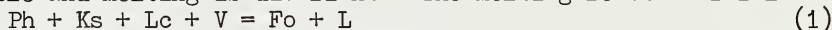


THE SYSTEM $K_2O-MgO-Al_2O_3-SiO_2-H_2O-CO_2$: PHASE RELATIONS OF THE JOINS
 $Ph-H_2O-CO_2$ AND $Ph-En-Mag$ AT HIGH TEMPERATURES AND HIGH PRESSURES AND
 APPLICATIONS TO THE GENESIS OF ALKALIC MAGMAS

R. F. Wendlandt (Geophysical Laboratory, 2801 Upton St., N. W.,
 Washington, D. C. 20008)

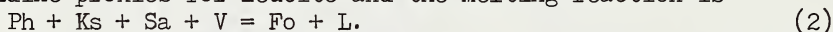
Volatile-bearing minerals in the upper mantle, such as carbonate and phlogopite, can buffer the composition of a coexisting vapor and can restrict the range of temperatures of melting and of melt compositions (Eggler and Holloway, 1977; Wyllie, 1977). While carbonates have been the subject of considerable experimental attention in the past several years, the role of phlogopite in the genesis of alkalic magmas, especially in the presence of a CO_2-H_2O vapor, and the melting behavior of coexisting phlogopite and carbonate are less well understood.

The stability of phlogopite has been investigated at 20 kbar as a function of X_{CO_2} , with emphasis on low total volatile contents (Fig. 1). Melting can occur either under conditions of high a_{H_2O} , such that all potential phlogopite in the system is saturated, or under conditions of low a_{H_2O} , in which case phlogopite coexists at subsolidus temperatures with its breakdown products. In the former case, the vapor and liquid compositions are variable and melting is divariant. The melting reaction for low a_{H_2O}



is univariant; the CO_2-H_2O vapor composition is buffered at subsolidus conditions (a "zone of invariant vapor composition"; Eggler and Holloway, 1977) and the liquid composition is independent of the volatile content of the system.

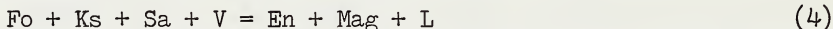
Reaction (1) is characterized by a vapor composition that becomes increasingly CO_2 -rich with increasing pressure. The reaction originates at the CO_2 -absent invariant point, I_{10} in Fig. 2, located at approximately 1.5 kbar and 1160°C (Yoder and Kushiro, 1969). At pressures between 22-30 kbar, sanidine proxies for leucite and the melting reaction is



The liquid produced is silica-undersaturated and alkalic. At 30 kbar, the melting reaction intersects the devolatilization reaction

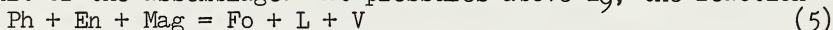


generating I_9 and introducing magnesite as a solidus phase. The phlogopite-absent reaction



emanates from the H_2O -absent invariant point, I_8 , and is characterized by decreasing X_{CO_2} as it trends toward I_9 . The vapor composition at I_9 is approximately $X_{CO_2}=0.60$.

Reactions involving the assemblage $Ph+En+Mag$ have been investigated to pressures of 50 kbar and the results are presented in P-T projection in Fig. 3. The devolatilization reaction (3) represents the low pressure stability limit of the assemblage. At pressures above I_9 , the reaction



involves two volatile-bearing minerals as solidus phases. At 32.5 kbar, phlogopite persists above the solidus for most compositions in the $Ph-En-Mag$ join and the liquid generated is haplocarbonatitic. At 40 kbar, liquids are more potassic; the supersolidus volume for magnesite is enlarged and that of phlogopite is diminished relative to the situation at 32.5 kbar. Pyrope is encountered as a product of reaction (5) at pressures of 40 kbar and higher. At 50 kbar, magnesite persists above the solidus over a wide

range of compositions in the Ph-En-Mag join. Phlogopite is believed to be a solidus phase, however, none of the compositions investigated provided direct evidence of a supersolidus volume. The vapor composition along reaction (5) is initially CO_2 -rich at pressures above I_9 but becomes increasingly H_2O -rich with increasing pressure.

The system $\text{K}_2\text{O}-\text{MgO}-\text{Al}_2\text{O}_3-\text{SiO}_2-\text{H}_2\text{O}-\text{CO}_2$ models a Ca-deficient mantle and portions of the system have been investigated to elucidate the origins of potassic magmas, carbonatites, and kimberlites. Theory and experiment show that melting of peridotite in the presence of small amounts of volatiles is restricted by the volatile-mineral assemblage. In the present investigation, vapor compositions are buffered by phlogopite and magnesite and the compositions of liquids in equilibrium with these vapors are restricted. The fundamental peridotite melting reaction was found to be

- (1) at P less than 22 kbar,
- (2) at P = 22-30 kbar, and
- (5) at P greater than 30 kbar.

The pressure of magma generation appears to be the critical variable; pressure determines the volatile-mineral assemblage and this in turn buffers the vapor composition. Accordingly, different liquids are produced by partial melting at different pressures. The liquids produced by reactions (1) and (2) are silica-undersaturated and alkalic, whereas those produced by reaction (5) are carbonatitic at pressures slightly above I_9 but become increasingly alkalic and silicic with increasing pressure.

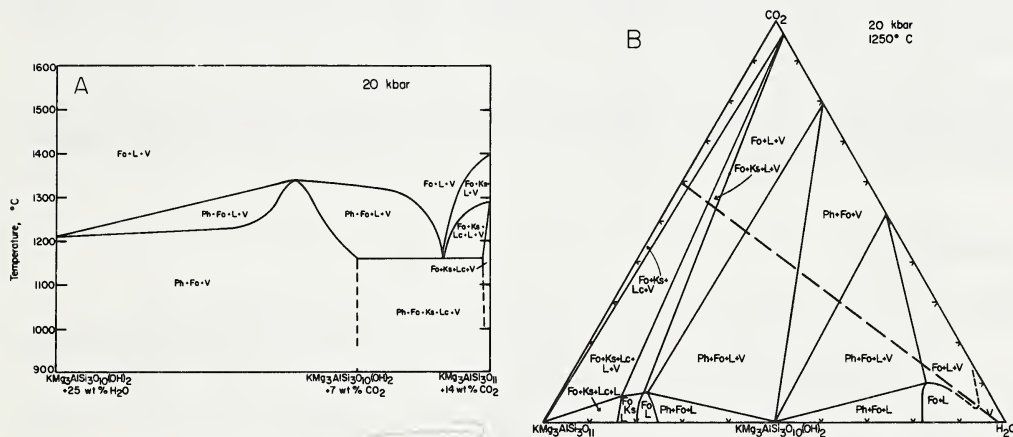


Figure 1-(A). An isobaric section through the join $\text{KMg}_3\text{AlSi}_3\text{O}_{11}-\text{H}_2\text{O}-\text{CO}_2$ illustrating the stability of phlogopite as a function of volatile composition at 20 kbar (the location of the section is shown in Fig. 1B). Compositions to the left of the azeotropic-like point are characterized by high $a_{\text{H}_2\text{O}}$ and divariant melting behavior. Compositions to the right of the point are characterized by low $a_{\text{H}_2\text{O}}$ and the liquid is generated by eutectic-like melting. (B). A schematic isobaric-isothermal section of the join $\text{KMg}_3\text{AlSi}_3\text{O}_{11}-\text{H}_2\text{O}-\text{CO}_2$. Compositions are in mole per cent and vapor compositions are schematic.

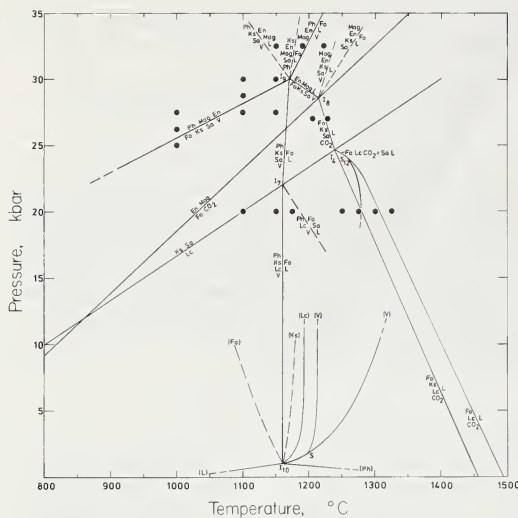


Figure 2 (left)-A P-T projection of phase relations involving Ph, En, Mag, Fo, Sa, Ks, Lc, L and V. The invariant point, I_9 , involves six components and an H_2O-CO_2 vapor; I_8 and I_7 are quinary and I_4 and I_{10} are quaternary. The data for I_{10} is from Yoder and Kushiro (1969). The reaction $Lc = Ks + Sa$ is from Lindsley (1966) and the reaction $En + Mag = Fo + CO_2$ is from Newton and Sharp (1975).

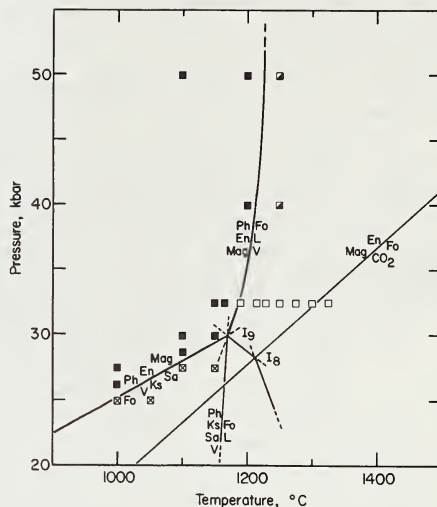


Figure 3 (right)-A preliminary P-T projection of reactions involving the assemblage Ph + En + Mag. Pyrope is observed in the products at pressures greater than 40 kbar.

REFERENCES

- Eggler, D. H., and J. R. Holloway, Partial melting of peridotite in the presence of H_2O and CO_2 : principles and review, in Chapman Conference on Partial Melting in the Upper Mantle, Oreg. Dep. Geol. Miner. Ind. Bull., in press, 1977.
- Lindsley, D. H., P-T projection for part of the system kalsilite-silica, Carn. Inst. Wash. Yb. 65, 244-247, 1966.
- Newton, R. C., and W. E. Sharp, Stability of forsterite + CO_2 and its bearing on the role of CO_2 in the mantle, Earth Planet. Sci. Lett., 26, 239-244, 1975.
- Wyllie, P. J., Mantle fluid compositions buffered by carbonates in peridotite- CO_2 - H_2O , J. Geol., 85, 187-207, 1977.
- Yoder, H. S., Jr., and I. Kushiro, Melting of a hydrous phase: Phlogopite, Am. J. Sci., Schairer Vol., 267A, 558-582, 1969.

32m calcite + Mg + Fe
 0-600s more like now Si: K₂O (poly on solidus)
 Pyrope red and 2600s & 1800s 2600s