REPORT ON MARS.—No. 7.

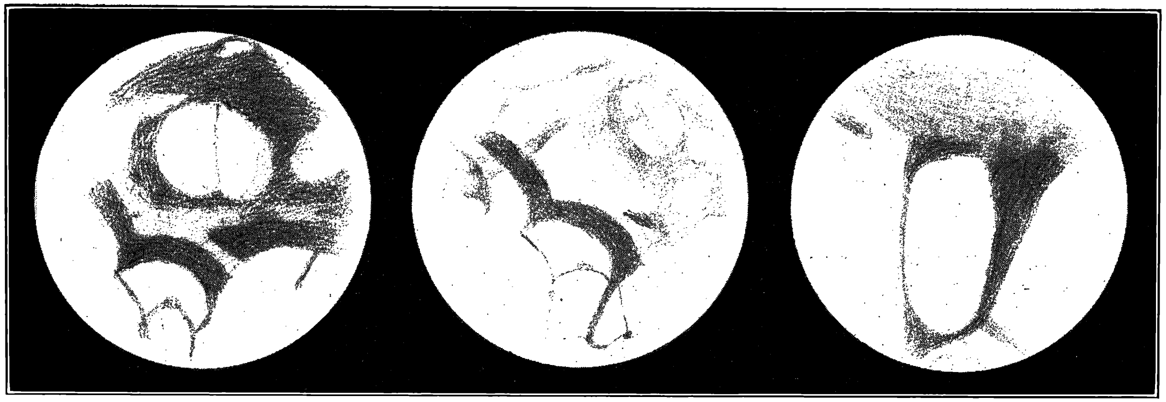
WILLIAM H. PICKERING.

Ever since the writer first observed the canals of Mars in 1890, he has felt the need of some method of accurately measuring their breadth and darkness. The filar micrometer is of no use at all. First, because the mere superposition of the threads upon the surface of the planet causes all fine detail in their vicinity immediately to disappear, and secondly because the breadth of the finest spider web as compared to that of a martian or lunar canal is, to use a homely comparison, as a broomstick to a telegraph wire. The only method of measurement that has hitherto given results that are at all satisfactory consists in making careful drawings of the canals which can later themselves be measured. This plan however, while more or less successful with canals over one hundred miles in width, gives very unsatisfactory results with canals that are narrower. Indeed the results are little better than guesswork, based on estimates of relative visibility.

A simple plan lately occurred to the writer which has proved very successful in the case of the moon, but which was devised so recently that only one comparison with the Martian markings was possible before the planet retired beyond the range of practical observation. It consists simply in attaching to the side of the telescope near the object glass, and at right angles to its axis a paper scale, with canals of varying width drawn upon it. These are illuminated by a 5 c.p. tungsten light placed close to them, but screened from the eye of the observer. The observer himself simply looks alternately at the canal and at the scale, until he has made up his mind which division of the latter the canal most nearly matches.

The scale consists of six canals 30mm in length by 1, 2, 4, 6, 8, and 10mm in breadth, drawn with a No. 4 or H pencil. It is placed at a distance of 4.80 meters from the observer, so that with a magnification of 430 times, a breadth of 1mm corresponds to exactly $0''.1$. One can readily interpolate to quarters of a division, for the wider canals, or to $0''.05$. When Mars is at its nearest, this latter distance would correspond to nine miles (15 km), and it seems as if we should be able to measure the width of the canals, when well seen, by this means to that degree of accuracy with reasonable certainty. Measures made with different eye-pieces give independent results, which may later be compared. The lamp is placed 6.5 inches (16 cm.) from the scale, and with our 11-inch objective it is found that the brightness of the latter is

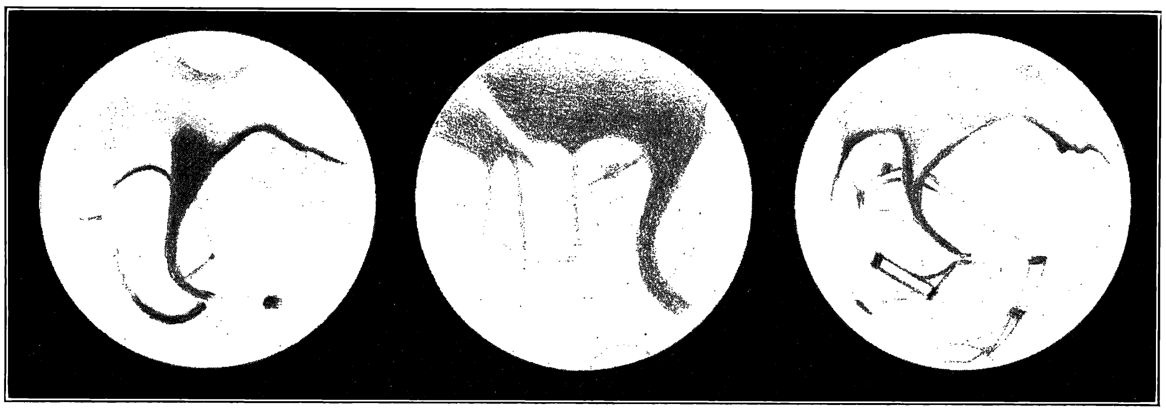
PLATE XXX



1
1877, Oct. 14
Dec. 28

2
1879, Oct. 28
Feb. 1

3
1882, Mar. 13
May 2



4
1884, Feb. 19
May 12

5
1886, May 21, 22
July 12

6
1888, June 5
Aug. 9

equal to that of Mars when viewed under a magnification of 430. At the time this observation was made Mars was practically at aphelion The scale was appreciably redder than the planet.

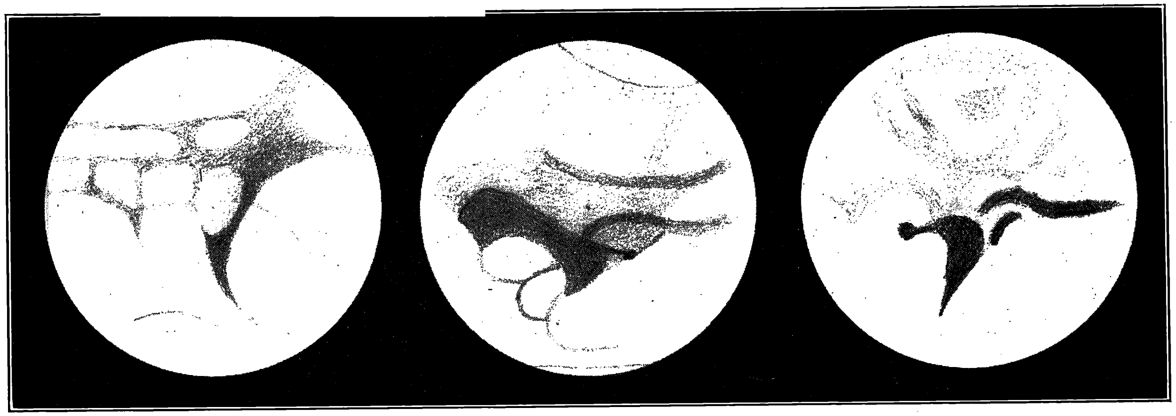
A similar scale may be used to measure the martian lakes. The one actually in use at the present time was prepared by comparison with the lakes of the moon, but since many of these appear exactly like those on Mars, there is no doubt but the scale will be found applicable when Mars again approaches us. This scale was drawn with a No. 3 or M pencil, the diameters of the circles being 2, 4, 6, 8, 10, and 12mm.

The first practical application of this was to the canals of the lunar crater Aristillus, described in the last number of POPULAR ASTRONOMY. When using a magnification of 430 with the 11-inch telescope, the diameter of the emergent pencil of light is one-fortieth of an inch. In order to make sure that a canal on a bright surface seen through a small aperture appears of the same breadth as an equal canal on a fainter and yellower surface seen with the naked eye, a special apparatus was devised. This consisted of a box five feet in length, divided by a longitudinal partition. Two similar scales of canals were employed whose widths were 0.25, 0.5, 1, and 1.5 mm. These were placed at one end of the box, one being illuminated by a tungsten lamp as above described, and the other by daylight coming through a hole in the side of the box, so arranged that its size could be regulated. When the latter scale was seen through an aperture one-fortieth of an inch in diameter, it was so illuminated as to appear of the same brightness as the other scale seen with the naked eye. The observer in the mean time sat in comparative darkness.

It was so planned that one scale should be viewed with one eye and the other with the other, but on account of the difference in my eyes it was found best to observe them alternately with my observing eye. When the canals were placed vertical or inclined from right to left the two sets of canals appeared of the same breadth. When they were placed horizontal, or inclined from left to right the canals illumined by the sky appeared slightly broader and fainter, the difference being equivalent to 0″.05 as measured in the telescope. It therefore appears that this method of measurement of the martian canals involves no large systematic error. On the other hand if we use a much smaller emergent pencil, of for example half the size, all of the narrower canals appear of the same breadth, differing from one another only in density. We must therefore avoid using too high a magnification in these measurements, for instance not over 40 or 50 to the inch of aperture.

Although it is the writer's custom in these articles to deal with the past rather than the future, an exception may profitably be made in

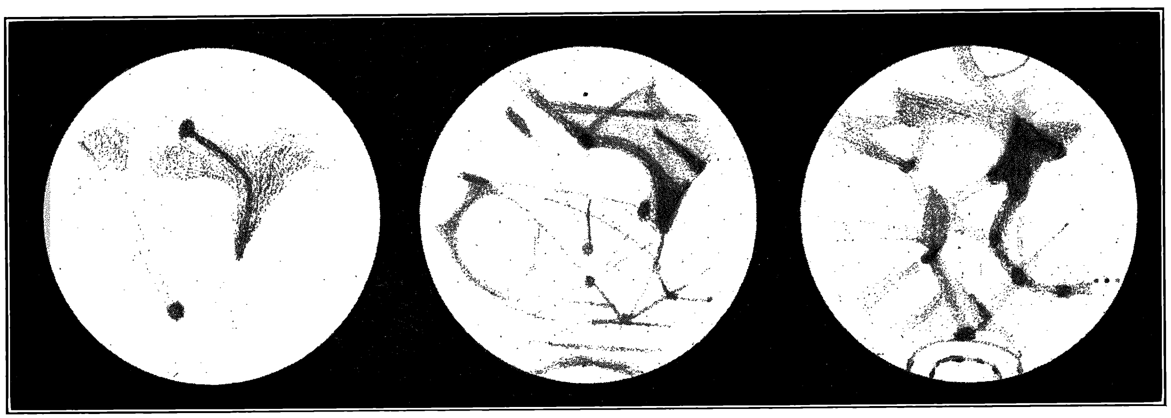
PLATE XXXI



7
1890, May 19
Aug. 23

8
1890, July 17
Oct. 22

9
1894, Oct. 25
Jan. 21



10
1897, Feb. 24
Apr. 27

11
1899, Feb. 28
May 8

12
1901, Jan. 23
May 12

the present instance. For many years the British Nautical Almanac has used the value 4″.68 for the semi-diameter of Mars. This value was fully corroborated at the Lowell Observatory in 1894, Annals **1**, 75, from observations made by all three of the observers, but chiefly by Professor Douglass, and is probably correct to within a little over 0″.01. The American Ephemeris on the other hand uses the value 5″.05, which is certainly wrong, and was deduced many years ago by Peirce. For the next opposition both almanacs use the American computation based on the value 5″.05, for both the diameter and for q, although the British Almanac by an inadvertance repeats on another page from former editions the statement that the value 4″.68 is used. Those observers therefore who have in the past depended for their physical ephemeris on the British Nautical Almanac should notice the change, which will amount in the case of the diameter to over 1″.

In our Reports Nos. 3 and 4 attention was called to the apparent gradual shifting both in latitude and longitude of certain sharply defined points, bays, and promontories upon the surface of the planet. The fact that certain areas were sometimes light and sometimes dark had been known for many years, but that well defined points and lines slowly shifted their positions, rendering accurate mapping impossible, had not been generally recognized. It is not even probable that we can map the surface accurately for a given position of the planet in its orbit, that is, for a given season of its year, as we shall show a little later, for what is correct one year may not be correct the next at the same season.

When an unexpected result depends entirely on the drawings of a single observer, it is always open to the suspicion, at least among others than the observer himself, that his drawings were not very accurate in the first place. When two independent observers reach the same conclusion however, neither having any previous knowledge of the other's investigation, it should carry greater weight. In the present case the two explanations offered for the discrepancy prove to be entirely different.

If we turn to the Observations of Planetary Surfaces made at the Observatories of M. Jarry-Desloges **3**, 237, we shall find that M. G. Fournier made a series of determinations of the positions of 98 points on the planet's surface, during the opposition of 1911. Instead of merely taking the mean position from all the observations of each point, he made a separate determination and map of the location of every point at each of the five different presentations observed. Selecting 20 of these that lay in very different latitudes, and were clearly identified and sharply defined, he found that there was a gradual shifting of the latitudes of these points, so that between the first and the fourth presentation there was a mean shift of nearly 3°.

On investigating the matter the writer found that the shift amounted to 2°.7 ±1°.8. It is doubtful if the latter figure means anything however, since it is probable that some of the latitudes really shifted more than the others. Seventeen of the differences in latitude were negative, two positive, and one zero. That is to say the latitudes shifted on the whole towards the south. M. Fournier ascribes this shift to an error in the adopted inclination of the axis of the planet. Since during the one hundred and twenty days involved, the planet would barely have traversed 60° in its orbit, it is quite impossible that any error in the inclination could be so great as to cause so large a deviation in that interval.

It occurred to the writer that it would be interesting to note if the longitudes also shifted. The four most southern stations were located on lines running nearly east and west, and were therefore not adopted for this investigation. They were consequently rejected. The remaining sixteen were well defined in longitude, and showed a mean increase of 2°.9 ± 1°.9. The shift was slightly greater therefore than that in latitude. Thirteen results were positive, two negative, one zero.

The point showing the greatest shift in both latitude and longitude was, oddly enough, Fastigium Aryn, the point from which all martian longitudes are reckoned, and which we may expect was observed with the greatest care. It shifted 6° in latitude, and 7° in longitude. The five successive determinations of its latitude were −3°, −3°, −6°, −9°, and −4°, of its longitude 357°, 357°, 357°, 4°, and 0°.5. Other points showing a notable shift of position were Astarte Lacus on the northern border of the Mare Cimmerium, which shifted 6° in latitude, Oxia Palus at the northern extremity of Margaritifer Sinus, which shifted 7° in longitude and 4° in latitude, and a point on the northern border of Aurorae Sinus, which shifted 6° in longitude. The eastern end of Mare Sirenum, which is not included among his selected points, but lies in the region where the writer found the greatest change, shifted 4° in latitude and 9° in longitude.

The accuracy of longitude determinations is affected somewhat by uncertainty as to the exact position of the terminator of the planet, so that they are not so accurate as those made in latitude. Opposition occurred during the third presentation. The first and second presentations gave practically identical results, only two latitudes and two longitudes showing any difference. The fourth presentation showed the maximum change in latitude, and the fifth the maximum in longitude 3°.8.

If now instead of dealing with only one opposition, we note the changes that take place upon the planet in a given region during a long series of years, we shall find some of those observed are very marked. In his last Report on Mars, No. 6, the writer stated his belief that it was to these changes rather than to the shape of the markings themselves, that we should turn in order to obtain information as to the nature and origin of the canals, and light on the question of their possibly artificial character. To facilitate this investigation he has arranged in Plates XXX, XXXI and XXXII what seem to him the best drawings in his collection of one particular region on Mars, and presents them, all drawn on a uniform scale, to the readers of POPULAR ASTRONOMY.

These drawings represent the region between the Syrtis major and the canal Amenthes as it appeared at each of the last eighteen oppositions. In Table I the first four columns give the number and date of the drawing, the name of the observer, and the reference. In this last column Flammarion's great work on Mars has been referred to as far as possible, since some of the original memoirs are now very difficult to obtain. The fifth column gives the aperture of the telescope in inches, and a letter to indicate whether a lens or a mirror was employed. The sixth column gives the heliocentric longitude of Mars, the seventh the corresponding longitude of the sun ⊙, and the last the resulting Martian date. In order to avoid giving a preponderance of weight to the style of drawing of any particular individual, the writer has made use of the work of as many different observers as practicable, twelve in all.

Under each drawing is given its number and the terrestrial and Martian dates. The Syrtis major is the prominent and funnel-shaped marking shown in all of the drawings, and particularly conspicuous in number 3.

TABLE 1.

DESCRIPTION OF FIGURES IN PLATES XXX, XXXI AND XXXII.

No.	Date	Observer	Reference	Tel.	H. L.	⊙	M.D.
1	1877 Oct. 14	Schiaparelli	Flammarion I 295	8 *l*	7.9	280.1	Dec. 28
2	1879 Oct. 28	Schiaparelli	" I 336	8 *l*	41.8	314.0	Feb. 1
3	1882 Mar. 13	Burton	" I 365	9—	131.0	43.2	May 1
4	1884 Feb. 19	Schiaparelli	" II 5	8 *l*	140.3	52.5	May 12
5	1886 May 21,22	Perrotin	" I 405	30 *l*	200.6	112.8	July 12
6	1888 June 5	Schiaparelli	" II 24	18 *l*	228.8	141.0	Aug. 9
7	1890 May 19	Guillaume	" I 477	8*m*	242.0	154.2	Aug. 23
8	1892 July 17	Pickering	Unpublished	13 *l*	301.6	213.8	Oct. 22
9	1894 Oct. 25	Campbell	Flammarion II 183	36 *l*	30.6	302.8	Jan. 21
10	1897 Feb. 24	Lowell	Annals L.O. II 416	24 *l*	116.1	28.3	Apr. 17
11	1899 Feb. 28	Cerulli	Flammarion II 469	15 *l*	137.1	49.3	May 8
12	1901 Jan. 23	Douglass	Annals L.O. III Sup. 50	24 *l*	140.3	52.5	May 12
13	1903 Apr. 2	Molesworth	Mem. B.A.A. Pl IV	13*m*	189.5	101.7	July 1
14	1905 June 7	Antoniadi	Mem. B.A.A. Pl III	8.5*m*	243.1	155.3	Aug. 24
15	1907 Aug. 2	Jarry-Desloges	Obs. J-D. I 18	11 *l*	300.0	212.2	Oct. 21
16	1909 Oct. 29	Jarry-Desloges	Obs. J-D. II 36	11 *l*	22.5	294.7	Jan. 12
17	1911 Nov. 11	Jarry-Desloges	Obs. J-D. III 36	8.5 *l*	54.7	326.9	Feb. 14
18	1913 Dec. 10	Pickering	Unpublished	11 *l*	92.5	4.7	Mar. 24

The chief reason why some of the drawings of it at first look out of proportion is on account of the inclination of the axis of Mars. Thus in

Figures 1, 8, and 16 the south pole of the planet was inclined towards the earth, while in Figures 4 and 12 the north pole was turned towards us, presenting this region to much better advantage.

An important question is how far the personality of the observer affects the drawings. The two figures in which the canals are represented the widest are numbers 12 and 14 by Messrs. Douglass and Antoniadi, and these observers usually represent them wider than they appear to most astronomers. In the other cases there is practical unanimity as regards the breadth of the narrower canals shown, except as regards Figure 9 by Professor Campbell, who shows only the Nepenthes. His other markings are not canals properly speaking. In other drawings however he shows the canals as narrow lines, like the other observers.

The most important question of the observer's personality however relates to the proportions and position of the main markings and canals. Here however the writer believes that personality has but little effect, and that the general shape is in all these cases pretty accurately represented. To test this question of general accuracy as well as that of the representation of fine detail, he proposed a year ago that a number of well known observers should make drawings of the planet in six different martian longitudes previously adopted, all the drawings being on the same scale. The drawings were to be forwarded to the Secretary of the British Astronomical Association to be published together in its Memoirs. The writer recently wrote asking what progress was being made in this publication, but, probably owing to the excitement in England at the present time, no answer had as yet been received, and it is feared that some further delay may ensue.

While it is not thought, as far as the fainter markings are concerned, that there is much difference in the eyes of different observers, provided their eyesight is keen, which term doubtless applies to all those whose work is here represented, yet some are probably more willing than others, to record as certain very faint markings that are seen with difficulty. In this paper we shall therefore consider merely the more obvious markings, which all under similar circumstances would be likely to record. A more important difference that we should consider, depends on the seeing. It is probable that Burton, who had a very keen eye, and also Antoniadi would have recorded finer detail had they been located under more favorable atmospheric conditions, that is in a more southern latitude.

The aperture of the telescope appears to have but little influence on the results beyond the fact that we find from the Table that the smallest aperture whose results have been accepted is eight inches. Neither Figures 5 or 9, made with refractors of the largest size, show as fine detail as many of the others made with much smaller apertures. This

PLATE XXXII

13
1903, Apr. 2
July 1

14
1905, June 7
Aug. 24

15
1907, Aug. 2
Oct. 21

16
1909, Oct. 29
Jan. 12

17
1911, Nov. 11
Feb. 14

18
1913, Dec. 10
Mar. 24

confirms the opinion of several of the more modern observers of Mars, who make it a practice at times of bad seeing to reduce the apertures of their telescopes by means of diaphragms.

With regard to the duplication of the canals, only Schiaparelli, Perrotin and Lowell show it in their drawings. M. Jarry-Desloges writes (Observations **3**, 264,) that both of his assistants saw it independently on the same night, but that he could not see it himself. The writer has seen it clearly in a modified form upon the moon, as stated in the November number of POPULAR ASTRONOMY (The Double Canal in Aristillus). This canal will serve as a standard for comparison with the visibility of any martian doubles observed in the future. Messrs. Douglass, Antoniadi, and the writer have all suspected duplications on Mars, but have not succeeded in convincing themselves as yet that what was seen was an objective reality. As shown in Report No. 5, oppositions occurring near February 7 and June 1 are particularly well adapted for showing it. The next opposition of the planet occurs February 9, 1916, and is therefore an unusually favorable one.

Although the different drawings present a great variety of detail, no two closely resembling one another, save in their general outlines, yet seasonal changes do not seem to be as pronounced on Mars as we should naturally expect. Such changes should be most marked near the poles of the planet, but as these regions are usually very near the limb, the middle latitudes of the temperate zones are the regions most favorably located for our investigation. The bright region of Hellas, in south latitude 40°, shown just above the center of Figure 1 is traversed by a single canal. In Figure 2 it is crossed by two, while in Figure 16 there are three. It seems to be seen to the best advantage during the martian months of December, January, and February, their summer, although also visible in October, Figure 8, when no canals were visible. Near the equator a bright band divides the Syrtis in Figures 1, 2, 9, 11, 16, and 17. These all correspond to martian dates in December, January, and February, their dry season before the floods are released, save Figure 11 which occurs in May.

In the north temperate zone, in latitude 50° we find the Boreosyrtis, the dark horizontal marking near the bottom of Figure 18. We notice that it is visible in Figures 3, 4, 12, 13, 17, and 18. The corresponding martian dates are in February, March and May, but also one in July. Since it is due primarily to the melting of the northern polar cap, it is clear why it is seen mainly in the spring months, but not why it should appear in July. In this latter month, Figure 13, it forms a large area, though hardly visible at all at about the same season in Figures 5 and 6. Moreover it is invisible in Figures 10 and 11, corresponding to April and May, just the months when we should expect it to be conspicuous.

There is another kind of seasonal change, however, that is quite unlike those previously mentioned, in that it pertains to the whole surface of the disk. It is found that between March and August the dark markings and canals lie in a general north and south direction, while between August and March their direction is more or less east and west. Thus compare figures 4, 10, 12, and 13 taken in April, May and July with Figures 1, 8 and 16 taken in October, December, and January. Again, those drawings taken during the summer and winter months show rather more detail than those taken during the spring and autumn.

Thus we may say that while this face of the planet does present seasonal changes, yet they do not always occur. There seem to be many exceptions. Some of them, notably those of Boreosyrtis, might be ascribed to droughts and freshets, and should be especially looked for in the future.

Turning now to what we may call the non-seasonal changes, we may note that the clearly marked lake in the upper part of Figure 10 is shown again in Figure 11, but it will be seen that the northern boundary of the dark region has retreated, and has shifted in latitude at that point through some 15°, or 600 miles, although the season on Mars is only one month later. Figure 10 is corroborated by Figures 7 and 17, Figure 11 by 14 and 15. The bulge in the outline to the right of the Syrtis shown in Figures 8 and 17, is usually replaced by a concavity, see Figures 7 and 9, but has been corroborated in certain photographs of the planet.

One of the most striking changes is the varying breadth of the Syrtis at its northern extremity. Changes in this region were long ago pointed out by Flammarion, Planéte Mars **1**, 575. In Figure 1 the northern extension was narrow. It widened in Figures 2 and 3, was still wide in Figures 4 and 5, then narrowed until Figure 8, and disappeared in Figure 9. It remained narrow until Figure 18, when it again suddenly broadened. It is shown as wide in the drawings of Messrs. Douglass and Antoniadi, Figures 12 and 14, but, as we have already seen, all canals are represented as wide by these observers.

A change of still different character pertains to the canal Thoth. This canal lies in a north and south direction between Amenthes and the Syrtys Major. Amenthes is clearly shown in Figures 3, 14 and perhaps 15, to the left of the Syrtis, It is also shown on the extreme left of Figure 6, the upper portion being single, the middle missing, and the northern end double. Between it and the Syrtis, joining two lakes, lies the Thoth. It is also shown in Figures 2, 12, 13, 15, 16, 17, and 18. The difficulty that sometimes arises in identifying the canals is well illustrated in some of the other drawings. Thus in Figures 4, 5, 7, 10, and 11 a canal is shown occupying very nearly this same place, but extending further south. Evidently the same canal is represented in these five drawings, but is it the Thoth or the Amenthes? Schiaparelli identifies it in Figure 4 as Thoth; Cerulli in Figure 11 agrees with him. Lowell identifies it in Figure 10 as the Amenthes. It really seems to lie between the two, as they were named and represented by Schiaparelli, see Figure 6. Compare also with Figures 2 and 3 where the region is central. The following observers agree as to the position of Amenthes:—Burton, Schiaparelli, Antoniadi, and Jarry-Desloges. The following agree as to Thoth:—Schiaparelli, Douglass, Molesworth, Jarry-Desloges, and Pickering. The following agree as to the location of the intermediate canal:—Schiaparelli, Perrotin, Guillaume, Lowell and Cerulli.

It is likely that the last five observers, who agree so well with one another, could all have made the same mistake in wrongly locating this canal? If they have, what shall we call it Thoth or Amenthes? If they were not mistaken, is the canal a new one replacing the two others? In that case should it have a new name? Should we for instance follow the precepts of the lamented Lewis Carroll, and call it the Thamenthes? Finally has one of the original canals merely shifted its position? If that is the case the fact is clearly a matter of some importance, since it may dislocate our whole system of nomenclature, and be the cause of endless confusion. In our Report No. 6 evidence was presented that the canals encircling Elysium were subject to a gradual shift of position, and it is the writer's opinion that this is the true explanation of the phenomenon here recorded.

Thoth exhibits still another change that clearly is not seasonal. While a canal has existed in this immediate vicinity for a great number of years, yet in all the earlier drawings it has been a faint and apparently insignificant object. In 1911 however, Figure 17, it became much more pronounced, while in the last figure it is shown as one of the four most conspicuous canals visible upon the disk, the others being Sabaeus, Cerberus, and the northern prolongation of the Syrtis. A similar change has taken place in Cerberus, and also, as these figures show, in the Syrtis itself. We might imagine some slow growing form of vegetation like our trees or shrubs gradually establishing itself there, and then, judging by the case of the Syrtis, even more gradually dying out again. It will be interesting to watch for its appearance at the next opposition.

Measures of Thoth taken from Figure 18, and from other drawings made during the past year give it a length of 2000 miles, and a width of about 150.

The contemplative reader before adopting any theory of the martian changes, may well ask himself the following questions. (*a*) Is it possible to offer a probable explanation of this change without calling in the aid of a martian vegetation? (*b*) If not, can a change on such a large scale have taken place without the aid of some directing intelligence? (*c*) Do such conspicuous non-seasonal changes occur at the present time upon earth, or did they before the advent of civilized man, for instance in North or South America.

It is obvious that if we were to cut down an extensive forest, or were to plant certain dark colored vegetation on lighter colored plains, we could now produce just such a change in the appearance of our planet, if it were desirable to procure food in this manner, or for any other reason. That is an easy explanation to offer, but can we find an equally plausible one that avoids the necessity of assuming a martian intelligence?

In the Monthly Report on Mars No. 6, three hypotheses were given involving martian intelligence, and were designated as (*a*), (*b*) and (*c*).

Two others requiring vegetation but not intelligence were also given, one depending on volcanic activity, and the other on a change in meteorological conditions, notably the moisture bringing winds. These may be designated respectively as (*d*) and (*e*). To make this list complete, and include every hypothesis of which the writer is aware, that is not obviously impossible, we should mention here the ice floe theory of M. Baumann. This theory which we will call (*f*) requires neither vegetation nor intelligence, and is perhaps the most plausible of all those which do not demand the existence of the latter upon the planet. He suggests that the so-called seas are continents, the lakes are islands, and the desert regions ice floes, colored by volcanic deposits,—and perhaps vegetation. Where the ice floes crack showing the water beneath them we have the canals. There are obvious objections to this theory, which he deals with in great detail*, but overlooking these, or accepting his explanations, it certainly has its merits for the consideration of those who decline to recognize any theory which involves the existence of intelligent life, outside of our own world.

* Der Planet Mars. A. Baumann.