
Introduction: Though the polar deposits of Mars are promising locations to observe recent to long-term climate history through delineation and correlation of hundreds of layers of ice and dust, many aspects regarding the form, structure, and composition of these deposits are not well documented, particularly at varying scales of investigation afforded by modern data. The primary goal of this investigation is to use the process of geologic mapping to document the stratigraphy of diverse, yet under-studied, north polar sequences that are exposed along a complex series of troughs and scarps known as Olympia Cavi and Rupēs (Fig. 1). The Olympia Cavi region is especially well-suited for detailed geologic mapping because it displays the full suite of polar layered deposits from the uppermost recent residual ice and Late Amazonian layered deposits to the lowermost, Late Hesperian Rupēs Tenuis unit that underpins the entire polar plateau. We are producing geologic maps at 1:100,000 scale at three non-contiguous sites along Olympia Cavi in order to characterize the continuity and variability of polar layered deposits and establish their three-dimensional architecture. Our investigation focuses on mapping unconformity-bounded units and measuring strata thicknesses and orientations using high-resolution, co-located HiRISE and CTX images and stereo-derived topography. Base maps consist of CTX image mosaics that are overlapped by digital terrain models (DTMs) from HiRISE and CTX, allowing a spatial range of detailed observations that have not yet been used for the construction of polar geologic maps or polar layer correlations.

Rationale: The two most recently-published geologic maps of Planum Boreum are Tanaka and Fortezzo (2012) at 1:2M scale [1] and Skinner and Herkenhoff (2012) at 1:500K scale [2]. These two maps identified roughly equivalent units in the Olympia Cavi (OC) region, including a stratigraphically lowermost, dark, thinly-stratified unit exposed predominantly within polar cavi (unit A0b2 of [1] and unit A0c1 of [2]) and bright, rhythmically-layered units exposed on south-facing trough walls (units A0b1, A0b1, and A0b1 of [1] and units A0b1 and A0b2 of [2]). There are, however, discrepancies between these two maps. In particular, the Planum Boreum 2 (A0b2) unit of [1] corresponds to the Olympia Cavi 1 (A0c1) and 2 (A0c2) units of [2]. Tanaka and Fortezzo (2012) interpreted unit A0b2 as superposing the older layered deposits while Skinner and Herkenhoff (2012) interpreted unit A0c1 as underpinning those same layered deposits. Contrary to interpretations of [1], [2] interpreted that the erosion of Planum Boreum units was specifically accompanied by deposition of Olympia Cavi units, mostly within local depressions associated with the polar troughs. The discrepancies in both of these maps, which were produced using different data sets at different scales, are central to the current investigation. Mapping work thus far has included reconciling and adapting those past maps to one another as well as to different base data (CTX and HiRISE orthimages and DTMs) produced for this investigation. These efforts – though procedurally subtle – have highlighted critical differences regarding how scale-based geologic mapping can simultaneously yield similar and different (and in some instances contradictory) results.

Results: We have leveraged previous maps and their adaptations at our 1:100,000 mapping scale to identify and describe indisputable units, sideling those, and then mapping landforms, contacts, and units in areas of geologic and stratigraphic ambiguity. We have completed identification of major landform classes and geologic units in all CTX sub-areas for the eastern, central, and western quads as well as all HiRISE subunits in those same regions (Fig. 1). Unambiguous major units identified thus far in both CTX and HiRISE sub-areas include (1) the uppermost polar ice unit (~A0b of [2]), (2) a single rhythmically-layered unit (~A0b1 and A0b2 of [2]), and (3) a duneform unit (~A0u of [2]). We specifically note that we currently identify no discernible difference in units that were previously considered to be two separate sets of polar layered deposits. Rather, these rhythmically-layered deposits appear continuous throughout the regions of interest based on observations at both CTX and HiRISE scales. This is a critical difference in interpretation thus far as it implies that, contrary to previous geologic mapping and topical studies, there was no significant (or at least discernible) erosional event or depositional hiatus that occurred over the last 5 Myr, at least in the Olympia Cavi region of Planum Boreum.

Ambiguous units (those that were discrepant in previously-published maps) that we identified include (1) the dark-toned A0c1-equivalent “basal” unit of [2] (~A0b of [1]) and (2) surficial mass-wasting units (no equivalent in previous maps) that appear to source from particular horizons in the lowermost rhythmically-layered deposits and “basal” unit. Though [1] identified potential outcrops of a lowermost unit (dubbed therein
the Rupes Tenuis unit, Hb-) within the deep (<4200 m) cavi in the eastern quad, we have yet to identify any horizontally traceable contacts or variations in character within the “basal” units to justify the existence of this unit within the study areas. This, too, is an important result thus far in the investigation as it undercuts the potential of outcrops of an underpinning Hesperian-age unit within the study region despite the fact that all three HiRISE sub-areas transect this contact in the 1:2M scale geologic map of [1]. We note that this does not suggest that a Hesperian-age unit does not exist beneath Planum Boreum but, rather, that it might not be as continuous as previously believed, perhaps explained by the existence of erosion-created paleotopography of this unit prior to the deposition of dark- and light-toned deposits during the Amazonian.

Despite the absence of evidence supportive of a lowermost, underpinning unit equivalent to the Rupes Tenuis unit, we have observed a wide variety of landforms and textures within the dark-toned basal units exposed within the deepest cavi including cross-stratification (aeolian cross-beds), layer truncations and pinch-outs (unconformities), and narrow arcuate ridges. The latter landform occurs on the surfaces of individual, near-horizontal beds within the basal unit and is surprisingly similar to relict duneform “footprints” observed in some arid regions on Earth. Surficial units identified thus far are comprised almost exclusively of mass-wasting deposits, which appear to source predominantly from the bright-layered deposits located immediately (<100 m) above its contact with the subjacent dark-toned “basal” deposits. We note that the source section of the light-toned layered deposits is pervasively disrupted by what appear to be near-vertical joints or fractures, which facilitates gravity-assisted block-falls and sediment slides. We observe little thus far in our work to suggest that emplacement of these units included liquid water.

Our mapping work, particularly HiRISE-based sub-area mapping, has significantly advanced our understanding of the contact relationships between the more ambiguous, stratigraphically older units of the Planum Boreum, how these grade into the less ambiguous stratigraphically younger units, the nature of how these older units accumulated, and how they might have been deformed by secondary processes after deposition. These observations lead us to believe that our quad and sub-area geologic maps might portray similar units to previously-published maps, but will have significantly increased fidelity in contact placement, will offer advanced understanding of the character and timing of primary (depositional) and secondary (modification) that affected these units, and will portray surficial (mass-wasting) units and processes in a way that previous maps were unable to achieve.


Figure 1. The Olympia Cavi region of Planum Boreum showing the locations of the three 1:100,000 scale geologic maps. Each “quad” contains one CTX DTM and three HiRISE DTMs. Each CTX DTM also contains a co-located HiRISE DTM. DTMs were produced specifically for this project via SOCET Set photogrammetry.