European Mineralogical Conference
Vol. 1, EMC2012-86, 2012
European Mineralogical Conference 2012

The hydrous nature of the Heldburg phonolite revealed by reaction rim formation on entrained mantle xenocrysts: nature and experiments.

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The Heldburg Phonolite, Central Germany contains abundant upper mantle, spinel lherzolite xenocrysts and shows no signs of any feldspar fractionation prior to its genesis. It is therefore thought to have originated from the upper mantle, just like a handful of other localities, dubbed 'high-pressure phonolites' (Irving and Price 1981). Due to chemical disequilibrium with the host melt, the xenocrysts have reacted to form a variety of secondary rim assemblages consisting of; phlogopite mica and diopside around olivine, and either amphibole + phlogopite or amphibole + diopside rims around orthopyroxene. The PT-H_2O conditions are explored in order to ascertain the likely origins of the phonolite, and the role of volatiles in this system.
Experiments using mixtures of an Fe-free synthetic phonolite melt and crystal separates of either San Carlos olivine, synthetic forsterite, synthetic enstatite or a natural OPX from Kilosa, Tanzania were run in piston cylinder apparatus. Water was added via micro-syringe. Pressures of 10-14kbar and temperatures of 900-1000°C are able to reproduce the reaction rim mineralogy seen at Heldburg, and comply well with estimates given in the literature for its origin. However, within this PT range the water content is crucial, not only for the formation and stabilization of hydrous rim phases, but also to reduce the stability of feldspar, being over 5wt.% at 900°C and 10kbar. If this phase forms, reaction rims are significantly inhibited. Combined with the effects of pressure and temperature, which also reduce its stability, means that the required water content to exclude feldspar diminishes as they increase, but also that the reactions will favour higher PT.
Hence, hydrous phonolites at mantle depths can act as potent metasomatic agents but only under limited conditions. Furthermore, preliminary results on the addition of F or Cl show adverse effects on the system, reducing the efficiency of the reaction. Volatile budgets of evolved alkali rich melts at upper mantle conditions can vary greatly, and have profound effects on the melt's behavior. By constraining the parameters in which these reactions occur it is possible to produce estimates of their rates of growth, providing us with geo-speedometric data. It would appear that the natural reaction rims were formed within a matter of several weeks to a couple of months, suggesting relatively rapid transport of deep originating phonolites to the surface. Despite being rarely observed, high-pressure phonolites could well be far more common in the upper mantle than previously thought.

Irving, A.J., Price, R.C. (1981). Geochemistry and evolution of the lherzolite-bearing phonolitic lavas from Nigeria, Australia, East Germany and New Zealand. Geochimica et Cosmochimica Aca, 45, 1309-1320.