ASTROBIOLOGICAL IMPLICATIONS OF MICROBES IN BASALTIC PILLOW LAVA CRUSTS: A CASE STUDY FROM RECENT (BIO-)ALTERATION RIMS, CORAL PATCH SEAMOUNT, ATLANTIC OCEAN.

Barbara Cavalazzi[1], Frances Westall[2], Roberto Barbieri[1] and Frédéric Foucher[2]. [1]Dipartimento di Scienze della Terra e Geologico-Ambientali, Univeristà di Bologna, Via Zamboni 67, I-40127 Bologna, ITALY, barbara.cavalazzi@unibo.it; roberto.barbieri@unibo.it, [2]Centre de Biophysique Moléculaire-CNRS and Université d'Orléans, F-45071 Orléans cedex 2, FRANCE, westall@cnrs-orleans.fr, frederic.foucher@cnrs-orleans.fr

INTRODUCTION. Discoveries of microorganisms living within modern oceanic (glass) crust have expanded the range of known microbial (extreme) environments and demonstrated the crucial role of microbes in bio-alteration processes [1-4]. Microbes can bioerode and colonize surfaces and fractures in the glassy selvages of pillow lavas, leaving behind fossil traces of their activity [1, 2]. Microbial alteration features described from Early Archaean oceanic crusts are claimed as a biosignature for life on early Earth and perhaps on Mars [3, 4]. Palagonite, an alteration product of basaltic glass that can be produced both abiogenically and biogenically, has been detected on the martian surface [5] suggesting the presence of liquid water and subaqueous (bio?-)alteration of basaltic glass. The understanding of microbial alteration processes and the recognition of their fossil remains from pillow basalts is an important target in the exploration for life on Mars and elsewhere in the solar system. To recognize evidence of microbial life in the rock record requires the understanding of modern analogues. Here we describe the use of a combination of observational and analytical techniques that are non destructive and only slightly invasive, such as laser scanning, environmental scanning electron microscopes and atomic force microscopes (LSM, ESEM, AFM), that was used to detect potential microfossil biosignatures in the altered rims of recent basaltic pillow lava, and to test their biogenicity.

MATHERIALS AND METHODS. The studied samples were collected in August-September 2004 during the scientific cruise SWIM 2004 aboard the R/V URANIA. We examined dredged samples from the station 29 (SWIM04-29: Lat 34°58.3106' N, Long -11°57.3238' W, depth 1011.8 m depth below sea level) along the cruise track across Coral Patch Seamount, off Morocco in the Gulf of Cadiz, Atlantic Ocean. The studied material was sub-sampled from a large fragment of reddish, basaltic pillow lava encrusted by pelagic limestone. For microfacies analyses, standard petrographic thin sections were examined by optical, laser scanning (LSM) and atomic force microscopes (AFM). Slightly etched (1% HCl for a few seconds), air dried and non-coated thin sections were prepared for environmental scanning electron microscopic (ESEM) examination. Mineralogical and elemental compositions were determined by X-ray powder diffractometry and an X-ray energy dispersive spectrometer system.

MICROBIAL MORPHOLOGIES. Microfacies analyses revealed the pervasive distribution of microbial-like morphologies within vesicles/porous zones of the basaltic glass preserved in the pillow rims. These morphologies include tubular and spheroidal structures encompassing the size range of bacterial filaments and coccoids. They mainly consist of aggregates of 1) tubular/filamentous structures with sinuous and straight morphologies and constant diameter (~2.5-3µm), and 2) small (~3µm) and larger (~5µm) spheroidal structures (Fig.1).

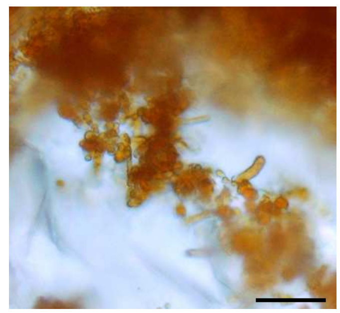

Fig. 1. Transmitted light microphotographs of a petrographic thin section (OlympusBX51) showing a dense aggregation of microbial-like morphologies (filamentous and spheroidal structures) from pillow lava alteration rims. Scale bar: 20µm.

Small spheroidal structures (micro-spheres) are mainly organized in chains as indicated by LSM and ESEM-EDX detailed observations (Fig.2, 3). In particular, LSM was used for testing the auto-fluorescence pattern distribution along microbial-like morphologies (Fig.2). The distribution of auto-fluorescence could be related to the presence of organic matter.

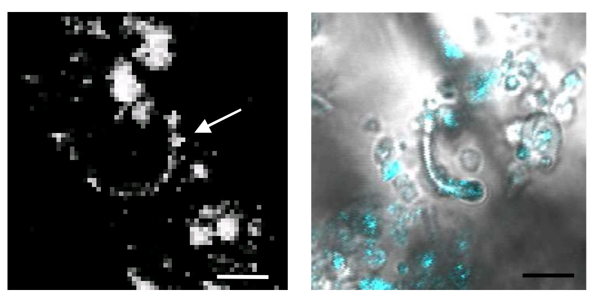

Fig. 2. LSM (LSM 510/3 META Zeiss) microphotographs of filamentous microbial morphology composed by chain of micro-spheres (arrow). Note the auto-fluorescence (blue) distributed along the biogenic-like structures, which could be related to the presence of organic matter. Scale bar: 5µm.

ESEM-EDX analyses revealed fine details of the delicate microbial-like morphologies (Fig.3). The filamentous structures mainly consist of amorphous, C-rich tubules. Their walls resemble a dehydrated membrane/biofilm and the structures themselves are infilled by clay minerals similar in composition to host-matrix (palagonite), formed during basaltic glass alteration. The original interspace between the replaced filaments, the membrane-like structures and the host rock could be interpreted as the product of the shrinking of drying sheaths during early mineralization (i.e. fossilization) processes. A C-enrichment is observed around the microbial-like morphologies, and C-rich membrane-like structures are associated/stained with few micrometer-scale S- and Ti/Fe-rich grains. In this way, the pattern distribution of S and Ti/Fe-oxides could be interpreted as bio-elements [6].

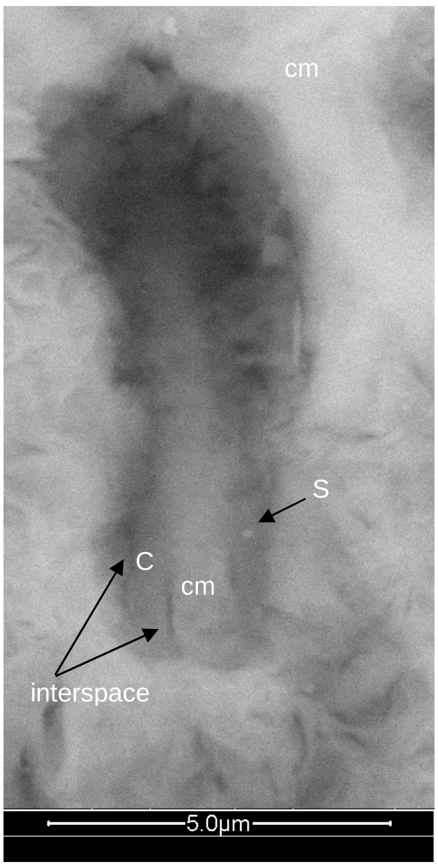

Fig. 3. ESEM (Quanta Fei 200) micrograph of filamentous structures (see detail in the text). The ESEM observation was conducted in LowVacuum (=1Torr) on slightly HCl-etched (1%, 1-2 sec), and no coated thin section. C: C-rich memabrane like structures; cm: clay minerals; S: sulphur grain.

The described morphologies are commonly detected along fractures and from vesicles of glass at the pillow lava surface, where seawater penetration and circulation could be expected which suggests a cryptoendolithic organism, possibly using a chemolithoaotutrophic metabolic pathway. The size, shape, composition and distribution of biological-interpreted activities along the alteration front of the basaltic glass strongly suggest some feedback interaction between cryptoendholitic microorganisms and (bio-)alteration leading to biomineralization processes leading to fossil formation.

CONCLUDING REMARKS. The biogenicity of the detected morphologies is based on: 1) the evidence of morphological structures at different magnifications, and their comparison with modern and fossil analogues; 2) the geological and environmental context that support the syngenicity of the microbial-like morphologies; 3) the x-ray mapping and spot analyses of the elemental distributions that exhibit significant concentrations bioelments (C, S) within the filamentous morphologies.
The preferred microscope techniques in astrobiology-oriented investigation are those that use non-destructive and/or non-invasive procedures [7, 8]. This study documents the utility of LSM for detailed and non-invasive investigations of subsuperficial morphologies and related textures of purported microbial origin. It also strongly suggests the potential of LSM technique if combined with other microscope techniques, in search for evidence of life on valuable (rare or scarce) samples as Archaean or extraterrestrial samples returned.

REFERENCES. [1] Furnes, H., Banerjee, N.R., Staudigel, H., Muehlenbachs, K., McLoughlin, N., de Wit M., Van Kranendonk, M. (2007) *Precambrian Research 158,* 156-176. [2] Mcloughlin, N., Brasier, M.D., Wacey, D., Green, O.R., Perry, R.S. (2007) *Astrobiology 7,* 10-26. [3] Furnes, H., Banerjee, N.R., Muehlenbachs, K., Staudigel, H., de Wit M. (2004) *Science 304,* 578-581. [4] Banerjee, N.R., Furnes H., Muehlenbachs, K., and Staudigel, H. (2004) *LPS XXXV,* Abs. 1248. [5]**.** Michalski J. R., Kraft, M. D., Sharp, T. G., Williams, L.B., Christensen, P.R. (**2005)** *Icarus 174,* 161-177. [6] Westall, F. (1999) *Journal of Geophysical Research 104(E7),* 16437-16451. [7] Cady, S.L., Farmer, J.D., Grotzinger, J.P., Schopf, J.W. and Steele, A. (2003) *Astrobiology 3,* 351-368. [8] Cavalazzi, B. (2007) *Astrobiology 7,* 402-415.

ACKNOWLEDGMENTS. The Authors would like to thank Nevio Zitellini and Lucilla Capotondi, CNR Bologna, for providing the samples used in this investigation. Thanks are due to Gilles Breuzard, CBM-CNRS Orléans, Massimo Tonelli, CIGS-Università di Modena, and Roberto Braga, DSTGA-Università di Bologna, for their support during the LSM, ESEM observations and for petrographical data interpretations, respectively. This study was partially supported by a CNR (Italy) – CNRS (France) 2006-2007 International Program.