

Ganges 2:

The ILD (7.4°S/313.1°E) is located in the eastern Valles Marineris (Fig. 2, 10), in Ganges Chasma (Fig. 28), east of Ganges 1 (Fig. 52). Ganges 2 shows a N-S strike, measures 22 by 8 km and is situated at -4700 m to -4000 m.

It features a streamlined morphology and a dome-like cross-section (Fig. 54B, 54C). A huge accumulation of dark material partially formed into dunes surrounds the ILD. Its western and northern side are partially frayed, with sharp borders at the southern side. Erosion must have come from the east because the material there seems more eroded and shows a sharp border. The western part seems flat, unlike the conspicuously steep (south-) eastern scarp (Fig. 54E).

The ILD is characterised by the parameters shown in Table 18.

The overall relative albedo is high (Sect. 3.2.1). The upper part shows a higher albedo than the lower part. The top looks rough and massive. Loose dark aeolian material covers surface depressions that are mainly located at the top while in steeper regions dark ripples wander downslope along fractures, causing apparent lineation.

The ILD can be subdivided into two units (Fig. 54F). The lower part (unit 1) appears slightly darker and shows layering on HRSC and MOC NA images (Sect. 3.2.1). On a HiRISE-scale, the unit looks pitted (cf. Sect. 5.1) and laminated strata can be observed (Fig. 54D). Dark aeolian material is trapped on bedding planes. It is exposed from -4700 m to -4200 m (estimated thickness 500 m). The upper unit (unit 2, Fig. 54D, 54F) shows a higher albedo and is finely layered, which is visible in HiRISE (Sect. 3.1.4, 3.2.1; Fig. 54D). On MOC-images the top appears massive comparable to cap units elsewhere but shows in detail undulating strata (Fig. 54D). The surface shows pitting, flutes and grooves (cf. Sect. 5.1). It is exposed from -4200 m to -4000 m (estimated thickness 200 m; Table 18).

On the whole, the ILD is light-toned and looks freshly eroded. The upper part that appears massive and rough and shows a fractured surface of a lighter tint than the slightly darker lower part, as can be seen on HRSC and HiRISE false colour images (Fig. 54D). Unit 1 features breakage structures indicating enhanced weathering. Besides, the units differ in consolidation, as suggested by the slope angles (Fig. 54E). Nevertheless, it shows gradient-related weathering since material erosion and transport intensifies in steeper regions. Unit 2 exhibits monadnocks, indicating that erosion affected this unit differently, and that the material is inhomogeneous.

The TI is intermediate (Table 18) and suggests either cemented or rocky material (Sect. 3.2.2). Talus and boulders are observed on the steeper eastern side. The slightly laminated unit 1 shows there is alternating strata of more incompetent material and more competent that breaking into talus and boulders (Fig. 54D).

Unfortunately, this ILD is spectrally neutral to CRISM [Roach and Mustard, 2008] although the surface is hardly covered by aeolian material and appears freshly-eroded. Spectrally neutral means the material shows no iron or hydration features, carbonates or nitrates in the required spectral range (Table 8; Sect. 3.1.8). Thus, spectrally neutral minerals might be other sulphates (e.g. anhydrite), halite or sylvite, or even silica (plagioclase) that show no absorptions in the VNIR. In the vicinity (Ganges 1), sulphates were detected (kieserite and PHS).

Layering geometry measurements were not performed as layering is not clearly traceable all around the ILD (Sect. 3.2.3).

Table 18: Parameters of Ganges 2.

Morphology	Relative Albedo	Elevation [m]	Thickness [m]	Consolidation of Materials	Mineralogy	Layer Geometry
Streamlined, dome-like-profile	High	-4700±12.5 to -4000±12.5	Unit 1: 500±12.5 unit 2: 200±12.5	Intermediate TI TIØ: 385 SI ±51 (surrounding: 308 SI±43) no BT-data talus and boulders observed	Featureless in the spectral range of CRISM	-

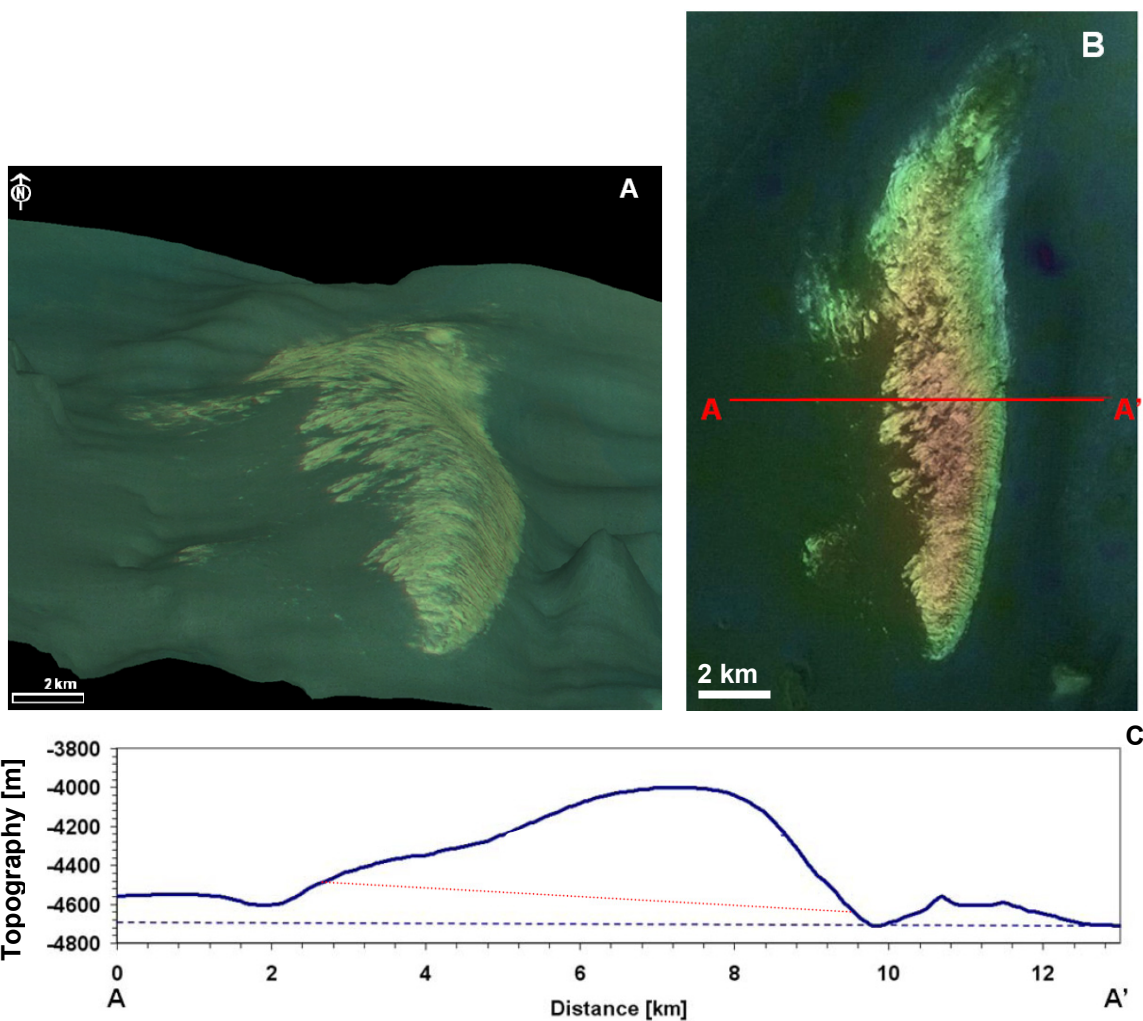
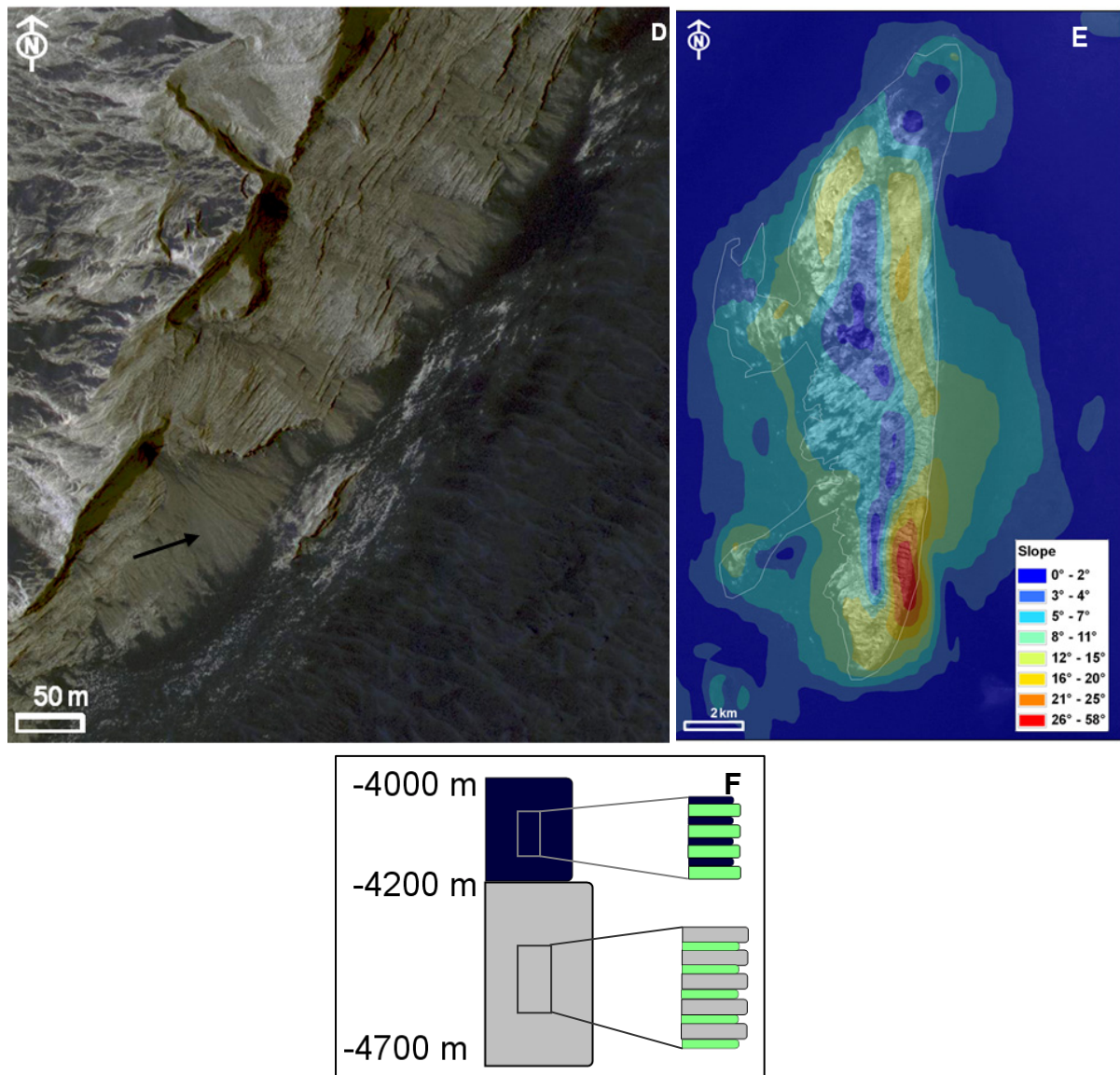


Figure 54: Characteristics of Ganges 2. (A) HRSC perspective view (h2178_0000; exaggeration factor 3; 7.4°S/313.0°E) showing the freshly eroded ILLD surface that is partially covered by windblown material (cf. 53D). (B) Location of W-E trending profile shown in 54.3 (HRSC orbit h2178_0000). (C) Profile showing the exposed ILLD (Fig. 54B). The extent to the ground is unknown, indicated by a blue line. Material above red line is exhumed and visible on HRSC images. Accuracy: Distance ±0.1 km, topography ±12.5 m (HRSC DTM orbit h2178_0000).



(D) HiRISE false colour image (PSP_005952_1725; 7.4°S/313.0°E) showing both units. Note the similarity in tint between talus (arrow) and unit 1 as well as differences in layering and steepness (cf. 54E). The tone of the material cropping out below unit 1 seems similar to that of unit 2. Unit 1 shows laminated strata and unit 2 undulating strata as observed in Aureum 2, Iani 2, Arsinoes and Aurorae (cf. Sect. 4.1.2-4.1.5). (E) MOLA slope map (7.4°S/313.0°E) illustrating the distribution of scarps which are areas of higher BT and mostly free of aeolian coverage (cf. Fig. 54A, 54D). (F) Thickness profile illustrating ILD is observed within -4700 and -4000 m. Two units were distinguished. Unit 1 shows laminated strata and a lower albedo than unit 2 which shows small-scale layering that partly is undulated (cf. Fig. 54D).

Ganges 3:

This ILD (8.4°S/313.3°E; cf. Fig. 52, 28) consists of four high-albedo blocks that are supposed to have been connected and later separated by erosion and weathering and/or mass wasting. The whole extent is 6 by 6 km. The ILD is situated at -4700 m to -3700 m. It shows a streamlined morphology. The surface features marked fractures and evidence of wind erosion. The blocks display possible slumping especially southern and northern blocks, indicating consolidated or rock material. In the lower parts, the material seems layered while the upper parts are massive on HRSC and MOC scale (Sect. 3.2.1).

The ILD is characterised by the parameters shown in Table 19.

The overall albedo is high (Sect. 3.2.1), but there are albedo differences between the lower and upper part of the ILD. However, HiRISE images confirm that there is small-scale layering even in the massive-looking upper part of the ILD.

Two units have been distinguished. Unit 1, the lower unit, features lower albedo, steep scarps, laminated strata and a higher BT (Table 19, Fig. 55A, 55C, 55E). Unit 2 –the capping unit– is characterised by a higher albedo and a flat surface which appears massive and exhibits flutes and grooves (Fig. 55E; cf. Sect. 2.3.1, 5.1) but shows undulating strata in parts. Unit 1 is exposed at an elevation of -4700 m up to -4300 m (thickness: 400 m) and unit 2 from ~-4300 m up to -3700 m (thickness: 600 m, Fig. 55F).

Dark talus is visible on the N, E, and S slopes (Fig. 55A). Talus production (Fig. 55A) is favoured by physical weathering (e.g. fracturing by release of pressure, thermal weathering). As no HiRISE images are available, the presence of boulders is not certain but assumed from similarities to Ganges 2. TI is high overall (Table 19) indicating rocky or highly consolidated material (Sect. 3.2.2, 5.5).

False colour images confirm that the ILD is yellowish, whereas dark sandy material appears green-blue and dust brownish and likewise talus (Fig. 55A). There is no CRISM coverage in this region.

Layering geometry was not measured because the layering is not clearly traceable all around the ILD (Sect. 3.2.3).

Table 19: Parameters of Ganges 3.

Morphology	Relative Albedo	Elevation [m]	Thickness [m]	Consolidation of Materials	Mineralogy	Layer Geometry
Streamlined, dome-like profile	High	-4700±12.5 to -3700±12.5	unit 1: 400±12.5 unit 2: 600±12.5	High TI TI ϕ : 498 SI±61 (surrounding: 387 SI±66) BT: 195-204°K (surrounding: 184-198°K) talus observed	No data, 2 units identified	-

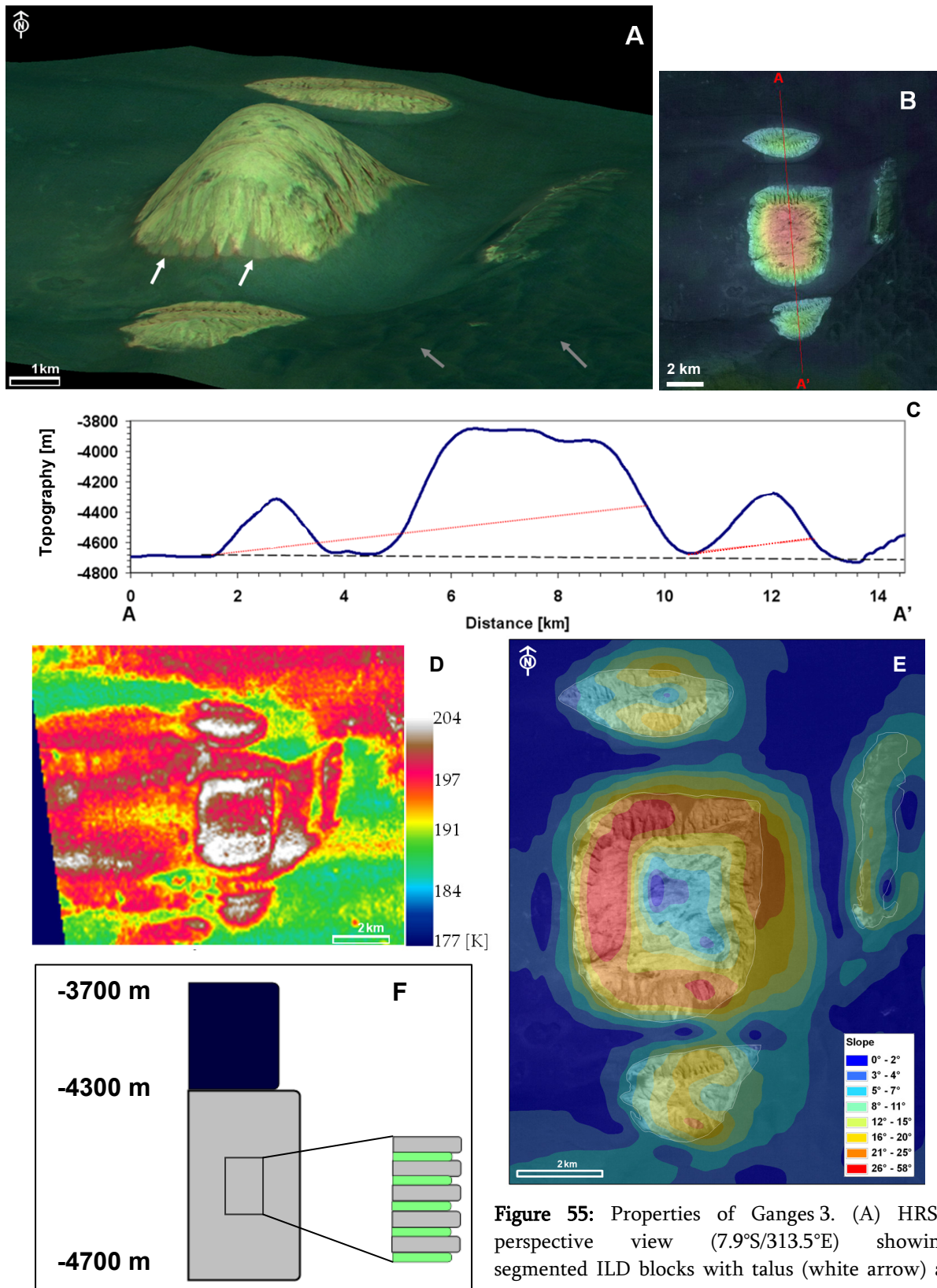


Figure 55: Properties of Ganges 3. (A) HRSC perspective view (7.9°S/313.5°E) showing segmented ILD blocks with talus (white arrow) at their base surrounded by dark ripples (grey arrow)

to the southeast (orbit h2178_0000; exaggeration factor 3). (B) HRSC nadir overlain by DTM showing location of N-S trending profile (orbit h2178_0000). (C) N-S trending profile section covering three of four blocks. Above the red line, the ILD is exhumed. The dashed line indicates the potential base of the ILD. Accuracy: Distance ± 0.1 km, topography ± 12.5 m (HRSC DTM orbit h2178_0000). (D) BT map indicating BT is high (~ 204 K) on the steep flanks mostly found on unit 1 (cf. 54E, 54F). Dusty parts also have high BT, whereas regions covered with dark ripples have much lower BT (due to thickness and coverage?). Below the dust, there is apparently more solid material as the ILD continues below the dust coverage (THEMIS orbit

I14824015; Ls=195 →S-spring). Note ILD continues below loose material coverage towards the west and north (northeast). (E) MOLA slope map underlain by HRSC nadir image (orbit h2178_0000) showing the distribution of scarps and planes on segmented blocks. (F) Thickness profile showing the ILD is exposed between -4700 and -3700 m. Two units were distinguished. Unit 1 has an estimated thickness of 400 m and shows laminated strata. Unit 2 (capping unit) is 600 m thick and appears massive, shows undulating strata and is fluted and grooved.

Ganges 4:

Like Ganges 3, this ILD (8.6°S/314.3°E; Fig. 52, 28) appears as segmented blocks of light-toned freshly eroded material (Fig. 56A). Two blocks out of a possible total of four are exhumed (Fig. 56C, 56D). Aligned NE to SW, The ILD measures 7 by 3 km and is exposed at an elevation between -4700 m to -4300 m (Fig. 56E). Loose aeolian material surrounding the ILD forms ripples on the chasma floor, especially to the west and south of the ILD (Fig. 56A). The northeastern part looks eroded, while the southwestern part of the ILD seems more frayed. The surface is affected by wind erosion, and dark aeolian material covers surface fractures. Talus can be observed on the northern, (eastern) and southern side of the easternmost block. Layering appears in the lower and upper parts of the ILD, but the upper parts are supposed to show finer layering in HiRISE images when compared to Ganges 2 + 3.

The ILD is characterised by the parameters shown in Table 20.

The overall albedo is intermediate (Table 20, Sect. 3.2.1, 5.2).

It seems reasonable to subdivide this ILD into unit 1 and unit 2 like Ganges 2 and Ganges 3 (Fig. 56A, 56C, 56E). Unit 1 shows laminated strata and a lower albedo than unit 2. Unit 2 – the capping unit – has a higher albedo and BT besides steep scarps (Fig. 56C) and less aeolian coverage. It is almost entirely flat in parts and aeolian material is trapped in fractures, flutes, and grooves (Sect. 2.3.1, 5.1) and features undulating strata. Unit 1 is exposed at an elevation of -4800 m to -4600 m (thickness 200 m) and unit 2 from -4600 m up to -4200 m (thickness 400 m, Fig. 56E). The ILD material is white to brownish (Fig. 56A), while the surrounding aeolian sand sheets and ripples appear blue.

As no HiRISE images are available, the presence of boulders is not certain but assumed from similarities to Ganges 2 but talus is present as named above.

The ILD surface appears freshly eroded (Fig. 56A, 56B) but the present minerals are featureless in the spectral range of CRISM [*Roach and Mustard, 2008*] i.e. no iron or hydration features, carbonates or nitrates in the required spectral range (Table 8; Sect. 3.1.8).

Layering geometry was not measured because the layering is not clearly traceable all around the ILD (Sect. 3.2.3).

Table 20: Parameters of Ganges 4.

Morphology	Relative Albedo	Elevation [m]	Thickness [m]	Consolidation of Materials	Mineralogy	Layer Geometry
Streamlined dome-like-profile	High	-4800±12.5 to -4200±12.5	Unit 1: 200±12.5 unit 2: 400±12.5	Intermediate TI TI Ø: 379 SI±38 (surrounding: 325 SI±32) BT: 185-195°K (surrounding: 174-185°K) talus present	Spectrally neutral	-

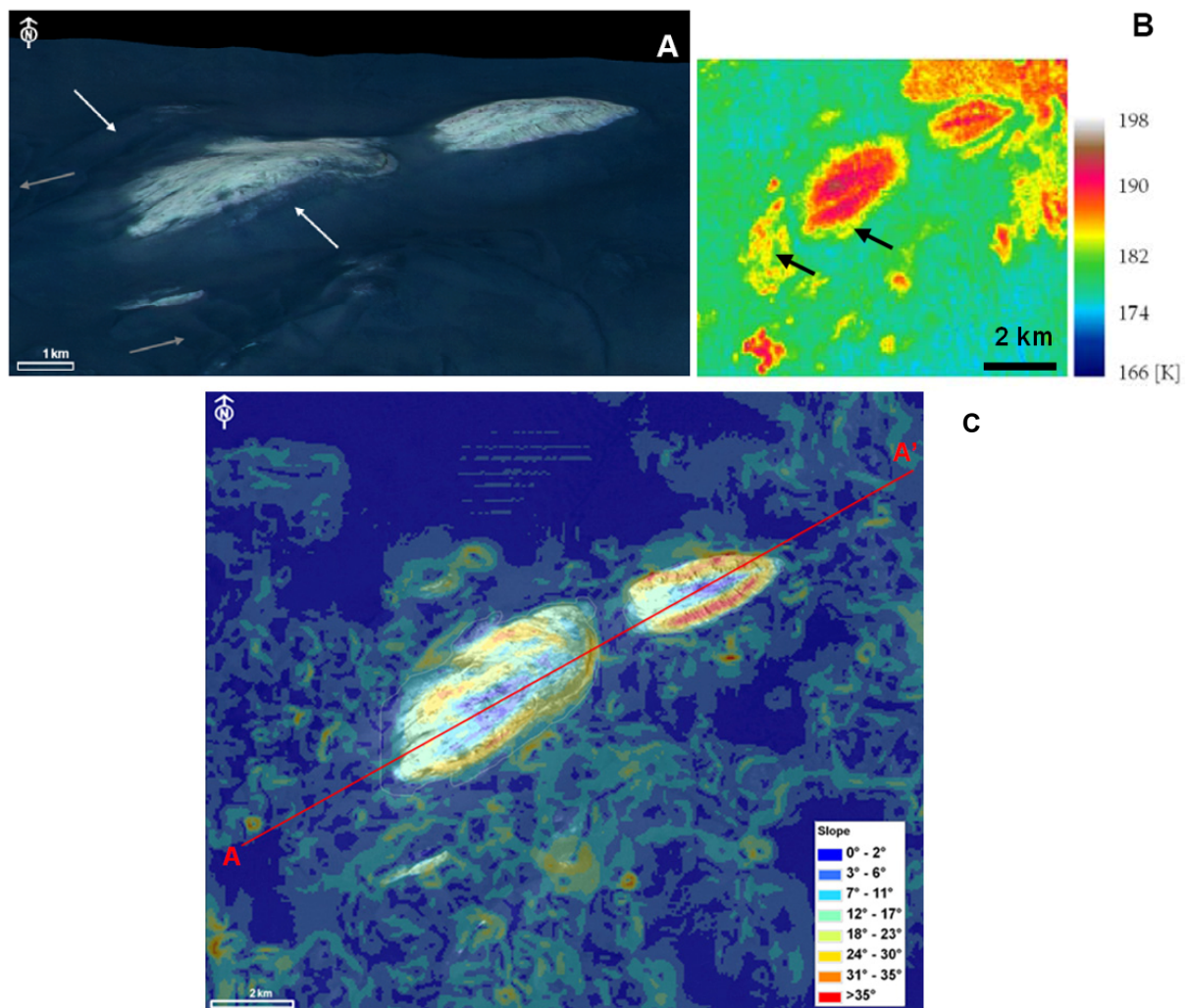
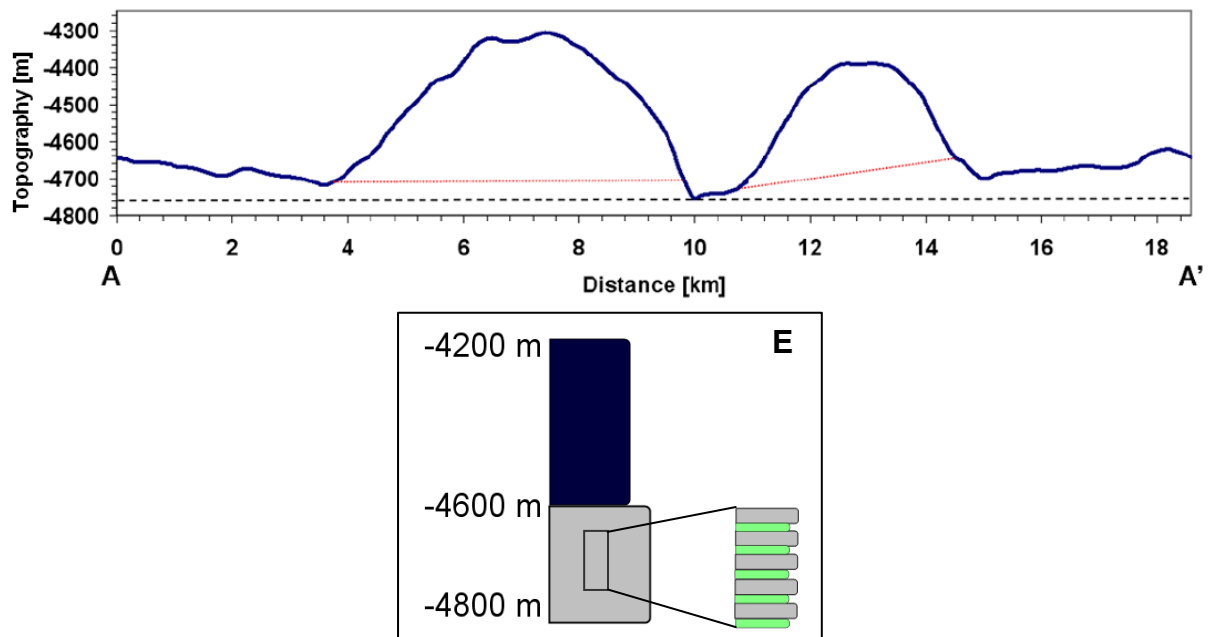


Figure 56: Properties of Ganges 4. (A) HRSC false colour image perspective view (orbit h2145_0000; exaggeration factor 3; 8.7°S/314°E). Note the slight differences in tint between the upper and lower unit (Fig. 56A). The surface is freshly eroded, partially covered bluish, mafic sandy material (white arrows) and often surrounded by dark dunes (grey arrows). (B) THEMIS BT map (orbit I18805003; $L_s=23.6 \rightarrow S$ -fall) indicating higher BT (~ 195 K) in most parts as there is low coverage of loose material. Note that solid (potentially ILD) material continues below the loose material cover towards the north (northeast), suggesting the extent of the ILD is much greater than it appears (cf. Fig. 56D). (C) HRSC nadir image overlain by slope map with course of profile (orbit h2145_0000). The whole ILD looks very fresh and eroded, but the steep scarps (20-40°) are less covered by windblown dark material (Fig. 56A) than the flat areas ($<10^\circ$).



(D) SW-NE trending profile covering two ILD blocks (cf. Fig. 56C). The red line marks the elevation above which the ILD material has been exhumed. Obviously, it continues below the loose material cover. The dashed line indicates the potential base of the ILD. Accuracy: Distance ± 0.05 km, topography ± 12.5 m (HRSC DTM orbit h2145_0000). (E) Thickness profile showing the ILD is exposed between -4800 m to -4200 m. Two units were distinguished (cf. Fig. 56A, 56D). Unit 1 has an estimated thickness of 200 m and shows laminated strata and lower albedo. Unit 2 is 400 m thick, shows undulating strata and is heavily fluted and grooved.

Ganges 5:

The ILD (7.5°S/315.3°E, Fig. 52, 28) is exposed on the south-facing hillsides Ganges Chasma to the east/northeast of Ganges 1-4. Aligned north to south (Fig. 57A), it measures 15 by 8 km and is exposed at -3800 m to -3500 m. Its northern and eastern parts have sharp edges, whereas the southern and western parts are frayed (Fig. 57A). On knobs to the west of the ILD, light-toned material is also observed (Fig. 57A, 57D), which may indicate ILD material extended much farther and partly is covered by dark material.

The ILD is characterised by the parameters shown in Table 21.

Overall, the albedo (Sect. 3.2.1) is high but slightly differs between the lower and the upper part.

Like Ganges 2-4, the lower part features a lower albedo than the top. But here only one unit is identified (Fig. 57C). Its surface appears mostly flat (Fig. 57C). It features small-eroded mesas demonstrating monadnocks and indicating material discrepancies (Fig. 57G). Undulated strata are observed within the ILD. However, mainly it appears rough, massive and grooved (Sect. 2.3.1, 5.1) exhibits some steep areas (Fig. 57C, 57G). The ILD is exposed from -3800 m to -3500 m (estimated thickness 300 m).

TI is high (Table 21) indicating rock or highly consolidated material (Sect. 3.2.2, 5.5). Neither talus nor boulders are observed, possibly because the ILD has few steep parts and is exposed on the hillside experiencing strong erosion by wind indicated by possible yardangs (Fig. 57C-E, 57G, 52).

The ILD material is yellow and in parts brownish due to dust; coverings, windblown mafic sand and ripples appear bluish. Unfortunately, there are no CRISM data covering

this region.

Layering geometry was not measured because the layering is not clearly traceable all around the ILD (Sect. 3.2.3).

Table 21: Parameters of Ganges 5.

Morphology	Relative Albedo	Elevation [m]	Thickness [m]	Consolidation of Materials	Mineralogy	Layer Geometry
Streamlined, dome-like profile	High	-3800±12.5 to -3500±12.5	300±12.5	High TI TI Ø: 491 SI±68 (surrounding: 436 SI±80) BT: 203-215°K (surrounding: 196-205°K)	No data	-

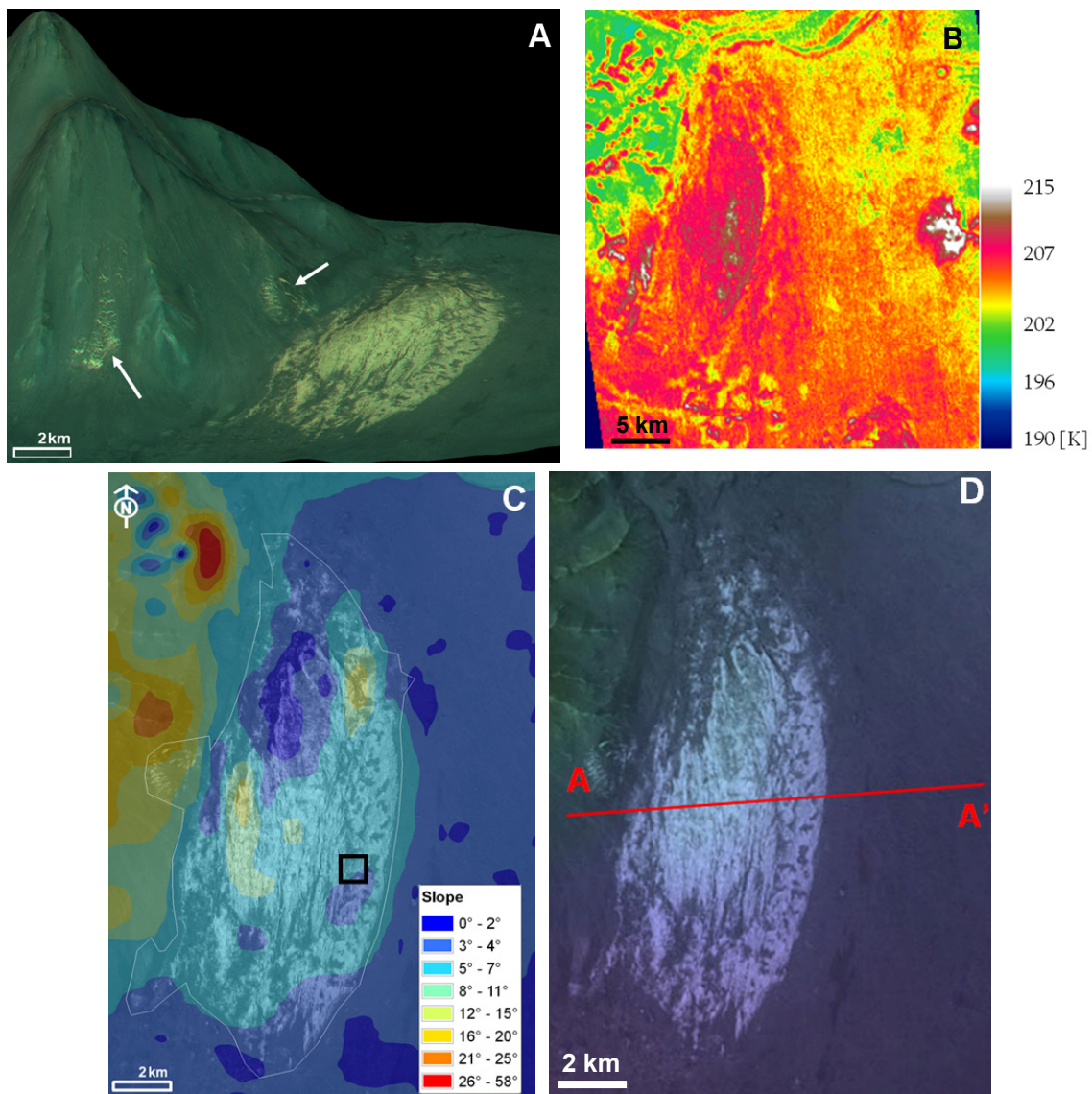
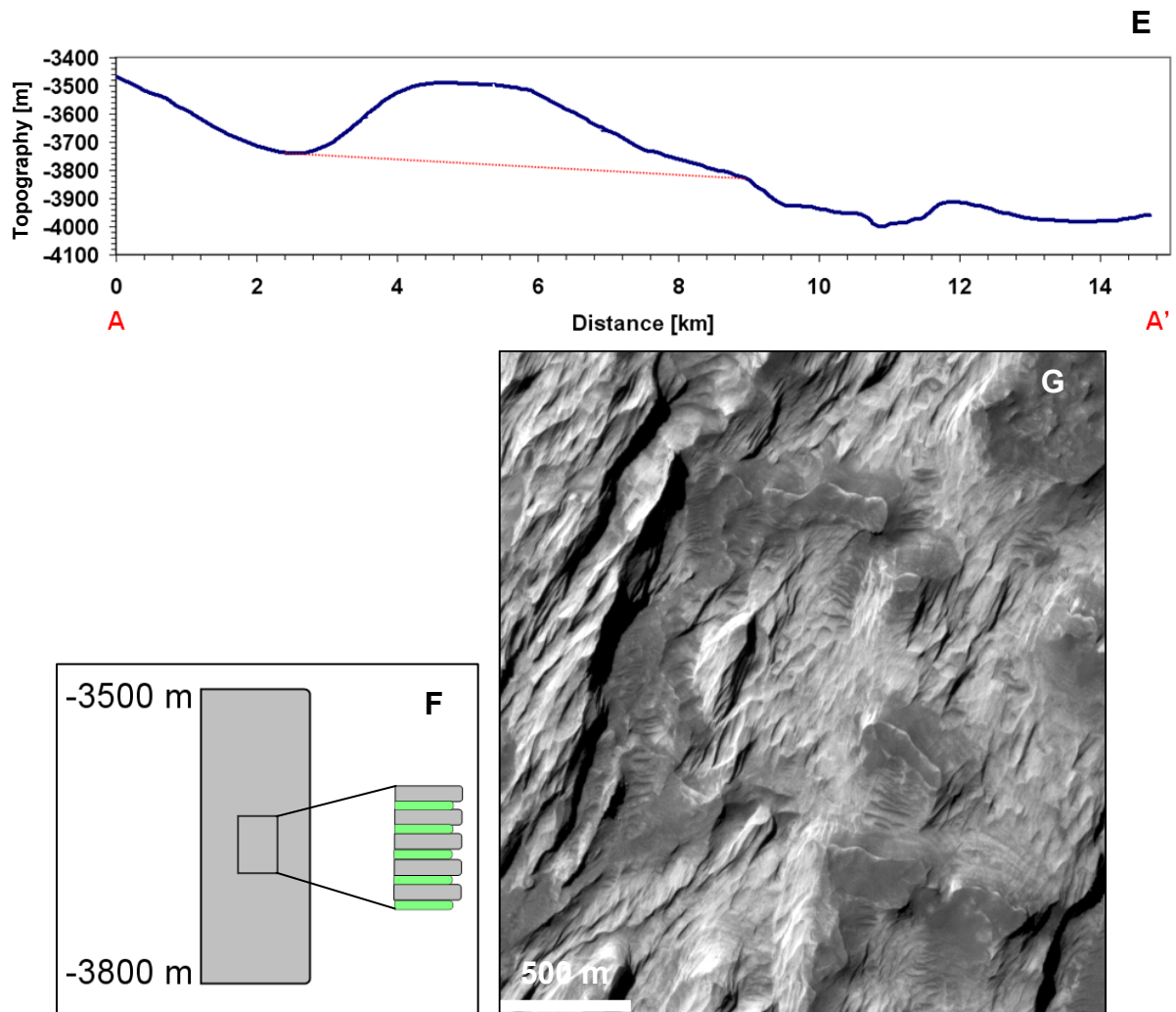


Figure 57: Properties of Ganges 5. (A) HRSC false colour image perspective view (orbit h2156_0000; exaggeration factor 3; 7°S/315.2°E). The ILD is exposed on the marginal northern part of the Valles Marineris walls. The surface is freshly eroded. ILD material is also visible in the mounds (white arrows) possibly indicating low-albedo mantling of ILD units or even eroded wall rock, which is now buried by ILD

material. (B) BT map showing steep fresh material corresponding to higher BT (cf. Fig. 57A, 57D) around 210 K (THEMIS orbit I0882006; LS=332.6 →S-summer). (C) MOLA slope map indicating few steep parts within the ILD that show high BT (Fig. 57B). (D) HRSC-DTM underlain by nadir image (orbit h2156_0000) showing course of the profile (Fig. 57E).



(E) W-E trending profile (cf. Fig. 57D). Above the red line, material is exhumed. Accuracy: Distance ± 0.1 km, topography ± 12.5 m (HRSC DTM orbit h2156_0000). (F) Thickness profile showing the elevation at which the ILD is observed. This unit shows the presence of small low-albedo mesas indicating material differences by the presence of these monadnocks and strong erosion (cf. Fig. 57G) comparable to Ganges 1. Undulated strata are observed within the unit. The thickness is estimated to 300 m. (G) MOC-image (orbit M2100524; 7.2°S/315°E) showing low-albedo mesas on the heavily eroded (fluted, grooved) massive-looking ILD surface. A thickness of 300 m was estimated. The mineralogy of the ILD is unknown. For context, see Fig. 57C.