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Anatectic origin of albite-spodumene pegmatites: a geochemical model

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Albite-spodumene ($LiAlSi_2O_6$) pegmatites are a valuable source of Li and other rare elements. They are generally considered to be the product of extreme fractionation of melts or fluids deriving from large alkaline granite intrusions. Anatectic melts deriving from partially molten metasediments are in contrast not believed to be a possible source for such pegmatites.

In the Austroalpine Unit of the Eastern Alps, albite-spodumene pegmatites are associated with simple pegmatites and relatively small inhomogeneous leucogranite bodies, all of them being Permian in age. Large parent granites were however never observed. Instead, field relations, petrography, geochronology as well as phase and whole rock major- and trace-elements geochemistry suggests that these pegmatites and leucogranites derived from anatexis in upper amphibolite facies of Al-rich metapelite. Bulk rock and LA ICPS-MS mineral geochemistry indicate that before melting, metapelites could have contained significant Li (in average 120 ppm) and that the main Li-carrier in the protholith was staurolite (with up to 800 ppm Li). The aim of this contribution is to test with geochemical modelling if melting of such metapelites could be the origin of albite-spodumene pegmatites.

The modelling approach consists in three steps. (1) Thermodynamic modelling is carried out in the NaCaKF-MASH system with the Theriak-Domino software package, the tc6 thermodynamic database and the most recent set of activity models for sub- and suprasolidus metapelite. It is used for calculating the proportion of solid and melt phases during prograde melting of metapelite. (2) Phase proportions and Li-partitioning coefficient are used for calculating the Li-distribution between solid phases and melt. Different melting models are considered: batch melting, fractionated melting and melting with overstepping. (3) Fractionation of Li in simple pegmatite and leucogranite of known Li-concentration is modelled with mass-balance.

Using conservative parameters and realistic hypotheses, these models show that 15 to 25 vol% melt containing more than 200 ppm Li can escape the migmatite, in case melting is associated with destabilization of staurolite. Following fractionation of the melt with 99% in mass within simple pegmatite and leucogranite containing 100 ppm Li yields high-evolved melts with 10,000 ppm Li. This value corresponds to the Li saturation in felsic melts necessary for crystallizing spodumene.

Our geochemical model shows that transfer of Li to the melt phase coeval with breakdown of staurolite during partial melting of Al-rich metapelites, followed by fractionation is a realistic genetic process for the formation of the albite-spodumene pegmatites of the Austroalpine Unit. This model is likely to apply to other tectonic settings (e.g. Himalaya, European Variscan Orogen).