A RAND NOTE

# The Preliminary Geodetic Control Network of Venus

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Prepared for the
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## PREFACE

This Note, prepared for the Jet Propulsion Laboratory, was written in preparation for the Magellan spacecraft mission. It should be of interest to those preparing maps of the surface of Venus and to planetary cartographers in general.

## SUMMARY

This brief Note describes the coordinate system of Venus adopted by the Magellan project, Venus coordinate transformations, the control point numbering system, and the preliminary control network of Venus. Figures and tables provide greater detail.

## CONTENTS

## FIGURES

# TABLES

# 1. THE COORDINATE SYSTEM OF VENUS

The coordinate system of a planet is defined by the direction of its north pole, its rotation period, and an arbitrary selection of a prime meridian (or some other meridian). In 1979 the IAU Working Group on Cartographic Coordinates (Davies et al., 1980) recommended using the values for the direction of the north pole and rotation period derived by Shapiro et al., 1979. The prime meridian was defined so that the planetographic longitude of the central meridian of Venus as observed from the center of the Earth was 320.0° at $0^h$ on 20 June 1964 (JED 2438566.5) (Trans. IAU 14B, p. 128, 1971). With these definitions, the coordinate system of Venus was described by

$$\alpha_0 = 272.8^\circ \qquad \text{B1950}$$
$$\delta_0 = 67.2^\circ$$
$$W = 213.63^\circ - 1.4814205^\circ\ d$$

where d is the interval in ephemeris days from the standard epoch 1950 January 1.0 ET, that is, JED 2433282.5.

The location of the prime meridian is expressed by the angle $W$, measured easterly from the intersection of the B1950 standard Earth equator and Venus' equator. The 1982 IAU report (Davies et al., 1983) did not modify the recommended Venus equations , however, the new J2000 coordinate system was introduced. The IAU 1982 coordinate system was used for the Venera 15, 16 cartographic program.

By 1985, with the Venera 15, 16 data and the high-resolution 1983 Arecibo radar pictures, it became apparent that the definition of the prime meridian was not unique. Every time that a new rotation period was introduced, the longitudes on the surface of Venus would shift. Thus, it was decided to select a surface feature to define the prime meridian. D. Campbell and Y. Tjuflin identified and measured six craters common to both data sets and selected one, later named Ariadne, to define the prime meridian on Venus. The prime meridian passes through the central peak of this crater. During this period, I. I. Shapiro reported a new solution for the rotation period and the direction of the north pole in a letter to D. Campbell. These values were adopted by the IAU in the 1985 report (Davies et al., 1986). The defining equations were

$$\alpha_0 = 272.69^\circ \qquad \text{J2000}$$
$$\delta_0 = 67.17^\circ$$
$$W = 160.39^\circ - 1.4813291^\circ\, d$$

where d is the interval in days from the standard epoch 2000 January 1.5, that is, JD 2451545.0 TDB.

This coordinate system was adopted by the Magellan project.

## 2. VENUS COORDINATE TRANSFORMATIONS

In order to convert the latitude and longitude of one system into another, the first step is to compute Cartesian coordinates of the unit vector by

$$
\begin{aligned}
X &= \cos\phi \ \cos\lambda \\
Y &= \cos\phi \ \sin\lambda \\
Z &= \sin\phi
\end{aligned}
$$

where $\phi$ is the latitude and $\lambda$ the longitude of the point. Then a transformation matrix A can be determined that will convert coordinates from one system into another.

As mentioned, the Venera project used IAU 1982 coordinates and Magellan used IAU 1985 coordinates, so it is necessary to find the matrix A that will transform IAU 1982 coordinates into IAU 1985 coordinates. The matrix A is a function of the three angles $\alpha_0, \delta_0, W$ of the two coordinate systems. Because $W$ is a function of time, an epoch must be chosen. It was decided to choose JD 2445709.6657 because that was when Venera 15 took the radar image of Ariadne. The matrix A is the product of two matrices. The first transforms IAU 1982 coordinates into inertial coordinates and the second transforms inertial coordinates into IAU 1985 coordinates. The A matrix can be found in Table 1.

The Venera images were mostly north of 35° latitude. However, the 1983 Arecibo images covered a large region in the southern hemisphere as well as some in the north. Six common points were identified and measured. A least squares fit was computed to determine the A matrix that would transform the 1983 Arecibo coordinates into the Venera IAU 1985 coordinates. This matrix is given in Table 1. A third matrix is presented in Table 1 that will transform Pioneer Venus coordinates to IAU 1985 coordinates. This matrix was computed by Peter Ford of MIT.

Table 1

Venus Coordinate Transformations

$$X = \cos \Phi \cos \lambda$$

$$Y = \cos \Phi \sin \lambda$$

$$Z = \sin \Phi$$

$$\begin{vmatrix} X \\ Y \\ Z \end{vmatrix}_{\substack{IAU \\ 1985}} = A \cdot \begin{vmatrix} X \\ Y \\ Z \end{vmatrix}$$

VENERA TO IAU 1985

$$A = \begin{vmatrix} .999\ 997\ 087 & -.002\ 380\ 124 & -.000\ 398\ 768 \\ .002\ 379\ 790 & .999\ 996\ 819 & -.000\ 836\ 184 \\ .000\ 400\ 757 & .000\ 835\ 233 & .999\ 999\ 571 \end{vmatrix}$$

1983 ARECIBO TO IAU 1985

$$A = \begin{vmatrix} .999\ 997\ 878 & .001\ 647\ 448 & -.001\ 236\ 640 \\ -.001\ 650\ 597 & .999\ 995\ 387 & -.002\ 549\ 966 \\ .001\ 232\ 434 & .002\ 552\ 002 & .999\ 995\ 984 \end{vmatrix}$$

PIONEER VENUS TO IAU 1985

$$A = \begin{vmatrix} .999\ 990\ 805 & .001\ 520\ 115 & -.004\ 009\ 573 \\ -.001\ 530\ 001 & .999\ 995\ 801 & -.002\ 462\ 105 \\ .004\ 005\ 809 & .002\ 468\ 222 & .999\ 988\ 929 \end{vmatrix}$$

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## 3. THE CONTROL POINT NUMBERING SYSTEM

A format has been prepared by Raymond Batson (USGS) for the production of 1:5,000,000 scale maps (see Fig. 1). The planet will be mapped onto 62 sheets numbered from 1 at the north pole to 62 at the south pole.

The control point numbering system is designed to describe the region of the planet on which it lies. Each point is given a five digit number. The first two digits define the map sheet (from 01 to 62). The third digit indicates the approximate region of the sheet that contains the point (see Fig. 2). The final two digits are arbitrary.

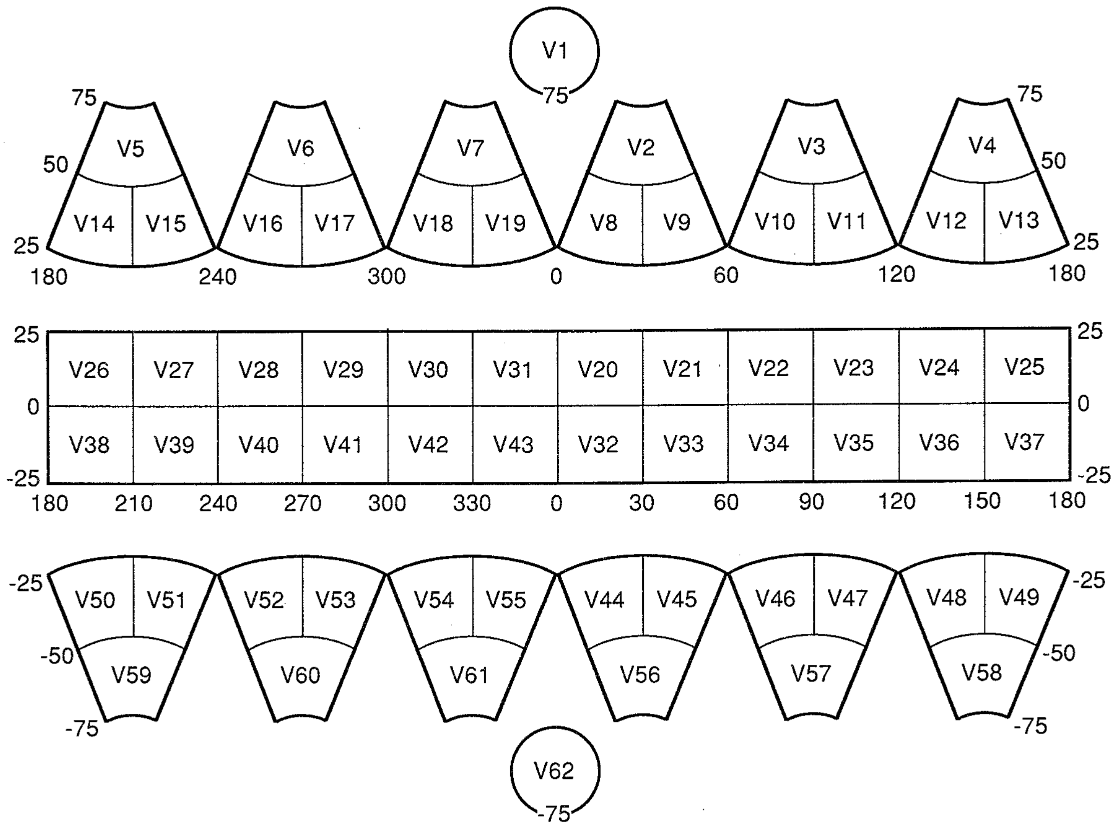


**Fig. 1—The 1 : 5,000,000 Map Sheets of Venus**

1. Each point will be given a five-digit number.
2. The first two digits will identify the Batson quadrangle 01-62.
3. The next digit will indicate an approximate region of the quadrangle.
4. The last two digits are arbitrary.

Quadrangle regions

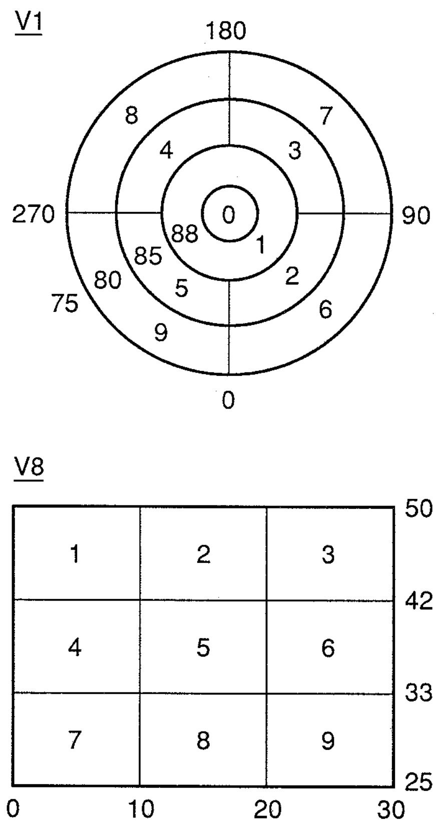


**Fig. 2—Venus Point Numbering System**

## 4. THE PRELIMINARY CONTROL NETWORK

The preliminary control network contains 160 points identified on 24 of the 62 map sheets. Most of them are in the north polar region. Table 2 contains the coordinates of the points. The points are craters (C), hills (H), or central peaks (P) in craters; these identifiers are indicated in Table 2 just before the point numbers.

Table 3 summarizes the distribution of the control points among the map sheets.

Table 2

Preliminary Control Network of Venus

| | 1983 ARECIBO | | VENERA | | IAU 1985 | |
|---|---|---|---|---|---|---|
| POINT | LAT | LONG | LAT | LONG | LAT | LONG |
| C 01001 | | | 89.68 | 222.50 | 89.63 | 225.70 |
| C 01002 | | | 88.32 | 95.52 | 88.37 | 96.62 |
| C 01003 | | | 88.70 | 315.35 | 88.68 | 313.31 |
| C 01004 | | | 89.24 | 345.90 | 89.25 | 342.07 |
| C 01005 | | | 88.31 | 17.24 | 88.35 | 16.03 |
| H 01006 | | | 88.39 | 33.05 | 88.44 | 32.18 |
| C 01007 | | | 88.34 | 48.70 | 88.39 | 48.33 |
| C 01101 | | | 85.14 | 227.37 | 85.09 | 227.69 |
| C 01102 | | | 85.52 | 214.36 | 85.47 | 214.83 |
| C 01103 | | | 86.18 | 207.45 | 86.14 | 208.06 |
| H 01104 | | | 86.42 | 196.05 | 86.38 | 196.81 |
| H 01105 | | | 86.44 | 186.50 | 86.41 | 187.35 |
| C 01106 | | | 87.23 | 251.50 | 87.18 | 251.50 |
| H 01107 | | | 87.24 | 222.43 | 87.19 | 222.97 |
| C 01108 | | | 87.59 | 182.83 | 87.56 | 184.06 |
| H 01109 | | | 86.06 | 170.54 | 86.04 | 171.41 |
| H 01110 | | | 86.25 | 143.74 | 86.26 | 144.67 |
| H 01111 | | | 85.81 | 116.25 | 85.84 | 116.96 |
| C 01112 | | | 87.81 | 156.80 | 87.81 | 158.32 |
| C 01113 | | | 87.08 | 93.81 | 87.13 | 94.47 |
| C 01114 | | | 85.32 | 87.78 | 85.37 | 88.18 |
| C 01115 | | | 87.21 | 85.21 | 87.68 | 85.81 |
| C 01116 | | | 87.02 | 68.29 | 87.07 | 68.50 |

| | | | | |
|---|---|---|---|---|
| C 01117 | 85.87 | 73.60 | 85.92 | 73.86 |
| C 01118 | 86.24 | 34.28 | 86.29 | 34.01 |
| C 01119 | 87.41 | 1.62 | 87.43 | 0.70 |
| H 01120 | 86.31 | 337.08 | 86.31 | 336.39 |
| C 01121 | 87.68 | 303.04 | 87.65 | 302.07 |
| C 01122 | 85.37 | 277.41 | 85.33 | 277.19 |
| P 01201 | 84.58 | 77.15 | 84.63 | 77.41 |
| C 01202 | 84.43 | 51.85 | 84.48 | 51.87 |
| C 01203 | 83.70 | 42.70 | 83.75 | 42.72 |
| C 01204 | 82.88 | 44.63 | 82.93 | 44.62 |
| H 01205 | 83.11 | 34.17 | 83.16 | 34.08 |
| C 01206 | 83.93 | 16.14 | 83.97 | 15.90 |
| C 01301 | 82.38 | 150.89 | 82.38 | 151.42 |
| C 01302 | 83.12 | 160.92 | 83.11 | 161.49 |
| C 01303 | 83.92 | 167.13 | 83.91 | 167.75 |
| H 01304 | 83.76 | 147.94 | 83.77 | 148.56 |
| H 01305 | 84.28 | 130.90 | 84.30 | 131.52 |
| C 01306 | 83.44 | 119.35 | 83.47 | 119.87 |
| C 01307 | 84.10 | 108.33 | 84.14 | 108.83 |
| C 01401 | 82.52 | 215.80 | 82.47 | 216.13 |
| C 01402 | 83.20 | 195.26 | 83.17 | 195.73 |
| C 01403 | 83.11 | 235.28 | 83.06 | 235.49 |
| C 01404 | 83.78 | 214.57 | 83.73 | 214.95 |
| C 01405 | 84.34 | 186.30 | 84.31 | 186.89 |
| C 01406 | 84.42 | 262.25 | 84.37 | 262.22 |
| C 01501 | 84.36 | 357.27 | 84.38 | 356.91 |
| C 01502 | 83.56 | 338.43 | 83.56 | 338.10 |
| H 01503 | 83.04 | 328.49 | 83.03 | 328.19 |
| P 01504 | 84.92 | 324.32 | 84.91 | 323.87 |

| | | | | |
|---|---|---|---|---|
| H 01505 | 84.53 | 304.04 | 84.50 | 303.70 |
| H 01506 | 84.36 | 275.38 | 84.31 | 275.24 |
| P 01601 | 75.92 | 55.42 | 75.97 | 55.52 |
| P 01701 | 75.69 | 127.63 | 75.71 | 127.95 |
| P 01702 | 78.42 | 174.61 | 78.40 | 174.99 |
| H 02601 | 61.69 | 56.84 | 61.74 | 56.96 |
| H 02701 | 57.27 | 3.81 | 57.30 | 3.87 |
| H 02801 | 52.32 | 23.53 | 52.30 | 23.62 |
| C 02802 | 53.81 | 35.29 | 53.86 | 35.39 |
| p 03201 | 68.46 | 94.17 | 68.51 | 94.37 |
| p 03401 | 59.68 | 65.58 | 59.73 | 65.72 |
| C 03501 | 59.14 | 81.51 | 59.19 | 81.67 |
| H 03601 | 62.12 | 106.68 | 62.16 | 106.88 |
| H 03701 | 52.17 | 69.90 | 52.22 | 70.04 |
| P 03702 | 56.10 | 62.10 | 56.15 | 62.23 |
| P 03703 | 51.50 | 60.80 | 51.55 | 60.93 |
| C 03801 | 55.30 | 96.04 | 55.35 | 96.22 |
| p 04101 | 72.24 | 122.32 | 72.27 | 122.60 |
| H 04401 | 58.61 | 139.40 | 58.62 | 139.62 |
| P 04501 | 60.26 | 154.28 | 60.26 | 154.51 |
| H 04601 | 60.94 | 163.99 | 60.93 | 164.22 |
| P 04602 | 65.51 | 169.16 | 65.50 | 169.41 |
| H 04701 | 51.34 | 120.93 | 51.37 | 121.12 |
| H 04702 | 57.89 | 133.49 | 57.91 | 133.71 |
| C 04801 | 53.22 | 157.14 | 53.22 | 157.35 |
| P 04802 | 52.00 | 143.80 | 52.01 | 144.00 |
| H 05201 | 69.81 | 208.89 | 69.77 | 209.11 |
| P 05301 | 69.19 | 236.39 | 69.14 | 236.55 |
| C 05501 | 64.04 | 202.92 | 64.00 | 203.13 |

| | | | | | | |
|---|---|---|---|---|---|---|
| C 05801 | | | 51.54 | 201.56 | 51.50 | 201.74 |
| P 05901 | | | 55.62 | 222.33 | 55.57 | 222.50 |
| C 06501 | | | 60.10 | 273.08 | 60.05 | 273.17 |
| H 06601 | | | 58.81 | 297.74 | 58.78 | 297.81 |
| C 06701 | | | 53.75 | 243.87 | 53.70 | 244.01 |
| H 06801 | | | 57.39 | 274.09 | 57.34 | 274.19 |
| C 07201 | | | 70.90 | 334.94 | 70.90 | 334.92 |
| H 07301 | | | 72.86 | 356.89 | 72.88 | 356.87 |
| C 07501 | | | 62.12 | 329.71 | 62.12 | 329.75 |
| H 07701 | | | 50.94 | 318.93 | 50.93 | 319.00 |
| C 07901 | | | 50.19 | 355.26 | 50.21 | 355.34 |
| P 08100 | 43.85 | 0.23 | 43.90 | 359.91 | 43.92 | 0 |
| P 08201 | 43.93 | 11.81 | 44.00 | 11.51 | 44.03 | 11.61 |
| P 08202 | 47.66 | 15.29 | 47.71 | 14.87 | 47.74 | 14.96 |
| H 08501 | | | 33.24 | 12.35 | 33.27 | 12.46 |
| H 08601 | | | 35.61 | 28.24 | 35.65 | 28.35 |
| P 08701 | | | 29.50 | 0.45 | 29.52 | 0.56 |
| P 08901 | | | 32.15 | 22.71 | 32.19 | 22.82 |
| C 09101 | | | 44.76 | 32.56 | 44.81 | 32.67 |
| P 09201 | | | 45.15 | 49.70 | 45.20 | 49.82 |
| C 09501 | | | 40.93 | 43.14 | 40.98 | 43.26 |
| H 09502 | | | 33.95 | 43.45 | 34.00 | 43.57 |
| H 09701 | | | 27.52 | 30.00 | 27.56 | 30.12 |
| H 09901 | | | 31.05 | 59.02 | 31.10 | 59.15 |
| C 10401 | | | 38.26 | 65.33 | 38.31 | 65.47 |
| C 10501 | | | 39.33 | 79.01 | 39.38 | 79.16 |
| P 10601 | | | 40.31 | 87.19 | 40.36 | 87.34 |
| P 10801 | | | 28.27 | 72.59 | 28.32 | 72.73 |

| | | | | |
|---|---|---|---|---|
| H 10901 | 29.39 | 83.82 | 29.44 | 83.97 |
| C 11401 | 40.71 | 98.87 | 40.75 | 99.03 |
| H 11403 | 35.54 | 96.72 | 35.58 | 96.88 |
| H 11601 | 40.32 | 110.58 | 40.36 | 110.75 |
| C 11603 | 34.57 | 119.87 | 34.60 | 120.04 |
| H 11701 | 29.70 | 92.82 | 29.75 | 92.97 |
| P 11802 | 28.07 | 106.75 | 28.11 | 106.91 |
| P 12301 | 46.36 | 143.97 | 46.37 | 144.16 |
| P 12401 | 41.68 | 122.54 | 41.71 | 122.72 |
| P 12402 | 36.03 | 121.39 | 36.06 | 121.56 |
| P 12901 | 31.19 | 143.45 | 31.20 | 143.62 |
| H 13201 | 45.46 | 172.34 | 45.44 | 172.53 |
| C 13401 | 38.85 | 155.03 | 38.85 | 155.21 |
| H 13701 | 31.54 | 159.89 | 31.53 | 160.06 |
| P 14601 | 39.35 | 203.85 | 39.31 | 204.01 |
| H 14602 | 40.35 | 205.75 | 40.31 | 205.91 |
| P 14801 | 31.44 | 193.97 | 31.41 | 194.13 |
| P 14901 | 28.50 | 203.83 | 28.46 | 203.99 |
| H 15201 | 42.23 | 222.76 | 42.18 | 222.91 |
| H 15401 | 33.58 | 211.02 | 33.54 | 211.18 |
| H 15402 | 34.85 | 211.90 | 34.81 | 212.06 |
| H 15601 | 34.62 | 235.84 | 34.57 | 235.98 |
| C 16201 | 44.81 | 254.47 | 44.76 | 254.60 |
| H 16202 | 43.65 | 258.42 | 43.60 | 258.54 |
| H 16401 | 37.88 | 242.53 | 37.83 | 242.67 |
| H 16501 | 34.58 | 258.87 | 34.53 | 259.00 |
| H 16701 | 29.23 | 242.84 | 29.18 | 242.98 |

| | | | | | | |
|---|---|---|---|---|---|---|
| P 17201 | 45.40 | 283.44 | 45.27 | 283.02 | 45.23 | 283.12 |
| C 17202 | 47.11 | 288.81 | 47.00 | 288.45 | 46.96 | 288.55 |
| P 17301 | 48.45 | 297.00 | 48.38 | 296.58 | 48.35 | 296.67 |
| P 17401 | | | 36.46 | 270.51 | 36.41 | 270.63 |
| C 17402 | | | 36.54 | 272.14 | 36.49 | 272.26 |
| H 18101 | | | 45.66 | 304.40 | 45.63 | 304.49 |
| H 18301 | | | 45.10 | 329.21 | 45.10 | 329.29 |
| H 18401 | | | 36.88 | 304.15 | 36.85 | 304.25 |
| H 18402 | | | 40.29 | 305.03 | 40.26 | 305.13 |
| C 18403 | | | 35.03 | 303.10 | 35.00 | 303.20 |
| H 18501 | | | 38.26 | 310.38 | 38.24 | 310.48 |
| P 18901 | | | 30.91 | 329.94 | 30.91 | 330.04 |
| H 19401 | | | 39.67 | 334.81 | 39.67 | 334.90 |
| C 19402 | | | 40.09 | 331.50 | 40.09 | 331.59 |
| H 19501 | | | 36.39 | 348.04 | 36.40 | 348.14 |
| H 19601 | | | 39.27 | 359.71 | 39.29 | 359.81 |
| H 21101 | | | 23.65 | 30.02 | 23.69 | 30.14 |
| H 44701 | -31.91 | 0.14 | | | -31.83 | 0.13 |
| P 54201 | -46.14 | 315.00 | | | -46.19 | 315.07 |
| P 54301 | -43.65 | 321.98 | | | -43.68 | 322.04 |
| H 54601 | -39.54 | 324.11 | | | -39.57 | 324.15 |
| P 55101 | -45.56 | 335.67 | | | -45.56 | 335.74 |
| C 60601 | -63.00 | 289.47 | | | -63.11 | 289.60 |
| P 61801 | -52.40 | 329.73 | | | -52.41 | 329.85 |

Table 3

Venus: Status of Preliminary Control Network

62 BATSON SHEETS

| MAP | NUMBER OF CONTROL POINTS | MAP | NUMBER OF CONTROL POINTS | MAP | NUMBER OF CONTROL POINTS |
|---|---|---|---|---|---|
| 1 | 57 | 23 | 0 | 45 | 0 |
| 2 | 4 | 24 | 0 | 46 | 0 |
| 3 | 8 | 25 | 0 | 47 | 0 |
| 4 | 9 | 26 | 0 | 48 | 0 |
| 5 | 5 | 27 | 0 | 49 | 0 |
| 6 | 4 | 28 | 0 | 50 | 0 |
| 7 | 5 | 29 | 0 | 51 | 0 |
| 8 | 7 | 30 | 0 | 52 | 0 |
| 9 | 6 | 31 | 0 | 53 | 0 |
| 10 | 5 | 32 | 0 | 54 | 3 |
| 11 | 6 | 33 | 0 | 55 | 1 |
| 12 | 4 | 34 | 0 | 56 | 0 |
| 13 | 3 | 35 | 0 | 57 | 0 |
| 14 | 4 | 36 | 0 | 58 | 0 |
| 15 | 4 | 37 | 0 | 59 | 0 |
| 16 | 5 | 38 | 0 | 60 | 1 |
| 17 | 5 | 39 | 0 | 61 | 1 |
| 18 | 7 | 40 | 0 | 62 | 0 |
| 19 | 4 | 41 | 0 | | |
| 20 | 0 | 42 | 0 | TOTAL | 160 |
| 21 | 1 | 43 | 0 | | |
| 22 | 0 | 44 | 1 | | |

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