HISTORICAL and BIBLIOGRAPHIC INDEX concerning the development and improvement of the COMPASS.

by

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In the following bibliographic Index, we have grouped in chronological order, various data on the publications which cover the technique of the magnetic compass. The origin of this instrument, which is of primary importance to navigation, gave rise, especially in the second half of last century, to a very animated controversy of which we reproduce in the following pages the fundamental historical facts, together with some curious quotations which have now become classical. With reference to the long period during which the compass was only a rudimentary instrument, i.e. the two centuries from 1600 to 1800, we have confined our remarks to mentioning a few older usual treatises on navigation where the nautical properties of the magnetic compas are alluded to.

In connection with more recent times, when this interesting application of magnetism progressed to the great benefit of intercontinental relations, we have endeavoured to mention the fundamental works to which can be attributed the improvement and more adequate use of the compass, which, together with the log and the sounding apparatus, enables the navigator, wherever he may be on the oceans, to get his dead reckoning.

We have utilised, for this compilation, various extracts from the records of the Department of Nautical Instruments of the Hydrographic Office of the French Navy (prior to 1924), and also all the data placed at the disposal of the International Hydrographic Bureau by the Hydrographic Offices of its States Members, since the foundation of this Bureau in 1921.

In such a compilation, it is unavoidable that certain important works may have been overlooked. We apologise to our readers for these omissions and shall be very glad to receive the remarks of those who are interested in research of this kind, as technical catalogues on the matter are either lacking or far from complete.

To cover this restricted subject, we have not deemed it necessary to open several chapters. However, in order not to destroy the chronological order which is the most convenient whenever a research is effected, we have added to each of the special articles one of the following letters, which serves to distinguish them in the general nomenclature :

those works referring to the history of the compass are preceeded by the letter ..... H

those works referring in a general way to navigation are preceeded by the letter ..... N

those works referring to gyroscopic compasses are preceeded by the letter ..... G

further, several works in connection with the radio compass are marked ..... W

DIVISION OF THE INDEX.

I. — Early history of the Magnetic Compas up to the year 1600.

II. — Development of the Magnetic Compass for 1600 to 1800.

III. — Improvement of the Magnetic Compasses etc. since 1800.

Monaco, 12th February 1941.

I

EARLY HISTORY OF THE MAGNETIC COMPASS UP TO THE YEAR 1600.

(2600 B. C.) — From the work of **Père J.B. Du Haldes** "Description géographique et historique, chronologique, politique et physique de l'Empire de la Chine et de la Tartarie Chinoise" 4 volumes, Paris 1735 *(English translation 1738)*, the following statement appears with reference to Hoang Ti (about 2600 B.C.) giving battle to Tchi Yeou :

"...He perceiving that thick fog saved the enemy from his pursuit and that the soldiers rambled out of the way and lost the course of the wind, made a carr which showed'em the four cardinal points. By this method he overtook Tchi Yeou, made him prisoner and put him to death. Some say there were engraved in this carr, on a plate, the characters of a rat and a horse, and underneath was placed a needle to determine the four parts of the world".

(1100 B. C.) — It is recorded by **Baron Alexander von Humboldt** in his "Kosmos" Vol. V *(Stuttgart 1849-1858)* that in later vehicles, or "magnetic waggons", as they are called, a freely floating needle directed a small figure whose outstretched hand (fig. 1) always pointed towards the South. A waggon of this description called *Fse-Nan* (meaning indicator of the South) was presented to the ambassadors of Tonquin and Cochin China during the dynasty of the Tscheu (1100 B.C.) to guide them on their homeward journey over the vast plains which they would have to traverse.

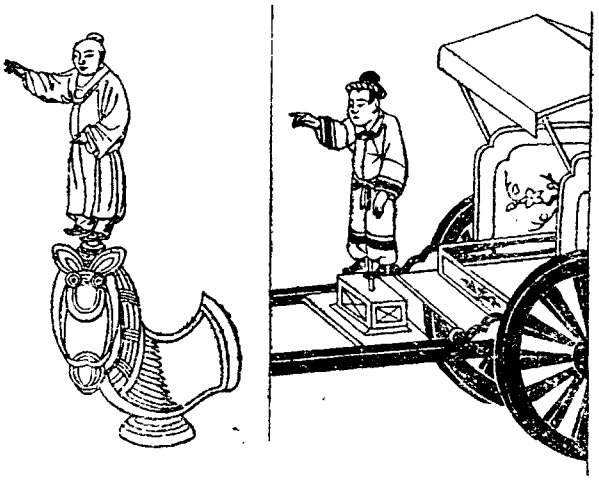


FIG. 1. — *Fse-Nan (Magnetic Waggon).*

It would therefore appear from these statements that the directive power of the magnet, or the use of the compass, was utilised at first to cross long stretches on land before being applied to sea navigation. However, it was later proved that these vehicles comprised solely a mechanical device to which magnetism was in no way applied.

(600 B. C.) — In accordance with **Dr. J.B. Kramer** (lecture made to the Newcomen Society, at Birmingham, on 2nd March 1932), the discovery of the magnet was made quite by chance about 600 B.C. by one of the Greeck tribes called the *Magnetes,* coming from Thessalia and residing in the province of Lydia in Asia Minor

Lucretius (95-53 B.C.) states in "De natura rerum" that the magnet attracts at a certain distance, that they induce magnetism in iron, and that they repel as well as attract.

(250 A. D.) — It is supposed that the compass was first used at sea about the year 250. However there is a difference of opinion amongst historians as to when and where this took place.

IVth Century — Some persons state that the use of the magnetic needle was transmitted to Arabs and Persians, and from them to western navigators by Chinese mariners, who, as early as the 4th century, would have sailed on the Northern Indian Ocean. In such a way the use on this instrument would have reached the western populations about the tenth century. However, as, long after this epoch, Chinese navigation remained very primitive, it is difficult to credit the truth of this mode of transmission.

Other statements maintain that western navigators first introduced the use of the magnetic needle to sea navigation, after learning from travellers the use made by the Chinese of this instrument for trips on land.

XIth Century — The Arab geographer **El Edrisi,** of Ceuta (1099-1164) mentions in European literature the polarity of the magnet.

1148 — The Norwegian historian **Ara Frode,** in his account of the discovery of Iceland, speaking of the trip made in the direction of this island by Flocki Vilgerdsson in 868, states that

"he took with him three trained ravens to serve as a guide... for in those times seamen had no lodestone (leidarsteinn) in the northern countries".

The following articles show that the mariner's compass was in general use at sea in western waters during the XIIth century.

1180-1187 — **Alexander Neckam** of St Albans (1157-1217) held a class in Paris at the foot of Mount Sainte Geneviève :— "**De Naturis rerum libri duo**" *(ed. Thomas Wright, London,* 1863, p. 183) "**De utensilibus**" *(B. Boncompagni, Roma,* 1868, p. 103), where he states :

"Qui ergo munitam vult habere navem... habeat etiam acum jaculo superpositam; rotabitur enim et circumvolvetur donec cuspis acus respiciat septentrionem, sicque comprehendent quo tendere debeant nautae, cum Cynosura latet in aëris turbatione, quamvis ad occasum numquam tendat propter circuli brevitatem".

He adds in another publication *(De Naturis rerum):*

"Nautae etiam mare legentes, cum beneficium claritatis solis in tempore nubilo non sentiunt, aut etiam cum caligine nocturnarum tenebrarum mundus obvolvitur, et ignorant in quem mundi cardinem prora tendat, acum sive magnetem inspiciunt, quae circulariter circumvolvitur utque dum, ejus motu cessante, cuspis ipsius septentrionalem plagam respiciat".

He speaks of a needle carried on board ship, which being allowed to take its own position of repose shows the mariners their course when the pole star is hidden. Further he writes :

"Mariners at sea, when, through cloudy weather in the day which hides the sun, or through the darkness of the night, they lose the knowledge of the quarter of the world to which they are sailing, touch a needle with the magnet, which will turn round till, on its motion ceasing, its point will be directed towards the north".

(W. Chappell, *Nature,* London 1876).

1190-1205 — The French poet **Guiot de Provins (Hugue de Bercy)** in "**La Bible Guiot**" *(Paris, Bibliothèque Nationale,* N° 25405) defines the *magnete* or floatting calamita, in the following manner; it was a « pierre laide et brunette, appelée "marinette" ou compagnon des marins ».

De notre Père l'Apostoile
Vouisisse qu'il semblast l'étoile
Qui ne se muet: moult bien la voient
Li marinier qui s'i avoient;
Par cele estoile vont et viennent
Et lor sens et lor voie tiennent;
Ils l'appellent la Tresmontaine,
(Tramontaine)
Celle est attachié et certaine
Toutes les autres se removent
Et lor leus eschangent et movent
Mais celle cstoile ne se muet.

Un art font, qui mentir ne peut
Par la vertu de la mannète (marinière)
Une pierre laide et brunète
Où li fers volontiers se joint
Ont: si esgardent le droit point
Puis qu'une aiguille l'ait touchié
Et en un festu l'ont fichié

En l'ève la mettent sans plus
Et li festu la tient dessus
Puis se torne la pointe toute
Contre l'estoile, si sans doute

Que jà por rien ne faussera,
Et mariniers nul doutera.

Quand la mer est obscure et brune
Qu'on ne voit estoile ne lune
Donc font à l'aiguille alumer
Puis n'ont-il garde d'esgarer
Contre l'éstoile va la pointe;
Par ce sont li marinier cointe
De la droite voie tenir.
C'est un art qui ne peut faillir.

.....

Qui une aiguille de fer boute,
Si qu'ele pert presque toute,
En un poi de liège, et l'atise
A la pierre d'aimant bise.
S'en un vaissel plain d'yaue est mise
Si que nus hors de la déboute,
Si tost (toût) comme l'iaue s'aserise
Car dous quel part la pointe vise
La Tresmontaine est là sans doute.

(Lais inédits, by Francisque Michel, Paris, 1836).

Through the magnet (la manette or l'amanière, l'adamant or l'iman), an ugly brown stone to which iron turns of its own accord, mariners possess an art that cannot fail them. A needle touched by it, and floated by a stick on water, turns its point towards the pole-star, and a light being placed near the needle on dark nights, the proper course is known. (BARBAZAN, *Histoire littéraire de la France,* Fabliaux II, page 328).

Lorimer (1795) gives the following interpretation of the above in his work "A Concise Essay on Magnetism":

"This same (the pole) star does not move,
(and) they (the mariners) have an art which cannot deceive,
By the virtue of the magnet,
An ugly brownish stone,
To which iron adheres of its own accord,
Then they look for the right point,
And when they have touched a needle (on it)
And fixed it on a bit of straw,
Lengthwise in the middle, without more,
And the straw keeps it above;
Then the point turns just
Against the star undoubtedly.
When the night is dark and gloomy,
That you can see neither star nor moon,
Then they bring a light to the needle,
Can they not then assure themselves
Of the situation of the star towards the point (of the needle) ?
By this the mariner is enabled
To keep the proper course;
This is an art which cannot deceive".

From the above it will be gathered that the mariner's compass in its earliest form consisted of a magnetic needle which was kept afloat in a basin of water by means of a straw, and was thought to derive its directional power from the pole star. Later the straw was dispensed with, by passing the needle through a piece of wood as shown in fig. 2, which depicts a magnetic needle of a date somewhere between 1185 and 1200.

FIG. 2.

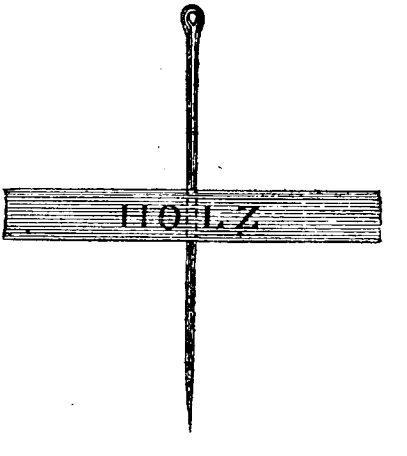


FIG. 2. — *Calamita* (XIIIth Century).

1218-1225 — Cardinal Jacques de Vitry bishop of Acon in Palestine in his "**Histoire de Jérusalem**" *(Historia Orientalis) (Jacobi Vitriaco Aconensis Episcopi Historia Hierosolimitana) (cap.* 89) speaks of the magnetic needle as "most necessary for such as sail the sea".

"Acus ferrea, postquam adamantem contigerit, ad stellam septentrionem..... semper convertitur; unde valde necessarius est navigantibus in mari".

— **Vincent de Beauvais** († 1264), a crusader contemporary of Vitry, states the adamant (lodestone) is found in Arabia and mentions a method of using a needle magnetized by it which is similar to that described by Kibdjaki; he further specifies :

"Angulus quidem ejus, cui virtus est attrahendi ferrum, est ad « zaron » idest septentrionem; angulus autem oppositus ad « afon »; id est meridiem". (Speculum, Livre VIII, cap. IX).

1242 — Baïlak el Kibdjâki, in his "**Tresor des Marchands pour la connaissance des pierres**", written in Cairo in 1282 (Merchants' Treasure in the science of stones) states that at the time of his voyage from Tripoli to Alexandria (1242) :

"They say that the captains who navigate the Indian seas use, instead of the needle and splinter, a sort of fish made out of hollow iron, which, when thrown into the water, swims upon the surface and points out the north and south with its head and tail (Klaproth p. 57).

The magnet at the fish mouth "prenait la direction du Pôle Sud :— Mystère de la Création".

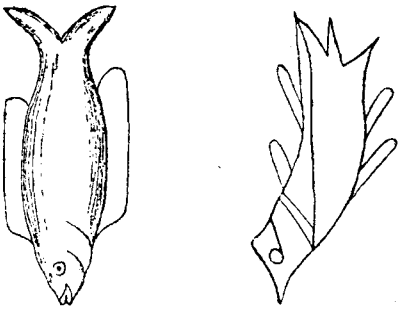


FIG. 3. — *Fish floats* (XIIIth Century).

Baïlak el Kibdjaki writes as follows :

"When sailing in the Syrian seas, when the night is so dark that no star can be seen, the captains place a jar full of water in a spot protected from the wind. They throw therein a needle embedded in a wooden peg or in a calamo shaped like a cross. Then they take a magnet as large as the palm of the hand, place their hands near the surface of the water and rotate them towards the right, in such a way that the needle swerves on the surface of the water. They then suddenly remove their hands and the needle points south and north". (Baïlak el Kibdjaki, according to Klaproth).

1248 — Huges de Bercy, monk at Cluny **(Guiot de Provins)** gives new details on construction of the magnetized needle, now supported on two floats in a glass cup.

1252-1255 — Heinrich von Krolewitz — writes as follows :—

"So wollen wir tun, und das ist gut,
Wie der Seefahrer tut,
Wenn er sich werrirt
Und dass sein Widerwind ihm wird,
Und dass die Nacht angeht
Und er der Sterne nicht sehet;
So kann er sich nicht erregen bass,
Er giesset Wasser in ein Fass
Und wirfet eine Nadel drein
Und weiset ihr des Magneten Schein.
Der Stein das Eisen zu sicht ziehet
Und das ist gar wunderlich :
Dass sie sich dicke umedreht
Und danne rechte besteht
Zugegen dem Leitsterne.
Das sollen auch wir tun gerne
Wenn wir irre gewesen.
.....
Geht an unsere Frauen,
Die wir sollen schauen
Wunderlich gerne
Gleich dem Leitsterne
Und an ihrem Sohn Christ,
Der der wahre Mittag ist."

1260 — In his encyclopaedia, "**Le Livre dou Tresors**", **Brunetto Latini** alludes thus to the compass :

"Por ce nagent li marinier a l'enseigne des estoiles qui i sont, que il appelent tramontaines, et les gens qui sont en Europe et es parties de decà nagent à la tramontaine de

septentrion, et li autre nagent à cele de midi. Et qui n'en set la vérité, praigne une pierre d'aimant, et troverez que ele a ij faces l'une qui gist vers l'une tramontaine, et l'autre gist vers l'autre. Et a chacune des ij faces alie la pointe d'une alguille vers cele tramontaine à cui cele face gist. Et por ce seroient li marinier deceu, se il ne se preissent garde et porce que ces ij estoiles ne se muevent, avient il que les autres estoiles qui sont enqui entor ont plus petit cercle et les autres plus long".

He also gives the italian names, in use by mariners, of the points of the compass, which will henceforth replace the Roman and mediaeval names perpetuated by Isidore de Seville.

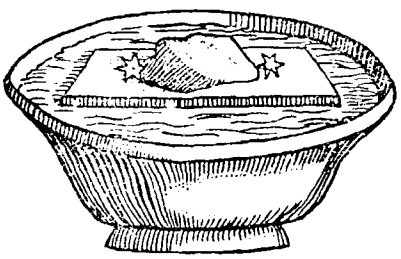


FIG. 4. — *Brunetto Latini* (1260).

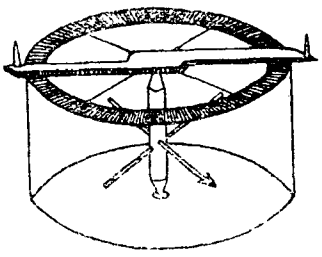


FIG. 5. — *P. de Maricourt* (1269).

1266-1267 — **Roger Bacon** in Opus majus and Opus minus speaks in detail of the properties of the magnet, and states that if it swerves freely towards the poles, this is not due to the pole star, but to the influence of the northern region of the heavens.

8th Aug. 1269 — **Petrus Peregrinus de Maricourt** in "Epistola de Magnete", written during the siege of Lucera in the Pouilles. *(cf. the P. Timoteo Bertelli, Bolletino di Bibliografia... da B. Boncompagni,* Roma, 1868) *(edition P. Gasser,* Augsburg, 1558, *English translation Silvanus Phillips Thomson,* London, 1902) *(edition Dr. Silvanus P. Thomson, Proc. British Academy,* Vol. II, London 1906) gives the earliest unquestionable description of a pivoted compass. (Fig. 5). He describes first an improved floating compass with fiducial line, a circle graduated with 90 degrees to each quadrant and provided with movable sights for taking bearings. He then describes a new compass with a needle thrust through a pivoted axis, placed in a box with transparent cover, cross index of brass or silver, divided circle and an external "rule" provided with a sighting arm.

He speaks of an improvement in the magnetic needle. The magnet stone when placed

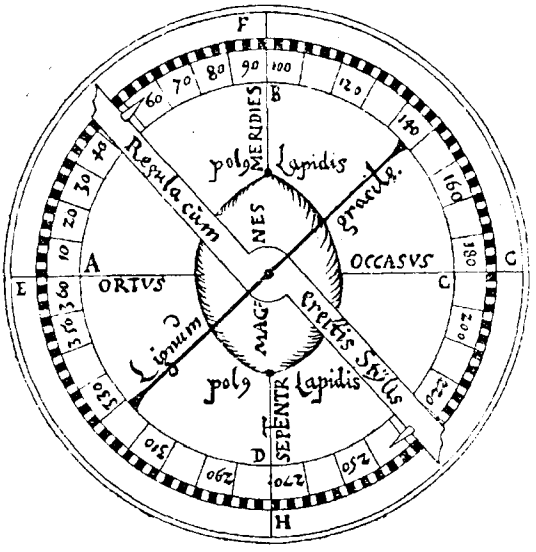


FIG. 6. — *Pierre de Maricourt Card* (1269).

in a small round box which floated on the water, always directed its point towards the north : this property was also apparent in an iron needle rubbed with the magnet and fixed on a tiny piece of wood or a straw placed in the water. He then describes :

" un instrument bien meilleur et d'un effet plus sûr: soit une boîte ronde, « ad modum piscidis », de bois ou de cuivre, peu profonde, au couvercle transparent de cristal ou de verre: et même il vaudrait mieux que la boîte toute entière fût transparente. Disposez au centre un petit pivot de cuivre ou d'argent percé de deux trous à angle droit. Par ces trous passeront une aiguille de fer aimantée qui indiquera le nord et le sud, et une aiguille d'argent ou de cuivre qui marquera simultanément l'est et l'ouest. Ces quatre points cardinaux seront portés sur le couvercle, et leurs intervalles gradués en 90 degrés: une alidade transparente servira à mesurer les angles azimutaux. Tournez la boîte de façon que l'aiguille marque le nord. Et ainsi vous vous dirigerez par terre ou par mer, vers les cités ou les îles, pourvu que leurs longitudes et leurs latitudes vous soient connues ".

Previously to 1269, Italian mariners used the floating magnet, called *calamite,* of the Amalfi pilots.

The poet **Antonio le Panormita,** of Palerme (1394-1471) writes in his " **History of the Kingdom of Naples** " : " Prima dedit nautis usum magnetis Amalphis "

(Flavius Blondus who alludes thereto in his " **Italia illustrata** ", 1450, adds, however, that the certainty of the origin is not known.

In 1511, **Baptista Pio** in his " **Commentary** " repeats the opinion as to the invention of the use of the magnet at Amalfi as related by Flavius.

Gyraldus, writing in 1540 " **Libellus de re nautica** ", misunderstanding this reference declared that this observation of the direction of the magnet to the poles had been handed down as discovered " by a certain Flavius ". From this passage arose a legend, which took shape only in the 17th century, that the compass was invented in the year 1302 by a person to whom was given the fictitious name of Flavio Gioja, of Amalfi *(P. Timoteo Bertelli - Studi storici intorno alla bussola nautica. Acad. Lincei,* Roma, 1894).

FIG. 7.

In this connection, **Wm. Barlowe** in 1597, had already remarked in his " **Navigator's Supply** ":

" the lame tale of one Flavius at Amelphus, in this Kingdome of Naples, for to have devised it, is of very slender probabilitie ".

(Breusing - Flavio Gioja und der Schiffcompass - Zeitsch. der Gesellsch. fur Erdkunde, Berlin, 1869).

(J.C. Husslein - Flavio Biondo als Geograph der Frühhumanismus, Würzburg, 1901).

In the middle ages, the compass was called calamite, marinette, magnete, manete or needle. The word "boussole" is derived from the Italian "bussola" = buxola, which means "boite de buis". Thus the name of the container has been given to the contents.

It was probably as a skilful maker of compass boxes that Flavio Gioja gained a name in the story of the compass. At the beginning of the XIVth century, Italian designers improved the ship's compass by affixing to the pivoted needle a light card on which was painted the rose of the winds: "Rosam chartae rotundae inscriptam superadaptavit chalybi magnetico".

1269 — **Pierre Adsiger,** in a manuscript in the Leyden Library, speaks of the existence of the declination of the magnetic needle.

1272 — **Raimon Lull** of Majorca, in "De contemplatione" is well informed on the use of the magnet at sea. His work "De virtute magnetis" is a simple reproduction of l'*Epistola* by Pierre de Maricourt.

1286 — **Raimon Lull** mentions the adoption of the Italian rose by Catalonian mariners. Previously the Greeks utilised the 12-rhumb wind-rose of Timosthene (IIIrd century) the Latins that of VITRUVE "De Architectura" Würtsburg edition 1548 or of SUÈTONE (69-141). Then the 24-rhumbs rose described by Archibishop Isidore de SÉVILLE (560 636) in "Etymologias". The 16-rhumb Italian rose only appeared in the middle of the 14th century with the Amalfi school. That covering 32 winds appeared in 1637 on a map of the Pizzigani brothers which has been kept in the Parma Library.

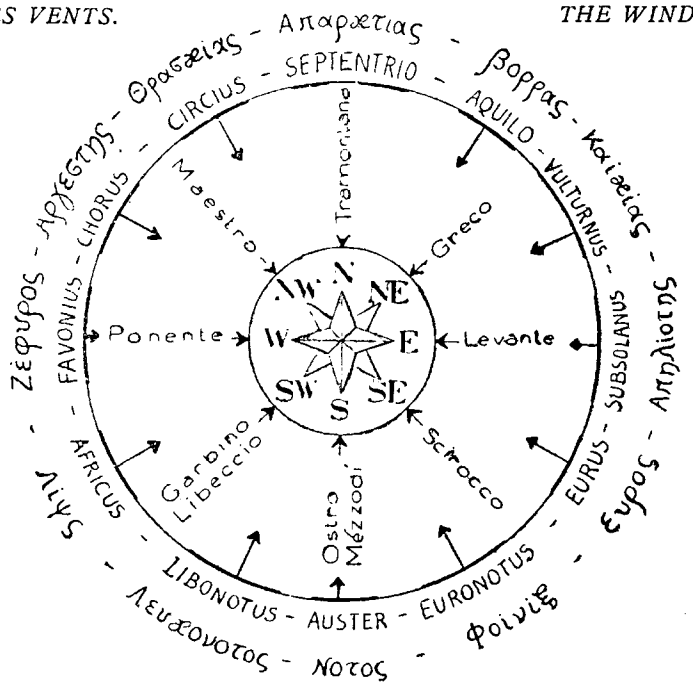


FIG. 8.

LEGEND:

Exterior circle: 12-wind Greek rose (Thimosthenes IIIrd century).

Interior circle: 12 or 24-wind Latin rose { Vitruve (1st century B.C.). Suètone (69-141). Isidore de Séville (560-636).

In the centre: a) 16-rhumb Italian rose - Amalfi (XIVth century).
b) Frankish rose (1536).

It was currently used at the time of the big discovery expeditions which were undertaken at the instigation of Don Henri le Navigateur of Portugal (1394-1460).

The following illustrations gives the equivalents, usually recognised, of the Italian and Latin terms for the Winds.

The Frankish rose (N.S.E.W.) for naming the points of the compass, was utilised as early as 1536 by Flemish navigators for the graduation of their compass cards, and this system was adopted shortly after by Spanish and Portuguese navigators. During the course of the XVIIth century, the use of colours and Italian initials was replaced by the Frankish notations which are still in general use. This notation became international following the International Hydrographic Conference of 1932, which adopted common abbreviations for designating the various rhumbs in all nautical publications.

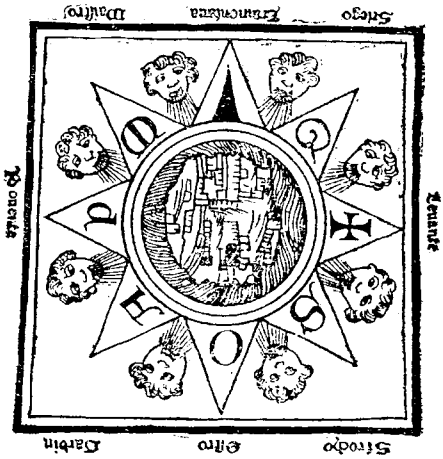


FIG. 9.
Wind Rose
Francesco degli Stabili (1519).

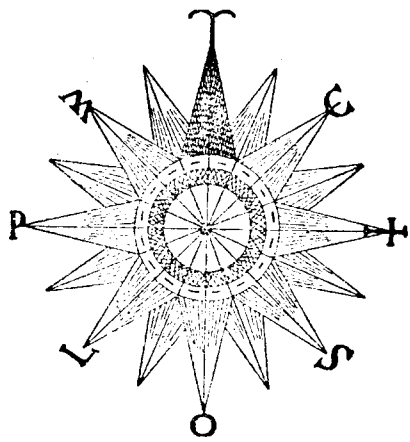


FIG. 10.
Nicolaus de Nicolay Compass Rose
(1560).

1294 — The ship's inventory of the ship "St Nicolas" of Messina mentions, at this time, a "bussola" used in conjunction with a "aiguille de mer" (magnetic needle) carried by a reed: "Calamita cum apparatibus suis et bussola de ligno" (Ch. de la RONCIÈRE - Un inventaire de bord en 1294, et les origines de la navigation hauturière. Ecole des Chartes, Paris).

1297 — Klaproth admits that, prior to that date, there exists no original report concerning the use of a Chinese marine compass. Later on, these instruments, in China, were quite rudimentary and little used in Oriental navigation.

1300 — **Haukr Erlendsson** in l'"**Hanksbok**" (Colonization of Iceland) reproduces the following paragraph: "Floki Vilgerdsson (on a journey to Iceland (circa 868) recently discovered) instituted a great sacrifice, and consecrated three trained ravens which should show him the way (to Iceland); for at that time no men sailing the high seas had any lodestones (leidarsteinn) up in northern lands". This paragraph was found in the lost manuscript of an earlier work 1148, of **Styrmir Karason** who died in 1245.

1308 — According to the "**l'Arte general ultima**" of **Ramon Lull,** written at Pisa, the needle carried by a floater was still used at that time (Antonio Raymondo PASQUAL, *Descubrimiento de la aguja nautica,* Madrid, 1789).

1324 — Referring to the rose and its adjunction to the magnetic needle, **F. Da Buti** (La Sfera) states that sailors use a compass in the middle of which is pivoted a wheel of light paper to turn on its pivot, on which wheel the needle is fixed and the star (wind rose) painted.

" Anno li naviganti uno « bussolo » che nel mezzo è un perno, in sul quale stà una rotella di carta leggieri, la quale gira in sul dicto perno ".
(E. Gelcich — L'infanzia della scienza nautica, Rivista Marittima, 1890).
(Le P. Pépin — Origines de la boussole marine, 1897).

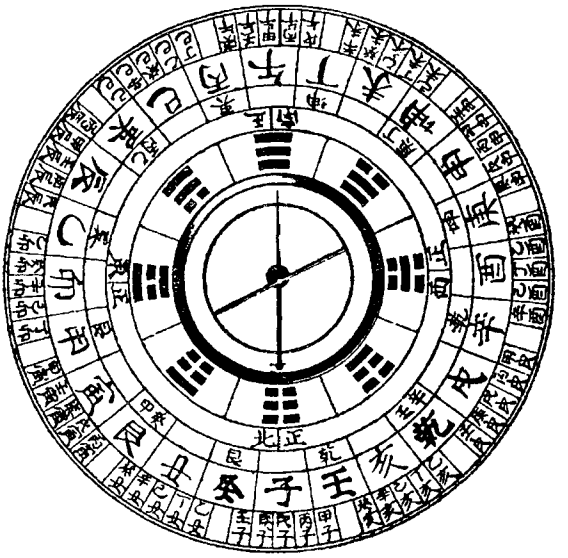


FIG. 11. — *Chinese Card.*

1379 — In the " **Inventory of the furniture** of Charles V ", King of France, the following items are mentioned :

N° 1988 " Item, une aiguille de mer en ung estuy de cuivre ".
N° 2259 " Item, une petite aiguylle de mer à un estuy de cuir bouilly ".
N° 2646 " Item, une aiguille de mer d'argent, pesant sans l'estuy, ung marc douze estellins obole ".

(Labarte, Paris, 1879).

1384 — About this time, the rose sometimes appears drawn on the portulanos (Portulan de Pinelli). It did not, however, appear, on the first ones known (Carte Pisane, G. de Cavignano, about 1300). Beginning in 1502 (Cantino map) the draugthsmen multiplied the roses, as if to set a seal upon their handiwork.

1391 — **Chaucer** in his " **Treatise on the Astrolabe** " states that the wind-rose was already subdivided. He writes :

" Now is thin Orisonte departed in xxiiii partiez by thi azymutz, in signification of xxiiii partiez of the world: all be it so that ship men rikne thilke partiez in xxxii ".

(Skeat edition, Early English Text, Soc. 1872).

1420 — **Nicolas de Conti,** crosses the Indian Sea and states that the sailors use no compass thereon. On the other hand, Ludovico di Varthema says that around 1500, during his trip from Borneo to Java, use was made of the compass. (Travels, p. 31 and p. 249).

1422 — **Leonardo Dati** (La Sfera) — Lo bussolo de la calamita *(Nordenskjold, Periplus,* Stockholm, 1897).

1492 — About this time, the North point, indicated in some of the oldest compass cards with a broad arrow-head or a spear, as well as with a T for *Tramontano,* gradually developed by a combination of these, into a *fleur de lis,* still universal, although it has been said that this sign was introduced by a manufacturer desirous of obtaining the protection of the Bourbons, in the person of Charles d'Anjou.

Another suggestion is that it represents a spear-shaped magnetic needle supported between two flat wooden floats such as was used in the early water compass. (fig. 13).

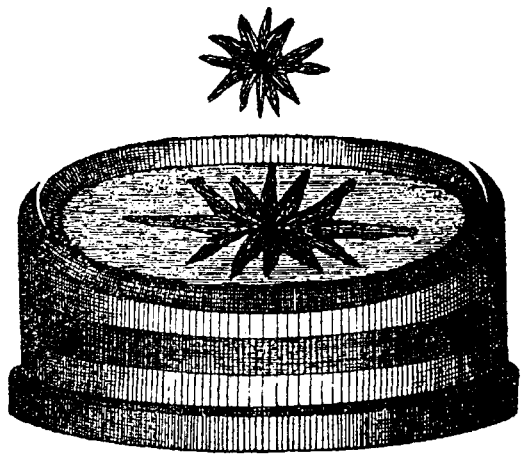


FIG. 12.
Bussola (L. Dati - 1422).

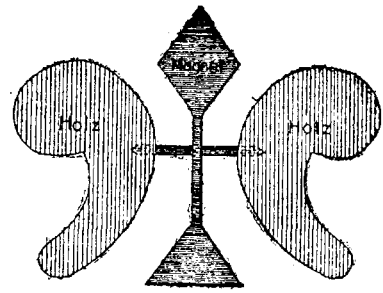


FIG. 13.
Needle with woden floats.

The earliest known wind-roses of the *portulani* or sailing charts of the Mediterranean pilots have almost invariably the eight principal points marked with the initials of the principal winds, Tramontano, Greco, Levante, Scirocco, Ostro, Africo (or Libeccio), Ponente and Maestro, or with a cross instead of L to mark the East point.

The cross at the East continued till about 1700.

Its origin, as a sign to mark the East, goes back to the world map included in the manuscript of Saint Isidore de Seville "Itimologias", copied in 946, and belonging to the Monastry of San Miguel da Cagola (Spain).

1492 — On the 13th September, of that year **Christopher Coloumbus** discovered the variation the needle swerving 6° to the west of the Polar Star.

"En estedia, al comienzo de la noche, las agujas noruesteaban, y à la mañana nordesteaban algun tanto".

He noticed, later, that needles of various metals and makes, did not produce the same angles of deviation.

Variation, according to Saussure, was known by the Chinese as early as the 8th or at least the XIth century. A Nuremberg sun dial, dating from 1451, and kept in the Innsbruck Museum, together with maps of Central Europe much prior to 1500, show this variation by the picture of a deviated needle. (fig. 14).

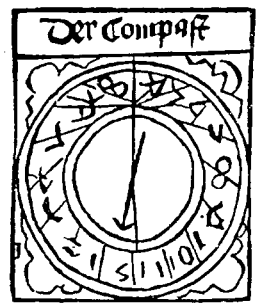


FIG. 14. — *The Variation - from a German Map (early XVth Century).*

An Atlas of **Andrea Bianco,** published in 1436, gave the observed variations at different places.

João de Lisboâ, speaking of French and Genoese needles, states that

"nordestearem e noroestearem differentemente..... e porque os «antigos» nao sentiram esta variaçâo andavam mudando os ferros da agulha ferrados fora da flor de lis.....".

It would thus seem that, prior to the first trip of Christopher Columbus, variation was already known, as the lag of the needle was modified by the pilots in accordance with the Fleur de Lis.

In fact, in 1492, Columbus determined a line of no variation in the vicinity of the Azores, and, the same year, the Jesuit Father Acosta is said to have determined four others. The progressive change of variation, as he journeyed from East to West, appears to have induced Columbus to seek by this method a way of determining longitude, which problem, since that time, has occupied the mind of many scientists and navigators.

1503 — **Orontius Finaeus** — Margarita Philosophica - Argentoratum.

N 1509 — **Hermão de Campos** (impr.) — Regimento do Estrolabio e de Quadrante Tractado da spera do Mundo - Lisboã *(fac simile,* Munich, 1914),

Translation in Portuguese of the treatise of SACROBOSTO, 1488 " Regimento or Manual of Munich ".

H 1510 — **Ludovico di Varthema,** le Viateur " Itinerario " - Travels (1502-1508) - Mentions the use of the compass in the East Indian seas. *(Trans. J.W. Jones, ed. the Rev. G.P. Badger,* Hakluyt Society 1863 - *Translation J. Balarin de Raconis,* Paris, 1888).

1510 — The cleric **Giorgio Hartmann,** of Bamberg (1489-1564), during a stay in Rome, measured the Magnetic Variation with the object of constructing pocket sun-dials. He later continued this work in Nürnberg, and in March 1544, ,he forwarded his famous report to the Duke Albert of Prussia, wherein his operations are described. *(G. Hellmann* " Rara Magnetica ", Berlin, 1898).

1514 — **Joâo de Lisboâ** — **Libro de Marinharia - Tratado da agulha de Marear.** - *(Edição Lisboã,* 1903). At that time, the needles were composed of two iron pieces which the pilots magnetised from time to time with the *pedra de cevar.*

He describes in his book, a box with two fixed opening bored therein, which instrument the pilots of the Indian squadron are said to have used as compass for taking bearings.

João de Lisboã, in his *Livro de Marinharia,* states that it is possible to determine the difference of longitude by the variation of the needle. This fact is also attributed either to Ruy Faleiro who had drawn up " technical instructions " for Magellan's trip (1517), or to a certain Felipe Guillen (1525), " boticario sevilhano " manufacturer of sun dials and of an azimuthal compass which utilises the shade of the sun and to which the Spanish cosmographer, Alonso de Santa Cruz (1539) alludes in his " Libro de las longitudines " (Sevilha, edition, 1921). This method " por el *nordestear* o *noruestear* del aguja de marear... se podia dar muy bien la longitud ".

Pedro Nunes (1537) and João de Castro (1538) had already implicitly condemned this method, which, however, was again propounded later by G. Mercator (1546) and William Bourne. *(A Regiment for the Sea,* London, 1577).

1524 — **Petrus Apianus** — Cosmographicus Liber - Chap. XV - **De Ventis - " Organum viatorum (Horologium viatorum), quod vulgo Compassus dicitur ".** *(Gemma Frisius,* Anvers, 1553, completavit).

1525 — **Felipe Guilen,** manufacturer in Seville, was also, according to Alonso de Santa Cruz, the inventor of the first pelorus with dial divided into 360° and metal pendulum which serves to determine the variation in conjunction with the compass. In 1535, Francisco Faleiro also invented an instrument for observing the sun azimuths, comprising a graduated horizontal disk, in the centre of which the compass was placed. He indicates the method for determining the variation at the time of the sun's transit through the meridian.

Simao d'Oliveira in his " Arte de Navegar " (Lisboa, 1606) describes an azimuthal instrument perfected by Pedro Nunez in 1537, with " balanças e caixa de agulha acostumada " - that is, already fitted with suspended gimbals.

1532 — **Giovanni Quintino** — Dei venti e della Bussola da navicari.

1535 — **Francisco Faleiro** — Tratado del Esphera y del arte del marear - Seville *(fac simile, Joaquim Bensaude,* Munich, 1915).

1535 — **Pierre Garcie dict Ferrande** — Le grand Routtier, Pillotage et Encrage de Mer - (Poictier editions 1584, Rouen, 1589 & 1632).

1537 — **Pedro Nunez** — Tratado da Sphera - Tratado em defensam da Carta de marear - Tratado sobre certas duvidas da navegaçâo - Coimbre *(fac simile J. Bensaude,* Munich, 1915). (1566 edition: *Arte e Ratione Navigandi).*

1538 — On the 5th of August, at Mozambique, **Joâo de Castro** is said to have registered for the first time the deviation of the needle, while utilising :—

"o instrumento das sombras para verificar a variaçâo das agulhas..... achei-as tâo desconcertadas que isto me teve muito suspenso, até que entendi a causa, e foi un berço que estava no mesmo lugar, o ferro do qual chamava a si as agulhas e as fazia desvariar desta maneira.....". (Roteiro de Lisboa a Goa — edition Andrade Corvo, Porto, 1843, page 308).

This discovery would, therefore, have taken place a century prior to that attributed to Guillaume Denys (1666). This same João de Castro discovered in December 1538 the local attraction which he attributed to the presence of a rock :—

"de especie e natureza do manhete, a materra e composiçâo ferrenha, e por esta causa atrairem para si o ferro da agulha desviando - o do seu natural lugar" (loc. cit. page 99).

1539 — **Alonzo de Santa Cruz** was the first to think of constructing charts of magnetic variation *(Libro de las Longitudines,* Sevilha, 1550).

N 1545 — **Pedro de Medina** (1493-1567), cosmographer of the Casa de Contratacion de las Indias, in his "Arte de Navegar", Valladolid (edition, Venice, 1557) *(French translation by Nicolai, of Dauphiné,* Lyons, 1554, 1576 and 1633). *(Italian translation, V. Paletino,* 1554 and 1609), denies, however, the existence of declination; all variations were attributed to the weakness or age of the needles. On the contrary, Martin Cortes in his "Brevo Compendio de la sphera y de la arte de navegar" (1556) believes in declination, but supposes that the needle always swerves towards the same spot in the sky. This idea had also been that of Columbus and Cardan (1501-1576) who believed that the needle pointed always towards the Polar Star; "ridiculous and impertinent belief" declared Père Fournier, in his "Hydrographie" (1643).

N 1552 — **Pedro de Medina** — Regimiento de Navegacion, Sevilha.

N 1550-1560 — **Ferdinandus Oliverius de Sancta Columba** — Ars nautica, Aveiro.

1550 & 1572 — **Alonso de Santa Cruz** — Libro de las Longitudines, Sevilha, shows that "a longitude variava com o nordestear e o noroestear das agulhas".

1556 — **Martin Cortes** in his "Breve compendio de la sphera y de la arte de navegar" believes in declination, but supposes that the needle always points towards the same spot in the sky, idea which Columbus also shares.

1573 — **Pedro Nunes** — (Petri Nonii Salaciensis). De arte atque ratione navigandi libri duo, Conimbrice. Figura nautici instrumenti quod Hispani acum appellant.

1576 — **Robert Norman,** English sailor and instrument maker, was experimenting the balance of a compass card on its pivot with unmagnetised needles. On magnetizing the needles he found the balance upset, it sloping downwards towards the North. From this he was lead to the discovery of the dip of the needle, and his book contains a table of the declinations then known, due to Wlliam Burrough, who had tried to express them by a formula. *(Philosoph. Transact.* 1738).

(The New Attractive, or Account of the First Invention of the Dipping Needle. See 1721, Wm. Whiston).

1577 — **Simon Stevins** (Reginaldus Petraeus) — "Limeneuretika" published by Hugo de Groot, Leiden, describes a compass with azimuthal alidade. In 1597, Barlowe describes an alidade compass in "The Navigator's Supply".

The first pelorus attributed to Zamorano (1581) is cited in "Arcano del Mare" (1646) by Robert Dudleigh, Duke of Northumberland, who describes a more perfected instrument, comprising a portable tray fitted with a handle, with an alidade also with handle.

1580 — Although, **Edw. Wright,** at his time, proposed to add to the compass a movable alidade centered on the rose, this instrument was fitted for two more centuries with two fixed sights diametrically opposed and fixed on the edges of the portable box: it was, therefore, necessary, to turn the whole box in order to point in any direction with the sights. It was only about 1860 that it became the general practice to fix the compass permanently on board, in the same was as the standard compass of the British Navy. (Caillet, "*Traité de Navigation*", 4th edition, 1868).

N 1582 — **Gemma Frisius** — Les Principes d'Astronomie et Cosmographie avec l'usage du Globe. *(Translation Claude de Boissière,* Paris).

1584 — **Wm. Bourne** — A regiment for the Sea - London.

Describes a compass with three parallel needles; he insists upon the necessity of collating variation observations.

1584 — **Peter Appianus** — "Cosmographia" - Antwerpen.

1586 — **Richard Polter** stated that various needles touched with different magnetic stones showed different declinations. The aim, therefore, was to obtain perfect needles which did not decline.

N 1588 — **Antony Ashley** — The Mariner's Mirrour.

N 1594 — **John Davis** — The Seaman's Secrets.

N 1595 — **Joâo Baptista Lavanha** (1555-1625) — Cosmographo mor - Regimento Nautico - Lisbõa.

1596 — **William Borough** — A discourse on the Variation of the Compass or Magnetical Needle - London.

1596 — **Abraham Ortelius** — "Thesaurus geographicus recognitus et auctus" Antwerpiae, 1596, alludes as follows to the discovery of the compass by the Amalphi pilots :

"Melphi hodie, ut puto, in Lucania - Ab huius urbis cive, Joanne Goia magnetis usum navigantibus traditum Anno 1300 putant".

1597 — **William Barlowe** (Archdeacon of Salisbury) - "Navigator's Supply", London, states that compasses of primitive description, not brought from the western countries, were employed in the East Indies. At that time, the iron of the magnet was shaped like a lozenged perimetre. *(Magnetical Advertisements,* London, 1616). He thus describes the compass at that time :

"A round wooden bowl, closed above with glass; a pin fixed upright in the middle bears the fly-card. The magnetized needles are fixed to it below. The bowl hangs balanced horizontally in a brass ring, pivoted on another ring attached to the proper stand or "pinnacle" fixed in the ship; thus the bowl levels itself to the plane of the horizon though the ship is tossed about in various directions by the waves. The needles are either two, with their ends brought together, or one of nearly oval form (Pl. 1), with pointed ends which performs its duty more surely and swiftly. The attachment of the needle, or needles; is such that on account of the variation, artificers in different cities, connect in different ways the needle to the card. In the Mediterranean cities, the magnetic iron is attached to the fly-card with its length parallel to the diameter through the rose or lily, so that any place where there is no variation, the true North and South points are shown by this diameter. In Dantzic, the Baltic Sea and the Belgian provinces, the needles are fixed 3/4 of a point to the east of the lily. In Russia the difference adopted is 2/3 of a point. Lastly compasses which are made in Seville, Lisbon, "Rapella", Bordeaux, Rouen and anywhere in England have an interval of 1/2 a point between the lily and the direction of the needles".

1599 — First declination tables, from the observations of Dutch navigators, acting under the orders of the Prince of Nassau. A series is found in Simon Stevin's booklet, entitled "Haven finding art".

1600 — **Guilelmus Gilbertus (Dr. Wm. Gilbert, of Colchester)** in his "Physiologia nova de magnete, magneticisque corporibus et de magno magnete tellure, *(English translation - Silvanus Phillips Thomson and others,* London, 1900) -

London (also 1663), asserts that : Marco Polo introduced the compass into Italy from the East in 1260. This assertion has since been refuted by Marco Polo's historians (Sir H. Yule - *Book of Marco Polo).*

The work of **Gilbert** "De Magnete", is based on "199 magnetic experiences". He discovered and proved that the earth itself is a colossal natural magnetic needle, and invented thus the science of terrestrial magnetism and the real reason of the orientation of the magnetic needle.

Round about 1600, **Stevinus** of Bruges **(Simon Stevin)** placed the fixed rose at the bottom of the box, below the needle, which practice was followed by the makers of Nüremberg in the 16th century (Limeneuretika).

II

DEVELOPMENT OF THE MAGNETIC COMPASS FROM 1600 TO 1800.

1600 — **Joâo Bautista Lavanha,** Cosmographer, drew up the Tabuas da largura urtiva de leste a oeste; first tables of the sun's amplitude, which were followed in 1614 by those of **Manoel de Figueiredo,** intitled : Taboa do apartamento do Sol ao nascer de Leste, prototype which was translated into French and covered the width from the 45° to the 55°; in 1631, Le Tellier extended to 66° 1/2 of latitude.

1602 — **Pedro de Siria** — Arte de la verdadera navegacion - En que sa trata de la machina del mundo, es a saber;... de las mareas; del Aguja de marear; del modo de hazer cartas de navegar: del uso dellas: de la declination y rodeo, que communmente hazen los pilotos..... Valencia.

In this work he suggested the establishment of tables of magnetic variation. He attributed these variations of the compass to the fact that the magnetic poles does not coincide with the real pole which he places 4 to 5 degrees below.

1603 — **Guillaume le Nautonier,** Sieur de Castelfranc-sur-Lot, en Languedoc — "La Mécométrie de Leymant... Toulouse, ou l'art de trouver la longitude par la déclinaison de l'aimant.

This book which is based more on imagination than on accurate measurements, was refuted in 1611 by Dounod of Bar-le-Duc.

1604 — **Joâo Bautista Lavanha** — Roteiro de navegaçâo da India e derrotas com ha agulha ferrada debaixo da flor de lis e differensas della..... Lisboa.

The earliest description of the *Cardine* (that is hinged or pivoted) for the suspension of the compas, erroneously attributed to Cardan (1501-1576).

The term binnacle, bittacle derives from the portuguese *abitacolo,* to denote the housing enclosing the compas, probably originating with the Portuguese navigators.

N 1604 — **Manoel de Figueiredo** — Hydrographia, Exame de Pilotos, variaçâo d'agulha - Lisboa.

believes that the needle can decline up to 22°, 5, with 4 meridians of no variation.

N 1605 — **Paulus Merula (Paul van Merle)** — Cosmographia generalis - Amsterdam.

1605 — **Simâo d'Oliveira** in his "Arte de Navegar" (Lisboa) states in what manner were manufactured the metal parts of the needle which generally numbered two.

"se tomarâo dois fios da aço delgados, limpios e todos eguais, os quais dobrados de mode que fiquem juntos nas pontas e largos no meio, se porâo as suas pontas debaixo do rumo de Norte Sul, graduando - os com um papel por baixo, o que feito se tocarâo na **pedra de cevar** * por este modo".

* (the "lapis herculeu" of the Latins, the "piedra iman" of the Spaniards and the "calamita" of the Italians).

N 1607 — **John Davis** the Navigator - The Seamen's Secrets. - (edition 1594).

1607 — **Crescentius (Bartolomeo Crescenzio)** "Nautica Mediterranea".

He states that a needle in the shape of a V only slightly opened, does not decline.

1608 — **Luiz da Fonseca Coutinho** — Arte de Agulha fixa, e do modo de saber por ela a longitud. - Sevilha.

1609 — **Everts Keteltas** — Het Gebruyck der Naeld-Wiisinge tot dienste der Zee vaert - Amsterdam.

describes a portable compass with gimbal suspension which bears an alidade and graduated circle.

N 1614 — **Manoel de Figueiredo** — Hydrographia, Exame de Pilotos..... etc. Lisboa.

1616 — **Wm. Barlowe** — in his treatise "Magnetical Advertisements" Tells us that at that time the compasses used by English mariners were yet of a very primitive description. He complains that :

"the Compasses needle being the most admirable and useful instrument of the whole world, is both amongst ours and other nations for the most part, so bungerly and absurdly contrived, as nothing more".

For the needle he recommends the form of :

"a true circle, having his Axis going out beyond the circle, at each end narrow and narrower, unto a reasonable sharpe point, and being pure steele as the circle it selfe is, having in the middest a convenient receptacle to place the capitell in".

1618-1619 — **Diego Ramirez de Arellano** draws up a chart of the Variations of the Needle. (Magellan Straits).

1622 — **Edmund Gunther,** discovered the change in declination in a same spot - confirmed by Professor Gellibrand in 1635 by comparison with the observations of Wm. Burrough.

1623 — On board eleven Dutch vessels sailing together towards the East Indies, via South America, it was noticed that there was a big difference between the various compasses.

1625 — **Samuel Purchas** or **Hakluytus Posthumus** — His Pilgrimes.

N 1628 — **Antonio de Najera** — Navegacion Especulativa y Practica, Reformadas Sus Reglas, y Tablas por las Observaciones de Ticho Brahe, com emienda de algunes Jerros essenciales - Lisboa.

1629 — **Nicolaus Cabeus** — Philosophia Magnetica - Coloniae.

1631 — **Jean Le Tellier** — Le vray moyen de trouver la variation de l'aymant par la Table des Amplitudes avec une observation sur le Bussole au lever ou au coucher du Soleil. - Dieppe.

1637 — **Norwood** — Seaman's Practice.

1643 — **Père Georges Fournier,** in his "Hydrographie" speaks of the installation on board of "the binnacle or "gésole", a sort of cupboard placed at the base of the mizzen-mast and divided into three compartments: the middle one used for the lantern, and the two others for the compasses, placed broadwise, in such a way that the steersman, on whatever side he stood, had a compass in his range of sight Above these instruments was placed the "poudrier (sandglass) ou horloge" - Paris. *(other edition* in 1679).

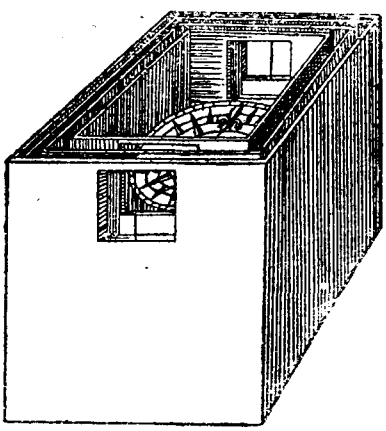


FIG. 15. — *Azimuth Compass according to Père G. Fournier* (1643).

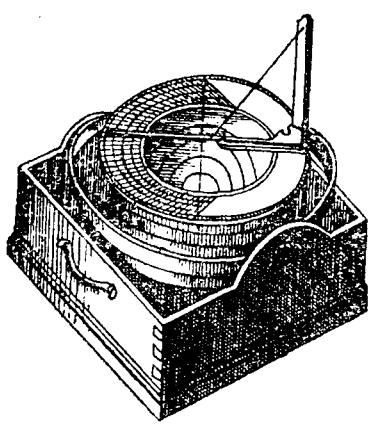


FIG. 16. — *Ed. Halley Azimuth Compass* (1698).

1643 — **Anastasius Kircher** — Magnes sive de Arte Magnetica - Köln.

1646 — **Robert Dudleigh,** Duke of Northumberland - "Arcano del Mare" - describes a pelorus with an azimuthal disc.

1650 — **Bond** — in his Seaman's Kalendar said he had found a formula giving the declination for a stated place. He described it in 1676 in his publication "The Longitude Found" which was soon refuted, in 1678, by **Beckborrow** in "The Longitude not found".

N 1659 — **John Collins** — Navigation by the Mariners Plain Scale new plain'd, or A treatise of Geometrical and Arithmetical Navigation; wherein Sayling is performed in all the three Kindes by a right Line, and a Circle divided into equal parts - London.

1660 — **John Newton** — Mathematical Elements in III Parts - London - (with a chapter on variation of the compass) (avec un chapitre sur les variations du compas).

1661 — **Riccioli** — Geographia e Hydrographia reformatae - Bononiae.

1665 — **Andrew Wakely** — The Mariner's Compass Rectified : containing Tables shewing the True Hour of the Day, the Sun being upon any point of the Compass - London - (1st *edition).*

1666 — **Antonio Maris Carneiro,** Cosmographer — Roteiro da India Oriental, compiled in view of certain differences which had been observed by him and other pilots, in the movements of the compass.

1666 — **Guillaume Denys,** Prêtre Pilote Hydrographe de S.M. — L'Art de Naviguer perfectionné par la cognoissance de la variation de l'aimant ou Traicté de la Variation de l'aiguille aimantée - Dieppe. - *(chez Nicolas du Buc).*

He found that two compasses, placed in two different parts of a ship, did not coincide.

1673 — **Don Lazaro de Flores** — Arte de Navegar - La Havane.

1677 — **C.F. Millet Dechales** — L'Art de naviguer - Paris.

Describes the metal parts of the compass in the shape of the sides of a lozenge.

1685 — **Joachim d'Alencé** — Traité de l'aiman - Amsterdam.

1686 — In the Mémoires de l'Académie des Sciences, attention is drawn to the fact that the declination of the needle was quite different when placed in a copper or a wooden box.

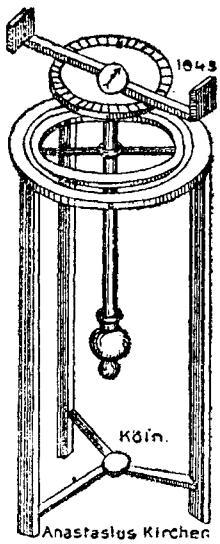
1688 — **Francisco de Seixas y Lovera** — Theatro Naval Hydrographico de los Fluxos... y de las diferencias de las variaciones de la aguja de marear... Madrid - gives a table of the variations of the compass in all the known seas and countries of the world.

1698 — **Bouguer** — Traité complet de Navigation - Paris - *(edition* 1753 et 1781).

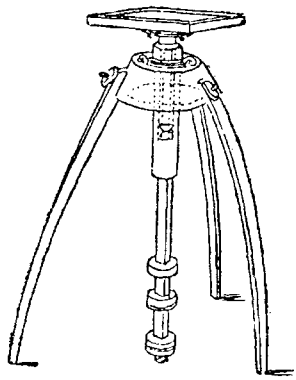
1698-1700 — **Edmund Halley** was ordered by the King on board the "Paramour Pink" for "proceeding with her on an expedition to improve the longitude and the variations of the compass". He discovered the existence of the magnetic poles as apart from the true poles of the earth.

1700 — **Edmund Halley** — drew up, after his expedition, the first charts of Lines of Equal Variation.

However, during the 16th century, Portuguese navigators were in the habit of noting in their registers the variations of the needle, and it would appear that an Italian jesuit, **Guilherme Bruno** (or Borrô) in the instructions to pilots which he wrote in Lisbon, drew up a chart of isogones prior to that of Halley.



A. Kircher (1643).



Chr. Carl Lous (1773).

FIG. 17. — *Azimuths tripods.*

1702 — **Wm. Jones** — A New Compendium of the Whole Art of Practical Navigation - contains also the method of finding the variation of the compass).

1702 — **Aubin** — Dictionnaire de Marine - Article : Boussole ou Compas de Route... *(chez Pierre Brunel)* - Amsterdam.

1705 — **La Hire** rejects needles in the shape of a ring, a shuttle or an arrow, and adds that those shaped like a lozenge "are not worth much more when one of the sides loses its strength".

1710 — **Delisle** collated from 8.000 to 10.000 observations of variation dating back to 1534, and found a second line in the Indian Ocean of no variation. He thought that Halley's zero line in the Atlantic Ocean, which passed through the Bermudas in 1700, was the same as that which, in 1600,, passed by the Cape Agulhas, South-East of Cape of Good Hope, and which had given rise to the name of this famous Cape where, on the India road, the needle of the compass had a South-North direction.

N 1715 — **Albrizzi Girolamo** — Introduzione al l'Arte Nautica per uso de Piloti, e Capitani di Nave, e per il migliore Servizio de Commandanti sopra il Mare - Venezia

1716 — In connection with the divergencies of compasses, **La Hire** proposed to place them in marble boxes, as brass caused perturbations. It was said that "the compasses used at sea are so 'rough-and-ready' that it is a wonder they are relied upon for sailing a ship"; but it is true that "one has nothing better or more convenient".

1720 — **P. Francisco da Costa** — Arte de Navigar, Tratado da Hidrographia e Breve Tratado do Uso da Carta de Marear Globlosa e compasso triangular - *(Traduction portugaise de l'ouvrage Flamand de John Veen).*

1720 — **Alfonso Costadau** — Traité historique et critique - Chap. XX. De la bussole ou du Cadran de Mer... Lyon.

1721 — **Wm. Whiston** — The Longitude and Latitute found by the Inclinatory or Dipping Needle, wherein the Laws of Magnetism are also discovered; together with Robert Norman's Account of the First Invention of the Dipping Needle.

1722 — **Graham** discovered the diurnal change of the compass needle.

1727 — **Radouay** — Remarques sur la navigation -
Radouay complains of the faulty construction of compasses, the rose being stuck against the lozenge-shaped needle and sagging East or West where it has no support. Needles in the shape of a hollow large lozenge with thin sides had been tried, but in that case the magnetic axis was not fixed.

1729 — **Petrus van Musschenbroek** — De Magnete - Leiden.

N 1730 — **Joseph Harris** — A treatise of Navigation - London.
shows the peripheric graduation of the Rose in degrees from 0 to 90, for each quadrant.

1730 — **Servington Savery** of Chilston — Magnetical observations and Experiments *(Philosoph. Transaction R.S.* Vol. 36 - London).

1731 — **Bouguer,** hydrographe du Roy au Havre-de-grace — De la méthode d'observer en mer la Déclinaison de la Boussole - Paris - pièce qui a remporté le prix proposé par l'Académie Royale des Sciences pour l'année 1731.

1733 — **de la Condamine** — Nouvelle manière d'observer en mer la déclinaison de l'aiguille aimantée *(Mémoires Acad. R. des Sciences,* Paris, 1735).
Describes a portable compass with sighting alidade fixed to the box.

1740 — **Seller** — Practical Navigation - *(a former edition) (édition antérieure).*
describes an azimuthal compass with a square for observing variations.

1741 — **G. Grimaldi** — Dissertazione sopra al primo inventore della Bussola - *(Acad. Etrusca de Cortona,* T. III, p. 195).

1744 — **Mountaine & Dodson** — draw a chart of Magnetic Variation *(Royal Society, London),* with a further edition in 1756, comprising tables based on the results of 50.000 observations collated since Halley's chart in 1700 *(Philosoph. Transact.* Vol. 50, year 1757).
In 1765, M. Bellin, attached to the *Dépot des Plans de la Marine,* in Paris, prepared a new edition of this publication accompanying "Petit Atlas Maritime", adding in uniform fashion 1° 1/2 to the values of 1756.

1744-1746 — The French Academy proposed the magnet as a subject for prize essay.

N 1745 — **Pedro Manuel Cedillo,** Director of the Naval Academy at Cadiz — **Tratado de la Cosmographia y Nautica** - Cadiz.
(with numerous tables of Astronomical calculations).
(avec de nombreuses tables pour les calculs d'Astronomie).

1748 — **Abondio Collina** — Considerazioni Istoriche sopra l'origine della Bussola nautica nell'Europa e nell'Asia. - Faenza.

N 1749 — **Giovanni Pagnini,** prof. d'Hydrographie à Malte — **Trattato della sfera ed introduzione alla navigazione per uso de piloti** - Venezia.

1750 — **Dr. Gowan Knight (John Smeaton)** — A description of the Mariners' Compass *(Philosoph. Transact. R.S.* Vol. 46, London)
states that the needles of merchant ships were made of two pieces of steel bent in the middle and united in the shape of a rhombus, and proposed to substitute straight steel bars of small breadth, suspended edgewise and hardened throughout. He describes a pelorus compass fitted with a pivoted sight arm.

1750 — **Thomas Riley Blanckley** — A Naval Expositor, London, 1750.
describes the "Hanging Compass" and states that "Flag officers are generally furnished with them to hang up in their great Cabins".

1750 — **Duhamel** — seeks a way of perfecting the compass to prevent the needles being " volage " (flighty) and invented the barbed damping for the rose.

1753 — **Bouguer** — Nouveau Traité de Navigation - Paris.
describes a way of rendering the rose immovable once the bearing is taken.

C.K. Lous of Copenhague described another method in 1773 in " Tentamina ad Compassum perficiendum ". - Hafniae.

1754 — Elementi dell'Arte nautica, Livorno, translation of the work of Pézenas, professor of hydrography at Marseilles.

N 1755 — **Wm. Emerson** — Navigation; or the Art of Sailing upon the Sea, London.

1757-1760 — **T. Aepinus** — Abhandlung über einige neue Verbesserungen der Magnetnadel und des Seekompasses - Hamburg.

N 1757 — **Jorge Juan** — Compendio de Navegacion por el uso de los Cavalleros Guardias Marinas — Cadiz.

1761 — **S. Kotelnikow** — De Commoda Acus declinatoriae suspensione dissertatiuncula *(Ac. Science, St Petersburg* - Tome VIII - 1761).

N 1766 — **Coubard et Lemonnier** — Abrégé de Pilotage - Paris.

1766 — **Père Pézenas S.J.,** professeur d'hydrographie — Astronomie des Marins - Avignon.
describes an azimuthal compass, also described in the class on navigation held by Bezout for the marines in 1765.

1769 — **Wm. Falconer** — An Universal Dictionary of the Marine etc... Gowin Knight's Compass..... - London.

1769 — The **Académie de Marine** states that the copper in the boxes causes perturbations in the compasses.

1771 — In 1771, **D'Après de Mannevillette** effected researches ordered by the Académie Royale de Marine, and stated that, contrary to the usual practice, one should not place two compasses in the binnacle, one on either side of the central lantern, owing to their mutual perturbations. He noted that the sphere of activity of magnetic needles spreads sometimes over a distance of 12 feet " although shut up in a box under glass ".

Lieutenant **E. Fleurieu,** in the report which he wrote in 1773 on his Voyage effectué en 1768-69 pour éprouver en mer les horloges marines mentions the important differences in the variations of needles, and adds :

" what can be expected from most of the needles placed in the compasses which the common navigators employ ? When one has seen them, one can judge how little faith can be attached to the observations made therewith ".

He points out the " singular mistake " of M. Bellin regarding the uniformity which he attributes to the variations of magnetic declination. He also argues against the lack of convenience for sighting with the *Variation Compass* where :

" one is obliged to move the whole instrument to seek the sun with the sighting vanes fixed in the box; the exterior, box measuring about one square foot, feels the effect of considerable rubbing and one is obliged to move it roughly ".

He therefore proposes the manufacture of a new instrument suspended by a vertical pivot, which " he submits to the judgment of Navigators ", in order to take bearings in degrees on a large graduated circle, and no longer " by simply designating that one of the 32 points of the compass to which the bearing refers ". He seals with a better installation of the *Steering Compass,* and points out " the danger there is in placing two compasses in the same binnacle, owing to the sailors fear that one of the compasses should *fall asleep* " (sluggish).

1771 — **Retail** — Compass manufacturer during 20 years, at Hennebont, for the *Compagnie des Indes,* uses red copper only, with the exception of brass.

1773 — **Christian Karl Lous** — Tentamina ad Compassum perficiendum - Copenhagen - counsels the use of needles made of several parallel bars equidistant from the centre of the rose, and fixed on a perpendicular wooden lath which bears the cap.

1773 — The **Académie de Marine** obtains the direction and supervision of compass making in France; dial works were installed at Brest. Previously the needles were made outside the port by a cutler.

1774 — **C.J. Phipps** — Voyage towards the North Pole - 1773.

1774 — **Van Swinden** — Recherches sur la meilleure manière de fabriquer les aiguilles aimantées etc... - Paris.

N 1774 — **Samuel Dunn** — A new Epitome of Practical Navigation - London.

1776 — **Lemonnier** — Loix du Magnétisme - Paris.

He describes a new compass comprising four needles made up of thin blades 150 × 4 × 1,5 mm., in accordance with the method of some Danish artists (Lous).

1777 — **Coulomb,** Capitaine au Corps Royal du Génie — Recherches sur la meilleure manière de fabriquer les aiguilles aimantées... *(Mémoires de Mathématiques et de Physique* - Tome IX - Paris, 1780).

He studies, by the method of oscillations, the influence on magnetism of the shape and dimensions of the needle; he finds that small multiple needles are more magnetic than the big needles.

1777 — The **Science Academy in Paris** proposes for the second time a prize with regard to the perfecting of the compass and the laws of variation.

1779 — **De Gaulle,** hydrographe du Hâvre — Nouveau Compas Azimuthal à réflexion - sorte d'instrument réunissent l'octant à la boussole. - Le Hâvre.

He states that in the small vessels of the King, the two roses of the binnacle separated by the middle compartment, which is reserved to the light, are distant 15 to 18 inches from each other, and under these conditions, with needles measuring 6 inches 9 in length and 4 in width, and an agate cap, the inequalities reach 26°. The *Académie de Marine* had researches effected in this connection, the results of which were communicated to all the ports of the Kingdom.

1780 — **J. Robertson** — The Elements of Navigation - London.

1781 — **Gaigneur** — Le Pilote Instruit - Nantes.

It is he who counselled fixing the compass on a soft base "for example on a hood or overcoat", in order to make it stable and to direct it from any part of the ship from where the star or point to be fixed can be easily seen.

1782 — **Christian Carl Lous** — Theorieen af Styrmands Konsten... Kiøbenhavn.

1786 — **Francesco de Barreda** — El Marinero instruido en el arte de navegar especulativo y practico - San Telmo, Sevilla.

1787 — **Lassale** — Cours d'Hydrographie ou de Navigation.

He describes a portable compass, fitted with a circular plate and a movable alidade attributed to Halley (about 1750). This instrument is mentioned in "A naval expositor" by Thomas Riley Blanckley, London, 1750, under the name of Azimuth-Compass.

1788 — **Buffon** — Histoire des Minéraux - Tome V. - insists once more on the "mecometry" based on the observation of the dip, when seeking longitudes, and gives voluminous tables in this connection.

1789 — **Kenneth Mc Culloch** — An account of the new improved sea compasses London.

N 1790 — **Thos. Gregory** — A plan of mathematical learning taught in the Royal Academy, Portsmouth.

1791 — **Gabriel Wright,** maker at Islington, created a double-pivot compass, and in 1796 a device for immobilizing the needle.

N 1793 — **J. Lalande** — Abrégé de Navigation - Paris.

1793 — **Christian Karl Lous,** maker at Copenhagen, places lathes under the rose to deaden the oscillations in the liquid placed in the bottom of the basin, beneath the rose.

1795 — **J. Lorimer** — "A concise Essay on Magnetism".

25 June 1795 — Foundation of the *Bureau des Longitudes,* to which is also assigned the study of terrestrial magnetism at sea.

1796 — **John Flavel** — Navigation Spiritualized; or a New Compass for Seamen, consisting of XXXII Points; of Pleasant Observations, Profitable Applications, and Serious Reflections, all conducted with so many spiritual Poems - Newburyport (Mass).

PLANCHE I.

Les Aiguilles de Compas. *Compass Needles.*

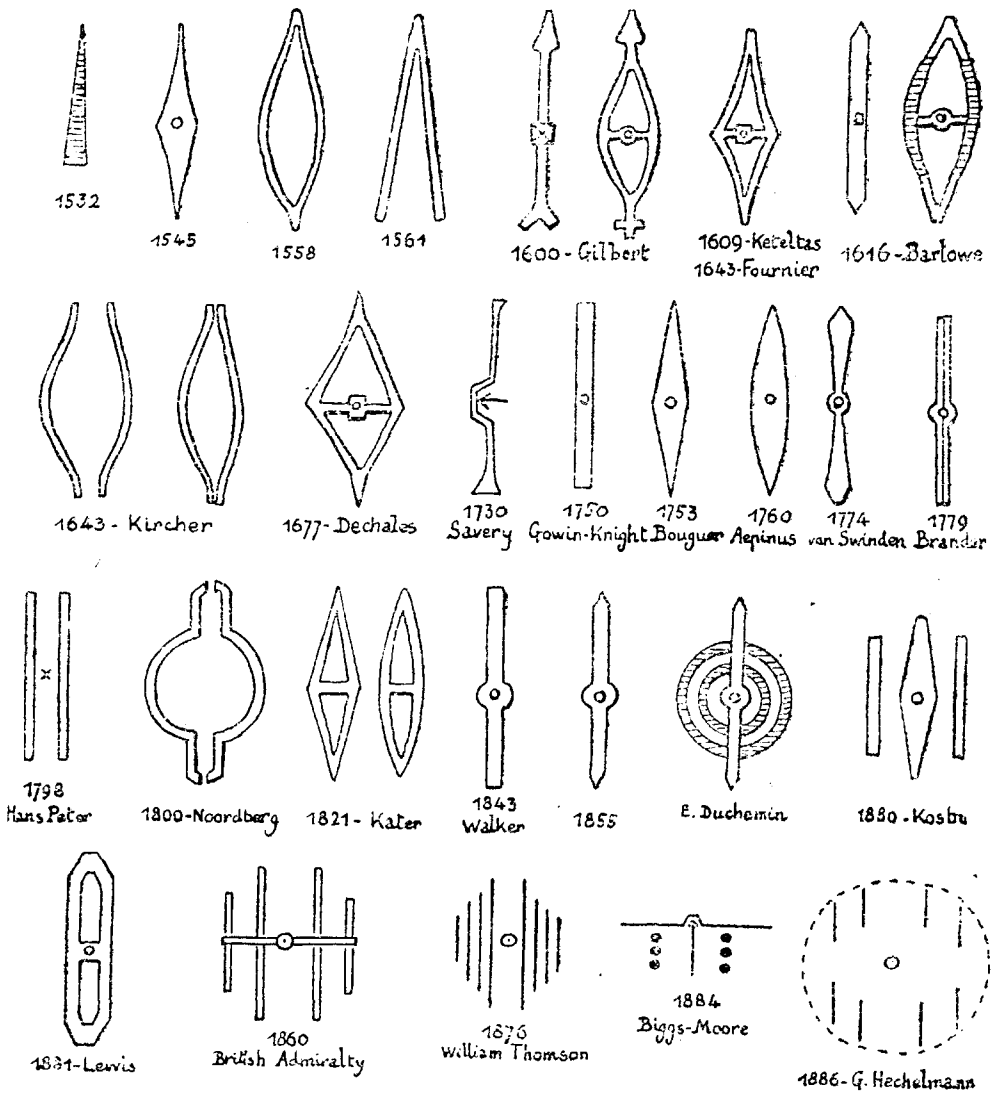
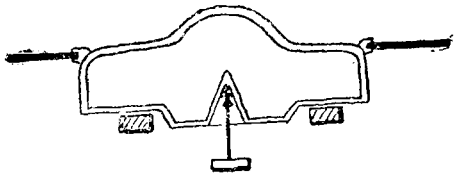


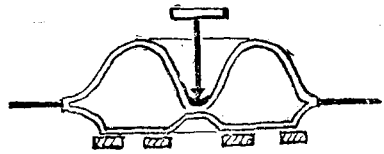
PLANCHE 2.

Flotteurs de Compas liquides.

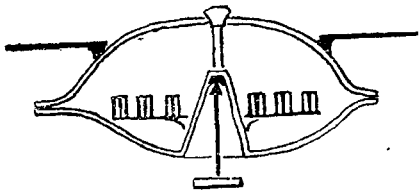
Liquid Compass Floats.



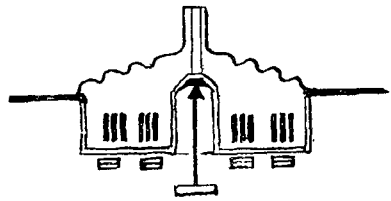
1885 - C. Plath



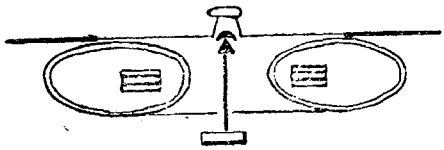
1889 - Dubsky



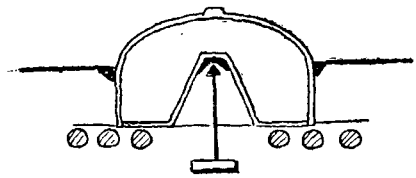
1898 - Magnaghi



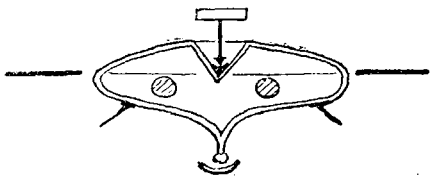
1903 - Bamberg



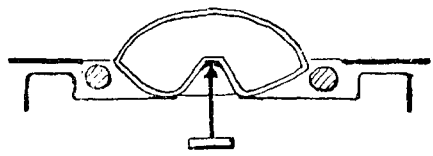
1905 - Doignon



1908 - Ritchie



1909 - Chetwynd



1924 - Hughes "Dead-beat"

III

IMPROVEMENTS OF THE MAGNETIC COMPASS, etc... SINCE 1800.

1801-03 — **M. Flinders** — Experiments on compass deviation made in H.M.S. "Investigator" in 1805 published on account of his discovery that deviation of the compass depended upon attractive bodies in the ship *(Philosoph. Transact. Royal Society,* 1805). Experiments verifying this discovery were afterwards made by him in 1812 on board 5 ships commissioned by order of the Admiralty.

In 1810 he introduce the expression "Swinging the ship".

Flinders suggested that the error, other than that caused by variation, and due to vertical iron stanchions or bolts of the planking of wooden ships at that time, could be entirely corrected by placing the compass in such a neutral position as to have the iron in the ship equally distributed before and abaft the binnacle; but this being an inconvenient position in which to place the compass he placed upright vertical iron stanchions abaft the compass to neutralise the error.

H 1809 — **D.A. Azuni** — Dissertation sur l'origine de la Boussole - Paris - *(Edition originale,* Firenze, 1795).

1813 — **Francis Crow** invented a liquid compass.

N 1814 — **Rossel** — Traité de Navigation de Bezout 1765.

1814 — **Matthew Flinders** — "A voyage to Terra Australis" undertaken for the purpose of completing the Discovery of that vast country in 1801-03, in H.M.S. "Investigator", and subsequently in the "Porpoise" and "Cumberland" with an account of the Shipwreck of the "Porpoise", arrival of the "Cumberland" at Mauritius, and emprisonment of the Commander during six years and a half in that Island. Vol. ii, appx ii - Atlas.

1817 — **W. Bain** — Essay on the Variation of the Compass - Edinburgh

1815-17 — **Dr. Scoresby** — Voyage au Groenland et au "Spitzberg" *(Philosoph. Transact.* 1819, "Esk").

1818 — **Wm. Scoresby** — On the Anomaly in the Variation of the Magnetic Needle as observed on shipboard *(Philosoph. Transact.* London, 1819, p. 96).

Dr. Scoresby established the fact that the horizontal force of the compass needle decreased as the dip increased from the equator polewards. The practical applications of this discovery was later on worked out by Prof. Peter Barlow who introduced a method of compensation which was extensively used in wooden ships.

1819 — **Christopher Hansteen** — Untersuchungen über des Magnetismus der Erde *(uebersetz von P. Treschow Hanson)* - Christiania.

1819 — **Edw. Sabine** — On irregularities observed in the direction of the compass needle of H.M.S. "Isabella" and "Alexander", in their late voyage of discovery, and caused by the attraction of the iron contained in the ship *(Philosoph. Transac. Royal Society* - 1819, page 112).

1820 — **Dr. Thomas Young** — Magnetism of Ships - Computations for clearing the compass of the regular effect of a ships permanent attraction. *(Brande's Quaterly Journal of Science,* London, 1820, page 372).

1820 — **P. Lecount** — On the Compass.

1820 — Prof. Peter Barlow, F.R.S. *(cf.* 1823-1824) — reported to the British Admiralty that half the compasses in the Navy were mere lumber and ought to be destroyed. He introduced a pattern having 4 or 5 parallel straight strips of magnetized steel fixed under the card - a form which remain the Standard Admiralty type until the introduction of the modern Thomson (Kelvin) compass in 1876.

He experimented on the effects produced on the needle by a sphere — hollow or solid — magnetized by the earth; he proposed to correct the deviation by the action of a sphere or plate located by trial and error.

1828-1824 — Edw. Sabine — Voyage of Parry and Ross to the discovery of the N.W. passage.

1821 — Henry Kater — On the best kind of Steel and form of a Compass needle *(Philosop. Transat.* London).

1823 — Peter Barlow — An Essay on Magnetic Attractions, and on the Laws of Terrestrial and Electro Magnetism (2nd Edition) (1re édition 1820) *(Edinburgh Philosop. Magaz. V* - 1821, page 262).

1824 — Peter Barlow — Account of experiments made on board H.M. Ships Leven, Conway, and Griper, for correcting the Local Attraction of those Vessels.

1824 — Prof. P. Barlow — Essay on Magnetic attractions.*(Correcting plate of soft iron).*

1824 — Popular view of Mr. Barlow's Discoveries. *(Edinburgh. Phil. Journal* 1824).

1824 — M. Poisson — Mathematical Theory of the Deviations of the Compass (5th *Volume of the Memoirs of the Institute,* Tome V, page 533).

1827 — F. Arago — Sur les moyens de soustraire en mer les aiguilles de déclinaison aux actions qu'exercent les masses de fer répandues dans les Bâtiments. *(Connaissance des Temps,* 1827, p. 357).

1831 — J.C. Pillar — Handleiding tot de beschouwende en werkdadige Stuurmannskunst. - Leiden.

He describes the pinnule (of the alidade) with sighting wire.

H 1834 — J. Kalproth — Lettre à M. le Baron A. de Humboldt sur l'invention de la boussole - Paris.

1835 — Captain E.J. Johnson, R.N. — Practical illustrations of the necessity for ascertaining the Deviations of the Compass - *(other - autres editions* 1847, 1852).

H 1835 — Vincenzio de Ritio — Della colonna dei venti Formiana, e dell'antico bussole da navigare di Amalfi. *(Fasc. XVI - Annali Civili di Napoli,* Vol. VIII, p. 95).

1836 — Alex. de Humboldt — Examen critique de l'Histoire de la Géographie du Nouveau Continent et des progrès de l'Astronomie nautique aux XVe et XVIe Siècles - Paris.

1836 — Capt. E.J. Johnson — Report of Magnetic Experiments tried on board an Iron Steam Vessel.

1837 — Nautical Magazine - page 837.

1837-1840 — Admiralty Compass Committee (Adm. Sir F. Beaufort, Sir James C. Ross, Capt. Johnson, Mr. Christie, Général Sabine).

This Committee was appointed to deal with the question of the deviations of the compass in iron built ships were much larger errors were experienced as compared with wooden built ones.

1838 — **M. Poisson** — Mémoire sur les déviations de la boussole, produites par le fer des vaisseaux - (Memoir on the Deviations of the Compass caused by the Iron in a Vessel). *(Mémoires de l'Académie des Sciences,* Paris, Tome XVI, page 547 et *Connaissance des Temps,* 1841, page 113).

1839 — **C. Guéprate** — Problèmes d'Astronomie Nautique et de Navigation - 2 Vols. - *Vade mecum du Marin* - Brest.

1839 — **Lieut. Colonel George Graydon** — "Celestrial Compass" - Chelsea.

1839 — **Sir George Biddell Airy** (later Astronomer Royal) — Method and Practical Rules for correcting the Compass by permanent magnets and soft iron *(Philos. Trans.* 1839).

(Traduc. française M. Darondeau, 1842 - *Annales Hydrograph.,* Paris 1858).

1839 — **Sir G.B. Airy** — Account of Experiments on Iron-built ships, instituted for the purpose of discovering a correction for the Deviation of the Compass produced by the Iron of the Ship. *(Philosop. Transact.* 1839).

1840 — **Sir G.B. Airy** — Results of Experiments on the Disturbance of the Compass on Iron-built ships.

These experiments resulted in Mr. Airy being able to separate the different causes of deviation affecting the compass of iron ships into three kinds. He introduced namely the expression "quadrantal deviation", and he drew practical rules for their correction with the aid of magnets and soft iron correctors in the shape of parallelipipedes or of sheeted cylinders.

Up to this time there had been but minor changes in the design of ships compasses to that described by Gilbert in 1600, with the exception that all nations had now adopted the original Italian method of fixing the needle in line with the North and South marking on the card.

The Admiralty Committee recommended certain improvements which resulted in the production of an Admiralty pattern compass. The bowl was made of copper or brass and the card was a thin disk of mica divided at the circumference into degrees with the 32 points marked inside the degree circle. The oval needle recommended by Gilbert was condemned and two or more pairs of parallel straight bars of flat clock spring substituted. Also a jewelled cap bearing on a fine point of iridium-osmium which would not rust was introduced.

1840 — **E.J. Johnson** — The Application of Native Alloy for the Pivots of Magnetic Compasses.

1840-45 —

Expedition of the *Erebus, Terror* and *Pagoda* commanded by Ed. Sabine, especially in the southern oceans for the determination at sea of the three magnetic elements; and the discovery of the North Magnetic Pole by Captain James Clark Ross (1841).

1840-49 — **Lieut.-Col. Edw. Sabine** — Contributions to Terrestrial Magnetism.

1842 — **Christopher Hansen** — Disquisitiones de mutationibus, quas patitur momentum acus magneticae - Christiania.

1842 — Admiralty Compass Committee (F. Beaufort, J.C. Ross, E.J. Johnson, Mr. Christie, Edw. Sabine). *(Cf. Practical Rules...* etc. 1845).

1842 — **E.J. Johnson** — On placing compasses on board Iron-ships - London.

1843 — **Wm. Walker** — The Magnetism of Ships and the Mariners Compass - Plymouth.

1844 — **E. Dent** — On the Patent Azimuth and Steering Compass.

H 1844 — **Edouard Biot** — Note sur la direction de l'aiguille aimantée en Chine. *(C.R. Acad. Sciences,* Paris, XIX, 1844, p. 822).

1845 — **Adm. Compass Committee** — Practical Rules for ascertaining those Deviations of the Compass which are caused by the Iron in a Ship - Other editions: 1851, 1855, 1862, 1868, 1879, 1899 and Supplement 1855. etc.

H 1846 — **Reinaud** — Relation des voyages faits par les Arabes dans le IX^{me} Siècle - Paris.

1846 — Philosophical Transactions - London, page 347.

1847 — **E.J. Johnson** — Practical illustrations of the necessity for ascertaining the Deviations of the Compass, London *(edition* 1852).

1849 — **Edw. Sabine** — Directions for the Use of a small apparatus to be employed with a Ship's Standard Compass for the purpose of ascertaining at any time, whether at sea or in harbour, the changing part of the deviation in the pointing of the Compass occasioned by the Ship's iron; or that part of the deviation which is usually different in different parts of the Globe. London, Edition 1857 *(Principe des déflecteurs). (Principle of the deflector).*

1849 — **John Ross** — On the deviation of the Mariners Compass.

1849 — **Lamont** — Handbuch des Erd-Magnetismus - Berlin.

H 1849 — **Santarem** — Essai sur l'Histoire de la Cosmographie et de la Cartographie pendant le Moyen Age. - Paris.

H 1849-1858 — **Baron Alex. de Humboldt** — "Kosmos" - Stuttgart.

1849 — **J.F.W. Herschel** — Admiralty Manual of Scientific Enquiry - 1st Edition 1849, 2nd edition 1851, 3rd edition 1859, 4th edition 1871. *(Rev. Robert Main),* 5th edition 1886.

1850 — **Dent** — Stormcompass - London.

1850 — **Archibald Smith** — Instructions for the Construction of the best Table of the Deviations of a Ship's Compass, from Deviations observed on 4, 8, 16 or 32 points. (Another edition 1851) *(Mechanical Correction of the Deviation).*

1852 — **Captain Johnson** — On placing Compasses on board Iron-ships.

1852 — **Captain Johnson, R.N.** — On the Deviations of the Compass, Practical Illustrations (2nd Edition).

G 1852 — **L. Foucault** — Sur une nouvelle démonstration expérimentale du mouvement de la Terre... *(C.R. Acad. Sc.,* Paris, 35 pp. 421-427).

H 1852 — **Vicomte de Santarem** — Essai sur l'histoire de la cosmographie et de la cartograpie pendant le Moyen Age, 3 Vol., Paris.

H 1852 — **Joachim Lelewel** — Géographie du Moyen-Age - Bruxelles.

1853 — **Paul Cameron** — The Variation and Deviation of the Compass rectified by azimuth and altitude tables (Edition 1859) (4° Edition in 1872).

1853 — **W. Walker** — The Magnetism of Ships and the Mariners Compass - Plymouth.

1854 — The Mariner's Compass, or, a Word of Warning and Instruction to Seamen - Sunderland.

1854 — **J.C. Tuxen** — Compasnaalen's Deviation - *(Traduc.* 1856).

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After three years of research on his yacht the " Salla Rookh " he produced his compass card and the deflector.

He developped a stable card and made into a practical possibility the accurate and exact correction of the quadrantal deviation as invented by Airy by the use of spheres. He solved the problem by the use of small needles. He worked out the present rules for practical compensation, A and E being negligeable. He also introduced the use of the " Flinders " bar such as we know it today.

Thus producing a compass which since has with minor improvements been standard of sea services of most maritime countries up to the present day.

For a compass card of 10 inches in diameter the Sir W. Thomson's Compass has eight needles of thin steel wire from 3 1/2 to 2 inches long attached to the card by two parallel rows of silk thread; the cup of aluminium with sapphire is borne on a fine iridium pivot. The entire weight of the card is 170 1/2 grains i.e.: about 1/7 of the weight of the ordinary compass card hitherto used. The binnacle contained fitted appliances by which the compass could be fully compensated for all errors with ease and certainty by Airy's method, this being rendered practicable for the first time - Iron Globes were substituted for the chain boxes previously used for correcting quadrantal error; also a brass cylinder is provided for correcting vertical soft iron transient magnetism by means of Flinders bar.

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Note: a) The compass-bowl, its suspension, its method of balancing, the pivots of the compass cards, its access, device for immobilizing and the replacement as well as the illumination have been perfected since the year 1850 by various firms and these have been made the subject of numerous patents. These are too numerous to enumerate here without being accompanied by profuse illustrations. We shall therefore restrict the citations to the names of the following firms :

1850 — I.I. Weilbach - Kjobenhavn.
1850 — August Augsburg - Kjobenhavn.
1853 — Wm. Walker - Plymouth.
1854 — John Gray - Liverpool.
1859 — Paul Cameron - Glasgow.
1874 — N. Garbich - Triest.
1875 — Mayes - London.
1876-79 — William Thomson - Glasgow.
1879 — A. Gareis - Pola.
1879 — Stephan Longfellow - Philadelphia.
1879 — Carl Bamberg - Berlin/Friedenau.
1880 — Postel Vinay - Paris.
1880 — August Carstens - Hamburg - (card with suspended magnets - rose à aimants suspendus, 1890).
1880 — Duncan Mc Gregor - Liverpool.
1884 — James White, Wm. Thomson - Glasgow.
1886 — Hechelmann - Hamburg.
1890 — C. Plath - Hamburg.
1890 — F. Wm. Smith - London.
1891 — Wm. David Whyte & James Thomson - Glasgow.
1893 — Florian - Pola.
1895 — G.W. Heath - Crayford, London.
1899 — Heinrich Bruns - Bremen.
1899 — John David Castle - Hull.
1901 — John Clark Dobbie - London.
1902 — Kelvin & James White - Glasgow.
1903 — F. Wilke-Stettin - (ring magnets card - rose à aimants annulaires).
1904 — W. Ludolph - Bremerhaven.
1906 — George Wilson Heath - London Hezzanith).

b) A float for liquid compass is appended to the card of Dent compass (London, 1833). The following firms then undertook to carry out improvements on the liquid compasses :—

1879 — Carl Bamberg - Berlin/Friedenau.
1889 — C. Plath - Hamburg (liquid expansion device - dispositif à dilatation du liquide).
1889 — Dubsky - Pola.
1895 — Siriex C° - San Francisco.
1898 — G.B. Magnaghi - Ufficio Idrografico - Genova, 1904.
1901 — F.J.F. Lemcke - Stockholm.
1903 — Carl Bamberg - Berlin/Friedenau - (16 blades large magnetic moment card - Rose à gros moment magnétique à 16 lames de 6000 gs; autre modèle 1908).
1905 — Doignon - Paris.
1905 — Neufeldt & Kuhnke - Kiel.
1907 — John Clark Dobbie - London - Dobbie's R.D.C. Compass (Reduced Diameter Card).
1906-08 — L.W.P. Chetwynd - Kingston/Thames (équilibrage par huile de ricin et dispositif de suppression de la bulle - Ricin oil counterpoise and bulb suppression device).
1909 — Wm. David Whyte - Glasgow.
1909 — Kelvin & James White Ltd., L. W. P. Chetwund, F. W. Clark - Glasgow.
1914 — Dobbie Mc Innes, Ltd., - Glasgow.
1915 — E.S. Ritchie - Boston.
1918 — Gaumont - Paris.

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1902 — **F. Bradhering** — Kurze Geschichte des Schiffskompasses - Magdeburg.

1902 — **Radler de Aquino** — Descripçâo e theoria da agulha de Lord Kelvin. - Magnetismo dos navios - Rio de Janeiro.

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This compass has a 6 1/2 inch card contained in a 10 inch bowl. To the card is fixed two 2 1/2 inch needles of a high magnetic moment which renders the compass nearly free from the influence of all mechanical disturbance and allows heavy damping without making it sluggish. Being free from lag the instrument remains steady under conditions that would disturb any other compass.

Ce compas possède une rose de 6 pouces 1/2 (164 millimètres) contenue dans une cuvette de 10 pouces (254 millimètres). Deux aiguilles de 2 pouces 1/2 (64 millimètres) à fort moment magnétique sont fixées à la rose; ce qui libère presque entièrement le compas de l'influence de tous les troubles mécaniques, et permet un fort amortissement sans que le compas soit paresseux. Comme il n'y a pas d'entrainement, l'instrument donne des indications stables dans des conditions qui perturberaient tout autre compas.

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