vista	Magnesite	IPMRCF
11	Fábrica	Magnesite and talc	IPMRCF and silicate facies
12	Pedra de Ferro/Catiboaba	Magnesite	IPMRCF
13	Cordeiro	Talc and magnesite	IPMRCF
14	Coité	Talc and magnesite	IPMRCF and siliceous dolostone
15	Cabaceiras	Magnesite and talc	Siliceous dolostone and IPMRCF
16	Pirajá	Magnesite and talc	IPMRCF and silicate facies
17	Gravatá-Mineiro	Magnesite	IPMRCF and siliceous dolostone
18	Taboa	Talc	Silicate facies
19	Grota da Lavadeira	Talc	Silicate facies
20	Morro do Sobrado	Talc	Silicate facies
21	Covil das Onças	Talc	Silicate facies
22	Sâo Lourenço	Dolomite	Siliceous dolostone

IPMRCF – iron-poor magnesian-rich carbonate formation

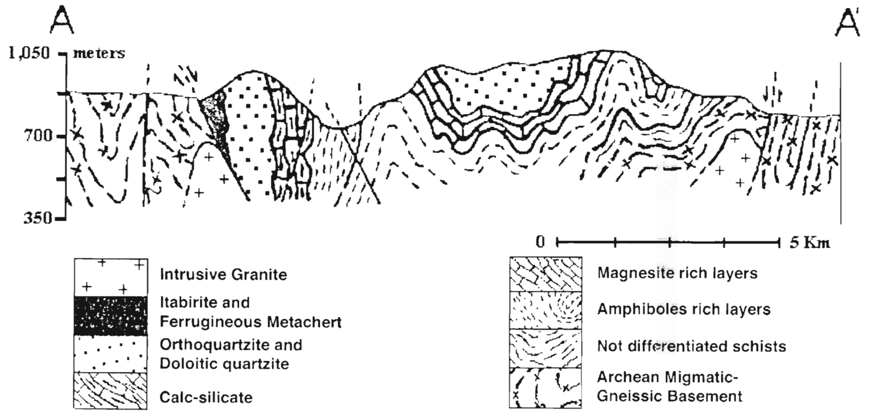

Fig. 3. Geological cross section of the central portion of the Serra das Eguas (modified from Oliveira et al., 1997).

IPMRCF can not be considered as carbonate facies of BIF.

The calc silicate suite of rocks mainly occurs in the western flank of the Serra das Eguas synclinorium and it is in the same stratigraphic position as that one positioned by the previously described magnesian carbonates. With this in mind it may be assumed that the calc-silicate rock suite are the product of siliceous metasomatism on chemical sediments. Carvalho (2000a, b) pointed out that the silica that affected the preexisting chemical sediments may result from the processes of migmatization and granitization. However the idea that this rock suite may represent a primary facies variation of the IPMRCF may not be neglected. This compositional change in the IPMRCF which is marked by the increasing in silica towards west may resulted from a more effective silica supply during the depositional process. The mineral assemblage includes diopside, tremolite-actinolite, quartz, hematite, epidote, talc, dolomite, and magnesite. In places the content of one of these minerals may overwhelm in proportion the others to constitute rock types like diopsidite, tremolitite, quartzite, epidosite, steatite, and dolomitic and magnesitic marbles.

Siliceous dolostones and dolomitic quartzites occur as vertical facies variation by enrichment in silica of both IPMRF and calc silicate suite. They have a mosaic texture made up of coarse to medium sized grains of dolomite and quartz. These minerals may be concentrated in elongated seams and clots and they are present in variable proportions that led to the formation of lithotypes that change in composition from almost pure orthoquartzite to siliceous dolomitic marbles. It is succeeded in the vertical by the orthoquartzite, ferrugineous metachert and itabirite.

Metachert and oxide facies of BIF: In the Serra das Eguas metachert and itabirite mainly occur overlaying the siliceous dolostones and dolomitic quartzites). This is a silica-rich facies that occurs (a) as metacherts and quartzites that may contain accessory amounts of carbonates, iron oxide and silicate minerals that may be concentrated in poor defined bands, (b) ferrugineous chert that may grade into true itabirite.

Geochemistry of magnesite deposits

The most of the exploited magnesite is medium grain sized carbonate of distinct white, pink, green, gray, and chestnut shades of colour. The crystal chemistry of the magnesite (Carvalho, 2000b) shows a MgO average content of 44.96 %, and <1 % of CaO, <0.6 % of FeO, <0.3 % of SiO_2, <0.1 % of MnO, <0.01 % of BaO, traces (<0.006 %) of Al_2O_3 and absence of TiO_2, NiO and Cr_2O_3. These compositional values are not too much different from those ones of the bulk composition of the dis-

Tab. 2
Types of exploited magnesitic ores classified on the basis of the composition of the commercial products

Type of ore	Comercial product						Major destination
	Kind of ore treatment		Chemical specification (%)				
	Calcination	Calcination plus sinterization	MgO	CaO	SiO_2	Fe_2O_3	
Type caustic	Caustic magnesia		87–92	2.0–2.5	1.0–4.0	< 4.5	Metallurgy, ceramic, cosmetic, fertilizer, pharmo-chemicals, animal ration, paper
Type Mg-s		Magnesian sinter	> 92	≤ 2.0	≤ 0.6	2.5–4.5	Refractory industry to manufacture several types of products to meet the needs of the cement, steelmaking, non ferrous and glass industries
Type 1		M-10 Sinter	93–95	≤ 1.0	≤ 1.5	≤ 2.5	
Type 2		M-20 Sinter	≥ 95	≤ 1.0	≤ 1.0	≤ 2.0	
Type 3		M-30 Sinter	≥ 98	≤ 1.0	< 1.0	< 1.0	

(Source: Silva, 1973 and Queiroz, 1997)

Tab. 3
Data of $\delta^{13}C$ and $\delta^{18}O$ from the Boquira (1) and the Ibitira-Brumado (2) metavolcanosedimentary complexes

Analyzed sample	(Provenance) Remarks	$\delta^{13}C$	$\delta^{18}O$
Coarse sparry calcite from the mineral assemblage of the Pb-Zn sulfide ore	(1) Gang mineral. Boquira Pb-Zn ore	-3.85 -4.18 -5.24 -5.55	12.96 14.08 13.67 14.20
Sparry calcite from crosscut vein in the silicate facies	(1) Host unit of the Boquira Pb-Zn ore	-4.03	21.46
Micritic carbonate from transitional zone between carbonate and silicate facies (>5 % of martite)	(1) Pelado. Cruzeiro and Sobrado mines of Boquira	-0.39 -1.03 -1.26 -2.16 -2.23 -2.66 -3.58	9.97 9.06 11.03 10.25 8.58 11.10 9.28
Silicate bearing carbonate facies (tremolite >25 % and <5 % martite)	(1) Contendas dolomitic marble	-0.61 -0.88 -0.97	14.04 13.45 13.77
Silicate bearing carbonate facies (<10 % tremolite, <5 % chlorite, accessory martite, traces of talc)	(1) Magnesite bearing Contendas dolomitic marble	3.34 3.28	14.83 14.79
White crystalline magnesite	(2) Serra das Eguas	-1.37 -2.55	19.67 21.15
White crystalline magnesite with accessory tourmaline, and reddish spots	(2) Serra das Eguas	-0.25	17.52
White crystalline magnesite with accessory thin tourmaline crystals	(2) Serra das Eguas	-0.42	21.54
Fine crystalline chestnut magnesite with accessory magnesite	(2) Serra das Eguas	-1.52	19.12
Concretionary micritic white magnesite	(2) Serra das Eguas	-6.31	26.43
Sparry dolomite	(2) Serra das Eguas	1.78	-14.76
Fine grained whitish dolomite	(2) Serra das Eguas	-0.73 0.94	20.11 16.92
Fine grained white dolomite with disseminated accessory amphibole crystals	(2) Serra das Eguas	-1.40	23.23
Grayish crystalline dolomite with accessory amphiboles	(2) Serra das Eguas	-1.82	23.08
Gray crystalline dolomite with accessory amphibole and pyroxene	(2) Serra das Eguas	-0.91	21.41
Fine crystalline chestnut dolomite with accessory amphibole	(2) Serra das Eguas	-1.92	16.91

(Sources: 1 – Carvalho et al., 1982 and 2 – Lima, 1986)

tinct magnesitic lithotypes. The range in the compositional data presented by Queiroz (1997) for the majority of the exploited ore is: 47.6 to 51.0 % for L.O.I., 44.4 to 48.2 % for MgO, 0.3 to 2.6 % for SiO_2, 0.1 to 1.5 % for Fe_2O_3, 0.1 to 1.0 % for CaO and 0.0 to 0.6 % for Al_2O_3. For the deposits located in the siliceous dolomitic facies (e. g. Lagoa do Fundo e Barroca do Veado) it is reported a higher degree of impurities that shifts the average MgO content to 40.7 %. The ore is classified into five types which are in accordance with the MgO content of the commercial sintered magnesia (dead burned magnesite) (Tab. 2). Besides magnesite the mineral assemblage includes accessory to traces content of dolomite, quartz, opal, hematite, talc, amphiboles (mainly tremolite), tourmaline (mainly dravite), calcite, garnet, and chlorite.

Although there is no precise stratigraphic control, the most important talc deposits are spatially related to the magnesite deposits. The stable isotopic analyses and car-

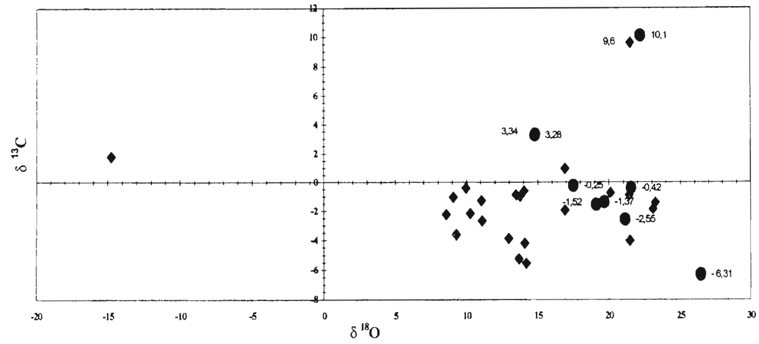

Fig. 4. Dispersion diagram of the isotopic data presented in Tab. 3 plus data presented by Melezhik et al (2001) for Paleoproterozoic magnesian carbonates of the NW-Fennoscandian Shield (Caption. • – magnesite, ♦ – other carbonates).

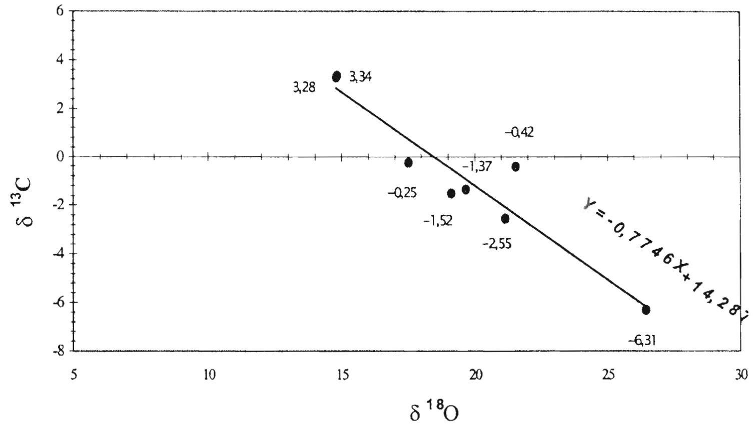

Fig. 5. Dispersion of the oxygen and carbon isotopic data shown in Tab. 3 for magnesite from Bahia.

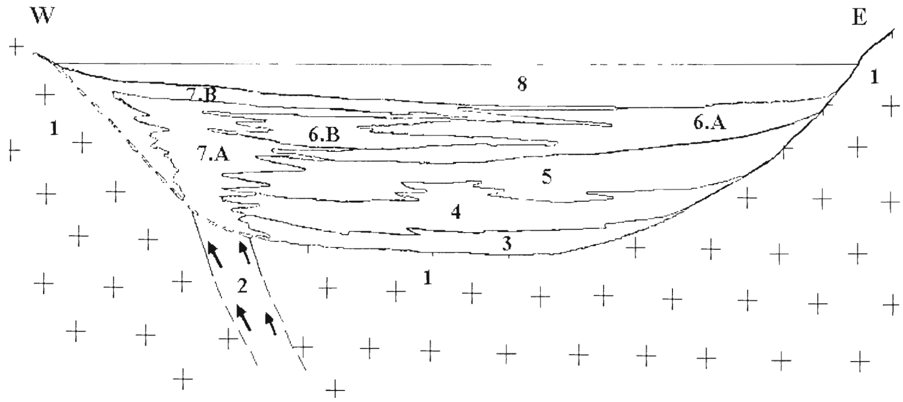

Fig. 6. Sketch of the idealized sedimentary model for the Serra das Eguas. 1 – archean basement, 2 – feeder zone, 3 – volcanic tuffs and flows, 4 – silicate facies, 5 – IPMRCF, 6.A – siliceous carbonate, 6.B – dolomitic quartzite, 7.A – metachert and orthoquartzite, 7.B – ferrugineous chert and itabirite, 8 – high soluble salts ("salada" type deposit), 9 – Paleoproterozoic atmosphere

bon and oxigen reported by Lima (1986) for magnesite and dolomite from the Serra das Eguas are presented in Tab. 3 that also brings data from Carvalho et al. (1982) for carbonates from the Boquira complex that includes a magnesitic sample from Contendas, south of the Boquira Pb-Zb District (Fig. 1). These data are plotted in the $\delta^{18}O_{SMOW}$ and $\delta^{13}C_{PDB}$ diagram of Fig. 4 that also includes the average values obtained by Melezhik et al. (2001) for Paleoproterozoic magnesian carbonates from the NW-Fennoscandian Shield. The $\delta^{18}O_{SMOW}$ and $\delta^{13}C_{PDB}$ data brought in Tab. 3 for the magnesites from the Serra das Éguas are plotted in Fig. 5. For the magnesites from Serra das Éguas the $\delta^{13}C_{PDB}$ and $\delta^{18}O_{SMOW}$ values range from -2.55 to -0.25 ‰ and from 17.52 to 21.54 ‰. Lower $\delta^{13}C_{PDB}$ and higher $\delta^{18}O_{SMOW}$ is yielded for the very fine concretionary magnesite. For the coeval dolomites the $\delta^{13}C_{PDB}$ values shift from -1.92 to 0.94 ‰ and the $\delta^{18}O_{SMOW}$ from 16.91 to 23.23 ‰. From these data it is observed that (a) in spite of the magnesite tends to be slightly richer in the heavy isotopes than the overall coeval calcite-dolomite carbonates, the magnesite and carbonates from the Serra das Eguas exhibit a similar enrichment in ^{18}O relative to ^{16}O, (b) in the dispersion $\delta^{18}O$ X $\delta^{13}C$ diagram the data from the Serra das Eguas magnesites exhibit a well defined linear distribution whose expression of regression is $\delta^{13}C = -0.77746\ \delta^{18}O + 14.287$, and (c) the carbonates from the Boquira and Ibitira-Brumado metavolcanosedimentary complexes are much more enriched in ^{12}C than those ones from the NW-Fennoscandian Shield.

The higher $\delta^{13}C$ values for the Russian deposits are interpreted by Melezhik et al. (2001) as due to perturbation of the carbon cycle of the global carbon reservoir at 2.0 Ga which is assumed around 5 ‰, and from local factors to include evaporation and high bioproductivity.

Final discussion and conclusion

The common geological features reported for the metavolcanosedimentary complexes shown in the Fig. 2 support the idea that they were generated by similar processes that took place from the end of the Archean to the beginning of the Proterozoic (Carvalho, 2000b; Carvalho et al., 1997) and throughout an extensive but already individualized crustal segment. There is no stratigraphic control for the chemical sediments; in many places they have a gradual metasomatic contact with the gneissic-migmatitic basement or they grade into the volcanic derived rocks that constitute undifferentiated schists. In these places it is frequent the association with calc-silicate rocks and talcification. Carvalho (2000b) also pointed out that the common geological features of these complexes reflect a common origin in which history the chemical deposition occurred from brines in specialized basins. Similar genetic model has been recently suggested for the deposits of the Liaoning and Jilin Chinese provinces (Jiang et al., 2001), the deposits of eastern Austria (Prochaska, 2001), and for the Russian deposits described by Melezhik et al. (2001), Krupenin and Ellmies (2001), and Nasedkin et al. (2001). However as it is suggested from the models of Prochaska (2001) and Krupenin and Ellmies (2001), if it is assumed that in the Serra das Eguas there was migration of descending Mg-enriched fluid, meteoric water was not significantly involved in the process. This interpretation is assigned by the fact that the magnesite from the Serra das Eguas is slightly enriched in ^{16}O (average $\delta^{18}O = 19.8$ ‰) in comparison with the coexisting dolomitic carbonate (average $\delta^{18}O = 20.3$ ‰). In the Serra das Eguas thick layers of magnesite mainly occur in the IPMRCF, as facies variation of dolomitic and subordinately in the calc silicate strata. The latter mostly occur in the western border of the synclinorium structure. As it was pointed out by Oliveira et al. (1997), there is a lateral and vertical change in the composition of the IPMRCF. Actually it is recorded in this stratigraphic unit that the silica, alumina, total iron, and lime contents increase upwards and towards west. This chemical change may be due to (i) the post depositional metasomatism as well as (ii) an inheritance from the original composition of the chemical sediments. To accept the statement as in (i) it must be assumed that the silicified rocks that are mainly reported in the western border are the product of the siliceous metasomatism on the primary chemical sediments. This kind of metasomatism resulted from the processes of migmatization and granitization and it was also responsible for the generation of talc in places where these processes affected the silicate facies and the carbonates of the IPMRCF. The other assumption as it is considered in (ii) is explained by subaqueous deposition in an evaporitic basin whose main supply of the chemical components in the brine may be hot springs from hydrothermal sources that percolated deep fractures. These feeder zones may include the NE–NW fault system, and as it can be seen from the sketch in Fig. 6, this spatial situation made possible the presence of more silicified carbonates in the western portion of the depositional basin.

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Egyptian magnesite and talc deposits: A brief review

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Abstract

Magnesite and talc deposits are considered as some of the most important mineral resources which are widely requested in several industries (chemical, metallurgical, pharmaceutical, ceramics... etc).

In Egypt, magnesite and talc ores occur in many localities in the central and southern parts of the Eastern Desert. These ores are usually associated with metavolcanic and serpentinite rocks. The ores are found in different grades of purity and relatively of economic reserves. The geological field relations, mineralogical and chemical compositions as well as the physical and thermal properties of magnesite and talc ores are presented in the paper Assessment of Egyptian magnesite and talc varieties have to be done through studying the optimum parameters controlling the technological properties using various techniques.

Key words: magnesite, talc, location, qualitative, characteristics, Egypt

Introduction

The present article aims to review the mineralogy, chemistry and metallogeny of the Egyptian magnesite and talc ores in correlation to similar deposits in other parts of the world. Understanding the metallogeny as well as the correct characterization of such deposits will help in prospecting and improve chances to find new ore deposits. This will be achieved by characterization of the ore deposits and selecting the appropriate mineral process to meet the industrial specifications.

Evaluation of Egyptian magnesite and talc deposits involves studying the geological setting and determination of the physical, mechanical, mineralogical, chemical and ceramic properties. This was obtained, in the laboratory, using petrographic, minerological and physico-chemical as well as heat treatment techniques. The present review will tackle carefully the geological field studies, mineralogical and chemical characterization, studying of firing characteristics, following up the vitrification behaviour as well as pore-size distribution, microstructure, microchemistry (EDAX) and phase compositions (El-Sayed, 1995; Salem et al., 1997; El-Maghraby, 2001 and El-Sharkawy et al., 2001). The obtained results from the previously mentioned techniques will lead to selecting the appropriate mineral processes to meet the different industrial specifications.

In the last decades, interest was given to some varieties of Egyptian mineral resources such as magnesite and talc as a source for many basic industries (paints, plastics, rubber, paper, cosmetics and ceramics, ...). The suitability of these ores depends on the study of mineralogical and chemical compositions as well as the physical characteristics of magnesite and talc ores from some localities in the Eastern Desert of Egypt.

Talc-carbonate rocks

Talc-carbonate rocks in the Eastern Desert of Egypt are frequently encountered and were extensively studied by many geologists. The first was Hume (1907) who gave them the name *Barramiya rocks* and later (1934) reported that the talc-carbonate rocks are of light-colour, very soft, talcose and weather into cavities giving the rock a cavernous appearance. Attia (1948) agreed with Hume that the cavernous appearance in the talc is due to the leaching of the carbonates by weathering. These rocks consist mainly of talc and dolomite with minor amounts of antigorite and magnetite. The parent rocks include both dunite and peridotite (Ibrahim, 1942; Amin, 1955 and Shukri and Lotfi, 1955).

According to El-Ramly and Akaad (1960), the serpentinites of the Eastern Desert are typically of the Alpine-type, characterized by the alteration of the peripheral parts of large masses into talc-carbonate rocks as a result of CO_2 metasomatism. Basta and Abdel-Kader (1969) studied the Egyptian talc-carbonates from different localities and stated that these rocks consist mainly of densely packed aggregates of magnesite embedded in a fine-grained matrix of talc.

Akaad and Noweir (1972) studied the serpentinites and their associated talc-carbonates along the Qift-Quseir road. They reported that these serpentinites are highly susceptible to alteration into talc-carbonates as a result of carbon dioxide metasomatism. The talc-carbonates are of wide distribution and occur either in close association with serpentinites or as separate isolated masses.

The Geological Survey of Egypt (1992) studied the talc-carbonate rocks in Gabal Beizah area and reported that the talc-magnesite rocks are the most dominant variety in this area and occur as irregular masses. The proved talc-ore reserves reach up to six million tonnes and the possible ore reserves reach some 500 million tonnes. Within the same framework, Al-Wakeel (1996) studied the talc-carbonate rocks at Wadi El-Barramiya, Atud and Gabal El-Mayit areas. The talc-carbonate at these localities are a mixture of talc and magnesite in different proportions in addition to small amounts of dolomite, serpentine minerals and chlorite.

Magnesite

Magnesite contains 52.4 % CO_2 and 47.6 % MgO. Pure magnesite is rarely found in nature. It is usually associated with small percentages of calcium, silicon, iron and aluminium. Except silica the presence of these elements does not reduce the utility of magnesite for various purposes. Two main commercial grades of magnesia are derived from magnesite ($MgCO_3$): dead burned magnesite (refractory) and light burned magnesite as many industries use magnesia (MgO) as a raw material. Generally, magnesite occurs in two physical forms:

1. cryptocrystalline, amorphous or microcrystalline,
2. crystalline, macrocrystalline or sparry magnesite.

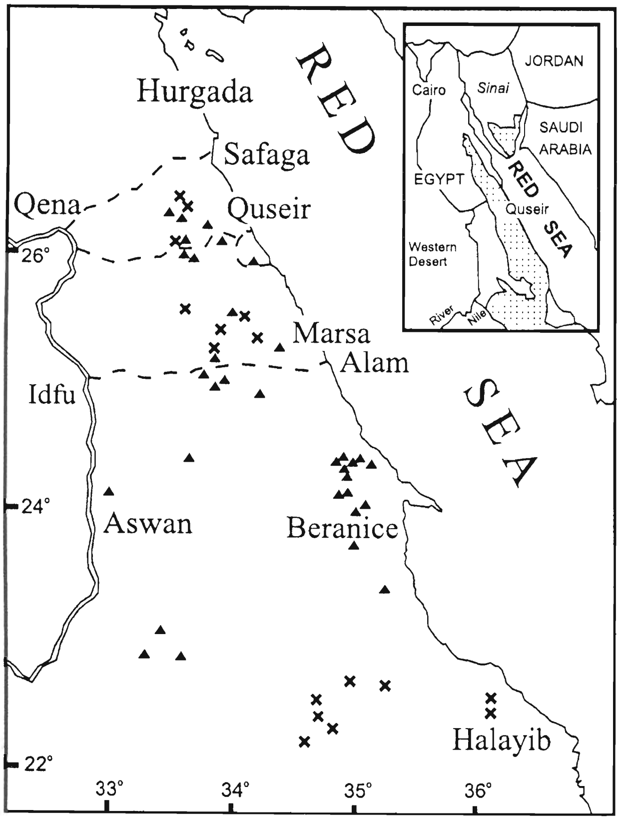

Fig. 1. Location map of magnesite (x) and talc (black triangle) deposits.

Formation of magnesite took place from Proterozoic till Recent. The genesis of magnesite can be explained by metasomatism; magnesites formed by CO_2 metasomatism and those formed by Mg metasomatism. A practical nomenclature of magnesite type could be:

1. Cryptocrystalline, in or affiliated with ultramafics.
2. Crystalline, in sedimentary or metamorphic rocks.
3. Evaporitic magnesite (saline or hypersaline).
4. Magnesites in intramontain fresh water basins.

Concerning magnesite deposits in the world, Pohl (1990) classified magnesite deposits allover the world into two types: *Veitsch type* forming large stratabound lenses within marine platform sediments, which are often interbedded dolomites with limestone and siliceous clastic sediments and *Kraubath type* which is characterized by snow-white cryptocrystalline or microcrystalline magnesite grains and mostly occurs as monomineralic veins or stock present in ultramafic rocks including serpentinites.

Egyptian magnesite deposits are mainly of the Kraubath type. Several authors studied these deposits in different localities (e. g. Umm Salatit, El-Rubshi, Saqi, El-Mayit, Ambaout, Abu Dahr, Sul-Hamed and others) in the Eastern Desert of Egypt. The geology, mineralogy, chemistry and origin of the Egyptian magnesite deposits were recently studied by El-Sayed (1995), Salem et al. (1997), Hassan et al. (1997), EGSMA(1998), Ghoneim et al. (1999), El-Maghraby (2001) and Nasr (2001). The ore occurs as thin veinlets, stockworks and pockets of different lengths and widths. Magnesite was formed during the process of serpentinization to accommodate the excess Mg released during this process (Hussein, 1990).

The petrographic textures and mineralogy of the magnesite veins of El-Rubshi area were studied by Salem et al. (1997) using both stained thin and polished sections, X-ray diffraction (XRD), infrared spectroscopy (IR) and thermal analyses (DTA, TG, DTG). These analyses revealed that the mineral components are represented by magnesite, dolomite, calcite, lizardite and rare amounts of talc. According to the chemical analyses results, the magnesite deposits of Gabal El-Rubshi are classified into: medium-grade ore (44–38 % MgO), low-grade ore (38–30 % MgO) and very low-grade ore (<30% MgO).

The principal use of magnesite is in the preparation of basic refractory bricks. It is manufactured from dead burned magnesite at a temperature of 1600–800 °C when all carbon dioxide is driven off. For commercial purposes, magnesite is graded into two categories: < 2.5 % silica and < 2.5 % up to 4 % silica. Magnesite usually contains impurities like CaO, SiO_2, Fe_2O_3 and Al_2O_3, of all the impurities, silica is regarded most deleterious.

Magnesite deposits are widely distributed in 18 localities in the central and southern Eastern Desert. Magnesite occurs as packets, veinlets and veins of variable lengths and widths within the ophiolitic serpentinites and talc-carbonate rocks. High purity and relatively good reserves characterize the magnesite deposits of Umm El Tuyur El-Tahtani, Sul-Hamed, Abu Dahr, El-Rubshi and Wadi

Saqi areas. Ghoneim et al. (1999) classified the magnesite ocurring in the ophiolitic serpentinite rocks of Gebel El-Maiyit into five types: pure magnesite, dolomite–magnesite, dolomite–lizardite–magnesite, lizardite–magnesite and lizardite–dolomite–magnesite. Nasr (2001) reported proved and possible magnesite reserves in Sul-Hamed area by about 5 million tonnes. Two grades are recorded: high grade magnesite with <1.5 % CaO and low grade magnesite (up to 3.5 % CaO).

Talc

Talc is hydrated magnesium silicate [$Mg_3Si_4O_{10}(OH)_2$] or 3MgO, $4SiO_2.H_2O$ which corresponds to 63.5 % SiO_2, 31.7 % MgO and 4.8 % H_2O. It has a very wide range of industrial applications which are based mainly on physical properties such as softness and whiteness as well as chemical inertness. The different grades of talc are used as fillers in the insecticides, paper and rubber industries; as a polishing agent for rice and as an ingredient in cosmetics. In the ceramics industry, it is used in the manufacture of electric insulators and wall tiles; and recently talc is mixed with kaolin and bauxite for the production of cordierite as low-thermal expansion refractories (Salam, 1993). Talc is valued commercially for its softness, smoothness, whiteness, lubricating power, high surface area, oil absorption, high electrical and heat conductivity, higher refractoriness and low thermal expansion. Commercial grades of talc range from very white, high purity cosmetic grades to grey low-grade material (< 50 % talc). The mineralogical composition of the commercial talc is very important because of the different ceramic properties of the associating minerals (e. g. tremolite, quartz, carbonates, serpentine minerals and chlorite). The compact variety of talc is called steatite. Soapstone is a massive, soft, greenish talcose rock containing a mixture of talc and various other magnesium minerals. The impure and hard variety is called potstone.

Egyptian talc deposits were reported in the central and south Eastern Desert in the following localities: Wadi Reida, Darhib, Gabal Khashir, Wadi Gulan El-Atshan, Abu Marwa, Abu Gurdi, Bir Disi, Wadi Kharit and Mikbi. Talc deposits from El-Atshan, Darhib and Khashir areas are considered among the best qualities of the world. Recently, two new localities are discovered at Wadi El-Allaqi (southeast of Aswan) with the same high grade. The deposits at these localities yield several grades of talc. The impure grades contain minor amounts of tremolite, chlorite and sometimes muscovite.

At Darhib, talc lenses are confined to a thick shear zone cutting the basement rhyolite. At Atshan, steatite is produced from a shear zone running through the greenstones (metadolerites, metaandesites and amphibolites). On the whole, the formation of talc and steatite is due to the hydrothermal alteration of some basic rocks. This alteration took place along shear zones which might have developed in the Late Pre-Cambrian.

The average chemical composition of the Egyptian talc given by many authors is 58.86–63.3 % SiO_2, 28.03–31.93 % MgO, 0.43–9.43 % Al_2O_3 and 0.12–3.60 % Fe_2O_3. Based on the mineralogical composition, the Egyptian talc deposits were classified into: pure talc, talc–chlorite, talc–tremolite, talc–quartz and talc–quartz–chlorite.

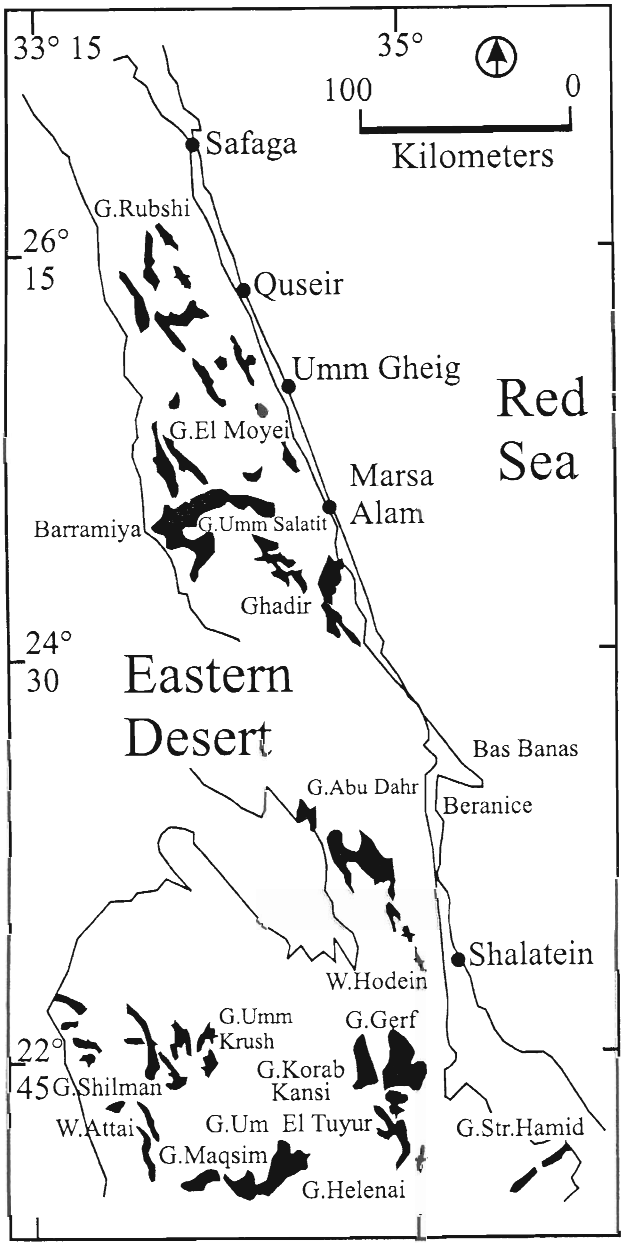

Fig. 2. Distribution of serpentinites and talc-carbonate rocks in the Egyptian Eastern Desert.

Although the talc paragenesis with certainity is not an easy matter, Hassan (1969) came to the conclusion that the steatitic deposits at Atshan were formed by metasomatic replacement of original metavolcanics of basic to intermediate composition through hydrothermal solutions rich in Si, CO_2, Fe, S, etc… active along shear zones.

Abdel-Kader et al. (1982) suggested that talc deposits at Atshan appear to have been originally volcanic rocks of tholeiitic affinity which have been subsequently transformed by successive phases of metasomatism (serpentinization, sericitization, and steatitization) into serpentinites, talc and talc-carbonate rocks.

Because commercial talcs commonly contain silicates of similar compositions, chemical analyses are not reliable guides to mineral content. Particle shapes are thought to be significant in some properties, rate of settling, durability of paint and shrinkage of ceramic bodies (Basta and Kamel, 1969).

The ground talcs as well as the fired bodies generally fall within a whiteness range of 97 to 99 % (whiteness of magnesium carbonate = 100). Oil absorption from 40 to 47 ml/100 gm are ordinarily specified in paint industries. It may be lowered by adding highly tremolitic material. Talc to be marketed to the paint and textile industries is ground (99.5 %) to less than 50 microns. Talc to be used as tile ingredient is ground (96–99 %) to less than 75 microns. The major uses of the different grades of talc are:

1. Manufacture of wall tiles due to its high fusion point, low shrinkage, resistance to heat shock, whiteness when fired.

2. As an extender in paints, due to the whiteness of the ground material, high oil absorption, chemical inertness, grindability to small particle sizes.

3. As a filler in textiles, paper, and rubber industries as well as an insecticides carrier, due to the whiteness, softness, smoothness, chemical inertness, good retention and grindability.

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Mineralogy and firing characteristics of some Egyptian talc-serpentinite rocks

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Abstract

Mineralogy of five technological talc-serpentinite rock samples, collected from El-Naba and El-Thamila El-Zarka areas, occurring in the Egyptian Eastern Desert, were investigated by polarizing microscope, electron microprobe microanalyzer as well as XRD and DTA methods. In order to assess their suitability for ceramic manufacturing, their firing characteristics were studied by following their vitrification up to 1500 °C. Phase composition and pore-size distribution as well as microstructure and microchemistry of selected vitrified samples were investigated using XRD, pore-sizer as well as SEM and EDAX techniques. The talcose sample is recommended for application as a ceramic tile manufacture. On the other hand, talc and serpentinite samples are recommended for the production of cordierite and forsterite ceramics, respectively

Key words: talc, serpentinite, mineralogy, microchemistry, microstructure, Eastern Desert, Egypt

Introduction

In Egypt, talc deposits are found in great reserves at many localities in the Eastern Desert, e. g. Darhib, El-Atshan and Marahiq (Geological Survey of Egypt, 1992). Serpentinites are widely distributed as large masses and blocks within the metamorphosed volcanosedimentary succession of the central and southern Eastern Desert (Abu El Ela, 1996). In addition to serpentinites, these rocks include talc-carbonate rocks with minor chromitites, chlorites and talcose rocks. Geology, mineralogy and geochemistry of talc deposits and their hosting rocks have been studied by Salem et al. (1987), Hussein (1990), Awad (1997), Salem (1992) and Salem et al. (1997, 1999). Some other workers assessed these deposits for ceramics and other industries, e. g. Basta and Kamel (1970), Sallam et al. (1986), Ibrahim et al. (1994), Hassan et al. (1997) and Hussein et al. (1997). Moreover, Grosjean (1985, 1993) studied the reaction taking place in pure and chloritic talc and recommended the use of chloritic talc for the production of cordierite. Also, Nakahara et al. (1994) attributed to the formation of cordierite from talc.

The aim of the present work is to study the mineralogy and firing characteristics of El-Naba and El-Thamila El-Zarka deposits and their host serpentinite rocks in order to assess their suitability for manufacturing of some varieties of ceramic products.

Geological setting

Serpentinites, talcose rocks and talc deposits of El-Naba and El-Thamila El-Zarka areas which situated in the central part of the Egyptian Eastern Desert between latitudes 25° 8' and 25° 11'N and longitude 34° 20' and 34° 28' E are studied (Fig. 1). These rocks occur as irregular masses and shear pods structurally emplaced within metavolcanic rocks in both areas and are generally associated with talc-carbonate and talc chlorite rocks. Two types of serpentinites are distinguished in the southern part of Wadi El-Naba: a relatively soft greyish and brown serpentinite as well as hard greenish type. Talc-carbonate bodies are soft, light-creamy or buff colour and exhibit characteristic cavernous appearance. At Wadi El-Thamila El-Zarka, talc is exposed as lense-like bodies associated with talcose rocks.

Experimental techniques

Five technological samples representing talc, talcose and serpentinite rocks of El-Thamila are referred to as T-1, T-2 and T-3, while K-1 and K-2 are the symbols used for El-Naba talc and talcose rocks, respectively. Mineral chemistry as well as calculated mineral formula were determined using an electron-probe microanalyzer (EPMA) of Camscan (Model EEM). Mineralogical and chemical compositions of the field and technological samples are also given. X-ray diffraction (XRD) and differential thermal analysis (DTA) methods were applied. A PW 1390 Philips diffractometer and a Perkin Elmer 7 Series thermal analyzer were used. On the other hand, a VRA-33 X-ray fluorescence (XRF) spectrometer was applied for determining the chemical composition (major and some trace elements). For studying firing characteristics, the technological talc-serpentinite fine powders were semi-dry pressed into cylindrical samples. The shaped samples were fired on magnesia spinel refractory plate between 1200 and 1500 °C with an interval of 50 °C. Five cylin-

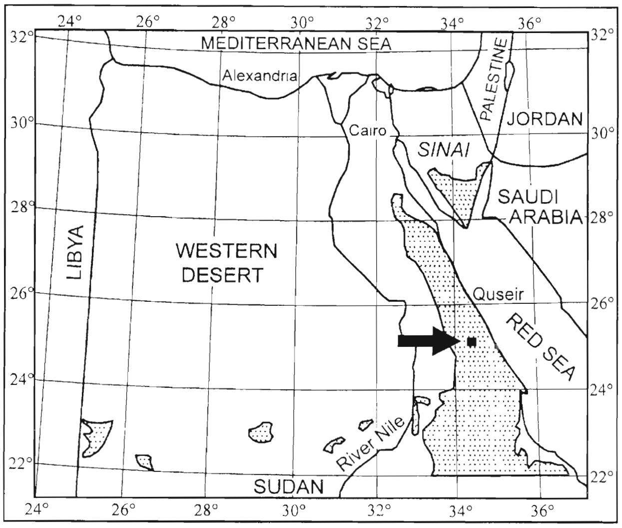

Fig. 1. Location map of studied area.

ders from each technological sample were fired at each temperature. Firing characteristics were studied by following up their vitrification behaviour up to 1500 °C as well as by investigating pore-size distribution, microstructure, microchemistry and phase composition of the vitrified samples. Phase composition was determined by XRD, whereas a Philips Scanning Electron Microscope (SEM) attached with a computerized EDAX unit was applied for studying microstructure and microchemistry. On the other hand, a Micromeritics Pore Sizer was used for determining of pore-size distribution.

Results and discussion

Mineralogy

According to the mineral assemblages revealed by microscopic examination of the field samples, they could be classified into four main types. The first type is impure talc as represented by T1 and K1 samples. Talc is the predominant mineral with subordinate amount of chlorite. Electron microprobe analyses (Tab. 1) show relative enrichment in SiO_2, MgO and Al_2O_3 with depletion in FeO in El-Thamila (T1) talc as compared with El-Naba talc (K-1). The chemical composition of El-Thamila and El-Naba talc is represented by structural formulae respectively:

$$Mg_{5.61}Fe^{2+}_{0.15}Cr_{0.01}Si_{7.60}O_{10}(OH)_2 \text{ and}$$
$$Mg_{5.38}Fe^{2+}_{0.37}Si_{7.62}O_{10}(OH)_2$$

The second type is composed of almost equal amounts of tremolite and chlorite with minor talc and antigorite minerals. Mineral chemistry data (Tab. 1) confirm the presence of calcic-amphibole, i. e. tremolite (Leake, 1997). The third type is mainly composed of chlorite-talc as represented by K2 sample. It shows predominant fine-grained talc whereas chlorite exists as small green shreds

Tab. 1
Chemical composition of the minerals present in the Talc ore samples

Mineral	Talc			Chlorites					Tremolite
Ore type	Talc			Chlorite-talc					Tremolite-talc
Sp. No.	T-2	K-26	K-1	K-20	K-24	K-26	T-1	T-12	T-1
SiO_2	65.65	64.71	65.18	37.26	33.50	37.48	33.19	37.25	58.71
TiO_2	0.00	0.08	0.00	0.00	0.36	0.00	0.01	0.00	0.05
Al_2O_3	0.04	0.06	0.00	16.75	22.11	16.00	23.71	14.85	0.62
FeO	1.54	5.03	3.74	15.00	12.12	12.52	10.95	11.05	4.39
MnO	0.04	0.00	0.02	0.35	0.15	0.16	0.17	0.09	0.17
MgO	32.53	29.76	30.86	30.58	31.54	32.10	31.49	32.92	22.93
CaO	0.00	0.04	0.00	0.08	0.00	0.11	0.01	0.11	13.07
Na_2O	0.03	0.09	0.08	0.00	0.00	0.03	0.40	0.00	0.02
K_2O	0.03	0.00	0.03	0.01	0.01	0.36	0.00	0.01	0.05
Cr_2O_3	0.11	0.23	0.00	0.00	0.21	1.20	0.00	3.72	0.00
Cl	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Total	99.97	100.00	99.92	100.01	99.99	100.00	100.00	99.99	100.00
	Cations/22 (O)			Cations/28 (O)					23 (O)
Si	7.602	7.626	7.621	6.414	5.713	6.418	5.632	6.372	7.830
Ti	0.000	0.000	0.000	0.000	0.046	0.000	0.005	0.000	0.005
Al	0.006	0.009	0.000	3.396	4.441	3.227	4.738	2.992	0.079
Fe^{3+}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.484
Fe^{2+}	0.150	0.566	0.366	2.159	1.729	1.793	1.554	1.581	0.006
Mn	0.004	0.000	0.002	0.051	0.022	0.023	0.024	0.013	0.019
Mg	5.614	5.961	5.379	7.847	8.019	8.195	7.966	8.395	4.559
Ca	0.000	0.006	0.000	0.015	0.000	0.020	0.002	0.020	1.868
Na	0.007	0.023	0.019	0.000	0.000	0.010	0.132	0.000	0.005
K	0.004	0.000	0.004	0.002	0.002	0.079	0.000	0.002	0.009
Cr	0.010	0.024	0.000	0.000	0.028	0.162	0.000	0.503	0.000
Cl	0.000	0.002	0.000	0.000	0.000	0.012	0.000	0.000	0.000

T-1, T-2, T-12 samples from El-Thamila area; K-1, K-24, K-26, K-29 samples from El-Naba area

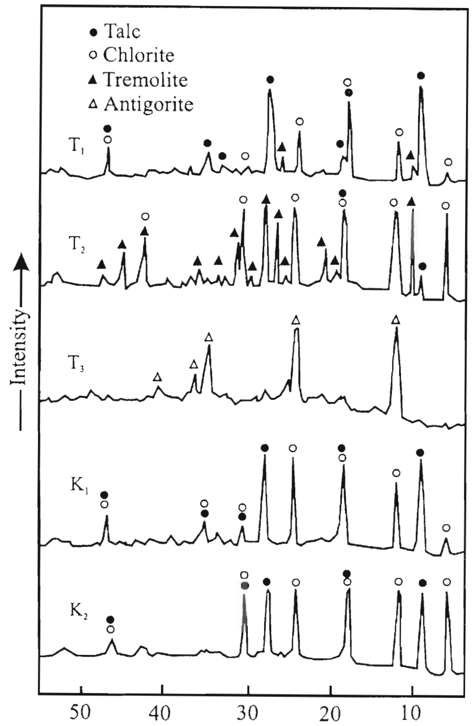

Fig. 2. XRD patterns of the talc-serpentinites technological samples.

intimately intergrow with talc. Microprobe analyses of chlorite (Tab. 1) revealed that it belongs to clinochlore and penninite according to Hey's classification (1954). The fourth type is serpentinite (sample T3), which is mainly composed of antigorite associated with small amounts of chlorite, talc and carbonate minerals. Antigorite occurs as fibrous aggregates or shreds while opaque minerals are represented by magnetite.

XRD patterns and DTA curves of the technological samples confirm their mineralogical composition by microscopic examination. Fig. 2 shows that T1 and K1 samples are mainly composed of talc, beside minor amounts of chlorite. This is also confirmed from their DTA curves. Concerning the talcose samples, (i. e. T2 and K2) their XRD patterns (Fig. 2) show that T2 is mainly composed of tremolite and chlorite, whereas chlorite and talc are the main minerals detected in K2. Fig. 2 also confirms that T3 sample is related to serpentinite rocks. It is mainly composed of antigorite in addition to minor amounts of chlorite and talc minerals.

The XRF chemical analysis data of the technological samples as summarized in Tab. 2 have also supported their mineralogical composition, XRD, and DTA investigations.

In conclusion, talc of both El-Naba (K1) and El-Thamila El-Zarka (T1) areas is of low-grade type. It is considered as non-aluminous and ferruginous talc and mainly composed of talc mineral associated with some chlorite, and accessory minerals, e. g. chromite and magnetite. On the other hand, both areas include some talcose rocks. El-Thamila talcose (T2) is mainly composed of tremolite and chlorite minerals at the expense of talc, whereas El-Naba type (K2) contains almost equal amounts of talc and chlorite. The presence of tremolite as a major mineral in El-Thamila talcose raises its CaO content up to ≅9.5 % at the expense of their MgO and SiO_2 contents. Samples of El-Thamila area include ferruginous serpentinite (T3) which is mainly composed of antigorite with minor chlorite, talc and carbonate minerals.

Firing characteristics

In order to assess the suitability of the studied talc-serpentinite rocks for ceramic industries, their firing characteristics are followed up on firing up to 1500 °C. Densification behaviour of the fired samples are followed in relation to the changes occurred in their phase composition and microstructure.

Fig. 3 exhibits densification parameters of El-Thamila and El-Naba samples, respectively in terms of bulk density and apparent porosity as function of firing temperature up to 1500 °C. It is evident that talc (T1 and K1), chlorite-talc (K2) and serpentinite (T3) samples are densified by liquid phase, i. e. vitrified at a steady rate up to 1350 °C. This is indicated from rising their bulk density up to maxima 1350 °C with simultaneous decrease of apparent porosity down to minima at this temperature. This is attributed to the development of increasing amounts of liquid phase on firing such ferruginous talc-serpentinite samples between 1200 and 1350 °C. These samples mainly consist of SiO_2 and MgO as well as Fe_2O_3 (Al_2O_3), in addition to variable amounts of other impurity oxides (0.70–2.40 %) namely, transition-metals, calcium and alkali oxides (Tab. 2). The coexistence of such level of the impurity oxides results in lowering the binary eutectic temperature of MgO–SiO_2 system (Te = 1543 °C) to less than 1200 °C (Bergeron and Risbud, 1984). This leads to develop increasing amount of liquid phase on firing between 1200 and 1350 °C.

On further firing up to 1500 °C, vitrification process is deteriorated due to the development of excessive amounts

Tab. 2
Chemical analyses of technological samples of talc and serpentinites

Locality	El-Thamila area			El-Naba area	
Sp. No.	T-1	T-2	T-3	K-1	K-2
SiO_2	60.93	55.13	52.17	60.37	52.83
TiO_2	0.05	0.05	0.04	0.14	0.66
Al_2O_3	0.77	5.25	0.29	0.95	7.33
Fe_2O_3	5.80	5.43	6.81	6.27	8.28
MnO	0.14	0.40	0.25	0.15	0.27
MgO	26.94	18.62	26.92	26.02	20.38
CaO	0.12	9.45	1.27	0.23	0.62
Na_2O	0.13	0.36	0.53	0.06	0.05
K_2O	0.24	0.03	0.02	0.03	0.03
P_2O_5	0.05	0.02	0.04	0.06	0.28
Cr_2O_3	0.10	0.10	0.12	0.03	0.01
NiO	0.90	0.80	1.00	0.01	0.00
L.O.I	5.04	5.40	12.10	5.87	9.36
Total	101.21	101.04	101.56	100.19	100.10
MgO/SiO_2	0.44	0.33	0.52	0.43	0.38

Samples T-1, K-1, Talc. Samples T-2, K-2 Talcoser rocks. Samples T-3 Talc-serpentinite

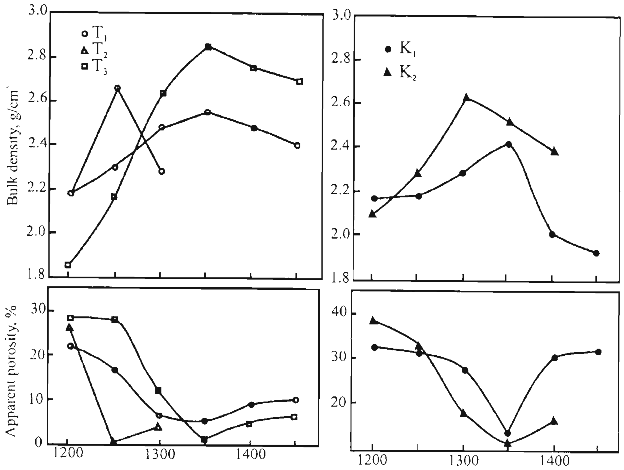

Fig. 3. Densification parameters of the studied technological samples.

of liquid phase, which leads to redecrease of bulk density with reincrease of apparent porosity up to 1450 °C. This is followed by partial melting at 1500 °C. On the other hand, talcose sample (T2) is completely vitrified on firing only up to 1250 °C and partially melted at 1300 °C. This is mainly due to its appreciably higher content of lime (CaO = 9.45 %). The presence of such amount of lime, beside SiO_2, MgO, Fe_2O_3, Al_2O_3 and other impurity oxides leads to significant change in its phase composition with the development of high liquid-phase content at temperature as low as 1250–1300 °C (Bergeron and Risbud, 1984). Therefore, T2 sample was excluded from further study and recommended for application as a fluxing material in ceramic-tiles manufacturing.

Vitrified talc (T1) and serpentinite (T3) samples were selected to investigate their pore-size distribution as well as phase composition, microstructure and microchemistry. It is evident that most of the large open-pores of both samples were closed by liquid phase during its vitrification up to 1350 °C. Most of the open pores of both samples have sizes below 1 μm. In talc sample, pore sizes are concentrated at 0.1–1.0 μm, whereas finer sizes exist between 0.02 and 0.2 μm. Some larger pores with sizes ranging between 1 and 100 μm are detected in both samples.

The microstructure of vitrified talc and serpentinite samples was investigated by SEM, while their microchemistry was revealed by EDAX-point analyses. Talc sample shows agglomerated enstatite particles with different sizes and rounded edges. These particles contain some Al_2O_3, Cr_2O_3 and/or Fe_2O_3 in solid solution and include bright phase in its interstitial spaces. The latter phase is iron-rich Mg-silicate containing some Al_2O_3 and Cr_2O_3. On the other side, serpentinite sample, shows large enstatite patch bonded by rounded particles of iron-rich forsterite and enstatite phases with bright and light grey colours, respectively.

The presence of enstatite and forsterite in vitrified serpentinite sample is supported by XRD which exhibits also that vitrified talc sample is mainly composed of enstatite, in addition to cristobalite and tridymite silica minerals. The low MgO/SiO_2 ratio of the talc sample (Tab. 2) is responsible for the coexistence of free silica minerals after its vitrification up to 1350 °C. Meanwhile the increase of this ratio in serpentinite sample, leads to the formation of forsterite beside enstatite according to the binary $MgO–SiO_2$ phase diagram (Bergeron and Risbud, 1984).

In conclusion, serpentinite sample is recommended for manufacturing refractory forsterite ceramics, after the addition of proper amount of pure raw or calcined magnesite before its firing to produce grains mainly composed of forsterite ($2MgO.SiO_2$). Due to the low MgO/SiO_2 ratio of talc sample, it is recommended for manufacturing cordierite ceramics ($2MgO–2Al_2O_3$-$5SiO_2$) after correcting its chemical composition by adding the proper amount of raw kaolin.

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Talc deposits in Japan: A review

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Abstract

Talc deposits in Japan were formed by metasomatism of serpentinite in metamorphic rocks and in the Paleozoic to Mesozoic sedimentary rocks. Accumulative domestic production of talc in Japan (1953–1999) is approximately 3.8 million tonnes, occupying a relatively low rank among the talc-producing countries in the world. Following the change of the mode of use, mineral aggregates containing minerals other than talc were exploited as talc.

Key words: talc, production, industrial mineral, Japan

Introduction

Talc is used as a source of fine-grained powdery material. In this regard, the category of "talc" as a mineral commodity includes not only talc, but also white powder of Mg-chlorite and antigorite in Japan. In this report, the talc as a mineral commodity is named as "talcose ore."

Types of "talcose ore"

Talc deposits are genetically classified into two major types as follows: (1) Deposits metasomatized from sedimentary carbonate formations; (2) Deposits metasomatized from serpentinites. All of the talc deposits in Japan belong to the second type (Hirano and Sudo, 1994). Soft green schist is also included into the category of "talcose ore" in the official mineral statistics report. Talc deposits and "talc-like" deposits in Japan are classified in terms of mineral composition into the following three types: (1) Deposits composed mainly of talc; (2) Deposits composed mainly of talc and carbonates; (3) Deposits composed mainly of the minerals other than talc. This classification is shown in Tab. 1.

Talc (Type A)

Deposits of this type are found along the boundary between serpentinites and hosting pelitic schists of regional metamorphic belts. This type is characterized by high contents of talc, but dimension of each ore body is small. Therefore, deposits of this type were mined at early time since the 1900s and the majority was mined out by the 1970s.

Talc + Carbonates (Type B)

This type of ore deposit is also originated from serpentinite. The schistose parts with lower carbonate contents were exploited by underground mining at the beginning of mining. After the 1970s, massive parts with higher contents of carbonates were also exploited because of technical development of machinery for exploitation and pulverization. The size of ore bodies is comparatively large, but they contain a considerable amount of carbonate minerals.

Others (Type C)

This type of ore is soft chlorite schist derived from mafic volcanic rocks containing less felsic minerals. It was mined since 1960s in Kanra-Ogawa area in central Japan. At the beginning of mining, ore bodies composed of pure talc were exploited. But, later, due to the exhaustion of the reserve and new use of powdery materials into building materials (as paint carrier), the mining shifted for soft schistose rocks composed mainly of chlorite and amphibole. This type of ore contains impurities such as

Tab. 1
Classification of talcose ore deposits

Type	Major mineral	Original rock	Note
A	talc	serpentinite (ultramafic rock)	occurring in low-grade metamorphic rocks of green schist facies or epidote-amphibolite facies
B	talc, carbonates	serpentinite (ultramafic rock)	occurring in low-grade metamorphic rocks and in sedimentary rocks of the Paleozoic-Mesozoic age
C	chlorite	mafic rock	chlorite-rich part of green schists

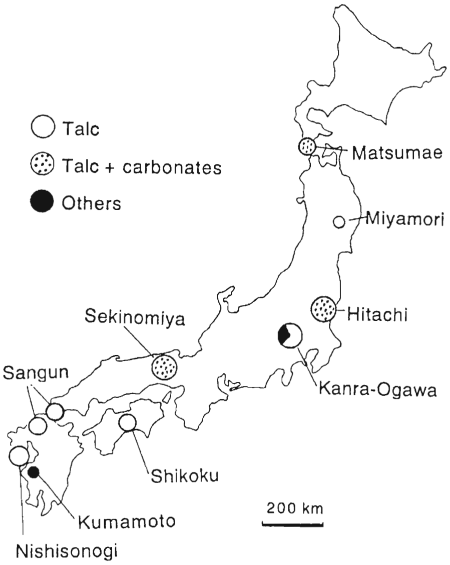

Fig. 1. Distribution map of talcose ore deposits in Japan. Relative sizes of deposits are based on the total mine production from the areas.

feldspars, epidote, pyroxene and quartz. Its use has been decreasing since 1990s.

Distribution and mode of occurrence

Talc deposits metasomatized from serpentinites are distributed in accordance with the distribution of serpentinite bodies in metamorphic belts in Japan. Representative deposits are, from north to south, Matsumae (South Hokkaido), Hitachi (Ibaraki Pref.), Kanra-Ogawa area (Gunma and Saitama Pref.), Sekinomiya (Hyogo Pref.), Shikoku area (Kochi and Ehime Pref.), Nishisonogi (Nagasaki Pref.), and Sangun (Yamaguchi and Fukuoka Pref.) (Fig. 1; Tab. 2). Many of the ore deposits are formed in serpentinite bodies, or along the boundary between serpentinite and the hosting crystalline schist (psammitic schist and pelitic schist). The mode of occurrences of some representative deposits is described here in some more details.

Type A examples (Talc deposits in Shikoku)

Talc deposits in Shikoku are associated with small serpentinite bodies hosted by pelitic schist in the Sambagawa metamorphic belt (Fig. 2). In the pelitic schist around the ore bodies the garnet and biotite occur being formed by the Sambagawa regional metamorphism of the Jurassic to Cretaceous age (Higashino, 1990; Isozaki and Itaya, 1990). Known deposits Besshi, Funaki, Fujiwara, Shirataki, and Nishinomine are classified as Type A.

Size of ore bodies is small, with thickness of the part of talc concentration of 0.5–2 m. In many cases, zonal structure is observed within the ore bodies (Fig. 3). Scale of each ore body is at a range of 100–500 tonnes. They were exploited by underground mining, and were mined out by the 1960s.

Similar talc deposits are distributed in Kanra-Ogawa in the Sambagawa metamorphic belt of central Japan, Sangun in the Sangun metamorphic zone (West Japan), and Nishisonogi in the Nagasaki metamorphic zone (Kyushu).

Type B examples (Hitachi talc deposits)

Talc deposits in the Hitachi area are associated with small serpentinite bodies distributed in the Hitachi metamorphic rocks of the Cretaceous age. The ore bodies are classified as Type B.

Pelitic schist around the deposit is regionally metamorphosed to epidote-amphibolite facies: Namely, biotite-muscovite-andalusite in pelitic schist, and hornblende-epi-

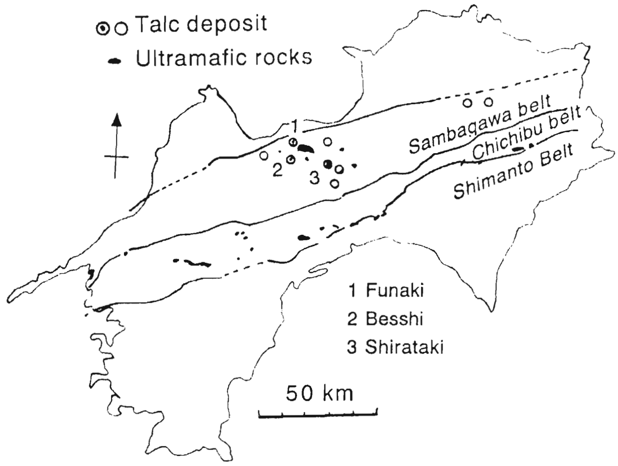

Fig. 2. Distribution map of talc ore deposit and ultramafic rock (serpentinite) in Shikoku.

Tab. 2
List of talcose ore deposits in Japan

Area	Name of deposit or mine	Ore type	Major (and minor) mineral	Size of each ore body etc.
Matsumae	Matsumae, Iwabe, Yugan, Inakurazawa	B	talc, chlorite, magnesite, (dolomite, antigorite)	1,000–50,000 tonnes
Miyamori	Iwanezawa, Kunimine	A?	talc, tremolite	metamorphosed by Cretaceous granite
Hitachi	Asahinata, Hase, Sato	B	talc, magnesite, (dolomite, chlorite)	1,000–50,000 tonnes
Kanra-Ogawa	Nihon talc, Kanra, Yawata, Matsunaga	A	talc, chlorite, (antigorite, calcite, tremolite)	50–1,000 tonnes
	Sugiura, Mayama	C	chlorite, actinolite, (epidote, albite, pyroxene)	>100,000 tonnes
Sekinomiya	Seicho, Asakura	B	talc, (magnesite, quartz, chlorite)	>50,000 tonnes
Sangun	Kagawa, Abe, Sue	A	talc	50–500 tonnes
Shikoku	Shirataki, Besshi, Funaki, Arakawa	A	talc, chlorite, (dolomite)	50–1,000 tonnes
Nishisonogi	Nishinihon, Konoura	A	talc, chlorite, (dolomite)	50–500 tonnes
Kumamoto	Sanno-Akamatsu	C	antigorite, (chlorite)	>50,000 tonnes

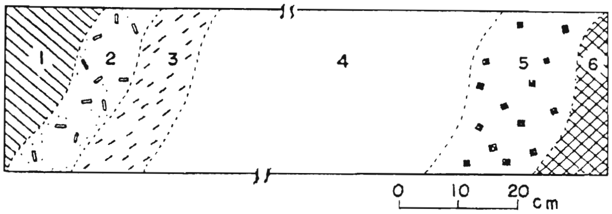

Fig. 3. Zonation of the Besshi talc deposit (Type A) occurred between serpentinite and host pelitic schist in the Sambagawa metamorphic belt, Shikoku (Uchida, 1960). 1 – graphite-sericite-quartz schist, 2 – chlorite-sericite (-tourmaline) zone (10 cm width), 3 – actinolite zone (10 cm), 4 – talc zone (170 cm), 5 – talc carbonate zone (20 cm), 6 – serpentinite.

dote-oligoclase in mafic schist (Tagiri, 1973). In this area, Sato, Asahinata, and Hase deposits are known (Fig. 4).

Size of each ore body is comparatively large, thickness of the part of talc concentration reaches 10–20 m. The following mineral zoning is observed from serpentinite toward the center of the deposit (Fig. 5):

(1) serpentinite (antigorite)
(2) talcose serpentinite zone (talc-magnesite-antigorite)
(3) talc-carbonate zone (massive; more than 40 % of magnesite with talc)
(4) carbonate-talc zone (less than 40 % carbonate minerals; talc-dolomite-magnesite-chlorite)
(5) talc-dominant zone (talc predominant)

Size of each ore body is at a range of 1,000–5,000 tonnes. By the 1960s, underground mining was operated targeting talc-dominant zone and carbonate-talc zone. Later, exploitation was switched to open pit mining, and talc-carbonate zone became an additional target.

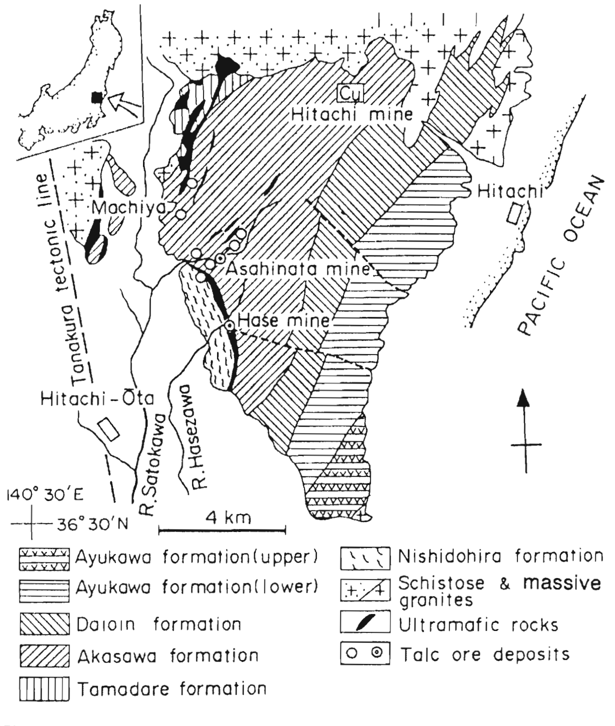

Fig. 4. Distribution map of talc ore deposit (Type B) and serpentinite in the Hitachi area.

Talc deposits of Type B are also distributed in the Matsumae area, Hokkaido (Bamba and Yajima, 1974). They are associated with serpentinite bodies in the slightly metamorphosed sediments of slate intercalated with limestone and chert of the Paleozoic to Mesozoic age.

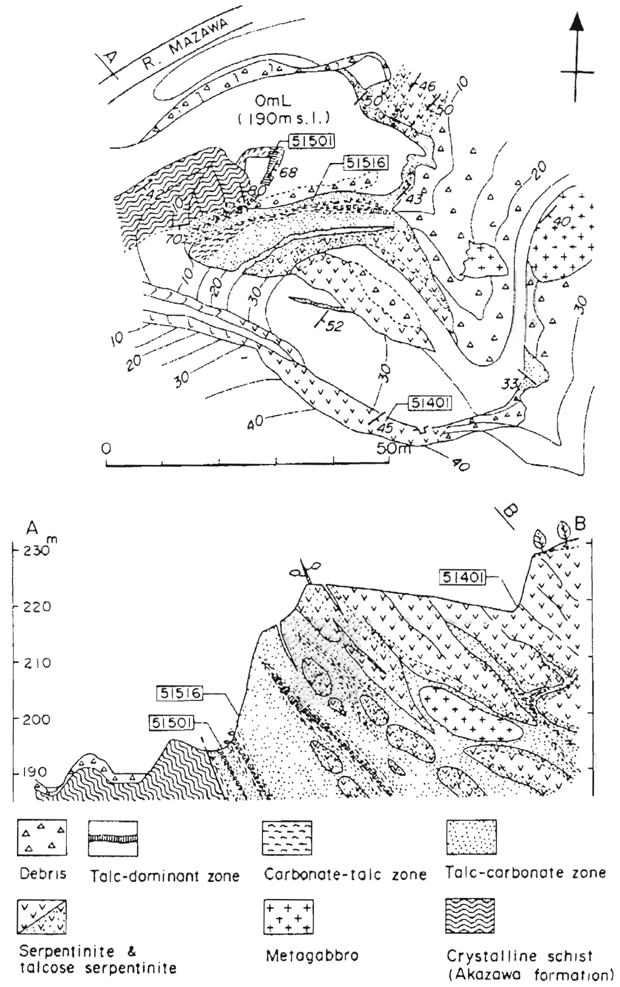

Fig. 5. A map showing occurrence of the Asahinata talc deposit (Type B) in Hitachi area.

The deposits of Type B show the following common characteristics: (1) large content of carbonate minerals; (2) massive shape of ore body; and (3) relatively large size of ore bodies. Large content of carbonate minerals and irregular massive shape of ore bodies strongly suggest that these deposits were formed by hydrothermal activity related to felsic magmatism (Hirano and Fujinuki, 1985).

Talc deposits in the Sekinomiya area (Hyogo) contain a considerable amount of carbonate minerals, and are characterized by the association of quartz with talc ores. However, they are classified as Type B in this report.

Tab. 3
Chemical composition of talc ore

Area	Matsu mae	Miyamori	Hitachi	Hitachi	Sekino miya	Shikoku	Shikoku	Nishi sonogi
Deposit/Mine	(concentrate)	Iwane bashi	Hase	Asahinata	Seicho	Besshi	Funaki	Konoura
SiO_2	63.28	54.42	29.28	37.50	60.10	59.50	60.53	58.78
TiO_2	0.02	–	0.00	0.00	–	–	–	–
Al_2O_3	0.24	1.17	0.90	0.52	2.83	0.06	2.86	1.28
tot. Fe_2O_3	–	7.24	–	–	5.68	4.83	5.42	–
Fe_2O_3	0.72	–	5.26	3.14	–	–	–	1.64
FeO	2.80	–	2.74	1.88	–	–	–	2.84
MnO	0.03	–	0.09	0.03	–	–	–	–
MgO	25.93	26.94	34.26	34.76	25.42	28.64	27.50	28.46
CaO	0.03	2.90	0.09	0.07	0.83	0.17	1.50	1.48
Na_2O	0.12	0.03	0.03	0.04	–	–	0.15	–
K_2O	0.02	tr	0.01	0.10	–	–	–	–
P_2O_5	0.01	–	0.00	0.00	–	–	–	–
H_2O^+	6.63	–	3.37	1.98	–	–	–	–
H_2O^-	0.14	–	–	–	–	–	–	–
CO_2	–	–	22.50	18.98	–	–	–	–
Ig.loss	–	7.28	–	–	4.54	5.02	1.46	4.96
Cr_2O_3	0.01	–	0.76	0.25	–	–	–	–
Total	99.98	99.98	99.29	99.25	99.40	98.22	99.42	99.44
Ref	B. Y. 74	Tsu. 50	H. F 85	H. F 85	CeAs 65	U T. 73	Uchi. 60	U. M. 58

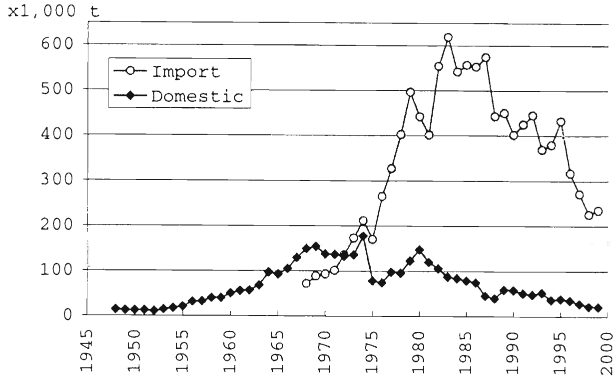

Fig. 6. Change of domestic production and import for talcose ore. (Data from MITI, 1945-99)

Mineral and chemical composition of ores

Talc ores produced in Japan contain impurities such as carbonates (dolomite, magnesite and calcite), amphibole, chlorite, antigorite, magnetite and/or pyrite. As to chemical composition, iron content is usually at a level of 5 wt. % (Tab. 3).

Production, import and use

Mining of talc in Japan started in around the 1900s targeting Type A in western Japan for the use as rock pencils. After the 1930s, talc of high quality was imported from China and the Korean Peninsula. After the 1950s, both domestic production and import quickly increased as the demand for paper, ceramics, and paint and insecticide carrier boosted. Annual domestic production recorded at about 180,000 tonnes in 1974 as the highest record, but has fallen down to about 20,000 tonnes in recent years due to the insufficient quality, being gradually replaced by imported talc (Fig. 6).

Domestic talc is high in iron content in general, being causing pale bluish gray or pale greenish gray color. Therefore, its use is limited for paint and insecticide carrier. Soft crystalline schists (chlorite schist) contain amphiboles such as actinolite, partly resembing with its acicular shape the asbestos. Their use has been decreasing since around 1990 because of this reason.

Annual talc import has been about 250,000 tonnes recently. Main exporting countries are China, Australia, and Korea. Among them, China shares more than 50 % of the total. The imported talc is mainly used as high-grade white powder materials, mainly for paper (for coating of high quality paper such as calendars), ceramics, cosmetics, welding rods, and paint carriers.

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Magnesite and talc – the Indian scenario

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Abstract

Magnesite and talc deposits associated with serpentinised ultramafic rocks and metasedimentary sequences are located at different parts of India. The most important magnesite deposit is confined to deformed and metamorphosed peridotite set in the high grade granulite terrain while the largest talc deposit of the country is in northwestern India associated with dolomitic limestone metamorphosed under low to medium grade conditions. The mineralisation generally seen as veins and bands is structurally controlled and is syn- to post-tectonic.

Key words: India, magnesite, talc, ultramafics, structural control, shear zone

Introduction

Magnesite deposits of the world are associated either with carbonate sediments or with serpentinised ultramafic rocks ranging in age from Archaean to Jurassic. In India, most of the magnesite deposits occur in association with serpentinised ultramafic rocks and to a lesser extent with sedimentary dolomitic limestone. Deposits of talc are also located in the same geological milieu as that of magnesite but with an exception that major talc deposits are associated with metasedimentary sequence. Though Indian reserves of magnesite and talc account only for about 1.5 % and less than 1 % respectively, deposits of various size and associations exist in different parts of India, both in the high- as well as low-grade metamorphic terrains. Total recoverable reserve of magnesite in India is 245 million tonnes (Tab. 1). The major deposits are confined to Tamil Nadu, Karnataka, Rajasthan and Uttar Pradesh while minor deposits are located in Andhra Pradesh and Kerala (Fig. 1). The reserves of talc/steatite/soapstone in India are assessed at 213.7 million tonnes (Tab. 1). Substantial quantities of recoverable reserves are established in Rajasthan (80 %), Uttar Pradesh (7 %), Kerala (4 %), Maharashtra and Madhya Pradesh (3 % each) and the rest in the other states like Andhra Pradesh, Bihar, Karnataka and Tamil Nadu. In 1999–2000 the production of magnesite was 329,790 tonnes, Tamil Nadu contributing about 75 % (Tab. 1). During the same period the production of talc was about 527,687 tonnes, the major share being contributed by Rajasthan. Though Indian contribution of magnesite and talc to the world market is not high, it is significant that Indian magnesite and talc, especially from

Tab. 1
Recoverable reserves and production of magnesite and talc

(Qty in tonnes)

Location/State	Reserves Magnesite	Talc/Steatite	Production in 1999–2000 Magnesite	Talc/Steatite
Andhra Pradesh	...	3,546,000	...	43,602
Bihar	...	289,000	...	945
Gujarat	..	7,000	...	524
Jammu & Kashmir	3,432,000	...	...	.
Karnataka	1,229,000	1,622,000	36,120	96
Kerala	35,000	8,131,000	...	..
Madhya Pradesh	..	6,217,000	...	3,810
Maharashtra	...	6,520,000	..	.
Orissa	..	117,000	...	1,287
Rajasthan	5,487,000	170,340,000	573	460,353
Tamil Nadu	48,919,000	1,909,000	245,980	238
Uttar Pradesh	185,747,000	14,946,000	47,117	16,832

Source: Indian Mineral Yearbook – 1999–2000

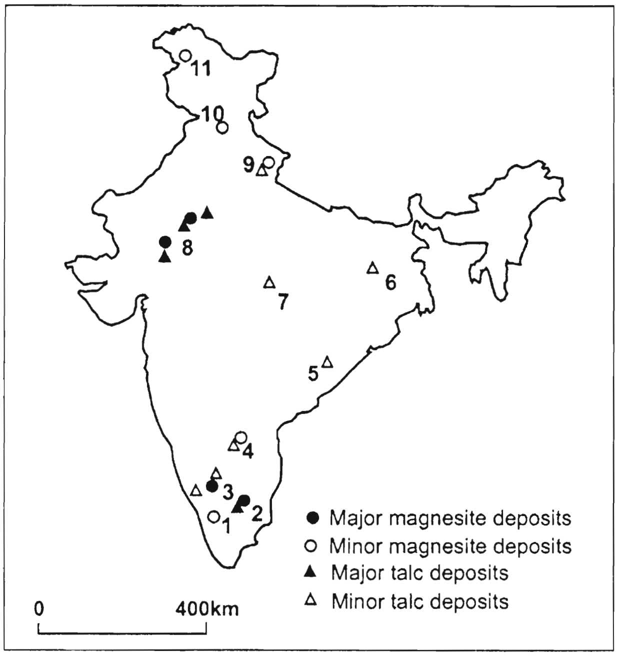

Fig. 1. Locations of magnesite and talc deposits of India. 1 – Attappadi, Kerala, 2 – Salem, Tamil Nadu, 3 – Dodkanya, Karnataka, 4 – Andhra Pradesh; 5 – Bihar; 6 – Orissa, 7 – Madhya Pradesh, 8 – Rajasthan; 9 – Almora, Uttar Pradesh; 10 – Himachal Pradesh; 11 – Jammu and Kashmir

Tamil Nadu and Rajasthan respectively, are of high quality and are comparable with the best available in other countries. This paper attempts a brief review of the mode of occurrence and salient features of the magnesite and talc deposits of India.

Major magnesite deposits

Magnesite deposits associated with serpentinised peridotites occur at several places in India. In south India, magnesite is exploited from Tamil Nadu and Karnataka. Minor quantities of magnesite occur in the states of Andhra Pradesh and Kerala. In Salem, Tamil Nadu, magnesite occurs in a series of hillocks known as the Chalk hills. Magnesite, mostly cryptocrystalline, occurs chiefly as encrustations, veins and stringers in ultrabasic rocks like dunite and peridotite. Stringers and veins occur irregularly in fractures giving rise to various patterns such as cross-veins, stockworks and ladder veins. The ultramafic rocks that form low-level hillocks in an otherwise plain country around Dodkanya in Karnataka (Fig. 1) are intersected by a network of magnesite veins and bands. Magnesite is mostly of pure white hard variety while grayish white as well as soft powdery and rarely cryptocrystalline varieties also occur at places. The area around Dodkanya, which forms a part of the older rocks (Sargur schists) consists of a number of N–S to NNE–SSW trending enclaves of metavolcanics, metasedimentary units, basic granulites, metabasics and serpentinised ultramafic rocks within the gneissic country rocks of granodiorite composition (Peninsular Gneiss). Enclaves vary in thickness from 3 m to 2 km. Numerous bands of serpentinised ultramafic rocks varying in width from 2 m to 500 m are exposed over a stretch of 2 km. Magnesite is restricted to the ultramafic rocks as the veins do not extend into the surrounding gneiss that enclose the ultramafics. The veins which vary in thickness from 1mm to 3 m coincide with the NE–SW and E–W trending joints in the rocks and it is notable that massive serpentinised dunite without fractures are devoid of mineralisation. Magnesite is confined to the ultramafics that constitute a tectonically dismembered part of a layered ultramafic complex emplaced into c. 3.3 Ga old supracrustal rocks (Peucat et al., 1995).

Minor magnesite deposits

In Kerala magnesite occurs as veins and veinlets in a lenticular body of peridotite, composed mostly of olivine and subordinate amount of clinopyroxene, enclosed in hornblende gneiss and amphibolite at the western termination of Bhavani shear zone (Prasannakumar and Nair, 2001). These magnesite veins, structurally controlled by fractures in host rocks are post-tectonic. The deposits at Tamil Nadu and Kerala are in the same tectonic framework as both are located in the same shear zone. Besides, there are similarities in general character, associated rocks and chemistry of magnesite from these deposits (Tab. 2).

Tab. 2
Characteristics of magnesite deposits

Deposit	Type	Associated rocks
Tamil Nadu	White-grayish white Cryptocrystalline	Dunite, peridotite, pyroxene
Karnataka	White-grayish white Lenses of soft and powdery	Serpentinised peridotite
Kerala	White-grayish white Rarely cryptocrystalline	Serpentinised peridotite
Andhra Pradesh	Pale gray Crystalline	Dolomite, limestone, shale
Uttar Pradesh	White to gray Crystalline	Dolomitic limestone

Minor amounts of magnesite occur in the Precambrian ultramafic rocks in different parts of Rajasthan. In the case of all these deposits magnesite is confined to ultramafic rocks subjected to metamorphism under amphibolite to granulite facies conditions and are devoid of the association of carbonate bearing rocks. While all these deposits are associated with ultramafic bodies the magnesite is also reported from Precambrian sediments. Low-grade magnesite is reported from middle to upper Proterozoic sediments consisting predominantly of dolomite, limestone, shale, chert and quartzite in Andhra Pradesh (Fig. 1). The dolomites host several mineral deposits like asbestos, steatite and serpentine (Sinha et al., 1989). Crystalline magnesite is also reported from Almora in Uttar Pradesh where it occurs in the dolomitic limestone of calcareous series, which are intruded by basic sills, and dykes. This series exposed in the form of tectonic windows may possibly be correlated with Krol Formation of Permo-Triassic age (Muktinath and Wakhaloo, 1962).

Origin and localization

Magnesite, when found associated with ultramafics, occurs as veins of varying thickness generally following the trend of regional joints or the joints in the ultramafics like dunite, or peridotite. Analysis of fracture and vein pattern at Attappadi, Kerala, reveals that the major magnesite veins have preferred the N30W–S30E trending regional fractures whereas the veinlets are localized along N25E–S25W and N45W–S45E trending fractures in peridotite host rocks (Tab. 3). Such fracture controlled veins and stockworks indicate that the formation of magnesite is post-tectonic and that the fractures facilitated the migration of CO_2 fluids. In most of the cases magnesite bearing host rocks are serpentinised peridotite and dunite. The ultramafics show varying degree of serpentinisation, and the intensity decreases at depth. At many localities the magnesite formation is restricted to about 35–50 m, which usually coincides with the depth of water table in the respective areas. The observed features of deposits of Tamil Nadu, Karnataka and Kerala indicate that magnesite genesis can be due to late stage of hydrothermal activity associated with ultramafic to mafic magmatism. However, the available data is inadequate to ascertain the modality and timing of Mg migration in relation to serpentinisation and the possible derivation of carbon from biogenic soil source.

Tab. 3
Fracture and vein pattern at Attappadi, Kerala

Magnesite Veins	Major	N30W–S30E N30E–S30W
	Minor	N45W–S45E N20E–S20W
Fractures	Regional	N30W–S30E N75W–S75E N55E–S55W
	Peridotite	N25E–S25W N45W–S45E

Major talc deposits

Rajasthan is the major producer of talc in India and accounts for more than 85 % of total production (Tab. 1). Unlike small deposits of talc associated with magnesite and located in the ultramafics the major deposits in the northern part of India are associated with Precambrian metasedimentary sequence. The metasediments of Rajasthan, represented by dolomite and siliceous dolomitic limestone and forming a part of the Aravalli Supergroup, are considered to have been deposited in the near shore shelf sea environment (Roy et al., 1988). The gray, white and pink varieties of dolomite host the largest talc deposits of India. Talc is massive to foliated in nature, light green to white in colour and generally occurs along with tremolite, calcite and chlorite. Talc deposits occur as thin bands/stringers and occasionally as prominent veins and lodes within adjoining quartzite. Mineralised bands are formed parallel to the foliation in the country rocks. These deposits are formed as a result of steatisation of thin bands of dolomite interbedded with quartzite (Shekhawat and Bharadwaj, 2000). Dolomite in some cases has undergone only partial steatisation. Talc deposits mostly occur within the dolomitic bands away from phyllite. Thin bands of chlorite schist occurring in the area have sympathetic relationship with that of talc deposits. Contrary to this type of occurrence the frequent association of talc, asbestos, serpentine and kaolin with hornblende schist, amphibolite and epidiorite derived from ultrabasic rocks also occur in Rajasthan.

Minor talc deposits

In Andhra Pradesh, South India, steatite varying in colour from shades of green and gray to pure white along with minute fibres and flakes of talc occurs in the form of thin bands, laminations and lenses which conform in orientation to the plane of stratification of the limestonnes belonging to Cuddapah Supergroup. Individual layers vary from a few centimetres to as much as 15 cm in thickness and run for considerable distance. Impure steatite and talc are found in the Dharwar rocks of north Kerala. The talcose rocks occur as detached outcrops in a linear configuration, extending for about 2–3 km with width varying from 30 to 40 m. Low-grade talc is reported from Tamil Nadu and Karnataka also.

Origin

Talc is widely distributed and occurs in metamorphic rocks either as workable deposits formed by steatisation of dolomitic limestone or as minor occurrences consisting of impure talc-schist/soapstone derived from the metamorphism of basic to ultrabasic rocks. In Rajasthan the talc is seen associated with chlorite schist. The association of chlorite schist with talc suggests that the thin bands of chlorite schist and talc deposits are the outcome of steatisation of siliceous dolomite by metamorphogenic fluids generated during metamorphism of these rocks under greenschist facies conditions. Where talc is confined to the ultrabasic rocks, regular gradation from the least altered types characterized by high temperature minerals to the most altered low temperature minerals, are observed and in most of the cases talc formation is considered to be the result of metamorphism and hydrothermal alteration.

Conclusion

Magnesite and talc occur in association with metamorphosed ultramafic rocks as well as dolomitic limestone. It is noteworthy that in India though both magnesite and talc occur in association with metasedimentary as well as ultramafic rocks, most of the major workable magnesite deposits are confined to ultramafics, while talc deposits are associated with metasedimentary sequence containing dolomitic limestone. Talc deposits of economic importance are related to steatisation of dolomite while magnesite formation succeeds serpentinisation of peridotite and dunite. Shearing and metamorphism might have facilitated release and remobilization of magnesium and might have provided pathways for the CO_2 bearing fluids. The general characteristics of the deposits point to post tectonic action of CO_2 rich hydrothermal solution along preexisting fractures. In a few cases the assemblages are indicative of steatisation of siliceous dolomite by metamorphogenic fluids. The silica required for talc formation in such cases can be attributed to silica bearing sediments as intercalations. The near shore shelf sea environment suggested for the sedimentary rocks of Rajasthan, with which talc is associated, and the rock assemblages at Salem and Attappadi, suggestive of ophiolitic character, further invoke the possibility of marine environment of formation of these deposits. More detailed work involving fluid chemistry and isotope studies would be helpful in arriving at a model for the genesis of magnesite and talc deposits of India.

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Geovestník

Informačný spravodajca pre geológiu, baníctvo, úpravníctvo a životné prostredie

Príloha časopisu Mineralia Slovaca, roč. 33 (2001), č. 6

Obsah

Projekt UNESCO a IUGS IGCP 443 v plnom rozbehu

IUGS UNESCO IGCP

IGCP 443

Magnesite and Talc

Geological and Environmental Correlations

Od prípravy k riešeniu

Medzinárodný geologický korelačný program *IGCP 443 Magnezit a mastenec – geologické a environmentálne korelácie* schválilo 28. zasadnutie vedeckej rady projektov IGCP v Paríži vo februári 2000 na roky 2000–2004. Jeho medzinárodnými vedúcimi a vedúcimi tematických skupín sú: Ing. M. Radvanec (Slovensko), prof. W. Prochaska (Rakúsko), prof. A. C. Gondim (Brazília) a prof. Kchaj Kche-čchin (Čína). Medzinárodným koordinátorom projektu je Ing. Z. Németh (Slovensko).

Projekt je orientovaný predovšetkým na geologické otázky magnezitu a mastenca, ale v záujme komplexnosti neobchádza ani ložiskovoprieskumnú a úpravnícku problematiku. Osobitný dôraz kladie na environmentálne problémy.

Na lepšiu koordináciu výskumu sa v rámci projektu vytvorili tematické pracovné skupiny, a to *1. Geológia a štruktúra ložísk magnezitu a mastenca* (vedúci W. Prochaska, Rakúsko), *2. Geológia, petrológia a mineralógia* (vedúci M. Radvanec, Slovensko), *3. Metódy geologického prieskumu, výskum technologických vlastností suroviny a úpravníctvo* (vedúci A. C. Gondim, Brazília) a *4. Geoenvironmentálne metódy* (vedúci Kchaj Kche-čchin, Čína).

V krajinách, ktoré sa na plnení projektu zúčastňujú, pôsobia národné pracovné skupiny. Ich tematické skupiny majú odlišné zloženie, a to v závislosti od špecifického zamerania príslušnej národnej skupiny a účasti odborníkov špecializovaných na konkrétne úlohy.

Keďže medzinárodné projekty UNESCO/IUGS sa sústreďujú na koreláciu a transfer vedeckých poznatkov, výskum sa financuje z národných projektov v participujúcich štátoch. Finančné prostriedky projektov IGCP sú určené iba na pokrytie výdavkov na pracovné stretnutia, terénne korelácie a – len v menšej miere – na čiastočné pokrytie nákladov na vydávanie spoločných publikácií.

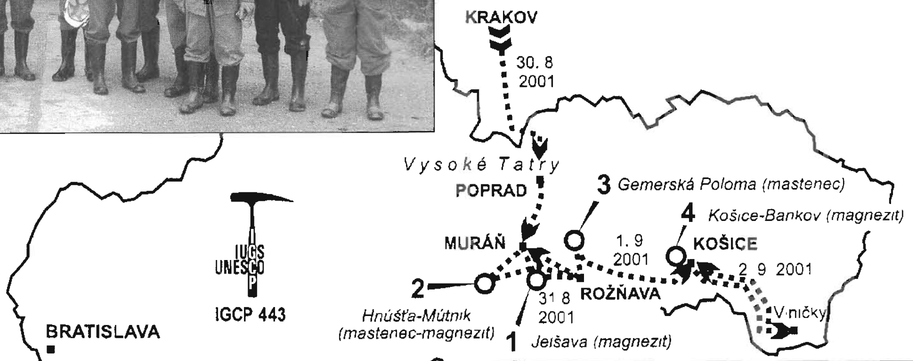
Projekt má celosvetovú povahu a v súčasnosti sú doň zapojené nasledujúce krajiny (štáty s vyššou aktivitou v prvých dvoch rokoch sú označené hviezdičkou): Argentína*, Austrália*, Brazília*, Chile, Čína*, Egypt*, Fínsko*, Grécko, India*, Japonsko*, Juhoslávia*, Kanada, Kórea, Kuba, Namíbia, Nemecko, Pakistan*, Rakúsko*, Rusko*, Slovensko*, Taliansko*, Ukrajina* a USA.

Priebeh plnenia projektu sa zverejňuje na internetovej stránke **www.unesco.org/science/earthsciences/igcp/** a **www.gssr.sk/igcp443**.

Doterajší priebeh plnenia projektu

V roku 2000 sa činnosť v rámci projektu IGCP sústredila na sumarizáciu poznatkov o magnezite a mastenci v krajinách zapojených do jeho plnenia a na tento cieľ sa koncentrovalo aj pracovné stretnutie 28.–31. mája 2000 v Korutánsku (Rakúsko), ako aj terénna korelácia na mastencových ložiskách v štáte Paraná (Brazília) 14.–17. augusta 2000. Inauguračné zasadnutie projektu bolo súčasťou 31. medzinárodného geologického kongresu 9. augusta 2000 v Riu de Janeiro (Brazília). V závere roka 2000 vyšiel úvodný spravodajca pod názvom *Introductory Newsletter,* zhrňujúci stav poznania problematiky magnezitu a mastenca v krajinách participujúcich na projekte.

Prvé ročné pracovné stretnutie účastníkov sledovaného projektu *(Annual Meeting 2001)* sa konalo 29. augusta 2001 počas bienále ložiskových geológov SGA a SEG v Krakove (Poľsko) a popri desiatich odborných vystúpeniach boli jeho obsahom aj stručné informácie o projekte IGCP a organizačné pokyny pre účastníkov terénnej korelácie zameranej na Slovensko a jeho magnezitové a mastencové ložiská.



Na tejto korelácii (konanej pod názvom *Field Correlation 2001* 30. augusta – 2. septembra 2001) sa zúčastnili odborníci z Brazílie, Indie, Japonska, Ruska, Fínska, Rakúska a Slovenska. Centrom akcie bol Rožňavský okres.

Prvý deň exkurzie sa účastníci zoznámili s geologickou a tektonickou stavbou Západných Karpát. Geotraverzou počas presunu z Krakova do obce Muráň vo Veporských vrchoch sa analyzovala zonálnosť regionálnej stavby od vonkajších Karpát cez pieninské bradlové pásmo a vnútorné Karpaty. Muráň sa stal východiskovým bodom korelácie v nasledujúcich dňoch a zároveň miestom večerných odborných vystúpení, diskusií a debát. Problematiku magnezitu a mastenca na Slovensku priblížili odborné referáty o geologickom a tektonickom vývoji Západných Karpát (Z. Németh), o petrologických aspektoch genézy týchto surovín (M. Radvanec), o ekonomických otázkach magnezitového a mastencového priemyslu na Slovensku i o jeho histórii (Z. Novek), o ťažobných metódach (M. Leško) a ekológii (M. Bobro, F. Jenčík a P. Baláž).

Prvou navštívenou lokalitou sa stalo magnezitové ložisko *Jelšava.* Cieľom fárania (31. augusta 2001) bolo zoznámenie sa s ťaženou surovinou a so sprievodnými horninami, ako aj s používanými dobývacími metódami. Prehliadku úpravníckych zariadení uzavrela diskusia o úspešnom prekonávaní environmentálnych problémov. Na záver (2. septembra 2001) sa navštívilo aj ďalšie pracovisko SMZ Jelšava – úpravnícky komplex *Bočiar,* ktorý v súčasnosti produkuje magnezitový slinok zo zachyteného úletu v Jelšave.

1. septembra 2001 sa účastníci exkurzie na magnezitovom a mastencovom ložisku *Hnúšťa-Mútnik* pri prehliadke banskej prevádzky zoznámili s geologickou stavbou a litológiou ložiska, so selektívnou ťažbou mastenca, magnezitu, ale aj dolomitu podľa požiadaviek odberateľov a potom aj s technológiou úpravy. Popoludní prebiehala ukážka ťažobných a úpravníckych technológií používaných na ložisku mastenca *Gemerská Poloma,* ktoré sa v súčasnosti sprístupňuje razením úpadnice.

Medzi základné povinnosti organizátorov terénnych korelácií UNESCO organicky patrí aj približovanie kultúrnych a prírodných osobitostí usporiadateľskej krajiny. Pri presune do Rožňavského okresu mala medzinárodná delegácia jedinečnú možnosť vychutnať krásy tatranskej prírody a Slovenského raja a neskôr ju v okolí Rožňavy zaujala majestátnosť planín Slovenského krasu.

Na vysokej úrovni bola aj spoločenská stránka tejto významnej akcie. Ocenenie si zaslúži najmä prijatie účastníkov korelácie primátorom Rožňavy Ing. F. Kardošom a priblíženie histórie i súčasnosti Rožňavského okresu. Pri rozprávaní o bohatej banickej minulosti mesta aj celej oblasti sa účastníci exkurzie stretli aj so zástupcom baníckeho spolku Bratstvo. Spoločenským vyvrcholením podujatia medzinárodného vedeckého významu bola návšteva pivníc v tokajskej oblasti a degustácia chýrneho vína vo Viničkách.

Organizátori aj účastníci exkurzie vyjadrili vrelé poďakovanie generálnemu riaditeľovi SMZ v Jelšave Ing.

O. Šeševićkovi, Ing. O. Grendovi, Ing. J. Mathesovi a radu ich spolupracovníkov v Jelšave aj v Bočiari za pomoc pri organizovaní náročnej akcie a za jej úspešný priebeh. Slová vďaky patrili aj predstaviteľom Gemerskej nerudnej spoločnosti, s. r. o., z Hnúšte Ing. P. Cibuliakovi, Ing. M. Mrnkovi, Ing. I. Baboľovi a ich spolupracovníkom, ako aj Dr. O. Rozložníkovi zo s. r. o. ROZMIN a rožňavskému primátorovi Ing. F. Kardošovi, ktorému navyše bolo adresované poďakovanie aj za predstavenie Rožňavského okresu v celosvetovom meradle. Jemu zároveň patrilo želanie, aby sa vrátila banícka sláva tohto regiónu.

Plánované akcie

1.–4. septembra 2002 sa bude v Bratislave konať seminár IGCP 443 v rámci 17. kongresu Karpatsko-balkánskej asociácie. Ročné pracovné zasadnutie a terénna korelácia bude 9.–15. septembra 2002 vo Fínsku a na záver roka vyjde 2. číslo spravodajcu *Newsletter*.

Miesto konania ročného zasadnutia a korelácie v roku 2003 nie je definitívne určené a o ich organizáciu sa uchádza Čína, Rusko, Egypt i Sardínia. V závere roka 2003 vyjde 3. číslo spravodajcu *Newsletter*.

Rok 2004, záverečný rok plnenia projektu, bude venovaný príprave a vydaniu monografie *Magnezit a mastenec* a vedecký prínos projektu IGCP 443 sa zhodnotí na 32. medzinárodnom geologickom kongrese vo Florencii (Taliansko).

Zo Slovenska je v súčasnosti do projektu IGCP 443 zapojených 19 odborníkov zo ŠGÚDŠ v Bratislave, Spišskej Novej Vsi a v Košiciach, špecialisti z Technickej univerzity v Košiciach, Prírodovedeckej fakulty UK v Bratislave, Univerzity veterinárneho lekárstva v Košiciach, zo SAV v Košiciach a zo Štátneho zdravotného ústavu v Rožňave.

Korelačný program IGCP 443 je počas celého riešenia pre odbornú verejnosť otvorený, a preto sa do budúcnosti predpokladá ešte širšia účasť slovenských a iných odborníkov na jeho plnení.

Z. Németh a *M. Radvanec*

Obr. 1. Trasa terénnej korelácie v roku 2001 s vyznačením navštívených lokalít.

Obr. 2. Časť účastníkov terénnej korelácie 2001 po vyfáraní na ložisku mastenca a magnezitu Hnúšťa–Mútnik. Zľava: W. Prochaska (Rakúsko), I Tuokko (Fínsko), A. C. Gondim (Brazília), Z. Novek (Slovensko), V Prasannakumar (India), Z. Németh (Slovensko), S. V. Krupenin (Rusko), J Togaši (Japonsko), V V Nasedkin (Rusko), I. G. Carvalho (Brazília).

Obr. 3. Tradíciou terénnych korelácií UNESCO sú aj spoločenské akcie Recepcia u rožňavského primátora Ing. F Kardoša (druhý zľava).

Obr. 4. Prehliadka úpravne Bočiar Zľava. W Prochaska (Rakúsko), J Togaši (Japonsko), V Prasannakumar (India), A. C. Gondim (Brazília), Z. Novek (Slovensko), V V Nasedkin (Rusko), I. Tuokko (Fínsko), S. V Efremovová (Rusko), M. T Krupenin (Rusko), J Augustín (Slovensko, sprievodca zo závodu Bočiar), M. Bobro (Slovensko) a I. G Carvalho (Brazília).

Obr. 5. Degustácia tokajského vína v pivnici vo Viničkách – záver terénnej korelácie.

Zjazd Slovenskej geologickej spoločnosti 2001 Banská Štiavnica – mesto na vulkáne

Zjazd SGS 2001 sa konal 27.–29. júna 2001 v Banskej Štiavnici, v meste postavenom na vulkáne, čo motivovalo aj názov tejto významnej vedeckej a spoločenskej akcie.

Starobylé banícke mesto, obkolesené sopečnými horninami, nebolo ako miesto zjazdu vybrané náhodne, lebo vulkanológovia zo ŠGÚDŠ v Bratislave práve v tom období úspešne zavŕšili tvorbu regionálnych geologických máp v mierke 1 : 50 000 všetkých neovulkanických regiónov Slovenska, a tak sa nové poznatky stali prirodzeným predmetom rokovania. Zjazd sa sústredil najmä na geologickú stavbu, nerastné suroviny a životné prostredie stredoslovenských neovulkanitov.

Zjazd SGS 2001 zorganizovala vulkanologická odborná skupina SGS s pomocou banskobystrickej pobočky SGS a jeho program tvorilo jednodňové spoločné rokovanie a dva exkurzné dni. Záštitu nad ním prevzal minister životného prostredia SR prof. RNDr. László Miklós, DrSc., a primátor Banskej Štiavnice Ing. Marián Lichner, CSc.

V rámci slávnostnej dopoludňajšej časti odznel príhovor generálneho riaditeľa sekcie GaPZ Ministerstva životného prostredia SR RNDr. J. Franzena, primátora hostiteľského mesta Ing. M. Lichnera, CSc., riaditeľa GÚ SAV doc. RNDr. J. Michalíka, DrSc., riaditeľa ŠGÚDŠ doc. RNDr. M. Kaličiaka, CSc., hodnotiaci prejav

predsedu SGS doc. RNDr. D. Plašienku, CSc., ako aj príhovor predsedu organizačného výboru zjazdu SGS 2001 RNDr. L. Šimona, PhD., ktorý neskôr otvoril aj pracovné rokovanie zjazdu.

Milou slávnosťou úvodnej časti zjazdu bolo udelenie Medaily Jána Slávika SGS RNDr. Dušanovi Kubínymu, CSc., za prínos do rozvoja geologických vied v Slovenskej republike a dlhoročnú aktívnu činnosť v SGS, RNDr. Jaroslavovi Lexovi, CSc., za významný rozvoj geologických vied v oblasti neogénneho vulkanizmu a jeho metalogenézy, a doc. RNDr. Petrovi Reichwalderovi, CSc., za prínos do vedeckého poznania mladopaleozoicko-mezozoických komplexov južných zón Západných Karpát, za rozvoj geologických vied na Slovensku a výchovu generácie geológov.

SGS pri tejto príležitosti udelila aj čestné členstvo v SGS RNDr. Vlastimilovi Konečnému, CSc., za vedecký prínos do poznania vulkanologických procesov v Západných Karpatoch, za tvorbu geologických máp Slovenska a vedecko-popularizačné šírenie vulkanologických poznatkov.

Pracovné rokovanie bolo pripravené tak, aby prednášky zahrnuli všetky oblasti výskumu neovulkanitov a obsahovali vedecké informácie o geologickej stavbe územia, o metalogenéze aj ťažbe, o histórii výskumu a prieskumu, o geotermálnej energii, ale i krajinnoekologické hodnotenie oblasti a využívanie výsledkov environmentálnej geológie pri urbanistickom hodnotení regiónu.

Počas celého rokovania zjazdu boli vystavené geologické mapy v mierke 1 : 50 000 a 1 : 500 000, a to nie iba z územia neovulkanitov, lež aj z ďalších slovenských regiónov a vo forme posterov sa prezentovali aj nové výsledky bádania a prác z rozličných geologických oblastí.

Odborné referáty, obsah exkurzií a abstrakty pod názvom Banská Štiavnica – mesto na vulkáne (zostavil L. Šimon, V. Konečný a J. Lexa) vyšli tlačou ako samostatné číslo vedeckého periodika Mineralia Slovaca (33, 2001, č. 3). Publikácia bola súčasťou zjazdových materiálov.

Rokovací deň uzavrela spoločenská večera pre účastníkov zjazdu. V súlade s cieľom usporiadateľov sa na nej vytvorila mimoriadne srdečná atmosféra a všestranne sa zužitkovala na priateľskú debatu členov geologickej komunity z rozličných oblastí Slovenska.

Dvojdňová exkurzia mala vysokú odbornú úroveň, jej účastníci mali možnosť zoznámiť sa s vulkanologickými a geologickými fenoménmi stredoslovenských neovulkanitov – s geologickou stavbou, metalogenézou, hydrogeológiou, s environmentálnymi otázkami a pod. Exkurzii prialo aj počasie, a tak po jej skončení v Leviciach odzneli slová chvály o jej vysokej odbornej úrovni, ale aj na adresu jej organizátorov a celého zjazdu.

Zjazd SGS 2001, nesúci názov Banská Štiavnica – mesto na vulkáne, úspešne naplnil vytýčený cieľ. Po štyroch rokoch sa na ňom opätovne zišla slovenská geologická pospolitosť a predstavila časť najnovších poznatkov z geológie stredného Slovenska. Zo záverov zjazdu SGS 2001 (predchádzajúci bol v septembri 1997 a zorganizovala ho bratislavská pobočka) vyplynulo, že organizačnú štafetu preberá košická pobočka SGS a pripraví stretnutie SGS v roku 2005 zamerané na výsledky geologického výskumu a prieskumu východného Slovenska. Užší výbor SGS navrhol, aby sa takáto vrcholná celoslovenská vedecká akcia konala pod novým, vhodnejším názvom, a to kongres SGS.

Predseda organizačného výboru zjazdu SGS 2001 RNDr. L. Šimon, PhD., v závere zaželal organizátorom kongresu SGS 2005 úspech pri vytváraní dobrého organizačného tímu, trpezlivosť, zanietenosť, ale aj pomoc ostatných geologických inštitúcií pri príprave a realizácii kongresu. Zároveň poďakoval všetkým, ktorí sa zaslúžili o dokonalú organizáciu, výborný priebeh a vysokú úroveň

zjazdu SGS 2001, najmä organizačnému výboru, ktorý húževnato a obetavo pracoval v zložení: RNDr. M. Elečko, CSc., RNDr. V. Konečný, CSc., RNDr. J. Lexa, CSc., RNDr. M. Háber, CSc., Mgr. E. Kočická, RNDr. P. Reichwalder, CSc., Ing. J. Smolka, CSc., Mgr. I. Töröková, RNDr. Ľ. Iglárová, RNDr. J. Zerola, RNDr. I. Martinský a G. Poláková.

Ocenil spoluprácu a organizačnú pomoc Katedry UNESCO Technickej univerzity Zvolen so sídlom v Banskej Bystrici a poďakoval za ňu. Vyjadril vďaku za mimoriadne výdatnú pomoc ŠGÚDŠ, jej riaditeľovi doc. RNDr. M. Kaličiakovi, CSc., a redakcii časopisu Mineralia Slovaca, vďaka ktorej bol materiál venovaný zjazdu SGS 2001 distribuovaný účastníkom včas a na vysokej odbornej i technickej úrovni.

Predseda organizačného výboru napokon poďakoval všetkým za účasť na zjazde (162 prítomných) a vytvorenie priateľskej a tvorivej atmosféry, zaželal im veľa pracovných úspechov a vyjadril presvedčenie a potešenie, že sa znova stretnú na kongrese SGS 2005.

Ladislav Šimon

Foto 1. Čestné predsedníctvo zjazdu SGS 2001 Zľava. RNDr M. Elečko. CSc., RNDr J Franzen. Ing. M. Lichner. CSc., doc. RNDr J Michalík. DrSc., doc RNDr M. Kaličiak. CSc., doc. RNDr D. Plašienka. CSc., RNDr. L. Šimon. PhD., RNDr. J. Lexa. CSc., RNDr V Konečný

Foto 2. Účastníci zjazdu v aule TU Zvolen v Banskej Štiavnici.

Foto 3. Slávnostné odovzdávanie Medaily J. Slávika SGS.

Foto 4. Priateľská atmosféra na spoločenskej večeri účastníkov zjazdu.

Foto 5. Úvodná exkurzná prednáška na banskoštiavnickom stratovulkáne.

Foto 6. Diskusia na bazanitoch najmladších lávových prúdov vulkánu Putikov vŕšok.

Foto 7. Exkurzná lokalita Trojičné námestie – inžinierskogeologické otázky ochrany historického jadra Banskej Štiavnice.

Foto 8. Účastníci zjazdu na poslednej exkurznej lokalite v Leviciach.

Seminár SGS 22. marca 2001

M. KOHÚT: Granitoidné mylonity sparistodolinského typu – odraz kriedovej tektoniky na styku tatrika a veporika

Mylonitické a ultramylonitické horniny vzniknuté z pôvodných granitoidných hornín pri alpínskej kolíznej a strižnej deformácii sa študovali v rámci komplexného metalogenetického výskumu (Petro et al., 2000) vo veporickej časti Nízkych Tatier na S od Bacúcha. V údolí Bacúšskeho potoka, Leňušskej, Krškovej, Zamrzlej a Sparistej doliny sa vyskytujú intenzívne deformované granitoidné horniny, ktoré sa pôvodne označovali ako granity typu Sparistej doliny (Miko, 1981). Krehkoduktilná až duktilná deformácia má penetratívnu povahu v celom telese pôvodných granitických hornín a možno pri nej rozlíšiť dva textúrne typy, a to strednozrnné porfyroklastické (očkaté) granitoidné mylonity a relatívne homogénne jemnozrnné až strednozrnné ultramylonity. Pre rast deformácie spätej so zmenšovaním zŕn sa typická S-C mylonitická stavba miestami pretransformovala na jednofoliačnú stavbu ultramylonitov. Primárne zloženie pôvodnej magmatickej horniny pri tlakovodeformačnej metamorfóze zatlačila nová metamorfná minerálna asociácia plagioklasovo-albitového zloženia, jemnozrnný muskovit (sericit), K živec, biotit, ± epidot, klinozoisit, chlorit, karbonát, titanit, granát, rutil ± bauerit a sagenit. Minerálne zmeny v hornine sú sprevádzané alochemickými procesmi, ktoré dokumentujú mobilitu niektorých hlavných aj vedľajších chemických prvkov pri obmedzenej cirkulácii vonkajších fluíd. Kompozičné zmeny voči predpokladanému tonalitickému prekurzoru odráža najmä výnos Fe, Mg, Mn, Ca, Sr, Ba a Ti, ako aj K, Li a Rb. Obsah fengitového komponentu (Si až po 7,1) v rámci štruktúrneho vzorca svetlej sľudy v asociácii muskovit – draselný živec – biotit – kremeň indikuje tlak až 12 kbar, ale v prvej progresívnej fáze deformácie predbežne predpokladáme priemerný tlak okolo 9 kbar, ktorý odráža tvorbu ultramylonitov, kým mylonity v druhej perióde vykazujú priemerný tlak iba 6 kbar. Takéto tlakové podmienky spolu s teplotou 350–550 °C sú charakteristické pre metamorfózu konvergentných platňových okrajov orogénnych pásiem. Vznik týchto mylonitov potvrdzuje tvorba svetlej sľudy s vekom 78 ± 1,3 Ma. Keďže sme obdobné mylonitické granitoidné horniny priamo nadväzujúce na prašivské granity našli aj na južných svahoch tatrickej časti Nízkych Tatier a obdobný vek majú aj mylonity vo Veľkej a Malej Fatre, ako aj v Malých Karpatoch, vznik týchto mylonitov spájame s finálnym kolíznym dosunutím veporika na tatrikum po násune príkrovov. (Podrobnejšie pozri v štúdii M. Kohút, W. Frank a M. Petro, 2000: The Sparistá dolina Granitic Mylonites – Products of the Alpine Deformation. Slovak Geological Magazine, 6, 4, pp. 347–361).

M. KOVÁČIK: Muránske ortoruly – poznámky o tektonike, litológii a polymetamorfnej histórii

Spomedzi viacerých horninových typov tento komplex hornín charakterizujú najmä usmernené bieloružovkasté hrubozrnné litotypy s výrastlicami K živca, ktoré sa chápu ako ortoruly pochádzajúce z predkinematických granitov (Zoubek, 1932) alebo ako nižšiemetamorfované produkty kyslého paleovulkanizmu (Hovorka et al., 1987). V otázkach protolitu sa všeobecne prikláňame k novšej predstave, aj keď pôvod hrubozrnných porfyrických typov možno odvodzovať skôr z granitových porfýrov. Terénne pozorovania naznačujú, že sa v areáli tzv. muránskych ortorúl zachovali niektoré predmetamorfné znaky poukazujúce na isté zákonitosti v priestorovom usporiadaní pôvodného vulkanickosedimentárneho prostredia. V staropaleozoických jednotkách kryštalinika strednej časti kohútskej zóny zaujímajú skúmané ortoruly spodnú etáž, ktorú takmer pravidelne lemuje horizont svorovo-rulových hornín. Smerom na J (až JV) postupne prechádzajú do biotitických rúl a migmatitov a tam susedia s hlavnou masou granitoidov kohútskej zóny. Kontaktnú zónu muránskych ortorúl s nadložnými metamorfitmi sprevádza zvýšený výskyt amfibolických polôh, ale aj masívne jemnozrnné variety „muránskych ortorúl“ (tzv. leptinity). Pôvodné litologické usporiadanie má zhruba smer V–Z a v značnej miere sa využívalo pri hercýnskej deformácii. Podľa minerálnej asociácie susediacich metapelitov (almandín, staurolit, ojedinele kyanit), ako aj granatických leptinitov a amfibolitov uzatváraných v litológii „muránskych ortorúl“ možno podmienky hercýnskej regionálnej metamorfózy stotožňovať s nižšou (maximálne strednou) časťou amfibolitovej fácie. Miestami – najmä vo vrásových osiach – sa objavujú hrubozrnné segregácie leukokratnej taveniny zložené z kremeňa, albitu, K živca, príp. biotitu a turmalínu. Minerálne zloženie, obdobné ako v základnom type „muránskych ortorúl“, pripomína haplogranitový eutektický systém s teplotou kryštalizácie okolo 620–650 °C. Smer V–Z väčšinou kopíruje aj alpínska tektonometamorfóza a metamorfný stupeň v tejto oblasti dosahoval až hranicu medzi fáciou zelených bridlíc a amfibolitovou fáciou.

Významné životné jubileá členov Slovenskej geologickej spoločnosti v roku 2002

Päťdesiatroční jubilanti

RNDr. Miroslav Drahoš
Mgr. Ján Jahn
Prof. RNDr. Michal Kováč, DrSc.
RNDr. Mária Lipovská
RNDr. Ján Ostrolucký
RNDr. Igor Petrík, Csc.
RNDr. Vladimír Šťastný
P. g. Dagmar Takáčová
RNDr. Kamil Vrána, Csc.
Ing. Daniela Wanieková

Šesťdesiatroční jubilanti

RNDr. Igor Bajo
Doc. RNDr. František Baliak, Csc.
Ing. Viera Dojčáková
Ing. Jozef Daniel
RNDr. Oľga Fejdiová, CSc.
RNDr. Jozef Segíň
RNDr. František Slavík
P. g. Jozef Stolečan

Šesťdesiatpäťroční jubilanti

RNDr. Marta Balkovičová
RNDr. Ján Beňo
RNDr. Ladislav Dublan, CSc.
RNDr. Jarmila Ďurkovičová, CSc.
RNDr. Milan Háber, CSc.
RNDr. Rudolf Halouzka
RNDr. Vladimír Hanzel, CSc.
RNDr. Miroslav Jelenský
Doc. RNDR. Štefan Kahan, CSc.
Ing. Mária Kizáková
Doc. RNDr. Ing. Vladimír Letko, CSc.
RNDr. Michal Lukaj
Doc. RNDr. Jozef Malgot, CSc.
Doc. RNDr. Igor Modlitba, CSc.
RNDr. Ladislav Novotný
Ing. Anton Olšavský
RNDr. Milan Petro
RNDr. Ivan Repčok
RNDr. Zora Suchánková
P. g. Ivan Šalaga
Doc. Ing. Ján Šefara, DrSc.

Sedemdesiatroční jubilanti

Ing. Marta Abonyiová
RNDr. Vincent Holička
RNDr. E. Hýrošová
Ing. Dušan Ďurica, CSc.
Ing. Mikuláš Ingr
RNDr. Michal Lukáč
RNDr. Anna Mihaliková
RNDr. Ján Otepka
Ing. Dominik Polakovič
RNDr. Jozef Salaj, DrSc.
Doc. RNDr. Viliam Sitár, CSc.
RNDr. Paulína Snopková, CSc.
RNDr. Eugénia Vaškovská, CSc.
RNDr. Ľubomír Zbořil, CSc.

Sedemdesiatpäťroční jubilanti

Ing. Ján Baran. CSc.
Ing. Ján Bartalský, CSc.
P. g. Ondrej Falát
Ing. Ivan Kravjanský
Ing. Lubor Uiehla

Osemdesiatroční jubilanti

RNDr. Oto Fusan, DrSc.

V mene celej geologickej verejnosti všetkým jubilantom srdečne blahoželáme a do ďalších rokov želáme veľa tvorivých síl a dobré zdravie.

Doc. RNDr. Dušan Plašienka, CSc.
predseda SGS

Plán odborných akcií Slovenskej geologickej spoločnosti na 1. polrok 2002

V I polroku usporiadajú pobočky Slovenskej geologickej spoločnosti (Bratislava, Banská Bystrica, Košice) a odborné skupiny (štruktúrnej geológie, vulkanologická, uhoľná, geofyzikálna, geochemicko-mineralogická, hydrogeologická, inžinierskogeologická, paleontologická, sedimentologická a skupina ropnej geológie) tieto akcie:

Bratislavská pobočka (predseda RNDr. P Uher, CSc.)

21. 2. 2002
Seminár Naši geológovia na zahraničných cestách.
Miesto: ŠGÚDŠ, Bratislava, zasadačka 3. poschodie, 13,30 hod.

7. 3. 2002
Prednáška:
Prof. Martin Thoeni (Universitat Wien): Garnet chronometry in the Eastern Alps: problems and progress in deciphering the history of polymetamorphic rocks.
Miesto: ŠGÚDŠ, Bratislava, zasadačka 3. poschodie, 13,30 hod.

21. 3. 2002
Seminár Aktuálne problémy kryštalinika Západných Karpát.
Miesto: ŠGÚDŠ, Bratislava, zasadačka 3. poschodie, 13,30 hod.
Máj 2002
Terénna exkurzia:
Terénna exkurzia do Malých Karpát: Borinská jednotka, granity, zlaté zrudnenie.

Banskobystrická pobočka (predseda RNDr. M Háber, CSc.)

14. 2. 2002
Prednáška:
J. Spišiak: Continental Deep Drilling – súčasný stav poznatkov a perspektíva.
18. 4. 2002:
Konferencia 20. výročie založenia pracoviska Geologického ústavu SAV v Banskej Bystrici (súbor referátov; organizačný vedúci RNDr. J. Soták).

Košická pobočka

Marec 2002
Prednáška:
RNDr. O. Franko, DrSc: Minerálne a termálne vody Slovenska.
Apríl 2002
Prednáška:
Prof. M. Thoni: Results of geochornologica research in the Eastern Alps.
Máj 2002
Prednáška:
Dr. P Tropper: Metamorphic evolution of Central Alps.

Skupina štruktúrnej geológie (predseda RNDr. F Marko, CSc.)

Máj 2002
Workshop: 2-dňový medzinárodný terénny workshop v bradlovom pásme na Orave (organizovaný v spolupráci s Galicja Tectonic Group, Poľsko, Krakov).

Vulkanologická skupina (predseda RNDr. L. Šimon, PhD.)

11. 4. 2002
Prednáška:
L. Šimon: Charakter vulkanickej aktivity na stratovulkáne ETNA za posledných 10 rokov.
Miesto: ŠGÚDŠ, Bratislava, zasadačka 3. poschodie, 13,30 hod.

Uhoľná odborná skupina Prievidza (predseda Ing. J. Fazekaš, CSc.)

Február–Apríl 2002
Prednáškové popoludnie:
Nové výsledky geologického a banského výskumu v Hornonitrianskych baniach.

Geofyzikálna skupina (predseda RNDr. J. Lanc, CSc.)

14. 3. 2002
Seminár
P Kubeš et al.. Atlas geofyzikálnych máp a profilov
Miesto: ŠGÚDŠ, Bratislava, zasadačka 3. poschodie, 13,30 hod.

Geochemicko-mineralogická skupina (predseda doc. RNDr M. Chovan CSc.)

Apríl 2002
Prednáška:
prof. Zdenek Pertold: Nové poznatky o metalogeneze Českeho masivu.
Miesto: ŠGÚDŠ, Bratislava, zasadačka 3. poschodie, 13,30 hod.

Hydrogeologická skupina (predseda D. Marcin)

28. 3. 2002
Prednáška:
P Malík a D. Bodiš Hydrogeologické pomery Licinskej pahorkatiny (Gemer).
Miesto: ŠGÚDŠ, Bratislava, zasadačka 3. poschodie, 13,30 hod.

Inžinierskogeologická skupina (predseda RNDr Ľ. Iglárová)

25. 4. 2002
Prednáška:
Ing. Jana Frankovská, CSc.. Nové požiadavky na laboratórne skúšky v inžinierskej geológii a pripravované europské normy
Miesto: ŠGÚDŠ, Bratislava, zasadačka 3. poschodie, 13,30 hod.

Paleontologická skupina (predseda RNDr. J. Michalík, DrSc.)

Marec 2002
Seminár
Výsledky prác mladých paleontológov.
Miesto: ŠGÚDŠ, Bratislava, zasadačka 3. poschodie, 13,30 hod.

Máj 2002
Spoluorganizátori terénnej exkurzie:
- viď. bratislavská pobočka

Jún 2002
Spoluorganizátori konferencie:
Stretnutie slovenských a českých paleontológov

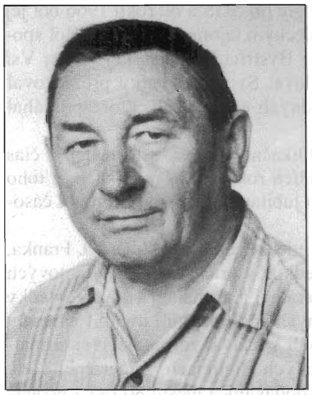
Sedimentologická skupina (predseda RNDr I. Baráth, CSc.)

18. 4. 2002
Odborný seminár
Tektogenéza Viedenskej panvy – štruktúra podložia, história zapĺňania, vývoj paleonapätí.
Miesto: ŠGÚDŠ, Bratislava, zasadačka 3. poschodie, 13,30 hod.

Skupina ropnej geológie (predseda RNDr P Ostrolucký, CSc.)

4. 4. 2002
Prednáška:
I Hrušecký et al.. Štruktúrno-tektonické štýly vývoja bazénov a na ne viazané akumulácie uhľovodíkov
Miesto: ŠGÚDŠ, Bratislava, zasadačka 3. poschodie, 13,30 hod.

Životné jubileum RNDr. Ondreja Franka, DrSc.



V máji 2001 oslávil svoje sedemdesiatiny RNDr Ondrej Franko, DrSc., významný slovenský hydrogeológ a dlhoročný vedúci vedecký pracovník GÚDŠ v Bratislave.

O. Franko sa narodil 24. mája 1931 v Párnici na Dolnej Orave. Po štúdiu na Gymnáziu v Dolnom Kubíne, maturite na Pedagogickom gymnáziu v Žiline a krátkom pôsobení ako učiteľ strednej školy v Nesluši pri Kysuckom Novom Meste začal v roku 1952 študovať na Geologicko-geografickej fakulte UK v Bratislave. Štúdium hydrogeológie zavŕšil roku 1956 na Geologicko-geografickej fakulte KU v Prahe ako promovaný geológ. V roku 1967 získal akademickú hodnosť RNDr., roku 1968 vedeckú hodnosť kandidáta geologicko-mineralogických vied a v roku 1991 – po obhájení práce Geotermálna energia Slovenska – DrSc.

Po skončení univerzitných štúdií pracoval v Ústave stavebnej geológie v Žiline, odtiaľ roku 1958 prešiel do GÚDŠ v Bratislave a pôsobil tam až do konca roku 1994. Od 1. januára 1995 je na dôchodku.

Jubilantova vedecká, odborná a organizačná činnosť je mnohostranná a je významným prínosom do rozvoja slovenskej aj svetovej hydrogeológie. Popri regionálnom a metodicko-teoretickom výskume sa sústredil najmä na problematiku minerálnych a termálnych vôd, ich ochranu a na výskum a využívanie zdrojov geotermálnej energie. Zaoberal sa aj tvorbou a redigovaním máp, hlbokými vrtmi, paleohydrogeológiou i históriou hydrogeológie. Vo veľkom rozsahu sa venoval aj pedagogickej, odbornej organizačnej a popularizačnej činnosti. Výsledky jeho práce našli doma i v zahraničí široké praktické uplatnenie. Dobré meno slovenskej hydrogeológie, GÚDŠ a Slovenska šírila aj jeho práca v domácich a medzinárodných spoločnostiach a komisiách. O. Franko patrí medzi vyhranené vedecké osobnosti, o čom okrem iného svedčí aj jasnosť a svojská lapidárnosť, s akou dokáže názorne a zrozumiteľne svoje poznatky a predstavy prezentovať.

Jubilant v prvých rokoch práce v Žiline získaval skúsenosti z hydrogeologického prieskumu kvartérnych a neogénnych sedimentov na zásobovanie pitnou vodou a zoznamoval sa i s problematikou minerálnych a termálnych vôd (Liptovský Ján, Lipovce, Bojnice). Prvou úlohou, ktorú v GÚDŠ plnil v rokoch 1958–1959, bol návrh dočasných ochranných pásiem a opatrení pre minerálne liečivé a stolové vody Slovenska. V rokoch 1960–1961 skúmal pôvod, rozšírenie a výstupné cesty CO_2 a minerálnych vôd v modrokamenskom uhoľnom ložisku vo vzťahu k odplyňovaniu CO_2 pri ťažbe uhlia. V rokoch 1962–1968 riešil vzťah bojnických liečivých termálnych vôd k ťažbe uhlia v nováckom ložisku, čo vyústilo do nového návrhu ochrany bojnických termálnych vôd. Zároveň skúmal aj termálne vody v Chalmovej, v Malých a vo Veľkých Bieliciach. V rokoch 1966–1970 sa so S. Gazdom a M. Michalíčkom venoval otázkam tvorby a klasifikácie minerálnych a termálnych vôd Západných Karpát. V ich výskume v rokoch 1971–1976 pokračoval v Liptovskej kotline a v rokoch 1975–1980 vo Zvolenskej pahorkatine. V rokoch 1971–1980 s M. Zakovičom a Ľ. Mateovičom pokračoval aj v rekognoskácii minerálnych a termálnych vôd Slovenska. V rokoch 1966–1980 sa tak vykonalo 918 kompletných rozborov, ktoré sú doteraz najúplnejšími rozbormi minerálnych a termálnych vôd Slovenska. S M. Michalíčkom zhodnotil jodobrómové vody Slovenska a s M. Poťfajom spracoval geologický projekt výskumného vrtu FPJ-1 na takéto vody v Oravskej Polhore.

Jubilant bol iniciátorom regionálneho výskumu minerálnych a termálnych vôd a zdrojov geotermálnej energie na Slovensku a pokladá sa za spoluvtvorcu a priekopníka hraničnej vedeckej disciplíny – hydrogeotermie. V rokoch 1971–1994 sústavne skúmal zdroje geotermálnej energie. V rokoch 1971–1984 študoval geotermálne vody komárňanskej kryhy a centrálnej depresie podunajskej panvy (zo začiatku sám, neskôr s A. Remšíkom, v závere s M. Fendekom). Inicioval aj výskum zdrojov geotermálnej energie v Liptovskej kotline na roky 1986–1990 (vrt v Pavčinej Lehote v rokoch 1976–1977 a v Bešeňovej v rokoch 1986–1987). Popri úlohách, ktoré riešil, sa z jeho iniciatívy plnil rad ďalších výskumných úloh zameraných na geotermálne vody. Výchovou mladých hydrogeológov hydrogeotermikov sa zaslúžil o vznik novej vedeckej generácie s všestranným prístupom k využívaniu geotermálnej energie.

O. Franko bol v rokoch 1969–1970 expertom OSN (hydrogeológ konzultant) v Salvádore (geotermálne ložisko Ahuachapán) a v roku 1981 členom expertnej misie v Alžírsku (príprava podkladov na rozvoj alžírskeho kúpeľníctva).

Výsledky regionálneho výskumu jubilant zobrazil vo viacerých mapách. Je spoluautorom Hydrogeologickej mapy ČSSR v mierke 1 : 1 000 000 (1966), Mapy regiónov podzemných vôd ČSSR v mierke 1 : 500 000 (1967), listu Nitra Hydrogeologickej mapy v mierke 1 : 200 000 (1982) a Hydrogeologickej mapy regiónu Horná Nitra v mierke 1 : 50 000 (1993). Poznatky o minerálnych vodách Západných Karpát zobrazil v Mape minerálnych vôd ČSSR v mierke 1 : 500 000 (1983). Mapu a vysvetlivky zostavil s M. Kolářovou a katalóg obaja spolu s Ľ. Mateovičom. V rokoch 1986–1990 s M. Hazdrovou vytvoril rukopisnú Geotermálnu mapu ČSSR v mierke 1 : 500 000. S M. Fendekom zhodnotil tepelnoenergetický potenciál 25 perspektívnych oblastí na 5538 MW. Vrcholným a unikátnym vedeckým mapovým dielom, ktoré O. Franko zostavil a ktorého je spoluautorom, je slovensko-anglický *Atlas geotermálnej energie Slovenska* z roku 1995 (na jeho tvorbe sa zúčastnil aj A. Remšík a M. Fendek). Na tomto atlase pod Frankovým vedením pracovalo 25 odborníkov z šesť organizácií. Na medzinárodnej výstave INTERSTONE'97 v Trenčíne zaň GSSR získala I. miesto. Jubilant sa zúčastnil aj na tvorbe hydrogeologickej mapy Podunajskej nížiny v rámci medzinárodnej spolupráce na projekte DANREG a európskeho atlasu geotermálnej energie.

Jubilant popri regionálnom výskume a tvorbe máp venoval veľkú pozornosť metodike aj teórii. Jeho prvou významnou publikáciou tohto druhu je *Problematika výskumu termálnych vôd Slovenska*, v ktorej zhodnotil stav poznatkov, sformuloval problémy výskumu, načrtol etapy výskumných prác aj ich metodiku. V ďalších dielach potom objasnil režim termálnych vôd vo vzťahu k zrážkam (dopĺňanie a vyprázdňovanie zdrojov termálnej vody a jej retardácia), definoval hydrogeologickú štruktúru a navrhol delenie štruktúr a vývěrových oblastí. Pri riešení ochrany bojnických termálnych vôd rozpracoval metodiku výskumu a filozofiu ochrany (od vývěrovej postupovať k tranzitno-akumulačnej a potom k infiltračnej oblasti). S L. Snopkom vysvetlil genézu dusíkových akratotermiem v Spišsko-gemerskom rudohorí, s M. Poťfajom genézu jodobrómových vôd v Oravskej Polhore a s M. Fendekom princíp termosifónu termálnych vôd. Do celosvetového vývoja hydrogeologickej metodiky významne zasiahla jubilantova metodika tvorby Mapy minerálnych vôd ČSSR v mierke 1 : 500 000.

O. Franko venoval pozornosť aj paleohydrogeológii: vyčlenil (s D. Bodišom) štyri etapy hydrogeologického vývoja minerálnych a termálnych vôd vnútorných Západných Karpát a na základe veku travertínových telies a ich pozície k terasám riek vysvetlil históriu termálnych vôd v Bojniciach a v Dudinciach. Pri tvorbe Mapy minerálnych vôd ČSSR (s M. Kolářovou) potvrdil vzťah výskytov uhličitej vody k tektonickým rozhraniam hlbinných blokov siahajúcich do vrchnej časti plášťa Zeme. Od roku 1995 na základe izotopov C, S, O a H s J. Michalkom a A. Šivom objasňuje pôvod a vývoj minerálnych a termálnych vôd. Zhodnotil vplyv horninového prostredia vývěrov na hodnotu $\delta^{13}C$, podľa hodnoty $\delta^{14}S(SO_4)$ určil pôvod sulfátov SO_4 z hornín spodného a stredného triasu rôznych tektonických jednotiek a podľa izotopov O a H vody zhodnotil pôvod vôd. Podľa izotopu ^{14}C a veku travertínu stanovil aj vek vôd a ich vývoj v priestore a čase. V rokoch 1971–1972 zhodnotil význam nových geotermických údajov pre štúdium hlbokých hydrogeologických štruktúr. Neskôr vymedzil 24 perspektívnych oblastí a štruktúr a geotermickou bilanciou hodnotil ich tepelnoenergetický potenciál. Na základe 15-ročných praktických skúseností spracoval metodiku hodnotenia perspektívnej oblasti, realizácie geotermálnych vrtov a ich skúšok. S O. Fusánom, M. Králom a D. Majcinom po prvýkrát zhodnotil rozloženie vysokoteplotných (nad 180 °C) a strednoteplotných (130–180 °C) vôd a tepla suchých hornín. Publikoval metodiku hodnotenia tepelnoenergetického potenciálu geotermálnych zdrojov a s O. Fusánom, J. Frankom a M. Králom poukázal na možnosti vyhľadávania ďalších zdrojov geotermálnej energie na Slovensku. Ako prvý v Západných Karpatoch aplikoval McKelveyove členenie potenciálu geotermálnych zdrojov, ako aj Mufflerovu klasifikáciu geotermálnych oblastí. S O. Fusánom a M. Králom podal najnovší ucelený prehľad hydrogeotermálnych pomerov Slovenska. Zúčastnil sa aj na príprave metodickej príručky výskumu hydrogeotermálnych zdrojov RVHP a *Terminologického slovníka minerálnych a termálnych vôd* komisie pre minerálne a termálne vody IAH. Ako predseda hydrogeologickej terminologickej komisie bol iniciátorom, spoluautorom a s J. Jetelom zostavovateľom terminologického slovníka *Hydrogeológia* (1998).

V súlade so zásadou, podľa ktorej je história matkou múdrosti, jubilant s použitím prekladov A. Rebra z latinčiny porovnal poznatky a predstavy slovenských bádateľov zo 16.–18. stor so súčasnými Publikoval históriu hydrogeológie minerálnych vôd na Sliači a s L. Meliorisom a V Hanzelom na Slovensku vôbec. Neskôr zverejnil bibliografiu podzemných vôd Slovenska za roky 1918–1955 a práce o prínose D. Andrusova, M. Maheľa a O. Hynieho pri riešení problematiky podzemných vôd Slovenska.

Jubilantovo pedagogické vzdelanie a bohaté hydrogeologické vedomosti boli dobrým východiskom pri jeho externých prednáškach o minerálnych vodách na Katedre inžinierskej geológie a hydrogeológie PFUK v Bratislave v rokoch 1962–1965. Po vedení viacerých diplomových prác bol od roku 1982 školiteľom vedeckých ašpirantov O výsledkoch výskumu prednášal na mnohých domácich a zahraničných konferenciách a seminároch Na požiadanie organizátorov vystúpil s odborným referátom na svetovom geotermálnom kongrese v Havaji, v NSR, Dánsku a na geotermálnom kurze v Meaux.

Odborné organizačné schopnosti RNDr O. Franka, DrSc., sa úspešne využívali pri vedení štátnych úloh po celý čas jeho pôsobenia v GÚDŠ. Poznanie cieľov dlhodobého výskumu mu umožnilo predkladať projekty na desiatky rokov vopred (projekt výskumu minerálnych a termálnych vôd na roky 1966–1970 s výhľadom do roku 1985; výskum zdrojov geotermálnej energie na roky 1976–1980 s výhľadom do roku 2000). V roku 1990 pripravil podklady na rokovanie vlády Islandu a Slovenskej republiky o spolupráci v geotermálnej energii a bol spoluzakladateľom slovensko-islandského podniku na využívanie geotermálnej energie, ktorý nazval SLOVGEOTERM. Medzi prvé úlohy tejto spolupráce patrila reinjektáž v Podhájskej, vykurovanie sídliska Galanta-sever a spolupráca v školstve. V roku 1991 pripravil slovensko-izraelské zasadanie o spolupráci pri využívaní geotermálnej energie v Košickej kotline. Ako člen informačnej komisie Medzinárodnej geotermálnej spoločnosti v roku 1991 zorganizoval zasadanie rodiacej sa európskej pobočky v GÚDŠ. Ako člen komisie pre minerálne a termálne vody pri Medzinárodnej spoločnosti hydrogeológov (IAH) v roku 1994 zorganizoval jej zasadanie v Bojniciach. V roku 1994 založil Slovenskú geotermálnu asociáciu. Od roku 1986 bol členom redakčného okruhu Západné Karpaty – série Hydrogeológia a inžinierska geológia a od roku 1990 vedeckým redaktorom tejto edície. Od roku 1990 bol aj členom vedeckej rady ústavu, redakčného okruhu Geologické práce – Správy, edičnej rady geologických publikácií ústavu a Národného geologického komitétu. Od roku 1993 bol členom komisie Grantovej agentúry 2 pre vedy o Zemi a vesmíre. V roku 1963 založil odbornú skupinu hydrogeológie pri SGS a od roku 1966 bol jej predsedom. V rokoch 1981–1994 bol vedeckým tajomníkom SGS. Bol spoluzakladateľom pobočky SGS v Banskej Bystrici a v Spišskej Novej Vsi a odbornej skupiny geofyziky v Bratislave. Svoje poznatky prezentoval aj na mnohých domácich a medzinárodných exkurziách, ktoré pomáhal organizovať.

Mimoriadne bohatá je jubilantova publikačná činnosť, a to nielen z čias jeho pôsobenia v GÚDŠ, ale aj z neskorších rokov (238 publikácií, z toho 38 už po odchode do dôchodku). Zoznam jubilantových prác zverejnil časopis Geologické práce – Správy 106.

O úspešnosti celoživotnej odbornej a vedeckej činnosti RNDr. O. Franka, DrSc., svedčí bohaté využívanie jej výsledkov v praxi. Podľa jubilantových návrhov sa 40 rokov chránili zdroje minerálnej a termálnej vody. Výsledky jeho riešenia ochrany bojnických termálnych vôd umožnili uvoľniť na ťažbu 170 mil t hnedého uhlia. Jeho vrty dovolili využívať zdroje liečivej termálnej vody v Bojniciach, Chalmovej a Malých Bieliciach, minerálnej vody v Čačíne, pitnej vody v Trnave (vodáreň dodávajúca mestu 80 l/s) a geotermálnu vodu na vykurovanie (sídlisko a nemocnica v Galante, skleníky v Kráľovej pri Senci, Topoľníkoch, Tvrdošovciach, Hornej Potôni, Vlčanoch a Bešeňovej) a v rekreačných kúpaliskách (Diakovce, Bešeňová a i.).

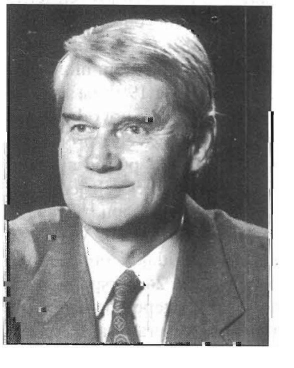
O mimoriadnom vedeckom prínose jubilanta do hydrogeológie a praxe svedčí rad vyznamenaní. V roku 1985 sa stal zaslúžilým pracovníkom rezortu SGÚ, v roku 1991 mu SAV udelila Zlatú plaketu Dionýza Štúra za zásluhy v prírodných vedách a roku 1991 Predsedníctvo SNR Národnú cenu Slovenskej republiky za poznanie zákonitostí rozšírenia geotermálnej energie, objavenie a zhodnotenie jej zdrojov V roku 1994 dostal Medailu Jána Slávika SGS za rozvoj slovenskej geológie a za zásluhy o SGS. Pri 60. výročí založenia ŠGÚDŠ v roku 2000 získal Zlatú medailu za rozvoj geológie na Slovensku a propagáciu Slovenska vo svete.

RNDr Ondrej Franko, DrSc., vždy venoval všetky svoje sily a neúnavný entuziazmus slovenskej hydrogeológii a geológii. Odborná verejnosť s obdivom hodnotí jeho neochabujúcu plodnú aktivitu, ktorú neovplyvnil ani odchod jubilanta do dôchodku.

Priatelia a spolupracovníci, ako aj celá odborná verejnosť oceňujú zásadovosť, tvorivú húževnatosť, priamosť, ľudský prístup, svedomitosť a pracovný elán RNDr O. Franka, DrSc., ktorý mu môžu závidieť aj jeho mladší nasledovníci, a pri príležitosti dôležitého životného jubilea mu želajú pevné zdravie, ďalšie tvorivé nápady, silu na ich naplnenie a napokon aj udržanie doterajšieho elánu a optimizmu.

Michal Elečko a *Ján Jetel*

Doc. RNDr. Peter Reichwalder, CSc., šesťdesiatročný



V roku 2001 oslávil svoje šesťdesiatiny významný slovenský geológ doc. RNDr Peter Reichwalder, CSc.

Jubilant sa narodil 27 júna 1941 v Krompachoch. Vrúcny vzťah ku geológii sa uňho prejavil veľmi skoro, a tak si vybral štúdium na Priemyselnej škole geologickej v Spišskej Novej Vsi a zavŕšil ho maturitou roku 1959. Jeho cesta potom viedla do Bratislavy na Prírodovedeckú fakultu UK. Univerzitné štúdiá v odbore základná a ložisková geológia úspešne ako promovaný geológ skončil roku 1964. Na Prírodovedeckej fakulte UK neskôr za prácu o kryštaliniku Vysokých Tatier získal aj akademický titul RNDr V roku 1970 obhájil kandidátsku dizertáciu *Geologická stavba juhovýchodnej časti paleozoika Spišsko-gemerského rudohoria* a získal titul kandidáta geologických vied (CSc.).

P Reichwalder začal profesionálnu činnosť v spišskonovoveskom závode n. p. Uránový prieskum, ale už po krátkom čase prešiel na vrcholové vedecké pracovisko – GÚDŠ. Tomuto ústavu venoval dvadsaťdva rokov života a práce a najmä ako námestník riaditeľa v rokoch 1977–1986 vo veľkej miere formoval profil tejto dôležitej inštitúcie. Z uvedenej funkcie mu vyplynul aj rad ďalších povinností. Bol členom a neskôr predsedom komisie na schvaľovanie hlbokých vrtov geologického výskumu, členom vedeckej rady GÚDŠ a ÚÚG, členom medzinárodnej a medzinárodnej pracovnej skupiny na využívanie diaľkového prieskumu Zeme v ČSSR, členom sekcie pre rozvoj surovinovej a materiálnej základne pri Slovenskej komisii pre vedecko-technický a investičný rozvoj, členom rady kľúčového smeru štátneho programu základného výskumu II-4 *Geologické a geochemické procesy*, členom komisie pre aprobáciu geologických máp, predsedom knižničnej komisie GÚDŠ, ako aj členom komisií n. p. Geofyzika v Brne. Zorganizoval viac tektonických konferencií v Smoleniciach.

Výskumne sa doc. P. Reichwalder sústredil na ekonomicky najvýznamnejšiu slovenskú oblasť – Spišsko-gemerské rudohorie a Slovenský kras. Išlo o geologický výskum, geologické mapovanie, ako aj o štruktúrnogeologickú analýzu. Medzi prvými aplikoval poznatky tektoniky litosférických dosák pri rekonštrukcii geologického vývoja a paleotektoniky v gemeriku a meliatiku. Detailne rozpracoval najmä problematiku juhogemerického mladšieho paleozoika a vysokotlakové horninové asociácie spájané so subdukčno-akrečnými procesmi. Venoval sa aplikácii metód diaľkového prieskumu Zeme pri regionálnogeologickom a tektonickom výskume a pri tvorbe geologických máp. Schopnosti na vykonávanie tejto špecifickej činnosti získal počas trojmesačného študijného pobytu zameraného na využívanie kozmických snímok pri geologickej interpretácii na Ministerstve geológie ZSSR v Moskve. Je spoluautorom prvej kozmotektonickej mapy strednej a východnej Európy. Spolupracoval pri tvorbe šiestich publikovaných máp a vysvetliviek k nim.

Významná bola jubilantova výskumná a pedagogická činnosť v zahraničí, venovaná dvom africkým krajinám – Zambii a Etiópii. V rokoch 1971–1975 pracoval v Geologickej službe Zambie (prostredníctvom podniku zahraničného obchodu Polytechna). Venoval sa predovšetkým komplexnému geologickému výskumu – geologickému mapovaniu, štruktúrnogeologickému bádaniu a geochemickej prospekcii – vo východoafrickom riftovom pásme. Utvoril a publikoval prvú geologickú mapu tohto územia v mierke 1 : 50 000 zachycujúcu vyše 6000 km^2.

V rokoch 1988–1989 pôsobil P. Reichwalder v Etiópii ako expert OSN v rámci projektu *New methods of mineral exploration*. Išlo o postgraduálny kurz pre mladých etiópskych geológov, geochemikov a geofyzikov zameraný na moderné metódy laboratórneho a komplexného regionálnogeologického výskumu, najmä na Au mineralizáciu.

Vedecké konferencie, kongresy a sympóziá, ako aj študijné či pracovné cesty zaviedli jubilanta do mnohých ďalších krajín. Boli to USA, ZSSR (Rusko, Ukrajina, Gruzínsko), Rumunsko, Bulharsko, Poľsko, Maďarsko, Juhoslávia, Rakúsko, Francúzsko, Tanzánia aj Island.

Doc. P. Reichwalder, CSc., v druhej fáze svojej profesionálnej životnej púte bol a je v prvom rade univerzitným učiteľom. Táto jeho cesta sa začala v roku 1986, keď ho vymenovali za docenta a vedúceho Katedry geológie a paleontológie Prírodovedeckej fakulty UK. Vďaka organizačným schopnostiam a skúsenostiam, ako aj príkladnej usilovnosti a húževnatosti katedru skonsolidoval i zveľadil. Prednášal a postupne rozpracoval deväť odborných disciplín. Ťažiskom bola regionálna geológia (ČSR, strednej Európy, sveta), štruktúrna geológia a na ňu nadväzujúca geotechnika, metódy terénneho výskumu, interpretácia leteckých a družicových snímok, organizácia a riadenie geologickej služby, ako aj exkurzie a mapovacie kurzy. V poslednom čase vedno s doc. E. Jablonským prednáša základný geologický predmet – všeobecnú geológiu.

Okrem už spomenutej pedagogickej činnosti v afrických krajinách jubilant v angličtine prednášal geológiu zahraničným študentom Stavebnej fakulty STU a na Varšavskej univerzite mal v roku 1998 tridsaťhodinový cyklus prednášok pre doktorandov o centrálnych a vnútorných Západných Karpatoch. Kus užitočnej práce vykonal aj v skúšobných či kvalifikačných komisiách rozličného druhu (DrSc., CSc., PhD., RNDr. štátne záverečné skúšky magisterského štúdia a pod.).

Tretím významným okruhom činnosti doc. P. Reichwaldera bola a je organizačná práca pre geologickú komunitu. Na medzinárodnom poli išlo o funkciu tajomníka tektonickej komisie Karpatsko-balkánskej asociácie (1983–1996), členstvo v pracovnej skupine RVHP pre diaľkové metódy výskumu družicami a lietadlami v geológii a v pracovnej skupine morfológie a genézy tektonických štruktúr v rámci mnohostrannej spolupráce akadémií vied socialistických krajín. Doma je členom Slovenskej geologickej rady (1996–2001) a Slovenského národného geologického komitétu (1994–2001), ako aj šiestich redakčných rád slovenských geologických časopisov a periodických publikácií.

Priam srdcovou záležitosťou jubilanta je pôsobenie v SGS. Je členom jej výboru, predsedom bratislavskej pobočky, od roku 1994 predsedom SGS a v tejto funkcii viac ráz reprezentoval Slovensko v zahraničí. Výrazne sa zapojil do organizácie dvoch zjazdov SGS – v septembri 1997 v Bratislave a v júni 2001 v Banskej Štiavnici. V roku 1997 s výborom SGS, ktorý viedol, zorganizoval zjazd aj medzinárodnú konferenciu *Alpine evolution of the Western Carpathian and related areas*, venovanú stému výročiu narodenia akad. D. Andrusova.

Jubilant – osobitne ako predseda – zodpovedným prístupom a s citom pre situáciu dokázal v tomto – pre SGS neľahkom – období udržať činorodosť SGS a plniť jej poslanie v geologickej obci Slovenska.

Pri vzácnej príležitosti nemožno obísť ani jubilantove zásluhy o popularizáciu geológie, osobitne filmami s geologickou problematikou. Široká verejnosť ho dobre pozná z jedenásťdielneho cyklu *Cez Karpaty*, nakrúteného v spolupráci Slovenskej a Poľskej televízie. Jubilant vlastní najrozsiahlejšiu filmotéku (videotéku) geologických filmov na Slovensku.

Doc. Peter Reichwalder, CSc., patrí medzi ľudí, pre ktorých je geológia nielen zamestnaním a povolaním, ale aj hlbokou osobnou záľubou. Skromné vystupovanie, široký odborný rozhľad i zmysel pre spravodlivosť mu priniesli množstvo priaznivcov, obdivovateľov a dobrých priateľov. Pri významnom životnom jubileu mu želáme pevné zdravie, pracovnú pohodu a veľa radosti v rodinnom kruhu.

Milan Mišík a *Michal Elečko*

Prehľad publikovaných prác

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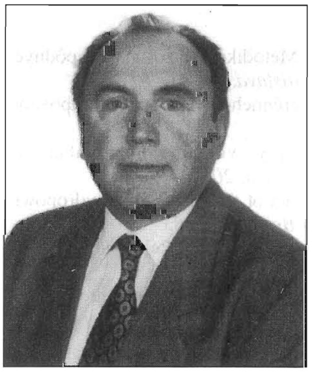
Náučno-vedecké filmy

Cez Karpaty (C 1998–1999 Poľská televízia)
(C 2000 STV – slovenské znenie)
11-dielny dokumentárny seriál – geologické putovanie po slovenských Karpatoch (spoluautor scénara a realizácie)
Jednotlivé časti seriálu: Malá Fatra, Stredné Považie 1. a 2. časť, Strážovské vrchy, Malé Karpaty, Nízke Tatry, Slovenský kras, Stredoslovenské vulkanity, História slovenského baníctva, Cerová vrchovina, Vulkanity východného Slovenska.

Doc. RNDr. Ján Čurlík, CSc., šesťdesiatročný



Začiatkom augusta v plnom zdraví a v príkladnom pracovnom nasadení završil šieste decénium svojho plodného života doc. RNDr Ján Čurlík, CSc., vynikajúci geochemik a priekopník nových, moderných geochemických špecializácií.

Ján Čurlík sa narodil 4. augusta 1941 v Petrovciach v okrese Vranov nad Topľou. Základnú školu vychodil v Hanušovciach nad Topľou a v roku 1959 zmaturoval na Vyššej priemyselnej škole geologickej a baníckej v Spišskej Novej Vsi V rokoch 1959–1960 pracoval ako technik v Pozemných stavbách v Prešove pri prieskume stavebných surovín. Po základnej vojenskej službe roku 1962 študoval na Prírodovedeckej fakulte UK v Bratislave a štúdiá úspešne skončil roku 1967.

Po absolvovaní univerzity nastúpil ako vedecký pracovník do Výskumného ústavu pôdoznalectva a výživy rastlín v Bratislave. Na požiadanie prof. S. Cambela prešiel roku 1975 na rodiacu sa Katedru geochémie Prírodovedeckej fakulty UK, kde bol najskôr vedeckým pracovníkom, potom odborným asistentom a od roku 1987 docentom v odbore geochémia.

V roku 1972/1973 absolvoval postgraduálne štúdium pôdnej mineralógie a mikromorfológie v Holandsku a v roku 1973 mesačnú stáž v Pedologickom ústave Dokučajeva v Moskve. V roku 1974 získal akademický titul RNDr a v roku 1976 na Katedre mineralógie a kryštalografie Prírodovedeckej fakulty UK vedeckú hodnosť kandidáta vied (CSc.). V roku 1986 bol na jednosemestrovom prednáškovom pobyte na Štátnej univerzite v Gente v Belgicku. V roku 1990 prešiel do Výskumného ústavu pôdnej úrodnosti v Bratislave, kde pôsobí ako vedecký pracovník doteraz a vedie oddelenie pedológie.

Jubilant vo svojom doterajšom odbornom a pedagogickom pôsobení urobil kus dobrej práce na vedeckom, pedagogickom aj organizačnom poli V pôdoznaleckom ústave vybudoval laboratórium mineralógie a mikromorfológie, na katedre laboratórium geochémie a mikroskopie a v ústave, v ktorom pracuje teraz, oddelenie pedológie.

Doc. RNDr J Čurlík, CSc., zaviedol na Katedre geochémie Prírodovedeckej fakulty nové, moderné učebné disciplíny – geochémiu životného prostredia, geochémiu sedimentárnych procesov, geochémiu hypergénnych procesov, geochémiu krajiny, ochrany ovzdušia, pôdy a vody Pracoval na koncepciách moderného geochemického aj environmentálneho štúdia na fakulte. Takpovediac za pochodu pripravoval obsah nových geochemických disciplín, spracoval najprv interné a po nich aj oficiálne učebné texty.

Išlo najmä o texty z geochémie životného prostredia (1983) – vôbec prvé v Československu – a neskôr z geochémie hypergénnych procesov (1988). Jedny aj druhé dostali v roku ich vydania cenu rektora UK. V spoluautorstve napísal aj skriptá z pedológie (Nitra, SPU) a interné skriptá z pedogeochémie.

Bohatá je aj doterajšia jubilantova pedagogická činnosť. Prednášal nielen na Prírodovedeckej fakulte UK, ale aj na Masarykovej univerzite v Brne (1982–1990), na Academii Istropolitana (1992–1994) a príležitostne aj na Slovenskej poľnohospodárskej univerzite v Nitre. V pedagogickej práci sa opieral o vlastné vedecké bádanie a o najnovšie poznatky svetovej vedy. Doteraz vychoval okolo tridsať diplomantov, doktorantov (RNDr.) a vedeckých ašpirantov. Aj v súčasnosti externe prednáša pedogeochémiu a geochémiu krajiny na Prírodovedeckej fakulte UK a je školiteľom doktorandov.

Doc. RNDr. J. Čurlík, CSc., začal svoju vedeckú dráhu komplexným prieskumom pôdy na Slovensku, získal o nej výborný prehľad a to rozhodlo o jeho ďalšom vedeckom smerovaní. Položil základy mineralogického a mikroskopického štúdia pôdy, geochemického štúdia hypergénnych procesov a environmentálnych otázok na Slovensku. Systematickou prácou zameranou na túto problematiku zdôvodňoval potrebu rozvíjať nové disciplíny a orientovať geochemický výskum na riešenie problémov životného prostredia a ochrany pôdy na Slovensku.

Jubilant je uznávaným pedológom, geochemikom hypergénnych procesov, odborníkom v environmentálnej geochémii a pedogeochémii nielen doma, ale aj v zahraničí. Jeho publikačná činnosť je rozsiahla a pestrá. V zahraničí sám alebo s inými domácimi a zahraničnými autormi publikoval 30 vedeckých prác, z nich štyri monografie. Napísal a zverejnil vyše 55 vedeckých štúdií v domácich odborných časopisoch, okolo 35 v rozličných zborníkoch, vytvoril okolo 100 máp a množstvo záverečných správ z vedeckovýskumných projektov. Napísal aj niekoľko príležitostných článkov pri rozličných udalostiach, jubileách, rad recenzií a populárno-vedeckých prác.

Je riešiteľom i koordinátorom rozličných vedeckých projektov na národnej aj medzinárodnej úrovni. Zúčastnil sa na plnení siedmich veľmi významných medzinárodných projektov. Z národných projektov bol mimoriadne dôležitý *Geochemický atlas a súbor máp geologických faktorov životného prostredia Slovenskej republiky*, kde bol J. Čurlík riešiteľom pedologickej problematiky. Autori tohto projektu dostali cenu ministra životného prostredia Slovenskej republiky.

Výsledky svojej vedeckovýskumnej práce jubilant zverejňoval v podobe vyžiadaných prednášok v zahraničí, na vedeckých konferenciách, sympóziách a iných odborných stretnutiach. Ako uznávaný vedec sa stal členom medzinárodnej komisie UNESCO pre otázky cezhraničného znečisťovania ovzdušia (CLTAP), členom medzinárodnej expertnej skupiny pre kontaminovanú krajinu a v súčasnosti vedie expertnú skupinu kritických limitov ťažkých kovov v pôde. Zorganizoval rad domácich aj medzinárodných vedeckých akcií.

Jubilant je riadnym členom a v súčasnosti aj členom predsedníctva Slovenskej akadémie poľnohospodárskych vied, členom vedeckých spoločností a bol členom viacerých vedeckých a redakčných rád.

V mene súčasných spolupracovníkov z Výskumného ústavu pôdnej úrodnosti v Bratislave, bývalých z Katedry geochémie Prírodovedeckej fakulty UK, vedeckých ašpirantov a študentov, ktorých viedol, ako aj v mene celej geologickej a pedologickej pospolitosti želáme doc. RNDr. Jánovi Čurlíkovi, CSc., pri jeho významnom životnom jubileu všetko najlepšie, pevné zdravie, pohodu, spokojnosť, doterajší elán pri napĺňaní predsavzatí a nové úspechy vo vedeckovýskumnej práci.

J. Veselský, P. Ševčík, O. Ďurža

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IGCP 443 – MAGNESITE AND TALC – GEOLOGICAL AND ENVIRONMENTAL CORRELATIONS

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Magnesite and Talc

Geological and Environmental Correlations

IGCP 443 NEWSLETTER No. 1

Edited by

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Antonio C. Gondim
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Mineralia Slovaca, Bratislava, 2001

Preface

This issue of Newsletter No. 1 presents the results of 2001 research activities of scientists included to UNESCO/IUGS International Geological Correlation Programme IGCP 443 Magnesite and Talc – Geological and Environmental Correlations. In comparison with previous IGCP 443 Introductory Newsletter, issued in December 2000 and targeted to resume the-state-of-the-art in magnesite and talc knowledge in individual participating countries, recent one widens all formerly dealt topics.

Newsletter No. 1 is referred also to findings presented and discussed during IGCP 443 Annual Meeting 2001 in Krakow, Poland, lead by M. Radvanec and W. Prochaska on 29 August 2001, but mainly to the Field Correlation 2001 Slovakia on 30 August–2 September 2001 guided by Z. Németh. Topics of Slovak magnesite and talc geology, industry and environmental protection are therefore ranked in continual block at the beginning of issue. Regarding to visited localities there were incorporated also two larger articles about ups and downs of magnesite production in Slovakia by Z. Novek et al.

Newsletter No. 1 reflects the research results in all thematic groups of IGCP 443. (1) Geology and structure of magnesite and talc deposits as well as (2) Geochemistry, petrology and mineralogy are treated in contributions by M. Radvanec and W. Prochaska, M. Fiori and S. M. Grillo, M. Niemelä, V. V. Nasedkin et al., A. C. Gondim, I. G. Carvalho, M. A. Mandour et al., H. Hirano and Y. Togashi as well as V. Prasannakumar and S. N. Kumar. (3) Methods of exploration, investigation of the raw materials are mainly dealt in contributions by M. Tréger and P. Baláž, Z. Novek et al., M. Niemelä, A. C. Gondim, M. A. Abou Elmaaty et al. and H. Hirano and Y. Togashi. (4) Geoenvironmental models and related topics are preferably treated by M. Bobro and J. Hančuľák, F. Jenčík et al. and A. C. Gondim.

In 2001 the IGCP 443 abandoned the "summarizing" beginnings and focussed its activities on targetted research in Thematic groups. These are built in individual National working groups of 26 participating countries, though there is no strict rule to have organized all Thematic groups in each National working group.

We believe that the "warming up" of research and correlation on magnesite and talc framed by IGCP 443 was successful. Presented Newsletter No. 1 intends to demonstrate this.

December 2001

Martin Radvanec, Antonio Carlos Gondim and Zoltán Németh

Rady autorom

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Už pri príprave obrázka treba zvážiť, či sa umiestni na jeden stĺpec alebo na dva stĺpce. resp. na celú tlačenú stranu. Vhodne upravený obrázok (veľkosť písmen. hrúbka čiar) možno reprodukovať aj v pomere 1:1 alebo odporúčame urobiť kresby (perovky) väčšie. ako sa predpokladá ich veľkosť po vytlačení. Perovky majú byť zhotovené sýtym čiernym tušom. Pri obrázkoch urobených na počítači treba redakcii poslať originálne obrázky (nie xeroxové kópie) vytlačené na pauzovacom papieri - *tlač laserovou tlačiarňou v kamerálnej podobe pri vysokom rozlíšení (min. 300 DPI)*. Pri zostavovaní obrázkov redakcia odporúča pracovať s programami vo vektorovom zobrazení (napr. Corel Draw — TIFF). Neodporúčame používať veľmi tenké čiary (tzv. vlasovej hrúbky) ani na obrysy ani vo výplni.

Úmerne k predpokladanému zmenšeniu treba zvoliť hrúbku čiar. veľkosť písma. čísiel. hustotu šrafovania a pod. Text možno napísať väčším aj menším písomom (nie verzálkami - veľkými písmenami). a to podľa toho. čo sa má zvýrazniť. Optimálna veľkosť písma v časopise po zmenšení je pri veľkých písmenách a číslach 2 mm a pri malých písmenách 1,6 mm.

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1. Úprava textu včítane zoznamu literatúry prispôsobte súčasnej úprave článkov v časopise.
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6. Neopakovať údaje z tabuliek a obrázkov. iba ich komentovať a odvolať sa na príslušnú tabuľku. resp. obrázok.
7. Text treba členiť nadpismi. Hlavné nadpisy písať do stredu. vedľajšie na ľavý okraj strany. Voliť najviac tri druhy hierarchických nadpisov. Ich dôležitosť autor vyznačí ceruzkou na ľavom okraji strany: 1 - hierarchicky najvyšší. 2 - nižší, 3 - najnižší nadpis.
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   V prípade ilustrácií vytvorených na počítači prosíme o ich zaslanie na diskete 3.5" vo formáte CorelDraw (PC). Adobe Illustrator (PC. Mac) alebo Aldus FreeHand (Mac).
2. Ilustrácie pripravovať s vedomím. že sa budú zmenšovať (zvyčajne o 50 %) na šírku stĺpca (81 mm) alebo strany (170 mm). Podľa toho pripravovať ich veľkosť a formou. resp. ich zoskupenie.
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Tabuľky

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