

## PLANETARY PHOTOGRAPHY.

THE recording on photographic plates of the canals of Mars is as significant from a technical point of view as it has proved of widespread interest in its result; for the method which alone rendered success possible had first to be developed, previous celestial photographic processes being inadequate to the task. At the request of the editor of NATURE, I propose to give some account of the method pursued, and the more gladly in that it is evident from attempts to follow it that its principles are as yet as much a *terra incognita* as have for so long remained the canals themselves. The process is the outcome of four years' study by Mr. Lampland, who, to a knowledge of the end desired, acquired from visual work on the planet, added experimental research on the means to attain it. Of the difficulty of the subject the best testimony are the words Schiaparelli wrote the writer on receiving in 1905 the first prints from the plates:—"I would never have believed the thing could be done."

The fundamental distinction between planetary photography and photography of the stars is that with the former definition, not illumination, is the primary point. To imprint upon the plate such delicate tracery as the canals of Mars requires a definition so far beyond celestial photography in general as to constitute a class of work by itself. For one is here concerned with quantities of the second order of minuteness.

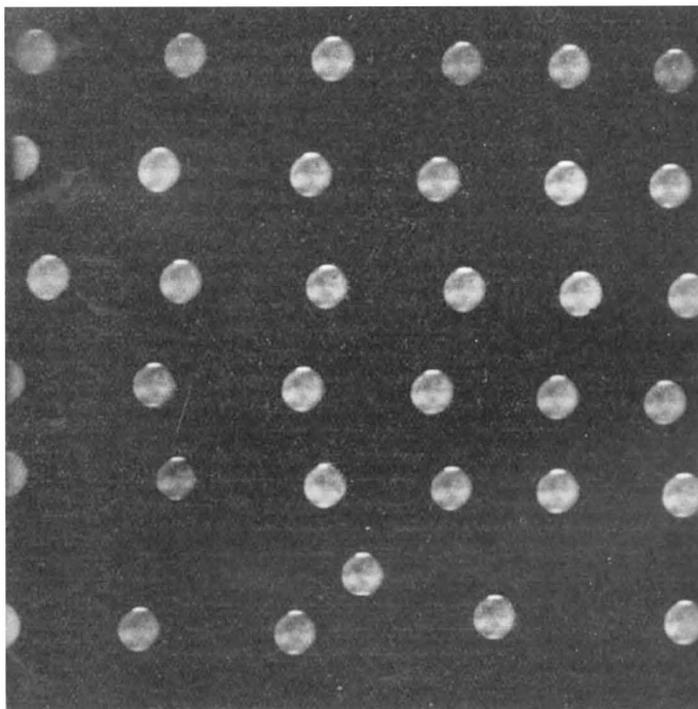
Definition, therefore, had to be studied. The chief disturber of the image is the atmosphere. A knowledge of how this conditions the seeing is, then, the first requisite to success. Living as we do under a gaseous ocean in constant turmoil, no image from beyond it stays perfect for long, soon being either distorted or displaced by the shifting refraction of differently dense layers of air. The effect we notice every day in the twinkling of the stars. To educate the eye to sift the fleeting impressions it receives is thus the first step to becoming an observer of Mars. Distrust of its own revelations because of their short-livedness is one chief cause of failure to see the canals. More, not less, is a like handicap true of the camera; for the eye is some thousands<sup>1</sup> of times as sensitive as the films we can employ. So that at first it would seem hopeless to attempt to part the good moments of definition from the bad, and thus to prevent the superposition of a poor or shifted image upon a clear-cut one, to the resulting disheartenment of a general blur.

To catch the planet's fugitive expressions of itself, speed of exposure becomes imperative; and that as many such as possible might be seized, a special camera had to be devised, something which should realise the demon-machine of Clerk-Maxwell for images in place of molecules, to let the good ones through and stop the bad. The mechanical part of this Mr. Lampland contrived by a plate-holder fitted with a lateral ratchet motion worked by a bulb, and capable of being pushed up and down after each line of images had been secured. At the opposition of 1905 this camera was worked without guiding, as the exposure time seemed not to necessitate it, but for that of 1907 Mr. Lampland suggested the use of, and fitted on, the 6-inch as a finder. In spite of the very short exposure possible, the guiding thus introduced turned out an improvement.

The next difficulty in definition lies with the glass. In spite of its name, no achromatic lens is achromatic. Though the departure from perfection is practically

imperceptible to the eye, such is not the case with the sensitised film; for the rays of different colours form their images in different focal planes. Of these, the eye selects what it will attend to, while the camera cannot, and so, on the plate, if an image made by one colour be in focus, it must perforce be surrounded by others that are not. A reflector, of course, avoids this blur of superposition, since all the rays are brought to one focus, but, on the other hand, it introduces more serious errors of spherical aberration; for not only does any want of figuring or of sag in the mirror, but any disturbance in the air produces three times the distortion it does in the glass. It is thus problematic whether a reflector can ever be used for such fine work, though we intend to give it a trial with a 3-foot mirror.

To secure approximate monochromatism, and thus a more clear-cut image, a screen or filter of coloured glass, or of a coloured solution between glass, had to be used to cut off certain of the rays. This device is the same that was used visually by Schiaparelli, and that has been used at Flagstaff in like research, though it has not been



Photographs of Mars; Ganges region. Taken by Prof. Percival Lowell at Flagstaff, July 28, 1907.

found there so effective as a neutral-tinted glass, because, as mentioned above, the eye does its own sifting for the rays it elects to observe. Photographically it was first employed by Ritchey in his photographs of the moon, and here its value is inestimable. The general method of making the screens is to determine first the colour-curve of the objective, that is, the curve in which the abscissæ represent the wave-lengths of the rays of differing refrangibility and the ordinates their focal lengths. From this curve it becomes possible to select what rays shall be allowed to pass to secure a sufficient approximation to monochromatisation, and the screen is then coloured to attain the result. In the construction of such screens Mr. R. J. Wallace is preeminent, and by him in this manner were made those for the Flagstaff glass.

The next crux entered with the plates. In consequence of the greater relative deviation in focal length suffered by the blue rays, which are the ones most actinic, and those to which the ordinary plates are sensitised, such plates cannot be used for interplanetary photography. To get enough light with them to approach instantaneity the

<sup>1</sup> With the Flagstaff objective diaphragmed down to 12 inches, and with a power of 303 further weakened by a screen that takes off at least three-quarters of the light the eye sees on Mars' canals in less than the twentieth of a second which it takes the plate two seconds to register with a magnification of 150 and under the full aperture of the 24-inch glass.

blue rays would have to be made use of, and they would irretrievably blur the image. Plates sensitised to other parts of the spectrum must be employed, and as it has not been possible to make such adapted only to the yellow and orange rays, a coloured screen must be used in connection with them. Only when more restricted emulsions shall have been produced will it become feasible to dispense with the sifter.

The plates most nearly giving us what we wanted proved to be Cramer's isochromatic instantaneous plates. They are neither instantaneous nor isochromatic, but their two negatives nevertheless combine to the best affirmative it is now possible to obtain; for beyond their mountain mass of reaction in the violet and blue, to speak figuratively of their curve of sensitiveness, they have a hillock in the yellow with sides of great abruptness. By Mr. Lampland, who carefully experimented with every kind of plate, these were found, and for the above reason, to yield the best results in the way of speed *with* definition. Their chief drawback consists in their not being so finely grained as one could wish.

This brings us to another difficulty that had to be encountered. In the sensitising of plates speed is inevitably associated with coarseness of grain, and *vice versa*. Finely grained emulsions are necessarily slow. To avoid the Scylla of over-exposure is to fall into the Charybdis of under-definition. As speed must be got at all hazards, the images of Mars are not so fine in texture as those securable of earthly scenes, as, for example, by lantern-slide plates. This is to be remembered in scanning the images. Anything beyond a slight magnification of the original negatives results in perceptible, though not always perceived, blurring of the details due to the showing of the grain. Photographic experts will thoroughly appreciate this, and trace the linearity of the canals clearly through its partial disguise.

After all other points have been attended to, there still remains the question of aperture; for the smaller the aperture the sharper the definition for the same sized magnification, the gain from the point of view of the air-waves vastly exceeding the loss due to a larger spurious disc. Thus with an image magnified to four hundred diameters, a 12-inch gives ninety-nine times out of a hundred more clear-cut detail than a 24-inch. This, which is so decided a gain in visual work, is partially offset in photographic work by the necessary increase in exposure time, and the consequent greater chance of mixing poor moments with the good. As the exposure time decreases inversely as the square of the radius of the glass, while the improved definition increases inversely as that radius, Mr. Lampland, in 1907, used only the full aperture of the 24-inch. In this decision I quite concur from the results at the last opposition, merely adding the gloss that with the larger aperture one is more certain of a good image; with the smaller, one will score an even greater success on exceptional occasions. This, of course, is to be taken within limits.

By the general method I have outlined Mr. Lampland secured the first photographs of the canals at the opposition of Mars in 1905. Some fifty of the canals show upon his plates. This success was entirely due to his exhaustive study and attention to all the factors I have formulated. During the time between 1905 and 1907 Mr. Lampland continued his research, and in June, 1907, took his first plates at the opposition just passed. The images showed a marked advance. In 1905 he had registered the Nilokeras double ( $12^\circ$  apart). In June, 1907, the Gihon ( $5^\circ.0$  apart) stood duplicate in his photographs, while the Euphrates ( $4^\circ$  apart) pretty certainly showed in the same manner, though from principles of conservatism I was not willing to commit myself to its announcement. At the same time plates were taken by me showing in like manner a great number of single canals, and the double Gihon and almost unquestionably the double Euphrates appear. For the same opposition an expedition was undertaken by the Lowell Observatory to the Andes under the charge of Prof. Todd, Mr. E. C. Slipher, of the Lowell Observatory, being detailed upon it armed with a duplicate of our apparatus, and thoroughly coached beforehand by Mr. Lampland in its employ. Mr. Slipher, by whom all the work of the expedition on Mars, both photographic and

delineatory, was done, secured plates in July at Alianza, Chile. The place had been chosen primarily because of its lying in the solar eclipse belt, Prof. Todd being desirous of observing the annular eclipse there, but it proved, although but 4000 feet above sea-level, probably the best locality that could have been selected. By a skill and assiduity deserving of the highest praise, Mr. Slipher obtained some 10,000 images of the planet in the course of a couple of weeks. Owing to the remarkable steadiness of the air and the high altitude of the planet, his plates show a wonderful amount of detail. The doubling of the Gihon and of the Euphrates previously registered at Flagstaff were also exhibited on them, besides canals and oases in profusion. As an instance of the latter I may mention the distinct showing of the two little oases in the Trivium. His drawings were no less remarkable. As an example, the double Ganges, which for two oppositions now the writer has observed stronger on its right or western side than on its eastern, appears with this same differentiation in Mr. Slipher's picturing, although he had no previous acquaintance of the fact. Having discovered that he has an eye for planetary detail, he is to continue such study in the future.

The future promises even more than the past has fulfilled. Several improvements have been effected, or are in contemplation, which were not put into operation at the opposition of 1907. One of them is a new screen devised by the writer. Though both conceived and constructed before the opposition, it was only tested this last summer, but enough to show an improvement in definition from its use. Its basic principle was the integration of the greatest amount of illumination with the least focal difference of wave-length. To explain the idea, suppose that the light reaching the plate for each ray be weighted according to its proximity for focal length to a given focal distance by an inverse function of such departure, the function becoming negative after a certain discrepancy because the inclusion of the ray then does more harm than good. Suppose this light summed for all the rays between certain limits. The most effective screen will be that for which the integral is a maximum. The point up to which the rays should be cut off, as indicated by an examination of the colour curve of the 24-inch glass, seemed to lie at  $\lambda=5000$ , and for this, accordingly, I asked Mr. Wallace to construct a special screen. The result, though for some reason not so effective practically with bathed plates as was theoretically to be expected, proved successful with Cramer's isochromatic instantaneous plates, owing to the insensitiveness of the plate for the red and ultra-red rays, and to the fact that  $\lambda=5000$  marked a minimum in its action followed by a rise.<sup>1</sup>

Other devices which should improve the process are also to be practised, and these, with the increased presentation of the planet's disc, should result in another decided advance in photographic presentation; for the planet will in 1909 be more advantageously placed for Flagstaff on three counts:—

- (1) A larger disc.
- (2) A greater altitude.
- (3) A more developed condition of the canals due to the advance in the Martian season.

In spite of the interest which the taking of such photographs has caused, it must be remembered that after all the eye remains our most potent instrument of research. So thoroughly was this realised at Flagstaff that the photographs were originally undertaken simply with a view to their educational value. Inasmuch as these photographs in good air are superior to untrained eye observations in a poor one, they serve to dispel directly a modicum of doubt, though they cannot at present equal what the trained eye can see under similar conditions. But indirectly they do more; for they corroborate completely, so far as they go, visual observations which have been so extensively denied, and establish, therefore, a very strong presumption that those visual detections are true also beyond what the photographic plate has power to portray. In this connection it is interesting to note that more than one astronomer who has seen the canals from a middle ground of definition neither good nor bad has

<sup>1</sup> For a more detailed account of the device, see the Lowell Observatory Bulletin, No. 31.

adduced the photographs as he interprets their features as corroborating his own observations, forgetting that this implies that he sees the originals only a fraction as well as he should.

Yet even so the photographs have surpassed our hopes, for they disclose more than one could have ventured to imagine. An eye versed in photographic perception and interpretation will easily see in them the canals as lines and the little spots, the oases, at their junctions. Indeed, the camera has shown itself capable of rising beyond the confirmatory into the discovery stage; for one of the plates of the writer was instrumental in the detection of a new canal. A stranger appeared on the plate which when searched for visually in consequence proved to be there. At the next opposition, with our newly devised improvements and with the planet so much nearer the zenith for northern observers, it is confidently to be expected that we shall do still more.

PERCIVAL LOWELL.

### HYDROLOGY IN THE UNITED STATES.

IN some of the more recent reports on the hydrology of the United States, the book is prefaced by a general statement as to the intention and scope of the surveys that are being carried out by the geological department of the Government relating to the water resources of the country.

Water supply is regarded as one of the principal national assets, and of more importance to the life and pursuits of the people than any other natural resource. In the arid States the limit of agricultural development is determined by the amount of water available for irrigation. In other States, where the rainfall is greater and more evenly distributed throughout the year, the lack of rain at the proper season often reduces a crop to one-half what it would have been with one additional wetting at the time most needed. Storage, providing water for use when most wanted, will in such a case be as beneficial as where irrigation has to be depended on exclusively. This is especially the case in those districts where market gardening is one of the most profitable agricultural pursuits. Here irrigation is a necessity for making the business profitable.

The increase in the population of cities and towns makes necessary additional water supplies for domestic and industrial uses, in procuring which both the quantity and quality of the water that can be obtained must be considered.

The location of manufacturing plants may depend largely on the water-power facilities and the character of the water. Electric transmission of power has led to the utilisation of water-power for the operation of manufacturing establishments and lighting plants. Water-power is also largely used in some States for log driving, lumbering, and saw-mills, and also for the manufacture of paper from wood pulp and straw.

For all or any of these purposes a knowledge of the flow of the streams and of the conditions affecting that flow, based on trustworthy data, and of the underground resources is essential. For the want of this many schemes for water supply have ended in failure, the plans being made without sufficiently trustworthy information.

The United States Geological Survey has therefore, by means of appropriations by Congress, for several years systematically been engaged in obtaining records of stream flow, the number of stations at which streams were under observation in 1906 being 700. Records are also obtained in regard to floods, precipitation, the relation of the rainfall to run-off of water, evaporation, water pollution, the flow of underground streams, the use of artesian and surface wells, and generally all matters relating to water supply.

The reports relating to the above matters, and also as to the water resources of different States and districts, are issued from time to time, upwards of 200 reports having already been issued.

Notices of these reports, directing attention especially to those papers which are of general interest, have appeared in NATURE at various times.

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The most recent reports of which we have received copies,<sup>1</sup> eleven in number, relate to the water resources of Georgia, New England, and other districts, the information contained in them being principally of local interest, except Paper No. 201, which has an introduction dealing with the system followed in obtaining the discharge of streams.

### THE TESTING OF MATERIALS.

THE official report of the proceedings of the fourth Congress of the International Association for the Testing of Materials was recently issued. The congress was held at Brussels in September, 1906, and the report contains a condensed account of the reports presented and a summary of the discussions upon the reports and papers. The congress met in three sections, one dealing with papers on metals, another with papers on cement and artificial stones, and the third dealing with miscellaneous investigations, such as protection of metals against rust, testing of timbers, rubber, &c. Before the sections began their proceedings, Prof. Schüle delivered an address dealing with the life and work of the late president and founder of the association, Ludwig von Tetmajer.

One of the most important matters discussed in the metal section was the method of testing notched bars; after a lengthy discussion the congress eventually adopted the following resolution:—"The congress recognises that the method of testing notched bars appears capable of giving extremely interesting results." The congress did not, however, adopt a resolution which was moved to the effect that the method should be experimentally introduced into certain specifications.

In regard to the subject of ball-pressure tests, the congress eventually adopted the following resolution:—"The present congress desires that in the acceptance of metallic materials tests of tenacity should be supplemented as often as possible by a determination of the Brinell hardness number, the latter test being performed for the object of collecting information."

During the meeting of the association a metal-testing laboratory was installed at Brussels in order to show in action the various modern processes employed in the testing of materials. The tests made were micrographic, determination of the critical points, impact tests on notched bars, Brinell ball tests, and shearing tests. The congress has published a small illustrated pamphlet descriptive of the various testing appliances which were at work in this metal laboratory, with a brief note on the results obtained.

T. H. B.

### UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The Vice-Chancellor gives notice that the election of a professor of agricultural botany will take place on Monday, March 16. Candidates for this professorship are requested to communicate with the Vice-Chancellor on or before Wednesday, March 11.

Sir Ernest M. Satow, G.C.M.G., has been appointed to the office of reader on Sir Robert Rede's foundation for the present year. The lecture will be given in the Senate house on Saturday, June 13.

LONDON.—In connection with the supplementary vote of 6000*l.* for the Imperial College of Science and Technology at South Kensington, being part of the annual Government subvention of 20,000*l.* to the college, Sir Philip Magnus inquired last Friday in the House of Commons whether the 20,000*l.* was in excess of the cost of maintenance of the Royal College of Science and the Royal School of Mines, which had been incorporated in the Imperial College. In reply, Mr. Lough explained that the grant of 20,000*l.* was arranged by the Board of Education under the late Government; in addition, the Imperial College would have the fees paid by students, including fees paid by the Board of Education for scholars nominated by the Board. In reply to a further inquiry by Sir Philip

<sup>1</sup> Water Supply and Irrigation Papers. (Washington: Government Printing Office.)