CHEMICAL COMPOSITION VARIATIONS IN LUNAR MICROCRATER PIT CLASSES

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Glasses lining pits formed by meteoroid impacts onto a lunar rock were analyzed using standard electron microprobe techniques. The rock selected for study was 65315, an almost monomineralic anorthosite consisting of plagioclase (An97) and rare grains of pyroxene and olivine. Sixteen pits greater than 0.5 mm in diameter on about 2 cm² of rock surface were studied optically and with a scanning electron microscope equipped with a solid state x-ray analyzer. Clear or transparent glass lined 10 pits. In 3 of these the glass was darker away from the center of the pit. Black glass, usually with a more uneven surface and containing more vesicles, lined 4 pits. The surface of one of these was dotted everywhere with mounds rich in Fe, Ni, and S. Two pits were irregular, containing both transparent and black glass.

Five pits, 0.5 to 1.4 mm in diameter, were selected for detailed examination: 2 with clear glass, 2 with black glass (one of these with Fe-Ni-S mounds), and one with both clear and black glass. Vertical polished sections through each pit were prepared. Concentrations of detectable elements were measured at micron-sized spots located along profiles perpendicular to the originally exposed surface of the pit. Numerous analyses of spots several tens of microns below the exposed surface yielded the following composition, in weight % of the oxide, for the host material: Si = 43.0 ± 1.0, Al = 36.5 ± 0.5, Ca = 20.0 ± 0.6, Na = 0.36 ± 0.08, Mg = 0.14 ± 0.04, Fe = 0.14 ± 0.04.

For clear pit glasses 13 profiles, each consisting of about 6 spots, were measured. All profiles yielded host rock compositions at depths of more than 5 to 10 microns below the surface. At shallower depths a striking pattern was observed in 4 of the 13 profiles. This pattern for one profile is shown in Fig. 1. Oxides of Si and Na are depleted nearer the surface, while Al and Ca are correspondingly enriched. We interpret these trends as being due to preferential loss of Si and Na or retention of Al and Ca occurring during the meteoroid impact event and arising because of corresponding differences in the vaporization/condensation temperatures of the oxides of these elements. It is not immediately clear whether preferential Si and Na volatilization occurred from a melt phase or whether preferential Al and Ca condensation occurred from an expanding silicate vapor "cloud." The fact that all 4 profiles showing the effect are located a topographic "highs" within the pit favors the latter possibility. The higher Mg and Fe content near the surface is characteristic of one clear glass but not the other and, therefore, may represent a contribution from the impacting meteoroid. The Ca, Al, and Si contents we measured for the fractionated near-surface glass is nearly the same as those established for high-alumina silica-poor (HASP) glass spherules found in Apollo 16(1) and 17(2) core soils, thus supporting a local impact origin for these and similar glasses.

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Shown in Fig. 2 is one of 6 profiles measured for the pit with black glass but without Fe-Ni-S mounds. MgO and FeO increase by factors of 35 and 20, respectively, between depths of 6 and 2 microns below the surface. The oxides of Al and Ca are correspondingly reduced, while Si remains unchanged. Analysis of a spot just at the exposed surface showed still higher Mg and Fe contents while the analysis total dropped to about 50%. Trends similar to those shown in Fig. 2 were found in all 6 profiles measured in this pit. These data support the view that impacting meteoroid material can be identified in pit glasses and that in this case the meteoroid was probably an Fe-Mg silicate with a MgO/FeO ratio between 1 and 2.

Profiles in the glass containing Fe-Ni-S mounds are similar to that shown in Fig. 2, except that in this case the S content is as high as 2 weight % of the metal at some near-surface spots. A scanning electron micrograph of an Fe-Ni-S mound (Fig. 3) shows at least 2 phases to be present. Measurements with a Si(Li) solid state x-ray analyzer indicate the brighter area is composed of metallic FeNi and the darker area is enriched in S. Apparently, the impacting meteoroid contained Fe, Ni, and S, probably in metal and/or sulfide phases, and also an Fe-Mg silicate phase.

Data for the clear glass in the irregular pit are similar to those for other clear glasses. However, profiles in the black glass in this pit yielded Ti concentrations of several % at depths greater than 10 microns along with correspondingly large Fe and Mg concentrations. While this could represent the impacting meteoroid composition, we suggest that in this case the black glass was derived from lunar soil adhering to the rock surface when the impact occurred.

In summary, each of the 5 impact pits analyzed yielded results which called for different interpretations. This may explain some of the wide variety of results obtained by others working on this problem (3, 4, 5, 6, 7, 8, 9, 10). Analysis of a statistically significant number of pits will be required to establish effects of different meteoroid sizes, compositions, and impact velocities and other variables. Identification of some material derived from the impacting meteoroid was accomplished for 3 of the 5 pits studied; and the expected location of this material, in the outermost 5 microns of the pit glass, was established. Finally, that either Si and Na oxides were selectively volatilized or Al and Ca oxides were selectively condensed during one impact forming a mm-sized pit was demonstrated.

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References
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Figure 1

Figure 2

Figure 3

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