A RAND NOTE

Phoebe: A Preliminary Control Network and Rotational Elements

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PREFACE

This Note, prepared for the National Aeronautics and Space Administration, presents a preliminary control network and rotational elements for the Saturnian satellite Phoebe. The Voyager 2 spacecraft returned 16 images of Phoebe, the outermost satellite in the Saturnian system. The distinct albedo features revealed in these images were used in the measurement calculations.

The results represent the first set of control points and rotational elements defined for Phoebe.

SUMMARY

A preliminary control network for the Saturnian satellite Phoebe has been determined based upon six distinct albedo features mapped on 16 Voyager 2 images. Using an existing map and an analytical triangulation program which minimized the measurement error, the north pole of Phoebe has been calculated to be $\alpha_0 = 355.0° \pm 9.6°$, $\delta_0 = 68.7° \pm 7.9°$, where α_0, δ_0 are standard equatorial coordinates with equinox J2000 at epoch J2000. The prime meridian of Phoebe was computed to be $W = 304.7° + 930.833872d$, where d is the interval in days from JD 2451545.0 TDB.

ACKNOWLEDGMENTS

CONTENTS

PHOEBE: A PRELIMINARY CONTROL NETWORK AND ROTATIONAL ELEMENTS

Phoebe, the outermost satellite of the Saturnian system, was viewed by the Voyager 2 spacecraft in September 1981 from a distance of approximately two million km. The resulting images revealed Phoebe as a small (110 km mean radius),[1] slightly ellipsoidal, relatively dark satellite with a surface albedo averaging 0.06.[2]

Phoebe's orbit around Saturn is retrograde at a mean distance of 13 million km. It travels far from Saturn's equatorial plane in an eccentric path ($e = 0.163$) inclined at 150°.[3] These orbital characteristics indicate that Phoebe might be a captured asteroid.

During the encounter, Voyager 2 took many images of Phoebe. Because of the low resolution of the images (40 km/line pair at best), individual topographic features cannot be distinguished. However, Thomas et al.[3] have produced a preliminary map of distinct regions of highly contrasting albedos. This map and several images of Phoebe show the brightest area on the satellite to be at approximately 50°N latitude and 20°W longitude. In addition, a low albedo band extends along the equatorial region of Phoebe. Through tracking of these albedo features, Phoebe's period of rotation was initially determined to be 9.4 ± 0.2 hr.[3] By deriving a light curve based upon CCD (charge-coupled device) observations taken on 13 nights over a period of 21 nights at Lowell Observatory, Kruse et al.[4] revised this estimate to 9.282 ± 0.015 hr.

Six prominent albedo features were measured on 16 Voyager 2 clear filter images taken during an 18-hr period covering approximately two rotations. These features establish a preliminary control network for Phoebe. However, these control points differ qualitatively from points normally used in establishing planetary control networks. Typically, centers of craters constitute control points, but craters are not discernible on the low-resolution images of Phoebe. Points 1 through 6 on Fig. 1 refer to the approximate centers of the albedo features.

Point 1, located at 8.5°N and 11.3°W, is the center of a low albedo area along the dark equatorial band, and was mapped on five Voyager 2 images. Point 2 is the brightest albedo feature on Phoebe. It occurs within a broad bright albedo region located at 50.0°N, 20.0°W and was mapped on four Voyager 2 images.

Point 3 was used as a control point on six Voyager 2 pictures, and point 4 was mapped on seven images. They lie west of points 1 and 2. Point 3, located at 11.7°N, 123.8°W, is another dark region along the extensive low albedo equatorial band. Bordering point 3 to the south is an elongate high albedo area containing point 4 (32.5°S, 116.3°W).
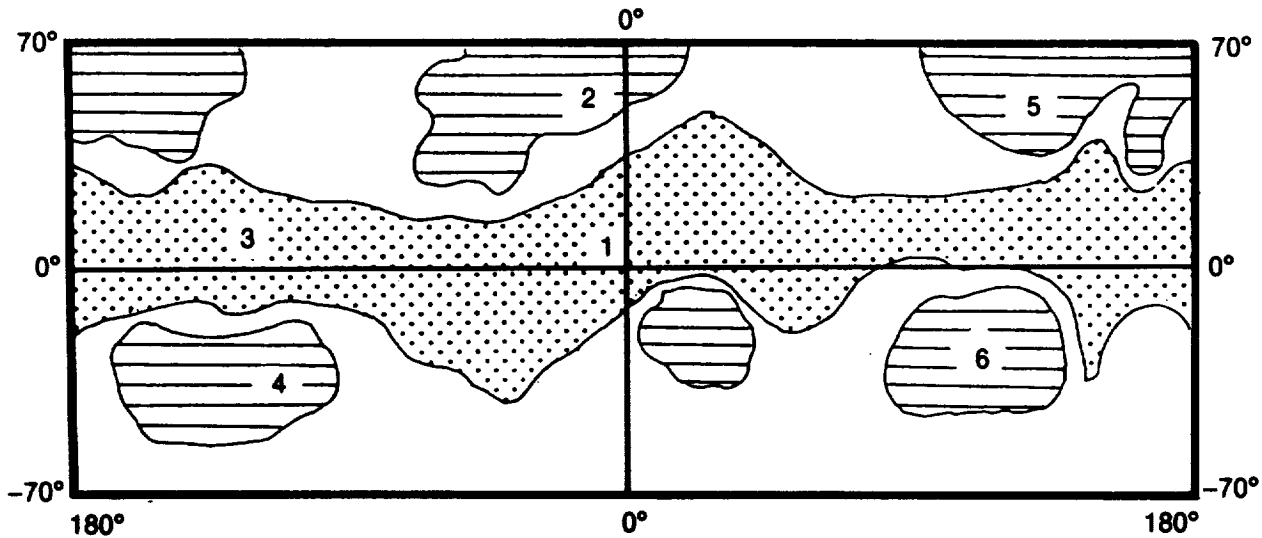
Fig. 1—Map of regions with highly contrasting albedos on Phoebe based on the sketch map by Thomas et al.[3] The central (dotted) region represents the dark equatorial band, and striped regions are the brightest albedo features. Points 1 through 6 are approximate locations of the control points.

Points 5 and 6, prominently displayed on four Voyager 2 images, complete the preliminary control network. They are centered at approximately 48.1°N, 239.8°W and 26.3°S, 250.6°W, respectively. These points occur in semicircular, high albedo regions divided by the darker equatorial belt.

After these control points were identified on the selected Voyager 2 images, their locations were measured in pixel coordinates, and their latitudes and longitudes were approximated using the sketch map of Thomas et al.[3] A consistent net is achieved as a result of the fixed sketch map. The control points are not tied together around the satellite because of the paucity of overlapping data. The pixel measurements were then corrected for geometric distortions and converted to millimeter coordinates in the camera focal plane. Software from the Navigation Ancillary Information Facility (NAIF) of the Jet Propulsion Laboratory was used to compute spacecraft positions, and a limb finding program was used to improve camera pointing angles. These data form the basis of a least squares solution determined by analytical triangulation, as described in Davies et al.[5] The direction of Phoebe's north pole in terms of its right ascension (α_0), declination (δ_0), and the constant W_0 in the expression for the prime meridian position were determined by minimizing the measurement error resulting from this analysis. The definitions of the location of the north pole and prime meridian follow the standards of the IAU/IAG/COSPAR Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites.[1]

The analytical triangulation resulted in a minimum measurement error of 13 μm with the following values for the direction of Phoebe's spin axis in standard equatorial coordinates with equinox J2000 at epoch J2000:

$$\alpha_0 = 355.0° \pm 9.6°$$
$$\delta_0 = 68.7° \pm 7.9°$$
$$W = 304.7° + 930.833872d,$$

where d is the interval in days from the JD 2451545.0 TDB. These results represent the first set of control points and rotational elements defined for Phoebe.

REFERENCES

1. Davies, M. E., et al., "Report of the IAU/IAG/COSTAR Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites: 1988," (submitted to *Celestial Mechanics*).

2. Smith, B. A., et al., "A New Look at the Saturn System—The Voyager 2 Images," *Science* **215**, pp. 504-537 (1982).

3. Thomas, P., et al., "Phoebe: Voyager 2 Observations," *J. Geophys. Res.* **88**, pp. 8736-8741 (1983).

4. Kruse, S., J. J. Klavetter, and E. W. Dunham, "Photometry of Phoebe," *Icarus* **68**, pp. 167-175 (1986).

5. Davies, M. E., T. A. Hauge, F. Y. Katayama, and J. A. Roth, *Control Networks for the Galilean Satellites: November 1979*, The RAND Corporation, R-2532-JPL/NASA (1979).