THE SHERMAN ASTRONOMICAL EXPEDITION

BY the courtesy of Prof. Peirce, Superintendent of the U.S. Coast Survey, I am permitted to lay before the readers of NATURE, at the request of its editor, a brief account of the operations and results of the party which was stationed during the months of June, July, and August last at Sherman, the summit of the Union Pacific Railway.

The expedition was organised under the auspices of the Coast Survey; the observations, other than those for determining the mere geographical and topographical constants of the station, being provided for from a special appropriation of 200,000 dols. granted by Congress, at the request of the Superintendent, and placed at his disposal for the purpose of securing a series of astronomical and meteorological observations at some elevated point on or near the Pacific Railway.

The party was under the charge of General R. D. Cutts, one of the most experienced officers of the Survey, and consisted of himself, Assistant Mosman, and Aid Colonna, with myself, my colleague Prof. C. F. Emerson, who was kind enough to act as my personal assistant, and a young friend, Mr. C. K. Wead; we had also a photographer, a mechanician, and a couple of servants. A detail of about a dozen of the most intelligent soldiers from Fort D. A. Russell at Cheyenne served as an escort, and

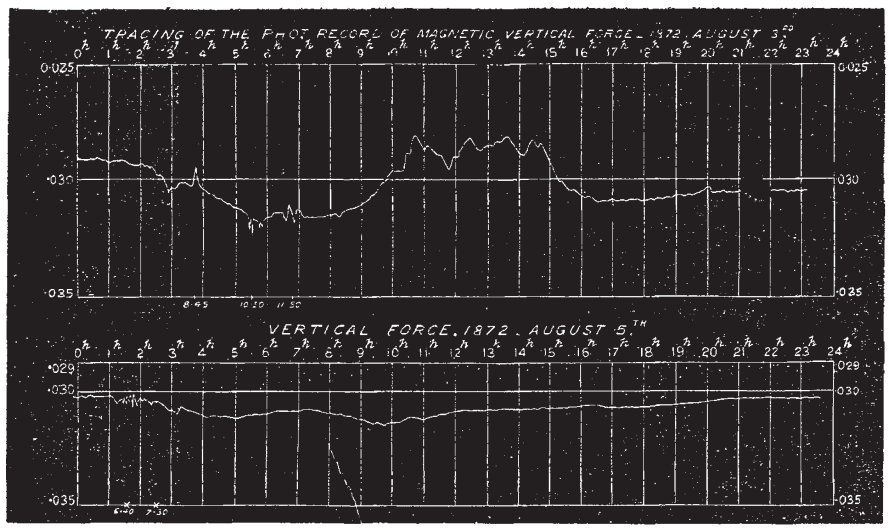

FIG. 1.

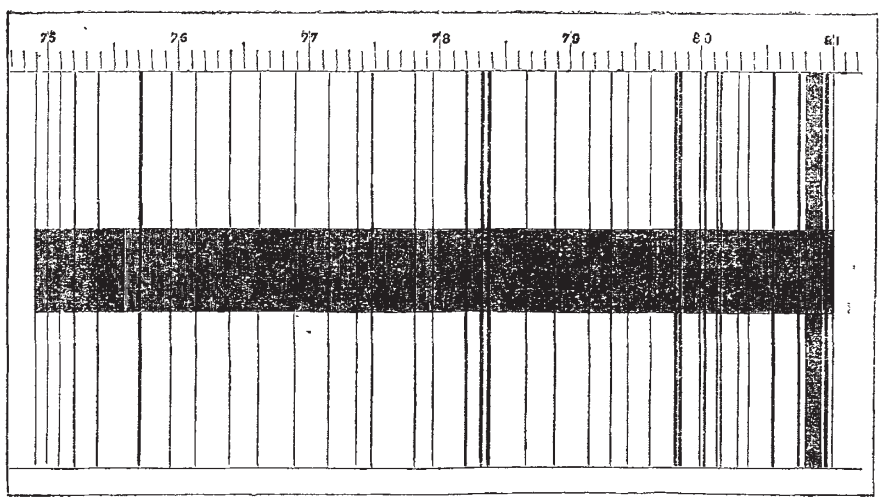

FIG. 2.—Spectrum of a Solar Spot.

were invaluable in keeping up the hourly series of meteorological observations, and in many other ways, as well as in protecting us from any undesirable attentions of our red brethren; not that the protection was ever actually needed, for we hardly saw half a dozen Indians during the whole summer, except as passengers upon the railway trains.

The station was established in June, but it was not until July that I was able to join the party with Prof. Emerson and Mr. Wead. Our instrument had been forwarded by express, and was already on the ground. It was the Dartmouth College equatorial, having an aperture of $9\frac{4}{10}$ in., with a focal length of 12 ft., provided with clockwork and all the usual accessories, and fitted with an

automatic spectroscope having the dispersive power of 13 prisms. The instrument was loaned for the occasion by the trustees of the College, who, for the good of science, have never hesitated to send their most valuable apparatus to any portion of the earth; and thus far, I am happy to say, have met with no loss in so doing.

Our observatories, one for the transit instrument, one for the meteorological apparatus, and one for the equatorial, were "shanties" of rough boards, placed upon the summit of a slight elevation, some 150 yards S.E. of the railway station, and some 40 or 50 ft. above the track. The altitude of the observatory was about 8,300 ft. above the sea; the approximate latitude was 44° 7′; the longitude about 1h. 53·2m. west of Washington, or 7h. 1·4m. west of Greenwich. I give only approximations, the accurate reduction of the observations being not yet completed.

To the east the horizon was bounded by hills of no great apparent elevation, nor was there anything in the general aspect of the nearer landscape to remind the careless observer of his altitude. To the north, at a distance of about three miles, but seeming not more than half a mile away, rose some picturesque piles of granite several hundreds of feet in height; to the north-west lay the so-called Laramie hills; and from the north-west to the south, across the broad green Laramie plains, toward the mountains, many of them capped with perpetual snow. In the south were Long's and Gray's peaks, some 60 miles away; nearly west lay somewhat nearer the great mass of Medicine Bow; and between them, over the lower ridges, rose some of the high mountains of the Colorado parks. None of these snow-capped peaks have an elevation of less than 13,000 ft., and several exceed 14,000.

Our principal object was to ascertain what advantage would accrue to astronomical, and especially to spectroscopic, work, by placing the instrument at a great elevation. Theory declares that the gain ought to be great, since it is certain that our atmosphere, by its continual currents, its impurities, and its reflective power, is a most serious hindrance to telescopic work, and at the height of 8,000 ft.—more than a fourth of the whole is left below. The experiment of Prof. Piazzi Smyth, in 1856, on the Peak of Teneriffe, had already given a practical demonstration of the fact, so far as relates to ordinary telescopic work; but that was before the day of spectroscopy.

Although, on account of unfavourable weather, the amount of work accomplished was to some extent diminished, the results obtained were of considerable interest and value.

In the first place, the geographical co-ordinates of the station were completely determined; so that henceforth it will be a reference point and base for all the numerous surveys, geological and others, which are going on in that part of the country.

Then a complete hourly meteorological record was obtained for nearly the whole of the months of June, July, and August, a record which, from the exceptional character of the station, on the very back-bone of the continent, must possess the highest value, unless the fact that the season was also an exceptional one should prevent us from applying confidently to other years the conclusions it would indicate.

If we may credit the residents of the country, especially an old trapper who had lived among the mountains for nearly twenty years, the amount of cloudy and rainy weather during the summer was most unusual. Deducting a single week, during which every night and the greater part of every day was fine, clear nights were very rare, and clear days only a little less so. Indeed during our whole stay there were but two afternoons during which work upon the sun could be kept up uninterruptedly from noon to sunset, though during the same time there were more than twenty mornings.

Undoubtedly the explanation of this state of things is to be found in the enormous quantity of snow which fell last winter, and was still, in the middle of July, lying 8 ft. deep on the plateau at the base of the Medicine Bow mount.

Whenever the sky was unclouded the air was usually of most exquisite transparency. At night multitudes of stars, invisible at lower elevations, were easily seen; so that it was estimated that nearly all the stars of the seventh magnitude were fairly within reach of the naked eye. For instance, in the quadrilateral which forms the bowl of the "Dipper" I could see distinctly nine stars, with glimpses of one or two more, while at home I can only perceive the three brightest of them.

The power of the telescope was correspondingly increased. Without being able to devote a great deal of time to stellar observation, I ascertained that, with my $9\frac{4}{10}$ inches of aperture, nearly everything could be fairly seen which, at the sea-level, is within the reach of a 12-inch object-glass.

Some most exquisite views of Saturn will always be remembered, in which, notwithstanding the planet's nearness to the horizon, the inner satellites, and the details and markings of the rings, especially a dark stripe upon the outer ring, about a third of its width from the outer edge, were clearly shown under powers ranging from 500 to 1,200.

But in the use of the spectroscope the advantage was even greater. At Hanover I had been able to make out a list of 103 bright lines in the spectrum of the chromosphere; at Sherman the number was extended to 273; and at moments of unusual solar disturbance there were glimpses of at least as many more.

Sulphur, strontium, and cerium are pretty conclusively shown to be constituents of the solar atmosphere. Zinc, erbium, didymium, and iridium are also indicated, but not so certainly.

At the very base of the chromosphere, and to a distance of perhaps 1″ or 15″ from the edge of the photosphere, it was found that those dark lines which are not actually reversed lose their intensity, and vanish more or less completely. This is substantially a confirmation of an old and somewhat disputed observation of Secchi's, who reports at the edge of the sun a layer giving a continuous spectrum.

This is not strictly correct, however, since when the transparency of the air is so much increased as to cause the most persistent of the dark lines to vanish, a multitude of the others appear reversed. There can be little doubt that were the effect of our own atmosphere entirely removed, this lowest portion of the solar atmosphere would give the same spectrum of bright lines which is seen at the beginning and end of totality during an eclipse.

It is noteworthy that of the 170 new lines found in the chromosphere spectrum, not a single one lies below C, and that for no want of careful examination. The only new lines of much importance are the two Hs at the extreme violet end of the spectrum. These were found almost constantly reversed, probably quite so, but the observation was so difficult that we could not be perfectly sure of it on every occasion.

What is still more remarkable, it was found that these two lines (not the hydrogen lines, as has been erroneously reported) are also usually, and I am pretty confident always, reversed in the spectrum of sun-spots, not so clearly, moreover, in the nucleus as in the penumbra, and over a somewhat extensive region surrounding it. This reversal of the H lines does not involve at all the disappearance of the dark shade, but a bright streak rather than a line makes its appearance in the centre of the shade, which itself is, if anything, a little intensified.

The spectra of several different spots were carefully studied, and a catalogue was drawn up of 155 lines which are more or less affected, usually by being greatly widened, but in some cases by a weakening or reversal. Several

bright lines were also found in the spot spectrum, and between C and D some very peculiar shadings terminated sharply at the less refrangible limit by a hard dark line, but fading out gradually in the other direction at a distance of three or four of Kirchhoff's scale divisions. The interpretation of such markings is not quite clear, but would rather seem to point to such a reduction of temperature over the spot-nucleus as permits the formation of gaseous compounds by elements elsewhere dissociated, since these shaded spectra are quite probably characteristic of non-elementary substances, a view fortified by Schuster's recent beautiful investigations upon the spectrum of nitrogen.

Many more or less remarkable solar eruptions were observed, though none on quite so magnificent a scale as some before recorded. On several occasions velocities of from 150 to 200 miles per second in the ejected matter were observed by means of the displacement and distortion of the hydrogen lines, and on one occasion a velocity of nearly 250 miles was attained. One of the finest eruptions was visible on the surface of the sun itself in the immediate neighbourhood of a large spot.

A careful comparison of some of these observations with the corresponding magnetic records at Greenwich and Stonyhurst, for copies of which records I am indebted to the courtesy of Sir G. B. Airy and Rev. S. J. Perry, goes far to show that, although probably the *greatest* magnetic disturbances are due to terrestrial causes, or at least are only indirectly results of solar or cosmical influences, yet, on the other hand, every solar paroxysm does have a distinct, direct, and immediate effect upon the magnetic elements. Thus on August 3 such solar paroxysms were noted at 8.45, 10.30, and 11.55, also on August 5 from 6.20 to 7.30 A.M. (Sherman time), and the last was the only outburst during the day.

Now the annexed figure (Fig. 1), from a photographic copy of the vertical force curve for these days at Greenwich, shows marked and characteristic disturbances at the points indicated, which, allowing for the longitude, correspond to the very instants when the solar disturbances were noted. Further comparisons of such phenomena will be necessary to establish the conclusion with absolute certainty; but in the meantime it seems altogether probable that every solar disturbance receives an immediate response from the earth, and that the magnetic impulse travels with, sensibly, the velocity of light.

I must not close without alluding to certain observations that enable us to distinguish, to some extent, between the substances ejected from the sun, and those constituting the atmosphere into which the irruption takes place. Certain lines during these outbursts were distorted and displaced, while others near them, equally conspicuous, were wholly unaffected.

Thus on August 3 and 5, the former class included the lines of hydrogen, D_3, the lines of sodium, magnesium, and many of those of iron; in the latter were K534, 1474, 1505, 1515, 1528, 1867, 2007 (1870 and 200 were intensely disturbed), 2581, and probably the two Hs; I say probably, because the observation of these lines was too difficult to permit absolute certainty, still I feel very confident that they were unaffected. The barium lines also seldom seemed to participate in any disturbance.

The obvious moral of our summer's work seems to me this, that no time ought to be lost in occupying points of such advantage with the most powerful instruments: the great telescopes now building should be put in a position to profit by such atmospheric conditions as will secure their utmost efficiency, for while it is of little consequence to science whether ordinary glasses are placed where their power will be increased by 25 per cent., it may make a difference of years and decades in her advance if the new artillery opens its attack upon the heavens from the mountain-tops instead of from the plains.

Dartmouth College, Nov. 25 C. A. YOUNG

THE TRANSIT OF VENUS

AT the meeting of the Astronomical Society on November 8, a sketch was given of Lord Lindsay's preparations for the forthcoming transit of Venus. Lord Lindsay has selected the island of Mauritius as his station, on account of its highly favourable meteorological conditions. He intends, if possible, to combine the following methods of observation:—1. Observations of the internal contacts to be worked out on the plans of Halley and Delisle. 2. Observations of the first external contact at the chromosphere, to be made with the spectroscope. 3. Photographic pictures. 4. Heliometric measures. For the longitude it is at present intended to use the transits of the moon with an altazimuth made by Simms. As it is expected that the Germans will also have a station on the Mauritius, Lord Lindsay will connect his station with theirs by triangulation. The transit instrument is by Cooke, and has four inches aperture. The chronograph, which can be kept in motion for four hours, has four barrels, each of which can be worked separately, thus avoiding all confusion. The photographic method to be used is that of Prof. Winlock, who suggests a telescope of 40 feet focal length, placed horizontally, and a heliostat to reflect the sun's image along it. The lens is to be an achromatic one. It is intended to have two planes to the heliostat, one mounted on a polar axis, and another to send the rays down the tube. Lord Lindsay has ordered a Foucault siderostat with 16-inch mirrors, and has obtained a 13-inch unsilvered mirror to fit the telescope to be taken out. He intends to use a heliometer, though it is not much in favour in this country, Messrs. Respald, of Hamburgh, having undertaken to make one for him with all the improvements used in the Oxford instrument, as well as in some others. The Germans intend to send one to Kerguelen Land, and the Russians will use it at Lake Baikal and the mouth of the Amoor. Lord Lindsay's will include the motion of the halves of the object-glass in curved slides, so that the images will remain in focus; unlimited rotation of the tube in the cradle; the measurement of the position angle at the eye end, and measures of the micrometer read there also. Some new points are;—the graduation of the slides of the object-glass side by side, so as to be read by the same microscope; an arrangement to shut off light from half the object-glass, so as to equalise the light of the images; and the introduction of a thermometer at the end of the tube. Lord Lindsay proposes to eliminate errors of division as affected by temperature, by placing the instrument on one of the collimating piles of his transit circle at home, and heating the room by gas to different temperatures. It is hoped that, by taking a large number of measures, and by taking the most careful precautions, the original error of observation may be reduced to less than $0''.5$, and thus make the result one of extreme accuracy.

Lord Lindsay will be glad to receive the advice and assistance of astronomers accustomed to use the heliometer. Mr. D. Gill will accompany Lord Lindsay, the two dividing the work of observing between them.

THE "CHALLENGER"

ON Friday last, Dec. 6, several members of the council and "the Circumnavigating Committee" of the Royal Society, by invitation of the Lords of the Admiralty, inspected at Sheerness H.M. ship *Challenger*, which sailed on Saturday on her three or four years' scientific circumnavigating expedition. The Government have all along consulted the Royal Society as to the fitting out of this expedition, and have liberally carried out every suggestion made by the Circumnavigation Committee. The visitors to Sheerness on Friday included many distinguished men of science, among them being Sir William