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Heterogeneous Nature of Adiabatic Decompression Melts Generated in Upwelling Mantle Plume Heads

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Adiabatic decompression melts generated in the starting-heads of upwelling mantle plumes are believed to be preserved in komatiite and continental flood basalt successions. Such melts are relatively rare at the Earth's surface due to the effects of crystal fractionation, lithospheric contamination and magmatic underplating. Compositions of these primary melts have been estimated using: (i) the compositions of olivine phenocrysts and bulk-rock chemistry together with appropriate partition coefficients; and (ii) fO_2 values calculated from olivine-spinel pairs. It is clear from these estimates that uncontaminated (ε_{Nd}>0), high-MgO primary melts exhibit wide variations in major element abundances (e.g. FeO*=8 to 18 wt%, Al_2O_3=2 to 14 wt%) at given SiO_2 contents (Fig. 1). They also show large ranges in chondrite-normalised rare-earth element ratios (e.g. $[La/Sm]_n$=0.5 to 2.5, $[Gd/Yb]_n$=1 to 3.5). For an individual suite of lavas, these variations can not be readily explained by partial melting of a 'primitive' mantle source at variable pressures (Gibson et al., 2000) unless the top of the melting column (i.e. base of the lithosphere) changes by ~100km in a few Ma.

Estimated primary melts of the most FeO*-rich picrites have high Ni contents (>700 ppm). These high concentrations, together with moderate contents of SiO_2, are not compatible with partial melting of a garnet pyroxenite or eclogite mantle source. They require that the convecting mantle entrained in mantle plumes is heterogeneous, consisting of 'streaks' of Fe-rich peridotite. The occurrence of these Fe-rich magnesian melts in the lower parts of picrite and komatiite successions suggests that they are some of the earliest decompression melts to form in the starting-heads of upwelling mantle plumes. This interpretation is consistent with the low solidus temperatures predicted in experimental studies for Fe-rich peridotite relative to 'normal' peridotite (Kushiro, 1996). Numerical modelling of REE abundances (by inversion) and variations in Fe_{15} and Na_{15} suggest that the Phanerozoic Fe-rich picrites (e.g. Siberia, Paraná-Etendeka CFB's) were formed by <20% partial melting in mantle plume starting-heads at Tp= ~1550°C and between ~ 4.5 to 2.5 GPa. Low Sm/Nd ratios and positive ε_{Nd} values suggest that the high-FeO* primary mantle melts were derived from a source region that had undergone an early depletion event followed by LREE enrichment, during or shortly before melting. This may represent recycled lithospheric mantle that has been stirred, but not completely homogenised by convection in the Earth's mantle.

The occurrence of both high (>13wt%) and low FeO* (~10 wt%) magnesian melts in large igneous provinces, ranging from Archean to Recent in age, suggests that the convecting mantle has been chemically heterogeneous for >3.4 Ga. There is no direct evidence to suggest that the Earth's mantle has shown a secular decrease in FeO (c.f. Francis et al., 1999). The occurrence of FeO*-rich komatiites in the Archean and FeO*-rich picrites in the Proterozoic and Phanerozoic is, however, consistent with models that invoke higher Archean mantle potential temperatures and hence greater depths of melting (Richter, 1988).

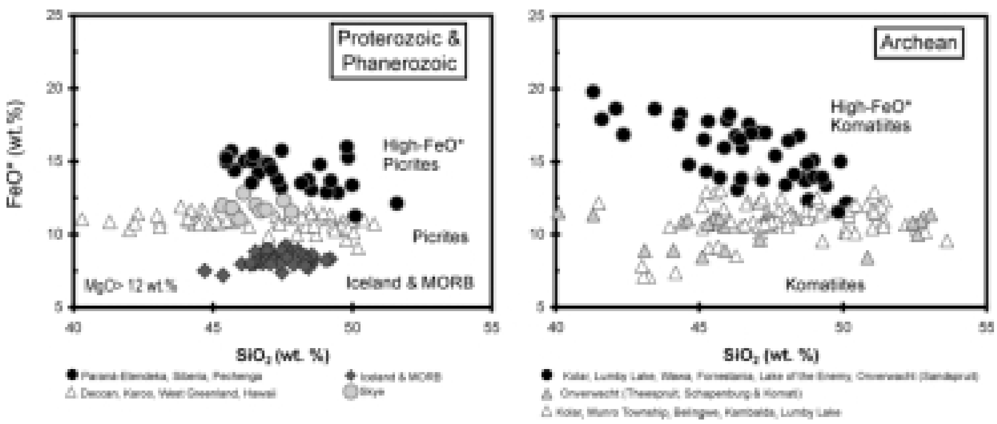

Figure 1: Variation of FeO* with SiO_2 in Archean to Recent high MgO (>12 wt%) igneous rocks

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