The Distribution of Columnar Lavas on Mars as Seen by HiRISE

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Introduction

The High Resolution Imaging Science Experiment (HiRISE) on the Mars Reconnaissance Orbiter (MRO) recently discovered multi-tiered columnar jointing on Mars [1, 2]. Since the initial discovery image, more columns, some with entablature, have been observed at 13 sites. Nearly all of these sites occur in the uplifted walls of impact craters in regions with histories of flood volcanism. Blind extension of the modeling of terrestrial columnar lavas by [3] to the martian columnar lavas and entablature discussed in [2] (and seen in observation PSP_005917_2020) suggest that they cooled over approximately five years, during which time they were subject to multiple episodes of inundation by liquid water.

Formation of Columnar Lavas

In terrestrial lavas, narrow (less than a meter to several meters wide), constant-width colonnade form when still hot lavas are inundated by liquid water [3]. This inundation greatly increases the cooling rate compared with conduction alone, causing rapid contraction of the nearly-solid lavas, which results in stress fracturing perpendicular to the cooling front. The spacing of the contraction fractures (joints) is inversely proportional to the cooling rate [4]. A high cooling rate associated with water influx will generate entablatures (thin, hackly colonnade, sometimes with splaying or radiating patterns) with column widths a few centimeters to tens of centimeters. Entablatures often form in response to irregular (i.e., non-planar) cooling fronts, giving them their splaying, radiating, or other non-parallel patterns; this is because the high rate of infiltration of water may allow it to briefly collect in irregularities within the lava flow, reorienting the cooling front from the usual top-down orientation. A lower (steam and water convection-controlled) cooling rate generates colonnade with widths less than a meter to several meters, usually with vertically aligned joints. HiRISE has a resolution of about 75 centimeters to 1 meter (a scale of 0.25 to 0.3 m/pixel), so many of the most definitive features are at the limit of detectability.

Identifying Columns on Mars from Orbit

Most observations of martian columnar lavas to date occur in the uplifted walls of relatively uneroded impact craters. The uplifting and tilting of horizontally oriented columnar lavas during an impact decreases the foreshortening of the columns, making identification from orbit possible. Large piles of blocks at the feet of cliffs—a la Devil's Postpile in California—are not seen, probably because there is no efficient mechanism to remove dust from the blocks once it is deposited. It seems likely that there are many more sites of columnar lavas that are invisible to orbiting spacecraft due to the geometry of the columns; long, skinny, vertically oriented columns are difficult to identify from above.

HiRISE has observed other types of jointed rocks, some with columnar aspect ratios. For various reasons, including geologic context, we do not interpret all of these as columnar lavas. The observations listed here all contain features we interpret as possible or likely columnar jointing in lavas, sometimes with entablature.

Distribution of Columnar Lavas on Mars

Table 1 [2] lists the observations that show columnar jointing; a thorough search through the many thousands of HiRISE images is ongoing.

Figure 1 graphically shows the 13 sites of possible columnar jointing (with or without entablature) identified with yellow dots and observation IDs. We will present an updated map at the conference.

References

[1] Milazzo, MP, Jaeger, WL, Keszthelyi, L, et al. *LPSC 39* 2062–+ (2008). [2] Milazzo, MP, Keszthelyi, LP, Jaeger, WL, et al. *Geology*, 37:171–174 (2009). [3] Long, P and Wood, B. *Geol Soc Am Bull*, 97:1144–1155 (1986). [4] Lore, J, Gao, H, and Aydin, A. *JGR*, 105:23695–23710 (2000).

Table 1: List of HiRISE observations that may show columnar jointing

Observation ID	Latitude[a]	Longitude[a]	Confidence	Entablature?	Exposure[b]
PSP_002266_2190[c]	38.54°	137.38°	Possible	No	Crater wall
PSP_002411_2190[c]	38.55°	137.38°	Possible	No	Crater wall
PSP_003611_1970[c]	16.93°	141.73°	Possible	No	Crater wall
PSP_005309_2030	22.77°	223.31°	Possible	No	Crater wall
PSP_006681_2045	24.21°	203.89°	Possible	No	Crater wall
PSP_007081_1495[c]	-30.39°	89.31°	Possible	No	Crater wall
PSP_007437_1495[c]	-30.40°	89.31°	Possible	No	Crater wall
PSP_007843_1905	10.29°	156.86°	Possible	No	Cerberus Fossae
PSP_007856_1490	-30.72°	166.68°	Possible	No	Crater wall
PSP_007829_2045	24.11°	177.43°	Likely	No	Crater wall
PSP_004151_1810	0.87°	160.69°	Likely	No	Crater wall
PSP_004244_1970[c]	16.94°	141.73°	Definite	No	Crater wall
PSP_009863_1465	-33.20°	86.62°	Definite	No	Crater wall
PSP_004044_1640[c]	-15.71°	203.62°	Definite	Maybe	Crater wall
PSP_004110_1640[c]	-15.71°	203.62°	Definite	Maybe	Crater wall
PSP_007921_2015	21.27°	185.47°	Definite	Yes	Crater wall
PSP_005917_2020[c]	21.52°	184.35°	Definite	Yes	Crater wall
PSP_006774_2020[c]	21.57°	184.30°	Definite	Yes	Crater wall
PSP_006985_2020[c]	21.52°	184.20°	Definite	Yes	Crater wall
PSP_007341_2020[c]	21.58°	184.30°	Definite	Yes	Crater wall

[a]Planetocentric lat., east lon. [b]Geologic context [c]Stereo pair or repeat observation. Data location: `http://hirise.lpl.arizona.edu`.

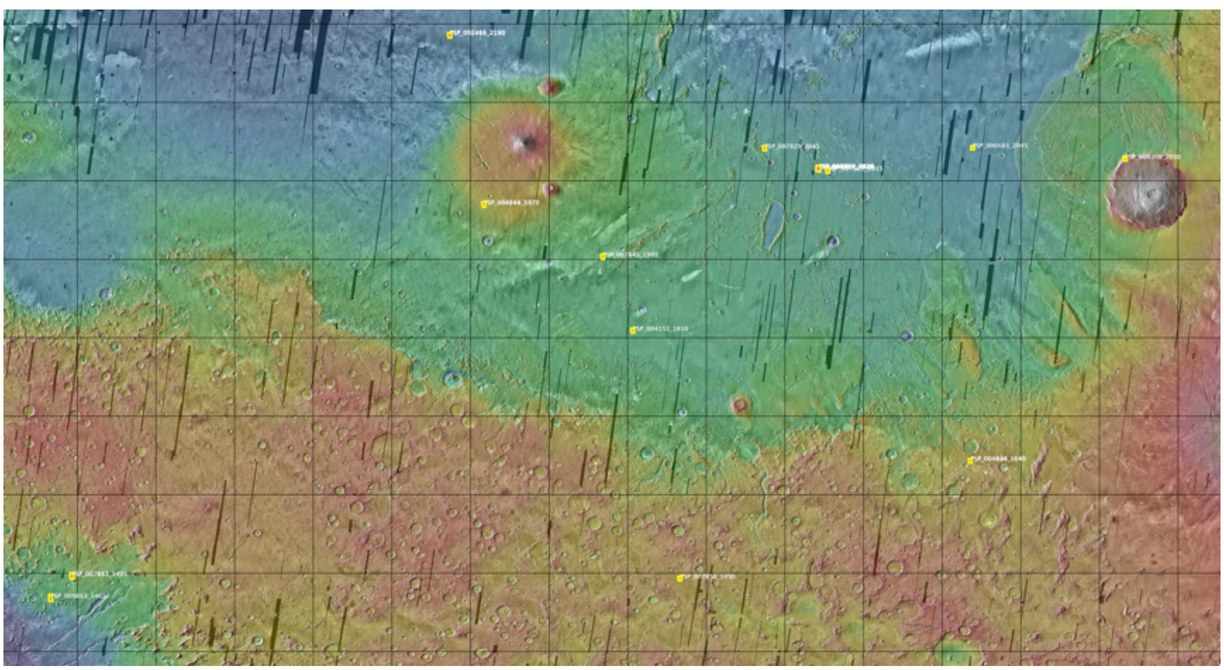

Figure 1: Locations of columnar joints observed by HiRISE on a combination of the THEMIS daytime mosaic and MOLA colorized topography; black areas are where the THEMIS mosaic is missing data. Most outcrops are seen in areas with clear histories of flood volcanism.