Introduction: Several of the largest craters on Venus, including Mead, Meitner and Isabella, exhibit well-developed floor fracture patterns combining a central set of radial features with a peripheral set of concentric fractures. This pattern strongly resembles the fracture patterns observed in the largest floor-fractured craters on the Moon (e.g. Humboldt, Gauss, Petavius). Although most lunar floor-fractured craters apparently reflect crater modification by igneous intrusions and volcanism [1,2,3], we propose that the fractures in these larger craters represent domical flexure events in response to post-impact isostatic uplift. Since the extent of uplift and surface failure in this model depends on both the size of the basin cavity and the local lithospheric thickness, this interpretation also provides a means for constraining lithospheric thicknesses on Venus. Based on the apparent onset diameter of isostatic crater modification, we derive lithospheric thickness estimates for the Moon of ~80-100 km, and for Venus of ~50-70 km.

Large Floor-fractured Craters: As noted in a companion abstract [4], ten craters on Venus show patterns of concentric or polygonal fractures resembling failure patterns observed in lunar floor-fractured craters. These craters are comparable in size (~20-90 km) to most of the lunar examples, and three craters in particular contain well-defined, moat-like structures around a scarp-bounded central floor plate identical to features observed in the most extensively modified craters on the Moon [5]. Since formation of such uplifted floor plates is best modeled by deformation over a shallow, crater-centered intrusion [3], we have identified these ten craters as likely sites for igneous crater modification on Venus [4,5].

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In addition to these proposed floor-fractured craters, however, four of the largest craters on Venus (Table) exhibit a distinctive pattern of floor modification structures unlike those observed in the majority of lunar floor-fractured craters. As illustrated at Isabella (figure 1), this pattern comprises a central set of irregular radial lineaments inside an annulus of concentric fractures near the edge of the central basin floor. Further, the two largest proposed floor-fractured craters below 100 km in diameter (Potanina and Mona Lisa) also exhibit radiating structures inside a fracture annulus (Table), but in both instances, these central features contain prominent polygonal elements as well. Based on these observations, therefore, crater modification on Venus appears to vary with crater size. For craters smaller than ~60-100 km, failure produces predominantly concentric and polygonal fracture patterns, whereas radial fractures dominate failure within the central floor of larger craters.

A similar variation in crater modification with crater size also occurs on the Moon. Specifically, although most floor-fractured craters on the Moon exhibit polygonal or concentric fractures consistent with uplift and failure of the crater floor over a crater-centered intrusion [1,3], the largest floor-fractured craters on the Moon (e.g. Humboldt, D=207 km; Gauss, D=177 km; Petavius, D=177 km; and Schrödinger, D=320 km) feature predominantly radial fracture patterns with peripheral concentric elements, minimal volcanism and negligible changes in apparent crater depth [1,3]. These failure patterns might reflect cone-sheet-like failure over very deep igneous intrusions [3], but there is little independent evidence for such intrusions beneath these craters. For the terrestrial Sudbury structure (D=180 km), which also shows evidence for an early episode of crater-centered radial fracturing [3,6], geophysical evidence precludes emplacement of any large contemporaneous intrusion at depth [7]. We therefore favor an alternative origin for these radial fracture patterns related to post-impact isostatic uplift in large craters.

Isostatic Flexure Mechanism: To first order, the excavation of an impact crater on any planet should create a negative load favoring isostatic uplift and flexure of the crater floor and surrounding lithosphere [3,8]. Since most craters are significantly smaller than the relative stiffness length of the respective planetary lithospheres, however, significant crater-centered uplift or deformation is likely only for the largest craters on any given planet [9]. Both cavity collapse and mantle uplift at these scales may limit the magnitude of such large cavity loads, but total isostatic equilibration of large craters by these processes seems unlikely. Even at larger multi-ring basin scales, clear signatures of post-impact, basin-centered uplift can be recognized [10,11].

Based on the work of Baldwin [8] and Broitman and Silvestro [9], therefore, crater-centered uplifts during post-impact isostatic adjustment should produce failure by domical flexure of the crater floor. Since such flexure results in a central sequence of radial failure inside a narrow region of concentric fracturing [12], this mechanism can produce the distinctive failure patterns observed on Venus. Further, since small craters should not induce sufficient isostatic adjustments to initiate failure, this model also explains the restriction of such failure to the largest craters on both the Moon and Venus.
Implications for Lithospheric Thickness:
In addition to explaining the apparent transition from igneous crater modification at small crater diameters to domical flexure at large crater diameters, the isostatic crater modification model also provides a basis for estimating the thickness of the flexural elastic lithosphere on Venus. Specifically, if the smallest craters containing a combined radial and concentric failure pattern are identified with the transition diameter at which isostatic uplift first initiates failure, this crater size provides a model for the load required to achieve a specific lithospheric yield strength. Since the transition diameter on Venus appears to be between 80 and 100 km (Table), figure 2 shows modeled hoop stresses for these diameters over a range of lithospheric thicknesses. In each case, a cylindrical load equivalent in diameter to the crater floor was assumed in order to partially account for the effects of cavity collapse and subsurface mantle uplifts on crater equilibration. If we then assume that the failure strength of the crater floor materials is ~300 bar, roughly equivalent to terrestrial rock strengths [13], the indicated lithospheric thickness for Venus is on the order of 48-72 km. A similar calculation for the Moon, where apparent crater depths are greater and the transition diameter is between 175 and 200 km, indicates a lunar lithospheric thickness of ~80-100 km. These latter values are consistent with the maximum lithospheric thicknesses (>75 km and 100-150 km) derived by [14] for flexure on the Moon in response to basin-filling mare loads.