

A RAND NOTE

**The Preliminary Geodetic Control
Network of Venus**

Merton E. Davies, Patricia G. Rogers

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The research described in this report was sponsored by the Jet Propulsion Laboratory under Contract No. 953613.

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N-3437-JPL

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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.

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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

$$\begin{aligned}\alpha_0 &= 272.8^\circ && \text{B1950} \\ \delta_0 &= 67.2^\circ \\ W &= 213.63^\circ - 1.4814205^\circ d\end{aligned}$$

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

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$$\begin{aligned}\alpha_0 &= 272.69^\circ && \text{J2000} \\ \delta_0 &= 67.17^\circ \\ W &= 160.39^\circ - 1.4813291^\circ \text{ d}\end{aligned}$$

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 ϕ is the latitude and λ 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 α_0, δ_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

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

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

$$Z = \sin \Phi$$

$$\begin{array}{|c|} \hline X \\ \hline Y \\ \hline Z \\ \hline \end{array} = \begin{array}{c} \\ \\ \text{IAU} \\ \text{1985} \end{array} \cdot \begin{array}{|c|} \hline X \\ \hline Y \\ \hline Z \\ \hline \end{array}$$

VENERA TO IAU 1985

$$A = \begin{array}{|c|} \hline .999 \ 997 \ 087 \ -0.002 \ 380 \ 124 \ -0.000 \ 398 \ 768 \\ \hline .002 \ 379 \ 790 \ .999 \ 996 \ 819 \ -0.000 \ 836 \ 184 \\ \hline .000 \ 400 \ 757 \ .000 \ 835 \ 233 \ .999 \ 999 \ 571 \\ \hline \end{array}$$

1983 ARECIBO TO IAU 1985

$$A = \begin{array}{|c|} \hline .999 \ 997 \ 878 \ .001 \ 647 \ 448 \ -0.001 \ 236 \ 640 \\ \hline -0.001 \ 650 \ 597 \ .999 \ 995 \ 387 \ -0.002 \ 549 \ 966 \\ \hline .001 \ 232 \ 434 \ .002 \ 552 \ 002 \ .999 \ 995 \ 984 \\ \hline \end{array}$$

PIONEER VENUS TO IAU 1985

$$A = \begin{array}{|c|} \hline .999 \ 990 \ 805 \ .001 \ 520 \ 115 \ -0.004 \ 009 \ 573 \\ \hline -0.001 \ 530 \ 001 \ .999 \ 995 \ 801 \ -0.002 \ 462 \ 105 \\ \hline .004 \ 005 \ 809 \ .002 \ 468 \ 222 \ .999 \ 988 \ 929 \\ \hline \end{array}$$

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.

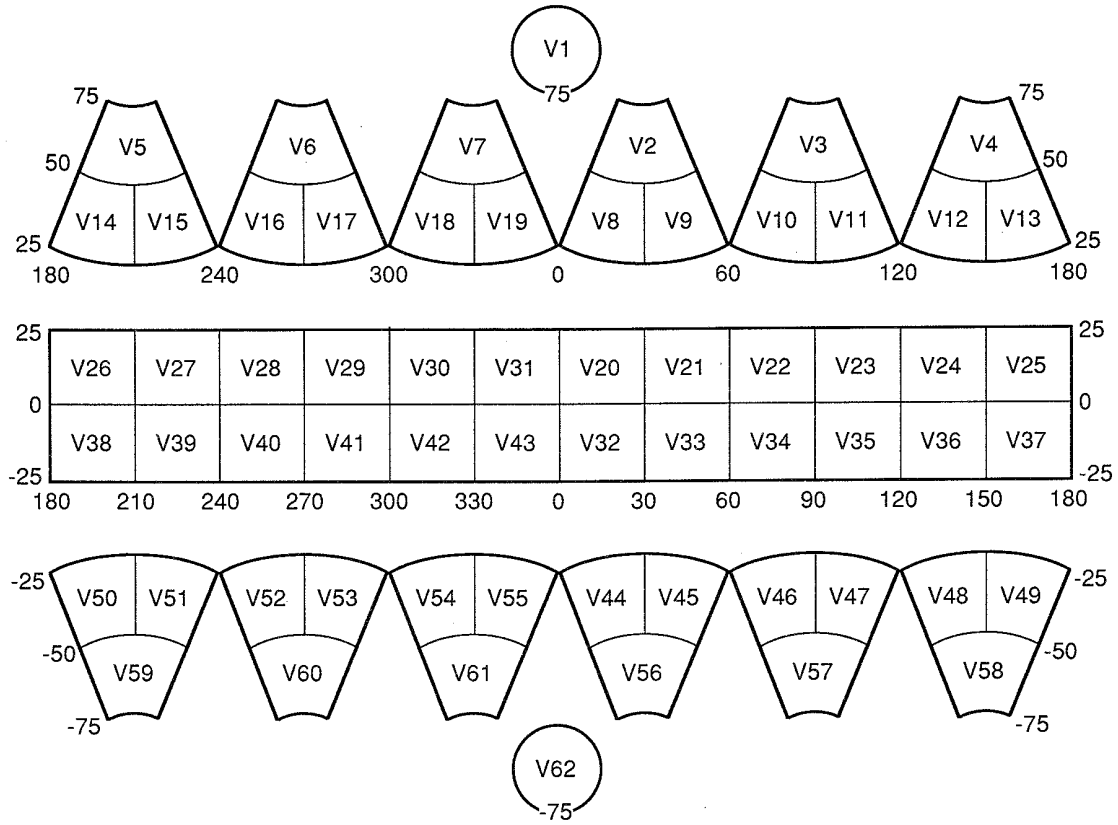


Fig. 1—The 1 : 5,000,000 Map Sheets of Venus

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

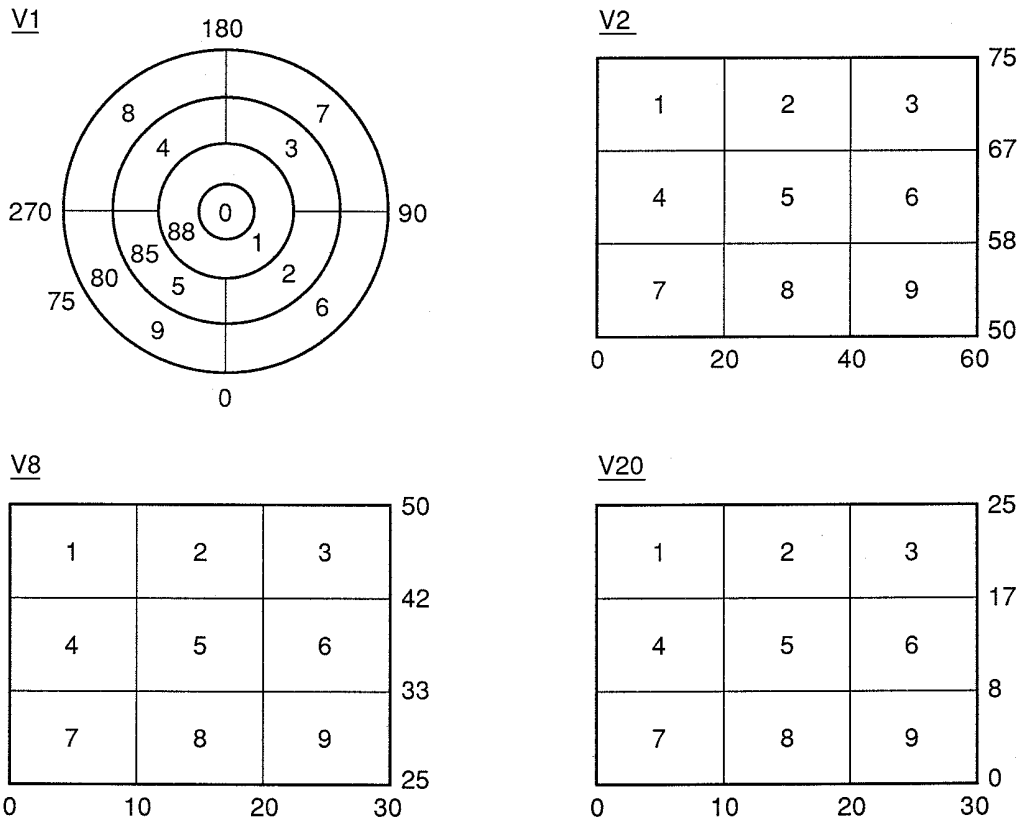


Fig. 2—Venus Point Numbering System

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

POINT	1983 ARECIBO		VENERA		IAU 1985	
	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		

NOVEMBER 1988

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RAND/N-3437-JPL