THE IMPORTANCE OF SAND FOR UNDERSTANDING DUNE PROCESSES AND SURFACE CONDITIONS OF TITAN. Jani Radebaugh[1], Jason W. Barnes[2], Shannon Mackenzie[3], Sarah Horst[4], Xinting Yu[4], Ralph D. Lorenz[3], Matt Telfer[5], Jonathan Lunine[6], Jeff Johnson[3], Mike Malaska[7], Catherine Neish[8], Sebastien Rodriguez9, Elizabeth Turtle[3], Corbin Lewis[1], Brad Bishop[1]. [1]Department of Geological Sciences, Brigham Young University, Provo, UT (janirad@byu.edu), [2]University of Idaho, Moscow, ID, [3]Johns Hopkins University Applied Physics Laboratory, Columbia, MD, [4]Johns Hopkins University, Baltimore, MD, [5]University of Plymouth, Devon, England, [6]Cornell University, Ithaca, NY, [7]Jet Propulsion Laboratory, Pasadena, CA, [8]University of Western Ontario, London, ON. [9]University of Paris Diderot, Paris, France.

Introduction: Titan is an eolian world when measured by the areal coverage of dunes and predicted volumes of dune sediments. Nearly 20% of the body is covered in dunes [1]; volume estimates are similar to that of the combined sand seas of Egypt and Libya [2]. The sand that makes up the dunes is known from Cassini at infrared and microwave wavelengths to be consistent with a broadly organic composition, ultimately from atmospheric breakup of methane and recombination into organic molecules [3, 4]. How this material eventually becomes dune sand is unknown. However, because the materials are organized into dunes, the particles must behave like sand – be of a small size (~0.18-.25 mm) [5], round to subround and loose for ease of saltation by wind [6]. We draw comparisons with Earth and Mars to answer major questions that still remain about processes and conditions in the sand seas of Titan – essentially through handfuls of sand.

The Importance of Sand: The study of sands can provide a record of how dunes accumulated and developed over time, as well as the physical, chemical and climatic conditions present [7, 8, 9]. Simple properties such as color and texture (grain size and shape), along with more detailed studies, can reveal much about the dune environments and histories [7, 9].

Color Reveals History: A sample of sand from Bagnold Dunes in Gale Crater, Mars [10] (Fig. 1) has a variety of particles containing a detailed regional history. Basaltic volcanism occurred, creating grey vesicular and green (olivine) crystals, with neither being altered to clays, indicating lack of current regional surface water. Oxidizing conditions led to the presence of reddish sedimentary rocks of the surrounding Murray formation, and standing water led to lakebed clays, along with abundant (~40%) amorphous materials. Fragments of all these materials were mixed and sorted by aeolian processes [10]. A dune sample from central Utah comes from a similar environment, in a mountain valley in the shadow of a modern cinder cone and with clay interdunes (Fig. 2). The dark color of Titan's sands is consistent with a broadly organic composition, as water ice should be bright [11]. Color alone thus revealed a key piece in the origin of Titan's sands.

Texture Reveals Process: Grain shape and size can reveal maturity of the sand, which usually translates to the distance traveled [12]. Determining what range of sand size may exist in Titan's dunes requires an understanding of organic properties, how the sand formed, and dune dynamics. Lab work on the creation of sand from tholins indicates interparticle forces may help smaller molecules clump together into larger particles [13, 14]. This may progress to the point where many sizes are available for sorting by wind.

Fig. 1. Black Rock Desert, UT (bottom) and Bagnold dunes, Mars (top, 2x scale of bottom, PIA20171).

Combined fluvial and aeolian processes dictate that in simple terms, the closer to the source, the coarser the sand, because finer particles will transport farther. However, crestline and ripple formation, particle composition and armoring can alter this distribution [15]. Particle size may also reveal relative ages. The large linear dunes found in the Sahara and Arabia may have been assembled during windy Pleistocene conditions, and thus have larger particle sizes [7, 8]. Active portions of these dunes may only be currently present at the crestlines, which are generally finer-grained [7, 8]. Finding that sand at the base of a dune on Titan is coarser than at the crest may reveal the dunes have undergone a similar evolution to that on Earth. Conversely, uniform sand size across Titan's dunes may indicate the large linear dunes are undergoing formation now, possibly by elongation [16].

Unique Deposits Reveal Environments: Sometimes many factors come into play to reveal the local conditions, history and process. Deposits of large, 1 mm, red, translucent quartz grains can be found on the flanks of giant, megabarchan dunes surrounded by groundwater-fed playas in the Rub al Khali near Liwa (Fig. 2) [17]. Unusually large grains are typical of old barchan dunes, and iron oxide coatings progress best in hot, arid environments that experience periodic but not prolonged wetting [7]. The sands thus reveal the environmental conditions of the Liwa megabarchans.

Methane groundwater may affect Titan's sands and create coatings or leach materials [18]. Perhaps these signatures are visible from Cassini data; interdune compositions are certainly different from dunes on Titan, as indicated by grain size, roughness and composition [11, 19, 20, 21].

Fig. 2. Oxide-coated lag sands of UAE megabarchans.

The Source of Sand: Most sand that fills the sand seas of Earth appears to be derived from nearby alluvial fans [22]. Rub al Khali sands are largely derived from a giant, preexisting alluvial fan in the NW, and southern Great Sand Sea sands are likely from an old fan shed off the Gilf Kebir plateau [7]. Alluvial processes are vital to the production of large amounts of sand. Dune materials in Gale Crater, Mars, may also derive in part from nearby crater-rim fans [10].

Titan is also a fluvial world, having a high density of channels in many locations [23] and some alluvial fans [24, 25]. Perhaps the sand on Titan derives from erosion of organic sedimentary bedrock, with materials originating from the atmosphere and hardened by organic cements [19]. VIMS indicates that Titan's surface is dominated by organics, while water ice is found in a crystalline basement occasionally exposed by erosion [4]. Organic sediments may be eroded, transported and deposited in alluvial fans, some of which may now be buried under dune sands.

The region that remains an exception to the wraparound coverage of Titan's equatorial regions by dunes is Xanadu [26]. This region is covered in eroded bedrock, exposed water ice, and fluvial channels, some of which terminate at the southern margin in fans. In Egypt, the Great Sand Sea is missing in the Sarir Dalma, where it is thought that floods and channels washed away the sands [7]. Fluvial channels may have similarly washed sand out of Xanadu [26].

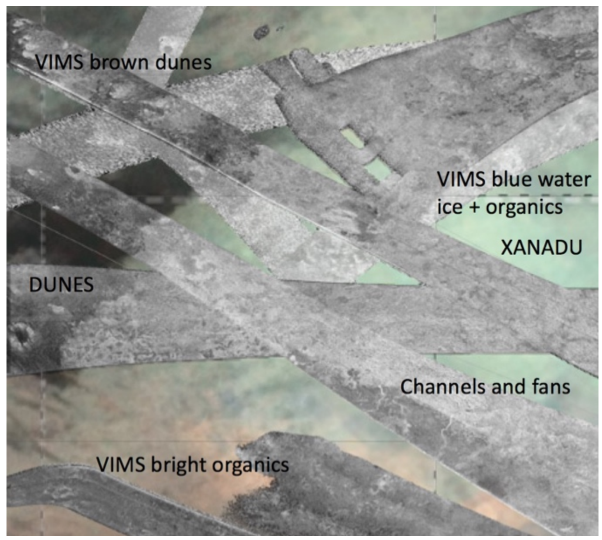

Fig 3. The Shangri-La sand sea (left) halts at Xanadu, which is dominated by eroded mountains and channels.

The World in a Handful of Sand: As terrestrial and martian in-situ studies have revealed, planetary dune studies benefit greatly by close-up analyses of sand. A handful of sand would continue to open the understanding gained from orbit of the modern, regional, and coupled surface-atmosphere processes that led to the existence of the vast sand seas of Titan.

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