ECLOGITE-GARNETITE TRANSFORMATIONS IN BASALTIC AND PYROLITIC COMPOSITIONS AT HIGH PRESSURE AND HIGH TEMPERATURE

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Extensive experimental studies have been made in our laboratory on high-pressure phase equilibria in basalt and pyrolite compositions at pressures to 18 GPa and temperatures of 1200 - 1400°C. The compositions studied so far are 1) primitive MORB (Green et al., 1978; Liu, 1980; Irifune et al., 1986), 2) alkali-poor olivine tholeiite (Ringwood, 1967; Irifune et al., 1986), and 3) pyrolite minus olivine (Sun, 1982; Irifune, 1986), as listed in Table 1. Further, a corresponding study on the composition of an eclogitic garnet inclusion in diamond (A1-24; Moore and Gurney, 1985) is currently in progress. We summarize herein these experimental data and discuss the nature of the garnet-eclogite transformation in these compositions. Implications for the constitution of the earth's mantle are also discussed.

High-pressure experiments were carried out using an MA8 type apparatus with truncated split-sphere guide blocks (Ohtani et al., 1986). Seimi-sintered MgO was used as a pressure medium and two sheets of TiC + MgO were used as heaters. Temperature was measured by a Pt-Pt10%Rh thermocouple. Glass and amphibolite with about 1% water were used as starting materials, and the quenching method was employed to identify phases in the run product. Further details of the experimental techniques are given in Irifune and Hibberson (1985) and Irifune et al. (1986).

Figure 1 shows lattice parameters of garnet in basalt and pyrolite compositions as a function of pressure. Electron microprobe analyses revealed that the variations of the garnet lattice parameters below 12 - 13 GPa are due to chemical changes, specifically in Ca contents, in these garnets. The lattice parameters thereafter increase rather rapidly, which is mainly caused by solution of pyroxene in the garnet structure. The lattice parameters level off at pressures above 14 - 16 GPa, indicative of formation of single phase garnetite (± stishovite). Formation of garnetite at these pressures is also confirmed by electron microprobe analysis.

Figure 2 depicts the chemical composition change of garnet in the pyrolite minus olivine composition as a function of pressure. Garnet becomes aluminum-deficient with increasing pressure and the numbers of M^{2+} (Ca + Mg + Fe) and Si^{4+} increase in a complementary manner, which indicates substitution of $M^{2+} + Si^{4+}$ for Al^{3+} at high pressure. Further, the sodium contents of garnet increases with increasing pressure, indicative of the coupled substitution of $Na^{+} - Si^{4+}$ for $M^{2+} - Al^{3+}$. Moore and Gurney (1985) denied the possibility of this substitution because of the existence of a negative correlation between Si and Na in high-Na garnet inclusions as shown by the region of group B garnets in Fig. 3. However, our experimental data show that positive correlations exist between Si and Na and suggest the negative correlation in group B garnet is superficial. Similar variations in chemical compositions of garnets are observed for other bulk compositions.

The Na-rich garnet is considered to be formed at extremely high pressures, above 10 GPa, as seen in Fig.3. The most Al-deficient garnet in group B (A1-24) so far reported is found to be formed at pressures above 14 GPa at 1200 C. As the temperature dependence of the eclogite-garnetite

Table 1. Compositons of starting materials

	(1)	(2)	(3)	(4)
SiO_2	50.39	47.20	51.78	47.63
TiO_2	0.57	0.10	0.46	0.88
Al_2O_3	16.08	14.51	11.44	11.29
Cr_2O_3	-	-	0.92	0.20
FeO	7.68	11.81	3.12	10.95
MgO	10.49	12.10	23.14	22.05
CaO	13.05	13.19	9.50	7.10
Na_2O	1.87	0.65	0.94	0.48
TOTAL	98.26	99.56	101.30	99.77

(1) DSDP, (2) alkali-poor olivine tholeiite, (3) pyrolite minus 62 % olivine, (4) A1-24.

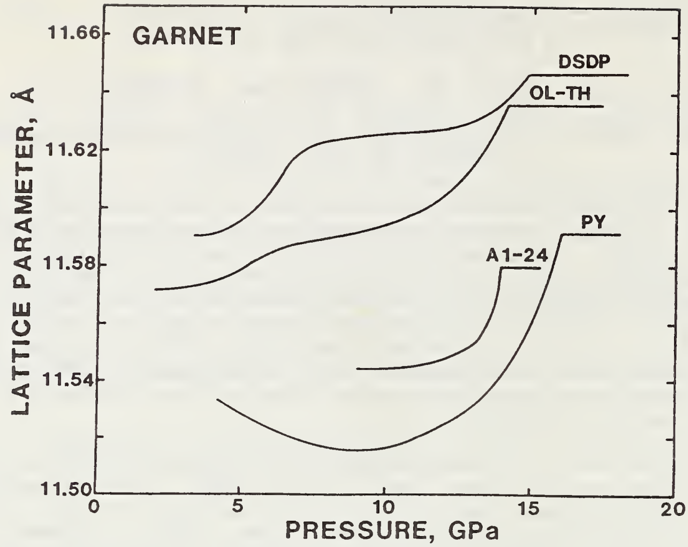

Fig.1 Lattice parameters of garnets in basaltic and pyrolitic compositions as a function of pressure.

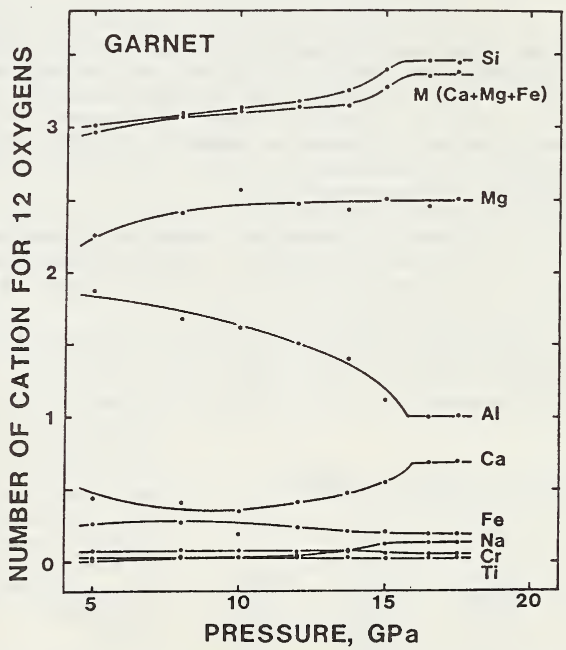

Fig.2 Compositions of garnets in "pyrolite minus olivine" as a function of pressure.

transformation is quite small, in the order of 0.002 GPa/°C (Irifune, 1986), it is evident that this garnet is derived from a depth of at least 400 km and accordingly represents the most deep-seated mantle minerals available to date. On the other hand, the low Na and Si garnet inclusions (group A) are formed at relatively low pressures, below 10 GPa.

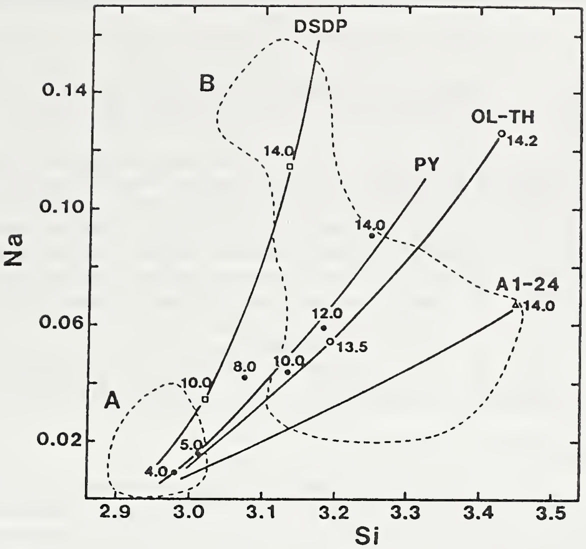

Fig. 3 Correlations between atomic Na and Si in garnets of various starting compositions. Numbers indicate pressure in GPa. Group A represents normal eclogitic inclusion garnets and group B represents garnets containing pyroxenes in solid solution, as described by Moore and Gurney (1985).

Mineralogy and density changes in descending oceanic crust and surrounding mantle are evaluated on the basis of our experimental data. Basaltic materials are substantially denser than surrounding mantle to depths of at least 600 km and possibly throughout the mantle. The results of this study combined with seismological data confirm that it is most unlikely that eclogitic materials comprise a large portion of the upper mantle.

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