Terrestrial Magnetism
and
Atmospheric Electricity

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THE BEGINNINGS OF MAGNETIC OBSERVATIONS.[1]

By G. Hellmann.

After Christopher Columbus discovered the magnetic declination, on the 13th of September, 1492—or, as others think, the geographical variation of the same—mariners began to bestow increased attention on the compass.[2] Voyages to the West Indies becoming now more frequent, showed that the declination of the magnetic needle from the astronomical meridian, which on the west coast of Europe was easterly, decreased gradually toward the west, vanished in the neighborhood of the Azores, and then passed over into a westerly declination. What wonder, then, that it was thought that in this way the geographical longitude could be determined! Christopher Columbus and Sebastian Cabot had already thought of the possibility of such a solution of this, the most important of the nautical problems of that time, and in the sixteenth century the number of those who sought to ascertain the longitude magnetically increased very materially. The fact that the line of no declination, or the agonic line, almost coincided with the zero meridian as adopted at that time—at least in that part of the Atlantic Ocean traversed by voyagers to the West Indies—certainly helped not a little to continually strengthen the belief in the possibility of de-

[1] Translated by Mrs. L. A. Bauer from the original article in the *Zeitschrift der Gesellsch. für Erdkunde zu Berlin*, Bd. XXXII, Heft 2, with some additions by the author.

[2] Further information, documents, and explanations follow at the close of the article, but could not be given with the translation.

[PLATE III.]

Chas. A. Schott

termining the longitude with the aid of the compass. The agonic line was looked upon as a point of departure given by Nature herself for the reckoning of longitude.

While the hope of finally arriving at a correct solution of the longitude problem was continually and most directly inciting the mariners of the sixteenth century to observations and speculations concerning the distribution of magnetic forces over the surface of the earth, the students on *terra firma* remained almost altogether unaffected by these questions. Uninfluenced by the discoveries of Columbus and his successors, they were led, on the other hand, to a separate and quite independent discovery of the magnetic declination. As I will show, it was the construction of sun-dials that first brought those on land to a true perception of the declination of the magnetic needle from the astronomical meridian.

Besides fixed sun-dials, the use of which may be traced back into the Babylonian-Chaldean period, they had also, in olden times, portable sun-dials for traveling purposes. These were first made, however, in simple and practical form, after the directive property of the magnetic needle became known. Then simple horizontal sun-dials, provided with compasses, were constructed. When and where this first occurred, I shall not venture to state; but concerning the time of this innovation, so much may at least be said, that it most probably occurred after the advance had been made from the water compass to the pivot suspension of the magnetic needle, hence toward the end of the twelfth century. But whether really at so early a period such sun-dials were constructed, must remain undecided, since none have been preserved for us from that time, nor any written testimony concerning their existence; though, to be sure, the astronomical-physical manuscripts, which are buried in libraries and archives, have not as yet been thoroughly examined.

The oldest portable sun-dials, which are preserved in the museums of London, Paris, Dresden, Vienna, Berlin, Nuremberg, Prague, Darmstadt, and elsewhere, date from the beginning of the sixteenth century. A large—indeed, perhaps, the larger—portion of them is of German origin. The reason of this is that Peuerbach and his pupil, Regiomontanus, caused gnomonics to be revived, and especially, also, taught the art of constructing portable sun-dials. Peuerbach, who lectured at the University of Vienna from 1454–1460, left, besides a pamphlet "Canones Gnomonis cum nova tabula," a manuscript entitled "Compositio Compassi cum

regula ad omnia climata." At that time, moreover, as I shall soon show, the word "compassus" meant nothing else than a horizontal sun-dial, provided with a magnetic needle. From Regiomontanus also we learn that he constructed such compasses; indeed, according to the testimony of J. G. Doppelmayer ("Historische Nachricht von den Nürnbergischen Mathematicis und Künstlern," p. 56, note t), he appears to have been the first to introduce them in Nuremberg. In any case, this art found an especially favorable foothold in Nuremberg (later, also, in Augsburg); for the just mentioned authority gives us, not only the biographies of the noted compass-makers of Nuremburg—Georg Hartmann, Hieronymus and Paul Reinman, Hans Troschel and Etzlaub Erhard—but also the following important information, which I shall quote here word for word (p. 9, Note a):

"Die Kunst Kompasse zu machen, wurde nach des Regiomontani Zeiten von mehrern, und dabey sehr lang allein zu Nürnberg, ausgeübet, desswegen A. 1510 20 Kompass-macher daselbsten bey einem Hochlöbl. Magistrat auch Ansuchung thaten, um ihnen, wie andern Handwerckern, eine Ordnung fürzuschreiben, welche sie nach ihren Begehren erlanget."

We must conclude from this that, at the beginning of the sixteenth century, Nuremberg was especially a manufacturing center for compasses of this kind, which were constructed in such numbers that they not only satisfied the requirements of the inland trade, but were also exported. I shall in fact cite, later, two authorities showing that in the first half of the sixteenth century Spanish and Portuguese mariners used German sun-dials with magnetic needle, and indeed, a century later, sun-dials of this kind still passed in Italy as of German manufacture.

Some might here remark, perhaps, that by a compass-maker at that time might be understood a circle-maker (maker of pair of dividers) or similar mechanician, since the word means also a circle or pair of compasses in the romance languages. To meet such an objection, I refer to Grimm's German Dictionary (Vol. V, p. 1685, Leipzig, 1873), and add as additional evidence the following two uses of the word compass. The previously-mentioned Georg Hartmann, who, from 1518 to the end of his life, lived in Nuremberg, and served as vicar of the Church of St. Sebaldus, possessed an unusual skill in the making of mathematical instruments, among which sun-dials occupied a prominent position. He constructed such sun-dials in great number for princes and persons of high

rank, among others for Duke Albert of Prussia, with whom he corresponded. This correspondence has fortunately been preserved for us (Kgl. Staatsarchiv in Königsberg) and has been made known by J. Voigt (Briefwechsel der berühmtesten Gelehrten des Zeitalters der Reformation mit Herzog Albrecht von Preussen. Königsberg 1841. 8°.) From this correspondence it becomes clear beyond a doubt that by a compass is to be understood nothing else than a sun-dial with magnetic needle. In the following manner writes Hartmann on the 5th of March, 1544, upon sending to the duke a compass ordered the year previous:

"Gnädigster Fürst, es kommt die Zeit, dass die Compasse zu gebrauchen sind mehr denn im Winter; ich habe deshalb vor einem Vierteljahr verfertigt acht derselben von Elfenbein, darunter sechs auf 55 Grad Preussischer Polhöhe zugerichtet sind, die andern zwei auf 54 Grad Polhöhe. Auch habe ich gemacht vier kleine Compassle, alle von Buxbaumstock, auf 55 Grad Polhöhe mit meinem möglichen Fleisse zugerichtet. . . ."

That the Latin word *compassus* was also used with the same meaning is proved, for example, by the "Horologiographia," by Sebastian Münster (Basileae, 1533. 4°), in which is found on page 7: "*Verum horarium illud, quod vulgo compassum vocant, habens lineae meridianae magneticum indicem, praecellit sua nobilitate et commoditate omnes cylindros, anulos. . . .*"

The preceding references are certainly sufficient to prove that at the beginning of the sixteenth century horizontal sun-dials, with compasses were greatly in vogue and much used. Therefore, it must often have happened that the deviation in the pointing of the magnetic needle from the astronomical meridian was observed, whenever the observer possessed the means or knowledge to determine in some manner the true astronomical meridian.

Such desultory observations alone were not sufficient to shake the belief, prevailing in the occident for at least four hundred years, that the needle pointed true to the pole; for indeed much later the deviations of the needle were regarded as imperfections in the construction, or were explained as being due to the various sources from which were obtained the loadstones used in magnetizing the needles. However, the thought must soon have come to a man versed in astronomy, who himself constructed many sun-dials with compasses and in that connection repeatedly observed that the magnetic needle always deviated from the meridian in the same direction, that therein an obedience to law was concerned. This man

was the above-mentioned Georg Hartmann, who, during his residence in Rome, in 1510, was the first to determine on land the variation of the magnetic needle (6° E.) We discover this from a letter, which he addressed on the 4th of March, 1544, to Count Albert, of Prussia, in which we read among other things:

"Noch ist an dem Magnetstein dieses grösser zu verwundern, dass die Züngle damit bestrichen nicht gerade laufen der Mitternacht zu, sondern wenden sich ab von der rechten Mittag-oder Mitternachtlinie und kehren sich gegen den Aufgang zu, in etlichen Ländern um 6 Grad, wie ich solches selbst gefunden und gesucht habe zu der Zeit zu Rom, da E. F. G. Markgraf Gumprecht und Seiner F. G. Bruder bei einander zu Rom waren; aber hier zu Nürnberg finde ich, dass solcher Ausschlag ist 10 Grad und von andern Orten mehr oder minder. Solches wird auch allezeit mit einem schwarzen Strichle unter dem Gläslein in den Compassen angezeigt, welches Strichle, wie man sieht, allwege nicht gerade auf die Mitternacht zeigt, sondern lenket sich herum gegen den Aufgang."

That we on *terra firma* are indebted to the sun-dial for our earliest knowledge of the magnetic declination, not to the discovery of Columbus, of which nothing appeared in print, is also clearly set forth in the well-known Geography of Heinrich Loriti of Glarus, which appeared first in 1527 (D. Henrici Glareani Poetae Laureati De Geographia Liber Unus. Basileae. 4°), where we read on page 9^b:

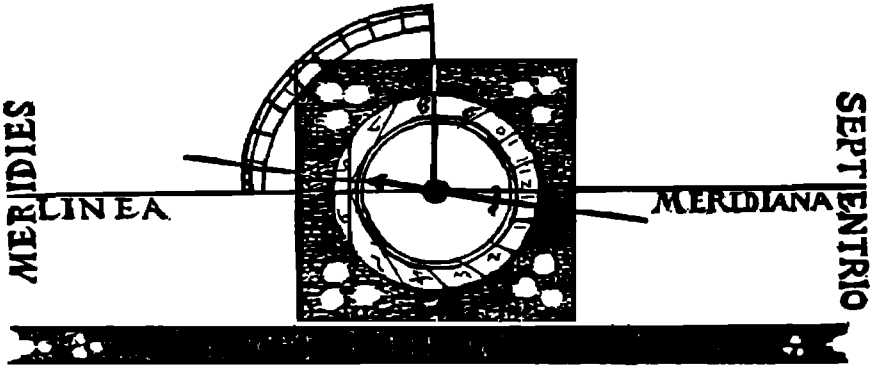

Figure 1

"*In horologiis nostrae aetatis lingula illa tremula, quae circumvolvitur, lineam meridianam ostendit, quanquam non prorsus ad amussim. Neque enim eodem meridiano nobiscum, invenitur lapis ille, sed aliquanto magis orientali.*"

As we see from the extract, Glareanus seeks to explain the easterly declination of the magnetic needle by the fact that the loadstone was found under an easterly meridian; he is thinking, namely, of the loadstone from Asia Minor or India.

Furthermore, if we look at Fig. 1, which is a facsimile reproduction of the illustration of a horizontal sun-dial with magnetic

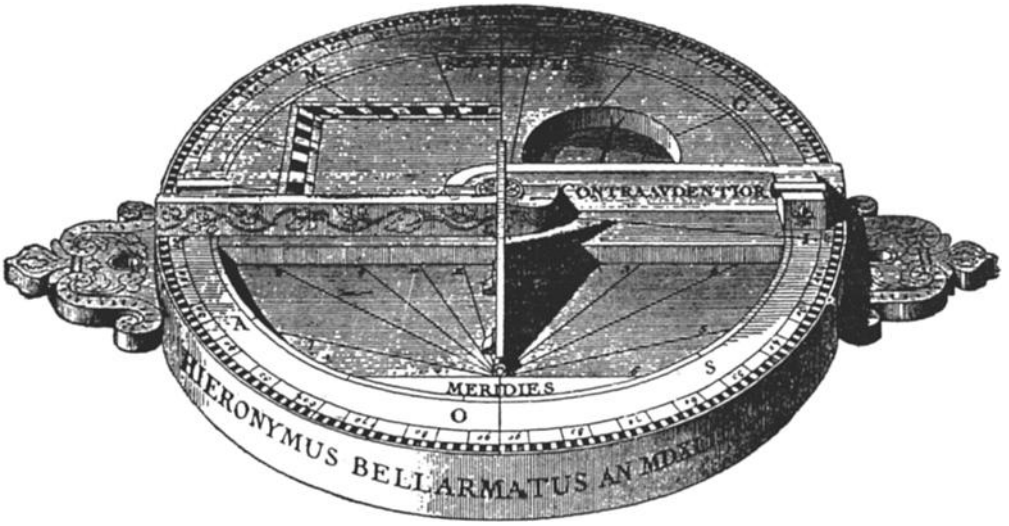

Figure 2

needle, which Petrus Apianus gives in his "Cosmographicus Liber" (Landshut. 1524. 4°), in Col. 51, we must assume an easterly declination of about 10°. This agrees very well with the statement of Georg Joachim Rheticus to the effect that Apianus had found a declination of 10°, while the text belonging to the illustration makes no reference to such declination, but assumes that the direction of the magnetic needle coincides with the meridian line. This contradiction is hard to explain. Perhaps Apianus regarded the declination of 10° as a peculiarity of his own magnet, not as one common to all; with this the opinion of Rheticus, expressed more than twenty years later, would agree.

So, also, we get the oldest known value of the magnetic declination in Paris from a sun-dial, that Le Monnier (Histoire de l'Académie Royale de Sciences, Année 1771, p. 29) found in the collection of Prince de Conti, as we see from the accompanying facsimile (Fig. 2) of the drawing there given of this ivory sun-dial, constructed in 1541 by Hieronymus Bellarmatus. We perceive from this that the declination of the magnetic needle at Paris, in 1541, must have been about 7° E.

Besides these observations made with the aid of sun-dials, there were some other determinations of the magnetic declination in the first half of the sixteenth century, which were obtained in another way, or by a method of which we know nothing. There are the following, in chronological order:

A Florentine mariner, Piero di Giovanni d'Antonio di Dino, writes, in January, 1519, that during a voyage to the East Indies, he noticed, with great wonder, a change in the magnetic needle; beyond Guinea the variation amounted to 11¼° E. (one point), and after the passage of the Cape of Good Hope it was westerly.

To about the same time may be referred Tannstetter's observation of the declination of the magnetic needle in Vienna, concerning which an important document of Georg Joachim Rheticus informs us; for Joh. Georg Tannstetter, of Rhain in Bavaria, was occupied from 1509 to the end of his life (1530) in Vienna. The declination at that time amounted to something more than 4° E.

About the year 1530 must have been made the observation of the magnetic declination on the coast of Palestine, which is graphically represented on Plate V of the work by Jacob Ziegler, Syriae ad Ptolemaici operis rationem. . . . (Argent. 1532. Fol.)

As A. v. Nordenskiöld has already remarked (Facsimile Atlas, p. 105 of the English Edition), this must be the earliest statement of the variation on a map. If we are willing to regard the representation (Fig. 3) as reliable, we have a declination of 25° W., which seems to be too great. Perhaps it is only meant that the declination on the coast of Palestine is westerly.

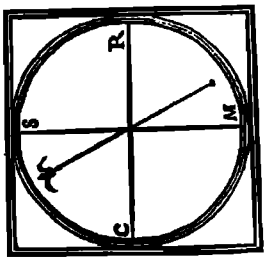

Figure 3

A determination of the magnetic declination as early as the year 1534 is at hand for Dieppe, which must have been made by one of the two pilots, François of Dieppe, or Crignon. They found 10° E., while Ger-

hard Mercator, in a letter dated February 23, 1546, gives the declination in the neighborhood of the Island of Walcheren (perhaps Flushing) as 9° E.

The declination of more than 13° E., obtained by Georg Joachim Rheticus at Dantzic, must be referred to the year 1539, since Rheticus accompanied Copernicus in the summer of this year on a journey from Culm to Dantzic. This observation agrees surprisingly well with the variation for Dantzic, obtained theoretically by Mercator, and calculated by him to be 14° E.

I give now a brief tabular presentation of the values of the magnetic declination in the first half of the sixteenth century which have thus far become known. In this I shall disregard for the present the first great series of such determinations, obtained by João de Castro, since I shall speak of these later in greater detail. I shall give here only that value for Lisbon, epoch 1538.

Year	Place	Magnetic Declination	Observer or Authority
1510±	Rome	6° E	Georg Hartmann.
1518±	Bay of Guinea	11¼ E	Piero di Giovanni d'Antonio di Dino.
1520±	Vienna	4 E	Johann Georg Tannstetter.
1524±	Landshut (Bav.)	10 E	Petrus Apianus (Bienewitz).
1534	Dieppe	10 E	François or Crignon.
1537	Florence	9 E	Mauro (Sphera volgare novamente tradotta. Venetia 1537. 4°. fol. 53[a]).
1538	Lisbon	7½ E	Pedro Nunes or João de Castro.
1539	Dantzic	13 E	Georg Joachim Rheticus.
1541	Paris	7 E	Hieronymus Bellarmatus.
1544±	Nuremberg	10 E	Georg Hartmann.
1546±	Is. of Walcheren	9 E	Gerhard Mercator.

Although, therefore, the deviation of the magnetic needle from the astronomical meridian had been confirmed at different places up to about 1550, it would be very misleading to assume that this knowledge—at any rate, among scholars—soon became common property. On the contrary, up to about the end of the sixteenth century, most of the writers on magnetism and dials made no mention whatever of the declination of the magnetic needle.

The reason for this should be sought for in the fact that no contemporaneous account of the above-mentioned observations appeared in print which would have contributed to their wider diffusion, as also to the circumstance spoken of above, that the deviation was regarded simply as a peculiarity of the magnet concerned, but not of the station, as the documents of Rheticus distinctly show. Again, these first determinations of the magnetic declination were

subject to a great uncertainty. This, namely, was the case with the observations made on shipboard, where the imperfect methods, as well as the frequently poor construction of the compass, were to blame. The values of the declination obtained by pilots agreed so poorly with each other—indeed, often directly contradicted each other—that doubts of the correctness of the magnetic declination arose everywhere anew, which doubts were most comprehensively given expression to, in 1545, by Pedro de Medina, in his "Arte de navegar" (Lib. VI. Cap. III–VI).

The method of the determination of the declination consisted originally, as the notice in the diary of Columbus of the date September 17, 1492, already shows us, simply in sighting from the compass to the Pole Star, and thus obtaining the deviation of the magnetic needle on the disk of the compass. That in this way no great accuracy could be attained is self-evident. It is also to be questioned whether the movement of Polaris, which describes about the North Pole a circle of about 5 degrees in diameter, was always taken into account. Already among the older writers on the magnet do we find, namely, an uncertainty in this regard; at one time they say that the magnetic needle points always towards the North Pole; at another, they assign to it the property of being ever directed toward the Pole Star.

An improvement in the method of determining the declination at sea was, therefore, a first essential, if the hope, cherished with so much love and perseverance, of a solution of the longitude problem by magnetism, was to be realized. An apothecary of Seville, Felipe Guillen, of whom, unfortunately, we know nothing further, was the one who thought out with this aim a new and better method of determining the declination. It is in this connection interesting to note that the German dials (compasses in the foregoing meaning of the word) furnished to the Spanish observer, not only the suitable magnetic needle, but indirectly also the method itself; for this consisted simply in determining with an arrangement like a sun-dial with magnetic needle, the magnetic azimuth of the sun at equal altitudes before and after noon by means of a centrally placed style or gnomon. The half difference of the azimuths, which were reckoned from N. through E. to S. and from N. through W. to S. as far as 180°, was the desired declination of the magnetic needle from the meridian.

Felipe Guillen, who presented this instrument (*brújula de variación*) in 1525, to the king of Portugal, João III, has unfortunately

left behind no writing concerning it. He appears to have remained in Portugal where the instrument was well received. We are indebted to the Spanish cosmographer and major pilot, Alonzo de Santa Cruz, who occupied himself much with the idea of a solution of the longitude problem by means of the compass, for an accurate description of the instrument.

The first who made known in print practical methods for the determination of the magnetic declination was Francisco Falero or Faleiro, a Portuguese in the service of the Spanish navy, to whom we owe also the first real text-book on navigation. This work is so extremely rare that at times its existence has been doubted. It was never seen even by Martin Fernandez de Navarrete, the learned author of "Biblioteca maritima española" (Madrid, 1851. 8°. 2 vols., I, p. 459). At present the Biblioteca Nacional in Madrid has a copy of it. The title runs: "Tratado del Esphera y del arte del marear; con el regimiẽto de las alturas; cõ algũas reglas nueuamẽte escritas muy necessarias. Con priuilegio ymperial. MDXXXV." (Seville, Juan Cromberger. 4°, 52 unnumbered folios, Gothic type.) In the eighth chapter of the second part with the inscription "Del nordestear de las agujas," is the matter of the declination discussed in detail for the first time in print; the author gives three methods for its determination. These are perhaps designed for the instrument of Felipe Guillen, but of this no mention occurs anywhere. They consist: 1st. In the azimuth determination of the magnetic needle at true noon, when the shadow of the style falls to the north; 2d. In observation of the shadow azimuths at corresponding sun altitudes before and after noon; 3d. In observation of this azimuth at sunrise and sunset.

The permission to print Falero's work was granted on August 18, 1532, but it appears to have been written much sooner; since we gather from Castanheda's Historia do descobrimento da India, that an astrologer Faleiro gave to Magalhães, at the beginning of his voyage around the world in the year 1519, a work in thirty chapters, with the aid of which he could determine the longitude in three different ways. Now Falero's published work consisted of about the same number of chapters; namely, thirty-one. This Faleiro was perhaps Ruy Faleiro, the brother of Francisco, who had originally formed the plan of this great journey in common with Magalhães, but later withdrew. Magalhães wanted to place Francisco in command of a ship on the condition "*que su hermano Rui Falero entregase á los oficiales de la casa y á él su método de observar la*

longitud de leste-oeste con los regimientos correspondientes" (Navarrete, Coleccion IV, p. L). Francisco, however, did not accompany him. Perhaps we have therefore before us in Falero's printed work the collaborated labor of Ruy and Francisco, and therewith likewise the knowledge of the Portuguese pilots of the first quarter of the sixteenth century.

Soon afterwards Pedro Nunes,[1] who, in 1537, likewise pointed out the actual existence of a variation, and emphasized the need of its determination for nautical purposes, improved the Guillen instrument merely by adding to it a contrivance for the determination of sun altitudes, and at the same time devised a new method for determining the latitude at any hour of the day. Both methods are found explained in the very rare writing: "Tratado da Sphera com a Theorica do Sol e da Lua. E ho primeiro liuro da Geographia de Claudio Ptolemeo Alexãdrino. Tirados novamente do Latim em lingoagem pello Doutor Pero Nunes, Cosmographo del Rey Dõ João ho terceiro deste nome nosso Senhor. E acrecẽtados de muitas annotações e figuras per que mais facilmente se podem entender. Item dous tratados que o mesmo Doutor fez sobre a carta de marear. Em os quaes se decrarão todas as principaes duuidas de navegação. Cõ as tauoas do movimento do Sol: e da su declinação. E o regimẽto da altura assi ao meyo dia: como nos outros tempos" (Lisbon, German Galharde, 1537; Fol.); to which also as supplement, in the same year and by the same printer, appeared "Tratado em defensam da carta de marear com o Regimento da altura."

A remarkable opportunity now soon offered itself to prove in a most comprehensive manner both methods, which were first carefully tested in 1533 at Evora. The Infant Dom Luiz, who had received instruction in mathematics and astronomy from Pedro Nunes himself, and had shown great interest in all nautical problems, presented such an instrument to his comrade in study and friend, João de Castro, who commanded one of the eleven ships that sailed to the East Indies in 1538, with the charge to thoroughly test and examine this instrument as well as the new method of determining the longitude. João de Castro, later the fourth viceroy of India, performed his task most brilliantly. He investigated—to consider here only the magnetic side of the matter—not only the variation

[1] Contrary to the common custom, I write intentionally Nunes, not Nuñez, because, for all who were not Spaniards, there is no reason for following the later Spanish custom in writing. In his Portuguese writings this scholar inscribes his name always Nunes; in the Latin, Nonius.

as often as possible, but he made also all kinds of observations regarding the method itself, concerning the influence of the magnetic needle and its magnetization from the obtained value of the declination, concerning magnetic disturbances, concerning the deviation of the compass, etc. Indeed, he was also the discoverer of the magnetism of rocks, of which with us nothing was said before the seventeenth century. João de Castro carried on his observations also during his voyage along the west coast of India and in the Red Sea, so that we possess a series of 43 determinations of the declination between the years 1538–1541—the first series of this kind that has come down to us. This remarkable mariner kept very copious journals concerning all his nautical, magnetic, meteorological, and hydrographic observations, which contain indisputably the greatest and most valuable treasure of records of that kind of the first half of the sixteenth century, and are worthy the zealous study of all those who intend writing the history of physical geography or of navigation during that period. Since I have read these journals myself, I do not hesitate to pronounce *João de Castro to be the most important representative of scientific maritime investigations at the end of the epoch of discoveries.*

The logbooks, or Roteiros, of João de Castro, kept during the years 1538–1541, which he sent to his patron, the Iuſant Dom Luiz, remained, lying for three centuries as good as unused, in the archives of Portugal, until they were brought to light and made known by Nunes de Carvalho, Diogo Köpke, and João de Andrade Corvo. Their respective publications are as follows:

1. Roteiro de Lisboa a Goa por D. João de Castro. Annotado por João de Andrade Corvo. Lisbon, 1882. 8°, with charts and drawings.

2. Primeiro Roteiro da Costa da India desde Goa até Dio: Narrando a viagem que fez o Vice-Rei D. Garcia de Noronha em socorro desta ultima cidade. 1538–1539. Por Dom João de Castro, Governador e Vice-Rei, que depois foi, da India. Segundo MS. Autographo. Publicado por Diogo Köpke. Porto 1843. 8°, with portraits and drawings, as well as an atlas of charts and plans.

3. Roteiro em que se contem a viagem que fizeram os Portuguezes, no anno de 1541, partindo da nobre cidade de Goa atee Soez, que he no fim, e stremidade do Mar Roxo. Com o sitio, e pintura de todo o syno arabico por Dom Ioam De Castro, decimo terceiro governador, e quarto viso-rey da India . . . pelo Doutor

Antonio Nunes de Carvalho. . . . Paris, 1833. 8°. With portraits and a chart, and an atlas of charts and plans.

In order to show the method followed by João de Castro, I give here—as a sample—his first determination of the magnetic declination made on April 13, 1538, near the island of Madeira:

" Primeira consideração antes do meo dia
Estando o sol em altura de, ... 57 graos
ho estilo lançou a sombra, ... 71 graos
contando do norte pera a banda daloeste.
Segunda consideração antes do meo dia
Estando o sol em altura de, ... 61 graos
ho estilo lançou a sombra, ... 64 graos
contando do norte pera a banda daloeste.
. . . . . .

Tendo por esta maneira vereficado a altura do sol a toda a ora, esperei que depois de meo dia tornasse o sol ás duas alturas em que o tomei pela menhãa, pera me certificar do que fazião as agulhas no merediano destas ilhas, e passou desta maneira.

Primeira consideração depois do meo dia.
Estando o sol em altura de, ... 61 graos ½
ho estilo lançou a sombra, ... 53 graos
contando do norte pera a banda de leste:

foi logo o arquo dante o meo dia maior que o de depois de meo dia per esta operação 11 graos, os quaes partidos pello meo, ficão 5 graos ½, que he a quantitade que neste lugar a agulha nordestea.

Segunda consideração depois do meo dia.
Estando o sol em altura de, ... 57 graos
ho estilo lançou a sombra, ... 60 graos
contando do norte pera leste:

foi logo nesta operação o arco de depois de meo dia 11 graos, os quaes partidos pello meo, virão á parte 5 graos ½, que he a quantitade que neste lugar a agulha nordestea."

Both values for the magnetic declination are identical.

The three Roteiros contain detailed records regarding the measurements of the variation. Usually, several determinations of the azimuth were made before and after noon, those corresponding with equal sun altitudes were combined, and so also several values for the variation of the magnetic needle were obtained. These agree pretty well with each other, since the differences fluctuate only between 0 and ¾°. We may look upon these differences not altogether as errors of observation; for, disregarding other inaccuracies, those real differences in the value of the variation caused by the progress of the ship could not be taken into account.

The method of determining the declination, first tested by João de Castro, soon was universally introduced on ships, and was even at the end of the sixteenth century recommended anew by mariners and scholars in Spain, England, and Holland. They did not know that this method was of Spanish-Portuguese origin, and was already fifty or perhaps a hundred years old. For neither Rio Riaño (1589), nor William Borough (1581), nor Edmund Gunter (1622), nor Henry Gellibrand (1635), nor, finally, Simon Stevin (1599), mention the names of Felipe Guillen, Francisco Falero, or Pedro Nunes. I therefore consider it of importance to make clear here the true state of things and their connection.[1]

[1] The greater part of the documents alluded to in the preceding pages has been meanwhile reproduced in facsimile in "Rara Magnetica," No. 10 of Hellmann's "Neudrucke" (see *T. M.*, Vol. III, 190).