THE GEOMETRY OF FURROWS ON GANYMEDE, Paul M. Schenk and W. B. McKinnon, Department Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130.

The geometry of the ancient furrow system on Ganymede, which forms a crudely concentric pattern (Fig. 1), has been cited as evidence both for and against an impact origin (1,2,3,4,5). We reexamine the geometry of this system in light of recent results on the geometry (i.e., circularity) of the multi-ring Valhalla structure on Callisto (6). The proposed impact origin for the Ganymede furrow system continues to be debated because many parts of this system, including the apparent central region, have been resurfaced by younger grooved terrain, and because furrows in the two largest preserved polygonal remnants, Galileo and Marius Regio, appear to be nonaligned and noncircular (7). Zuber and Parmentier (7) concluded that the apparent noncircularity of the furrows can be explained by either subsequent penetrative deformation or an initially noncircular impact structure. We have shown that while most ring segments of the preserved Valhalla multi-ring structure on Callisto are roughly circular and concentric, azimuths of some ring segments in the outer northeastern zone of the structure deviate by up to 30° from small circles (ref. 6; Fig. 2, arrows). The cause(s) of these asymmetries is unclear but may be related to preexisting impact structures, differences in lithospheric thickness or mechanical properties, or the mechanics of ring formation itself.

Noncircularity of some furrows on Ganymede could explain why the calculated centers of curvature for the furrows of Galileo and North and South Marius Regio (7), respectively, do not agree. The analysis of (7), which minimized the least-squared differences between furrows and circular arcs, weighted long furrows (such as found in northwest Galileo Regio) preferentially over short furrows. Ganymede furrows identified on Voyager images and located on USGS Atlas of Jovian Satellites quadrangle charts were mapped into cylindrical coordinates (Fig. 1). A comparison of furrows with small circles drawn about the best-fit center for Galileo Regio, -39°, 178° (7) shows disagreement in southeastern Galileo Regio and Marius Regio (Fig. 3a, arrows). The best fit of furrows in (7) occurred in western Galileo Regio (where most longer furrows are located), but our analysis shows a discrepancy here as well (Fig. 3a). A better fit overall was achieved by moving the center of curvature northward to -20°, 180° (Fig. 3b). There is still a small amount of divergence locally and in northwestmost Galileo Regio, at the top of the figure, reminiscent of Valhalla. The good overall fit of furrows to small circles about this center of curvature indicates that, despite some local deviations of furrows from circularity, lateral motion between units of dark terrain (8) is not required by furrow geometry, in agreement with (7). The furrows do appear to follow small circles, contrary to (5). Arguments against an impact origin for Ganymede furrows based on nonalignment and deviations from circularity of furrows, and the supposed "rectilinearity" of furrows (5) are unfounded. We argue that the apparent nonalignment and deviations from circularity of the Ganymede furrows and ring segments in general are likely inherent properties of multi-ring structures on icy satellites, as demonstrated by the Valhalla example (Fig. 2), and that the geometric aspects of the Ganymede furrow system discussed here are consistent with an impact origin (1,2,3).

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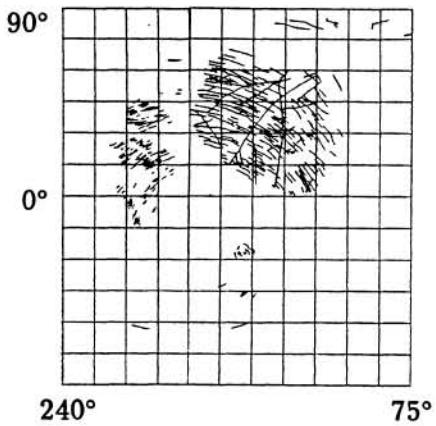

Fig. 1: Cylindrical map of furrows on part of Ganymede. Largest group occurs on Galileo Regio.

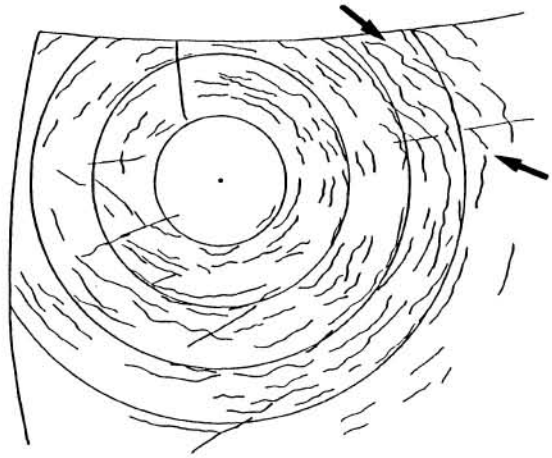

Fig. 2: Orthographic map of Valhalla ring segments on Callisto and small circles about its center. Spacing between small circles is 7.5° (320 km).

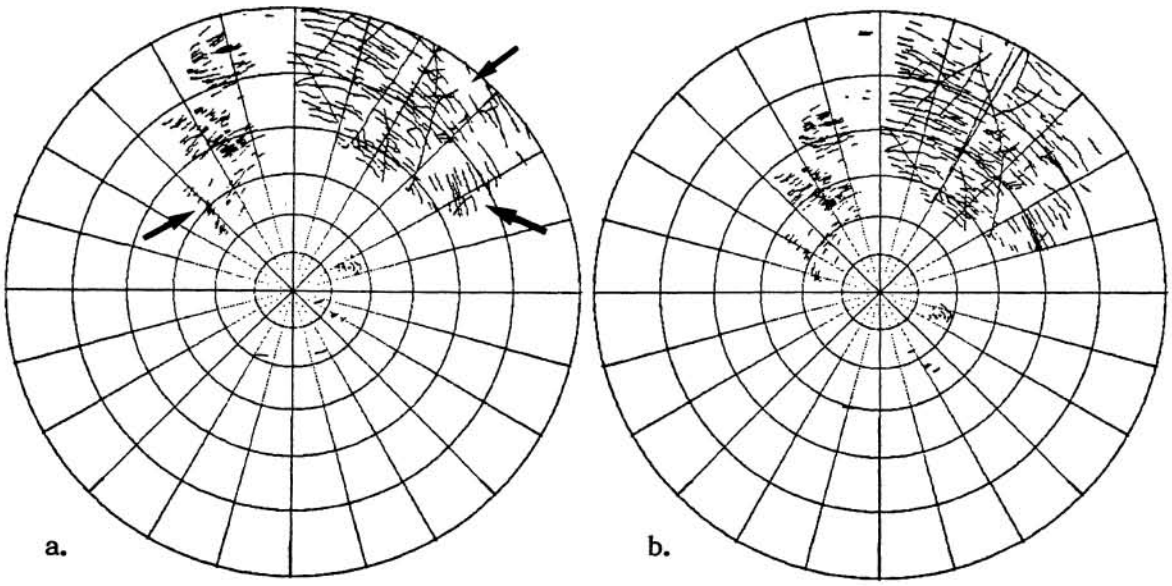

Fig. 3: Stereographic maps of Ganymede furrows and small circles drawn around centers of curvature at (a) -39°, 178° (from [7]), and (b) -20°, 180°. Spacing between small circles is 15° (690 km).