

A DIVERSITY OF CALCIUM-RICH CARBONATES IN EETA 79001. P. B. Niles¹, M. ElShenawy², T. Sun³, E.L. Berger⁴, and M.E. Evans¹ ¹NASA Johnson Space Center, Houston, TX 77058 (paul.b.niles@nasa.gov), ²University Space Research Association, Johnson Space Center, ³Rice University, ⁴Jacobs, NASA Johnson Space Center, Houston, TX 77058,.

Introduction: Carbonate minerals of martian origin are present in several martian meteorites in trace concentrations (< 1%) and possess unique isotopic signatures that suggest that the martian environment and/or isotopic reservoirs are very different from the Earth's [1–3]. Carbonates are most common in the older martian meteorites (ALH 84001 and the nakhlites), however, there have been reports of carbonate in the younger shergottites including EETA 79001 [1,4]. Acidification studies of Zagami and Shergotty have shown that CO₂ is released suggesting that carbonate phases are present in these meteorites [4], but the origin of these phases is controversial.

The young ages of the shergottites [5] makes them important samples for understanding the modern martian environment. The carbonates in EETA 79001 are the best-characterized secondary minerals in a shergottite, but their origin remains controversial. Gooding et al. [1] argued that two types of carbonate occur within the glassy parts of the meteorite. One type, nearly pure CaCO₃ associated with Ca-sulfate shows textural evidence for being present in the rock prior to it being shocked, suggesting formation on Mars. The second was more abundant and consists of Ca-rich carbonate, possibly with finely intergrown Mg-phosphate, but does not possess any textural relationships indicative of a martian origin. Carbon and oxygen isotopic studies of this carbonate yielded oxygen isotopes that potentially suggest a martian origin as well [6, 7] (Fig 1).

Are EETA 79001 Carbonates Terrestrial? Many of the ordinary chondrites collected in Antarctica exhibit some form of weathering, and studies have shown that carbonates are a typical weathering product [8, 9]. Velbel et al. [9] suggest that at least 5% ordinary chondrites collected in Antarctica show visible white crusts, while spectroscopic measurements suggest that this weathering may be ubiquitous [10]. The most well studied example of Antarctic carbonate formation would be LEW 85320 which has been shown to contain hydrated Mg-carbonate with an isotopic composition consistent with formation from terrestrial reservoirs [11]. In addition, the ¹⁴C signature of this carbonate weathering product suggests formation in the past 40 years [11].

Indigenous carbonate is rare in ordinary chondrites of higher petrologic type (types 4-6) which therefore can serve as reliable witness plates for Antarctic weathering processes.

Jull et al. [14] performed several acidifications of portions of EETA 79001 and measured large ¹⁴C concentrations suggesting that the carbonates in EETA 79001 are largely from Antarctic weathering. Jull et al. [14] also noted that the stable isotope compositions were very similar to carbonates from ordinary chondrites (Fig. 1).

This study seeks to separate the terrestrial weathering products from the indigenous carbonate through a careful, coordinated analysis program combining state of the art FIB/TEM/NanoSIMS studies with high precision multi-isotope analyses of stepped extractions.

Methods: A small ~100 mg chip from the interior of EETA 79001 was gently crushed to expose fracture surfaces. Several smaller pieces were mounted and coated with platinum for Scanning Electron Microscope imaging (SEM). Two different carbonate deposits identified during SEM imaging (Fig 2) were selected for Focused Ion Beam (FIB)-SEM sampling (Fig 2), and the resulting FIB section was analyzed on a Transmission Electron Microscope (TEM) and NanoSIMS at Johnson Space Center.

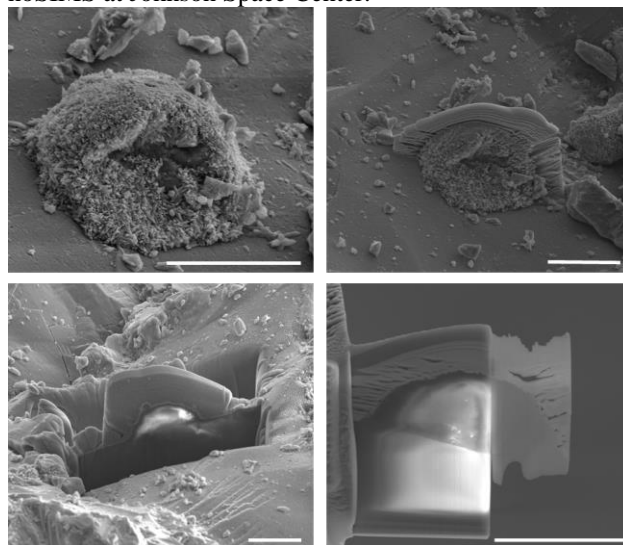


Figure 1. FIB-SEM sectioning of carbonate from EETA 79001. A protective platinum cap was placed over the region of interest, and material surrounding the region was milled out. Final FIB section at lower right contains a thinned region for TEM analysis on right and a thick (bright) section for future NanoSIMS analysis. White scale bars are 10 μm.

Results and Discussion: The first carbonate region identified in EETA 79001 showed extremely fine nano-scale crystalline structure (Fig 3). Measurements from

selected area electron diffraction patterns and EDS spectral data were used to identify the carbonate grains as aragonite. The deposit resembled carbonate clusters identified in Gooding et al. [1]) that showed common “massive, structureless” carbonates. The crystals detected were relatively pure CaCO_3 and contained no detectable impurities. The carbonate region sampled here is not the only type of carbonate found in the meteorite but is perhaps the most common [1]. NanoSIMS analysis showed large oxygen isotope variations suggesting formation from a thin film.

The second carbonate region identified was also micro-crystalline and was identified as Mg-calcite.

Aragonite and Mg-calcite formation is not common at colder temperatures on Earth, but can form in solutions with Mg : Ca ratio of 4:1 or higher [15]. These conditions are consistent with what might be expected on Amazonian Mars, however it is unclear if aragonite formation is a common Antarctic weathering product.

References:

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