DIAGENETIC OVERPRINTS ASSOCIATED WITH THE CLAY-SULFATE TRANSITION IN GALE CRATER, MARS. C. H. Seeger[1], J. P. Grotzinger[1], A. C. Cowart[2], [1]California Institute of Technology, 1200 E California Blvd, MC 170-25, Pasadena, CA 91125 (cseeger@caltech.edu), [2]Planetary Science Institute, College Park, MD.

Introduction: The diagenetic processes of cementation and later stage alteration provide a valuable textural and compositional record of fluids that interact with sediments and sedimentary rocks. This record comprises cements with specific chemistries, or mineral assemblages that reflect specific environments, or alteration products produced by later-stage fluid movement throughout the rocks (e.g. veins, nodules, color variations, etc.).

On Earth, understanding diagenesis helps to elucidate the history of groundwater flow through sedimentary basins. This is also true for Mars, and though water-rock interactions occur in basaltic rather than dominantly granitic sediments, we can still use terrestrial examples and present-day alteration products observed by rovers to understand the chemistry and timing of groundwater fluid flow, perhaps even after liquid water ceased to exist on the surface. Previous studies have cataloged diagenetic features in Meridiani Planum, Gusev crater, and Gale crater, as investigated by the Mars Exploration Rover (MER) and Mars Science Laboratory (MSL) Curiosity rover missions [e.g. 1, 2, 3].

In this study, we investigate a new suite of diagenetic features emergent in the region of Curiosity's traverse explored from sols 2904-3612, from the Mary Anning drill target in the clay-bearing rocks of Glen Torridon to the Canaima drill target in the sulfate-bearing unit of the Carolyn Shoemaker formation. This region has long been of interest: orbital spectral signals suggest a major climatic shift from wet to dry environments, as reflected in a transition from phyllosilicate-bearing to sulfate-bearing rocks [4, 5]. Features were analyzed in the context of relatively constant bulk rock chemistry, demonstrating that this transition region is dominated by changes in primary facies and diagenetic textures, but not substantially in elemental abundances (though it is important to note that mineralogy may vary despite constant chemistry).

Methods: We primarily use the close-up imagery of the Mars Hand Lens Imager (MAHLI) taken at 25cm and 5cm standoff distances from the surface to perform a detailed analysis of the different diagenetic features and their cross-cutting relationships. Ongoing work suggests that some of these features—particularly nodules—correlate with localized enrichments, particularly in Mg and S [e.g. 6, 7]. Here, we will use quantitative measurements of nodule size distributions and abundance by area to track changes with stratigraphy and correlate subtle variations in bulk rock chemistry as measured by the Alpha Particle X-Ray Spectrometer (APXS) with diagenetic feature abundance.

Diagenetic feature types: Post-depositional diagenetic features have been documented in abundance throughout Curiosity's traverse [e.g. 3]. In the clay-sulfate transition region, both familiar and new fabric elements were encountered.

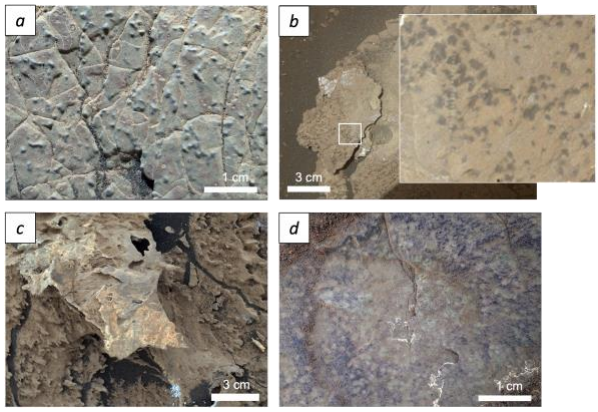

Figure 1. Type examples of diagenetic features encountered throughout clay-sulfate transition region. (a) Color variations (examples traced in white in upper left of panel), pits, and nodules in sol 3004 target Tomb of the Eagles; (b) Small dark subangular features from sol 2922 target Groken; (c) Protruding fin-like vein with embedded small dark subangular features in sol 3112 target Pezuls; (d) Pervasive concentric fabric in sol 3024 target Coutures.

Irregular raised and rounded bumps. The most abundant features encountered along this section of the traverse are the irregularly shaped, usually dark-toned, high relief nodular features. They range from sub-mm to several cm across, but exhibit similar morphologies across all scales (Figure 1a). Most can be described as rounded, isolated nodules that sometimes amalgamate into vermiform chains or larger popcorn-shaped features that do not disrupt primary laminae. In some instances, groups of nodules are arranged into distinctive, organized patterns in cm-scale relief from the surface, such as evenly spaced chevron-like ridges or ridges forming polygon boundaries.

Pits & color variation. Pits are negative relief, sub-mm circular features embedded within the mudstones of the Carolyn Shoemaker formation, and almost

exclusively co-occur with color variations in the rock, with only a few examples of independent formation (Figure 1a). Color variations occur as cm-scale irregularly bounded redder-toned splotches that are otherwise texturally indistinguishable from the rest of the rock (Figure 1a).

Small dark subangular features. In two localities (Groken and Pezuls), there are very abundant mm-scale, dark gray subangular features that tend to be confined to specific bedding planes (Figure 1b). This fabric has a unique manganese and phosphorous enrichment [8, 9].

Veins and Fins. White fracture-filling veins are pervasively distributed throughout the strata of Gale crater, and are the result of (most commonly) calcium-sulfate precipitation in fractures [e.g. 3, 10, 11]. Vein formation is a late-stage diagenetic process due to their cross-cutting of bedding and some earlier generations of veins. Veins appear often through the clay-sulfate transition, and may weather resistantly to form thin, flat fins that project above the outcrop surface (Figure 1c).

Pervasive Concentric Fabric. In the lower portions of the Carolyn Shoemaker formation, there are several occurrences of a pervasive concentric fabric, with mm- to cm-scale circles of white rock that sometimes has cores or concentric rings of different colors (Figure 1d). This fabric occurs in such abundance that it dominates the entire rock surface. There is no differential relief associated with these features, and they otherwise have identical texture to the surrounding rock.

Feature abundance and distribution: The diversity and abundance of the described feature types changed drastically over the course of Curiosity's clay-sulfate transition region traverse (Figure 2). From Mary Anning to Mont Mercou, diversity increased dramatically and all types of features were observed, though primary stratigraphy was still observable.

In instances where multiple feature types occur within the same outcrop, complex cross-cutting relationships abound. Chains of nodules are often cut by veins, but there are instances where these chains appear to possibly truncate veins instead. Nodules do not appear inside of color alteration zones, but the spatial distribution of them both suggests that there could have been zones of depleted solute around the nucleation sites of each feature during the event(s) of precipitation/oxidation in flowing fluids that formed them [as in 2].

In the upper part of the ~8m tall cliff of Mont Mercou, primary stratigraphy became entirely overprinted by diagenetic fabrics (particularly nodules). In the Pontours member, nodules increasingly overprinted bedding and were extremely abundant around the transition from the Carolyn Shoemaker formation to the Mirador formation. Clustered nodules occur in more sporadic patches throughout the aeolian deposits of the Mirador formation, though they have increasing Mg-sulfate enrichments (as measured by [6]) that may contribute to the orbital spectral signal that is not so easily observed in the bulk rock chemistry.

Conclusion: The clay-sulfate transition region spans an important paleoenvironmental milestone of the Curiosity rover mission, and has been inferred from orbital data to represent a shift from wet to dry conditions at Gale, and possibly at a more global scale. While bulk rock chemistry only changed subtly through this study area, the diversity and abundance of diagenetic features varied dramatically. Some of these features—nodules in particular—contain Mg and S enrichments, and tracking their abundances within the host rock can provide perspective on their contribution to bulk rock chemistry. Delineating the order in which the diverse set of diagenetic features formed through detailed characterization provides valuable constraints on the timing of subsurface fluid flow in this region of significant environmental transition.

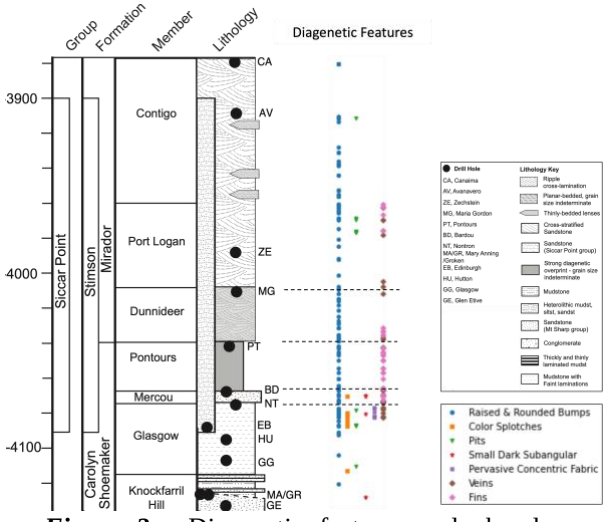

Figure 2. Diagenetic features and abundances change throughout stratigraphic sequence within the clay-sulfate transition region.

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