PROJECT MAGNET
THE CANADIAN FLYING SAUCER STUDY

Project Magnet was authorized in December 1950, following a request made to the Canadian Department of Transport by W. B. Smith, for permission to make use of the Department's laboratory and field facilities in a study of unidentified flying objects and physical principles which might appear to be involved.

The program consisted of two parts. The first part was the collecting of as much high quality data as possible, analysing it, and where possible drawing conclusions from it. The second part consisted of a systematic questioning of all our basic concepts in the hopes of turning up a discrepancy which might prove to be the key to a new technology.

Unfortunately, the program was plagued by well meaning but misguided journalists who were looking for spectacular copy, or copy which could be turned to political account, to such an extent that both those who were working on the project and the Department of Transport found themselves in an embarassed position. Consequently, when the Project Magnet Report was made and permission sought to extend the scope of the investigation through Federal financial support, the decision was finally made in 1954 that this would not be advisable in the face of the publicity from which the whole project had suffered.

Project Magent was officially dropped by the Department of Transport in October 1954, although the Department indicated its willingness to permit the continued use of laboratory facilities, provided this could be done at no cost to the public treasury. The project has been continuing under these conditions, and to this extent may be said to have gone underground. The Government of Canada are not participant in the project and not in any way responsible for its conclusions.

The conclusions reached by Project Magnet and contained in the official report were based on a rigid statistical analysis of sighting reports and were as follows: There is a 91% probability that at least some of the sightings were of real objects of unknown origin. There is about a 60% probability that these objects were alien vehicles. (Alien meaning not of earthly fabrication).

The conclusions based on studies of the basic physical concepts were as follows: Many of our fundamental concepts are inherently ambiguous and quite a different philosophy can be built up on the alternatives. Several of these alternatives lead to much simpler arithmetic, and presentations which do not have to resort to patchwork corrections to make them all-embracing. Furthermore, some of our ideas with respect to fields and their behaviour are wrong.

Recent Project Magnet activities have dealt with following up any and all leads. Many of these leads were dead ends, but a few were quite significant and well worth the overall effort. At the present time a definite pattern is emerging, and the groundwork is being laid for a new technology which may literally lead us to the stars.

W. B. Smith

NOAA National Data Centers, NGDC Navigate Our Web Site

Project Magnet Data

NGDC is pleased to announce the availability of the complete Project Magnet data collection on CD-ROM - **Product Number 1089-A27-002**. You can **order** this CD and other geomagnetic data products from NGDC on-line.

Project Magnet data from the U.S. Naval Oceanographic Office, include low altitude, high density individual track line surveys, high altitude vector data and regional magnetic anomaly grids.

From 1951 through 1994, the U.S. Navy, under its Project Magnet program, continuously collected vector aeromagnetic survey data to support the U.S. Defense Mapping Agency's world magnetic modeling and charting program. The cd-rom consist of flight surveys in binary format, (high-level survey coverage image) documentation, and meta-data (histograms and help files).

The data on this compact disc were assembled to simplify the work of scientists performing regional and global geophysical studies, including research into the nature of Earth's magnetic field. NGDC's multi-platform browse and retrieval software, GeoVu, is included with the CD.

Download the latest Project MAGNET CD-ROM menu file for GeoVu. (March 23, 1998)

The entire aeromagnetic inventory is searchable on-line.

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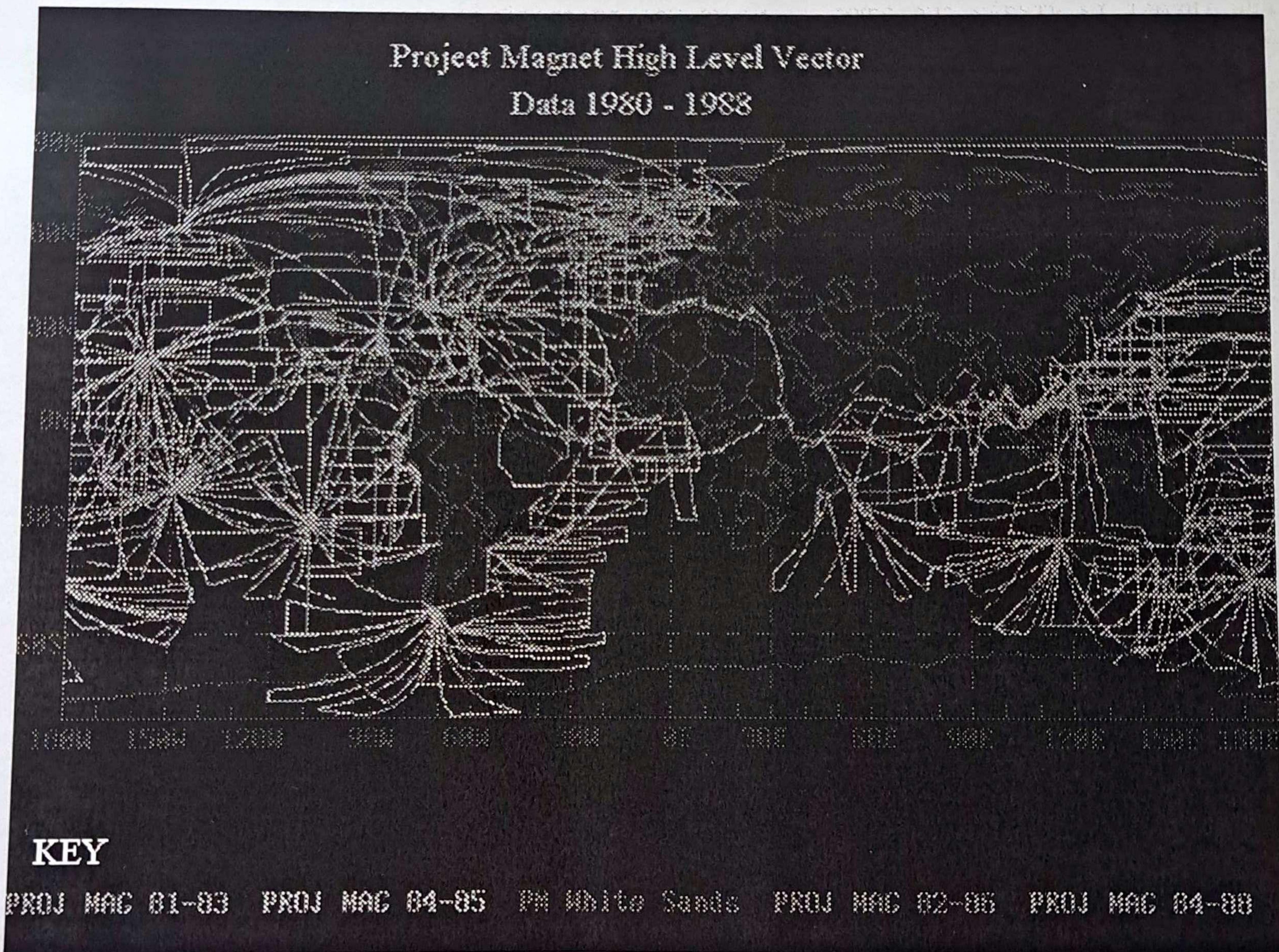
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PROJ MAG 04-05
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PROJ MAG 02-06
PROJ MAG 04-08

Vacquier, V. Geomagnetism in Marine Geology
Elsevier Pub Co. NY 1972

CHAPTER 4

THE EARTH'S MAGNETISM AND ITS HISTORY

THE ELEMENTS OF THE GEOMAGNETIC FIELD

At the general point on the earth's surface the geomagnetic field can be specified by a sufficient number of so-called elements depicted on Fig.27. From harmonic analysis of

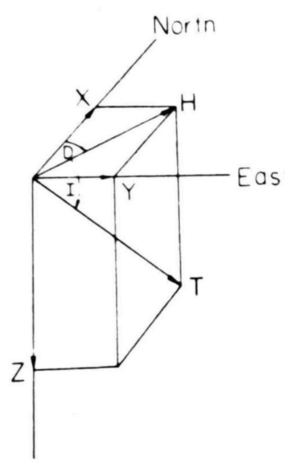


Fig.27. Conventional designation of geomagnetic elements. T = total intensity also called F; Z = vertical intensity; H = horizontal intensity; X = north component of H; Y = east component of H; D = declination; I = inclination or dip angle.

the few magnetic intensity measurements available to him, Gauss was able to prove in 1835 that most, if not all, of the geomagnetic field is of internal origin. Vestine et al. (1947) found that sources external to the earth contributed less than 1% to the global magnetic field. Despite the small size of the external field, it varies rapidly with time and thus limits the precision of marine surveys unless special recordings are made in the immediate vicinity of the survey to remove the time-varying part, as is done at times in the case of geophysical prospecting surveys on land, a procedure that is not economically practical at sea.

TIME FLUCTUATIONS

Rapid magnetic fluctuations are caused by electric currents in the ionosphere flowing at heights generally in excess of 100 km. The time-varying magnetic fields of these currents induce electric currents in the earth and in the water of the ocean which tend to oppose the changes of the magnetic fields of the sources. At the edge of islands and continents local magnetic fluctuations arise from the configuration of the coasts which affects the distribution of induced electric currents in the water making it difficult to use records of coastal magnetic observatories for correcting marine magnetic surveys, although this has been attempted for example in the Gulf of Aden (Whitmarsh and Jones, 1969).

There are two kinds of rapid magnetic fluctuations pertinent to marine surveys: the daily variation and the storm-type variation. The daily variation is produced by two large current whorls, one flowing in the upper, the other in the lower half of the sunlit hemisphere. They are produced by the motion of the ionosphere in the magnetic field of

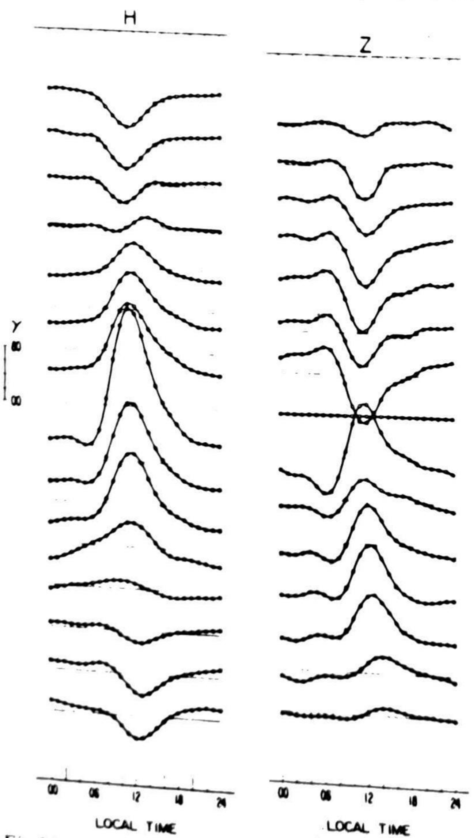


Fig.28. Average quiet day geomagnetic variations in H and Z during the equinox from 60°N to 60°S. The first curves from the geomagnetic equator are at approx. 5° latitude. After approx. 10° they are spaced 10° apart. (Matsushita, 1967, p.323.)

the earth. The motion is caused by tidal forces and expansion and ionization of the ionosphere by radiation from the sun. The average magnetic field variations are plotted against local time for different latitudes on Fig.28. We see that marine magnetic surveys may be subject to large errors in the auroral zone and in the equatorial belt in the vicinity of the electrojet, where errors as large as 200 γ can occur.

Magnetic storm variations happen simultaneously all over the earth. They are caused by a sudden increase in corpuscular emission from the sun. This corpuscular stream now called *solar plasma* contains as many positively charged particles as negatively charged ones. When it comes under the influence of the earth's magnetic field, the electrically charged particles become trapped and circulate in various ways forming the *magnetosphere*, thus causing erratic swings of the geomagnetic field reaching several hundred gamma amplitude and also some small quasi-periodic fluctuations called *micropulsations*. In addition to these phenomena the principal feature of a magnetic storm can be explained by the drift of the charged particles in the equatorial plane at a distance of six earth radii called the *ring current*. During the main phase of the storm the ring current is

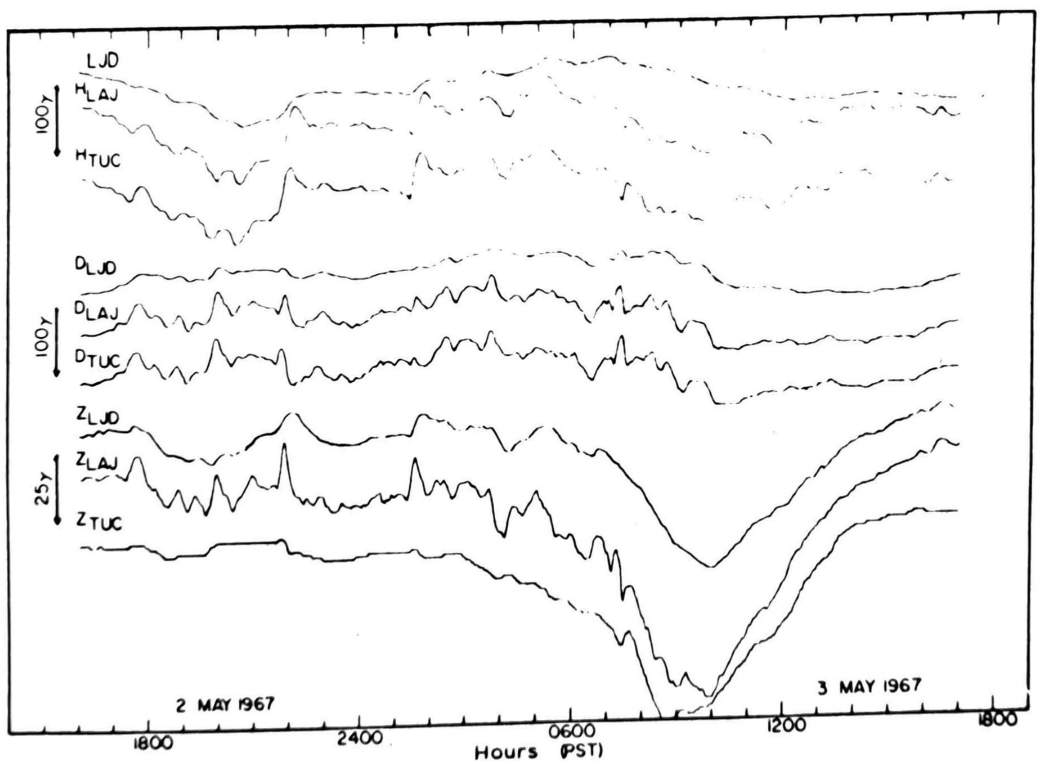


Fig.29. Record of a small magnetic storm at Tucson magnetic observatory (*TUC*), La Jolla, California (*LAJ*) and at the bottom of the ocean about 50 km seaward of the foot of the continental slope west of La Jolla (*LJD*). Note the attenuation of the high-frequency fluctuations at the deep water station (*LJD*) and their magnification in the *Z* component in *LAJ*. The magnification is attributed to "coast effect" (see Chapter 13) caused by electric currents induced in sea water and also perhaps due to probable seaward shallowing of isotherms in the earth's mantle. (Greenhouse, 1972.)

in such a direction as to oppose the dipole field. It takes several days for the ring current to decrease to its normal value. Thus, the mean value of the geomagnetic field is depressed during years of high sunspot activity which follows an 11-year cycle. Lately the structure and the behavior of the magnetosphere have been investigated by space probes (Matsushita, 1967, vol. II). The record of a small magnetic storm recorded at the bottom of the ocean is shown on Fig.29. The frequency of magnetic storms is governed by the 11-year sunspot cycle. On the average they might occur about 10 times per year. Days are characterized by magnetic activity measures one of which is the international index number k, which ranges from 0 to 9, and which is calculated at observatories from departures of the three magnetic elements from their three-hourly means. The values are adjusted according to the latitude of the observatory to make results from all observatories comparable. In compiling magnetic intensity data from marine surveys it is good practice to chart the k number as a measure of their reliability.

SECULAR VARIATIONS

Repeated world-wide observations of the geomagnetic field in historic times, as well as changes in its direction from the measurement of the magnetization of archeologically dated clays in pottery, pottery firing kilns, historic lava flows and varved clay deposits in

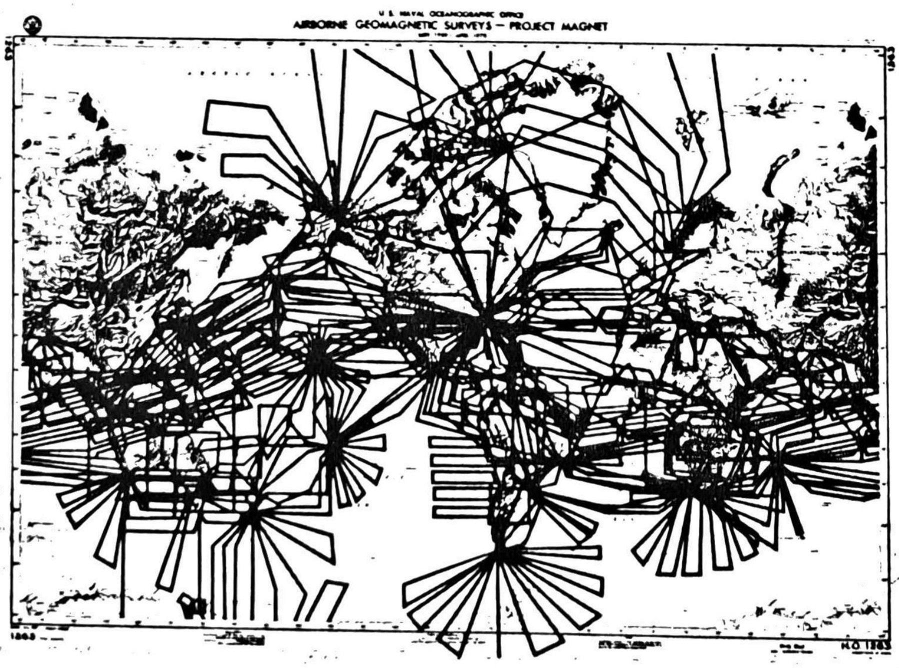


Fig.30. World coverage by Project Magnet as of April 1970 (Chart H. O. 1263, U.S. Naval Oceanographic Office).

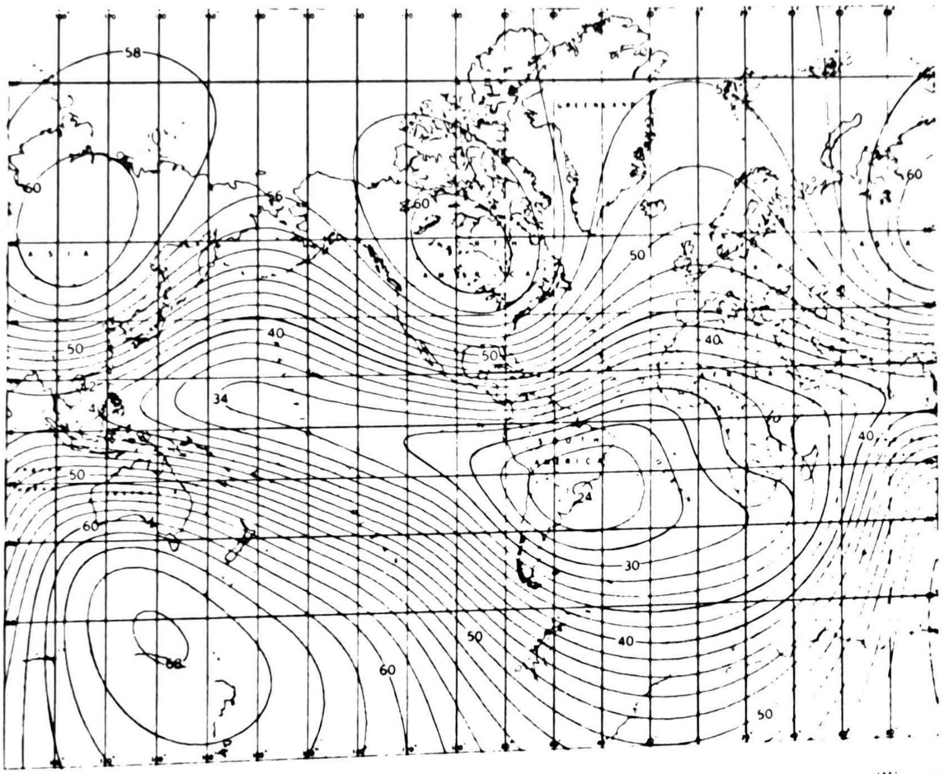


Fig. 31. World chart of total magnetic intensity for 1965. Contours are labeled in tens milligauss. (Fabiano and Peddie, 1969.)

lakes, have shown that the geomagnetic field experiences secular changes in magnitude and direction. It is the custom to describe the earth's internal field as consisting of a dipole at the center of the earth directed toward the south geographic pole which produces a field of constant direction but slowly varying magnitude (see Fig.38) and of a smaller nondipole part which at any particular time is a function of position expressed in spherical harmonic series of latitude and longitude. The "variation" of the magnetic compass from geographic north is caused by this nondipole field. As we shall discuss it later on, there is unassailable experimental evidence that over 10,000 years, the nondipole part of the geomagnetic field is averaged out to zero by the secular variation leaving only the dipole part for magnetizing the large masses of rock which produce the magnetic field anomalies we measure. This means that departure of the thermoremanent magnetization of a large body of igneous rocks from the present direction of the dipole part of the geomagnetic field can be interpreted as caused by geographic displacement in latitude and azimuth of the site after the rock cooled down. It is the fundamental concept for interpreting paleomagnetism in terms of plate tectonics.

However, if we have the task of combining in the same area observations taken only a

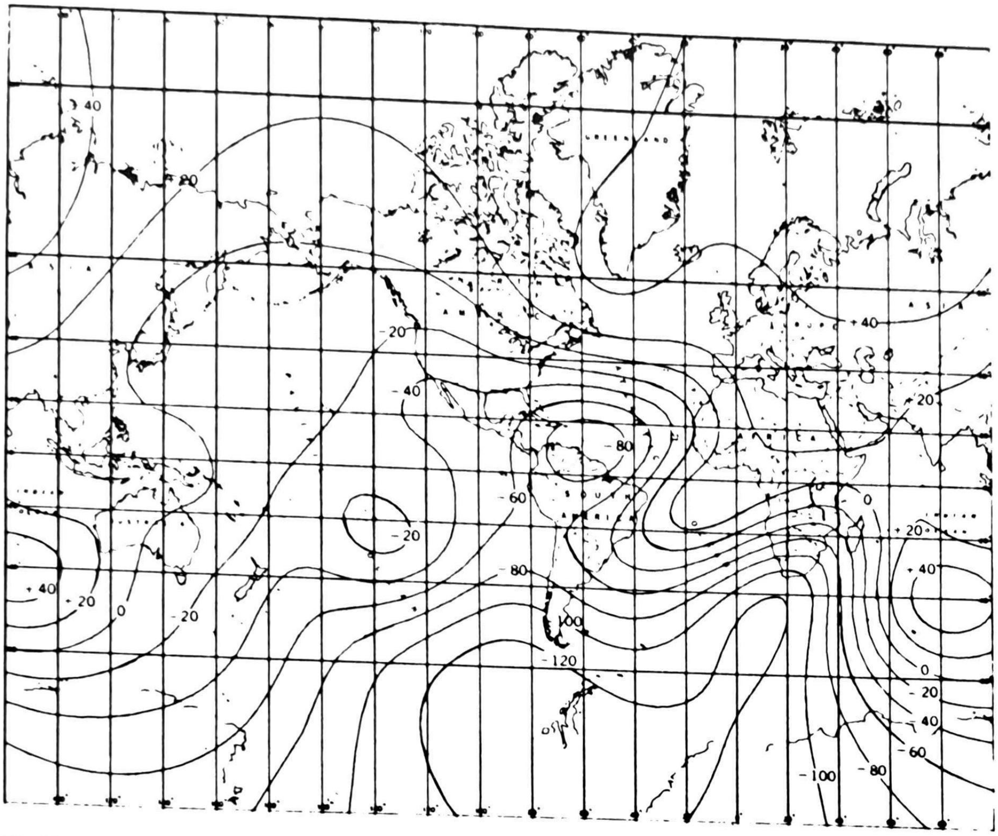


Fig.32. World chart of annual change of total magnetic intensity for 1965. The contour interval is 20 γ. (Fabiano and Peddie, 1969.)

few years apart, then secular variation which can be as large as 120 γ per year, has to be taken into account.

Secular variation is sufficiently rapid to require constant measurement of the magnetic field at magnetic observatories, repeat stations and by Project Magnet airplanes of the United States Navy Oceanographic Office. Information from these sources are combined for the publication of world charts of the magnetic elements every 10 years by the U.S. Coast and Geodetic Survey and by the British Admiralty. Fig.30 gives the world coverage of Project Magnet, the source of the most numerous magnetic data in the oceans. In the future, it is expected that the geomagnetic field and its secular variation will be obtained more accurately from total intensity measurements aboard low orbiting (1,500 km altitude) satellites. An uncertainty of 50 γ, 30 γ of which is attributed to the magnetosphere has been calculated from existing satellite observations (Cain, 1971). The satellite observations cover the earth's surface uniformly and are undisturbed by anomalies from rock magnetism which often are 200–400 γ in amplitude. Fig.31 and Fig.32 show world charts of the total magnetic intensity and its annual variation for 1965. In the past, the reference field was obtained by interpolation from these charts. Nowadays there has been set up by international agreement the International Geomagnetic Reference Field, for which the harmonic coefficients are given in Appendix 1. The coefficients with their secular variation are inserted in appropriate computer programs to give the reference field for a given date at corners of a latitude-longitude grid. The field between the grid points is obtained by linear interpolation. Bullard (1967) shows that with a 1° grid interval the maximum error from the linear interpolation is 2 γ. The reference field so obtained is subtracted from the observed field in the computer to give the anomalous field.

CHRONOLOGY OF GEOMAGNETIC FIELD REVERSALS

The direction of the geomagnetic field in the geologic past is recorded in rocks and sediments in the oceans as well as on land. For several decades it has been known that the

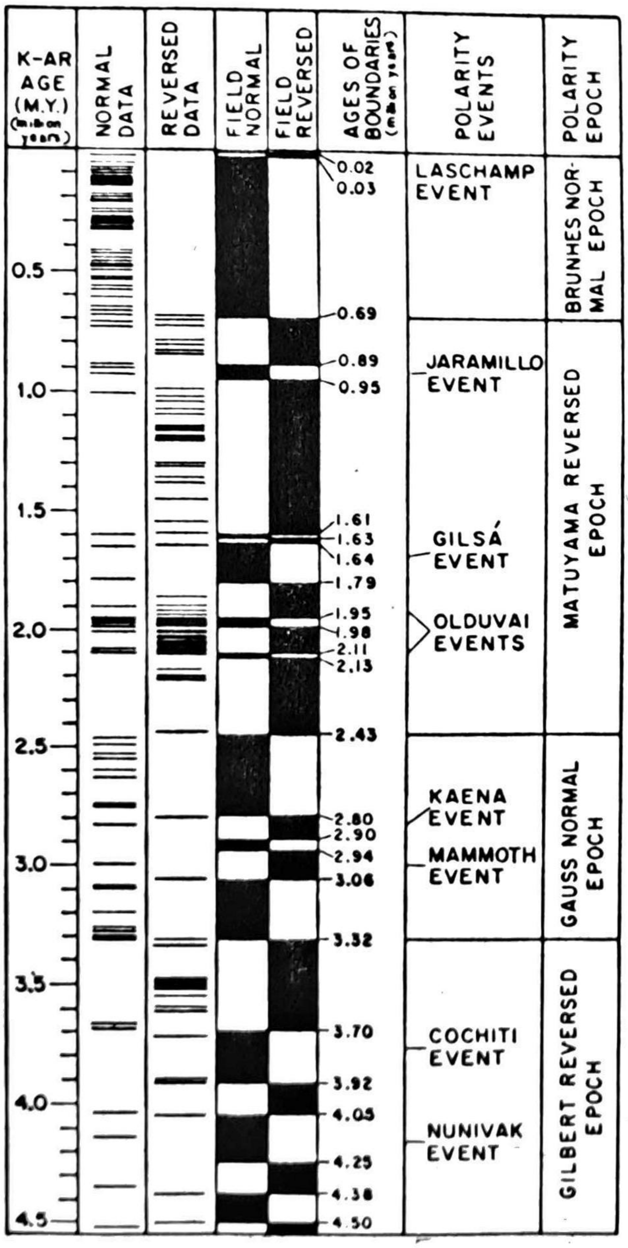


Fig. 33. Chronology of geomagnetic field reversals from K-Ar age determinations on lava flows. (Cox, 1969.)

magnetization of successive lava flows on land was often reversed to the direction of the geomagnetic field, the normal and the reversed directions occurring in a definite pattern. These reversals were attributed to the geomagnetic field having a reverse orientation at the time the lavas cooled down, or to mineralogical mechanisms which produced a magnetization in the opposite direction to the ambient field during cooling. Intermediate directions were absent. Reverse magnetization from mineralogical mechanisms are now generally regarded as being rare isolated occurrences. By dating the lava flows by the potassium–argon method, one can establish the chronology of geomagnetic reversals back to about 4.5 million years before present (m.y.B.P.) before the errors of age determination become large enough to mask the reversals. Fig.33 shows the chronology of geomagnetic reversals so obtained. "Epochs" of normal and reversed polarity are interrupted at random by short "events" of opposite sign. The "epochs" and "events" have been given proper names which are now generally accepted in paleomagnetic literature. Some of the events are so short that their identification is subject to heated controversies (Watkins, 1972).

THE THEORY OF VINE AND MATTHEWS

Vine and Matthews (1963) and independently Morley and Larochelle (1964), proposed that the lineated magnetic anomalies found in the Northeast Pacific by Mason and Raff (1961) (Fig.34) were generated by the spreading of the sea floor postulated by Hess (1962) and Dietz (1962). Prior to this, Vacquier et al. (1961) found displacements of 1,400 km of the anomaly patterns across the Mendocino and Pioneer fracture zones which suggested mobility of rigid pieces of ocean floor, even though their original interpretation as transcurrent fault displacements was incorrect. The Vine and Matthews (1963) concept is illustrated on Fig.35 which shows a magnetic profile normal to the Juan de Fuca Ridge. Basalt rises at the ridge crest moving symmetrically outward, cools in the geomagnetic field acquiring a thermoremanent magnetization in the same direction as the field. When the field reverses direction, a band of oppositely magnetized basalt is laid down. If the spreading is uniform, geomagnetic reversals are recorded in the ocean bottom in a similar way to the tape of a magnetic tape recorder. The observed symmetry of the magnetic anomalies about the ridge axis supports the validity of the simple symmetrical spreading of Fig.35 and it is also found that the same idealized pattern of alternately magnetized strips produces computed magnetic anomalies similar to those observed in different parts of the world. The shape of the anomalies depends on the latitude and the orientation of the ridge, but the pattern of sea-floor magnetization reversals is the same everywhere with respect to time. This has been demonstrated beyond the shadow of a doubt (to most geophysicists at least) that alternate directions of magnetization of rocks and sediments have been caused by world-wide reversals of the geomagnetic field. Descriptions of lineated magnetic anomalies will be presented in detail in Chapters 5, 8–12. At this time we shall bring up only evidence needed to establish the

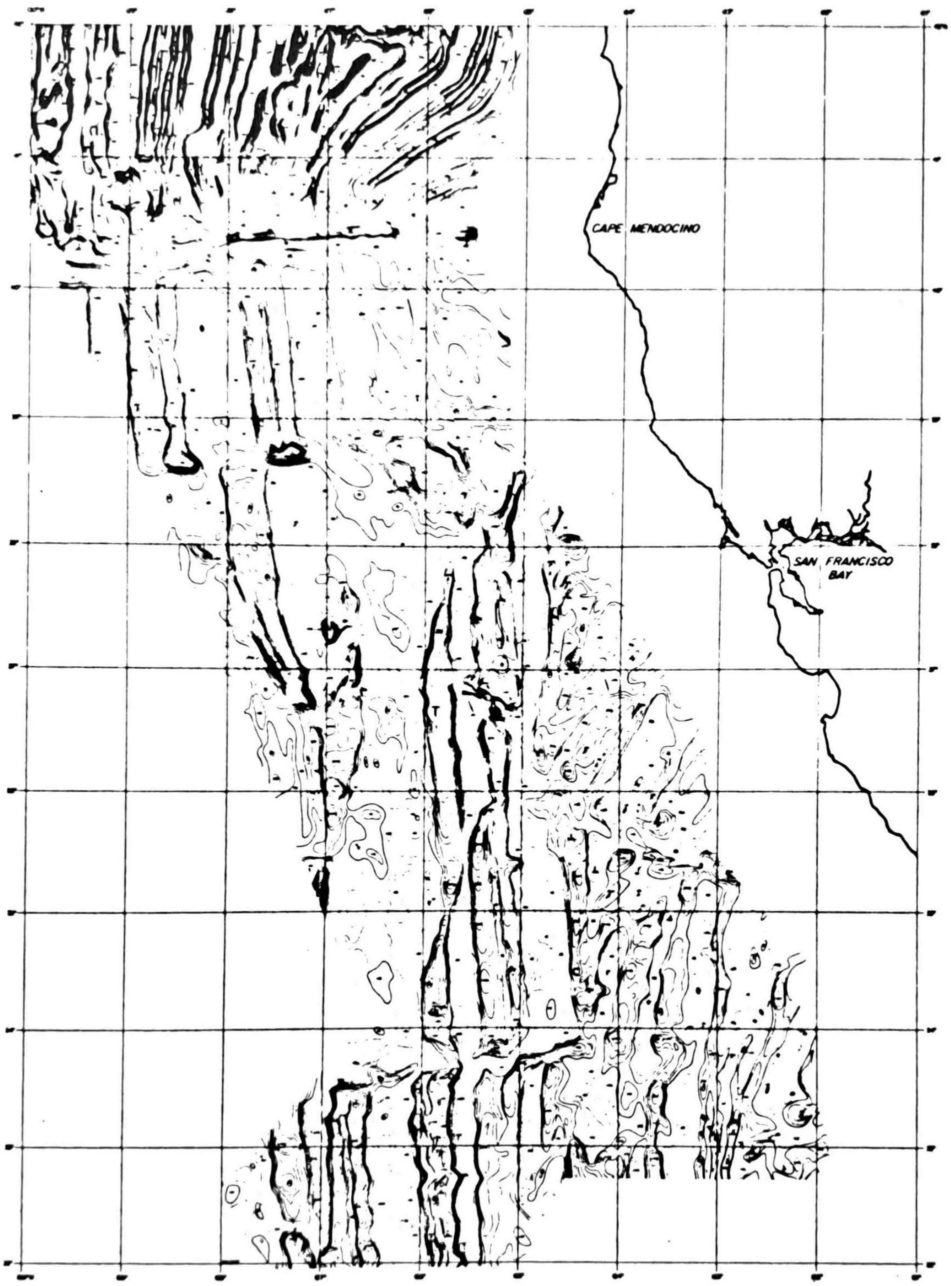


Fig.34. Total magnetic intensity anomaly chart off the west coast of California. Contour interval 40 λ. (Mason and Raff, 1961.).

character and the chronology of geomagnetic field reversals from data taken in the oceans.

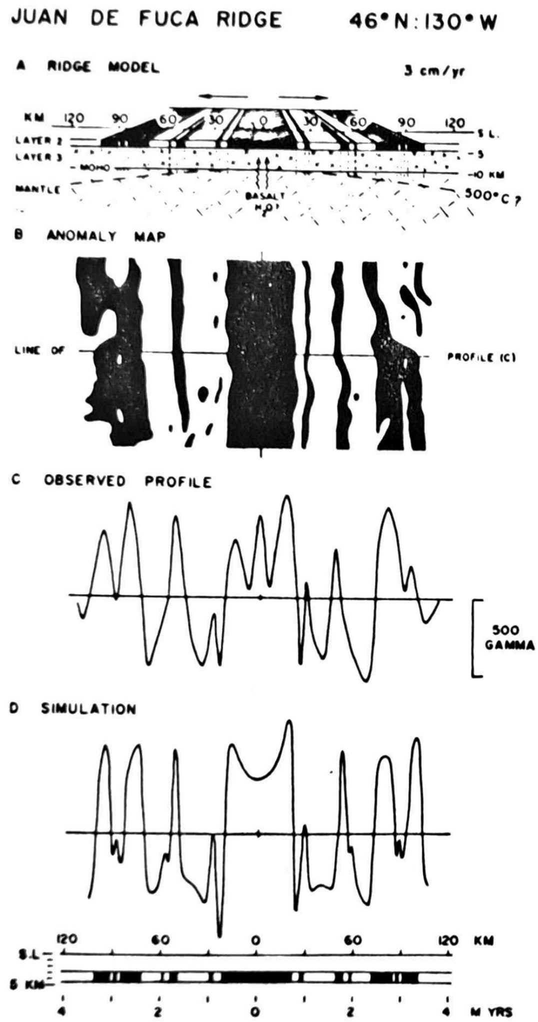


Fig.35.

A. A schematic representation of the crustal model discussed in the text, applied to the Juan de Fucca Ridge, southwest of Vancouver Island. Shaded material in layer 2, normally magnetized; unshaded, reversely magnetized.

B. Part of the summary map of magnetic anomalies recorded over the Juan de Fuca Ridge (Raff and Mason, 1961). Black, areas of positive anomalies; white, areas of negative anomalies.

C. A total-field magnetic anomaly profile along the line indicated in B.

D. A computed profile assuming the model and reversal time scale discussed in the text. Intensity and dip of the earth's magnetic field taken as 54,000 γ and +66°; magnetic bearing of profile 087°. ($1 \gamma = 10^{-5}$ Oe. *S.L.* = sea level.)

Note: Throughout, observed and computed profiles have been drawn in the same proportion: 10 km horizontally is equivalent to 100 γ vertically. Normal or reverse magnetization is with respect to an axial dipole vector, and the effective susceptibility assumed is ±0.01 except for the central block at a ridge crest (+0.02). (From Vine, 1968.)

REVERSAL CHRONOLOGY IN OCEAN SEDIMENTS

The inclination of the direction of magnetization to the axis of a core of oceanic sediment can be measured by ordinary paleomagnetic methods. Some of the fine particles $1-10\,\mu$ in diameter constituting marine sediments come from weathering of rocks containing magnetic minerals, mostly titaniferous magnetite. Despite compaction and the thorough mixing of the first few cm of sediment by burrowing marine animals, the ancient geomagnetic field direction is faithfully recorded in cores of marine sediments. On the other hand, laboratory re-disposition in quiet water of the very same sediment usually leads to flattening of the magnetic inclination of the order of $5-20°$ because elongated particles are more magnetic than spherical ones and tend to settle with their long dimension horizontal. Even if the particles are spherical, if they roll some as they settle on the bottom, the average dip angle will be shallower than the inclination of the field (Griffiths et al., 1962). It is thus likely that marine sediments acquire their magnetization not during settling but after deposition. Experiments by Lloyd (quoted in Clegg et al., 1954) tend to confirm this hypothesis. Triassic marl was crushed to powder and allowed to settle in a tank. Magnetization of the resulting sediment showed a flattening of 8° in a field inclined 65°. Sediment of the same marl deposited in zero field could also be magnetized by standing in a weak field. The magnetization of that sediment showed no inclination error provided the water content of the deposit exceeded 50%. A similar experiment is quoted by Irving (1964, p.32) on a mixture of magnetite and quartz sand grains ranging in particle size from coarse silt to fine sand. The ingredients were mixed dry, then flooded with water and allowed to stand over night in a weak magnetic field. The magnetization of the resulting sediment was parallel to the external field which had an inclination of 65°. In all probability the depositional magnetization of marine sediments has been erased by subsequent reworking by animals, and the magnetism we measure has been acquired by standing in the earth's field while they still contained much water by a mechanism that is still obscure. The rate of deposition in the deep oceans away from continents is about a millimeter per thousand years, so that we may expect the secular variation to be nearly averaged out in a sample about 1 cm big. The rate of sedimentation determines the length of the time interval recorded in a deep-sea core. When sedimentation is slow as in Fig.36, most of the time scale of Fig.33 appears in the magnetization reversals of the core. The length in cm of polarity epochs in the core differs somewhat from the K–Ar scale, reflecting variations in rates of deposition. Nevertheless the pattern of field reversal epochs determined on continental lavas is evident in the sedimentary record in the ocean.

When the rate of sedimentation is rapid, it may reveal very short polarity events which are likely to be missed in a series of discrete continental lava flows. Thus reversal events have been found as short as 4,000 years. Rapid sedimentation also shows that the geomagnetic field switches sign in just a few thousand years as shown on Fig.37. It does so not by slowly swinging around, but by decreasing in intensity to nearly zero and then growing in the opposite direction. The intensity of the earth's field in the geologic past

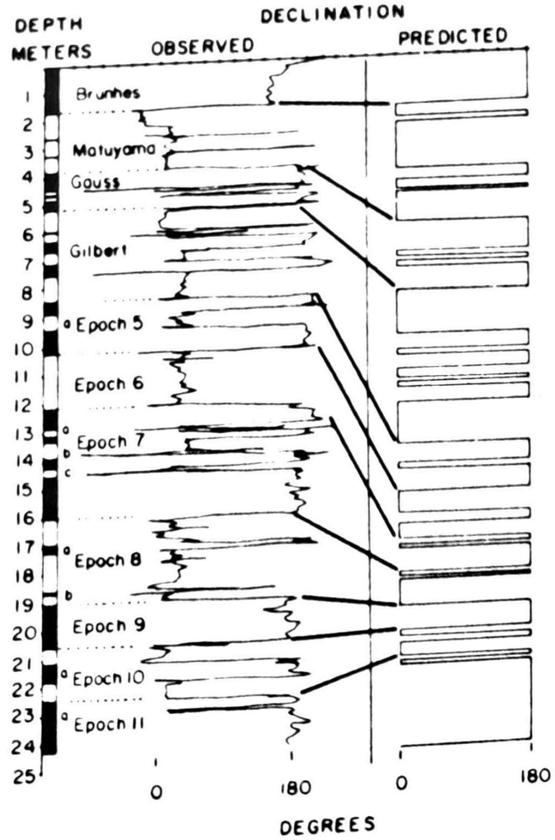


Fig.36. The change of magnetic declination in Conrad 12-65 after partial demagnetization of 50 Oe with respect to the split face of the core as a function of depth, compared with the reversal sequence predicted by the sea-floor-spreading time scale of Vine (1968). The black (normal) and white (reversed) bar diagram on the left indicates the proposed extension of the geomagnetic time scale based on this study. (Foster and Opdyke, 1970.)

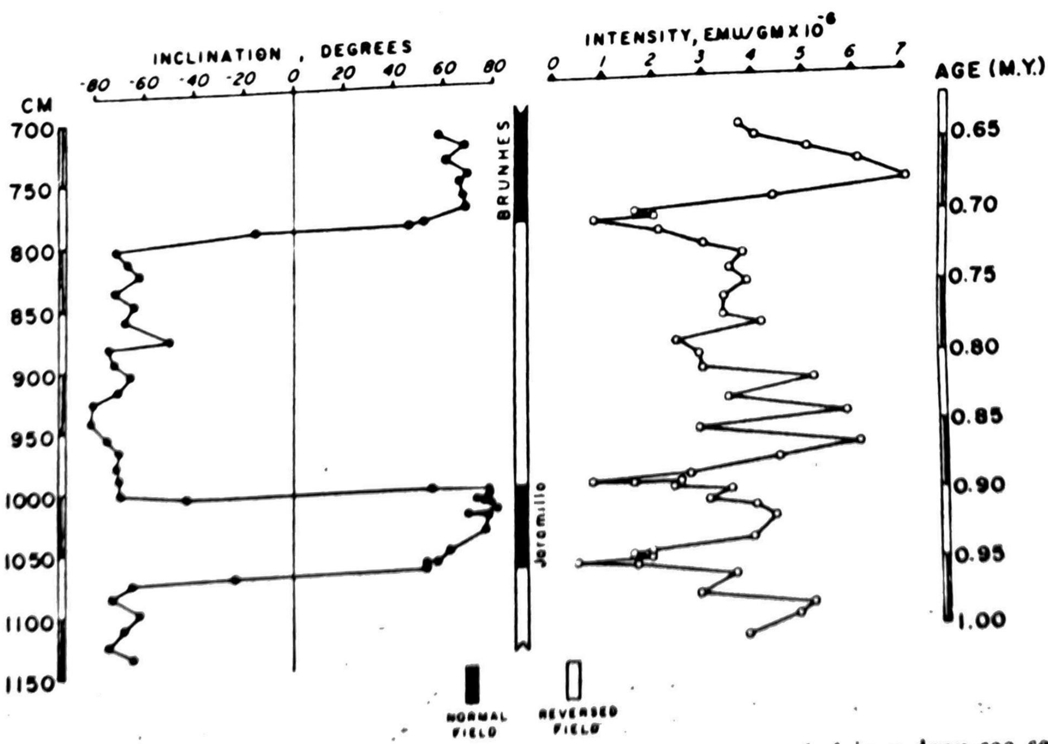


Fig.37. Character of the geomagnetic reversal process as recorded in a deep-sea sediment core. (After Opdyke, 1968.)

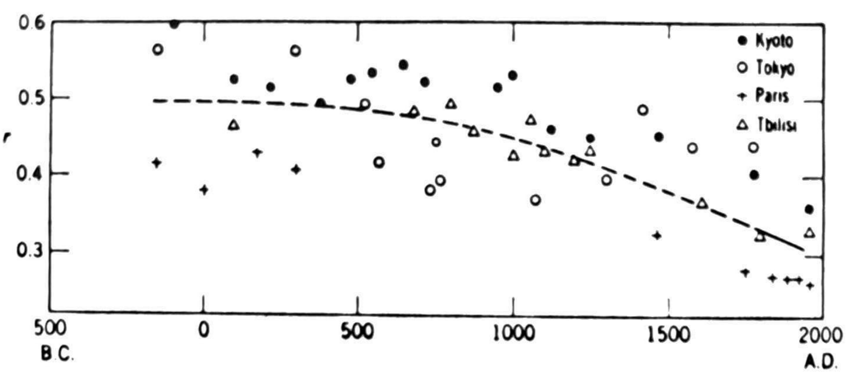


Fig.38. Intensity variation of the geomagnetic field over 2,000 years from measurement of four archeomagnetic groups. All values have been adjusted to give field intensities at the equator, assuming that the field was a simple dipole, a procedure which is expected to introduce up to 20% errors in individual observations but cannot affect the trend apparent in all of the data taken together. Figure from Sasajima (1965, quoted in Stacey, 1969) by permission of the Society of Terrestrial Magnetism and Electricity, Japan, and the author. (From Stacey, 1969.)

has also been investigated by measurements on rocks baked by geologically dated lava flows. In the study of Bolshakov and Solodovnikov (1969), the values of the ancient field for eight dated lava flows ranging from Late Quaternary to Oligocene vary from 0.48 to 1.05 of the present day value, whereas archeomagnetic results on ancient pottery and bricks suggest that about 200 A.D. the geomagnetic field was 1.6 times stronger than it is now (Burlatskaia et al., 1969). The paleointensity measurement consists of comparing the NRM of a specimen to the TRM it acquires in laboratory experiments from a weak field of known strength (Théllier and Théllier, 1959). Archeomagnetic measurements summarized in Fig.38 indicate the intensity of the geomagnetic field is now decreasing at a rate that will bring it to zero in about 2,000 years.

World-wide sampling of paleomagnetic directions of recent rocks has shown that on the average the geomagnetic field did not depart from the field of an axial dipole directed to geographic south in the last 10 m.y. Therefore if the magnetic inclination is faithfully recorded in oceanic sediments, it should be related to geographic latitude λ by $\tan I = 2 \tan \lambda$. That this is indeed true is proved by Fig.39 where the mean inclination from samples from the Brunhes and Matuyama epochs taken from 52 cores of ocean floor sediment obtained at various geographic latitudes are plotted with the inclination curve given by the formula.

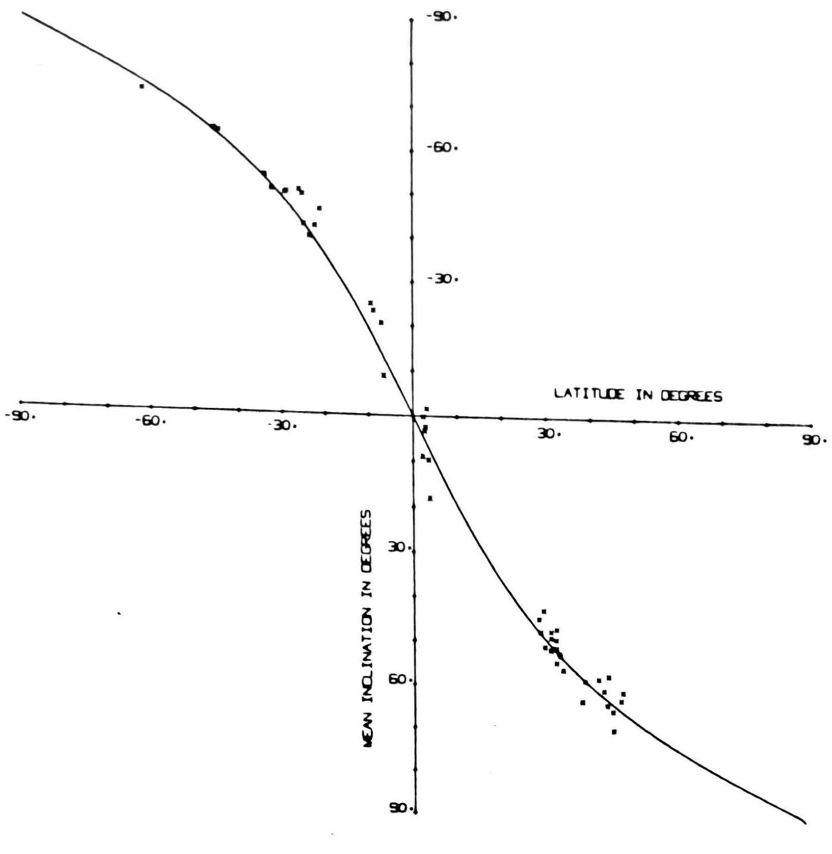


Fig.39. Magnetic inclination in 52 ocean cores for Brunhes and Matuyama epochs plotted against geographic latitude. The smooth curve is the theoretical relation tan I = 2 tan λ for the geocentric dipole. (From Opdyke and Henry, 1969.)

EXTRAPOLATION OF REVERSAL CHRONOLOGY FROM LINEATED ANOMALIES

So far we have built a time scale of geomagnetic field reversals based on K–Ar measurements and paleomagnetic measurements on lavas and oceanic sediments which extends to 4.5 m.y.B.P. To apply this scale to the Vine and Matthews (1963) method of measuring sea-floor spreading, we have to compare the anomaly computed from a model with the lineated anomaly pattern measured in the ocean. The model consists of parallel strips of normally and reversely magnetized rock parallel to the ridge crest, the top of which lies at the surface of the ocean bottom. The vertical thickness of the magnetized crust is usually taken as being constant and lying within the "basaltic" layer (Layer 2 of seismology), although it is conceivable that it could extend down to the Curie point isotherm, the maximum value of which is about 575°C (Vine, 1968). As a rule, the thickness of the model strip is taken between 0.5 and 2.5 km but since the ocean is generally 4 km deep, the shapes of the calculated anomalies are not seriously affected by the assumed thickness of the model. Recent measurements by Irving et al. (1970) on basalt samples from the Mid-Atlantic Ridge suggest a thickness of only 200 m for the magnetic layer. The models usually assume that the rock was magnetized by the field of the geocentric dipole at present latitude. This is not necessarily the case when north–south spreading of ancient age has displaced the site in latitude. The shape of the anomalies is also dependent on the azimuth of the profile. In Appendix 2, computation of sea-floor spreading magnetic anomalies from strip models is described in detail.

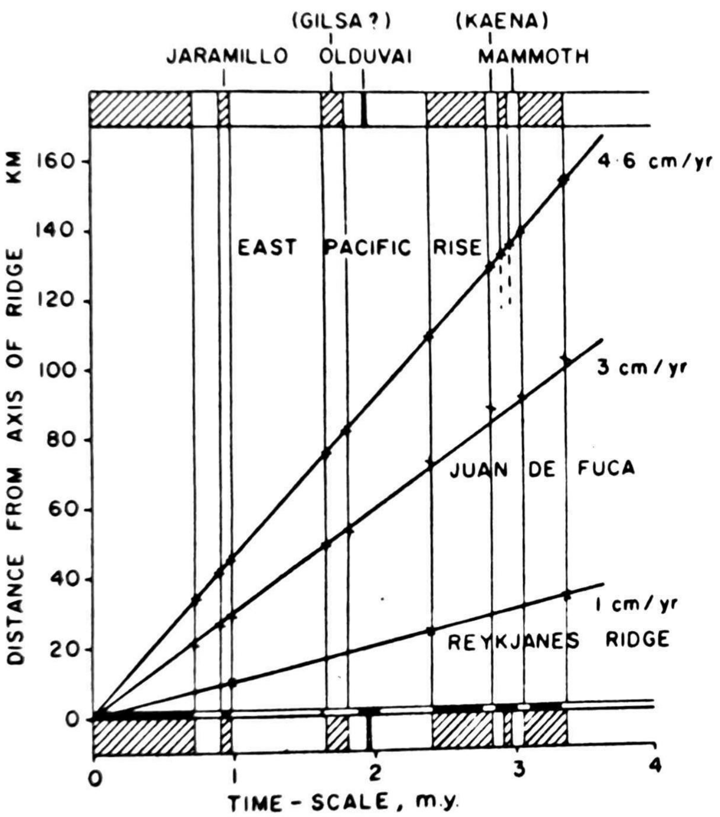


Fig.40. Inferred normal-reverse boundaries in the oceanic crust plotted against a suggested reversal time scale. (Shaded intervals, periods of normal polarity.) The thin black-and-white time scale indicated immediately above the abscissa is that suggested by Cox (1969). (From Vine, 1968.)

On Fig.40 the boundaries between the normal and reversely magnetized strips of the model are plotted against distance from the ridge crest for three different ridges. Along the horizontal axis the time scale of geomagnetic field reversals is also shown up to 4 m.y.B.P. The spreading rates given by the slopes of the lines appear to be uniform for the three ridges.

Heirtzler et al. (1968) assumed that the spreading rate in the South Atlantic remained constant for the whole sequence of recognizable magnetic anomalies. On this assumption, and from paleontological evidence of a South Atlantic core, the oldest recognizable magnetic anomaly was laid down about 80 m.y. ago. The magnetic anomalies which were

TABLE III[1]
Intervals of normal polarity (m.y.)
(After Heitzler et al., 1968)

0.00- 0.69	18.91-19.26	40.03-40.25
0.89- 0.94	19.62-19.96	40.71-40.97
1.78- 1.93	20.19-21.31	41.15-41.46
2.48- 2.93	21.65-21.91	41.52-41.96
3.06- 3.37	22.17-22.64	42.28-43.26
4.04- 4.22	22.90-23.08	43.34-43.56
4.35- 4.53	23.29-23.40	43.64-44.01
4.66- 4.77	23.63-24.07	44.21-44.69
4.81- 5.01	24.41-24.59	44.77-45.24
5.61- 5.88	24.82-24.97	45.32-45.79
5.96- 6.24	25.25-25.43	46.76-47.26
6.57- 6.70	26.86-26.98	47.91-49.58
6.91- 7.00	27.05-27.37	52.41-54.16
7.07- 7.46	27.83-28.03	55.92-56.66
7.51- 7.55	28.35-28.44	58.04-58.94
7.91- 8.28	28.52-29.33	59.43-59.69
8.37- 8.51	29.78-30.42	60.01-60.53
8.79- 9.94	30.48-30.93	62.75-63.28
10.77-11.14	31.50-31.84	64.14-64.62
11.72-11.85	31.90-32.17	66.65-67.10
11.93-12.43	33.16-33.55	67.77-68.51
12.72-13.09	33.61-34.07	68.84-69.44
13.29-13.71	34.52-35.00	69.93-71.12
13.96-14.28	37.61-37.82	71.22-72.11
14.51-14.82	37.89-38.26	74.17-74.30
14.98-15.45	38.68-38.77	74.64-76.33
15.71-16.00	38.83-38.92	
16.03-16.41	39.03-39.11	
17.33-17.80	39.42-39.47	
17.83-18.02	39.77-40.00	

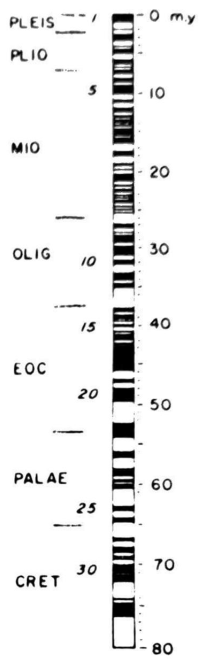


Fig.41. The geomagnetic time scale. From left to right; time scale for geologic eras, numbers assigned to bodies and magnetic anomalies, geomagnetic field polarity with normal polarity periods colored black. (Heirtzler et al., 1968.)

[1] McKenzie and Sclater (1971) identify a small positive anomaly after 32 and a strong positive 33 on most profiles in the North Pacific and Indian Oceans. Starting with the third line from the bottom of Table III, their modification of the Heirtzler et al. time scale is: 71.22–72.01; 74.01–74.21; 74.35–75.86; 76.06–76.11; 76.27–.

considered easy to identify were given reference numbers, as shown on Fig.41 and Table III, which have been adopted in the literature. Fig.42 presents the actual and the computed anomalies for the North and the South Pacific from presently spreading ridges. From the heavy vertical lines connecting the same anomalies on different profiles, it is apparent that variations of spreading rates have occurred. By comparing spreading rates in different oceans one might spot the places where changes of spreading rates have happened. This is done in Fig.43 where the distance to a given magnetic anomaly in the

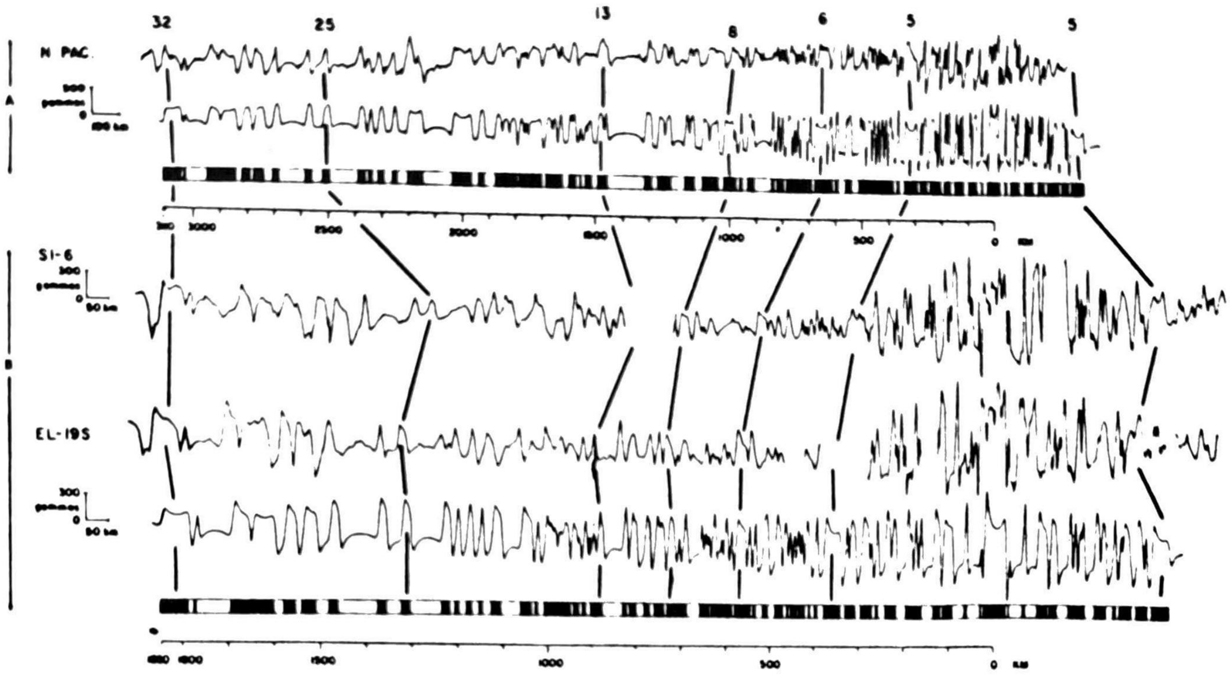


Fig.42. A. North Pacific composite profile. Bottom is the set of model blocks for the North Pacific, immediately above which is the computed anomaly profile. B. Top shows the *SI-6* and the *EL-19S* magnetic anomaly profiles from the South Pacific. Bottom is the set of model blocks derived for the South Pacific and immediately above is the computed magnetic profile. Time scale is related to distance by extrapolation from the Gilbert reversed epoch. (Pitman et al., 1968.)

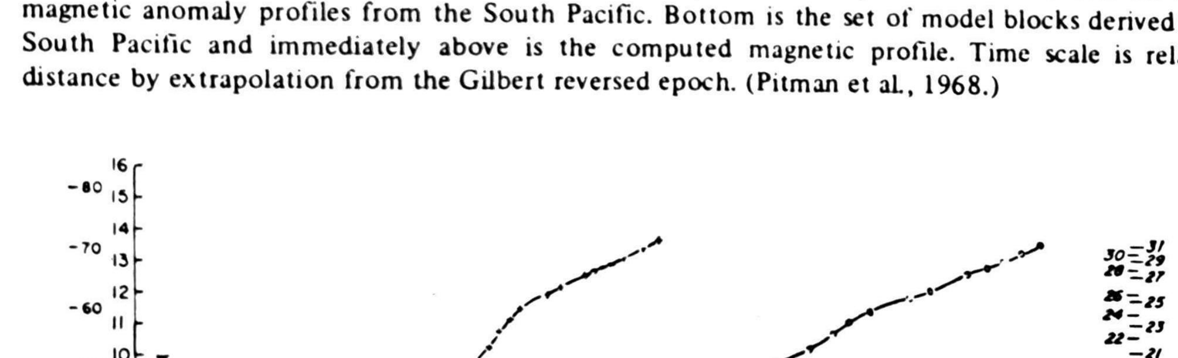
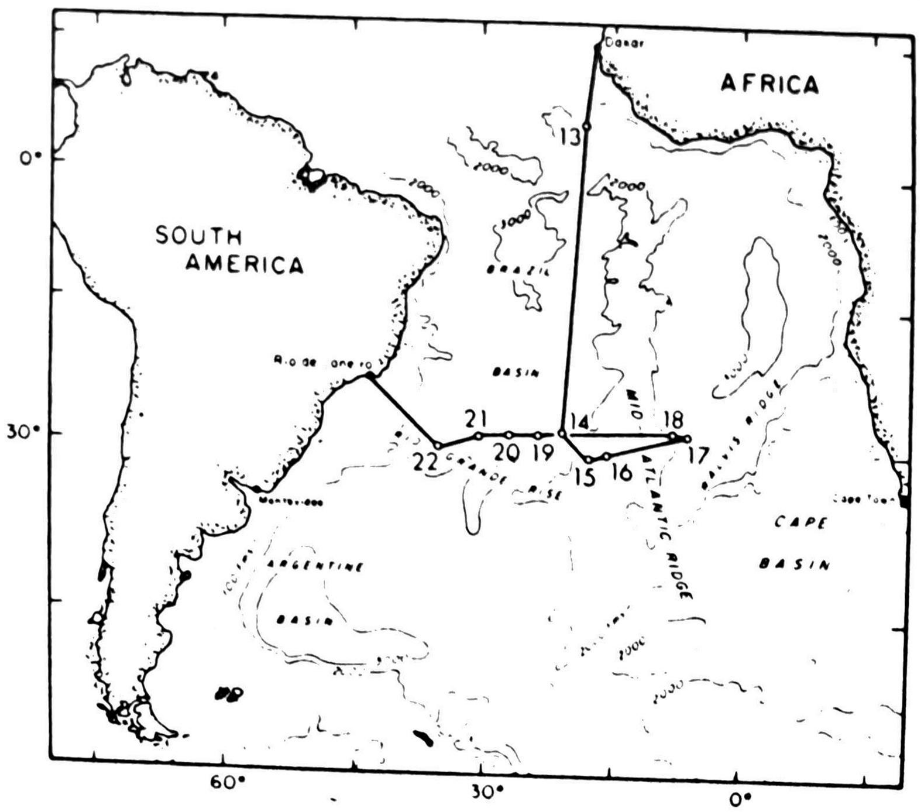


Fig.43. The distance to a given anomaly in the South Atlantic versus distance to the same anomaly in the South Indian, North Pacific, and South Pacific oceans. Numbers on right refer to anomaly numbers. (Heirtzler et al., 1968.)

South Indian, North Pacific and South Pacific Oceans is compared to the distance to the same anomaly in the South Atlantic. The three curves should show coherent departures from linearity if the spreading rate varied in the South Atlantic. After anomaly 6 (21 m.y.B.P.) spreading in the North Pacific appears to have slowed down by a ratio of about



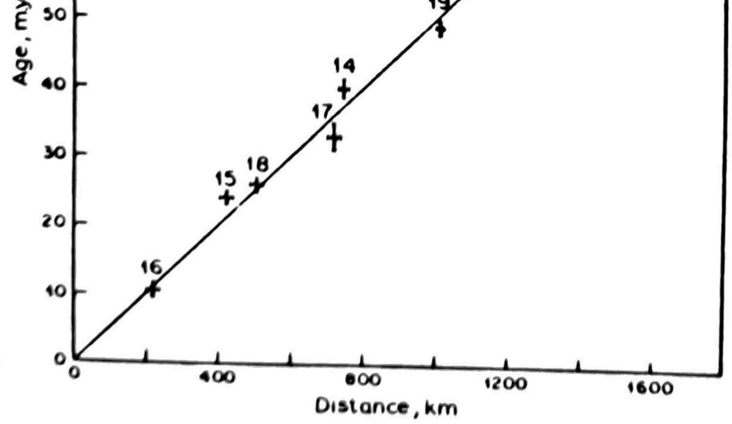


Fig. 44. Comparison of paleontológical and magnetic anomaly ages from deep-sea drilling in the South Atlantic. The paleontological age of the sediment immediately above the basalt is plotted against distance from the ridge axis. The index number of the points refers to the drilling locations shown on the map. Slightly revised from Peterson (1969).

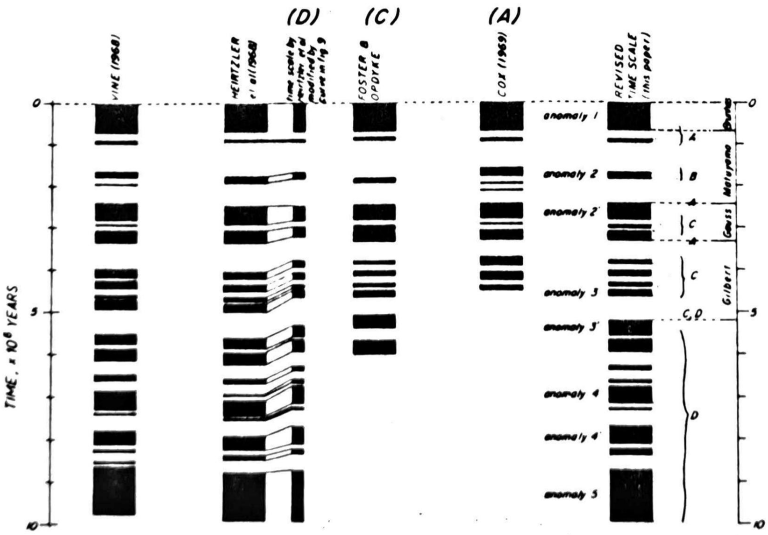
TABLE IV

Paleontological age of sediment from JOIDES cores immediately above basalt in the South Atlantic compared with extrapolated age of magnetic anomalies of Heirtzler et al. (1968)

Site no.[1]	*Magnetic anomaly no.*	*Age from magnetic anomaly time scale (m.y.)*	*Paleontological age of sediment above basement (m.y.)*	*Distance from ridge axis along arc about rotation center at 62°N 36°W*
16	5	9	11 ± 1	221 ± 20
15	6	21	24 ± 1	422 ± 20
18	-	-	26 ± 1	506 ± 20
17	-	34-38	33 ± 2	718 ± 20
14	13-14	38-39	40 ± 1.5	745 ± 10
19	21	53	49 ± 1	1010 ± 10
20	30	70-72	67 ± 1	1303 ± 10
21	-	-	76	1686 ± 10

[1] Basement rock not reached at site 21.

3/2 from 4.4 cm/year to 2.9 cm/year as pointed out by Vine (1966). The other two curves do not show a kink at this ordinate, so we can presume it happened in the North Pacific. Similarly we can argue that the spreading rate increased in the South Pacific about anomaly 24 time (60 m.y.B.P.). Tentatively one might conclude that spreading rates stay the same for long stretches of time. The geomagnetic reversal time scale of Heirtzler et al. (1968), as given on Fig.41 was confirmed by deep-sea drilling in the South Atlantic (Table IV, Fig.44). Since its publication in 1968 the first 10 m.y. of the Heirtzler



0.00–0.69 m.y.
0.89–0.95
1.71–1.86
2.43–2.84
2.94–3.04
3.10–3.32
3.78–3.88
4.01–4.17
4.31–4.41
4.48–4.66
5.18–5.58
5.66–5.94
6.26–6.39
6.59–6.68
6.75–7.17
7.24–7.30
7.69–8.11
8.21–8.37
8.71–9.94

Fig.45. Proposed reversal chronologies. The revised chronology is shown at the right. The dotted lines to the right of this plotted time scale serve to indicate the source of the age for a particular reversal. Source B is Opdyke and Foster (1971, quoted in Talwani et al., 1971). The revised intervals of normal polarity are given in the table to the right. (Talwani et al., 1971.)

et al. geomagnetic reversal scale has suffered several revisions. Fig.45 reviews them and gives the latest revised intervals of normal polarity.

LENGTH OF POLARITY EPOCHS

Within the span of 80 m.y. covered by the reversal time scale, the geomagnetic field spent approximately the same amount of time in the normal and the reversed polarities (Fig.46). On the average, the magnetic field spends 0.45 m.y. in each polarity which

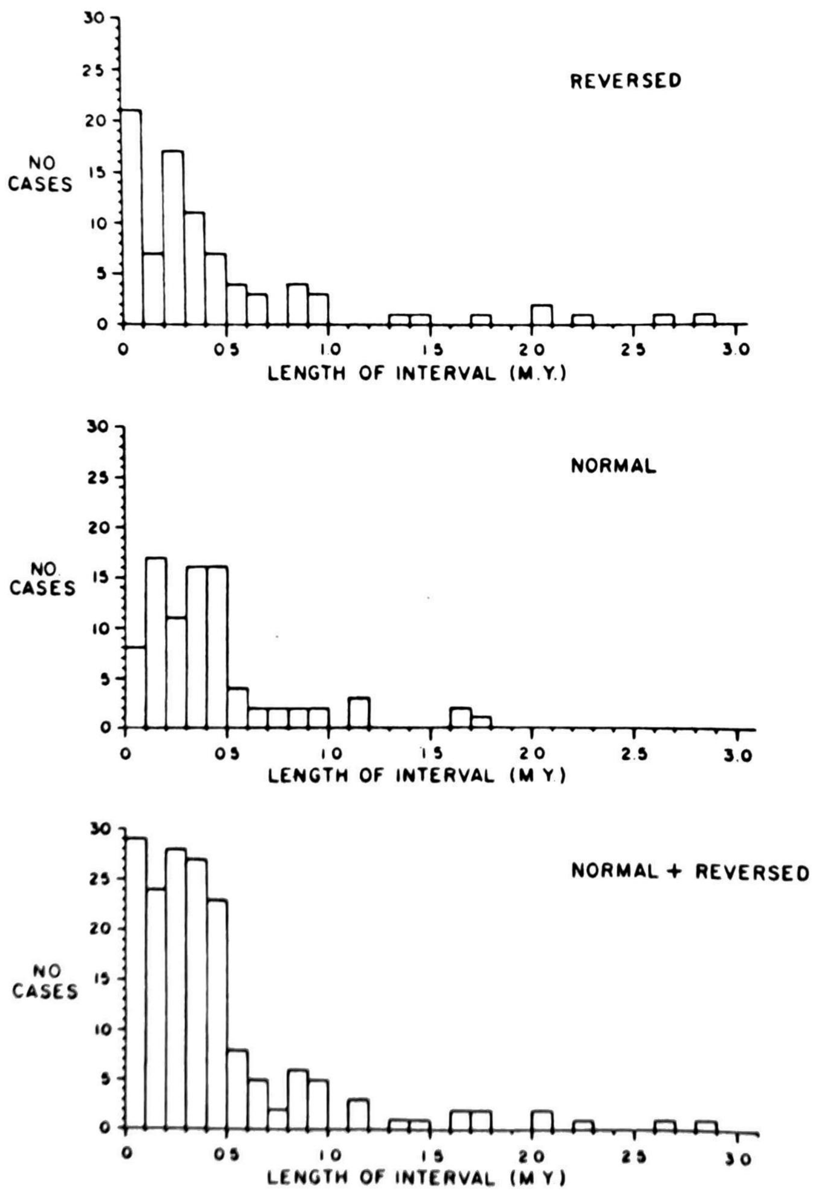


Fig.46. Distributions of the lengths of magnetic states for reversed polarity and normal polarity and for the lengths of intervals regardless of polarity. (Heirtzler et al., 1968.)

appear to be equally stable. The frequency of geomagnetic reversals, however, has shown a marked increase (Fig.47). The increase in frequency of oscillation of the anomalous field as one approaches the ridge also is evident on Fig. 42.

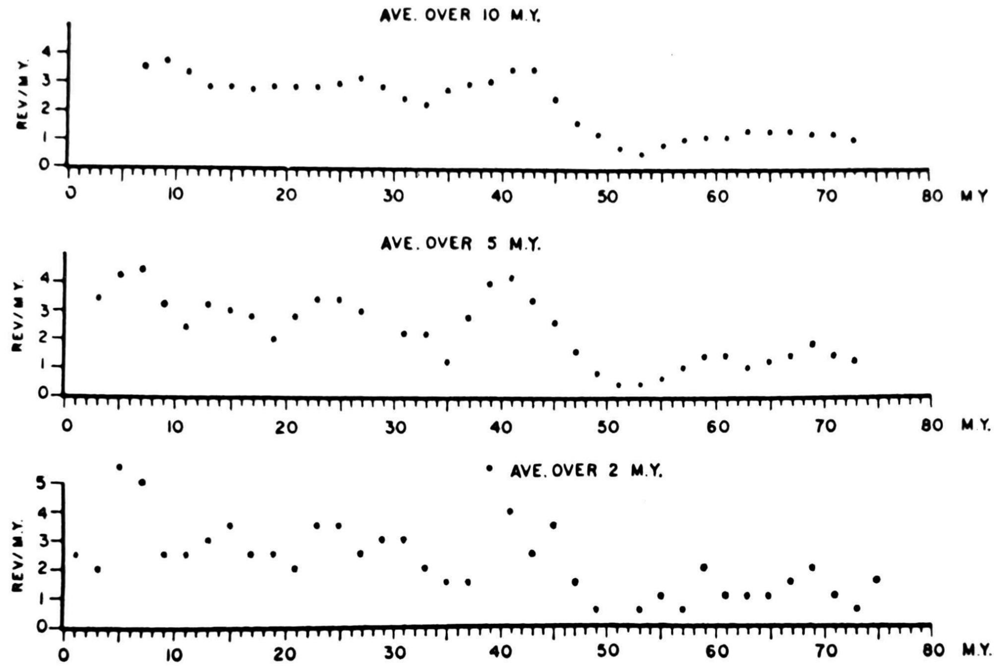
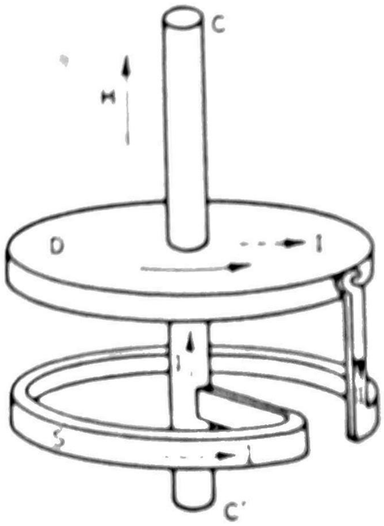


Fig.47. Frequency of geomagnetic field reversals as a function of time averaged over intervals of 2, 5, and 10 m.y. (Heirtzler et al., 1968.)

THE GEOMAGNETIC DYNAMO

Bullard (1968) discusses the impact of these data on the theories of the origin of the geomagnetic field. Convection of the electrically conducting substance of the earth's liquid core from an unspecified source of energy under the influence of the earth's rotation and in the presence of an infinitesimally small magnetic field produce electric currents which regeneratively grow to a steady value to give the present geomagnetic field (Elsasser, 1955). The mechanism is presumed to be analogous to the behavior of a disc homopolar generator of Fig.48, in which the current and magnetic field may point in either direction.

Two such dynamos, rotating at different speeds and connected in series as shown on Fig.49, can give by proper choice of circuit constants an oscillating electric current which will periodically change its sign as shown on Fig.50. The extension of this model to the spherical case of the earth's liquid core is very complex and has not as yet been carried out. Quoting Bullard (1968): "It is possible that the essential electromagnetic features of the mechanism producing the earth's field are simulated or realistically caricatured by the double dynamo".



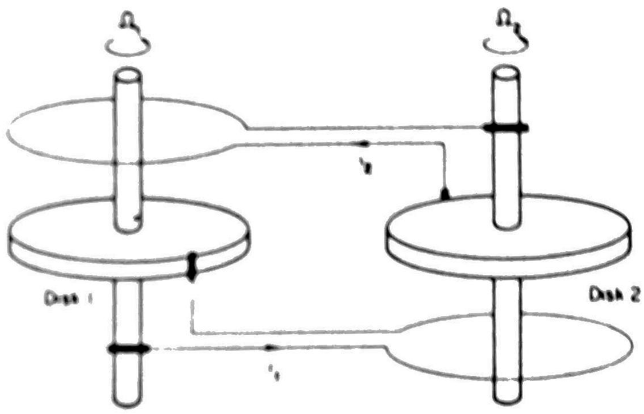


Fig.48. Bullard disk dynamo. (Bullard, 1968.) CC' = axis; D = rotating disk; S = spiral wire.

Fig.49. Two Bullard disk dynamos connected in series. (Rikitake, 1968.)

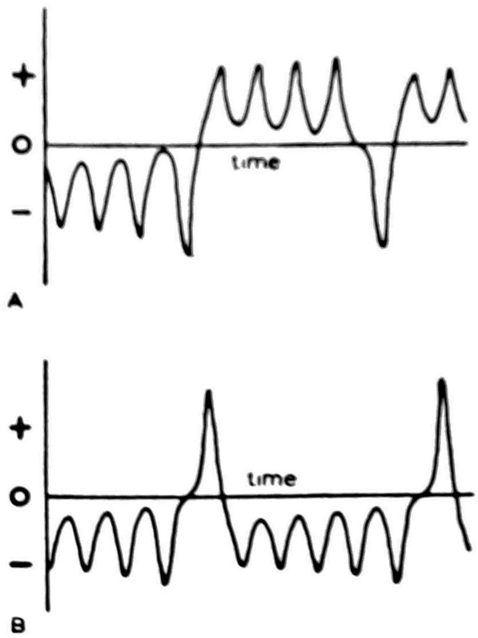


Fig.50. One of the currents in a pair of coupled disk dynamos. In (A) the current oscillates about one equilibrium value and then reverses and oscillates about the other. In (B), which is an earlier part of the same solution, the reversal only lasts for a short time.(From Allan, 1962, quoted in Bullard, 1968.)

~~TOP SECRET~~

DEPARTMENT OF TRANSPORT

INTRA-DEPARTMENTAL CORRESPONDENCE

Declassified See memo Dec 14/79

OTTAWA, Ontario, November 21, 1950.

PLACE DATE

YOUR FILE	SUBJECT	OUR FILE
	Geo-Magnetics	(R.ST.)

Downgraded to CONFIDENTIAL See memo 15/4/69 CF

MEMORANDUM TO THE CONTROLLER OF TELECOMMUNICATIONS:

For the past several years we have been engaged in the study of various aspects of radio wave propagation. The vagaries of this phenomenon have led us into the fields of aurora, cosmic radiation, atmospheric radio-activity and geo-magnetism. In the case of geo-magnetics our investigations have contributed little to our knowledge of radio wave propagation as yet, but nevertheless have indicated several avenues of investigation which may well be explored with profit. For example, we are on the track of a means whereby the potential energy of the earth's magnetic field may be abstracted and used.

On the basis of theoretical considerations a small and very crude experimental unit was constructed approximately a year ago and tested in our Standards Laboratory. The tests were essentially successful in that sufficient energy was abstracted from the earth's field to operate a voltmeter, approximately 50 milliwatts. Although this unit was far from being self-sustaining, it nevertheless demonstrated the soundness of the basic principles in a qualitative manner and provided useful data for the design of a better unit.

The design has now been completed for a unit which should be self-sustaining and in addition provide a small surplus of power. Such a unit, in addition to functioning as a 'pilot power plant' should be large enough to permit the study of the various reaction forces which are expected to develop.

We believe that we are on the track of something which may well prove to be the introduction to a new technology. The existence of a different technology is borne out by the investigations which are being carried on at the present time in relation to flying saucers.

While in Washington attending the NARB Conference, two books were released, one titled "Behind the Flying Saucer" by Frank Scully, and the other "The Flying Saucers are Real" by Donald Keyhoe. Both books dealt mostly with the sightings of unidentified objects and both books claim that flying objects were of extra-terrestrial origin and might well be space ships

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Smith advises his superiors at the Canadian Ministry of Transport that flying