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The Influence of Volatiles on Impact Craters in Arabia Terra, Mars

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Abstract

Arabia Terra, Mars, is a unique region where water and ice have influenced the evolutionary history of the region. We are conducting a study of how surficial and subsurface volatiles have affected the formation and subsequent modification of impact craters within Arabia Terra. We find that some crater morphologies are present throughout the region while others are limited to certain areas of Arabia Terra. These results are helping us to constrain the types and timing of H_2O-related processes which have affected this Martian province.

1. Introduction

Arabia Terra consists of the largest expanse of heavily cratered terrain in the northern hemisphere of Mars. The western part of the province displays some of the lowest elevation of any heavily cratered material on Mars while the eastern region is similar in elevation to the rest of the highlands. The ~25-45 km crustal thickness of the western part of Arabia is the thinnest of any heavily cratered region on Mars and has led to the suggestion that Arabia is the site of an ancient basin, perhaps of impact origin, which has been heavily modified by subsequent events. Arabia has a higher albedo and lower thermal inertia than the surrounding highlands, consistent with orbital observations of thick dust deposits which may be volcanic in origin [1]. Neutron Spectrometer analysis indicates that Arabia Terra is enriched in H_2O within the upper 1-2 m, with concentrations ranging from 2 mass % to 16 mass % [2]. Elemental and mineralogic analysis suggests that water has played a major role in the modification of Arabia Terra since its formation during the Noachian period (see references in [3]).

Impact craters in Arabia Terra display a wide variety of morphologies which collectively are not seen in any other single region of the planet. Some of these morphologies are primary and provide insights into target properties at depths greater than those investigated by remote sensing instruments. Other craters display the effects of post-formation modification. This study is classifying the interior and ejecta morphologies of impact craters in Arabia Terra and investigating the role of H_2O in the formation of these morphologies.

2. Methodology

This study is cataloguing all impact craters ≥1-km-diameter within the Arabia Terra region located north of the equator (~0-40°N, 330°E-85°E, exclusive of Syrtis Major Planum). We are using Mars Odyssey Thermal Emission Imaging Spectrometer Visible (THEMIS VIS), Mars Reconnaissance Orbiter (MRO) Context Camera (CTX), and MRO High Resolution Imaging Science Experiement (HiRISE) data to classify the crater morphologies. Diameter and latitude/longitude information is obtained using ArcGIS tools. Among the morphologies included in our database are:

- Layered ejecta blankets, generally considered to be produced by impact into subsurface volatiles [4].
- Central pits, believed to be produced by interactions with target volatiles during crater formation [5].
- "Terrain softening", the relaxation and creep of crater features due to ice in the target material [6].
- Nested craters ("inverted sombrero craters"), produced by impact into a weak layer overlying a stronger layer [7]. The nested crater morphology has been observed in terrestrial marine impact craters and has been proposed to support the theory of oceans/seas on Mars [8].

- Inverted craters, formed when the crater has been filled with deposits which undergo compaction and the surrounding area is subsequently removed.
- Scalloped or serrated rims, produced by erosional processes in structurally weak materials.
- Lineated floor deposits, suggested to be ice-rich glacial deposits [9].
- Chaotic floor textures, suggestive of removal of underlying volatile-rich material.

Once the morphologies are compiled, we import the information into ArcGIS and investigate the distributions of these features relative to location, elevation, geologic unit, composition, etc. Crater depths also are being determined using MOLA and shadow estimates to estimate the amount of crater modification/infilling which has occurred. Size-frequency distribution analysis will be conducted to constrain the timing of the specific geologic processes.

3. Results

To date, we have added over 5700 craters in the 1.0-5.0-km-diameter range to our existing impact crater database in Arabia (which contains ~6000 craters ≥5.0-km-diameter) and have classified the morphologies of over 3000 craters. Our analysis is on-going, but we already are seeing some trends:

- Layered ejecta blankets and central pit craters (both floor pits and summit pits) are found throughout the Arabia Terra region, suggesting that subsurface volatiles are common throughout the region and have been present for extended periods of time.
- Craters with lineated floor deposits are concentrated in the northern part of the province, consistent with their formation by ice deposited during high obliquity periods. A few examples of crater floors covered with polygonal terrain have been identified in the same region.
- Craters with serrated rims are more common in the southern part of the province, indicating weaker materials in this area.
- At present, we see no correlation of nested craters with lower topography regions which may have been covered by shallow oceans or seas.

As the analysis continues, it will provide new insights into the extent and timing of geologic processes involving surficial and subsurface volatiles in Arabia Terra.

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