ENDOLITHIC COLONIZATION OF FLUID INCLUSION TRAILS IN MINERAL GRAINS. J. Parnell[1], M.Baron[1], C.S. Cockell[2], [1]Dept. of Geology, University of Aberdeen, Aberdeen AB24 3UE, U.K., (J.Parnell@abdn.ac.uk), [2] Open University, Milton Keynes MK6 7AA, U.K.

Endoliths in sandstones: Many scenarios for the colonization of planetary surfaces by microbial life involve endoliths [1, 2]. The need to avoid the damaging effects of ultraviolet radiation makes colonization of the immediate sub-surface desirable, particularly at an early stage of evolution before screening pigments have been developed [3, 4]. Minimal (millimetre- to sub-millimetre-scale) penetration of the surface may filter ultraviolet radiation but admit enough light for photosynthesis. Endolithic borings in minerals are found through the terrestrial geological record at least back to the Proterozoic [5], and are an important potential trace fossil that may be sought in extraterrestrial materials [6]. Endolithic communities in sandstones have been studied in detail, particularly in the quartzose Beacon Sandstone in the dry valleys of southern Victoria Land, Antarctica [1, 2, 7], where they inhabit a hostile (cold, dry) terrestrial environment. These rocks also contain permineralized fossil endoliths [1]. Cyanobacteria inbetween sand grains in the Beacon Sandstone can photosynthesize because the quartz grains are highly translucent. The present study records that some of the microbial mass colonizes microfractures in the quartz grains, i.e. it is intragranular as well as intergranular.

Fluid inclusions: Fluid inclusions are micron-scale volumes of fluid trapped during mineral growth. In most cases the fluids represent the ambient aqueous fluid present during growth, although entrapment of oils and gases is also possible. Aqueous fluids are not pure water, but contain dissolved salts: most aqueous inclusions are more saline than sea water, in some cases substantially so. Some fluid inclusions are formed during mineral deposition; others are formed during healing of microfractures. Microfractures are ubiquitous in quartz grains in sandstones, although commonly only evident under cathodoluminescence [8] because they are very rapidly healed by new quartz growth. Microfractures are even developed in incompletely consolidated sands [9], so that sand that has only experienced shallow burial can be microfractured. On Earth, much sand has experienced multiple cycles of deposition, burial, uplift and erosion, and contains multiple sets of microfractures. On planetary surfaces that have been subject to repeated, widespread impact events, microfracturing should be more intense: planar deformation features (pdfs) in quartz sand grains are an expression of this [10]. The microfractures are marked by linear trails of fluid inclusions, and polished surfaces of grains show trails of pits representing the exhumed inclusions (Fig. 1).

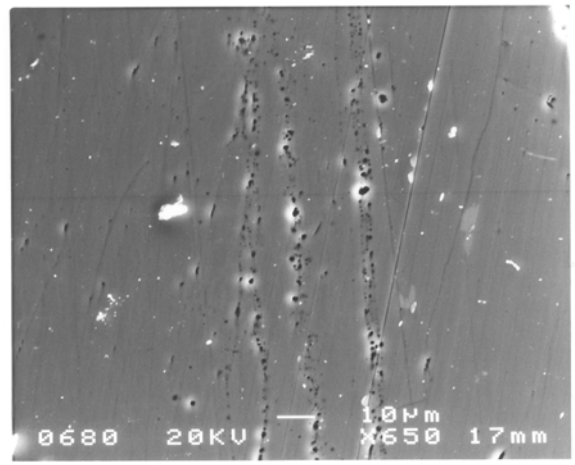

Fig. 1. Polished surface of quartz grain showing linear trails of pits representing exhumed fluid inclusions.

Endolithic colonization of fluid inclusions: Samples of Beacon Sandstone examined in polished thin section show that the cyanobacteria extend from the intergranular environment into the interior of the sand grains (Fig. 2). In particular they colonize the trails of aqueous fluid inclusions. As the inclusion trails represent healed microfractures, these are the mechnically weakest planes in the grains, as quartz does not possess a cleavage, so are the most likely sites for endolithic penetration (consider, as an analogue, plants penetrating fractured paving slabs). There is also some limited colonization of fluid inclusions concentrated at the boundaries between detrital grains and quartz overgrowths (cement).

The fluid inclusion trails also include decrepitated (ruptured, emptied of fluid) fluid inclusions, which can appear dark and, feasibly, could be confused with organic matter. However they show negative crystal shapes, and can be distinguished from the irregular shapes of the microbial matter.

In this case, the endoliths inhabit pre-existing inclusions. The reverse relationship has also been recorded elsewhere, in which endolithic microborings have been transformed into fluid inclusions [6], and up to 85% of the boring length has been preserved. It is important to distinguish these two scenarios, as the

inferred age of the endoliths is very different (syn-depositional vs. later colonization of exhumed rock). However the alternatives emphasize the value of studying fluid inclusions for an endolithic record, and for astrobiology in general [11].

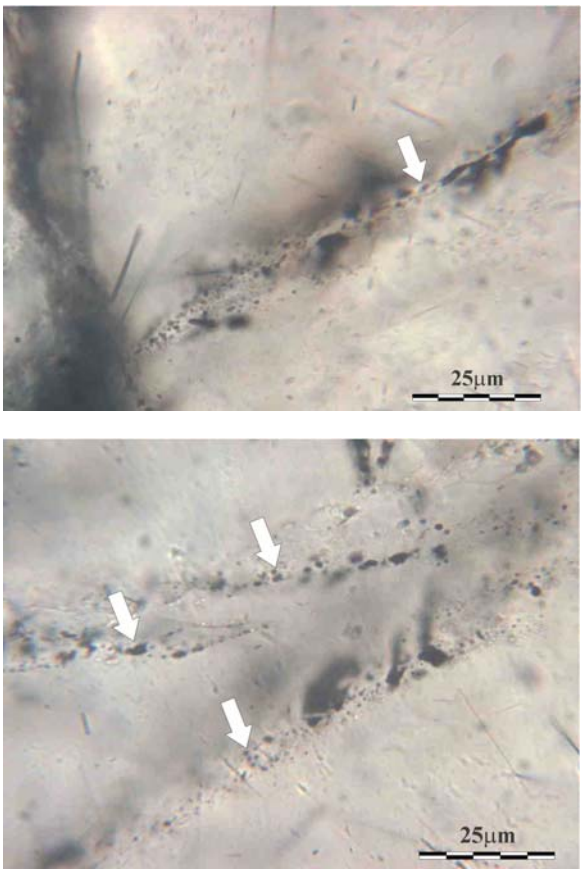

Fig. 2. Planes of fluid inclusion trails, colonized by cyanobacteria (black, arrowed). Beacon Sandstone, Antarctica.

Benefits from colonization of inclusions: An advantage of colonization of the microfractures in quartz sand is that they allow additional protection from erosion and desiccation.

Access to the contents of the inclusions provides water, and some nutrients dissolved in the water. The water itself would almost certainly be available regardless through condensation, but there is a possible consequence of the dissolved salts. A salt-rich brine may have a eutectic point at –21 ºC (for sodium chloride) and as low as –50 ºC, substantially increasing the proportion of the year that the enclosed water is liquid. In environments where low temperature is combined with low precipitation (exemplified in Antarctic, and potentially on other planets such as Mars) it could extend the period of annual activity. A further advantage applicable to low-temperature environments is that diurnal freeze-thaw cycles might be mitigated, reducing freeze-thaw stress to the microbes.

The dissolved salts are probably the only nutrients available within the quartz grains, as quartz contains few trace elements and is difficult to dissolve.

Colonization in quartz: Colonization in quartz is possible because of the high degree of light penetration of quartz grains [12, 13]. Although the endoliths in the Beacon Sandstone have been widely suggested as potential analogues for microbial colonization on the Martian surface [1, 2, 7], the sand on Mars is largely dominated by volcanogenic minerals, including olivine, feldspar and pyroxenes [14]. These minerals are either opaque or have low translucency, so the potential for colonization of inclusions is low. However, on extrasolar planets with plate tectonics and buoyant granite formation, which is the main origin of abundant quartz in the crust [15], the intragranular setting for endoliths is feasible. Other minerals that can have high translucency *could* occur on Mars, such as sulphates, which are candidates for high-albedo dune sands [16].

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