COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1966/87

SECULAR VARIATION OF THE MAGNETIC FIELD, AUSTRALIA

1915-1965

by

J. van der LINDEN

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SUMMARY

Information about the secular variation of the magnetic field in Australia can be derived from 20 field magnetic stations as well as the magnetic observatories at Watheroo and Toolangi. At Toolangi (or at Melbourne before the Toolangi observatory was built) changes in the direction of the magnetic field are available as far back as 1858.

Isoporic charts constructed from this information indicate considerable rotation of the D isopors. The westward drift of the magnetic declination is greater in the south than in the north. The westward drift of the H isopors was interrupted during 1915-45 by a south-easterly drift of a positive focus.

1. INTRODUCTION

In 1962 and 1963 the Bureau of Mineral Resources, Geology and Geophysics, established a network of first-order magnetic stations over Australia (van der Linden, 1965a & 1965b). The object of this network is to establish a basis for more accurate measurements of the secular variation of the elements of the geomagnetic field.

Twenty of these stations were repeat stations and had been occupied a number of times since they were first established in the 1912-1914 period by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

For each field station and also for the magnetic observatories at Toolangi and Watheroo, graphs are presented showing the variation with time of the measured or derived magnetic elements, declination (D), horizontal intensity (H), and inclination (I). The positions of the stations are shown in Plate 1.

Based on these graphs, isoporic charts have been drawn showing :

(a) The secular variation of D and H for ten-year periods from 1915 to 1965.

(b) The secular variation of the vertical intensity (Z) and inclination (I) for the period 1955 to 1965.

(c) The overall secular variation during the period 1912 to 1962 of each element D, H, I, and Z.

2. SOURCES OF DATA

The graphs and isoporic charts are based on observations at 20 first-order field stations reoccupied in the 1962 and 1963 surveys.

Values of earlier observations were obtained from publications by Bauer and Fleming (1915), Bauer, Fleming, Fisk, Peters, and Barnett (1921), Fisk (1927), and Wallis and Green (1947) and from reports and records of the Bureau of Mineral Resources, Geology and Geophysics.

The yearly mean values resulting from continuous recordings at the magnetic observatories at Toolangi and Watheroo provided accurate data for the construction of graphs of secular change at these places. The magnetic observatory at Watheroo was replaced by Gnangara, about 80 miles further south, in 1958. During 1958 both observatories were in operation.

3. TREATMENT OF DATA

Field stations

For each field station, graphs showing the variation of the magnetic elements D, H, and I were drawn smoothly connecting the observed or derived values at known epochs.

At some stations, there was too large a time lapse between repeat observations. The rate of change of the magnetic elements is not constant with time. To allow for this non-linearity, graphs at stations with large time lapses were drawn to conform in shape to the graphs at the nearest magnetic observatory or the nearest magnetic stations having more information. When the interval between observations exceeds five years, the graphs represent the values of the elements with considerable uncertainty.

Observatories

Similar graphs for Toolangi and Watheroo were drawn by connecting the yearly mean values of D, H, and I for each observatory. The graphs for

Watheroo were extended from 1958 to 1962 by using the values from the Gnangara observatory corrected for station difference. The relatively short distance (80 miles) between the observatories allows this extrapolation.

By plotting the yearly values of D and I at Toolangi from 1958 to 1962 an illustration of the variation of the direction of the vector field was obtained.

Isoporic charts

Secular variation. From 1915 to 1935, there were more changes in secular variation in D and H than in the following years. For this interval the rate of change per year was scaled from the graphs of each station for $2\frac{1}{2}$-year periods.

For 1935 to 1965 the rate of change was scaled for the periods 1935-45, 1945-55, and 1955-65. For the last period the secular variations of I and Z were also scaled or derived.

For each element the secular variation values were plotted and charts were drawn showing the isopors (lines of equal magnetic change) in Australia. The charts for the $2\frac{1}{2}$-year periods were used as a basis to draw charts of the mean value of secular variation for the periods 1915-25 and 1925-35.

Total change. The differences of the observed or derived value between 1912 and 1962 for each magnetic element D, H, I, and Z were plotted and charts were drawn showing the isopors of the total change over Australia during this fifty-year period.

For D, a chart was produced showing bar diagrams at each magnetic station and observatory. Each bar represents the magnitude of the secular change every successive ten years of the fifty-year period.

4. PRESENTATION OF DATA

All data are presented by graphs and charts. The positions of the magnetic stations and observatories of which data are used are shown in Plate 1.

In Plates 2 to 23, graphs are presented showing the variation of the magnetic elements D, H, and I from 1912 to 1962 at each of the twenty field stations and at the obaervatories at Toolangi and Watheroo. Plate 24 shows the variation from 1858 to 1962 of the direction of the total intensity at Toolangi.

Secular and total variation charts are shown in Plates 25 to 33.

5. DISCUSSION OF RESULTS

The graphs and charts depict the history, over the last fifty years, of the change with time of the components of the magnetic field over Australia.

With the exception of the two observatories, no accurate assessment of the secular variation is obtained. The time lapses between repeat observations have been too great at many field stations. The interpolations necessary allow only a generalised picture of the secular change to be shown on most of the graphs.

However, a broad outline has been obtained and the graphs can serve as a basis for the isoporic charts. These give a fairly good indication of the mean rate of secular variation of D and H during ten-year periods from 1915 to 1965, of the total change in D, H, I, and Z over the last fifty years, and of the mean rate of secular variation of I and Z in the last decade.

Declination

During the period 1915-25 the secular variation of D was small. There was a weak negative change over eastern Australia and a small positive change (change of D towards the east) of two minutes of arc in the most western part.

In the following periods the secular variation was positive over Australia, the positive change becoming stronger. The strongest gradient was in 1945-55, when the secular variation varied from 0 in the north to +6 minutes per year in Tasmania.

The pattern of the isopors shows an anti-clockwise movement, which is most apparent from 1925 to 1955. In Plate 33 the bar diagrams at each magnetic station show the values of mean secular variation and the relation to each decade.

The total change over fifty years (Plate 27) ranges from 10 minutes/year eastward in the far north to 150 minutes/year eastward in Tasmania, a gradual change with the isopors almost parallel in an east-west direction.

In Australia the isogonic lines (lines of equal magnetic declination) are in a north-south direction in a fan-like pattern. The apex of the fan is in Antarctica.

An eastward change of declination means that an isogonic line will move westward. The total change chart indicates that during the last fifty years the westward drift of the isogonic lines was much greater in the south than in the north. For example, the plus-five-degrees isogon drifted about **75 miles, or 1 degree of longitude, to the west in latitude 10°S and about 300 miles, or 5 degrees of longitude, to the west in latitude 40°S.**

Horizontal intensity

From 1915 to 1955 (Plates 28 to 30) the pattern of the H isopors was strongly influenced by a positive zone. This was situated near Java during 1915-25 and expanded over Australia in a south-easterly direction until 1945-55. From then it moved to the south-west away from Australia.

This expansion divided a negative zone, which was over Australia in 1915-25, into two parts. The south-western part moved to the south-west and is off the charts in 1935-45. The eastern part remained stationary, but when the positive zone began its westward swing in 1945-55, it also moved to the west and formed a negative focus of -20 gammas/year near the east coast of Australia. In 1955-65, the positive zone has moved west over the Indian Ocean and a negative zone was well established in Australia, with a focus of -30 gammas/year in the north.

The foci of the H isopors normally have a westward drift. This was interrupted during 1915-1945 by the south-easterly drift of a positive focus. This caused an inflection in most of the plots of H as a function of time.

As with the isopors of D, the isopors of H also have a tendency to turn anti-clockwise.

The total change over fifty years (Plate 30) indicates a decrease in horizontal intensity of 800 gammas along the north-east coast, gradually decreasing to 300 gammas along the west coast. This indicates a rotation of H isodynamic lines about a point in the Indian Ocean.

Inclination and vertical intensity

The secular variation chart for inclination for 1955-65 (Plate 31) shows an area of about +3 minutes per year (inclination increases negatively by three minutes per year) in the north. The plus-one-minute isopor is approximately coincident with the coastline over the southern part of Australia. The total change over fifty years ranges from +100 minutes in the north to +40 minutes in Tasmania. This indicates a separation of the isoclinic lines, which

run roughly east-west.

The secular variation chart for vertical intensity for 1955-65 (Plate 32) shows an isopor of +35 gammas/year in the north-west. The isopors gradually diminish to -15 gammas/year in the south-east. As with inclination, the vertical intensity is negative in most of the southern hemisphere; an increase thus means increasing negatively. The total change over fifty years ranges from +400 gammas along the coast of New South Wales to +1600 gammas along the west coast of Australia. This pattern indicates a rotation of Z isodynamic lines about a point in the Pacific Ocean.

6. FUTURE WORK

More control stations and reoccupations every five years are planned.

New instruments will be introduced in the 1966 field season. A three-component (D, H, and Z) fluxgate magnetograph is being developed to enable continuous recording of the magnetic field during the reoccupation of a field station. The magnetograph will be standardised at each field station by observations with a declinometer, a QHM, and a proton magnetometer. The vertical intensity will be derived from the proton magnetometer readings and H-scalings from the fluxgate magnetograph.

7. REFERENCES

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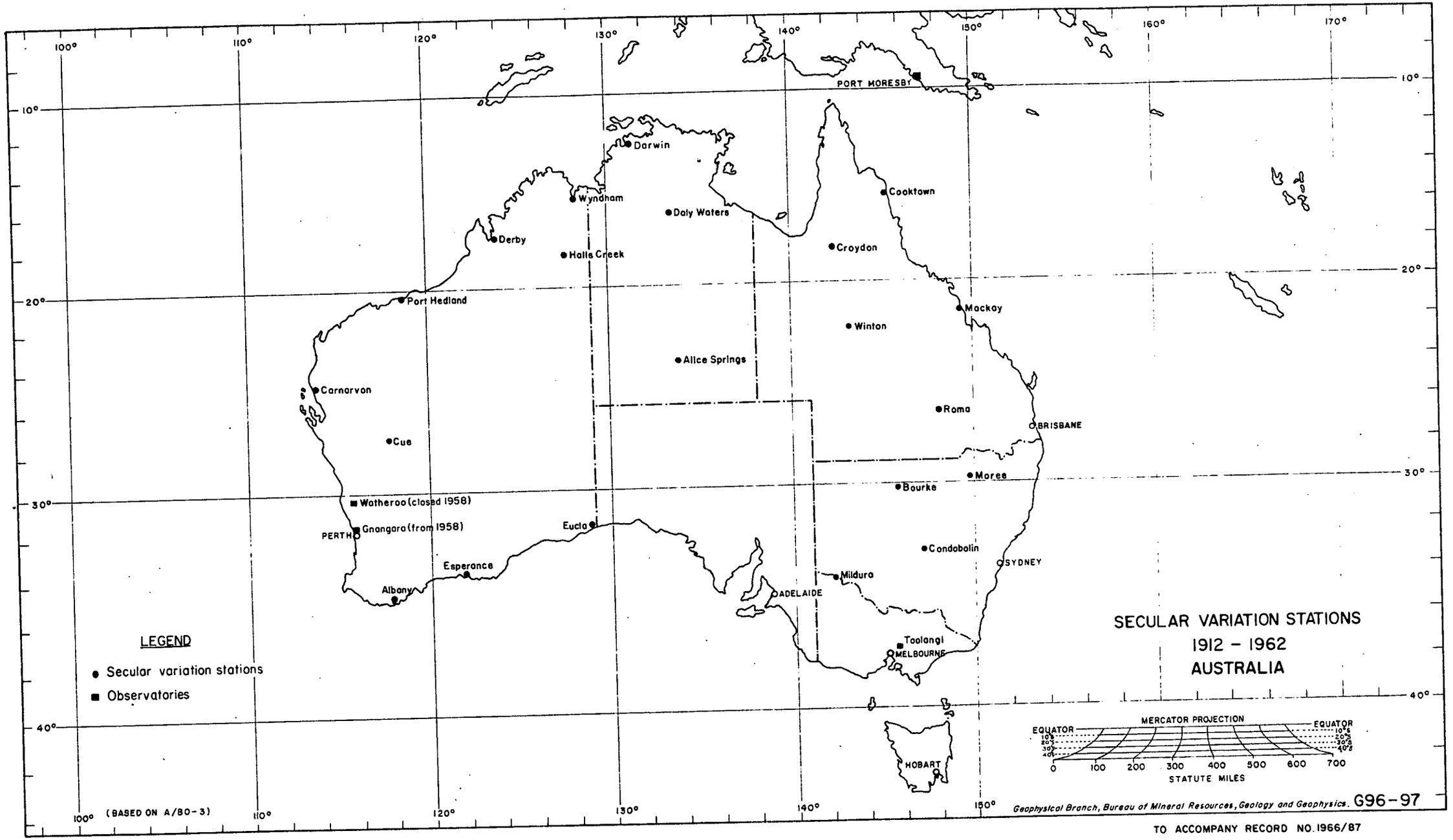
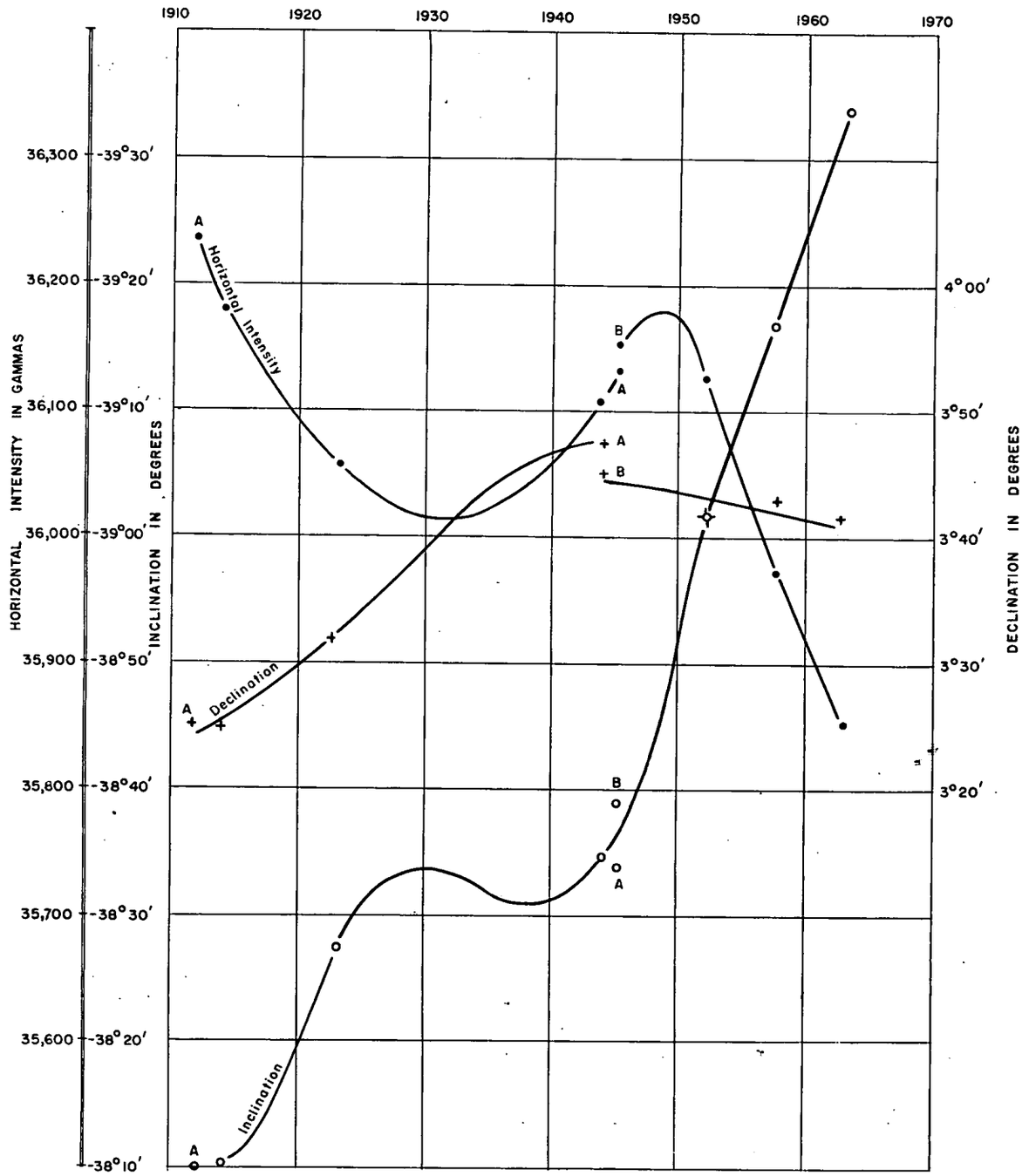

100°
110°
120°
130°
140°
150°
160°
170°
10°
20°
30°
40°
PORT MORESBY
Darwin
Wyndham
Daly Waters
Cooktown
Derby
Halls Creek
Croydon
Port Hedland
Mackay
Winton
Alice Springs
Carnarvon
Roma
BRISBANE
Cue
Moree
Bourke
Watheroo (closed 1958)
Gnangara (from 1958)
PERTH
Eucla
Condobolin
SYDNEY
Esperance
Mildura
Albany
ADELAIDE
Toolangi
MELBOURNE
HOBART
LEGEND
Secular variation stations
Observatories
(BASED ON A/80-3)
SECULAR VARIATION STATIONS
1912 – 1962
AUSTRALIA
MERCATOR PROJECTION
EQUATOR
EQUATOR
0
100
200
300
400
500
600
700
STATUTE MILES
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. G96-97
TO ACCOMPANY RECORD NO. 1966/87
PLATE 1

PLATE 2



Variation of Magnetic Elements at DARWIN NT between 1911 and 1962

A Latitude 12°26·7' S.
Longitude 130°50·0' E.

B Latitude 12°26·7' S
Longitude 130°49·9' E

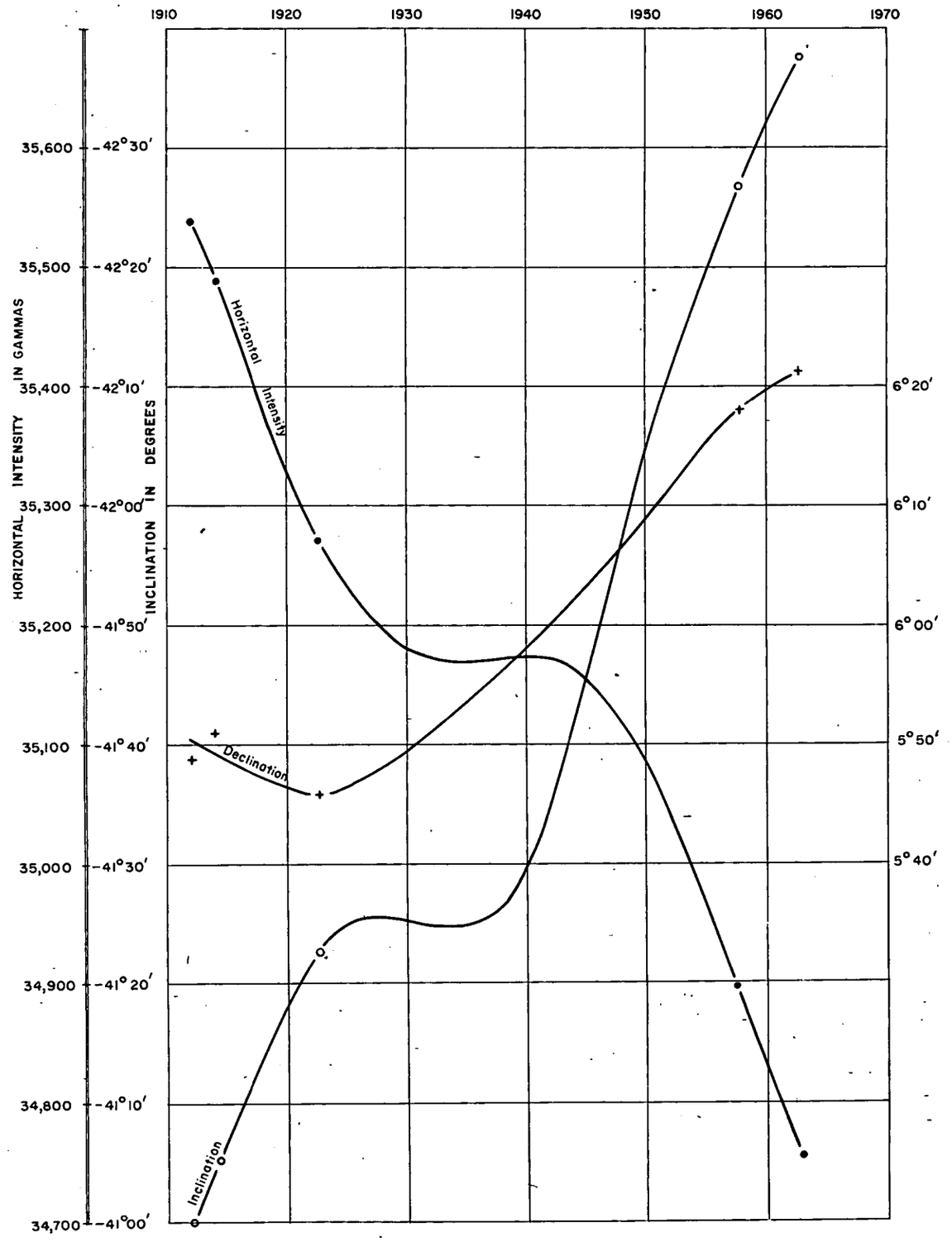
(Based on G96-71

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-127

TO ACCOMPANY RECORD NO. 1966/87

PLATE 3



Variation of Magnetic Elements at COOKTOWN QLD between 1912 and 1962

Latitude 15°28·6′ S.
Longitude 145°14·8′ E.

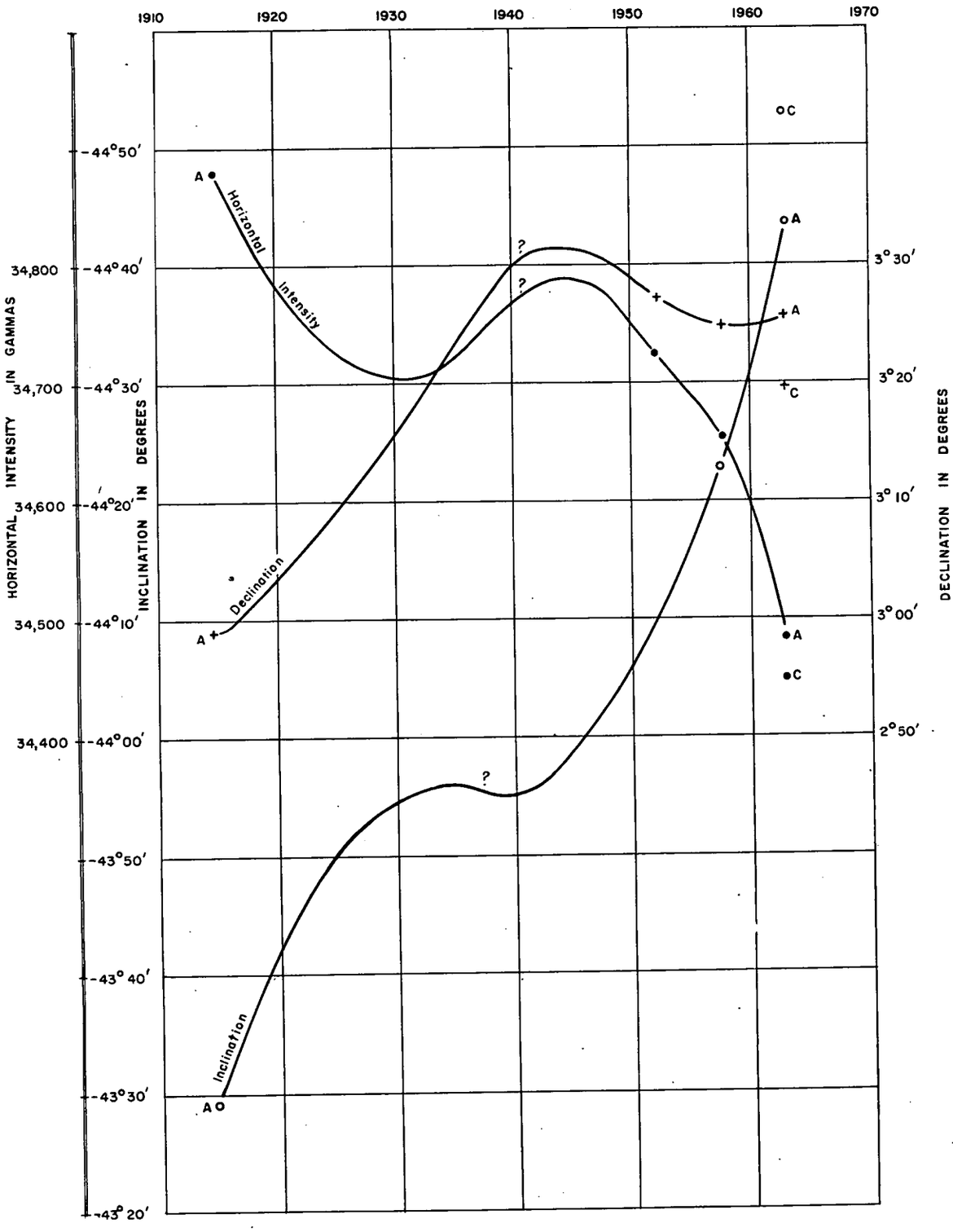
(Based on G96-71

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-110

TO ACCOMPANY RECORD NO. 1966/87

PLATE 4



Variation of Magnetic Elements at WYNDHAM WA between 1914 and 1962

A Latitude 15° 30·0′ S.
Longitude 128° 07′ E.

C Latitude 15° 30·9′ S
Longitude 128° 08·6′ E

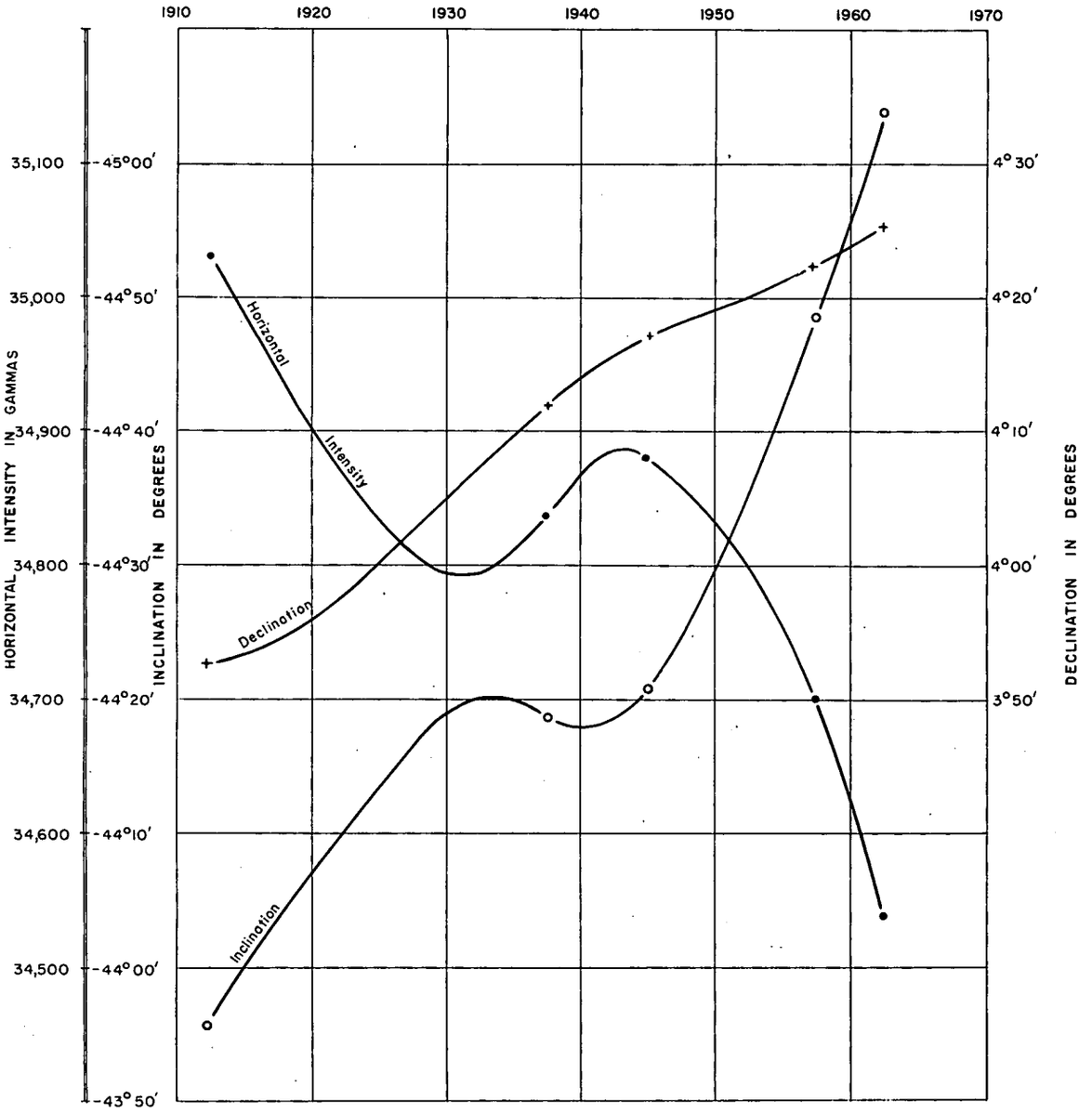
(Based on G96-71)

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-111

TO ACCOMPANY RECORD NO. 1966/87

PLATE 5



Variation of Magnetic Elements at
DALY WATERS NT
between 1912 and 1962

Latitude 16° 17·4′ S.
Longitude 133° 22·6′ E.

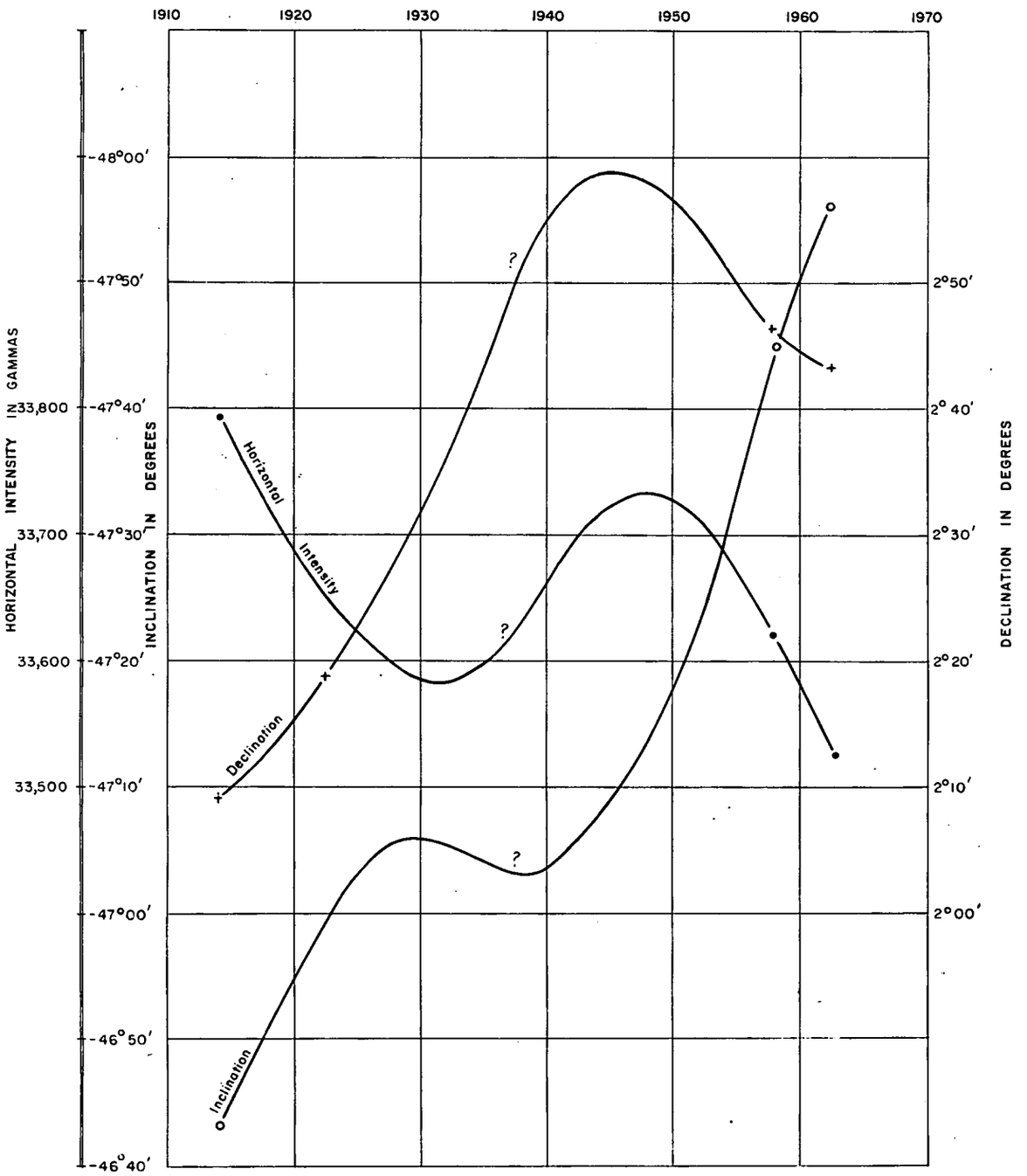
(Based on G 96-71

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-112

TO ACCOMPANY RECORD NO. 1966/87.

PLATE 6



Variation of Magnetic Elements at

DERBY WA

between 1914 and 1962

Latitude 17°22·2' S.
Longitude 123°39·6' E.

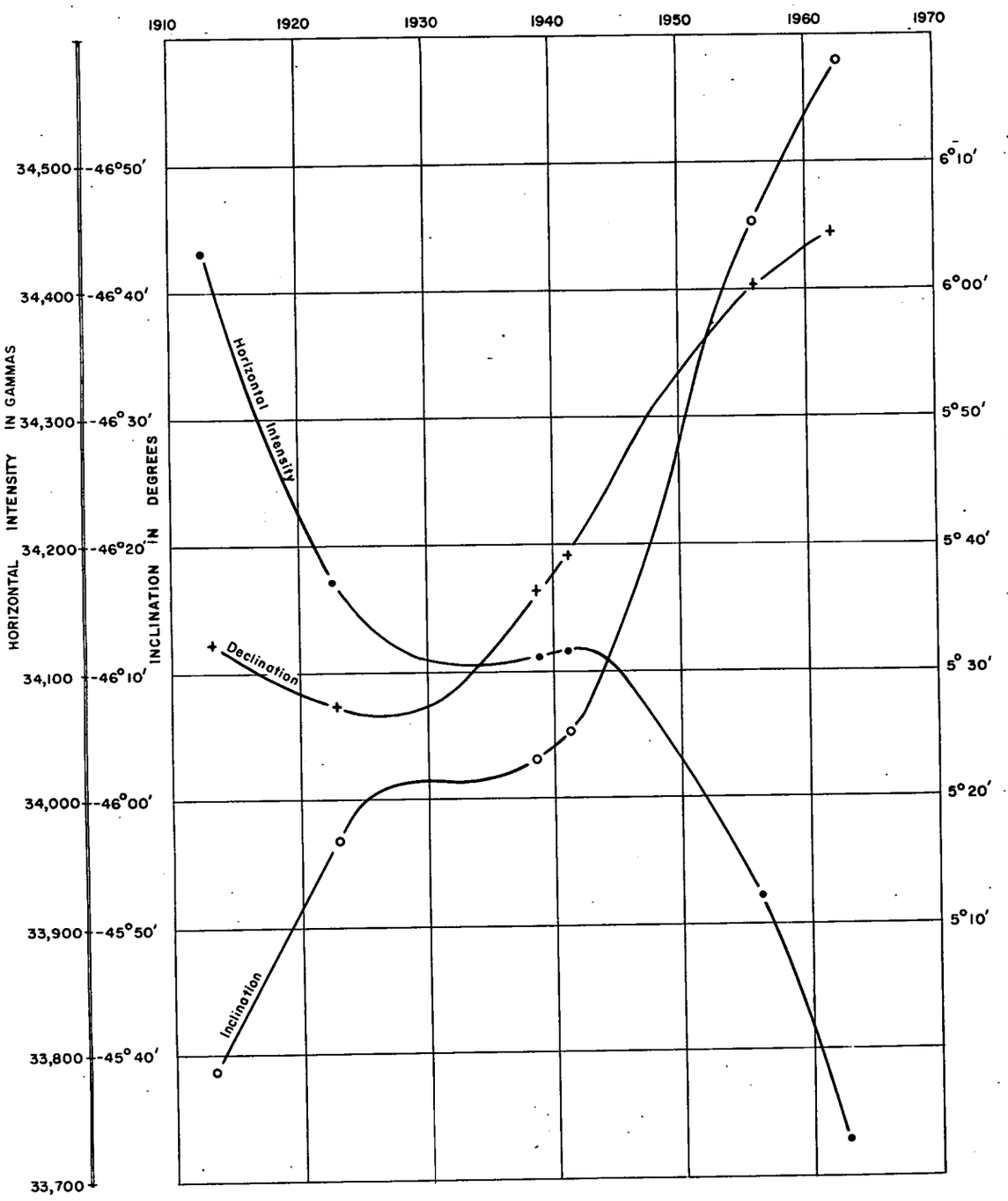
(Based on G 96-71

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-113

TO ACCOMPANY RECORD NO. 1966/87

PLATE 7



Variation of Magnetic Elements at CROYDON QLD between 1913 and 1962

Latitude 18°12·7′ S.
Longitude 142°14·4′ E.

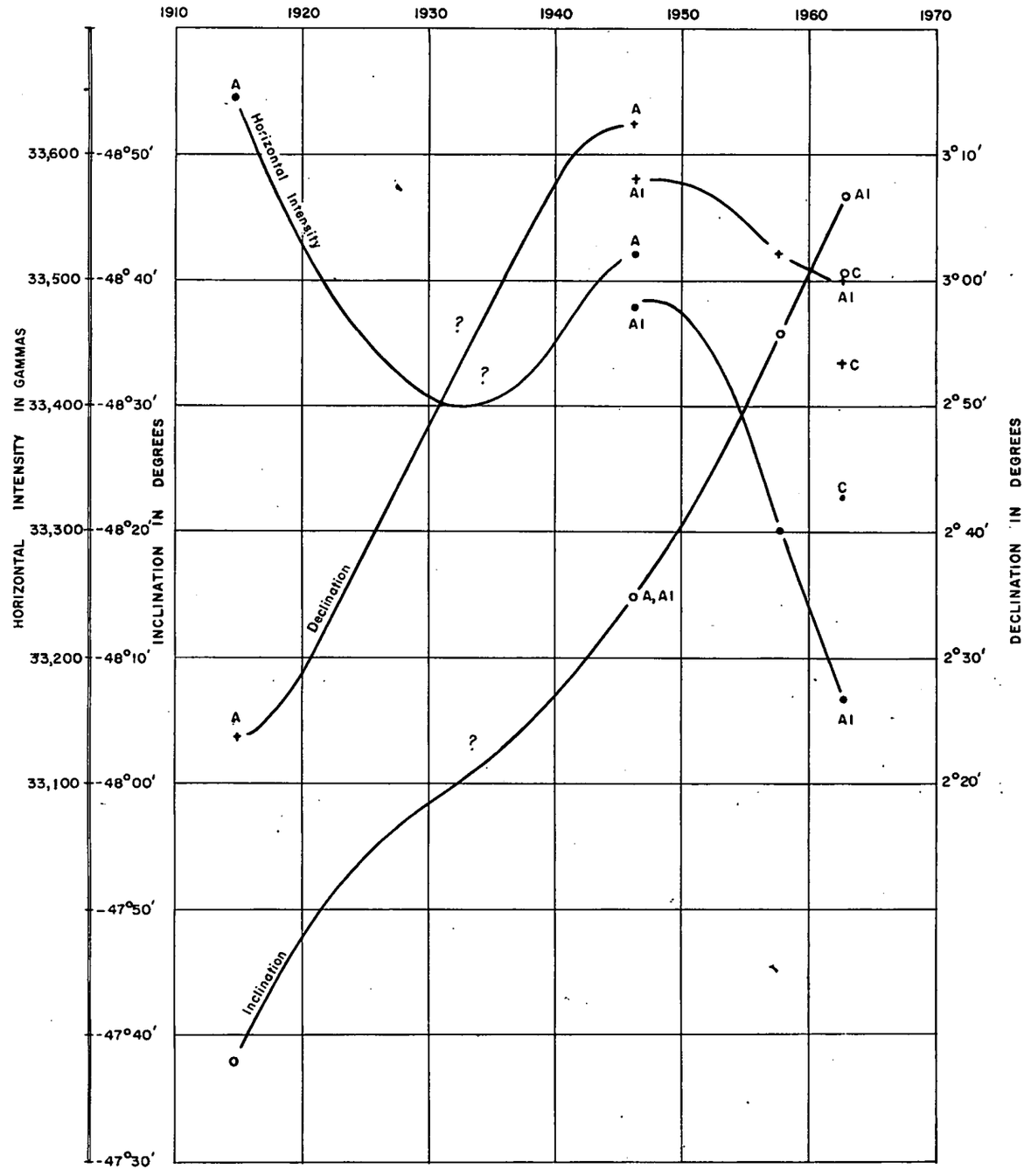
(Based on G96-71

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-114

TO ACCOMPANY RECORD NO. 1966/87

PLATE 8



Variation of Magnetic Elements at
HALLS CREEK WA
between 1914 and 1962

A,Al — Latitude 18°16·1′ S.
Longitude 127°45·3′ E.

C — Latitude 18°14·7′ S.
Longitude 127°40·3′ E.

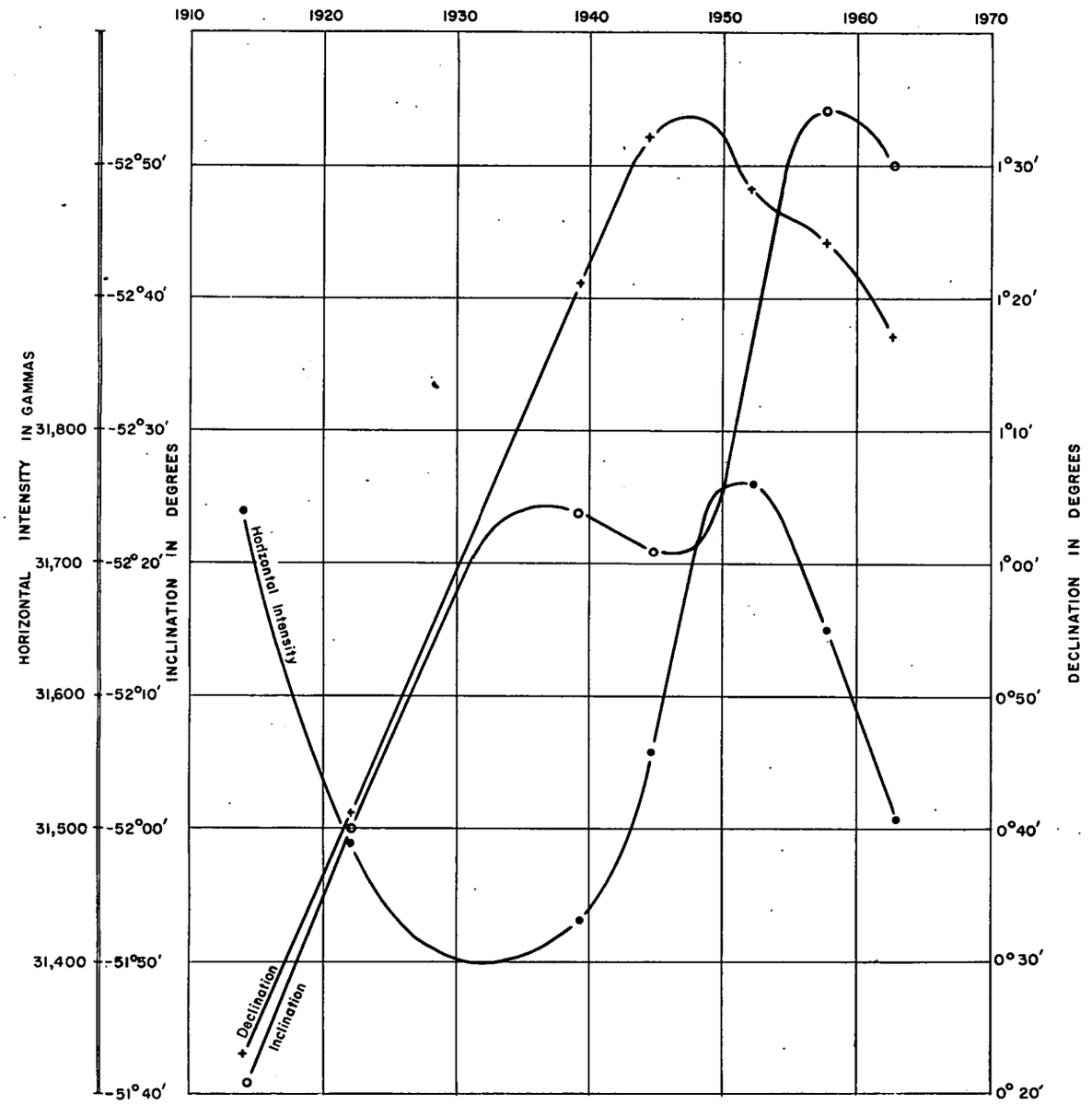
(Based on G96-71

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-115

TO ACCOMPANY RECORD NO. 1966/87

PLATE 9



Variation of Magnetic Elements at
PORT HEDLAND WA
between 1914 and 1962

Latitude 20° 18·9′ S.
Longitude 118° 37·0′ E.

(Based on G96-71

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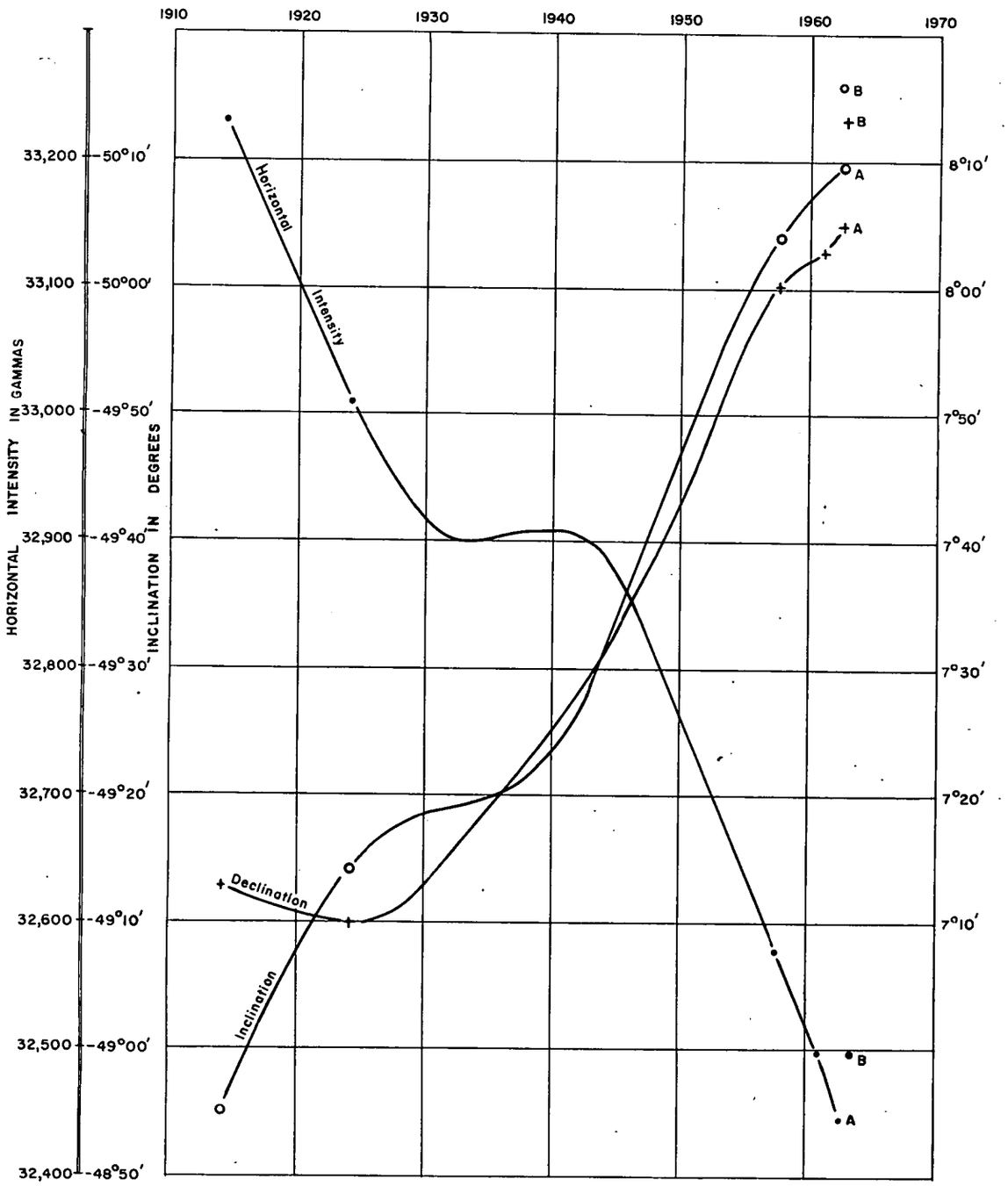
G96-116

TO ACCOMPANY RECORD NO. 1966/87

PLATE 10



Variation of Magnetic Elements at MACKAY QLD between 1912 and 1962

A Latitude 21°09·5′ S.
Longitude 149°10·8′ E.

B Latitude 21°10·9′ S.
Longitude 149°10·3′ E.

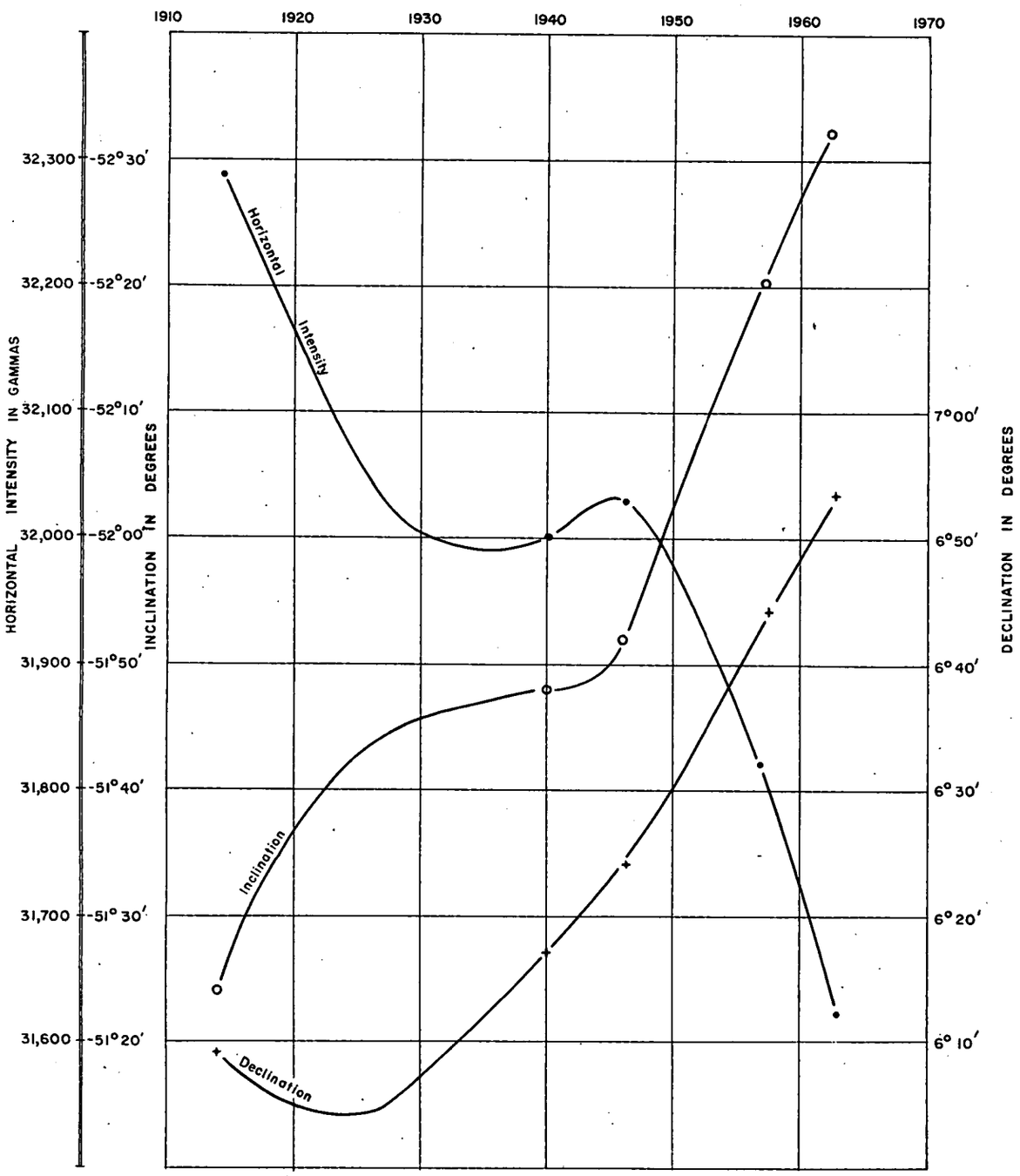
(Based on G96-71

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-117

TO ACCOMPANY RECORD NO. 1966/87

PLATE II



Variation of Magnetic Elements at WINTON QLD between 1913 and 1962

Latitude 22°23·9′ S.
Longitude 143°03·2′ E.

(Based on G96-71

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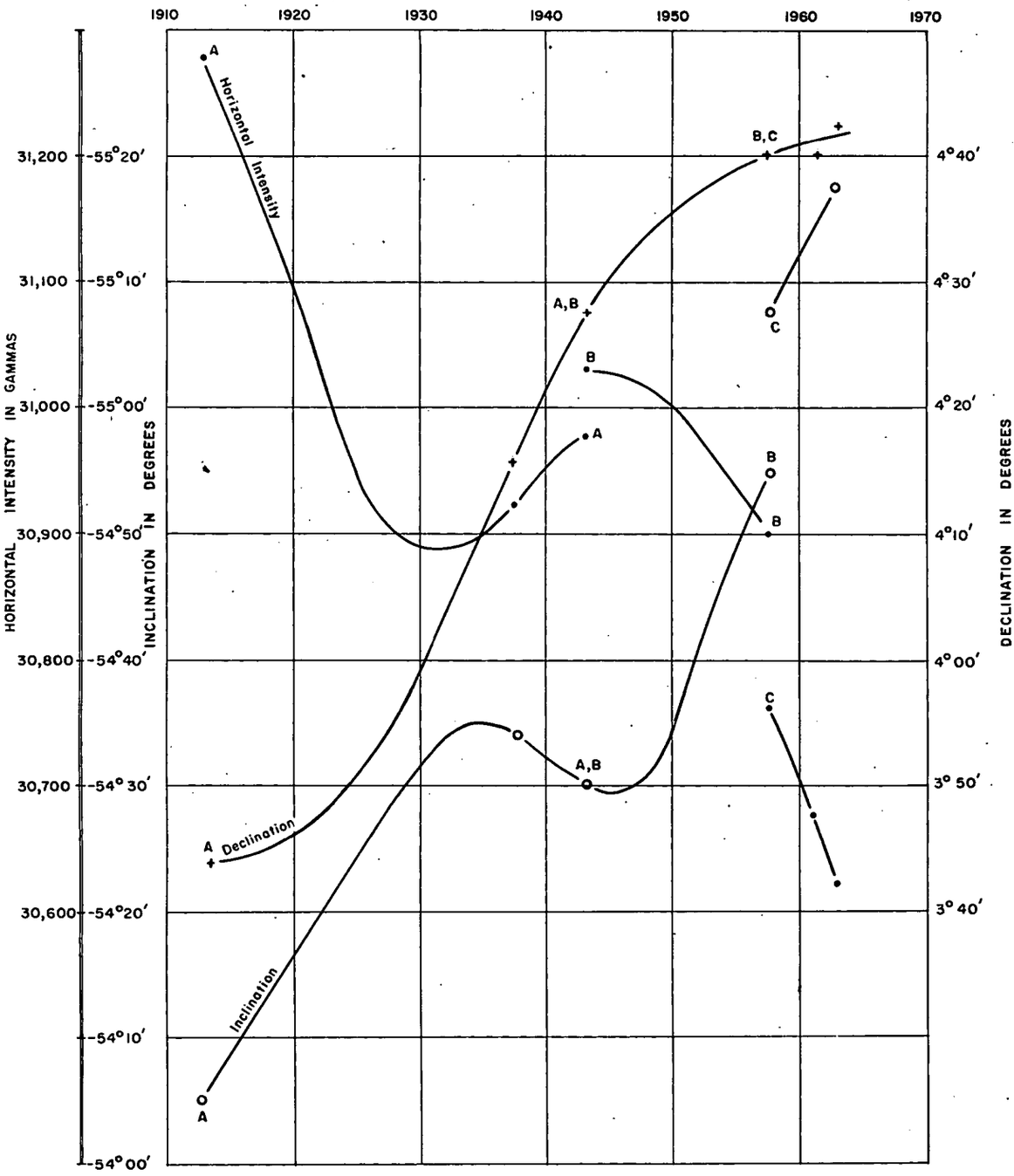
G96-118

TO ACCOMPANY RECORD NO. 1966/87

PLATE 12



Variation of Magnetic Elements at ALICE SPRINGS NT between 1913 and 1962

A,B	Latitude 23°40·8′ S. Longitude 133°54·0′ E.
C	Latitude 23°48·4′ S. Longitude 133°53·9′ E.

(Based on G96-71

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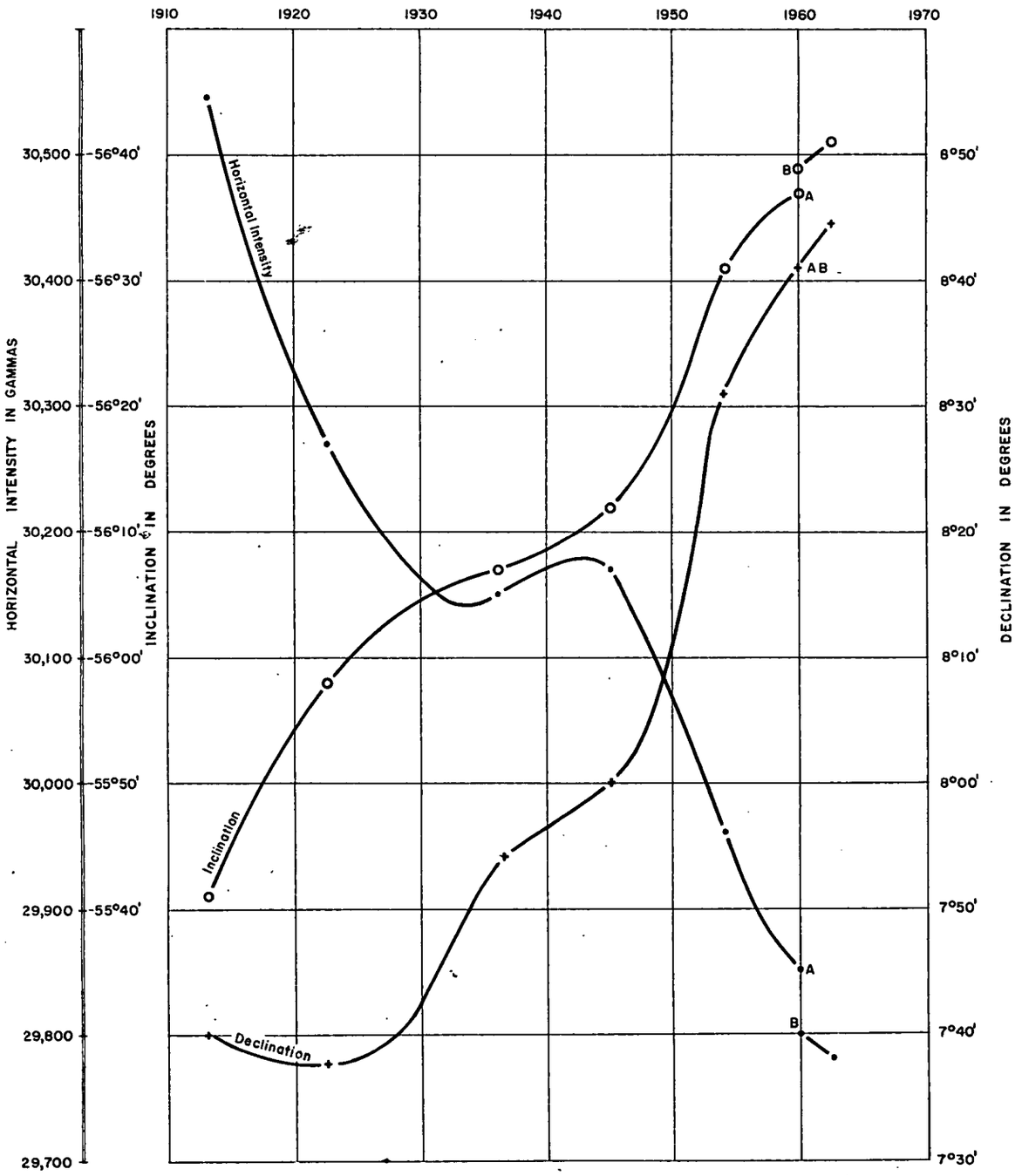
G96-119

TO ACCOMPANY RECORD NO. 1966/87

PLATE 13



Variation of Magnetic Elements at ROMA QLD between 1913 and 1962

A Latitude 26°34·0' S.
Longitude 148°45·0' E

B Latitude 26°33·7' S.
Longitude 148°48·1' E.

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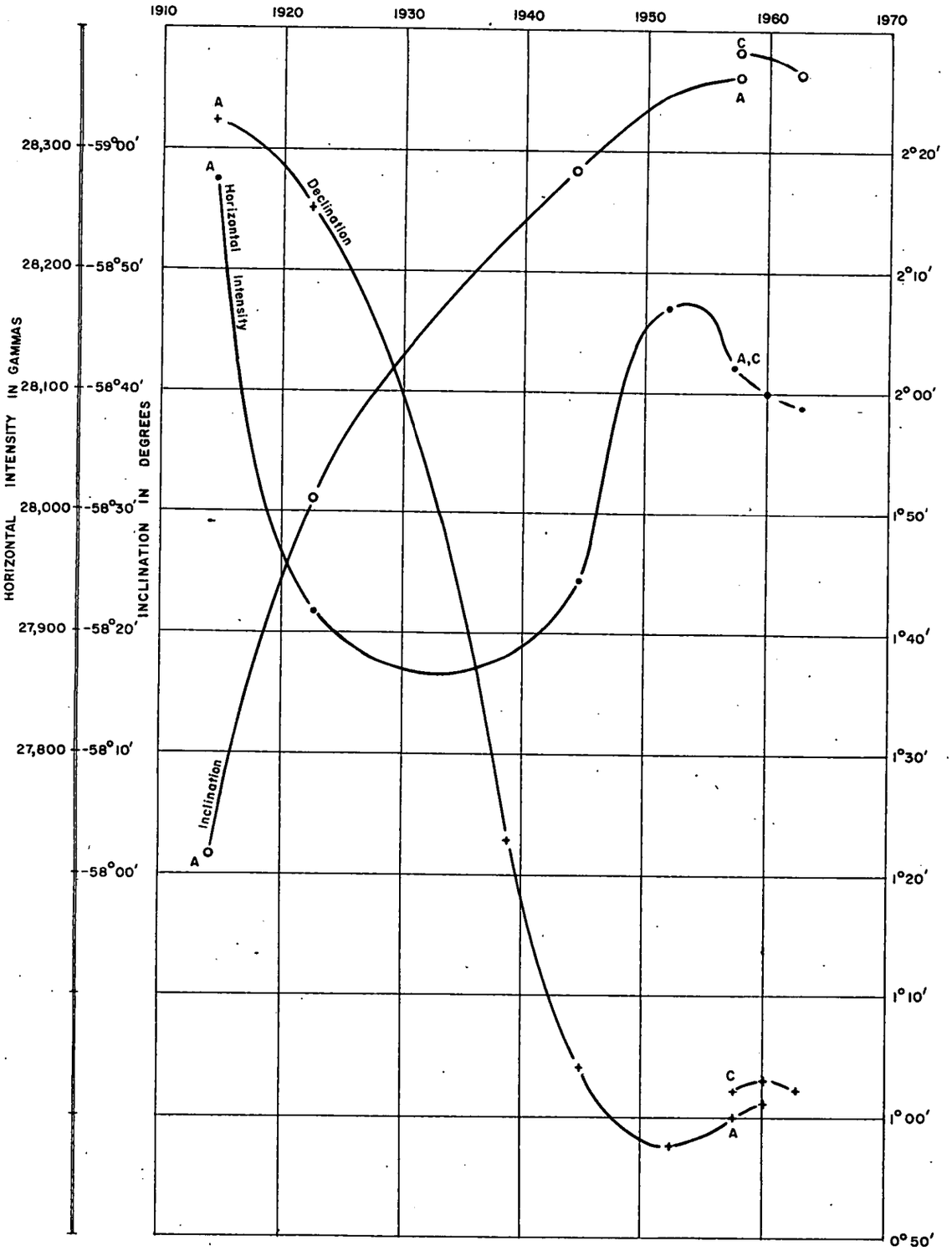
G96-62

TO ACCOMPANY RECORD NO. 1966/87

PLATE 14



Variation of Magnetic Elements at CARNARVON WA between 1914 and 1962

A Latitude 24°53·2′ S.
Longitude 113°39·0′ E.

C Latitude 24°52·5′ S.
Longitude 113°39·3′ E.

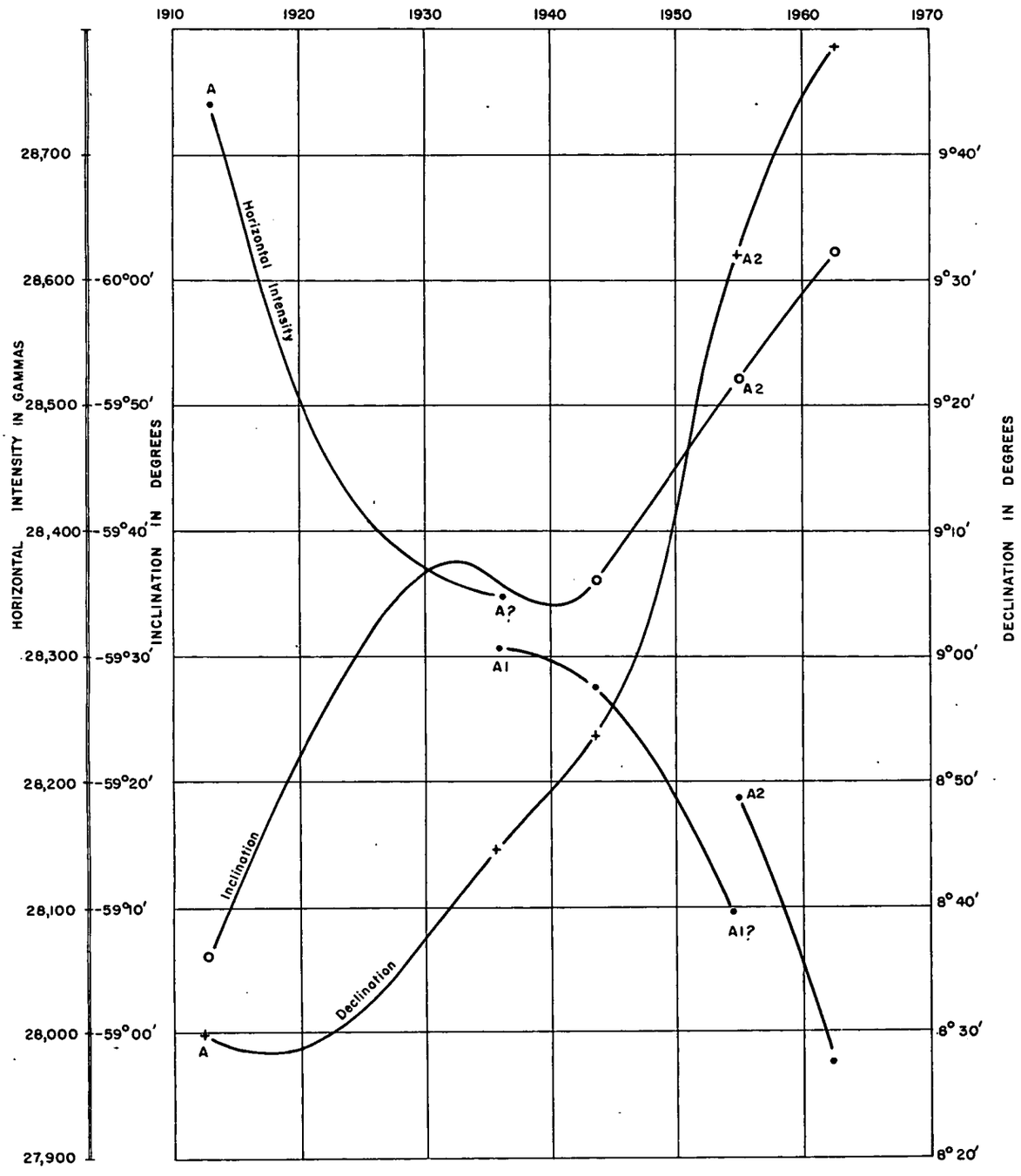
(Based on G96-71)

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-120

TO ACCOMPANY RECORD NO. 1966/87

PLATE 15



Variation of Magnetic Elements at MOREE NSW between 1913 and 1962

A, A1, A2 Latitude 29°28·3′ S.
Longitude 149°57·4′ E.

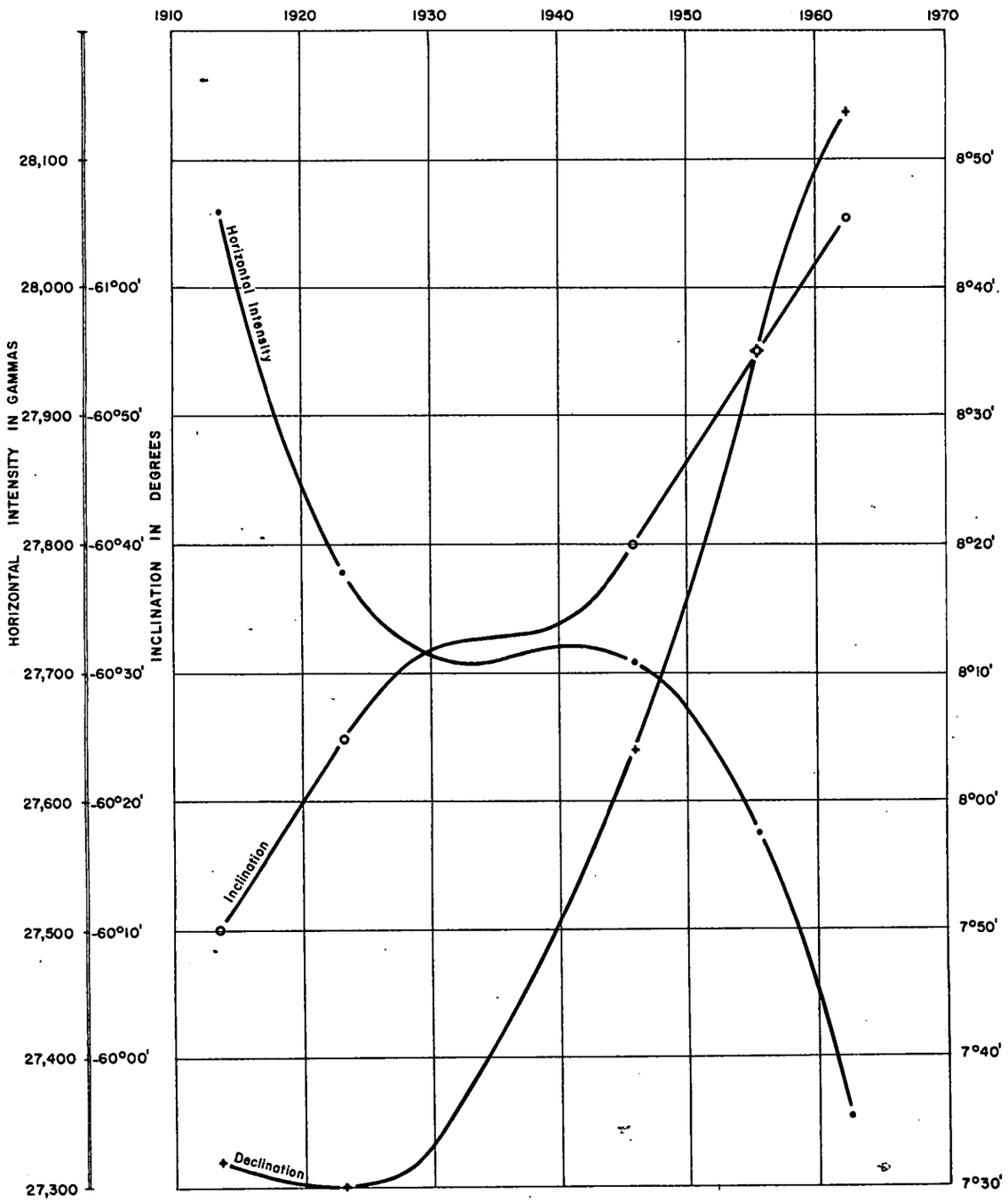
(Based on G96-71

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-121

TO ACCOMPANY RECORD NO. 1966/87

PLATE 16



Variation of Magnetic Elements at BOURKE N S W between 1913 and 1962

Latitude 30°03·1'S.
Longitude 145°57·5'E.

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-65

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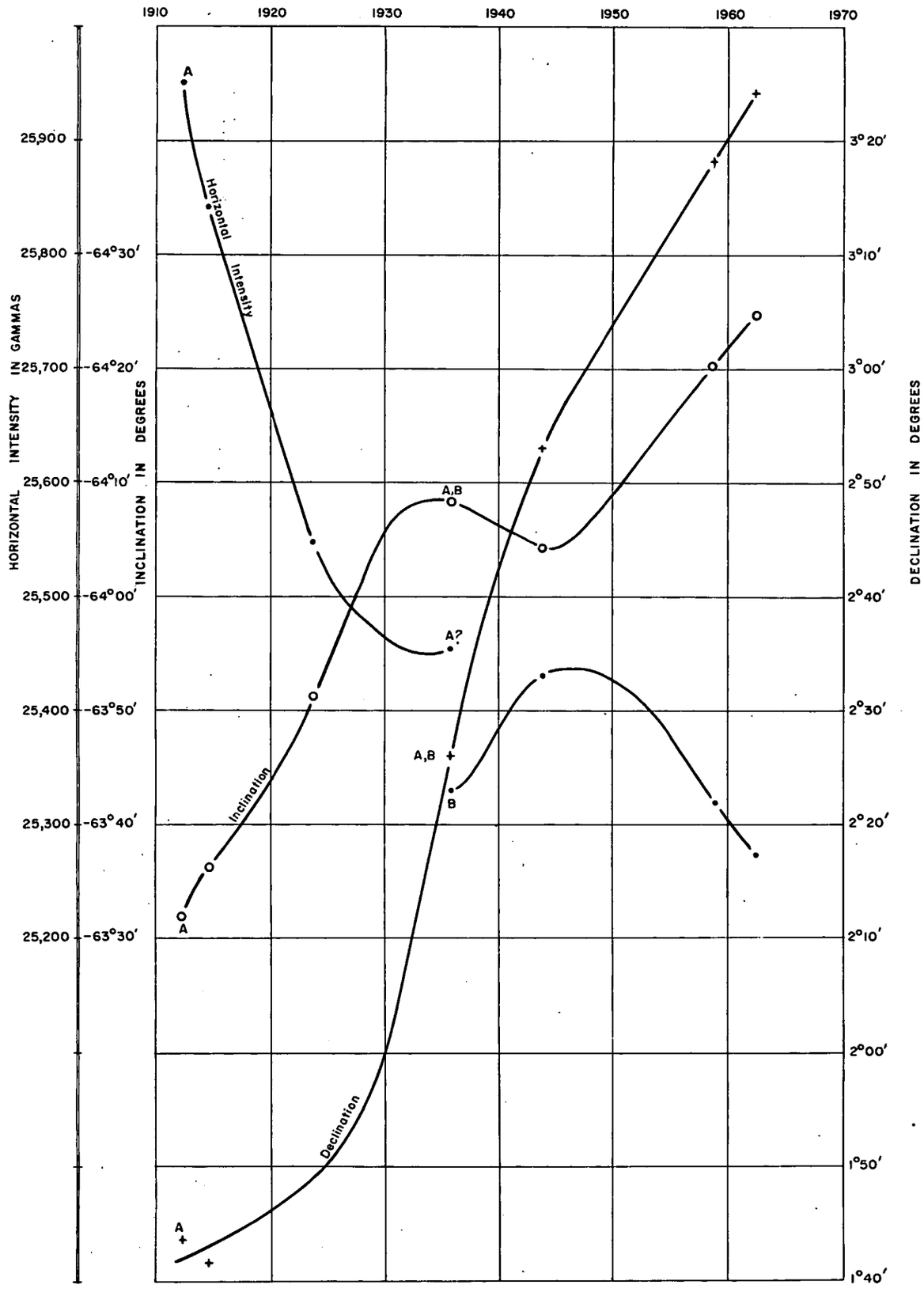
PLATE 17



Variation of Magnetic Elements at EUCLA WA between 1911 and 1962

A,B Latitude 31° 43·0′ S.
Longitude 128° 52·8′ E.

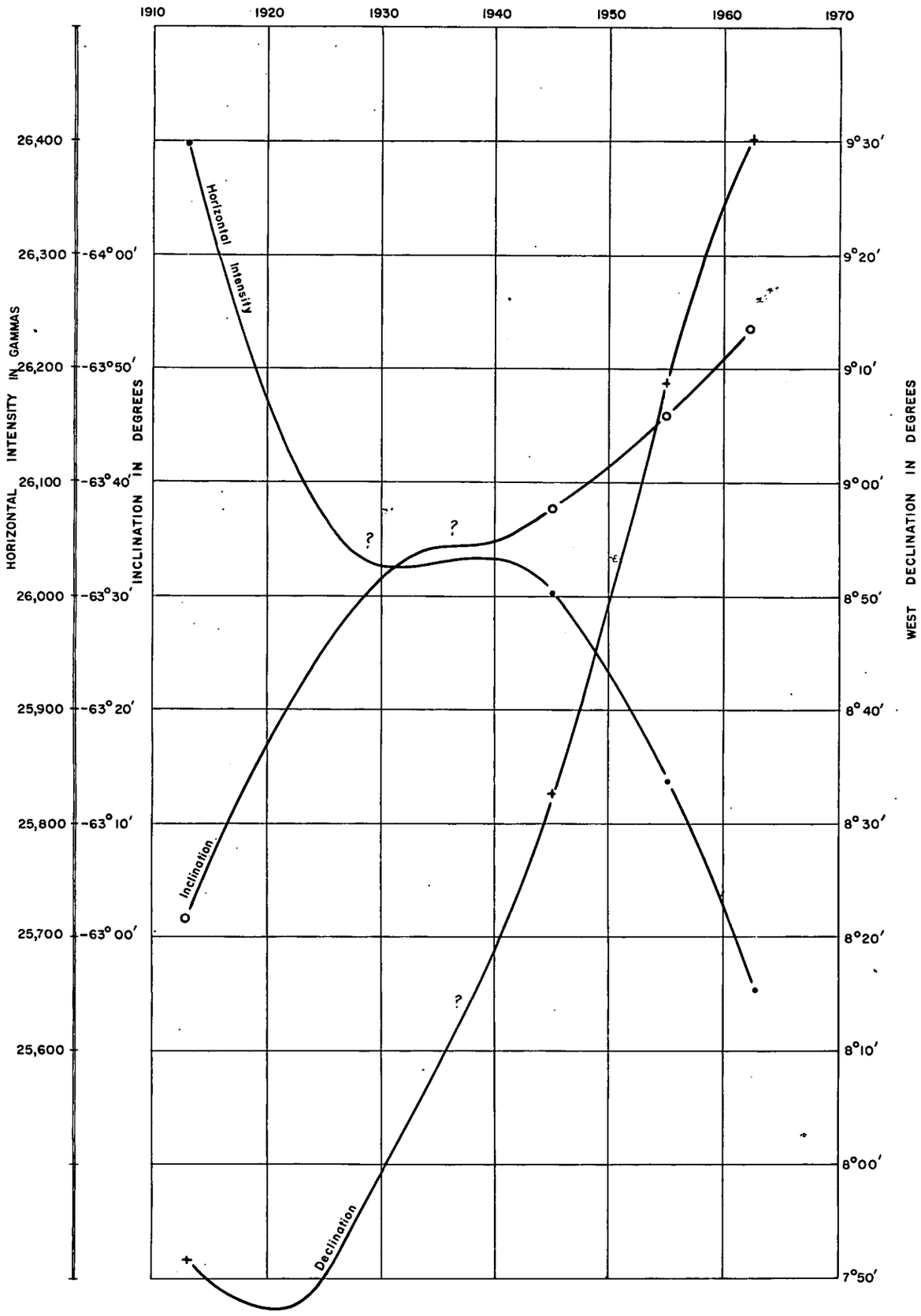
(Based on G96-71

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-123

TO ACCOMPANY RECORD NO. 1966/87

PLATE 18



Variation of Magnetic Elements at CONDOBOLIN NSW between 1913 and 1962

Latitude 33°06·0 S.
Longitude 147°08·7 E.

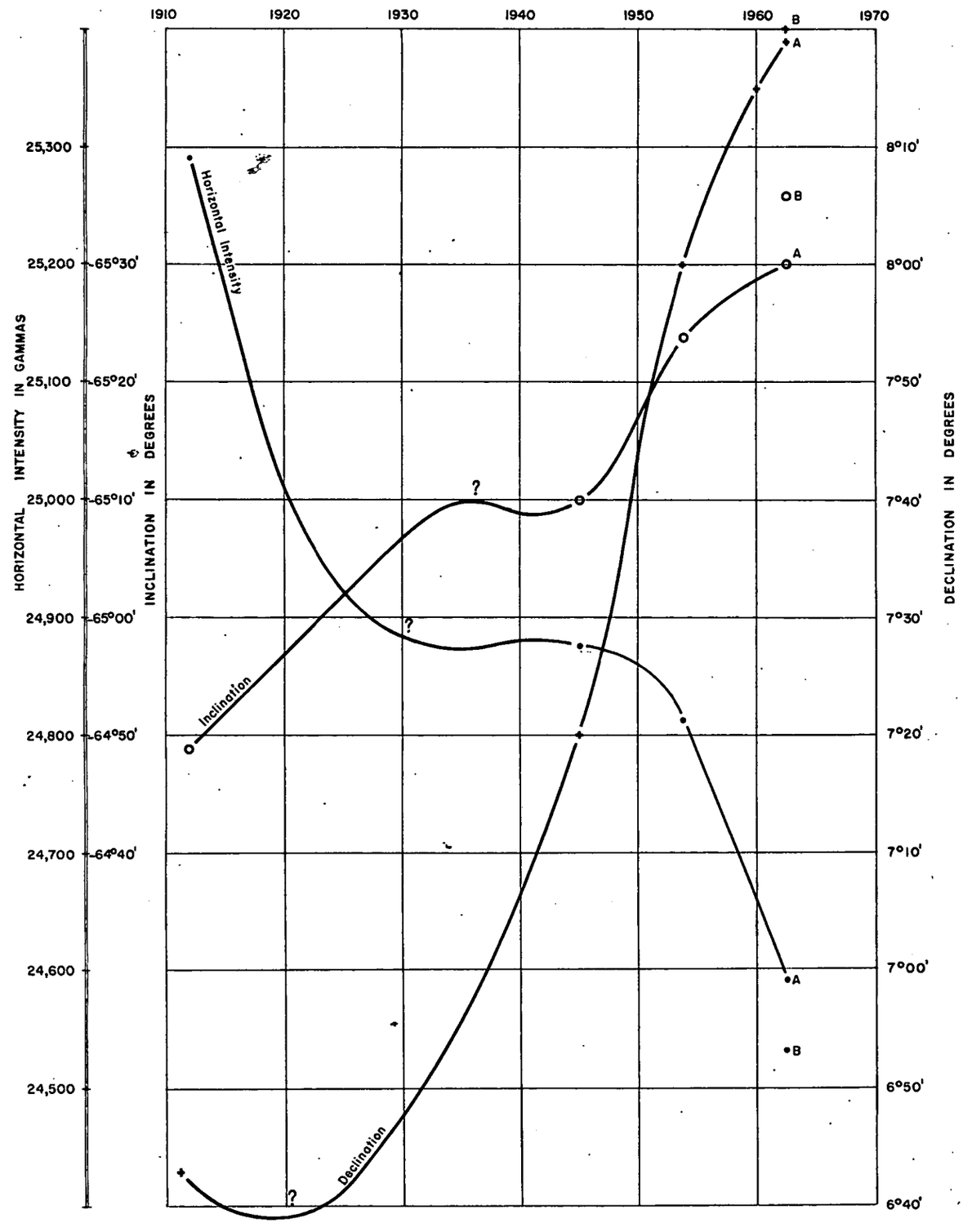
(Based on G96-71

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-124

TO ACCOMPANY RECORD NO. 1966/87

PLATE 19



Variation of Magnetic Elements at MILDURA VIC between 1911 and 1962

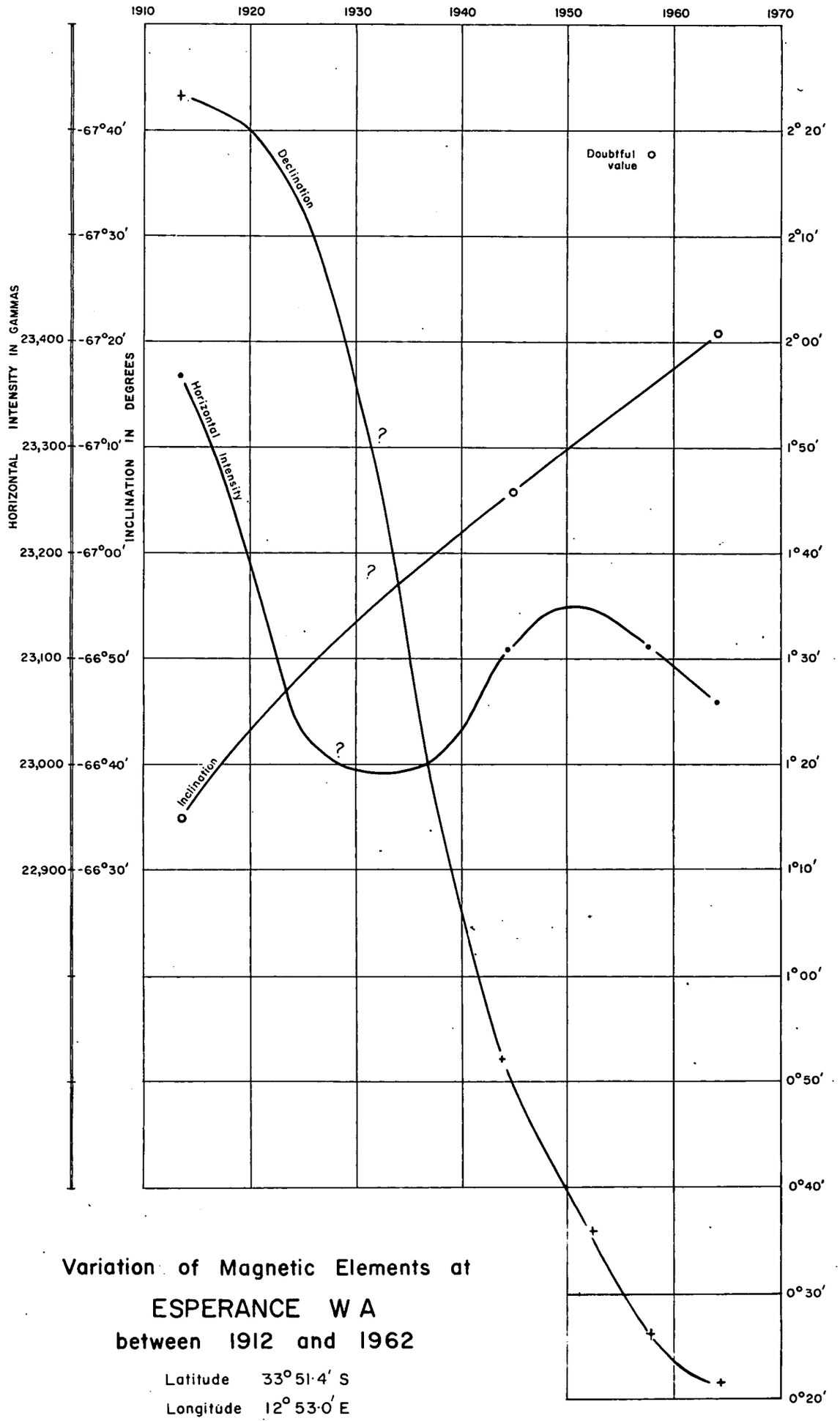
A Latitude 34°12·2'S.
Longitude 142°08·1'E.

B Latitude 34°13·9'S.
Longitude 142°03·0'E.

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-68

TO ACCOMPANY RECORD NO. 1966/87



Variation of Magnetic Elements at

ESPERANCE W A

between 1912 and 1962

Latitude 33° 51·4′ S

Longitude 12° 53·0′ E

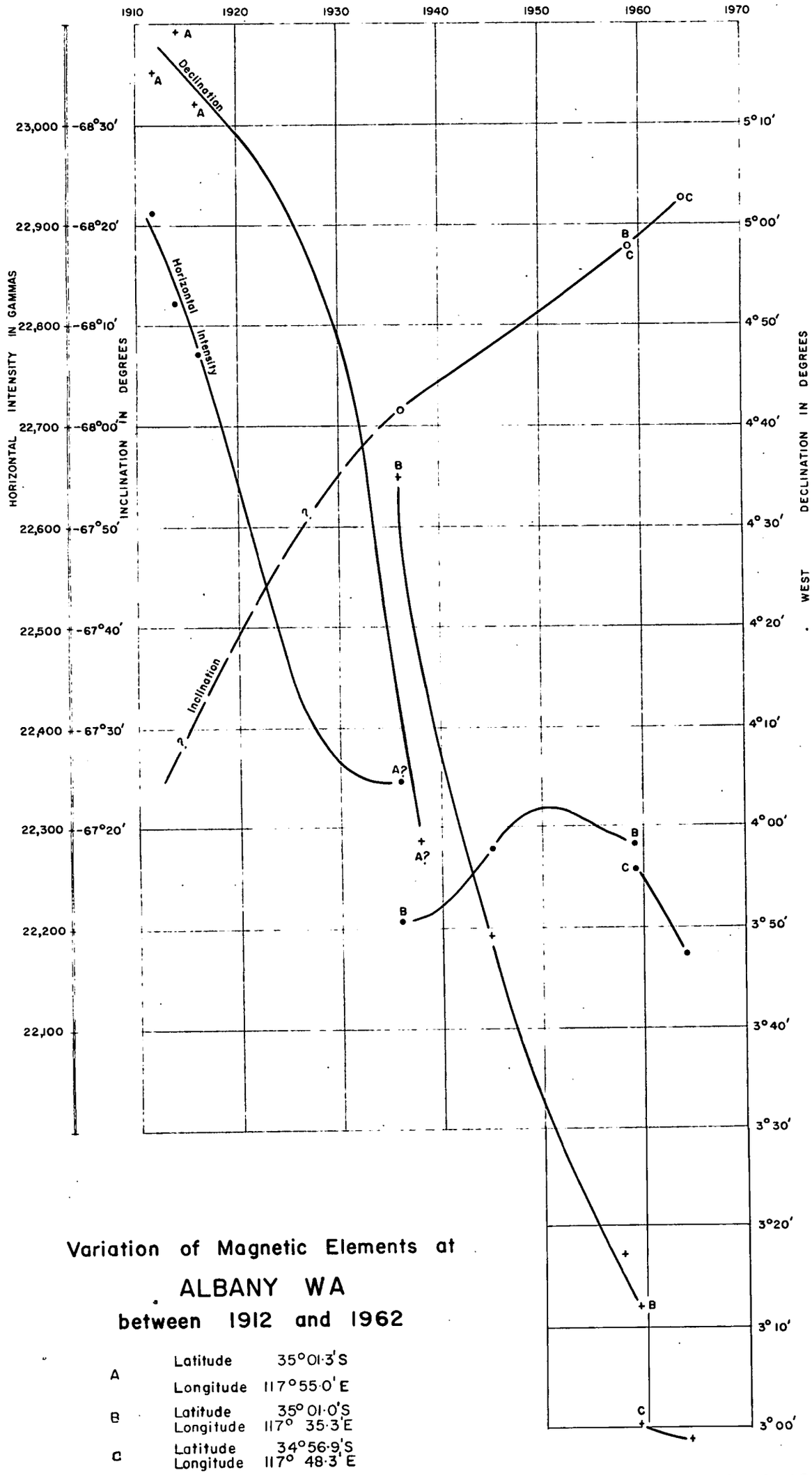
(Based on G96-71)

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-125

TO ACCOMPANY RECORD NO. 1966/87

PLATE 21



Variation of Magnetic Elements at

ALBANY WA

between 1912 and 1962

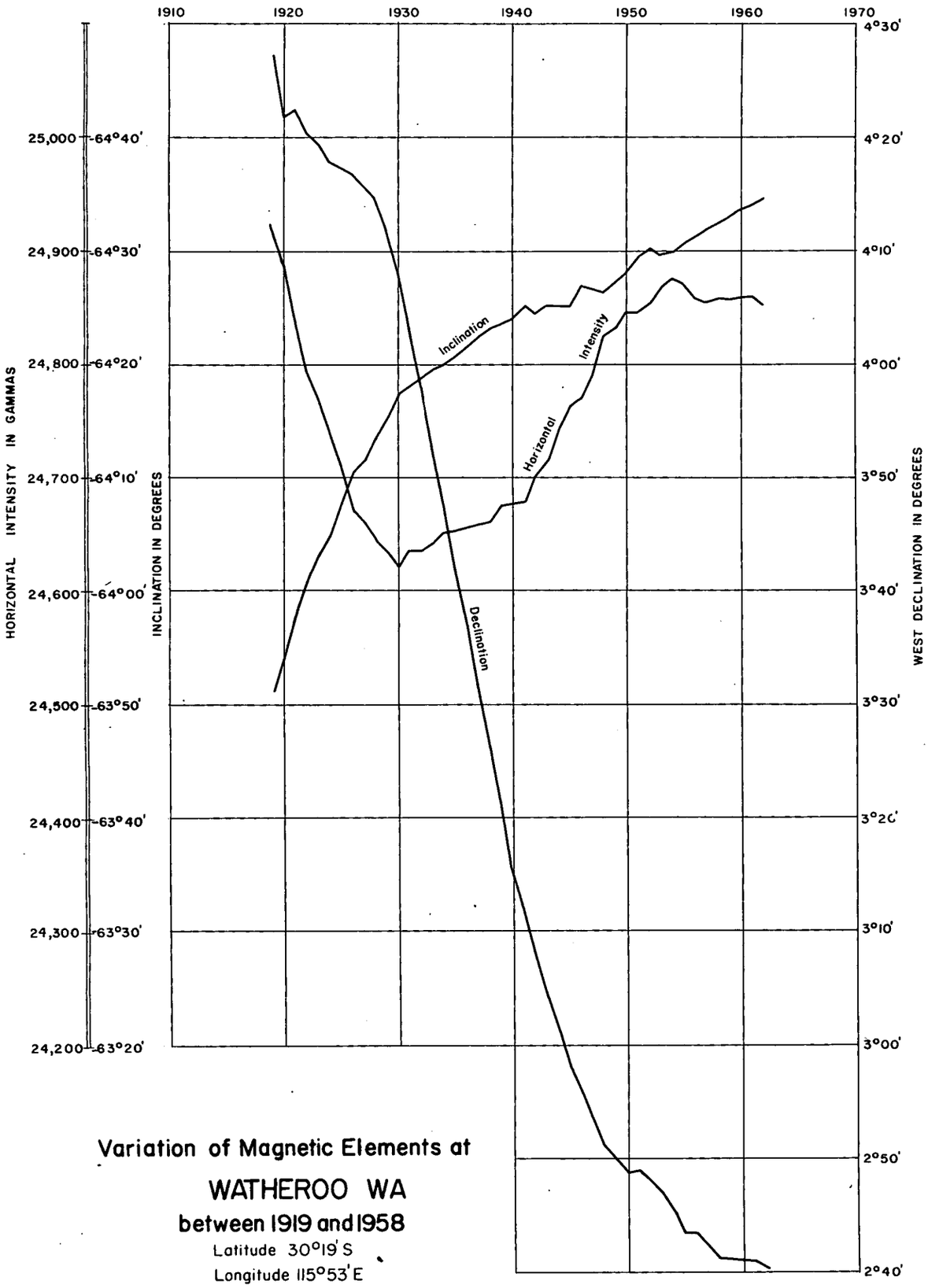
A	Latitude	35°01·3'S
	Longitude	117°55·0'E
B	Latitude	35°01·0'S
	Longitude	117° 35·3'E
C	Latitude	34°56·9'S
	Longitude	117° 48·3'E

(Based on G 96-71)

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. G 96-126

TO ACCOMPANY RECORD NO. 1966/87

PLATE 22



Variation of Magnetic Elements at

WATHEROO WA

between 1919 and 1958

Latitude 30°19'S

Longitude 115°53'E

Extension to 1962 based on

GNANGARA WA

Latitude 31°47'S

Longitude 115°57'E

Station differences D = 11·5' W

H = -910 GAMMAS

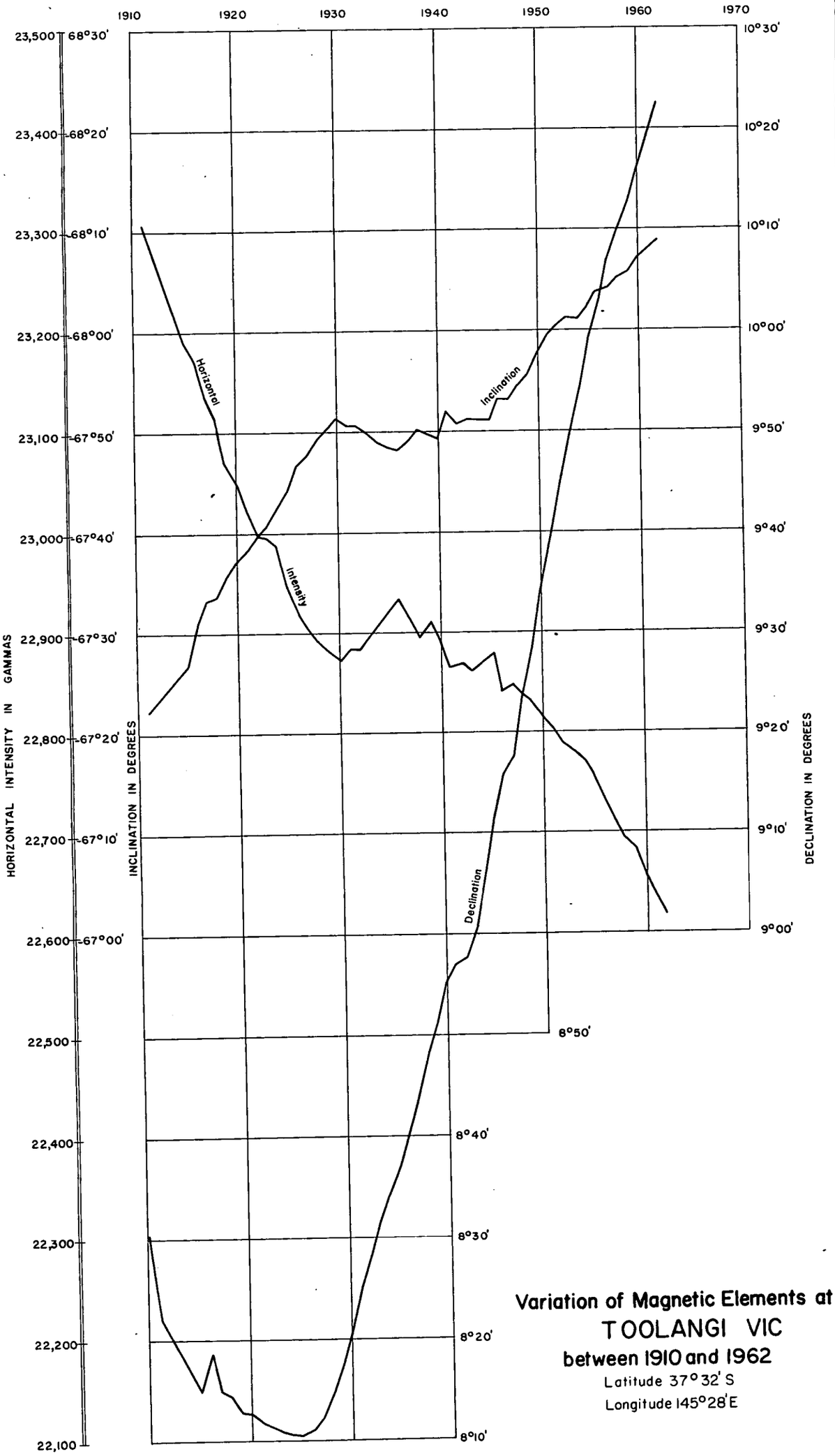
I = +1°14·0'

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

G96—84

TO ACCOMPANY RECORD NO. 1966/87

PLATE 23



Variation of Magnetic Elements at TOOLANGI VIC between 1910 and 1962

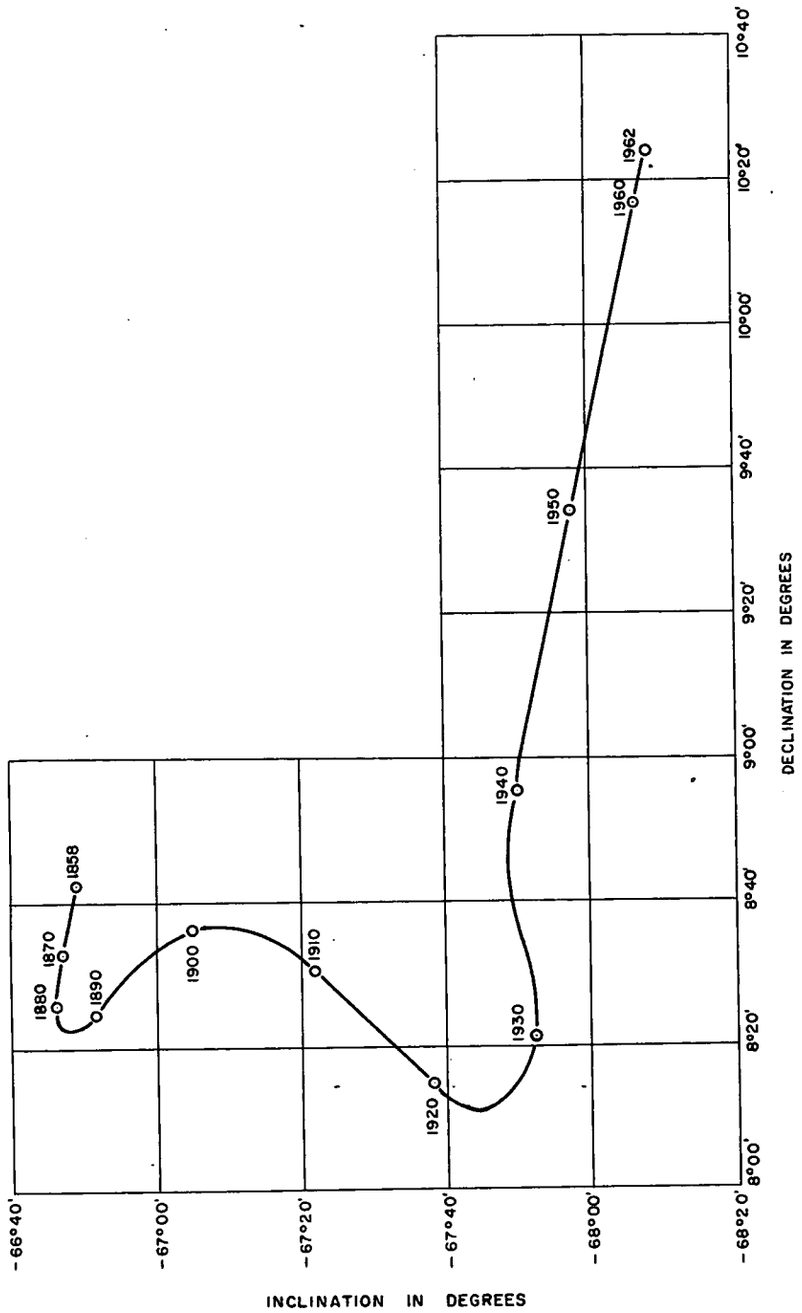
Latitude 37°32' S
Longitude 145°28' E

G96-83

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

TO ACCOMPANY RECORD NO. 1966/87

PLATE 24



Direction of Magnetic Field at

TOOLANGI VIC

between 1858 and 1962

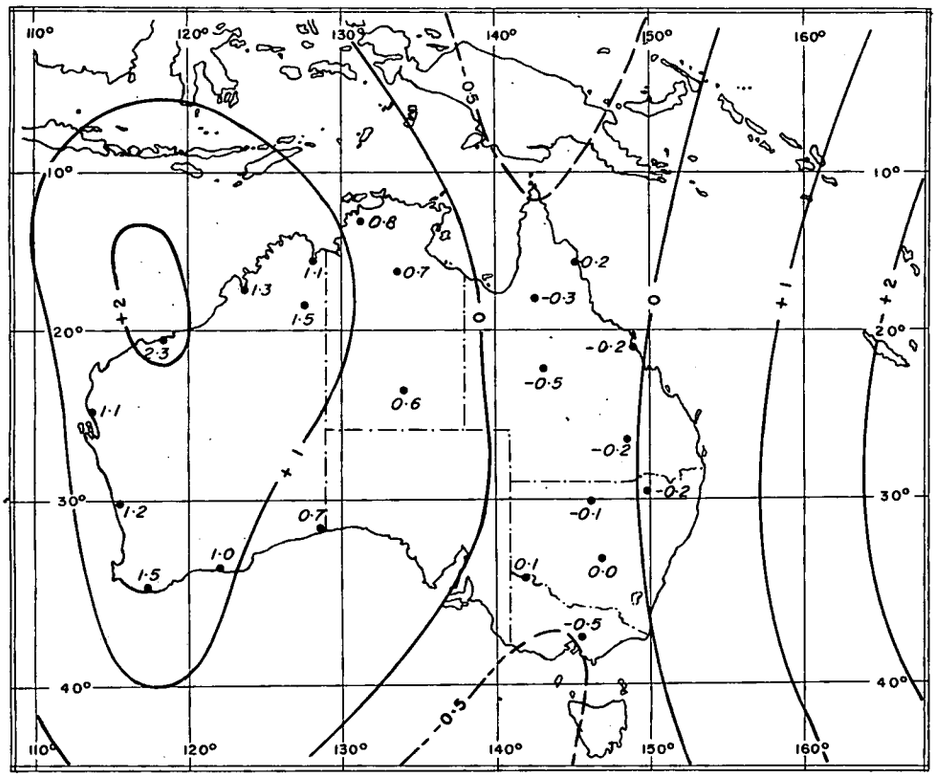
Latitude 37°32' S.

Longitude 145°28' E.

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96-82

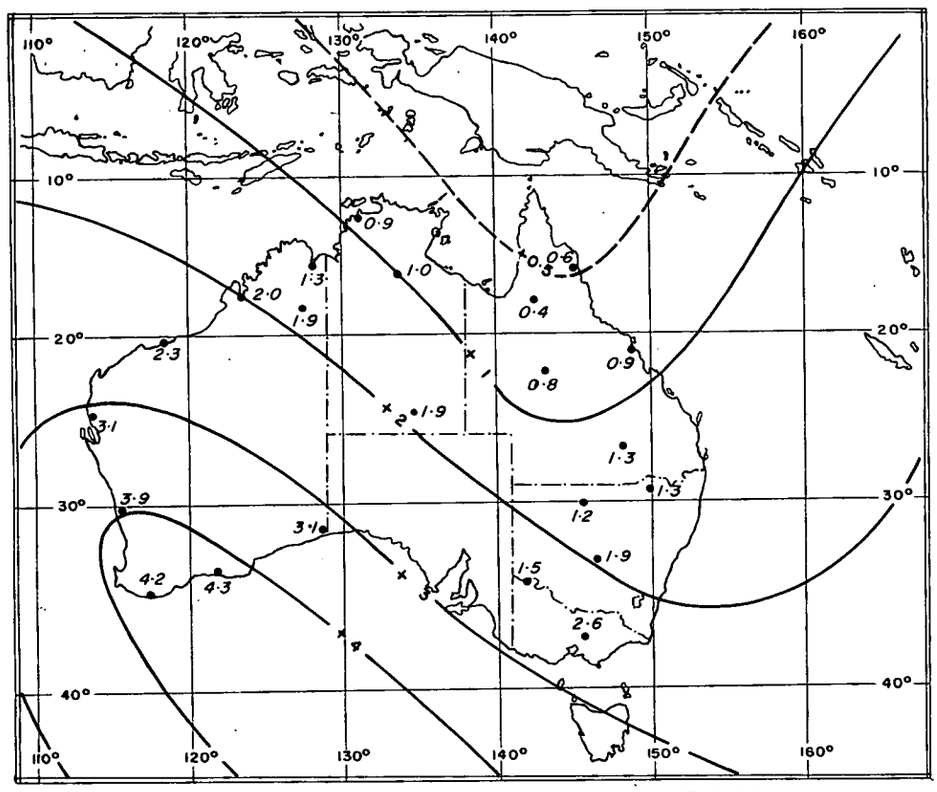
TO ACCOMPANY RECORD NO. 1966/87



SECULAR VARIATION

RATE OF CHANGE OF DECLINATION (1915–25) IN MINUTES PER YEAR

Positive value indicates value is increasing easterly

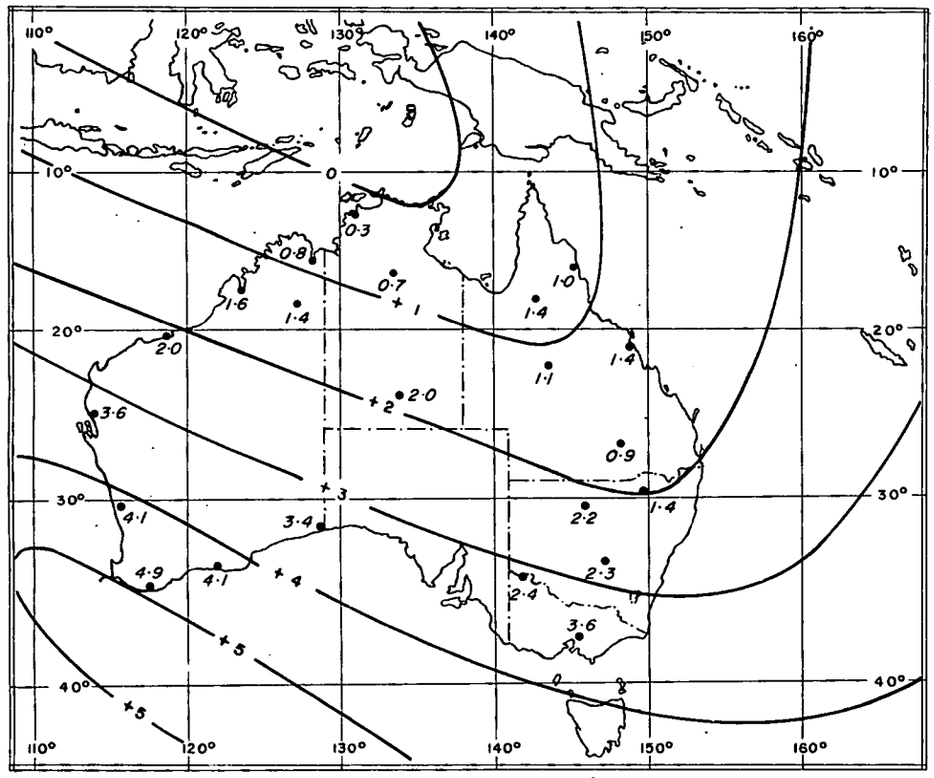


RATE OF CHANGE OF DECLINATION (1925–35) IN MINUTES PER YEAR

Positive value indicates value is increasing easterly

(Based on G96-81) *Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.* G96–128

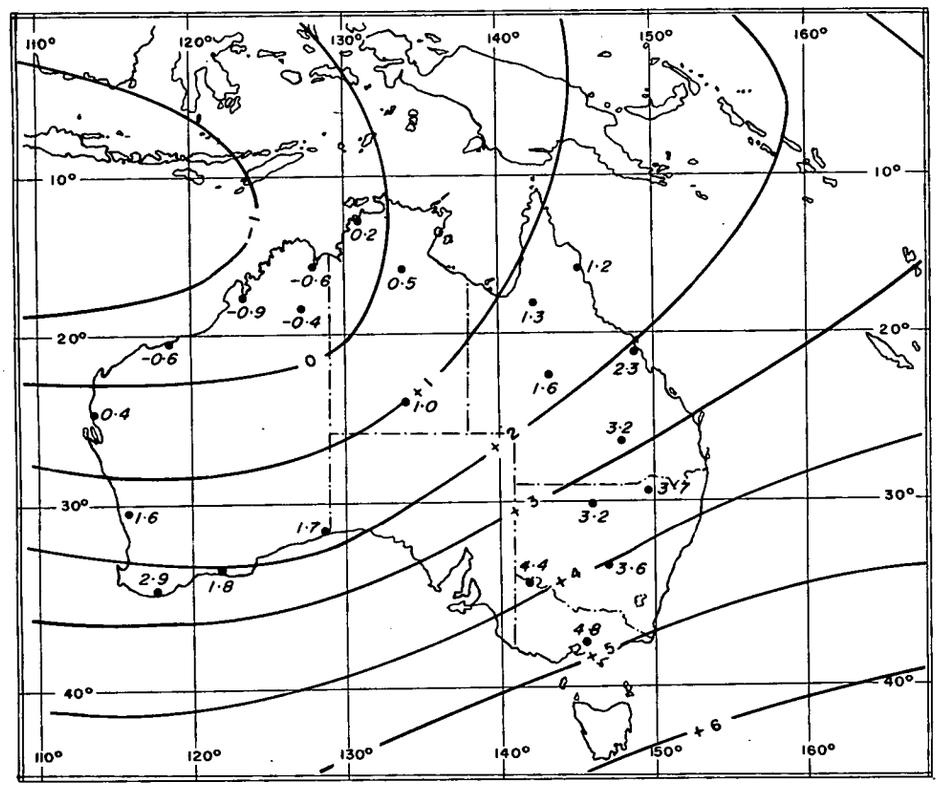
TO ACCOMPANY RECORD NO. 1966/87



SECULAR VARIATION

RATE OF CHANGE OF DECLINATION (1935–45) IN MINUTES PER YEAR

Positive value indicates value is increasing easterly

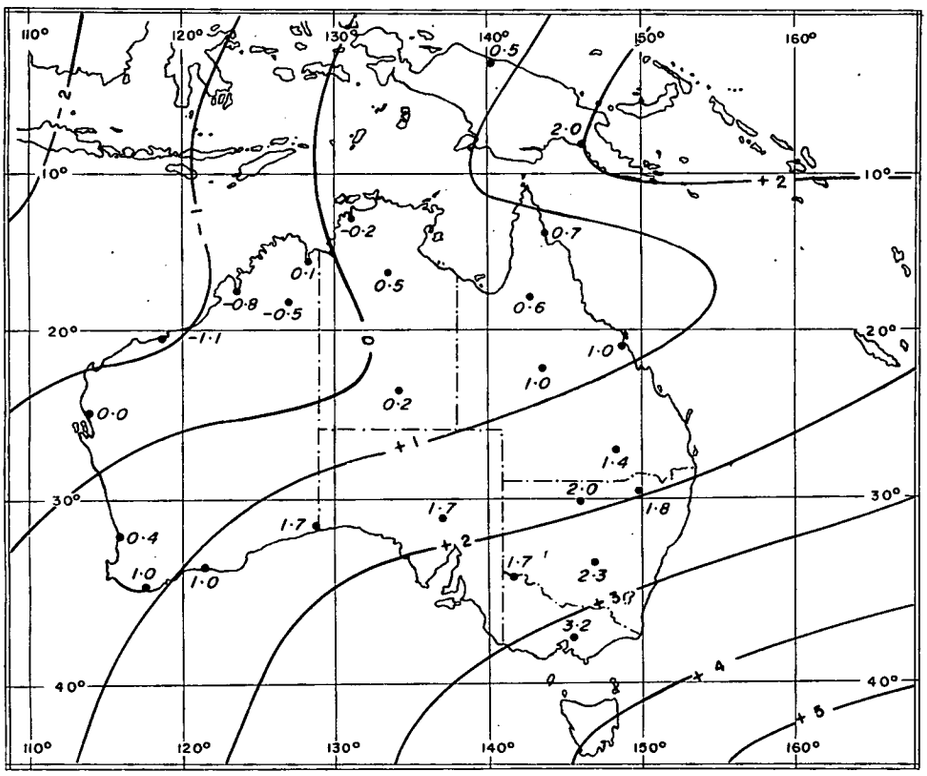


RATE OF CHANGE OF DECLINATION (1945–55) IN MINUTES PER YEAR

Positive value indicates value is increasing easterly

(Based on G96-81) *Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.* G96–129

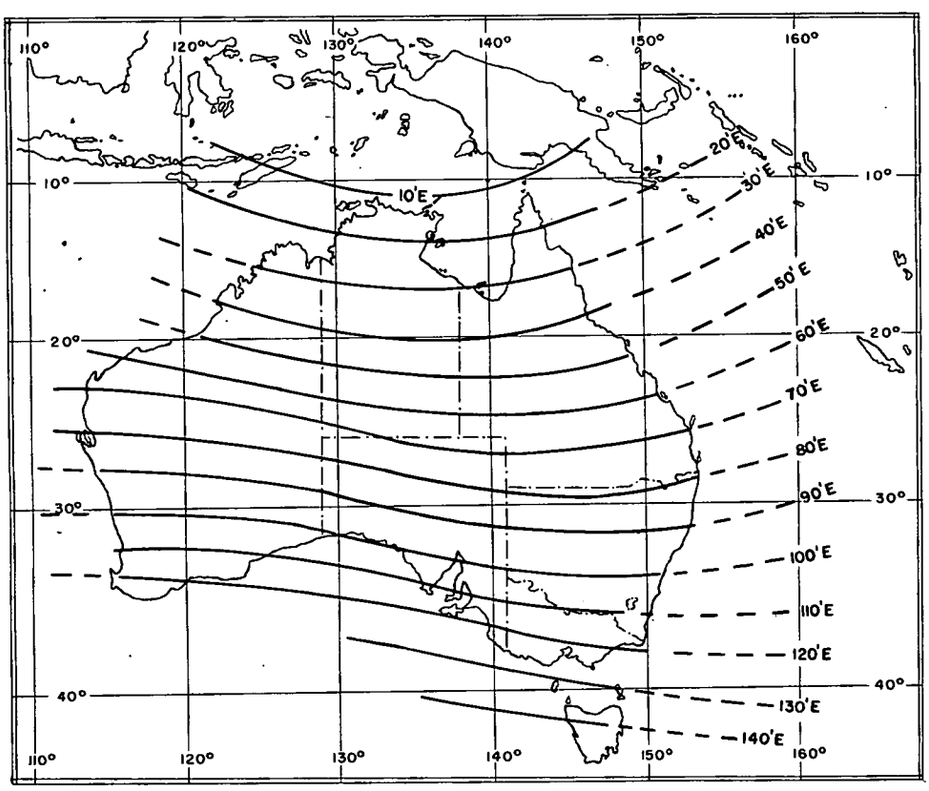
TO ACCOMPANY RECORD NO. 1966/87



SECULAR VARIATION

RATE OF CHANGE OF DECLINATION (1955–65) IN MINUTES PER YEAR

Positive value indicates value is increasing easterly



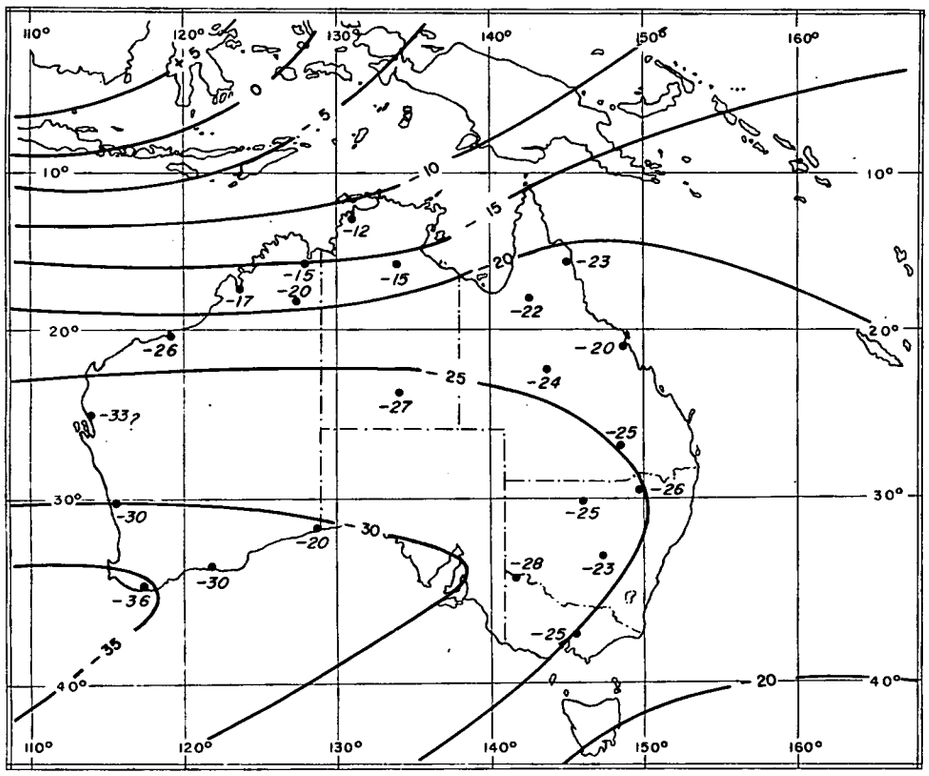
TOTAL CHANGE OF DECLINATION FROM 1912 TO 1962

(Based on G96-81)

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

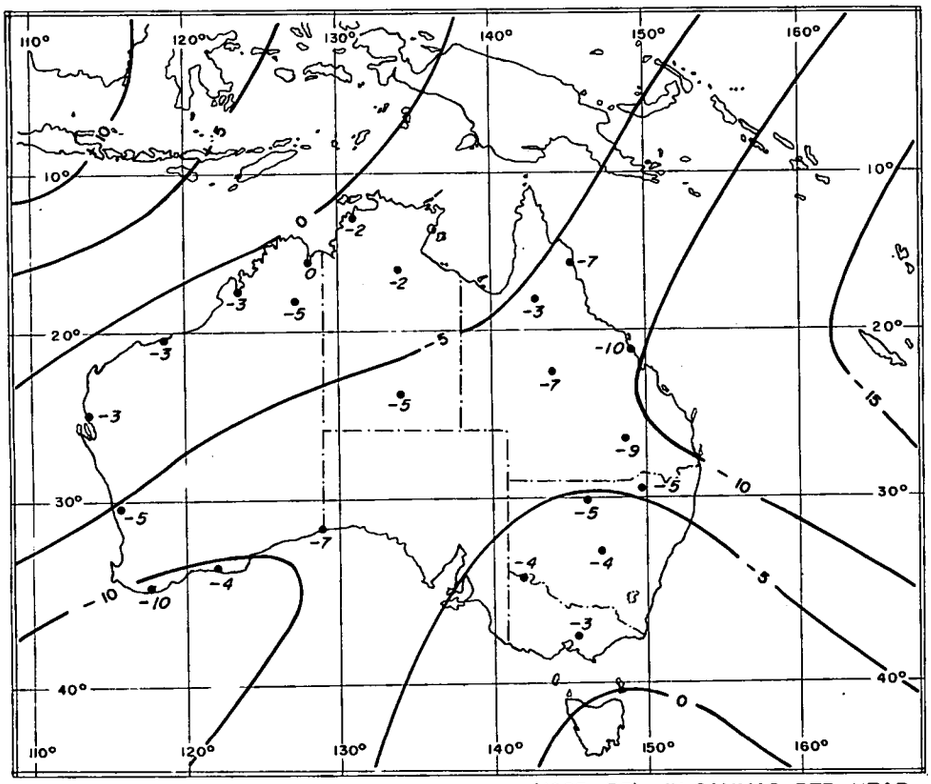
G96–130

TO ACCOMPANY RECORD NO. 1966/87



SECULAR VARIATION

RATE OF CHANGE OF HORIZONTAL INTENSITY (1915–25) IN GAMMAS PER YEAR



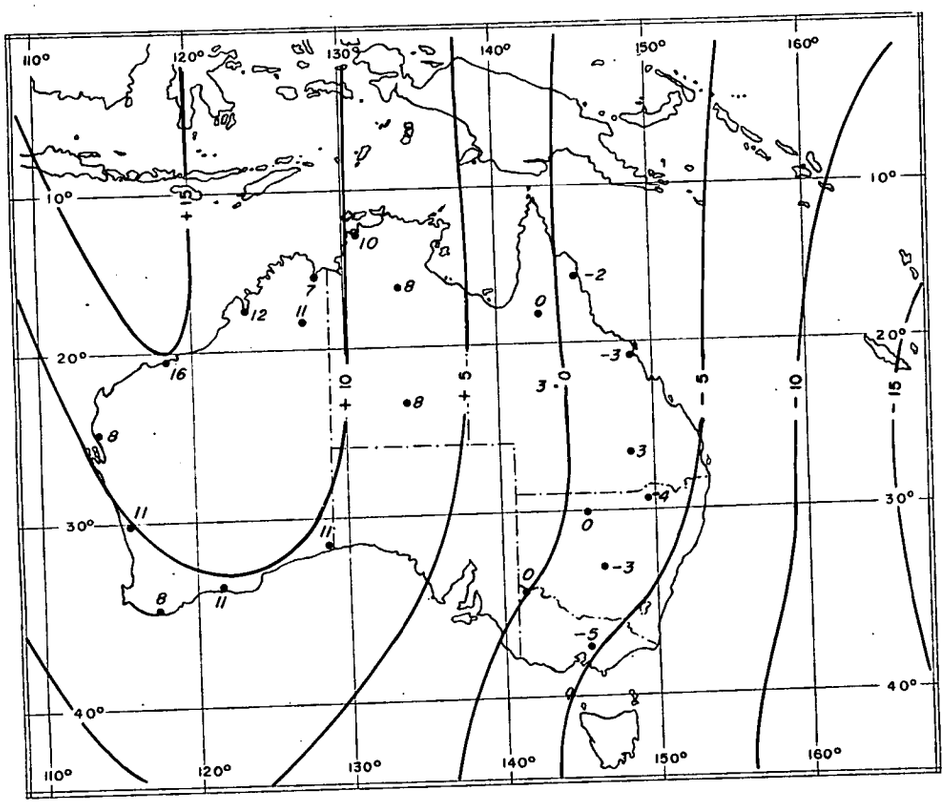
RATE OF CHANGE OF HORIZONTAL INTENSITY (1925–35) IN GAMMAS PER YEAR

(Based on G96-81)

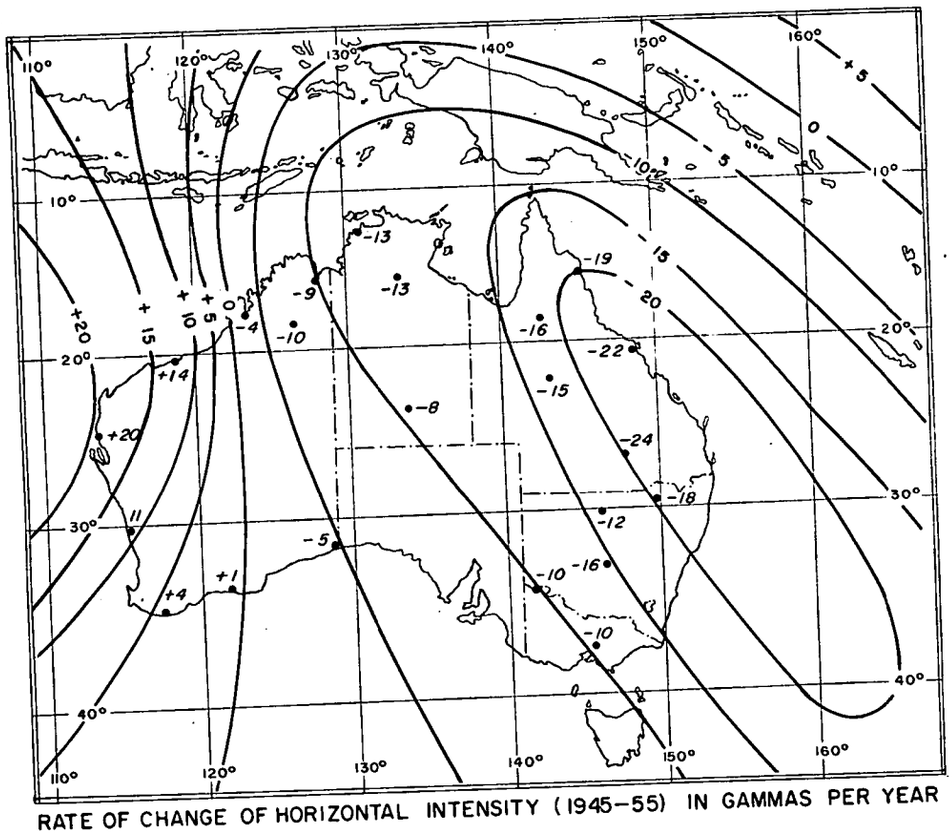
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96–131

TO ACCOMPANY RECORD NO. 1966/87



SECULAR VARIATION
RATE OF CHANGE OF HORIZONTAL INTENSITY (1935–45) IN GAMMAS PER YEAR



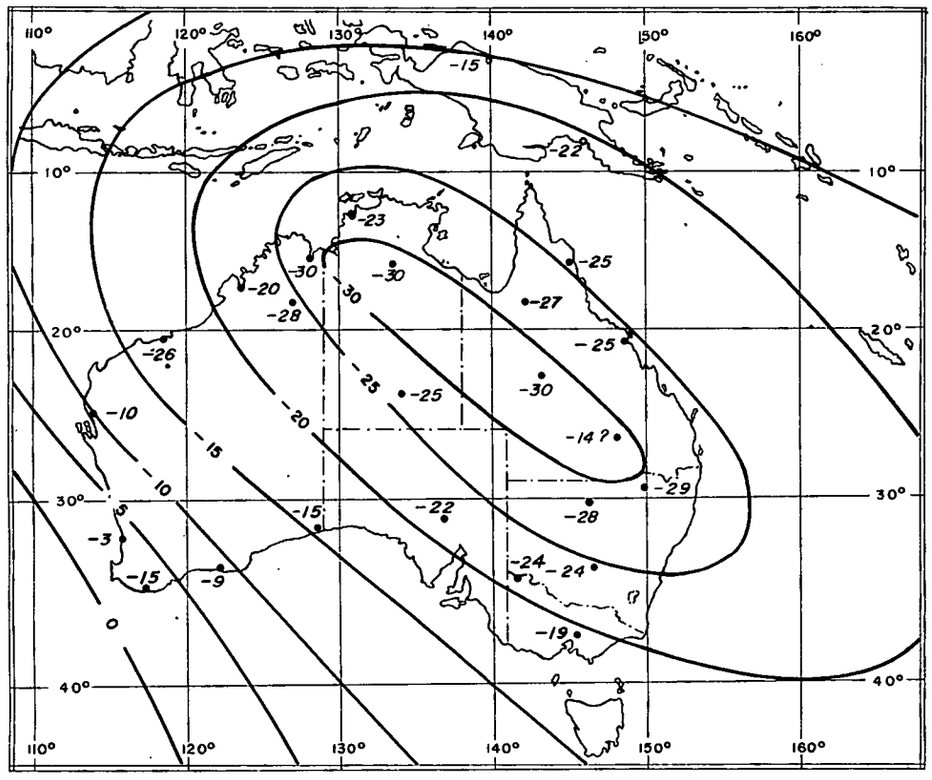
RATE OF CHANGE OF HORIZONTAL INTENSITY (1945–55) IN GAMMAS PER YEAR

(Based on G96-81)

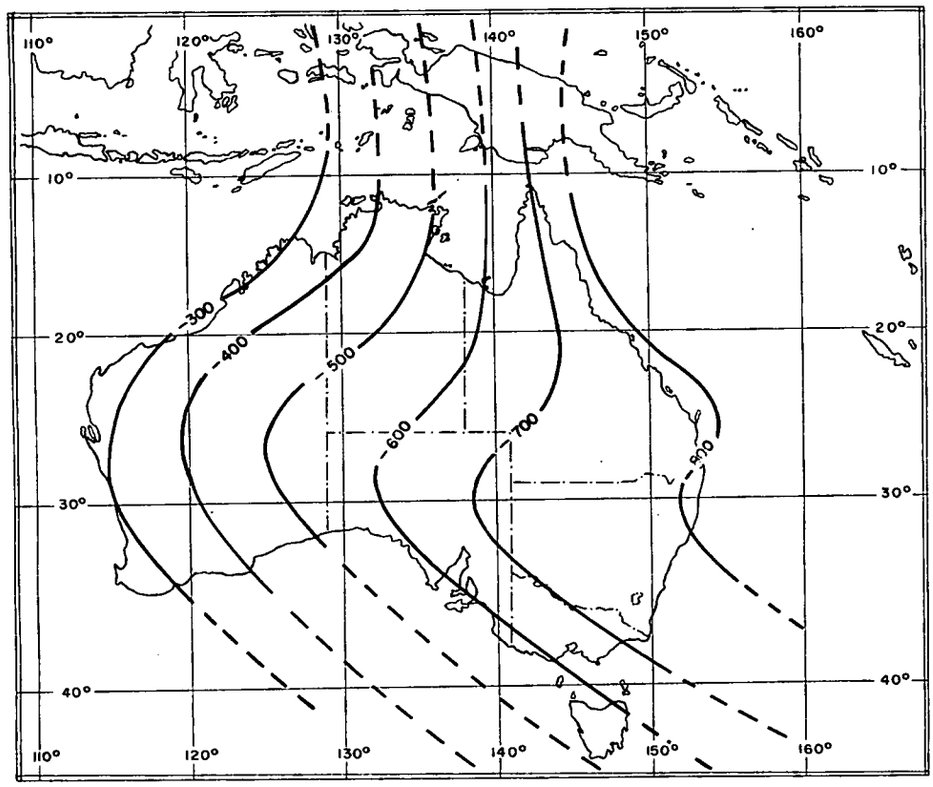
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96–132

TO ACCOMPANY RECORD NO. 1966/87



SECULAR VARIATION
RATE OF CHANGE OF HORIZONTAL INTENSITY (1955–65) IN GAMMAS PER YEAR



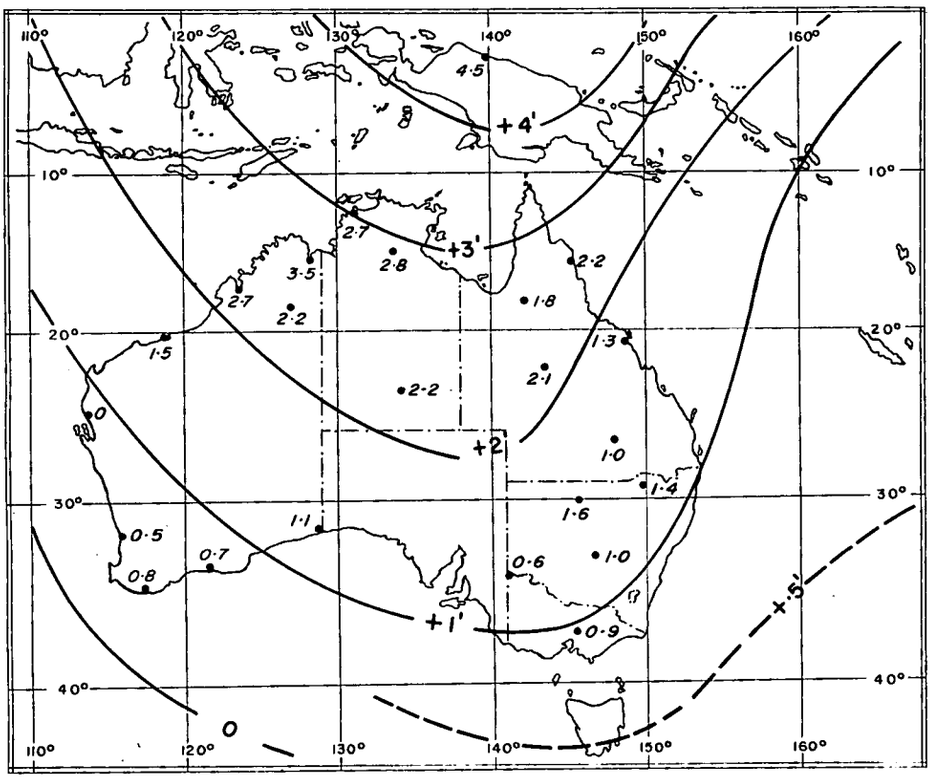
TOTAL CHANGE OF HORIZONTAL INTENSITY FROM 1912 TO 1962 IN GAMMAS

(Based on G96–81)

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96–133

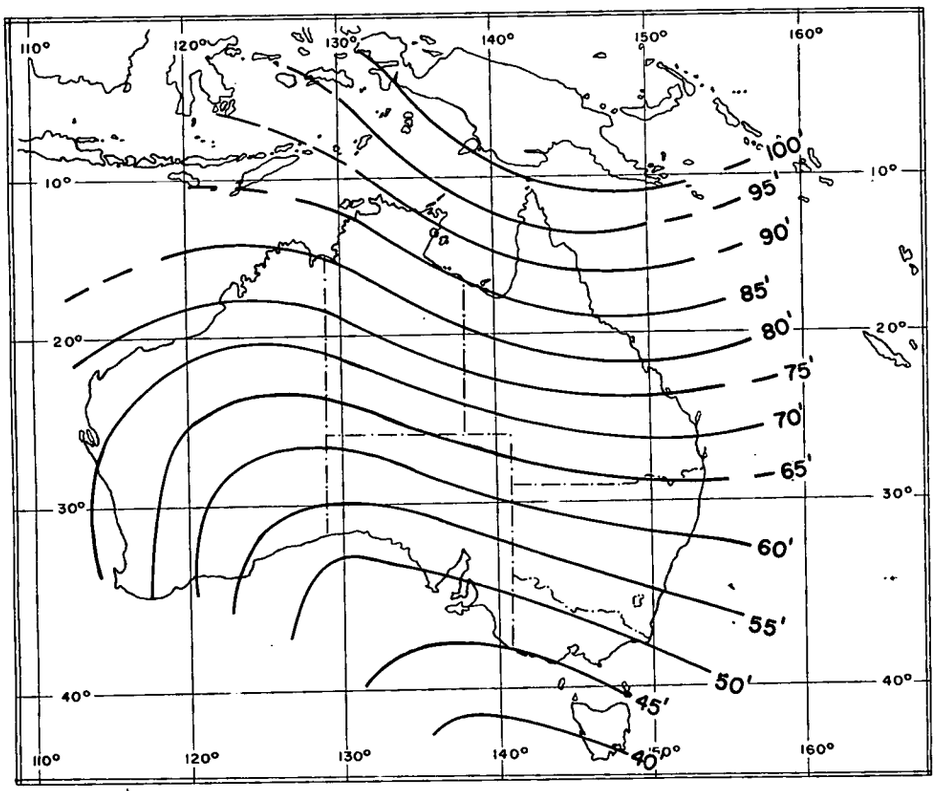
TO ACCOMPANY RECORD NO. 1966/87



SECULAR VARIATION

RATE OF CHANGE OF INCLINATION (1955–65) IN MINUTES PER YEAR

Positive value indicate value is increasing negatively



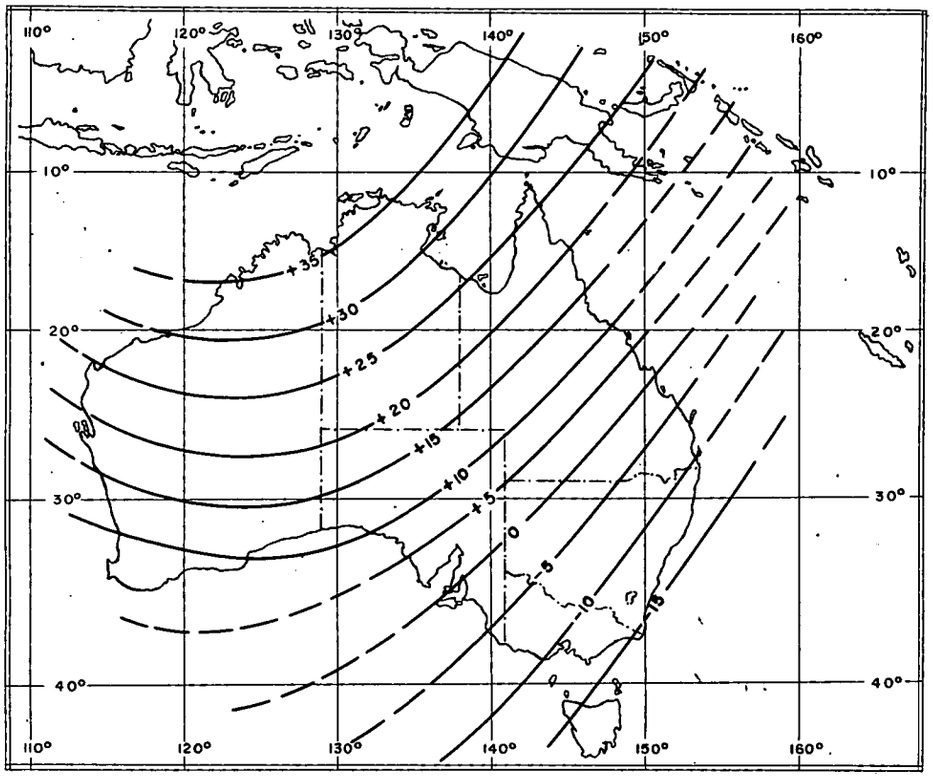
TOTAL CHANGE OF INCLINATION (1912–62) INCREASING NEGATIVELY

(Based on G96-81)

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G96–134

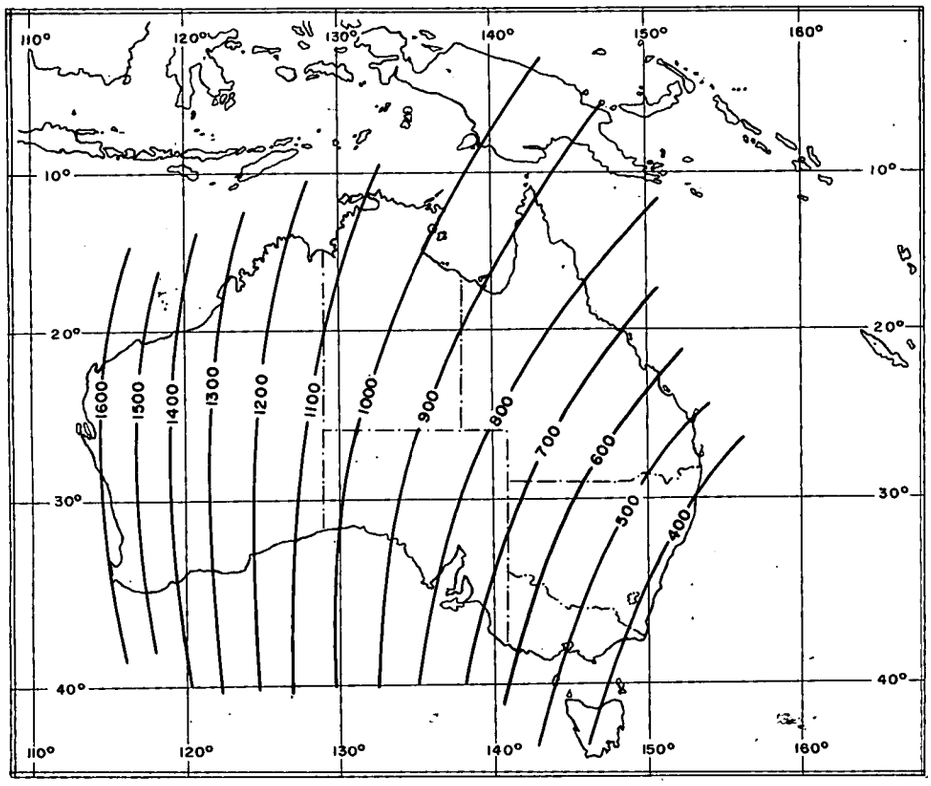
TO ACCOMPANY RECORD NO. 1966/87



SECULAR VARIATION

RATE OF CHANGE OF VERTICAL INTENSITY (1965·0) IN GAMMAS PER YEAR

Positive values indicate increasing negatively

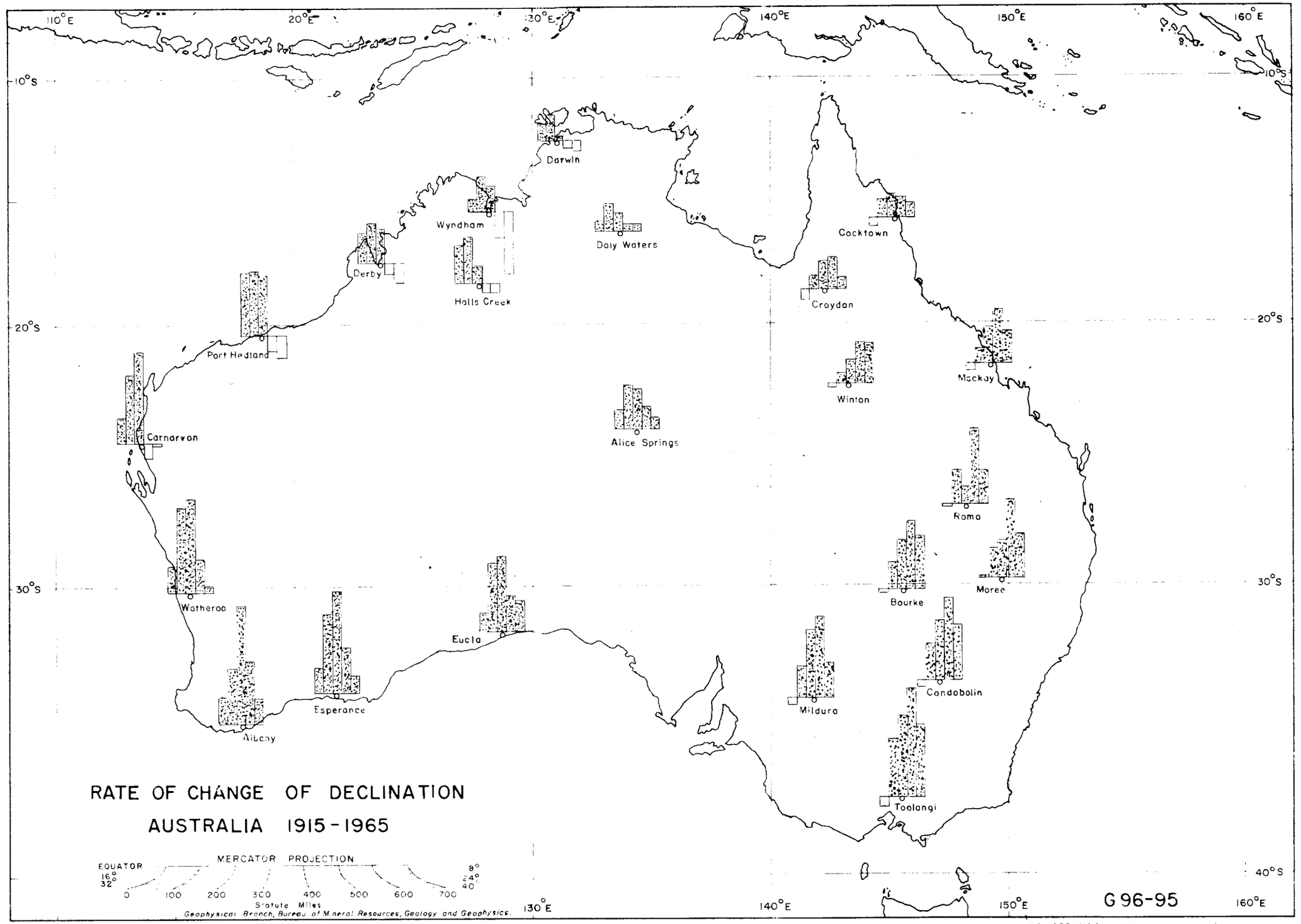


TOTAL CHANGE OF VERTICAL INTENSITY FROM 1912 TO 1962 (increasing negatively)

(Based on G96-81) *Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.* G96—94

TO ACCOMPANY RECORD NO. 1966/87

PLATE 33



LEGEND

A B C D E

A = 1915-25
B = 1925-35
C = 1935-45
D = 1945-55
E = 1955-65

+5
+4
+3 Rate in minutes per year
+2 for each period.
+1 Positive values indicate
-0 increasing easterly.
-1
-2

RATE OF CHANGE OF DECLINATION
AUSTRALIA 1915-1965

EQUATOR 16° 32°

MERCATOR PROJECTION

0 100 200 300 400 500 600 700

Statute Miles

8° 24° 40°

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G 96-95

(Based on G 20-45)

TO ACCOMPANY RECORD NO. 1966/87