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GEOMAGNETISM AS AN INDEPENDENT SCIENCE

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ABSTRACT

At its beginning, Geomagnetism was involved into a mystical atmosphere. Neckham and Norman´s experiments, and the practical use of the compass by Columbus had no significance to disconnect it from a mysterious understanding. In spite of the magnificent Gilbert´s treatise, the general belief about Geomagnetism remained enigmatic. Gauss´creative methods to measure the Earth´s Magnetism were the most important step to place geomagnetic phenomena into the frame of physical rational sciences. Many of those phenomena continued to be considered as low atmospheric events, and they were treated as meteorological ones. In 1851, Liais proved that a typical geomagnetic phenomena, the aurora borealis, occurs far from the "meteorological atmosphere", but his results were only recognized in our century, when IATME, and latter, IAGA were created. The influence of Geomagnetism as a seed of great scientific programs (e. g. the 1st. and the 2nd. Polar Years, and the IGY) puts Geomagnetism in its proper place as an independent science.

RESUMEN

En su principio el Geomagnetismo estuvo envuelto en una atmósfera mística. Los experimentos de Neckham y Norman y el uso práctico de la brújula por Colón no fueron suficientes para separar esa incipiente ciencia de una significación misteriosa. A pesar de la publicación del magnífico tratado de Gilbert, el entendimiento general sobre el Geomagnetismo fue enigmático. Los métodos originales creados por Gauss para medir el Magnetismo Terrestre fueron los pasos más importantes para poner sus fenómenos en el esquema de las ciencias físicas. No obstante ese éxito, muchos de aquellos fenómenos continuaron en ser considerados como eventos de la baja atmósfera y por eso, ellos eran tratados como perteneciendo a la Meteorología. En 1851, Liais probó que un fenómeno típico del Geomagnetismo, la aurora boreal, ocurre mucho más arriba de la "atmósfera meteorológica", pero sus conclusiones sólo fueron reconocidas en nuestro siglo, cuando la IATME y después, la IAGA ya existían. La influencia del Geomagnetismo, como la semilla creadora de grandes programas científicos (por ejemplo, el Año Geofísico Internacional) ha proporcionado a esa ciencia su lugar propio como una ciencia independente.

1. PREHISTORICAL PERIOD

In spite of its prominent place in the history of science, Geomagnetism was involved into a mystical atmosphere, from its beginnings up to recent times. Certainly, that unhappy childhood provoked many wrong interpretations of its phenomena and an inconvenient placement in the frame of Science. It is well known that the Chinese civilization used a magnet on land and nautical orientation. According to Needhm (1962) the earliest quotation about the compass´use was made in 1088 AD. by Shen Kua. On the other hand, the first European reference to a compass was made by Alexander Nekham in 1190. It is possible that the Marco Polo imaginative descriptions of the technology in China had contributed to the practical use of the magnetic stone properties. These characteristics were also discovered some centuries before from the strange characteristics of the loadstone as it was quoted by Plinius (Malin, 1987).

Since there are no clear written documents about a widespread use of the compass, it is possible to call "Prehistoric Period" the time before the Great Navigation. For this reason, some speculative statements about the use of the compass could be proposed to explain some nautical success occurred during that crucial historical period (May 1956). Vicking's trips to America and the initial Portuguese discoveries could be connected to the use of the compass. A fortunate coincidence joined the two intrepid nations. Eric of Pomerania was married with Philippa, a cousin of Enrique o Navigator (Henry the Navigator), the great founder of the Sagres School (Barreto, 1987).

If we give a look to a Portugal map, we could see Sagres promontory as a veritable caravel prow pointing out to the Atlantic Ocean. At that defiant place, the Infante Dom Enrique founded a scientific center, where astronomers, geographers, cartographers and navigators from various countries prepared one of the most audacious adventures of the mankind. The opportune coincidence of a linkage between Sagres and the Vickings made very probable the assumption that one or more Portuguese sailors joined the Vicking during their heroic trip to Greenland. In spite of the lack of written documents, the use of the compass on Navigation by Sagres' scholars should be considered as very possible.

As a consequence of the economical and political importance of the navigation and discoveries, it is easy to understand the scarcity of clear historical references about the navigational techniques. Geography and Cartography were classified subjects, and Portugal used the experience from Sagres to expand its power over the new lands. The "variation of the needle variation" or, in modern language, the "declination change with the geographic position", was a common method to obtain longitudes, and it was well known in Sagres. It is conceivable that the scholars from Sagres knew that in the 15th Century the isogonic lines were close to the meridians direction in the Southern Atlantic, but they had somewhere an Eastern-Western direction in the Northern Atlantic. This old regional peculiarity of the geomagnetic field could be a strong reason to underestimate the distance between Europe and the Unknowing Continent, America, and a very probable argument for the Portuguese choice of a Transafrican route to India and the refusal of the Columbus´project by the Lisbon Crown (Barreto, 1991).

A historical injustice was learned some years ago in primary school books:" Brazil was discovered by a fortuitous error of the Cabral´s fleet". The Admiral Pedro Alvarez Cabral organized his expedition to India with the best requirements of his time by using Sagres knowledge of the Southern Atlantic, including a rough estimate of the isogonic lines (Barreto, 1987). It was a routine task of Portuguese sailors to measure the magnetic declination during their voyages. Sometimes, a crude isogonic chart was traced, and the famous Castro´s magnetic chart of the Indian Ocean is a typical example (Chapman and Bartels, 1940). In fact, Castro´s work represents the end of the "Prehistorical Period" because, after it, there are confident documents. Among them, the notable Halley´s Atlantic Chart (Halley, 1693). The History of Geomagnetism was born.

2. FROM CASTRO TO GILBERT

The Great Navigation represents one of the most remarkable periods of the History of Mankind. Sometimes, it is compared to the Space Age, but we must consider it as an heroic one, in spite of its limited terrestrial proportions. It occurred before the advent of the scientific method with its technological consequences. The unknowing oceanic dangers, with the fantastical monsters was more terrific than the present space with its known perils.

In the 15th and 16th centuries, a great lot of mystic explanations were used to interpret natural phenomena. Old and grotesque superstitions were considered as absolute truths. The main scientific goals were the same from the Middle Age, the search for the "philosopher stone", the "long-life elixir" and the official use of mendacious astrological predictions. Even though those risible interpretations were common in all scientific branches, with respect to the Earth´s Magnetism they persisted until the last century, in spite of some notable discoveries and experimental activities, and the importance of the practical use of the compass. There are written documents about that persistent wrong interpretations. Old books on Physics show crude explanations of the geomagnetic phenomena.

In fact, it is necessary to find out the reasons for this long-lived kind of sorcerous thinking, from which Mathematics, Mechanics and some subjects of Physics had escaped. Perhaps the influence of great men, such as Copernicus, Galileo, Kepler, Newton and Leibnitz could explain that good riddance. Strugles among intellectual groups, during and after the Renaissance, caused the birth of the Reformation, the Catholic Counter-Reformation, the Absolutism and the consequent fall of the

Feudalism. As an effect of those quarrels, many times warlike and bloody discords, a new scientific thinking was born. The search to explain Nature by general laws substituted the old beliefs on traditional unexplained credulities.

To achieve such generalization, new and powerful mathematical methods were created. It was the beginning of the Natural Determinism and the birth of the Scientific Method. Since then, a primordial attention was given to experience and the analysis of its results by means of predictable observed events. Now, a scientist auscultate the Nature to obtain its answers, and human laws were not capriciously imposed to it.

Notwithstanding the greatness of that intellectual revolution and its practical consequences was not a sufficient reason to consider the Terrestrial Magnetism as a real rational science. In fact, the use of the compass was a kind of a practical technique to help sailors. Castro's and other similar magnetic charts were a sort of a "portolano", a practical navigation guide. The famous Halley's charts had different characteristics. They were the result of scientifically made observations. The Halley great work was a consequence of another notable advancement, the admirable "De Magnet", published by William Gilbert hundred years before. That publication constitutes a gratifying exception in the Geomagnetism beginning. Actually it could be considered as the first ever scientific textbook (Malin, 1987). The newcomer Scientific Method was the guide in De Magnet pages.

Geomagnetism was not treated as a hidden force with an inexplicable origin and then, its study had surpassed the low level of a mere navigation aid. It was the result of many years of careful experiments (Gilbert, 1600) by using a modern scientific approach.

3. A PIVOTAL NAVIGATION TOOL

Although Gilbert'treatise had given to Geomagnetism a new scientific reputability, the compass'use persisted as its most known aspect. The Great Navigation period was succeeded by the epoch of the new lands conquest. More and more magnetic charts were produced by the pioneers, Portugal and Spain, as well by other European countries, mainly by British navigators. It is interesting to notice that Portuguese and Spanish nautical interests were not connected to a scientific study of that important nautical aid. On the other hand, England became the main source of the studies on the Terrestrial Magnetism. Speculative activities about the origin of the Terrestrial Magnetism and experimental enquires had their high point in Gilbert's treatise.

The discovery of magnetic inclination by Norman, in 1581, was followed by the first isoclinic chart prepared by Whiston in 1721. One of the most impressive contributions in that period was the discovery that declination and inclination suffered time changes in a quasi-regular way. Gunter, in 1584, by comparing his declination values with those ones obtained 40 years before by Borough, concluded that a sensible change had occurred. Those contribution and many others came from British scientists. The British Admiralty perceived the necessity of such activities, and its support was fundamental to improve Geomagnetism. The determination of longitudes was one of the most serious problems on Geography and Cartography in the 16th to the 19th centuries. It is probable that the Spanish accordance to sign with Portugal the Tordesillas Treaty was the result of a lack of knowledge about longitude determination. Portugal gained some millions of square miles and, in consequence, Brazil has today its great area.

Some astronomical methods were used as a complement of declination and inclination measurements to estimate the longitude. The astronomical determination of latitude was not a problem, but for the longitude, there were many puzzling questions. The observations of Moon hide, and the Jupiter´satellites eclipses were not satisfactory procedures. They depended on clear skies, correct astronomical predictions, and a reasonable time-keeping. On the other hand, longitude determination by declination measurements was a function of well elaborated isogonic charts.

In spite of some substantial scientific accomplishments and the elimination of many mystical aspects, the Geomagnetism continued to be considered as a complement of nautical techniques. In fact, the general magnetic phenomena were not well understood, and its relationships with the new discovered Electricity was also an incoming subject. It is possible that an unexpected question was placed to the 19th Century scientists: "What is the Science in which field the Terrestrial Magnetism could be included?" An independent science was out of order. Its subjects were so narrow and peculiar, that it was impossible to conceive such status. On the other hand, Meteorology presented, since the early days of the last Century, an extraordinary development and good scientific procedures. For these reasons, it was a natural choice to place the "Terrestrial Magnetism" and the so called "Atmospheric Electricity" into the limits of the Meteorology.

4. A NEW SCIENCE IS BORN: GAUSS

One of the Lord Kelvin´best statements was his lapidary phrase about the importance of a quantitative consideration of natural phenomena. The advancements of the Terrestrial Magnetism until the third decade of the last century had produced a considerable amount of information about a scientific nameless entity, today called "geomagnetic field". At a specific point of the Earth´s surface, and at a definite instant, the values of two different things were obtained: the declination and the inclination of a magnetic needle.Both are angles. Those values represented a kind of deviation from a "normal" position of the needle, in fact only qualitative concepts, a sort of peculiar characteristic of that unknown entity, at those place and instant. In that epoch, vectorial concepts were not well understood. Declination and inclination gave only the direction of the undefined vector B, the "geomagnetic field". Its numerical and modular value, the "intensity", remained undefined.

The experiments made by Humboldt in South America in the 18th Century, showed that there was a relationship between the oscillation of a magnetic needle and the strength of the magnetic effects (Malin, 1987). Carl Friedrich Gauss, one of the greatest names on Science, could be considered as the Father of the Scientific Geomagnetism. The multiplicity of his activities and the penetrating wisdom of his works are present in many scientific fields. Gauss had an extraordinary aesthetic sense and the perfection of his works will maintain his discovered truths alive, through centuries.

In a spontaneous and crude comparison between two great fields of the human mental creation, Science and Music, Gauss could be understood as the J. S. Bach of the Science. Gauss settled the frame of the scientific theories, as Bach established the frame of the Music. First of all, Gauss studied the best measuring instruments to analyse a natural event, taking into account the precision and the errors of the measuring method. It was the "first movement" of his symphony, an "adagio maestoso". Secondly, he obtained a large series of measures, by using a carefully chosen method. It was the second movement, certainly a "largo".

The third movement, in "crescendo" was the establishment of a general theory of the studied phenomenon. Finally, the last movement, an "allegro cantabile" was the experimental test of the theory. The best "Gauss symphony" was the creation of the methods for geomagnetic measurements. The establishment of a rational system of coherent units called for Gauss´attention. He intended to apply the basic idea of the Metric System, created few years ago, toa new physical entity, the "magnetic intensity". For this reason, Gauss called "absolute" the result of a measurement in which only the units of length, time and weight were used to define a final value. In fact, a measure cannot be "absolute", but Gauss used that expression for a lack of a better one.

Around 1832, Gauss and Weber (Malin, 1987) created the famous *deflections-oscillations method* to measure the modulus of the horizontal component of the geomagnetic field. In fine, the vector B had been completely defined by three independent components, D, I, and H. To compose the *second movement*, perhaps the most beautiful of his *symphony*, Gauss analysed a great lot of measures, in order to obtain the most probable value. To perform this part of his *opus*, Gauss created the *mean squares method*, one of the best *melodic themes* even created on Science.

The *Gaussian forth movement* was the construction of simple but very precise instruments, the fibre suspended magnetometers, in order to check his theory. The high quality of such devices is the reason why they are used up-to-now at many magnetic observatories. Kelvin'statement had been adopted: a new Science was born.

Gauss was aware of the strong necessity to study the new science in a worldwide scale. For many other sciences, such aspect was not important but in this case as well that one of the Meteorology, an earthly consideration is crucial. We must remember that the existing communication means in the first part of the 19th Century were very precarious. Today, scientists could perform a cooperative research in an on-line way but, in Gauss epoch, a letter was the unique process to communicate a result or an important question. The worldwide use of the telegraph was not established.

In order to attenuate such bad condition, Gauus created in 1834 the Göttingen Verein (Fukushima, 1994), usually called the Magnetic Union. From the historical point of view, the Göttingen Verein could be considered as the direct ancestor of the actual IAGA and, in a broader sense, the first scientific union.

For the first time, in spite of its newness, Geomagnetism presented its precursory influence. Although the notable event is not generally recognized , since then Geomagnetism was an independent science.

5. GEOMAGNETISM AND METEOROLOGY

Up to the end of the 19th Century the Earth'sciences were considered as an additional consequence of astronomical studies or, in some cases, as the complement of astronomical researches. It was the case of Geodesy, the basis of a reference frame for Astronomy. When a natural event could be linked to the Earth crust, it was naturally connected to Geology. It was the case of Seismology. Geomagnetic phenomena were difficult to be classified.

On that time, Electricity was a fast developing science and its practical applications began to be present to change the Civilization. After Benjamin Franklin's famous experiment on lightning rods, the Atmospheric Electricity becomes a very important scientific subject. Its connection with meteorological phenomena was an obvious reason to its inclusion in that discipline. On the other hand, the initial discoveries on Electromagnetism settled a natural assembly between Electricity and Magnetism.

It is easy to understand the simple solution that was found to place geomagnetic studies into the frame of a well studied science, the Meteorology. For this reason, in the second part of the 19th Century the scientific centers, mainly at the principal European astronomical observatories, a department or service on "Meteorology, Terrestrial Magnetism and Electricity" was created (Flamarion, 1911).

An interesting occurrence on this matter is slightly known by the History Science (Barreto, 1995): the influence of Emmanuel Liais to understand Geomagnetism as an independent science. Emmanuel Liais is most known as a classical astronomer, a skilful producer of precise instruments, and a courageous explorer.

Liais was born at Cherbourg, France, in 1826 and, since his early years he demonstrated an extraordinary ability on exact sciences, mainly on their experimental aspects. In 1852, Liais visited the Paris Observatory and he caused a vivid impression on Arago, the old and respected Director (Liais, 1853 I). One of the last Arago's wills was the promise to nominate Liais as a Paris Observatory astronomer.

After Arago's death, Le Verrier, a national name in France, was appointed as the Director of Paris Observatory. He maintained Arago's promise, and in 1854, Liais was nominated Assistant-Astronomer. Only three years latter he rode to the status of Titular-Astronomer, and received the title of Chevalier de la Legion d'Honour (Ancellin, 1986). That fast professional ascent was due to an intense and original scientific work that was recognized by Le Verrier, who was parsimonious on explicit quotations about his colleagues (Barreto, 1995).

After a friendly beginning, step by step, Liais and Le Verrier relationships were been deteriorate, because the differences and similarities between those two great men were conspicuous (Barreto, 1995). In spite of the historical interest of that quarrel, a detailed analysis of it cannot be presented here (Ancellin, 1986; Flamarion, 1911; Barreto, 1995; Morize, 1927). We must be restricted to Liais activities on the Terrestrial Magnetism.

Few years latter his appointment to Paris Observatory, Liais was the Head of the Meteorological Division. In 1885, he presented to Le Verrier a detailed project to reorganize that Division. The use of the telegraph on meteorological forecasts was a revolutionary improvement to increase the percentage of exactitude. In spite of a small interest from Le Verrier, in 1858 Liais finished the complete reorganization of the French Meteorology. Besides his great efforts to improve meteorological activities, Liais started a scientific research on Geomagnetism with an intuitive tendency to split it from Meteorology. His work to install original variometers with photographic records is not well known. The first photographic *variographs* were introduced by Brooke and Ronalds in 1847 (Malin, 1987) but their continuous operation for many years was due to Liais improvement of a special driving device (Ancellin, 1986).

Notwithstanding the importance of such activities on Terrestrial Magnetism, his principal result on this discipline was obtained few years before his arrival at Paris. In three articles (Liais, 1851, 1852, 1853 II) he proposed and applied an observational method to measure the height of the Polar Aurora, to prove that such phenomenon occurs above the atmospheric regions were meteorological events took place.

The discord between Liais and Le Verrier arrived at an unsupportable point, and Lias'permanence at Paris Observatory becomes impossible. For this reason, he accepted a friendly invitation from the Brazilian Emperor, Pedro the Second to be the

Director of the Imperial Observatory of Brazil. In his second country Liais and his wife, Margarita, performed many difficult and important scientific activities (Ancellin, 1986; Barreto, 1987; Liais, 1881; Liais, 1888). However, his last scientific effort had been unsuccessful. He intended to repeat in Brazil his work on Geomagnetism, and he tried to install at Rio de Janeiro the first magnetic observatory in Latin-America. The story of Liais struggle against the stupid bureaucracy and the hypocritical envy from some politicians is a real historical learning for us, because such drama is alive today with other players (Barreto, 1995). Defeated by his enemies, he returned to France and becomes a politician, as the "Maire" of Cherbourg. Liais´proof that a typical geomagnetic phenomenon, the polar aurora, occurs far from the meteorological level was only recognized many years latter.

On the other hand, Gauss´work was fruitful. The Göttingen Verein becomes the nucleus of a new sort of scientific stations, the first network of magnetic permanent stations. 50 magnetic observatories, now independent from their previous meteorological tasks, formed that scientific network (Malin, 1987). Humboldt published six reports of the Magnetic Union (1830-1841), a pioneer result. He stimulated E. Sabine to install permanent stations in the British Colonies, on behalf of the Royal Society. A remarkable result was obtained in India: the installation of an observatory at Colaba in 1841. In 1906 that observatory was moved to Alibagh. Today, we wonder of more than 150 years of continuous recording , thereby one of four selected observatories which can claim this honour (Indian Institute of Geomagnetism, 1991).

It would be possible to consider that extensive distribution of permanent magnetic stations was a sufficient reason to a general acceptance of the importance of Geomagnetism. In the same way that many specific geomagnetic researches were been developed, from a narrow but general point of view, the Geomagnetism maintained its restricted characteristic of a particular activity to help navigation.

It was necessary the accomplishment of international scientific campaign, that had been motivated by the geomagnetic phenomena, to obtain an unquestionable understanding that Geomagnetism is the unique science with a natural and accessible laboratory, the Earth, to study a fundamental property of the Universe the Magnetic Field.

6. THE FIRST AND THE SECOND POLAR YEARS. THE IGY

The close association between Geomagnetism and Aeronomy, that was only a conventional bond until recent times, was indeed a very useful one to develop geomagnetic researches. Aldredge (1981) explained in a very clear way, the painful process to create a new and independent science. Fukushima´description (1994) about this subject is also very instructive.

In 1873, the International Meteorological Organization (IMO) was created and a special *Commission of Terrestrial Magnetism and Atmospheric Electricity* was one of its parts. That Commission formalized an International Polar Year Commission to plan the *First International Polar Year* to be executed in 1892 to 1893. One of the most important objectives of that first international scientific campaign was the study of polar aurora and simultaneous ground level geomagnetic observations. Around twenty papers about those observations had been published (Robin, 1958). It was the first general acceptance of the necessity of a global study of geomagnetic phenomena.

After the inspired Balfour Stewart's article in the Encyclopaedia Britannica (1878 edition), the attention on external electromagnetic events received an increasing consideration. Such interest became larger after the invention and development of radio-waves propagation. The study of the Kennelly-Heaviside layer, involved many groups of radio-engineers and physicists. It was the beginning of the ionospheric studies. In opposition to the effect of dissociating linked disciplines, an interesting phenomenon occurred from the necessity of a multidisciplinary researches of natural events. Truly global scientific associations were created as a consequence of that necessity. Their names suffered changes as it was explained by Aldredge (1981) and Fukushina (1994).

The International Council of Scientific Unions (ICSU, 1976) brought together twelve academies and twelve scientific unions. One of those unions was the International Union of Geodesy and Geophysics (IUGG). Under the IUGG organization, the International Association of Terrestrial Magnetism and Electricity (IATME) was in charge of the geomagnetic studies.

One of the most important IATME realizations was the Second International Polar Year (1932-1933), an improved version of the First Polar Year. Now, many new scientific subjects were included, such as the study of airglow, rapid magnetic variations, Earth currents and radio propagation.

An unusual return to the discussions about an overlap of interests between IATME and the IAM (International Association of Meteorology) took place. In fact, it was difficult to define the real limits of the Atmosphere. However, I guess that an etymological interpretation could be used to solve such intricate question. Meteor comes from the Classical Greece, and it means all known phenomena up to the discovery of the Ionospheric Physics, whose main characteristics are electromagnetic ones.

On the other hand, it is impossible to disconnect ionospheric and magnetospheric events from their association with the Earth's magnetic field, as it is measured from the surface of our planet. Many vivid discussions about this controversy occurred at successive IUGG Meetings. Fukushima (1994), and Aldredge (1981) gave interesting reports about them. Finally, Chapman closed the dispute with a happy thought by creating the neologism *Aeronomy.*

According him: *Aeronomy signifies that part of the Science of the high atmosphere wich is not usually considered by meteorologists.* There is a curious anecdote about Chapman's proposal. After the approval of his suggestion at the IUGG 1954 Assembly, Chapman was questioned about his neologism, and he answered: *Do you know the meaning of Aeronomy ? No? I do not know too.*

The IAGA (International Association of Geomagnetism and Aeronomy) was born, to substitute IATME functions. An interesting question was placed about the words *Geomagnetism* and *Aeronomy.* The word Geomagnetism was also suggested by Chapman (1938). His etymological arguments were irrefutable, and they are skilfully improved by Fukushima (1994). Since 1951, at the Brussels IUGG Assembly, the idea of a 3rd. International Polar Year gained support from the various IUGG branches. However, a broader campaign was necessary. A worldwide coverage of geophysical phenomena was imposed by the development of new disciplines and a sensible improvement of communications on Science. The International Geophysical Year (IGY) was approved by ICSU to be executed in the period July 1957 to December 1958 (Robin, 1956).

The IGY was the greatest scientific effort even made by Mankind. For its results and consequences, it could be considered as a turning point in the History of Science. If we consider that sixty seven counties and more than 30,000 scientists were involved on its programs, it is possible to understand its magnitude.

A personal remembrance from IGY publications is alive in my memory. After the IGY campaign, I was charged to organize all related papers and reports. I remember the smile of the late Lelio Gama, Director of the National Observatory of Brazil, when he said: "It will be a good opportunity to learn Geophysics". A large room was plenty of books and papers. Some months were spent to finish my task.

All branches of Geophysics presented a real jump on their development. The Space Age was born with the Sputnik and the Explorer. The Van Allen radiation belts were discovered. A new scientific landscape was visible. Our Science, the Geomagnetism, grew-up to its actual high scientific level. If we make a statistical survey about the number of magnetic observatories in operation, it is possible to understand such explosive development (Malin, 1987).

Unfortunately, the number of active observatories in 1958, about 200, had been drastically reduced. Many important permanent stations had been closed, such as Easter Island and Paramaribo observatories. Cheerfully, the quality of the remaining stations has grown, and new observatories are planned to be installed.

We must be very confident on a bright future for our Geomagnetism, an Independent Science.

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