Post-magmatic evolution of phosphate assemblages in the Varuträsk pegmatite, Sweden

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The Varuträsk deposit (Skellefte District, Northern Sweden) is a well-zoned and extremely differentiated granitic pegmatite of the petalite subtype, which is of historic significance since it was investigated to determine the first phosphate transformation sequences (Quensel, 1937; Mason, 1941). New petrographic and geochemical data indicate that minerals of the triphylite-lithiophilite solid solution, as well as wolfeite and montebrasite, are the main primary phosphates crystallizing during the magmatic stage (Figure 1). Iron-manganese phosphates are mainly originating from the wall zone of the pegmatite, and their $Fe_{tot}/(Fe_{tot} + Mn_{tot})$ ratios decrease from 0.627 to 0.186 when approaching the inner intermediate zone. Fractionation trends of triphylite- lithiophilite are consistent with the chemical evolution of closely associated tourmaline-group minerals, confirming that phosphates evolve in equilibrium with the pegmatitic melt and with the coexisting mafic silicates, rather than in a closed system.

The occurrence of Al-phosphates in the inner pegmatite zones, associated with Li- and Cs-bearing minerals, clearly indicates that the fractionation degree required for the formation of these phosphates is higher than that needed for the crystallization of iron-manganese phosphates. Moreover, montebrasite shows a limited incorporation of fluorine (F < 3.76 wt.%), indicating an unusually low F concentration in the melt (≈ 1% wt.% F). During the magmatic-hydrothermal stage, a high-temperature aqueous fluid exsolves from the saturated residual melt, initiating the replacement of primary phosphates by high-temperature metasomatic secondary species (Figure 1). The F content of the fluid is lower than that of the melt, as shown by the crystallization of F-poor secondary montebrasite in veins crosscutting the primary montebrasite.

Triphylite-lithiophilite remains unaltered or undergoes a partial to complete replacement by the more oxidized species of the ferrisicklerite sicklerite and heterosite-purpurite series, or by alkali-rich varulite during the Na-metasomatic phase. Several substitution mechanisms have been observed in alluaudite-type phosphates, and electron-microprobe analyses indicate the presence of varulite $NaNaMn(MnFe^{3+})(PO_4)_3$, hagendorfite $NaNaMn(Fe^{2+}Fe^{3+})(PO_4)_3$, alluaudite $[]NaMnFe^{3+}{}_2(PO_4)_3$, and of a new possible oxidized species □□$Mn^{3+}Fe^{3+}{}_2(PO_4)_3$.

Finally, at lower temperatures, OH and/or H_2O-rich phosphates crystallize, and triphylite is replaced by veins of vivianite and fairfieldite under poorly oxidizing conditions. A second stage of low-temperature hydrothermal transformations is characterized by an increasing Ca activity in the aqueous fluid, combined with more oxidizing conditions, thus allowing the crystallization of Ca- and Fe^{3+}-bearing secondary species such as jahnsite s.l., as replacement product of vivianite and fairfieldite (Figure 1). Apatite-group minerals also crystallized during the Ca-metasomatic phase, and their compositions show significant increases of the Cl, Mn, and Sr contents, as well as a decrease of the F content, thus highlighting changes in the fluid composition during the pegmatite evolution processes. Moreover, trace element analyses were performed on both primary Fe–Mn and Al-bearing phosphates, as well as on numerous secondary phases formed during subsolidus processes. These results allow us to determine the main crystal-chemical and geochemical constraints controlling the trace elements distribution in pegmatitic phosphates and to elucidate the behaviour of these elements during hydrothermal transformation processes.

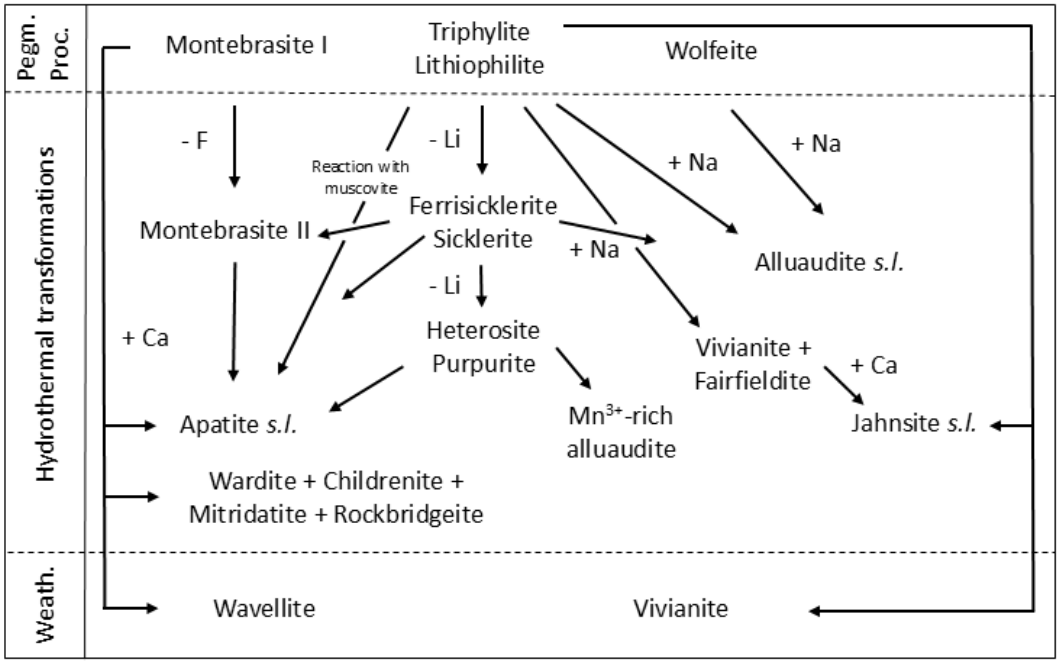


Figure 1. The genetic sequence of phosphate minerals at Varuträsk.

References

Quensel, P. (1937) Minerals of the Varuträsk pegmatite. I: The lithium-manganese phosphates. Geologiska Föreningen i Stockholm Förhandlinger 59, 77–96.

Mason, B. (1941) Minerals of the Varuträsk pegmatite. XXIII. Some iron-manganese phosphate minerals and their alteration products, with special reference to material from Varuträsk. Geologiska Föreningen i Stockholm Förhandlinger 63, 279–284.