NEW ANALYSIS OF HYDROGEN ABUNDANCE IN THE SHEEPBED MEMBER OF YELLOWKNIFE BAY USING *IN SITU* GEOCHEMICAL DATA

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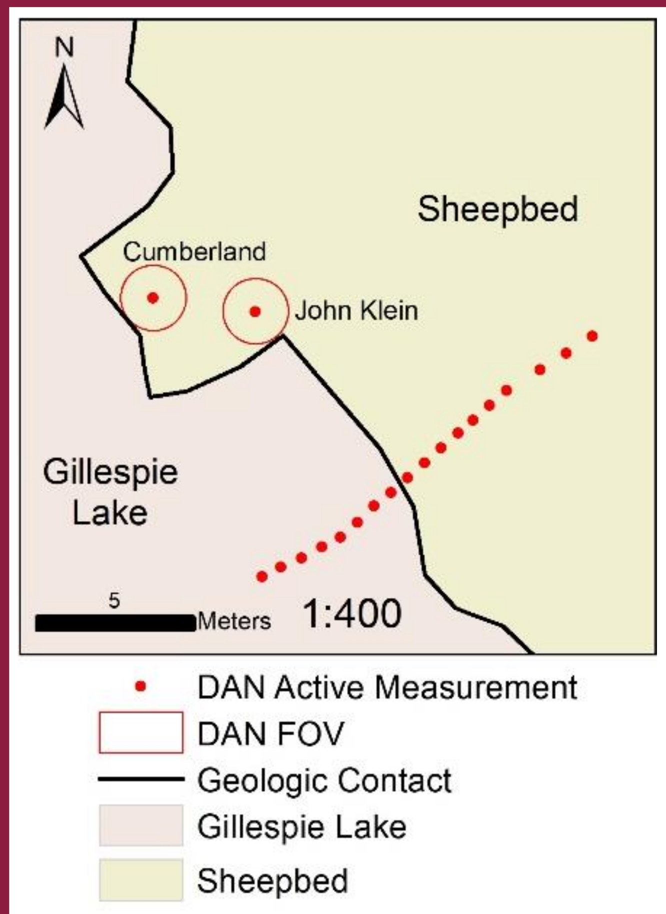
Key Points

- We constrain the bulk geochemistry and hydrogen abundance of a martian mudstone using active neutron data.
- Our modeling differs from previous efforts by using:
  - *In situ* geochemical data
  - Isotopic abundances
  - An updated, higher-fidelity, rover model
- Our models show a 6 cm thick top layer depleted in hydrogen at the Sheepbed mudstone drill sites.
- Locally, the dehydrated top layer is also enriched in neutron absorbers, consistent with APXS data trends at most drill sites.



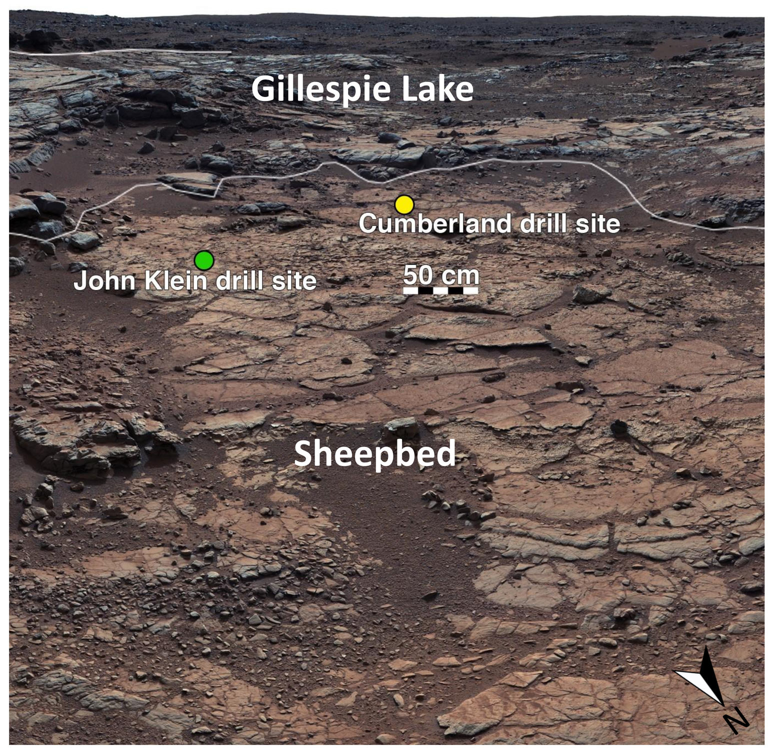


Figure 1: Geologic map modified from [1] (left) and annotated MastCam mosaic (right). Image credit: NASA/JPL-Caltech/MSSS

Setting and Measurements

- The John Klein (JK) and Cumberland (CB) drill sites are in the Sheepbed unit, a lacustrine mudstone in Gale crater, Mars [1] (Fig. 1).
- *In situ* data indicate that hydrogen [2] and Σ_{abs} may increase with depth in the Sheepbed (Fig. 2).
- **We model the subsurface using *in situ* elemental/WEH abundances in a top layer, and vary these abundances in a bottom layer.**

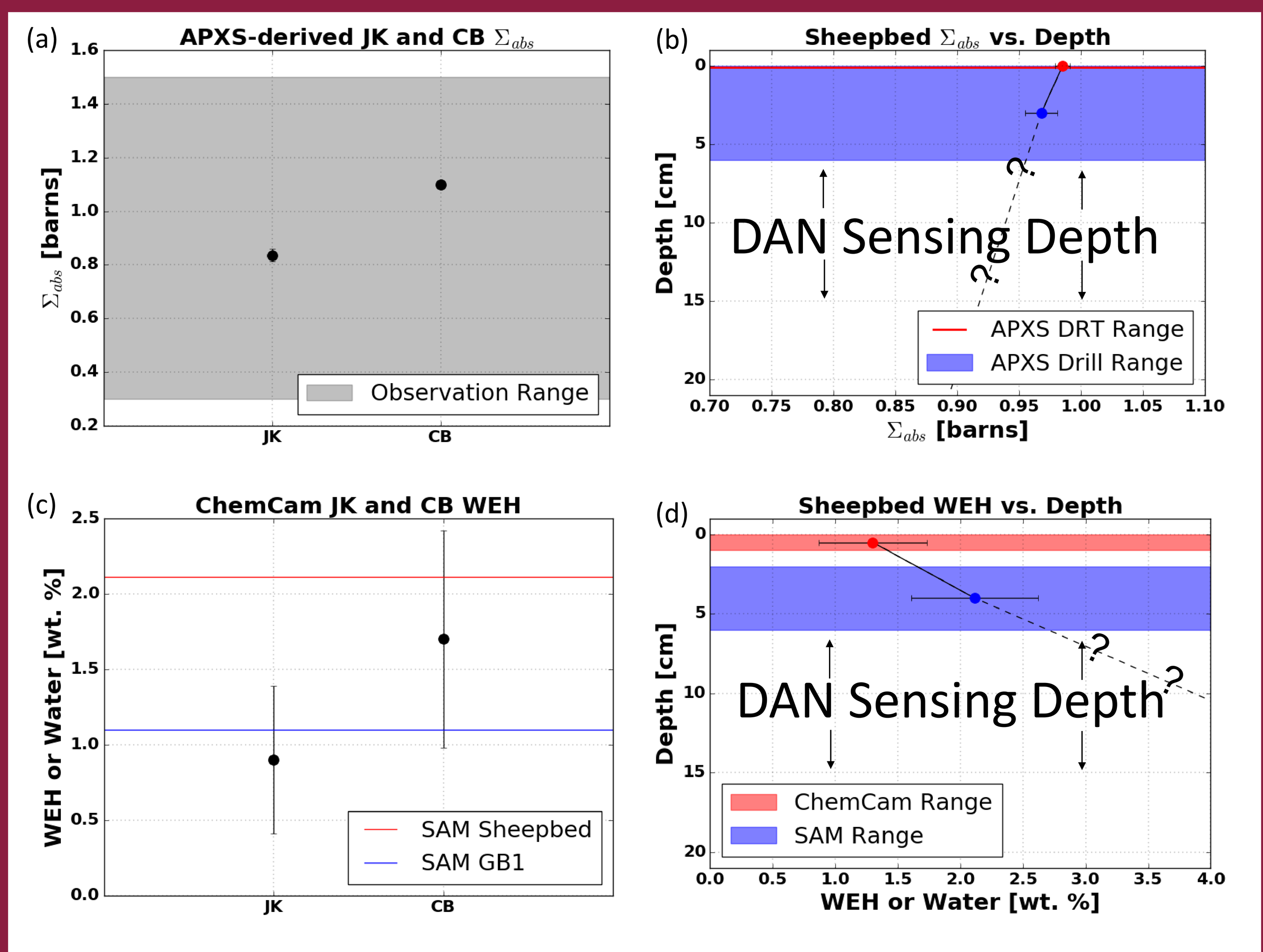


Figure 2: Neutron absorption cross section (Σ_{abs}) is the probability of a neutron being absorbed in a material. (a) Σ_{abs} from drill tailings of the JK and CB sites. (b) The mean drill value is less than the mean surface (DRT) value. (c) ChemCam WEH values from JK and CB are less than the SAM value. (d) This suggests WEH increases with depth.

Cumberland Simulations

- We simulated the previously published best-fit model for the CB site (Fig. 3a) [5] using isotopic abundances and an updated neutron transport model including interactions with the rover body/wheels.
- Our models used *in situ* ChemCam WEH atop a layer of variable WEH, with *in situ* APXS geochemistry in both layers.
- **Our best-fit CB site model had geochemistry derived from the JK site in both layers and 2.9 wt. % WEH in the bottom layer (Fig. 3b).**
- Our model fits the DAN data from CB better than the previous best-fit model (Fig. 3c,d).

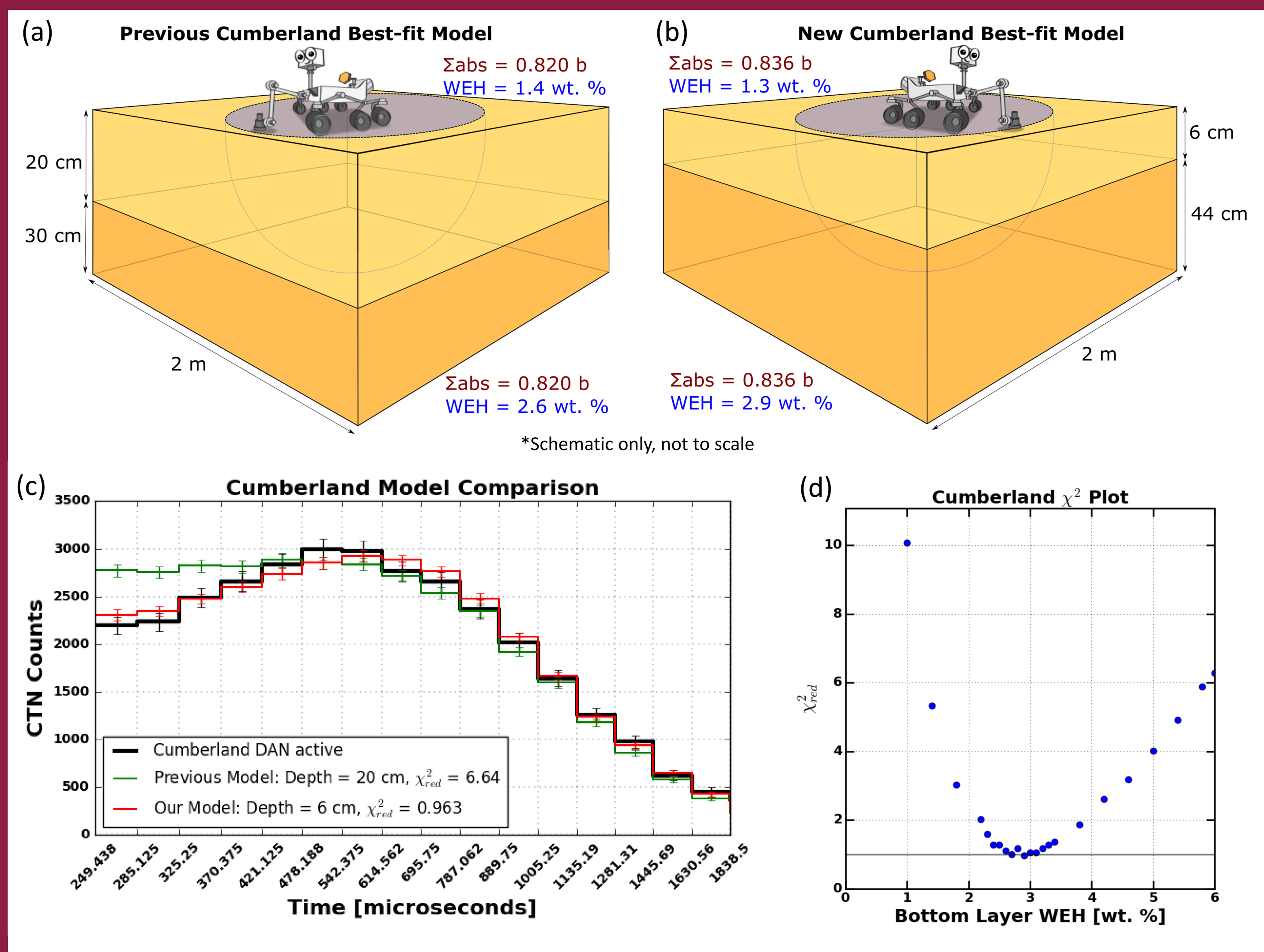


Figure 3: (a) The previous best-fit CB model [5]. (b) Our new best-fit CB model. (c) Plot comparing the previous best-fit and new best-fit CB models to CB DAN data. $\chi_{reduced}^2$ is a goodness of fit measure. We consider a value less than 1 to be a good fit. (d) CB $\chi_{reduced}^2$ values for our best-fit model set.

John Klein Simulations

- Similarly, we analyzed the JK site starting with the previous best-fit model [5] (Fig. 4a).
- **Our new best-fit JK model has a smaller Σ_{abs} in the bottom layer than in the top layer, and a bottom layer WEH of 3.2 wt. % (Fig. 4b).**
- Our model fits the DAN data from JK better than the previous best-fit model (Fig. 4c,d).

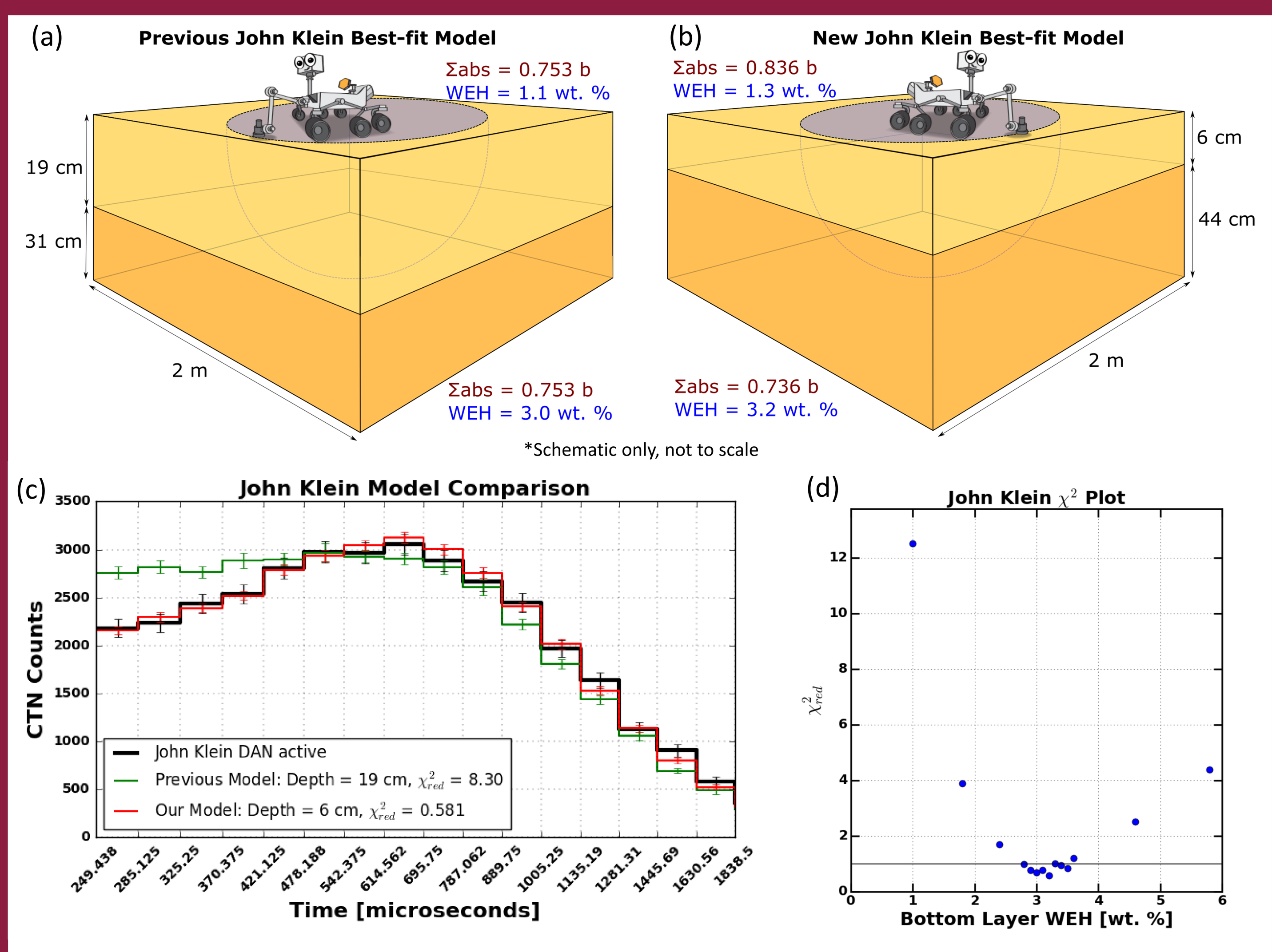


Figure 4: (a) The previous best-fit JK model [5]. (b) Our new best-fit JK model. (c) Plot comparing the previous best-fit and new best-fit JK models to JK DAN data. $\chi_{reduced}^2$ is a goodness of fit measure. We consider a value less than 1 to be a good fit. (d) JK $\chi_{reduced}^2$ values for our best-fit model set.

Discussion and Conclusions

- We have revised the top layer thickness of the JK and CB sites to ~6 cm from the previously published ~20 cm thickness [5].
- Σ_{abs} decreases with depth at JK (Fig. 5a), a trend seen at most MSL drill sites.
- WEH increases with depth in the Sheepbed (Fig. 5b). We propose two preliminary mechanisms by which the surface layer could have been dehydrated:
  - Atmospheric conditions may have dehydrated the near-surface through desorption of intergranular water from the top ~ 6 cm.
  - Diagenetic features in the Sheepbed (Fig. 6) have been proposed to be the result of gas bubble exsolution [1,6,7]. The alteration of forsterite to smectite clay could have provided an H_2 source [6]. Our models are consistent with exsolved H_2 gas bubble escape from the near-surface.
- In fine-grained terrestrial sediments, dehydration reduces erodibility [8,9]. Dehydration could also have affected the geomorphologic history of the Sheepbed, helping preserve it as a resistant unit.

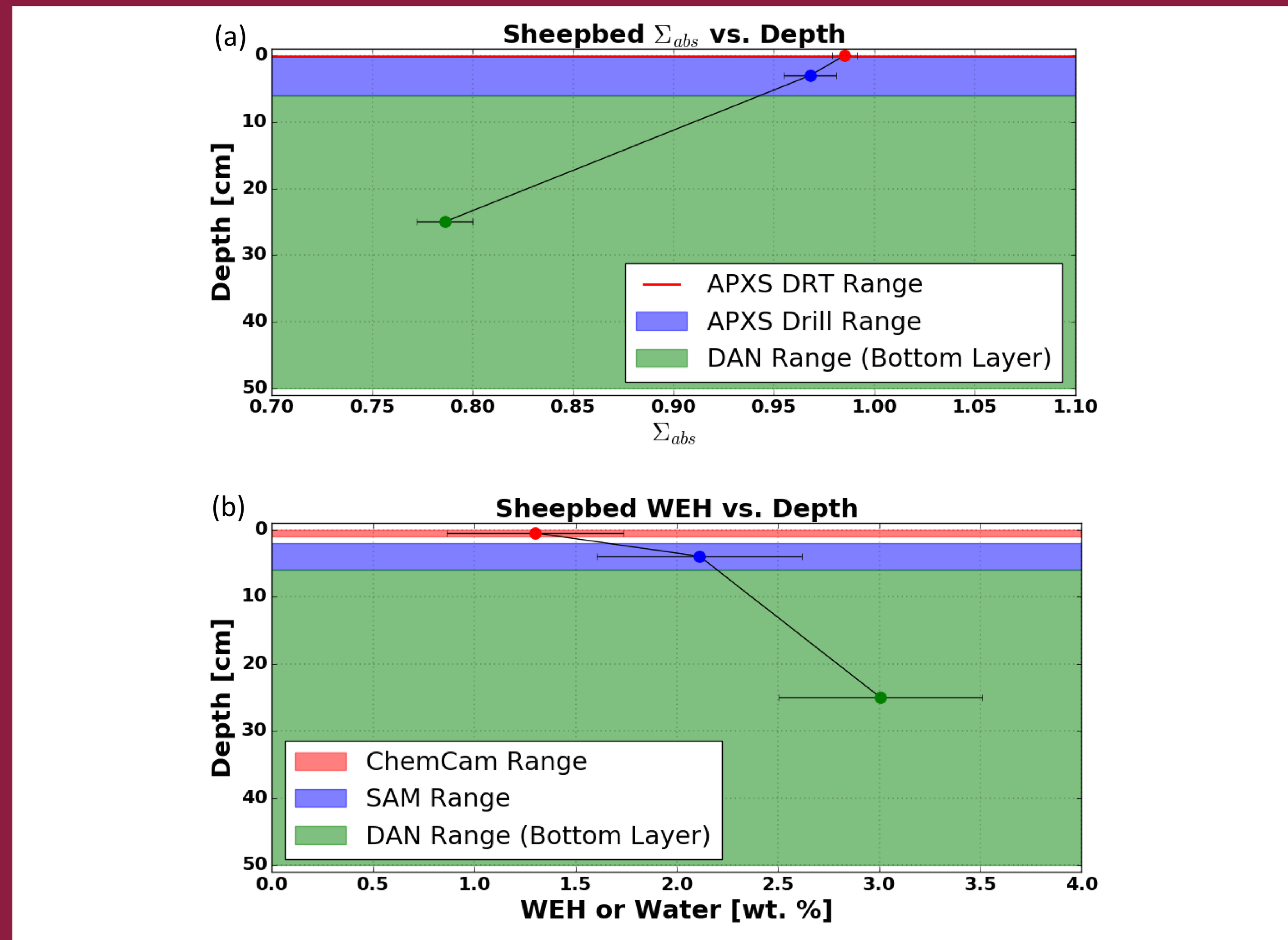


Figure 5: (a) Observed Σ_{abs} depth-dependence in the Sheepbed member. This plot shows that neutron absorbers are enriched in the near-surface with respect to the subsurface. (b) Observed WEH depth-dependence in the Sheepbed member. This plot shows that WEH increases with depth, resulting in a dehydrated surface layer.

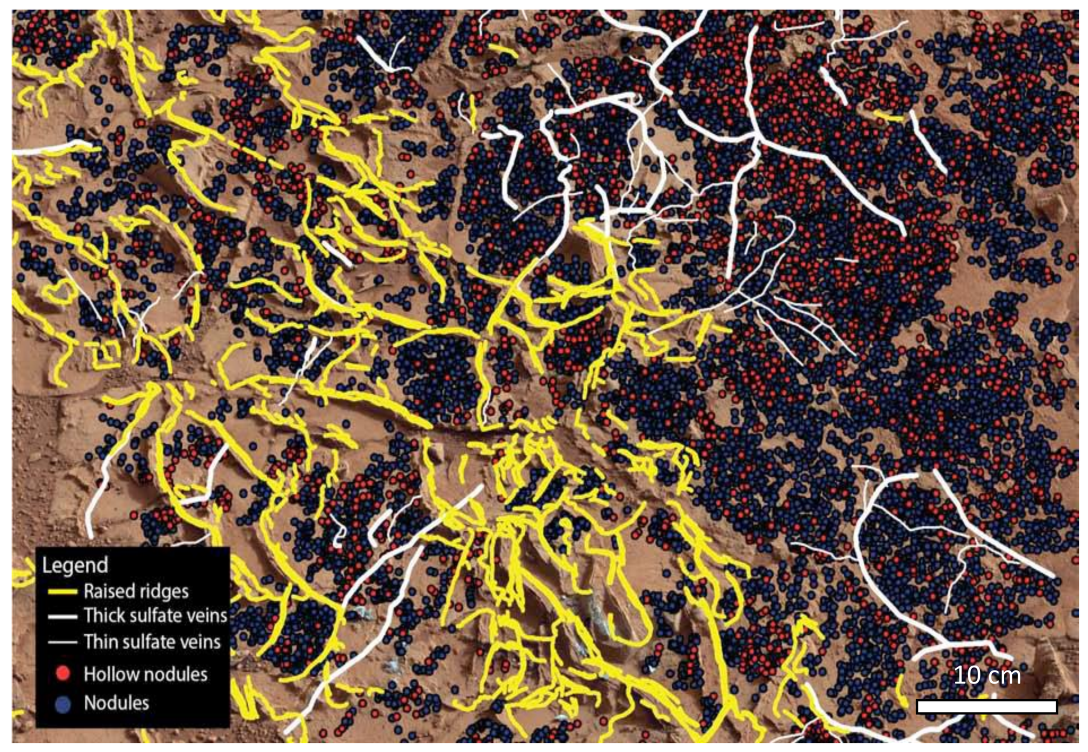


Figure 6: Diagenetic features observed near JK. Hollow nodules and raised ridges have been proposed to be the result of gas (possibly H_2) exsolution. The surface dehydration observed in our models is consistent with preferential loss of H_2 from the near-surface. Image modified from [1].

References

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