GYPSUM DUNES FROM WHITE SANDS NATIONAL MONUMENT – POTENTIAL TERRESTRIAL ANALOG TO NORTH POLAR DUNES ON MARS. A. Szynkiewicz[1], L.M. Pratt[1], M. Glamoclija[2], and D. Bustos[3], [1]Indiana University (Department of Geological Sciences, 1001 East 10th Street, Bloomington, IN 47405-1405, aszynkie@indiana.edu; [2]Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Branch Road NW Washington, DC 20015; [3]White Sands National Monument, P.O. Box 1086, Holloman Air Force Base, NM 88330).

Introduction: Rare on Earth, gypsum dunes are restricted to semi-arid areas where older sulfate-rich sedimentary rocks undergo dissolution by meteoric waters on/near the surface. New evaporitic deposits are also formed from solutes transported by surface runoff, meteoric and/or hydrothermal groundwaters. Overall, gypsum dune appearance is linked to increased aridity and temperature changes that have occurred since the last global glaciaciation on Earth. The White Sands gypsum dunes (WSgd) are the largest known on Earth. The WSgd geological setting, however, differs from the gypsum-rich dunes of Olimpia Undae (OUgd) on Mars. In spite of these differences, similar morphological features between WSgd and OUgd might provide insights regarding the climate history of polar processes on Mars.

The OUgd in the North Polar region of Mars had complex chemical and physical evolution [1,2,3,4]. Gyspum is found only in dunes, with decreasing content from the eastern edge of the main polar north dune sea toward the west, following the main wind direction [1,2]. Dunes contain gypsum grains from a few tens of micrometers to milimiters in size and show elevated concentration within the dunes crest [1]. Mafic minerals and oxides comprise the remaining fraction of the dunes. The source area for gypsum has not yet been determined. The spatial distribution of gypsum suggests that meltwater channels could have contained evaporites precipitated from water originating from the Chasma Boreal melting events [2,4]. The regional geological and morphological comparison suggests that gypsum deposits may result from circulation of hydrothermal groundwater associated with magmatism at Alba Patera and that later eolian activity excavated these deposits [3]. Alternatively, Fishbaugh et al. [1] proposed that elevated gypsum content may result from in-situ alteration of sulfide and high-calcium-pyroxene-bearing dunes during melting of the layered polar deposits[1]. However, for this to occur roughly 30 times more sulfide is needed than what has been detected within the OUgd [1].

Geological settings: WSgd are located in southern central New Mexico, in the closed-drainage Tularosa Basin that formed by extensional tectonics in the Rio Grande Rift. The pluvial Lake Otero existed in the northern part of the Tularosa Basin during the late-Pleistocene and left evaporative sequences with laminated clays and silts, laminated gypsiferous marls, limestones, and massive silts containing large gypsum crystals; today, these sediments are exposed in gullies and incised by at least 20 playa lakes [5]. The aeolian processes are controlled mainly by hydrological changes in groundwater table [5], but vegetation and surface cementation acts to limit deflation as well [6].

Results and discussion: Three aspects of WSgd evolution relating to climate variation will be discussed in comparison to OUgd: i) gypsum sources, ii) groundwater discharge into interdunes areas, and iii) dessication of dunes.

Gypsum sources – sulfur isotope analysis on gypsum from dunes (mean $\delta^{34}S$, 13.2‰), lake beds ($\delta^{34}S$ from 11.3 to 14.3‰), domes on the playa surface (mean $\delta^{34}S$, 13.1 ‰) and SO_4^{2-} dissolved in local groundwater system (mean $\delta^{34}S$: 11.3‰ and 13.3‰) showed that SO_4^{2-} most likely originated from the dissolution of two different sequences of Permian evaporites located on and beneath the surface. The contribution from each source is related to a given climate condition, wetter or drier, that governed varied inputs of sulfate from shallow or deeper circulating groundwater systems, respectively. Additionaly, the alignment of some domes implies that local tectonism could have released a deeper water in the past through faults extending into the playa surface.

Today, eolian processes are limited by a relatively high groundwater table, advanced dunes cementation and re-exposure of an old lacustrine clay sequence on the playa surface which was a gypsum source for the WSgd in the past. The clay remains moist, most if not all of the time, and contains secondary gypsum crystals, varying in size (fine to coarse grained), that originated from groundwater currently discharging on the playa's surface. This example suggests that, depending on the type of deposited sediments exposed on the playa surface in the past, the source region may be subjected to exhaustion of gypsum. In comparison to OUgd, it may be proposed that lack of a currently observable source area for gypsum there implies limited amounts of gypsiferous sediments in the north polar region of Mars.

Groundwater discharge into the interdune areas – was observed during the winter of 2006/2007. This process was last observed in WSgd around 60 years ago. The

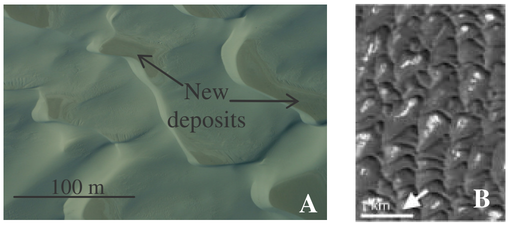

Fig. 1. A) New gypsum sediments formed after groundwater discharge into interdune areas during winter 2006/2007. Field of traverse dunes in White Sands National Monument. Photo taken by first author from altitude about 1,500 feet on October 2007. A dark color of interdune areas resulted from higher moisture content; B) Examples of Olimpia Undae dunes on Mars with associated bright patches in interdune areas which may be gypsum [1].

2006 monsoon season caused a rapid discharge of groundwater and flooding of interdune areas that led to the formation of shallow ponds. After evaporation, a thin layer of new gypsum-rich sediments was deposited on the surface of interdune areas (Fig. 1A). These new sediment deposits consist of fine-grained gypsum reworked by waves and further evaporitic cementation. The OUgd enclose bright patches of material in low areas between dune crests (Fig 1B) that resemble the new deposits observed in WSgd. The bright patches are relatively low in gypsum compared to the dunes themselves but grain-size effects resulting from orbiter camera limitations may cover up the actual interdune content of gypsum in the OUgd [1].

Desiccation of dunes – were manifested by cross-cutting cracks with an angle of 90º after the hot summer of 2007 (Fig. 2A). One system of cracks, propagating parallel to the cross-bedding, originated from dunes migration. The second system of cracks did not follow any sedimentary structures. Some of OUgd have an eroded rather than fresh appearance indicating inactivity and possible induration (Fig. 2B). The close similarity in crack propagation between WSgd and OUgd suggests a possible important loss of water by OUgd in the past. More advanced incision of OUgd may have resulted from further eolian erosion rather than surface or groundwater activity.

Conclusions: Based on the origin and evolution of WSgd, the reported chemical composition and advanced physical weathering of OUgd on Mars [1] may indicate complex processes that have taken place under different climate conditions (episodes). At least two wet episodes and two dry episodes can be considered regarding the evolution of OUgd:

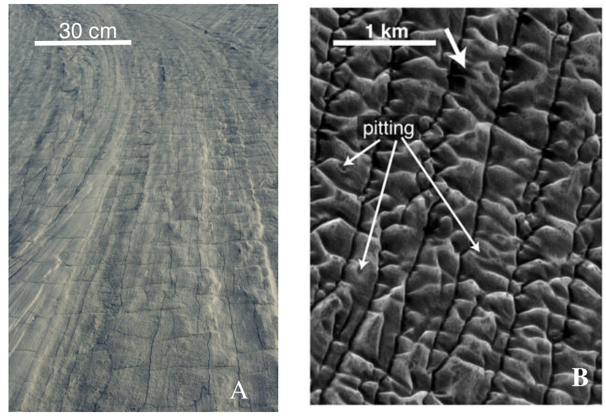

Fig. 2. A) Cross-cutting cracks formed at dune slopes after summer. Photo taken by first author in the White Sands National Monument area of traverse dunes on October 2007; B) examples of eroded and possibly indurated dunes within Olympia Undae dunes on Mars[1].

1) wet condition – deposition of sulfate-rich sediments in the region of meltwater channels most likely from precipitation of evaporites from water originating from the Chasma Boreal melting events;
2) dry condition – formation of gypsum-rich dunes by eolian deflation of sediments deposited earlier in the region of melting channels;
3) wet condition – cementation of dunes by capillary fringe, groundwater discharge and/or other sources of surface water; formation of interdune deposits;
4) dry condition - dessication of dunes and formation of cross-cutting cracks; further erosion of dunes through existing cracks most likely by wind.

Acknowledgments: This study was supported by the NASA Astrobiology Institute team award directed by L.M. Pratt. Sincerest thanks are due to Parker Bradley and Kevin Dunshee from a Division of Heron Aerospace Corp. in Alamogordo for organizing the flight and permission from the White Sands Missile Range for flying over the dune field of White Sands; to Esther Singer for help in preparation of lake sediments for sulfur isotopic analysis.

References: [1] Fishbaugh K.E. et al. (2007) *JGR, 112, E07002*. [2] Fishbaugh K.E. et al. (2006) *LPSC XXXVII,* Abstract#1642. [3] Tanaka (2006) *Fourth Mars Polar Polar Science Conference,* Abstract#8024. [4] Langevin et al. (2005) Science, 307,1584-1586. [5] Langford R.P. (2003) *Quatern Internat, 104, 31-39*. [6] Schenk C.J. and Fryberger S.G. (1988) *Sediment Geol 55, 109-120*.