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Australian Geological Survey Organisation

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Abstract

A data set is prepared which contains 10,533 observations of total magnetic intensity made at 1-min intervals on the 1975/76 BMR long aeromagnetic traverses over Australia. Errors in the location of the aircraft are estimated from consideration of navigational methods and aeromagnetic profiles at crossovers. A typical locational error of 5 km results on average in an absolute error in observed total magnetic intensity of about 35 nT. Of the various external geomagnetic fields affecting the data set, diurnal variation is the most significant, however most of the base stations run during the traverses are contaminated by the geomagnetic coast effect. A method is developed using the AWAGS data set that enables the estimation of the phase difference and amplitude ratio of the diurnal variation at a site relative to the diurnal variation observed at another site. Using this method on the base station recordings to correct part of the aeromagnetic data set results in a reduction in the mean magnetic anomaly over Australia relative to the IGRF from -8 nT to -2 nT.

Introduction

In 1975/76 a series of total intensity aeromagnetic traverses covering the whole of continental Australia and Tasmania were flown at 10,000 ft elevation by the BMR. The purpose was to provide a data set suitable for use in a study of long-wavelength magnetic anomalies in the Australian region. The results were published by Wellman et al. (1985). This Record presents the aeromagnetic data set and discusses the two main causes of uncertainties in it, namely errors in navigation and contamination by external magnetic fields. Where base station recordings exist they are used to correct the aeromagnetic data for diurnal variation.

Description of the Survey Programme

The aircraft made a total of 90 flights, some of them along nominally coincident paths, between 8 November 1975 and 8 March 1976 (Figure 1). Details of each flight are given in Table 1. The observing altitude was 10,000 ft (3048 m), with the exception of flight 89 (Quilpie-Maryborough) which was flown at 4000 ft (1219 m). Aircraft speed was around 300 km h^{-1} (83 m s^{-1}). Total magnetic intensity was measured about once a second by a proton precession magnetometer and the results recorded in analogue form on a paper chart recorder. The analogue record was subsequently digitized at 1-min intervals, with a spacing between data points of about 5 km.

Details of the method used to navigate the aircraft are uncertain. At the very least the aircraft was flown between clearly identified waypoints with the aid of a magnetic compass and detailed maps. Positional information was obtained by a camera with a wide-angle lens that was mounted so as to look directly beneath the aircraft. During the flight a continuous series of photographs of the Earth's surface was taken, and when a clearly identified feature was overflown the analogue record was annotated with the time. Subsequently, geographic co-ordinates were associated with these times. The position at each minute of the flight was then estimated by linear interpolation. The number of reference landmarks used for each flight is listed in Table 1.

The object of the survey was to measure the internal (core plus crustal) geomagnetic field, which is constant on the time-scale of individual flights. However, the external geomagnetic field can vary significantly on time-scales from seconds upwards, and these variations are indistinguishable from the internal field on an aeromagnetic profile. The external field has a regular component which is driven by the daily passage of the Sun. Known as the diurnal variation, it peaks in amplitude at around midday local time (between 0200 and 0500 UT in Australia) and its amplitude is typically of order 10 nT. The external field also has an

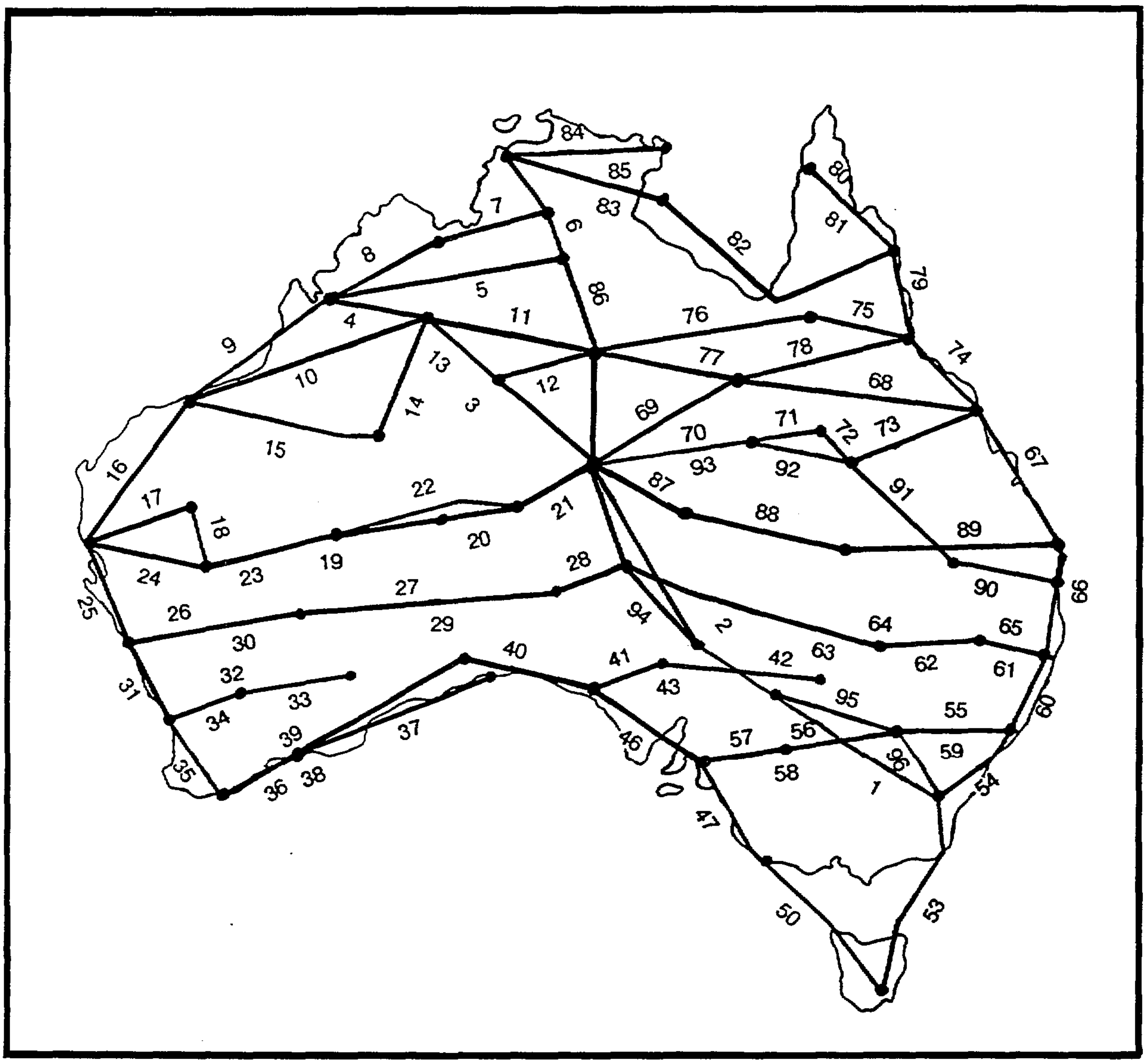


Figure 1. Flight lines of the 1975 / 76 long aeromagnetic traverses.

irregular, or disturbed, component which varies with the level of solar activity. This disturbance field was monitored at the Canberra geomagnetic observatory and flying was halted when it became significant. Diurnal variation, however, will be present to some degree in all flights as they were made during daylight hours (all flights were completed between 1919 and 0952 UT). For 57 flights (63% of the total) a base station, consisting of a continuously-operating proton precession magnetometer recording on a paper chart recorder, was run at the regional flying base to determine an external field correction for the aeromagnetic observations. When transiting between flying bases no base station was run. However geomagnetic observatories at Gnangara, Toolangi, and Port Moresby were operational throughout the period of the flying programme.

Errors in the Aeromagnetic Data Set

For lack of information to the contrary, it is assumed that the proton precession magnetometer mounted in the aircraft recorded total magnetic intensity without contamination by stray fields originating from the aircraft itself. Two potentially serious sources of error remain. Firstly, the accuracy of the location assigned to each observation is limited by the accuracy with which points along the flightpath are identified, and the precision with which linear interpolation between pairs of these points approximates to the actual flightpath. Secondly, time-varying external magnetic fields are superimposed on the internal field that it is desired to observe. In the following sections the uncertainties associated with each of these two sources of error are discussed, amplitudes of the resulting errors are estimated, and corrections are applied to the data set where this is possible.

Locational Errors

Locational errors are of two kinds, the first of which is the incorrect estimation of the position of the aircraft relative to a landmark. If the camera mounted in the aircraft is not pointing straight down when a landmark is photographed then the aircraft position will be incorrectly assigned. A departure from the vertical of 5° at a height of 3000 m leads to a lateral error of around 300 m at the Earth's surface. This error is likely to be compounded by distortion caused by the camera's wide-angle lens if the landmark is not directly overflown. There is also a timing error associated with annotation of the analogue record. A likely timing error of 5 s will result in a locational error of around 400 m. Thus the total error in the position assigned to a landmark may be as much as 1 km.

The second kind of error is potentially much more important. Locations between two landmarks are determined by the linear interpolation of latitude and longitude on the basis of the time taken to fly between the two points. This procedure requires that the aircraft flew at a constant speed and on a straight line course. Assuming that a magnetic compass was used to maintain a heading, and that this was maintained within 3° of the correct heading, over a typical flight leg of 100 km the departure from the interpolated path could be up to 5 km. As flight legs vary in length from a few tens of kilometres to hundreds of kilometres, this error can vary considerably. In Table 1 the number of landmarks overflown is listed alongside the total distance covered on each flight. These two figures indicate the average length of the legs on each flight, and hence the size of the possible error due to an incorrect heading. Variations in the aircraft's velocity due to fluctuating winds will also contribute a locational error, possibly of a similar order to the error due to incorrect heading.

Evidence for errors in location are apparent upon examination of the analogue records from pairs of flights made between the same locations and whose paths appear (from navigational data) to cross. Over common landmarks values of total magnetic intensity are usually in agreement, particularly if the variation in the external field can be allowed for. However, at points where the interpolated paths of two flights are calculated to cross there is invariably a disparity between the observed values of total magnetic intensity that can only be explained either by assigning the crossover to a different point on the tracks or by separating the tracks so that they do not cross at all. Examination of several such pairs of tracks indicates that the combined error in the location of two tracks is up to 15 km, with 5 km being a typical value. The error is usually greater on longer flight legs. These errors in location are consistent with the estimated errors in navigation discussed earlier. Averaging the absolute difference between consecutive observations of total magnetic intensity on the flights results in a mean gradient of about 7 nT km^{-1}. A typical locational error of 5 km thus corresponds on average to an absolute error in the observed total magnetic intensity of about 35 nT.

Errors Due to External Geomagnetic Fields

The effects of external geomagnetic fields are usually removed by operating a fixed base station in the survey region and subtracting the time-variations observed at the base station from the survey results. This method of correction is based on the assumption that the external field is homogeneous throughout the survey region. However the external field does vary spatially, and the usefulness of a particular base station is critically dependent on this variability.

The primary external field is solar-driven. At all times the Sun causes a current system to flow in the ionosphere that produces a smoothly varying day-time field known as the diurnal variation. In the absence of significant solar activity this is the dominant external field. At times of high solar activity magnetic storms or substorms occur. These are characterized by strong, irregular fields caused by magnetospheric and ionospheric current systems which typically vary at periods of seconds to hours. When such disturbances occur survey work is usually halted. At southern mid-latitudes, such as over most of Australia, the diurnal variation field is dominated by a clockwise horizontal ionospheric current system, fixed relative to the Sun, which peaks in strength around local midday. The diurnal variation in Australia thus varies spatially with latitude and local time. Irregular primary fields, on the other hand, can occur at any time and are usually less spatially variable by virtue of the remoteness of their magnetospheric sources.

Included in the classification "external field" are fields due to the eddy currents induced in the Earth by varying ionospheric and magnetospheric primary fields. These secondary fields typically have half the amplitude of the primary fields. The spatial variation of the secondary field depends on both the electrical conductivity of the Earth and the properties of the primary field. The depth of penetration into the Earth of the primary field depends on period. Irregular events are strongest at short periods (of order 1 hour) and are therefore influenced mainly by conductivity of the crust, whereas diurnal variation fields are influenced by conductivity down to depths of about 500 km.

Lilley (1982) recognized that secondary or induction fields can cause errors of tens of nanoteslas in magnetic surveys. The need to study this problem was one of the main reasons for conducting the Australia-wide array of geomagnetic stations (AWAGS) experiment (Chamalaun and Barton, 1990). This experiment involved continuous monitoring of the geomagnetic field at 57 sites throughout Australia for a period of eight months. The pattern of induction effects across the continent was mapped by determining induction arrows for a magnetic storm (Figure 2). Induction arrows point towards a strong subsurface conductor and their length is proportional to the strength of that conductor. In Figure 2 a continental conducting zone is apparent, while around the coastline the influence of electric currents flowing in the deep ocean (the geomagnetic coast effect [Parkinson and Jones, 1979]) is clear. In general the geomagnetic coast effect dominates at diurnal periods, intra-continental conductors having a measurable but lesser effect.

During the 1975/76 aeromagnetic traverses, work was halted when the geomagnetic field was strongly affected by irregular solar activity. The Kp index, a global measure of the level of irregular external field activity, exceeded a level of 4 (equivalent to a peak-to-peak variation in the irregular horizontal field in Australia of more than 60 nT in a 3-hour period) on only 19% of the flights. Because all flights were made during daylight hours, most during the period around local midday when diurnal variation peaks, diurnal variation is the dominant

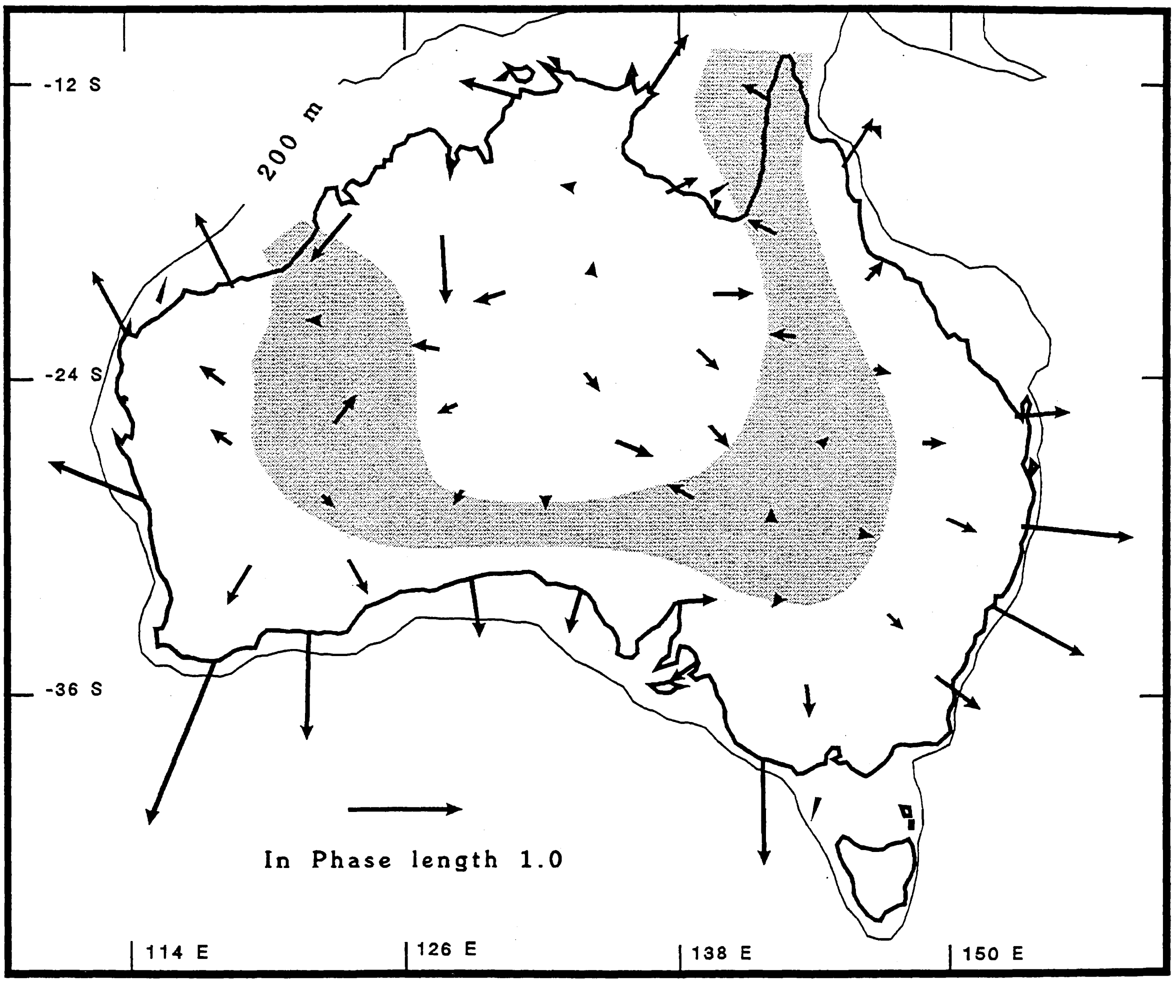


Figure 2. Induction arrows at AWAGS stations for a period of 42.7 min. The shaded area represents a zone of high subsurface conductivity inferred from the induction arrows. From Chamalaun and Barton (1990).

external field. Since diurnal variation has a maximum departure from quiet night-time levels in Australia of about 50 nT and long-wavelength anomalies in Australia have amplitudes of order 100 nT (Wellman et al., 1985), clearly it is desirable to remove diurnal variation from the aeromagnetic data.

Correction of Aeromagnetic Data for Diurnal Variation

During most of the 1975/76 aeromagnetic traverses a base station was run, however the aircraft often operated at large distances (up to several thousand kilometres) from its base station, reducing the usefulness of the observed external field for correcting the aeromagnetic observations. Also, all 14 of the base stations, with the exception of Alice Springs, were on the coast and thus were affected to some degree by the geomagnetic coast effect. Lilley and Parker (1976) show that the vertical component of diurnal variation can vary between inland and coastal sites by as much as a factor of 3. The question is thus raised as to how reliable is an observation of diurnal variation made at a point on the coast of Australia as an estimate of diurnal variation at another point, either coastal or inland, well separated from the first?

A means of answering the question empirically exists in the form of the set of observations made during the AWAGS experiment (Chamalaun and Barton, 1990). The 57 AWAGS stations were spread more or less uniformly over Australia and each provided data for up to eight months. A two-dimensional array of stations should show that diurnal variation has a strong dependence on local time, and the pattern at any given local time varies characteristically with latitude. The geomagnetic coast effect is usually apparent as an enhancement of the vertical component near a coastline, the enhancement decreasing inland with a scale distance of order 100 km.

Riddihough (1969) described a method for comparing diurnal variation observed at two different sites. He filtered observations of total magnetic intensity made at 10-min intervals using a 3-hour running mean so as to remove irregular external fields, and then determined the correlation coefficient and amplitude ratio at the two sites for each day. This was done for a range of time differences, or phases, to allow for the dependence of diurnal variation on local time. The phase at which the correlation coefficient was maximum, and the corresponding amplitude ratio, characterized the relationship between diurnal variation at the two sites. Using the Valentia observatory in Ireland as the primary site and other observatories and temporary stations throughout Europe as secondary sites, Riddihough contoured phase and amplitude ratios and showed the influence of the geomagnetic coast effect and possible lithospheric effects in diurnal variation over Europe.

A similar approach was applied to the first four months of AWAGS data. Three stations were chosen to test the method, Geraldton on the west coast, Grafton on the east coast, and Alice Springs in the centre of the continent. The other AWAGS stations were divided between corresponding western, central, and eastern zones. Correlation coefficients and amplitude ratios at a range of phases were determined for each of the three primary stations and the secondary stations in its zone for each of 66 consecutive days. These days (November 19, 1989, to January 23, 1990) coincide with the time of year at which the 1975/76 aeromagnetic traverses were flown. Phase and amplitude ratios for each secondary station on days when the maximum correlation coefficient exceeded 0.9 were averaged and the resulting values contoured (Figures 3 and 4). In Figure 3 the amplitude ratio shows a strong latitudinal dependence in the central zone but is clearly influenced by the geomagnetic coast effect in the eastern and western zones, particularly the western zone, where the amplitude decreases inland from Geraldton to nearly half of its coastal value. These results are consistent with those from earlier studies of diurnal variation across Australia, e.g., Lilley and Parker (1976). The contour map of phase at maximum correlation (Figure 4) is more difficult to interpret. Dependence solely upon local time would result in approximately north-south contours. The contours are clearly disturbed in the south-west of Australia and appear to be "compressed" in the east.

Riddihough's method was extended by using values of phase and amplitude ratio determined in the above fashion to apply quantitative diurnal variation corrections to the aeromagnetic observations. The effectiveness of this approach was tested in a circular fashion using the AWAGS data. Using the amplitude ratio and phase determined from days with high correlation coefficients, the diurnal variation at each station on each of the 66 days was estimated from the diurnal variation observed at the appropriate zone primary station. The rms (root mean square) value of the time-varying field at each station was determined with and without the correction applied, and the ratio of rms corrected to rms uncorrected values at each station was contoured for each zone (Figure 5). Examples of rms corrected and rms uncorrected values are: 14 nT and 49 nT (Geraldton), 4 nT and 11 nT (Alice Springs), and 6 nT and 15 nT (Grafton). As expected, the ratio increases with distance away from the primary station, but the rate of increase varies across the continent. The value at a primary station (typically 0.3) indicates the level of irregular(short-period) external field activity.

Equivalent values of phase and amplitude ratio were determined by treating each of the other 11 base stations run during the 1975/76 aeromagnetic traverses as a primary station. This was made possible by the fact that, with the exception of Mackay and Ingham, all base station sites were also AWAGS sites. Values for Mackay and Ingham were estimated using the nearby Charters Towers geomagnetic observatory as the primary station. Values of phase and amplitude ratio determined in this way were assigned to the start and finish of each flight, values at points in between being determined by linear interpolation.

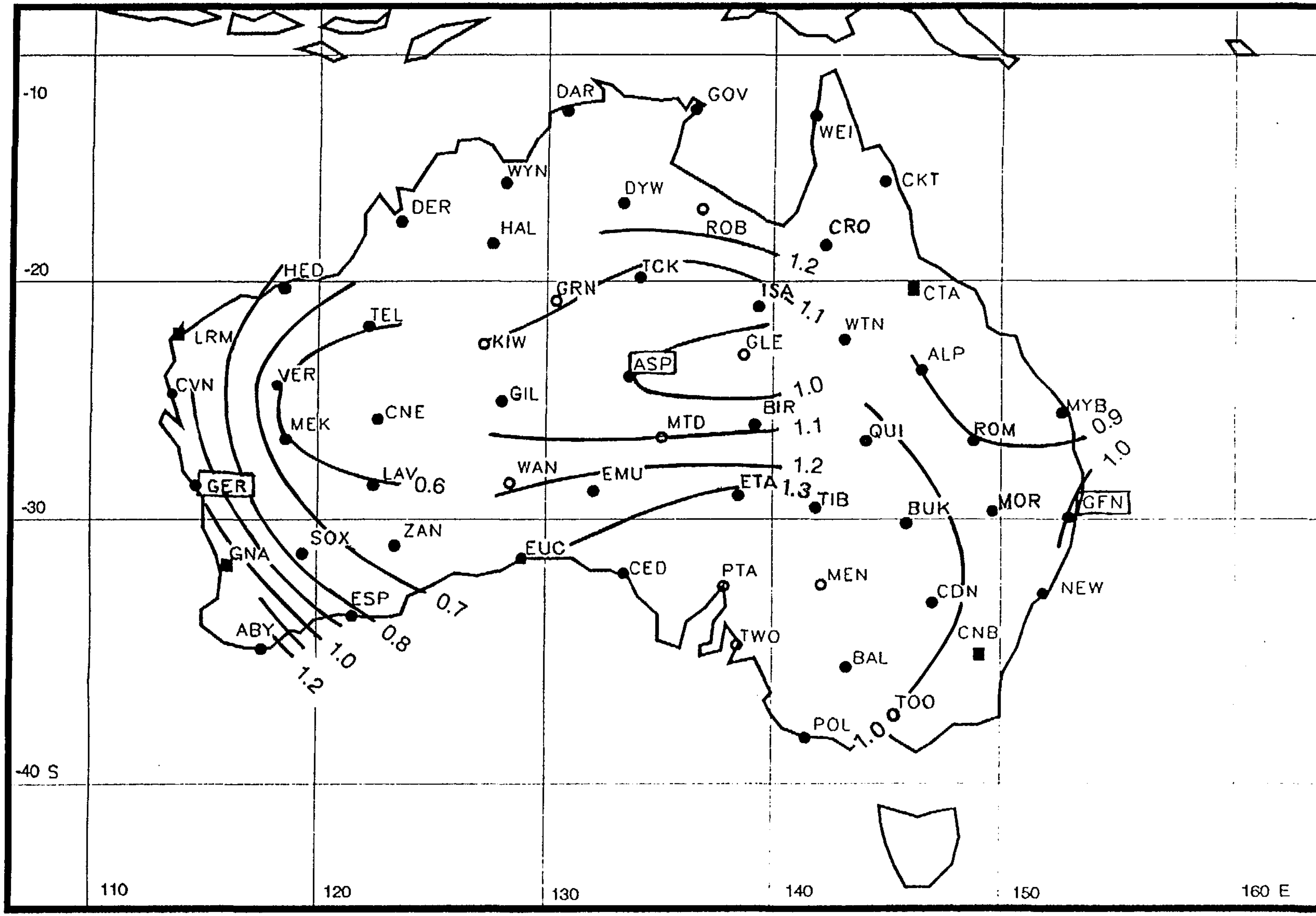


Figure 3. Contoured amplitude ratio of diurnal variation (phase shifted for maximum correlation) at primary and secondary AWAGS stations on days when correlation is greater than or equal to 0.9. GER, ASP, and GFN are the primary reference stations for the western, central, and eastern zones respectively.

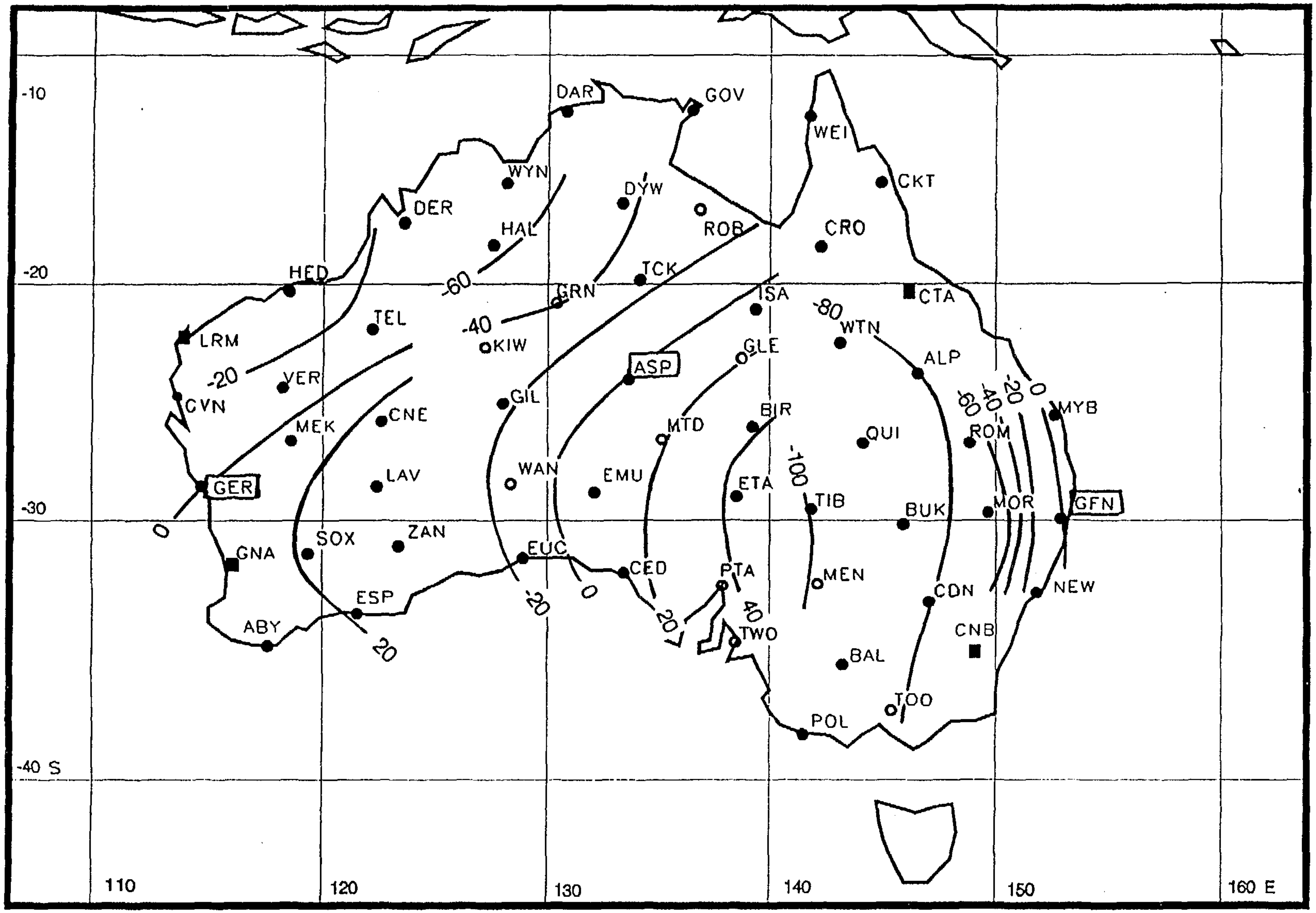


Figure 4. Contoured phase difference in minutes at which the maximum correlation between diurnal variation at primary and secondary AWAGS stations occurs. GER, ASP, and GFN are the primary reference stations for the western, central, and eastern zones respectively.

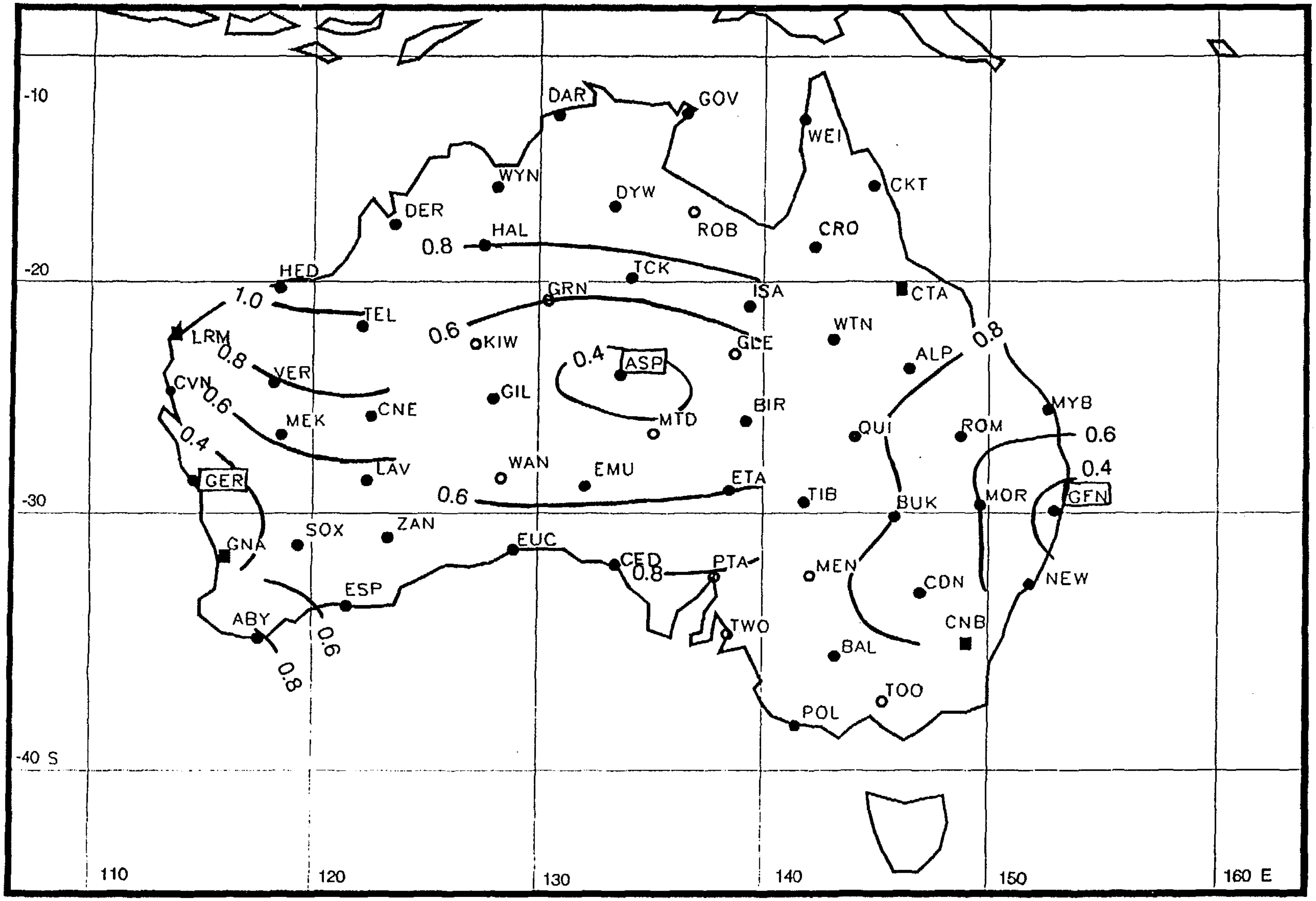


Figure 5. Ratio of rms corrected to rms uncorrected values of the time-varying total magnetic field at AWAGS stations. Corrections are based on diurnal variation at GER (western zone), ASP (central zone), and GFN (eastern zone)

Flights on which the estimated ratio of rms corrected to rms uncorrected values of the time-varying field exceeded 0.8 were left uncorrected (flights 63, 64, 89, and 90), as also was flight 22 because its base station recording was dominated by short-period disturbances. This left 57 out of a total of 90 flights (63%) corrected for diurnal variation. The mean anomaly for the entire data set (10,533 one-minute observations of total magnetic intensity) calculated using the IGRF (IAGA Division I Working Group 1, 1986) as a reference field is -5 nT; this differs from the value of -91 nT calculated by Wellman et al. (1985) because they determined the IGRF at the Earth's surface instead of at the aircraft's altitude. Of this data set, 4928 observations can be corrected for diurnal variation with the base station recordings that are available. These observations have a mean anomaly value of -8 nT before correction and -2 nT after correction. This difference of 6 nT indicates a mean diurnal variation in total magnetic intensity during these flights of -6 nT, consistent with the fact that most flights were made during the middle part of the day when total intensity is depressed.

The shift of the mean anomaly value towards zero is encouraging, provided that the IGRF is an unbiassed estimator of the mean geomagnetic field over Australia as observed on an aeromagnetic survey. In favour of this proviso is the fact that IGRF coefficients for the 1970s are strongly influenced by Project MAGNET aeromagnetic data. This should improve the agreement between the IGRF and other aeromagnetic data sets, such as the present one.

The Published Data Set

The data set is stored as an ASCII file named 7576.aero in the directory /geomag/donmk/trav on the Geomagnetism Section's Sun Sparcstation (Lodestone on the AGSO network). Observations are stored one per line in I10, 2F10.3, 4I10 format. Following are some lines from 7576.aero:

4	-17.404	123.763	3048	49982	49982	0
4	-17.394	123.715	3048	49975	49975	0
4	-17.383	123.667	3048	49960	49960	0
0	.000	.000	0	0	0	0
5	-17.333	123.667	3048	49912	49933	50020
5	-17.319	123.702	3048	49910	49931	50020
5	-17.305	123.738	3048	49898	49919	50020

Parameters recorded are flight number, latitude, longitude, altitude, observed total field, corrected total field, and base station total field. Where no diurnal variation correction has been applied, the base station total field is set to zero.

Appendix 1 shows the process by which the data set was prepared. All data files and programs listed in Appendix 1 are stored in the same directory as 7576.aero. Supplementary information is given in Table 1, in particular details of the path, timing, and length of each flight, the reliability of the navigation in the form of the number of landmarks identified, the level of external geomagnetic field disturbance in the form of the maximum K_p index for the flight, and the base station used to estimate the diurnal variation.

References

Chamalaun, F. H., and C. E. Barton, 1990, Comprehensive mapping of Australia's geomagnetic variations, Eos Trans. AGU, 71, 1867 & 1873.

IAGA Division I Working Group 1, 1986, International Geomagnetic Reference Field revision 1985, Geophys. J. R. Astron. Soc., 85, 217-220.

Lilley, F. E. M., 1982, Geomagnetic field fluctuations over Australia in relation to magnetic surveys, Bull. Aust. Soc. Explor. Geophys., 13, 68-76.

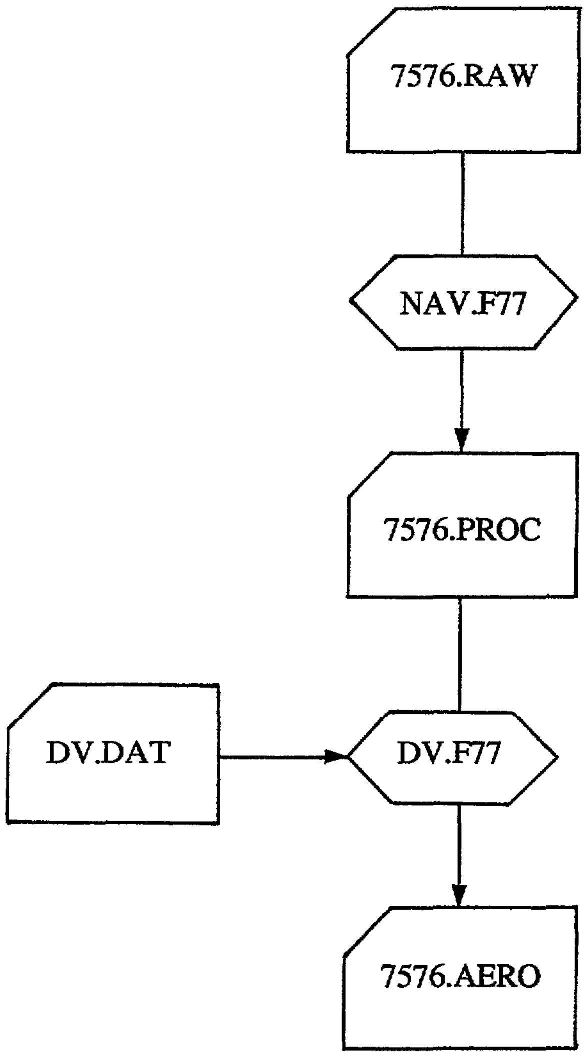
Lilley, F. E. M., and R. L. Parker, 1976, Magnetic diurnal variation compared between east and west Australia, Geophys. J. R. Astron. Soc., 44, 719-724.

Parkinson, W. D., and F. W. Jones, 1979, The geomagnetic coast effect, Rev. Geophys. Space Phys., 17, 1999-2015.

Riddihough, R. P., 1969, A geographical pattern of daily magnetic variation over North-West Europe, Ann. Geophysique, 25, 739-745.

Wellman, P., A. S. Murray, and M. W. McMullan, 1985, Australian long-wavelength magnetic anomalies, BMR J. Australian Geol. Geophys., 9, 297-302.

Appendix 1. Processing Scheme for Aeromagnetic Data



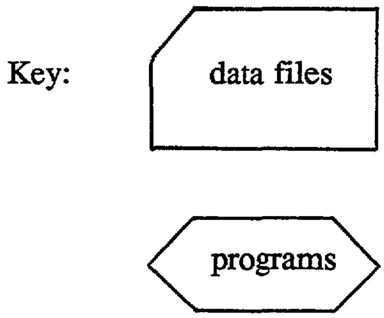


Table 1. Details of the 1975/76 Long Aeromagnetic Traverses Over Australia

Flight	Origin	Destination	Start time, date (UT)		Finish time, date (UT)		Dist. (km)	Land-marks	Kp (max)	Base station
1	Canberra	Leigh Creek	2014:30	07/11/75	0007:00	08/11/75	1142	16	2+	
2	Leigh Creek	Alice Springs	0132:00	08/11/75	0426:30	08/11/75	875	11	2o	
3	Alice Springs	Halls Creek	2312:00	08/11/75	0207:00	09/11/75	891	14	2o	
4	Halls Creek	Derby	0338:00	10/11/75	0459:00	10/11/75	434	8	2-	
5	Derby	Daly Waters	0154:00	11/11/75	0517:40	11/11/75	1071	18	4o	Derby
6	Daly Waters	Tindal	0707:30	11/11/75	0746:30	11/11/75	220	3	2+	Derby
7	Tindal	Wyndham	2212:00	11/11/75	2345:00	11/11/75	465	8	3-	Derby
8	Wyndham	Derby	0128:30	12/11/75	0308:00	12/11/75	521	12	4-	Derby
9	Derby	Port Hedland	0058:00	13/11/75	0252:00	13/11/75	569	9	1+	
10	Port Hedland	Halls Creek	2216:30	14/11/75	0128:00	15/11/75	969	8	1o	Port Hedland
11	Halls Creek	Tennant Creek	0302:30	15/11/75	0521:00	15/11/75	730	7	1o	Port Hedland
12	Tennant Creek	The Granites	2220:00	15/11/75	2334:30	15/11/75	410	5	3o	Port Hedland
13	The Granites	Halls Creek	0148:00	16/11/75	0301:00	16/11/75	378	6	2+	Port Hedland
14	Halls Creek	Kidson	2225:00	16/11/75	0008:00	17/11/75	910	4	1o	Port Hedland
15	Kidson	Port Hedland	0331:30	17/11/75	0614:00	17/11/75	730	7	2o	Port Hedland
16	Port Hedland	Carnarvon	0109:20	18/11/75	0325:45	18/11/75	702	10	3o	
17	Carnarvon	Mount Vernon	2236:00	19/11/75	0006:30	20/11/75	469	5	2+	Carnarvon
18	Mount Vernon	Meekatharra	0323:00	20/11/75	0408:00	20/11/75	266	4	2o	Carnarvon
19	Meekatharra	Giles	1958:00	20/11/75	2253:30	20/11/75	995	5	3+	Carnarvon
20	Giles	Ayers Rock	0216:00	21/11/75	0305:30	21/11/75	279	5	5-	Carnarvon
21	Ayers Rock	Alice Springs	0046:30	22/11/75	0144:00	22/11/75	290	5	2o	Carnarvon
22	Alice Springs	Carnegie	2050:00	22/11/75	0045:30	23/11/75	1021	8	6+	
23	Carnegie	Meekatharra	0242:00	23/11/75	0348:30	23/11/75	317	4	4+	Carnarvon
24	Meekatharra	Carnarvon	2217:00	23/11/75	2353:00	23/11/75	523	6	1o	Carnarvon
25	Carnarvon	Geraldton	0222:30	24/11/75	0352:00	24/11/75	443	7	1+	
26	Geraldton	Laverton	2132:00	25/11/75	2347:30	25/11/75	752	12	2+	Geraldton
27	Laverton	Oodnadatta	0315:15	26/11/75	0711:00	26/11/75	1297	10	4+	Geraldton
28	Oodnadatta	Emu	2020:00	26/11/75	2054:00	26/11/75	205	3	1o	Geraldton
29	Emu	Laverton	2232:00	26/11/75	0121:00	27/11/75	789	6	2+	Geraldton
30	Laverton	Geraldton	0312:00	27/11/75	0519:00	27/11/75	605	7	1-	Geraldton
31	Geraldton	Perth	2342:00	27/11/75	0029:00	28/11/75	252	4	3-	Gnangara
32	Perth	Zanthus	2246:00	28/11/75	0058:15	29/11/75	734	8	2o	Gnangara

Table 1. Details of the 1975/76 Long Aeromagnetic Traverses Over Australia (ctd)

Flight	Origin	Destination	Start time, date (UT)		Finish time, date (UT)		Dist. (km)	Land-marks	Kp (max)	Base station
33	Zanthus	Southern Cross	0332:30	29/11/75	0421:45	29/11/75	262	4	3-	Gnangara
34	Southern Cross	Perth	0610:15	29/11/75	0645:00	29/11/75	178	4	5-	Gnangara
35	Perth	Albany	0041:00	05/12/75	0139:15	05/12/75	375	7	2+	Gnangara
36	Albany	Esperance	0402:00	05/12/75	0508:00	05/12/75	395	5	1+	Albany
37	Esperance	Eucla	2216:00	05/12/75	0019:00	06/12/75	626	4	2o	Albany
38	Eucla	Albany	0241:30	06/12/75	0632:00	06/12/75	1040	7	2o	Albany
39	Albany	Forrest	2236:00	07/12/75	0128:00	08/12/75	883	9	2o	
40	Forrest	Ceduna	0254:00	08/12/75	0438:00	08/12/75	547	7	4o	
41	Ceduna	Woomera	2028:30	08/12/75	2110:30	08/12/75	206	3	5-	Ceduna
42	Woomera	Wilcannia	2351:00	08/12/75	0135:30	09/12/75	547	6	5-	Ceduna
43	Wilcannia	Ceduna	0322:30	09/12/75	0620:30	09/12/75	941	14	3o	Ceduna
44	Not flown									
45	Not flown									
46	Ceduna	Adelaide	0117:40	10/12/75	0303:00	10/12/75	546	11	0+	
47	Adelaide	Portland	0438:00	10/12/75	0605:30	10/12/75	481	7	1-	
48	Not flown									
49	Not flown									
50	Portland	Hobart	2009:00	12/12/75	2226:00	12/12/75	704	8	1-	
51	Not flown									
52	Not flown									
53	Hobart	Canberra	0005:30	16/12/75	0304:00	16/12/75	881	4	4-	
54	Canberra	Newcastle	2354:00	01/02/76	0108:00	02/02/76	419	6	4+	
55	Newcastle	Condobolin	2144:00	02/02/76	2300:45	02/02/76	410	6	3o	Newcastle
56	Condobolin	Mildura	0044:30	03/02/76	0218:30	03/02/76	492	5	4-	Newcastle
57	Mildura	Parafield	0413:00	03/02/76	0511:30	03/02/76	323	6	2+	Newcastle
58	Parafield	Condobolin	0007:15	04/02/76	0258:30	04/02/76	814	9	3+	Newcastle
59	Condobolin	Newcastle	0440:30	04/02/76	0612:30	04/02/76	433	6	2o	Newcastle
60	Newcastle	Grafton	2305:45	05/02/76	0014:15	06/02/76	357	5	3+	
61	Grafton	Moree	1919:00	07/02/76	2016:30	07/02/76	310	5	4o	Coffs Harbour
62	Moree	Bourke	2145:30	07/02/76	2254:30	07/02/76	380	6	3+	Coffs Harbour
63	Bourke	Oodnadatta	0102:00	08/02/76	0433:30	08/02/76	1062	5	4+	
64	Oodnadatta	Moree	2342:30	12/02/76	0408:15	13/02/76	1256	13	5o	

Table 1. Details of the 1975/76 Long Aeromagnetic Traverses Over Australia (ctd)

Flight	Origin	Destination	Start time, date (UT)		Finish time, date (UT)		Dist. (km)	Land-marks	Kp (max)	Base station
65	Moree	Grafton	2220:30	13/02/76	2356:00	13/02/76	310	6	4o	Coffs Harbour
66	Coffs Harbour	Maryborough	0209:30	14/02/76	0345:15	14/02/76	538	8	5-	
67	Maryborough	Mackay	0049:45	16/02/76	0240:45	16/02/76	563	12	1+	
68	Mackay	Mount Isa	2127:00	16/02/76	0032:00	17/02/76	1011	11	2-	
69	Mount Isa	Alice Springs	0215:45	17/02/76	0423:30	17/02/76	674	6	2o	
70	Alice Springs	Boulia	2354:45	17/02/76	0200:00	18/02/76	636	9	5-	Mackay
71	Boulia	Winton	0335:45	18/02/76	0440:15	18/02/76	331	6	4-	Mackay
72	Winton	Longreach	0703:30	18/02/76	0736:30	18/02/76	171	3	4o	Mackay
73	Longreach	Mackay	2234:30	18/02/76	0030:30	19/02/76	569	8	4o	Mackay
74	Mackay	Ingham	0235:30	19/02/76	0358:30	19/02/76	423	9	4o	
75	Ingham	Croydon	2244:00	20/02/76	0003:30	21/02/76	414	6	4-	Ingham
76	Croydon	Tennant Creek	0158:45	21/02/76	0447:30	21/02/76	868	10	3+	
77	Tennant Creek	Mount Isa	0036:00	22/02/76	0234:00	22/02/76	565	6	4-	Ingham
78	Mount Isa	Ingham	0352:00	22/02/76	0615:00	22/02/76	748	11	3+	Ingham
79	Ingham	Cooktown	0438:30	23/02/76	0553:00	23/02/76	367	8	2o	
80	Cooktown	Weipa	2335:00	23/02/76	0100:00	24/02/76	477	5	0+	Cooktown
81	Weipa	Cooktown	0238:45	24/02/76	0425:00	24/02/76	480	7	1-	Cooktown
82	Cooktown	Groote Eylandt	2330:00	24/02/76	0252:00	25/02/76	1126	9	1o	
83	Groote Eylandt	Darwin	0435:00	25/02/76	0629:00	25/02/76	627	7	2-	
84	Darwin	Gove	2357:30	26/02/76	0212:15	27/02/76	657	14	3+	Darwin
85	Gove	Darwin	0712:00	27/02/76	0914:30	27/02/76	647	13	3o	Darwin
86	Darwin	Alice Springs	0157:30	01/03/76	0614:00	01/03/76	1223	15	4o	
87	Alice Springs	Birdsville	2115:00	02/03/76	2312:00	02/03/76	557	10	5o	Alice Springs
88	Birdsville	Quilpie	0037:00	03/03/76	0155:00	03/03/76	413	4	4o	Alice Springs
89	Quilpie	Maryborough	0308:00	03/03/76	0602:00	03/03/76	828	12	4o	
90	Brisbane	Roma	2350:00	03/03/76	0113:00	04/03/76	376	8	5-	
91	Roma	Longreach	0253:00	04/03/76	0427:00	04/03/76	450	6	4+	Alice Springs
92	Longreach	Boulia	0535:00	04/03/76	0647:00	04/03/76	332	4	3o	Alice Springs
93	Boulia	Alice Springs	0811:00	04/03/76	0952:00	04/03/76	491	9	3-	Alice Springs
94	Alice Springs	Broken Hill	2253:00	07/03/76	0251:00	08/03/76	1108	10	6-	
95	Broken Hill	Condobolin	0402:00	08/03/76	0527:00	08/03/76	453	4	6o	
96	Condobolin	Canberra	0630:00	08/03/76	0708:00	08/03/76	199	3	6-	