

### 1) Clinopyroxene Analyses

Four of the analyzed clinopyroxenes of Table 11 co-exist with orthopyroxene + liquid, one co-exists with olivine + liquid and one co-exists only with liquid. The four clinopyroxenes which co-exist with orthopyroxene are lower in CaO content and may be classified as sub-calcic augites. Within this group there is an increase in CaO content with decrease in temperature (analyses 2 and 3) and the more magnesian clinopyroxenes have higher CaO contents at similar temperatures than more iron-rich clinopyroxenes (analyses 1 and 3, Fig. 3).

These relationships are a consequence of the widening of the Opx-Cpx immiscibility gap (BOYD and SCHAIRER, 1964; DAVIS and BOYD, 1966) with decreasing temperature and the narrowing of this gap with increasing Fe-content or decreasing Mg/Mg + Fe content of the pyroxenes.

In contrast to the four clinopyroxenes described above, the pyroxene compositions in equilibrium with the alkali olivine basalt liquid at 1,320°C, 18 kb and in equilibrium with olivine + liquid at 1,220°C, 9 kb (analysis 4), lie outside the pyroxene immiscibility gap for their compositions and P-T conditions. These pyroxenes are richer in CaO than those co-existing with orthopyroxene.

The clinopyroxenes generally contain more Al<sub>2</sub>O<sub>3</sub> than the co-existing orthopyroxene although more data is needed to substantiate this. Thus clinopyroxene analyses 2 and 5 have similar or slightly greater Al<sub>2</sub>O<sub>3</sub> contents than their co-existing orthopyroxenes but clinopyroxenes 1 and 3 have much greater Al<sub>2</sub>O<sub>3</sub> contents than co-existing orthopyroxene. The 100 Mg/Mg + Fe values for the clinopyroxenes are consistently lower than co-existing olivine or orthopyroxene.

The analyzed clinopyroxenes and co-existing orthopyroxenes have been projected on to the experimentally determined phase diagram for the CaMgSi<sub>2</sub>O<sub>6</sub>-MgSiO<sub>3</sub> system at atmospheric pressure (BOYD and SCHAIRER, 1964). DAVIS (1963) and DAVIS and BOYD (1966) have demonstrated that the position of the pyroxene solvus at a given temperature is virtually unaffected by pressure. The data from the microprobe analyses demonstrate that the width of the pyroxene solvus is greatly decreased by increasing Fe content. Surprisingly, the solubility of diopside-hedenbergite in enstatite-hypersthene is less than that determined for the simple magnesian system, but the solubility of orthopyroxene in calcic clinopyroxene is much greater. The data of Fig. 3 demonstrate preliminary

Table 12. Garnet compositions determined by electron microprobe. Fe, Ca, Al determined by direct analysis, other components calculated

	Olivine basalt		
	18	18	27
Pressure (kb)	1,330	1,320	1,460
Temp. (°C)			
SiO	41.6	41.4	42.1
Al <sub>2</sub> O <sub>3</sub>	23.3	22.6	23.9
FeO	11.5	11.8	8.7
MgO	16.9	16.6	19.5
CaO	6.4	6.6	5.7
Al <sub>2</sub> O <sub>3</sub> *	23.6	23.6	24.0
100 Mg Mg + Fe (mol.)	72.3	71.5	80.0
<i>Mol. Proportions</i>			
Almandine	23.0	23.6	17.2
Pyrope	60.5	59.4	68.3
Grossular	16.5	17.0	14.5
<i>Coexisting</i>			
Crystalline Phases	Cpx	Cpx	Nil

\* Al<sub>2</sub>O<sub>3</sub> value calculated from FeO, CaO values assuming garnets are ideal almandine-pyrope-grossular solid solutions.

results in a method of obtaining a pyroxene-diagram for natural basaltic magmas at high pressures.

### m) Garnet Analyses

In the olivine basalt composition, two garnets co-existing with clinopyroxene at 18 kb and the liquidus garnet at 27 kb have been analyzed. As the oxidation state of iron cannot be determined with the microprobe the garnets are assumed to contain no andradite molecule but to consist entirely of grossular + almandine + pyrope solid solutions. With this assumption it is possible to calculate

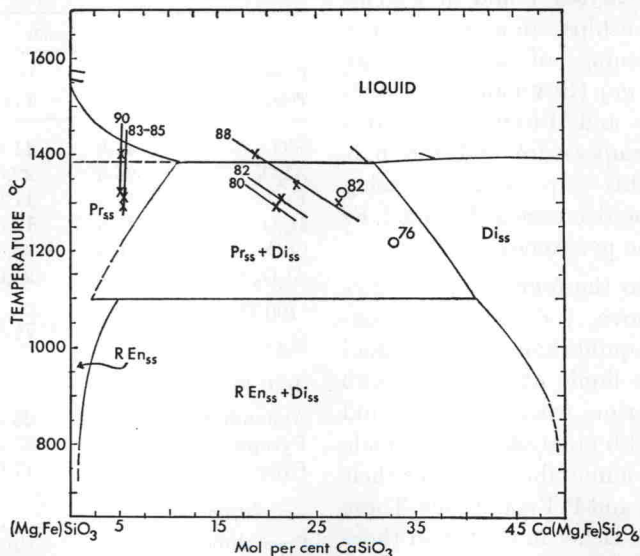


Fig. 3. Diagram illustrating the degree of solid solubility in co-existing orthopyroxene and clinopyroxene. The pyroxene solvus for pure  $\text{MgSiO}_3$ — $\text{CaMgSi}_2\text{O}_6$  is taken from BOYD and SCHAIRER (1964) and the compositions of the pyroxenes observed in the partial melting runs on basalt are projected on to this solvus.  $\times$  = two pyroxene + liquid assemblages;  $\circ$  = clinopyroxene + liquid only; 90, 88 etc. values of 100 Mg/Mg + Fe for the pyroxene — note that the clinopyroxene always has a lower 100 Mg/Mg + Fe ratio than the co-existing orthopyroxene

the whole garnet composition from the Fe and Ca determinations. The  $\text{Al}_2\text{O}_3$  contents calculated in this way compare well with the directly determined  $\text{Al}_2\text{O}_3$ .

No phases co-existing with garnet have been analyzed but the liquidus garnet at 27 kb with 100 Mg/Mg + Fe = 80 is much more iron-rich than the liquidus olivine at 9 kb (100 Mg/Mg + Fe = 89.6) or the liquidus orthopyroxene at 13.5 kb (100 Mg/Mg + Fe = 89.1) or 18 kb (100 Mg/Mg + Fe = 89.0).

### Fractional Crystallization of Basaltic Magmas

The nature of the fractionation trend and the derivative liquid compositions from any primitive basaltic magma may be determined if we know the composition of the crystalline phase or phases and the proportions of liquid and crystals.