GLACIAL LANDFORMS IN IUS CHASMA, MARS – INDICATORS OF TWO GLACIATION EPISODES.

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Introduction: Ius Chasma is one of twelve depressions constituting the trough system of Valles Marineris located in the equatorial area of Mars. The chasma experienced multiple processes which enlarged, carved, and modified its walls and floors, including tectonic, eolian, and mass-wasting processes, as well as water erosion, glacial erosion, and ponding sedimentation. The mapping procedures performed on the basis of CTX image mosaics led to the development of detailed geomorphological classifications of over fifty landforms and features recognized in the trough [1]. The abstract presents cartographic results from survey of depositional and erosional features of glacial origin.

Study area: Ius Chasma is the largest trough in the western part of Valles Marineris. The trough displays length of ~850 km, width up to 120 km, and depth locally exceeding 8 km. Two parallel, E-W trending valleys of Ius Chasma are separated by Geryon Montes which is a 270 km long, ~5 km high, and up to 26 km wide inner ridge. It is a border between two grabens constituting northern and southern sub-basins. The most distinct geomorphological features located in the chasma are extensive sapping channel systems [2], huge landslides [3, 4], abundant spur-and-gully wall morphology [5], light-toned layered deposits on the plateau south of the trough [6], and glacial features in central [7, 8] and western areas of Ius Chasma.

Data and methods: The geomorphological map of Ius Chasma was drawn on the basis of 100 panchromatic MRO Context Camera images (CTX), supplemented predominantly by MRO High Resolution Imaging Science Experiment images (HiRISE) and MGS Mars Orbiter Laser Altimeter data (MOLA). The map was produced in GCS Mars 2000 Sphere coordinate system and plate carrée projection (equirectangular projection). The map generation procedure was divided into three major steps, i.e. image gathering (JMARS), image processing and mosaicking (ISIS), and geomorphological mapping (ArcGIS). The entire process was composed of twenty individual steps, predominantly performed in ISIS The spatial resolution of resultant CTX images was decreased from 6 to 12 m/pixel which optimized the mapping procedure in ArcGIS software. The prepared set of CTX images was subsequently divided into three mosaics (western, central, and eastern) covering the total area of over 375 000 km^2. The map of Ius Chasma [1] is available in the scale of 1:260 000 and contains 86 048 km^2 of mapped units.

Glacial eorisonal and depositional features in the central area of Ius Chasma were descriped in detail in [7, 8]. Here, this classification has been expanded and adjusted after detailed visual survey of CTX images conducted in the scale of 1:10 000. The glacial depositional landforms in the western part of the trough were mapped on the basis of comparative studies performed between terrerstial and martian landforms and presented here for the first time.

Results: The glacial history of Ius Chasma is visible in two areas. The central part of the trough contains trimlines, basal escarpments, and benches which are associated with valley glaciers which were once present in these localities. The western area of Ius Chasma is filled with extensive glacial deposits which flowed into the trough from Noctis Labyrinthus.

Central area. Trimlines, marking the maximum glacier height, appear in numerous places of northern and southern grabens in the central part of Ius Chasma [7]. They display a total length of 408 km. In many localities, trimlines constitute a border between basal escarpment (*Be*) and flat-lying higher bench (*Bh*). Higher benches appear as either relicts of ancient valley infill which was vastly removed by glaciers, or relicts of glacier deposits which preserved near walls. They have been recognized in seventeen areas displaying a cumulative area of 536 km^2. Higher bench surfaces are located at relatively uniform elevations in the range from -2200 to -1800 m. They exhibit either smooth or hummocky morphologies, which might indicate that the aforementioned scenario of glacier relict ice is more probable. In one location (at 7°28'S, 83°37'W), a higher bench is covered by landslide deposits of *small coarse* morphology [9].

Western area. The western part of Ius Chasma is covered with widespread deposits of glacial origin. They flowed into the trough from Noctis Labyrinthus, where extensive, smooth, and cracked landforms resemble large ice relicts and blocks. The Ius glacial features are interpreted as moraines (*Gm1* and *Gm2*), till plains (*Gtp*), and outwash plains (*Gop1* and *Gop2*). In addition, three smaller areas appear as patterned grounds (*Gpg*) – all presented in Fig. 1.

The first moraine type (*Gm1*) is located near the western border of the map and continues westward, beyond the map extent. *Gm1* unit, within the mapped section, covers an area of 315 km^2 and displays four curvilinear ridges, interpreted as a part of larger termi-

nal moraine. The second moraine type (*Gm2*) occurs to the south, where irregular and gentle deposits cover a mapped area of 703 km^2. They display no ridges, but instead exhibit a few rounded and elongated shallow depressions resembling kettle holes, which in terrestrial conditions are developed by retreating glaciers. The *Gm2* unit is interpreted as a ground moraine.

In two areas, glacial materials appear as smooth surfaces, locally cracked and disintegrated. They might be till pains (*Gtp*) composed of partially degraded ice, covered with sediments. The northern mapped *Gtp* area occupies 291 km^2 and possesses one, rectangular and relatively large plate of putative ice, bordered by linear, stretched cracks. The southern till plain area (379 km^2) displays a slightly different morphology. Its smooth surface is cracked in oval manner which highlights the central, extensive, but shallow depression. The formation of depression might have been caused by inner ice melting by e.g. localized internal heating.

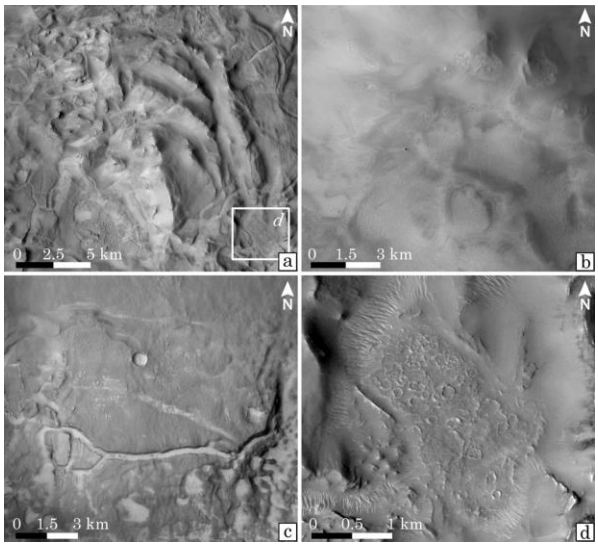

Figure 1. Glacial deposits in the western area of Ius Chasma: (***a***) moraine deposits of *Gm1* unit with curvilinear ridges, interpreted as terminal moraine, (***b***) moraine deposits of *Gm2* unit with gentle surfaces, interpreted as a ground moraine, (***c***) till plains in the northern part of glacial area with a large platy landforms interpreted as a relict ice covered with sediments, (***d***) patterned ground of circular morphology; CTX images no.: (***a***, ***b***, ***d***) P05_003079_1714_XN_08S091W, (***c***) P13_006125_1738_XN_06S091W; images centered at: (***a***) 6°09'S, 91°51'W, (***b***) 7°21'S, 91°39'W, (***c***) 6°13'S, 91°30'W, (***d***) locality indicated in Fig. 1*a*

The supplementary landforms in this area are outwash plains. They developed by meltwater outwash localized below the glacier terminus and display rough morphology. There are mapped two types of this feature. The first type (*Gop1*) contains either numerous depressions resembling kettle holes (in the northern area), or linear streaks on the surface implying water flow (in the southern area; centered at 7°34'S, 91°29'W). The second type of outwash plains is present only in the northern area, in the distal part of glacial deposits. These outwash plains appear as a lobate landform, which was partially covered with material transferred from *Gop1* unit. The deposits of the first and second outwash plains occupy areas of 671 and 142 km^2, respectively.

The western glacial region contains also three areas of patterned grounds. They display rounded surface depressions, which strongly resemble terrestrial features developed under periglacial conditions. Rounded depressions are ~100-150 m in diameter and appear to be strictly limited to flat surfaces of clearly recognizable boundaries.

Conclusions: Ius Chasma is especially important for the hypothesis of glacial processes in Valles Marineris, because not only the trough has been the entrance for glacier bodies flowing from Noctis Labyrinthus, but also is a host of layered deposits, trimlines, and basal escarpments within both grabens, which imply that the glacial evolution was not limited to the main, northern passage. The southern Ius graben displays evidence of glaciation up to the longitude of 83°44'W, where last basal escarpments are visible. The area located west of this place is filled with features of lacustrine origin.

Although the main glacier which flowed from Noctis Labyrinthus and so profoundly changed the morphology of Valles Marineris eventually retreated, younger glacial deposits originating from the same source area are still visible in the westernmost part of Ius Chasma. Lateral and ground moraines, till and outwash plains, and patterned grounds occur in the western trough. These materials flowed from huge blocky deposits located in Noctis Labyrinthus. These large blocks might still contain ice, mixed rock and dust. Repeated growing and thawing of glaciers indicates cycles of glaciation which could have been affecting Valles Marineris since ancient times. The periods of intervening glaciations and deglaciations are the result of obliquity cycles [10].

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