N94-16397

GRAIN SURFACE FEATURES OF APOLLO 17 ORANGE AND BLACK GLASS.

David S. McKay, NASA Johnson Space Center, Houston TX and Sue J. Wentworth, Lockheed, 2400 NASA Rd. 1, Houston TX 77058.

Background: Lunar soil sample 74220 and core samples 74001/2 consist mainly of orange glass droplets, droplet fragments, and their crystallized equivalents. These samples are now generally accepted to be pyroclastic ejecta from early lunar volcanic eruptions (1,2). It has been long known that they contain surface coatings and material rich in volatile condensable phases including S, Zn, F, Cl, and many volatile metals. (3) summarizes the voluminous published chemical data and calculates the volatile enrichment ratios for most of the surface condensates. In an attempt to more completely understand this enrichment of surface volatiles, we have searched for carbon and carbon-bearing phases on droplet surfaces.

Approach: We have reviewed many of our existing photomicrographs and energy dispersive analysis (EDX) of grain surfaces and have reexamined some of our older SEM mounts using an improved EDXA system capable of light element detection and analysis (oxygen, nitrogen, and carbon). In addition, we have made fresh mounts using procedures which should minimize carbon contamination or extraneous carbon x-rays and have analyzed for carbon.

Textures: *Micromounds* : The 74001/2 glasses have micromound coatings which were first described by (1) and appear to be characteristic of other lunar volcanic glasses such as the Apollo 15 green glasses (4). Individual micromounds range in size from ~20-300 Å. (5). The micromound coatings commonly contain scrapes and gouges which suggest that the glasses were abraded while the micromound coatings were still soft, i.e., during fire fountaining. Similar textures can be produced in laboratory vapor deposition processes as thin deposited coatings coalesce into micromounds during deposition. While other forms of condensed material appear to be present, the micromounds are the most pervasive textures and are present on virtually all original droplet surfaces in both 74220 and 74001/2 samples. Such micromounds were also found on all of the green glass droplets (4), and the presence of micromounds may be a definitive characteristic of volcanic glass droplets from anywhere on the moon.

Continuous coatings, Shrinkage cracks, and vesicles : Occasional droplets are covered by relatively thick and continuous coatings of vapor condensates; some of the continuous coatings contain cracks and vesicles which may have resulted from shrinkage during cooling, from desiccation, or by evolution of a volatile species. (5). Thick or continuous coatings of volatiles are quite rare.Such thickly coated droplets may have spent longer times in the plume, or may have been in some particularly vapor-rich zone of the eruption cloud.

Discrete condensate phases. The surfaces of most droplets display many small adhering grains a few micrometers or less in typical dimension. Some of these grains are rounded and appear to be very tiny splash droplets of glass. Other grains are subhedral to euhedral and have chemistries corresponding to volatile condensates of various sorts. The most unambiguous condensates phases are chloride such as NaCl phases and sulfur-rich forms (5). While such discrete grains or crystals of condensate material can be found on many grains, the volume or mass of condensates in these grains appears to be much less than that in the micromound coatings. Other adhering grains are anhedral or fragmental in appearance, and have compositions more typical of the glass or minerals in the glass (mainly olivine and ilmenite). These grains may be fragmental ash material produced in the original eruption or they may be fragmental material produced in the later events which fragmented many of the droplets.

Carbon: Using SEM EDX techniques, we have analyzed original surfaces of many droplets using a relatively low voltage beam (6KV) to enhance x-ray return from the outermost surface materials. Analysis of some droplet surfaces revealed a carbon peak in many of the spectra (Fig. 1). Because the grains were originally mounted on carbon planchettes, we first attributed the carbon signal to stray x-rays from the planchette. However, freshly prepared and mounted grains using Cu planchettes and thin aluminum conductive coatings still showed significant carbon peaks, even though we had taken considerable care to eliminate the possibility of carbon contamination or stray x-rays. Many of the droplets with carbon also show enhanced Zn and S peaks. In most cases, the carbon peak is not present on nearby chipped surfaces (Fig 2). The chipping apparently occurred on the moon, but the absence of micromound coatings on many chipped surfaces indicates that chipping likely occurred late in the eruption sequence after much of the condensate had formed. While it is difficult to quantify the amount of carbon represented by the peaks, under the same analysis conditions, carbon-coated silica glass slides containing about a 300 Å thick layer of carbon produced about the same size peak as typical droplet carbon peaks. This suggests that if the carbon is present as a simple continuous coating on the droplets, it is about the same order of thickness. However, the carbon may be present in forms more complex than a continuous carbon coating. The fact that uncoated droplets exhibit considerable charging in the electron beam argues against the presence of a natural conductive coating of carbon or graphite on these droplets.

Discussion: Sample 74220 does not contain much carbon; (6) measured only 11 ppm total carbon, and noted that about half of it was released as CO2 with a light isotopic composition (-15 δ^{13} C_{PDB} per mil) which is closer to indigenous lunar carbon than to solar wind carbon. Both (6) and (7) suggested that carbonate-like phases might provide some of the thermally-released carbon.

(8) proposed that the driving gas for the pyroclastic eruption was CO. Normally CO gas would not leave a condensable trace. However, it is possible that during the rapid changes in pressure and temperature associated with the pyroclastic eruptions, a number of chemical reactions may have taken place which produced a condensable carbon phase. Because of rapidly changing conditions, these reactions would not necessarily reflect equilibrium conditions. An example might be a disproportionation reaction $CO \rightarrow C + CO_2$ which could have deposited carbon (graphite) on droplet surfaces during some phase of the eruption and cooling. Another possibility is that a metal carbonyl was formed during some late stage of the eruption or after deposition and that this carbonyl may have decomposed and deposited iron and some carbon on grain surfaces. Yet another possibility is the formation of carbonates at lower temperatures, e. g. $ZnCO_3$, during the late stages of the eruption or after deposition of the ejecta blanket. Such carbonates could form if CO_2 becomes a significant phase in the transient gas environment, produced, for example by the disproportionation reaction described above. Additional studies, including TEM analysis are necessary before the carbon-bearing phase can be fully identified.

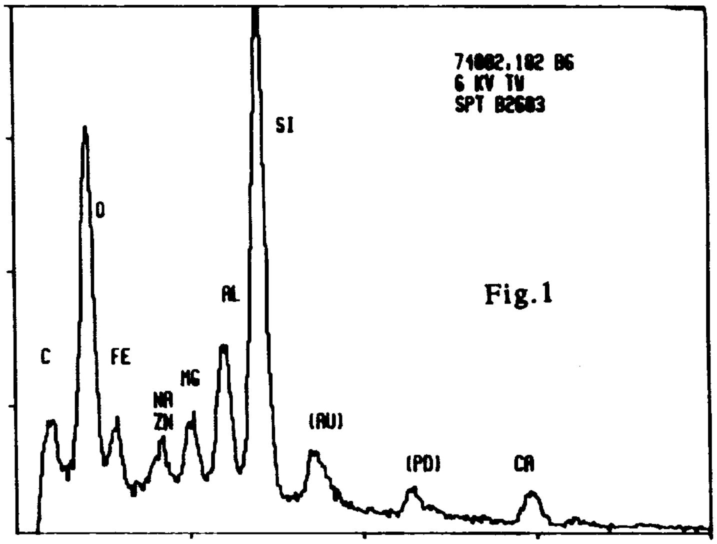

Fig.1

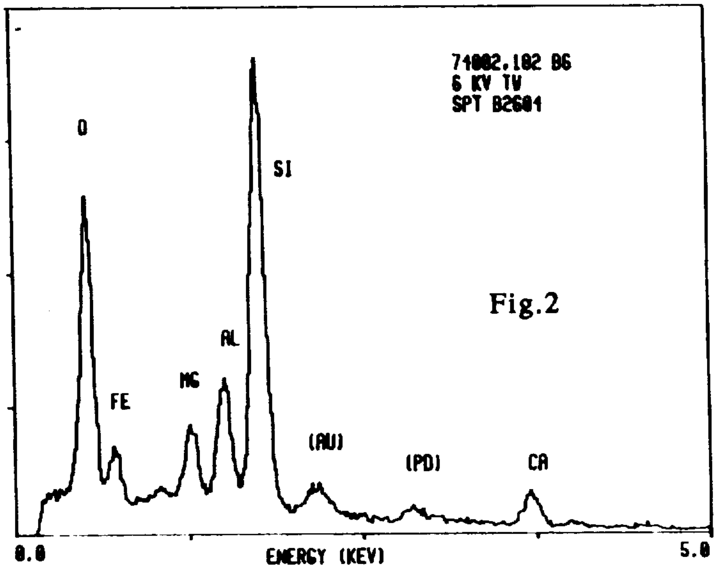

Fig.2

1. Heiken G., et. al. (1974) GCA 38, 1703-1718.
2. Heiken G. and McKay D. (1978) LPSC 9th p.1933-1944.
3. Meyer, C. (1990) LPI Workshop on Lunar Volcanic Glasses. LPI Tech. Rept. 90-02, p. 50-51.
4. McKay et al. (1973) LPSC 4th, p. 225-238.
5. Clanton U., et al. (1978) LPSC 9th, p. 1945-1957.
6. Chang et al. (1974) LPSC 5th, p. 1785-1800.
7. Gibson E. and Moore G. (1973) EPSL 20 p. 404-408.;
8. Sato (1979) LPSC 10th, p. 311-325.