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Analysis of Mars relevant minerals – suggestions for next missions

Zsuzsanna Kapui (1), **Ákos Kereszturi** (2), Dóra Kesjár (1), Csilla Király (3), Ivett Kovács (1), Zoltán Szalai (3) and Vittori Zanon (4)
(1) MTA Research Centre for Astronomy and Earth Sciences, Institute for Geological and Geochemical Research, (2) MTA Research Centre for Astronomy and Earth Sciences, Konkoly Observatory, Budapest, Hungary, (3) MTA Research Centre for Astronomy and Earth Sciences, Geographical Institute, Budapest, Hungary, (4) Centro de Vulcanologia, Universidade dos Açores, Ponta Delgada, Portugal (kapui.zsuzsanna@csfk.mta.hu)

Abstract

Several instruments can be used for the identification of rock-forming minerals of Mars analogue samples. One of the most important methods is the X-ray powder diffraction, because the general mineral composition can be identified (e.g. there are olivine, pyroxene and plagioclase in samples). But the infrared and Raman spectroscopy are useful additional methods, because more precise identification (species of these minerals (e. g. pyroxene is augite, plagioclase is anorthite) could be done in several cases. While the most capable method for identification of phyllosilicates is the X-ray analysis, but it is also possible by infrared spectroscopy.

1. Introduction

The basic-ultrabasic magmatic rocks on Mars are covered by regolith by the slow weathering. The components of this regolith are olivine, volcanic glass and sulphates (e.g. jarosite, gypsum), carbonates (e.g. artinite, Ca-Fe-Mg carbonates), layer silicate (smectite), iron oxides-hydroxides (e.g. hematite, goethite, magnetite). The identification and the knowledge of the formation conditions of minerals on Mars are important to understand its geological history and astrobiology aspects. Analyses of analogue samples could help the development of instruments for Mars surface missions, including rovers. The aim of this study is to present the strengths and weaknesses of the different laboratory methods, observational possibilites and characteristics of some basic minerals, demonstrating how the requested information could be acquired from them.

2. Methods

X-ray powder diffraction, infrared spectrometry and Raman spectroscopy were used for the identification of minerals in the analyzed samples. The XRD studies were carried out on a Rigaku Miniflex-600 X-ray diffractometer with CuKα radiation equipped with a graphite monochromator. While an FTIR Vertex 70 (Bruker) infrared spectrometer was applied to acquire IR reflection bulk spectra showing minerals' peak positons together. Mineral analyses can also be made with a Raman spectroscope (Kaiser Optical Systems RamanRxn1™). The spectral performance of this instrument changes from 150 cm^{-1} to 1850 cm^{-1} and the resolution is 6 cm^{-1} in mid-range. The wavelength is 785 nm.

3. Samples

Several Mars analogue samples were analyzed: six basalts from Azores Island (unweathered and varying degrees of weathered basalt) [1] and nine samples: basalt, attapulgite, sepiolite, bentonite, kaolinite-montmorillonite granules from the collection of the Natural History Museum, London and the European Space Agency called ESA2C [2, 3, 4].

4. Results

These samples were measured by X-ray diffraction, infrared analyses and Raman spectroscopy.

2.1 Infrared Spectroscopy

On the average two-three minerals could be identified: olivine, anorthite or augite were found in the basalts sample from the basalt samples. While mainly sepiolite, dolomite and quartz could be detected in different samples from the ESA2C collection (Table 1).

2.2 X-ray diffraction analysis

Most minerals could be detected in this way, so a general picture was get from the composition of the measured samples. A few minerals (plagioclase, K-feldspar, mica and smectite) could be identified from Azores samples, while average 6-7 minerals could be found in the samples from the ESA2C collection (Table 1).

2.3 Raman spectroscopy

The best results came from the basalt samples, like feldspar (anorthite), pyroxene (augite) and olivine (Figure 1). In addition, quartz, muscovite and montmorillonite could be detected from samples of the ESA2C collection. The analysed grains were selected to be representative from among the scanned particles, however the crystallized ones were preferred, which fortunately give more useful spectra.

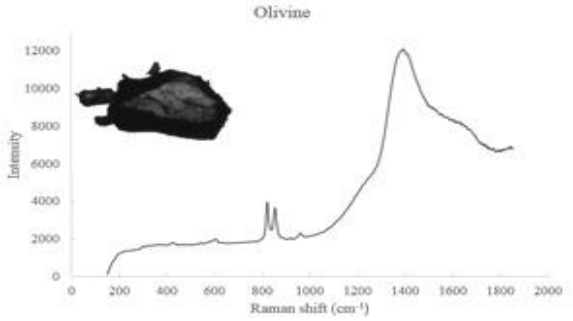

Figure 1: Typical Raman spectra of olivine from the basalt sample of Azores Island.

Table 1: The identified minerals from different type of samples with the used methods: AZ-2017_03 (basalt), 16CY01-6d (kaolinite-montmorillonite granules), 16ES01-6d (sepiolite granules), 16SN01_6d (palygorskite granules). The following acronyms were used: An- anorthite, Aug- augite, Cal-calcite, Cb- carbonate, Dol- dolomite, Ilm- ilmenite, Fsp- feldspar,Gp-gypsum, Kln- kaolinite, Mca- mica, Mnt- montmorillonite, Ol –olivine, Paly-palygorskite, Pl-plagioclase, Px-pyroxene, Q- quartz, Sep-sepiolite, Sme- smectite.

Samples	Infrared spectro.	XRD	Raman spectro.
AZ-2017_03	Ol, An, Aug	Pl	Ol, Px, Ilm
16CY01-6d	Kln, Mnt, Q, Cb (Dol)	Q,Sme, Kln, Mca, Cal,Pl	Q
16ES01-6d	Sep, Dol	Q,Dol, Cal,Mca, Sme, Fsp, Gp	
16SN01_6d	Sep, Dol, Q	Paly,Sep, Fsp, Q Dol,Sme	Dol

5. Summary and Conclusions

Based on our results, the most information, moreover general composition of the rock-forming minerals of samples were obtained by X-ray methods, for example typical basalt minerals, like olivine, pyroxene or sulphate, Fe-oxide minerals could be also detected. But in certain cases, the Raman spectroscopy seemed to be the most informative about the species of the mainly primary minerals (e.g. pyroxene is augite, plagioclase is anorthite). The most capable method for identification of products of weathering (e. g. smectite, kaolinite or sepiolite) is the X-ray analysis (after preparation), but it is also possible by infrared spectroscopy in ideal situation based on the occurrence of water in these minerals. This water content of the minerals could be detected the easiest by infrared spectroscopy. In summary, the best methods to analyse the bedrock on Mars would be the XRD and Raman spectroscopy, but if the main question is the detection of traces of weathering, the XRD and infrared spectroscopy would be the best choice. In addition the most important aim of the EXM 2020 is the search of the traces of life, which is worth looking for by infrared spectroscopy, because the organic material content of the sample can detected from the 5-10% (the other methods can not detected such small amounts of organic material).

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