Lherzolite partial melting: closer to primary liquids

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Introduction and method

Recent models of MORB genesis show that the mantle melting processes involved are probably closer to fractional melting than batch melting (McKenzie and Bickle, 1988; McKenzie and O'Nions, 1991; Kinzler and Grove, 1992a and b). Such models require the knowledge of the composition of the liquid produced by low-degrees of partial melting (melt fraction F ≈ 0–0%). However, most of liquids obtained in melting experiments performed on mantle rocks (e.g. Falloon *et al.*, 1988; Takahashi *et al.*, 1993) correspond to higher melt fractions, and it seems difficult to provide realistic liquid compositions for F lower than 5–10%, even using the new diamond aggregate technique of Hirose and Kushiro (1993) and Baker and Stolper (in press), due to difficulty of equilibrating the residual phases.

Walter and Presnall (in press) used an alternative approach to determine the composition of the lowest melt fraction : when the degree of freedom of the assemblage studied is constrained bulk composition can be modified to obtain charges with analysable quantities of liquid (i.e. > 30%). Such a constraint can only be imposed in simplified systems. We added iron to the system $CaO-MgO-Al_2O_3-SiO_2-Na_2O$ (CMASN, Walter and Presnall) to obtain a much more realistic model of phase equilibria for the upper mantle. We have studied the stability of pl- and sp-lherzolite assemblages at the key pressure of 10 kb.

TABLE 1

	1260°C	1235°C
SiO_2	52.7	55.3
Al_2O_3	19.6	20.6
FeO	5.7	4.2
MgO	7.5	5.4
CaO	9.0	5.8
Na_2O	5.6	8.3
Tot	100.0	99.5
Mg#	0.70	0.70

Results

Experimental results were obtained at 10 kb in CMASNF and phase compositions have been determined along an isocore $Mg^{\#}_{liq}$ = 0.70, where liquid is expected to be in equilibrium with residual olivine (≈ Fo_{88-92}).

The stability field for sp-lherzolite expands down to ~ 1270°C and pl-lherzolite at lower temperatures.

Composition of liquids in equilibrium with ol-opx-cpx-pl can reach whose indicated in Table 1.

If a mantle rock (MR) is able to be in equilibrium with one of these liquids in the plagioclase field at these conditions (10 kb, 1235 or 1260°C), a mass-balance calculation will provide phase proportions and indicates the position relative to the solidus: MR = Σ%i.Xi, %i and Xi respectively standing for proportion and composition of the phase 'i'. Among mantle compositions from the literature, none of them is able to produce any melt at 1235°C, and only extremely fertile mantle (pyrolite, Jacques and Green, 1980; McKenzie and Bickle, 1988) can generate the 1260 liquid near its solidus. The residue of this first increment of fusion is in good agreement with modal proportions of pl-lherzolites: 64/21/11/4 respectively for ol/opx/cpx/pl.

The effect of chromium on the spinel stability field (e.g. Onuma and Tohara, 1983) is to move the pl + sp-lherzolite boundary towards lower temperatures (i.e. higher sodium contents in the liquid). Thus, during upwelling, a mantle diapir should not reach the pl-lherzolite field until the pressure drops below 10kb.

This study of the pl-lherzolite paragenesis stability in CMASNF at 10kb shows that during mantle melting, plagioclase-bearing lherzolites could be stable for pyrolite-like compositions, i.e. for extremely fertile mantle and chromium-free systems. Plagioclase can only be involved in the melting process at pressures below 8-10 kb for pyrolite-like compositions. Even if very fertile mantle is involved in first stage of a fractional melting process, a certain amount of incremental melting is necessary to produce primitive MORBs.

References

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