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Multi-spectral investigation of volcanic deposits and their alteration processes on Vulcano/ Italy

K. Stephan (1), S. Schröder (2), M. Baque (1), K. Rammelkamp (2), J. Haber (3), I. Varatharajan (1), G. Ortenzi (1), Alessandro Pisello (4), R. Parekh (1), F. Sohl (1), R. Jaumann (1), L. Thomson (5), V. Unnithan (5), (1) Institute of Planetary Research, DLR, Berlin, Germany, (2) Institute of Optical Sensor Systems, DLR, Berlin, Germany (3) Purdue University, Indiana, USA, (4) Dept. of Physics and Geology, University of Perugia, Italy, (5) Department of Physics & Earth Sciences, Jacobs University Bremen, Germany. (Katrin.Stephan@dlr.de)

Abstract

During the fifth International Summer School held on Vulcano (Eolian Islands, Italy) in June 2019 we used the opportunity to investigate volcanic deposits with three different spectral instruments, i.e. a portable visible and near infrared spectroradiometer, a portable LIBS (laser-induced breakdown spectroscopy) and a portable Raman system and thus combining mineralogical, elemental and molecular information. The island of Vulcano presents an extremely large variety of products, for what concerns volcanological record (from lava flow to phreatomagmatic ash deposits) and geochemical features (from basalts to shoshonite to alkaline rhyolites) [1]. This, together with ongoing activity (subaerial and submarine fumaroles), provides extreme alteration conditions.

1. Instrumentation

In the field we used a portable spectro-radiometer (PSR+3500) that works in the visible and near-infrared spectral range (350 – 2500 nm) with a spot size of 3 by 3 mm and is best used for mineralogical content of the investigated deposits.

LIBS - a form of atomic emission spectroscopy for the elemental analysis at a sub millimeter scale - (commercial hand-held LIBS instrument /SciAps Z 300) uses a laser to ablate a small amount of sample material and to produce a plasma spark, whose spectral analysis permits rapid in-situ multi-elemental analysis in the field.

Finally, the RaPort handheld Raman instrument by EnSpectr equipped with a 532 nm (same as used for the ExoMars2020 rover mission) excitation laser operating at <60 mW laser power has a spectral range is 120 - 4000 cm^{-1} (> 2.5µm) at 6-9 cm^{-1} spectral resolution with a spot size of around 0.5 mm.

2. First results

Sampled areas reach from classical basalt with dark and bright phenocrysts and dark glass to extensive ash deposits from different phases of the volcanic activity on the island. In addition, recently active fumaroles offered the measurements of numerous sulphur samples deposited onto the basalt surface. Of particular interest, however, was the alteration of the basaltic rocks due to the extreme environment with the lava directly deposited at the coastline and thus under influence of sea water and ongoing submarine volcanic activity. Figure 1 shows to close up views onto the lava deposits with major portions already strongly altered with particular crystal growth.

Fig. 1: Basalt blocks with strongly altered surface (top) that partly re-crystallized (bottom).

The preliminary analysis of the first portion of measured VIS/NIR spectra in comparison with the spectral libraries provided by USGS and PDS implies enrichment in alteration minerals in this area. So far next to iron bearing oxides and clay minerals several sulphates could be identified. Figure 2 shows a selection of Vulcano spectra taken from the locations shown in Figure 1.

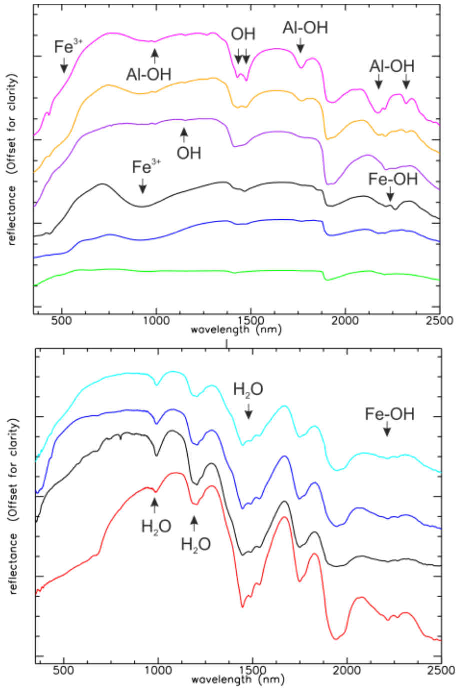

Fig. 2: Example of visible and near-infrared spectra taken from locations as seen in Fig. 1 with a sequence of spectra showing the transition from less weathered basalt to strongly weathered surface (top) with the alteration products partly appearing as individual crystals (bottom).

The spectra analysed so far show a nice transition from more iron-bearing basaltic material to material dominated by sulfates such as Alunite and Jarosite with the characteristic Al-OH and Fe-OH absorptions near 2.17 and 2.27µm, respectively [4]. Both minerals appear to be rich in K in the studied area, which was also seen in the LIBS data (accompanied by a strong signal of Sr) (Fig. 3).

Jarosite is a common weathering product of oxidied iron sulphides under acid conditions and is known to be formed together with ferric oxyhydroxides. Alunite - an analog of jarosite - is a well-known weathering product in volcanic rocks and often found near hydrothermal activity and fumaroles [3]. The observed crystals could be mainly associated with Gypsum ($CaSO_4 \cdot 2H_2O$) due to their characteristically shaped H_2O absorption near 1.5µm (Fig. 2) and a high Ca signal in the LIBS data (Fig. 3). Gypsum is a typically deposited from seawater, hot springs, but also volcanic vapours [5]. Also, the hand-held Raman spectroscopy confirmed the VIS/NIR data for mineral recognition and was also able to identify traces of biomolecules on the colonized rock surfaces (of high interest for habitability and the search for life on Mars: carotenoids).

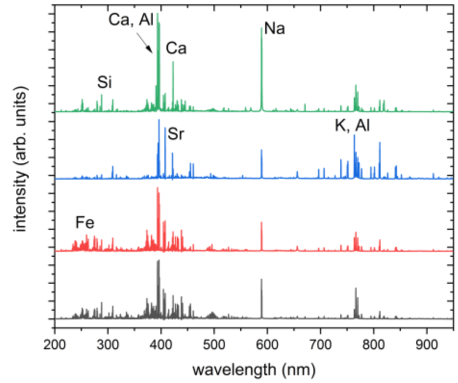

Fig. 3: Elemental variations seen in LIBS data from different positions.

3. Discussion

This *in situ* survey, and its comparison with laboratory instruments, will serve to inform on the capacities of such techniques to characterize extraterrestrial environments and therefore provide a unique training ground for instruments and techniques foreseen for future robotic missions to Mars and other bodies of high astrobiological interest (e.g. Mars2020 and ExoMars2020 rovers [6, 7], Europa Clipper [8], JUICE [9].

Acknowledgements

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