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Fingerprinting crustal anatexis with apatite trace element, halogen, and Sr isotope data

SHUAIQI LIU[1], GUIBIN ZHANG SR.[1] AND HUIJUAN LI[2]

[1]Peking University

[2]Center for High Pressure Science & Technology Advanced Research

Presenting Author: 1901110576@pku.edu.cn

Apatite geochemistry can fingerprint the various anatectic reactions during crustal melting. We observe marked differences in major and trace element, as well as halogen (F and Cl) contents in apatite from three groups of leucosomes, corresponding to different melting reactions. Apatite REE, Y, Mn, F, and F/Cl values exhibit a decreasing trend, whereas Sr/Y and Cl values show an increase, from muscovite dehydration melting, to hydration melting, and to amphibole dehydration melting. Amphibole dehydration melting results in similar CaO, Sr, and Eu/Eu* values in apatite to hydration melting, but the latter leads to lower $(La/Yb)_N$ ratios in apatite. These geochemical differences in apatite can be explained by different minerals participating in the melting reactions and varying melt polymerization resulted from the different melting reactions. The F and Cl contents in partial melts were calculated based on apatite composition, which exhibit an increasing trend from hydration melting to muscovite hydration melting, and to amphibole hydration melting. Such a trend can be explained by different proportions of hydrous minerals (muscovite and amphibole) participating in the melting reactions, with amphibole responsible for the high Cl content in melt and apatite.

In addition, the apatite Sr isotopic compositions record the Sr isotopic disequilibrium during partial melting and exhibit distinct evolutional trends resulting from different anatectic reactions. Muscovite dehydration melting forms melt with higher $^{87}Sr/^{86}Sr$ values than the restite due to radiogenic Sr released by muscovite. Apatite therefore records progressively decreasing $^{87}Sr/^{86}Sr$ values during melt evolution before the isotopic homogenization between the partial melt and the restite. In contrast, apatite crystallized from the melt of hydration melting show an evolutional trend of increasing $^{87}Sr/^{86}Sr$ values. In summary, the elemental and isotopic compositions of apatite can be related to different types of melting reactions, and can therefore be used as an indicator of the mechanisms of melt formation during crustal anatexis.