The Control of Biotite on the Lithium, Fluorine and REE Budget of Crustal Silicate Magmas

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Of the common rock-forming minerals, biotite contains the highest concentration of lithium and fluorine in both alkaline and calc-alkaline magmatic suites globally. Its control on the distribution of minor and trace-elements, including Li and F, and its impact on metal enrichment, however, is not well understood. Here, we use experiments to quantify that control in sodic (per)alkaline H_2O-saturated magmas with variable F-content at 650–800 ºC, 200 MPa total pressure, and log fO_2 ~FMQ +1. Biotite-glass pairs from (tephri)phonolite fall deposits from Tenerife, Canary Islands complement our experimental data set. Our results, alongside a literature compilation covering a wide compositional range constrain empirical models that: (1) describe the exchange of F and OH between the silicate melt and the biotite W-site; (2) predict the partitioning of 1+ cations Li–Cs between silicate melt and the biotite A- and M-sites. The models use the major-element composition of biotite and melt, pressure and temperature as input. Lithium partition coefficients vary from 0.06 to 33 and are lowest in Al-rich, Si-poor biotite formed at high temperature. Residual enrichment of Li should therefore be most efficient during crystallisation of high Al/Si magmas, a finding consistent with the association between peraluminous granites and lithium-caesium-tin pegmatites. Further, biotite-melt $Kd_{F/OH}$ exchange coefficients are 1.2–51, with minima for Al-rich, Mg-poor biotite. Where $Kd_{F/OH}$ values are high, crystallisation of even small amounts of biotite will strip fluorine from the melt. In silica undersaturated peralkaline magmatic systems, biotite $Kd_{F/OH}$ values are low and fluorine can be residually enriched during crystallisation, complexing with REE in the melt and facilitating their enrichment too. Our partitioning models can be used to interrogate biotite from natural systems to determine the composition of their source melt, or to forward model the metal budgets of mafic to evolved igneous systems at upper-mantle to crustal pressures.