A MARINE MAGNETIC SURVEY
IN THE
MACKENZIE BAY / BEAUFORT SEA AREA
ARCTIC CANADA

by

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ABSTRACT

This thesis presents an investigation of the variations in the magnetic field obtained in the Mackenzie Bay/Beaufort Sea area of the Canadian Arctic.

It was found that the variations obtained at sea were strikingly correlated with those recorded at Point Atkinson, a fixed station on land, 150 miles from the survey area. In addition, it was found that the higher frequencies present in the marine records were severely attenuated with respect to the corresponding frequencies in the Point Atkinson recordings. It was concluded that the Mackenzie Bay/Beaufort Sea area is geomagnetically anomalous and that this situation is probably caused by higher electrical conductivity material underlying the Mackenzie Bay/Beaufort Sea area, abutting lower conductivity material of the North American craton underlying Point Atkinson. This conclusion has important implications relating to the tectonic history of the Canadian Arctic.

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With respect to data collection, this thesis would not have been possible without support from all members of the cruise on the CSS PARIZEAU--particularly the Master, Captain Colin Angus and the Chief Hydrographer, Stan Huggett. In addition, I would also like to thank Dr. Don Tiffin of the west-coast Marine Sciences group, Geological Survey of Canada in Vancouver for his generous support of this project. Brian Clarke of the Marine Sciences Branch, Department of the Environment (formerly the Canadian Hydrographic Service) must be mentioned for his prowess in computer-program bug-finding.

Much time was spent on the computer-processing of the large amount of data gathered in this survey. I have obtained meaningful results only with the help of the superb staff at the Computing Centre here at the University of British Columbia

Numerous others have given heartfelt encouragement and made studies at this university a great pleasure. To each and every one, I am very grateful.

INTRODUCTION

The purpose of this thesis was to carry out, integrate and interpret a marine magnetic survey in the Mackenzie Bay/ Beaufort Sea area in the Canadian Arctic. The survey was conducted on board the Canadian government oceanographic ship, CSS PARIZEAU, in the summer of 1970.

The first chapter deals with data collection and contains details of the equipment used as well as general statistics regarding the survey.

Chapter 2 is concerned with data reduction and includes discussion of the method of reduction, processing and of the computation techniques involved. The actual computer programs which were written and used for the data reduction are detailed in Appendix II. The source listings are given in Appendix III.

Data correction is dealt with in Chapter 3. It was found that the marine magnetic data reflected the magnetic noise and diurnal variations which were monitored at a fixed shore station at Point Atkinson, approximately 150 miles east of the survey area. However, though remarkably well correlated, the magnetic noise recorded at sea was found to be severely attenuated compared to the noise recorded at Point Atkinson. Further, the attentuation was found to be highly frequency dependent. This observation suggested that a geomagnetic variation anomaly exists in the intervening area between the Mackenzie Bay area and Point Atkinson--this anomaly was investigated further and is discussed in Chapter 4. Due to the geomagnetically anomalous conditions, reliable corrections for magnetic noise cannot be made to the Mackenzie Bay marine magnetic data which are therefore presented as uncorrected maps.

The geomagnetic variation anomaly found, named the Mackenzie Bay geomagnetic variation (g.v.a.) is investigated and discussed in Chapter 4. The frequency attenuation characteristics of the anomaly parallel those of another anomaly known to exist at Mould Bay on Prince Patrick Island approximately 600 miles towards the north-east(Whitham, 1963). A third anomaly at Alert on Ellesmere Island(Whitham et al, 1960), approximately another 700 miles north-east from Mould Bay, brings to three the number of anomalies now known in the Canadian Arctic.

Geomagnetic variation anomalies appear to occur preferentially in the zone affected by a tectonic plate boundary. Study of those anomalies known throughout the world that are not explainable by the coast effect support this concept(Law and Riddihough, 1971). This is because tectonic and geological situations that would give rise to geomagnetically anomalous conditions occur in the tectonically active zones at plate boundaries. The Mackenzie Bay anomaly is no exception--it occurs in the region suggested to be the edge of the stable North American craton(Geol. Surv. of Canada, 1969; King, 1969).

It is apparent from this survey that noise corrections for marine magnetic surveys within a geomagnetically anomalous zone, particularly in the high latitudes present extremely serious problems. This is especially true if the shore monitor station is far removed from the survey area. The problems encountered in the present survey probably also apply to the magnetic data collected by the CSS BAFFIN and the CSS HUDSON during the same period especially since both ships surveyed areas suspected to be over the central region of the Mackenzie Bay geomagnetic variation anomaly.

Further investigation of the Mackenzie Bay geomagnetic variation anomaly is required before more quantitative results can be obtained. Of particular interest would be to determine the extent of this anomaly. There would be strong plate tectonic implications if it is found to extend and connect up with the Mould Bay anomaly to the north-east.

CHAPTER 1

DATA COLLECTION

INTRODUCTION

The marine magnetic data was collected from the CSS PARIZEAU by the usual method of towing a total-field precession magnetometer sensor astern. A magnetic reading was obtained every six seconds and the readings were recorded, along with the G.M.T. time every minute, on a paper-tape punch. In addition, the positions of the ship at various times were logged. Interfacing of the paper-tape data and the ship's positions produced the required result of the ship's position with a marine magnetic reading and time attached.

In all, 44 days were spent in the survey area, resulting in approximately 3 600 nautical miles of magnetic data. Subsequent editing, integrating and processing yielded 134 000 magnetic readings on which this thesis is based.

In general, the accuracy of the survey is regarded as good. The magnetometer is capable of ±1 gamma precision while the navigation is regarded as being accurate to ±110 meters.

THE MARINE MAGNETOMETER

The instrument used to measure the Total Magnetic Field at sea was a Barringer Oceanographic Magnetometer, Type OM-104. This is a precession-type magnetometer, accurate to ±1 gamma (Barringer, 1970). It was towed approximately 600 feet astern of the ship at depths in the order of 50 feet below the surface of the sea.

DATA LOGGING

Two sets of data were logged for the survey.

The first set consisted of the Total Field readings obtained from the marine magnetometer--these readings and the G.M.T. times at which they were taken were recorded on punched paper-tape, encoded in Friden-code. The G.M.T. times were derived from an electronic clock on board.

The second set of data consisted of the ship's positions and the G.M.T. times at which it occupied these positions.

Combining the two sets of data produced the magnetic readings, the positions at which these were taken and the corresponding times. Computations of the positions and the combinations of the two sets of data are covered in Chapter 2.

THE NAVIGATION SYSTEMS

Two navigation systems were used for this survey--a DECCA 6F system and a DECCA Minifix system (registered trade names owned by the Decca Navigator Company). Both systems utilise the same principles of operation--electromagnetic waves are radiated from three shore stations, these waves forming standing wave patterns. Between the three stations, two such patterns are set up--so that in plan view, one would see essentially two sets of waves, similar to the two sets of waves that would be generated if three stones were simultaneously thrown into a pond, a short distance apart. Note that two sets of waves are required for a position to be obtained since two lines of intersection (i.e. two co-ordinates) are needed to define a position in any two-dimensional co-ordinate system.

For the 6F and Minifix Decca systems used, the patterns of the waves are not circular as are ripples in a pond--they are hyperbolic as shown in Figure 8, because they are interference patterns. Decca waves for the 6F and Minifix systems used, are waves of constant phase difference between the two sets of circular waves radiated by two stations. These waves are hyperbolae since for any hyperbolae, the differences between the distances from points along the hyperbolae to the two foci are constant. The constant distance difference is expressed as a phase difference for the Decca system--so that the hyperbolic waves are waves of constant distance differences which means they are waves of constant phase differences.

It is usual to use another term for Decca waves--lanes, akin to lanes of traffic. All positions obtained through the use of a Decca system (such as the 6F and Minifix system) are therefore obtained in terms of Decca lanes, akin to obtaining one's position at a city intersection by noting the streets forming the intersection--except Decca lanes intersect one another at different angles since they are hyperbolae themselves. It should be remembered that implicit in the word 'lane' is the fact that all lanes are hyperbolic in plan view.

In using Decca navigation systems, three kinds of errors can be expected. The first is a Repeatability Error--a measure of how accurately one may repeatedly position oneself within a given system. This error is larger for positions further away from the shore stations since, the further out to sea, the more obscure the intersections between lanes become. Repeatability of the Decca 6F system in the survey area is approximately ±100 meters--that of the Minifix system is smaller (CHS, 1970).

The second kind of error is one caused in part by pattern variations. Patterns may shift as a result of the warming of the atmosphere with daylight. To determine pattern shifts, pattern readings were monitored at a fixed station over the period of the survey. It was found that pattern shifts were less than ±0.06 lane for the period of the marine magnetic survey (CHS, 1970).

The third kind of error is related to the magnetic survey alone. The ship's position was recorded only for the start and end of each line run--no positions were recorded in between and it was assumed that the ship maintained constant speed for the duration of the line. Since the lines run were relatively short--2 hours sailing time or 32 nautical miles approximately--the error in this assumption is not too serious. The ship's path of travel in between the start and end of the line was either a straight line or a hyperbola. The straight line case occurs when the ship's course is direct--while the hyperbolic case occurs when the course is along some Decca lane, staying to within ±0.05 of a lane, this accuracy being ascertained from the ship's logs.

Combining the estimates of the three kinds of errors involved, the r.m.s. error that can be expected in the position of the ship is approximately ±110 meters. Errors measured in lanes were converted to errors in metres by using the fact that the baseline lane width, i.e. the maximum lane width, for the Decca 6F system is 561 metres.

The system characteristics for both Decca 6F and Decca Minifix systems is given in Appendix I.

CHAPTER 2

DATA REDUCTION

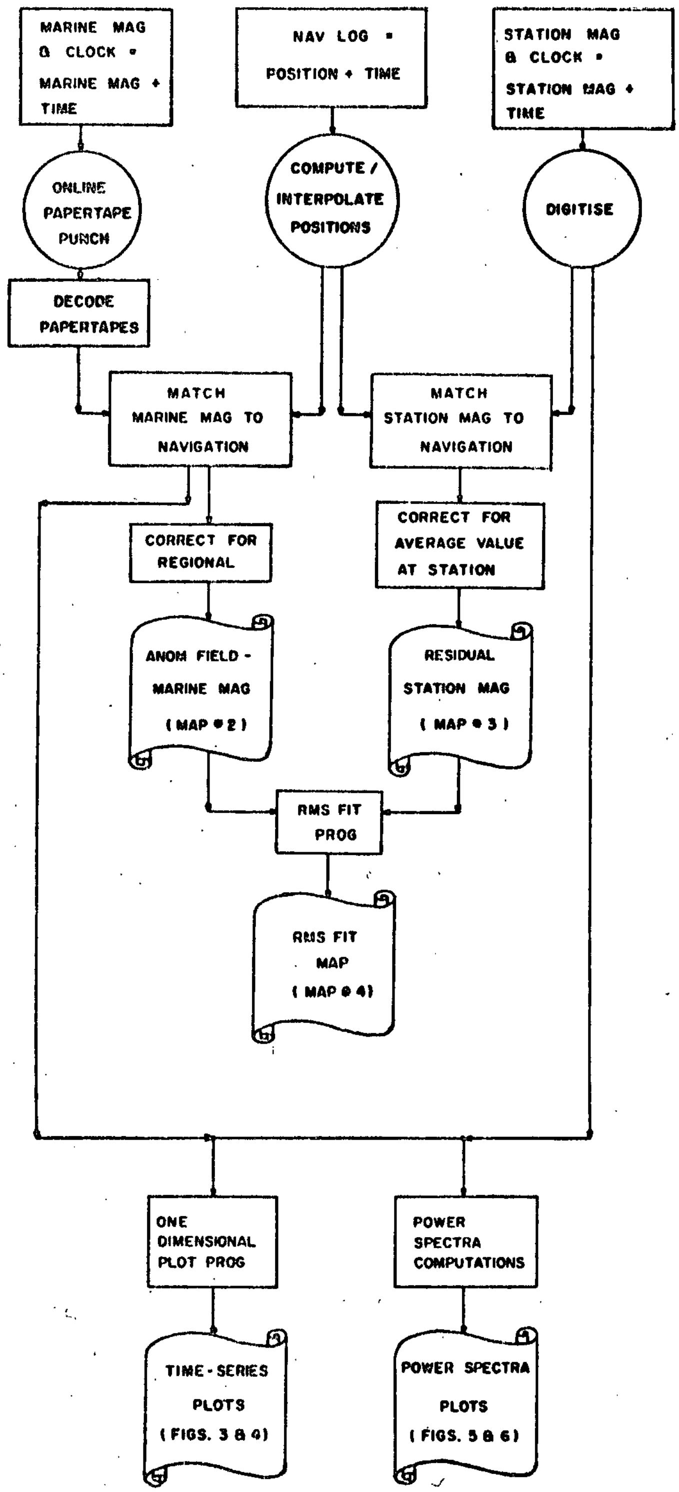
INTRODUCTION

Most of the programs required for the computer-processing of the data were written as part of this thesis. A list of the programs is given in Appendix II.

The overall sequence of data processing is shown in Flow Chart 1. The papertapes which contain, encoded in Friden, a time parameter and the total field reading taken at that time, were transcribed onto magnetic tape. This tape was then decoded using the program 'PTAPE DECODER'. The navigation data, recorded by hand separately, consisted of a time parameter and the Decca co-ordinates of the ship at various times. Program 'DECNAV' converted these Decca co-ordinates into more recognisable geographic and UTM co-ordinates, with proper interpolations in time suitable for the next stage of processing. Having time/total field on the one hand, and time/co-ordinates on the other, the next stage of processing was to match the two on a basis of time. This was done by the matching program 'MAGNAVM'. In addition to matching, 'MAGNAVM' also computed the regional field and the anomalous field readings for each set of co-ordinates produced by 'DECNAV'. The output of 'DECNAV', being a series of scattered data points, was then prepared for plotting--this necessitated gridding the data onto

FLOW CHART 1

OVERALL DATA REDUCTION FLOW CHART



a rectangular grid acceptable to plotting/contouring programs available at the University of British Columbia. The gridding and plotting were done by 'GRID' and 'PLOTTER' respectively.

In addition to the total field readings obtained from the ship-towed magnetometer, a Station Magnetometer was set up at Point Atkinson, approximately 150 nautical miles from the survey area. This magnetometer (a Barringer precession magnetometer similar to the one used at sea--accuracy ±1 gamma) monitored the total magnetic field at the single location so that any fluctuations in this field would represent the 'magnetic noise' present at the time--this magnetic noise would include any time variations in the Earth's magnetic field.

NAVIGATION INTERPOLATION SCHEME

Special mention has to be made of the scheme of interpolation used in the navigation program 'DECNAV'. During the survey, only the start positions/times and end positions/times were recorded for each line traversed. It is known from ship's logs, that in between the start and end, the ship kept to within a pre-selected path within certain limits of error. This pre-selected path was either a straight line or a hyperbolic Decca lane. Interpolations for the straight line path are simple enough--since, knowing the starts and ends of the line, we can interpolate linearly. For the hyperbolic case, however, a heuristic approach was developed and used.

Knowing the Decca lane travelled on by the ship, any number of reference lane-positions can be computed. The ship would have travelled over these lane-positions within the limits of steering error. The next step is to determine the total distance covered by the line traversed and this is done by adding up the distances between successive lane-positions. From the start and end times, the time taken to cover this distance can be found--dividing the distance by the time would give the average speed of the ship for that line. Since positions are required on a time-interval basis e.g. every two minutes, the interpolations have to be carried out in time-fashion. Using the ship's speed and the time taken to traverse the line, the distance intervals corresponding to any chosen time-interval can be computed since these distance intervals correspond to intervals along a hyperbolic line. The lane-positions previously computed are used. The distances between successive lane-positions are known. Hence, interpolations can be carried out between successive lane-positions on a distance-interval basis.

As a test, the navigation program performing these interpolations was fed the start and end parameters for a line of known location. The line was selected for its high degree of hyperbolicity (i.e. it was highly curved) which should produce maximum errors in the interpolation scheme used. The most hyperbolic lines for systems such as the Decca 6F and the Decca Minifix are to be found in the areas closest to the shore stations as shown in Map 5. For the actual survey, none of the lines traversed were as hyperbolic as the test line shown in the map. Using the test line parameters, both hyperbolic and linear interpolation schemes used in 'DECNAV' were tested and the Figure 7 shows the results. It is seen that the positions computed for the highly-hyperbolic test line fit the test line location very closely(to within ±100 m. at least) and it appears that the heuristic approach taken here is valid.

THE MATCHING PROGRAM 'MAGNAVM'

Special mention has also to be made with regard to the matching program 'MAGNAVM'. For data such as these being processed, it is seldom possible to record continuously--discontinuities in data are inevitable e.g. due to equipment malfunction. In attempting to match two sets of data such as the navigation and the magnetics, discontinuities in the data have to be accounted for. To this end, 'MAGNAVM' is capable of matching two sets of data with discontinuities in either set. This ability proved useful since MAGNAVM was able to match the navigation data to not only the marine magnetic data but also to the station magnetometer data which were recorded at entirely different time-intervals.

GENERATION OF THE MAPS

In this final section on Data Reduction, the generation of the maps is discussed. Four maps are presented later on in this thesis--these are:

(i) The Track Plot--a plot of the ship's positions for the whole survey,

(ii) The Anomalous Field--Marine Magnetics Map,

(iii) The Residual Station Magnetics Map,

(iv) The RMS Fit Map.

(i) <u>The Track Plot</u> - to generate this, the track-plotting program, 'TRACKER' was used. 'TRACKER' reads in the ship's positions for the whole cruise and plots all or a fraction of these positions. For this survey, the ship's positions for the whole cruise were available at two minute time intervals (two minutes are equivalent to approximately 3 200 feet in distance)--of these positions, every fifth was plotted so that the Track Plot, Map 1, is a plot of the ship's position every tenth minute or approximately 16 000 feet. The number of positions shown in this map is roughly 1 300.

(ii) <u>The Anomalous Field--Marine Magnetics Map</u>--for this map data points at two minute time intervals were used, approximately 6 700 in all. These data points were gridded onto a square grid and then contoured.

(iii) The Residual Station Magnetics Map - The Station Magnetometer data (at 5 minute time-intervals) were matched to the navigation data (at 2 minute time-intervals). This resulted in a data point every 10 minutes or roughly 1 300 for the survey. These data points were gridded onto a square grid and then contoured.

For both the Anomalous Field--Marine Magnetics Map and the Residual Station Magnetics Map, all the data points had to be gridded prior to contouring. The contouring programs available at the University of British Columbia at the present, are able to contour only data on a rectangular or square grid--they are unable to contour scattered data. This just means that the data points to be contoured have to be regularly spaced such that adjacent data points are the same distance apart on a rectangular grid. To 'load' all the data points onto a grid requires a large number of computations--because the value at each point on the grid is affected by the values of any of the scattered data points close to it. In other words, when many scattered data points are close to a grid point, the value that is assigned to this grid point must take into account each of the scattered data points, taking into account the proximity of the point as well. Obviously the closer a scattered data point is to a grid point, the more weight must be attached to the value of the scattered data point when attempting to assign a value to the grid point.

The whole process of gridding scattered data points onto a square grid is done by weighting--each grid point acquires a value which is the mean of all scattered data point values close to it, with these scattered data point values weighted in some fashion as to reflect their proximity to the grid point. Various techniques of computing the weights have been used--but the one available at the University of British Columbia adopts a heuristic appraoch. For each grid point, the area surrounding it is divided into octants. The closest scattered data point within each octant is weighted by a factor of $(1/d^2)$ where d is the distance between the particular scattered data point and the grid point, and the mean of the weighted points in all octants is calculated and assigned to the grid point in question. Should more than four adjacent octants be empty of data points, the grid point in question is assigned a large negative number which causes the contouring program to bypass it.

With the large number of data points obtained for this survey, and realising the large amount of computer-time involved in gridding these onto even the smallest grids, it was decided to load all the data points for the survey onto a 50 x 50 grid. This causes aliasing of data but aliasing is not regarded as serious for two reasons. Firstly, the magnetic variation spectrum falls off rapidly with increased frequency as Chapter 4 shows. Secondly, the amount by which aliasing will affect the data is not significant when compared with corrections for magnetic noise monitored during the survey, which cannot be made (see Chapter 3).

(iv) The RMS Fit Map- this map was obtained by a pseudo- 'RMS-fit' technique. The RMS values of two input maps, one the signal map and the other the noise map, are first computed--the noise map is then multiplied by a factor equal to the ratio of the RMS values of the two maps, such that the noise map has the same RMS value as the signal map. The modified noise map is then subtracted from the signal map.

Interpretation of all maps mentioned here is covered in Chapter 3.

CHAPTER 3

DATA CORRECTION

In the two previous chapters, aspects of data collection and data reduction were covered--in this chapter, the problem of data correction is discussed.

For this survey, the data corrections are of two types--the first being correction for Regional Field, and the second being correction for magnetic noise. The term 'magnetic noise' is used in a collective sense and includes both the time variations and the magnetic 'noise' usually most obvious during magnetic storms.

REGIONAL FIELD CORRECTIONS

For areas such as the Mackenzie Bay/Beaufort Sea area, where the regional magnetic field is not well-known, one can, at best, predict on a theoretical basis, what the regional field should be. The predicted theoretical field, called the IGRF(International Geomagnetic Reference Field), is based upon theoretical considerations of how best to model the magnetic field of the Earth. Out of these considerations, a mathematical expression is evolved (Cain, 1965) from which the regional field may be computed for a given geographic location. However, there are complications--the mathematical expression, commonly called the PGRF (Polynomial for the Geomagnetic Reference Field) cannot simulate the complicated magnetic field of the Earth for all regions at all times. To do this accurately, spatial variations are allowed for in the PGRF in the form of coefficients, called the PGRF coefficients. Different sets of coefficients apply to different areas and therefore a consistent level of accuracy in the prediction of the Earth's magnetic field in all areas is maintained. Calculations of suitable coefficients entails tortuous mathematical computations and for this survey, the PGRF coefficients were, thankfully supplied by Ron Macnab of the Atlantic Oceanographic Laboratory of the Bedford Institute.

With these PGRF coefficients in hand, correction for the regional field was made by computing it for every geographic location in the survey. The anomalous field is then computed as the difference between the total field and the regional.

MAGNETIC NOISE CORRECTIONS

As previously mentioned, the term 'magnetic noise' is used here in the collective sense to include both the diurnal variations in the Earth's magnetic field, and the magnetic 'noise' commonly prevalent during magnetic storms. For our purposes, both these are extraneous and not geological effects and must therefore be removed.

For most magnetic surveys, the magnetic noise present is established by monitoring it at some locale close to or within the survey area for the duration of the survey. This is done by setting up a magnetometer at some fixed location-- such a magnetometer is commonly called a Station Magnetometer. Being at a fixed point, the station magnetometer necessarily measures only the ambient field at that point plus any time variations in the Earth's magnetic field there, these variations being both the diurnal type and the 'storm' type. By removing the ambient field, the time variations at the station magnetometer may be extracted and represent a record of the magnetic noise present in the area during the survey.

In general, magnetic noise sources are located high up in the ionosphere so that the noise present at a station magnetometer is also present in the general survey area if it is close by. The practice in correcting for magnetic noise is therefore to subtract the time variations of the magnetic field at a station magnetometer from the magnetic readings recorded at simultaneous times over the survey area.

For this survey, the station magnetometer was set up at Point Atkinson approximately 150 nautical miles eastward from the survey area. The station magnetometer readings were digitised at 5 minute intervals to give a record of the magnetic noise during the whole survey. In addition to supporting this survey in this manner, the station magnetometer at Point Atkinson also supported magnetic surveys run concurrently by the CSS BAFFIN and the CSS HUDSON in contiguous areas along the Arctic coast nearby.

Figure 2 shows several days of station magnetometer readings compared to several days' marine magnetic surveying in the Mackenzie Bay/Beaufort Sea area. This figure shows three features.

The first feature is that the readings at both the survey area and at the station magnetometer are highly correlated. This implies that the readings taken at sea in the survey are heavily doped with magnetic noise.

The second feature is that the amplitudes of the magnetic noise signal measured at the station magnetometer are generally much larger than the similar signal recorded at sea. This is particularly true for noise of higher frequencies as Figure 2 shows. We therefore appear to have some suppression of higher frequency signals--a major problem in the correction of the data for magnetic noise.

The third feature of Figure 2 is the apparent phase displacement between magnetic noise recorded at the station magnetometer and that recorded at sea. It appears that this phase displacement is variable in sign--on some occasions the station magnetometer signal leads the signal recorded at sea, on other occasions the reverse is true. This variability in phase displacements between station magnetometer signal and that recorded at sea further complicates the correction of the sea-data for magnetic noise. The reasons are as follows.

In the first instance, the commonly used method of correction - subtraction of station magnetometer variations from the survey data - is certainly not useable for this survey. For example, in Figure 2, at approximately Day 249, the large variations of roughly 400 gammas displayed by the station magnetometer, when subtracted from the smaller variations of roughly 150 gammas recorded at sea, would result in an apparent anomalous field of -250 gammas which is clearly due to the magnetic noise -- the station magnetometer profile points this out.

In the second instance, because the amount of suppression of the magnetic field appears to be dependent on the frequency of the magnetic variations, and because the phase displacement between station-recorded noise and sea-recorded noise seems to be variable, it would not be meaningful to broadly assume that the suppression is constant over the survey area, and compute a suppression factor.

Magnetic noise corrections for this survey therefore appear not to be meaningful - the marine magnetics maps prepared are in fact, an attenuated reflection of the magnetic noise. It is in this context that one must views the maps which are presented in the next section.

MARINE MAGNETICS MAPS

As mentioned in the previous section, correction for magnetic noise (diurnals and storm variations) appear to be impossible for this survey. Bearing this in mind, the following maps are presented:

Map 1 ... The Ship's Track Plot

Map 2 ... The Anomalous Field - Marine Magnetics Map

Map 3 ... The Residual Station Magnetics Map

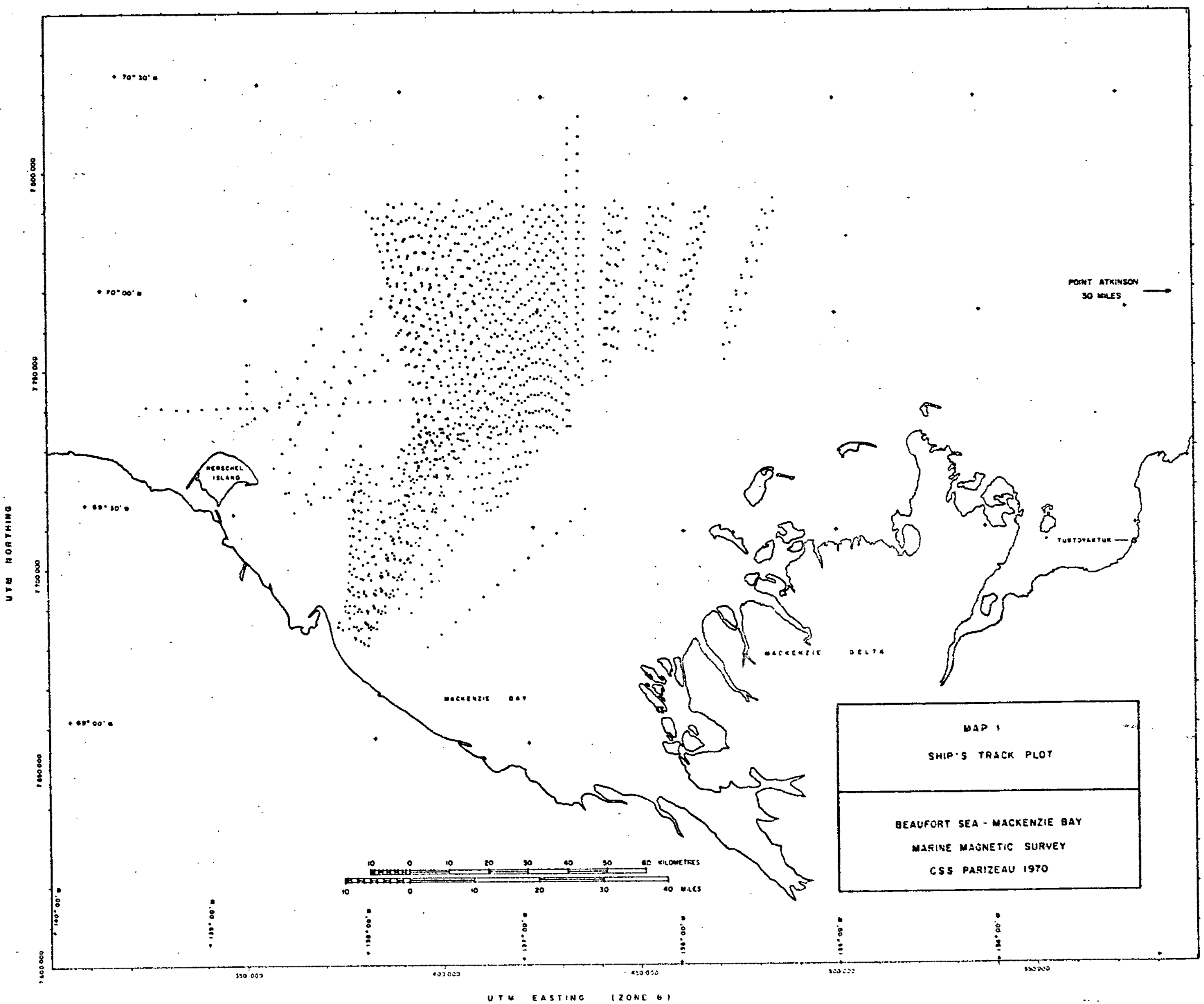
Map 4 ... The RMS Fit Map

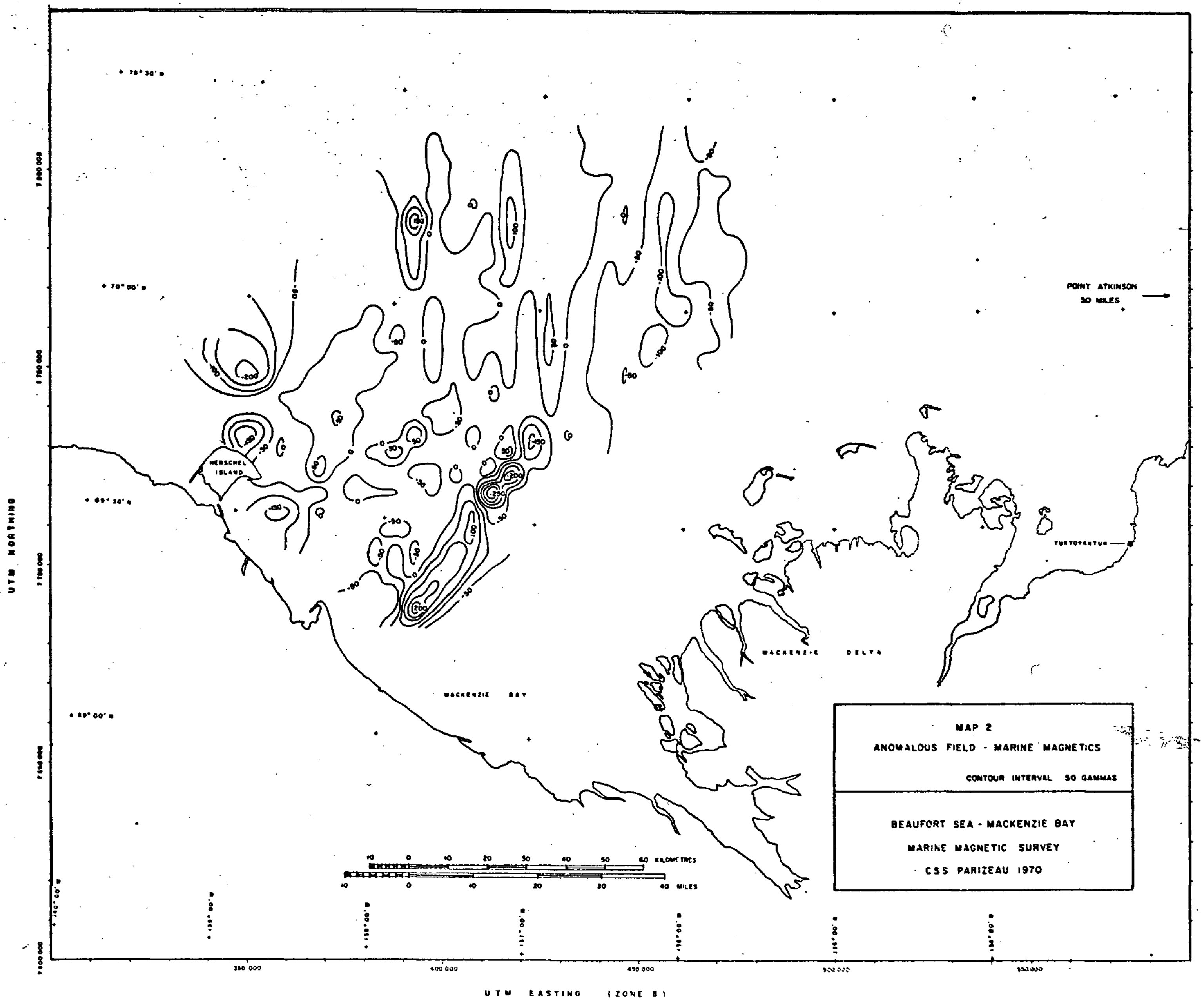
MAP 1 SHIP'S TRACK PLOT

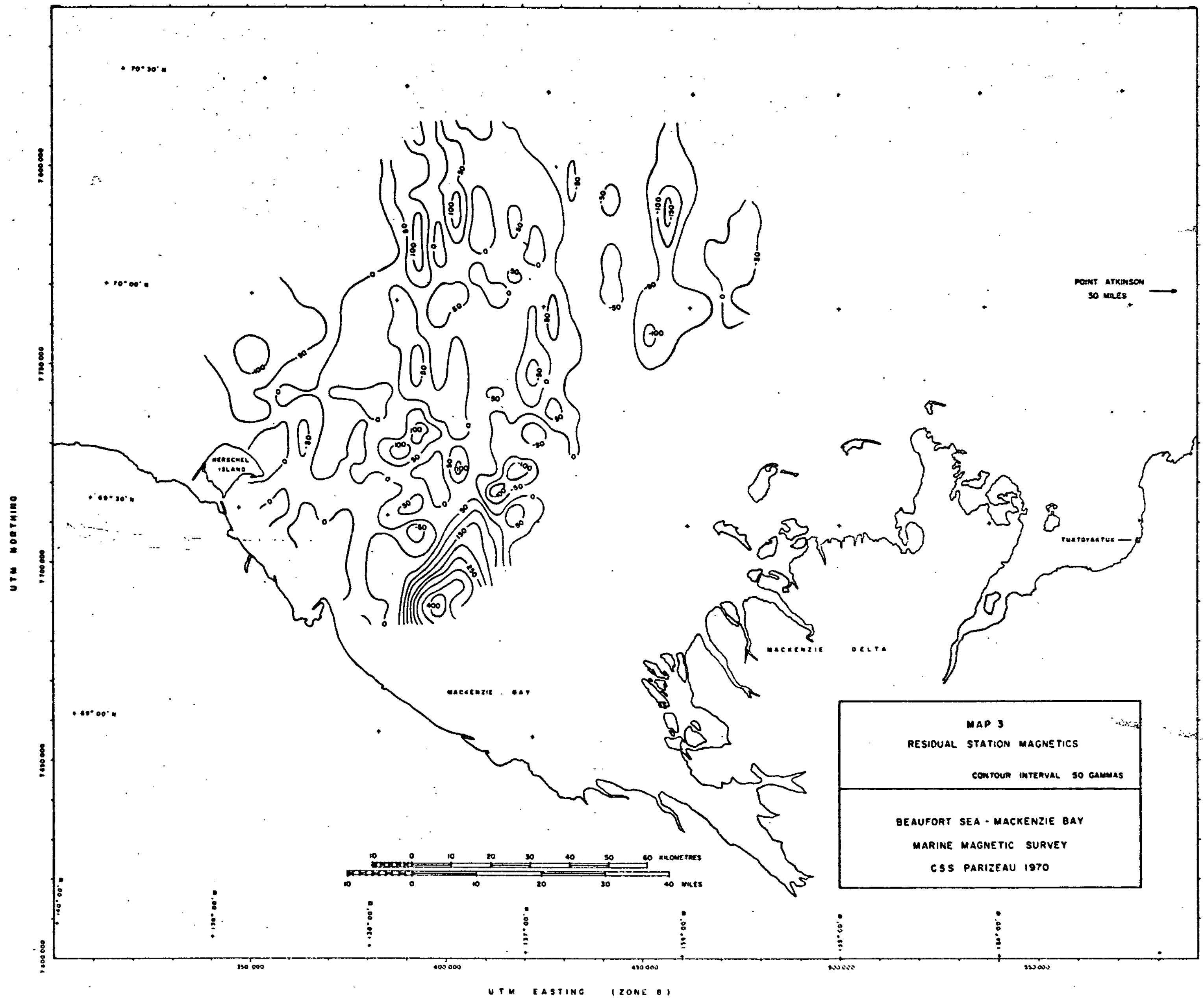
This shows positions occupied by the ship at every tenth minute of time. In relation to this, the other maps presented here can be examined.

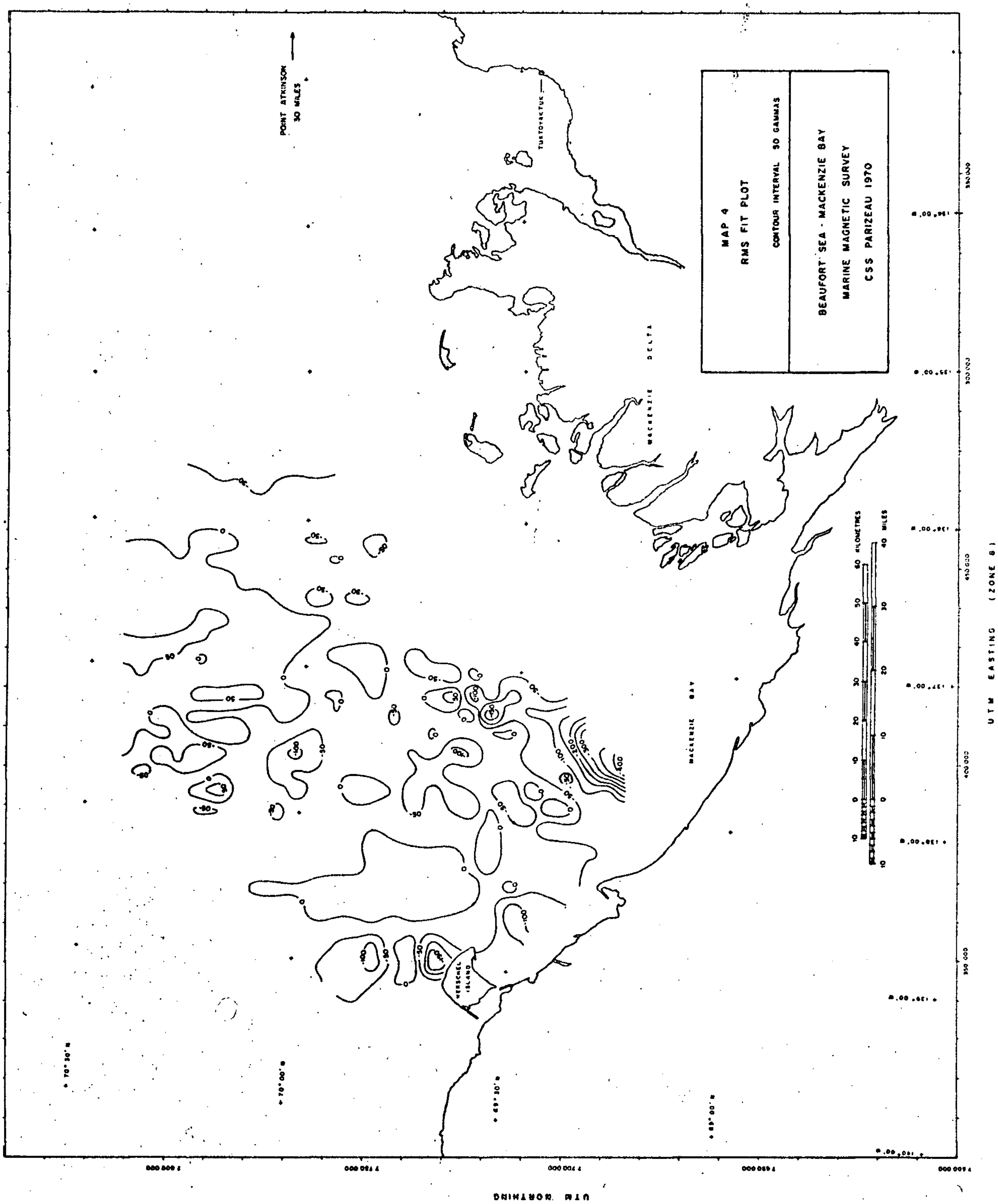
Map 2, The Anomalous Field - Marine Magnetics Map, was generated from data points at 2-minute intervals. This means that the number of positions of the ship displayed in the Track Plot (Map 1) is approximately one-fifth the number used to generate the Anomalous Field - Marine Magnetics Map.

Map 3, The Residual Station Magnetics Map, was generated from data points at 10-minute time intervals. Since this time interval is the same as that of the Track Plot, the positions shown on the Track Plot are approximately those used to generate the Residual Station Magnetics Map.


MAP 1
SHIP'S TRACK PLOT
BEAUFORT SEA - MACKENZIE BAY
MARINE MAGNETIC SURVEY
CSS PARIZEAU 1970
POINT ATKINSON
30 MILES
HERSCHEL ISLAND
TUKTOYAKTUK
MACKENZIE DELTA
MACKENZIE BAY
UTM NORTHING
UTM EASTING (ZONE 8)
KILOMETRES
MILES


MAP 2
ANOMALOUS FIELD - MARINE MAGNETICS
CONTOUR INTERVAL 50 GAMMAS
BEAUFORT SEA - MACKENZIE BAY
MARINE MAGNETIC SURVEY
CSS PARIZEAU 1970
POINT ATKINSON
30 MILES
HERSCHEL ISLAND
MACKENZIE BAY
MACKENZIE DELTA
TUKTOYAKTUK
KILOMETRES
MILES
UTM NORTHING
UTM EASTING (ZONE 8)


MAP 3
RESIDUAL STATION MAGNETICS
CONTOUR INTERVAL 50 GAMMAS
BEAUFORT SEA - MACKENZIE BAY
MARINE MAGNETIC SURVEY
CSS PARIZEAU 1970
POINT ATKINSON
50 MILES
HERSCHEL ISLAND
MACKENZIE BAY
MACKENZIE DELTA
TUKTOYAKTUK
KILOMETRES
MILES
UTM NORTHING
UTM EASTING (ZONE 8)
70° 30' N
70° 00' N
69° 30' N
69° 00' N


MAP 4
RMS FIT PLOT
CONTOUR INTERVAL 50 GAMMAS
BEAUFORT SEA - MACKENZIE BAY
MARINE MAGNETIC SURVEY
CSS PARIZEAU 1970
POINT ATKINSON
30 MILES
TUKTOYAKTUK
MACKENZIE DELTA
MACKENZIE BAY
HERSCHEL ISLAND
KILOMETRES
MILES
UTM EASTING (ZONE 8)
UTM NORTHING

As a matter of interest, it can be seen on the Track Plot that many of the skip's tracks are hyperbolic in shape, the result of sailing 'down a Decca lane'.

MAP 2 - ANOMALOUS FIELD - MARINE MAGNETICS MAP

As mentioned previously, this is a map of the Anomalous Field calculated by subtracting the theoretical regional(IGRF) field from the Total Field measured at sea. Two features are apparent.

The first feature is the large 'anomaly' at the south end of the map. It's peak amplitude is of the order of 200 to 250 gammas. However, it is felt that this 'anomaly' is due almost totally to magnetic noise - this will be shown in the discussion of the next map.

The second feature is that the 'anomalies' shown on this map appear to be linear i.e. stretched out, along the ship's track. This is true of the large 'anomaly' at the south end of the map and of several 100-gamma 'anomalies' at the north end of the map. These lineations can be seen by inspecting this map, Map 2, and the Track Plot, Map 1, simultaneously. These features are again attributed to magnetic noise. If magnetic noise is strong, the marine magnetometer towed by the ship will record the noise. If the noise is of relatively high frequency, of the order of 60 minutes say, then in the 60 minutes the noise takes to cycle from one amplitude extreme to the other, the ship travelling at about

16 knots will have travelled roughly 16 nautical miles. The marine magnetometer will then appear to have recorded an 'anomaly' 16 nautical miles long. Should the ship continue to travel and the noise continue to cycle, then the marine magnetometer would record a series of 'anomalies', each 16 nautical miles long. On a map, such 'anomalies' would appear as a series of closures, with perhaps a mean value contour (roughly the zero-gamma contour for an Anomalous Field Map) following 'alongside' all these little closures--so the net result would probably be a map showing linear-shaped features with pockets of closed contours dotting the crests of these features.

Finally, if as we suspect, the 'anomalies' shown on this Anomalous Field - Marine Magnetics Map are almost entirely due to magnetic noise, and, as we shall see in the next discussion, they are almost all accounted for in this way, then it may be surmised that the survey area must have little magnetic character of its own, at least in relation to the smaller 100-gamma 'anomalies' due to the magnetic noise. If the area has strong magnetic character of the order of 100 gammas or so, then these would alter the map in such a way that it would be unlikely that a large number of the 'anomalies' shown on the Anomalous Field - Marine Magnetics Map could be attributed to magnetic noise. That the area has little magnetic character is not a surprising inference since it is known, from exploratory wells drilled onshore, that sediment thicknesses are of the order of 13 000 feet. The first exploratory well in the area, B.A. Shell 10E Reindeer D-27, bottomed in sediments at 12 668 feet (Chamney, 1970).

MAP 3 - RESIDUAL STATION MAGNETICS MAP

This map was generated by taking the magnetic noise recorded by the station magnetometer at Point Atkinson and matching it on a time basis to the ship's locations throughout the survey. If there had been no magnetic noise present during the survey, this map would show no relief at all. However, as in the case of the previous map, the Anomalous Field - Marine Magnetics Map, two features are apparent.

The first feature, the large 'anomaly' at the south end of the map, is also present on this map (Map 3) except the peak value of the 'anomaly' is of the order of 400 gammas instead of roughly 200 gammas.

The second feature, that of lineation of the 'anomalies' along the ship's tracks, is also seen in this map.

The most interesting result in comparing the two maps - the first map which was hoped to be mainly signal and the second map which is the noise map - is that the two are highly correlated. Almost all 'anomalies' shown on the first map (the Anomalous Field - Marine Magnetics Map) are mirrored by similar 'anomalies' on the second map (the Residual Station Magnetics Map). We therefore conclude that almost all 'anomalies' recorded at sea are caused by magnetic noise.

But in addition to this, the two maps highlight the initial conclusions regarding the suppression of the magnetic variations in the survey area (see first part of this chapter for the discussion). For example, the large 'anomalies' at the south ends of the two maps, though highly correlated, are very different in amplitude - the one recorded at sea is only half as strong as the one recorded at the station magnetometer at Point Atkinson. On the other hand, the 100-gamma 'anomalies' at the north ends of the two maps appear to have similar amplitudes in both maps-- thus, in this instance, little or no suppression is present.

This strong suppression of the magnetic variations is particularly interesting and leads to the conclusion that we are in fact observing a geomagnetic variation anomaly in a rather unorthodox manner. A discussion of this phenomenon will be presented in Chapter 4.

MAP 4 - THE RMS FIT MAP

By fitting the r.m.s. value of the Residual Station Magnetics Map to that of the Anomalous Field - Marine Magnetics Map, a sort of r.m.s. fit between the two maps was performed (see end of Chapter 2 for details) and the result is shown in Map 4. This map shows two features.

The first feature is that the large 'anomaly' in the south end of the two maps fitted together, is still present. This indicates the r.m.s. fit technique has failed to remove it, a result that is not surprising since it was found that the ratio of the r.m.s. values of the two maps fitted together was roughly 0.9--looking at the two fitted maps (Maps 2 and 3), we can see that a r.m.s. ratio of roughly 0.5 would be required for the large 'anomaly' to be removed by the r.m.s. fit technique has successfully removed most of the smaller amplitude magnetic noise and in turn re-emphasizes the high degree of correlation between the Anomalous Field - Marine Magnetics Map and the Residual Station Magnetics Map.

CHAPTER 4

AN ANOMALY IN GEOMAGNETIC VARIATIONS

In the previous chapters it was shown that analysis of the marine magnetic data collected in this survey was complicated because magnetic noise corrections were impossible to apply. This was due to the fact that magnetic noise variations recorded at sea in the survey area were found to be suppressed in amplitude at the higher frequencies, when compared to variations recorded at the station magnetometer located on shore at Point Atkinson.

The suppression of the higher frequency magnetic variations indicated that a geomagnetic variation anomaly(g.v.a.) was present. This chapter deals with the investigation of the nature of this anomaly. A brief introduction to g.v.a.'s is first given. The evidence for a g.v.a. in the Mackenzie Bay area is presented in the latter part of the chapter.

AN INTRODUCTION TO GEOMAGNETIC VARIATION ANOMALIES

A geomagnetic variation anomaly, as the name implies, is an anomaly in geomagnetic variations. It is, as Schmucker(1970) pointed out, essentially a difference between the geomagnetic variations recorded at two stations that constitutes an anomalous condition. To understand what g.v.a.'s are, consider the following model, shown in Figure 1.

Consider a magnetic disturbance (source field) due to, say, an ionospheric line current, I_1. These are called the primary magnetic disturbance and the primary current respectively, for reasons which will be clear later.

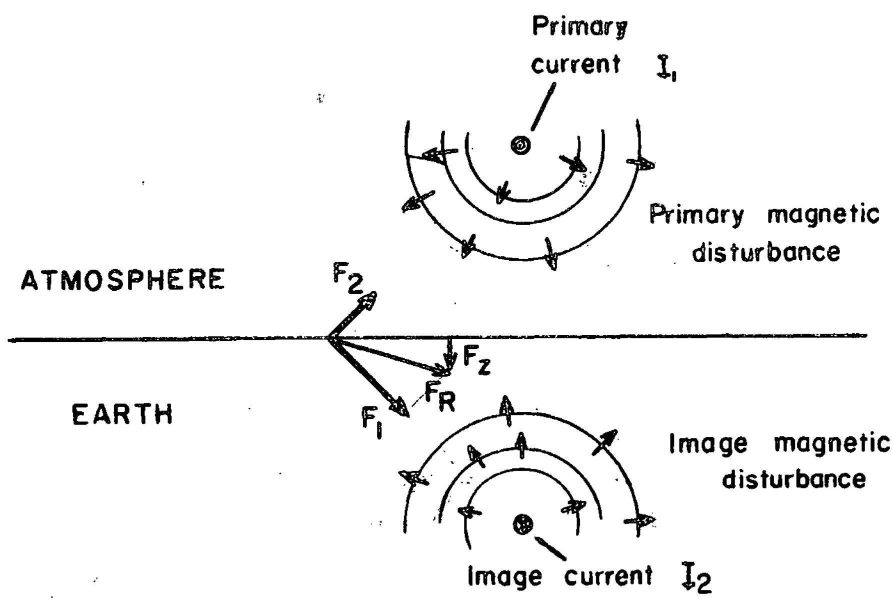


FIGURE 1 A SIMPLE MODEL OF GEOMAGNETIC INDUCTION

When the primary disturbance impinges upon some point, P, on the Earth's surface, as is seen in Figure 1, it produces a primary magnetic field F_1, there. This field will induce currents in the Earth, the strength of the induced currents depending on the conductivity of the Earth in the region. If the Earth were perfectly conductive the fields of the induced currents may be represented by an image current, I_2, of exactly the same strength as the primary current but flowing in such a manner as to produce opposite effects to those produced by the primary current. Hence, with an image current I_2 of equal magnitude, the induced field, F_2, at the point P will be of the same magnitude as the primary field F_1. The resultant field at P, being the vector sum of these two fields, F_1 and F_2, will be along the horizontal, with no vertical component at all. The vector F_z shown in figure will not exist.

However, with a non-perfectly conducting Earth, the image current I_2 will have a smaller magnitude compared with the primary current I_1 so that the magnitude of the induced field at P will be smaller. The resultant field at P, F_R, again the vector sum of F_1 and F_2, will now be inclinded to the horizontal and will therefore have a vertical component F_z as shown in Figure 1.

Clearly, then, both the resultant magnetic field F_R and the vertical magnetic field F_z depend on the conductivity of the Earth. Spatial variations in F_R and F_z will, assuming a spatially uniform source for the magnetic disturbance, reflect conductivity variations in the Earth. The above model is only valid for regions of the earth that are approximately horizontally layered. The field relationships are more complex near regions of lateral conductivity variations.

Now consider what happens when the magnetic disturbance varies with time. As this disturbance impinges upon the Earth, the depth of penetration depends on various factors summarised in the expression:

$$\text{Skin Depth, } d = \left(\frac{2}{\sigma\mu\omega}\right)^{1/2} \text{ in MKS units.}$$

This expression shows that the depth at which the amplitude of the magnetic disturbance falls to 1/e of its initial value, the skin depth is inversely proportional to the electrical conductivity σ, to the magnetic permeability of the material μ, and to ω the angular frequency of the magnetic disturbance. In other words, higher frequency disturbances are more rapidly attenuated with depth than lower frequency disturbances.

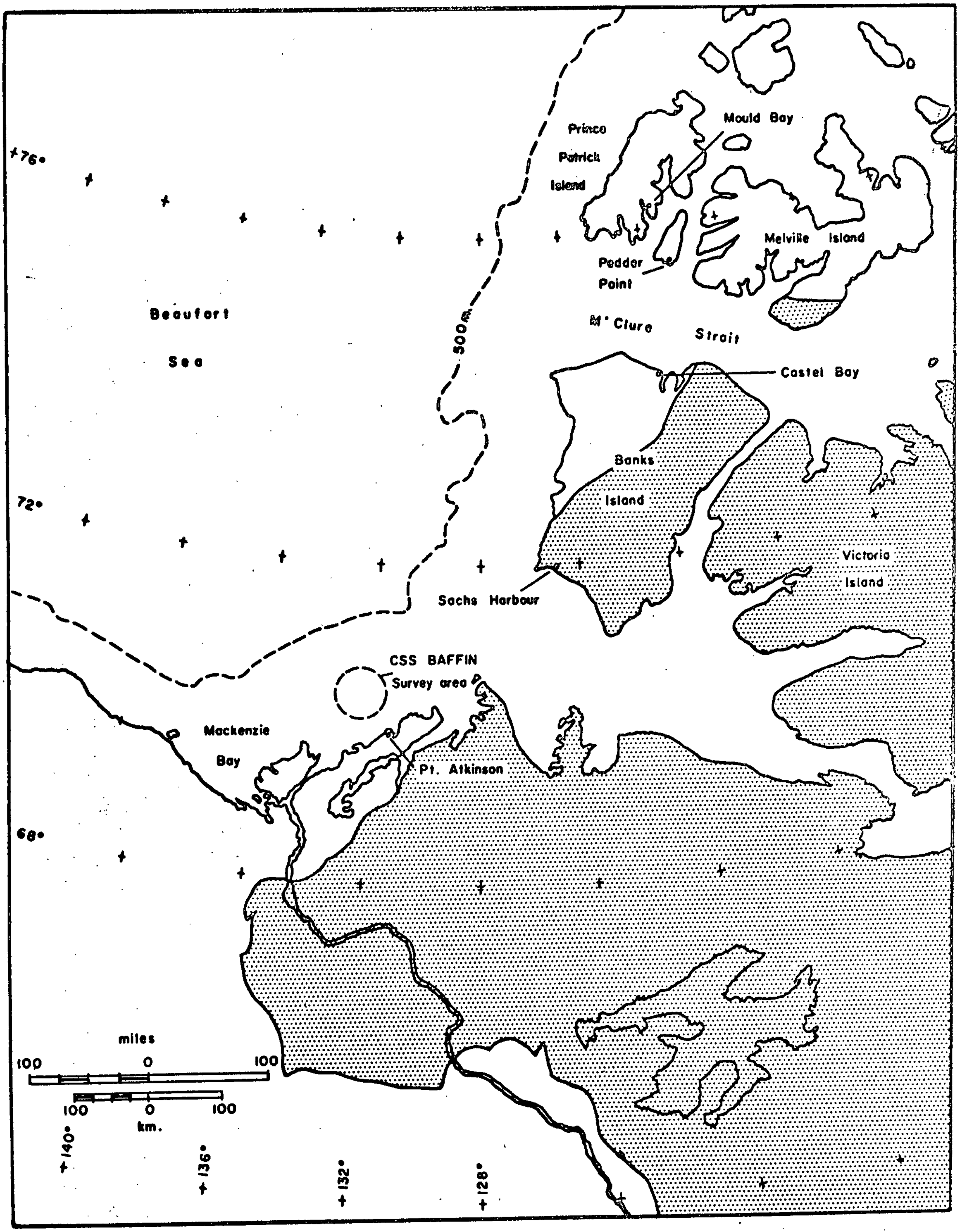
Then if we consider a conductive layer, we find that the vertical variations for high frequencies are strongly attenuated (strong image currents) while low frequency variations pass through the layer and are little attenuated (weak image currents).

WORLDWIDE G.V.A.'S

G.v.a.'s have been described in many parts of the world. Some can be attributed to the effect of nearby deep oceans since a deep ocean affects geomagnetic variations both as a highly conductive body (Mason 1963) and as a relatively highly conductive oceanic crustal province. This effect, called the cost effect, naturally accounts for only those g.v.a.'s near deep oceans. The rest of the g.v.a.'s in the world must be due to other causes.

Many explanations for non-coastal g.v.a.'s have been proposed. All of these rely on apparent electrical conductivity contrasts between two areas. Hyndman and Hyndman(1968) and Caner(1970) for example, suggest hydration as a cause for increased conductivity in certain parts of the crust. This hydration, perhaps in the form of interstitial water, may, as suggested by Hyndman and Cochrane(1971), in their study of the area of the continental shelf of Eastern Canada, be associated with evaporite, salt layers. Uyeda and Rikitake(1970) have also shown that many g.v.a.'s are related to areas of high heat flow.

In the Canadian Arctic, two g.v.a.'s have been documented--one at Alert on Ellesmere Island first reported by Whitham et al (1960) and the other at Mould Bay on Prince Patrick Island first reported by Whitham (1963). Mould Bay is shown in Map 5. Both g.v.a.'s appear to be due to the presence of a highly conducting layer deep



MAP 5 LOCATION MAP (after Geol. Surv. Canada, 1969)

Known North American craton area shaded.

in the Earth's crust. The Alert anomaly involves lateral conductivity contrasts. Only the Mould Bay anomaly is examined in detail here since it is the one to which the Mackenzie Bay anomaly is probably related.

THE MOULD BAY ANOMALY

The anomaly in the Mackenzie Bay area appears to be related to the Mould Bay anomaly for two reasons--the first is that the frequency suppression characteristics of the two anomalies are similar, and the second is the proximity of the two anomalies. Before examining the data for the Mackenzie Bay anomaly in detail, a summary of information currently available for the Mould Bay anomaly is presented.

Whitham (1963) reported that at Mould Bay, geomagnetic variations of short periods were severely attenuated. The energy density curves for the anomaly showed a 10:1 energy density attenuation for variations of 40-minutes period when compared to variations of 100-minutes period. Ionospheric causes of the anomaly were eliminated by normalising Mould Bay records to records obtained at Resolute Bay on Cornwallis Island which is felt to be in a 'non-anomalous' zone. Various models were used in attempts to simulate the frequency characteristics of the Mould Bay anomaly--the one which fitted best has a highly-conductive(10^{-11} e.m.u.) layer 20 km. thick at the bottom of the Earth's crust. Whitham suggested thermal doming of mantle material into the crust as the cause of this layer, but this necessitated regional upwarping of the 1400°C isotherm in order to produce the required conductivity. At this temperature, ionic semi-conduction in olivine is believed to yield the required 10^{-11} e.m.u. conductivity for the model. Calculations also showed the thermal time constant of such a body i.e. the time taken for anomalous heat flow to reach the Earth's surface, or, the time required for anomalous isotherms to develop at the surface, would be of the order of 10^5 to 10^6 years. Available aeromagnetic profiles over the area discounted basement mineralisation as the cause of the g.v.a. Finally, evidence indicates the anomaly is not accountable for by the coast effect since, firstly, Point Barrow in Alaska does not show anomalous geomagnetic characteristics such as those observed at Mould Bay in spite of the fact that Point Barrow is closer to deep ocean than Mould Bay is, and, secondly, Mould Bay appears to be too far away from deep ocean to be affected by it. Data obtained by Zhigalov(1960) show that the effects of deep ocean (deeper than 2 km) are not noticed 130 km away. Ocean depths of even 500 metres appear to be at least 150 km away from Mould Bay as shown in Map 5.

Further work was done on the Mould Bay anomaly in 1964 by Law et al (1965) who measured the heat flow at ten stations in M'Clure Strait. It was found that heat flow values in the area, 130 km south of Mould Bay, were only 0.84 HFU or 57% of the world average, so that if thermal doming is the cause of the Mould Bay anomaly, then the anomaly must either be non-existent 130 km south of Mould Bay, or, the thermal doming causing the anomaly must be younger than 10^5 to 10^6 years (Quaternary), the thermal time constant for such a doming.

Later work at Pedder Point on Eglington Island(see Map 5) 100 km south of Mould Bay in the direction of the heat-flow stations, indicates that the area is geomagnetically 'anomalous' (Whitham, 1965) i.e. suppression of the higher frequency magnetic variations is present. This, therefore, means that the Mould Bay anomaly is probably not due to thermal doming, since the regional upwarping accompanying such a doming would have to vanish in the 30 km separating the southernmost known anomalous area, Pedder Point, and the thermally non-anomalous heat-flow stations in M'Clure Strait. Of course, the heat-flow values obtained in M'Clure Strait may be questionable, particularly because of the existence of very deep permafrost.

Other geophysical studies have been made of the Mould Bay anomaly. Niblett (1967) reported that in a period of 2 months in 1965, a swarm of 2 000 microearthquakes occurred 15 km south-east of Mould Bay at a depth of approximately 6 km. Studies of these microearthquakes have shown their cause to be probably tectonic and not volcanic and their relationship to the Mould Bay anomaly is believed to be highly speculative (Niblett and Whitham, 1967). Other seismological studies do not show any specific results supporting the idea of thermal doming.

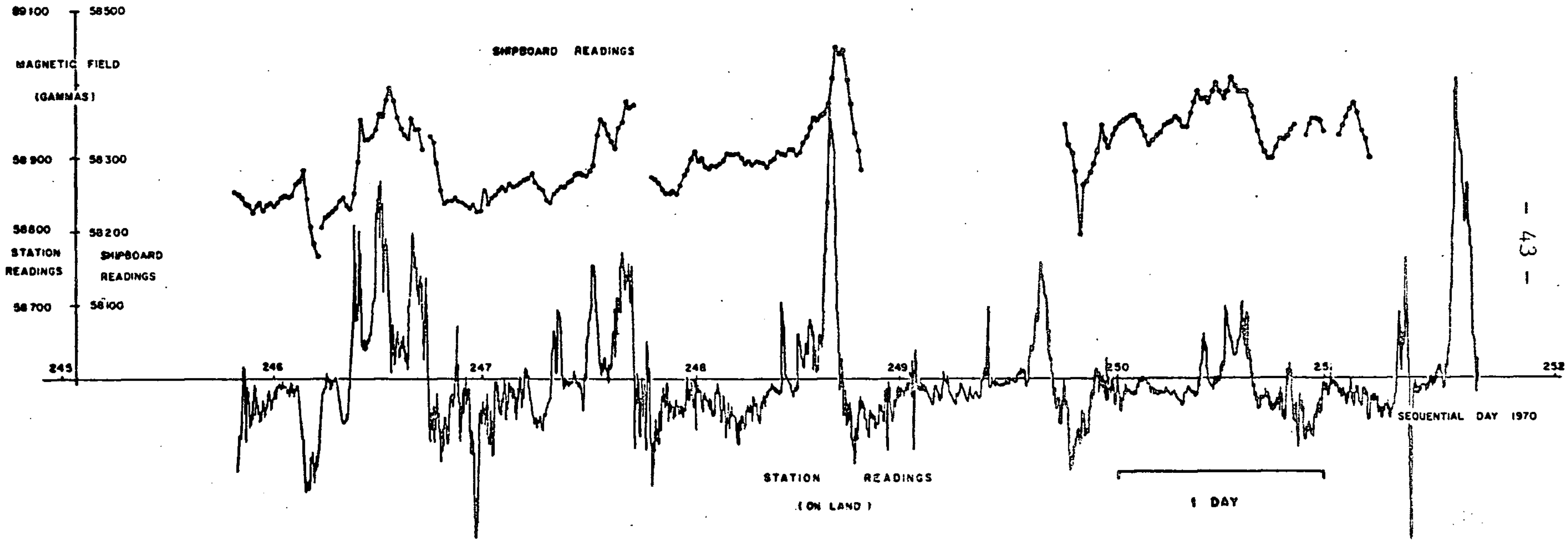
A MACKENZIE BAY G.V.A.

Evidence for a g.v.a. in the Mackenzie Bay area derived from marine magnetic data collected during this survey is now presented. So far, it has been shown that a geomagnetically anomalous condition exists if geomagnetic variations recorded at one location differ markedly from those recorded at another location over the same period of time. In particular, for the Mould Bay anomaly, the g.v.a. characteristics are suppression of the vertical field which implies severe attenuation of the higher frequency components of the total geomagnetic field variations (Whitham et al, 1960), since the main field lines are nearly vertical at this geomagnetic latitude.

As mentioned earlier, during the whole of this survey, a station magnetometer was in operation on land at Point Atkinson (see Map 5 for location) approximately 150 miles from the survey area. Two other oceanographic ships were making studies in the immediate area, particularly the CSS BAFFIN in an area north of Point Atkinson.

Figure 2 shows the time-series plots of the magnetic variations recorded by the station magnetometer at Point Atkinson compared with the variations recorded at sea. More detailed plots of the two recordings were made and these are shown in Figure 3

FIGURE 2 COMPARISON BETWEEN SHIPBOARD MAGNETIC VARIATIONS AND STATION MAGNETIC VARIATIONS



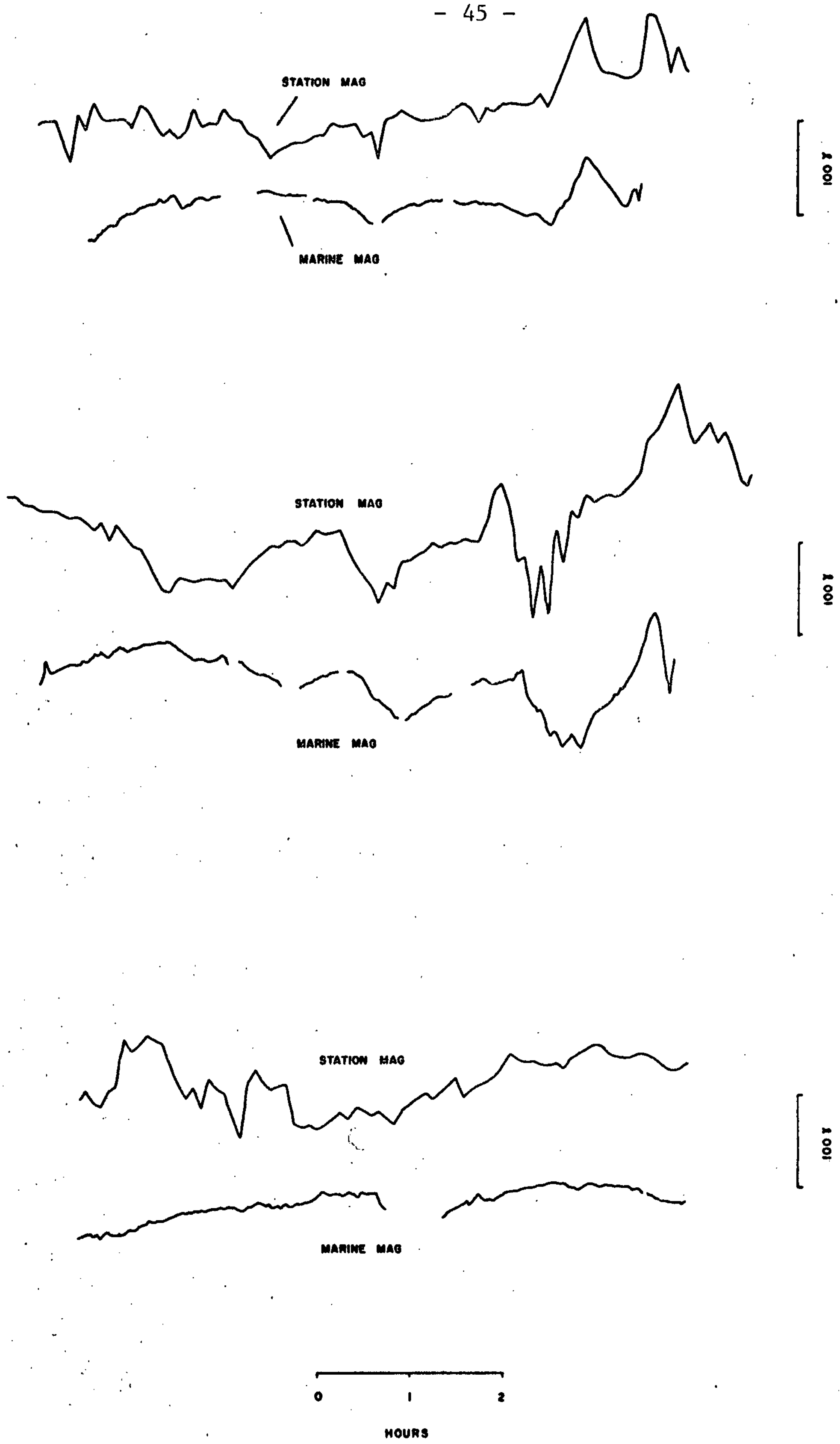


FIGURE 4 DETAILED PROFILES COMPARING MARINE AND STATION MAGNETIC VARIATIONS

and Figure 4. Three features are noticed in these figures.

The first feature is that in almost all plots shown there is remarkable correlation between the variations recorded at the two locations.

The second feature is that, though there is remarkable correlation between the variations recorded at the two locations, the variations recorded at sea show a strong attenuation of the higher frequency components. In almost all cases, the variations recorded at sea are much smoother in appearance, lacking the 'spikiness' of the variations recorded at Point Atkinson. Any high frequency components of the variations evident from Point Atkinson records that still appear in the variations recorded at sea, are strongly attenuated in amplitude.

The third feature of these plots is that there appear to be phase differences between the variations recorded at the two locations. These differences do not appear to be constant.

These three features are typical of a g.v.a. --in particular, they appear to be similar to those of the Mould Bay anomaly (Whitham, 1970).

Geomagnetic variation anomalies are usually investigated with three-component magnetometers. With such instruments, it is then possible to obtain not only time-series records of geomagnetic variations but also directions can be established since all three components are known. In this survey, since only the Total field was measured, no directionality of the geomagnetic variations can be determined. All that is known is that there is suppression of the total field in amplitude and that there is attenuation of the higher frequency components of the geomagnetic variations. The frequency characteristics of the Mackenzie Bay g.v.a. are now examined.

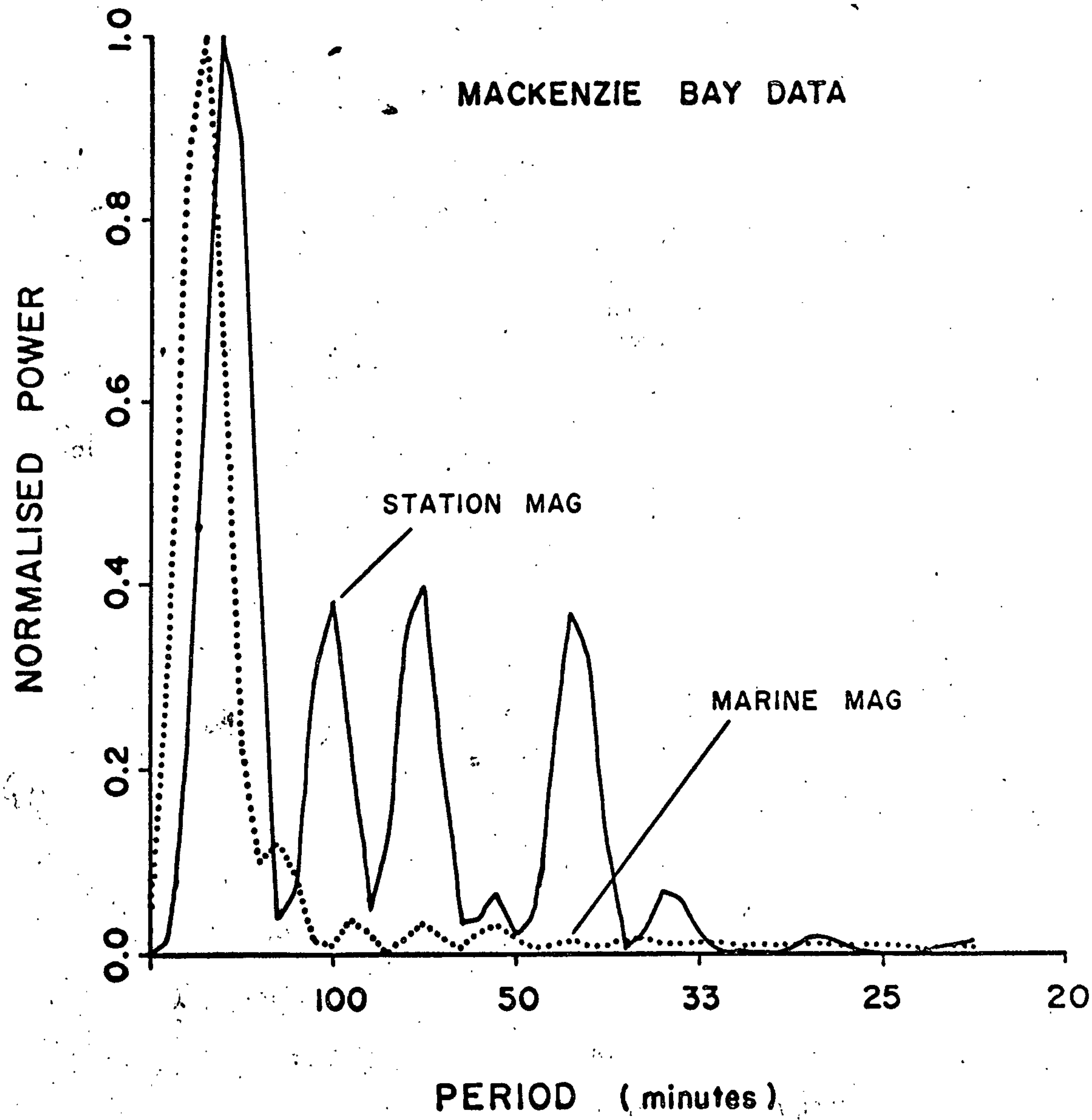
Figure 5 shows the power spectra for the same time period of station magnetometer variations and of the marine magnetometer variations. Comparing the two curves, it is apparent that the higher frequency components shown in the marine magnetometer records are severely attenuated compared to those of the station magnetometer. From power spectra such as these, an attempt to compute power ratios at various frequencies was made. Figure 6 shows the power ratios computed from selected time periods of the survey. Though substantial scatter is present, the figure does show that magnetic variations of periods around 20 minutes are attenuated severely compared to variations of 100 minutes.

The power spectra were computed using the periodogram method (Jones 1965). The trend was first of all removed from each time period segment and end effects were minimised by tapering the end of each segment using a cosine bell function.

Since the differences in geomagnetic variations are between the two locations of Mackenzie Bay and Point Atkinson, the g.v.a. must lie in the intervening region. Further delineation of the g.v.a. is suggested by data obtained by the CSS BAFFIN. When compared to the same station magnetometer records, the marine magnetic data recorded at sea by the CSS BAFFIN see Map 5 appear to show little or no suppression of the magnetic variations

FIGURE 5

POWER SPECTRA



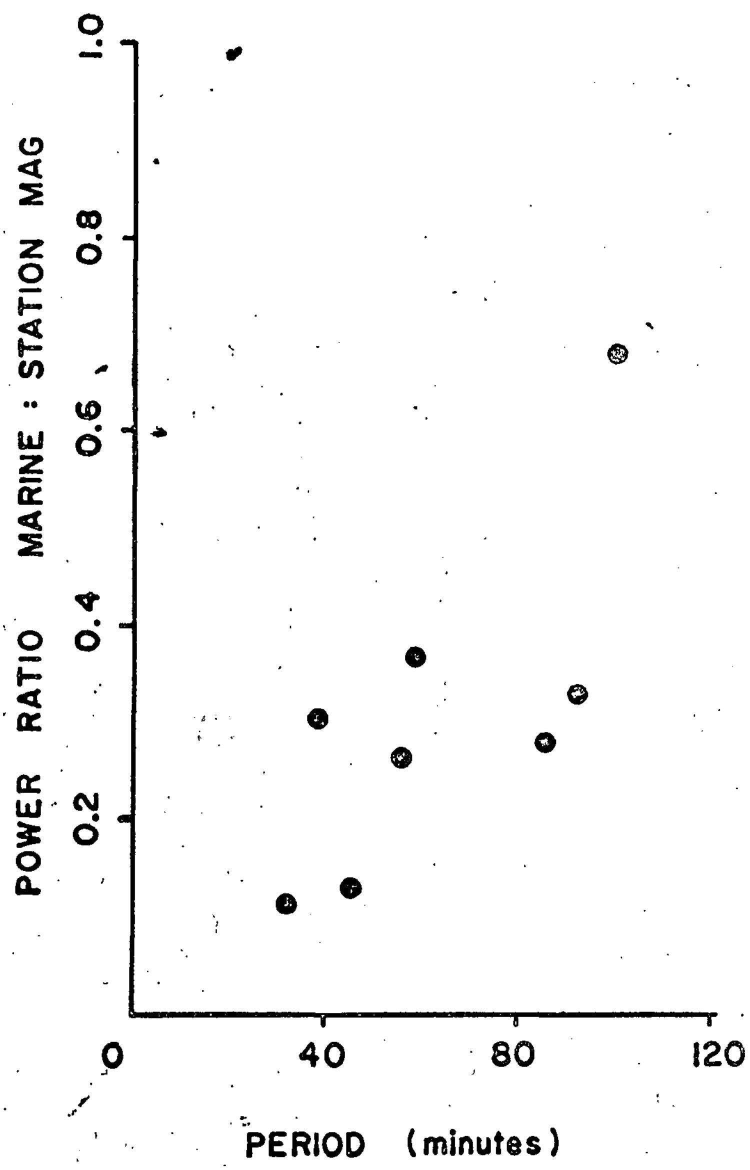


FIGURE 6 POWER RATIO BETWEEN MACKENZIE BAY MARINE DATA AND PT. ATKINSON STATION DATA

(Srivastava, pers. comm.). This infers that the CSS BAFFIN survey area and Point Atkinson must lie in the same 'geomagnetic zone'. In that case the Mackenzie Bay g.v.a. must lie between the Mackenzie Bay area on the one hand, and the CSS BAFFIN survey area and Point Atkinson, on the other.

Summarising the evidence, therfore, it is seen that the Mackenzie Bay g.v.a. appears to have similar geomagnetic characteristics as the Mould Bay g.v.a. From the locations of the magnetic variation records examined, the Mackenzie Bay g.v.a. must lie between the general Mackenzie Bay area and Point Atkinson.

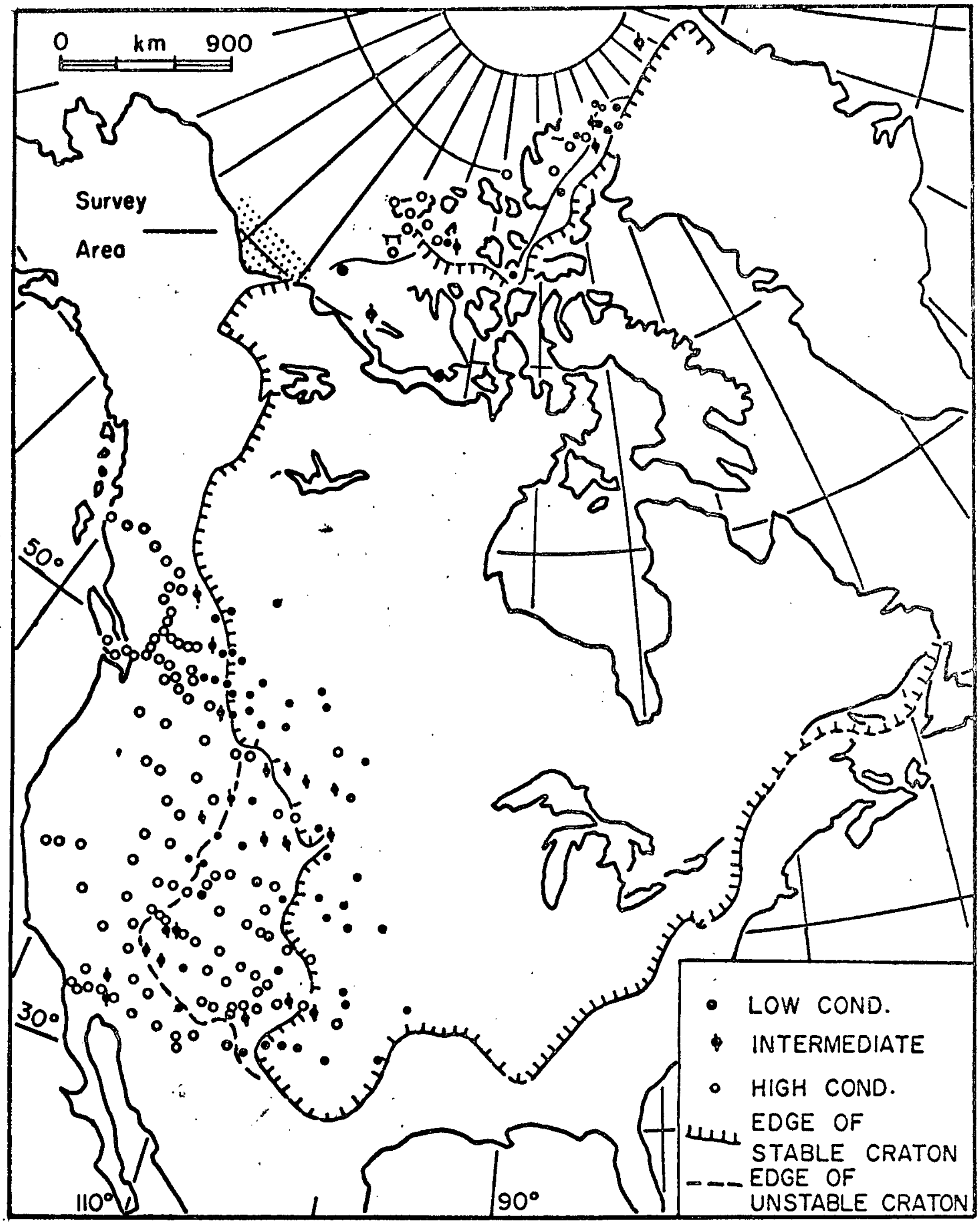
IMPLICATIONS OF THE MACKENZIE BAY G.V.A.

Probably the most exciting implications of the Mackenzie Bay are those related to plate tectonics. Law and Riddihough(1971) in their study of the geographical relation between tectonic environments and all g.v.a.'s known in the world, show that all g.v.a.'s not explainable by the coast effect appear to occur at plate boundaries. Classifying all these non-coastal g.v.a.'s in terms of their tectonic environments, they show that all these g.v.a.'s fall into one of three tectonic environments with the exception of Japan. The tectonic environments are --"along the edge of stable cratons; within fold belts; along major fault and rift structures" (Law and Riddihough, 1971). Law and Riddihough add that this should not be surprising since the various geological situations such as hydration of certain parts of the crust and high heat flow regions believed to cause the electrical conductivity contrasts associated with g.v.a.'s do occur preferentially in the zones affected by a plate boundary. Japan appears to fall into a separate tectonic classificatinn of its own, that of an island arc. However, studies of g.v.a.'s in island arc situations are very sparse and Japan may be an exceptional structure.

In particular, Law and Riddihough show that for North America, all known g.v.a.'s not attributed to the coast effect either lie at the edge of the North American stable craton or within fold belts. Map 6 shows their ideas.

In the Canadian Arctic, the two previously documented g.v.a.'s do indeed fall into one of the three tectonic environments. They lie within fold belts. The Alert anomaly lies within a region of "Eugeosynclinal (magmatic) folding that sweeps across Ellesmere Island and continue in a north-easterly direction over the northern tip of Greenland" (Niblett and Whitham, 1970). The Mould Bay anomaly lies within another fold belt, the Parry Islands Fold Belt.

As Map 5 shows, the edge of the North American craton appears to run northwards along the Mackenzie River, then north-eastward to cut across Banks Island and finally eastward to the Eastern Arctic. That it cuts across Banks Island is significant.



MAP 6. MAP SHOWING GEOGRAPHICAL RELATIONSHIP BETWEEN GEOMAGNETIC SITUATIONS & TECTONICS. CRATON BOUNDARIES FROM KING (1969).

(map after Law & Riddihough 1971)

Preliminary data from g.v.a. stations occupied on Banks Island (Figure 7) by the Geomagnetic Division of the Earth Physics Branch of the Department of Energy, Mines and Resources show that a g.v.a. exists between Sachs Harbour to the south of Banks Island and Castel Bay, to the north of Banks Island. Castel Bay records show suppression of higher frequency magnetic variations so that the material underlying the Castel Bay area is of higher conductivity compared to that underlying Sachs Harbour.

Looking at the location of the Mackenzie Bay g.v.a. then, (Map 5) we see that though it lies close to the edge of the North American craton, the edge as drawn on the map (Geol. Surv. of Canada, 1969) lies to the south. Further work on the Mackenzie Bay g.v.a. should resolve this discrepancy by defining the extent of the anomaly better, but for now, it appears that the craton edge does pass through the region between the Mackenzie Bay and Point Atkinson as the g.v.a. infers.

Since the Mackenzie Bay anomaly, the Mould Bay anomaly and the anomaly recorded at Banks Island all appear to lie in the Parry Islands Fold Belt, it may be speculated that all three are related. Again, further work in the area is necessary; it may then be possible to relate with more confidence, the g.v.a.'s in the region to the tectonics. The tectonics of this region may be important in our understanding of the evolution of the Canada Basin.

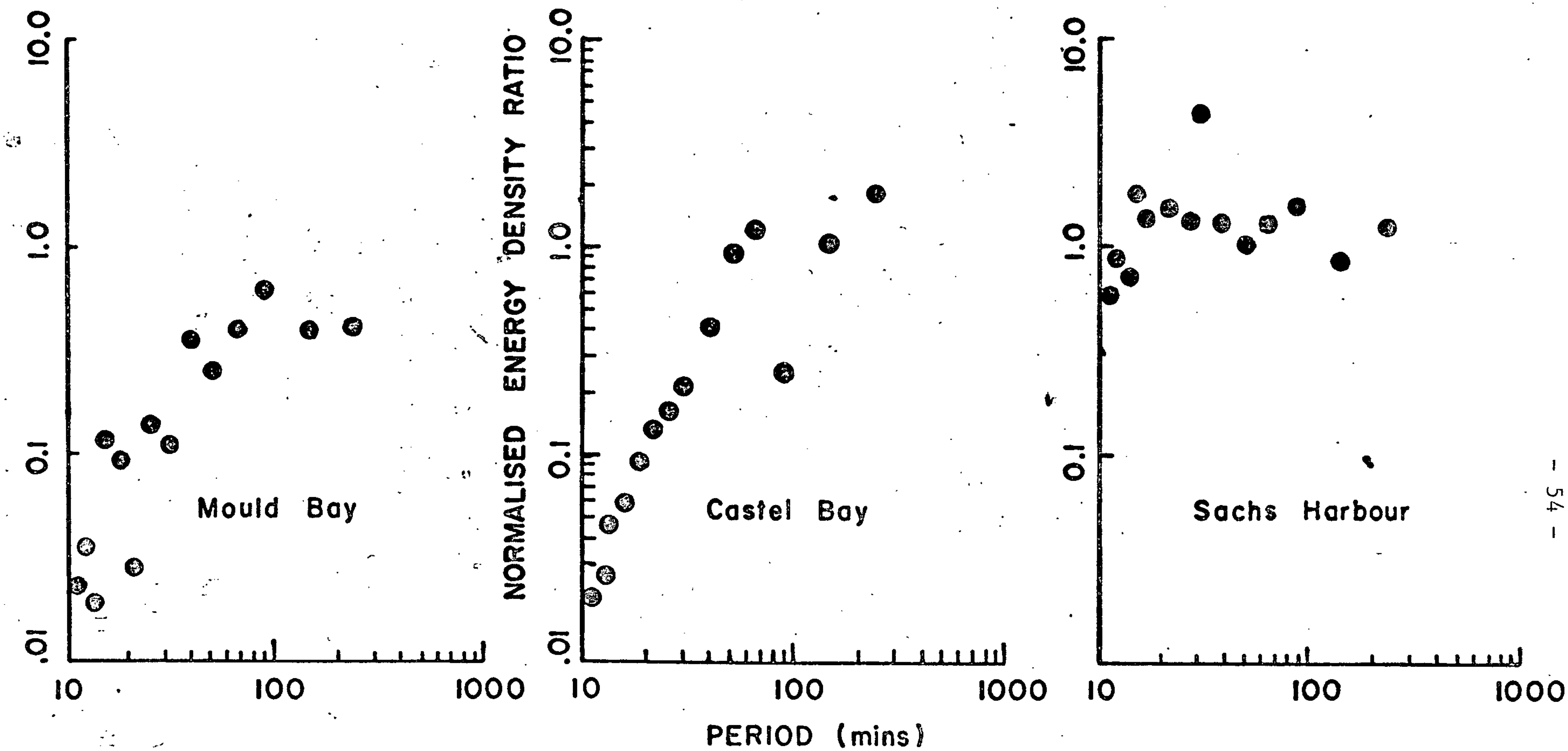


FIGURE 7 GRAPHS SHOWING ATTENUATION AT HIGHER FREQUENCIES FOR GEOMAGNETIC VARIATIONS RECORDED AT MOULD BAY & CASTEL BAY COMPARED WITH SACHS HARBOUR. ENERGY DENSITIES NORMALISED TO RESOLUTE BAY.

(Graphs courtesy of L.K. Law)

CONCLUSIONS

The marine magnetic data obtained in this survey is heavily doped with magnetic noise--this is clearly seen when the records obtained at sea are compared with records obtained simultaneously on land by a fixed station magnetometer at Point Atkinson. There is remarkable time-correlation between the two sets of data. The high frequency components of the data taken at sea are severely attenuated in comparison with the land data. In addition, some phase displacement is evident. The net result is that the noise variations monitored by the station magnetometer cannot be directly applied to the marine magnetic data as corrections. It appears that no technique available can be used to apply these corrections to yield reliable results. Since little magnetic character is evident amidst all the noise, it is inferred that the Mackenzie Bay/Beaufort Sea area surveyed has little magnetic character. This is not surprising in view of the fact that the area is the site of vast thicknesses of sediments.

The frequency attenuation of the variations recorded at sea and monitored at Point Atkinson in the Mackenzie Bay survey area, suggest a geomagnetic variation anomaly lies in the intervening region. This g.v.a., called the Mackenzie Bay g.v.a., appears to have similar geomagnetic characteristics as the anomaly at Mould Bay--whether the two anomalies are connected is not known.

Further work on the Mackenzie Bay g.v.a. would determine this as well as provide more quantitative data.

Since this was not a proper g.v.a. survey in the usual sense, the cause of the Mackenzie Bay g.v.a. cannot be determined. But it is interesting to note that it lies in the region thought to be where the edge of the North American is presently located. The relationship of this anomaly to its tectonic environment adds strength to the concept that g.v.a.'s tend to occur in the zones affected by plate boundaries, since, it would appear, such zones among all others should provide the necessary tectonic and geological situations conducive to the formation of zones of contrastin electrical conductivities thought to cause g.v.a.'s.

From the experiences of this survey, it is suggested that all magnetic surveys conducted in the as yet ill-defined areas affected by the Mackenzie Bay g.v.a. or any of the other Arctic g.v.a.'s for that matter, be treated with great care especially with regard to correction of the data for the large amplitude magnetic noise variatons so common in the Arctic. For marine surveys, a buoy or sea-floor station magnetometer located within the survey area may give the most reliable data for use in these corrections.

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APPENDIX I

DECCA 6F NAVIGATION SYSTEM CHARACTERISTICS

Frequencies: Red (Pattern 1) 355.92 kHz

Green (Pattern 2) 266.94 kHz

Propagation Speed 299 650 km/sec.

Decca Master (Hooper Island)	69° 41' 32.186"N	Zone 8	N	7 731 381.78
	134° 55' 53.786"W	Zon	E	502 649.21
Decca Red(Point Atkinson)	69° 41' 32.186"N	Zone 8	N	7 762 342.307
	134° 55' 43.786"W		E	636 554.457
Decca Green(Herschel Island)	69° 34' 07.947"N	Zone 8	N	7 722 501.814
	138° 54' 53.706"W		E	347 563.076

Base-line lengths: Master-Red 137 482.2 m.

Master-Green 155 387.8 m

DECCA MINIFIX NAVIGATION SYSTEM CHARACTERISTICS

Frequency 1702 kHz

Propagation speed 299 650 km/sec.

Master (Shingle Point)	69° 00' 01.497" N	Zone 8	N 7 656 233.87
	137° 28' 49.528" W		E 400 817.93
Slave I(Kay Point)	69° 05' 03.893" N	Zone 8	N 7 664 007.32
	136° 07' 32.287" W		E 455 153.98
Slave II(Pitt Island)	69° 15' 55.932" N	Zone 8	N 7 687 375.22
	138° 19' 56.160" W		E 368 354.65

Baseline lengths	Master - Slave I	54 907.60 metres
	Master - Slave II	44 995.60 metres

APPENDIX II

TABLE OF COMPUTER PROGRAMS

PTAPE DECODER

DECNAV + DECCA + DISTAN + MINTY + UNMINT

MAGNAVM + IGRF + TMINT + UMIN

GRID + MXGEN

PLOTTER + MXPAND + PLOT2D

TRACKER

SMPLOTTER

ONEDEE

The following section gives brief notes concerning the above programs.

PROGRAM COMMENTS

PTAPE DECODER

This program reads in Friden-encoded data, checks for completeness and correctness of a whole data unit (one minute's data), decodes the characters, forms data words from these characters, and outputs the data words in EBCDIC (numeric decimal characters). see Flow Chart 2.

DECNAV + SUBROUTINES

The main program, DECNAV as shown in Flow Chart 3, reads in the Start/End Times, the Decca co-ords for the Start/End, the Decca navigation system in use (6F or Minifix) and the type of track run (straight line or hyperbolic) for each line. It computes/interpolates between the Start/End of the line and outputs Times and Geographic/UTM co-ordinates at specified time intervals. The interpolations performed are either linear for a straight-track or hyperbolic for a hyperbolic lane-run.

The subroutine DECCA is adapted from a version generously loaned by the Canadian Hydrographic Service (now the Marine Sciences Branch, Department of Environment). DECCA converts Decca co-ordinate readings into Geographic or UTM co-ordinates.

The subroutine DISTAN computes the distance in nautical miles, between two points given the geographic co-ordinates of these points.

The subroutine MINTY converts the Time parameters recorded during the survey, Sequential Day/GMT Time (e.g. Day 267, Time 2345 hours), into a more manageable single quantity for computing purposes, Sequential Minutes.

The subroutine UNMINT undoes what MINTY does - namely, it converts Sequential Minutes back into Sequential Day/GMT Time. This is done purely because Sequential Minutes are very large numbers which do not lend themselves to easy reading, and because Day/time are used in the ship's operations.

MAGNAVM + SUBROUTINES

The main program, MAGNAVM, reads in the Magnetic Data (Day/Time/ Mag) on the one hand, and the Navigation Data (Day/Time/Co-ordinates) on the other. It then matches the two sets of data on the basis of the time parameter (Day/Time). Flow Chart 4 shows how this is done.

MAGNAVM calls the subroutine IGRF which computes the Regional Magnetic Field (IGRF value) at a point given the Geographic co-ordinates of that point.

The two other subroutines that MAGNAVM calls, subroutines TMINT and UMIN, are the real-number versions of the previously-mentioned subroutines MINTY AND UNMINT respectively.

GRID + SUBROUTINE MXPAND

The main program, GRID, sets up the data, X-Y co-ordinates of the scattered data points, so that they are ready to be gridded onto a square-grid necessary for plotting. The gridding is done by the subroutine MXGEN which 'remembers' how it generates this grid after it has done it once. This 'memory' is fed to the subroutine MXPAND used in the next stage of processing.

MXGEN and MXPAND are both programs written and generously loaned by Mike Patterson of the Department of Geography of the University of British Columbia.

PLOTTER + SUBROUTINES

The main program reads in the Z value (may be Total Field reading for instance) for the scattered data points fed into the above Main Program GRID. Since the subroutine MXGEN, used in conjunction with GRID, remembers how to generate the grid, and passes this information to the subroutine MXPAND, MXPAND merely reads in the Z co-ordinate and places it in an appropriate location in the square grid to be generated after weighting this Z co-ordinate according to the gridding information.

This 'remembering' of the gridding procedure results in having to actually grid the scattered data points just one - because once the gridding information is recorded, any set of Z co-ordinates for the same scattered data points can be gridded very quickly. As an example, gridding 6700 scattered data points onto a 50 by 50 square grid suitable for plotting takes approximately 500 seconds of CPU time for the UBC IBM System/360/67. If this gridding had to be done for say, three sets of Z co-ordinates e.g. Total Field, Regional Field, and Anomalous Field, the amount of computer CPU time would be 1500 seconds CPU time.

However, using MXGEN/MXPAND and 'remembering' the gridding procedure results in 500 seconds CPU for gridding the first set of Z co-ordinates but only 1.5 seconds CPU for gridding each subsequent set of Z co-ordinates.

After gridding via MXPAND, the main program PLOTTER calls the subroutine PLOT2D which plots and contours the data-grid. PLOT2D was written by Dr. T. J. Ulrych of the Department of Geophysics of the University of British Columbia, who unselfishingly loaned it. The contouring routines called by PLOT2D are those available at the University of British Columbia.

PLOTTER generated the maps shown as Map 1 to Map 4.

TRACKER

TRACKER plots the ship's positions for the whole cruise. A position every minute or a position every 'n' minutes are plotted where 'n' is selected by the user. For this cruise, a position every 10 minutes was plotted as seen in Map 1.

SMPLOTTER

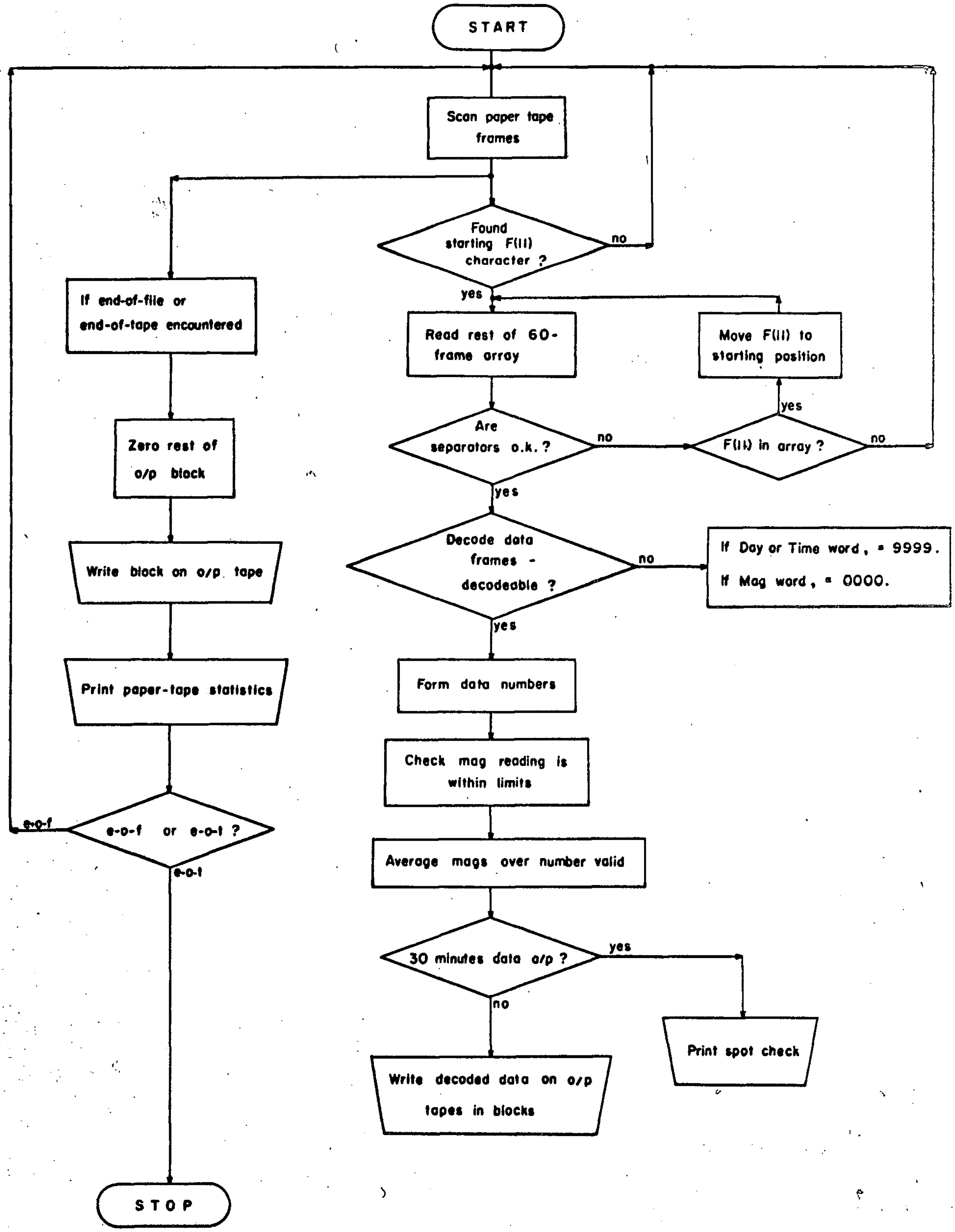
SMPLOTTER merely plots selected periods of station magnetometer data. The periods are selected by the user who supplies the program with the station magnetometer data, usually on magnetic tape. SMPLOTTER scans the data for, and plots, the periods selected, along with the appropriate axes etc... The station magnetometer traces in Figure 3 and Figure 4 were generated by this program.

ONEDEE

ONEDEE reads from the user, instructions as to which marine magnetic lines(traverses) are to be plotted in profile. It scans an input tape containing marine magnetic data for all lines, picks out data for the line selected, and scales/plots the data for that line in time-series. Profiles of marine magnetic data shown in Figure 3 and Figure 4 were plotted by this program.

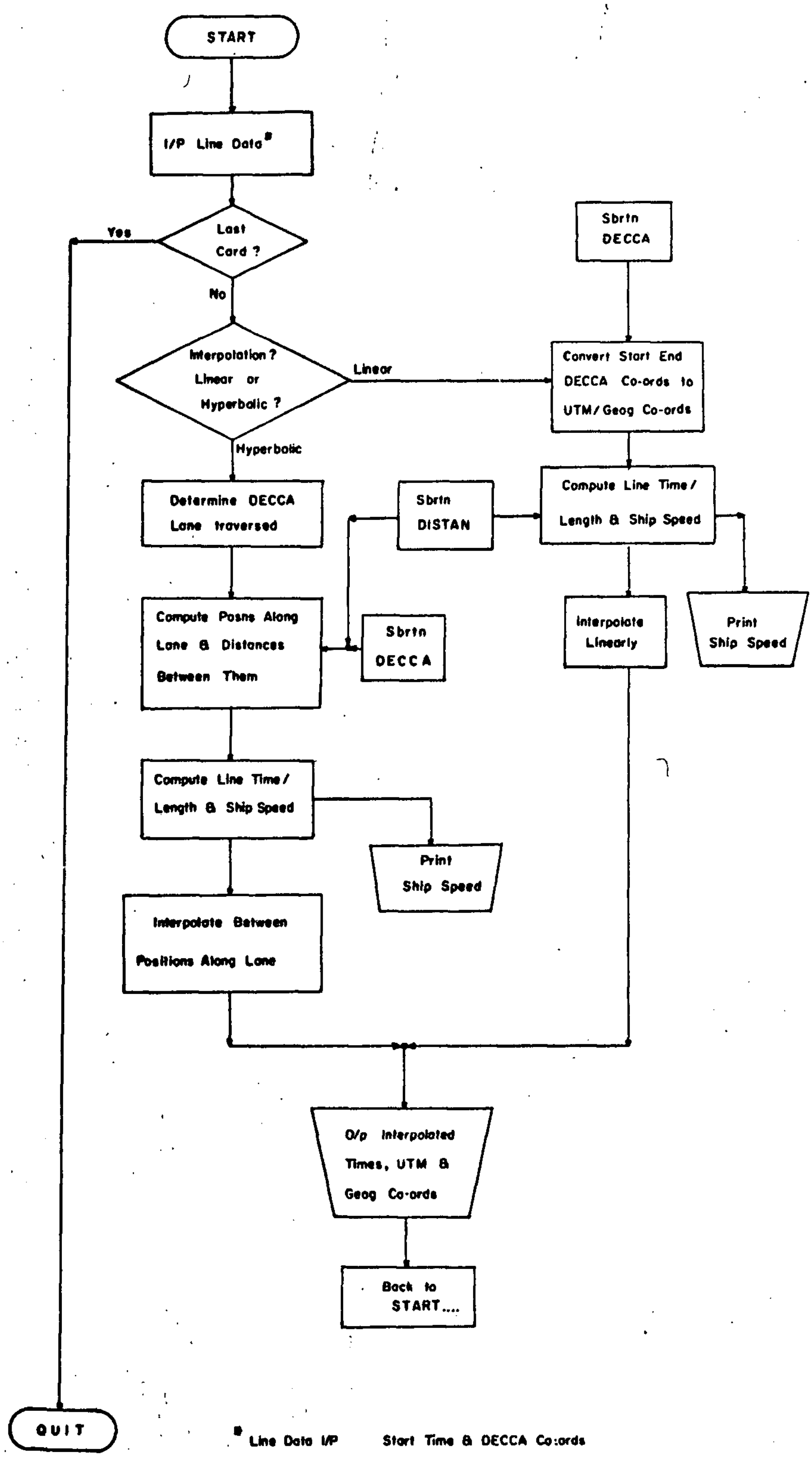
FLOW CHART 2

PROGRAM 'PTAPE-DECODER' - FLOW CHART



FLOW CHART 3

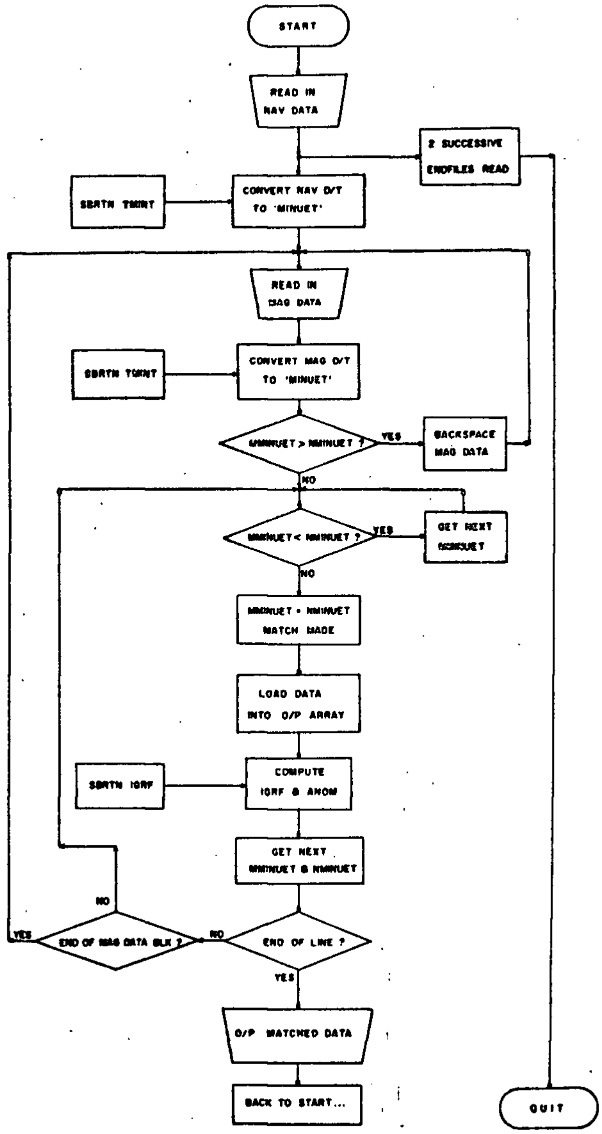
PROGRAM 'DECNAV' - FLOW CHART



Line Data I/P   Start Time & DECCA Co:ords
End Time & DECCA Co-ords

FLOW CHART 4

PROGRAM 'MAGNAVM' - FLOW CHART



PROG I/P = NAVIGATION DATA = DAY + TIME + X-Y CO-ORDS
MAGNETIC DATA = DAY + TIME + TOTAL FIELD MAG READING

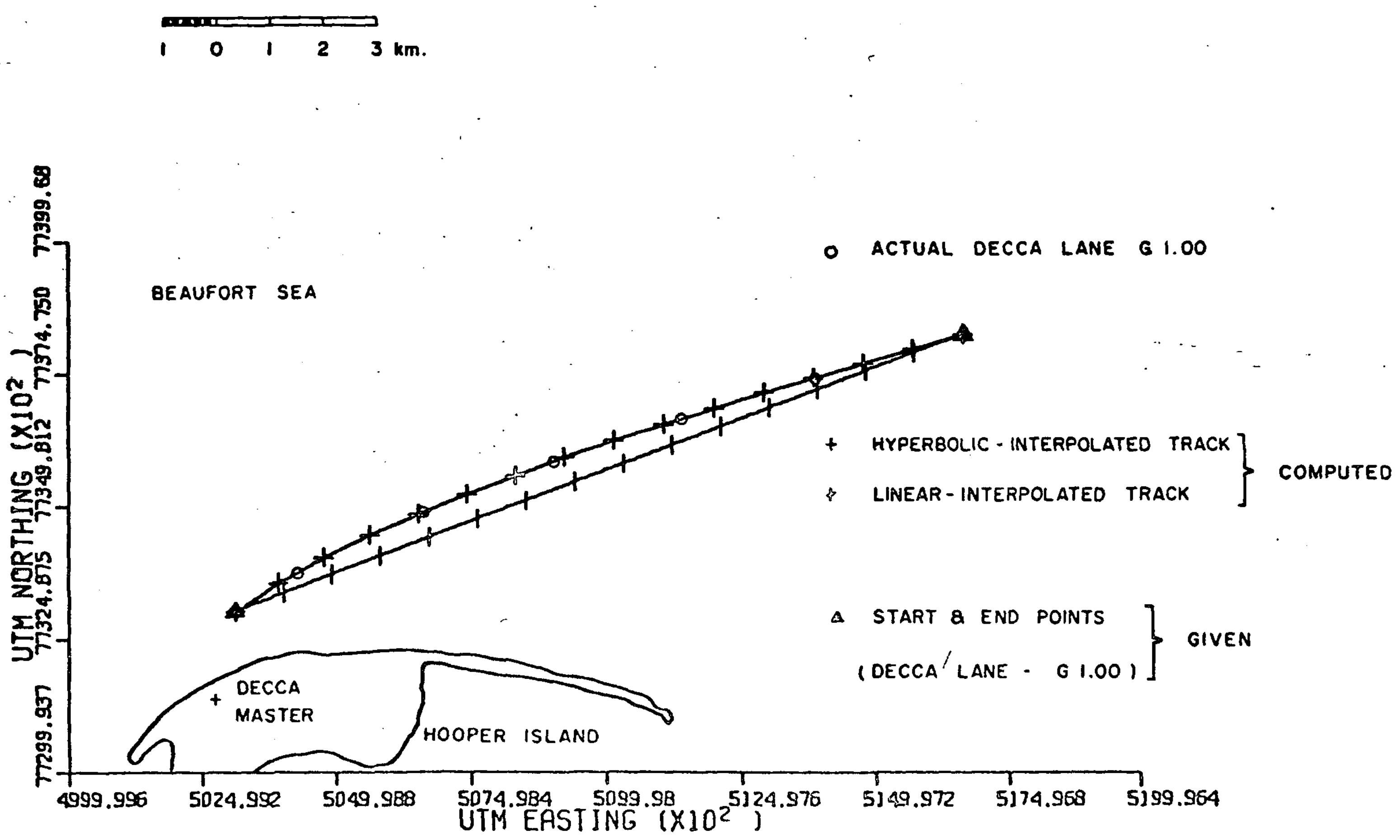
PROG O/P = MATCHED DAY + TIME + X-Y CO-ORDS + TOTAL FIELD MAG READING
+ COMPUTED REGIONAL (IGRF) & ANOMALOUS (ANOM) FIELDS

ABBREVIATIONS = D/T = DAY + TIME
MINUET = SEQUENTIAL MINUTE EQUIVALENT OF DAY + TIME
MMINUET = MAG DATA MINUET
NMINUET = NAV DATA MINUET

FIGURE 8

NAVIGATION PROGRAM 'DECNAV'

TEST OF INTERPOLATION ROUTINES USED IN PROG



APPENDIX III

This contains the source listings of all the programs used in the reduction of data for this survey, with the exception of the Subroutines MXGEN and MXPAND which were written by and available only from Mike Patterson of the Department of Geography at the University of British Columbia.

A table of all the computer programs can be found at the beginning of Appendix II, while Flow Charts for three of the major programs can be found at the latter part of the same Appendix II.

```
CNTR >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>XX

RFS NO. C40274                      UNIVERSITY CF B C COMPUTING CENTRE    MTS(AN192


** COMPUTING CENTRE WILL BE OPEN EASTER HOLIDAYS , 8AM TC 5PM ***
=====================================================================================
=
= FILE FOR DELIVERY = FILE FCR DELIVERY = FILE FCR CELIVERY = FILE FOR DELIVERY
=
=====================================================================================
*
******************** PLEASE RETURN TC GEOPHYSICS DEPARTMENT ********************
$SIGNON RGOH T=3C P=75 COPIES=4C PRIO=L
**LAST SIGNCN WAS: 10:54:15   THU MAR 3C/72
 USER "RGOH" SIGNEC ON AT  C8:36:10 CN FRI MAR 31/72
$COPY *SOURCE*@¬CC *SINK*
C******************   PROGRAM 'PTAPE DECODER'   **************************
C**THIS PROGRAM DECCDES FRIDEN-CCDEC PAPERTAPE NUMBERS INTO DECIMAL NUMBERS
C PERFORMS VARIOUS CHECKS, AVERAGES THE DATA & WRITES THE O/P CN COMPUTER-TAPE.
C WRITTEN FCR MARINE-MAG DATA - DAY,TIME,1C MAGS.     RCCQUE GCH UBC JUNE.1971.
C*******************************************************************************
C-----PCNT=(I/P) PAPERTAPE FRAME CCUNT. CCNT=(C/P) DATA-PCINT CCUNT WITHIN
C   AN O/P BLOCK(SIZE SET BY OCNT MAX.). FCR EACH PAPERTAPE, Q IS THE NO.
C   CF C/P BLCCKS SC THAT THE TCTAL NC. OF DATA-POINTS O/P FOR THAT P-TAPE,
C   (TCCNT), IS GIVEN BY: TCCNT=((G-1)*BLKSIZE)+CCNT(FOR LAST BLCCK)
C-----IN EACH MINUTE OF PTAPE, THERE ARE FPM FRAMES/MINUTE, WPM DATA-WORDS/MIN.
C   WITH TMAG MAG-READINGS OF WHICH PERHAPS VMAG ARE VALID(MAGS).
C-----FCR THE PAPERTAPE, THERE ARE FPDP FRAMES/DATA-PCINT(WHICH INCLUDES THE
C   SEPARATOR-FRAME) OF WHICH FPW FRAMES MAKE UP A DATA WORD.
C-----F11 IS A CCUNT WHICH IS INCREMENTED EVERY TIME A F(11) CHARACTER IS FOUND
C   WHETHER THE DATA FCLLCWING IT IS VALID OR NCT.
C-----THE F( ) & T( ) ARRAYS IN NAMELIST STORE THE FRIDEN-CODE CHARACTERS AND
C   THEIR CORRESPONDING TRUE(DECIMAL) NUMBERS RESPECTIVELY.
C-----CHAR( ) IS AN ARRAY CCNTAINING SUCCESSIVE CHARACTERS THAT MAKE UP A NUMBER
C   EACH OF WHICH IS STORED IN A NUMBER( ) ARRAY, WPM LCNG.  THE NUMBERS ARE
C   MANIPULATED AND THEN O/P INTO THE DATA( ) ARRAY  WHICH IS C/P CN MAGTAPE.
C-----DATA( ) IS THE FINAL ARRAY INTO WHICH THE DATA IS PUT PRIOR TO O/P ON MAG
C   TAPE. ITS LCCATIONS CONTAIN DAY, TIME & AVMAG IN SUCCESSIVE LOCATIONS.  NC
C   CTHER DATA IS O/P ON THE MAGTAPE. AVMAG=AVERAGE CF 1 MINUTE'S MAG-READINGS.
C-----A DATA-POINT IS DEFINED AS A NUMBER DESCRIBING A DATA PARAMETER BE IT DAY
C   CR TIME OR AVMAG. SC, CCNT, THE DATA-POINT CCUNT, UPS IN THREES FOR EACH
C   MINUTE OF DATA DECCDED AND C/P.
C-----FRAME( ) IS ARRAY CONTAINING 1 MINUTE'S PAPERTAPE FRAMES
C     DUMM( ) & FRIME( ) ARE CTHER ARRAYS OF THE SAME SIZE AS FRAME( ).
C-----OLIM=TOTAL NO. OF MAG-READINGS FCUND(IN A PTAPE) CUTSIDE LIMITS SPECIFIED.
C-----BUMF=TOTAL NO. OF PAPERTAPE FRAMES FOUND INDECCDEABLE(IN A PTAPE).
C
C********O/P BLCCKSIZE - OPTIMUM BLCCKSIZE FOR UBC IBM 360/67 IS 4096 BYTES.
C        WRITE FORMAT FCR C/P TAPE=I5 PER DATA-WCRD. WE HAVE 3 DATA-WCRDS(DAY,
C        TIME & AVMAG) PER DATA-SET, HENCE 15 BYTES. SO MAX. BLCCKSIZE=4096/15
C        =27C DATASETS(MINS.=4HR.33MINS). SC SET OCNT=27C*3=81C MAX.
C
C********DON'T FORGET - ASSIGN O/P MAGTAPE TO I/O UNIT 3!!!!!!!!!!!
C*******************************************************************************
C
      IMPLICIT INTEGER*4(A-Z)
      DIMENSICN CHAR(4), NUMBER(12), F(13), T(13), FRAME(6C), FRIME(6C),
     +DUMM(6C), DATA(81C)
C--------I/P DATA CONSTANTS
      DATA FPW,FPDP,FPM,TMAG,WPM,F(1),F(2),F(3),F(4),F(5),F(6),F(7),F(8)
     +,F(9),F(10),F(11),F(12),F(13),T(1),T(2),T(3),T(4),T(5),T(6),T(7),
```

```
     +T(8),T(9),T(1C),T(11),T(12),T(13)/4,5,60,1C,12,1,2,19,4,21,22,7,8,
     +25,32,128,98,84,1,2,3,4,5,6,7,8,9,0,128,98,84/
C***********************************************************************
C
   98 PTNO=30
C--------SET UP CCUNTS FOR EACH PAPERTAPE PROCESSED
   99 BUMF=0
      PCNT=0
      F11=0
      G=1
      CLIM=C
C
C********SET CCNT UP(OCNT CHECKED TO SEE IF O/P BLOCKSIZE REACHED)
C        CCNT=0 UNTIL FIRST MINUTE'S GOOD DATA FCUND(SEE 142 & 17C)
  1CC OCNT=C
C
C********SCAN PAPERTAPE FOR F(11) CHARACTER
  101 CALL PTAPE(IFRAME,&11,&21)
      PCNT=PCNT+1
  102 K=1
  104 FRAME(K)=IABS(IFRAME)
      IF(FRAME(K).EQ.F(11)) GC TC 106
C--------F(11) NCT FCUND. SCAN AGAIN.(PRINT MSG IF THIS IS NCT START OF PTAPE)
C       (MSG NOT PRINTED IF FRAME(K)=C WHICH IS GENERATED BY BLANK PAPERTAPE)
      IF(FRAME(K).EQ.C) GC TC 1C1
      IF(OCNT.GT.C) WRITE(6,7) FRAME(K), CCNT, NUMBER(1), NUMBER(2)
    7 FORMAT(1X, 'LOST F11. FOUND', I5, '. NO DATA LOST IF END CF PAPERT
     +APE SECTICN. CCNT=', I4, ' - APPROX DAY', I4, '/TIME', I5, '   ****
     +*****')
      GO TO 101
C--------F(11) FOUND. PRINT MSG & READ IN REST CF FRAMES FOR 1 MINUTE OF DATA
C         KEEPING PCNT GCING
  1C6 F11=F11+1
      IF(F11.GT.1) GO TO 1C7
      WRITE(6,1) PTNO, PCNT
    1 FCRMAT('C', 3X, 'PAPERTAPE NC. ', I2/1X, 'FIRST F(11) CHARACTER FO
     +UND AT FRAME NO. ', I5)
  107 DO 120 K=2, FPM
      CALL PTAPE(IFRAME,&11,&21)
      FRAME(K)=IABS(IFRAME)
      PCNT=PCNT+1
  120 CCNTINUE
C--------NOW HAVE 1 MINUTE'S FRAMES. CHECK SEPARATORS PRESENT.
  13C IF(FRAME(FPDP+1).NE.F(12)) GC TO 142
      M=WPM-1
      DO 139 N=2,M
      L=(FPDP*N)+1
      IF(FRAME(L).NE.F(13)) GO TO 142
  139 CCNTINUE
      GO TO 16C
C
C********SEPARATORS GOOFED UP. BOMB WHCLE PROGRAM IF PCNT.GT.6CO & STILL NO GCCD
C         DATA FCUND YET. CTHERWISE SCAN INSIDE ARRAY FOR F(11) TO RESTART.
C         TEST FCR BCMB-OUT ONLY MADE FCR START CF PTAPE(I.E. BLOCK 1)
  142 IF(G.GE.2) GO TO 143
      IF(PCNT.GE.600.AND.OCNT.EQ.C) GO TO 4CC
  143 DO 144 J=2,FPM
      IF(FRAME(J).EQ.F(11)) GO TO 147
  144 CONTINUE
C--------F(11) NCT IN ARRAY - PRINT MSG & RESTART SCAN CF PTAPE FOR F(11)
```

```
      WRITE(6,9) OCNT, NUMBER(1), NUMBER(2), FRAME
    9 FORMAT(1X, 'SEPARATORS GOOFED & F11 NOT IN ARRAY. ONE MINUTE''S DA
     +TA LOST AT OCNT=', I4, ' - APPROX DAY', I4, '/TIME', I5, '  ******
     +*****'/1X, 'GOOF IS IN THIS ARRAY .....'/1X, 30I4/1X, 30I4)
      GO TO 101
C--------F(11) IN ARRAY. UP F11 COUNT. SHIFT ARRAY SO J IN 1ST ARRAY LOCATION
C        USE DUMM( ) FOR TEMPORARY ARRAY. PRINT MSG, LOCATION & GOOFED ARRAY
  147 F11=F11+1
      WRITE(6,8) OCNT, NUMBER(1), NUMBER(2), FRAME
    8 FORMAT(1X, 'SEPARATORS GOOFED & F11 IS IN ARRAY. ONE MINUTE''S DAT
     +A MAY BE LOST AT OCNT=', I4, ' - APPROX DAY', I4, '/TIME', I5, '
     +*******'/1X, 'GOOF IS IN THIS ARRAY .....'/1X, 30I4/1X, 30I4)
      DO 148 JJ=1, FPM
  148 DUMM(JJ)=0
      JJ=1
      DO 149 NN=J, FPM
      DUMM(JJ)=FRAME(NN)
      JJ=JJ+1
  149 CONTINUE
      M=FPM-J+1
      JJ=1
      DO 151 N=1,M
      FRAME(N)=DUMM(JJ)
      JJ=JJ+1
  151 CONTINUE
C--------READ IN SOME MORE FRAMES TO FILL ARRAY. THEN CHECK SEPARATORS AGAIN.
      L=FPM-J+2
      DO 153 K=L,FPM
      CALL PTAPE(IFRAME,&11,&21)
      FRAME(K)=IABS(IFRAME)
      PCNT=PCNT+1
  153 CONTINUE
      GO TO 130
C
C********SEPARATORS O.K. SET FRIME( )=FRAME( ) : FRIME( ) USED FOR SPOT-CHECKS
C        UP OCNT, PRINT MSG IF OCNT=1 - THEN DECODE DATA FRAMES.
  160 DO 165 P=1, FPM
      FRIME(P)=FRAME(P)
  165 CONTINUE
  170 OCNT=OCNT+1
      IF(OCNT.GT.1.OR.Q.GT.1) GO TO 171
      TCNT=PCNT-FPM+1
      WRITE(6,2) F11, TCNT
    2 FORMAT(1X, 'FIRST MINUTE WHERE SEPARATORS O.K. AFTER ', I5, ' F11
     +CHARACTERS FOUND - AT FRAME NO. ', I5/)
C--------SET UP VALID-MAG COUNT WHICH DROPS AS EACH INVALID MAG FOUND
  171 VMAG=TMAG
C
C********DECODING.
C         TACKLE ALL WORDS IN ONE MINUTE.
  172 DO 199 I=1,WPM
      JZ=(I*FPDP)
      IZ=JZ-(FPDP-2)
C--------TACKLE EACH FRAME, STORE IN WORD ARRAY FORMING NUMBERS FROM WORDS
C        AS EACH WORD STORED.
      M=1
      DO 177 K=IZ,JZ
C--------HERE IS THE KEY DECODING LINE - FIND WHAT FRIDEN CHARACTER EACH FRAME
C         IS & THEN SET FRAME TO CORRESPONDING TRUE(DECIMAL) NUMBER.
      DO 174 J=1,10
```

```
      IF(FRAME(K).EQ.F(J)) GO TO 176
 174 CONTINUE
C---------FRAME NOT DECODEABLE - INVALID CHARACTER(PTAPE PUNCHING ERROR?)
C         NOTE I CONTROLLED BY STATEMENT 171
C-----(A)IF MAG-FRAME, ZERO WHOLE WORD(NUMBER(I) & DROP VALID-MAG COUNT
      ECNT=PCNT-FPM+K
      IF(I.LE.2) GO TO 175
      WRITE(6,10) FRAME(K), ECNT, OCNT, NUMBER(1), NUMBER(2)
  10 FORMAT(1X, 'FRIDEN CHARACTER', I5, ' INVALID:MAG-FRAME NO.', I7, '
    + - OCNT IS', I4, '. MAG-READING ZEROED. APPROX DAY', I4, '/TIME',
    +I5, '   *******')
      NUMBER(I)=0
      VMAG=VMAG-1
      BUMF=BUMF+FPW
      GO TO 199
C-----(B)IF DAY OR TIME FRAME, 9999 WHOLE WORD & CONTINUE NEXT WORD
 175 WRITE(6,3) FRAME(K), ECNT, OCNT, NUMBER(1), NUMBER(2)
   3 FORMAT(1X, 'FRIDEN CHARACTER', I5, ' INVALID:DAY/TIME FRAME NO.',
    +I7, ' - OCNT IS', I4, '. DAY/TIME SET TO 9999. APPROX DAY', I4, '/
    +TIME', I5, '   *****')
      NUMBER(I)=9999
      BUMF=BUMF+FPW
      GO TO 199
C---------FRAME DECODEABLE. SET FRAME TO TRUE NO. & FORM WORD FROM CHARACTERS.
 176 FRAME(K)=T(J)
      CHAR(M)=FRAME(K)
      M=M+1
 177 CONTINUE
C
C********CONVERT CHAR ARRAY INTO SINGLE NUMBER(AUTO SKIPPED IF NUMBER=0 OR 9999)
C---------GET LAST DIGIT
      NUMBER(I)=CHAR(FPW)
C---------NOW GET OTHER DIGITS. NOTE 'I' CONTROLLED BY DO STATEMENT 171.
      TEMP=FPW-1
      DO 182 Z=1, TEMP
      FNC=FPW-Z
      NUMBER(I)=NUMBER(I)+(CHAR(FNC)*(10**Z))
 182 CONTINUE
C
C********NOW CHECK MAG-READINGS WITHIN CHOSEN LIMITS SO BAD VALUES REJECTED
C         FOR MACBAY, HI-LIMIT=X9000 GAMMAS, LO-LIMIT=X7500 GAMMAS(UNDERSTOOD X=5)
 187 IF(I.LE.2) GO TO 199
      IF(NUMBER(I).GT.9000.OR.NUMBER(I).LT.7500) GO TO 192
C---------MAG-READING INSIDE LIMITS - O.K.
      GO TO 199
C---------MAG -READING OUTSIDE LIMITS - ZERO MAG, DROP VMAG-COUNT & UP OLIM-COUNT
 192 WRITE(6, 4) NUMBER(1), NUMBER(2), NUMBER(I)
   4 FORMAT(1X, 'DAY', I5, '/TIME', I5, ' - MAG-READING OF', I5, ' OFF
    +LIMITS SO WAS SET TO ZERO    ***************')
      NUMBER(I)=0
      VMAG=VMAG-1
      OLIM=OLIM+1
 199 CONTINUE
C
C********NOW HAVE NUMBER ARRAY WITH DAY, TIME & VMAG-MAGS. IF VMAG=0, PRINT MSG,
C         SET AVMAG=0 FOR O/P(ON TAPE)
 200 IF(VMAG.GT.0) GO TO 202
 201 AVMAG=0
      WRITE(6,5) NUMBER(1), NUMBER(2)
   5 FORMAT(1X, 'NO VALID MAGS AT ALL AT DAY ', I5, ' - TIME ', I5)
```

```
C--------VMAG NOT ZERO - SET UP 'DATA' ARRAY TO O/P AS A BLOCK. STORE DAY-TIME
C        -AVMAG CYCLICLY AND WRITE ON O/P TAPE ONCE BLOCKSIZE REACHED.
C-----(A)STORE DAY IN 'DATA' ARRAY
 202 DATA(OCNT)=NUMBER(1)
C-----(B)STORE TIME
     OCNT=OCNT+1
     DATA(OCNT)=NUMBER(2)
     IF(VMAG.GT.0) GO TO 204
C--------VMAG=0 SO BYPASS MAG-AVERAGING & SET AVMAG=0
     OCNT=OCNT+1
     AVMAG=0
     GO TO 209
C-----(C)STORE AVMAG - CALCULATE AVMAG FIRST(ROUND INTEGER UPWARDS)
 204 OCNT=OCNT+1
     SUM=0
     DO 207 I=3, WPM
     SUM=SUM+NUMBER(I)
 207 CONTINUE
     AVMAG=1.*SUM/VMAG+.5
 209 DATA(OCNT)=AVMAG
C********FOR SPOT-CHECK, PRINT PTAPE FRAMES & DECODED O/P FOR VISUAL COMPARISON
C       EVERY 30 MINS OF DATA(PERIOD SET BY XX IN 'MOD(OCNT,XX) WHERE XX IS THE
C       OCNT PERIOD=(PERIOD IN MINS)*3  (SINCE I MIN. DATA O/P UPS OCNT BY 3)
 210 IF(MOD(OCNT,90).EQ.0) WRITE(6,6) OCNT, Q, FRIME, NUMBER, AVMAG
   6 FORMAT(1X, '.....SPOT-CHECK AT OCNT OF', I4, ' O/P BLOCK NO.', I3/
    +1X, 'THE FRIDEN-CODED FRAMES ARE '/1X, 30I4/1X, 30I4/1X, 'THE DECO
    +DED O/P NUMBERS ARE '/1X, 12I5/1X, 'COMPUTED AVERAGE MAG-READING =
    + AVMAG = 5', I4, ' GAMMAS')
C
C********CHECK IF BLOCKSIZE REACHED - YES? WRITE ON O/P TAPE WITH I5 FORMAT.
C       BLOCKSIZE MAX. OF 810 CHOSEN AS PER COMMENTS AT START OF PROGRAM.
     IF(OCNT.LT.810) GO TO 101
     WRITE(3,999) DATA
 999 FORMAT(90(9I5))
     Q=Q+1
     GO TO 100
C
C********WHEN END OF PTAPE FOUND(CALL PTAPE EXIT &11)
C--------WRITE DATA( ) ARRAY ZEROING UNUSED LOCATIONS. CALCULATE TOTAL O/P
C       DATA-POINT COUNT(TOCNT) FOR THE PTAPE.
  11 KK=OCNT+1
     DO 220 IK=KK, 810
     DATA(IK)=0
 220 CONTINUE
     WRITE(3,999) DATA
     TOCNT=(Q-1)*810+OCNT
     MINCT=TOCNT/3
     TEMPO=OCNT
     TEMPO1=TEMPO-1
     TEMPO2=TEMPO1-1
     WRITE(6,12) PTNO, PCNT, BUMF, MINCT, Q, OLIM, DATA(TEMPO2),
    +DATA(TEMPO1), DATA(TEMPO)
  12 FORMAT('0', 4X, 'FINAL STATISTICS FOR PAPER-TAPE NO.', I3/1X,'PTAP
    +E FRAMES COUNTED = ', I7, ' - NUMBER INDECODEABLE = ', I5/1X,'NUMB
    +ER OF MINUTES OF DATA O/P =', I5, ' IN', I3, ' BLOCKS ON MAGTAPE'/
    +1X, 'NUMBER OF MAG-READINGS OUTSIDE SET LIMITS =', I4/1X, 'END OF
    +PTAPE FOUND AT DAY', I4, ', TIME', I5, ', AVMAG 5', I4, ' GAMMAS'/
    +/1X, '***********************************************************
    +*****************************'/)
C--------WRITE END-OF-FILE ON O/P MAGTAPE & CHANGE ON TO NEXT PAPERTAPE
```

```
      ENCFILE 3
      PTNC=PTNC+1
C-------GCTC 5CC INSTEAC IF EXIT AFTER 1 PTAPE WANTEC. FCRMAT STMT 999 O.K.?
      GO TO 99
C
C********WHEN ENC CF ALL PTAPES FCUNC(CALL PTAPE EXIT &21)
C        REPEAT STEPS AS &11 EXIT BUT EXTRA WRITE MSG & EXTRA ENCFILE
   21 KK=OCNT+1
      CC 221 IK=KK, 810
      DATA(IK)=C
  221 CONTINUE
      WRITE(3,999) CATA
      TCCNT=(Q-1)*810+CCNT
      MINCT=TOCNT/3
      TEMPO=CCNT
      TEMPO1=TEMPC-1
      TEMPO2=TEMPC1-1
      WRITE(6,12) PTNO, PCNT, BLMF, MINCT, Q, OLIM, DATA(TEMPC2),
     +DATA(TEMPO1), CATA(TEMPO)
      WRITE(6,22)
   22 FORMAT(1X, 'THATS ALL THE PAPER TAPES ****************************')
C---------WRITE TWC ENDFILES ON C/P MAGTAPE AND QUIT
      ENDFILE 3
      ENCFILE 3
      GO TO 5CO
C
C********BCMB CUT CPTION
  4CC WRITE(6,31) PTNC
   31 FORMAT(1X, '***** BOMB OUT ***** SEPARATORS GOOFED EVEN AFTER FIRS
     +T 6CO PTAPE FRAMES READ. CHECK INFUT CATA. PTAPE NO. = ', I3)
  500 STOP
      ENC



$CCPY *SKIP *SINK*
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```
$COPY *SOURCE*@¬CC *SINK*@¬CC
C     ******   DECCA NAVIGATION PROGRAM 'DECNAV'   ******
C
C  DAY/TIME/DECCA CO-ORDS OF AN OBSERVER ARE READ IN AND
C DAY/TIME/SEQUENTIAL MINUTES/GEOGRAPHIC CO-ORDS ARE COMPUTED.
C  DECCA CO-ORDS INPUT ARE FOR START/END OF A LINE - THE TYPE OF LINE(STRAIGHT
C OR HYPERBOLIC) AND THE DECCA CHAIN(6F OR MINIFIX) USED ARE I/P : THE PROG
C WILL INTERPOLATE(STRAIGHT OR HYPERBOLIC) ACCORDINGLY, AND USE THE APPROPRIATE
C CHAIN PARAMETERS.
C..BEFORE COMPILING/EXECUTING, SET UP DECCA CHAIN PARAMETERS & OPTION LIST.
C      LCNT,MCNT=COUNTS TO PRINT CHAIN PARAMETERS ONCE ONLY.
C*** LOGICAL UNIT 6 = LINE PRINTER,   5 = DECCA CO-ORD DATA(PRECEDED BY FORMAT)
C                   4 = PROGRAM O/P(USUALLY COMPUTER TAPE).
C                   8 = DEBUGGING & MINOR ERROR MSG O/P - SET=*DUMMY* TO KILL.
      IMPLICIT REAL*8(A-H,O-Z)
      INTEGER*4 DAY, TIME
      DIMENSION LINE(2), FMT1(20), FMT2(20), DAY(1000), TIME(1000), PATT
     +1(1000), PATT2(1000), MINUET(1000), GN(1000), GE(1000), DLAT(1000)
     +, DLON(1000), DIST(1000), FIXX(1000), FIXY(1000), OMIN(1000), BDIS
     +T(1000),IYAD(1000),EMIT(1000),GEOGX(1000),GEOGY(1000)
      DATA H/'H'/,Q/'L'/,P/'M'/,S/'S'/
      COMMON FIXIN, H, Q, P, S, LCNT, MCNT
C.....OPTION LIST.  PLEASE SET UP ACCORDING TO REQUIREMENTS.
C      FIXIN IS FIX INTERVAL IN DECCA LANES - FIXES WILL BE COMPUTED EVERY
C      FIXIN LANES FOR INTERPOLATION (IF HYPERBOLIC).
C      ZMINT=TIME INTERVAL(IN MINS) BETWEEN FINAL O/P FIXES COMPUTED.
C      ZMINT=2.0
C      SET IDTM=0 IF DAY/TIME/MINUET/POSITIONS O/P WANTED.
C          IDTM=1 IF DAY/TIME/POSITIONS O/P WANTED.
C          IDTM=2 IF MINUET/POSITIONS O/P WANTED.
C      SET UTM GRID CONSTANTS AT STMT 1000.
C      FIXIN=1.0  SET UP AFTER STATEMENT #90.
      IDTM=0
      ZMINT=2.0
C.....READ IN FORMAT BEING USED FOR DECCA CO-ORD I/P.
      READ(5,50) (FMT1(I), I=1,20)
   50 FORMAT(20A4)
C      FOR MACBAY, (1X,I5,1X,I4,1X,I4,1X,F7.3,1X,F7.3,1X,A1,1X,A1,1X,A3)
C.....SET UP COUNTS. RESET NOT NEEDED - PRINT ONCE ONLY PER PROGRAM EXECUTION.
   80 LCNT=1
      MCNT=1
C.....READ IN LINE I.D./DAY/TIME/DECCA CO-ORDS/SELECTIONS.
C      SELECTIONS: CHAIN = M FOR MINIFIX CHAIN.
C                  CHAIN = S FOR 6F CHAIN(BOTH CHAINS ARE DECCA SYSTEMS).
C                  TRACK = H IF SHIP'S TRACK IS HYPERBOLIC.
C                  TRACK = L IF SHIP'S TRACK IS A 'STRAIGHT' LINE.
C                  LINE CODE=1:START OF LINE (E.G. 10011 FOR START OF LINE 11)
C                           =9:END   OF LINE (E.G. 90011 FOR END   OF LINE 11).
C                           =99999 IF LAST CARD.
   90 I=1
      FIXIN=1.0
  101 READ(5,FMT1,ERR=8000,END=9000) LINE(1),DAY(I),TIME(I),PATT1(I),PAT
     +T2(I),CHAIN,TRACK,PTNC
C.....CHECK IF LAST CARD.
      IF(LINE(1).NE.99999) GO TO 120
      WRITE(6,110)
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  110 FORMAT(1X, 'NORMAL JOB TERMINATION')
      STOP 1
C.....CHECK IF CARD IS FOR START OF LINE.
  120 LCHK=LINE(1)/10000
      IF(LCHK.EQ.1) GO TO 125
C     CARD IS NOT FOR START OF LINE. PRINT MSG & READ NEXT CARD.
      WRITE(6,126)
  126 FORMAT(1X, 'THIS IS NOT CARD FOR START OF LINE.....')
      WRITE(6,8050)
      WRITE(6,FMT1) LINE(1),DAY(I),TIME(I),PATT1(I),PATT2(I),CHAIN,TRACK
     +,PTNO
      GO TO 90
  125 CALL MINTY(DAY(I),TIME(I),MINUET(I))
C     PRINT 127, I, DAY(I), TIME(I), MINUET(I)
C 127 FORMAT(1X,'FOR I=',I5,' DAY/TIME/MINUET=', 3(1X,I7))
C.....READ IN NEXT CARD AND CHECK IF FOR END OF SAME LINE. READ AGAIN IF NOT.
  130 J=1000
      READ(5,FMT1,ERR=8080,END=9000) LINE(2),DAY(J),TIME(J), PATT1(J), P
     +ATT2(J), CHAIN, TRACK, PTNO
      LDIFF=IABS(LINE(2)-LINE(1))
      IF(LDIFF.NE.80000) GO TO 146
      CALL MINTY(DAY(J),TIME(J),MINUET(J))
C     PRINT 136, J, DAY(J), TIME(J), MINUET(J)
C 136 FORMAT(1X,'FOR J=',I5,' DAY/TIME/MINUET=', 3(1X,I7))
      GO TO 160
  146 WRITE(6,150)
  150 FORMAT(1X, '*** ERROR...START/END CARD-PAIR NOT FOUND. CARDS ARE')
      WRITE(6,FMT1) LINE(1),DAY(I),TIME(I),PATT1(I),PATT2(I),CHAIN,TRACK
     +,PTNO
      WRITE(6,FMT1) LINE(2),DAY(J),TIME(J),PATT1(J),PATT2(J),CHAIN,TRACK
     +,PTNO
  153 GO TO 90
C.....HAVE START/END CARDS FOR SAME LINE. CHECK WHAT INTERPOLATION NEEDED.
C     'H' FOR HYPERBOLIC : 'L' FOR STRAIGHT LINE.
  160 WRITE(6,162)
  162 FORMAT(1X, 'START & END OF LINE BEING PROCESSED ...')
      WRITE(6,8050)
      WRITE(6,FMT1) LINE(1),DAY(I),TIME(I),PATT1(I),PATT2(I),CHAIN,TRACK
     +,PTNO
      WRITE(6,FMT1) LINE(2),DAY(J),TIME(J),PATT1(J),PATT2(J),CHAIN,TRACK
     +,PTNO
      IF(TRACK.EQ.H) GO TO 170
      IF(TRACK.EQ.Q) GO TO 700
C.....TRACK TYPE UNSPECIFIED. ERROR.
      WRITE(6,165)
  165 FORMAT(1X, 'TRACK TYPE UNSPECIFIED FOR THIS LINE....')
      WRITE(6,8050)
      WRITE(6,FMT1) LINE(1),DAY(I),TIME(I),PATT1(I),PATT2(I),CHAIN,TRACK
     +,PTNO
      WRITE(6,FMT1) LINE(2),DAY(J),TIME(J),PATT1(J),PATT2(J),CHAIN,TRACK
     +,PTNO
      GO TO 90
C*****HYPERBOLIC INTERPOLATION NEEDED.
C     HAVE DECCA CO-ORDS FOR START/END OF LINE. DETERMINE WHICH IS TRACK LANE.
  170 IF(PATT1(I).EQ.PATT1(J)) GO TO 210
      IF(PATT2(I).EQ.PATT2(J)) GO TO 280
C.....SOMETHING WRONG. NO TRACK LANE FOUND. PRINT MSG & READ NEXT CARD.
      WRITE(6,190) LINE(I)
  190 FORMAT(1X, 'NO TRACK LANE FOUND FOR LINE ',I5,' *************')
      GO TO 90
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C.....PATTERN 1 (RED) IS OUR TRACK LANE. GET LOWER PATTERN 2 READING SO WE
C      KNOW IF FIXIN IS POSITIVE OR NEGATIVE.
  210 IF(PATT2(I).LT.PATT2(J)) GO TO 222
C     PATT2(J) IS LOWER READING. SET FIXIN NEGATIVE.
      FIXIN=-FIXIN
C.....COMPUTE POSITIONS WITH SBRTN DECCA FROM PATT2(I) TO PATT2(J) EVERY
C     FIXIN LANES.  REMEMBER PATT 1 IS CONSTANT. SO USE PATT1(1) ONLY.
  222 CALL DECCA(LINE(1),PATT1(1),PATT2(I),GN(I),GE(I),DLAT(I),DLON(I),C
     +HAIN,&90,&9999)
C     PRINT 223, I, J
C 223 FORMAT(1X, 'AT 222, VALUE OF I IS', I7, ' - J IS ', I7)
      I=I+1
      K=I-1
      PATT2(I)=PATT2(K)+FIXIN
C.....MAKE SURE LAST POSITION(PATT2(J)) IS COMPUTED.
      IF(PATT2(I).LE.PATT2(J)) GO TO 222
C.....IF EQUAL TO, LAST POSITION(FOR PATT2(J)) ALREADY DONE - SO EXIT.
      IF(PATT2(K).EQ.PATT2(J)) GO TO 300
C.....NOT EQUAL,MUST BE GREATER. SO COMPUTE FOR PATTERN2(J) AFORE EXIT.
      PATT2(I)=PATT2(J)
      CALL DECCA(LINE(1),PATT1(1),PATT2(I),GN(I),GE(I),DLAT(I),DLON(I),C
     +HAIN,&90,&9999)
      GO TO 302
C.....PATTERN 2 (GREEN) IS TRACK LANE. REPEAT AS STMTS 210-220 BUT PATT2 CONST.
  280 IF(PATT1(1).LT.PATT1(J)) GO TO 292
      FIXIN=-FIXIN
  292 CALL DECCA(LINE(1),PATT1(I),PATT2(1),GN(I),GE(I),DLAT(I),DLON(I),C
     +HAIN,&90,&9999)
C     PRINT 293, I, J
C 293 FORMAT(1X, 'AT 292 VALUE OF I IS ', I7, ' - J IS ', I7)
      I=I+1
      K=I-1
      PATT1(I)=PATT1(K)+FIXIN
      IF(PATT1(I).LE.PATT1(J)) GO TO 292
      IF(PATT1(K).EQ.PATT1(J)) GO TO 300
      PATT1(I)=PATT1(J)
      CALL DECCA(LINE(1),PATT1(I),PATT2(1),GN(I),GE(I),DLAT(I),DLON(I),C
     +HAIN,&90,&9999)
      GO TO 302
C.....FIXES ALL COMPUTED. GET DISTANCE BETWEEN FIXES & TOTAL LINE LENGTH.
C.....TDIST=TOTAL LENGTH OF LINE.
C     THIS IS THE 'K' EXIT - VALUE OF 'I' TOO HIGH BY 1.
  300 I=I-1
C     THIS IS THE 'I' EXIT. VALUE OF 'I' O.K. STORE IT(IT IS MAX. HERE).
  302 L=I
C     PRINT 303, L
C 303 FORMAT(1X, 'AT 302, L IS ', I6)
      TDIST=0
      DO 350 M=2,L
      N=M-1
      CALL DISTAN(DLAT(M),DLON(M),DLAT(N),DLON(N),DIST(N))
C     PRINT 340, M,N,DLAT(M),DLON(M),DLAT(N),DLON(N),DIST(N)
C 340 FORMAT(1X,'FOR M/N=',2(1X,I3),' DLAT(M)/DLON(M),DLAT(N)/DLON(N)/DI
C    +ST(N) ARE',5(1X,F10.3))
C     PRINT 343, N, DIST(N), TDIST
C 343 FORMAT(1X,'FOR N=',I3,' DIST(N)',F10.3,' ADDS UP TO TDIST OF',F10.
C    +3)
  350 TDIST=TDIST+DIST(N)
C.....NOW HAVE ARRAY OF FIXES & DISTANCES BETWEEN THEM. COMPUTE SHIP'S SPEED.
      ELAPSE=DFLOAT(MINUET(J)-MINUET(1))
```

```
C      PRINT 360, ELAPSE, MINUET(J), MINUET(1)
C 360 FORMAT(1X, 'ELAPSE=',F6.1,' - SHOULD BE',I6,' MINUS ',I6)
      SPEED=(TDIST/ELAPSE)*60.
      WRITE(6,380) LINE(1),TDIST,ELAPSE,SPEED
  380 FORMAT(1X, 'CHECK : LINE ',I5,' - SAILED ',F8.3,' NM IN ',F8.3, 'M
     +INS - SPEED = ', F8.3, ' KNOTS')
C.....SET MINUTES-BETWEEN-FIXES-INTERVAL REQUIRED.
C      1 MINUTE APPROX. EQUAL TO 1600 FEET AT 16 KNOTS.
C 450 ZMINT=2.0
C.....DIVIDE START/END TIMES OF LINE BY ZMINT TO GET 'ZFIX', THE NO. OF FIXES
C      FOR LINE. DIVIDE LINE LENGTH 'TDIST' BY ZFIX TO GET DISTANCE INTERVAL
C      BETWEEN FIXES 'FDINT'.
      ZFIX=ELAPSE/ZMINT
      FDINT=TDIST/ZFIX
C.....GET INTEGER(ZFIX), ADD 1 - THIS IS NO. OF FIXES WE END UP WITH FOR LINE
      NFIX=(IDINT(ZFIX))+1
C      PRINT 460, ZMINT,ZFIX,FDINT,ELAPSE,LINE(1)
C 460 FORMAT(1X,'EVERY',F5.2,'MIN GIVES',F7.2,' FIXES',F7.2,' DIST APART
C    + OVER',F8.3,'MIN FOR LINE #',I6)
C*****INTERPOLATION LOOP. USE NFIX AS LOOP CONTROLLER.
C      FDIST=CUMULATIVE DISTANCE TWEEN FINAL O/P FIXES(FDINT MINS. APART).
C      DDIST=CUMULATIVE DISTANCE TWEEN DECCA POINTS COMPUTED ABOVE.
C      CAUTION:DDIST SHOULD ADD UP TO TDIST(LINE LENGTH) BUT NEVER QUITE DOES.
  475 DDIST=0
      FDIST=0
C      SET UP FIRST O/P FIX.
  480 FIXX(1)=GN(1)
      FIXY(1)=GE(1)
      OMIN(1)=DFLOAT(MINUET(1))
C      PRINT 483, OMIN(1),FIXX(1),FIXY(1)
C 483 FORMAT(1X,'FIRST O/P FIX SET UP. OMIN(1)/FIXX(1)/FIXY(1) ARE', 3(1
C    +X,F10.3))
C.....NOW GET OTHER FIXES WHICH NEED INTERPOLATION THOUGH. FIX TO BE COMPUTED
C      MUST ALWAYS BE DEFINED BY POINTS(J) & POINTS(I).
C      J=2,NFIX - I=J-1   NFIX=NO. OF O/P FIXES.
C      M=1,N    - L=M-1       N=NO. OF POINTS CO-ORDS KNOWN(DECCA COMPUT. ABOVE)
      M=1
  500 DO 600 J=2,NFIX
      I=J-1
      FDIST=FDIST+FDINT
C      PRINT 505, J, FDIST, FDINT
C 505 FORMAT(1X,'FOR J=',I3,' FDIST/FDINT ARE',2(1X,F8.3))
C.....CHECK IF FIX DEFINED BY DECCA POINTS IN HAND.
  510 IF(FDIST.GT.DDIST) GO TO 525
C.....DEFINED - GET 'DIFF' & GO TO INTERPOLATING STATEMENTS.
      DIFF=DDIST-FDIST
      GO TO 550
C.....NOT DEFINED. UP M & GET NEW DDIST. RECHECK DEFINITION BY NEW POINTS.
C 525 PRINT 529, J, DDIST, FDIST
C 529 FORMAT(1X,'AT 525, FOR J=',I3,' DDIST/FDIST ARE',2(1X,F8.3))
  525 M=M+1
      L=M-1
      DDIST=DDIST+DIST(L)
C      PRINT 533, M,L, DDIST, DIST(L)
C 533 FORMAT(1X,'AT 525+, M/L ARE',2(1X,I3),' DDIST/DIST(L) ARE',2(1X,F8
C    +.3))
      GO TO 510
C.....INTERPOLATING STMTS. FIX DEFINED BY POINTS(M) & POINTS(L).
  550 FIXX(J)=GN(M)-(((GN(M)-GN(L))*DIFF)/DIST(L))
      FIXY(J)=GE(M)-(((GE(M)-GE(L))*DIFF)/DIST(L))
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```
      OMIN(J)=OMIN(I)+ZMINT
C     PRINT 571, J,M,L
C 571 FORMAT(1X,'FOR J/M/L OF',3(1X,I5),' WE HAVE ..')
C     PRINT 573, FIXX(J),DLAT(M),DLAT(L),DIST(L)
C 573 FORMAT(1X,'FIXX(J),DLAT(M),DLAT(L),DIST(L) ARE',4(1X,F10.3))
C     PRINT 577, DIFF, J
C 577 FORMAT(1X,'DIFF IS',F10.3,' FOR J OF',I3)
C     PRINT 579, OMIN(J),OMIN(I),ZMINT,I
C 579 FORMAT(1X,'OMIN(J)/OMIN(I)/ZMINT ARE',3(1X,F10.1),' FOR I=',I6)
  600 CONTINUE
C.....ALL INTERPOLATIONS DONE - GO TO O/P AREA.
      GO TO 1000
C*****STRAIGHT TRACK LINE. WE HAVE START/END - SO CONVERT TO GEOG-POSNS FIRST.
  700 CALL DECCA(LINE(1),PATT1(I),PATT2(I),GN(I),GE(I),DLAT(I),DLON(I),C
     +HAIN,&90,&9999)
      CALL DECCA(LINE(2),PATT1(J),PATT2(J),GN(J),GE(J),DLAT(J),DLON(J),C
     +HAIN,&90,&9999)
C.....NOW HAVE 2 GEOG POSNS. COMPUTE SHIP'S SPEED.
      CALL DISTAN(DLAT(J),DLON(J),DLAT(I),DLON(I),DIST(1))
      TDIST=DIST(1)
      ELAPSE=DFLOAT(MINUET(J)-MINUET(1))
      SPEED=(TDIST/ELAPSE)*60.
      WRITE(6,380) LINE(1),TDIST,ELAPSE,SPEED
C.....FROM 2 GEOG POSNS & ZMINT(STMT 450) GET NO. OF FIXES NEEDED FOR LINE.
      ZFIX=ELAPSE/ZMINT
      NFIX=(IDINT(ZFIX))+1
C     GET DIFFERENCES IN LAT/LON BETWEEN POSNS.
      DIFGN=GN(J)-GN(I)
      DIFGE=GE(J)-GE(I)
C.....COMPUTE GN/GE INCREMENTS BETWEEN INTERPOLATIONS - CALLED UPGN/UPGE.
      UPGN=DIFGN/ZFIX
      UPGE=DIFGE/ZFIX
C.....NOW INTERPOLATE. REMEMBER NFIX=(INTEGER PART(ZFIX))+1=NO.OF FIXES.
C     INITIALISE FIXX, FIXY, OMIN.
      FIXX(1)=GN(1)
      FIXY(1)=GE(1)
      OMIN(1)=DFLOAT(MINUET(1))
      DO 800 IM=2,NFIX
      IN=IM-1
      FIXX(IM)=FIXX(IN)+UPGN
      FIXY(IM)=FIXY(IN)+UPGE
      OMIN(IM)=OMIN(IN)+ZMINT
  800 CONTINUE
C.....HAVE ALL FIXES.  GO TO O/P AREA.
      GO TO 1000
C*****  O/P AREA.....
C     ALL FIXES IN UTM CO-ORDS DONE. CONVERT TO GEOG CO-ORDS, THEN O/P
C     ACCORDING TO TYPE OF 'TIME' O/P DESIRED.  NOTE NFIX=NO. OF FIXES.
C     SF=SCALE FACTOR; DR=DEGREE-RADIAN CONVERSION FACTOR;
C     ORE=FALSE EASTING; ORN=FALSE NORTHING; IZONE=UTM ZONE.
 1000 SF=0.99960
      DR=0.01745329252
      ORE=500000.
      ORN=0.
      IZONE=8
      GL=IZONE*6.
      GL=183.-GL
      DO 1002 K=1,NFIX
      CALL B51211(AA2,B2,FIXY(K),FIXX(K),SF,ORE,ORN)
      GEOGX(K)=AA2/DR
```

```
 1002 GEOGY(K)=(B2/DR)+GL
      IF(IDTM.EQ.2) GO TO 1010
      IF(IDTM.EQ.1) GO TO 1020
      IF(IDTM.EQ.0) GO TO 1020
      WRITE(6,1004)
 1004 FORMAT(1X, 'FATAL ERROR - TYPE OF TIME O/P WANTED UNRECOGNISED')
      STOP 8
C.....MINUTE-ONLY O/P WANTED. NO MORE COMPUTATIONS NEEDED.
 1010 WRITE(4,1012) LINE(1), NFIX
 1012 FORMAT(I6,1X,I6)
      WRITE(4,1013) (OMIN(I),FIXX(I),FIXY(I),GEOGX(I),GEOGY(I),I=1,NFIX)
 1013 FORMAT(F10.2,1X,F15.3,1X,F15.3,1X,F15.8,1X,F15.8)
      GO TO 1050
C.....DAY/TIME WANTED. CONVERT MINUET BACK.
 1020 DO 1024 I=1,NFIX
      CALL UNMINT(OMIN(I),IYAD(I),EMIT(I))
 1024 CONTINUE
C.....NOW O/P ACCORDING TO IDTM CHOSEN.
      IF(IDTM.EQ.1) GO TO 1028
C.....IDTM=0 - DAY/TIME/MINUET O/P WANTED.
      WRITE(4,1026) LINE(1), NFIX
 1026 FORMAT(I6,1X,I6)
      WRITE(4,1027) (IYAD(I),EMIT(I),OMIN(I),FIXX(I),FIXY(I),GEOGX(I),GE
     +OGY(I), I=1,NFIX)
 1027 FORMAT(I5,1X,F7.2,1X,F10.2,1X,F15.3,1X,F15.3,1X,F15.8,1X,F15.8)
      GO TO 1050
C.....IDTM=1 - DAY/TIME ONLY O/P WANTED.
 1028 WRITE(4,1029) LINE(1), NFIX
 1029 FORMAT(I6,1X,I6)
      WRITE(4,1030) (IYAD(I),EMIT(I),FIXX(I),FIXY(I),GEOGX(I),GEOGY(I),
     +I=1,NFIX)
 1030 FORMAT(I5,1X,F7.2,1X,F15.3,1X,F15.3,1X,F15.8,1X,F15.8)
C.....O/P WRITTEN.  SIGNAL THIS. WRITE ENDFILE ALSO.
 1050 WRITE(6,1053) NFIX,LINE(1)
 1053 FORMAT(1X,I5,' FIXES O/P ON UNIT 4 - LINE',I6,' PROCESSED'/)
      END FILE 4
      GO TO 90
C.....READ ERROR. TRY AGAIN. TERMINATE ONLY OF ENDFILE OR '99999-LAST CARD'.
 8000 WRITE(6,8010)
 8010 FORMAT(1X, '*****  READ ERROR ON FOLLOWING ... ')
      WRITE(6,8050)
 8050 FORMAT(2X, 'LINE  DAY TIME   PATT1   PATT2 C T PT#')
      WRITE(6,FMT1) LINE(1),DAY(I),TIME(I),PATT1(I),PATT2(I),CHAIN,TRACK
     +,PTNO
      GO TO 90
 8080 WRITE(6,8010)
      WRITE(6,8050)
      WRITE(6,FMT1) LINE(2),DAY(J),TIME(J),PATT1(J),PATT2(J),CHAIN,TRACK
     +,PTNO
      GO TO 90
C*****ENDFILE ENCOUNTERED. BOMB OUT.
 9000 WRITE(6,9010)
 9010 FORMAT(1X, '*** ENDFILE ENCOUNTERED. ERROR OR LAST CARD NOT ''9999
     +9''')
      STOP 9
C*****NAV SYSTEM UNSPECIFIED.  BOMB OUT.
 9999 STOP 3
      END
C*************************************************************************
      SUBROUTINE DECCA(MFIX,R1,R2,GN,GE,DLAT,DLON,CHAIN,*,*)
```

```
C***  DECCA NAVIGATION PROGRAM - COURTESY MARINE SCIENCES VICTORIA  ***
C..DECCA RECEIVES THE DECCA CO-ORDINATES OF AN OBSERVER & COMPUTES HIS/HER
C POSITION FIRST IN UTM & THEN IN GEOGRAPHIC CO-ORDINATES.
C..TWO DECCA SYSTEMS WERE USED IN THE MACBAY AREA(CALLED THE 6F & THE MINIFIX
C SYSTEMS) - SO DECCA DETERMINES WHICH IS BEING USED BEFORE COMPUTATIONS
C COMMENCE.
C..ALL CO-ORDINATES ARE ASSUMED BY DECCA TO BE IN THE SAME UTM ZONE.
C
C....LINE=I.D. OF LINE OR POINT BEING PROCESSED.
C     R1/R2=PATTERN 1 & PATTERN 2 DECCA CO-ORDINATES OF OBSERVER.
C     DLAT/DLON=LAT & LON OF OBSERVER RETURNED BY DECCA. DEGREES ONLY(E.G. 49.51
C***** SET UP PARAMETERS FIRST. UTM-ZONE, CHAIN PARS & SCALE FACTOR FOR AREA.
C
      IMPLICIT REAL*8(A-H,C-Z)
      COMMON FIXIN, H, Q, P, S, LCNT, MCNT
C     DATA P/'M'/,S/'S'/
C.... SET UP PRINT COUNTS. LCNT FOR 6F, MCNT FOR MINIFIX.
C     MCNT=1
C     LCNT=1
C 109 READ(5,110,END=880) MFIX,R1,R2,CHAIN
C 110 FORMAT(1X,I5,1X,F7.2,1X,F7.2,1X,A1)
C.....SET UTM-ZONE.
      IZONE=8
C.....SET SCALE FACTOR, USUALLY MEAN SCALE FACTOR FOR WHOLE AREA.
      SF=0.9996
C......SET CHAIN PARAMETERS.
C     V=SPEED OF PROPAGATION OF E.M. WAVES IN KM/SEC.
C     Q1=FREQUENCY FOR SLAVE 1 IN KHZ.
C     Q2=FREQUENCY FOR SLAVE 2 IN KHZ.
C     IF SYSTEM IS SINGLE FREQUENCY, MAKE Q2=Q1
C     XM,YM = EASTING AND NORTHING OF MASTER STATION
C     XS1,YS1=EASTING AND NORTHING OF SLAVE 1
C     XS2,YS2=EASTING AND NORTHING OF SLAVE 2
C.....SKIP 6F CHAIN PARS IF MINIFIX IS SYSTEM BEING USED.
      IF(CHAIN.EQ.P) GO TO 312
      IF(CHAIN.NE.S) GO TO 900
C.....6F SYSTEMS PARAMETERS ARE:
  308 V=299650.0
      Q1=355.92
      Q2=266.94
      YM=7731381.78
      XM=502649.21
      YS1=7762342.307
      XS1=636554.457
      YS2=7722501.814
      XS2=347563.076
C.... CHAIN PARAMETERS COMING UP - PRINT WHICH CHAIN FIRST.
C     WRITE(6,310) OR WRITE(6,311)
  310 FORMAT(/1X, 'FOR DECCA 6F SYSTEM')
  311 FORMAT(/1X, 'FOR DECCA MINIFIX SYSTEM')
C     CHAIN PARAMETERS FORMAT.
C     WRITE(6,321) IZONE,SF,V,YM,XM,YS1,XS1,YS2,XS2
  321 FORMAT(1X, 'CHAIN PARAMETERS INPUT ARE ....'/1X, 'AREA-WIDE : UTM-
     +ZONE', I3, ' & SCALE-FACTOR ',F9.7/1X, 'VELOCITY OF PROPAGATION AS
     +SUMED IS ',F10.2,' KM/SEC'/1X,' MASTER CO-ORDS IN UTM = NORTHING '
     +,F12.3,' - EASTING ',F12.3/1X,'SLAVE 1 CO-ORDS IN UTM = NORTHING '
     +,F12.3,' - EASTING ',F12.3/1X,'SLAVE 2 CO-ORDS IN UTM = NORTHING '
     +,F12.3,' - EASTING ',F12.3/)
C.....PRINT CHAIN HEADING & PARAMETERS ONCE - DISPLAY ONLY
      IF(LCNT.GT.1) GO TO 120
```

```
      WRITE(6,310)
      WRITE(6,321) IZONE,SF,V,YM,XM,YS1,XS1,YS2,XS2
      LCNT=LCNT+1
C.....SKIP OVER OTHER CHAIN NOW.
      GO TO 120
C......SET UP MINIFIX SYSTEM PARAMETERS NOW. MACBAY SLAVE 1/SLAVE 2 REVERSED.
  312 V=299650.0
      Q1=1702.
      Q2=1702.
      YS1=7664C07.32
      XS1=455153.98
      YM=7656233.87
      XM=400817.93
      YS2=7687375.22
      XS2=368354.65
C.....PRINT CHAIN HEADING & PARAMETERS ONCE FOR DISPLAY.
      IF(MCNT.GT.1) GO TO 120
      WRITE(6,311)
      WRITE(6,321) IZONE,SF,V,YM,XM,YS1,XS1,YS2,XS2
      MCNT=MCNT+1
C
C-----COMPUTE BASELINES
C
  120 A1=DSQRT((XM-XS1)**2+(YM-YS1)**2)
      A2=DSQRT((XM-XS2)**2+(YM-YS2)**2)
      X1=XS1-XM
      X2=XS2-XM
      Y1=YS1-YM
      Y2=YS2-YM
      AK=X1*Y2-Y1*X2
      ZQ=(A1**2*Y2-A2**2*Y1)/2./AK
      ZT=(A2**2*X1-A1**2*X2)/2./AK
      V1=V*SF
90    AK1=1.-((R1*V1)/(Q1*A1))
      AK2=1.-((R2*V1)/(Q2*A2))
      ZP=((A2*Y1*AK2)-(A1*Y2*AK1))/AK
      ZS=((A1*X2*AK1)-(A2*X1*AK2))/AK
      ZR=((A1**2*Y2*AK1**2)-(A2**2*Y1*AK2**2))/2./AK
      ZV=((A2**2*X1*AK2**2)-(A1**2*X2*AK1**2))/2./AK
      B1=ZT-ZV
      B2=ZQ-ZR
      B3=ZP**2+ZS**2-1.
      B4=ZP*B2
      B5=ZS*B1
      B6=B4+B5
      B7=B6**2
      B8=B3*(B2**2+B1**2)
      IF(B7)20,20,30
30    RADIC=B7-B8
      IF(RADIC)40,40,50
50    D=(-B6-DSQRT(RADIC))/B3
      IF(D)60,60,70
60    D=(-B6+DSQRT(RADIC))/B3
      IF(D)80,80,70
70    X=ZP*D+B2+XM
      Y=ZS*D+B1+YM
      GN=Y
      GE=X
      GO TO 1000
20    WRITE(6,12) MFIX, R1, R2
```

```
12    FORMAT(1X,'SOLUTION INVALID. NO FIX FOR LINE ',I7, 'WHICH IS PATT1
     +', F8.3, ' - PATT2 ', F8.3)
      RETURN 1
C     STOP
40    WRITE(6,13) MFIX, R1, R2
13    FORMAT(1X,'SOLUTION  IMAGIN. NO FIX FOR LINE ',I7, 'WHICH IS PATT1
     +', F8.3, ' - PATT2 ', F8.3)
      RETURN 1
C     STOP
30    WRITE(6,12) MFIX, R1, R2
      RETURN 1
C     STOP
1000  SCFACT=SF
      DR=0.01745329252
      ORE=500000.
      ORN=0.
      GL=IZONE*6
      GL=183.-GL
C
C     CONVERSION FROM GRID TO GEOGRAPHIC
C
      CALL B51211(AA2,B2,GE,GN,SCFACT,ORE,ORN)
C
      AL2=AA2/DR
      IAL2=AL2
      XMIN=(AL2-IAL2)*60
      MIN=XMIN
      ASEC=(XMIN-MIN)*60
      ALO2=B2/DR+GL
      IALO2=ALO2
      XMIN=(ALO2-IALO2)*60
      IMIN=XMIN
      BSEC=(XMIN-IMIN)*60
C84   WRITE(6,22)MFIX,R1,R2,GN,GE,IAL2,MIN,ASEC,IALO2,IMIN,BSEC,IZONE
C22   FORMAT('0',2X,I5,5X,F8.3,3X,F8.3,3X,F11.3,F12.3,4X,2I3,F6.2,6X,
C    52I3,F6.2,5X,I2)
C
C.....CONVERT DEG/MINS/SEC TO DEGREES-ONLY.
      DLAT=IAL2+(MIN/60.)+(ASEC/3600.)
      DLON=IALO2+(IMIN/60.)+(BSEC/3600.)
C     WRITE(6,86) MFIX,DLAT,DLON
C  86 FORMAT(1X, I5, 2X, F10.4, 2X, F10.4)
C     GO TO 109
C 880 STOP 8
      RETURN
C.....ERROR EXIT. NAV SYSTEM UNSPECIFIED.
  900 WRITE(6,901)
  901 FORMAT(2X,'*** ERROR - NAV SYSTEM NEITHER MINIFIX NOR 6F ***')
C     STOP 9
      RETURN 2
      END
      SUBROUTINE B51211 (DA,DC,GE,GN,SCFACT,ORE,ORN)
      IMPLICIT REAL*8(A-H,O-Z)
C      GRID TO GEOGR.  ANY SPHEROID      PROGRAM B51211 (P203)
C
C
C     ** INPUT,
C
C           GE = EASTING
C           GN = NORTHING
```

```
C       SCFACT = CENTRAL SCALE FACTOR
C          ORE = FALSE EASTING
C          ORN = FALSE NORTHING
C
C
C     ** OUTPUT,
C
C           DA = LATTITUDE, NORTH(+), SOUTH(-)
C           DO = DIFF. OF LONGITUDE, (+) FOR POINT WEST OF MERIDIAN
C
C
      A1=6378206.4
      P2=0.67686579973D-2
      DELT=0.68147849459D-2
C
C         A1 = EQUATORIAL SEMI-AXIS
C           P2 = EXCENTRICITY SQUARED
C       DELT = P2/(2.-P2)
C
      X=  -(GE-ORE)/SCFACT
      YY=  (GN-ORN)/SCFACT
      Y=DABS(YY)
      C1=.75*P2
      C2=C1*P2*.9375
      C3=C2*P2*.9722222222
      C4=C3*P2*.984375
      C5=A1*(1.-P2)
      P3=P2*.5
      P4=1.-P3
      P5=DSQRT(P4)
      P6=P4*P5
      PZ=P4*P4
      PX=P6*P4
      PY=P2*P2
      P7=1./(1.-P2)
      P8=P7*P7
      P9=P8*P7
      YA=(Y-4984727.1000)/A1
      YB=YA*YA
      YC=YB*YA
      AT=.7853981634+P6*YA*P7-.75*P2*PZ*P8*YB+PY*PX*P9*YC
      IPASS=0
      ZX1 = 1.0
      ZX  = 0.0
   25 CONTINUE
      IPASS=IPASS+1
      IF(ZX1-ZX)28,28,27
   28 IF(IPASS-2)27,27,26
   27  ZX1 = ZX
      CS1=DCOS(AT)
      CS2=CS1*CS1
      SS2=1.-CS2
      SS1=DSQRT(SS2)
      GX=P2*SS2
      HX=GX*GX
      OX=HX*GX
      PX=OX*GX
      QX=PX*GX
      BN1=1.+.5*GX+.375*HX+.3125*OX+.2734375*PX+.24609375*QX
      BN2=BN1*BN1
```

```
      RHO=C5*BN2*BN1
      DO=CS1*SS1
      PK=DO*SS2*.6666666667
      QK=DO+PK
      SU=AT+C1*(AT-DO)+C2*(AT-QK)
      IF(AT-.175) 2,2,1
    1 PK=PK*SS2*.8
      QK=QK+PK
      SU=SU+C3*(AT-QK)
      IF(AT-.525) 2,2,3
    3 SU=SU+C4*(AT-QK-PK*SS2*.8571428571)
    2 DI=C5*SU
      XX=Y-DI
      DELA=XX/RHO
      DELB=DELA*DELA
      DELC=DELB*DELA
      ZJK=1.E-4
      ZX=DABS(XX)-ZJK
      GB2=-3.*P2*SS1*CS1*BN2
      GB3=.75*GB2*GB2-3.*P2*(CS2-SS2)*BN2
      AT=AT+DELA+GB2*DELB*.5+GB3*DELC*.1666666667
      IF(ZX)26,25,25
   26 CONTINUE
      CS1=DCOS(AT)
      CS2=CS1*CS1
      SS2=1.-CS2
      SS1=DSQRT(SS2)
      GX=P2*SS2
      HX=GX*GX
      OX=HX*GX
      PX=OX*GX
      QX=PX*GX
      BN1=1.+.5*GX+.375*HX+.3125*OX+.2734375*PX+.24609375*QX
      T1=SS1/CS1
      T2=T1*T1
      T4=T2*T2
      T6=T4*T2
      AN2=DELT*CS2
      AN4=AN2*AN2
      AN6=AN4*AN2
      AN8=AN4*AN4
      Q1=X/(A1*BN1)
      Q2=Q1*Q1
      Q4=Q2*Q2
      Q6=Q4*Q2
      H1=Q1/CS1
      H2=Q2*(1.+2.*T2+AN2)*.1666666667
      H3=Q4*(5.+6.*AN2+28.*T2-3.*AN4+8.*T2*AN2+24.*T4-4.*AN6+4.*T2*AN4+
     124.*T2*AN6)*0.8333333333D-2
      H9=Q6*(61.+662.*T2+1320.*T4+720.*T6)/5040.
      DO=H1*(1.-H2+H3-H9)
      H4=T1*Q2*(1.+AN2)*.5
      H5=Q2*(5.+3.*T2+AN2-4.*AN4-9.*AN2*T2)*0.8333333333D-1
      H6=Q4*(61.+90.*T2+46.*AN2+45.*T4-252.*T2*AN2-3.*AN4+100.
     1*AN6-66.*T2*AN4-90.*T4*AN2+88.*AN8+225.*T4*AN4+84.*T2*AN6-192.*T
     12*AN8)*0.2777777778D-2
      H7=Q6*(1385.+3633.*T2+4095.*T4+1575.*T6)*0.49603174603D-4
      DA=AT+H4*(-1.+H5-H6+H7)
      IF(YY) 10,20,20
   10 DA= -DA
```

```
   20 RETURN
      END
C***********************************************************************
      SUBROUTINE DISTAN(X1,Y1,X2,Y2,DIST)
C     SBRTN COMPUTES DISTANCE BETWEEN TWO POINTS ON THE EARTH.
C     SUPPLY LAT/LONG OF POINTS(X/Y) IN DEGREES ONLY(E.G. 69.52).
C     SBRTN USES TRIG EQN OF P.62 'BASIC MATHS FOR ENGNRS' BY F.M. WOOD
C                                QUEEN'S UNIVERSITY SEPT. 1954.
C     1 NAUTICAL MILE = 6076.1 FEET = 1.151 STATUTE MILES = 1.852 KM.
C     F=DEGREES-RADIANS CONVERSION FACTOR. G=RADIANS-DEGREES CONVERSION FACTOR.
      IMPLICIT REAL*8(A-H,O-Z)
      F=3.14159/180.
      G=10800./3.14159
      ARCRAD=(DARCOS((DCOS((90.-X1)*F))*(DCOS((90.-X2)*F))+(DSIN((90.-X1
     +)*F))*(DSIN((90.-X2)*F))*(DCOS((Y1-Y2)*F))))
      DIST=ARCRAD*G
      RETURN
      END
C***********************************************************************
      SUBROUTINE MINTY(DAY,TIME,MINUET)
C**THIS SBRTN CONVERTS SEQUENTIAL DAY AND GMT-TIME IN HOURS(E.G. 1859 HRS),
C INTO 'MINUTES-OF-THE-YEAR'(MINUET) - E.G. 12345TH GMT MINUTE OF THE YEAR.
C**USE INTEGER ROUND-OFFS TO EXTRACT HRS & MINUTES SEPARATELY FROM 'TIME'.
      IMPLICIT INTEGER*4(A-Z)
C  EACH DAY CONTRIBUTES 24 HRS WHICH IS 1440 MINUTES.
   10 DMIN=DAY*1440
C  CHECK IF TIME=0000(MIDNITE).
      IF(TIME.NE.0000) GO TO 30
      HMIN=0
      MMIN=0
      GO TO 40
C  EXTRACT HOURS FROM 'TIME' - EACH HOUR CONTRIBUTES 60 MINUTES.
   30 HRS=TIME/100
      HMIN=HRS*60
C  EXTRACT MINUTES FROM 'TIME'. MINUTES=(TIME-IHRS). SUM CONTRIBUTIONS.
      IHRS=HRS*100
      MMIN=(TIME-IHRS)
   40 MINUET=DMIN+HMIN+MMIN
C     PRINT 50, DAY, TIME, MINUET
C  50 FORMAT(1X, 'DAY/TIME OF',I5,'/',I5,' CONVERTED TO MINUET OF', I7)
      RETURN
      END
C***********************************************************************
      SUBROUTINE UNMINT(OMIN,IYAD,EMIT)
      IMPLICIT REAL*8(A-H,O-Z)
      IF(OMIN.NE.0) GO TO 10
      IYAD=0
      EMIT=0.
      GO TO 20
   10 IYAD=IDINT(OMIN/1440.)
      DMINS=OMIN-((DFLOAT(IYAD))*1440.)
      HOUR=IDINT(DMINS/60.)
      RMINS=DMINS-(HOUR*60.)
      EMIT=HOUR*100.+RMINS
C     PRINT 3, OMIN, IYAD, EMIT
C   3 FORMAT(1X,'MINUET OF',F9.2,' CONVERTED TO DAY/TIME OF', I7, '/',F7
C    +.2)
   20 RETURN
      END
```

```
$CCPY *SCLRCE*@¬CC *SINK*
C          *****   PRCGRAM 'MAGNAVN'    *****
C
C          PRCGRAM REACS IN NAVIGATICN DATA(FROM AN I/P DEVICE) & ATTEMPTS TC
C        MATCH MAGNETIC CATA(READ IN FRCM ANCTHER I/F CEVICE) TC IT.  THE MATCHED
C        DATA ARE THEN O/P TO A THIRD DEVICE.  'MAG/NAV' ARE MATCHED - 'MAGNAVM'
C
C..NAV DATA - CHRCNC PARAMETER + X/Y CC-ORD PARAMETERS  ) MATCH THEREFORE BASED
C  MAG DATA - CHRCNC PARAMETER + MAG READING            ) ON CHRONO PARAMETER
C  3 WAYS(EACH) OF NAV & MAG CATA I/P.  SEE OPTION LIST.
C..NAV FARAMETERS FRECEDEC BY A 'N' OR 'V' WHERE POSSIBLE E.G. VMIN, NDAY.
C  MAG FARAMETERS FRECEDEC BY A 'M' CR 'G' WHERE POSSIBLE E.G. MMIN, GDAY.
C *****    OPTICN LIST
C      WITH APPROPRIATE FORMAT STMTS, THE FOLLOWING MAY BE CHOSEN:
C       1) NAVIP=1 IF NAV CATA I/P IS MINUET+X-Y CO-CRDS(LAT-LCN)+UTM N-E.
C       2)       =2                   CAY+TIME+X-Y CC-ORDS
C       3)       =3                   DAY+TIME+MINUET+X-Y CC-CRCS.
C       A) MAGIP=1 IF MAG CATA I/P IS MINUET+MAG READING.
C       B)       =2                   CAY+TIME+MAG.
C       C)       =3                   CAY+TIME+MINUET+MAG.
C ....SET UP NAVIP & MAGIP VALUES IN STMT 3.
C      (MINUET=SEQUENTIAL MINUTES CF THE YEAR FRCM CCCC HRS JAN. 1ST EACH YEAR).
C ....SET UP NAVIGATION 'FIX TIME INTERVAL', FTINT, IN STMT 3.
C ****     LOGICAL I/O UNITS TO BE ASSIGNED:
C      UNIT 6 = LINE PRINTER (PROCESSING MSGS & ERROR MSGS) - CEFAULTS.
C           5 = CARC READER(*SCLRCE*) - CEFAULTS.
C           4 = NAVIGATION DATA - NO DEFAULT.
C           3 = MAG        DATA - NO DEFAULT.
C           2 = C/P NAV+MAG MATCHEC CATA - NC CEFAULT.
C           8 = ERRCR MSGS - *SINK* IF MSGS WANTEC, *DUMMY* CTHERWISE.
C ****     SUBROUTINES REQUIREC:
C       A) UNMINT - CONVERTS MINUET TC DAY+TIME - MANCATCRY.
C       B) TMINT  - CCNVERTS DAY+TIME TO MINUET - CNLY IF NAVIP=2 CR MAGIP=2.
C       C)  IGRF  - COMPUTES REGIONAL MAG FIELD FOR GIVEN LAT-LCN - MANDATORY.
      IMPLICIT REAL*8(A-H,O-Z)
      INTEGER*4 CF
      DIMENSION VTIME(1000),VMIN(1CCC),NCAY(10CC),XN(1C00),YN(1CCO),MDAY
     +(1000),MTIME(1C00),MINUEM(1CCO),GTIME(1CCC),GMIN(1000),MAG(1000),
     +GDAY(1000),ZT(1C00),ZX(1C00),ZY(1CCO),ZM(1000),VDAY(1000),GMAG(100
     +C),GEOGX(1CCC),GEOGY(1CCC),ZLAT(1CCO),ZLCN(1C0C),IZDAY(1CCO),ZTIME
     +(1000),ZIGRF(1000),ZANOM(1CCC)
C ****    SET UP CCNSTANTS & CFTICNS.
C      LNCNT:COUNT WHICH CCNTRCLS RESET OF MAG CATA CCUNT AS EACH BLK READ IN.
C      MTCH=1 SKIPS MAG-BLOCK CHECKING RCUTINE - FIRST MATCH MACE.
    3 MAGIP=2
      NAVIP=3
      FTINT=2.C
      LNCNT=1
      MTCH=0
C ****    SET UP NAV CATA FCRMAT & READ IN NAV CATA.
C      FOR BEAUMAC CATA, NAV FORMAT IS LINE# + NC.CF FIXES AS FER FORMAT 5.
C      FCLLOWEC BY FIXES+TIME AS PER FORMAT 6.
    5 FORMAT(I6,1X,I6)
    6 FORMAT(I5,1X,F7.2,1X,F1C.2,1X,F15.3,1X,F15.3,1X,F15.8,1X,F15.8)
C ****  SET UP COUNTS ETC..
C      NECF=CCLNT CF NO. OF SUCCESSIVE ENDFILES READ FCR NAV CATA.
```

```
C     MEOF=CCUNT OF NO. OF SUCCESSIVE ENDFILES READ FOR MAG DATA.
C      OP=O/P DATA POINT CCUNT.
C ****START PRCCESSING LINE    ****
  1C NECF=C
C      MEOF=0 SET UP IN STMT 7C
     CP=1
     JV=1
  13 GO TO (2C,3C,4C), NAVIP
     WRITE(6, 15)
  15 FORMAT(//1X,'I/P DATA FORMAT UNRECCGNISEC. EXECUTICN TERMINATED')
     STOP 9
C ....START READING IN NAV DATA.
  20 READ(4,5,END=50) LINE, NFIX
     READ(4,6,END=6C) (VMIN(K),XN(K),YN(K), K=1,NFIX)
     GC TO 7C
  30 READ(4,5,END=50) LINE, NFIX
     READ(4,6,END=6C) (NDAY(J),VTIME(J),XN(J),YN(J), J=1,NFIX)
     DO 35 L=1,NFIX
     VDAY(L)=DFLOAT(NDAY(L))
  35 CALL TMINT(VDAY(L),VTIME(L),VMIN(L))
     GC TO 70
  4C READ(4,5,END=5C) LINE, NFIX
     READ(4,6,END=60) (NDAY(M),VTIME(M),VMIN(M),XN(M),YN(M),GEOGX(M),GE
    +OGY(M), M=1,NFIX)
     GO TO 7C
C ****   ENDFILE ENCOUNTERED. IF CNE ONLY, KEEP GCING.  IF TWC, QUIT.
  50 NECF=NEOF+1
     IF(NEOF.GT.1) GC TC 55
     GO TO 13
C ****  END OF DATA SINCE TWO SUCCESSIVE ENDFILES FOUND.
  55 WRITE(6,57) LINE
  57 FORMAT(//1X,'LAST LINE PRCCESSED - LINE',I6/1X,'TWC SUCCESSIVE END
    +FILES READ ON UNIT 4 - END OF NAVIGATICN DATA ASSUMED')
     STOP 0
C ****   ENDFILE ON READING NAV DATA.  SOMETHING WRCNG - GO TC NEXT LINE.
  60 WRITE(6,62) LINE
  62 FORMAT(/1X,'UNEXPECTED ENDFILE IN NAV DATA - APPROX. LINE #',I6/1X
    +, 'DATA IGNCRED - GOING CN TC NEXT LINE'/)
C ****  NAV DATA READ IN O.K. - NOW SET UP MAG DATA FORMATS,THEN READ 1 DATA BLK
C       BEAUMAC DATA = MAGIP=2, BLOCK=270(3I5) WHERE 3I5=IDAY,ITIME,MAG.
  7C MECF=0
     NEOF=C
     IMAG=270
C ****  SIGNAL THAT NAV DATA READ IN O.K.
     WRITE(6,73) LINE
  73 FORMAT(1X,'NAV DATA FOR LINE NO.',I6,' READ IN C.K.')
C ....IF LINE BEING PROCESSED IS AFTER FIRST(LINE), DON'T READ ANY MAGS BUT
C      JUST CONTINUE MATCHING.
C ....ANY TIME MAG DATA IS READ, KG MUST BE RESET =1.
  77 IF(LNCNT.GT.1) GO TO 184
  78 KG=1
     GC TO (80,85,9C), MAGIP
   7 FORMAT(90(9I5))
     WRITE(6,15)
     STOP 7
  8C READ(3,7,END=95) (GMIN(I),MAG(I), I=1,IMAG)
     GO TO 10C
  85 READ(3,7,END=95) (MDAY(I),MTIME(I),MAG(I),MDAY(I+1),MTIME(I+1),MAG
    +(I+1),MDAY(I+2),MTIME(I+2),MAG(I+2), I=1,268,3)
     DO 87 M=1,IMAG
```

```
      GDAY(M)=DFLOAT(MDAY(M))
      GTIME(M)=DFLOAT(MTIME(M))
   87 CALL TMINT(GDAY(M),GTIME(M),GMIN(M))
      GO TO 100
   90 READ(3,7,END=95) (MDAY(I),MTIME(I),GMIN(I),MAG(I), I=1,IMAG)
      GO TO 100
C ****  ENDFILE ENCOUNTERED. QUIT ONLY IF 2 SUCCESSIVE EOFS READ.
   95 MEOF=MEOF+1
      IF(MEOF.GT.1) GO TO 97
      GO TO 78
C ****   END OF DATA. NO MORE MAG DATA TO MATCH NAV DATA.
   97 WRITE(6,98) GMIN(1)
   98 FORMAT(//1X,'MAG DATA BLOCK STARTING AT MINUET OF',F10.2,' LAST TO
     + BE READ'/1X,'TWO SUCCESSIVE ENDFILES READ ON UNIT 3 - ASSUMED NO
     +MORE MAG DATA'/)
      STOP 1
C ****  BOTH MAG & NAV DATA READ IN O.K. CHECK MAG DATA FOR ODD VALUES.
C       SUCH AS DAY OR TIME = 9999, OR MAG = 0 IN BEAUMAC DATA.
C       SKIP DAY/TIME CHECK IF MAGIP=1.
  100 MEOF=0
      IF(MAGIP.EQ.1) GO TO 115
      DO 110 N=1,IMAG
      IF(MDAY(N).EQ.9999) GO TO 106
      IF(MTIME(N).EQ.9999) GO TO 106
C ....SPECIAL IF STMTS FOR BEAUMAC DATA - DAYS 155 & 955 INVALID.
      IF(MDAY(N).EQ.155) GO TO 106
      IF(MDAY(N).GT.365) GO TO 106
      GO TO 110
  106 GMIN(N)=99999.9
      WRITE(6,108) LINE, MDAY(N), MTIME(N)
  108 FORMAT(1X,'FOR LINE',I6,' - GMIN SET TO 99999.9 FOR DAY/TIME OF',
     +2I6)
  110 CONTINUE
  115 DO 120 N=1,IMAG
      GMAG(N)=DFLOAT(MAG(N))
      IF(GMAG(N).NE.0.) GO TO 120
      GMAG(N)=-9999.9
      WRITE(6,117) LINE, MDAY(N), MTIME(N)
  117 FORMAT(1X,'    *******  FOR LINE #',I6,'  AT DAY/TIME=',2I5,' - MAG
     +=0 SO SET TO -9999.9 FOR PLOTTING *****')
  120 CONTINUE
C ****  MAG DATA READY FOR MATCHING TO NAV DATA ON BASIS OF SEQUENTIAL MINUTE
C       PARAMETERS 'GMIN' & 'VMIN' RESPECTIVELY.
C        CHECK IF MAG BLOCK IN HAND IS TOO FAR ALONG IN TIME FOR MATCH.
C       IF SO, BACKSPACE ONE FILE OF MAG DATA.
C      IF FIRST MATCH MADE ALREADY, SKIP TO STMT 230.
  130 IF(MTCH.EQ.1) GO TO 230
      IF(GMIN(1).NE.99999.9) GO TO 132
C ....GMIN(1) NOT USEABLE FOR TEST - USE NEXT GMIN INSTEAD.
      IF(VMIN(1).GE.GMIN(2)) GO TO 180
      GO TO 134
  132 IF(VMIN(1).GE.GMIN(1)) GO TO 180
C ....BACKSPACE REQUIRED. SKIP OVER FILEMARK BY READING, USING END= EXIT.
  134 BACKSPACE 3
      WRITE(6,135) LINE, GMIN(1), VMIN(1)
  135 FORMAT(/1X,'    BACKSPACE UNIT 3 CALLED    - GMIN MUST BE .GT. VMIN'
     +, F13.3,'.GT.',F13.3,' ?'/)
      READ(3,140,END=145) EOF
  140 FORMAT(F6.3)
C ....EOF NOT ENCOUNTERED - SOMETHING WRONG. SKIP TO NEXT LINE.
```

```
      WRITE(6,143) LINE
  143 FORMAT(/1X,'    ENDFILE NCT FCUNC CN READ/BACKSPACE    LINE #',I6,'
     +NOT PROCESSED'/)
      GC TC 10
C ....BACKSPACE/SKIP - EOF C.K.  RECHECK MAG BLCCK IF O.K.
  145 WRITE(6,147) LINE
  147 FORMAT(1X,'    LINE #',I6,'  BACKSPACE/SKIP-EOF O.K.')
      GO TO 130
C ****   MAG BLOCK IN HAND IS C.K.     ** MATCH BEGINS **
C        SCAN MAGS TILL GMIN MATCHES VMIN. IF NOT FOUND, CHECK
C       DURING EACH SCAN : IF GMIN IS MISSING, GMIN IN HAND WILL BE .GT.VMIN.
C        ROUND TWC - FIRST MATCH MACE - REST SHCULC BE EASY TO MATCH.
C ....MAKE SURE WE'RE NOT OUT OF DATA. BOMB OUT IF NAV, GET NEXT BLOCK IF MAG.
  18C IF(JV.GT.NFIX) GO TO 187
      IF(KG.GT.IMAG) GO TC 78
  184 IF(VMIN(JV).EQ.GMIN(KG)) GO TO 2C0
C ....NC MATCH.  CHECK IF SCANNEC PAST MISSING GMIN. IF NOT, GET NEXT GMIN.
      IF(GMIN(KG).EQ.999999.9) GC TC 195
      IF(GMIN(KG).GT.VMIN(JV)) GC TC 19C
C ....NOT SCANNEC PAST - WANTED GMIN STILL AHEAC - SCAN FOR IT.
      KG=KG+1
      GO TO 18C
  187 WRITE(6,188)
  188 FCRMAT(//1X,'    OUT OF NAV CATA BEFORE FIRST MATCH - SOMETHING WRO
     +NG    '//)
C       GET NEXT NAV LINE CATA.
      LNCNT=LNCNT+1
      GC TC 10
C ....SCANNED PAST - WANTED GMIN MISSING. GET NEXT VMIN & RETRY MATCH.
  19C WRITE(8,193) JV,KG,VMIN(JV),GMIN(KG)
  193 FCRMAT(1X,'AT 190 - SCANNEC PAST COS GMIN MISSING. JV/KG ARE',2I7,
     +' VMIN(JV)/GMIN(KG) ARE',2F13.3)
      JV=JV+1
      GO TO 180
C ....GMIN NCT USEABLE - SKIP TC NEXT GMIN ANC RETRY MATCH.
  195 KG=KG+1
      GO TO 18C
C ****     MATCH RCUNC CNE WON.  FIRST MATCH FOUND. PRINT MSG.
C       PAD MAG WITH FIRST DIGIT '5' - COMPUTE REGICNAL(IGRF) & ANOMALY.
  2CC ZT(OP)=VMIN(JV)
      ZX(CP)=XN(JV)
      ZY(CP)=YN(JV)
      ZLAT(OP)=GECGX(JV)
      ZLCN(OP)=GEOGY(JV)
      CALL UNMINT(ZT(OP),IZCAY(OP),ZTIME(OP))
      ZM(CP)=GMAG(KG)+5CC0C.
      CALL IGRF(ZLAT(CP),ZLCN(CP),ZIGRF(OP))
      ZANOM(OP)=ZM(CP)-ZIGRF(OP)
      WRITE(8,207) LINE,VMIN(JV),GMIN(KG),ZX(OP),ZY(CP),ZM(OP)
  2C7 FORMAT(1X,'LINE #',I6,' FIRST MATCH FCUNC AT NAVTIME',F12.3,' - MA
     +GTIME',F12.3/1X,'CORRESP X-Y & MAG ARE',3F15.3)
C ....UP C/P CATA PCINT CCUNT.
      OP=OP+1
      WRITE(8,2C9) OP
  209 FCRMAT(1X,'AFTER 200, CP IS NOW',I7)
C ****NOW STARTS MATCH RCUND TWC.  REST CF CATA.
  220 JV=JV+1
      KG=KG+1
      IF(KG.LE.IMAG) GO TO 221
      MTCH=1
```

```
      GO TO 78
  221 CCNTINUE
      WRITE(8,223) JV,KG
  223 FORMAT(1X,'AFTER 2CC-22C, JV/KG ARE',2I7)
  230 IF(VMIN(JV).EG.GMIN(KG)) GO TC 300
C ...WANTED GMIN TC COME, MISSING CR 999999.9.  NCTE GMIN CAN BE .LT.VMIN
C     'CCS TIME INTERVALS IN MAG & NAV CATA MAY CIFFER.
C     IF GMIN.LT.VMIN, GET NEXT MAG WHICH MAY BE WANTED ONE.
      IF(GMIN(KG).GT.VMIN(JV)) GC TC 236
      KG=KG+1
      IF(KG.LE.IMAG) GO TO 230
      MTCH=1
      GC TC 78
C ...GMIN.GT.VMIN - IF GMIN=999999.9 GET NEXT MAG. IF NOT GET NEXT NAV 'COS
C     WANTEC GMIN MISSING.
  236 IF(GMIN(KG).EG.999999.9) GC TC 260
      WRITE(8,243) GMIN(JV),GDAY(JV),GTIME(JV)
  243 FORMAT(1X,'MAG MINUTE',F1C.3,' MISSING OR NO GOOD. DAY/TIME OF ',
     +2F10.3,'  **********')
      JV=JV+1
      IF(JV.LE.NFIX) GO TO 23C
      CP=CP+1
      GO TO 400
C ....GMIN=999999.9 - GET NEXT MAG.
  260 KG=KG+1
      IF(KG.LE.IMAG) GO TO 230
      MTCH=1
      GO TO 70
C ****  CNE MCRE MATCH MACE.   STORE IN O/P ARRAYS AND TRY NEXT MATCH.
C        AGAIN PAD MAG WITH FIRST CIGIT '5' - COMPUTE REGICNAL & ANOMALY.
C       DCN'T LOAD DATA INTC C/F ARRAY IF BAC MAGS(TIMES REJECTEC ALREACY)
  300 IF(GMAG(KG).NE.-9999.9) GO TC 304
      WRITE(6,302) VMIN(JV)
  3C2 FORMAT(1X,'*****    AT APPRCX MINUET CF',F10.2,' MAG VALUE WAS ZERO
     + - NO DATA O/P FOR THAT TIME    *****')
      IF(JV.LT.NFIX) GO TO 220
      OP=OP+1
      GO TO 400
  304 ZT(CP)=VMIN(JV)
      ZX(CP)=XN(JV)
      ZY(OP)=YN(JV)
      ZLAT(OP)=GECGX(JV)
      ZLCN(CP)=GECGY(JV)
      CALL UNMINT(ZT(CP),IZDAY(CP),ZTIME(CP))
      ZM(OP)=GMAG(KG)+5CCCC.
      CALL IGRF(ZLAT(OP),ZLON(OP),ZIGRF(OP))
      ZANCM(CP)=ZM(CP)-ZIGRF(CP)
      WRITE(8,3C9) VMIN(JV),GMIN(KG),ZM(CP),ZX(CP),ZY(OP),ZLAT(CP),ZLON(
     +OP)
  309 FCRMAT(1X,'MATCHEC VMIN/GMIN=',2F10.3,' MAG/X/Y=',3F15.3,2F15.8)
C *****   SPOT CHECK MSG.
      IF(MOD(OP,1C).EQ.0) WRITE(6,311) LINE,CP,VMIN(JV),XN(JV),YN(JV),GE
     +CGX(JV),GECGY(JV),GMIN(KG),MAG(KG),IZDAY(OP),ZTIME(OP),ZT(OP),ZX(O
     +P),ZY(OP),ZLAT(CP),ZLCN(CP),ZM(CP)
  311 FORMAT(1X,'SPCT CHECK - LINE #',I6,' - ',I3,'TH CATA POINT .....'/
     +1X,'I/P NAV -             MINUET=              ',F9.1,' - XN=',F10.1,'
     +YN=',F10.1,' GECGX=',F13.8,' GEOGY=',F13.8/1X,4X,'MAG -          M
     +INUET=               ',F9.1, 70X,' MAG=',I5/1X, 'C/P      - CAY/TIME/M
     +INUET=', I4,'/', F6.1,'/',F9.1, ' - XN=',F1C.1,' YN=',F1C.1,'    LAT
     +=',F13.8, '    LON=',F13.8,' MAG=',F7.1)
```

```
C ....CHECK IF END CF LINE REACHEC. IF YES, WRITE O/P ARRAY & GET NEXT LINE.
      IF(JV.EQ.NFIX) GO TO 4CC
C ....NCT END CF LINE. UP O/P CATA POINT COUNT & TRY NEXT MATCH.
      OP=CP+1
      GO TO 220
C ***   LINE MATCHED.  WRITE C/P ON UNIT 2 & PRINT MSG. GO ON TO NEXT LINE.
 4CO WRITE(2,409) LINE, CP
 4C9 FORMAT(1X,I6,1X,I6)
      WRITE(2,413) (IZDAY(J),ZTIME(J),ZT(J),ZX(J),ZY(J),ZLAT(J),ZLCN(J),
     +ZM(J),ZIGRF(J),ZANCM(J), J=1,CP)
 413 FORMAT(I4,1X,F6.1,1X,F11.2,1X,F12.3,1X,F12.3,1X,F13.8,1X,F13.8,1X,
     +F7.1,1X,F7.1,1X,F7.1)
C ....WRITE END-CF-FILE ON UNIT 2.
      ENDFILE 2
      WRITE(6,417) LINE, OP
 417 FORMAT(1X,'LINE', I6, ' MATCHED & O/P',I6,' FIXES : GOING CN TO NE
     +XT LINE'//)
C ....UP LNCNT SC KG ISN'T RESET=1 'CCS NEXT LINE MAG MAY BE IN BLCCK IN HANC.
      LNCNT=LNCNT+1
      GC TO 10
      END
C*****************************************************************************
      SUBROUTINE IGRF(DLAT,DLON,GIGRF)
C
C    PROGRAM CCMPUTES INTERNATICNAL GECMAGNETIC REFERENCE FIELC(THE THEORETICAL
C   REGIONAL MAGNETIC FIELD FCR THE EARTH) AT ANY LOCATICN.  CCMPUTATICNS
C   ARE DONE FROM PGRF COEFFICIENTS SET FOR AREAS DEFINED.
C    PGRF COEFFICIENTS FOR AREAS MUST BE SET IN PRCGRAM & IF MCRE THAN ONE SET
C   CF COEFFICIENTS ARE REGUIREC, ENSURE 'IF' STATEMENTS WILL INITIALISE THE
C   APPROPRIATE COEFFICIENTS ACCORDING TC CO-ORDS CF THE LOCATICN I/P.
C         I/P LCCATICN LATITUCE & LONGITUCE(CLAT & DLCN) IN DECIMAL CEGREES AND
C         C/P WILL BE THE IGRF VALUE(GIGRF).
C    COMPUTATIONS ACAPTED FROM BEDFCRD INSTITUTE PROGRAM F69RX4.
C    ****  SET I/C UNIT 5 = PGRF CCEFFICIENTS I/P DEVICE.
C                       8 = MESSAGES & CEBUG PRINTS.  FOCGUE GCH JAN 1972.
      IMPLICIT REAL*8(A-H,O-Z)
C ****SET LAT/LCN LIMITS OF AREA COVERED BY COEFFICIENTS.
C      BLATA=BIG(HI) LAT CF AREA A; SLATA=SMALL(LO) LAT OF AREA A;  ETC..
      BLATA=75.
      SLATA=69.
      BLCNA=137.
      SLCNA=125.
      BLATB=75.
      SLATB=69.
      BLCNB=149.
      SLCNB=137.
C  2C READ(5,23,END=99) DLAT,CLCN
C  23 FORMAT(F2C.1C,F20.1C)
      X=CLAT
      Y=DLON
C ****CHECK IF LON IS IN LON DEFINED BY AREA A CR AREA B.
      IF(Y.GT.BLCNA) GO TO 3C
      IF(Y.LT.SLCNA) GO TO 3C
C ....Y IS IN AREA A IN LCN VALUE - CHECK LAT VALUE.
      IF(X.GT.BLATA) GO TO 4C
      IF(X.LT.SLATA) GO TO 40
C ....LAT & LON C.K. - LOCATICN X/Y IS IN AREA A.
      GO TO 300
C ****NCT IN AREA A'S LON - CHECK IF IN AREA B'S LON - IF NOT, QUIT.
  3C IF(Y.GT.BLCNB) GC TC 999
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      IF(Y.LT.SLONB) GO TO 999
C ....LON IN AREA B - CHECK LAT - IF NOT, QUIT.
      IF(X.GT.BLATB) GO TO 999
      IF(X.LT.SLATB) GO TO 999
C ....LAT & LON O.K. - LOCATION X/Y IS IN AREA B.
      GO TO 400
C ****Y NOT IN AREA A LAT-WISE BUT IN LON-WISE ONLY. CHECK IF IN AREA B LAT-WIS
   40 IF(X.GT.BLATB) GO TO 999
      IF(X.LT.SLATB) GO TO 999
C ....IN AREA B LAT-WISE - CHECK LON-WISE.
      IF(Y.GT.BLONB) GO TO 999
      IF(Y.LT.SLONB) GO TO 999
C ....LAT & LON O.K. - LOCATION X/Y IS IN AREA B.
      GO TO 400
C ****INITIALISE AREA A'S PGRF COEFFICIENTS.
  300 A0=4.247960403E 04
      A1=-3.451645372E 03
      A2=2.574685812E 03
      A3=1.219954594E 01
      A4=4.242508330E 01
      A5=-2.556075603E 01
      A6=1.204279482E-01
      A7=-1.412472005E-01
      A8=-3.374476887E-01
      A9=1.047481346E-01
      B0=6.987690585E-04
      B1=1.268989639E-03
      B2=-1.621840510E-03
      B3=5.364373328E-04
      B4=-3.242870896E-04
      GO TO 500
C ****INITIALISE AREA B'S PGRF COEFFICIENTS.
  400 A0=2.020575714E 05
      A1=8.973467845E 02
      A2=-1.489228463E 03
      A3=2.048578270E 01
      A4=-8.203015717E 01
      A5=-7.301147450E 00
      A6=-2.832256954E-01
      A7=1.811406643E-01
      A8=1.116083454E 00
      A9=4.382587724E-02
      B0=5.566800097E-04
      B1=-5.341548291E-04
      B2=9.374785339E-06
      B3=-4.639294727E-03
      B4=-6.485305502E-05
      GO TO 500
  500 GIGRF=A0+A1*X+A2*Y+A3*X*Y+A4*(X**2)+A5*(Y**2)+A6*(X**2)*Y+A7*X*(Y*
     +*2)+A8*(X**3)+A9*(Y**3)+B0*(X**3)*Y+B1*X*(Y**3)+B2*(X**2)*(Y**2)+B
     +3*(X**4)+B4*(Y**4)
      WRITE(8,33) DLAT,DLON,GIGRF
   33 FORMAT(1X,'AT LAT/LON OF',F15.8,1X,F15.8,' IGRF COMPUTED =',F10.3)
      GO TO 97
C ****DLAT/DLON FOR LOCATION NOT IN AREAS FOR WHICH COEFFICIENTS SUPPLIED.
  999 GIGRF=-10E30
      WRITE(6,997) DLAT, DLON
  997 FORMAT(1X,'DLAT/DLON',F15.8,1X,F15.8,' NOT IN PGRF AREAS *******')
      GO TO 97
C  99 STOP
```

```
   97 RETURN
      END
C*****************************************************************************************
      SUBROUTINE TMINT(DAY,TIME,SMIN)
C  THIS SUBROUTINE CONVERTS SEQUENTIAL DAY+TIME INTO SEQUENTIAL MINUTES.
      IMPLICIT REAL*8(A-H,O-Z)
C   4 READ(5,6,END=99) DAY,TIME
C   6 FORMAT(F10.3,1X,F10.3)
C  EACH DAY CONTRIBUTES 1440. MINUTES.
   10 DMIN=DAY*1440.
C  CHECK IF TIME=0000.(MIDNITE) SO WE DON'T TRY TO DIVIDE BY 0.
      IF(TIME.NE.0.) GO TO 30
      HMIN=0.
      XMIN=0.
      GO TO 40
C  EXTRACT HRS FROM 'TIME' & CONVERTS HRS TO MINUTES.
   30 IHRS=IDINT(TIME/100.)
      HMIN=IHRS*60.
C  EXTRACT MINUTES FROM 'TIME'.
      JHRS=IHRS*100
      HRSJ=DFLOAT(JHRS)
      XMIN=TIME-HRSJ
   40 SMIN=DMIN+HMIN+XMIN
C       WRITE(8,50) DAY,TIME,SMIN
C  50 FORMAT(1X,'DAY/TIME OF',F10.3,1X,F10.3,' CONVERTED TO SMIN OF',F15
C     +.3)
C       GO TO 4
C  99 STOP
      RETURN
      END
C*****************************************************************************************
      SUBROUTINE UNMINT(OMIN,IYAD,EMIT)
      IMPLICIT REAL*8(A-H,O-Z)
      IF(OMIN.NE.0) GO TO 10
      IYAD=0
      EMIT=0.
      GO TO 20
   10 IYAD=IDINT(OMIN/1440.)
      DMINS=OMIN-((DFLOAT(IYAD))*1440.)
      HOUR=IDINT(DMINS/60.)
      RMINS=DMINS-(HOUR*60.)
      EMIT=HOUR*100.+RMINS
C       PRINT 3, OMIN, IYAD, EMIT
C    3 FORMAT(1X,'MINUET OF',F9.2,' CONVERTED TO DAY/TIME OF', I7, '/',F7
C     +.2)
   20 RETURN
      END


$COPY *SKIP *SINK*
```

```
$COPY *SOURCE*@¬CC *SINK*
C        *******   GRIDDER   *******
C   GRIDDER IS A PROGRAM WHICH IS USED IF SEVERAL Z-VALUES ARE TO BE GRIDDED AND
C  PLOTTED.  NORMALLY, EACH SET OF Z-VALUES HAS TO BE GRIDDED SEPARATELY BUT
C  THIS USES UP UNECESSARY CPU TIME SINCE THE GRIDDING FOR EACH SET OF Z-VALUES
C  IS THE SAME PROVIDED THE SAME X-Y CO-ORDS ARE USED EACH TIME.
C   SINCE THE GRIDDING IS THE SAME FOR EACH SET OF Z-VALUES, IF WE CAN RECORD
C  THE GRIDDING INSTRUCTIONS FOR A SINGLE GRIDDING RUN, WE CAN THEN USE THESE TO
C  LOAD(WEIGHTING CORRECTLY ETC..) ANY NUMBER OF SETS OF Z-VALUES.  THIS IS WHAT
C  GRIDDER DOES - IT 'REMEMBERS' THE GRIDDING INSTRUCTIONS.
C   THE GRIDDING PROGS ARE COURTESY OF MIKE PATTERSON, DEPT OF GEOGRAPHY, UBC.
C
C   IN CALL MXGEN(XP,IX,YP,IY,DATA,N) : N=+7000 IF MXGEN-OUTPUT TO SEQ. FILE
C                                        =-7000                   MAG TAPE.
C   FOR TAPE, PRECEDE THIS PROG EXEC BY MOUNTING TAPE & LABELLING IT WITH A
C  DATA-SET NAME VIA THESE COMMANDS : $COPY *SOURCE* TO *TAPE*@CC
C                                     DSN MXGEN-OUTPUT
C                                     $ENDFILE     ... THESE COMMANDS ON CARDS.
C   CONCANTENATE SBRTN MXGEN/MXPAND TO BE SURE...
C   SET LOGICAL UNITS  4 = I/P FORMAT OF DATA TO BE GRIDDED.
C                          & X-Y CO-ORDS OF GRID ORIGIN(2F20.5)
C                          & MAX X-Y CO-ORDS OF GRID(2F20.5)
C                          & +1 OR -1 FOR ISIGN - SIGN OF N(I2)
C                      3 = X-Y CO-ORDS OF POINTS TO BE GRIDDED.
C                      1 = GRIDDER O/P - THESE ARE THE GRIDDING INSTRUCTIONS.
C   TO CHANGE GRID SIZE, CHANGE DIMENSIONS OF XP & YP AND IX @ APPROX STMS 30+
C     ***  WARNING : DO NOT USE DOUBLE PRECISION NUMBERS  ***
      DIMENSION FMTI(20), XP(50), YP(50), DATA(3,7000), ATAD(3,7000)
      NPTS=1
C ....READ IN I/P FORMAT
      READ(4,10) FMTI
   10 FORMAT(20A4)
C ....READ IN X-Y CO-ORDS TO BE GRIDDED.
   20 READ(3,FMTI,END=99) (DATA(I,NPTS), I=1,3)
      NPTS=NPTS+1
      GO TO 20
C ....END OF FILE READ - ASSUMED NO MORE DATA TO BE GRIDDED.
   99 NPTS=NPTS-1
      IF(NPTS.LE.0) GO TO 900
      WRITE(6,30) NPTS
   30 FORMAT(1X,'LAST DATA POINT READ IN WAS NO',I6,' AND WAS ...')
      WRITE(6,FMTI) (DATA(I,NPTS), I=1,3)
C ....SET IX-IY GRID SIZE.
      IX=50
      IY=IX
C ....NOW READ IN X- & Y-COORDS OF GRID ORIGIN - TO BE PLOT ORIGIN ALSO.
      READ(4,40) XMINT, YMINT
      READ(4,40) XMAXT, YMAXT
   40 FORMAT(2F20.5)
      WRITE(6,41) XMINT, YMINT
   41 FORMAT(1X, 'I/P GRID ORIGIN CO-ORDS IN X-Y ..', 2F15.3)
      WRITE(6,14) XMAXT, YMAXT
   14 FORMAT(1X,'I/P MAX CO-ORDS OF GRID IN X-Y ..',2F15.3)
C ....READ IN SIGN TO KNOW IF MXGEN O/P IS FILE(+VE) OR TAPE(-VE).
      READ(4,42,END=43) ISIGN
   42 FORMAT(I2)
```

```
      WRITE(6,46)
   46 FORMAT(1X,'SIGN SPECIFIED : +1=FILE; -1=TAPE O/P FOR MXGEN')
      GO TO 50
C ....NO SIGN SPECIFIED - ASSUMED FILE O/P - ISIGN=+1.
   43 WRITE(6,44)
   44 FORMAT(1X, 'NO SIGN SPECIFIED - ASSUMED MXGEN O/P TO GO ON FILE')
      ISIGN=1
C ....NOW REFERENCE ALL DATA X-Y COORDS TO ORIGIN SPECIFIED.
   50 DO 52 I=1,NPTS
      ATAD(1,I)=(DATA(1,I)-XMINT)
   52 ATAD(2,I)=(DATA(2,I)-YMINT)
      WRITE(6,51) ATAD(1,NPTS), ATAD(2,NPTS)
   51 FORMAT(1X,'REORIGINED LAST DATA POINT : X =',F15.3,' Y =',F15.3)
C ....SET UP GRID CROSSING COORDS XP( ) & YP( ).
C      REMEMBER ORIGIN IS (XMINT, YMINT)....
      XP(1)=0.
      YP(1)=0.
C ....SET UP GRID INCREMENTS.
      DXP=(XMAXT-XMINT)/(IX-1)
      DYP=DXP
      DO 53 K=2,IX
      XP(K)=XP(K-1)+DXP
   53 YP(K)=YP(K-1)+DYP
      WRITE(6,54) XP(1), YP(1), DXP
   54 FORMAT(1X,'GRID IS TO BE ORIGINED AT X=',F15.3,' Y=',F15.3,' WITH
     +GRID INTERVAL=',F10.3,' AXES UNITS')
      WRITE(6,62) XP(IX), YP(IY)
   62 FORMAT(1X,'GRID STRETCHES TO X =',F15.3,' Y =',F15.3)
C ....SET UP NO OF POINTS 'N' - +VE IF FILE, -VE IF TAPE O/P FOR MXGEN.
      N=NPTS*ISIGN
C ....CALL GRID GENERATOR - NPTS +VE IF FILE, -VE IF TAPE FOR MXGEN O/P.
      CALL MXGEN(XP,IX,YP,IY,ATAD,N)
      WRITE(6,55)
   55 FORMAT(1X,'MXGEN CALLED & ALL POINTS GRIDDED')
      STOP 1
C ....NO DATA TO BE GRIDDED SINCE ENDFILE READ ON FIRST ROUND.
  900 WRITE(6,909)
  909 FORMAT(/1X,'NO DATA TO BE GRIDDED??  UNIT 3 EMPTY??')
      STOP 9
      END
C***************************************************************************
C               MXGEN LISTING AVAILABLE ONLY FROM
C           MIKE PATTERSON  DEPT OF GEOGRAPHY  UBC


$COPY *SKIP *SINK*
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```
$COPY *SOURCE*@¬CC *SINK*@¬CC
C           *****   PLOTTER    *****
C
C     IN PLOTTING DATA FROM SCATTERED POINTS, THESE MUST FIRST BE 'EXPANDED' TO
C  A SQUARE GRID.  MXGEN, A GRID GENERATOR PROG, KEEPS THE EXPANSION
C  INSTRUCTIONS & FOR THE SAME DATA POINTS, ONLY THE Z-COORD TO BE PLOTTED
C  NEEDS TO BE I/P SINCE THE X&Y CO-ORDS ARE ALREADY KNOWN(BY MXGEN).
C   WITH THE MXGEN GRID EXPANSION INSTRUCTIONS ACCESSIBLE VIA UNIT 1, THE
C  Z-COORDS I/P ARE WEIGHTED ETC.. BY MXPAND.
C  AFTER THE Z-COORDS ARE GRIDDED, SBRTN 'PLOT2D' IS CALLED TO PLOT THE DATA.
C   THIS PROG WRITTEN INITIALLY FOR MAX OF 7000 DATA POINTS TO BE ON
C  A 50 X 50 GRID.
C     SET THE I/O UNITS   1 = MXGEN O/P(GRID GENERATING/WEIGHTING INSTRUCTIONS
C                                      OBTAINED FROM MXGEN RUN)
C                         2 = Z-COORDS TO BE GRIDDED/PLOTTED.
C                         4 = Z-COORD FORMAT FOLLOWED BY ...
C                             PLOT-SIZE ALONG Y-AXIS,
C                             NO. OF CONTOURS TO BE PLOTTED IN RANGE OF Z,
C                             X-COORD/Y-COORD OF PLOT ORIGIN,
C                             INCREMENTS/PLOT INCH ALONG X- & Y-AXES RESP.
C                         7 = GRIDDED DATA : O/P IN BINARY.
C                         9 = PLOT COMMANDS O/P.
C       ***  RUN THIS PROG WITH MXPAND AND PLOT2D ETC.. CONCANTENATED.
C     MXPAND/MXGEN ARE COURTESY OF MIKE PATTERSON, GEOGRAPHY, UBC
C     PLOT2D AND SCAL2D COURTESY OF TAD ULRYCH, GEOPHYSICS, UBC.
C     THIS JIG-SAW PIECEWORK PUT TOGETHER 10 FEB 1972  ROCQUE GOH GEOPHYSICS UBC
C
      COMMON/DEBUG/FLAG
      LOGICAL FLAG
      FLAG=.TRUE.
      DIMENSION FMT(20), XP(50), YP(50), GRID(50,50), DATA(7000)
C ****READ IN Z-COORD FORMAT FROM UNIT 4
      READ(4,10) FMT
   10 FORMAT(20A4)
      WRITE(6,12) FMT
   12 FORMAT(1X, 'Z-COORD FORMAT IS..', 20A4)
C ****READ IN PLOT PARAMETERS - INITIALISE PLOT SUBROUTINES.
      CALL PLOTS
      READ(4,20) SZY
      READ(4,22) NCONT
      READ(4,24) XCOOR, YCOOR
      READ(4,24) DX, DY
      READ(4,22) IX
   20 FORMAT(F20.5)
   22 FORMAT(I2)
   24 FORMAT (2F20.5)
      WRITE(6,30) SZY,NCONT,XCOOR,YCOOR,DX,DY,IX,IX
   30 FORMAT(1X, 'PLOT PARAMETERS I/P ARE..'/1X, 'SIZE Y =', F10.3,3X,
     +'NO. OF CONTOURS IN RANGE =',I6/1X, 'X- & Y-COORDS OF PLOT ORIGIN
     +=', 2F13.3/1X, 'INCREMENTS ALONG X- & Y-AXES ARE', 2F10.3/1X, 'GRI
     +D IS TO BE', I6, ' X ', I6/)
C ****CALL YSIZE IF LARGE PLOT REQUESTED.
      IF(SZY.GT.10.5) CALL YSIZE(29.0)
      IY=IX
      IDIMX=IX
      IDM= IX
```

```
      JDM=IX
      LTH=1
C ****NOW READ IN Z-COORDS TO BE GRIDDED/PLOTTED.
      NPTS=1
   40 READ(2,FMT,END=50) (DATA(NPTS))
      NPTS=NPTS+1
      GO TO 40
C ****ENDFILE READ - ASSUMED NO MORE DATA POINTS.
   50 NPTS=NPTS-1
      WRITE(6,52) NPTS
   52 FORMAT(1X, 'NO. OF DATA POINTS READ IN =', I6,'.LAST DATA POINT:')
      WRITE(6,FMT) DATA(NPTS)
C ****GRID Z-COORDS USING GRIDDING INSTRUCTIONS FROM MXGEN.
      CALL MXPAND(GRID,50,IX,IY,DATA,NPTS)
      WRITE(6,60)
   60 FORMAT(1X,'POINTS GRIDDED - PLOTTING NEXT')
      WRITE(6,65) ((GRID(I,J), J=1,10), I=1,10)
   65 FORMAT(1X,'FIRST 10 X 10 OF ''GRID'' ARRAY IS ...'/(10G13.5))
C ....WRITE GRIDDED DATA OUT.
      WRITE(7) ((GRID(I,J), J=1,50), I=1,50)
      WRITE(6,75)
   75 FORMAT(' GRIDDED DATA O/P IN BINARY ON UNIT 7')
C ****CALL PLOT2D TO PLOT/CONTOUR DATA.
      CALL PLOT2D(GRID,IDM,JDM,IX,IY,SZY,NCONT,XCOOR,YCOOR,DX,DY,LTH)
C ****THAT'S ALL - TERMINATE PLOT SUBROUTINES
      CALL PLOTND
      WRITE(6,80)
   80 FORMAT(//1X, '    ***  LOOKS LIKE A GOOD PLOT  ***   ')
      STOP 1
      END
C*****************************************************************************
C              MXPAND LISTING AVAILABLE ONLY FROM
C           MIKE PATTERSON  DEPT OF GEOGRAPHY  UBC
C*****************************************************************************
      SUBROUTINE PLOT2D(G,IDM,JDM,IX,IY,SZY,NCONT,XCOOR,YCOOR,DX,DY,LTH)
C    PLOT2D PLOTS 2D DATA
C    G(IX,IY) IS THE DATA TO BE PLOTTED OF OUTSIDE DIMNS. (IDM,JDM)
C    SZY IS THE REQUIRED LENGTH IN THE Y DIRECTION IN ".
C    NCONT IS THE NUMBER OF CONTOURS REQUIRED IN THE RANGE
C    XCOOR AND YCOOR ARE THE COORDS OF THE ORIGIN
C    DX AND DY ARE THE INCREMENTS IN X AND Y
C    IF DX AND/OR DY ARE -VE THEY ARE COMPUTED BY PLOT2D
C    LTH CHOOSES EVERY LTH CONTOUR TO BE LABELED
C    *****************************************************************
      DIMENSION G(IDM,JDM),XP(300),YP(300)
C    DETERMINE THE SIZE IN THE X DIRECTION
      SZX=SZY*FLOAT(IX-1)/FLOAT(IY-1)
C    CENTER THE PLOT
      SUB=10.0
      IF(SZY.GT.10.1) SUB=29.0
      CY=(SUB-SZY)/2.0
      SZP=SZY+CY
C    SET UP THE ARRAYS TO SCALE
      DO 1 I=1,IX
1     XP(I)=FLOAT(I-1)*SZX/FLOAT(IX-1)
      DO 2 I=1,IY
2     YP(I)=FLOAT(I-1)*SZY/FLOAT(IY-1)+CY
      IF(DX.LT.0.0) DX=FLOAT(IX-1)/SZX
      IF(DY.LT.0.0) DY=FLOAT(IY-1)/SZY
C    PLOT THE AXES
```

```
      CALL AXIS(0.,CY,1H ,-1,SZX,0.,XCOOR,DX)
      CALL AXIS(0.,CY,1H ,+1,SZY,90.,YCOOR,DY)
      CALL PLOT(0.,SZP,+3)
      CALL PLOT(SZX,SZP,+2)
      CALL PLOT(SZX,CY,+2)
C   NOW SCALE THE MAP
      CALL SCAL2D(G,IDM,JDM,IX,IY,GMAX,GMIN,NCONT,CMAX,CMIN,CINT)
C   WRITE THE RELEVANT VALUES
      WRITE(6,111) GMIN,GMAX,CMIN,CMAX,CINT
111   FORMAT(//' MINIMUM VALUE ON MAP =',1PE15.5/' MAXIMUM VALUE ON MAP
     +=',1PE15.5/' MINIMUM CONTOUR VALUE =',1PE15.5/' MAXIMUM CONTOUR VA
     +LUE =',1PE15.5/' CONTOUR INTERVAL ='1PE15.5///)
C   PLOT THE CONTOURS
C   LABEL EVERY LTH CONTOUR ONLY
      IF(LTH.EQ.0) LTH=1
      SEP1=3.0
      IF(SZY.LT.6.1) SEP1=2.0
      IF(SZY.GT.10.5) SEP1=4.0
      LOOP=-1
      NUMC=(CMAX-CMIN)/CINT+1.1
      CN=CMIN
      DO 3 I=1,NUMC
      LOOP=LOOP+1
      SEP=0.
      IF(LOOP.EQ.1) SEP=SEP1
      CALL CNTOUR(XP,IX,YP,IY,G,IDM,CN,SEP,CN)
      CN=CN+CINT
      IF(LOOP.EQ.LTH) LOOP=0
3     CONTINUE
      SXS=SZX+5.0
      CALL PLOT(SXS,0.,-3)
      RETURN
      END
C   ****************************************************************
      SUBROUTINE SCAL2D(G,IDM,JDM,IX,IY,GMAX,GMIN,NCONT,CMAX,CMIN,CINT)
C   SCAL2D SCALES THE MAP FOR PLOTTING
C   G(IX,IY) IS THE DATA TO BE SCALED OF OUTSIDE DIMNS. (IDM,JDM)
C   GMAX AND GMIN ARE THE MAX AND MIN VALUES OF G
C   NCONT IS THE NUMBER OF CONTOURS
C   CMAX AND CMIN ARE THE MAX AND MIN CONTOUR VALUES
C   CINT IS THE CONTOUR INTERVAL
C   ****************************************************************
      DIMENSION G(IDM,JDM),A(5),B(5)
C   FIND MAX & MIN OF G
      GMAX=-10.0E6
      GMIN=10.0E6
      DO 10 I=1,IX
      DO 10 J=1,IY
      IF(ABS(G(I,J)).GT.10.0E20) GO TO 10
      IF(G(I,J).GT.GMAX) GMAX=G(I,J)
      IF(G(I,J).LT.GMIN) GMIN=G(I,J)
10    CONTINUE
C   RANGE IS DIVIDED INTO NCONT PARTS
      DG=(GMAX-GMIN)/FLOAT(NCONT)
C   FIND ORDER OF INTERVAL INT
      INT=ALOG10(DG)
C   INCASE INT IS -VE
      IF(DG.LT.1.0) INT=INT-1
      DGN=DG/10.0**INT
C   DGN NOW LIES BETWEEN 1.0 & 10.0
```

```
C    CHOOSE THE BEST CONTOUR VALUE
      DATA A(1),A(2),A(3),A(4),A(5)/1.0,2.0,2.5,5.0,10.0/
      TEMP=11.0
      DO 20 J=1,5
      B(J)=ABS(DGN-A(J))
      IF(B(J).LE.TEMP) IVALU=J
      IF(B(J).LE.TEMP) TEMP=B(J)
20    CONTINUE
      CINT=A(IVALU)*10.0**INT
C    0.0 MUST BE A CONTOUR
      ITEMP=GMIN/CINT
      CMIN=CINT*(ITEMP-1)
      ITEMP=GMAX/CINT
      CMAX=CINT*(ITEMP+1)
      RETURN
      END


$SIGNOFF
```

```
$CCPY *SOURCE*@¬CC *SINK*
C       ********     TRACKER     ********
C
C     PROG PLCTS SHIP'S TRACK - GIVEN SHIP'S CC-CRCS, EVERY NFLCT-TH POSITION
C   IS PLOTTEC ....  SET UP 'NPLOT' IN STMT #9 ....
C    THIS PROG WRITTEN INITIALLY FCR MAX OF 7000 CATA POINTS  ..
C                             2 = SHIP'S FCSITICNS TC BE PLCTTEC
C                             4 = Z-COORD FORMAT FOLLOWED BY ...
C                                 PLCT-SIZE ALCNG Y-AXIS,
C                                 NC. CF CCNTCURS TC BE PLOTTEC IN RANGE OF Z,
C                                 X-COORD/Y-COORD CF PLCT ORIGIN,
C                                 INCREMENTS/PLOT INCH ALCNG X- & Y-AXES RESP.
C                             9 = PLCT COMMANCS O/P.
C      WRITTEN TO PLCT CSS PARIZEAU 197C MAG CATA : 28 FEB 1972  ROCQUE GCH UBC
C
      COMMON/DEBUG/FLAG
      LCGICAL FLAG
      FLAG=.TRUE.
      DIMENSION FMT(2C), X(700C), Y(7CCC)
C ****EVERY NPLCT FCSITIONS ARE PLOTTEC ...
    9 NPLCT=5
C ****READ IN SHIP'S POSITIONS FCRMAT FROM UNIT 4
      READ(4,10) FMT
   1C FCRMAT(20A4)
      WRITE(6,12) FMT
   12 FORMAT(1X, 'SHIP''S POSITIONS CO-ORD FORMAT IS..', 20A4)
C ****READ IN PLCT PARAMETERS - INITIALISE PLCT SUBROUTINES.
C      NCONT NOT REQUIRED FCR THIS PROG - SC THIS IS JUST A DUMMY READ ..
      CALL PLOTS
      READ(4,20) SZY
      READ(4,22) NCCNT
      READ(4,24) XCCCR, YCCCR
      READ(4,24) CX, DY
      READ(4,22) IX
   2C FORMAT(F2C.5)
   22 FORMAT(I2)
   24 FCRMAT(2F2C.5)
      WRITE(6,3C) SZY,NCCNT,XCCCR,YCCCR,CX,CY,IX,IX
   30 FORMAT(1X, 'PLOT PARAMETERS I/P ARE..'/1X, 'SIZE Y =', F1C.3,3X,
     +'NC. CF CCNTOURS IN RANGE =',I6/1X, 'X- & Y-COCRDS OF PLCT CRIGIN
     +=', 2F13.3/1X, 'INCREMENTS ALCNG X- & Y-AXES ARE', 2F10.3/1X, 'GRI
     +D IS TO BE', I6, ' X ', I6/)
C ****CALL YSIZE IF LARGE PLOT REQUESTEC.
      IF(SZY.GT.1C.5) CALL YSIZE(29.0)
      IY=IX
      ICIMX=IX
      ICM=IX
      JDM=IX
      LTH=1
C ****NOW READ IN Z-COORDS TO BE GRIDDED/PLOTTED.
      NPTS=1
   4C READ(2,FMT,END=50) (X(NPTS), Y(NPTS))
      NPTS=NPTS+1
      GC TO 40
C ****ENDFILE READ - ASSUMED NC MCRE CATA PCINTS.
   5C NPTS=NPTS-1
```

```
      WRITE(6,52) NPTS
   52 FORMAT(1X, 'NC. CF DATA FCINTS REAC IN =',I6,'. LAST DATA PCINT:')
      WRITE(6,FMT) X(NPTS), Y(NPTS)
C ****NOW REFERENCE ALL SHIP CO-ORDS TC MAP CRIGIN & SCALE THEM TC PLOT-INCHES
      CC 69 I=1,NPTS
      X(I)=(X(I)-XCCCR)/DX
   69 Y(I)=(Y(I)-YCOCR)/DY
C ****NCW PLCT AXES ...
      CALL AXIS(0.,C.,1H ,-1,SZY,0.,XCCCR,DX)
      CALL AXIS(C.,C.,1H ,+1,SZY,9C.,YCCCR,CY)
C ****NOW PLOT EVERY NPLOT-TH POSITION - SHIFT TO FIRST POSITICN 'PEN UP' ..
      CALL PLCT(X(1),Y(1),+3)
      DO 75 K=1,NPTS,NPLOT
   75 CALL SYMBOL(X(K),Y(K),C.C35,3,9C.,-1)
C ****THAT'S ALL - TERMINATE PLOT SUBROUTINES
      CALL PLOTNC
      WRITE(6,8C)
   8C FORMAT(//1X, '    ***  LOOKS LIKE A GOOD PLCT  ***   ')
      STCP 1
      END


$CCPY *SKIP *SINK*
```

```
$COPY *SOURCE*@¬CC *SINK*
C          **********   STATION MAG PLOTTER   **********
C
C    PRCG PLCTS STATION MAG CATA - CATA FORMAT CCMPATIBLE WITH ATLANTIC
C    OCEANOGRAPHIC LABORATCRY STATICN MAC CATA  ......
C    GEEZCICIHATEWRITINGTHISONE   ... 3 MARCH 1972  ROCQUE GOH  GEOPHYSICS UBC
C    SET I/O UNITS    8 = MAG CATA TC BE PLOTTEC(STATION MAG)
C                     5 = CCNTRCL CCMMANCS - TIME-PERICDS TO BE PLOTTED
C                     9 = PLOT COMMANDS O/P
C    WRITTEN PRIMARILY TO PLOT ATKINSCN POINT STATION MAG - 197C
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*4 XPLOT(1CCO),YPLOT(1CCC)
      DIMENSICN MAG(1000),SMAG(1CCC),STIME(1CCC),SMIN(1CCO),
     +PX(1CCO),PY(1CCO)
      COMMON/DEBUG/FLAG
      LOGICAL FLAG
      FLAG=.TRUE.
C ****NMAG = NO CF STATION MAG READINGS PER HCUR IN CNE RECORC ...
      NMAG=12
C ****LPCINT = LCAC POINTER USEC FCR LCADING C/P ARRAYS  ....
   18 READ(5,2C,END=995) PSDAY,PSTIME,PEDAY,PETIME
      LPOINT=1
   20 FCRMAT(4F20.3)
      CALL TMINT(PSCAY,PSTIME,PSMIN)
      CALL TMINT(PEDAY,PETIME,PEMIN)
      WRITE(6,30) PSDAY,PSTIME,PEDAY,PETIME
   3C FCRMAT(' YCU HAVE ASKEC FCR THE FCLLOWING CATA TC BE PLCTTEC ...'/
     +' START : DAY',F6.1,' - TIME',F6.1,' / ENC : CAY',F6.1,' - TIME',
     +F6.1/' I''LL TRY TO FIND AND PLOT IT .....'/)
C ****READ IN MAG CATA & CHECK IF IT IS TO BE PLOTTED ....
   35 MEOF=0
   4C READ(8,45,END=9CO) MDAY,MHOUR,(MAG(I), I=1,NMAG)
   45 FCRMAT(2X,I3,1X,I2,12I6)
      DC 50 MM=1,NMAG
      SMAG(MM)=FLCAT(MAG(MM))
      SDAY=FLCAT(MDAY)
      SHCUR=FLCAT(MHCUR)
      STIME(MM)=(SHCUR*100.)+FLCAT((MM-1)*5)
      CALL TMINT(SDAY,STIME(MM),SMIN(MM))
   5C CCNTINUE
      DC 51 MM=1,NMAG
      IF(PSMIN.EQ.SMIN(MM)) GO TO 6C
      IF(PSMIN.LT.SMIN(MM)) GO TO 98C
   51 CCNTINUE
      WRITE(6,52) MDAY, MHCUR
   52 FORMAT(' SKIPPED RECORD FCR DAY/HOUR',2I6,'  .......')
      GC TC 35
C ****FCUND MAG DATA NEEDED - START LOADING INTC C/P ARRAYS ..
   6C WRITE(6,64) SMIN(MM)
   64 FCRMAT(' FCUNC CATA TO BE PLOTTED AT SEQUENTIAL MINUTE =',F15.2)
      WRITE(6,66) PSMIN, PEMIN
   66 FORMAT(' CCMPARES WITH START-MIN OF',F10.2,' & END-MIN CF',F10.2)
      DO 70 K=MM,NMAG
      PX(LPOINT)=SMIN(K)
      PY(LPOINT)=SMAG(K)
      IF(PEMIN.LE.SMIN(K)) GO TO 91
```

```
      LPOINT=LPOINT+1
   70 CONTINUE
C ****READ IN MAGS & KEEP LOADING TILL END OF PERIOD WANTED IS SENSED ....
C      NOTE LOAD POINTER IS READY FOR NEXT LOAD
   77 READ(8,45,END=900) MDAY,MHOUR,(MAG(I), I=1,NMAG)
      DO 80 J= 1,NMAG
      SMAG(J)=FLOAT(MAG(J))
      SDAY=FLOAT(MDAY)
      SHOUR=FLOAT(MHOUR)
      STIME(J)=(SHOUR*100.)+(FLOAT((J-1)*5))
      CALL TMINT(SDAY,STIME(J),SMIN(J))
      PX(LPOINT)=SMIN(J)
      PY(LPOINT)=SMAG(J)
      IF(PEMIN.LE.SMIN(J)) GO TO 91
      LPOINT=LPOINT+1
   80 CONTINUE
      GO TO 77
C ****ENUFF DATA LOADED  ....
   91 LPOINT=LPOINT-1
C ....CHECK FOR ZERO MAGS - IF ZERO, SET TO MAG VALUE CLOSEST TO IT ..
C      THIS ISN'T THE MOST SATISFACTORY OF SETTING ZERO READINGS, BUT ...
      DO 92 I=1,LPOINT
      IF(PY(I).GT.0.) GO TO 92
      IF(I.EQ.1) PY(I)=PY(I+1)
      IF(I.GT.1) PY(I)=PY(I-1)
   93 WRITE(6,94) PX(I), PY(I)
   94 FORMAT(/' MAG.LE.ZERO AT SMIN OF',F10.2,' - SO SET TO',F10.2)
   92 CONTINUE
      WRITE(6,95) PX(1),PX(LPOINT),PSMIN,PEMIN
   95 FORMAT(/' FIRST & LAST DATA POINTS LOADED ARE ...'/' FIRST SMIN=',
     +F10.2,' - LAST SMIN=',F10.2,' - ARE THEY REQUESTED POINTS WHICH AR
     +E',2F15.2)
C ****READY TO PLOT - SET UP PLOT BOUNDARIES ....
      CALL DERMAX(PX,LPOINT,PXMAX)
      CALL DERMIN(PX,LPOINT,PXMIN)
      CALL DERMAX(PY,LPOINT,PYMAX)
      CALL DERMIN(PY,LPOINT,PYMIN)
      DY=50.0
      DX=30.0
C ****FIND NICELY ROUNDED CO-ORD BOUNDARIES ....
      YOR=(FLOAT(IDINT(PYMIN/DY)))*DY
      XOR=(FLOAT(IDINT(PXMIN/DX)))*DX
      WRITE(6,102) XOR, YOR
  102 FORMAT(' PLOT WILL BE ORIGINED AT X =',F10.2,' - Y =',F10.2)
      YMAX=((FLOAT(IDINT(PYMAX/DY)))*DY)+DY
      XMAX=((FLOAT(IDINT(PXMAX/DX)))*DX)+DX
      SZX=(XMAX-XOR)/DX
      SZY=(YMAX-YOR)/DY
      IF(SZY.GT.10.) CALL YSIZE(29.0)
      WRITE(6,108) SZX, SZY
  108 FORMAT(' PLOT SIZES WILL BE - X =',F10.2,' - Y =',F10.2)
C ****SCALE DATA TO PLOT INCHES ....
      DO 115 K=1,LPOINT
      XPLOT(K)=(PX(K)-XOR)/DX
  115 YPLOT(K)=(PY(K)-YOR)/DY
C ****AND WE START TO PLOT ....
      CALL PLOTS
      CALL AXIS(0.,0.,'STATION MAG(GAMMAS)',+19,SZY,90.,YOR,DY)
      CALL AXIS(0.,0.,'TIME - MINUTES',-14,SZX,0.,XOR,DX)
      CALL LINE(XPLOT,YPLOT,LPOINT,+1)
```

```
      XSYM=SZX+C.5
      CALL NUMBER(XSYM,0.5,C.14,PSDAY,90.,-1)
      CALL WHERE(X,Y)
      X=XSYM
      Y=Y+0.84
      CALL NUMBER(X,Y,0.14,PSTIME,90.,-1)
      X=XSYM
      CALL SYMBOL(X,Y,0.14,'     TO ',9C.,8)
      CALL WHERE(X,Y)
      X=XSYM
      Y=Y+0.42
      CALL NUMBER(X,Y,0.14,PEDAY,9C.,-1)
      CALL WHERE(X,Y)
      X=XSYM
      Y=Y+C.84
      CALL NUMBER(X,Y,0.14,PETIME,9C.,-1)
C ****RE-ORIGIN PLOT FOR NEXT ONE ....
      XNEW=SZX+1C.0
      CALL PLOT(XNEW,C.,-3)
      WRITE(6,120) PSDAY,PSTIME,PEDAY,PETIME
  12C FORMAT(/' PLOT GENERATED FOR PERIOD',2F10.2,' TO',2F1C.2///)
      GO TO 18
C ****THESE ARE THE EXITS .....
  9C0 WRITE(6,903)
  9C3 FORMAT(/' INSUFFICIENT MAG DATA - PLOT NOT GENERATED')
      STOP 9
  980 WRITE(6,983)
  983 FORMAT(/' MAG DATA HAS HOLES - PROG CANNOT PLOT IT')
      STOP 7
  995 WRITE(6,997)
  997 FORMAT(' ENDFILE ON UNIT 5 - NO MORE PLOTTING REQUESTED')
      CALL PLOTND
      STOP 1
      END
C ***************************************************************
      SUBROUTINE TMINT(DAY,TIME,SMIN)
      IMPLICIT REAL*8(A-H,O-Z)
   1C DMIN=DAY*1440.
      IF(TIME.NE.C.) GO TO 30
      HMIN=0.
      XMIN=0.
      GO TO 40
   3C IHRS=IDINT(TIME/100.)
      HMIN=IHRS*60.
      JHRS=IHRS*1C0
      HRSJ=DFLOAT(JHRS)
      XMIN=TIME-HRSJ
   40 SMIN=DMIN+HMIN+XMIN
      RETURN
      END
C ***************************************************************
      SUBROUTINE DERMAX(X,N,DMAX)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION X(N)
      DMAX=-10.E30
      DO 20 I=1,N
      IF(X(I).GT.DMAX) DMAX=X(I)
   20 CONTINUE
      WRITE(6,35) DMAX
   35 FORMAT(' MAXIMUM VALUE FOUND =',F15.2)
```

```
      RETURN
      END
C ***************************************************************
      SUBROUTINE DERMIN(X,N,DMIN)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION X(N)
      DMIN=+10.E30
      DO 30 I=1,N
      IF(X(I).LT.DMIN) DMIN=X(I)
   30 CONTINUE
      WRITE(6,37) DMIN
   37 FORMAT(' MINIMUM VALUE FOUND =',F15.2)
      RETURN
      END


$COPY *SKIP *SINK*
```

```
$COPY *SOURCE*@¬CC *SINK*
C       ******   ONEDEE PLOTTER    ******
C
C    PRCG PLOTS MAG CATA IN TIME SERIES - ONE-CIMENSIONALLY ..
C    DATA MUST BE ORGANISED IN LINES WITH LINE# & # CF PCINTS PRECEDING EACH
C    LINE DATA ...
C                  8 = MAG DATA TC BE PLOTTEC
C                  9 = PLCT CCMMANDS C/P
C    WRITTEN PRIMARILY TO PLOT BEAUFCRT SEA/MACKENZIE BAY MAG DATA
C    WRITTENINAHURRY .... 2 MARCH 1972  ROCQUE GOH  GEOPHYSICS  UBC
      DIMENSION SMIN(1000), ZMAG(1CCO), DUMMY(1CCO)
      COMMON/DEBUG/FLAG
      LOGICAL FLAG
      FLAG=.TRUE.
      IFLAG=C
C ****READ IN CONTROLS CARDS TO KNOW WHICH LINE IS TC BE PLCTTED ...
   18 READ(5,20,END=995) PLINE
   20 FORMAT(F2C.3)
C ....DON'T READ IN ANY MAG DATA IF IFLAG>C ...
      IF(IFLAG.GT.0) GO TO 27
C ....READ IN DATA AND CHECK IF IT IS TC BE PLCTTED ...
      MEOF=0
   22 READ(8,25,END=30) LLINE, NPTS
   25 FORMAT(1X,I6,1X,I6)
      QLINE=FLOAT(LLINE)
C ....CHECK IF LINE IN HAND IS TO BE PLOTTED ...
   27 IF(PLINE.EQ.QLINE) GO TO 40
      IF(PLINE.LT.QLINE) GC TC 35
C ....DATA NOT TO BE PLOTTED - SKIP AND GET NEXT SET ....
      IFLAG=0
      MECF=0
      READ(8,28,END=991) (DUMMY(I), I=1,NPTS)
   28 FORMAT(F10.2)
      WRITE(6,26) QLINE
   26 FORMAT(' LINE #',F10.2,' SKIPPED CVER ........')
      GO TO 22
   30 MECF=MECF+1
      IF(MECF.GT.1) GO TO 33
      GO TO 22
C ****TWC ENDFILES READ - NO MORE MAG DATA TO PLOT ..
   33 WRITE(6,34) PLINE
   34 FORMAT(' LAST LINE PROCESSED WAS',F10.2,' - TWC EOFS ON UNIT 8')
      CALL PLOTND
      STCP 5
C ****LINE TO BE PLOTTED NOT FOUND - GET NEXT CONTROL CARD ...
   35 WRITE(6,36) PLINE
   36 FORMAT(/' LINE #',F10.2,' NOT FOUND - NOT PLOTTED')
      IFLAG=1
      MEOF=0
      GO TO 18
C ****FOUND LINE TC BE PLOTTED - READ IN LINE DATA ...
   4C MEOF=C
      IFLAG=0
      READ(8,50,END=991) (SMIN(K),ZMAG(K), K=1,NPTS)
   5C FORMAT(12X,F11.2,55X,F7.1,16X)
      WRITE(6,53) PLINE
```

```
  53 FORMAT(' PLOT DATA FOR LINE #',F10.2,' READ IN - LAST DATA POINT')
     WRITE(6,50) SMIN(NPTS), ZMAG(NPTS)
C ****SET UP PLOT PARAMETERS
     DY=50.
     DX=30.
C ****FIND MAX/MIN VALUES OF SMIN & ZMAG ....
     CALL DERMIN(SMIN,NPTS,SSMIN)
     CALL DERMAX(SMIN,NPTS,BSMIN)
     CALL DERMIN(ZMAG,NPTS,SZMAG)
     CALL DERMAX(ZMAG,NPTS,BZMAG)
C ****FIND HUNDRED-GAMMA VALUE JUST BELOW LOWEST ZMAG ..
     YOR=(FLOAT(INT(SZMAG/DY)))*DY
C ****FIND PLOT-INCH JUST BELOW LOWEST SMIN ....
     XOR=(FLOAT(INT(SSMIN/DX)))*DX
     WRITE(6,55) XOR, YOR
  55 FORMAT(' PLOT WILL BE ORIGINED AT X =',F10.2,' - Y =',F10.2)
C ****FIND HUNDRED-GAMMA VALUE JUST ABOVE HIGHEST MAG ...
     YMAX=((FLOAT(INT(BZMAG/DY)))*DY)+DY
     SZY=(YMAX-YOR)/DY
     IF(SZY.GT.10.) CALL YSIZE(29.0)
C ****FIND DAY JUST HIGHER THAN THE LARGEST SMIN VALUE ..
     XMAX=((FLOAT(INT(BSMIN/DX)))*DX)+DX
     SZX=(XMAX-XOR)/DX
     WRITE(6,56) XMAX, YMAX
  56 FORMAT(' MAXIMUM CO-ORDS ARE X =',F10.2,' : Y =',F10.2)
     WRITE(6,57) SZX, SZY
  57 FORMAT(' PLOT SIZES WILL BE - X-AXIS =',F10.2,' - Y-AXIS =',F10.2)
C ****SCALE DATA ...
     DO 70 M=1,NPTS
     SMIN(M)=(SMIN(M)-XOR)/DX
  70 ZMAG(M)=(ZMAG(M)-YOR)/DY
C ****START PLOTTING - AXES FIRST, POINTS NEXT ...
     CALL PLOTS
     CALL AXIS(0.,0.,'MARINE MAG - GAMMAS',+19,SZY,90.,YOR,DY)
     CALL AXIS(0.,0.,'TIME - MINUTES',-14,SZX,0.,XOR,DX)
     CALL LINE(SMIN,ZMAG,NPTS,+1)
C ****RE-ORIGIN PLOT AXIS FOR NEXT PLOT ...
     XNEW=SZX+5.0
     CALL PLOT(XNEW,0.,-3)
C ****GET NEXT CONTROL CARD FOR NEXT PLOT ..
     WRITE(6,78) PLINE
  78 FORMAT(' LINE #',F10.2,' PLOTTED')
     GO TO 18
C ****UNEXPECTED ENDFILE ON MAG DATA TO BE PLOTTED ...
 991 WRITE(6,992)
 992 FORMAT(' UNEXPECTED ENDFILE ENCOUNTERED ON UNIT 8 - MAG DATA')
     STOP 9
C ****NO MORE LINES TO BE PLOTTED ...
 995 WRITE(6,996) PLINE
 996 FORMAT(' LAST LINE PLOTTED',F10.2,' - NORMAL TERMINATION')
     CALL PLOTND
     STOP 1
     END
     SUBROUTINE DERMAX(X,N,DMAX)
     DIMENSION X(N)
     DMAX=-10.E30
     DO 20 I=1,N
     IF(X(I).GT.DMAX) DMAX=X(I)
  20 CONTINUE
     WRITE(6,35) DMAX
```

```
   35 FORMAT(' MAXIMUM VALUE FOUND =',F15.2)
      RETURN
      END
      SUBROUTINE DERMIN(X,N,DMIN)
      DIMENSION X(N)
      DMIN=+10.E30
      DO 30 I=1,N
      IF(X(I).LT.DMIN) DMIN=X(I)
   30 CONTINUE
      WRITE(6,37) DMIN
   37 FORMAT(' MINIMUM VALUE FOUND =',F15.3)
      RETURN
      END
$COPY -A *PUNCH*


$SIGNOFF
```