

A MODEL OF PHASE RELATIONS IN THE SYSTEM $\text{MgO-SiO}_2\text{-H}_2\text{O-CO}_2$ AND PREDICTION OF THE COMPOSITIONS OF LIQUIDS COEXISTING WITH FORSTERITE AND ENSTATITE

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A P-T net, consistent with experimental studies of dehydration and melting reactions and with Schreinemaker's rules, has been derived for the system $\text{MgO-SiO}_2\text{-H}_2\text{O}$. Phase relations near the solidus of the system $\text{MgO-SiO}_2\text{-H}_2\text{O}$ are similar to those in the system $\text{MgO-SiO}_2\text{-CO}_2$. The positions of dehydration reactions which intersect the solidus in the system $\text{MgO-SiO}_2\text{-H}_2\text{O}$ are calculated on the basis of experimental studies at lower P and T, thermochemical data, and water fugacities predicted by the modified Redlich-Kwong equation of state. They occur at lower temperatures and higher pressures than the analogous decarbonation reactions in the system $\text{MgO-SiO}_2\text{-CO}_2$. The reaction $\text{Mg(OH)}_2 \rightarrow \text{MgO} + \text{H}_2\text{O}$ intersects the solidus at about 1250°C and 45 kbar, and the reaction $\text{Mg(OH)}_2 + \text{MgSiO}_3 \rightarrow \text{Mg}_2\text{SiO}_4 + \text{H}_2\text{O}$ intersects the solidus at about 1200°C and 90 kbar. Isobaric liquidus diagrams show that a large field for Mg(OH)_2 must exist not far above the pressure at which Mg(OH)_2 first becomes stable on the solidus.

A P-T net for the system $\text{MgO-SiO}_2\text{-H}_2\text{O-CO}_2$ has also been derived. Those reactions involving both forsterite and enstatite are shown in figure 1. A model mantle whose composition is equivalent to forsterite plus enstatite plus a small amount of volatiles may contain a vapor phase only in the P-T region enclosed by the reactions shown with heavy lines. P-T-X calculations indicate that at invariant point B, liquids coexisting with forsterite, enstatite, and vapor whose mole fraction of CO_2 is greater than 0.005 also coexist with magnesite.

The transition from vapor-present to vapor-absent melting in the upper mantle may be illustrated by a series of T-X sections through figure 1. Figure 2A shows that forsterite, enstatite, and liquid may coexist with a vapor phase having any mole fraction of CO_2 at 20 kbar. However, in figure 2B it may be seen that the assemblage forsterite plus enstatite plus liquid may not coexist with a vapor phase richer in CO_2 than that at the isobaric invariant point. The small amount of magnesite present in a volatile-poor model mantle would be completely reacted at that point. The mole fraction of CO_2 in the vapor at higher temperatures will then be controlled by the reaction $\text{Fo} + \text{En} + \text{V} \rightarrow \text{L}$. When the temperature maximum on that reaction is exceeded, all volatile must be dissolved in the liquid and any further melting will be vapor-absent. At pressures above about 90 kbar all H_2O and CO_2 are combined in brucite and magnesite. Melting takes place in the absence of a vapor phase, in the form of a simple eutectic shown in figure 2C.

The estimated composition of first liquids formed in a model mantle with an $\text{H}_2\text{O:CO}_2$ ratio of 3:1 at pressures of 20 kbar, 50 kbar, and 90 kbar is given in Table 1. In figure 3, the position of the plane of liquid compositions coexisting with forsterite and enstatite in the system $\text{MgO-SiO}_2\text{-H}_2\text{O-CO}_2$ is shown at 20 kbar and 90 kbar. At 20 kbar the first liquid is enstatite-quartz normative. However, at higher pressures the presence of magnesite on the solidus requires the composition of the first liquids to be highly silica-undersaturated. The appearance of the eutectic involving forsterite, enstatite, brucite, and magnesite at about 90 kbar requires the compositions of first liquids to be nearly constant as pressure is further increased. The

compositions of any first liquids formed at a pressure greater than 90 kbar must be periclase-forsterite normative.

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Table 1. The composition of first liquids coexisting with forsterite and enstatite in a model mantle with an $\text{H}_2\text{O}:\text{CO}_2$ ratio of 3:1. All compositions are given in mole percent.

<u>Pressure</u>	<u>MgO</u>	<u>SiO₂</u>	<u>H₂O</u>	<u>CO₂</u>	<u>Normative Minerals</u>
20 kbar	19.8	22.0	57.0	1.2	enstatite, <u>quartz</u>
50 kbar	37.6	9.6	24.3	28.5	forsterite, periclase
90 kbar	31.6	18.4	38.7	11.3	forsterite, periclase

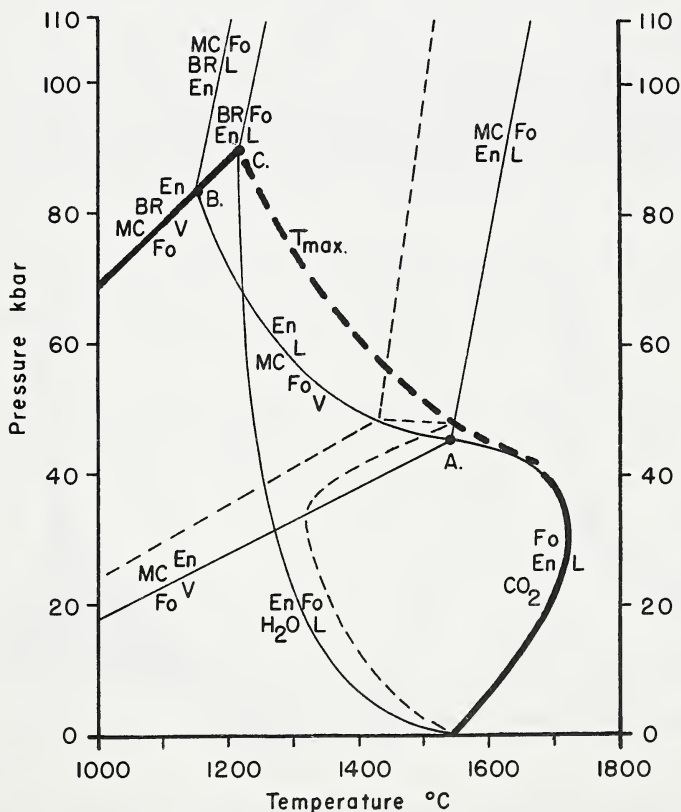


Figure 1. P-T projection of the system $\text{MgO-SiO}_2\text{-H}_2\text{O-CO}_2$ showing only reaction involving both forsterite and enstatite. The P-T range in which a model mantle could contain a vapor phase is bounded by heavy lines. The light dashed lines show a section through the system at $X_{\text{CO}_2} = 0.2$.

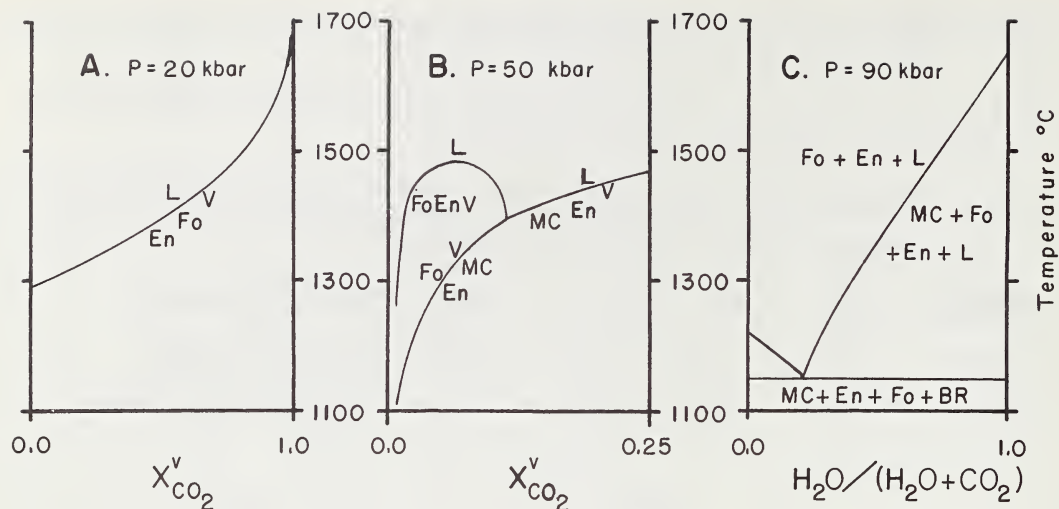


Figure 2. Sections through Figure 1 at 20, 50, and 90 kbar. The range of vapor compositions with which forsterite plus enstatite may coexist becomes smaller as pressure is increased, until at about 90 kbar they no longer coexist with vapor and the first melting takes the form of a eutectic.

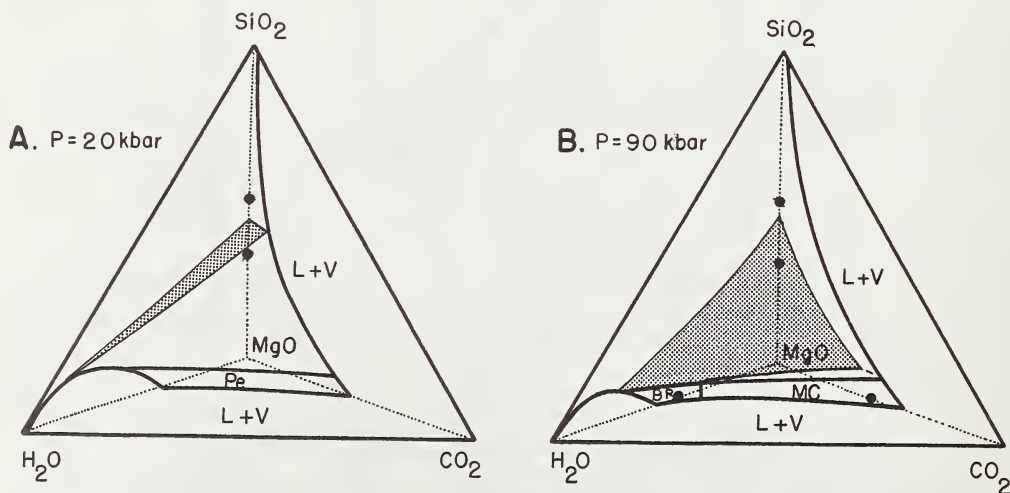


Figure 3. Partial isobaric liquidus diagrams for the system $\text{MgO-SiO}_2\text{-H}_2\text{O-CO}_2$ at 20 and 90 kbar. The plane of liquid compositions coexisting with forsterite plus enstatite is stippled. As pressure increases, the volatile-rich parts of that plane become increasingly silica-undersaturated. The compositions of stable binary compounds are shown by large black dots. All compositions are mole percent.