Identifying biosignatures in a Mars-analogue volcanic rock: The ~3.5 Ga Kitty's Gap chert

Laura Clodoré[1], Frédéric Foucher[1], Keyron Hickman-Lewis[2], Stéphanie Sorieul[3], Matthieu Réfrégiers[1], Guillaume Collet[1] and Frances Westall[1]
[1]CNRS-Centre de Biophysique Moléculaire, Orléans, France (laura.clodore@cnrs-orleans.fr)
[2]Natural History Museum, London, UK
[3]University of Bordeaux, CNRS, IN2P3, CENBG, Gradignan, France

Introduction: Did life ever exist on Mars? This is the question that the ExoMars mission, to be launched in 2022 to the Red Planet, will try to answer. The main objective of this mission is to detect possible traces of life on Mars using a highly complementary suite of instruments (Vago et al., 2017). Although the present conditions on Mars make the presence of extant life inconceivable at the surface, morphological and mineralogical evidence indicates that Mars could have been habitable in the past, at least locally (Poulet et al, 2005; Bibring et al., 2006), suggesting that possible traces of fossil life could be found in martian rocks or in the subsurface. If life ever appeared on Mars, it must have remained relatively primitive (chemotrophic or anoxygenic photosynthetic microorganisms) and the associated traces are expected to be very subtle, rather similar perhaps to the traces found in terrestrial rocks from the Archean (Westall et al., 2006).

Biosignatures study: On Earth, we study traces of life associated with volcano-sedimentary materials whose biological signatures are possible analogues of the signatures of life that could be found on Mars.

Environmental conditions of the Kitty's Gap chert.

We are studying past traces of life in 3.5 Ga-old volcanic sands, whose littoral depositional environment is an analogue to Noachian environments on Mars. The 3.446 Ga Kitty's Gap chert (Pilbara, Australia) is a typical example of silicified volcanic sediments deposited in a shallow, littoral water environment, and in the vicinity of a hydrothermal vent linked to a volcanic system (Fig. 1A; Orberger et al., 2006; Westall et al., 2006, 2011).

Colonization by micro-organisms in the Kitty's Gap chert.

The Kitty's Gap chert hosted microorganisms interpreted as anaerobic and autotrophic chemolithotrophs that colonize the surfaces of volcanic particles, as well as the dusty matrix (Fig. 1B-C). These kinds of microbes were common on the early Earth, living in anaerobic, volcanic environmental conditions similar to those on early Mars (Westall et al., 2015). The microorganisms occur as silicified, small (< 1 µm) coccoidal structures (Fig. 1D). Nevertheless, the total sediment is low in organic carbon (0.01–0.05 atomic %). Therefore, the carbonaceous remains of these microorganisms are very subtle and difficult to identify, and their analyses required a multi-technique approach.

Multi-technique study of traces of life

The characterization of primitive fossils microbes requires the identification of morphological, elemental and molecular biosignatures. For this purpose, the carbonaceous matter around the volcanic particles (Fig. 1C) is studied using different observation techniques (optical and electronic microscopy, Raman spectroscopy, fluorescence spectroscopy), and different analytical techniques (Raman spectroscopy, EDX, ToF-SIMS, FTIR). Metallic elements associated with the microbial metabolisms prior to silicification may be also identified using techniques such as Particle-Induced X-ray Emission, X-ray micro-fluorescence, LA-ICP-MS.

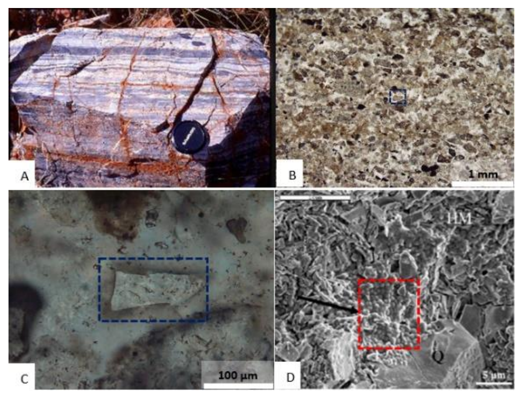

Fig. 1. (A) Outcrop of the volcanic sediments in the Kitty's Gap chert; (B) optical image of the volcanic particles in the rock; (C) volcanic particle (outlined in B) surrounded by organic matter (brown); (D) SEM micrograph showing colonies of chemolithotrophs in volcanic sediments (Westall et al., 2006).

Summary: Documentation of primitive terrestrial life signatures and the methods used in their characterization will be relevant for identifying biological signatures on Mars during the ExoMars 2022 mission. In the framework of the NASA Mars 2020 mission, this may also help in the selection of samples to be sent back to Earth in following Mars Sample Return in the 2030s.

References:

Bibring, J. P. et al. (2006) *Science*, *312*, 400-404.
Orberger, B. et al. (2006) *Geological Society of America*, *405*, 133-156.
Poulet, F. et a. (2005) *Nature*, *438*, 623-627.
Vago, J. L. et al. (2017) *Astrobiology*, *17*, 471–579.
Westall, F. et al. (2006) *Geological Society of America*, *405*, 105–131.
Westall, F. et al. (2011), *Planetary and Space Science*, *59*, 1093–1106.
Westall, F. et al. (2015), *Geology*, *43*, 615–618.