THE EARTH A MAGNET.

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There is a very prominent but erroneous opinion that the magnetic needle points to the north. The peculiarity that the magnetic needle does not, in general, point to the north, is the first of a series of peculiarities which we now propose briefly to describe. The irregularity is called by sailors the needle's variation, but the term more commonly used by scientific men is the declination of the needle. It was probably discovered a long time ago, for 800 years before our era the Chinese applied the magnet's directive force to guide them in journeying over the great Asiatic plains; and they must soon have detected so marked a peculiarity. Instead of a ship's compass they made use of a magnetic car, on the front of which a floating needle carried a small figure whose outstretched arm pointed southwards. We have no record, however, of their discovery of the declination, and know only that they were acquainted with it in the twelfth century. The declination was discovered, independently, by European observers in the thirteenth century.

As we travel from place to place the declination of the needle is found to vary; Christopher Columbus was the first to detect this. He discovered it on the 13th of September, 1492, during his first voyage, and when he was six hundred miles from Ferro, the most westerly of the Canary Islands. He found that the declination, which was towards the east in Europe, passed to the west, and increased continually as he travelled westwards.

But here we see the first trace of a yet more singular peculiarity. We have said that at present the declination is towards the west in Europe. In Columbus' time it was towards the east. Thus we learn that the declination varies with the progress of time, as well as with change of place.

The Genius of modern science is a weighing and a measuring one. Men are not satisfied now-a-days with knowing that a peculiarity exists; they seek to determine its extent, how far it is variable—whether from time to time or from place to place, and so on. Now the results of such inquiries applied to the magnetic declination have proved exceedingly interesting.

We find first, that the world may be divided into two unequal portions, over one of which the needle has a westerly, and over the other an easterly, declination. Along the boundary line, of course, the needle points due north. England is situated in the region of westerly magnets. This region includes all Europe, except the northeastern parts of Russia; Turkey, Arabia, and the whole of Africa; the greater part of the Indian Ocean, and the western parts of Australia; nearly the whole of the Atlantic Ocean; Greenland, the eastern parts of Canada, and a small slice from the northeastern part of Brazil. All these form one region of westerly declination; but singularly enough, there lies in the very heart of the remaining and larger region of easterly magnets, an oval space of a contrary character. This space includes the Japanese Islands, Manchouria, and the eastern parts of China. It is very noteworthy also, that in the westerly region the declination is much greater than the easterly. Over the whole of Asia, for instance, the needle points almost due north. On the contrary, in the north of Greenland and of Baffin's Bay, the magnetic needle points due west, while still further to the north (a little westerly) we find the needle pointing with its north end directly to the south.

In the presence of these peculiarities it would be pleasant to speculate. We might imagine the existence of powerfully magnetic veins in the earth's solid mass, coercing the magnetic needle from a full obedience to the true polar summons. Or the comparative effects of oceans and of continents might be called into play. But unfortunately for all this we have to reconcile views founded on *fixed* relations presented by the earth, with the process of *change* indicated above. Let us consider the declination in England alone.

In the fifteenth century there was an easterly declination. This gradually diminished, so that in about the year 1657 the needle pointed due north. After this the needle pointed towards the west, and continually more and more, so that scientific men, having had experience only of a continual shifting of the needle in one direction, began to form the opinion that this change would continue, so that the needle would pass, through northwest and west, to the south. In fact, it was imagined that the motion of the needle would resemble that of the hands of a watch, only in a reversed direction. But before long observant men detected a gradual diminution in the needle's westerly motion. Arago, the distinguished French astronomer and physicist, was the first (we believe) to point out that "the progressive movement of the magnetic needle towards the west appeared to have become continually slower of late years" (he wrote in 1814,) "which seemed to indicate that after some little time longer it might become retrograde." Three years later, namely on the 10th of February, 1817, Arago asserted definitely that the retrograde movement of the magnetic needle had commenced to be perceptible. Colonel Beaufoy at first oppugned Arago's conclusion, for he found from observations made in London, during the years 1817-1819, that the westerly motion still continued. But he had omitted to take notice of one very simple fact, viz., that London and Paris are two different places. A few years later and the retrograde motion became perceptible at London also, and it has now been established by the observations of forty years. It appears from a careful comparison of Beaufoy's observations that the needle reached the limit of its western digression (at Greenwich) in March, 1819, at which time the declination was very nearly 25 degrees. In Paris, on the contrary, the needle had reached its greatest western digression (about 22½ degrees) in 1814. It is rather singular that although at Paris the retrograde motion thus presented itself five years earlier than in London, the needle pointed due north at Paris six years later than in London, viz., in 1663. Perhaps the greater amplitude of the needle's London digression may explain this peculiarity.

"It was already sufficiently difficult," says Arago, "to imagine what could be the kind of change in the constitution of the globe, which could act during one hundred and fifty-three years, in gradually transferring the direction of the magnetic needle from due north to 23 degrees west of north. We see that it is now necessary to explain, moreover, how it has happened that this gradual change has ceased, and has given place to a return towards the preceding state of the globe. How is it," he pertinently asks, "that the directive action of the globe, which clearly must result from the action of molecules of which the globe is composed, can be thus variable, while the number, position, and temperature of these molecules, and, as far as we know, all their other physical properties, remain constant?"

But we have considered only a single region of the earth's surface. Arago's opinion will seem still more just when we examine the change which has taken place in what we may term the "magnetic aspect" of the whole globe. The line which separates the region of westerly magnets from the region of easterly magnets, now runs, as we have said, across Canada and eastern Brazil in one hemisphere, and across Russia, Asiatic Turkey, the Indian Ocean, and West Australia in the other; besides having an outlying oval to the east of the Asiatic Continent. Now these lines have swept round a part of the globe's circuit in a most singular manner since 1600. They have varied alike in direction and complexity. The Siberian oval, now distinct, was, in 1787, merely a loop of the eastern line of no declination. The oval appears now to be continually diminishing, and will one day probably disappear.

We find here presented to us a phenomenon as mysterious, as astonishing, and as worthy of careful study as any embraced in the wide domains of science. But other peculiarities await our notice.

If a magnetic needle of suitable length be carefully poised on a fine point, or better, be suspended from a silk thread without torsion, it will be found to exhibit each day two small but clearly perceptible oscillations. M. Arago, from a careful series of observations, deduced the following results:—

At about eleven at night, the north end of the needle begins to move from west to east, and having reached its greatest easterly excursion at about a quarter past eight in the morning, returns towards the west to attain its greatest westerly excursion at a quarter past one. It then moves again to the east, and having reached its greatest easterly excursion at half-past eight in the evening, returns to the west, and attains its greatest westerly excursion at eleven, as at starting.

Of course, these excursions take place on either side of the main position of the needle, and as the excursions are small, never exceeding the fifth part of a degree, while the mean position of the needle lies some 20 degrees to the west of north, it is clear that the excursions are only nominally eastern and western, the needle pointing, throughout, far to the west.

Now if we remember that the north end of the needle is that farthest from the sun, it will be easy to trace in M. Arago's results a sort of effort on the part of the needle to turn towards the sun—not merely when that luminary is above the horizon, but during his nocturnal path also.

We are prepared, therefore, to expect that a variation having an annual period shall appear, on a close observation of our suspended needle. Such a variation has been long since recognized. It is found that in the summer of both hemispheres, the daily variation is exaggerated, while in winter it is diminished.

But besides the divergence of a magnetized needle from the north pole, there is a divergence from the horizontal position, which must now claim our attention. If a non-magnetic needle be carefully suspended so as to rest horizontally, and be then magnetized, it will be found no longer to preserve that position. The northern end *dips* very sensibly. This happens in our hemisphere. In the southern it is the southern end which dips. It is clear, therefore, that if we travel from one hemisphere to the other we must find the northern dip of the needle gradually diminishing till at some point near the equator the needle is horizontal, and as we pass thence to southern regions a gradually increasing southern inclination is presented. This has been found to be the case, and the position of the line along which there is no inclination (called the *magnetic equator*) has been traced around the globe. It is not coincident with the earth's equator, but crosses that circle at an angle of twelve degrees, passing from north to south of the equator in logitude three degrees west of Greenwich, and from south to north in longitude 187 degrees east of Greenwich. The form of the line is not exactly that of a great circle, but presents here and there (and especially where it crosses the Atlantic) perceptible excursions from such a figure.

At two points on the earth's globe the needle will rest in a vertical position. These are the magnetic poles of the earth. The northern magnetic pole was reached by Sir J. G. Ross, and lies in seventy degrees north latitude, and 263 degrees east longitude, that is, to the north of the American continent, and not very far from Boothia Gulf. One of the objects with which Ross set out on his celebrated expedition to the Antarctic Seas was the discovery if possible of the southern magnetic pole. In this he was not successful. Twice he was in hopes of attaining his object, but each time he was stopped by a barrier of land. He approached so near, however, to the pole that the needle was inclined at an angle of nearly ninety degrees to the horizon, and he was able to assign to the southern pole a position in 75 degrees south latitude 154 degrees east longitude. It is not probable, we should imagine, that either pole is fixed, since we shall now see that the inclination, like the declination of the magnetic needle, is variable from time to time, as well as from place to place; and in particular, the magnetic equator is apparently subjected to a slow but uniform process of change.

Arago tells us that the inclination of the needle at Paris has been observed to diminish year by year since 1671. At that time the inclination was no less than 75 degrees; in other words, the needle was inclined only 15 degrees to the vertical. In 1791 the inclination was less than 71 degrees. In 1831 it was less than 68 degrees. In like manner the inclination at London has been observed to diminish, from 72 degrees in 1786 to 70 degrees in 1804, and thence to 68 degrees at the present time.

It might be anticipated from such changes as these that the position of the magnetic equator would be found to be changing. Nay, we can even guess in which way it must be changing. For, since the inclination is diminishing at London and Paris, the magnetic equator must be approaching these places, and this (in the present position of the curve) can only happen by a gradual shifting of the magnetic equator from east to west along the true equator. This motion has been found to be really taking place. It is supposed that the movement is accompanied by a change of form; but more observations are necessary to establish this interesting point.

Can it be doubted that while these changes are taking place, the magnetic poles also are slowly shifting round the true pole? Must not the northern pole, for instance, be further from Paris now that the needle is inclined more than 23 degrees from the vertical, than in 1671, when the inclination was only 15 degrees. It appears obvious that this must be so, and we deduce the interesting conclusion that each of the magnetic poles is rotating around the earth's axis.

But there is another peculiarity about the needle which is as noteworthy as any of those we have spoken about. We refer to the intensity of the magnetic action, the energy with which the needle seeks its position of rest. This is not only variable from place to place, but from time to time, and is further subject to sudden changes of a very singular character.

It might be expected that where the dip is greater, the directive energy of the magnet would be proportionably great. And this is found to be approximately the case. Accordingly the magnetic equator is very nearly coincident with the "equator of least intensity," but not exactly. As we approach the magnetic poles we find a more considerable divergence, so that instead of there being a northern pole of greatest intensity nearly coincident with the northern magnetic pole, which we have seen lies to the north of the American continent, there are two northern poles, one in Siberia nearly at the point where the river Lena crosses the Arctic circle, the other not so far to the north—only a few degrees north, in fact, of Lake Superior. In the south, in like manner, there are also two poles, one on the Antarctic circle about 130 degrees east longitude in Adelie Island, the other not yet precisely determined, but supposed to lie on about the 240th degree of longitude, and south of the Antarctic circle. Singularly enough there is a line of lower intensity running right round the earth along the valleys of the two great oceans, "passing through Behring's Straits and bisecting the Pacific on one side of the globe, and passing out of the Arctic Sea by Spitzbergen and down the Atlantic on the other."

Colonel Sabine discovered that the intensity of the magnetic action varies during the course of the year. It is greatest in December and January in both hemispheres. If the intensity had been greatest in winter one would have been disposed to have assigned seasonal variation of temperature as the cause of the change. But as the epoch is the same for both hemispheres we must seek another cause. Is there any astronomical element which seems to correspond with the law discovered by Sabine? There is one very important element. The position of the perihelion of the earth's orbit is such that the earth is nearest to the sun on about the 31st of December or the 1st of January. There seems nothing rashly speculative, then, in concluding that the sun exercises a magnetic influence on the earth, varying according to the distance of the earth from the sun. Nay, Sabine's results seem to point very distinctly to the law of variation. For, although the number of observations is not as yet very great, and the extreme delicacy of the variation renders the determination of its amount very difficult, enough has been done to show that in all probability the sun's influence varies according to the same law as gravity—that is, inversely as the square of the distance.

That the sun, the source of light and heat, and the great gravitating centre of the solar system, should exercise a magnetic influence upon the earth, and that this influence should vary according to the same law as gravity, or as the distribution of light and heat, will not appear perhaps very surprising. But the discovery by Sabine that the moon exercises a distinctly traceable effect upon the magnetic needle seems to us a very remarkable one. We receive very little light from the moon, much less (in comparison with the sun's light) than most persons would suppose, and we get absolutely no perceptible heat from her. Therefore, it would seem rather to the influence of mass and proximity that the magnetic disturbances caused by the moon must be ascribed. But if the moon exercises an influence in this way, why should not the planets? We shall see that there is evidence of some such influence being exerted by these bodies.

More mysterious, if possible, than any of the facts we have discussed is the phenomenon of magnetic storms. The needle has been exhibiting for several weeks the most perfect uniformity of oscillation. Day after day the careful microscopic observation of the needle's progress, has revealed a steady swaying to and fro, such as may be seen in the masts of a stately ship at anchor on the scarce-heaving breast of ocean. Suddenly a change is noted; irregular jerking movements are perceptible, totally distinct from the regular periodic oscillations. A magnetic storm is in progress. But where is the centre of disturbance, and what are the limits of the storm? The answer is remarkable. If the jerking movements observed in places spread over very large regions of the earth—and in some well-authenticated cases over the whole earth—be compared with the local time, it is found that (allowance being made for difference of longitude) *they occur precisely at the same instant.* The magnetic vibrations thrill in one moment through the whole frame of our earth!

But a very singular circumstance is observed to characterize these magnetic storms. They are nearly always observed to be accompanied by the exhibition of the aurora in high latitudes, northern and southern. Probably they never happen without such a display; but numbers of auroras escape our notice. The converse proposition, however, has been established as a universal one. No great display of the aurora ever occurs without a strongly marked magnetic storm.

Magnetic storms sometimes last for several hours or even days.

Remembering the influence which the sun has been found to exercise upon the magnetic needle, the question will naturally arise, has the sun anything to do with magnetic storms? We have clear evidence that he has.

On the 1st of September, 1859, Messrs. Carrington and Hodgson were observing the sun, one at Oxford and the other in London. Their was directed to certain large spots which, scrutiny at that time, marked the sun's face. Suddenly, a bright light was seen by each observer to break out on the sun's surface and to travel, slowly in appearance, but in reality at the rate of about 7000 miles in a minute, across a part of the solar disc. Now it was found afterwards that the self-registering magnetic instruments at Kew had made at that very instant a strongly marked jerk. It was learned that at that moment a magnetic storm prevailed at the West Indies, in South America, and in Australia. The signalmen in the telegraph stations at Washington and Philadelphia received strong electric shocks; the pen of Bain's telegraph was followed by a flame of fire; and in Norway the telegraphic machinery was set on fire. At night great auroras were seen in both hemispheres. It is impossible not to connect these startling magnetic indications with the remarkable appearance observed upon the sun's disc.

But there is other evidence. Magnetic storms prevail more commonly in some years than in others. In those years in which they prevail most frequently, it is found that the ordinary oscillations of the magnetic needle are more extensive than usual. Now, when these peculiarities had been noticed for many years, it was found that there was an alternate and systematic increase and diminution in the intensity of magnetic action, and that the period of the variation was about eleven years. But at the same time a diligent observer had been recording the appearance of the sun's face from day to day and from year to year. He had found that the solar spots are in some years more freely displayed than in others. And he had determined the period in which the spots are successively presented with maximum frequency to be about eleven years. On a comparison of the two sets of observations it was found (and has now been placed beyond a doubt by many years of continued observation) that magnetic perturbations are most energetic when the sun is most spotted, and *vice versa*.

For so remarkable a phenomenon as this none but a cosmical cause can suffice. We can neither say that the spots cause the magnetic storms nor that the magnetic storms cause the spots. We must seek for a cause producing at once both sets of phenomena. There is as yet no certainty in this matter, but it seems as if philosophers would soon be able to trace in the disturbing action of the planets upon the solar atmosphere the cause as well of the marked period of eleven years as of other less distinctly marked periods which a diligent observation of solar phenomena is beginning to educe.