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Experimentally-derived phase equilibria and trace element partitioning of H_2O undersaturated andesite, garnet and amphibole: implications for adakites formation

R. Alonso-Perez (1), P. Ulmer (1), and O. Müntener (2)

(1) Department of Earth Science, ETH Zürich, Switzerland, (2) Institute of Geological Science, University of Bern, Switzerland (raquel.alonso@erdw.ethz.ch)

The high or even extremely high Sr/Y (>400) and La/Yb ratios of Archean TTG series or modern adakites are commonly related to the presence of garnet as a residual phase during generation of these magmas. Previous melting experiments on natural basaltic compositions or on Archean amphibolites have shown that garnet is usually only stable at high pressure exceeding 1.4 GPa (Johnston and Wyllie, 1988; Rapp et al., 1991; Sen and Dunn, 1994; van and Wyllie, 1992). A limited number of studies revealed garnet-stability at lower pressure, 1.0-1.2 GPa, (Rapp et al., 2003; Rapp and Watson, 1995). Therefore, melting of mafic rocks requires minimum depth of 30- 40 km, conditions found either in thickened crust or in subducted oceanic crust. In fact, all of the present models used to explain high Sr/Y and high LREE/HREE ratios are based on the assumption that garnet is stable only at high pressures (>1.4 GPa) and, therefore, high pressure and high temperature trace element partitioning data obtained from relatively low SiO_2 content bulk compositions (basaltic) and comparatively high Mg# of the liquid phase have commonly been used in geochemical models to explain the generation of these particular magmas. In order to evaluate alternative models for the generation of such magmas, e.g. by crystal fractionation of calc-alkaline magmas, garnet-melt and hornblende-melt partitioning data in hydrous Fe-bearing systems at relatively low temperature – pressure conditions are required.

Here we report the results of an experimental study conducted on hydrous undersatured andesite using variable H_2O contents and pressures between 0.8 and 1.2 GPa that produced adakitic melts containing garnet, but no plagioclase as residual phases

at high pressure. The REE contents of the experimental glasses exhibit strongly fractionated adakite-like patterns associated with low HREE contents. The presence of residual hornblende and/or Fe-Ti oxides in some of the experiments lead to additional, negative Nb-Ta anomalies reinforcing a potentially already existing island-arc trace element signature that is typical for adakites. The observed trace element systematic demonstrates that beside the well-established crystal-chemical control on trace element partitioning, there is a significant influence of the liquid compositions on the partitioning behavior in hydrous calc-alkaline systems.

Our experimental results have subsequently been used for trace element modeling to reconcile specific features of adakite-like magmas such as there particular and discriminant Sr/Y and Nb/Ta ratios. Straightforward trace element modeling suggests that many of the Adakite-type magmas that have been interpreted as lower-crustal or slab-derived partial melts have most probably obtained their chemical signature by crystal fractionation of parental, already differentiated, andesitic magmas in magma reservoirs located in the arc lower crust. The internally consistent set of partition coefficients obtained in this experimental study allows rigorous evaluation of the potential role of fractional crystallization as a potential process leading to Adakite-like magmas and to clarify the relative roles of garnet, amphibole and plagioclase in deep-seated fractionation processes in subduction-related magmas.