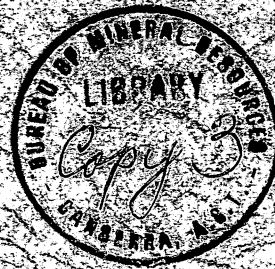


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REPORT 159

Isomagnetic Maps of the Australian Region for Epoch 1970.0

D. M. FINLAYSON

DEPARTMENT OF MINERALS & ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

REPORT 159

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D. M. FINLAYSON



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SUMMARY

Isomagnetic maps of the Australian region for the epoch 1970.0 are presented for seven magnetic components and their respective annual rates of change.

The maps are based mainly on the results from magnetic surveys completed in the years 1966-70 but observations from all surveys completed since 1955 have been used at various stages in the map compilation.

INTRODUCTION

The Bureau of Mineral Resources, Geology and Geophysics (BMR) maintains a continuing program of regional magnetic surveying in the Australian region to meet the general needs of the mining and petroleum industries, land surveyors, and navigators (land, sea, and air). Australian regional magnetic surveys were started in 1911 by the Carnegie Institution of Washington (Bauer & Fleming, 1915; Bauer et al., 1921) and surveys by various institutes have continued up until the present time. An analysis of the early Australian results was included in Carnegie Institution Publication No. 578 (Vestine et al., 1948).

The first isogonic map of Australia was produced for the epoch 1944.5 (Rayner, 1944). Subsequent isogonic maps have been produced for epochs 1950.5 (Holmes, 1951), 1955.5 (Wood & Everingham, 1953), 1960.5 (Parkinson, 1959), 1965.0 (van der Linden, 1965a), and 1970.0 preliminary (Finlayson, 1970a). The only complete set of isomagnetic maps for the Australian region published was for epoch 1957.5 (Parkinson & Curedale, 1960, 1961, and 1962).

Before the present series of maps all map compilations were based on second order magnetic survey data in which the corrections for diurnal variations in the field were derived from world-wide analysis (Vestine et al., 1948) or from the results of geomagnetic observatories as far off as 1 500 km. The desirability of making magnetic variograph recordings at each station to record not only diurnal variation but also other short period transient variations has always been recognized. This has been put into practice only with the setting up a network of first order magnetic stations, in the last three years.

Since 1955 a considerable amount of field work has been completed. Seventy-two first order regional magnetic stations have been established and surveyed to give precise data on the geomagnetic field and its rate of change in the Australian region (Finlayson, 1970b, 1971a, b, c; van der Linden 1965b, 1965c, 1968, 1969). In addition, a program of third order magnetic surveying has been undertaken which has been designed to map regional magnetic anomalies. At the time of production of the maps presented here, southern Queensland, New South Wales, and Victoria had been mapped in this way (van der Linden, 1970, 1971).

The maps presented in this report are derived mainly from the magnetic data obtained since 1955, but data from earlier surveys have been useful in defining trends.

Throughout this report centimetre-gram-second (CGS) units are used; the unit of magnetic intensity is 10^{-5} Oersted (= 1 gamma) and angular measurements are in degrees and minutes of arc. The magnetic components discussed and mapped are: horizontal intensity (H), north intensity (X), east intensity (Y), vertical intensity (Z), total intensity (F), inclination (I), declination (D), and their respective annual rates of change.

FIELD SURVEYS AND INSTRUMENTS

Any magnetic survey program must take into account both the spatial distribution of the geomagnetic field and its short and long term changes with time. Many aspects of mapping the spatial distribution of the field have been discussed by the World Magnetic Survey Board (WMS, 1967; Vestine, 1961). A power spectrum analysis of a single magnetic profile around the world indicates strong harmonic terms down to wavelengths of approximately 5 000 km, a weak spectrum between 3 000 km and 300 km, and an increase in power again in wavelengths from 150 km down to 15 km (Alldredge et al., 1963; Alldredge, 1965). The longer wavelengths are attributed to sources in the earth's core and the shorter wavelengths to sources in the earth's crust. The weak spectrum in the wavelength region 3 000 km to 300 km indicates a lack of geomagnetic field sources in the region of the earth from approximately 25 km to 2 900 km depth. Thus the magnetic field measured at the earth's surface is due mainly to the geophysical processes taking place in the earth's core (the main magnetic field) plus the effect of the earth's crust to a depth of approximately 25 km.

The changes with time that occur in the geomagnetic field can be separated broadly into long and short term changes. The majority of short term changes are caused by variations in the small contribution to the measured field due to ionospheric currents and have characteristic periods of 24 hours and less. Thus in field surveys they can be corrected for by making magnetic recordings for two or three days. The effects of magnetic storms, which may last for a week or more, can be estimated by referring to magnetic observatory records. The long term non-cyclic change (secular variation) is due to geophysical processes in the earth's core. The change is measured at magnetic observatories and at magnetic stations where magnetic observations are repeated every few years.

BMR has adopted two types of regional magnetic surveys for mapping purposes, with effective station intervals of approximately 500 km and 80 km, and thus should be able to resolve wavelengths greater than or equal to twice the station interval (Blackman & Tukey, 1958). The surveys should therefore be capable of mapping the regional components of the main magnetic field and the larger regional anomalies. Anomalies of smaller extent (local anomalies) can only be resolved by adopting more detailed survey methods.

First order magnetic surveys

Since 1965, BMR has established a network of 72 first order magnetic stations in the Australian region, which is designed so that repeat observations can be made for the foreseeable future (Plate 1). Many of the

stations are in the vicinity of earlier magnetic stations, thus providing valuable information on secular variation in the region.

The secular variation in the magnetic components is of the order of 10 gammas/year in intensity and 1 minute/year in arc (Plate 2), and thus the survey method must be capable of resolving such changes. BMR surveys achieve this by setting up a three-component fluxgate variograph (Seers, 1966) at each first order survey station visited and recording geomagnetic variations over a period of about 3 days, during which the associated control observations are made. Plate 3 illustrates the equipment used. The survey results give values of the H, D, and Z magnetic components which average out diurnal and other transient changes in the geomagnetic field over a 24 hour period. The systematic errors in the measurements of H and Z are within the limits ± 5 gammas and D within the limits ± 1.0 min.

Control observations in the first order surveys were made with the following types of instruments:

Horizontal Intensity (H) - La Cour Quartz Horizontal Magnetometer (QHM) or Horizontal Torsion Magnetometer (HTM). Both instruments operate on the same principles (La Cour, 1936). All instruments were compared before and after each survey against the Australian standard instruments kept by Toolangi magnetic observatory (van der Waal, 1966).

Total Intensity (F) - Elsec Proton Precession Magnetometer (PPM).

Crystal frequency is checked regularly. (Littlemore, 1960).

Declination (D) - Askania declinometer. (Askania, 1953). All instruments are compared against the Australian standard kept by Toolangi magnetic observatory. Azimuths were determined from sun observations and positions from data of the National Mapping Division of the Department of National Development and from the Department of Civil Aviation.

Control for the Z variograph record was derived from the H and F control observations mentioned above.

Third order magnetic surveys

Single readings of H, D, and F are made at 15 km intervals along road traverses so that on average there is a station within 40 km of all points in the region. The instruments used on the surveys are the same

as those used for control observations in first order survey work. In addition, a calibrated Wilde compass theodolite is often used for measuring declination (D). Azimuth control is obtained by making a single sun observation at each station and positions are read from 1:250,000 scale maps.

DATA PROCESSING AND CONTOURING

Data Preparation

The contoured values of the magnetic components on the maps accompanying this report are tied to the values of the field at the 81 stations listed in Table 1. Seventy of the stations are BMR first order magnetic stations, three are BMR magnetic observatories (Toolangi, Mundaring, and Port Moresby), two are magnetic observatories operated by the New Zealand government (Amberley and Apia), one is an observatory operated by the Indonesian government (Tangerang), and the remaining five (Djajapura, Honiara, Noumea, Ocean Island and Tibar) are stations from which comprehensive magnetic data are available. Two BMR first order stations (Rabaul and Aropa) have been omitted from the list because of the anomalous values of the field measured at these stations; however, they do provide valuable secular variation data. The locations of all these stations are shown in Plate 1.

Secular variation data are available at 65 of the stations in Table 1. Most of the BMR first order magnetic stations have a good record of re-occupation since 1955. Until 1968, the magnetic observations at these stations were of second order standard i.e. several observations of three magnetic components spread over one or two days but without variograph recording. Since 1968, all the stations have had a first order occupation as described above.

The H, D, and Z values observed since 1955 were plotted with respect to year of observation for all stations and a smooth curve drawn through the values of each component. These curves were extrapolated to give the 1970.0 values of H, D, and Z at all stations, and the gradients of the curves at 1970.0 were taken to be the secular variation for 1970.0.

From the H, D, and Z values for 1970.0 and their respective secular variations, the values for all other magnetic components were derived using the relations listed below.

Magnetic component:

$$X = H \cos D$$

$$Y = H \sin D$$

$$F = (H^2 + Z^2)^{1/2}$$

$$I = \arctan (Z/H)$$

Rate of change with time: $dX/dt = dH/dt \cdot \cos D - H \cdot \sin D \cdot dD/dt$

$$dY/dt = dH/dt \cdot \sin D + H \cos D \cdot dD/dt$$

$$dF/dt = (H \cdot dH/dt + Z \cdot dZ/dt)/F$$

$$dI/dt = (dZ/dt - (Z \cdot dH/dt)/H)/H \cdot (1 + Z^2/H^2)$$

Data from approximately 2 500 third order stations in eastern Australia have been used to produce detailed contouring in that region. Other data from approximately 250 second order survey stations throughout Australia which have been occupied since 1955 have been used to supplement the first order results. The year 1955 has been taken as the earliest from which data have been used in the production of the isomagnetic maps because good secular variation observations are available for updating to epoch 1970.0.

Data contouring

No internationally adopted procedures are laid down for the contouring and presentation of isomagnetic maps, although various suggestions regarding map scales and format have been made by the World Magnetic Survey Board (WMS, 1967; Vestine, 1961). BMR has adopted a Mercator projection base map on a scale 1:10,000,000 at the equator and has presented two sets of magnetic contours: (1) smoothed contours with detail dictated by the interval between first order magnetic stations, and (2) regional contours in eastern Australia with detail dictated by the effective interval between third order magnetic stations.

Secular variation maps

The H, D, and Z maps of secular variation are derived from data at 65 stations throughout the region (Table 1). Maps were hand-contoured for the epochs 1960.0 and 1970.0 and the data incorporated in a computer program used to update second and third order observed magnetic values to epoch 1970.0. The 1970.0 secular variation contours shown on the isomagnetic maps must be regarded as approximate because of the difficulty of accurate determination at stations which are not permanently occupied. The root mean square deviations of the observed values from the contoured values for H, D, and Z magnetic components are ± 5 gammas/year, ± 0.3 minutes/year and ± 4 gammas/year respectively. The secular variation values for the other magnetic components were derived from the H, D, and Z values.

Third order data contouring

The third order survey data were updated to epoch 1970.0 using secular variation data from first order surveys, and plotted by computer at scale 1:2,500,000 for all magnetic components. These plots were then hand-contoured, with the contours tied to the first order station data in the region. The resulting contours were then reduced to scale 1:10,000,000.

First order data contouring

The first order station data given in Table 1 were first contoured by hand for each magnetic component. Available supplementary information has been used to influence the contours. Thus in eastern Australia the contours were made consistent with the smoothed contours derived from equal area averaging of the third order data contours. In other regions, the contours were influenced by the 250 second order stations from which data were available. In the Tasman Sea and Arafura Sea regions, the D contours have been influenced by data from Qantas Airways Ltd (Qantas, 1968).

These contours were then tested against computer - contoured maps based on the first order station data. The computer contouring method has been developed by the BMR marine gravity group (Briggs, in prep.); it is based on fitting a two-dimensional spline through unevenly distributed data points. The hand-contoured maps were adjusted where necessary to be consistent with the computer contours. The computer-contouring program was not developed sufficiently to produce the final magnetic maps because of the uneven distribution of data in the oceanic areas around Australia.

The first order data were compared with the International Geomagnetic Reference Field (IGRF) for epoch 1970.0 (Cain et al., 1967). The results are tabulated in Table 2. The IGRF was also computer-contoured for all components and compared with the BMR contours. The ranges of differences are listed in Table 3.

Map presentation

The epoch 1970.0 isomagnetic maps for seven geomagnetic components and their annual rates of change are presented in the folio accompanying this Report.

By international agreement on the cartesian co-ordinate system used to define the magnetic components, the following sign conventions are observed.

- F - positive everywhere
H - positive everywhere
X - positive everywhere except in polar regions
Y - positive easterly, negative westerly
Z - positive in northern hemisphere, negative in southern hemisphere
D - positive easterly, negative westerly
I - positive in northern hemisphere, negative in southern hemisphere

The colour convention adopted for the map series is as follows:

Positive magnetic field values - red contours

Negative magnetic field values - blue contours

Positive annual change values - red stippled contours

Negative annual change values - blue stippled contours

Examples of the application of the chart data to estimate values at another epoch are given below.

Town	Date	Magnetic Component	Field 1970.0	Secular Change	Field at date
Birdsville	1/1/72	H	+29450	-60	+29390 gammas
"	"	Z	-46050	-16	-46066 gammas
"	"	F	+54620	-22	+54598 gammas
"	"	X	+29180	-64	+29116 gammas
"	"	Y	+3320	+6	+3326 gammas
"	"	D	+6° 28'	+2'	+6° 30'
"	"	I	-57° 30'	-4'	-57° 34'

DISCUSSION OF RESULTS

The isomagnetic maps of the various magnetic components give regional values of the geomagnetic field and are not designed to highlight magnetic anomalies with linear dimensions less than the effective station spacing. The extent of regional anomalies can be gauged from the third order contouring in the east Australian region; similar departures from the smoothed contours can be expected in other regions. Local anomalies may produce further differences from the smoothed contour field values but these can only be mapped effectively by detailed magnetic surveys. Aeromagnetic surveys give very useful information on where such local anomalies occur.

Although the magnetic component data from all individual survey stations are mutually consistent, the contours have been derived independently with no attempt to make them mutually consistent in terms of electromagnetic theory. This is in accordance with the principle that they should represent observed data.

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TABLE 1: EPOCH 1970.0 FIRST ORDER MAGNETIC STATION AND MAGNETIC OBSERVATORY DATA

STATION	SITE	LAT.	LONG.	H	$\frac{dH}{dt}$	D	$\frac{dD}{dt}$	Z	$\frac{dZ}{dt}$	F	$\frac{dF}{dt}$	X	$\frac{dX}{dt}$	Y	$\frac{dY}{dt}$	I	$\frac{dI}{dt}$
ALBANY	C	-34 56.9	117 48.3	22060	-22	-2.98	0.0	55050	-7 60142	-15 22030	-22 -1147	1	68.48	1.0			
ALEX BRIDGE		-34 9.8	115 11.8	22040	-18	-4.18	-0.4	55400	-4 59809	-10 21981	-18 -1606	-1	68.38	0.9			
ALICE SPRINGS	D	-23 46.5	133 51.4	30460	-30	4.77	0.4	44240	4 53712	-14 30355	-30 2533	1	55.45	1.7			
ALPHA		-23 39.3	146 35.2	30910		8.17		42550		52592		30596	4393		54.00		
AMBERLEY		-43 9.0	172 43.0	21790	-45	21.33	4.5	54700	-28 58880	-43 20297	-52 7926	10	68.28	1.8			
APIA		-13 48.0	138 13.0	34670	-20	12.14	1.4	20270	-12 40161	-23 33895	-23 7291	10	30.31	-0.0			
AYERS ROCK		-25 20.9	131 3.7	29220	-26	4.35	-0.9	46540	2 54953	-12 29136	-25 2216	-10	57.88	1.4			
BIRDSVILLE	B	-25 54.6	139 21.1	29440	-44	6.27	0.8	46010	10 54023	-15 29264	-44 3215	2	57.39	2.7			
BOULIA	B	-22 54.8	139 53.5	31150	-38	6.53	1.0	42250	23 52492	-4 30948	-39 3542	5	53.60	2.9			
BOURKE	D	-30 3.1	145 57.1	27140	-33	9.08	1.2	49530	3 56478	-13 26800	-34 4283	4	61.28	1.8			
CAMBRIDGE		-42 49.7	147 30.2	19000	-38	13.50	3.0	40100	-11 63032	-22 18475	-41 4435	7	72.46	1.8			
CARNARVON	C	-24 52.9	113 39.9	28000	-11	-1.15	-1.1	46010	-6 54631	-11 27994	-11 -562	-9	59.17	0.4			
CANBERRA		-35 17.3	149 18.0	24150	-30	11.70	1.9	53250	-5 59017	-17 23648	-32 4897	7	65.85	1.5			
CARNEGIE		-25 48.2	122 56.7	28400	-14	1.87	-1.1	47460	-6 56368	-12 28385	-14 927	-10	59.10	0.6			
CEDUNA	D	-32 7.8	133 42.8	25180	-25	4.88	0.6	53100	-3 58768	-13 25089	-25 2142	2	64.63	1.2			
COCOS IS		-12 11.9	96 50.1	33030	6	-2.97	-0.9	33200	-12 46832	-4 32986	6 -1711	-9	45.15	-0.9			
CONDOLIN	C	-33 6.0	147 8.1	25400	-36	9.75	1.6	52350	-1 58187	-17 25033	-37 4301	6	64.12	1.9			
COOKTOWN	B	-15 28.5	145 15.0	34610	-16	6.44	1.0	32090	18 47198	1 34389	-17 3906	8	42.84	1.8			
CHRISTMAS IS.		-10 25.1	105 40.6	35030	-3	0.67	0.4	30120	5 46199	1 35028	-3 410	4	40.69	0.4			
CROYDON	A	-18 12.9	142 15.2	33520	-28	6.17	0.6	36260	14 49380	-9 33326	-28 3603	3	47.25	2.1			
CUE	A	-27 25.3	117 52.5	26780	-16	-0.25	-1.4	49250	-6 56060	-13 26780	-16 -117	-11	61.46	0.7			
DALY WATERS	B	-16 16.4	133 22.4	34350	-23	4.32	-1.0	34790	15 46890	-5 34252	-22 2587	-12	45.36	1.9			
DARU	C	-9 5.2	143 12.3	36470	-18	5.32	0.8	23492	30 43381	1 36313	-19 3381	7	32.79	2.8			
DARWIN	D	-12 26.8	130 50.0	35710	-12	3.55	-1.6	29740	15 46472	0 35641	-11 2211	-17	39.79	1.4			
DERBY	B	-17 22.1	123 39.6	33390	-16	2.58	-1.3	37220	3 50002	-8 33356	-15 1503	-13	48.10	1.0			
EMU		-28 36.9	132 13.2	27160	-31	4.58	0.5	49630	12 56576	-4 27073	-31 2169	1	61.31	2.0			
ETADUNA		-28 43.1	138 38.0	27710	-22	6.72	-0.4	49090	-3 56371	-13 27520	-21 3243	-6	60.56	1.1			
ESPERANCE		-33 41.0	121 49.2	23190	-23	-0.15	-0.5	55430	-5 60085	-13 23190	-23 -61	-3	67.30	1.1			
EUCLA	B	-31 42.9	126 53.5	25080	-33	3.42	0.0	52770	-3 56427	-17 25035	-33 1496	-2	64.58	1.7			
GERALDTON	C	-28 46.6	114 42.1	25670	-13	-1.95	-1.0	50760	-12 56882	-17 25658	-13 -873	-7	63.17	0.4			
GILES		-25 2.1	126 17.8	29170	-20	3.40	-0.6	46290	0 54714	-11 29119	-20 1740	-6	57.78	1.1			
GNANGARA		-31 47.0	115 57.0	23820	-22	-2.97	-1.2	53490	-2 58554	-11 33788	-22 -1234	-7	66.00	1.1			
GOVE		-12 22.6	136 49.4	35960		4.83		28960	46171	35832		3028	38.85				
GRAFTON		-29 46.0	153 1.2	27700	-55	10.84	1.6	47930	3 56359	-25 27202	-56 5228	2	59.98	3.1			
GRANITES	B	-20 33.5	130 19.5	32020	-23	3.42	-0.5	40110	8 51480	-8 31963	-23 1910	-6	51.54	1.5			
GURNEY		-10 18.7	150 20.3	36120	-17	6.71	1.2	23930	23 43328	-1 35873	-18 4220	11	33.53	2.3			
HALLS CK	C	-18 14.1	127 40.0	33230	-15	2.73	-1.2	37990	10 50472	-2 33192	-14 1583	-12	48.82	1.2			
HOLLANDIA		-2 34.3	140 30.8	37190		4.15		14800	40027	37093		2678	21.70				
HONIARA		-9 25.4	160 2.8	35810		8.95		20460	41342	35374		5571	29.98				
INGHAM	B	-18 39.6	146 8.9	33240		7.18		36560	40412	32979		4165	47.72				

LAE	B	-6	43.7	147	0.1	36750	-19	6.03	1.5	19420	27	41556	-4	36547	-21	3861	14	27.83	2.7
LAVERTON	A	-28	25.5	122	24.7	26680		1.04		50360		57433		26676		484		62.32	
MACKAY	B	-21	10.1	149	10.9	32320	-21	8.40	1.2	39170	7	57783	-8	31973	-22	4721	8	50.47	1.4
MARYBOROUGH	B	-25	30.8	152	43.1	30200	-41	10.00	1.6	43440	8	54071	-17	29741	-43	5244	7	55.32	2.5
MEEKATHARRA		-26	36.8	118	32.7	27240		1.31		49030		56039		27233		623		60.94	
MILDURA	B	-34	14.3	142	5.1	24340	-30	8.53	1.9	54080	-2	59305	-14	24071	-32	3610	9	65.77	1.5
MONOTE		-2	4.0	147	25.4	37010	-13	5.09	0.5	42880	30	39187	-2	36864	-13	3244	4	19.19	2.9
MOREE	C	-29	30.0	149	53.0	27620	-50	10.08	1.9	48420	12	54918	-14	27194	-52	4834	6	60.40	3.0
MT VERNON		-24	13.8	118	14.2	28940	-14	0.63	-0.8	45880	0	54245	-7	28938	-14	318	-7	57.76	0.8
NAURU		-0	33.3	166	55.2	35240		9.53		7100		35948		34754		5844		11.39	
NEALE		-28	17.3	125	49.0	27080		2.15		48220		58304		27061		1016		60.68	
NEWCASTLE		-32	47.8	151	50.0	25870	-37	11.50	1.7	51400	-5	57543	-21	25351	-39	5158	5	63.28	1.8
NORFOLK IS		-29	2.5	167	56.2	29070		14.57		43760		52536		28135		7313		56.40	
OCEAN IS		-0	50.9	169	32.0	35610		9.62		6100		36129		35109		5951		9.72	
ONslow		-21	38.2	115	6.3	30100	-11	0.42	-0.2	43410	-3	52989	-9	30099	-11	221	-2	55.39	0.5
OPADATTA	B	-27	33.6	135	27.2	28360		5.35		48400		58097		28236		2644		59.63	
PARAFIELD		-34	47.5	138	38.6	23500	-30	7.57	1.7	55200	-2	60029	-14	23384	-31	3108	8	66.86	1.5
PORT HEDLAND	C	-20	18.8	118	36.7	31410	-10	1.14	-1.0	41500	7	52046	-0	31403	-10	647	-9	52.80	0.8
PORTLAND	B	-38	23.1	141	37.4	21570	-28	8.92	1.4	57560	-5	61469	-15	21309	-29	3345	4	69.46	1.4
PORT LINCOLN	C	-34	36.5	135	52.4	23730	-27	5.08	1.5	55420	2	60471	-9	23637	-28	2101	8	66.89	1.5
PORT MORESBY		-9	24.5	147	9.2	36210	-26	6.22	1.1	23030	33	44403	-3	35997	-27	3923	9	33.46	3.3
QUILPIE		-26	36.5	144	15.2	29170	-36	7.77	0.9	46190	11	54630	-10	28902	-37	3944	3	57.73	2.3
ROMA	B	-26	33.7	148	46.7	29500	-40	9.05	2.0	45340	10	54092	-13	29133	-42	4640	11	56.95	2.5
SWINDELLS		-21	4.9	123	25.3	31270		2.21		42020		52378		31247		1266		53.34	
TANGERANG		-6	10.0	106	38.0	37170	-5	1.05	-1.2	23900	1	44191	-4	37164	-5	621	-13	32.74	0.3
TIBAR		-8	34.0	125	28.0	36800				24500		44210						33.65	
TIBOOBURRA		-29	26.9	142	3.2	27400	-39	7.91	1.2	49410	6	58674	-14	27139	-40	3771	4	61.09	2.2
TODMORDEN		-27	8.4	134	45.2	28600	-34	5.00	0.5	47870	-2	55763	-19	28491	-34	2443	1	59.14	1.7
TOOLANGI		-37	32.0	145	28.0	22400	-32	10.62	1.8	56390	-5	60676	-16	22015	-34	4128	6	68.34	1.6
VANIMO		-2	41.9	141	18.3	37230	-8	4.24	0.4	14520	33	39961	5	37126	-8	2778	4	21.31	2.9
WARAG		-5	29.5	143	43.6	36880	-10	5.03	0.7	18080	30	41073	4	36734	-11	4234	7	26.12	2.6
WARRACKNABEAL		-36	15.1	142	24.3	23030	-32	9.28	1.1	55740	-3	61310	-15	22720	-33	3714	2	67.55	1.6
WEIPA		-12	41.1	141	54.4	35970		5.43		29520		46532		35809		3404		39.38	
WEWAK	D	-3	35.2	143	40.1	37230	-10	4.70	0.2	15430	30	40378	2	37105	-10	3051	1	22.77	2.7
WILCANNIA	D	-31	30.9	143	22.7	26120	-32	8.54	1.2	51380	8	57638	-7	25828	-33	3847	4	63.05	1.9
WILLIS IS		-16	17.8	149	58.5	34310	-25	7.70	1.3	32400	18	47190	-6	34001	-27	4507	10	43.36	2.2
WINTON	B	-22	23.9	143	3.5	31390	-35	7.02	0.6	41340	10	51917	-13	31155	-35	3846	1	52.79	2.2
WONARAH		-19	53.7	136	20.3	32530	-25	5.12	0.5	39230	15	57943	-4	32400	-25	293	2	50.33	1.9
WOOMERA		-31	6.1	136	46.9	25910	-37	6.12	1.3	51770	10	57892	-6	25762	-38	2742	6	63.41	2.2
WYNDHAM	C	-15	30.6	128	8.8	34380		3.05		34460		44677		34331		1829		45.07	
ZANTHUS	B	-31	2.2	123	34.1	25080	-26	1.15	0.4	52410	-6	52252	-17	25075	-26	583	2	64.51	1.2

Units:— H,Z,F,X,Y,

D,I

dH/dt, dZ/dt, dF/dt, dX/dt, dY/dt

dD/dt, dI/dt

— gamma

—degrees

—gamma/year

—min/year

TABLE 2: COMPARISON OF OBSERVED MAGNETIC DATA AND IGRF VALUES FOR EPOCH 1970.0

STATION	LAT,	LONG,	OBS H	CALC H	DIFF H	OBS D	CALC D	DIFF D	OBS Z	CALC Z	DIFF Z
ALBANY	C-34	56,9 117 48,3	22060	21931	129	-2,98	-2,91	-0,07	55950	56454	-504
ALEX BRIDGE	-34	9,8 115 11,8	22040	22210	-170	-4,18	-4,12	-0,06	55600	55729	-129
ALICE SPRINGS	D-23	46,5 133 51,4	30460	30594	-134	4,77	4,91	-0,14	44240	44251	-11
ALPHA	-23	39,3 146 35,2	30910	31082	-172	8,17	8,06	0,11	42550	42348	202
AMBERLEY	-43	9,0 172 43,0	21790	21890	-100	21,33	21,24	0,09	54700	54746	-46
ARIA	-13	48,0 188 13,0	34670	34601	69	12,14	11,72	0,42	20270	19146	1124
AYERS ROCK	-25	20,9 131 3,7	29220	29530	-310	4,35	4,25	0,10	46540	46388	152
BIRDSVILLE	B-25	54,6 139 21,1	29440	29610	-170	6,27	6,53	-0,26	46010	46080	-70
BOULIA	B-22	54,8 139 53,5	31150	31288	-138	6,53	6,29	0,24	42250	42469	-219
BOURKE	D-30	3,1 145 57,1	27140	27449	-309	9,08	9,19	-0,11	49530	49569	-39
CAMBRIDGE	-42	49,7 147 30,2	19000	19141	-141	13,50	13,79	-0,29	60100	60080	20
CARNARVON	C-24	52,9 113 39,9	28000	28174	-174	-1,15	-0,87	-0,28	46910	47017	-107
CANBERRA	-35	17,3 149 18,0	24150	24375	-225	11,70	11,72	-0,02	53850	53942	-92
CARNEGIE	-25	48,2 122 56,7	28400	28635	-235	1,87	1,94	-0,07	47460	47563	-103
CEDUNA	D-32	7,8 133 42,8	25180	25351	-171	4,88	5,31	-0,43	53100	53296	-196
COCOS IS	-12	11,9 96 50,1	33030	33215	-185	-2,97	-2,64	-0,33	33200	33234	-34
CONDOBOLIN	C-33	6,0 147 8,1	25400	25620	-220	9,75	10,34	-0,59	52350	52355	-5
COOKTOWN	B-15	28,5 145 15,0	34610	34626	-16	6,48	6,49	-0,01	32090	32055	35
CHRISTMAS IS,	-10	25,1 105 40,6	35030	35238	-208	0,67	0,43	0,24	30120	30172	-52
CROYDON	A-18	12,9 142 15,2	33520	33569	-49	6,17	6,23	-0,06	36260	36170	90
CUE	A-27	25,3 117 52,5	26780	27072	-292	-0,25	-0,08	-0,17	49250	49545	-295
DALY WATERS	B-16	16,4 133 22,4	34350	34295	55	4,32	4,38	-0,06	34790	34694	96
DARU	C -9	5,2 143 12,3	36470	36434	36	5,32	5,31	0,01	23492	23399	93
DARWIN	D-12	26,8 130 50,0	35710	35743	-33	3,55	3,80	-0,25	29740	29674	66
DERBY	B-17	22,1 123 39,6	33390	33429	-39	2,58	2,83	-0,25	37220	37236	-16
EMU	-28	38,9 132 13,2	27160	27552	-392	4,58	4,66	-0,08	49630	49924	-294
ETADUNNA	-28	43,1 138 38,0	27710	27888	-178	6,72	6,69	0,03	49090	49274	-184
ESPERANCE	-33	41,0 121 49,2	23190	23233	-43	-0,15	-0,14	-0,01	55430	55419	11
EUCLA	B-31	42,9 128 53,5	25080	25260	-180	3,42	3,42	0,00	52770	53305	-535
GERALDTON	C-28	48,6 114 42,0	25670	25780	-110	-1,95	-1,86	-0,09	50760	50980	-220
GILES	-25	2,1 128 17,8	29170	29540	-370	3,40	3,51	-0,11	46290	46284	6
GNANGARA	-31	47,0 115 57,0	23820	23931	-111	-2,97	-2,50	-0,47	53490	53739	-249
GQVE	-12	22,6 136 49,4	35960	35743	217	4,83	4,62	0,21	28960	28877	83
GRAFTON	-29	46,0 153 1,2	27700	27981	-281	10,88	11,15	-0,27	47930	47938	-8
GRANITES	B-20	33,5 130 19,5	32020	32177	-157	3,42	4,00	-0,58	40310	40666	-356
GURNEY	-10	18,7 150 20,3	36120	35946	174	6,71	6,84	-0,13	23930	24079	-149
HALLS CK	C-18	14,1 127 40,0	33230	33223	7	2,73	3,48	-0,75	37990	37949	41
HOLLANDIA	-2	34,3 140 30,8	37190	37447	-257	4,13	4,07	0,06	14800	14320	480
HONIARA	-9	25,4 160 2,8	35810	35840	-30	8,95	8,76	0,19	20660	20904	-244
INGHAM	B-18	39,6 146 8,9	33240	33406	-166	7,18	7,13	0,05	36560	36164	396

LAE	B	-6	43.7	147	0.1	36750	36654	96	6.03	5.71	0.32	19400	19521	-121
LAVERTON	A	-28	25.5	122	24.7	26680	26898	-218	1.04	1.35	-0.31	50860	50399	461
LACKAY	B	-21	10.1	149	10.9	32320	32342	-22	8.40	8.29	0.17	39170	38854	316
MARYBOROUGH	B	-25	30.6	152	43.1	30200	30302	-102	10.00	9.98	0.02	43640	43379	261
MEEKATHARRA	B	-26	36.8	118	32.7	27240	27670	-430	1.31	0.37	0.94	49030	48677	353
MILDURA	B	-34	14.3	142	5.1	24340	24528	-188	8.53	8.82	-0.29	54080	54230	-150
MOMOTE	C	-2	4.0	147	25.4	37010	36947	63	5.09	5.18	-0.09	12880	12850	30
MOREE	C	-29	30.0	149	53.0	27620	27978	-358	10.08	10.21	-0.13	48620	48289	331
MT VERNON	C	-24	13.8	118	14.2	28940	29132	-192	0.63	0.81	-0.18	45880	46097	-217
NAURU	C	-0	33.3	166	55.2	35240	35607	-367	9.53	9.14	0.39	7100	7090	10
NEALE	C	-28	17.3	125	49.0	27080	27301	-221	2.15	2.56	-0.41	48220	50062	-1842
NEWCASTLE	C	-32	47.8	151	50.0	25870	26115	-249	11.50	11.73	-0.23	51400	51174	226
NORFOLK IS	C	-29	2.5	167	56.2	29070	29142	-72	14.57	14.17	0.40	43760	43585	175
OCEAN IS	C	-0	50.9	169	32.0	35610	35502	108	9.62	9.60	0.02	6100	6784	-684
ONSLOW	C	-21	38.2	115	6.3	30100	30329	-229	0.42	0.48	-0.06	43610	43333	277
OODNADATTA	B	-27	33.6	135	27.2	28360	28435	-73	5.35	5.60	-0.25	48400	48410	-10
PARAFIELD	C	-34	47.5	138	38.6	23590	23896	-306	7.57	7.56	0.01	55200	55199	1
PORT HEDLAND	C	-20	18.8	118	36.7	31410	31474	-64	1.18	1.60	-0.42	41500	41479	21
PORTLAND	B	-38	23.1	141	37.4	21570	21643	-73	8.92	9.56	-0.64	57560	57792	-232
PORT LINCOLN	C	-34	36.5	135	52.4	23730	23808	-78	5.08	6.37	-1.29	55620	55362	258
PORT MORESBY	C	-9	24.5	147	9.2	36210	36226	-16	6.22	6.08	0.14	23930	23309	621
QUILPIE	C	-26	36.5	144	15.2	29170	29405	-235	7.77	7.99	-0.22	46190	46153	37
ROMA	B	-26	33.7	148	46.7	29500	29602	-102	9.05	9.20	-0.15	45340	45326	14
SWINDELLS	C	-21	4.9	123	25.3	31270	31471	-201	2.21	2.56	-0.35	42020	41995	25
TANGERANG	C	-6	10.0	106	38.0	37170	37223	-53	1.05	1.12	-0.07	23900	24036	-136
TIBAR	C	-8	34.0	125	28.0	36800	36984	-184	7.91	3.07	0.04	24500	24728	-228
TIBOOBURRA	C	-29	26.9	142	3.2	27400	27616	-216	7.91	7.87	0.04	49610	49567	43
TODMORDEN	C	-27	8.4	134	45.2	28600	28654	-54	5.00	5.36	-0.36	47870	48026	-156
TOOLANGI	C	-37	32.0	145	28.0	22400	22577	-177	10.62	11.00	-0.38	56390	56521	-131
VANIMO	C	-2	41.9	141	18.3	37230	37380	-150	4.28	4.21	0.07	14520	14424	96
WABAG	C	-5	29.5	143	43.6	36880	36977	-97	5.03	4.96	0.07	18080	18177	-97
WARRACKNABEAL	C	-36	15.1	142	24.3	23030	23191	-161	9.28	9.40	-0.12	55740	55943	-203
WEIPA	D	-12	41.1	141	54.4	35970	35569	401	5.43	5.50	-0.07	29520	28673	847
WEWAK	D	-3	35.2	143	40.1	37230	37154	76	4.70	4.70	-0.00	15630	15450	180
WILCANNIA	D	-31	30.9	143	22.7	26120	26393	-273	8.58	8.70	-0.12	51380	51460	-80
WILLIS IS	C	-16	17.8	149	58.5	34310	34313	-3	7.70	7.61	0.09	32400	32388	12
WINTON	B	-22	23.9	143	3.5	31390	31636	-246	7.02	6.98	0.04	41340	41387	-47
WONARAH	B	-19	53.7	136	20.3	32530	32718	-188	5.12	5.19	-0.07	39230	39140	90
WOOMERA	C	-31	6.1	136	46.9	25910	26252	-342	6.12	6.36	-0.24	51770	51958	-188
WYNDHAM	C	-15	30.6	128	8.8	34380	34494	-114	3.05	3.54	-0.49	34460	34247	213
ZANTHUS	B	-31	2.2	123	34.1	25080	25253	-173	1.15	1.32	-0.17	52610	52948	-338

Units:— H,Z —gamma
D —degrees

TABLE 3: DIFFERENCE BETWEEN 1970.0 IGRF AND BMR ISOMAGNETIC
MAPS

The values listed are the range of corrections to be applied
to IGRF maps to fit BMR maps.

Magnetic Component	Correction Range	Comments
H	-100 to -300 gammas	agreement in TPNG region
D	0 to -0.7°	approx. +1.0° Tasman Sea region
Z	+400 to -400 gammas	
X	-100 to -300 gammas	agreement in TPNG, Vic, Tas regions
Y	0 to -200 gammas	
F	0 to -300 gammas	
I'	0 to +0.5°	agreement in Southern Australia

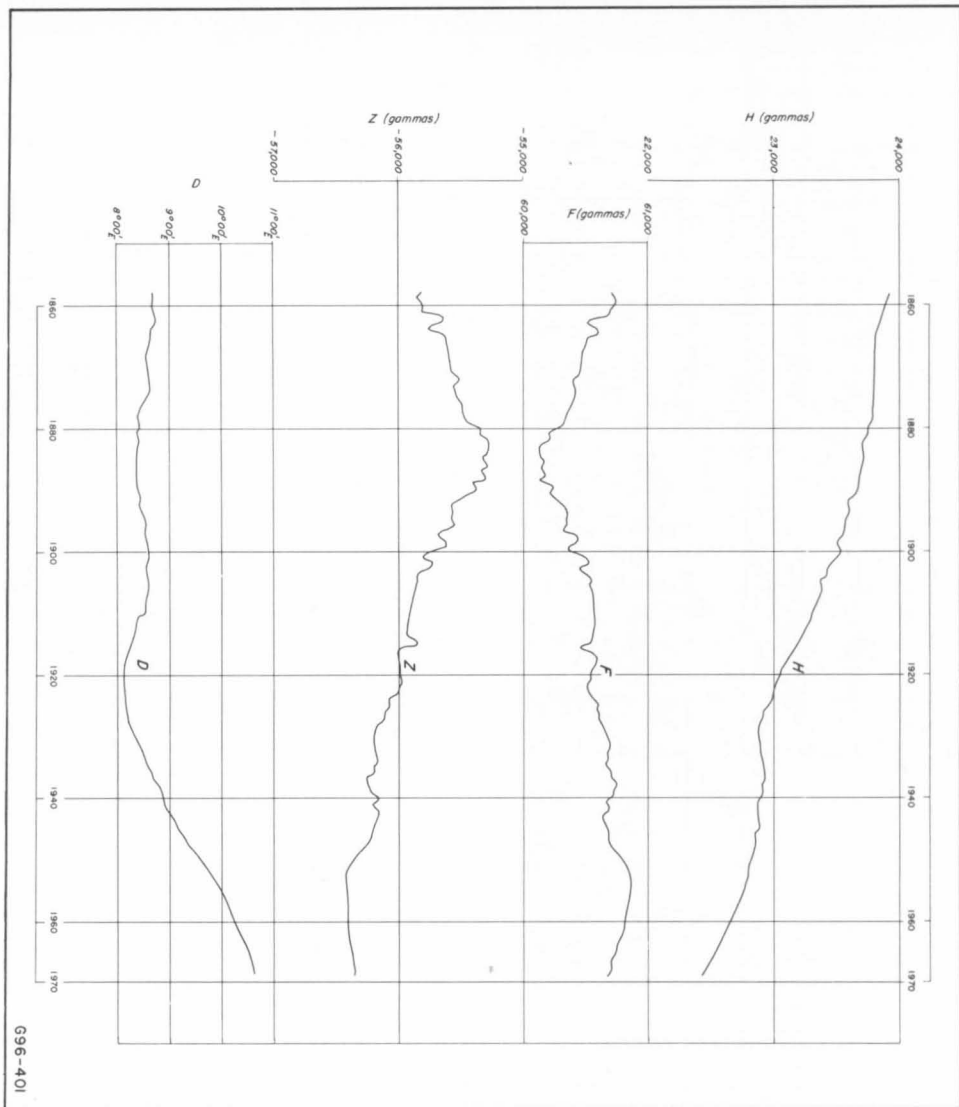
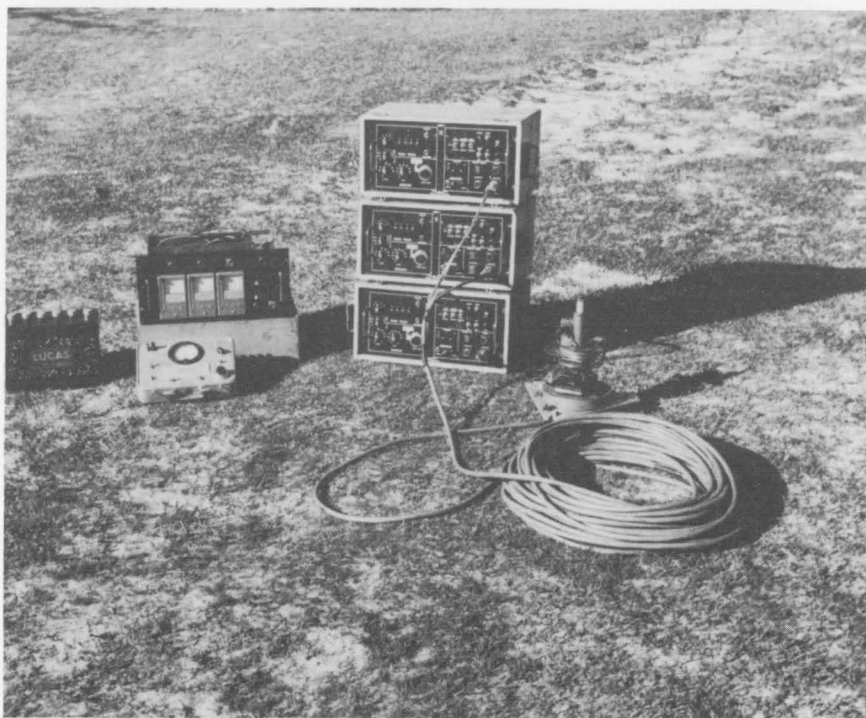


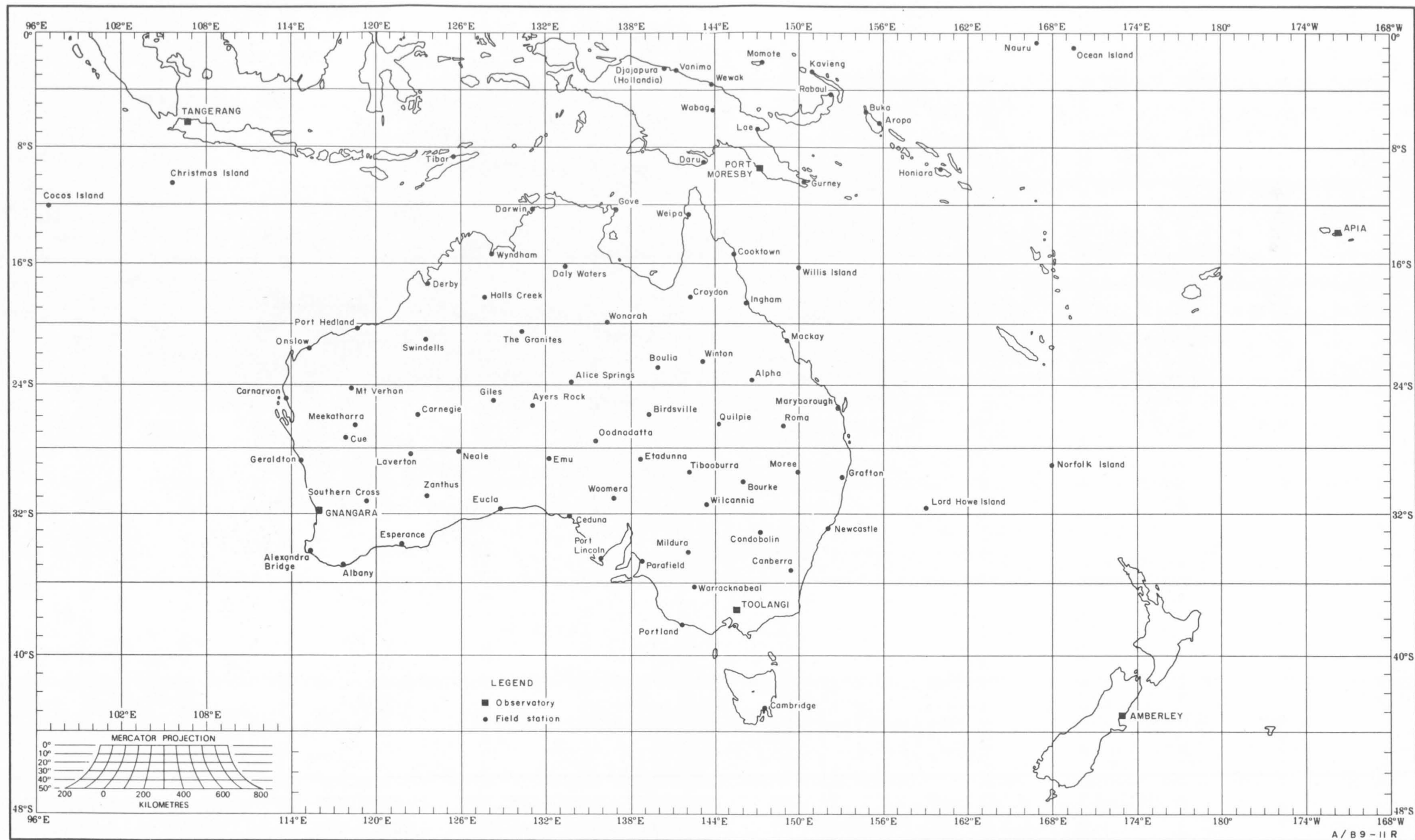
PLATE 3
FIELD INSTRUMENTS USED ON FIRST ORDER GEOMAGNETIC SURVEYS



Elsec proton precession magnetometer, Askania declinometer
and QHM magnetometer



BMR three-component fluxgate variograph



(Based on G20-14)

Z

Vertical magnetic intensity in gammas
(1 gamma = 10^{-5} centimetre-gram-second unit)
The wider stippled line indicates approximate annual change of vertical
magnetic intensity in gammas.
Red — Increasing algebraically
Blue — Decreasing algebraically

LEGEND

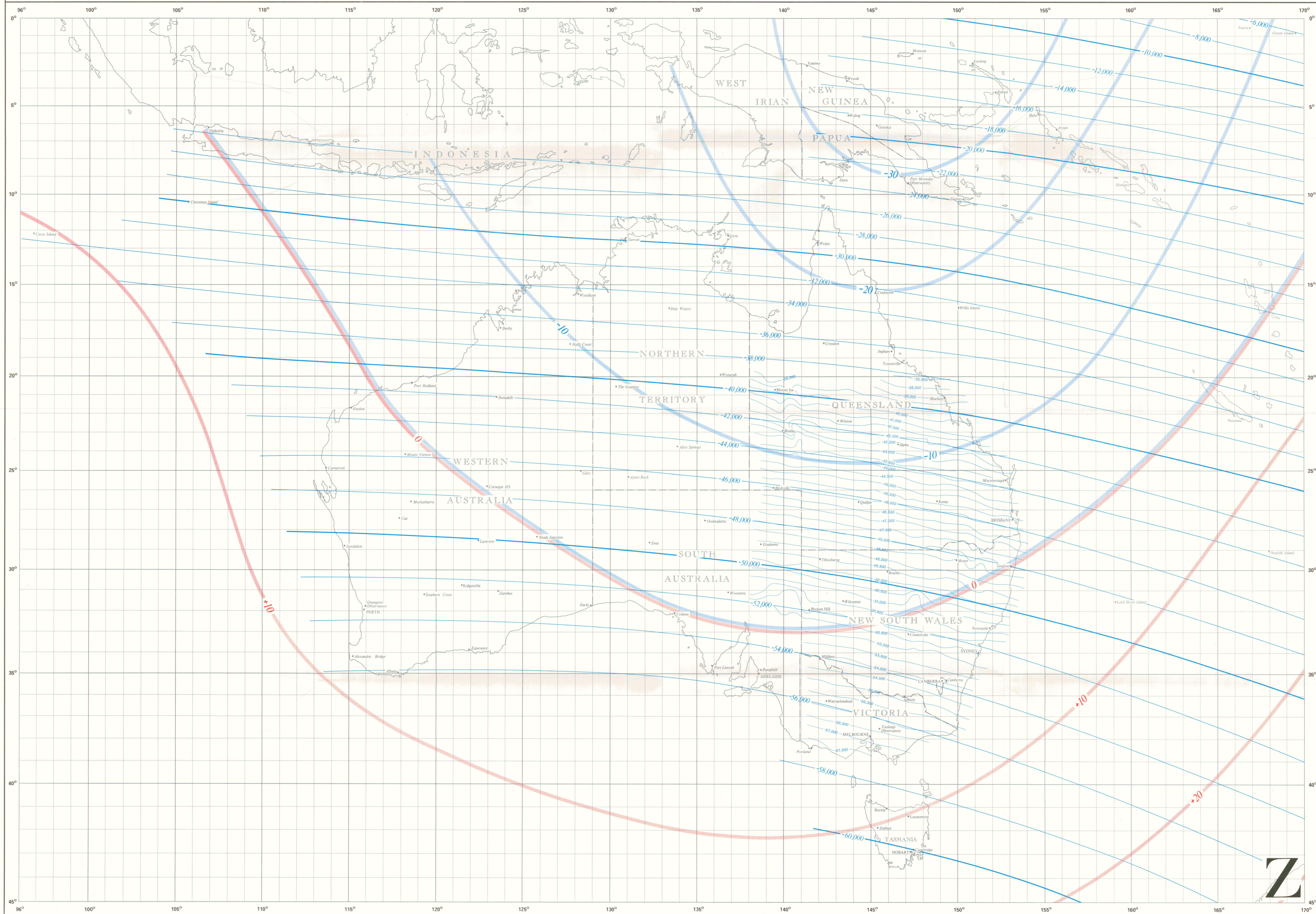
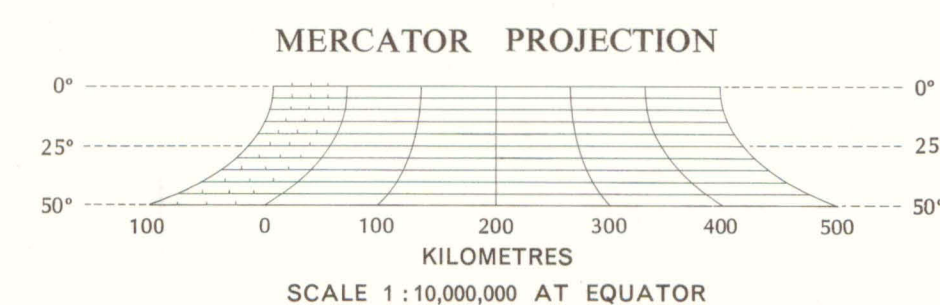
Geraldton • First-order regional magnetic station
Kavirang • Second-order regional magnetic station
ADELAIDE • City
Mount Isa • Town

AUSTRALIA AND SURROUNDING AREAS

VERTICAL MAGNETIC INTENSITY

EPOCH 1970.0

COMPILED BY GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS, CANBERRA



Z

Y

East magnetic intensity in gammas
(1 gamma = 10^{-5} centimetre-gram-second unit)
Red — positive (easterly) Blue — negative (westerly)
The wider stippled line indicates approximate annual change of east magnetic intensity in gammas
Red — Increasing easterly Blue — Increasing westerly

These contours in eastern Australia show the departures from the smoothed contours caused by regional magnetic anomalies; similar departures may be expected in other areas. Local anomalies may cause greater departures at any given location.

Legend
Geraldton • First-order regional magnetic station
Karrung • Second-order regional magnetic station
ADELAIDE • City
Mount Isa • Town

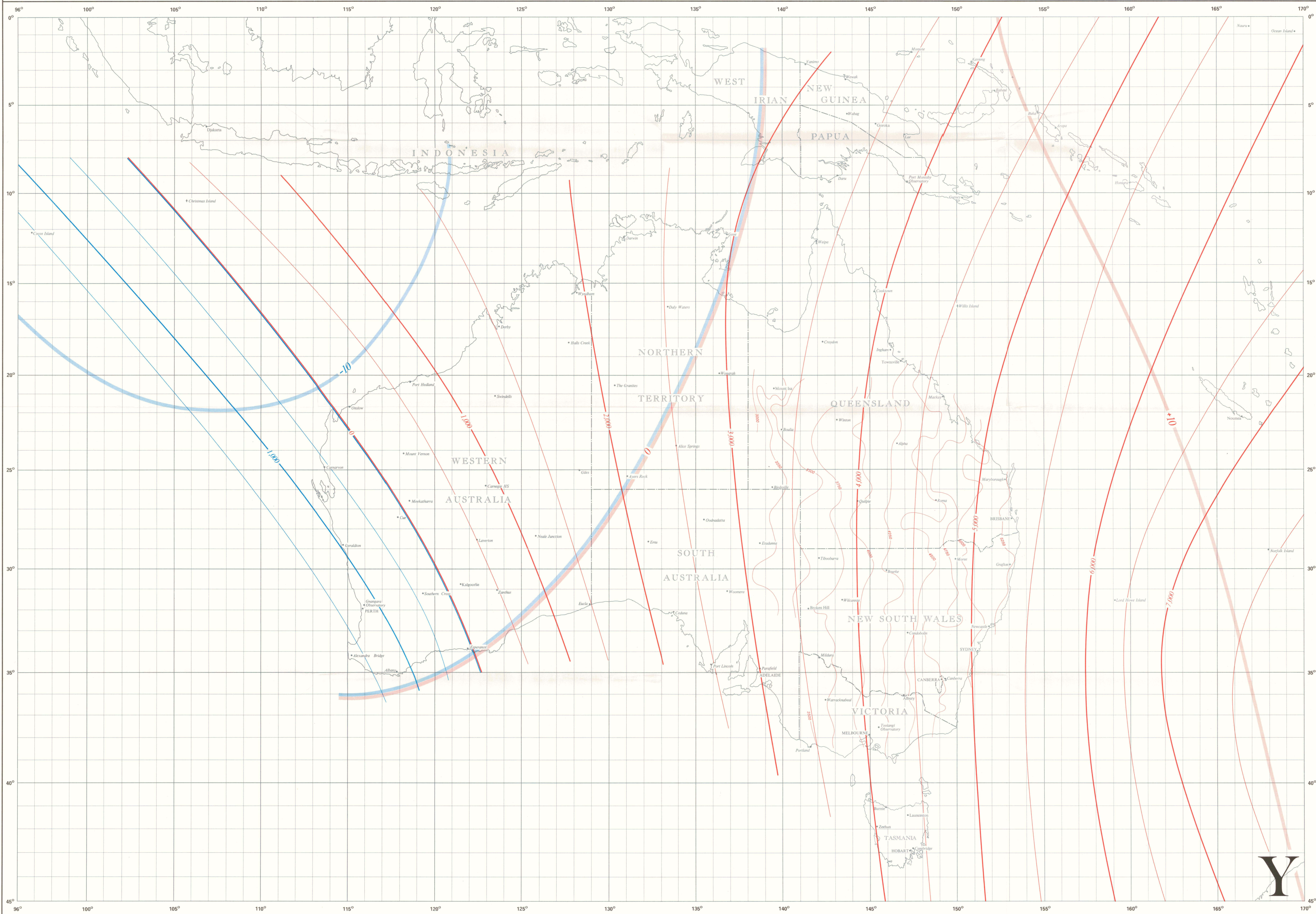
AUSTRALIA AND SURROUNDING AREAS

EAST MAGNETIC INTENSITY

EPOCH 1970.0

COMPILED BY GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS, CANBERRA

MERCATOR PROJECTION
0° 25° 50°
100 0 100 200 300 400 500
KILOMETRES
SCALE 1:10,000,000 AT EQUATOR



Y

X

North magnetic intensity in gammas
(1 gamma = 10^{-5} centimetre-gram-second unit)

The wider stippled line indicates approximate annual change of north magnetic intensity in gammas.
Red — Increasing
Blue — Decreasing

LEGEND

Geraldton • First-order regional magnetic station

Kavieng • Second-order regional magnetic station

ADELAIDE • City

Mount Isa • Town

These contours in eastern Australia show the departures from the smoothed contours caused by regional magnetic anomalies; similar departures may be expected in other areas. Local anomalies may cause greater departures at any given location.

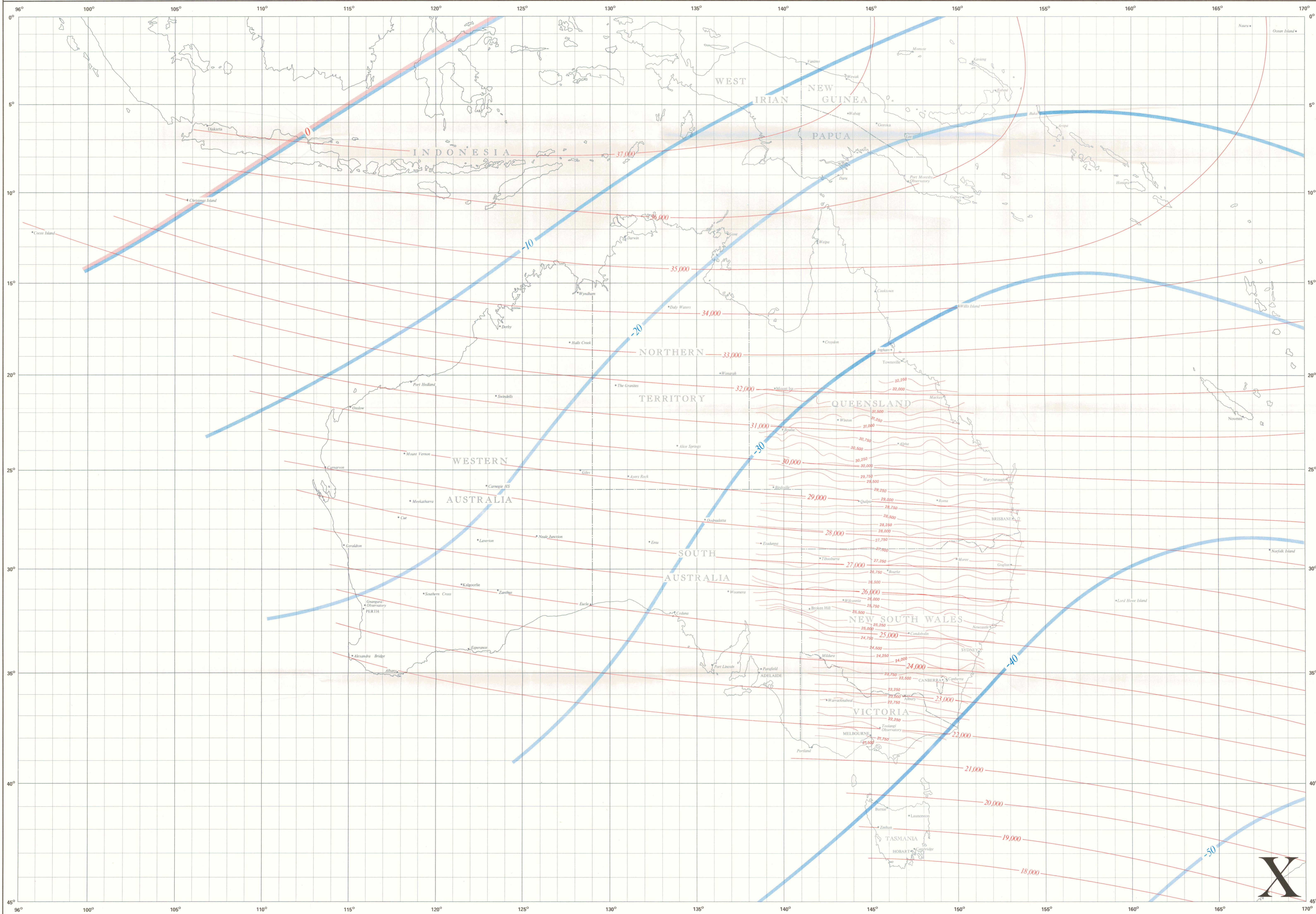
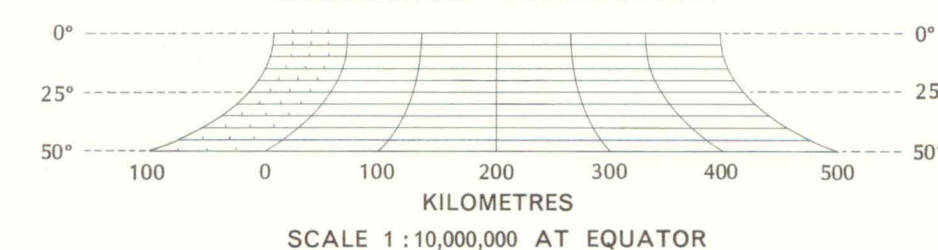
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AUSTRALIA AND SURROUNDING AREAS

NORTH MAGNETIC INTENSITY

EPOCH 1970.0

MERCATOR PROJECTION



X

I

Magnetic inclination in degrees

The wider stippled line indicates approximate annual change of magnetic inclination in minutes of arc

Red — Increasing algebraically
Blue — Decreasing algebraically

LEGEND

Geraldton • First-order regional magnetic station

Karrington • Second-order regional magnetic station

ADELAIDE • City

Mount Isa • Town

These contours in eastern Australia show the departures from the smoothed contours caused by regional magnetic anomalies; similar departures may be expected in other areas. Local anomalies may cause greater departures at any given location.

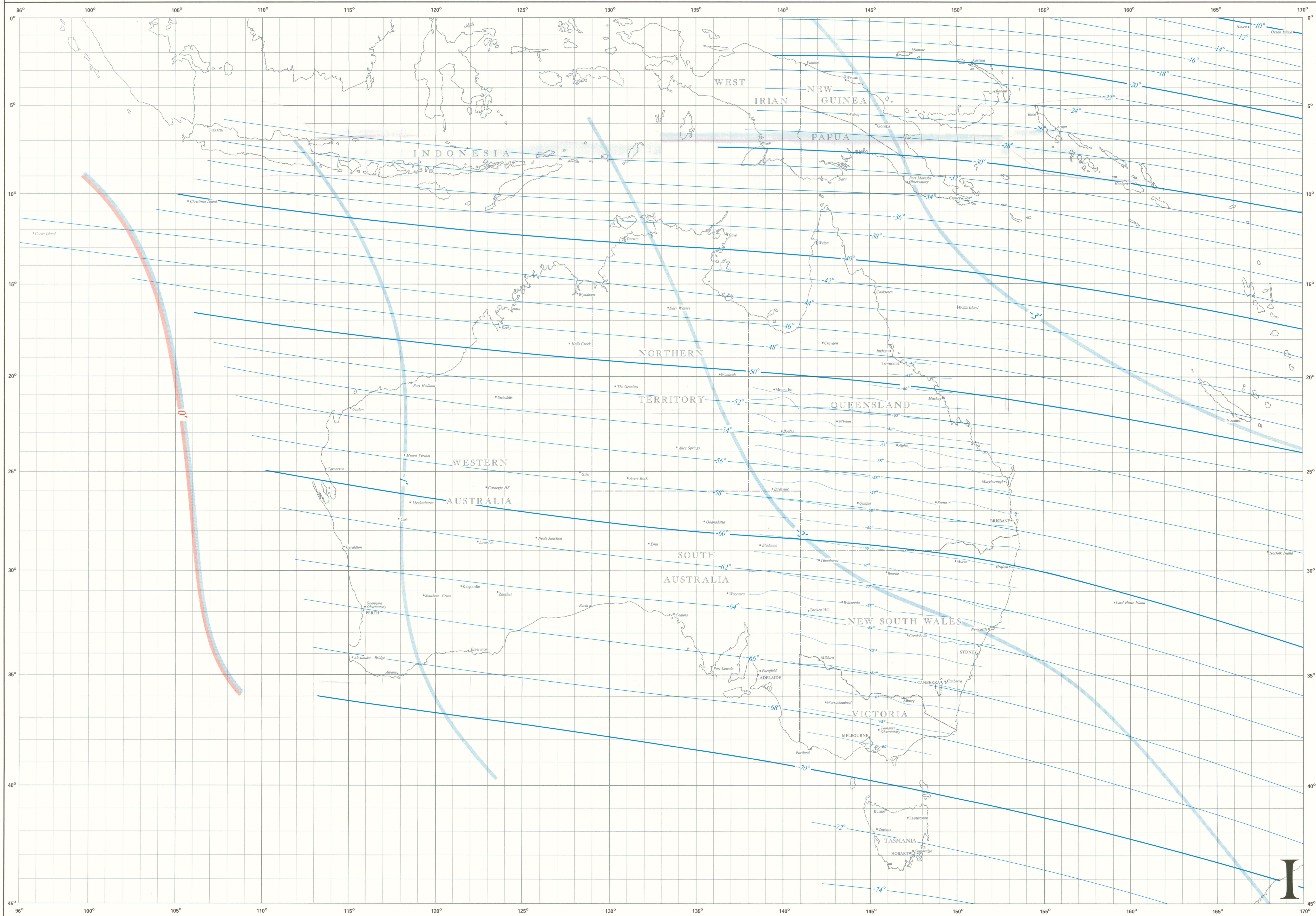
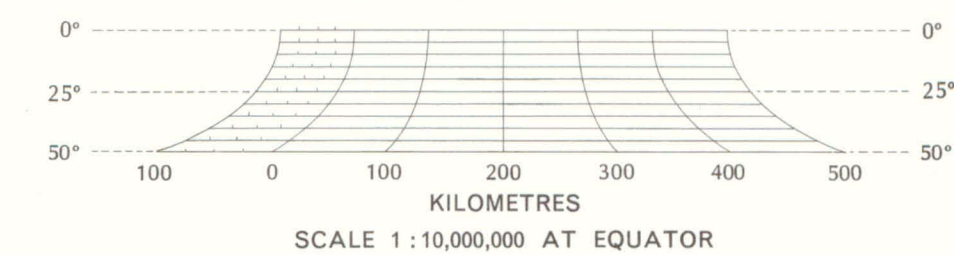
AUSTRALIA AND SURROUNDING AREAS

MAGNETIC INCLINATION OR DIP

EPOCH 1970.0

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MERCATOR PROJECTION



I

H

Horizontal magnetic intensity in gammas
(1 gamma = 10^{-5} centimetre-gram-second unit)
The wider stippled line indicates approximate annual change of horizontal magnetic intensity in gammas.
Red — Increasing
Blue — Decreasing

LEGEND

Geraldton * First-order regional magnetic station
Karrington * Second-order regional magnetic station
ADELAIDE * City
Mount Isa * Town

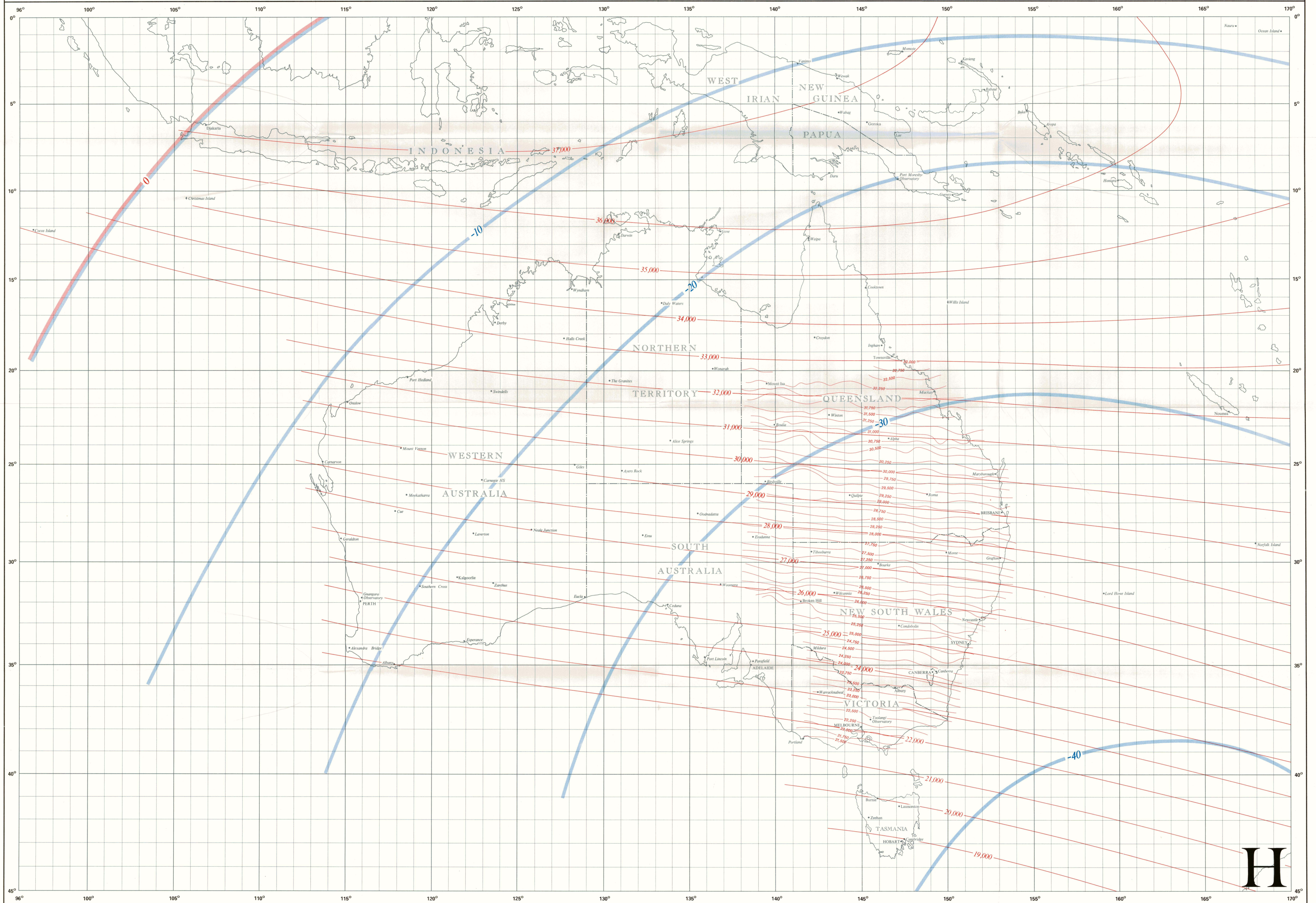
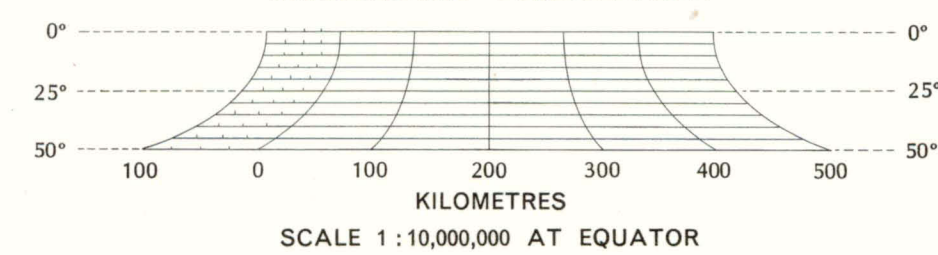
AUSTRALIA AND SURROUNDING AREAS

HORIZONTAL MAGNETIC INTENSITY

EPOCH 1970.0

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MERCATOR PROJECTION



H

F

LEGEND

Total magnetic intensity in gammas
(1 gamma = 10^{-5} centimetre-gram-second unit)

The wider, stippled line indicates approximate annual change of total magnetic intensity in gammas.

Red — Increasing
Blue — Decreasing

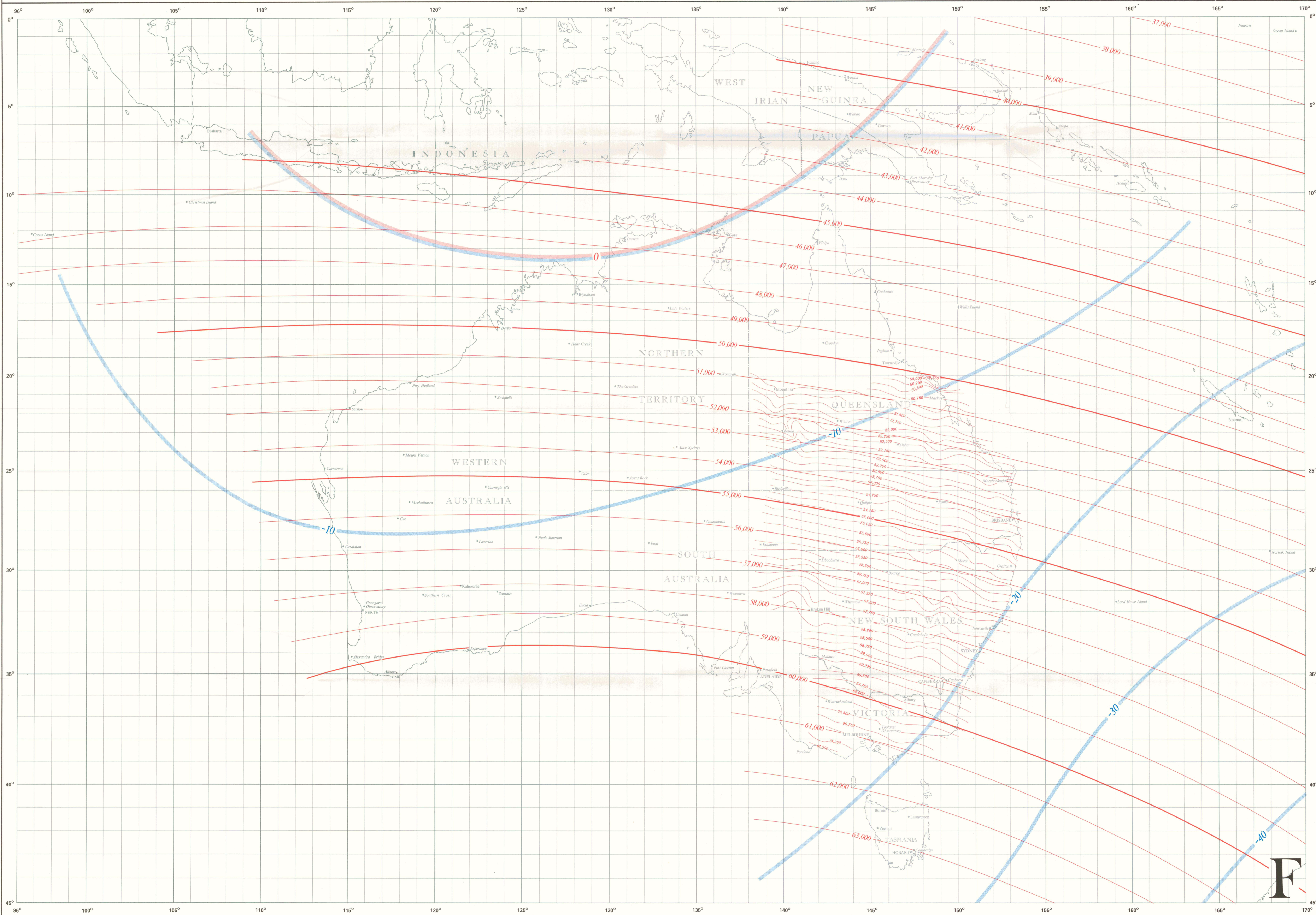
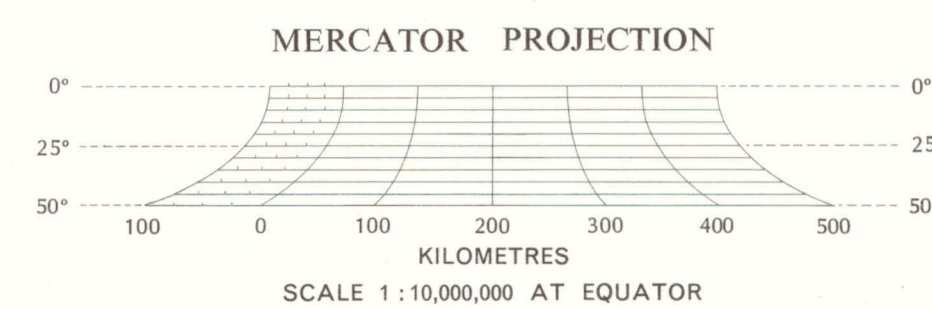
Geraldton • First-order regional magnetic station
Karrington • Second-order regional magnetic station
ADELAIDE • City
Mount Isa • Town

AUSTRALIA AND SURROUNDING AREAS

TOTAL MAGNETIC INTENSITY

EPOCH 1970.0

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F

D

Magnetic declination in degrees
Red — East declination
Blue — West declination
The wider stippled line indicates approximate annual change of magnetic declination in minutes of arc
Red — Increasing easterly
Blue — Increasing westerly

LEGEND

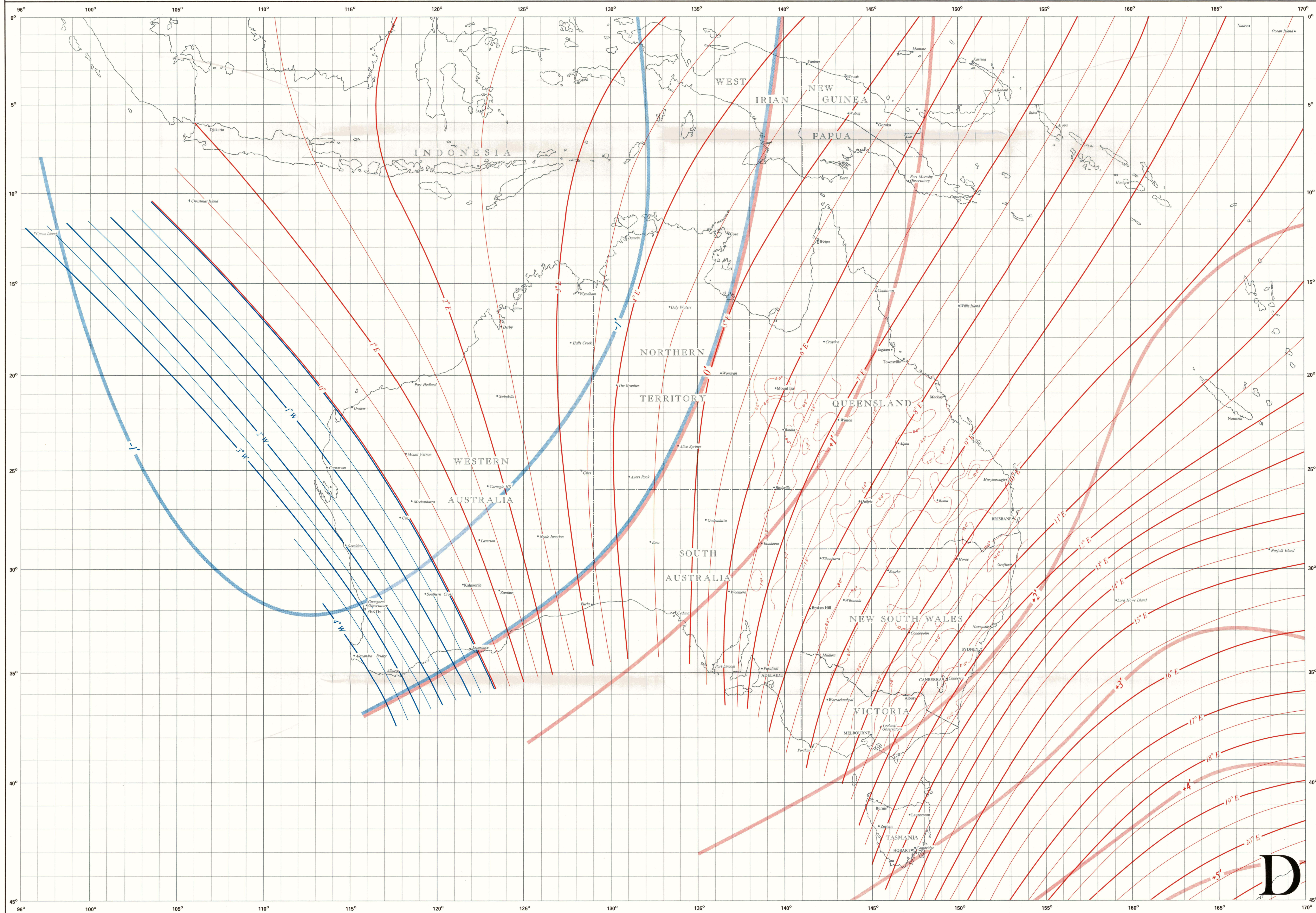
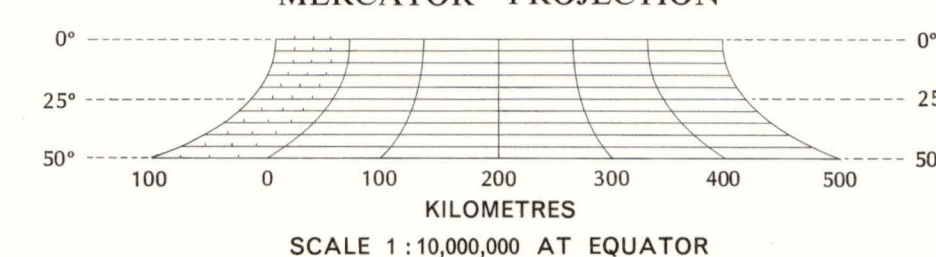
Blue — West declination
Blue — Increasing westerly

Geraldton * First-order regional magnetic station
Karratha * Second-order regional magnetic station
ADELAIDE * City
Mount Isa * Town

AUSTRALIA AND SURROUNDING AREAS
MAGNETIC DECLINATION OR VARIATION
EPOCH 1970.0

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MERCATOR PROJECTION



D