GEOLOGIC MAPPING OF THE ADIRI REGION OF TITAN. D.A. Williams[1], M.J. Malaska[2], R.M.C. Lopes[2], J. Radebaugh[3], J.W. Barnes[4], E.P. Turtle[5], R. Kirk[6]. [1]School of Earth and Space Exploration, Arizona State University, Box 871404, Tempe, AZ 85287 (David.Williams@asu.edu), [2]NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, [3]Brigham Young University, Provo, UT, [4]University of Idaho, Moscow, ID, [5]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, [6]U.S. Geological Survey, Flagstaff, AZ.

Introduction: We have just been funded by NASA's Outer Planets Research Program to construct a geologic map of the Adiri region of Saturn's moon Titan (**Figure 1**). In this abstract we discuss the goals and objectives of the project, review the data available and approaches we will use, discuss the challenges for mapping Titan and this region, and our timetable for completion.

Goals and Objectives of Mapping: The *general* objective of this project is to determine the geologic history of the "Adiri quadrangle" (20˚N-20˚S, 150-240˚W) region of Titan. This will include using geologic mapping to investigate the relative roles of various geologic processes by mapping the areal extents and distributions of process-related units and determining their stratigraphic relations. More *specific* scientific objectives include: 1) to investigate quantitatively whether exogenic processes (fluvial erosion or aeolian modification) are the dominant geologic processes modifying the surface in the Adiri region *throughout its history*; 2) conversely, to investigate the potential role of endogenic processes (tectonic modification and/or cryovolcanism) in this region *throughout its history*; and 3) to further assess the utility of the *Cassini* data sets, particularly the RADAR and ISS data, for making a basemap for a potential global geologic map of Titan after the *Cassini* Solstice Mission is complete. Overall, we seek to address the current controversy about whether Titan is a geologically active world in terms of endogenic processes with cryovolcanism and/or tectonism [1,2], or whether these processes are mostly relegated to Titan's past, such that Titan is now dominated by exogenic processes (hydrocarbon cycle, aeolian activity).

Data Available and Approach: We will use *Cassini* RADAR data in Synthetic Aperture Radar (SAR) mode (spatial resolution: 300-1,500 m/pixel, oversampled to 175 m/pixel (256 pixels per degree) ground sample distance) as the primary base for our map. The *Cassini* RADAR data will be supplemented by *Cassini* Imaging Science Subsystem (ISS) and Visual and Near Infrared Mapping Spectrometer (VIMS) data to provide added context to interpret surface features, via integrated analysis & mapping with ArcGIS™ software.

The unofficial "Adiri quadrangle" ranges from 20˚N to 20˚S and 150-240˚W, and includes the landing site (LS) of the European Space Agency's (ESA) *Huygens* probe [3]. *Huygens'* instruments provided groundtruth about the surface properties of the LS, which contains icy, cm-sized pebbles and cobbles and a dark, relatively soft surface that is thought to be composed of a fine-grained sediment saturated with liquid hydrocarbons [4,5]. The immediate surroundings of the *Huygens* LS have been studied through initial comparisons of RADAR, VIMS, and ISS data to *Huygens* DISR and other data [6,7,8,9]. For example, about 30 km north of the LS the VIMS dark brown spectral unit correlates with the fields of linear dunes observed in RADAR observations [7]. The *Huygens* LS occurs near the boundary between two other VIMS spectral units: 1) the bright unit, which does not correlate with specific RADAR features and is interpreted as highlands (incised by channels indicative of erosion by both methane rainfall and methane sapping) mantled by a fine tholin aerosol dust [7]; and 2) the dark blue spectral unit that is consistent with water ice-rich substrate [7,8]. However, a more integrated mapping study linking the *Huygens* landing site to the surrounding Adiri, Dilmun, and Shangri-La regions has not been done.

Challenges in Mapping Titan: Geologic mapping is more challenging when using radar data as the basemap for a number of reasons [10,11]. First, geologic units are visible only if their backscatter characteristics are different from surrounding units. This may not always be the case, particularly in lava flow fields or plains units. Thus, older and younger units could be mistakenly combined into a single unit. If there are lateral changes in a geologic unit, then its radar signature can also vary, and thus one unit could be mistakenly mapped as two or more units. Second, structures are more easily identified when they are oriented normal to the radar-look direction [12]. Third, *Cassini* RADR images are rather noisy and have much lower spatial resolution than *Magellan* Venus images, such that morphologic attributes that might distinguish units are not always visible.

There are additional challenges to consider when mapping radar data of Titan, which is an icy body whose surface is characterized by solid hydrocarbons (dielectric constant ε = 2.0–2.4; [13]), water ice (ε = 3.1), water–ammonia ice (ε = 4.5), or combinations thereof. Methane can be trapped in an ice-like solid called clathrate hydrate. The dielectric constant of clathrates is determined by the proportion of ice/methane molecules in the clathrate hydrate structure [14], slightly lower than solid hydrocarbons or ice alone, thus suggesting the possible presence of clathrates on Titan surface [15,16]. Because the *Cassini* SAR is a single-polarization instrument, the relative contributions to SAR brightness from factors such as topography, surface roughness, material composition, and volume scattering are not well understood. *Janssen et al*. [17] reported that *Cassini* radiometry data indicates that volume scattering does contribute to radar backscatter, especially in radar-bright regions, thus potentially leading to misinterpretation of the radar signature of a surface. To a first order, however, as demonstrated in *Williams et al*. [18] and *Stofan et al*. [19] and *Lopes et al*. [20], volume scattering effects do not inhibit the definition and characterization of process-related geologic units for mapping, as evidenced by the *Cassini* RADAR team's recognition of a variety of geological surface features in the data: impact craters, cryovolcanic calderas, domes, and flows, fluvial channels, lakes, mountains, dunes, alluvial surfaces, and plains. Nevertheless, *caution will be used in the definition-characterization of map units.*

Stratigraphic correlation of map units is a key outcome of geologic mapping, as it places process-related geologic units in the chronological order of their formation. Because of the low abundance of impact craters that prohibit using crater dating techniques, we must rely on superposition, embayment and cross-cutting relations to identify local stratigraphic relations *within* the regional map.

Timetable: Funding of this 3-year project began in mid-September 2015, and we are assembling an ArcGIS™ mapping database with all useful RADAR, VIMS, and ISS data, including RADAR topography data provided by Collaborator Kirk. During Year 1 we want to integrate all data sets in ArcGIS, and do an initial study of the data to define and characterize a set of map units. In December 2014 we had a 2-day mini-Titan Mapping Workshop at ASU with mappers from Cornell University and JPL, to come to agreement on the global variety of map units. We will refine and reach consensus on these units during the rest of Year 1.

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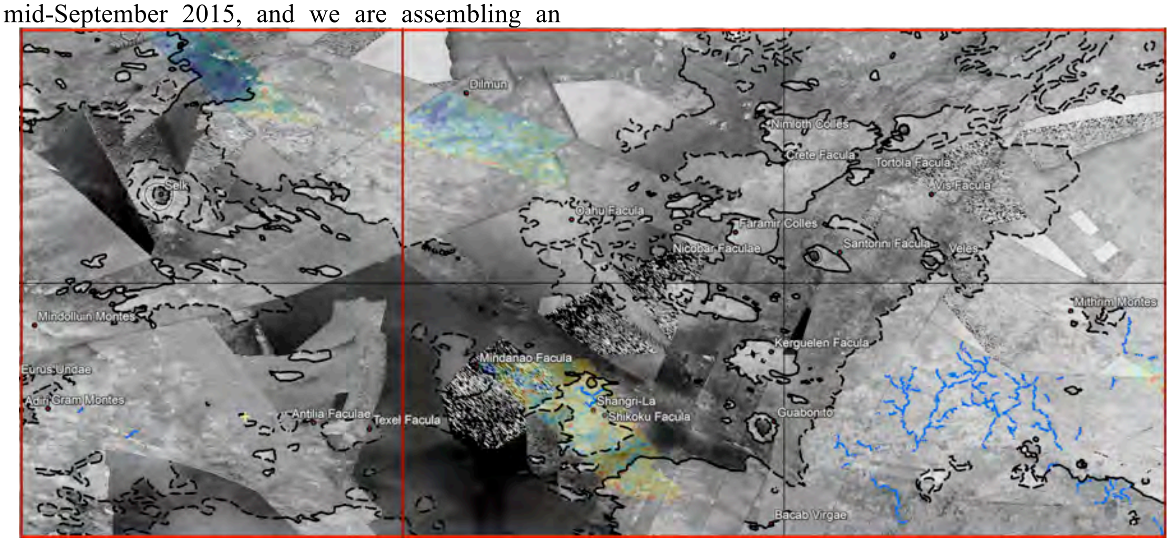

Figure 1. The Adiri "quadrangle" of Titan (20˚N-20˚S, 150-240˚W), extracted from our ArcGIS™ project. Redlines mark mapping boundaries and 180˚ longitude. Black lines (solid & dashed) mark tentative certain and approximate contacts between different units, respectively. Blue lines mark channels in Xanadu. Color-coded DTMs show topography (blue low, red high).