EVIDENCE OF EXTENSIONAL AND COMPRESSIONAL TECTONISM AND EROSION IN TITAN'S XANADU PROVINCE. J. Radebaugh[1], P. Valora[1], R.D. Lorenz[2], S.D. Wall[3], R.L. Kirk[4], C.A. Wood[5], J.I. Lunine[6], E.R. Stofan[7], R.M. Lopes[3], T.G. Farr[3], G. Mitri[3], and the Cassini Radar Team. [1]Department of Geological Sciences, Brigham Young University, Provo, UT 84602, jani.radebaugh@byu.edu, [2]Johns Hopkins Applied Physics Laboratory, Laurel, MD 20723. [3]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109. [4]Astrogeology Division, U.S. Geological Survey, Flagstaff, AZ 86001. [5]Wheeling Jesuit University, Wheeling, WV 26003. [6]Department of Planetary Sciences, University of Arizona, Tucson, AZ 85721. [7]Proxemy Research, PO Box 338 Rectortown, VA 20140.

Introduction: Titan's enigmatic Xanadu province, located on Titan's trailing hemisphere and extending 100° degrees of longitude and over 1000 km, has been seen in some detail with instruments from the Cassini spacecraft. Bright to Cassini RADAR Synthetic Aperture Radar (SAR) and visible-near infrared (v-nIR) instruments, the region contains some of the most rugged, mountainous terrain on Titan, with relative elevations over 3000 meters. Xanadu contains evolved river channels, impact craters, and dry basins filled with smooth, radar-dark material, perhaps sediments from past lake beds. Arcuate and parallel mountain chains give evidence of past compression, and lineations associated with mountain fronts and valley floors give evidence of extension. Yet the overall elevation of Xanadu is puzzlingly low compared to surrounding sand sea basins. We suggest Xanadu is one of the oldest terrains on Titan and that its origin and evolution have been controlled and shaped by compressional and extensional tectonism in its icy crust.

Evidence of Erosion: Xanadu's varied terrains include rugged mountains and flat-topped plateaus as seen by SAR, all of which have been carved by fluvial processes, as evidenced by the presence of hundreds of kilometers of stream channels. On the western portion of Xanadu are several sets of very well-developed and dendritic drainages [1,2]. These channels are most likely formed by rainfall of methane, carved into bedrock containing water ice, as observed by the Visual and Infrared Mapping Spectrometer [3]. The rivers do not flow to the west, toward the SAR-dark Shangri-La sand sea, but instead toward the south [2]. This indicates that either there is currently a gentle, regional gradient toward the south or there was at the time of the formation of the river drainages. Since the drainages are so well-developed, they must be mature, and indicate erosion has been active on this part of Xanadu for some time.

Many rugged mountain peaks are found in the central portion of Xanadu, from 90° to 120° W longitude and beyond. These also show evidence of erosion, as there are visible channels throughout the terrain and there are aureoles of bright, probably erosional, material surrounding the mountains. In addition, they are similar in morphology to rugged, eroded mountains in, for example, Tibet, as viewed by Earth-based radar [4]. In the middle of Xanadu, near 100° W longitude, are many large, SAR-dark, or smooth or absorbing, patches interspersed between the mountains. These roughly follow enlarged drainage patterns, similar in morphology to drowned river valleys (Fig. 1). These dark areas are not nearly as dark as the north polar lakes [5], some of which return no signal at all. Thus it is thought that these valleys are not currently filled with liquid. They are most likely filled with solid materials that are smooth or mostly absorbing to microwaves, perhaps deposited by methane/ethane liquids that could have previously existed there. In general, valleys appear to be filled or drowned typically only when there has been a change in regional base level, or the level to which liquids will flow. This indicates that perhaps Xanadu was once more elevated and has since sunk below regional base level.

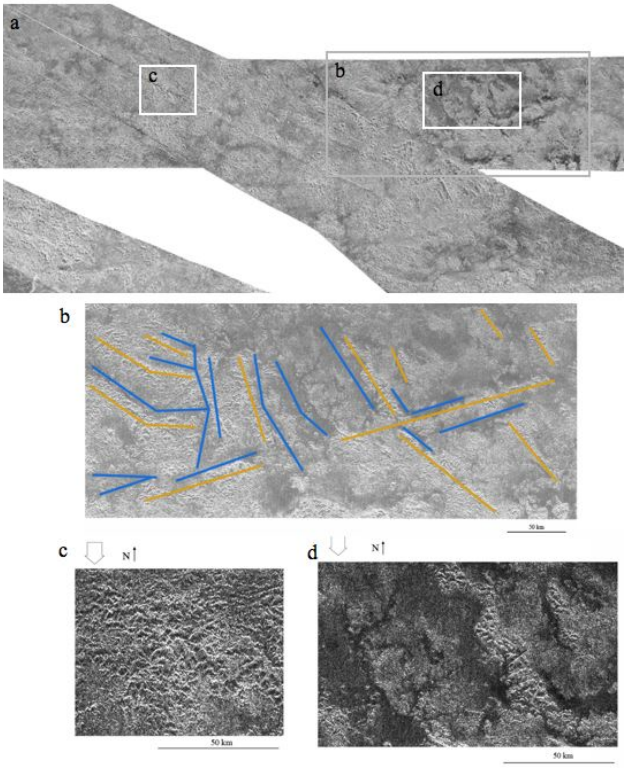

Fig. 1. Rugged mountains (c) and large smooth channels (d) in central Xanadu are cut by lineations (b).

Evidence of Tectonism: Many of the margins of widened valleys and mountain blocks in Xanadu's central region have straight morphologies (Fig. 1). Some of these lineations stretch for up to 100 km; many are subparallel to one another. These patterns indicate there are some regional tectonic controls on the evolution of the mountain blocks and associated river valleys. Lineations having these relationships are typical of regional extension, in this case having occurred in at least two main directions, one NE-SW and another NW-SE.

In the central and eastern portion, the mountains are organized into arcuate trends of bright peaks that we call belts. These arcuate belts are concave southward, and they appear to be interrupted only periodically by large drainages (Fig. 2).

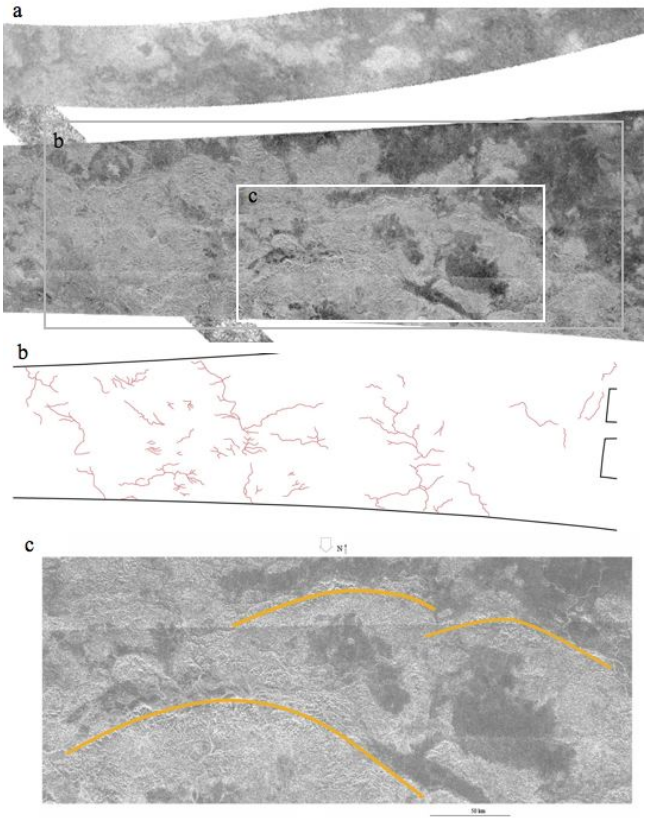

Fig. 2. Drainage traces show a distinctive trellis pattern (b) due to tectonic controls. Mountains show arcuate morphologies, perhaps due to compression.

The drainages and other river systems in the area are fairly well developed, but appear to have more of an angular, or trellis, pattern than their western Xanadu counterparts. The drainages are not as interconnected as those in Xanadu's western region, and are fewer in number. We conclude there have been tectonic controls on the formation or evolution of these drainages. In fact, many rivers trend east-west along the northern margins of the belts, which are periodically exploited by southward drainage slices. The N-S and E-W drainages connect, so that the overall drainage is to the south, the characteristic drainage gradient for most of Xanadu.

In Xanadu's south-central region, near 110° W longitude, are several E-W oriented mountain ranges, parallel to other E-W lineations in the area. We conclude these are the result of N-S compression [6].

History of Xanadu: We propose an evolutional history for Xanadu that begins with N-S oriented compression, which may have acted in many locations near Titan's equatorial regions [6]. This produced the extensive, rugged mountain ranges and large-scale folds, expressed as parallel ridges and arcuate ranges. Subsequently, extension occurred, leading to lineations clearly exposed in mountains and valleys. It is possible this extension occurred elsewhere on Titan but has been obscured by sand sea or organic precipitate sedimentation. Finally, Xanadu experienced extensive erosion and perhaps downdropping along south-bounding faults, as evidenced by cryovolcanic deposits on Xanadu's southern margin [7].

Xanadu has clear examples of extensional and compressional tectonism on Titan, evidence that Titan's internal activity is manifest at its surface. In addition, its heavily eroded morphologies indicate the unique Xanadu province may be an old terrain existing under an active atmosphere.

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