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Metamorphic conditions of kyanite-garnet-chloritoid schists associated with eclogites in the Lake Zone, SW Mongolia

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The kyanite-garnet-chloritoid schists associated with eclogites from the Alag Khadny metamorphic complex, Chandman district, Lake Zone, SW Mongolia, consist of garnet, chloritoid, muscovite, phengite, chlorite, paragonite, kyanite, rutile, ilmenite, zircon, quartz and carbonaceous matter. Garnets occur as subhedral to anhedral porphyroblast up to 5 mm across and they are almandine-rich variety in composition. The garnets are zoned with inclusion-rich cores and inclusion-poor rims. The garnets display a prograde pattern of compositional zoning, X_{Sps} decreasing and X_{Prp} increasing from core to rim. The cores contain inclusions of muscovite (*Si*=6.06-6.29 cations per formula unit, *pfu*), paragonite, chlorite, chloritoid and quartz. The rims contain inclusions of kyanite (Fe_2O_3 <1.24 wt%; $Cr_2O\{3\}$ <0.03 wt%), phengite (*Si*=6.40-6.63 *pfu*), chloritoid (X_{Mg} [Mg/(Fe+Mg)]=0.08-0.18), chlorite (X_{Mg}<0.42), and quartz. A well-developed schistosity is defined by preferred orientation of chloritoid (X_{Mg} = 0.11-0.21), chlorite (X_{Mg}=0.36-0.53) and white micas [phengite (*Si*=6.57-6.63 *pfu*) and muscovite (*Si*=6.23-6.34 *pfu*)] in the matrix.

Based on the textural relationship and chemical composition of minerals, following metamorphic stages are distinguished in the kyanite-garnet-chloritoid schists, i.e. (i) pre-peak stage, (ii) peak metamorphic stage, and (iii) retrograde stage.

The porphyroblastic garnets represent a typical prograde zoning, X_{Sps} decreasing and X_{Prp} increasing from core to rim. The pre-peak stage (i) is defined by the mineral inclusions in the cores of the garnets. They are muscovite (*Si*=6.06-6.29 *pfu*), paragonite, chlorite, chloritoid (X_{Mg}=0.08-0.13) and quartz, and they indicate relatively low-pressure and low-temperature conditions such as the greenschist facies. The peak metamorphic stage (ii) is defined by the mineral assemblage of the inclusions in the rims (X_{Prp}<0.13) of the garnets, i.e. kyanite, phengite (*Si*=6.40-6.63 *pfu*), chloritoid (X_{Mg}=0.08-0.18), chlorite (X_{Mg}=0.42), rutile and quartz, and schistosity forming minerals, i.e. chloritoid (X_{Mg} = 0.11-0.21), phengite (*Si*=6.57-6.63 *pfu*), and chlorite (X_{Mg}=0.36-0.53) coexisting with the rims of porphyroblastic garnet. THERMOCALC (V. 3.33) (Powell and Holland, 1994) calculations for the rim of the garnet coexisting minerals of kyanite, phengite, chloritoid, and chlorite yielded P-T conditions of T=575-585^{o}C and P=10-11 kbar of high-pressure epidote-amphibolite to low-pressure eclogite facies conditions of the high-pressure intermediate type metamorphism which are distinctly lower in metamorphic pressure than accompanied eclogites (T=590-610^{o}C, P=20-22.5 kbar; Stipska et al., 2010) even though the similar temperature conditions. However, $^{40}Ar/^{39}Ar$ muscovite plateau ages of the eclogite (543 +/- 3.9 Ma) and kyanite-garnet-chloritoid schist (537 +/- 2.7 Ma) are similar (Stipska et al., 2010), indicating simultaneous exhumation of both metamorphic rocks to the crustal level. There is no evidence of high-pressure type metamorphic event similar to the eclogites in the kyanite-garnet-chloritoid schists. These fact suggest that subduction within low-geothermal gradient conditions to produce the eclogites occurred first, subsequently relatively high-geothermal gradient metamorphism for the kyanite-garnet-chloritoid schists took place, and then whole sequence of metamorphic rocks were exhume to the shallower levels at ˜ 540 Ma.

Reference:
Powell, R. and Holland, T.J.B. (1994). Amer. Miner., 79, 120-133
Stipska, P., Schulmann, K., Lehmann, J., Corsini, J., Lexa, O. and Tomurhuu, D. (2010) J. of Meta. Geol., 28, 915-933

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