CONSTRAINING AMORPHOUS PHASE AND CLAY HYDRATION ABUNDANCES IN GALE CRATER, MARS AND UTILITY FOR MARS SAMPLE RETURN.

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Introduction: The NASA Mars Science Laboratory (MSL) Dynamic Albedo of Neutrons (DAN) instrument on the Curiosity rover measures subsurface hydration in Gale crater. Recent work has suggested that DAN is sensitive to the abundance of specific hydrated phases like clay minerals [1]. Here we report on efforts to constrain the abundance of hydrated amorphous phases and the hydration of clay minerals in Gale crater using rover geochemical, mineralogical, and hydration results. We also describe the utility of techniques developed here for use with returned samples such as with the Mars Sample Return (MSR) program.

Methods: We compare the time-resolved thermal neutron count rates measured by DAN to simulated data produced by the MCNP6 neutron transport code. MCNP6 simualtes neutron histories in a 3D environment including subsurface geochemistry. We use geochemical models with variable abundances of water and neutron absorbers (e.g., iron, chlorine). Neutron count data from this subsurface geochemical model "grid" are compared to DAN active data using an Markov-chain Monte-Carlo routine to determine a mean best-fit water value and associated uncertainty for each measurement location [e.g., 2]. We use published CheMin mineralogical abundances from each of >20 drilled samples [3-7] to subtract the hydration of crystalline phases from the bulk hydration measured by DAN at each drill location to obtain the amorphous + clay interlayer hydration (WEH_{aci}). We use published amorphous fraction chemistry derived by subtracting crystalline chemistry from bulk chemistry measured by APXS of drill tailings.

Preliminary Analysis: Fig. 1 is a plot of sample amorphous fraction vs. WEH_{aci} symbolized by clay mineral type. The positive trends indicate that WEH_{aci} is correlated with amorphous fraction, as expected. A similar plot of clay mineral abundance vs. WEH_{aci} (Fig. 2) does not show positive trends, suggesting that clay minerals are not significantly hydrated. However, nontronite samples (blue points) have elevated WEH_{aci}/:clay ratios compared to other samples, suggesting that the nontronite may be hydrated. In this case the negative trend in Fig. 2 may be due to a general negative trend between a more hydrated amorphous fraction and a less hydrated clay fraction (Fig. 3).

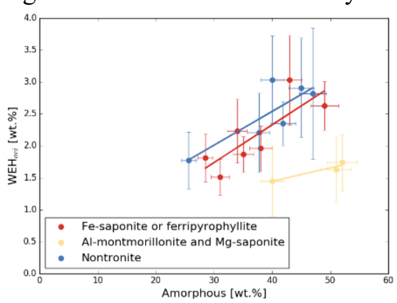

Figure 1: Amorphous fraction vs. WEH_{aci} symbolized by clay mineral.

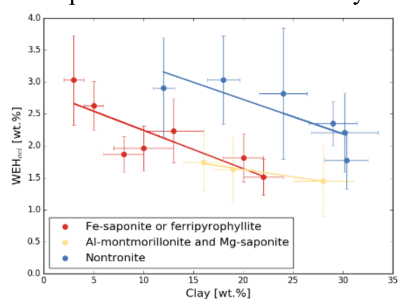

Figure 1: Clay fraction vs. WEH_{aci} symbolized by clay mineral.

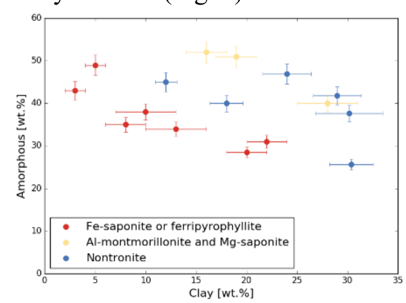

Figure 3: Clay fraction vs. amorphous fraction symbolized by clay mineral.

Amorphous Phase Analysis: To constrain the abundances of amorphous phases and clay hydration present in these samples, we will implement a similar amorphous phase analysis as in [2]. We will randomly generate amorphous phase compositions as combinations of 12 candidate amorphous phases. The model amorphous phase chemistry and hydration will be calculated and compared to the known amorphous fraction chemistry and hydration as described above. If each chemical abundance (SiO2, FeOT, etc.) of the amorphous model matches (within error) the known amorphous fraction, the model is accepted as a possible amorphous composition. We will generate 10,000 possible amorphous phase compositions for a each drill sample, allowing us to independently constrain minimum and/or maximum abundances for the candidate amorphous phases and a pure water phase that represents water in clay minerals.

Utility for Mars Sample Return: An active neutron spectrometer like DAN can be implemented in a standard preliminary measurement architecture for samples acquired as part of the MSR program. MCNP6 simulations can include a model the Ti MSR sample tubes, allowing data collection without removing the sample tube. Additionally, neutron spectroscopy is non-desctructive and provides data from the bulk sample. DAN does not include a gamma ray spectrometer, but a large gamma ray flux is induced by active neutron experiments like DAN. Including a gamma ray spectrometer in a lab setting would take advantage of this gamma ray flux to determine bulk elemental abundances for all major rock forming elements.

References: [1] Czarnecki, S., et al. (2022) *JGR: Planets, 128*. [2] Gabriel, T. S. J. et al. (2018) *GRL, 45*. [3] Vaniman, D.T., et al. (2014) *Science, 243* [4] Rampe, E.B., et al. (2017) *EPSL, 471*, 172-185. [5] Bristow, T.F., et al. (2018) *Sci. Adv., 4*. [6] Rampe, E.B., et al. (2020) *JGR: Planets, 125*. [7] Thorpe, M. T., et al. (2022) *JGR: Planets, 127*.