The Mars northern residual ice cap: new geomorphologic facts about its formation and evolution.

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Summary. The North polar layered deposits of Mars (NPLD) form an elliptic dome centered on the pole and it is connected to a lobe nicknamed "Titania Lobe". These two entities are separated by Chasma Boreale. They are joined by a transition zone with unique geomorphologic characteristics: 1) a saddle like shape of its surface, 2) the absence of troughs, 3) the direction changes of troughs mainly at its eastside edge, 4) compression ripples, and 5) shear stress display on the ice causing shearing planes and crevasses. They can be explained by ice flow mechanism. Thereof, we propose this scenario for the recent history of the NPLD: the formation of the Titania Lobe was triggered initially by glacial flowage from the main polar dome towards a lower topographic area, its direction being mainly determined by the shape and slopes of the underlying area. The flow probably initially occurred downward the flank of the basal unit detected underneath the elliptic dome but not under the Titania lobe. Both the dome and the lobe later evolved through local accumulation/sublimation mechanism. Within the scope of this scenario, Chasma Boreale becomes an opened westward depression formed by these two parallel glacial entities. Its floor, sometimes marked by well preserved impact structures, should correspond to an exposure of the basal unit, and its current shape would be controlled by a balance between ice flow and sublimation/ablation enhanced by catabatic winds effects.

Background. The NPLD on Mars consist of a 3 km thick layered structure lying within a 5 km deep hemispheric depression at the Martian's North Pole [1]. Radar sounding data suggests that they are mostly made of layered water ice containing a very small fraction of impurities [2]. The build up of the ice cap has been a complex process, as revealed by Sharad data emphasizing its stratigraphy [3,4]. Prevailing theories revolve around the Martian orbital cycles, especially obliquity, influencing the climate and the accumulation of ice and dust in the polar region. There has been debate about the processes that controls the domal shape of the current ice cap and the observed topography in the troughs. It can be explained by ablation/sublimation [5,6], or by glacial flow and deformation [7,8]. In the past and in certain areas, flowage may have been an active mecanism in the formation of the ice cap [9]. NPLD are marked by troughs. Their arrangement is more in series of arcuate parallel scarps on the lobe (in its lower part), contrary to a spiral pattern on the dome. The lobe is usually considered to be a part of the dome that has been isolated possibly by catastrophic phenomena which carved the Chasma Boreale[10,11,12,13]. This large reentrant shows asymmetric slopes and odd particularities all over its floor (crater impacts, polygonal features, ice lobes). A 150 km wide transition zone, east of Chasma Boreale joins the two entities (Fig. 1).

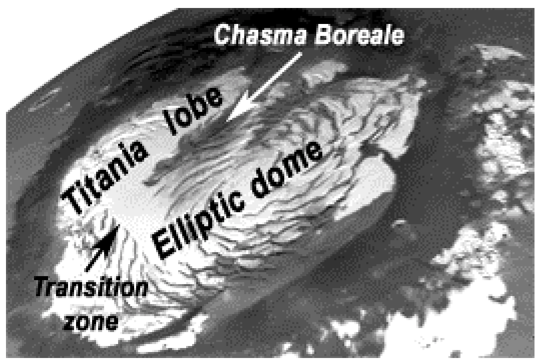

Figure 1. The North Pole of Mars. Adapted from NASA/Goddard Space Flight Center.

Datasets and processings. Topographic and geomorphologic data extracted from DEM/MOLA, Themis and HiRise remotely sensed images and Sharad radar soundings contributed to the elaboration of this scenario. Digitally processed images, mainly produced with IDRISI software was put into contribution. In fact, linear and surface elements were brought out by the use of Sobel filters, contrast enhancement techniques, georeferencing and merging of various digital data hence creating a Geographic information system.

Results. Links between different topographic and geomorphologic facts helped us in establishing a causal relationship between the elliptic dome and the "Titania lobe". In fact, many observations within the transition zone were key pieces for establishing an ice flowage hypothesis (fig. 2): 1) the bent troughs particularly at the eastside limit of the zone that could be explained by a movement of ice toward the lobe, 2) the absence of though within the transition zone points out a sufficiently high ice flow so that their conservation or build up is improbable, 3) the compression ripples and the ice rupture could be explainable by tension existing in the ice, 4) when the ice cannot creep, crevasses (never detected before in this area) appears as consequences of shear stress (fig. 3).

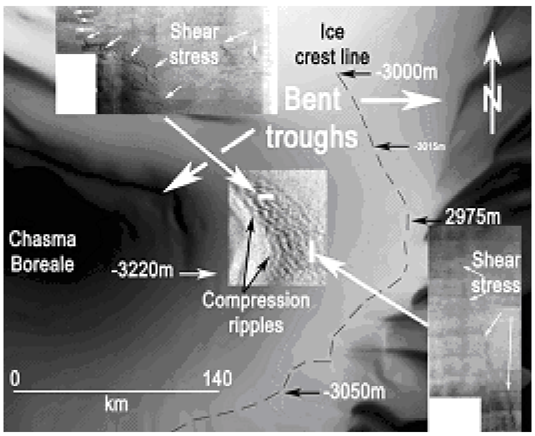

Figure 2. Surface phenomena in the transition zone indicating massive movement of the ice. Source: DEM/MOLA, Themis images.

At least forty major ice ages could have occurred during the past 5 Ma [14]. It indicates that climatic environments were at time favourable for ice flowage. Hence, the combination of topographic, geomorphologic (and stratigraphic) considerations supports the hypothesis of ice flowage during the last build up of the ice cap.

Discussion. The gathering of observations and analysis of surface data, coupled with the presence of unconformities and disruptions found in the Titania lobe and the transition zone enable to suggest the following scenario: 1) the build up of an elliptic dome within a regional scale depression, 2) an overflow of ice accumulation mixed with precipitations generating a lobe mainly parallel to the southern flank of the elliptic dome, its western orientation being determined by local base level topography. The hollow that has thus been drawn up corresponds to the Chasma Boreale.

References. [1] M. T. Zuber et al; *Science*, **282**, 2053, 1998. [2] G. Picardi et al; *Science,* **310**, 1925, 2005. [3] N. E. Putzig et al; *7th Int. Mars Conf*, **Abs.**,1, 2007. [4] J. J. Plaut et al; *European Mars science and Exploration Conference*, 2007.

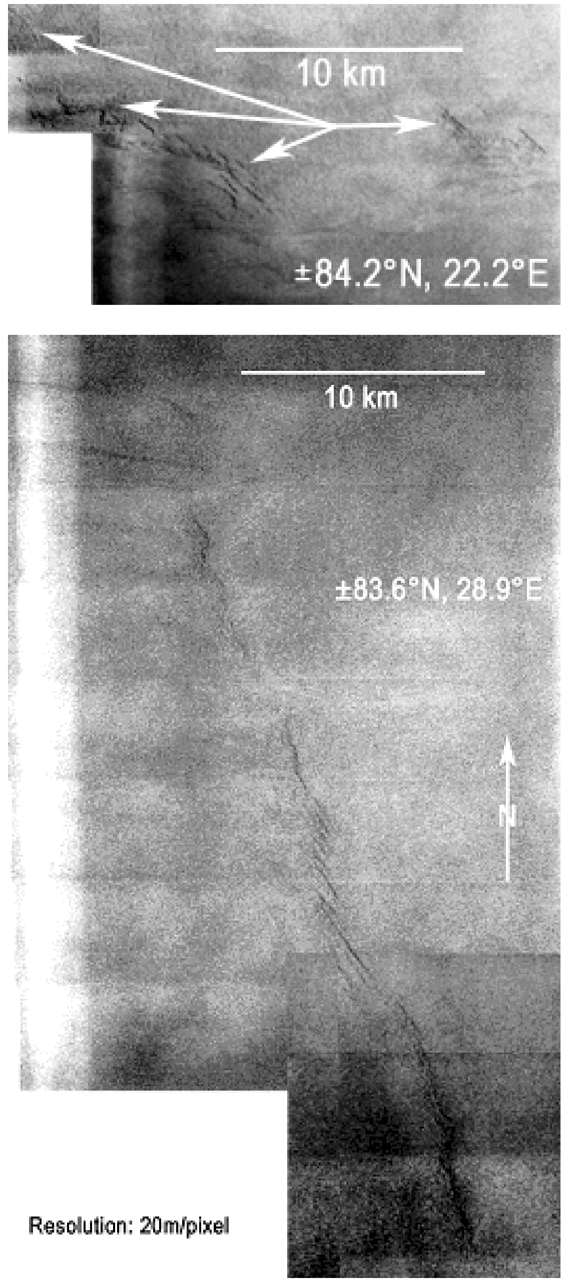

Figure 3. Close up of the shear stress effects: the presence of crevasses. Source: Themis.

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