MONTHLY REPORT ON MARS.—No.2.

WILLIAM H. PICKERING.

On looking over some of his early drawings of Mars, made at Cambridge in 1890, the writer was gratified to find a few that clearly show some of the canals. These drawings were made shortly after the autumnal equinox of Mars, under conditions precisely similar to those obtaining at the present opposition, excepting that they are for the southern instead of the northern hemisphere. Some of the canals represented in these drawings were dark and very broad, which accounts for their visibility, at Cambridge. They should readily have been visible with seeing 6. Therefore observers in our eastern states should not be discouraged from looking for the canals at the present time, and it is possible that by careful watching they may see a few of them. Under favorable circumstances they may be seen with a 5-inch aperture.

In our last report we noted that the northern polar cap was gradually increasing in size as the winter progressed, exactly as it does upon the earth. By October 30, the beginning of the Martian spring, it had reached as far south as latitude 52°, corresponding to the latitude of England and of southern Labrador. Two nights later a considerable further increase occurred, large areas having been "snowed under," and it was found now to extend to latitude 42°. This proved to be its southern limit and maximum size, the corresponding equivalent terrestrial date being March 5.

It will thus be seen that the polar caps of Mars are less extensive than those of the earth. This does not necessarily imply a warm climate. It may be due entirely, to what we know to be the fact, that there is less water upon Mars. If there is less water, the snow caps would be thinner, and therefore more quickly melted during the daytime. This last addition to the snow cap may in fact have been a very thin layer,—just enough to cover the ground. Now oddly enough, we have some evidence to indicate that this was really the case although usually we do not attempt to gauge the snow fall of our neighbour.

Since the northern pole of the planet was inclined towards the earth at an angle of 9°, the observed outline of the snow cap was usually seen to be convex, but this night in spite of its greater size, the boundary line went straight across the disk till it reached the sunset terminator, the remainder of its course being hidden from view. Now the only possible explanation of this fact is that, along the central meridian

of the planet the edge of the snow cap was nearer to the pole than it was at the limb, that is it was nearer the pole at noon than at sunrise, in other words it was rapidly melting.

Unfortunately this explanation did not occur to the writer at the time, so that the next observation was not made until six days later, November 7, when the cap had retreated to latitude 59°. The mere fact of the retreat of the cap in six days through 17° of latitude, about 100 miles a day, is sufficient in itself to show that it could have been of very little depth, but however thin we assume it to have been, the amount of water liberated must have been enormous. The area uncovered was a trifle over five million square miles, or more than once and a half the area of the United States.

By November 26 the snow cap was materially reduced in size, its boundary being in a mean latitude of 67°. It had increased somewhat by November 28, reaching latitude 61°, but the whole disk was reported as hazy. A still further increase in size occurred by November 30, to latitude 56°, and the snow was now recorded as quite free from cloud. Again the boundary of the snow stretched straight across the disk from the limb, but this time it was seen to curve northerly as the terminator was approached. That is the boundary was nearer the pole at sunset than at sunrise. Another increase in the snow cap December 8, accompanied by the same phenomenon made it clear that a causal connection existed between the two, that we were really seeing the snow melt on Mars in the course of a few hours, and that the snow cap was really very thin at its advancing edge. This is of course what we should expect, but it is of interest as having been found without being directly looked for. At the end of the period considered in this Report, December 16, the boundary of the snow has receded to latitude 70°, the latitude of northern Alaska and of the north cape in the case of the earth. The equivalent terrestrial date is March 27. As the edge of the snow was usually sharp, although sometimes indented, as we shall later describe, it is probable that the precipitation occurs mainly at night.

The clouds along the limb continued to be a prominent feature during this period, though perhaps less so towards its close. They were sometimes irregularly distributed, but more often stretched in a band of gradually decreasing breadth from the south pole to a little beyond the equator, the north temperate and northern torrid zones showing the greatest number of clear mornings. On December 2 a belt of cloud stretching from pole to pole along the limb, reached 0.3 way across the disk towards the terminator, obliterating everything but the very strongest contrasts beneath it. Two days later a considerable increase in the size of the polar cap occurred, which increase continued for four days longer.

During the whole of this period there was a clearly shown southern cap, usually much larger than the northern one, and of constantly varying size and shape. Although often nearly as brilliant as that at the north, it was not white, but yellow, and towards the end of the period light green. Just when the change of color occurred is not recorded, and it was probably gradual. On December 4, the cap was painted in a drawing made at the time as bright yellow, while on December 12 it was painted light green. The green is possibly due to vegetation seen between passing clouds.

We are now at a very interesting period of the planet's year. When the snow was first detected at the north pole it was not bounded by a dark band, but this soon after developed, and increased rapidly in intensity. The band was by no means uniform in breadth however. On November 17 it increased fully 900 miles in width at the terminator, and not over fifty at the limb. It was moreover concentrated in four knots. The first of these appeared at the northern end of Amenthes on September 30 in longitude 240°, later shifting with the retreat of the snow to longitude 270°. At the next presentation on November 7 it had greatly increased in both size and density, stretching as far south as latitude 30°. It was the darkest area visible upon the disk, and was colorless, simply a dark grey, with no trace of green. At its southern end it was now joined by the two canals Eunostos and Amenthes, each about 250 miles in breadth and very dense. At the next presentation, December 10 to 15, Eunostos had disappeared, and was replaced by Hephaestus, which however was extremely faint. But the interesting feature of this presentation was that the dark area near the snow began showing a faintly bluish tint on December 10, which two days later was clearly marked, and continued so, as long as it was visible. Water had now clearly appeared in the liquid form, and was reflecting the light of the Martian skies.

The second dark spot to appear on the grey border of the northern snow cap was the Acidalium Mare, in longitude 35°, and was a much larger and more interesting object than its predecessor. When first detected, October 30, it was not very dark, indeed less so than the Sinus Sabaeus north preceding it, but the grey southern border of the snow cap was now of extraordinary breadth, fully 900 miles, reaching from one-third to one-half way across to the southern *maria* between Sabaeus and Aurorae Sinus, Straight across the intervening bright regions lying between the northern and southern dark areas stretched a faint broad grey band, as if the southern *maria* were being fed directly from the northern snows.

We have all of us watched a distant thunder cloud, with the rain falling from it in a dark uniform sheet. The appearance of this band

was just like the rain, if we can imagine the grey border of the snow cap sending the water due south a thousand miles to irrigate the southern *maria*. The preceding edge of the band lay nearly in the center of the disk, and was oriented precisely north and south as nearly as I could determine it. It seemed to be a development of the straight narrow band observed September 17, and recorded in the first Report. At the next presentation in November the band had swung around pointing to the southeast until it crossed the equator, when it turned and pointed southwesterly. East and west are here used in the astronomical sense, the reverse of their terrestrial meaning. This is precisely what it should have done if it were an atmospheric phenomenon controlled by the influences that affect our trade winds. Possibly its darkness was due to vegetation developed in a desert region by the current of moist air arising from the Acidalium Mare, and flowing across the equator to the southern *maria*.

It should be noted that neither the two bays at the following end of Sabaeus nor the Margaritifier Sinus had yet appeared. The coast line between 0° and 60° was nearly a straight line, and probably coincided pretty closely with the equator, or perhaps even a little north of it, but at the next presentation in November it had already receded southerly, and soon began to present its characteristic features. At our first view November 26, the broad border to the snow cap had entirely disappeared for half its length between Acidalium and the limb. Acidalium itself was well seen however, and appeared about as it did in October, except that it was darker. Its length north and south was 350 miles. From it proceeded two very faint curved canals. One of these reached Aurorae Sinus, and the other was headed towards Margaritifer, but only reached two-thirds way. These canals were seen November 30, and both were then complete. A third broad one extended from the forked bay of Sabaeus, which had now begun to develop, half way across to the northern dark regions surrounding the snow cap. These three canals were not seen clearly again, though the one leading to Margaritifer was suspected December 3. No trace of the broad band, other than the two canals, was found November 26, perhaps because it was too near the limb, but it appeared again two days later, reaching little more than half way to Margaritifer and following now the course of Nilokeras. Its breadth was about 700 miles December 1 and it bent sharply in the preceding direction, following the Ganges, advancing to within 250 miles of Aurorae, which it reached on the following day. December 10 there was evidence of the re-formation of the band between Acidalium and Sabaeus, but perhaps the most interesting changes in this region took place in Acidalium itself.

As we have seen, the dark portion of it November 26 was 350 miles in length. Two days later it measured about 500 miles north and south, while November 30 its outline was sharply defined and its length just 1000 miles. In the last two days Sabaeus and Margaritifer had also developed. The former appeared as a semicircular knob, the point of Aryn between the two bays having not yet appeared. Margaritifer, which could hardly be detected November 26, two days later was readily seen as a flattened angle. December 1 it presented its usual form, except that it was still rather short, about 350 miles, but rapidly increased in length. December 2 it measured 600 miles, and December 4, 750. The mean rate of growth was 4 miles an hour. The bay in Sabaeus grew at about the same rate, and both it and Margaritifer advanced towards the north. The former was much the darker of the two. November 28 Acidalium was of a dull grey color, but two days later it was distinctly bluish as compared to Sabaeus, which was nearly equally dark. The blue continued to increase in intensity, until December 4, when it was very striking. Judged by the experience of former years the blue will not last for more than a month or two, when it will be again replaced by grey, or a chocolate brown. Generally the dark areas are bluest nearest the ice. Polariscope tests made in 1892 and 1894 showed that the blue areas were the only ones on the planet reflecting polarized light. This we attributed at the time to a shiny surface reflecting the Martian atmosphere. It is expected that later both Sabaeus and the northern portion of the Syrtis Major will turn blue, but at present they are merely of a dull uniform grey color, quite different from Acidalium.

The first appearance of the third and fourth dark regions was rather sensational. A slight darkening was noted on the terminator November 17, which was seen again December 13, but was not visible two days later. The next night however, December 16, a sharply defined triangular bay of the shape and size of Margaritifer was conspicuously visible in longitude 185°. The following night to my surprise another bay exactly like it appeared, in longitude 160°. These two bays were about 700 miles in length, and half as wide at their northern ends. Their southern ends at first were pointed but later became more rounded, and a narrow strip of cloud crossed the following one December 19, dividing it in two parts. Later cloud veiled the whole of it for a few days making it appreciably fainter than its companion. Both exhibited a bluish tint at times.

Judged by the drawings made prior to December 16 and 17, it does not appear likely that these bays existed in their present form prior to these dates. The writer has written to certain European astronomers however, who, owing to their different longitude, should be able to

answer this question definitely. The bays occupied a position just north of Propontis, and it is thought that the shading has never before been observed in this particular and striking form.

The outline of the snow cap was not always circular but was at times indented in three different places, in longitudes 185°, 35°, and 260°, corresponding to the positions of three of the four dark bays. These indentations were usually noted when the cap was diminishing in size, the snow melting faster where the water was found. The first of them was first noted October 12 as a slight indentation, which was not very conspicuous. The second was clearly marked on October 30, but was not noticed when it next appeared November 26 and 28, but at the time of the great expansion of the Acidalium, November 30, it reappeared as a slight notch, by no means as marked as before. The northerly end of the notch had changed but little since the previous month, but the sides had melted away, the polar cap having receded 4° of latitude in the meantime, thus reducing the depth. The polar cap continued to recede on December 1, 2, 3, and 4, and the notch was entirely eliminated on the first two days, but reappeared deeply cut December 3, owing perhaps to a warm spell of weather. On December 4 it had again disappeared, but it was recorded, and painted, as an unusual feature, that on December 1, 2 and 4 the portion of the snow just north of water differed from the rest, being of a light blue color. That was the last we saw of it for several days; the notch had apparently filled up by freezing, and we were looking at the fresh ice at a very low angle, and not at snow. This is the most sharply marked change of temperature, if our explanation is correct, of which we have secured any evidence. A warm spell December 3, followed by a cold wave the next day. It is not to be expected that any relation should be found between Martian and terrestrial temperatures, but by a curious coincidence December 4 was the coldest night we have had for nearly two years, our minimum thermometer dropping to 57°.

The region was again seen December 10. The ice had melted, and the notch was now deeper than ever, in fact it nearly if not quite reached the limb, dividing the polar cap into two unequal parts, by a narrow channel about 100 miles in width. It was with interest that we waited until the gradual rotation of the planet should in a few days show us where the other end of the channel came out. We did not have to wait long. On December 15, on the side of the snow cap towards the terminator, a narrow black line appeared, one hundred miles in width, dividing the cap in two, and pointing directly across to where the other end had been last seen. On plotting the two observations in polar projection it was found that the channel was not quite straight, but curved around the pole towards longitude 120°, the two ends being

situated at 35° and 185°, or nearly on opposite sides of the pole. The channel practically followed the course of Lowell's canal Hypanis. This would seem to imply that the canal occupied a depressed area.

But a curious thing now happened: the next night the channel had entirely closed up, and extending south from the polar cap in the same longitude, 185°, we found the long triangular sea, already described as number 3. One might almost think that water had crossed the polar cap from the Acidalium Mare through this relatively narrow channel (its length was a trifle over 2000 miles,) and had come out and formed this new bay. The writer is not prepared to say that this is what really occurred, because the transportation of large quantities of water through a comparatively, if not absolutely, level channel, through such an enormous distance, presents almost insuperable difficulties, whether we attribute the ultimate source of energy to natural or artificial sources.

It is of no use however to keep on accumulating isolated facts without any explanation whatever. It seems to the writer that by far the best plan is to try and piece together what has been learned, according to some form of hypothesis. Whether this ultimately proves to be correct, or not, at all events our facts will be strung together according to some orderly system, where later they can be found when wanted.

We have already seen that under the warm spring sun the Martian polar cap melts so fast, that we can see the change occurring in the course of a few hours. We have also seen that, after an interval of six days, its boundary had retreated northwards a distance of some six hundred miles. Both of these facts indicate that the ice is thin. In our next report we hope to present in either tabular or graphical form a representation of our measures of the size of the ice cap. This will show that on several occasions for nearly a week at a time it has retreated northwards at a nearly uniform rate. This would imply that it is not mere hoarfrost, which would all melt at once, but a layer of snow of appreciable and gradually increasing thickness. That is we are dealing with actual snow storms on Mars.

Now as far as the water is concerned, let us take the largest body observed, the Acidalium Mare. On November 28 its meridional length was 500 miles; two days later it measured 1000. Its mean breadth was 700 miles, not including the narrow strip bordering the ice. At the same time that it increased in length, the polar cap was advancing, from latitude 61° on the 28th to 56° on the 30th, making the increase in length about 200 miles more. Neglecting this latter feature however for the moment, we find that we have a body of water measuring 500 by 700 miles deposited in some manner where two days before no water was visible. Admitting that it was water, which its shiny surface

and blue color can hardly leave open to question, it is reasonably certain that it could not have been very deep. The most plausible hypothesis would seem to be that we have here a marsh, whose great size confirms our views obtained from other sources, that the surface of Mars is extremely level as compared with that of either the earth or moon. Our largest terrestrial marsh lies along the Amazon valley for perhaps a thousand miles. During the rainy season an area several hundred miles in breadth is flooded to the depth of several feet.

This area on Mars is very dark, with a moderate amount of blue,—just enough to enable one to be sure of its existence when compared with the color of other portions of the planet. The appearance, it is thought, might be produced by a moist level plain full of little pools of water, reflecting the Martian sky. A slight depth of water only would therefore be required, which might be produced by an exceptionally heavy rainfall, occurring at night. The fact that the polar cap was increasing in size at the same time that the water appeared supports this explanation. So again we have evidence of heavy clouds and storms upon Mars, and not a mere deposition of frost or dew. Heavy snow and rainstorms almost necessarily imply an atmosphere of considerable density.

With regard to the canal crossing the polar cap, the simplest explanation of its closing up is that it froze over. The three other marshes it is thought were flooded in a similar manner. When we consider the vast amounts of water transported across the surface of our own planet by our ordinary cyclonic winter storms, it seems much easier to believe that something similar occurs upon Mars during the night time, when we know it to be much more cloudy than by day, than to believe that the distribution of its water supply is maintained by an enormous system of irrigation canals, the motive power for which is supplied either by natural or artificial means.

It is recorded that no green was visible upon the disk either November 1 or 7, although from previous observations it was expected to appear soon after the snow cap began to melt. But November 17 the whole of the southern *maria* appeared of a distinct greyish green tint, quite unlike the northern shaded regions, which were as dark, and in places nearly as wide. They were simply dull grey, but the green at the south was recorded as unmistakable. The equivalent terrestrial date was March 13. Since then portions of the southern *maria* have been constantly recorded as green or greenish, but no green has yet been observed north of the equator, which is rather surprising since it is from there that all the water comes.

In Lowell's brilliant paper on "The Cartouches of Mars" published in Bulletin No. 12 of his observatory, he states that the canals in successive latitudes develop one after another as the water reaches them from the melting of the polar caps, that after crossing the equator the water continues on towards the other pole, developing canals as it goes. He finds that the water requires 52 days to descend from latitude 72° to 0°, or at the rate of 2.1 miles per hour.

If we consider the appearance of the green color in the *maria* as the bursting forth of vegetation on the first receipt of water from the melting snows, we find that the first green in the southern hemisphere developed 15 days after the northern snow cap had reached its maximum size, and 14 days before the northern vernal equinox of the planet.

On November 7, 17, and 28 the southern portions of the southern *maria* were shown as distinctly darker than the northern portions,—a most unusual appearance, possibly due to thin cloud along the northern border. Immediately afterwards the northern border began to develop its characteristic detail and outlines, as previously described. This practically coincided with the northern vernal equinox.

Other material which would naturally appear in this Report will be deferred to the next, as the present paper is already longer than was originally intended. In computing the accompanying table of Data the writer has concluded to abandon the use of the Heliocentric Longitude of Mars, and instead to substitute the Planetocentric Longitude of the Sun ⊙, since the latter quantity is based on the same fundamental elements that are used in computing the remainder of the Physical Ephemeris of the planet. When Mars reaches ⊙ = 0°.0 the equivalent terrestrial date will be designated as March 20, and the Martian orbit will be divided into 365 equal angular divisions, the date increasing directly in proportion to ⊙.

Another change which experience has suggested is in the relocation of the six reference sections upon the planet's surface. It was at first proposed that each section should be 60° in width, the central meridian of the first section lying in longitude 0°. It was found however that with this arrangement all the more striking features of the planet would present themselves near the limb, and would therefore not be seen to advantage. To remedy this defect the central meridian of the first section has been changed to longitude 40°. The other central meridians are consequently 100°, 160°, 220°, 280°, and 340°. This causes all of the prominent features of the planet to be well seen. An endeavor will be made to have future drawings constructed with one or the other of these meridians nearly central.

TABLE OF DATA.

No.	1913	⊙ °	T. D.	Long. °	Lat. °	Sun °	Diam. ″	Seeing
12	Nov. 1	345.2	Mar. 5	306	+ 9	—6	10.5	8
13	7	348.3	8	242	+10	—5	10.9	9
14	17	353.3	13	187	"	—3	11.9	6
15	26	357.8	17	51	"	—1	12.7	4
16	28	358.8	18	55	"	"	12.9	4
17	30	359.8	19	0	"	0	13.1	8
18	Dec. 1	0.3	20	42	"	"	13.2	9
19	"	"	"	60	"	"	"	7
20	2	0.8	"	4	"	"	13.3	4
21	"	"	"	29	"	"	"	"
22	3	1.3	21	346	"	+1	13.4	8-7
23	"	"	"	27	"	"	"	6
24	4	1.8	"	40	+9	"	13.5	12-11
25	"	"	"	49	"	"	"	—
26	8	3.7	23	306	"	+2	13.9	4
27	10	4.7	24	273	"	"	14.0	8
28	"	"	"	352	"	"	"	10
29	"	"	"	1	"	"	"	8
30	12	5.7	25	252	"	"	14.2	8
31	13	6.2	26	221	+8	"	14.3	6
32	"	"	"	237	"	"	"	"
33	15	7.1	27	227	"	+3	14.4	10
34	16	7.6	"	192	"	"	14.5	8-6
35	"	"	"	224	"	"	"	—

It may be mentioned in this connection that the writer has opened correspondence with a number of observers in different longitudes around the world, and it is hoped by this means to be able to secure information about any particular detail upon Mars, after, owing to planetary rotation, it has turned so as to be no longer visible in the writer's own longitude. It is also hoped to be able to reciprocate in kind, and to furnish information to others desiring it about any formation that may have passed beyond the range of their vision. It is thought that the Table of Data published with these reports, besides being useful to those readers interested in studying the precise conditions on the planet, when any particular change was noted, with reference to use at future oppositions, will also be useful to others in other longitudes. By examining them they will be able to see exactly on what dates any formation in which they may be interested, was observed by the writer, and thus whether he can give them any desired information about it.