NEWLY MAPPED EXTENT, MORPHOLOGY AND INTERNAL STRATIGRAPHY OF THE MARTIAN NORTH POLAR CAVI UNIT.

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Introduction: The basal unit (BU) is a sedimentary deposit that underlies the north polar layered deposits (NPLD) in the Planum Boreum (PB) of Mars [1-3]. It is divided into the rupes unit and the cavi unit. [2]. The latter records climate conditions and geomorphic processes from ancient times until NPLD accumulation [4]. Cavi unit is easily distinguished from the overlying water ice deposits due to its characteristic aeolian cross strata and low albedo, both readily apparent in high-resolution orbital imagery [4-5]. Therefore, imagery has long been the basis for stratigraphic mapping, but we need the means to correlate the distant, scattered visible exposures. The Shallow Radar (SHARAD) on Mars Reconnaissance Orbiter [6] detects the morphology of the BU underneath the NPLD [3] and reveals its internal structure. In this study, we integrate imagery and radar interpretations to reveal the full extent of the BU, the cavi unit in particular, thus providing the stratigraphic context necessary to correlate distant outcrops. We also find new details of morphology that reveal renewed depositional and erosional activity in cavi unit after the NPLD started to accumulate.

Methods: We tracked radar reflectors ("horizons") across ~1100 SHARAD profiles in a seismic interpretation environment (Landmark DecisionSpace®). We depth-converted the time delay horizon information assuming a water ice composition for the NPLD (ε_r=3.1, [7]) and a mixture of water ice and sand for the BU (ε_r=7.4, [8]), thus allowing thicknesses to be calculated for each body using ESRI ArcMap®.

Cavi unit extent: Analysis of SHARAD profiles indicates that the cavi unit extends over a larger area than previously thought (Fig. 1). This work revealed the presence of a weak radar reflector located beneath the NPLD and adjacent to the previously mapped cavi unit [3]. This reflector is interpreted as the top of the Vastitas Borealis interior unit (on which Planum Boreum sits, [4]), and delineates the base of a sedimentary body up to 200 m thick (assuming ε_r=7.4, [8]) that appears continuos to cavi unit. In fact, the basal reflector can be traced beneath cavi unit and the two overlying, adjacent units share similar radar scattering signatures. At the presently mapped extent, this lobe extends from the western edge of Gemina Lingula to a visible exposure in the eastern end of Olympia Undae, covering an area of over 80,000 km^2. HiRISE images taken over the outcrop location reveal flat lying terrains forming terraces and characterized by sinuous forms and cross strata (Fig. 2, 3). Our observations suggest that this lobe is a

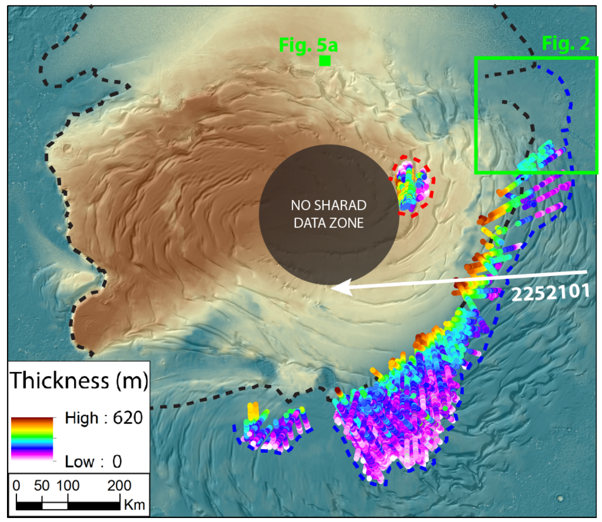

Figure 1: Extent and computed thicknesses of the bodies examined by this study: BU from previous mapping ([3], black line), cavi lobe (blue line) and putative dune field (red line). Colors in the background represent BU thickness (blue = 0 m, brown = 1250 m), with superimposed shaded relief of the modern Planum Boreum topography. The white arrow indicates location and directionality of the radar profile in Fig. 4.

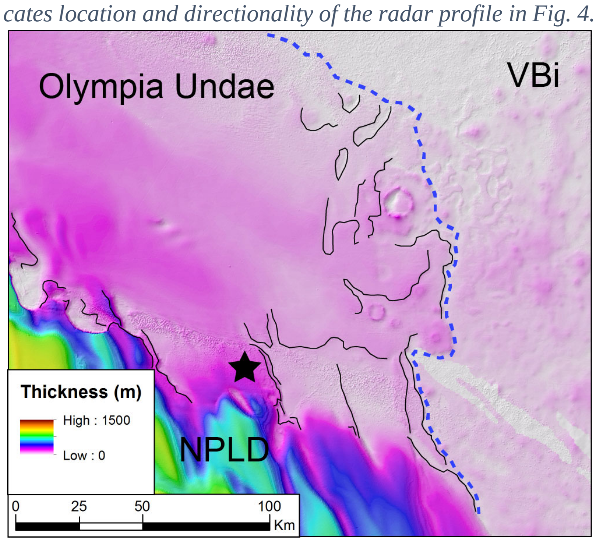

Figure 2: Thickness map of Eastern Olympia Undae and the cavi lobe outcrop mapped in this study. The blue dotted line indicates the boundary with VBi, black lines delineate terraces. The black star indicates location of Fig. 3.

relatively thin veneer of cavi material that extends farther to the south than previously determined.

Cavi unit morphology and stratigraphy: Our radar-based topographic mapping also reveals a series of elongated depressions along the edge of cavi tens to hundreds of meters deep (Fig. 4). In some cases, the base of these depressions are flat and appear to continue

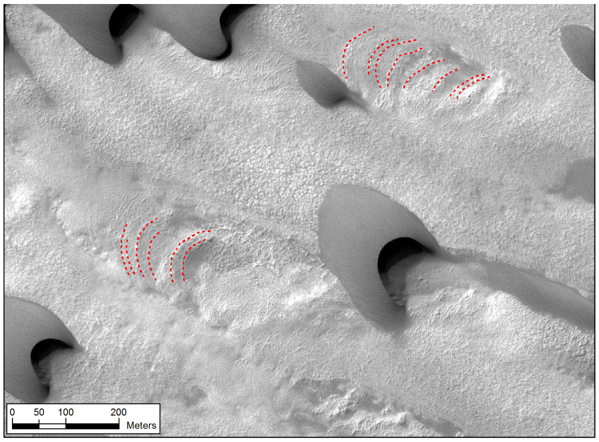

Figure 3: Sample of HiRISE image ESP_035925_2770. The red dotted lines delineate cross strata.

as reflectors internal to cavi for hundreds of kilometers. We interpret these reflectors as significant changes in composition within cavi, delineating sequences that exhibit different resistance to erosion, thus forming terraces that are observed in radar profiles, visible imagery and altimetry data. The location of the elongated depressions coincides with the presence and shape of the buried chasma observed by [9], suggesting that cavi was eroded in the same event that shaped the chasma.

Although SHARAD does not generally detect subtleties of the gradation between cavi and the NPLD, perhaps due to the limited vertical extent of the transition and its gradational nature, we did find evidence of a lens of isolated material located between cavi unit and the NPLD. The top of this deposit is a relatively sharp reflector protruding from the underlying cavi unit, followed by a diffuse return and a reflection-free zone. This feature extends over an area of ~4000 km^2 (Fig.1).

Discussion: Our study, based on integration of radar profiles and orbital imagery, revealed that the BU, its cavi member in particular, is significantly more extensive than previously thought. The area covered by the lobe of cavi material is equivalent to ~13% of the previously mapped BU [3], and adds ~2% to its volume. The new topography maps will be used to provide context to cavi outcrops and reveal potential exposure. One of these, the newly discovered cavi lobe outcrop, likely records climate conditions just prior to NPLD deposition and its flat topography exposes cross strata in plan view, a rare occurrence in cavi outcrops. For this reason, this location should be target for high-resolution imaging in the near future.

We interpret interpret the lens of material located above cavi as a late episode of aeolian sand accumulation on top of cleaner water ice. We have found a potential, yet smaller analog of this feature in the central region of Olympia Cavi, where a scarp exposes a scattered dune field sitting on top of a ~150 m thick NPLD package (Fig. 5). This could be the first detection of such transitional deposits in radar profiles and provides new

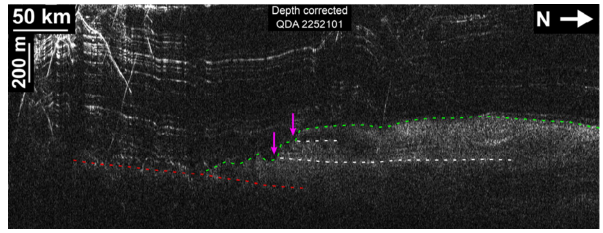

Figure 4: Sample of SHARAD profile 2252101 showing cavi unit depressions (pink arrows) and internal reflectors (white dotted lines). Note the continuation of the flat base of the depressions with reflectors.

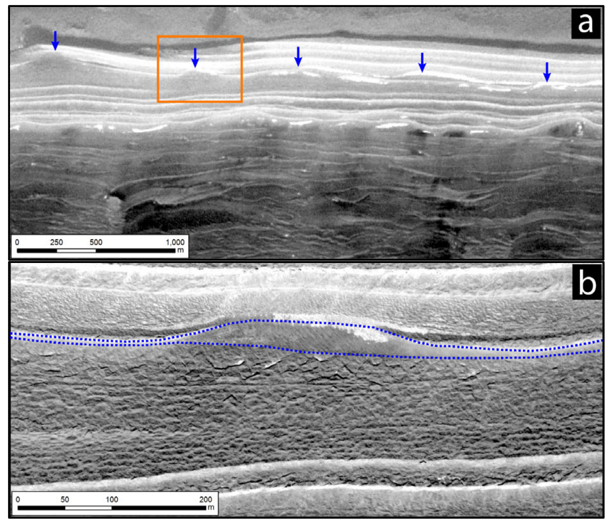

Figure 5: (a) Scattered dune field within NPLD in Olympia Cavi as seen in CTX image G22_026631_2650. The sand dunes, indicated by blue arrows, are a record of renewed siliciclastic material deposition long after the NPLD started to accumulate. (b) Details of a sand dune in HiRISE image ESP_026631_2650, location in orange box above.

information on the potential size of these features.

In general, out study revealed new details of cavi morphology that indicate a more complex history than previously thought, characterized by late, renewed deposition and erosional activity. The resulting morphology must have had an impact on subsequent NPLD accumulation and evolution, and we hypothesize that some throughs and depressions visible on the modern surface result from the depressions mapped in this study.

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