

## **Peter Pilgrim and His Letter**

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August 8, 1269 AD, a soldier in camp at the siege of Lucera, a town in southern Italy, completed his famous Treatise on the Magnet, the earliest known scientific work devoted to the magnet. The author calls himself Petrus Peregrinus of Maricourt, a name which is as enigmatic as the man himself. This modest treatise is significant because it presents the experimental facts that form the foundation of magnetic science.

The document itself contains all we know for certain about the man who composed it. Its author, Petrus Peregrinus of Maricourt, also is known as Pierre of Maricourt, a town in Piccardy France. He is also known as Magister or Master Peter the Piccard, who is described in Roger Bacon's book *Opus tertium*. We know nothing of his birth, death, and life except what Bacon tells us of him. His surname Peregrinus is a mystery. It is an honorific title or appellation given to participants of pilgrimages, explaining why sometimes his name appears as Peter the Pilgrim. But the title was also applied to participants in official church sanctioned crusades. A fact that suggests the conclusion that Peter was an engineer in the army of Charles of Anjou, King of Sicily, during a crusade sanctioned by the Pope against the town of Lucera, near the east coast of southern Italy, in the year 1269.

The treatise, composed in the form of a letter to Sygereus of Foncaucourt, is a landmark in the history of science. It is widely acknowledged as the earliest known scientific work. Yet it is an enigmatic and strange document. The identity of its author is obscure. Roger Bacon tells us almost all we know of him as follows: "...and the business of experimenting no one in Western Europe understands, save only Master Peter." Bacon goes on in detail to explain that Magister Peter, is the only man who "...merits praise in the works of science..." But, we are not sure this Master Peter, is the same Peter Peregrinus of Maricourt author of the *Treatise on the Magnet*. If we believe what Bacon says, then he was surely a great master of all the various arts of science and technology.

Magister Peter's background is equally unknown. Some authors have claimed that he was Roger Bacon's master or teacher, who taught Bacon the use of experimental method. Was he warrior, scholar, noble, or cleric? These facts are as unknown as the other facts of his life. From the letter we can see that he was obviously an educated man, expert in the mechanical arts, and knowledgeable in the sciences, particularly astronomy. In a time when magic and science were almost as one, it is clear that Peter was skilled and knowledgeable in both of these arts. At times, the treatise employs the concepts of magic as easily as those of experimental rational science.

Sygerius, to whom the letter is addressed, is even more obscure than Magister Peter. We know nothing of him at all. The letter is addressed to him, says Peter, in order to answer his questions regarding the hidden nature of the magnet, so that natural philosophers may delight in the beauty and wonder of its secrets revealed in the light of knowledge for philosophers to contemplate. The letter is obviously intended to be copied and circulated among the learned natural philosophers, and Sygerius dutifully performs this function. The letter was apparently widely circulated. There are thirty one known copies in manuscript form, of which twenty nine are in Latin and two are in

Italian. Five others, thought to have existed, are now lost. But, this wide distribution in the libraries of Europe did not mean that the work was known to a wide audience of philosophers and scholars. This was not accomplished until 1558 when a Latin version was published in Augsburg. Thus the work was relatively unknown for 300 years, a fact which explains its obscurity prior to the scientific revolution. It is likely that the work was known only to the librarians and compilers of manuscripts because we do not encounter any reference to it in works of magnetism prior to the publication of Gilbert's treatise on the Magnet.

The letter is an enigmatic work. It appears as a work of experimental science, presents experiments as proofs of assertions, then provides technical descriptions for the construction of two types of magnetic compasses, the first known which actually provide details of construction with diagrams, yet ends with a proposal to build a perpetual motion machine from legends of magic. We are left wondering, at the curious combination of experimental science and magical practice. This is the problem that this chapter seeks to solve.

### **Significance of Peregrinus Treatise**

It is a commonly accepted belief that no proper scientific facts of magnetism were developed prior to the publication of William Gilbert's book On The Magnet in 1600 an event which has been generally accepted as marking the beginning of the scientific revolution. Charles Pierce, who made a detailed study of Magister Peter's treatise in the nineteenth century, concluded that "Gilbert...has always been overrated, even from the first,...because it is not known that a large part of his work was plagiarized from Peregrinus." Pierce's admiration and enthusiasm for Peregrinus work was unbounded. He praised it for its experimental method saying "But when a man invents a special apparatus, for the purpose of investigating a given natural phenomenon, and surrenders himself to experimentation with it, I do not think we can deny to that man the name of a scientific man." The appearance of Peregrinus treatise in the year 1269, 331 years before the beginning of the modern scientific era deserves our attention and careful study. It is a prototype of experimental science in an age widely believed to be devoid of the scientific spirit.

Magister Peter's treatise is a significant scientific work because it establishes experimentally the foundations of magnetic science. This accomplishment in the year 1269 AD, deep within the later medieval period dominated by the scholastic philosophy, indicates that the period was not hostile to the scientific spirit as usually assumed. However following Peter's treatise, there were no significant advances in the science of magnetism until Gilbert's book was published in 1600. Gilbert's work is best interpreted as a revision and extension of Magister Peter's treatise, because most of the foundations of magnetic science, as defined by Peter, remain unchanged today in the modern era.

The treatise presents the most significant discoveries in magnetism since the discovery of the compass. It is divided into two parts. The first part being a discussion of the theory of magnetic action based upon experiments and demonstrations. It forms the foundation of his magnetic theory. The second part is a description of two instruments for the directional measurement of celestial bodies and a machine of perpetual motion based on magnetic energy. The experimental results that are the most significant are: the description of magnetic repulsion, elucidation of magnetic polarity, which is described in ample detail, and the description of the attractive and

repulsive magnetic actions. Equally important, but not as well established experimentally, was the conclusion that the directive property of the loadstone as well as its attractive and repulsive power was derived from power of the heavens.

Magister Peter is not simply presenting magnetic facts based on experiment, he is revealing his theory that the magnet draws its power from the celestial vault of the heavens. His theory is essentially astrological. The magnet is caused to point to the poles of heavens because “it is from the poles of the heavens that the poles of the magnet receive their virtue”. Magister Peter’s experiments are designed to support this belief that the magnet draws its power from the heavens. He says”...in this way we may suppose not only that the poles of the stone receive their influence and virtue from the poles of the world, but that the whole stone does so from the whole heavens...”

Magister Peter’s treatise contains the germ for the modern idea of a magnetic field. Peter notices the similarity of the forces at the surface of a spherical magnet with the geometric meridians of the heavens. This analogy, between the lines of force on the magnet with the geometric description of the heavens, is the basis of his theory that the magnetic power is derived from the heavens. Later, Gilbert uses the same method to describe the power of the magnet and formulates a primitive field theory which he calls the orb of virtue. The significance of these ideas is that they employ a method which maps the virtue or power of the magnet using geometric methods to map the field of magnetic power.

Certainly the most significant innovation is the modern method of the demonstration experiment. The approach anticipates the modern scientific method, particularly the method of proof which employs the construction of a machine or instrument whose principle of operation embodies the principle to be proved. The operation of the machine or instrument then becomes the proof of the hypothesis. This is modern science. Proof is accomplished by technological machines which are constructed on the basis of scientific knowledge. The success of the machines in performing beneficial service to mankind is proof of the knowledge and justification of the expense used to construct them. One purpose of the treatise is to justify the construction of instruments and machines beneficial to mankind. It proposes a machine that runs perpetually from the magnetic power of the heavens. It is a curious proposal. It combines a scientific method of proof with a concept from the legends of magic. A mill of perpetual power. Hence, the letter is an enigma, is it science or magic?

Magister Peter’s treatise is an example of the close connection of experimental science with magic during the thirteenth century. This connection prompted Lynn Thorndyke to conclude that magicians were the first to experiment and that science borrowed the experimental method from magic. This thesis has gradually gained acceptance as historians have marshalled evidence that scientific ideas and methods grew out of the magical arts. But, the scientific community continues to reject this idea.

To properly understand Peregineus work, we must interpret it as both a work of science and the magical arts. It borrows from both worlds ideas that are combined together to form the first work of knowledge devoted to magnetism. Because the boundary between magic and rational science

is unclear during this early era, we should not be surprised to find the ideas of science and magic in a Treatise on the Magnet.

### **Magister Peter's Experimental Proofs**

The most important scientific fact that is proved by Peregrinus is the property of magnetic repulsion. This is an important addition to magnetic knowledge that appears here for the first time in a clear and unambiguous description. Did Peter Peregrinus discover the property of magnetic polarity, a property of magnets second only in importance to the phenomenon of magnetic attraction? This is not fully established with certainty. Alfred Still in Soul Of Loadstone claims that the repulsive force of magnets was known to Lucretius and cites the following as his proof :

“It also happens at times that iron moves away from this stone; its tendency is to flee and to pursue by turns. I have even seen Samothracian rings of gilded iron jump up and iron filings grow restive inside copper cups when this magnet stone was put under them. So eager, it seemed, was the iron to run from the stone. The reason why the interposition of copper causes such a turmoil is doubtless this. After the effluence of the copper has first taken possession of the open passage ways in the iron and occupied them, along comes the effluence of the magnet and finds everything full in the iron and so has no way of passing through as before. It is therefore compelled to pelt and batter the texture of the iron with its stream. In this way it repels the iron from itself and through the copper it drives away what otherwise it normally attracts.”<sup>9</sup>

Here we encounter an example of an ambiguous experimental result. Is this an experimental proof of magnetic repulsion? To answer this we need to specify what exactly we mean by repulsion, and specify how the experiment proves or demonstrates the expected result. Magnetic repulsion means a repulsive force entirely caused by magnetic action, usually explained as the repulsion of like magnetic poles. So we see that this is not a case of magnetic repulsion by poles, but it is an example of an apparent repulsion for iron inside copper cups. The experiment is ambiguous because we can not ascertain whether the repulsion is necessarily caused by the copper, or by the magnet. Lucretius, claims that it is not an effect of the magnetic effluence alone, but depends on the competing action of the copper effluence, and so we can not consider it a case of a repulsive magnetic force acting alone.

Between the years 1220 and 1250 AD, an encyclopedist compiler, Bartholomew the Englishman, wrote the following in his description of the magnet:

“Indeed there is another species of magnet in Ethiopia which repels iron and flees from itself. Furthermore, the magnet sometimes attracts iron from one angle and repels it from itself in another [angle]. “

This description is insufficient to determine whether there is a repulsive force of the magnet. This proof is first presented by Peregrinus in complete detail. Bartholomew shows the poor quality of the prevailing method that relied upon the knowledge contained in books that was based upon the vague and unsubstantiated reports of ancient sources.

The second experimental fact that is proved is the fundamental law of magnetism regarding the law of attraction and repulsion of the poles of a magnet. Peregrinus states it as follows in Part One Chapter VI:

“Know you then as the rule, that the Northern ...attracts the Southern... and the Southern the Northern. But if you do the opposite, namely, bring Northern part near the Northern, the stone...will seem to repel... and if you apply the Southern part to the Southern, the same will happen...”

This is the earliest known statement of this law which is taught first in magnetism that like poles repel and unlike poles attract.

In The Bibliographical History of Electricity and Magnetism Mottelay argues that the polarity of the magnet was unknown to the Greeks and Romans:

“With reference to the magnetic attraction to the pole, it is well to bear in mind that no allusion whatsoever is made thereto by any of the writers of classical antiquity...It certainly appears to have escaped the attention of the ancient Greeks and Romans whose admiration...was excited solely by the attractive property of the loadstone.”

Additionally, there is no evidence that this law is recorded in any work prior to its appearance in Peter’s treatise.

In support of this conclusion Mottelay quotes from a study by Rev. Father Joseph de Costa, Natural and Moral History of the Indies:

“I finde not that, in ancient bookes, there is any mention made of the use of the Iman or loadstone, nor of the compasse (aquja de marear) to saile by; I believe they had no knowledge thereof... Plinie speakes nothing of that virtue it hath, alwaies to turn yron which it toucheth towards the north...Aristotle, Theophrastus, Dioscorides, Lucretius, Saint Augustine, nor any other writers or Naturall Philosophers that I have seene, make any mention thereof, although they treat of the loadstone.”<sup>10</sup>

It is clear that a very important contribution to scientific knowledge was contained in Peregrinus work that described the attraction and repulsion of the magnetic poles. The lack of a clear description of magnetic poles prior to the publication of Peregrinus treatise, supports the contention that he should be given credit for this discovery.

In Part One Chapter VII Peregrinus tells us “How iron touched with a magnet turns to the poles of the earth.” He admits that knowledge of the directive property of the magnetized needle “Is known to all who have tried it”. He adds the important experimental proof that attempts to prove that the iron is attracted to the poles of heaven. He tells us that:

“...you must know that the part of the iron which shall have touched the south of the stone, will turn toward the North of the heavens. And the converse will be the case concerning the part of the iron which the North part of the stone shall have touched.”

This law forms the basis of the modern law governing magnetic induction. This law specifies that a north pole induces a south pole in the needle and vice versa.

Finally, Peregrinus presents the well-known law of magnets that when a magnet is divided in half, it forms two new complete magnets. These possess the original poles as well as two new poles determined to have polarity opposite to the original ones. The two divided magnets can be rejoined, forming the original magnet as before. In the process, the two new poles unite as one and disappear, leaving only the original poles. He proves this law from a comprehensive series of experiments and demonstrations described in Part one Chapter IX.

### **Magister Peter's Method: The Demonstration Proof**

In part one, the epistle begins with a thoroughly experimental approach. A wonderful model to be followed. The experimental procedure is specified in detail. Instructions are provided that are intended to instruct the reader on the means to construct the experimental apparatus. This is an important innovation. It is followed by a detailed description of the method used to conduct the demonstrations which lead to the experimental proofs. Part one ends with an extraordinary chapter which tells us that the power or virtue of the loadstone derives from the poles of the heavens. A remarkable conclusion, made more surprising in its contrast to the beautiful experimental approach used to elucidate the poles. It seems to stand as a compelling result because of the previous proof of the existence of the poles.

Although the treatise emphasizes the role of demonstration experiment as proof, its main purpose is to prove that the magnetic virtue derives from the power of the heavens, because as Peter explains it to Sygerius the power arises from the fact:

“that this stone bears in itself the likeness of the heavens... There are in the heavens two points more important than all others, because on them, as on pivots, the celestial sphere revolves: these points are called, one the arctic or north pole, the other the antarctic or south pole. Similarly you must fully realize that in this stone there are two points styled respectively the north pole and the south pole.”

After this introduction, two methods whereby the poles are recognized or discovered in a spherical loadstone or *terrella* are described. The first ascertains the location of the poles as follows:

“...a needle ... is then placed on top of the loadstone and a line is drawn in the direction of the needle or iron, thus dividing the stone into two equal parts: The needle is next placed on another part of the stone and a second median line drawn. If desired, this operation may be performed on many different parts, and undoubtedly all these lines will meet in two points just as all meridian or azimuth circles meet in the two opposite poles of the globe. One of these is the north pole, the other the south pole.”

Peregrinus second method is simpler and very elegant, but depends on the first to initially identify the poles as proof that the latter method actually identifies them correctly. Using the second method the poles are identified as

“where the point of the needle clings most frequently and most strongly ; for this will be one of the poles as discovered by the previous method...Break off a small piece of the needle or the iron...then put it on the spot which was found to be the pole by the former operation. If the fragment stands perpendicular to the stone, then unquestionably, the pole sought; if not, then move the iron fragment about until it becomes so; mark this point carefully; on the opposite end another point may be found in a similar manner. If all this has been done rightly, and if the stone is homogenous throughout and a choice specimen, these two points will be diametrically opposite, like the poles of a sphere.”

The justification that this method works is given in an experimental proof that the locations found by these procedures are the poles. This is performed as follows. The magnet, which has been marked with the pole locations, is placed on “a wooden vessel, rounded like a platter or dish” and then floated inside a vessel containing water. The proof follows from the result that the vessel containing the loadstone will turn “until the north pole lies in the direction of the northern pole of the heavens, and the south pole of the stone points to the south pole of the heavens.”

Peregrinus method and proof is based on his observation that there is a similarity between the geometric method defining the poles of heaven, by the intersection of the celestial meridians of longitude, with the field lines marked on the spherical magnet. In both cases the poles are defined by the intersection of the meridians. The experimental method for marking the meridians of magnetism is similar to the modern method used to map the magnetic field. It is a field method because it marks or constructs the meridian, by supposing the iron needle lies in or indicates, the tangent to the meridian at its location upon the loadstone. This being equivalent to the determination of the direction of the lines of magnetic force or field strength. When the iron needles are placed upon the loadstone they act as if they are tiny compass needles and point in the direction of the field lines. Peregrinus has invented a field mapping method, the first example of its use applied to magnetism or electricity. The second method is also a field mapping procedure, because it maps or determines the strength of the field at a point on the loadstone by the criteria that the needle stands vertically at the point of maximum field strength, which is always a pole. Later William Gilbert extends these methods making them more precise and justifying their correctness. The procedures are elementary applications of the methods of modern field theory, which are not fully developed and justified mathematically, until the work of James Clerk Maxwell in the 1860s.

Underlying Peregrinus method, we see that there are some hidden assumptions which he does not mention or define. First, is the basic assumption that the poles of the heavens possess magnetic attraction for the poles of a magnet. Second, is the assumption that a spherical magnet reflects within itself the similitude of the heavens, and that a loadstone formed into a sphere forms an adequate analog to the celestial sphere and its magnetic properties. Both of these working assumptions are questionable. The justification for them ultimately being that the method works, it correctly determines the poles and explains the directional behavior of magnets.

The justification is provided by experiments described in Chapter VI. Here he proves that north poles attract south poles and vice versa:

”Know then that this is the law: north pole of one loadstone attracts the south pole of another, while the south pole attracts the north. Should you proceed otherwise and bring the north pole of one near the north pole of another, the one you hold in your hand will seem to put the floating one to flight. If the south pole of one is brought near the south pole of another the same will happen.”

In Chapter VII Peregrinus shows by experiment that an iron needle touched by a magnet turns towards the poles of the earth. He says the following proves it:

“It is well known to all who have made the experiment, that when an elongated piece of iron has touched a loadstone and is then fastened to a light block of wood or to a straw and made to float on water, one end will turn to the star which has been called the Sailor’s star because it is near the pole; truth is, however, that it does not point to the star but to the pole itself...you will observe that the part of the iron which has touched the south pole of the loadstone will turn towards the north and conversely that part which had been in contact with the north pole will turn to the south.”

In Chapter X, Magister Peter presents the proof that a loadstone acquires its virtue from the poles of the heavens. It consists of a two part argument. The first argues that the virtue can not come from mineral deposits in the north or south because the deposits must be evenly distributed around the earth and not concentrated to the northern or southern regions. In the second part, he says:

”Since the loadstone points to the south as well as to the north, it is evident from the foregoing chapters that we must conclude that not only from the north but also from the south pole rather than from the veins of the mines virtue flows into the poles of the loadstone. This follows from the consideration that wherever a man may be, he finds the stone pointing to the heavens in accordance with the position of the meridian; but all meridians meet in the poles of the world; hence it is manifest that from the poles of the world the poles of the loadstone receive their virtue. Another necessary consequence of this is that the needle does not point to the pole star but to the poles of the world...From all these considerations, it is clear that the poles of the loadstone derive their virtue from the poles of the heavens.”

This is followed by a passage where Peregrinus offers a peculiar experimental method and enters the realm of philosophical speculation. He says: “You may test this in the following manner.” But, we know that the proof he describes is impossible. It involves the construction of a perpetual motion machine made by mounting a loadstone upon frictionless bearings through the magnetic axis so that it may turn freely upon its axis. The idea being; as the heavenly sphere rotates in its daily cycle, the magnetic virtue of the heavens will cause the loadstone to rotate in unison with it. His reasoning is flawed because the magnetic virtue does not come from the poles of heaven but, as we know, comes from the magnetic field of the earth’s core. But Peregrinus is so entirely convinced of the truth of his theory, that he tells the reader:

“Now if the stone then move according to the motion of the heavens, rejoice that you have arrived at a secret marvel. But if not, let it be ascribed rather to your own want of skill than to a defect of Nature. But in this position, or mode of placing, I deem the virtues of the stone to be properly conserved, and I believe that in other positions or parts of the sky its virtue is dulled, rather than preserved.”

He then goes on to describe how the instrument may be used as a celestial clock. His experimental method is a peculiar concept. His proof is so certain that it can not be disproved by an experiment. If the experiment fails, it is not a refutation of it, but a failure in construction of the instrument.

The justifiable fame of the work of Peregrinus does not derive from his erroneous theory of the poles of heaven and his perpetual motion machine, but from his elegant method of presenting magnetic experiments, and his demonstration of the Law of magnetic poles. This method forms the basis of the work of William Gilbert who uses the method to demonstrate the elementary facts of magnetism. Peregrinus fame derives from the fact that his method forms the foundation of magnetic science.

### **The Invention of The Magnetic Compass**

This section describes Part II of Peregrinus epistle. This part contains three chapters. and describes two forms of a magnetic compass and a practical construction of a wheel of perpetual motion. The thesis of this section is that Petrus Peregrinus de Maricourt was the first to provide a detailed account of the modern mariners compass as well as to give a satisfactory explanation or theory for its operation. The reasoning is two fold. First, it appears earliest in the historical record, and second, the theoretical explanation, although flawed in one respect, gives the first scientifically accurate account for the action of the magnetic needle based on experimental facts related to its operation. Peregrinus thesis is that the poles of the loadstone or magnetized needle were drawn to point towards the poles of the heavens by magnetic attraction between poles. Putting aside the false concept that the magnetic virtue emanated from the heavenly poles, it is a remarkably accurate conclusion regarding the explanation of the compass.

Unfortunately for Petrus, his thesis that the magnetic power emanated from the heavenly poles was incorrect. This power derives from inside the earth. Hence being internal and not external in the heavens, his wheel of perpetual motion was doomed to fail. It is not known if it was ever tried. But we do know that it must have failed because the magnetic power arises from the earth and not the heavens. The important discovery by Peregrinus was that magnetic force was directive because the loadstone and other magnetized bodies experienced a force dependent on the location of magnetic poles in external relation to those of a magnetized body. He was able to describe this relation experimentally and show that the force acted to bring the magnetic poles of a compass into a directional alignment. Hence magnetized bodies were observed to move towards externally located magnetic poles. This is basically the explanation of the compass with the modification that the magnetic poles are located inside the earth.

In the second and last part of the book, he gives details on the construction of two types of compasses. One, suitable for use on land, which employed a loadstone floating on water, and a

second which employed a magnetized needle suspended in a cylindrical case with a transparent cover, directional markings and a sighting method. This device is nearly identical with the modern hand compass. Finally, in the last section he describes the construction of a “wheel of perpetual motion”. A device designed to move continuously deriving its motive power from the “virtue or power of the lodestone.” It gives the detailed design for a perpetual motion machine using the attractive forces derived from the poles of heaven to provide the motive force on magnets mounted inside a wheel, which turned diurnally following the heavenly motion. One wonders if this device was actually built. Probably not. It was an extrapolation based on his researches on magnetic poles.

In chapter 1 of the second part, Peregrinus undertakes to describe the construction of instruments which depend for their operation on the knowledge of those facts regarding the attraction of magnetic poles. The main innovation which is included is the provision of a method for performing the measurement of direction. This is done in the manner of an astrolabe. The loadstone is enclosed within two capsules, made of light wood, placed in a round vessel of water. A smooth strip of wood containing sighting pins is placed over the capsules in the manner of a diameter. A procedure is then described for finding the points of direction and marking them around the rim of the water vessel. The resulting instrument, described by S.P. Thompson as “the earliest compass with proper divisions” was used as follows:

”If therefore, you desire to take the azimuth of the sun, place the capsules in water and let them move freely until they come to rest in their natural position. Hold them firmly in one hand, while with the other you move the ruler until the shadow of the pins falls along the length of the ruler; then the end of the ruler which is towards the sun will indicate the azimuth of the sun.... The same method, namely by sighting may be followed at night for determining the azimuth of the moon and stars.”

In chapter 2 the construction of an instrument resembling a hand compass is described. Peregrinus says, “I will describe the construction of a better and more efficient instrument.” It has the following features which provide the improvements over the instrument described in chapter 1: It is contained in an enclosed box sheltering the needle from the wind, the needle is permanently mounted upon an axis inside the enclosure, the box has a transparent cover for observing the needle. The enclosure is “circular in shape with a cover of glass or crystal”. A vertical axis mounted on bearings is placed between the top on bottom of the cylindrical enclosure. At the middle of this axis, apertures are provided for the insertion of a magnetized steel needle and a second brass or silver needle perpendicular to the steel one. The cover is divided into four parts then further subdivided into 90 parts. The four quadrants are then marked with the four cardinal points; north south east and west. “Add thereto a ruler of transparent material with pins at each end.” After magnetizing the steel needle, the device is used in accordance with the following description:” turn the vessel until the needle stands in the north south line already marked on the instrument; after which turn the ruler towards the sun if day-time, and towards the moon and stars at night...By means of this instrument you can direct your course towards cities and islands and any other place wherever you wish to go by land or sea, provided the latitude or longitude of the places are known to you.”

Chapter 3 describes the art of making a wheel of perpetual motion. The description provided is not sufficiently detailed to fully appreciate its operation and does not appear to be fully worked out in sufficient detail to permit its construction. Its principle of operation involves the alternate magnetic attraction and repulsion between a loadstone and iron teeth mounted inside the wheel. "When one of the teeth comes near the north pole and owing to the impetus of the wheel passes it, it then approaches the south pole from which it is rather driven away than attracted, as is evident from the law given in a preceding chapter Therefore such a tooth would be constantly attracted and repelled." Peregrinus appreciates that this is not sufficient to maintain the continuous motion of the wheel. He proposes that a iron made of brass be placed between the teeth so that as the wheel moves the weight falls from tooth to tooth in a direction opposite to that of the motion of the wheel. This seems to defeat the expected power derived from the magnetic field. Hence the actual method remains unclear to the reader. In any event the wheel can not operate as described and provoked criticism from William Gilbert and others.

## **An Evaluation**

It is a curious fact that although the Chinese and Europeans understood the directive property of the magnet, they failed to provide a correct explanation until William Gilbert. To understand why, consider the state of philosophy and the method used by Peregrinus.

In chapter 1, he declares his purpose as public utility in the following:

"I will now make known to you, in an unpolished narrative, the undoubted though hidden virtue of the loadstone, concerning which philosophers up to the present time give us no information, because it is characteristic of good things to be hidden in darkness until they are brought to light by application to public utility...The disclosing of the hidden properties of this stone is like the art of the sculptor by which he brings figures and seals into existence...But the things that are hidden from the multitude will become clear to astrologers and students of nature, and will constitute their delight, as they will also be of great help to those that are old and more learned...Whoever wishes to experiment, should be acquainted with the nature of things, and should not be ignorant of the motion of the celestial bodies. He must also be skillful in manipulation in order that, by means of this stone, he may produce these marvelous effects."

This gives us little insight into the philosophy behind his method. It is apparently designed to reveal a hidden secret. This secret being the wheel of perpetual motion, which is an important discovery for the benefit of the public utility. Its principle is based on the notion that the circular motion of the heavens can be communicated via the power of the magnetic attraction. Peregrinus sets out to perform experiments which support this conclusion. Hence, his purpose is to justify his invention of a perpetual motion machine.

Charles Pierce summarizes the importance of the epistle on the magnet as follows:

"The brief treatise on the lodestone by Petrus Peregrinus, dated 1269, occupies a unique position in the history of the human mind, being without exception the earliest work of experimental science that has come down to us..."

We see from the introduction to the epistle that experimental method is not the main purpose of the treatise. The consequential irony is that the conclusion of his beautifully performed, and highly lauded experiments is false. Peregrinus proves in his epistle that the magnet draws its power from the poles of heaven. Based on this experimentally proven result, he designs a perpetual motion machine which can not work. Clearly his method is flawed, but in what way? The answer is that the use of experimental method alone is not a sufficient guarantee of truth.

The reason that Peregrinus falls into a false conclusion is twofold. He commits a mistake in logic, and his experiments are insufficient to prove the thesis. The logical mistake is teleology. It is the same mistake we encountered with Thales. Peregrinus reasons that because the poles of a loadstone point to the poles of the heavens, this is sufficient proof that the virtue of a loadstone is obtained from them. Teleological reasoning is used because the proof that the loadstone draws its power from the poles of heaven, is provided by the experiment that demonstrates the poles of a loadstone are drawn to the poles of heaven. Hence the proof is drawn from the evidence that suggests the explanation.

Here we see the strength and error of scientific experimentation. The strength derives from the power of the phenomena to shape our ideas. Hence, by experimentation we seek to learn more about it. This knowledge then allows the discarding of the inadequate theories or explanations. The experimental flaw in Peregrinus argument is that he does not adequately perform experiments to really demonstrate the proof. He does not use his designs for the compass to perform the needed experiments that show the loadstone always points to the celestial poles at all times and all places. The discovery that the compass needle sometimes points away from the poles would have been a conclusive proof that his theory was wrong. But, Peregrinus never performed these experiments. Sometimes experiment leads us into error by confirming our preconceived ideas. The error goes undetected because we never perform the experiments which lead to a falsification of our theory. Experimentation stops when the experimental proof is obtained that fits the expected result.

Peregrinus epistle on the magnet is a curious mixture of modern experimental science and mystical speculation. The nonscientific parts are usually ignored. Here I mention them to point out the curious mixture they present to a modern interpretation. The epistle follows the modern practice of a scientific paper. It is divided into two parts. The first part presents the theory and the second part presents the construction and use of the instruments he has invented. The treatise ends with proposal to build machines to demonstrate his assertion that the magnetic power is derived from the heavens.

In evaluating Peter Peregrinus scientific contributions, we focused on the experimental part of his treatise and considered his magnetic theory of the poles as an example of speculation based on his experimental results. A practice commonly used by scientists. We must remember however that his main motivation or purpose is ultimately to describe the construction and operation of a perpetual motion machine using magnetism. It has the flavor of what today we would regard as a grant application or proposal written as if Petrus main goal was to secure financial support for the construction of his “wheel of perpetual motion”. In another sense, this makes Peregrinus treatise modern because it is an attempt to make an invention using science for the benefit of mankind.

Peter's treatise commands our interest in the history of magnetic science for three reasons. First, it is the earliest known example in western history of an experimentally based scientific argument. Second, its primary purpose is the application of scientific knowledge to "public utility", which is the primary justification of the pursuit of science as a public good. Finally, the treatise gives a theory of magnetism which attributes it to the power which resides in the heavens. Although this power is never clearly stated as being divine, is it clear that this is implied by the prevalent ideas of the Christian church. From this we can infer that for Peregrinus magnetism derived its source of power from God.

**Next Chapter**

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