Exploring Regolith Depth and Cycling on Mars

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Introduction

A widely accepted model for Mars's upper subsurface is a fractured crust buried by a surficial regolith of variable thickness (e.g., Fig. 1). Regolith is typically poorly-sorted uncemented sediment with high porosity, and underlying basement materials may be fractured, but basically remains in place. At some depth, the fractures in this basement bedrock close due to overburden pressure.

This model for Mars is based in part on what was learned about the Moon from the lunar seismic experiments. However, high-resolution imaging of Mars from MOC and HiRISE, and of the Moon from LROC, reveal many critical qualitative differences between these two bodies: (1) boulders on the Moon generally have much shorter lifetimes than on Mars, so boulders are less common on the surface of the Moon than on the surface of Mars, (2) unmantled bedrock exposures are more common on Mars than the Moon, and (3) sediment transport processes differ dramatically on these two bodies.

For this reason, we are interested in improved constraints on Mars' regolith depth, with the ultimate goal of understanding these observation in the context of Mars' landform evolution and regolith cycle.

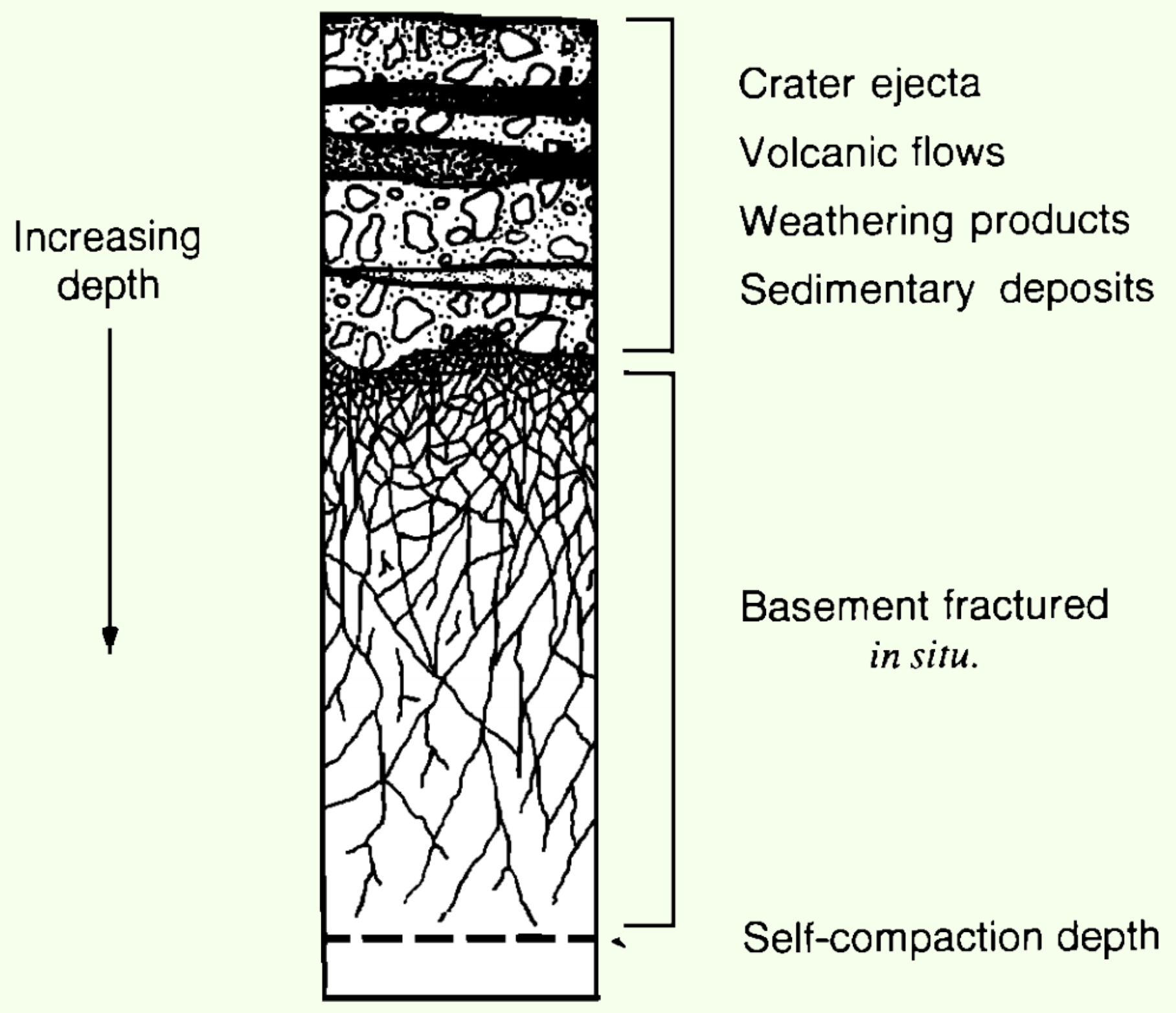

Fig. 1. Notional model of Mars upper crust and regolith [Clifford, 1993].

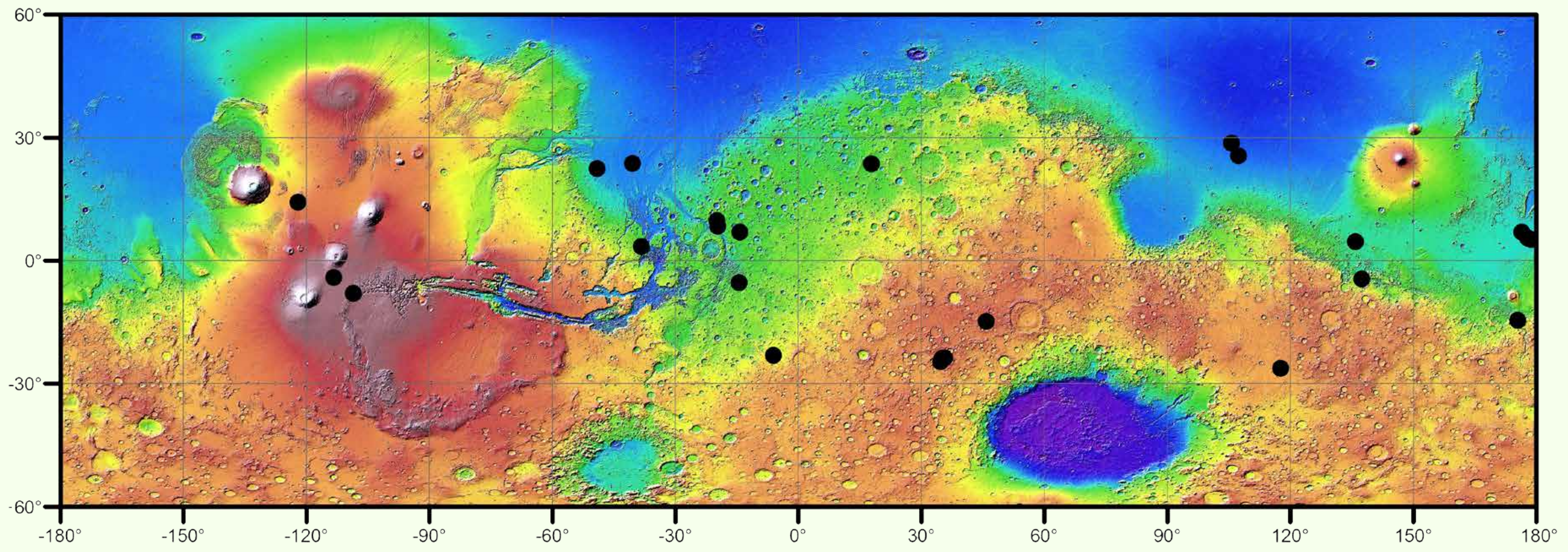

Fig 2. 23 HiRISE images (black dots) were selected on 19 discrete geologic units as mapped on the latest USGS global map of Mars [Tanaka et al., 2014], all between 30°N and 30°S, chosen to avoid regions where Late Amazonian ice-related mantling covers the surface [e.g., Mustard et al., 2001]. Crater data from Platz et al. [2013], Robbins & Hynek [2012], Grant et al. [2014], and Warner et al [2017] were used to calculate model ages based on D≥1 km craters.

Craters Not Excavating Boulders

Craters Excavating Boulders

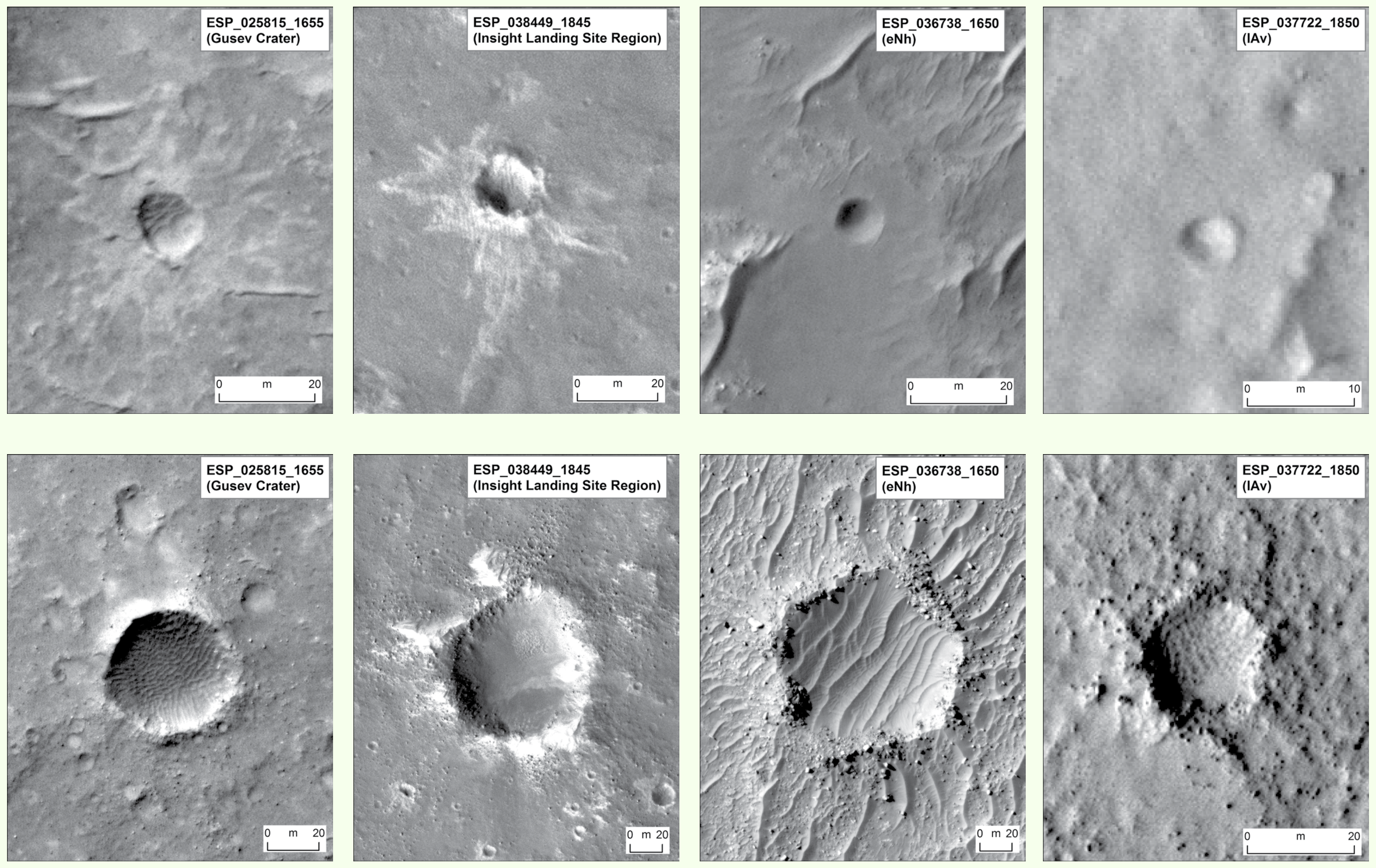

Fig. 3. On each image, fresh craters were classified as either excavating boulders or boulder-free. The presumption of this method is that craters that excavate boulders reached intact bedrock, and those that fail to excavate boulders failed to reach bedrock. Because the maximum excavation depth of simple craters is a well-understood fraction of their size (~0.1D, where D is a crater diameter), this measurement can be used to assess the local regolith thickness.

Fig. 4. Each of these plots shows the number of fresh craters excavating boulders (orange) and that do not excavate boulders (blue) mapped in HiRISE image(s) of a given geologic unit. Degraded craters, ambiguous cases, and obvious secondaries were excluded. The crossover value between not excavating boulders and excavating boulders gives a sense of the typical regolith thickness in a region (~0.1D).

Examples:

Gusev Crater, 25815_1655, 1.7 m	Insight Landing Site, 38449_1845, 1.7 m
Amazonian lava, 17969_1855 etc., 1.3 m (zero in places)	Gale Crater/Peace Fan, 10639_1755, 0.9 m
Plains, W. Arabia (eNh), 39589_1900, 7.7 m (nearby areas less thick)	Ancient highlands, eNh, 35578_1550 etc., 1.2 m (zero (!) in places)

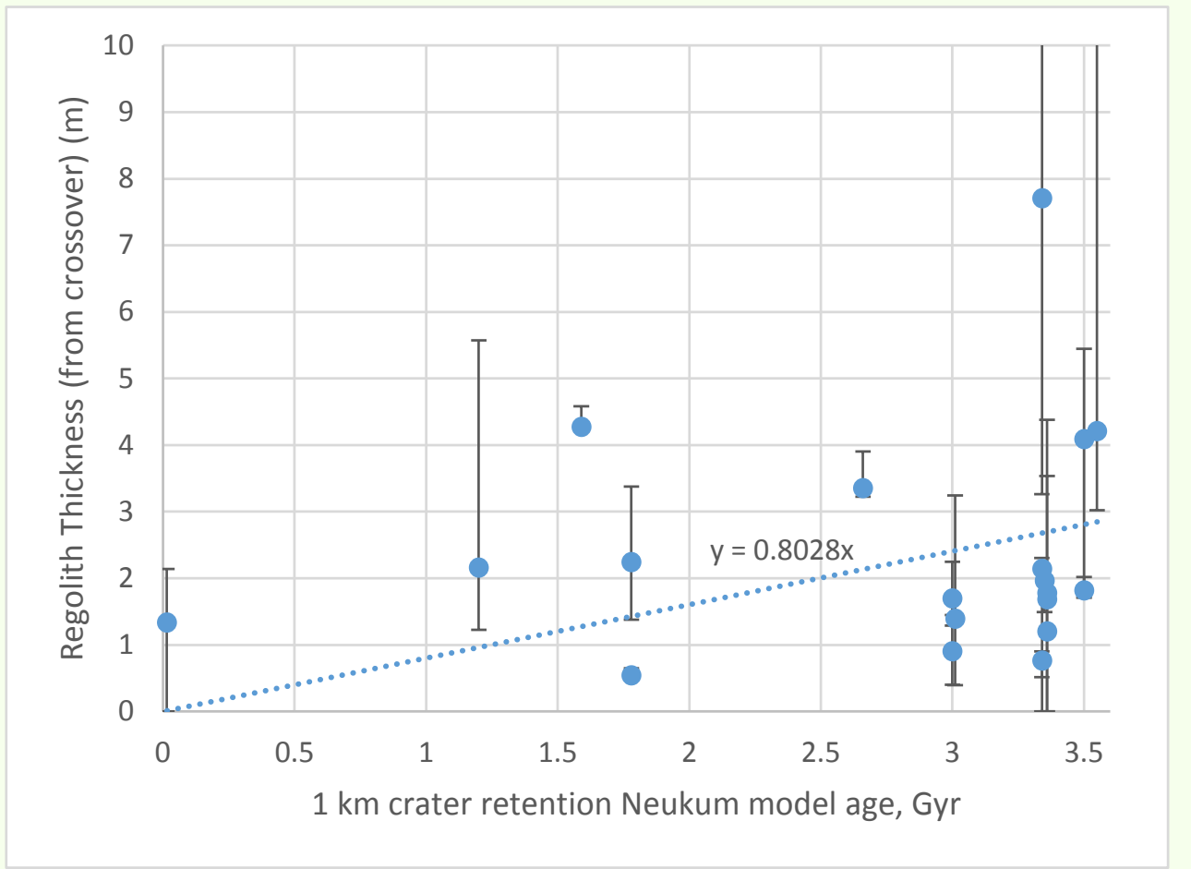

Fig. 5. N(1) age versus the observed regolith thickness. The N(1) crater retention age may postdate the unit age because of poor crater retention. The error bars capture implied variation in thickness. There is a modest correlation of regolith thickness with age.

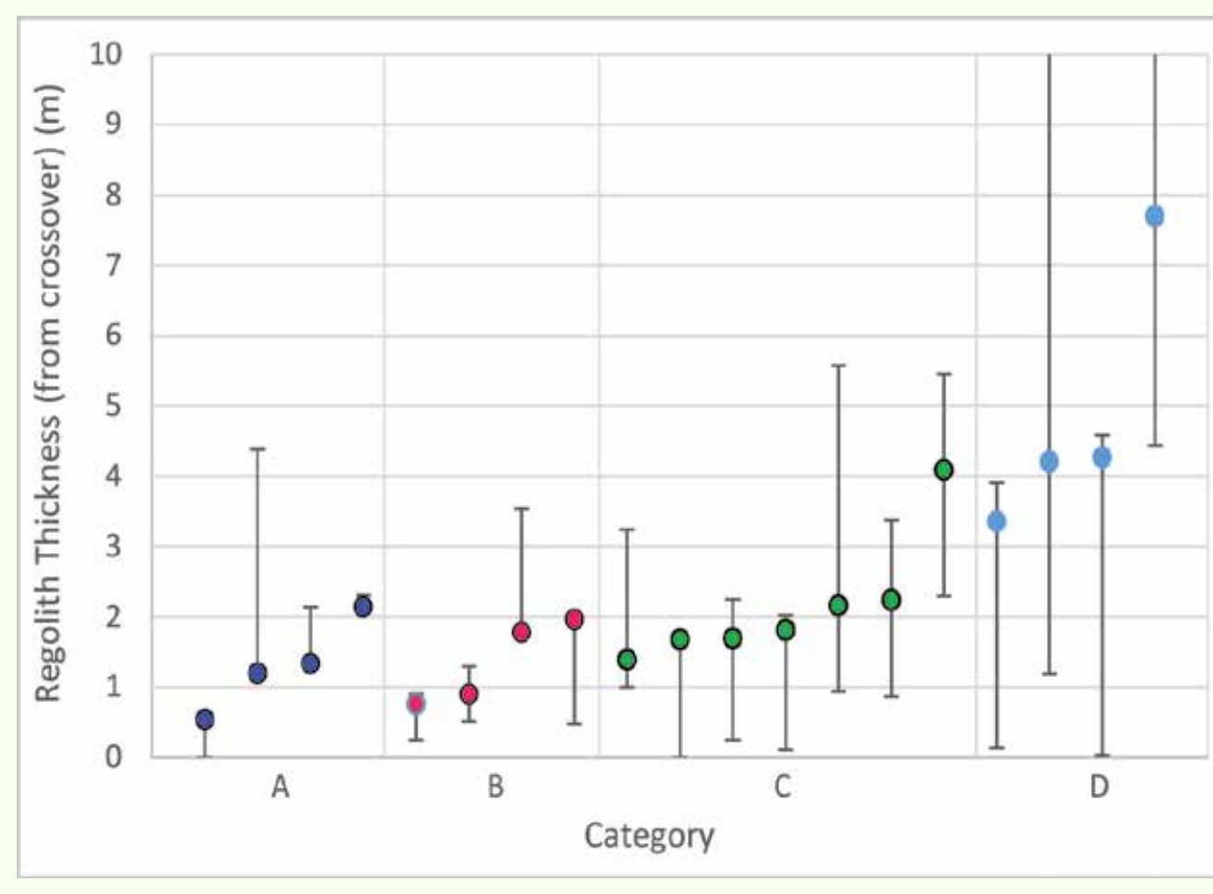

Fig. 6. Classification of texture in images into four classes shows a correlation of regolith thickness based on qualitative assessment and the crater excavation metric.

A: Frequent Bedrock Exposed
B: Some Bedrock Exposed
C: Very Rare Bedrock
D: No bedrock/deeply mantled

Interpretations

- There is a weak trend towards thicker depth-to-bedrock with age. An average, order-of-magnitude growth rate of ~0.8m Gyr^{-1} is suggested (smaller than a 1.8 m/Gyr estimate from Warner et al., 2017 based on very detailed analysis of the Insight landing site). Qualitative assessment of regolith properties from texture are consistent with block excavation measurements.
- This trend of regolith thickening with age is much less strong on Mars than on the Moon, and Mars' regolith stratigraphy is much more complicated. Bedrock in some relatively old regions remains common at the surface.
- Although regolith transport is important on the Moon, it is a comparatively slow, so regolith growth occurs in a transport-limited domain. On Mars, the regolith in some locations is weathering-limited. This means that there are some areas where removal of mobile fines limits the growth of a thick regolith. This may be most efficient in places (e.g., Gale) where the bedrock itself is fine-grained.
- Some young terrains are very deeply buried by dust (e.g., many meters thick burial of young lava flows on Tharsis). The rapidity with which some of these units were buried implies that the specific sinks for fines may be volumetrically important when assessing the regolith cycle of Mars.

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