CONSTRAINING THE MECHANISMS OF SLIPFACE FAILURE ON MARTIAN SAND DUNES FROM A NEW GLOBAL SURVEY. E. Czaplinski and B. Horgan, Department of Earth, Atmospheric, and Planetary Science, Purdue Univerisity, West Lafayette, IN (eczaplin@purdue.edu)

Introduction: Previous studies have identified a wide range of mass-movement features on martian dune slipfaces, and several possible mechanisms have been proposed for their formation. These mechanisms include sublimation of CO_2 frost, dry sand flow, and sublimation or melting of water ice. However, the origin of some of the features is still unclear. The aim of this study is to determine the range of morphologies of mass-movement features on dune slipfaces and their causes by conducting a global survey to determine the distribution of these features on all dune types and at all latitudes (Figure 1a). Different combinations of these slipface features lead to grouping them into ten different classes. Here, we will discuss the most common combinations observed: alcoves, channels, and fans (ACF), alcoves and channels (AC), alcoves and fans (AF), and slope streaks (SS).

Alcoves: These are wedge or V-shaped indentations that initiate at the brink of the dune. They are wide at the top and narrow down the slipface. Alcoves may be simple or complex. Simple alcoves (Figure 2a) do not contain channels, are relatively narrow (a few to tens of meters wide), and sometimes terminate in channels or depositional fans. Complex alcoves (Figure 2e) are usually wider (tens to hundreds of meters), have channels or other linear features inside the alcove, have steep walls down the side of the alcove, and usually terminate in depositional fans. Alcoves are common in the north polar sand sea and the mid latitudes of both hemispheres. For ACF and AF, we find alcoves on slipfaces oriented in all directions, but they are more common on east/west-facing slopes.

Channels: Channels are long, linear depressions on the slipface that initiate at the termination of the alcove, the dune crest, or further down slope. They can form by themselves, with alcoves, or with alcoves and depositional fans. When isolated channels form, they tend to have thin, straight, and simple morphologies. When alcoves are present, channel formation is almost always initiated at the terminus of the alcove, and their shape is sinuous, straight, or slightly curved. Channels are only found in the southern hemisphere south of 45°S and are primarily on south-facing slopes.

Fans: Fans are conical deposits at the end of an alcove or channel. Depositional fans can be found in conjunction with alcoves, channels, or both (Figure 2e). They are formed at the base of the dune, and can extend for several tens to several hundreds of meters, and can even extend beyond the edge of the dune field in some cases.

Alcoves & Channels (AC): This class is primarily seen on slipfaces oriented to the south/southwest and is restricted to the southern hemisphere from 47°-64°S. At the termini of some of the south-facing channels, several circular, pit-like features were observed (Figure 2b). Channel formation for AC is not entirely understood, but the two main hypotheses are fluidization of sand by water, water ice, or CO_2 ice, and downslope movement of solid CO_2 ice. Since the southern hemisphere winter is longer, more ice can accumulate on the dunes that will later melt and cause fluidization [1]. In the summer, the south-facing slipfaces receive more sunlight, which can sometimes be enough to melt water ice [2]. Previous experiments were more consistent with channels and pits due to CO_2 frost rather than water-based debris flow [3].

Alcoves & Fans (AF): Both simple alcoves (Figure 2d) and complex alcoves (Figure 2e), as well as small and large fans occur in this class. All slipfaces are either oriented east or west, which is indicative of an aeolian origin [4]. Lengths and widths of the alcoves and fans cover a wide range from tens to hundreds of meters. AF have previously been reported as extremely common in the north polar dune sea, and here we report that AF are also common in the midlatitudes of the southern hemisphere (47-54°S).

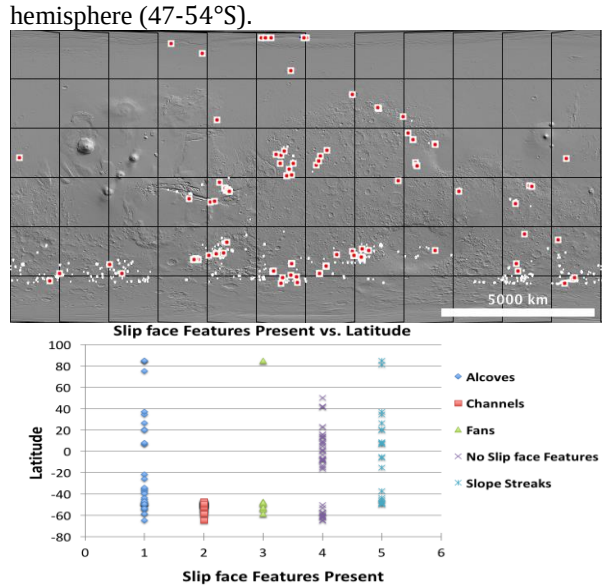

Figure 1: (a) Global distribution of dunes surveyed (red dots) with USGS Mars Dune Database (small white dots). (b) Presence of slipface features across all latitudes.

AF formation in the north polar dune sea has been observed between consecutive summer and spring seasons, and new alcoves are seen beneath spring CO_2 frost [5]. This implies that they formed between mid-summer and early fall, before or concurrent with deposition of CO_2 slab ice in the fall [6]. An origin related to dry grain flow for AF is supported by the fact that alcove orientations are consistent with recent wind directions [6] and morphologies resemble other dry grain flows [7]. The observation that AF also occur at southern mid-latitudes but not equatorial latitudes (where small alcoves and slope streaks dominate, see below) suggests that ice does play a role in the formation of these feautres, perhaps by causing near-surface induration and enhanced oversteepening, and thus larger slope failures [4].

Alcoves, Channels, & Fans (ACF): Where alcoves, channels, and fans are present these features are referred to as dune gullies (Figure 2e). ACF are found only in the southern hemisphere from -47° to -58° latitude. There is a wide range of lengths and widths for each feature (meters to hundreds of meters), except for channel widths which were consistently between 1 and 5 meters. Alcoves in ACF have the most variation in size, since some are small and simple, while others are large and complex. Slipface directions are not uniform, but are somewhat more common on slipfaces facing East. Because temperatures in the spring are too cold for liquid water to be stable, it was proposed that gully formation results from CO_2 sublimation that creates a lubricated flow down the slipface [8].

Slope Streaks (SS): These are very thin, streak-like lines that start at the crest of the dune and run down the slip face. They are identified based on albedo differences compared to the surrounding slipface, which can be either lighter or darker than the streaks. Slope streaks are found on all slipface orientations, and at almost every latitude including the north polar sand sea. Dark streaks are commonly found in association with dust devil tracks (Figure 2c) although they can occur independently as well. However, we have not found an example of bright streaks and dust devil tracks on the same slipface. Widths of the streaks are consistently between 1 and 5 m, but lengths varied from tens to hundreds of meters. Alcoves are sometimes present with the slope streaks. These alcoves typically have lengths of 1-15 meters and widths consistently between 1-3 meters. These alcoves are usually very shallow and undefined. Alcoves and slope streaks have been observed recently by MSL in Gale Crater (Figure 2f). Slope streaks are thought to form by dry grain flows caused by oversteepening of dune slipfaces due to wind and saltation [9]. A previous study in Rabe Crater (35° E, 44°S) showed that slope streak formation is limited to midwinter through midsummer, with few forming in late summer through fall [9]. This suggests that grainflow could be restricted by many factors including indurated/frozen sand or very weak winds [9].

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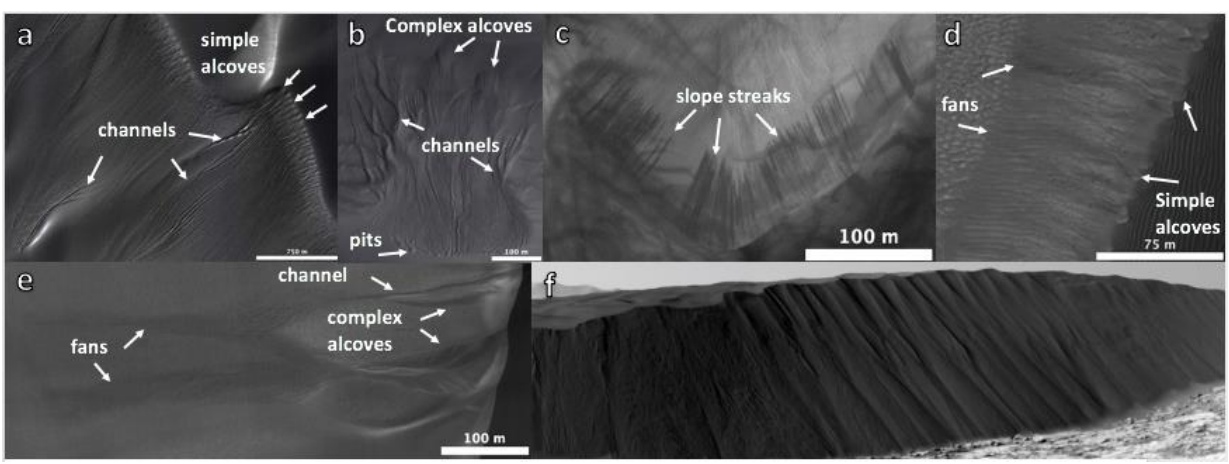

Figure 2: Example HiRISE images of dune slipface features. (a) Simple alcoves and channels (AC) in the Russell Crater megadune (ESP_036357_1255). (b) Complex alcoves and channels (AC) with circular pits at the terminus. (ESP_030624_1295). (c) Dark slope streaks with dust tracks nearby (ESP_025278_1345). (d) Simple alcove and fan (AF) in Russell Crater (ESP_024041_1250). (e) Complex alcove with channel and fan (ACF) in Proctor Crater (ESP_013821_131). (f) Small alcoves and slope streaks on Namib Dune, Gale Crater, as observed by Mars Science Laboratory (NASA/JPL/Caltech/Thomas Appéré).