REPORT ON MARS, NO. 33.

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THE MARTIAN SURVEY.

In this Report we shall describe a survey that we have made of the planet in the interval between the years 1913 and 1922 inclusive. At the first opposition recorded, that of 1914, the solar longitude ⊙ was 16°.8. At the last opposition it was 171°.3. The solar longitude at the planet's vernal equinox is 0°.0, and at the autumnal 180°.0. At all five oppositions therefore the northern hemisphere was turned toward the sun, and also toward us. At the oppositions of 1924, 1926, and 1928 the southern hemisphere was and will be presented to the sun, and a second survey is proposed which will include them. These two surveys, which will cover the whole surface of the planet, will both be based exclusively on drawings, because this is by far the most rapid and most complete method of studying the surface. Transits have also been taken of special points, and it is hoped to discuss them in a future Report.

In 1924 a brief series of micrometer measures was made by Mr. Hamilton, with the same telescope that was used for the drawings. Latitudes only were determined. In all 30 measurements of 18 different points were secured, each measurement consisting when possible of 12 readings, giving 3 measures from each limb. Eight of the points were observed from two to five times. The average deviation of a single measurement consisting of twelve readings was found to be ±1°.62. The average deviation of a single measure of these same eight points taken from the drawings was ±2°.49. Squaring these numbers and dividing, we find that one micrometer measurement is as accurate as the mean of 2.4 drawings. The twelve readings required on the average 14 minutes. The total time required to make eleven very complete, large scale, drawings, fully shaded, in May 1920 was 361 minutes. From them we derived for our survey 64 measures of points near the central meridian. Average time for each point 5.6 minutes. This was exceptional, but a fair average for measures from drawings made near opposition would certainly not exceed 8 minutes. In order to obtain the same accuracy with drawings that we secure with the micrometer requires therefore 1.35 times as long. At the same time we get a shaded and finished picture, to which we can refer at any time in the future for other information, and also if required, in order to measure other points which we had not thought of measuring before. Incidentally the drawings give us also the longitudes, which if measured with the micrometer require as much time as the latitudes, and if measured by transits of the central meridian, about as long. The advantage for survey work of the method by means of drawings, if one has a reasonably correct eye, over the micrometer method becomes at once obvious.

In order to give a preliminary idea of the accuracy of the work, we may say that the combined probable errors of the latitudes and longitudes of the 10 best known points on Mars, each drawn from 9 to 20 times, averages ±25.1 miles. This is equivalent to ±0.68 of one degree of latitude. Taking the angular diameter of Mars at an average northern apparition as 14″, we have 1″ = 300 miles, so that the probable error of the mean in the location of these 10 points is ±0″.084, a result that compares very favorably with the better measures of double stars made with our larger telescopes. The distance 25.1 miles is 0.59 of one per cent of the diameter of the planet, and is the width of a rather narrow canal. The ten points here referred to in the order of the accuracy with which their positions are determined, the most accurate coming first, are Elysium N., Elysium S., Nepenthes c., Niliacus S., Thymiamata f., Ismenius, Syrtis N., Aromatum p., Neith N. f.,

TABLE I.

Martian Latitudes and Longitudes.

CLASS A

No.	Station	Diam.	Ephemeris		A	O	Corrected	
		″	°	°			°	°
3	Sabaeus f.	15.3	— 5.6±2.8	8.2±1.9	5	5	— 4.9±2.6	8.3±1.8
5	Margaritifer N.	14.6	+15.8±1.2	17.6±2.8	5	10	+16.3±1.7	17.0±3.0
6	Oxia	15.1	+14.6±2.0	18.0±2.8	4	6	+15.2±1.3	17.6±2.8
7	Thymiamata f.	14.7	— 1.3±2.3	19.3±2.8	5	20	— 0.7±2.2	19.3±2.8
8	Aromatum S. p.	14.5	— 1.7±2.4	30.4±2.8	5	15	— 1.0±1.8	30.5±2.8
11	Niliacus S.	13.9	+28.3±2.6	36.8±2.7	5	19	+28.9±2.5	35.9±2.7
18	Lunae c.	11.7	+20.4±2.8	61.6±2.8	4	8	+19.7±2.8	60.9±2.9
23	Maeisia	15.7	—11.6±1.3	72.0±3.1	5	5	—11.5±1.3	72.4±3.1
32	Phoenicis	14.8	—11.7±2.4	106.1±2.2	4	7	—12.0±2.4	106.5±2.4
43	Titanum N.	14.6	—18.4±2.9	165.1±2.6	5	13	—18.0±2.2	165.6±2.4
54	Elysium N.	14.3	+35.3±3.1	212.6±1.9	5	20	+35.6±2.2	211.5±1.9
55	Elysium S.	14.3	+13.4±3.3	212.8±2.0	5	20	+13.6±2.1	212.4±2.0
63	Triton N.	15.0	+19.0±4.0	256.8±2.8	5	10	+19.2±2.8	256.2±2.7
68	Libya S.	14.8	— 8.8±3.5	268.8±1.5	5	10	— 8.6±2.7	269.1±1.4
69	Nepenthes c.	13.7	+10.8±3.1	269.7±1.9	5	20	+10.9±2.6	269.4±2.0
71	Neith N. f.	15.1	+46.3±2.5	279.5±3.2	5	9	+46.2±1.5	277.5±3.0
74	Syrtis N.	13.7	+25.4±3.3	285.7±3.4	5	20	+25.4±2.5	285.0±3.2
75	Meroe S.	15.0	+22.5±1.2	288.0±2.5	4	5	+22.3±1.7	287.2±2.2
87	Sirbonis	13.3	+13.3±2.8	321.6±2.4	3	6	+13.8±3.1	321.2±2.3
91	Ismenius	13.7	+45.7±2.5	331.8±3.4	5	20	+45.9±2.6	330.0±3.6
92	Juturna	14.5	+20.8±4.1	330.6±2.6	3	6	+20.1±2.9	330.0±2.9
96	Furca N. p.	14.3	+ 7.0±2.5	351.2±2.4	5	10	+ 7.2±1.8	351.0±2.4
98	Furca N. f.	13.9	+ 8.6±1.9	359.0±2.6	5	5	+ 9.0±1.2	358.7±2.5
99	Furca S.	14.1	— 8.0±2.9	358.7±2.6	5	5	— 7.7±1.3	358.9±2.6

CLASS B

No.	Station	Diam.	Ephemeris		A	O	Corrected	
17	Aurorae N.	14.3	— 8.0±3.0	55.0±4.6	5	10	— 7.5±2.9	55.2±4.6
24	Solis N.	15.3	—22.0±1.6	84.1±5.2	5	5	—21.9±1.1	84.7±5.1
46	Aesculapius c.	14.6	+ 0.5±2.0	175.5±2.6	5	5	+ 1.0±1.8	175.5±2.6
50	Laestrygonum N.	15.0	—14.5±2.8	196.5±3.6	5	5	—14.2±1.8	196.9±3.7
58	Cimmerium N.	15.0	— 2.2±1.8	231.9±4.3	5	10	— 2.1±2.2	232.0±4.3
94	Edom S.	13.8	— 2.6±2.7	346.3±3.8	5	15	— 2.4±2.6	346.4±3.8

TABLE I.—Continued.

CLASS C

No.	Station	Diam.	Ephemeris		A	O	Corrected	
		″	° °	° °			° °	° °
14	Tempe p.	13.8	+45.9±3.5	48.6±2.9	5	10	+45.9±3.3	46.8±2.7
52	Elysium p.	15.6	+25.8±2.1	201.1±2.2	5	5	+26.0±3.3	200.3±2.0
56	Elysium f.	15.6	+22.9±4.7	225.7±1.6	5	5	+23.3±4.6	225.1±2.0
60	Thoth c.	15.4	+27.6±3.0	251.9±2.3	5	5	+27.6±4.3	251.2±1.8
93	Sigeus N.	15.5	— 4.7±3.3	335.5±0.9	5	5	— 4.2±2.3	335.5±0.9

CLASS D

No.	Station	Diam.	Ephemeris		A	O	Corrected	
		″	° °	° °			° °	° °
4	Acidalium p.	14.9	+53.4±2.2	14.0±5.5	5	5	+53.5±3.0	11.8±6.6
12	Acidalium N.	11.7	+63.3±2.0	44.4±9.6	3	9	+64.0±1.2	40.1±8.9
15	Acidalium f.	14.9	+54.6±3.0	54.0±4.8	5	5	+55.3±3.2	52.2±5.5
16	Baltia S. p.	14.5	+60.7±1.6	58.2±7.6	2	4	+60.8±2.8	53.4±7.8
22	Nectar p.	14.8	—25.6±4.8	62.7±4.2	5	10	—25.5±4.0	63.5±4.2
25	Ceraunius p.	15.0	+55.0±3.5	87.4±6.0	5	5	+55.1±2.7	84.8±5.7
26	Solis c.	14.3	—27.0±2.4	86.5±3.7	5	17	—26.2±2.3	87.1±3.8
28	Solis f.	15.3	—28.4±2.9	93.4±4.8	5	5	—28.0±2.7	94.1±5.0
29	Thaumasia S.	13.8	—46.4±3.1	94.4±4.0	3	4	—46.6±2.0	95.0±3.2
34	Arcadia N.	12.9	+51.4±2.7	118.9±4.2	4	7	+52.3±3.0	116.0±4.6
35	Icaria N.	14.8	—38.5±3.5	120.0±2.4	4	6	—38.2±3.4	121.3±2.4
39	Castorius p.	14.2	+50.4±2.9	148.3±2.0	4	5	+50.5±3.0	145.6±2.0
42	Arsenia N.	13.5	+58.8±3.3	163.5±2.6	4	12	+59.7±3.3	160.0±3.1
45	Olympia p.	13.2	+80.8±3.8	187.1±11.5	2	4	+80.3±4.4	172.1±14.8
47	Electris N.	14.1	—41.5±2.8	179.2±2.2	5	9	—40.8±2.1	180.9±2.0
51	Olympia c.	13.0	+78.9±1.2	213.8±4.7	2	4	+78.8±1.5	198.8±5.4
53	Gyndes S.	15.1	+56.9±3.3	209.3±3.8	5	5	+57.3±1.5	207.3±3.9
57	Olympia f.	13.5	+79.2±3.4	240.6±8.1	2	4	+79.7±3.5	225.6±7.7
65	Boreosyrtis N.	13.3	+69.4±2.9	270.7±2.6	3	5	+70.4±3.9	264.0±2.7
66	Achates S.	11.7	—38.4±7.2	264.9±1.1	2	4	—38.3±4.5	264.8±1.8
77	Hellas N.	13.8	—29.5±3.9	291.2±4.8	5	5	—29.2±3.7	292.2±5.0
78	Boreosyrtis N. f.	13.1	+67.0±1.3	299.7±7.1	2	4	+67.6±1.6	293.4±7.2
89	Arethusa	14.4	+62.2±1.0	331.2±3.2	2	4	+61.8±0.8	326.4±2.5

CLASS E

No.	Station	Diam.	Ephemeris		A	O	Corrected	
		″	° °	° °			° °	° °
2	Pandora f.	14.6	—23.0±2.8	7.1±4.6	3	4	—23.0±4.3	7.8±4.4
9	Acidalium S.	13.3	+41.1±3.3	32.2±3.0	5	20	+41.3±3.7	30.9±3.2
19	Lunae S.	15.0	+11.7±4.0	61.9±3.4	5	5	+12.4±4.9	61.6±3.4
31	Croesus	9.8	+27.6±2.3	106.0±2.3	4	4	+29.0±2.4	104.8±2.6
40	Castorius S.	13.9	+37.6±3.0	156.7±5.0	4	10	+38.7±3.6	155.1±5.2
41	Castorius c.	15.7	+36.6±1.2	157.6±4.2	3	4	+35.6±0.8	155.6±4.1
48	Propontis S.	14.6	+38.6±4.0	183.1±4.1	5	5	+39.1±3.5	181.7±4.3
49	Propontis c.	16.0	+42.8±2.2	185.7±3.5	3	4	+41.6±1.4	183.7±3.3
59	Utopia f.	15.6	+49.0±5.2	248.8±3.6	5	5	+49.6±4.7	247.4±4.3
61	Nuba S.	13.6	+27.6±3.0	252.5±4.1	3	5	+29.5±3.0	251.6±4.0
62	Syrtis minor N.	13.9	0.0±2.6	254.6±7.0	5	8	+ 0.1±3.4	254.6±7.0
64	Euxinus S. p. M.	13.5	—17.4±3.8	262.2±10.0	2	3	—16.4±3.6	263.0±10.0
67	Euxinus N. p. M.	13.7	+ 8.1±4.5	268.2±5.4	3	6	+ 9.7±4.0	268.0±5.3
70	Vulturnus N.	10.9	—24.0±1.6	277.5±2.7	2	4	—24.0±1.8	277.4±3.3
72	Euxinus p. m.	12.7	+ 9.7±3.1	280.6±3.2	5	10	+ 9.6±2.9	280.3±3.2
73	Libya f.	13.9	— 2.2±4.1	282.3±3.6	5	5	— 2.2±2.8	282.4±3.6
76	Euxinus S. m.	12.4	+ 3.2±5.5	289.1±4.2	5	10	+ 3.7±5.8	289.0±4.2
79	Euxinus S. f.	15.1	+ 4.4±3.8	295.2±3.9	5	5	+ 4.7±2.3	295.1±3.9
80	Euxinus S. M.	13.7	—14.1±3.5	294.9±5.3	4	8	—12.9±4.5	295.3±5.5
83	Boreosyrtis S. f.	13.7	+47.2±3.4	299.2±3.8	5	9	+48.0±4.6	297.3±3.2
86	Hammonis S.	13 3	—10.5±2.7	319.2±3.8	5	15	—10.2±3.0	319.5±3.8
95	Edom f.	13.7	+ 0.1±3.4	350.3±4.0	5	15	+ 0.3±3.0	350.3±4.0
100	Siloe	14.8	+37.5±2.2	1.3±0.9	4	4	+37.5±2.8	359.7±1.2

TABLE I.—Continued.

CLASS F

No.	Station	Diam.	Ephemeris		A	O	Corrected	
		″	° °	° °			° °	° °
1	Pandora S.	14.9	—37.6±2.0	1.8±1.7	1	2	—34.7±1.9	1.8±1.2
10	Horarum S.	14.1	—27.9±1.6	31.7±1.0	2	3	—26.5±1.9	32.7±0.9
13	Nia N.	15.0	—36.2±2.2	45.5±0.9	1	2	—33.8±2.0	46.6±0.7
20	Juventae N.	17.8	+ 6.1±1.4	62.7±3.3	2	3	+ 4.7±0.9	62.6±3.2
21	Juventae S.	15.6	— 4.9±1.6	62.5±3.3	2	3	— 5.0±0.7	62.7±3.4
27	Ascuris	9.4	+43.9±0.8	94.4±1.9	1	2	+44.2±0.6	91.8±1.8
30	Mandevia	14.0	+36.3±2.9	102.3±3.7	3	3	+36.9±0.6	101.3±4.2
33	Thaumasia f. m.	15.0	—38.6±0.4	106.5±2.7	1	2	—35.8±0.4	106.5±2.7
36	Biblis	14.6	+ 4.5±4.0	124.5±3.6	3	3	+ 2.9±4.7	124.4±3.6
37	Thaumasia f. M.	20.4	—30.1±1.4	123.8±5.0	1	2	—32.8±1.2	124.6±5.2
38	Bandusia	13.5	+21.2±3.8	138.8±4.7	2	2	+19.4±3.3	138.0±4.9
44	Moreh	15.8	+20.4±1.6	172.0±2.7	3	3	+19.5±2.0	171.1±2.9
81	Coloe	14.2	+31.0±1.6	297.6±0.6	3	3	+30.5±1.8	296.7±0.7
82	Pseboas	10.8	+47.8±1.4	299.7±7.5	2	2	+46.2±1.6	297.1±7.6
84	Bonis	8.3	+19.8±2.6	306.4±2.3	1	2	+19.2±3.1	305.4±2.2
85	Hellespontus N.	14.4	—30.8±3.0	313.1±2.6	2	3	—33.3±2.4	313.5±3.0
88	Noachis p.	16.8	—38.2±1.2	322.7±2.7	1	2	—41.1±1.1	323.2±3.0
90	Pandora p.	18.1	—26.5±1.7	326.2±2.3	2	3	—28.7±1.2	327.0±2.2
97	Aryn S.	17.8	+ 5.4±2.4	357.2±2.9	1	3	+ 2.6±2.4	357.1±2.9

and Titanum N. The added letters have the usual meanings, N and S for north and south, p and f for preceding and following, and c for center or middle. It may be remarked here that certain points in the table really have smaller probable errors than some of these ten, but were eliminated from consideration because we believed the small values in their cases were due to accident. No point in the table has been measured on more than 20 drawings, made on as many different nights, and none was included unless it had been measured on at least two. Nine of these latter are found, and these are presumably the least accurate determinations that we have made. Their average probable error in latitude and longitude combined is ±105 miles, ±2°.8, or ±0″.35.

The whole investigation involved 712 measurements in latitude, and the same number in longitude, of 224 drawings, of 100 points on the surface of the planet. The results are shortly to be published in full in the Harvard Annals, **82**, but in the meantime a summary of them has been prepared, and is given in Table I. The first column gives the number of the station, by means of which it can be found upon a map which will accompany our next Report. These numbers are given in the order of the longitudes of the stations as recorded in the last column. In the second column, following the name, the letters M and m signify, when used, the maximum and minimum extent of a formation which is subject to change of size. It is a rather singular circumstance that the most conspicuous marking on the planet, the large dark gray, or sometimes bright blue area, which is located at the northern end of the Syrtis, and is usually sharply defined at the south, as well as at the north, has never received a name. As we shall have frequent occasion in this and subsequent Reports to refer to it, I have decided to call it Euxinus, a name which seems appropriate, since many of Schiaparelli's markings have reference to the countries and rivers in the immediate vicinity of that sea. The third column gives the mean diameter of the planet, taken from the Ephemeris, on the nights when the several drawings of the station were made.

The fourth and fifth columns give the latitude and longitude of the stations computed from the Ephemeris, $\pm$ the average deviation of the single measurements from their mean. This quantity, the deviation, it is believed will be more satisfactory in this place than the probable error of the mean of the series of measures, which will be given for the best known stations with the detailed table in the Annals. A comparison of the average deviations of the different stations among themselves is thus rendered possible. It is not as widely known as it should be to the intelligent reading public that the term "average deviation" is ambiguous, meaning two distinctly different things. To most persons it means the average of a series of deviations from the mean value of a quantity, in other words the mean of the residuals, and may be expressed as

$$\Sigma\, d/n.$$

In that sense it is used in this paper. But to the mathematician it means the average deviation from the unknown true value of the quantity, in other words the computed deviation, and is expressed as

$$\Sigma\, d/\sqrt{n\,(n-1)}.$$

With this meaning of the expression, the formula is analogous to that for probable error.

The next two columns give the number of apparitions in which the point was drawn and measured, and the total number of drawings of it which were measured. Every point has been measured at every apparition possible, and an equal distribution among the apparitions has always been secured unless the point was only occasionally seen at some of them. In following out this rule it has been found necessary sometimes to reject many excellent drawings in certain apparitions in favor of the same number of less satisfactory ones in others. While this has doubtless diminished the accuracy of the result for these particular apparitions, and increased the probable errors over what would have been obtained had all the measures been confined to a single apparition, yet it has been done in order to definitely decide as far as is at present possible as to which points move over the surface, and which ones are stationary. Incidentally it also enables us to determine more satisfactorily the increase in accuracy secured by making use of the Corrected position of the planet's axis, as compared with the position given by the Ephemeris. The latitudes and longitudes using this Corrected position are given in the last two columns. The method of making these corrections is given in full, together with the curves employed, in Report No. **28**. In correcting the longitudes the mean latitude rather than the individual ones has been used.

On comparing the various average deviations in latitude between the fourth and eighth columns, it will be seen that those in the latter column are sometimes larger and sometimes smaller than those in the former. If we consider only the best determined latitudes, however, the thirty contained in classes A and B, we shall find that in only five cases are the average deviations larger in the latter column, in three cases there is no difference, while in 22 cases the latter column gives an improved result, and in many cases this is quite marked. Similar but less marked results are obtained by comparing the deviations in the longitudes given in the fifth and last columns. This matter will be further discussed presently in our description of Table II.

Among the 100 objects observed, 50 have been recorded at each of the five apparitions, and in 43 of these an equal number of measures at each apparition has been made. When 20 measures of a point have been secured it indicates that it was conspicuous at each apparition, and more measures could have been made of it had it been thought necessary. When 15 were made, it implies that not over three good drawings were secured at one or more of the five apparitions. When only 10 or 5 measures were recorded it does not necessarily mean that more could not have been obtained, but in many cases, merely that that number was considered sufficient for our purpose. No object was measured more than once on any one night. That an object was not recorded at an apparition does not necessarily mean that it was not seen. It may have been seen, but our weather may have been such that it was never drawn when near the central meridian of the planet, which is the only place where it can be satisfactorily measured.

Taking up the table now in more detail, we find that the 100 points have been divided into six classes according to their character, latitude, and the assumed accuracy of the measures. Class A consists of 24 points, which are believed to be stationary, or nearly so, and whose positions are accordingly accurately known. No point is admitted to this class which has not been observed on at least 5 different nights. Although two of them were visible at only 3 apparitions, since they were measured at every apparition when they were visible, this seems to offer no reason for excluding them. The three largest average deviations in longitude in the last column are for Maeisia, Syrtis N., and Ismenius. Correcting them for their latitudes, it is found that in each case the linear deviation is less than 3°.0 measured in latitude. The largest deviation in this class is therefore for the latitude of Sirbonis, and amounts to ±3°.28.

Class B consists of curves of long radius which lie in an east and west direction, such for instance as the boundary lines of Solis N. and Edom S., and also of points which like Aurorae N. and Cimmerium N. appear to travel back and forth in an east and west direction, 6 in all. We hope to deal with some of these travelling points in a future paper. No average deviation in latitude exceeds ±2°.9. The deviations in longitude are more or less meaningless, but some of them are of considerable size. Class C consists of curves lying in a meridional direction. Their deviations in latitude mean but little, but the deviations in longitude in no case exceed ±2°.7. Sigeus apparently sometimes shifts in latitude and is therefore put in this class, although a consideration of its deviations alone would justify us in placing it in Class A. No points are admitted into either of these classes which were observed on less than 5 nights. They have all been drawn at every apparition.

All of the points included in classes A, B, and C lie between latitudes +50° and —25°. The limit to the north is set by the fact that some of the points in these high latitudes move about through a limited range in both latitude and longitude, while others, at times covered by the polar cap, were seen at only 2 or 3 apparitions. The limit to the south is set by the winter clouds, which often cover these extreme southern regions. Class D consists of all the well observed points, 23 in number, whose latitudes north and south exceed these limits. Among the points visible at only two apparitions several occur which might have been measured more frequently during those years, but were so clearly defined, or were so obviously changeable, that it did not seem worth while to do so. It is evident that the large average deviations recorded in longitude would be equivalent in actual distance to a much smaller number of degrees measured in latitude, or in longitude at the equator. Excepting for their high latitudes, several of these points such as Electris and Gyndes might have been admitted into the first three classes. The largest deviation of all, Olympia p. ±14°.8 is equivalent in miles to only ±2°.4 measured in latitude. While three or four of these points, like Arethusa, have very small average deviations and probable errors, they are not any of them considered as suitable for points of reference. Class E consists of 23 points, most of which are believed to shift about within certain limits over the surface of the planet. We do not consider that any of them would serve as satisfactory points of reference, although the four lakes Croesus, Castorius c., Propontis c., and Siloe are probably stationary. No point is admitted into either class D or E, with one exception, which has not been measured at least 4 times. The exception is Euxinus S. p. m. in class E, which was observed three times. It was included because this branch of the Euxinus rarely forms, but was measured every time it was detected. Being large and conspicuous it was well observed, and it was thought best to include it with the five other stations connected with this marking.

The 19 points in class F have all been insufficiently observed. The more southern ones were only seen at one or two apparitions. All the others except Aryn are lakes. In December of 1913 Pandora did not reach Horarum sinus just to the south of Margaritifer, as is often the case, but stopped short of it, and sent out a branch to the south. It was through this branch that the so-called flood came down to the Euxinus from the south pole at the time of the melting of the polar cap in 1892, and which is described and illustrated in Report No. 4 (Popular As-

TRONOMY, 1914, **22**, 231). This phenomenon has never been seen since that year. The branch is entered as Pandora S under F. The small dark areas Solis, Lunae, and Niliacus are not considered to be true lakes in this paper. Of the 20 that we have measured, 6 are included in class A, one in class D, 4 in E, and the remaining 9 in class F, which thus becomes the class of lakes. Only 3 of them, Juventae S., Maeisia, and Phoenix, are located in the southern hemisphere. Including these three, 7 were seen at the apparition of 1914, 9 in 1916, 17 in 1918, 12 in 1920, and 15 when the planet was nearer, in 1922. Like the canals they are most numerous in the summer season of the planet.

It must be mentioned here that even when a lake is entered in the table, it does not necessarily mean that it was seen as a dark spot or area. When a lake occurs at the junction of two well known canals, and these canals are clearly visible, the location of the junction has been measured even if the lake was not seen as such. We considered that an accurate determination of the location was of more importance than the mere question of visibility. The lakes are usually small black points, but occasionally they appear as large fuzzy objects, something like Lunae, but smaller. This does not depend on the seeing. If the seeing is poor the lakes are not seen at all. Most of them are seldom visible, but when they are seen, they sometimes come out very clearly. Thus Ascuris was once recorded when the diameter of the planet was only 7″.4, Sirbonis was drawn at 7″.9 and Croesus when the planetary diameter was 6″.7, and again 7″.8. Neither of these lakes was often seen, especially Ascuris. Excepting for these three lakes no measures of planetary detail were made when the diameter was less than 8″, and comparatively few when less than 10″, as may be judged by the third column of the table. While Ismenius, the most completely observed lake, does show a steady tendency to move southerly about 3° from the first to the last apparition, and a not wholly continuous tendency to increase its longitude by 6° during the same interval, yet its motion if real is hardly sufficient to take it out of class A, and the evidence is pretty strong that the lakes as a whole are practically stationary. Only two out of the twenty, Biblis and Bandusia, show evidence of motion by their large average deviations. When so few drawings occur however, the size of the deviation is more probably explained by supposing either that one of the drawings was a poor one, or that two different lakes were observed at the two apparitions. Therefore excluding Ismenius, which may possibly be analogous to Solis and Lunae, we may lay it down as an acquired fact that the lakes for all practical purposes are stationary points on the planet's surface.

On a map for the sake of clearness, and in tables for sake of brevity, it is always desirable to avoid all unnecessary lettering or printing. The generic terms such as Lacus, Sinus, Fastigium, etc., have, therefore, all been omitted. As in our previous reports, it has not been thought desirable to change the well known names such as Aurorae, Lunae, etc., from the genitive to the nominative case by dropping the e, and our readers may therefore imagine Sinus, Lacus, etc., added where necessary to meet the requirements of Latin construction. In identifying the lakes, if our position agrees within 5° or 10° with that of some previous authority, his name for the lake has been used. If it does not agree with any previously named lake we have named it. There are two Juventaes differing in latitude by about 10°. They have appeared alternately in different apparitions, Juventae S. in 1914 and 1920, Juventae N. in 1916 and 1922, but they have never been seen at the same time. The position of Juventae on our standard map lies halfway between them, and agrees with that given by Schiaparelli on his first map showing this marking, that of 1882. There is also a third Juventae much smaller than the others, and seen for the first time in 1924. It lies 5° or 10° to the east of the southern one.

Position of the Axis of Mars.

It has been thought desirable to give the latitudes and longitudes in Table I both according to the Ephemeris, and according to the Corrected position of the axis of Mars, in order that those who prefer the for-

TABLE II.

Deviations Obtained with the Ephemeris and Corrected Poles.

Classes A and B combined. Latitudes.

No.	Station	Obs.	1914 E	1914 C	1922 E	1922 C	'14—'22 E	'14—'22 C	1918 E	1918 C	'18—M E	'18—M C
			°	°	°	°	°	°	°	°	°	°
3	Sabaeus f.	3	— 9.5	— 6.6	— 2.4	— 5.0	— 7.1	—1.6	— 3.3	— 2.0	+2.7	+3.8
5	Margaritifer N.	6	+13.2	+15.9	+15.8	+13.3	— 2.6	+2.6	+16.7	+17.4	+2.2	+2.8
7	Thymiamata f.*	12	— 2.0	+ 0.8	+ 1.6	— 1.0	— 3.6	+1.8	— 2.1	— 0.9	—1.9	—0.8
8	Aromatum S. p.*	9	— 3.7	— 1.0	+ 2.6	— 0.1	— 6.3	—0.9	— 1.7	— 0.9	—1.1	—0.3
11	Niliacus S.*	12	+28.8	+31.6	+31.4	+28.9	— 2.6	+2.7	+28.4	+29.2	—1.7	—1.0
23	Maeisia	3	—14.8	—11.9	—10.7	—13.1	— 4.1	+1.2	—11.5	—11.7	+1.3	+0.8
32	Phoenicis	3	—14.3	—11.5	—11.8	—14.4	— 2.5	+2.9	....	....	...	...
43	Titanum N.*	9	—19.8	—16.9	—13.9	—16.7	— 5.9	—0.2	—18.6	—18.2	—1.8	—1.4
54	Elysium N.*	12	+33.3	+36.0	+39.4	+36.6	— 6.1	—0.6	+34.0	+34.5	—2.4	—1.8
55	Elysium S.*	12	+ 8.7	+11.5	+17.2	+14.4	— 8.5	—2.9	+12.5	+13.0	—0.5	0.0
63	Triton N.	6	+16.0	+18.9	+27.8	+24.9	—11.8	—6.0	+19.4	+19.5	—2.5	—2.4
68	Libya S.	6	—15.1	—12.3	— 3.0	— 5.8	—12.1	—6.5	— 7.5	— 7.2	+1.5	+1.8
69	Nepenthes c.*	12	+ 5.9	+ 8.8	+13.7	+10.9	— 7.8	—2.1	+13.4	+13.6	+3.6	+3.8
71	Neith N. f.	5	+42.8	+45.7	+49.3	+46.6	— 6.5	—0.9	+46.4	+46.4	+0.4	+0.2
74	Syrtis N.*	12	+22.0	+24.8	+28.8	+26.0	— 6.8	—1.2	+25.4	+25.4	0.0	0.0
87	Sirbonis	6	+14.6	+17.4	+18.9	+16.1	— 4.3	+1.3	+10.5	+10.8	—6.3	—6.0
91	Ismenius*	12	+45.9	+48.6	+47.8	+45.1	— 1.9	+3.5	+45.2	+45.6	—1.6	—1.2
92	Juturna	6	+17.5	+20.4	+24.9	+22.1	— 7.4	—1.7	+16.2	+16.8	—5.0	—4.4
96	Furca N. p.	6	+ 4.7	+ 7.5	+10.7	+ 7.8	— 6.0	—0.3	+ 6.2	+ 6.6	—1.5	—1.0
98	Furca N. f.	3	+ 5.5	+ 8.4	+11.1	+ 8.3	— 5.6	+0.1	+ 6.9	+ 8.0	—1.4	—0.4
99	Furca S.	3	—12.4	— 9.5	— 5.7	— 8.6	— 6.7	—0.9	— 8.1	— 7.3	+0.9	+1.7
17	Aurorae N.	6	—10.4	— 7.7	— 2.4	— 5.2	— 8.0	—2.5	— 7.4	— 6.0	—1.0	+0.4
24	Solis N.	3	—22.9	—20.0	—18.6	—21.5	— 4.3	+1.5	—21.6	—21.5	—0.8	—0.7
46	Aesculapius c.	3	+ 2.3	+ 5.2	+ 3.8	+ 0.9	— 1.5	+4.3	— 3.1	— 2.0	—6.1	—5.0
50	Laestrygonum N.	3	—19.5	—16.8	—13.1	—16.0	— 6.4	—0.8	—13.8	—12.8	+2.5	+3.6
58	Cimmerium N.	6	— 1.7	+ 1.2	— 0.3	— 3.1	— 1.4	+4.3	— 2.8	— 2.5	—1.8	—1.5
94	Edom S.*	9	— 5.2	— 2.4	— 0.7	— 3.4	— 4.5	+1.0	— 2.7	— 2.5	+0.3	+0.4
	Means						—5°.64	—0°.07			—0°.85	—0°.33

*One of the 13 original stations.

mer, or find them more convenient for their special investigations may have them for that purpose. The method of reducing the measures from one axis to the other has, as already stated, been fully described in Report No. **28**. Except in the polar regions, where it is of small consequence, the correction has but little effect on the longitudes. A glance at the average deviations in latitude will however quickly show that those in the column headed Ephemeris are larger than those in the column under Corrected. The mean of the values for class A are Ephemeris ±2°.64, Corrected ±2°.16. In class B we have Ephemeris ±2°.32, Corrected ±2°.07. The differences in favor of the corrected values are small, because these columns contain drawings made during five different apparitions, and at some of these apparitions the correction was insignificant. If we consider however merely those years at which the correction would be at its maximum, the apparitions of 1914 and 1922, when the planet was at its two equinoxes, the difference becomes more marked.

In Table II Classes A and B are combined. These are the only stations whose latitudes are accurately known. Out of the 30 stations comprising these two classes, only the 27 which were drawn in both 1914 and 1922 are included in this table. The third column gives the total number of observations for each station at the three apparitions of 1914, 1918, and 1922. The total number of all the observations considered is 188. The fourth and fifth columns give their latitudes as determined in 1914, using the Ephemeris and Corrected axes of the planet. The sixth and seventh columns give their latitudes as determined in 1922. These latitudes should of course be identical with those determined in 1914, since all of these stations are believed to be stationary on the planet. The eighth and ninth columns give the difference between the determinations in 1914 and those in 1922 for the two axes. Summing them up at the bottom of these columns, we find that if we adopt the axis of the Ephemeris, these points will in that interval every one of them have moved northerly an average distance of 5°.64, or a trifle over 200 miles measured on the surface of the planet. The least northerly motion of any of them, that of Cimmerium, was 50 miles. According to the Corrected position of the axis, the mean motion northerly was 0°.07 or a trifle less than three miles. Three miles for an average motion of nearly thirty points is however three miles too much, and we shall presently proceed to correct it. The correction to the axis should of course be only one half of 5°.64, or 2°.82, but this of necessity is rather too small, since all the drawings were not made in those portions of the orbit where the error is most marked. The original 13 stations employed in Report No. **26** gave us an error of 2°.95. Although it is true that 10 of these stations, those marked with an asterisk, are included in the present investigation, yet we see that there are 17 other stations which agree in yielding practically the same result. It might be suggested that we should have weighted these 27 stations in proportion to the square roots of the number of observations of each. This has not been done in this place however, since all those stations having more than 8 observations, whose importance would thus be emphasized, were the very ones used in the first place to locate the Corrected axis. The correction —2°.82 gives us approximately the angular error of the Ephemeris axis in azimuth,—that is in a direction at right angles to the angular error in inclination. This latter error we shall now proceed to investigate.

In the tenth and eleventh columns of the table are given the latitudes of 26 of these points as determined in 1918. Phoenicis was not detected at all that year. Subtracting the mean of the two values in 1914 and 1922 from the value in 1918 gives us in the last two columns the errors in the Ephemeris, and in the Corrected positions of the axis. In our first determination of the inclination in Report No. **26**, we concluded that the error was only —0°.256. Subsequently we decided that this value was probably too small, and in the construction of the curves used in this research called it —0°.4. Later, in Report No. **28**, after a considerable amount of computation had already been done, it was concluded that the error was probably nearer —0°.82, but that it was not sufficiently assured to make a recomputation of the location of the stations necessary. The present result leads us to believe that it is numerically a little over —0°.6.

Having now reached the desirable position of having discovered 26 points and lines on the surface of the planet whose latitudes appear to have remained constant during 5 apparitions, we will proceed to make use of them to secure still more accurate determinations of the values of the constants *C* and *D* used in locating the axis. In Table III the first three columns are identical with those in Table II excepting that Phoenicis is omitted. The fourth column is taken from the ninth of Table II, since the value of *C*, —2°.9, is near enough for our present purpose. The fifth column is computed like the last of Table II, except that *D* is now assumed to be —0°.6. Weights have been assigned to the stations in proportion directly to the square root of the number of times that they have been drawn. These weights are given in the sixth column. The last two columns give their effect on the corrections to *C* and *D*. The first must be divided by 2. Applying these corrections to the assumed values we obtain the new and final values **C = —3°.00 D = —0°.78.** The results obtained from these 26 stations are almost identical with those obtained from the original 13, as given in Table II of Report No. **28**, —3°.02 and —0°.79. A deviation of 0°.01 measured on the surface of Mars is equivalent to a distance of 2000 feet.

The question may now be asked had we used these Revised constants in the computation of Table I, instead of the preliminary Corrected ones *C* = 2°.9, and *D* = 0°.4, what differences would have occurred in our results? By actual trial we find that while in many cases there will be no change, in no case would the difference between the computed latitudes exceed 0°.3, or 11 miles. The latitudes of all points are shifted slightly towards the north at the time of the summer solstice, and with the Revised constants they would stay there at all seasons. Regarding the longitudes, there is no change until we have passed latitude 20°. In higher latitudes the difference increases at first slowly, but later more rapidly, until by the time we reach 60° the difference in extreme cases may amount to 0°.65.

We have illustrated here a very practical case of wishing to determine the latitudes and longitudes of a considerable number of points on Mars, in this instance 26, by means of a survey, made we have assumed only at the three apparitions of 1914, 1918, and 1922. The points here considered are those contained in classes A and B. The

TABLE III.

DETERMINATION OF THE CONSTANTS *C* AND *D*.

No.	Station	Obs.	2 Δ C	Δ D	Wts.	M	N
			°	°		°	°
3	Sabaeus f.	3	—1.6	+4.0	1.7	— 2.7	+ 6.8
5	Margaritifer N.	6	+2.6	+3.0	2.4	+ 6.2	+ 7.2
7	Thymiamata f.	12	+1.8	—0.6	3.5	+ 6.3	— 2.1
8	Aromatum S. p.	9	—0.9	—0.1	3.0	— 2.7	— 0.3
11	Niliacus S.	12	+2.7	—0.8	3.5	+ 9.4	— 2.8
23	Maeisia	3	+1.2	+1.0	1.7	+ 2.0	+ 1.7
43	Titanum N.	9	—0.2	—1.2	3.0	— 0.6	— 3.6
54	Elysium N.	12	—0.6	—1.6	3.5	— 2.1	— 5.6
55	Elysium S.	12	—2.9	+0.2	3.5	—10.2	+ 0.7
63	Triton N.	6	—6.0	—2.2	2.4	—14.4	— 5.3
68	Libya S.	6	—6.5	+2.0	2.4	—15.6	+ 4.8
69	Nepenthes c.	12	—2.1	+4.0	3.5	— 7.4	+14.0
71	Neith N. f.	5	—0.9	+0.4	2.2	— 2.0	+ 0.9
74	Syrtis N.	12	—1.2	+0.2	3.5	— 4.2	+ 0.7
87	Sirbonis	6	+1.3	—5.8	2.4	+ 3.1	—13.9
91	Ismenius	12	+3.5	—1.0	3.5	+12.2	— 3.5
92	Juturna	6	—1.7	—4.2	2.4	— 4.1	—10.1
96	Furca N. p.	6	—0.3	—0.8	2.4	— 0.7	— 1.9
98	Furca N. f.	3	+0.1	—0.2	1.7	+ 0.2	— 0.3
99	Furca S.	3	—0.9	+1.9	1.7	— 1.5	+ 3.2
17	Aurorae N.	6	—2.5	+0.6	2.4	— 6.0	+ 1.4
24	Solis N.	3	+1.5	—0.5	1.7	+ 2.6	— 0.8
46	Aesculapius c.	3	+4.3	—4.8	1.7	+ 7.3	— 8.2
50	Laestrygonum N.	3	—0.8	+3.8	1.7	— 1.4	+ 6.5
58	Cimmerium N.	6	+4.3	—1.3	2.4	+10.3	— 3.1
94	Edom S.	9	+1.0	+0.6	3.0	+ 3.0	+ 1.8
	Mean					—0°.19	—0°.18

position of the axis of Mars has been determined by earlier astronomers for this very purpose, in order to locate accurately points on the surface of the planet. I do not really know of any other reason why we should care to locate the axis. We have determined the errors in its position as given in the Ephemeris by what is certainly the best method, in Reports **26-28**, and the present article; and also in Report **32** by the older method of observing the polar caps, as practiced by Schiaparelli, Lowell and others. Both methods lead to the same result,—that the position of the axis given in the Ephemeris is in error,—and by a very considerable amount. We trust that the Washington authorities will see their way before long to spend the necessary money to correct this serious defect.

The inclination of the planet's axis to the pole of its orbit now becomes **24° 56′**, lying about midway between Struve's value 25° 13′, obtained from the motion of the orbits of the satellites, and those of Schiaparelli and Cerulli, 24° 42′ and 24° 45′ respectively. Lohse's and Lowell's values 23° 57′ and 23° 16′ appear to be hopelessly at variance with the others. The location of the northern pole in the heavens on April 1, 1918, was in α **315° 07′** δ **+51° 49′**. The most marked change produced by the use of the new Revised constants will be to shift the vernal equinox back 7°.16, from heliocentric longitude 87°.89 to 80°.73, equivalent to 14 days, and to increase the solar longitude ⊙ of the Ephemeris by this same amount. The Martian dates of the equinoxes and solstices now become, vernal February 43, summer June 11, autumnal September 23, and winter December 1.

We have attempted to locate the axis of the planet by means of the deviations in longitude, at different apparitions, of points in high latitudes. Although perfectly possible theoretically, it is not a practicable method. Even out of the 100 points that we have measured, those in high latitudes, Class D, number only 23. But only 12 of these were visible both in 1914 and 1922, and only 10 if we include also 1918. The others were hidden at times either by the northern polar cap, or by the southern clouds. Of these 10, only 6 points are believed to be stationary. These are Solis c., Icaria N. and Electris N. in the southern hemisphere, and Acidalium f., Ceraunius p., and Gyndes S. in the northern, with which to compare them. Indeed it is by no means certain that all of these points, particularly the last one, can be located with accuracy, and it is clear that with so few points, and also with so few observations, no satisfactory result could be obtained. This investigation was therefore closed, and our results secured by means of latitudes are given as our final figures.

Private Observatory, Mandeville, Jamaica, B. W. I.,
December 4, 1925.

Note on the Presence of Oxygen in the Atmosphere of Mars.

Since writing Report No. **31** my attention has been called to the fact that in referring to the existence of both water vapor and oxygen in the atmosphere of Mars, although I had mentioned the Lowell Observatory in connection with the existence of the former, I had quite overlooked the important fact that the presence of oxygen in the Martian atmosphere had first been proved as long ago as 1909 at the Lowell Observatory, Lowell Bulletin No. 41. This was accomplished by means of spectra photographed by Dr. V. M. Slipher and measured by Professor F. W. Very. The latter found that the percentage in the Martian atmosphere, as judged by the intensity of the B line, was 15 percent of that reflected to us by the moon through the earth's atmosphere. Since the light received by us from Mars passes twice through its