THE ANTARCTIC PLATEAU: TYPE EXAMPLE OF A PLANETARY WIND DOMINATED LANDSCAPE.

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Introduction: The deep field of Antarctica is a hyperarid, cold, high desert with a landscape dominated by snow or ice and occasional rocky nunataks protruding up through the glacial ice. The surface is never exposed to liquid and is entirely shaped by the competing actions of deposition by snowfall and erosion by ice-carrying wind or sublimation by wind and sun. Regularly spaced landforms are produced in this environment similar to sand dunes and yardangs, features found in other terrestrial and planetary deserts. Under Antarctic conditions, however, the materials have properties that enable them to behave as sand, as a light and strong cemented sedimentary deposit, and as a sublimating vapor, unique except among planetary surface ices. Given the extreme and simple conditions of the Antarctic deep field, this region is a type locale from which to understand the requirements for formation of similar features in other regions on Earth, Venus, Mars, Titan and Pluto.

Depositional to Erosional: During the 05-06, 08-09, 13-14 and 16-17 Antarctic Search for Meteorites (ANSMET) field seasons, several different field sites were visited and these landscapes observed on the Antarctic plateau, at elevations of 7-9K feet ASL, all in locations on or near compacted blue glacial ice (Fig. 1).

Fig. 1. Barchan snow dune, ~3 m across.

During every field season, snows were observed to fall. Under initial conditions of no wind, the snow was deposited in a uniform blanket. Persistent southerly winds are typical for the Antarctic plateau, so as the storm moved out, the winds resumed and blew the snows, often with the texture of small, sand-like ice crystals, into dunes (Fig. 1). At the time of deposition, the dunes were soft, but within a day (24 hour daylight during summer field seasons) the snow dunes were hard enough to walk on without depressing the surface. In the sun and wind the individual snow sands sinter together through metamorphism to form hard and dense firn [1]. Layering of particle sizes from the snowfall and wind transport is visible in this otherwise uniform deposit.

Within several days to weeks, the solidified dunes undergo erosion from wind stripping. This erosion is dominantly as linear striations parallel to and aligned with the wind direction [1]. Fig. 1 shows a barchan snow dune with horns pointing downwind that then underwent erosion from winds in the same direction, forming striations, blunt noses and layer separations.

Fig. 2. Further erosion of firn into striated sastrugi.

Sastrugi and Yardangs: The striations on firn deposits may begin at imperfections, but soon the wind action is communicated across features and a regular spacing is established (Fig. 2). Large peaks and troughs are produced in the resultant form known as sastrugi, a landform unique to snow environments [2]. In many ways, these features are similar to yardangs, wind-carved ridges that form in hyperarid deserts on Earth [3, 4, 5], Mars [3, 6], Titan [7, 8] and perhaps Venus and Pluto [9]. Yardangs are formed in materials like firn – in low-density, indurated volcanic ash or lightly cemented lakebed clays. These materials undergo wind erosion under arid conditions.

The mode of transition from a uniform surface to a yardang-dominated landscape is still under study [e.g.

10], but observing the rapid formation of sastrugi from initial snowfall conditions may provide insight. Before the development in sastrugi of sharp linear peaks and deep troughs, there is the formation of an udulatory surface, with regularly spaced peaks sloping away at low angles (<10°; Fig. 3).

Fig. 3. Undulatory sastrugi in Antarctica, spacing ~1 m. Deeper troughs forming at the margins.

Fig. 4. Undulatory bedrock in volcanic ash in the Puna. Forms starting to protrude up above saltation layer.

Fig. 5. Undulatory surface in interdune clay, small yardang-like feature forming in foreground.

A similar surface is observed in the high Puna desert of Argentina (Fig. 4) in indurated volcanic ash of hardness ~30 MPa [11] (compared with ~2 MPa for clay and between those [12] for firn). The difference in scale may be related to hardness – smaller forms are found in softer materials, such as interdune clays in the Himalayan plateau (Fig. 5), while large forms are in the harder ash [10, 11]. Perhaps this undulatory surface forms under conditions of minor local wind deflection, followed in the right conditions by deeper trough erosion and transition to sastrugi or yardangs.

Sublimation: The most advanced stage of progression of sastrugi formation includes significant sublimation of the material. This occurs through action of sun and wind and is characterized by pitting and fluting (foreground of Fig. 3). We observed pitting to begin to form in new surfaces within ~2 weeks, and then change only slowly, while more advanced pitting was observed in surfaces predating our arrival. This is in contrast to the rapid timescale of hardening (1 day) and formation of undulatory and striated (several days) forms. Sublimation is important in planetary ices, including those of varied compositions in the Kuiper Belt. Several landforms observed on Pluto have morphologies similar to yardangs (Fig. 6) [13], and some dunes observed on Sputnik Planitia have morphologies transitional to sublimation textures [14, 15].

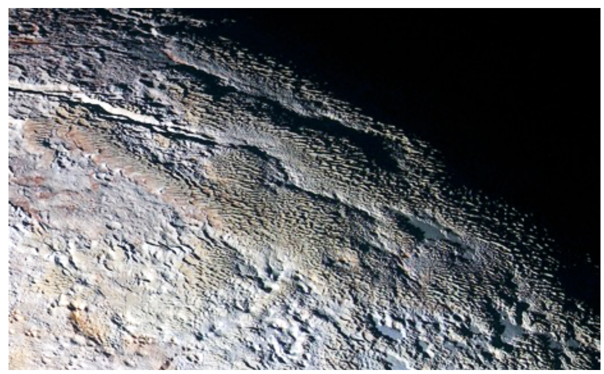

Fig. 6. Snakeskin terrain on Pluto.

Conclusions: The Antarctic deep field has conditions and materials important for understanding the action of wind and sun on a planetary surface in the absence of surface liquids and vegetation. Carefully observing relative timescales for feature formation in Antarctica can help illuminate planetary surface histories.

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