Is there evidence for major left-lateral shear across lineament I where it separates Galileo Regio and Perrine Regio? (2) Are lineaments II and IIa related to a zone of distributed left-lateral shear surrounding Galileo Regio? (3) Are lineaments III and IIIa, which are approximately aligned and which both exhibit evidence for right-lateral shear, distinct features or parts of a single, larger structure? (4) Do high resolution images of features proposed to have been offset support the shear zone hypothesis? (5) In areas not yet observed at Voyager scale resolution, are regional groove orientations consistent with an effect of shear strain? (6) How common are compressional or transpressional features? (7) What is the small-scale structure of reticulate terrain? Was reticulate terrain deformed by widespread, pervasive shear?

Speculation on the Origin of Shear Motions

At least five geologic processes that could reasonably have occurred on Ganymede are capable of causing deformation on the scale of that of the proposed shear zones: tidal deformation due to orbital recession; lithospheric extension, transform faulting, and subduction; nonsynchronous rotation of a decoupled lithosphere; global expansion; and mantle convection. The plausibility of each of these processes having driven the proposed shear offsets is now evaluated.

Orbital recession. *Melosh* [1980] showed that collapse of the tidal bulge of a synchronously rotating Jovian satellite is capable of causing strike-slip faults, oriented so that the acute angles formed by conjugate fault sets radiate away from the sub- and anti-Jovian points (Figure 20*a*). However, the magnitudes of offsets across such faults would not exceed several hundred meters to a few kilometers, given the several kilometer height of Ganymede's tidal bulge. Therefore this mechanism is incapable of having caused shear offsets of the magnitudes that are proposed.

Finite extension, transform faulting, and subduction. Spreading and subduction of lithosphere was proposed by early investigators as a mechanism of formation of light grooved terrain [e.g., *Lucchitta*, 1980]. This process, if it occurred, could have created significant shear offsets by transform faulting. However, more recent investigations [e.g. *Parmentier et al.*, 1982; *Schenk and McKinnon*, 1985; *Murchie et al.*, 1986] have provided considerable evidence that light grooved terrain formed by downdropping, shallow resurfacing, and fracturing of segments of a globally continuous dark terrain lithosphere. Nevertheless, localized transform faulting and subduction, especially if accompanied by finite extension rather than spreading (Figure 20*b*), cannot conclusively be ruled out and could have caused tens of kilometers shear offsets.

Nonsynchronous rotation. *Greenberg and Weidenschilling* [1984] have shown that nonzero torques may be exerted on the lithospheres of Io and Europa by the gravitations of Jupiter and the other Galilean satellites. *Helfenstein and Parmentier* [1985] showed that this torque could cause nonsynchronous rotation of a floating, mechanically decoupled Europan lithosphere, and they described zones of compressional, extensional, and shear deformation that would result from nonsynchronous rotation.

If Ganymede once underwent the conditions necessary for nonsynchronous rotation of a decoupled lithosphere, and if its lithosphere contained globally continuous zones of weakness approximately parallel to lines of latitude, then globe-encircling strike-slip faults could have resulted. The scenario for this to occur is depicted in Figure 20*c*. A previously healed zone of weakness migrated from west to east, and once in the zone of extensional deformation, it failed as a tension fracture. The open fracture passed into the zone of shear deformation, a shear stress was resolved across it, and an incremental offset occurred. The open fracture then passed into the zone of compression and healed. This sequence was repeated over the course of many nonsynchronous rotations of the decoupled lithosphere; significant left-lateral offset could have accumulated across a zone of weakness north of the equator, and significant right-lateral offset could have accumulated across a zone of weakness south of the equator.

This scenario could explain the minor shear zones proposed to occur on Ganymede, but unfortunately is inconsistent with independent observations and interpretations. *Passey and Shoemaker* [1982] as well as S. Murchie et al. (submitted manuscript) have documented leading edge-trailing edge asymmetries in cratering of both light and dark terrains that imply that the lithosphere has rotated synchronously and has been bombarded by a heliocentric impactor population. Therefore it is concluded that nonsynchronous rotation is probably unsuitable as a driving mechanism for the proposed shear offsets.

Global expansion. At least two configurations of fault zones would have allowed global expansion to create shear offsets. As is depicted in Figure 20*d*, termination of two or more extensional features against some preexisting fracture zone would have resulted in minor shear across the fracture zone between the terminations. However, the small amounts of strain believed to have been experienced by extensional features on Ganymede (several percent [*Golombek*, 1982]) would have limited these types of shear offsets to magnitudes of several kilometers at most.

Alternatively, global expansion could have caused rotation of a circular block of lithosphere, as is proposed to be the case for Galileo Regio (Figure 20*e*). If a circular cap were surrounded by grooves having a dominant orientation at an oblique angle to the margin of the cap, then extension within the grooves could have caused a net lateral translation of the cap relative to the surrounding area. An upper limit to such translation may be calculated by assuming some extreme conditions: (1) all global extension occurring by groove formation within a circular band; (2) a dominant groove orientation at a 45° angle to the cap's margin; and (3) an angular radius of the cap of 90°. In this extreme case, total shear offset would equal $\pi r(\Delta r/r)(\cos 45°)$ or about 60 km, where r is Ganymede's radius (2630 km) and $\Delta r/r$ is the fractional change in planetary radius during global expansion, probably no more than about 0.01 [*Golombek*, 1982; *McKinnon*, 1982]. This maximum offset is comparable to the offsets across the proposed smaller-magnitude shear zones, but the physical requirements for such a large offset are not observed. Therefore it is concluded that global expansion alone is incapable of having created shear offsets of the magnitudes proposed to have occurred.

Mantle convection. *Phillips* [1987] showed that mantle convection cells beneath a thin lithosphere, such as that of Ganymede [*Golombek*, 1982], may create large stresses in a stretching mode at long wavelengths. Given this theoretical result, rotation of a circular block of lithosphere (Figure 20*f*) or shear offset across a throughgoing fault zone is conceivable. One possible model for formation of such an offset is as follows: Global expansion and tension caused a preexisting zone of weakness to fail as a tension fracture. Contemporaneous, radially nonsymmetric mantle convection cells caused a nonzero shear stress to be resolved across the fracture. If the zone of weakness was curvilinear or possessed appropriately configured