CIRCULAR LOWS, A GENETICALLY DISTINCT SUBSET OF CORONAE? K. McDaniel[1] and V. L. Hansen[1], [1]Department of Geological Sciences, University of Minnesota Duluth, Duluth, MN 55812 (mcda0054@d.umn.edu; vhansen@d.umn.edu).

Introduction: Venus hosts ~515 coronae with diameters ranging from ~60 - 2600 km [1]. Coronae, circular to quasi-circular structures characterized by an annulus of fractures or ridges, variably display radial fractures, lava flows, and double ring structures [2, 3]. In plan view some coronae display elliptical forms with aspects ratios as much as 2:1.Coronae topographic profiles range from domical to plateau-shaped, rimmed depressions, to amphitheater-like depression, to no topographic expression [3]; the range of topographic profiles has been attributed to developmental stage [4]. Coronae have been interpreted as both exogenic products and endogenic products, including impact craters, caldera, and the surface expression of diapirs on the lithosphere diapiric structures [5, 6, 7], although most workers accept a diapiric origin [2, 8, 3, 9]. Given the wide range of coronae characteristics, coronae might form by more than one process.

In this contribution we examine coronae marked by circular amphitheater-like depressions; we call these features circular lows in order to highlight them as a subset of coronae, with attention to description rather than possible mode of formation.

Circular Lows: A reconnaissance global survey identified ~ 50 circular lows on Venus with diameters ranging from ~60 to 380 km. Each circular low displays a circular amphitheater-shape depression. We constructed detailed geologic maps of 8 circular lows in order to unravel their individual geologic histories to provide clues to formation. Four are discussed briefly here: Zemlika, Aramaiti, Ohogetsu, and Thouris. In each map area we mapped a region well outside of the targeted circular low in order to place the circular lows in spatial and temporal context . Map areas were selected based on completeness of data; Magellan SAR and altimetry comprised the major basic data sets. We downloaded full resolution SAR imagery from USGS map-a-planet. When possible we used cycle 1, 2 and 3 data. All SAR images were viewed both normal and inverted modes. Where data allowed we constructed true stereo views [10]; and in each case we used synthetic stereo imagery [11] constructed with macros developed by D.A. Young. Mapping was conducted digitally using Adobe Illustrator™; images were stretched and inverted using Adobe Photoshop™.

Zemlika (33.5S/50.0E; 150 km diameter) occurs within the map area that extends from 29.3S to 37.5S and 54E to 46E. The region represents a lowland that hosts a large ribbon terrain tessera inlier with WNW-trending folds and orthogonal ribbon fabric and three 'pristine' impact craters. Zemlika lies within the tessera inlier, which shows little disruption of surrounding delicate folds and ribbon fabrics, and structural trends around Zemlika are collinear. Regional fractures trend NE and wrinkle ridges trend NW; both structural suites deform local intratessera fill.

Topographically Zemlika is marked by a 1 km deep interior circular depression, and a ~0.5 km high and ~ 50 km wide rim. (Note all heights are given relative to local base level outside the circular low). The rim does not completely surround Zemlika's central region. A well-defined concentric fracture suite defines Zemlika structurally. Concentric fractures occur along the rim walls as well as the crest of the rim. Along the northern margin of the circular low concentric fractures extend beyond the crest outside the rim. Concentric fracture spacing typically ranges from 1 to 2 km and shows tighter spacing from 6 to 10 o' clock of the structure. From 1 to 6 o' clock concentric fractures correlate spatially with a 0.5 km raised rim. Within the depression wrinkle ridges trend parallel to regional wrinkle ridges. Zemlika clearly formed after the tessera-terrain; Zemlika cuts the delicate tessera structural fabric in cookie-cutter manner with little to no disruption to the surrounding folds or ribbons, yet within the region of Zemlika tessera fabrics are completely obliterated. Interior wrinkle ridges parallel the region suite, indicating that the interior of Zemlika is flooded with a thin layer, and that wrinkle ridges formed after Zemlika and after minor flooding.

The Aramaiti map area, which extends from 22.5S to 29.5S and 88.5E to 79.5E, hosts two circular lows, *Aramaiti* (23.3S/82E; 350 km diameter) and *Ohogetsu* (27.0S/85.7E; 175 km diameter), as well as ribbon-tessera terrain, and one impact crater. Regional fractures trend ENE and regional wrinkle ridges trend ENE and NW, defining two suites; wrinkle ridges are best developed in the northeast corner. Wrinkle ridges also cut a radar smooth material unit that surrounds Ohogetsu and a radar smooth unit material in the northwest corner of the map touching the edge of Aramaiti's rim.

Topographically Aramaiti is defined by a ~1km deep and 350 km wide depression, and a ~ 0.5 km high and ~25 km wide rim. A 100 km wide (~0.5 km high) dome surrounding by a ~80 km wide and ~ 1 km deep moat lie within the interior. The dome surface preserves subdued radial fractures. Aramaiti cuts tessera terrain along its northeastern margin; delicate tessera-terrain structural fabrics are obliterated within Aramaiti, but appear pristine northeast of Aramaiti. A well-developed suite of concentric fractures structurally defines Aramaiti. From 4 to 7 o' clock concentric fractures spaced 1-6 km occur along the inside rim wall. From 8 to 2 o'clock concentric fractures spaced 1-2 km occur along the inside rim wall.

Ohogetsu is defined by a 0.5 km deep, 175 km wide depression with a small central peak, ~0.5 km high and ~15 km wide rim; the rim is partially developed around the structure and cuts into tessera terrain. Interior wrinkle ridges that surround the central peak trend parallel to regional wrinkle ridges. Well-defined concentric fractures define Ohogetsu structurally. Concentric fractures are most tightly spaced (1-2 km) and best developed from 5 to 12 o'clock, and occur along the topographic rim wall and crest, and extending locally outside the rim. From 12 to 5 o'clock concentric fractures occur along the basin floor.

Aramaiti and Ohogetsu both formed after the local tessera terrain; both features cut tessera fabric and obliterate fabric within their rims and interiors, yet delicate structural fabric trends within the tessera-terrain lack disruption immediately away from each circular low. Wrinkle ridges post-date the formation of both circular lows.

Thouris (6.5N/12.9E; 190 km diameter) occurs within the map area that extends from 3S to 10S and 8.4E to 17.4E. This map area also hosts two large coronae, Atargatis (8.0S/8.6E; 350 km diameter) and Kuan Yin (4.3S/10.0E; 310 km diameter), and one impact crater. Well-developed regional wrinkle ridges trend ENE orthogonal to regional fractures, which trend NNW, and concentrate in the southeast corner of the map area. A 50 km wide zone of north-striking regional fractures transects the middle of Thouris. Within the fracture zone, 10-30 km long and ~1-2 km wide graben cut the north and south rim of Thouris, and parallel the regional fracture suite.

Topographically Thouris is defined by a ~ 0.5 km deep, 190 km wide depression surrounded by a ~ 0.1-0.3 km high and ~10-20 km wide rim that surrounds most of the structure. Concentric fractures, which structurally define Thouris, occur along the inside wall and rim crest. Along the north and south margins of Thouris graben (~1-2 km width, ~5-20 km length) trend NW cutting into rim and interior wall of the depression. The central region of Thouris hosts two small volcanoes with minor flooding; interior wrinkle ridges trend parallel to regional wrinkle ridges, indicating that wrinkle ridges post-date Thouris formation.

Thouris likely post-dates the formation of the two large coronae in the western portion of the map area because Thouris trends do not appear diverted by coronae trends; although the spatial separation of the three features makes robust relative timing relations difficult to constrain.

The mapped circular lows share the following characteristics: 1) an amphitheater shape, 2) concentric fractures, 3) lack of radial fractures, and 4) lack of disturbance to surrounding areas.

Discussion: The formation of diapiric structures has been studied by a range of workers using techniques from experimental, analytical models and finite element models [12, 13, 14]. These studies indicate a general sequence of events during layer impingement from below of a buoyant diapir. As the diapir reaches the layer from below, the surface domes upward and radial fractures form outward from the dome crest. As the diapir flattens and spreads along the base of the layer, a topographic rim and/or rim structures may develop, consisting of concentric fractures, which become more focused close to the rim as the diapir continues to spread below the layer. In the final stages of diapir emplacement, the central region of the dome may become depressed below the surrounding area [14]. Radial fractures are common elements of diapiric structures, although radial structures might not develop due to the regional stress field. Fractures may develop parallel to orientation of the minimum principal compressive stress but in this case the resulting diapiric structure is elongate rather than circular [12,13].

Map relations may be inconsistent with diapiric formation of the circular lows, given the lack of radial fractures. Circular lows appear to not have disturbed the surrounding area. Theoretically diapiric emplacement would cause deformation to the surrounding area based on the predicted models [12,13,14]. Therefore the mapped circular lows are not easily accommodated within a diapiric model.

The characteristic features might be more consistent with formation of calderas or impact features. Perhaps circular lows represent ancient impact craters formed under different environmental conditions than the conditions at which the ~1000 currently recognized impact craters formed. Interpreting circular lows as ancient impact craters can address problems that diapir models could not. Ancient impact craters would explain the lack of radial fractures and the obvious development of concentric structures because an impact punches through the surface, and may lack radial fractures. This might also accomdate the circular planform. Rims could represent impact ejecta; all four circular lows have some sort of rim. An ancient impact crater model could address the circular low causing a lack of deformation to the surrounding area. If an impact crater impacts tessera terrain, it does not disturb surrounding tessera terrain. The circular lows appear to have sharp contacts as if they were punched out like a cookie cutter. For a better understanding on whether these circular lows possibly represent ancient impact craters or calderas more mapping.

References: [1] Stofan E.R. et al. (2001) *GRL*, 28, 4267-4270. [2] Stofan E.R. et al. (1992) *JGR*, 97, 13347-13378. [3] Stofan E.R. et al. (1997) pp. 931-965 in *Venus II*, Univ. Arizona Press, Tuscon. [4] Smrekar S.E. & Stofan E.R. (1996) *Sci.*, 277, 1289-1294.[5] Vita-Finzi C.et al.(2004) *LPSC XXXV,* Abstract #1564. [6] Jones A.P. (2004) *GSA Spec. Paper* (In Press). [7] Hamilton W.B. (2004) *GSA Spec. Paper* (In Press). [8] Squyres S.W. et al. (1992) JGR. 97, 13,611-13,634. [9] Hansen V.L. (2003) *GSAB*, 115, 1040-1052. [10] Plaut J.J. (1993) pp. 14-18. [11] Kirk R.L. et al. (1992) JGR, 97, 16371-16380. [12] Withjack M. & Scheiner C. (1982) *AAPG*, 66, 3002-3016. [13] Cyr K.E. & Melosh H.J. (1993) *Icarus*, 102, 175-184. [14] Koch D.M. & Manga M. (1996) *GRL*, 23, 175-184.