**Evolution of Meteorite Chip Samples During Typical Storage Methods: A Seven and A Half Year ALH 84001 Case Study.** Craig S. Schwandt Lockheed Martin, 2400 Nasa Parkway, C23, Houston, TX 77058, USA craig.s.schwandt1@jsc.nasa.gov

**Introduction:** A reasonable amount of effort and expense is utilized in the collection and curation of meteorite samples as evident from protocols and practices used at Johnson Space Center (JSC) for example. Visiting the JSC curation web-site (http://curator.jsc.nasa.gov/curator/antmet/antmet.htm) it is evident that great care is used for meteorite storage and specimen division. An inference is that these efforts are undertaken in order that the meteorites alter as little as possible. These efforts are a “no-brainer”. However, questions arise such as, do most meteoriticists utilize dry nitrogen storage cabinets (as a minimum attempt at sample preservation), or freezers? Should everyone? How is the outcome of research changed due to undetected or unidentified alteration during non-standardized uncontrolled storage? These are not new questions, but examination of an ALH84001, 278 sample chip intermittently over the course of the past seven years suggests that significant alteration transpires much quicker than anticipated or acknowledged.

**Case Study**: Gounelle and Zolensky [1,2] outlined how the meteorite Orgueil, which fell in 1864 was not reported to contain white sulfate veins until 1961, a time span of 97 years. They concluded, “This <<historical study>> points out that the mineralogy of extraterrestrial matter can be affected to a great extent by the sojourn of meteorites on our volatile-rich planet... Although remobilization of sulfates in veins may not change the bulk composition of CI1 chondrites, some other modifications taking place on Earth may generate chemical changes, at least for the most mobile elements.”

Current observations of an allocation chip (,278) of ALH 84001 reveal remarkable element mobility and growth of alteration minerals occurring within five years of allocation. The chip was affixed to a brass sample stub using carbon tape, and coated with 5 nanometers of carbon using a high resolution ion beam coater with a dry vacuum system, and examined using field emission scanning electron microscopy (FESEM) and energy-dispersive X-ray analysis extensively after allocation. It was hoped that after initial electron microscopy characterization, the chip could be analyzed with computer assisted X-ray tomography to search for carbonate concentrations without disaggregating the sample. However, experiments with analog samples suggested that the spatial resolution and atomic number contrast was insufficient to yield acceptable results. The 278 chip was examined with FESEM intermittently through 1998 and into 1999 (Fig. 1). During this time no changes were noticed. The sample was stored in a locked cabinet, subject to air-conditioned Houston, Texas atmosphere. The sample was not disturbed or examined again until July of 2002. No additional sample preparation was undertaken; it was simply placed back into the FESEM. Upon first imaging, it was immediately obvious that something new appeared on the surface of the 278 chip. Numerous sub-micrometer (approximately 100 nm) sized halite crystals had grown on the surface (Fig. 2).

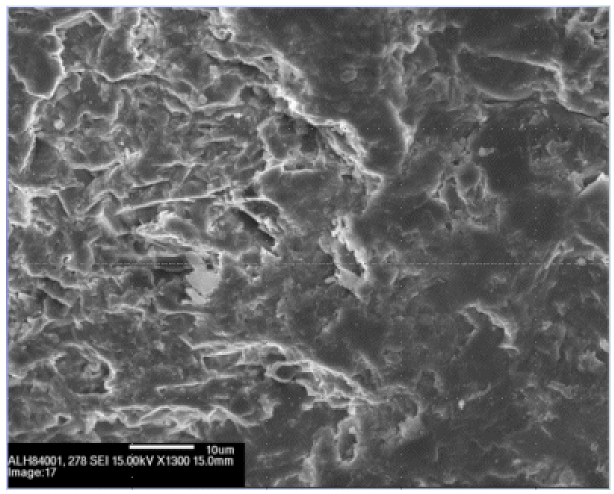

Fig.1: Secondary electron image of meteorite surface observed shortly after allocation. The representative surface is relatively clean. Scale bar = 10 µm.

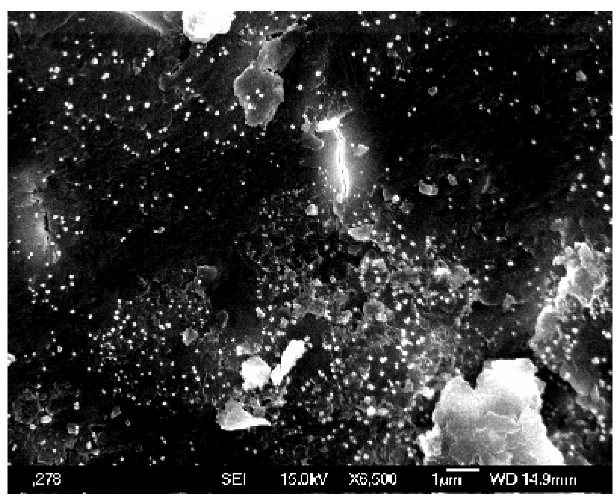

Fig. 2: Secondary electron image taken in July 2002. The surface is covered with sub-micrometer halite crystals. Scale bar = 1 µm.

Starting in July 2002 the 278 chip was placed into a desiccator and locked in a cabinet. While it was intended that an abstract would be written for the next LPSC meeting, another two and half years elapsed. Recent examination of the 278 chip, concurrent with the writing of this abstract, reveals even more interesting changes. Halite appears to have coalesced and is now present as larger 10 micrometer accumulations (Fig. 3). In addition, there are sulfur crystals and copper and zinc sulfate crystals on the surface of the chip (Fig. 4).

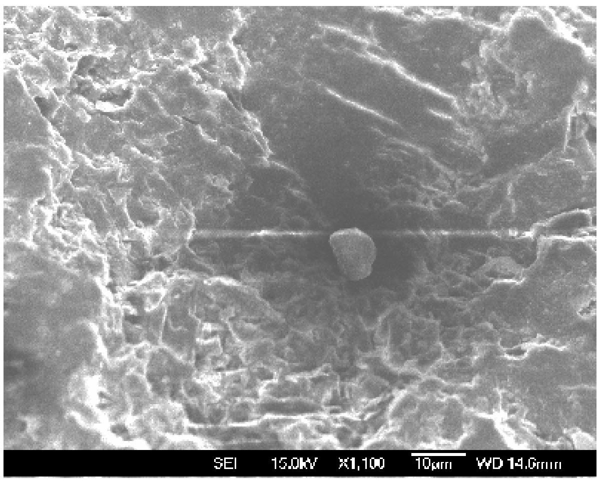


Fig. 3: Secondary electron image taken in December 2004. Halite occurs as 10 micrometer accumulations on the surface. Scale bar = 10 µm.

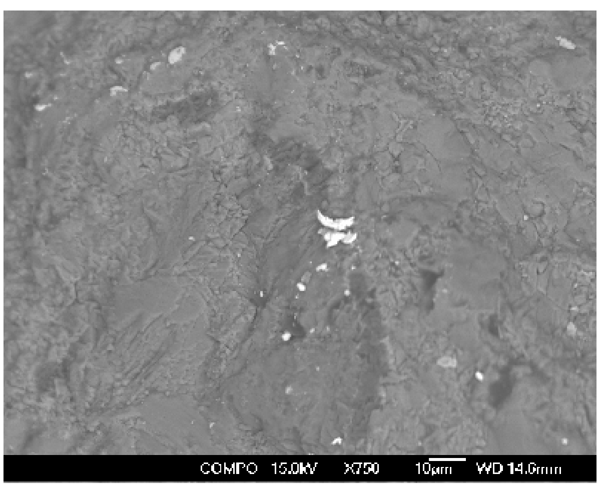


Fig. 4: Backscattered electron image taken in December 2004, showing Cu-Zn-S mineral. Scale bar = 10 µm.

The historical review by Gounelle and Zolensky [2] demonstrates that salts within porous meteorites are easily mobilized and recrystallized. While the CI1 chondrites they examined allowed decades to pass between first inspection and discovery of these alteration products, the observations presented here demonstrate that these processes occur very rapidly. Only a few years are required when no special precautions are taken.

While ALH84001 is certainly not a porous CI1 chondrite, it is highly fractured [3], therefore containing a reservoir for Martian volatiles. In addition, the Martian meteorites like EET 79001 lithology C have a high sulfur content [4]. The origin of chlorine, sulfur, and other volatiles is likely Martian. However, current observations of salt and sulfates are likely to be re-crystallized terrestrial alteration minerals formed partially of the original Martian components. Importantly, the presence of the halite and sulfates lends credibility to the hypothesis that the carbonates precipitated from brines [5].

**Implications**: To minimize possibility of forming erroneous conclusions, investigators must at least be prepared for the presence of alteration minerals resulting from even short-term storage, or ideally provide appropriate curatorial measures for the long-term storage of meteorite samples. The interaction between ambient humidity and meteorite samples is sufficient to dissolve, alter, and re-crystallize salts contained within the meteorites.

These observations are thought provoking relative to the Mars Exploration Rover observations. Just how much water is sufficient on Mars to create some of the remotely observed artifacts?

**Conclusion**: Everyone needs to consider curatorial measures for their meteorite storage, especially if allocations will not be utilized immediately. Special care should probably even be afforded to thin sections as the this type of alteration has been observed with thin sections as well [2].

**References**: [1] Gounelle and Zolensky (2001) *LPSC XXXII*, 1609. [2] Gounelle and Zolensky (2001) *MAPS*, 36, 1321-1329. [3] Mittlefehldt (1994) *Meteoritics*, 29, 214-221. [4] Rao, Borg, McKay, Wentworth (1999) *GRL*, 26, 3265-3268. [5] Bridges, Catling, Saxton, Swindle, Lyon, and Grady (2001) *Space Science Rev.*, 96, 365-392.