EFFECTS OF VISCOSITY ON THE MORPHOLOGY OF MARTIAN FLOW FEATURES

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Introduction: Martian slope streaks are readily identified in images due to their sharp albedo difference with their surroundings [1,2]. Images show that the hundreds of meters long streaks originate from a point source, widen down slope before narrowing again and terminating in digitate forms [1]. Terrains containing slope streaks often slope between 7 and 25 degrees and occur in areas of low thermal inertia [1]. Both dry flow and wet flows have been proposed as slope streak formation mechanism [3].

Slope streaks were first identified in Viking images but despite subsequent research, their formation mechanism is still highly debated. Although the current preferred theory is formation by dry avalanche [1], the acceptance of the idea of liquid water stability on Mars is producing new models of a wet origin for slope streaks [3]. We have used our previous experience with Mars flow feature simulations [4] to produce slope streaks from liquids of viscosities similar to some liquid brines [5]. Here we report on the similarities in morphology between our simulations and imaged Martian slope streaks.

Methods: Simulations were conducted in a $0.5x3m^2$ wooden flume (Fig. 1); the top 2 meter section is adjustable to different slope angles. A funnel was attached to a 15m long piece of polyethylene tubing with a 19 mm diameter resting on the surface of the substrate. The flume was filled with medium grain size sand, unconsolidated and dry, sieved to a maximum grain size of 600 microns.

To test a variety of viscous solutions, a natural cellulose ether (Natrosol) was added to water. Natrosol, a commercial thickener, alters the viscosity of water without changing other properties, such as density. The powder was added to the water and mixed using a magnetic stirrer for 6-8 hours, depending on the concentration. Three to four drops of food coloring were added to the solution for greater contrast between liquid and substrate.

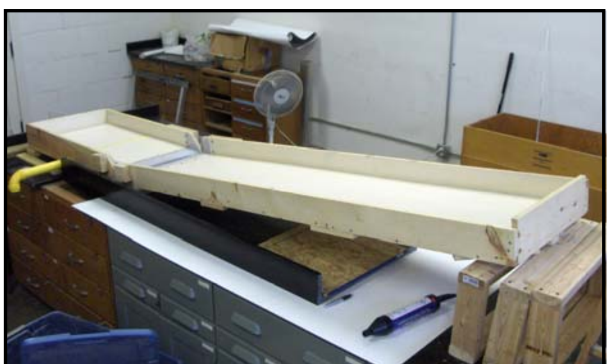

Figure 1: A wooden flume was constructed in order to examine morphology resulting from flow processes. Each wooden square, pictured in the lower right, can raise the flume up 10°.

After mixing, 100 ml of the solution was hand poured into the funnel and allowed to flow down the slope. Flow movement was timed to give an average velocity over 5 cm of the leading bulbous front half way down the slope. Simulations were run at slopes of 10° and 20°, comparable to angles slope streaks are form on. When the flow terminated, images were taken to record morphology and measurements were recorded. At every 5cm interval, the width and depth of the segment was measured. The viscosity of the fluid was calculated from viscosity ball drop tubes.

Results: The viscous fluid (~1.0 Pa s) exited the tubing on the sand, quickly spreading out and then losing energy, resulting in fluid converging to form slope streak like features. Throughout the length of the flow there were tiny levees, approximately one sand grain high, extending from the top of the flow to near the bulb shaped advancing front.. The over all shape was strikingly narrow and linearly except where irregularities in the substrate diverted the flow. Lengths of simulated streaks from higher viscosity fluids (~1.0 Pa s) ranged from 95cm-112cm with maximum widths that ranged between 5.7cm-6.9cm for 20º slope; 58cm-80cm long and 8.3cm-10.3cm wide for 10º slopes.

Less viscous flows (~0.07-~0.02 Pa s) were much narrower than higher viscosities flows and their widest section formed farther down slope. At 10º slope, less viscous flows produced streaks 64cm-120cm long and 4cm-11cm wide. Levees at these viscosities were high and wide enough to be measured (average of 0.20cm high and 0.26cmwide) but were still the only topographic features created by the flow

Discussion: As high viscosity fluid exited the tube, it quickly spread laterally. As it spread, energy is lost and the flow converges to form a narrow shallow channel and lobate shaped front. The viscosity of the solution is high enough that the fluid does not infiltrate far into the substrate and consequently passively glides over the surface. A few grains are incorporated into the flow but are not transported far inwards; this lack of upward transport of the grains suggests the flow is dominated by laminar flow. The only discernable topography of the

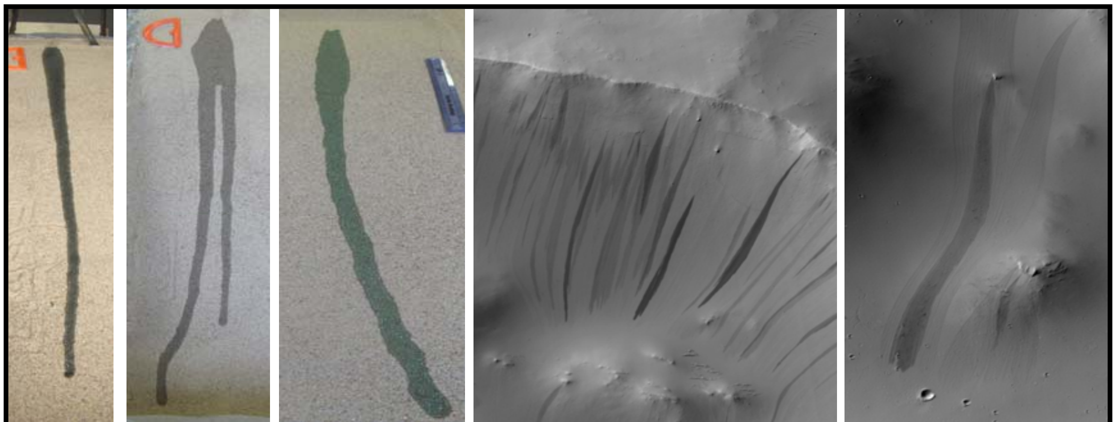

Figure 2: From left to right: A) Simulated slope streak using 100 mL of ~1.0 Pa s; B) simulated slope streak using same viscosity by 200 mL, note the divergence of the flow into two branches, which is similar to many Martian slope streak features; C) simulated slope streak using 100 mL of ~0.070 Pa s, note the difference in morphology from the higher viscosity flows that match even more closely the slope streaks on Mars; D) a group of slope streaks on Mars; E) close up image of a single Martian slope streak. Morphologies shown in A-C are comparable to those seen on Mars in D and E, indicating that slope streaks can be formed by liquid flow.

flow is this slight build up of sand grains on the edges of the flow and the resulting depression from the site of grain removal.

The lower viscosity flow did not spread as laterally as the high viscosity flows, which created narrower and longer streak features. These lower viscosity flows had maximum widths farther downslope from their point source, more consistent with the slope streaks seen on Mars.

Simulations using viscous fluids result in flow morphologies with remarkable similarities to Martian slope streaks. As seen in figure 2, both simulated and Mars slope streaks start at a point source, widens as the flow progresses, narrows, and ends in digitate form. From images, it is obvious that Martian slope streaks follow the local topography of the surface; this also occurs in our simulations. There are no depositional or erosive features associated with Martian slope streak and they are known to preserve underlying patterns; again, our simulated streaks show the same characteristics. Simulated streaks also have similar width to length ratios to Martian slope streaks (Table 1 measurements taken from HiRISE PSP_001656_2175 and PSP_009790_1920).

There are some differences in the appearance of Martian slope streaks to those simulated in the flume. Especially interesting to note is the distance from the point source at which the flow widens and then narrows; in the higher viscosity flows, the widest part of the flow is closer to the point source than the lower viscosity flows and Martian slope streaks. Possible explanations stem from not exactly being able to match the viscosity of the fluid or the local conditions where the slope streaks form.

Table 1 : Width/Length ratios for scale comparison

	Width/Length
Slope streaks on Mars	0.07
1 Pa s simulations at 20°	0.06
1 Pa s simulations at 10°	0.14
0.07-0.02 Pa s Pa s simulations at 10°	0.09

Conclusion: Our simulations have produced long, narrow features with little topography by running experiential simulations with viscous fluids up to 1.0 Pa s. The solution flows out of a source point, over the substrate without affecting the underlying texture and terminates as a lobate front. At slightly lower viscosities, we are creating features that are more consistent with Martian slope streaks. Most important are the overall shape of the feature, the ability to preserve underlying structures and the lack of associated topography, which are problems associated with other dry flow models.

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