ABIOTIC CORROSION MICROTEXTURES IN VOLCANIC GLASS: REEVALUATION OF A PUTATIVE BIOSIGNATURE FOR EARTH AND MARS. J. E. French[1] and D. F. Blake[2], [1]Department of Earth and Atmospheric Sciences, University of Alberta, 1-26 Earth Science Building, Edmonton, AB, Canada, T6E 2E3, jef@ualberta.ca, [2]NASA Ames Research Center, MS 239-4 Moffet Field, CA, USA, 94035-1000, David.F.Blake@nasa.gov.

Introduction: Understanding the impact of radiation damage on characteristic microtextures developed during the natural abiotic corrosion (palagonitization) of basaltic glass by seawater is critical to interpreting alteration microtextures in glasses on both Earth and Mars. Microscopic microbial trace fossils (biogenic etch features) are reported to be widespread in partially palagonitized submarine volcanic glasses on Earth [1]. However, alternative abiotic explanations for such conspicuously 'biogenic looking' microtextures in volcanic glass (i.e. grooves, tubular and granular textures) have recently been proposed [2]. It has been suggested that the presence of such microtextures in Martian basaltic glasses, should they be found, would constitute evidence for past microbial life on that planet [3], an hypothesis that should be critically reexamined.

Basaltic glass and palagonite are thought to be widespread on Mars [4], and there is abundant evidence for past action of liquid water on its surface [5]. In preparation for future Sample Return missions from Mars, it is imperative that we understand what constitutes a true microscopic morphological biomarker in terrestrial volcanic glass, and what alteration microtextures are abiotic in origin and simply 'look' biogenic to our eyes.

In the present study we highlight a rich diversity of microtextural corrosion features that occur in partially altered (palagonitized) basaltic glass pillow margins from Deep Sea Drilling Project (DSDP) Hole 418A, North Atlantic Ocean (Figs. 1-3). Although these various alteration microtextures look conspicuously like microbial trace fossils (e.g. microbial borings), we propose that they are all abiotic in origin, the result of preferential corrosion of radiation damage (alpha-recoil tracks and fission tracks) caused by radioactive decay of U and Th in the glass. Pressure solution fingering also seems to be an important compounding process in forming these complex networks of microscopic etch-tunnels at the glass-palagonite interface, caused by incremental increase of hydrostatic pressure (29 to 63 MPa) as the oceanic crust subsides under a deepening ocean with age. Features resulting from the abiotic (U-Th-Pb) radiogenic corrosion of basaltic glass by seawater appear to explain these and other putative 'tubular' and 'granular' microbial trace fossil microtextures, reported from a variety of environments including basaltic glass in the in situ oceanic crust, ophiolites, and greenstone belts dating back to ~3.5 Ga [1].

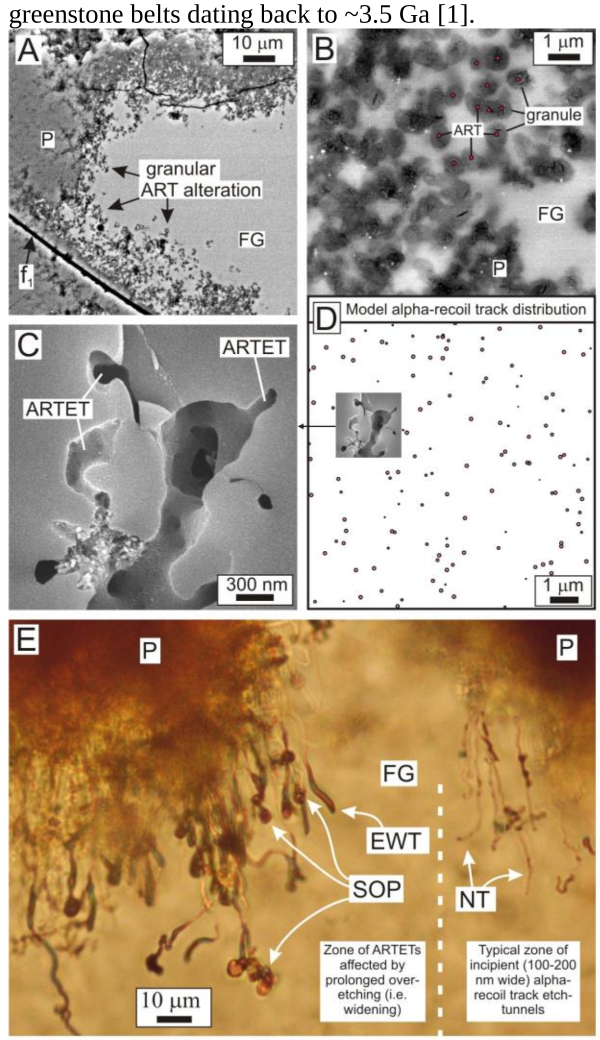

Fig. 1. A diverse suite of microtextures caused by abiotic corrosion of alpha-recoil track radiation damage in basaltic glass by seawater. **A**-**B**) Granular palagonite alteration caused by preferential palagonitization of alpha-recoil tracks (back-scattered electron images of a thin section). **C**) Alpha-recoil track etch-tunnels found at the glass-palagonite interface (secondary electron image of a freshly fractured surface). **D**) Calculated distribution of alpha-recoil tracks in DSDP-418A-75-3[120-123] basaltic glass (inset of **C** is shown at the same scale). Note the similarity in distribution of palagonite granules (**B**) with alpha-recoil tracks (**D**). **E**) Photomicrograph (uncrossed polars) of a thin section showing a diverse suite of etch-tunnel types related to incipient alpha-recoil track etch-tunnelling (right), including those which have been widened by prolonged over-etching (left). ART - alpha-recoil track; ARTET - alpha-recoil track etch-tunnel; EWT - elongate wide tunnels; f_1 - early fracture; FG - fresh basaltic glass; NT - nanotunnels; P - palagonite; SOP - string-of-pearls texture. (**A**-**B**) are from sample DSDP-418A-68-3[40-43]; (**C**-**E**) are from DSDP-418A-75-3[120-123].

U-Th-Pb Radiogenic Corrosion Microtextures: A comprehensive multidisciplinary study of two glassy pillow margins from DSDP 418A reveals the presence of several distinctive abiotic corrosion microtextures at the glass-palagonite interface, including granular palagonite alpha-recoil track ("ART") alteration (Figs. 1A-B), ART etch-tunnels (Fig. 1C), and a diversity of wider etch-tunnel types formed by prolonged over-etching of incipient alpha-recoil track etch-tunnels, including elongate wide tunnels and string-of-pearls texture (Fig. 1E). Numerical modeling of alpha-recoil track damage in DSDP 418A basaltic glass based on U and Th concentrations in fresh glass measured by ICP-MS, indicates that the 108 million year old glass is riddled with radiation damage in the form of ~120 nm wide alpha-recoil tracks (Fig. 1D), which suggest a genetic relationship with nanoscopic 'tubular' etch-tunnels and 'granular' palagonite at the glass-palagonite interface (Fig. 1). These observations call into question the biogenicity of so-called 'tubular' etch-tunnels and 'granular' palagonite observed in worldwide samples of basaltic glass [1, 6].

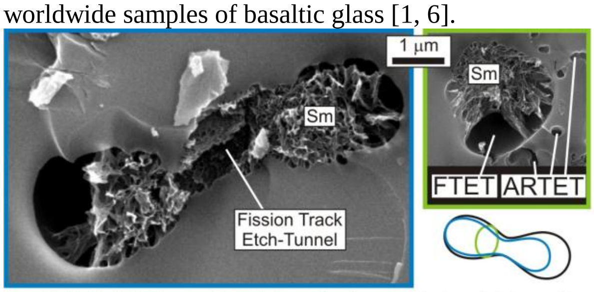

Fig. 2. Typical fission track etch-tunnels observed in the etch-tunnelling zone at the glass-palagonite interface in submarine basaltic glass. (secondary electron images of freshly fractured surface of sample DSDP-418A-75-3[120-123]). Typical ~8 µm long, peanut shape of FTETs shown at lower right. ARTET - alpha-recoil track etch-tunnel; FTET - fission track etch-tunnel; Sm - authigenic platy smectite.

Rare, larger (1-2 µm wide by ~8 µm long), peanut-shaped etch-chambers are also observed (Fig. 2) along with the smaller and more abundant nanoscopic tunnel variety (e.g. ARTETs in Figs. 1C, 2) at the glass-palagonite interface, and these larger etch-chambers are identified as naturally etched fission tracks (Fig. 2). These features might also be confused with microbial borings.

Naturally formed fission track etch-tunnels are always partially infilled with authigenic platy smectite showing dissolution/co-precipitation textures with glass (Fig. 2). The smaller, more abundant variety of nano-tunnels (alpha-recoil track etch-tunnels) are typically empty (Fig. 1C), although many contain authigenic imogolite $(OH)_3Al_2O_3SiOH$, which forms flexible 20 Å wide nanofilaments observable with high resolution scanning electron microscopy (Fig. 3) [7]. Imogolite filaments are identified as such by direct comparison with the known dimensions and morphology of typical imogolite filaments (superimposed blue/pink lines in Fig. 3), and considerations of the geological setting (imogolite is typically described as the initial weathering product of glassy volcanic ash [8]). It is important to note that these imogolite filaments (Fig. 3) might potentially be confused with the elongate filaments that can occur in desiccated exopolysaccharide mucus produced by bacteria in rocks [9], and they are also identical in size and form to filamentous strands of DNA imaged by atomic force microscopy [10] - biofilaments that coincidentally, are also exactly 20 Å wide.

Consequently, when evaluating corrosion microtextures in returned samples of Martian glass, nanofilaments within etch-tunnels should also be viewed as abiotic unless compelling evidence of biogenicity is presented.

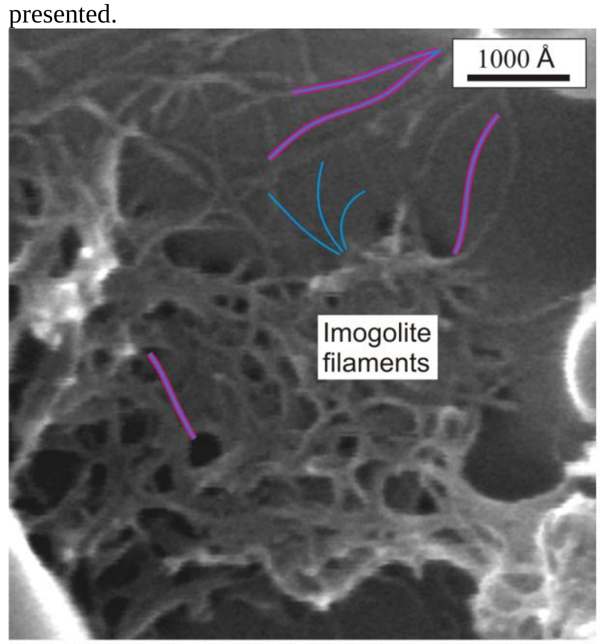

Fig. 3. High resolution secondary electron image of authigenic nanoscopic filaments of imogolite found within alpha-recoil track etch-tunnels in basaltic glass. Actual size of 20 Å wide hypothetical imogolite filaments shown in blue, with the 20 Å iridium coating shown in pink. Note similarity in size of hypothetical iridium coated imogolite with the natural nanofilaments. Sample DSDP-418A-75-3[120-123].

References: [1] Furnes, H., et al. (2007) *Precambrian Research*, *158*, 156-176. [2] French, J. E. and Muehlenbachs, K. (2009) *Journal of Nanomaterials*, *2009*, 1-14, doi:10.1155/2009/309208. [3] Izawa, M. R. M., et al. (2010) *Planetary and Space Science*, *58*, 583-591. [4] Allen, C. C., et al. (1981) *Icarus*, *45*, 347-369. [5] Squyres, S. W. (1989) *Icarus*, *79*, 229-288. [6] McLoughlin, N., et al. (2009) *Journal of the Geological Society of London*, *166*, 159-169. [7] Gustafsson, J. P. (2001) *Clays and Clay Minerals*, *49*, 73-80. [8] Dubroeucq, D., et al. (1998) *Geoderma 86*, 99-122. [9] Barker, W. W., et al. (1997) Cover photo of *Reviews in Mineralogy*, *35*. [10] Anselmetti, D. (2000) *Single Molecules*, *1*, 53-58.