NOACHIAN MARTIAN HIGHLANDS: THE HABITAT OF ANCIENT LIFE?

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Abstract
About 40% of the total Martian crust consists of heavily cratered Noachian crust (older than 3.7 Ga), also called the Martian highlands. To date, only one of the found Martian meteorites is derived from these Noachian highlands, the so-called ALH84001. The antiquity of the ALH84001 meteorite indicates that it originated from the Martian Highland area, and that these highlands may have been the habitat of ancient Martian life.

The part of the Martian highlands centered on 180° exhibits large magnetic anomalies. However the origin of the magnetic anomalies remains enigmatic and it is not clear yet what the relation is between magnetite in the meteorite and the magnetic anomalies.

In 2004, one of the MER landers, called Spirit, will study the Gusev crater which straddles the boundary between the Martian highlands and the northern lowlands. 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. This provides a geological framework in anticipation of lander geochronological analysis of rock samples.

Introduction
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 (Gibson et al., 2001; Weiss et al., 2000). 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.

The Gusev Crater highlands
Gusev crater is situated at 185 degrees west longitude 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 Earth's crustal magnetization (Acuna and al., 1999). 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 may explain the magnetic anomalies. It is interesting to note that Gusev crater itself does not show a magnetic anomaly. This may be the result of impact shock demagnetization. This would suggest that Gusev crater formation postdated the decline of the Martian geodynamo.

Figure 1
Hemispheric projection of the global map of Mars radial magnetic field at 200-km altitude (Connerney et al., 2001). Situated at 175 deg East and 15 deg South, the non-magnetized Gusev crater, indicated with a star, is surrounded by areas of strong magnetic anomalies.

In 2004 two landers will 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 the Spirit MER rover, will land in Gusev Crater. Both landers should perform geochronological analyses of rock samples that occur as boulders in the impact
craters. Beagle-2 is to look for current and fossil signs of life. Whether or not water is or was present in these lander areas is crucial to the question of the presence of traces of life. The epithermal neutron flux measured with the Neutron Spectrometer on Mars Odyssey (Boynton et al., 2002) 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 hydro-thermally 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 (Bandfield et al., 2000). 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 basal 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. A possible hypothesis is that early Martian life could have developed in this habitat. Data from the upcoming 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 possible of this area in unprecedented detail.

References