EVIDENCE FOR GROUNDWATER ACTIVITY AND SULFATE ORIGIN IN THE BASAL UNIT AND OLYMPIA UNDAE DUNES ON MARS. A. Szynkiewicz[1] , J. L. Bishop[2], L. Fenton[2], M. Parente[3], [1]University of Tennessee, Knoxville, TN (aszynkie@utk.edu), [2]SETI Institute, Mountain View, CA, [3]University of Massachusetts, Amherst, MA.

Introduction: Elevated concentrations of gypsum have been measured within the Olympia Undae dunes on Mars, mainly along dune crests, but spectral signatures of gypsum can be traced for thousands of kilometers in all circumpolar basaltic dune fields and within the sand layers of the paleo-erg (basal unit) currently underlying the North Polar ice cap [1-3]. Although various geochemical models have been proposed for the origin of this sulfate, including atmospheric and aqueous weathering processes [4], there is a growing consensus that the gypsum is sourced from erosion of the thick sand deposit of the basal unit [1,2,4].

Planar surfaces of the basal unit currently exposed in the interdunes of Olympia Undae show distinctive bright albedo (white) surfaces (Fig. 1A-C). The latter can be also traced along the scarps of the upper basal unit exposed under the North Polar ice cap. New CRISM results [5] suggest that regions in eastern Olympia Undae where these white surfaces are more prevalent contain bassanite ($CaSO_4$•$0.5H_2O$) rather than gypsum ($CaSO_4$•$2H_2O$), as well as basaltic sand. Further, on the slopes and crests of the dunes there appear to be more mixtures of bassanite and gypsum.

Secondary sulfate- and chloride-rich minerals are common in terrestrial dune fields where rising groundwater evaporates near the surface. In the White Sands dune field in New Mexico, this process leads to distinctive cementation of the interdunes and dunes' cross-beds by secondary gypsum with trace amounts of chloride and carbonate minerals (Fig. 1D-E). Therefore, the main goal of this study is to use HiRISE imagery and dune morphology to look for evidence of similar groundwater rise and evaporitic salt formation within the upper sections of the basal unit currently underlying the Olympia Undae sand sea.

Morphological Observations with HiRISE: In the eastern and central portions of Olympia Undae we studied, the white surfaces of the basal unit are usually accompanied by polygons and planar cross-bedding with preserved shapes of dune cross-bedding strata (Fig. 1A-B). Often, these cross-bedding features form distinctive ridges across the interdunes, which are covered with white polygons. In some areas, the abundant white ripples (Fig. 1C) suggest subsequent reworking of the white surfaces through aeolian processes. Generally, the white planar cross-bedding regions do not clearly relate to the current, transverse-type dunes of Olympia Undae, supporting the notion that this once active eolian surface has been deflated and stabilized. This surface likely caps a previous dune constructional event, most likely during formation of the paleo-erg. This is in contrast to the White Sands gypsum dune field, where the shapes of interdune cross-bedding can be correlated to the crests of current dunes (Fig. 1D).

Evidence for past groundwater in the basal unit: The morphological features (e.g., cross-bedding, polygons) of the white surfaces present in the Olympia Undae interdunes (Fig. 1A-B), and their close resemblance to the White Sands interdunes (Fig. 1D-E), strongly suggest past groundwater rise and evaporation near the deflated surfaces (e.g., old interdunes of the paleo-erg), where evaporitic minerals could have accumulated in higher amounts in the past. The latter is strongly supported by the presence of both bassanite and gypsum on CRISM images of the Olympia Undae [5]. These are common secondary minerals with bright (white) colors forming in dry environments, either as a result of water evaporation or cryogenic processes [4,6], and correlate with the presence of the distinctive white surfaces in the Olympia Undae interdunes with low ice spectral signatures [3].

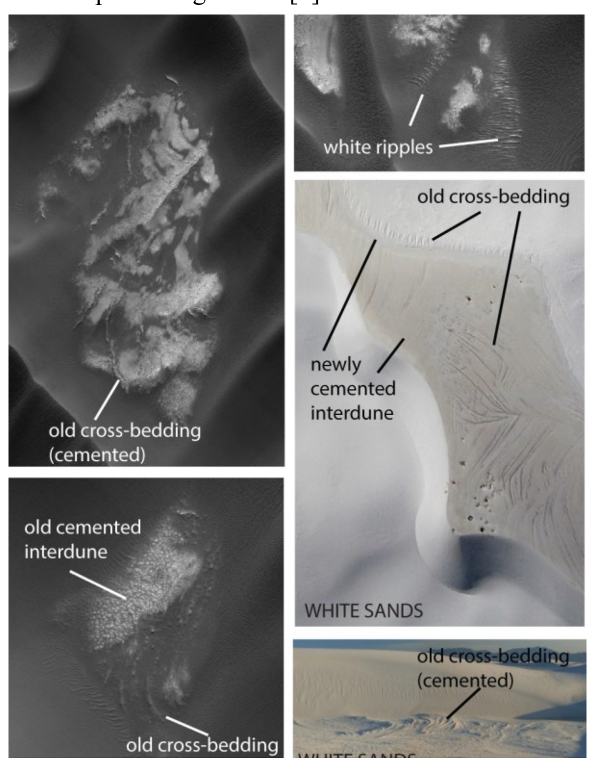

Figure 1. A-B – cemented cross-bedding strata with polygonal features and **C** – white ripples in the interdunes of eastern Olympia Undae (HiRISE image: ESP_027514_2615). **D-E** – cementation of interdunes and cross-bedding strata in the White Sands gypsum dunes (New Mexico).

In the White Sands dune field, the interdunes are subjected to a rising groundwater table after periods with intense precipitation (rain) in the surrounding high elevation areas, which becomes incorporated into the basin groundwater reservoir and raises the water table. Only during rare wet events, the interdunes fill entirely with rising groundwater. Under typical dry conditions, the groundwater table remains near the interdune surface, thus raising the accumulation surface for the sand. This accounts for wetting and eventual cementation of dune cross-bedding strata by secondary gypsum within the interdunes and the lower parts of the dunes. Polygonal features are usually associated with complete drying of the deflation surfaces and thermal contraction due to gypsum precipitation. This is common on the surfaces of modern playa lakes in White Sands. However, the polygonal features are rare in the interdunes because of the continuous rise of groundwater leading to incomplete water evaporation in the interdune areas. Consequently, the White Sands interdunes remain wet throughout the year with only partial cementation of the sand by secondary gypsum and traces of other evaporitic minerals (e.g., chlorides, carbonate).

In contrast, polygons are common on the white surfaces of the interdunes in the Olympia Undae region, suggesting stronger cementation by evaporitic minerals in the past than in modern White Sands. The prevailing abundance of bassanite in the interdunes to the east [5] supports the notion that complete evaporation of rising groundwater and further desiccation of the white surfaces took place within the basal unit in the past. While bassanite usually forms as a result of subsequent gypsum dehydration at higher temperatures, it can also precipitate directly from highly saline waters at lower temperatures and/or form via cryosuction under polar conditions [6,7]. The latter processes are in agreement with the expected dry polar conditions during the Amazonian when the paleo-erg of the basal unit was last active.

Sulfate Origin: Direct association of bassanite with the white polygons and cemented cross-beds on the old deflated surfaces of the basal unit [5] is an invaluable marker of past groundwater rise and its subsequent evaporation/desiccation. These processes likely occurred during paleo-erg activity, thus prior to formation of the North Polar ice cap, at the time when conditions might have been different and liquid water was still stable on the surface of Mars. Using terrestrial knowledge on aqueous sulfate formation, the groundwater of the paleo-erg was likely enriched in sulfate from both atmospheric deposition and sulfide weathering [4]. Any evaporation of this groundwater would have resulted in the formation of secondary minerals (bassanite and gypsum salts), which would stabilize the deflated eolian surfaces of the paleo-erg in the past (Fig. 1A-B). This process appears to be similar to modern terrestrial dune fields such as White Sands (Fig. 1D-E).

New CRISM results [5] suggest that spectral signatures of bassanite and gypsum are also present on dark surfaces (slopes) of the Olympia Undae dunes. This implies a secondary origin and likely subsequent wind erosion of the cemented, white surfaces present in the interdunes. The latter is supported by the presence of white ripples (Fig. 1C) likely derived by deflation of the sand from the white interdune areas. It is also likely that gypsum on dune slopes may have formed more recently from hydration of small bassanite grains during eolian transport and/or seasonal frost accumulation.

It is noteworthy that if chloride salts are also present within the white interdunes, they may support stronger cementation within the deflated and stabilized surfaces of the basal unit. This is consistent with Earth studies showing that chloride-rich crusts show less dust emission than those enriched in sulfate minerals [8].

Conclusions: We propose that bright albedo (white) surfaces accompanied by polygons and cemented cross-bedding in the Olympia Undae interdunes are likely a result of the past rise of groundwater table within the paleo-erg (basal unit) that led to precipitation of evaporitic minerals such as bassanite. A rise in the water table likely raised the accumulation surface, which explains the cementation and preservation of dune cross-bedding features within the paleo-erg. These white surfaces represent an older stabilized surface, which underlies the current Olympia Undae dunes and is only exposed by deflation in the interdunes. The presence of bassanite and gypsum on the surfaces of Olympia Undae dunes [5] suggest a secondary origin, mainly from wind erosion of the white surfaces and possible later hydration of bassanite to gypsum.

These new morphological and mineralogical features revealed by HiRISE and CRISM appear to indicate the change(s) in paleoenvironmental conditions during evolution of the paleo-erg, likely controlled by climate fluctuations in the North Polar region of Mars prior to formation of the ice cap. Similar features in other exposures of the basal unit around the ice cap suggest a regional-scale effect.

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