

and, at the same time, to make accessible a wealth of statistical functions built into R. Nevertheless the main aim was to free the igneous geochemists for inventive thinking.

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# Composition of Fluids and their Effect on Stability Fields of Silicate Minerals in Amphibolite Facies Metamorphic Rocks

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Mineral reactions and reological properties of rocks critically depend on the presence and composition of fluids during metamorphism. Fluid inclusions and phase equilibria from most amohibolite/granulite facies rocks indicate the presence of low water activity fluids. This is confirmed in the whiteschist locality of Sare Sang (Afghanistan), where metamorphic minerals with structural CO<sub>2</sub>, H<sub>2</sub>O, halogens, sulfur and boron are widespread. The host rocks of these minerals are marbles, different varieties of calc-silicate rocks and whiteschists. Sedimentary origin of these rocks as well as of CO<sub>2</sub> and brines is also supported by stratigraphic control of the occurrence of carbonate and Na-, Al- or Mg-rich minerals that follow bedding in the Sare Sang Series. The origin of calc-silicates and whiteschists is connected with the occurrence of carbonate-evaporite layers within psammopelitic rocks. Textural relations and mineral compositions indicate a high-pressure amphibolite facies metamorphism with various stages of retrogression. The main volatile-bearing phases in the rocks are carbonates, sodalite-group minerals, scapolite, amphibole and biotite. However, most of these minerals have retrograde origin. Minerals stable at peak P-T conditions were carbonates, graphite, scapolite, apatite, amphibole, phlogopite, talc, clinohumite, pyrrhotite and pentlandite. Low water activity of fluids during metamorphism is documented by high X<sub>Cl</sub>

and X<sub>F</sub> content in amphibole and biotite as well as by the presence of sodalite and fluorapatite veins in the rocks. Besides lithology, variation of volatiles in minerals was controlled by avoidance criteria of elements in mineral structure. The high F or Cl contents led to the stability of F-phlogopite, Cl-biotite and Fe (Cl)- amphibole. Calculated log (X<sub>F</sub>/X<sub>OH</sub>) and log (X<sub>Cl</sub>/X<sub>OH</sub>) in coexisting biotite and amphibole indicate preferential partitioning of Cl into amphibole and F into biotite. Chlorine enters biotite and amphibole structure by factor near 1:1. However, F indicates preferential partitioning by factor of 9:4. F-OH and Cl-OH partitioning coefficients for apatites showed preferential entering of F into apatite relative to biotite. The degree of preference depends on temperature and Fe concentration in biotite. The retrogression that was accompanied by granite formation led to recrystallization of these minerals as well as to fluid infiltration and metasomatic reactions in the surrounding rocks. The crystallization of numerous minor discordant intrusions of post-metamorphic granite would have released water, which permeated through the carbonate-evaporite sequence having enriched it with S, Cl and CO<sub>2</sub>. These proccersses led to formation of the main lapis-lazuli deposit in the Sare Sang locality. The best evidence of this model is the accumulation of lapis lazuli near the granite contact.