Polar magnetism: a paper read before the American institute on the cause of polar magnetism; the attraction of the needle to the pole; the variations of the compass, and the phenomena incident to the same. By John A. Parker.

Parker, John A.
New York, J. Wiley & son, 1868.

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32. Dec. 1871.

The Gift of
H. W. Longfellow, Ld. D.
of Cambridge
January 18, 1870.
2
The Gift of
Rev. Benj. F. De Costa
of New York, N.Y.
1870, Jan. 11.

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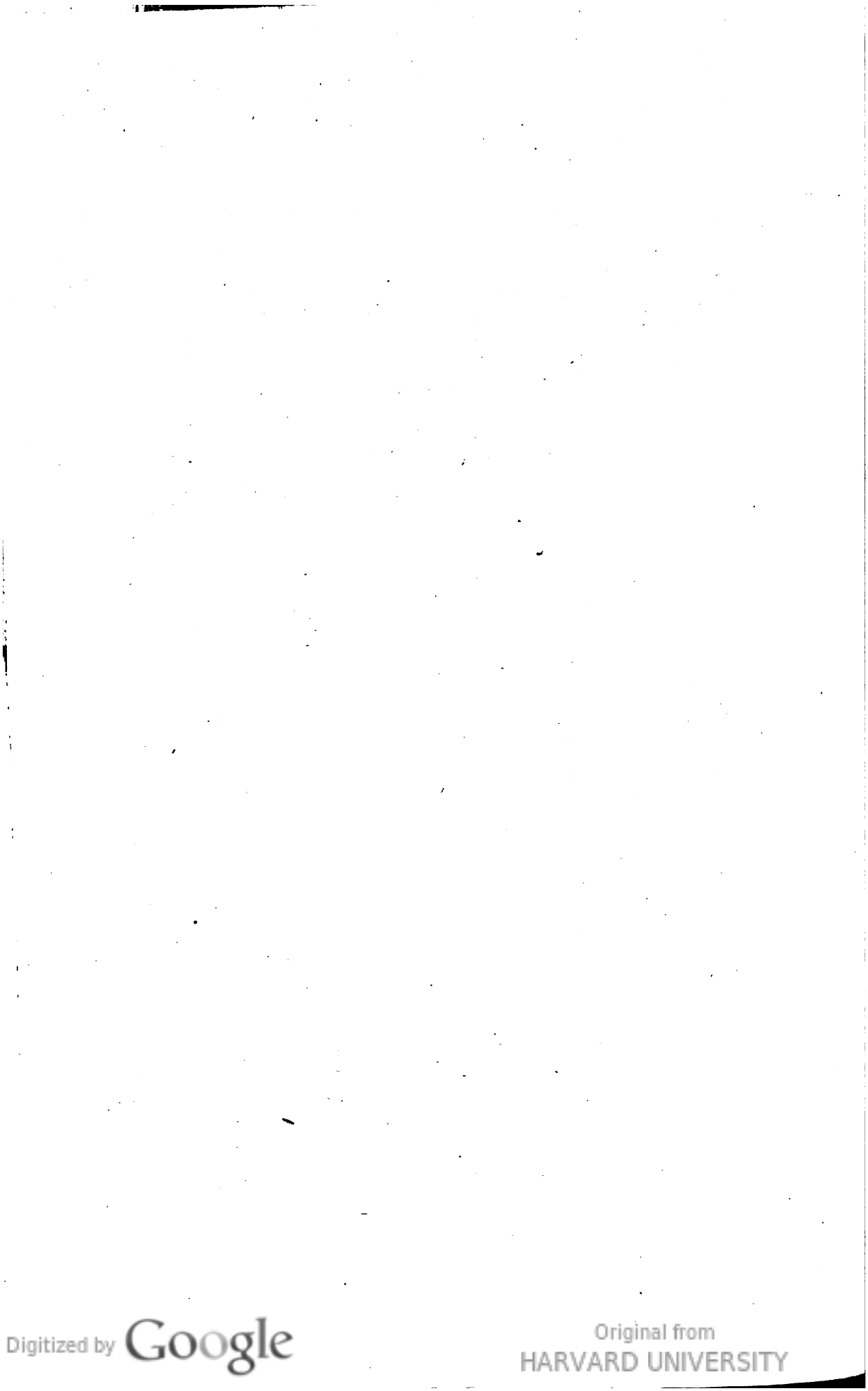

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1. See Opposite.

2. Parker, J. A. Second Lecture on Polar Magnetism: its Astronomical Origin, its Period of Revolution, etc. New York. 1869.

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POLAR MAGNETISM:

A PAPER READ BEFORE THE

AMERICAN INSTITUTE,

ON

THE CAUSE OF POLAR MAGNETISM; THE ATTRACTION OF THE NEEDLE TO THE POLE; THE VARIATIONS OF THE COMPASS, AND THE PHENOMENA INCIDENT TO THE SAME.

By JOHN A. PARKER.

NEW YORK:
JOHN WILEY & SON, 2 CLINTON HALL,
ASTOR PLACE.
1868.

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1870, Jan. 18.
Gift of
Henry W. Longfellow,
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POLAR MAGNETISM.

With the consent of the society, I propose this evening to read a paper which I have prepared, on the subject of polar magnetism—the attraction of the needle to the pole—the variations of the compass, and the phenomena observable as incident to the same.

The subject stretches over a vast area of natural truth, and therefore on an occasion like the present I must necessarily be very brief on each particular point. I do not propose to examine, criticise, or discuss any of the written theories on the subject, but to limit myself to my own personal observations and reflections, and to draw conclusions only from such phenomena as are manifest to our vision and sense, irrespective of all previous theories and speculations in regard to them. The subject has not only a vast scientific importance, but also a great commercial value, and it is in this latter connection chiefly that, in the first instance, I have been led to consider it.

Some knowledge of polar attraction is necessary to the study of astronomy; it is of national importance, inasmuch as the direction of the needle is oftentimes the

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arbiter of the lines and boundaries of our national domain, as it is also of our private estates; we rely upon it when, in traversing the continent, we plunge into the depths of the forest, and it is our only safe guide over a trackless ocean, through darkness and tempest, to the haven we seek. Tens of thousands of lives, and hundreds of millions of property throughout the world, are every hour dependent on it for safety; any inquiry therefore into its causes, and the laws which govern it, is invested with an interest second to no other; and, notwithstanding this, it may safely be said that, in comparison with the whole that may be known, very little is at present positively known concerning it.

The existence of polar magnetism was first revealed to us by the discovery of the compass. There is some doubt as to the exact time of that discovery, but it is supposed to have been first put to practical use by the early navigators in their commerce on the Mediterranean Sea. At that time, and long afterward, the needle was supposed to tend always toward a fixed point in the north; and therefore, when Columbus undertook his voyage of discovery, he was greatly surprised and not a little perplexed to find that, as he sailed westward, the needle gradually changed its direction; and his crew became so much alarmed by it, that all the steadiness of mind which that great navigator possessed was necessary sufficiently to calm their fears to prevent an open mutiny, and thus defeat his enterprise. In later times, by the observations

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of later voyagers, explained by charts, together with improved instruments for observation, and the means invented for determining the variation at any point, navigation has been made quite safe and certain to the careful and skilful navigator. But, so far as I am informed, the *cause* of these variations of the compass, and the laws which govern them, are wholly unknown to science.

I shall not detain you with a detail of the course of reasoning by which I have, in my own judgment, arrived at a full conclusion in this matter, but state broadly, and at once, what that conclusion is, and then explain some of the evidences on which it rests.

The CAUSE, then, of the variations of the compass, which some have supposed to proceed from the oscillations of the Earth, is, in my judgment, THE REVOLUTION OF THE MAGNETIC POLE AROUND THE NORTH POLE.

By the Magnetic Pole we mean that point on the Earth's surface within the Arctic circle to which the needle points. By the North Pole, we mean of course the polar axle of the Earth on which she turns in her diurnal revolution. And by the variations of the compass, we mean the divergence of the needle's point east or west, from the true north point, with its variableness at different times and in different places.

The revolution of the Magnetic Pole occurs gradually, through a long period of time, and, according to the best data which I can obtain, is completed only once in about six hundred and forty years. The time may be found to

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be somewhat longer or shorter when settled by accurate observation.

The exact position of the Magnetic Pole has never been accurately known. It is known, however, to be at present situated on the North American Continent, in a high latitude, and considerably west of the longitude of New York. This was made manifest by the observations of Captain Ross in his polar expedition. He placed the Magnetic Pole in about latitude 70° 30′ north, and longitude 96° west from Greenwich. It has changed considerably since that time, and is at present both farther north, and farther west, than he placed it.*

The variation of the compass from the true north point at London or Greenwich is at present westerly. At New York it is still westerly in a less degree, and at the islands in the Pacific Ocean it is easterly. Now, if the accurate variation at each of these points be taken (all local attractions being absent), and lines in the direction

* That Captain Ross did not quite reach the Pole, is, I think, self-evident, because if the situation of the Pole had been in 70° 30′ north, and longitude 96° west, it would have given a greater variation at London than existed at that time. But that his was the nearest approximation to the truth ever before known, is nevertheless quite certain. Almost at the same period of time, Humboldt placed it in his estimation in latitude 79 °north, and longitude 27° west from Greenwich. This was certainly very far from the truth, as the observations of Captain Ross, and all other authentic facts, conclusively show. For myself, I am unable to perceive on what basis of known truths Humboldt could have grounded his opinion.

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of the needle be produced northerly, they will meet at a point not far from 76° north latitude and 118° west longitude from Greenwich. And that point, wherever they do meet, may safely be affirmed to be the present position of the North Magnetic Pole. It is not necessary for our present purpose that we should fix the exact point, nor are the means at hand to do it if needed—it must be done by careful and repeated observations at the same time on different and widely separated meridians, so as to exclude all possibility of error.

The only point necessary for us to determine for our present purpose is, to show that which has already been shown, viz., that the Magnetic Pole is situated at a considerable distance from the North Pole, and that being proved, we must now look for the evidence that it REVOLVES ABOUT THE NORTH POLE, which we will proceed to do.

In the year 1658, as shown by the records at Greenwich, the needle pointed due north from that position.* It is, then, certain, that in 1658 the Magnetic Pole was situated on the meridian of Greenwich and between Greenwich and the North Pole, or, coinciding with the North Pole, or in a line beyond it, at 180° west. No other supposition is possible. From 1658 the needle began to have a westerly variation at Greenwich, which continued to increase till the year 1818, a period of 160 years, when it had obtained its greatest variation. Now, on the suppo-

* Brand's Dictionary of Science, article "Magnetism."

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sition of the revolution of the Magnetic Pole, it is evident that it would attain its greatest variation when it had passed over 90° in the circle in which it revolves, and that in its progress of revolution the variation would then become less. Accordingly we find that in the year 1818 the westerly variation at Greenwich began to grow less, and from that time to the present has continued to decrease, which is in accordance with the necessity of the case in the supposed revolution.

From 1818 to 1868 are fifty years, in which time, supposing the period of one hundred and sixty years to have been the exact time in which the Magnetic Pole, by its revolution, passed over ninety degrees of longitude in the circle in which it revolves, in fifty years it would pass over twenty-eight degrees more, which would place it at this time in longitude 118 degrees west, where it is found to be, as nearly as can be determined.*

Coming now to the longitude of New York, although we have no record here going back to 1658, yet we know the fact that the westerly variation is increasing at New York, while it is decreasing at London or Greenwich, and this also is a necessity of the case in the supposed revolution; and if the hypothesis of revolution be true, and the period from 1658 to 1818, when it passed from zero to

* In placing the Pole at 118° west, I give it the same ratio of progress which it appears to have had for 160 years, viz., from 1658 to 1818. But if we consult the present variation as observed at New York, it would appear to be not quite so far west, or at about 116° west.

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its greatest westerly variation at Greenwich, be perfectly accurate, then it will continue to decrease at Greenwich till the year 1978, when the needle will again point due north at Greenwich; while at New York (longitude 74° west) the westerly variation will continue to *increase*, and will not attain to its greatest point till the year 1950. And corroborative of all this, supporting the hypothesis of revolution, it is known, that about the year 1790 the needle pointed due north from New York, as it should do, while to-day it has a westerly variation of nearly eight degrees, which again is in perfect accordance with, and indeed an absolute necessity in, the supposed revolution. The period from 1658 to 1790 is one hundred and thirty-two years, being the *pro rata* time necessary to pass over 74 degrees of longitude; and here it will be apparent that in 1790, when the needle pointed due north at New York, the magnetic pole was then situated on the meridian of New York, and it is now 44 degrees west of it; thus showing the progress of revolution.

Going still farther west to the islands in the Pacific Ocean, we find there, that the variation is *easterly* and growing less, still fully supporting the hypothesis of revolution.

I will mention but one other fact in proof of my position. Dr. Bowditch in his Navigator mentions, that in 1580 (a period 78 years earlier than any yet mentioned) the needle at London then pointed *eleven degrees and some minutes* EAST. The Magnetic Pole must then have been situated in

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about latitude 76 degrees north and 45 degrees *east* from London, and between that time and 1658 it had moved up to the meridian of London. Now, if we add to this the facts already proved, that from 1658 to the present time the Magnetic Pole has moved from the meridian of London to 118 degrees west of it, and having passed over the meridian of New York, the proposition, that the MAGNETIC POLE REVOLVES ABOUT THE NORTH POLE once in about 640 years, is then, I think, fully demonstrated; and there is nothing lacking in the demonstration but the exact time of the revolution, which, as I have said before, must be determined by future careful and accurate observation. It no doubt may be determined with nearly as much accuracy as the periodical return of an eclipse.*

* The only evidence which I have seen going to disprove my hypothesis of revolution, is a remark of Dr. Bowditch in his Navigator; while at the same time giving some dozen or twenty statements of the variations of the compass at different times and different places, all of which are perfectly consistent with, and corroborative of, the truth of my position. He also says that in 1708 the variation of the compass in Massachusetts (probably at Cambridge) was 8° west—in 1742 6° west—and in 1780 2° west. This is not possible with the truth of my position, and one or the other must be in error. If he had said east instead of west, it would have been in perfect accordance. It may be an error of print, or the difference may have been caused by local attraction; but I am more inclined to think that the difference arose from the fact that the observers in these cases *reversed the poles*, and that their meaning was, that the variation of the true north from the needle's point was so many degrees west. If we suppose this to have been the case, and that the variations, as we now define variation, were east and not west, their

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Two other important facts are also proved by what has been shown. First, that in 1658, when the needle pointed due north at London, the Magnetic Pole was then situated on the meridian of London, and between that and the North Pole, and not on the opposite side of the North Pole, at 180 degrees; and *secondly*, that the revolution is from east to west. Because, had the Magnetic Pole then been situated on the opposite side of the North Pole from London at 180 degrees (and it must have been on one or the other of these points), and revolving in the ratio as we have seen, in order to produce a westerly variation at Greenwich or London, the revolution must have been from west to east. And although in that case the variations at London would have been precisely the same as they have been, yet in passing over 118 degrees of longitude it would place the Magnetic Pole to-day in longitude 62 degrees west, where we know it is not, and the variation at New York would have been at present easterly and increasing, instead of westerly and increasing in that direction as we now know it is. It is therefore certain that the revolution is from east to west.

record would then be in perfect conformity with both the theory and progress of revolution as we have explained it. Such a supposition is not improbable when we consider that one hundred and sixty years ago the whole subject was but little understood or attended to in this country; and when we reflect that from 1658 to the present time the Magnetic Pole has occupied two hundred and ten years in passing from the meridian of London to its present position, it could not have been in a situation to give a westerly variation at Cambridge in 1708, and the foregoing solution of the Cambridge record is the only one possible.

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Having now gone so far, and as I believe demonstrated beyond a doubt, the fact of the revolution of the Magnetic Pole, the subject rises to a higher sphere, and the questions naturally suggested to the mind are, what is Polar Magnetism? and what is the *cause* of this revolution?

These are lofty questions indeed when we consider the source and influence of the things we are to inquire about, and they are only to be approached with caution and reverence. I will, however, as in the former case, answer these questions at once, as I believe to be the true solution of them, and then give a synopsis of the reasons which direct my judgment to such conclusions.

I regard magnetism as a universal principle, pervading all space, and impressed on all matter, and one of the forces employed to regulate and control the universe; and I consider the revolution of the Magnetic Pole as being *caused* by magnetic attraction *to the highest centre or system, to which the Earth in her various revolutions is immediately related.* The attraction is from centre to centre, and the magnetic needle balanced in its horizontal position becomes an *indicator only of the line of attraction*, and directs itself always to that point on the Earth's surface which is in a line with the centre of attraction. There is therefore no absolute Polar Magnetism, or Magnetic Pole. It is ideal, not real, and like the Earth's axis it is only imaginary, but necessary to be considered in order to illustrate a truth.*

* In saying that there is no absolute polar magnetism, I must be un-

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I have said that I regard magnetism as a universal principle, and I so regard it because it is everywhere present in our world—in every place ever visited, in every imaginable position, it is there, possessing the same attributes and exerting the same influence. That which we call a "magnet," however, is not magnetism, any more than an electrified body is electricity—it is simply a magnetized body or substance, capable only of retaining its magnetism for a limited period. Both magnetism and electricity are latent and hidden principles in nature, the very existence of which is a mystery, and of which we know nothing except as we can witness their effects. They are natural forces, and although latent in themselves, they are yet capable of rising to a force little short of infinite, whenever circumstances combine according to their nature to call them into action. They are not the same, although they may be different phases of the same principle; but I doubt if enough has been learned of either, to justify a decision in that particular. They have many affinities in common, such for example as the attraction of iron—also the power of some bodies to arrest and turn away their current, and of others to receive and retain for a longer or a shorter period an impregnation of their qualities, which is again imparted to other bodies when placed in contiguity or brought into contact. The load-

derstood to mean that there is nothing there, at the Pole, to cause the attraction of the needle; its motion is governed by a higher law, and by a force with which the locality of the Pole has nothing to do.

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stone is only such a substance, to which magnetism has a strong affinity, and which has therefore the power of absorbing and retaining longer than any other known substance the magnetism it has received.

Both magnetism and electricity may be excited to activity by motion or revolution. Everybody has seen electricity excited by a revolving machine, and if you stand under a revolving belt in a manufactory, you will feel magnetism enough to raise the hair on your head; but no one will for a moment suppose that either magnetism or electricity is created by these motions—they are simply roused from inactivity, as latent heat is rendered active by motion, concussion, or attrition. The difference between the two I conceive to be, that the force of electricity is eccentric, diffusive, and equalizing; that of magnetism is concentric—attracting to the centre.

From all the phenomena which I have been able to see or observe, I have come to the conclusion that what we call polar magnetism is the result of a magnetic force rendered active by revolution. As before stated, the force is concentric, attracting to the centre. It is therefore centripetal, and, considered as a universal principle of nature, it identifies itself with that force which astronomers call the "attraction of gravitation," a force known to exist, but for which no satisfactory cause has ever been assigned; and we are here led to ask, what is that force, if it be not magnetism? By whatever name it may be called, we believe it to be the same force which directs

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the needle to the Pole, and which we habitually call "magnetism." That it is a natural force derived from a latent principle, and put in motion by a forward revolution, I think fairly deducible from what is well known to every astronomer, viz., that the magnetic attraction, or "attraction of gravitation," call it by what name we please, in revolving bodies is the opposite of that centrifugal force created by their revolution, *and always equal to it.* And since the motion of the heavenly bodies is sometimes faster and sometimes slower, as proved by Kepler's law, that in passing round their elliptical courses, they pass over equal areas in equal times, therefore the centrifugal force created by their motion is sometimes greater and sometimes less, which must always be met by an equal development of the opposite and concentric force to keep the planet in her orbit. And it is well known that such development is always obedient to the rate of motion of the body revolving. It is evident, therefore, I think, that the activity of the magnetic force is produced and regulated by FORWARD REVOLUTION.

That the attraction of the needle is to the centre of the Earth, I think is shown by a variety of circumstances. *First*, the shape of the globe is such that direct rays falling upon its surface, necessarily concentrate at its centre, and the attracting force would seem to be of that character; and *secondly*, if a needle be magnetized in but one end, that end will point downward towards the centre, though not at all increased in weight; but if both ends be

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magnetized, and the needle balanced to a horizontal position, it then points *in the direction of a line with the magnetic current.* For the same reason that the attraction is to the centre, if a compass be placed near the magnetic pole and compelled to keep its horizontal position, it refuses its duty and will turn every way at random; but if left to itself its point tends downward towards the centre of the Earth, and this is what is called in navigation "the dip of the needle," which increases always as you approach towards the Pole.

From these circumstances it has been sometimes assumed that the interior of the Earth is a powerful natural magnet; and even with my theory it is so, though not in the sense as has been supposed; for it will be seen at once that, if the attraction were to the centre of the Earth, by a fixed magnet, then there could be no change of variation in the same locality; and as we have seen that such change does take place, that theory is at once exploded.

We prefer, then, to follow our own choice, and assume that the direction of the needle to the Pole is only an indicator of a line of higher attraction; and that the immediate motive power is a concentric magnetic force, rendered active and *in*volved by revolution. Let us see then what will be the result.

We will suppose that the revolution of the Earth on her axis is the governing cause, or controlling force, the attraction being to the centre of the Earth; then the needle being balanced to a horizontal position, would always,

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and in all places, point due north and south, in a line with the centre of motion; which it never does, except in two places at a time (the antipodes of each other and through their lines of longitude); and there could then be no revolution of the magnetic pole, and no variation or change of variation. We must, therefore, look further for our evidence in support of the truth of our position.

Let us suppose, then, that the earth's revolution round the sun is the governing cause, the line of attraction being from the sun's centre to the centre of the earth.* It will be seen at once that in the earth's revolution round the sun, or with the sun round any other centre, her axle on which she performs her daily revolution, does not, and can not lie in a line with the line of attraction from centre to centre, but must lie at an angle to it. And how is this? If we draw a line from the north pole to the south polar axle through or over the Atlantic Ocean, and parallel to

* We make no question here of the laws of gravitation as demonstrated by Newton, or the character or degree of its force, which is always directly as the masses of the heavenly bodies, and inversely as the squares of their distances; the only question is the identity of the gravitating force with the magnetism which directs the needle to the pole, by whatever name we may designate either. It is worthy of remark here, that Mr. Barlow, in his experiments to correct the influence of iron in the ship on the compass, found that the attraction of iron on the magnet was of the same force and character as the "attraction of gravitation," although he does not appear to have observed it himself. He found that a hollow globe of thin iron had the same influence on the magnet as a solid globe of the same surface dimensions. In other words, he found the attractive force to be directly as the mass, and inversely as the square of the distance.

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the earth's axis, we find that the north magnetic pole lies west of such line at an angle to it, and the south magnetic pole lies east of such line at the same angle to it, and the result so far answers to the theory. But here we meet with difficulty; for if the earth's revolution round the sun should be the cause of polar attraction, the line of attraction being at an angle to the earth's axis, then because one body revolving about another body also in motion gains one revolution of the body around which it revolves, therefore the magnetic pole should revolve about the north pole once in every year, which it does not. Again, we have another difficulty —the earth does not revolve about the sun with either pole turned towards him; but the tropical zone is forever turned towards the sun, and never the polar regions; and the line of polar attraction is seen to be at a wide angle to the line of the sun's attraction. Confirmatory of our theory, however, there is an inferior polarity in the Indian Ocean, north of the equator, sufficient, in passing over it, to disturb the needle; and another in the Pacific Ocean, south of the equator, the two at about the same angle to the equator, as the north and south poles to the earth's axis. These polarities may answer to the sun's attraction, and the two, that is to say, the equatorial polarities and the north and south magnetic poles, are, as I believe, travelling together in perfect unison with each other. The south Pacific polarity was, I think, discovered by Captain Cook, and has since its discovery, as laid down by him, moved some twenty or more degrees west, thus keeping pace with the north magnetic pole on this continent.

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It is evident, I think, from what has been shown, that the north and south are the superior polarities, to which all others are secondary, because all others are in their influence purely local, while the influence of the north and south is paramount and universal.

We must, therefore, look to a yet higher source for the origin of that magnetic attraction which shall *cause* the revolution of the magnetic poles in the period of time in which we have seen that they do revolve.*

We have already seen that magnetism is a universal principle, and one of the forces which nature employs in the government of the universe; we have seen, too, that the force which it exerts is centripetal, and identifies itself with the force which controls the motion of gravitating bodies; we have seen that the line of attraction from any centre around which the earth may revolve must be at an angle to her axis on which she daily turns, and that the polar attraction *is* at such an angle; we have seen that if the attraction of the needle to the pole be governed and controlled by the attraction of magnetism from a centre around which the earth revolves, and such attraction is at an angle to the earth's axis, then, that point on the earth's surface to which the needle is directed, and which we have called the magnetic pole, shall revolve about the north pole in the same time in which the earth revolves about the governing centre of attraction; and we have seen that

* The North and South Poles revolve together, each being always opposite to the other, and at an angle to the Earth's axis.

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the magnetic pole does revolve about the north pole once in about six hundred and forty years, taking the period of one hundred and sixty years to be accurate, in which it has been seen that ninety degrees of the revolution has been performed.

All these conditions are necessary to the truth of our theory (and more might be both cited and proved), and they are conditions, all of which we have seen to exist; and one of these conditions, viz., the revolution of that subtile influence and immaterial point which we have called the "magnetic pole," could not exist or be performed by any other means than the magnetic attraction to the centre around which the earth revolves.

Our limited astronomy has given us the data of no higher revolution of the earth than that around the sun, although it is inferred from the order of things that she may revolve in company around a higher sphere, and to that we must look for the attracting force that will fulfil the necessity of the case. I shall here be found trespassing slightly on some of those creations of astronomical science which imagination has built on too slight foundations of truth, and which time will, I think, sweep away by discoveries in revolution as simple as that which swept away the ancient systems of astronomy from the faith of mankind. The simple turning of the earth on her axis was found to perform all those wonders, and account for all the phenomena, which men's minds had for centuries supposed employed

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the might of Heaven to move the whole universe around us for the accommodation of light to our comparatively little world.

The earth, we know, is balanced within a planetary system, revolving about the sun in perpetual order. We must then admit one of two things, to wit: That either the sun, with his system, revolves about another and a higher system, which is beyond our power of immediate observation; or, that the sun is fixed in the centre, and that his system embraces the whole visible and invisible heavens—which we have good evidence that it does not. The supposition is contrary to reason, and contrary to the order of revolution. We therefore assert, as a necessity, that the sun, with his system, revolves about another and a higher system, carrying the earth with him in the same manner as the earth revolves about the sun, carrying the moon with her. This is not a disputed proposition, and I only state it in this form to connect the thread of my argument.

The fact being admitted, it is reasonable to conclude that this is the highest revolution or source of magnetic attraction to which the earth—separately considered--is immediately related. First, because the attraction will necessarily be from system to system; and, secondly, because the earth being situated in the midst of the solar system, a part of it, and only a point in it, the line of attraction would be always nearly the same; or if affected at all by any other revolution, in a planet of the earth's

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magnitude relatively to these great systems, the effect would be a scarcely perceptible vibration. *

If these premises be all true, then it will follow that what we call the magnetic pole shall revolve about the polar axles of the earth in the same time in which the earth moving forward in company with the solar system performs a complete revolution relatively to that system around which the sun himself revolves. Let me not be misunderstood; this is not the sun's period; that of course is very much greater. The earth is only a satellite of the sun, and in the revolution of which we speak she has but repeated exactly, but on a grander scale, the same phenomenon which our own satellite, the moon, performs monthly; accompanying the earth in her orbit, at the re-

* I have not time or room here to attempt the demonstration of the truth, but I have no doubt whatever that, although the higher revolution is the governing cause of all, there is yet a daily and a yearly revolution which it would not be difficult to trace. Dr. Bowditch mentions a daily vibration (which is no doubt a revolution), amounting to some minutes of a degree, and I recollect that a few years since the same thing was observed by M. Leverrier, Director of the Observatory at Paris, which for want of another reason he ascribed to expansion by the sun's heat; but although magnetism is more or less intense in a high or low temperature, I cannot accept this as a sufficient cause for a change of variation. It may be caused by the sun's attraction, he being sometimes east and sometimes west of us; but the return of the needle during the night to its position of the previous day is too gradual to be caused by temperature alone. The yearly revolution, when traced out, will, I think, explain satisfactorily why the motion round the great circle is sometimes faster and sometimes almost stationary, or even slightly retrograde.

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turn of every full she has performed a complete revolution, *relatively to the sun's centre*, around which the earth herself revolves. So also the earth, moving onward in company with the solar system, performs a complete revolution, *relatively to that centre around which the sun revolves in his orbit.* We have seen that the magnetic poles (for the north and south poles revolve together) perform a complete revolution round the north and south polar axles of the earth once in about six hundred and forty years, and hence we infer that in THE SAME PERIOD OF TIME, the earth, still keeping her place in the solar system, performs a complete revolution relatively to another and higher system around which the sun himself, with all his attendant train, revolves. This revolution is accomplished by the simple fact that, because the sun is in motion in an orbit, therefore the earth, in her yearly revolution around his centre, performs more than a complete revolution of one primary circle in space; and consequently, in a series of revolutious round the sun, gains one complete year relatively to that centre around which the sun revolves. It is a demonstrable truth that every period of time marked by the revolution of the heavenly bodies is greater than one primary circle, for the reason that each and all of the heavenly bodies are themselves also in motion. Our theory then is seen to be that the magnetic attraction to that high centre is the force which directs the needle to the pole—that our revolution around that centre is the cause of the revolution of the so-called magnetic pole, which last

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is again the cause of the variations of the compass. The reasons given for the truths shown are sufficient for the effect—the effect is purely mechanical and plain to the sense; in harmony with the mechanism of the heavens and the order of revolution, and, until a better reason is shown, I am compelled to believe in its entire truth.*

The cause of gravity has never yet been explained or understood, notwithstanding that much is known of the laws which regulate it. Newton discovered that a falling body was governed by certain laws, and that these laws were applicable to the motions of the heavenly bodies, and this he called gravity, or the "attraction of gravitation." But neither he nor any one else, that I am aware of, ever explained in any satisfactory manner, even to himself, the *cause* of this gravity. But if my positions

* In limiting the period of the revolution to 640 years or thereabouts, it will be observed that the correctness of that period depends entirely on the accuracy of the observations and record of the variations of the needle from time to time. And as a consequence of the sensitiveness of the needle to diverting causes from local attraction, and the slowness of the motion, which renders it difficult to note the exact period of its passage of any particular meridian, together with the probable imperfection of the instruments in early use for observation, on which the records depend, even if all we have here said be perfectly true in principle, the actual period when found may prove to be somewhat longer or shorter than the period here named. Astronomers have suggested an indefinite period of six or seven hundred years, which I have sometimes seen mentioned, and which marks an epoch with them. They may, perhaps, find little difficulty in harmonizing it with this revolution.

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be true, it will appear that one law governs polar attraction, centripetal force, and the gravitation of bodies, viz.: a latent magnetism set at liberty, rendered active, and *involved* by a forward revolution.

The earth attracts all bodies to its centre, and a stone, because of its greater density, will fall quicker through the atmosphere than a feather; but I regard density as only an element of velocity in overcoming the resistance of a medium, and the atmosphere being withdrawn, the feather, attracted by the magnetic force, will fall as quick as a stone.*

There is one other result that must follow the truth of my hypothesis, too important to be omitted here.

It is well known that the motion of any body revolv-

* The subtilty and force of magnetism was illustrated by Laplace, under the name of gravitation. He says, "that if a new planet were thrown into space, it would instantly feel the force of attraction from surrounding bodies whatever their distance, and the velocity of that force, from one body to the other, would be many million times greater than that of light;" but I am not aware that he ever associated magnetism with gravitation, or treated of it as a universal principle and an active force in nature. Certainly he never considered the two as identical. Most of the inquiries of scientific men into the principles of magnetism have, as I believe, been expended in experiments on *magnets*, instead of *magnetism*. I can very well believe Laplace as to the velocity of magnetic attraction. We have an example of velocity in the Atlantic Cable. The electric influence is computed to have passed over a distance of 2,000 miles in $\frac{6}{1000}$ of a second,—but even that time was probably employed by the thought of the observer in marking the time, and the electric current passed in no appreciable space of time.

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ing about another body, also in motion, is necessarily spiral, and therefore the motion of the magnetic pole, revolving about the north pole, and being governed and controlled by the attraction of a body in motion around which the earth is revolving, shall also be spiral, never returning to exactly the same point. And hence because one law and one force governs both the motion of the earth and the revolution of the magnetic pole, therefore the polar axle of the earth *shall change* its position with every revolution of the magnetic pole, in such manner that the present poles of the earth's axis, in her diurnal revolutions, will, or may, at length reach the present line of the equator, and the equator will then become the poles; and thus the idea suggested by geology, that the present poles of the earth have, at some time of the earth's existence, been an equatorial region, becomes a problem solved, and reduced to a simple and undeniable truth. Not a doubt exists in my mind that such has been the fact and will be again; and I am not less satisfied that the Glacial theory of Professor Agassiz, so far as the fact is concerned, that parts of our own land, and of others in Europe and elsewhere, have at some time been the country of glaciers, is no longer a speculative idea, but a *mathematically demonstrable truth.**

* There is a truth known to astronomers, which I think strongly confirms this point of my argument. It is this: In the longitude of Athens it is known that the sun in Cancer does not come so far north, by nearly a degree, as it did two thousand years ago. Astronomers have inferred

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The early system of astronomy was, I think, incompetent to the solution of a question like the revolution of the solar system; and modern astronomy has done so little towards it, that it must be considered as yet open to examination and argument. I have hope, therefore, that the suggestions here made may prove a step towards a more perfect knowledge of it.

Years ago, when I first thought of the subject here treated of, it was only in relation to the variations of the compass as observed at sea, and its practical application in commerce and navigation. But I perceive that I have risen to much higher themes, and perhaps some may say, meddled with things too high for me; but I am unable to perceive that I have at any time gone beyond a just inference from the truths shown.

The simplification of the vast speculative ideas of geologists and others, which this examination has suggested

therefrom that the tropics are narrowing, and the earth consequently is drawing nearer to the sun. But this I think is a mistake, and that the phenomenon mentioned proceeds from the change in the line of the equator, as I have explained it; and that if we had had the opportunity, two thousand years ago, of observing south on the meridian of Athens, it would then appear that Capricorn has receded south to the same extent as Cancer, and *vice versa* at the Antipodes. It would also depend on what distance the meridian of Athens may be from the point where the former line of the tropic would bisect the present line, whether on some other meridian, distant from Athens, the sun's recession may not have been much greater than is seen at Athens. But for all evidence of this kind, the observations of astronomers are totally wanting.

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to my mind—my thorough conviction of their essential truth, and that the truths here shown may be availed of for the increase of knowledge and the improvement of science, are my reasons for making public my reflections on these matters. I submit them to the fate which future developments may award to their truth or falsity.

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NOTES BY THE AUTHOR.

I RESPECTFULLY desire the reader of the foregoing to regard the subjects treated of, as in *two divisions.*

FIRST.—The revolution of the magnetic pole round the north pole, which is based on observations of known data, and of record; and if the record be true, there can be no difference of opinion about the result. It is of *itself*, independently of what follows, a truth of the highest importance to science.

SECONDLY.—The origin and nature of polar magnetism, and the *cause* of the revolution of the magnetic pole.

This part of my subject is based on reasoning from natural laws, and the conclusions are the inferential consequences of such laws. It is, therefore, more open to criticism than the first division; but the only debatable question is, do the reasons sustain the conclusions? If they do, that ends the discussion, till other and stronger reasons are opposed to it.

On page 26, I have asserted the gradual changing of the poles of the earth, "in such manner that the equator may at length become the poles." It is not probable that in the progress of such change, the north pole, for example, can move southward, in any direct line. That also may revolve, and perhaps surround the globe spirally, following the plane of the ecliptic, and to that

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opinion I am inclined, as the most natural, and the mechanical result of the force exerted.

Astronomers have observed some change in the poles of the earth, relatively to the north star, but I am not aware that they have considered it as an actual change of the position of the pole itself, and without that, their efforts to account for the geological formations, and the glacial epochs, are, to my mind, unnatural, laborious, exceedingly complex, and *wholly insufficient.*

It has been suggested to me, that my assertion that "there is no absolute magnetic pole," and constantly treating it as real, is contradictory and unintelligible; and I admit that it requires a better explanation than has yet been given. It is unfortunate for us, that to make ourselves understood we are obliged to use the imagery of material things to express an idea of immaterial things; magnetism and electricity are without the pale of matter such as we can comprehend, and therefore, to describe the subtile and peculiar influence concentrated at the magnetic pole, we must help our thoughts by a figure. I would describe the magnetic pole then, not as a moving point, but as a focus of mingling rays, the centre of which is the daily revolution. If we could be present at that centre we should neither see nor feel anything different from what we do here, but the magnet would be sensitive to any approach to it, and probably feel its influence far off, like the gravitating force of water on its approach to the Maelstrom.

In a foot note, page 22, I have said that I have no doubt but there is a daily revolution of the magnetic pole, which has been considered by astronomers as a mere vibration, caused by expansion from the sun's heat. But let it be understood that it is a revolution as we have explained it,

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and caused by the revolution of the earth on her axis. It will be recollected that while the earth turns round once on her axis, she at the same time moves forward more than one million six hundred thousand miles in her orbit. Now if we can determine or assume the diameter of this daily revolution, or breadth of the vibration, whichever we please to term it, it is a basis for calculating the distance of the attracting force which governs the revolution. And the distance of the attracting force, which is such as to reduce the angle, which has over one million six hundred thousand miles for its base, to a few minutes of a degree on the earth's surface, is thousands of millions of miles from us; and, incomprehensible as it may seem, that distance may yet be known.

The idea is attributed to Sir David Brewster, that "magnetism is most intense in a low temperature." That is, no doubt, quite true by itself, and yet, the truth may reach much farther than that. What if it should be found that variations in the intensity of magnetism are the *cause* of changes of temperature? There is much reason to suspect that to be the case. It is seen that the temperature on the northern part of this continent, where the magnetic pole is at present situated, is subject to greater extremes than on the shores of Europe, or the coast of the Pacific in the same latitudes. I have reason to believe also, that the Polar Sea is more open by an eastern route round the North Pole, than by the route of Hudson's or Baffin's Bay, and next to my surprise that the voyage round the pole should ever be undertaken, is, that it should not be undertaken by the eastern route or by Behring's Straits. Four hundred years ago, when the magnetic pole was situated on the opposite side of the North Pole from Greenland, history tells us that that

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country was literally a *green land.* Since that time the magnetic pole has passed near to or over its northern portion, and it has become a country of ice and snows. The south magnetic pole is situated in about longitude 62° east (opposite the north), and if I am not mistaken, in that region, the barriers of ice obstruct the southern progress in a lower latitude than in other parts of the Southern Ocean. These things are highly worthy of a careful investigation by the learned.

A friend of very acute perceptions, and who has taken a great interest in the problems which I have endeavored to solve, asks me the question, "What will you do with the flattened poles of the earth,—does the earth change her shape with the changes of the pole?"

The question is pertinent and of force, and if required to answer it, my answer for the present would be this: Admitted that the poles are really flattened as they appear to be. It is known that both the north and south poles are situated in the midst of a wide and deep sea. The breadth of these seas is such that, admitting the truth of my hypothesis, the poles must have been within their area for many centuries past, and will continue to be so for many centuries to come. Let us suppose that the extreme radius of the flattened surface is fifteen degrees of the earth's surface on all sides of the pole; at that distance from the centre (the polar axle) the velocity of the earth's revolution on her axis will become such, as may tend, by its centrifugal force, to raise the surface of the water, or so to lessen its gravity towards the centre of the earth as to raise the surface somewhat. By a natural consequence, this force will increase towards the equator till you reach that point, or the greatest diameter of the earth east and west. By the same natural conse-

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quence, the centrifugal force will diminish as, from the radius of fifteen degrees distant, you approach the pole, where the centrifugal force is entirely lost. The water at the poles, then, being undisturbed in its gravity by the centrifugal force, will press outward from the centre and the poles become flattened. I see nothing irrational in this supposition; and it will be obvious at once that when the poles shall have passed over these seas, and be centred on the firm continents, the waters will assume their even gravity, and the earth assume her perfect globular shape.

Or, if this reason is not satisfactory, perhaps it may be thought to be a tidal influence, caused by the attraction of the sun and moon, which gathers the waters towards the equator, and draws them away from the poles; the effect would still be the same in causing the flattening of the poles, and restoring the earth to her globular shape, when the poles have passed the area of the wide seas in which they now exist.

There are many evidences to show that the waters of the Atlantic Ocean, and of its bays and sounds, are fuller now than they have been at some other time long past—such as the washing away of the headlands and islands of our sea-coast. Witness the northern shore of Long Island and the numerous bluffs now half sunk in the Sound; witness the numerous islands in Massachusetts Bay and their steep crumbling sides and diminished areas; go across to the British Channel and examine the Cliffs of Dover and the bottom of the sea around them, and abundant evidence may be found, both that many centuries have been employed to undermine and pull down their lofty crests, and that time was when they were not so as they are at present, and when the sea did not reach their base. There is a bluff on my own farm on Long Island sixty feet high,

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which has been washed away full eight hundred feet inland, and the boulders have fallen down, and are now covered with the tide. Once or twice every year the storms and high tides rise up over the beach and lap up and carry away a furrow at its base, which is filled up again by the washing of the rains, the same to be repeated year after year. At the rate the process is now going on, say about two inches of the whole face yearly, it would occupy four thousand eight hundred years to accomplish what has been done, and examining the channel outside of it, I would say that the water is now twelve or fifteen feet higher than it *could have been* when the headland was perfect.

The problems of new and exceeding interest which would result from the acceptance of the truths which I claim to have demonstrated, would be, I think, almost without bound; but I must leave them to those whose leisure and legitimate pursuits will allow them to follow out in minute particulars that which I have only sought to grasp as a whole.

JOHN A. PARKER.

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SECOND LECTURE

ON

POLAR MAGNETISM:

ITS ASTRONOMICAL ORIGIN, ITS PERIOD OF REVOLUTION,

AND THE

SYNODICAL PERIOD OF THE EARTH IDENTICAL.

BY

JOHN A. PARKER.

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POLAR MAGNETISM.

ITS ASTRONOMICAL ORIGIN; ITS PERIOD OF REVOLUTION AND THE SYNODICAL PERIOD OF OUR EARTH IDENTICAL.

In a paper published by me, as read before the Society of the American Institute in March last, on the subject of Polar Magnetism, I showed, from the records of the variations of the compass for nearly three hundred years past, that the Magnetic Pole, in its movement westward, had in that period passed over more than 160 degrees of longitude in its revolution round the North Pole or Geographical Pole of the Earth.

The reasoning on this subject appearing to be conclusive, that the Magnetic Pole revolves about the North Pole, we were naturally led to the inquiry, What is Polar Magnetism? and what is the cause of this revolution? Those who have read my published paper on this subject with care, will know that our solution of those questions was in effect: that the forces of magnetism and gravitation are identical,—that the force which directs the needle to the Pole is wholly astronomical,—that the

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source of the governing attraction is from the highest centre to which the Earth in her various revolutions is immediately related,—that the revolution of the Earth relatively to that centre is the cause of the apparent revolution of the Magnetic Pole,—that the period of the revolution, as indicated by the recorded variations of the compass, is about 640 years, more or less, to be determined,—that the Earth in that period, as a satellite of the Sun, performs a revolution round the Sun relatively to the central point of the Sun's orbit, exactly similar to that which our own satellite, the Moon, performs in her synodical period, in which she revolves about the Earth relatively to any given meridian, from opposite the Sun's centre (the central point of the Earth's orbit) to opposite that centre again.

These are our main positions, which we are bound to prove by direct and unequivocal evidence, and also to defend and sustain against all contrary evidence which the ingenuity and skill of scientific men may bring against it.

If these things shall prove to be true, a Reviewer has said, "they will rank among the most daring and felicitous in the annals of scientific discovery;" and if I may be allowed the expression of my own judgment in the matter, taken with all their adjuncts, they will prove as useful for the extension of knowledge as any scientific discoveries ever made.

Before we proceed further, however, to illustrate and prove our own theory, it may be well to examine the

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position which the science of the schools at present occupies on this subject. We shall do so disembarrassed of the technicalities with which scientific men have surrounded the general subject, and which, as I believe, are a bar to their own progress and discovery. It must be recollected, however, that we are not discussing the general principles of magnetism, or its abstract quality, nor the particular properties of magnets, or the numerous experiments to which they have been subjected, and which have occupied so large a share of the attention of scientific men; our subject limits itself and all inquiry to that paramount law, which, local and disturbing influences apart, at all times and in all places claims the direction of the needle to the Pole. We must therefore confine our remarks to what is at present understood in the schools in respect to this branch alone of magnetic phenomena.

From the earliest date of discovery of any change in magnetic attraction, it became a subject of inquiry by what law these changes were governed. For a very long time knowledge was confined to the observations of a few individuals in limited spheres; and these served little purpose except to establish the fact that changes were taking place, but without being able to assign any reason for it. Explorers and navigators finally became the largest contributors to the knowledge of the world on this subject. By visiting almost every accessible part of the globe, and reporting their observations at home, a vast amount of facts were furnished for the use of investiga-

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tors; as these discoveries increased, the manifest importance of the subject enlisted the aid of governments in the interest of the schools, and the last half century has witnessed a more extended effort than ever before, if possible to discover the laws of polar attraction. For this purpose the observations of all time have been brought together, and the minds of eminent men have been engaged, to see what results could be obtained from the facts thus collected.

These results can be soon stated. It has been discovered that there is a line surrounding the globe, bisecting the terrestrial Equator at an angle of twelve or fourteen degrees, which they have called the Magnetic Equator. It is that line where the needle has no inclination or dip, but rests perfectly horizontal. It requires the minutest possible observation to be able to locate it within a degree or more of latitude.

As at present indicated, it passes over the wide continent of Africa where no observations at all have been had. It passes over the widest portion of South America, where very few observations have been had, and it passes over the kingdom of Siam and the Island of Borneo, where there have been no surveys at all. To supply the deficiency of observations over all these regions and wide intermediate tracts of ocean, other means were resorted to in their endeavors to locate the Magnetic Equator throughout. It was discovered that the inclination or dip of the needle increased in nearly a regular progression as we proceed

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northward from the line of the Equator towards the Magnetic Pole, and this fact was made use of with apparent good judgment to assist in determining the locality of the Magnetic Equator, and consequently also of the Magnetic Pole. But when, by careful calculation from all the premises and ascertained facts at hand, the Equator was supposed to be determined, it was found to be no Equator at all—that it was wholly irregular and without symmetry, and hence of no use whatever in determining any truth relatively to itself or to the Magnetic Pole. Nothing discouraged however by the want of success, the eminent men and scholars engaged in the work have enlarged their labors—they have collected together all the observations made to this end in every part of the world, both those which are recent and for a long series of years past—they have divided the globe into eastern and western hemispheres, in reference solely to the east and west variations of the needle, and they have covered the globe as it were with the lines produced from the observations so collected—but all without success to discover a law which should govern polar attraction and thus point to the Pole itself.

The same course of reasoning is still being pursued, and scientific men in Europe and America are engaged in collecting new observations, and drawing lines as deduced therefrom;—lines of declination, of inclination, and intensity—lines parallel, convergent, and divergent—lines in fact of every imaginable name and description, with a view to determine accurately the position of the Magnetic

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Equator at any given time with its corresponding Pole, and the laws which govern their changes as observed from time to time: and I need not say that all this has been without success for the objects intended. The only positive knowledge which these exertions have given us, is a knowledge of the facts which explorers have communicated, but with no law whatever to govern them;—no two theorists agree in their results. Humboldt, who may be supposed to have been among the most learned in theory, placed the Magnetic Pole by calculation in latitude 79° north and 27° west, almost at the same time when Ross found it by practical observation to be situated approximately in 70½° north and 96° west. Where there is so great a discrepancy between fact and theory, there is necessarily a fundamental error either in the theory itself or in its manipulation.

Whatever of truth and sound reason there may be in the use made by scientific men (and there is, no doubt, very much of both) of the facts in their possession in this regard, their inevitable failure from inherent causes to arrive at true results is, I think, manifest.

First.—Because the facts from which they reason, for want of means to distinguish, necessarily include the disturbances due to the sensitiveness of the needle, but which do not belong to the law of polar attraction.

Second.—The changes going on are such that, with their method of applying facts, that which was true a year ago is not true at the same point to-day.

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Third.—Many, and indeed most of the facts collected together, and which form the material of their work, are facts determined by observations made by different persons, and at different times, so wide apart, that although all of them were perhaps true at the time and place of observation, yet only one of them could be true at the same time, and not one of them is exactly true to-day.

Fourth.—It is self-evident, I think, that no true result can ever be arrived at by the method of imaginary lines, unless the facts on which such lines are based could be determined in all parts of the world at the same time, which has never been done and does not admit of a possibility.

In all the experiments of scientific men, they have regarded the Earth as the source of magnetism. Not a half century ago, many of them considered the centre of the Earth as a fixed magnet, and all magnetic influence was referred to that cause; but the changes observed contradicted that idea, and they have latterly imagined magnetic veins running through the Earth, which they have endeavored to trace by lines drawn upon its surface. To account for the changes going on, these veins have been supposed to be shifting, so as to accommodate the veins to the changes. Some have gone so far as to imagine a constant circulation of the molecules or atomic principles composing the Earth, thus producing the changes of the magnetic tendency. The celebrated Arago treated this idea with seriousness.

It has been observed that temperature, the aurora bore-

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alis, and other natural phenomena, have an influence on the magnet, and it is doubtless true; but these influences, being a part of the general law of magnetism, they do not touch that paramount law which claims the direction of the needle as soon as these influences are removed.

The Sun's heat is supposed to cause the daily vibration of the needle—the periodical return of spots on the Sun have been supposed to have an influence on the declination of the needle, and some one has suggested that the Moon has such influence also, but by *no one, before myself, has it ever been advanced that the cause of polar attraction is wholly astronomical.*

I have thus given as full and true a statement of the condition of science in the schools on the subject of polar magnetism as our limited time and space will permit. I would remark that revolution as a cause or accompaniment of magnetic attraction was not heard of among them till since the publication of my pamphlet in March last. Since that time the *Cornhill Magazine* of June, the *Scientific American* of October, and *Silliman's Journal* of November, have each of them published an article indicating revolution, but without any acknowledgment of my paper, though it was sent to all of them.

We now turn to our own hypothesis, as explained in the opening paragraph of this paper:

In all inductive reasoning on physical laws, there are truths in nature which may be laid down as axioms, from which the reasoning admits of no departure, and I there-

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fore here lay down as axioms—*First*, that the laws of mechanics are the laws of nature. *Second*, that the construction of the universe, and the relations of the heavenly bodies to each other, and of our Earth to them, *is Nature herself*, and consequently in the relations of the heavenly bodies to each other, and of our Earth to them, we shall find the perfection of all mechanical laws. I think there can be no objection to these principles.

The question has been asked me by some intelligent persons, whose perceptions were not quite clear on the subject, "by what mechanical process the revolution of the Magnetic Pole around the North Pole can be accomplished by astronomical attraction?" I will therefore give an illustration, which I have given before at a private reading of my first paper on the subject, and which I think explains it.

Let us suppose that the globe before us is transparent in such a way as to admit a line of light passing through it. Let us then suppose that a single ray of light, emanating from some distant centre, shall strike the globe at twelve or fourteen degrees from either Pole, and passing through the centre of the globe at an angle to its axis in a line to the opposite side. It is seen that the ray of light will make a point on either side of the surface of the globe, each at the same distance from the geographical Poles, but at opposite angles to the globe's axis. Now let the globe revolve eastward on its axis: it is seen that the ray of light is stationary, but the points of light on the surface

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appear to revolve westward, while the globe is revolving eastward.

Now if you let the ray of light represent the line of attraction from the great centre around which our hypothesis assumes that the Earth is revolving, you will have a perfect mechanical idea of the revolution of the Magnetic Pole around the geographical Pole, caused by astronomical attraction, with this difference only, that whereas the ray of light appears to revolve with each revolution of the Earth on her axis, the Magnetic Pole only revolves in that period of time in which the Earth gains one complete year in moving eastward round the Sun, just as we gain one entire day when we travel eastward round the Earth, and just as the Moon, in moving eastward round the Earth, gains one revolution of the Earth on her axis, and just as the Earth, in moving round the Sun from opposite a fixed star to opposite that star again, gains one sidereal day.

Now let us observe that if the cause of the revolution of the Magnetic Pole be such as I have described, viz., attraction to a higher centre relatively to which the Earth is revolving, then *because* the Earth moves eastward on her axis and in her orbit, therefore, by the mechanical law which is our axiom in the case, the apparent revolution of the Magnetic Pole SHALL BE WESTWARD—and that the Magnetic Pole is known to have been moving westward for nearly three centuries, is a positive proof as far as it goes of the truth of our hypothesis; whereas if the Earth be the source of magnetism, as the schools teach us, this effect would be

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mechanically impossible. This is one of the many phenomena that confirm the truth of our theory, and we may safely ask the question, can anything be shown to the contrary sustained by an equal mechanical test of its truth?

The irregularities heretofore observed in the variations of the needle (and I would include *inclination* with *declination*) which have baffled inquiry, and led to the conclusion by many, that it was not governed by any law definable by reason, are, in my judgment, when examined upon their merits and aside from local and disturbing causes, a perfect evidence of the revolution of the Magnetic Poles, their equable motion through space, and the astronomical influence controlling their apparent motion. I will mention a few facts illustrative of that view, and in doing so I will keep to the axiom of mechanical truth and necessity.

London is situated in latitude 51° north, and the present declination of the needle there is about 20½° west. The Island of New Nantucket or Baker's Island in the Pacific is in longitude 176° west, nearly on the opposite side of the globe from London, and in latitude 13′ 30″ north,—the variation or declination there in 1866 was 9° 30′ east, or less than half that at London. Why then, being so nearly on the opposite meridian to London, has it not the same amount of variation east that London has westerly? Chiefly for the reason that being farther south, if a circle be described from each centre (London and

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Baker's Island) through the Pole, the radius of the circle described from Baker's Island is more than twice as long as that described from London, and the length of a degree in the circumference of such circle is more than twice as great, and consequently, the Poles being nearly fixed points, the variation is less than half as great at Baker's Island as at London.

Again, we suppose the Magnetic Pole to revolve in about 76° north. London is situated in 51° north and New York in 41° north. We at New York are therefore more than one-third farther from the line traversed by the Magnetic Pole than London is—consequently, for the reasons explained above, the variation or declination at New York can never attain to a greater amount than something less than two-thirds of the greatest variation observed at any time at London.

The greatest westerly variation ever observed at London was in about the year 1818 equal to 24½°—the greatest therefore it can ever attain at New York will not exceed about 15 or 16° west. But if we move northward on the meridian of New York to the latitude of London, the variation there (local causes aside) will always be precisely the same as at London whenever that point stands in the same position as London relatively to the Magnetic Pole, and will attain to the same extent as the greatest observed at London (24½°) whenever the Magnetic Pole shall reach the meridian of 90° west of it.

Again, it will be evident that although the Magnetic

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Pole moves through its orbit with a nearly equal motion (and entirely so except the small daily and yearly revolution), yet the variation of the needle changes much more rapidly at some times than at others at the same point, and very unequally at different points at the same time. The cause is easily seen.—Whenever the Magnetic Pole is on any particular meridian, as of London for example, it moves almost at a right angle to that point, and the variation increases rapidly; but before the Magnetic Pole reaches the meridian of 90° from the point of starting it moves at an angle so small relatively to the point of observation, that any increase of variation is scarcely perceptible, and as the change of variation becomes slower at London it becomes faster at New York. We have but to trace the motion of the Poles on the lines of the globe to have ocular demonstration of all these truths.

Similar apparent discrepancies exist in regard to *inclination* as well as the "variation" or declination, and from not dissimilar causes.

It has been quoted to me for example that my theory of the revolution of the Magnetic Pole cannot be true, because from the records of the observed *inclination* at London, it had changed but little more than 6° in 140 years, and at that rate it would take 7900 years to complete a revolution; but if we examine the mechanical effect of inclination upon the principle of the revolution of the Magnetic Pole, we shall soon see what inclination has to do with the latter. Inclination in north latitude

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is simply the downward tendency of the north end of the needle, which increases in a ratio not exactly determined as we proceed northward from the line of no inclination towards the Magnetic Pole. At the Pole the inclination is 90°.

Now, on the supposition of the revolution of the Magnetic Pole, it is self-evident that the inclination at London will be greatest when the Magnetic Pole is nearest, and least when it is farthest off. The Pole will be nearest when it is on the meridian of London, and farthest off when on the meridian of 180° from London.

As the Pole moves westward from the meridian of London, variation or declination will begin at zero and increase, and *inclination* will begin from its maximum point to diminish until the Pole reaches 90° of longitude, when variation will begin to diminish, and both *variation* and *inclination* will go on diminishing till the Pole reaches 180°. Thus we see that in obedience to the requirements of revolution, inclination has been diminishing at London from 1740 (the earliest record) to the present time. It must continue to diminish till about 1983, when the Pole shall reach 180° west from London. It will be seen also, that from the maximum to the minimum of inclination indicates half a revolution of the Magnetic Pole, and from the minimum to the maximum the other half; but the maximum at London can never reach 90°, because London is never at the Magnetic Pole, and the minimum can never descend to zero

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because London is never 90° of a circle of the globe from the Magnetic Pole.

These remarks might be continued almost indefinitely, and with appositeness to the case; but I trust that I have said enough to show that the seeming irregularities which have heretofore baffled inquiry, are in fact a necessity, and perfectly regular when applied to the revolution of the Magnetic Pole, and their existence is therefore the best proof we can have of the truth of our theory, so far as a perfect explanation of their apparent irregularities is concerned.

But our principles involve much higher truths than the apparent irregularities of magnetic attraction which it is proper that we should state here. They claim that magnetism and the attraction of gravitation are identical *in fact.* They are known to be so in the *degree* of their forces, and since nothing whatever is professed to be known of what causes gravitation, and since by its equality of force magnetism is seen to be capable of doing all that gravitation is supposed to do, the evidence is all in favor of their identity.

Secondly.—Our principles involve the necessity that all planets are magnetic, and hence their attraction one to another, and hence that attraction towards the Earth which governs the revolution of the Magnetic Pole.

The Earth being a planet and magnetic, it is justifiable to assume that other planets are magnetic also. I think their relative motions and reciprocal influences demonstrate

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this truth, and if magnetism and gravitation are identical, it is impossible to be otherwise.

Our Earth, on which we reside, is a lower order of planet—it is a centre to itself and to its own satellite, but to none else. All motion from that centre is therefore necessarily outward from that centre, onward and upward in an ascending ratio from the lower to the higher; as, of the Earth on her axis, the Moon about the Earth, the Earth and Moon together about the Sun, and the Earth, Sun and Moon about a higher centre. In obedience to the axiom of mechanical law, the ascending ratio must also be in strict geometrical progression, for geometry is neither more nor less in this case than exact mechanical proportion. Geometry is pure mechanics, and the one cannot be separated from the other. The period of the Earth, Sun, and Moon is the third in the ascending ratio as above named, and consequently the third also in geometrical progression. These facts being admitted, we are prepared to prove the period of the revolution of the Magnetic Pole by proving the period of the Earth's revolution relatively to the highest centre to which in her various revolutions she is immediately related.

In my work on the Quadrature, published in 1851, after demonstrating the circumference and diameter of one primary circle to be as 20612 to 6561, and the motion of three gravitating bodies to be as four to three of one primary circumference, I then establish the following geometrical proportion, viz.: "As one primary circum-

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ference of a circle is to the Moon's time round the Earth, so is the Moon's time round the Earth to the Earth's time round the Sun (see the Quadrature, page 114 in practical questions, and proposition 4, page 130); and the proportion stands thus: (the Moon's time round the Earth being 27.482666 +) 20612 : 27482666 :: 27482666 = 366.43555, which, pointing off three figures for units in consequence of the increase of diameter of the circle, is the number of revolutions the Earth performs on her axis in revolving about the Sun (the time being circular time), and this period it will be seen is the second in the order of ascension as we have before described. The *third*, which *is our period* of the revolution of the Magnetic Pole, will then stand as follows: 20612 : 366.43555+:: 366.43555+ =651.4409+, the revolutions *being years* instead of *days*, and this I believe to be the exact period of the revolution of the Magnetic Pole around the Geographical Poles of the Earth.

The brevity of this demonstration will not probably suit the judgment of those gentlemen learned in astronomical science as at present taught, who, following the angular system of their predecessors of more than twenty centuries, have developed nothing definitely relative to any period such as we have here given. We must, therefore, for our own satisfaction as well as theirs, examine this period a little more minutely, that we may see what is its significance apart from and beyond its government of the motions of the Magnetic Pole.

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As I have said in my last published paper on this subject, "this is not the Sun's period—that, of course, is much greater." The question then comes home with force, what period is it? and I answer, that it is the EARTH'S SYNODICAL PERIOD—a period never calculated, if indeed at all considered by astronomers—a period in which the Earth as a satellite of the Sun repeats on a grander scale exactly the same phenomenon which our own satellite the Moon performs every time she makes a complete revolution of the Earth relatively to the Sun's centre.

In this period the Moon having the Earth for the centre of her orbit, and starting from a point where she conjoins the Sun's centre (which is the centre of the Earth's orbit) with any given meridian on the Earth, she pursues her journey eastward round the Earth till she conjoins with the Sun's centre and that same meridian again; and this is her synodical period. She conjoins with no two meridians however at the same instant, but with every meridian on the Earth's surface in the course of one revolution of the Earth on her axis; and this is the highest revolution of the Moon which is exclusively her own, and once completing this, she goes on repeating it forever, following the Earth round the Sun.

So also the Earth having the Sun for the centre of her orbit, and starting from a point where she conjoins with any given meridian crossing the Sun's equator and the centre of the Sun's orbit, she pursues her journey

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eastward round the Sun till she conjoins with the centre of the Sun's orbit, and that same meridian on the Sun's surface again. And this is the Earth's synodical period in revolving about the Sun. She conjoins with no two meridians however on the Sun at the same instant, but with every meridian in the course of one revolution of the Sun on his axis; and this is the highest revolution of the Earth which is exclusively her own. After this she goes on repeating the same forever, following the Sun in his orbit round his great centre.

We have given the Earth's synodical period as 651.4409 + years.* The Moon performs her synodical period round

* From the solution of the problem of three gravitating bodies as shown by the Quadrature, pages 100 to 116, there results a series by which the Earth's synodical period is reached as the fourth in order from one primary circumference, the same as it is the third in order by geometrical progression.

For example, let C be the primary circumference of a circle (20612.), then C plus $\frac{1}{8}$=D plus $\frac{1}{8}$=E plus $\frac{1}{8}$=F plus $\frac{1}{8}$=G. Then G=651.4409+ which, pointing off three figures to the left for years, is the Earth's synodical period.

To show the direct connection of this series and this period with solar time, take the following example: Let C=1, then C plus $\frac{1}{8}$=D plus $\frac{1}{8}$=E plus $\frac{1}{8}$=F plus $\frac{1}{8}$=G, then G=3.160493+ to infinity. Now G is found to be exactly equal to the circumference of one solar day in its relation to the circumference of one diameter; hence G × 5153, the area of one primary circle, and ÷ 5184 the unit of one solar day as evolved by the multiple 6 will give 3.1415942+ to infinity, equal to the decimal circumference of one diameter. It is therefore competent from this series to produce the circumference of one diameter from any number whatever, and to any number of places of figures required, and with the use of any equal multiple or divi-

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the Earth in a little more than twenty-nine and a half revolutions of the Earth on her axis from opposite the Sun's centre to opposite that centre again, or twenty-nine and a half solar days (it is 29.530588+).

If therefore we give to the Sun the same number of revolutions on his axis, relatively to the centre of his orbit, from one conjunction to another (and he can have neither more nor less without breaking the order of revolution), it will prove that the Sun revolves on his axis relatively to the centre of his orbit once in twenty-two years and twenty-one days. Any fixed spot on the Sun's disc will therefore return in eleven years and ten and a half days from the time of its disappearance, or in half a revolution of the Sun on his axis relatively to the centre of his orbit. Herschell in his Astronomy gives the periodical return of the Sun's spots as eleven and eleven one hundredths years—equal to eleven years and thirty-nine days. Herschell did not claim to know anything of the period which we are endeavoring to prove; but the coincidence of time of the return of the Sun's spots abundantly proves its truth. But as the Sun's individual spots are not clearly identified, and some may doubt the entire

sor of the primary circle and the solar day. This series may also be made a perfect test of the truth of my ratio of circumference and diameter, and of the deficiency of geometers' ratio which it is not in the power of numbers or geometry to disprove. Many of these things, which are considered by mathematicians as mere curiosities of figures, are in fact mechanical truths of the very highest order.

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accuracy of time, we will not rest our evidence here,—we have a more sure testimony in what follows.

The Sun appears to revolve on his axis relatively to us in twenty-six or twenty-seven days. It is therefore certain that the above revolution of plus twenty-two years relatively to the centre of his orbit must be accomplished by a small daily precession over mean or sidereal time. Herschell gives the Sun's synodical period on his axis (*i.e.* relatively to the Earth and the Moon) as $27^d\ 5^h\ 5'$. The Moon's sidereal time round the Earth is $27^d\ 7^h\ 43'\ 3''$; at that rate therefore, according to Herschell, there is a precession of the Sun on his axis of $2^h\ 38'\ 3''$ in a sidereal lunation. We have thus the right amount of the Sun's precession in his axial motion relatively to us to conform to the period of 22+ years relative to the centre of his orbit. More exactly I think the amount of that precession is $5'\ 43''\ 32'''$ daily, equal to $2^h\ 36'\ 25''\ 57'''$ in a sidereal lunation, differing from Herschell's period but $1'\ 37''$ in a lunar month.* At that rate of motion, in plus twenty-two years the Sun by his precession will gain one complete

* Whatever difference there may be in the relative motions of the Sun on his axis and of our Earth, it being the primary of all relative motions, it can be neither more nor less than unit, and the unit of circumference irrespective of magnitude is 20612, which expressed in the divisions of time= $5'\ 43''\ 32'''$, which I assume, therefore, is the true difference in the relative motions of the Sun and our Earth on their respective axles; and I prefer this as a principle of motion rather than the result of Herschell's instrumental observation, which, like all other observations, is at best only a very close approximation.

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synodical period of the Moon and one precession added; and the Earth having passed twenty-two times round the Sun will have gained of solar time twenty-two times the amount of one precession of the Sun on his axis, the whole together equal to $32^{d}\ 0^{h}\ 51'$. This is just as it should be; the motion is perfectly mechanical, and the time agrees with Herschell's demonstration of the Sun's precession within a few minutes in plus twenty-two years. Neither one of these phenomena could exist without the other—they are in fact creative of each other; the existence of the period creates the precession, and the existence of the precession proves the necessity of the period.

I consider the evidence perfect in itself, and it is therefore certain, I think, that plus 651 years is the Earth's synodical period, and that the Sun turns on his axis relative to the centre of his orbit once in plus twenty-two years, in which, revolving about the Sun, the Earth conjoins with any meridian on the Sun, and the centre around which the Sun revolves. The fact that this same period is or is not also the period of the revolution of the Magnetic Pole turns wholly upon the admission or denial whether or not the attraction of the needle is caused by astronomical or planetary influence. If that be admitted, it is then an absolute necessity that the superior attractions which govern the Earth's motions relatively to the Sun and the centre of his orbit, must also govern the movement of the Magnetic Pole.

If I understand correctly the principles and necessities

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of combined motion, these orbs revolving together and about each other, all governed by the same laws, and their forces all equalized between themselves in respect to their relative magnitudes, distances, and velocities, can no more fail to make these conjunctions in the ascending and progressive order exactly as begun, without getting out of place in respect to each other, than the hands of a clock can fail to conjoin at 12 M. without getting out of place in respect to time. The perfect observance and exact fulfilment of this order is in fact a part of the law which keeps the Earth in her perfect balance, fulfilling her seasons in exact time, and with perfect safety.

I must here ask attention to the fact that in proving the exact period of the revolution of the Magnetic Pole, I have at the same time explained and proved the Earth's synodical period—a period not before known or understood in the science of the schools—and this is done chiefly by the aid of the Quadrature, so long condemned by the schools as a useless question.

I consider the evidence perfect in itself, yet I have no doubt but it will be rejected by those who contend for the orthodox and angular system of demonstration, which in my opinion is incompetent to discover the truth in either case. The true and immediate reason of its rejection however will be, that its simplicity and truthfulness to nature does not flatter the ostentatious pretensions of speculative learning. *Victory*, however, will not always hang in the balance, but must eventually be declared on the side of truth.

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There is another truth of Astronomy with which this period has something to do—it is the precession of the equinoxes.

Two forces are always active in revolution; and in order that revolution may be continuous it is necessary that one of the forces should always precede the other a little. Wherever there is continuous revolution, therefore, there is always a precession of one of the forces which govern it. It is a universal principle and a mechanical law, without which motion cannot be continued. It may be best illustrated by the steam-engine, and it is just as observable and necessary in the motion of the heavenly bodies as in the steam-engine.

In the construction of the engine one of the first difficulties encountered was to overcome the force of gravity. It was found that when the two forces of gravity and steam-power came exactly opposite each other the engine stopped. Something was wanted to carry forward motion beyond the centre of gravity, and this is exactly the same thing as precession in the motion of the heavenly bodies. Ingenuity and perseverance at length overcame the difficulty with the steam-engine, and it is a remarkable fact and worthy of attentive consideration, that the principle by which the difficulty is overcome is precisely the same as is observable in the relative motions of our Earth and the heavenly bodies, viz.: by a slight difference in time in the action of one of the forces,—a moment's precession of one force over the other. Thus, as we have just now seen,

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the Sun, the source of the governing attraction in his revolution on his axis, takes precession of the Moon in his orbit more than five minutes daily, and fulfils his revolution more than two hours sooner in a lunar month than the Moon completes her orbit relatively to a fixed star.

The Earth appears to be moving between two forces—the attraction of the Sun as the centre of the solar system to which the Earth belongs, and a force outside of the solar system which controls and limits the sidereal or mean year. But in the motions of the Earth the Sun's attraction always takes precedence, or has the precession, because, as I suppose, that the Earth is nearer to him than to the opposite force, and because the Earth undoubtedly belongs to the Sun's system.

Thus, while the Earth is turning on her axis, the Sun actually goes before, and the Earth is nearly 3′ 56″ longer in turning on her axis from opposite the Sun's centre to opposite that centre again, than she is in turning from opposite a fixed star to opposite that star again. The Earth in her daily revolution is thus carried forward beyond the gravitating centre of the two forces, the solar and sidereal, and the amount which she is thus carried forward is the Sun's daily precession.

Again, in the Earth's revolution round the Sun the Sun arrives at his solstitial points nearly forty-five seconds before the star arrives at the same meridian, and the solar year is ended before the sidereal year is ended; and this again is

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the Sun's annual precession at his solstitial points over sidereal time, or the mean year.

So also the Sun arrives at his equinoctial points about $3\frac{1}{2}$ seconds of time and plus 51″ of a degree before the star arrives at the same meridian, and this is what is termed the "precession of the equinoxes," in which, according to *our* theory, the Sun by his precession carries the Earth beyond the centre of gravity of the two forces which govern her motion; and this precession will surround the globe in about 25,000 years, sometimes called the great year of the Earth.

We are now to see what our period of the revolution of the Magnetic Pole and the Earth's synodical period has to do with the precession of the equinoxes.

In my work on the Quadrature, pages 97 to 99 inclusive, I have shown that "all periods of time are greater than the revolution of one primary circle in space, because all the heavenly bodies by which time is measured are themselves also in motion." The revolution of one primary circle in space when reduced to time is 23^h 51′ 23″ 20‴— and the sidereal revolution is the exact mean between one circular and one solar day, less 44″ 52‴, which is the Sun's precession at his solstitial points. In other words, the excess above the mean between a circular and sidereal and a sidereal and solar day is the Sun's precession at his solstitial points.*

* The solar day equals 24 hours, difference greater than circular day.....8′ 36″ 40‴

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As the Earth's synodical period is the same revolution as her annual period, only continuous for a longer time, and relatively to a higher centre, which is on a scale of geometrical progression above the annual period, it is therefore evident that the Sun's daily precession in the Earth's synodical period shall be the *mean of the difference* between a circular and sidereal and a sidereal and a solar day, and any excess of the actual period above the mean of such *difference*, shall be the Sun's precession at his equinoctial points. In this we follow the exact rule as seen to exist in the annual revolution and the Sun's precession at his solstitial points.

The actual mean as described above is found by calculation to be 2′ 9″ 10‴ solar time,* and the actual time of the Sun's daily precession in the Earth's synodical period is 2′ 12″ 37‴+ ;† the difference above the mean is 3″ 27‴+,

The sidereal day equals 23 h. 56′ 4″ 6‴, difference less than solar day.....3′ 55″ 54‴

The circular day equals 23 h. 51′ 23″ 20‴, difference less than sidereal day.....4′ 40″ 46‴

Excess of difference above the mean.....0′ 44″ 52‴

* The difference between one circular and one sidereal day is 4′ 40″ 46‴, half equals.....2′ 20″ 23‴

The difference between one sidereal and one solar day is 3′ 55″ 54‴, half equals.....1′ 57″ 57‴

Together = ...4′ 18″ 20‴

Half equals..... .....2′ 9″ 10‴

† The period 651.4409+ × 365.24225+ the days and fractions of days in

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which is the Sun's daily precession above the mean as before stated; and because in performing one complete revolution round the Sun, the Earth has gained one entire revolution on her axis from the Sun to the Sun, or one solar day, therefore the Sun, on the completion of the full year, arrives at his equinoctial point preceding the star by exactly the excess (3″ 27‴+) of the whole daily precession above the mean of the DIFFERENCE between a circular and sidereal and a sidereal and solar day, as before stated,—just as at his solstitial point, the Sun precedes the star by exactly the excess above the mean between a circular and sidereal and a sidereal and solar day.

The calculations by which these results are reached are perfectly simple and reliable, but the detail of figures would be too dry for rehearsal here, although some very curious and interesting facts might be developed thereby.*

The precession of the equinoxes is therefore seen to be

the mean year, gives the product 237933.74+, equal the number of solar days in the whole period; and this product 237933.74+ divided into the mean year reduced to the smallest appreciable divisions of time (thirds, or 60ths of a second) will give the required Sun's precession daily to accomplish the whole revolution. Thus, 651.4409+ × 365.24224=237933.74 + and 365 d. 5 h. 48′ 50″ 53‴ reduced to its lowest denomination = 1893415853 ÷ 237933.74=7957.74+, which is the amount of the Sun's daily precession over mean time, the time being in thirds or 60ths of a second, and 7957‴+ expressed in the proper divisions of time = 2′ 12″ 37‴+ the Sun's actual daily precession in the Earth's synodical period.

* The elements of the exact period of the Sun's orbit are, I think, developed in these calculations, which I am induced to believe is exactly 25,000 years,

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the natural and necessary result of the mechanical laws of motion, and not the result of accidental and extraneous causes, as has been taught by astronomy.

To speculate on the cause of an observed phenomenon and make a show of reason out of it is one thing, and to demonstrate the necesssity of such phenomenon, its cause and exact value by a mechanical law of universal application is quite another thing. And this is the real difference between me and the astronomers of the schools in regard to the cause of the precession of the equinoxes.

In my last published paper on this subject I said that "problems of new and exceeding interest, almost without bound, would follow the acceptance of the truth of my demonstrations." As yet I have scarcely touched upon their number or interest; others of a more startling nature than any yet mentioned, and not less clear and conclusive, are in reserve and ready to be demonstrated whenever the principles of revolution and the value of the quadrature are admitted. These demonstrations will contradict no *known* truth, but they will add many new truths to those already known. As in the case of the precession of the equinoxes, they will set aside some of the speculative causes of the observed phenomena, and substitute in their room a natural and efficient cause. They will correct false theories; and no one need be surprised if in a very short time from this astronomers should find themselves compelled to in-

but with a lap or precession at the end indicative of another revolution that will take over 13,000,000 years to fulfil.

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quire whether they have not always been mistaken in supposing the unnatural existence of a projectile force.

Sir J. F. W. Herschell in his Astronomy has remarked that "Astronomy, unlike the other sciences, can never change." His meaning doubtless was, that the truths of astronomy were fixed from eternity in the laws of nature, and therein he was right, and astronomy can never change. But some who have not Herschell's perceptions of truth, have construed him to mean that the science of astronomy as taught, being already perfect in itself, can suffer no change. But this is a very great mistake. There are many things taught as truths in astronomy which are purely conjectural. I speak not now of any of the observed phenomena, but of the causes assigned for such phenomena, which are often accepted by the learned only for want of a better explanation; and if my demonstration be true, such has been the case in regard to the precession of the equinoxes; by attributing it to a wrong cause they have been led into another error to find the cause of nutation. I believe that if the principle be accepted, that the Magnetic Pole revolves by astronomical attraction, gradually, but very slowly changing the equator and the Poles, it will at once explain all those curvilinear phenomena about the Poles of the Ecliptic, which have led to the assumed cause of precession and nutation. Precession and the appearance of nutation will still exist, but the cause of them will be quite another affair. They are simple, natural and mechanical truths, the result of a compound motion.

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I do not believe the story which the savans tell us to account for precession and nutation,—that this Earth of ours, which bears us all so kindly and smoothly on her bosom, is in fact a hump-back, and that she wags herself lewdly in presence of her lord the Sun when he approaches the equator. I am satisfied that she has no such deformity or infirmity, and that she will at length vindicate herself against all such aspersions of vain and presumptuous philosophers.*

* It is held by astronomers that the cause of the precession of the equinox is an accumulation of matter and protuberances of the Earth about the equator,—and that the attraction of the Sun and Moon acting upon the increased mass, gives to the Earth a disturbed motion, causing a vibratory movement on her axis, and this they call nutation or a *nodding*. I have no belief in such a cause.

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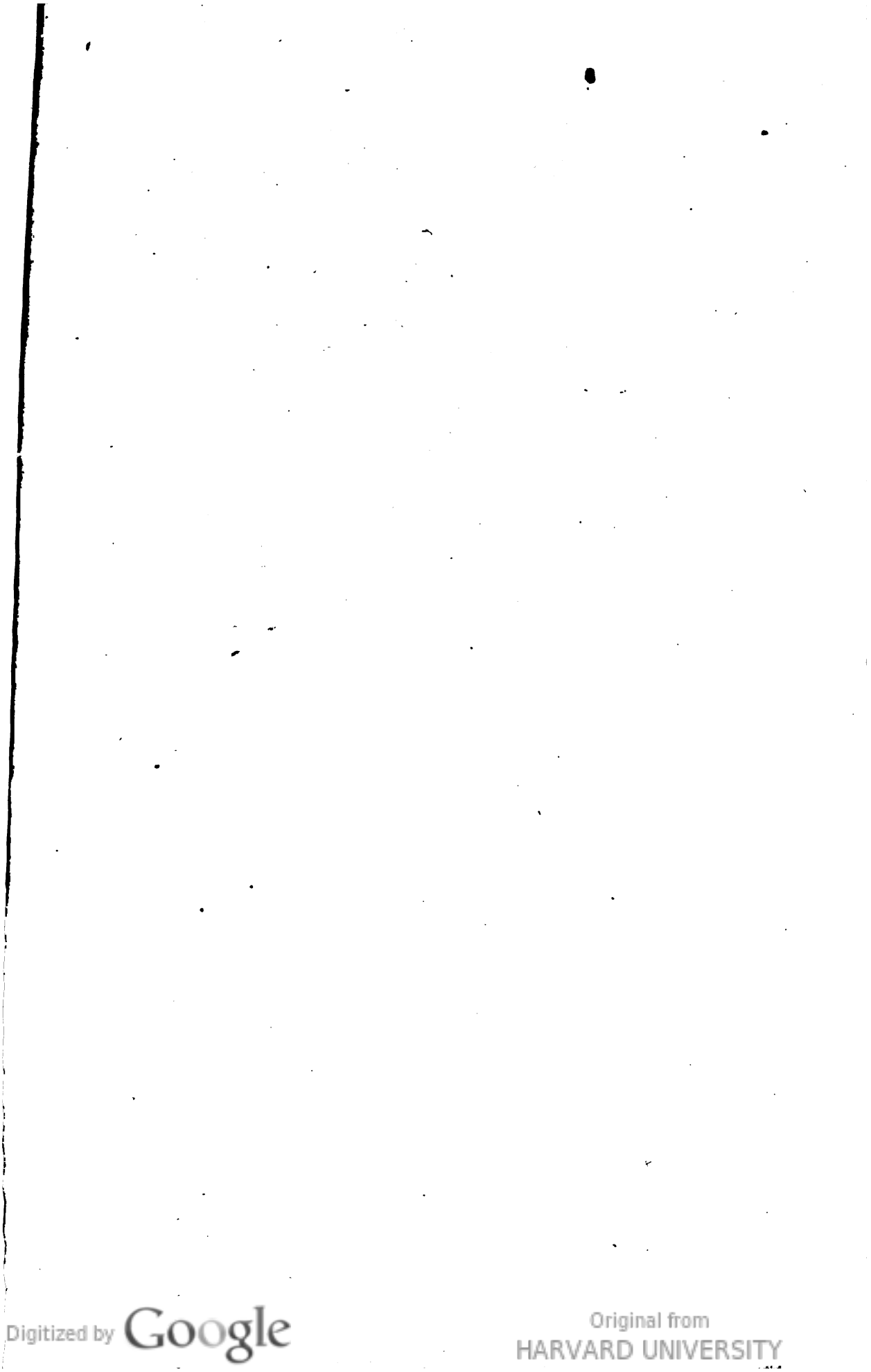

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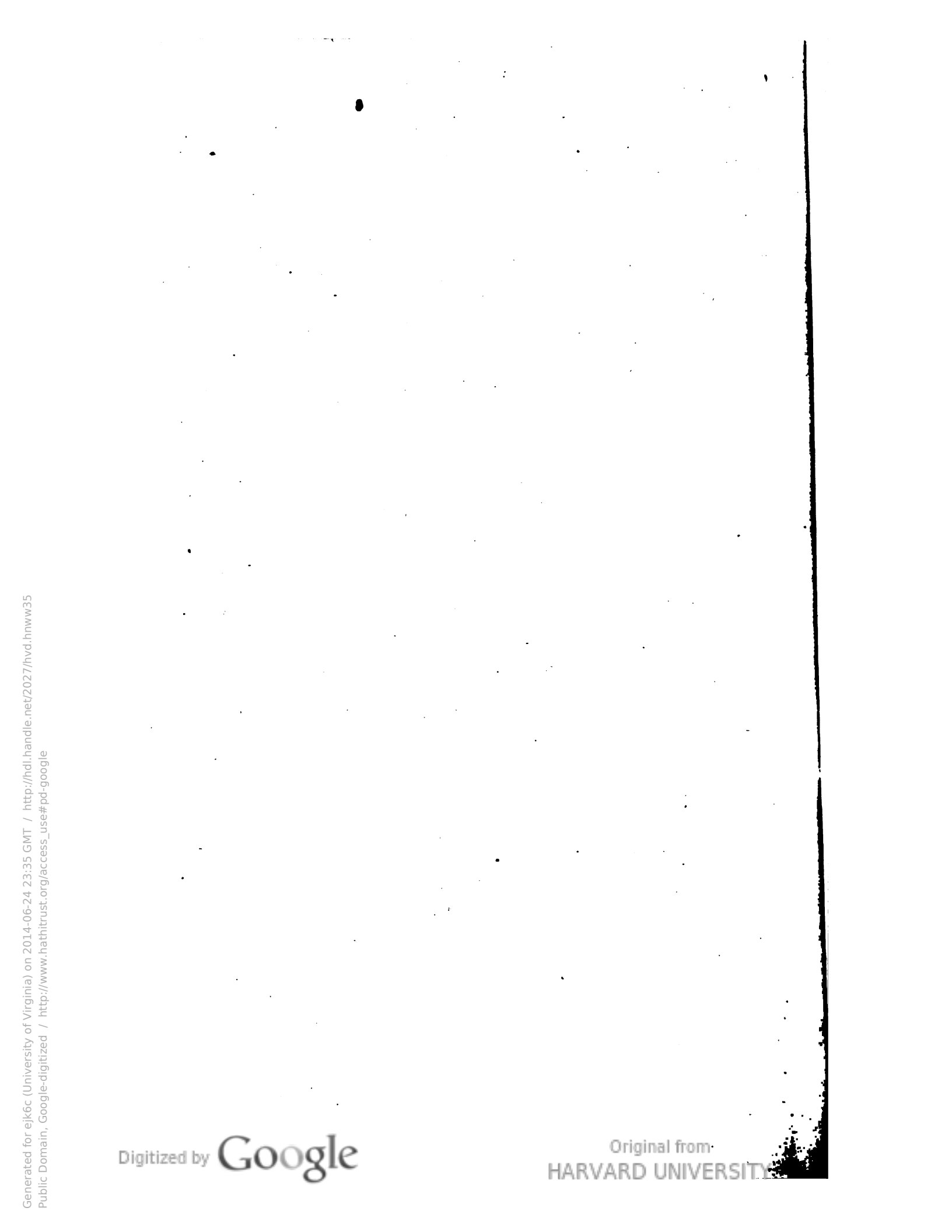

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