SIMILARITY OF NANOMETER-SIZE SPHEROIDS IN MARTIAN METEORITE DHOFAR 019 & ENCLOSING CALICHE SOIL: SOUTH-POLE VS. DESERT FORMS.

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Summary: Similar to other Martian meteorites found in hot deserts [1,2], nanometer-scale ovoids found within the caliche on the outside of Dhofar 019 appear to be identical in size and morphology to those in the meteorite proper. Also, there are only minor differences between the nano-scale ovoid morphologies in ALH 84001 [3,4] and those in Dhofar 019. No evidence exists for a Martian origin for the nanometer spheroids in this small sample of Dhofar 019.

Introduction: The presence of nano-fossil-like forms in Martian meteorite ALH 84001 as possible evidence for life on Mars [4] focused attention on such morphologies in samples from both meteorites and Earth. Two locales with contrasting climates have been the source of several SNC meteorites: the Antarctic blue ice and the desert regions of northern Africa and east of the Red Sea. In January, 2000, a new Martian meteorite [5,6] was found partially embedded in the desert caliche soil of Oman. This presents us with the opportunity of contrasting possible nano-fossil morphologies from the extreme cold and hot regions of Earth.

Description: Dhofar 019 [5,6] is classified as a basaltic shergottite consisting of subhedral grains of pyroxene (64 vol%), mostly pigeonite commonly rimmed with augite; feldspar converted to maskelynite (25 vol.%); and xenocrysts of olivine (9.5 vol.%), with accessory Ti-chromite and ilmenite. Shock features include fracturing and mosaicism, maskelynite, and rare impact-melt pockets. Secondary terrestrial phases are calcite, gypsum, smectite(?), celestite, and Fe hydroxides. Calcite is present mainly as a caliche coating on the lower part of the meteorite, but also as veins cross-cutting the meteorite. There are numerous zoned smectite-calcite-gypsum "orangettes", morphologically similar to those in ALH84001 [4,5].

Methodology: The minute fragment used for this present study was 0.5x2x2 mm and directly attached to the caliche crust on the outer portion of the meteorite. Thus, we observed only the outer 0.5 mm of the meteorite, the part that is most likely to have been affected by terrestrial processes. In order to avoid introduction of sawing artifacts, a small (0.5 mm) piece was broken off the corner of the meteorite; most of the following discussion concerns this freshly fractured area. The sample was etched for 1 minute in 1% HCl, to exhume bodies in the carbonate, and Au-coated for only 30 sec, to prevent formation of coating artifacts. The sample was examined by SEM at up to 50,000 X using 30 Kv, a very close working distance, and a broad, dim spot size.

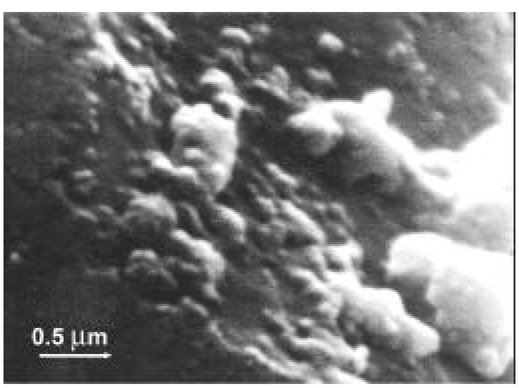

Figure 1. Caliche soil on exterior of Dhofar 019 SNC meteorite. Abundant 60-160 nm ovoids, possibly nannobacteria cells .

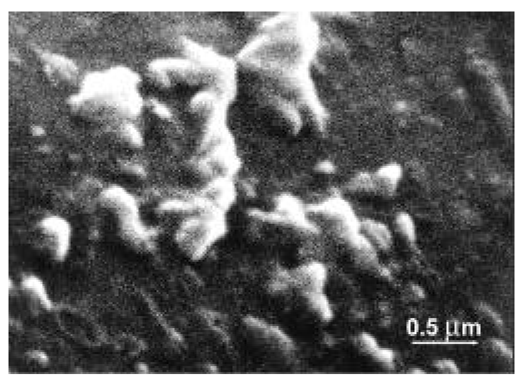

Figure 2. Inside Dhofar 019 about 0.1 mm from contact with caliche. Abundant 70-200 nm, probably nanno-bacteria introduced from the caliche.

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Results: The nanometer-scale ovoids found within the caliche are identical in size and morphology to those in the contaminated outer portions of meteorite itself (Figs 1-2). There is no evidence for a Martian origin for the nanometer spheroids in this small sample of Dhofar 019. The Oman caliche, similar to other Earthly samples, commonly contains 50-250 nm spheroids and ovoids, interpreted as fossils of soil nanobacteria [7]. (However, there exists reasonable uncertainty that these morphologies may not be nanofossils; therefore, herein we will refer to them as "nanoforms.") The meteorite surface that was in contact with the caliche before it was etched away, is covered with abundant similar morphologies in the 50-200 nm size range, possibly feeding on the abundant heavenly-provided source of fresh Fe (Fig. 3). These nano-forms are also abundant along micron-scale cracks that extend throughout the 0.5 mm thickness of our sample. Newly fractured mineral surfaces are clean (Fig. 4). There is no visible distinction either in size, shape, or 'colonial affinities' between the nannobacteria-like forms in the caliche and those within the meteorite itself.

Only minor differences exist between the nanobacterially-altered pyroxenes in ALH 84001 [3] and those in Dhofar 019. 1) A population of smaller nanoforms (50-100 nm) is more pervasive and abundant in ALH 84001; in both meteorites, they are concentrated in fractures, with similar morphologies, from spheres through ellipsoids to sausages. 2) A population of longer, bacilliform-like bodies (300 nm X 100 nm) is rather common in ALH 84001, but has not been found in Dhofar 019. 3) Evidence of pyroxene etching by possible biologic processes is rather common in ALH 84001, but has not been found in our piece of Dhofar 019. These facts suggest that ALH 84001 underwent a longer and/or more intense period of weathering (whether on Mars or Earth) than Dhofar 019.

The critical point in assessing whether such alterations and nannobacteria-like morphologies are truly Martian or Earthly should be addressed by making dissections of the rocks from rim to center, evaluating the presence/absence of nanoforms and weathering products on both Dhofar 019 and ALH 84001. Similar comparative studies need to be made on terrestrial igneous rocks (i.e., clearly not of Martian origin) indigeneous to Oman and Antarctia. If these nanometer-scale ovoids are really biologic organisms of some sort, and if they are heavily contaminating meteorites (and indigenous rocks) in such far-fetched places as Antarctic ice and deserts like Oman, they deserve focussed study by professional microbiologists, as they may represent a huge undiscovered biomass on Earth.

References: [1] Gillet et al. (2000) *EPSL*; [2] Kearsley et al. (2000) *GSA Abstr*; [3] Folk & Taylor (2000) *GSA Abstr*; [4] McKay et al. (1996), *Science*; [5] Taylor et al. (2000) *Met. Soc. Mtg.*; [6] Shearer et al. (2000) *GSA Abstr;* [7] Folk (1999) *Sed. Geol.*.

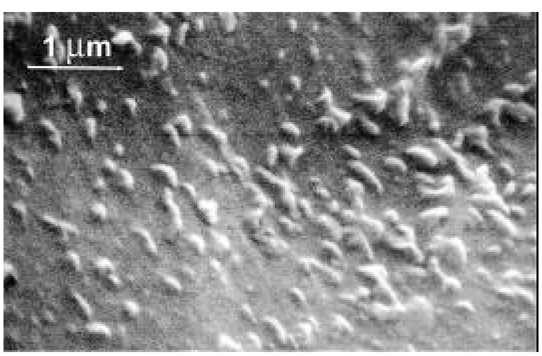

Figure 3. "Wormfield" on a fracture in Dhofar 019. Crowds of 70-150 nm balls and sausage-shaped forms.

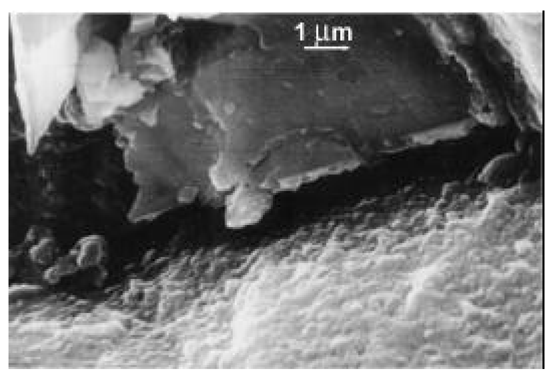

Figure 4. Dhofar 019 meteorite with a horde of 120-240 nm nannobacterial (?) cells invading along an old fracture. Fresh new fracture is clean.