Dark Streak Features in Mongolia: Implications for Formation Mechanisms of Recurring Slope Lineae on Mars

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Recurring Slope Lineae (RSL) are dark, narrow features that appear and lengthen on steep (~30°) slopes in warm seasons and fade in cold seasons of Mars (e.g., McEwen et al., 2011). Although the formation mechanism of RSL is still in debate, several processes have been proposed, including liquid brine flows triggered by melting of subsurface ice (a wet process) (e.g., Stillman et al., 2016), and granular flows on slopes (a dry process) (e.g., Schmidt et al., 2017). However, neither wet nor dry processes can explain all of the observables of RSL. In especially, the wet process seems to be inconsistent with the absence of absorptions due to liquid water on RSL and the fact that RSL appear only on steep slopes (McEwen et al., 2014).

Here, we report RSL-like dark streak features in cold, arid areas of Khangai Mountains, Mongolia, on Earth. In this area, discontinuous permafrost and underground ice melt seasonally (Szuminska, 2016). We find that dark streak features in this area show seasonal variation similar to RSL on Mars. Although the slope angles of the terrestrial analogues (~10°) are shallow, the observed similarities in morphology and seasonal activity suggest that the streak features in Mongolia can be promising terrestrial analogues of RSL on Mars.

We also conducted geological survey for the terrestrial RSL analogues found in Mongolia in August 2018. By analyzing the visual images taken by a unmanned aerial vehicle, a three-dimensional topographic structure was constructed. In the geological survey, we measured water contents of soils on site on and outside the dark streak features. The mineralogical compositions and grain size distributions were measured for the collected soil samples.

Although no water flowed during the survey, dark streak features appeared in the terrestrial RSL analog sites in Mongolia. The upstream of the dark streaks are dented in a few centimeters, which becomes shallower toward the downstream. These observations suggest that erosion of surface soils occurred along with the dark streak features in the past. This view is supported by our results of the flow accumulation analysis. Although the formation of the dark streaks relate with water flow, darkening itself is not caused by the presence of liquid water. Water contents in surface soils on the dark streaks show no significant difference from those outside the streaks within errors. The surface of the dark streaks contains less bright sands and more dark silts than the surfaces outside the dark streaks. These results suggest that selective traction of the bright sand-sized grains by surface runoff results in remnant of the dark silt-sized grains on the slopes, which darkens the streak features after dryness. The required friction velocity for the traction is estimated to be ~20 mm/sec, consistent with flow rate due to melting of ground ice in the research area.

Based on the formation mechanism of the terrestrial RSL analogues, we can address the two issues in the

wet process for RSL formation on Mars; 1) no remote-sensing detection of liquid water, and 2) the fact that RSL appear only on steep slopes. At RSL sites on Mars, a thin layer of fine soils is considered to cover basaltic bedrocks on the slopes (Ruff and Christensen, 2002). If liquid brine flows due to melting of underground ice, this can remove fine sands on the slopes. Consequently, dark streak features appear on the slopes due to exposure of underlying basaltic bedrocks after dryness of brine. Given the difference in gravity between Earth and Mars, we suggest that a friction velocity of surface runoff similar to the terrestrial RSL analogs can be achieved when a slope with angle > ~25–30° on Mars, if the depth and width of water flow are same. Our results suggest that RSL on Mars would appear only on steep slopes due to its low gravity.

Keywords: Mars, Recurring Slope Lineae (RSL), Terrestrial analogues

