degrees of crystallization are required to produce small changes in silica content and in degree of undersaturation. Such fractionation is accompanied by depletion in calcium and enrichment in iron relative to magnesium. These effects are inconsistent with characteristics on natural magmas of mantle derivation which show increasing Ca-contents with increasing degree of undersaturation and demonstrate similar or higher $\frac{Mg}{Mg+Fe^{++}}$ values for the very undersaturated magma types, relative to olivine tholeiites. Separation of garnet and clinopyroxene under upper mantle conditions undoubtedly occurs in specific cases (xenoliths of garnet clinopyroxenite in the Delegate or Salt Lake Crater tuffs are in part probably examples of such accumulates) but it is concluded that it is not the process responsible for the natural magma series from olivine-rich tholeiite to olivine nephelinite and olivine melilitite.

Experiments on the effect of water on the liquidus phases of the basanite and nephelinite compositions of table 1 (Bultitude and Green 1968, Green 1969a, b) show that whereas olivine and clinopyroxene or clinopyroxene alone may be the liquidus phases under dry conditions (liquidus 1,400 - 1,450° C, 20 - 30 kb), if the liquidus is depressed to 1,200 - 1,300° C by the addition of 2 - 5% water, then olivine and orthopyroxene, or olivine, orthopyroxene and clinopyroxene may occur at or near the liquidus. This effect has been substantiated for the olivine-rich basanite composition and an alkali olivine basalt composition with experiments using sealed capsules and known quantities of water (Green 1969a, b, Green and Hibberson 1969). It should be noted that the near-liquidus clinopyroxene under dry conditions at 1,400 - 1,450° C is rather sub-calcic, and with the rapid widening of the pyroxene miscibility gap at lower temperature, such a composition would be represented by ortho-pyroxene and clinopyroxene. Thus depression of the liquidus by the addition of water may bring in orthopyroxene as a liquidus phase, not as a consequence of any major compositional shift of the cotectic between olivine and orthopyroxene (cf. Kushiro 1969), but as a direct consequence of the sensitive temperature dependence of the pyroxene solid solutions.

The important near-liquidus role of orthopyroxene in water-bearing basanitic and nephelinitic magmas at high pressure may permit fractionation of magmas through olivine-rich basanites to olivine nephelinites at 20 - 25 kb and through picritic basanites and picritic nephelinites to olivine melilite nephelinites at $\sim$ 27 kb.

5. APPLICATION OF BASALT CRYSTALLIZATION STUDIES TO PARTIAL MELTING

If we consider an olivine tholeiite magma then the experimental studies (Green and Ringwood 1967b) have shown that by separation of approximately 15% crystals at 13 - 18 kb we may produce an olivine basalt magma type. The crystal extract would be dominantly orthopyroxene with very minor olivine. Further crystallization ($\sim$15%) of orthopyroxene, now joined by sub-calcic clinopyroxene and possibly still accompanied by very minor olivine, will produce a liquid of alkali olivine basalt type. If crystals have remained in contact with the liquid, then we have a chemical system in which an alkali olivine basalt liquid is in equilibrium with minor olivine, minor sub-calcic clinopyroxene and major orthopyroxene. The proportion of crystals to liquid is approximately 30:70 but it will not

affect the composition of either liquid or crystals nor the equilibrium between them if we grossly change the proportions of the crystals adding a very large amount of olivine, a little more orthopyroxene but no more clinopyroxene so that the proportion of crystals to liquid becomes approximately 80:20. We are now considering a total composition which is peridotitic, and have a model of partial melting or batch melting of that total composition. By increasing the temperature on the peridotitic bulk composition we can envisage all the clinopyroxene, major orthopyroxene and minor olivine entering the melt and changing the melt composition back through olivine basalt to reach olivine tholeiite at a stage of about 30% melting.

This discussion illustrates the way in which the experimental studies on basalt crystallization can be applied to a model of partial melting. This reasoning can *only* be applied if the observed liquidus phases of the series of basaltic liquids are the same as the observed phases in the postulated source composition at the same P and T. This particularly applies to $\dfrac{Mg}{Mg+Fe}$ ratio — a basalt with olivine of Fo_{80} as the liquidus phase could not be in equilibrium with a peridotite having olivine Fo_{90} under any conditions. In this example a prediction that a basalt with similar normative mineralogy but suitably higher $\dfrac{Mg}{Mg+Fe}$ ratio would have olivine of Fo_{90} as liquidus phase at the same pressure, is probably valid. The situation is more complex with the pyroxenes, however, for the extent of mutual solid solution of calcium-rich and calcium-poor pyroxenes is very dependent on both temperature and $\dfrac{Mg}{Mg+Fe}$ ratio. Thus if a particular basalt had a clinopyroxene of $\dfrac{100\ Mg}{Mg+Fe}=80$ as the liquidus phase at a particular pressure it is difficult to predict whether a more magnesian basalt of the same normative mineralogy will have orthopyroxene or clinopyroxene or even olivine as the liquidus phase at the same pressure, since the pyroxene solid solution limits will be considerably different (less extensive) for the more magnesian pyroxenes. This discussion illustrates the caution that is necessary when attempting to extrapolate from simple iron-free systems to natural basalts, and emphasizes the limitations of projections in which Mg and Fe are equated and on which basalts, peridotites, and mineral compositions of very different $\dfrac{Mg}{Mg+Fe}$ ratio are plotted with attempts to derive generalized liquidus phase fields and cotectics (e.g. O'Hara 1968). Such techniques may have illustrative value if applied to closely coherent groups of compositions, but remain qualitative and invalid for deductive purposes unless augmented by treatment of the total chemical composition.

(a) *Pyrolite as a source rock for the experimentally studied basalts*   In the discussion of basalt crystallization and fractionation it was suggested that by about 30% crystallization of olivine tholeiite at 13 - 18 kb, derivative alkali olivine basalt magmas could be obtained. The accumulate would be dominated by aluminous orthopyroxene, with minor sub-calcic clinopyroxene and minor olivine. Referring to the detail of the analyzed basalts (Green and Ringwood 1967b), the olivine tholeiite and olivine basalt compositions (table 1) had liquidus olivine and orthopyroxene with