MAGNETIC SURVEYS TO PROBE THE LUNAR SUBSURFACE. J. A. Richardson[1,2], E. Bell[2], B. E. Strauss[1,3], N. C. Schmerr[2], J. R. Espley[1], D. A. Sheppard[1], P. L. Whelley[1,2], C. B. Connor[4], and K. E. Young[1]. [1]NASA Goddard Space Flight Center, Greenbelt MD 20771 (jacob.a.richardson@nasa.gov), [2]University of Maryland, College Park MD 20742, [3]NIST, Gaithersburg MD 20899, [4]University of South Florida, Tampa, FL 33620.

Introduction: When iron-rich igneous rocks like basalt cool in the presence of a magnetic field, they preserve records of the intensity and orientation of that field. Samples retrieved from the Moon's surface during the Apollo missions hold records of an ancient lunar dynamo field at least as strong as that of the present-day Earth [1]. The igneous rock population at the surface of the Moon spans nearly the entire history of the satellite (100 Ma to 4.5 Ga) and mare volcanism was primarily emplaced between 3-4 Ga [2], overlapping in time with a strong ~78 μT lunar dynamo field (~3.9-3.6 Ga) and a transition to a weaker (~5 μT by 3 Ga) dynamo [1,3] (Fig. 1). Modern magnetic field strengths measured *in situ* at Apollo sites range up to 327 nT [4].

Improved characterization of magnetized rocks of a variety of ages at the lunar surface would enable the creation of more rigorous timelines and dynamic models of the lunar dynamo. Mapping magnetized rocks on the lunar surface can also help prospect for exploration-enabling resources (ore deposits and void spaces) and clarify the emplacement history of igneous rocks based on magnetic anomalies from buried geologic units.

***In situ* Magnetic mapping of lava flows and void spaces:** We have performed magnetic surveys of lava flows and tubes on Earth with a magnetometer placed 2-3 meters above the ground on a non-magnetic pole on a walking researcher. In this operational setup, analogous to performing a lunar surface EVA survey, measurements are taken at a rate of 1-5 Hz and georeferenced.

Field analogs. Using a proton precession magnetometer over basalt lavas with little to no sediment cover, Bell *et al.* [5,6] mapped magnetic anomalies of >3000 nT created by the lava flow itself, including subterranean lava tubes (Fig. 2). Surveys by George *et al.* [7] using a Cesium-vapor magnetometer, found that lava flows buried 150 m by non-magnetic alluvial material can produce surface anomalies of > 400 nT.

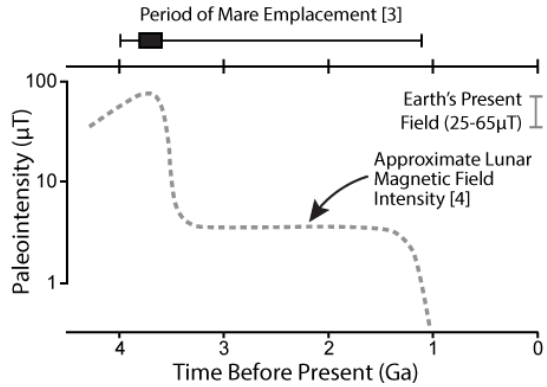

Figure 1. The lunar magnetic field has varied in intensity over lunar history. Times of change should be recorded by igneous rocks that erupted from 1.2-4 Ga.

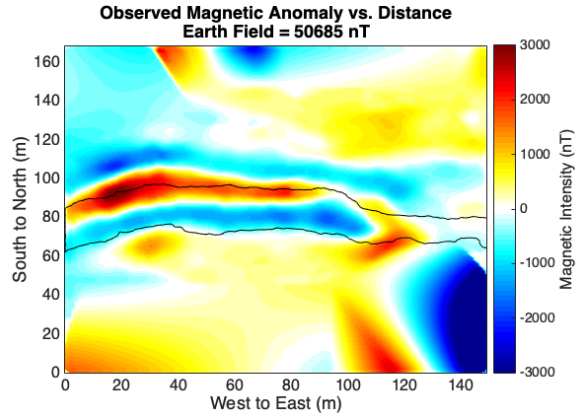

Figure 2. Magnetic anomaly maps can help identify buried structures like lava tubes. Skull cave (outlined in black; Lava Beds National Monument, California) can be visually identified on this magnetic map produced by [7].

Magnetometer instrument requirements on the lunar surface: Magnetic anomalies on the lunar surface may be similar in amplitude to anomalies detected in volcanic terrains on earth (100s to 1000s of nT). Although with no ambient dynamo field the total magnetic field strength is likely ≤ 1000 nT in most areas, and the primary source of the magnetic anomalies will be remnant magnetization of the rocks, . Fluxgate magnetometers are ideal for lunar geophysics exploration because of their ability to measure a large range of magnetic field values with a precision of ~0.1 nT or better, which is adequate to map magnetic anomalies of near surface igneous rocks on Earth. Care must be taken to provide as magnetically quiet an environment as possible in the presence of nearby electronic assets (e.g., suits, rovers). A prototype hand-held fluxgate magnetometer has been recently developed by the Goddard magnetometry group. A flight version of this would leverage Goddard's heritage of developing fluxgate instruments.

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