

Synthesis of beryllian sapphirine in the system MgO-BeO-Al₂O₃-SiO₂-H₂O and comparison with naturally occurring beryllian sapphirine and khmaralite, Part 2: A chemographic study of Be content as a function of *P*, *T*, assemblage and FeMg₋₁ exchange

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ABSTRACT

Beryllium is a significant constituent in sapphirine in some metamorphic and pegmatitic rocks, and thus could have a major effect on its stability relationships. Using the stoichiometries of reactions involving sapphirine and associated phases in the MgO-BeO-Al₂O₃-SiO₂ (MBeAS) system in conjunction with molar volume data, we have plotted maps of the sapphirine solid-solution field in both μ - μ and μ -*P* space, where μ is the chemical potential of an exchange component such as (BeSi)(AlAl)₋₁. These maps give a pressure sequence of stable MBeAS univariant reactions and divariant assemblages that are consistent with experimental data, e.g., they show how Be stabilizes sapphirine + forsterite, which is rare in nature but readily synthesized over a wide *P*-*T* range in the presence of Be. We generate a MBeAS petrogenetic grid for sapphirine-bearing assemblages over the approximate range *T* = 700–900 °C, *P* = 0–2.5 GPa, identify divariant and univariant assemblages containing sapphirine with maximum Be, and determine the sense of variation of maximum Be content with *P*. At lower *T*, maximum Be occurs at the low-*P* limit of surinamite stability, ca. 0.5 GPa. At higher *T*, maximum Be increases with *P*, following the MBeAS univariant reactions involving (sapphirine + surinamite + orthopyroxene + chrysoberyl + forsterite or spinel).

Natural assemblages containing sapphirine and its Be-rich near-analog khmaralite from the Napier Complex, Enderby Land, East Antarctica formed at higher *T* (900–1100 °C) than the experiments and in bulk compositions containing substantial Fe. Associated minerals include garnet, sillimanite, quartz, and magnesiotaaffeite-6N3S (“musgravite”), whereas forsterite is absent and cordierite is a local, late phase. $\mu_{(\text{BeSi})(\text{AlAl})-1} - \mu_{\text{FeMg}-1}$ diagrams show that the stability of magnesiotaaffeite-6N3S causes the maximally beryllian khmaralite to shift from a magnesian composition in equilibrium with orthopyroxene + surinamite + forsterite + chrysoberyl, as in the MBeAS subsystem, to a more Fe-rich composition associated with garnet + surinamite + magnesiotaaffeite-6N3S + chrysoberyl. Khmaralite associated with sillimanite + garnet + surinamite + magnesiotaaffeite-6N3S or chrysoberyl in a Napier Complex pegmatite from Khmara Bay is predicted to be the most Be-rich possible in the presence of sillimanite, whereas the sillimanite + quartz ± orthopyroxene ± garnet associations in quartz granulites requires a sapphirine much lower in both Be and Fe; analyses are roughly in accord with these predictions. The shape of the sapphirine/khmaralite solid-solution field is such that there is a positive correlation between high Be and high Fe²⁺, a chemographic effect independent of any crystal chemical effects due to the clustering of Fe and Be in the crystal structure of khmaralite.

The diagram for FMBeAS shows that sapphirine + quartz, which is often cited as evidence for ultrahigh temperatures (e.g., ≥ 1040 °C), is stabilized to lower *T* and higher *P* than in the corresponding Be-free system. Hence, this minimum *T* may be valid only in rocks with relatively abundant sapphirine and/or very low bulk Be content so that what Be is present in the system is not concentrated in sapphirine.