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RESEARCH

Allen Hills and Schopf-like putative fossilized bacteria seen in a new type of carbonaceous meteorite

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Fossilized "wormlike forms" were found in a putative new type of carbonaceous meteorite which recently fell on Polonnaruwa, Sri Lanka. The similarities between these forms and structures described by Schopf, as the earliest fossilized life forms on Earth and claimed fossilized bacteria in the Allen Hills meteorite are discussed.

Introduction

Worm-like forms (WLFs) claimed to be putative fossilized bacteria have been seen in both meteorites and rock samples from ancient Earth (Schopf & Packker, 1987). The WLF seen in the Allen Hills (McKay *et al.* 1996, Trieman, 1999) meteorite is the most well known of these, and is probably the single most extensively studied geological sample in science. Initially, the worm-like from (WLF) seen in this meteorite was definitely ascribed to being a fossilized nonobacterium when it was first reported in 200. During a televised press release given the then President of the United States, Bill Clinton informed the world that it provided clear evidence for the one time existence of microbial life on Mars. Since this announcement, there has been considerable debate on the question of whether the Allen Hills WLF is a fossil bacterium or merely a mineral artefact (Trieman, 1999), a debate which is still continues. Similar WLFs have been reported being seen in a lunar meteorite (Dalton, 2002, Sears & Kral, 1998, Van Zuilen *et al.*, 2002), in siliceous sinter deposits from Nevada (Lynne *et al.*, 2008) and by Schopf and colleagues as claimed examples of the first ever fossilized Earth life forms. Again, after general initial acceptance, this last mentioned claim has been countered by suggestions that, rather than being fossilized bacteria, Schopf forms are mineralised artefacts (Brazier *et al.*, 2002, Dalton, 2002.

During a recent scanning electron microscope study, WLFs were seen in what has been claimed is new type of carbonaceous meteorite which fell in Polonnaruwa, Sri Lanka in 2013 (Wickramasinghe *et al.* a, b, c). Here, we describe these WLFs and discuss their morphology and location within the claimed-meteorite in relation to the reports of similar forms being seen in both meteoritic and Earth-derived samples.

Materials and Methods

A portion of the Polonnaruwa meteorite was sectioned and then examined under the scanning electron microscope. Using a hot plate the sample was fixed to a polymer stub using wax which was then staged in the wire saw setup (Well 3241 Wire Saw). The wire saw uses a subtle slope to encourage the wire to gently press up against the front face of the staged sample and the gradient of this slope can be altered so as to increase or decrease the force which the wire places upon the sample. The wire used was approximately 0.17mm thick and coated with very fine diamond particles of mode size, circa 30 microns; when activated, the wire makes slow and delicate progress through the sample. After the sample was cut, one half was placed in a staging chamber with the face to be analysed flush to the base. Konductomet phenolic mounting compound (20–3375–016) was used to stage the sample. Surface grinding and then polishing of the sample surface is usually undertaken at this point however, in this case only an instantaneous grinding process was conducted. This was done to remove any build up that might be present on top of the surface to be studied and to ensure that only fresh sample material was exposed. The coarseness of pile used was 120 microns using a Bueler Automet 250 for 5 seconds with a touch force of 20N, a head speed of 50 RPM and a Platen speen of 140 RPM. Due to the relatively low conductive nature of the samples and in order to minimise charging effects and optimise image acquisition the samples was coated in gold using an Emscope gold sputter coater. The sample was coated for deposition duration of 1 minute at 15 milliamps. Before being introduced into the SEM (JEOL 6500F) the sample was placed in a vacuum chamber overnight to remove any remaining moisture.

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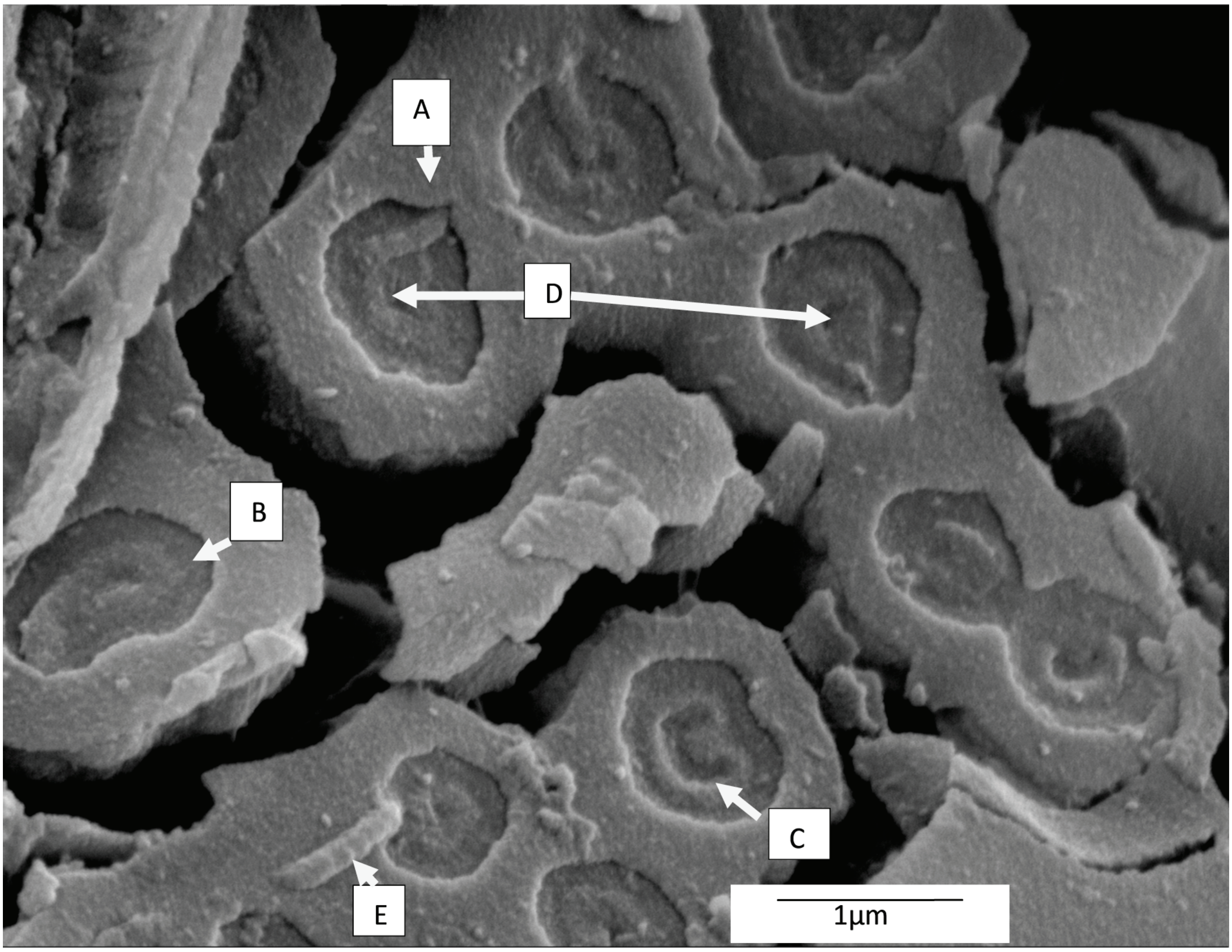

Fig. 1: A cross-section of the Polonnaruwa meteorite sample viewed under the scanning electron microscope

Results and Discussion

A cross section view of a sample of the Polonnaruwa meteorite sample is shown in **Fig. 1**. The inorganic background (A) is seen to be made up of round and ovoid chambers inset into the inorganic matrix (B) of the claimed meteorite. Within these chambers can be seen comma-shaped cavities one of which appears to be empty (C), the remainder containing a single WLF (D). An individual WLF is clearly seen in the lower middle region of the photograph (E). This form is approximately 0.6 micron in length and is divided into 0.1 micron sections. It is not clear whether this is a single structure or is made of smaller sections. This free WLF is of as size that would have allowed it to fit into one of comma-shaped cavities (C), from where it may have originated. The WLF seen inside the chambers (D) are morphologically similar to the free form, but are somewhat longer.

The individual free WLF and the others seen in **Fig. 1** are essentially identical to the Allen Hills worm-like form which it is claimed is a fossilized bacterium. The main difference between the WLFs seen from these two sources is that P- worm-like forms are around 1micron in length (**Figs. 1** and **2**) (and therefore of a size typical of many modern Earth dwelling bacteria), while the Allen Hills form is 100nm in length and is considered to be a nanobacterium. Claims that the Allen Hills WLF is a fossilized bacterium have been criticised on the basis that it is too small to have contained all the genetic and metabolic equipment necessary to sustain life (Benner, 1999), a criticism which does not apply to the WLFs seen here which are similar in size to modern bacteria.

As was mentioned above there is considerable debate as to whether or not both the Allen Hills and Schopf forms represent fossilized bacteria, or are mineralized artefacts. We are similarly unable to de prove that the WLFs seen in the Polonnaruwa meteorite are fossilized bacteria or mineral artefacts, and it is unlikely considering the decades of study that have been devoted to the Allen Hills WLF that (considering our relatively limited resources) we are ever likely to distinguish unequivocally between these two possibilities. We therefore present the images given here and claim only that the forms seen in the Polonnaruwa meteorite are identical to those claimed by others to be fossilized meteoritic bacteria and the earliest suggested fossil bacterium and life forms, in general, found on Earth. A contribution to the resolution of this issue is however provided by **Fig. 1** in that it a providence for the source of WLFs (i.e. similar to the Allen Hills and Schopf forms) in the meteoritic chambers and comma-shaped grooves seen here. Figure 1 shows that we have cut across a serious of meteoritic chambers which occur together in clumps and which can be regarded as being

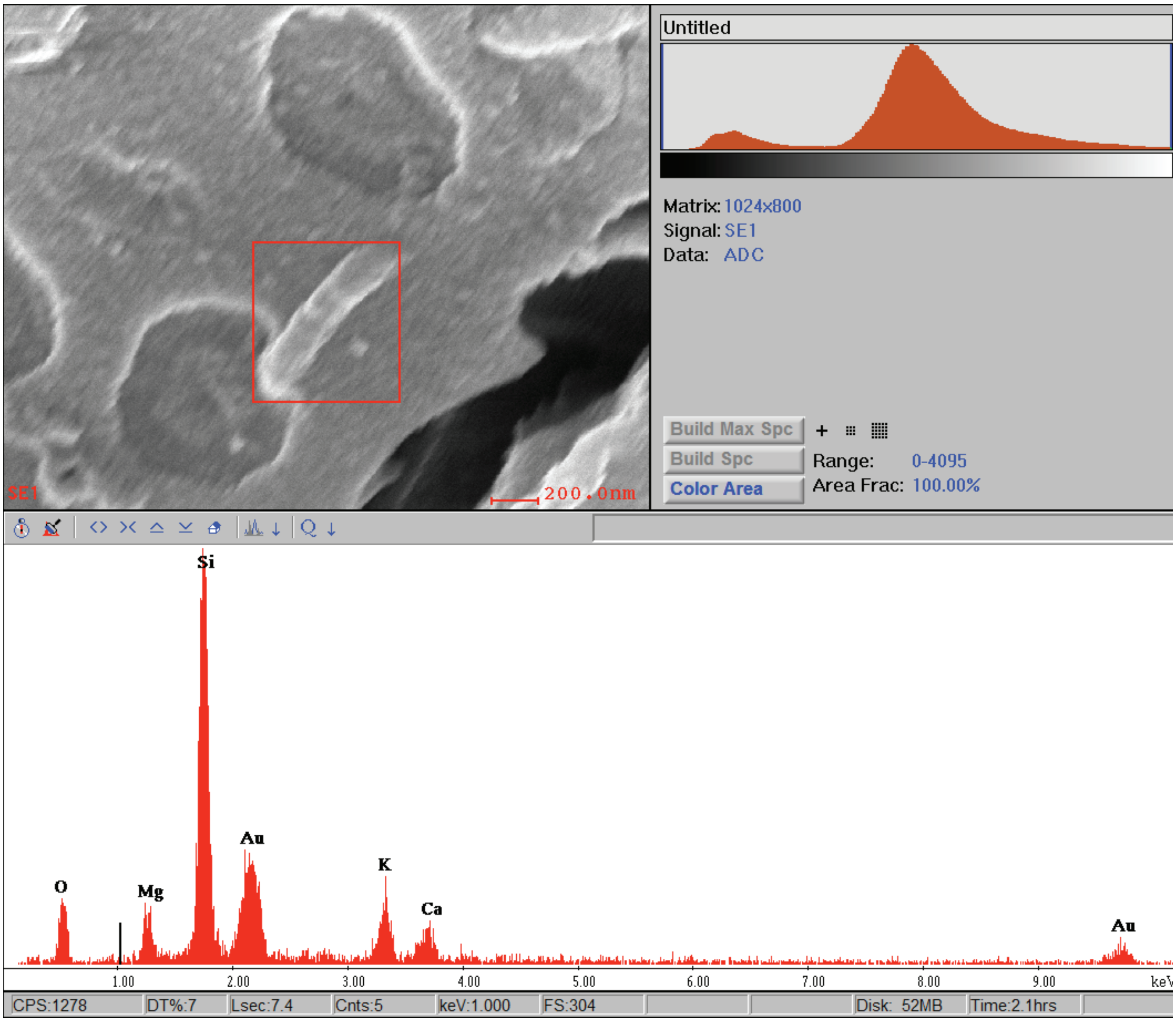

Fig. 2: EDX analysis of a single WLF

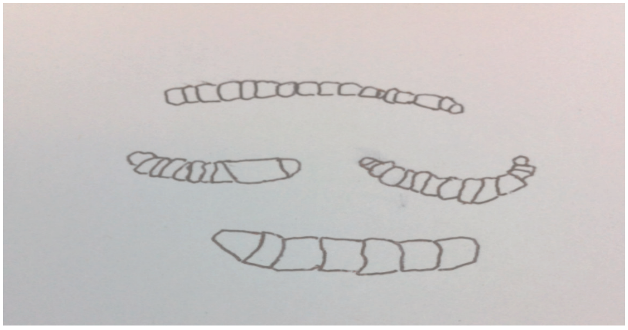

Fig. 3: Tracing of Wormlike forms seen in topmost figure, the Allan Hills meteorite, middle two seen in ancient rocks by Schopf and co-workers, and lower figure from the PS. (Not drawn to scale).

micro-stromatolites. Within these chambers are seen comma like depressions in which are housed putative fossil bacteria which are similar to the Allen Hills and Schopf forms. Analysis, using EDX, of a group of WLFS shows that the WLF (E), like the surrounding matrix consists of primarily of silicon with smaller amounts of calcium, oxygen and potassium (**Fig. 2**), showing that it not a living organism, but a putative fossil bacterium.

Wickramasinghe *et al.* 2003; Wallis *et al.*, 2003) have provided evidence that the Polonnaruwa sample (PS) is a new type of meteorite. Wickramasinghe *et al.*, 2003 (a, b, c); who also report the presence of fossilized diatoms in the surface of the Polonnaruwa meteorite (Wickramasinghe *et al.* 2013d).

The WLFs seen in the Polonnaruwa meteorite are also essentially identical to Schopf fossils (**Fig. 3**), which, it has been claimed, represent the earliest known terrestrial fossils, both in relation to bacteria and life in general. It worth noting however, that the reported WLFs differ considerably in size from the nanobacteria –like forms of in the Allen Hill meteorite to WLFs of size around one micron and larger. If these are indeed fossilized bacteria, then this size difference may reflect different ages of a single organism or the fossilization of a range of organisms of similar morphology.

Despite the controversy associated with the WLFs seen here, we conjecture that the forms seen in **Fig. 1** are present in a new species of carbonaceous meteorite and are similar to modern *Cyanobacteria* as well as to the Allen Hills and Schopf fossil forms. For the moment, we have to be content to provide the evidence given about and tentatively claim that we have found WLFs in a new form of carbonaceous meteorite (the origin of which we do not presently know) which are putative, normal sized, fossilized bacteria.

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