ICEBERGS ON EARLY MARS. A. G. Fairén[1,2], A. F. Davila[1,2], D. Lim[1,2] and C.McKay[2]. [1] SETI Institute, 515 N Whisman Road, Mountain View, CA 94043, USA. [2] Space Science and Astrobiology Division, NASA Ames Research Center, Moffett Field, CA 94035, USA. Email:alberto.g.fairen@nasa.gov

Introduction: The flat, smooth and featureless topography of the Martian lowlands has been equated to an ancient ocean basin [1 and references therein]. Recent HiRISE images have revealed the presence of meter-sized boulders and crater-like strusctures scattered throughout the northern plains [2]. They are difficult to reconcile with the notion of fine-grained sediments deposited in a deep ocean basin. This has been used to cast doubts on the concept of an ocean on Mars [2]. Here we show that the presence and distribution of boulders and other morphological features in the northern lowlands are consistent with iceberg transport and grounding, a common terrestrial process.

HiRISE observations:

1. Boulders: The boulders are distributed at quasi-uniform densities throughout the entire lowlands, including the Vastitas Borealis Formation (VBF) and Isidis and Utopia Basins. The size (from 0.5 to ~2 m in diameter) and number of boulders are difficult to explain considering liquid water transport mechanisms: there are no visible features suggesting dragging or surface transport of rock fragments. McEwen et al. [2] suggested that the boulders may have been excavated and exposed through impacts or periglacial processes.

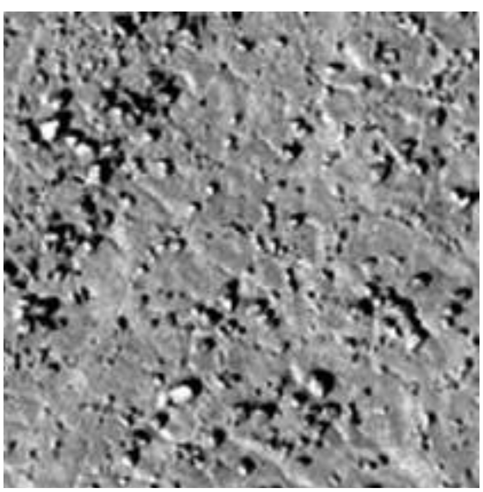

Fig. 1: Meter-scale boulders. Image TRA_000846_ 2475 centered at 67.0° N, 0.0° E.

2. Dump structures: Dark boulder clusters are revealed at large scales by their slightly darker tonality with respect to the surrounding terrain. These clusters have sizes ranging from several hundred meters to 1-2 km, and are irregularly shaped, from almost circular, to highly elongated or totally amorphous. At smaller scale, the clusters are characterized by a high density of relatively large boulders. The near circular dumps have a relatively shallow profile and lack any evidence of impact ejecta blankets or other features commonly associated to impact craters, such as ground deformation, concentric rims or central pits [3,4].

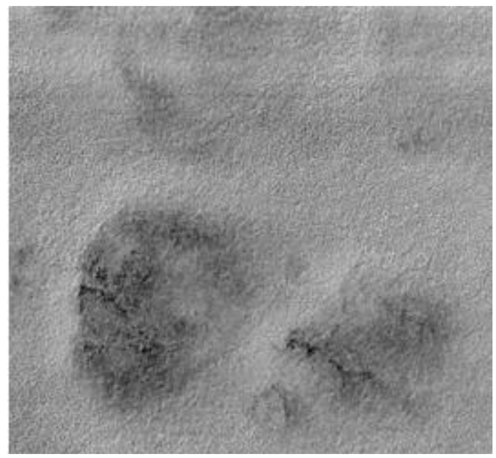

Fig. 2: Dark regions with a high concentration of boulders.

3. Chains of craters: High-resolution images of Utopia and Isidis Basins also reveal chains of crater-like structures several hundred meters wide and 1 to 5 km long. These structures are relatively shallow when compared to neighbouring isolated craters, and have straight contours and a strong anisotropic orientation. Some of the crater-chains contain up to 15-20 circular or elongated depressions with diameters ranging between 100 and 400 m., a similar size and shape, and are interconnected or superimposed.

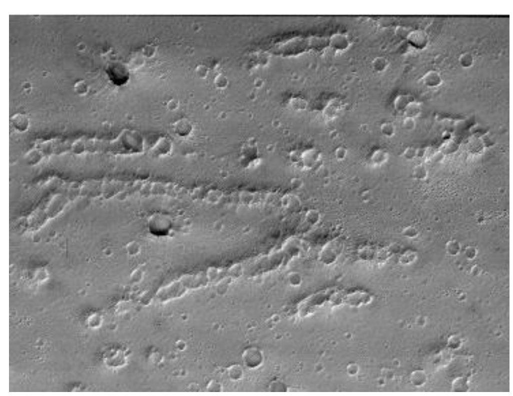

Fig. 3: Chains of crater-marks in Utopia Planitia.

Icebergs in ancient oceans on Mars: We propose that the occurrence and distribution of boulders, clusters and craters in the northern lowlands could be attributed to the effects of iceberg-rafted rock fragments, eroded by glaciers in the highlands and transported towards the lowlands during times when the plains were covered by large bodies of standing and very cold water.

1. Boulders: On Earth, continental glaciers intensively erode the terrain and transport large rocks on their surface, and within the ice flowing. Icebergs form as a result of glacier melt and break up, and are released into the ocean, where they can be transported thousands of km before they disappear. As icebergs melt, rock fragments ranging in size from sand to boulders are deposited on the ocean floor [5,6,7].

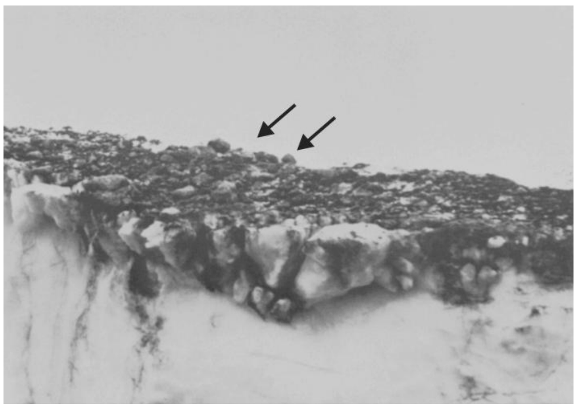

Fig. 4: Photograph of an overturned iceberg. Sediment grain size ranges from large boulders approximately 0.5 m. diameter (arrows) to cobbles, pebbles and fines. From [7].

2. Dump structures: On Earth, when an iceberg anchors on the ocean floor due to a sudden decrease in sea level or to local topography, it discharges its rock cargo in a relatively constrained area, resulting in localized clusters of rock fragments [8]. Dumps may also form by the breakup and overturning of boulder-laden, floating icebergs and the consequent release of large amounts of debris to the bed. [9,10].

3. Chains of craters: Iceberg rafting on Earth also generates characteristic morphologies in the ocean sediments, including crater marks that remain imprinted on the deep ocean-floor for extended periods of time [6,7]. Iceberg crater marks and pits form on the seabed as response to impact and loading by a rolling and grounding iceberg [6,8]. The vertical motion of the iceberg due to wave action induces the excavation of a crater several tens of meters in diameter [6]. Occasionally, iceberg-generated craters form in linear associations or in chains, with neighbouring craters being interconnected, superimposed or separated approximately 20-30 meters. These chains form as icebergs ground and roll due to wave motions and ocean currents [6]. Documented iceberg-generated crater chains on Earth show that crater shape and size vary between different chains, but are similar between craters in the same chain. Most crater marks have lips or berms and the crater depths typically do not exceed 2-3 m [6], although single iceberg-generated craters can reach depths of up to 10 m [11].

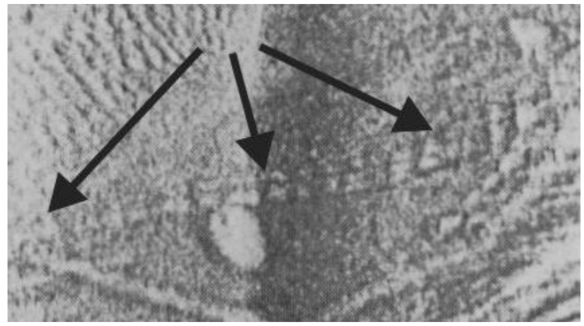

Fig. 5: Part of a sidescan mosaic from Saglek Bank showing a chain of iceberg-induced double-craters. From [6].

Conclusions: All the morphological features highlighted by HiRISE are consistent with the effects of iceberg rafting and grounding in cold, large and long-lasting bodies of liquid water in the northern plains. Our analysis also imply the occurrence of continental glaciers forming in the highlands and streaming northward towards the lowlands, and towards the Hellas and Argyre Basins. Large armadas of icebergs formed at the glaciers termini would then have created boulder pavements all over the Martian lowlands. Our interpretations support the idea of a “cold and wet Mars” [12], characterized by a global hydrosphere governed by ice-semicovered oceans and seas, glaciers, icebergs and massive polar caps, similar to the Polar Regions on Earth.

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