STRUCTURAL EVIDENCE FOR REORIENTATION OF MIRANDA ABOUT A PALEO-POLE: R. Pappalardo and R. Greeley, Arizona State University, Tempe AZ, 85287.

Summary: Two structural arguments support the premise that Miranda has reoriented with respect to Uranus over its geologic history. Orientations of major extensional and compressional features are consistent with a major satellite reorientation similar to that previously suggested based on cratering asymmetry. Furthermore, structures within Elsinore Corona provide supporting evidence that this reorientation took place about a paleo-pole located near (-75°, 80°), suggesting a second minor reorientation of Miranda.

Previous evidence for reorientation of Miranda: The distribution of small, fresh craters on Miranda shows an asymmetry consistent with predictions of leading/trailing cratering asymmetry [1,2], but the apex of motion suggested by the asymmetry is near the anti-uranian point, ~90° from the true apex. The observed crater distribution might have been produced by a reorientation that switched Miranda's a and b axes [1]. Furthermore, the location of Miranda's three coronae, near the south pole and the leading and trailing points of the satellite's motion, is consistent with their being negative mass anomalies whose origin caused satellite reorientation [2,3]. In discussions of possible reorientation, Miranda's rotation is assumed to be synchronous.

Structural evidence for a major reorientation: Figure 1 shows the pattern of tectonic deformation predicted for a 90° reorientation of a satellite about its pole, approximated as discreet events involving relaxation and growth of a tidal bulge [4]. Relaxation of a former bulge would result in longitudinally-oriented compression in a circular region within about 30° of the pole-a (predicted present b) axis, accompanied by parallel extension within about 30° of the satellite pole. As the bulge repositioned along the present a axis, longitudinally-oriented extension would occur there, with parallel over-the-pole compression predicted as well. Strike-slip faulting would be favored elsewhere across the satellite. Currently, the dimensions of Miranda's a and b axes differ by 6 km, about 2.5% of the satellite's mean radius [5]. Applying the observed axis dimensions to the method of [4], exchange of Miranda's a and b axes could produce differential stresses ~100 bar, enough to have caused deep lithospheric faulting [6].

The geology of Miranda (Fig. 2) can be compared to that predicted from reorientation. A major longitudinally-oriented ridge, probably compressional in origin, is observed along 210°, most prominent equatorward of 40° latitude. In the polar region, this ridge transforms into an extensional rift zone that forms the southern extent of Inverness Corona. Near the current a-axis is Verona Rupes, trending longitudinally, and prominent equatorward of 30° latitude. Extending poleward from Verona Rupes is an extensional band, rather than the predicted compressional features, ultimately linking with an extensional zone and a small extensional band near the Arden Corona. Hence, propagation of more easily formed extensional features from Verona Rupes may have precluded formation of predicted polar compressional features; alternatively, discreet bulge relaxation and formation events may be too simple a model for the true reorientation stress field. Pre-existing structures certainly had a role in guiding the location and evolution of Verona Rupes as evidenced by the more ancient, mantled [2,7] tectonic terrace that parallels Verona to the west. Analogous cratered terrain deformation is not apparent in the present leading hemisphere of Miranda, but might be hidden by materials of Arden Corona.

The observed broad-scale cratered terrain tectonism is generally consistent with relaxation of a former bulge near 210° longitude and growth of the current tidal bulge along 0° longitude, corresponding to a ~45° satellite reorientation. The resulting deformation can be summarized as a westward (ccw) rotation of a single large plate containing present-day Silicia Regio and Elsinore Corona.

Initiation of major reorientation: An impact event has been invoked to account for the apparent satellite-wide mantling of Miranda [7] and may have initiated chaotic rotation and heating of the satellite [8]. If a basin created by a mantle-forming impact induced reorientation [7], and/or if chaotic rotation ensued, the distribution of fresh (post-mantling) craters necessitates a time lag be invoked before reorientation, during which mantle was completed and the asymmetric distribution of fresh craters developed with respect to the satellite's original orientation. It is more likely that diapirism related to corona formation triggered reorientation some time after the mantling event. This does not discount the possibility that an impact mantled Miranda; indeed, diapirc upwelling induced by basin relaxation may have initiated reorientation.

Structural evidence for a paleo-pole: We note that the 210° ridge-rift and the Verona rift systems meet not at Miranda's south pole, but near (-75°, 80°). This invites the suggestion that this location represents a paleo-pole about which reorientation took place. Further evidence for a paleo-pole comes from the orientation of ridges and troughs within the east-west trending Ridged Band of Elsinore Corona (Fig. 2).
MIRANDA REORIENTATION: Pappalardo, R. and Greeley, R.

Ridges and troughs of the Ridged Band were likely shaped by a combination of normal faulting and fissure extrusion along tectonically-induced trends, suggesting formation of Elsinore Corona above an upwelling mantle plume [9]. A diapirc "riser" model of corona formation [3,10] predicts hoop stresses about the center of upwelling that may account for the generally concentric form of the outer belts of Miranda's coronae and structures contained within. However, we believe the actual squared shape of each corona is likely due to superposition of a concentric stress field onto a pre-existing fracture pattern.

At the western and eastern extents of the Ridged Band, ridges and troughs show NW-SE and NE-SW trends, respectively, but through much of the band (longitudes 235° to 290°), structures trend nearly east-west. An east-west trending structural fabric can be understood as resulting from despinning in combination with moderate satellite expansion, with despinning fractures expected to be concentric to the satellite pole [11]. We have constructed great circles perpendicular to the trends of individual Ridged Band structures, expected to intersect at a center of concentricity if one exists.

Preliminary analysis shows that the great circle intersections scatter somewhat but concentrate near (-75°, 80°). This suggests that the Ridged Band's east-west structural fabric may be due to despinning not about the current satellite pole, but about the same paleo-pole of Miranda's major reorientation event, 65 km from the current pole location. A second, minor reorientation of Miranda is thus implied to account for the satellite's present orientation, perhaps resulting from late diapirc activity.

Conclusion: Structural evidence suggests that despinning and post-mantling reorientation of Miranda took place about a paleo-pole near (-75°, 80°). A second minor reorientation then brought Miranda to its current position with respect to Uranus. Reorientation was likely the result of corona formation and partial satellite differentiation involving diapirism. The major reorientation proposed here is somewhat different from that previously suggested on the basis of cratering studies [1], and Miranda's fresh crater distribution remains to be reexamined in this light.


Figure 1.

Figure 2.