

**THE SOLFATARA CRATER, ITALY: CHARACTERIZATION OF HYDROTHERMAL DEPOSITS, BIOSIGNATURES AND THEIR ASTROBIOLOGICAL IMPLICATION.** M. Glamoclija<sup>1</sup>, L. Garrel<sup>1</sup> and P. López-García<sup>2</sup>, <sup>1</sup>International Research School of Planetary Sciences (Viale Pindaro 42, 62127 Pescara, Italy, mihaelag@irsps.unich.it, garrel@sci.unich.it), <sup>2</sup>Unité d'Ecologie, Systématique & Evolution, CNRS UMR 8079, Université Paris-Sud, (bât. 360, Orsay Cedex, France, puri.lopez@ese.u-psud.fr )

**Introduction:** Solfatara is geologically young volcanic formation (~4,000 yr BP), with a hot (45-95°C) and acidic (pH 1.7) environment, exhibiting strong sulphur and iron mineralization characteristic of hydrothermal sites. We tried to demonstrate necessity of multidisciplinary investigation: paleontological biogeochemical and biological; in search for microbial remains or more precise biosignatures.

Modern hydrothermal systems can provide significant information about processes and life thriving at these environments, that could help in understanding and providing better interpretations of their fossil counterparts.

Furthermore, the site of Solfatara with its extreme environment, geological and chemical characteristics are very good analogues to possible hydrothermal systems on Mars. In this term here we present our preliminary work conducted in the area of Dao Vallis and Niger Vallis near the Hellas impact basin.

**Geological settings:** The Solfatara crater is placed in the central-eastern part of the Campi Phlegrei Caldera (volcanic province of central-southern Italy). The Campi Phlegrei Caldera is a nested, collapsed, 12 km wide structure, whose formation was strongly conditioned by two main collapses 37,000 and 12,000 years ago [1]. Previous researches suggest that volcanic activity of Campi Phlegrei Caldera was once fed by large magmatic reservoir [2]. Solfatara's subareal volcanic activity belongs to the last volcanic epoch of the Campi Phlegrei Caldera. During the past, explosive and effusive eruptions occurred within short-time intervals, while extensive volcanism of the Solfatara finished with explosive reactions 4,000 yr BP.

Today, activity of the Solfatara is localised on hydrothermal emission sites: hydrothermal springs in the central sector of the crater, and fumarolic activities in the vicinity of the wall. The whole area is tectonically controlled by local and regional fault systems. Hydrothermal activity inside the crater is connected with fault system: springs where local faults radially running through the crater, and fumarolic activity with a regional fault system. According to Chioni *et al.* [3], the hydrothermal system of Solfatara is fed by a 1.5 km deep

geothermal aquifer of low permeability, with a mixed magmatic-meteoritic origin.

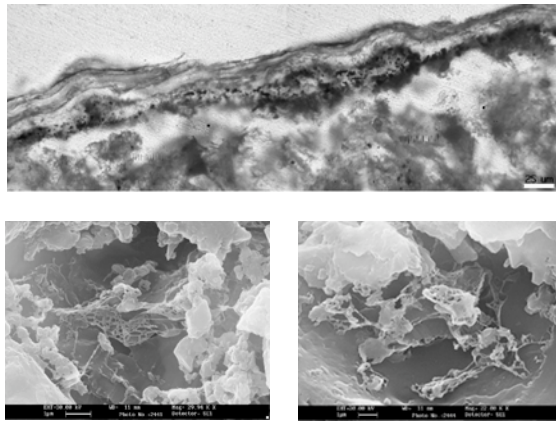
**Material and methodology:** Products of Solfatara's activity, that have been sampled, consist of breccia, covered by a stratified deposit made of layers of pisolitic ashes and coarse ashes. A base surge structure containing beds of well sorted pumice lapilli. The surges cover the east-northeast wall of the crater and have overflowed the east and west crater edge. Incoherent products, often with trahytic occurrences, are Solfatara's volcanics. Water samples and mud from the springs, as well as, iron and sulphur rich crusts have been collected.

For the petrological characterisation of the sampled materials, XRD analysis in combination with petrologic light microscopy have been employed. Temperature ranging from 95°C for the boiling water from the springs, up to 45°C of the surrounding area has been attained by measurements on each of sampling points. A pH value of 1.7 was measured on water samples in the laboratory. Geochemical analysis reveals a low TOC (Total Organic Carbon) level, ranging from 0.13 to 0.53%, the  $\delta^{13}\text{C}$  falls in the range of -17.09 to -27.39 ‰, and total nitrogen values are from 0.03 to 0.12%. Furthermore, observations of thin sections were conducted under an optical light microscope and SEM was used to find morphological evidence of microbial presence within the Solfatara deposits. CPMAS  $^{13}\text{C}$  NMR, FT-IR and GC-MS analysis were performed in order to characterise organic biomarkers. Preliminary biological analysis reveals the presence of bacteria, as deduced from specific 16S rRNA gene amplification of DNA extracted from various Solfatara samples. Incorporation of biological data obtained by microscopy of thin sections (paleontological data), and biogeochemical data is possible because of more or less stable environmental conditions during the time.

**Results and discussion:** Thermal characteristics of the Solfatara crater (45° - 95°C) along with very low pH value (1,7) result in the presence of moderate to extreme thermoacidophilic organisms. Geochemical analysis resulted in very low values of TOC,  $\delta^{13}\text{C}$ , and N, suggesting communities inhabiting crater, during the past as well as today, are

composed only of micro-organisms. That has been confirmed by field and laboratory observations.

Deposits characteristic, such as the lack of carbon component, way of minerals alteration and low pH imply mainly a reduced habitat for micro-communities. Light microscopy in combination with SEM observation revealed presence of delicate net-like structure (Fig.1) composed of iron oxy-hydroxide. The position of the structure (on one of the walls of a micro fracture, filled by sulphur rich fluid) in combination with mineral assemblage that has developed in a microenvironment imply an organic origin of this structure.



**Figure 1.** Up: (scale 25µm) Microfracture observed in thin section, fracture is filled by sulphur rich material, on the wall a net-like structure has been observed, this structure is accompanied by a layer rich in magnetite; Left and right: (scale 1µm) net structure that could be one of the early state in biofilm development, on left photo, right cubic mineral of magnetite is visible.

Microbes whose influences on mineral alteration or development of structures have been detected are involved in sulphur cycle, and iron production within the Solfatara deposits. Search for organo-chemical biosignatures resulted in the identification of linear alkanes and hopanoids. Presence of these lipids and absence of steroids suggest that bacteria were the main constituents of microbial community. Low diversification of microbial world, living at Solfatara, is partially confirmed by biological analysis.

**Astrobiological application:** Potentially and astrobiologically interesting sites are the outflow channel systems of Dao and Niger Vallis that extend through the eastern Hellas region. Dao Vallis has previously been interpreted to have formed by collapse of volcanic and sedimentary plains, possibly triggered by volcano-ice interactions in the

subsurface [4, 5]. Consequently, valleys can be assumed as evidence of magmatically-driven fluvial erosion of late Noachian/early Hesperian and probably Amazonian age [6, 7], where magmatism have provided heat to raise subsurface temperature near or above freezing point of water, intrusive activity might fractured aquifer that release ground volatiles. Why do we believe that the area was warm/hot? The lack of drainage integration might originate from flows that occur quickly or in short bursts, or this type of drainage could be controlled by tectonic structures that is not the case on the flank of Hadriaca Patera. Thus, the heat source appears to be strong enough to release such a large amount of water. Furthermore, a TES global map revealed high level of sulfates [8] and a global gamma ray spectrometer mapped high iron content [9] in the depositional area (upper northeastern part of the Hellas basin and one portion of valleys) of these valleys. These contents occur at the site of Solfatara as well, and represent products of hydrothermal activity. In the future, we planned more detailed work on this area in order to define locations with characteristics of hydrothermal activities, such as ponds, shallow subsides valleys, etc.

**Conclusion:** We can assume that the community that has been living at the Solfatara crater is mainly composed of thermoacidophilic, chemosynthetic bacteria, especially those involved in sulphur cycle.

This kind of communities were most probably inhabiting hydrothermal sites in early history of the Earth, and likely, they could be good analogues of possible life forms that could develop on early Mars in similar conditions.

Moreover new available data from Mars (MOC and TES images), ongoing and future Mars missions could provide essential information for the better recognition of hydrothermal deposits on the red planet, that together with our knowledge of terrestrial analogues would put us in a condition to be able to recognize where and how to look for possible life traces on Mars.

**References:** [1] Rosi M. et al.(1987) Phlegrean Fields, CNR, 114, 9 [2] Panichi C. et al. (1999) *J. Volcanol. and Geotherm. Res.*, 91. 321-328 [3] Chioni R. et al. (1984) *Boll. Volcanol.*, 47. 295-302 [4] Crown, D.A. et al. (1992) *Icarus* 100, 1-25 [5] Squyers, S.W. et al. (1987) *Icarus* 70. 385-408 [6] Gulick, V.C. et al. (1990) *J.Geophys.Res.*, 95. 14325-14344 [7] Scott C.M. et al., (2001) *Icarus* 153. 89-110 [8] Hoefen, T. et al. *USGS TES mineral map 2000* [9] *Map of Martian iron at mid-latitudes* NASA/JPL/University of Arizona