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)

S. P. KORIKOVSKY[1], M. PUTIŠ[2] and L. TURANOVÁ[2]

[1]*Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry (IGEM), Russian Academy of Sciences, Staromonetny per. 35, Moscow, 109017 Russia; korik@igem.ru*

[2]*Comenius University, Faculty of Natural Sciences, Department of Mineralogy and Petrology, Mlynska dolina, SK–84215 Bratislava, Slovak Republic; putis@fns.uniba.sk*

[2]*Comenius University, Faculty of Natural Sciences, Geological institute, Mlynska dolina, SK–84215 Bratislava, Slovak Republic; turanova@fns.uniba.sk*

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^{o}C, P – 7.9-8.5 kbar, X_{CO2} 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_{Fe} values, %). The **magnesite marbles** are dominated by magnesite ($Mgs_{1\text{-}8}$) with rare dolomite grains ($Dol_{1\text{-}6}$), small flakes of talc ($Tlc_{0\text{-}3}$) and Mg-chlorite ($Chl_{1\text{-}6}$) (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 ($Tlc_{0\text{-}4}$), or of talc with Mg-chlorite, or with Mg-chlorite and phlogopite ($Tlc_{1\text{-}8}$ + $Chl_{3\text{-}5}$ ± $Phl_{7\text{-}17}$) (fig. 1.*1*), 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 ($Bt_{20\text{-}45}$ + $Chl_{18\text{-}40}$).

The **calcite-dolomite** marbles consist of calcite, dolomite ($Dol_{0\text{-}5}$), and acicular tremolite ($Tr_{0\text{-}7}$) but have never been determined to contain magnesite. The **calc-silicate rocks** contain calcite, quartz, wollastonite, Mg- or Fe-Mg vesuvianite, clinopyroxene ($Cpx_{15\text{-}16}$), 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 ($Hbl_{15\text{-}50}$), chlorite ($Chl_{14\text{-}40}$), biotite ($Bt_{18\text{-}45}$), clinozoisite, plagioclase (*An* 8-28), and quartz ± calcite or ankerite ($Ank_{20\text{-}30}$), (fig. 3.*1*). The garnet amphibolites are high in iron and consist of the progradely zoned garnet (Prp 3-9%, Grs 30-18%, X_{Fe} in the margin 87-90%), tschermakitic hornblende ($Hbl_{50\text{-}66}$), chlorite ($Chl_{46\text{-}60}$), clinozoisite, oligoclase (*An* 20-29), and quartz (fig. 2.*2*).

The X_{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 (*An* 13-29), ankerite or dolomite ($Dol\text{-}Ank_{3\text{-}30}$), and quartz. The *Grt*-bearing schists contain high-Fe progradely zoned garnet (*Prp 5-7 %*, Grs 16-17%, X_{Fe} in the margin 90-91%), $Chl_{51\text{-}59}$, 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 (Korikovsky 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; Kráľ et al. 1996; Kováčik et al. 1997; or 95-60 ± 10 Ma - Janák et al., 2001).

References

Bezák, V., 1982: Metamorphic and granitoid complexes in Kohút zone of Veporides. *Geol. Práce*, Spr. 78, 65-70 (in Slovak).

Bibikova, E.V., Cambel, B., Korikovsky, S.P. et al., 1988: U-Pb and K-Ar isotopic dating of the Sinec (Rimavica) granites (Kohút zone of the Veporides). *Geol. Zborn.-Geol. Carpathica*, 39, 147-157.

Dallmeyer, R.D., Neubauer, F., Handler, R., Fritz, H., Müller, W., Pana, D., Putiš M., 1996: Tectonothermal evolution of the internal Alps and Carpathians: Evidence from $^{40}Ar/^{39}Ar$ mineral and whole-rock data. *Eclogae Geol. Helv.,* 89, 203-227.

Graham, C.M. & Powell, R., 1984: A garnet-hornblende geothermometer: calibration, testing, and application to the Pelona schists, Southern California. *Jour. Metamorph. Geol.*, 2, 13-21.

Janák, M., Plašienka, D., Frey, M., Cosca, M., Schmidt, S. Th., Lupták, B., Méres Š., 2001: Cretaceous evolution of a metamorphic core complex, the Veporic unit, Western Carpathians (Slovakia): P-T conditions and in situ $^{40}Ar/^{39}Ar$ UV laser probe dating of metapelites. *Jour. Metamorph. Geol.*, 19, 2, 197-216.

Kohn M.Y. & Spear F.S., 1990: Two new geobarometers for garnet amphibolites, with application to southeastern Vermont. *Amer. Miner.,* 75, 89-96

Korikovsky, S.P., Dupej, J., Boronikhin, V.A., Zinovieva, N.G., 1990: Zoned garnets and their equilibria in mica schists and gneisses of the Kohút crystalline complex, Hnúšťa region, Werstern Carpathians. *Geol. Zborn.-Geol. Carpathica*, 41, 99-124.

Korikovsky, S.P., Dupej, J., Zinovieva, N.G., 1989: Genesis of zoned garnets from the Rimavica (Sinec) granites in the Kohút zone of the Veporides). *Geol. Zborn.-Geol. Carpathica*, 40, 697-714.

Kováčik, M., Kráľ, J., Maluski, H., 1997: Alpine reactivation of the southern Veporicum basement: metamorphism, $^{40}Ar/^{39}Ar$ dating, geodynamic model and correlation aspects with the Eastern Alps. In: Grecula, P., Hovorka, D., Putiљ, M. (eds.): Geological Evolution of the Western Carpathians. *Monograph, Mineralia Slovaca*, 163-174.

Kráľ, J., Frank, W., Bezák, V., 1996: $^{40}Ar/^{39}Ar$ spectra from amphiboles of amphibolic rocks in veporicum. *Miner. Slovaca*, 28, 501-513 (in Slovak, Engl. summary).

Krogh Ravna E., 2000: Distribution of Fe^{2+} and Mg between coexisting garnet and hornblende in synthetic and natural systems: an empirical calibration of the Grt-Hbl Fe-Mg geothermometer. *Lithos*, 53, 265-277.

Maluski, H., Rajlich, P., Matte, Ph., 1993: $^{40}Ar/^{39}Ar$ dating of the Inner Carpathian Variscan basement and Alpine mylonitic overprinting. *Tectonophysics*, 223, 313-337.

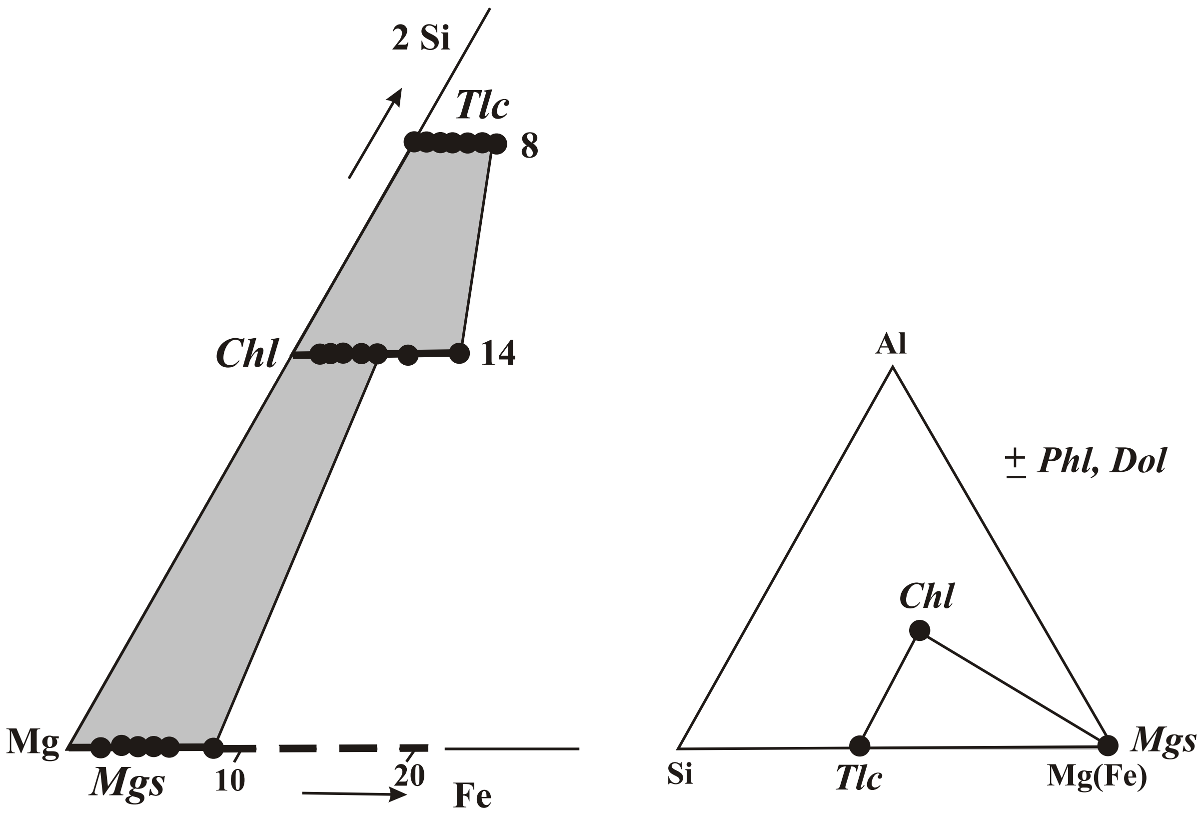
Perchuk L.L., 1989: Intercorrelation of Fe-Mg geothermometers using the Nernst law. *Geokhimia*, 1989, 611-622.

Turanová, L., Turan, J., & Stankovič J., 1997: Skarnoidná mineralizácia v ložisku Hnúšťa-Mútnik. *Miner. Slovaca*, 29, 417-426 (in Slovak, Engl. summary).

Fig. 1 Associations of the impure magnesite marbles and the magnesian-mica layers in them: 1 – X_{Fe} 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.

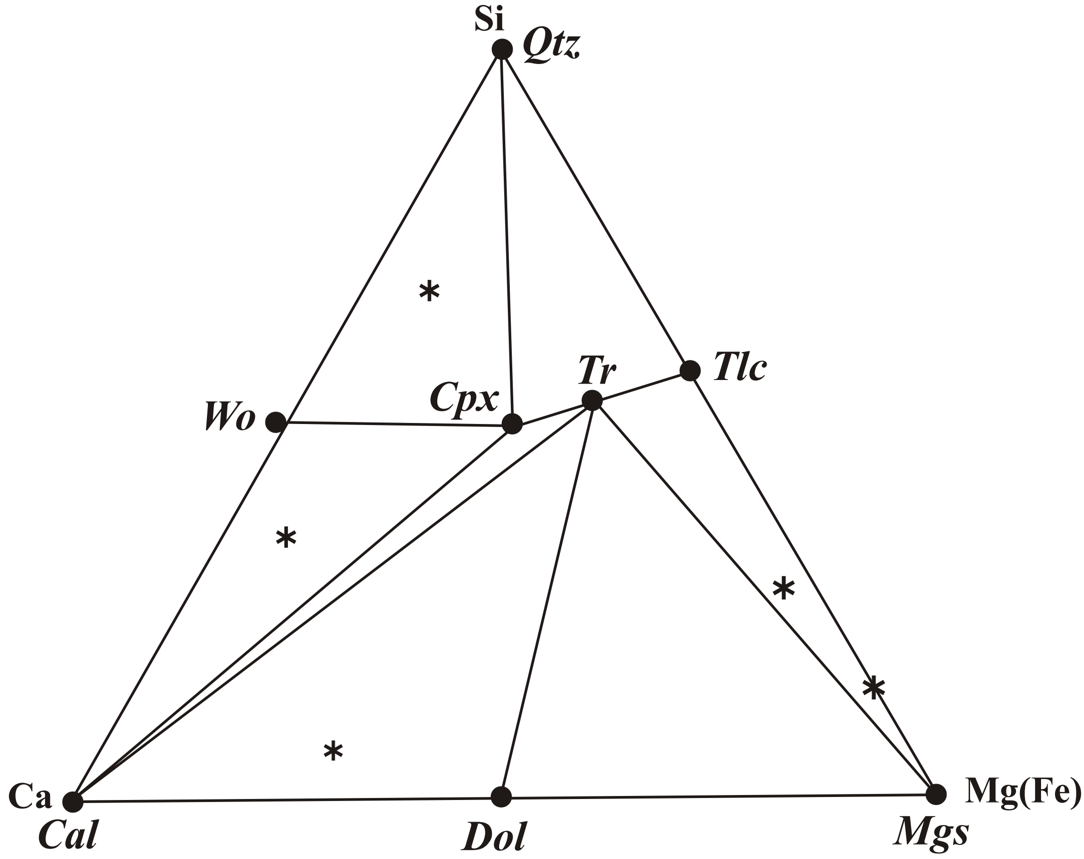
Fig. 2 Phase relations in the Al-free impure magnesite and calcite-dolomite marbles, and Qtz- and Cal-bearing calc-silicate rocks on the Ca-Mg(±Fe)-Si diagram. Asterisks denote the assemblages found.

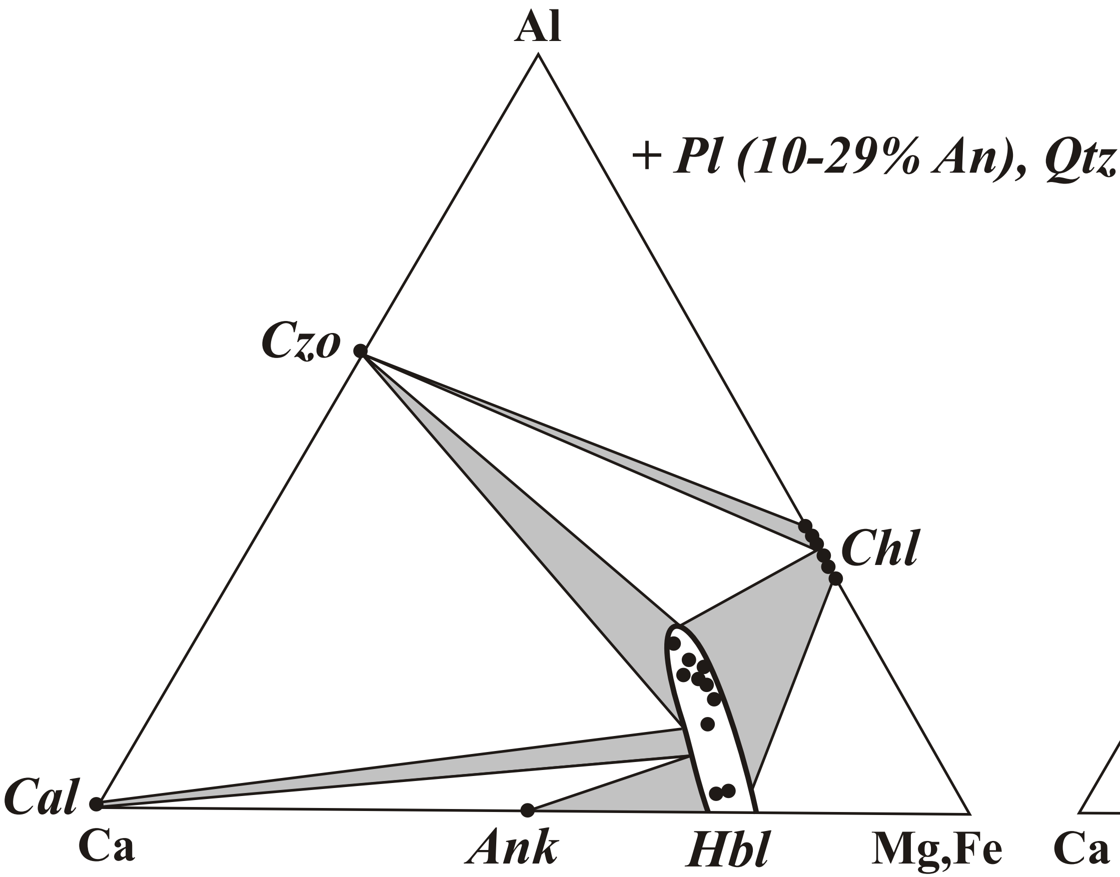
Fig. 3 Mineral associations in paraamphibolites intercalated with marbles: 1 – the medium-Fe and magnesian, Grt-free rocks, 2 – the Fe-rich Grt-bearing rocks. The ACF diagram projected from the acid Pl.



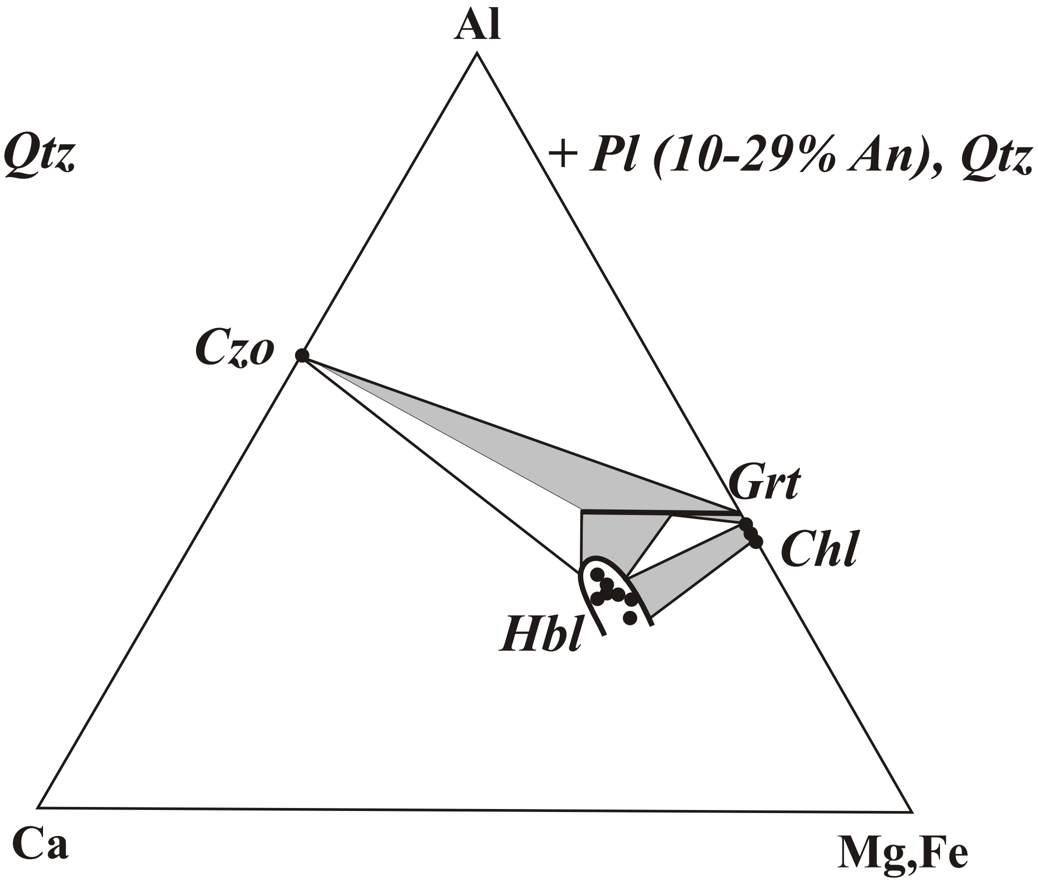
1

2


Si
Qtz
Tlc
Tr
Cpx
Wo
Ca
Cal
Dol
Mgs
Mg(Fe)


Al
+ Pl (10-29% An), Qtz
Czo
Chl
Cal
Ca
Ank
Hbl
Mg,Fe

1


Al
+ Pl (10-29% An), Qtz
Czo
Grt
Chl
Hbl
Ca
Mg,Fe

2