

tholeiite containing ~18% normative olivine (Macdonald and Katsura 1961) or 17% normative olivine (Murata and Richter 1966). Green and Ringwood (1967b) used an olivine tholeiite composition modelled closely on Macdonald and Katsura's estimate as a reasonable inferred composition for an olivine tholeiite magma derived from the upper mantle with little or no low pressure fractionation.

(c) *Crystal fractionation—olivine tholeiite to alkali olivine basalt* The compositions and CIPW norms of some of the basalt types which have been studied experimentally are listed in Table 1. The experimental results for olivine tholeiite (fig. 4) show olivine as the liquidus phase at low pressure, orthopyroxene at intermediate pressure, clinopyroxene at about 20 kb, and garnet at 27 kb. Electron probe analyses of the near-liquidus crystals and estimation of the percentage crystallization allow calculation of the derivative liquid compositions. In this way it has been shown that, at atmospheric pressure, parental olivine tholeiite will yield derivative quartz tholeiite liquids, at about 9 kb derivative liquids will be characteristically high-alumina olivine tholeiites, and at 13-18 kb derivative liquids will move rapidly into the nepheline-normative field. The validity of the major role of orthopyroxene in defining the trend from parental olivine tholeiite to derivative alkali olivine basalt was confirmed by experiments on an olivine basalt, an alkali olivine basalt, and on a picrite composition, the latter being saturated in olivine to higher pressures than the other three compositions but having orthopyroxene as the second phase to crystallize at 13-18 kb. It is emphasised that the calculation of crystal fractionation trends must be carried out on all oxide components of the basalt—plots of oxide trends, or projections into 'simple component planes' can be extremely misleading and should be used only for illustrative and not deductive purposes. In fig. 5, the molecular norms of the experimental compositions and of their calculated derivatives (Green and Ringwood 1967b) have been plotted as they would appear on a plane approximately parallel to the base of the 'basalt tetrahedron' (Qz-Ol-Cpx-Ne) of Yoder and Tilley (1962). The calculated fractionation trends are shown as solid lines—these show the possible fractionation behaviour of a magma batch of the chosen composition if cooled at the pressures indicated. Thus at 13.5 kb the olivine tholeiite (OT₁) crystallizes orthopyroxene alone near the liquidus and fractionation produces the trend illustrated. At the same pressure, a second olivine tholeiite (OT₂), prepared by adding 5% more olivine (FO₉₀) to the initial olivine tholeiite, crystallizes olivine alone (see fig. 4). However, at 13.5 kb it obviously cannot fractionate by olivine separation *through* the point OT₁. Thus before the liquid crystallizes 5% olivine, orthopyroxene appears and dominates the further crystal extract giving the trend shown as a dashed curve for 13.5 kb. A similar relationship is apparent between the picrite (PB) and olivine basalt (OB) at 13-18 kb. These compositions and their crystallization paths illustrate clearly that although olivine must appear (at appropriate P, T) with orthopyroxene as a liquidus phase for any liquid derived by partial melting of a pyrolite source rock, the olivine is a minor phase in the crystal accumulate formed if the magma separates and begins to crystallize at depths equivalent to 12-18 kb. The type of crystal accumulate formed would be an olivine orthopyroxenite. When clinopyroxene joins the precipitating phases, any olivine not removed from contact with the liquid may react with liquid. A reaction (olivine + liquid₁ → clinopyroxene + liquid₂) has been observed

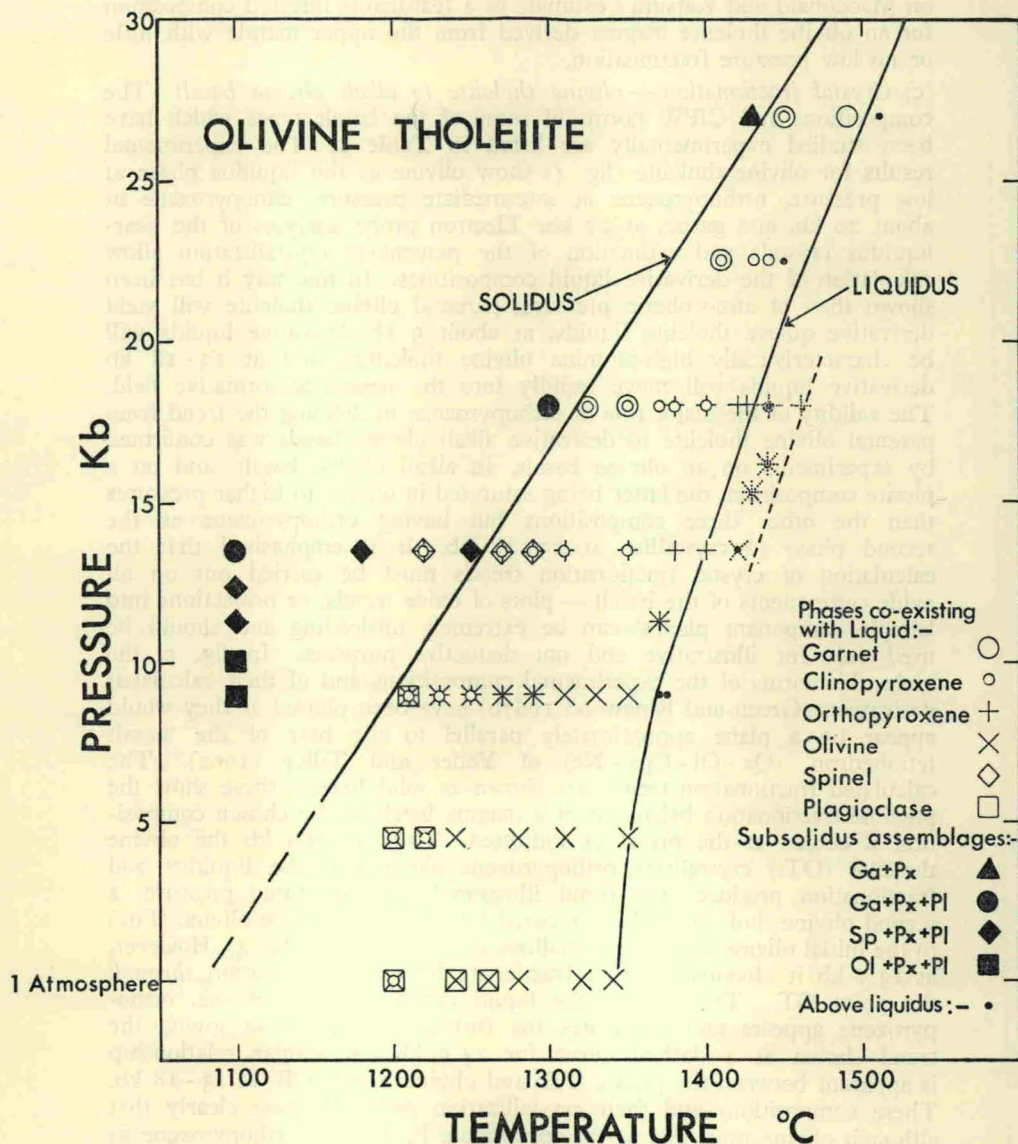


FIG. 4 (Green 1969b). Experimental crystallization of olivine tholeiite (Table 1) at various pressures. Data (dotted symbols) for an olivine-enriched tholeiite was prepared by addition of 5% olivine (Fo₉₀) to the olivine tholeiite of Table 1.