

**PHASE RELATIONS AND METAMORPHIC *P-T* CONDITIONS OF INTERCALATING  
SILICATE-BEARING MAGNESITES AND CALC-SILICATE ROCKS (MARBLES),  
AMPHIBOLITES, AND SCHISTS FROM  
THE MÚTNIK DEPOSIT, SOUTHERN VEPORIC (W. CARPATHIANS)**

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**Abstract:** Mineral assemblages of *Tlc-Chl±Phl*-bearing magnesites, *Tr-Cal-Dol* marbles and *Wo-Vs-Cpx-Czo-Grt(Grs-Adr)-Cal-Qtz* calc-silicate rocks, intercalated with *Grt*-bearing and *Grt*-free *Hbl-Chl-Czo-Cal-Ank-Qtz* paraamphibolites and schists in the Southern Veporic were studied. Parameters of the prograde metamorphism are the following : *T* – 520-525°C, *P* – 7.9-8.5 kbar, *X*<sub>CO<sub>2</sub></sub> in fluids: 0.15-0.20 in the magnesites, and 0.1 in the calc-silicate rocks.

**Key words:** magnesite, calc-silicate rock, amphibolite, *P-T* data

### **Introduction and geological setting**

The crystalline basement of the Southern Veporic is quantitatively dominated by garnet-mica schists with layers of *Cld-Chl-Grt-Ky-Ms* and *St-Cld-Grt-Chl-Ms* schists (the Ostrá Complex, Bezák, 1982) and includes a specific lithological horizon of magnesite and magnesite-dolomite marbles interlayered by rare calcite-dolomite marbles with mica-carbonate and garnet-mica schists, garnet amphibolites, graphite quartzites, and thin laminas of mafic quartz-free high-Mg *Tlc-Chl±Phl* schists. All of these rocks have conformable contacts, show texturally equilibrated mineral assemblages, and affiliate with the same temperature grade without evidence of metasomatism, and traces of magmatic injections. Any metaultramafic, mafic or acid metamagmatic rocks are missing from marbles, and, thus were most probably produced from carbonate sediments with minor admixtures of clayey material, intercalated with aleurolites, shales and carbonate-silicate marles and sandstones. All of them were similarly metamorphosed under medium-temperature conditions.

The metacarbonate rocks are dominated by the impure marbled magnesites with occasional tremolite-calcite-dolomite marbles and very rare calc-silicate wollastonite-

vesuvianite-clinopyroxene-garnet-epidote-calcite-quartz rocks. The latter were initially ascribed to the calcareous skarn (Turanová *et al.*, 1997). But the absence of igneous rocks in this unit, the absence of magnesian skarns in the most widespread magnesites as well as the lack of the typical skarn zoning and the finely laminated structures of the calc-silicate rocks suggest that these are most probably normal impure limestones.

### Phase relations and P-T estimates

The main rock types contain the following mineral assemblages (subscripts indicate  $X_{\text{Fe}}$  values, %). The **magnesite marbles** are dominated by magnesite ( $\text{Mgs}_{1-8}$ ) with rare dolomite grains ( $\text{Dol}_{1-6}$ ), small flakes of talc ( $\text{Tlc}_{0-3}$ ) and Mg-chlorite ( $\text{Chl}_{1-6}$ ) (fig. 1). The marbles often contain thin conformable 0.1-1.5-m-thick mafic magnesian-mica layers of unknown length, which consist either of talc alone ( $\text{Tlc}_{0-4}$ ), or of talc with Mg-chlorite, or with Mg-chlorite and phlogopite ( $\text{Tlc}_{1-8} + \text{Chl}_{3-5} \pm \text{Phl}_{7-17}$ ) (fig. 1.I), containing single grains of magnesite and dolomite, and are completely devoid of quartz and feldspar. The mafic layers higher in Fe have a biotite-chlorite composition ( $\text{Bt}_{20-45} + \text{Chl}_{18-40}$ ).

The **calcite-dolomite** marbles consist of calcite, dolomite ( $\text{Dol}_{0-5}$ ), and acicular tremolite ( $\text{Tr}_{0-7}$ ) but have never been determined to contain magnesite. The **calc-silicate rocks** contain calcite, quartz, wollastonite, Mg- or Fe-Mg vesuvianite, clinopyroxene ( $\text{Cpx}_{15-16}$ ), grossular (73-86%)-andradite (14-27%) garnet, and clinozoisite, which make up either calcite-free or calcite-bearing calc-silicate thin intercalating layers. Mineral associations of the impure magnesite, calcite-dolomite, and calcite marbles without aluminosilicates are shown on fig. 2.

Some of the marbles include thin conformable layers of the **Grt-bearing or Grt-free paraamphibolites and schists** with calcite or/and ankerite. The garnet-free amphibolites have medium-Fe or magnesian compositions and consist of Fe-Mg hornblendes or actinolitic hornblendes ( $\text{Hbl}_{15-50}$ ), chlorite ( $\text{Chl}_{14-40}$ ), biotite ( $\text{Bt}_{18-45}$ ), clinozoisite, plagioclase ( $\text{An}_{8-28}$ ), and quartz  $\pm$  calcite or ankerite ( $\text{Ank}_{20-30}$ ), (fig. 3.I). The garnet amphibolites are high in iron and consist of the progradely zoned garnet ( $\text{Prp}_{3-9\%}$ ,  $\text{Grs}_{30-18\%}$ ,  $X_{\text{Fe}}$  in the margin 87-90%), tschermakitic hornblende ( $\text{Hbl}_{50-66}$ ), chlorite ( $\text{Chl}_{46-60}$ ), clinozoisite, oligoclase ( $\text{An}_{20-29}$ ), and quartz (fig. 2.2).

The  $X_{\text{Fe}}$  of biotite and chlorite in the **mica- and mica-carbonate schists** vary from 9 to 42%; Fe-Mg micas occur in assemblage with clinozoisite, phengite (up to 0.48 {Mg+Fe} p.f.u.), plagioclase ( $\text{An}_{13-29}$ ), ankerite or dolomite ( $\text{Dol-Ank}_{3-30}$ ), and quartz. The Grt-bearing schists contain high-Fe progradely zoned garnet ( $\text{Prp}_{5-7\%}$ ,  $\text{Grs}_{16-17\%}$ ,  $X_{\text{Fe}}$  in the margin 90-91%),  $\text{Chl}_{51-59}$ , clinozoisite, muscovite, paragonite, and quartz, but are devoid of carbonates.

Given the equilibrium and monofacial character of all assemblages, and intercalation of the carbonate, carbonate-silicate, and silicate rocks to one another, the *P-T* metamorphic conditions of the whole complex were assayed using the *Grt*-bearing paraamphibolites and schists. According to the *Grt-Hbl* thermometer, the metamorphic culmination occurred at a temperature of 460-480°C (Krogh Ravna, 2000), or 520-525°C (Perchuk, 1989), or 600°C (Graham & Powell, 1984) ; the *Grt-Chl* thermometer (Perchuk, 1989) gives 520-525°C. The pressure was estimated at 7.9-8.5 kbar by the *Grt-Hbl-Pl-Qtz* barometer (Kohn & Spear, 1990). Taking into consideration the stability of the *Cld + Chl ± St* assemblage in the host high-Al schists of the Ostrá Complex, the broad stability of Fe-Mg chlorite ( $X_{Fe}$  - up to 60% in *Qtz*-bearing rocks), the stability of talc and tremolite in the Mg- or Mg-Ca marbles in the absence of forsterite, Mg-cummingtonite, and Mg-anthophyllite in them, 520-525°C as the upper temperature limit of metamorphism, according *Grt-Hbl* and *Grt-Chl* thermometers of Perchuk (1989) seems to be the most reasonable. Kyanite crystallization in the metapelites and the absence of sillimanite in them confirms the high value of a total pressure.

The fact that the magnesite marbles contain the *Tlc ± Mgs* assemblage instead of serpentine and forsterite, and that vesuvianite, and also wollastonite in association with the *Cal + Qtz* assemblage are stable in the calc-silicate rocks led us to conclude that the  $X_{CO_2}$  of the metamorphic fluids varied in different types of rocks, and attained 0.15-0.20 in the magnesite marbles, and no more than 0.1 in the calc-silicate wollastonite- and vesuvianite-bearing rocks.

### **The age of metamorphism**

The age of the prograde, undoubtedly single-stage metamorphism of marbles, paraamphibolites and mica schists from the Ostrá Complex remains uncertain, as well as the age of the protolith. The U-Pb zircon age of veins of the Rimavica granite (Bibikova *et al.*, 1988) cutting of *Grt-Chl-Bt-Czo-Phn* gneisses of the south-Veporic Hladomorná Dolina Complex (another lithological structural complex of the South-Veporic basement) equals 350 Ma. Considering this dating, and formation of secondary *Grt* rims (strongly enriched in grossular) around more ancient garnet grains both in mica gneisses and the Rimavica-type of metagranites in this area (Korikovskiy *et al.*, 1989, 1990), at least some of the medium-temperature metamorphic rocks of the southern Veporic (very similar with the Ostra Complex ones) had the Variscan age of their primary metamorphism, and pre-Carboniferous age of a protolith. However, according to  $^{40}Ar$ - $^{39}Ar$  dating of the high-Al *Cld-Chl±St-Ms* metapelites of the Ostrá Complex, to which marbles belong, the prograde metamorphism was Alpine in age (105-84 Ma -

Malusky et al. 1993; Dallmeyer et al. 1996; Král' et al. 1996; Kováčik et al. 1997; or 95-60 ± 10 Ma - Janák et al., 2001).

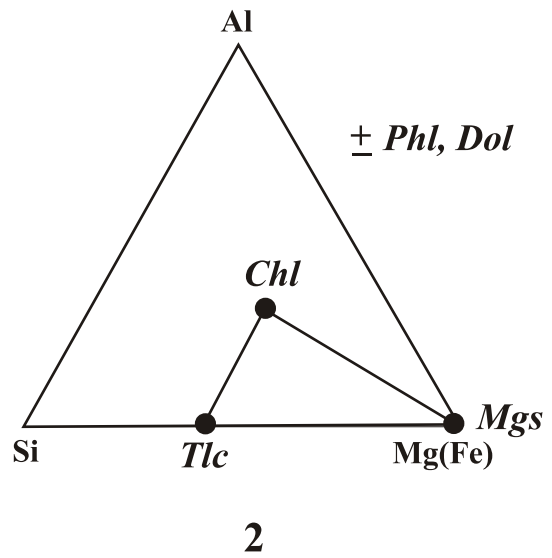
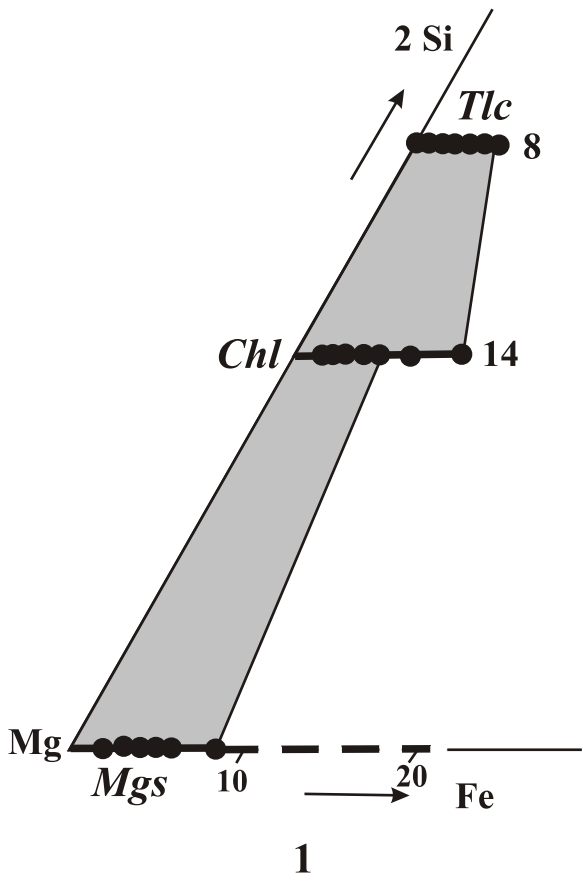
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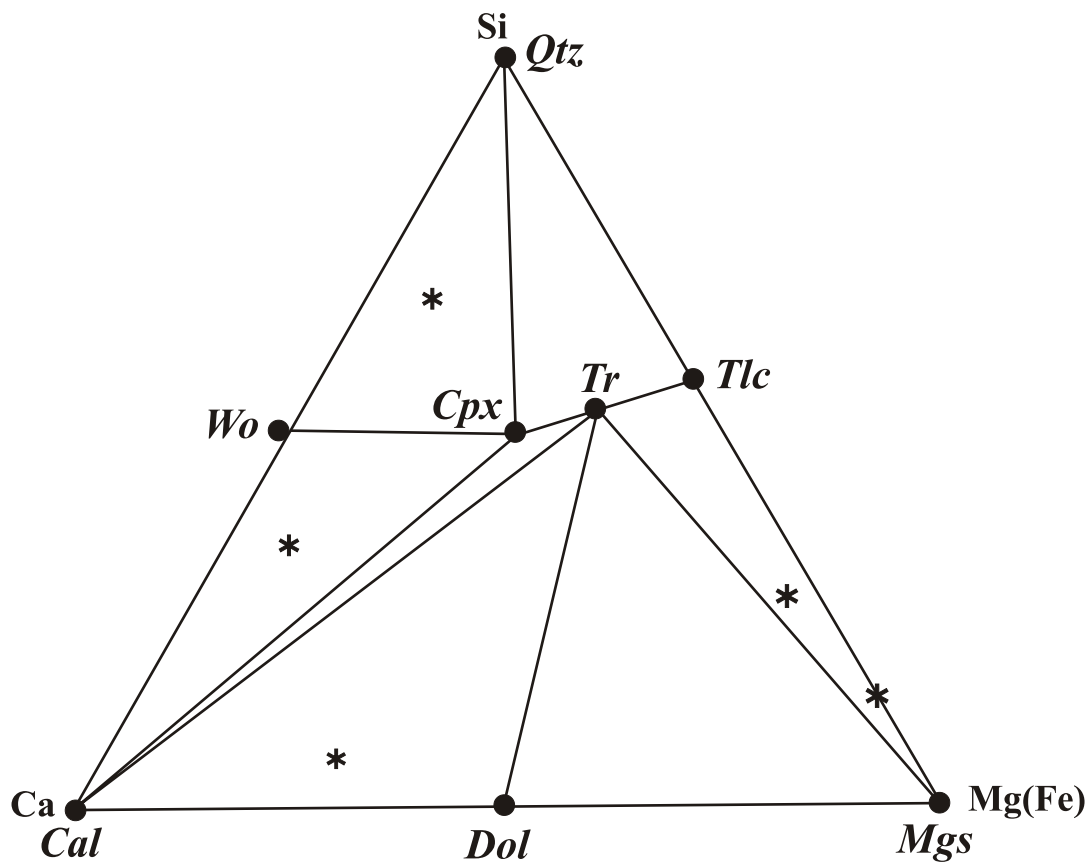
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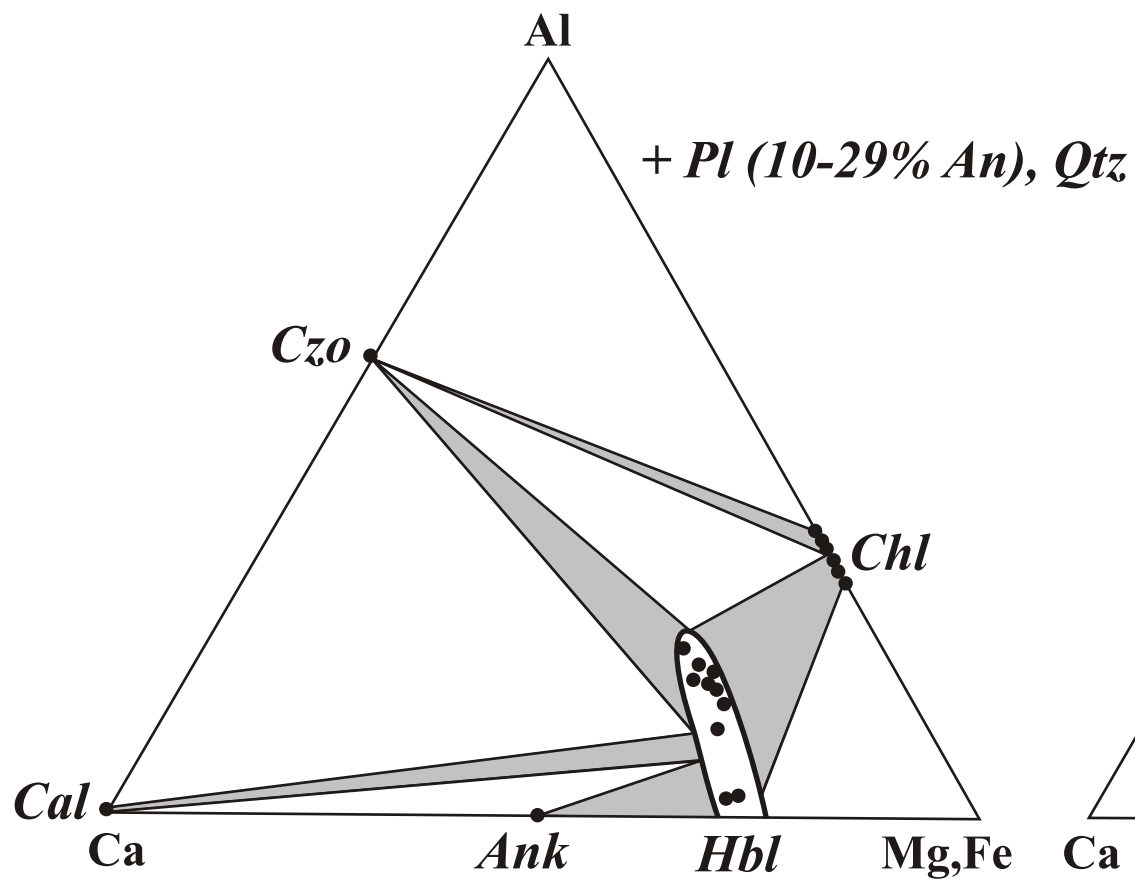
**Fig. 1** Associations of the impure magnesite marbles and the magnesian-mica layers in them: 1 – X<sub>Fe</sub> values in coexisted magnesite, talc and Mg-chlorite (the Mg-corner of the Mg-Fe-2Si plot); 2 – general phase relations on the Mg(Fe)-Si-Al diagram.

**Fig. 2** Phase relations in the Al-free impure magnesite and calcite-dolomite marbles, and Qtz- and Cal-bearing calc-silicate rocks on the Ca-Mg(±Fe)-Si diagram. Asterisks denote the assemblages found.

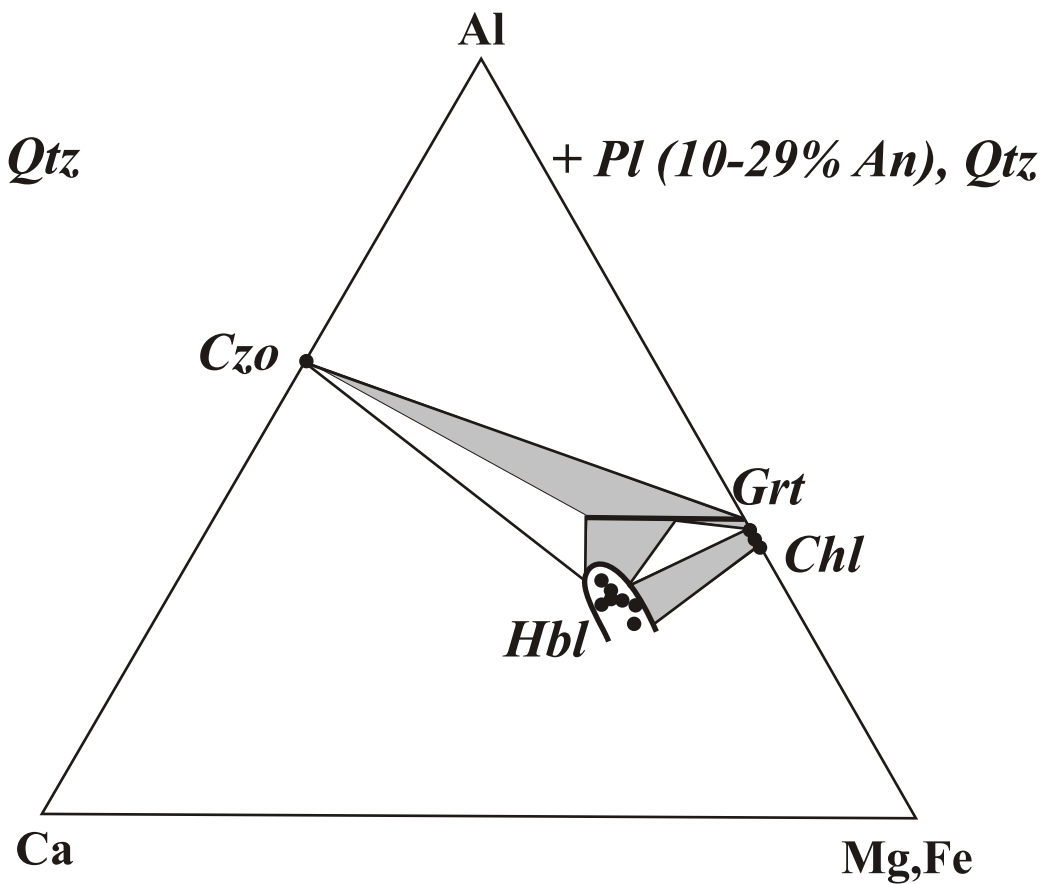
**Fig. 3** Mineral associations in paraamphibolites intercalated with marbles: 1 – the medium-Fe and magnesian, Grt-free rocks, 2 – the Fe-rich Grt-bearing rocks. The ACF diagram projected from the acid Pl.







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