MARS' NORTH POLAR GYPSUM: POSSIBLE ORIGIN RELATED TO EARLY AMAZONIAN MAGMATISM AT ALBA PATERA AND AEOLIAN MINING.

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Introduction. The OMEGA visible and near-infrared spectrometer onboard the Mars Express spacecraft detected the presence of a strong concentration of gypsum ($CaSO_4 \cdot 2(H_2O)$) at the eastern end of the north polar erg, named Olympia Undae [1] (Fig. 1). Gypsum is an evaporitic mineral that precipitates out of saline aqueous solutions. The formation of the Olympus Undae gypsum deposits has been attributed to precipitation from hydrothermal groundwater near volcanic sites, from melted acid snow and leaching of salts, and from polar basal melting and discharge of hypersaline water [1-2].

Here, I discuss the regional geologic and geomorphologic context of the observed sulfate deposits and their concentrations. These assessments lead me to propose that the gypsum may have been deposited during the Early Amazonian as a consequence of (a) magmatism at Alba Patera that drove hydrothermal groundwater circulation along subsurface structures and (b) aeolian mining that resulted in the exposures in the north polar region.

Regional geologic setting. Recently completed northern plains and preliminary north polar geologic mapping [3-5] contribute significant understandings to this part of Mars. At the end of the Hesperian, catastrophic fluvial discharges of the circum-Chryse region likely led to deposition of thick, water-rich sediments that were later modified. These deposits are mapped as the Vastitas Borealis units, which define the base of the Amazonian [3]. Complex reworking of these and underlying materials near the northern fringe of Alba Patera may have occurred via soft-sediment diapirism, mud volcanism, and aeolian transport during the Early Amazonian, leading to emplacement of the Scandia region unit [3]. Stratigraphic relations suggest this resurfacing was coeval with Alba Patera magmatism and tectonism.

While the mapped margin of Alba Patera is ~1000 km south of the gypsum, the buried margin of Alba Patera and the radial, Tantalus Fossae graben appear to extend 300 km and perhaps farther north beneath the Scandia region unit, which obscures the flows of Alba Patera and the graben. Tantalus Fossae may have facilitated dike propagation far into the northern plains, as well as provided structural conduits for hydrothermal and gravity-driven groundwater inputs within the Scandia region [*cf* 6]. The rugged terrains of Scandia Tholi and Cavi occur in a broad zone that extends for several hundred kilometers north to south. These terrains generally have tens to hundreds of meters of relief, including circular plateaus and irregular mountains tens to hundreds of kilometers across, some having moats and interior depressions. Irregular depressions, some several hundred meters deep, are common within the region. The gypsum-rich dunes occur on the northern margin of these terrains.

North of the gypsum, Planum Boreum forms a geologically complex polar plateau ~1000 km in diameter. Much of it appears to be underlain by the evenly-layered, Early Amazonian Rupes Tenuis unit [5]. That unit is partly overlain and surrounded by Late Amazonian wavy bedded material (Olympia Undae unit) covered by virtually uncratered layered deposits (Planum Boreum 1 and 2 units). In addition, the Olympia Undae unit forms the dune fields that encircle Planum Boreum [3]. These dunes seem to be largely stagnant since emplacement of Planum Boreum 2 unit and the mid-latitude mantle [5] identified by [7].

Wind-circulation patterns. The circum-polar dunes document the most recent wind directions [8]. Olympia Undae occur within a relatively warm topographic trough bordered by the partly ice-covered Planum Boreum and Scandia Tholi [8]. The prominent gypsum signature occurs within this westward-blowing wind region, and the minor signatures to the southeast occur in an eastward-blowing wind zone (Fig. 1).

Problems with basal Planum Boreum discharge scenarios. One scenario put forth to explain the gypsum occurrence is that hypersaline, sulfate-rich brines were discharged from the base of Planum Boreum through Chasma Boreale down to where the gypsum occurs, presumably along a channel that hugs the Rupes Tenuis scarp along the margin of Planum Boreum west of the mouth of Chasma Boreale [1-2]. The actual source of the brines is suggested to be a hummocky area along the margin of Planum Boreum (Fig. 1). However, a careful examination of this landscape proves otherwise, as follows. First, there is no evidence for fluvial dissection of the irregular Early Amazonian Chasma Boreale and Vastitas Borealis surfaces in the proposed fluvial pathway. In addition, the mouth of Chasma Boreale forms a terraced plateau a few hundred meters high, which should have been deeply dissected by any substantial flooding. Second, the natural basin for a discharge from Chasma Boreale is the lower-lying plains to the south, away from the observed sulfate-rich dunes that are toward the west. A basin exceeding 10^6 km^2 and a few hundred meters deep would have to be overtopped for the water to spill out toward Olympia Undae and the gypsum deposits. The size of the needed basin is further increased given the -4800 m elevation reached by the source deposit. Third, there is no gypsum signature exposed in this broad basin or in other depressions along the topographic pathways from Chasma Boreale to the gypsum sites, even though much of the surface appears to have low albedo and thus are dust free (Fig. 1).

Preferred scenario: ***Alba Patera magmatism generated the gypsum, which is exposed by aeolian mining.*** I propose that the Olympia Undae gypsum originally formed during the Early Amazonian, while Alba Patera was still active magmatically. The region upslope from the gypsum to Alba Patera may have been partly to extensively covered by lava flows, debris flows, and ash fall-out from the shield during the Hesperian. Such a paleo-landscape is topographically and geologically similar to the currently exposed Early Amazonian lava flows and fluvial and volcaniclastic deposits that resulted from eruptions and discharges from the Elysium rise, which traveled more than 2000 km downslope into Utopia Planitia [3]. Alba-related volcanic materials would have been largely buried by Chryse outflow channel deposits during the Early Amazonian, partly represented by the Vastitas Borealis units.

I suggest that tectonically controlled dike intrusions peripheral to Alba Patera led to hydrothermal groundwater circulation of saline brines along the radiating Tantalus Fossae graben system, including along buried extensions into the Scandia region. Therefore, hypersaline groundwater could have surfaced at the northern terminus of the Alba Patera regional slope (Fig. 1).

Expulsion of groundwater from radiating graben has occurred in numerous instances on Mars on the flanks of the Tharsis and Elysium rises, including in areas where no clear signature of synchronous, nearby surface volcanism was evident [e.g., 9]. Thus, heat transfer from a distant magma reservoir by hydrothermal groundwater circulation or by dike intrusions along fractures to a surrounding location is possible.

Dune migration directions indicate that the Olympia Undae gypsum absorption is strongest at the upwind margin of the dunes. These margins all occur in local, shallow (tens of meters) topographic depressions (-4950 to -4850 m elevations), except where obscured by low-albedo material. This scenario has similarities with explanations for the sulfate-rich deposits at Meridiani Planum [9]. Aeolian erosion and deflation by saltating sand may account for exposure of the deposits, which are elsewhere buried by mantle material and sand deposits from other sources. The Olympia Undae gypsum deposit includes spectrally neutral material [1] that likely served as the erosive agent. Downwind, the Olympia Undae gypsum spectral absorption gradually weakens. This indicates possible dilution by neutral sands, which may result from dune trains entering Olympia Undae from other adjacent and subjacent sources, notably reducing the gypsum signal (Fig. 1). In addition, comminution of gypsum grains with distance traveled can also account for the westward weakening of the gypsum spectral signature [2] .

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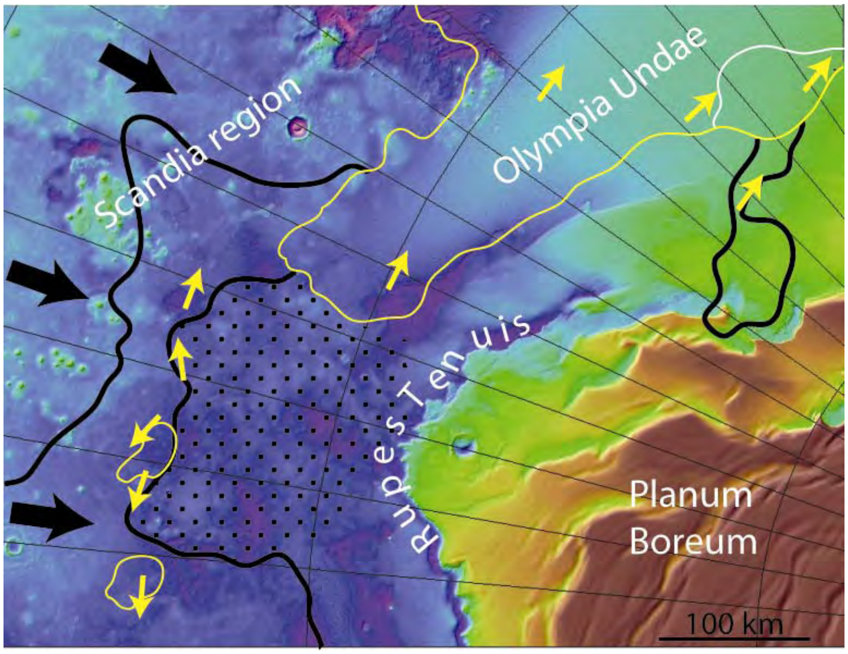

Fig. 1. Gypsum-rich signatures at Olympia Undae and two other spots occur in areas bounded by yellow lines, based on the OMEGA 1.94 micron spectral absorption band [1]. Dunes are prevalent in these areas. Black and yellow lines enclose low-albedo regions. Wind directions shown by yellow arrows based on dune orientations. White line encloses area of relatively low gypsum absorption possibly resulting from mixture of spectrally neutral material from the ENE. Stippled area near center is putative gypsum source deposit of [2]. The Scandia region is at the northern end of a regional slope (black arrows) that extends off of northern Alba Patera. (Image base is MOLA color shaded-relief with 5º lat/lon grid, which includes the 80ºN parallel; polar stereographic projection, north pole at lower right.)