OVERVIEW OF FOGO ISLAND, CABO VERDE AS A TERRESTRIAL ANALOG FOR MARTIAN VOLCANOLOGY. E. A. Lalla[1,2], M. Aznar[3], A. Sanz-Arranz[4], G. Lopez-Reyes[4], M. Veneranda[4], A. Barlow[5], J. Freemantle[1], E. Sawyers[1], M. G. Daly[1], E.A. Cloutis[6], J. Martinez-Frias[7], M. Konstantinidis[8], and F. Rull-Perez[4]. [1]York University, Toronto ON, Canada; [2]Canadensys Aerospace Corporation, Bolton, ON, Canada; [3]Universidade de Cabo Verde, Praia, Cabo Verde; [3]Unidad Asociada UVA-CSIC-CAB. Boecillo, Valladolid, Spain; [5]University of Waterloo, Waterloo, ON, Canada,[6]Department of Geography, University of Winnipeg, Winnipeg, MB, Canada; and [7]Dinamica Terrestre y Observacion de la Tierra, Instituto de Geociencias, Ciudad Universitaria, Madrid, Spain. [8]Institute of Health Policy, Management and Evaluation, University of Toronto, ON, Canada.

Introduction: Several space missions from NASA and ESA have visited and will land on Mars in search of life. The last NASA mission to arrive was the Mars 2020 Perseverance rover on 18 February 2021. The next mission to Mars will be the ExoMars Rosalind Franklin rover, expected to touch down sometime after 2028. Both Mars2020 and ExoMars are equipped with Raman spectroscopic systems: SuperCam and SHERLOC on Perseverance and Raman Laser Spectrometer (RLS) on Rosalind Franklin (RF) [1]. These instruments will identify rocks, minerals, and potential organic biosignatures on the Martian surface. Many challenges are associated with the qualitative and quantitative analysis of resulting data from missions on Mars. Studies of new terrestrial Martian analogues can help to overcome these challenges. The analysis of Martian analogues allows us to understand better the processes that have shaped the surface of Mars, including its geological and geochemical evolution. Analogue site investigations will enable us to evaluate the potential for the emergence of life and the preservation of different fossil biomarkers throughout the planet's history [2].

Young volcanoes are environments with great importance as analogues of Mars because of the following characteristics: 1) they can have great mineralogical diversity; and lack of nutrients; and 3) the existence of fumaroles, volcanic tubes and associated hydrothermal processes [3]. Here, we introduce Chã das Caldeiras Outcrop, Fogo Island, Cabo Verde, as a relevant volcanic terrestrial analog for Mars. We sampled several areas of relevance in Chã das Caldeiras and conducted a complete band analysis of Raman spectra for targets from this site. Additional studies included ATR-FTIR and XRD. Chã das Caldeiras can be used to compare them with ancient Martian volcanism and their relevance in the possible existence of Martian life in the past.

Geological Description: The Cape Verde archipelago comprises ten islands and several islets located about 550 km west of the west coast of Africa, between 21-25º W and 15-17º N. This archipelago and the Azores, Madeira and the Canary Islands form the so-called Macaronesia group. The formation of the Cape Verde islands was likely initiated by a significant underwater volcanic eruption and later was complemented by a fissure network manifested as the Pico de Fogo outcrops. It is mainly dominated by eruptions of magmatic and pyroclastic materials (scoria, or "lapilli" and ash) of predominantly basaltic composition [4]. Thus, the archipelago is essentially constituted by basic volcanic rocks with a predominance of basaltic rocks, and two different types of magmatism can be found: a) Tholeiitic magmatism (magnesium-rich, primitive initially erupted or emplaced rocks) and b) Alkaline magmatism (more iron-rich) [5]. In the particular case of Fogo Island, the main edifice of Fogo Island is mainly constituted by four different geological structures: 1) the Monte Amarelo stratovolcano, 2) the subsequent landslide of its eastern flank with sub-vertical walls of up to 1,100 m of uneven structures (so-called “Bordeira”), 3) the Pico de Fogo, a stratovolcano nested inside this caldera, and 4) an almost flat plateau between both structures called Chã das Caldeiras [4]. The selected area is the Cha das Caldeiras, where the last volcanic eruption of Fogo began on November 23, 2014, in Chã das Caldeiras until 2015 (72 days). The eruption formed six eruptive mouths in the western foothills of Pico de Fogo, practically in the same place where the previous eruption of 1995 occurred. The lavas initially presented a’a morphologies, and the secondary flows exhibited pahoehoe morphologies. The eruptive cone is >100 m in height and formed by the accumulation of pyroclastic materials of different sizes.

Experimental Setup: The XRD instrument is a portable inXitu (now Olympus) Terra-185 system. The diffractometer includes a CoKα excitation source (300 kV, 300 µA), a vibrating sample holder cell and a 2D Peltier-cooled CCD detector. X-ray diffraction is recorded from 5 to 55º 2θ with an average resolution of 0.25 - 0.30º 2θ (FWHM).

The FTIR-ATR instrument is a Perkin Elmer Spectrum 100 FT-IR Spectrometer system equipped with a universal ATR sampling accessory. The measurement conditions chosen were a spectral resolution of 4 cm^{-1}, 16 scans, and a 500-4000 cm^{-1} spectral range.

The FT-Raman is a Raman Bruker RFS100/S system with a 1064 nm Klastech laser and a Bruker D418 CCD detector. The measurement conditions chosen were a laser power of 500 mW and a laser spot

on a sample of 1000 µm to obtain a low irradiance and to avoid thermal damage to samples. The spectral resolution was 4 cm^{-1}, 512 or 1024 scans, a scanning speed of 1.6 kHz, and a spectral range from 0 to 3500 cm^{-1}.

The 785 nm Raman instrument was composed of a BWTEK BRM-OEM-785 laser, a BWTEK BAC100-785E Raman probe, and a BWTEK Prime T spectrometer-Hamamatsu S10141-1107S CCD. Laser power on the sample was chosen on each point to avoid thermal damage. The head probe focused the laser through a 20× lens, and the spot size was 85 µm with 0-3000 cm^{-1} spectral range and a resolution of 4 cm^{-1}.

Results: Table 1 summarizes the detected minerals with the different detection techniques used in the current research.

Minerals	XRD	Raman	FTIR
Oxides			
Anatase		x	
Goethite		x	
Hematite		x	
Magnetite	x	x	
Chromite		x	
Carbonates			
Calcite		x	x
Dolomite		x	
Phosphate			
Apatite		x	
Silicates			
Olivine			x
Forsterite	x	x	
Pyroxene			x
Augite	x	x	
Diopside	x	x	
Hedenbergite	x		
Muscovite	x		
Feldspar and Plagioclases*		x	x
Albite	x	x	
Anorthite	x	x	
Orthoclase	x	x	
Bytownite	x	x	
Sanidine	x		
Feldspathoids			
Leucite	x		
Zeolite			
Analcime	x		
Chabazite	x		
Organics			
Carbon*	x	x	

Table 1. Summary of the Minerals detected by XRD, Raman Spectroscopy and ATR-FTIR for the different groups in Chã das Caldeiras.

The Chã das Caldeira's site could be a possible new volcanic analogue for Mars considering the following points: 1) the similarities to other volcanic places in the Canary Islands; 2) the exclusive geological evolution that is only present in the volcanic emplacement from the Macaronecia-group; 3) the pristine quality of the samples from the outcrop; 4) secondary and alteration minerals detected by XRD, FTIR and Raman spectroscopies. The samples have been studied by Raman spectroscopic and ATR-FTIR and XRD techniques for the first time. We detected several crystalline primary phases, such as olivine, pyroxene, oxide, and feldspar, and secondary minerals detailed in this paper [6]. The crystalline mineral species described in this paper have also been reported from analysis of Mars observations and detected by different rover missions. However, the mineral detected presents differences in secondary mineral species, such as dolomite, chabazite, chromite, and amorphous carbon. The continuous enlargement of knowledge about mineralogy from terrestrial analogues helps planetary research with implications for the development of future Martian missions (i.e., ExoMars). The continued studies of terrestrial spectroscopic databases, such as PTAL, with the possible inclusion of new data from this study, will support upcoming results from Mars. The results reinforce the value of combined spectroscopic measurements such as Raman-IR and test prototypes (e.g., LIRS and lunar Raman breadboard) on selected samples from terrestrial volcanic analogues, like *Chã das Caldeiras* on Fogo Island, among others [7]. In conclusion, we recommend conducting future field analyses of *Chã das Caldeiras* with the portable version of equipment similar to instruments used or to be used for the exploration of Mars.

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References [1] Rull et al. (2021) *Anal. Chim. Acta, 339003*. [2] Lalla et al. (2021) *Appl. Spectrosc., 75*, 9,1093-1113. [3] Lalla et al. (2016) *Geosci. Front*, 7, 673-681. [4] Day et al. (1999) *J Volcanol Geotherm*,94, 1-4, 191-218. [5] Capello et al. (2016) *JGR* 121, 2290-2303. [6] Aznar et al. (2023) *Adv. Space Res (in press).* [7] Cloutis et al (2021) *52nd LPSC*, Abstract #2548.