GRAIN PROPERTIES FROM SYNTHETIC APERTURE RADAR: TERRESTRIAL RADAR ANALOGS FOR TITAN'S ALLUVIAL SEDIMENT. A. D. Maue[1], L. K. Carnes[2], and D. M. Burr[1]; [1]University of Tennessee, Knoxville, TN, 37996, [2]Arizona State University, Tempe, AZ, 85281; amaue@vols.utk.edu.

Introduction: Remotely-sensed Synthetic Aperture Radar (SAR) data of terrestrial alluvial sediment can be related to in-situ measurements of physical grain properties to "ground-truth" planetary radar measurements. For cm-wavelength SAR, radar return of a field of gravel-scale sediment may be well-described by scattering theory [1]. The efficient retroreflection of low-loss spheroidal particles comparable in size to the wavelength of incident light has been interpreted to explain the high-radar-brightness of some fluvial features on Saturn's moon Titan [2]. The interpretation of such features as ephemeral braided rivers [3] is consistent with the presence of cobble-rich deposits that may have been rounded by abrasion during transport and deposition.

Models of individual scatterers and beds of uniform scatterers indicate increasing backscatter with increasing grain size, roundness, and compositional purity [2]. Complicating a quantitative theoretical representation, realistic alluvial sediment may have broad or bimodal grain size distributions and lithology-dependent roundness. Measured downstream trends in radar brightness on Titan appear inconsistent with simple downstream fining of uniform sediment from a single source [4]. The present work aims to develop quantitative correlations of realistic changes in grain size, shape, and sorting for analogous sediment on Earth to improve interpretation of sedimentological processes viewed in SAR on Titan.

Alluvial fans in arid deserts on Earth provide expansive stretches of unconsolidated sediment for analysis. Minimal vegetation, an absence of moisture, and well-constrained source rock lithologies allow for the development of tight constraints on the sediment properties that influence radar return. For such sites, SAR images predominately indicate changes in surface roughness relative to the radar wavelength (i.e., grain properties and bedforms) [5].

Death Valley National Park is the host of many well-studied alluvial fans that can be explored for the present study (**Fig. 1**). For example, previous works have used these sites to distinguish depositional processes on fans [6] and understand recent geological histories at this location [7]. Efforts in the 1970s collected X-band (λ=3 cm) and L-band (λ=25 cm) SAR images by aircraft and demonstrated relationships between radar return and grain-size-based surface roughness [1,5]. The present pilot study expands on analyses of the relationship between SAR and various grain properties measured in the field.

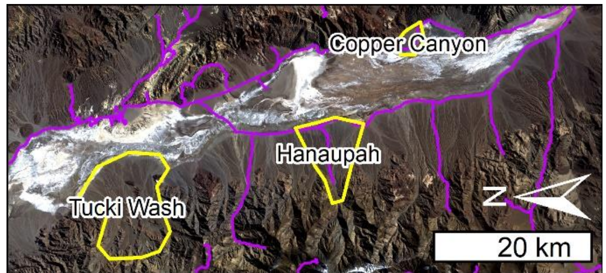

Figure 1. Landsat-8 visible image providing context for alluvial fans in Death Valley, CA. Three relevant fans are outlined in yellow and roads are delineated in purple.

Methods: Field study in or around Death Valley is planned for collecting data of surficial sediment properties for interpretation of SAR images.

Field procedure. For hand measurements of grain size and shape, we apply a point count method based on a nylon grid of 200-mm spacing in a 1.6x1.6-m PVC frame. This spacing was selected to reasonably accom-modate the expected dominant gravel grain sizes of ~5 to 100 mm [e.g., 7]. The ~2.5 m^2 sample area is small enough that users can access samples without disturbing sediment within. Two sets of eight evenly-spaced threads of nylon intersect perpendicularly to form 64 sample points. The grain at each intersection point is measured in three dimensions using a caliper. Images of sample sites taken from consistent height (~2 m) and an-gle (and similar lighting when possible) provide an ad-ditional dataset to be digitally analyzed for approximate grain properties [e.g., 8]. Such semi-automated image analysis can be compared to hand measurements and al-low for greater spatial coverage of fan sediments.

To produce distributions representative of SAR units, we scout for relatively homogenous surfaces on which the grid can be laid multiple times to produce a robust sample size. Sample sites are selected to provide a diverse representation of fan sediment properties approaching the end-member conditions of coarse vs fine, round vs angular, and sorted vs unsorted.

SAR analysis. SAR images from the spaceborne Sentinel-1 mission are used to understand surface properties at C-band (5.5 cm) wavelength. This sensor provides linearly-polarized images of 10-m spatial resolution with a revisit time of 1-2 weeks, allowing for remote sensing of the selected sites very near to the timing of field work. It has more than an order of magnitude finer spatial resolution than the best resolution of the Cassini radar instrument. Operating at ~2.5 times the Cassini radar wavelength, the Sentinel-1 SAR images “see” a larger grain size, though also in the range of gravel. Analyzing additional images captured at other wavelengths, such as that of the SIR-C/X-SAR mission, could provide data on roughness at other scales. High-resolution terrestrial SAR images can be downsampled to match Cassini SAR resolution for comparison.

We will develop correlations between the in-situ measurements of grain properties and remote radar brightness data to produce quantitative mixing models of the effect of size, shape, and sorting on radar return. These models will then be applied to better understand Titan’s surface.

Initial Results & Implications: As a proof-of-con-cept before field work, available SAR im-ages of possible sample sites were compared to existing sedimentary field studies. Alluvial fans may be moder-ately radar-bright, dimming rapidly near their terminus as the matrix of surface sediment transitions from gravel- to sand-dominated [9]. Opposing the bajadas of the west flank of Death Valley, the Copper Canyon Fan and other eastern fans exhibit an archetypal conic shape. Radar brightness is relatively constant for the upper fan, then decreases until reaching the radar-bright coarse evaporite deposits at the floor of Death Valley (**Fig. 2**). Radar dimming appears to begin hundreds of meters up-stream from the rapid grain size change that occurs at the toe of other fans [e.g., 5]. Changing radar brightness while mean diameter and roundness are constant could indicate other controls are

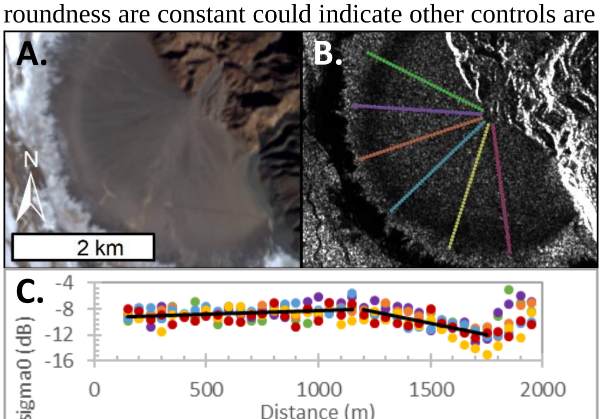

Figure 2. Copper Canyon Fan (A) Landsat-8 visible image, (B) Sentinel-1 SAR image with sampling, (C) mean radar cross section of 25 m around each point.

Whereas fan lengths may be insufficient for commi-nution by abrasion, a rapid decrease in radar brightness can be expected at the fan toe where flows lose compe-tence and deposits rapidly fine to sand. This size-de-pendent radar signal, seen from the L-band measurements of Schaber et al. [5], is also evidenced at the shorter wavelengths of Sentinel-1 (**Fig. 3**). On the nearby Hanaupah Fan, Ibbeken et al. found homogene-ity of grain size distributions and roundness across the fan surface, including within the major incised chan-nel—the main distinction being poorer sorting within the radar-bright channel [7]. Conversely, the Dog Can-yon Fan in New Mexico displays exponential grain size fining and increased sorting with distance down-fan in the most prominent alluvial channel [10]. To provide a diverse range of grain properties, multiple locations on fans (e.g., upper, lower, active channel, etc.) as well as multiple types of fans (e.g., debris-flow- vs. sheetflood-dominated [2,9]) can be sampled.

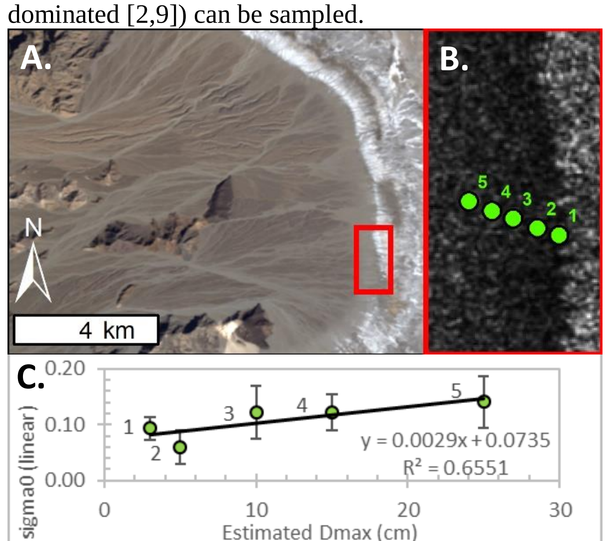

Figure 3. Tucki Wash Fan (A) Landsat-8 visible im-age, (B) Sentinel-1 SAR image of fan toe with 5 sam-ple sites of [5], (C) mean radar cross section of 25-m radius around each sample site.

Future Work: This pilot study enables an under-standing of the feasibility of methodology and basic re-lationships between sedimentology and SAR imaging. Preliminary results from available data and subsequent SAR analysis will be presented at LPSC. A future study with a greater number of sample points, possibly ob-tained by drone, will allow for robust quantification of SAR images of alluvial deposits on Earth and Titan in terms of sediment properties.

References: [1] Daily et al. (1978) *JPL Pub. 78-19*. [2] Le Gall et al. (2010) *Icarus, 207*, 948-958. [3] Burr et al. (2014) *GSAB 125*, 299-321. [4] Maue et al. (2018) *LPSC XLIX*, #1113. [5] Schaber et al. (1976) *GSAB, 87*, 29-41. [6] Blair (1999) *Sedimentology, 46*, 1015-1028. [7] Ibbeken et al. (1998) *Earth Surf. Process. Land., 23*, 481–492. [8] Buscombe (2013) *Sedimentology, 60*, 1709-1732. [9] Cartwright & Burr (2017) *Icarus, 284*, 183-205. [10] Miller et al. (2014) *GRL, 41*, 7191-7199.