

## Lower-mantle composition

# High-pressure melting studies

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GEOCHEMICAL variations within the Earth's interior are an important guide to the history of the planet as it accreted, differentiated and cooled. This makes an understanding of the processes involved one of the most important problems of geophysics. Recent laboratory studies of the melting of samples with mantle compositions at high pressure have simulated conditions in the upper mantle and transition zone<sup>1,2</sup>. Now experiments mimicking the lower mantle, with pressures up to 25 gigapascals (GPa)—250,000 atmospheres—are reported by Ito and Takahashi on page 514 of this issue<sup>3</sup> and also by Ohtani and Sawamoto<sup>4</sup>.

The experiments show that upper-mantle peridotite compositions have the properties of liquids formed at or near their eutectic-like equilibria and thermal minima<sup>5</sup>. Their pressures of stability are yet to be calibrated, but probably span the range 10–25 GPa. The logical inference is that the upper mantle formed from the solidification of these liquids.

It would be a surprise indeed if the planetesimals that accreted to make the

Earth had compositions similar to these peridotite liquids. If instead the bulk composition of the Earth is chondritic (with a lower Mg/Si ratio), then the lower mantle must be rich in SiO<sub>2</sub> compared with the upper mantle, probably as a pyroxene phase such as perovskite. But is there a mechanism that could have caused this differentiation to occur?

The new experimental studies are significant because they provide a simple answer to this question. They show that the liquidus phase for peridotite and chondrite compositions is majorite from about 13 to 25 GPa, and perovskite<sup>1–4</sup> at about the same or higher pressures. Both, of course, are high-pressure polymorphs of pyroxene. Because they are much more dense than peridotite liquids, they could have fractionated into the lower mantle. In effect, the lower mantle could contain a significant cumulate/residuum component<sup>5</sup> of liquidus perovskite or of liquidus majorite transformed to perovskite. It is also reasonable to infer that this differentiation event happened soon after the Earth formed, when it was hot enough

for melting to have extended to great depths. This hypothesis would predict geochemical differences between the upper and lower mantles that depend on the amount of majorite and/or perovskite fractionated.

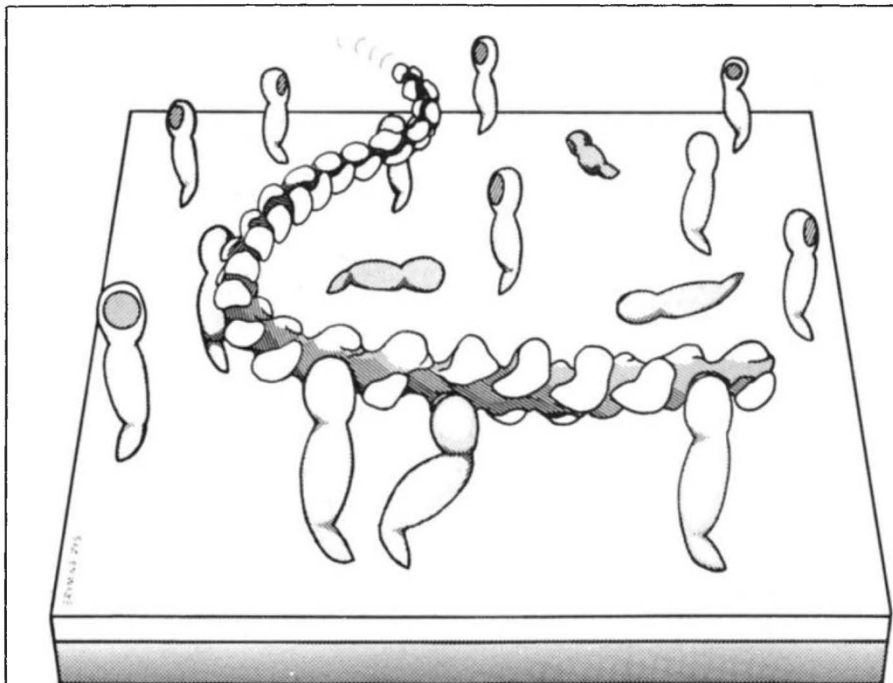
From a geochemical interpretation of their data, Ito and Takahashi decide that majorite fractionation could not have occurred, and that perovskite fractionation was not important after all. There are important difficulties, however, with their interpretation. Specifically, modified spinel eventually joins liquidus majorite as a coprecipitating phase, but is not included in the analysis of Ito and Takahashi. Problems also arise for the ratios Ca/Al and Al/Si in majorite, because they vary with bulk composition<sup>2,4</sup>.

Kato, Irifune, and Ringwood<sup>6</sup> also conclude that majorite or perovskite fractionation was not important, basing their judgement on major-element and rare-earth-element partitioning experiments between majorite and liquid. Again, there are problems with this interpretation. The major-element geochemistry of majorite crystallizing from the komatiite composition used in their experiments is a poor test of the hypothesis because it differs from liquidus majorites in a chondritic Earth<sup>2,4</sup>. The rare-earth elements, however, should be a quintessential record of majorite or perovskite fractionation had it occurred<sup>6</sup>, yielding a primordial upper mantle that was high in the gadolinium to ytterbium ratio and enriched in the light rare-earth elements. Indeed, this kind of garnet signature is typical of the ancient granular-garnet peridotite nodules from South Africa. As for the present-day mantle from which mid-ocean-ridge basalts are produced, would the geochemical record of liquidus majorite or perovskite fractionation be preserved after 4 billion (4 × 10<sup>9</sup>) years of partial melting?

These are all important considerations when modelling the Earth's interior. In the whole-mantle convection model, perovskite may have to become concentrated somewhere in the lower mantle because its geochemical signature is not obvious in any mantle rocks studied so far. In the two-layer convection model, silica enrichment might occur at the 670 kilometre discontinuity. Whatever the correct interpretation, the new experimental work<sup>1–4</sup> from Japan demonstrates that it is difficult to avoid the conclusion that the lower mantle is enriched in silica. □

1. Takahashi, E. *J. Geophys. Res.* **91**, 9367–9382, (1986).
2. Ohtani, E. & Sawamoto, H. *Nature* **322**, 352–353, (1986).
3. Ito, E. & Takahashi, E. *Nature* **328**, 514–517 (1987).
4. Ohtani, E. & Sawamoto, H. *Geophys. Res. Lett.* **14**, 733–736 (1987).
5. Herzberg, C.T. & O'Hara, M.J. *Geophys. Res. Lett.* **12**, 541–544 (1985).
6. Kato, T., Irifune, T. & Ringwood, A.E. *Geophys. Res. Lett.* **14**, 546–549 (1987).

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MYOSIN, a two-headed molecule with a long tail, is the protein that hydrolyses ATP to produce muscle contraction. On page 536 of this issue, Toyoshima *et al.* describe a new *in vitro* motility assay for proteolytic fragments of myosin. As previously reported in the News and Views article by Clive Bagshaw (*Nature* 326, 746; 1987), they observed movement of actin filaments over subfragment 1, the isolated myosin head, randomly arrayed on a nitrocellulose film, as depicted above. They find that the movement directed by subfragment 1 and myosin is similar, suggesting that the molecular engine of myosin is fully within the myosin head. □