APOLLO 14 IMPACT GLASSES: ISOTOPIC AGES AND GEOCHEMISTRY. 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 fifty-one (151) lunar glasses from the Apollo 14 landing site (regolith 14259,624) have been analyzed by electron microprobe and determined to be of impact origin (84% of total number of samples selected). Seventeen of the impact glasses have been dated by the $^{40}Ar/^{39}Ar$ technique, with 9 having well-determined ages (2σ uncertainites ~ 10% of the age). By comparing impact glass composition to orbital data in concert with time of formation (age), we illustrate how lunar impact glasses can provide constraints on the local and regional geology of the Moon [1,2,3], including its impact history [4].

Lunar Impact Glasses: Lunar impact glasses possess the refractory element ratios of the original fused target materials at the site of impact [5] and 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 [6], orbital data [e.g.1] has been used to show that glass composition(s) most often represent regolith composition(s). Since lunar impact glasses are droplets of melt produced by energetic cratering events, their compositions indicate their original geology, oftentimes several hundreds of kilometers away from the site where they were collected by the Apollo astronauts [e.g. 4]. In this way, "exotic" and "local" regolith compostions can be determined (Figure 1, [1]).

The Apollo 14 Landing Site: Apollo 14 was sent to sample the Fra Mauro Formation, which is interpreted to be dominated by Imbrium ejecta. Ridges of the Fra Mauro Formation are roughly radial to the Imbrium Basin and were probably formed by material flowing along the ground during excavation of the basin [7,8]. Although orbital data [1,2,9] show the surface of the Apollo 14 region to be KREEP-rich, several outcrops of feldspathic material are seen on crater rims [1].

Sample Analysis: 151 glasses from Apollo 14 regolith 14259,624 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. These compositions can be seen in Figure 2.

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: Information about the geochemistry of these lunar impact glasses has been detailed in [1], wherein it was interpreted that glasses with compositions different from that of the local surface were either (a) ballisticaly transported to the site from a distant location or (b) excavated locally from underlying units at the site. We would expect the local regolith to show a range of impact ages, reflecting a constant bombardment, and exotic regolith to show evidence for only distant impact events whose energies were large enough to transport impact glasses to the Apollo 14 site.

Ages (± 2σ) for 13 impact glasses, with over 30% of ^{39}Ar released, can be seen in Figure 3. Overall, the ages (± 2σ) range from 345 ± 10 Ma to 3692 ± 16 Ma. Though a small data set, no "recent" impact activity has been recorded in these impact glasses, as reported by [10] at the Apollo 12 landing site.

Three of the glasses show impact ages consistent with an impact event ~800 Ma ago: 783 Ma ± 4 Ma, 783 ± 76 Ma, and 769 ± 6 Ma; and 2 others show outgassing events at around that same time. While these data don't conclusively demonstrate an enhanced impact flux at ~800 Ma, they do suggest that compositionally distinct regions of the Moon experienced impact evnts that delivered these exotic glasses to the Apollo 14 landing site. Similar evidence has been recorded in lunar impact glasses from other Apollo landing sites [11].

Conclusions: Lunar impact glasses from the Apollo 14 landing site show a wide range of compositions and ages, with no evidence of recent increased impact activity. 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. *et al.* (2007) *MAPS*, **42**, 6, 993-1004. [5] Delano, J.W. (1991) *GCA*, **55**, 3019-3029. [6] Hörz, F. (2000) *Science*, **288**, 2095. [7] Swann, G.A. *et al.* (1977) *U.S. Geol. Survey Prof. Paper 880*, 103. [8] Wilhelms, D.E. (1987) *U.S. Geol. Survey Prof. Paper 1348*, 302. [9] Elphic, R.C. *et al.* (2000) *JGR*, **105**, 23000. [10] Levine, J. *et al.* (2005) *GRL*, **32**, L15201. [11] Zellner, N.E.B. *et al.* (2006) *LPSC XXXVII*, 1745.pdf.

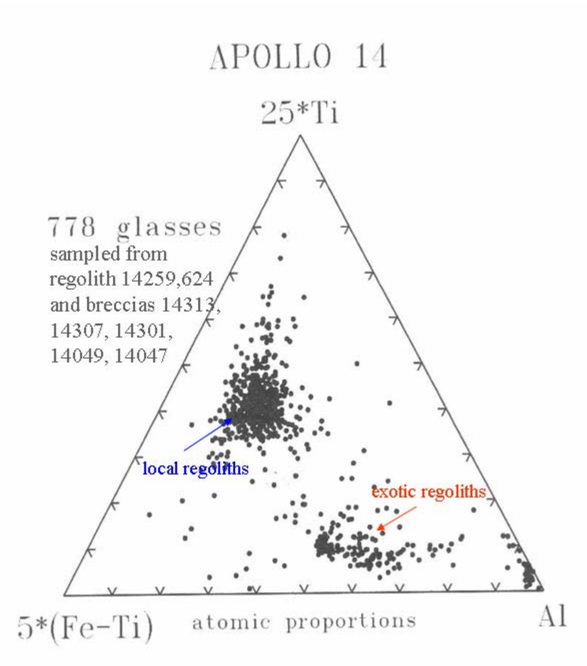

Figure 1. Compositional range of 778 impact glasses from regolith and breccia samples (adapted from [1]).

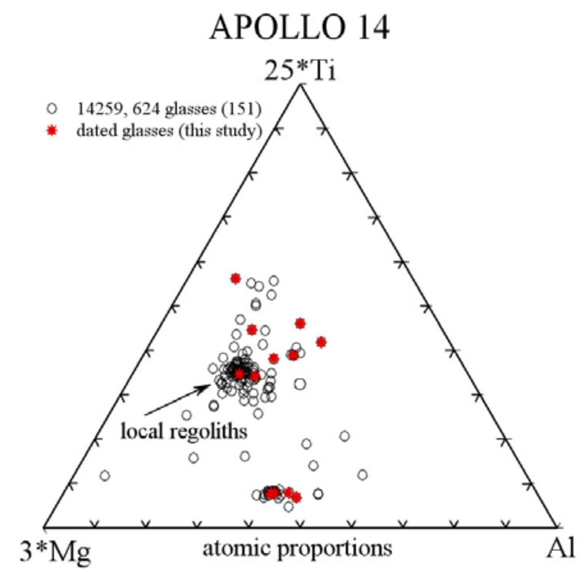

Figure 2. Compostional range of lunar impact glasses from regolith 14259,624.

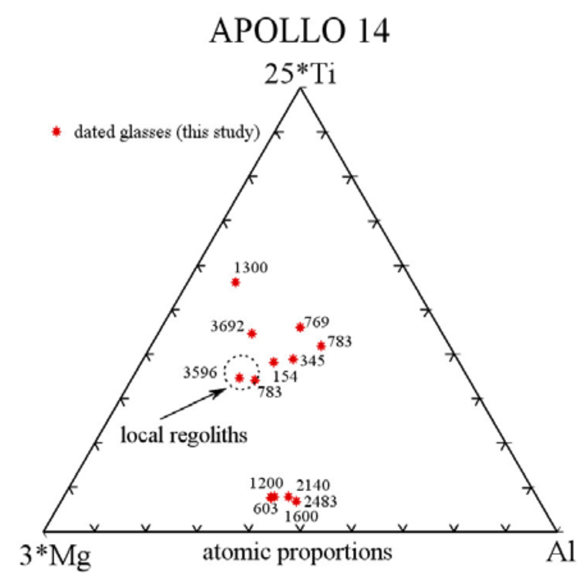

Figure 3. Compositions and ages of 13 impact glasses from regolith 14259,624.