PROBING THE NORTHERN PLAINS STRATIGRAPHY WITH IMPACT CRATERING. L. Pan1 and B. L. Ehlmann1,2, J. Carter3, C. M. Ernst4. 1California Institute of Technology (1200 E California Blvd, MC 150-21, Pasadena, CA, 91125. Email: lpan@caltech.edu), 2Jet Propulsion Laboratory, 3European Southern Observatories, 4Johns Hopkins University Applied Physics Laboratory

Introduction: Large craters excavate stratigraphy from several kilometers beneath the surface of the planet [1], and are thus good probes for understanding the subsurface. Within the northern plains of Mars, large craters reveal hydrated minerals [2] and mafic minerals [3], interpreted to be Noachian basement and Hesperian lava flows, respectively. These findings open a new window for understanding the northern plains’ geologic history. Here we present first results from an on-going survey of impact craters in the northern plains with mafic minerals and hydrated minerals detections, starting with the largest, previously reported to contain one or both mineral classes. Using simple scaling of impact cratering processes [4], we have estimated the excavation depth of each crater. By doing so throughout the plains in craters of various sizes, we seek to generate local and regional stratigraphic columns to better determine the relationships for different geological units.

Mineral detections: Using visible/near-infrared data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on board the Mars Reconnaissance Orbiter, we did a preliminary survey of large craters in Acidalia and Chryse Planitia. Specifically, we compared CRISM images with the global detection mineral maps [5-6] to characterize the craters with hydrated mineral detections.

To date, we have closely investigated 6 large craters (Figure 1), in the northern plains. Craters Bonestell, Kunowsky, Davies and Wahoo have both mafic minerals and hydrated features (Figure 2a-c) while the smaller ones, Gamboa and Yuti, only yielded mafic detections. Several occurrences of the hydrated features in Kunowsky and Davies showed clear absorptions at 1.4, 1.9, and 2.3 µm, which are consistent with Fe/Mg phyllosilicates (Figure 3). Other hydrated phases are more subtle and difficult to identify. What follows is a detailed discussion of spectral detections in Kunowsky crater.

Example: Kunowsky Crater

Kunowsky Crater is a 62-km-diameter crater in the northern part of Acidalia Planitia (9.3° W, 56.8° N). To date, the most diverse spectral features in Acidalia are found in Kunowsky, where strong olivine signatures are very common on the crater floor (Figure 2a and 3b). They are also found associated with dark sand dunes of mafic composition. Unlike olivine detections, hydrated minerals are more confined, only found within close proximity to the central peak.

There are at least 3 different spectral classes of hydrated minerals in Kunowsky: typical Fe/Mg

Figure 1: Summary of mineral detections in large craters in Acidalia and Chryse Planitia.

smectite with 1.4; 1.9 and 2.3 µm absorptions; chlorite/prehnite phases with 1.4; 1.9 and 2.35 µm absorptions; and a more subtle hydrated feature with a slight hint at 1.9 µm. These minerals all occur in different patches in the crater near the central peak.

Figure 2: Mineral detections within/around craters: a) Kunowsky; b) Bonestell and c) Davies. Notice the preferred occurrence of hydrated mineral within the central peak for all three craters.
The preferential occurrence near the central peak indicates the hydrated minerals may be the deepest strata excavated by the crater, with the caveat that the excavation signal may be disrupted in the central peaks by impact-induced hydrothermal system, which should be later discriminated with observations of ejecta and central peak clay morphology.

Excavation depth
After careful survey of CRISM maps, scaling relationships were used to estimate the maximum excavation depths of the craters (Table 1). Here with the assumption \( Z = 2.71 \) and \( R_t = 0.65 \) \( R_f \), the maximum excavation depth is given by: \( H_{ex} = 0.195 R_t \), where \( R_t \) is the transient radius and \( R_f \) is the final radius [4]. This gives a simple expression for calculating the original depth of the mafic and hydrated minerals.

Summary and discussion:
From initial study, we have found that excavation depth calculated for the largest craters agrees with the idea that any phyllosilicate-bearing units are more deeply buried than olivine-bearing units.

Similar-sized large craters near outflow channels had weaker detections than craters further north, e.g. there band depths at Wahoo crater were weaker than at Kunowsky. This could be a result of mantling by sediments from the outflow channels, so infilling of craters that might influence detectability of phases will be examined in future work with high-resolution imagery. However, the fact that a smaller fresh crater (Yuti) yields strong olivine detections suggests that the mantling layer can be penetrated by craters smaller than 20 km. A careful study of smaller craters might be fruitful.

Future work:
The survey of impact craters with CRISM-discriminable mineralogy within the northern plains will continue, especially with observations of impact ejecta to distinguish between hydrothermal alteration and impact excavation scenarios. With a more complete database of crater detections in the northern plains, two analyses should follow.

First, we need to identify the relationship of crater size/location and the mineral detections. Second, we’d want to quantify the layer thickness using the Maxwell Z-model to characterize the impact cratering process and apply that to large craters with typical mineral detections and clear geological units within the crater. These together would help build a more accurate picture of the stratigraphy of northern plains.

Acknowledgements: This research is supported by the NASA Mars Data Analysis program award NNX12AJ43G.

References:

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<th>Crater name</th>
<th>Longitude</th>
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Figure 3: Sample spectra from Kunowsky crater central peak (FRT0000BAD4). a) The hydrated features. The shift in the 2.3 \( \mu m \) absorption band indicates a diverse mineralogy from Fe/Mg smectite to chlorite etc. b) Olivine detections in Kunowsky. In some cases (cyan and blue) the olivine is mixed with a hydrated feature resulting in a subtle absorption at 1.9 \( \mu m \).