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Evidence of alkali rich melt reactions with mantle peridotite : Natural observations and experimental analogues

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The Heldburg Phonolite, (Thuringia, Germany) is peculiar in its nature due to its absence of a Eu anomaly, and hence lack of feldspar fractionation, as well as the presence of spinel lherzolite xenocrysts. These observations suggest a higher than normal (mantle) pressure of origin, and its potential as a metasomatic agent at depth is explored in this work. Disequilibrium between the phonolite and its entrained upper mantle xenocrysts resulted in the development of secondary reaction rim assemblages of; (1) phlogopite + minor diopside around olivine, (2) pargasitic amphibole, phlogopite and minor diopside around orthopyroxene. We document both the natural rims and the attempts to reproduce them under experimental conditions, in order to elucidate the likely origin of the phonolite and its efficacy for metasomatising the upper mantle.

Platinum capsules were loaded with mixtures of crushed mineral separates, (of pure synthetic forsterite, San Carlos olivine, synthetic enstatite or a natural enstatite from Kilosa, Tanzania) with a synthetic Fe-free phonolite melt in a 16:84% weight ratio, respectively. Experiments were run in a piston cylinder apparatus with CaF2 as the pressure medium. In addition to varying PT conditions, a wide range of water contents were tested (0-14wt%). It was found that pressures of 10-14 kbar, and temperatures of 900-1000°C, satisfy the conditions at which the reactions can form, thus, it is likely that the phonolite existed at upper mantle conditions. Water must be present to stabilize the desired hydrous phases, with >6wt% required at 900°C and 10 kbar. The destabilization of feldspar is also essential to the process, hence higher water contents are needed at the lowest PT conditions compared to 4-5 wt. % H_2O at greater PT. The formation of amphibole around enstatite appears to be affected by sluggish reaction kinetics and the orientation of the host pyroxene, sometimes leading to diopside single rims. Furthermore we note some of the effects of the addition of F and Cl to these reactions.

Although phonolitic and other evolved alkaline magmas normally only exist within the crust, the evidence presented here suggests that in some cases deeper origins are possible. Wherever present volatile rich alkalic melts such as phonolites will be highly reactive with mantle peridotite lithologies, however the volumes and occurrences of such reactions are of debate. Occurring as very low melt fractions of pre-metasomatised mantle, or as residual melts from more primary compositions their volumes may well be low, and hence due to their high reactivity give them a low probability of erupting. Therefore, it can be postulated that highly alkaline melts within the mantle are more common than their surface volcanic records would suggest.