
REPORT ON MARS, No. 19.

WILLIAM H. PICKERING.

This Report will be devoted mainly to a consideration of certain recent views regarding the nature of the so-called canals, but first we must briefly consider an interesting application of Green's Tetrahedral Theory of the Earth to the planet Mars, suggested by our associate Dr. Lau (A. N. 4878, 204, 122). Briefly stated, this theory is that in a slowly contracting sphere with a solid surface, the shape which would permit of the greatest contraction of volume with the least contraction of surface is the tetrahedron. Therefore the contracting planet should, while retaining a nearly spherical shape, tend to exhibit four equidistant protuberances and four intermediate flattened surfaces. Dr. Lau places one protuberance at the north pole, and the corresponding surface opposite it at the south. The other three protuberances should then be in latitude -20° , and the centers of the other three surfaces in latitude $+20^\circ$. These three surfaces Lau identifies as Acidalium, mean latitude $+43^\circ.5$; Propontis, latitude $+35^\circ.0$; and Utopia, latitude $+34^\circ.5$.

We naturally cannot demand that an exactly geometrical form be produced, and a reasonable deviation from it may be expected, but these deviations, while all of them rather large, have the serious defect that they all lie in the same direction, too far to the north, and are therefore located too near together. The three darkest spots on the planet near latitude $+20^\circ$, and which we have reason to believe are really depressions, are Lunae Lacus, latitude $+19^\circ$ longitude 65° ; Trivium Charontis, latitude $+17^\circ$ longitude 195° ; and the marsh in the Syrtis Major, latitude $+14^\circ$ longitude 285° . If we locate the theoretical centers of the three dark areas at longitudes 60° , 180° and 300° , then the three deviations will be $+5^\circ$, $+15^\circ$, and -15° .

The three depressed regions suggested by Dr. Lau lie slightly to the east of those above indicated, and seem to be way stations to them, the current of moisture in each case curving westerly as it travels southward. While the deviations that we have found are not excessive, the theory does explain, as pointed out by Dr. Lau, the existence of the depression and consequent dark areas in the southern hemisphere, and the existence of the three routes traversed by the moisture on its way from the north pole through the depressed areas to that hemisphere.

The statement is often made that the canals always follow the course of great circles. It is possible that this is occasionally true, but it is certain that it is by no means usually the case. The great majority that are well seen are obviously curved. Most of the remainder are either too broad or too short to make any accurate statement possible. A few others seem to be straight for a portion of their course, and a very few indeed among the fainter ones seem to exhibit no deviation for hundreds of miles. What is rather striking is that several of these latter follow an approximately meridional course. Some of the others follow for considerable distances along parallels of latitude, thus describing arcs of small circles. These latter are generally found in northern latitudes and are associated with the snow cap.

The surface of Mars is extremely level as compared with that of our Earth, and it is not believed that the canals lie in hollowed out channels upon its surface, but rather that they are simply marshes deposited as the result of the passage of heavy rain storms occurring at night. The more permanent tropical ones may in some cases support vegetation. In the night time the rare atmosphere of Mars would permit a considerable fall of temperature, and if well saturated with moisture, heavy showers should ensue. In Jamaica our tropical showers are often very heavy, and their edges very marked. Thus on several occasions we have observed it to be raining quite sharply on one side of our house, and not raining at all on the other. The showers vary from a fraction of a mile up to several miles in diameter, and traverse the island from east to west. If instead of a rich tropical vegetation, the country presented nothing but a barren sandy plain, which we could view from a sufficient elevation, the track of each shower would appear to us as a straight narrow dark band of fairly uniform width. Supposing now the Martian canals to be due to this cause, let us next see what courses we should expect them to follow, for it is clear that they could not pursue a straight line for any very great distance on account of the rotation of the planet.

Before starting in on this investigation, however, we will begin by investigating something quite different. We all know that a frictionless marble acted on only by gravity, if projected across a level surface, will continue to move forever in a straight line with uniform velocity. If projected upon the surface of a stationary sphere, gravity acting towards its center, the marble will describe a great circle with uniform velocity. It cannot under any circumstances describe a small circle. If the sphere revolve, the marble can only continue to trace a great circle in case its velocity is infinite. If it is finite the marble will follow a curve, which if confined to one hemisphere will consist of a series of loops resembling an epicycloid. These will be executed at

uniform velocity along some given parallel of latitude dependent upon the speed, the marble being constantly deflected to one side of its course in such a manner that for most of the time the curve will lie between the parallel and the equator. In the case of the Earth the general direction of motion of the marble will be towards the west for either hemisphere, quite regardless of the direction in which it was originally projected. If given sufficient speed the marble will cross back and forth across the equator, and may then go either towards the west or towards the east. If projected towards the east, it will maintain that direction, following a sinusoidal curve. This proposition may be demonstrated indirectly by the Foucault pendulum.

It must be understood that it is the absolute velocity of the marble that is uniform, and that relatively to the motion of the surface of the sphere in different latitudes it will vary. In Figure 1 let E S W N represent the Earth, or the planet Mars, the arrowhead at the center

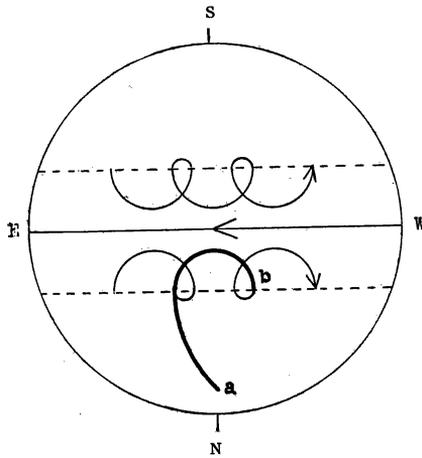


FIGURE 1.

indicating the direction of its rotation. Then the two curved lines will represent the course which the marble must follow in either hemisphere, if it moves at only a moderate velocity. If the marble starts near the pole, and moves with a rapidly diminishing velocity, it will follow some course such as *a b*.

Turning now from the case of the marble to quite a different subject, the velocity of the wind, we know that if atmospheric air is admitted at sea level into a perfect vacuum it will attain a maximum velocity of 950 feet per second, or 648 miles per hour. It is theoretically impossible for any wind at the Earth's surface to be higher than this, and at great elevations this velocity must be considerably reduced. The highest wind velocity ever recorded at the surface of the earth is 185 miles per hour, measured by the Weather Bureau on Mt. Washington, in

the White Mountains of New Hampshire, altitude 6290 feet. A speed of 230 miles per hour has however been recorded for some of the higher clouds at the Observatory on Blue Hill, near Boston. The higher clouds float in general at an altitude of six to nine miles. At seven miles the atmospheric pressure is reduced to one quarter of that at sea-level, and the maximum possible velocity of the wind to one-half, or 324 miles. We thus reach the rather surprising result that at these altitudes the observed velocities occasionally reach two-thirds of the possible theoretical maximum.

Having now stated some of our fundamental facts and theorems, we will next turn to the meteorology of our Earth. We know from observation that there is a band along the equator where the barometer is permanently low caused by the heat of the Sun, that there is an irregular band on either side of it, most uniform in the southern hemisphere, and located in latitude 30° , where it is permanently high, and that near the poles it is again permanently low. At the south pole itself there is a high barometer. Over the oceans the equatorial band is known as the doldrums. Here the air is constantly rising, producing a cloudy sky, rains and calm weather, disturbed only by local squalls. The two belts where the barometer is high are known as the horse latitudes. Here the air is constantly descending, producing cloudless skies and generally calm weather. The writer has found that the best location for an astronomical observatory, as far as atmospheric conditions are concerned, is on the equatorial side of these belts.

If we consider these regions of high barometer as hills, then in the northern hemisphere our marble dropped down on the southern side of them would roll towards the equator, being apparently deflected, however, by the Earth's rotation towards the west. If it were dropped on the northern side of them it would roll towards the pole, but be deflected at first towards the east. All these belts shift a few degrees north and south with the change in declination of the Sun. It will be observed that what we may call the heart of the terrestrial circulation, its driving motor, is located in the doldrums along the equator, where the Sun's heat starts the upward currents in our atmosphere which keep the whole of it in motion.

On Mars, where there are no permanent oceans, the case is different. There must be a belt of low pressure along the equator as in the case of the Earth, but since the atmosphere of Mars consists very largely of water vapor, which is generated by the melting of the snow at the summer pole and removed from the atmosphere by condensation at the pole where it is winter, we must necessarily have a marked high barometer in the spring time at the pole where the vapor is generated, and marked low at the pole where it is condensed. The barometric

gradients must be steeper in proportion to the deflective force of the planet's rotation than on the Earth, and the winds lie in a more nearly north and south direction. The steepness of the gradients will be especially marked on the night side of the planet in the hemisphere where the snow is melting.

Let us now imagine a rain storm on Mars starting in a northern latitude in the spring of the year, and gliding down the steep barometric gradients upon the night side towards the equator, with an ever increasing speed, accelerated both by the force of gravity and by the rush of vapor generated from the melting polar cap. Soon the retardation due to friction with the rest of the atmosphere will reduce this acceleration, and before long it will become zero. While this condition continues the velocity of translation of the storm will be constant, and the case similar to that of our frictionless marble. Assuming the broad curving canals leading southward from the polar cap to be marshes fed by storms, the problem to be solved is to determine the direction of motion, and the speed of the storm, that will trace out one of these marshes. Figures 2, 3, 4, and 5 are copied from Figures 6, 14, 18 and 22 of Report No. 17. On each figure is marked the central meridian,

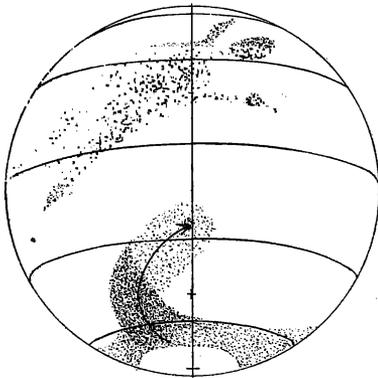


FIGURE 2.

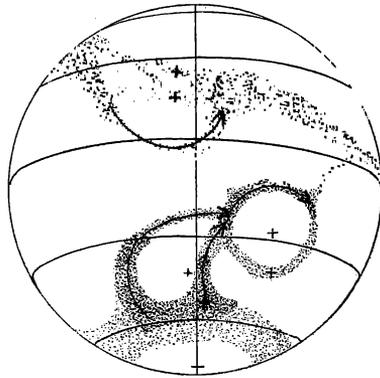


FIGURE 3.

the north pole, the equator, and the parallels of 30° and 60° . On the main curving canals are drawn arcs of circles, coinciding as nearly with them as possible, and from the direction of their curvature and its radius, the direction and velocity of the corresponding storm is computed. The direction is indicated in each case by an arrowhead, the center of curvature by a small cross, or when it changes by two crosses.

Let V be the velocity of the wind in the canal, R the observed radius of curvature, r the computed radius of curvature for a wind blowing one mile per hour, ϕ the latitude of the selected point where

the velocity is to be measured, and 24.62 the sidereal period of Mars expressed in terrestrial mean time hours. Then

$$r = 24.62/2\pi \sin \phi \text{ and } V = R/r = 2\pi R \sin \phi / 24.62.$$

The longest radius of curvature, and the highest corresponding velocity of the wind in any of these southward leading polar canals, is found in the northern portion of Casius-Thoth, Figure 5, shortly after the storm has started from the Boreosyrtris region. The distance from the little cross near the center of the figure to the middle of the canal where it crosses latitude $+35^\circ$ is 1572 miles. Dividing this by 6.83, the computed value of r for this latitude, gives us a velocity of 230 miles per hour.

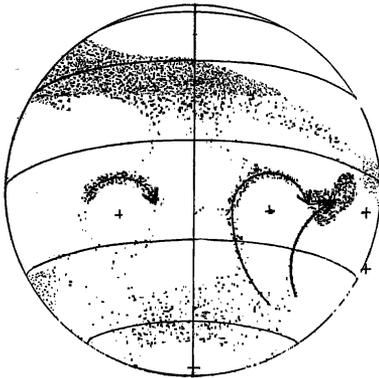


FIGURE 4.

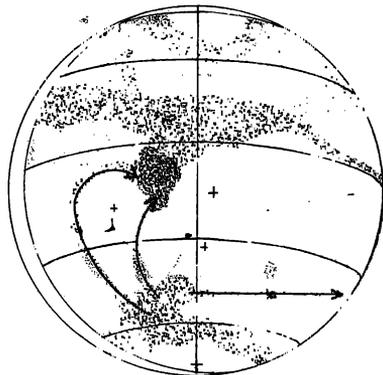


FIGURE 5.

But the speed is really somewhat higher than this, since Thoth is not located on the central meridian and part of the curvature is due to this cause. In Figure 4 where it is more nearly central, and the meridians curve in the other direction, the speed appears to be 222 miles per hour. There is another correction to be made to these figures however. The computation is made for a frictionless storm, or more accurately speaking for a storm where the acceleration is balanced by the friction, and the velocity is constant. If the acceleration is in excess it tends to straighten the path, if the friction is in excess it tends to curve it. This effect is seen farther south, where in Nepenthes in latitude 10° the radius of curvature is reduced to 426 miles, and dividing this by 22.57 gives us a velocity for the wind of only 19 miles per hour. The velocity of the storm at the beginning of its course, where it was first expelled from the polar regions, was probably somewhat less than 230 miles per hour, and towards the end rather more than 19.

Let us assume now, however, that the wind on Mars in the north temperate zone does sometimes reach a velocity of 230 miles per hour,

or the same as that observed for the upper clouds near Boston. Then the maximum theoretical velocity cannot be much less than 324 miles, nor the corresponding pressure less than one quarter of a terrestrial atmosphere, or 7.5 inches of mercury. From various considerations, such as the small force of gravity on Mars, the small bulk of its snow caps, the transparency of its atmosphere, and the lack of permanent oceans, we conclude that the maximum possible value of the pressure cannot be very far above this figure. The boiling point of water upon Mars must therefore be approximately 150°F (66° C), and cannot be much lower. While these results can lay no claim to great accuracy, it is satisfactory to have at last got beyond the point of mere guesses at this important figure.

If now the density of the atmosphere of Mars is one quarter that of the Earth's, the pressure exerted by a wind of 230 miles an hour would be no greater than that of a terrestrial storm blowing at the rate of 115 miles. But a mean velocity of 102 miles for an interval of over five minutes has been recorded by the Weather Bureau at St. Paul, Minnesota, so it would appear that the effect of Martian storms may be no more severe than our own. It must moreover be remembered that the climate of Mars is one of extremes. It has no great oceans or dense atmosphere to modify its surface temperature, which must be subject to a great daily range. The relative atmospheric pressure when dry and when saturated with moisture must have a great range also when compared with our own. These extremes of temperature and pressure must both tend to produce high winds, while on the other hand the rarity of the atmosphere would offer little resistance to reduce their velocity. Our result is therefore no higher than we might reasonably expect.

On the other hand the case of Thoth seems to be rather an exceptional one. It is by no means a permanent canal. Its appearances are sporadic, appearing for a few years in succession, after which it may not be seen again for several years at a time. It together with Nilosyrtris serves to fill the Syrtis marsh, the only large area remote from the polar caps where conspicuous floods occur. This of itself implies the transmission of large quantities of water, but besides this, Thoth is the only one of the five chief polar canals that succeeds in forcing its way into the torrid zone. The other four stop when the tropic is reached, and we might therefore naturally expect that their curvatures would indicate lower velocities. The incursion of Thoth into the tropics results as we have seen in a great reduction in the original velocity, clearly due to atmospheric friction.

TABLE I.
VELOCITY OF THE WINDS ON MARS.

Fig.	Name	Lat.	r	R	Vel.
2	Acidalium	60	4.53	586	129
"	"	35	6.83	959	140
3	Eumenides	-5	44.97	853	19
"	Gigas	-5	44.97	560	12
"	Brontes	45	5.54	694	125
"	Erebus	25	9.29	986	106
"	Hades	40	6.10	773	127
"	Cerberus	12	18.85	533	28
4	Cerberus	10	22.57	426	19
"	Casius-Thoth	35	6.83	1518	222
"	Nepenthes	10	22.57	426	19
"	Nilosyrtris	30	7.84	853	109
5	Casius-Thoth	35	6.83	1572	230
"	Nepenthes	10	22.57	426	19
"	Nilosyrtris	30	7.84	773	99

Each one of the other canals retains nearly its original velocity as far as the tropic. Thus Acidalium, as shown by the last column of Table I, begins with a velocity of 129 miles and ends with one of 140, that is to say it is practically constant. The other columns refer to the Figure, the parallel of latitude where the measurement is made, the computed radius r , and the measured radius of curvature expressed in miles. The velocity of the wind in the canal Brontes, in Figure 3, soon after leaving the Propontis region is 125 miles, and in its continuation Erebus 106. In Hades it is 127. Cerberus is not a polar canal, since it starts in the Trivium Charontis. Two determinations of its velocity were made, and the highest, 28 miles, is probably correct, since in Figure 4 the circular area Elysium is certainly drawn too small. Two determinations of the speed in Nilosyrtris were made. On account of the curvature of the meridians it must be rather less than 109 miles, as judged by Figure 4, and rather more than 99 miles as judged by Figure 5. All of these velocities are materially less than that in Thoth. A comparison of these drawings with those of the other observers given in Report No. 17 shows that they would yield similar results for these canals. Since these six canals are all located in the northern hemisphere they must necessarily all curve to the right, and consequently as we see they all lead away from the pole. This is indicated by their arrowheads.

If the velocity of the Martian winds is due in part to an excess of atmospheric pressure, caused by the evaporated moisture of the polar cap, then as the cap diminishes in area we should expect less moisture to be evaporated, and consequently that the velocity of the wind and the radius of curvature of the canals would diminish, the canals shifting

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their positions to that extent. If we turn to Report No. 7 we shall find a series of drawings of the region of the Syrtis major, each drawing being the best obtainable, and representing the appearance of the formation for every opposition extending from 1877 to 1914. Below the terrestrial date the equivalent Martian Date is given in each case. The revised Martian calendar did not appear until somewhat later, but the deviation from the revised date is in no case very great. Among the earlier drawings the longest radius of curvature, that is, the straightest representation of the Syrtis and the highest wind velocity, is that for 1882, March 13. The equivalent Martian date is given as May 2, and on the revised calendar it would be April 35. At this season the polar cap was melting very rapidly. In the two previous drawings it had hardly begun to melt, but in those that follow, as the Martian season progressed, we see the Syrtis gradually curling up, until in 1894 its northern extension had entirely disappeared. Although faint, it is comparatively straight again in 1897, Martian date April 27. It again curls up in the drawings that follow, and its extension disappears in 1905. It reappears in 1907 and 1911. In the latter year the snow has only just begun to melt, but the sharp curvature is in part also due to the proximity of the limb. In 1913 and in Figure 5 of the present article it has straightened appreciably, and as the polar cap diminishes in size this next year and the wind dies down, we again expect to see it curl up and assume a shorter radius of curvature.

But besides these polar canals or marshes, certain others are shown, which do not follow in the track of the polar winds. Cerberus, already mentioned, is one of these. Those marshes completing the circuit of Elysium in Figures 3 and 4 probably indicate merely a continuation of this wind whirl. The northern side of Elysium is extremely faint, and a careful search should be made this year to see if its radius of curvature is smaller than on the south side as it should be, and as appears from these drawings to be the case. The canal due north of Elysium shown in Figure 4, and lying between Aesacus and Anian upon our standard map, Report No. 15, does not appear on the drawings of either of the other observers, and was seen only twice by the writer. Like the other canals branching from Elysium in various directions, which are not always seen, and which are often quite faint, it must be due to what we might describe as an accidental storm. Since all the others lie near the equator their courses are comparatively straight, probably within the limits of error for such small and faint objects.

There is only one canal south of the equator indicating distinct evidence of curvature, and that is the one shown in Figure 3. It is true that it crosses the equator as far as north latitude 3° , but it is

soon swept back again by the general circulation of the atmosphere towards the south, due to the condensing vapor at the south pole. The curvature is sharpest at the right hand end, showing that the wind had less velocity there, and that consequently it was blowing from the east and curving to the left, which is what it must do if due to an aerial current in the southern hemisphere (see Figure 1). The velocity diminished according to Table I, where the canal is designated as Eumenides and Gigas, from 19 to 12 miles. The latitude with regard to the heat equator is assumed to be -5° .

There is a nearly straight canal faintly shown to the south of Eumenides. It was seen but once by the writer, and is not given by either of the other observers. There is another straight canal however well shown near the bottom of Figure 5, and recorded by all of the observers. To the left of the little lake it is known as Protonilus, and to the right of it as Deuteronilus. It leads from the same polar marsh as Casius-Thoth and Nilosyrtris, is apparently straight, and seems therefore to present an exception to the rule which has hitherto applied to all the other canals. If we examine into the matter however we shall see that if it really were straight it would follow along the course of an ellipse whose center was at the center of the figure, and which was tangent to the canal where the latter crossed the central meridian. Since it does not follow this course, it clearly curves to the right, thus bearing the characteristic of all northern aerial currents.

Its radius of curvature is evidently large, however, and cannot be measured by the simple graphical process hitherto employed. It can nevertheless be computed from the latitude and longitude of points taken from the drawing, and also from the standard map. Its deviation from the great circle above described amounts to 37° in 90° of longitude. This gives it a radius of curvature of 2580 miles for latitude 45° , and a corresponding velocity of the wind of 480 miles per hour. Measures from the map give a radius of 2980 miles for latitude 37° and a corresponding wind velocity of 460 miles per hour. These velocities are clearly impossible, so that the canal in spite of its correct curvature still apparently presents an exception to the rule. It also presents an exception to another rule, namely that all the large polar canals leave the polar marshes in an approximately southerly direction. It and the temporary canal between Aesacus and Anian have of late years always been the last of the polar canals to develop, Nilosyrtris being the first. It never even attained completion in 1914, only a small portion of Protonilus showing to the east of the little lake Ismenius, and a portion of Deuteronilus showing to the west of it. Since its duration is very

brief it is clearly of inferior importance in the seasonal economy of the planet. Its function seems to be to relieve the high pressure in Boreosyrtyis by permitting it to discharge into Acidalium.

Regarding its great velocity we noted earlier a difference between the terrestrial and Martian meteorology, in that while our melting polar caps are taken care of by our oceans, and we have in consequence a marked low barometer in our polar regions, especially at the south, the Martian polar cap simply melts and evaporates, producing a high barometer with marked gradients at the summer pole. When the polar cap melts, the water collects at the three depressed regions on its border indicated by the tetrahedral theory of the planet's formation. Their positions are shown near the central meridians of Figures 2, 3, and 5. Over these marshy spots the storm clouds gather, and are swept away to the south as we have seen. But the atmospheric currents are leaving the pole for the equator in all directions, although it is only where the water collects that a permanent trace is left upon the surface of the planet. These invisible currents must therefore strike the westward moving stream of cloud over Protonilus-Deuteronilus at right angles to its course, sweeping it southerly, and straightening out the curve. This is evidently the reason that the measured radius of curvature of its track is so large. Thus we see that for currents so located, and having a westward course, the radius of curvature can really give us no clew whatever to the actual velocity of the wind.

These southerly winds it will be noted have a two-fold origin. They are due in part to the permanent low barometer at the equator, and in part to the melting of the northern polar cap. As the snow cap decreases in size with the advance of the season, if this latter cause is of importance, the force of these southerly currents should at first increase and then diminish in intensity, and we should therefore expect as the season advances to find the canal at first gradually shifting to the south, and then later shifting back again to the north.

In order to secure information on this point we may consult the maps of the planet published in the Reports of the Martian section of the British Astronomical Association. We shall find from them that in 1899 and 1901 when the polar cap was just beginning to decrease in size, the canal Deuteronilus discharged its contents directly into Niliacus, a large dark area located to the north west of Margaritifer, and forming the southern tip of Acidalium. In 1903 when the melting was well under way, and the wind in consequence blowing strongly from the north, the canal had shifted towards the south, and discharged mainly into Margaritifer, by means of a new branch canal called Tritonilus. In 1905 when the polar cap was still smaller, and the wind had decreased in intensity, Tritonilus was fainter, and the discharge

was about equally divided between Margaritifer and Niliacus. Finally in 1907, observed at a date still later in the Martian year, Tritonilus had disappeared altogether, and Deuteronilus discharged as in 1899 and 1901 directly into Niliacus. From this we conclude that, while the equatorial low barometer may be of paramount importance in deflecting this canal to the south, the rush of vapor from the melting snow cap, when the latter is diminishing in size, also produces an effect by no means to be neglected.

During our December observation of this region at the last opposition, in 1915, $\odot 31^{\circ}.9$, M. D. April 11, the canal was seen for the first time that year. It was then pointed towards Niliacus, but did not reach beyond longitude 5° . Margaritifer had not yet developed. In January 1916, $\odot 47^{\circ}.9$, M. D. April 45, Margaritifer had developed in full, and also the canals Oxus and Indus. Deuteronilus had advanced to longitude 15° , but did not yet carry enough moisture to close the connection either with Niliacus, or with Margaritifer, through Oxus. In the following March, $\odot 63^{\circ}.2$, M. D. May 23, as shown in Report No. 17, Figure 2, the connections with both Margaritifer and Niliacus were established. By April, $\odot 77^{\circ}.1$, M. D. May 55, the connection with Niliacus was severed, and the canal was discharging only into Margaritifer and Sabaeus. Thus again we find that as the snow cap melted, the canal was obliged to discharge its contents farther to the south. At the present opposition it is thought we may see the continuation of the process, and the return of the canal to the north, thus again directing its discharge into Niliacus. It is believed we are thus at last beginning to find a reason for the mysterious changes that are sometimes found to occur in the location of the canals.

At the last opposition the snow cap decreased very rapidly in size during the Martian month of May, being reduced from its original diameter of 70° to but 16° at the end of that month; yet the canal area as a whole showed no diminution at that date, in fact on the contrary it had rather increased in size. If the canals are marshes or marshy ground, this observation would indicate their efficiency to serve as reservoirs of moisture during the three succeeding Martian months, until the moisture is again released by the melting of the southern polar cap. From the end of the Martian May until the autumnal equinox upon the planet, when the snow again begins to melt, is rather more than six of our months.

HISTORICAL SUMMARY.

A brief reference may now be made to some of the earlier explanations of the Martian canals, omitting the more absurd and improbable ones, such as that they were ploughed up by glancing asteroids, or that

they were isthmuses between light colored seas. The first canal and lake clearly seen and accurately plotted were Nectaris and Solis Lacus, which appear on Beer and Maedler's map of the planet in 1840 (*Planète Mars*, p. 107. Flammarion). Up to 1877 about a dozen astronomers, including De la Rue, Secchi, Lockyer, Lassell, Kaiser, Dawes, and Green had each seen a few canals. Proctor had indicated half a dozen on his map in 1867, and Flammarion a few more on his in 1876. In 1878 Schiaparelli first attracted general attention to the subject however by publishing a map containing some forty canals and several lakes. Since then they have been widely discussed, but only very few explanations of them have ever been generally accepted.

The first to meet general favor was that they were really water channels. This was discredited somewhat later however, when it was shown that some of them crossed the so-called seas (*Astron. Astro-Physics* 1892, 11, 668). The next suggestion was that the surface of Mars consisted in large part of desert areas, and that only the comparatively small dark spots or seas were due to vegetation (*Science* 1888, 12, 82). This view still holds, and is in fact generally maintained at the present day. Then came the suggestion that the canals were bands of vegetation watered by invisible central ditches. This view was enthusiastically embraced and adopted by the late Dr. Lowell, and in its original form was first published by him in 1895 in his book entitled *Mars* (p. 165). Through his skill as a popular lecturer and writer, and also owing doubtless in part to his addition to it of the suggestion that the water was pumped through the ditches artificially, thus making the suggestion much more picturesque, this view has been very widely accepted by the general public.

It has indeed heretofore always been found very difficult to account for the canals without having recourse to some sort of intelligent action, and various suggestions based on this idea have been offered to explain them, none of which however, as our information increased, have proved entirely satisfactory (see *Report on Mars* 6, 12, and 7, 9). Owing to the increased accuracy of recent observations we are now beginning to learn the real shape of the canals, and that once determined, it was but a step to apply to them Ferrel's theory of the winds. The writer is therefore now prepared to offer this explanation of all the broader and more important canals to the astronomical world, and particularly to the meteorologists, for their criticisms and suggestions, in the hope that they may find in it a more satisfactory explanation of this much discussed phenomenon than in those theories that have preceded it.

With regard to the narrower or secondary type of canals, a few of which are shown in Figure 5, it should be noted that they only appear late in the season, but are then very numerous. Over 500 have been

located and named at the Lowell Observatory since its foundation in 1894. The main question to be settled regarding them is as to their origin. (a) Are they artificial, as has been claimed, or (b) do they simply indicate the paths of local more or less accidental showers, or finally (c) is their uniformity and apparent straightness merely an illusion, like that of the lunar pseudo-canal, visible with an ordinary opera glass, which resemble them, and are described in detail in Report No. 6?

Without attempting to decide between these explanations, the writer is inclined to believe that there are certain positions where these canals readily form, and certain others where they are seldom seen, and that there is a great deal still to be learned with regard to them.

Especial attention should be paid to their curvature, hourly changes, duration, stability of position, longitudinal development, and the formation and disappearance of any lakes in connection with them. Since on account of the season on Mars this will be an unusually favorable opposition for their study, every one able to distinguish them should do all in his power to settle the question of their origin. There is no question, however, but that they are very difficult telescopic objects, and it is probable that there are but three observatories in the world, namely those which have resolved the Aristillus test, that possess the necessary combination of climate and equipment to see them distinctly. The Lowell Observatory is already definitely committed to the explanation that they are artificial, and in any case the seeing there in the early spring is not as good as it is later, with the arrival of warm weather. It is uncertain whether the Jarry-Desloges Observatory at Setif will be opened this year on account of the war, but it is known that if it is, it will not have the observers and equipment that it employed in former years. Our station, although well enough equipped for the study of the broader canals, will suffer in the study of the finer ones from the smallness of our aperture. Every effort will nevertheless be made to solve the problem this year, if it is possible to do so.

SUMMARY OF THE PRESENT THEORY.

We may now briefly summarize what may be termed the "Theory of Aerial Deposition," as applied to the broader Martian canals. As distinguished from the "Theory of Irrigating Ditches," it starts out with the statement that the function of the canals is not to conduct the water from the northern polar cap to the southern hemisphere, where most of the vegetation is to be found, but rather to retard its transportation. Without these natural marshes or reservoirs, it is believed that the water evaporated from the summer pole would find its way