TERRESTRIAL METEORITES AS PRESERVERS OF EARLY BIOMARKERS: IMPLICATIONS FOR SELECTION OF GOLDEN SPIKE LANDING SITES.

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Introduction: The earliest isotopic evidence for life's emergence is generally placed around 3.8 Ga, which is around the same time as the Late Heavy Bombardment's (LHB) cessation. Interesting questions are whether and how many times life started during and following the LHB and if evidence exists to demonstrate life's extinction prior to its re-emergence (e.g. [1], [2]). The Moon provides a unique natural laboratory to address these questions: with its paucity of endogenic geological activity, it preserves a record of the bombardment history of the Earth-Moon system (e.g. [3]), including material delivered from Earth.

Early terrestrial meteorites may contain isotopic and/or microfossil evidence of Earth's earliest life and may be used to place constraints on mechanisms and timing of terrestrial abiogenesis (transition from chemical to biological evolution). Indeed, [4] predicts the survival near the lunar surface of terrestrial meteorites spanning a broad age range. [5] predicts 7 ppm of lunar regolith is composed of terrestrial contamination from meteorites. Here, I 1) explore selenological environments that are most likely conducive to such preservation and detection; and 2) recommend hardware for Golden Spike Missions.

Table 1. Criteria and search constraints for sampling early terrestrial meteorites, possibly containing biomarkers.

Criteria	Corresponding Constraint on Search
Ancient	Oldest landscapes
Preserved	Protected from impact gardening under volcanic deposits
Accessible	Shallow mare; therefore search near mare margins
	Recently exposed around young craters; therefore search near deepest ejecta near crater rim
	Newly exposed cryptomare in dark halo crater ejecta

Criteria: The oldest lunar terrains near crater saturation likely contain terrestrial meteorites though not likely intact nor concentrated in any appreciable quantity due to the extreme bombardment environment. To locate early terrestrial samples it is therefore necessary to formulate and follow a criteria set. The criteria in Table 1 seem reasonable for locating biomarker-containing early terrestrial meteorites in paleoregolith and/or cryptomare deposits that have been recently re-exposed ([4], [5], [6]).

Remote Sensing Campaign: A search conducted in remote sensing datasets could reveal mineralogies and lithologies specific to Earth (e.g., quartz/stishovite/coesite, carbonates, alkali feldspars, clays) or possibly Mars. If such deposits were found they would make natural choices for landed missions searching for and studying early Earth biomarkers in terrestrial meteorites.

Landing Site Case Study & Instrumentation: A logical search area would be mare since they date to the LHB and after. As such, they may sequester terrestrial material-bearing highlands crust. The southwestern portion of Oceanus Procellarum embays terra topography and is therefore likely shallow. Furthermore, isopach maps from [7] indicate a mare depth here of 0-500 m based on the extent of crater flooding. A small (~11 km), fresh, bright ray crater (8°S, 297°E) (Fig. 1) with smaller impacts on its continuous ejecta deposit satisfies Table 1's criteria: The ancient terra covered and preserved by the Procellarum lava flows is likely accessible in the continuous ejecta of the small crater, especially given that the cratering event appears to have exhumed bright terra material from below the mare. The preserved record would reveal histories from between the formation of mare basins to their subsequent flooding with lava.

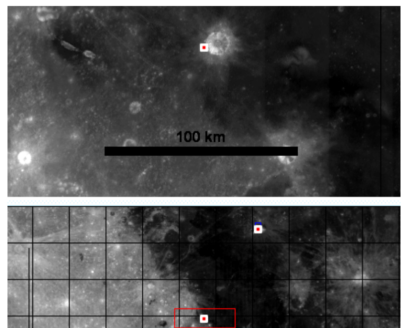

Fig. 1. Example of recently exhumed terra from beneath a shallow mare. SW Procellarum (8°S, 297°E). LROC WAC.

Perhaps two missions here would be justifiable to return biomarkers meteorites. The first mission would scout, using lander-mounted hyperspectral imaging to search for (if not previously identified from, say, M^3) obvious terrestrial material during landing. An Apollo 14-style Modular Equipment Transporter could be equipped with another hyperspectral imager to characterize mineralogies to sub-cm scales. After the hyperspectral data analysis—perhaps after the conclusion of the first sortie—a sample-return mission could retrieve candidate terrestrial materials, though the goals could conceivably be incorporated into one mission.

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