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THE EFFECTS OF ECLOGITIC HETEROGENEITIES ON UPPER MANTLE MELTING

Gregory M. Yaxley and **David H. Green**

Research School of Earth Sciences, The Australian National University, Canberra ACT 0200, Australia.

ABSTRACT

INTRODUCTION

The formation of flood basalt provinces (e.g. Karoo, Siberian Traps, or Deccan Traps), involves eruption of millions of km^3 of basaltic and picritic lava on time-scales of only a few million years, and hence records some of the most catastrophic volcanic events in the Earth's history. A popular model to explain these impressive events involves adiabatic ascent of discrete plumes of anomalously hot peridotite from a thermal boundary layer deep in the mantle (probably the core-mantle boundary). As this hot material ascends across the peridotite solidus, it partially melts, leading to the observed volcanism.

However, unless a plume's potential temperature is very high, it is unlikely that the degree and rate of melting would be sufficient to explain the extremely voluminous and rapid nature of flood volcanism (Cordery et al., 1997). For this reason, the suggestion has been made (Campbell, 1998; Cordery et al., 1997) that eclogitic or pyroxenitic heterogeneities in the peridotite-dominated upper mantle, derived from recycling of mafic oceanic crust at convergent margins, may have an important role in enhancing melt productivity of mantle plumes. In order to constrain petrogenetic models for flood basalts, we have experimentally investigated the potential effects of eclogitic heterogeneities on upper mantle melting.

EXPERIMENTAL TECHNIQUES

Experiments were conducted at 3.5 GPa on synthetic sintered oxide mixes, using standard piston-cylinder techniques (Yaxley and Green, 1998). Two end-member compositions were used; MORB-pyrolite (MPY90) representing fertile upper mantle peridotite (Green et al., 1979), and an average altered oceanic basalt composition (GA1) representing recycled oceanic lithosphere (Yaxley and Green, 1994). We first determined the phase relations and partial melt compositions of GA1. We then investigated reaction and mixing processes between eclogitic bodies entrained in peridotitic upper mantle by running a series of layered experiments in which a basaltic GA1 layer (typically ca. 10 wt%) was sandwiched against the peridotitic (MPY90) layer (ca. 90 wt%). We also investigated the phase and melting relations of homogeneous mixtures along the compositional join GA1-MPY90, emphasising the pyrolite-rich half of the join.

EXPERIMENTAL RESULTS AND DISCUSSION

A discrete body of eclogite entrained in an adiabatically upwelling, peridotite-dominated mantle plume, will partially melt earlier (deeper) than the peridotite wall-rock (Yasuda et al., 1994). Our melting experiments on the GA1 composition indicate that the high pressure near-minimum melts of oceanic basaltic compositions are dacitic or rhyodacitic. The layered GA1/MPY90 experiments indicate that if these highly siliceous liquids are able to segregate from their eclogitic source, and migrate into the surrounding peridotite wall-rock, they will react out of existence, forming an orthopyroxene-rich, olivine-depleted layer at the contact between eclogite and peridotite. Further heating or ascent to lower pressures may result in further melting of the residual eclogitic body, producing andesitic to basaltic andesitic melts, which will also react with surrounding peridotitic wall-rock. At some point during this process of redistribution of the eclogitic heterogeneity, further melting will be buffered by the surrounding orthopyroxene-enriched peridotite assemblage, will most likely occur at the margins of the relatively Fe-rich opx-rich zone, where lherzolite phases are co-located, and will produce nepheline-normative picritic liquids at high pressures. These melts, on segregation, will re-equilibrate with surrounding normal garnet lherzolite and freeze. This process will result in progressive redistribution and rehomogenisation of the original eclogitic heterogeneity, producing refertilised, hybrid peridotite. In this peridotite, phase compositions will tend towards homogeneity, but phase proportions will be distinctive, resulting in bands and schlieren of orthopyroxene-enriched peridotite, websterite and garnet lherzolite.

The homogeneous experiments on the join GA1-MPY90 demonstrate that the resultant rehomogenised compositions will crystallise garnet lherzolite ± quenched partial melt at sub-solidus temperatures and at temperatures just above the solidus, over the compositional range MPY90 to $GA1_{50}MPY90_{50}$. Thus, near-solidus melts of source compositions from MPY90 to $GA1_{50}MPY90_{50}$ are buffered by residual peridotite mineralogy and are expected to be nepheline-normative picrites at high pressures. The solidus temperature is slightly decreased from ~1500°C for MPY90 to ~1450°C for $GA1_{50}MPY90_{50}$. The liquidus phase was olivine for bulk compositions from MPY90 to $GA1_{30}MPY90_{70}$, and orthopyroxene from $GA1_{30}MPY90_{70}$ to $GA1_{50}MPY90_{50}$. The intersection of olivine-out and orthopyroxene-out occurred at $GA1_{30}MPY90_{70}$ and resulted in a deep minimum on the liquidus surface, corresponding to the intersection of the GA1-MPY90 compositional join and the olivine-orthopyroxene cotectic on the liquidus surface (Yaxley and Green, 1998).

During adiabatic ascent of source material, the melt productivity is partially controlled by the variation in dF/dT (where F = melt fraction) in the melting interval between solidus and liquidus, particularly at low F. Compositions similar to $GA1_{30}MPY90_{70}$ have 100% melting compressed into a melting interval which is approximately 50-60% smaller than that for pure MPY90, due to the liquidus minimum. This, in combination with the lower solidus of the hybrid compositions compared with MPY90, would ensure that a source material with a few 10's of % of MORB-like basalt homogeneously mixed with peridotite, is potentially extremely productive of picritic liquids during adiabatic melting at high pressures. Mixtures of recycled oceanic crust and peridotite in mantle plumes may therefore provide a viable source for some flood volcanics.

REFERENCES

Campbell I.H., 1998. The mantle's chemical structure: Insights from the melting products of mantle plumes. In: I. Jackson (Ed.), The Earth's mantle: Composition, structure and evolution. Cambridge University Press, Cambridge, p. 259-310.

Cordery M.J., Davies G.F. and Campbell I.H., 1997. Genesis of flood basalts from eclogite-bearing mantle plumes. J. Geophys. Res., 102: 20179-20197.

Yasuda A., Fujii T. and Kurita K., 1994. Melting phase relations of an anhydrous mid-ocean ridge basalt from 3 to 20 GPa: implications for the behaviour of subducted oceanic crust in the mantle. J. Geophys. Res., 99: 9401-9414.

Yaxley G.M. and Green D.H., 1994. Experimental demonstration of refractory carbonate-bearing eclogite and siliceous melt in the subduction regime. Earth Planet. Sci. Lett., 128: 313-325.

Yaxley G.M. and Green D.H., 1998. Reactions between eclogite and peridotite: mantle refertilisation by subduction of oceanic crust. Schweiz. Mineral. Petrogr. Mitt., 78: 243-255.