GEOLOGY OF NOACHIAN MARTIAN HIGHLANDS SURROUNDING THE GUSEV CRATER

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Introduction: About 40% of the total Martian crust consists of heavily cratered Noachian highland crust older than 3.7 Ga. Only one of the Martian meteorites found so far is derived from these old terrains. The ALH84001 orthopyroxenite meteorite contains carbonate blebs, which may contain evidence for ancient life on Mars in the form of biogenically produced magnetite grains and reduced carbon [1,2]. The pyroxenite itself was dated at ~4.5 Ga, whereas the carbonate blebs were dated at ~4 Ga. These ages indicate that this meteorite originated from the Martian Highland area, and therefore provides the unique "ground truth" of the Martian highlands. Part of the Martian highlands, centered on 180°, exhibits large magnetic anomalies. However the origin of the magnetic anomalies remains enigmatic.

In 2004, one of the MER Lander Spirit landed in the Gusev crater, which lies in the northern part of the highlands that contain the remanent magnetization. To characterize the highland areas neighboring the landing site craters we study the available visual and IR image data (THEMIS, MOC), TES spectroscopy data and MOLA altimetry data. In addition, we plan to use Mars Express HRSC data from and early Spirit flyover.

The Gusev Crater highlands: Gusev crater is situated at 155 degrees latitude and 15 degrees south of the equator, within the highlands.

This part of the Martian highlands exhibits large magnetic anomalies (Figure 1). The Martian anomalies are much larger in size than terrestrial ocean floor magnetic anomalies (200 x 2000 km per "stripe") and the magnetization is about an order of magnitude stronger than Earths crustal magnetization [4]. Several alternative hypotheses have been proposed to explain these anomalies, including folding, hydrothermal alteration, dyke intrusion and accretion of terrains. However, Viking and THEMIS images of the magnetic area do not show any large scale geological features that my explain the magnetic anomalys. It is interesting to note that Gusev crater itself does not show a magnetic anomaly. This may be the result of impact shock demagnetization. That would suggest that Gusev crater formation postponed the decline of the Martian dynamo. Alternatively, the magnetic anomaly may reside in the uppermost Martian crust that was ejected from the crater during the Gusev impact.

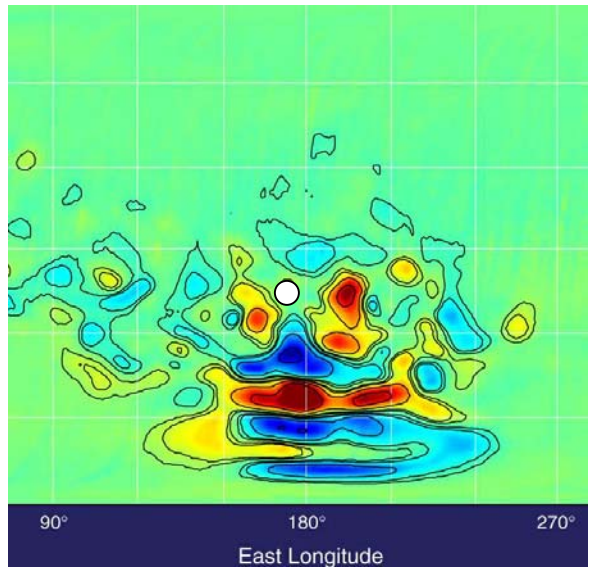

Figure 1: Part of the global map of Mars radial magnetic field at 200-km altitude [3]. The Gusev crater is situated in the northern part of the area with strong magnetic anomalies. However, the crust at Gusev Crater itself, represented by the white dot, does not show any remanent magnetization.

In 2004 two Landers are planned to study large impact craters that straddle the boundary between the Martian highlands and the northern lowlands. The Beagle 2 will land in Isidis Planitia and one of the Mars Exploration rovers, called Spirit, will land in Gusev Crater. The Spirit landed successfully in January, but contact was lost with the Beagle 2 after descent to Mars. The Lander will perform geochemical analyses of rock samples that occur as boulders in the impact crater. Whether or not water is or was present in these Lander areas is crucial to the question of the presence of traces of past or extant life. The epithermal neutron flux measured with the Neutron Spectrometer on Mars Odyssey [5] indicates the presence and distribution of water in the Mars surface. The Gusev crater and surrounding highlands appear to be rich in water with up to 8 wt% water. Water may be present as ice in a rock ice mix, or it may be present as hydrothermally bound water in for example clay minerals.

On the other hand, the beagle 2 landing site appears to be part of a relatively dry area with only 2 wt% water.

No in-situ outcrops of basement rocks are expected within the landing site craters, but the boulders are likely to have been derived from the surrounding highland terrains.

To characterize the highland area neighboring the Gusev crater we study the available visual and IR image data and MOLA altimetry data.

The highlands around Gusev crater are characterized by a plateau of most likely basalt [6]. The most conspicuous features in the highland plateau are impact craters. Towards the northwest of Gusev crater the plateau is transformed into a chaotic terrain, with lower altitude. The basalt plateau rises about 2000 m above the crater basin.

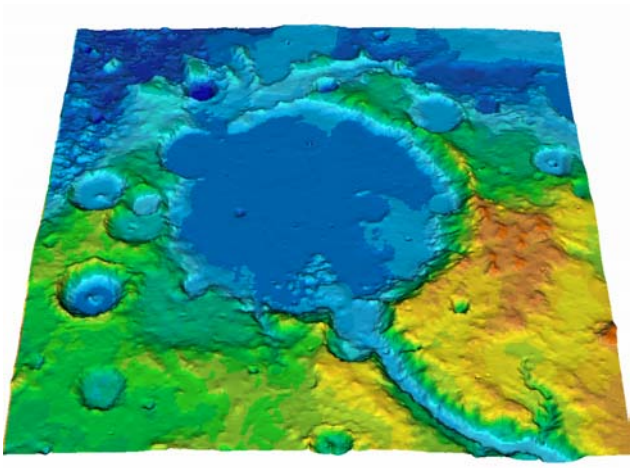

Figure 2: MOLA topography of the Gusev area. The base of the Gusev crater is at approximately –2000 m, whereas the basaltic plateau is at +50 m.

Discussion: The highlands around the Gusev crater may be considered as a typical source area for the ALH84001 meteorite: hydrothermally altered mafic/basaltic plateau of great age (high impact density) with deep impact (2000 m deep) structures. Hydrothermal alteration may have been related to meteorite impacts or volcanic structures. Hydrothermal systems related to impacts are a likely response to the energy of the impact and brecciation of the target rock in an area where water is present in the subsurface or at the surface. Although large meteorite impacts on Earth are usually though to be associated with mass extinctions, impact sites may represent an ideal site for the evolution of early life on Earth, and potentially on Mars. The impact results in a depression that fill with a standing body of water if water is available. The brecciation of target rocks results in a porous host rock with a large subsurface water-rock interface that can provide sheltered conditions for early life. In addition, hydrothermal circulation after the impact provides an energy sources in analogy to black-smokers on the ocean floor. In combination, whenever water is available, large impact sites provide ideal conditions for early life to develop.

Data from the Spirit Mars Exploration Rover in Gusev Crater, combined with higher resolution and stereo images (HRSC) and hyper spectral data (OMEGA) from Mars Express, will make a geological interpretation of this area possible in unprecedented detail.

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