RELATIONSHIP OF MELILITE-BEARING ROCKS TO KIMBERLITE: THE SYSTEM AKERMANITE - CO_2

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The notion that kimberlite is genetically related to melilite "basalt", attributed to H. C. Lewis (1897), was revived after olivine melilitite was discovered in close association with a kimberlite breccia (Ukhanov, 1963). Reports of melilite in kimberlite have been rare and then the identification of the mineral was dubious or based on the interpretation of alleged pseudomorphs. Both CO_2 and H_2O play an important role in kimberlite groundmass (olivine + phlogopite + calcite); however, akermanite (Ak), the principal component of melilite, was found to be stable only at water pressures below 10.2 kbar (Yoder, 1968). Because the stability field of phlogopite enlarges with CO_2, akermanite was investigated in the presence of CO_2.

Two mixtures having the composition $2CaO:MgO:2SiO_2:CO_2$ (= Ak + CO_2) and $3CaO:MgO:2SiO_2:2CO_2$ (= Merwinite + $2CO_2$) were studied up to 10 kbar total pressure at temperatures from 950° to 1475°C. The results of the first composition run in gas-media, high-pressure apparatus for times up to 1 week are presented in Fig. 1.
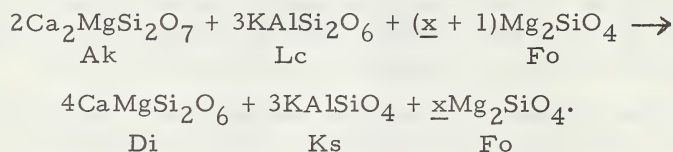
The maximum stability limit of akermanite in the presence of excess CO_2 was found to be 6.1 kbar. At relatively lower temperatures and below that pressure, akermanite reacts with CO_2 to form diopside (Di) + calcite (Ct). The reaction takes place through a range of temperatures because of possible solid solutions in dolomite in calcite, akermanite in diopside, and a variety of solid solutions in akermanite. The reaction curve, extended through the measurements of Walter (1963), terminates at its junction with the breakdown curve of akermanite → wollastonite + monticellite (Yoder, 1968) near 685°C at a pressure less than 100 bars. The appearance of diopside in the Ak + CO_2 composition is due primarily to the solution of additional components in the gas phase (G).

The melting of akermanite in the presence of CO_2 appears to be congruent and produces liquids which quench to a clear glass. The lowering of the melting curve relative to the anhydrous melting curve of Kushiro (1964) is believed to be due to the solubility of CO_2 in the liquid. The melting of Di + Ct also yields a clear, homogeneous glass without quench products. It is concluded that carbonatite is not necessarily a product of immiscibility from all ultrabasic compositions. New preliminary data on the melting of calcite cleavage blocks in the absence of excess CO_2 and the melting of diopside in the presence of CO_2 (Eggler, 1973) are given in Fig. 2.
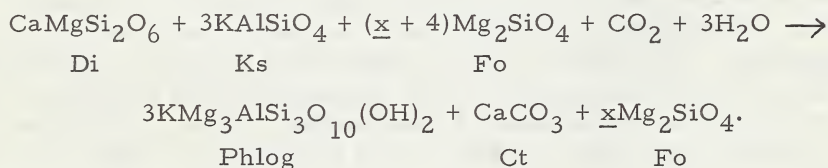
The restriction of akermanite to relatively low pressures in the presence of excess CO_2 is evident in Fig. 1. In the absence of free CO_2, the assemblage Ak + Di + Ct, related to the alnoites, is stable

and would persist until the breakdown of Ak itself at about 15 kbar. In-
clusion of the soda melilite component may extend this range to higher
pressures; however, the minerals in natural melilite-bearing rocks
were shown to react at high pressures to form pyroxenites in the ab-
sence of water and CO_2 (Tilley and Yoder, 1968). Similar behavior
would be expected in the absence of the additional phase calcite. It is
not uncommon to see veins of calcite crossing pyroxenites without the
formation of melilite. If kimberlite is derived from the mantle, then
melilite-bearing rocks are not likely sources.

Melilite is commonly associated with leucite (Lc), kalsilite (Ks),
and phlogopite (Phlog). Olivine melilite leucitite (ugandite) is probably
related to olivine kalsilite pyroxenite (mafurite) by the reaction:

$$2Ca_2MgSi_2O_7 + 3KAlSi_2O_6 + (\underline{x} + 1)Mg_2SiO_4 \longrightarrow$$
$$\text{Ak} \qquad\qquad \text{Lc} \qquad\qquad \text{Fo}$$

$$4CaMgSi_2O_6 + 3KAlSiO_4 + \underline{x}Mg_2SiO_4.$$
$$\text{Di} \qquad\qquad \text{Ks} \qquad\qquad \text{Fo}$$

Diopside + kalsilite occurs with melilite in metamorphosed sedimentary
blocks at Brome Mountain, Quebec (Philpotts, Pattison, and Fox, 1967),
and at Hendricksplaats, Bushveld (Willemse and Bensch, 1964). It is
important to note that the three phases akermanite, monticellite, and
leucite, which commonly occur together, all break down at relatively
low pressures. Addition of CO_2 and H_2O to different proportions of the
above products yields the kimberlite groundmass assemblage:

$$CaMgSi_2O_6 + 3KAlSiO_4 + (\underline{x} + 4)Mg_2SiO_4 + CO_2 + 3H_2O \longrightarrow$$
$$\text{Di} \qquad\qquad \text{Ks} \qquad\qquad \text{Fo}$$

$$3KMg_3AlSi_3O_{10}(OH)_2 + CaCO_3 + \underline{x}Mg_2SiO_4.$$
$$\text{Phlog} \qquad\qquad\qquad \text{Ct} \qquad\qquad \text{Fo}$$

It appears that there is some support for the suggestion that a magma
having melilite affinities could be transformed into kimberlite with the
aid of suitable volatiles. Loss of volatiles in transit or crystallization
at low pressure would yield a melilite-bearing assemblage within the
upper crust.

From the relations exhibited in Fig. 1 and the equations listed
immediately above, it would seem that clinopyroxene ought to be a
common residual phase in kimberlite. It is in fact a rare phase and
then may be derived in part from fragmented xenoliths incorporated in
the kimberlite. The large array of intermediate rocks that do contain
clinopyroxene, melilite, and the major phases in the groundmass of
kimberlite are usually described as alnoite.

The results presented in Fig. 1 are also of importance to the
metamorphism of carbonaceous rocks. The reaction Di + Ct $\longrightarrow$

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Ak + CO_2 is Bowen's (1940) step 8 in the metamorphism of a siliceous dolomite. Because of the exceptionally high temperatures involved where the CO_2 pressure is the total pressure, it would appear that the reaction runs in nature at very low partial pressures of CO_2.

References

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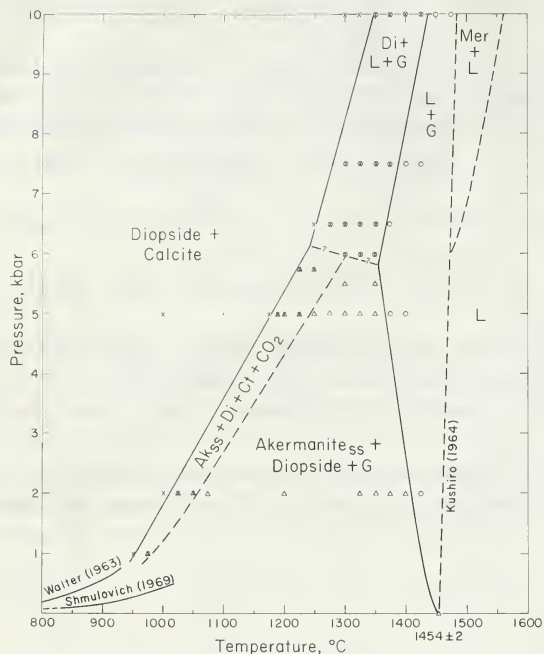Yoder, H. S. (1968) Carnegie Inst. Wash. Year Book 66, 471-477.

Fig. 1.   Pressure-temperature dia-
gram illustrating new results
for akermanite-CO_2 using
the diopside + calcite (1:1
mole) composition.   Short-
dash curves represent an
extrapolation to low pres-
sures of the melting data of
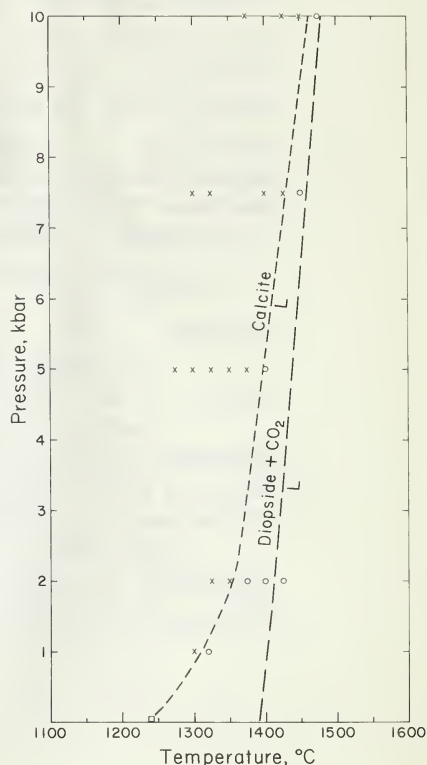Kushiro (1964) for aker-
manite.

Fig. 2.   Preliminary pressure-
temperature curve for
the melting of calcite
cleavage blocks.   In-
variant point (square)
from Baker (1962) and
1-kbar bracket from
Wyllie and Tuttle
(1960).   The melting
of calcite is compared
with that of diopside
in the presence of an
excess of CO_2(Eggler,
1973).   Calcite may
melt at slightly lower
temperatures in the
presence of excess
CO_2.

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