

GEOMAGNETIC RESEARCHES IN THE INTERNATIONAL GEOPHYSICAL YEAR

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The widely advertised and exhaustive study of our earth and its surroundings, that we know as the International Geophysical Year (IGY), has far-reaching implications for all mankind, including in particular those who live and work by application of the earth's phenomena, as do mariners and navigators.

Sea-going people may have their world revolutionized by new discoveries about the seas and what happens within them, about radio, which permits communications and higher types of navigation, about weather, which sometimes exerts controlling influences on their voyaging, and about many other physical facts including geomagnetism, the principle behind the historic use of compasses in navigation.

Geomagnetism has surpassing interest to the scientists of IGY, because of its broad implications in the study and understanding of many aspects of earth physics, such as the state of the earth's interior, and the electrical phenomena of the atmosphere, including the ionosphere and radio wave propagation, auroral phenomena, cosmic rays, even thunderstorms. It is of concern to mariners since it controls the application of magnets for use in compasses, because every mariner is vitally interested in radio communications and the use of radio navigational aids, and because it may lead to better understanding of auroral phenomena, airglow, and other natural displays that have attracted the attention of mariners since the dawn of history.

The great mystery of the geomagnetic field — one of the classic problems of history and one not yet satisfactorily solved — may yield to the scrutiny of the scientists of 67 nations in the IGY. If it does, we will perhaps know better why a compass acts as it does, and how to make its use even more certain.

The ancients had no compasses. Vessels upon the open sea were dependent, when the heavens were obscured, upon the master's precarious judgment of wind and sea. This uncertain feature of the seagoing life had

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a tendency to stifle exploration. In the 12th century, however, man's interest in the behaviour of the lodestone, an age-old curiosity dating from the 7th century BC, resulted in a great discovery. Magnetized materials, when freely mounted, had the gift of finding directions ! It didn't take long to find practical use of this property. At first, bits of lodestone were floated on wooden chips. Later magnetized needles were hung on threads or balanced on needle points.

With growing technical competence and the help of his new tool, man no longer needed to grope blindly over the sea. He ventured farther into the unknown, confident of finding his way back. Thus he found an insistent new spirit of adventure, ushering in the age of exploration. Inevitably there was expansion of the known world, familiarity with many of its odd corners, charting of the waterways, development of new areas, and now our modern industrial world. The compass was an important influence in the beginnings of this growth.

Man never succeeded in explaining the mysterious lodestone. It is easy to see, therefore, why we have a store of ancient superstition holding it to be a cure for dropsy, gout, fever — even domestic discord ! Early mariners feared the needle would lose its virtue by the odor of onions or garlic. Mariners were enjoined to forego these delicacies.

Science has explained the effects, if not the nature, of magnetism. In 1269 Peregrinus described pivoted compasses, writing in a spirit of experimental approach we now term the scientific method, showing the way for the later great works of Copernicus, Galileo, Francis Bacon, Gilbert, and Newton. Onions and garlic gradually returned to favor !

In the 19th century, in the course of many explorations of the Arctic, mariners noted mysterious phenomena of nature, including auroral displays which they found to be related in some unknown way to the fluctuations of their compasses. These manifestations led, in fact, to the first of three great international undertakings to observe and understand such phenomena of nature. The first two, in 1882-3 and 1932-3, were termed International Polar Years, whereas the present vastly greater program, because of its world-wide scope, is called the International Geophysical Year. As we have seen, geomagnetism is one of its fundamental problems.

Geomagnetism, an inscrutable force completely enveloping the earth, goes everywhere and cannot be escaped or tampered with. The ancients thought it to stand immovable and unchangeable through light and darkness, fair weather and storm. We know better now, but we have never explained it !

One of the most persistent quests in the realm of science has been man's effort to measure, study, and understand this mysterious force. In 1600 Dr. Wm. Gilbert, after exhaustive experiments, produced his important work *De Magnete*. This foundation stone in the science of electricity and magnetism summarized the then-known properties of magnetic bodies, and suggested that the earth is a great magnet.

This was brilliant insight in view of what was then known of geomagnetism. Indeed, in a general way, this magnetic field is similar to that of a very small, inconceivably powerful bar magnet, or dipole, near the earth's center. Actually it would have to be 342 km off center, and tipped at an angle of 11 degrees. However, the idea of the earth being a magnet — a lump of lodestone, so to speak — just doesn't fit the facts. The interior

is too hot to be capable of magnetization. Moreover, irregularities of distribution, and a condition of slow change, do not fit Gilbert's idea.

A better and more plausible model is the magnetic field surrounding a flowing stream of electric current, though we have no good explanation of what started or maintains such a current, or why it changes as it must to produce the phenomena we see. Various schemes have been described, showing circulation of the earth's interior materials, by convection or dynamic causes, resulting in dynamo effects. Computations based on these speculations support the physical plausibility of the idea.

A great deal is now known about the nature and configuration of the earth's magnetic field, including the regional effects of declination, dip or inclination, the location of the magnetic poles and the poor compass response in their vicinity, of local anomalies, and of the secular changes that alter the magnetic effects, slowly but surely, in all localities. But the concern of the IGY is not with these basic features, rather with another notorious feature of the field — its superficial instability and continuous fluctuations, seen most strikingly as the disturbances known as magnetic storms. It was this instability, most noticeable in polar regions, that attracted the attention of polar explorers a hundred years ago.

The magnetic field is no frozen image — rather an undulating form like the face of the sea. Hopeless confusion would result if we didn't have means for keeping track of things. There are, therefore, on earth more than 70 permanent magnetic stations where variometers, in dead darkness and well shielded from temperature effects and stray magnetic disturbances, silently work year in and year out, recording the play of the earth's magnetic forces. This number has been augmented by an equal number of temporary IGY magnetic observatories, in the effort to clear up some of the open questions asked by magnetic scientists.

These changing magnetic effects are of many kinds, with important implications for navigation. Magnetic storms, though known to be related to the causes of radio fadeouts, are not completely understood. We know them to be closely related to sunspots, their frequency varying directly with the sunspot cycle of 11.2 years. We even anticipate such storms when we see great sunspots coming around the sun.

Just how it works is not so obvious; however, it is generally believed that magnetic storms are the evidence of transient magnetic fields from confused electrical currents in the upper atmosphere. These currents are generated when solar disturbances radiate ultra-violet light and nuclear particles, ionizing the atmospheric molecules and creating the necessary conditions. The ionized region is called the ionosphere.

One of the important results is the effect on radio communications. Under normal radiation, the ionospheric layers are uniform and undisturbed radio signals are then reflected, as light is reflected from a mirror, so that they pass around the curvature of the earth. It is due to this fact that long-distance radio communications are possible. When sunspots and other solar disturbances occur, however, intense and erratic showers of particles and changing ultra-violet light destroy the uniformity of the ionosphere. In effect, the mirror is clouded. Radio signals become sporadic or disappear altogether beyond the turn of the horizon.

But we find also a possible advantage in such conditions. This is the forward scatter effect, by which very high frequency radio waves, which

normally go right through the ionosphere and become lost, can sometimes be employed, with the use of great power, for long-distance signalling by a scattering effect caused by irregular clouds of ionized gases. This effect is, in fact, now in use, particularly in the polar regions where unusual impairment of normal radio communications is experienced. Rare cases of television interference from distant broadcast stations are attributed to this effect. This is perhaps an undependable phenomena — or on the other hand, it may become extremely useful when much better understood. Possibly, one day, television broadcasts across the oceans can be made by its use. So the fact is clear that we need much more information about these effects, and this information will be obtained, in part, by the magnetic observatories which in their way keep watch on the pulse of the events far above us in the ionosphere.

It is the very complex streams of electricity in our upper atmosphere which IGY scientists now want to chart. This can be done in part by observing radio phenomena and in part perhaps by the study of rocket observations in the ionospheric region. However, the evidence of the magnetic effects of such currents will be our best way of approaching the problem.

The currents are known to be most evident in the polar regions — especially in the zones of greatest ionospheric disturbance, where the activity of the air molecules puts forth the illumination we call the aurora. There are many theories why this activity is greatest near the poles. The answer, although not clear in its details, undoubtedly lies in the fact that the earth's main magnetic field directs the cosmic rays and atomic particles coming to us from space into patterns that include a funnel effect toward both the north and south polar regions.

All of this indicates why radio fadeouts and auroral displays are most common when the sun is badly spotted and emitting clouds of atomic particles, and why these effects are most prominent in the polar regions, and why they are identified with, and in fact predicted by, magnetic disturbances.

In the IGY, a great effort is being made by many countries to collect the evidences of geomagnetism, the aurora and the airglow, radio wave phenomena, and the ionosphere, in the Antarctic counterpart of our better-known northern regions. Great expeditions have constituted an unprecedented invasion of the great icy wastes of the south polar continent, and the results of their recording will tell us much of the overall shape of the cosmic events that have so mystified us. We will know whether auroral displays occur simultaneously in the north and the south, whether magnetic storms are of equal frequency, and how the radio performs during these events.

In the equatorial region, the IGY is also finding much of interest. One of the most dramatic of the problems under study is the so-called equatorial electrojet, so named by the British geophysicist Sidney Chapman because of its similarity in some respects to the well-known atmospheric jet-streams of such importance in aviation. Here, following the magnetic equator and meandering north and south of the geographic equator, is an intense, closely concentrated electrical current of millions of amperes, which flows only during daylight hours because it depends on the solar illumination of the upper atmosphere for its generation.

To study this effect, numerous special IGY observatories have been planted in the tropics, as near as possible to the magnetic equator. One such point of outstanding appeal to magnetic scientists is Jarvis Island, 1500 miles south of Honolulu in the Pacific, where the magnetic and geographic equators intersect. Here the United States are operating an IGY magnetic station to watch the daily changes in the magnetic fields generated by the great direct-current stream overhead. Companion stations are operated on Palmyra and Fanning Islands, some hundreds of miles distant, as control points for the Jarvis readings. Jarvis is but 1-1/2 miles in greatest dimension, and only a few feet above the sea — indeed it has been awash at times during the operation of the IGY station. Treeless and uninhabited, the occupation has been difficult in the extreme, but the objective is information that can be obtained in no other way.

The IGY, through its great world-wide coordinated program of magnetic investigation, will most certainly go far to tell today's scientists about the nature of the cosmic rays and solar particles that permeate space — possibly in lethal concentration outside our shielding atmosphere — and about the mechanism by which these forms of radiation ionize and electrify our upper air, creating luminous displays in the night skies, magnetic storms, radio fadeouts and other effects that we must understand before we can devise effective means of surmounting the difficulties they place in man's path.

Man, in all his endeavors, will benefit by the IGY in many ways that may now be unpredictable. There is no doubt that he, in his future conquest of space in the universe, must know intimately the facts of the environment he will have to adapt himself to once he leaves earth's atmosphere.