

VNIR Spectral Characteristics of Terrestrial Igneous Effusive Rocks as Possible Martian Analogues: Mineralogical Composition and the Influence of Texture. C. Carli¹, S. De Angelis¹, G. Serventi², L. Serrano³, M. Massironi³, C. De Sanctis¹, F. Altieri¹, F. Capaccioni¹, and M. Sgavetti², ¹IAPS-INAF (Via Fosso del Cavaliere 100, 00133, Roma, Italy; cristian.carli@iaps.inaf.it), ²Department of Physics and Earth Science, University of Parma; ³Department of Geoscience, University of Padova.

Introduction: Mars surface is characterized primarily by volcanic products. Initially, basalt was considered as the primary rock type, then andesitic, ultramafic or alkaline material were suggested or identified (see [1]). Visible and Near-Infrared (VNIR) reflectance spectroscopy is an important technique to map mineralogy and mineralogical variations across planetary surfaces using remotely sensed data. Absorption bands in this spectral range are due to electronic or molecular processes directly related to mineral families or specific compositions. Effusive igneous rocks are widely recognized on the surfaces of terrestrial planets, and are formed by primary minerals that can be discriminated by electronic absorptions (e.g. crystal field absorptions). Future rover missions (e.g. Exomars2018, and likely Mars2020) will have onboard VNIR hyperspectral spectrometers which will acquire spectra on soil and rocks with spatial resolution comparable with laboratory setups. Improving our capability to discriminate different effusive rocks, which are expected to be the most abundant materials on Martian surface, is an important goal.

Here, we present spectral analysis of effusive rocks compositions obtained by studying crystal field absorption in VNIR reflectance spectroscopy. Moreover we investigate how different petrographic characteristics influence the mineralogical interpretation of such rock compositions.

Effusive products: Volcanic rocks are characterized by an aphanitic texture, i.e. a very fine-grained groundmass in which most of the individual crystals cannot be distinguished with the naked eye, and which is presumed to be formed by relatively fast cooling [2]. The classification of volcanic rocks is defined either by modal (QAPF diagram, indicating quartz, alkali feldspar, plagioclase and feldspathoid; [3]) or, more commonly, by chemical analysis (the TAS, total alkali silica, diagram; [2]). Mineral names, textural terms and other terms can also be used to further distinguish the rock type [2]. The abundance of glassy phases is also important, as well as the presence of phenocrysts, which are the first crystals that form in the lava at depth, and xenocrysts, which are ripped from the crust through which lava rises.

Methods: To explore the influence of several factors on spectra, due to both chemical and physical variation of a surface/regolith, we are investigating samples

with different compositions, textures and sizes (considering the combined effect of both crystal and grain sizes, see also [4]).

Sample preparation and characterization. The reflectance spectra were measured on rock powders with fine to coarse (mm) grain sizes and on slab samples. Powders and slabs were prepared from the rock portion adjacent to the thin section used for petrographic and chemical analyses (EMPA). On slabs, the measured surface was slightly polished to remove the asperities left by the saw, but without producing a mirror-like surface. In order to preserve the original rock composition in powdered samples, the rocks were first ground to prepare a <2.00 mm coarse grain size. The powders were then quartered and each fraction was ground under smaller sizes (e.g. <0.250 mm). Each powder grain size class therefore contains a range of grain dimensions beneath the upper limit. Bulk rock compositions were also measured with an X-ray fluorescence spectrometer (XRF).

Spectra measurements. The reflectance spectra were measured with a FieldSpec-Pro spectrophotometer mounted on a goniometer in use at SLAB (Spectroscopy LABoratory) at IAPS-INAF, Rome, at room conditions. The calibration of the spectrophotometer was performed with Spectralon optical standard (registered trademark of Labsphere, Inc.). The spectra were acquired with a spectral resolution of ~3 nm in the visible and of ~10–12 nm in the near-infrared, and 1 nm spectral sampling, between 0.35 and 2.50 μm, with $i = 30^\circ$ and $e = 0^\circ$. The source used was a Quartz Tungsten Halogen lamp. The illuminated spot was ~0.5 cm².

Results: Igneous rocks are mainly composed of mafic (e.g ortho-(opx), clinopyroxene (cpx), olivine (ol)) and sialic minerals (e.g. plagioclase (pl), quartz, k-feldspar) which show diagnostic C.F. absorptions in the VNIR due to iron transitions in crystal lattice [5]. These phases are the constituents of both intrusive and effusive rocks with comparable bulk rock compositions, so analogue absorption bands characterized samples of those products, but spectra of intrusive and effusive rocks can be generally distinguished with albedo, band contrast and spectral shape. Fig.1 shows the spectral behavior of a norite sample (intrusive) and a tholeiitic basalt (effusive). Despite very close bulk rock compositions [see 4] effusive samples are characterized

by pyroxene with higher Ca content (1 and 2 μm bands are slightly shifted), strongly reduced spectral contrast and lower reflectance.

Mineral mixtures are generally used to evidence the spectral variability of regoliths or rock powders, but their spectral variations are in general more compatible with powders of intrusive than effusive rocks, for both reflectance and spectral contrast as shown in [4]. So, the analysis of mineral mixture cannot be sufficient to better understand the spectral behavior of regoliths mainly composed of effusive products, like lava field regions. This aspect is intrinsically related with the microcrystalline texture of the groundmass of effusive samples which generate even for very low grain size (tens of micron) multi-crystalline grain where the optical coupling [5] play an important role.

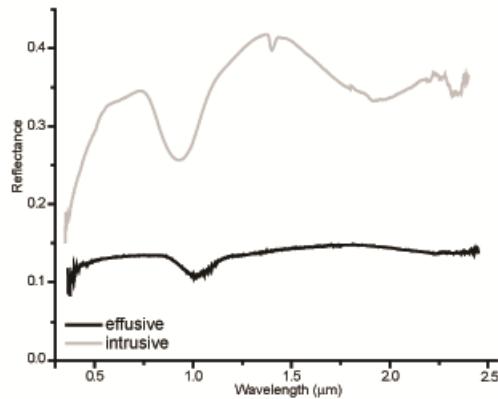


Figure 1 – Spectra of effusive and intrusive samples with very close bulk rock composition [4].

Moreover, effusive rocks can be influenced by other characteristics of the texture which can reduce the spectroscopical information respect to the expected mineral absorptions, like iso-orientation of crystal or the presence of variable amount of glass, due to the quickly cooling.

The presence of glass, in particular, can strongly reduce the intensity of the absorption expected by mafic minerals in samples. Figure 2 shows spectra from samples of a vertical section of 1983 Etna's lava flow with increasing glass amount in the ground mass. Et13 sample come from the inner part of the section and it has a holocrystalline groundmass, and shows clear information of mafic silicates (cpx+ol) at 1 μm . Et14, Et12, Et15 samples are from outer portion of the lava flow with an increasing amount of glasses. Those samples have the same bulk rock composition as well as analogues mineral association but the 1 μm band area is reduced to almost featureless spectra in Et15 which has a vitrophyric groundmass.

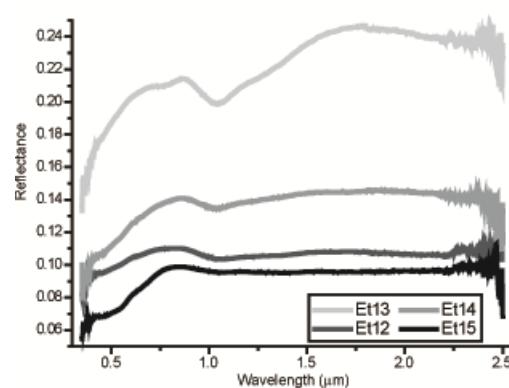


Figure 2 – Spectra of powders (<0.250 mm) of 4 samples of 1983 Etna's lava flow [4]. Increasing the glass amount in the ground mass, reflectance and spectral contrast are reduced to almost featureless spectra in Et15.

Ongoing work: Despite effusive material are preferentially classified by chemical analysis (e.g. TAS diagram), variation on bulk rock composition are also directly related to variation in minerals association in holocrystalline samples. [6], [7], [8] introduced qualitatively indication of the difference from ultramafic/mafic, intermediate or acidic effusive products. We are working more systematically to improve our capability to separate specific volcanic materials due to variable mineral association using the VNIR reflectance absorption with the goal of more quantitative information.

References: [1] McSween Jr, H. Y., et al. (2009) *Science*, 324, 736-739. [2] LeMaitre, R. W., et al. (2002) *Cambridge University Press*, pp. 236. [3] Streckeisen, A. (1978) *Neues Jahrbuch für Mineralogie*, 143, 1-14. [4] Carli, C., et al. (2014) *GSL-Special Publication*, 401. [5] Burns, R. G. (1993) *Cambridge University Press*, pp. 551 [6] Hapke, B. W. (2012) *Cambridge University Press*, pp. 513. [7] Hunt, G. R., et al. (1973) *Mod. Geol.*, 4, 217-224. [8] Hunt, G. R., et al. (1973) *Mod. Geol.*, 4, 237-244. [9] Hunt, G. R., et al. (1974) *Mod. Geol.*, 5, 15-22.

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