TABLE 4. Ejecta Load Models for HC Formation

Transient Cavity Radius, km	Ejecta Load Radius, km	T, km	Min Ejecta Thickness, km	Cavity Depth, km,	$D:d$
900	1800	350	2.69	27	70:1
900	2300	100	1.5	24	75:1
600	2300	100	1.5	55	20:1
450	2300	100	1.5	98	9:1

aspect ratio would result in an ejecta load of ~4 km mean thickness extending 1500 km from the basin center. For the values of lithospheric thickness predicted by thermal history calculations, such a load would be expected to initiate fracture outside the basin scarp. The absence of observed structures around Isidis and the large discrepancy in modeled ejecta thicknesses relative to the minimum load derived from the flexure inversions indicate an excessive transient cavity size in these models. By reducing the transient cavity radii to ~80% of the massif ring radii and fixing aspect ratios in the range of 20:1 to 25:1, ejecta thicknesses can be derived which are consistent both with the load derived from the HC inversion and with the absence of canyon forms around Isidis.

The one weakness of this mechanism for HC formation is that the width of the canyons may be unreasonably large for formation by flexure. Lunar and terrestrial flexural models treat fractures only a few kilometers in width [*Solomon and Head*, 1980], and the massif ring graben of Isidis and Hellas rarely exceed 10 km in width. The distant Hellas concentric canyons, however, achieve widths of up to 100 km, and widths less than 30 km are rare. This increase by more than an order of magnitude over typical values of lithospheric flexure may indicate either widening of the flexure structures by lateral mass wasting or an entirely different deformation process. Modification by any mechanism, however, must occur soon after the Hellas impact, as later activity is limited by the derived ages. One possible modification sequence is analogous to that of the Valles Marineris structures around Chryse [*Schultz et al.*, 1982; *Wichman and Schultz*, 1988*b*], where structurally controlled or released catastrophic floods and lateral mass wasting widened flexurally formed structures into broad canyons. The outflow channels responsible are not presently recognized about the HC and were perhaps obscured by Isidis ejecta and later intercrater plains.

In summary, a flexural origin for the distant Hellas–concentric canyons requires an extremely large surface load emplaced shortly after basin formation and an increase in the resulting feature width by over an order of magnitude. Basin–filling loads must be transient in nature and require an exceptionally thick lithosphere if confined to the interior of the basin scarp. Formation by flexure under a more extensive static ejecta load is possible, but other mechanisms may account for the HC with equal or greater facility.

Impact–Induced Ring Fracture

Because the distant concentric canyons of Hellas date from just after the Hellas impact, it is reasonable to suspect that the impact may have triggered canyon formation. With the exception of flexure under an ejecta load, this requires consideration of dynamic mechanisms for ring fracture, such as those developed from study of the Valhalla system of ring scarps on Callisto [*McKinnon and Melosh*, 1980; *Melosh*, 1982*a*]. *McKinnon and Melosh* [1980] interpret the rings of Valhalla to result from dynamic collapse of the transient cavity. They propose that any transient cavity penetrating an elastic lithosphere is unstable in the presence of an underlying viscous asthenosphere. Cavity collapse results in flow of the asthenosphere along a topographically derived hydrostatic gradient into the transient cavity, and drag at the base of the lithosphere from this influx leads to surface faulting. The extent and degree of faulting depend primarily on the comparative size of the impact relative to the lithospheric thickness. For transient cavity depths of the order of the lithospheric thickness, only a few concentric fractures are expected, and for cavity depths greater than lithospheric thickness, extensive ring fracturing is predicted. For very fluid asthenospheres, complete surface disruption is possible [*McKinnon and Melosh*, 1980].

Melosh [1982*b*] subsequently developed a numerical model for this process with the assumption that the lithosphere responds as a Bingham plastic and derived a sequence of concentrically zoned lithospheric deformation around the basin (Figure 16). The innermost zone is a narrow band of strike–slip faulting encircled by an annulus of "enhanced flow," characterized by the separation of lithospheric blocks along concentric fractures. Outside this region is a zone of stable plastic flow and ordinary concentric normal faulting. Another annulus of strike–slip deformation theoretically encircles this zone of stable flow, but for sufficiently large impacts this stress regime is suppressed by planetary curvature [*Melosh*, 1982*b*]. The outer limit of lithospheric failure is defined by the transi-