POSSIBLE ROLE FOR SLOPE WINDS IN FORMING GALE CRATER'S MOUND (AND OTHER SEDIMENT MOUNDS ON MARS): THE SLOPE WIND ENHANCED EROSION AND TRANSPORT HYPOTHESIS.

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Summary: The origin and original extent of the mound in Gale Crater (Mount Sharp / Aeolis Mons), the primary target of MSL, is unknown. New measurements of strata within the mound indicate ~3° outward dips (Fig. 1). Although mounds are widely considered to be erosional remnants of a once crater-filling unit, these measurements suggest that the mound's current form is close to its maximal extent. Instead we propose that the mound's structure, stratigraphy, and current shape can be explained by growth in place near the center of the crater mediated by wind-topography feedbacks. Our model shows how sediment can initially accrete near the crater center far from crater-wall katabatic winds, until the increasing relief of the resulting mound generates mound-flank slope-winds strong enough to erode the mound. The slope-wind enhanced erosion and transport (SWEET) hypothesis indicates sediment mounds on Mars formed primarily by aeolian deposition. (Our paper on this topic is in-press at *Geology* [1]).

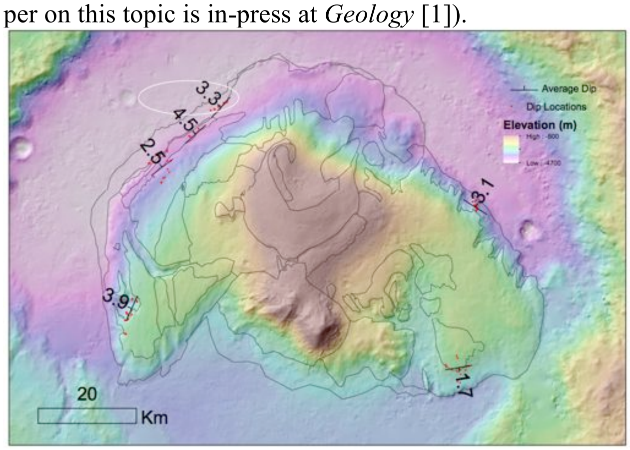

Fig. 1. Bedding orientation measurements from six locations around the Gale mound. Individual measurements are marked in red, with the average at each site indicated by dip symbol. At each location, beds consistently dip away from mound center, consistent with the proposed model. Elevation data from HRSC. Superimposed geologic units from Ref. [11].

Gale mound layer orientations: We obtained bed-orientation measurements from 6 1-m-scale HiRISE stereo elevation models using planar fits to bedding profiles [2]. We find that layers have shallow but significant dips away from the mound center, implying 3-4 km of pre-erosional stratigraphic relief if these dips are extrapolated to the rim. Postdepositional radially-outward tilting is unlikely. Differential compaction or lithospheric flexure would tilt layers inward, not outward. We find no evidence for halotectonics or karstic depressions at km scale. Deformation by mantle rebound would require Gale's mound to accumulate extremely quickly. Therefore, our measurements permit only a minor role for deposition mechanisms that preferentially fill topographic lows (e.g., lacustrine sedimentation), but are consistent with aeolian processes. This suggests the mound grew with its modern shape, and that the processes sculpting the modern mound may have molded the growing mound.

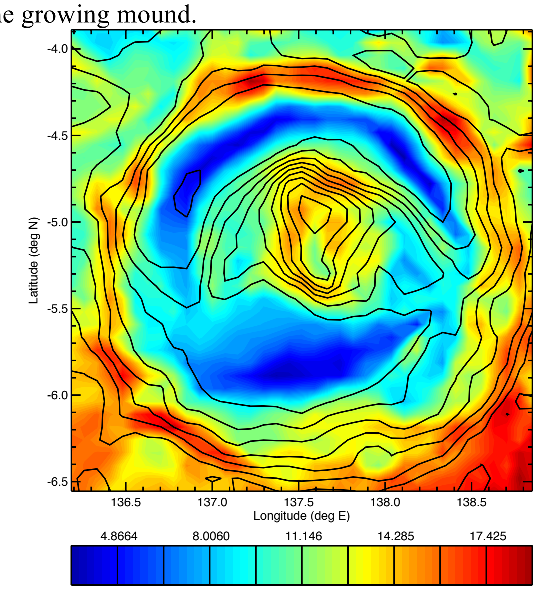

Fig. 2. Gale annual maximum wind speed (m/s) at ~1.5 m above elevation from MarsWRF simulations at 4km resolution. Topography contour interval is 500m. Winds in Gale are expected to peak on steep slopes.

Slope wind erosion on Mars: Saltating sand-sized particles are in active motion on Mars. Aeolian erosion of rock occurred < ~1-10 Ka ago [3] and is probably ongoing. Slope winds are expected to dominate the circulation in craters and canyons [4], confirmed by our Gale-specific MarsWRF simulations (Fig. 2) [5]. Downslope-oriented yardangs and crater statistics suggest that sedimentary mounds are being actively eroded by slope winds. Slope-enhanced winds appear to define both the topography and stratigraphy of the polar layered deposits (e.g., [6]). Radar sounding of intracrater ice mounds near the north polar ice sheet proves that these grew from a central core, suggesting a role for slope winds [7]. Aeolian deposits likely represent a volumetrically significant component of the sedimentary rock record (e.g., [8]). These data suggest that sedimentary deposits formed by accretion of atmospherically-transported sediment formed readily on early Mars as well as more recently. Slope-wind erosion of indurated or lithified aeolian deposits cannot explain our data unless the topographic depression surrounding the mound existed during mound growth. This implies a coupling between mound primary layer orientations, slope winds, and mound relief.

Model: In one horizontal dimension (x), topographic change dz/dt is given by **[** dz/dt = D – E] where D is an atmospheric source term and $E(x,t)$ is erosion or sediment entrainment rate. Initial model topography (Fig. 3) is a basalt (nonerodible) crater/canyon with a flat floor of half-width R and 20° slopes. We initially assume D is constant and uniform. E typically has a power-law dependence on maximum shear velocity magnitude: $E = k\ U^{\alpha}$ where k is an erodibility factor and α ~ 3-4 [9]. We assume that sediments have some cohesive strength, e.g. from cementation. Eroded material is removed from the crater. We model shear velocity magnitude as

$$U(x) = Uo + \max\left| \int_{x}^{\pm\infty} \frac{\partial z'}{\partial x'} \exp\left(\frac{-|\,x - x'\,|}{L}\right) \mathrm{d}x' \right|$$

which is the sum of a background bed shear velocity U_o and the component of shear velocity due to slope winds. ‘max|±()|’ returns the maximum of downslope (nighttime) or upslope (daytime) winds, z' is local topography, x and x' are distances from the crater center, and L is a slope-wind correlation length scale; slope winds are most sensitive to slopes within L of x.

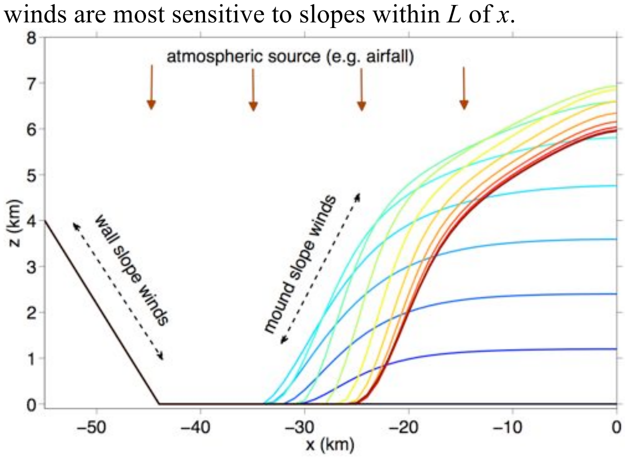

Fig. 3. *Simulated sedimentary mound growth and form for α=3, R/L=2.4, D' =0.4. Colored lines in correspond to snapshots of the mound surface equally spaced in time (blue being early and red being late), for a radial cut from crater wall to crater center. Black line corresponds to the initial topography. D' is defined as the deposition rate divided by the mean erosion rate on the crater/canyon floor at simulation start. Lines inward of the final red line show preserved stratigraphy.*

Results. Model output characteristically produces Gale-like mound structure and stratigraphy (Fig. 3). Crater-slope katabatic winds inhibit sediment layer accumulation both on the walls and for an inertial run-out length on the floor that scales with L. Layer accumulation in the quiet crater interior is not inhibited. The gradient in slope-wind shear velocity causes a corresponding gradient in sediment accumulation, which over time defines a moat and a growing mound. When mound relief becomes comparable to that of the crater walls, slope winds induced by the mound itself become strong enough to erode earlier deposits at the toe of the mound. Erosionally-steepened topography causes stronger winds and more erosion. This evolution does not require any change in external forcing with time. Exposure of layering at all elevations on the Gale mound show it has entered the late, erosional stage. Exhumed layers are buried to kilometer depths, but relatively briefly, predicting minimal clay diagenesis which can be tested with MSL. Gale-like shapes and stratigraphy arise for a wide range of reasonable L and D values. Decreased D' over time allows winds flowing down the crater rim to expose layers and form a moat even when layers are originally near-horizontal.

Tests with MSL: Upon arriving at the mound, MSL can immediately begin to collect observations that will test our model. MSL can confirm a dominantly aeolian origin using sedimentology measurements, and constrain present-day winds using its meteorology package, past winds by imaging fossilized bedforms, post-depositional tilting by measuring stream-paleoflow directions, and subsurface dissolution using geochemical measurements. Unconformities, if present, should be oriented away from the mound center. Gale Crater’s geology is diverse, and records many environments including alluvial fans, channels, and possibly lacustrine sediments at the very bottom of the mound. If the bulk of the mound did form by slow, perhaps orbitally-paced, aeolian sedimentation, the preservation potential of organic carbon would be low [10].

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