GEOMORPHOLOGICAL EVIDENCE OF PLAUSIBLE WATER ACTIVITY AND EVAPORITIC DEPOSITION IN INTERDUNE AREAS OF THE GYPSUM-RICH OLYMPIA UNDAE DUNE FIELD.
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Introduction: The Olympia Undae Dune Field encircles the North Polar ice cap on Mars and contains the largest aerial exposure of gypsum on the planet. Although the dune sand is likely to be mainly composed of pyroxene-bearing sand, in some areas the gypsum appears in greater concentrations than mafic minerals [1]. Presence of gypsum within Olympia Undae is important because it provides geochemical evidence of the presence of near surface water in the North Polar region [1]. Two different processes by which gypsum may have been incorporated into Olympia Undae are (1) in situ chemical alteration of sulfur-bearing minerals within the dune sand by water originating from melting of the north polar ice cap [1] and (2) aeolian transport (e.g., dust plume) from a localized, confined source area containing gypsum [2].

HiRISE images reveal dune cross-strata within the interdune areas of Olympia Undae (Fig. 1) which we suggest indicates a deflated surface stabilized by water, ice or evaporite cementation. We also suggest that bright patches in the interdunes are evidence of deposition of evaporitic material in the interdunes of Olympia Undae. Using HiRISE images and the White Sands Dune Field, New Mexico as a terrestrial analog, we develop a hydrological model for Olympia Undae related to the evolution of the dune field. We suggest that the origin of bright material in the interdunes and the evolution of the dune field was mediated by the episodic rise of groundwater.

Dune Cross-strata: The presence of cross-strata in Olympia Undae, which do not clearly relate to the current dune field, indictates that this once active aeolian surface has been deflated and stabilized. This surface likely represents a deflational sequence surface, which caps a previous dune constructional event. At White Sands Dune Field, where the dune cross-strata can be correlated to the modern dunes, the near surface water-table controls the accumulation of cross strata (Fig. 2) [2]. Similar in appearance, cross-strata in Victoria Valley Dune Field, Antarctica, accumulated and have been stabilized by snow and ice [3].

Interdune bright material: The high albedo material (bright patches) of Olympia Undae are found within the interdune associated with the cross-strata and polygon features (Type 1). Less common are bright patches on dune lee and stoss slopes in the form of ripples (Type 2). The characteristic high albedo of the bright patches was proposed to result from higher gypsum content [1]; however, CRISM data indicate that the bright patches are low in gypsum compared to higher gypsum abundance on dune crests [4].

In terrestrial systems, the interdunes may be subjected to a rising groundwater table, which usually coincides with changes in local precipitation and evaporation driven by seasonal climate fluctuations. In White Sands Dune Field, the episodic rise of the groundwater table into the interdunes is controlled by precipitation (rain, snow) in the surrounding high-elevations of San Andres and Sacramento Mountains, which becomes incorporated into the basin groundwater reservoir and raises the water-table. During the winter of 2006/2007 the groundwater table rose above the interdunes, which led to the erosion of interdunes and deposition of new evaporitic crust. The resulting morphology is charcterized by small ponding shorelines which contour along the dune lee slope and interdune [Fig. 2].

The Type 1 bright patches within the interdunes at Olympia Undae have a similar morphology to the interdune sediments formed after the rise of the groundwater table at White Sands Dune Field. Based on the morphologic characteristics and the presence of gypsum it is inferred that a rise in the groundwater table might have taken place within Olympia Undae, which was followed by deposition of evaporatic minerals in the interdune areas. A rise in the groundwater table would also raise the accumulation surface, which would account for the presence of dune cross-strata

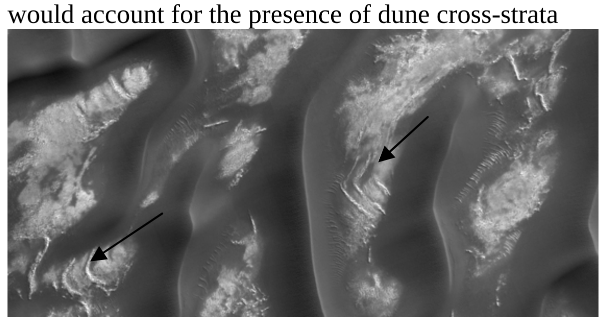

Figure 1. Examples of the cross-bedding strata for the Olympia Undae Dune Field. Portion of HiRISE image PSP_009898_2615

within the interdune. Alternatively, the Type 1 bright patches and cross-strata may represent an older stabilized surface which underlies the current dune field and is only exposed by deflation in the interdunes. The bright patches of Type 2 resemble the aeolian ripples likely derived by deflation of sand from the intedune areas.

Although in White Sands the preferential precipitation of gypsum is controlled by equilibrium reactions and an on-going active hydrological cycle, for Olympia Undae a single episodic rise of groundwater table into interdunes, followed by subsequent evaporation, could have involved precipitation of a variety of evaporatic minerals (gypsum, halite, etc.). Therefore, a lower content of gypsum in the interdunes compared to a higher content in the dune crests, as detected by CRISM, might result from the presence of evaporitic minerals (e.g., halite), other than gypsum, in the interdune deposits, which are spectrally unrecognizable by current instruments in orbit.

Hydrologic Model: Olympia Undae lies juxtaposed with Planum Boreum, which is a significant reservoir of water on Mars and may have undergone some melting in the past [5, 6]. Subsurface melting of the ice in the past may have involved the formation of water circulation which drained from the front of north polar ice cap into or beneath the dune field [1].

The exact source of groundwater and dissolved salts will remain speculative without in situ measurements for Olympia Undae. One reasonable explanation is that melting of ice and dissolution of dust, trapped in the north polar layered deposits, might have led to formation of fluids with elevated salt content. Alternatively, the basal unit underlying Olympia Undae may have contained highly mineralized groundwater or brines, which were brought to the surface when melt water from the polar ice caps infiltrated into the groundwater reservoir and induced a rise in the water table. The second explanation follows a model of groundwater flow and the upward migration of brines into White Sands Dune Field. These brines show elevated concentrations of SO_4, Cl and Na and Ca, Mg and K in the interdunes. Higher salt content result from i) long-term water-rock interaction controlled by dissolution of Permian evaporite strata which lie beneath and flank the dune field [2], and ii) higher rates of evaporation.

Conlusions: We propose that higher albedo patches in Olympiae Undae interdunes might be a result of the rise of groundwater table in the interdunes that led to precipitation of gypsum and other evaporitic minerals. Alternatively, the bright patches and cross-strata may represent an older stabilized surface which underlies the current dune field and is only exposed by

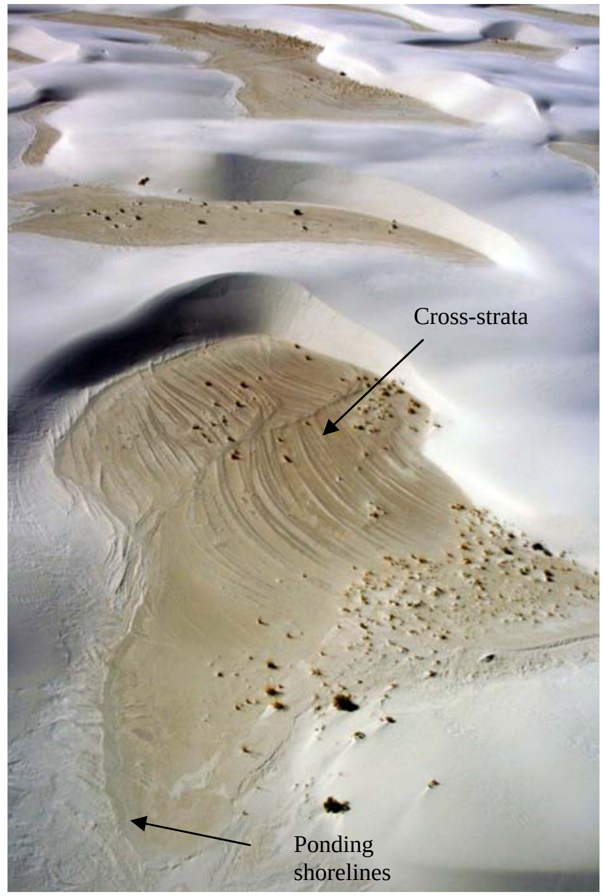

Figure 2. Examples of the cross-bedding strata and interdune deposits for the White Sands Dune Field, October of 2007.

deflation in the interdunes. A rise in the water table would also raise the accumulation surface, which would explain for dune cross-strata within the interdune.

These new morphological features revealed by HiRISE appears to indicate the change(s) in paleoenvironmental conditions likely controlled by climate fluctuations in the North Pole of Mars. Similar features in Chasma Boreale and Siton Undae [7] suggesting a regional-scale effect.

References: [1] Fishbaugh K.E. et al. (2007) *JGR, 112*. [2] Szynkiewicz A. et al. (2009) *Geomorphol., (in press)*. [3] Bourke M.C. et al. (2009) *Geomorphol., (in press)*. [4] Roach L. H. et al. (2007) *LPS XXXVII*, Abstract#1970. [5] Clifford (1987) *JGR, 92*. [6] Fishbaugh and Head (2002) *JGR*, *107*. [7] Bourke M.C. and Gardin E. (2009) *LPS - this volume*.