RAMAN-XRD ANALYSIS OF SELECTED SAMPLES FROM CHAMORGA (ANAGA MASSIF) - TENERIFE (SPAIN): PLANETARY AND ASTROBIOLOGICAL IMPLICATIONS FOR MARS.

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Introduction: Several volcanic places have been used as possible terrestrial analogues taking into account the volcanic activities and the huge variety of geological processes discovered on Mars heretofore. Thus, the improvement of the understanding the geological diversity of these terrestrial analogues will help us to: (1) to increase our knowledge of the past Martian volcanic activities and (2) to test the new instrumentation for future space missions such as ESA-ExoMars mission, the Scanning Habitable Environments with Raman & Luminescence for Organics and Chemicals Instrument on NASA (SHERLOC) or SuperCam on NASA-France consortium for the NASA mission in 2020 [1], [2]. The Island of Tenerife show a huge diversity of volcanic landscapes, volcanic channels and several emplacement of lave deposits with strong similarities to the volcanoes on the red planet (geomorphology). However, Tenerife also presents several mineralogical similarities due to the existence of the primary and secondary mineralogy caused alteration processes and rock/ fluid interactions (marine, hydrothermal and meteoritic water) [3]. In this regard , Tenerife´s geology have all major conditions as Martian volcanic analogue considering the geological complexity and heterogeneity of the volcanic surface detailed before (see Figure 1).

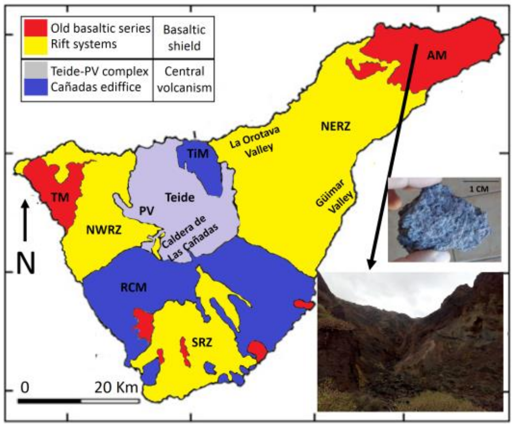

Figure 1. Simplified geological map of Tenerife, Spain showing the selected volcanic outcrop for planetary implications. (TM: Teno massif; NWRZ: North-west Rift zone; SRZ: South Rift zone; NERZ: North-east Rift zone; TiM: Tigaiga massif; AM: Anaga massif; PV: Pico Viejo; RCM: Roque del Conde massif).

Geological setting. The selected outcrop (Chamorga formation) belong to the old basaltic series formation of the volcanic formation of Tenerife island (see Figure 1 and 2). The Anaga massif (AM) is mainly composed by a basinitic composition from“8Ma”, an alkali basalt around from “5.8 Ma” and a basinitic activity from“4.2 Ma”. Moreover the zone present the existence of fossil hydrothermal systems and the existence of Fe-rich silica amorphous phase alteration to a groundmass of celadonite and opaline mixture rich in Fe-(hydro) oxides [1, 4].

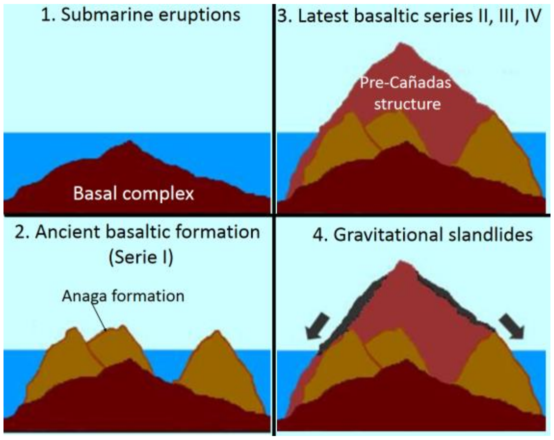

Figure 2. Simplified scheme of the Tenerife formation: (1) Submarine eruptions (20–50 Ma); (2) ancient basaltic formation (7 Ma); (3) latest basaltic series-II, III, IV(3 Ma); (4) gravitational landslide (0.8 Ma)

Experimental setup. The laboratory mineralogical characterization of the samples (in bulk mode) was performed by micro-Raman spectroscopy, using a microscope Nikon Eclipse E600 coupled to a spectrometer KOSI Holospec f/1.8i illuminated by a laser REO LSRP-3501, He-Ne 632.8 nm. The detection was performed with a CCD Andor DV420AOE- 130. The acquisition parameters on the micro-Raman system were: 30 second integration time, 10 accumulations and laser power varying depending on the sample. Also, FT-Raman measurement have been done by a FT Raman spectrometer composed by a Nd:YAG Laser at 1064 nm, spectrograph with spectral range 851–1695 nm (NIR), with a best spectral resolution of 2 cm^{-1} and a detector is a Bruker CCD model D418T cooled by liquid N_2. In addition, X-ray diffraction was performed on the samples (with XRD diffractometer Philips PW1710).

Results and discussions. Table 1 compiles and summarizes the mineral species and phases identified by Raman Spectroscopy and XRD on the Chamorga outcrop.

Minerals	Chamorga Outcrop		
	Raman	XRD	On Mars
Oxides			
Magnetite (Fe_3O_4)	X	X	X
Haematite (Fe_2O_3)	X	X	X
Goethite (α-FeO(OH))	X	X	X
Phosphate			
Apatite	X		
Silicate			
Inosilicates			
Piroxenes			
Diópside ($MgCaSi_2O_6$)	X	X	X
Augite ($(Ca,Mg,Fe)_2(Si,Al)_2O_6$)	X	X	X
Nesosilicates			
Olivine			
Forsterite ($(Fe,Mg)_2SiO_4$)	X	X	X
Tectosilicates			
Feldspars and plagioclase	X	X	X
Anorthoclase ($(Na,K)AlSi_3O_8$)	X		
Albite($NaAlSi_3O_8$)	X		
Labradorite ($(Ca,Na)(Si,Al)_4O_8$)	X		
Zeolites			
Analcime ($NaAlSi_2O_6\cdot H_2O$)	X	X	X

Table 1. Resume of the mineral species detected on Tenerife and the Mineral comparison with Mars.

The mineral species detected correspond to a primary and secondary mineralization, where secondary minerals detected correspond to a different variety of origins such as hydrothermal processes or submarine processes.

The most important bands of the hematite state at: 221, 245, 295, 305, 410, 490, 607 and 1323 cm^{-1}. On the other hand, the magnetite present the most intense peaks are present at 660, 550 and 504 cm^{-1}. In the case of the goethite, it Raman bands are at 244, 299, 385, 480, 550 and 681 cm^{-1} [5]. In our results, it is important to quote the high concentration of iron-oxides produced by the hydrothermal processes, being an alteration product from iron-rich silica amorphous of the basal complex.

The phosphate in the basaltic minerals is considered as an accessory mineral and is an incidator of the kind of alteration produced in the volcanic outcrop´s sample. In this case, the mineral phase detected is the apatite with the principal vibrations at 1017, 960 y 563 cm^{-1} and it is formed on the groundmass as grain aggregates which could replace the feldspar and zeolites [6].

The primary mineralogy corresponds to olivine (with the most intense bands at 850 and 823 cm^{-1}), pyroxenes (where the principal Raman vibrations are at 1000 and 660 cm^{-1} approximately) and the feldspar/plagioclase (with the characteristic triplet or doublet bands, located on the 450–515 cm^{-1} region) [1].

Concerning to the zeolite mineral phases, the analcime shows the principal bands 384, 480 y 1100 cm^{-1}. However, this zeolite (analcime) can: (1) crystallize directly from a silicate melt without the formation of any intermediate mineral or (2) be formed as secondary mineralization from the ion exchange reaction silicate groundmass + Na* + H_rO : analcime + K at subsolidus temperatures (from low temperature hydrothermal process) [7].

Conclussions. The samples were characterized and studied by Micro-Raman spectroscopic techniques and other complementary techniques (FT-Raman and XRD) through a complete analysis of the mineralogy from the selected materials. Moreover, crystalline primary phases such as olivine, pyroxene, oxide, feldspar; and secondary minerals like oxy-hi(droxides), zeolite and phosphate have been confirmed, being similar with the mineralogy detected at the moment on Mars. A discussion of the possible alteration processes have been carried out. For last, an enlargement of the knowledge on terrestrial analogues and their mineralory helps on the planetary research with astrogeological implications, specially focused on the development of future Martian missions such as the Exo-Mars mission.

References: [1] E. A. Lalla et al. (2015) *GSF, in press.* [2] N. Boost et al. (2015), *Planet Space Sci, 108, 87-97* [3] E. A. Lalla et al. (2015), *Est. Geol., (71)-2, e-35.* [4] J. A. Rodriguez-Losada et al. (2000), *J. Volcanol. Geoth. Res., 103, 367-376.* [5] F. Rull et al. (2004), *J. Raman Spectroc, 35 (6), 497-503.* [6] I. S. Torres-Alvaro et al. (2007), *Rev. Mex. Cienc. Geol, 24, 15-24.* [7] H. Karlsoon and R. Clayton (1991), *Amer. Min., 76, 189-199.*