SURFACE COATINGS ON APOLLO 15 VOLCANIC GLASS BEADS. S. J. Wentworth,[1] Kathie L. Thomas-Keprta[1], Simon J. Clemett[1], and David S. McKay[2], [1]ESC Group, Mail Code C23, NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX, 77058 (susan.j.wentworth@nasa.gov); [2]NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX, 77058.

Introduction: Volcanic glass beads are present in most lunar regolith samples. They formed during as a result of fire-fountaining (Fig. 1) at ~3.4-3.5 Ga (during the time of mare volcanism). Earlier studies [1-7] showed that the volcanic beads had tiny surface deposits of unusual materials; e.g., "micromounds" of uncertain nature, unusual minerals such as possible ZnS and halite, and surface-correlated geochemical enrichments in In, Cd, Zn, Ga, Ge, Au, Pb, and Na. The technology available for the earlier studies was not sufficient to characterize the bead surfaces in detail. We are now using improved electron beam capabilities to perform high-resolution imaging and analysis of surfaces of the lunar volcanic glasses.

Samples and Procedures: Volcanic (or picritic) glass beads are highly enriched in some Apollo 15 and 17 samples; therefore, the three major volcanic glass types that have been identified are known as Apollo 15 green glass, Apollo 17 orange glass, and Apollo 17 "black" glass, all of which have mare compositions (e.g., high Fe and Mg along with low Ca and Al compared to nonmare materials). The Apollo 15 green glasses have primitive compositions while the Apollo 17 orange and black glasses are enriched in TiO_2 and quite similar in composition to high-Ti mare basalts. Compositions of the Apollo 17 orange and black glasses are essentially identical; the black ones are opaque, quench-crystallized equivalents of the orange ones. Extensive studies of the petrology and geochemistry of the volcanic glasses have yielded much information the lunar interior and the igneous history of the moon [e.g., 8-10]. One characteristic that the green, orange, and black glasses all have in common is that the surfaces of individual glasses have tiny deposits of a variety of unusual (with respect to lunar samples in general) materials, as noted above. It is thought that these deposits formed from the volcanic gases that drove the fire fountain eruptions.

We are studying the surfaces of individual volcanic glass beads using state-of-the-art field emission SEM and TEM techniques, which have improved significantly since the glasses were first examined. Our initial work has been a feasibility study to analyze Apollo 15 green glasses from D. McKay's existing allocations. Some future work will require pristine samples because it is likely that some surface features have been affected by being in air since the samples were allocated. Samples used for this study were ultramicrotomed thin sections cut normal to glass bead surfaces, and they were examined and mapped using a JEOL 2500SE field-emission STEM equipped with a custom large area, thin window energy dispersive X-ray spectrometry (EDS) sytem.

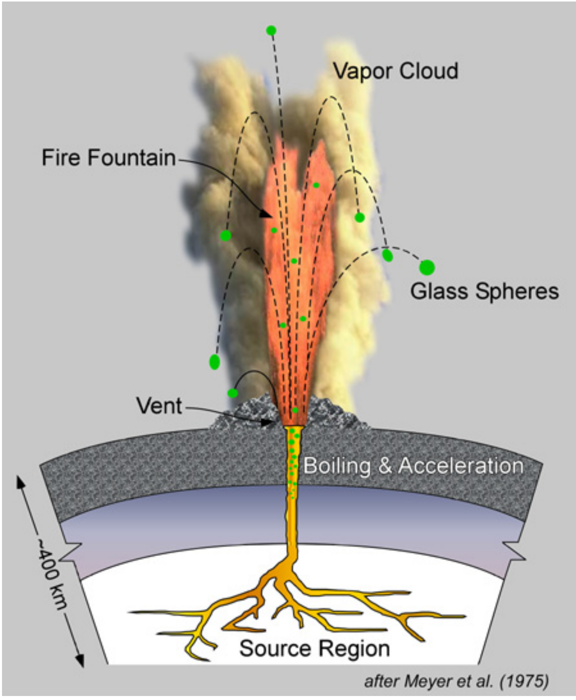
Results and Summary: Based on initial studies, layered surface deposits are present on the green glasses. The deposits range in thickness and range from ~ 20 to 150 nm (Fig. 1). The bulk composition of the volcanic glass substrate is primarily Si, Mg, Fe, and Al, with minor Ca and Cr and trace amounts of Ti, as expected for green glass. Surface deposit compositions are quite different; they are Si-poor and consist of at least two compositionally distinct layers. The innermost layer is primarily Fe with minor S while the outer layer is composed of Fe and no detectable S. In addition, some of the deposit material contains Zn (not shown here), which appears to be partially correlated with S.

This preliminary study demonstrates that surface deposits are present and that they are heterogeneous at the nanometer scale. Layering is clearly present in the surface deposits; this feature has not been documented previously. Isolated individual crystals have not yet been identified on the glass surfaces but it seems likely that they are present. Further studies will determine whether layering is common or isolated on the Apollo 15 green glasses, and whether such features are also present on the Apollo 17 orange and black glasses. Continued work will enhance our understanding of the mineralogy and nanoscale compositions of individual volcanic condensates, which will enable further development of realistic models of lunar volcanism and the processes that drove fire fountain eruptions on the moon.

References: [1] Meyer et al. (1975) *Proc. LSC 6th*, 673; [2] McKay et al. (1973) *Proc. LSC 4th*, 225; [3] Heiken and McKay (1974) *Proc. LPSC 5th*, 843; [4] Butler (1978) *Proc. LPSC 9th*, 1459; [5] Heiken and McKay (1978) *Proc. LPSC 9th*, 1933; [6] Clanton et al. (1978) *Proc. LPSC 9th*, 1945; [7] Wasson et al. (1976) *Proc. LSC 7th*, 1583; [8] Delano (1990) *Lunar Volc. Gl. Wkshp.*, 28; [9] Longhi (1992) *GCA 56*, 2235; [10] Shearer and Papike (1993) *GCA 57*, 4785.

Wentworth et al.: Volcanic green glass surface coatings.

Figure 1: Schematic diagram of fire fountaining eruption on the moon (after [1]).



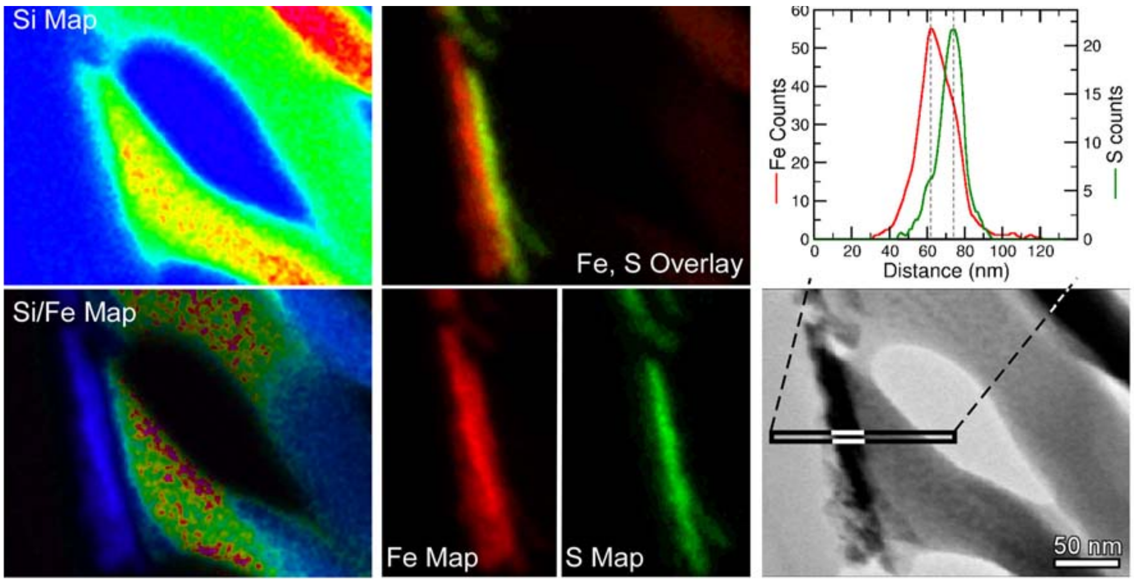


Figure 2: FESTEM/EDS X-ray map of surface deposits on cross-section of Apollo 15 volcanic green glass bead.