DETERMINE LUNAR CRUSTAL MAGNETIC FIELDS AND THEIR ORIGIN.

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Introduction: Solving the enigma of lunar magnetism, a major scientific surprise of the Apollo program, would provide fundamental insights into the thermal history of the lunar core/dynamo and crust, and into the physics of magnetization and demagnetization processes in large basin-forming impacts. This will require a focused program of high resolution mapping of crustal magnetic fields from orbit, together with surface magnetometer surveys of select regions and the return of oriented samples.

Value: Understanding lunar magnetism will provide a powerful tool for probing the thermal evolution of the lunar crust, interior and core; as well as the physics of large basin-forming impacts. These insights will certainly be applicable to Mars, which exhibits similar but much stronger crustal magnetism, and likely applicable to other terrestrial bodies and impact processes in general. Determining the distribution and properties of strong magnetic anomalies will clarify potential magnetic shielding benefits for co-located lunar bases.

Science Background: The Moon does not presently have an active core dynamo, but it (like Mars) has numerous localized remanent crustal magnetic regions of ~few to hundreds of km scale distributed over its surface, indicating the presence of strong magnetizing fields in the past [1,2]. Measurements of remanent magnetism on the Earth provided the crucial evidence for our understanding of the evolution of the Earth's interior and surface (e.g., sea floor spreading and plate tectonics), and understanding the processes responsible for lunar (and Martian) magnetism hold similar promise. Orbital mapping by Apollo 15 & 16 Sub-Satellites and Lunar Prospector magnetometers and electron reflectometers show strong surface magnetic fields in regions antipodal to the large impact basins of ~3.65-3.85 billion years age (while the basins themselves are weakly magnetized or un-magnetized) and in some of the ejecta from those impacts, suggesting shock remanent magnetization (SRM) by the high shock pressures, possibly together with amplification of ambient magnetic fields by plasma produced in the impact process [1,2,3,4]. Some measurements on Apollo returned lunar samples, however, suggest thermal remanent magnetization (TRM) acquired in a strong (of order ~1 Gauss) core dynamo magnetic field during the same era [5]. Resolving these puzzles and understanding the origins of lunar magnetism would provide the basis for unraveling the thermal history of the lunar core/dynamo and crust, as well as the physics of basin-forming impacts, both likely to be important at Mars as well.

Methodology: A focused program of targeted near-surface high resolution orbital measurements, surface magnetometer traverses, and returned oriented samples would allow a determination of the properties of surface crustal remanent magnetization, including the mode of remanence acquisition (shock, thermal, etc.), strength, age, direction and coherence - all required in order to understand the physics of crustal magnetization and the magnetic history of the Moon. Initially (this step could be performed immediately), a small lunar-orbiting spacecraft with magnetometers and electron and ion instruments could provide high spatial resolution mapping of the intensity and orientation of the crustal field by targeting low periselenes (<~15 km) over the key South Pole Aitken region, encompassing the strongly magnetized regions antipodal to the Crisium, Imbrium and Serenitatis basins, and preferably also a nearby demagnetized basin (Orientale) and two nearby basins with central magnetic anomalies (Moscoviense and Mendel-Rydberg). These measurements would be compared with surface geology in order to constrain the age distribution of crustal magnetism and quantify its relationship with impact basins, ejecta and antipodal regions. Later (during the early robotic phase and/or early human phase), rovers or humans would conduct magnetometer traverses over selected surface locations. Finally (during the human phase), oriented samples, from cores or deep craters, would be returned from key antipodal regions, mare basalts, magnetized ejecta, and large impact basins, for analysis.

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