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Lipid biomarker preservation under extreme and prolonged dryness in the Atacama Desert, Chile and implications for Mars

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Abstract

Lipid biomarkers were analyzed from soils collected in the Yungay hyperarid core of the Atacama Desert. This region has experienced extreme and prolonged (>2 Ma) hyperaridity, thereby greatly limiting biologic activity over that timescale. Total lipid extracts reveal a remarkable degree of preservation in the diversity of lipid biomarkers despite the age of the soils, indicating that typical diagenetic processes influencing lipid destruction are very depressed in the Atacama.

1. Introduction

Molecular fossils or biomarkers [1] are the most direct biosignatures of early life on Earth and a key target in the search for life elsewhere [2]. The geologically short-lived nature of the majority of molecular biomarkers presents a challenge for reconstructing potential past biologic activity on Mars. Lipid biomarkers, which have a refractory hydrocarbon backbone, are known to survive oxidative degradation and are robust indicators of microbial presence and activity in extant ecosystems and in past environments recorded billions of years ago [3]. Prior to lithification, the environmental conditions and the biotic and abiotic processes that impact initial biomolecular preservation are key to establishing a geologically significant biomarker record.

The hyperarid core of the Atacama Desert in northern Chile offers a unique natural laboratory to investigate biomarker taphonomy under prolonged hyper-aridity. This region has been arid to semi-arid since the late Jurassic (150 Ma) and has experienced prolonged and largely continuous hyperaridity for at least the last ~2 Ma, possibly up to 15 Ma [4,5,6]. This extreme aridity has dictated the pedogenesis [7], lack of habitation by plants or lichens, a sparse microbial population, and an inventory of organic carbon in the soils lower than elsewhere on Earth [8,9,10,11].

This work focuses on understanding the accumulation on degree of preservation of lipids in million-year-old hyperarid soils where primarily abiotic conditions influence their taphonomy.

2. Methods

2.1 Sampling

Due to the low biomass content in the soils, samples were collected by scientists wearing cleanroom suits, masks, glasses, and gloves to minimize contamination during sampling. Soils were collected with solvent cleaned tools, placed into ashed glass jars, and kept frozen until returned to NASA Goddard Space Flight Center for storage at -20 C°.

Samples were collected in September 2014 with depth in a ~2 m deep soil pit in the Yungay hyperarid core of the Atacama Desert, which experiences << 2 mm of precipitation per year. Surface soils were also collected in a slightly less hyperarid region near Chañaral which experiences ~12 mm of precipitation per year.

2.2 Laboratory Analysis

For each unique sample, approximately 100 g of soil was pulverized with a mortar and pestle. Soils were extracted three times using a modified Bligh Dyer [12] extraction protocol in which a slurry was created using a monophasic mixture of geo-clean water, methanol, dichloromethane, and soil. This mixture was separated and then resultant lipid fraction was collected and evaporated to near dryness. Medium acid methanolysis [13] and derivatization with Bis-

(trimethylsilyl) trifluoroacetamide (BSTFA) was performed on the concentrated lipid fraction to ensure detection of both free fatty acids and membrane-bound fatty acids. Extracts were run on GC-MS and LC-MS. Peak areas were quantified by comparison to an internal standard.

Additionally, evolved gas analysis (EGA) was performed on approximately 20 mg of pulverized soil. EGA parameters were similar to that of the Sample Analysis at Mars (SAM) instrument aboard the Mars Science Laboratory.

3. Preliminary Results

3.1 Total Lipid Extracts

A number of classes of lipids were identified in the total lipid extracts of soils including fatty acid methyl esters (FAMEs), free fatty acids, primary fatty alcohols, monoalkylglycerol ethers, steranes, plant waxes, mid-molecular weigh organic acids, and glycerol dialkyl glycerol tetraethers.

Despite the age of the deposits, the lipid content resembled that of a modern microbial population because the labile (fragile) lipids such as ester-linked membrane fatty acids were not degraded. Additionally, there was high relative concentration of free fatty acids (FFAs) and mid-molecular weight organic acids. FFAs are generated when cells die and their cellular membranes break down. These compounds are a rich food source for other microbes, and typically do not persist in the environment. The detection of FFAs in Yungay soils indicate a lack of microbial degradative activity, which supports the growing body of evidence that typical diagenetic processes influencing lipid destruction are very depressed in the Atacama.

Significant trends were observant in the abundance and diversity of lipids between surface and subsurface samples, and as a function of rainfall (Figure 1). The diversity and abundance of lipids at depth points to a remarkable degree of preservation under prolonged and extreme hyperaridity and in the absence of significant biological activity.

3.2 SAM-like Evolved Gas Analysis

Surface soils across a precipitation gradient transect from Yungay to Chañaral had very similar EGA signals, dominated by H_2O and CO_2. O_2 and HCl traces were relatively featureless and two to three orders of magnitude less abundant than H_2O. The SO2 signal was quite complex, with four major peaks. In soil pit samples known to contain more organic material than surface soils, masses consistent with cholobenzene were present in the EGA signal.

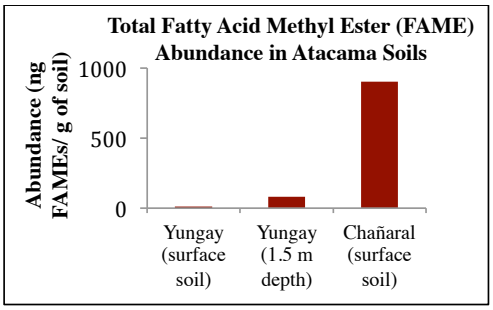

Figure 1: Membrane-bound fatty acid content of soils from the Atacama Desert.

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References

[1] Summons, R.E., Albrecht, P., McDonald, G., Moldowan, J.M.: Space Science Reviews 135, 133-157, 2007. [2] Summons, R. E., Amend, J. P., Bish, D., Buick, R., Cody, G. D., Des Marais, D. J., ... & Sumner, D. Y.: *Astrobiology*, *11*(2), 157-181, 2011. [3] Eigenbrode, J. L.: *Strategies of Life Detection* (pp. 161-185). Springer US, 2008. [4] Hartley, A. J., Chong, G., Houston, J., & Mather, A. E.: *Journal of the Geological Society*, *162*(3), 421-424, 2005. [5] Hartley, A. J., & Chong, G.: *Geology*, *30*(1), 43-46, 2002. [6] Amundson, R., Dietrich, W., Bellugi, D., Ewing, S., Nishiizumi, K., Chong, G., ... & Caffee, M.: *Geological Society of America Bulletin*,*124*(7-8), 1048-1070, 2012. [7] Ewing, S. A., Sutter, B., Owen, J., Nishiizumi, K., Sharp, W., Cliff, S. S., ... & Amundson, R: *Geochimica et Cosmochimica Acta*, *70*(21), 5293-5322, 2006. [8] Warren-Rhodes, K. A., Rhodes, K. L., Pointing, S. B., Ewing, S. A., Lacap, D. C., Gómez-Silva, B., ... & McKay, C. P.: *Microbial Ecology*, *52*(3), 389-398, 2006. [9] Lester, E. D., Satomi, M., & Ponce, A.: *Soil Biology and Biochemistry*, *39*(2), 704-708, 2007. [10] Connon, S. A., Lester, E. D., Shafaat, H. S., Obenhuber, D. C., & Ponce, A.: *Journal of Geophysical Research: Biogeosciences (2005–2012)*, *112*(G4), 2007. [11] Amundson, R.: *Annual Review of Earth and Planetary Sciences*, *29*(1), 535-562, 2001. [12] Bligh, E. G., & Dyer, W. J.: *Canadian journal of biochemistry and physiology*, *37*(8), 911-917, 1959. [13] Parenteau, M. N., Jahnke, L. L., Farmer, J. D., & Cady, S. L.: *Astrobiology*,*14*(6), 502-521, 2014.