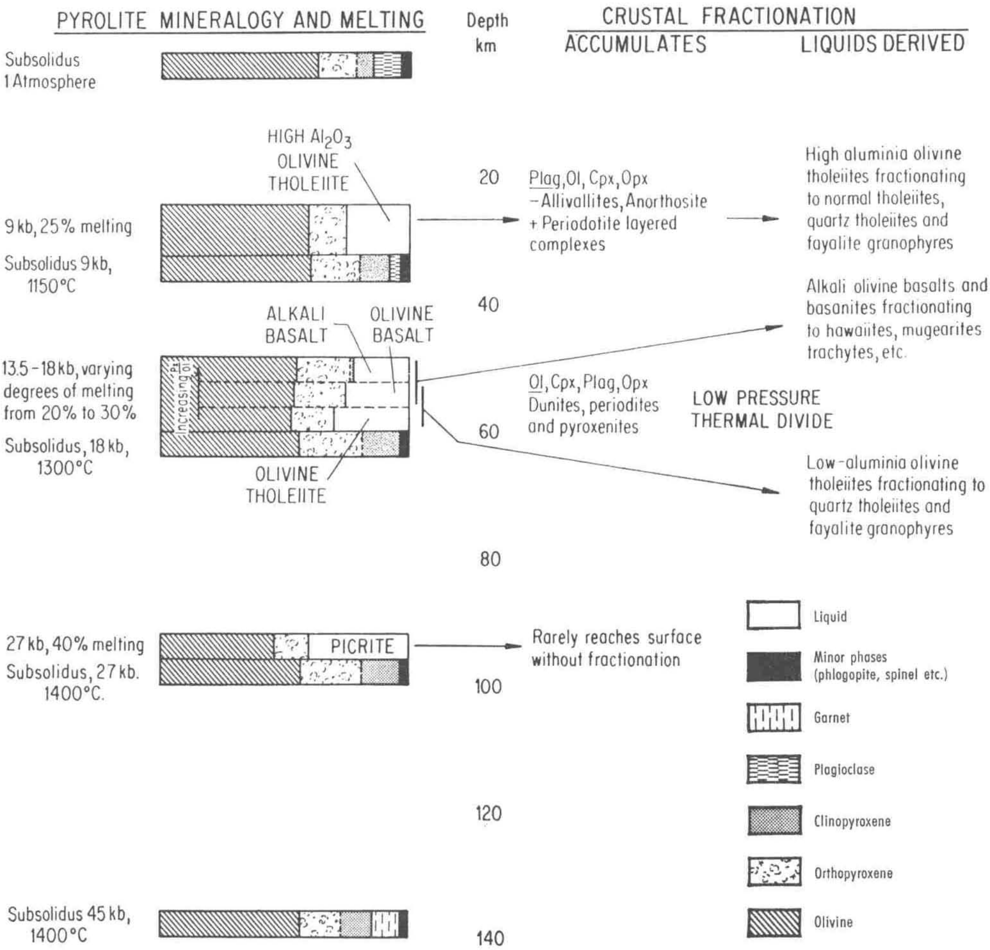

Fig. 13. Diagram illustrating the variation in the near-solidus mineralogy of pyrolite, the degree of partial melting and nature of both the liquid and the refractory residuum at various depths within the mantle

e) Depth of Magma Segregation 15—35 km

Results of experimental crystallization of the olivine tholeiite are given in Table 14. At 1,250° C, the separation of about 12 percent of olivine (Fo_{91-86}) and 3 percent of orthopyroxene (En_{87}, $Al_2O_3 = 5\%$) produced a residual liquid similar to high-alumina olivine tholeiite. Since the liquid is saturated with these phases under the stated conditions, it would be possible to increase these proportions to any desired amount without affecting liquid composition, e.g. 60 percent of olivine and 15 percent of enstatite (5% Al_2O_3) could be added, giving a bulk composition essentially identical to pyrolite. It follows that fractional melting of 20—25% of pyrolite followed by magma segregation under these P, T conditions would yield a high alumina olivine tholeiitic liquid.

This liquid might thus be erupted directly to the surface after segregation or it might undergo crystal fractionation at a slightly higher level under closed system conditions leading to even greater enrichment in Al_2O_3 due to separation of olivine and pyroxenes as previously discussed.

f) Depth of Magma Segregation 35—70 km

The compositions of liquidus orthopyroxenes from the olivine tholeiite and olivine basalt are close to the compositions of natural orthopyroxenes of the olivine + aluminous orthopyroxenes + spinel mineral assemblage in peridotites. Previously Green and Ringwood (1964) have noted that near-liquidus olivine and orthopyroxene from the picrite composition at 13.5 kb closely match the compositions of olivine and orthopyroxene from the olivine + aluminous pyroxenes + spinel assemblage of lherzolite nodules. Olivine was not observed during the crystallization of olivine tholeiite or of the olivine basalt at 12—20 kb. However it was present on the liquidus of the picrite composition. It follows from a consideration of these three compositions that the olivine tholeiite and olivine basalt are almost saturated with olivine between 12—20 kb. We have already noted that they are saturated with highly aluminous orthopyroxene. Accordingly, a fairly large degree of fractional melting of pyrolite under these conditions would yield an olivine tholeiite magma closely resembling our chosen composition, but containing slightly more normative olivine. Such an olivine tholeiite would be in equilibrium with a refractory assemblage of olivine + aluminous orthopyroxene possessing Fe/Mg ratios identical to natural peridotite nodules.

The crystallization experiments upon picrite, olivine tholeiite and olivine basalt at 12—20 kb showed that these magmas would fractionate by means of the crystallization of substantial amounts of aluminous orthopyroxene ± aluminous clinopyroxene to the composition of alkali-olivine basalts. Thus we see that an alkali olivine basalt (with a slightly higher content of normative olivine than the one which we investigated), can be in equilibrium with olivine + aluminous enstatite ± aluminous clinopyroxene. This assemblage would be identical on cooling at pressure to the assemblage found in many lherzolite nodules which are commonly found in alkali olivine basalts and basanites (pages 181—185). These relationships show that olivine-rich alkali basalt may be formed by direct fractional melting of pyrolite.

Whether an olivine tholeiite or an alkali olivine basalt is formed by melting and magma segregation under these conditions depends simply upon the extent of partial melting. With a relatively small degree ($\sim$20%) of partial melting of pyrolite, the residual crystals consist of olivine, abundant aluminous enstatite ± aluminous clinopyroxene, and the liquid has the composition of an olivine-rich alkali basalt. However, as the temperature is increased, the extent of partial melting increases, the clinopyroxene and then a large amount of aluminous orthopyroxene enter the liquid, changing its composition to an olivine tholeiite at about 30 percent partial melting. The situation is exactly the reverse of fractional crystallization of the olivine tholeiite.

The series of liquids developed by different degrees of partial melting at 35 to 70 km would be lower in SiO_2 content and in Al_2O_3 content than the series of liquids developed at 9 kb (30 km approx.) with similar degrees of melting of