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MONTHLY REPORT ON MARS.

WILLIAM H. PICKERING.

Introduction.

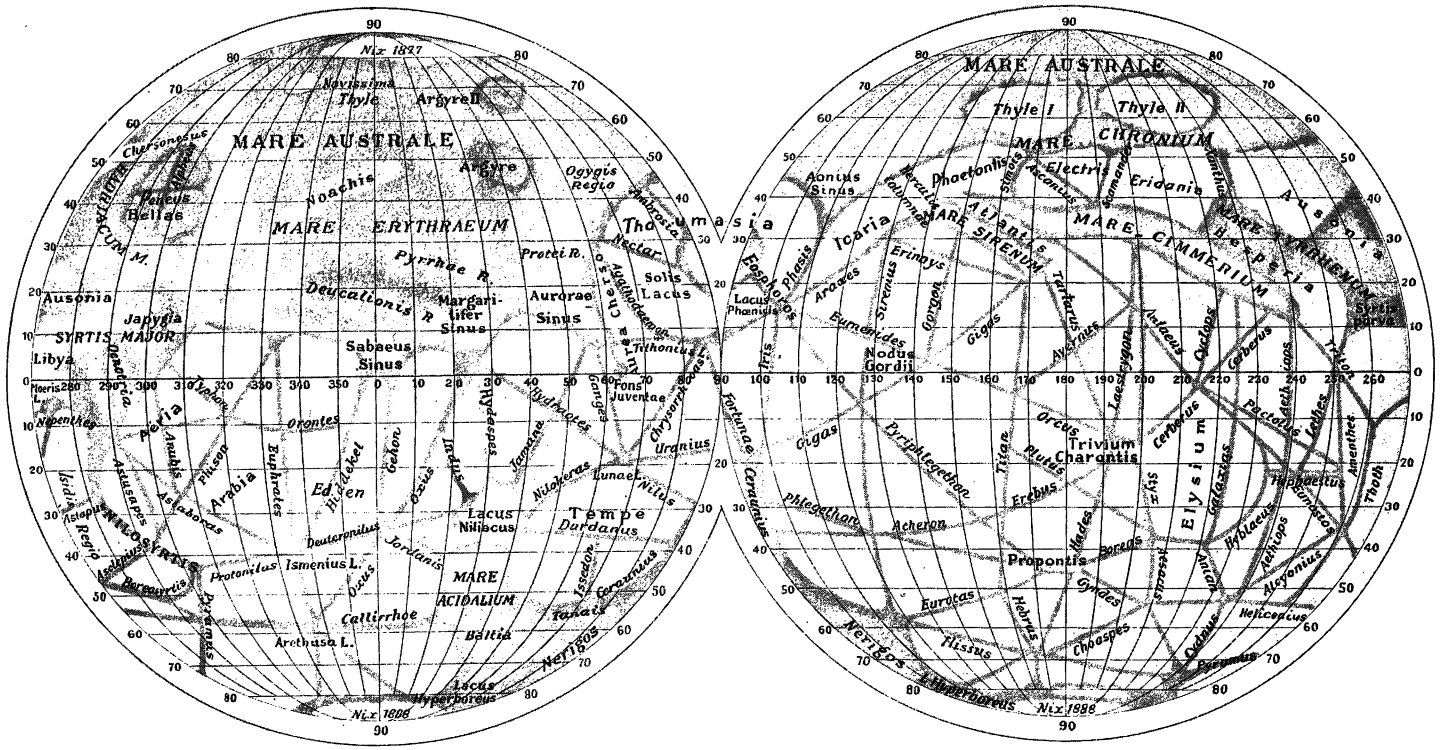
The Jamaica Astronomical Station of Harvard College Observatory, where the observations described below were made, is located near Mandeville, Jamaica, in longitude $5^h\ 10^m.2$ (77° 33′ W), latitude 18° 01′ N, and at an altitude of 2100 feet (630 metres). The instrument employed is an 11-inch (28 cm) Clark refractor, loaned to the observatory by Mrs. Henry Draper. The magnification used in all cases, unless specified to the contrary is 660.

The only planetary bodies in the solar system whose surfaces present to us constant physical change are Jupiter, the Moon, and Mars. The changes on the first are easily seen, but are due simply to shifting cloud masses; those on the second are rather difficult to observe, on account of the confused character of the surface detail when seen under high illumination, which is the only condition under which these changes occur. The changes upon Mars cannot be described as conspicuous, except when the planet is viewed under very favorable conditions, but in their general character they may be detected by careful study, even by those who are not fortunate enough to reside in those portions of the world where the seeing is habitually good.

In order to emphasize this constant change, in the case of Mars, and show its resemblance to what we find occurring upon the Earth, it occurred to the writer that it might be of general interest to publish a regular monthly report under the above heading, until the planet becomes so remote that it can no longer be observed to advantage.

This is the first time, it is believed, that it has been proposed to report regularly the news from another planet. In order that the expectations of the readers of this column should not be unduly raised, however, it should be stated at once that the news will consist mainly of meteorological items and I would have added "crop reports", except that this latter term would

PLATE I



SCHIAPARELLI'S MAP OF MARS, 1888

With a few names added from his earlier charts.

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seem to imply artificial cultivation. Meteorological changes undoubtedly occur on Mars, and vegetation undoubtedly progresses with the seasons, but whether this progress is of such a character as to imply artificial direction we have as yet no means of knowing. It is in fact one of the objects of this column to put before astronomers and the public in general at as early a date as possible the nature of these changes, as far as they may be determined. Each individual can then make up his own mind whether it is necessary to call in artificial cultivation in order to explain them, or not.

After each opposition of Mars of late years we have received various reports from different observers, of the changes in the appearance of the planet which they have noted since the previous two or three oppositions. Each opposition, however, presents the planet in a different portion of its orbit, and consequently at a different season as well as in a different year. That the planet's surface changes both with its seasons and also in different years is now so well known, that the reports give us no new light on the planet's physical economy, although the facts recorded are of value for future reference. The present plan on the other hand proposes to differentiate these two changes from one another, giving us only the seasonal change. It will also give us another change, namely that taking place from day to day, when this is sufficiently conspicuous to be of interest. Changes of this third kind are necessarily mainly meteorological.

With regard to nomenclature, the terms "seas", "canals" and "lakes" will constantly be used. The last two names were originally applied by Schiaparelli, although both the canals and lakes were originally discovered by Beer and Maedler. When the canals first appear in the spring they are comparatively broad markings. As the season progresses they become very much narrower and finally disappear. It is practically certain that both the canals and lakes as well as the seas are due to vegetation, but it is not at all clear that the surrounding region is an absolute desert, as it changes appreciably in redness, and also in brightness, from time to time. That the canals are bounded by straight lines, or even smooth curves is by no means certain, indeed it is exceedingly doubtful. Such usually appears to be the case, however, owing to our insufficient optical power. The writer has never yet seen the canals double, although he has observed the planet many times under most favorable conditions. Something analogous has, however, been seen upon the moon.

Clouds are nearly always visible upon the disk, but they are not usually reported, because they are difficult to observe. This, oddly enough, is on account of the lack of contrast in color between them and the soil. That is to say the clouds appear to be yellow, and not

white, as we should naturally expect. This is probably because they do not occur in solid masses, but rather as groups of individuals, between which we see the surface of the planet. While each individual may be as much as several miles in extent, yet they are not seen separately as such, the combined effect being to brighten the whole region while affecting its color but slightly. In the polar regions the clouds are sometimes so white, as to be with difficulty distinguished from the snow. They are believed to be clouds since they usually have hazy boundaries, since they are seen to shift, to form, and to disappear and sometimes to project beyond the limb and terminator. After they have disappeared at the poles, the ground is often seen to be white with freshly fallen snow.

The clouds are sometimes so widespread and numerous, or perhaps so thin, like our cirrus, as to partially conceal the detail of a whole hemisphere. This was the case in 1894, and again at one of the more recent oppositions. Photography shows (Harvard Annals **53**, 167) that an equatorial belt of cloud is often present, but this must be very thin, since it has not as yet been observed visually. As regards color, it may be noted that our own terrestrial clouds are by no means as white as snow. Sometimes when the sun is low and behind us, two clouds may be seen, the nearer of which is much darker than the other, though it is not possible for either of them to be in shadow. The cause of this seems to be a matter of theoretical interest which has been neglected by our meteorologists.

The more conspicuous Martian clouds lie along the limb of the planet, where their existence can be most readily detected by their irregular distribution. They are also found upon the terminator, especially near opposition, but on account of their wider separation from one another they are not so conspicuous there as upon the limb. Since they are found both at sunset and sunrise, it is believed that cloudy nights are not infrequent upon the planet. On account of its comparatively low pressure, the atmosphere of Mars must at certain seasons contain a larger proportion of water vapor than that of the earth. Some of this would be precipitated at night by the cold, and cloudy nights are therefore what we might naturally expect.

It is believed that the annual circulation of moisture from pole to pole takes place upon Mars as upon the Earth, chiefly by floods and through the atmosphere. Upon the Earth our floods are taken care of, except in a small way, cosmically speaking, by our oceans, but on Mars they must be much more severe. Even upon the Earth, however, where large masses of land occur and the snow fall is heavy, as in Siberia, the spring floods offer a startling demonstration of the intensity of our sunlight. Compared to one of these huge Siberian

freshets, our own western floods sink into insignificance. On Mars it is thought that the first description of one of these semi-annual cataclysms is given in Astronomy and Astrophysics, 1892 **11**, 668. At the present writing another one is in progress, this time starting from the north polar cap. An account of it will appear in our next report.

We have no means of knowing what is the pressure of the Martian atmosphere, but as far as observational evidence is concerned it might differ from that of the earth only in proportion to the intensity of gravitation at the surfaces of the two planets. On a clear night we find from a series of observations that southern stars of the fifth magnitude, crossing our meridian at an altitude of 7° to 8° have the same brilliancy as stars of the sixth magnitude near the zenith. Their light is therefore reduced by sixty per cent. If our earth were viewed from such a distance that its angular diameter was 15″, then the brilliancy of its surface would be reduced by sixty per cent at a distance of 0″.3 from the limb, that is in those portions of the world where the atmosphere was perfectly clear. Whether the light of Mars at this distance from the limb, where unaffected by clouds, is reduced as much as this, we have no means of knowing, but it is certain that the best photographs show some falling off of the light as we approach the edge of the disk, when no planetary clouds or haze are present. Over the high plateau of the Andes, in western Bolivia, the cumulus clouds rise to a height of six miles above sea level. If the Martian atmosphere were equal to our own, on account of the diminution of the surface gravity, we should expect them to rise two and a half times as high. The best observations of clouds on the terminator indicate an altitude of fifteen to twenty miles. While our present information is quite inadequate to settle the question of the surface pressure of the atmosphere of Mars we may conclude that it is likely to lie between one-half and one-tenth of that found at the surface of the earth.

The canals and lakes of Mars are never visible with any aperture however large, unless the seeing reaches at least 8 on the writer's "Standard Scale". Since it is believed that this quality of seeing is never attained in our northeastern states, it is hopeless for readers in that section of the country to look for them. Certainly the writer has never succeeded in seeing them at Cambridge. He has with a 6-inch aperture, however, and a magnification of 300 to 400, been able to see the changing colors upon the disk, especially the greens of early spring, which are now beginning to appear, and the variation in size of the polar caps.

An early paper on the planet's meteorology is given in the Harvard Annals **53**, 155. I believe the subject has not been treated by

other observers. The earliest, perhaps the only detailed account of the color changes on the planet will be found in Astronomy and Astrophysics 1892 **11**, 449 and 545.

In describing what he sees, the writer proposes to use terrestrial terms, but if the reader feels doubt as to their correct interpretation, for the word "snow" he may substitute "white spot", for "cloud" "bright yellow or yellowish white spot," and for "vegetation" "grey or green spot." Each month the changes described will be preceded by a table giving the data of the observations. The observations themselves will be described under four headings: Snow, Clouds, Colors and Shading, Canals and Lakes. It is to be noted that with the approach of daylight the surface of the planet becomes strikingly more red in appearance, all observations of color, in order to be comparable, must therefore be made while the sky is still dark. The daylight color is, however, undoubtedly the true one. The surface of the planet will be divided into six sections, each section extending through 60° of longitude, as follows:—

Section	**1**	330° to 30°	Section	**4**	150° to 210°
"	**2**	30 " 90	"	**5**	210 " 270
"	**3**	90 "150	"	**6**	270 " 330

In describing the canals and lakes the date of each observation will be followed by the number of the section in which the central meridian of the disk lay. The changes that occurred in each section can thus be more readily detected. Reference to the visibility of other features of the planet, such as "gulfs" and "regions" will occasionally be made under this heading.

In the following table of data the first two columns give the number of the observation and its date, the third the heliocentric longitude of the planet, and the fourth the corresponding equivalent date in the terrestrial year, based on Professor Lowell's determination that the Vernal Equinox of Mars, corresponding to March 20 for the earth, lies in heliocentric longitude 86°. The fifth column gives the longitude of the central meridian of the planet, the sixth the latitude of the center of the disk, and the seventh the same as seen from the sun. The eighth column gives the angular diameter, and the last the quality of the seeing on the writer's Standard Scale, described in the Harvard Annals **61**, 29, extended to 12, 10 being perfect for a 5-inch (12.7 cm) aperture, and 12 for one of 11 inches (28 cm).

Report of Observations extending from July to November.

TABLE OF DATA.

No.	1913	H.L. °	T.D.	Long. °	Lat. °	Sun °	Diam. ″	Seeing
1	July 27	18	Jan. 11	180	—10	—22	6.2	10
2	Aug. 6	24	" 17	92	— 8	—21	6.5	8
3	" 14	29	" 22	4	— 6	—20	6.7	9
4	" 25	35	" 28	262	— 3	—19	7.0	6
5	Sept, 2	40	Feb. 2	183	— 1	—17	7.2	10
6	" 13	46	" 8	80	+ 2	—16	7.6	8
7	" 17	49	" 11	36	+ 3	—15	7.8	8
8	" 30	56	" 18	258	+ 5	—12	8.4	9
9	Oct. 12	62	" 24	160	+ 7	—10	9.1	9
10	" 19	66	" 28	94	+ 8	— 9	9.5	8
11	" 30	72	Mar. 6	346	+ 9	— 6	10.3	9

SNOW.

When first observed no snow could be detected upon the planet, but the north polar zone was enveloped in cloud, as indicated by its bright yellow color, and the pole itself was turned away from us, as shown by the table, at an angle of 10°. The south polar zone was distinctly reddish, as far as the pole itself, and was apparently clear of cloud. August 14 a greenish white spot was seen in the extreme north, extending along the limb some 20°. It was whitish for about 20° farther, and then faded into yellow. The greenish white is probably a contrast effect, and quite different from the greenish grey due to vegetation, which will be noted later. This seems to have been the first appearance of snow. Its diameter was 1300 miles, assuming it to continue past the terminator in the same direction to the limb. This would indicate that the snow cap had at this time reached as far south as mean latitude 72°. At the next observation the pole was enveloped in cloud, but by September 2 a slight greenish tint was again seen, and the border was sharply defined against the reddish yellow of the soil. Diameter 1800 miles. Latitude 65°. On September 13 and 17 small areas of snow were visible through the clouds at the north, and on the latter date it was suspected through the clouds at the south pole as well. The center of the south polar cap does not coincide with the geographical pole, and the cap itself is more or less permanent. At the time of this observation it would be turned towards us as much as possible.

September 30 the snow was clearly seen at the north as a white patch, measuring 1700 miles in diameter. Latitude 67°. Vegetation beginning to spring up along its edge, or else marshy dark soil, forms a narrow irregular grey band, but not of the blue black intensity which is seen later in the season as the result of melting. October 12 the north polar regions were again of a yellowish color indicating cloud, but the grey border was more uniform and pronounced than before. Diameter of the snow 2300 miles. Latitude 58°. October 19, clouds at the limb

yellow; over the snow whitish yellow. Diameter of snow 2100 miles. Latitude 61°. October 30, the northern white spot was at first described as greenish, but an hour later as drab or yellow, and not particularly bright, less bright in fact than a small area near the south pole, which was perhaps really snow. Diameter 2600 miles. Latitude 53°.

Clouds.

In July the only cloud detected was towards the north pole. August 6 it extended along the limb as far as the equator. August 14 it was unusually cloudy, 0.4 of the surface of the disk being enveloped in cloud. The north polar zone was practically clear, but the cloud nearly reached the central meridian in the north temperate. The south temperate zone was the clearest of all, while the south polar was completely clouded. September 2 the disk was largely free from cloud, only the south polar and the southern part of the south temperate zones being still enveloped. It is probable that a narrow strip of cloud extended the length of the limb, but was not over 0″.3 in breadth. September 13 the cloud band along the limb was 0″.8 in breadth increasing to 1″.3 in the south temperate zone. General Martian haze. September 17 the cloud band along the limb had further increased in breadth to from 1″.0 up to 1″.2. September 30 two very sharply bounded luminous cloud masses stretched along the limb, the larger for about one thousand miles in the south temperate zone, the other near the equator. From the latter a band of less brilliant cloud 0″.8 in breadth reached to the south polar cap, which seemed to be free of cloud. Even in the course of a couple of hours these clouds materially changed in shape, size, and brilliancy. October 12 a little cloud extended along the limb, but it was not continuous. October 19 the cloud over the planet was clearing, only a little lay along the limb, and none in the south temperate zone, which at this season of the year seems to be the clearest part of the planet. The band varied in breadth in different latitudes from 0″.8 to 0″.3. October 30 the same description applied, but more cloud was now found to the south and less to the north than before.

Colors and Shading.

In the first observation the surface south of the southern seas was quite as red as to the north of them. In the second the red still persisted, but by August 14 it had become very faint. August 25 the color is described as orange, turning again to red September 2. September 13 the red is very faint as if seen through a general Martian haze. This longitude on the planet, which generally presents very clearly marked details, was extremely indistinct through Octobor. A very slight darkening just to the south of the clouds covering the northern snow

cap was detected, and this became much more pronounced and extended in the next observation, September 17. The snow cap was still covered and the darkening was broad and faint, but extended now across the north temperate zone following the course of the Ganges to Auroræ Sinus. Its breadth was about 400 miles where it crossed the equator. This was the first evidence of the arrival of moisture from the north pole. Whether the darkening was due to vegetation or merely a change in the color of the soil, due to moisture, is not clear, but it apparently persisted, for at the next presentation of the region, October 30, it was if anything still more clearly marked, and had now broadened in a preceding, that is westerly, direction as far as Sinus Sabaeus, and measured some 1500 miles in width. On September 17 there was no red or even orange visible upon the planet, only yellow and grey, the former a little deeper towards the center of the disk, and the grey only faintly marked. A general haze seemed to envelop the whole planet. September 30. The clouds had now cleared from the snow, and a very narrow dark line bordering it on the south was seen for the first time. This was the first direct evidence of its melting. Although the snow was perfectly clear on September 2 and this line was then looked for, as we knew it should soon appear, it could not then be seen. The two canals, Hyblaeus and Nilosyrtis, appeared in the sketch of September 30, connecting the dark line with the northern seas. The former was 180 miles in width and led nearly due south to Hephaestus. The other was perhaps two-thirds as wide, but much darker, and led to a very dark large area in the Syrtis Major. The line bordering the snow was some 200 miles wide at the Fretum Anian west of Hyblaeus, but less than half that width to the east of it. The whole region north of Cimmerium and as far as Elysium, extending from the Sinus Titanum to the Syrtis Major, was dark, Libya and Aethiops, being of a lighter shade. The dark areas seem to spread to the north in these longitudes at this season. On October 12 a forked broad faint shading proceeded north-east and north-west from Titanum following somewhat the course of Tartarus Gigas. It was not seen again either before or after this date. The more striking features of October 30 have already been mentioned, but in addition we may note that the line bordering the melting polar cap had now so far broadened as to be described better as a band than a line. Its breadth varied in different places from 350 to 700 miles. At the Acidalium Mare it had so far darkened as nearly to equal Sabaeus, and the snow cap was clearly notched at that point. At the former presentation of this region, September 17, not a trace of this very conspicuous marking was visible.

CANALS AND LAKES.

July 27. **4** Cerberus and Erebus suspected rather than seen.
Aug. 6. **3** No identifiable detail.
Aug. 14. **1** Sinus Sabaeus.
Aug. 25. **5** Syrtis Major.
Sept. 2. **4** Cerberus, Orcus, Erebus, Antaeus, named in the order of visibility, the first being the most conspicuous. Trivium Charontis.
Sept. 13. **2** Fortunae, Chrysorrhoas, Ganges, Pithonius Lacus, Lunae Lacus. All very faint.
Sept. 17. **2** Ganges very wide and clearly marked. In strong contrast to its appearance four days earlier. The other canals and lakes had disappeared.
Sept. 30. **5** Nilosyrtis, Hyblaeus, Eunastos. The regions known as Libya and Aethiops were clearly shown and slightly shaded.
Oct. 12. **4** Gigas, Tartarus. Both very broad and faint. Sinus Titanum, Trivium Charontis and Ceraunius, the first very distinct.
Oct. 19. **3** Tithonius Lacus. The whole region south of it was dark, and it is surprising that neither Solis Lacus nor Lacus Phoenicis, both usually very marked features, and both near the central meridian, should be visible.
Oct. 30. **1** Orontes drawn, but described as uncertain. Sinus Sabaeus Sinus Aurorae, and Acidalium Mare clearly shown. Deucalionis Regio was also seen.

The canals most clearly visible during the three months covered by these observations were Cerberus, Erebus, and Ganges, each recorded twice, and Nilosyrtis and Hyblaeus, each recorded once.

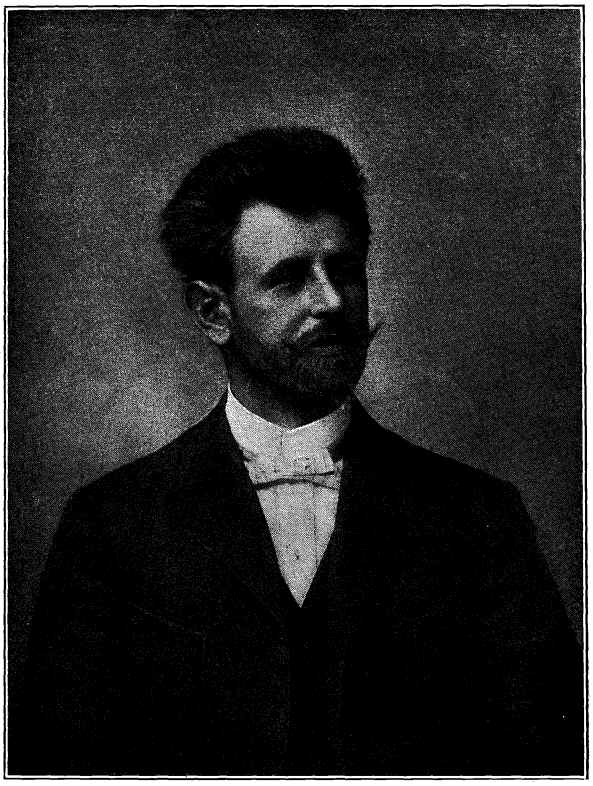
Mandeville, Jamaica, W. I.
Dec. 4, 1913.

JOHANN NEPOMUK KRIEGER.*

There can be no greater tragedy in scientific history than the death of an enthusiast who had just realised what should be his life-work and had just fitted himself to begin it in real earnest. Such a man was Johann Nepomuk Krieger, and such, almost, was his fate. He had, indeed, done two or three years' real work on the moon, which has fortunately been preserved for us; but it provides only imperfect material for one or two of the eight volumes which he had projected and serves chiefly perhaps to show what a loss the astronomical world

* From an Oxford Note Book (H. H. Turner) in *The Observatory*, August, 1913.

PLATE II



JOH. NEP. KRIEGER

1865-1902.