

Table 15. *Fractionation of alkali olivine basalt at 9 kb*

P, T conditions (kb)	9	9
(°C)	1,270	1,220
Nature and estimated percentage of crystals	Nil	5% Olivine 10% Clinopyroxene
<i>Composition of crystal extract</i>		
SiO ₂		46.0
Al ₂ O ₃		6.0
FeO		12.3
MgO		25.5
CaO		10.2
<i>Composition of liquid phase</i>		
	(Initial liquid)	
SiO ₂	45.39	45.3
TiO ₂	2.52	3.0
Al ₂ O ₃	14.69	16.2
Fe ₂ O ₃	1.87	2.2
FeO	12.42	12.4
MnO	0.18	0.2
MgO	10.37	7.7
CaO	9.14	9.0
Na ₂ O	2.62	3.1
K ₂ O	0.78	0.9
P ₂ O ₅	0.02	—
<i>CIPW norm</i>		
Or	4.5	5.5
Ab	18.0	19.0
An	26.2	27.5
Ne	2.2	3.9
Di	15.7	14.2
Ol	25.8	21.0
Ilm	4.8	5.7
Mt	2.9	3.2
100 Mg	59.8	52.5
Mg + Fe ⁺⁺		

the same parent magma may fractionate to yield high-alumina basalts of slightly different SiO₂ contents and normative olivine and hypersthene contents depending on the particular pressure in the 5–10 kb range at which fractionation occurs.

KUNO (1960, p. 125) considers that high-alumina basalts are chemically transitional between tholeiites and alkali basalts, except in Al₂O₃ content. YODER and TILLEY (1962, p. 416–417) also note that high-alumina basalts are not restricted to either the tholeiites or alkali basalt and include analyses of hawaiites within the group. Our data suggests that at 8–10 kb pressure there is no well defined thermal divide close to the Ol-Cpx-Plag plane of critical undersaturation but rather this fractionation trend runs obliquely to this “plane” and directly towards plagioclase enrichment. Thus, while a “parental” olivine tholeiite with low

normative hypersthene content may fractionate with moderate degree of crystallization to yield nepheline-normative, high- Al_2O_3 residual liquids, parental olivine tholeiites with higher normative hypersthene are unlikely to yield nepheline-normative residual liquids but would produce high- Al_2O_3 , olivine tholeiites (5–15% normative olivine).

c) Fractionation at 35–70 km Depth

The experimental partial melting runs carried out at 13.5 and 18 kb provide the data on which the following discussion is based. The liquidus phases in all compositions studied, except the picrite⁴, are pyroxenes, and orthopyroxene plays a dominant role in the early stages of fractionation within this depth interval. Clinopyroxene appears early in the fractionation sequence and, if accompanied by orthopyroxene, is a very sub-calcic variety. Both clinopyroxene and orthopyroxene are aluminous. Garnet does not appear above the solidus at 13.5 kb but appears late in the crystallization sequence at 18 kb. Spinel and plagioclase appear near the solidus at 13.5 kb but are absent at 18 kb.

The compositions of derivative liquids from the basaltic compositions can be calculated using the analyzed minerals of Tables 9, 11 provided that an estimate can be made of the proportions of crystals present. The mineral analysis data show that co-existing olivine and orthopyroxene have almost identical ratios of 100 Mg/Mg + Fe, at least for values of this ratio between 85 and 90 (Table 10). Also, where the compositions have orthopyroxene as the liquidus phase, this has a similar 100 Mg/Mg + Fe ratio to the liquidus olivine observed at lower pressure. For these reasons it is possible to use the empirical partition coefficient

$$\left(\frac{100 \text{ Mg}}{\text{Mg} + \text{Fe}}\right)_{\text{Opx}} / \left(\frac{100 \text{ Mg}}{\text{Mg} + \text{Fe}^{++}}\right)_{\text{Liquid}} = 1.33$$

to obtain an estimate of the degree of crystallization in the olivine tholeiite (cf. pages 143–144). At 13.5 kb, orthopyroxene is the only phase present on the liquidus and very uncommon clinopyroxene first appears in the 1,350° C run. The calculated proportion of orthopyroxene crystallized between the liquidus and the first appearance of clinopyroxene is 14.5%, using the composition of the orthopyroxene in the 1,350° C, 13.5 kb run in the calculations. This is in good agreement with the amount of orthopyroxene observed optically. At 18 kb, clinopyroxene is absent in the 1,425° C and 1,420° C runs but moderately common in the 1,400° C run. Assuming separation of orthopyroxene (as analyzed at 1,400° C, 18 kb) alone between the liquidus and 1,400° C the percentage of orthopyroxene crystallized may be calculated as 12.5%. This is likely to be an over-estimate as clinopyroxene probably appears at about 1,410° C.

In Table 16 we have calculated derivative liquid compositions assuming 15% crystallization of orthopyroxene alone at 13.5 kb and crystallization of 10% orthopyroxene + 5% clinopyroxene at 18 kb. The derivative liquids are very similar in chemistry and in normative mineralogy although the extraction of

⁴ Orthopyroxene occurred as the liquidus phase in the picrite at 1,325° C, 18 kb in the preliminary runs reported by GREEN and RINGWOOD, 1964. The absence of olivine presumably resulted from the access of water, possibly with some resulting oxidation, and suppression of the liquidus temperature by about 100° C.