A SHORT-LIVED LUNAR IMPACT SPIKE INDUCED BY COPERNICUS CRATER-FORMING SESQUINARIES VERSUS A LONG-DURATION GLOBAL IMPACT RESURFACING ~800 MA AGO FROM A MODELING PERSPECTIVE. Y.-H. Huang1, D. A. Minton2, J. R. Elliott3, C. Andronicos4, P. Q. Nguyen5 and N. E. B. Zellner6 1Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA (yahuei@mit.edu), 2Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, West Lafayette, Indiana 47907 USA, 3Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan 48824 USA, 4Department of Physics, Albion College, Albion, Michigan 49224 USA.

Introduction: Lunar “exotic” impact glass spherules and shards (broken spheres) likely source from geochemically distinct regions that are hundreds of kilometers away from where astronauts collected the lunar regolith [1]. The 40Ar/39Ar-derived age distributions of “exotic” impact glass spherules and shards can be used to interpret an impact record that is separate from the everyday background flux [2]. As a result, the impact probability interpreted from the age distributions of “exotic” glass spherules and shards may reflect a series of distant, large cratering events.

Considering only “exotic” glass spherules and shards (hereafter called glasses), the 40Ar/39Ar-derived age distributions of those “exotic” glasses from Apollo 14, 16, and 17 [3] and the Apollo 12 roopy glasses [4] in regolith samples show a higher concentration of ages between 700 and 900 Ma (Figure 1). It is straightforward to suggest that several other large cratering events, including Copernicus Crater (e.g., [4]), occurred 800 Ma ago on the Moon. However, the relationship between the ages of ~700-900 Ma of “exotic” glasses and the formation age of Copernicus Crater is uncertain. Meanwhile, it should be noted that many parent bodies appear to have experienced an impact shock heating event around 800 Ma (e.g., [5]). It is also suggested to be dynamically feasible that an asteroid family breakup event (e.g., Flora family) produced sufficient sizes of fragments hitting Earth beginning 1 Ga ago that also bombarded the Moon [6].

Motivation: The coincidence between an excess of 800-Ma-old exotic glasses and the formation age of Copernicus Crater motivates us to consider two possible hypotheses.

Hypothesis 1: 800-Ma-old “exotic” glasses were directly produced by the formation of Copernicus Crater, which is expected to generate an extensive amount of melt that would form glasses. The main constraint for Hypothesis 1 is whether those 800-Ma-old “exotic” glasses are geochemically consistent with the target lithology underneath Copernicus Crater. To test this hypothesis, we compiled data from samples that could best represent Copernicus Crater’s melts and its subsurface lithology to see how plausible it for all of our “exotic” glasses to have formed from melting subsurface materials (see Figure 2).

Hypothesis 2: the Copernicus Crater-forming sesquinary crater population produced all of the 800-Ma-old “exotic” glasses. Sesquinary (1.5-ary) impact craters are formed via impact ejecta that escape a satellite, going into the orbit around the primary, and later re-impacting the same satellite [8]. The largest uncertainty for Hypothesis 2 is the production of melt via medium-to-low velocity impact of lunar sesquinaries. Note that the lunar secondaries (<lunar escape velocity) are excluded due to a negligible amount of melts. This hypothesis must satisfy two main observational constraints: 1) the fraction of Copernicus Crater’s ejecta that re-impacts with sufficient velocity to generate glasses is sufficient, and 2) the sizes of sesquinary impact craters can account for the exotic origin of impact glasses in our observed dataset.

Methods and Results: For Hypothesis 1, the compositional heterogeneity of the 800-Ma-old exotic glasses may be consistent with the fact that Copernicus Crater is sitting in a region where a diverse lithology of a lunar material is present. The Copernicus Crater region is suggested to have covered a relative thin mare basalt lying on the top of a thick Imbrium Basin ejecta underlain by the pre-Imbrium megarregolith materials (e.g., [9]). The youngest member of Copernicus Crater’s stratigraphy is Apollo 12 mare soil (e.g., [10]; orange points in Figure 2), which is compositionally similar to the underlain Apollo 12 mare basalts (e.g., [11]; red points). Underneath mare basalts are Apollo 12 gray-mottled KREEP breccias [12] and Apollo 12 KREEP glass fragments (light and dark purple points) to represent the Imbrium Basin ejecta. The gray-mottled

Figure 1: The relative impact probability and histogram of 15 “exotic” glasses from Apollo regolith samples 14259, 64501, 66041, 71501 [3], and one Apollo 12 roopy glass [4]. The Copernicus Crater forming event is thought to be ~800 Ma (two dashed lines are arbitrary). The y-axis on the right of the figure is the number of glasses.
KREEP refer to orthopyroxene-plagioclase assemblage that are commonly attached to Apollo 12 ropy glasses or Type A norite-anorthosite [13]. Marvin et al. suggested that mixtures of gray-mottled materials and mare basalts form ropy glasses from the Copernicus Crater event [14]. For the lowest member of the stratigraphy, ferroan anorthosites, feldspathic lunar meteorites, MgO, Al2O3, and K2O interpreted by the Lunar Prospector Gamma-Ray Spectrometer [18] and performed a linear least squares regression for each exotic glass. We found that 15 glasses may come from a few hundred km away from their local site. This long distance-origin of “exotic” glass in general implies that the required size of a crater that delivers them is more than tens or hundreds of kilometers, rather than hundred meter-sized or kilometer-sized craters for the case of lunar sesquianaries.

Nevertheless, we estimated the total production of glasses formed from the Copernicus Crater sesquianary population. Using planar impact approximation, we estimated the peak shock pressure for a given impact velocity and compared the calculated shock pressure with the experimental and numerical experiment results for the shock-induced melting. It was found that impact velocity as low as 3 km/s is possible to generate melts [19]. This implies that only about 0.2% of total Copernicus Crater ejecta can contribute to the abundance of 800-Ma-old exotic glass (much less if considering the impact angle). We found that Copernicus Crater glass-forming sesquianaries, if they exist, would generate the approximately one year-long bombardment record.

**Discussion and Conclusion:** We examined two hypotheses regarding the source of our 800-Ma-old “exotic” glasses. For Hypothesis 1, Figure 2 shows that the compositions of our 15 “exotic” glasses cross many different subsurface lithologies that are assumed to be the targets of Copernicus Crater. Preservation of a distinct composition of an “exotic” glass is challenging to reconcile with the melting process that homogenizes the target materials. For Hypothesis 2, the negligible production of melt by sesquianaries cannot explain the abundance of 800-Ma-old “exotic” glasses. Consequently, the formation of Copernicus Crater is independent of the concurrency of an excess of 700-900 Ma ages of “exotic” glasses. This implies a global impact spike may have occurred 800 Ma ago on the Moon [2] or ejecta material mixing upon impact-generated melting requires a better understanding.

**References:**