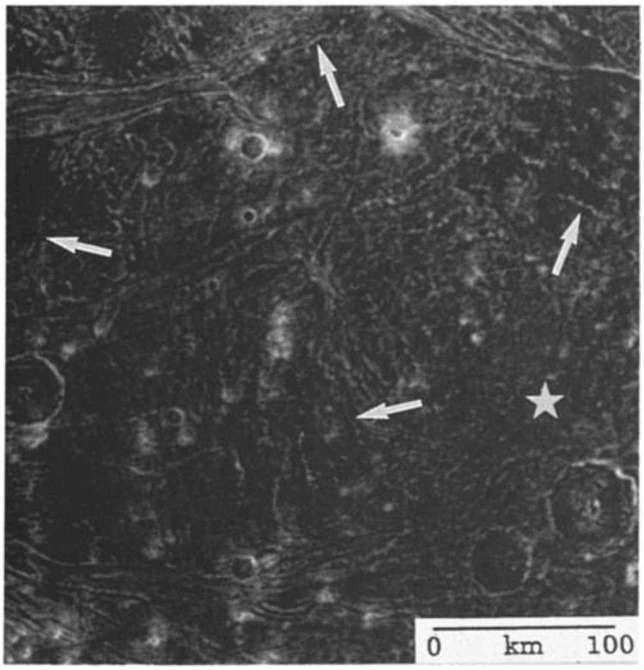

Fig. 7. Ring graben surrounding a large palimpsest south of Marius Regio. The star is placed in the center of the palimpsest, and the arrows point to several of the prominent troughs. Note that the east-west oriented groove lane crosscut by the troughs is easily recognizable. (Voyager 2 image 20637.47, centered near 27°S,156°W.)

decreased enough, large-scale foundering of the silicate-rich layer would have occurred. *Janes and Melosh* [1988] showed that deformation over a large-scale negative diapir would include proximal, radially arranged ridges and distal concentric troughs. Superposition of uniform stress during deformation would have resulted in either expansion or contraction of the domain of extension.

Model 6: Reactivation of conjugate tidal fractures (Figure 6f). This model, proposed by *Thomas et al.* [1986], invokes relict zones of weakness created by either tidal despinning or orbital recession that were reactivated by volcanism and extensional tectonism. The model predicts (1) two sets of troughs occurring at mid- to equtorial latitudes and intersecting at a 60°-70° angle, (2) northeast and northwest orientations of the trough sets, unless global reorientation or polar wander has occurred [*Melosh*, 1977, 1980], (3) variable crosscutting relations of the trough sets, (4) variable regional trough ages, (5) association of the troughs with volcanic deposits, and (6) lack of a concentric or radial fracture pattern.

Model 7: Reactivation of parallel tidal fractures (Figure 6g). The primary difference between this model and the previous one is the orientation of the relict zones of weakness. *Melosh* [1977, 1980] showed that the least principal stresses created by both tidal despinning and orbital recession are oriented north-south. Parallel east-west tidal zones of weakness could have resulted from either of two processes, (1) dike injection perpendicular to the least principal stress or (2) high-latitude extensional deformation by tidal despinning. The predictions of this model are (1) parallel troughs that approximately define a small circle system, (2) east-west trough orientation unless global reorientation or polar wander has occurred, (3) association of the troughs with volcanic deposits, and (4) variable regional trough ages.

Model 8: Reactivation of an impact-generated, multiringed structure (Figure 6h). This model, proposed for systems I and III by *Murchie and Head* [1987] and *Murchie et al.* [1988], envisions prolonged reactivation of a multiringed structure by volcanism and extensional tectonism. The original rings need not be graben; they may be single normal faults or tension fractures, possibly buried or intruded by younger igneous materials, which served as loci for later activity. Predictions of the model include (1) dominant concentric and fewer long radial troughs, representing the configuration of the impact-generated fractures, (2) possibly short radial fractures terminating against the concentric fractures, formed as a result of failure in tension of impact fracture-defined rings, (3) a central, degraded impact feature, (4) association of the troughs with volcanic materials, (5) variable regional trough ages, and (6) variable crosscutting relations of the trough sets.

Remsberg [1981] showed that the Valhalla ring system on Callisto is apparently transitional to the type of trough system described above. The Valhalla system contains concentric ridges, scarps, and troughs that are centered on a large palimpsest (Figure 8*a*), and is widely interpreted to have originated from a large impact .[*Smith et al.*, 1979*a*; *McKinnon and Melosh*, 1980; *Passey and Shoemaker*, 1982; *Melosh*, 1982; *Squyres and Croft*, 1986; *Schenk and McKinnon*, 1987]. However, the structure also appears to have undergone some endogenic modification. Bands of hummocky intermediate-albedo material are observed at the bases of scarps hundreds of kilometers from the central palimpsest. These materials embay preexisting craters (arrows, Figure 8*b*) and have a crater density significantly lower than does surrounding terrain, suggesting a younger age and emanation of fluid material from the impact-generated fractures [*Remsberg*, 1981].

Model 9: Reactivation of fractures created by an impact-induced tsunami (Figure 6i). This model is similar to the one just described, except that the impact-generated fractures would have had a somewhat different origin and arrangement. Relict radial and concentric zones of weakness would be similar in abundance and morphology, so that there would be no fracture-defined rings that could later fail in tension. Predictions of the model include (1) abundant radial and concentric troughs, (2) association of the troughs with volcanic materials, (3) variable regional trough ages, (4) variable crosscutting relations of the radial and concentric troughs, and (5) a central smooth area resulting from the original impact.

GEOLOGY OF DARK TERRAIN AND THE FURROW SYSTEMS

In the following discussion, each of the three furrow systems will be treated separately and in order of decreasing calculated crater age. Each system's structure, stratigraphy, age, and association with volcanic and impact features will first be examined. Next, these observations will be used to test the models of furrow formation that were just described. Finally, the results of this analysis will be integrated to develop a geologic history of each furrow system.

System III

Description. Mapped structures in system III are shown in Figure 9. The dominant type of structure is concentrically arranged arcuate furrows, which are generally several hundred kilometers in length and occur at distances of up to 5000 km from the center of curvature (two-thirds of the distance to the antipode). There are no abrupt discontinuities in arcuate furrow