"LIFE IN CI CHONDRITES": NOT LIFE, NOT EXTRATERRESTRIAL, NOT EVEN INTERESTING.

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Summary: A recent article in an online journal [1] claims to find fossils of native, extraterrestrial microbes in CI meteorites permineralized by sulfates. An alternative explanation is presented here, namely that the filamentous forms observed in [1] are well-documented, common CI sulfate minerals in filamentous form. The primary rationale presented in [1] is the author's perception that filamentous sulfates within the meteorite share morphological similarity with terrestrial microbes. Furthermore, the composition of these filaments is described as being unlike any known mineral. However, Raman spectroscopy shows that CI sulfate filaments are common sulfate minerals in accordance with existing literature [2-6]. These sulfates can be observed to grow in a matter of minutes or hours on freshly-exposed CI meteorite surfaces as ambient humidity drives the hydration of meteoritic sulfides [2]. While contamination by terrestrial microbes can provide a plausible explanation for filamentous morphologies when identified as biological by an expert, in this case the most plausible explanation is that the "microbes" are in fact sulfate filaments previously documented in literature.

Discussion: The claim that extraterrestrial microbe fossils are found in CI meteorites was made in Hoover (2011) [1]. The author describes filamentous structures on "internal surfaces" of Ivuna and Orgueil CI1 samples using field-emission scanning electron microscopy (FESEM). Hoover describes biomorphological features of these filaments and proceeds to claim that they are fossilized based on the fact that no nitrogen is detectable by energy diffraction spectroscopy (EDS) measurement. The lack of nitrogen is also used to state that the forms are not modern contaminating microbes. Data presented in Hoover (2011) consistently show that EDS measurements of the filaments include Mg, S, O, Si, ±C ([1], Figures 1, 2, 3). The interpretation offered is that the filaments are fossils formed by sulfate mineralization with remnant carbonaceous species. No interpretation is offered for the presence of silicon other than the claim that these filaments are "…not consistent with known species of minerals." The author concludes that these filamentous morphologies are the fossilized remnants of microbes native to the CI parent body.

The following features of CI filamentous morphologices are relevant to this discussion:

Sulfate filaments in CIs: Sulfate minerals have been noted previously in the CI meteorites as early as 1961 [3]. While debate has flourished as to their origin (terrestrial or parent body, or both) [2-6], the presence of sulfate veins and filaments is well supported by available literature. Notably, Gounelle and Zolensky (2001) [2] note that sulfates are found as alteration minerals in "all CI chondrites", both as veins and surficial decoration. This paper shows sulfate filaments growing from the surface of a prepared CI thin section (Figure 1 in [2]), indicating that these filaments appear on very short time scales even with careful sample handling. They conclude that sulfates to include filaments form via terrestrial alteration in contact with humidity, "…filling the many open spaces offered to them by the very porous rock." Others have also noted that sulfate filaments can grow rapidly on freshly-fractured surfac-

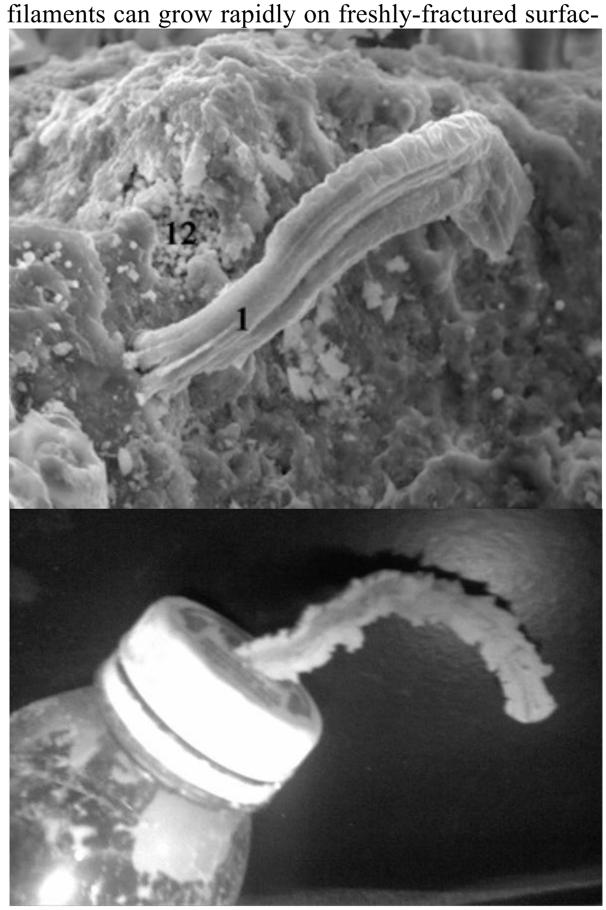

Figure 1: Extruded morphology of "microbes". Top: Image adapted from Figure 2a of Hoover (2011) showing purported extraterrestrial microbe. Bottom: Image of clay extruded from a homemade extruder showing similar morphology. "Microbes" are extruded from the porous CI matrix as sulfides alter to sulfates under the influence of ambient humidity. Image credit: Lauren Vork, www.ehow.com

es of CI meteorites [M. Fries, unpublished data, and C. Smith, pers. comm.).

To summarize, sulfates form readily in CI meteorites via oxidation/hydration of CI sulfides by ambient moisture. The filamentous morphology of some CI sulfates occurs by extrusion of the growing sulfate through CI matrix porosity (Figure 1). Therefore, their morphology can be altered by varying the meteorite's exposure to atmospheric humidity as the filaments grow. Simply moving a sample in and out of a desiccator cabinet, for example, could produce the lobate, "pinched" or other morphologies identified as biogenetic in Hoover (2011). Filaments presented in [1], however, are predominently invariant in cross-section, consistent with extruded material produced under relatively invariant conditions ([1], Fig. 2a, 3a).

Mineralogy of Sulfate Filaments: Previous work has identified CI sulfates as a mixture to include hexahydrite ($MgSO_4$•$6H_2O$), epsomite ($MgSO_4$•$7H_2O$) and gypsum ($CaSO_4$•$2H_20$) (see [2] Table 2 for a list). A Tonk CI1 filament observed as identical in morphology to those presented in Hoover (2011) was recently identified as gypsum via Raman spectroscopy (Figure 2). The salient point is that sulfate filaments in CI chondrites are both easily identified and readily represented in available literature. This conclusion is readily supported by data in Hoover (2011) itself, which includes EDS data of multiple filaments (see above). The compositions listed are readily explained as Mg sulfates (Mg, S, O) with the EDS interaction volume extending into the CI matrix behind the filaments to include a contribution of carbon and silicon. This interpretation also supports the absence of nitrogen without the need to invoke an alien biosphere somehow habituating the cold, irradiated, atmosphere-free CI parent body.

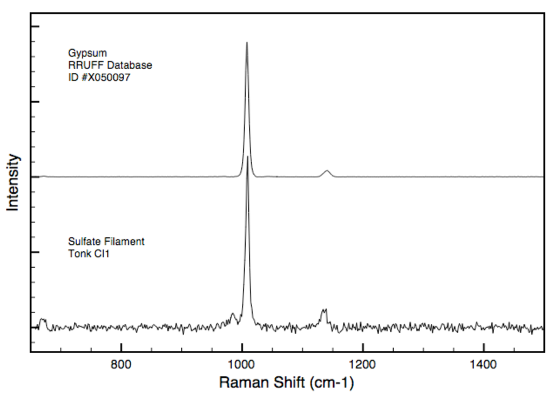

Figure 2: Raman spectrum of a Tonk CI1 filament (Bottom) identical in appearance to those in Hoover (2011) showing a mineralogical match to gypsum (Top).

Conclusions: The Hoover (2011) paper arrives at the conclusion that filaments in CI meteorites are biological in origin. Filaments in CI meteorites are better explained by an abiological origin.

Morphology: Small-scale variations in filament morphology that are identified as biological in origin are more readily explained as variations in the extrusion rate of sulfate. Changes in the humidty experienced by the rock could produce the various forms noted. This is a robust, simple explanation that does not require invoking the existence of an entire biosphere on a hostile parent body.

Composition: Hoover (2011) claims that the mineralogy of the filaments represents an unknown mineral species. This argument is presumably based on the EDS composition of Mg, S, O, Si, ±C. Raman spectroscopic data (and available literature) show that CI filaments are a mixture of common sulfates. EDS data presented by Hoover (2011) are sufficient to identify the filaments as Mg-sulfates with the addition of Si and C from the CI matrix in the EDS interaction volume behind the filaments.

The claim is made that the filaments are fossilized microbes based on the lack of nitrogen [1]. This argument requires that the filaments are microbial, and then because the "microbes" contain no nitrogen they must be ancient and have lost their nitrogen through alteration of their organic matter to a devolatilized kerogen. It is a far simpler explanation that CI sulfate filaments are simply aqueous alteration products of CI sulfides as has been reported repeatedly in the available literature. With this explanation in place, no explanation for the lack of nitrogen is logically required.

Overall: The hypothesis that filaments in CI meteorites are biogenic in origin is not supported by the data presented in Hoover (2011). Far and away the simplest and most scientifically plausible explanation is that filamentous sulfates in CI meteorites are aqueous alteration products, and that minor variations in their morphology are due to slight changes in ambient humidity during growth. Their composition is straightforward, as is their formation mechanism.

References: [1] Hoover R., Internet resource, http://journalofcosmology.com/Life100.html (2011) No longer available as of 07 Nov 2011. [2] Gounelle M., Zolensky M., *MAPS* **36** (2001) 1321-1329. [3] DuFresne E. and Anders E., *Geo. et Cosmo. Acta* **26** (1961) 200-208. [4] Fredricksson K., Kerridge J., *Meteoritics* **23** (1988) 35-44. [5] Tomeoka K., Buseck P., *Geo. et Cosmo. Acta* **52** (1988) 1627-1640. [6] Airieau S. *et al*, *Geo. et Cosmo. Acta* **69** (2005) 4166-4171.