SEDIMENT SUPPLY AS A CONSTRAINT ON YARDANG FORMATION NEAR MEAD CRATER, VENUS. T. M. Ganey[1], M. S. Gilmore[1], and J. Brossier[1], [1]Department of Earth and Environmental Sciences, Wesleyan University, Middletown CT (tganey@wesleyan.edu)

Introduction: Yardangs are streamlined ridges that form from erosion of friable substrate. These wind-abraded features occur in a variety of arid settings on Earth, as well as on Mars, most famously in the Medusae Fossae Formation [1-3]. On Venus, a possible yardang field has been identified near the 270 km diameter Mead crater, located at 60.5ºE, 9ºN (Fig. 1) [4]. Because yardangs are aeolian landforms that form via removal of sediment, their characteristics allow for inferences regarding paleo-wind direction and regional sediment volume. Considering that all of the sediment on Venus is thought to be derived from impact cratering, we hypothesize that the Mead yardangs are eroded from loosely consolidated gravel, sand, and dust produced by the Mead impact. Here we calculate the original volume of sediment emplaced and compare to the predicted volume removed by the yardangs in order to evaluate the conditions for yardang formation on Venus and investigate the likelihood that the Mead features are indeed yardangs.

The Mead features are ~25 km long, 0.5 km wide, and are spaced at intervals of 0.5–2 km, which makes them of analogous size to the typical form of a mega-yardang described in [5]. The Mead field covers an area of 40,000 km^2 and is located ~480 km southeast of the crater rim [4]. The resolution of Magellan SAR imagery (~75 m/px) should be sufficient to allow for a qualitative distinction between mega-yardangs and linear dunes, despite the morphological similarities of the two types of features [6]. The sharply defined margins and curvilinear shapes of the Mead features also differentiate them from wind streaks [4,7].

Conditions for Yardang Formation: Mature terrestrial yardangs are formed by abrasion at the windward end and deflation at the downstream end, leaving them with a characteristic "whaleback" shape that minimizes drag in the wind [1,3]. Although most terrestrial yardangs are formed from lacustrine or fluvial deposits, they have also been observed in ignimbrites on both Earth and Mars [2,3,8]. Yardang formation is dependent on aeolian conditions (wind speed and direction) and non-aeolian controls (lithology, sediment supply) [3]. Since yardangs on Earth and Mars follow similar geomorphological patterns, we assume venusian yardang evolution should be governed by the same basic processes [3].

Wind Speed and Direction: The orientation of the Mead yardangs suggests a local northeast-southwest wind regime [4]. However, near-surface winds inferred from wind streaks and global climate modeling predict dominance of southward winds in the Mead region [7,9]. This inconsistency in wind direction can be explained by regional topography [7], since the yardangs are located in a small, elongate depression bordered to the southeast by Aphrodite Terra and to the northwest by an elevated ridge belt. Aphrodite Terra may be able to redirect dominant southward winds to the southwest, forcing them to flow through the basin parallel to the observed features. The formation of yardangs would require these winds to be actively eroding over periods of 10^3–10^6 years under Earth conditions [1,3,4].

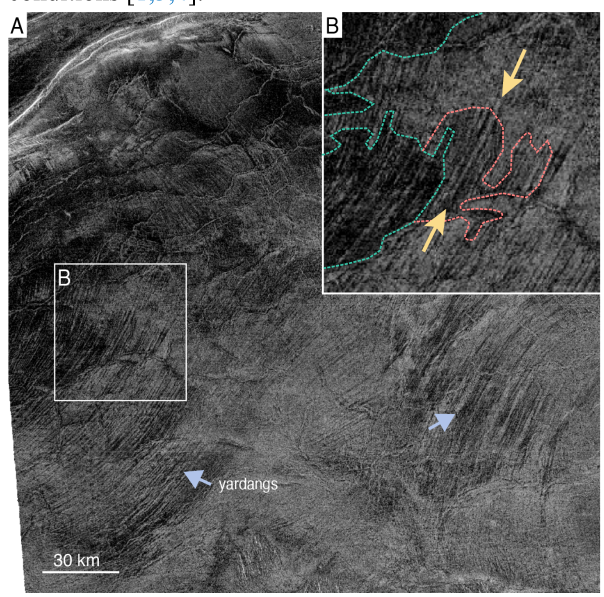

Figure 1. (A) Magellan left-looking SAR image of the Mead crater yardang field, centered at 60.5ºE, 9ºN. Yardangs are the radar-bright curvilinear features oriented roughly northeast-southwest. The incidence angle is 46º. (B) Two lava flows (green and pink) embay a set of yardangs. Arrows indicate single yardang embayed by volcanic flows.

Greeley et al. [10,11] showed that sand particles on Venus are transportable by saltation if winds exceed 0.63 m/s. Wind velocities on the order of ~1 m/s are common at the surface and may keep sand grains in constant saltation [12]. Dust particles are carried in suspension [10]. The ability of local winds to entrain small particles suggests that the Mead yardangs could have formed via abrasion by sand-sized grains and deflation by removal of unconsolidated dust- or sand-sized sediment in the current wind regime.

Lithology: Most terrestrial yardangs are carved from soft sediment such as paleo-lakebeds or other fluvial/lacustrine deposits; however, large yardangs with high aspect ratios are commonly derived from hard bedrock [2,3]. This could imply that the Mead features, which obey a 50:1 aspect ratio, are composed of a harder substrate than unconsolidated sand and dust. Venus impact deposits are thought to be composed of accretionary impact lapilli facilitated by the higher rates of melting on Venus than on Earth [13]. Accretionary lapilli on Venus would be held together by molten material and could be emplaced along with melt fragments or droplets, as seen in suevite deposits associated with impact craters on Earth [e.g., 14]. These materials would be less erodible than loose sand and could therefore explain the extreme size of the features.

On Mars, yardangs in the Medusae Fossae Formation are formed from ignimbrites [2,3]. These yardangs were embayed by lava flows, which were then eroded into secondary yardangs [8]. We observe that the Mead features also appear to be embayed by two distinct volcanic flows (Fig. 1), requiring that the yardangs are both strong enough to have survived lava embayment and have persisted over the time of lava emplacement.

Sediment Budget: The formation of erosional features requires removal of the original deposit emplaced by the Mead impact. We approximated the amount of original material present in the yardang field by modeling the thickness of Mead crater's impact deposit. Using the method of McGetchin et al. [15], we found that sediment in the location of the yardang field would have been ~5–20 m thick at the time of deposition. This thickness multiplied by the field surface area (40,000 km^2) yields an original sediment volume between 200 and 800 km^3.

To determine how much of this original volume was eroded, we calculated the volume of sediment removed from the yardang field based on the approximate size of the features. Length-width-height ratios for terrestrial yardangs are given as 10:2:1 and 9.9:2.7:1 in [16] and [17], respectively. Since the Mead features do not obey the ~10:2 length-to-width ratio, we applied the length-to-height and width-to-height ratios separately which predict that each yardang should be 185–2525 m tall.

We calculated upper and lower bounds for field volume using these two heights as limits. The volume of sediment removed around one feature is best approximated as the length of the field (the square root of the area: ~200 km) multiplied by the height and spacing of the yardangs. The total volume removed is then the individual feature volume summed as many times as it would occur over the length of the field. Using this method, we calculated that the volume of sediment removed from the yardang field is between 7400–101,000 km^3. This volume of eroded material is 1–3 orders of magnitude larger than our estimate of original impact ejecta volume, which requires that a sizable source of extra sediment must be identified.

Summary: A field of possible yardangs has been identified on Venus in the vicinity of Mead crater (Fig. 1) [4]. Although yardang evolution is well-documented on Earth and Mars there has been no formal evaluation of the conditions for yardang formation on Venus. We find that the present-day aeolian conditions (wind speed and direction) in the Mead field seem consistent with the production of the observed yardangs. Surface winds should keep dust- and sand-sized particles in constant saltation and/or suspension, allowing for both abrasion and deflation associated with these landforms [10-12].

The high length-to-width ratio (50:1) of the Mead yardangs and their embayment by at least two generations of lava flows suggests formation from substrate with a greater strength than soft sediments. We hypothesize that the lithology of the Mead field is lithified and partially lithified suevites and breccias produced by the Mead impact and deposited exterior to the crater. If the yardangs are comprised wholly of Mead deposits, the size of the yardangs implies a deposit that is 10-100x thicker than what is predicted based on semi-empirical modeling of the thickness of impact ejecta around lunar craters [15].

The formation of the Mead yardangs requires the removal of 10^3–10^5 km^3 of sediment from the field. This is 1–3 orders of magnitude larger than our estimate of ~10^2 km^3 of original material produced by the Mead impact. Therefore, a significant source of additional sediment must be identified in order to support the hypothesis that the Mead features are indeed yardangs.

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