THE DISCOVERY OF COLUMNAR JOINTING ON MARS. Moses P. Milazzo[1], Windy L. Jaeger[2], Laszlo P. Keszthelyi[2], Alfred S. McEwen[1], Ross A. Beyer[3], and the HiRISE Team, [1]*The University of Arizona, Tucson, AZ, USA*, [2]*US Geological Survey, Flagstaff, AZ, USA*, [3]*NASA Ames, Moffet Field, CA, USA*.

1 Introduction: Multi-tiered Columnar Lavas on Mars

While liquid water (and potential life) is the focus of NASA's Mars Exploration Program, Mars is fundamentally a volcanic planet. As such, one of the most promising ways to locate past, near-surface water is to look for lava-water interaction features. HiRISE has already shown unequivocal evidence of such interaction in the form of "rootless" cones in Athabasca Valles [1] and elsewhere. Other expressions of lava-water interaction that we might expect are pillow lavas, hyaloclastites, peperites, maars, and columnar jointing [2]. Here, we report on the surreptitious discovery of columnar jointing on Mars.

In late October, 2007, the High Resolution Imaging Science Experiment (HiRISE) on the Mars Reconnaissance Orbiter (MRO) acquired image PSP_005917_2020, an observation of a large, fresh, unnamed crater near Marte Vallis, centered at 21.52° planetocentric latitude and 184.35° east longitude. This is the first observation of columnar jointing in lavas on a planet other than the Earth. We describe this observation and briefly discuss the conditions under which the columnar jointing may have formed.

2 Description

Figure (1) shows the relevant portion of the HiRISE image. The stack of lavas have been exposed in cross section by the impact. The impact also tilted the strata, which caused a decrease in foreshortening of the columns, allowing us to identify them. The columns and associated features are recognizable in outcrops along the entire length of the crater rim. Some outcrops (Figs.3, 4, 5)show several different layers of columnar lavas, possibly separated by more massive flows, which implies there were multiple eruptive episodes with intermittent joint formation.

The exposures exhibit the classical features seen in multi-tiered columnar jointing on the Earth, including entablature and colonnade (Fig. 3) [3, 4]. Colonnade is typically found in the upper or lower third of a flow and is made up of well-formed columns that are usually perpendicular to the flow base and range in width from less than a meter to two or more meters and can be many meters long [3]. The entablature overlies the basal colonnade and typically makes up the inner one-third or upper half of the flow. The entablature has closely spaced joints (a few to tens of cm) and irregular or hackly columns, which may form fans or other radiating patterns that often are not oriented perpendicular to the base of the flow [3]. Often, when the lavas encounter substantial amounts of standing water, there is a gradation from entablature to pillow lavas [5, 6].

In PSP_005917_2020, the lengths of the columns vary, but can be up to about fifteen meters. The joint spacing widths also vary, from less than a meter to more than two meters. There are some outcrops that have what appear to be rounded boulders near the columns. This softened, rounded appearance may simply be due to dust covering or to non-igneous rocks, or the rounded rocks may be pillows as seen at the bases of columnar basalts in the Columbia River Basalts (CRBs) [5, 6]. This possible interpretation is hampered by the fact that the scale of these features is at the edge of HiRISE resolvability. In Figures (3 and 5), we see distinct layers of columns and of entablatures, indicating multiple lava flow events, each with entablature and column formation.

3 Discussion

On the earth (Fig. 2), entablature forms when lava is chilled when water inundates the solidifying lava, infiltrating into hot cracks, causing advective cooling, greatly accelerating the cooling rate beyond that achievable by conduction alone. The joints are formed as the lavas contract and cracks extend perpendicular to the cooling front. Thus, the joint spacing is a function of cooling rate, with faster cooling producing smaller joint spacing *e.g.*[3]. Moderately heavy rainfall is inadequate to quench flow interiors and form entablature. It is expected that extensive flooding by lava-dammed rivers or extremely heavy rainfall ($\gg$ 250 cm/yr) is required to produce entablatures on the Earth, although the heavy rainfall is only necessary during the entablature formation [3].

Is water the driving fluid during entablature formation on Mars? It is difficult to imagine another martian fluid with the properties necessary to advect large amounts of heat over the short time period necessary to form entablature. These exposures are very near Marte Vallis, which has been suggested as a drainage channel from Elysium Planitia into Amazonis Planitia [7]. Elysium Planitia is thought to have been the site of recent, extensive, and likely coincident fluvial and volcanic activity [7, 1, 8].

We suggest that the lavas that formed the entablature seen in this image were emplaced when there was enough liquid water readily available to quench the lavas. One scenario is that lava erupted and dammed a pre-existing channel, then water quickly erupted from the same fissures and flooded the cooling lava. Another scenario is the dike emplacement model of [9], with water flooding followed by lava, then followed by more water.

References

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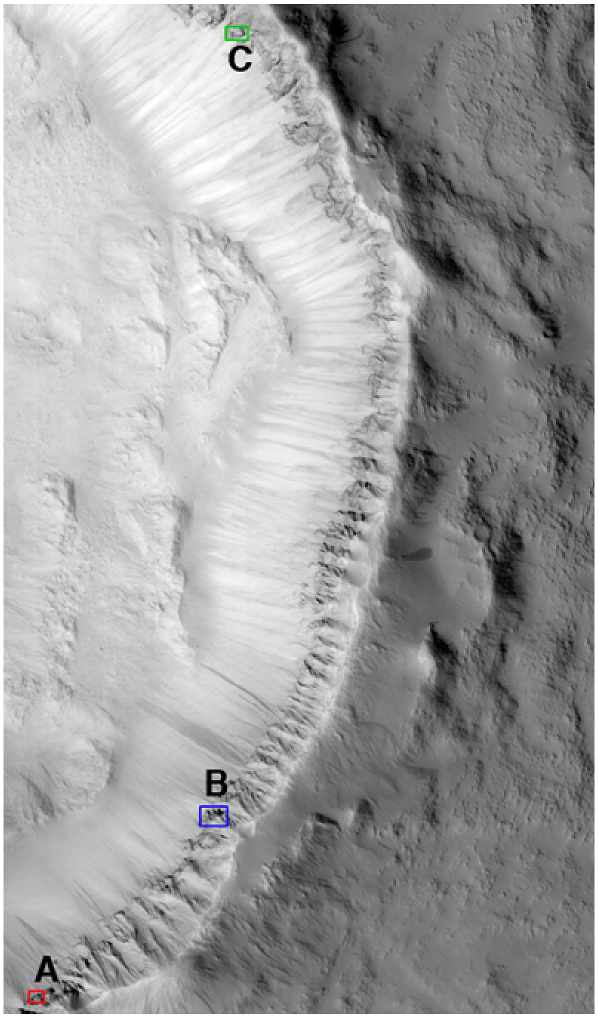

Figure 1: HiRISE image PSP_005917_2020. The columnar jointing is seen in the rocky outcrops that were exposed and tilted by the impact crater. The image has been cropped to fit the page. North is approximately up and to the right.

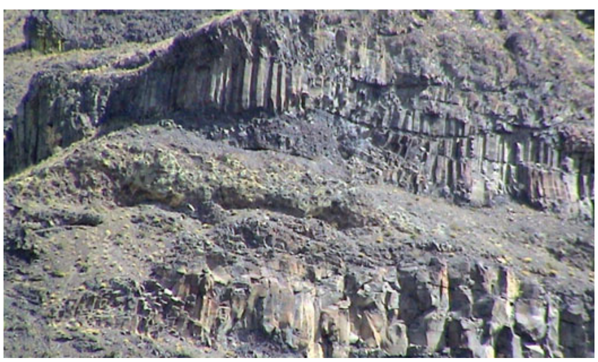

Figure 2: Image of columnar joints in the CRBs. The columns are several tens of cm across. The lumpy, yellow material between the column outcrops is a pile of pillow basalts in hyaloclastite.

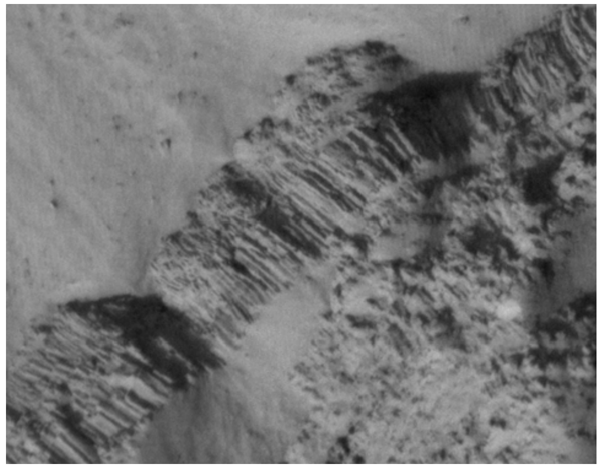

Figure 3: Box (A) from Fig.(1). The most well-exposed columns are seen in this outcrop. Entablature is apparent above and below the columns, suggesting multiple episodes of column formation. The columns are approximately ten meters long and two meters wide. The image is ∼120 meters wide.

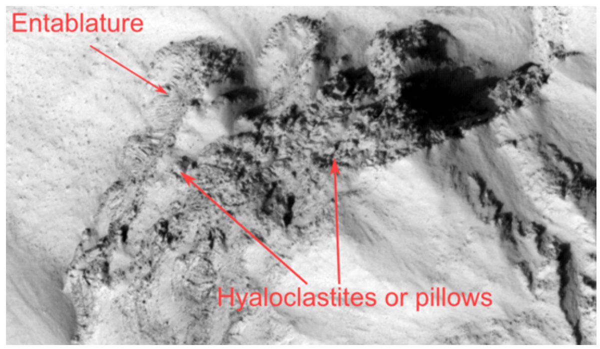

Figure 4: Box (B) from Fig.(1). While some of these features are on the edge of resolvability, we interpret this outcrop to have colonnade, entablature, and some rounded, clumpy features reminiscent of pillows (Fig.2). The image is ∼300 meters wide.

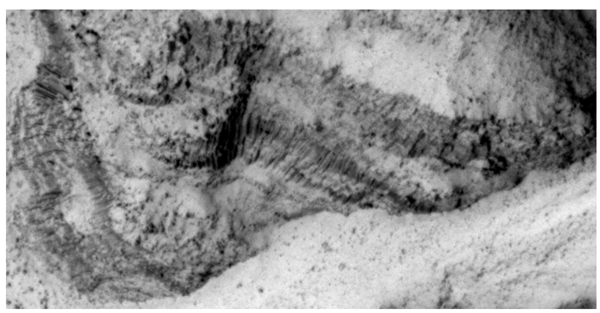

Figure 5: Box (C) from Fig.(1). Multiple and distinct layers of columns and/or entablature are visible at this outcrop. The image is ∼175 meters wide.