

LITHIFICATION AND AQUEOUS ALTERATION OF AEOLIAN SEDIMENTS ALONG THE UNCONFORMITY AT GREENHEUGH PEDIMENT EXPLORED BY AN ANALOG SITE IN THE UNITED ARAB EMIRATES. Vigneshwaran Krishnamoorthi¹, Dimitra Atri¹ ¹Center for Space Science, New York University Abu Dhabi, PO Box 129188, Abu Dhabi, UAE, vk2346@nyu.edu ; atri@nyu.edu

Introduction: The Curiosity rover has discovered the youngest lithified aeolian sandstone deposits, stratified in Stimson formation, Siccar point group rocks at the Gale crater [1][2]. The fluvio-lacustrine deposit of Gale Crater was capped by the Stimson lithified dunes, which were deposited in a dry environment [1]. Earlier geochemical studies with data from APXS and ChemMin revealed the presence of mafic minerals, altered by late-stage aqueous activity, causing the sediments to lithify [2]. Since then, the rover has investigated the Stimson formation extension at Greenheugh Pediment (GP) slope between sols 3374-3466 (site 93 & 94). In addition to Gale Crater, the lithified aeolian deposits are found in few other areas, such as the Meridiani planum [3] and Apollinaris Sulci [4]. In order to reconstruct the lithification process, we analyzed images and data from the rover which aided us in finding an analog site in the UAE desert. The role of aqueous environments and organic preservation during the lithification of UAE dunes is explored in this study in order to better understand the possibility of organic preservation on sulfate rich deposits of Stimson formation and its unconformity.

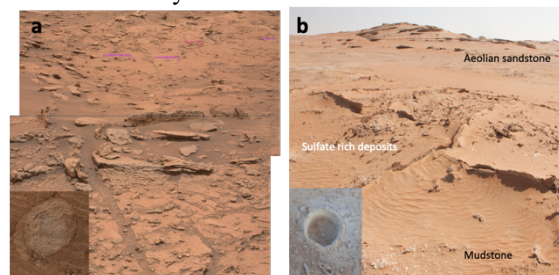


Fig. 1a. Mars flower bearing unconformity captured by Mastcam at sol 3392, 1b. Vein and concretion bearing unconformity at the UAE analog site.

Methods: The GP unconformity has been explored by geochemical analysis (SO_3 & Cl) of 41 APXS bedrock targets along the slope and the geological features have been characterized by Mastcam images (Fig. 1a). The Mastcam found flower shaped concretions on sol 3396 and the composition of these concretions were obtained from LIBS spectra. The field work was carried out at UAE sand dunes where we found an analog with similar geological features as the GP slope. Field investigation and an experimental dune setup were used to characterize the lithification process. During our fieldwork, we obtained 15 drilled samples of bedrocks and concretions (Fig. 1b) from the analogue site. Their geological characteristics and

preserved organics were investigated by SEM-EDX, PXRD, CT scan, CHNS elemental analyzer and GCMS instruments.

GP unconformity: The APXS SO_3 weight % variation on the GP bedrocks assists to differentiate the fluvio-lacustrine Carlyon Shoemaker (CS) formation (avg~9 including site 92) and unconformably overlying youngest aeolian Stimson formation (avg~4.1) (Fig. 2). The sulfate enriched fine grained laminated mudstone are stratified into CS formation which has an impermeable character [5]. The cross bedded well sorted and well rounded dark aeolianite sandstones is identified as an extension of the Stimson formation, Siccar point group which has distinct geochemical composition [1][2]. The Mastcam observed white toned cementation between sandstone laminate and CaO , SO_3 weight% witnessed the Ca S rich fluid flow and cementation [2]. The contact region of the aeolian and lacustrine rocks are stratified into Siccar point group unconformity [7]. The sulfate and chlorine rich rocks were found on this unconformity. In this study we explored this unconformity alteration and recrystallization from Cl and SO_3 enrichment at sol 3392 to 3397 (Fig. 2) flower concretion observation (Fig. 4a).

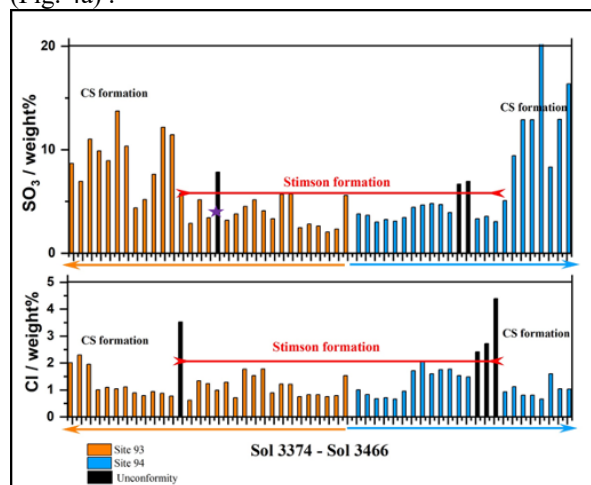


Fig. 2 APXS data analysis reports sulfate and chlorine rich unconformity.

Lithification process: In our field investigation in the UAE, lithified (Fig. 3a,3b) and currently water saturated quaternary sand dunes (Fig. 3c) [8] were identified as a potential analogue for Stimson formation. Evaporite crust on interdune flats (Fig.

3c,3d) and groundwater capillary laminar flow along sand sheets (Fig. 3e) witnessed groundwater saturation and evaporation on dunes. The recreation of sand dunes water flow with an experimental laboratory setting and also in the field demonstrates water capillary movement along sand sheets without destroying laminations (Fig. 3f). Because of impermeable bedrock and extensive aquifers at the unconformity layer, the late-stage water over-saturated and altered the sulfate enriched bedrock to form sulfate rich concretions deposits along the unconformity at UAE and Mars [9], which propose the wet dune evaporative system [3]. Here the unconformity is referred to as a capillary fringe zone[9] based on the observation of sulfate rich materials like gypcetes (known as flower concretions on Mars) (Fig. 4b). This study hypothesizes Mars Stimson formation was lithified by groundwater capillary flow and saturation on dune with evaporative dry environment.

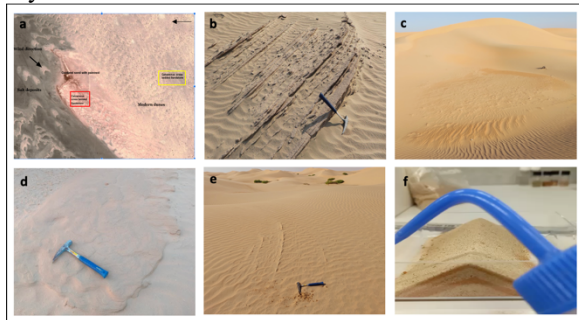


Fig. 3 a. The UAE analog site, b. Lithified aeolian sandstone c. Evaporite minerals found at interdune d. Groundwater capillary flow and saturation along the dune sheets f. Experimental setup to study dune water flow.

Analysis: The Quaternary sand dunes were deposited in an arid environment overlying the preexisting impermeable sedimentary rocks in our analog site [8]. During the late stage of geological formation, sulfate rich groundwater rose, cementing the aeolian sediments, and nucleating to form gypsum, gypsum veins, gypcrete, iron oxidized gypcrete and preserved plant root fossils along the unconformity (Fig. 4c) [9][10]. Ca carbonate and Ca sulfate cementation on lithified rocks were explored by SEM EDX elemental mapping. Using SEM EDX, the concretions were identified as Ca sulfate rich nucleated gypcrete and are an analog feature of Mars flower concretion (Fig. 4a, 4b). A hypersaline interdune sabkha at Liwa oasis provides a plausible analog for the microbial habitat system on Mars [10]. These microbes can also exist and were preserved on these sulfate rich unconformity deposits [9]. Micro elemental analyzers show the presence of organic carbon in gypcrete. GCMS is used

to quantify the Volatile Organic Compounds and BTEX compounds in our sulfate rich deposits (Fig. 4d).

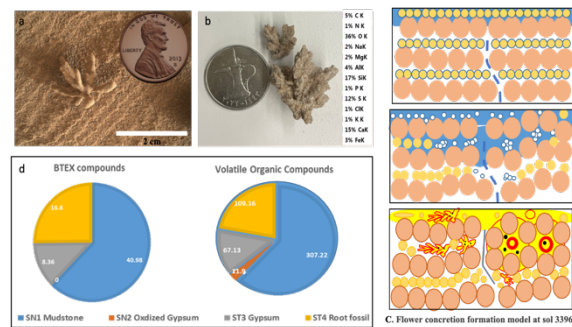


Fig 4 a. Mars flower concretion captured by Mastcam, b. UAE analogue flower concretion and its composition, c. A suggested schematic representation of the flower concretion formation, d. GCMS analysis of the rocks revealing the preserved organics concentration.

Summary: We explored the lithification process based on the UAE analog site and experimental studies. Based on our studies, we suggest that groundwater saturated dry aeolian deposits could create a late habitable environment for pre-existing life on Mars, similar to an oasis found in the UAE desert. Using GCMS, preserved organics were detected and identified along these unconformity sulfate deposits. Due to this lithification process, sulfate flower concretion with Chlorine rich layer indicate the possibility of organic preservation along this GP unconformity on Mars. Lithified aeolian deposits have been observed in several regions of Mars, which might trap the paleo environment and insulate it from the present harsh environments. These results suggest that similar unconformity layers on Mars can also act as a habitable and preservation zone for pre-existing organics and serve as potential targets for future life-search missions.

References: [1]Banham C. G. et al 2018 *Sedimentology* 65, 993–1042 [2] Bedford C. C. et al 2022 *JGR-Planets*, 126, e2020JE006554 [3] J.P. Grotzinger et al 2005 *EPSL* 240 (2005) 11 – 72 [4] A.R.G hunt et al 2022 *Icarus* 373 (2022) 114788 [5] Fedo, C. M et al 2022 *JGR-Planets* 127, e2022JE007408 [6] Thompson, L. M et al 2022 *JGR-Planets* 127, e2021JE00717 [8]Alsharhan AS,2020 SpringerCham ebook pageno 398 <https://doi.org/10.1007/978-3-030-31684-6> [9]M.I. El-Sayed, 2000 *Sedimentary Geology* 134 (2000) 305±330 [10] Susanne Douglas 2004 *PSS52* (2004) 223 – 227 [11] Insam, H., Seewald, M.S.A .2010 *Biol Fertil Soils* 46:199–213