SLOPE STREAKS AND ITS RELATIONSHIP TO HYDROGEN ABUNDANCES AND THERMAL INERTIA ON MARS: A CASE OF MEDUSAE FOSSAE FORMATION.

S. Mihira[1,2], T. Ruj[2], and T. Usui[2], [1]Department of Earth and Planetary Science, Graduate school of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo, [2]Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), 3-1-1 Yoshinodai, Sagamihara, Kanagawa 252–5210, Japan (shunmihira@g.ecc.u-tokyo.ac.jp).

Introduction: Recent improvements in observation technology using Mars orbiters and rovers have revealed a new path of Mars research. The existence of present-day ice caps in the polar regions [1] and the evidence of hydrous minerals and channel landforms in low-latitude regions have revealed the existence of a thick atmosphere and liquid water on Mars in ancient times [2]. On the other hand, the current Mars is a dry planet, and liquid water has not been reported on the surface. The presence of liquid water on non-terrestrial planets is an important clue to the possibility of the existence of extraterrestrial life.

A slope streak is a narrow linear feature showing an albedo considerably darker than its surrounding area on Mars [3]. They are mainly located on steep slopes in dusty regions in the mid and low latitudes (between latitudes ±40°) of Mars [4]. Slope streaks have often been debated and noted as having been formed by running water on recent Mars [5].

The formation process of slope streaks has not been clear yet. There are hypotheses that this phenomenon is most likely caused by the movement of large amounts of loose fine-grained material on steep slopes like dust avalanches [4]. The avalanche strips away the bright dust layer from the surface, exposing a darker substrate. On the other hand, the role of water and other volatiles in the formation of streaks has also been discussed [3, 6, 7] and taken into consideration. Bhardwaj et al. 2017 [7] found that the distribution of slope streaks coincides with areas of high Water Equivalent Hydrogen (WEH). However, the physical relationship between WEH and slope streaks has not been clear yet. This study aims to reveal the substantive relationship between slope streaks and WEH to understand the formation mechanism.

Methodology: We compared the number of slope streaks in and around the Medusae Fossae Formation (MFF). The MFF is located in the equatorial region (135°E - 257°E, 15°N - 15°S). This region shows the high WEH abundance [8] by epithermal neutron data from the Gamma-Ray Spectrometer [9] onboard Mars Odyssey. Additionally, the region is also one of the areas with a very high density of slope streaks distribution [10].

WEH abundances were measured by Fine Resolution Epithermal Neutron Detector (FREND) data onboard the ExoMars Trace Gas Orbiter [11]. Slope streaks facing the crater slopes were mapped through high-resolution context (CTX) camera images [12] in an area corresponding to the spatial resolution of FREND (1° × 1°) in an ArcGIS environment (Figure. 1). The length of the crater rim in each area was measured and the number of slope streaks was normalized by the length of the crater rim (we define it as slope streak density). Additionally, the thermal inertia values of the craters in each area were also measured to determine the effect of thermal inertia values on the slope streaks distribution. Thermal inertia values were obtained by The Thermal Emission Imaging System (THEMIS) [13] on board the Mars odyssey.

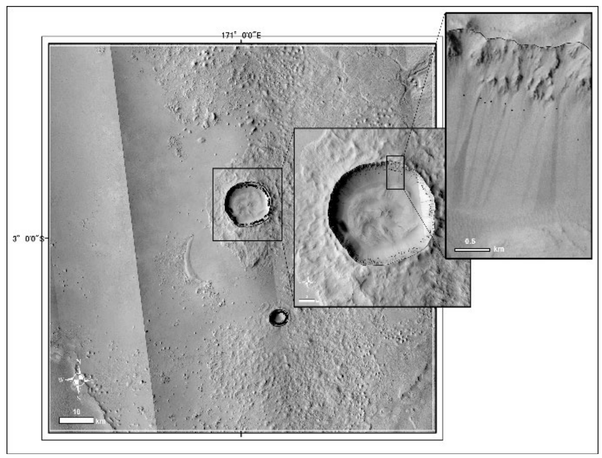

Fig. 1. An area that corresponds to the spatial resolution of FREND. Insets show slope streaks observed there.

Result: We have identified 11,697 slope streaks in 91 areas and measured the thermal inertia of 317 craters in the MFF.

Most of the craters with thermal inertia values below 160 J m^{-2} k^{-1} $s^{-0.5}$ had slope streaks, but contrastingly, about half of the craters with thermal inertia values above 160 J m^{-2} k^{-1} $s^{-0.5}$ did not have slope streaks. We defined 160 J m^{-2} k^{-1} $s^{-0.5}$ as the threshold thermal inertia value that affects slope streak formation (Figure. 2a).

The first results of the comparison of slope streak density and WEH abundances showed no relationship between them. While comparing WEH abundances and slope streak density only for areas with thermal inertia values greater than 160 J m^{-2} k^{-1} $s^{-0.5}$, those relationships showed a clear negative correlation (correlation value is -0.69) (Figure. 2a). This result is opposite to the results of the study by Bhardwaj et al. 2017 [7].

Discussion: The identity of the substance indicated as WEH is not known, but the non-detection of hydrated salts in the MFF suggests that the WEH signal indicates the possible presence of H_2O ice [14]. The negative correlation between slope streak density and WEH abundances suggests that the existence of moisture inhibited the formation of slope streaks by intergranular cohesion. This implication can support the particle flow (dry) mechanism. The initiation of particle movement occurs when the threshold or critical shear stress exceeds the resisting gravitational stress [15]. Because of the difficulties involved in measuring floor stress, the initiation of movement is often defined as a situation where the shear velocity exceeds the threshold shear velocity.

Several models simulate the effect of moisture content on the threshold shear velocity [16, 17]. The threshold shear velocities calculated with the WEH data by the equation conceived by Belly (1962) [16] have a negative correlation with the slope streaks density (Figure. 2b). This negative correlation suggests that moisture on the Martian surface increases the threshold shear velocity and depresses the sand movement, resulting in the low slope streak density. Since shear velocity indicates the likelihood of initiating particle movement, our results showing a greater number of slope streaks in areas with low shear velocity support the hypothesis that slope streaks are formed by a dry mechanism such as particle flow initiated with grain movement.

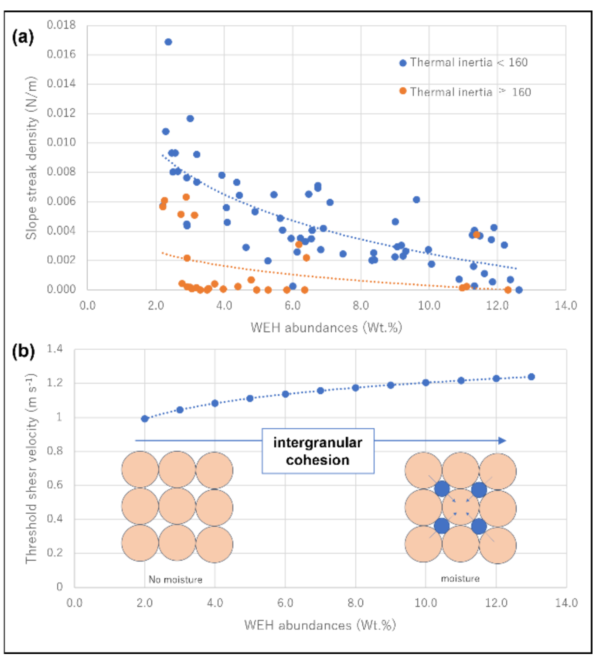

Fig. 2. (a) The relationships between slope streaks density, WEH abundances, and thermal inertia. (b) The change of threshold shear velocity with WEH abundances.

Conclusions: Slope streaks have often been debated as water-related phenomena [3, 6, 7]. Since water is unstable in low latitude regions of Mars, if slope streaks occur as a water-related formation process, our understanding of the Martian hydrosphere would be significantly changed. Although the results of this study do not constrain the formation process of slope streaks, the negative correlation between slope streak density and WEH abundance provides new information for the discussion of the formation process of slope streaks. We propose that evaluating the influence of intergranular cohesion by moisture on Mars and clarifying the relationship between the formation of slope streaks and share velocity is important for understanding the formation process of slope streaks.

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