

PHASE RELATIONSHIPS IN NATURAL AND SYNTHETIC PERIDOTITE-H₂O AND
PERIDOTITE-H₂O-CO₂ SYSTEMS AT HIGH PRESSURES

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Phase relationships to about 30 kbars and 1200°C have been determined in the presence of H₂O and H₂O-CO₂ vapors with controlled a_{O_2} and a_{H_2O} for four peridotite nodules (including one from the Wesselton Mine) and a garnet websterite nodule. Their compositions (Rocks A-E, respectively) are SiO₂ = 45.7 (wt %), 43.7, 45.10, 44.82, 45.58; Al₂O₃ = 1.6, 4.0, 3.92, 8.21, 13.69; CaO = 0.70, 3.50, 2.66, 8.12, 11.78; Na₂O = 0.09, 0.38, 0.27, 0.89, 1.27; K₂O = 0.04, 0.01, 0.02, 0.03, 0.02; Mg/(Mg + Fe²⁺) = 0.94, 0.89, 0.90, 0.85, 0.88. Additional data to 1350°C and 35 kbars were obtained from experiments on synthetic phlogopite-bearing peridotites in the system K₂O-MgO-CaO-Al₂O₃-SiO₂-H₂O at conditions of $P_{H_2O} \sim P_T$ and $P_{H_2O} \ll P_T$.

Temperatures of the vapor-saturated solidii for the nodules with a mol fraction of H₂O in vapor ($X_{H_2O}^V$) ~ 1 are shown in Fig. 1. Lowering the a_{H_2O} by the addition of CO₂ to the vapor raises the temperature of the beginning of melting, as shown for rock B in Fig. 2.

The stable crystalline assemblages at all of the vapor-saturated solidii include Ol (absent in nodule E), Cpx, Opx, and Amph. Amphiboles are stable on the solidii of the nodules for values of $X_{H_2O}^V$ as low as 0.25. These amphiboles range from pargasitic [CaO/(CaO + Na₂O + K₂O) ~ 0.80] at 800°C to tshermakitic (~ 0.93) at 1100°C for nodule D + H₂O at 15 kbars.

Micas do not occur except in a series of experiments in which the nodules were spiked with 3 to 10 wt % synthetic phlogopite. However, for the synthetic peridotites with larger proportions of phlogopite components, mica is stable to high temperatures. For example, the assemblage diopside_{SS} + phlogopite_{SS} + enstatite_{SS} + forsterite + pyrope begins to melt at 1350°C at 35 kbars (Modreski and Boettcher, 1972; 1973). Experiments at higher pressures suggest that phlogopite may persist to depths as great as 175 km.

As shown in Fig. 3, liquids formed as much as 150°C above the solidii of the peridotites are SiO₂-rich (quartz normative) to the highest pressures investigated under conditions of $X_{H_2O}^V$ of 1.0 to 0.6. At lower values (higher a_{CO_2} and lower a_{H_2O}), the liquids are under-saturated in SiO₂ and rich in CaO and Al₂O₃; they may represent models of CO₂-charged kimberlite magmas. This phenomena is in part related to the change from the congruent melting of enstatite at high pressures under anhydrous conditions (Boyd *et al.*, 1964) to incongruent melting (to a SiO₂-rich liquid) at high a_{H_2O} (Kushiro *et al.*, 1968). It also results in part from a reduction in the proportion of amphibole as a_{H_2O}

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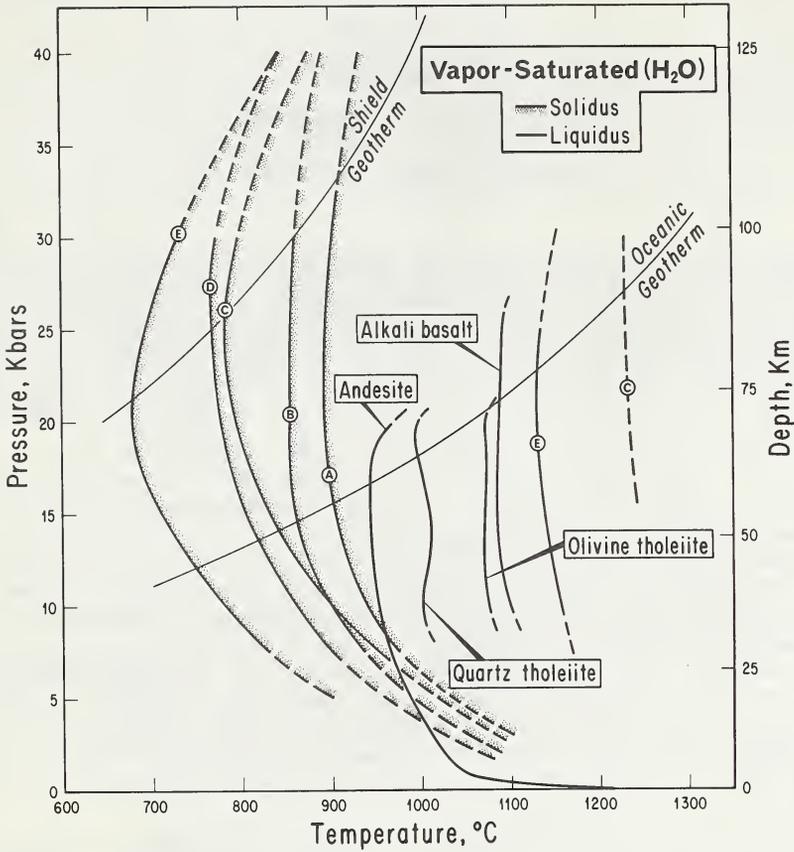


Fig. 1 P-T projection of the vapor-saturated ($X_{\text{H}_2\text{O}}^{\text{V}} \sim 1$) solidi for nodules A-E. Also shown are the vapor-saturated liquidii ($X_{\text{H}_2\text{O}}^{\text{V}} \sim 1$) for andesite, quartz tholeiite, olivine tholeiite, and alkali basalt (all from Allen *et al.*, 1972) and for nodules E and C (this work). The continental geotherm is from Clark and Ringwood (1964). The oceanic geotherm is from Ringwood *et al.* (1964).

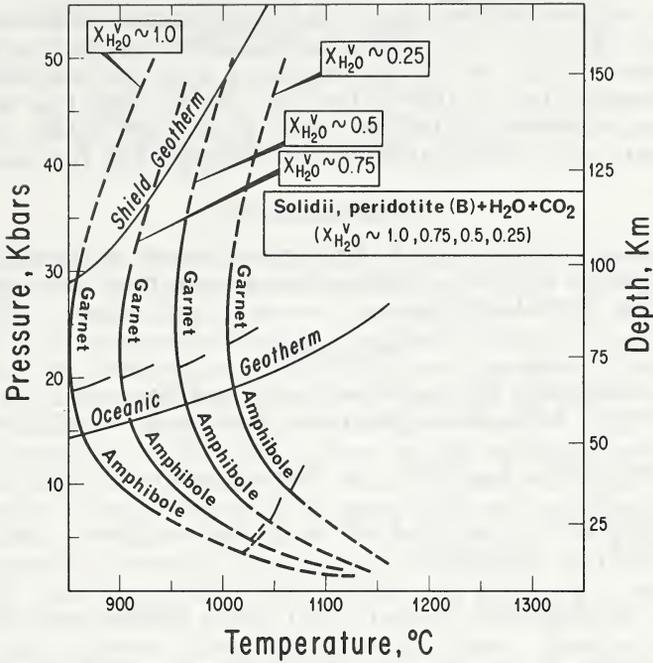


Fig. 2 P-T projection showing vapor-saturated solidii, garnet stability, and amphibole stability for nodule B with $X_{H_2O}^V \sim 1.0, 0.75, 0.50,$ and 0.25 . See also Fig. 1.

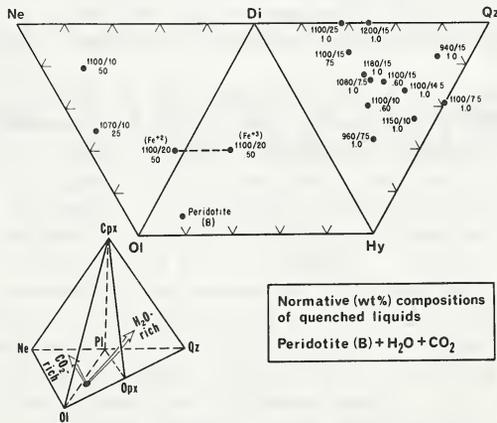


Fig. 3 Compositions of quenched liquids for nodule B+H₂O+CO₂. 1080/7.5 indicates 1080°C at 7.5 kbars with $X_{H_2O}^V=1.0$. All Fe was calculated as Fe⁺². The effect of calculating all Fe as Fe⁺³ is shown for one point.

is lowered by decreasing the $X_{\text{H}_2\text{O}}^{\text{V}}$. Our data indicate that under conditions of, say, $X_{\text{H}_2\text{O}}^{\text{V}}$ of ~ 0.25 to 0.50 , melting of peridotite would begin at depths of 100 to 175 km, depending upon the geothermal gradient and the composition of the peridotite. This range lies athwart the diamond \rightleftharpoons graphite equilibrium curve (Berman and Simon, 1955), and it is in concert with the minimum depths proposed for the genesis of kimberlites.

Acknowledgments

I thank E. D. Jackson, D. A. Pretorius, and R. W. White for providing the valuable nodules. This work was supported by National Science Foundation Grant NSF GA-12737.

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