could see the chromosphere at third contact. I hoped to get some star images on the plates of the six meter camera but I don't believe that we got very many stars for the reason already stated.

The geographical position of the Station was $+24° 43' 55'' \pm 1''$ and $6^h 55^m 22^s.4 \pm 0^s 1$ west of Greenwich.

The Meteorological observations made in Yerbanis were not of any value due to the bad conditions. The actinograph, however, shows the decrease of temperature, but I can not compare it because of the presence of the cloud.

The Leguna Seca Party in charge of Professor J. M. Chacon, with assistants E. Ortega, F. Estanol and J. Tapia, secured five plates with an object glass of 8 meters focal length and some pictures of the partial phase with a photoheliograph. At this place the sky was better than at Yerbanis but a haze prevented securing better results.

Under separate mail I am sending you a picture of our camera at Yerbanis, two pictures with the 19 meter camera, two with the 6 meter and two others of Laguna Seca and a partial view of the camp in that place.

REPORT ON MARS, NO. 26.

By WILLIAM H. PICKERING.

The Axis of Mars.

In order to secure quantitative results with regard to the shifting of the Martian detail over the surface of the planet, both with the seasons and also independently of them, it is necessary to obtain accurate measures of various reference points on the surface, in both longitude and latitude. To do this we must know the position of the polar axis of the planet with considerable precision. Its position was determined by Schiaparelli and his predecessors by means of observations of the polar caps, and this method has been universally adopted since his time. The position used at present in the Ephemeris was determined by Lowell and Crommelin, and is there given to seconds of arc and time. Such accuracy is deceptive however, and is by no means justified by the accuracy of the results, since the error appears to be expressed in degrees, as we shall presently see.

Many years ago I suggested to Lowell that instead of using the polar caps, he should use exclusively latitudes and longitudes of points on the surface of the planet. The idea however did not appeal to him. The objection to using the polar caps is well illustrated by observations made in the autumn of 1913, and very evidently in the summer of 1922, when although the northern pole of Mars was inclined towards us at an angle of 9°, and the outline of that portion of the northern polar cap which was visible to us should have been distinctly elliptical, yet its southern boundary was sometimes clearly seen as a straight line going directly across the disk from limb to terminator. The explanation was obvious. As any given point of the cap was brought by the rotation of the planet to the central meridian of the disk, the snow or frost melted, and did not form again until the following afternoon and night. Consequently the latitude of the cap was higher at Martian sunset than it was at sunrise. Moreover it would always be so, even if it were not detected. This difference was also exhibited throughout the month of June 1922 by means of a comparison of position angles taken on the snow with those based on the Ephemeris.

That the daily melting of the snow or frost should have been sufficient to have made itself visible in this manner is certainly surprising, and clearly indicates not only the thinness of the snow, but also why the error of any determination of the location of the pole based on such an observation would be considerable. It must also be remembered that these observations cannot be continued throughout the Martian orbit, in which case the errors might possibly neutralize one another. At certain seasons neither cap is visible, the one turned towards the earth being hidden beneath Martian clouds. The southern cap is very eccentric, and when it is small is hidden behind the planet in some longitudes, and situated on the disk away from the limb in others. When the cap is large the melting is found to be considerable, with consequent displacement in latitude. The northern cap which is best suited for locating the axis of the planet is sufficiently small for this purpose for only a few months of the year.

While the position of the polar axis could be determined either by latitudes or by longitudes of points on the disk, measured in different portions of the planet's orbit, yet the former are much the better suited for our purpose. In order to use the method of longitudes it would be necessary to measure points located in high latitudes. But such points are seldom well defined, and moreover in general have a very distinct and considerable proper motion, that is to say they shift about over the surface of the planet in an irregular manner. The method by means of latitudes on the other hand requires the use of points near the planet's equator, and these can always be observed near the centre of the disk, under the most favorable conditions. While there is evidence that these also exhibit a considerable motion in latitude that can be measured from the earth, yet we shall presently show that the extent of this motion may be greatly reduced by a simple change of the position of the polar axis from that given in the Ephemeris.

If we could find a single point on the surface of the planet whose position we knew to be stationary, or if we could find a dozen whose proper motions lay within the limits of accuracy of our present observations, all would be well. Unfortunately however such is not the case. Thirteen different points have been selected for accurate observation which were sufficiently distinct to be clearly recognized on several different nights, at each of the past apparitions of the planet.

In order to understand the method that is employed to locate the planet's axis, we must note first that all that is required is simply to determine the right ascension and declination of the point in which it

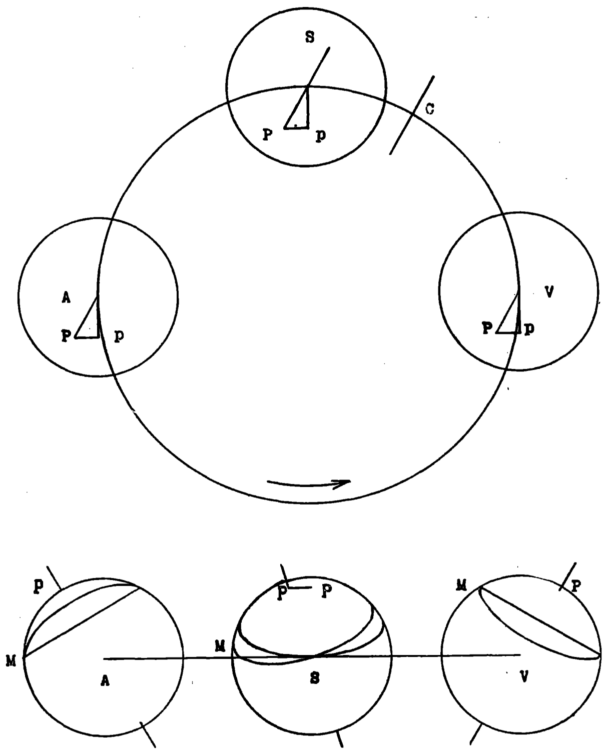

FIGURE 1.

would intersect the celestial sphere. In order to see how we have determined this point, in Figure 1 let the large circle represent the planet's orbit as seen from the north, and the small circles V and A the planet itself at its assumed vernal and autumnal equinoxes. S shows its position at the summer solstice. The point P in each circle indicates its true north pole, and p its pole according to the Ephemeris. The distance between these is greatly exaggerated in the figure, since in point of fact they nearly coincide. The center of each small circle indicates the pole of the planet's orbit. The latitude according to the Ephemeris, for any observed point on any given date is readily calculated from p by means of the tables. The three circles below indicate the appearance of the planet in the three positions as seen from the sun.

In the case that P coincided with p, then at the two equinoxes a point M would describe a straight line across the disk. If P were located, as shown in the drawing, to the left of p, M would then describe a curved course, its latitude being to the south of that computed, in the Martian spring, and to the north of the computed value in the autumn. At the summer solstice on the central meridian the two values would coincide, although the actual course described would not coincide with the theoretical one. Observations of latitude and longitude can only be made with accuracy when the points observed are near this meridian. The effect of a displacement of the true pole P from that of the Ephemeris, as shown in the upper portion of the drawing, is to shift the summer solstice backwards on the orbit to C, and to carry the other solstice and equinoxes backwards with it through the same number of degrees.

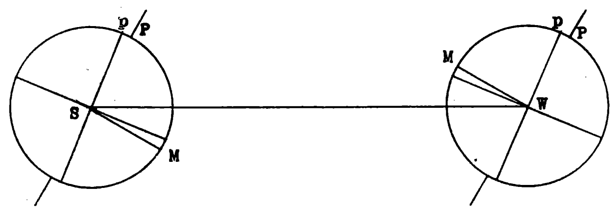

FIGURE 2.

To determine the inclination of the planet's axis to its orbit, which gives the distance between their two poles, observations must be secured at the solstices. In Figure 2 let the line $S\,W$ represent the plane of the planet's orbit, and the two circles its position at the solstices. P and p represent as before the true pole and that of the Ephemeris. Let M be a point on the true equator. Then at the summer solstice S, its observed latitude when computed, will appear to be south of its latitude when observed at the winter solstice. This then is the result when the assumed inclination of the planet's axis to the axis of its orbit is too small, and we may thus determine completely the location of the planet's axis in space.

While for the sake of simplicity we have referred these observations to the sun, and to the equinoxes and solstices, yet the position of the planet's axis may be determined from any other point in space by correcting the position of Mars for the location of the observer. In practice the tangential shift of the planet's pole around the pole of its orbit is determined when the planet is near its geocentric equinoxes, if we may so call them, that is those measured with regard to the earth, instead of with regard to the sun. Similarly the inclination, or radial shift, is determined when its poles are turned alternately towards us, in analogy to the Martian solstices. These positions of the planet are given to us directly by the Ephemeris, as we shall presently see.

Let us turn now to our actual results. Our observations so far have extended through five apparitions of the planet, during which time it has been observed through a range of geocentric longitudes of 176°. This excludes all those observations where the diameter of the disk was less than 10″. While the observations will not really be completed until after the apparition of 1928, yet since the future is always uncertain, and an inspection of our results leads us to believe that the later observations would not add materially to the accuracy of our conclusions, it has been thought best to publish them at once for the benefit of other observers. It is believed that any errors that may exist in them are unlikely to affect materially any future observations until our present standard of acruracy is very considerably increased.

The latitudes and longitudes of about ninety points on the surface of the planet have recently been computed and catalogued, and from these the thirteen points have been selected which have been used in the present investigation. Of the two methods of determining latitudes on Mars, by means of the micrometer and by means of drawings, as has been shown in Reports No. **13** and **18**, there is little to choose in accuracy. The objection to the use of the micrometer however, especially for the present kind of investigation, is because of the large systematic errors which occur in planetary measures made with this instrument when small distances of only a few seconds are involved. These would be most marked when the point observed passed well to the north or south of the center of the disk. These errors as has been already shown in H. A. **32**, 139, may well overbalance the somewhat larger accidental errors that occur in the drawings.

In every case four or more drawings, made on four different nights have been measured, of each of the selected points, at each equinox. At the one solstice observed, eight observations were secured of each point. In order that a drawing may be suitable for this investigation the point should lie on, or within a few degrees of the central meridian, the seeing should be recorded as satisfactory, that is in general as not less than 7, and the diameter of the disk should be as great as 10″. In only two instances was it found necessary to measure a smaller disk. In all 131 drawings have been used in this investigation. On many of them two or more points have been measured. The total number of measured positions recorded in the 208 entries in Table I is 219.

It will be noticed that the name of each station in the table is preceeded by a number which indicates its position in the catalogue, and is followed by the letters N, S, p, f, c, or m, indicating that the point observed was the extreme north, south, preceding, following, center, or middle. The first column gives the date of the drawing, or drawings in case there are two or more of them made on the same night, the second gives the value of $A_\oplus$ taken from the Ephemeris, and the third the latitude of the station as measured from the drawing, cor-

TABLE I.

SELECTED STATIONS.

8 Thymiamata S. f.

Date	$A_{\oplus}$	B	B′	ΔB′
	°	°	°	°
'13 Dec. 2	24.9	—0.4	+2.4	+3.4
'14 Jan. 4	16.7	—3.5	—0.6	+0.4
'14 Jan. 5	16.3	—4.5	—1.6	—0.6
'14 Jan. 6	16.0	—7.1	—4.2	—3.2
Mean		—3.87	—1.00	
'18 Feb. 17	94.1	—3.3	—3.3	+0.2
'18 Mar. 16	84.9	—4.7	—4.2	—0.7
'18 Mar. 22	82.4	—1.8	—1.2	+2.3
'18 Mar. 23	82.0	—4.5	—3.9	—0.4
'18 Mar. 24	81.6	—5.5	—4.9	—1.4
'20 May 10	118.4	—1.7	—2.9	+0.6
'20 May 11	118.2	—2.8	—4.0	—0.5
'20 May 12	117.9	—2.3	—3.5	0.0
Mean		—3.32	—3.49	
'22 June 2	174.6	—1.5	—4.5	—3.1
'22 July 4	166.9	+3.4	+0.5	+1.9
'22 July 6	166.6	+3.7	+0.8	+2.2
'22 July 9	166.3	+0.7	—2.2	—0.8
Mean		+1.58	—1.35	

10 Aromatum S. p.

Date	$A_{\oplus}$	B	B′	ΔB′
	°	°	°	°
'13 Dec. 4	24.7	—2.7	+0.1	—0.4
'14 Jan. 4	16.7	+1.9	+4.8	+4.3
'14 Jan. 5	16.3	—5.2	—2.3	—2.8
'14 Feb. 8	8.3	—3.6	—0.6	—1.1
Mean		—2.40	+0.50	
'18 Feb. 12	95.0	+1.8	+1.7	+3.3
'18 Mar. 16	84.9	—2.3	—1.8	—0.2
'18 Mar. 22	82.4	0.0	+0.6	+2.2
'18 Apr. 21	74.9	—3.0	—2.0	—0.4
'18 Apr. 28	74.9	+2.6	+3.6	+5.2
'20 Mar. 4	132.6	—4.1	—6.0	—4.4
'20 May 6	119.6	—3.4	—4.7	—3.1
'20 May 8	119.0	—2.8	—4.1	—2.5
Mean		—1.40	—1.59	
'22 July 4	166.9	+3.4	+0.5	+1.3
'22 July 6	166.6	+3.6	+0.7	+1.5
'22 Aug. 11	170.0	+0.7	—2.2	—1.4
'22 Sept. 15	184.0	+0.9	—2.1	—1.3
Mean		+2.15	—0.78	

11 Acidalium S.

Date	$A_{\oplus}$	B	B′	ΔB′
	°	°	°	°
'13 Dec. 31	18.1	+40.3	+43.2	—0.8
'14 Jan. 4	16.7	+42.5	+45.4	+1.4
'14 Jan. 5	16.3	+39.5	+42.4	—1.6
'14 Feb. 10	8.2	+41.8	+44.8	+0.8
Mean		+41.02	+43.95	
'18 Feb. 9	95.3	+44.9	+44.8	+2.4
'18 Feb. 12	95.0	+45.9	+45.8	+3.4
'18 Mar. 13	86.2	+39.3	+39.7	—2.7
'18 Mar. 16	84.9	+39.3	+39.8	—2.6
'18 Mar. 22	82.4	+42.0	+42.6	+0.2
'18 Apr. 21	74.9	+41.8	+42.8	+0.4
'18 Apr. 28	74.9	+44.3	+45.3	+2.9
'20 Jun. 21	118.6	+39.8	+38.5	—3.9
Mean		+42.16	+42.41	
'22 May 26	176.1	+47.4	+44.4	+4.8
'22 Jun. 30	167.6	+46.4	+43.5	+3.9
'22 Jul. 4	166.9	+40.3	+37.4	—2.2
'22 Aug. 8	169.2	+35.8	+32.9	—6.7
Mean		+42.48	+39.55	

12 Niliacus S.

Date	$A_{\oplus}$	B	B′	ΔB′
	°	°	°	°
'13 Dec. 2	24.9	+29.9	+32.7	+4.9
'13 Dec. 30	18.5	+21.0	+23.9	—3.9
'13 Dec. 31	18.1	+20.8	+23.7	—4.1
'14 Jan. 5	16.3	+27.9	+30.8	+3.0
Mean		+24.90	+27.78	
'18 Feb. 6	95.5	+26.4	+26.3	—2.2
'18 Feb. 9	95.3	+24.5	+24.4	—4.1
'18 Feb. 12	95.0	+30.2	+30.1	+1.6
'18 Mar. 13	86.2	+27.8	+28.2	—0.3
'18 Mar. 16	84.9	+26.5	+27.0	—1.5
'18 Mar. 22	82.4	+27.2	+27.8	—0.7
'18 Apr. 21	74.9	+27.9	+28.9	+0.4
'18 Apr. 28	74.9	+34.1	+35.1	+6.6
Mean		+28.08	+28.48	
'22 Apr. 29	177.1	+31.4	+28.4	—0.1
'22 May 26	176.1	+34.2	+31.2	+2.7
'22 Jun. 2	174.6	+30.7	+27.7	—0.8
'22 Jun. 30	167.6	+29.4	+26.5	—2.0
Mean		+31.42	+28.45	

TABLE I—*Continued.*

23 Solis c.

Date	$A_\oplus$	B	B′	ΔB′
	°	°	°	°
'13 Dec. 30	18.5	—28.6	—25.7	+0.6
'13 Dec. 31	18.1	—28.4	—25.5	+0.8
'14 Feb. 5	8.5	—29.3	—26.3	0.0
'14 Feb. 7	8.4	—30.8	—27.8	—1.5
Mean		—29.28	—26.32	
'18 Feb. 6	95.5	—22.5	—22.6	—4.0
'18 Feb. 9	95.3	—25.1	—25.2	—1.4
'18 Mar. 13	86.2	—24.9	—24.5	—2.1
'18 Mar. 14	85.8	—28.8	—28.4	+1.8
'18 Apr. 20	75.0	—25.9	—24.9	—1.7
'20 Mar. 27	132.1	—27.7	—29.6	+3.0
'20 May 5	119.9	—27.2	—28.5	+1.9
'20 May 6	119.6	—27.5	—28.8	+2.2
Mean		—26.20	—26.56	
'22 May 25	176.2	—29.1	—32.1	+1.2
'22 Jun. 29	167.8	—26.8	—29.7	—1.2
'22 Jun. 30	167.6	—27.2	—30.1	—0.8
'22 Jul. 1	167.4	—28.6	—31.5	+0.6
Mean		—27.92	—30.85	

41 Titanum N.

Date	$A_\oplus$	B	B′	ΔB′
	°	°	°	°
'13 Dec. 29	18.7	—19.5	—16.6	+1.6
'14 Jan. 21	11.2	—19.0	—16.0	+2.2
'14 Jan. 27	9.8	—23.5	—20.5	—2.3
'14 Feb. 1	9.0	—22.7	—19.7	—1.5
Mean		—21.18	—18.20	
'18 Feb. 1	95.6	—14.7	—14.8	+4.4
'18 Mar. 5	89.3	—15.7	—15.5	+3.7
'18 Mar. 6	89.0	—21.2	—21.0	—1.8
'18 Apr. 8	76.8	—18.8	—17.9	+1.3
'20 Feb. 14	128.8	—17.4	—19.1	+0.1
'20 Apr. 23	124.2	—21.4	—22.9	—3.7
'20 Apr. 28	122.3	—21.6	—23.0	—3.8
'20 Jun. 1	115.6	—18.5	—19.6	—0.4
Mean		—18.66	—19.22	
'22 May 19	177.1	—16.3	—19.3	—2.2
'22 Jun. 17	170.6	—10.8	—13.7	+3.4
'22 Jun. 20	169.8	—13.9	—16.8	+0.3
'22 Jun. 21	169.6	—15.7	—18.6	—1.5
Mean		—14.18	—17.10	

50 Elysium N.

Date	$A_\oplus$	B	B′	ΔB′
	°	°	°	°
'13 Dec. 16	22.7	+33.9	+36.8	+0.6
'13 Dec. 17	22.5	+34.4	+37.3	+1.1
'14 Jan. 18	12.0	+31.9	+34.9	—1.3
'14 Jan. 20	11.5	+32.9	+35.9	—0.3
Mean		+33.28	+36.22	
'18 Mar. 3	90.1	+35.8	+36.0	+1.8
'18 Mar. 5	89.3	+35.4	+35.6	+1.4
'18 Apr. 4	77.8	+31.0	+31.8	—2.4
'18 Apr. 5	77.6	+33.1	+33.9	—0.3
'18 May 9	76.1	+35.7	+36.6	+2.4
'18 May 14	77.1	+31.5	+32.3	—1.9
'20 Apr. 20	125.3	+36.5	+34.9	+0.7
'20 May 29	115.6	+33.3	+32.2	—2.0
Mean		+34.04	+34.16	
'22 Jun. 13	171.7	+39.1	+36.2	—0.3
'22 Jun. 14	171.4	+41.0	+38.1	+1.6
'22 Jul. 21	166.2	+38.1	+35.2	—1.3
'22 Jul. 22	166.3	+39.5	+36.6	+0.1
Mean		+39.42	+36.52	

52 Elysium S.

Date	$A_\oplus$	B	B′	ΔB′
	°	°	°	°
'14 Jan. 18	12.0	+10.9	+13.9	+2.7
'14 Jan. 20	11.5	+ 8.1	+11.1	—0.1
'14 Feb. 24	8.8	+ 8.4	+11.4	+0.2
'14 Feb. 25	9.0	+ 5.5	+ 8.5	—2.7
Mean		+ 8.22	+11.22	
'18 Mar. 1	90.8	+16.8	+16.9	+2.5
'18 Mar. 3	90.1	+14.2	+14.4	0.0
'18 Mar. 5	89.3	+15.3	+15.5	+1.1
'18 Apr. 4	77.8	+14.0	+14.8	+0.4
'18 Apr. 5	77.6	+10.5	+11.3	—3.1
'18 May 9	76.1	+13.1	+14.0	—0.4
'20 Apr. 20	125.3	+17.3	+15.7	+1.3
'20 May 29	115.6	+14.0	+12.9	—1.5
Mean		+14.40	+14.44	
'22 Jun. 13	171.7	+17.3	+14.4	+0.4
'22 Jun. 14	171.4	+17.6	+14.7	+0.7
'22 Jun. 15	171.2	+18.0	+15.1	+1.1
'22 Jul. 21	166.2	+14.5	+11.6	—2.4
Mean		+16.85	+13.95	

TABLE I—*Continued.*

63 Nepenthes m.

Date	$A_\oplus$	B	B′	ΔB′
	°	°	°	°
'13 Dec. 10	24.0	+11.6	+14.4	+2.8
'13 Dec. 12	23.6	+ 6.6	+ 9.4	—2.2
'14 Jan. 15	12.9	+ 8.1	+11.1	—0.5
'14 Jan. 18	12.0	+ 8.6	+11.6	0.0
Mean		+ 8.72	+11.62	
'18 Jan. 22	94.8	+11.8	+11.8	—1.5
'18 Feb. 18	93.9	+12.3	+12.3	—1.0
'18 Feb. 19	93.7	+10.5	+10.5	—2.8
'18 Feb. 27	91.5	+10.7	+10.8	—2.5
'18 Apr. 4	77.8	+14.3	+15.1	+1.8
'18 May 5	75.5	+16.6	+17.5	+4.2
'18 May 9	76.1	+15.6	+16.5	+3.2
'20 May 27	115.6	+12.8	+11.7	—1.6
Mean		+13.08	+13.28	
'22 May 9	177.6	+15.8	+12.8	+0.6
'22 Jun. 13	171.7	+11.3	+ 8.4	—3.8
'22 Jul. 13	166.1	+15.9	+13.0	+0.8
'22 Jul. 17	166.1	+17.6	+14.7	+2.5
Mean		+15.15	+12.22	

74 Syrtis N.

Date	$A_\oplus$	B	B′	ΔB′
	°	°	°	°
'14 Jan. 15	12.9	+23.8	+26.8	+2.4
'14 Jan. 17	12.3	+22.6	+25.6	+1.2
'14 Jan. 18	12.0	+21.7	+24.7	+0.3
'14 Feb. 15	8.2	+17.5	+20.5	—3.9
Mean		+21.40	+24.40	
'18 Feb. 16	94.3	+25.9	+25.9	+0.4
'18 Feb. 18	93.9	+25.8	+25.8	+0.3
'18 Feb. 19	93.7	+23.2	+23.2	—2.3
'18 Feb. 27	91.5	+22.0	+22.1	—3.4
'18 Apr. 3	78.1	+25.9	+26.7	+1.2
'18 Apr. 4	77.8	+29.9	+30.7	+5.2
'18 May 2	75.1	+23.8	+24.8	—0.7
'18 May 5	75.5	+23.6	+24.5	—1.0
Mean		+25.01	+25.46	
'22 Jun. 5	173.8	+26.6	+23.6	—2.6
'22 Jun. 13	171.7	+30.4	+27.5	+1.3
'22 Jul. 13	166.1	+29.4	+26.5	+0.3
'22 Jul. 17	166.1	+30.0	+27.1	+0.9
Mean		+29.10	+26.18	

82 Hammonis S. p.

Date	$A_\oplus$	B	B′	ΔB′
	°	°	°	°
'14 Jan. 6	16.0	—19.7	—16.8	—2.2
'14 Jan. 10	14.6	—16.2	—13.2	+1.4
'14 Jan. 17	12.3	—19.0	—16.0	—1.4
'14 Feb. 12	8.2	—15.3	—12.3	+2.3
Mean		—17.55	—14.58	
'18 Feb. 17	94.1	— 9.9	— 9.9	+2.0
'18 Mar. 21	82.8	—12.4	—11.8	+0.1
'18 Mar. 22	82.4	—15.2	—14.6	—2.7
'18 Apr. 3	78.1	—10.4	— 9.6	+2.3
'18 Apr. 28	74.9	—10.8	— 9.8	+2.1
'20 Mar. 13	133.2	—14.5	—16.4	—4.5
'20 May 15	117.2	—13.0	—14.2	—2.3
'20 May 19	116.4	— 7.4	— 8.6	+3.3
Mean		—11.70	—11.86	
'22 May 3	177.4	— 5.7	— 8.7	+1.1
'22 Jul. 9	166.3	— 8.0	—10.9	—1.1
'22 Jul. 11	166.2	— 8.0	—10.9	—1.1
'22 Aug. 17	171.8	— 5.7	— 8.7	+1.1
Mean		— 6.85	— 9.80	

86 Ismenius c.

Date	$A_\oplus$	B	B′	ΔB′
	°	°	°	°
'14 Jan. 10	14.6	+44.0	+47.0	—1.5
'14 Jan. 11	14.2	+48.2	+51.2	+2.7
'14 Jan. 12	13.9	+46.8	+49.8	+1.3
'14 Feb. 15	8.2	+43.0	+46.0	—2.5
Mean		+45.50	+48.50	
'18 Feb. 17	94.1	+47.3	+47.3	+1.9
'18 Mar. 21	82.8	+42.5	+43.1	—2.3
'18 Mar. 22	82.4	+41.6	+42.2	—3.2
'18 Apr. 3	78.1	+42.7	+43.5	—1.9
'18 Apr. 28	74.9	+47.4	+48.4	+3.0
'18 Jun. 3	83.4	+46.4	+46.9	+1.5
'18 Jun. 9	85.9	+45.5	+45.9	+0.5
'18 Jun. 10	86.4	+45.6	+46.0	+0.6
Mean		+44.88	+45.41	
'22 May 3	177.4	+47.5	+44.5	—0.4
'22 Jun. 4	174.1	+46.9	+43.9	—1.0
'22 Jul. 9	166.3	+49.0	+46.1	+1.2
'22 Jul. 11	166.2	+47.9	+45.0	+0.1
Mean		+47.82	+44.88	

TABLE I—*Continued.*

89 Edom S.

Date	$A_{\oplus}$	B	B′	ΔB′
	°	°	°	°
'14 Jan. 4	16.7	— 8.9	— 6.0	—1.7
'14 Jan. 6	16.0	—10.2	— 7.3	—3.0
'14 Jan. 10	14.6	— 2.9	+ 0.1	+4.4
'14 Feb. 14	8.2	— 7.1	— 4.1	+0.2
Mean		— 7.28	— 4.32	
'18 Feb. 17	94.1	— 4.9	— 4.9	—2.5
'18 Mar. 16	84.9	+ 0.3	+ 0.8	+3.2
'18 Mar. 21	82.8	— 2 9	— 2.3	+0.1
'18 Mar. 22	82.4	— 3.4	— 2.8	—0.4
'18 Mar. 24	81.6	— 6.8	— 6.2	—3.8
'18 Apr. 28	74.9	+ 0 3	+ 1.3	+3.7
'20 Mar. 4	132.6	+ 1.0	— 0.9	+1.5
'20 May 12	117.9	— 3.1	— 4.3	—1.9
Mean		— 2.44	— 2.41	
'22 Apr. 29	177.1	0.0	— 3.0	+0.5
'22 May 3	177.4	— 3.4	— 6.4	—2.9
'22 Jun. 2	174.6	0 0	— 3.0	+0.5
'22 Jul. 9	166.3	+ 1.4	— 1.5	+2.0
Mean		— 0.50	— 3.48	

rected for the latitude of the center of the disk and for the phase when necessary. Means of these latitudes have been taken for each equinox, and for the summer solstice.

TABLE II.

REDUCTION OF OBSERVATIONS.

No.	Station	Vernal	Summer	V cor.	S cor.	S-V	A-S	Sun	Lat.
		°	°	°	°	°	°		°
8	Thymiamata S.	—2.72	—2.17	+0.18	—2.31	—2.49	+2.13	A A	— 1.18
10	Aromatum S. p.	—2.28	—1.28	+0.64	—1.45	—2.09	+0.81	A A	— 0.14
11	Acidalium S.	—0.73	+0.41	+2.20	+0.66	—1.54	—2.86	A W	+41.75
12	Niliacus S.	—3.26	—0.08	—0.34	+0.36	+0.70	—0.02	WW	+28.12
23	Solis c.	—0.68	+2.40	+2.26	+2.02	—0.24	—4.28	A W	—28.58
41	Titanum N.	—3.50	—0.98	—0.55	—1.57	—1.02	+2.12	A A	—17.65
50	Elysium N.	—3.07	—2.31	—0.15	—2.21	—2.06	+2.36	A A	+36.37
52	Elysium S.	—4.32	+1.86	—1.36	+1.86	+3.22	—0.50	WW	+12.58
63	Nepenthes m.	—3 22	+1.14	—0.30	+1.36	+1.66	—1.06	WW	+11.92
74	Syrtis N.	—3.85	—0.24	—0.89	+0.17	+1.06	+0.72	W A	+25.29
82	Hammonis S. p.	—5.35	+0.50	—2.39	+0.33	+2.72	+2.06	W A	—12.19
86	Ismenius c.	—1.16	—1.78	+1.81	—1.28	—3.09	—0.53	A W	+46.69
89	Edom S.	—3.39	+1.45	—0.42	+1.49	+1.91	—1.07	WW	— 3.90
		°	°	°	°				
Algebraic Mean		—2.887	—0.083	+0.053	—0.044				
				°	°				
Arithmetical Mean				±1.04	±1.31				

The difference between the latitudes at the vernal and at the autumnal equinoxes divided by two, with the proper sign attached, gives the latitude at the vernal equinox minus the mean. These numbers are entered in the third column of Table II. The latitude at the summer solstice minus the mean latitude at the two equinoxes is entered in the fourth column. In Figure 3 both ordinates and abscissas represent latitudes, north and south. The intersection of the 0° co-ordinates indicates the mean latitude for each of the points observed. The abscissas taken from the third column of Table II therefore give the deviation in latitude at the vernal equinox in degrees from the mean, and the ordinates taken from the fourth column, the deviation at the summer solstice.

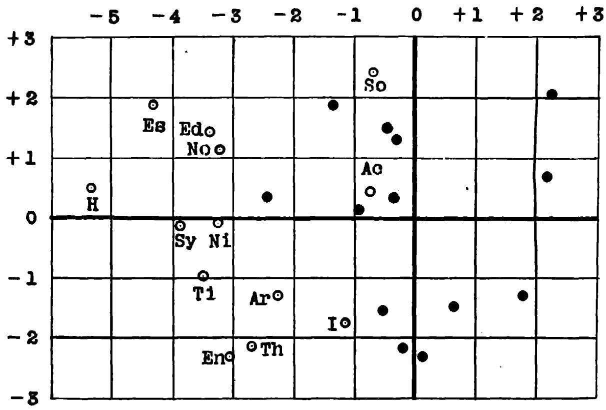

FIGURE 3.

If now any point could be found which was absolutely stationary on the planet, if it were accurately observed, and if the planet's axis were correctly located in space, then both of its co-ordinates would be zero. Since however none of these conditions appears to be fulfilled we shall assume that the mean of the two values at the vernal and autumnal equinoxes gives the true latitude for each point. The observed positions are indicated by the open circles, and the following abbreviations are used: Ac Acidalium S., Ar Aromatum S. p., Ed Edom S., En Elysium N., Es Elysium S., H Hammonis S. p., I Ismenius c., Ne Nepenthes m., Ni Niliacus S., So Solis c., Sy Syrtis N., Th Thymiamata S. f., Ti Titanum N.

It will be noticed in the first place that all of the stations are located to the left of the zero abscissa, indicating that, based on the Ephemeris, the latitude of every one of them appeared to be more southerly at the vernal equinox than at the autumnal. The average distance is about 3° (See third column of Table II). That is to say the difference in latitude of these points between the vernal and autumnal equinoxes averaged about 6°. This may be explained most simply, as we have seen, by supposing that the true north pole of the planet, as shown in Figure 1, is located 3° of a great circle to the left of the pole according to the Ephemeris. The alternative supposition is that all thirteen points moved northerly over the planet's surface between the vernal and autumnal equinoxes an average distance of 218 miles, some more and some less.

We next notice that the mean position of the stations coincides pretty close with the 0° ordinate. This indicates that on the whole, they do not move very far north or south at the summer solstice, and accordingly that the adopted inclination of the planet's axis to the axis of the plane of its orbit 23° 59′ is very nearly correct. We must next recall that while the dates of the drawings that were measured were so selected as to be as near as possible to the dates required by theory, yet they necessarily were not identical with them. Therefore the plots of these points in the figure are approximate, but not quite accurate. In order to render them so, and at the same time to bring their mean positions nearer to the intersection of the zero co-ordinates, we may apply the formula

$$B' = B - C \cos(-A_{\oplus}) + D \sin(-A_{\oplus})$$

where B' is the mean of the latitudes at the two geocentric equinoxial points, B is the observed latitude of the station on each night taken from the third column of Table I, C and D are constants to be determined by successive approximation and $A_{\oplus}$ is the planetocentric right ascension of the earth, measured in the plane of the planet's equator from its vernal equinox, as given in the Ephemeris. The maximum numerical values of the third and fourth terms of the equation will lie at the planet's geocentric vernal equinox and summer solstice, that is to say, at those positions in its orbit where $A_{\oplus}$ equals 0° and 90° Since the algebraic means of the third and fourth columns of Table II are both negative, this necessarily makes the sign of the third term in the equation negative, and the fourth positive. Our equation may, however, more conveniently be written

$$B' = B - C \cos A_{\oplus} - D \sin A_{\oplus} .$$

It is believed that all future latitude determinations based on the present Ephemeris should be corrected by this formula. The numbers in the fourth column of Table I are computed by means of it, and their deviations from their mean value are given in the fifth. In this computation we have made $C = -3°.0$ and $D = -0°.2$. Correcting the resulting positions still further, we find that C should be $-2°.947$ or $-2°\ 57'$, and that D should be $-0°.256$ or $-15'$. Correction C therefore diminishes the accepted tangential angle of position of the pole with regard to the pole of its orbit, while correction D diminishes the radial position, or inclination of the axis to the orbital plane. In other words it increases the inclination of the axis of the planet to the axis of its orbit, changing it from the accepted value 23° 59′ to 24° 14′. It may be noted that the last four determinations of the inclination of the planet's axis, the only ones made since 1830, were by Schiaparelli

24° 42′, Lohse 23° 57′, Cerulli 24° 45′, and Lowell 23° 16′. Their mean value is 24° 10′.

In Figure 3 the blackened circles are plotted from the fifth and sixth columns of Table II, which are derived from the fourth column of Table I by the same process, already described, as was employed in deriving the two previous columns of Table II. These circles may be readily identified, since in each case their abscissas are about 3° greater than those of the corresponding open circles. The difference in their ordinates is the result of the application of the formula. Unlike the open circles, their positions are exact.

On viewing the figure, the question at once arises, having now corrected the results for the error in the location of the axis of the planet, how much of the remaining deviation from the zero co-ordinates is due to proper motions of the stations, both seasonal and from week to week, and how much to accidental errors of the observations themselves. This question can be answered only by two or more independent series of observations, either of drawings and micrometer measures by the same observer, or better still by different observers. It would seem that an investigation of the proper motions, and their classification was a subject that might add materially to our knowledge of the conditions prevailing on the surface of the planet. The probable errors of our observations of the thirteen points are entered in the second, third, and fourth columns of Table III, while the fifth column gives the means of the three preceding ones, and shows that the

TABLE III.

Probable Errors of the Stations

Stations	Vernal °	Summer °	Autumnal °	Mean °	Equinoxes °
8 Thymiamata	±0.93	±0.24	±0.98	±0.72	±0.68
10 Aromatum	1.05	0.85	0.67	0.86	0.62
11 Acidalium	0.56	0.74	2.15	1.15	1.11
12 Niliacus	1.94	0.70	0.68	1.11	1.03
23 Solis	0.35	0.72	0.46	0.51	0.29
41 Titanum	0.93	0.77	0.90	0.87	0.65
50 Elysium N.	0.40	0.52	0.40	0.44	0.28
52 Elysium S.	0.70	0.41	0.56	0.56	0.45
63 Nepenthes	0.67	0.74	0.94	0.78	0.58
74 Syrtis	0.95	0.58	0.62	0.72	0.57
82 Hammonis	0.89	0.77	0.54	0.73	0.52
86 Ismenius	0.98	0.60	0.33	0.64	0.52
89 Edom	1.14	0.68	0.72	0.85	0.67
Mean	±0.88	±0.64	±0.76	±0.76	±0.61

average mean probable error amounts to 0°.76. By it we see that the deviations of the observations of Acidalium and Niliacus are the largest, while those of Elysium North and South and Solis are the smallest recorded. The last column gives the probable error between the two equinoxes. Mean value ±0°.61.

That a seasonal change among the markings occurs, we have had reason to believe before, as has been stated in several previous Reports, sometimes from changes in their shapes, as when Elysium changed from a pentagon to a circle, sometimes from changes of longitude, as when Lowell twice showed that Aryn had not transitted the central meridian at the computed time. He believed however that the cause was due to an error in the period of rotation, and suggested on different occasions two different periods, one shorter and one longer than the accepted value. We now know however, both from his observations and from those of many others, that the difference was due merely to a shift of Aryn across the surface of the planet. These shifts are usually not extensive, seldom much exceeding 150 miles, or the width of a very wide canal. Thus taking extreme cases, between the vernal and autumnal equinoxes, Hammonis, as is indicated by the black dot in Figure 3, moved $2^\circ.39 \times 2$ or 175 miles to the north, while Solis during the same interval moved 166 miles towards the south. The probable error of our measures between the two equinoxes is as we have just seen $0^\circ.61$, which is equivalent to 22.4 miles measured on the surface of the planet. Taking the average diameter of Mars during these observations to have been about 14″, this would give us 300 miles to 1″ at the center of the disk, therefore the probable error of our measures of this motion based on the drawings is $\pm 0''.075$.

The seventh column of Table II is derived by subtracting the quantities given in the fifth column from those given in the sixth, the eighth column by changing the sign of the quantities in the fifth, and subtracting those in the sixth from them. The seventh column therefore gives the change in latitude from the vernal equinox to the summer solstice, and the eighth the change from the solstice to the autumnal equinox. It will now be seen by comparing these columns that the change in the case of Hammonis occurred fairly uniformly throughout the year, while in the case of Solis it did not really begin until after the summer solstice. Too much stress however must not be laid on the distribution of the change by seasons. As noted in Report **25** and elsewhere, it is believed that extensive changes sometimes occur from night to night, changes which in some cases exceed the average seasonal change. (See also observations made by M. G. Fournier at the observatory of M. Jarry-Desloges. Observations des Surfaces Planetaires, **3**, 249.)

One of the most curious changes occurred in that protean body Elysium. From spring to summer its southern border moved 118 miles to the north, while in the same time its northern border moved 76 miles to the south. After the summer solstice these motions were reversed, southern Elysium moving 18 miles southerly, while northern Elysium moved northerly 86 miles in the same time. From spring to summer its meridional diameter therefore decreased by 194 miles, while it enlarged again by 104 miles in the autumn. It will be noted that Elysium now lies wholly in the northern hemisphere. In our last

Report we showed that it changed its shape materially in 1920. Early in October 1922, corresponding to the middle of the Martian November, it had faded and apparently again shrunk. In December of the same year it was not visible at all. It first appeared in 1913 on November 7, corresponding to the middle of the Martian February, diameter of the planet 10″.9. It then extended 0°.5 south of the equator, or some 480 miles south of its mean equinoxial position, and was in contact with the southern maria, which had moved northerly 20° at that time, presumably not by a direct motion, but by a gradual uniform darkening of the intervening desert region. In the Martian October in 1892 it appeared as seen from Arequipa as a small elliptical spot, with a dark center. Although one of the most conspicuous of the northern markings, it was only discovered by Dawes in 1864, and mapped thirteen years later by Proctor. Since it is bounded exclusively by canals, we see how these markings shift over the surface of the planet.

Ismenius is an instance of a shifting lake. It moved 133 miles southerly, chiefly prior to the solstice, carrying with it the two conspicuous canals Protonilus and Deuteronilus, which both lie in an east and west direction. It does not appear therefore that these markings can be bands of vegetation watered by irrigation ditches, as is sometimes supposed. If according to the other theory we imagine that they are merely shower tracks, or perhaps heavy depositions of moisture from fog, the chief objection appears to be that they shift less than we should expect. That they are deposited at night, and every night, if they are deposited at all, and possibly are formed in wide shallow depressed areas as is the case with our fogs, may possibly help to explain their fixity.

But whatever explanation we choose to adopt in this connection is immaterial, the fact appears to be that the canals and other markings do shift about over the surface of the planet to a certain extent. In this respect they resemble the snow caps, but are better situated to locate the axis of the planet, since they cross the disk near its center. Moreover only the northern snow cap, when it is small, during the two and a half to three Martian months about the summer solstice, is really well suited, as we have already seen, for locating the planet's axis. On the other hand we have a dozen dark markings on Mars, suitable for this purpose, most of them visible throughout the whole of the planet's year. We have therefore taken their mean position to locate the axis, regardless of any theory with regard to their origin.

We may mention here however that their apparent shiftings seem to bear some relation to their latitudes, but none to their longitudes. Judged by the fifth and sixth columns of Table II the six stations showing the least motion, arranged in the order of their magnitude, are Niliacus, Syrtis, Nepenthes, Edom, Aromatum, and Titanum. Their mean latitude is 14°. The mean latitude of the seven remaining stations is 26°, thus bearing out the statement made earlier in this paper that stations in high latitudes shifted the most. The four stations last named lie near the equator, and should be suitable for micrometric measurements. Of the nine remaining stations, Solis was the only one that was not always well situated for observation. At the solstice it lay three-quarters way from the center towards the southern limb.

In the ninth column of Table II an *A* indicates that the direction of motion of the marking was opposite to, or against that of the sun, while a *W* indicates that is was with it. Thus prior to the solstice the motion of Acidalium was against the sun, that is southerly while the sun was moving north. Later when the sun turned south the motion of Acidalium was still southerly. Of the twelve largest shifts of position, each exceeding 2°, four were with the sun, and eight against it. The last column gives the mean latitudes of the thirteen stations at the two equinoxes.

Since the probable error of the three series of measures for any given point averages as we have seen $\pm 0^\circ.76$ or $\pm 45'$, for the whole thirteen stations it would average $\pm 13'$ in the location of the axis. Reducing our corrections to right ascension and declination, we find that the pole is situated in

$$\alpha = 20^h\, 58^m\, 06^s + 1^s.56\ (t - 1918)$$
$$\delta = +\, 52^\circ\, 12'\, 50'' + 12''.6\ (t - 1918)\,.$$

Perhaps the most important effect that this changed position of the pole will have on our observations will be to shift the equinox of the planet back 7°.16 on its orbit from 87°.89 to 80°.73. This will increase each Martian Date by 14 days. Longitudes as well as latitudes will be affected, but the longitudes mainly for markings remote from the equator. As has been above suggested, should these measurements be checked at the coming, or at future apparitions of the planet, the micrometer should be used as well as drawings. For the micrometer, objects whose latitude exceeds 15° are of little value at the solstice which brings them nearest to the limb. Besides the thirteen objects used in this paper several others have been tried, but found unsuitable. Of these the best was Oxia Lacus, which would be an excellent object to add to our list but for the fact that near the vernal equinox we found it to be invisible.

In closing, I cannot omit to mention the very valuable and important aid rendered me by my two assistants, Mr. and Mrs. G. H. Hamilton, without whose help it would have been quite impossible to complete the long series of computations which were involved in the preparation of this paper. The former also measured most of my drawings for me.

Mandeville, Jamaica, June 23, 1923.