

- V. "A Comparison of the most notable Disturbances of the Magnetic Declination in 1858 and 1859 at Kew and Nertschinsk, preceded by a brief Retrospective View of the Progress of the Investigation into the Laws and Causes of the Magnetic Disturbances." By Major-General EDWARD SABINE, R.A., President of the Royal Society. Received April 28, 1864.

(Abstract.)

The author commences this paper by taking a retrospective view of the principal facts which have been established regarding the magnetic disturbances, considered as a distinct branch of the magnetic phenomena of the globe, from the time when they were first made the objects of systematic investigation by associations formed for that express purpose, at Berlin in 1828 and at Göttingen in 1834, and dwelling more particularly on the results subsequently obtained by the more complete and extended researches instituted in 1840 by the British Government on the joint recommendation of the Royal Society and of the British Association for the Advancement of Science.

The Berlin Association, formed under the auspices of Baron Alexander von Humboldt, consisted of observers in very distant parts of the European continent, by whom the precise direction of the declination-magnet was recorded simultaneously at hourly intervals of absolute time, at forty-four successive hours at eight concerted periods of the year, which thence obtained the name of "Magnetic Terms." By the comparison of these hourly observations it became known that the declination was subject to very considerable fluctuations, happening on days which seemed to be casual and irregular, but were the same at all the stations, consequently over the continent of Europe generally. This conclusion was confirmed by the Göttingen Association, established at the instance and under the superintendence of MM. Gauss and Weber, by whom the "Term-observations" were extended to six periods in the year, each of twenty-four hours' duration, the records being made at intervals of five minutes. The number of the stations at which these observations were made was about twenty, distributed generally over the continent of Europe, but not extending beyond it. They were continued from 1834 to 1841. The observations themselves, as well as the conclusions drawn from them by MM. Gauss and Weber, were published in the well-known periodical entitled 'Resultate aus der Beobachtungen des magnetischen Vereins.' The synchronous character of the disturbances, over the whole area comprehended by the Association, was thoroughly confirmed: the disturbing action was found to be so considerable as to occasion frequently a partial, and sometimes even a total obliteration of the regular diurnal movements, and to be of such general prevalence over the greater part of Europe, not only in the larger, but in most of the smaller oscillations, as to make it in a very high degree improbable that they could

have either a local or an atmospherical origin. No connexion or correspondence was traceable between the indications of the magnetical and meteorological instruments; nor had the state of the weather any perceptible influence. It happened very frequently that either an extremely quiescent state of the needle or a very regular and uniform progress was preserved during the prevalence of the most violent storm; and as with wind-storms, so with thunder-storms, as even when close at hand they appeared to exercise no perceptible influence on the magnet. At some of the most active of the Göttingen stations the fluctuations of the horizontal force were observed contemporaneously with those of the declination-magnet, by means of the bifilar magnetometer devised by M. Gauss: both elements were generally disturbed on the same days and at the same hours. The magnitude of the disturbances appeared to diminish as their action was traced from north to south, giving rise to the conclusion that the focus whence the most powerful disturbances in the northern hemisphere emanated might perhaps be successfully sought in parts of the globe to the north or north-west of the area comprehended by the stations. The inter-comparison of the records obtained at the different stations showed moreover that the same element was very differently affected at the same hours at different stations; and that occasionally the same disturbance showed itself in different elements at different stations. The general conclusion was therefore thus drawn by M. Gauss, that “we are compelled to admit that on the same day and at the same hour various forces are contemporaneously in action, which are probably quite independent of one another and have very different sources, and that the effects of these various forces are intermixed in very dissimilar proportions at various places of observation relatively to the position and distance of these latter; or these effects may pass one into the other, one beginning to act before the other has ceased. The disentanglement of the complications which thus occur in the phenomena at every individual station will undoubtedly prove very difficult. Nevertheless we may confidently hope that these difficulties will not always remain insuperable, when the simultaneous observations shall be much more widely extended. It will be a triumph of science should we at some future time succeed in arranging the manifold intricacies of the phenomena, in separating the individual forces of which they are the compound result, and in assigning the source and measure of each.”

In the British investigations, which commenced in 1840, the field of research was extended so as to include the most widely separated localities in both hemispheres, selected chiefly with reference to diversity of geographical circumstances, or to magnetic relations of prominent interest. Suitable instruments were provided for the observation of each of the three magnetic elements; the scheme of research comprehended not alone the casual and irregular fluctuations which had occupied the chief attention of the German associations, but also “the actual distribution of the magnetic influence over the globe at the present epoch in its mean or average state,

together with all that is not permanent in the phenomena, whether it appear in the form of momentary, daily, monthly, semiannual, or annual change, or in progressive changes receiving compensation possibly, either in whole or in part, in cycles of unknown relation and unknown period." The magnetic disturbances to which the notices in the present paper are limited, form a small but important branch of this extensive inquiry, and are referred to in the instructions prepared by the Royal Society in terms which are recalled by the author on the present occasion, because they are explanatory of the principles on which the coordination of the results obtained in such distant parts of the world has been conducted, and the conclusions derived from them established. In pages 2 and 3 of the Report embodying the instructions drawn up by the Royal Society, it is stated that "the investigation of the laws, extent, and mutual relations of the casual and transitory variations is become essential to the successful prosecution of magnetic discovery . . . because the theory of those transitory changes is in itself one of the most interesting and important points to which the attention of magnetic observers can be turned, as they are no doubt intimately connected with the general causes of terrestrial magnetism, and will probably lead us to a much more perfect knowledge of those causes than we now possess." In the opinion thus expressed, the author, who was himself one of the committee by whom the Report was drawn up, fully concurred; and having been appointed by Her Majesty's Government to superintend the observations made at the British Colonial observatories, and to coordinate and publish their results, he has endeavoured to show in this paper that the methods pursued have been in strict conformity with these instructions, and also that the conclusions derived are in accordance with the anticipations expressed therein.

Inferences regarding the "general causes of terrestrial magnetism" must be based upon the knowledge we possess of the actual distribution of the magnetic influence on the surface of the globe, since that is the only part which is accessible to us. In regard to this distribution, the Report itself refers continually to two works, then recently published, as containing the embodiment of the totality of the known phenomena, viz. a "Memoir on the Variations of the Magnetic Force in different parts of the Earth's Surface," published in 1838 in the Reports of the British Association, and M. Gauss's '*Allgemeine Theorie des Erdmagnetismus*,' published in 1839. In both these works the facts, as far as they had been ascertained, were conformable in their main features to the theory, first announced by Dr. Halley in his Papers in the Philosophical Transactions for 1683 and 1693, of a *double* system of magnetic action, the direction and intensity of the magnetic force being, at all points of the earth's surface, the resultants of the two systems. In both these works the Poles, or Points of greatest force (in the northern hemisphere) were traced nearly to the same localities—viz. one in the northern parts of the American continent, and the other in the northern parts of the Europæo-Asiatic continent,—their

geographical positions, as taken from M. Gauss's 'Allgemeine Theorie,' being, in America, lat. 55° , long. 263° E., and in Siberia lat. 71° , long. 116° E. Combining then the expectation expressed in the Report of "a probable connexion existing between the casual and transitory magnetic variations and the general phenomena of terrestrial magnetism," with M. Gauss's conclusion from the Göttingen researches, that "the sources of the magnetic disturbances in Europe might possibly be successfully sought in parts of the globe to the north or to the north-west of the European continent," it seemed reasonable to anticipate that a connexion might be found to exist between the "points of origin" of the disturbances, if these could be more precisely ascertained, and the critical localities of the earth's magnetism above referred to. To put this question to the test, the first step was to ascertain in a more satisfactory way than had been previously attempted, the laws of the disturbances themselves. The process by which a portion of the observations exhibiting the effects of the disturbing action in a very marked degree may be separated from the others, and subjected to a suitable analysis for the determination of their general laws, has been fully described elsewhere. The immediate effect of its application was to show that, casual and irregular as the disturbances might appear to be in the times of their occurrence, they were, in *their mean effects*, strictly periodical phenomena, characterized by laws distinct from those of any other periodical phenomena with which we were then acquainted, and traceable directly to the Sun as their primary source, inasmuch as they were found to be governed everywhere by laws depending upon the solar hours. To those who are familiar with the theory by which the passage of light from the sun to the earth is explained, an analogous transmission of magnetic influences from the sun to the earth may appear to present no particular difficulty. It is when the influences reach the earth that the modes of their reception, distribution, and transmission are less clearly seen and understood; but these are within our own proper terrestrial domain and sphere of research; and accordingly it was to these that the author's attention was directed. Wherever the disturbances had been observed and were analyzed, it was found that those of the declination were occasionally deflections to the east and occasionally deflections to the west of the mean position of the magnet, and those of the horizontal and vertical forces occasionally increased and occasionally diminished the respective forces. The disturbances of each element were therefore separated into two categories, according as they belonged to one or to the other class. Each category was found to present diurnal progressions, of systematic regularity, but quite distinct from one another, and so far in accordance with M. Gauss's inference of the existence of various forces contemporaneously in action, independent of one another, and having different originating sources. Confining our view, for simplicity, to one alone of the elements, viz. the declination, its two categories (of easterly and of westerly deflection) presented, wherever they were examined,

the same distinctive features; the local hours or maximum and minimum varied at different stations, but the same two dissimilar forms were everywhere presented by the curves representing the two diurnal progressions.

Having thus traced apparently two sources in which the disturbances might be supposed to originate, the possible connexion of these with the points of maximum attraction in the two systems of the magnetic terrestrial distribution presented itself as the next object of fitting research. It was inferred that if two stations were selected in nearly the same latitude, but situated one decidedly on the eastern side and the other decidedly on the western side of one of the points referred to, the curve of the easterly deflection at the one station would perhaps be found to correspond with the curve of westerly deflection at the other station at the same hours of absolute time, and *vice versd.* The Kew photograms in the five years 1858 to 1862 supplied the necessary data for one of the two stations, viz. the one to the west of the point of maximum attraction of one of the two magnetic systems, whilst Pekin, where hourly observations from 1851 to 1855 inclusive are recorded in the '*Annales de l'Observatoire Central Physique de Russie,*' might supply a station on its eastern side. As this comparison might be regarded somewhat in the light of a crucial experiment, the reliance to which the Pekin observations were entitled was examined by the very delicate test afforded by rewriting the observations recorded at solar hours in hours of lunar time, and examining the lunar-diurnal variation thence derived. When this is found to come out systematically and well, and similarly in different years, the observations which have furnished it may be safely regarded as trustworthy. The Pekin observations corresponded satisfactorily to this test, and in the *Philosophical Transactions* for 1863, Art. XII., the comparison was made of the Kew and Pekin disturbance-deflections, the result showing that "the conical form and single maximum which characterize the curve of the easterly deflections at Kew, characterize the curve of the westerly deflections at Pekin at approximately the same hours of absolute time." For a further trial of this important result, a second comparison of the same kind was made, being that of the curves of the disturbance-deflections at Nertschinsk from 1851 to 1857, also recorded in the '*Annales de l'Observatoire,*' &c., with those from 1858 to 1862 at Kew. Nertschinsk is about 12° north of Pekin, and is nearly in the same longitude as that station, whilst its latitude is almost identical with that of Kew. The Nertschinsk observations were subjected to the same test in respect to accuracy as those of Pekin, and with a similarly satisfactory result. The comparison of the disturbance-deflections showed a still more perfect accord between the curves representing the easterly deflections at Kew and the westerly at Nertschinsk at approximately the same hours of absolute time.

The present paper contains a further comparison of the nearly synchronous disturbances at Kew and at Nertschinsk on the days of most notable disturbance at both stations in 1858 and 1859, the comparison being

limited to those two years inasmuch as the Kew record did not commence until January 1858, whilst the hourly observations at Nertschinsk for 1860 and subsequent years have not yet reached England. The deflections at Nertschinsk from the normals of the same month and hour, on forty-four days in 1858 and 1859, are given in a Table similar in all respects to the Table, in the Philosophical Transactions for 1863, showing the deflections on the most notable days of disturbance at Kew in the same years. The comparison of the two Tables is discussed in some detail ; but it is sufficient to state here that the general conclusions are quite in accordance with those arrived at in the previous comparisons.

The steps by which the author was led to a discovery of the *decennial variation* in the magnetic disturbances, and to its identification in period and epochs with the variation in the magnitude and frequency of the sun-spots resulting from the observations of M. Schwabe since their commencement in 1826, are too well known to need repetition on this occasion. But they furnish the ground on which, in this paper, he has for the first time suggested the possibility that a cosmical connexion of a somewhat similar nature may be hereafter recognized as the origin and source of one of the two magnetic systems which cooperate in producing the general phenomena of the variations of the magnetic direction and force in different parts of the globe. The author's suggestion is, that the one of the two systems which is distinguished by its possessing a systematic and continuous movement of geographical translation, thereby giving rise to the phenomena of the secular change, may be referrible to direct solar influence operating in a cycle of yet unknown duration. The phenomena of the secular change in the earth's magnetism have hitherto received no satisfactory explanation whatsoever ; and they have all the characters befitting what we might suppose to be the effects of a cosmical cause. Some of the objections which might have impeded the reception of such an hypothesis before we had learnt to recognize in the sun itself a source of magnetic energy, and to identify magnetic variations observed on the earth with physical changes which manifest themselves to our sight in the photosphere of the sun, are no longer tenable. It is true that we do not yet possess similar ocular evidence of a solar cycle of the much longer duration which would correspond to the secular change in the distribution of terrestrial magnetism. But careful observations of the variable aspects of the solar disk can only be said to be in their commencement, and it would be premature to assume that no visible phenomena will be discovered in the sun which will render the evidence of connexion as complete in the one case as in the other. Such evidence, however, is not a necessary condition of an existing connexion ; the decennial period would have been equally true (though not so readily perceived by us) if the sun-spots had been less conspicuous.
