

**DARK LINEAE ON THE EQUATORIAL LAYERED DEPOSITS; ARE THESE RECURRING SLOPE LINEAE (RSL) OR SMALL DEBRIS FLOWS?** D. E. Stillman<sup>1</sup>, R. E. Grimm<sup>1</sup>, F. J. Calef<sup>2</sup>, Y. Lu<sup>2</sup>, and T. I. Michaels<sup>3</sup>, <sup>1</sup>Dept. of Space Studies, Southwest Research Institute, 1050 Walnut St. #300, Boulder, CO 80302 (dstillman@boulder.swri.edu), <sup>2</sup>Jet Propulsion Laboratory, California Inst. of Technology, <sup>3</sup>SETI Institute

**Introduction:** To gain insight into the formation and recharge mechanism(s) of recurring slope lineae (RSL), we have been using HiRISE images to search for candidate RSL sites. As of the December 2016 HiRISE release, we have cataloged 577 candidate RSL sites, of which 74 have been confirmed to exhibit RSL. Confirmed sites show recurrence, incremental lengthening, and fading of dark lineae, while candidate RSL sites have dark lineae that look like RSL but do not possess all three of the characteristics in available imagery. Each site is categorized by its number of RSL characteristics and by a qualitative ranking of the likelihood of it containing true RSL [1]. We speculate that any site rated “good” or above has a better than 50% chance of becoming a confirmed RSL site if adequate HiRISE images can be acquired.

We have identified four RSL regions: southern mid-latitude (SML), Valles Marineris (VM), Equatorial (EQ), and Chryse and Acidalia Planitiae (CAP) [1]. VM has the highest RSL areal density and the longest RSL on the planet. EQ RSL are the least understood, with only the closely-spaced candidate EQ RSL sites within Gale crater studied so far [2]. Another interesting aspect of EQ and VM RSL is that many sites are found on light-toned layered deposits. Many of these layered deposits have spectra indicating hydrated sulfates and gray hematite [3-8]. Furthermore, layered deposits are likely evaporite deposits possibly formed via groundwater-bedrock interaction, groundwater fed springs, or lakes [3-9]. Here, we will show and discuss examples of RSL on equatorial layered deposits and discuss whether these features suggest that they are RSL created via brine or just small rock/debris falls.

**Equatorial Layered Deposit** dark lineae (**Fig. 1**) have been found in the interlayered deposits of VM at Capri, Ganges, Juventae, Coprates, Melas, Ius, Ceti, Candor, Ophir, and Hebes Mensa and in Juventae Chasma [1]. They are also found covering many chaos terrains to the east of VM (Aram, Iani, Aureum, Pyrrhae, Aurorae, and Eos Chaos) and in mounds within larger craters (Gale, Danielson, Crommelin, Firsoff, Coimbra, and Becquerel). Lastly, they are found in small craters in Meridiani Planum and on the Meridiani etched terrain. Of these equatorial layered deposit sites, eight RSL sites have been confirmed (**Fig. 1**; red points). This type of RSL site differs from others in that some of these RSL appear to progress over bedrock.

*Aram Chaos* has the only confirmed EQ site outside of VM and on a layered deposit. At this site there are also many dark lineae that appear to never fade. Meanwhile, neighboring RSL recur, incrementally lengthen, and fade. Non-fading dark lineae have been detected in other locations (e.g., Rauna crater), but not at this magnitude. Further complicating the matter is that incremental lengthening of the EQ RSL sites from 13°S to 4°N appears to occur twice a year, over two periods approximately centered on the equinoxes. Overall, EQ RSL lengthen ~60% of the year, and stay dark and static for an additional ~15% of a Mars year. Sufficient seasonal imagery coverage is important, as HiRISE sampling preferentially occurs during the warmest time (best illumination) of the year when these RSL are always dark.

*Near Opportunity* candidate RSL sites are detected in Cape Victory on the southwest side of Victoria crater and on the east side of Endeavour crater. The candidate RSL in Cape Victory have been imaged via 14 HiRISE images and show recurrence and fading, but no incremental lengthening (**Fig 2**). The ~12-m long RSL were serendipitously imaged via the Panoramic Camera (Pancam) on Opportunity (**Fig 2**). Using a HiRISE- (1 m/px) and Pancam- (0.44 m/px) derived DEM we find that this RSL is on a slope of 30±5°, with a steeper uphill portion (**Fig. 3**). This is the first image of a candidate RSL recorded from the surface!

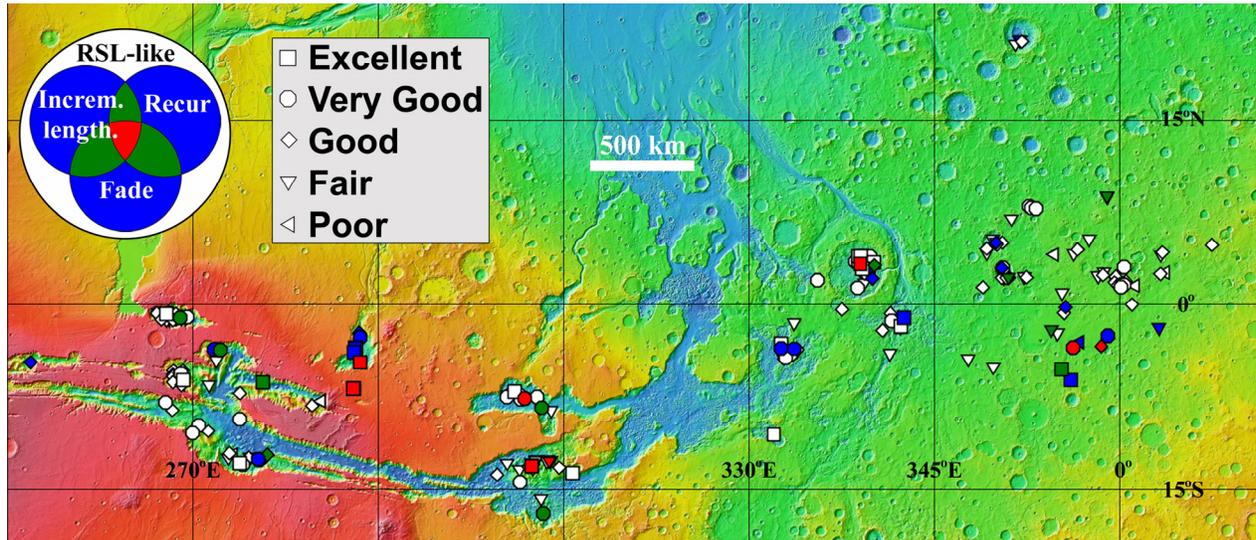
*Near Curiosity* candidate RSL at site 46 [2] have been now been detected to fade and recur. This site is ~5 km from MSL's current location, and MSL is planning on driving much closer, thus enabling future imaging via ChemCam's remote micro-imager [10].

**Conclusions:** Candidate RSL are detected in most HiRISE images covering layered deposits with hydrated sulfates. If additional HiRISE images are able to confirm that RSL are being formed at locations where groundwater reached and altered the surface billions of years ago, this finding would support the hypothesis that RSL are formed and recharged via groundwater and that discharge groundwater is accessible to search for extant life or to be used as a resource for human exploration. Alternatively, if these dark lineae never show incremental lengthening, fading, and recurrence, then we conclude that dark lineae in the hydrated sulfate layered deposits are debris flows. This would suggest these layered deposits are weak and could be used

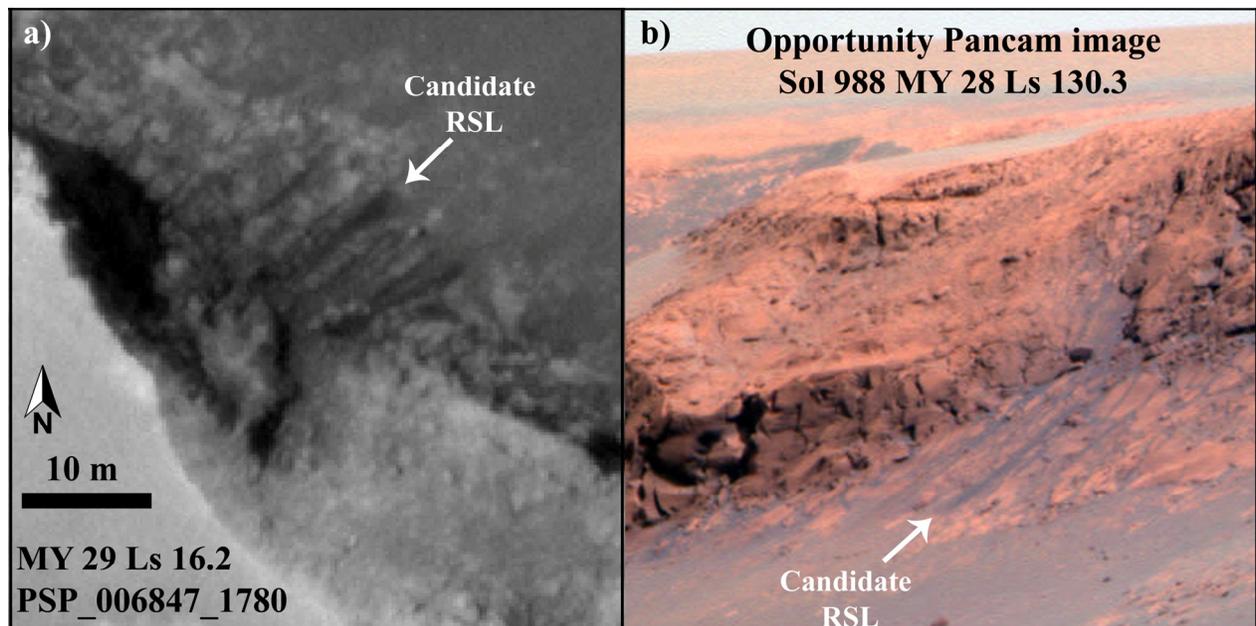
to chemically extract water from as a resource for human exploration.

**Acknowledgments:** This work was carried out at SwRI, SETI Institute, and the Jet Propulsion Laboratory (California Institute of Technology), under a NASA contract. We thank Kiri Wagstaff for helping find Opportunity's image of the RSL in Victoria crater.

**References:** [1] Stillman, et al. (2017) *Icarus*, in press. [2] Dundas and McEwen, (2015) *Icarus*, 254, 213-218. [3] Murchie, et al. (2009), *JGR*, 114, E00D05. [4] Bishop et al. (2009) *JGR*, 114, E00D09. [5] Masse et al. (2008) *JGR*, 113, E12006. [6] Noe Dobrea et al. (2008) *Icarus*, 516-534. [7] Glotch and Rogers (2007) *JGR*, E06001. [8] Wiseman et al. (2010) *JGR*, E00D18. [9] Pondrelli et al., (2015) *GSA Bulletin*, B31225. [10] Anderson, R.B., et al. (2016) *LPSC*, 1770.



**Figure 1.** Candidate and confirmed RSL sites in the hydrated sulfate layered deposits or in craters near the layered deposits. Background map is MOLA topography. Note that the shape is the qualitative ranking [1], with color indicating the number of RSL characteristics.



**Figure 2.** (a) This HiRISE image shows the darkest and longest candidate RSL at Cape Victory on the SW rim of Victoria crater at ~750 m in diameter crater. Other HiRISE images show these candidate RSL recurring and fading. (b) False color Pancam image from Opportunity (MER-B) at Cape Verde on 04 Nov 2006 using filter L2 (red), L5 (green), and L7 (blue). This image shows the candidate RSL beneath Cape Victory from ~300 m away. The arrow points to the same candidate RSL in (a) and (b). Not shown is a HiRISE image that is taken 10 sols after the MER image showing the candidate RSL more faded than they are in (a).