to indicate that the initiation of groove formation often occurred by reactivation of buried arcuate and radial furrow-related zones of weakness. Grooves and especially "groove lanes" also have a globally dominant orientation at low angles to small circles centered on a pole of approximately 70°-75°N,95°-110°W [*Bianchi et al.*, 1986; *Murchie and Head*, 1986*a*; *Murchie*, 1988]. Bianchi et al. suggested that this global "structural fabric" is the result of strain created by global-scale axisymmetric mantle convection during grooved terrain formation. Murchie and Head proposed that the global structural fabric is the result of control of groove orientation by relict structures. Specifically, the latter workers proposed that (1) a lithospheric structural fabric originated by tidal despinning, and (2) the the fabric's axis of symmetry was offset from the rotational axis by global reorientation induced by the formation of the basin Gilgamesh. Alternatively, the lithospheric fabric could represent the combined effects of the three furrow systems, or the effects of still another system of arcuate furrows now buried by dark terrain resurfacing. *McKinnon and Parmentier* [1986] suggested that fractures in Ganymede's lithosphere probably healed in a geologically short time; thus any reactivated structures are likely to have contained weak material, such as icy dikes intruded into a more silicate-rich groundmass.

Two fundamental questions regarding the history of the anti-Jovian arcuate furrow system (system I) are whether it is the disrupted remnant of a more concentric set, and if so how this disruption was related to grooved terrain formation. *Lucchitta* [1980], *Passey and Shoemaker* [1982], and *Shoemaker et al.* [1982] noted visual misalignment of the trends of arcuate furrows in Galileo Regio and Marius Regio (Figure 4) and suggested that the two areas had been offset by left-lateral shear. The interior of Galileo Regio consists of undeformed, dark furrowed terrain, so that left-lateral shear would require either major lateral translation of Marius Regio or clockwise rotation of the block of lithosphere containing Galileo Regio.

A detailed study of the proposed shear offset was completed by *Zuber and Parmentier* [1984*a*], who used a least squares fit of furrow traces to small circles to calculate poles of furrow concentricity for three areas of dark terrain (Table 1): Galileo Regio (regions "A" and "B" in Figure 7*a*), northern Marius Regio (region "C" in Figure 7*a*), and central plus southern Marius Regio (regions "D," "E," and "F" in Figure 7*a*). Zuber and Parmentier also examined crater circularity in the light terrain between Galileo Regio and Marius Regio, as a test for shear strain. They found no evidence for pervasive shear subsequent to cratering of light terrain and concluded that the furrows either were originally nonconcentric or were deformed before most light terrain was emplaced.

In a more recent study, *Schenk and McKinnon* [1987] remeasured poles of concentricity of the system I arcuate furrows, using improved coordinate control and a least squares fit to small circles of furrow segments averaging 35.7±17.7 km in length (Table 1). They considered three areas, slightly different from those examined by *Zuber and Parmentier* [1984*a*]: Galileo Regio (regions "A" and "B" in Figure 7*a*), central Marius Regio (regions "D" and "E" in Figure 7*a*), and southern Marius Regio (region "F" in Figure 7*a*). They also measured poles for six subregions of Galileo Regio, two of which are more distant than 75° of arc from the average center of furrow curvature, and four of which are less distant. The four proximal subregions were found to have poles of concentricity clustered within about 3° of 27°S,183°W, but the two distal subregions were found to have furrow traces that are markedly deviant from circular. These results could be interpreted to indicate that concentricity of system I arcuate furrows breaks down principally 70° of arc and farther from the center of curvature. Schenk and McKinnon also found furrow poles for central Marius Regio and southern Marius Regio of respectively 25°S,170°W and 20°S,183°W; the pole for the proximal part of Galileo Regio is significantly to the west of the pole for central Marius Regio. On the basis of furrow nonconcentricity in the distal part of Galileo Regio, Schenk and McKinnon attributed the Marius-Galileo furrow pole separation to widespread furrow noncircularity and noted that such noncircularity is also observed in the Valhalla ring structure. They proposed that the true center of system I lies at 21°S,179°W (at the star in Figure 7*c*).

There is an alternative, equally plausible interpretation of the results of Schenk and McKinnon. First, too rigorous a comparison of arcuate furrows with the Valhalla structure must be viewed with caution because of the important differences between the geology of the features. Second, central Marius Regio is entirely within 70° of arc of the center of furrow curvature, at which distance nearly circular furrows are observed in undeformed Galileo Regio. In fact, the furrows in Galileo Regio are significantly more circular than are Valhalla rings. If no large-scale deformation of the furrows occurred subsequent to their formation, then one might expect the pole for central Marius Regio to lie within a few degrees of the furrow pole for the proximal part of Galileo Regio. In reality, the central Marius Regio pole differs by at least 10°. For this reason, it is suggested here that minor deviation of furrow traces from circularity may not by itself explain the large apparent offset of furrow trends between Galileo Regio and Marius Regio.

This study is a reexamination of the questions of relative motions of large segments of Ganymede's lithosphere and of the effect of any motions on grooved terrain formation. The misalignment of the arcuate furrows is reinvestigated, and other types of morphologic evidence for motions of large blocks of lithosphere are examined. Four important differences in the investigation of furrow misalignment from the studies of *Zuber and Parmentier* [1984*a*] and *Schenk and McKinnon* [1987] are discussed below and were implemented in an attempt to better determine poles of furrow concentricity and in order to independently test any apparent pole separations. First, only average trends of linear furrow segments longer than 100 km were considered in determinations of furrow poles, to reduce the effect on pole determinations of short-wavelength variations in furrow trend. Second, by combining data sets from smaller regions with closely similar calculated poles, larger areas having distinct furrow poles were selected quantitatively. Third, arcuate furrows in eastern Marius Regio, not mapped or measured in the two previous studies, were included in furrow pole determinations. Fourth, the hypothesis of relative motions of large segments of lithosphere was tested independently by determining if there evidence for brittle deformation of the types consistent with furrow pole separations.

PROCEDURE

Mapping and Measurement of Furrows

Resolvable furrows in both hemispheres were mapped in as great detail as possible using Voyager 1 and 2 images and, as base materials, U.S. Geological Survey controlled, shaded-relief quadrangle maps. Furrow traces were digitally compiled from