THE ONSET OF THE CATACLYSM: IN SITU DATING OF THE NECTARIS BASIN IMPACT MELT SHEET. B. A. Cohen, NASA Goddard Space Flight Center, Greenbelt MD 20771 (barbara.a.cohen@nasa.gov)

Introduction: The impact history of the Moon has significant implications beyond simply excavating the surface of our nearest neighbor. The age distribution of lunar impact breccias inspired the idea of a catastrophic influx of asteroids and comets about 4 billion years ago and motivated new models of planetary dynamics [1, 2]. An epoch of heavy bombardment after planets had atmospheres and continents would have influenced the course of biologic evolution [3]. The story of a cataclysmic bombardment, written in the rocks of the Moon, has far-reaching consequences.

Linking lunar samples to specific basins underpins the lunar cataclysm. The inferred age of Imbrium, being the stratigraphically penultimate basin with a distinctive KREEP signature, is well-accepted ~3.96 Ga. Until recently, we thought we also had definitive dates of Nectaris, Serenitatis, and Crisium. Luna 20 samples also yielded ages of 3.85–3.89 Ga [4], but their relationship to the Crisium basin are unknown. Apollo 17 samples contain impact-melt rocks with ages around 3.89 Ga argued to be ejecta from the Serenitatis basin [5]; however, debate continues about the geological relationships at the site and the relative age of Serenitatis [6, 7]. The age of materials thought to originate in Nectaris varies wildly, from 3.9 to 4.2 Ga, with little agreement on what samples in our collection represent Nectaris, if any [8, 9]. The lack of definitive ages for major basins throws the key arguments supporting a lunar cataclysm into doubt. We are therefore working on a potential Discovery mission concept that would directly constrain the onset of the cataclysm by dating a lunar basin age.

The case for Nectaris: The Decadal Survey twice recognized the importance of understanding the cataclysm by recommending sample return from the South Pole-Aitken basin, which would enable high-precision measurements by complementary laboratory methods to resolve sample petrology and ages. However, it may be possible to understand the formation age of individual craters using in situ dating in a Discovery-class package. The Nectaris basin is a defining stratigraphic horizon based on relationships between ejecta units [10]. Although the Nectaris basin itself has experienced both basaltic infill and impact erosion, small “draped” deposits were identified as remnants of the Nectaris basin impact melt sheet [11]. For such a key basin, outcrops of recognizable, datable impact-melt rocks are a significant find.

Assessing the onset of the cataclysm using the age of the Nectaris Basin may require only coarse precision: if Nectaris were 3.9 Ga, we would infer a robust cataclysm; if 4.1 Ga (as suggested by some older samples), a more expansive epoch of bombardment would be allowable; if even older, there may have been no unusual spike in flux but rather a declining rate. These intervals can be recognized with ages ±200 Myr (or less), currently achievable with in situ techniques.

There is no PKT-compositional halo around Nectaris, so the impact-melt sheet should be aluminous and possibly slightly iron-rich. Such samples would be easily distinguished from KREEPy Imbrium and basaltic Mare Nectaris materials, which are likely to be present based on mixing models [12] and Clementine spectral data [11], though no changes were observed near small craters that would suggest compositional variability with depth in these units [11].

Mission Concept: A stationary lander could retrieve tens to hundreds of small (1-3 cm) sized rocks by scooping and sieving the regolith, similar to MoonRise [13]. Sieved samples would be characterized and prioritized using a microscopic imager and Laser-Induced Breakdown Spectroscopy (LIBS), which would be capable of distinguishing between KREEPy, basaltic, and aluminous samples. Samples of interest would be collected in a chamber for geochronology using LIBS to measure the K abundance and to release gases; mass spectrometry to measure the evolved Ar, and optical measurement of the ablated volume. These components have been flight proven and provide essential measurements (complete elemental abundance, evolved volatile analysis, microimaging) as well as in situ geochronology. Multiple laboratories have worked to advance and propose the LIBS-MS technique for planetary missions, including ours [14-16].

This mission concept would constrain the onset of the cataclysm by determining the age of samples directly sourced from the impact melt sheet of a major lunar basin, as well as understand lunar evolution by characterizing new lunar lithologies far from the Apollo and Luna landing sites, and provide ground truth for remote sensing measurements.

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