Pyroxenes and Olivines from Oceanus Procellarum

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Pigeonite phenocrysts mantled by complex zones of augite and pigeonite in rock 12021 provide a more complete picture of pyroxene crystallization in lunar lavas than has previously been available. The pigeonite cores are relatively homogeneous with compositions near $Wo_{11}En_{61}Fs_{28}$. They are believed to have formed under quiescent conditions at depth in the moon. The mantles are predominantly Ca-rich and they show a remarkable oscillatory and sectorial zoning. Bands of augite alternate with pigeonite and the general trend of compositional variation is for the margins of these phenocrysts to be enriched in Fe relative to the inner portions. However, there are many reversals in the trend towards more Fe-rich compositions. There is usually an abrupt compositional break between zones of pigeonite and zones of augite in crystallization on (110) but there are progressive compositional transitions in growth along a and b. These gradations between pigeonite and augite are presumed to be metastable. Except for the gradations along a and b, augite and pigeonite have crystallized alternately rather than simultaneously and these relations are therefore believed to reflect the influence of a peritectic. The oscillatory zoning is believed to have been produced by crystallization in fluid, turbulent lava streams on the lunar surface, where partially cooled and fractionated lava was being mixed with fresh lava.

Coarse olivine phenocrysts in rocks 12052, 12004, and 12022, are chemically uniform, varying little from a composition of $Fo_{70}Fa_{30}$, and are twice as rich in Cr (.4% $Cr_2O_3$) as those analyzed in Apollo 11 rocks. In contrast, olivines from 12040 are strongly zoned toward fayalite at the grain margins. All of these olivines contain inclusions

of chromian spinel and metal alloys (Fe-Ni) which differ in composition from spinels and metals in the ground mass. Chrome spinel inclusions are among the most Fe-rich (35.2% FeO) and Cr-poor (40.4% $Cr_2O_3$) of those analyzed in the Apollo 12 samples, and the metallic inclusions are some of the most Ni-rich (30% Ni) of those analyzed from Apollo rocks. Ni was not detected in the olivine host ( $<$ 0.01% Ni). If the olivines formed in equilibrium with their inclusions, the partition of Ni was evidently similar to that observed in metal slag systems formed at low $P_{O_2}$ where Ni is concentrated in the metallic phase rather than the silicate and liquid phases.