EVIDENCE FOR LARGE RESERVOIRS OF WATER/MUD IN ACIDALIA AND UTOPIA PLANITIAE ON MARS. M.A. Ivanov, H. Hiesinger, G. Erkeling, and D. Reiss.

Introduction: The occurrences of the etched flows near the central portion of Utopia Planitia (UP) and progressive changes of morphology of impact craters ejecta from ballistic/rampart to pancake-like toward the center of UP have been interpreted as evidence for the presence of a large reservoir of water and mud in this region of Mars during the Early Hesperian [1].

The likely presence of the water/ice reservoir in UP is consistent with the hypothesis of existence of a large standing body of water (an ocean) within the northern plains of Mars [2-6]. In the framework of this hypothesis, the features of UP that suggest the presence of the reservoir may not be unique to this area and occur in the other regional topographic lows of the northern plains. One of such regions is Acidalia Planitia (AP). The large circum-Chryse outflow channels are opening into this area and it was the first place where the channel effluents were accumulated and a large body of water/mud may have been formed. Such a regional setting of AP suggests that in this region one can expect the presence of the set of features that are consistent with the large water/mud reservoir in UP. In order to test this hypothesis, we have conducted detailed geological mapping of a portion of AP (45N, 325E - 20N, 345E) adjacent to the mouth of Tiu Vallis using a complete set of high-resolution images and topographic data.

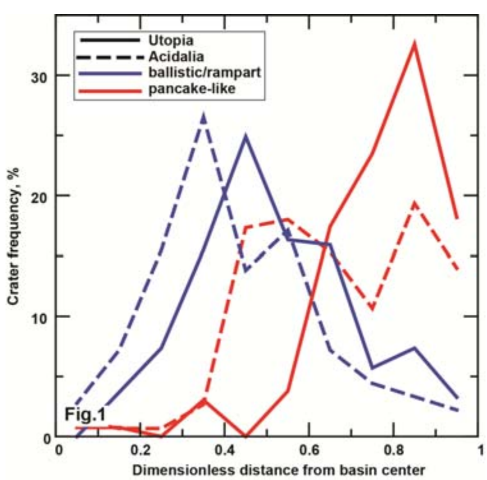

Fig. 1. Spatial distribution of ballistic/rampart and pancake-like ejecta in the southern portions of Utopia and Acidalia Planitiae.

Characteristic features of Acidalia and Utopia Planitiae: The results of our mapping show that similar/identical features characterize the AP and UP regions. These are as follows: (1) The main unit that covers the majority of the surface of AP and UP is the Vastitas Borealis Formation (VBF) [7-9]. In both regions, the VBF is characterized by a very prominent and continuous southern margin. The margin consists of a series of lobes that are 10-20 km wide and long, convex southward, and are bounded by a low (a few tens of meters) scarp. In AP, besides the lobes, the VBF forms long (a few hundreds of kilometers) tongues that ingress deeply into the mouth of the outflow channels (Tiu Vallis in our mapped area). The length of the contact mapped in AP is ~6,000 km and its mean elevation is ~-3.9 km (± 70 m, 1 σ); in UP, the mapped length of the contact is ~1,500 km and its elevation is ~-3.6 km (± 54 m, 1 σ) [1].

(2) Polygonal terrains characterize the surface in AP and UP [e.g., 10-12]. In Utopia, however, the polygonal troughs are broader [12] and the polygons outlined by the troughs are larger [13].

(3) Shallow circular depressions that are interpreted as strongly degraded impact structures (ghost craters) buried by materials of VBF [14-16] populate the floor of both AP and UP.

(4) The obvious impact craters in AP and UP show ballistic, rampart, and pancake-like morphologies of ejecta [17]. The ballistic and rampart ejecta display little evidence for the post-formational modification. In contrast, the pancake-like ejecta are characterized by strong degradation patterns (voids in the ejecta blanket where the underlying surface is exposed, remnants of ejecta completely separated from the main ejecta body, etc.). These differences likely indicate a greater amount of volatiles in the targets where craters with the pancake-like ejecta formed [1]. The spatial distribution of craters with the different types of ejecta in both AP and UP is a prominent function of the distance from the "center" of either the Acidalia or Utopia basins: the ballistic and rampart ejecta preferentially occur closer to the basins periphery, whereas the pancake-like ejecta are concentrated closer to the central portions of the basins (Fig. 1). In AP and UP, impact craters appear to either predate (ghost craters) or postdate (obvious craters) VBF and there are no craters that are partly embayed by VBF.

(5) Etched flows (Fig. 2). These features have been recently discovered on the floor of UP [1]. Their overall shape (broad nappes hundreds of kilometers wide and several tens of meters high with lobate margins and marginal scarps) indicates that they are flows of low-viscosity materials overlying the surface of VBF. Their characteristic morphology (strongly degraded surface, scalloped edges, rimless pits on the surface, Fig. 2a) suggests that they represent mudflows [1]. In UP, the flows are concentrated closer to the center of the basin at elevations below ~ -4.5 km [1] where the craters with pancake-like ejecta dominate (Fig. 1). Morphologically identical flows (Fig. 2b) occur within AP. The flows in AP have about the same dimensions as those in UP and also are concentrated at the lower elevations (below ~ -4.3 km) where the pancake-like ejecta prevail (Fig. 1). In contrast to UP, however, the etched flows of AP occur in tight spatial association with small pitted coned/domes (Fig. 2b).

Ages: The SFD of craters superposed on the surface of VBF in AP and UP gives an estimate of the absolute model age to be ~ 3.5-3.6 Ga. The model age of the surfaces that underlie VBF in UP is estimated to be ~

3.7 Ga [1] and the age of the bed surface of Tiu Vallis that underlies VBF in AP is ~ 3.6 Ga. The oldest age of the etched flows that superpose VBF in UP is ~ 3.5 Ga [1]. This estimate provides the upper time limit for the emplacement of VBF in UP. The etched flows that

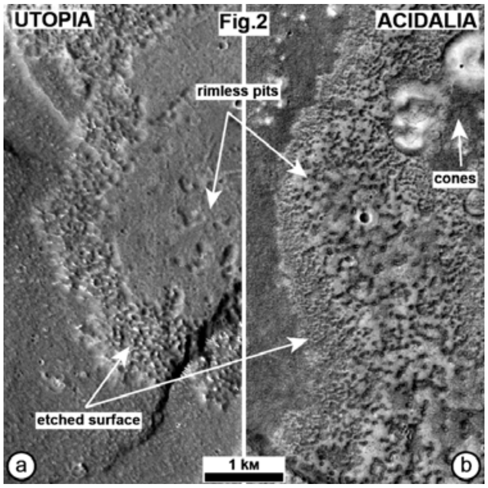

Fig. 2. Etched flows in Utopia and Acidalia Planitiae.

overlay the surface of VBF in AP are more degraded than those in UP and their SFD is approximated by an isochron 1.2 Ga. Thus, the upper time bound of the emplacement of VBF in AP is poorly constrained.

Discussion: The results of detailed mapping in AP and UP shows that these regions possess similar/identical features indicative of the presence of large water/mud reservoirs in these broad topographic depressions. These findings satisfy the general requirements of the northern ocean hypothesis.

The nearly constant topographic position of the southern margin of VBF that is observed separately in AP and UP indicates that both regions have been filled by masses of liquefied materials, which is one of the specific requirements of the ocean hypothesis [e.g., 18]. It also puts important constraints on the filling history of AP and UP because it indicates that both basins have been filled up to about the same level.

The most important of these features are the etched flows and the progressive changes of crater morphology in both regions. The specific morphology of the etched flows in AP and their similarity to the flows in UP (Fig. 2) provide strong evidence for extensive mud volcanism sourced from a large subsurface reservoir in the central/deeper portions of AP. The flows in AP typically occur in tight spatial association with pitted cones/domes (Fig. 2b) that commonly are interpreted as mud volcanic constructs [19-21]. The pronounced trend of concentration of the pancake-like ejecta toward the center of AP (Fig. 1) indicates that volatiles were more abundant in the target rocks in the center of AP, which provides independent evidence for the presence of large reservoirs of water/mud in this area.

The time of formation of the water/mud reservoirs in AP and UP is constrained from below by the ages of the bed surfaces in the outflow channels in AP and the surfaces that underlie VBF in UP. The age of the surface of the VBF itself provides the upper time limit. At the temporal resolution of the crater dating, these ages are tightly clustered around the value of ~3.6 Ga [1] and suggest that AP and UP have been filled by large amounts of water/mud at about the same time. The lack of craters partially embayed by VBF suggests that this filling has happened faster than the rate of accumulation of impact craters. The fast and nearly simultaneous filling of AP and UP is the requirement of the ocean hypothesis.

Nevertheless, the ocean hypothesis faces two difficulties: (1) the apparent absence of the spillover marks at the crest of the divide that separates the North Polar basin and Utopia basin [6,23] and (2) the distinctly different (~300 m) elevation of the margins of VBF in AP and UP [23,9], which is poorly consistent with a single equipotential level. Although an alternative hypothesis of independent filling of AP and UP [23,9] avoids these difficulties, it faces its own major problems, the most important of which is the lack of obvious sources of water in the surroundings of UP during the Early Hesperian. Besides, this hypothesis must consider as large-scale coincidences two important facts: (1) the apparently same age of the bed surfaces in Tiu Vallis in AP and VBF in AP and UP, which would be a natural consequence of the ocean hypothesis, and (2) the close topographic position of the margin of VBF in AP and UP, which indicates that both topographic lows have been filled up to about the same level.

Although none of the alternative hypotheses can be confidently accepted or rejected, the ocean hypothesis appears to provide more natural explanations to the larger number of observations.

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