IMAGING OF AN UNKNOWN ORGANISM ON ALH84001. A.Steele[†], D. T. Goddard[!], D. Stapleton[*], J. K.W. Toporski[*], G. Sharples[‡], D. D. Wynn-Williams[&] and D. S. McKay[†]. † Mail code SN. NASA, Lyndon. B. Johnson Space Centre, Houston. Texas, 77058, USA. * Department of Geology, University Of Portsmouth, Portsmouth. PO1 2DT. UK. ! BNFL,, Springfields Site, Preston. UK. ‡ School of Biomolecular Sciences, John Moores University, Liverpool, L3 3AF, UK. & British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET. UK.. (andrew.steele@easynet.co.uk)

Organic analysis of ALH84001 has revealed that contamination is present within this meteorite, but, all authors to this point have tried to explain this contamination through influx of organic species (PAHs and Amino acids) from the Antarctic ice (1,2). However, in both cases the amount of liquid water, which would have to pass through the meteorite in order to deposit such amounts of contaminants seems to be out of phase with the weathering patterns of the meteorite (4). The actual process of contamination is therefore poorly understood.

Our research has concentrated on Field Emission Gun Scanning Electron Microscopy (FEGSEM) and Atomic Force Microscopy (AFM) of chips of ALH84001. During our investigations, over 40 chips of the meteorite have been imaged by SEM, using a variety of coatings. For 38 of these chips, nothing that could be described as contamination has been found. However, on two of the chips (both ALH84001,198) carbon rich, morphologically biogenic structures in the 200 nm diameter range, have been observed (Figure 1). Further investigation of this structure by AFM revealed its 3-D characteristics and showed the presence of what appears to be aerial and substrate hyphae. Samples of Antarctic Cryptoendolithic communities, from several sites around Antarctica, were then imaged for a comparison and a morphologically similar organism was characterised. It is therefore our contention that the observed structures on ALH84001 are an Antarctic organism. Probably transmitted to the meteorite in the times when it has been exposed to the environment. Further investigations lead us to believe it is a terrestrial Actinomycete for the reasons listed below;

- The filaments are in the correct size range for substrate hyphae (0.2-0.3 μm in diameter) and are multi-branched, with characteristic V or Y shapes (Figure 1), showing both aerial and substrate forms.
- The hyphae in some cases have clavate endings and the spherical objects shown on the surface and protruding from the mycelium are probably developing aerial hyphae.
- Cord-like structures are formed by individual hyphae joining together which are typical of the hyphal aggregations formed by *Actinomycetes* under conditions of nitrogen limitation.
- The breakdown of the hyphal structures produces individual rods of about 2 μm.
- The organism is spread about the surface as distinct individual colonies, suggesting multiple origins from single colony forming units (spores).
- *Actinomycetes* have been found in both Siberian permafrost and in the Antarctic.
- The presence of similar structures in terrestrial cryptoendolithic communities and the correlation of these with known *Actinomycetes* suggest that the structures are almost certainly terrestrial in origin.
- Small swellings along some of the filaments have been seen which could be developing 'chlamydospores' although these structures were somewhat small.

The location of these forms in the outermost portion of the meteorite, within 1 mm of the fusion crust, along with the complete absence from nearly all of the chips lacking fusion crusts suggests that these organisms had a terrestrial source and were introduced before the rock was broken up.

A defence mechanism for organisms against freezing is the production of exopolymers (EPS) which help to maintain liquid water within the organisms, in what is usually a very xeric environment. Although this sample received no biological pre-treatment or fixing, the EPS is undamaged by the electron beam, which is surprising as normally the polymer disintegrates under these circumstances. This suggests that these structures could be somewhat mineralised

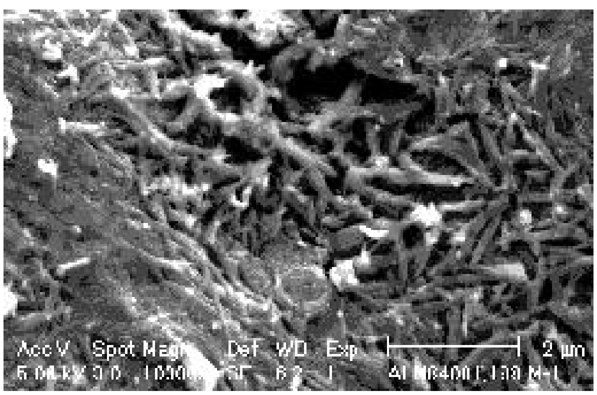
Furthermore the presence of this organism within cracks spreading into the meteorite and the fact that these communities secrete a large amount of EPS suggests that contamination could have spread to areas deep within the surface. This polymer would not be associated with cells and therefore extremely difficult to characterise. As only 2 chips of 40 have been shown to be contaminated by cells, this suggests a high degree of heterogeneity of contamination and therefore a low degree of predictability as to where else contamination occurs.

As to the possible metabolism of the organism, it has already been shown that ALH84001 contains a number of different organic molecules including amino acids and polyaromatic hydrocarbons. Some *Actinomycetes* have been shown to utilise carbon sources as diverse as petroleum, oil and phenol. Furthermore, Mautener and colleagues (1997), demonstrated that, among other organisms, an *Actinomycete*, *Nocardia* flourished using the organic compounds contained within Murchison meteorite.

One interesting point to mention is that, *Actinomyces* are heterotrophic and require a carbon source for nutrition, and therefore an exposed meteorite is a haven for windblown spores. Therefore only the spores will input light carbon into the meteorite, any developing organism would utilise the organics around it and therefore presumably this organism is partly synthesised out of Martian organic material. So although analysis of Amino Acids, PAH's and carbon isotopes have been interpreted as contamination all these techniques failed to identify an organism composed of Martian organic material.

The issues surrounding possible life in meteorites have all suffered from the cry of contamination and then the research has stopped and little attempt made to characterise the source of contaminants in a systematic way. However, with Astrobiology a reality, and a growing understanding of the difficulties faced to detect life, it is contaminated meteorites that could provide the best tool to aid in the search for life elsewhere within the solar system.

Figure1. An SEM image of the organism contaminating ALH84001.



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Acknowledgements

BNFL, NRC, G. Morton, M. Grady

Figure 2. A higher Magnification image of the organism (bar – 500nm).

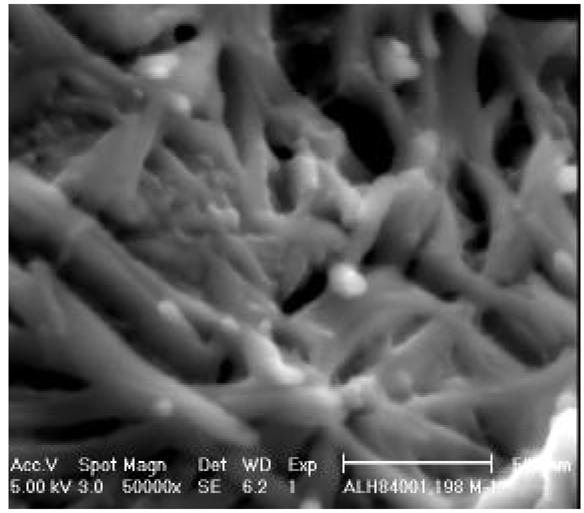

Figure 3. A 3-D AFM image showing aerial hyphae, the lighter colours are higher than the darker (size-2µm).

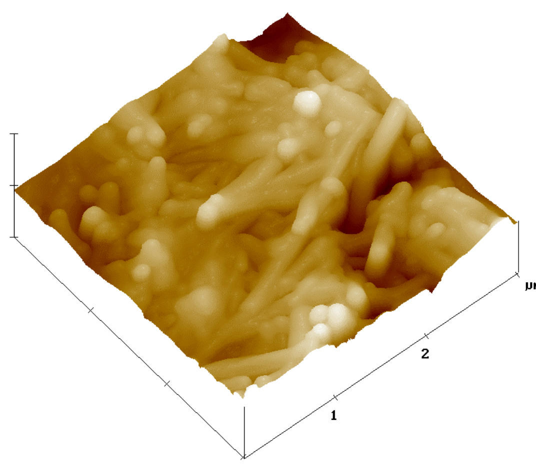

Figure 4.(a) An SEM image of structures on ALH84001 (x20,000). (b) An SEM image of a probable *Actinomycete* from an Antarctic cryptoendolithic community (x30,000).