TOTAL BIOMASS AND ORGANICS ALONG A N-S MOISTURE GRADIENT OF THE ATACAMA REGION, CHILE.

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Introduction: The Atacama desert, one of the oldest and driest desert 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].

We present the results of a multi-component investigation involving microbiological and geochemical analysis of soil samples collected along a latitudinal moisture gradient (0.5 to 120mm/y rainfall) in the Atacama Region (Chile) (Figure 1 and Figure 2).

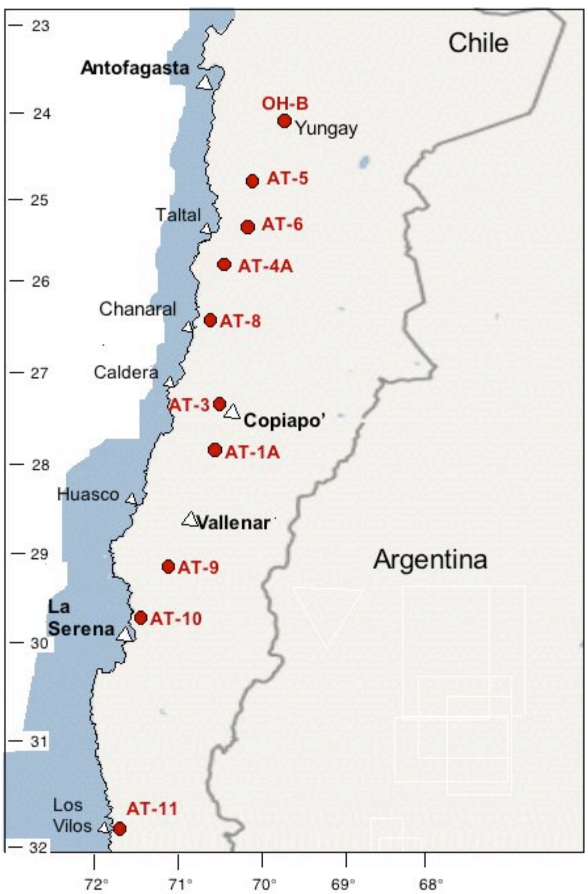

Figure 1. Transect and location of sampling sites from the town of Antofagasta to Los Vilos. Spatial resolution between sites is a. 60-200km.

Background & Study Site: The Atacama desert extends across 1000 km (30ºS to 20ºS) along the Pacific coast of South America (Figure 1) within the rain shadow of the Andes and the cold Humbolt current.

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]. Soils in this core desert, located in the "fog shadow" region of a 3000 m-high coastal crest-line, represent 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. More recently, a high variability in the surface-nearsurface distribution of organics and biomass (packiness) have been described in soil samples from the hyperarid core [1,6-8]. Furthermore, the preservation of these organics is affected by complex interactions with oxidants formed within the soil.

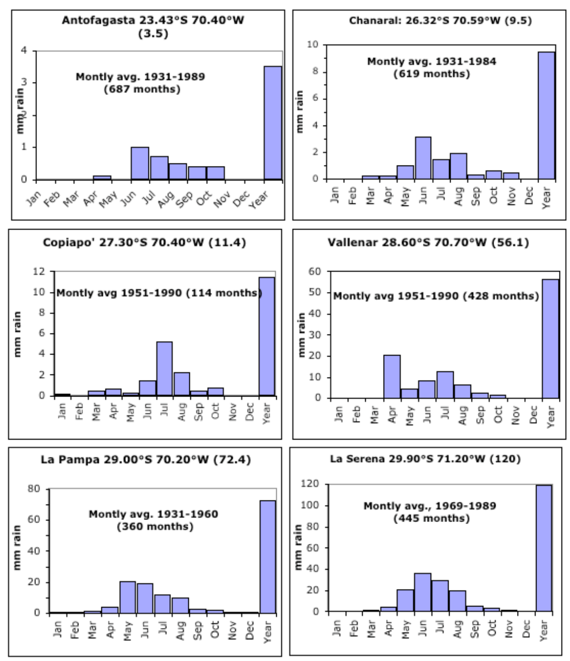

Figure 2. Mean Annual Precipitation data from N-S weather stations along the transect (See Figure 1).

In contrast, the southernmost lesser arid region of the Atacama desert (South of 27 ºS; Figure 1) is characterized by a typical vegetation [e.g., 5]. This is primarily composed by short-lived annual plants, summer dormant shrubs, and bulbous geophytes that bloom and grow after shorth-lived rainfall events exceeding the 15-mm rain average in winter [5].

Approach and Methods: In addition to the complex packiness issue, the transition between bacteriabearing soils and the "Mars-like" soils along the moisture gradient is also not yet understood. To understand where the transition from sterility/ life-poor to life-rich conditions is placed, we compared the amount of total organic carbon (TOC), total nitrogen (N-tot), C:N ratios, and total biomass in soil samples gathered along a North-South transect (Figure 1). Specifically, we sampled these soils from the hyperarid core (Yungay Station: ~24ºS and ~0.5mm/y rain) to the lesser arid locations (down to the town of Los Vilos: ~32ºS and >120 mm/y rain). We choose this approach to test for the hypothesis that the hyperarid/ arid transition is gradual, with microbial biomass and bulk organics monotonically increasing with moisture supply (Figure 2) in plant-barren vs. plant-rich surface soils.

The elemental CN and naturally occurring stable isotopes i.e., δ^{13}C-org and δ^{15}N-tot, were determined with a Carlo Erba NA-1500 Elemental Analyzer coupled with a Finnigan Mat Delta Plus XL Isotope Ratio Mass Spectrometer (EA-IRMS). 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). We subsequentely calibrated the semiquantitative ATP assay-based biomass data (as Relative Luminosity Units, or RLUs) vs. Phospholipid Fatty Acid (PLFA)-based total biomass (cell/g soil). The PLFA analysis was performed by Microbial Insights, Knoxville (Tennessee) on subaliquots of primary soil samples tested for ATP.

Results: The total biomass regularly increases in surface soils along the N-S gradient with a positive correlation (R = 0.900) between the total biomass estimated by using the two independent assays. Samples collected North of Lat 26º S, in the hyperarid core, including the Yungay Site (Lat 24ºS) where vegetation is absent or sparse (Figure 3), are characterized by one-two folds smaller amount of bulk organics (C-org = 0.026 to 0.056 %Wt), low C:N ratios (1.6 to 5.5), and more negative δ^{13}C-org values (-30.3‰ to -28.9‰). In these soils the total biomass ranges from 5.26 X 10^{6} and 8.47 X 10^{6} cell/g soil, which correspond to ATP counts of 262 to 388 RLUs (~10^{-16} Moles ATP), respectively.

In contrast, soil samples collected South of Lat 26ºS (Lat 26.5ºS to 30ºS), where conditions are less arid and the vegetation cover is present or frequent, are characterized by the highest amount of organic carbon (C-org = 0.093 to 2.24 %Wt), highest C:N ratios (7.4 to 36.6), and less negative δ^{13}C-org values (-21.5‰ to -26.5‰). These geochemical features correspond to a high total biomass dominated by Eukaryotes, which varies from 8.55 X 10^{7} cell/g soil to 4.06 X 10^{8} cell/g soil and corresponds to values of 72,902 to 195,684 RLUs and ATP contents of ~10^{-13} to ~10^{-12} Moles, respectively.

Conclusions: The distribution of organics and total biomass follows the N-S moisture gradient whith a clear difference in soils collected North and South of Lat. 26 ºS.

Results from different investigators [1,6-8] suggest that the hyperarid core of the Atacama is a complex environment characterized by an extremely high variability and patchiness in the distribution of surface organic matter and microorganisms. Here the dry limit for life has a complex and variable pattern over short time/ spatial scale [1,6, 8].

In order to address such complexity we need to design Desert studies at higher spatial resolution along well-known moisture gradients. This will improve our understanding of the boundary conditions between hyper-arid and life-hostile environments, and lesser dry and life-supporting extreme environments on Earth. It is possible, in fact, that conditions in the Atacama desert were also occurring on a still dry ancient Mars, but on a Mars that was wetter enough to potentially harbor some microbial life [2]. Exploring such a complex and variable dry limit for flourishing vs. rare/ resilient life is relevant to astrobiology research. For instance, it will support data interpretation from future missions to Mars searching for organic materials and signs of extant and/ or past life (as we know it).

Figure 3. Sampling Site AT-1B with sparse colonial cactus.

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