

# ALFRED RUSSEL WALLACE

Is Mars habitable? A critical examination of Professor Percival Lowell's book "Mars and its canals," with an alternative explanation

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# Alfred Russel Wallace

## Is Mars habitable? A critical examination of Professor Percival Lowell's book «Mars and its canals,» with an alternative explanation

### PREFACE

This small volume was commenced as a review article on Professor Percival Lowell's book, *Mars and its Canals*, with the object of showing that the large amount of new and interesting facts contained in this work did not invalidate the conclusion I had reached in 1902, and stated in my book on *Man's Place in the Universe*, that Mars was not habitable.

But the more complete presentation of the opposite view in the volume now under discussion required a more detailed examination of the various physical problems involved, and as the subject is one of great, popular, as well as scientific interest, I determined to undertake the task.

This was rendered the more necessary by the fact that in July last Professor Lowell published in the *Philosophical Magazine* an elaborate mathematical article claiming to demonstrate that, notwithstanding its much greater distance from the sun and its excessively thin atmosphere, Mars possessed a climate on the average equal to that of the south of England, and in its polar and sub-polar regions even less severe than that of the earth. Such a contention of course required to be dealt with, and led me to collect information bearing upon temperature in all its aspects, and so enlarging my criticism that I saw it would be necessary to issue it in book form.

Two of my mathematical friends have pointed out the chief omission which vitiates Professor Lowell's mathematical conclusions—that of a failure to recognise the very large conservative and *cumulative* effect of a dense atmosphere. This very point however I had already myself discussed in Chapter VI., and by means of some remarkable researches on the heat of the moon and an investigation of the causes of its very low temperature, I have, I think, demonstrated the incorrectness of Mr. Lowell's results. In my last chapter, in which I briefly summarise the whole argument, I have further strengthened the case for very severe cold in Mars, by adducing the rapid lowering of temperature universally caused by diminution of atmospheric pressure, as manifested in the well-known phenomenon of temperate climates at moderate heights even close to the equator, cold climates at greater heights even on extensive plateaux, culminating in arctic climates and perpetual snow at heights where the air is still far denser than it is on the surface of Mars. This argument itself is, in my opinion, conclusive; but it is enforced by two others equally complete, neither of which is adequately met by Mr. Lowell.

The careful examination which I have been led to give to the whole of the phenomena which Mars presents, and especially to the discoveries of Mr. Lowell, has led me to what I hope will be considered a satisfactory physical explanation of them. This explanation, which occupies the whole of my seventh chapter, is founded upon a special mode of origin for Mars, derived from the Meteoritic Hypothesis, now very widely adopted by astronomers and physicists. Then, by a comparison with certain well-known and widely spread geological phenomena, I show how the great features of Mars—the 'canals' and 'oases'—may have been caused. This chapter will perhaps be the most interesting to the general reader, as furnishing a quite natural explanation of features of the planet which have been termed 'non-natural' by Mr. Lowell.

Incidentally, also, I have been led to an explanation of the highly volcanic nature of the moon's surface. This seems to me absolutely to require some such origin as Sir George Darwin has given it,

and thus furnishes corroborative proof of the accuracy of the hypothesis that our moon has had an unique origin among the known satellites, in having been thrown off from the earth itself.

I am indebted to Professor J. H. Poynting, of the University of Birmingham, for valuable suggestions on some of the more difficult points of mathematical physics here discussed, and also for the critical note (at the end of Chapter V.) on Professor Lowell's estimate of the temperature of Mars.

BROADSTONE, DORSET, *October* 1907.

## CHAPTER I. EARLY OBSERVERS OF MARS

Few persons except astronomers fully realise that of all the planets of the Solar system the only one whose solid surface has been seen with certainty is Mars; and, very fortunately, that is also the only one which is sufficiently near to us for the physical features of the surface to be determined with any accuracy, even if we could see it in the other planets. Of Venus we probably see only the upper surface of its cloudy atmosphere.<sup>1</sup> As regards Jupiter and Saturn this is still more certain, since their low density will only permit of a comparatively small proportion of their huge bulk being solid. Their belts are but the cloud-strata of their upper atmosphere, perhaps thousands of miles above their solid surfaces, and a somewhat similar condition seems to prevail in the far more remote planets Uranus and Neptune. It has thus happened, that, although as telescopic objects of interest and beauty, the marvellous rings of Saturn, the belts and ever-changing aspects of the satellites of Jupiter, and the moon-like phases of Venus, together with its extreme brilliancy, still remain unsurpassed, yet the greater amount of details of these features when examined with the powerful instruments of the nineteenth century have neither added much to our knowledge of the planets themselves or led to any sensational theories calculated to attract the popular imagination.

But in the case of Mars the progress of discovery has had a very different result. The most obvious peculiarity of this planet—its polar snow-caps—were seen about 250 years ago, but they were first proved to increase and decrease alternately, in the summer and winter of each hemisphere, by Sir William Herschell in the latter part of the eighteenth century. This fact gave the impulse to that idea of similarity in the conditions of Mars and the earth, which the recognition of many large dusky patches and streaks as water, and the more ruddy and brighter portions as land, further increased. Added to this, a day only about half an hour longer than our own, and a succession of seasons of the same character as ours but of nearly double the length owing to its much longer year, seemed to leave little wanting to render this planet a true earth on a smaller scale. It was therefore very natural to suppose that it must be inhabited, and that we should some day obtain evidence of the fact.

### *The Canals discovered by Schiaparelli.*

Hence the great interest excited when Schiaparelli, at the Milan Observatory, during the very favourable opposition of 1877 and 1879, observed that the whole of the tropical and temperate regions from 60° N. to 60° S. Lat. were covered with a remarkable network of broader curved and narrower straight lines of a dark colour. At each successive favourable opposition, these strange objects called *canali* (channels) by their discoverer, but rather misleadingly 'canals' in England and America, were observed by means of all the great telescopes in the world, and their reality and general features became well established. In Schiaparelli's first map they were represented as being much broader and less sharply defined than he himself and other observers found by later and equally favourable observations that they really were.

### *Discovery of the Double Canals.*

In 1881 another strange feature was discovered by Schiaparelli, who found that about twenty canals which had previously been seen single were now distinctly double, that is, that they consisted of two parallel lines, equally distinct and either very close together or a considerable distance apart.

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<sup>1</sup> Mercury also seems to have a scanty atmosphere, but as its mass is only one-thirtieth that of the earth it can retain only the heavier gases, and its atmosphere may be dust-laden, as is that of Mars, according to Mr. Lowell. Its dusky markings, as seen by Schiaparelli, seem to be permanent, and they are also for considerable periods unchangeable in position, indicating that the planet keeps the same face towards the sun as does Venus. This was confirmed by Mr. Lowell in 1896. Its distance from us and unfavourable position for observation must prevent us from obtaining any detailed knowledge of its actual surface, though its low reflective power indicates that the surface may be really visible.

This curious appearance was at first thought to be due to some instrumental defect or optical illusion; but as it was soon confirmed by other observers with the best instruments and in widely different localities it became in time accepted as a real phenomenon of the planet's surface.

*Round Spots discovered in 1892.*

At the favourable opposition of 1892, Mr. W. H. Pickering noticed that besides the 'seas' of various sizes there were numerous very small black spots apparently quite circular and occurring at every intersection or starting-point of the 'canals.' Many of these had been seen by Schiaparelli as larger and ill-defined dark patches, and were termed seas or lakes; but Mr. Pickering's observatory was at Arequipa in Peru, about 8000 feet above the sea, and with such perfect atmospheric conditions as were, in his opinion, equal to a doubling of telescopic aperture. They were soon detected by other observers, especially by Mr. Lowell in 1894, who thus wrote of them:

"Scattered over the orange-ochre groundwork of the continental regions of the planet, are any number of dark round spots. How many there may be it is not possible to state, as the better the seeing, the more of them there seem to be. In spite, however, of their great number, there is no instance of one unconnected with a canal. What is more, there is apparently none that does not lie at the junction of several canals. Reversely, all the junctions appear to be provided with spots. Plotted upon a globe they and their connecting canals make a most curious network over all the orange-ochre equatorial parts of the planet, a mass of lines and knots, the one marking being as omnipresent as the other."

*Changes of Colour recognised.*

During the oppositions of 1892 and 1894 it was fully recognised that a regular course of change occurred dependent upon the succession of the seasons, as had been first suggested by Schiaparelli. As the polar snows melt the adjacent seas appear to overflow and spread out as far as the tropics, and are often seen to assume a distinctly green colour. These remarkable changes and the extraordinary phenomena of perfect straight lines crossing each other over a large portion of the planet's surface, with the circular spots at their intersections, had such an appearance of artificiality that the idea that they were really 'canals' made by intelligent beings for purposes of irrigation, was first hinted at, and then adopted as the only intelligible explanation, by Mr. Lowell and a few other persons. This at once seized upon the public imagination and was spread by the newspapers and magazines over the whole civilised world.

*Existence of Seas doubted.*

At this time (1894) it began to be doubted whether there were any seas at all on Mars. Professor Pickering thought they were far more limited in size than had been supposed, and even might not exist as true seas. Professor Barnard, with the Lick thirty-six inch telescope, discerned an astonishing wealth of detail on the surface of Mars, so intricate, minute, and abundant, that it baffled all attempts to delineate it; and these peculiarities were seen upon the supposed seas as well as on the land-surfaces. In fact, under the best conditions these 'seas' lost all trace of uniformity, their appearance being that of a mountainous country, broken by ridges, rifts, and canyons, seen from a great elevation. As we shall see later on these doubts soon became certainties, and it is now almost universally admitted that Mars possesses no permanent bodies of water.

## CHAPTER II.

### MR. PERCIVAL LOWELL'S DISCOVERIES AND THEORIES

#### *The Observatory in Arizona.*

In 1894, after a careful search for the best atmospheric conditions, Mr. Lowell established his observatory near the town of Flagstaff in Arizona, in a very dry and uniform climate, and at an elevation of 7300 feet above the sea. He then possessed a fine equatorial telescope of 18 inches aperture and 26 feet focal length, besides two smaller ones, all of the best quality. To these he added in 1896 a telescope with 24 inch object glass, the last work of the celebrated firm of Alvan Clark & Sons, with which he has made his later discoveries. He thus became perhaps more favourably situated than any astronomer in the northern hemisphere, and during the last twelve years has made a specialty of the study of Mars, besides doing much valuable astronomical work on other planets.

#### *Mr. Lowell's recent Books upon Mars.*

In 1905 Mr. Lowell published an illustrated volume giving a full account of his observations of Mars from 1894 to 1903, chiefly for the use of astronomers; and he has now given us a popular volume summarising the whole of his work on the planet, and published both in America and England by the Macmillan Company. This very interesting volume is fully illustrated with twenty plates, four of them coloured, and more than forty figures in the text, showing the great variety of details from which the larger general maps have been constructed.

#### *Non-natural Features of Mars.*

But what renders this work especially interesting to all intelligent readers is, that the author has here, for the first time, fully set forth his views both as to the habitability of Mars and as to its being actually inhabited by beings comparable with ourselves in intellect. The larger part of the work is in fact devoted to a detailed description of what he terms the 'Non-natural Features' of the planet's surface, including especially a full account of the 'Canals,' single and double; the 'Oases,' as he terms the dark spots at their intersections; and the varying visibility of both, depending partly on the Martian seasons; while the five concluding chapters deal with the possibility of animal life and the evidence in favour of it. He also upholds the theory of the canals having been constructed for the purpose of 'husbanding' the scanty water-supply that exists; and throughout the whole of this argument he clearly shows that he considers the evidence to be satisfactory, and that the only intelligible explanation of the whole of the phenomena he so clearly sets forth is, that the inhabitants of Mars have carried out on their small and naturally inhospitable planet a vast system of irrigation-works, far greater both in its extent, in its utility, and its effect upon their world as a habitation for civilised beings, than anything we have yet done upon our earth, where our destructive agencies are perhaps more prominent than those of an improving and recuperative character.

#### *A Challenge to the Thinking World.*

This volume is therefore in the nature of a challenge, not so much to astronomers as to the educated world at large, to investigate the evidence for so portentous a conclusion. To do this requires only a general acquaintance with modern science, more especially with mechanics and physics, while the main contention (with which I shall chiefly deal) that the features termed 'canals' are really works of art and necessitate the presence of intelligent organic beings, requires only care and judgment in drawing conclusions from admitted facts. As I have already paid some attention to this problem and have expressed the opinion that Mars is not habitable,<sup>2</sup> judging from the evidence then available, and as few men of science have the leisure required for a careful examination of so speculative a subject, I

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<sup>2</sup> *Man's Place in the Universe* p. 267 (1903).

propose here to point out what the facts, as stated by Mr. Lowell himself, do *not* render even probable much less prove. Incidentally, I may be able to adduce evidence of a more or less weighty character, which seems to negative the possibility of any high form of animal life on Mars, and, *a fortiori*, the development of such life as might culminate in a being equal or superior to ourselves. As most popular works on Astronomy for the last ten years at least, as well as many scientific periodicals and popular magazines, have reproduced some of the maps of Mars by Schiaparelli, Lowell, and others, the general appearance of its surface will be familiar to most readers, who will thus be fully able to appreciate Mr. Lowell's account of his own further discoveries which I may have to quote. One of the *best* of these maps I am able to give as a frontispiece to this volume, and to this I shall mainly refer.

*The Canals as described by Mr. Lowell.*

In the clear atmosphere of Arizona, Mr. Lowell has been able on various favourable occasions to detect a network of straight lines, meeting or crossing each other at various angles, and often extending to a thousand or even over two thousand miles in length. They are seen to cross both the light and the dark regions of the planet's surface, often extending up to or starting from the polar snow-caps. Most of these lines are so fine as only to be visible on special occasions of atmospheric clearness and steadiness, which hardly ever occur at lowland stations, even with the best instruments, and almost all are seen to be as perfectly straight as if drawn with a ruler.

*The Double Canals.*

Under exceptionally favourable conditions, many of the lines that have been already seen single appear double—a pair of equally fine lines exactly parallel throughout their whole length, and appearing, as Mr. Lowell says, "clear cut upon the disc, its twin lines like the rails of a railway track." Both Schiaparelli and Lowell were at first so surprised at this phenomenon that they thought it must be an optical illusion, and it was only after many observations in different years, and by the application of every conceivable test, that they both became convinced that they witnessed a real feature of the planet's surface. Mr. Lowell says he has now seen them hundreds of times, and that his first view of one was 'the most startlingly impressive' sight he has ever witnessed.

*Dimensions of the Canals.*

A few dimensions of these strange objects must be given in order that readers may appreciate their full strangeness and inexplicability. Out of more than four hundred canals seen and recorded by Mr. Lowell, fifty-one, or about one eighth, are either constantly or occasionally seen to be double, the appearance of duplicity being more or less periodical. Of 'canals' generally, Mr. Lowell states that they vary in length from a few hundred to a few thousand miles long, one of the largest being the Phison, which he terms 'a typical double canal,' and which is said to be 2250 miles long, while the distance between its two constituents is about 130 miles.<sup>3</sup> The actual width of each canal is from a minimum of about a mile up to several miles, in one case over twenty. A great feature of the doubles is, that they are strictly parallel throughout their whole course, and that in almost all cases they are so truly straight as to form parts of a great circle of the planet's sphere. A few however follow a gradual but very distinct curve, and such of these as are double present the same strict parallelism as those which are straight.

*Canals extend across the Seas.*

It was only after seventeen years of observation of the canals that it was found that they extended also into and across the dark spots and surfaces which by the earlier observers were termed seas, and which then formed the only clearly distinguishable and permanent marks on the planet's surface. At the present time, Professor Lowell states that this "curious triangulation has been traced over almost every portion of the planet's surface, whether dark or light, whether greenish, ochre, or brown in colour." In some parts they are much closer together than in others, "forming a perfect network of

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<sup>3</sup> This is on the opposite side of Mars from that shown in the frontispiece.

lines and spots, so that to identify them all was a matter of extreme difficulty." Two such portions are figured at pages 247 and 256 of Mr. Lowell's volume.

*The Oases.*

The curious circular black spots which are seen at the intersections of many of the canals, and which in some parts of the surface are very numerous, are said to be more difficult of detection than even the lines, being often blurred or rendered completely invisible by slight irregularities in our own atmosphere, while the canals themselves continue visible. About 180 of these have now been found, and the more prominent of them are estimated to vary from 75 to 100 miles in diameter. There are however many much smaller, down to minute and barely visible black points. Yet they all seem a little larger than the canals which enter them. Where the canals are double, the spots (or 'oases' as Mr. Lowell terms them) lie between the two parallel canals.

No one can read this book without admiration for the extreme perseverance in long continued and successful observation, the results of which are here recorded; and I myself accept unreservedly the substantial accuracy of the whole series. It must however always be remembered that the growth of knowledge of the detailed markings has been very gradual, and that much of it has only been seen under very rare and exceptional conditions. It is therefore quite possible that, if at some future time a further considerable advance in instrumental power should be made, or a still more favourable locality be found, the new discoveries might so modify present appearances as to render a satisfactory explanation of them more easy than it is at present.

But though I wish to do the fullest justice to Mr. Lowell's technical skill and long years of persevering work, which have brought to light the most complex and remarkable appearances that any of the heavenly bodies present to us, I am obliged absolutely to part company with him as regards the startling theory of artificial production which he thinks alone adequate to explain them. So much is this the case, that the very phenomena, which to him seem to demonstrate the intervention of intelligent beings working for the improvement of their own environment, are those which seem to me to bear the unmistakable impress of being due to natural forces, while they are wholly unintelligible as being useful works of art. I refer of course to the great system of what are termed 'canals,' whether single or double. Of these I shall give my own interpretation later on.

## CHAPTER III. THE CLIMATE AND PHYSIOGRAPHY OF MARS

Mr. Lowell admits, and indeed urges strongly, that there are no permanent bodies of water on Mars; that the dark spaces and spots, thought by the early observers to be seas, are certainly not so now, though they may have been at an earlier period; that true clouds are rare, even if they exist, the appearances that have been taken for them being either dust-storms or a surface haze; that there is consequently no rain, and that large portions (about two-thirds) of the planet's surface have all the characteristics of desert regions.

### *Snow-caps the only Source of Water.*

This state of things is supposed to be ameliorated by the fact of the polar snows, which in the winter cover the arctic and about half the temperate regions of each hemisphere alternately. The maximum of the northern snow-caps is reached at a period of the Martian winter corresponding to the end of February with us. About the end of March the cap begins to shrink in size (in the Northern Hemisphere), and this goes on so rapidly that early in the June of Mars it is reduced to its minimum. About the same time changes of colour take place in the adjacent darker portions of the surface, which become at first bluish, and later a decided blue-green; but by far the larger portion, including almost all the equatorial regions of the planet, remain always of a reddish-ochre tint.<sup>4</sup>

The rapid and comparatively early disappearance of the white covering is, very reasonably, supposed to prove that it is of small thickness, corresponding perhaps to about a foot or two of snow in north-temperate America and Europe, and that by the increasing amount of sun-heat it is converted, partly into liquid and partly into vapour. Coincident with this disappearance and as a presumed result of the water (or other liquid) producing inundations, the bluish-green tinge which appears on the previously dark portion of the surface is supposed to be due to a rapid growth of vegetation.

But the evidence on this point does not seem to be clear or harmonious, for in the four coloured plates showing the planet's surface at successive Martian dates from December 30th to February 21st, not only is a considerable extent of the south temperate zone shown to change rapidly from bluish-green to chocolate-brown and then again to bluish-green, but the portions furthest from the supposed fertilising overflow are permanently green, as are also considerable portions in the opposite or northern hemisphere, which one would think would then be completely dried up.

### *No Hills upon Mars.*

The special point to which I here wish to call attention is this. Mr. Lowell's main contention is, that the surface of Mars is wonderfully smooth and level. Not only are there no mountains, but there are no hills or valleys or plateaux. This assumption is absolutely essential to support the other great assumption, that the wonderful network of perfectly straight lines over nearly the whole surface of the planet are irrigation canals. It is not alleged that irregularities or undulations of a few hundreds or even one or two thousands of feet could possibly be detected, while certainly all we know of planetary formation or structure point strongly towards *some* inequalities of surface. Mr. Lowell admits that the dark portions of the surface, when examined on the terminator (the margin of the illuminated portion), do *look* like hollows and *may be* the beds of dried-up seas; yet the supposed canals run across these old sea-beds in perfect straight lines just as they do across the many thousand miles of what are admitted to be deserts—which he describes in these forcible terms: "Pitiless as our deserts are, they are but faint forecasts of the state of things existent on Mars at the present time."

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<sup>4</sup> In 1890 at Mount Wilson, California, Mr. W.H. Pickering's photographs of Mars on April 9th showed the southern polar cap of moderate dimensions, but with a large dim adjacent area. Twenty-four hours later a corresponding plate showed this same area brilliantly white; the result apparently of a great Martian snowfall. In 1882 the same observer witnessed the steady disappearance of 1,600,000 square miles of the southern snow-cap, an area nearly one-third of that hemisphere of the planet.

It appears, then, that Mr. Lowell has to face this dilemma—*Only if the whole surface of Mars is an almost perfect level could the enormous network of straight canals, each from hundreds to thousands of miles long, have been possibly constructed by intelligent beings for purposes of irrigation; but, if a complete and universal level surface exists no such system would be necessary.* For on a level surface—or on a surface slightly inclined from the poles towards the equator, which would be advantageous in either case—the melting water would of itself spread over the ground and naturally irrigate as much of the surface as it was possible for it to reach. If the surface were not level, but consisted of slight elevations and expressions to the extent of a few scores or a few hundreds of feet, then there would be no possible advantage in cutting straight troughs through these elevations in various directions with water flowing at the bottom of them. In neither case, and in hardly any conceivable case, could these perfectly straight canals, cutting across each other in every direction and at very varying angles, be of any use, or be the work of an intelligent race, if any such race could possibly have been developed under the adverse conditions which exist in Mars.

*The Scanty Water-supply.*

But further, if there were any superfluity of water derived from the melting snow beyond what was sufficient to moisten the hollows indicated by the darker portions of the surface, which at the time the water reaches them acquire a green tint (a superfluity under the circumstances highly improbable), that superfluity could be best utilised by widening, however little, the borders to which natural overflow had carried it. Any attempt to make that scanty surplus, by means of overflowing canals, travel across the equator into the opposite hemisphere, through such a terrible desert region and exposed to such a cloudless sky as Mr. Lowell describes, would be the work of a body of madmen rather than of intelligent beings. It may be safely asserted that not one drop of water would escape evaporation or insoak at even a hundred miles from its source.<sup>5</sup>

*Miss Clerke on the Scanty Water-supply.*

On this point I am supported by no less an authority than the historian of modern astronomy, the late Miss Agnes Clerke. In the *Edinburgh Review* (of October 1896) there is an article entitled 'New Views about Mars,' exhibiting the writer's characteristic fulness of knowledge and charm of style. Speaking of Mr. Lowell's idea of the 'canals' carrying the surplus water across the equator, far into the opposite hemisphere, for purposes of irrigation there (which we see he again states in the present volume), Miss Clerke writes: "We can hardly imagine so shrewd a people as the irrigators of Thule and Hellas<sup>6</sup> wasting labour, and the life-giving fluid, after so unprofitable a fashion. There is every reason to believe that the Martian snow-caps are quite flimsy structures. Their material might be called snow *soufflé*, since, owing to the small power of gravity on Mars, snow is almost three times lighter there than here. Consequently, its own weight can have very little effect in rendering it compact. Nor, indeed, is there time for much settling down. The calotte does not form until several months after the winter solstice, and it begins to melt, as a rule, shortly after the vernal equinox. (The interval between these two epochs in the southern hemisphere of Mars is 176 days.) The snow lies on the ground, at the outside, a couple of months. At times it melts while it is still fresh fallen. Thus, at the opposition of 1881-82 the spreading of the northern snows was delayed until seven weeks after the equinox: and they had, accordingly, no sooner reached their maximum than they began to decline. And Professor Pickering's photographs of April 9th and 10th, 1890, proved that the southern calotte may assume its definitive proportions in a single night.

"No attempt has yet been made to estimate the quantity of water derivable from the melting of one of these formations; yet the experiment is worth trying as a help towards defining ideas. Let us

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<sup>5</sup> What the evaporation is likely to be in Mars may be estimated by the fact, stated by Professor J.W. Gregory in his recent volume on 'Australia' in *Stanford's Compendium*, that in North-West Victoria evaporation is at the rate of ten feet per annum, while in Central Australia it is very much more. The greatly diminished atmospheric pressure in Mars will probably more than balance the loss of sun-heat in producing rapid evaporation.

<sup>6</sup> Areas on Mars so named.

grant that the average depth of snow in them, of the delicate Martian kind, is twenty feet, equivalent at the most to one foot of water. The maximum area covered, of 2,400,000 square miles, is nearly equal to that of the United States, while the whole globe of Mars measures 55,500,000 square miles, of which one-third, on the present hypothesis, is under cultivation, and in need of water. Nearly the whole of the dark areas, as we know, are situated in the southern hemisphere, of which they extend over, at the very least, 17,000,000 square miles; that is to say, they cover an area, in round numbers, seven times that of the snow-cap. Only one-seventh of a foot of water, accordingly, could possibly be made available for their fertilisation, supposing them to get the entire advantage of the spring freshet. Upon a stint of less than two inches of water these fertile lands are expected to flourish and bear abundant crops; and since they completely enclose the polar area they are necessarily served first. The great emissaries for carrying off the surplus of their aqueous riches, would then appear to be superfluous constructions, nor is it likely that the share in those riches due to the canals and oases, intricately dividing up the wide, dry, continental plains, can ever be realised.

"We have assumed, in our little calculation, that the entire contents of a polar hood turn to water; but in actual fact a considerable proportion of them must pass directly into vapour, omitting the intermediate stage. Even with us a large quantity of snow is removed aërially; and in the rare atmosphere of Mars this cause of waste must be especially effective. Thus the polar reservoirs are despoiled in the act of being opened. Further objections might be taken to Mr. Lowell's irrigation scheme, but enough has been said to show that it is hopelessly unworkable."

It will be seen that the writer of this article accepted the existence of water on Mars, on the testimony of Sir W. Huggins, which, in view of later observations, he has himself acknowledged to be valueless. Dr. Johnstone Stoney's proof of its absence, derived from the molecular theory of gases, had not then been made public.

*Description of some of the Canals.*

At the end of his volume Mr. Lowell gives a large chart of Mars on Mercator's projection, showing the canals and other features seen during the opposition of 1905. This contains many canals not shown on the map here reproduced (see frontispiece), and some of the differences between the two are very puzzling. Looking at our map, which shows the north-polar snow below, so that the south pole is out of the view at the top of the map, the central feature is the large spot Ascræus Lucus, from which ten canals diverge centrally, and four from the sides, forming wide double canals, fourteen in all. There is also a canal named Ulysses, which here passes far to the right of the spot, but in the large chart enters it centrally. Looking at our map we see, going downwards a little to the left, the canal Udon, which runs through a dark area quite to the outer margin. In the dark area, however, there is shown on the chart a spot Aspledon Lucus, where five canals meet, and if this is taken as a terminus the Udon canal is almost exactly 2000 miles long, and another on its right, Lapadon, is the same length, while Ich, running in a slightly curved line to a large spot (Lucus Castorius on the chart) is still longer. The Ulysses canal, which (on the chart) runs straight from the point of the Mare Sirenum to the Ascræus Lucus is about 2200 miles long. Others however are even longer, and Mr. Lowell says: "With them 2000 miles is common; while many exceed 2500; and the Eumenides-Orcus is 3540 miles from the point where it leaves Lucus Phœniceus to where it enters the Trivium Charontis." This last canal is barely visible on our map, its commencement being indicated by the word Eumenides.

The Trivium Charontis is situated just beyond the right-hand margin of our map. It is a triangular dark area, the sides about 200 miles long, and it is shown on the chart as being the centre from which radiate thirteen canals. Another centre is Aquæ Calidæ situated at the point of a dark area running obliquely from 55° to 35° N. latitude, and, as shown on a map of the opposite hemisphere to our map, has nearly twenty canals radiating from it in almost every direction. Here at all events there seems to be no special connection with the polar snow-caps, and the radiating lines seem to have no intelligent purpose whatever, but are such as might result from fractures in a glass globe

produced by firing at it with very small shots one at a time. Taking the whole series of them, Mr. Lowell very justly compares them to "a network which triangulates the surface of the planet like a geodetic survey, into polygons of all shapes and sizes."

At the very lowest estimate the total length of the canals observed and mapped by Mr. Lowell must be over a hundred thousand miles, while he assures us that numbers of others have been seen over the whole surface, but so faintly or on such rare occasions as to elude all attempts to fix their position with certainty. But these, being of the same character and evidently forming part of the same system, must also be artificial, and thus we are led to a system of irrigation of almost unimaginable magnitude on a planet which has no mountains, no rivers, and no rain to support it; whose whole water-supply is derived from polar snows, the amount of which is ludicrously inadequate to need any such world-wide system; while the low atmospheric pressure would lead to rapid evaporation, thus greatly diminishing the small amount of moisture that is available. Everyone must, I think, agree with Miss Clerke, that, even admitting the assumption that the polar snows consist of frozen water, the excessively scanty amount of water thus obtained would render any scheme of world-wide distribution of it hopelessly unworkable.

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