Maxwell Montes in Ishtar - A collisional plateau on Venus?

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Many mechanisms are known to cause small areas of uplifted topography on the Earth (e.g. volcanism, offsets in strike slip faulting), but only one mechanism has been shown to be adequate for the formation of huge elevated areas: continental collision. The 5,000 m high, 2,000,000 km² Tibetan plateau provides the current example. Although at present apparently undergoing east west extension, with formation of north-south normal faults (e.g. ref.1), the Tibetan plateau was formed by NS crustal shortening as the Indian continent converged on the Eurasian. The continental collision which initiated formation of the plateau commenced about 45 my ago, and continues to the present day. India is estimated to be converging on Asia at an estimated 5 cm yr⁻¹ (2, 3, 4). Thus, the Tibetan plateau, which is much the largest elevated region on Earth, is also one of its youngest physical features.

Topographically, the plateau is characterised by east west trending mountain ridges and valleys, resulting from folding and thrusting, (e.g. the Tsang Po valley containing the Indus suture). Spacing of the predominant east-west ridges is variable but ranges from 20 to 50 km. The east-west structures are cut obliquely by major strike slip faults (e.g. Kun Lun and Al'yn Tagh), and by large irregular circular structures up to 100 km in diameter (e.g. the giant "kidney" of N'gan glaring Tso). Some of these cross cutting features may be related to silicic igneous activity because ignimbrites have been collected from the area (5) and boiling springs abound (6), but no major caldera has yet been clearly identified.

On Venus, Ishtar Terra has been identified on morphological grounds as the nearest counterpart to a terrestrial continent (7, 8). Within Ishtar, Maxwell Montes forms an elevated pork chop shaped uplifted area covering some 500,000 km², and rising 4.5 km above Venus' datum topographic level (9). High resolution radar studies show that surface roughnesses of the Maxwell plateau have a conspicuously linear, banded pattern, running NNW-SSE, with a spacing between bands of 10-20 km. Similar terrain types are found at Akna and Freya Montes, where the banding parallels the strike of the topography (9, 10). Lower parts of Ishtar show tantalizing indications that the banded terrain may be more widespread. Maxwell Montes contains a large circular structure 100 km in diameter.

Solomon and Head (8) and Campbell et al. (9) interpreted the banded terrains as products of deformation, but did not attempt to specify the processes involved, on account of the low resolution of the radar images, and the general absence of firm geological information on Venus. Specifically, Solomon and Head showed that the band spacing was compatible with models for either compressive or extensional tectonics. While mindful of the limitations of working with the radar data, we suggest that there is a case for interpreting the banded terrain in terms of compressional tectonics, and we suggest that this may have been developed in a collisional environment akin to the Tibetan plateau.

Factors supporting this contention are:

1. Fold "closures" appear to be visible in the banded terrain.
2. The linear bands are far more extensive and continuous than the fault bounded blocks observed in areas of terrestrial extensional tectonics, such as the Basin and Range. Fold and thrust belts, by contrast, are commonly conspicuously continuous and extensive, and are strongly reminiscent of the
radar roughness images of Maxwell Montes. (E.g. Appalacheans, Bolivia, China.

3. Morgan and Phillips (11) have argued from thermal considerations that elevations as high as Maxwell Montes can exist on Venus only as a result of crustal thickening, and not as a product of lithospheric thinning. This precludes lithospheric extension or heating as mechanisms to produce the elevated terrain, although an area of already thickened crust could be undergoing lithospheric extension, as Tibet is. Weertman (12) concluded from creep considerations that, in the absence of dynamic processes, major mountainous areas could only be supported for long periods on Venus if mantle materials were extremely dry. Phillips et al. (8) have further argued from lithospheric stress considerations that elevated areas such as Maxwell Montes must be young. Given the youthfulness of the terrestrial Tibetan plateau, we see no a priori reason why the most elevated part of Venus should not also be young.

The crustal thickening apparently required to support Ishtar (11) raises the intriguing possibility that Ishtar and Maxwell Montes represent fractionated, low density crust. Because the ring structures of the Tibetan plateau have been attributed to partial melting of continental crust (13), we wish to suggest the possibility that the great ring within Maxwell Montes represents a caldera or caldera complex resulting from partial melting of Venerean continental crust. Thus, both Ishtar and Tibet may represent elevated regions which are (1) areally extensive; (2) Underlain by low density crust; (3) folded and (4) partially molten at depth.

While we are confident that the remote sensing and geophysical data indicate a compressive tectonic regime for Ishtar, confirmation of the collisional hypothesis will require much more detailed knowledge of the geology of Venus. Specifically, the nature of the postulated collisional events producing Ishtar and Maxwell Montes can hardly be addressed with our present knowledge of Venus. We tentatively hypothesize, however, that by analogy with Tibet, the broad extent of the banded terrain suggests that continental collision, rather than oceanic/continental convergence may be involved. The broadest region of elevated ground along the Andean plate margin is the 3-4000 m high Bolivian altiplano, which is only 250 km wide. Compressional tectonics extend up to 700 km inland from the Andean volcanic belt. The Tibetan plateau, by contrast, is by itself over 1,000 km across and deformation within Asia extends more than 2,000 km from the Himalayan front. On this interpretation, Ishtar would have to be a continental area lately formed by suturing of two separate continental fragments, and Maxwell Montes would form high ground close to the suture zone.