IS COMANCHE CARBONATE EVIDENCE FOR A LAKE IN GUSEV CRATER, MARS?

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Introduction: The origin of outcrops rich in Mg-Fe carbonate (16-34%) recently discovered by the Spirit rover in the Columbia Hills of Gusev crater [1] is enigmatic (Fig. 1). A hydrothermal origin was suggested by [1] to explain the abundant carbonate in the outcrops dubbed Comanche, based largely on analogy with the carbonate globules in the Martian meteorite ALH 84001, laboratory synthesis of hydrothermal carbonate globules, and similar ones found in volcanic rocks in Spitsbergen, Norway. But a major difference between these carbonate globules and Comanche is the remarkable abundance of carbonate in the latter. Among the many competing hypotheses for the origin of ALH 84001 carbonate globules, precipitation from evaporating brine was proposed by [2] and [3]. In this model, infiltration of ponded water into fractures of existing rock followed by evaporation could precipitate the kind of carbonates observed in the meteorite. Here I present a set of observations that are consistent with such an origin for Comanche carbonate.

Mini-TES Observations: Thermal infrared spectra (~380-1800 cm^{-1}) from Spirit's Miniature Thermal Emission Spectrometer demonstrate that the carbonate in the Comanche outcrops is distributed uniformly throughout (Fig. 2). At the base of the larger outcrop, a spectrally and texturally distinct unit is present. It appears to be spectrally transitional between the Comanche carbonate outcrop and stratigraphically lower Algonquin outcrops. The latter are olivine-rich clastic rocks of likely pyroclastic origin [4]. The Comanche spectrum is modeled even more precisely than shown by [1] (Fig. 3) using an average Algonquin spectrum as an end-member (Fig. 4). In doing so, Comanche can be modeled as an addition of Mg and Fe-rich carbonates to Algonquin, along with a low-silica amorphous component. To achieve the notably good spectral fit, no phyllosilicate or high-silica phases are required, suggesting that little alteration other than the introduction of carbonates into Algonquin class rocks is sufficient to produce Comanche class rocks. Mössbauer (MB) spectra also lack evidence for any Fe-rich phyllosilicates [1].

Noteworthy in the spectral modeling of Comanche is the need for multiple carbonate phases. A single phase, like the Mg-Fe carbonate used by [1] fails to produce the broadening of a feature attributable to one of the carbonate fundamental absorption features near 900 cm^{-1} (Fig. 3). Multiple carbonates also produce a distortion of the low wavenumber (<500 cm^{-1}) carbonate fundamental in a way that, when combined with the Algonquin spectrum, better fits two narrow peaks in this part of the Comanche spectrum (Fig. 4). Together, these improved fits suggest that two or more Mg and Fe-rich carbonate phases are present in Comanche, perhaps due to zoning.

Texture and Morphology: A relationship between Comanche and Algonquin rocks is evident via textures shown by Spirit's Microscopic Imager. Although [1] described their "granular" vs. "massive" textures, respectively, close inspection reveals both to be clastic rocks dominated by sharply angular and fragmented grains but also notably rounded, even circular grains (Fig. 5). The granular surface texture of Comanche appears to result from grains that are etched into relief, perhaps as a carbonate matrix is dissolved.

The morphology of the Comanche outcrops is notable for its knob-like expression (Fig. 1). Algonquin outcrops are similar, although the knobs are composed of meter-scale rounded boulders. Both have the appearance of an erosional process like exfoliation.

Discussion: The near absence of phyllosilicate phases in ALH 84001 was used by [2] and [3] to support the case for direct carbonate precipitation from an evaporating brine to produce the observed globules. A hydrothermal origin is expected to produce secondary hydrated silicates. Although the detection limits for such phases are higher with Mini-TES and MB data, there is nevertheless no detection in Comanche, an observation that similarly must be reconciled. The zoned carbonates in the meteorite also could be produced from an evaporating brine [2][3] and may be present in the Comanche outcrops.

As one of many possible origin hypotheses for Comanche carbonate, I propose that brine from an evaporating lake in Gusev crater (perhaps filled repeatedly) infiltrated Adirondack class rocks and precipitated abundant Mg and Fe-rich carbonates. The distinctive morphology of the eroding Comanche outcrops is perhaps a manifestation of the dissolution of the carbonate over time and may be expressed in the nearby terrain dubbed "the Promised Land" and similar "rubble terrain" that is widespread on the floor of Gusev crater as presented by [5].

References: [1] Morris, R. V., et al. (2010), Science, 329, 5990, 421-424, DOI: 10.1126/science.1189667. [2] McSween Jr., H. Y., and R. P. Harvey (1998), Int. Geol. Rev., 40, 9, 774 - 783. [3] Warren, P. H. (1998), J. Geophys. Res., 103, E7, 16,759-716,773. [4] McCoy, T. J., et al. (2008), J. Geophys. Res., 113, E06S03, 10.1029/2007JE003041. [5] Ruff, S. W., et al. (2007), Lunar Planet. Sci., 38, Abstract #2063.

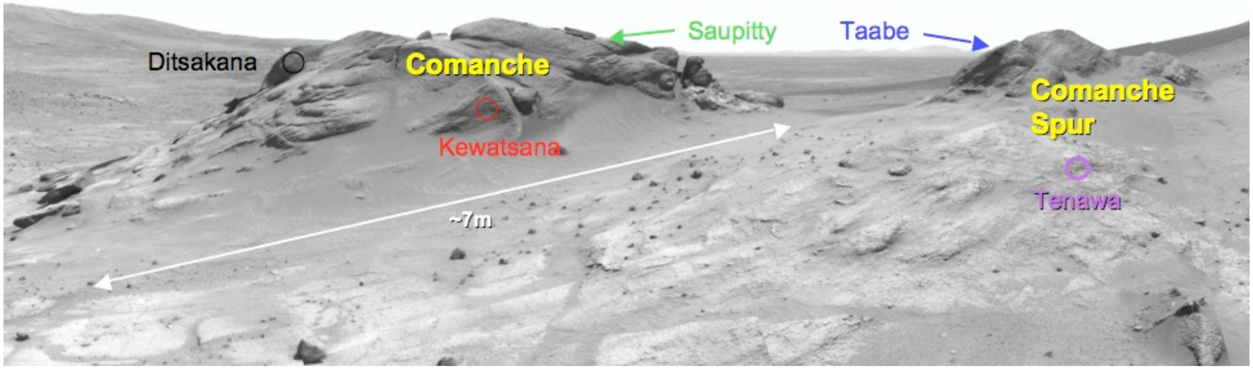

Figure 1. Navcam view of Comanche outcrops with locations of the 5 Mini-TES observations shown in Figure 2.

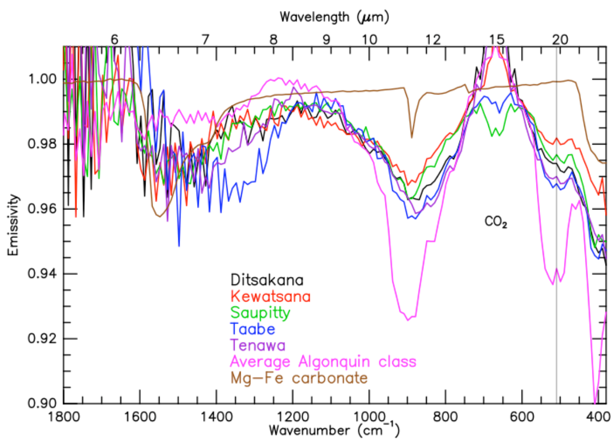

Figure 2. Mini-TES spectra of Comanche outcrops showing carbonate features (brown) along with others due to additional components including surface dust. A narrow peak at 510 cm^{-1} (vertical line) is common to all Comanche spectra and that of Algonquin class rocks (pink). It is attributable to Mg-rich olivine.

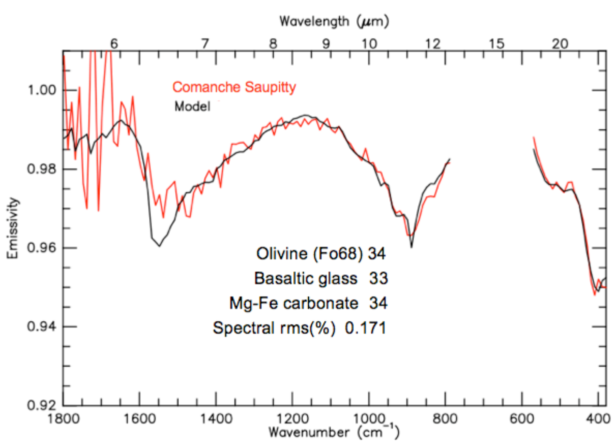

Figure 3. Modeling (deconvolution) of Comanche as presented by [1]. Three mineral phases (plus dust) in roughly equal abundance provide a reasonably good fit.

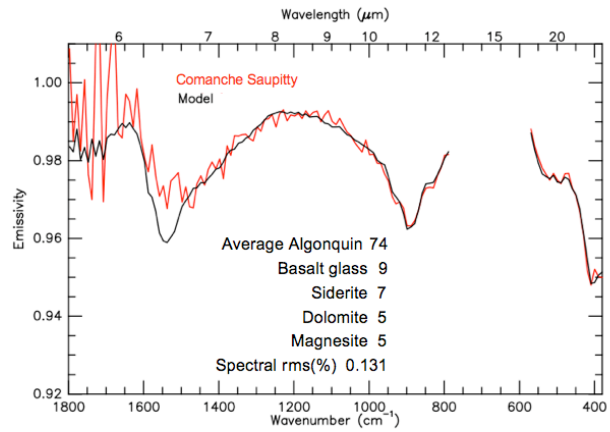

Figure 4. Using the average Algonquin class spectrum as and end-member provides a superior fit and demonstrates a link between the two classes.

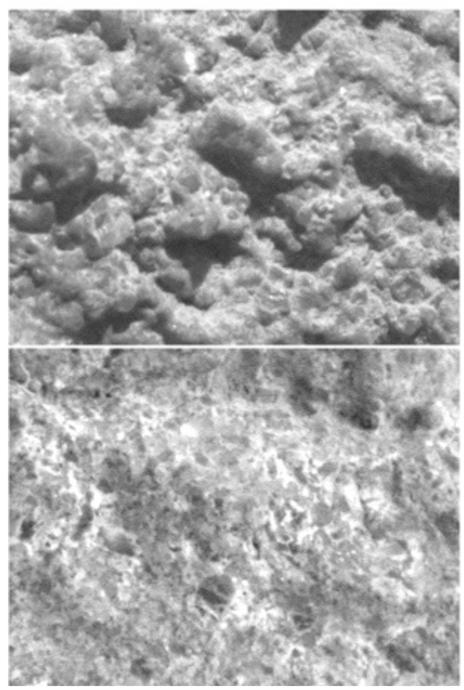

Figure 5. MI images (~1 cm across) showing angular clasts of Algonquin (bottom) and in Comanche where they are etched into relief (top).