BIOMASS AND HABITABILITY POTENTIAL OF CLAY MINERALS FROM DESERT ANALOGS: ASTROBIOLOGY INVESTIGATIONS FOR MSL11 LANDING SITES CANDIDATES.

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Introduction:

Next decade of planetary missions including the US 2011 Mars Science Laboratory (MSL11) and the ESA 2016 Pasteur ExoMars will primarily seek key information of the geological and biological history of Mars. All of the four MSL11 landing site candidates (http://marsoweb.nas.nasa.gov/landingsites/index.html) include clays deposits that have been hierarchically ranked by relevance with respect context, diversity, habitability and preservation potential of organics [1-4] in mineralogical/ geological environments suggesting water activity e.g., [9]. Although habitability has been the most ambiguous criteria to be defined, it will be the most discriminating criteria for the final selection.

In this context, a deeper understanding of preservation of biosignatures and habitability of phyllosilicate- and hematite/sulfate-rich analog materials can be achieved by studying new analog environments on Earth where these minerals are simultaneously present.

We present preliminary results of a multi-component investigation involving mineralogical and microbiological analysis of a varierty of phyllosilicate samples from a geographic (latitudinal) moisture gradient (arid/hyperarid, rain and fog shadow vs. coastal fog Mediterranean region).

Background & Study Site: Phyllosilicate and hematite deposits under study are from a broad range of climate settings, i.e., mean annual precipitation (MAP) <0.2 to ~700 mm/y rainfall, and geographic regions, i.e., the Atacama Desert, Chile; Death Valley, and the California Coast, USA) as well as diversely inhabited by life (plant-rich to plant-barren surfaces with TOC <0.01 to ~12 wt.%). The Atacama desert extends across 1000 km (30ºS to 20ºS) along the Pacific coast of South America (Figure 2.1) within the rain shadow of the Andes. The core region of the Atacama, near Yungay, represents the driest place on Earth [1-2] because it is 50 times drier than other arid and hyperarid regions on Earth e.g., Mojave, Negev, and Gobi [3-4]. Relevant mars analogs, or "Mars-like soils" [1-2] as they may contain very low levels of refractory organics (at the 0.1% level), the origin of which is not yet fully understood.

The Atacama desert, one of the oldest and driest deserts on Earth, has been considered a key analog model for life in dry conditions [2-4]. Therefore, soil from this region represents an ideal test bed for constraining the limits of life/ or its preserved remnants on Earth as well as on an early/ present-day Mars [1-2].

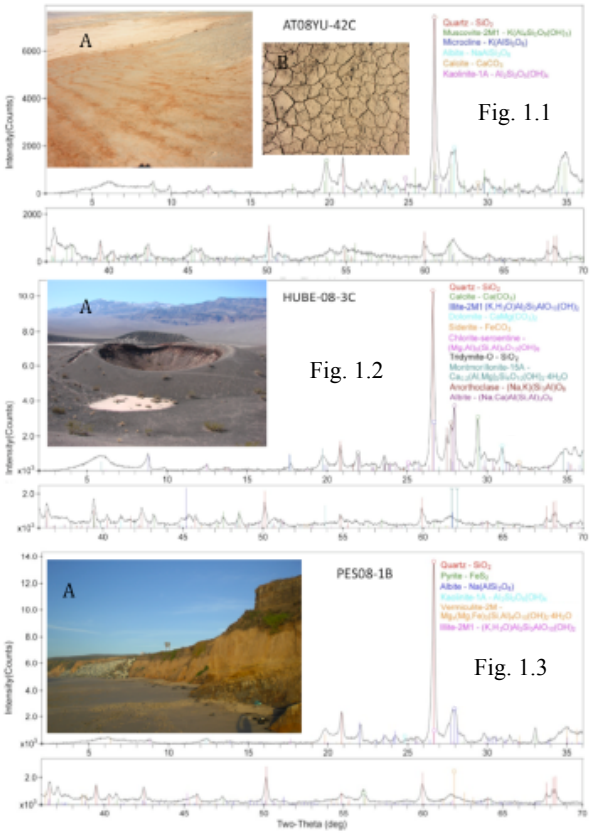

Figure 1. Diffrattogram data for clay samples. Background-subtracted data for Sample AT08-42C, YU from the Atacama (Fig. 1.1a-b), Sample HUBE08-3C (Fig. 1.2a) from the Little Hebe (Death Valley), and Sample PES-08- from Pescadero Unit (Fig. 1.3a).

Approach and Methods: In order to explore the preservation of organic biosignatures/habitability potential in phyllosilicate-bearing/rich materials, we applied the LAL assay to quantify the LPS biomarker and determine the Gram negatives biomass. This is a rather novel as well as rapid, although successful, approach for this application. In this work we compare 1) living biomass of various clays deposits over a rainfall gradient from arid and hyperarid desert as well as the coastal fog region of California (as control). 2) biomass content in clays vs. non-clays minerals from each of the above sites. We choose this approach to see if the increasing biomass with moisture relationship seen

for sandy-clay minerals poor soils is also true in clay rich-substratum soils.

Phyllosilicates and hematite-rich deposits from the Atacama Desert (Chile), the Death Valley CA, and the California Coast (USA), encompassing a broad arid-hyper-arid climate range (annual rainfall <0.2 to~700mm/y), were analyzed for Gram-negatives biomass (LAL assays).

X Ray Diffraction: Mineralogy of crushed samples (<53-μm sieve) was assessed with a Rigaku Ultima III diffractometer in standard θ:2θ coupled geometry with Cu radiation, variable slits and a diffracted beam monochromator.

Total living biomass: We measured the *in situ* Adenosine 5′-triphosphate (ATP)-based total biomass in soil samples with a Luminometry portable system (Lightning-MVP, BioControl Systems, Inc., WA). ATP assay-based biomass data (as Relative Luminosity Units, or RLUs) are then calibrated vs. Phospholipid Fatty Acid (PLFA)-based total biomass.

Total Gram-negatives biomass: The endotoxin-producing Gram-negative biomass in the mineral samples was determined with a portable system (Charles River Laboratories PTS System Package 550®) based on the Limulus Amebocyte Lysate assay, or LAL [33]. This is an extremely sensitive non culture-based method to measure, in a relatively rapid and accurate manner, the amount of lipopolysaccarides, or LPS (a.k.a. the microbial's endotoxin) in the environment. LPS are present in the external cellular membrane of a wide range of Gram-negative-like microorganisms, including cyanobacteria [34], unicellular algae [35], and even in select vascular plants, i.e., eukaryote chloroplasts, and green algae [36].

1-g of well-homogenized mineral and soils samples underwent triple water extraction. In 15mL sterile falcon tubes a 2mL-aliquot of high quality ultrapure water (Milli−Q® Advantage A10) was added each time to samples, which were vortexed (20s), sonicated (5 minutes), and centrifuged at high speed for 5-10 minutes per [37] NASA Procedural Requirements, NPR 5340, 2007). Basically, bacterial's endotoxin in samples catalyzes the activation of a proenzyme in the LAL assay triggering a colorimetric variation (change in color) that is measured by the spectrophotometer (405-410 nm). This yields a value expressed in Endotoxin Units (EU/mL) that can be directly converted into total Gram-negative microbial biomass i.e., cell/g (1EU/mL is equivalent to about 10^5 cells/mL, E. coli-like cells).

Results and Conclusions: *1. Comparison over rainfall gradient:* When comparing phyllosilicate-rich samples against the aridity/moisture gradient, there is an overall, significant difference between biomass content of clay samples from the hyper-arid Atacama (MAP <2mm/y) and the arid Death Valley settings, but no significant difference between the latter site and those from the ten-time moister (>700 mm/y) California coastal site. This last result is counterintuitive and seems to imply that increasing moisture in these clays analogue environment does not necessarily translate to higher biomass content.

To explain similar biomass contents in clays from arid and highly moist conditions, factors such as clay type assemblages and abundances, grain size, and variable water contents could be responsible for the encountered differences.

2. When comparing biomass in clays vs. non-clays, we can distinguish three contrasting cases: 1) there is no systematic pattern in biomass content of clays vs. non-clays (oxidized) materials; 2) Atacama desiccation polygons (~$6.0x10^4$cells/g) and contiguous hematite-rich deposits contain the lowest biomass (~$1.2 x10^5$cells/g), which is even lower than that of coarse-grained soil nearby ($3.3\text{-}5.0x10^5$cells/g); 3) The Atacama clays (muscovite and kaolinite) are three-order magnitude lower than surface clays (montmorillonite, illite, and chlorite) from the Death Valley (~$6.4x10^7$cells/g); and 3) Finally, and unexpectedly, the Gram-negative (~10^7cells/g) of clay minerals-rich materials from the arid Death Valley region is about the same than that (~1.5 to~$3.0x10^7$cells/g) of water-saturated massive clays (kaolinite, illite, and vermiculite) from the wetter and coastal fog dominated California coast.

From these preliminary results it is unclear weather or not clay minerals-rich environments have a higher habitability potential with respect that of background, non clays environment. Therefore, a wider number of study sites should be tested to determine the effective role of minerals in hosting viable biomass ad/or preserving related organic biosignatures.

Understanding the limit for organic preservation and habitability potential of these mineralogical analogues will provide critical information in support of landing site selection for the MSL11 and the EU/US Pasteur ExoMars Missions.

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