

EXPERIMENTAL STUDIES OF DIFFUSION OF WATER IN CRYSTALLINE PERIDOTITE AND PARTITIONING OF SOME TRACE ELEMENTS BETWEEN WATER-RICH VAPOR AND CRYSTALS IN THE UPPER MANTLE

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Striking features of peridotite nodules sampled by kimberlite are porphyroblasts of phlogopite and richterite (e.g., Aoki, 1974) and large enrichments of light REE. Chondrite-normalized heavy REE contents are frequently less than unity (Shimizu, 1974). The enrichment of incompatible trace elements is particularly striking in light of the depletion of low-temperature fusible components in many of these nodules (Nixon and Boyd, 1973). These observations point to the possibility that metasomatism is a viable process in the segments of the upper mantle that are associated with formation and evolution of kimberlite. Experiments have been conducted, therefore, to determine diffusion rates of volatiles and the distribution of certain trace elements between such volatiles and crystalline peridotite.

Water was chosen as a first approximation to the composition of a volatile phase in the mantle. The diffusion rate of H_2O was determined by spiking H_2O with some 3H (activity ~ 1 mCi/mg). This H_2O was stored in synthetic serpentine which was loaded in the bottom of 1 cm long Au capsules and run in 3/4"-diameter furnace assemblies in a solid-media, high-pressure apparatus (Kushiro, 1976). The serpentine was overlain by powdered, dried garnet peridotite of about 100 μm grain size. The samples were annealed at 400°-425°C and desired pressure for a time period sufficient so that the diffusion rate was independent of the annealing time. During this time period, some serpentine broke down. The H_2O thus released migrated through the peridotite and coated the olivine grains in the peridotite with serpentine. About 1-2% serpentine was formed in the peridotite during this time period. At the temperatures of the experiments (650°-850°C) most of the serpentine broke down, and a front of water-rich vapor moved through the slightly serpentized peridotite making amphibole in the process. The distance traveled by the tritiated water was determined with the help of beta-track mapping (Mysen and Seitz, 1975) by measuring the distance (on K-2 nuclear emulsions supplied by the Ilford Co.) from the serpentine-peridotite interface to the level in the experimental charge beyond which only the original serpentine was found. The latter interface is sharp (< 0.01 mm wide) making such measurements rather accurate. Results of replicate experiments and measurements indicate about 10% relative uncertainty.

Experiments with different run lengths at given temperature and pressure reveal that diffusion rate of H_2O is independent of run time thus suggesting that the water is moving by infiltration. Experiments were carried out in the pressure range 15-30 kbar. The results show that the diffusion rate depends strongly on pressure, and is a nearly linear function of f_{H_2O} (Fig. 1). It is also evident that the diffusion rate is on the order of several mm/hr under the pressure and temperature conditions of the upper mantle.

Partition coefficients, $K^{\text{vapor/crystal}}$, were determined for cpx and ga in equilibrium with H_2O -rich vapor at 20 kbar at 1100°C using 4 day run durations and determining Sm and Tm contents of the crystalline phase with ^{151}Sm and ^{171}Tm as source of beta particles. Initial experiments were conducted with crystals together with vapor that contained radioactive tracer. A split of crystals after such an experiment was then run together with a vapor containing no radioactive isotope. The trace element content of the vapor was determined with mass balance calculations. Reversal experiments agreed within 10-20%. Average values of partition coefficients from reversal runs were used. Partition coefficients involving light REE and other peridotite phases were calculated from the data of Mysen (1977). Results are shown in Table 1.

TABLE 1. Partition coefficients

	Cerium	Samarium	Thulium
Garnet	120 ± 30	2.5 ± 0.6	0.9 ± 0.2
Clinopyroxene	27 ± 6	13 ± 3	21 ± 5
Orthopyroxene	160 ± 40	160 ± 40	120 ± 30
Olivine	380 ± 90	360 ± 80	320 ± 70
Pargasite	220 ± 50	110 ± 20	140 ± 30

It is evident from the data in Table 1 that a water-rich vapor in equilibrium with garnet peridotite minerals will be enriched in light REE relative to the peridotite. Furthermore, REE partition strongly into the H_2O -rich vapor relative to the crystals.

The experimental data reported here show that metasomatism in the mantle is a possible mechanism for redistribution of trace elements. The data therefore support an hypothesis that such a mechanism plays a role in determining the mode of formation and evolution of kimberlite.

References

- Aoki, K., 1974, *Contr. Mineral. Petrol.*, 48, 1-7.
 Kushiro, I., 1976, *Carnegie Instn. Washington, Year Book* 75, 832-833.
 Mysen, B. O., 1977, *Ibid.*, 76. In Press.
 Mysen, B. O., and Seitz, M. G., *J. Geophys. Res.*, 80, 2627-2635.
 Nixon, P. H., and Boyd, F. R., 1973, p. 48-56 in *Lesotho Kimberlites* (ed.: P. H. Nixon). Cape and Transvaal Printers Ltd., Cape Town, South Africa. 350 pp.
 Shimizu, N., 1974, *Carnegie Instn. Washington, Year Book* 73, 954-961.

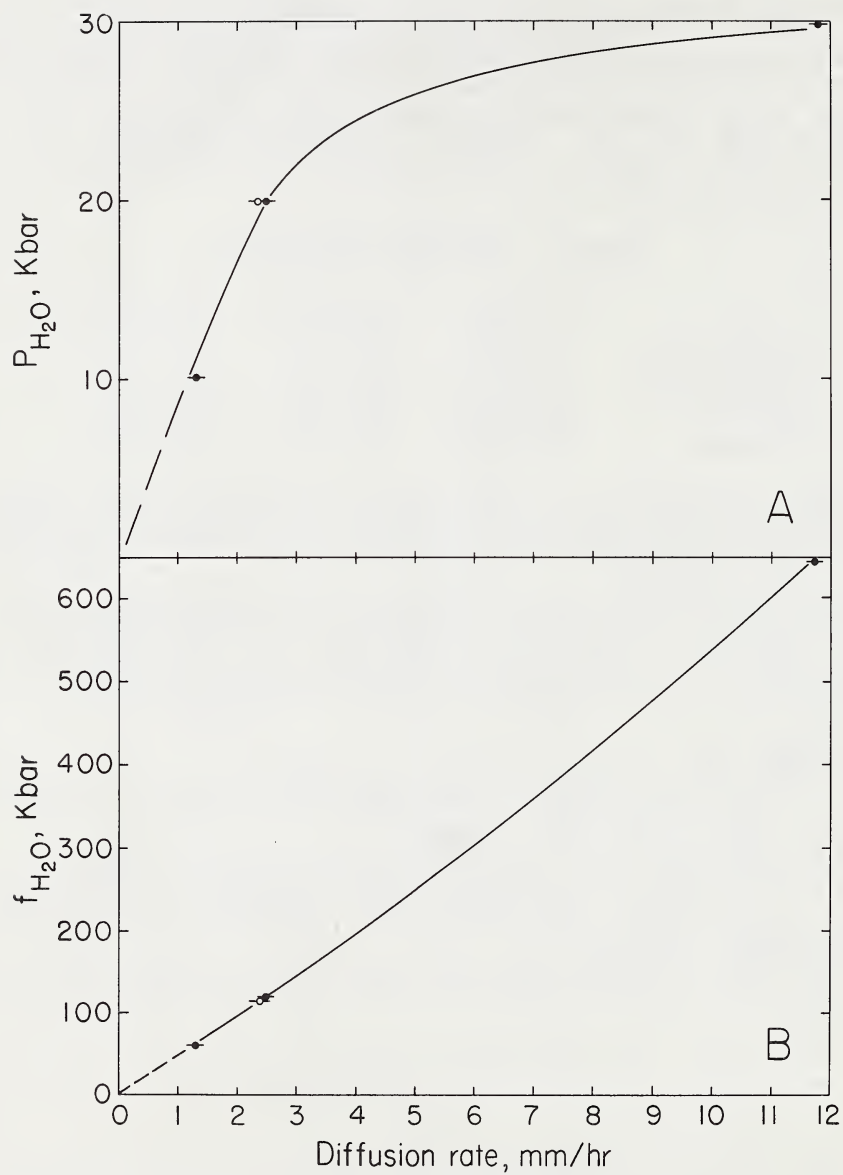


Figure 1. Diffusion rate of H_2O as function of P_{H_2O} and f_{H_2O} .
 Closed symbols - 850°C.
 Open symbols - 650°C.