BIOSIGNATURES OF CHEMOTROPHIC MICROBIAL ACTIVITY IN MARS-ANALOGUE, SUBSURFACE VOLCANIC SEDIMENTS.
F. Westall[1], K. Hickman-Lewis[1], F. Foucher[1], F. Gaboyer[1], B. Cavalazzi[2], P. Gautret[3], K.A. Campbell[4], J.L. Vago[5], [1] CNRS-CBM, Orléans, France (frances.westall@cnrs-orleans.fr), [2]Univ. Bologna, Italy, [3]CNRS-ISTO, Orléans, France, [4]Univ. Auckland, New Zealand, [5]ESA-ESTEC, Noordwijk, The Netherlands.

Introduction: Chemotrophic microorganisms inhabiting subsurface environments are known to leave a variety of fossilized signatures of their presence, not simply remnant organic molecules, but also morphological, isotopic and mineralogical vestiges. We here describe the kinds of chemotrophic fossilized biosignatures occurring in hydrothermally-influenced, Mars-analogue, early Archaean (3.5-3.3 Ga) volcanic sediments.

The early Earth is an excellent analogue both for early Mars and for subsurface martian conditions which, perhaps, still harbour endolithic life[1-2]. In the Early Archaean, Earth was characterized by an anaerobic extreme, volcanic and hydrothermal environment in which nutrients were provided by leaching of volcanic and hydrothermal deposits, H_2 produced by hydothermal serpentinisation processes, as well as organic molecules, both buried with the sediments and of hydrothermal origin. Carbon sources included CO_2 (the atmosphere was enriched in CO_2, also dissolved in seawater and present in the subsurface porosity) and also organic sources from extraterrestrial and hydrothermal origin, as well as degraded bio-organics within the buried sediments.

We here document the types of chemotrophic biosignatures observed in volcanic sediments from the 3.5-3.3 Ga Barberton (South Africa) and Pilbara (Australia) greenstone belts. Study of martian analogue rocks from these sequences allows understanding of the types of biosignatures that could be preserved, how they are preserved, and how they can be studied either *in situ* on Mars or in returned martian samples.

Subsurface chemotrophic biosignatures in ~3.5 Ga volcanic sediments: Subsurface volcanic sediments of Early Archaean age from the Barberton and Pilbara regions were colonized by both chemo-lithotrophic and chemo-organotrophic life forms[2-4], preserved due to rapid encapsulation within silica-enriched, hydrothermally-influenced pore waters.

Chemolithotrophic biosignatures. Chemo-lithotrophic traces are distinguished from organotrophic traces by their direct association with the surfaces of volcanic particles. Thus, on the surfaces of volcanic particles altered to phyllosilicates, we observe colonies of lithotrophs that coated, and produced EPS-filled corrosion pits upon, the surfaces of the particles[2-4]. The preserved, <1 µm-sized, coccoidal and rod-shaped cells show a variety of typical morphological features, such as cell-division, lysis, EPS coatings etc. Associated organic carbon is highly degraded in these ancient, lower greenschist metamorphosed sediments, but still has a recognizable molecular composition and structure of biogenic origin, and a C isotopic signature consistent with biogenicity[2-4]. In oligotrophic environments away from direct hydrothermal influence, the colonies form monolayers on particle surfaces. Their biomass is restricted, bulk carbon contents are low (< 0.02%) and their identification thus requires high-power, *in situ* observation techniques.

Chemo-organotrophic biosignatures. We observe organotrophic microbial colonies as clots of carbon floating in hydrothermal silica that permeated the subsurface volcanic sediments, which exhibit spiky morphologies suggestive of *in situ* growth, *i.e.* they are not detrital flocs of carbon. We also suspect that thickened carbon coats on volcanic particles in hydrothermal areas likely represent organotrophic colonization of previous lithotrophic colonies. Again, the morphology and organic and isotopic signatures suggest a biogenic origin. The organotrophs appear to be strictly limited to hydothermal environments.

Conclusions: Although chemotrophic biosignatures are widespread in the Early Archaean volcanic sediments, their development is limited in oligotrophic environments. Rapid encapsulation in a mineral matrix is essential to their long-term preservation. *In situ* identification on Mars of biosignatures generically distributed in sediments could be challenging unless the subsurface environment had been fed by nutritious hydrothermal fluids flowing through veins and fractures. Fractures and veins penetrated by silica-rich fluids are thus particularly interesting locations for subsurface biosignature preservation.

References: [1] Westall, F. *et al.*, (2013) *Astrobiology, 13*, 887-897. [2] Westall, F. *et al.*, (2015) *Astrobiology, 15,* 998–1029. [3] Westall, F. *et al.*, (2015) *Geology, 43,* 615–618, [4] Westall *et al.*, (2011) *Planet. Space Sci. 59*, 1093–1106.

Acknowledgements: CNRS, CNES, the MASE project (FP7 grant n° 607297), Marsden Fund (RSNZ) to K.C., FP7-PEOPLE-2013-CIG (nr 618657) to B.C.