Icarus 224 (2013) 86–96

Contents lists available at SciVerse ScienceDirect

Icarus

journal homepage: www.elsevier.com/locate/icarus

Multiple techniques for mineral identification of terrestrial evaporites relevant to Mars exploration

N. Stivaletta [a,*], F. Dellisanti [b], M. D'Elia [c], S. Fonti [c], F. Mancarella [c]

[a] Dipartimento di Scienze della Terra e Geologico-Ambientali, Università di Bologna, Via Zamboni 67, 40126 Bologna, Italy[1]
[b] ANALITICA, Material Research Laboratory, San Lazzaro di Savena, I-40068 Bologna, Italy
[c] Dipartimento di Matematica e Fisica "Ennio De Giorgi", Università del Salento, Via Arnesano, 73100 Lecce, Italy

ARTICLE INFO

Article history:
Received 1 March 2012
Revised 19 January 2013
Accepted 4 February 2013
Available online 1 March 2013

Keywords:
Mars
Exobiology
Experimental techniques
Mineralogy
Spectroscopy

ABSTRACT

Sulfates, commonly found in evaporite deposits, were observed on Mars surface during orbital remote sensing and surface exploration. In terrestrial environments, evaporite precipitation creates excellent microniches for microbial colonization, especially in desert areas. Deposits comprised of gypsum, calcite, quartz and silicate deposits (phyllosilicates, feldspars) from Sahara Desert in southern Tunisia contain endolithic colonies just below the rock surface. Previous optical observations verified the presence of microbial communities and, as described in this paper, spectral visible analyses have led to identification of chlorophylls belonging to photosynthetic bacteria. Spectral analyses in the infrared region have clearly detected the presence of gypsum and phyllosilicates (mainly illite and/or smectite), as well as traces of calcite, but not quartz.

X-ray diffraction (XRD) analysis has identified the dominant presence of gypsum as well as that of other secondary minerals such as quartz, feldspars and Mg–Al-rich phyllosilicates, such as chlorite, illite and smectite. The occurrence of a small quantity of calcite in all the samples was also highlighted by the loss of CO_2 by thermal analysis (TG–DTA). A normative calculation using XRD, thermal data and X-ray fluorescence (XRF) analysis has permitted to obtain the mineralogical concentration of the minerals occurring in the samples.

The combination of multiple techniques provides information about the mineralogy of rocks and hence indication of environments suitable for supporting microbial life on Mars surface.

© 2013 Elsevier Inc. All rights reserved.

1. Introduction

Evaporite deposits are widespread in terrestrial environments and ancient gypsum deposits such as the Miocene and Permian succession, have been studied extensively (e.g. Spencer and Lowenstein, 1990). Nevertheless, geological studies about the textural and compositional characteristics of sulfates in modern environments (e.g. Stoertz and Ericksen, 1974; Benison et al., 2007; Douglas et al., 2008) are still patchy.

There is abundant evidence that portions of the martian surface are rich in sulfate salts (Flahaut et al., 2010; Langevin et al., 2005; Sowe et al., 2012; Squyres et al., 2004; Thomson et al., 2011; Vaniman et al., 2004; Wendt, 2011) in environmental settings interpreted as analogous of terrestrial continental sabkhas (Gendrin et al., 2005; McLennan et al., 2005; Murchie et al., 2009; "sabkha" is a salt flat and its geological usage implies intra-sediment evaporite growth beneath a flat geomorphic surface with an elevation dictated by the top of the capillary fringe, Warren and Kendall, 1985).

These sulfate deposits occurring in a broad area might hint to a specific period of sulfate rich material formation at the end of the Early Mars era (from Late Noachian to Late Hesperian) (Bibring et al., 2006). The discovery of sulfate deposits on Mars surface by the OMEGA and CRISM spectrometers, on board of Mars Express Orbiter (Bibring et al., 2006) and the Mars Reconnaissance Orbiter (Murchie et al., 2007) respectively, highlights the need for studying the gypsum characteristics and its mineral associations. Instruments on board of Mars Science Laboratory, launched in November 2011, and ExoMars, scheduled for launch in 2018, will provide a view of minerals and rock texture at a scale ranging from micrometer to centimeter. In the field of remote mineral identification, visible and infrared spectroscopy are highly successful techniques for mineral identification of geological materials on planetary surfaces. However the study of rock composition needs multiple mineralogical analyses; the use of a single technique cannot avoid some degree of uncertainty in the mineral identification (see

* Corresponding author.
E-mail addresses: nunzia.stivaletta@gmail.com (N. Stivaletta), f.dellisanti@analitica-lab.it (F. Dellisanti), marcella.delia@le.infn.it (M. D'Elia), sergio.fonti@le.infn.it (S. Fonti), francesca.mancarella@le.infn.it (F. Mancarella).
[1] The address where the work was carried out.

0019-1035/$ - see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.icarus.2013.02.007

Section 3). Mars research is using this concept by combining X-ray diffraction (XRD) and X-ray fluorescence (XRF) in the development of the new generation of surface instruments suites, such as CheMin for NASA's Mars Science Laboratory (Vaniman et al., 1998; Sarrazin et al., 2005). The combination of such techniques helps in determining the past conditions in which the examined samples were formed, investigating lithologies and niches that may harbor extant or fossilized life forms. Since a number of landforms, mineral compositions and geological processes on Mars have terrestrial analogs, laboratory studies of such analogs materials are needed for a correct interpretation of the data produced by the rover and orbiter observations of Mars.

This paper investigates modern geological structures, called spring mounds (Fig. 1A), that are located in southern Tunisia at the edge of Sahara Desert. Gypsum outcrops occur extensively in the area of ephemeral salt lakes (locally called "Chotts") (Drake et al., 2004). In particular, along the border of the Chott el Jerid, characteristic mound-shaped gypsum occur (Roberts and Mitchell, 1987, Fig. 1A). The water emerges into the Chott el Jerid through a thin clay aquiclude of Quaternary age (Roberts and Mitchell, 1987). This generally allows temporary flooding of the Chott during the winter. Currently, these springs are dry because of the overexploitation of the aquifer due to the recent (last tens years) local demographic growth. Previous studies have characterized the endolithic communities of the mounds by optic and environmental scanning electron microscopy (ESEM), as well as by molecular and chromatographic techniques (Stivaletta and Barbieri, 2009; Stivaletta et al., 2010). The purpose of the present study is to extend the previous investigation using multiple mineralogical techniques in order to better characterize a lithology suitable for microbial colonization in arid environments. On Earth the occurrence of the sabkha environment and their deposits indicate the presence of extreme environments. Inhabitants of arid environments include stress-resistant microorganisms adapted to high salt concentration, desiccating conditions, rapid changes in salinity and water availability, very intense sun light and high UV radiation. A key factor in the adaptation to stressful parameters is the production of suites of protective mechanisms, such as the strategies of colonization of protected microhabitats that may provide more or less transient episodes of habitability. Microniches, such as the endolithic mode of life, might have also occurred in martian environments, when the Mars surface became progressively drier and colder (Friedmann and Koriem, 1989). The search for evidence of life on Mars will require the identification of rock types that could have preserved them. Spectral analyses of samples from terrestrial sabkhas provide remote sensing information useful in searching for analogs environments on Mars surface. Moreover, a combination of XRD, scanning electron microscopy–energy dispersive X-ray spectroscopy (SEM–EDX), thermogravimetric analysis (TG–DTA), visible and near infrared (VNIR) and thermal infrared (TIR) reflectance and transmittance presented in this work illustrates the utility of multiple datasets.

2. Material and experimental procedures

Samples were collected from mound evaporite deposits (Fig. 1A) located in the desert area of southern Tunisia (33°44′28″N; 08°53′10″E). In particular, salt precipitation, especially gypsum, on the top of the evaporite mounds makes characteristic superficial crusts (Fig. 1B). A distinct green–brown layer

Fig. 1. (A) Panoramic view of spring mound along the border of the Chott el Jerid. (B) Gypsum crusts at the top of the spring mounds. (C) Cross fracture of the gypsum crust. The green layer is indicative of the endolithic colonization. Scale bar in (C): 1 cm. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Download English Version:

https://daneshyari.com/en/article/1773532

Download Persian Version:

https://daneshyari.com/article/1773532

Daneshyari.com