MARS' NORTH CIRCUM-POLAR DUNES: DISTRIBUTION, SOURCES, AND MIGRATION HISTORY.

K. L. Tanaka[1] and R. K. Hayward[1], [1]U. S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ 86001 (ktanaka@usgs.gov, rhayward@usgs.gov).

Introduction: North polar dunes were previously mapped using Viking image data, showing their distribution, morphology, and inferences of sand supply and migration direction [1]. Transverse dunes occur where sand is abundant and summer winds are strong, including Hyperboreae Undae within Chasma Boreale and Olympia Undae across lower Olympia Planum (Fig. 1). The latter occur in a warm zone between areas of residual summer ice in upper Olympia Planum and in the Scandia region, where cyclones develop having counter-clockwise rotation and eastward drift [1]. Recent work based on higher-resolution images has added to this picture. Particularly noteworthy is the recognition of dark, variably-bedded materials from which dark sand is being eroded [2-3].

In this study, we use available post-Viking datasets to map the distribution of the north circum-polar dunes in greater detail, creating a Geographical Information Systems (GIS) geospatial database of dune fields and comparing this information and previous work with recent mapping of dune sources [3]. Based on this comparison, we develop a scenario for the recent migration history of the circum-polar sands.

Dune field and wind-direction mapping: The dune fields in the north polar region are outlined using Thermal Emission Imaging System (THEMIS) infrared images [4] and the Viking image mosaic. The Viking-based north polar geologic map at 1:15,000,000 scale [5] was also consulted, using an updated version that is georeferenced to the more accurately-located Mars Orbiter Laser Altimeter data [6]. Refinements to the dune field mapping and wind-direction measurements are based on THEMIS visible (VIS) [4], Mars Orbiter Camera narrow angle (MOC NA) [7], and Mars Reconnaissance Orbiter (MRO) Context Camera (CTX) [8] images. We also subdivided dune fields based on the dune density, using a relative density parameter defined as the ratio of mean dune length vs. dune crest separation (Fig. 1).

Dune-based wind-direction azimuth measurements were made using MOC NA, THEMIS VIS, and CTX images in instances where image quality permitted sufficient resolution of wind directions based on dune morphology (which entails inspection of slipface orientations). To further simplify our method, we only use the dunes that formed under a unidirectional wind regime (i.e., barchan, barchanoid and transverse), as multi-directional wind regimes often create morphologies that require detailed study to decipher. We then group and average spatially-clustered azimuths, resulting in inferred, local prevailing wind orientations for the latest period of major dune modification. The averaged azimuths are subdivided by color according to the number of measurements averaged (Fig. 1).

Dune mapping results: The overall distribution of circum-polar dune fields matches well with results of Tsoar et al. [1]. The fields entirely ring the north pole in the plains encircling Planum Boreum and upper Olympia Planum, mostly between 70° and 85°N, with a couple gaps a couple tens of kilometers wide over a horizontal range of ~4800 km. Also, a few dense dune fields emerge from depressions in flank areas of Planum Boreum and course southwestward where they meet with a "circum-polar ring"—a collection of dunes that encircles Planum Boreum that is mostly within 100 to 300 km of its periphery. Its farthest southern extent is ~600 km south of Chasma Boreale, which is the deepest part of the northern plains of Mars (<-5000 m elevation). Locally, the circum-polar dune fields embay scattered, high-standing crater rims and ejecta blankets as well as irregular knobs, ridges, and rises in the Scandia region. The densest dune fields appear to be made up of transverse dunes trains that collectively form broad platforms tens to ~200 m thick. These include Olympia, Hyperboreae, Siton, and Abalos Undae (Fig. 1).

The wind-direction measurements appear to be largely consistent with those measured by Tsoar et al. [1], confirming their four wind belts but with some modifications. The off-plateau belt includes the dense dune fields that migrate mostly southwestward from reentrants in polar deposits (including Tenuis, Boreum, and Olympia Cavi). The fields extend down broad valleys carved into polar deposits; the sandy Planum Boreum cavi unit mapped by [3] (red lines and dots in Fig. 1) appears to be the primary source of these dune fields. The Olympia Undae defines a second wind belt that chiefly has migrated east to west, consistent with both dune orientations [1] and the dispersion of gypsum detection in OMEGA spectral data [9]. Tanaka et al. [3], in agreement with [2], suggested that the cavi unit also underlies most of eastern Olympia Undae and perhaps the western half as well, thus material underlying Olympia Undae may be the primary source of the dune sand (exposure of the cavi unit in Olympia Cavi also contributed to Olympia Undae). East of Olympia Undae a third wind belt is defined by mostly intermediate density dune fields that extend to the prime meridian. These fields are augmented by off-plateau sand migration at Abalos Undae and Hyperboreae and Siton Undae; the latter field is the southernmost high-density dune field and indicates effective transport and deposition of sand from its apparent western and northern sources. The final wind belt surrounds about 60% of Planum Boreum, extending from Scandia to the prime meridian. It includes intermediate- and low-density dune fields, which occur preferentially in lows of Scandia and surrounding the low plateaus of Olympia Mensae. In places west of Olympia Undae on its northern flank, some west-trending wind directions occur, but most others point east to northeast. We think that the belt's most likely sources are sands of Olympia Undae and Cavi, based on its overall westward decrease in dune density. The eastward and northeastward wind trends may reflect recent activity that realigned dune orientations but that did not cause substantial dune-field movement. Finally, the separation between Planum Boreum and most dune fields indicates that off-planum katabatic winds keep the sands pushed away from the planum; the dark surfaces in these areas may be loose sand or exposed bedrock.

If these interpretations are largely correct, north polar dunes preserve a history of largely traceable migration from their source outcrops. Most other possible sources, such as other older plains and polar materials [3], may be largely buried by young mantle materials [e.g., 10] and thus protected from erosion. An exception may be the gypsum in Olympia Undae, which might be scoured from underlying, plains-forming bedrock [3, 11]. Further investigation of wind directions of lower-order or contradictory to the overall pattern may reveal excursions in wind patterns.

References: [1] Tsoar H. et al. (1979) *J. Geophys. Res. 84,* 8167. [2] Byrne S. and Murray B. (2002) *J. Geophys. Res., 107,* E6. [3] Tanaka K.L. et al. (2008) *Icarus, in press.* [9] Langevin Y. et al. (2005) *Science 307,* 1584. [4] Christensen P.R. et al. (2008) *THEMIS Public Data Releases*, http://themis-data.asu.edu. [5] Tanaka K.L. and Scott D.H. and Tanaka, K.L. (1987) *USGS Map I-1802-C*. [6] Skinner J.A. Jr. et al. (2006) *LPSC XXXVII*, Abs. #2331. [7] Malin M.C. et al. (2008) *Mars Orbiter Camera Image Gallery,* http://www.msss.com. [8] Malin M.C. et al. (2007) *J. Geophys. Res., 112*, E055S04. [10] Mustard J. et al. (2001) *Nature 412,* 411. [11] Tanaka K.L. (2006) *4th Mars Polar Sci. Conf.,* Abs. #8024.

Figure. 1. *North polar region of Mars showing distribution of dune fields of low to high relative density (white, ~0.01-0.1; gray, 0.1-0.6; black, >0.8). Wind-direction vectors (arrows) inferred from averaged dune orientations (averaged from <10 (yellow), 10-19 (orange), and ≥20 (red) measurements). Red lines and dots are exposures of the Planum Boreum cavi unit, a main source of dune sand [3] (MOLA color shaded relief base, 5° grid, polar stereographic projection; prime meridian at bottom).*