CRYOVOLCANIC FEATURES ON TITAN'S SURFACE AS REVEALED BY THE CASSINI RADAR.

R.M. Lopes[1], C. Elachi[1], E. Stofan[2], F. Paganelli[1], C. Wood[3], R. Kirk[4], R. Lorenz[5], A.D. Fortes[6], J. Lunine[5], S.D. Wall[1], and the Cassini RADAR Team. [1]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, Rosaly.M.Lopes@jpl.nasa.gov. [2]Proxemy Research, PO Box 338, Rectortown, VA 20140. [3]Planetary Science Institute, Managaua, Nicaragua Branch. tychocrater@yahoo.com. [4]US Geological Survey, Flagstaff, AZ 86001. [5]Lunar and Planetar Laboratory, University of Arizona, Tucson, AZ 85721. [6]University College London, Gower St., London WC1, UK.

Introduction: The Cassini Titan Radar Mapper [1,2] obtained Synthetic Aperture radar images of about 1.1% of Titan's surface during the spacecraft's first targeted fly-by on October 26, 2004 (referred to as the Ta fly-by). These images revealed that Titan is very complex geologically. Features identified include a possible volcanic dome or shield, craters that appear to be of volcanic origin, and extensive flows. We will discuss these features and others that will likely be revealed during Cassini's T3 Titan fly-by of February 15, 2005, during which a swath covering comparable amount of the surface will be obtained. Results from the radar instrument are also discussed by Elachi et al., Kirk et al., Stofan et al., Lorenz et al., Wood et al., and Paganelli et al. (this volume).

Cassini RADAR: Cassini carries a multimode Ku-band (13.78 GHz, λ=2.17 cm) radar instrument [1,2] designed to probe the surface of Titan and that of other targets in the Saturn system in four operating modes – imaging, altimetry, scatterometry, and radiometry. (An overview of Titan results using all four modes is given by Elachi et al. [2]). The SAR mode is used at altitudes under 4,000 km, resulting in spatial resolution ranging from ~ 400 m to 1 km. Images are acquired either left or right of nadir using 2 to 7 looks. A swath 120-450 km wide is created from 5 antenna beams. SAR coverage is dependent on spacecraft range and orbital geometry.

The Ta and T3 Titan fly-bys: The SAR mode was used in Ta and will be used in T3. The SAR strip obtained during Ta extends from 133^0 W, 32^0 N and continues through closest approach (at a range of 1174 km) to 12^0 W, 29^0 N. The total area covered by SAR is 5.6 x 10^5 km^2. The coverage is shown in Stofan et al. (this volume). The planned SAR coverage for T3 will be larger and at lower latitudes and overlap, for the first time, with coverage by the optical remote sensing instruments aboard Cassini, such as ISS and VIMS.

The SAR Ta swath revealed a wide variety of geologic features, including radar-bright flows, a circular volcanic construct, linear features that may be channels, and radar-smooth terrains. Dark patches were tentatively identified as hydrocarbon ponds or organic sludge [2, see also Lorenz et al., this volume]. The T3 fly-by will reveal part of the region known as Xanadu. This large, optically bright feature could be a continent, or could be the result of an impact exposing fresh material from below, or else a feature formed by cryovolcanism [e.g. 4]. New results from the T3 fly-by that pertain to cryovolcanism will be discussed.

Possible Cryovolcanic features from the Ta fly-by: The SAR Ta swath shows several features that are likely to be cryovolcanic in origin.

Circular Structure (dome or shield): The most prominent feature in the SAR Ta strip is a large circular feature about 180 km in diameter, whose central coordinates are approximately 49.7 N, 87.3 W (Fig. 1). Almost all of this feature is seen in the Ta swath. This is interpreted as a volcanic construct, either a dome or shield. The feature is radar-bright at the edges, particularly at the southern edges which face the radar. The feature has an apparent central depression about 20 km in diameter which is interpreted as a volcanic pit crater or caldera. The central part of the circular feature is radar dark except for a few patches of bright, lobate features interpreted as flows. At least four sinuous channels or ridges can be seen meandering from the central crater to the edges, which are possibly cryolava channels running down the flanks of the volcanic feature. One of the sinuous channels can be traced for over 90 km and may be the source of a radar-bright flow, consistent with the interpretation that these may be cryolava channels.

It is worth noting that this Titan circular feature has morphological similarities to pancake domes on Venus revealed by Magellan [5]. The Titan feature is significantly larger in diameter (~180 km) than the Venus domes (typically 20-30 km diameter), but like the Venus domes it is circular, radar dark in the central part, shows a central depression and channels or cracks on the flanks. However, so far we have no conclusive evidence that the Titan feature has steeply sloping sides, or that is central part is flat.

Flows: Numerous lobate, radar bright features are seen in the Ta swath and are interpreted as cryovolcanic flows. Both sheet-like and more digitate examples are seen and these extend from tens of kilometers to > 200 km in length. An example of a large cryovolcanic flow or flow field is shown in Fig. 2. Several flow-like features are also seen in Fig. 1, which appear to extend from near the central part of the circular volcanic feature to its edges and beyond.

Craters or Calderas: No features that can be unambiguously identified as impact craters can be seen in the Ta swath (see Wood et al., this volume). Two craters that appear to have flows emanating from them are seen in the Ta swath. One example is shown in Wood et al. (this volume). Although the possibility that these may be impact craters cannot be eliminated at this time, their irregular shape and emerging flow in one direction only supports a volcanic origin.

Feasibility of Cryovolcanism on Titan: Titan is sufficiently large that, during accretion, much of the body may have melted. Its interior may still contain a substantial layer of water-ammonia liquid [6,7] which may erupt on the surface. The possibility of finding cryovolcanic features on Titan has been suggested [e.g. 8,9] as a way to replenish methane to the atmosphere. Cryovolcanic features have been detected on other outer planet satellites [e.g. 10]. Cryovolcanism on Titan is expected to be different from that on other satellites, as the presence of a thick atmosphere on Titan will affect the vesiculation of bubbles in a cryomagma, the distribution of explosive products, and the cooling of cryolavas [7]. Cryomagma composition is likely a mixture of water ice and ammonia [9,10,11]. According to Lorenz [9] cryovolcanic eruptions on Titan, either present day or in the past, are more likely effusive than explosive as gas expansion from the cryomagma is limited by the significant atmospheric pressure. The SAR swath shows evidence of extensive effusive cryovolcanic features (such as flows and a dome or shield), but so far no features have been found that appear to have resulted from explosive eruptions (such as plume deposits or steep-sided volcanic edifices).

If the Ta SAR swath is showing a typical landscape on Titan, we can expect that many other cryovolcanic features will be found elsewhere on Titan during future fly-bys. Present-day cryovolcanic activity is feasible [9], with cryomagma transported to the surface via cracks. Detection of active cryovolcanism, if any exists, can be attempted by searching for surface changes in overlapping SAR swaths from different fly-bys, and by comparing SAR images with data from other remote sensing instruments on Cassini.

References: [1] Elachi et al. (1991). [2] Elachi et al. (2004), Submitted to Science. [3] Smith, P.H., et al. (1996). *Icarus*, 119, 336-349. [4] Lorenz, R. and J. Mitton (2002). Lifting Titan's Veil. Cambridge University Press, 260 pp. [5] McKenzie, D.F., et al. (1992) JGR, 97(E8), 15967. [6] Stevenson, D.J. (1992) ESA SP-338, pp. 167-176. [7] Tobie, G., et al. (2005). Icarus, in press. [8] Lorenz, R.D. 1993. ESA J., 17, 275-292. [9] Lorenz, R. D. 1996. Planet. Space Sci., 44, no. 9, 1021-1028. [10] Kargel, J.S., 1995. Earth, Moon, and Planets 67, 101-113. [11] Kargel, J.S., et al. 1991. Icarus 89, 93-112.

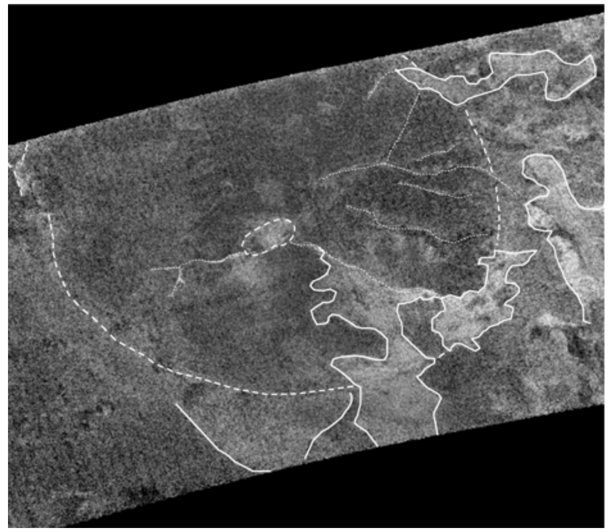

Fig. 1: Large circular feature interpreted as a dome or shield. The outline of the feature is shown in dashed lines, sinuous features that are interpreted as possible cryolava channels and flows are outlined in solid lines. The circular feature is about 180 km in diameter.

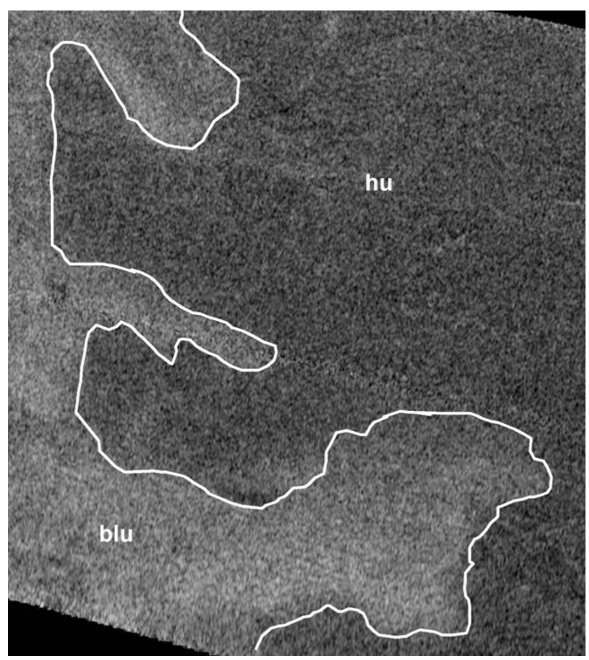

Fig.2: Bright lobate feature (blu) over a homogeneous unit (hu). The bright lobate feature is interpreted as a cryovolcanic flow. Image is ~ 190 km across.