PETROLOGY OF ULTRAMAFIC XENOLITH SUITE FROM TAHITI AND REACTIONS WITH ENCLOSING BASALT

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Introduction:

Boulders of alkali olivine basalt in the Faataua valley, near Papeete, Tahiti, contain numerous xenoliths of ultramafic rock up to 10 cm in diameter. The basalt may be either a flow or hypabyssal dike or sill; in any case, it is not vesicular. The basalt is notable for its low silica and high magnesia contents (Table 1) and is interpreted to represent a primitive mantle-derived magma. Magnesian olivine phenocrysts (up to Fo 88) are nearly as magnesian as olivine in xenoliths. For a discussion of basalt petrology and mineral chemistry, see Tracy and Robinson (1977).

Petrology of Xenoliths:

Xenoliths include coarse and fine-grained spinel lherzolites, wehrlite, and dunite; no garnetiferous xenoliths have yet been found. Lherzolites are dominantly olivine (~60 modal percent) and orthopyroxene (~30 modal percent) with minor clinopyroxene and spinel. Olivines in all rock types have a limited compositional range (Fo 89 - Fo 91). Lherzolite opx is variable mainly in Al₂O₃ content, different xenoliths ranging from 3 to 6 wt.%, while CaO and Mg/Mg+Fe (.88 - .90) are relatively constant. Lherzolite cpx contains considerable Al₂O₃ (4 - 7 wt.%), Na₂O (up to 1.5 wt.%) and Cr₂O₃ (up to 1.6 wt.%). Spinels in lherzolite xenoliths show considerable variation in Cr/Al ratio (0.02 to 0.45), while spinels in wehrlite or dunite are richer in Cr. All minerals in xenoliths are homogeneous except at the periphery of the nodules where reaction with basalt has occurred. Opx, cpx and spinel within each xenolith appear to have equilibrated in terms of Cr/Al ratio (Fig. 1). Compositions of coexisting pyroxenes in lherzolites, as well as cpx in wehrlites, are shown in Figure 2, a portion of the pyroxene quadrilateral. Geothermometry of spinel lherzolites yields the following estimates: 1050 - 1100°C (Di-En solvus of Davis and Boyd, 1966, corrected by Boyd); 1100-1150°C (using Al(VI) and Ti(VI)-corrected compositions applied to corrected Di-limb of Mysen, 1976); 1150-1200°C (using the 20 Kbar Di-En solvus of Lindsley and Dixon, 1976); 1100-1200°C (using various calibrations of Al content of opx coexisting with olivine + spinel). Pressure estimates are quite crude, but suggest a maximum pressure of about 20 Kbar, based upon the absence of garnet even in xenoliths with low Cr/Al ratio.

Reaction between Xenoliths and Basalt:

The most spectacular effect is seen where opx comes in contact with basalt at the periphery of a nodule. The outermost 200-400 microns of opx has been converted to a symplectite of silica-rich glass + olivine + high-Ca cpx which can be interpreted as representing incongruent melting of opx. The outer edge of this symplectite commonly grades into a coarse "cockscomb" overgrowth of titanaugite growing into basalt. The glass in the symplectite is typically very low in CaO, MgO, FeO and TiO₂ and rich but strongly zoned in SiO₂, Al₂O₃ and alkalies; representative analyses of inner and outer portions of this glass are given in Table 2. Composition trends in the glass suggest that its initial composition has been altered through element diffusion and exchange with a *residual basaltic liquid* (Table 1) rather than with a liquid close to the bulk composition of the basalt.

Normally homogeneous xenolithic olivine and spinel become zoned at xenolith edges. Olivine crystals have overgrowths of more iron-rich olivine while spinels are zoned toward Fe and Tiricher compositions typical of basalt groundmass titanomagnetite. The zoning paths in xenolith spinels (Fig. 3) suggest that they first reacted toward intermediate Cr-Ti-Al spinel compositions which probably represented the compositions of spinel in equilibrium with partially crystallized basaltic magma. The composition trend of spinel crystallizing from the magma through most of its history has been determined by analyzing small euhedral spinel inclusions in olivine phenocrysts which apparently record virtually the entire range of equilibrium spinel compositions from liquidus to near-solidus conditions. The zoning trends of different xenolith spinels seem to be different (Fig. 3), possibly indicating relative times of xenolith incorporation into the magma.

The above data seem to be consistent with two explanations: 1) That the xenoliths represent upper mantle material which was captured by an already partially crystallized magma from deeper within the mantle, and immediately began to react with the residual liquid; 2) That the xenoliths resided in the magma for some time without reaction, and only reacted near the surface when the magma itself had begun to crystallize substantially. The second explanation is supported by the symplectite data, since incongruent melting of opx is restricted to pressures of less than about 5 Kbar in a dry system. On the other hand, it is hard to understand why the xenoliths of country rock should not begin to react immediately upon being engulfed by the basaltic magma. In answer to this, the primitive nature of the magma and the abundance of xenoliths may be taken as evidence that the magma ascended very rapidly toward the surface; the xenoliths may thus have been carried upward into the crust rapidly enough to have escaped reaction until very near the surface. The strongest argument in support of explanation (1), above, is the diversity of zoning trends in xenolith spinels. This diversity suggests that the time of xenolith incorporation, relative to the crystallization history of the basalt, is imprinted indelibly upon each xenolith. It is possible, however, that this zoning may record times when nodules break apart, exposing fresh surfaces to the magma. In any case, it is apparent that an understanding of these reaction features is essential for any interpretation of where the xenoliths came from and how they were carried to the earth's surface.

