

Present and Future Magnetic Exploration of Mars

The Mars Global Surveyor (MGS) magnetometer experiment has provided an intriguing data set with which to probe the planet's evolution. The discovery of intense crustal magnetism, dominantly present in the ancient southern highlands, confirms the existence of a global magnetic field in Mars' past, whereas no global internal field exists there today. These crustal magnetic field data are being used to probe the timing of the Martian dynamo, and to characterize the processes that created and modified the crust. We have analyzed the magnetic field data in conjunction with gravity data from the radio science investigation on MGS, as well as high-resolution topography from the MGS Mars Orbital Laser Altimeter (MOLA). The potential field data provide a perspective limited in spatial resolution to ~200 km for the magnetic field and ~400 km for the gravity field. Distinct variations in crustal properties within the Terra Cimmeria region of the southern highlands, where the most intense magnetic anomalies are found, are revealed by examining the ratio of Bouguer gravity to topography as a function of wavelength (admittance). These density and crustal thickness variations correlate with the magnetic anomalies. The thinnest, highest density crust is associated with the very intense positive anomaly centered at 50S, 178E. Modeling of the magnetic anomaly pattern in Terra Cimmeria, guided by the density/thickness constraints from the admittance study, indicates that the positive anomalies drive the pattern, favoring a contrast between positively magnetized regions and non-magnetic (or uniformly magnetized) crust within the regions of observed negative anomalies. Two possible scenarios to explain this result are demagnetization of previously-magnetized crust within the region of negative anomalies, or acquisition of magnetization in the regions of positively magnetized crust subsequent to the major phase of crustal formation, which would have formed prior to the dynamo initiation. The absence of magnetic anomalies in vast regions of the southern highlands argues for the latter scenario, indicating that the initiation of Mars' dynamo may have been delayed relative to the initial cooling phase, similar to the Moon's evolution. The presence of anomalies in the northern lowlands and on the Tharsis Rise argues for a prolonged period of dynamo activity, extending perhaps to 2 Ga. The resolution limit of the magnetic field prevents an understanding of the true magnetism of the Martian crust and hinders interpretation of the magnetic anomaly record. Therefore, future exploration of the magnetic field of Mars must obtain high-resolution data to test hypotheses posed using the MGS data, and to search for high frequency anomalies that may correlate with surface geology that is dated by crater-counts, in order to refine the magnetic field history. We advocate a balloon aerial platform as an efficient and technically feasible approach to provide these data at the same resolution as a ship on the Earth's ocean.