EPSC Abstracts
Vol. 6, EPSC-DPS2011-1798, 2011
EPSC-DPS Joint Meeting 2011

Mineralogical study of the hyper-arid Mars like-soils from Pampas de La Joya, southern Peru and its implications in the geochemistry of dry environments

J. Valdivia-Silva (1*), F. Ortega (2) and C. McKay (1)
(1) Space Science & Astrobiology Division, NASA Ames Research Center, Moffett Field, California, 95054, USA, (2) Instituto de Geología, Universidad Nacional Autónoma de México, D.F. 04510, México
*(julio.e.valdiviasilva@nasa.gov / Fax: +1-650-604-6779)

Abstract

The Pampas de La Joya is located in southern Peru between 16°S and 17°S latitude and is part of the hyper-arid region of the Atacama Desert. Recently, this place has acquired an increased interest by astrobiology community because it presents Mars-like soils regarding with the very low levels of organic matter, high oxidant activity, marked driest conditions, and very low levels of microorganisms. This work describes petrology, X-ray diffraction, and EDS-electron microscopy of 119 samples collected on the surface and shallow subsurface of the desert. The samples were divided in six types of soil due to its physical properties. Overall, our results show that the detrital components of the soils come essentially from the Andean volcanic chain and local outcrops of Precambriam gneisses and Cretaceous granitic batholiths. Current and past microclimates allowed the formation of paleolakes and the consequent heterogeneous deposits of evaporitic minerals.

1. Site description

Pampas de La Joya is located between Precambrian crust in the south and Neogene volcanics in the north [1]. On the east is bordered by Mesozoic sedimentary, volcanic and plutonic units. The stratigraphy of the Cenozoic is dominated by the Moquegua Formation, which forms the walls of the main rivers as they start their course through the desert. The Arequipa basin is located to the NE of the Pampa La Joya, at the foot of two large Quaternary volcanoes: Misti and Chachani. Note that the wide part of the Sihuas and Vitor rivers is undelain only by Cenozoic strata, but it becomes extremely narrow and deeper when incised in crystalline basement (Figure 1).

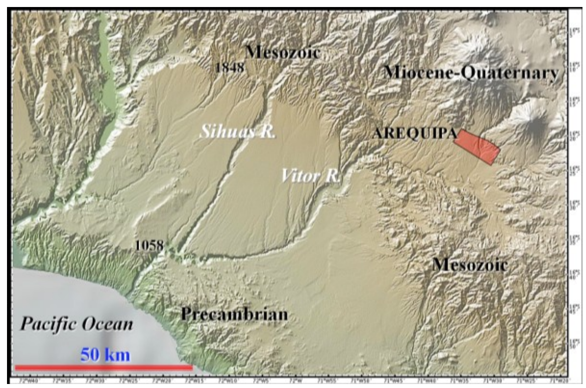

Figure 1: Pampas de La Joya, southern Peru. *Black numbers represent the altitude in meters above the level sea.*

1.1 Desert plain

The hyper-arid area of the Atacama Desert extends from northern Chile to southern Peru along a strip almost 1,200 km and up to 180 km width. It is considered one of the oldest subtropical deserts on earth, where hyper-arid conditions were established since the Miocene [2]. On the other hand, Pampas of La Joya, with a mean altitude of 1,200 m above sea level, represents the northernmost extension in Peru of the Atacama Desert, although the timing of its very dry conditions has not been established. The basement rocks exposed on the floor of La Joya desert region range in age from 1.8 to 1.1 Ga (Mollendo Complex) to the Cretaceous (granitic batholiths), and is bordered to the north by the great Andean volcanic chain of late Cenozoic age. The Cenozoic virtually horizontal strata is well exposed in the walls of the Rivers Vitor and Sihuas, where the entire succession reaches a maximum thickness of about 600 m near Pitay close to the Andes foothills in the northwest, but reduces to about 100 m at the margin of the desert plain in the southwest.

Soils forming the present desert plain of La Joya desert are coarse regolith with local accumulation of large fragments of white quartz, alluvial apron deposits, lacustrine beds (gypsum and salt) and eolian sands. The regolith is chiefly formed by blocks and coarse, sand-sized clasts of the underlying Mollendo Complex, variously mixed with volcanic, granitic and sedimentary detritus transported from the Andean cordillera and foothills. Clasts are loosely cemented by clayed minerals, gypsum and hydrous iron oxides. The most striking features of the coarser regolith are the angular shape of all particles and the abundance of fresh silicates, which suggests in situ origin. The sand grains and glass fragments associated with the present desert soils, on the other hand, may have been transported by water and wind for considerable distances.

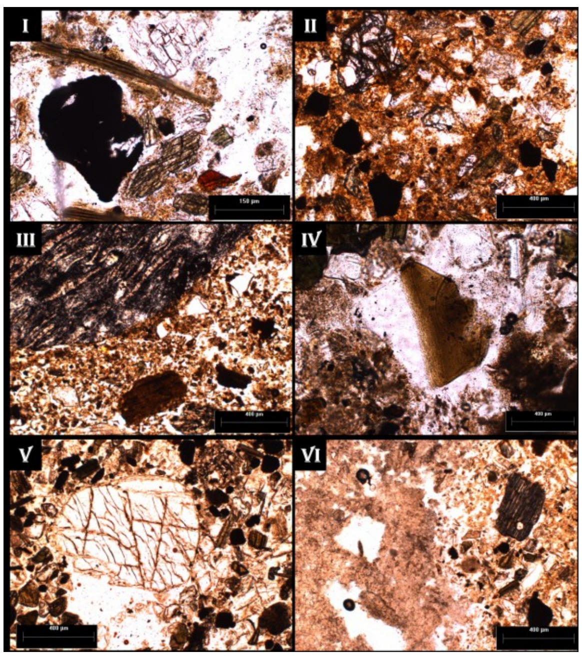

Figure 2: Thin sections of soils from Pampas de La Joya. *Scale= 150 µm for soil type 1 and 400 µm for type 2 to 6.*

2. Chemistry and mineralogy

Minerals, lithics and glasses found in thin section and identified by analytical methods were derived from five lithological sources in order of abundance: a) volcanic, b) metamorphic, c) plutonic, d) sedimentary, and e) diagenetic/hydrothermal. The six types of soils mainly presented glass, quartz, plagioclase, hornblende, pyroxene (low-Al), olivine, Fe-Ti oxides, biotite, vitrophyres, subvolcanic porphyries, and aphanites (Figure 2).

X-ray diffraction mineralogy of La Joya soils showed the next phases listed in order of abundance: quartz, plagioclase, muscovite, gypsum, amphibole, halite, anhydrite, and hematite. Interestingly, halite and anhydrite were highly abundant in paleolakes (Figure 3).

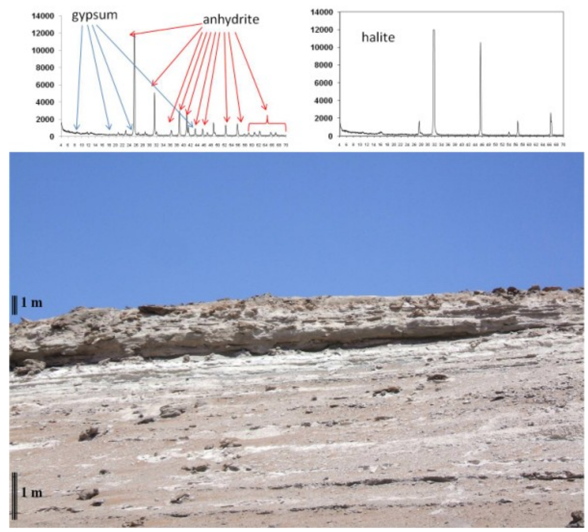

Figure 3: X-ray diffraction of evaporitic sediments in ancient paleolakes.

The EDS electron microscopy showed that the most abundant detrital components in the sand fraction in soils of the study area were high-grade metamorphic lithics and granulite facies minerals derived mainly from the local gneisses of the Precambrian Mollendo Complex. Granet was essentially an almandine-pyrope solid solution with approximately the same molecular proportion of each end-member and characteristic of very high-grade metamorphism, whereas sillimanite contained relatively high iron oxides. Magnetite (titanomagnetite) showed a high molecular proportion of ulvospinel, also indicating high-grade conditions of metamorphism. Feldspar comprised both alkaline (albite an orthoclase) as well as calcic plagioclase, indicating in this case derivation from both metamorphic and granitic nearby sources (Mollendo Complex and La Caldera batholith, respectively).

Mafic mineral phases (pyroxene, hornblende and biotite) displayed compositions that may correspond to both igneous and high-grade metamorphic rocks. The abundance of titanium in hornblende, and biotite in particular, indicated very high temperatures of formation (>800º C) consistent with ultrahigh temperature conditions of metamorphism in the source (Mollendo Complex) or volcanic origin.

3. Summary

These data show that the detrital components of the soils come essentially from the Andean volcanic chain and local outcrops of Precambriam gneisses and Cretaceous granitic batholiths. The presence of paleolakes and evaporitic minerals in this region give an interesting framework for future microbiological studies and are the first part of more exhaustive evaluation in the interaction between minerals and organic molecules in highly oxidant dry-environments, as it has been demonstrated in this region [3].

Acknowledgements

Funding for this research comes from Grants from NASA Posdoctoral Program, and by the National Aeronautics and Space Administration Astrobiology Science and Technology for Exploring Planets Program. The authors thank to Instituto Geofísico of the Universidad Nacional San Agustin, Arequipa-Peru for its support during field trips.

References

[1] Valdivia-Silva J.E., Navarro-González R., Ortega-Gutierrez F., Fletcher L., Pérez S., Condori R., and McKay C.: Multidisciplinary approach of the hyperarid desert of Pampas de La Joya in southern Peru as a new Mars-like soil analog, Geochim Cosmo Acta. Vol 75, pp. 1975-1991, 2011.

[2] Dunai T.J., Gonzalez-Lopez G.A. and Juez-Larre J.: Oligocene–Miocene age of aridity in the Atacama Desert revealed by exposure dating of erosion-sensitive landforms, Geology, Vol 33, pp. 321-324, 2005.

[3] Valdivia-Silva J.E., Navarro-González R., and McKay C.: Thermally evolved gas analysis (TEGA) of hyperarid soils doped with microorganisms from the Atacama Desert in southern Peru: implications for the Phoenix mission, Adv. Space Res. Vol 44, pp. 254–266, 2009.