

Phase relations for the former basaltic crust of the slab in the perovskite facies of the lower mantle

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Irifune & Ringwood (1993) showed that subducted slabs become less dense than surrounding perovskitic lower mantle at depths between 660–800 km because of the survival of garnet in former basaltic crust. At these depths, this latter lithology consists of stishovite, calcium silicate perovskite and an aluminous phase with the Ca-ferrite structure, plus garnet which is no longer majoritic but approaches compositions on the pyrope-almandine join. MORB had not yet transformed to perovskite at the highest pressures that Ringwood & Irifune attained (27 GPa). Indeed, O'Neill and Jeanloz (1994) have recently proposed that garnet in the subducted slab may persist well into the lower mantle, to depths of ~1200 km (~50 GPa)

There is as yet no experimental demonstration of the widely accepted belief that the basaltic crust of the slab would eventually transform to a perovskitic lithology stable within the lower mantle. We have accordingly investigated phase relations in some analog systems that are relevant to the transformation of MORB to perovskite, and have also carried out experiments with a synthetic MORB glass.

Experiments were carried out in a diamond anvil high pressure cell, and heated with the infrared beam of a YAG laser. The laser is unstabilised and so no attempt was made to measure or control

temperature. Pressure was monitored by means of standard ruby fluorescence techniques. Samples were recovered from the diamond anvil cell and a thin foil was prepared by ion-beam thinning. Experimental phases were characterised by transmission electron microscopy and energy-dispersive microanalysis.

We have carried out reconnaissance experiments on the high pressure stability limit of basaltic garnet by synthesising a glass equivalent in composition to the garnet that Irifune & Ringwood found at 27 GPa, except that its Mg-number was readjusted back to 69 to compensate for FeO loss in these authors' experiments. In diamond cell experiments designed to impose a substantial pressure gradient between the centre and the edge of the sample disc, we observe that this same garnet crystallises below about 30–35 GPa but does not occur at higher pressures. Above ~30–35 GPa the phase assemblage instead comprises stishovite, a sodic and aluminous Ca-ferrite type phase and amorphous material with garnet stoichiometry and Mg-number ~71 (former aluminous perovskite destroyed during ion-beam thinning?).

Experiments on synthetic MORB glass at ~45 and 80 GPa define the mineralogy and phase chemistry of MORB in the perovskite facies of the lower mantle. The phase assemblage comprises

Table 1. Representative chemical compositions of coexisting phases formed from synthetic MORB glass at 45 and 80 GPa

GPa	Mg,Al PvsK		Ca pvsK		Stish		Ca-ferrite	
	45	80	45	80	45	80	45	80
SiO ₂	40.6	43.0	56.5	56.7	96.5	88.5	23.6	26.0
TiO ₂	2.1	na	<0.5	na	0.1	na	<0.5	na
Al ₂ O ₃	16.4	20.5	2.3	2.1	2.8	10.3	45.1	45.1
FeO	17.0	13.9	0.8	2.6	<0.5	<0.5	7.8	9.0
MgO	22.6	20.2	0.5	1.4	<0.5	<0.5	11.7	8.9
CaO	<0.5	0.6	39.9	36.7	0.	<0.5	0.9	0.8
Na ₂ O	0.8	1.9	0.	0.4	0.	<0.5	10.7	10.3
Mg#	70	72	55	50			73	64

stishovite (10 wt% Al_2O_3 in solid solution at 80 GPa), an amorphous phase equated with former CaSiO_3 perovskite (only ~ 2 wt% Al_2O_3), aluminous magnesian perovskite with 17–21 mole % Al_2O_3 and an aluminous phase with the Ca-ferrite structure that contains most of the Na_2O inventory. TiO_2 is preferentially partitioned into magnesian perovskite. The Mg-number and aluminous nature of magnesian perovskite are entirely consistent with our determinations of perovskite phase relations across the join $\text{Mg}_3\text{Al}_2\text{Si}_3\text{O}_{12}$ – $\text{Fe}_3\text{Al}_2\text{Si}_3\text{O}_{12}$. We show that solid solution of Al_2O_3 greatly expands the stability of perovskite to at least 75 mole % of the ferrous endmember (Kesson *et al.*, 1994).

Our determinations of lattice parameters and phase chemistry yield zero-pressure densities for aluminous stishovite, for the Ca-ferrite phase and for aluminous perovskite. In conjunction with data from the literature, we can now estimate the density differential between the former basaltic crust of the slab, and surrounding mantle at these depths. (We derive the density of each phase at P,T by correcting the zero-pressure density for compressibility and thermal expansion and have

not attempted to allow for the effects of P or T on these latter parameters). Our simple calculations show that MORB is marginally more dense than a reference PREM mantle, by at least 0.06 g/cc below 900 km. Although the uncertainties in our calculations are probably of the same magnitude as the differential, the unequivocal evidence that MORB is no longer buoyant below ~ 900 km has important implications for mantle dynamics. It means that any slab that succeeds in penetrating ~ 300 km below the 660 km discontinuity and transforms to perovskite, would encounter no further barrier to entrainment in the convective circulation of the lower mantle.

References

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