

## Quest for low-degree mantle melts

SIR — Baker *et al.*<sup>1</sup> report an experimental study at pressures of 1 GPa (1,000 million Pa) to determine the composition of a silicate melt produced at anhydrous, near-solidus conditions from a lherzolite composition. They obtained a composition at 1,250 °C with ~57% SiO<sub>2</sub> and ~5.7% Na<sub>2</sub>O, which is 'andesitic' in the sense of its low normative diopside (5%), high normative hypersthene (>15%), and high normative plagioclase (>75%, andesine). These results conflict with earlier conclusions that anhydrous melts of fertile lherzolite at 1 GPa are basaltic, with ~15–20% normative diopside, >10% normative olivine and, at low degrees of melting, nepheline-normative<sup>2</sup>. From our own experience and experimental tests, we suggest the following possible explanations for the observations of Baker *et al.*

(1) The diamond-aggregate technique they used retains internal pore pressure less than the experimental load pressure, until the pores are filled by the melt phase. Initial melt compositions may thus reflect  $P \ll P_{\text{load}}$ , and may tend towards the 1-atmosphere minimum melt composition (which is quartz-normative). Adjustment to higher pressure equilibrium is diffusion-controlled in relation to the lherzolite mineralogy outside the diamond aggregate. Tests of the diamond-aggregate technique at higher degrees of partial melting and higher temperatures (>1,300 °C) are not necessarily transferable to low-degree melting experiments at 1,250 °C.

(2) In Baker *et al.*'s 'two-stage experi-

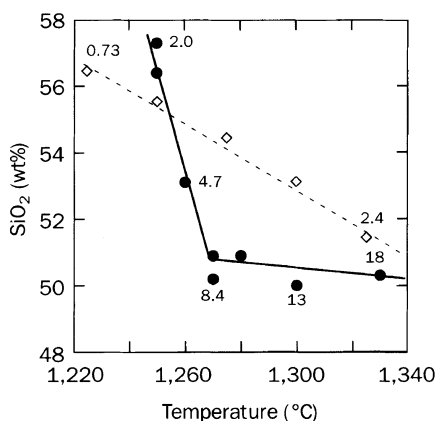


FIG. 1 SiO<sub>2</sub> contents versus temperature for peridotite partial melts determined using the diamond-aggregate technique for the peridotite composition MM3<sup>1,5</sup> compared with peridotite partial melts from MM3 modelled using the MELTS program<sup>1</sup>. Note the linear variation produced by MELTS versus the 'dog-leg' trend of the diamond-aggregate experiments. The number next to data points is the measured or calculated degree of melting; note the large discrepancy between MELTS and the experimental results on MM3<sup>1,5</sup>.

ments' the melt composition migrating into the diamond aggregate could be a remobilized, quench-modified melt from the stage-one experiment; that is, a remelted glass derived by olivine + quench clinopyroxene growth during quenching of the melt formed from the mineral mix in the stage-one experiment.

(3) The use of a mix of naturally occurring olivine, aluminous pyroxenes and Cr–Al spinel mineral separates from spinel lherzolites as starting materials introduces considerable uncertainty in distinguishing between disequilibrium and equilibrium melting. Aluminous clinopyroxene and orthopyroxene, formed at higher pressures and probably lower temperatures, have been shown to melt incongruently and to exsolve a SiO<sub>2</sub>-, Na<sub>2</sub>O- and Al<sub>2</sub>O<sub>3</sub>-rich glass when held at lower pressures and temperatures of 1,100–1,300 °C (ref. 3).

Disequilibrium melting of a mineral assemblage run outside its pressure and temperature stability field can produce a liquid at temperatures below the true solidus. The methodology of the mineral mix and diamond-aggregate technique requires crushing of the diamond aggregate, and identification and analysis of juxtaposed residual phases adequately, nor to identify whether glass formed within phases or at particular mineral interfaces.

(4) The movement of melt into pore spaces of the diamond aggregate is a time-dependent process, as is the reaction, melting and attempted re-equilibration of the natural mineral mix. The time-dependent separation of melt from its reactants is obviously undesirable, and diffusion-controlled run products must be expected. Baker *et al.* note clinopyroxene crystallization within the diamond aggregate and mineral zoning in the peridotite. In these circumstances, the 'reacting composition' is unknown and is not the same as the bulk peridotite composition.

(5) Baker *et al.* initially considered that their experiments were anhydrous, but in their correspondence with us they argue that we have not incorporated the 'right amount' of water to reproduce their results in our reversal experiments (our experimental glasses are H<sub>2</sub>O-free, as demonstrated by infrared spectroscopy). Unknown and very high water contents in melts of lherzolite at 1 GPa will indeed produce quartz-normative liquids, albeit of a different nature from that found by Baker *et al.*<sup>4</sup>.

The experimental melting data for MM3 is compared with liquids calculated by the MELTS program<sup>1</sup> in Fig. 1. Figure 2 illustrates the disagreement between

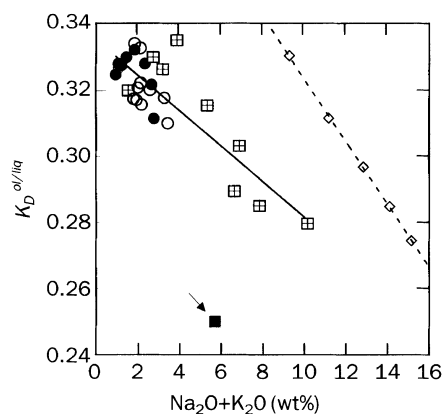


FIG. 2 Olivine/liquid Fe/Mg exchange coefficient ( $K_D$ ) determined for the Baker *et al.*<sup>1</sup> result compared with other experimental data over a large range of alkali contents and with values calculated by MELTS<sup>1</sup>. ■, Run 70a in ref. 1 (arrowed); ○, peridotite sandwich experiments of ref. 2; ●, diamond-aggregate experiments of ref. 5 at temperatures >1,270 °C; □, olivine/liquid  $K_D$  determined in ref. 6 in the system SiO<sub>2</sub>–K<sub>2</sub>O–FeO–MgO; ◇, modelling using MELTS at QFM for MM3 (ref. 1) at 1 GPa.

olivine/liquid partitioning of Fe and Mg as measured by E. Takahashi and calculated by MELTS, and the 1,250 °C data point published by Baker *et al.*<sup>1</sup>. Both figures presented here suggest disequilibrium melting and quenching problems in the recent experiments.

To summarize, the experimental results of Baker *et al.*<sup>1</sup> must be treated with caution. The experimental problems are twofold, relating first to time-dependent pressure gradients, time-dependent diffusion and time-dependent pore filling of the diamond aggregates; and second, to disequilibrium melting of natural mineral starting mixes. A third problem — uncertainty in water content — is possibly an additional source of error.

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