DESCRIPTION OF MAP UNITS

Unit descriptions and interpretations are based on morphology, texture, albedo, and stratigraphic position as observed in HrSC, CTX, THEMIS daytime infrared, THEMIS visible, HiRISE, and MOLA images.

Descriptions, symbols, colors and ages are based on the *Geologic Map of MTM –20012 and –25012 Quadrangles, Margaritifer Terra Region of Mars* by J.A. Grant et al., 2009.

PLAINS MATERIAL

HNp Older plains material (Early Hesperian to Late Noachian)
Observation- In many instances unit is dissected by valley network material. It is the most widespread unit in the map and it has a relatively low relief. It has lightly craterd plains surface and some moderately degraded craters. Unit is exposed, not too old, and is dissected by the Npld unit. It is older than HNf and has a smooth surface.
Interpretation- This unit is evidence for a mixture of fluvial/ alluvial deposits, colluvium, volcanic deposits and/or impact debris. The smooth surface of HNp appears to be covering most of the dissected rough surface of Npld as the topography of Npld is lower than the topography of HNp.

HNp2 Plains material 2
Observation- This unit can be seen in crater 2, 3 and 4. Sediment deposition can be seen on the crater rim. In crater 3 the deposit can be seen in the south east section of the crater floor and the crater rim. The crater 4 floor is filled with this deposit. The smooth mantle deposits are deposited on the north west side of the crater covering a section of this unit.
Interpretation- Deposited in low lying areas likely by the flow of water. It appears that this sediment deposit came down from the crater rim in crater 2. There might have been alluvial fans and landslides but it is not too visible. The surrounding gullies and channels appear to have carved the crater wall and brought sediment in. The rims of craters 2 and 3 are relatively high in elevation. Sediment deposited in the south of crater 3 could be as a result of sediments eroding the crater wall.

MASS WASTING MATERIAL/ LANDSLIDE

Ahls Landslide (Amazonian to Hesperian)
Observation- Isolated material that originates in an alcove from a steep crater wall and extends towards the crater floor. This unit overlies the older fan material (unit HNf).
Interpretation- Likely due to failure of crater wall rock material. The mass wasting is younger than the unit HNf in the surrounding area. However, the degraded material appears to be inconsistent with very recent activity.

AHmw Mass-wasting material
Observation- Material originated from the west side of the crater 1 wall. It has a steep front and it is more cratered than the nearby alluvial fans (fans 2 and 3) but less cratered than alluvial fan 1 and the bajada. It appears to have similar cratering as the landslide. It doesn't appear to overlie any vallis material.
Interpretation- The mass wasting could be due to the failure of crater wall rock material. Steep fronts indicate that there must have been water in the crater when this event took place. It appears to be older than alluvial fans 2 and 3 but younger than alluvial fan 1 and the bajada. It appears to be cratered the same way as the landslide in crater 1. There is a possibility that the mass wasting event and the landslide occurred at the same time.

PLATEAU AND HIGHLAND MATERIAL

Npld Dissected unit of the plateau sequence (Early to Middle Noachian)
Observation- A heavily cratered rough surface. It has been dissected by valley networks and has high-relief.
Interpretation- This surface appears to be older than the HNp unit. The material likely formed during the period of high-impact flux. The material consists of lava flows, pyroclastic material and impact breccia.

VALLIS MATERIAL

HNf Older fan material (Hesperian to Late Noachian)
Observation- Fan shaped deposits appear to range from smooth to variably rough and are locally elevated. Preserved multiple channels and depositional lobes can be seen. Surface gradients of the fans vary. A bajada can be seen in the north eastern part of the crater. Alluvial fan 1 and the bajada in crater 1 are more cratered than the other alluvial fans (unit AHf) and have steep fronts.
Interpretation- Alluvial fans, deltas, and associated alluvium contain relatively coarse alluvium and/or partially lithified material deposited on crater floors. Steep fronts hold clues to crater-lake settings. Alluvial fan 1 and the bajada in crater 1 appear to be older than other alluvial fans since they are less cratered. Preserved lobes and distributary channels can be seen. This shows either a sustained or an episodic flow occurring or existing at the same period as the widespread valley formation (unit HNvn).

AHf Younger fan material (Middle Amazonian to Late Hesperian)
Observation- Smooth to moderately rough, lobe-shaped deposits can be seen on the floor of crater 1. Deposits may have buried older fan deposits (unit HNf) but evidence for such activity is not visible. Channels and lobes appear to be fairly uniform. A channel is seen connected to the Alluvial fan 2. Alluvial fan in crater 5 does not have a steep front.
Interpretation- Fans and distal alluvium could be composed of relatively coarse alluvium and/ or partially lithified material. Alluvial fans 2 and 3 are relatively young compared to other fans in the crater and does not have steep fronts. This suggests that the discharge was subaerial and some of the material could be debris flows. Preserved lobes show episodic flow. Water ponded from the south west direction to the crater 1 must have allowed the water to flow in to the crater and create alluvial fans through a narrow channel. Sediment deposits may extend across crater floors and beyond lobes. Alluvial fan 4 in crater 5 shows no evidence of a crater lake.

HNvn Older valley network material (Hesperian to Late Noachian)
Observation- This appears to be part of a smooth and distributed valley network from the north-west direction. It appears to have carved the unit Npld and branched a little bit as channels or gullies. The valley could be integrated and preserved as the first or second order tributaries valley floor does not appear to be preserved.
Interpretation- Sedimentary materials must have eroded from surrounding plains, uplands and deposited by water flowing the valley networks. It appears to have flowed in with older plains material (unit HNp) and it must have come from the north direction. Small valleys probably formed by fluvial processes related to precipitation-recharged groundwater sapping.

CHAOTIC TERRAIN MATERIAL

AHct Chaotic terrain material (Middle Amazonian to Hesperian)
Observation- The unit is closely spaced, rounded to flat, elongate plateaus, buttes, knobs, and linear ridges, usually separated by troughs. AHct occurs in depression. In crater 1, AHct is in the middle of the crater which is considered the lowest point of the crater. The material rise above the elevation of the surrounding plains. The unit is embayed and cuts the adjacent alluvial fan material.
Interpretation- A small remaining quantity of possibly more resistant alluvial (ice-rich?) deposits were put in place with older vallis material (unit HNvn) and followed by modification and explosion by most likely an aeolian process and/or alternate process. It appears that the collapse played a minimal role in formation. The rise in the material can be as a result of experienced substantial constructional contributions due to accumulation and upward expansion of ice or sedimentary diapirism. There seems to be differential erosion. This unit may be younger than ANb.

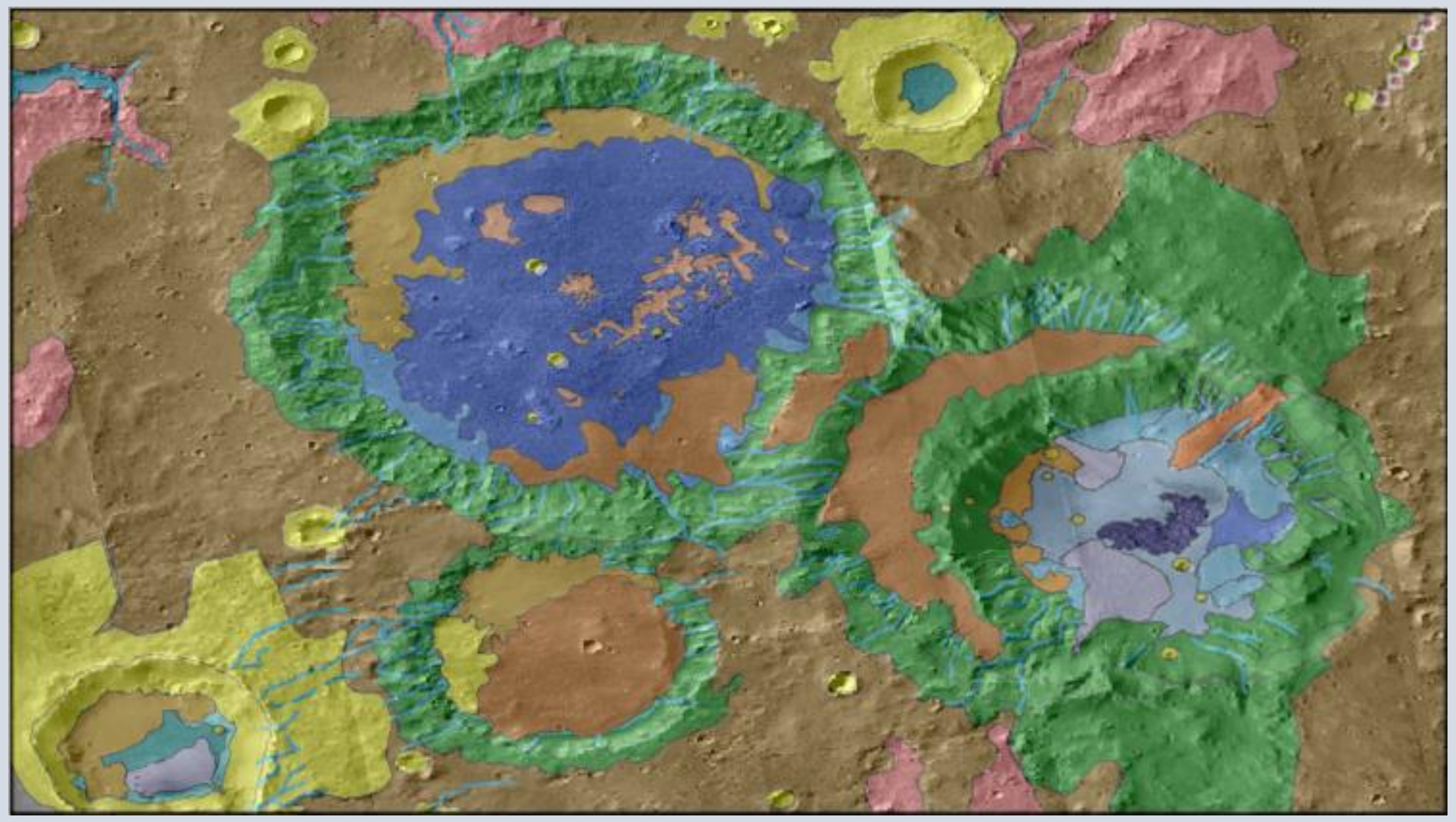


Figure 4. Geomorphic map of the study area showing units as described here. Colors correspond to the Description of Map Units.

CRATER MATERIAL

C2 Moderately degraded crater material
Observation- These craters consists of flat floors, central peak rings and exhibit terraces. They are complex craters and greater than 15 km. Crater floors appears to be infilled. Some crater floor material contains AHct which is a chaotic terrain. Partially buried or deflated ejecta blankets can be seen.
Interpretation- This unit shows impact craters with moderate degree of degradation. Most of the crater floors are modified by mass-wasting, Aeolian, and/ or fluvial processes.

C3 Well-preserved crater material
Observation- The material consists of crater rims elevated relative to surrounding material. A noticeable, continuous ejecta blankets can be seen. Rough surface with linear ridges going southwest and northwest in Crater 4.
Interpretation- Pristine crater material shows a small degradation. Crater 5 shows deposits due to mass-wasting, aeolian, and/or fluvial processes. Ejecta from Crater 5 in the southwest region of Crater 4.

HNcf1 Crater floor material 1
Observation- The northwest side is not so cratered and south east side is relative more crated. There appears to be a lot of activity occurring such as such as landslides, alluvial fans, mass wasting and chaotic terrain material.
Interpretation- The northwest side is relatively young compared to the south east side. The unit seems to have weathered and a few minor activities could have occurred but they are covered by relatively younger activities.

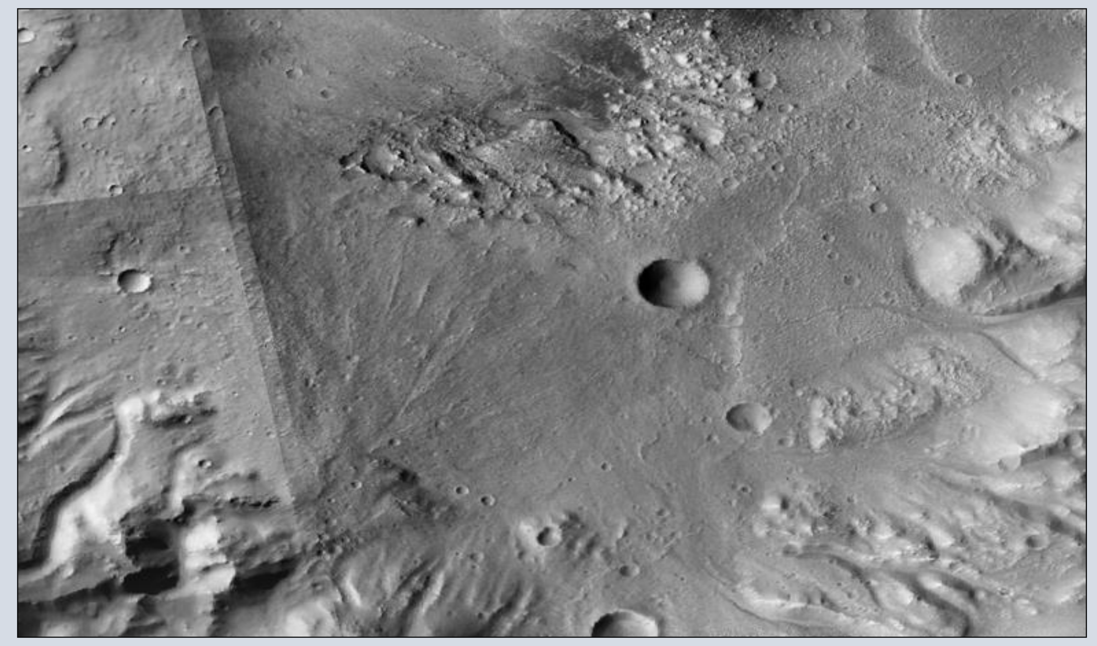
HNcf2 Crater floor material 2
Observation- The deposit is cratered. It appears as if the sediment was brought in from the crater wall to inside of the crater. There appears to be a steep front. But alluvial fan 1 and the bajada have greater steep fronts. The bajada and alluvial fan 1 have possibly deposited on top of the old mantle sediment deposit.
Interpretation- This unit appears to be somewhat old in age. It could have been a very old alluvial deposit but the existing evidence is very minimal for that. Alluvial fan 1 and the bajada are relatively young compared to this sediment deposit. The steep front give clues to crater lake settings. There could have been water when this sediment was deposited and the water level possible rose after some time where it matches the steep front of alluvial fan 1 and the bajada.

AHcf Crater floor material
Observation- This appears to be an aeolian deposit. Very few craters and one isolated knob in the middle of Crater 5 can be seen. There are some craters, much of the surface is covered by smooth material. Ripple forms present.
Interpretation- This unit is young. Alluvial fan 4 could be the same age as this unit. Smooth mantle deposit is partially accumulated on top of this unit. There is erosion due to aeolian processes. The knob is a possible central peak.

HNcf3 Knobby crater material
Observation- Relatively flat but heavily cratered. Some low areas are filled with aeolian sediments.
Interpretation- Material that filled in the crater floor, based on the rough appearance, appears to be consolidated material. This is an old crater. The deposit is a very old deposit compared to other crater floors in this area.

Asd Smooth deposit
Observation- Accumulation of sediment. Less cratered. Relatively smooth deposit. This can be seen in northwest part of Craters 3, 4 and 5. THEMIS IR nighttime shows slightly lower thermal inertia. There are isolated areas of adjacent to main deposits.
Interpretation- The deposit is young and most likely sediment/dust. The accumulation of sediment/dust can be due to the wind from the northwest direction to the craters. Crater 5 appears to have the most amount of sediment accumulated but this could be because Crater 5 is smaller than Craters 3 and 4. The wind moved from northwest to the southeast direction the accumulation of sediment has decreased. A small amount of deposit can be seen in Crater 1 but it is too small to include in the map. Lower thermal inertia indicates that the sediment is loose.

Asd2 Smooth deposit 2
Observation- Smooth surface between the small knobs. The deposition is accumulated in the east corner of the crater and few can be seen in the northwest direction. Sediment or dust seems to be deposited on the surface between the knobs.
Interpretation- It could be sediment deposited due to aeolian activity. The deposition between the knobs could be because of the low elevation compared to the knobs.



SYMBOL EXPLANATION

___ **Contact-** a line approximately located of gradational. Internal contacts differentiate impact features.

Channel/ Gully

Chain of secondary craters

Crater rim- shows crest where preserved and defined. Hatch marks point towards the crater.

Conclusions

Using images from NASA orbital instruments, the geomorphology and timing of events within the study area were determined. These images and data reveal Margaritifer Terra has experienced a variety of geologic processes over time due to fluvial activity that once existed. The Margaritifer Terra region of Mars shows evidence for aeolian and fluvial activity throughout Martian history in heavily dissected areas (Grant et al., 2009). The geomorphology of some areas in this region shows erosion, transport and deposition of material. After the fluvial activity declined, small impacts and aeolian process were the main resurfacing events (Fortezzo, 2009; Grant et al., 2009).

The alluvial fans can hold clues to habitable conditions on Mars (Grant et al., 2012) as liquid water is involved in alluvial fan formation. In the crater toward the east of the map, alluvial fan 1 and the bajada appear to be relatively old as these features are more cratered than the surrounding features. Alluvial fans 2 and 3 appear to be relatively young since they are less cratered than the other features. Steep fronts in Alluvial fan 1 and the bajada provide evidence for a crater lake setting. There must have been water in Crater 1 when the bajada and Alluvial fan 1 formed. Alluvial fans 2 and 3 must have occurred when there was no water in the crater as there are no steep fronts. Grant and Wilson (2012) explain that the morphometry and the existence of crater-bound fans in southern Margaritifer Terra were active approximately from the Hesperian to Amazonian boundary until the Early Amazonian. The geomorphology of the fans in the study area suggest the presence of a crater lake during Hesperian to Late Noachian. The crater lake formation could to have ceased during the Middle Amazonian. The landslide appears to be the youngest important geological feature in the map. In some areas runoff from melting snow could have given rise to mass wasting and landslides inside craters (Grant et al., 2012). There seems to be differential erosion in the chaotic terrain material located in the middle of the crater.

Small valleys and gullies around the craters probably formed by fluvial processes related to precipitation and surface flows or recharged groundwater sapping, but the evidence is minimal for groundwater sapping. The older valley network material on the northwest corner of the map likely connects to other larger channels.

In conclusion the fluvial features of this area suggest localized rainfall or snowmelt. As a result of rainfall and/or snowmelt, a lake may have existed in Crater 1 during formation of some alluvial fans. Other alluvial fans in Crater 1 formed after the lake no longer existed. By understanding when and where water existed on Mars, we can better understand past environments that may have supported life. This research helps advance our understanding of the past existence of water on Mars. In the area of this study, an interesting history of alluvial fan formation took place during and after the presence of a lake in one of the craters.

REFERENCES

Blair, T. C., and McPherson, J. G. (1994). Alluvial fans and their natural distinction from rivers based on morphology, hydraulic processes, sedimentary processes, and facies assemblages. *Journal of Sedimentary Research*, 64(3). Christensen, P.R., Engle, E., Anwar, S., Dickenshied, S., Noss, D., Gorelick, N., and Weiss-Malik, M.(2009). *JMARS – A PlanetaryGIS*, http://adsabs.harvard.edu/abs/2009AGUFMIN22A..06C. Fortezzo, C. M. (2009). *Geology, Geomorphology, and Hypsometry of Southeast Margaritifer Terra, Mars, and the Lower Escalante River, Utah* (Master's Thesis, Northern Arizona University), how many pages? Grant, J. A., The geomorphic evolution of Eastern Margaritifer Sinus, Mars, in *Advances in Planetary Geology*, NASA Tech. Memo., **89871**, 1–268, 1987. Grant, J. A., and Wilson, S. A. (2011). Late alluvial fan formation in southern Margaritifer Terra, Mars. *Geophysical Research Letters*, 38(8). Grant, J. A., and Wilson, S. A. (2012) A possible synoptic source of water for alluvial fan formation in southern Margaritifer Terra, Mars. *Planetary and Space Science*, 72(1), 44-52. Grant, J.A., Wilson, S.A., Fortezzo, C.M., and Clark, D.A. (2009). *Geologic map of MTM-20012 and -25012 quadrangles, Margaritifer Terra region of Mars*: USGS Scientific Investigations Map 3041. Moore, J. M., and Howard, A. D. (2005) Large alluvial fans on Mars, *Journal of Geophysical Research: Planets* (1991–2012), 110(E4). Parker, T. J., Geomorphology and geology of the southwestern Margaritifer Sinus-Northern Argyre region of Mars, Master's thesis, Calif. State Univ., Los Angeles, 1985. Saito, K., and Oguchi, T. (2005) Slope of alluvial fans in humid regions of Japan, Taiwan and the Philippines. *Geomorphology*, 70(1), 147-162. Saunders, S. R. (1979) *Geologic map of the Margaritifer Sinus Quadrangle of Mars*, scale 1:5M, *U.S. Geol. Surv. Map I-1144*, MC-19. Williams, K.K., C.M. Fortezzo, and J.A. Grant (2007) Mapping Margaritifer Terra, Mars: Fluvial Features, Basins, and Models, *LPSC XXXVIII*, Houston, TX, Abstract 2220.