COMPARISON OF ULTRAMAFIC AND MAFIC XENOLITHS FROM KILBOURNE HOLE AND POTRILLO MAAR, NEW MEXICO

James L. Carter (University of Texas at Dallas, P. O. Box 688, Richardson, Texas 75080)

A detailed mineralogical and chemical investigation of coexisting phases of ultramafic and mafic xenoliths from Kilbourne Hole and Potrillo Maar, New Mexico reveal major differences in the upper mantle and deep crust between these two localities which are only 15 kilometers apart. This is exemplified by Figure 1 which shows the relationship of nickel in olivines versus the fayalite content of olivines from various xenoliths from Kilbourne Hole and Potrillo. A preliminary investigation of the base surge deposits at Potrillo reveal at least seven major eruptive events (Figure 2) from probably three different vents within the main maar. Three of these major eruptive events are xenolith-bearing (Figure 2). Each event is characterized by a different xenolithic assemblage. The lowest xenolith-bearing assemblage consists primarily of basalt, small 4-phase (olivine, orthopyroxene, clinopyroxene and spinel) peridotites, and very rare 3-phase (clinopyroxene, spinel and olivine) pyroxenites. The middle xenolith-bearing assemblage consists of various types of volcanics in addition to rock types similar to the lowest assemblage. In addition, the average xenolith size of the peridotites has increased by at least a factor of two. The largest xenolith found was 40 centimeters in longest dimension. The upper xenolith-bearing assemblage is characterized by the presence of various types of greenschist facies metamorphic rocks and composite ultramafic-mafic xenoliths. Multiple xenolith-bearing eruptive events appear to have occurred also at the Kilbourne Hole maar but subsequent slumping, weathering, erosion and drifting sand has partially obscured the original relationships.

The composite xenoliths which are characteristic of the last xenolith-bearing eruptive event at Potrillo are less common at Kilbourne Hole. Detailed optical examination of these xenoliths reveal that they consist of 4-phase type mantle materials with metamorphic textures that were brecciated and the open cracks permeated by a liquid which partially reacted with the 4-phase assemblage, especially the pyroxenes. The resulting liquid crystallized to an average mixture of clinopyroxene (85 vol. %), spinel (10 vol. %) and olivine (5 vol. %).

As part of the continuing study of the nature and origin of the various types of xenoliths from these maars, an electron microprobe study of the coexisting phases was carried out to determine their detailed mineralogy and chemistry. This study reveals that the liquid represented by the 3-phase xenoliths equilibrated in the crust, whereas the 4-phase unreacted xenoliths equilibrated in the upper mantle. It is suggested from the estimated oxygen fugacity for the formation of the spinels from the various types of xenoliths that the spinels from the crystallized liquids and from the mafic xenoliths equilibrated over a relative range of oxygen fugacity of three orders of magnitude, possibly between 10^{-8} to 10^{-11}, whereas the spinels from the 4-phase xenoliths shows a relative range of oxygen fugacity of at least six orders of magnitude, possibly between 10^{-3} to 10^{-9}. This range of oxygen fugacity may reflect a large range in temperature, with the highest oxygen fugacity values indicating the highest relative temperature. A large range in temperature of formation is also suggested by distribution of K_D values for the Mg-Fe exchange reaction between spinel and olivine and spinel and pyroxenes (Figure 3). The slope of a line defines a K_D value. The large range of K_D values from approximately 1.2 to 4.1 suggest a large range in temperature of formation for the spinels. Since the most Cr-rich spinels have the largest K_D values and since very Cr-rich spinels generally have even higher K_D values, a continuous decrease in crystallization temperature from Cr-rich to Al-rich spinels is suggested. Applying the experimental data of James Dixon (personal communication, 1977) to the coexisting pyroxenes from the composite type xenoliths suggest temperatures from 1050 to 1350°C and pressures of 9 to 11 kilobars. These results are consistent with the physical process of a 4-phase mantle type xenolith being fractured and permeated with a hot liquid (3-phase xenolith) resulting in temperature and chemical reaction gradients at the same pressures.

A most unusual type of clinopyroxene xenolith is present at Kilbourne Hole but it has not been found at Potrillo. It consists of single crystals up to 15 centimeters in maximum dimension with olivine crystals in layers abount 0.5 to 1 centimeter apart parallel to the basal plane, and triangular shaped spinel and rods and spherules of pyrrhotite are oriented in rows parallel to the c-axis. The clinopyroxene has a composition very similar to the clinopyroxene occurring in the 3-phase xenoliths and may have a similar mode of origin. The presence of the various inclusions parallel to crystallographic directions suggest the possibility of exsolution. Olivine in solid solution in clinopyroxene has been observed by Kushiro (1972) in the synthetic system Fo-Di-Si at 1 atmosphere. The undersaturated nature of the liquid represented by the 3-phase xenoliths may favor solid solution of olivine in clinopyroxene. On the otherhand, the olivine and spinel may represent trapped liquid that crystallized to this assemblage.

The subsurface differences between Kilbourne Hole and Potrillo as suggested by the ultramafic and mafic xenolithic suite is supported by the study of crustal xenoliths (Padovani, 1977: Padovani and Carter, 1977). This difference is demonstrated especially by the presence of an extensive suite of greenschist metamorphic grade rocks which are present at Potrillo but are absent at Kilbourne Hole, and by the presence of an extensive sutie of garnet- and two-pyroxene-bearing granulites at Kilbourne Hole which are extremely rare at Potrillo. Only two examples of garnet-bearing granulites have been found at Potrillo and no example of a two-pyroxene-bearing granulite.

The almost total lack of mixing of the various xenolith-bearing horizions at Potrillo suggests that the present expression of the maar is close to the original maar limits. If this is correct, then the crater forming event was extremely energetic with very little fall back of the rubble into the crater. Energy calculations suggest that the Potrillo and Kilbourne Hole maar eruptive events fall within the top 5 to 10 most energetic volcanic events on earth. The relationship of the xenolith-bearing horizons is interesting in that the crustal-bearing assemblages were apparently the last to come up. This relationship suggest at least a two stage eruptive process, possibly with a long residence time for the magma within the upper mantle or lower crust.

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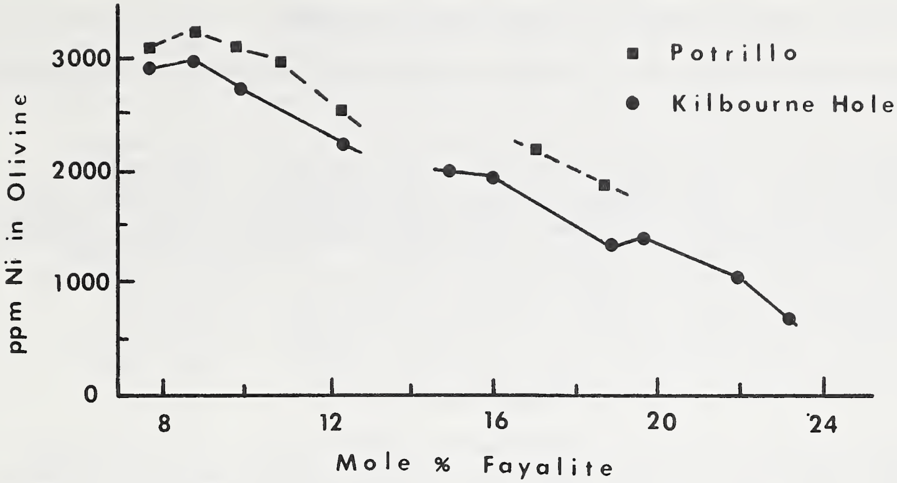

Fig. 1

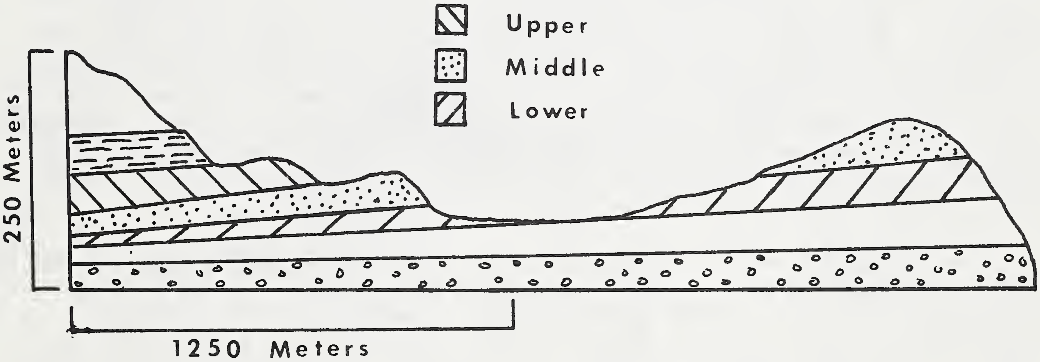

Fig. 2

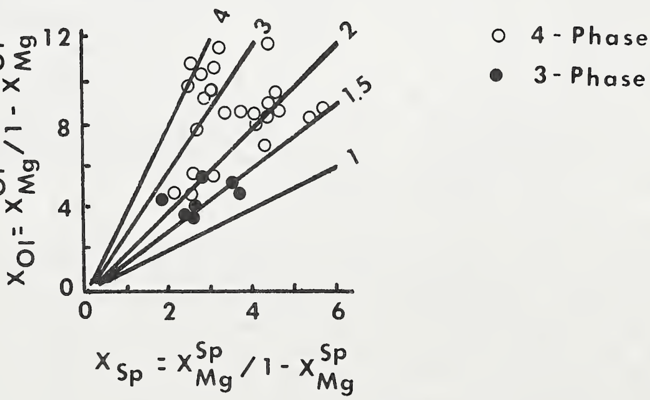

Fig. 3