The photograph is almost self-explanatory. The bearings in the table are tapers of steel in brass. The earth is carefully mounted to avoid friction and will spin for several minutes. The frame holding it can be shifted in its clamps, permitting the effect of any obliquity from zero to ninety degrees to be shown.

The apparatus has now been used for two classes and the results seem to be more satisfactory than anticipated. The darkening of the room, save for the light of the "sun" in the apparatus, creates a dramatic interest that holds the students' attention while the instructor explains zones, climates, the effects of different obliquities upon man, etc., etc. Previously for the majority of students these were poorly visualized and as a result were dull.

There must be many instructors with pieces of demonstration apparatus which would aid the rest of us. Rumor tells me that Harvard, for instance, has many such. Cannot descriptions and photographs of these be published for the benefit of all?

University of Kansas, February 19, 1925.

REPORT ON MARS, NO. 31.

By WILLIAM H. PICKERING.

Formation and Melting of the Polar Caps.

Since the Jamaica Observatory was established in 1912 we have observed the planet Mars through six apparitions with the Draper 11-inch refractor. As this instrument has now been returned to Harvard, at their request, the present seems a suitable occasion to summarize some of our results with it, rather than awaiting the next apparition, when we hope, by means of another telescope, that we shall be able to complete our observations for the whole of the planet's orbit and year.

The seasonal variation in the size of the polar caps, first noted by Sir William Herschel, is the most obvious change occurring upon Mars, and we shall devote a large part of the present Report to a discussion of this phenomenon. We may in general remark that prior to the equinoxes the polar regions of the planet are shrouded in yellowish white cloud, no brighter than that which is frequently seen upon the limb. At about the time that the vernal equinox is reached this cloud rapidly clears away, exposing the dazzling white snows beneath it to our view. The snow cap is then of nearly its maximum size, and after sometimes a light increase, rapidly diminishes with the approach of the summer solstice.

Table I contains our measures of the two caps. These measures are based exclusively upon drawings. This is the only satisfactory method of measuring planetary detail, since micrometer measures of small bright areas always contain a large systematic error, varying from 0″.20 to 0″.30, dependent upon which of the two methods of measurement is adopted. This fact has been determined by means of measures of remote artificial disks (*H. A.* **32**, 133). Only a comparatively few drawings at each apparition were measured, but these were selected as giving characteristic and representative values. The table is divided into sections, each section being headed by the year in which the corresponding opposition took place. Under several of the sections the first line contains the word "cloud." The corresponding entry in

TABLE I.

Melting of the Polar Caps.

NORTHERN CAP

Miles	Mars	Date	⊙	M. D.
		1914		
Cloud	8″.4	'13 Sept. 30	328°.2	Jan. 53
2400	13.1	'13 Nov. 30	359.8	Feb. 55
2000	14.2	'13 Dec. 12	5.6	Mar. 12
1500	14.4	'14 Jan. 15	21.8	Mar. 45
900	12.0	'14 Feb. 8	32.8	Apr. 12
1500	11.6	'14 Feb. 12	34.6	Apr 16
1500	5.0	'14 June 8	85.6	June 17
		1916		
Cloud	5″.3	'15 Aug. 27	332°.9	Feb. 5
2500	5.8	'15 Sept. 22	346.6	Feb. 31
2400	7.2	'15 Nov. 4	8.2	Mar. 17
2000	8.5	'15 Nov. 27	19.2	Mar. 40
1500	10.9	'15 Dec. 25	31.9	Apr. 11
1000	11.3	'16 Mar. 19	69.3	May 37
500	9.6	'16 Apr. 6	77.1	May 55
650	7.8	'16 May 3	89.0	June 25
		1918		
1900	4″.5	'17 Sept. 4	359°.5	Feb. 56
2100	4.8	'17 Sept. 29	12.0	Mar. 23
2000	5.0	'17 Oct. 10	17.1	Mar. 35
1500	7.0	'17 Dec. 11	45.3	Apr. 40
1000	10.8	'18 Feb. 1	68.1	May 34
500	12.6	'18 Feb. 18	75.5	May 51
850	13.5	'18 Mar. 1	80.4	June 6
500	13.8	'18 Mar. 5	82.1	June 10
300	7.2	'18 July 4	138.0	Aug. 15
0	7.0	'18 July 8	140.1	Aug. 19
700	6.9	'18 July 10	141.1	Aug. 21
1400	6.7	'18 July 18	145.1	Aug. 29
1000	6.1	'18 July 20	146.1	Aug. 31
		1920		
1600	4″.5	'19 Oct. 23	42°.7	Apr. 34
1500	5.0	'19 Nov. 19	54.6	May 4
1000	6.2	'19 Dec. 26	70.8	May 40
800	10.7	'20 Feb. 29	98.5	June 45
400	11.1	'20 Mar. 4	101.3	June 51
800	12.4	'20 Mar. 15	105.3	July 6
500	13.0	'20 Mar. 20	108.5	July 11
0	13.3	'20 June 5	145.6	Aug. 30
400	13.2	'20 June 6	146.1	Aug. 31
400	11.8	'20 June 21	153.9	Aug. 45
Cloud	6.2	'20 Oct. 26	228.0	Nov. 2

SOUTHERN CAP

Miles	Mars	Date	⊙	M. D.
		1920		
Cloud	9″.2	'20 Feb. 14	92°.8	June 23
1300	13.2	'20 June 6	146.1	Aug. 31
2000	10.4	'20 July 9	163.5	Sept. 7
1500	8.0	'20 Aug. 24	189.5	Sept. 52
1300	4.6	'21 Jan. 28	287.0	Dec. 39
		1922		
2000	14″.5	'22 Apr. 29	149°.0	Aug. 36
2500	15.1	'22 May 3	151.0	Aug. 40
2800	18.6	'22 May 25	162.6	Sept. 5
2500	19.9	'22 June 5	168.5	Sept. 16
2000	19.5	'22 July 6	186.1	Sept. 46
1500	13.8	'22 Aug. 22	214.2	Oct. 35
2000	11.6	'22 Sept. 14	228.6	Nov. 3
1000	11.5	'22 Sept. 15	229.2	Nov. 4
700	7.0	'22 Dec. 6	280.9	Dec. 29
1600	6.0	'23 Jan. 6	299.6	Jan. 4
		1924		
Cloud	8″.3	'24 Apr. 10	162°.2	Sept. 5
2600	8.6	'24 Apr. 15	164.8	Sept. 9
2900	9.7	'24 Apr. 29	172.6	Sept. 23
2700	10.6	'24 May 10	178.8	Sept. 34
2300	11.1	'24 May 14	181.1	Sept. 38
2000	11.7	'24 May 21	185.1	Sept. 44
2100	18.3	'24 July 5	212.1	Oct. 31
1500	20.8	'24 July 18	220.0	Oct. 45
1000	24.9	'24 Aug. 28	245.7	Nov. 29
500	18.8	'24 Oct. 5	269.7	Dec. 11
250	14.6	'24 Oct. 29	284.6	Dec. 35
400	12.0	'24 Nov. 18	296.7	Dec. 54
150	10.7	'24 Nov. 30	303.8	Jan. 11
300	9.7	'24 Dec. 11	310.2	Jan. 22
Cloud	6.9	'25 Jan. 23	334.1	Feb. 7

the third column indicates the earliest date on which a distinct cloud was recorded at the pole in question. The next line refers to the first date on which snow was clearly visible. The first column in the table then gives the diameter of the polar cap in miles, the second the apparent diameter of the planet, the third the terrestrial date of the observation, the fourth the solar longitude, and the last the corresponding Martian Date.

The results given in this table are represented graphically in Figure 1, where the abscissas give the solar longitudes. That is to say they represent time, 360° to the Martian year. The location of the vernal and autumnal equinoxes, and of the summer and winter solstices for each hemisphere are indicated by their initials at the bottom of the graph. The ordinates give the diameters of the snow caps in miles. When these are very small they may have been cloud in some cases, but the diameters of what was recognized as certainly cloud were not plotted. For this reason each of the two dotted curves extends through only half a Martian year. The numbers indicate the year of the opposition of the full lines, but not necessarily the year in which the observation was made. The dotted lines give what is believed to be a mean result. The left hand curve refers to the northern cap, and the right hand one to the southern. The northern cap reaches its minimum about the middle of the Martian August, and the southern one early in January, as is indicated by the terminations of the two dotted lines.

Both caps may disappear entirely, but in any case they very soon reform, and rapidly increase in size, varying their dimensions and shapes from night to night in a striking maner, such as can only be due to cloud. Sometimes the cloud forms before the cap disappears, in which event the latter never reaches a very small size, although it may later be seen to have vanished. Such was the case in 1914, 1920, and 1922, as indicated in the figure. For several Martian months following the disappearance of the snow, these clouds shift about and sometimes disappear, exposing the polar regions beneath them. Later in the season, after the winter solstice, this clearance apparently always takes place for a few weeks. After that the clouds reform, and the steady deposition of the polar cap begins. This fact proves that the caps are really snow, and not hoar frost, as some observers formerly thought. We thus see that twice a year, about midway between each solstice and the following equinox, both polar regions always become clouded.

This is indicated for the northern hemisphere by the inclined sharply rising dotted line at the extreme left of the figure. Following along towards the right, we note that from the vernal equinox until midway between it and the summer solstice the snow is visible, and the corresponding pole is therefore always clear. It is often clear much longer, in which case as we have said the cap sometimes may disappear, but heavy clouds of rapidly varying size and shape will presently certainly form. These probably originate from moisture evaporated from the northern hemisphere, and condensed by the gradually falling temperature. Our curve stops here, but following along in the figure, through the autumnal equinox of the northern hemisphere, and between it and the winter solstice, clear spells of a few days duration occur. These grow longer and more frequent as the solstice is approached. The polar regions are then bright, and are frequently described as "greenish, brightness 8." This would imply that these regions were as bright as the limb clouds, but differed from them in color. Possibly small green areas, too small to be separately distinguished, are seen between small scattered clouds. As we approach the winter solstice the polar regions for orbital reasons can only be observed under unfavorable circumstances, as will be shown in more detail presently. The clearance after the winter solstice for the same reasons is also never well seen. Heavy clouds derived from the melting of the southern polar cap now appear at the north, and this completes the planet's year for the northern hemisphere, bringing us back to our starting point.

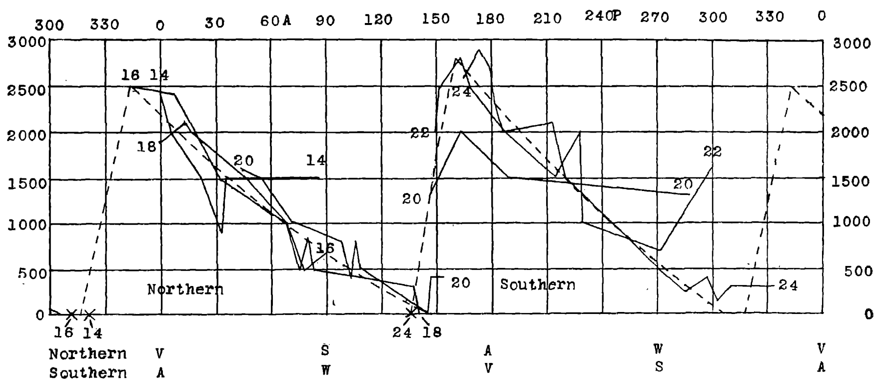

Fig. 1.

The polar regions have much more cloudy weather in the daytime than any other portion of the planet, and it is probable that no daytime precipitation such as rain occurs elsewhere. On the line of the zero ordinate in the figure the three crosses indicate the last date in each of the corresponding years when the pole appeared to be wholly free of both snow and cloud. In 1918 and 1920 the planet was too remote at the proper season to observe the northern pole with regard to this question, and in 1922 and 1924 the northern pole was turned away from us. In 1914 and 1916 the planet was too remote to observe the southern pole, and in 1918 and 1920 this pole was turned away from us. In 1922, which would have been a favorable year for this particular observation, the writer was away from the observatory, and did not get back until the snow had already appeared. The crosses indicate that in these three years the two cloudy spells began just about 180° apart. The northern pole was free from cloud until ⊙ 315°, M. D. January 30, and the southern one until ⊙ 135°, M. D. August 10.

The northern pole thus received its water supply some five weeks earlier in its year than the southern one. At the top of the figure the

A and P indicate the location of the aphelion and perihelion of the planet's orbit. We can thus see one reason why the southern cap melts more quickly than the northern one, and why the moisture for the northern cloud cap therefore arrives somewhat earlier in its winter. The northern cap tends to disappear at about ⊙ 145°, M. D. August 29, and the southern one at ⊙ 305°, M. D. January 13. This indicates that the northern cap has melted ten weeks later in its year than the southern one.

When the planet is near us at opposition we can readily observe it while the two hemispheres are having their spring, summer, and autumn, but the hemisphere having its winter is always turned away from us. It is therefore only when the planet is remote, that these particular winter observatoins can be made. In point of fact when those indicated by the three crosses were secured the planet's diameter was 7″.8, 4″.8, and 6″.0 respectively. With good seeing, however, the observations are not difficult, and it appears evident that no snow is permanently deposited on one pole until all, or nearly all, of that on the other has melted. When both poles are bright at the same time, one or the other of the bright regions is due to cloud. It may be remarked that no region in high latitudes can ever be well seen within one month of its winter solstice. This is partly due to its position at the time with regard to the earth, and partly to the fact that the regions within the polar circles themselves are almost completely shrouded in night during this interval.

It now appears certain that there is no permanent deposit of snow at either pole until well past the winter solstice. This obviously cannot be on account of an assumed high temperature of the polar regions, but simply because there is no moisture there to deposit as snow. Each cap must wait on the melting of the other, and the transference of the moisture across the planet. As a result, we find that the formation of each snow cap under the clouds is very rapid, while its melting is very much slower.

From an examination of the dotted lines we conclude that the northern cap reaches its maximum size at about ⊙ 343°, February 24, after an interval of 28° or 50 Martian days from the time it began to form. Similarly the southern cap reaches its maximum at about ⊙ 160°, September 1, after an interval of 25° or 47 days. The northern cap is believed to be completely melted after an interval of 162°, or 341 Martian days, and the southern one after an interval of 146°, or 235 days, the eccentricity of the orbit accounting for the fact that the number of days is not proportional to the number of degrees. We therefore see by the Figure, not only that the southern cap is larger than the northern one, but that it melts more quickly. Indeed, the northern cap requires nearly half as long again to melt as the southern one, the ratio of the number of days being 1.451. The natural explanation of this fact would be that the northern cap is melting at the time of the aphelion of the planet, and the southern one at the perihelion. This in fact is the explanation that has heretofore been given for the phenomenon. If we express the matter quantitatively however, we shall find that this explanation is wholly inadequate. The mean distance of the sun from the planet when the northern cap is melting is 145 million miles, and its distance when the southern cap melts is 138 million. Squaring these numbers we obtain a ratio of only 1.104. The explanation is undoubtedly correct as far as it goes, but it only explains one-quarter of the observed ratio of the days of melting.

Looking further into the matter, we may assume that all the moisture coming from the northern cap not used for vegetation goes to form the southern one, and *vice versa*. As this moisture is spread out in the form of snow to cover an area 2900 miles in diameter for the southern cap, instead of only 2500 for the northern, it will melt quicker in the ratio of the squares of these numbers. This ratio is 1.346. Combining this with our previous ratio, caused by the difference in distance from the sun, we obtain 1.486, which agrees closely with the ratio of the number of days, 1.451. In other words, if we accept the fact that the southern cap melts in 235 days, we should then naturally expect the northern one to require 349 days, which is in fair agreement with the observed interval of 341 days.

Detailed Observations of the Polar Caps.

Following the description in the Table, we see that in 1913 the northern cloud cap was first clearly distinguished on September 30, diameter of the planet being 8″.4. It may have existed before that, but not before September 13, ⊙ 318°.7, indicated by the cross in the Figure, when the polar regions were last seen to be clear of cloud. The pole itself was not visible, however, since the Martian latitude of the sun was —15°.5. The clouds did not clear away exposing the cap until November 30, when the latter was shown at its maximum diameter for that year of 2400 miles. The corresponding Martian date was February 55, the end of their winter. The diameter of the cap first fell to 2000 miles on the Martian date of March 12, but fluctuated in size until M. D. March 45, much as our own does in the early spring, sometimes exceeding 2000 miles, but dropping on that date to 1500. From then until we ceased observing it on June 8 it continued to vary in size, but did not diminish very greatly (see Figure 1). The explanation of this last seeming anomaly is that the snow was probably covered or replaced by cloud, as we know has occurred at other apparitions. In this case, however, the planet was so remote that it was impossible to distinguish between them. It therefore appears that in this Martian year the northern snow cap, as seen from the earth, never reached a very small size. In nearly all the apparitions the earlier determinations of the size of the cap are a little uncertain, since generally it was necessary to estimate what portion of its extent was cut off by the unilluminated area of the planet next to the terminator.

The apparition of 1916 presented no unusual features. On account of absence from the observatory, the writer was unable to record the disappearance of the snow cap, or its concealment by cloud, whichever happened to occur. The apparition of 1918 was a rather unusually interesting one. Our first drawing was made on September 4, 1917, and it is stated that the cap was white not yellow, and therefore snow not cloud. After a slight increase, the cap gradually diminished in size, submitting to the customary variations, until it reached 500 miles, on the Martian date of May 51. It then appeared surrounded by a fainter whitish ring. This may have been cloud, and has been observed on previous occasions. It apparently presages an enlargement of the cap. The next night the fainter area had shifted to the sunset side of the cap. Bad terrestrial weather followed, and no more observations could be secured for eight days, but on February 27 and March 1 it was seen, as indicated in the Table, that a very considerable enlargement of the cap had occurred. On March 3 it had greatly diminished, and by March 5 had returned to its former size. The faint whitish marking now reappeared, this time on the sunrise side of the cap. The cap then slowly diminished in size, although not with perfect uniformity, until July 4. It was then only 300 miles in diameter, and had not exceeded 600 miles during the previous 17 weeks, a most unusually long period of fairly uniform size. On July 8 it is recorded that it had disappeared, but the seeing was poor, only 5. The next night it was again visible, and now rapidly increased in size as shown by the Table, submitting however to great fluctuations, such as always occur at this season of the year. This was undoubtedly due to clouds and snow storms, such as were observed to better advantage at the next apparition, and have been already described in Reports Nos. **20** and **23**.

In the apparition of 1920 at the time of our earliest observation, the size of the cap was already reduced to 1600 miles. During February, March, and the first part of April we got comparatively few observations, only fifteen nights in all, in large part due to unfavorable weather. On Mars too the weather was bad, as indicated in the Table by the extensive variations in the size of the northern cap. After Martian July 11, however, the weather there settled down, and no further large fluctuations occurred until August 30, when for one night it is recorded "with seeing 9 the northern cap has certainly gone." It may have been missing the two previous nights, when unfavorable weather prevented observations. The next night, however, it was visible of the usual size, and as a conspicuous object. It remained visible until August 45, after which the expected storms enlarged it greatly and irregularly, rendering any observations of position angle impossible. This was on the whole, however, a favorable year for this purpose, although not equal to the apparition of 1918. The clouds now gradually diminished in size, and the last one was seen on terrestrial October 26, as shown in the Table. The north pole which during the whole apparition had been very favorably placed with regard to us was then turned slightly away, and was concealed by the terminator. Our last observation was made on January 28, 1921. The diameter of Mars was then 4″.6, and the northern pole was turned away 24°.5. Just when the clouds returned to this region we therefore have no means of knowing. Owing to absence from the observatory our observations in 1922 did not begin until April 29, ⊙ 149°.0, M. D. August 36, diameter 14″.5. The snow cap had then melted, and extensive clouds covered the northern polar regions. Although the pole was located near the limb, these clouds were not always visible, and sometimes were very small. They were nearly always most marked towards the sunrise side of the disk. They reached their maximum size the latter half of Martian September and the first half of October, and frequently projected beyond both the limb and terminator, as recorded in Report No. 29. When they occasionally cleared away a fresh thin layer of snow could be seen beneath them. That it was snow, not cloud, was proved since on June 30, ⊙ 182°.6, M. D. September 40, two curved canals some 70 miles in width were clearly seen extending northerly from Acidalium for several hundred miles into the cap. Other similar canals were noted in early Martian October. Unlike the cloud cap preceding it, the southern edge of the snow was parallel to the planet's equator. A few days later clouds again covered this region. A couple of months later, in November, these clouds diminished and the snow was found to have disappeared, but in the Martian December the clouds reformed, and probably remained until the vernal equinox. The north pole was then turned away from us, however, so that definite information was unobtainable on this point. The northern cloud cap was frequently seen in 1924, but owing to the unfavorable position of the pole the observations are considered of little value. The inclination will be somewhat more favorable in 1926.

Turning now to the southern polar cap, the extreme southern bright regions Argyre I and II, Dia, Thyle I and II, and Novissima Thyle are believed to be simply temporary clouds. It is often difficult to distinguish between the brighter southern areas and the cloud cap. On November 1, 1913, ⊙ 345°.1, M. D. February 28, the southern cap is described as whitish yellow, and brighter than before. This seems to imply the presence of a cloud cap. Much cloud was evident in the southern hemisphere at the time of the southern autumnal equinox, but five weeks later all cloud had for a few days disappeared. It then reformed and persisted throughout the apparition, being last observed at ⊙ 72°.0, M. D. May 43. In 1915 the cloud cap was observed throughout the Martian March and occasionally later, but as the southern pole was now turned away from us from 15° to 20° the observations were of little value. The same was true throughout 1918 and in the early part of 1920. In the latter apparition the snow appeared on M. D. August 31. Its next appearance, as is shown by the Table, was on September 7, after which it was visible nearly continuously until we ceased observing. Although it was never very large, this is in part accounted for since the pole was turned away from us over 20° at this time. On the other hand it was never very small, and seems to have retained its size for an unusual period, doubtless due to cloud.

In 1922 the cap fluctuated remarkably in size, and these fluctuations were in all cases confirmed by several independent drawings. The disk was clear of cloud on the first night that we drew it, April 29. It then gradually increased in size to a maximum of 2800 miles. This was larger than the northern cap ever attained, and was fully confirmed by other drawings. An error of 100 miles would be unlikely. It slowly decreased to 1500 miles, gradually returned to 2000, and then in a single day, with nearly the same central meridian, dropped to 1000. Several drawings made on different nights both before and after this drop confirmed it, and also indicated that the cap was composed of snow, not cloud. Its diameter remained in the vicinity of 2000 miles for 10 weeks. The smallest size reached was 700 miles. In 1924 the cap attained an even larger size than in 1922, reaching 2900 miles. As in 1922 it remained at about 2000 miles for a considerable period, 7 weeks. It fluctuated somewhat in size in Martian December and reached its smallest diameter in January, being finally concealed by clouds on Martian February 7. Its actual disappearance has never been recorded here. How strikingly it differed in size, at the same season, from its appearance at the end of 1920 and 1922 is clearly shown by the Figure. Our last observation of the planet was on February 1, 1925. The next day the telescope was dismounted, preparatory to being shipped back to Harvard.

The Temperature of Mars.

In our last Report we discussed this matter, based on the radiometric observations made at the Lowell and Mt. Wilson Observatories, and concluded that their results gave minimum rather than true values of the temperature, especially so near the poles and limb, where the heat rays traversed a very considerable thickness of the Martian atmosphere. The Lowell observers stated that the polar regions gave out practically no planetary radiation, while those at Mt. Wilson concluded that the temperature of these regions was about —90° F. They admitted some doubt, however, as to the accuracy of this observation, but stated that the temperature at the limb must be much lower than +10°. The temperature of the center of the disk they placed at about +45°. With a particularly dense atmosphere on Mars, which would prevent any important lowering of the temperature at night, such a difference strikes us as improbable. However, we know exactly the temperature at the edge of the melting snow cap, which regardless of the pressure of the Martian atmosphere is just 32° F.

Had the thermocouple observations at Flagstaff and at Mt. Wilson indicated this temperature for the polar cap, then we should have concluded, as has been already pointed out by Coblentz (Popular Astronomy, 1925, **33**, 370), that Mars possessed an atmosphere of only slight density. The fact that the instrumental record indicates a very low temperature on the other hand shows that there is a very considerable amount of material between us and the cap, sufficient to entirely conceal the temperature of the latter, and to give us instead its own true temperature. We thus have still another argument in favor of a dense atmosphere for this planet. Indeed it is conceivable that we might determine its minimum density by assuming that the temperature at the center of its disk was identical with that on the earth in the same latitude, and comparing this temperature with that indicated by the thermocouple. If the temperature on Mars is higher than that on the earth, as now appears probable, the computed density of its atmosphere should be increased.

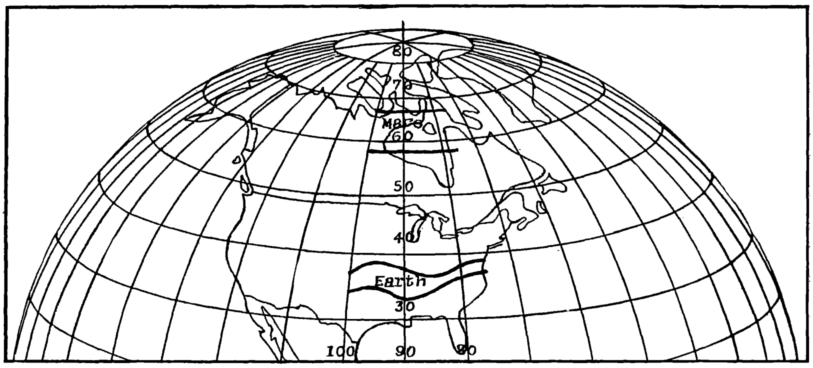

Fig. 2.

Let us now compare the limits of the Martian and terrestrial polar caps. During the winter and early spring months, the Weather Bureau at Washington publishes a chart giving the western and southern limit of snowfall for the United States. We have selected the March and April limits for the five years 1920 to 1924 inclusive, and averaged and plotted them (see Figure 2). The line below the word earth gives the average March limit, and the line above it that for April. It is regrettable that the authorities do not give the May limit, which would surely most of it lie within the boundaries of the United States. We have not carried the lines west of the 100° meridian, which crosses the middle of the Dakotas and Texas, because there the Rocky Mountains carry it far to the south, while the Pacific Coast carries it very far north. Only a small portion of the region east of 100° lies at a greater elevation than 2000 feet, and half of it at less than 1000.

On Mars we do not usually see the northern snow cap before the first of the Martian March, because it is covered by clouds. We have therefore plotted the limits of its polar cap for March and April only upon our map. This we have done by means of the two lines below and above the name of the planet. Owing in part to the fact that its atmosphere is much more extensive than ours, and in part to its smaller snow cap, we see that its climate in a latitude which on the earth would correspond to that of the northern part of Hudson's Bay, in the spring months of its year is identical in temperature with what we possess at the same season in southern Missouri and Kentucky. Those latitudes upon Mars must be very much warmer still, perhaps not tropical, but certainly not moist. In the eastern hemisphere the two corresponding latitudes are those of the Faroe Islands, half way between Scotland and Iceland and the northern part of Africa. In general we may say that the climate on Mars as we travel from its equator towards the poles must be much more uniform than it is upon the earth. This is further indicated by the bright greens visible in its polar regions during the late autumn months. With a dense protecting atmosphere, even the long arctic night may not be at all unbearable on Mars, and is doubtless distinctly less cold than our own. On the earth the most intelligent portion of the human race lives for a considerable portion of the year well within the limits of the polar cap. Could we be transported to Mars we should probably find the whole of its surface habitable,—a much larger area than is comfortably so upon the earth. In the course of 30 days our snow line retreats on the average about 3°.5 of latitude, or 245 miles. In the 56 days of a Martian month, its snow line at this season retreats 9° of latitude, or 330 miles. For the earth the mean rate is 8 miles per day, for Mars 6 miles. This latter figure is higher than we should expect, based solely on the relative distances of the two planets from the sun.

Habitability for Animal Life.

As this paper was just about to be completed most interesting news was received from our California friends. Some of the earlier spectroscopists thought that they detected the lines of water vapor in the atmosphere of Mars. Lowell with more powerful apparatus confirmed this. Campbell from the summit of Mt. Whitney, altitude 14,800 feet, while not denying their existence, stated that the vapor could not exceed in amount one-quarter of what he found in that portion of our atmosphere that was above him. His observations were made unfortunately in what was the dry season of the planet's year. Now Drs. Adams and St. John, with their 60-inch mirror, find definitely that water vapor exists in the atmosphere of Mars, and is of the order of 5 percent of that found normally in the earth's atmosphere (*Pub. Astron. Society Pacific,* 1925, **37**, 158). To compare it with the water vapor found over our deserts, we should perhaps multiply this figure by 4 or 5. Their observation was made on February 2, 1925. The southern hemisphere of the planet was then turned towards us, the central latitude being —21°.9. The solar longitude ⊙ was 338°.9. Turning now to Figure 1, we see that at this time clouds were heavily condensing to form the northern polar cap, and therefore that nearly all the moisture had left the southern hemisphere. That such was the case is not unfortunate, however, in fact it is distinctly the reverse, since we have now gotten a positive result. It appears that even at their driest season there is a very appreciable percentage of water in the Martian atmosphere.

This result is distinctly important, though of course we all knew before that Mars is a much drier planet than the earth. If we assume that the polar cap averages a depth of thirty feet of snow, which is certainly as much as could be melted by the sun's heat in a Martian half-year, and that this snow would supply the water for a lake of that size some three feet in depth, then the total amount of water available for natural irrigation, transported back and forth every year across the planet's surface, would be about as much as that contained in our system of Great Lakes. Compared with the water contained in even our smallest ocean, this amount is absolutely negligible.

But the most interesting result that the Mt. Wilson observers have achieved is yet to be mentioned. They have actually detected free oxygen in the Martian atmosphere, to the extent of 15 percent of that found in our own. We had no reason to doubt previously that oxygen existed on Mars, and in the form of iron oxide caused the red color of its soil, but we have had no distinct proof heretofore, other than the presence of vegetation, that oxygen existed in a free state in its atmosphere. According to all our terrestrial experience vegetation not only produces, but for its very existence demands the presence of free oxygen in the atmosphere, so that in that sense the discovery was only what we anticipated, but as a definite corroboration of our previous conclusions, it lays a firm foundation for our next step in advance. This discovery and proof is obviously of the very first importance therefore in connection with the belief that animal life is also present on the planet.

In the recent attempt to climb Mt. Everest it was found that Alpine explorers could climb, without compressed oxygen, to a height of 5.33 miles, and then walk for a couple of hours on a level, and return in safety. The amount of oxygen which they had there was only 35 percent of what we have at sea level. It is therefore clear that animal life, which had developed increased lung capacity, may readily exist on Mars. Indeed if the atmospheric pressure at the Martian surface is greater than with us, thus condensing the oxygen, as the results described in our last Report indicate, then very little modification of their physical structure, as compared with our own animal life, would seem to be necessary. A possibility therefore exists that even human life if transported to Mars might exist, and perhaps flourish there. It would appear that the years 1924 and 1925 have brought us a good deal of interesting information, confirming very satisfactorily our previous beliefs as to the habitability, and existence of animal life of some sort on our next neighbor in space.

Private Observatory,
Mandeville, Jamaica, B. W. I., August 26, 1925.