A TERRESTRIAL ANALOGUE FROM SPITSBERGEN (SVALBARD, NORWAY) FOR THE COMANCHE CARBONATE AT GUSEV CRATER, MARS. R. V. Morris[1], D. F. Blake[2], D. Bish[3], D. W. Ming[1], D. G. Agresti[4], A. H. Treiman[5], A. Steele[6], H. E. F. Amundsen[7], and the AMASE Team, [1]ARES NASA Johnson Space Center, Houston TX 77058 (richard.v.morris@nasa.gov), [2]NASA Ames Research Center, Moffett Field, CA 94035, [3]Indiana University, Bloomington, IN 47405, [4]University of Alabama at Birmingham, Birmingham, AL 35294, [5]Lunar and Planetary Institute, Houston, TX 77058, [6]Geophysical Laboratory, Carnegie Institution of Washington, Washington, D.C. 20015, [7]Earth and Planetary Exploration Services, Oslo, Norway.
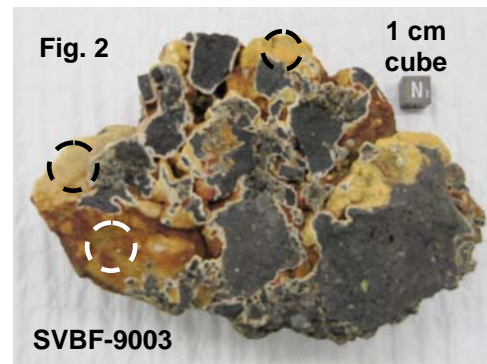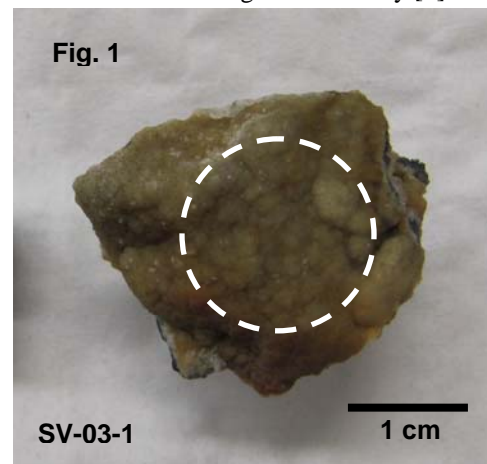
Introduction: Carbonate occurs at the Comanche outcrops in Gusev Crater on the basis of analyses made by the Mars Exploration Rover Spirit [1]. Taken together, mineralogical data from Spirit's Mössbauer (MB) and Mini-TES spectrometer and chemical data from the APXS spectrometer show that Comanche carbonate has an Mg-Fe-rich bulk chemical composition, is present at high concentrations, and is distributed throughout the outcrop and not just at the MB and APXS analysis location. The granular outcrop texture and the observation that it appears to be resistant to weathering compared with surrounding material [1] imply that the carbonate may be present as a cement.

A hydrothermal origin for the Comanche carbonate was inferred by analogy with laboratory experiments and with a carbonate occurrence within the Bockfjord volcanic complex on the island Spitsbergen (Svalbard, Norway) [1]. The laboratory carbonates, synthesized by precipitation from hydrothermal solutions, have (MB) parameters and average bulk chemical compositions that are characteristic of Comanche carbonate. The connection to Comanche carbonate is only through chemical data for certain occurrences of Spitsbergen carbonates. In fact, the common average bulk chemical composition for these Spitsbergen carbonates, the synthetic carbonates, the Comanche carbonate, and also the carbonate globules found in martian meteorite ALH84001 is a chemical constraint consistent with a hydrothermal formation process for all the carbonates [e.g., 1-3].

We develop here a link between MB data for the Comanche carbonate from MER and MB data for certain Spitsbergen carbonate occurrences from laboratory measurements. We also obtained visible and near-IR spectra on Spitsbergen carbonates for comparison with martian carbonate detections made on the basis of CRISM spectral data, e.g., in Nili Fossae [4].

Samples and Methods: Carbonate-cemented and coated breccia samples were collected on Sverrefjell volcano on the island of Spitsbergen in the Svalbard archipelago (Norway) as a part of the AMASE project. The coatings are typically <1 mm thick with exterior surfaces that are variably colored tan, orange, red, brown, and green. Sample SV-03-1 (Fig. 1) was broken from a larger sample and has one side with carbonate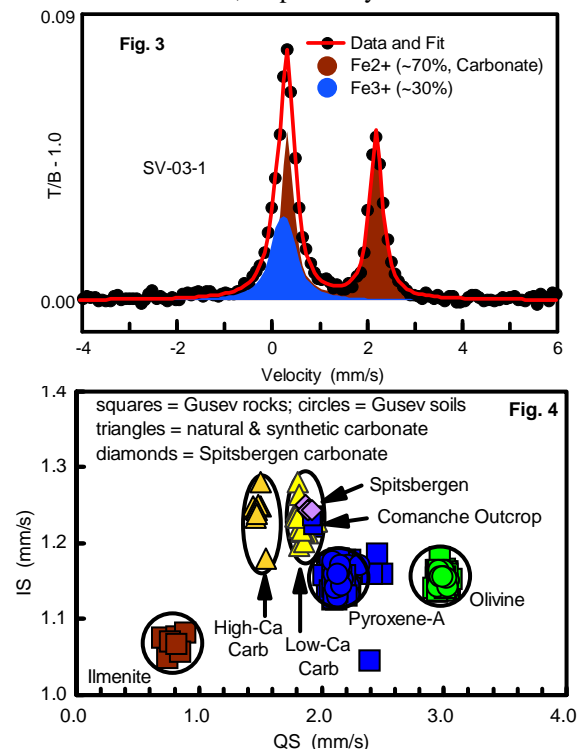 coating. Sample SVBF-9003 is a large, cemented breccia sample showing cement and coated exterior surfaces. Note that the coating is thin (<1 mm) and that subsurface carbonate is light-toned in color. These carbonates contrast with the thick (and generally light-toned) carbonate cements and coatings discussed by [5].

Fig. 1
SV-03-1
1 cm

Fig. 2
1 cm cube
SVBF-9003

Backscatter MB spectra were acquired at room temperature using MER-like MIMOS-II spectrometers from SPESI. MB velocity calibration was done using the spectrum for metallic Fe foil, the MIMOS-II differential signal spectrum, and the program *MERView* [6]. MB parameters (isomer or center shift (CS), quadrupole splitting (QS), hyperfine field strength (B_{hf}), and subspectral areas of Fe-bearing phases (A)) were obtained by a least-squares fitting procedure with the program *MERFit* [7]. VNIR reflectance spectra (0.35 to 2.5 µm) were obtained at room temperature using an Analogue Spectral Devices (ASD) FS3 spectrometer configured with a Mug Light. The dashed circles in Figs. 1 and 2 indicate the surfaces where MB and
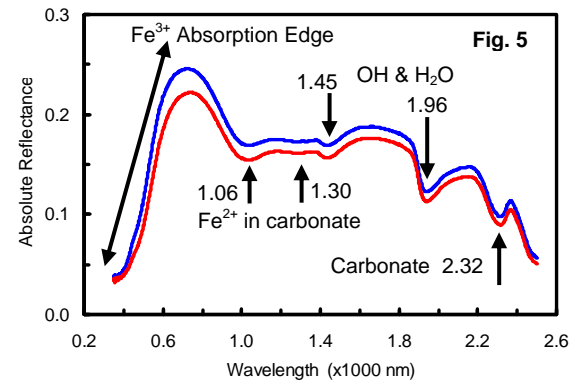
VNIR data were obtained. Carbonate powder was removed from the surface of SV-03-1 using a Dremel tool after MB and VNIR measurements, and powder X-ray diffraction data were obtained for this material using a Bruker D8 Advance instrument with CuKα radiation.

Results and Discussion: The MB spectrum and subspectra derived from the least-squares fit for SV-03-1 (Fig. 1) are shown in Fig. 3. This and similar spectra were fit by an Fe^{2+} doublet (CS=1.25 mm/s; QS=1.87 mm/s) and an Fe^{3+} doublet (CS=0.23 mm/s; QS=0.23 mm/s) having ~70% and ~30% subspectral areas, respectively. If the spectrum is treated as a single Fe^{2+} doublet with the asymmetry resulting from orientation effects, the values of CS and QS are 1.24 mm/s and 1.89 mm/s, respectively.

Fig. 3

Fig. 4

The doublet identification diagram (Fig. 4 after [1]) shows (1) that the Fe^{2+} doublet implies Fe-Mg carbonate (e.g., $FeCO_3$ - siderite) and not high-Ca carbonates like ankerite and Fe-bearing dolomite and (2) that the MB parameters for the Sverrefjell carbonate are the same as those for the Comanche carbonate. Preliminary Rietveld analysis of XRD powder patterns of the bulk carbonate indicates ~76% (Mg-Fe)-carbonate, ~21 % dolomite, and ~3% clinopyroxene. Presumably, there is an insufficient fraction of total Fe^{2+} associated with either dolomite or clinopyroxene to be detected by MB. The diffraction data show that all carbonate phases are very poorly ordered, with diffraction peaks considerably broadened because of strain effects (possibly cation-substitution effects).

The VNIR spectra for SV-03-1 for two orientations (Fig. 5) show a carbonate band at 2.32 µm, Fe^{2+} bands at 1.06 and 1.30 µm, and H_2O/OH bands at 1.45 and 1.96 µm. The position of the carbonate band is consistent with siderite, ankerite, calcite, and dolomite but not magnesite [8], but the presence of the Fe^{2+} carbonate bands implies Fe-bearing carbonate (e.g., siderite and/or ankerite). Because MB results imply Fe-Mg carbonate and not high calcium carbonate, the interpretation that is consistent with MB, XRD, and VNIR data is Mg-siderite at the very surface of the carbonate coating.

Fig. 5

Conclusions: Taken together, MB, XRD, and VNIR data constrain the very surface of the carbonate rind to (Mg,Fe)-carbonate as the simplest mineralogical interpretation. Minor dolomite may also be present at the very surface, but its detection by XRD was from a sample of bulk carbonate coating.

Spitsbergen carbonate as an MB analogue for Comanche carbonate strengthens the prior interpretation [1] that Comanche carbonate is secondary and hydrothermal in origin. Furthermore, dolomite may be present in the Comanche outcrops, although its presence at the very surface is precluded by APXS analyses [1]. The Spitsbergen carbonate spectral feature at 2.32 µm occurs at somewhat longer wavelength than the Nili Fossae occurrence (~2.295-2.305 µm [4]). If the Spitsbergen analogue extends to VNIR spectra, Comanche carbonate is more Fe-rich than Nili Fossae carbonate, although spectra for the latter also have a broad spectral feature at ~1.2 µm that can be interpreted as some Fe^{2+} in the carbonate [4].

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