

sub-calcic clinopyroxene at 18 kb results in a residual liquid with slightly higher hypersthene and lower anorthite content. Both compositions lie very close to the "critical plane of undersaturation" in the basalt tetrahedron (Fig. 1) and are olivine-rich basalts of the type transitional between olivine tholeiite and alkali olivine basalt. In chemistry and normative mineralogy the calculated compositions are very close to the "olivine basalt" composition chosen for detailed study and further fractionation beyond 15% crystallization can be best interpreted from the experimental results on this and the alkali olivine basalt. However it is worth noting that crystallization below 1,350°C at 13.5 kb in the olivine tholeiite involves extraction of both orthopyroxene and co-existing sub-calcic clinopyroxene. Thus the nature of the crystal extract remains rich in SiO₂ and in hypersthene molecule, and derivative liquids will move into the nepheline normative field. A similar relationship holds for the 1,380°C and 1,375°C runs at 18 kb. The disappearance of orthopyroxene in the 1,370°C 18 kb run would result in extraction of much higher CaO content in the crystalline phase and the appearance of garnet in the 1,350°C run would further divert the fractionation trend away from the direct path from hypersthene-normative to nepheline-normative olivine basalts.

In the olivine basalt composition at 13.5 kb there is a temperature interval of 10–20°C over which orthopyroxene alone separates from the liquid. Our data are insufficient to use the pyroxene compositions to estimate the degree of crystallization at 13.5 kb and instead we have calculated the derivative liquid composition assuming 10% crystallization of orthopyroxene as indicated by optical examination of polished surfaces. At 18 kb the orthopyroxene co-existing with liquid at 1,340°C has a lower 100 Mg/Mg + Fe ratio (89.0) than the orthopyroxene co-existing with clinopyroxene + liquid in the lower temperature and more extensively crystallized run at 1,335°C. This is apparently in conflict with the empirical partition relationship between liquid and orthopyroxene discussed previously. However the co-existing clinopyroxene at 1,335°C has 100 Mg/Mg + Fe = 88.2 so that the mean value of this ratio for the crystalline phase is <89.0. It is clear however that very little orthopyroxene may be extracted at 18 kb from the olivine basalt before the appearance of subcalcic clinopyroxene. In Table 17 we have calculated a residual liquid at 18 kb assuming crystallization of 5% orthopyroxene + 10% clinopyroxene as analyzed at 1,335°C, 18 kb. The residual liquids calculated for 10% crystallization at 13.5 kb and 15% crystallization at 18 kb are very closely similar. Both show decreased SiO₂ content from the original liquid and both are nepheline normative with over 2% nepheline and 24% normative olivine. In both chemistry and normative mineralogy these compositions are very close to the alkali olivine basalt composition and the experimental results on the latter composition may be used to further investigate the fractionation trend beyond 10 and 15% crystallization. The appearance of minor orthopyroxene at the liquidus of the alkali olivine basalt composition at 13.5 kb, supports the estimate of 10% orthopyroxene crystallized from the olivine basalt at 13.5 kb. These two compositions effectively demonstrate that orthopyroxene may crystallize from nepheline-normative magmas at moderate pressure and that in the chosen compositions it is the dominant role of orthopyroxene which determines the liquid fractionation trend from olivine-rich tholeiite to alkali olivine basalt.

Table 16. *Fractionation of olivine tholeiite at 13.5 kb and 18 kb*

P, T conditions (kb) (°C)	13.5 1,350	18 1,400
Nature and estimated percentage of crystals	15% Ortho- pyroxene	10% Orthopyroxene + 5% Clinopyroxene

Composition of crystal extract

SiO ₂	53.8	53.0
Al ₂ O ₃	6.0	7.3
FeO	7.2	6.3
MgO	30.2	28.6
CaO	2.8	4.8

Composition of liquid Phase

	(Initial liquid)		
SiO ₂	46.95	45.7	45.9
TiO ₂	2.02	2.4	2.4
Al ₂ O ₃	13.10	14.3	14.1
Fe ₂ O ₃	1.02	1.2	1.2
FeO	10.07	10.6	10.7
MnO	0.15	0.2	0.2
MgO	14.55	11.9	12.1
CaO	10.16	11.3	11.1
Na ₂ O	1.73	2.0	2.0
K ₂ O	0.08	0.1	0.1
P ₂ O ₅	0.21	0.2	0.2

CIPW norm of liquid Phase

Or	0.6	0.6	0.6
Ab	14.7	17.3	17.3
An	27.6	29.7	28.8
Di	17.0	20.5	20.3
Hy	12.3	0.2	2.0
Ol	21.9	24.9	24.2
Ilm	3.8	4.5	4.6
Mt	1.4	1.8	1.8
Ap	0.5	0.5	0.5
100 Mg	72.1	66.7	66.9
Mg + Fe ⁺⁺			

The residual liquids from the alkali olivine basalt, assuming 10% crystallization of orthopyroxene + clinopyroxene at 13.5 kb and 20% crystallization of clinopyroxene at 18 kb (Table 18) suggest that derivatives with higher normative nepheline contents, approaching olivine-rich basanites, may be produced. If both orthopyroxene and clinopyroxene crystallize together, the CaO content of derivative liquids remain roughly constant and the derivative liquids show increasing nepheline and diopside contents and decreasing albite and anorthite contents. Continuation of this trend appears appropriate for derivation of basanites. However, if orthopyroxene is absent, extraction of calcic clinopyroxene results in decreasing CaO content and atypical basaltic chemistry. The change in normative mineralogy is towards lower diopside content but the ratio of nepheline to albite