THE SKOURIOTISSA MINE: A NEW TERRESTRIAL ANALOGUE FOR HYDRATED MINERAL FORMATION ON EARLY MARS. N. Bost[1,2,3,4], C. Ramboz[2,3,4], F. Foucher[1], and F.Westall[1] .[1]Centre de Biophysique Moléculaire, UPR CNRS 4301, 45071, Orléans, France (bost.nicolas@orange.fr) ; [2]Univ d'Orléans, ISTO, UMR 7327, 45071, Orléans, France ; [3]CNRS/INSU, ISTO, UMR 7327, 45071 Orléans, France ; [4]BRGM, ISTO, UMR 7327, BP 36009, 45060 Orléans, France.

Introduction: Recent exploration of Mars has provided abundant evidence for hydrous alteration processes occurring in particular during the first 1.5 billion years [1]. The Mars Exploration Rovers "Spirit" and "Opportunity" and the orbiters Mars Reconnaissance Orbiter (MRO) and Mars Express detected minerals formed by aqueous alteration during hydrothermal activity and weathering at various temperatures and pH conditions. Better understanding of the mechanisms taking place during these processes is essential because some of the environmental conditions are compatible with the emergence and development of life. This can be achieved by study of terrestrial analogue sites in which volcanic rocks undergo similar alteration processes, for example in mines exploiting exposed, basaltic, crust.

Location: In this investigation, we present a mineralogical study of altered crustal basalts exposed by Volcanogenic Massive Sulphide (VMS)-mining activities at the Skouriotissa mine on Cyprus. The Skouriotissa mine is located on the northern flank of the Troodos ophiolite. These exposed crustal rocks offer a complete section through the oceanic crust lying on harzburgitic mantle, ranging from plutonic, to intrusive and volcanic rocks overlain by sediments.

Figure 1 : View of the SW Skouriotissa pit with the brown gossan at the top and the green quartz-chlorite pillow basalt formation at the bottom. Note the mechanical stripper in the lift bottom for scale.

The Skouriotissa mine is located in the very low grade metamorphed Upper Pillow Lava formation. Mining activities related to copper exploitation have resulted in acidic aqueous alteration of the basalts.

The outcrop (Fig. 1) consists of a vertical succession of lithological benches weathered by a drainage stream that becomes increasingly acidic with distance from the mine.

Materials and Methods: Fifteen samples from the stream groove and from the dump at the base of the exposure were dried and finely powdered for elemental analysis by ICP-OES/MS. Mineralogical characterization was made by XRD in reflected mode and by infrared spectroscopy in diffuse reflection. Polished thin sections were also prepared and studied by optical microscopy and Raman spectroscopy in spot mode and Raman confocal mapping spectroscopy.

Eight samples from the Skouriotissa outcrop are referenced in the International Space Analogue Rockstore (ISAR; http://www.isar.cnrs-orleans.fr) collection as 11CY08 to 11CY20 [2]. This collection is used for testing space instrumentation.

Results: The basalt was initially altered by seawater and hydrothermal processes on the seafloor and then subaerially by acidic waters (pH increasing from 5 to 3 with increasing distance from the source) associated with mining activities (Fig. 1). Hydrothermal alteration resulted in a quartz-chlorite alteration facies, sea water hydrothermal alteration in a smectite facies, while the acidic alteration favoured the formation of clays, such as smectites at pH 5 and zeolites and sulphates (gypsum and natrojarosite) at pH 3-4.

Most of the mineral assemblages described from the Skouriotissa exposure have been observed on early Martian terrains, sometimes over areas several km^2-wide. Comparison of the infrared spectra of the Skouriotissa samples with the reflective infrared spectra obtained with CRISM on samples outcropping at the surface of Mars show strong similarities (Fig. 2).

Conclusions: Our observations concur with the interpretations of mineral formation on Mars by aqueous alteration of basalts at different temperature and pH conditions. By analogy, the presence of smectites over large areas of the Martian surface could provide arguments in favour of extensive aqueous alteration at low to high temperatures, whereas chlorite-bearing facies on Mars could be indicative of hydrothermal alteration.

Obviously, they imply active circulation of hot fluids in the crust, driven either by volcanism, impact and/or geodynamic processes. Indeed, hydrothermal processes on Mars are highly relevant to considerations of habitability and the emergence of life. Basalts and their alteration products in general can provide important information relating to past habitability. The presence of a low temperature metasomatic mineral facies, such as smectite, immediately suggests habitable conditions in the form of water, nutrients, and chemical energy.

Study of terrestrial analogues showing juxtaposed sequences of alteration scenarios therefore provides useful information for understanding alteration processes on Mars.

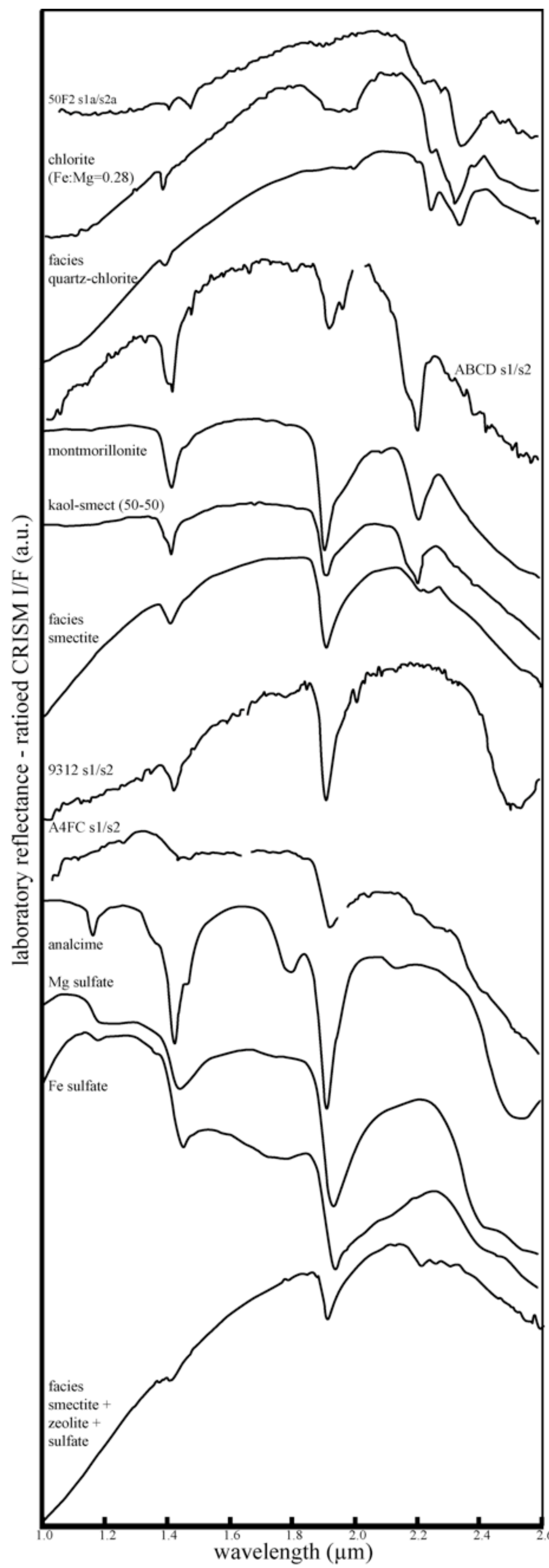

Figure 2: CRISM hydrated silicate spectral signatures in Mars and laboratory references(modified after [3]). Laboratory IR spectral signatures of samples from Cyprus.

References: [1] Ehlmann B.L. et al. (2011) *Nature, 479*, 53-60. [2] Westall F. et al. (2013) LPSC XXXXIV, Abstract # 1397. [3] Ehlmann B.L. et al. (2009) *J. Geophys. Res., 114*, E00D08.