TITAN'S GREAT CRUSTAL THICKENING EVENT AND RECENT GEOLOGIC HISTORY. Charles A. Wood, Planetary Science Institute, 653 Main St. Wheeling, WV 26003; cwood@psi.edu.

Introduction: Titan is a large world, bigger than the planet Mercury, and yet it is strongly deficient in at least three types of landforms common to many large bodies in the solar system. Titan has very few readily identifiable volcanoes [1]. Titan has little evidence of tectonics other than linear mountain ranges mostly near the equator [2]. Titan has fewer than a dozen certain impact craters and only about 3-4 dozen more likely and possible ones [3]. I propose that all of these observations are related.

Volcanoes: Very few likely volcanoes have been identified on Titan.

Sotra-Erebor region [1]. The very most convincing volcano complex is Sotra Patera at 14°S, 40°W. Stereo mapping reveals a 1.4 km high series of peaks with a deep depression decapitating one (Doom Mons). A lobate flow, Mohini Fluctus, extends more than 300 km to the north. Adjacent to and paralleling this flow is another with an unnamed caldera-like feature near its center. A third possible volcanic mountain is nearby Erebor Mons (5°S, 36°W) standing 1 km above the surrounding plains.

Hotei Regio [4, 5]. This is a 700 km wide depression containing flow-like plains (26°S, 78°W) bounded by an arc of mountains along the southeastern margin of Xanadu. Hotei has been interpreted as "a geologically young volcanic region" by Soderblom et al [5].

Hot Cross Bun [6]. The apparent top of this ~120 km wide landform (38°N, 203°W) is cut by two intersecting graben at near right angles. Radial fractures appear around the periphery of the feature. This "bun' has been compared to the ~50 km wide summit of the Kunapipi Mons volcano on Venus. Nearby on Titan are three other similar looking "buns" each having a mountainous radar dark area and superposed bright area with strong radial lineations. There is no altimetry available for this area but the radial lineations suggest that each "bun" is elevated, a mountain.

A, B, C, D Mountains [7]. Topographic mapping identified an arc of four isolated mountains at 35° to 49°S, stretching from 12° to 150°W. No image data suggest they are volcanoes, only their conical shapes as isolated mountains hints at such an origin.

North Polar Craters [8]. At various longitudes > 65°N are hundreds of typically 10-20 km wide circular depressions that are morphologically more like volcanic collapse craters than any other landform. Some have raised rims and many have nested depressions, suggesting multiple periods of collapse as is common on Earth for both maars and calderas.

Tectonics: The major indications that tectonic activity occurred on Titan are linear mountain ranges and occasional straight reaches of river channels. Analysis by Liu et al [2] show that many mountains are in equatorial regions and trend in east-west directions. The interpretation of most researchers [e.g. 2, 9] is that the mountains were formed by conpressional forces. Stratigraphically, mountains are the oldest terrains on Titan [10], and indeed, the greatest concentration of impact craters is on Xanadu [3], the most extensive mountainous area of titan.

Impact Craters: The paucity of certain, likely and possible impact craters implies that the surface of Titan is young, somewhere between a few hundred million and one billion years old [3, 11, 12]. All impact craters have been modified by dunes, dark floor materials, or rim breaches. The extreme paucity of impact craters indicates that all of the terrains on Titan formed in the last 10% of that body's history.

Hot Spots: Sotra/Erebor, the buns, and possible A, B, C, D volcanics are all relatively isolated mountains with no strong relations to tectonics. These may be hot spot volcanics, where significant mantle plumes fractured the crust to reach the surface. The Hotei Regio location along a curved mountainous area suggests that faulting associated with the mountains and/or Xanadu may control the occurrence of these putative lava flows [5]. The North Polar craters are scattered over a large portion of the polar region. This may be because the poles are considered to have a thiner ice crust [13] making it easier for magma to reach the surface than in most regions.

The Great Crustal Thickening Event:

The youthful surface age of Titan is consistent with the Tobie et al model [14] which posits that Titan had a thin crust for it's first 4 billion years. About a half billion years ago the crust rapidly thickened, which I call the Great Crustal Thickening Event (GCTE). Before then the thin crust could be easily penetrated downward by impacts and upward by widespread melting episodes. Like the "tempestuous tectonics" proposed for Hadean Earth [15], Titan's thin crust could not dynamically support long term preservation of impact craters, volcanic cones, mountains or any other significant topographic excess.

Blandlands:

I propose that frequent eruptions of very fluid icy lavas (flood basalt equivalents) produced a global smooth surface as on Jupiter's moon Europa. Furthermore, the widespread, featureless and flat blandlands

(Undifferentiated Plains of [16]) that occupy 17% of Titan's surface have those characteristics because they veneer the last vast sheets of ice lavas that erupted before the GCTE thickened Titan's crust. Lopes et al [16] rejected ice lavas as the material comprising the blandlands because spectroscopic and radar data indicate the surface material is more likely to be aeolian-deposited sediments. However, all of the evidence is for the upper microns to few meters [17, 18] depths of surface material. Sediments no doubt are tens to a hundred meters thick, but I suggest they rest on a topographically smooth surface, the pre-GCTE ice flood lavas that created a planet-wide smooth, continuous surface. Although blandlands are concentrated in temperate latitudes, patches extend from the equator nearly to the poles. This distribution is consistent with all of Titan having been globally covered with pre-GCTE flood lavas that more recent polar and equatorial processes have hidden and transformed. Under the sediments Titan is a volcanic world.

The Beginning of Recorded History:

Once the crust became thicker and stronger a half billion years ago, impact craters, mountains and other topographic features began to be preserved. The small number of most such landforms is due to their preservation for only the last 500 milion years, a time when the rates of volcanism and impact cratering had presumebly greatly decreased from prior eons. Titan has only one impact basin, Menrva, because ones formed earlier than 500 million years ago foundered or were erased by lava flooding.

As the crust thickened, sheets of ice lavas could no longer erupt. Only in places where unknown circumstances thin the crust do a few hotspot volcanoes exist. Their conical mountain shapes and relatively narrow flows (at Sotra) suggest more viscous ice lavas than before the GCTE. A thinner crust near the North Pole has permitted widespread eruptions of small batches of ice lavas, also perhaps more viscous than ancient flood lavas, creating hundreds of volcanic collapse craters. Some of these small craters have complete elevated rims suggesting that they are young. The polar crust may still be somewhat thin, allowing eruptions to continue today.

Slow, Not Dead:

Moore and Pappalardo [19] speculated that Titan was a dynamically dead world with impact, atmospheric, aeolian and fluvial processes creating nearly all surface landforms, including putative volcanoes and mountains. Perhaps their hypothesis is partially right. However, I believe that the volcanoes and mountains are of internal origin, with atmospherically-driven aeolian, fluvial and erosional processes creating dunes, lakes and rivers, and modifying the impact craters, volcanoes and mountains. During the last half billion years Titan's thickening crust limited volcanism to a few rare locations with hotspots or thin crust. Additionally, existing mountains are stratigraphically old because they may have formed only when the crust was intermediate in thickness, thin enough to allow tectonic forces to fold it, and thick enough to support the newly created mountain masses.

The Methane Mystery:

Titan's proposed repeated global resurfacing by ice lava sheets until a half a billion years ago may explain why Titan's atmosphere contains so much methane. Because photochemistry breaks down atmospheric methane molecules within tens of millions of years, methane must be periodically replaced or there was much more methane in the past than normally assumed [20]. Flood eruptions before the GCTE may have loaded Titan's atmosphere with great amounts of methane, with continuing hot spot and polar eruptions helping maintain levels.

The Most Important Event in Titan's History:

The Great Crustal Thickening Event, if it occurred, was arguably the most important event in Titan's history. It explains the youthful age of Titan's surface, and the paucity of impact craters and volcanoes. The proposed existence of a global, Europa-like smooth icy surface explains why Titan has relatively little topographic diversity, and provided a topographically clean surface to underlie the veneer of blandland sediments. Massive outflows of icy lava sheets before the GCTE could have loaded the atmosphere with methane that has been slowly being destroyed ever since.

References:

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