

## CHAPTERS IN THE HISTORY OF TERRESTRIAL MAGNETISM

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### I—ON THE DIRECTIVE PROPERTY OF A MAGNET IN THE EARTH'S FIELD AND THE ORIGIN OF THE NAUTICAL COMPASS

1—The science of Terrestrial Magnetism is based on the fact that a magnet, free to move about its center of gravity, tends to assume a position of relative rest in an approximately definite direction with respect to the geographical meridian and the vertical at the place of observation. That it should do so must be due to the existence of a field of force which is known as the terrestrial magnetic field [1], and the systematized knowledge of that field, of its variations in time and space, and of its relations with the subject-matter of other branches of terrestrial and cosmical physics, constitutes the science of Terrestrial Magnetism.

The object of these articles is to present a history, as complete as possible, of the development of this science. The method adopted will be that of collating the various accounts which have been given of the discovery of its fundamental principles and their gradual evolution into the form in which they are at present held. To assist the reader in forming his own conclusions, an attempt has been made to provide ample bibliographical references.

2—The first matter which arises for consideration in the history of the science is that relating to the discovery of the directive property of a magnet with reference to the Earth. By whom, at what date, and in what form, this was first recognized is now unknown, for the discovery was made in times long before the maintenance of careful scientific record. The investigation of this question has given rise to an extensive literature, but has led to few conclusions of a definite kind. Its treatment in standard works on magnetism is generally—and necessarily—confined to a brief statement which does not profess to be critical or discriminative, and for an adequate understanding of its many difficulties and obscurities we must examine the writings of those who have dealt with one or other of its numerous aspects. The matter practically resolves itself into an enquiry as to the origin or invention of the mariner's compass, and to the honor of this discovery several claims have been advanced.

3—The claim which goes furthest back in history is that made on behalf of the Chinese. It was first presented by Gaubil [2], Duhalde [3], Mailla [4], and Amiot [5]. It was repeated by Hager [6], Klaproth [7], and Biot [8], and has been supported or, at least, quoted by many later writers. In general terms it may be stated as follows. The ancient annals of the Chinese Empire contain passages which can only be construed as meaning that the directive property of a magnet in the Earth's field was known in China several thousand years ago; that in later ages there follows a succession of references indicating a constant tradition on the subject; that these gradually merge into others which mention the compass in its earliest form; and thus we reach the seventh or eighth century A. D., when this primitive instrument was employed for survey-

ing and navigation. It is thus contended that the compass is an adaptation in later times of a principle known to the Chinese for the last 4,500 years.

In examining the evidence in support of this claim, we have to distinguish between that which depends chiefly upon the mythological history of China and that which is gathered from the literature of more recent times.

With regard to the former, it is stated [9] that in 2634 B. C. the Chinese emperor Hoang-Ti was at war with a tributary prince named Tchi-Yeou, and that they fought a great battle in the plain of Tcho-luo. In order to escape defeat, or its consequences, Tchi-Yeou raised a dense fog which produced disorder in the imperial army—an anticipation of the smoke-screen of modern times. But Hoang-Ti constructed a chariot upon which stood the diminutive figure of a man with arm outstretched, and this figure being apparently free to revolve on its vertical axis, the arm always pointed to the south. By this means, the emperor was able to locate the direction of his enemy's retreat; Tchi-Yeou was captured and put to death. By the earliest European commentators on the Chinese annals—the Jesuit missionaries who went to China during the latter part of the seventeenth century [10]—it was at once inferred that the movable figure was actuated by a magnet, and this inference forms the basis of the claim now under consideration.

In the later Chinese literature, the story is given a different turn, the general outline being as follows [11]: In the year 1110 B. C., ambassadors from the country now known as Tonquin arrived at the Chinese court with presents for the emperor. As they were in doubt as to the direction of their homeward route, Tcheong-Kung, the emperor's uncle and chief minister, supplied them with five south-pointing chariots, similar to those ascribed to Hoang-Ti. These were to go in advance in order to make known the cardinal points, and thus indicate the way to the party following them. By these means the ambassadors were enabled to find their way "to the seas of Fun-an and Lin-i," and thus reach home. Some commentators add that Tcheong-Kung was the inventor of these south-pointing chariots.

The subsequent history of the contrivance is curious. It is natural to expect that, if it were a genuine application of some magnetic principle, repeated use during several centuries would lead not only to fuller understanding, but also to a wider application. This, however, we do not find. On several occasions between 200 and 1300 A. D. attempts were made to reconstruct the device, but these were only partially successful, and it is plainly stated that at certain times the art was lost or unknown [12]. The last version of the tradition throws some further light on this very obscure question, and possibly indicates the real character of the contrivance. "Under the reign of the emperor Jintsoung (1027 A. D.) Lou-tao-loung, one of the great officers of the palace, constructed a *ki-li-kiu* or chariot with a drum indicating the *li*. This chariot had . . . two floors, in each of which was a wooden man who held straight a wooden mallet. Directly the chariot had traveled one *li*, the wooden man on the lower floor struck a blow on a drum, and a wheel placed half its height turned once. After the chariot had traveled ten *li*, the wooden man on the upper floor gave a blow on a hand bell" [13].

A description, accompanied by a figure, of the south-pointing chariot is given in a Chinese cyclopedia [14] published in 1309, and this has been reproduced by Klaproth [15]. The description is not sufficiently clear to enable us to understand the construction or the mechanism. But it states that when the monastery of You-mon-ngan was built in 1314-20 A. D., the chariot was used to fix the alignment of the walls.

References to the south-pointing chariot occur in Japanese literature after the middle of the seventh century A. D., but no details as to their construction are given [16].

4—We have now to consider the extent, if any, to which reliance can be placed on this Chinese claim to priority, in so far as it is based on the south-pointing chariot. Since the story goes back, or has been carried back, to the 27th century B. C., we are at once confronted with the general question of the accuracy of Chinese chronology. This is founded on cycles of sixty years, which may be extended backwards indefinitely. But to place real events in their appropriate period is another matter, and there is absolutely no guarantee that this has been done on the basis of actual historical record. The question is too wide and too complicated for treatment here, nor is the present writer qualified to be its exponent. But perhaps it may be sufficient to state that the general consensus of opinion among those who have studied the matter seems to be that no reliance can be placed on any Chinese chronology earlier than 800 B. C. [17]. Again, the actual history of the documents upon which later historians have built up the Chinese annals is imperfectly known, nor has the extent of their freedom from alteration or interpolation been fully determined [18]. Lastly, the story of Hoang-Ti has all the *indicia* of myth, and cannot be accepted as an actual historical occurrence.

These are preliminary objections, and they might perhaps be regarded as sufficient to dispose of the matter, but the south-pointing chariot has been put forward so persistently as the basis of the Chinese claim that more detailed examination is necessary. Effective criticism must be directed to the literary history of the story, and also to the device itself. As regards the former, Legge has shown [19] that there is no authoritative mention of it before the second century A. D.; and others have proved [20] that the passage in the memoirs of the Chinese historian Se-ma-Tsien, in which the Tonquin embassy is referred to, is an interpolation. Lastly, the story did not pass without question in China itself, for we read [21] that Kao-tang-lung and Chin-lang, two scholars of the third century A. D., appeared before the Chinese court and argued that there never had been any such thing as a south-pointing chariot, and that the story was a fabrication.

As for the device itself, we know practically nothing of its details. In any case, there is no reference in any of the older accounts to any magnetic principle involved in its construction, although some of these accounts were written after a knowledge of the attractive power of the lodestone was more or less common property. Nor, apart from the name [22], is there any term used in its description which indicates a knowledge of any magnetic principle. It is true that these contrivances came to be known as "magnetic chariots," but this arose through the error of the Jesuit missionary Gaubil. Misled by the similarity between the Chinese name for the south-pointing chariot and that for the com-

pass, he concluded [23] that both were applications of the same principle. But there is no evidence whatever that steel magnets were known either in the 27th or in the 12th century B. C., and it is exceedingly doubtful whether any piece of lodestone could be obtained of magnetic moment sufficient to actuate any mechanism such as the figure on the south-pointing chariot.

With regard to other possibilities, there is distinct evidence [24] that one, at least, of the purposes of these chariots was the measurement of distance along a road or track, and there is much to support the belief that this was their only function. Indeed, Giles [25], supported by Hopkinson, was strongly of opinion that they were merely mechanical contrivances, and this is also the conclusion reached more recently by Hashimoto, Mikami, and Moule [26]. The fact, or the statement, that the art of constructing them was lost more than once points in the same direction, for this might happen with a clever mechanical device of which no plan or other copy existed, but not with a simple matter such as the directive property of a magnet. Once this was known, the knowledge would not be easily lost. Nor can it be said that these chariots were in real or common use for practical purposes. More than one of the early accounts [27] seem to regard them as ornaments for use on ceremonial occasions, and even then only by the highest dignitaries.

It is of importance to note that although the south-pointing chariot is referred to in Chinese literature down to a date long after a knowledge of the properties of a magnet had become, or are supposed to have become, common, yet there is no reference in that literature to the magnet in association with the south-pointing chariot, as would have been the case if a magnet had been the directing agent.

It may also be well to state the best that can be said for the case as also the worst that can be said against it. The former may be founded on a hint conveyed in one of the commentaries [28] of the fifth century A. D., which states that in order to make the contrivance work properly a man had to be stationed inside the box on which the figure was placed. If it be assumed that at this period the Chinese were acquainted with the directive property of the magnet, it is conceivable that the man might cause the arm of the wooden figure to follow the indications of some primitive form of compass also enclosed within the box. But this is mere conjecture, and beyond the hint referred to, there is nothing that can be quoted in its support. As for the latter, it cannot escape notice that much of the attention given in Chinese literature to the story comes after the "Burning of the Books" in 213 A. D. Doubtless, extraordinary efforts were made after this event to reconstruct the Chinese annals, and abundant opportunity would be offered for the interpolation of unauthorized matter. It is possible that the legend had its beginning in these circumstances. The fact of its being contradicted in the third century, as noted above, suggests this solution, and this view is supported in recent times by a Chinese writer [29]. Lastly, there is force in the contention of Giles, that the Chinese themselves have never claimed priority in the invention of the compass, and that it has been forced upon them by foreigners who have misinterpreted their chronicles.

The Chinese claim to priority, advanced on the story of the south-

pointing chariot, has had its defenders [30], but is now generally rejected. For the reasons given above, this rejection appears to be fully justified.

5—We have now to summarize the references to the compass as they occur in Chinese literature of historic times, in order to adjudge the claim, based thereon, for Chinese priority in the knowledge of the directive property and its applications.

There is evidence, slight but perhaps sufficient, to prove that the Chinese, like most nations, have known the attractive power of the lodestone from very early times [31]. But the date at which the further knowledge was reached that the lodestone can magnetize iron or steel is still uncertain. As for the directive property, it is usual among writers on the subject to quote as earliest mention of this fact the dictionary *Choue-wen*, compiled in 121 A. D. The word "magnet" or lodestone is here given as "the name of a stone with which we give direction to the needle," and this definition [32] is copied by later Chinese lexicographers [33]. The interpretation of this isolated passage is doubtful, for it may have one of two meanings. First, that after contact with lodestone a suitably mounted needle shows the directive property. Second, that such a needle assumes a particular direction when under the temporary influence of a piece of lodestone placed near it. The first involves a knowledge of the process of magnetization and of the directive property of the magnetized body; the second is but a slight advance on the knowledge of the simple attractive property of the lodestone. The absence of any reference to the north-south direction of the needle suggests that the second interpretation is to be preferred. The passage cannot, therefore, be accepted as proof, either presumptive or final, that the Chinese were acquainted with the directive property in 121 A. D., and we must look elsewhere for evidence. This, we are told by several writers [34] is to be found in the dictionary *Poei-wen-yun-fou*, which states that under the Tsin dynasty (265-419 A. D.) there were "ships pointing to the south," to which some commentators have quite unwarrantably added "by the magnet" [35]. The interpretation here is again doubtful, and it would be unwise to place reliance on the passage. Gaubil [36] stated that he had found, in a Chinese work of 220 A. D., a reference to the use of the compass to mark the cardinal points, but this book has never been seen by others and is certainly now unknown. To this may be added the fact that Gaubil and Amiot confused the south-pointing chariot and the compass.

So far, then, it may be stated with tolerable certainty that there is no clear and reliable evidence that the Chinese were acquainted with the directive property of the magnet before 400 A. D.

From this date there is a gap of seven hundred years in which, with one exception, to be mentioned presently, there is no known reference to the magnetic needle or compass in Chinese literature. This is a somewhat remarkable fact, and it forms a strong argument against the Chinese claim to priority in so far as that claim is based on the references already given. The exception referred to is also doubtful. Wylie stated [37] that in the life of the Buddhist astronomer Yih-hing, who lived about 700 A. D., it is said that "on comparing the needle with the north pole he found the former pointed between the constellations *hu* and *wei*," and in a direction nearly three degrees east of the north pole. But Wylie gave no exact reference which would allow of this passage

being identified, and although searched for by others [38], it has never been found. Its similarity to passages in other and later Chinese works raises the suspicion of interpolation. We have therefore to pass on to the period 1030-1093 A. D., the lifetime of the encyclopedist Shon-kua, who wrote the *Mung-khi-py-ihan*. He says [39] that "fortune tellers rub the point of a needle with the stone of the magnet in order to make it properly indicate the south." This was repeated by Keou-tsoung-chy in his medical and zoological treatise entitled *Pen-tsao-yan-i* [40], which was compiled between 1111 and 1117, from which again it was copied into another work of the same class entitled *Pen-tsao-kang-muh* [41]. It also appears in the twelfth century dictionary *Poei-wén-yun-fou* [42].

It may be convenient to pause here in order to consider the circumstances in which the statement of Shon-kua was published and repeated. If, as has been argued by several writers, the Chinese knew the properties of a magnetized needle about the beginning of the Christian era, why should an encyclopedist writing ten centuries afterwards take the trouble to refer to a matter of such common and long-acquired knowledge? On the other hand, the fact of his mentioning it indicates that it was knowledge recently acquired, especially when we remember that for several centuries previously no statement on the subject is found in Chinese literature. Further, the fact that it was copied into other Chinese works soon after its publication supports the view that Shon-kua's was an original statement. For these reasons it is safe to hold that this is the earliest reliable evidence of Chinese knowledge of the directive property of the magnet.

The application of this property by the Chinese to the construction of a compass is the next point for consideration. Klaproth [43] argued that the Chinese sailors who voyaged from Canton to India in the seventh and eighth centuries must have required the magnetic needle to guide them. To this, there are several weighty objections. The earliest known individual traveler in Eastern seas was the Buddhist pilgrim Fahien, who returned to China from India in the early part of the fifth century. He speaks [44] of the difficulty of finding direction at sea: "there is no means of knowing east or west; only by observing the Sun, moon, and stars was it possible to go forward"; and he does not refer to any compass. Renaudot [45] has shown from the record of voyages made by two Mohammedans to China in the ninth century that in all probability their navigation was from point to point along the coast, and the compass is not mentioned. Later researches into the records of other early voyagers fully confirm this conclusion [46]. Lastly, there is no positive evidence of the use of the compass by the Chinese either at this period to which Klaproth alludes or at any later time before the thirteenth century. It must be added that for the widespread belief that the Chinese were the first to use the compass for navigation, Humboldt is to be held responsible [47]. In his hands, the cautiously expressed inferences of Klaproth became actual historical occurrences. In the present instance he states in a quite unqualified manner that these early voyagers did actually use a compass. For this there was no warrant whatsoever.

The earliest mention of the use of the compass in China, though not by the Chinese, is that quoted by Hirth in the following passage, the importance of which requires that it should be quoted at length

[48]: "It occurs in a work of the twelfth century entitled *Ping-chou-ko-than*, and compiled by one Chu-yu, a native of Hu-chou in Chokiang. In the second chapter of this work the author has inserted a series of notes on the foreign trade at Canton which, previous to the arrival of the Portuguese in Eastern waters, had been in the hands of Arab and Persian navigators. Since, from what we know of the author's lifetime, he himself never lived at Canton, whereas his father, Chu-Fu, had held office there at the end of the eleventh century, the critics of the great catalogue of the Imperial Library (*Tsung-mu*, ch. CXLI, 15) hold that his information about the foreign trade in Canton is based on accounts of Chu, the father, and that it therefore dates from the latter part of the eleventh century A. D. This view is supported by the fact that the years 1086 and 1099 are mentioned in Chu-yu's paragraphs referring to Canton in other connections. Among these interesting notes I find one (ch. II, p. 2) referring to the foreign ships by which trade was carried on between Canton and San-fo-tsi (Palembang) on the coast of Sumatra, and further on to ports in Arabian countries, including India. It runs as follows: 'In clear weather the captain ascertains the ship's position at night by looking at the stars, in the daytime by looking at the Sun; in dark weather he looks at the south-pointing needle (*chi-nan-chou*).'"

The next piece of evidence is from the *Chu-fan-chi* of Chau Ju-kua, which has been assigned to the middle of the thirteenth century. It refers to "the boundless ocean where . . . the ships sail only by means of the south-pointing needle, if it be watched by day and night, for life or death depends on the slightest fraction of error" [49]. Another item of relevant evidence is that of Tcheon-tha-khoun. About the end of the thirteenth century he visited Cambodia, and in his *Tchin-la-fung-thou-ki* [50], describing the country and its usages, he gives sailing directions in terms of compass-bearings. Nothing is stated as to the nationality of the vessel in which he sailed. The last point is that Chinese ships must have been fully acquainted with the use of the compass by about 1400, for Fei-Hsin, the author of an account of four voyages in the Indian Ocean in the early part of the fifteenth century [51] quotes a Chinese sailors' song [52] which alludes to the compass.

The trend of the evidence thus summarized is towards two conclusions. First, that the Chinese knew of the directive property of the magnet by the eleventh century, and probably late in that century. Second, that the application of this property to the compass, in some primitive form, had been made by the end of the eleventh century, but this was then done, not by the Chinese, but by Arab or Persian navigators. But it must be carefully noted that the date in this latter conclusion depends not only upon a single document, but on a particular interpretation of that document.

The earliest form of the Chinese compass was that of a magnetized needle attached to a straw, or piece of wood or pith, which floated in a basin of water. This continued in use in China [53] and Korea [54] until the seventeenth century. The pivoted needle does not seem to have been generally used in China before the seventeenth century [55], and thus improvements were only effected after commercial relations with the outside world were fully established. It has been argued [56] that the form of the more recent Chinese compasses, with their shorter

needles [57], and division into twenty-four [58] instead of thirty-two points [59] is indicative of their independent and possibly earlier origin. But on the supposition of its being an imported invention, the compass might have first reached China in a very primitive form, and been there adapted to existing customs. Among these, the customary division of the circle into twelve or twenty-four parts would determine the form of the instrument. It was also suggested by Barrow [60], in view of the astrological and other symbols on many Chinese compasses, even of recent times, that the Chinese would never have condescended to use a foreign instrument for such purposes, and therefore that the compass must have had a Chinese origin. The obvious answer is that the earliest form of the Chinese magnetic needle was used, not for navigation, but by necromancers for purposes of divination, and that its development took place along these lines rather than the technical application it has found among other nations [61].

Two other comments on Chinese knowledge of terrestrial magnetism may be made in closing this section of the subject. The first is to point out, after Martin [62], that in no Chinese writing, ancient or modern, is there any allusion to magnetic repulsion. If this silence is to be used as a measure of their knowledge of the subject, it would mean that they have been far behind the Western nations. The second is that, if it be true that a knowledge of the directive property of the magnet and its application to the compass had been reached by the Chinese in the eleventh century, not to mention earlier assignments, it is more than strange that several hundred years should elapse before any reference to such matters is found in Japanese literature. The earliest record of the kind there, according to Hashimoto [63], does not occur until the middle of the Tokugawa period, 1603-1867.

Before attempting any general conclusions from the evidence which has now been summarized, it is necessary that we should deal with similar claims from other countries or races, and to this we next proceed.

6—In the historical order of the person concerned, the next [64] claim is that which ascribed a knowledge of the compass to Solomon, King of Israel. This was put forward by Goropius [65], Pineda [66], Fuller [67], and others [68]. In more recent times it was again advanced by Clarke [69]. Each of these writers had his own ground for the supposition, but the arguments employed cannot be taken very seriously. It was urged that the *Parvaim* of the Bible [70] is Peru, navigation to which would require a compass; that Tarshish [71] was the Spanish Tartessus, voyages to which were quite frequently undertaken by the Tyrian navigators, who were probably acquainted with the compass; or that the voyage to Ophir [72], wherever it might be, meant navigation over the open seas, thus again necessitating a knowledge of the instrument; or, lastly, on the general ground of the great wisdom of Solomon, presumably assisted by the practical experience of the "servants who have knowledge of the sea" [73]. But there is nothing in the Biblical references [74] to suggest more than the highly probable conclusion that, ten centuries before our era, navigation must have been a tedious and difficult business, and thus no real matter is provided which bears on the present issue. For contemporaneous criticism, reference may be made to Hakewill [75], Acosta [76], Kippingius [77], Bochart [78], and to the curious comment in *Purchas, His Pilgrims* [79].



7—The literature of classical antiquity contains many references to the attractive quality of the lodestone, but it is now certain that it reveals no knowledge of the polarity of the magnet, or of its directive property in the Earth's field. In every case in which a claim of the kind has been made, it can be shown that the interpretation put upon the passage is a forced one. The arrow which enabled Abaris to travel wherever he pleased was supposed by Salverte [80] to be a magnetic needle. Cooke [81] suggested that the cup given by Apollo (or Nereus or Oceanus) to Hercules by which he sailed the ocean might have been a compass. He also interpreted Homer's reference to the maritime skill of the Phaeacians as meaning that a compass was in use during the siege of Troy [82], and this was repeated by Buffon [83] and Mottelay [84]. But his rendering of the passage is widely different from that of modern scholars. A similar ingenuity has invoked the image of Jupiter Ammon, the Golden Fleece, and the ship Argo. Falconet [85] believed he had found, in one of the fragments of Euripides preserved by Suidas, evidence that the author knew of the repulsion of opposite poles of a magnet, but ultimately decided against this conclusion. Professor D'Arcy Thompson [86] is of opinion that the "magnes" to which Euripides refers is not the lodestone, but some substance having the false appearance of silver, and this agrees with the views expressed by Martin [87] and Buttmann [88]. Aristotle was credited by Albertus Magnus [89] and Vincent of Beauvais [90] with a knowledge of the directive property. These authors quoted from a tract, *De Lapidibus* [91], which some Arabic writer had represented as a work of Aristotle. This tract, which they admit they never saw, is now lost, but there are sound reasons for regarding it as a spurious production. The suggestion was made by several writers, among whom Levinus Lemnius was probably the first [92], that the word *versorium* as used by Plautus [93] meant a compass. But in reality this was an afterthought inspired by Gilbert's invention [94] of the word *versorium*, and its subsequent introduction into the literature of the subject by Cabaues [95]. The term used by Plautus probably means either the rudder of a ship or the rope fastened to the lower and leeward corner of a sail [96]. Sir Roger Lestrangle took an unusual and quite unwarranted liberty in his translation [97] of Seneca's *Morals*, when he represented the seamen of classical times as having a knowledge of the compass. He did not, however, go as far as did Poinsett de Sivry [98], who said that the ancients had a mechanical compass which contained no magnet. There are vague references in Plutarch [99] to repulsion between opposite poles of two magnets, but their significance is extremely doubtful. According to Betham [100] the Etruscans were acquainted with the compass, and this is founded on an inscription on an Etruscan tomb, accompanying the design of an eight-rayed star with the fleur-de-lis on one of the rays. The inscription was said to refer to "steering over the ocean by night or day," but this has been differently interpreted by the Italian archaeologists [101]. Practically the only direct evidence we have from classical writers which bears on the subject consists of two passages from Virgil and another from Ovid, and these clearly indicate that in classical times navigation was by means of the stars [102].

With regard to these supposed allusions to the directive property of the magnet, they are condemned by the silence of classical antiquity

generally. Bertelli [103.f.] examined the writings of more than seventy Greek and Latin authors between 600 B. C. and 1000 A. D., but none of them yielded any evidence of knowledge of this property. Acosta [104], Dutens [105], and Azuni [106], though after less exhaustive search, came to the same conclusion, and although Gibbon had said that Greek can give "a soul to the objects of sense and a body to the abstractions of philosophy," Azuni added that neither Greeks nor Latins had any word to express the idea of polarity. It is practically certain that if the directive property of the magnet had been known in the Roman Empire before 400 A. D., it would not have escaped comment in the *Magnes* of the poet Claudius [107]. But he is silent on the point. Nor is it likely that St. Augustine, in speaking at length [108] on the attractive properties of the magnet, would have omitted reference to its polar and directive properties if they had been known when he wrote his famous book, 413-426 A. D. The nearest approach is to be found in a passage of Marcellus Empiricus, who was physician to Theodosius the Great, and lived at the end of the fourth century. He speaks [109] of the magnet or lodestone repelling as well as attracting iron, and it is probable that he had been experimenting with pieces of magnetized iron or steel.

8—The Phenicians have frequently been credited with knowledge of some form of compass, chiefly on the general ground that their extensive voyages required such aid [110]. Had the annals of Tyre and Sidon been preserved to us, the question might have been answered definitely; as it is, nothing is known which points to any such conclusion. All we do know with regard to the navigation of the Phenicians indicates that they determined direction at sea by astronomical means. While the Greeks continued to use the constellation Ursa Major for this purpose, the Phenicians had found that the Cynosure in Ursa Minor was much nearer the pole of the celestial sphere, and this gave them their true north [111]. On this account, the pole star was known in antiquity as the Phenician star [112]. The most ancient Phenician book, written by, or ascribed to, Sanconiathan [113] is now believed to be a forgery by Philo of Byblus. But it contains a reference to "betulæ," or "stones which moved as having life," which has been interpreted by some commentators as meaning the lodestone. Even if it did have this meaning, it does not follow that a knowledge of the directive property had also been reached. Betham [114] took it as proof that the Phenicians were acquainted with the compass, but no evidence is forthcoming in support of this conclusion. Fuller [115] ascribed the magnet, known in early times as *lapis Heracleus*, to a Phenician navigator named Hercules, but gives no ground for his assertion, which is probably based on a passage in Photius [116]. Gilbert [117] concluded that the Phenicians could not have been acquainted with the use of the lodestone or magnet in navigation, otherwise the Greeks and Romans would have acquired the knowledge. But this is to prove too much, for it is known [118] that the Phenicians took extraordinary precautions to preserve all secrets connected with their trade and navigation. "To a Phenician commander, mystery was the great principle of his profession." The story told by Herodotus [119] of the circumnavigation of Africa by the Phenicians shows that they deduced the direction of a coast line by reference to the rising Sun [120]. A curious sequel to this story—based on the supposition of Osorius [121] that the compass was

brought to Europe by Vasco da Gama, who found it in use by the pirates about the Cape of Good Hope—was provided by Cooke [122], who made the rather wild proposal that these pirates were the lineal descendants of the Phenicians referred to by Herodotus.

It may be convenient to refer here to arguments which have occasionally been put forward [123] to show that the ancient Egyptians were acquainted with the directive property of the magnet, and that the orientation of the base of the Pyramid was accomplished by an application of that knowledge. But the fact is that the sides of the base of the Pyramid are directed north-south and east-west geographically, with a degree of accuracy unattainable by magnetic observations; and these directions being geographical and not magnetic, would also imply a knowledge of the declination. For this there is not the slightest ground. It has also been suggested that the names given by the Egyptians to certain kinds of iron can be best explained by supposing that they meant magnetized iron which pointed north and south. But there is nothing which can be quoted in support of this conjecture [124].

9—In recent years, the most general opinion with regard to the origin of the compass has been that a knowledge of the directive property of the magnet was obtained from the Chinese by the Arabs, and applied by the latter to the construction of some primitive form of compass, which was subsequently introduced by them to Europe, probably about the time of the Crusades [125]. This is, perhaps, the most difficult part of the whole question. The direct evidence is scanty, and its implications are frequently ambiguous. Of the writers who have propounded or repeated this conclusion, none has explained how, in the conditions prevailing before and during the Crusades, this transmission of valuable knowledge was actually effected. It has been given, and left, in the form of a conjecture, plausible yet unsupported. Whatever decision be reached, a certain weight has to be given to the dangerous argument—of varying value in different ages—that silence on a given subject implies ignorance regarding it. Reliance has also to be placed on considerations drawn from spheres of human thought and activity having only remote connection with our particular problem.

The wholly negative evidence available with regard to the use of the compass in eastern seas, down to 1000 A. D., may first be considered. The earliest known statement of the kind is that of Ptolemy [126], who wrote in the middle of the second century A. D., and said that navigation in the Indian seas was carried on by means of the star Canopus. The next record is that already quoted from the travels of Fahien, the Chinese pilgrim who made a journey to India overland and returned by sea during the fifth century. He sailed from the Hooghly to Ceylon, thence to Java, and on to Tsingtau. From what has been stated already [127], it is quite clear that any position or direction finding was by astronomical means, and there is no mention of guidance by the magnetic needle. No evidence is forthcoming as to the nationality of the vessel in which he sailed from Ceylon to China, but in all probability, as far as Java at least, it might be an Arab ship; less probably Indian. In their edition of the work of Chau Ju-kua, Hirth and Rockhill state [128] that Fahien's description of navigational methods was correct not only for the fifth century in which it was written, but even down to the twelfth century; that when pilots went out of sight of land,

they trusted to the regularity of the monsoons, steered by the Sun, moon, and stars, and took frequent soundings. Next, we have the records collected by Chavannes [129], Pelliot [130], and Ferrand [131] of voyages undertaken by Buddhist pilgrims and others, and by Levi [132] on the travels of Vajrabodi in the eighth century. These contain several references to navigation in the Indian and Indo-Chinese seas, but there is no mention of the magnetic needle or compass. Some, if not most, of these voyages would be in Arab ships. Another device of the times was the use of birds which, when released from a ship at sea, would seek the land if near or return to the ship—a method as old as the story of the Deluge, and reappearing at intervals down to the times of the Icelandic sagas [133]. Renaudot's account of the voyage of two Mohammedans from the Persian Gulf to China in the ninth century [134], has already been referred to as confirming the negative results of the foregoing evidence [135].

From the actual practice of navigation in eastern seas, we may turn to Arabic or Persian writings generally, in order to ascertain whether, before 1000 A. D., there is any reference to the use of the magnet at sea. It must be remembered, however, that sea-faring communities among the Arabs would form a class apart, holding little intercourse with those who wield the pen, and we have to wait until the fifteenth century before any Arab or Mohammedan navigator commits his ideas to writing. On the other hand, it must not be forgotten that the Arabs encouraged the study of astronomy and geography to a quite unusual extent, and, later on, that much of the speculative science of the earlier Renaissance period reached the western world through the Arabic schools of Spain. This is a source whose systematic exploration has only been undertaken in comparatively recent times [136], and the end is not yet. Thus we have a very considerable volume of Arabic writings dealing with cosmographic subjects, and these have to be examined for our present purpose. The Koran declared [137] that "He hath given you the stars to be your guides in the dark, both by land and sea," which indicates the methods used by navigators in the seventh century. After this, the next record is the manuscript of Thabet-ben-Corah [138], from which it may be gathered that towards the end of the ninth century the compass was not known to the western Arabs. Ibn-Al-Adari, an Arabic writer of Morocco, who lived in the fourteenth century, wrote a history of the Western nations [139] in which he refers to a battle in the year 854 during which a certain Qasim was killed. On this defeat, Qasim's brother, Safwan, wrote a verse in which the word *qaramit* occurs. Dozy, who translated the original, held that *qaramit* means *calamita*, one of the ancient names for lodestone. But the reading is doubtful, and if the word has this equivalent the verse is devoid of meaning. In any case, it reveals no knowledge of the directive property. The Arabic geographer, Ibn Khordadbeh, who died in 912, had excellent opportunities in his official capacity as "Postmaster General" under Motamed, the Baghdad Caliph, for ascertaining the details of navigational practice. He wrote [140] on the attractive properties of the lodestone, but has nothing to say as to its directive property. A similar negative result follows from an examination of the writings of other Arabic cosmographers before 1000 A. D., such as Mohammed (the Kharizmian) [141], Amron Aljahedh [142], Al-kindi [143], Abeladory [144], Abulfara-

gius [145], Ibn Muhallil [146], and especially Masoudi [147] and Geber [148]. The general conclusion from all these sources is that there is no evidence for Arabs, Persians, or Mohammedans generally having any knowledge of the directive property of the magnet, or of its application to navigation, before 1000 A. D.

The next step is to ascertain the general course of sea communication between east and west before and during the Crusades, the object being to obtain some idea of the conditions affecting the extent or frequency of contact between Chinese and Arabs and between Arabs and Europeans. The trade-routes, as far as these lay by sea, were (1) by the Red Sea, southern coast of Arabia, down the Malabar Coast, across or round the Bay of Bengal, through the Straits of Malacca, and on to China; (2) by the Persian Gulf to the Malabar Coast, and onwards by the first route. In dealing with these, it is more convenient to begin at the eastern end of the line, and with the Chinese. There is sufficient evidence [149] to show that, long before the period, 1000 to 1250 A. D., now dealt with, Chinese ships sailed to Java, Ceylon, and the Malabar Coast, although the trade to the west of the Malacca Straits suffered a check on more than one occasion, owing to the changing policy of their government [150]. They are reported as trading to India in the seventh century, and as being established at Quilon in 953 [151]. Their agencies were maintained on the Malabar Coast down to the fourteenth century [152], after which they seem to have been driven off for reasons or by means which are not clearly apparent. As regards extension westwards, it is more than doubtful whether they reached Aden, and their visits to Madagascar, relied on by Humboldt [153], are entirely apocryphal. As to the Red Sea, it is certain that they never entered it. Navigation there was difficult, and was entirely in the hands of sailors acquainted with local dangers. With regard to the Persian Gulf, Masoudi states [154] that Chinese ships traded to Siraf, then the port of Farsistan [155]. But this does not seem to have been the usual practice, for they are generally heard of as waiting in the Malabar ports for the change of monsoon to take them homewards [156].

In these eastern waters the Arabs were active from very early times. Originally the Red Sea trade was in the hands of the Greek sovereigns of Egypt, and afterwards passed under the Roman domination [157]. By the time of Strabo, who died in 25 A. D., the Romans had extended their part in the trade as far as India, but not further than the Indus, for Pliny says [158] that the Malabar ports were only beginning to be known in his day. This extension would tend to force Arab or Persian maritime activity farther eastward, and there are indications [159] that, even in these early times, there must have been trade between India and the Malacca Straits and, possibly, China. But at what stage this was fully established is unknown, nor is it quite clear by what country it was prosecuted. However, we learn that during the sixth, seventh, and eighth centuries Ceylon was an open market for Chinaman, Malay, and Arab [160]. Later, Arab trade extended eastwards to China and possibly to Korea, and was firmly established there, for Renaudot's two Mohammedans found populous colonies of their countrymen or coreligionists in China in the ninth century [161]. After the disturbed conditions of 878 A. D., China seems to have excluded the foreigner for a time, and Arab ships going east-

wards made Kalah, in the Malacca Straits, their terminal port. It is significant that this brought many Chinese traders to Kalah, showing that the Chinese ships must have been partially or wholly excluded from the Indian trade [162]. Westwards, the Arab ships went to Aden, and also up the Persian Gulf. At Aden, goods were transhipped into smaller local vessels and carried to Berenice or other port in Egypt, thence by land or river to Alexandria [163]. From the Persian Gulf ports, chiefly Busrah [164], trade followed the land or river routes to Persia, Baghdad, and possibly Damascus.

Before leaving this part of the subject it should be noted that there is still some difference of opinion as to the extent to which the Persians took part in this eastern trade. Rawlinson [165] was of opinion that the Persians were only freshwater sailors. Quatremere [166] held the same view; and Malcolm [167] suggested that the sailors referred to as Persians were really Arabs. Later opinion, as expressed by Ferrand [168] and Hasan [169] would make them out to have been as capable and enterprising as the Arabs. For present purposes, the point is of minor importance. There is also a similar question as to Indian participation in the trade. But the weight of evidence [170] is to show that maritime enterprise among natives of the west coast of India chiefly took the form of piracy. Indeed, one writer stated [171] that no Indian ships entered the Persian Gulf except for piratical purposes, and Alberuni [172], who wrote in 1030, refers to the activity of the pirates of Cutch and Somnath. Jordanus [173], who visited the Malabar coast about 1325, speaks with contempt of Indians as sailors. On the other hand, Wilson [174] was of opinion that many of the ships sailing in the East at the time of Fahien were Indian.

From the foregoing sketch—it cannot, in the circumstances, pretend to be more—it may be gathered that from the sixth century onwards there was considerable intercourse between the Chinese and the Cingalese, Arabs, Persians, and Mohammedans generally, and that with occasional intermission this continued down to the fourteenth century. That there was therefore opportunity for the transmission between these peoples of knowledge relating to methods in navigation seems quite well established.

The important point now to be considered is the interposition between East and West, of the Mohammedan Empire. By 1000 A. D., Islam had overrun Arabia, Egypt, Syria, Asia Minor, North Africa, and Spain, and extended from the Persian Gulf to the Straits of Gibraltar. It thus offered a solid obstacle to the unrestricted passage of merchandise, and certainly shut off all relations between the merchants and sailors of the East and those of Europe. There are abundant proofs that while the Mohammedan rulers of Egypt encouraged commerce, they reserved all rights over the transit trade between the Red Sea and Alexandria, and any facilities given to Europeans for trade at the latter port were generally the subject of special treaty [175]. Further, the importance of Alexandria as a market in the period before and during the Crusades, and the establishment there, under special regulation, of colonies of European merchants, indicate that the Mohammedan government of Egypt was jealous of European interference in the eastern carrying trade, and that Alexandria was a place of exchange rather than a forwarding agency [176]. In the Mediterranean the distribution of mari-

time activity varied in different areas and at different times. Before 900 A. D., Saracen enterprise generally took the form of piracy or of descents upon the European shores in search of plunder, while French and Italian ships were more usually engaged in legitimate trade. While the north and south shores of the Mediterranean were thus at constant war, there were occasional compacts between the Saracen and the Italian, in spite of papal and imperial interdiction against trade with the unbeliever [177]. But the growing commercial power of Italy gradually asserted its supremacy. Venice cleared the Adriatic from pirates by the year 1000. The Genoese and Pisans expelled the Arabs from Sardinia by 1015, and, later on, attacked them in their own African ports. Half a century later the Mediterranean was practically free from Saracen piracy [178], and the command of the sea, with the monopoly of trade, had passed wholly into the hands of the sailors of Venice, Amalfi, and Genoa. During the period now considered the position therefore was that while Arab navigation was active on the eastern side of Suez and Busrah, and while Venetians and Genoese were in command of the Mediterranean, there was no communication between the two; that is, between the merchants in the two areas who organized maritime enterprise. The Mohammedan control of trade acted as an effective barrier. In these circumstances the transmission of knowledge with regard to navigational practice would be highly improbable. And in the Mediterranean itself we cannot imagine the spectacle of a Saracen pirate holding amicable discussion on the fundamentals of terrestrial magnetism with a Genoese captain in the year of grace 1000.

The next step is to summarize the evidence, positive and negative, with regard to the appearance of the compass among Arabs, Persians, or Mohammedans. The earliest mention by any writer of this class is by Mohammed Al-Awfi, in his collection of Persian anecdotes, written in 1232 [179]. He describes a floating compass used to determine direction at sea, and from what is known of the author's lifetime, it is probable that he saw it in use during a voyage near the mouth of the Indus in the year 1220. He refers to the instrument as if it were a novelty. But the value of this statement is discounted by the fact that, as far as is known, his experience of ships and seafaring was very limited. The next reference from Arab sources is the allusion in the Spanish *Leyes de las Partidas* [180], written about 1250-1257, which refers to the use of the magnetic needle as a guide to mariners. It seems to point to a well-established practice of this means. It is, however, open to question how far this reference should be used as indicative of Arabic knowledge of the matter. This depends entirely on the author of that particular part of the work. The third source also comes from the Mediterranean, and occurs in a manuscript by Bailak of Kibdjadi [181], who is generally, but erroneously, referred to as the earliest Arabic writer on the subject. He describes, in 1282, a floating compass which he saw in use during a voyage from Tripoli, in Syria, to Alexandria, in 1242. But it is to be carefully noted that he said nothing as to the nationality of the vessel in which he sailed. At the time of his voyage the monopoly of the sea-trade in the Levant lay almost wholly in the hands of the Venetians, Genoese, and other Italians, and there is exceedingly small probability that it was an Arab vessel. Besides, Bertelli has remarked [182] that most pilots in Arab vessels were European slaves or rene-

gades. Bailak also stated that a similar form of the instrument was employed by those who sailed to India. But it is not clear whether he intended this to refer to 1242, the year of his voyage, or to 1282, when he wrote. It is not given as his own observation, and it has been criticized by Renaudot [183] and others. It was confirmed, but only after the lapse of two centuries, by Al-Magrizi [184], who lived 1364-1442, and described the hollow piece of iron, shaped like a fish, which was used as a magnetic needle by sailors in the Indian seas.

This, then, is all that is known regarding the knowledge of the compass among Arabs, Persians, or Mohammedans before 1250 A. D. But against the theory that the West derived its knowledge of the matter from the East, there stand two very important facts. The first is that, as will be shown later, the compass was known and used in western Europe by 1187, and as it is not referred to as if it were a novelty, it must have been in use for some considerable time. The second is that although it was known to some Arabs or Persians by 1220, that knowledge was very far from being general. For it is possible to quote from many Arabic writers of the time to show that, although they dealt with such questions, they were not acquainted with either the polarity of the magnet, or its directive property, or its application to navigation. Ibn Youni [185], the Arabic astronomer, does not mention any of these properties, although there is one part of his work where this might be reasonably expected if the knowledge had been acquired by his time. Al-Kati [186], a contemporary, distinguished between two kinds of iron, apparently steel and soft iron, but does not refer to their magnetic qualities. Alberuni [187], who wrote in 1030, refers to methods of determining direction, but makes no mention of the magnetic needle. The *Geography* of Shiref Edrisi [188], completed in 1153, makes it quite clear that in these days navigation, at least in the Red Sea, was from point to point along the coast. The pilot, as we might expect from the derivation of the word, sat at the bow of the ship and not at the stern, as he would have done if the compass were used as a guide in steering. But the compass is not mentioned, although Fournier [189] quotes several writers who thought they had detected it. Damasqui, who lived 1256-1327, wrote a treatise on cosmography [190] in which, although he does not mention the compass or magnetic needle, he refers to three kinds of lodestone: one attracts, another repels, while the third attracts at one side and repels at the other. This is of interest, first, because his statement is a repetition of what, as will be seen later, Alexander Neckam had said in the previous century, and second, because it not only shows the dawning of clearer ideas on the subject of magnetic polarity, but also proves that these ideas were developed earlier in western Europe than among Arab peoples. Aboul Hassan, a Spanish Arab, wrote a treatise [191] on the astronomical and other instruments of the Arabs, but does not mention the compass or magnetic needle. Lastly, if it is permissible to quote those writers who were probably influenced by the Arabic schools of Spain, it may be stated that there is no allusion to the directive property in the works of Marbod [192], Adelard of Bath [193], who traveled extensively in search of information, Gerard of Cremona [194], or Bernard Silvester [195]. Even down to a comparatively late date, we meet with silence on the subject where information might be expected. Except in one extremely doubtful



passage [196], Marco Polo does not refer to the compass, although he gives numerous details regarding his voyages in Eastern seas during the thirteenth century. Gilbert [197] gave him the credit of having introduced the compass into Europe from China. But the instrument was known and used in Europe for fully a century before he returned [198]. Ibn Batuta [199] describes numerous voyages he made in the East during the fourteenth century, but does not mention the compass. Nicolo Conti [200], in 1420, sailed the Indian seas in a vessel which, from its description, appears to have been Chinese, but might equally well have been Arab or Malay, and he says expressly that no compass was used on board. Lastly, the map of Fra Mauro [201], completed in 1457-59, contains in one of its "Rubrics" the statement that Indian (i. e., Arab) ships do not carry a compass, but were directed by an "astronomer" on board. This is the last statement of the kind, for in 1498 Vasco da Gama found the compass or "Genoese needle" in use by Mohammedan pilots on the east African coast [202], and in 1503-04 Varthema [203] sailed in a Malay vessel from Borneo to Java, when the pilot, probably a Malay, used a compass. It is significant that in this last case, the instrument was adjusted after the European, and not the Chinese, manner, its chief cardinal point being the north, not the south. It was therefore most probably a European compass.

Another aspect of the subject has still to be considered. In connection with the voyage of Vasco da Gama in 1497-98, he found that the local pilots in the Indian Ocean used a compass in which a plate of magnetized iron took the place of the needle [204]. Now it is rather curious that, according to Riccioli [205], sailors in the Baltic used a similar contrivance as late as the seventeenth century. Possibly this is the instrument to which Salverte [206] referred as having been used by the Finns "for ages unknown," but of which we have very little evidence. Adam of Bremen, for instance, does not refer to it [207]. Nevertheless, Benjamin [208] has founded upon it an argument which may be summarized as follows: The circumstances attending the appearance of the compass all indicate a radiation from some central point of origin. At the epoch of that appearance, Wisby, in Gothland, was a great center for all seafaring peoples. It is, according to Benjamin, more reasonable to suppose that a knowledge of magnetic polarity and of the directive property existed among the Finns than among other races gathered there, because of the affiliation of the Finns and Mongols (who are presumed to have had anterior knowledge of the matter), and because of the reputation of the Finns for peculiar skill in "sea-sorcery." He goes on to point out that a Finnish compass has been discovered [209] which lends support to this view, being of great antiquity, and having its card marked, not with the usual quadrants, but with divisions indicating the azimuth of sunrise and sunset at the two solstices for a latitude of  $49^{\circ} 20'$  north, which crosses Asia at the region which was the cradle of primitive civilization, and from which began the wanderings of the great family to which both Finns and Mongols belong. This theory must inevitably suffer on two accounts. First, it presumes that the Mongol races had some positive knowledge which could be transmitted. But it has already been shown that there is no evidence of such knowledge among Mongolian races before the eleventh century, and perhaps not even then. Second, the idea of using the magnetic needle

in navigation or in land journeys did not originate with the Chinese. To these there may be added the consideration that there is no obvious reason for the use of the compass on the land routes over Asia; if the route were unknown or uncertain, the compass would not discover it in the absence of a map. Also the fact that the so-called cradle of primitive civilization has yet to be finally located, and present indications do not point to the area chosen by Benjamin. The theory might therefore be set aside as untenable but for its later development in a somewhat different form by Hennig [210], and this has a bearing on the question of Arab influence in the matter. According to Hennig, the knowledge of the compass reached Northern Europe by the routes along which an active trade was carried on by the Normans with the Arab Caliphate several centuries before the Crusades. This, it is supposed, would explain the appearance of the compass in the north of Europe before the south. The hypothesis seeks support in the fact that many hoards of Arab coins have been found in Russia, the Baltic States, Scandinavia, and Germany, their dates extending from 698 to 1010 A. D. [211].

This theory is practically the only exception to the rule, already mentioned, that no writer on the subject has attempted any explanation of the means by which the supposed prior knowledge of the Arabs regarding the compass was passed into the western world. It is mainly founded on the facts relating to the trade which Arabs carried on with Bulgarians, Russians, Lithuanians, and Scandinavians in pre-Crusading times. That by these means there might be communication of knowledge on various subjects may be granted, but only with certain restrictions. The first of these is that there is very little evidence that Arabs ever penetrated into Russia farther than the country of the Khazars on the Volga. If there was any extensive interpenetration, it was rather due to the Normans traveling south by the Dnieper. The second is that Moslem trading enterprise had suffered a serious decline before the Crusades, and this before any supposed Arab knowledge of the compass existed. And third, the general consideration that it is improbable that any novelty in the art of navigation would be transmitted by travelers or merchants who were wholly occupied in land journeys over Central Asia or the Nearer East. But the chief objection to the theory is the utter absence of any evidence pointing to an early knowledge of the compass among the Normans. Had it been known to any seafaring people among them, it would be known to the Norwegians and Danes, and of this there is absolutely no proof. As for the earlier appearance of the compass in the north of Europe as compared with the south, this has by no means been established, and it certainly cannot be taken for granted. With regard to the hoards of coins, Heyd [212] is inclined to the belief that they may be the loot gathered by Normans who went ravaging southwards in the tenth century. Interesting and ingenious as this theory may be, it does not seem to carry us further towards an explanation.

We may now sum up the evidence bearing on the question of the transmission of the knowledge of the compass by the Arabs from China to Europe. The leading points are as follows. First, the statement of Shonkua, of uncertain date, but before 1093, showing Chinese knowledge of the directive property. Second, the notice, published by Hirth, of the use of the magnetic needle by Arabs trading to Canton about

1100. Third, the mention by Awfi of the use of the compass on the northwest coast of India in 1220. Fourth, the extent to which the Mohammedan empire restricted direct communication, and therefore interchange of ideas, between east and west. Fifth, the appearance of the compass in western Europe certainly before 1187, and in the Levant in 1204. Now, with regard to the first of these, reasons have already been given for holding Shonkua's statement to be the earliest of its kind, and there is no immediately apparent ground on which it can be discredited. But in reference to the second, there must be considerable doubt. It is an isolated statement, is confirmed by no contemporary writer, and depends for its value upon the date assigned to it by the Chinese scholars of the Imperial Library. That value is seriously discounted by the fact that for more than 120 years thereafter we hear no more of the compass in use by Arabs or Persians. It is quite possible that further critical examination of Chu-Yu's *Ping-Chou-ko-ihon* may confirm Hirth's conclusions. Meanwhile, it is proposed that it be held in suspense until this has been done.

Hence the conclusion reached on the matter is, that the Chinese were acquainted with the directive property of the magnet by 1100 A. D.; that they did not then employ it in navigation; that there were serious obstacles to the transmission of this knowledge from east to west; that the compass was in use in western Europe by 1187, and considering the time which must have elapsed between the discovery of the directive property and the application to the construction of a primitive compass, it is most probable that its origin in Europe was independent of, and possibly as early as, if not earlier than, that in China. The appearance of the compass in the Levant in 1204 probably derives from its western European origin. Where Awfi's compass of 1220 came from, we do not know; east or west are both possible, and the latter the more probable.

10—We have now to examine the literature of Europe from medieval times onwards, in order to collect the known or supposed references to the directive property of the magnet and to the compass. First of all, it may be well to clear away as far as possible any matter of a doubtful kind and to mention one or two points of negative evidence.

The earliest of several doubtful claims to priority is that put forward on behalf of Salamone Ireneo Pacifico, of Verona, who lived 778-846. This was first suggested by Posteraro [213], and was based on an inscription on the tomb of Pacifico in the cathedral of Verona. But Bertelli [214] has shown that Posteraro's interpretation of the inscription is erroneous.

The second is connected with the monk Gerbert, who, in 999, became Pope under the name of Sylvester II. There seems no doubt that he was one of the most learned men of his time. The Benedictine authors [215], in giving an account of his life, quote a passage from Ditmart [216], which has been taken by some to mean a telescope, and by others to refer to some form of compass. From Gerbert's own letter to the monk Constantine, Ameilhon [217] has shown that it can refer to neither, and the point has been discussed with similar results by Trombelli [218], Montucla [219], and Baldelli Boni [220].

The third is a passage, quoted by Gibbon [221] from the historical poem of Gulielmus Appulus as supporting the idea, widely prevalent

in Gibbon's time, that the compass was discovered by the sailors of Amalfi. This poem shows internal evidence of having been composed between 1088 and 1111, and the passage in question must have been completed after July, 1099. But it might equally well apply to navigation by the stars, and makes no explicit reference to the compass.

The fourth is that brought forward by Hansteen [222], according to which the Norwegian historian Ara Frode, born 1068, asserted in his *Islands Landnamabok* [223] that the lodestone was not used in navigation in the year 868, when Vilgerderson set out to discover Iceland; the presumption being that it was known and used by the time at which Frode wrote. But Kamtz [224] showed that the passage quoted by Hansteen is of much later date than the time of Frode, and that the work attributed to him was really the production of several later writers down to Haukr Erländson, who died in 1334. Kamtz also stated that three different manuscripts of the *Landnamabok* do not contain the passage relied on by Hansteen, and this has been confirmed by Klaproth [225]. It may be mentioned here that the Danes made some remarkable voyages before the end of the thirteenth century. But according to the Sagas, they did not use the compass. They calculated distance by a day's sail of 27 to 30 miles, and guessed at the direction of the nearest land by the flight of birds [226].

The last of these doubtful allusions is that which is ascribed to William the Clerk, also known as William the Norman, and was said to have been discovered by M. Paulin Paris, the distinguished French antiquary. The facts of this case may be summarized as follows: A manuscript, now in the Bibliothèque Nationale, Paris [227], contains a poem in which there occurs a reference to the attraction between the magnetic needle and the pole star, and describes a compass consisting of a magnetized needle inserted through a cork which floats on water. The first writer who referred to this poem was Fr. Michel [228], shortly before an article by M. Paulin Paris appeared in September, 1836 [229]. As stated in this latter article, the manuscript was transcribed in 1329 by Robert (or Robechonnet) de Gonnecourt, and it contains several poems. The fifth of these contains the allusion in question, and because it comes immediately after two others known to be by, or generally ascribed to, William the Clerk, M. Paulin Paris ascribed it to the same author and therefore dated it 1160. He gave no reason beyond this for the ascription to William the Clerk. But there are abundant reasons for doubting this conclusion. To begin with, the reason given is weak. Second, there is no assertion as to the authorship in the poem itself. Third, the passage relied upon bears such a very close resemblance to another in the well-known poem, *La Bible*, of Guyot de Provins, to be mentioned later, that it might well be regarded as having been inspired, if not copied, therefrom. Fourth, as regards the date of its composition, Wright [230] is of opinion that it probably belongs to the beginning of the fourteenth century, possibly to the century preceding. This would bring it down to a date fully a century later than that assigned to it by M. Paulin Paris, and certainly later than 1206, when Guyot wrote. In all probability, therefore, it was not written by William the Clerk. For these reasons the poem and the description of the primitive compass which it contains cannot be given the priority sought for, and the claim based upon it must be rejected.

11—We come at last to something of a perfectly definite and well-authenticated kind. Alexander Neckam, monk of St. Albans, who was born in 1157 and died in 1217 [231], wrote two treatises, *De Utensilibus* [232] and *De Rerum Naturis* [233]. The dates of their composition are not known exactly, but may with safety be assigned to the last quarter of the twelfth century, possibly not much later than 1187 [234]. In the first he describes the use of the magnetic needle to indicate the north, and states that mariners employ this means of finding their course when the sky is clouded so as to obscure sun or stars. In the second, he describes the needle as being placed on a pivot, and it is to be noted that this form of the early compass is generally understood to have been the second stage in its evolution. In neither treatise does Neckam represent the instrument as a novelty, but as one in common use.

This is the earliest mention in European literature of the polarity of the magnet, of its directive property, and of the application of that property to the art of navigation.

Almost contemporaneous with, but certainly later than, Neckam, we have the extensively quoted poem, *La Bible*, of Guyot de Provins [235]. Its date can be fixed as being later than 1204 and not later than 1209, most probably 1206 [236]. It describes a floating compass in use by navigators, and hence does not include the developed form described by Neckam. But it must be remembered that Guyot was a poet, and that he only introduces the compass as illustrative to his theme, whereas Neckam wrote for the instruction of others and had, therefore, to be more strictly accurate in technical detail. By a curious mistake, Guyot was identified by Pasquier [237] with another writer, Hugues de Bercy, a French poet of the time of St. Louis. Although this error was corrected by Barbazan [238] in 1759, and by the Comte de Caylus [239] in 1774, the belief that Guyot and de Bercy were one and the same person persists down to the present day [240]. Another side issue was the misinterpretation of the word "manate" which occurs in Guyot's poem. It really means "magnet," but was transcribed by Pasquier [241] as "marinette." Hence the statement, frequently made by encyclopedists, that the early French name for the compass was "marinette." This mistake recurs occasionally down to recent times.

The first attempt, on really scientific lines, at any systematic description of the properties of the magnet was that contained in a letter written in 1209 by Petrus Peregrinus, and addressed to Sigerius de Foucancourt [242]. For the full examination of all matters connected with this letter, we are indebted to the researches of Bertelli [243]. The author explained how the position of the poles in a spherical mass of lodestone may be determined and showed how they could be distinguished. He suggested or effected several improvements in the nautical compass, and devised the first form of azimuth-compass. That his letter is, for its time, a wonderful production there can be no manner of doubt. But there has been a tendency among some writers [244] to overrate his influence, and the statement that he was the first to introduce the pivoted needle is erroneous [245].

12—We have thus reached the period at which the directive property and its application to the compass has become generally known. There still remain several references to the compass which must be examined

in order to clear up certain issues which have been raised in connection with the matter.

Soon after Guyot wrote his poem, Cardinal de Vitry published, in 1218, a description of Palestine [246] in which he speaks of the compass as a necessary aid to navigation, having seen it in use in 1204. The fact that he refers to it as if it were a novelty, whereas Neckam and Guyot wrote as if it were in common use, might be employed to prove that the introduction of the compass was earlier in the western Mediterranean and the Atlantic seaboard than in the eastern Mediterranean, where de Vitry saw it in use. But the more probable explanation is that the Cardinal had but little experience and less knowledge of matters connected with navigation. He was followed by Thomas of Cantimpre [247], who gives a description of a floating-needle compass resembling that of Neckam. The date at which he wrote can only be fixed approximately, between 1228 and 1244 [248]. Riccioli [249] states that under the reign of St. Louis (1226-1270), French navigators used a floating needle as a compass, but cites no evidence in support of his statement. Michael Scot [250], writing some time after July, 1228, refers more than once to the directive property, hinting at its use in navigation, but in each case as if it were already well known. Klaproth [251] pointed out that the pseudo-Aristotle quoted by Albertus Magnus and Vincent de Beauvais exhibits some knowledge of the properties of steel. He suggests that the polar properties of the magnet were known to the Arabs before the time of these two writers, i. e., about 1250, and that what was then known came from Arabic sources. Vincent de Beauvais [252] refers to the polar and directive properties as if they were novelties, and this might seem to date the arrival of this knowledge in western Europe. But it has been shown that the compass was known in western Europe for at least half a century before the date mentioned, and that there are no conclusive reasons for attributing its introduction to Arabic influences. Here it would be well to remember that the evolution of the idea of polarity, and therefore of a directive property, must have been a slow process. Even as far back as the time of Pliny [253] there are references to varieties of lodestone, some of which attract and others that repel. These observations were repeated, or made independently, by Isidorus Hispaliensis [254] and the younger Psellus [255], but the qualitative law of attraction and repulsion had not been reached.

Poetical references to magnetic polarity now begin to appear more frequently, such as those of Gauthier d'Espinois [256] and Guinizelli [257]. Schück [258] has brought to light a poem, *Unser Vater*, by Krowlowiz, dated 1252-1255, in which a clear allusion of the kind is made. Torfaeus, in his Norwegian history [259], states that in 1266 the poet Sturla was rewarded for his poem on the death of the Swedish Count Byrgeris by the gift of a compass. If this be reliable, it would indicate that in the middle of the thirteenth century the compass was a novelty in Scandinavia. Quotations by Capmany [260] from the works of Raimon Lull, dated 1272, show that the latter was well acquainted with the use of the magnetic needle by navigators. Brunetto Latini [261], the tutor of Dante (who also mentions [262] it) speaks of the lodestone and magnetic needle. But the story, given by Klaproth [263] and repeated by many later writers [264], of the visit of Brunetto Latini to England during the reign of Henry III (1216-1272) when Roger Bacon

demonstrated to him the polarity of the magnet, is based upon letters [265] which were later acknowledged to be deliberate forgeries [266], and one of the most extraordinary things in the history of this subject is Klaproth's omission of this acknowledgment. Bacon himself refers to the subject [267], but not as if it were a novelty in his time. The Scottish poet Barbour, writing in 1375, says [268] that his hero, King Robert the Bruce, "na needil had na stane" to direct his course from Cantyre to Carrick in 1306, from which we may conclude that some form of compass was known in Scotland by the latter half of the fourteenth century.

13—Among the many statements made with regard to the origin of the compass, none has attained wider currency than that which attributes its discovery in 1302 to Flavio Gioja, a native of Amalfi, a small seaport in southern Italy. The history of this legend—for such it is, in spite of its being supported by official authority [269], and of its being quoted as genuine in a serious history of science of recent date—is interesting, if for no other reason than that it provided the occasion for the important historical researches of Bertelli [270]. It begins with a passage in the historical work of Flavio Blondo [271], who, writing about 1450, said: "*Sed fama est qua Amalphitanos audivimus gloriam, magnetis usum, cujus adminiculo navigantes ad arcem diriguntur, Amalphi fuisse inventus quicquid vero habeat in ea re veritas, certum est id noctu navigandi auxilium priscis omnino fuisse incognitum.*" He thus made a claim on behalf of the Amalphian navigators generally to the invention and first use of the compass. Four points must be noted in connection with this claim. First, the discovery is not ascribed to any particular individual; second, no date is assigned to it; third, the statement was made at least two hundred and fifty years after the compass in a primitive form—possibly in an improved form—was first known in western Europe; fourth, the statement was not accompanied by, nor is there any indication that it was based upon, any systematic examination of the facts of the case. The next stage comes about five years later, when Antonio Beccadelli, otherwise known as Antony of Bologna, or "the Panormitan," repeated in one of his poems the statement that the compass was first used by the Amalphians, although he does not credit them with the invention. His verse was not published until fully a century later, possibly first by Torello [272], certainly by Mazella [273] in 1586. Meanwhile, in 1489, Polydore Vergil [274] had said that it was not at all clear who was the inventor. The third stage was that at which Baptista Pio [275], quoting Blondo in 1511, makes the remark, "*Amalphi in Campania veteri magnetis usum inventus a Flavio traditur.*" Fourth, there came Giraldus, who had two contributions to make. In the first [276], possibly assignable to the early part of the sixteenth century, he credits the Amalphians with the earliest use of the magnetic needle, and describes what appears to be a circular compass-card attached to it. In 1539, Collenuccio [277] wrote to much the same effect. In his second contribution, of 1580, Giraldus [278] quoted Baptista Pio, but in doing so showed an entire misconception of the position. He says, "*Sed non multis retro seculis Amalfis in Campaniae oppido, antiquis navigandi usus incognitus per magnelem et chalybem, quorum indicio nauiae ad polos diriguntur a Flavio quadam excogitatus traditur.*" He thus ascribed the invention to a person named Flavio, whereas Flavio

was the name of the author of the original statement. This was the origin of the legend, and in this form it was repeated by Lopez [279], Cardan [280], Belon [281], Gasser [282], Lemnius [283], Bartolomeo [284], Aldrovandi [285], and others [286] in later times. But matters were made much worse when, in 1586, Mazella [287] gave a surname, Gioja, to the supposed inventor. He said, "*In Amalphi nell' anno 1300 fu (gloria degli Amalfitani) ritrovata di Flavio di Gioja la Bussola, tanto necessaria a naviganti.*" For this ascription to a person and a year no warrant was produced. It may seem difficult to account for the appearance of this surname, except on the hypothesis that it belonged to some actual individual. But the similarity between the French "Guyot" and the supposititious Italian "Gioja" suggests the explanation that Mazella had read somewhere about the former, and had given his name the Italian form. Be this as it may, the confusion was not lessened when Ortelio [288] gave the name of the inventor as Giovanni Gioja or Giri, and made the further mistake of shifting the scene of discovery from Amalphi to Melphi. During the three and a half centuries which have since elapsed, the error has been repeated so persistently that it might have passed permanently into the historical literature of science, had Bertelli [289] not shown how the legend arose. On the other side, it has had its patriotic defenders in Grimaldi [290] and Venanson [291]. It has also been supported by Briet [292], Voltaire [293], and others [294]. For reference to criticisms other than those of Bertelli, Signorelli [295], Camera [296], and Fiucati [297] may be consulted. Lastly, it may be mentioned that a statue to the mythical Gioja has been erected in the Exchange at Naples, and that the six hundredth anniversary of his supposed discovery was celebrated at Amalphi in 1901 [298].

With regard to this claim of Gioja—apart altogether from what has been stated above—it need only be said that the year to which it is assigned, 1302, is at least a century later than Neckam's description of the compass.

14—Before leaving this part of the subject, the reader will doubtless have noticed that much of the evidence collected on the history of the compass has had to depend on historians, poets, and others who are not concerned with the actual use of the instrument, and it will be obvious that it must be difficult to obtain such direct evidence of its use. Indeed, there are indications that the general introduction of the compass in western Europe was hindered by fears that those who used it might be accused of practicing magical arts. Voltaire [299] said that the first use of the compass was by the English during the reign of Edward III (1327-1377), but he gave no authority for his statement. That it was then in use can, however, be proved. Nicholas [300] cited instances from official records showing that, in 1338 and 1345, certain ships of the British Navy were supplied with "sailing needles and dial," as the compass was then termed. In one case they were purchased in Holland. This is the earliest record of the actual use of the compass in a given ship. Capmany [301] reported that while the compass is not mentioned in the inventory of a ship fitted out at Barcelona in 1331, nor in similar lists for the galleys of Don Pedro IV of Aragon in 1364, it is mentioned in the chronicle of Don Pedro Nino under 1403, and in the galley inventories of Alfonso V of Aragon in 1409.

The later history of the compass is only concerned with its technical



improvement as an instrument, no additional principle in terrestrial magnetism being involved. The matter need not, therefore, be pursued further, except to refer the reader to the work of Schück [302] for information on these later aspects of the question.

15—We have thus summarized the available evidence as to the origin of the knowledge of the directive property of a magnet in the Earth's field and of the application of this property to the nautical compass. It has been considered desirable that the facts of the case should be kept in prominent view, to the exclusion of opinion too often based on incomplete examination of the material. And it is believed that in this summary no original record of importance has been omitted. The case is therefore ready for such conclusions as may seem possible. But before these are stated, it is well that some general principles receive attention.

Granted a widely diffused knowledge among ancient peoples of the attractive qualities of the lodestone, the probable sequence of further discovery may be considered. Here we have to remember that the historical development of a science in the darker ages was very unlike the intensive processes of investigation in a modern physical laboratory. But it is reasonable to suppose that there were four stages in development: The magnetization of iron or steel; the polarity of a magnet; the directive property in the Earth's field; the application of that property in the construction of a compass. But we have no evidence that these constituted the general order of discovery in the case of any particular country or people. For instance, in China, the first reliable mention of the directive property is in connection with a magnetized needle; in Europe it is first clearly stated as a property of the lodestone. It has also to be noted that, at a certain stage, while there was a belief in some countries—China and the eastern Mediterranean, for example—that the directive property was evoked in iron or steel by the lodestone, there was no recognition of the fact that the property was already present in the lodestone itself.

To the science of to-day the qualitative laws of magnetic attraction and repulsion, and the elementary fact of the directive property, appear to be extremely simple conceptions. But it is less easy to appreciate the difficulty facing the investigator of, say, the tenth century. Polarity, at that time, would be an entirely new conception; the Greeks, and still more the Latins, had no word with which to express the idea. And the difficulty of expression would not be lessened by the circumstance that it was an age in which progress was believed to lie in wrangling over words rather than considering objective facts, and when argument was regarded as superior to observation or experiment. Add to this the lack of communication between learned men, and we cannot be surprised that advance was slow and hesitating; that it was frequently held up in the blind alleys of verbal disputation; and that the course of discovery may, in particular countries or races, have taken a direction which it is now impossible to retrace. It is a curious reflection that the study of terrestrial magnetism received its main impulse, not from the monk in his cell, nor from the professor in his academic chair, but from a class of men furthest removed from all such influences—the men who, as Solomon said, had "knowledge of the sea." The world owes more to its sailors than it has generally acknowledged.

On general grounds, it seems obvious that some considerable time must have intervened between the discovery of the directive property and its application to the compass. The difficulty is the determination of that interval. In China, it appears to have extended over two centuries, largely owing to the decay of maritime activity among the Chinese. As regards western Europe, we have no knowledge of its duration, for the first mention of the directive property is made along with the description of the first primitive compass.

16—To come nearer a final conclusion, we may proceed to the elimination of certain claims to priority. That the "magnetic chariot" of the Chinese was the earliest attempt at a compass must be excluded for reasons already given. Those made for the Phenicians, Egyptians, Etruscans, and the Greeks and Latins of classical times must also be set aside for lack of evidence. The same applies to the theory of Benjamin with regard to the Finns. Lastly, the claims made on behalf of particular individuals, Marco Polo, Pacifico, Gerbert, and Gioja, have been examined and rejected. This leaves us with three areas, or groups of races, in which the early knowledge of terrestrial magnetism may have developed; the Chinese, the Arabs, and the peoples of western Europe. The opinion most generally held hitherto, that it began with the first, and was carried by the second to the third of these groups, has already been explained and adversely criticized.

The final conclusion may be stated in the following form:

(I) That while it is possible that the Chinese were acquainted with the directive property of a magnet by 1093 A. D., they made no further use of that property for at least two hundred years thereafter.

(II) That there is no evidence of the origin of any such knowledge among the Arabs, and it is improbable that they transmitted any information on the matter to Europe, their earliest mention of the compass being nearly half a century after its first mention in Europe.

(III) That the compass was in use in western Europe by 1187 A. D., and taking into consideration the fact that the directive property must have been discovered much earlier, it is most probable that a knowledge of that property and its application in western Europe was of independent origin and as early as, if not earlier than, that in China.

#### *Bibliographical References and Notes*

[As a rule, only original sources of information are given. Secondary references are only mentioned when they include critical or additional matter of importance, or when there appears to be error in fact or interpretation. References which have not been examined and verified are indicated by an asterisk.]

[1] Gilbert, *De Magnete*, Chiswick Press, ed. vi, and bk. II, ch. vi, seems to have been the first to have clear ideas on this point. His "orbis virtutis," defined as "all that space through which the virtue of any lodestone extends," is the magnetic field. See Kelvin, *Popular Lectures and Addresses*, London, 1891, III, 246.

[2] Gaubil, *Observations mathématiques, astronomiques, géographiques, chronologiques, et physiques, tirées des anciens livres chinois*. Ed. by Souchet, Paris, 1729, 3 vols. Vols. II and III dealing with Chinese astronomy, are by Gaubil.

[3] Duhalde, *Description géographique, historique, et physique de l'Empire de la Chine et de Tartarie Chinoise*. Paris, 1735. English trans. (here referred to) by Brookes, *General history of China*, London, 1736.

[4] Mailla, *Histoire générale de la Chine*, Paris, 1377, 13 vols.

[5] Amiot. *Mémoires concernant l'histoire, les sciences, les arts, les mœurs, les usages, etc., des Chinois*. Paris, 1776-91. The *Abrégé chronologique de l'histoire universelle de l'Empire Chinois*, by Amiot, is in XIII, 74-308.

[6] Hager, *Memoria sulla bussola orientale*, Pavia, 1809 and 1810.

[7] Klaproth, *Leitre à M. le Baron A. de Humboldt sur l'invention de la Boussole*. Paris, 1834, to which reference is here made. German ed., Leipsic, 1885.

[8] Biot, *C. R. Acad. sci.*, XIX, 822-829 (1844).

[9] The earliest supposed reference to the south-pointing chariot is in the *Kiu-ku-tsi*, written in the 4th century B. C. It is there stated (sect. 10, quoted by Hirth, *Ancient history of China*, New York, 1911, 128) that the people of Chong use the contrivance when seeking for supplies of jade. But the authenticity of this work has been disputed. (See Giles, *Adversaria Sinica*, Shanghai, 1905, 110; but compare the criticisms of Hashimoto, *Memoirs of the Research Department of the Toyo Bunko*, Tokyo, 1926, No. 1, 74-75.) Another, possibly more distant, reference is found in the *Han-fei-tsen* (quoted by Hirth, 128), written before 233 B. C., which states that "the early kings constructed the *ssu-nan* or 'south-pointer' in order to show the position of morning and evening." Biot [8] 822, makes this out to be the earliest reference, and places it in the 4th century B. C. The first conclusion is doubtful; the second is in error. Gaubil [2] II, 94-95, through whom it first came to be known in Europe, quotes from the Chinese annals *Thoung-kian-kang-mou*, but gives no exact reference. Mailla [4] I, 316, refers the invention to the later time of Tcheoung-kong, but his editor, Abbé Grosier, paraphrases the story from that part of the annals known as the *Wai-ki*. Amiot [5] XIII, 227, also uses the annals, referring to the *Tsien-pien* under "Hoang-Ti." Klaproth [7] 72-73, quotes from the same source as Gaubil, Imperial Ed., 1707, *Ou-ti-ki*, fol. 22, v, and gives a translation of the passage. It may be added that the story is not given by Se-ma-Tsien, the most reliable of the ancient Chinese historians. "On remarquera que Se-ma-Tsien omet les légendes qui rapportent l'invention de tous les arts à l'époque de Hoang-Ti." (Chavannes, *Mémoires historiques de Se-ma-Tsien*, Paris, 1895, I, 35, note 1.) Mottelay, *Bibliographical history of electricity and magnetism*, London, 1922, puts it under 2637 B. C., for reasons given, relates the incident of the fog as a natural occurrence, and says it was a female figure which stood on the chariot. For the two latter statements there is not sufficient authority. His reference to Souchet should have been ascribed to Gaubil, and that to Saillant and Nyon to Amiot. With regard to the fog raised by Tchi-Yeou, the belief that such phenomena are producible by enchantment continued until comparatively recent times. See Yule's ed. of *Marco Polo*, London, 1871, I, 92. For the case of a genuine fog interfering with the progress of a battle in 1762, see his note, p. 100, and the reference there quoted.

[10] For a fairly full account of the European literature, particularly of the writings of the Catholic missionaries, down to 1825, see Morrison, *Chinese Miscellany*, London, 1825.

[11] It is somewhat difficult to give a strictly chronological arrangement of the different authorities to whom this version of the legend can be referred, and in what follows there may be departures from the best ascertained order. The same applies to [12] below.

The *Tai-ping-yu-lan*, a cyclopedia of the 10th century A. D., quotes the *Kiu-ku-tsi* (but see [9] above) to the following effect: "The Su-shon offered a white pheasant to Wou-wang. Lest they might lose their way on the journey, Tcheou-kung constructed the south-pointing chariot to accompany them" (Hirth [9] 128). See also Legge, *Chinese classics V, Shu-king*, 537, who holds that the first genuine mention of the south-pointing chariot in this connection is not older than the 2nd century A. D. Also Hashimoto [9], 70, note 5, regarding Legge's source of information. (Parker, *New China Review*, 1919-22, has examined the general question of the authenticity of Chinese writings of this period.) The *Thoung-kian-kang-mou*, 1701 ed., I, fol. 9, quotes from the memoirs of Se-ma-Tsien. The passage, as Klaproth [7] 82, pointed out, does not occur in the 1707 edition, but is found in the Manchu and other editions. As noted in [9], it is not in Chavannes' elaborate edition [9] of Se-ma-Tsien. The official history of the Song dynasty (420-478 A. D.) written by Shen-yo (441-513 A. D.), as quoted by Giles [9] 111, gives a fairly full account, and attributes the invention to Tcheou-kung. Klaproth [7] 71, quotes from the *Yeou-hio-kou-szu-khiong-liu*, an encyclopedia written about 100 B. C., the statement that Tcheou-kung made the south-pointing chariot and the compass (liv. IV, fol. II, v. 1), but Bertelli, *Mem. Acc. Nuovi Lincei*, IX, has shown that the words "and the compass" are an interpolation of later date. Gaubil [2] II, 95, mentions the ascription to Tcheou-kung, but gives no specific reference. Giles [9] 219-222, quotes from the chapter on "Chariots" in the history of the Song dynasty.

This passage recounts the original story of Hoang-Ti, also its later form now under reference, and then passes on to the further history of the invention. Mottelay's chronological account [9], although of considerable value generally, contains several errors, nearly all of which are traceable to Humboldt, who was very strongly prejudiced in favor of Chinese priority. Under B. C. 1110, Mottelay states that "Tcheoung-kung is said to have at this date taught the use of the needle-compass to the envoys from Youa-tchang." But there is no mention of the magnetic needle or compass in any Chinese writing of that period, or dealing with that period, and the statement that the south-pointing chariot contained a magnetic compass is an entirely unwarranted addition. Under 1022 B. C., he states that "at this period the Chinese magnetic cars held a floating needle," another example from Humboldt. He refers to Se-ma-Tsien for confirmation, but, as previously explained, the passage is extremely doubtful, and in any case makes no allusion to a floating needle. Under 1068 B. C. he quotes Humboldt, *Asie Centrale*, Paris, 1843, I, xxxviii-xlii, to the effect that in that year the magnetic chariots were used as a guide "across the boundless plains of Tartary," for which there is not a scrap of evidence. Thus Humboldt's sweeping statements have found wide currency, even down to the present day. They are given in an unrestricted, or even amplified, form in Knight's *Dictionary of practical mechanics*, col. 1396.

It should be mentioned that a curious sequel to the story of the Tonquin embassy and the south-pointing chariot was given in the *Ki-kin-chu*, written by Tsui-pau during the Tsin dynasty. (See *J. R. Asiat. Soc., N. China Branch*, N. S. XI, 123.) It states that the officers accompanying the returning ambassadors came back in the same carriages in a direction opposite to that in which they pointed. This is, of course, a spurious, and very late, addition to the story.

[12] The history of the Song dynasty, composed in the 5th century A. D., is the source generally used. Hirth [9] 129, quotes from ch. XVIII, 4, that the secret of the south-pointing chariot had been lost for many centuries, but was rediscovered by the astronomer Chang-hong (78-139 A. D.). His model was lost in the troublous times at the end of the Han dynasty, and was subsequently forgotten. This is also quoted by Klaproth [7] 83, but with a difference in date. Several authors state that the scholar Ma-kium, who lived about 235 A. D., reinvented the chariot, and that it was placed in the hall known as *Thoung-houa-tian*, where many curiosities were kept. Klaproth [7] 83, quotes this from the *Thoung-kian-kang-mou*, 1707, ed. xv, fol. 29, and also from the treatise on ceremonies which forms part of the history of the Song dynasty. This latter source is also used by Giles [9] 111. Parker, in *China Review*, XVIII, 197, quotes the *Sung-shu* to show that the chariot was made again under the emperors Shi-Hu (532 A. D.) and Yan-hing (about 400 A. D.), but Hashimoto [9] 72-73, remarks that Parker drew conclusions from a text which he misunderstood. According to Hirth [9] 131, the model made under Yan-hing is described in the biography of its engineer, *Nan-tsi-shu*, LII, 15; that it had no machinery at all, but whenever it was put in motion a man had to step inside in order to work the contrivance. The two models referred to fell into the hands of the Song emperors in 417 A. D., but "the machinery being too coarse, the south-pointer showed so often in the wrong direction that men were required to set it right again." Giles [9] 111, in the passage referred to above, quotes a statement that the south-pointing chariots made by the Thibetan tribes did not work well, and had to be taken slowly round any turn. It also represents them as having been made by an ingenious mechanician, Ysou-tsoung-tchi. The circumstances in which Wu-ti's chariot was finally made by Ma-yo are quoted by Klaproth [7] 89. Hirth [9] 132, refers to the *Chan-ye-tsien-tsai*, a work of the 8th century and quoted in the *Ko-chi-king-yuan*, XXIX, 25, as showing that in 692 A. D., a mechanic of Hai-chow constructed a chariot which showed the twelve hours of the day, by the shaft being pointed due south. But Hashimoto [9] 87, places a widely different construction on the passage. The same encyclopedia, p. 24, describes another south-pointing chariot as being 7½ inches long and 15 inches high. Tchin-in, quoted by Klaproth [7] 76, and others, said that nothing was known of the ancient form of these chariots; that the emperor Hian-tsoung (806-820 A. D.) had one made; that it consisted of a pavilion at four angles of which were wooden dragons; that on the pavilion was placed a wooden figure, the hand of which always pointed to the south, however the chariot might turn; and that some say that the chariot carried a compass. This is obviously a very late commentary. The same note states that one of the drums termed *Ki-lu-kou* was added to the chariot. This construction is referred to in the *Sung-shu*, CXLIX, 15, quoted by Hirth [9] 131, as being based on a complicated system of cog-wheels, and that it was reconstructed by the emperor Jin-tsoung in 1027 A. D. Another was made for the emperor Hiu-tsoung in 1107. Giles [9] 112, refers to the *Poei-wen-yun-fu* as giving other allusions, but containing nothing of additional interest.

[13] Klaproth [7] 90-91, from the *Thoung-kian-kang-mou*, 1707, ed., XXIV, fol. 22, 23.

[14] *San-thsai-thou-hoei*, V, fol. 10, ed. by Wang-khi.

[15] Klaproth [7] Plate II, Fig. A. Another, Fig. B, is taken from a Japanese cyclopedia of 1609. Klaproth's figures are reproduced by Davies in Thomson's *British annual*, 1837, and his Fig. B is given in the *J. Frank. Inst.*, XVIII, 69, and by Benjamin, *Intellectual rise in electricity*, London, 1895, 73. With regard to the alignment of the walls of buildings by means of the south-pointing chariot, Gaubil [2] III, 37, refers to the matter and to the attention paid to exactness. But the rules there given are based on astronomical principles, and do not mention either the south-pointing chariot or the compass.

[16] Klaproth [7] 93-94, cites passages from Kai-bara-Tok-sin, author of *Wazi-su*, published 1696, who quotes from an older Japanese history, *Nippon-ki*. The dates of construction are given as 658 and 666 A. D. Klaproth adds that, nevertheless, the lodestone was not known in Japan before 713 A. D. I have not been able to trace his authority for this statement. In Knight's *Dictionary* [11] 1397, it is stated that in 543 A. D., "the wheel which shows the south was sent to the Mikado by the court of Pesi (Korea)." There is no entry to this effect under that year in the *Nihongi* (Aston's translation, *Trans. and Proc. Japan Soc.*, London, 1896), which gives the two instances quoted by Klaproth.

[17] For a discussion of Chinese chronology, see Freret, *Mém. Acad. des Inscr.*, XVIII; Ideler, *Berlin Akad. Abh.* 1837, and his *\*Handbuch der mathematischen und technischen Chronologie*, Berlin, 1825-26. Remarks of a general kind are given by Davies [15]; also by Gouquet, *Origine des lois, des arts, et des sciences*, Paris, 1758, III, 293, who distrusted all Chinese records before the "Burning of the Books." See references and details given by him. For the chronology of Se-ma-Tsien, who rejected all dates before 841 B. C., see Chavannes [9] I, clxxxvii-clxxxviii.

[18] For comparatively recent criticism by the Chinese of their own literature, see "J. E." (Rev. J. Edkins), *China Herald*, March 1857, reprinted in the *Chinese and Japanese repository*, London, 1863-65, I, 66-69. Also Tang-Leang-Li, *Foundations of modern China*, London, 1928, 2, 6. He makes the somewhat uncompromising statement that the greater part of the records supposed to have escaped the "Burning of the Books" are forgeries by the scholars of the Han dynasty. He quotes authorities in support of his conclusions.

[19] Legge [11].

[20] See [9], [11].

[21] Quoted by Giles [9] 111, from Shen-yo's history of the Song dynasty.

[22] For lists of words in different languages to denote the lodestone, magnet, and compass, see Klaproth [7] 13-38; Martin, (a) *Atti Acc. Nuovi Lincei*, XVIII, 17-32, 97-123, and (b) *Mém. Acad. Inscr.*, VI, part i; Buttmann, *Museum der Alterthumswissenschaft* II, 5-52, 102-104; Robertson, *Historical disquisition concerning ancient India*, London, 1791, 227; Badger's edition of the *Travels of Ludovico di Varthema*, Hakluyt Soc.; Davies [15] 250-257; Edkins, *J. R. Asiat. Soc. N. China Branch*, VI, 73-104; Niebuhr, *\*Reisenbeschreibung nach Arabien und andern umliegenden Ländern*, Kopenhagen, 1778, II, 206-207; Brunot, *Notes lexicologiques sur le vocabulaire maritime de Rabat el Sale*, Paris, 1920. Also S. P. Thompson's notes on Gilbert [1].

[23] Gaubil [2] II, 94-95. Also in [5] XVI, 179, note 1, where he says that it was under the reign of Hian-tsoung (806-820 A. D.) that the Chinese gave to the compass the form in which he then knew it. Duhalde [3] I, 273, also gives the same interpretation of the contrivance, apparently repeating the opinion of Chinese commentators of his own time. Note that any purely Chinese reference to the compass or magnetic needle in association with, or in explanation of, the south-pointing chariot is of comparatively recent date, and certainly subsequent to the introduction of the compass in other countries.

[24] See text and [13].

[25] Giles [9] 219-222.

[26] Hashimoto [9]. The first of his final conclusions is that the south-pointing chariot had nothing to do with the lodestone or magnetic needle. For reference to Mikami, see *Isis*, 1928, XI, 124. Also Moule, *Toung Pao*, Leyden, 1924, XXIII, 83-97.

[27] Klaproth [7] 85-86. See also the remarks of Benjamin [15] 70, where the suggestion is made that the "south-pointing" of these chariots refers to their position

on ceremonial occasions. He quotes in support the account of the funeral of the King of Chow (1102 B. C.) as detailed in the *Shu-king*.

[28] Hirth [9] 131.

[29] Tang Leang Li [18].

[30] References have already been given to the writings of the missionaries who were the first Europeans to put forward the Chinese claim to priority, as based on the south-pointing chariot. To these may be added Martini, *Histoire de la Chine*, Paris, 1692, 106; Humboldt [11]; Wylie, *Chinese researches*, Shanghai, 1897, part III, 155. Lord Kelvin [1] 229-232, accepted Duhalde's account [3] on the ground that "the instrument which the Emperor Hoang-Ti is said to have used cannot possibly have been anything but a compass, as nothing else could have done what is said to have been done." But the question as to how it was done must be secondary, at present, to the other, whether it was done at all. The general opinion has been negative. Klaproth [7] 78-79, practically rejected it. Legge [11] held that the statements were fables invented to illustrate later knowledge. Chalmers, *China review*, XIX, 52, attributed the story to the national vanity of the Chinese, "who appropriate to themselves the invention of all sorts of things." Bertelli, *Mem. Acc. Nuovi, Lincei*, IX, only gave it a very qualified support. The opinions of Giles and Hashimoto have already been quoted. See also the article by van Hee on the *Chou-jen-Chuan* of Yuan Yuan, in *Isis*, VIII, 102-118.

On the other side, an article in *Nature*, Apr. 27, 1876, signed "K," supports the Chinese claim. But few details are given, and it also includes several erroneous statements with regard to Guyot de Provins and "Peter Adsiger." Another article in the same journal, July 30, 1891, copied from the *North China Herald*, also supports the claim, but many of the statements made are unauthenticated. Volpicelli, *Atti Acc. Nuovi Lincei* XIX, 205-218, and Beazley, *Dawn of modern geography*, London, 1897-1906, I, 51, both state that the Chinese were acquainted with the directive property before the Christian era. But neither condescends to any proof of this proposition. Hirth [9], who has examined the subject very carefully and has summarized it in chronological form, seems to hold the view that the original south-pointing chariot may have been an application of the directive property; that after some centuries the secret was lost; and that attempts made to evolve some mechanism which would produce the desired effect only resulted in the construction of a measurer of distance traveled. The description of the chariot by Amiot [5] XIII, 227, suggested to Azuni, *Dissertation sur l'origine de la boussole*, Florence, 1795, Venice, 1797, Paris, 1805, 67, that it was really a globe with a geographical chart upon it. Some of the later descriptions would seem to suggest a sun-dial. General remarks and criticisms will be found in Schück, *Die Natur*, Halle, XL, 606-609, 613-615; De Saussure, *Arch. Sci. Phys.*, 5th period, V, 149-181, 259-291, particularly on the interpretation of the Chinese words denoting the south-pointing chariot and the compass.

[31] The following example may be given for what it is worth: "When Confucius died (478 B. C.), he was buried on a hill, Kiu-fan, in Shantung, and there his disciples remained for three years, and Toz-kung for six years, during which time he covered the coffin with lodestone, which prevented the emperor Chin from destroying the tomb. For when he sent to have it opened, the mattocks were all arrested at the first blow by the attraction, and the soldiers were dragged to the ground by the action of the magnets on their coats of mail, so that the tomb remained intact." (No. 18 of the Chinese fables translated by Bowring from Gonsalvez, *Arte Chine*. Reprinted in *Chinese and Japanese Repository*, I, 248-254.) References to other cases in which the lodestone is mentioned in Chinese literature are given by Giles [9] 113. One of the early references is that by Kono-pho, who wrote on the magnet in 324 A. D. If this is genuine, it is curious, as Benjamin [15] 74, 81, points out, that the phenomena of magnetic attraction should be there explained according to a theory current among the Greeks eight centuries earlier, and on lines entirely foreign to Chinese conceptions. (See Pliny, *Natural History*, Bostock and Riley's ed. London, 1857, IV, 206, VI, 209.) Hashimoto, [9] 84, has also given some early references, the earliest being 249-237 B. C.

[32] Klaproth [7] 66-67. Hashimoto [9] 84-85, could not find this passage in the *Choue-wen*, and concludes that Klaproth was in error. He has brought to light a passage in the *Lun-heng*, written by Wan-chung (30-100 A. D.) which simply states that "a lodestone attracts a needle," but as proof of a knowledge of the directive property this is open to the same objections as are stated in the text against Klaproth's extract from the *Choue-wen*. There is also, according to Hashimoto, [9] 85, a passage to the same effect in the *Wa-myō-rui-ju-shō*, ch. II, a Japanese work of 923-930 A. D.

[33] Klaproth [7] 66.

[34] For example, Klaproth [7] 67, 84. Benjamin, [15] 75, deals with this point, and quotes from La Couperie, *Western origin of Chinese civilization*, London, 1894. Also from *Trans. Asiat. Soc. Japan*, VIII, 475, and *J. Asiat. Soc. N. China Branch*, N. S. XI, 123. But the origin of the story is found along with other apocryphal instances of the use of the south-pointing chariots. See [11]

[35] Klaproth [7] 67. Humboldt, *Examen critique de l'histoire de la géographie du nouveau continent*, Paris, 1836-39, III, 36-37. He adds that the Chinese "avaient reconnu aussi que la chaleur diminue cette force directrice." But he omits to state that this recognition is only found in an encyclopedia, *Ou-ih-sa-tsou*, compiled at the end of the 16th century, and that we have no guarantee of the purity of its text.

[36] Gaubil [2] 95.

[37] Wylie [30] 155.

[38] Hirth [9], Chronological summary under 700 A. D. Hashimoto, [9] 85, also failed to find Wylie's passage, either in the life of Yih-hing, or in the *Tang-shu*, which mentions the principal events in the life of Yih-hing. A passage in the *Tang-shu* resembles it, but has nothing to do with the magnetic needle.

[39] See Hirth [9] 132.

[40] Klaproth [7] 68.

[41] The *Pen-tsao-kang-muh* was completed about 1580 A. D.

[42] Klaproth [7] 67.

[43] Klaproth [7] 95. For the reasons given in the text immediately after this reference, it is almost certain that Klaproth was wrong in his conclusion. But it has been accepted by Beazley, [30] I, 490, who states quite explicitly that the Chinese used the compass in the third century A. D. For this there is no evidence. Speck, *Handelsgeschichte des Alterthums*, Leipsic, 1900, I, 29, 209, went even further. He thought the Chinese used the compass in navigation from the first century A. D. But no reasons are given for this conclusion.

[44] *Travels of Fa-Hian and Sung-yun*, trans. by Beal, London, 1869. See also Remusat, *Mém. Acad. Inscr.*, XIII, and his translation,\* *Foe-koue-ki*, new edition, with notes by Klaproth and Landresse, Paris, 1836. Reference should also be made to the passage relating to Fa-hian in Hirth and Rockhill's *Chau-jukua; his work on the Chinese and Arab trade in the twelfth and thirteenth centuries*, entitled *Chu-fan-chi*, St. Petersburg, 1911, 27.

[45] Renaudot, *Anciennes relations des Indes et de la Chine*, Paris, 1717, English trans., London, 1753, 142. With regard to the history of the documents upon which Renaudot based his *Relations*, see *J. des Savans*, Dec. 1764, 315; Robertson, [22] 224; and chiefly Renaud, *Relations des voyages faits par les Arabes et les Persans dans l'Inde et à la Chine*, Paris, 1845. Also, Ferrand, *Voyage du marchand arabe Sulaiman en Inde et en Chine, rédigé en 851, suivi de remarques par Abu Zayd Hassan*, Paris, 1922.

[46] In addition to Hirth and Rockhill [44] and Renaud [45], the following may be consulted: Chavannes, *Les religieux éminents, qui allèrent chercher la loi dans les pays d'Occident et Mémoire composé à l'époque de la grande dynastie Tang, par I-Tsing*, Paris, 1904; two important papers by Ferrand, *J. Asiat.*, 1919 and 1922, and another in 1924; Levi, *J. Asiat.*, 1900, and Braddell, *Chinese and Japanese Repository*, III, 57-72, 113-128 (a good summary, but quotes no authorities). With regard to the difficulties and risks of navigation by the Chinese in voyages to (what appears to be) the Philippine Islands, see Yule's *Marco Polo* [9], bk. III, ch. iv.

In none of these accounts of early maritime activity in eastern seas is there any mention of the compass, and in the first of the references it is explicitly stated that the pilots had to rely on "the regularity of the monsoons and steer solely by the Sun, moon, and stars." De Saussure, [30] 268, has suggested that the compass was not an absolutely necessary instrument in navigation during voyages of the kind; that from China to the Straits of Malacca they must have sailed along the coast; and that in the Indian Ocean they were guided as well as helped by the trade-winds or monsoon. There is some evidence in these records of early voyages that navigation from the Straits to Ceylon was by way of the Nicobars or Andamans, from which the northeast monsoon would give them a good "slant" for the Coromandel Coast, which they could then follow to Ceylon.

[47] Humboldt, *Asie Centrale*, I, xli, and *Cosmos*, London, 1849, II, 630. The most recent repetition of Humboldt's errors will be found in Sidgwick and Tyler's *Short history of science*, New York, 1918.

[48] Hirth [9] 133-134. This is referred to in the text as the earliest mention of the use of the compass in China. Another of nearly the same date is that quoted by Parker, *China Review*, XVIII, 197, and Edkins, *J. R. Asiat. Soc. N. China Branch*, XI, 128-134, according to which it was used by a Chinese envoy to Korea in 1122. But Hashimoto, [9] 88, says he has been unable to find any passage of the kind in any Chinese work. He refers, however, to another in the *Tung-hua-lu*, written by Tseng San-i about the end of the twelfth century, which speaks of the compass, and even describes the deviation of the magnetic needle.

[49] Hirth and Rockhill [44] ch. 46, 176. See also Schaer, *Arch. Gesch. Naturw. Tech.*, VI, 329-337.

[50] *Chrestomathie Chinoise*, Paris, 1833, 21, etc. A French translation is given by Remusat in *Nouvelles annales des voyages*, Paris, 1819, III, and in his *Nouveau mélanges Asiatiques*, Paris, 1828, I.

[51] Giles, *Chinese biographical dictionary*, London, 1898.

[52] Cordier's edition of *Marco Polo*, II, 277, gives it in the following form:

"With Kun-lun to starboard, and larboard the Cheu,  
Keep conning your compass whatever you do,  
Or to Davy Jones' locker go vessel and crew."

It is also referred to by Gaubil in [5] XIV, 53.

[53] Klaproth, [7] 97, quotes the cyclopedia *Ou-thsa-tsou*, written at the end of the sixteenth century. Carletti, *Ragionamenti sopra le cose vedute nei suoi viaggi*, Florence, 1701, 275.

[54] Nicolas Wetsen, *Noord en Oost Tartarye*, Amsterdam, 1705, 56.

[55] Carletti [53] 275. Fournier, *Hydrographie*, Paris, 1643, XI, i. Duhalde, [3] 283, however, refers to a compass, apparently with a pivotted needle, in 1687.

[56] Davies [15] 291. Also *Encyclopedia Britannica*, 9th ed. VI, 226.

[57] Staunton, *Authentic account of an embassy to the emperor of China*, London, 1747, I, 441. Fleuriau, *Annu. Bur. longit.*, Paris, 1894.

[58] De Saussure [30], where an explanation of the origin of the division of the circle into 12 or 24 parts is given. See also Dissertation III, *On the navigation and compass of the Chinese*, by Lord Macartney, in Vincent's *Commerce and navigation of the ancients in the Indian Ocean*, London, 1807, II, 656-660.

[59] The earliest mention of the division of the compass-card or circle into 32 points would appear to be that by Chaucer, *Treatise on the astrolabe*, ed. by Skeat, London, 1872, Part II, 31, line 6. For the origin of Chaucer's work, see note at the end of Halliwell's edition of Mandeville's *Travels*. But it is a mistake (*Principal facts of the Earth's magnetism*, Washington, 1909, 21) to read the passage in Chaucer as meaning that the actual adoption "by the English" of the 32-point compass was "delayed" until 1391, the year in which Chaucer wrote.

[60] Barrow, *Voyage to Cochin China in the year 1792-3*, London, 1806.

[61] Przyluski, *La divination par l'aiguille flottante et par l'araignée dans la Chine méridionale*, in *Toung Pao*, XV, 214-224.

[62] Martin [22, a] 27.

[63] Hashimoto [9] 92.

[64] Here we pass over several hypotheses, none of them supported by any evidence. Clarke, *Progress of maritime discovery*, London, 1803, I, vii, suggested that Noah employed the compass in the Ark. Kircher, *De arte magnetica*, Cologne, 1643, 19, mentions the statement of Rabbi Isaac Abarbanal that the Israelites knew and used the directive property of the magnet during their wanderings in the wilderness and in the construction of the tabernacle. Kircher also mentions other traditions of a like kind. With regard to the use of the compass in the Hedjaz from Cairo to Mecca, see Badger's edition of the *Travels of Ludovico di Varthema*, London, 1863, 31-32, with note. Ibn Majid, Vasco da Gama's Arab pilot, said that the nautical compass was invented by the prophet David, but was ascribed by some to Al-Hidr, the patron of the sea and protector of navigators. See Ferrand's commentary on MS. 2292, Bibliothèque Nationale, Paris, in *Ann. Géog.* XXXI, 289-307. Baily, *Histoire de l'astronomie ancienne*, Paris, 1781, 123, and Maurice, *History of Hindustan*, London, 1795-98, both state that the compass was known to the ancients, but give no evidence in support.

[65] Goropius, \* *Opera Joan Goropii*, Antwerp, 1580, iii, 29.

[66] Pineda, *Salamonis commentarii*, Mayence, 1613, lib. iv, c. iv, 270.



- [67] Fuller, *Miscellanea sacra*, London, 1617, bk. iv, 596.
- [68] See Huetius, *Commentarium de navigationibus Salamonis*, in *Thesaurus antiquitatum sacrarum*, Venice, 1747, VII, cccii-cccii.
- [69] Clarke [64] I, 397. Reviewed in *Phil. Mag.*, XVIII, 88.
- [70] 2nd Chronicles, III, 6. See Thompson's note in Gilbert [1], 10.
- [71] 2nd Chronicles, IX, 21.
- [72] 2nd Chronicles, VIII, 18.
- [73] 2nd Chronicles, VIII, 18.
- [74] Proverbs, XXX, 18, 19, has a reference to "the way of a ship in the midst of the sea" as being one of four things which Solomon was unable to understand. There is here, however, no necessary implication that Solomon was referring to any special art or contrivance by which ships at sea were guided in their course.
- [75] Hakewill, *An apologie or declaration of the power and providence of God*, 3rd ed. Oxford, 1635, lib. iii, c. 10, 323. He gives a list of references to earlier writers on the subject, the general trend of opinion being that the compass was not known in ancient times.
- [76] Acosta, *Historia natural y moral de las Indias*, Seville, 1590. English trans., *The naturall and morall historie of the East and West Indies*, London, 1604, I, 37, 40, 47.
- [77] Henricus Kippingius, *Antiquitates Romanorum*, Franquera, 1684, 833.
- [78] Bochart, *Geographia sacra*, Caen, 1646, lib. i, c. 38.
- [79] Purchas, *His pilgrims*, I, 8.
- [80] Salverte, *Des sciences occultes*, Paris, 1829. English trans. London, 1846, I, 251-252. He quotes from Suidas, *Abaris*; Iamblichus, *Vita Pythagorae*, xxviii; Herodotus, IV, 36; and Diodorus Siculus, lib. iii, c. xi. Similar suggestions had been previously made by Clarke, [64] LI.
- [81] Cooke, *An enquiry into the patriarchal and druidical religion*, London, 1755, 26-27.
- [82] The passage relied on by Cooke is *Odyssey*, viii, 557-563.
- [83] Buffon, *Supplément à l'histoire naturelle*, Paris, 1788, V, 269. Martin [23, a] 28, refers to this idea of Buffon's as "a hallucination."
- [84] Mottelay, [9], who gives readings by different translators. But he seems to withdraw his support of Buffon's statement on p. 7.
- [85] Falconet, *Mém. Acad. Inscr.*, IV, 613.
- [86] In letter of Feb. 17, 1928, to present author
- [87] Martin [22, a] 28.
- [88] Buttmann, [22], who concluded the substance was talc.
- [89] Albertus Magnus, *Opera*, Lyons, 1651, II, 243.
- [90] Vincent de Beauvais, *Speculum naturale*, Strassburg, 1476, ii, lib. 9, c. 19. For bibliography, see Daunou, in *Histoire littéraire de la France*, XVIII, 449-519.
- [91] The title is said to have been preserved by Diogenes Laertius, V, 26. The authenticity of this supposed work of Aristotle was examined very fully by Martin [22, a], 28-29. See also Klaproth, [7] 46-54, and Baron de Sacy, *Chrestomathie Arabe*, Paris, 1806, III, 447, 553, who has compared it with the *Traité des pierres* of Tei-fachi. Also Jourdain, *Recherches sur les traductions latines d'Aristote*, Paris, 1819, 350. I have not been able to find the corresponding passage in the edition of 1843.
- For the controversy as to the meaning of the terms *zohron* and *aphron*, which occur in the passage quoted in [89] from Albertus Magnus, see Klaproth, [7] 50-51, who said these words were Arabic; and Lipenius, *Navigatio Salamonis Ophritica illustrata*, Halle, 1660, V, sect. iii, 36, who said they were neither Arabic, nor Greek, nor Hebrew, nor Chaldean.
- With regard to the supposition of Rose, *Zs. Deutsch. Alterthum*, XVIII, 321-455, that Albertus Magnus and Vincent de Beauvais obtained their information from Arnold of Saxony, see Thorndike, *History of magic and experimental science*, London, 1923, II, 430, with references.
- [92] Levinus Lemnius, *Occulia naturæ miracula*, Antwerp, 1564. English trans. by Brookes, *The secret miracles of nature*, London, 1659, 198-199.
- [93] Plautus, *Mercator*, V, 2, and *Trinummus*, IV, 3.
- [94] Gilbert [1], bk. II, ch. ii.
- [95] Cabaeus, *Philosophia magnetica*, Ferrara, 1629.

[96] See Thompson's notes in Gilbert [1]. The passages from Plautus are quoted in full.

[97] Lestrangle, *Seneca's morals by way of abstract*, London, 1699, part II, ch. ix, 195.

[98] See his translation of Pliny, t. XII, 484.

[99] Plutarch, *De Iside et Osiride*, ch. 62. See also Pliny, *Natural History*, bk. XXXVI, ch. xvi. Klaproth, [7] 12, refers to the passage in Plutarch, but the interpretation he puts upon it seems to be forced.

[100] Betham, *Etruria-Celtica*, London, 1842, I, 267-269.

[101] Dennis, *Cities and cemeteries of Etruria*, London, 1879, II, 105.

[102] "Tres adeo incertos caeca caligine soles  
Erramus pelago; totidem sine sidere noctes." *Aeneid*, III.

"Clavumque affixus et haerens

Nusquam amittebat, oculosque sub astra tenebat." *Aeneid*, V.

The passage from Ovid is in *Tristia* (Bohn's ed., I, 327), "Ye Bears both Greater and the Less, which the one guides the Greek and the other the Sidonian ship." This is a reference to the fact that the Pole Star was known in classical times as the "Phenician Star."

[103] It may be convenient to collect together here all references to the papers of the learned scholar, Timoteo Bertelli, which have a bearing on the history of terrestrial magnetism. Taken as a whole, they form one of the most valuable pieces of bibliographical research of the last century. Their fullness and accuracy leave little room for addition by later commentators.

(a) Sopra Pietro Peregrino di Maricourt e la sua epistola De Magnete. *Bull. bibliogr. st. sci. mat. Fis.*, I, 1-32, 65-69, 101-139, 319-420.

(b) Intorno a due codici Vaticani della Epistola De Magnete di Pietro Peregrino di Maricourt, ed alle prime osservazioni della declinazione magnetica. *Bull. bibliogr. st. sci. mat. Fis.*, IV, 303-331.

(c) Sull'origine della parola calimita, uscita dagli Italiani ad esprimere la pietra magnete, l'ago e la bussola. *Moncalieri Oss. Bull.*, XI, 161-163, 177-178.

(d) Christoforo Colombo, scopritore della declinazione magnetica e della sua variazione nelle spazie. *Raccolta di documenti e studi pubblicata della Reale Commissione Columbiana nel quarto centario della scoperta di America*, Rome, 1892, Part IV, II.

(e) Riassunto di una memoria storica intorno alla scoperta della declinazione fatta da Christoforo Colombo nel 1492. *Atti Acc. Nuovi Lincei*, XLV, 97-100; *Moncalieri Oss. Bull.*, XII, 89-91; *U. S. Weath. Bur. Bull.*, XI, 486-492.

(f) Studi storici intorno alla bussola nautica. *Mem. Acc. Nuovi Lincei*, IX, Part I, 77-178, and Part II, 131-219.

(g) Appunti storici intorno all'antica Rosa nautica Italiana, *Riv. Maritt.*, Nov. 1893.

(h) Sopra alcuni nuovi esemplari dell'Epistola di Pietro Peregrino di Maricourt De Magnete. *Atti Acc. Nuovi Lincei*, t. LI, 55-56.

(i) Di un supposto lavoro intorno alla bussola pubblicato da Filippo Pigafetta nel 1586, *Atti Acc. Nuovi Lincei*, LI, 73-77.

(j) Dell'origine della bussola e di alcune sue principali modificazioni, *Moncalieri Oss. Ann.*, I, 7-16.

(k) Appunti storici intorno all'uso topografico ed astronomico della bussola fatti anticamente in Italia, *Riv. geogr. ital.*, VII.

(l) Sopra un nuovo documento riguardante l'invenzione della bussola nautica, *Riv. fis.*, 1901.

(m) Sulle recenti controversie intorno all'origine della bussola nautica, *Riv. geogr. ital.*, IX.

(n) Nuova conferma che la declinazione magnetica era ignota ai Cinesi prima di Christoforo Colombo. Pavia, 1903.

(o) La leggenda di Flavio Gioja, inventore della Bussola, *Riv. geogr. ital.*, X.

(p) Della declinazione magnetica presso i Cinesi, *Boll. Soc. geogr. ital.*, III.

(q) Sopra un nuovo supposto primo inventore della bussola nautica, *Riv. geogr. ital.*, XI, fasc. ix.

An abstract of (f), (m), (n), (o), and (p) above was given by D. L. Hazard in *Terr. Mag.*, VIII, 179.

- [104] Acosta [76] lib. i, c. 16.
- [105] Dutens, *Recherches sur l'origine de la découverte*, Paris, 1766, II, 34. English trans. London, 1769, 206.
- [106] Azuni [30] 24-29.
- [107] "Lapis est cognomine Magnes . . . in marmore flammæ."
- [108] Marcus Dods, *St. Augustine's City of God*, Edinburgh, 1871, II, 420, 457. At the Third Italian Geographical Congress, held at Florence in 1898, Col. Antonio Botto contributed a paper in which he maintained that St. Augustine's reference was to some form of compass. His paper, \**Contributo agli studi storici sull' origine della bussola nautica*, is printed in the *Acts* of the Congress. It was effectively answered by Bertelli in [103, m].
- [109] Marcellus Empiricus, *De Medicamentis*, in *Medici antiqui omnes*, Venice, 1546, 89. Also in *Corpus medicorum latinorum*, Leipsic, 1916, V. ed. by Niedermann.
- [110] For a full account of the maritime and commercial activities of the Phenicians, with numerous references to original sources, see Abbé Mignot's *Mémoires sur les Phéniciens* in *Mém. Acad. Inscr.*, particularly the 22nd *Mémoire* in XLII, 1-59. Also Ameilhon, *Histoire du commerce et de la navigation des Egyptiens sous le Règne des Ptolemies*, Paris, 1766. Details of sea routes used in these times are given. His conclusions confirm those of Campomanes, *Antigüedad marítima de la República de Carthago*, Madrid, 1756. Grote, *History of Greece*, ch. XVIII, gives an interesting account. More recent views on Phenician navigation, especially in relation to Homer's references on the point, are to be found in Victor Berard's elaborate work, *Les Phéniciens et l'Odyssée*, Paris, 1902-03, and in his shorter work, *Did Homer live?*, trans. by Rhys, London, 1931.
- [111] See [102]. Pliny, *Natural History*, bk. VII, ch. 56, refers to this, and says that the Phenicians were the first to use the stars in navigation. Also Strabo, bk. I.
- [112] Duncker, *History of antiquity* (Abbott's trans.), London, 1882, II, 293.
- [113] For details as to the *Sanconiaton*, see Betham [100], and Kenrick, *Phenicia*, London, 1855, 330-336, where a translation of nearly all that remains is given.
- [114] Betham [100] II, 8.
- [115] Fuller [67] lib. iv, c. 19.
- [116] Photius. See Kircher [64], 26.
- [117] Gilbert [1] 4.
- [118] Ptolemy, *Geographia*, I, 11; Strabo, *Geographia*, bk. III, c. v, 11. See also Clarke [64] *Introd.* lix.
- [119] Herodotus, IV, ch. 49.
- [120] Herodotus, IV, ch. 49.
- [121] Osorius, *Histoire du Portugal*, Geneva, 1581.
- [122] Cooke [81] 24.
- [123] See Benjamin [15].
- [124] See LaCouverie, *Western origin of early Chinese civilisation*, London, 1894, and Deveria, *Le fer et l'aimant dans l'ancienne Égypte*, Paris, 1870.
- [125] This view was originally suggested by Klaproth [7], and has been quoted by many later writers. See Hirth [9] 134.
- [126] Ptolemy, *Geographia*, lib. I, c. vii.
- [127] See [44].
- [128] See Hirth and Rockhill, [44] 27.
- [129] See [46].
- [130] Pelliot, *Deux itinéraires de Chine en Inde*, Paris, 1904.
- [131] See [46].
- [132] Levi, *Journal Asiatique*, 1900.
- [133] *Islands Landnámabók*, Copenhagen, 1774; also, 1900, I, ii, par. 7.
- [134] See [45].
- [135] Nevertheless, the claim has been made that the compass was in use in the eighth century in the seas round Java, though not, possibly, by Arabs. In Wilsen and Brummund's volume on the Buddhist temple at Boro-Boudour in Java, a description is given of certain stone carvings of ships. One of these shows small circular objects placed at bow and stern which, the editors believe, are intended to represent

compasses. These carvings are Malayan or Javanese, and are assigned to the eighth century. Their interpretation is a matter of considerable difficulty, and it is very far from clear that the objects—which are placed in a vertical, not a horizontal, plane—are intended to represent compasses. Had such been the case, some attempt would have been made to show the essential part of the instrument, the floating needle. But this is absent. See *Boro-Boudour dans l'Isle de Java* (Dutch Government publication), 1874.

[136] The reference here is to the work of Haskins, Thorndike, Wiedemann, and the editor of *Isis*.

[137] Koran, ch. VI.

[138] Thabet-ben-Corah, *De sideribus eorumque occasu ad artis nauticae usus accommodatis*; see Casiri, *Bibliotheca Arabo-Hispanico Escorialensis*, Madrid, 1760-70, I, 462.

[139] Wiedemann, *Verh. D. Phys. Ges.*, 1907, 764-773.

[140] Ibn Khordadbeh, *Livre des routes et provinces*, trans. by Maynard; *J. Asiat.*, ser. 6, V, 281. Also given in *Bibliotheca geographorum Arabicorum*, ed. by Goeje, Leyden, 1899; and by Sprenger, *Abh. Deutsch. Morgen. Ges.*, III, No. 3. According to Kremer, *Culturgeschichte des Orients*, I, 269, Ibn Khordadbeh wrote between 854 and 874.

[141] For bibliography, see *Encyclopædia of Islam*, London, 1927, II, 913.

[142] In so far as he is quoted by Masoudi [147]. The original work has not been preserved.

[143] See Casiri [138], and Flugel, *Abhandlungen für die Kunde des Morgenlandes*, 1859, I. Also *Encyclopædia of Islam*, [141] II, 1019-1020.

[144] See *Encyclopædia of Islam*, [141] I, 611-612.

[145] See Pocock's\* translation of the *Kitab-al-Fihrist*, Oxford, 1663.

[146] All that now remains of Ibn Muhalhil's travels has been collected by Schloetzer, *Abu Dolif Ben Muhalhil de itinere Asiatico commentarius*, Berlin, 1845.

[147] Masoudi, *Proaires d'Or*, ed. by Maynard and de Courteille, Paris, 1861-77, I, 182, etc.

[148] Geber. Two persons there were of this name, and they have occasionally been confused together. See references given by Wiedemann, *Sitz. Phys-medicin. Soc. Erlangen*, XXXVI, 309-351.

[149] The evidence in question can be gathered from various sources. The Chinese are known to have been in communication with Ceylon in 428 A. D. See Levy, *J. Asiat.*, XV, 412, and also McCrindle, *Christian topography of Cosmas*, London, 1897, 365-366. Later data are referred to in [46]. See also Breitschneider, *On the knowledge possessed by the ancient Chinese of the Arabs and Arabian colonies*, London, 1871, 3-5, 11; Reinaud, *Mém. Acad. Inscr.*, 1849, 124; Yule, *Proc. R. Geogr. Soc.*, IV, 649-660; Richthofen, *China*, Berlin, 1877-83, I, 569; Heyd, *Histoire du commerce du Levant au moyen âge*, Leipsic, 1885, I, 28. For Chinese acquaintance with the Malabar coast, see Ferrand's review of the *Book of Duarte Barbosa* in *J. Asiat.*, 1924, 115. The annals of the Tang dynasty (620-907) speak of expeditions to *Molai*, i. e., Malabar. See Heyd, *v. s.*

[150] Stanislas Julien, *J. Asiat.*, ser. 4, X, 113, 120.

[151] Ferrand [46], Chavannes [46].

[152] *Travels of Ibn Batuta*, trans. by Lee, London, 1829, ch. XVIII, or Gibb's edition, London, 1929, 234, 235, 238.

[153] As to Aden, see the reference to Ibn-el-Wardi in Cordier's edition of Yule's *Cathay*, London, 1915, I, 87. As to Madagascar, Humboldt, *Cosmos*, London, 1849, II, 628.

[154] Masoudi [147] I, 303, 308.

[155] Maynard, *J. Asiat.*, ser. 7, I, 574-575, gives a quotation from Ibn Haukal regarding a wealthy Persian, Abou Bekr, whose ships sailed from Siraf to India, Zanzibar, and China in the year 355 A. H.

[156] See [152].

[157] For general reference on this part of the subject, the reader may consult Pliny [102], Strabo [118], Ameilhon [110], Vincent [58], Charlesworth, *Trade routes and commerce of the Roman Empire*, Cambridge, 1924, and Warmington, *Commerce between the Roman Empire and India*, Cambridge, 1928.

[158] Pliny, *Natural History*, Bostock and Riley's ed., VI, c. xxii.

- [159] Hirth [9] 127. Reinaud, *Relations politiques de l'Empire Romain avec l'Asie Orientale*, Paris, 1863, 163.
- [160] Elliot, *History of India*, London, 1867-77, I, 118; Reinaud, *Mém. Acad. Inscr.*, XVIII, 2, p. 79; Heyd [149] I, 33.
- [161] Masoudi [147] I, 346. Khordadbeh [140] 294, 522.
- [162] See [150].
- [163] For details as to the canal connecting the Red Sea with the Nile and Mediterranean, see Heyd, [149] I, 40, where authorities are given.
- [164] After the Arab victory over the Persians in 635-636, the Arabs built the town of Busrah in order to exclude the Persians from the Gulf trade to Oman and India. See St. Martin, *Recherches sur l'histoire et la géographie de la Mesene et de la Characene*, Paris, 1838, 54, where Modjmel-al-Tewarikh is quoted.
- [165] Rawlinson, *Five great monarchies of the ancient Eastern World*, London, 1862-67, I, 544.
- [166] Quatremere, *Journal des Savants*, 1846, 681.
- [167] Malcolm, *History of Persia*, London, 1815, II; 63.
- [168] Ferrand, *J. Asiat.*, 1924, 193-257. See also Reinaud, [45] I, Intro., xxxvi.
- [169] Hasan, *History of Persian navigation*, London, 1928, 52.
- [170] Reference may be made generally to Heyd [149] I.
- [171] Reinaud [45] I, Intro., xxxvi.
- [172] Alberuni, *India*, edited by Sachau, London, 1888, ch. XVIII.
- [173] Jordanus, \* Paris Geogr. Soc. ed., p. 62.
- [174] Wilson, *Journal of the Asiatic Soc. of Great Britain*, V (1839), 5.
- [175] Details of these treaties are given by Heyd, [149] I.
- [176] From the statements of Strabo, bk. XVII, c. i, 14, we may gather that this was the case even in Roman times.
- [177] Heyd [149] I.
- [178] But see *Description de l'Afrique Septentrionale par El-Bekr*, trans. by Slane, *J. Asiat.*, ser. XIII, 73.
- [179] The anecdote in which Awfi refers to the compass is that given in the serial number 1997 in the *Introduction to the Jawami of Al Awfi*, by Mohammed Nizamud Din, Gibb Memorial Series, N. S. No. VIII, London, 1929. For translation and other details see Wiedemann, [139] 765. From the former work, p. 12, it may be concluded that the probable date of the voyage during which Awfi saw the compass being used—most likely near the mouth of the Indus—was about 1220. Anecdotes 1996 and 2008 also refer to the lodestone. For biographical details, see *Encyclopedia of Islam*, [141] I, 517. Wustenfled, *Die Wunder der Schöpfung*, Göttingen, 1848, has some comments.
- [180] *Las siete partidas del Sabio Rey don Alfonso el X*, Madrid, 1829, I, 473. This compilation was begun in 1250 and completed in seven years. See Southey's *Omniana*, London, 1812, I, 210 (pagination wrong).
- [181] The French title of Bailak's manuscript (Bibliothèque Nationale, MS. Arabe, No. 970) is *Trésor des marchands pour la connaissance des pierres*. See Klaproth [7] 57.
- [182] Bertelli [103, f] ch. II.
- [183] Renaudot [45] 142-145; Azuni [30]; Collina, *Considerazioni storiche sopra l'origine della bussola nautica nell' Europa e nell' Asia*, Faenza, 1740, 121, and his dissertation, \* *De acus nautica inventore in Comment. Bonon.*, II, 382.
- [184] Wiedemann, *Zs. Physik*, XXIV, 166-167, where references to original sources are given.
- [185] See Caussin, *Notices et extraits des manuscrits de la Bibliothèque du Roi*, VII, 16.
- [186] Stapleton and Azo, *Mem. Asiat. Soc. Bengal*, I, 531. Also Wiedemann [139].
- [187] Alberuni [172].
- [188] *Géographie d'Edrisi*, ed. by Jaubert, Paris, 1836.
- [189] Fournier, [55] lib. XI, c. i. Klaproth, [7] 55, could find nothing that could bear this meaning. Further examination of Jaubert's edition confirms this conclusion.

[190] His correct name was Shems ed-din-Abou Abdullah Mohammad de Damas. The title of his work is *Nokhbet ed-dahr Fi Adjaib-il-Birr Wal-Bahr*. It was translated by Mehren,\* *Manuel de la cosmographie du moyen âge*, Copenhagen, 1874-85.

[191] *Traité des instructions astronomiques arabes*, trans. by Sedillot, Paris, 1834.

[192] See Haskins, *Studies in the history of medieval science*, Cambridge, U. S. A., 1924, for bibliography and other details. Also Thorndike [91].

[193] Adelardus Bathonensis, *De eodem et diverso*, Willner's ed., Münster, 1903. See also references in [192]. One of the many curious mistakes made in the history of the subject will be found in Meig's book, *The story of the seaman*, Philadelphia and London, 1924, I, 265. He there states that Libri, *Histoire des sciences mathématiques*, Paris, 1838, II, 62, gives evidence showing that the first mention of the compass in European literature may be brought within narrow limits, viz., 1117-1130. But Libri said nothing of the kind. What he did say was that Adelard of Bath was *not* acquainted with the polarity of the magnet, and shows that Adelard's writings on the matter could be dated between 1117 and 1130.

[194] See references in [192].

[195] See references in [192].

[196] The passage referred to is on p. 236 of the Paris Geographical Society's edition of *Marco Polo*. Referring to the number of islands in the Indian Ocean, he gives their supposed number, "selone qe moister le compas et la scriture de sajas mariner qe uzent en cel mer de Yndie."

Beazley, *Dawn of modern geography*, London, 1897-1906, III, 150, renders this, "according to the writings and compass-reckonings of experienced seamen who navigated that sea." This would imply that Marco Polo believed that the compass was in use in the Indian Ocean about the middle of the thirteenth century. But I am informed on high authority that in thirteenth century French, the word "compas" did not mean "compass," the nautical instrument. Hence Beazley's rendering cannot be accepted. In his edition of Yule's *Marco Polo*, II, 424, Cordier confirms Yule's translation, "according to the charts and documents of experienced mariners who navigate that Indian sea." Olivieri's edition, Bari, 1912, has much the same rendering.

[197] This suggestion of Gilbert's, [1], Bk. I, ch. i, found wide currency, chiefly by repetition unaccompanied by examination of the evidence. The first to oppose it was Huet, *History of the commerce and navigation of the ancients*, London, 1717, 26. For reference to the planisphere supposed to have been brought from China by Marco Polo, and preserved at Venice, see Azuni, [30] 88, and Klaproth, [7] 61-62. In his edition of Gilbert's *De Magnete*, London, 1893, Mottelay gives a list, by no means exhaustive, of authors who had written on the compass before Marco Polo had returned from China.

[198] The reference here is to Neckam [232], [233].

[199] Ibn Batuta [152].

[200] Ramusio, *Navigazione e viaggi*, Venice, 1588, I, fol. 379.

[201] The original is in the Bibliotheca Marciana, Venice. See Azurara, *Chronicle of the discovery and conquest of Guinea*, trans. by Beazley and Prestage, London, 1896-99. Also, Zurla, *Il mappamondo di Fra Mauro*, Venice, 1806, 52, 128.

[202] *The three voyages of Vasco da Gama*, Hakluyt Soc. London, 1869, XV, 138. Also, *Journal of the first voyage of Vasco da Gama*, ed. by Ravenstein, Hakluyt Soc. London, 1898, 26. The former is based on Correa's *Landas da India*, which contained many errors. The latter is a translation of the *Roteiro*, written by some person unknown who accompanied Vasco da Gama on the first voyage. In this connection, see three papers by Ferrand, (a) *Ann. géogr.*, XXXI, 289-307; (b) XXXII, 298-312; (c) *J. Asiat.*, 1924, 193-257. The statement that Vasco da Gama's pilots used the compass has been disputed. See Ramusio [200] I, fol. 379; Barrow, [60] 355; Renaudot,\* *Dissertation sur les sciences des Chinois*, 288-289. But Ferrand's papers settle the matter definitely.

[203] Varthema [22] 31, 32 (notes), 248, with comments in Introduction.

[204] See [202].

[205] Riccioli, *Géographie et hydrographie*, Bologna, 1661, lib. x, c. 18.

[206] Salverte [80] 252. The only authority he quotes is *Nowvelles annales des voyages*, XVII, 414.

[207] Adam of Bremen, *Gesta Hammaburgensis Ecclesia Pontificum*, in Pertz, *Monumenta Germaniae*.

- [208] Benjamin [15] 140-141.
- [209] See Salverte's authority [206].
- [210] Hennig, *Verh. Deutsch. Naturforscher*, 1912, 95.
- [211] Details and references in Heyd [149] I, 57-58.
- [212] See Heyd [149] I, 59-60.
- [213] Posteraro's paper, *Origine italiana della bussola nautica inventata dal Veronese Salamone Ireneo Pacifico*, was communicated to the Fifth Italian Geographical Congress in 1904. See *Geogr. J.*, London, XXV, 334-335.
- [214] Bertelli [103, q].
- [215] *Histoire littéraire de la France*, VI, 609-610. The best account of Sylvester II is that of Picavet, Gerbert, *Un pape philosophe*, Paris, 1897.
- [216] *Dilmari Chronicon*, 1580 edition, lib. vi, 83. Also given by Bouquet *Rerum Gallicarum Scriptores*, X, 131. The passage is as follows: "In Magdeburg, horologium fecit, illud recte constituens, considerata per fistulam quadam stella, nautarum duce." The first to suggest that the last two words alluded to a compass or the magnetic needle was Majolus, *Dies Caniculares*, Mayence, 1610, 566-567. He was followed by Kirchner, *Ars Magnetica*, 1631, 27, who credited Gerbert with a knowledge of the directive property.
- [217] Ameilhon, *Mém. Acad. Inscr.*, XLII, 504, note. Gerbert's letter to Constantine is given by Mabillon, *Analecta Vetera*, Paris, 1723, 103.
- [218] Trombelli, *Comment. Acad. Sci. Bonon.*, XI, iii, 350.
- [219] Montucla, *Histoire des mathématiques*, Paris, 1799, II, 501.
- [220] Baldelli Boni, *Storia della relazioni vicendevoli dell'Europa e dell'Asia*, Florence, 1827, I, 333.
- [221] Gibbon, *Decline and fall of the Roman Empire*, ch. LVI, note. The poem of Appulus is reprinted in *Monumenta Germaniae Historica*, Wilman's ed., 1843, IX, iii, 478. Also in Muratori, *Rerum Italicarum Scriptores*, Milan, 1724, V, 267. The position of Amalphi as a centre having extensive commercial relations with the East might possibly justify the expectation that it, if any, would be the place at, or in connection with, which the compass might have been invented or improved. See the *History* of William, Archbishop of Tyre, in *Gesta Dei per Francos*, Honnoniae, 1611, 933, and the remarks of Bertelli [103, f]. Also Gibbon, *History of the Crusades*; Adler's edition of the *Itinerary of Benjamin of Tudela*; London, 1907, 9, 76; Scherer, *Histoire du commerce*, Paris, 1857, I, 285-286. Most of the original sources are summarized in Heyd [149] I.
- [222] Hansteen, *Magazin for Naturvidenskaberne*, 1, 2.
- [223] *Islands Landnámabók*, Copenhagen, 1774; also 1900, I, ii, par. 7. Bibliographical and other information is supplied by Möbius, *Ares Islanderbuch*, Leipsic, 1869, Introduction.
- [224] Kamtz, *J. Chem. Phys.*, XV, 61, note.
- [225] Klaproth [7] 39. In spite of this, the supposed reference in the *Islands Landnámabók* has been cited in recent times as the earliest mention of the compass in European literature. For example, Brockhaus, *Conversations-Lexicon*, Leipsic, 1902, X, 524-526.
- [226] Beamish, *Discovery of America*, London, 1841, 53. Macpherson, *Annals of Commerce*, London, 1805, I, 261.
- [227] The relevant passage is given by Wright, *A volume of vocabularies*, 1882, p. xviii. A translation is given by Benjamin [15] 149.
- [228] In the preface to his *Lais Inédits*, Paris, 1836.
- [229] *Bulletin du Bibliophile*, Sept., 1836.
- [230] Wright [227]. It is, of course, still possible to maintain that Guyot copied the passage in *La Bible* from William the Clerk, and this rather perverse supposition has been put forward by Benjamin, [15] 153. See also Wright, *Biographia Briannica*, London, 1846, II, 426.
- [231] According to Cave, *Scriptorum ecclesiasticorum historia literaria*, London, 1688, Neckam died in 1227, but this is a mistake. Practically all that is known of Neckam's life will be found in the *Dictionary of national biography*, with full list of sources.
- [232] Neckam's *De Utensilibus* was first printed by Wright in [227], I, 96-119. Wright also referred to Neckam in his *Biographia* [230], II, 449-459, and in *Popular treatises on science during the Middle Ages*, London, 1841. Copies of the MS. are in

the British Museum (MS. Cotton, Titus D, xx) and the Bibliothèque Nationale, Paris (MS. Latin, No. 217, and 7679). In his preface, Wright calls attention to a curious point in *De Utensilibus*. Neckam states that when the needle, after magnetisation, ceased moving, it pointed towards the east, *donec cuspidis acus respiciat orientem*. Wright offers an explanation for this mistake, but it does not seem to be altogether satisfactory. The matter is also referred to by Bertelli, [103, f] 144-145; D'Avezac, *Bull. soc. geogr.*, XV, 176-177; and Schück, *Ausland* (Stuttgart), 1892, 590. Whatever the explanation may be, the corresponding passage in *De Rerum Naturis* puts the matter correctly. See also Chappell, *Nature*, June 15, 1876, 147.

[233] *De Rerum Naturis* has been printed in the Rolls Series, vol. 34, with a preface by Wright, and also in his *Vocabularies*, [227] I, 114. Copies of the MS. are in the libraries of Magdalen College and St. John's College, Oxford, and in the British Museum, MS. Reg. 129, XI, fol. 53v.

[234] With regard to the date of composition of the *De Utensilibus*, Wright gives reasons for assigning it to the twelfth century. Neckam returned to his post as school-master at Dunstable in 1187, and his book was evidently intended for use as a school book. He only remained there a year, and it is probable that during that year he prepared the work for the use of his pupils. Mottelay [9] puts Neckam under the year 1207; while Busch, *Ann. Hydrogr.*, 1926, 120-126, 169-174, puts him at 1200. In neither case is any reason given in support.

The facts with regard to Neckam's contribution to the history of the compass have been known for a considerable time. It is therefore surprising that error regarding them should still persist. For example, see an article by Curtiss, *Account of the rise of navigation*, in *Pop. Astr.*, XXVI, April, 1918, reprinted in *Smithsonian Report*, 1918, 127-138, in which, among other mistakes, the author states that "the compass was introduced generally into Europe about 1400 A. D."

[235] The most complete edition of Guyot's works is *Les Oeuvres de Guiot de Provins, Poète Lyrique et Satyrique*, edited by Orr, Manchester, 1915. It is a most exhaustive recension of all Guyot's poems, together with full references to original sources and commentaries. The passage relating to the compass is p. 29-30, lines 632-654.

[236] Orr [235] xx. M. Paulin Paris had dated it 1190, and this was repeated by Fleurbaey, *Annu. Bur. longit.*, 1894, B1-B37; Meyer, *Conversations-Lexicon*, Leipsic, 1895, X, 424; Brockhaus, *Conversations-Lexicon*, Leipsic, 1902, X, 524-528; Sedgwick and Tyler, [47]. The *Nouveau Larousse Illustré* gave it as 1190. But Orr's argument disposes of the matter quite conclusively.

[237] Pasquier, *Recherches de France*, 1st ed. Paris, 1650, ch. xxii, 220-221, 405, 603. See Orr [235] xxx. The mistake arose through Pasquier using a manuscript in which *La Bible* of Guyot was followed by that of De Bercy. Misled by the resemblance between the two, and by the fact that while De Bercy is named in his own poem, Guyot is not named in his, Pasquier attributed both to De Bercy. Fauchet, *Recueil de l'origine de la langue et poésie françaises*, Paris, 1581, 88-90, used the same manuscript but did not make the same mistake.

[238] Barbazan, *L'Ordene de Chevalerie*, Paris, 1759, 100, 203.

[239] Comte de Caylus, *Hist. Acad. Inscr.* XXI, 191-197.

[240] Schück, *Arch. Gesch. Natur. Techn.*, IV, 41, held to this opinion after consideration of the evidence, and it has also been adopted by Nippoldt, *Erdmagnetismus, Erdstrom und Polarlicht*, Berlin, 1921, 17. Apart from the explanation given above as to the origin of the belief, another objection to the identification of Guyot with De Bercy is that the latter wrote much later than the former. It is admitted that De Bercy's date is only approximate.

[241] Pasquier [237]. Azuni [30] 105. See also Fauchet [237], and Orr [235] xxxi. An example of the error will be found in Brockhaus [225], 1885 ed., X, 447.

[242] First edited and published by Gasser, \**Maricuriansis de magnete*, Augsburg, 1558. This edition was plagiarised by Taisnier in his *Opusculum perpetua memoria dignissimum de natura magnetis*, Cologne, 1562; English trans. by Eden, London, 1579. See Bosman, *Revue des questions scientifiques*, October, 1921. Translation of the original MS. has been found difficult, but it has been given by Libri, *Histoire des sciences mathématiques*, Paris, 1838, II, 487; S. P. Thompson, Chiswick Press, London, 1902; Arnold, Troy, U. S. A. 1904 and Hellmann, *Zs. Erdk.*, XXXII, Heft 2, also published separately, Berlin, 1897, and a French translation in *Bul. Soc. belge. Astr.*, II. A version of the letter was also published in *Mém. Soc. géogr.*, Paris, VII. A good summary is given by Mottelay, [9] 47-53, who gives other references.



[243] Bertelli [103, a, b, h]. For bibliographical notes in addition to those of Bertelli, see Hellmann's *Neudrucke von Schriften und Karten über Meteorologie und Erdmagnetismus*, No. 4, Berlin, 1895. See also Schlund, *Archivium franciscanum historicum*, IV, 436-455, 635-643; V, 22-40.

[244] See Mottelay [9].

[245] Peregrinus was anticipated by Neckam with regard to this point. As far as the present writer has been able to ascertain, most of the statements that Peregrinus introduced the pivoted compass have been derived from Benjamin, [15] 185.

[246] Jacques de Vitry, *Historia Orientalis seu Hierosolymitana*. For bibliography, see *Bibliotheca geographica Palestinae*, edited by Rohricht, Berlin, 1890, 48-50.

[247] Thomas of Cantimpre, *De natura rerum*. For bibliography and references, see Thorndike, [91] ch. LIII, and 396-398.

[248] Thorndike [91].

[249] Riccioli [203] 473.

[250] Haskins [192]. Two passages bearing on the magnet are given, with references to original sources. See also *Isis*, IV, 250-275.

[251] Klaproth [7] 53.

[252] See [90].

[253] Pliny, *Natural History*, Bostock and Riley's ed. VI, 355.

[254] Isidorus Hispalensis, *Opera Omnia*, ed. by Arevale, Rome, 1797-1803. See the *Origines*, xvi, 4. Also his *De natura rerum*, ed. by Hecker, Berlin, 1857. Compare Ebert, *Geschichte der Literatur des Mittelalters im Abendlande*, I, 555, and Pouchet, *Histoire des sciences naturelles au Moyen Âge*, Paris, 1845.

[255] Michael Constantine Psellus, \* *De lapidum virtutibus*, Toulouse, 1615.

[256] See *Histoire littéraire de la France*, XXIII, 576, 831. For translation of his verses, see Mottelay [9] 33.

[257] See Ginguene, *Histoire littéraire de l'Italie*, I, 413. Translation is given in Mottelay [9] 44, and by Longfellow, *Poets and poetry of Europe*, p. 511.

[258] Schück, *Mitt. Gesch. Med. Natw.*, XIII, 333. In the same paper Schück refers to another early mention of the compass. It is contained in a poem by Reinfrid von Bruneswic, reprinted in *Bibl. lit. Ver.*, Stuttgart, Wien, 1869. Reinfrid wrote about the end of the 13th or the beginning of the 14th century.

[259] Torfaeus, *Historia rerum Norvegicarum*, Copenhagen, 1711, IV, 345.

[260] Capmany, *Memorias historicas sobre la marina, comercio, etc.*, Madrid, 1792.

[261] Brunetto Latini, *Li livres dou Tresor*, ed. by Chabaille, Paris, 1863, 147. The mention by Brunetto Latini of the polar properties of the magnet anticipates the letter of Petrus Peregrinus by about nine years. This is frequently forgotten by commentators.

[262] *Paradise*, canto xii, line 26.

[263] Klaproth [7] 46.

[264] The following is, perhaps, a sufficient list of examples: Major, *Life of Prince Henry the Navigator*, London, 1868, 58; Schück, *Arch. Gesch. Natw. Techn.*, III, 127-139; Gunther, *Early science in Oxford*, Oxford, 1921, I, 298; Benjamin [15] 162; Volpicelli [30] 209; Knight [11] 1397; Mottelay [9] 59; and Meigs, *Story of the seaman*, Philadelphia, 1924, 268.

[265] *Monthly Magazine or British Register*, London, 1802, XIII, 449.

[266] *Monthly Magazine*, XIV, Part II, 391. Klaproth's omission can only be accounted for by supposing that he had never seen the originals. Attention was first called to the acknowledgment of the forgery by Davies [15] 307-308, but this has been overlooked by most historians of the subject. It came near rediscovery when D'Avezac, *Bull. Soc. géogr.*, Paris, XV, 179, pointed out the suspicious circumstance that a portion, at least, of the supposed letter of Brunetto Latini was simply a prose version of a passage in *La Bible* of Guyot. Thirty-five years later it was again referred to by O'Neill, *The night of the Gods*, London, 1893, I, with the remark that "no one seems to have detected this." A still more curious feature is that Klaproth refers to the author of the letters as "an English scholar." As a matter of fact, his name was Dupré.

[267] Bacon, *Opus Minus*, Brewer's ed., London, 1859, 383-384.

- [268] Barbour's *Bruce*, bk. V, lines 19-23:  
 "Thai rowit fast with all thar nicht  
 Till that apon thame fell the nycht  
 That it wox myrk on gret maner  
 Swa that thai nist nocht quhar thai wer  
 For thai na needil had na stane."
- [269] *Principal facts of the Earth's magnetism* [59] 20.
- [270] Bertelli [103, f, j, m, o].
- [271] *Blondi Flavii Forlivenensis in Italia Illustrata*, Turin, 1527, 152.
- [272] Torello da Fano, *Digestorum seu Pandectorum ex Florentinis pandectis repraesentatis*, Florence, 1553.
- [273] Mazella, *Descrittione del regno di Napoli*, Naples, 1586, 41.
- [274] Polydore Vergil, *De inventoribus rerum*, Venice, 1507, lxxxia.
- [275] Baptista Pio, \* *In Caium Lucretium poetam commentarii*, Bonon., 1511, ccvii.
- [276] Giraldus, \* *De re nautica Caelii Calcagnini commentatio*.
- [277] Collenuccio, *Compendio dell' historia del regno di Napoli*, Venice, 1539, lib. I, 16B, 17A.
- [278] Giraldus, *Libellus de re nautica*, Basel, 1580.
- [279] Lopez, *Historia general de las Indias*, in the *Bibliotheca de autores españoles historiadores primitivos de India*, ed. by de Vedia, Madrid, 1852, I, 161.
- [280] Cardan, *De Subtilitate*, Norimberg, 1550, 386.
- [281] Belon, *Singularium et memorabilium observationum*, Paris, 1553, ch. xvi.
- [282] Gasser, in preface to his edition of Peregrinus [242].
- [283] Lemnius, [92] 1564 ed., lib. iii, cap. iii, 302.
- [284] Bartolomeo da Fano, in *Nuova seconda Solva rinnovato di varia lettione*, Venice, 1626, ch. xxxvi.
- [285] Aldrovandi, *Musaeum metallicum*, Bonon. 1648, 567.
- [286] The references immediately above show how soon and how widely the statement of Giraldus was repeated. In addition, see the uncompromising statements of Brechmann in *Thesaurus antiquitatum et historiarum Italiae, Neapolis, et Magnae Graeciae*, Leyden, 1723, IX, c. xxii. He stated, quite erroneously, that as evidence of the Amalphian origin of the compass, a representation of the instrument is incorporated in the arms of the town of Amalphi. This has been frequently repeated; its latest appearance being in Barker's *The compass, historical, theoretical, practical*, London, 1892. But it has been fully investigated and disposed of by Bertelli [103, f]. See also the references given by Brachmann, to which many more of like tenor might be added. As an example of the confusion produced, see Birkenmeyer, *Le curieux antiquaire*, London, 1729, I, 318, who, speaking of Amalfi, says, "L'on dit que Flavio Blondi inventa ici la Boussole."
- [287] Mazella [273].
- [288] Ortelio, *Theatro del mondo*, Antwerp, 1612.
- [289] Bertelli [103, o]. See Casanova, \* *Degli studi storici di T. Bertelli intorno alla bussola nautica*, (Rome?) 1895.
- [290] Grimaldi, *Saggi di dissertatione dell' Acad. Etrusca di Cortona*, 1741, III, 915.
- [291] Venanson, *De l'invention de la boussole nautique*, Naples, 1808. He is referred to as "Vellanson" by Benjamin [15] 104.
- [292] Briet, *Annales mundi*, Venice, 1693, VI.
- [293] Voltaire, *Essai sur les moeurs*, 1819, III, c, CXXI.
- [294] Botto, see [103, m]; Proto-Pisani, *Sull' origine della bussola*. Portici, 1901; Porena, *Nuova antologia*, November 1902.
- [295] Signorelli, *Vicende della coltura nelle due Sicilie*, Naples, 1810, II, 475.
- [296] Camera, *Istoria di Amalfi*, Naples, 1836, 231, and *Memorie storico-diplomatiche*, Salerno, 1876, cap. xxxi, 453.
- [297] Fiucati, *Il magnete, e la bussola, Rome*, 1878. Reference may also be made to a paper by Sevyllot, in *Bull. Bibliogr. st. sc. mat. fis.*, I, 161-166.
- [298] Poggendorff, *Geschichte der Physik*, Leipsic, 1879, 98-111.
- [299] Voltaire [293] III, 251.
- [300] Nicholas, *History of the Royal Navy*, London, 1847, II, 180.
- [301] Capmany, [260].
- [302] Schück, *Der Kompass*, Hamburg, 1911.