Further Analysis of Carbonates in Basanitic/Basaltic and Xenolithic Samples from Svalbard, Norway: An Earth Analog for Martian Meteorite Allan Hills 84001

Andrea M. Koziol

Dept. of Geology, University of Dayton, Dayton OH; akoziol1@udayton.edu

SYNOPSIS

Samples from Spitsbergen, Norway containing zoned carbonates are compared to those in Martian meteorite Allan Hills 84001 (ALH 84001). Similarities are noted, implying a similarity in origin.

INTRODUCTION

Terrestrial samples are from the island of Spitsbergen in the archipelago of Svalbard, politically part of Norway, in the Arctic Ocean. Here young (Quaternary) volcanoes have been built and partially eroded [1], exposing a variety of basaltic rocks, similar to the rock types seen on Mars. The volcanic rocks also contain mantle xenoliths, comprising minerals similar to those seen in Martian meteorite ALH 84001. Descriptions of the carbonate globules and comparisons to ALH 84001 have been done by [2], with further work on chemical zoning by [3]. It is suggested by [2] that all carbonate occurrences are secondary low temperature hydrothermal alteration.

Martian meteorite Allan Hills 84001 contains carbonate minerals and dates from early in Mars' history (about 4.5 billion years ago; see [4, 5] for discussion). This meteorite has been examined using many different techniques, but some ambiguity remains in interpreting some features (see [6] for discussion). The carbonates in this meteorite potentially hold a record of surface conditions in their major element chemistry and in their oxygen and carbon isotopes.

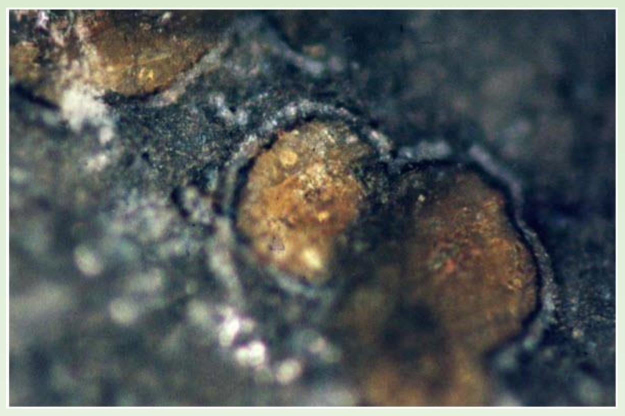

Figure 1. Close-up photograph of a small piece of Martian meteorite ALH84001 illustrating rounded carbonate inclusions with orange interiors and black-white-black rims. Size of round inclusion is ~100-200 microns. This photo, by Monica Grady, was originally published in Nature 374, 616. (NASA photo # S95-00690) Source: C. Meyer, Martian Meteorite Compendium, 2012

OBJECTIVES

The focus of this study is to examine the carbonate occurrences and compare these to Martian meteorite Allan Hills 84001. This is a continuation of the work of [7]. Eventually the plan is to compare chemical zoning of the two sets of samples, to elucidate possible hydrothermal history of carbonate deposition in ALH 84001, and hypothesize on the early history of Mars.

METHODOLOGY

Samples were collected from two volcanoes, Sverrefjell (SVF sample #'s) and Sigurdsfjell (SGF and WWB, BBW sample #'s) by earlier expeditions to Spitsbergen, including AMASE (Arctic Mars Analogue Svalbard Expeditions) expeditions. The general field relationships are described by [8, 9]. Thirty-nine different Spitsbergen thin sections were examined optically in the first phase of this research. In several cases multiple samples from certain localities were examined. Further thin sections are being prepared of selected carbonate-bearing samples for chemical analysis.

Two uncovered thin sections were requested of ANSMET of ALH 84001 but had not arrived by the time of preparation of this poster.

New thin sections for electron microprobe analysis are being prepared. Carbonates will be imaged by back scatter imaging and the chemical zoning will be measured. How alike or different are the carbonates from various localities?

DISCUSSION

General Sample Characteristics

Samples are of three types: basanitic or basaltic glass with phenocrysts of clinopyroxene, breccias of differing glass types, and xenoliths of olivine and pyroxene (lherzolites) with or without spinel. Some samples contain carbonate while other samples from nearby areas do not, demonstrating inhomogeneity. Of interest are carbonate globules that are half ellipsoids or disks similar to descriptions of [2] of samples from this area. They are described as cored by ankerite, siderite and magnesite, with a distinct dolomite (dolomite, magnesite, and/or calcite) layer. The carbonate globules can be small or large, and clear, pale brown, or dark red-brown in plane light. It is unclear at this time if the color variation seen here is due to major element or minor element variation.

Carbonate Occurrences in Xenoliths

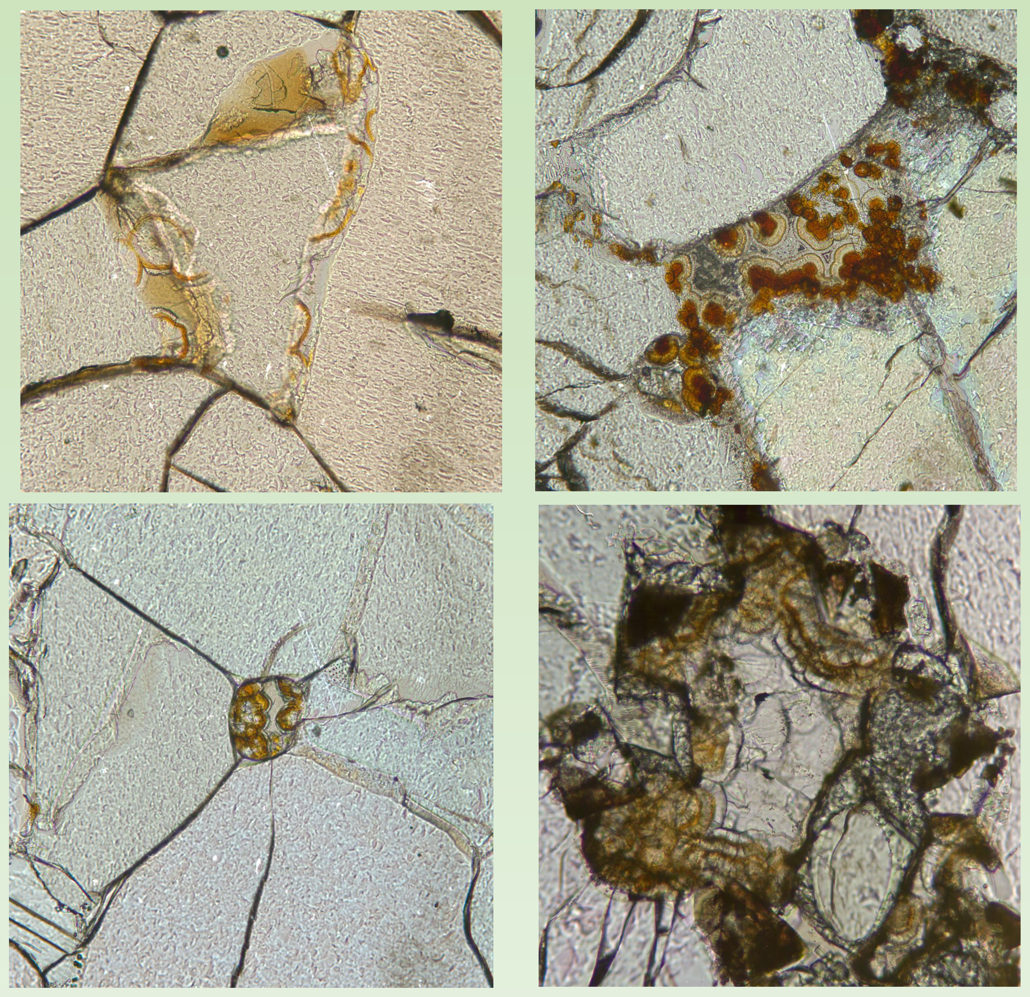

Figure 2. Upper left: clear rounded carbonates in crack; sample 01 SGF -12. Upper right: brown to pale brown layering; sample WWB 19. Lower left: group of small globules in area between olivine grains; sample WWB 21. Lower right: complex group of layered carbonates. Clear area in center is also carbonate. Sample 01 SGF 13A. For all: Field of view is 0.47 mm across.

Carbonate Occurrences in Glassy Basalts

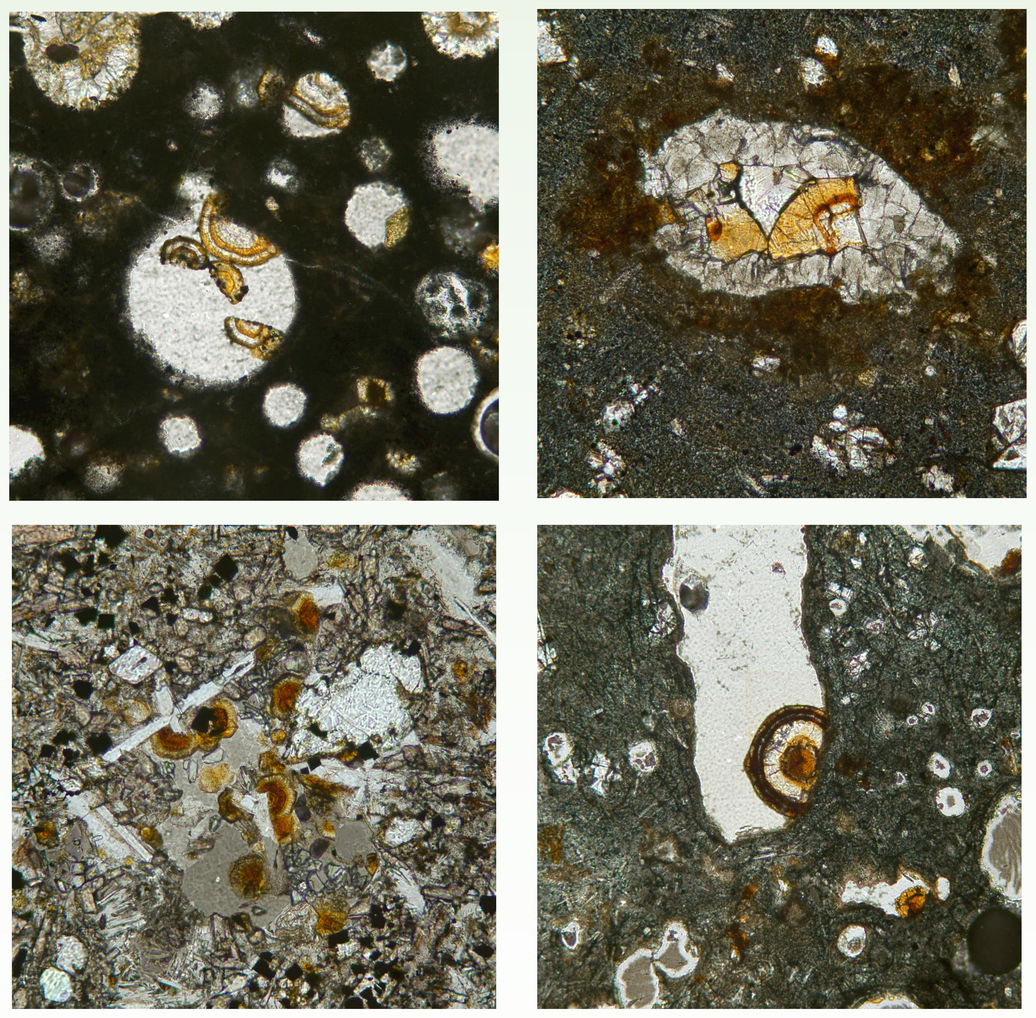

Figure 3. Upper left: Rounded globules in vesicles in basalt; sample BBW C1. Upper right: Zeolite (clear, lining vesicle wall) and carbonate in larger vesicle. Lower left: zoned brown globules among glass and crystallites. Lower right: Hemispherical carbonate exhibiting more complex zoning. Sample 01-SVF-10. For all: Field of view is 0.47 mm across.

DISCUSSION, CONT'D.

Carbonate coatings

Although one is drawn to the hemispherical or globular occurrences of carbonate, there are other forms of carbonate in these samples. Coatings of light and dark carbonate occur in a few cases.

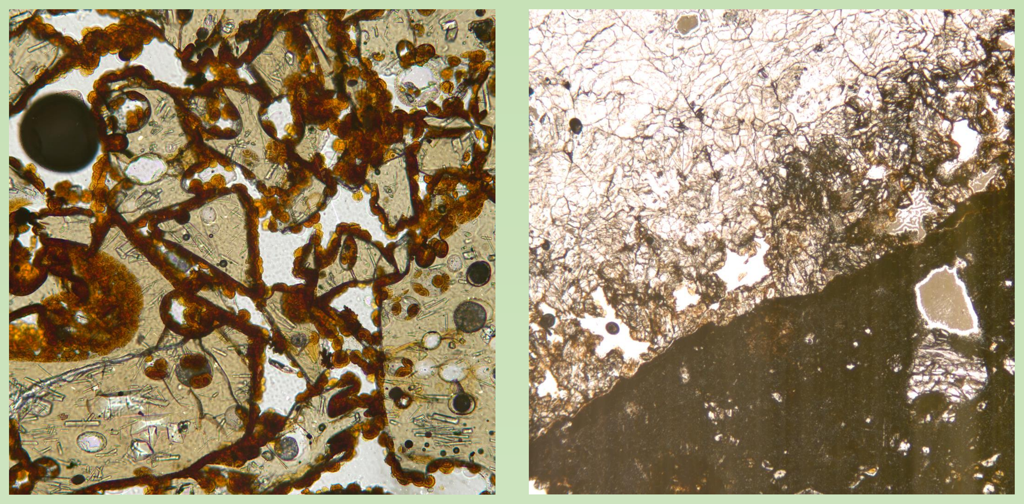

Figure 4. Left: Carbonate coating on basaltic glass pieces. Sample 01-SVF-8. Field of view: 0.47 mm across. Right: Clear carbonate coat against basaltic glass to lower left. Sample 01-SVF-10. Field of view: 1.9 mm across.

The study of [2] and this work confirms that carbonates, often similar in appearance to those in ALH 84001 (see fig. 1) occur in a inhomogeneous fashion – in some samples and not in others – even nearby. The work of [2, 3] also delineated the chemical zoning of the carbonate globules and noted that although compositions trend to Mg-rich values in the rims, each sample has a unique variation.

The work of [2] argues for a hydrothermal origin of the terrestrial carbonates: presence in different rock types; stable isotopic ratios more appropriate for near-surface material [10]; carbonate cementation of basalt breccias (see fig. 4); overgrowths of carbonate on zeolite minerals (fig. 3 upper right); and presence of magnesite not hydromagnesite. Variation in the occurrence and chemistry of the carbonates argues against precipitation from groundwater or seawater [2].

My study confirms the common occurrence yet inhomogeneity of the carbonate occurrences. I can also confirm the common occurrence of chemical zoning, as shown by variation in the color of the carbonate. The similarity to ALH 84001 (fig. 1) is apparent, though the Spitsbergen carbonates do not have a visible magnetite layer. The chemistry of the carbonate zoning is broadly similar but not identical [2, 3] to that seen in ALH 84001. However the similarities seen here imply a similar origin for each. Hydrothermal activity on Mars may be at a lower temperature, given the measurements of [11] on carbonate in ALH 84001.

Also implied is inhomogeneity of carbonate deposition on Mars. Martian occurrences have been noted [12] but carbonate may not permeate every rock in these localities. The source region for ALH 84001 may likely be inhomogeneous itself.

Further work should help infer conditions of formation for ALH 84001. Does the putative low-temperature hydrothermal origin of the ALH 84001 carbonates allow for conditions hospitable for bacterial life?

REFERENCES

[1] Skjelkvale, B.-L. et al. (1989) *J. Volcanol. Geotherm. Res*. 37, 1-19. [2] Treiman, A.H. et al. (2002) *Earth & Planet. Sci. Lett*. 204, 323-332. [3] Steele, A. et al. (2007) *Meteoritics & Planet. Sci*., 42, 1549 – 1566. [4] Nyquist, L.E. et al. (2001) in: Kallenback, Geiss and Hartmann (eds.) Chronology and Evolution of Mars, *Space Sci. Ser*., 96, 105-164. [5] Lapen, T.J. et al. (2010) *Science*, 48 347-351. [6] Treiman, A.H. (2003) *Astrobiology*, 3, 369-392. [7] Sekerak, M.A.J. and Koziol, A.M. (2015) *LPSC* 47, Abstract #1198. [8] Blake D.F. et al. (2011) *LPSC* 42, Abstract # 2167. [9] Amundsen, H.E.F. et al. (1987) *Tectonophysics*, 139, 169 – 185. [10] Mojzsis, S.J. et al. (1999) *LPSC* 30, Abstract #2032. [11] Halevy, I. et al. (2011) *PNAS*, 108, 16895-16899. [12] Niles, P.B. et al. (2013) *Space Sci. Rev*. 74, 301-328.

ACKNOWLEDGEMENTS

I gratefully thank Dr. Allan Treiman for sharing the Spitsbergen samples. The US Antarctic Meteorite program is thanked for current and pending loans of samples of Allan Hills 84001.