

**EVAPORITES ON ICE: HOW TO FORM GYPSUM ON ANTARCTICA AND ON MARTIAN NORTH POLAR RESIDUAL CAP?** A. Losiak<sup>1</sup>, A. Derkowski<sup>1</sup>, A. Skala<sup>1</sup>, J. Trzcinski<sup>2</sup>; <sup>1</sup>Institute of Geological Sciences, Polish Academy of Sciences, Poland (anna.losiak@twarda.pan.pl, ndderkow@cyf-kr.edu.pl, aleksander.skala@agh.edu.pl), <sup>2</sup>Faculty of Geology, University of Warsaw (jerzy.trzcinski@uw.edu.pl).

**Evaporites on Antarctica:** Evaporites are highly water soluble minerals, formed as a result of the evaporation or freezing of bodies of water. They are common weathering minerals found on rocks (including meteorites) lying on Antarctic ice sheet [1, 2, 3, 4, 5]. Evaporites are formed by interaction of cations from the weathering of primary minerals combined with anions coming at least partially from the atmosphere [2]. The water necessary for the reaction is produced by melting of ice below the dark-colored meteorites which can heat up to a few degrees above 0 °C due to insolation heating during wind-free summer days [7, 8]. In some cases, heating of dark rocks can take place also when they are located below the ice surface what leads to formation of cryoconites [9] or “melt ponds” formed by merging micro-cryoconite, developed around dust grains, into larger concentrations (Figure 1) [10].



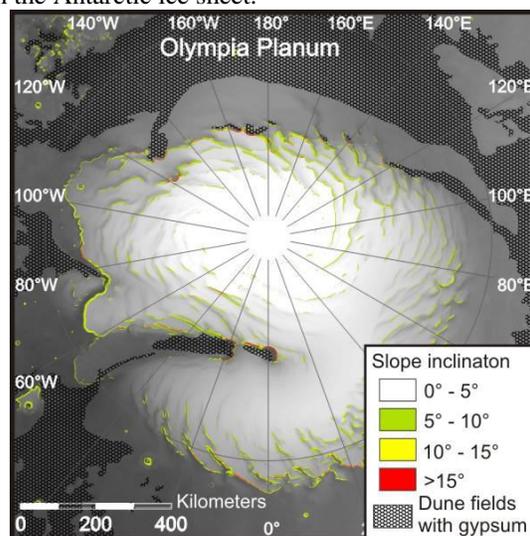
**Figure 1.** “Melt pods” within a tephra layer, the Barne Glacier, Antarctica. It shows that radiant heating of the dust layer can melt the surrounding ice leading to dust congregation into pods. Figure is from [10].

Evaporitic materials consist of mainly Mg- and Ca-carbonates and sulfates (e.g., gypsum  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ , jarosite  $\text{KFe}^{3+}_3(\text{OH})_6(\text{SO}_4)_2$ , epsomite  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ , nesquehonite  $\text{Mg}(\text{HCO}_3)(\text{OH}) \cdot 2\text{H}_2\text{O}$ , hydromagnesite  $\text{Mg}_5(\text{CO}_3)_4(\text{OH})_2 \cdot 4\text{H}_2\text{O}$ , starkeyite  $\text{MgSO}_4 \cdot 4\text{H}_2\text{O}$ , amorphous Mg-carbonate, as well as various unidentified K, Fe, and Mg sulfates [5, 11, 12].

On average 5% of all Antarctic ANSMET meteorites have evaporites visible in the hand-scale [4]. The percentage of evaporate-bearing meteorites varies with compositional group (up to ~50% for Karoonda carbo-

naceous chondrites), petrological type, location where the meteorite was found and, to some extent, the year of the collection [4]. However, when ANSMET meteorites are analyzed under microscope, nearly all of them include some amount of terrestrial evaporite minerals.

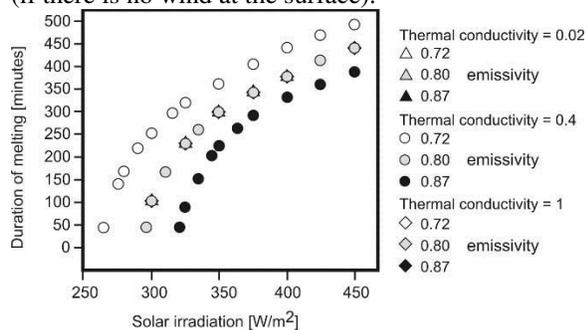
**(Possible) evaporites on Martian North Polar Residual Cap (NPRC):** The NPRC is surrounded by a young [13] dune field that is rich in evaporitic mineral: gypsum (Figure 2) [14]. Its existence implies that relatively recently in the Martian history (in late Amazonian, when surface conditions were comparable to the current ones) there was a significant amount of liquid water present on the Mars surface. It was initially proposed that gypsum was formed by precipitation of water emanating from polar layered deposits [15]. However, it is improbable that a large amount of bulk water could exist under current Martian low atmospheric pressure sufficiently long to form the observed deposits [16]. One of the proposed solutions to this problem is that gypsum is formed by weathering in ice [16, 17, 18, 19, 20], similarly to the process occurring on the Antarctic ice sheet.



**Figure 2.** Location of steep, south facing slopes within North Polar Cap (NPC), where ice melting due to radiant heating of dust laying on its surface may be taking place. Slope inclination based on MOLA data with spatial resolution of 463 meters, dune fields with detected signal of gypsum (based on [20]); grey scale MOLA elevation in the background. Figure is from [21].

Recently, [21] showed that during the warmest days of the Martian summer, solar irradiation may be sufficient to melt pure water ice located below a layer of dark dust particles (albedo < 0.13, emissivity 0.7-0.87) lying on the steepest sections of the equator-facing slopes of the spiral troughs within Martian NPRC. Under the current irradiation conditions, melting is possible in very restricted areas of the NPRC and last for up to couple of hours (Figure 3), but during the times of high irradiance at the north pole (every 51 ka; caused by variation of orbital and rotational parameters of Mars e.g., [22]) this process could have been much more pronounced.

Liquid water can be metastable at the NPRC because the pressure during the summer season is ~760-650 Pa (Mars Climate Database [23]) which is above the triple point of water. The rate of free-surface "clean" liquid water evaporation under average Martian conditions determined experimentally by [24] is comparable to the rate of melting determined by [21] (if there is no wind at the surface).



**Figure 3. Duration of melting for different values of solar irradiation, dust layer emissivity and thermal conductivity of a porous-dusty firm. The duration of melting increases with increase of solar irradiation and decreases with increasing emissivity. Thermal conductivity does not influence the duration of melting. Figure is from [21]**

**Objective:** Losiak et al. 2015 [21] showed that liquid water, a key part of the recipe for gypsum formation, is present on NPRC under current (+/- few Ma) NPRC conditions. However, if there is no sufficient time for the interaction between liquid water and basaltic dust, evaporites such as gypsum will not form. The objective of this study is to determine how many melting-freezing cycles are required to form detectable amounts of evaporites under simulated Antarctic and Martian conditions.

**Experiment:** The experiment consists of hundreds of cycles of freezing-melting of ice with either: 1) a few am layer of basaltic dust, or 2) a 5x5x2 mm basaltic cube, on top of it. At first experiment will be conducted under a terrestrial atmosphere to mimic condi-

tions on the Antarctica. In the second phase of the experiment, we will repeat observation in the simulated Martian atmosphere (CO<sub>2</sub>, 700 Pa).

After a given number of cycles (e.g., 10, 20, 50, 100, 200), a portion of the basaltic dust will be collected and analyzed with the X-Ray Diffraction. This will allow determining which mineral phases are formed after a certain number of cycles. In the same time a basaltic cube will be analyzed under scanning electron microscope with energy-dispersive X-ray spectroscopy to determine petrological associations of the newly formed weathering phases.

The first phase of the experiment will be performed in the beginning of 2016.

**References:** [1] Marvin 1980. Antarctic Journal of the United States 15: 54-55. [2] Jull et al. 1988. Science 242: 417-419. [3] Gounelle and Zolensky 2001. MAPS 36: 1321-1329. [4] Losiak and Velbel 2011. MAPS 46: 443-458. [5] Hallis 2013. MAPS 48: 165-179. [6] Schultz 1986. Meteoritics 21: 505. [7] Schultz 1990. Workshop on Antarctic meteorite stranding surfaces 56-59. [8] Harvey 2003. Chemie der Erde 63: 93-147. [9] Stanish et al. 2013. Environ. Res. Lett. 9 doi:10.1088/1748-9326/8/4/045006. [10] Harpel et al. 2008. J. Volcanol. Geoth. Res. 177: 549-568. [11] Velbel 1988. MAPS 23: 151-159. [12] Velbel et al. 1991. Geochimica et Cosmochimica Acta 55: 67-76. [13] Tanaka et al. 2008. Icarus 196: 318-358. [14] Langevin et al. 2005. Science 307: 1584-1586. [15] Fishbaugh et al. 2007. J. Geophys. Res. 112. 10.1029/2006JE002862. [16] Niles and Michal-ski 2009. Nat. Geosci. 2: 215-220. [17] Catling et al. 2006. Icarus 181: 26-51. [18] Zolotov and Mironenko 2007. J. Geophys. Res. 112: 10.1029/ 2006JE002882. [19] Masse et al. 2010. Icarus 209: 434-451. [20] Masse et al. 2012. Earth Planet. Sci. Lett. 317-318: 44-55. [21] Losiak et al. 2015. Icarus 262: 131-139. [22] Laskar et al. 2002. Nature 419: 375-377. [23] Millour et al. 2014. Mars Climate Database v5.0 User Manual. [24] Hecht 2002. Icarus 156: 373-386.