HABITABILITY POTENTIAL AND LIVING BIOMASS OF CLAY MINERALS: ASTROBIOLOGY INVESTIGATIONS FOR MSL11 LANDING SITES CANDIDATES. R. Bonaccorsi[1], C. P. McKay[1]. Space Science Division, NASA Ames Research Center M.S. 245-3-1000 Moffett Field, CA 94035 USA. rosalba.bonaccorsi-1@nasa.gov; cmkay@mail.arc.nasa.gov

Introduction:

Next decade 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 MSL landing site candidates (http://marsoweb.nas.nasa.gov/landingsites/index.html) include clays deposits that have been ranked by relevance with respect context, diversity, habitability and preservation potential of organics in mineralogical/ geological environments suggesting water activity e.g., [1]. Although habitability (the capability of an environment to support life) 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 habitability potential of phyllosilicate- and hematite/sulfate-rich materials can be achieved by studying new analog environments on Earth where these minerals are simultaneously present.

Key questions are: 1. are phyllosilicate-rich materials more habitable with respect to non-clays, or background mineral matrix; and 2) how the habitability potential of phyllosilicates correlate with the availability of water? We present preliminary results of a multi-component investigation involving mineralogical and microbiological analysis of phyllosilicate samples from a geographic moisture gradient i.e., arid/hyperarid to mediterranean (coastal fog) setting.

Background: Phyllosilicates, which record multiple episodes of aqueous activity on early Mars [1], have been identified on the surface of Mars by OMEGA, the visible-near infrared hyperspectral imager onboard Mars Express [3] and by the Spirit rover observation at West Spur, in Gusev Crater.

Furthermore, phyllosilicate-rich fluvial-lacustrine deposits, e.g., Eberswalde, Holden, and Jezero craters, Nili Fossae region have been identified by the Mars Reconnaissance Orbiter (MRO) instruments (e.g., CRISM). Stratigraphic units comprising thick deposits of Fe/Mg-smectites, e.g., nontronite, saponite [1-2] ferrous phases, hydrated silica, and Al-smectites, e.g., montmorillonite [2] were discovered in Mawrth Vallis.

Study Site: 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).

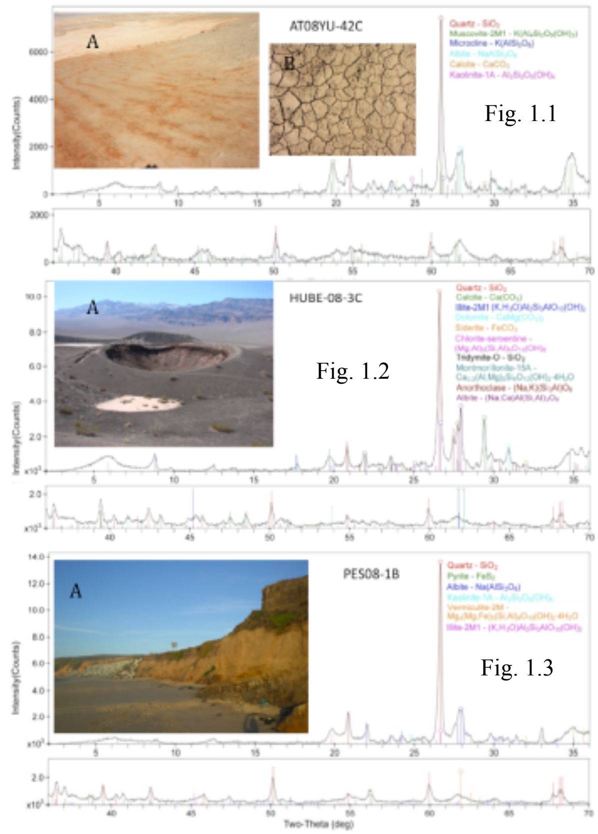

Figure 1. Study settings and diffrattogram data for clay samples analyzed here. Background-subtracted data for Sample AT08-42C, YU from the Atacama (Fig. 1.1a-b), Sample HUBE08-3C (Fig. 1.2a) from the Little Hebe (Death Valley), and Sample PES-08 from Pescadero Unit (Fig. 1.3a).

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 [7]. This is a rather novel as well as rapid, although successful, approach for this application. In this work we compared 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.

The Atacama Desert is the driest place on Earth [4-6] as it is 50 times drier than other arid and hyperarid regions on Earth e.g., Mojave, Negev, and Gobi.

Coarse-grained Atacama soil typically contains low amounts of clays, very low levels of refractory organics (at the 0.01%), and their total biomass/habitability is linearly increasing with moisture [5-6]. Importantly, phyllosilicates deposits in the hyper arid Atacama represent an improved ideal analog to constrain habitability potential where the limits of life has been crossed and extensively investigated [e.g., 4-6].

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 Gram-negatives biomass: We determine the endotoxin-producing Gram-negative biomass in mineral samples with a portable system (Charles River Laboratories PTS System Package 550®) based on the Limulus Amebocyte Lysate assay, or LAL. This is an extremely sensitive non culture-based method for the rapid and accurate measurement of lipopolysaccarides, or LPS amounts (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, unicellular algae, and even in select vascular plants, i.e., eukaryote chloroplasts, and green algae [e.g., reviewed in 8].

1-g of well-homogenized mineral and soils samples underwent triple water extraction. and centrifuged at high speed for 5-10 minutes per NASA Procedural Requirements, NPR 5340 (2007). Basically, bacterial's endotoxin in samples catalyzes a proenzyme activation triggering a colorimetric variation measured with a spectrophotometer (405-410 nm). This yields a value expressed in Endotoxin Units (EU/mL) that can be 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:* There is an overall, significant difference between biomass content of clay samples from the hyper-arid Atacama (MAP<2mm/y, yellow triangles) and the arid Death Valley settings (yellow circles), but no significant difference between the latter site and those from the ten-time moister (>700 mm/y) coastal site (yellow squares) (Figure 2). This last result is counterintuitive i.e., lower biomass in moister clays. To explain similar biomass contents in clays from arid and highly moist conditions, factors such as clay type assemblages and abundances, grain size, and 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 (~$6.0 x 10^4$cells/g) and contiguous hematite-rich deposits contain the lowest biomass (~$1.2 x 10^5$cells/g), which is even lower than that of coarse-grained soil nearby ($3.3\text{-}5.0 x 10^5$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 (~$6.4 x 10^7$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~$3.0 x 10^7$cells/g) of water-saturated massive clays (kaolinite, illite, and vermiculite) from the wetter, fog-dominated coastal site.

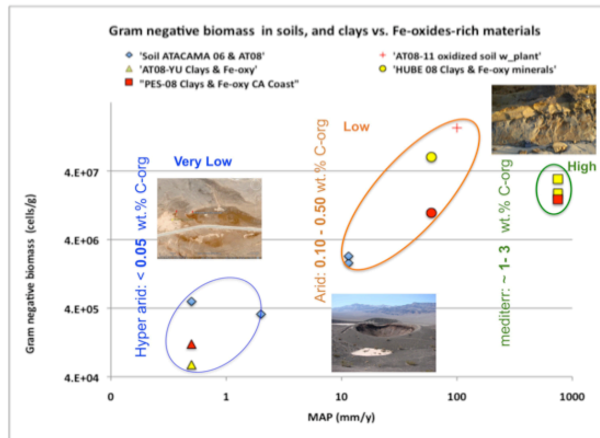

Figure 2. LPS-based biomass in study settings

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 environments. 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 habitability potential of these mineralogical analogues will provide critical information in support of landing site selection for the MSL and the EU/US Pasteur ExoMars Missions.

References: [1] Ehlmann et al., (2008) *Nature Geoscience* 1, 355-358; [2] Bishop et al., (2008). *Science*, 321, 830-833; [3] Bibring et al., (2006). Science, 312, 400-404; [4] Navarro-González et. al. (2003). *Science*, 302:1018-1021; [5] Warren-Rhodes et al.(2006) *Microbial Ecology* 52:389-398; [6] Bonaccorsi and McKay (2008) *LPSC.XXXIX,* #1489. [7] Raetz and Whitfield (2002) *Ann. Rev. Biochem.*71,635-700; [8]Bonaccorsi et al., (2010) in press Phylosophical Magazine.