LUNAR IMPACT GLASSES AND BIOMOLECULAR CLOCKS.

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Introduction: With the confirmation of a large impact having occurred at the time of the global K/T mass extinction event [e.g., 1], the role of cosmic events in affecting the course of biological evolution on Earth, although previously hypothesized [2], was demonstrated, and has generated widespread, multidisciplinary interest [e.g., 3]. Links between other important biological events in Earth history with large impacts have been proposed, but remain less certain. The lack of an accurate, detailed impact chronology of the Earth-Moon system contributes to this current state of affairs. While major biological events during the Phanerozoic eon (≤ 542 Ma) are well-defined using the fossil record of macro-organisms, most of Earth's history with its biological evolution occurred before the Phanerozoic (> 542 Ma) remains poorly constrained due to the micro-scopic nature of the fossilized organisms.

Timetree: Molecular sequences of >1600 families of organisms define a 'Timetree' [4]. Using biomolecular clocks, divergence times of organisms throughout Earth's history are being mapped. As argued by Ryder [5] and others, biochemists now believe that life on Earth originated at ~4200-4400 Ma [6] (i.e., before the lunar cataclysm at ~3800 Ma). How many of the biodivergence events were preceded by large impact events?

Impact glasses: Mature lunar regoliths typically contain >100 clast-free, impact glasses in the form of either spherules or shards with dimensions >100μm per 5-gram sample. Many of these glasses contain sufficient masses of either K and/or U to be isotopically dateable using the $^{40}Ar/^{39}Ar$ [e.g., 7-9] and $^{206}Pb/^{238}U$ [A. Nemchin, pers. comm., 2010] methods. To define an accurate, detailed record of the time-dependent impact flux, lunar glasses of impact origin must be confidently discriminated from glasses of volcanic origin. Criteria for doing this successfully, which are principally chemical in nature [10], have been successfully applied [e.g., 11]. Without chemically analyzing each glass prior to an isotopic age determination, a set of ages will be contaminated by volcanic events. While lunar glasses with ages <2500 Ma are likely to be wholly impact in origin, a set of lunar glasses with ages >2500 Ma that had not been chemically analyzed are certain to contain ages of volcanic and impact events. That may have occurred in one study [e.g., 7] since >20% of glasses in some Apollo 14 regolith samples are of volcanic origin [12]. Therefore, while impact glasses are abundant in mature lunar regolith, and have a rich story bearing on the time-dependent impact flux in the Earth-Moon system, chemical and petrographic analysis of each glass prior to isotopic analysis is needed to ensure a clean record of impact events (uncontaminated by volcanic events). The chemical compositions of the impact glasses provide information about the source provenance, which is a useful context for interpretations [e.g., 9]. The sheer abundance of impact-generated glasses in the mature regoliths from the Apollo missions ensures that an accurate, detailed chronology can be developed. That impact chronology is beginning to emerge showing spikes in the impact flux during the Phanerozoic, which may correspond with those independently observed in meteorites [e.g., 13, 14] and terrestrial studies [e.g., 15, 16]. With concerted effort in measuring the ages of lunar impact glasses and in refining the Timetree, the Moon would be the Rosetta Stone for linking cosmic events with major biomolecular events during the last ~3800 Ma.

Conclusions: (a) Lunar impact glasses are capable of providing an accurate and detailed record of the time-dependent impact flux during the last 3800 Ma. **(b)** Since questions linked to Astrobiology will increasingly capture the interest of NASA and the public for future missions, lunar science should consider finding important linkages to Astrobiology. This abstract describes one example.

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