GEOCHEMISTRY AND IMPACT HISTORY AT THE APOLLO 17 LANDING SITE.
N.E.B. Zellner[1], J.W. Delano[2], T.D. Swindle[3], and D.C.B. Whittet[4] [1]Department of Physics, Albion College, Albion, MI nzellner@albion.edu, [2]New York Center for Studies on the Origin of Life, Department of Earth and Atmospheric Sciences, University at Albany (SUNY), Albany, NY 12222, [3]University of Arizona, Lunar and Planetary Laboratory, Tucson, AZ 85721, [4]New York Center for Studies on the Origin of Life, Rensselaer Polytechnic Institute, Troy, NY 12180.

Introduction: One hundred and nineteen (119) lunar impact glasses from the Apollo 17 landing site have been analyzed by electron microprobe in this study. Eighty-four of the glasses (71%) are of impact origin. Eleven of the impact glasses have been dated by the $^{40}Ar/^{39}Ar$ technique and their ages may be used to deternine the impact history at the Apollo 17 landing site. By comparing these results to orbital data, we illustrate how lunar impact glasses can provide geochemical constraints on the local and regional geology of the Moon [1,2,3].

Lunar Impact Glasses: Lunar impact glasses are droplets of melt produced by energetic cratering events that were quenched during ballistic flight. They possess the refractory element ratios of the original fused target materials at the site of impact [4]. Impact glasses offer the potential for providing information about local and regional units and terrains. Although glass compositions have been interpreted as having rock compositions, based on rock types at the collection sites [5], this study uses orbital data to show that glass composition(s) most often represent regolith composition(s).

The Apollo 17 Landing Site: Taurus-Littrow is surrounded by three high, steep massifs, most of which are covered by a dark mantle pocked by several small, dark halo craters. The basic objective of the Apollo 17 mission was to sample basin-rim highland material and adjacent mare material and to investigate the geological evolutionary relationship between these two major units. The Taurus-Littrow region represents the most diverse landing site of the Apollo missions [6], and a key finding was the chemical diversity of the soil samples [7].

Sample Analysis: 119 glasses from Apollo 17 regolith 71501,262 were analyzed for Si, Ti, Al, Cr, Fe, Mn, Mg, Ca, Na, and K using a JEOL 733 electron microprobe in the Department of Earth and Environmental Sciences at Rensselaer. Five X-ray spectrometers were tuned and calibrated for each element analyzed in the glass sample. A 15 keV electron beam with a specimen current of 50 nAmps was used. Lunar working standards were used to assess analytical precision throughout the study. Count-times of 200 seconds were used for Na and K, while count-times of 40 seconds were used for the other elements. Backgrounds were collected for every element on every analysis. Uncertainties in the measurements were usually < 3% of the amount present.

Impact glasses were subsequently irradiated and analyzed in order to determine their $^{40}Ar/^{39}Ar$ ages. Samples were irradiated in the Phoenix Ford Reactor at the University of Michigan for about 300 hours, producing J-factors of 0.05776 ± 0.00030. CaF_2 salts and MMhb-1 hornblende samples were irradiated simultaneously, the former to correct for reactor-produced interferences and the latter to determine the neutron fluence. Laser step-heating on these samples was carried out in the University of Arizona noble gas lab, using a continuous Ar-ion laser heating system. Heating steps were determined by passing a roughly-focused beam over the sample's surface. The amperage was then increased incrementally until ^{40}Ar counts from the sample peaked then decreased to no greater than background levels. In addition to system blank and interference corrections, Ar isotopes produced by cosmic ray spallation and by implantation from the solar wind were subtracted from each sample.

Results: Glasses from 71501,262 had K_2O (wt%) abundances ranging from 0.0011 to 2.11, wider than expected; it is typical to find K_2O (wt%) concentrations between 0.02 and 0.07 [8]. Moreover, these glasses are much smaller in size when compared to the Apollo 14 [1] and Apollo 16 [9] glasses, and their compositions include mare, highland and mare/highland-mixed components.

Figure 1 shows a ternary diagram of the impact glasses analyzed in this study, along with glasses from regolith breccia 79135 [10] and glasses from rake sample breccias and drill core [11]. Refractory lithophile elements are plotted to infer the compositional nature of the target-materials. The geological diversity of the site is apparent, with MKFM and HKFM compositions dominating the ternary diagram. These compositions typify contributions from Mare Serenitatis, and may also represent ejecta from the Imbrium event [12]. A small offset toward highland compositions may imply that the Apollo 17 site is also influenced by components from the lunar farside or by anorthositic components not present at the site's surface. Finally, there is a paucity of highland basalt and basaltic andesitic [13] compositions.

Mixing between regolith components, however, can be seen and further identified by the positions of impact glasses from 71501,262 (Figure 2; open circles). Trendlines between high-Ti and low-Ti compositions and between high-Ti and highland compositions exist. Three distinct chemical groups, broadly corresponding to major geological and physiographic units, have been identified [7], but many of the impact glasses analyzed in this study represent different regions that are not necessarily local to the sample collection area. Therefore, impact glasses collected at the Apollo 17 landing site may represent more than just three distinct chemical groups.

Ages (± 1σ) for the 11 dated impact glasses (Figure 2; red stars) range from 102 ± 10 Ma to 3718 ± 12 Ma. While several impact glasses from this study have compositions typical of the local Apollo 17 regolith and may indeed have formed at that site, others possess exotic compositions and were likely transported to the Apollo 17 site by an impact event at some distant location.

Conclusions: Lunar impact glasses from the Apollo 17 landing site show a wide range of compositions and ages, again demonstrating the geological complexity of the Apollo 17 landing site. Interpreting these compositions, along with the ages, will help us continue to understand the impact processing of the lunar surface and the bombardment history in the Earth-Moon system.

References: [1] Zellner, N.E.B. *et al*. (2002) *JGR,* **107(E11)***,* 5102*,* doi:10.1029/2001JE001800. [2] Spudis, P.D. *et al*. (2002) LPSC. [3] Zellner, N.E.B. *et al.* (2002) *LPSC XXXIII*, 1225.pdf. [4] Delano, J.W. (1991) *GCA,* **55***,* 3019-3029. [5] Hörz, F. (2000) *Science,* **288***,* 2095. [6] NASA (1973) NASA SP-30. [7] Rhodes *et al.* (1974) *Proc. LPSC V*, 1097-1117. [8] Williams, R.J. and Jadwick, J.J. (1980) NASA RP-1057. [9] Zellner *et al.* (2005) *LPSC XXXVI*, 1199.pdf. [10] Delano, J. unpublished data. [11] Warner et al. (1979) UNM SP-20. [12] Haskin, L. (1998) JGR **103**, 1679-1689. [13] Ziegler, R. A. *et al.* (2004) *LPS-XXXV*, 2082.pdf.

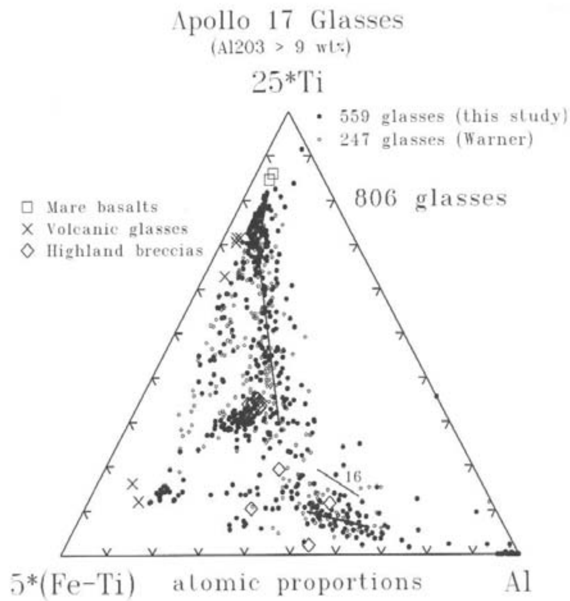

Figure 1. Compositions of impact glasses from Apollo 17 regolith samples.

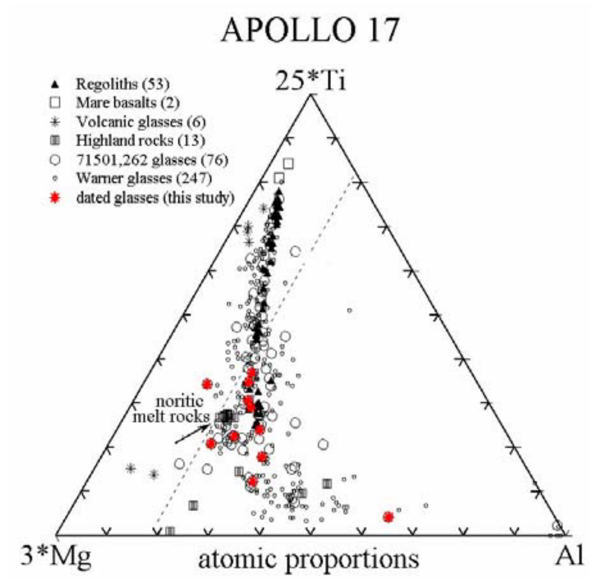

Figure 2. Compositions of impact glasses from re golith 71501,262 compared to other Apollo 17 sam ples.