CHAPTER 4 ILD OBSERVATIONS IN VALLES MARINERIS AND CHAOTIC TERRAINS

ILDs have been found and analysed in locations in Valles Marineris and in the chaotic terrains that lie east of Valles Marineris, from 18°S/309°E to 5°N/343°E. Ganges and Capri/Eos Chasma are related to chaotic terrain and outflow channels as well (Sect. 2.4). Even within the Valles Marineris, ILDs are enclosed by chaotic terrain. ILDs are often found in the form of erosional remnants as mesas or buttes (Sect. 2.4.3, 2.5). Exposures in the Ganges and Capri Chasmata as well as in Aurorae, Arsinoes, Aureum, Aram, and Iani Chaos (Fig. 28) were analysed in this thesis.

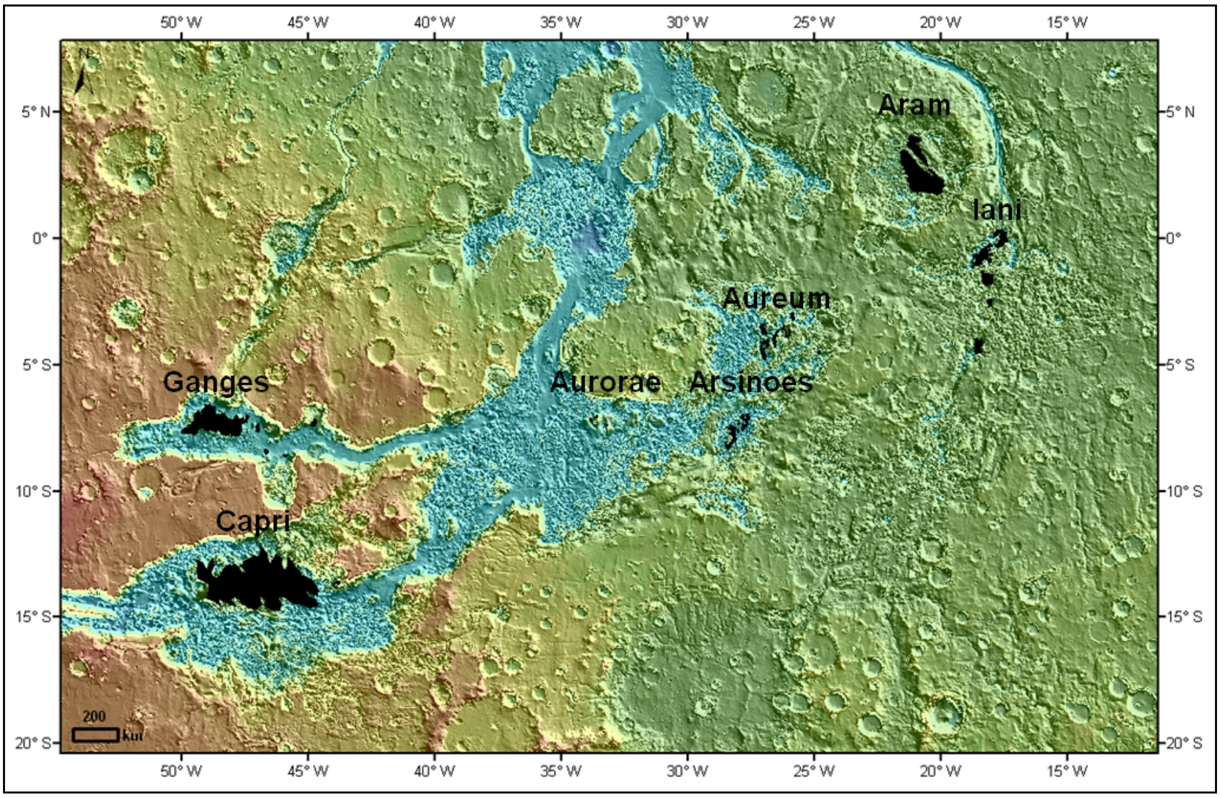


Figure 28: MOLA map of the research area. The research area is located in the eastern Valles Marineris and the Margaritifer Terra chaotic terrains. ILDs that are found and analysed are marked black and are situated between 18°S/309°E to 5°N/343°E.

4.1 CHAOTIC TERRAINS

4.1.1 Aram Chaos

Aram Chaos (3°N/338.8°E) is a 280 km-wide circular structure that is located between the Ares Vallis outflow channel to the east and Aureum Chaos, and Iani Chaos (Fig. 28). The ILD material measures 120 by 140 km and is located near the crater centre (Fig. 29). Elevation ranges from -3700 m to -2900 m (Fig. 31C).

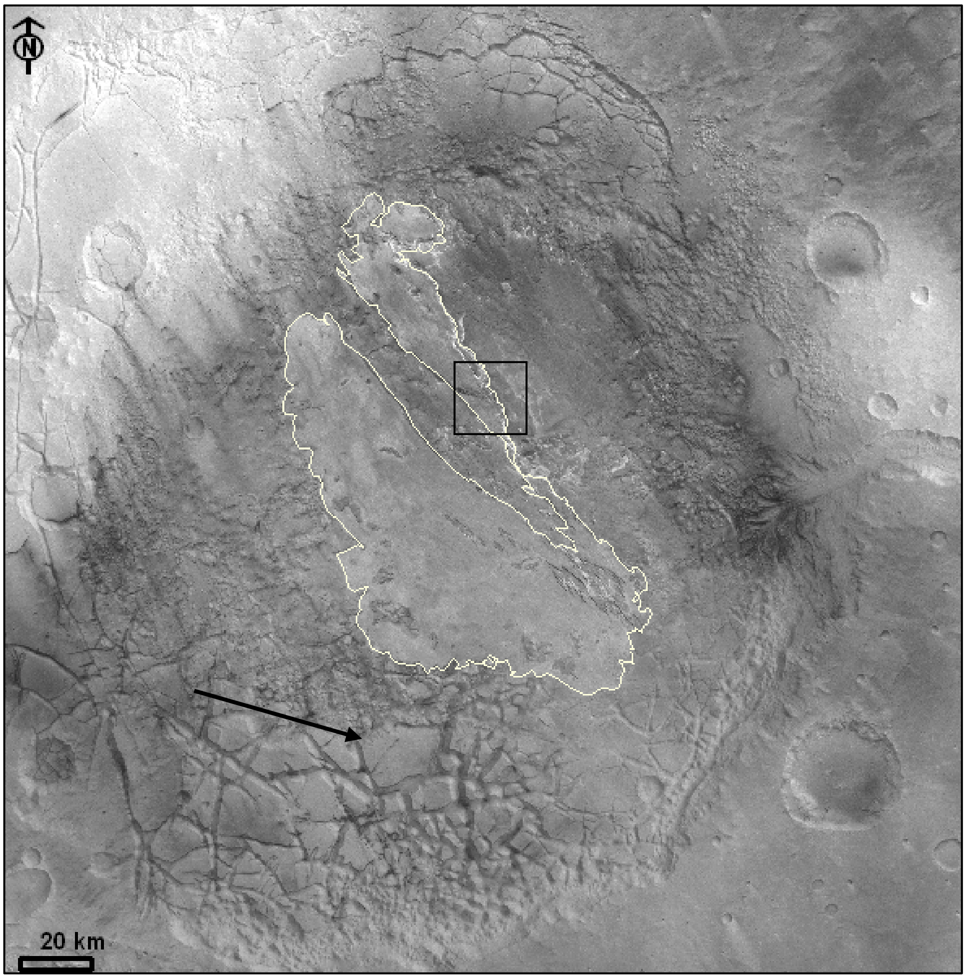


Figure 29: Aram Chaos impact crater (centred 3°N/338.8°E) exhibiting ILD material superimposed on heavily disrupted chaotic terrain. To the east, there is a gorge that empties into Ares Vallis (Fig. 28). ILD is outlined in white, chaotic terrain is indicated by an arrow. Box shows Fig. 30A.

The ILD is characterised by the parameters shown in Table 9. Aram Chaos features a cliff-forming NW-SE striking exposure of ILD material crossing the chaotic terrain near the centre of the crater (Fig. 29). The ILD has been eroded into mesas and buttes superimposed on the chaotic terrain which dominates the crater floor. The youngest unit in Aram Chaos is dark aeolian material which is deposited on flat parts of the ILD top (Fig. 30A, 31A) causing the low relative overall albedo of this ILD. Erosion was extensive throughout the whole ILD as the overall surface is heavily pitted and grooved. Besides, erosional windows are present on the ILD top that reveal its stratigraphy of disrupted chaotic terrain below a horizontally cap unit.

The cross-section (Fig. 31E) indicates the dome-like structure of the ILD. Corresponding to the morphology of mesas, the ILD features steep scarps (10-30°; Fig. 30A) and a flat top (2-10°). Scarps show high albedo (Fig. 31A, 31B) but look massive and pitted (31A). Besides, talus and boulders are often present (Fig. 31A).

From its morphology, two different units can be distinguished within the ILD (Fig. 31C). The lower unit (unit 1, Fig. 31A) exhibits steep scarps (Fig. 30A) with a higher albedo (Fig. 31A) than the upper unit. It comprises a thickness of 300 m (Fig. 31C, Table 9).The upper unit (unit 2; Fig.31C) appears rough and fractured. It features a lower albedo and a surface structure characterised by vugs and that are bounded by sharp crests and provide insights into lower layers (Fig. 30C, 30D, 31D). The unit is a cap rock that exhibits dark windblown material in surface depressions. Unit 2 features a stair-stepped morphology indicating material of different consolidation (Fig. 31D). Its thickness was estimated as 500 m (Table 9). The surface structure on top looks like it has been affected by dilution, dewatering or degassing. Unit 1 is mostly capped by unit 2, but there are also capless areas (Fig. 31B). This is the case in the eastern part of the ILD (Fig. 29, 31B). In these regions unit 1 appears smoother due to dark mantling (Fig. 31B). These areas are also highly affected by erosion and eroded into small mesas (Fig. 31B) as there is no protecting cap unit. This might also explain their lower TI, which is comparable to that of the surroundings.

Overall weathering has affected both units, as is demonstrated by the presence of boulders and talus (Fig. 31A, 30C, 30D). The yellowish material in the false colour images corresponds to the ILD (Fig. 30C, 30D). Bluish colours mainly represent dark windblown material (e.g. sand) of mostly mafic composition [*Mustard et al.*, 2005] and often formed into ripples. These are located in surface depressions that act as traps (Fig. 31A). The brownish material which covers many areas is likely to be more fine-grained, e.g. dust. Talus has a slightly different colour from the ILD material, which may be due to dust cover or even the fine-grained material eroded from the ILD itself. Meter-sized yellow-coloured boulders (3-5 m) are visible nearby (Fig. 31A). Dark talus shows on steep slope as smooth dark material while more light-toned boulders at the base are visible in HiRISE-colour images (Fig. 30C).

Kieserite and PHS (Sect. 3.2.2) were found by OMEGA (Sect. 3.1.7), whereas TES/THEMIS (Sect. 3.1.5, 3.1.6) mapped haematite (Sect. 3.2.2) along the fresh, light-toned eroded ILD cliffs [*Gendrin et al.*, 2005; *Glotch and Christensen*, 2005; *Glotch and Rogers*, 2007; *Noe Dobrea et al.*, 2008] belonging to unit 1 (Fig. 31B, 31C). Haematite is stratigraphically found below the sulphates at the base of scarps and is assumed to be eroded out of unit 1 [*Mangold et al*, 2007]. Unit 2 – the cap rock unit (Fig. 31C, 31D) - is haematite-free. The place where sulphates were detected is a region of very low albedo due to a cover of dark aeolian material, located east of the unit 1-unit 2-sequences (Fig. 31E). It is heavily eroded and features small mesas (Fig. 31B). As mentioned above, the sulphate-rich unit is a heavily eroded unit 1 that lacks unit 2. Sulphates lack in the central part of the ILD (Fig. 31E). This may be explained because this area is heavily affected by rock break-up (Fig. 31A) and it lacks a protecting mantling unit. Therefore, the eastern part might indicate an area in which material was reworked. *Rossi et al.* (2008), estimated a Late Amazonian age (Table 3) of 0.03-0.07 Ga for the eastern, sulphate-bearing part of the ILD (Sect. 2.4.3, Fig. 11). Strike and dip were not measured, as layering is not traceable all around the ILD (Sect. 3.2.3).

Table 9: Parameters of Aram ILD.

Morphology	Relative Albedo	Elevation [m]	Thickness[1] [m]	Consolidation of Materials	Mineralogy	Layer Geometry
Mesa, dome-like profile	Low[1]	-3700±25 to -2900±25	Unit 1: 300±25 unit 2: 500±25	High TI[2] TI: Ø 461 SI ±50 (surrounding: Ø 372 SI±43) BT: 185-193°K (surrounding: 175-185°K) boulders and talus present	Kieserite + PHS within unit 1, haematite below unit 1 as erosional lag	-

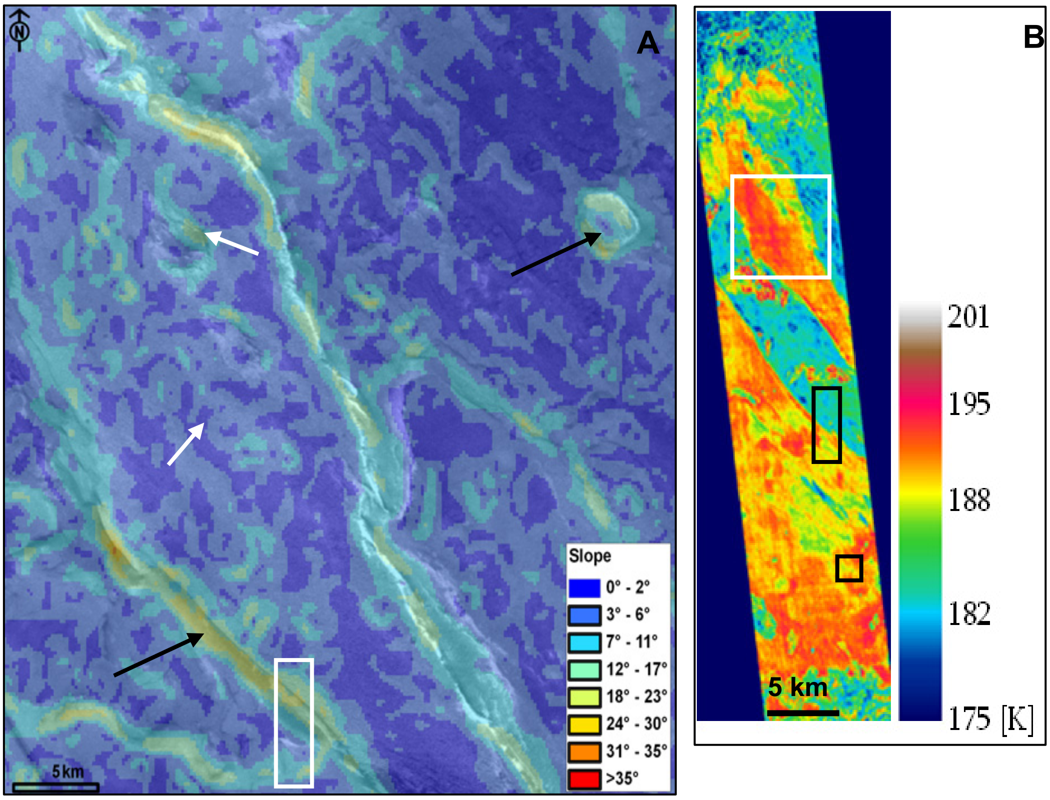
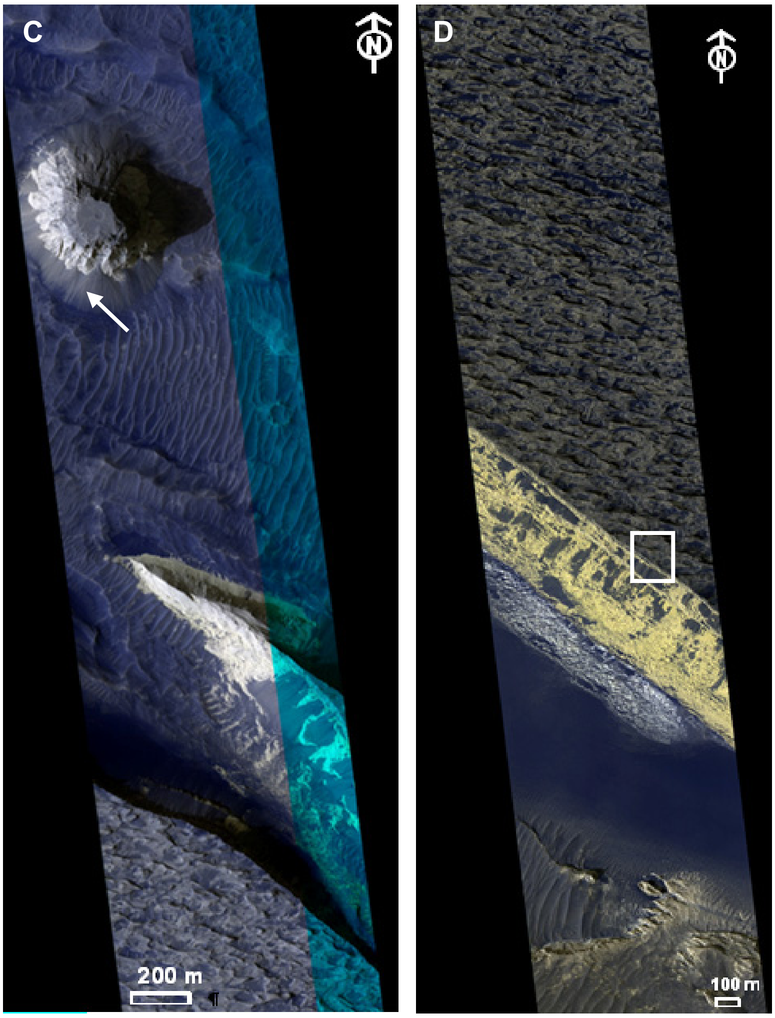


Figure 30: Properties of Aram Chaos. (A) Slope map of Aram Chaos. For context, see Fig. 29 (box) and Fig. 30B (white box). Steep (10-25°), high albedo scarps are present below a flat (0-2°) top demonstrating mesa morphology (HRSC orbit h0401_0001; 3.4°N/339.2°E). Steep scarps (black arrows) mark unit 1 (Fig. 31A). The few steep regions (8-15°; white arrow) on top are due to erosion and weathering that carved grooves and pits into the surface. Box shows Fig. 30D. (B)THEMIS BT (orbit I02404002RDR; Ls = 34.5 →N-spring) is situated at 185-193 K (Table 7). Note cap unit (unit 2; Fig. 30C, 30D, 31A, 31C, 31D) shows highest BT but no sulphate (Table 7). White box shows Fig. 30A, large black box corresponds to Fig. 30C, small black box to Fig. 30D.

[1] section 3.2.1
[2] section 3.2.2



(C) Detail shows ILD eroded into mesa and butte (3.2°N/339.2°E). For context, see Fig. 30B. Windblown material almost covers the whole ILD material. Especially the rough cap unit appearing in brown-bluish colours shows coverage of dust and other dark windblown material trapped there. Cliffs demonstrate freshly eroded yellowish ILD material (unit 1). The butte in the northern part shows talus all around the scarps, indicated by the white arrow (HiRISE false colour orbit PSP_002839_1825). Its top looks smoother as the cap unit lacks. (D) ILD material (yellowish-tan colours) seems heavily eroded as it exhibits depressions on top – cap unit - possibly caused by wind erosion in which dark windblown material is trapped (bluish colours). For context, see Fig. 30B. Brownish colours mostly represent dusty material that caps the ILD top and settles on other features (HiRISE false colour orbit PSP_003617_1835). Box shows Fig. 31A.

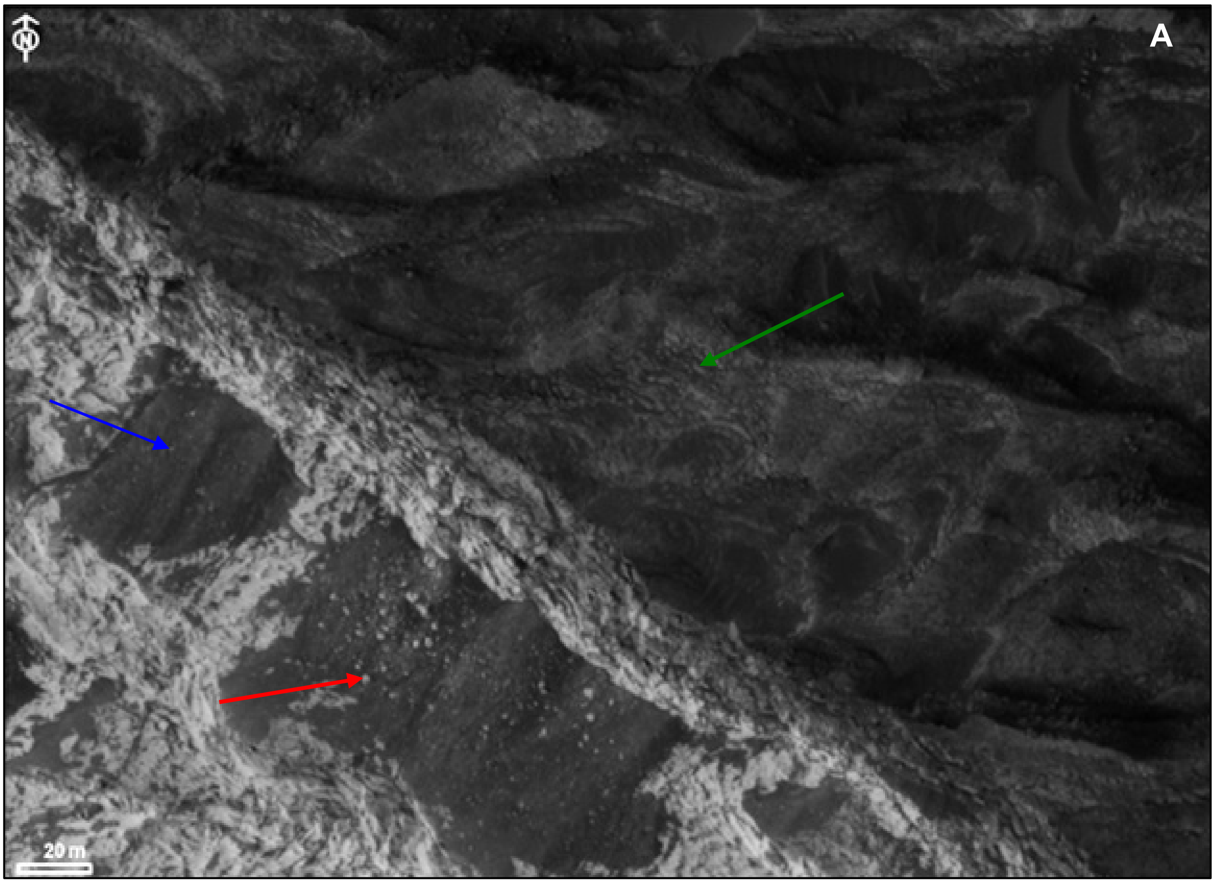
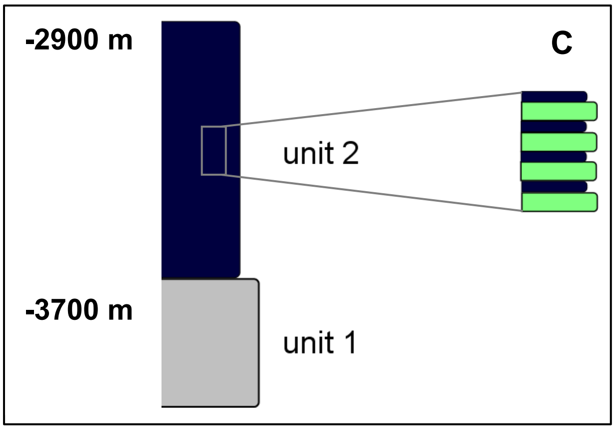
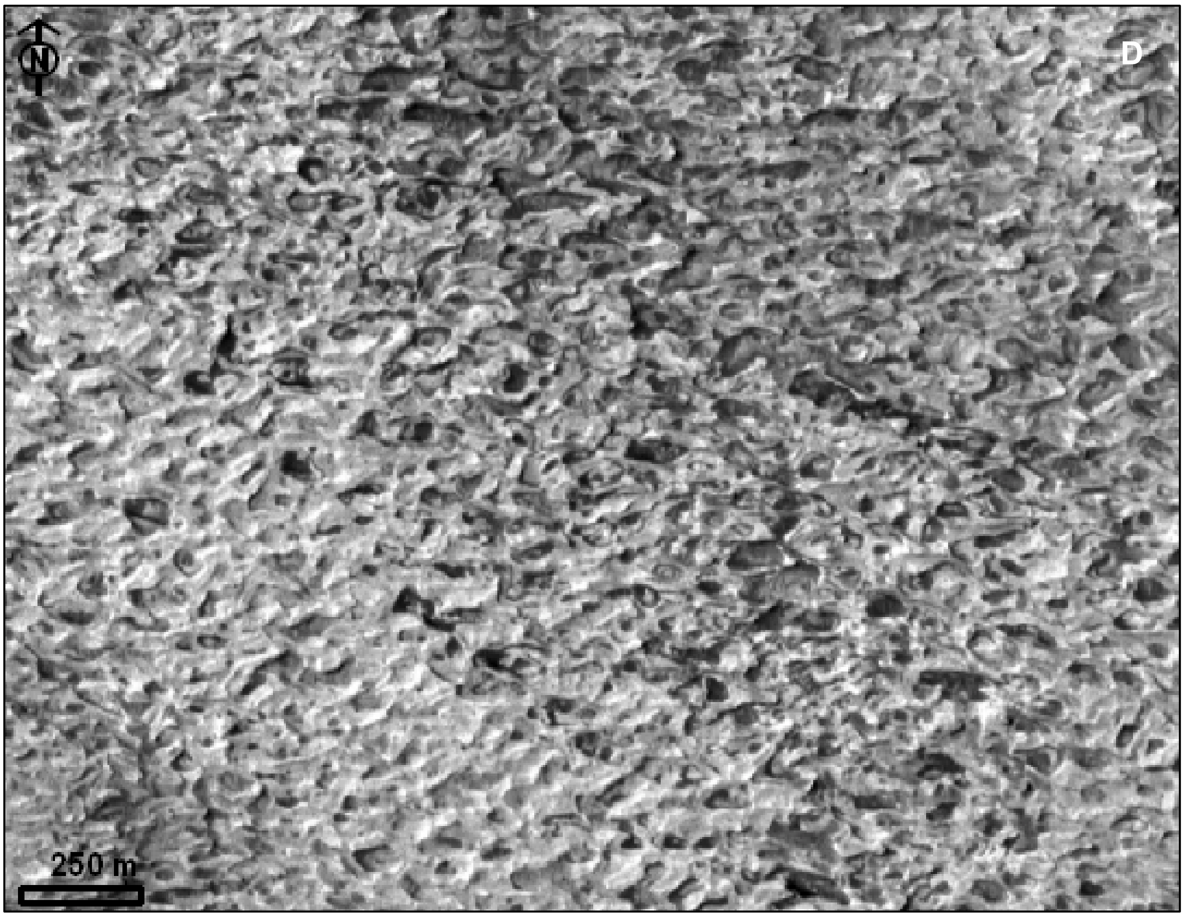


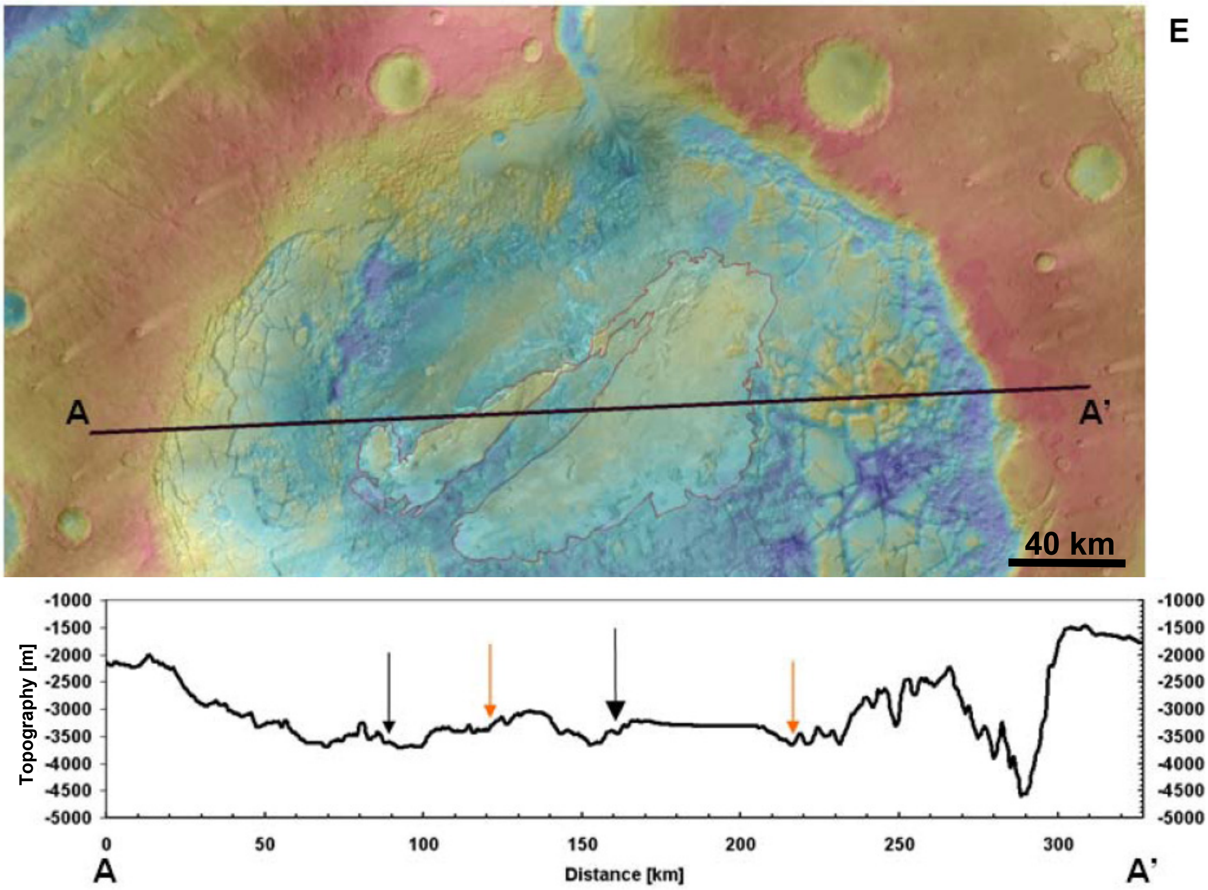
Figure 31: Identified Aram Chaos units. (A) Unit 1 shows a higher albedo and steep scarps exhibiting dark talus (blue arrow) and light-toned 3-5 m-sized boulders (red arrow). Unit 2 features a low-albedo surface. Surface vugs indicate underlying strata. Even unit 2 shows coarse-grained material (green arrow) either indicating rock break-up due to advanced weathering or grain-size corresponding to boulder (HiRISE orbit PSP_003617_1835; 2.9°N/339.4°E). For context, see Fig. 30D. (B) Low-albedo unit 1 exposure located ~5 km east of Fig. 30A indicating the region of sulphate detection. Here, the top of unit 1 is smoother because there is no unit 2. Unit 1 is heavily eroded into mesas and pitted. The ILD surface shows a low albedo (HiRISE colour image orbit PSP_002272_1835, 3.3°N/339.4°E).



(C) Thickness profile of Aram. Two units were distinguished within the ILD (Fig. 30C, 30D, 31A). A massive, cliff-forming, high-albedo unit (unit 1) with a thickness of 300 m and a distinctly layered heavily grooved and pitted unit that shows a lower albedo (unit 2) and a thickness of 500 m. Unit 2 features a stair-stepped morphology indicating material of different consolidation (Fig. 31A, 31D). In areas where parts of unit 2 are missing, unit 1 features a low-albedo top with small mesas (Fig. 31B). Kieserite and PHS were found within unit 1 and haematite was found below as erosional lag. The profile stretches across the ILD in Fig.31E.



(D) The top of unit 2 (cap rock unit) is heavily affected by erosion and weathering. For context, see Fig. 30B. The top is dissected by vale-like structures that are bounded by a sharp-edged resistant material causing a rough surface. These vale-like structures reveal underlying strata unless not covered by dark aeolian material. This structure on top appears affected by dilution, dewatering or degassing (MOC orbit E2000998, 2.7°N/339°E).



(E) *(top)* HRSC DTM (orbit h0401_0001) overlain onto nadir indicating the course of the profile. *(bottom)* NS-trending profile showing ILD material between arrows. Black arrows show the extent of the area in which kieserite, PHS and haematite were detected, which is coincident with a heavily eroded unit 1 (Fig. 31B). Red arrows mark the area of the unit 1-unit 2 sequence (Fig. 31A). Accuracy: Distance ±0.175 km, topography ±25 m (HRSC DTM orbit h0401_0000, 2.9°N/339.1°E).