ANTIDUNES ON MARS? P.E. Geissler[1] and J.T. Wilgus[2], [1]Astrogeology Science Center, U.S. Geological Survey, Flagstaff, AZ 86001 USA (pgeissler@usgs.gov) [2]Northern Arizona University, Flagstaff, AZ 86001 USA

Introduction: The decameter-scale bright crescents that are common on Mars were given the non-genetic name "transverse aeolian ridges" or TARs because their origin is unknown [1]. First seen in Viking [2,3] and MOC [4,5] images, whether the features are ripples or dunes or something else entirely remains a mystery to this day.

We are beginning a project to test a recently proposed hypothesis that TARs are sediments deposited by dusty turbidity currents in the martian atmosphere, in a manner similar to features formed by fluvial processes on Earth [6].

Background: This hypothesis supposes that dust is transported across the surface of Mars in turbulent winds with suspended aerosols concentrated close to the surface, similar to turbidity currents on Earth. Stationary gravity waves in these shallow flows could produce the semi-regular, periodic spacing of martian TARs.

On Earth, stationary waves in shallow fluid flows generate "antidunes" [7], sedimentary structures that are common in higher energy terrestrial fluvial deposits. The characteristic wavelength of antidunes is given by Equation 1 [8]:

$$\lambda = \frac{2\pi V^2}{g}$$

and the condition for critical flow needed to form stationary waves is given by Equation 2:

$$\frac{V}{\sqrt{gd}} = 1$$

where λ is the wavelength, V is the flow velocity, g is the gravitational acceleration on Mars, and d is the depth of the flow. The left hand side of equation 2 is known as the Froude number, and is simply the ratio of the flow velocity to the propagation speed of surface gravity waves in a shallow flow. Stationary waves form when the flow velocity matches the wave propagation velocity. Putting numbers into these equations for Mars' gravity and a 50 m wavelength gives a flow velocity of 5.4 ms^{-1}, corresponding to a flow depth of 7.9 m.

These equations are valid for the current-driven case of windblown dust that is flowing at a velocity that depends mainly upon the wind speed. However, even in the absence of wind, turbulent dust clouds should continue to cascade downslope under gravity because they are denser than the atmosphere, similar to the behavior of turbidity currents and base surges on Earth. In this gravity-driven case, antidunes form according to Equations 1 and 2 with a reduced gravity g' used to account for sediment buoyancy [9] (Equation 3):

$$g' = g\frac{\Delta\rho}{\rho_a}$$

where ρ_a is the ambient fluid density and $\Delta\rho$ is the density contrast between the current and the ambient density. The flow velocity of gravity-driven density currents depends on the square root of the surface slope (sin α) [9], so the wavelength of gravity-driven antidunes is predicted by Equation 1 to be directly proportional to the sine of the slope angle. Gravity cancels out of the ratio of flow depth to antidune wavelength, which remains $1/2\pi$ whether the antidunes are current-driven or gravity-driven.

Approach: We are examining the detailed morphology of martian TARs in order to determine how well this theory fits the observations. We are using publicly released digital terrain models (DTMs) produced from MRO HiRISE observations to measure the orientations, heights and spacings of TARs and the local slopes of the settings in which they are found. Regional slopes are also being measured at 10 km and 100 km scales from MOC MOLA elevation data. More than 140 study sites are being considered by this survey, all places where HiRISE DTMs captured and resolved TARs even though the DTMs were targeted at other features such as rock outcrops and craters. The features of interest to us are taller than 1 m and spaced more than 10 m apart, but smaller ripples are also noted and their orientations and spacings recorded.

Our goals are to test several predictions of the antidune hypothesis and learn more about how and when TARs formed on Mars. We assume that TARs cannot grow taller than the depth of the dusty turbidity current, so the maximum TAR height to wavelength ratio should be no more than $1/2\pi$, a prediction that we can test with our measurements.

We can learn whether the TARs were formed by winds or by gravity by determining the correlation between TAR spacing and surface slope. A closer correlation between wavelength and local slope would indicate that the dust was cascading downhill under gravity, whereas a closer correlation with regional slope would suggest that the dust was blown by (katabatic) winds.

Results: Figure 1 shows an example of this approach applied to unusual TARs in Syria Planum that are thought to be actively forming today [6]. The HiRISE DTMs have post spacings of 1-2 m and vertical precision in the tens of centimeters and easily resolve these bright dune-like features, which have heights of up to 4 m.

Our global survey of TARs has just begun but has already revealed many surprises, including TARs that are much taller than previously reported (up to 14 m in Kaiser crater) and TARs that are found at higher latitudes than previously reported. Much more work is needed to establish global trends and reach a conclusion about the origin of TARs.

References: [1] Bourke, M et al. LPSC 34, 2003 [2] Thomas, P et al. Icarus, 45, 124–153, 1981; [3] Zimbelman, J., Icarus 71, 257-267, 1987 [4] Thomas, P et al. Nature 397, 592-594, 1999; [5] Malin, M and Edgett, K, J. Geophys. Res., 106, 23429, 2001 [6] Geissler, P. E., J. Geophys. Res. Planets, 119, 2014. [7] Gilbert, G.K. 1914. US Geological Survey Professional Paper No. 86. [8] Kennedy, J.F., 1960. Ph.D. thesis, Cal Tech. [9] Kneller, B. and Buckee, C. 2000, Sedimentology, 47 (Supp. 1), 62-94.

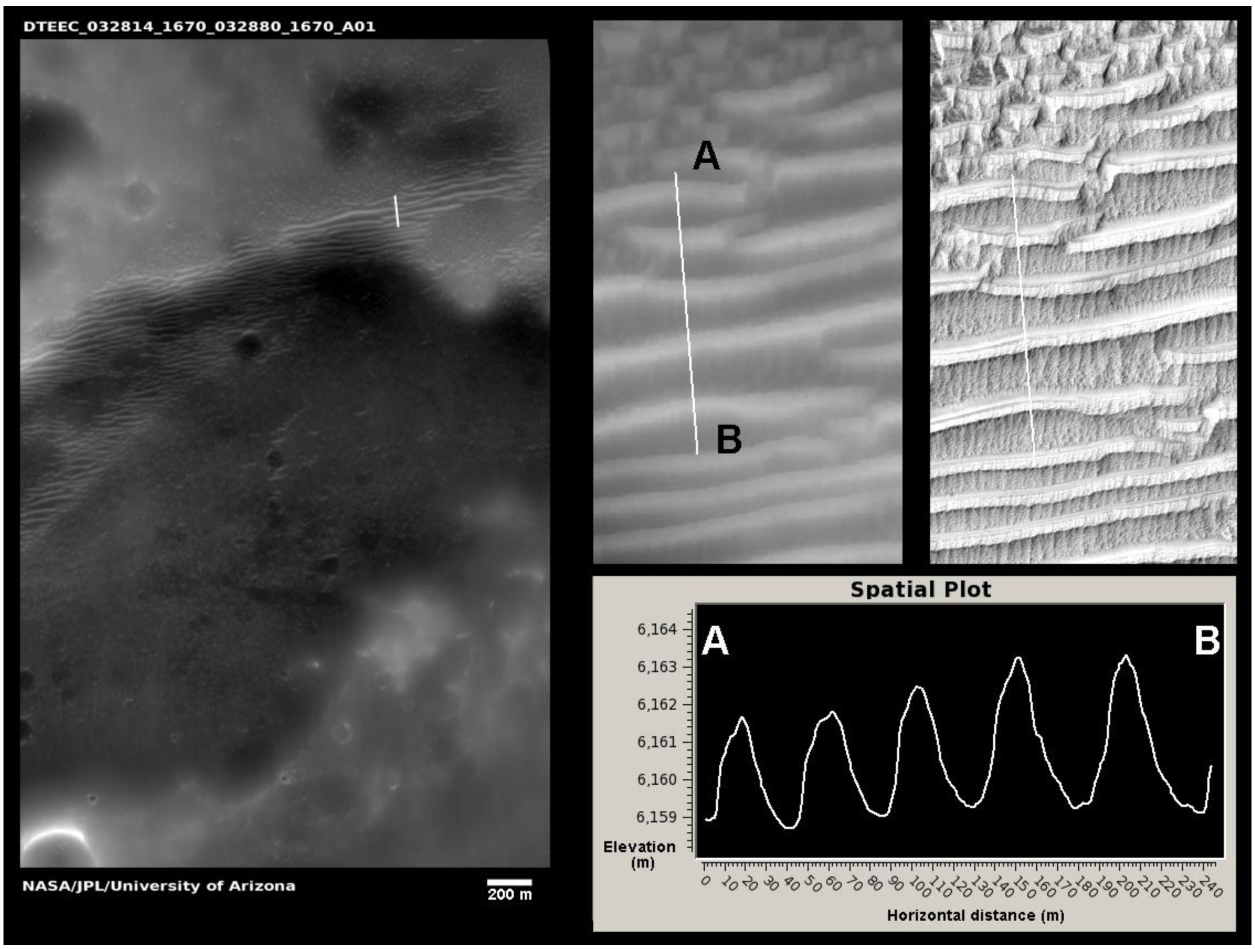

Figure 1. Elevation and topographic expression of dust deposits in Syria Planum. (Left) Cutout of digital elevation model DTEEC_032814_1670_032880_1670 showing bright dune-like features resolved along the north rim of a shallow canyon. Elevations portrayed here range from 6148 m (black) to 6182 m (white) above datum. A line shows the location of profile A-B. (Middle) Cutout of digital elevation model showing traverse from A to B. (Right) cutout of geometrically corrected (orthorectified) HiRISE image ESP_032814_1670 showing traverse. (Bottom) Topography along traverse from A to B. These bright dune-like features reach heights of up to 4 m and have slopes of up to 15°.