Paul Withers

Were slopes on Mars once flat? - Systematic Deviations of “Flat” Martian Features from an Equipotential Surface

Abstract

On Mars, the northern lowlands and floors of the two largest impact craters were thought to be flat. New data has shown them to have a systematic slope with respect to an equipotential surface. This suggests that the martian geoid has changed over time. Studying this change will constrain the geophysical evolution of Mars.

Proposal

The Mars Orbiter Laser Altimeter (MOLA) aboard the Mars Global Surveyor spacecraft is revealing the topography and gravitational field of Mars in unprecedented detail [Smith et al., 1998; Zuber et al., 1998; Smith et al., 1999]. NASA-Goddard staff control MOLA.

The shape of Mars can be approximated by a triaxial ellipsoid, the centre of which, called the centre of figure, is offset from the centre of mass by ~ 3 km in the direction of the south pole. Due to this offset, the global topography of Mars, given with respect to an equipotential surface called the geoid, is dominated by a systematic south-to-north slope of 0.036^o, giving the south pole a higher elevation than the north pole by ~ 6 km [Smith et al., 1999]. Centre of mass – centre of figure offsets on the order of 1 km are also found in Venus, Earth, and the Moon [Bindschadler and Schubert, 1993]. Various hypotheses have been offered for their existence, including variations in crustal thickness and asymmetric crystallization of a primordial magma ocean [Neagu, 1992 and references].

The martian surface is divided into heavily cratered highlands in the southern hemisphere and lightly cratered plains in the northern hemisphere. The southern highlands contain two large (1000 km size) impact craters, Hellas and Argyre. It has been known since the Viking missions that the floors of these two craters are approximately flat with respect to the geoid. This would make these crater floors equipotential surfaces, as would be expected from the crystallization of a huge melt sheet followed by infill of erosional debris. A large portion of the northern hemisphere, the northern lowlands surrounding the north polar cap, is also approximately flat with respect to the geoid and very smooth. It has been suggested that these northern lowlands are the site of a large impact or the bed of a vast ocean [Smith et al., 1998]. If the impact hypothesis is correct, then the same reasoning as above would explain their flatness. If the ocean hypothesis is correct, then sedimentation would explain their flatness.

Using data currently proprietary to its Science Team, MOLA has discovered that these features are not flat with respect to the geoid. They are not equipotential surfaces. Instead, they are flat with respect to the ellipsoid representing Mars’s figure [Smith, 1999]. This is most unexpected. There is every reason to believe that they were flat with respect to the geoid at their time of formation. It suggests that the current figure of Mars was once (but is no longer) an equipotential surface.

Significant changes in the martian geoid require significant changes in the geophysical structure of Mars, changes such as the formation of the large volcanic province of Tharsis or the hemispheric dichotomy. The history of the geophysical structure of Mars is not well constrained. What are the slopes of the floors of other large craters? Are there systematic changes with crater size or age? Is the entire floor of the proposed northern ocean at the same slope, or do some parts have slightly different slopes? Answering these questions and studying the present topography of other features which were flat with respect to the geoid at the time of their formation will provide some constraints.

What of other terrestrial bodies? Clementine data can be used to examine whether lunar features are flat with respect to the geoid, and Magellan data can do the same for large Venusian craters. New Galileo data may be able to constrain gravity and topography well enough to investigate the Galilean satellites.

Aims

Quantify the slopes of "flat" features on Mars. Use these results to constrain the shape of past martian geoids. Use history of martian geoid to constrain major geophysical events on Mars. Compare with Venus and the Moon.

Rough Timeline

Pre-Goddard	Review literature on MOLA instrument and published dataset
Week 1	Introduction to NASA-Goddard and proprietary MOLA dataset
Week 2	Reproduce Smith (1999) results for Hellas, Argyre, and northern lowlands
Weeks 3/4	Investigate topography of other martian features expected to be flat
Week 5	Examine results for correlations with size, age, etc.
Weeks 6/7	Investigate geophysical implications of results
Weeks 8/9	Extend investigation to Venus and the Moon after literature search
Week 10	Complete report

References

Bindschadler and Schubert, 1993, 24th Lunar and Planetary Science Conference, 109
Neagu, 1992, Meteoritics, **27**, 267
Smith, 1999, in the 5th International Conference on Mars, Pasadena
Smith et al., 1998, Science, **279**, 1686
Smith et al., 1999, Science, **284**, 1495
Zuber et al., 1998, Science, **282**, 2053

This proposal is written without clear knowledge of what the MOLA team are doing with their proprietary data and hence may be somewhat behind their unpublished work. Maria Zuber suggests that Dave Smith, or another member of the MOLA team, may be a suitable mentor.