pressures. This gas has never been liquefied, and it is probable that it never will be liquefied, as the attractive force is so weak." In concluding his lectures on the non-metallic elements delivered at the Royal Institution in 1852, and published the following year, Faraday said:* "There is reason to believe we should derive much information as to the intimate nature of these non-metallic elements, if we could succeed in obtaining hydrogen and nitrogen in the liquid and solid form. Many gases have been liquefied: the carbonic acid gas has been solidified, but hydrogen and nitrogen have resisted all our efforts of the kind. Hydrogen in many of its relations acts as though it were a metal; could it be obtained in a liquid or a solid condition, the doubt might be settled. This great problem, however, has yet to be solved, nor should we look with hopelessness on this solution when we reflect with wonder—and as I do almost with fear and trembling—on the powers of investigating the hidden qualities of these elements—of questioning them, making them disclose their secrets and tell their tales—given by the Almighty to man."

Faraday's expressed faith in the potentialities of experimental inquiry in 1852 has been justified forty-six years afterwards by the production of liquid hydrogen in the very laboratory in which all his epoch-making researches were executed. The 'doubt' has now been settled; hydrogen does not possess in the liquid state the characteristics of a metal. No one can predict the properties of matter near the zero of temperature. Faraday liquefied chlorine in the year 1823. Sixty years afterwards Wroblewski and Olszewski produced liquid air, and now, after a fifteen years' interval, the last of the old permanent gases, hydrogen, appears as a static liquid. Considering that the step from the liquefaction of air to that of hydrogen is relatively as great in the thermodynamic sense as that from liquid chlorine to liquid air, the fact that the former result has been achieved in one-fourth the time needed to accomplish the latter proves the greatly accelerated pace of scientific progress in our time.

The efficient cultivation of this field of research depends on combination and assistance of an exceptional kind; but in the first instance money must be available, and the members of the Royal Institution deserve my especial gratitude for their handsome donations to the conduct of this research. Unfortunately its prosecution will demand a further large expenditure. It is my duty to acknowledge that at an early stage of the inquiry the Hon. Company of Goldsmiths helped low temperature investigation by a generous donation to the Research Fund.

During the whole course of the low-temperature work, carried out at the Royal Institution, the invaluable aid of Mr. Robert Lennox has been at my disposal, and it is not too much to say that, but for his engineering skill, manipulative ability and loyal perseverance, the present successful issue might have been indefinitely delayed. My thanks are also due to Mr. J. W. Heath for valuable assistance in the conduct of the experiments.

JAMES DEWAR.

* See Faraday's Lectures on the Non-Metallic Elements, pp. 292–3.

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*SOME RECENT CONTRIBUTIONS TO TERRESTRIAL MAGNETISM.**

DURING the past five years a most remarkable interest in magnetic work has been shown throughout the civilized world. The present time can well be likened to the years when Gauss inaugurated a Magnetic Association, consisting of investigators from all countries, in order to carry out observa-

* A paper read before the Philosophical Society of Washington, March 17, 1900.

tions simultaneously at stated periods, for the purpose of deducing laws governing the complex phenomena of the earth's magnetism, and to recognize harmony in irregularities apparently subject to no law.

Almost every civilized country has either just completed a magnetic survey, or is taking the necessary steps for the inauguration of such work on a grander and more comprehensive scale than ever before. The writer remarked this especially during his recent visit at foreign observatories, undertaken for the purpose of comparing a set of the U. S. Coast and Geodetic Survey instruments with the Observatory Standards. A veritable boom in magnetic work seems to have set in. Thus Eschenhagen, in charge of the magnetic work of the Prussian Meteorological Institute is conducting a magnetic survey of Prussia. Captain Denholm Fraser, of the Royal Engineers of England, is at present actively engaged in making the necessary arrangements for inaugurating a detailed magnetic survey of India and Burma. Captain Lyons, of the Royal Engineers, in charge of the Geological survey of Egypt, who has for some years been making magnetic observations during his journeys in various parts of Egypt, is now planning to make a systematic survey of that country.

The Australasian Association for the Advancement of Science at its Sidney meeting in 1898, on the recommendation of Section A, created a committee for the purpose of promoting the study of Terrestrial Magnetism in the Australasian colonies, and passed a resolution ordering the New Zealand Government, in particular, to establish a permanent magnetic observatory in that colony, and subsequently to initiate a general magnetic survey. The Secretary of the Committee, Mr. C. Coleridge Farr, was very energetic and persistent in arousing the New Zealand people to take an interest in the matter, and the consequence was that the New Zealand Government passed a vote of 500 pounds sterling towards the establishment of a permanent station. Mr. Farr is at present making the preliminary arrangements for the establishment of a magnetic observatory and for the inauguration of a magnetic survey.

As another result of the 1898 meeting of the Australasian Association, the Melbourne Observatory has been granted funds for reducing the magnetic records of the past thirty years. It is extremely fortunate for the advancement of science of Terrestrial Magnetism in this part of the globe that such an energetic and enthusiastic investigator as P. Baracchi is at the head of the Melbourne Observatory.

There have been recently established new magnetic observatories at the following points: Munich, Germany; Genoa, Italy; Mexico City, Mexico. The important advance that this country has made towards setting on foot a detailed magnetic survey of our dominions and for the erection of the necessary observatories has already been described.

With these few prefatory remarks, I will now briefly mention a few of the important recent contributions to our knowledge of Terrestrial Magnetism.

The theoretical investigations of Dr. Adolf Schmidt of, Gotha, Germany.—Dr. Schmidt has just completed an elaborate harmonic analysis of the earth's permanent magnetic field. His investigations are, in a certain sense, an amplification and an extension of Gauss's great work entitled 'The General Theory of the Earth's Magnetism.' Many investigators fail to see that Gauss's investigations elaborated any *theory* of the earth's magnetism and the question, "What is Gauss's theory of the earth's magnetism?" may, therefore, deservedly occupy our attention for a few minutes. Were I asked this question, I would reply as the lamented Herz did in his book

on 'Electric Waves,' to the question "What is Maxwell's electro-magnetic theory of light?" Herz's reply was, "Maxwell's theory is that which is contained in his equations defining the electro-magnetic field," and so might I reply if I were hard pressed, that "Gauss's theory is that which is contained in his equations consisting of spherical harmonic terms defining the earth's permanent magnetic field." But what do his equations imply? His equations involve the following theoretical assumptions: That all of the earth's permanent magnetic field is due to causes residing within the earth's crust which are of a character that can be referred to a potential, so that, knowing the value of the potential, all the component parts, namely, that directed north and south along the meridan, that directed east and west along a parallel of latitude, and that directed vertically downward can be readily computed. If now, these theoretical equations, when applied to the actual observations of the earth's magnetic force in various parts of the globe, are satisfied within the errors of observation, then the assumptions underlying the equations have been proved, and that is what Gauss did, and therein, I should say, consists his theory. The equations then represent a definite physical fact.

Now, Dr. Schmidt, in view of the fact that, since the days of Gauss, observations have been greatly multiplied, decided to test the Gaussian hypothesis anew, and so in his analysis he does not begin by assuming the existence of an inner potential function governing the entire magnetic force, but, instead, makes a separate adjustment of each of the three rectangular components and so obtains *three* spherical harmonic expressions instead of *one* as Gauss did. He carries his expressions to terms of the sixth order, Gauss stopping at the fourth. The agreement or disagreement in the coefficients of the harmonic terms in the three separate expressions would test the Gaussian hypothesis, and Schmidt obtains the following conclusions:

The earth's magnetic force consists of three parts:

1. *The greatest part.*—This is to be referred to causes within the earth's crust and possesses a potential.

2. *The smallest part about $\frac{1}{40}$ of the entire force.*—This is due to causes outside the earth's crust and likewise possesses a potential.

3. *A somewhat larger part than the preceding.*—This does not possess a potential, and, in consequence, points to the existence of vertical earth air electrical currents. The currents amount, on the average, for the entire earth's surface, to $\frac{1}{6}$ of an ampere per square millimeter.

Parenthetically, I may remark that Dr. Schmidt is somewhat skeptical about the proof of the existence of the third portion, believing that errors of observation may have produced such a result. I simply wish to emphasize that, in the main, Gauss's theory (and I may now use this expression—having explained what I mean) has been verified.

This indefatigable worker, Dr. Schmidt, has, within a few months, made another notable contribution, namely, on the 'Cause of Magnetic Storms.'

If we compare the photographic traces, obtained at magnetic observatories, showing the variation in magnetic declination or in horizontal intensity during a magnetic storm at two neighboring points, a striking agreement at once appears to the eye. Examine these curves closer and you will find that the agreement consists principally in the number and position of the individual waves or peaks composing the curves, whereas the magnitudes of the corresponding peaks or hollows show distinct differences, so that at times a peak of one curve

appears greatly flattened out in the other one, and hence a maximum in one may correspond to a minimum in the other. The farther the stations are from each other, the more frequent and clearer become the differences between the curves, so that at very distant points there are but few details which the curves have in common. Especially characteristic of these fluctuations of the earth's magnetism is the continual change controlling them; remarkable similarity is followed in a few minutes by a pronounced dissimilarity—a violent outbreak in the one curve corresponds to an almost imperceptible bending of the curve in the other. This well known peculiarity in magnetic storms shows without doubt that local influences are the prime cause of the phenomena—occurrences of rapidly changing strength and extent which—now here—now there—make their presence strongly felt, and while the effect may reach practically simultaneously over a very extensive area, the maximum travels rapidly from place to place. Dr. Schmidt made a mathematical analysis of various magnetic storms and in particular of the one which occurred on February 28, 1896, and whose course was followed one hour, from 6 to 7 p. m. Greenwich time, at the suggestion of Professor Eschenhagen, simultaneously by 15 observatories distributed over the earth. His investigations clearly showed that the disturbance vectors at times converged to a point, at other times radiated from a point and, in times of magnetic calms (comparatively speaking), the vectors at the various stations were almost parallel to each other as though pointing to a distant force-center. Furthermore that the points of convergence, in general, moved progressively forward with a velocity of about one kilometer in a second and also that they were at times nearly stationary. In view of the fact that the cause of the diurnal variation of the earth's magnetism must apparently be referred to electric currents in the upper regions of the atmosphere, Dr. Schmidt believes that the immediate cause of the magnetic storms is to be referred to electric whirls or vortices which separate themselves from the general electric field in the atmosphere just as do the cyclones and anti-cyclones known to the meteorologists. Taking also into consideration the vertical disturbing components and applying Ampere's rule to the current systems revealed by the disturbing forces, it follows that, for the greater part, the causes of our observed magnetic storms come from outside of the earth's crust.

Professor Eschenhagen's recent work follows naturally upon this brief statement of the work of Dr. Schmidt, for it is largely due to his energy and the instrumental methods he has devised that Dr. Schmidt's investigations have been made possible.

We shall have thrown, presently, upon the screen a lantern slide showing the delicate transportable variation instruments devised by Eschenhagen. The results reached by him with these instruments revealed the desirability of again inaugurating a system of simultaneous observations of the earth's magnetic variations at various points, and so was begun the scheme of observation which furnished Dr. Schmidt with the necessary material. Eschenhagen has likewise made some very interesting investigations as to the effect of Berlin electric tramways at various distances, with the aid of his simple set of variation instruments.

You will see later on the screen curves obtained by these instruments showing the effect of the tramways at various distances. If these small variation instruments prove upon trial, covering a sufficiently long period, to be satisfactory in every respect, their small initial cost and also that of their maintenance will, without doubt, do much towards increasing the number of stations

recording the variations of the earth's magnetism, and so we may hope some day to get the material that is needed for a satisfactory study of these phenomena.

Dr. W. van Bemmelen, who has succeeded Professor van der Stok as Director of the Batavian Magnetic Observatory, has recently issued a new set of isogonic charts for the epochs 1500, 1550, 1600, 1650 and 1700. Magneticians owe a great debt of gratitude to this enthusiastic and painstaking investigator for the exhaustive search he has made for old magnetic data in the various European libraries. Only one who is engaged in similar work can appreciate the amount of love and perseverance necessary for such work. It is also exceedingly gratifying and commendable that the author gives in his publication the data upon which the charts are based.*

L. A. BAUER.

U. S. COAST AND GEODETIC SURVEY.

EXOTIC MOLLUSCA IN CALIFORNIA.

THE number of foreign molluscan species in California has notably increased in the past few years, and includes both terrestrial and marine forms, detected by various collectors in and around San Francisco bay.

With the single exception mentioned below, the introduction of these exotic forms has been purely accidental, simple incidents in the usual course of business traffic or commercial interchange.

First, among the land shells we find the well known snail *Helix aspersa*, a common European species, largely used for food on the continent and familiar to persons who have patronized the restaurants of Paris. This species was intentionally introduced or 'planted,' in California over forty years ago by Mr. A. Delmas, of San José, Santa Clara county, who brought the stock from France and turned it out among the vineyards on the west bank of the Guadalupe, a small river that flows northerly through Santa Clara Valley and empties into the southerly end of San Francisco bay near Alviso. The soil where the snails were placed is a rich sandy loam and the place well shaded. When the summer heats reach the maximum, the *Helices* descend into the ground several feet, hiding in the cracks that form, as the ground dries, and the gopher-holes also furnish cool retreats and protection. The region above named is one of exceeding fertility. It was settled by a few French families. The introduction of *H. aspersa* by Mr. Delmas was made for edible purposes, or in common parlance 'with an eye to the pot.' Mrs. Bush, of the Normal School in San José, informs me that the snails have thriven, and have extended their territory from the starting point on the west bank of the stream to the easterly side, and have multiplied to such an extent, that in some instances they are troublesome in the gardens. Mr. Delmas, the elder, also planted *H. aspersa*, in San Francisco and Los Angeles. I have never met with it in my collecting rambles in San Francisco or the outskirts of that city, nor heard of its having been detected by any collector. This particular plant was probably a failure, for a more unfavorable region than that of San Francisco forty years ago, with its cold sea winds, fog, sand-dunes and shifting sands and sparse ligneous scrubby vegetation it would be hard to find. At the present day the chances for success are altogether better, for the greater area of the city is covered by residences, with plats of grass, garden patches and flower-beds which are frequently watered and the general conditions are more promising. It would doubtless

*In connection with above paper there were exhibited 30 lantern slides, consisting of portraits of prominent magneticians, views of magnetic observatory buildings and instruments, and of photographic traces derived from magnetographs.