

problem of representative sampling and inhomogeneity. The partially residual or depleted character of many samples, relative to a potential basalt source composition, has already been demonstrated. These factors illustrate the difficulty of natural mantle-sampling processes in determining the mean upper mantle composition.

3. THE PYROLITE MODEL FOR THE UPPER MANTLE

If basaltic magmas are liquids derived from the upper mantle as products of partial melting then it would be possible to estimate the source-rock composition if the compositions of liquid and residue and their relative proportions were known. This is the rationale of the 'pyrolite' model for the mean upper mantle composition and it is emphasized that this approach is a general one (Ringwood 1962). Green and Ringwood (1963) calculated a specific pyrolite composition by combining an average basalt composition (Nockolds 1954) and very refractory dunite in the proportions 1:3. The proportion 1:3 was chosen to yield Al_2O_3 and CaO contents similar to those of the natural mantle-derived peridotites of the previous section and also similar to an estimated upper mantle composition based on the chondritic earth model. Later experimental work on basaltic compositions permitted more restrictive limitations on the nature of liquids and residues in basalt genesis. Ringwood (1966a) calculated a second pyrolite composition using Hawaiian olivine tholeiite as the liquid and harzburgite (olivine 80%, enstatite 19%, chromite 1%) as the residue. These were combined in the 1:3 ratio to give the composition, shown in column 9 of table 1, which has orthopyroxene : olivine and pyroxene : Al_2O_3 ratios much closer to those of the mantle-derived peridotites. With the models of liquid compositions, nature of residues, and proportions of liquid : residue (which are developed later in this lecture) one could calculate many such 'pyrolite' compositions, and if the concept of a mean upper mantle composition (acting as the source for a variety of magma types) has any validity then these calculated compositions should be very similar. Also as more extensive studies of mantle-derived peridotites become available, these may provide closer constraints by indicating trends of increasingly residual character from 'pyrolite'. At the present time the pyrolite composition of Ringwood (1966a) appears adequate in deriving internally-consistent models of mantle composition and basalt genesis, at least to the level of precision currently possible.

The stability relations of various mineral assemblages for the pyrolite composition have been experimentally determined (fig. 1) (Green and Ringwood 1967a, 1969; Green and Hibberson 1970). The boundary for the disappearance of spinel at high temperature to yield the olivine + aluminous pyroxenes assemblage and the boundary for appearance of garnet from the latter assemblage are sensitive to bulk composition, particularly the pyroxene : R_2O_3 proportions. In the pyrolite composition of Green and Ringwood (1963), spinel persists to the solidus and there is no distinct inflexion in the boundary for the appearance of garnet from the olivine + aluminous pyroxenes + spinel assemblage. In considering partial melting of the pyrolite composition (Ringwood 1966a) under dry conditions, the first liquids will be in equilibrium with olivine + pyroxenes + plagioclase at low pressures, olivine + aluminous pyroxenes at intermediate pressures and olivine + aluminous pyroxenes + garnet at high pressures. With increasing degree of melting, the minerals in equilibrium with the

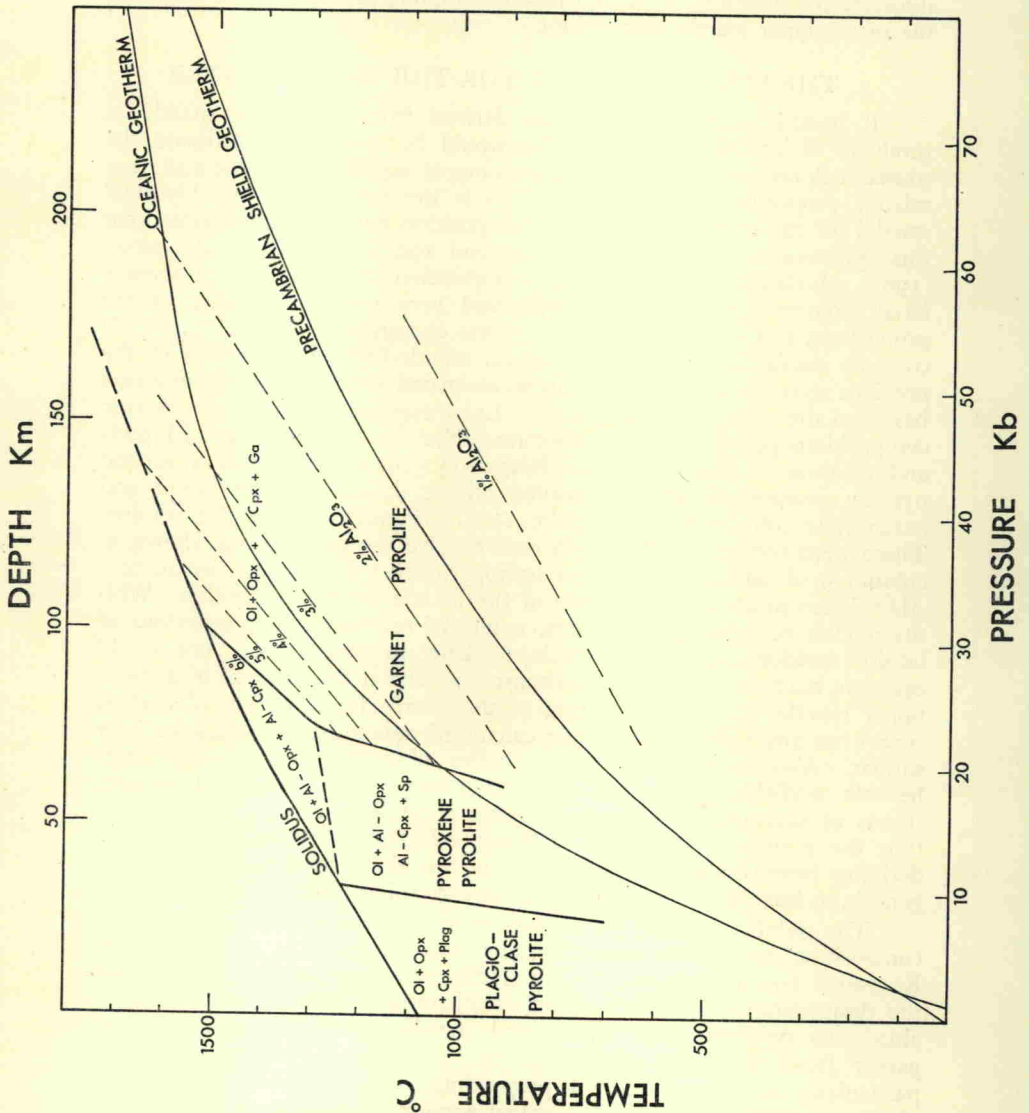


FIG. 1 (Green and Ringwood 1967a). Diagram illustrating the P, T, fields of different mineral assemblages in pyroxene composition under anhydrous conditions. The figures 1% Al₂O₃, 2% Al₂O₃, 3%, 4% etc. refer to the Al₂O₃ content of orthopyroxene in equilibrium with garnet, clinopyroxene and olivine in the garnet pyroxene field. Positions of two estimated geothermal gradients are also shown.