A History of Magnetism in Human Civilisation

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Magnetism on the Long Arc of Time

By

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To

Teetash & Atreyee

Tamaso Ma Jyotirgamaya

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Preface

> Science should treasure its own history, that historical scholarship should treasure science, and that the full understanding of each is deficient without the other.
>
> *Gerald J. Holton,*
> *The Advancement of Science and Its Burdens*

Sir Francis Bacon (c. 1561-1626) argued that Western scientific progress was built upon a foundation of three key technological discoveries which had changed man's ability to control the natural world. Those were the printing press, gunpowder and magnets. In this essay, the author humbly attempts to elucidate how our knowledge and understanding of the physical phenomenon, magnetism and its relation to the earth have been enriched. At the same time, we tread a long journey in the history of human civilisation; a long journey indeed and is undoubtedly a very challenging one, not only for those revered pioneers, philosophers, and scientists who dedicated their lives for the sole cause of understanding the beauty of natural physical phenomena, to be paraphrased – the *cosmic dance* in the physical worlds but also to me who has been able to collect only a few pebbles while wandering the shoreline in front a vast ocean.

The incredible human endeavour over many centuries and millennia has amassed such a significant level of understanding in the field of magnetism in general and geomagnetism in particular that no individual can recollect all and reproduce those in a limited space. Nevertheless, the author leaves no

stone unturned to mention the contributions of some great names. Despite such humble attempts, the author admits some omissions due to his ignorance or inability to find suitable space in this essay. The author, thus, owes an unqualified apology to the esteemed readers for such omissions.

The book's title gives enough scope for a reader to make an immediate impression that the book may cover some historical aspects of the science of magnetism, including some anecdotal evidence. The author believes that such an impression made by the readers is justified. In order to delve into the history of scientific methods, it is essential to build a coherent outline and an appropriate historiography using either solid pieces of evidence, wherever available, or pieces of anecdotal evidence. In that context, the following quotes are relevant here. "Whence can we guess the presence of a real relationship between observed data, if its existence has never been known (source: Science, Faith and Society by Michael Polanyi (c. 1891-1976))?" The author thus has attempted to look for how far back humans recognised some of the awe-struck properties of magnetism in general and geomagnetism in particular and how the observed attributes of magnetism had an impact on society that include (but not limited to) spirituality, religious believe, war, economics, honorific address, and many more.

While reading various chapters, readers may frequently encounter two words, magnetism and geomagnetism, which need clarification to be precise. The word magnetism is a natural physical phenomenon observed within a material and some other physical processes. Therefore, the topic of magnetism encompasses generality; on the other hand, the word geomagnetism is a portmanteau word made from geo (= earth) and magnetism, where *geo* is etymologically of Greek origin. The topic of geomagnetism thus possesses a limited scope. Therefore, magnetism becomes the root word where *geo* comes as a prefix. Indeed, the prefix has a role, but not without the root word. Therefore, one expects the discussion on magnetism to be more prevalent than geomagnetism in much of the book. The topics on geomagnetism become more pronounced slowly in the later part of the book, which seems normal, as synonymously, a person earns the prefix Reverend, Doctor, or Professor after a course of journey along one's metier.

Nevertheless, just like a castle (or a mansion) built with stones, bricks, woods, and mortars mixed with human blood, sweat and tears, the subject magnetism has been developed over many centuries by many souls with blood, sweat and tears, and also using both collective and individual wisdom. In this essay titled 'Magnetism on Long Arc of Time', the author attempts to bring forth the contributions of some of those great souls to the readers. The author, however, consciously decides not to make the subject more technical and scientifically rigorous, lest it lose the essence of easy reading and understanding. The author, indeed, cherishes the quote made by Albert Einstein "Make everything as simple as possible, but not simpler". Therefore, giving very brief outlines of every chapter a reader may expect while reading the entire essay makes sense.

The author informs readers that this essay falls under the category of history of science. Although society and science are two distinct entities, these two, nonetheless, exist in a symbiotic relationship. In the historical context, society has always steered science, and at the same time, the development of science has impacted society. Moreover, modern science in Europe, slightly more than five hundred years from now, was in the embryonic stage, whence the evolution of the societal framework gave the supportive ambience to grow. Therefore, the discussion on the history of science *sans* any reference to the societal framework in general and religion and ensuing politics, in particular, remains incomplete.

Therefore, readers will find, especially in the early few chapters of the book, some historical elaborations on society, politics and philosophical tenets that significantly influenced the development of the scientific discourse on magnetism. To this end, the author alerts readers with a caveat that one is likely to find the entire discussions on science, society, politics and philosophy have been built chiefly on the European perspective. The author cannot deny the overwhelming European influence in the development of modern science and their cultural hegemony (chiefly due to imperialism) throughout the globe.

Since the essay is essentially a time travel on understanding the science of magnetism, the chapters, as designed and labelled, are like time posts

erected on the time-travelled path. However, to maintain the entire course of discussion continuous and seamless, there is an overlap between consecutive time posts. The essay starts with the chapter **Ancient World**, in which the author discusses how humans perceived magnetism during pre-historic times, ancient civilisations up to almost a period a millennia earlier than now, in various parts of the globe. The chapter reveals how humans, shrouded with mysticism, could find some applications of magnetism.

Nevertheless, humans' perception of magnetism based on mysticism and divinity associated with the Christian Faith continued for several hundred years during the Medieval Period in Europe. The second chapter is time posted as **Medieval Europe** encompassing a timeline from the late 11^{th} to the late 15^{th} centuries. During this period, European people perceived magnetism more objectively, using appropriate design tools to use its directivity properties for navigation.

Overcoming the navigation issue was the primary motivation for those seeking to discover new lands and opportunities beyond the European mainland. The chapter titled **Early Age of Discovery** covers the timeline between the early part of 15^{th} century up to the end of 16^{th} century. The period was the watershed moment in modern European history, when the innovation of the printing press, social and religious reform, and the onset of 'Scientific Revolutions' took place. Mysticism on magnetism was slowly fading; instead, its practical usage of directivity property for navigation became the foremost concern, as competition for supremacy in economics and political power through discovering new lands and resources was fierce. Two new directivity attributes of magnetism, declination and inclination, were discovered, and new scientifically revolutionised thought processes emerged to explain natural phenomena.

The revolutionising thought process which emerged with the onset of the Scientific Revolution, which started nearly at the middle of 16^{th} century, continued for more than one and half centuries, brought the **Dawn of European Science** which is the chapter four of this essay. During this period, European nations were not only engaged in discovering new lands, habitats and economic opportunities but also in discovering new physical laws and

principles to understand various natural phenomena where magnetism found particular importance, both in terms of practicality in navigational usage and to satisfy the quest for the metaphysical and philosophical bends of mind. The chapter discusses at length the importance of the publication of *De Magnete* by Dr. William Gilbert and the onset of empiricism in scientific discourse. The discipline geomagnetism was born, and another new attribute, temporal variation of one of the magnetic directivity properties, was discovered. The motion of the geomagnetic Poles with inclined axis was conjectured.

However, within this timeline, the era of awakening transitioned into the era of enlightenment by the same motivating force that fuelled the scientific revolution in the early 16^{th} century and ultimately took centre stage. The era of awakening ushered the new philosophical indoctrination that decreed against mysticism associated with magnetism and promoted attempts to explain the phenomenological aspect of magnetism via empirical evidence supported by the doctrine of Cause and Effect. Serious reflection and fierce criticism of any conjecture and hypothesis became the rule. The slogan *Nullius in Verba* became the 'mantra' of the 17^{th} century natural philosophers.

The aura of rationalism continued, and the era of awakening transitioned into **At the Early Modern Era**, the fifth chapter of the essay. It ushered the onset of modern times with the light of modern science. The newly identified natural phenomenon of statical electricity, along with magnetism, occupied the minds of the researchers. The discipline of geomagnetism progressed further with the generation of a map of spatial variation of magnetic declination over the globe. The presence of a tilted geomagnetic dipole was rejected; instead, the four geomagnetic Poles theory was conjectured.

The **Early Modern Era** transcended into the **Age of Enlightenment**, comprising the sixth and seventh chapters of the essay. According to the timeline, this was 18^{th} century. The scientific discourse became rigorous, and more researchers were harmoniously involved in scientific studies. The new idea, besides directivity, of the magnetic force field germinated, prompting the establishment of the universal inverse square of the law of distance for magnetism. The discovery of new phenomena, the short-scale temporal variation on declination and inclination, ushered in a new understanding of

geomagnetic variation. The research on electricity, along with magnetism, was also accelerated, where it was not only restricted among the erudite academics but was even used for general public entertainment, bringing a new understanding of the phenomenological aspect of electricity and its effect on magnetism. The immediate effect was a significant pondering about the possibility of atmospheric electricity on the variation in geomagnetic activity.

The navigation method magnetically continued for decades, especially in determining longitude onboard a ship. The significant breakthroughs were the improved instrumentation and method of error minimisation in measuring magnetic declination and inclination. The renewed effort of preparing magnetic declination and inclination charts found priorities among the researchers. The long-standing issue of determining longitude onboard a ship was solved, but unfortunately, not the magnetic way. The solution to the navigation problem was possible as scientific development was not restricted to limited disciplines but spread across various fields, giving rise to the birth of mathematical physics. With the development of mathematics, many physical phenomena were investigated critically through rigorous mathematical discourse. There was an attempt to relate electricity and magnetism from a phenomenological point of view. Measurement of geomagnetic force field found priorities among researchers.

At the onset of the First Industrial Revolution, science found a new cohort, called technology, which focuses on the market economy by building industry to sustain consumerism. Chapter eight, titled **At the Age of Ushering Technology**, reflects on the development of the science of magnetism aided by a new vision of a demand-driven mercantile economy. The most significant development was Volta's battery, an innovation that helped illuminate scientific development. Nevertheless, studies on terrestrial magnetism focused on accurate measurements of magnetic force intensity worldwide, which led to the discovery of the geomagnetic equator. Researchers pondered whether, like other magnetic attributes, the geomagnetic force varies over time. The idea of four geomagnetic Poles on the earth's surface, once rejected during the middle of the 18^{th} century, again resurfaced. The research on geo-

magnetism left the European shore and spread globally through worldwide multi-national cooperation. The new avatar, electromagnetism, was born, which revolutionised the scientific and technological movement worldwide and ushered in New Science.

Chapter nine of the essay, titled **Ushering New Science**, provides a glimpse of the early years' new scientific and technological advances, where the discovery of electromagnetism played a vital role. The First Industrial Revolution, which started in the '60s of the 18^{th} century, attained a peak during the mid-'30s of the 19^{th} century and provided a significant boost in technology. The improved instrumentation and measurement methodologies helped generate revised charts of magnetic elements, such as declination, inclination and magnetic field intensity, on a global scale, which, in turn, helped establish the general theory of geomagnetism, an incredible feat in the early 19^{th} century leading to a strong foundation for the modern-day understanding of geomagnetism. However, the century-old effort of locating the geomagnetic North Pole succeeded. Researchers discovered magnetism in minerals, rocks, and other objects and various types of magnetism.

There was a synergy between science and technology, as entrepreneurship and enhanced consumerism demanded it. The **Age of Synergy** is thus chapter ten of the essay. The era ushered in altering the age-old idea of classifying materials between magnetic and non-magnetic, as magnetisation was not limited to iron. Almost any material was classified into three categories: ferromagnetic, paramagnetic and diamagnetic. The chapter covers a detailed discussion on characterising materials into those three categories. The scientific discourse, especially on physical properties, brought a new understanding of parametrising magnetic attributes in terms of attractive nature or ease of getting magnetised.

The **Age of Synergy** continued almost until the end of the 19^{th} century when technological development gained momentum due to the onset of the Second Industrial Revolution. Electromagnetism, discovered in the '20s of the 19^{th} century, developed significantly, establishing the general theory of electromagnetism. The influence of extra-terrestrial effects on terrestrial magnetism, especially the solar effect, was identified, which led to the

promotion of intense research through international cooperation. The chapter also discusses how the Second Industrial Revolution helped develop units and measures of physical and chemical processes.

The Second Industrial Revolution, which started during the '60s of the 19th century, continued until the *Great War* in the 20th century. However, the **Age of Synergy** slowly transformed into the **Age of Radicalism**, the title of chapter eleven. There was a radical change in the concept of science and technology, which helped in the rapid growth of industrialisation, consumerism, and modern science. Improved measurement techniques and the development of various disciplines of physics, especially astrophysics, helped vindicate solar radiation's effect on terrestrial magnetism. The understanding of remanent magnetisation, which can hold the history of the physical variation of the past, was established. A new discipline of geomagnetism, later called palaeomagnetism, was born. The studies on geomagnetism were not restricted only to Europe and America but also extended to the Far East. The new discipline, 'Geophysics', was born, promoting the probe of the earth's internal structure, which later helped understand the source of geomagnetism.

The 20th century ushered the New Physics, which completely revolutionised modern science and technology and brought the **Age of New World Order**, the title of chapter twelve. Quantum mechanics and nuclear science, with the discovery of sub-atomic particles and their attributes, revolutionised the concept of the phenomenological aspects of magnetism. It immediately helped categorise magnetic materials into six new types. In addition, the new concept helped in understanding phenomenological aspects of geomagnetism, especially various sources of geomagnetism. The theory of self-excited dynamo, which originated in explaining solar magnetism, took the lead role in explaining the primary source of geomagnetism. Geophysics with the knowledge of the deep interior of the earth allowed formalising geodynamo.

The development of mathematics and computational methods led to the development of New Physics. A period titled **Onset of Cyber World**, chapter thirteen of the essay, has appeared briefly at the onset of digital computers. The studies on rock magnetism, which started in the middle of 19th century, rejuvenated once again, especially in studying its remanence

property commensurate with the development in the field of earth sciences, especially in geophysics. The advent of the astatic magnetometer, a new kind of instrument studying rock magnetism, helped in the development of the discipline palaeomagnetism. The chapter discusses how an astatic magnetometer was designed and used in rock magnetic studies.

However, the reversal of magnetic polarity, which caused a particular interest in palaeomagnetism among researchers, was contested due to the discovery of the self-reversal property of magnetic materials. The period was ushering in new instrumentation, which made a paradigm shift in device technology. The sensor and device technology moved from mechanical to electrical or electronics-based arrangement. The short-period time varying terrestrial magnetism promoted the probe of the earth's conductivity structure, which helped develop a new subject magnetotelluric method.

The **Modern Cyber World**, the last chapter of the essay, appeared in the middle of the last century, and it has encompassed not only science and technology but our everyday life. The period in the history of human civilisation has made a significant mark, as in this period, human wisdom, especially in the field of science and technology, becomes explosive, opening up vistas of new paradigms of understanding. The development in the field of New Physics was so intense that it ushered in the development of new instrumentation, which helped measure the magnetic field at an unprecedented minute level. The advent of nuclear physics allowed dating rock samples with a high level of precision, which helped develop palaeomagnetism and ushered in the birth of a new avatar, plate tectonics. The development of New Physics and technology based on electronics has revolutionised measurements and experimentations and enhanced our understanding of the role of magnetism in other disciplines, such as environment, climate change, biology, and terrestrial and extra-terrestrial magnetism.

As the title suggests, the essay on magnetism encompasses a very long time travel. However, the space limitation compels the author to confine the description of such travel to fourteen chapters. The essay's objective is to sketch how the science of magnetism, one of the most intriguing physical phenomena, evolved in the human history of civilisation. Since scientific

discourse in understanding physical phenomena is inescapable, it has appeared, sometimes even in intense form, in this essay. The authors have made no stone unturned to make this essay easy to read and understand while maintaining relevance in the discussed topic. The author will be pleased if his effort gives readers the pleasure of reading this essay and if the readers can find any usefulness in their future pursuit on this subject.

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No humans ever perform anything significant singularly. If this essay is perceived as a musical score, then all hands of the orchestra must be attuned. The author in no account ever claims any accomplishment, and if there is any, that is mainly due to support from many souls, some of whom are obvious and others behind the curtain. The author owes them his heartiest gratitude.

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2. Internet Archive to access scarce and limited edition books.
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Chapter 1

Ancient World

> The passing on of knowledge from generation to generation is metaphorically referred to as a cultural 'ratchet effect', which creates greater complexity of culture over time.
>
> *David Despain,*
> *Evolution, Scientific American, 2010*

1.1 Introductory note

THE ancient world in this essay refers to the cultural world of modern humans in a distant past; neither that world nor the historical records on many occasions exist anymore. Nevertheless, researchers in the present day attempt to dig out some valuable evidential data parsimoniously through archaeological studies, including scientific pieces of evidence with the estimation of chronological time records and sometimes from the shreds of anecdotal evidence. This chapter of the complete essay entails the human understanding of magnetism and applications thereof during ancient times in many parts of the globe. Approximately the period that it covers is from the 6^{th} century BCE up to the first half of the 11^{th} century (in the case of China). However, a proper timeline in a strict sense is absent purposefully, as

the essay's theme highlights how humans, in their perceived civilised world, realised one of the fascinating natural phenomena, magnetism.

In that pursuit, we will notice some groups of humans restricted to one part of the world, identified by a specific civilisation, identified one attribute of magnetism and reacted differently from the other groups of people belonging to other specific civilisations (neglecting chronological or age differences between two such civilisations). This essay covers only a few civilised worlds in the context of modern human reaction to magnetism, such as Latin America, Greece, Rome, Egypt, India and China. However, this does not implicitly suggest that modern humans in the rest of the geographical world were unaware of this natural phenomenon.

* * *

1.2 Latin America

In prehistoric times, humans probably noticed strange attracting behaviour of some stones, possibly intrigued and fearful, but could not always record their experience intelligibly. Evidence from archaeological discovery suggests that people in the prehistoric period were not merely intrigued by magnetic materials (primarily as stones) but used those materials as ornaments or even for medicinal purposes, which the researchers engaged in anthropological studies believe.

In the fall of 1967, Dumbarton Oaks Research Library of Washington DC conducted the first conference on the Olmec, the oldest known civilisation in Mesoamerica, a region extending from central Mexico to Costa Rica. At that conference, an anthropologist, Professor Michael Douglas Coe (c. 1929-2019), revealed exciting findings from the archaeological site of San Lorenzo Tenochtitlán [1] in central Mexico.

The flood plain of the river Coatzacoalcos is the site of San Lorenzo Tenochtitlán, where the Olmec civilisation flourished in the period 1400-400 BCE. Like many other ancient civilisations, Olmec people also used ornamental stones, such as jade, obsidian and magnetite, but interestingly,

[1] Tenochtitlán was city-states, also known as *altepetl*