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600TH ORDINARY GENERAL MEETING,

HELD IN COMMITTEE ROOM B, THE CENTRAL HALL, WESTMINSTER, ON MONDAY, MAY 13TH, 1918, AT 4.30 P.M.

SIR FRANK W. DYSON, F.R.S., The Astronomer Royal, IN THE CHAIR.

The Minutes of the previous Meeting were read, confirmed and signed.

The SECRETARY announced the death of the Rev. H. A. Crosbie, an Associate of the Institute.

The CHAIRMAN then called on Dr. Sydney Chapman to read his paper on "Terrestrial Magnetism," which was illustrated by lantern slides.

TERRESTRIAL MAGNETISM. By SYDNEY CHAPMAN, Esq., M.A., D.Sc.

THE history of our subject for this afternoon began when men, long ages ago, discovered the power of attraction exercised towards iron by the mineral called lodestone. This property is mentioned in the writings of Thales (640–546 B.C.), so that it has been known for two thousand five hundred years or more. According to Lucretius (99–55 B.C.), the stone received the name of *magnet* from the place whence it was obtained, among the hills of Magnesia. From this the terms magnetism, magnetic force, and so on, are naturally derived.

As the attractive property of the lodestone was gradually investigated, it appeared that small pieces of iron are specially attracted by two particular parts of the lodestone, which, in a stone of regular shape, are opposite to one another. These are called the poles of the magnet, and the stone is said to be magnetized in the direction of the line joining them.

The next great discovery in magnetism related to the *directive* property of the lodestone. If a small magnet is mounted on a floating card or board, it is observed that the float and magnet will turn on the water till the magnetic axis, or line of poles, lies along a particular direction. Once the stone has assumed this direction, the tendency to motion ceases—there is no force on it tending to move it bodily. In early days the direction of the axis was supposed to be truly north and south, but it is now known that in most parts of the earth this is only approximately the case. This directive property of magnets was probably discovered independently among the Eastern and the Western nations, becoming known in Europe about the twelfth century of our era, and earlier still in China and Japan.

This second discovery was of great practical importance and was soon turned to use in navigation. The magnet points sufficiently nearly to true north for it to be of great value to mariners, since it provided a means, which had hitherto been wanting, of indicating direction when out of sight of land or—through cloudiness of sky—of the heavenly bodies. Thus the ship's compass was invented, the early forms consisting of a small needle-shaped magnet attached to a floating bowl or card, on which, later on, the points of the compass began to be marked. Many improvements in construction have been introduced in the course of centuries, and the use of iron in the structure of modern ships has necessitated the addition of special auxiliary devices to compensate for the disturbing effects on the compass. Fundamentally, however, the compass remains the same, and is still one of the most important aids to seamanship—and, it is becoming possible to say, of airmanship also.

In time it was found that the peculiar properties of the natural magnet could be communicated, by rubbing, to pieces of iron, and that, if the iron was not too soft, the magnetization is retained for a considerable period. It thus became possible to prepare artificial magnets and compass needles. The first European treatise on the magnet seems to have been written in 1269 by Petrius Peregrinus, a Frenchman, and a disciple of Roger Bacon. He made precise experiments on the magnetic aura or sphere of influence surrounding a magnet, to which its properties were generally referred; in the language of modern science, this is termed "a field of magnetic force," but without any essential difference of meaning. Peregrinus thus clearly describes how the direction of force at the surface of a magnet can be mapped out and its poles determined: "The stone is to be made in globular form and polished in the same way as are crystals and other stones. Thus it is caused to conform in shape to the celestial sphere. Now place upon it a needle or elongated piece of iron, and draw a line in the direction of the needle, dividing the stone in two. Then put the needle in another place on the stone, and draw another line in the same way. This may be repeated with the needle in other positions. All of the lines thus drawn will run together in two points, just as all the meridian circles of the world run together in two opposite poles of the world." The direction of the magnetic force, however, is not to be supposed to lie along the surface of the magnet. Indeed, Peregrinus observed that a small needle stands perpendicularly to the surface of the stone at the poles, where the magnetic force also is strongest.

A simple way of illustrating the distribution of magnetic force, not only on the surface but also in the space surrounding a magnet, is that of sprinkling iron filings over a sheet of paper or glass laid over or in the neighbourhood of the body. The little pieces of iron themselves become temporary magnets owing to the magnetic force surrounding the stone, and if the paper is lightly tapped they arrange themselves end to end so as to make the directions of the lines of magnetic force clearly apparent.

By analogy with a spherical lodestone such as Peregrinus used, our illustrious countryman, William Gilbert, Physician to Queen Elizabeth, was led to the conclusion that the earth itself is a great magnet. In his famous treatise *De Magnete* (1600) he describes the earth as being a great round lodestone, the magnetic poles of which were supposed to be coincident with the poles of rotation. Some years earlier, in 1581, Robert Norman, an instrument maker of London, and formerly a seaman, had announced that, as in Peregrinus' lodestone, the magnetic force of the earth does not lie along its surface, *i.e.*, it is not horizontal, but has also a vertical component. Ordinary compass needles are pivoted and weighted so as to swing horizontally, but if perfectly balanced before magnetization, after they are magnetized they will exhibit a tendency to dip; in the northern hemisphere the north-seeking, and in the southern hemisphere the south-seeking end is the one which dips. The natural angle of the dip in London is in round figures 65° measured from the horizontal. This was discovered by Norman in 1576, and is a salient feature in the analogy between the earth and a spherical lodestone. Norman himself undoubtedly had some inkling of the idea which Gilbert afterwards clearly stated; he perceived that the dipping of the needle indicates that the point or source of force which the needle "respects" is in the earth and not in the heavens.

In earlier times the North Star was usually regarded as the point to which the compass was directed.

When Gilbert's treatise was written, it was well known that the compass does not usually point true north, as, on his hypothesis of the earth as a spherical magnet with its poles on the axis of rotation, it should do. The error or *declination* of the compass first claimed serious attention among Western navigators at the time of Columbus' first voyage to the New World in 1492. At that time the error of the compass in Europe was not great, and if noticed was probably thought to be due to an imperfection of the instrument. A few days' voyage out from the Canary Islands, however, the ship's pilot discovered that the needle varied to the west of north by a whole point of the compass (11¼°). The seamen were thrown into terror and dismay, probably feeling that if the compass no longer remained faithful to the Northern Star, "all their foundations were out of joint." Columbus, who was troubled by no such fears, on learning the cause of their disquiet successfully allayed the distress by telling them that the needle truly pointed north, but that the Pole Star had a motion of its own. His great authority in astronomical learning caused this fictitious explanation to be accepted, but he seems also to have secretly altered the compass card so that the needle appeared to have become true once more. Columbus himself recognized the incident as the discovery of a new fact of nature, viz., that the compass diverges from true north by an amount which varies from place to place. In crossing from Europe to America he had gone from places of slight easterly declination to regions where the compass pointed west of north.

This fact took some time to become generally known, after which it was apparent that, if the compass was to retain its full value in navigation, the error in its direction at different places must be ascertained and allowed for. Voyagers began to make observations of the compass declination at various points on their course, when the sun and stars made it possible to determine astronomically the direction of true north. Chart-makers also began to enter these observations at the corresponding points on their maps, for the benefit of later navigators in those regions, who might be compelled, by cloudy weather to rely solely on their compass for direction. A better way of indicating the declination on maps was afterwards introduced, the first person to apply the method being Halley, the second Astronomer Royal (1720–1742).

For more than a century after Columbus' discovery, and beyond the time of publication of Gilbert's treatise, it remained unknown that not only does the direction of the compass vary from place to place, but also from time to time. This further important fact was first perceived by Gellibrand, a Gresham professor of mathematics, in 1634, on comparing an observation of declination then made by him, at Deptford, with earlier observations made in 1580 and 1622. The change of declination in the longer interval was about 7°. A new complication was thus introduced into the practical utilization of the magnetic properties of the earth, not only in navigation, but also in land and mine surveying. A chart or survey directed by the compass will not remain true, as judged by the compass, for many years. The fact is one of considerable economic importance, because in many countries old maps and surveyors' plans were drawn by compass rather than by astronomical directions. The magnitude of the change of compass declination, over a long period, is very great. Between 1580 and 1810 the declination at London changed from 11° E. to 24° W., a total variation of 35°. The compass now points about 14° west of north, in London, and is still diminishing, at present at the rate of 1° in six or seven years. These remarkable changes in the direction of the horizontal component of the earth's magnetic force are associated with changes in the magnetic dip, and also (as is now known) in the magnitude as well as direction of the force. They are manifestations of mysterious and far-reaching changes in the earth itself, but magnetic science has not yet succeeded in either explaining or predicting these secular variations. Their existence, however, renders it necessary for magnetic charts to be revised from time to time, at intervals of a few years, indeed, if they are to remain of value in navigation.

Halley, the author of the first chart of magnetic declination, aroused interest in the study of the earth's magnetism by the publication (in 1683) of a theory intended to explain the secular changes in the compass declination. He saw that the distribution of declination (at any one time) was too complicated for it to be supposed that the earth was a uniformly magnetized sphere with two poles, even if these were not regarded as coincident with the poles of the axis of rotation. He suggested that there were, on the contrary, four magnetic poles, "near each pole of the equator two," and he tried to explain the peculiar nature of the secular changes of declination by assigning different motions to the two magnetic axes. Even such a modification, it is now known, is insufficient to account for the irregularities of the actual distribution and changes of the earth's magnetic field.

The desirability of further observations was, however, brought into prominence by Halley's treatise of 1683, and in consequence the Government of King William III was induced to provide a ship on which, under Halley's command, observations of declination were to be made wherever possible in the north and south Atlantic ocean. On his return, after two years' continual voyaging (1698–1700), Halley embodied his and other observations on the first chart of lines of equal magnetic declination. This chart embraced mainly the Atlantic Ocean and the regions bordering upon it; about a year later, in 1702, he prepared a further chart covering the whole world, as far as the available observations allowed. These charts gained a wide popularity, and were frequently republished, and, later on, revised, as the secular change made this necessary.

The principle underlying their construction was very simple. Points at which the declination has a given value, say 5° west, are joined by a continuous line, different lines referring to different values of the declination, at intervals of 1°. At points between these lines the declination is gauged approximately by interpolation. It is not necessary, of course, to have observations of the compass "error" at all points of the lines of equal declination, these lines being drawn by a consideration of whatever observations are actually available.

The same principle can evidently be applied in the representation of the distribution of magnetic dip and intensity of magnetic force; this is, in fact, now done as part of the regular work of the hydrographic departments of various national governments. Since Halley's time, and especially during the nineteenth and present centuries, the magnetic field at the earth's surface, both by sea and land, has been the subject of much attention. The British Association initiated the first general magnetic survey of a whole country when, in 1836, Sabine, Ross, and others of its members combined to survey Great Britain from this aspect. The United Kingdom has been re-surveyed three or four times since then, and there are few, if any, civilized countries where at least one magnetic survey has not been made. At sea naval and other vessels frequently make magnetic observations, and many polar expeditions have been specially equipped for the investigation of the earth's magnetism in arctic and antarctic regions. The north and south magnetic poles, where a freely suspended needle assumes the vertical position, have thus been located, though not, it appears, actually reached. These poles slowly change their position, in correspondence with the general secular changes of the earth's magnetism; the motion, however, has not yet been ascertained with precision.

During the present century a great advance has been made towards the survey of the whole earth, within a comparatively limited period, partly by official action leading to modern surveys in India, America, Egypt, Japan, and elsewhere, and partly by the establishment of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. The latter body has not only surveyed many land regions where magnetic observations were scanty, but has also made a remarkably extensive oceanic survey embracing the whole globe, during the years 1910–1917. For this purpose a specially non-magnetic ship, the "Carnegie," has been constructed, whereby magnetic determinations at sea have been rendered far more accurate and speedy than is possible in ordinary ships. The work of this institution has materially improved the accuracy of recent magnetic charts of the world.

The magnetic maps so far referred to, while they are in the form most useful for navigation, do not give a good picture of the actual direction of the earth's lines of magnetic force. As regards the direction of horizontal force, which is what the compass shows, maps such as Duperrey's (as on the lantern slide), which give the lines of force themselves, afford the best idea. They converge to the magnetic poles in the two hemispheres, and their direction differs most from that of the meridians in polar regions.

Why the earth is a magnet, and why its magnetism changes from year to year, are mysteries which have as yet hardly at all yielded to attempts at explanation. One fact, however, concerning the *seat* of its magnetism, has been surely established. All except possibly a small fraction of the whole is known to have its origin *within* the earth, and not in the atmosphere, nor in extra-atmospheric regions. It has been conjectured, with some probability, that the rotation of the earth is the prime cause of its magnetization, and that any large rotating body would probably be likewise magnetic. The fact that the sun also appears to be a magnet, and one having its magnetization, on the whole, similarly related to the axis and direction of rotation, tends to support this theory of the origin of the earth's magnetism. But the laws which, on such a theory, connect the size and speed of rotation of a body with its degree of magnetization are quite unknown, nor has it been explained why, in the case of the earth, the magnetic axis diverges from, and moves relatively to, the axis of rotation. The great secular changes in the earth's magnetism confront us with the fact that the inner history of our planet is by no means concluded, and that within the interior, to the knowledge of which we have so few means of access, profound changes are still being wrought by agents as powerful as they are mysterious.

The earth's magnetism is also affected, more transiently and, in the long run, to a smaller degree, by causes into the nature of which we have gained more insight. At every station on the earth's surface the magnetic "elements," declination, dip, and intensity of force, show regular variations characteristic of the place, dependent partly on the time of day (or position of the sun), and partly on the position of the moon. These changes are found to have their origin above the earth's surface, in high layers of the atmosphere to which we have as little chance of direct access as we have to great depths within the earth. In the case of the variations depending upon the position of the moon, the primary cause seems to consist in a lunar tidal motion of the atmosphere. Living, as we do, at the bottom of the great aerial ocean which envelopes the earth, we are yet quite unconscious of this lunar tide, more unconscious, perhaps, as far as our physical sensations are concerned, than marine organisms at deep sea levels are of the ordinary ocean tides. Nevertheless the lunar atmospheric tide exists, and the air currents associated with it produce minute but ascertainable variations in the height of the barometer (or the pressure of the air), having maxima and minima each twice in a lunar day. These air currents extend up to high regions of the atmosphere, and it is in a layer perhaps 30 or 40 miles above the surface that conditions prove to be favourable to the production, by the air currents, of the magnetic variations in question. The motion of the air, in the presence of the earth's field of magnetic force, has results similar to those proceeding from the motion of the armature between the magnetic poles of a dynamo—there arises a tendency for electric currents to flow. This is the case at all levels, but at the earth's surface, and in other layers, the electrical resistance of the air is too great for the tendency to have much actual effect. There is evidence, however, independent of magnetic observation, indicating that at some high level the air is in a peculiar electrical condition, in which its resistance to the flow of currents is largely broken down. The air is said to be ionized, and another result of this is the production of ozone, which is known to exist in the upper atmosphere. The absorption of very blue (or, rather, ultra-violet) light from the sun seems to be the cause of the ionization of the air, so that, as we might expect, the atmosphere in the sunlit or "day" hemisphere of the earth is much more affected than that over the dark hemisphere. Thus the lunar tidal action produces most result over the former, which accounts for the observed fact that the aforesaid magnetic variations (and the electric currents in the upper air of which these variations are a direct result), while governed, as to type, by the position of the moon, are yet of greater intensity during the hours of solar day than of night.

The magnetic variations which depend solely on the position of the sun are produced in a similar manner, except that the atmospheric motions also are in this case governed by the sun, as well as the ionization. The atmospheric motions are due partly to thermal and partly to tidal action on the part of the sun. The two sets of electric currents, due to moon and sun, flow in the same ionized layer, and undergo similar modifications owing to the seasonal changes of ionization resulting from the varying incidence of the solar rays throughout the year.

A further connection between the earth's magnetism and the sun is revealed by the increase or decrease in the amount of these magnetic variations with the increase or decrease in the disturbance of the solar surface, as indicated by the number of spots and prominences visible upon it. This solar disturbance shows a fairly regular cycle of variation, with a period of about 11 years; the spots and prominences are probably not to be regarded as the main form of disturbance, but as merely symptomatic of great changes affecting the whole of the upper strata of the sun. The emission of heat and light from our luminary possibly shows small variations corresponding to the 11-year period, but these are negligible in comparison with the great variations which appear to occur in the emission of the ultra-violet rays which ionize the earth's upper atmosphere. At times of sunspot maximum the conducting power of the ionized layer seems to be about double that at sunspot minimum, so that the same atmospheric motions produce much larger magnetic variations at the one epoch than at the other.

Another circumstance connected with these daily magnetic variations deserves mention. A variable system of electric currents, wherever situated, tends to produce associated currents in neighbouring bodies, and will do so in so far as these are capable of conducting electricity. In the present case the electric currents produced in the upper air, in the manner described, vary regularly throughout the day, as the rotating earth carries its different parts through successive stages of light and darkness. There is consequently a tendency for a daily varying system of currents to flow within the earth itself, and the magnetic variations indicate that this tendency takes effect. There is some flow of current, indeed, within the first few miles beneath the surface, where the oceans and permeable strata are moderately good conductors. The evidence of the magnetic changes is, however, such as to indicate that the bulk of the internal currents flow within the central core of the earth, beyond a depth of about 1000 kilometres. Apart from the layers quite near the surface, the upper 1000 kilometres of the earth's substance seem to be badly conducting: beneath that the conductivity appears to be of about the same order as that of sea water.

One further important class of magnetic variations remains to be dealt with. Besides the regular daily variations the causes of which have just been referred to, and besides the slow but powerful secular changes, there are frequent irregular disturbances of a fleeting character. Sometimes they are of small intensity, but occasionally their magnitude is great and the fluctuations in magnetic force rapid—disturbances of this kind are called magnetic *storms*. They commonly commence with great suddenness, at times breaking out at a time of apparent magnetic calm. The commencement is simultaneous, to within a fraction of a minute, over the whole earth, and their effects are world wide. Auroral phenomena, both boreal and austral, are usually associated with them, and are visible in regions much less removed from the equator than those in which these lights are generally to be seen. Powerful earth currents also accompany magnetic storms, and are sometimes of such intensity and irregularity as to produce a temporary derangement in the telegraphic communications of this and other countries. At magnetic observatories, where the magnetic force is continuously registered photographically, the records show rapid and relatively intense fluctuations in the amount and direction of the force. Variations in the direction of the compass, for instance, which as a result of the slow secular change would take several years to produce, may occur and be reversed many times during a few hours of a magnetic storm. The disturbed condition may extend over one or more days. The intensity and irregularity of the disturbance is greatest in the high-latitude zones where auroral phenomena are most frequent.

There is a close connection between magnetic storms and solar disturbance, storms being frequent when the sun's surface is much spotted, and *vice versa*. They are consequently most numerous at times of sunspot maximum. Again, the sun rotates on its axis in a period which, as viewed from the earth, is between 27 and 28 days. Mr. Maunder has shown that there is a marked tendency for magnetic storms to recur after one or more such intervals of time. This indicates the sun as the source of the initiating factor in the production of magnetic storms, and suggests that this factor is communicated to the earth along narrow streams proceeding from, and apparently rotating with, the sun. As I conceive it, the action is somewhat as follows: The sun ejects electric particles from disturbed regions on its surface, and these particles travel outwards in limited streams which, on account of the great speed of ejection, seem to revolve with the sun. When such a stream happens to be directed towards the earth, many of the particles are precipitated into the earth's atmosphere, their paths being deflected to some extent, however, by the earth's own magnetic force. The bombardment of the upper atmosphere by these particles produces another ionized layer, like that due to the ultra-violet light from the sun, except that the former extends all over the earth. This layer, however, is not only ionized but electrically charged, and the entangled charges, when thus brought to comparative rest in our atmosphere, exercise a strong mutual repulsion. This results in an upward expansion of the air (the action resembling that of an electrically charged soap bubble, which, owing to the same cause, expands until either it bursts or the tension balances the repulsion). In this way the charge is enabled to escape, perhaps carrying away with it a portion of the atmosphere itself. Some of the most characteristic features of magnetic storms are explicable as consequences of these actions.

Before concluding, I would add a few words relating to magnetic observation. This is usually divided under two heads, observations of the first kind comprising those of which the object is to determine the value of one of the elements of magnetic force (declination, dip, or intensity) at a particular place and time. All observations at sea, and those made in the course of magnetic surveys on land, are of this class. The instruments employed are set up at the chosen station, the observation is made, and the instruments are then transported to the next station.

The observations of the other class are made at fixed observatories, and consist of a continuous photographic registration of the *variations* of the magnetic elements. The dark chamber in which this is carried on is usually carefully maintained at a nearly constant temperature, either by being built in the ground as a cellar, or by having thick double walls and internal temperature control. At such observatories absolute observations are also made, usually several times a week, in order to standardize the magnetic registers. These registers are the source of our knowledge of the daily and irregular magnetic variations, including magnetic storms. The absolute observations, at observatories and elsewhere, provide our information as to the main distribution of magnetic force over the earth, and as to its slow secular changes.

The facts thus obtained are, as I have endeavoured to show, both interesting in themselves and of considerable practical importance. Beyond this, however, lies the question of their significance and interpretation; the search after prior causes is one from which our minds, as constituted, are unable to refrain. In the case of terrestrial magnetism the results of the search, so far as it has been successful, are of great variety and interest. A comparatively few magnetic observations at the earth's surface have, even in the course of the present brief sketch of the subject, led our thoughts to strange and inaccessible regions. We have considered the tidal action of the moon upon the rarefied gases in high atmospheric layers, the mechanical effects of solar heat in these regions, and likewise the electrical consequences of a portion of the sun's radiation which never penetrates to the earth's surface. The Auroral Lights in arctic skies, no less than electric currents within the earth's crust, and at great depths in the intensely compressed and heated core, have claimed our attention, and continually we have had to refer to the varied emissions from the ever disturbed surface of the sun. Nevertheless, though much has been explained, further and great mysteries remain to be unfolded. Chief among these is the mystery of why the earth is a great "lodestone" or magnet at all, and why its magnetism is subject to changes so profound, in a period which, to the geologist at least, is but brief. Difficult as the problem may seem, we cannot but believe that in this, as in matters of greater and deeper import, honest and patient enquiry will in time find the solution. Happy is the man to whom it falls, first of his race, to think one—even the least—of "God's thoughts after Him."

Discussion.

The Chairman asked leave to tell once again the familiar story of Faraday. A visitor to his laboratory once asked : "What is the use of all these things ?" to which he gave the immortal reply : "What is the use of a baby ?" "These things,"—the electric batteries, the coils and cables—have now become part of our life. It is interesting to see how long the baby, which has been the subject of Dr. Chapman's address, took to grow. It began with Thales, 2500 years ago ; the next step was taken in the Middle Ages ; to-day we have its practical application to navigation and to all our electrical appliances.

This is typical of the other physical sciences. They appeal to two different classes of people ; one class asked : "To what use can we turn it ?"; the other class, which appealed more to his own mind, consisted of those who tried to explain what they saw. But this word "explain" is not appropriate, since men of science cannot "explain" anything, but they can only place observed facts in their right relationship to one another.

In the particular subject to which Dr. Chapman had called their attention, a connection had been traced between movements of the magnetic needle and the condition of the sun as shown by sunspots. Dr. Chapman had given more time and thought than most men to this subject, and the task of extracting the kernel of truth from a great mass of facts had fallen largely to his share. He (the Chairman) had great pleasure in proposing a hearty vote of thanks to Dr. Chapman for his address, and would call upon Mr. Maunder to second it.

Mr. E. Walter Maunder said that, with the Chairman's permission, he would like to say how privileged he felt himself to have been in having spent much the greater part of his life as a member of the staff of Greenwich Observatory. One thought which had often been on his mind had been emphasized by Dr. Chapman's paper, namely, the continuity of the work of Greenwich Observatory.

It was more than 240 years since John Flamsteed became the first Astronomer Royal, with full permission to provide himself with what instruments he thought necessary at his own expense. Amongst those instruments was a magnetic needle, the forerunner of the magnetic observatory that was established by Airy 80 years ago. Halley, the second Astronomer Royal, as Dr. Chapman had told them, was one of the great founders of the science of terrestrial magnetism ; he was the first to make a magnetic chart of the world, undertaking several voyages for that purpose. The latest magnetic chart of the world was that to which, since the War began, Dr. Chapman had devoted himself at Greenwich Observatory.

Airy had founded the magnetic department for the study of magnetic variation, but when iron ships superseded those of wood, and steamers the sailing vessels, fresh problems had to be solved. The best way of dealing with the disturbance of the mariner's compass—due to the presence in ships of great masses of iron, and of powerful machinery in rapid motion—had to be sought out, and Airy took a leading part in that work. Now when seamen had learnt to rely upon the performance of their chronometers as the simplest way of determining their longitude at sea, fresh difficulties had arisen, for electric dynamos were part of the equipment of modern vessels, and the magnetization of a chronometer or watch might seriously affect its performance.

When Dr. Chapman first came to the Observatory, seven years ago, this had become a practical question : "What intensity of magnetic field would alter the rate of a chronometer by one second a day ?" and Dr. Chapman at once set to work to obtain the answer, and he succeeded. His work at Greenwich Observatory had therefore been entirely on the lines of its historic continuity, and had been of great practical importance to the nation. And that afternoon he had given in short compass a complete review, admirably clear and simple, of a wide subject, some branches of which were quite new, and in which, moreover, he has himself been one of the leaders. On these and many other grounds, he (Mr. Maunder) begged to second the resolution.

The resolution was duly carried.

Several members asked questions of the lecturer, Colonel Alves inquiring "Is there any idea as to the approximate depth of the magnetic poles beneath the surface of the earth? As far as is known are there, as supposed by Dr. Halley, two magnetic poles in each hemisphere—four in all—or only one?" Mr. W. Hoste asked "How is it accounted for that the northern and southern magnetic poles are not exactly opposite, but are actually in the same hemisphere, seeing that the earth is of regular shape? Is there a tendency for this relative position to vary, and for the two poles to become opposite eventually?"

Lecturer's Reply.

The Lecturer replied: "The term 'magnetic pole' usually denotes a point on the earth's surface at which the dip needle becomes vertical. The poles roughly located by Ross and other polar explorers were of this kind. By definition, these lie at no depth, but on the surface. The word "pole" is also used in reference to the "foci" or points of maximum magnetic force, such as that in Siberia. It cannot at present be stated at what depth these local irregularities in the earth's magnetism have their origin.

"Halley's conception of the earth's magnetism, as resulting from the combination of magnetizations in two directions resulting in there being two magnetic poles in each hemisphere, is now known to be too simple to represent the actual facts. It is indeed hardly correct to speak of the earth as possessing a definite magnetic axis and magnetic poles at all, except in the sense above defined.

"The precise positions of the northern and southern magnetic poles are not of fundamental importance in the theory of the earth's magnetism, as they are determined partly by local irregularities in the earth's field. Why the main direction of magnetization of the earth is inclined to the geographical axis, however, and why there are such pronounced irregularities in the surface magnetic force, cannot yet be explained. Similarly it is at present impossible to say whether the poles will in time become opposite to one another.

There is no reason to suppose that this condition, even if attained, would long persist."

THANKS TO THE ASTRONOMER ROYAL.

Lieut.-Colonel MACKINLAY proposed a vote of thanks to the Astronomer Royal for presiding. He said: We have heard how much the Royal Observatory has helped our Navy : it has also very greatly helped the Victoria Institute, for at the present moment three of its most distinguished members are prominently doing so. I have had the temerity to make some observations on the Royal Observatory. I have observed, not only its great and continuous progress, but also the longevity of the successive Astronomers Royal. I venture to think there is some connection between these two facts. I am sure we all unite in expressing a hope that the present Astronomer Royal will maintain the high standard of his predecessors in this, as he does in all other respects ; and that he will long occupy his distinguished position, allotting some of the time before him to presiding on future occasions at Meetings of the Victoria Institute.

Having been duly seconded, this resolution was also carried, and duly acknowledged.