

The Nature of Crust-mantle Boundary and Compositional Variation of Magma in the Light of Experimental Evidence by Alok K. Gupta,

Department of Geology and Geophysics, University of Allahabad, Allahabad 211 002, India.

Mohorovicic discontinuity between the crust and the mantle is related to the phase transformation from gabbro/basalt to eclogite¹⁻³. Subsequent experimental studies⁴⁻⁶ show that basaltic rocks are converted to eclogites at pressures above 20 ± 3 kb. Thus there is experimental evidence in favour of the hypothesis put forward by Fermor¹, Lovering² and Kennedy³.

The density of upper mantle materials (3.4-3.95 g/cm³) as demanded by the propagation of P and S waves through this section of the earth agrees with that of eclogite (3.55-3.8 g/cm³). Thus, generation of basaltic liquid from eclogites appears at first sight to be a viable hypothesis. Since the mohorovicic discontinuity below the ocean floor occurs only at a depth of 10-15 km, the presence of eclogite at such a depth is questionable. Besides, the complete melting of eclogite is necessary to generate a basalt magma. There is geophysical evidence to suggest that only partial melting of the earth's upper mantle takes place in the low velocity zone within the earth (80-150 km).

Garnet peridotite/lherzolite (containing olivine and pyroxene with or without garnet) is considered by many to constitute the upper mantle. Kushiro⁷ made melting studies of garnet lherzolite at high pressures and noted that partial melting of such lherzolites under pressures of 10 and 20 kb produced tholeiitic and alkali basalt melts, respectively.

Meteorites are considered to be parts of disrupted planets and hence analogy of their compositions with certain segments of the earth is obvious. Chemistry of stony meteorites is similar to that of peridotites rather than eclogites. Experimental studies⁸ on carbonaceous chondrites from Allende showed that a liquid produced by partial melting under MW and IW buffers have the composition similar to that of some ferro basalts from the moon.

Fayalite (α olivine, orthorhombic structure) is converted to β olivine (spinel structure) under 53 kb at 1000°C, whereas more magnesian olivine (forsterite₅₀, fayalite₅₀, wt%) is transformed to β phase under 112 kb at 1000°C. At higher pressures (i.e. greater depth) the conversion should take place at higher temperatures. This change in olivine

structure adequately explains the change in the depth versus velocity profiles of P and S waves in the transition zone between lower and upper mantle.

Experimental studies^{9,10} on the system forsterite-kalsilite-SiO₂ under variable pressures with or without volatiles (H₂O and/or CO₂) show that the invariant point involving olivine-orthopyroxene and kalsilite (K-feldspar in case of isobaric sections at 20 kb or below) shifts more and more towards the alkali-rich side of the system. Comparison of the study⁹ on the system forsterite-nepheline-SiO₂ under 28 kb with that of others also show that the invariant point involving olivine, orthopyroxene and an alkali phase (nepheline or jadeite, depending on pressure) also shifts towards more alkali-rich side of the system under higher pressures. These observations suggest that the composition of the first batch of melts produced from all these systems (corresponding to the invariant point) are a function of depth of melting. The initial melts produced under hydrous conditions at shallow depths are more silica-rich and alkali-poor, whereas those formed at greater depths under dry conditions or in presence of CO₂ are more alkalic and silica-poor. These findings confirm Kuno's¹⁰ observation that while the basalts generated at shallow depths are silica-saturated, those coming from greater depths are more alkalic and silica-poor.

Study on the kalsilite-forsterite-SiO₂ system under 28 kb showed that from certain compositions under dry conditions olivine appeared as the first crystalline phase, the same compositions yielded orthopyroxene or phlogopite under CO₂ or hydrous conditions, respectively. Thus the composition of the residual liquid is greatly controlled by the fluid phase in presence of which melting takes place.

1. Fermor, L. L., *J. Geol. Surv. India*, 1913, **43**.
2. Lovering, J. F., *Trans. Am. Geophys. Un.*, 1958, **39**, 947.
3. Kennedy, G. C., *Am. Sci.*, 1959, **47**, 491.
4. Cohen, L. H., Ito, K. and Kennedy, G. C., *Am. J. Sci.*, 1967, **265**, 475.
5. Green, T. H., *Contrib. Mineral. Petrol.*, 1967, **16**, 84.
6. Gupta, A. K. and Yagi, K., *Petrology and genesis of leucite-bearing rocks*, Springer-Verlag, Berlin-Heidelberg-New York, 1980, p. 252.
7. Kushiro, I., In: *Partial melting of garnet lherzolites from kimberlite at high pressures*, (ed.) P. H. Nixon, Lesotho kimberlites, Lesotho

- National Development Corporation, Maseru, Lesotho, 1973, p. 294.
8. Seitz, M. G. and Kushiro, I., *Science*, 1974, **183**, 954.
 9. Gupta, A. K. and Green, D. H. (unpublished).
 10. Wendlandt, R. F. and Egger, D. H., *Am. J. Sci.*, **280**, 421.
 11. Kuno, H., In: *Volcanological and petrological evidences regarding the nature of the upper mantle*, (ed.) T. F. Gaskell, Academic Press, New York, 1967, p. 89.
-