The appearance of orthopyroxene rather than olivine as the liquidus phase at 18 kb, 1,325°C under "wet" melting conditions (Green and Ringwood, 1964) suggests the possibility that low partial pressures of water may suppress the temperature of appearance of olivine to a greater degree than orthopyroxene. This aspect of high pressure fractionation needs to be further explored experimentally.

d) Fractionation at about 70—100 km Depth

The experimental results at 22.5 kb and 27 kb are relevant to discussion of fractionation below 70 km depth. At 22.5 kb, clinopyroxene is the liquidus phase in all three basaltic compositions and also in the picrite. By analogy with the clinopyroxene in the alkali basalt at 20 kb, such clinopyroxenes are likely to contain CaO contents greater than the liquid, high Al_2O_3 content, and may also contain moderate Na_2O as jadeite solid solution. Fractionation by separation of clinopyroxene at this pressure would produce lower SiO_2 contents, lower CaO contents and lower 100 Mg/Mg + Fe ratios. Depending on the Na_2O content of the clinopyroxene, hypersthene normative liquids could possibly yield derivative nepheline-normative liquids but high degrees of crystallization would be required and resultant liquids would be atypical of basalt in having low CaO contents.

At 27 kb, garnet is the liquidus phase in the olivine basalt and alkali olivine basalt compositions and possibly garnet alone occurs on the liquidus of the olivine tholeiite at 27 kb. In all three cases, there is a relatively small drop in temperature before the appearance of clinopyroxene. The melting interval in all compositions and particularly in the picrite is quite small at 27 kb so that quite large amounts of a phase may precipitate over a small temperature interval.

We have calculated a residual liquid composition (Table 19) assuming 10% crystallization of garnet from the olivine basalt and using the composition of the garnet analyzed from the 27 kb, 1,460°C run. The effect of garnet extraction from this particular composition is to produce a nepheline-normative (0.6% Ne) liquid. This result supports the conclusions of Yoder and Tilley (1962) that the plane of critical undersaturation is not a thermal divide at 27—30 kb and, in particular, that extraction of garnet may produce liquids of alkali basalt type. However, separation of 10% garnet without the appearance of clinopyroxene is rather doubtful in the compositions studied, particularly in the olivine tholeiite where clinopyroxene possibly occurs with garnet at the liquidus. Extraction of garnet results in increased SiO_2 content and particularly in decreased Al_2O_3 content and is not as "efficient" as aluminous orthopyroxene in developing nepheline-normative residual liquids, e.g. while extraction of 10% garnet from the olivine basalt at 27 kb produces a residual liquid with 0.6% nepheline, extraction of 10% aluminous orthopyroxene at 13.5 kb produces a liquid with 2.4% normative nepheline. Extraction of garnet with its high Al_2O_3/SiO_2 ratio causes a decrease in normative anorthite and this imposes a rather severe restriction on the amount of garnet which can be extracted while retaining a basalt-like chemistry and normative mineralogy.

Calculations of the effects of extracting 10% garnet from the alkali-olivine basalt demonstrate an increase in normative nepheline content (from 2.2% to 4.0%) and decrease in normative anorthite content (from 26.2% to 21.5%). Similar

Table 19. *Fractionation of olivine basalt at 27 kb*

P, T conditions (kb) (°C)	Composition of initial liquid	27 1,460 Residual liquid after extraction of 10% garnet (1,460° C, 27 kb)
SiO_2	47.10	47.6
TiO_2	2.31	2.5
Al_2O_3	14.15	13.0
Fe_2O_3	0.42	0.5
FeO	10.64	10.9
MnO	0.16	0.2
MgO	12.71	12.0
CaO	9.86	10.3
Na_2O	2.21	2.5
K_2O	0.44	0.5
Norms		
Or	2.7	3.1
Ab	18.9	20.0
Ne		0.6
An	27.3	22.7
Di	17.6	23.0
Hy	1.3	—
Ol	27.2	25.2
Ilm	4.4	4.7
Mt	0.6	0.7
$\frac{100\,Mg}{Mg+Fe^{++}}$	68.1	66.3

extraction of 10% garnet from the olivine tholeiite decreases the normative hypersthene from 12.3% to 10.1% and normative anorthite from 27.6% to 23.3%. To obtain a nepheline normative liquid from the olivine tholeiite would require separation of more than 30% garnet without the appearance of clinopyroxene. This requirement is in direct conflict with our experimental data. Furthermore, it would produce non-basaltic residual liquids.

In the picrite composition at 27 kb, garnet, orthopyroxene and clinopyroxene all occur very close to the liquidus and the direction of fractionation cannot be estimated. Olivine is not a liquidus phase in the picrite at 27 kb suggesting that this composition is not appropriate as a "minimum melting liquid" derived by partial melting of mantle peridotite. We would anticipate that such a liquid would have olivine, with orthopyroxene or possibly clinopyroxene, as liquidus phases — these being the major phases of the residual peridotite with which the liquid would be in equilibrium.

We conclude that separation of garnet or a garnet-rich mixture of garnet + clinopyroxene may produce nepheline normative liquids from compositions rich in olivine but poor in hypersthene. Such fractionation, if significant, must be restricted in basaltic rocks as extraction of garnet with its high-Al_2O_3 content leads to residual liquids inconsistent with basaltic chemistry. If this process is significant in producing liquids (at 27 kb or similar pressures) which are parental to the low pressure divergent alkali olivine basalt and olivine tholeiite sequences, then