CHEMICAL INVESTIGATIONS OF FRIABLE DEPOSITS IN NORTHEAST ARABIA TERRA, MARS.

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Introduction: Arabia Terra is a chemically diverse region of Mars that has been scrutinized with respect to its origins, potential for volcanism, and the implications of the geological evolution of the planet at large. Adjacent to this region lies a layered, friable, mantling unit. While the deposit has been studied morphologically and given an approximate age of emplacement along the Noachian-Hesperian boundary [1], little is known about the deposits chemically. Proposed sources for this northeast friable deposit (henceforth known as NEFD) include Syrtis Major [1] and semi-circular depressions asserted to be of volcanic origin within Arabia Terra [2,3]. While the deposit covers a minute amount of surface area (only 15% in a concentrated region of study) following a mass-erosion event after emplacement [1,4] it still exists at depths of up to half a km in several of the more sheltering craters, suggesting induration. A combination of chemical analysis using Mars Odyssey Gamma Ray Spectrometer (GRS) data and thermal inertia derived from NASA's Thermal Emission Imaging System (THEMIS) mosaics were used to assess these deposits to determine their origin.

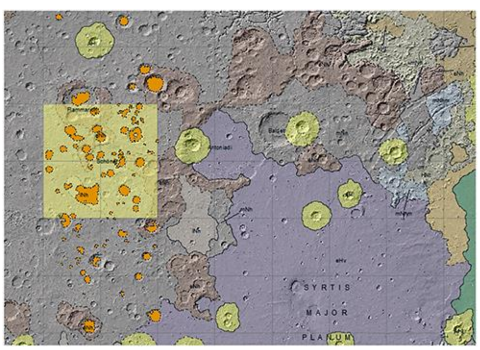

Figure 1. the NEFD are highlighted in orange as deposits that overlay eNh and mNh terrain but seem to correlate to smooth lnH deposits near Syrtis matching their approximate age. The CNEFD is highlighted in yellow, with a lat. of 15° to 25° and long. Of 45° to 55°.

Geochemistry: Chemical analysis using GRS was compiled and processed using Excel. The GRS chemical maps contain the location of and averaged geochemical data for elements Al, Si, Ca, Fe, H (as stoichiometric H_2O), S, Cl, K, and Th in 5°x5° bins by percentage mass fraction (wt%) and Th (mg/kg). The wt% of each element was reported at the centroid of each pixel. GRS has decimeter scale depth sensitivity, allowing it to measure geochemical signatures previously obscured within the Arabia Terra dust sink. Available GRS values (i.e., globally within ±55° latitude) for Al provided a limiting value range for a martian crustal proxy (MCP) that would enable comparison with the other sites at large. Additional calculations for the standardized oxides of each element were made from a modified volatile-reduction formula [5] to calculate and remove S rather than approximate using [Cl] to enhance and focus on igneous chemistry. From this, a modified version of Baratoux's method [6] was used to calculate MgO, Mg, and the Mg# from the oxides for the entirety of Mars where the majority of igneous provinces fall within the range 70 > Mg# > 40. Sites for comparison were chosen using a combination of the martian geologic [7] and chemical [5] maps of Mars, coupled with the initial identification of the NEFD [1] and focused and broad [3] Arabia regions, yielding 5 study provinces: CNEFD, NEFD, localized plains (LHP), focused (FAR) and broad (BAR) Arabia, Syrtis Major (SM) and Hesperia Planum (HP) delineated using ArcGIS. LHP, HP, and BAR provided regional comparisons. Twelve Modified box-whisker plots were made [8-10] as the 75th/25th, 50th/50th, and 25th/75th percentile (k) and where

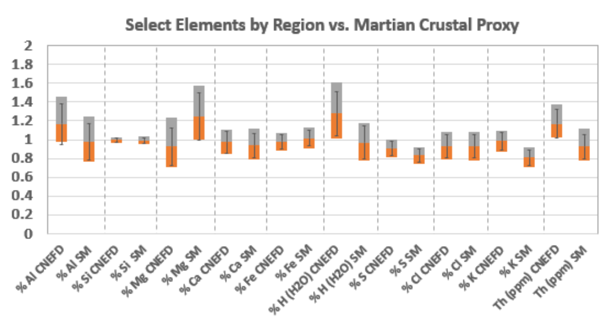

Figure 2. Modified box plot comparing the geochemistry of the CNEFD and SM to the MCP. There's enrichment in Al, H_2O, and Th, approximations in Si, Cl, and likely Ca and Fe. Both regions are depleted in S.

enrichment or depletion is ascertained relative to 1.

Thermal inertia: The quantitative THEMIS thermal inertia (TI) mosaic provides coverage from ±60°, with an error margin of roughly 10% per each pane within the global mosaic. Blue-colored areas have lower approx. TI and represent fine particles, such as dust or sand. Red-colored regions have greater approx. TI, potentially correlating to surface crusts, rock fragments, bedrock, or combinations thereof [11, 12].

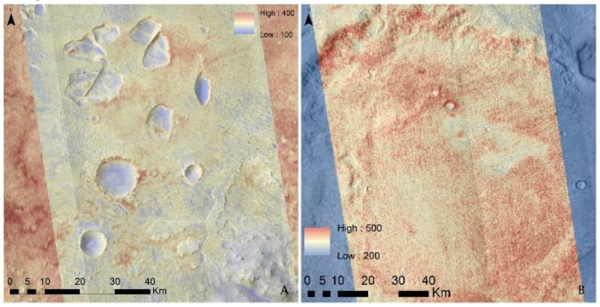

Figure 3. Pitting in the NEFD (A) highlighting dust collection in the CNEFD. B is located further North.

Stretching of the THEMIS data products was done using maximum-minimum to highlight differences. Eight sites for future work using the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) were chosen by combining thermal inertia via THEMIS and the Thermal Emission Spectrometer (TES) dust index [13].

Discussion: Syrtis Major is proposed to have had hydrothermal leaching leading to silicic deposits, mostly likely caused by high-temperature processes beyond groundwater alteration alone due to varied elevation [14]. However, the volatile content of the CNEFD resembles SM other than its quantity of H_2O, which may have been entrained within an eruptive plume following a volatile triggered eruption [15] through interaction with groundwater or ice. Tephra from explosive volcanism on Mars may scavenge water as ice and subject to low-temperature alteration away from direct heat (such as volcanic acid-fog) produce hydrated silica deposits [16, 18]. Such leaching could also explain reduced levels of Fe and Ca while leaving behind Al-rich phyllosilicates, which could have taken place prior to or during mass erosion of the NEFD following their emplacement in the Late Noachian. Given the variety of elevations at which the deposit is found, alteration was likely caused by a variety of sources potentially originating from Syrtis Major [14] coupled with later regional processes. Elemental abundances in FAR by comparison are likely the result of accrued material from Sinai, Solis, and Syria plana after leaching and fluvial activity during a period when Mars' climate was warm and wet in the Late Noachian [19]. FAR therefore resembles other proposed sedimentary basins containing volcaniclastics such as Isidis [5, 19, 20]. The deposits nearest to the western flanks of Syrtis beyond dust-obscured Arabia Terra have TI values roughly between 190-400 $Jm^{-2}K^{-1}s^{-1/2}$. This is within the range of consolidated ash to welded tuff and various sands from fine to coarse, suggestive of erosion rather than mere aeolian dust deposition [11, 12]. Given TI based particle size, volcanic deposition of the NEFD could not have occurred from a source farther than 2,000 km [12, 18]. This effectively eliminates not only nearby volcanoes located within HM, but the putative paterae within Arabia Terra as well.

Conclusion: Though GRS is more apropos for regional chemistry rather than targeted sites, we find using decreasing areal extent analysis that there are unique enrichments in Al and depletions in S for a concentrated study area bearing the friable deposits relative to its surroundings and the crust. The concentration also roughly approximates Syrtis Major in Si, Ca, Fe, and Cl, with H_2O and S enrichment, though both regions are volatile-depleted relative to the crust and surrounding terrain. Deposition models for volcanic accretionary products on Mars [18] limit the dispersal distance from their source. We find that the TI based grain-size (roughly 220-780 µm) for deposits with TI values not compromised by extant dust would not be able to travel much farther than 2,000 km [1, 18]. This effectively eliminates Michalski and Bleacher's putative paterae as the source, as well as Hesperia Planum sourced volcanism. The chemistry of the deposits in the study is consistent with multiple forms of aqueous weathering, potentially from a low-pH source, and volatile enrichment (H_2O) during eruptions from Syrtis Major. Paleo-winds from the Southeast may have contributed to transport.

Al-rich phyllosilicates identified in layered deposits elsewhere in Arabia Terra likely formed in low-pH environments [21]. Under acid-weathering as described above, deposits should be expected to contain amorphous silica, jarosite, and sulfates [4] via acid-fog interactions. For slightly higher pH, acidic surface stream formations, erosion of similarly aged, olivine-basalts like those found in Gusev Crater would produce goethite and Al-rich phyllosilicates [16]. Future research will investigate the CRISM targets identified using THEMIS for such mineralogic signatures.

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