relationship towards clinopyroxene. In discussion of the experimental results it was noted that there was a decrease in intensity of olivine as clinopyroxene became more abundant in the assemblages. However, olivine does not entirely disappear in any of the compositions, and microprobe analyses show that, in the olivine tholeiite at least, the olivine continues to become more Fe-rich even after crystallization of clinopyroxene commences. Our data therefore suggest that olivine partially reacts with liquid to precipitate aluminous, calcic clinopyroxene. This implies that it is possible to derive residual liquid compositions from these olivine-rich compositions which do not have olivine on the liquidus at 9 kb, but instead have clinopyroxene or clinopyroxene + orthopyroxene as liquidus phases. Furthermore, these derivative liquids, if crystallized at atmospheric pressure would have either olivine or plagioclase, or both, as liquidus phases. These aspects of basalt fractionation are being intensively studied by T. H. Green (Department of Geophysics and Geochemistry, Australian National University) and his results provide a much more complete documentation of the relationships than our present data.

The compositions of residual liquids can be calculated using the analyzed minerals of Tables 8, 9 provided that an estimate can be made of the proportions of crystals present. This can be done approximately by visual methods and the use of polished surfaces offers the possibility of modal analyses either on the specimen itself or on photographic reproductions of the surface. In the present paper we have used the known compositions of olivines and orthopyroxenes crystallized at various temperatures to estimate the proportions of crystals present. In a previous section we have discussed the empirical relationship between the molecular ratio 100 $Mg/Mg + Fe^{++}$ of a basaltic liquid and the same ratio of its liquidus olivine.

An empirical partition coefficient $K_{O,L}$ has been defined as

$$\left(\frac{100\,Mg}{Mg + Fe}\right)_{Olivine} \Big/ \left(\frac{100\,Mg}{Mg + Fe^{++}}\right)_{Liquid} = K_{O,L}$$

and for $(100\,Mg/Mg + Fe)_{Olivine}$ between 83 and 92, $K_{O,L}$ has a mean value of 1.33 at 9 kb. $K_{O,L}$ increases slightly with decreasing values of $(100\,Mg/Mg + Fe)_{Olivine}$ but as a first approximation the mean value of 1.33 is used in the following calculations (Table 3).

At 9 kb, the liquidus olivine of the olivine tholeiite at a temperature of about 1,360° C has $100\,Mg/Mg + Fe = 92$. At a lower temperature, e.g. 1,310° C, the olivine is more abundant and has $(100\,Mg/Mg + Fe)_{Olivine} = 89.4$. Olivine of this composition is the liquidus phase of the glass present in the run, and assuming the empirical relationship that $K_{O,L} = 1.33$ the liquid at this temperature has $(100\,Mg/Mg + Fe^{++})_{Liquid} = 89.4/1.33 = 67.2$. The first appearance of orthopyroxene in the olivine tholeiite is at 1,290° C, 9 kb and in a similar way the residual liquid at this temperature may be calculated to have the value $(100Mg/ + Fe^{++}) = 65.6$. The ratio [MgO]/[FeO] where [MgO] and [FeO] are expressed in weight percent can then be calculated for the residual liquid

$$\frac{[MgO]}{[FeO]}_{Liquid} = 1.07.$$

Since orthopyroxene is extremely rare in the 1,290° C run the residual liquid must be derived from the original composition by extraction of olivine alone. The olivine at 1,290° C 9 kb contains 12.3% FeO and 47.1% MgO and if the percentage of olivine crystals present is m% then

$$\frac{[\mathrm{MgO}]}{[\mathrm{FeO}]}_{\mathrm{Liquid}} = \frac{14.55 - \frac{\mathrm{m}}{100} \times 47.1}{10.07 - \frac{\mathrm{m}}{100} \times 12.3} = 1.07.$$

i.e. m = 11.1%.

The composition of the liquid phase, assuming 11% crystallization of olivine as analyzed at 1,290° C, 9 kb, is given in Table 14.

Between 1,290° C and about 1,260° C the olivine tholeiite composition consists of olivine, orthopyroxene and liquid. The first appearance of clinopyroxene was at 1,250° C. Both olivine and orthopyroxene have been analyzed from this run and have $(100\ \mathrm{Mg/Mg+Fe})_{\mathrm{Opx}} = 84.9$ and $(100\ \mathrm{Mg/Mg+Fe})_{\mathrm{Ol}} = 85.3$ respectively. The residual liquid has a calculated $100\ \mathrm{Mg/Mg+Fe^{++}})_{\mathrm{Liquid}} = 64$ but to calculate the degree of crystallization, the relative proportions of olivine and orthopyroxene crystallizing between 1,290° C and 1,250° C must be estimated. If this crystal extract consists of 25% olivine and 75% orthopyroxene then its composition is

SiO_2	49.66%
Al_2O_3	5.23%
FeO	10.38%
MgO	32.83%
CaO	2.10%

and, using the liquid composition determined at 1,290° C, the percentage of olivine + orthopyroxene crystals precipitating between 1,290° C and 1,250° C may be calculated as 3.4%, i.e.

0.9% Olivine
2.5% Orthopyroxene.

This method of estimation of degree of crystallization is potentially very useful, particularly as more data on liquid and liquidus phase partition coefficients become available. Using the estimates of degrees of crystallization obtained in this way as a guide, Table 14 contains the calculated compositions of the liquid phase in the olivine tholeiite at about 1,290° C assuming 11% crystallization of olivine, and about 1,250° C assuming 12% crystallization of olivine and 3% crystallization of orthopyroxene.

The appearance of clinopyroxene at 1,250° C appears to coincide with a relatively rapid increase in the proportion of crystals present. Although no analysis of the clinopyroxene was possible, its composition may well be similar to the clinopyroxenes which co-exist with orthopyroxene at 1,290° C, 13.5 kb and 1,310° C, 13.5 kb in the alkali basalt and olivine tholeiite composition. The clinopyroxene at 9 kb, 1,230° C would probably contain a lower Al_2O_3 content but similar CaO content and similar 100 Mg/Mg + Fe ratio to that from the alkali olivine basalt at 1,290° C, 13.5 kb. In Table 14 an approximate residual liquid composition assuming 30% crystallization (12% olivine, 4% orthopyroxene, 14% clinopyroxene) has been calculated for the olivine tholeiite at 9 kb and about 1,230° C.