

gentlemen, are the first persons who have dared to accompany me, and who are witnesses of the complete success obtained.'

"It appears that, at this time, Mr. Robert Fulton did not suspect that steam navigation might be one day applied upon the sea, and for traversing the ocean in much less time than with sailing vessels; he said nothing to us about it. I informed Mr. Fulton that I intended to return to France about the end of that year (1807). He then said that he had but lately returned thence; that, under his deep conviction of the importance of this application of steam to navigation, he had presented himself to the Ministers of the Navy and of War, that they might give him the means of making experiments, and finally to the Academy of Sciences of the Institute; that everywhere he had been well received, but that the first answer to him was always the want of money; that moreover the expansive force of steam was a thing long known, and that, as to the application which he proposed to make of it to navigation, its success was very doubtful, because very probably this force, powerful as it was, would not succeed in overcoming, at certain seasons of the year, the violence of the currents of rivers. This opinion was also expressed in a report made upon the subject to the Academy of Sciences, by the Minister of the Navy, Decrés. Rejected everywhere, Mr. Fulton returned to America. 'During my solicitations of the Ministers,' said he, 'I went to see M. Carnot. If, said he, I had still the honor to be Minister of War, I would not hesitate a moment to give you the means to make your experiment, the success of which is unquestionable, for I understand all the means of its action, and I foresee the immense results for the future. Since you are about to return to France,' added Mr. R. Fulton, 'have the goodness to call upon M. Carnot for me, and tell him that I shall never forget the kind reception which he gave me; tell him of the complete success of my efforts and my perseverance, of which you are the first witnesses; tell him that I shall always feel the deepest regret that France did not profit by my offers for the great enterprize which her government then meditated.'

"If we refer to this epoch, we find that the Emperor had resolved to make a descent upon England, and for that purpose had collected together an immense army at Boulogne, and had, to effect his debarcation, built a great number of vessels of all sizes. If, then, M. Carnot had still been Minister of War, and twenty steamboats had been constructed in a few months by Mr. Fulton, what might we not augur for the success of the enterprize? Then, without question, would France have become the first nation of the globe. Her power would have been lasting, for it would have had for its base the products of her agriculture, and not manufacturing industry, whose prosperity is always subject to events."

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*On the Diurnal Variations of the Magnetic Needle, and the Aurora Borealis.*

By M. AUGUSTE DE LA RIVE.

Extract of a Letter to M. ARAGO. Translated for the Journal of the Franklin Institute, from *Annales de Chimie et de Physique*, 3me serie, tom. xxv., p. 310.

Permit me to communicate to you, with the request that you will submit it to the Academy of Sciences, an extract from a memoir which I

recently read before our Society of Physics and Natural History, upon the cause of the diurnal variation of the magnetic needle, and of the Aurora Borealis. In proceeding in the reference of these two classes of phenomena to the same cause, I have only followed the route which you yourself have traced; for more than thirty years ago, you, with indefatigable perseverance, established by your numerous observations the remarkable concordance which exists between the appearances of the Aurora Borealis and the disturbances of the magnetic needle.

The following is my theory; you will remark that it rests only upon well established facts, and solidly established principles of physical science. I had already, in 1836, in a notice upon hail, (*Bibliothèque Universelle, nouvelle serie, tom. iii. p. 217.*) endeavored to prove that the atmospheric electricity owes its origin to the unequal distribution of temperature in the layers of the atmosphere. It is known that in a body of any kind, heated at one of its extremities and cooled at the other, the positive electricity passes from the warm toward the cold part, and the negative in the opposite direction; hence it follows that the lower extremity of an atmospheric column is constantly negative, and the upper end positive. This difference in the opposite electrical states must be greater in proportion as the difference of temperature itself is greater, and consequently more strongly marked in our latitudes in summer than in winter, and in general, more sensible in the equatorial than in the polar regions. It must be remarked that the negative condition of the lower portions of the atmospheric columns must communicate itself to the surface of the earth upon which they rest, while the positive state of the upper ends transmits itself from above downwards, along almost the whole length of each of the columns, according to the facility which the greater or less degree of moisture in the air presents for the propagation of the electricity. An atmospheric column is therefore like a pile of high tension, on account of the imperfect conductivity of the elements of which it is composed; a pile, the negative pole of which, in constant and direct communication with the terrestrial globe, discharges itself into it, while it charges itself with electricity from its positive pole, which is distributed with an intensity decreasing as we depart from that pole; which explains why it is that the positive electricity increases in proportion as we rise in the atmosphere.

The causes which determine the accumulation of negative electricity at the surface of the earth, and that of the positive electricity in the upper regions of the atmosphere, act continuously; an unlimited tension of the two opposite electrical conditions ought to result, were it not that, when they reach a certain degree of energy, they neutralize each other by the effect of different circumstances. In other words, when they reach a certain limit of tension, which varies with the state of the atmosphere, and of the surface of the soil, the two electricities cannot pass this, and they re-compose or neutralize each other beyond this limit. This neutralization is effected in two ways: in a constant or normal manner, and in an irregular or accidental manner.

This second mode presents itself under very varied forms; sometimes it is the mere moisture of the air, or better still, the rain or snow, which re-establish the electrical equilibrium between the earth and the atmosphere; in some cases tornadoes shew, in an energetic form, the mutual

action of the two electricities tending to unite together. Sometimes the winds, by mixing the air in contact with the surface of the earth, and like it negative, with the positive air of the higher regions, give rise to heat lightnings or to storms when the formation of clouds and condensation of watery vapors from the effect of the moisture, and different temperatures of the strata of air which are mixed together, take place at the same time.

The attraction of the clouds by the mountains, and the luminous phenomena which shew themselves upon elevated points are also due to the same cause. But I will not dwell any longer upon all these natural and easily understood consequences of the theory which I am developing; I will confine myself to a single remark, that is, that in observations on the atmospheric electricity, we must take into consideration that the intensity of the electric signs perceived is not always a proof of the intensity of the electricity itself, for the moisture of the atmosphere, by favoring the propagation of the electricity of the upper strata, may, as we often see in winter, give rise to very energetic electrical manifestations, even when the cause which produces them is not very powerful. We frequently see the reverse in summer.

I pass to the regular and normal mode of neutralization of the two electricities. I already hinted at the existence of this mode in my notice of 1836, but I did not indicate it expressly, as I then wanted a datum which Science now possesses, to wit: the perfect conductivity of the globe, which the use of the electric telegraph has made known.

To explain clearly my conception of this mode of neutralization, I suppose the atmosphere divided into annular strata parallel to the equator; the positive electricity accumulated in the outer portion of the stratum, cannot exceed a certain degree of tension without passing through the rarified and much less moist air to the polar regions, where, finding an atmosphere saturated with moisture, it will re-unite easily with the negative electricity accumulated upon the earth. Thus we have the circuit formed; each annular stratum of the atmosphere gives rise to a current, which travels in the upper regions from the upper portion of the stratum towards the pole, re-descends towards the earth through the atmosphere around the pole, and returns by the surface of the globe, from the pole to the lower part of the stratum from which it started. These currents will be, therefore, more numerous and more concentrated in proportion as we approach nearer to the pole; and as they move always in the same direction: that is, from south to north in the upper part of the atmosphere, and from north to south at the surface of the earth, their effect will become more sensible as we leave the equator and approach the pole. But as the currents produced by the equatorial strata are individually stronger than those which come from strata more towards the north, the difference, although real, will nevertheless be less than we might at first believe. What takes place in our northern hemisphere must occur similarly in the southern hemisphere; the currents pass also from the equator to the pole in the upper regions of the air, and from the pole to the equator upon the surface of the earth. Consequently for an observer going from the north to the south pole, the current would move in the same direction with him from the north pole to the equator, and in a contrary direction from the equator to the south pole. I speak here of the current which moves along the surface of the earth. I must

also remark, that the limit which separates the regions occupied by each of these two great currents is not, properly speaking, the equator, for it must be variable; it is, according to the theory which I am developing, that one of the parallels between the tropics which has the sun in its zenith, consequently it changes every day.

It is now easy to understand the cause of the diurnal variations of the magnetic needle. Conformably to the laws established by Ampere, the current which passes from the north pole to the equator ought to deflect the north pole of the needle to the west; this is what takes place in our hemisphere; and the current which passes from the south pole to the equator ought to deflect the north pole of the needle to the east; this is in fact what takes place in the southern hemisphere. The deviation at the same place ought to be greater in proportion as the difference of temperatures, and consequently of electric conditions, between the lower and upper strata of the atmosphere is greater; thus the deviation increases from the morning until 1h. 30m. P. M.; it is greatest in the months during which the sun is longest above the horizon, and is at its minimum in the winter months. Finally, these diurnal variations increase in amplitude in proportion as we leave the equator and approach the pole, a result still perfectly in accordance with what I have said of the increasing number of the currents towards the polar regions. In these regions, too, the variations may be very irregular, and perhaps null, if the magnetic needle be placed in situations where the electric currents traverse the atmosphere to reach the earth; in fact, a needle thus enveloped in currents on all sides is no longer affected, or at least is no longer affected in a regular manner. This remark may explain certain observations, particularly those made at Port Bowen, which appear to be anomalous.

I have been singularly struck, in examining very closely all the magnetic observations which I could obtain, and especially those of Colonel Sabine, by the remarkable manner in which they accord with the theory. I will cite but a single example: that is the very recent observations made at Saint Helena, which Colonel Sabine has just published. At Saint Helena the diurnal variation takes place towards the west so long as the sun is southward of the isle, towards the east as soon as the sun passes to the northward. In fact, in the first case, as I have remarked above, Saint Helena must be within the region in which the electric currents pass over the surface of the earth from the north pole to the equatorial regions; and in the second case in the region in which these currents go from the south pole to the equator. The hour of maximum diurnal variation is not the same for the island of Saint Helena as in continental countries, because the temperature of the surface of the ocean does not follow the same laws of diurnal variation as the temperature of the surface of the ground. Now the temperature of the lower stratum of the atmosphere must always be the same as that of the sea or land upon which it rests. This same circumstance explains certain apparent anomalies which the diurnal variations present in certain parts of the globe, as, for instance, at the Cape of Good Hope, which is surrounded on all sides by a vast expanse of ocean.

I desire it to be particularly remarked that, in what I have said, I have had reference only to the causes of perturbation of the direction of the magnetic needle, and by no means to the cause of that direction itself: that is,

of terrestrial magnetism, the cause of which I by no means believe to be of the same nature, but in reference to which I do not at present speak. I content myself with considering the terrestrial globe as a large spherical magnet, and I study the external causes which may modify the direction which it, as a magnet, tends to impress upon magnetic needles.

What is the Aurora Borealis upon the theory which I thus propose? It is the luminous effect of the electric currents which pass in the upper regions of the atmosphere towards the north pole; the effect due to the union of certain circumstances which do not always present themselves in the same manner, nor at all seasons of the year. It is now well proven that the aurora borealis is an atmospheric phenomenon, as you long since suggested. The name *magnetic storm*, by which M. Humboldt designates it in his *Cosmos*, in fact suggests the same idea, which, moreover, the interesting details which he gives about this meteor confirm. The observations of Parry, Franklin, and especially the numerous and well made ones of MM. Bravais and Lottin, are also entirely favorable to this opinion, which, moreover, was the result of the observations of M. Biot, at the Shetland Islands.

This point being admitted, the following is the way in which I explain the production of the aurora borealis. When the sun, having passed into the southern hemisphere, no longer heats ours so much, the watery vapor which had accumulated during the summer in this part of the atmosphere begins to condense; the kind of moist cap which envelops the polar regions extends continually more and more, and facilitates the discharge of the electricity accumulated in the upper parts of the air. But in these high latitudes, and especially at this epoch of the year, the watery vapors must generally pass into the state of small particles of ice or snow floating in the air, like those which give rise to halos; they form, as it were, a kind of semi-transparent mist. Now these half frozen fogs conduct the electricity to the surface of the earth near the pole, and are themselves, at the same time, illuminated by these currents or electrical discharges. In fact, all the observers agree in stating that the aurora borealis is always preceded by a mist which rises from the pole, the edges of which, less dense than the rest, are first colored. Thus, also, it is more frequent near the pole in the winter months, and particularly in those during which there is much vapor in the air. In order that it may be visible at great distances from the pole, it is necessary (and it cannot often occur) that these clouds, composed of icy particles, should extend in an almost continuous manner from the polar regions to latitudes well to the southward. It is these same clouds which, when they are partial, which then frequently happens, give rise to halos.

Now the analogy noticed by almost all observers, between the mists which accompany the aurora borealis and those which produce halos, is a circumstance not a little remarkable. It is easy to verify, by direct experiment, the identity between the light of the aurora borealis and that which we obtain in passing a succession of electric discharges through rarefied air containing much moisture, and more particularly through a very thin stratum of snow or frost upon glass. I have satisfied myself that air much rarefied, but perfectly dry, gives but feeble flashes, and that, in the experiment of the tube exhausted of air, it is essentially the moisture ad-

hering to the inner walls of the tube which, by conducting the electric discharges, gives rise to the luminous effects. It is evident that the electric discharges transmitted by this kind of net-work of ice, must, when concentrated near the pole, determine there a light much more vivid than that which they develop when they are spread over a greater surface.

But why is it the magnetic and not the terrestrial pole which appears to be the cause of the phenomenon? The following is my answer: Let the pole of a strong electro-magnet be placed under a large surface of mercury; let the surface be made to communicate with the negative pole of a strong pile; let the point of a piece of charcoal communicating with the positive pole be approached to it; immediately the voltaic arc forms, and the mercury is seen to be agitated above the electro-magnet; wherever this is placed, the luminous currents turn around this pole, and from time to time throw out very brilliant rays. There is also, as in the case of the aurora borealis, an obscure part, in the form of a circular point above the pole of the magnet; this peculiar effect ceases, without any interruption of the voltaic light, when the electro-magnet ceases to be magnetized. With a continuous current of ordinary electricity, arriving at the pole of a powerful electro-magnet in rarefied and moist air, luminous effects are obtained which are still more similar in appearance to those of the aurora borealis.

These phenomena are the result of the action of magnets upon currents. Now the same effect must be produced by the magnetic pole of the earth; the neutralization of the two fluids probably takes place over quite a large extent of the polar regions, but the action of the magnetic pole determines the conducting fogs to turn around it, throwing out those brilliant rays, which, by the effect of perspective, appear to us to form the auroral crown. The sulphurous odor and the noise, which it is asserted sometimes accompany the aurora, will not be inexplicable; that odor would be due, like that which accompanies lightning, to that modification which the passage of electric discharges causes in the oxygen of the air, which M. Schönbein has called *ozone*; and as to the noise, it must be analogous to that which is produced, as I have shown, by the voltaic arc, when it is under the influence of a magnet very near it. If it takes place only very rarely in the aurora borealis, it is because it is very seldom that the luminous arc is sufficiently near the earth, and consequently to the pole. But the description of this noise, given by those who have heard it, is perfectly identical with that which I, without suspecting their analogy, gave of the noise which the voltaic arc gives under the action of magnetism.

The magnetic perturbations which constantly accompany the appearance of the aurora borealis are now very easily explained. This accidental recombination of a greater amount of the accumulated electricities must derange the normal action of the regular current; as to the direction of the perturbation, it will depend upon the part of the current which acts upon the needle, and consequently upon circumstances which it is impossible to predict beforehand, since they depend upon the extent of the phenomenon, and the position of the needle in reference to it. In fact, according as the horizontal plane in which the needle moves passes above or below the region in which the greatest activity of the phenomenon takes place, it will be either the current which travels upon the earth, or that in the air, (currents which pass in opposite directions,) which will act upon the needle;

even during the continuance of the same aurora, it may be at one time one, and at another time the other, of these currents which act. The variable directions in which the needle is deflected during an aurora borealis, accord very well with this explanation, at least so far as I have been able to judge from the different observations reported in the *Annales de Chimie*, and in different scientific travels. The remarkable effect which M. Matteucci has observed in the apparatus of the electric telegraph between Ravenna and Piso, during the magnificent aurora of the 17th November last, shews clearly the existence of a current circulating upon the surface of the earth, and which, rising by the telegraph wire, passed partly by this better conductor. The sounds which are given in certain meteorological circumstances by long iron wires stretched in a north and south direction, are clear evidence that they are traversed by a current which probably arises from those which circulate upon the surface of the earth, from north to south in our hemisphere. It would be very interesting to take advantage of telegraph wires having a direction more or less coincident with that of the declination of the needle, for the purpose of making, when they are not in use for their usual purposes, some observations to detect and measure the electric currents which probably traverse them; which would be easily done by completing the communication of these wires with the ground at one of their extremities, by means of a multiplying galvanometer. The comparison of results thus obtained, with those of simultaneous observations of the diurnal variations of the magnetic needle, would certainly present much interest, and might lead to meteorological conclusions of a remarkable kind.

I cannot terminate this extract without remarking that M. Arago had already, in 1820, a short time after the discovery of *Ørsted*, indicated the possibility of acting upon the voltaic arc by his magnet, and the analogy which might result between this phenomenon and that of the aurora borealis.

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*Apparatus to preserve the Electric Light constant.*

At the sitting of the Academy of Sciences of Paris, held on the 18th January, 1849, M. L. Foucault reminded the Academy that five years ago he had, together with M. Donnè, an apparatus in which the electric light was used in obtaining upon a screen a magnified image comparable with that given by the solar microscope itself. But in this instrument there was a great inconvenience arising from the necessity of continually watching and adjusting the charcoal points. This apparatus he has since modified so as not only to keep the poles, by a spontaneous action, at the same distance apart, but also to keep the radiant point immoveable. These results he obtains by the following arrangements: The two points are pressed together by springs, but cannot move in that direction without setting in motion a train of wheels, the last of which is controlled by an escapement. The current of the apparatus passes around an electro-magnet, the energy of which of course depends upon the intensity of the current; this electro-magnet acts upon a piece of soft iron, which is pressed in the opposite di-