ANALYZING THE EFFECT OF HIGH-RELIEF TOPOGRAPHY ON ACTIVE NEUTRON MEASUREMENTS.

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Introduction: The Dynamic Albedo of Neutrons (DAN) instrument onboard the Mars Science Laboratory (MSL) is a neutron spectrometer that uses both active and passive methods to investigate subsurface hydration and geochemistry [1]. DAN has performed several experiments in the presence of high-relief topography. Previous work has shown that passive neutron counts increase when vertical topography is nearby [2]. Recent work has shown that active measurements, using the DAN pulsed neutron generator (PNG), near high-relief topography also result in increased neutron counts, which agrees with simulations [3] and may allow us to investigate the geochemistry of the feature. Here, we present our analysis of DAN active data taken at different sites throughout the traverse where high-relief topography was ~5 m or nearer to understand its effect on the time profile of thermal neutron arrival after active neutron pulses. We find that nearby, high-relief topography causes an increase in neutron counts in the bins after the primary peak in DAN active measurements.

Methods: When performing an active measurement, DAN's PNG emits pulses of high-energy neutrons isotropically, some of which interact with the nuclei of the material beneath the rover. The DAN detectors measure returning lower energy epithermal and thermal neutrons over the 100,000 μs following each pulse. The shape of the resulting "die-away curve" (neutron counts vs time) is sensitive to hydrogen and neutron absorbers (e.g., Fe, Cl) [4]. The addition of vertical topography provides another surface and volume of material for neutrons to interact with and increases the measured arrival times and neutron count rates measured by DAN.

We first identified several locations where measurements were taken near topographic features to investigate the contribution of vertical topography on active neutron count rates. We used several criteria to select sites, including the height of the feature relative to the detectors (using OnSight [5], figs. 1,2), the availability of "near" (< 5 m from the feature) and "far" (>10 m based on simulation results in [3]) data for each location, and the similarity of the lithology at "near" and "far" site pairs using OnSight. After verifying that each dataset met the criteria, we produced and co-plotted thermal neutron die-away curves for "near"/"far" data for each location. To account for differences in PNG output at the time of measurement, we normalized the area under the curve of the "near" data to that of the "far" data. Additionally, we estimated the time of arrival for the bulk of thermal neutrons coming from the topographic feature based on the distance to the feature (measured in OnSight) and assumed average thermal neutron energy (based on simulations presented in [1]).

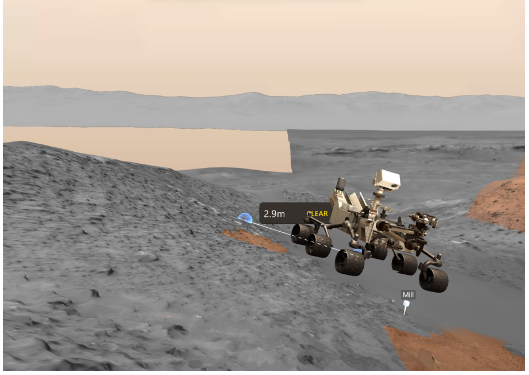

Figure 1: MSL at Jocko Butte on Sol 986, imagery acquired through the MSL OnSight tool [5].

Figure 2: MSL at Mont Mercou on Sol 3071.

Results and Discussion: *Locations with most significant change.* The locations that show the most significant change in detector response around the estimated time bin are Sol 986 ("Jocko Butte"), Sol 3071 ("Mont Mercou"), and Sol 3553 ("Bolivar"). At Jocko Butte (fig. 3), there is a statistically significant enhancement in the neutron counts around the expected thermal neutron arrival time (vertical dash-dotted line) for a topographic feature at the measured distance. Around this time bin, the "near" and "far" data have similar slopes, but the "near" data has a significant increase in counts (fig. 3), similar to the previous simulated results and analysis done for "Maria Gordon Notch" [2]. At Mont Mercou (fig. 4), the estimated time bin around which the bulk of thermal neutron counts returning from vertical features is ~1479µs, and the bin in which the “near” curve becomes distinguishable from the “far” curve is 1445µs.

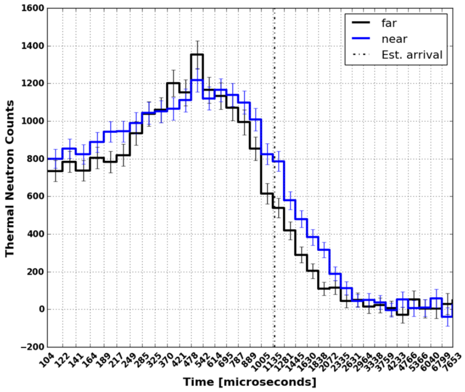

Figure 3: Normalized thermal neutron die-away curves for Jocko Butte featuring the “near” measurement (Sol 986), **“**far” measurement (Sol 987), and the estimated arrival time for thermal neutrons coming from the vertical feature.

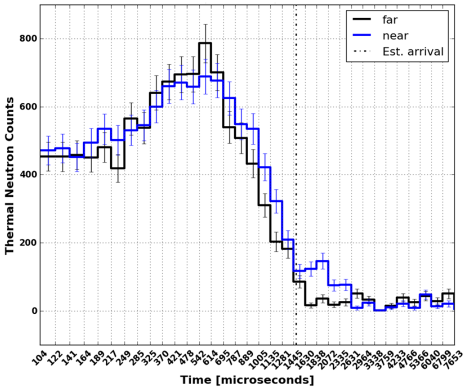

Figure 4: Normalized thermal neutron die-away curves for Mont Mercou featuring the “near” measurement (Sol 3071), “far” measurement (Sol 3049), and the estimated arrival time for thermal neutrons coming from the vertical feature.

Measurements at these three locations show similar increases in thermal neutron counts around the expected time due to a topographic feature of the approximate size and distance, however, there are differences in the slope of the thermal neutron increase after the primary thermal neutron peak. Our simulations suggest that these differences may be due to the slopes of these features. At Jocko Butte, the feature is a gentler slope and rising just above the height of the detectors (fig. 1). At both Mont Mercou and Bolivar, the feature has a much steeper slope that more resembles a wall and extends vertically for several meters (fig. 2). A discrete second peak is observed in Fig. 4 for the measurement at Mont Mercou around ~2,000µs after the pulse and well beyond the primary thermal neutron peak. Unlike the DAN data at Jocko Butte (Fig.3), which show a more smooth and uniform increase in thermal neutron counts after the primary neutron peak, the sharp and discrete secondary peak observed at Mont Mercou may be due to the more vertical geometry at the site. At Jocko Butte it is also possible that the increase in thermal neutrons could also be explained by differences in geochemistry at the “near” and “far” measurement sites.

Other locations. In addition to the locations listed above, three other locations were identified due to their proximity to high-relief topography, but the analysis of the data showed no significant increase in counts in the later time bins. This could be due to poor signal to noise due to the reduced output from the DAN PNG. We are also currently investigating if these data may be explained by the geometry at these locations or by differences in geochemistry.

Conclusions: For active neutron measurements acquired near the Mont Mercou, Jocko Butte, and Bolivar topographic features, there is a statistically significant increase in the measured thermal neutrons arriving later (i.e., after the primary thermal neutron die-away peak) when compared to measurements made at nearby locations but away from the topographic feature. This suggests that active neutron measurements may be used to interrogate the hydration and geochemistry of nearby topographic features, however, more measurements are required to characterize the behavior of the die-away curve. To continue this work, we will be expanding our simulation geometries for better comparisons to each location. We will also be investigating differences in geochemistry using other datasets to better understand the increase in thermal neutron counts near topography. As Curiosity continues its traverse into areas abundant in high-relief features, this work becomes increasingly important to understand the topography’s effect on DAN detector response and may enhance the capabilities of the active neutron investigation to interrogate the hydration and geochemistry of nearby topographic features.

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References: [1] Mitrofanov, I.G., et al. (2012) *Space Sci. Rev.*, 170, 559-582. [2] Dibb, S., et al. (2019) *LPSC L*, Abstract #2908. [3] Berner, A., et al. (2022) *LPSC LIII*, Abstract #2596. [4] Hardgrove, C., et al. (2011) *Nucl. Instrum. Method. Phys. Res. A.*, 659, 442-455. [5] Abercrombie, S. P., et al. (2019) *LPSC L,* Abstract #2268.