MORPHOGRAPHIC PROJECTIONS FOR MAPS OF NON-SPHERICAL WORLDS; Philip J. Stooke and C. Peter Keller, Dept. of Geography, University of Victoria, Box 1700, Victoria, B.C., Canada V8W 2Y2

The shapes of non-spherical worlds are of interest to planetologists and advanced mission planners. Most existing maps of bodies such as Phobos are sketched on cylindrical projection grids of a sphere, resulting in rectangular maps which give no indication of global shape, and which incorporate severe distortions (1,2,3,4). Variable radius ('morphographic') map projections solve this cartographic problem by substituting the local radius for the radius constant in conventional azimuthal map projection equations (5). Such a map of a 'hemisphere' of an irregular body has the same shape as the cross-section of that body in the dividing plane (5). Parallels and meridians serve as form lines to reinforce the impression of 3-D shape to the map user. Exact equivalence and conformality are lost in the morphographic versions of the azimuthal equivalent and stereographic projections, but distortions are very much smaller than in current cylindrical maps.

An estimate of the shape of a body must be made prior to mapping. Turner (6) made a physical model of Phobos from which he measured radii directly. Stooke (5) described a digital modelling technique in which an orthographic graticule is superimposed on a spacecraft image and moulded to match the limb topography and to eliminate grid/image parallax in all available images. The shape of the body is described by an array of radii called a 'phoboid', from which the local radius is read as each vector in the graticule is plotted. The phoboid is modified to mould the graticule as required. Batson and Edwards (7) describe a technique called digital sculpturing, by which an array of radii is used to generate a synthetic image. Differences between this and a real spacecraft image are minimized by iterative modification of the radius array. A 3-D mosaic of actual images of a body can be compiled and displayed in any orientation.

Once the shape has been modelled, a map on a morphographic projection can be easily prepared. All azimuthal projections can be derived from each other using appropriate radial functions (5). In this way, Stooke's orthographic graticule (5) or Batson and Edwards' 3-D mosaic (7) (in effect an orthographic projection) can be reprojected to quasi-equivalent or quasi-conformal displays. Distortions are most severe in areas of maximum curvature, and are minimized in aspects which place those areas at the periphery of the map. In areas of high relief, elevated regions may conceal low-lying terrain further from the centre of the map (the projection is not 'unique'). This can be avoided by placing those areas near the centre of the map, by use of a special symbol, or by representing extreme relief with shading or contours rather than phoboid modelling. Similarly, the centres of craters near the edge of the map will be offset if the phoboid follows their contours. Crater relief must be modelled for the accurate construction of overlay grids, but a more acceptable map is produced from a model of the smoothed surface on which smaller relief features are superimposed. Crater floors are projected onto that surface, which in turn is projected to the map plane. Two phoboids are required for this.

Figure 1 shows a fictitious body in orthographic, quasi-equivalent and quasi-stereographic projections. Figure 2 shows Janus with a grid overlay generated from a preliminary phoboid, part of which is given in Table 1. Figures 3 and 4 are respectively a contour map and a preliminary shaded relief map of the trailing side of Janus.

References: (1) Duxbury, T.C., 1974. "Phobos: Control Network Analysis", Icarus, 23, 290-299. (2) Thomas, P., 1979. "Surface Features of Phobos and Deimos", Icarus, 40, 223-243. (3) Thomas, P. and J. Veverka, 1985. "Hyperion: Analysis of Voyager Observations", Icarus, 64, 414-424. (4) Veverka, J., P. Thomas, M. Davies and D. Morrison, 1981. "Amalthea: Voyager Imaging Results", Journal of Geophysical Research, 86, 8675-8692. (5) Stooke, P.J., 1986. "Automated Cartography of Non-Spherical Worlds", Proceedings of the Second International Symposium on Spatial Data Handling, Seattle, July 1986., pp. 523-536. (6) Turner, R., 1978. "A Model of Phobos", Icarus 33, 116-140. (7) Batson, R.M. and K. Edwards, 1987. "Cartography of Irregular Satellites", NASA TM, in press.

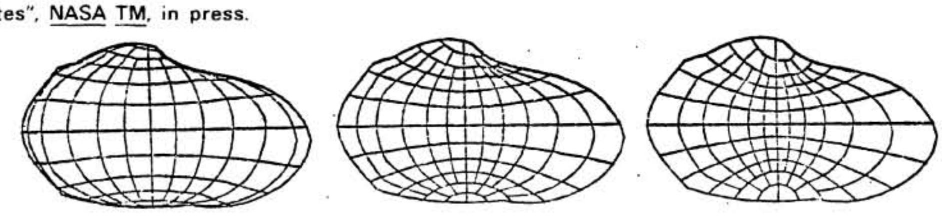

FIGURE 1. Fictitious body in orthographic, quasi-equivalent and quasi-stereographic projections.

MAPS OF NON-SPHERICAL WORLDS

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TABLE 1: Excerpt from Preliminary Janus Phoboid.

Lat.	0	330	300	270	240	210	180	150	120	90	60	30	Long.
+90	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	
+60	86.0	84.8	82.6	79.0	78.3	82.8	84.1	83.3	82.2	82.1	83.6	84.6	(radii
+30	96.5	98.5	92.5	90.1	90.3	98.1	100.2	100.0	95.5	91.2	88.3	91.1	in
0	95.8	96.5	96.0	95.6	98.2	100.7	104.0	104.7	92.4	87.9	86.0	91.0	km)
-30	99.5	93.1	90.2	88.1	91.3	87.4	91.1	91.2	82.1	80.1	82.5	91.1	
-60	87.0	84.7	83.6	83.1	83.6	82.1	81.8	79.7	76.1	75.6	78.7	85.5	
-90	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	

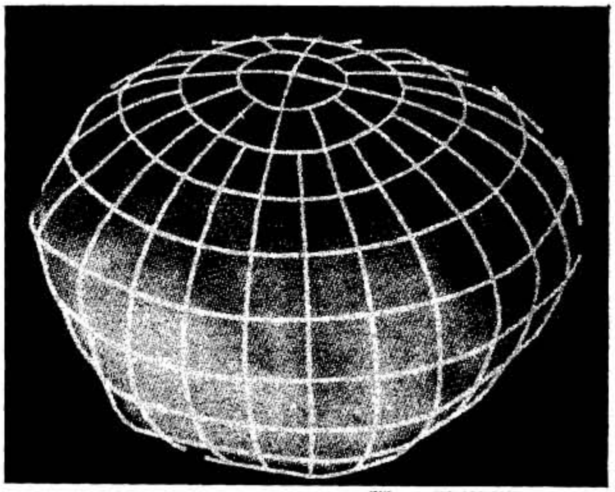

Figure 2: Janus with grid (Voyager 2 FDS 43997.46)

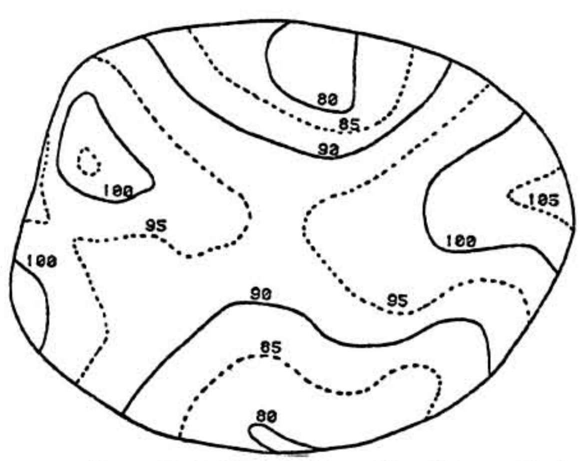

Figure 3: Radii on trailing side of Janus (km).

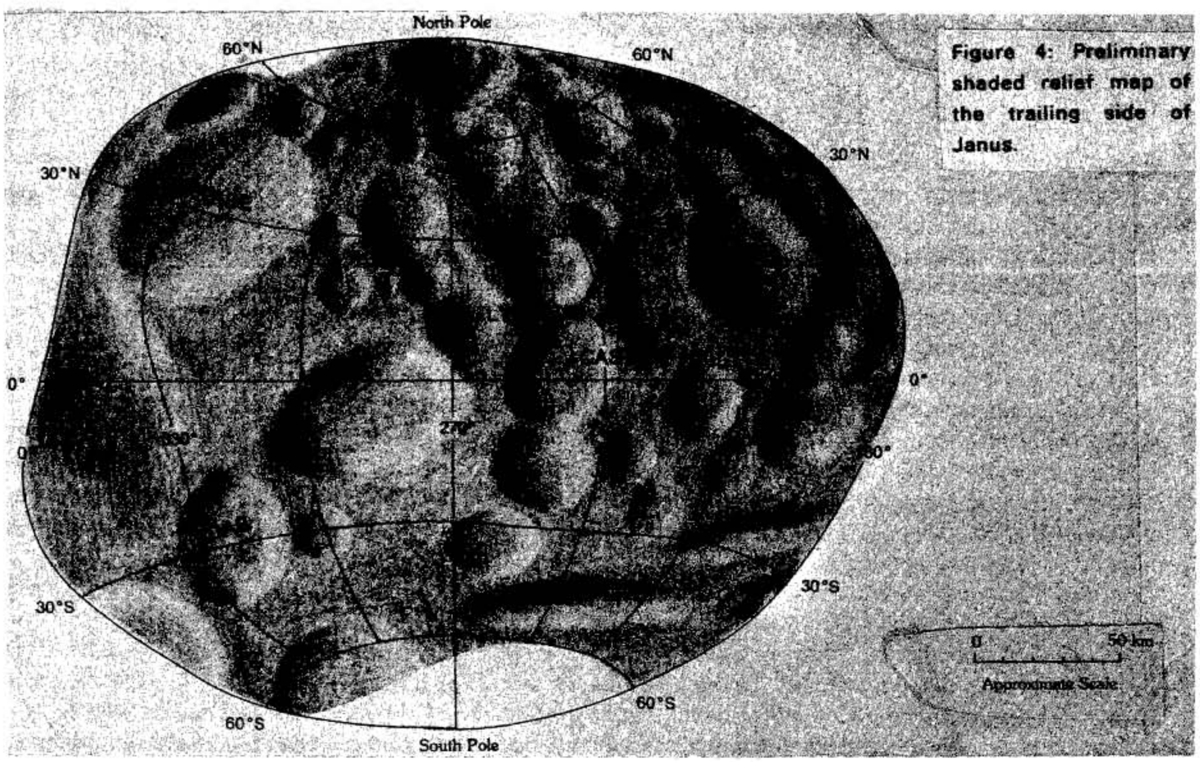

Figure 4: Preliminary shaded relief map of the trailing side of Janus.