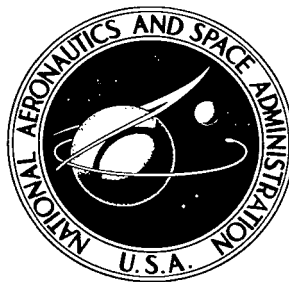


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# THE GEOMAGNETIC SECULAR VARIATION 1900 - 1965

*by Joseph C. Cain and Shirley J. Hendricks*

*Goddard Space Flight Center  
Greenbelt, Md.*



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# THE GEOMAGNETIC SECULAR VARIATION

1900 - 1965

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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## ABSTRACT

The GSFC (12/66) model of the main geomagnetic field uses linear and parabolic terms in time, to represent secular change over the interval 1900-1965. The predicted field is compared with observatory annual means to investigate systematic residuals. Deviations of the order of 100 $\gamma$  occur for short spans of years and only in limited regions. Otherwise, the trends of the computed field parallel the observations. Secular-change charts agree well with those drawn by earlier analyses.

The westward drift is generally apparent in the vector representation of the harmonic coefficients, except that a few terms predominantly undergo an amplitude change. The components below  $(g_6^6, h_6^6)$  that show a recognizable eastward drift are the (3,2), (5,1), and (5,2) terms.

Both dipole poles move smoothly northwestward over the interval, whereas the dipole position initially drifts eastward, reverses direction near 1920, and then moves westward at a rate up to about 0.07 degrees per year. Its 1965 position is found to be 78.8°N, 70.0°W.

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# THE GEOMAGNETIC SECULAR VARIATION 1900 - 1965\*

by

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## INTRODUCTION

In the last few centuries over a hundred papers have been written concerning the main geomagnetic field and its secular variation. These research efforts have followed two main lines of approach: (1) the data from fixed observatories or relocatable positions (repeat stations) are compared quantitatively over a year or two and the differences by components contoured on charts. These secular-change, or isoporic, charts can be compared at intervals (e.g., decades) to attempt to learn how the patterns are changing with time. (2) Magnetic charts for given epochs are constructed, using survey observations reduced to the epoch of the chart. These charts are subjected to spherical-harmonic analysis and the results compared for several epochs (Mauersberger, 1952; McDonald and Gunst, 1967).

Recently we have chosen a different approach making a numerical fitting to all of the *observational* data available through the Magnetic Division of the United States Coast and Geodetic Survey for the period 1900-1964 plus some recent global satellite data acquired by the OGO-2 satellite. The result of this work, designated the GSFC(12/66) field model (Cain et al., 1967), is intended for use as an initial tool in evaluating time variations in the field observed by OGO-2. A set of 120 spherical harmonics of the internal potential were obtained, including their first and second time derivatives.

The accuracy of this expansion in matching the observational data was expressed in terms of the residuals of fit by type of data, component, and epoch. It was shown that the non-satellite data was scattered about the fit with a Gaussian distribution ( $\sigma \sim 120\gamma$ ), apart from some higher-than-Gaussian tails. Over half the data of a given component lay within  $100\gamma$ , 75 percent within  $200\gamma$  and 95 percent within  $500\gamma$  of the fit. The distribution by component varied slightly, with the Gaussian "core" of the  $\Delta Z$  distribution being the widest at  $210\gamma$ , whereas the total field distribution (with a  $100\gamma$  core) was the narrowest. Inspection of the data makes it clear that the large non-Gaussian excursions of the survey data about the fitting surface are due to crustal anomalies.

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\*This paper was presented at the International Union of Geodesy and Geophysics 14th General Assembly St. Gall, Switzerland, September 30, 1967.

(Considering the fact that the distributions were obtained *without* our making any selection of the observations, and no corrections were made for short period variations, it is remarkable that only 5 percent of the data fall outside the 500 $\gamma$  limit.)

The satellite data are free from the influence of these crustal anomalies and depart by much less from the fitting surface. The OGO-2 total field data used were taken from a magnetically quiet period (October 29–November 15, 1965) and deviated with an almost Gaussian distribution whose constant was 12 $\gamma$ . The root-mean-square residuals of the survey data (those differing by more than 2000 $\gamma$  were rejected) were of the order of 180–260 $\gamma$  for individual years over the interval 1906–1964, after decreasing from a peak of 320 $\gamma$  in 1900. It was suggested in the previous paper that there may thus be systematic deviations of the secular change estimates from the fitting surface.

In creating the GSFC(12/66) field model, a deviation was made from previous practice. No special heavy weighting was given to the observatory data included in the fit. As explained in the discussion of the GSFC(12/66) derivation, the earlier evaluations (Cain et al., 1965; Hendricks and Cain, 1966; and Cain, 1966) used very heavy relative weights for the observatory data because these are more accurate than the field survey data. However, these analyses showed that the scatter of the observatory data was not appreciably different from that of the rest of the observations; the main disturbing factor is the presence of crustal anomalies and not measurement inaccuracies. The observatory annual means were thus entered into the fit with the same relative weights as the other surface data.

In past work on secular change, displays of comparisons between the observational data and the results of analysis have been surprisingly few. This paper shows how the parabolic series for the spherical harmonic coefficients matches the field variations measured at selected magnetic observatories, and points out how some features of secular change compare with those reported in past papers.

## COMPARISON WITH OBSERVATORY ANNUAL MEANS

Appendix A, consisting of a map (Figure A1) and 212 graphs (Figures A2 through A213) shows the results of comparing the field components computed from the GSFC(12/66) model with annual means observed at a selection of magnetic observatories. (Figure A1 shows the location of most of the observatories.) The graphs (plotted automatically) are arranged alphabetically by observatory name. An observatory is omitted only if it offers less than five annual means. Under each observatory's name is its latest location, given by geodetic longitude and latitude in decimal degrees (positive east and north) and its altitude in kilometers, if known and above 100 meters. The vertical scales, arranged from left to right, show H and Z in gammas with 1000 $\gamma$  between abscissa (Z positive down), and D in degrees (positive eastward) at 2-degree intervals. The computed values are traced by the solid lines and are labeled on the right side according as they are H, D, or Z. There is a break in the computed curves if the observatory was moved. The calculations are made as appropriate to the site of observation.

The observed annual means are plotted as  $\oplus$  for H,  $\odot$  for D, and  $\square$  for Z. In reproduction, these symbols are not always clear but may appear as filled circles or squares. (The symbols H, D, or Z also appear before the first hourly mean for each graph, as appropriate.) The computed values are fed to the cathode-ray-tube plotter for each year for which there are observations of a component. The plotter beam is left on between points and traces out a straight line. The continuous curves thus appear lighter for those years for which observed means are missing, since the beam moves more quickly; and, whereas a continuous set of points seems to give a smooth curve, large gaps in the data (e.g., Chelyuskin, Hel) result in a straight line connecting the points.

One feature of the plots is that the observed data occasionally disappear from the top or bottom of the plots. This problem arose in imperfections in the computer algorithm which was computed in order to give a scale that would suit all graphs. Since only a few plots were affected and the algorithm was already quite complex, it was decided to omit the worst offenders and keep the rest. Thus in a few instances (e.g., Dombas Z before 1928) there are more observed data than appear on the graphs. The fact that observed and measured data often parallel each other with up to a few hundred gammas displacement (e.g., Alibag) suggests that the absolute differences are due to crustal anomalies. This view is supported by such examples as Honolulu, where the observed values hopped from one side of the computed D and H curves when the station was moved, around 1947. The question then arises: does the total observed secular change represent that of the main field, or does it include a contribution from crustal matter with a "soft" permeability? Here we assume that the changes with time in the anomaly field are unimportant; they are probably of the order of the percentage secular change multiplied by the size of the anomaly. Thus, for the 95 percent of the data within  $500\gamma$ , variations of the anomaly field due to a change of the main field by a few percent would represent only a few gammas. The graphs indicate that the oscillation of the data from the fitting surface is more often of the order of  $100\gamma$ .

Eleman (1966) has pointed out another factor regarding the influence of anomalies. If a constant anomaly causes the observed annual means H and D to deviate from the normal field  $H_N$  and  $D_N$ , then a representation of secular change in terms of  $\dot{H}$  and  $\dot{D}$  can be erroneous. If  $\delta = D_N - D$ , the secular change of the normal field is given by

$$\dot{D}_N \approx (H/H_N)\dot{D} - (\dot{H}/H_N)\delta ,$$

$$\dot{H}_N = \dot{H} + H\dot{D}\delta ,$$

provided that  $\delta$  is sufficiently small, so that  $\cos \delta \approx 1$  and  $\sin \delta \approx \delta$ . Eleman showed that for Kiruna (1954-1955) the second terms amount to about 1 minute per year for  $\dot{D}$  and  $4\gamma$  per year for  $\dot{H}$ . A plot of the data in the orthogonal components X, Y, and Z should eliminate any concern over this geometric interaction. We have chosen to make the comparison here in terms of the observed values, since at this stage such refinements are not essential.

If the displacement due to crustal anomalies is taken into account, curve trends can be profitably compared with the observations. Considering that the fit was made to a selection of all data

without any corrections for storm variations or other transient effects such as the diurnal variations, the agreement is, in general, fairly good. For most observatories, the computed and measured H component trends not only are very nearly parallel but also show little absolute displacement. Declination trends agree somewhat less well. The vertical intensity curves show the largest displacements and the poorest agreement of the curves as a whole, and the largest scatter of individual points.

Significant discrepancies between predicted and observed data occur at the western edge of the Indian Ocean. Mauritius vertical-intensity and Tananarive declination curves have a smooth parabolic shape that differs considerably from the computed curves. Alibag vertical intensity, after tracking very well for the first 40 years, now shows an increasing deviation from computed values.

For most of the other graphs, the deviations from the computed curves must be real because they exceed any possible errors of measurement; but generally they can be regarded as second-order perturbations from the main trend of secular change. These deviations can matter seriously when the field model is used to compute a reference field, particularly when extrapolating beyond 1965.

A relationship may exist between the earth rotation rate and secular change (Dicke, 1966). In the period 1900-1920, for example, there may have been a short-lived reversal of the slowing of the earth's rotation rate that has otherwise appeared to be almost constant from 1800 through 1950 (Munk and MacDonald, 1960). The high residuals of fit from 1900 to 1910 noted in the previous paper (Cain et al., 1967) may have been related to this phenomena. In the absence of 18th-century survey data, it is uncertain that such an increase was not due to the numerical process of least squares, where the residuals are sometimes largest near the fringes of the data set—particularly when the data distribution is relatively thin (as it is for 1900-1910).

However, the graphs in Appendix A do show a definite trend away from the parabolic curves for 1900-1910 for some components and stations. The curves for all English and European observatories (e.g., Bochum, Stonyhurst, Kew, DeBilt, Greenwich, etc.) show that the measured secular change in H is significantly more positive than that computed. Likewise, for the same area the secular change in declination is more negative than that predicted. The boundaries of this phenomenon are somewhat vague but it is clearly not present in the Pacific, South America, and Asia (e.g., Melbourne, Hong Kong, Kakioka, Christchurch, Kodaikanal, Huancayo, Santiago, Colaba, etc.). In the United States (Cheltenham, Baldwin, Sitka) and central Russia (Sverdlovsk) the higher observed secular change in H is evident, but not the corresponding disparity in declination. It is undoubtedly such irregularities that have led investigators (e.g., Chapman and Bartels, 1940, p. 130) to conclude that secular variation is a regional phenomenon. Although the deviations seem to correlate for observing stations in a given region so that a very accurate mathematical model would require their inclusion in some way, it is apparent that the general character of secular change is well enough represented by this model.



## COMPARISON WITH EARLIER ISOPORIC CHARTS

Using the GSFC(12/66) coefficients it is possible to compute the secular change of the components at any epoch. This is a simple process for the orthogonal components (differentiating the expressions for those components and evaluating  $-\nabla\dot{V}$ ), but the representation of  $\dot{H}$ ,  $\dot{D}$ , and  $\dot{i}$  requires special expansions. It is therefore simpler to compute the field for a small increment of time (e.g., 0.5 year) on either side of an epoch and take the difference. This procedure was carried out for the epochs 1912.5, 1922.5, 1932.5, and 1942.5 for the components H, I, X, Y, Z, and F and isoporic charts drawn by means of an automatic contouring procedure similar to that described by Cain and Neilon (1963). These charts appear in Appendix B along with reproductions of the corresponding ones from Vestine et al. (1947). These charts may also be compared with those for 1922 by Fisk (Chapman and Bartels, 1940, p. 115-119).

Comparison with the earlier charts shows in all instances the same basic cell structure. The GSFC-map extreme values for the force components differ by a few tens of gammas per year from the values given by Vestine et al. and generally have a smaller absolute magnitude. For the inclination charts, the agreement with Vestine is within a few minutes per year for the center cells. Comparison with the diagrams by Fisk for 1922 also leads to the conclusion that the GSFC extreme values are of smaller absolute value than those on the earlier works. This suggests that the analysis using only 120 spherical harmonics may give too smooth a picture of the secular change patterns.

## THE GEOMAGNETIC SECULAR VARIATION FIELD IN 1965

For those wishing to use the GSFC(12/66) model as a reference at current epochs, Appendix C presents a set of surface charts for 1965.0 (Figures C1 through C13). These closely agree with the U. S. World Magnetic Charts for the same epoch; although, as previously noted in the comparison with the earlier isoporic charts, the GSFC(12/66) patterns are slightly broader and less intense.

Comparing the computed rate of change since 1960 with that observed at various observatories shows some systematic deviations over certain areas of the earth. For example, the observed rate of change in the vertical component over South America is of the order of 40 gammas per year greater than the computed rate. Increasing the computed rate for the area by this amount would sharpen the low cell pattern to the northeast and bring the GSFC(12/66) model into closer agreement with the U. S. Charts. Also, for the region around the Caspian Sea, the observed change in the horizontal intensity is about  $30\gamma$  per year *less* than that computed. Changing the computed rate by this amount would again result in better agreement with the U. S. Charts. Other regional deviations since 1960 were noted. In Europe and North America, the observed change in Z is about  $15\gamma$  per year less than that computed; in Europe and South America, the variation in H is about  $15\gamma$  per year greater than that computed; in Central America, the variation in H is about  $30\gamma$  per year less than that computed. The secular change in declination appears to be 1 to 2

minutes per year less than that computed in Europe and most of Russia, 2 to 4 minutes per year less in South America, and up to 10 minutes per year less along the northern coast of Scandinavia and Russia.

Thus, the present model apparently produces patterns of secular change that may, in general, be smoother than the observed changes, but it would be hard to improve the representation realistically over the whole sphere, using the present sparse data set. However, these comparisons do suggest that the user of the GSFC(12/66) model as a reference beyond 1965 should be wary of possible deviations of the order of magnitude indicated above.

## DRIFT OF HARMONIC COMPONENTS

Figure 1, a plot of  $g$  and  $h$  harmonic vectors, displays one aspect of secular change. The trace of the individual components is given from 1900 to 1970, with the arrow at the later date, for the components  $(g_1^1, h_1^1)$  through  $(g_6^6, h_6^6)$ . The scale is in gammas and must be divided by 5 for the  $(g_5^1, h_5^1)$  through  $(g_6^6, h_6^6)$  traces. Also, the scale is broken for the large  $h_1^1$  component. This figure is very similar to one that Cain and Hide (1966) show for the results of an earlier analysis. A single curved arrow is used for the whole interval without indicating the location of the points for the years between 1900 and 1970; however, a detailed inspection of the data revealed that the years fall almost uniformly along each path.

Consideration of the westward drift in terms of harmonic components was first discussed by Carlheim-Gyllensköld, who deduced that the harmonic components of the first few terms drifted westward at an increasing rate according to the degree of the expansion. Bartels disagreed with this deduction on the basis of his analysis of data from the period 1902-1920 (cf. Chapman and Bartels, 1940, p. 666). Phase changes for the spherical harmonics are also discussed in several later works (cf. Nagata, 1962) which conclude that all components up to  $(4, 4)^*$  drift westward with the exception of  $(3, 2)$ .

Figure 1 supports the general pattern of westward drift as indicated by the number of components moving clockwise about the origin. The components predominantly moving westward are  $(2, 1)$ ,  $(2, 2)$ ,  $(3, 3)$ ,  $(4, 1)$ ,  $(4, 2)$ ,  $(4, 3)$ ,  $(5, 4)$ ,  $(6, 1)$ ,  $(6, 2)$ ,  $(6, 3)$ ; those predominantly moving eastward are  $(3, 2)$ ,  $(5, 1)$  and  $(5, 2)$ . The others tend to be special cases. For example,  $(3, 1)$  and  $(4, 4)$  and  $(6, 5)$  show a large amplitude change and move predominantly westward;  $(5, 3)$  and  $(6, 4)$  show a large amplitude change and move predominantly eastward. The dipole term  $(1, 1)$  is drawn with a bar across at the 1900 starting point. It traces out from 1900 to about 1920 in an increasing-amplitude, eastward direction and then suddenly reverses and overlays itself with a slight westward motion. As pointed out earlier, it would be unwise to infer too much from this reversal before a systematic analysis is performed that includes pre-1900 data.

\*The notation  $(n, m)$  is used here to denote the components  $(g_n^m, h_n^m)$ .

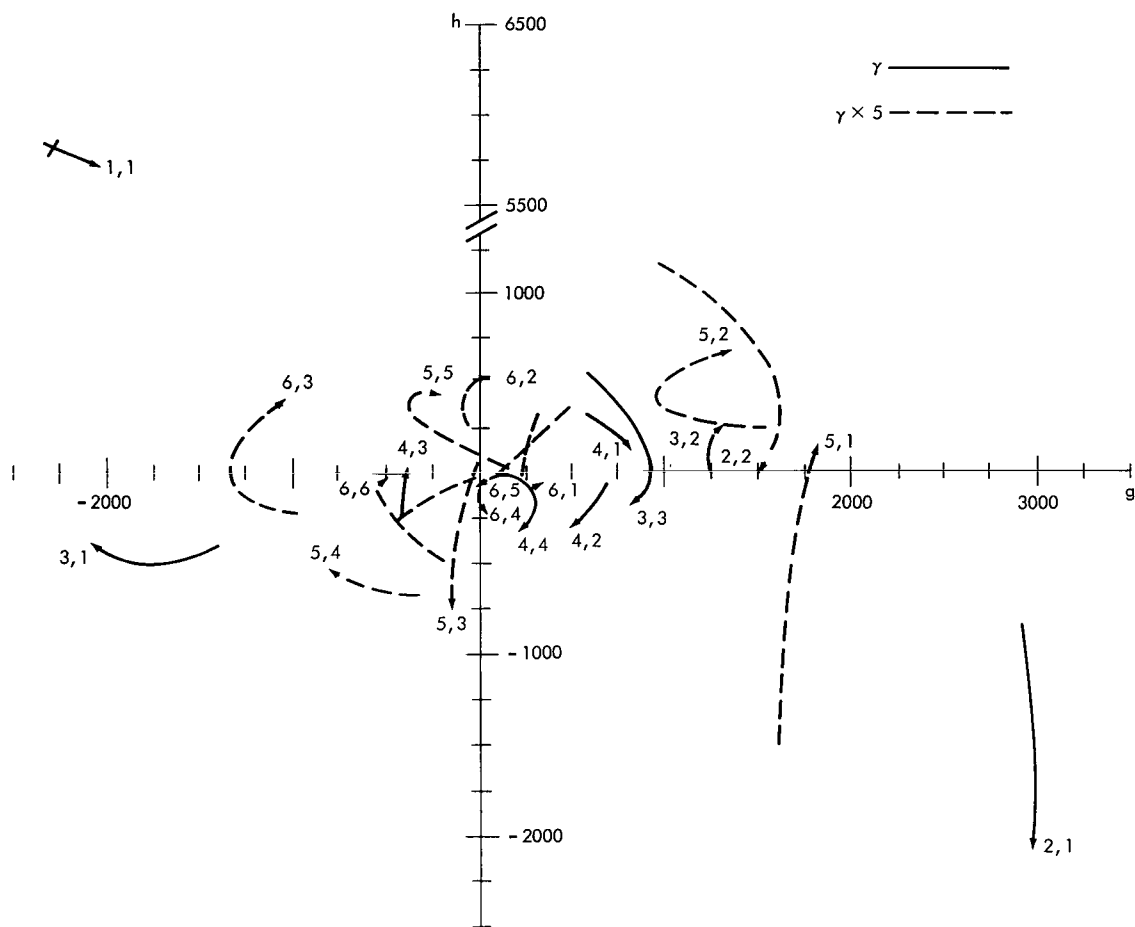


Figure 1—GSFC(12/66) coefficients 1900 to 1970.

The more constant and characteristic feature of this diagram, which was also discussed by Cain and Hide (1966), is that—with the exception of the (6, 1) and (5, 3) traces—both eastward- and westward-moving components have a clockwise curl.

## CHANGES IN SURFACE FEATURES

Bullard et al. (1950) treated the question of westward drift by considering the "non-dipole" field. This they defined by vectorially subtracting the eccentric-dipole field from a real field. This subtraction is commonly performed because the dipole contribution is so much larger than the others, appears to change differently, and thus may have a different physical basis. However, the *absolute* change in the (1, 1) component is not disproportionate to that in the other harmonic terms (Figure 1). The small angular change in its phase is due to its relatively large amplitude and a reversal of trend. At this juncture we shall discuss features pertaining to the whole field.

A cursory inspection of some of the surface features confirms the general westerly motion of the field depicted by our model. The 0.23-degree-per-year drift of the Brazilian minimum in total field for this model has already been discussed (Cain, Langel, and Hendricks, 1967). The Siberian high in  $F$  at the surface is estimated by the model to be located at  $61.8^\circ\text{N}$ ,  $107.6^\circ\text{E}$  in 1960 and moving at a rate of 0.03 degree per year north in latitude and 0.1 degree per year west in longitude. The Canadian high is also moving north from its 1960 position of  $56.7^\circ\text{N}$ ,  $98.0^\circ\text{W}$  at a rate of 0.08 degree per year, but has an easterly drift of about 0.03 degree per year.

## POSITION OF POLES

The GSFC(12/66) model shows both the north and south dip poles moving northwesterly. The change in position of these two points for the period of the data is shown in Table 1.

The 1965 latitude values agree exactly with those adopted for the U. S. (Hurwitz et al., 1966) and for the U. K. (Leaton, Malin, and Evans, 1965) World Magnetic Charts but the longitude values differ by a few tenths of a degree.

Although the positions of the computed dipoles varied smoothly over the period 1900-1965, the direction of motion of the dipole appeared to reverse, as already indicated in Figure 1. The positions of the boreal point are given in Table 2. After the reversal near 1920, the pole began to move westward at a current rate of about 0.07 degree per year.

The 1965 location given here can be compared with the  $78.6^\circ\text{N}$ ,  $70.4^\circ\text{W}$  position given by Leaton, Malin, and Evans (1965) and the  $78.6^\circ\text{N}$ ,  $70.0^\circ\text{W}$  position given by Hurwitz et al. (1966).

## DECREASE IN MAGNETIC MOMENT OF DIPOLE

The first three terms of the expansion can be used to compute an equivalent dipole moment and equatorial field (Chapman and

Table 1  
Drift of Dip Poles-GSFC(12/66) Model.

Date	North Dip Pole (degrees)		South Dip Pole (degrees)	
1900	71.2 N,	96.9 W	72.3 S,	153.2 E
1930	72.6 N,	99.0 W	68.8 S,	144.7 E
1960	75.1 N,	100.7 W	66.7 S,	140.7 E
1965	75.5 N,	101.0 W	65.5 S,	140.3 E

Table 2  
North Dipole Location - GSFC(12/66) Model.

Date	Latitude (degrees)	Longitude (degrees)	Westward Drift Rate (degrees/year)
1900	79.0 N	69.0 W	
1910	78.8 N	68.6 W	-0.03
1920	78.7 N	68.5 W	-0.01
1930	78.7 N	68.6 W	0.01
1940	78.7 N	68.8 W	0.02
1950	78.7 N	69.2 W	0.04
1960	78.7 N	69.7 W	0.05
1965	78.8 N	70.0 W	0.07

Bartels, 1940, p. 642). With a value of  $a = 6.3712 \times 10^8$  cm for a mean radius, the value of  $M$  and  $H_0$  are given in Table 3. Since field reversals are believed to have occurred in geological times (Cox et al., 1967), it has recently become popular (Leaton and Malin, 1967; McDonald and Gunst, 1967) to speculate on the demise of the main-field dipole (about 3700-4000 A.D.) by extrapolating a linear trend from such data as the above. Note, however, the tendency toward a reduction in the rate of decrease. Since our analysis included data for a time span during which there is only a 3-percent change in  $M$ , extrapolations to zero are most untrustworthy.

Table 3  
Dipole Moment and Horizontal Field of  
Equivalent Dipole.

Date	$M \times 10^{-25}$ (cgs)	$H_0$ ( $\Gamma$ )	$\dot{H}_0$ ( $\gamma/\text{year}$ )
1900	8.298	0.3209	-20
1920	8.197	0.3170	-18
1940	8.105	0.3134	-16
1960	8.023	0.3102	

## CONCLUSIONS

Since the GSFC(12/66) field analysis was performed on survey data without correcting them for short-period fluctuations such as Dst and Sq, it is remarkable that the main patterns of secular change represented agree so closely with earlier analyses in which the data were subjected to a careful screening and correction process. The main defects of the model result from the irregular regional changes superimposed on the general trends and the use of a parabolic representation over too long an interval. Therefore, extrapolation of the model to epochs beyond the last data used (1965.8) will be increasingly in error—by as much as a few tens of gammas per year, in some areas. This deviation may seem large, but better forecasts can hardly be made until recent satellite survey data are evaluated over a year or more, to allow for a more accurate *global* estimate of secular change. This work does indicate that there is no special need for fixed repeat stations for monitoring the secular change. Although data from such stations were indeed a valuable addition to the data set, the analysis ignored the fact that they remained in one location. It may later be possible to monitor the main field using only satellite data corrected for time variations as derived from the fluctuations observed at the surface observatories.

The westward motion of most of the spherical-harmonic vectors confirms earlier observations. The clockwise curvature pattern for almost all components is noted for the first time as a curious and unexplained fact. The sudden reversal of the eastward drift of the dipole poles near 1920 may be due to inaccuracies in the analysis resulting partly from the poor distribution of data. On the other hand, the change may be connected with the 1900-1920 anomalous increase of the earth's rate of rotation. The slight slowing of the rate of decrease of the moment of the earth's main dipole suggests that the field is not beginning a cycle of reversal. To check such suggestions requires subjecting a much longer span of magnetic-field observations to a consistent analysis.

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21. Vestine, E. H., I. Lange, L. Laporte, and W. E. Scott, "The Geomagnetic Field, Its Description and Analysis," *Carnegie Institution of Washington, Publication 580*, 1947.





Appendix A

**Comparison of Observatory Annual Mean Values 1900 - 1965  
With Elements Computed From GSFC (12/66)**





ABINGER  
 Lat 51.18 Long -0.38

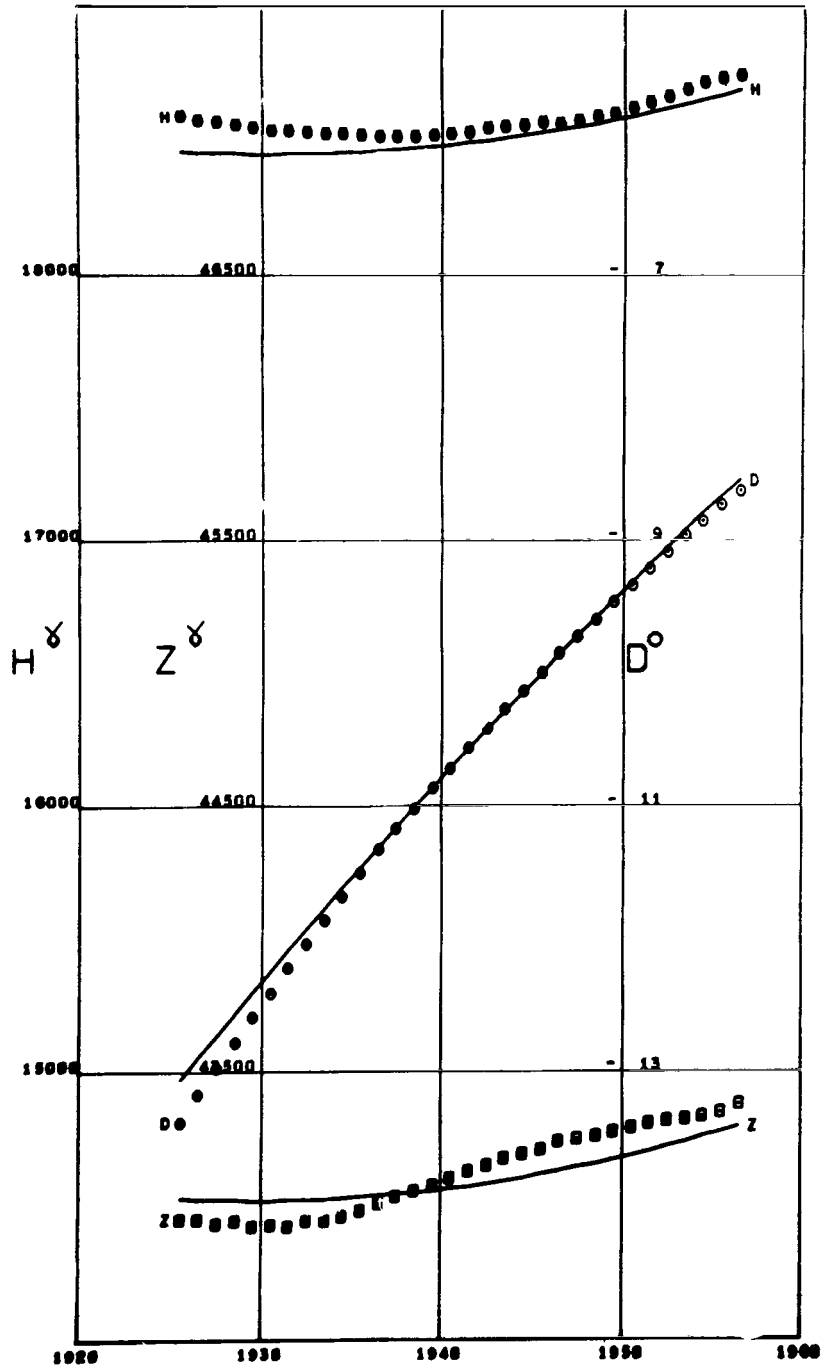


Figure A2

ABISKO  
 Lat 68.35 Long 18.82

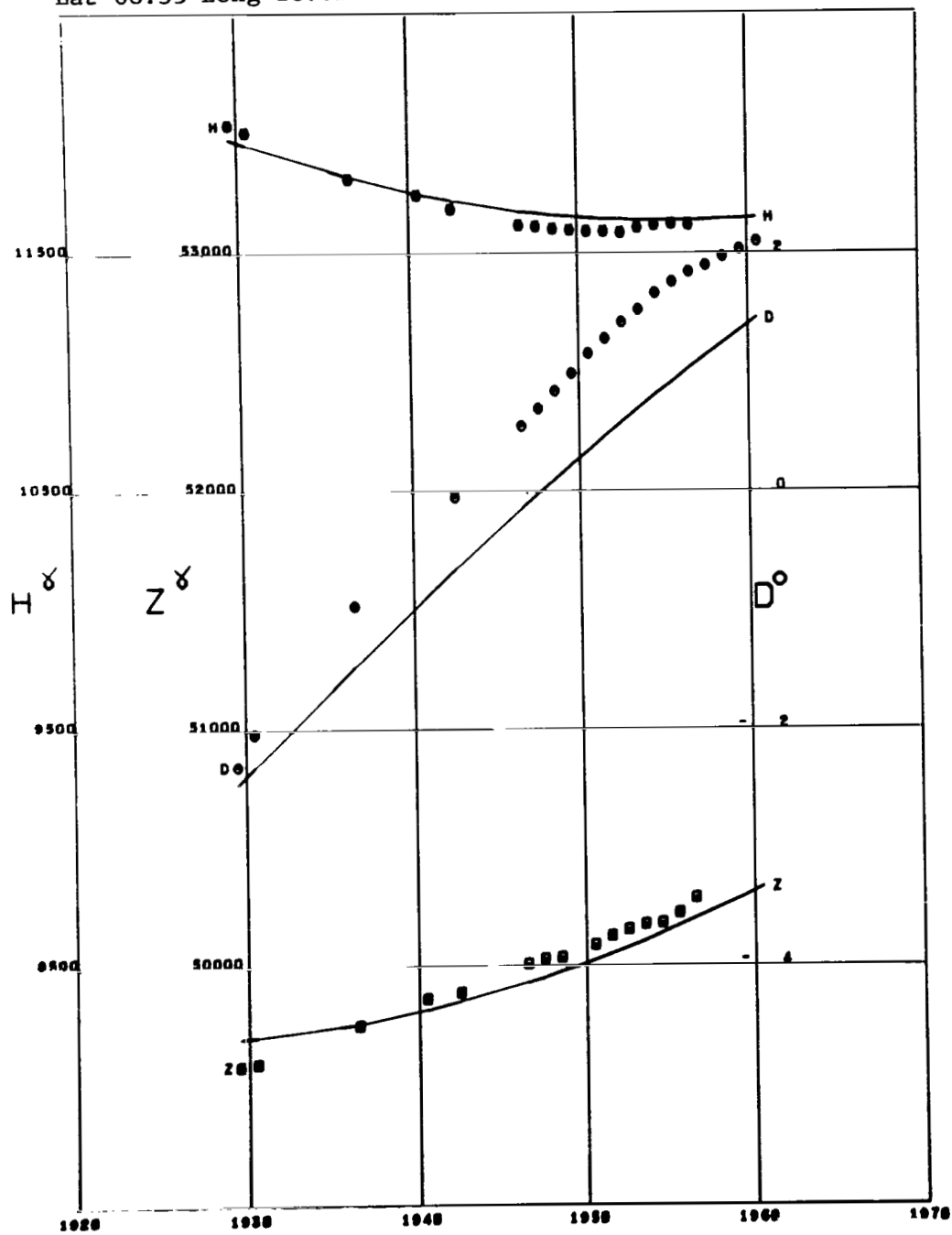


Figure A3

ADDIS ABABA  
 Lat 9.03 Long 38.76 Alt 2.44

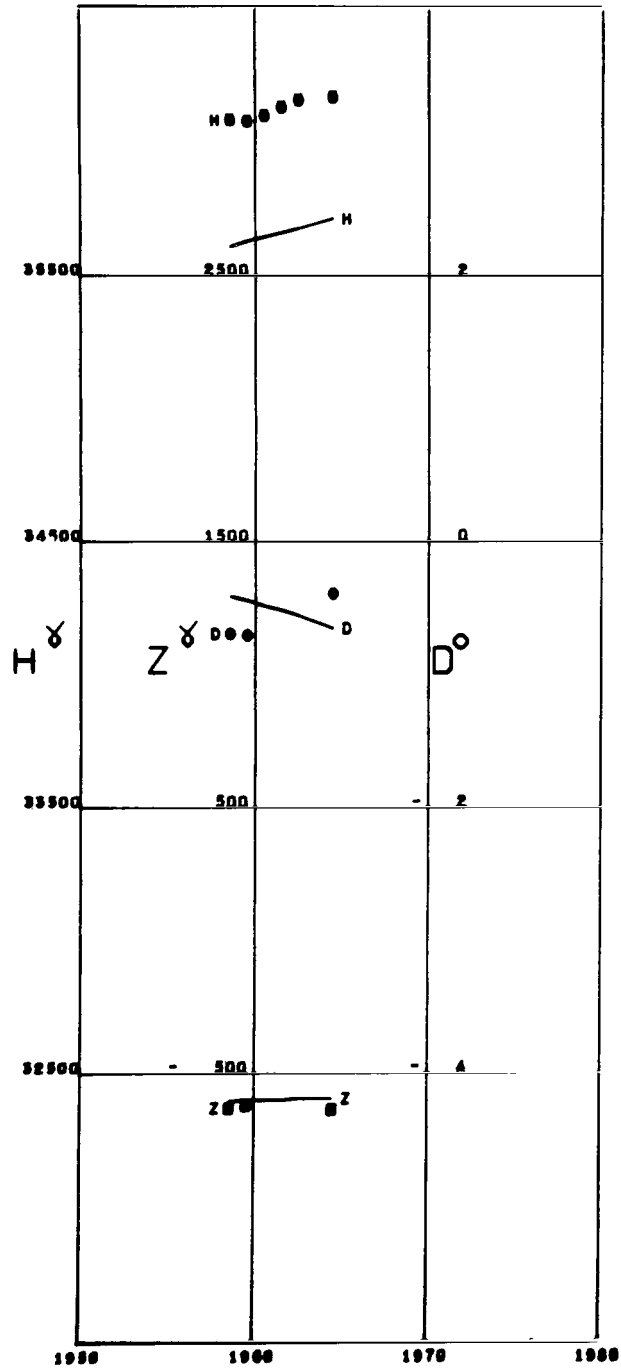


Figure A4

AGINCOURT  
 Lat 43.78 Long -79.26 Alt 0.18

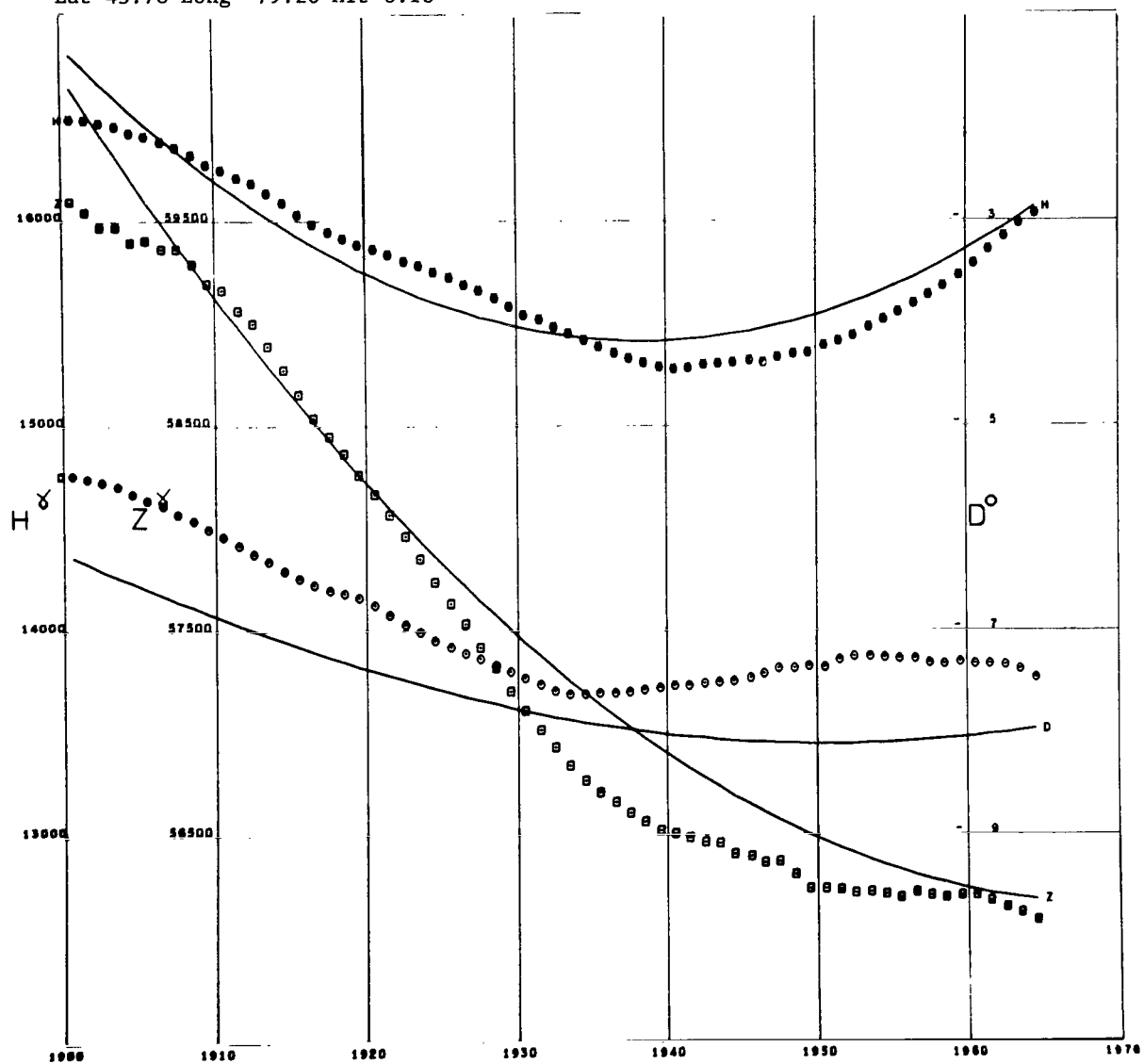


Figure A5

ALIBAG  
 Lat 18.63 Long 72.87 Alt 0.01

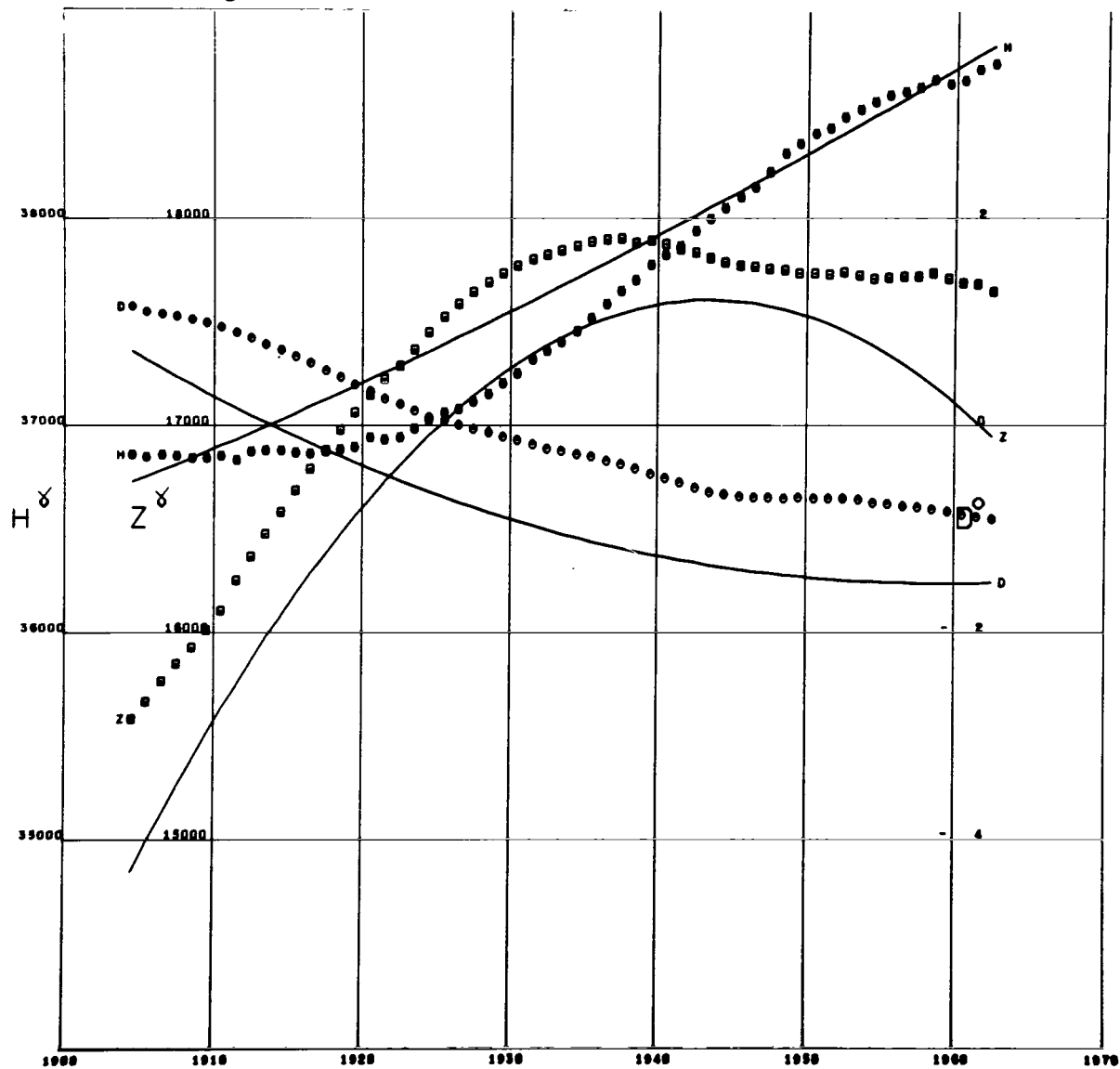


Figure A6



ALMERIA  
Lat 36.85 Long -2.46

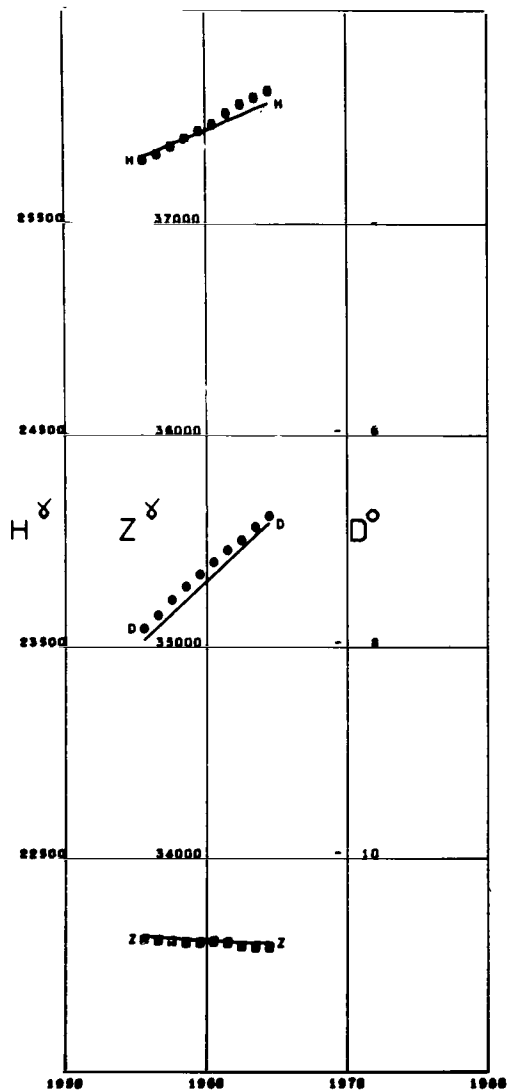


Figure A7

AMBERLEY  
Lat -43.15 Long 172.72 Alt 0.04

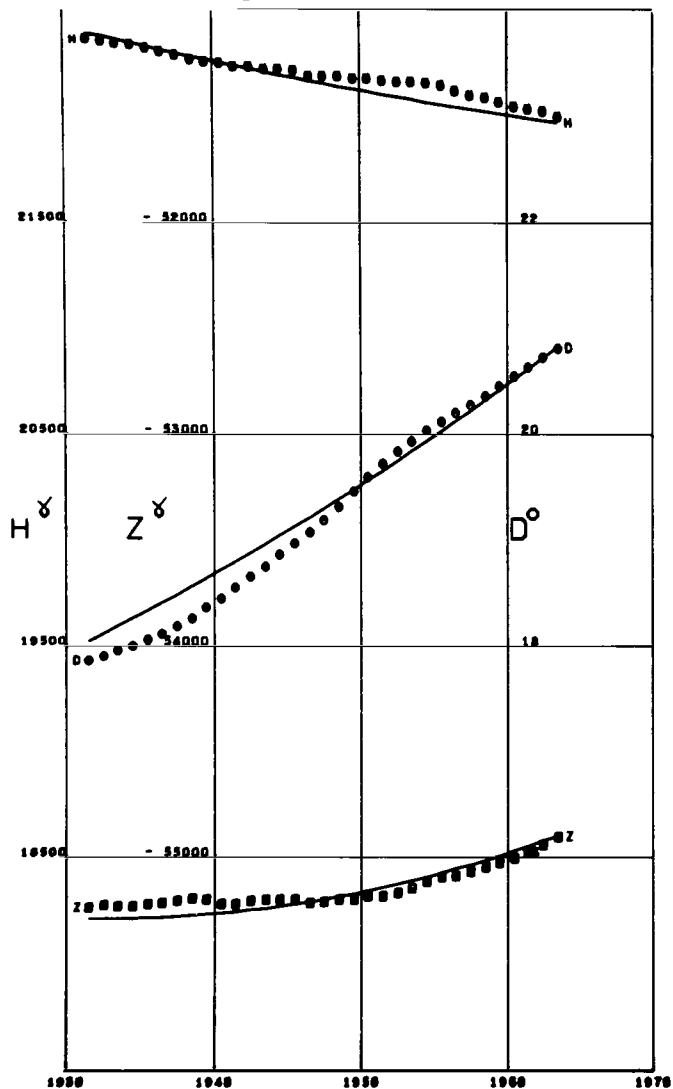


Figure A8

ANNAMALAINAGAR  
Lat 11.40 Long 79.68

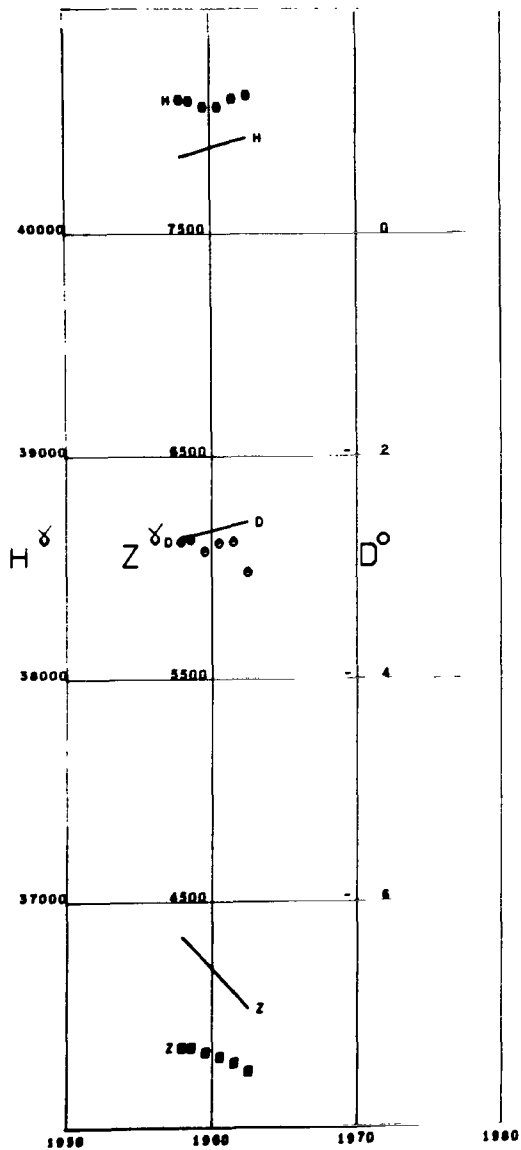


Figure A9

ANTIPOLO  
Lat 14.60 Long 121.16

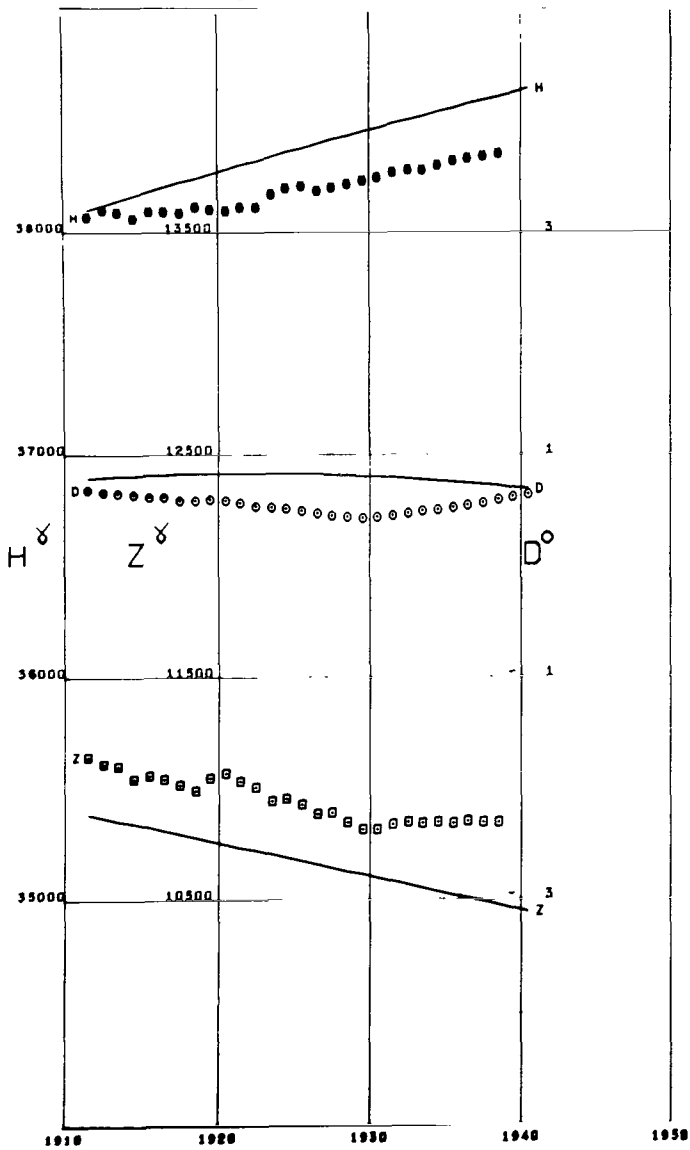


Figure A10

APIA  
 Lat -13.80 Long -171.77

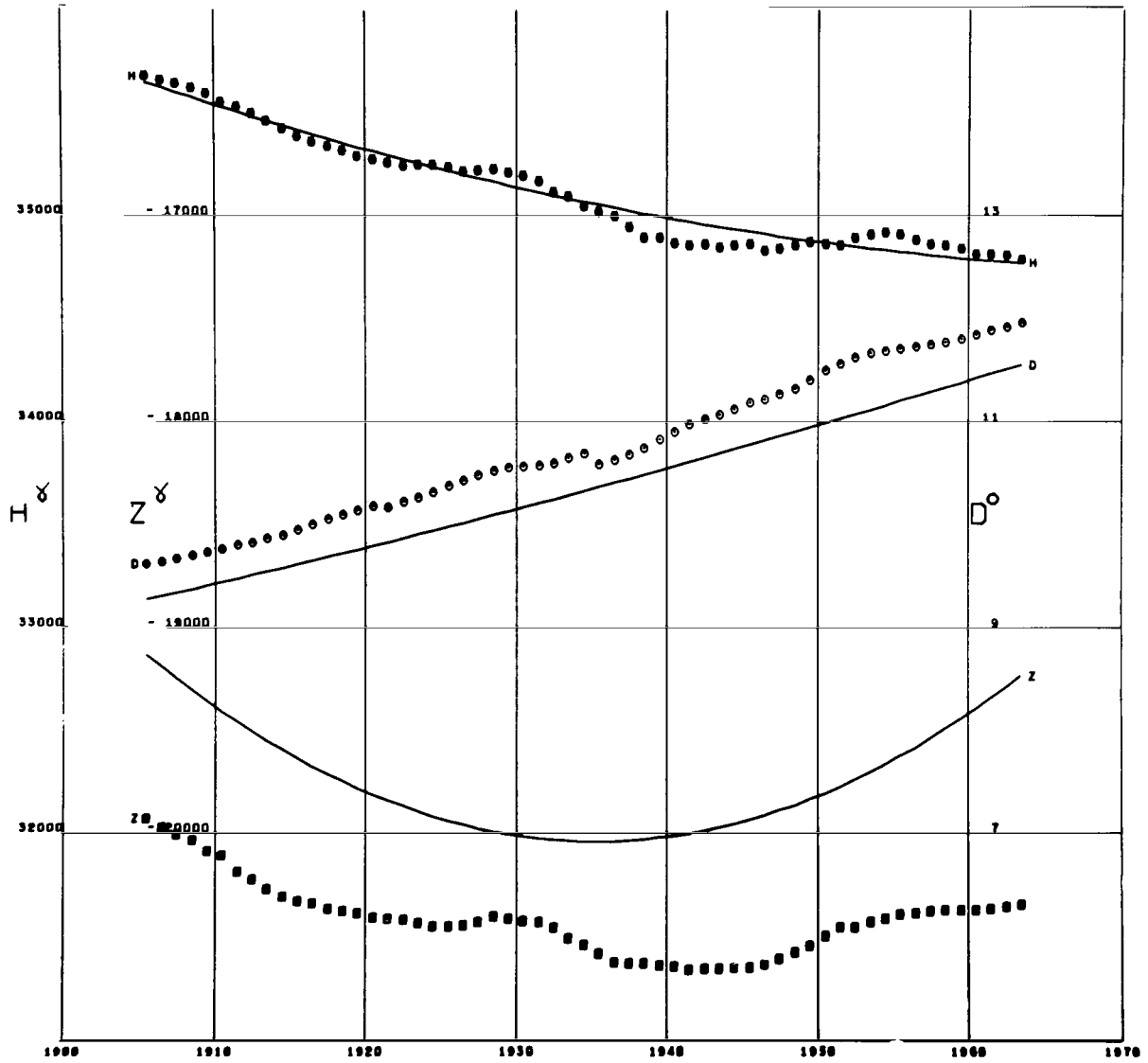


Figure A11

AQUILA  
Lat 42.38 Long 13.31

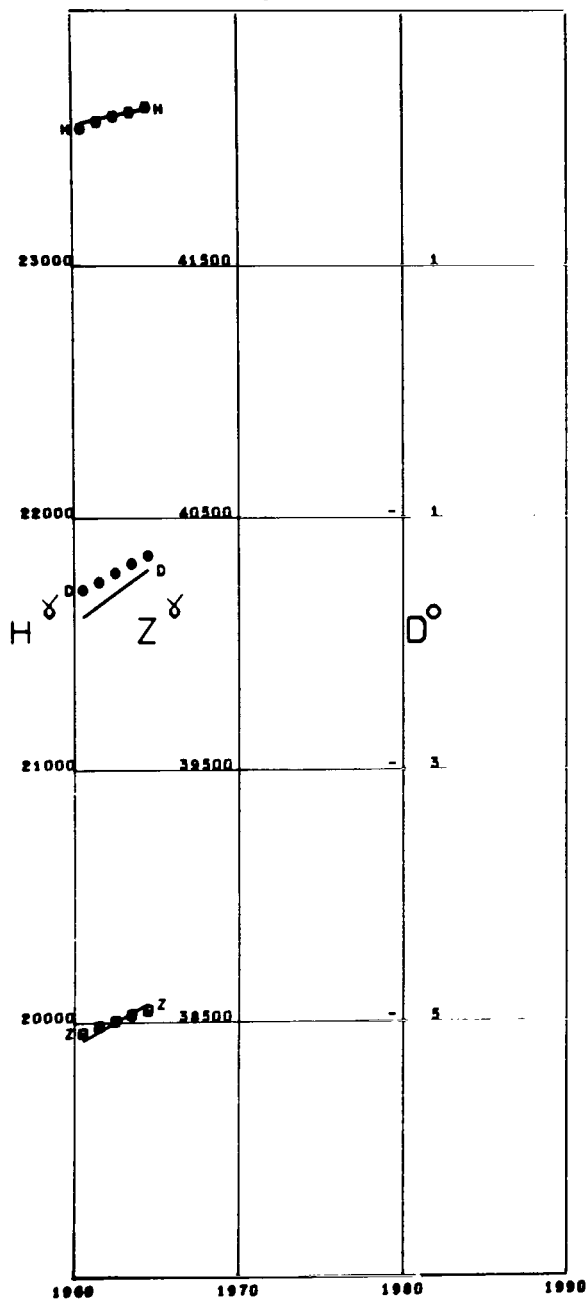


Figure A12

ARGENTINE ISLAND  
Lat -65.24 Long -64.25

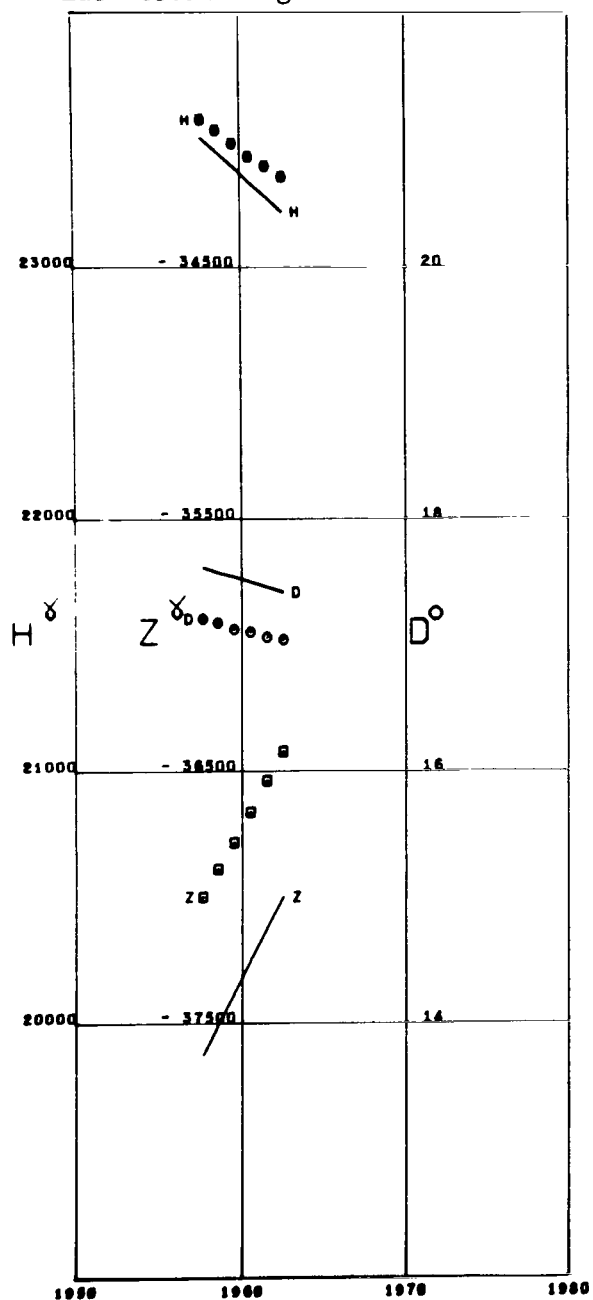


Figure A13

# ATHENS

Lat 37.97 Long 23.72

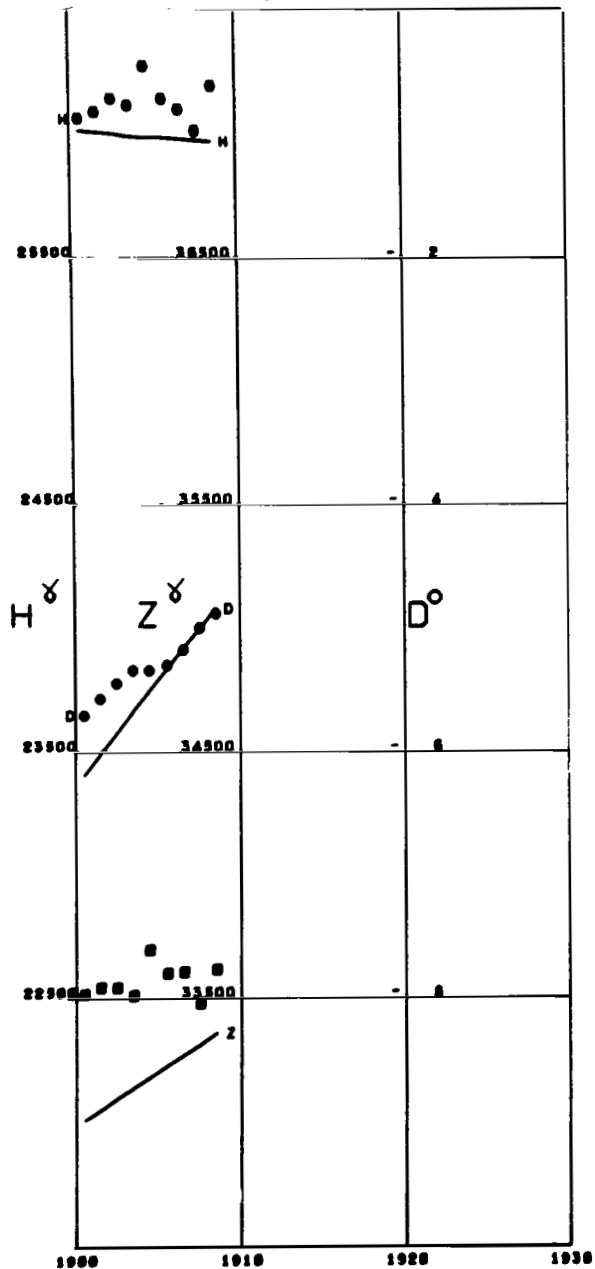


Figure A14

# AU TAU

Lat 22.44 Long 114.04

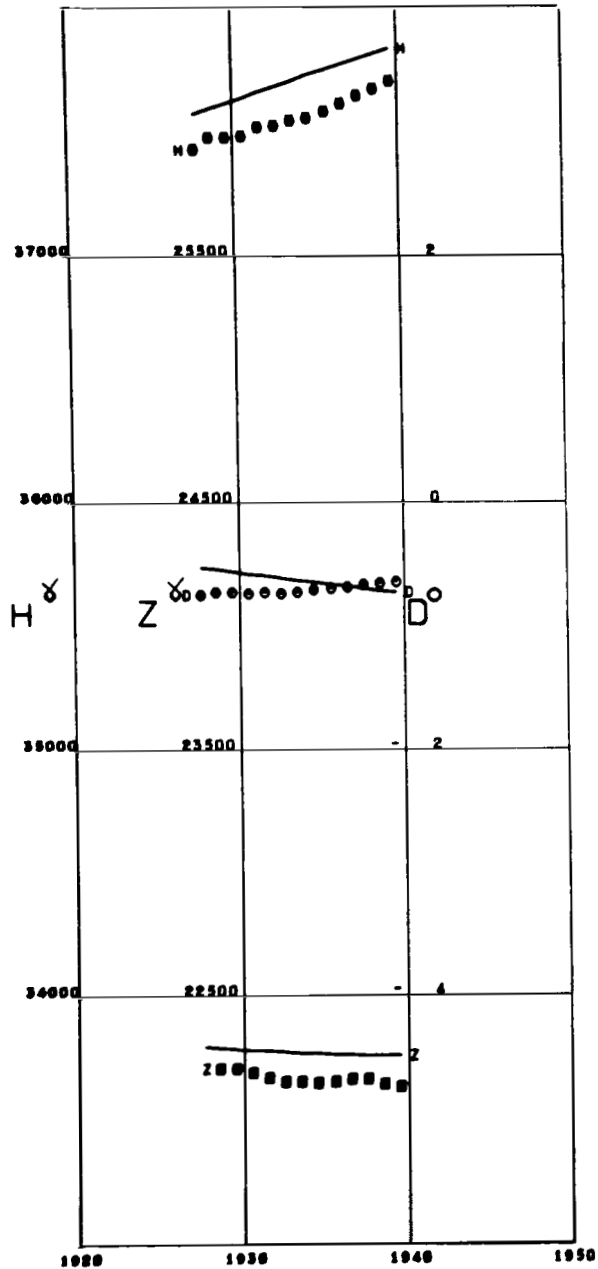


Figure A15

BAKER LAKE  
Lat 64.33 Long -96.03 Alt 0.04

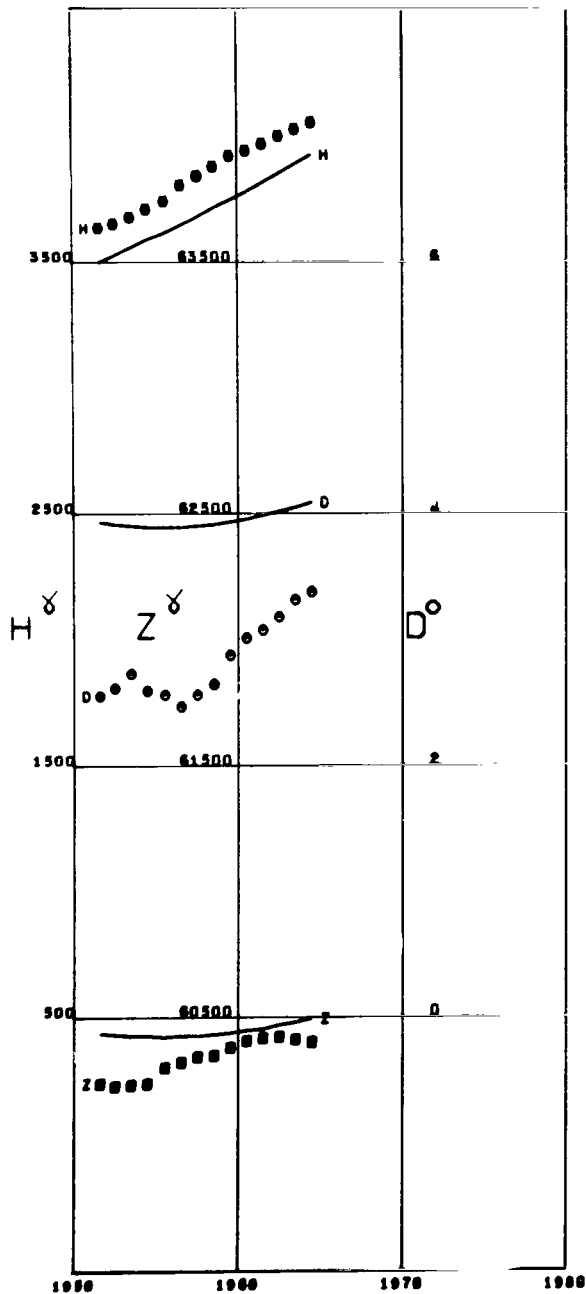


Figure A16

BALDWIN  
Lat 38.78 Long -95.16

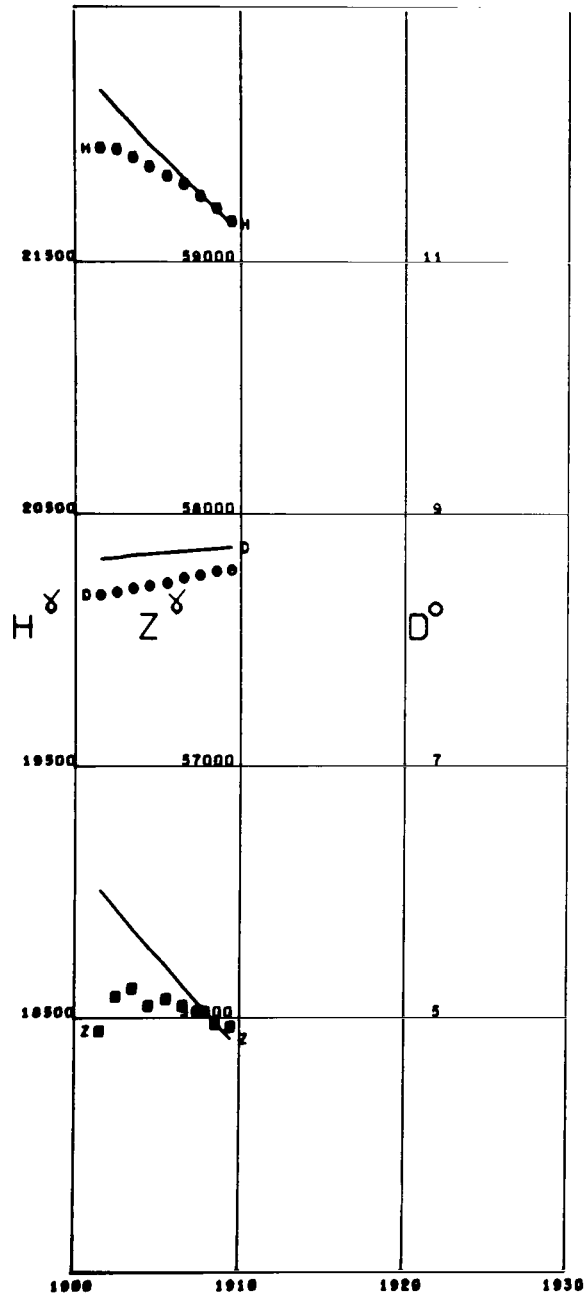


Figure A17

# BANGUI

Lat 4.43 Long 18.56 Alt 0.44

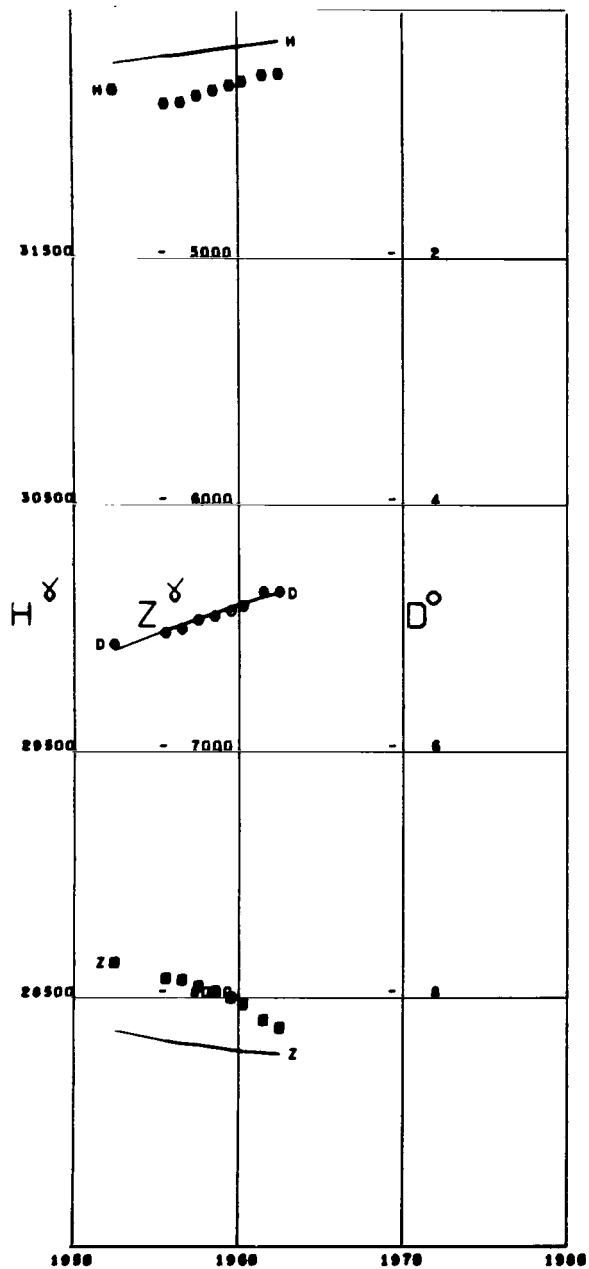


Figure A18

# BARRACKPORE

Lat 22.77 Long 88.36

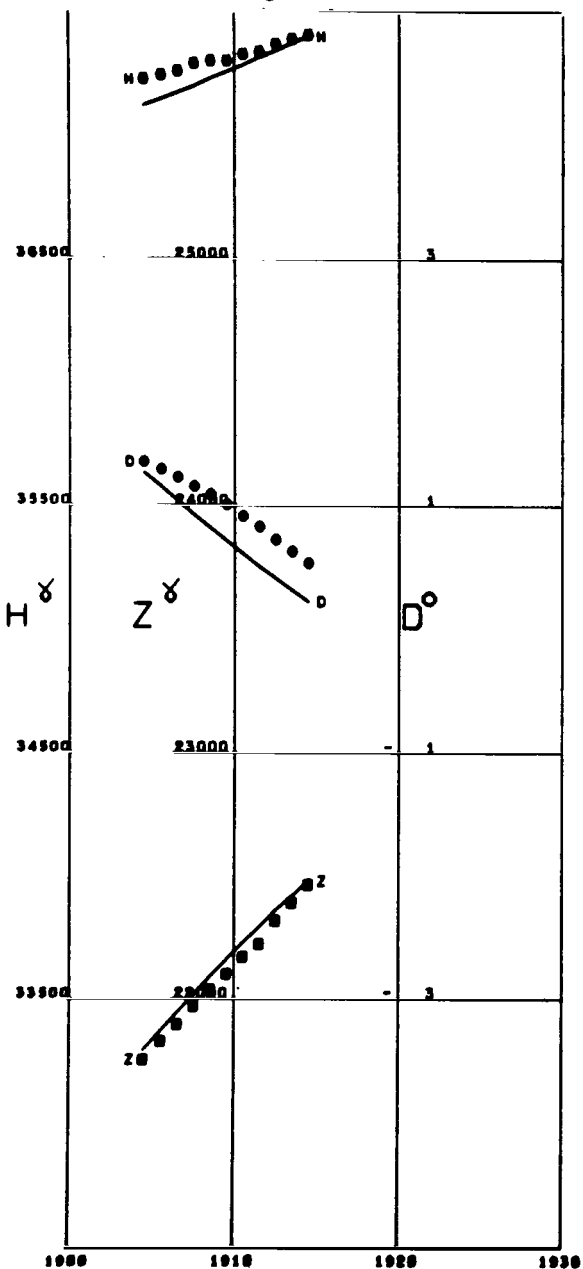


Figure A19

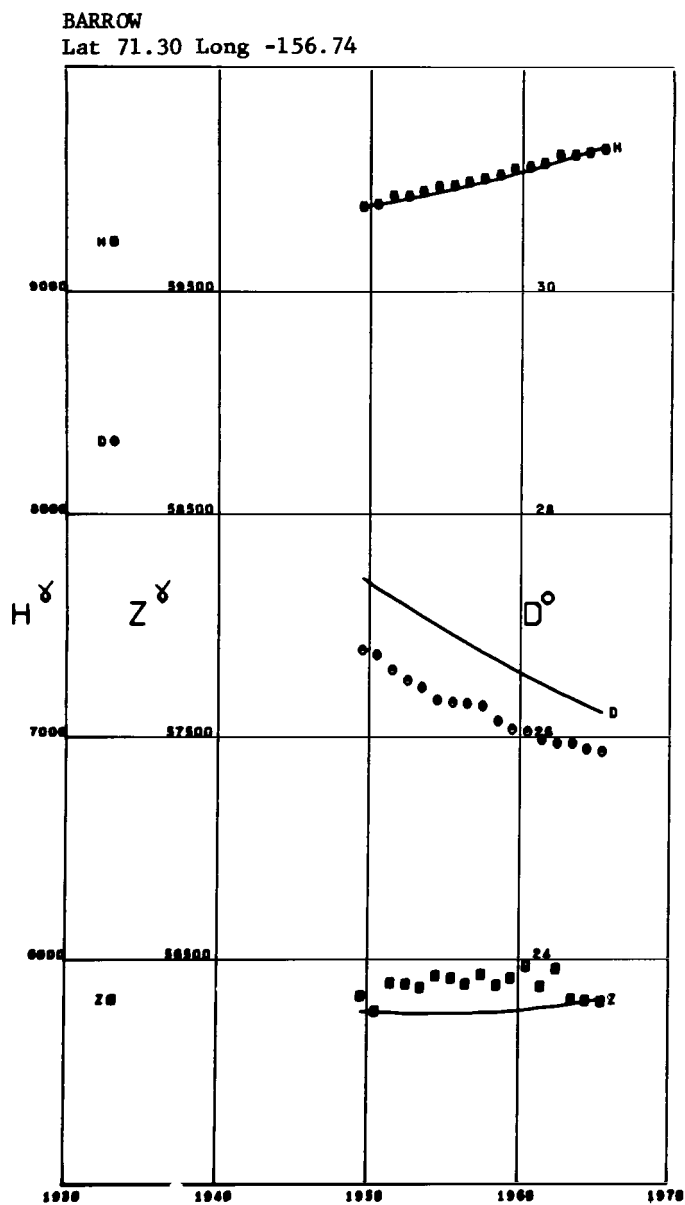


Figure A20

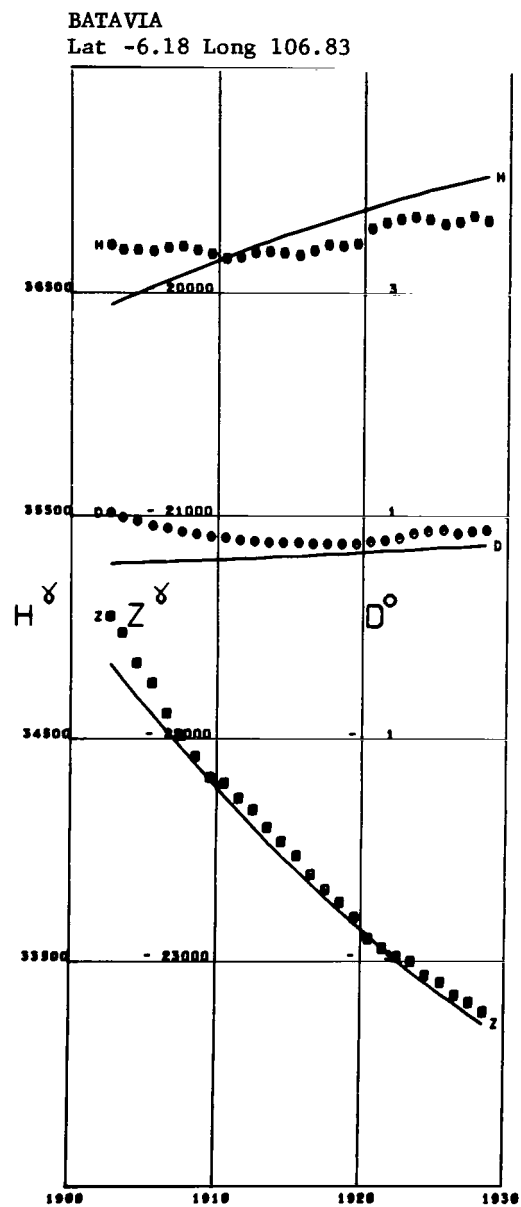


Figure A21



# BEUTHEN

Lat 50.35 Long 18.92

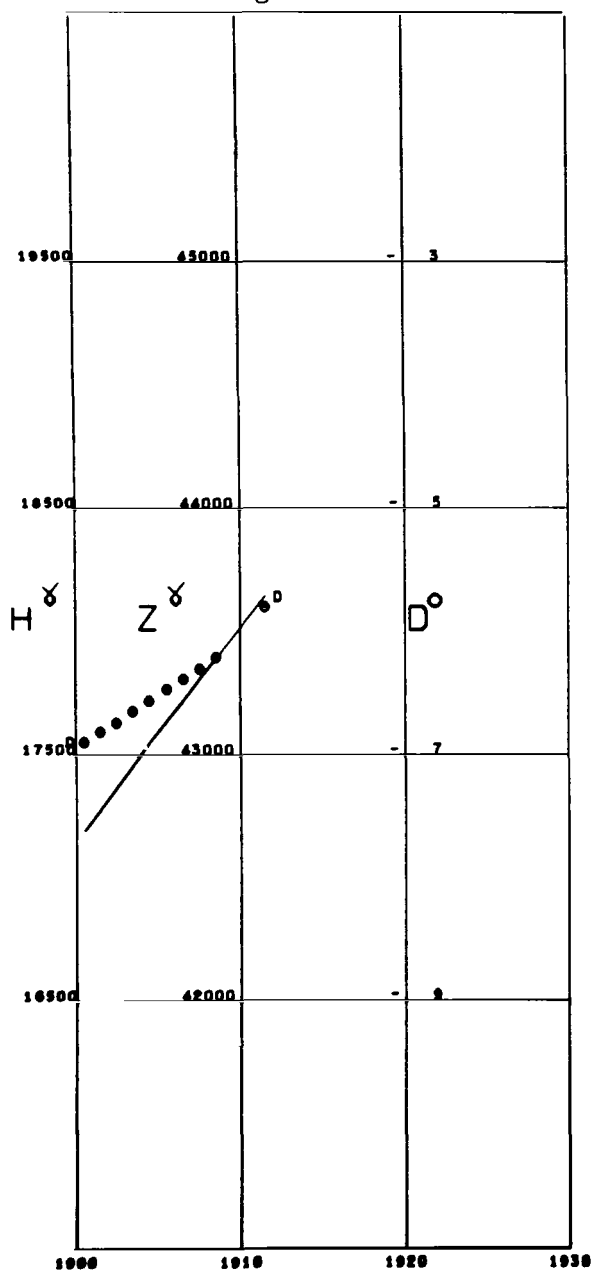


Figure A22

# BEUTHEN MIKILOW

Lat 50.15 Long 18.90

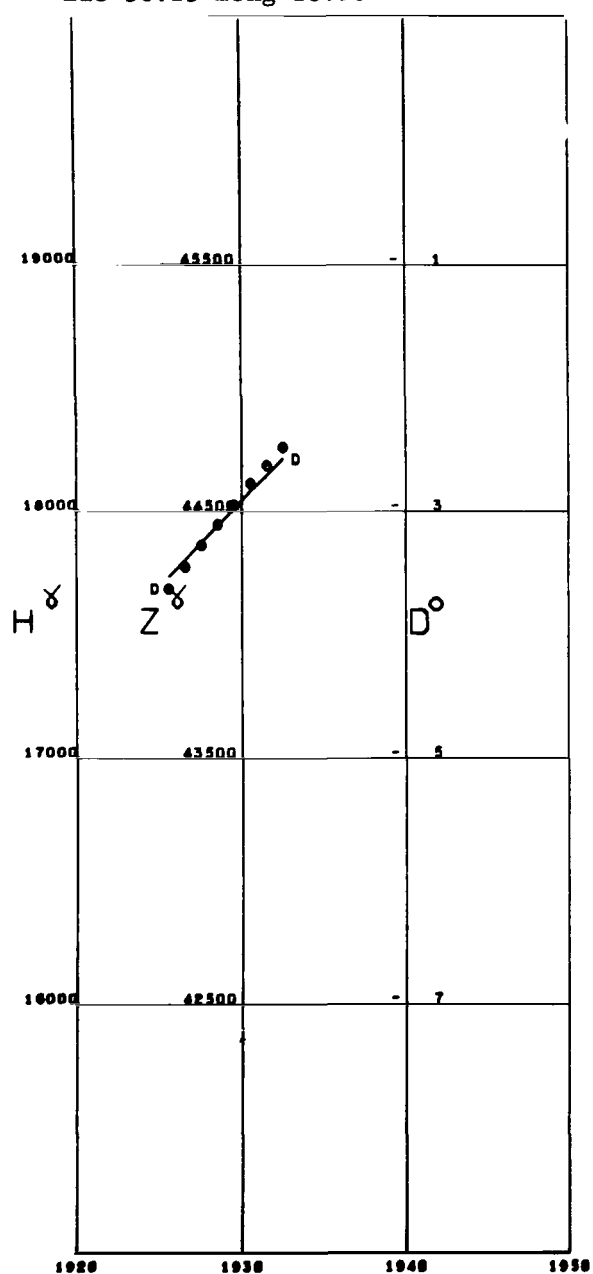


Figure A23

BJORNOYA  
 Lat 74.50 Long 19.20

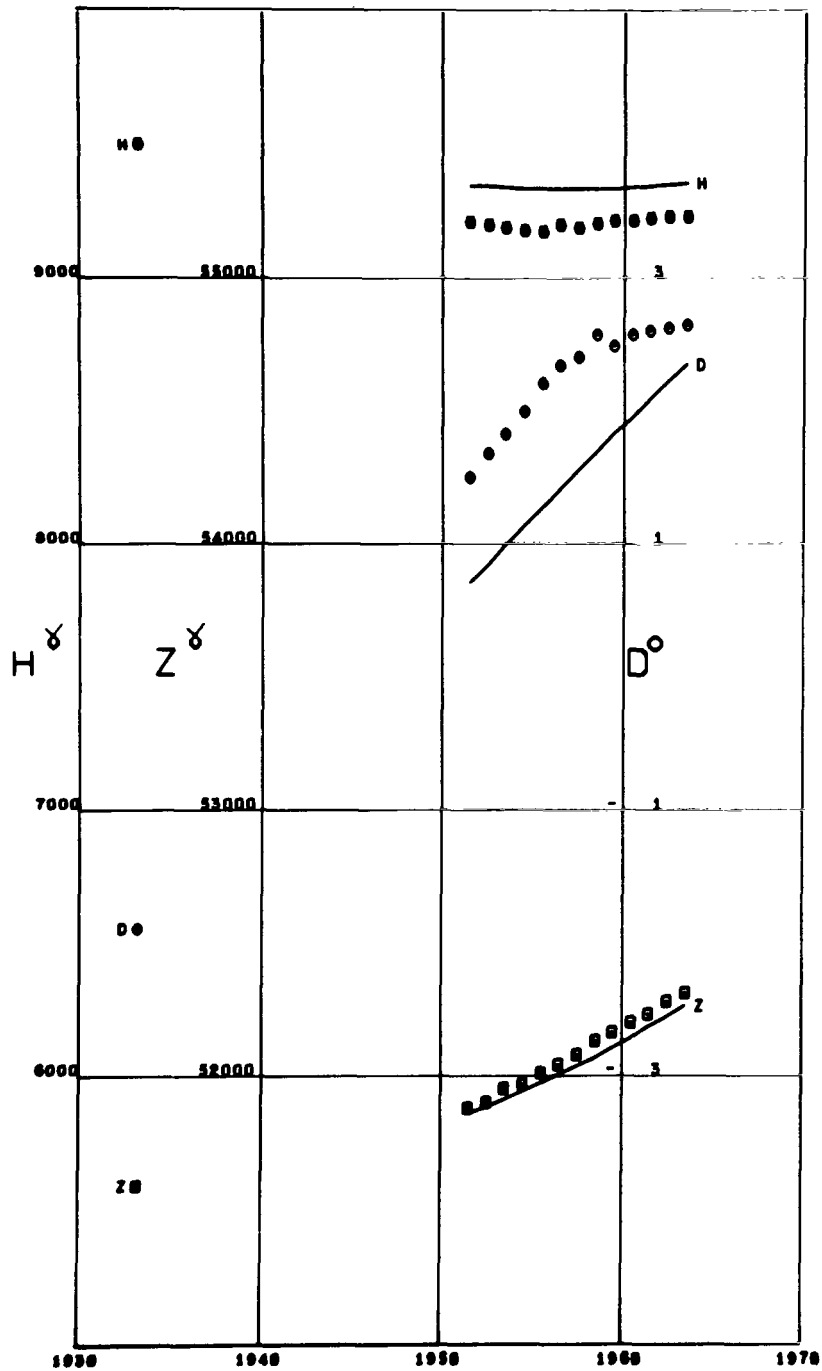


Figure A24

BOCHUM  
 Lat 51.49 Long 7.23

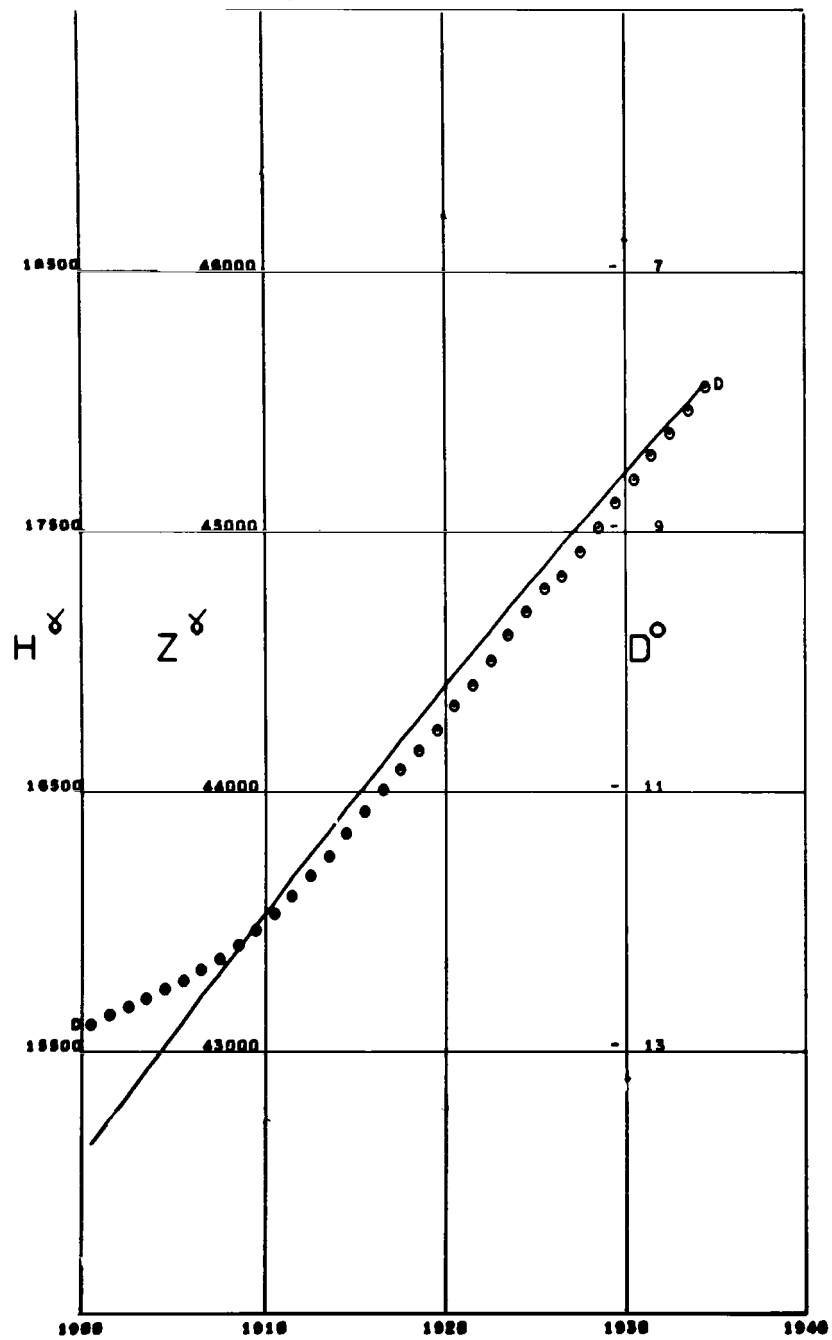


Figure A25

BOUZAREAH  
 Lat 36.80 Long 3.01

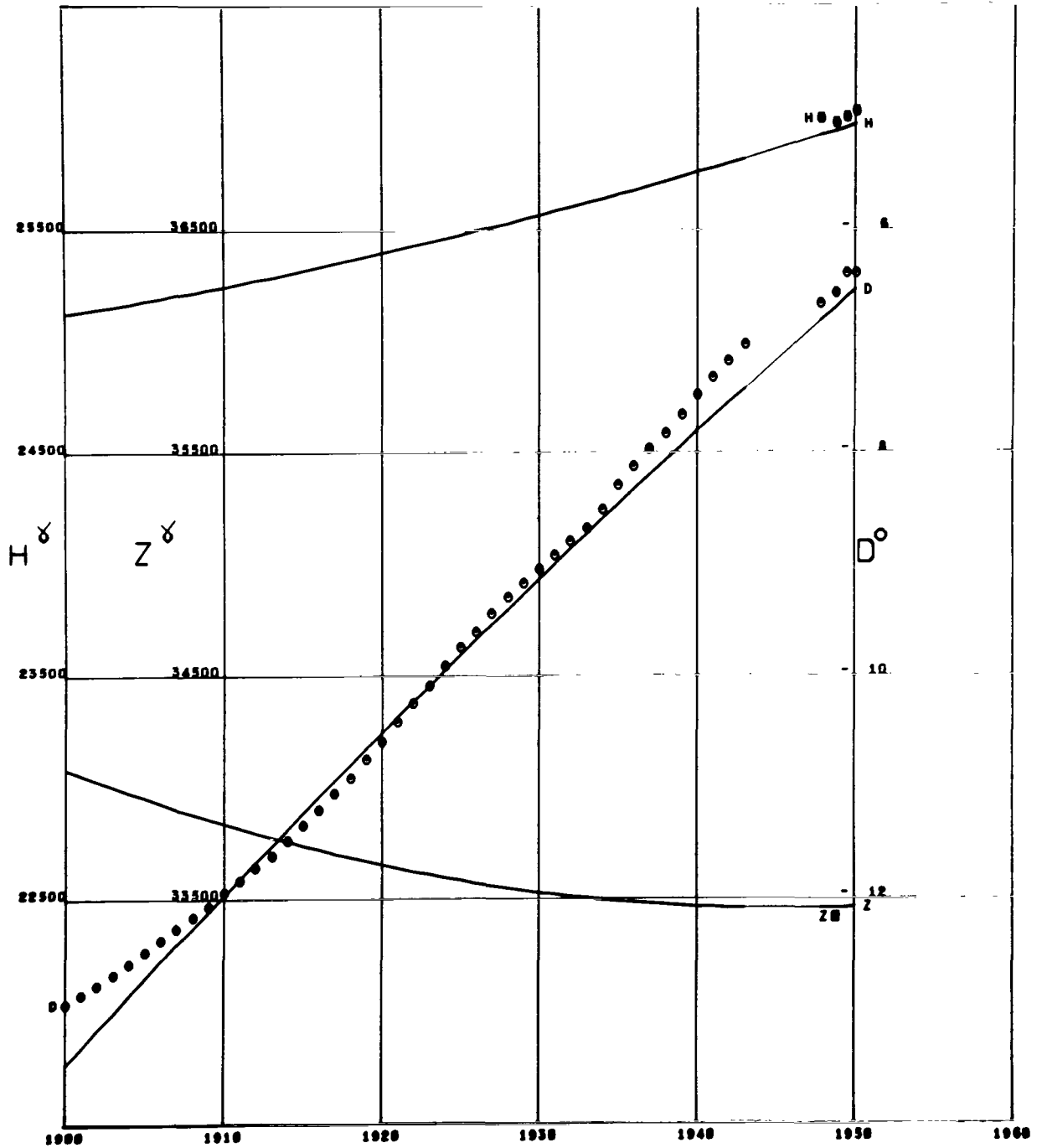


Figure A26

BUDAKESZI  
 Lat 47.52 Long 18.89

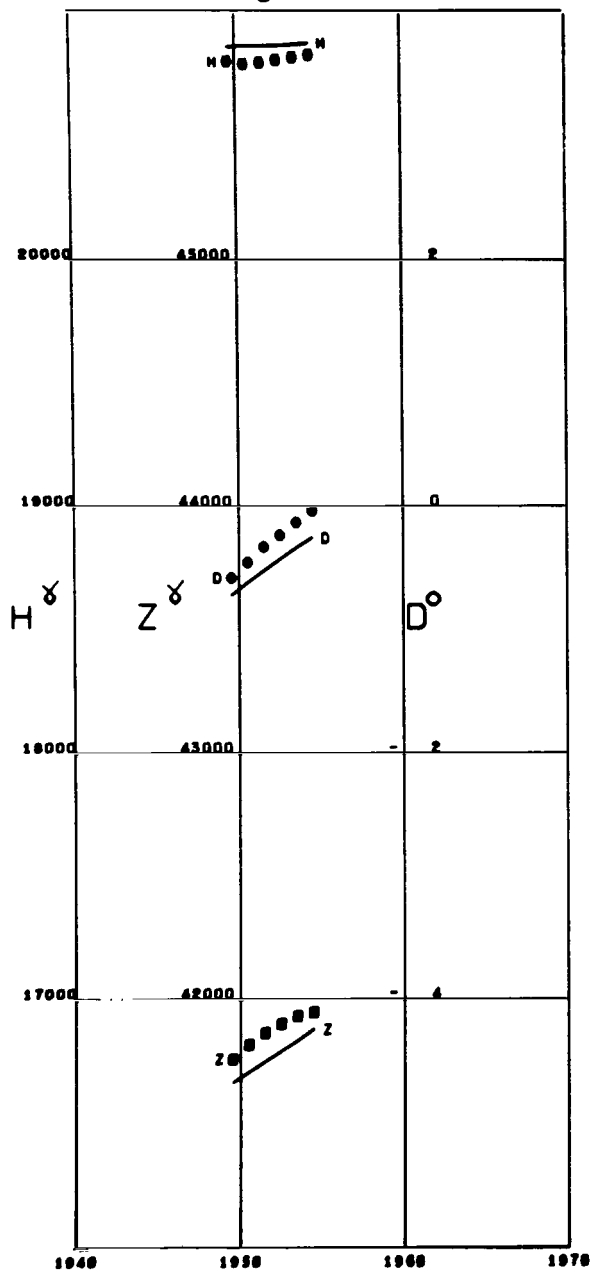


Figure A27

BYRD  
 Lat -80.01 Long -119.51 Alt 1.52

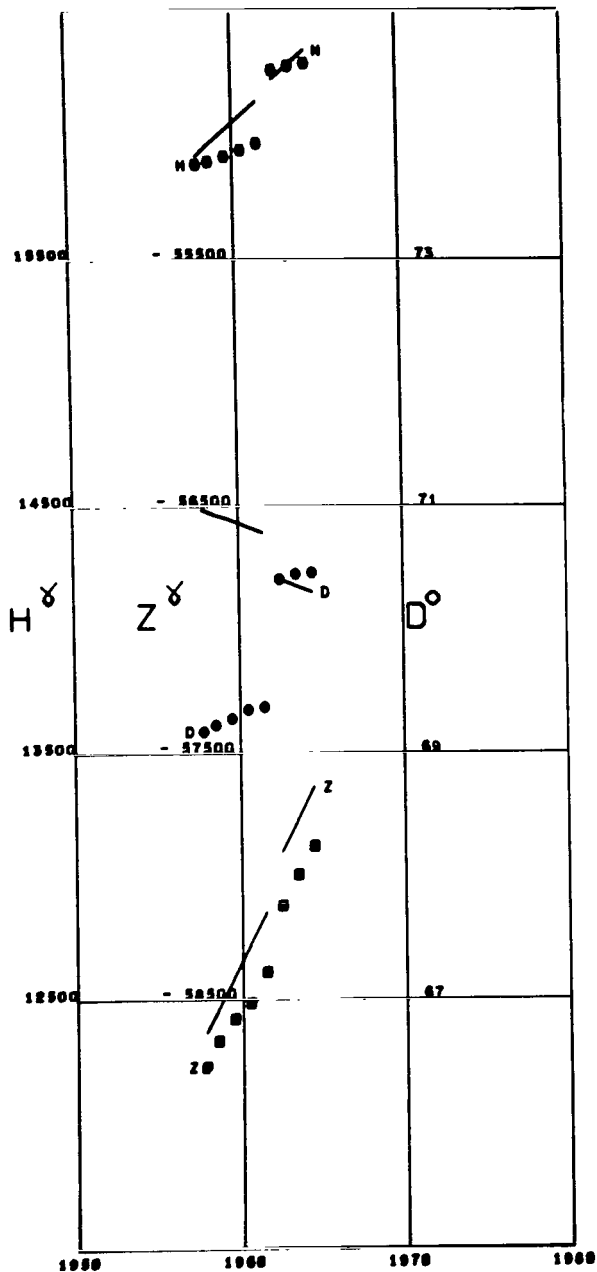


Figure A28

CAPE TOWN  
Lat -33.95 Long 18.46

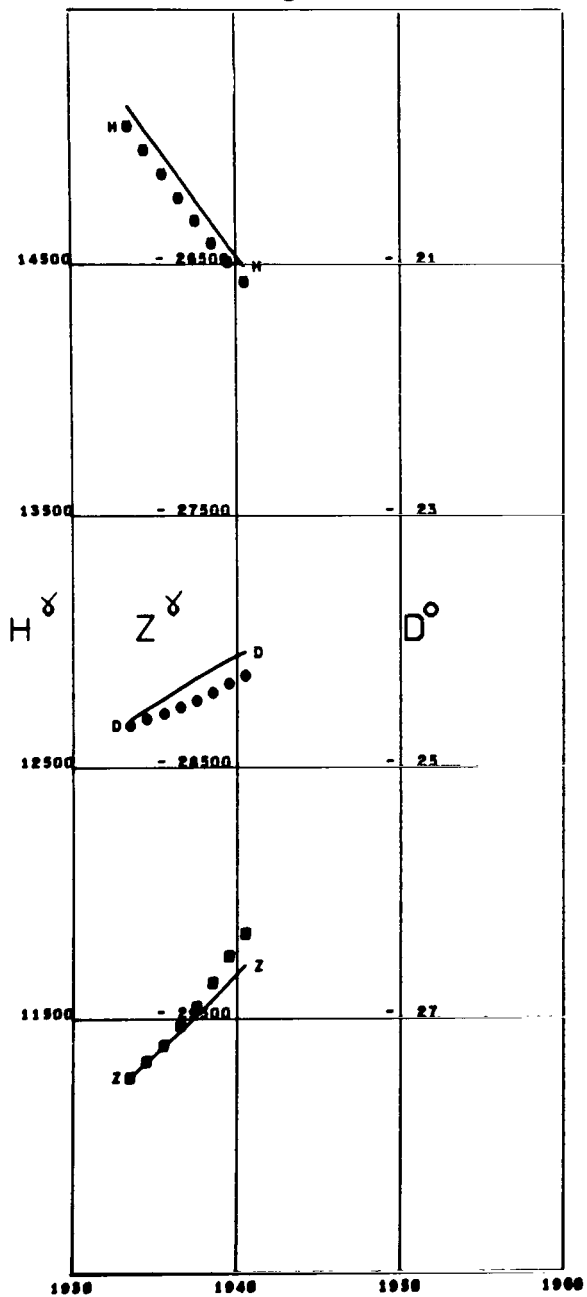


Figure A29

CAPODIMONTE  
Lat 40.86 Long 14.25

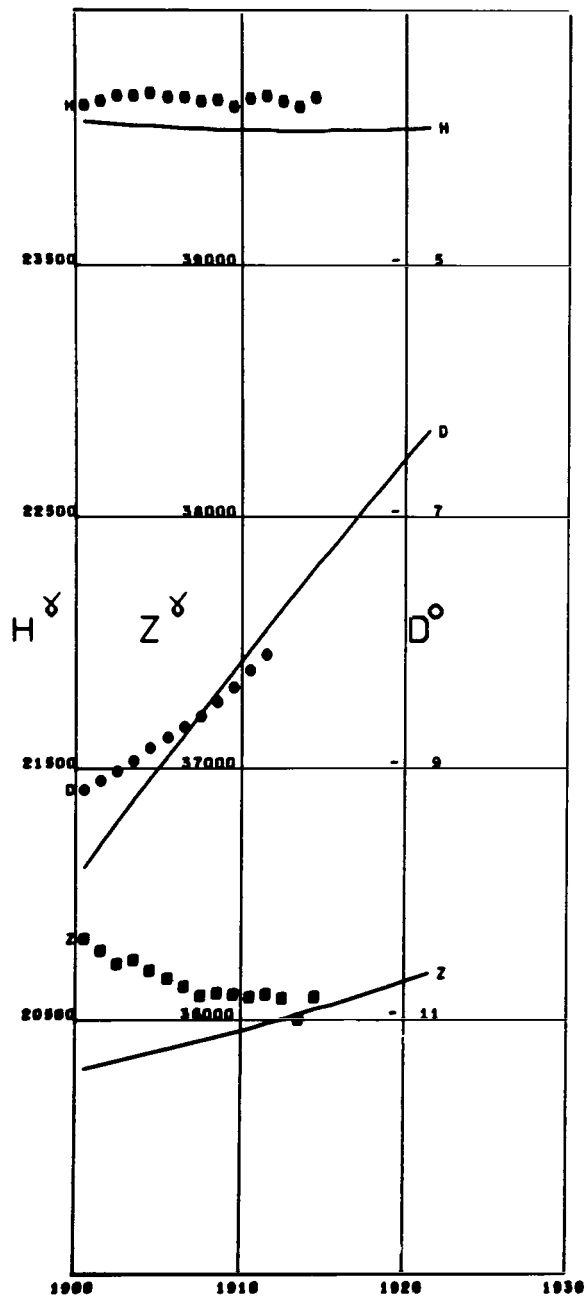


Figure A30

CASTELLACCIO  
Lat 44.43 Long 8.93

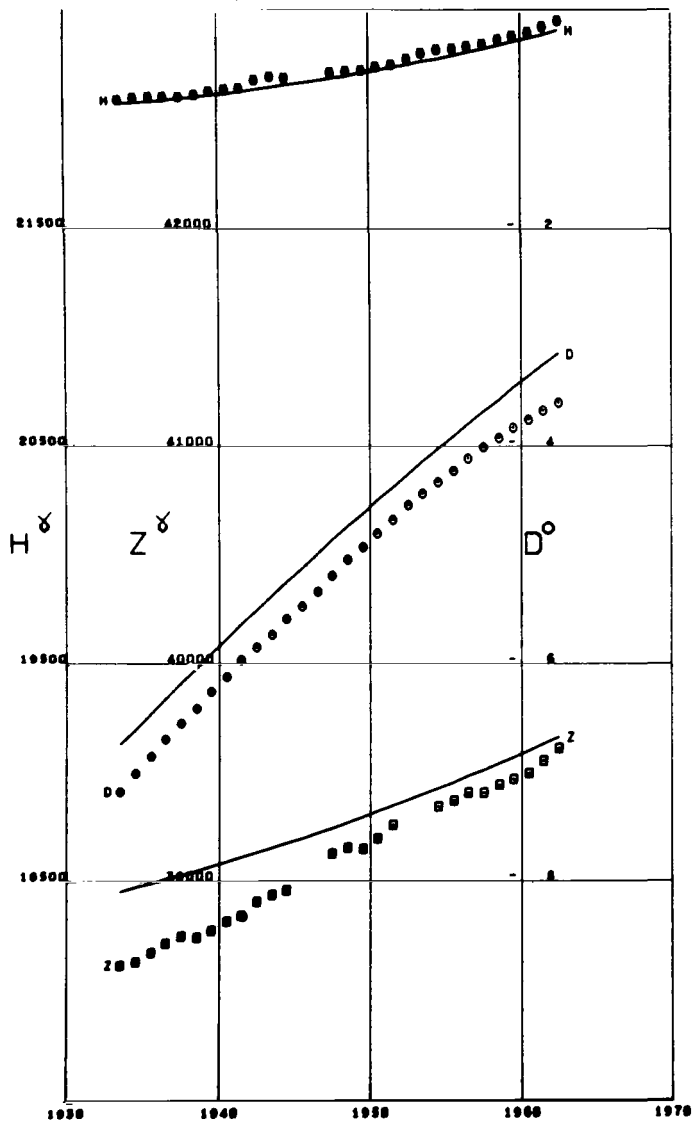


Figure A31

CHA PA  
Lat 22.35 Long 103.83

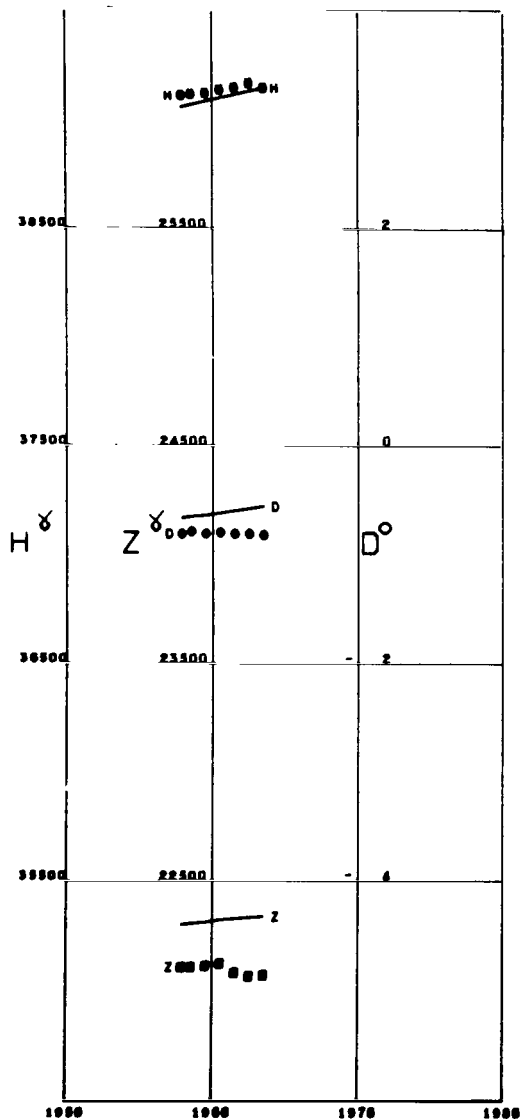


Figure A32

CHAMBON-LA-FORET  
 Lat 48.02 Long 2.26

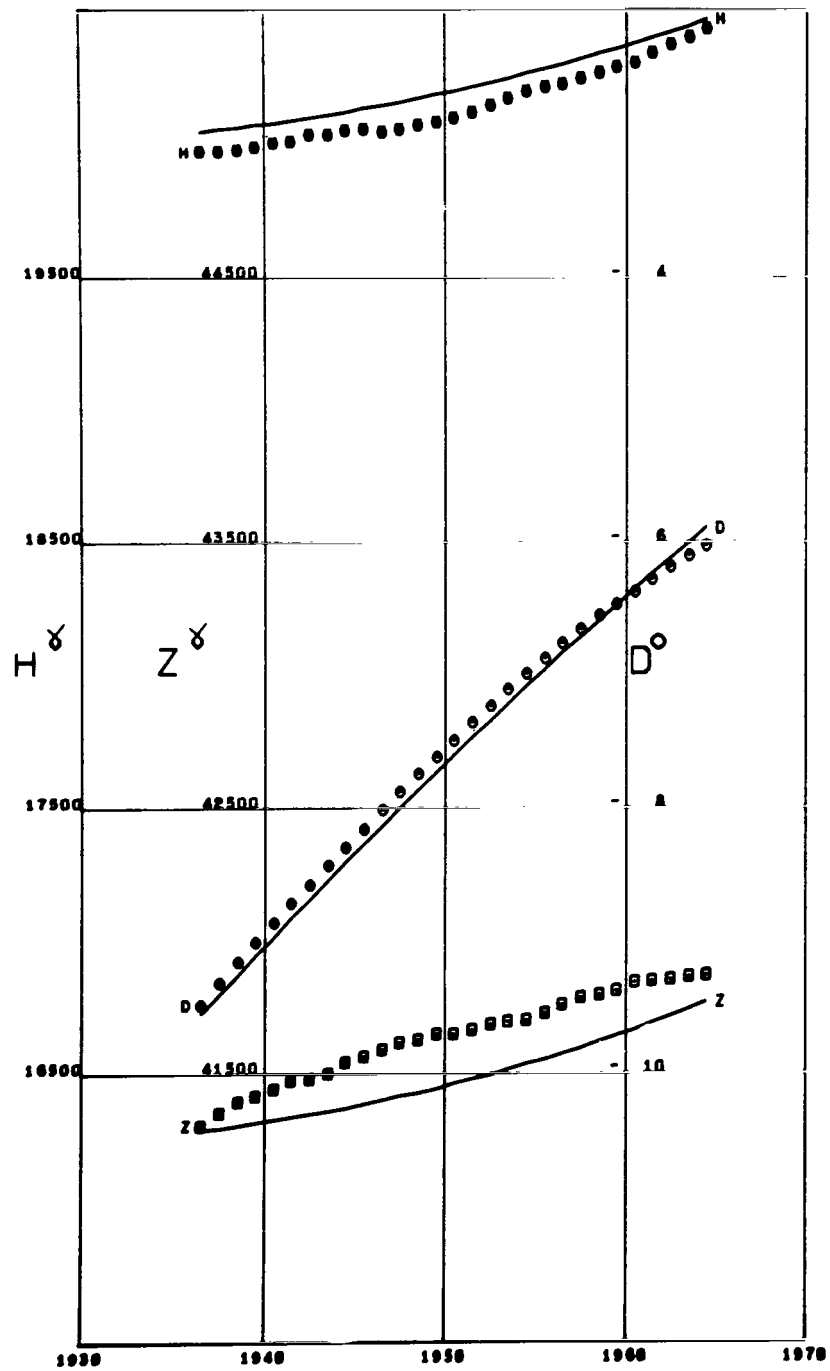


Figure A33



**G.**



CHELYUSKIN  
 Lat 77.71 Long 104.28

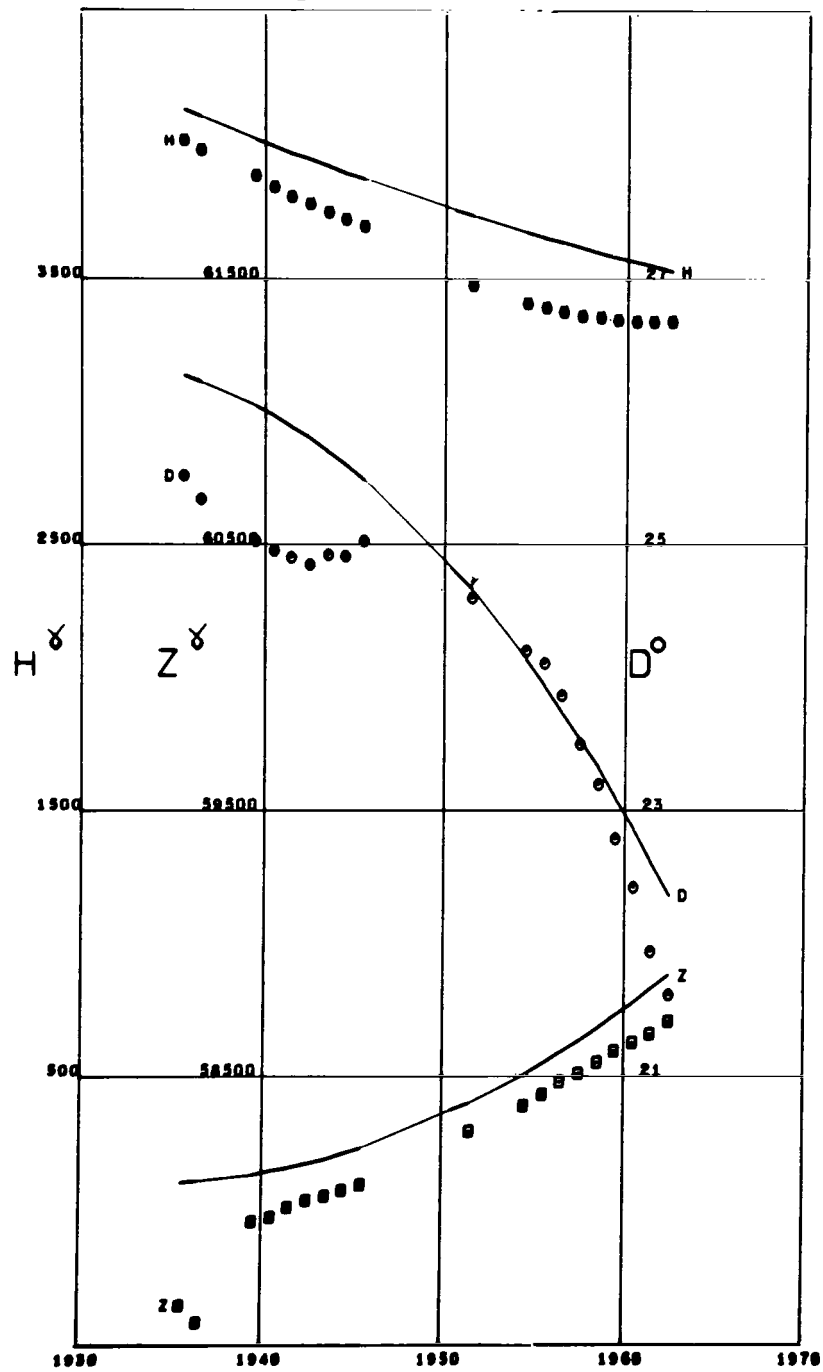


Figure A35

CHRISTCHURCH  
Lat -43.53 Long 172.62

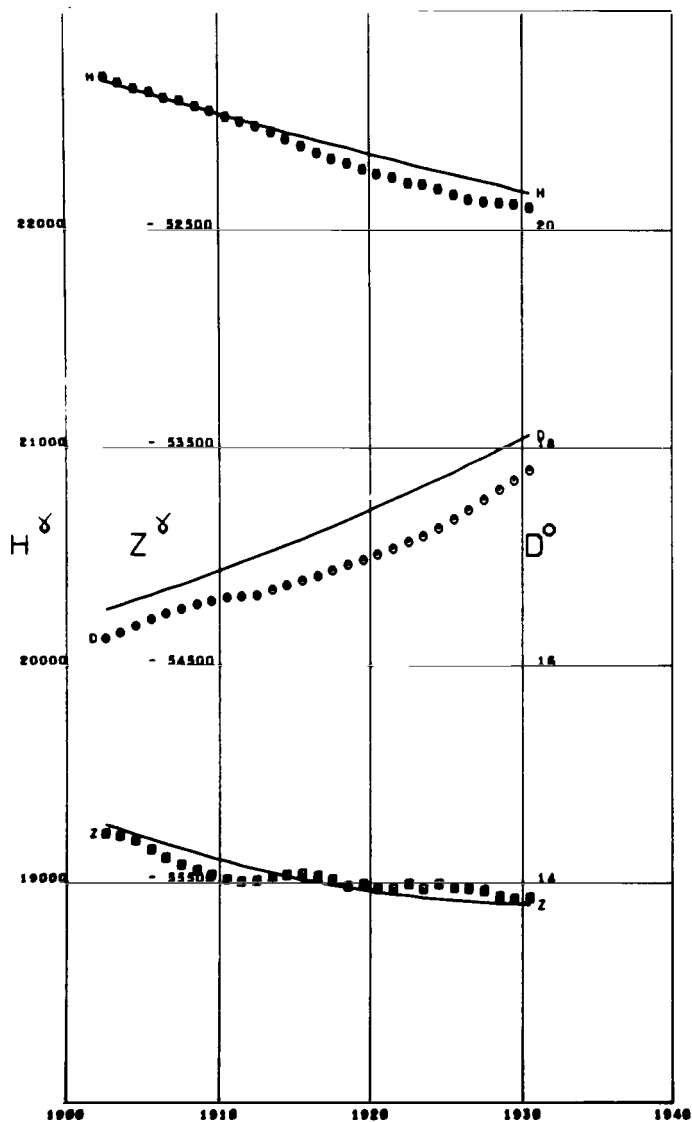


Figure A36

CLAUSTHAL  
Lat 51.80 Long 10.33

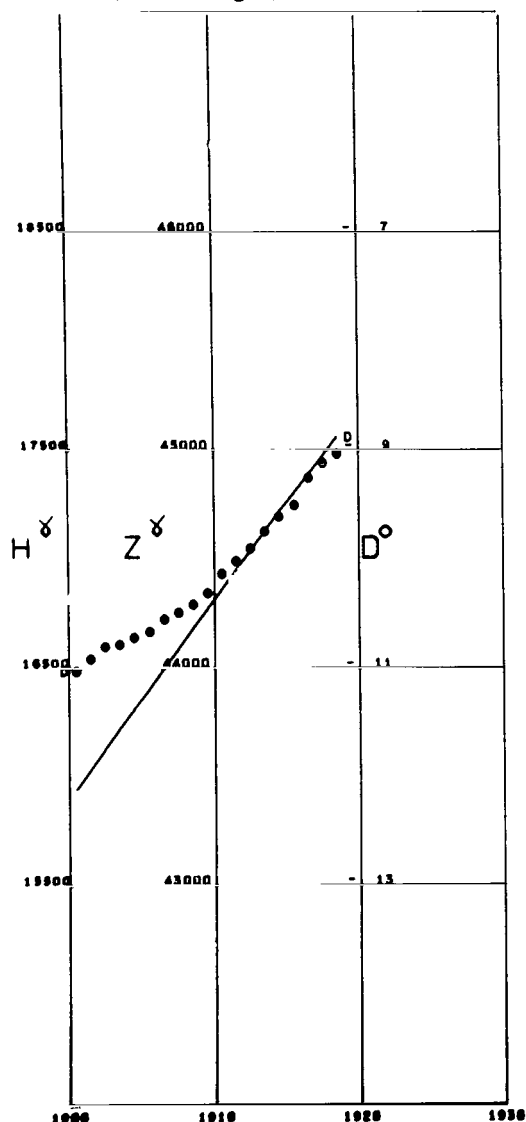


Figure A37

COIMBRA  
 Lat 40.22 Long -8.42

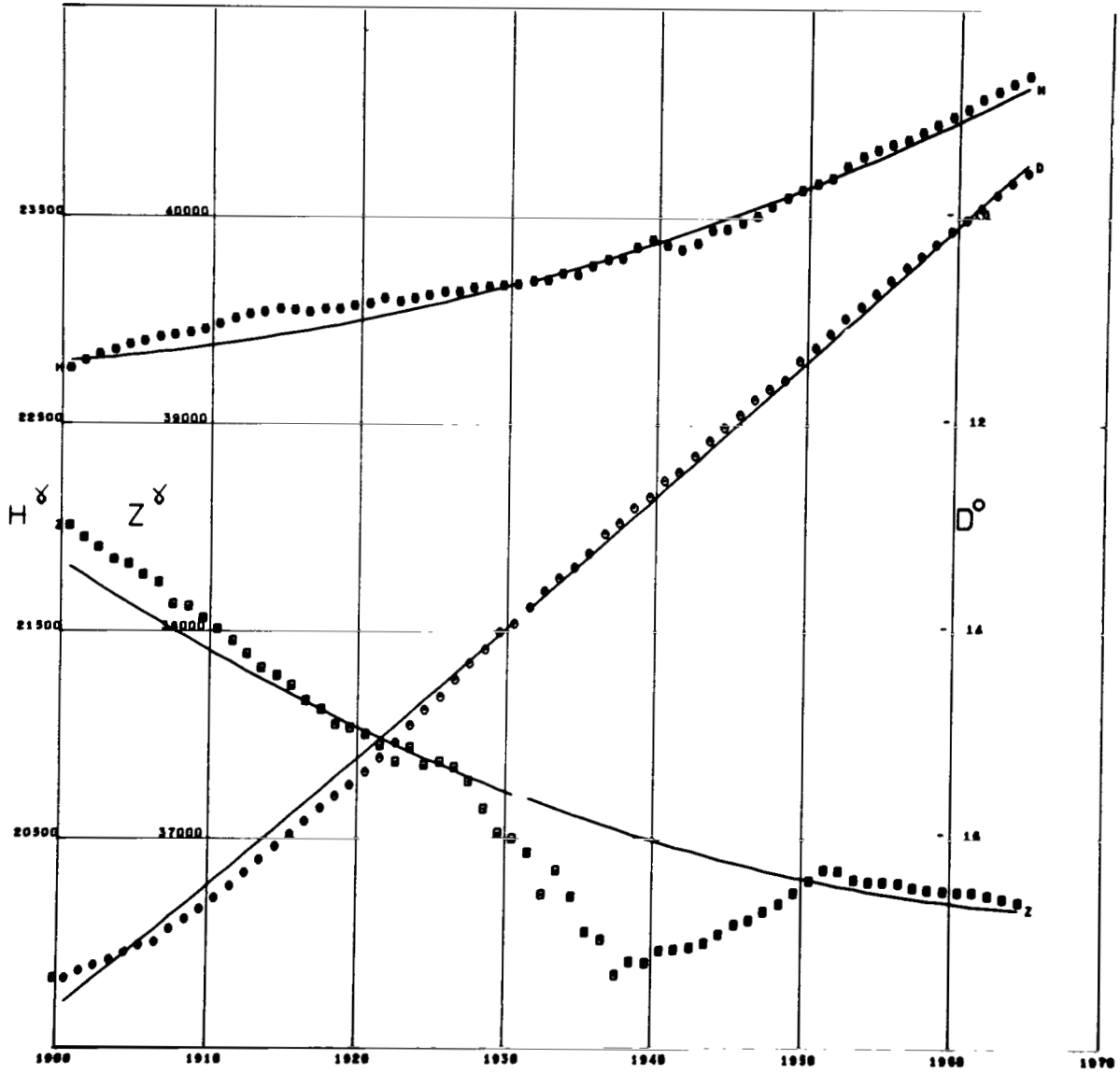


Figure A38

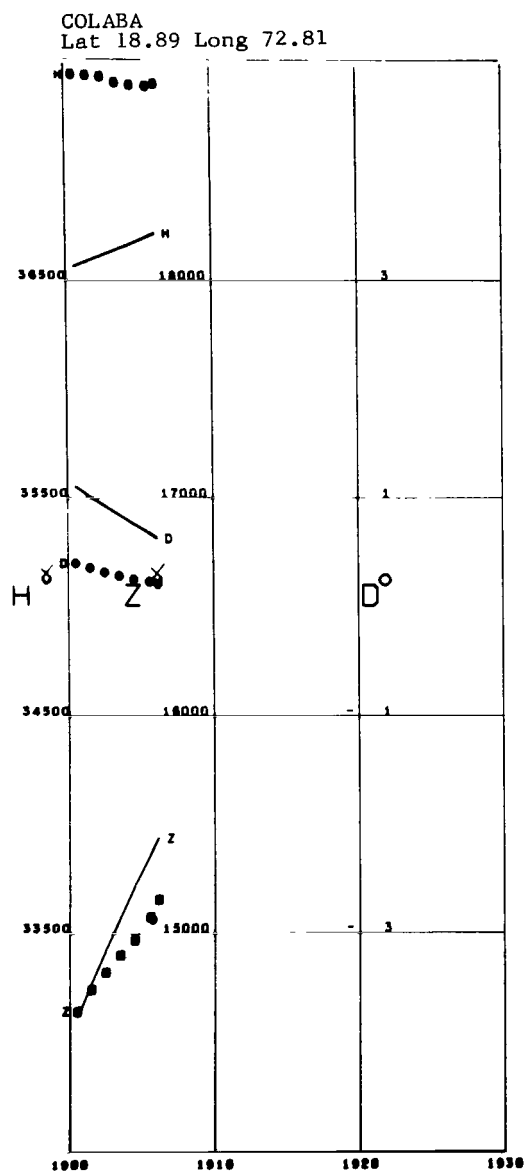


Figure A39

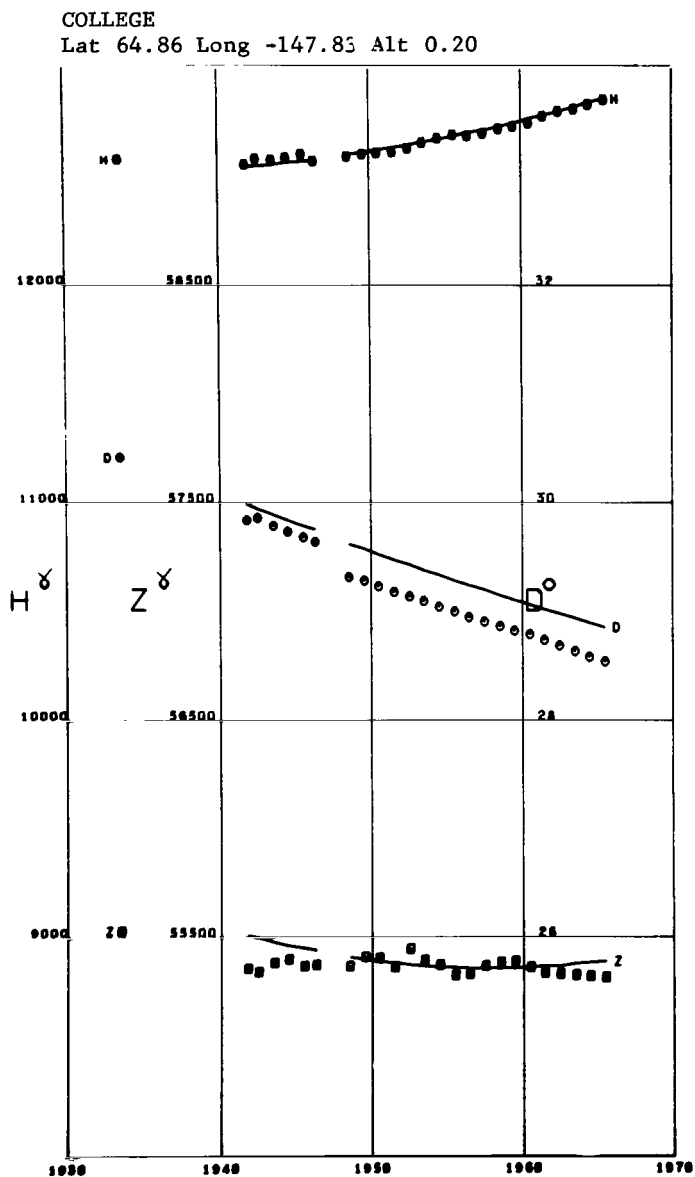


Figure A40

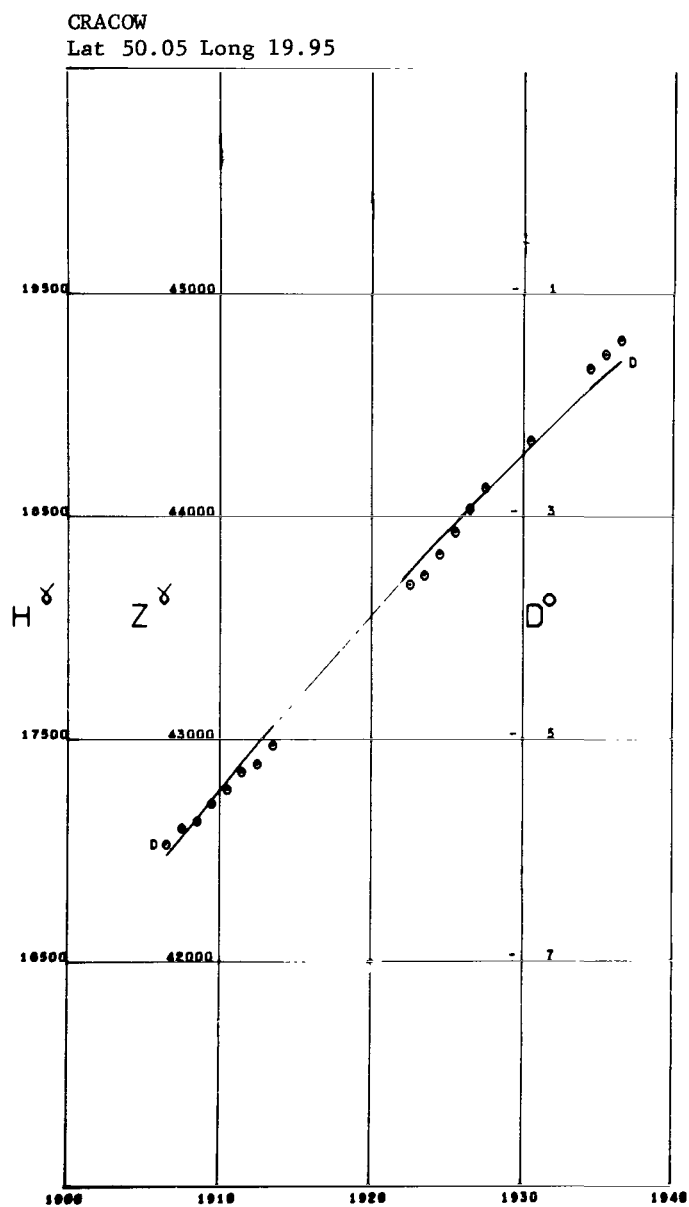


Figure A41

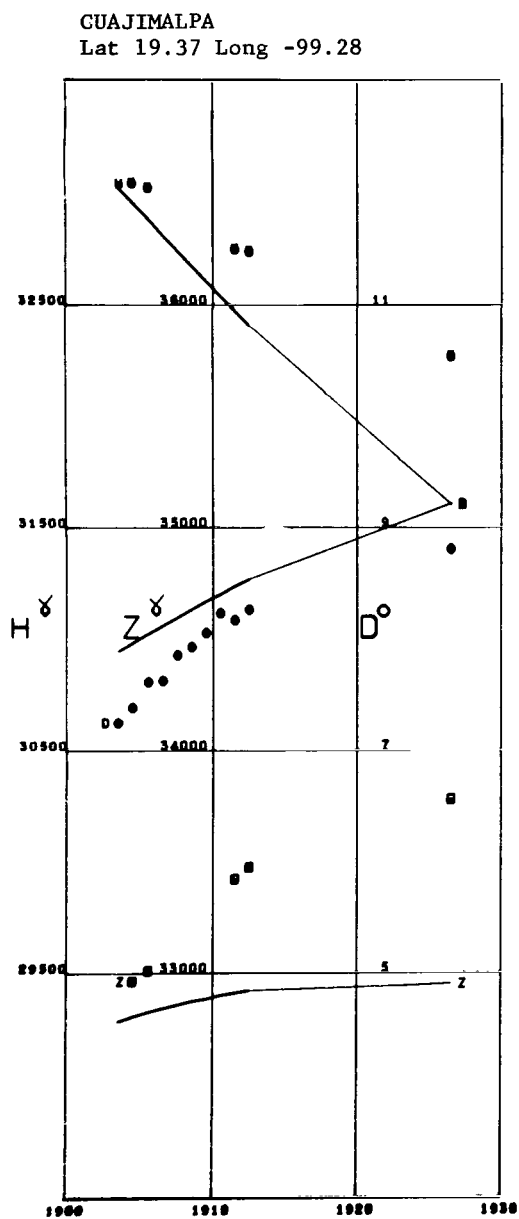


Figure A42

DE BILT  
 Lat 52.10 Long 5.17

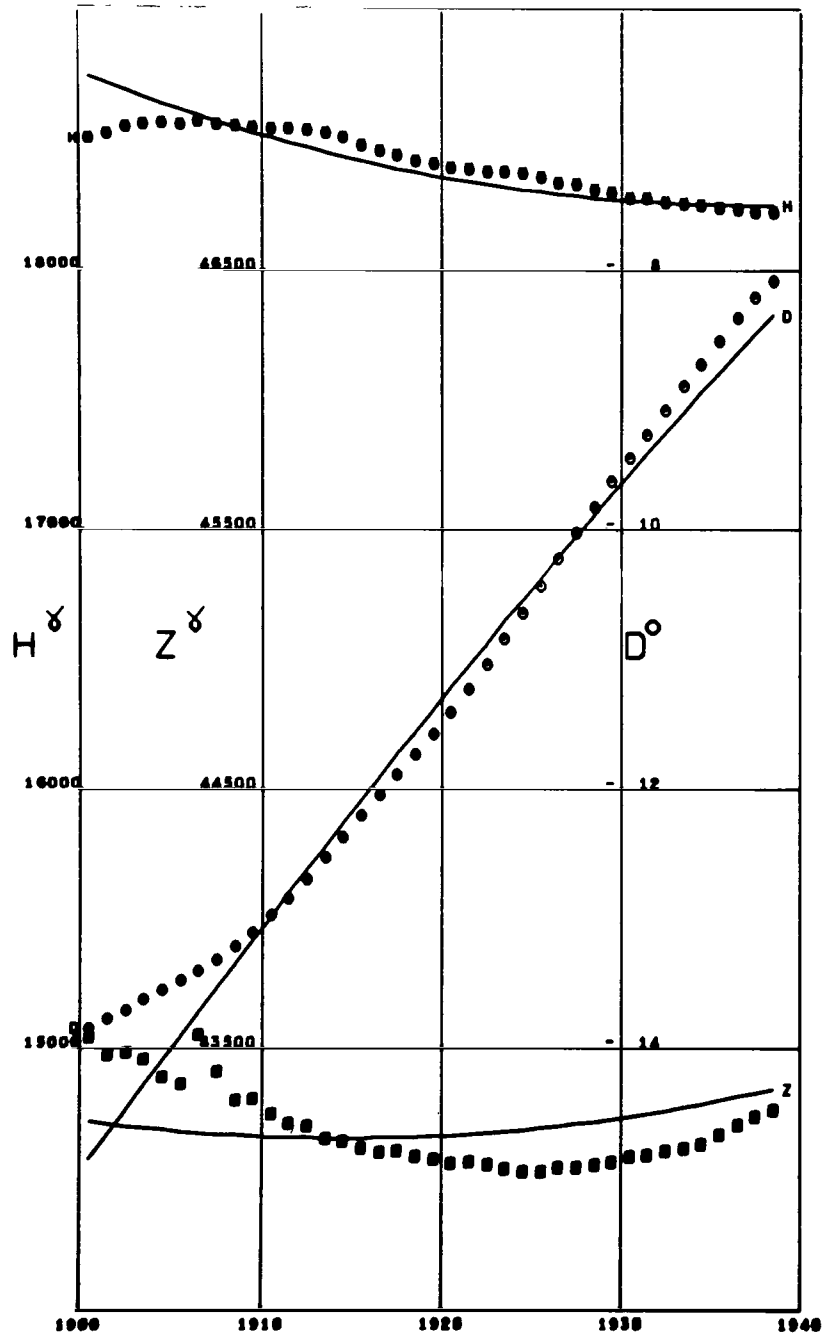


Figure A43

DEHRA DUN  
 Lat 30.32 Long 78.05

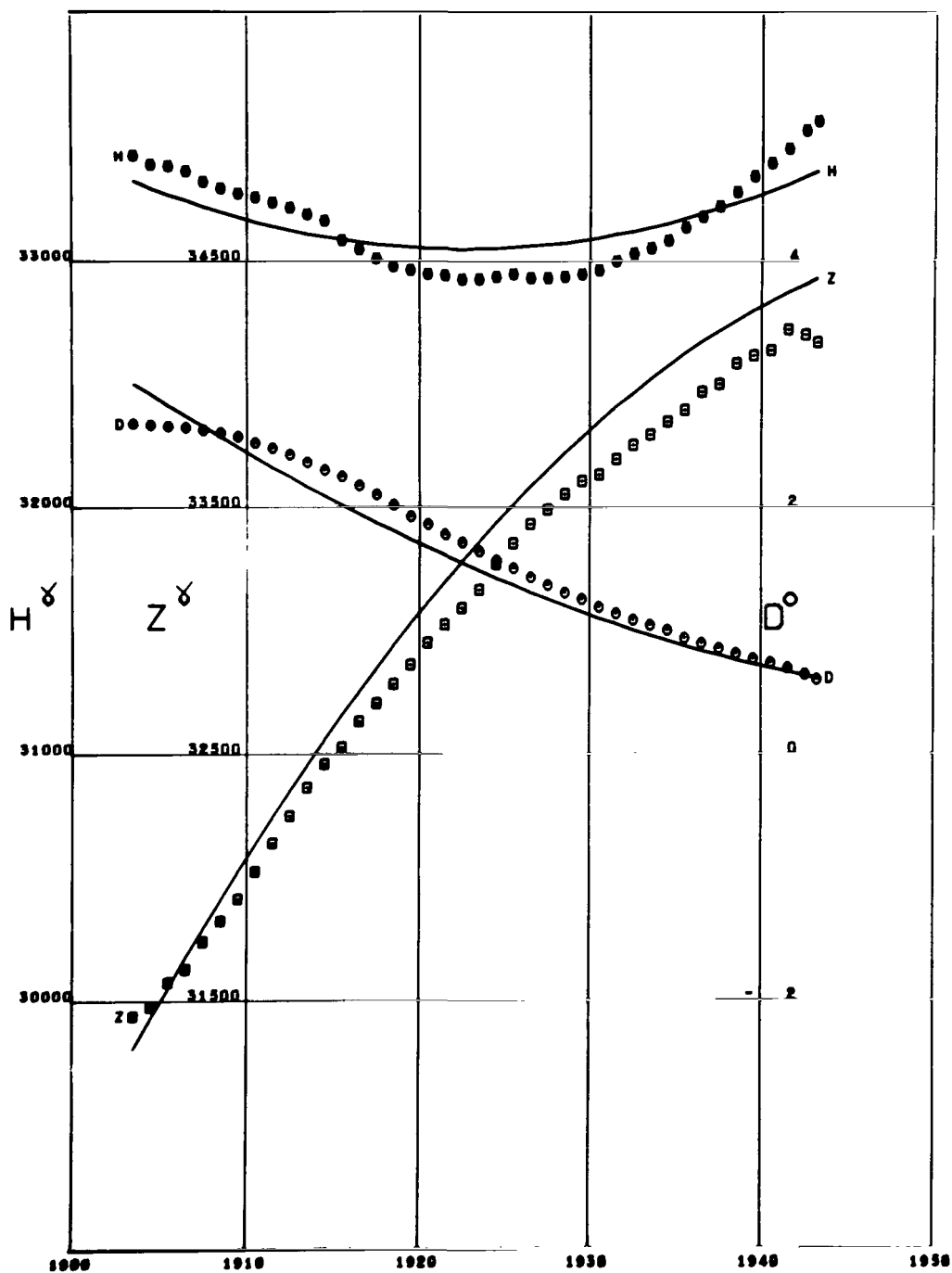


Figure A44



BEKELEIA

Lat 38.10 Long 23.77

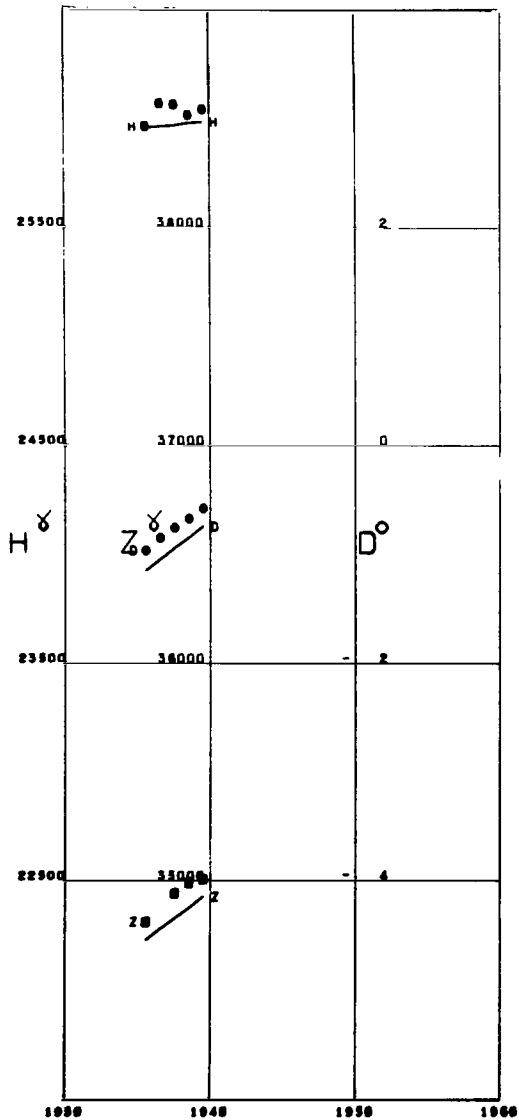


Figure A45

DIKSON

Lat 73.54 Long 80.56

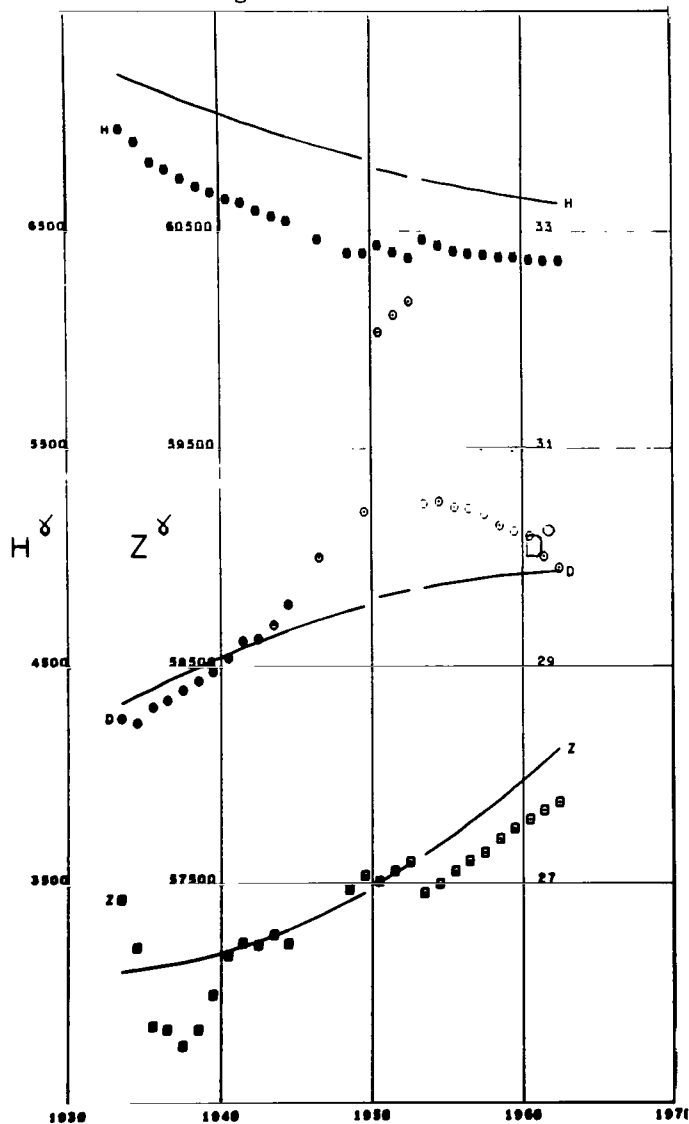


Figure A46

DOMBAS  
 Lat 62.07 Long 9.11

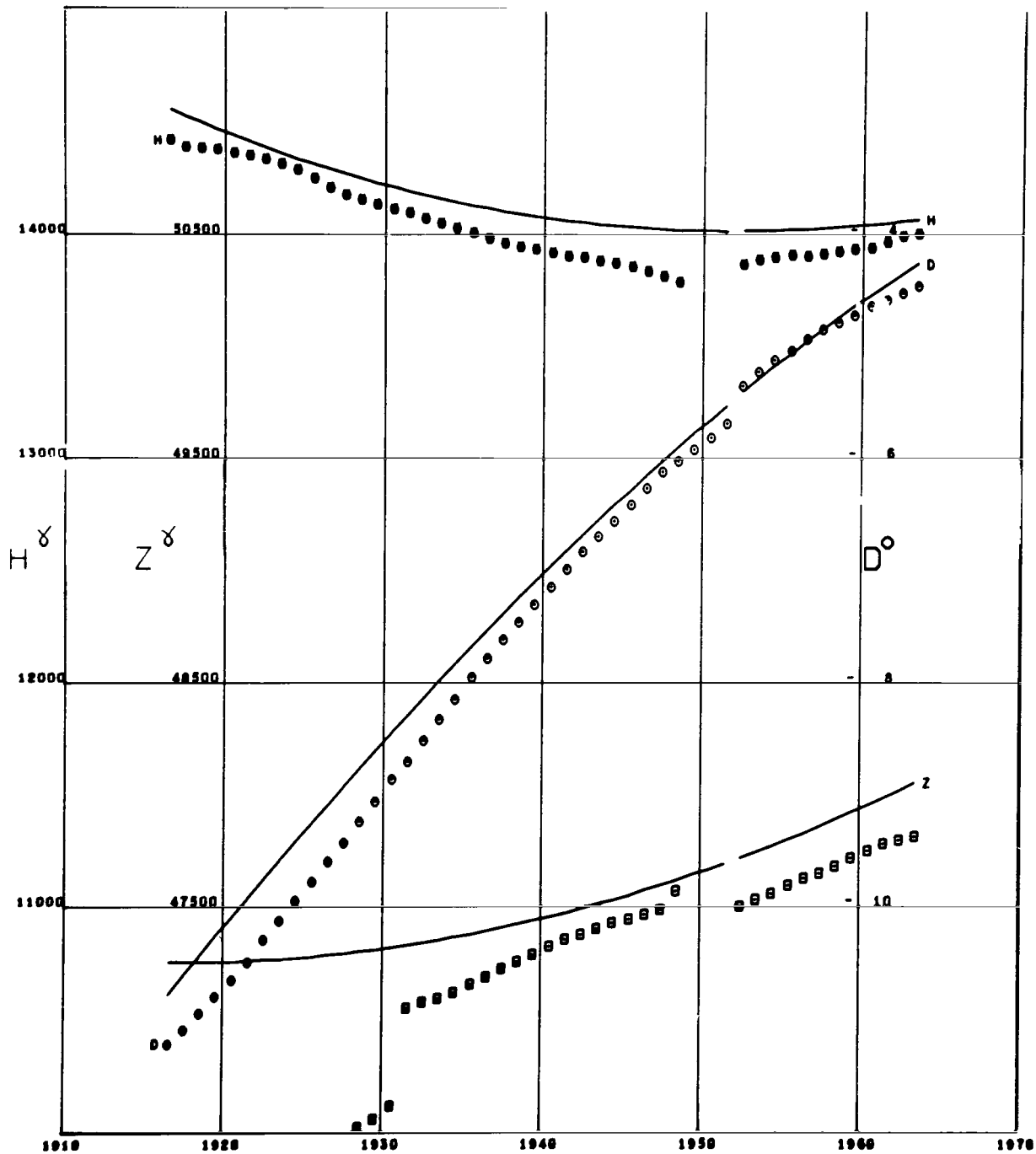


Figure A47

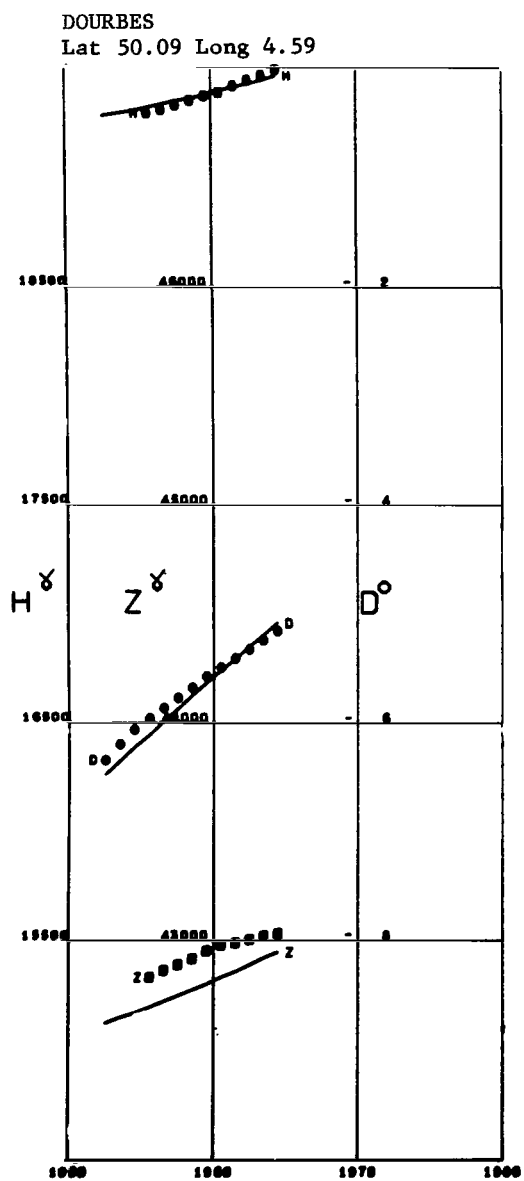


Figure A48

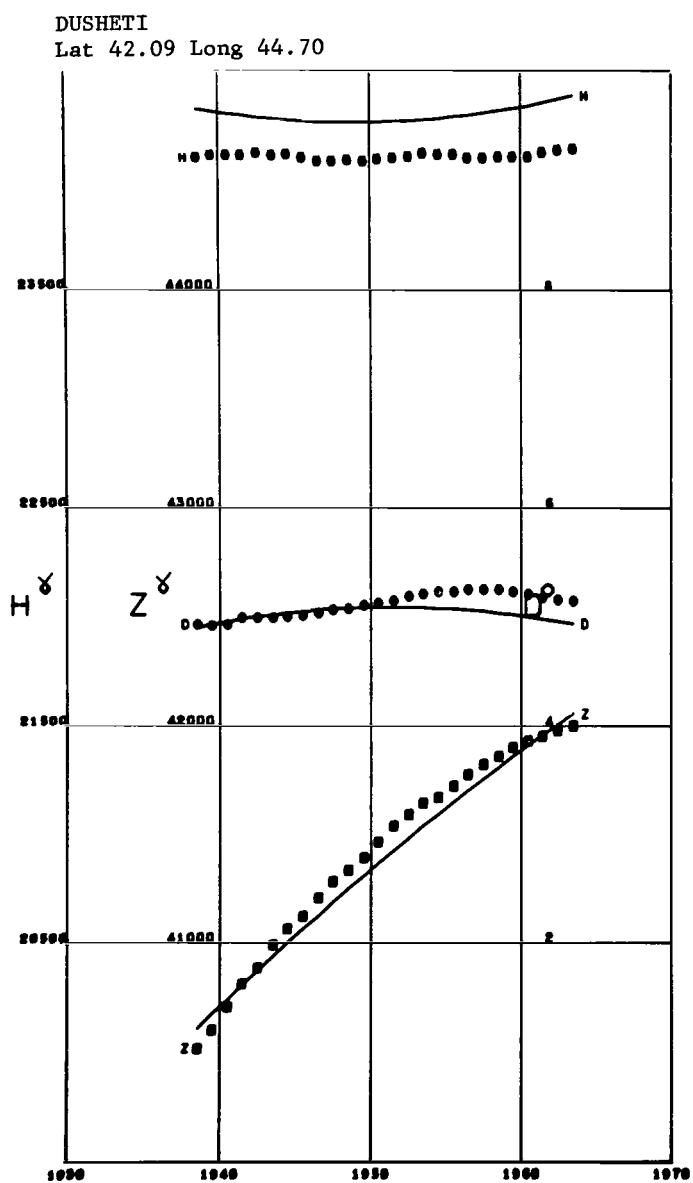


Figure A49

EBRO  
 Lat 40.12 Long 0.49 Alt 0.05

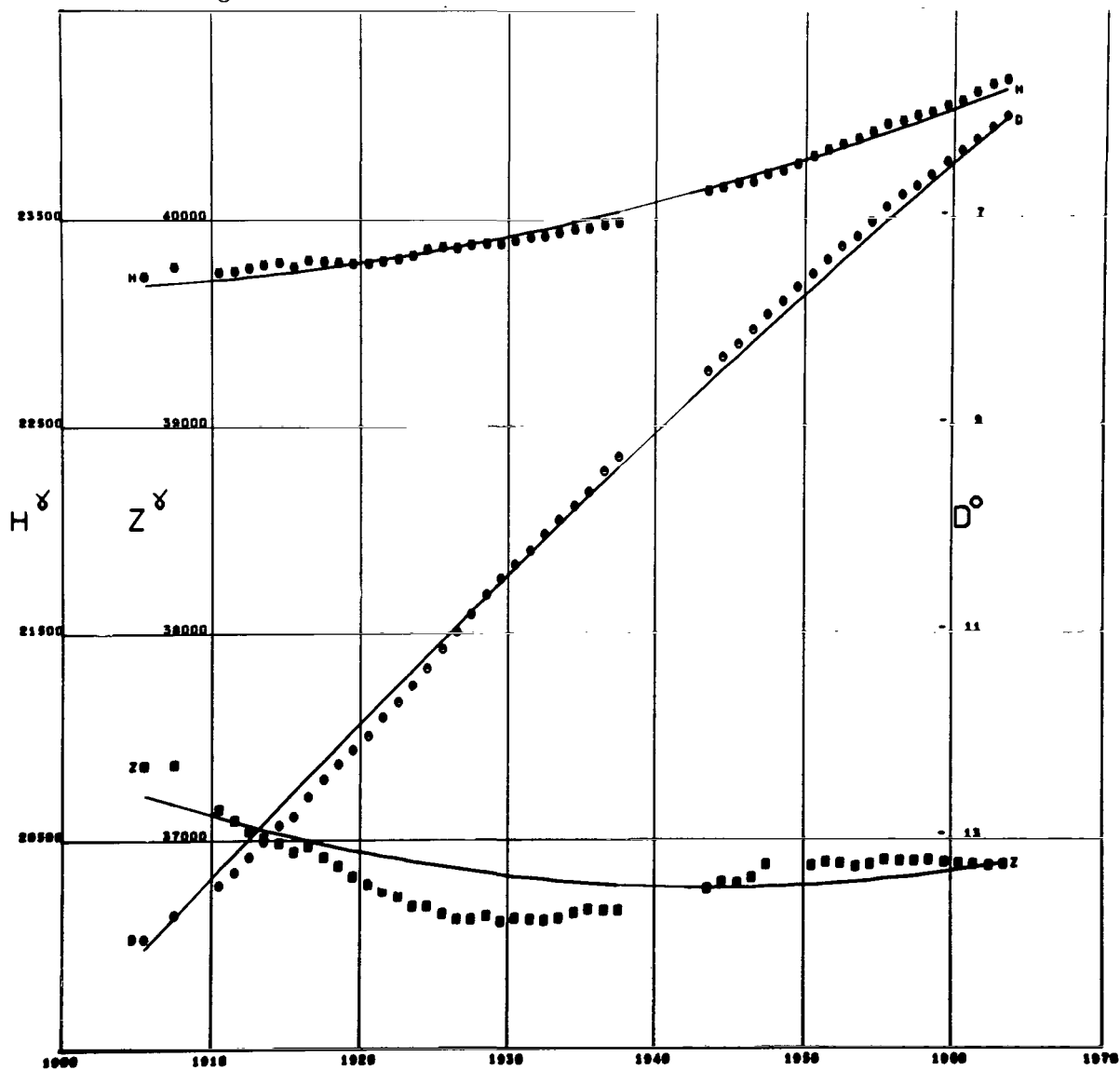


Figure A50

EL ABIOD SIDI  
Lat 32.90 Long 0.55

19

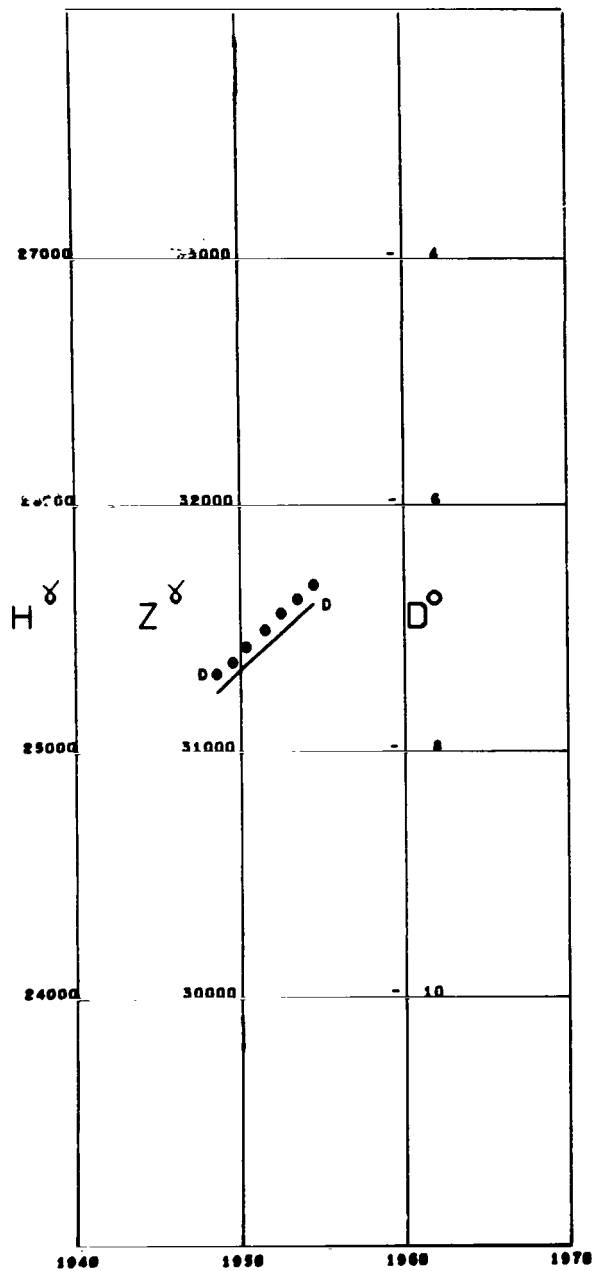


Figure A51

ELISABETHVILLE  
Lat -11.65 Long 27.46

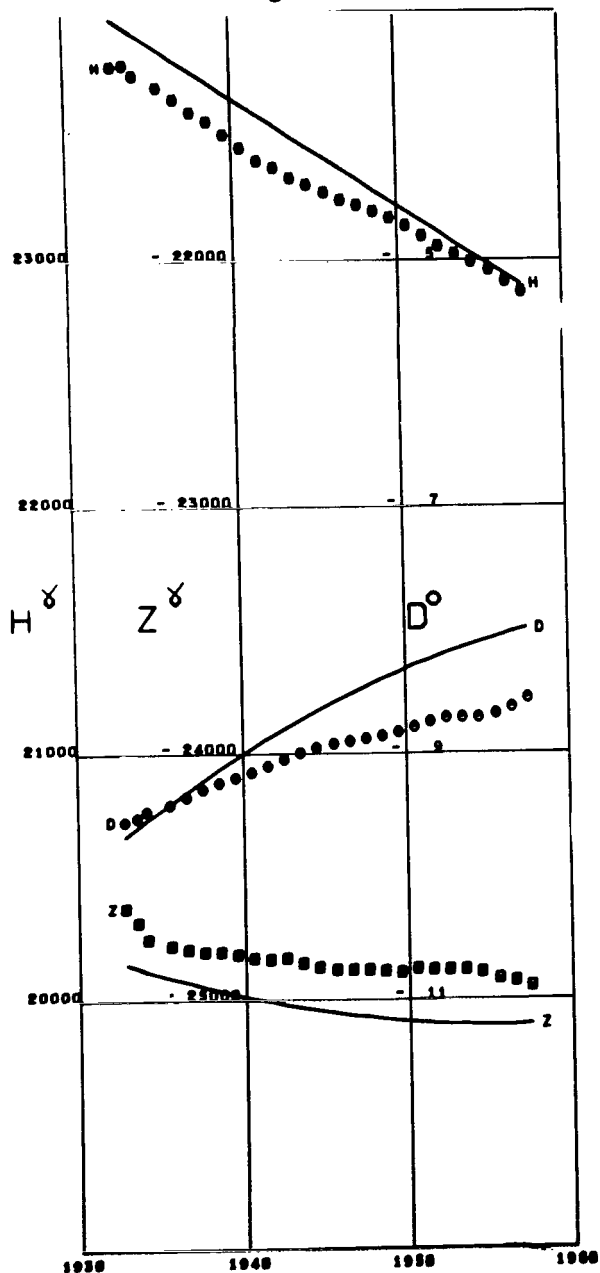


Figure A52

ESKDALEMUIR  
 Lat 55.31 Long -3.20

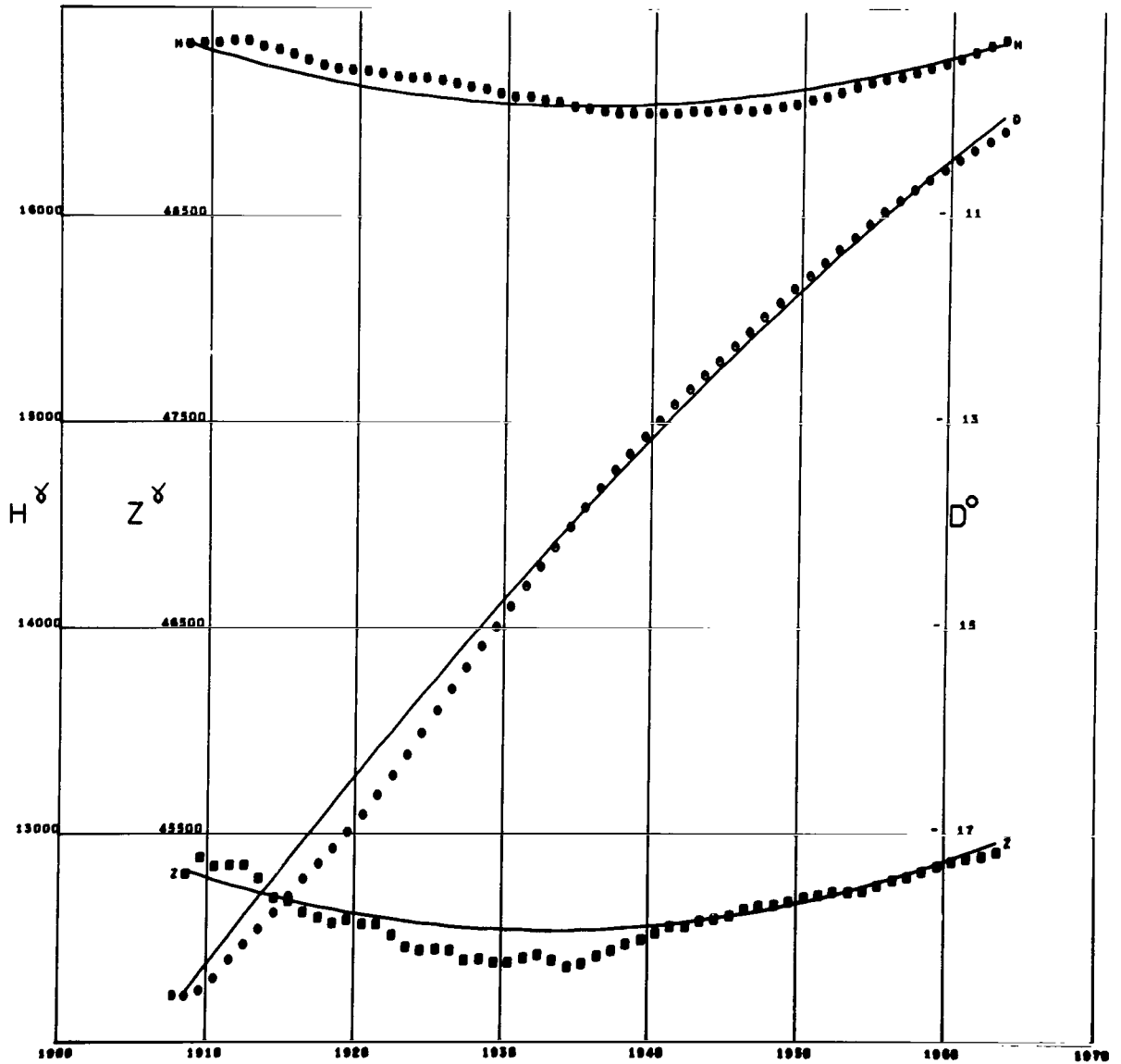


Figure A53

# FALMOUTH

Lat 50.15 Long -5.07

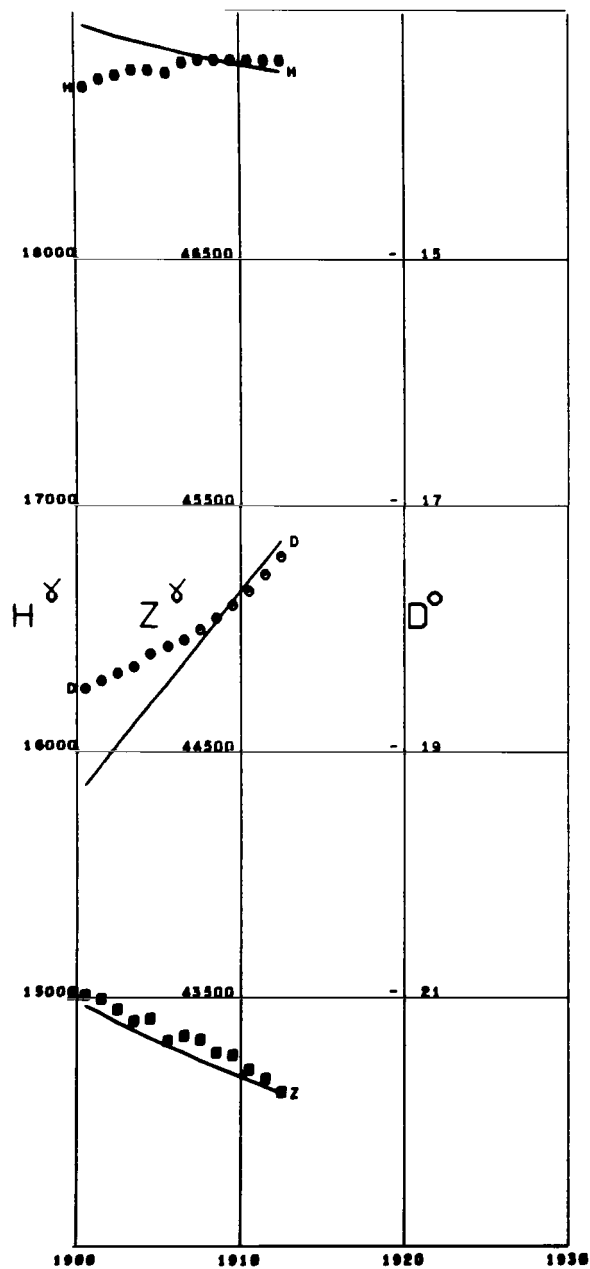


Figure A54

# FREDERICKSBURG

Lat 38.20 Long -77.37 Alt 0.07

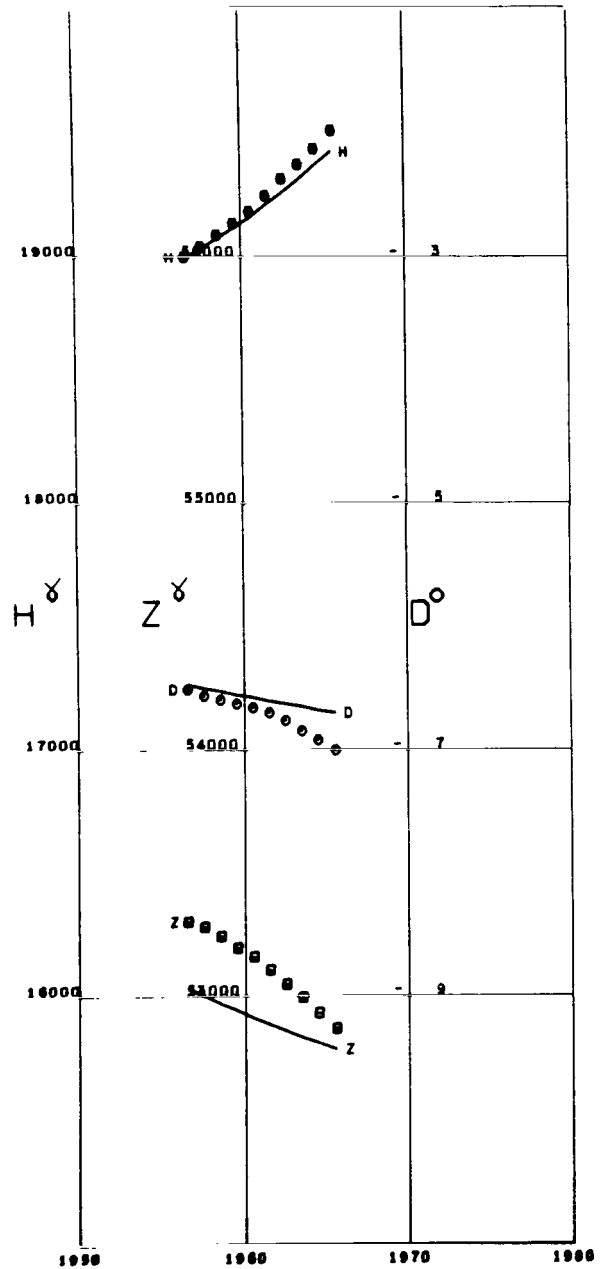


Figure A55

FUQUENE  
Lat 5.47 Long -73.73 Alt 2.54

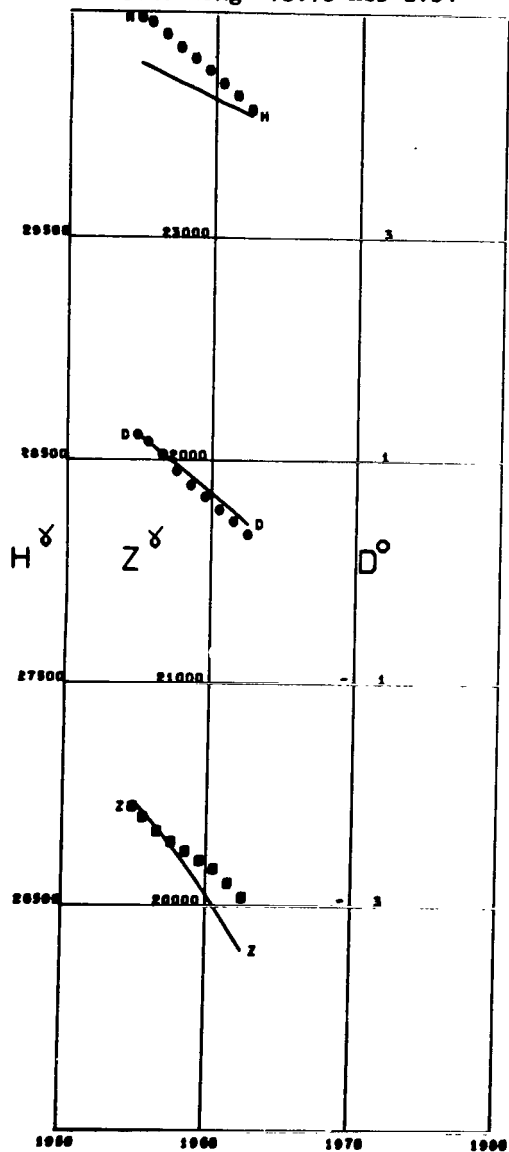


Figure A56

FURSTENFELDBRUCK  
Lat 48.16 Long 11.27 Alt 0.57

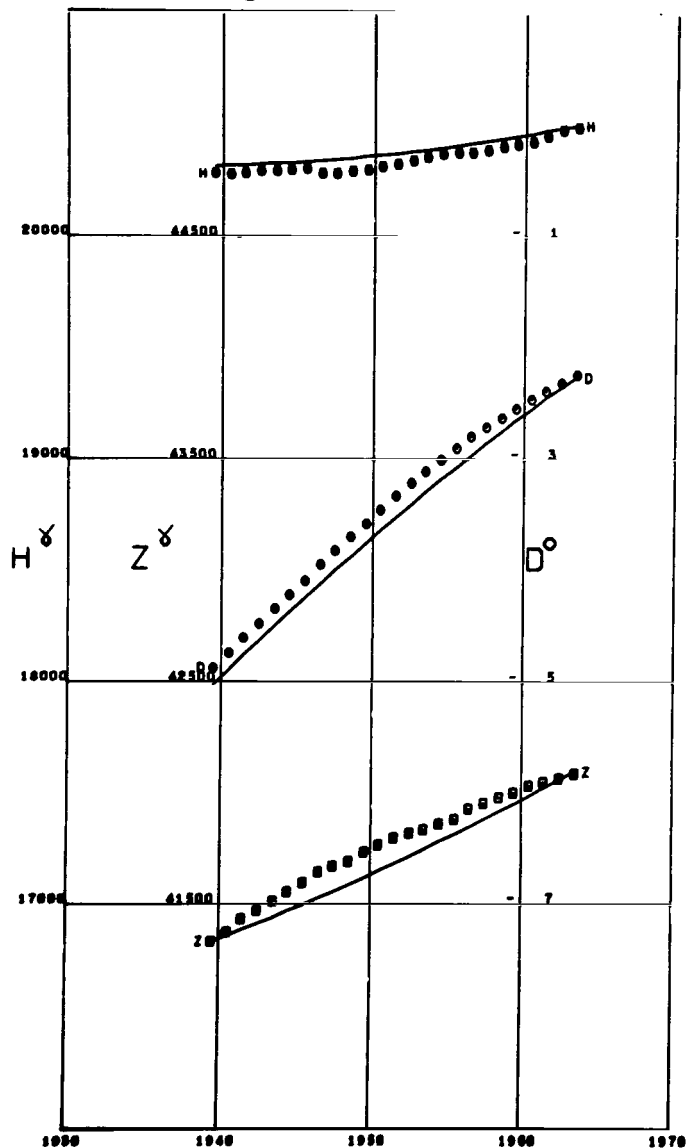


Figure A57



GNANGARA

Lat -31.78 Long 115.95 Alt 0.06

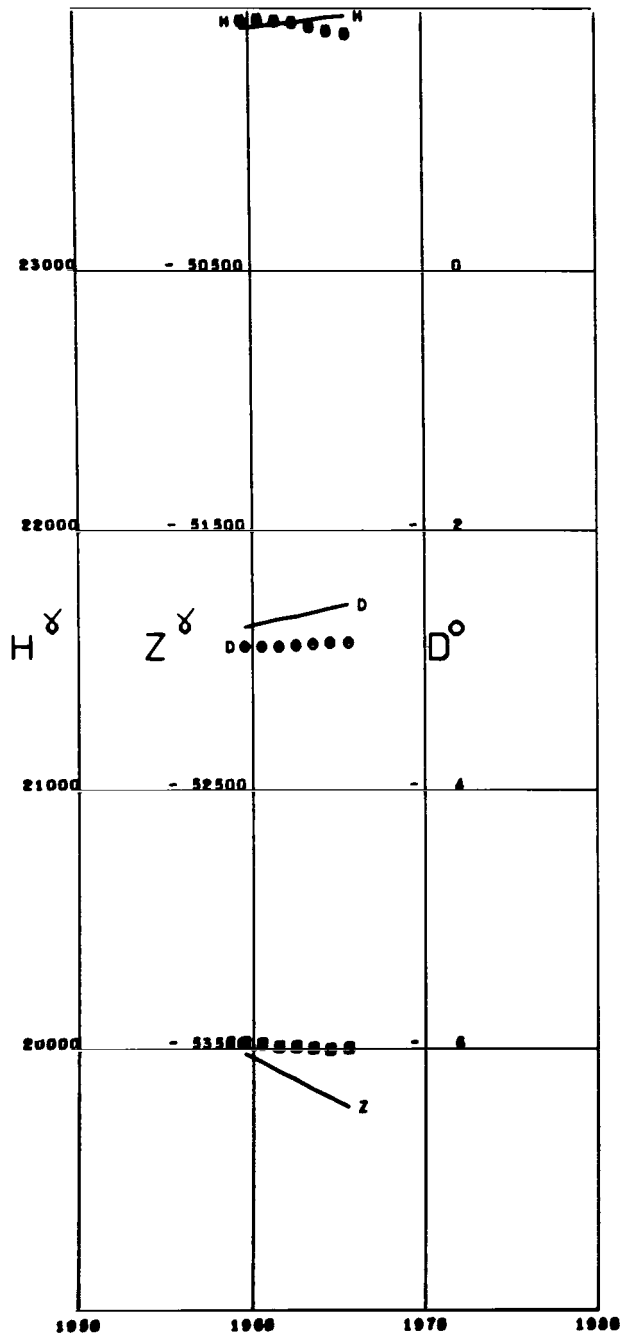


Figure A58

GODHAVN  
 Lat 69.24 Long -53.52 Alt 0.01

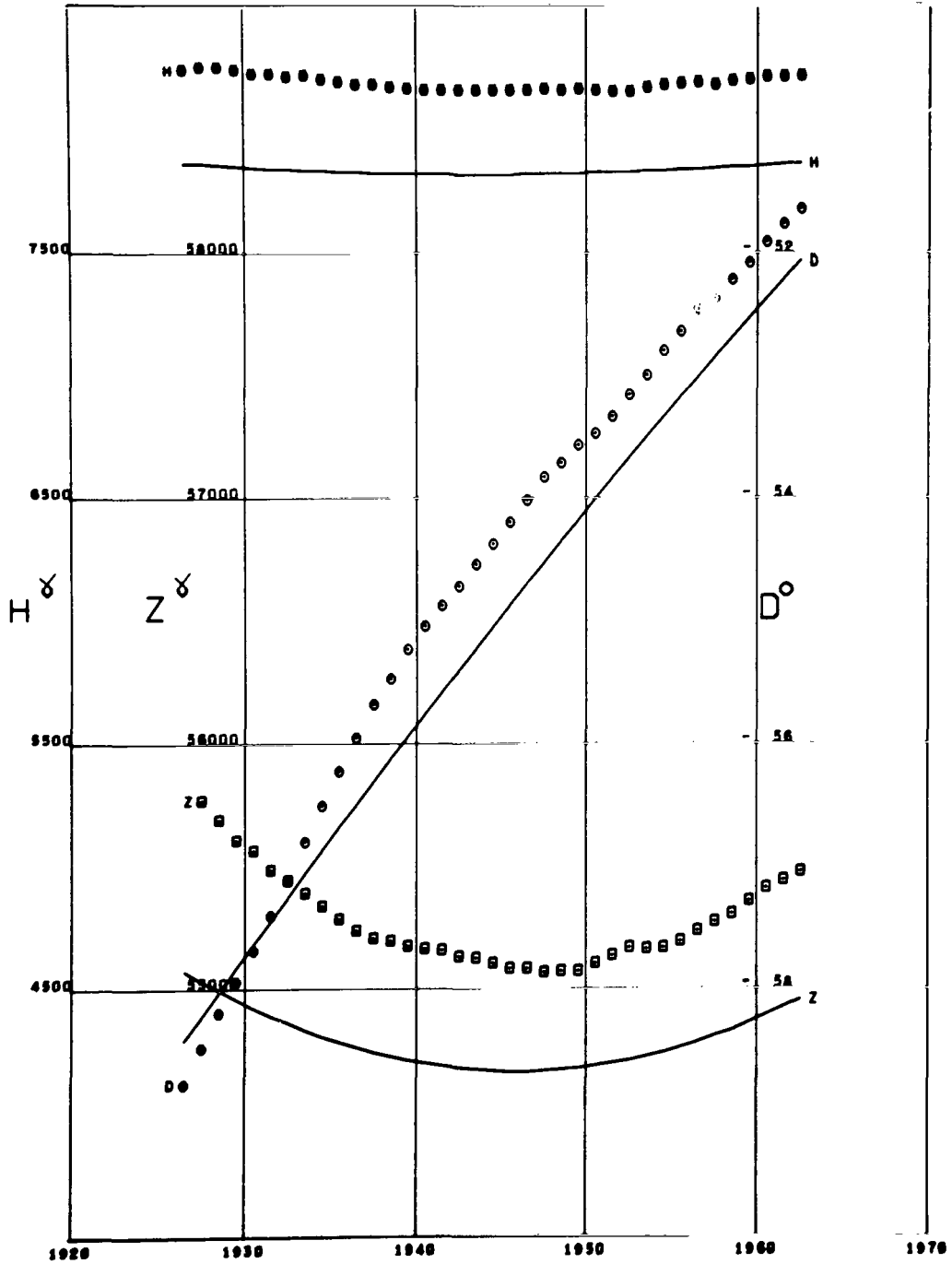


Figure A59

GORNOTAYEZHNAJA  
Lat 43.68 Long 132.16

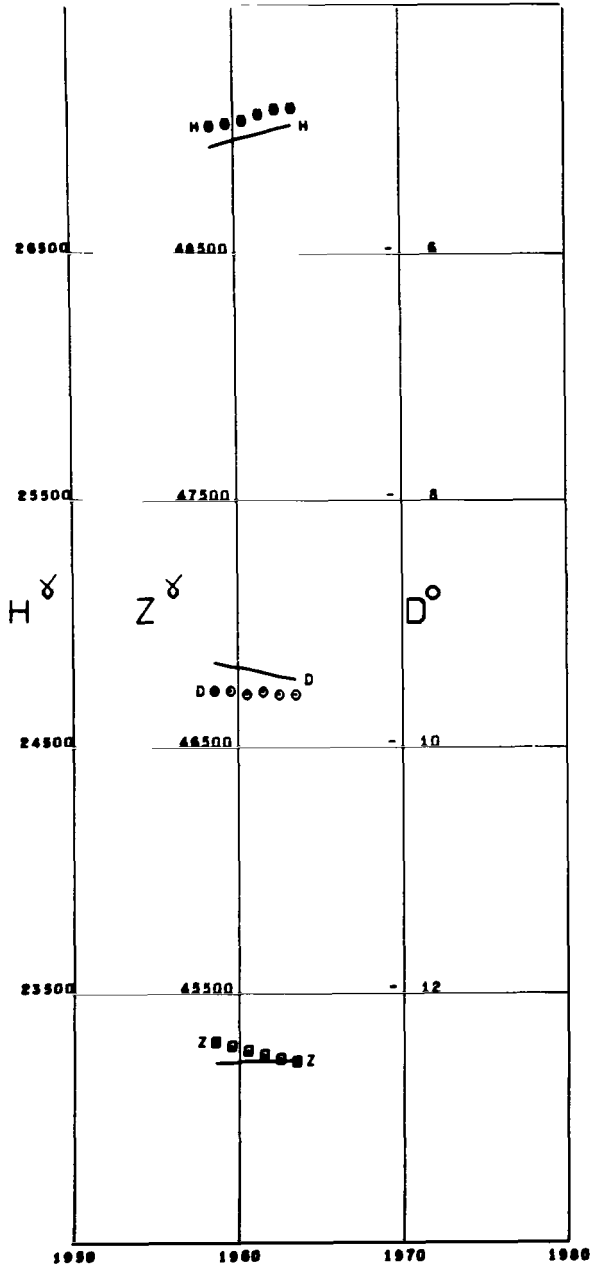


Figure A60

GREENWICH  
Lat 51.47 Long 0.00

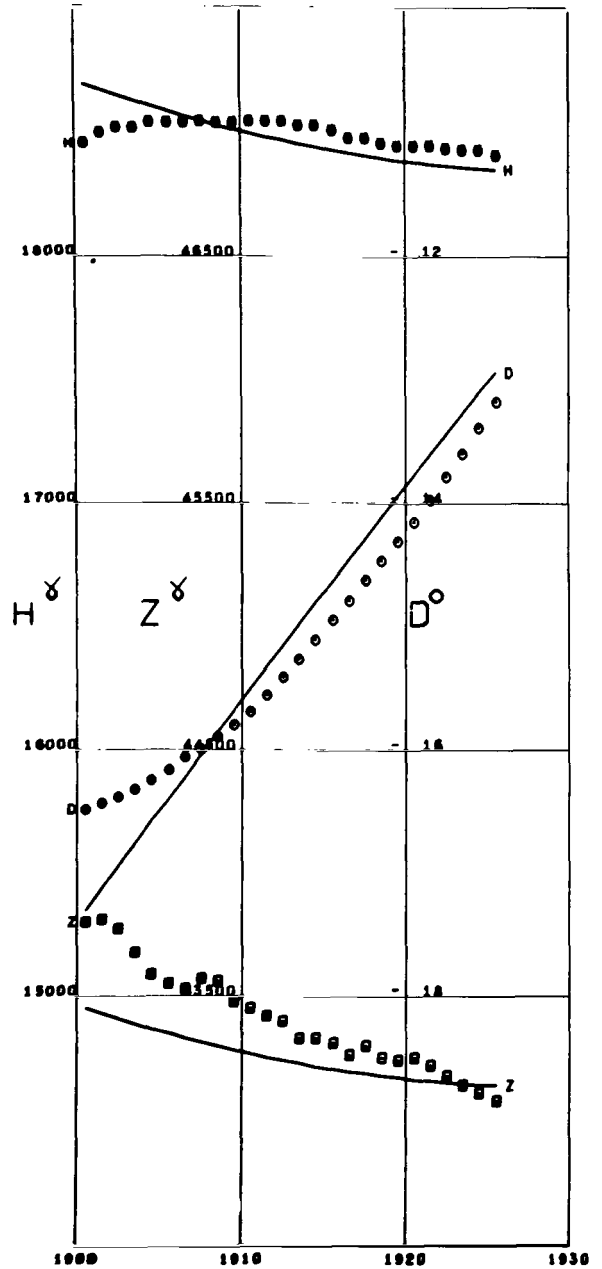


Figure A61

GROCKA

Lat 44.63 Long 20.76

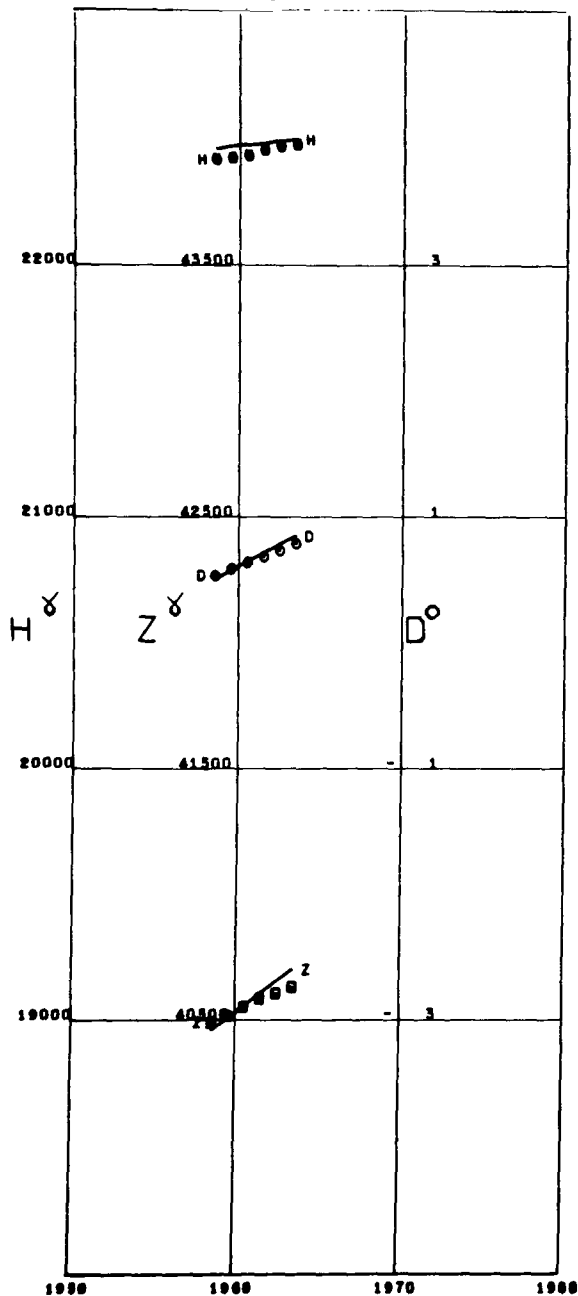


Figure A62

GUAM

Lat 13.58 Long 144.87 Alt 0.15

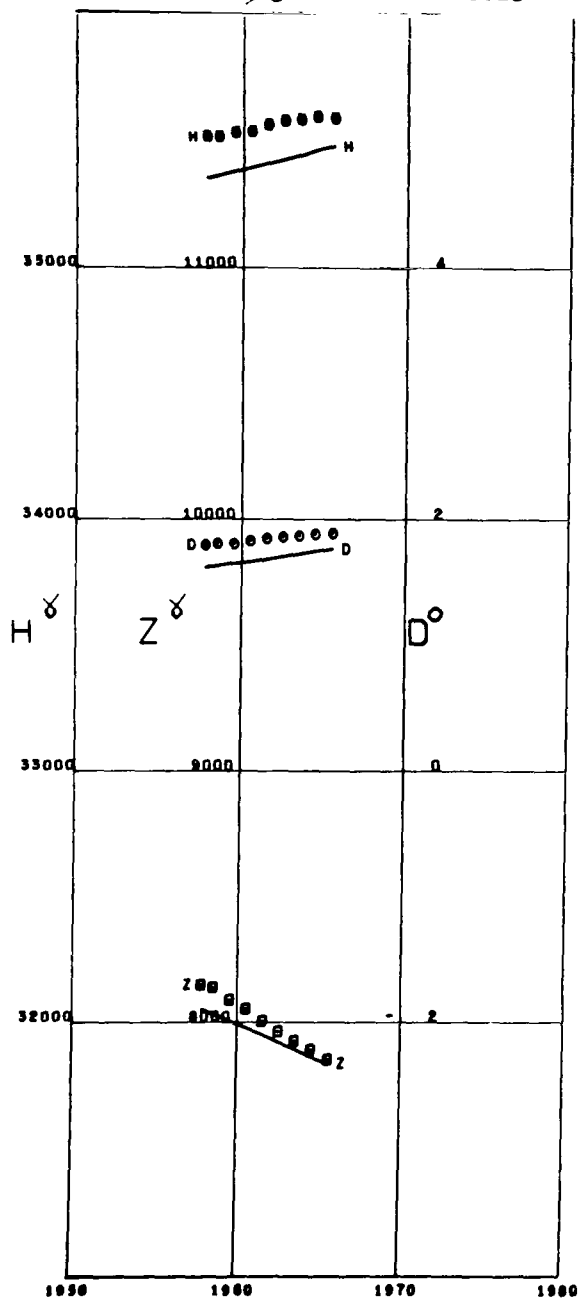


Figure A63

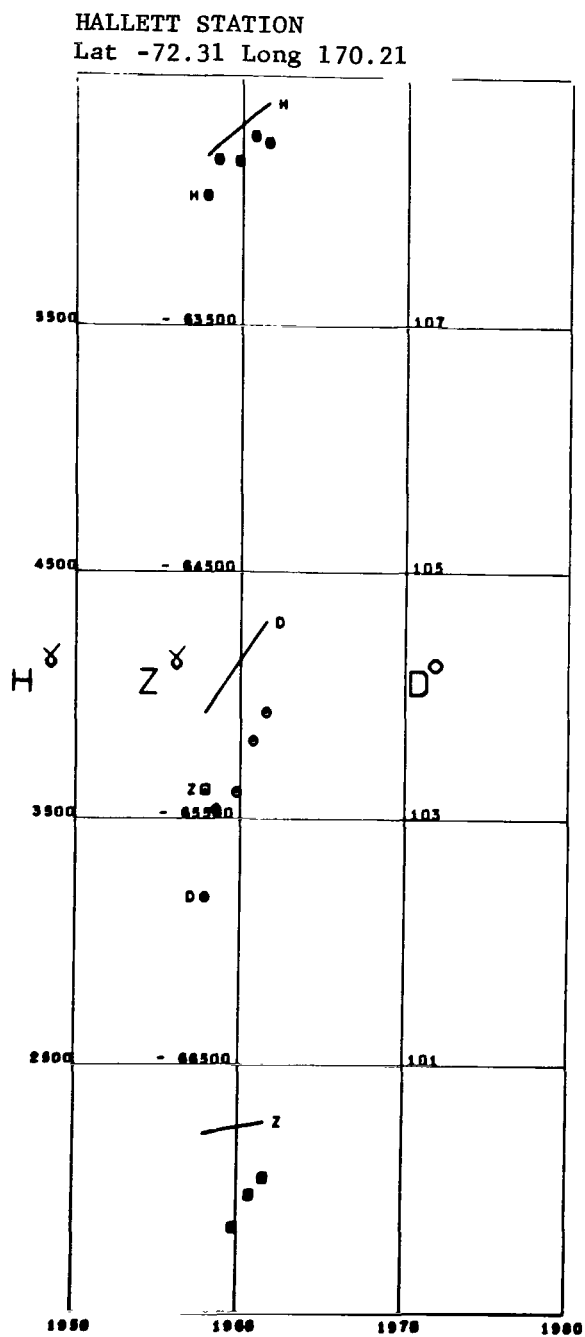


Figure A64

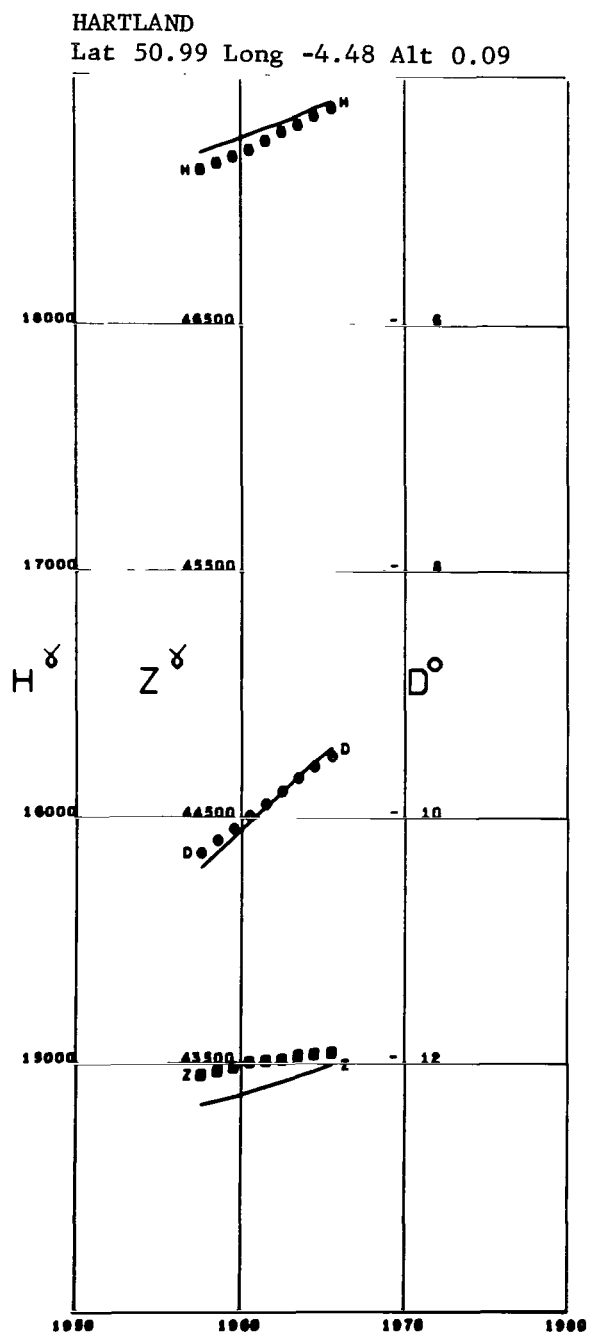


Figure A65

HEARD ISLAND  
Lat -53.03 Long 73.36

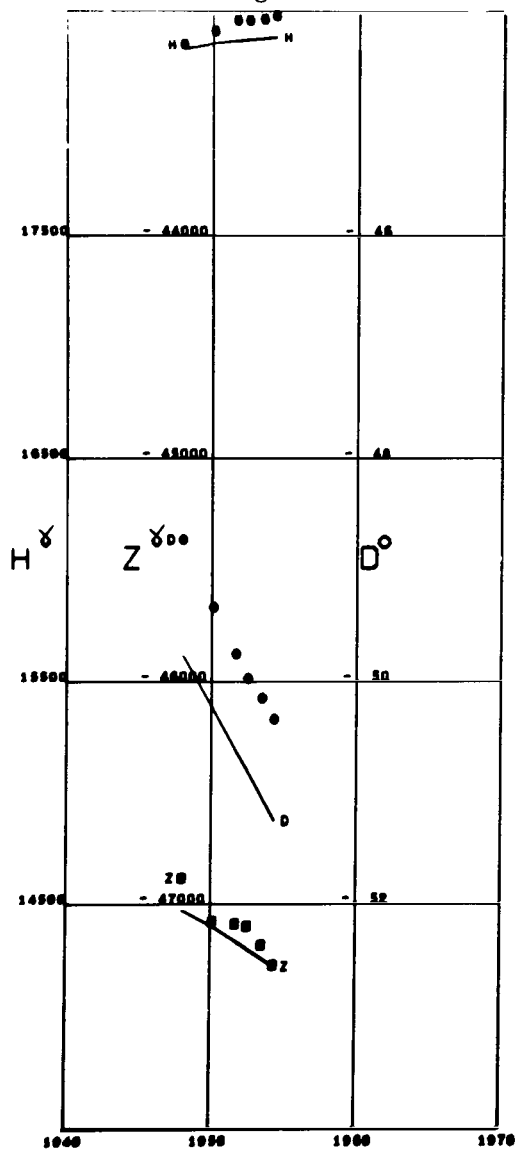


Figure A66

HEL  
Lat 54.60 Long 18.81

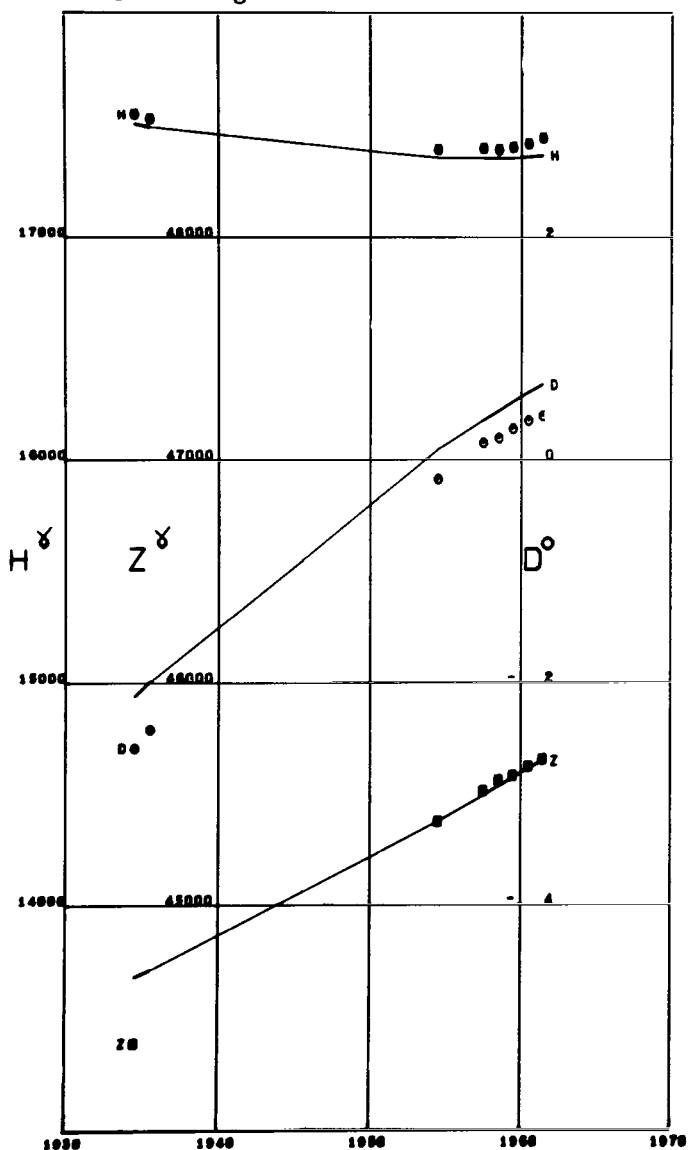


Figure A67

HELWAN

Lat 29.85 Long 31.34

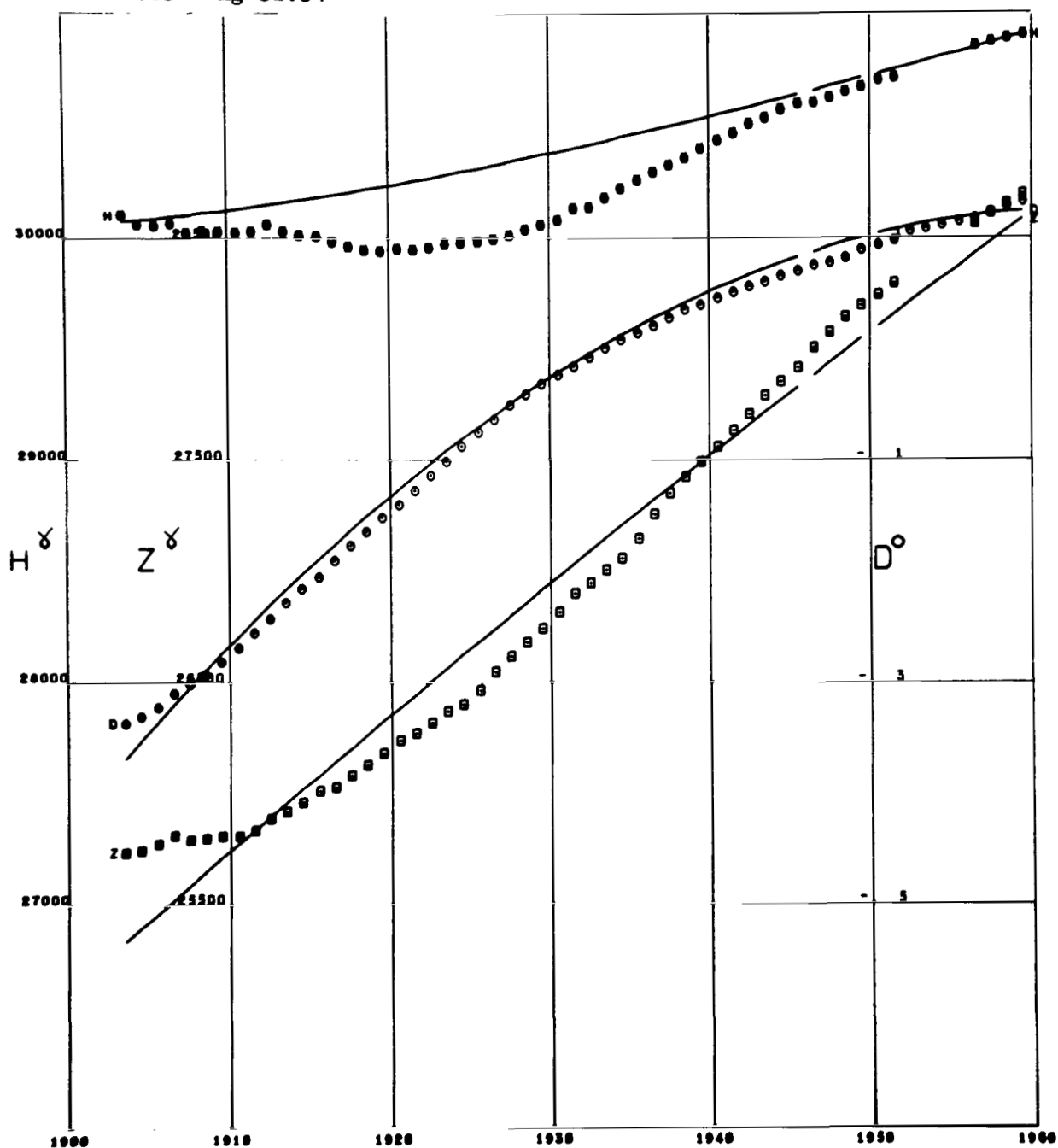


Figure A68

# HERMANUS

Lat -34.42 Long 19.22 Alt 0.02

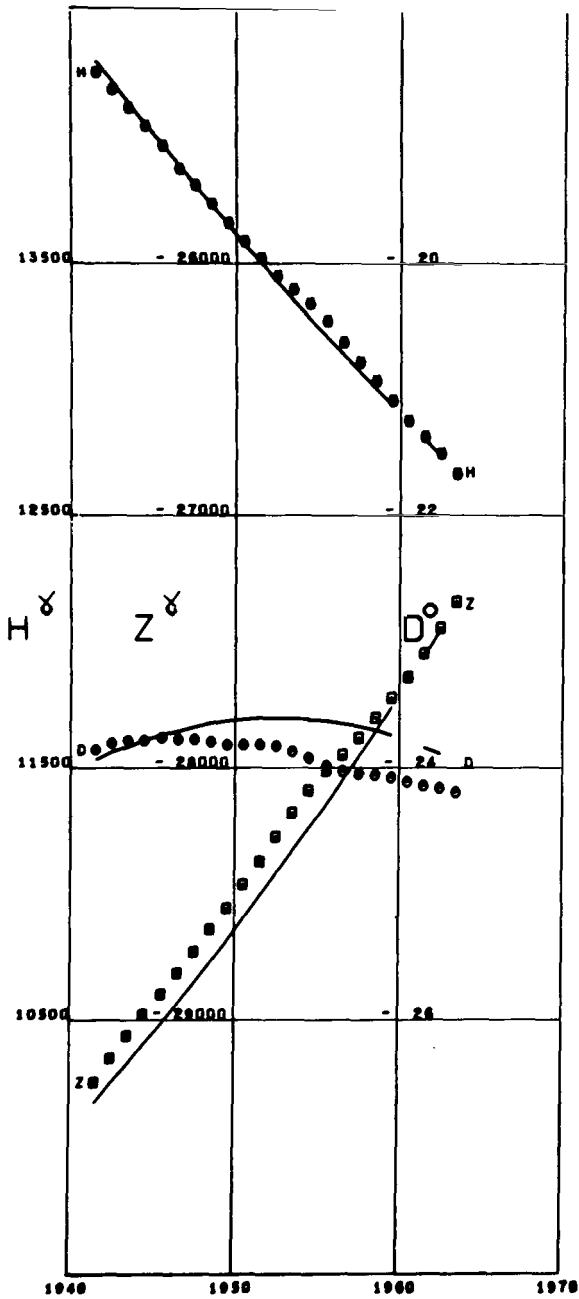


Figure A69

# HERMSDORF

Lat 50.76 Long 16.23

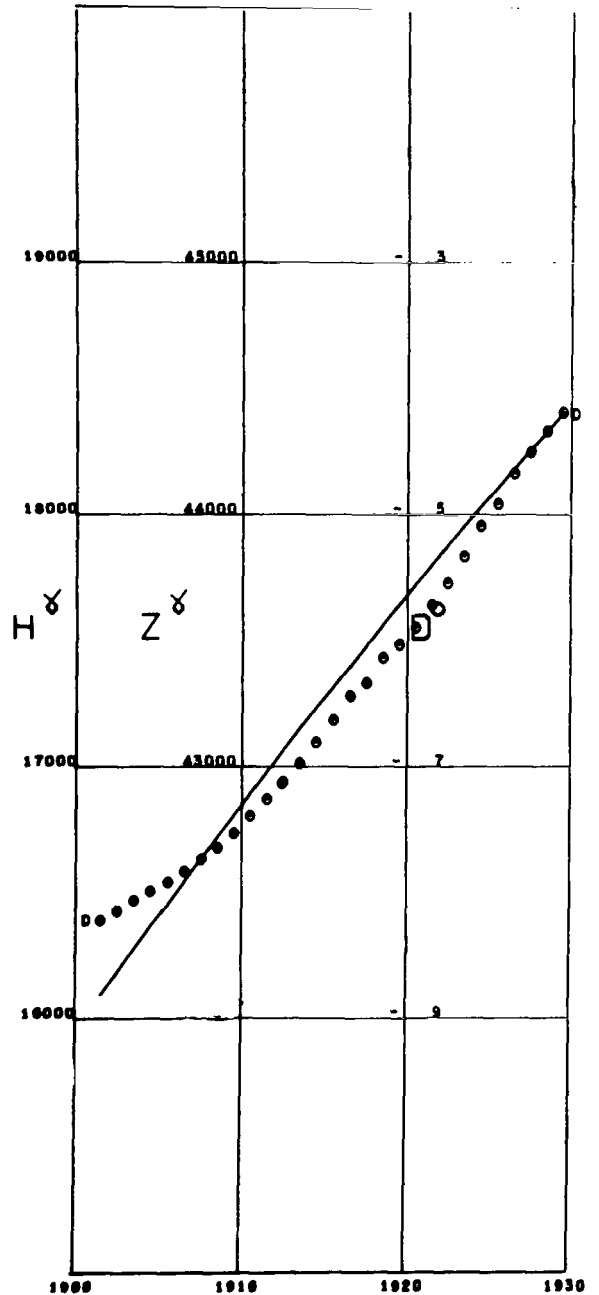


Figure A70



HOLLANDIA  
Lat -2.57 Long 140.51

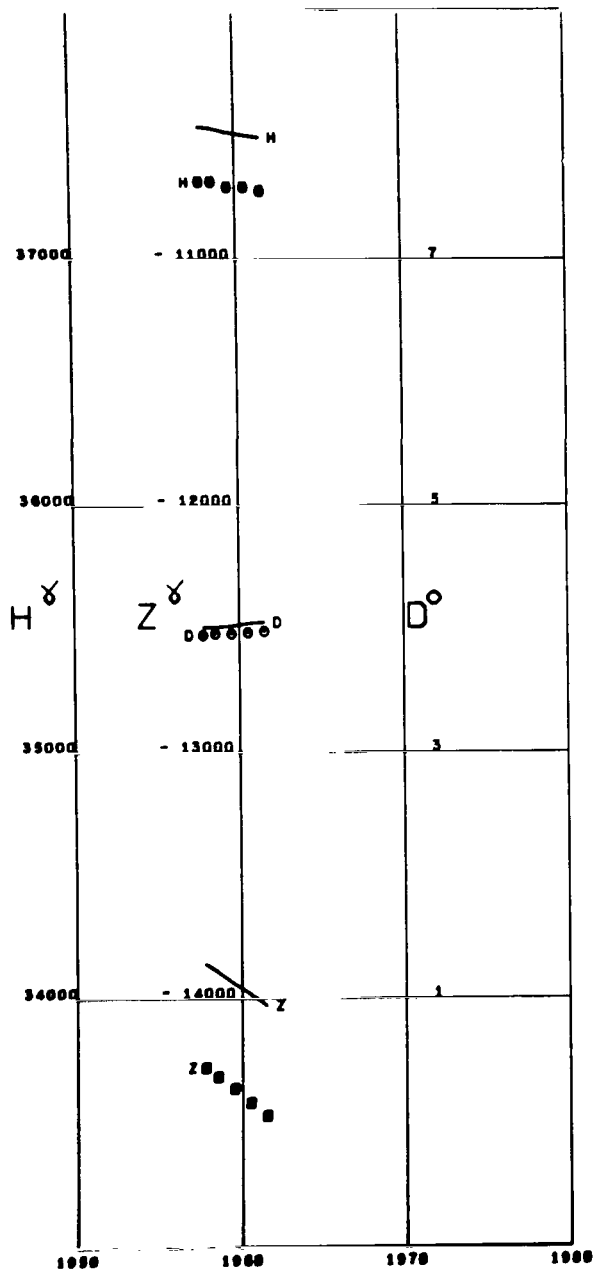


Figure A71

HONGKONG  
Lat 22.30 Long 114.17

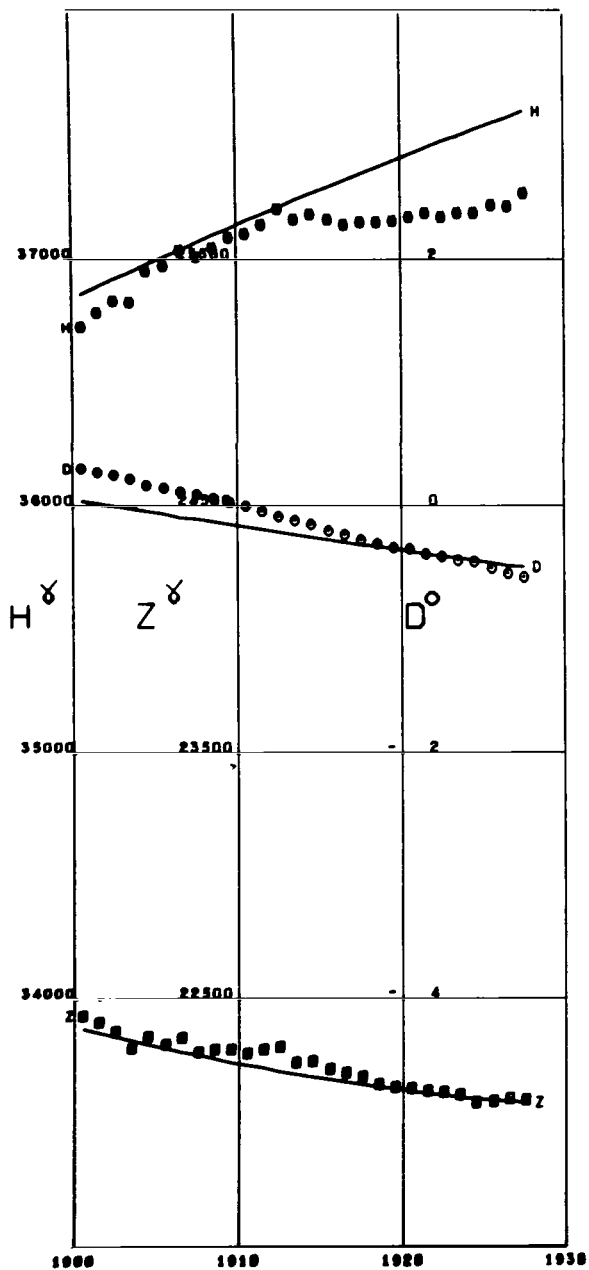


Figure A72

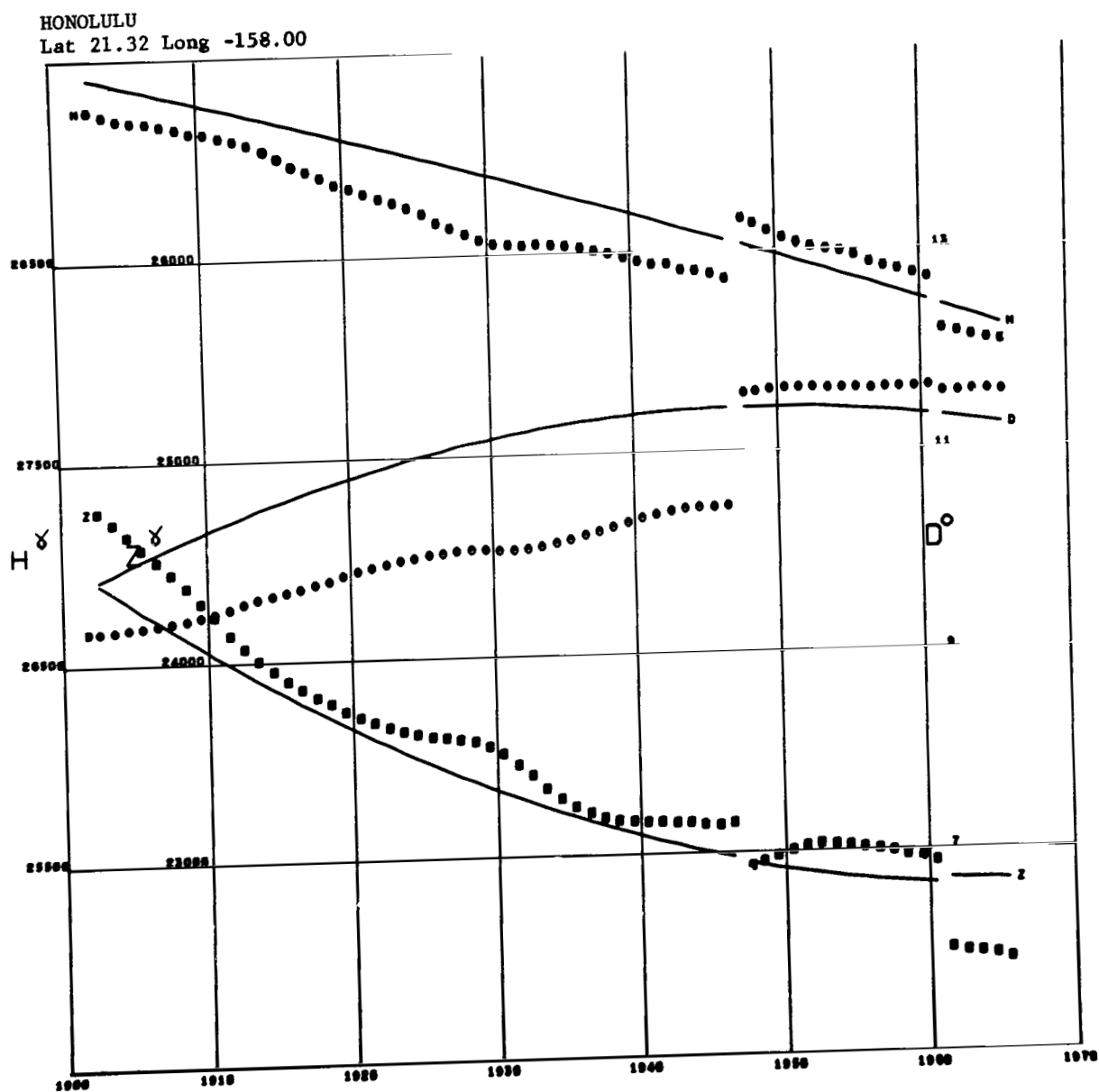


Figure A73

HUANCAYO  
 Lat -12.04 Long -75.34 Alt 3.35

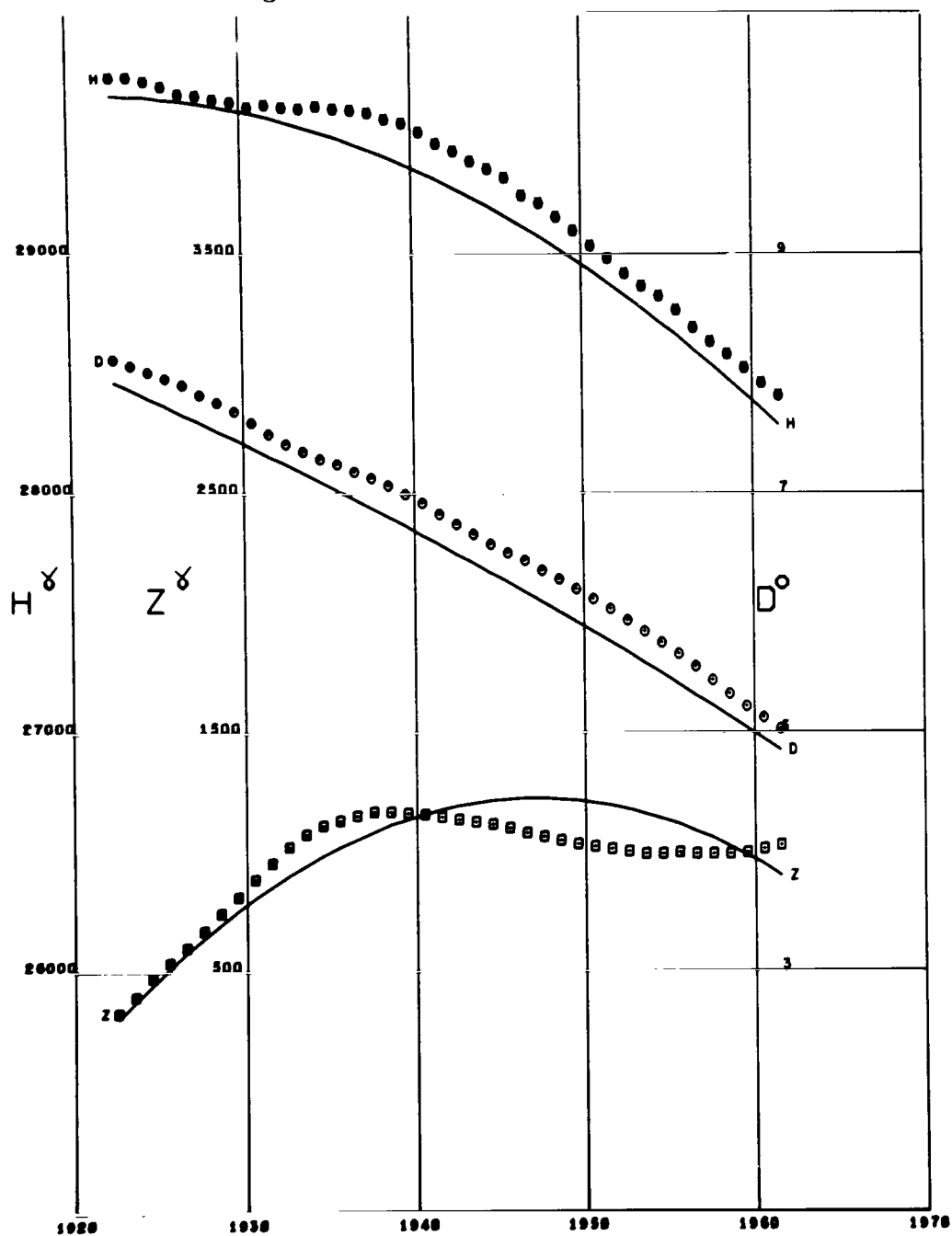


Figure A74

HURBANOVO  
 Lat 47.87 Long 18.19

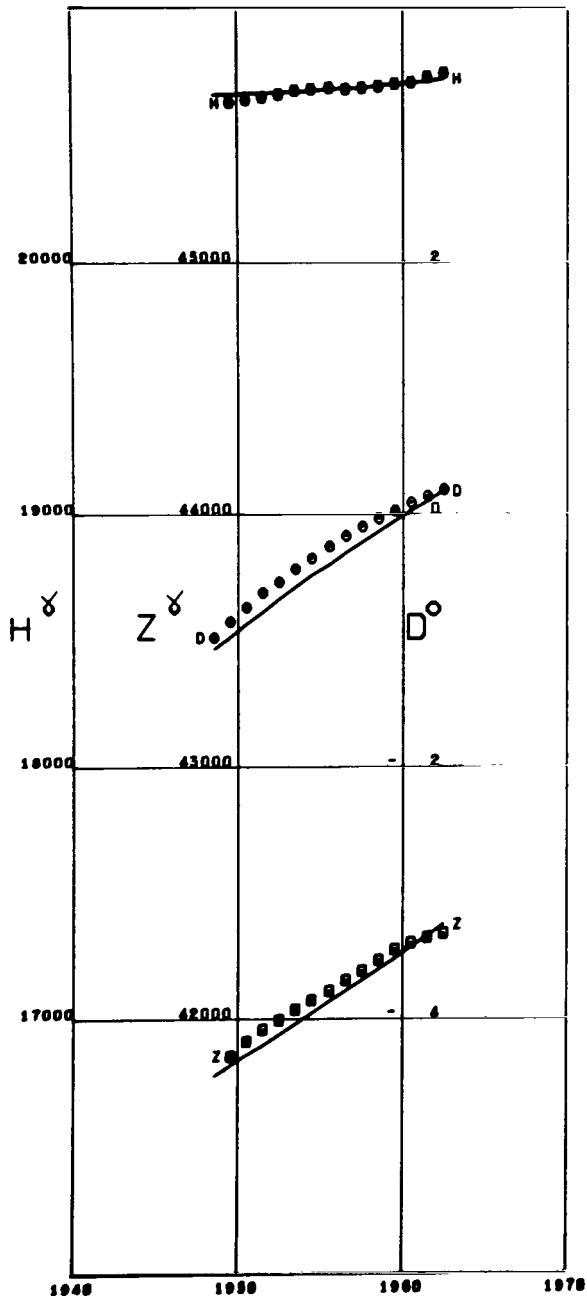


Figure A75

IBADAN  
 Lat 7.43 Long 3.90

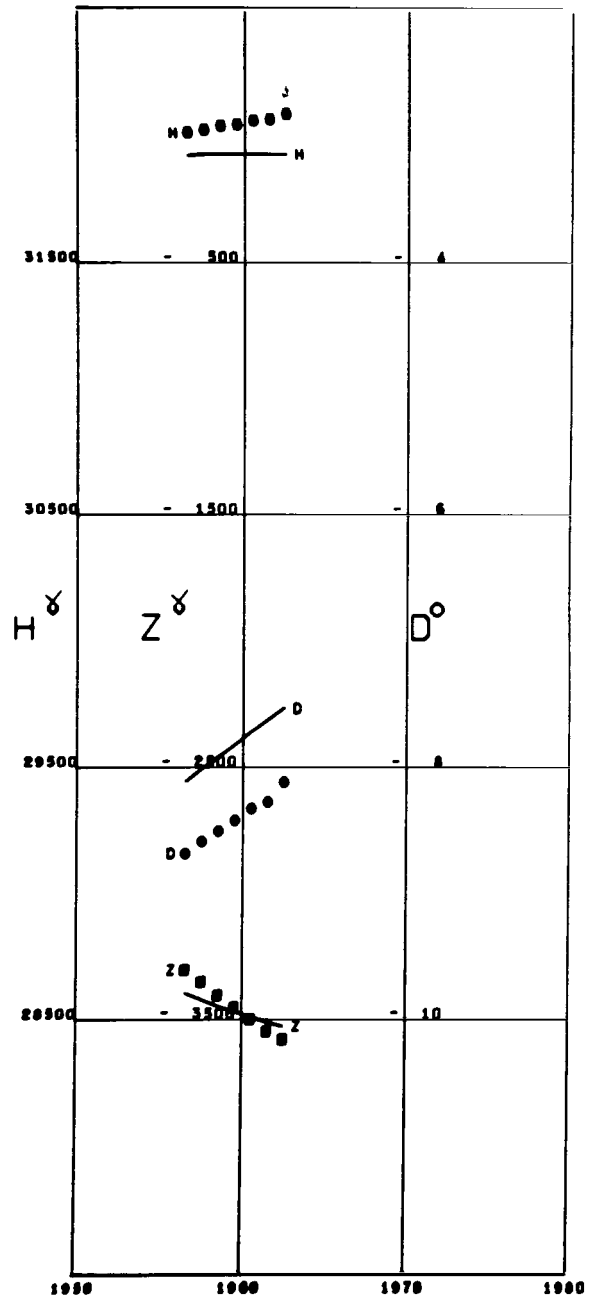


Figure A76

IRKUTSK

Lat 52.26 Long 104.26

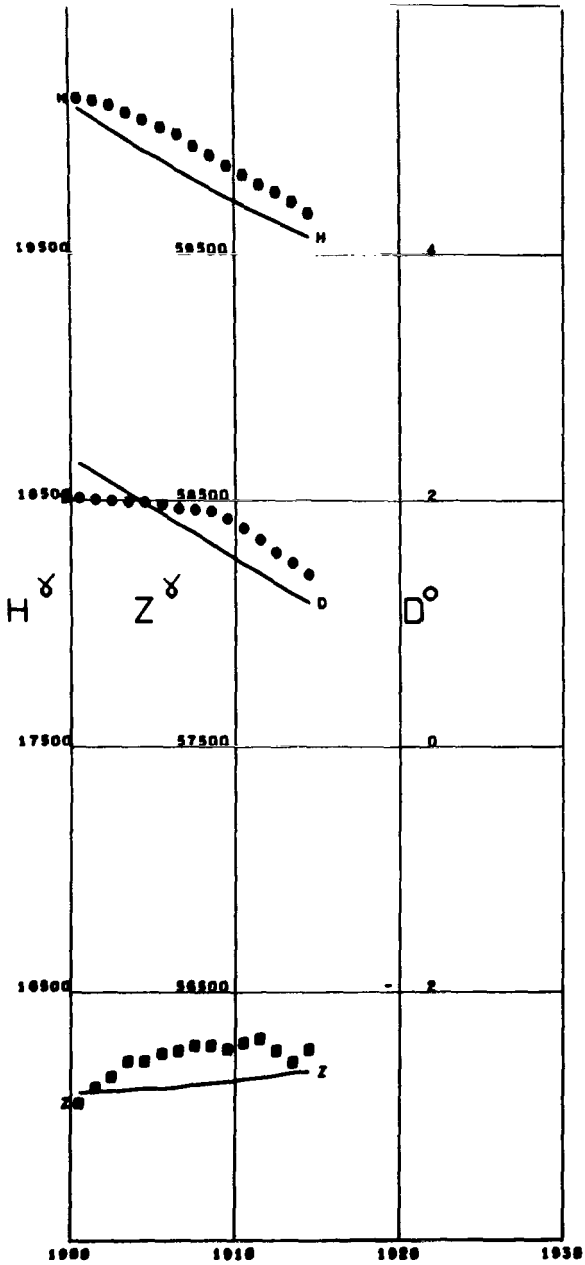


Figure A77

ISTANBUL KANDILLI

Lat 41.06 Long 29.06

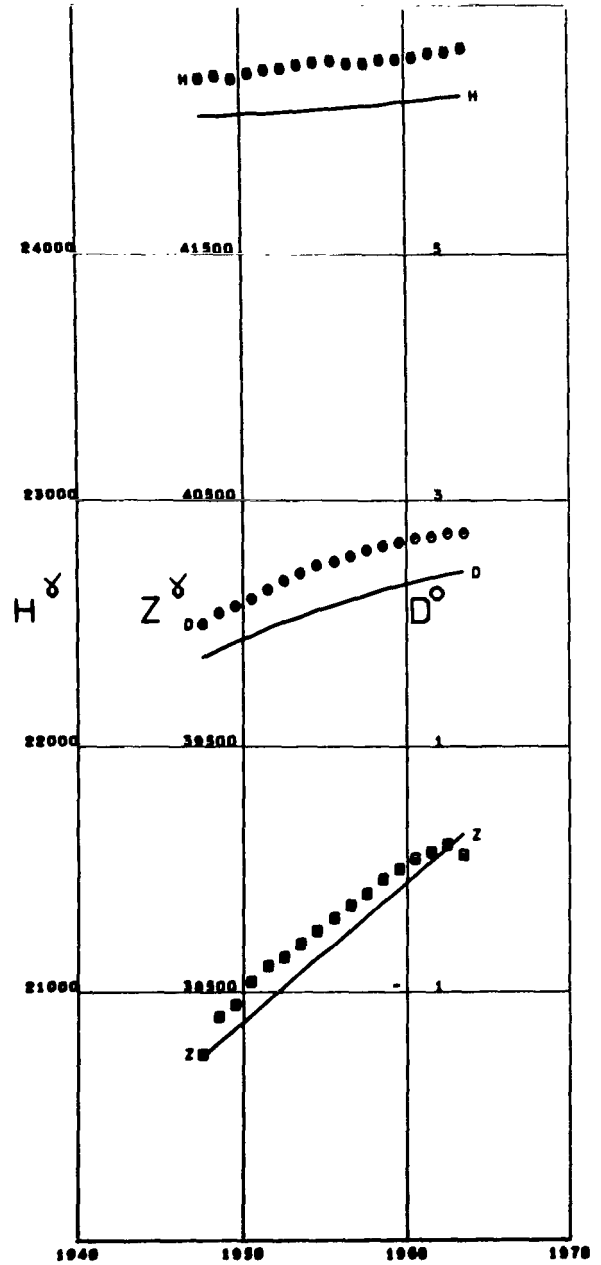


Figure A78

JALUIT  
Lat 5.91 Long 169.65

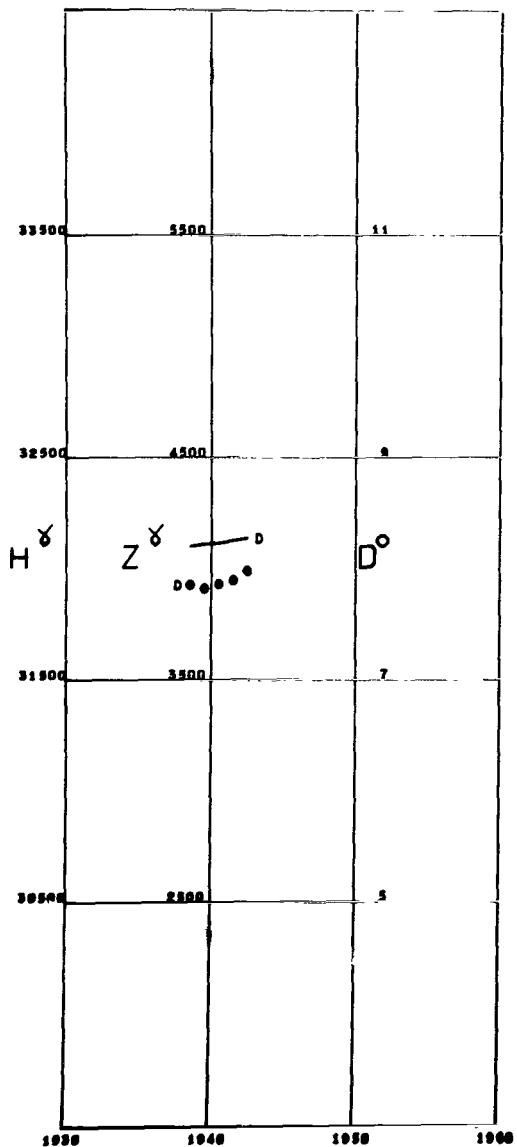


Figure A79

JASSY  
Lat 47.18 Long 27.53

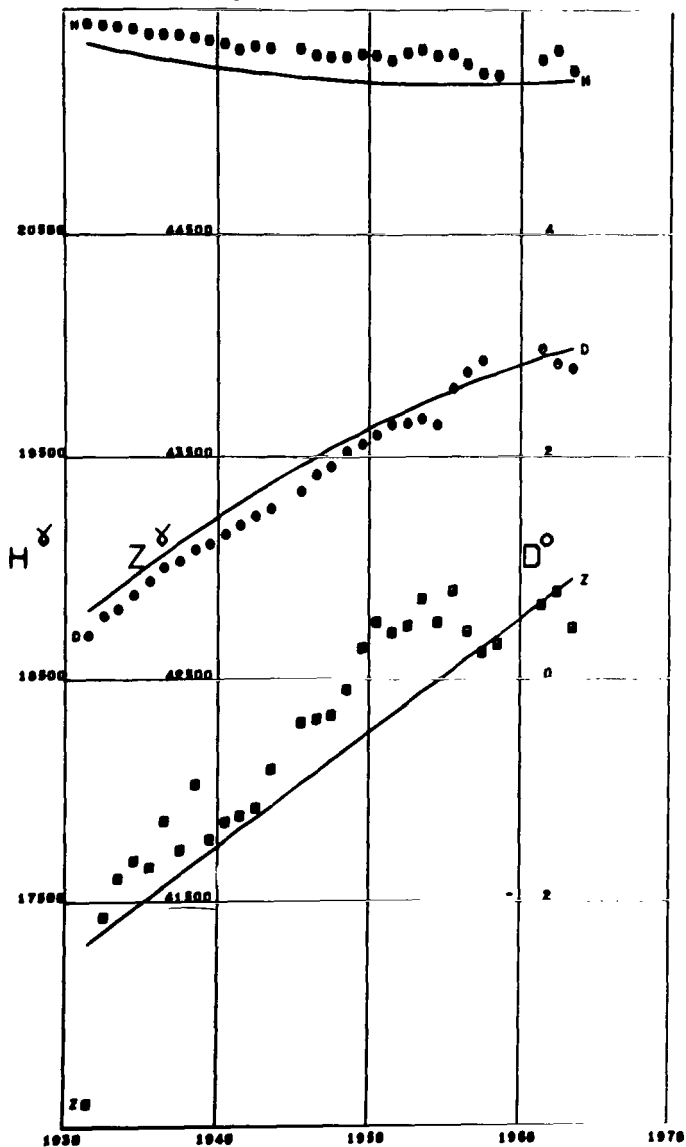


Figure A80

KAKIOKA  
 Lat 36.23 Long 140.19 Alt 0.03

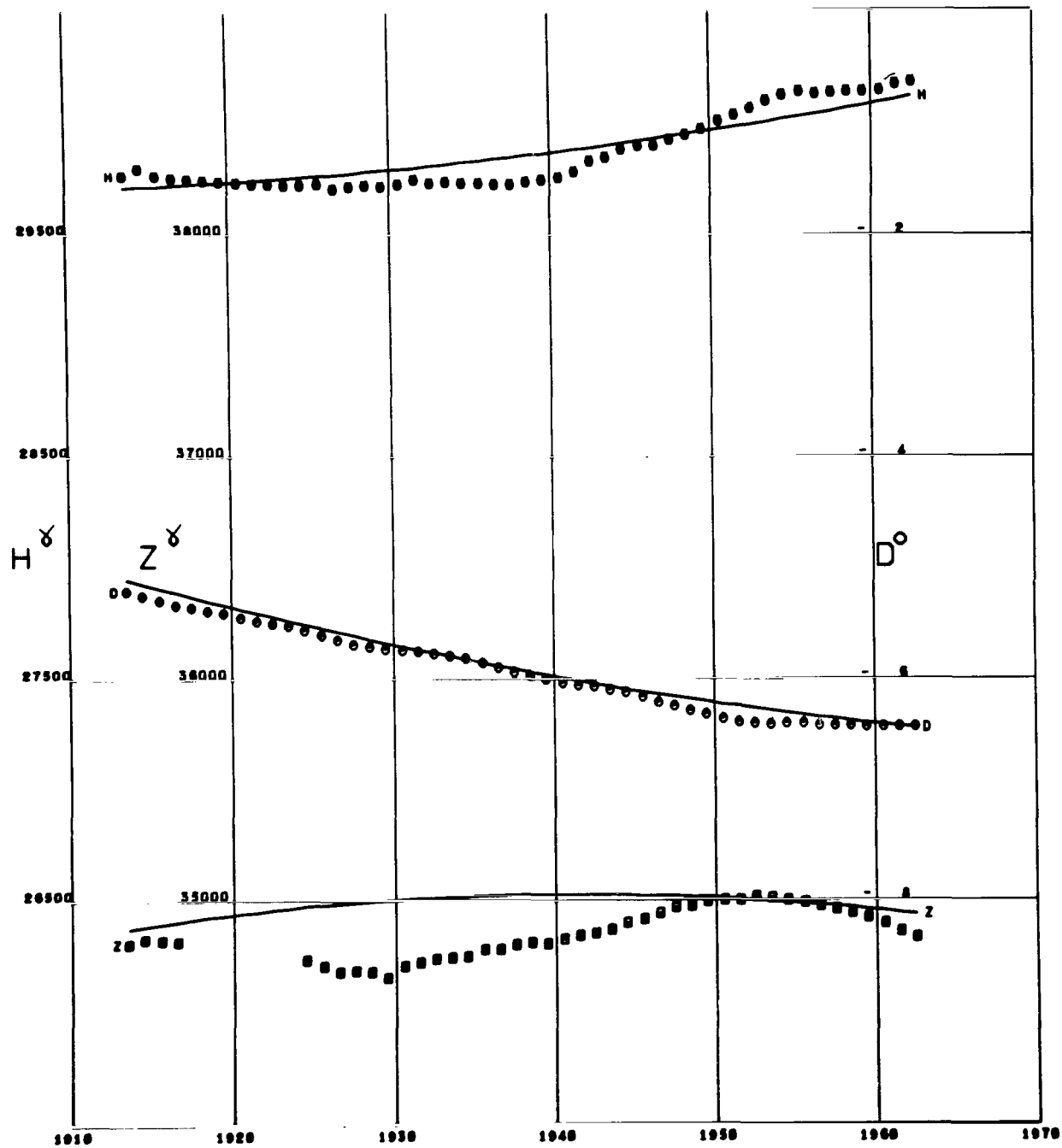


Figure A81

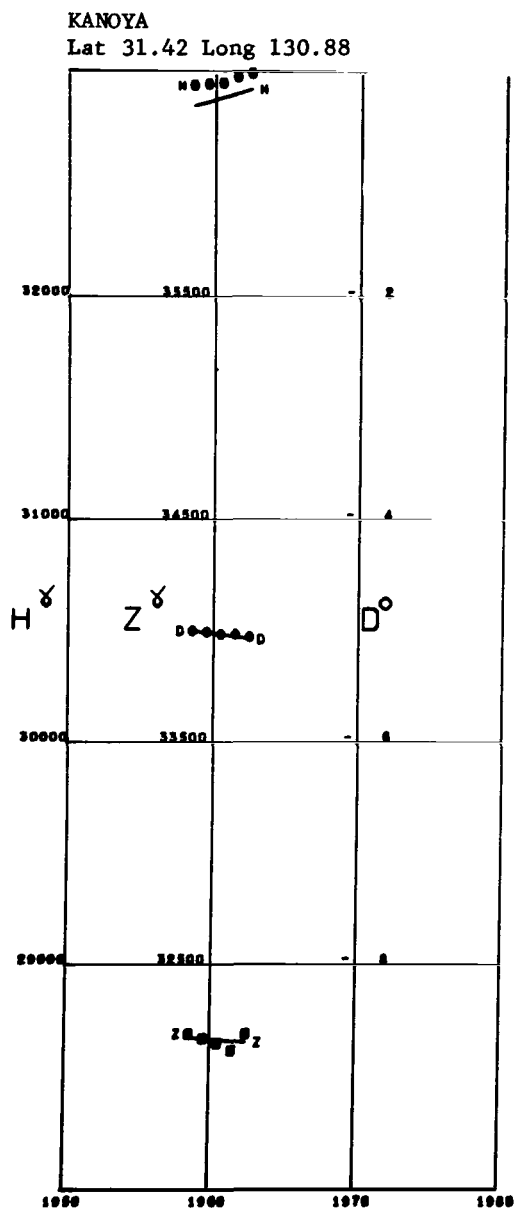


Figure A82

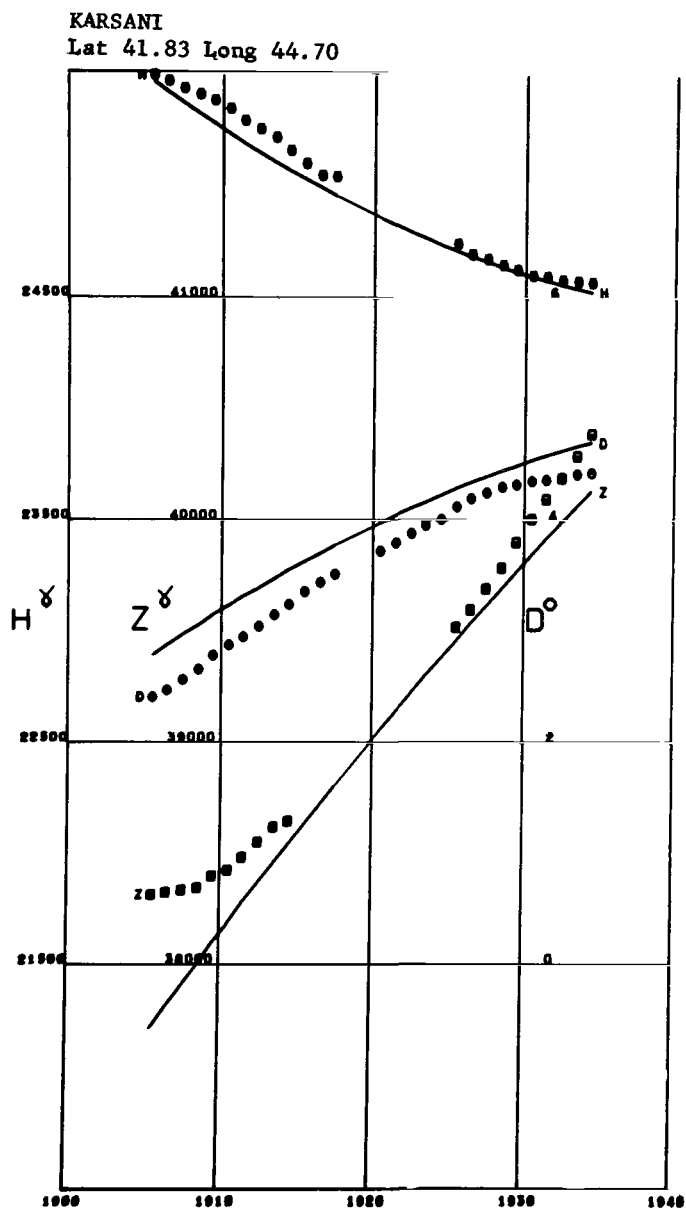


Figure A83



# KATUURA

Lat 33.63 Long 135.94

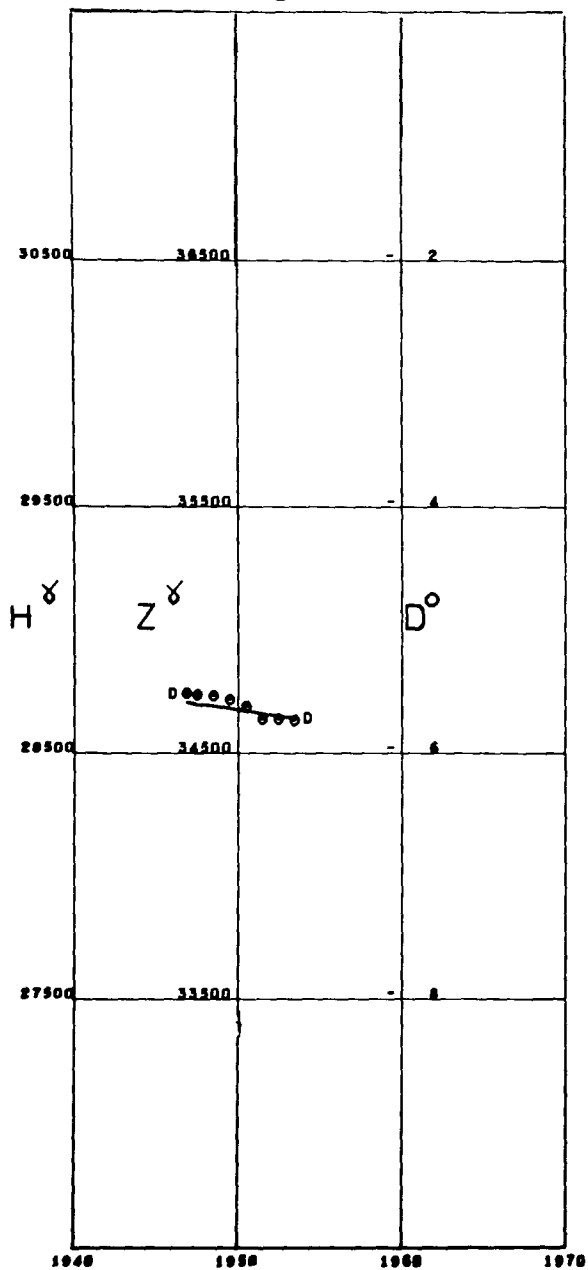


Figure A84

# KAZAN

Lat 55.78 Long 49.13

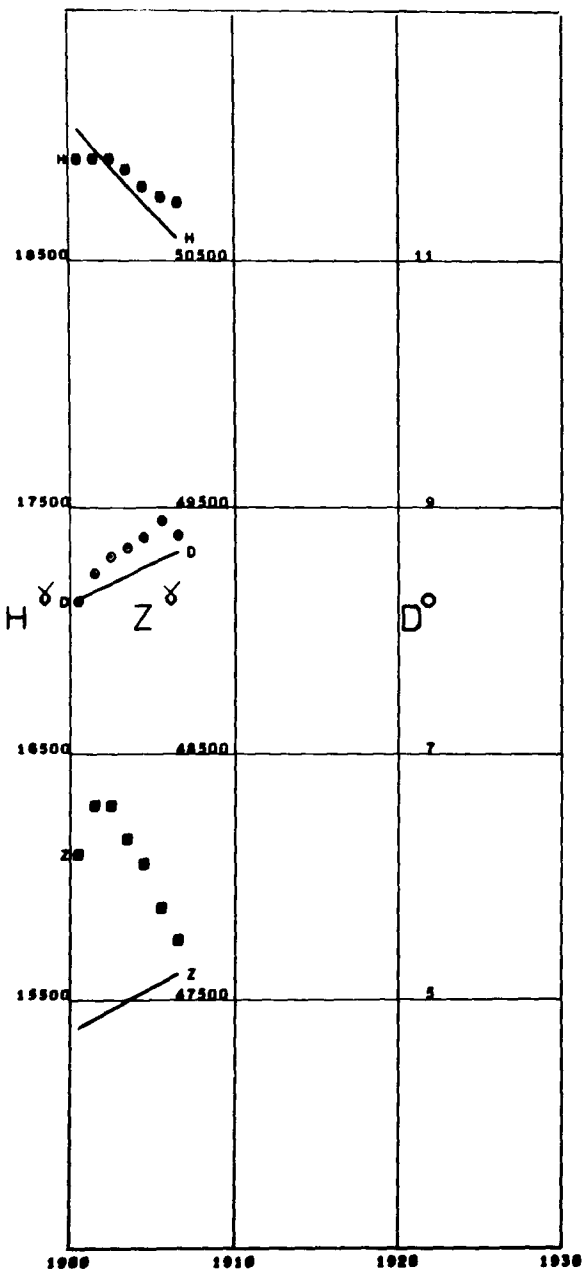


Figure A85

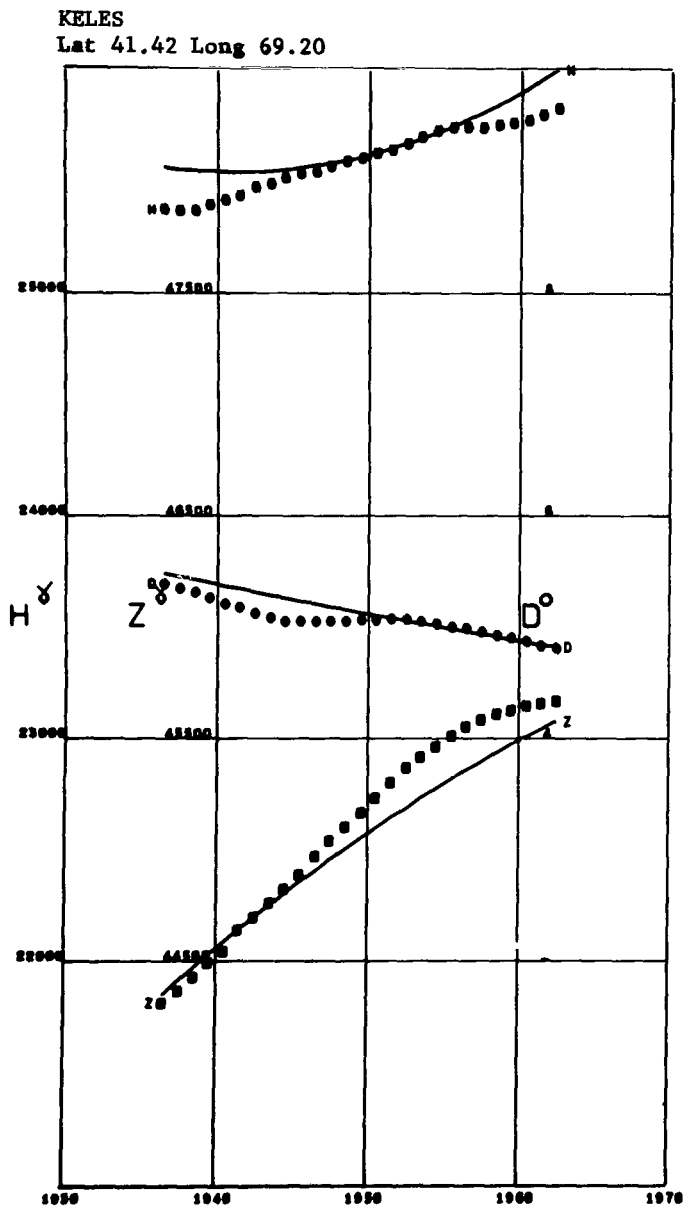


Figure A86

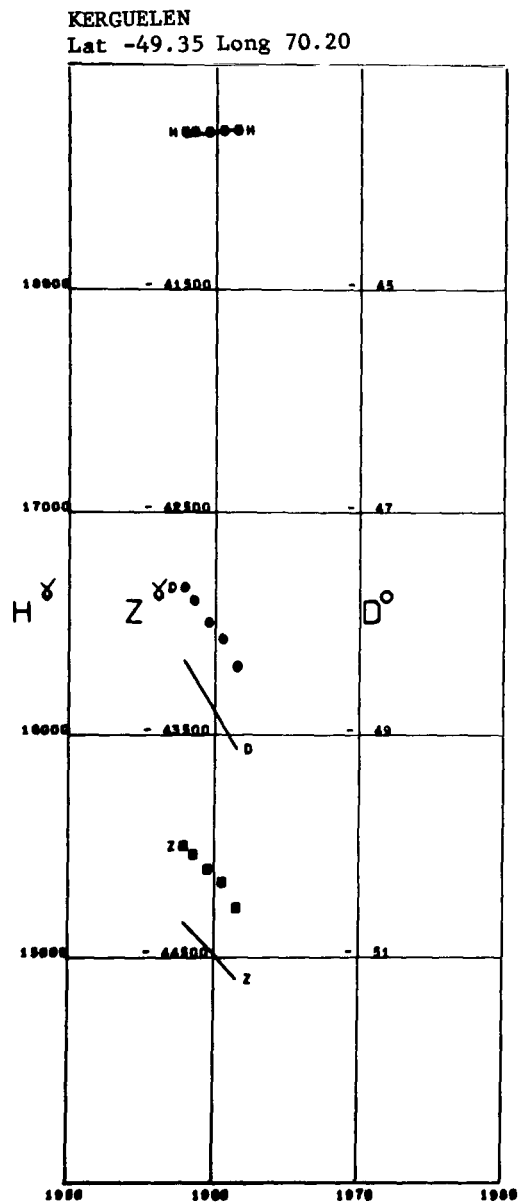


Figure A87

KEW  
Lat 51.46 Long -0.31

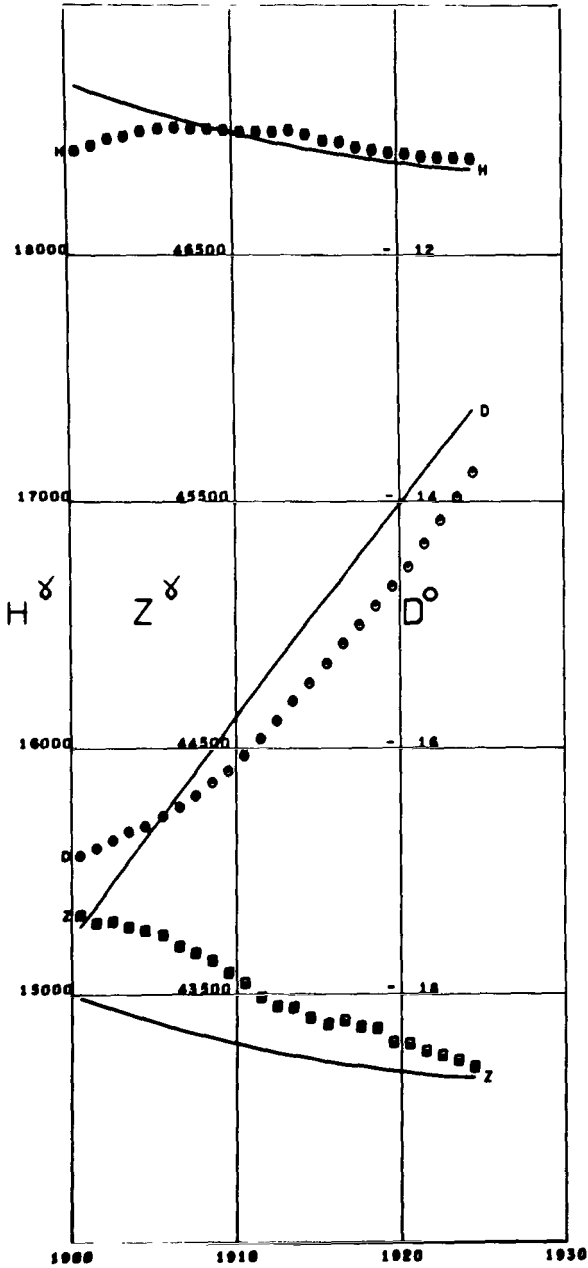


Figure A88

KIEV  
Lat 50.71 Long 30.30

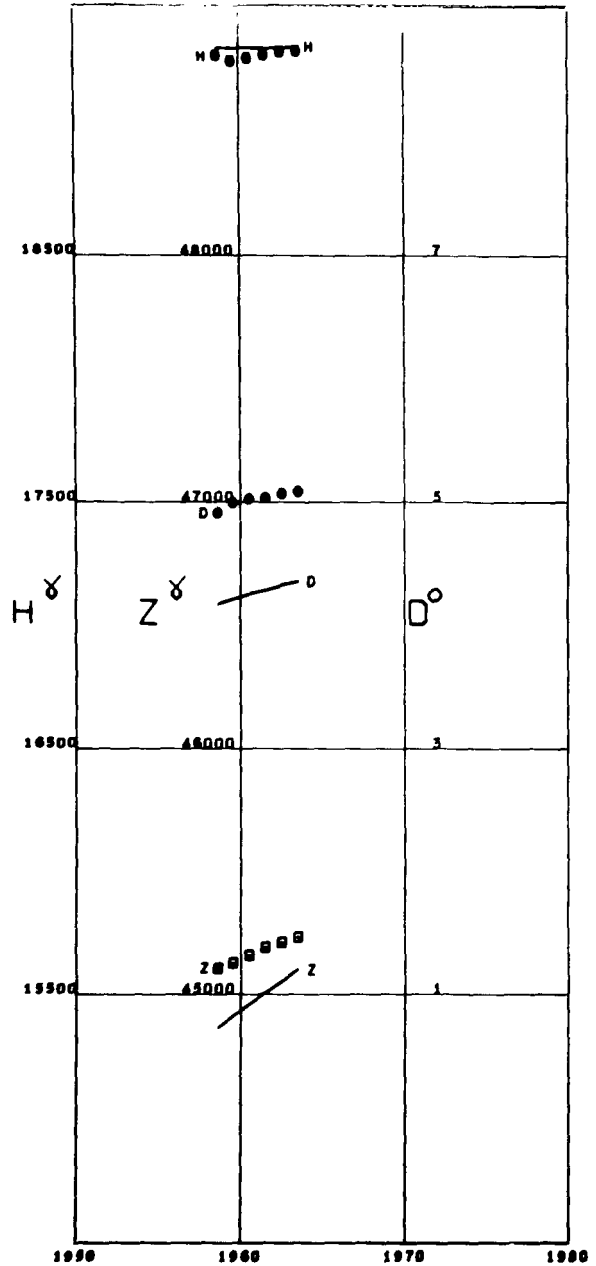


Figure A89

KODAIKANAL  
 Lat 10.23 Long 77.46

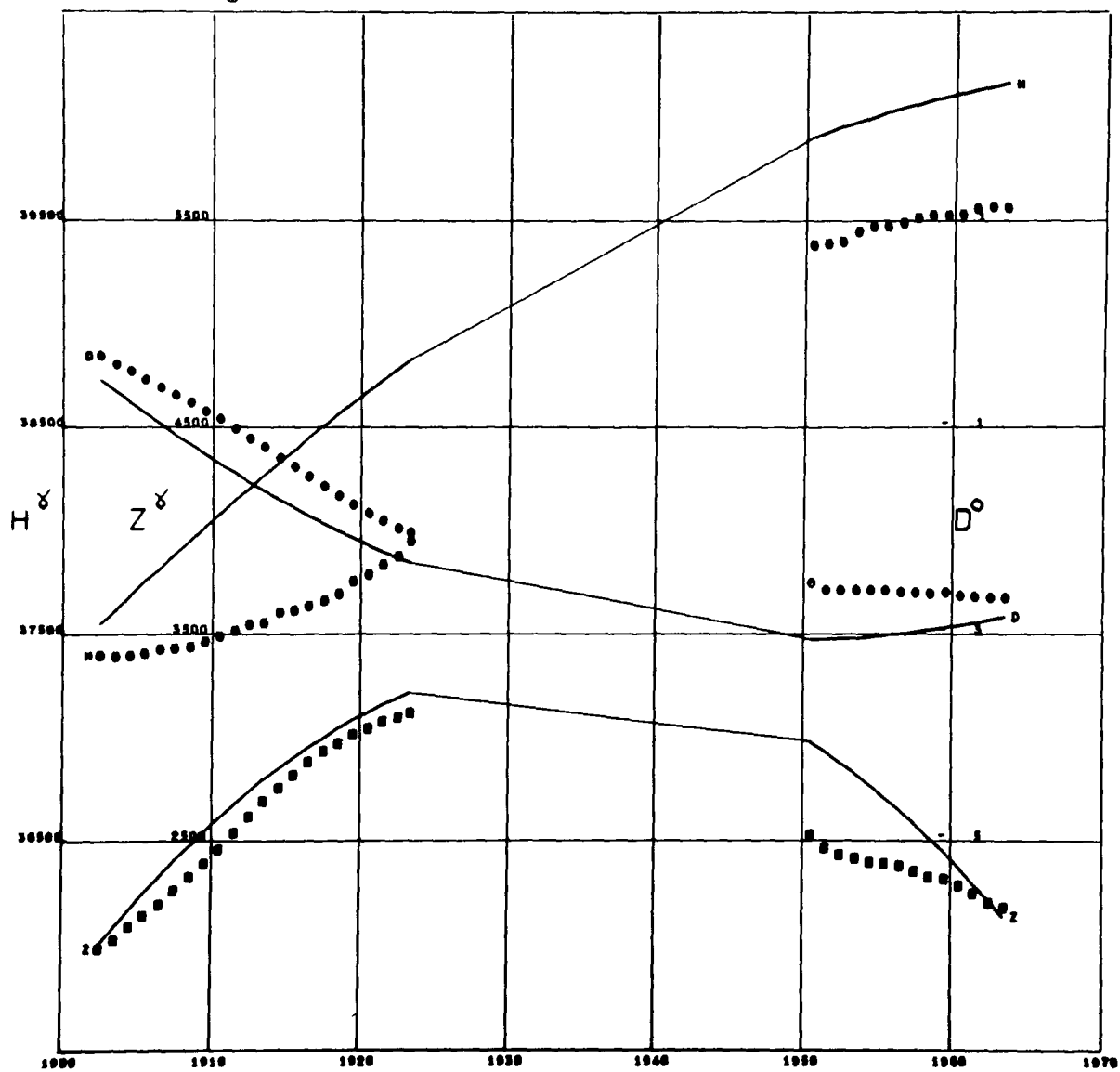


Figure A90

KRASNAYA PAKHRA  
Lat 55.47 Long 37.31

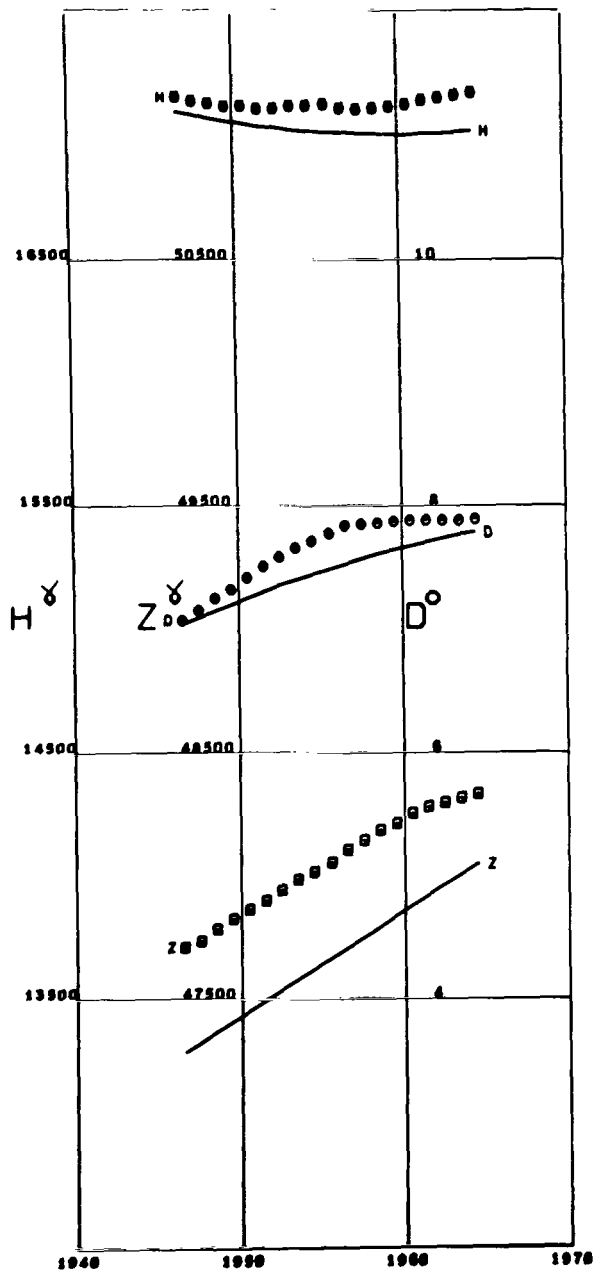


Figure A91

KREMSMUNSTER  
Lat 48.05 Long 14.13

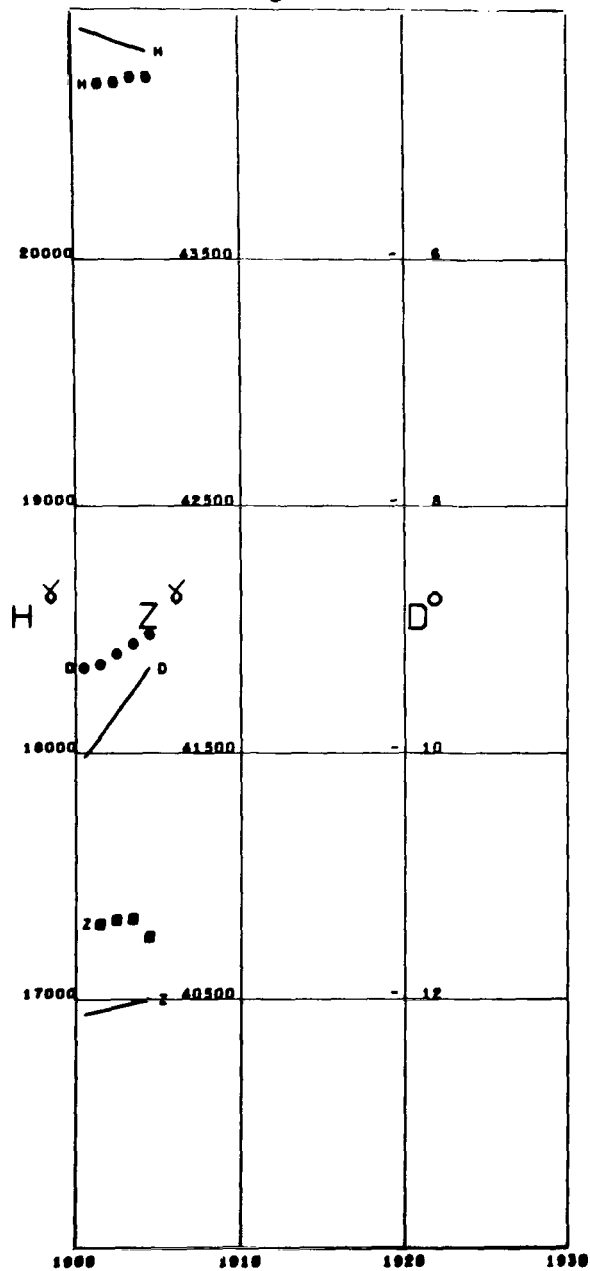


Figure A92

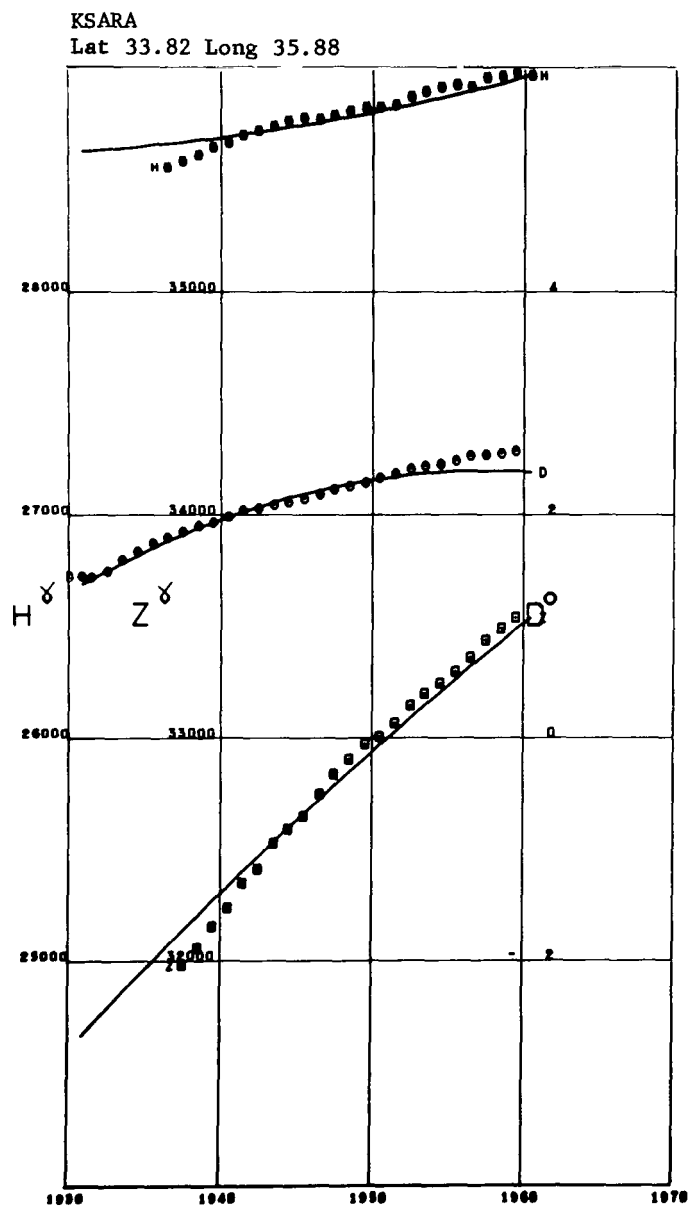


Figure A93

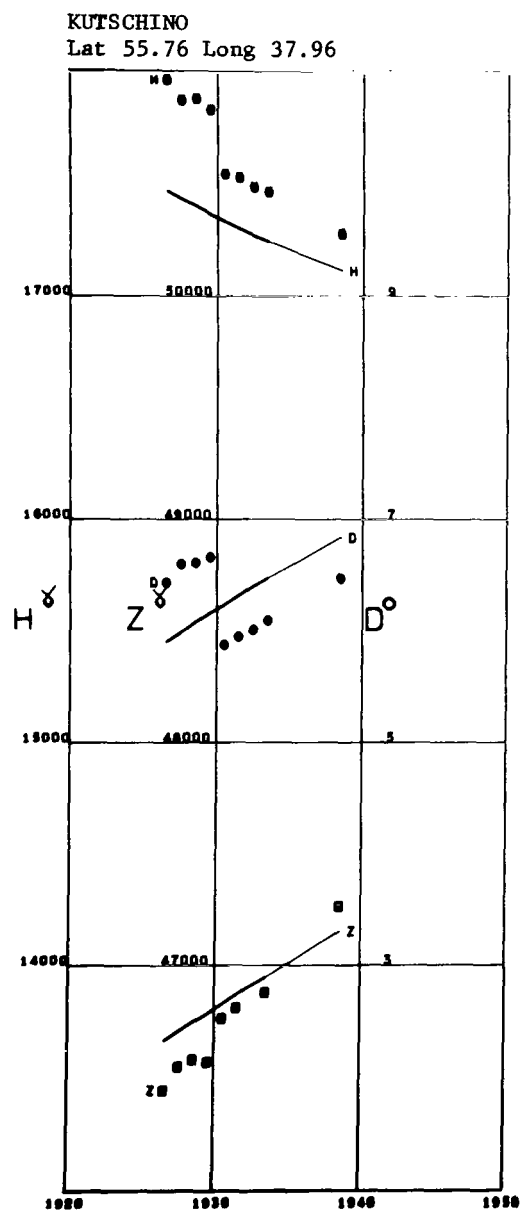


Figure A94

KUYPER  
 Lat -6.03 Long 106.73

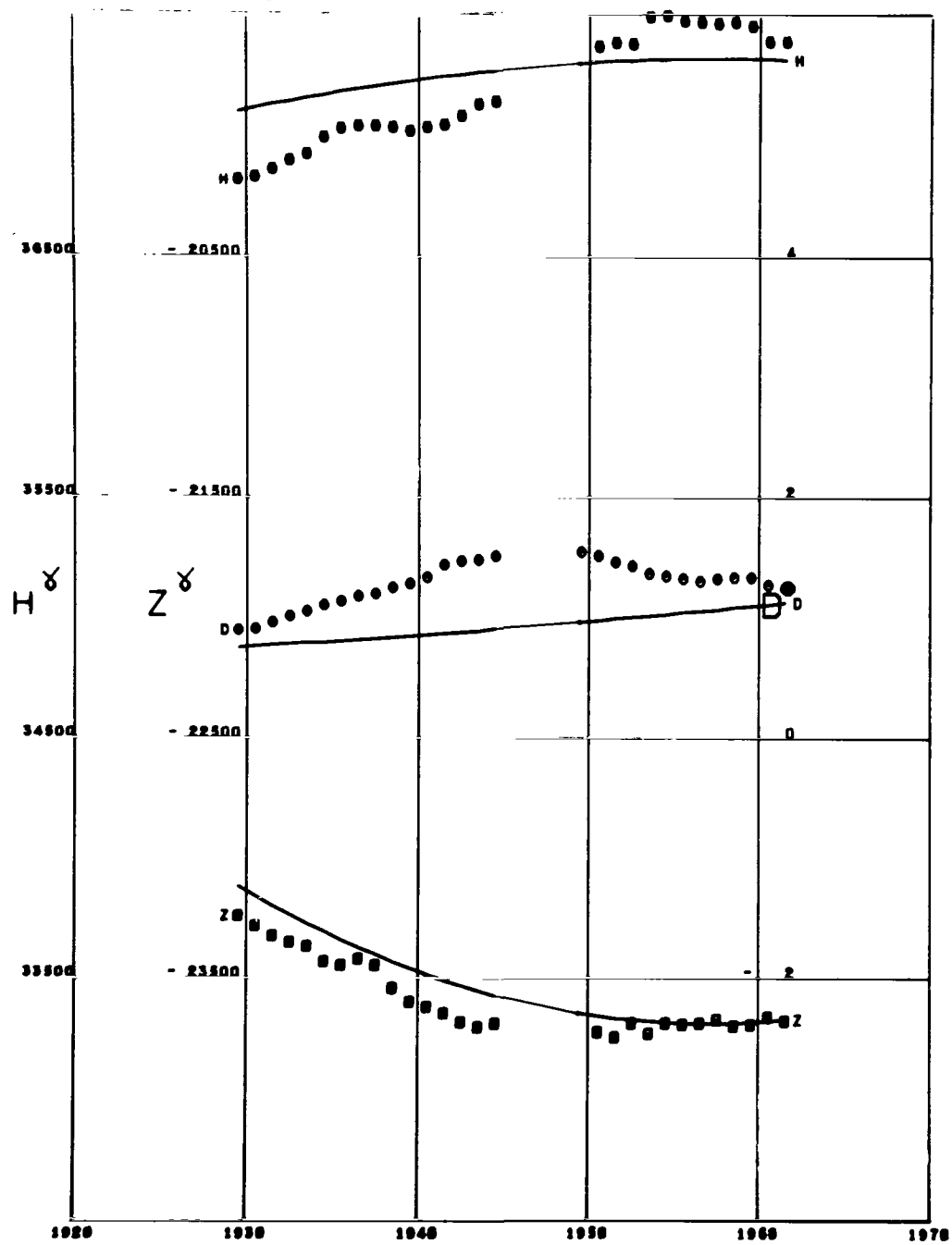


Figure A95

LEIRVOGUR  
 Lat 64.18 Long -21.70 Alt 0.01

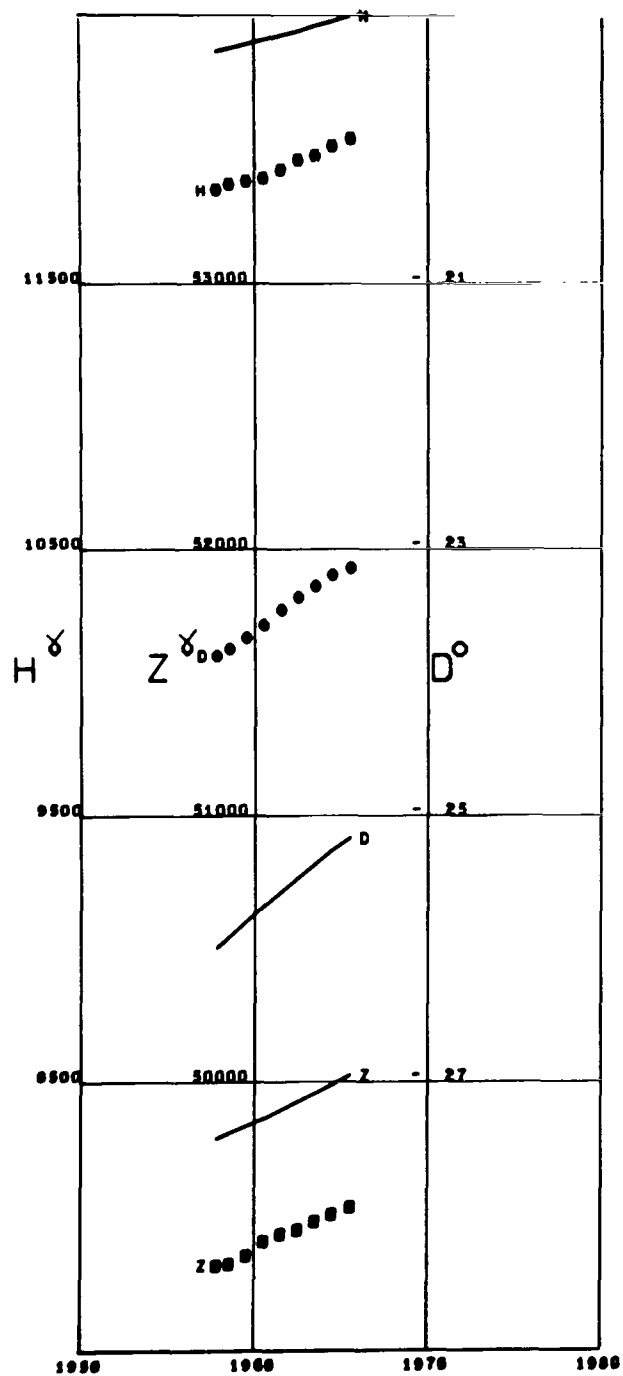


Figure A96



LERWICK  
 Lat 60.13 Long -1.18

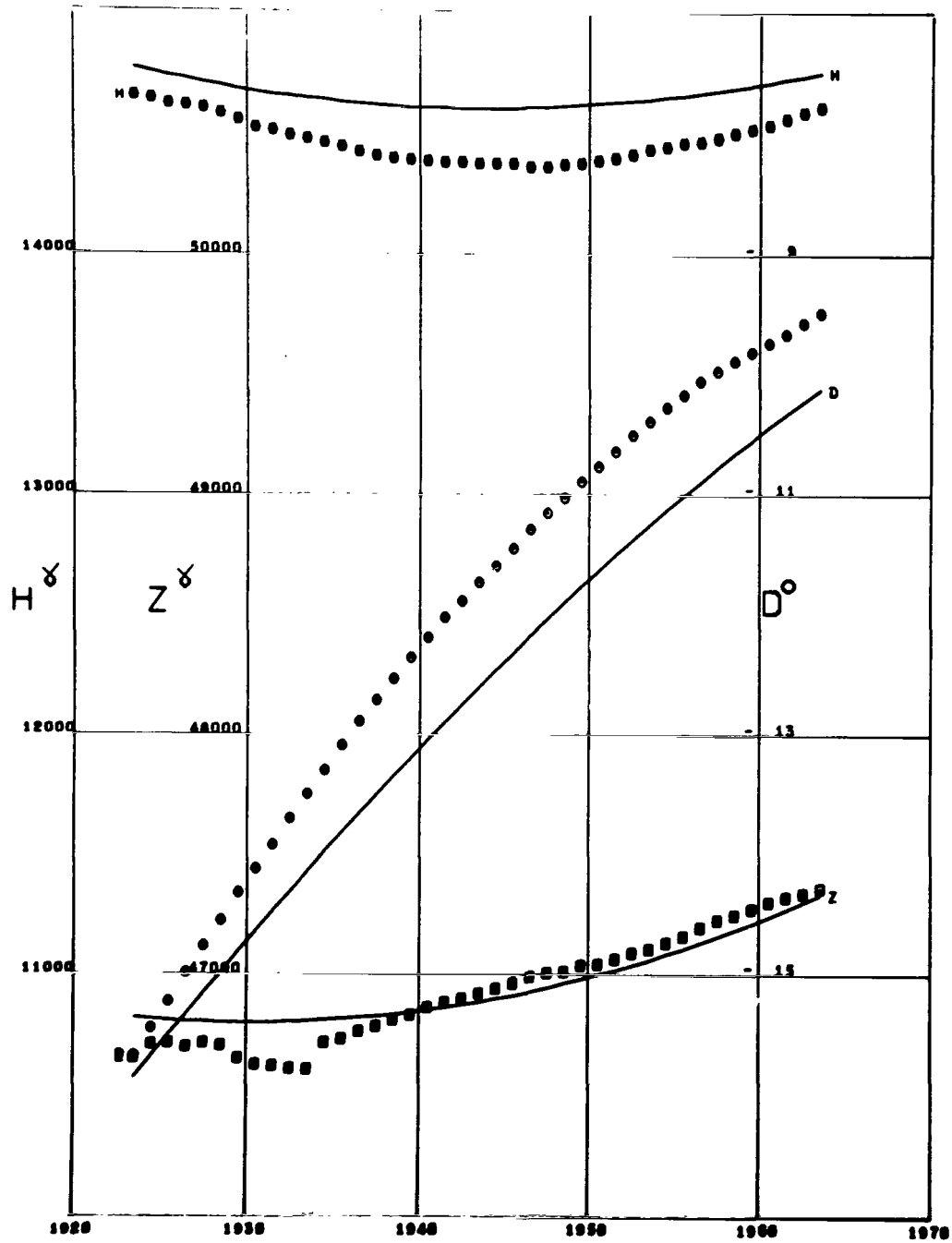


Figure A97

LOGRONO  
Lat 42.45 Long -2.50

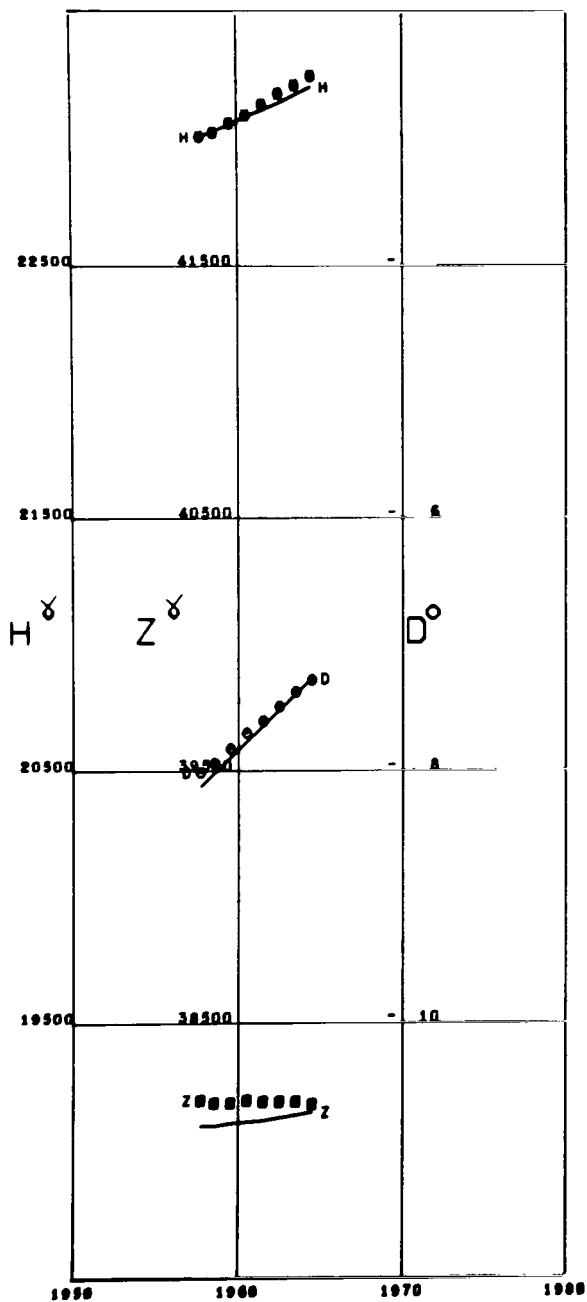


Figure A98

LOURENCO MARQUES  
Lat -25.91 Long 32.58

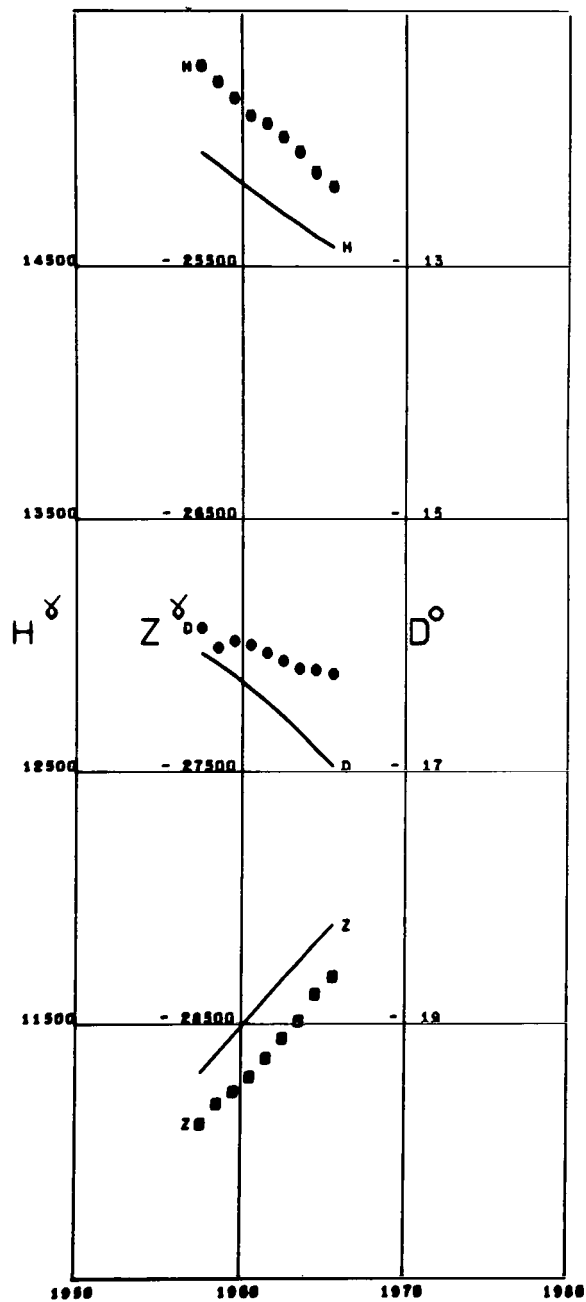


Figure A99

LOVO  
 Lat 59.34 Long 17.82 Alt 0.02

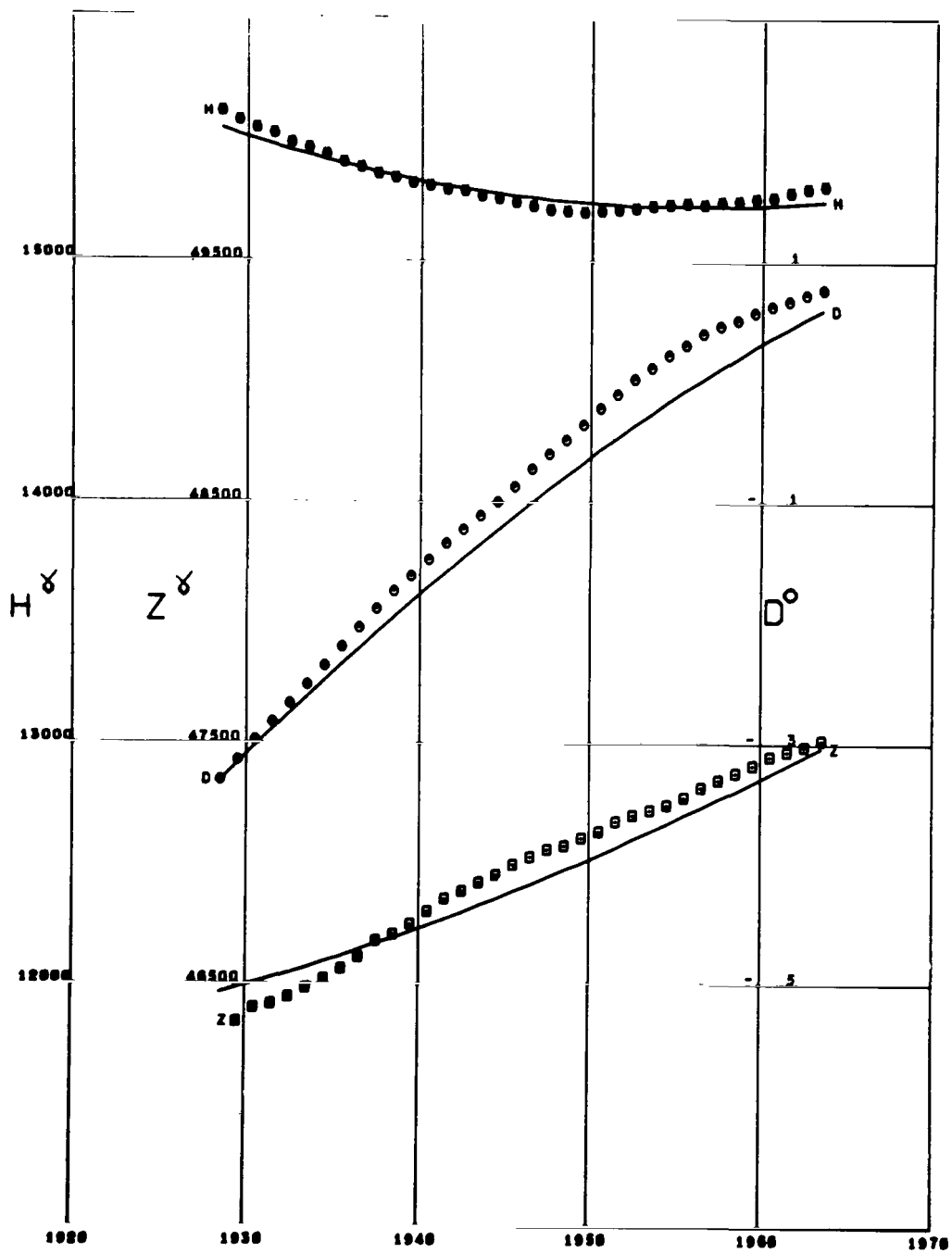


Figure A100

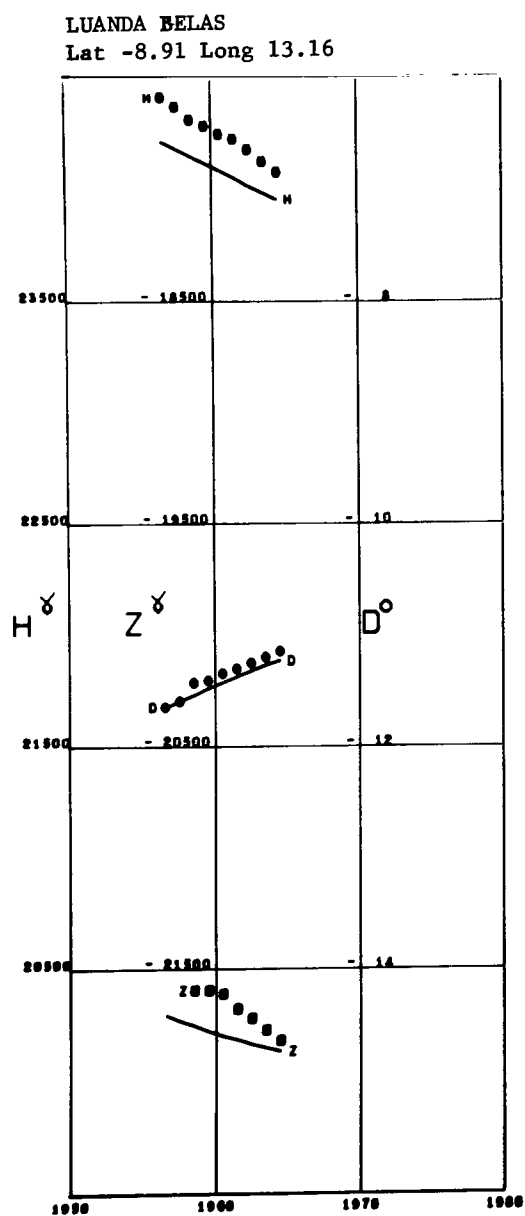


Figure A101

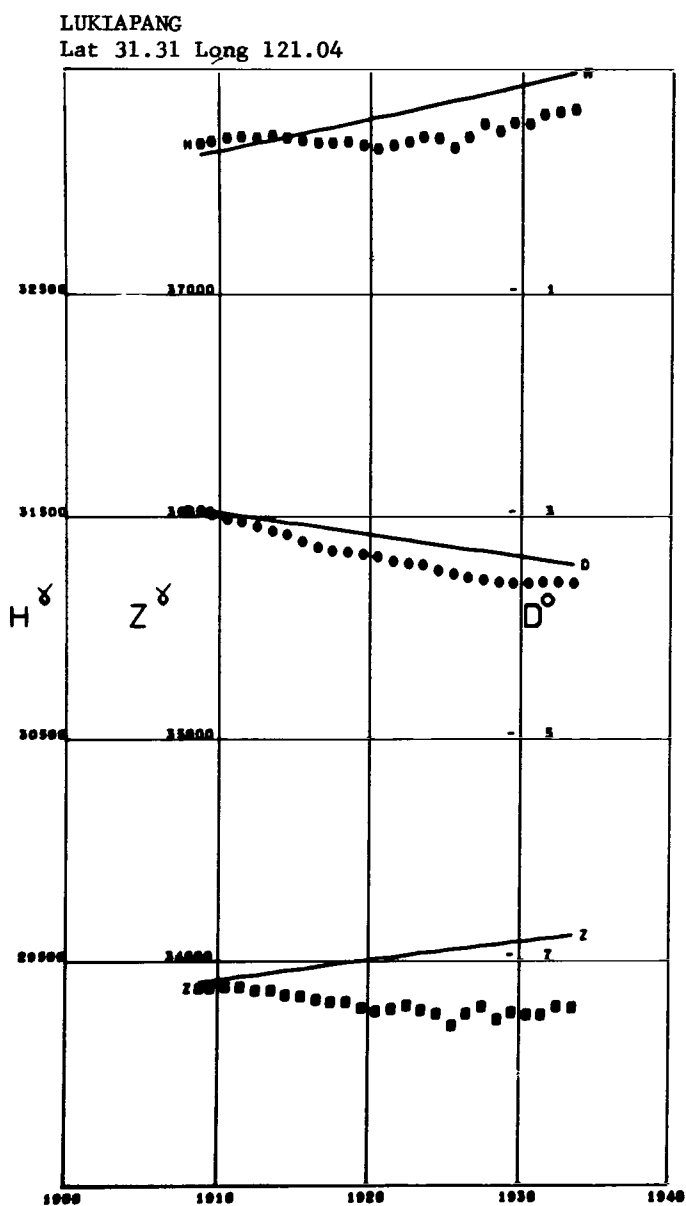


Figure A102

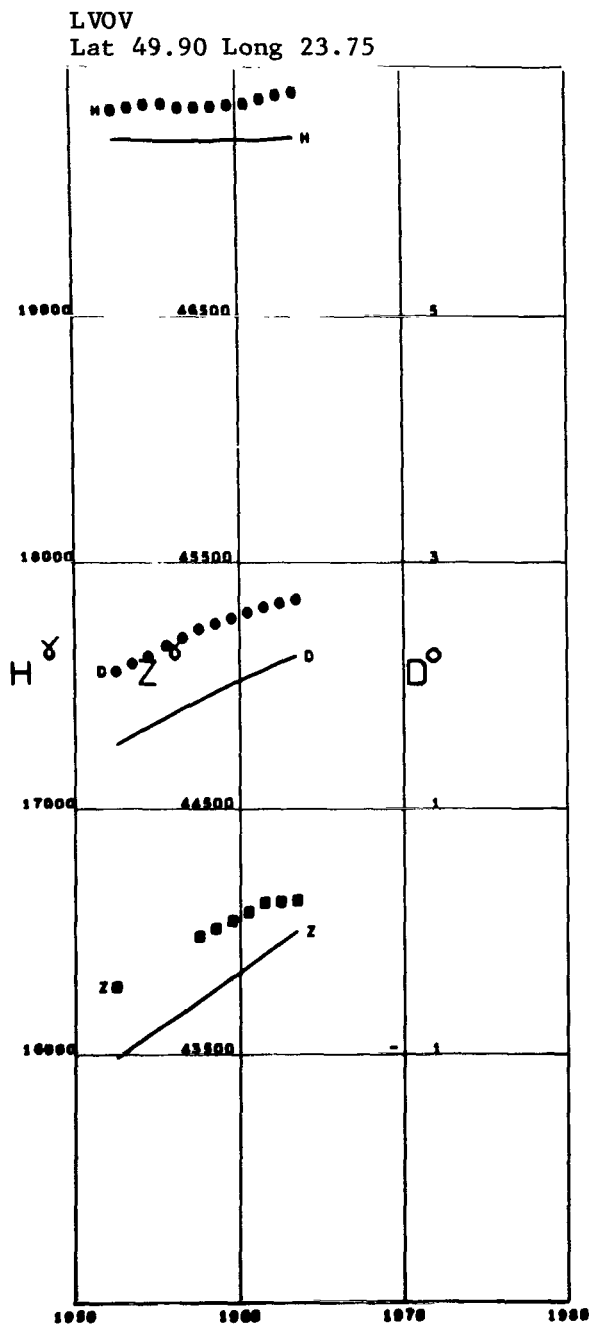


Figure A103

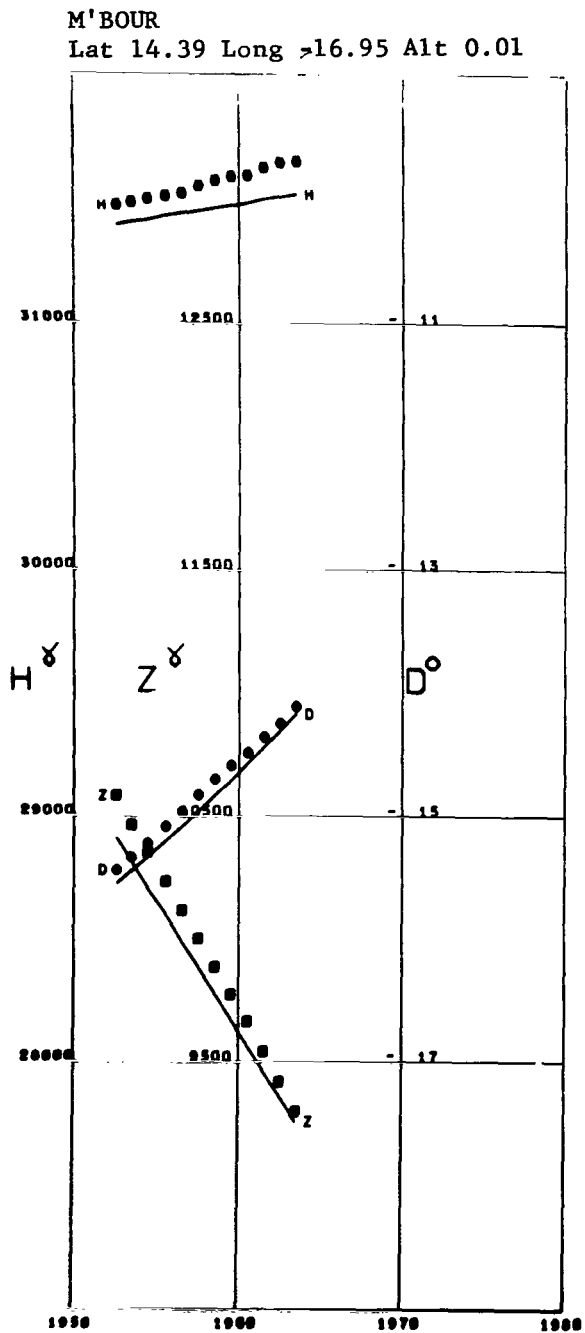


Figure A104

MACQUARIE ISLAND  
 Lat -54.50 Long 158.95 Alt 0.01

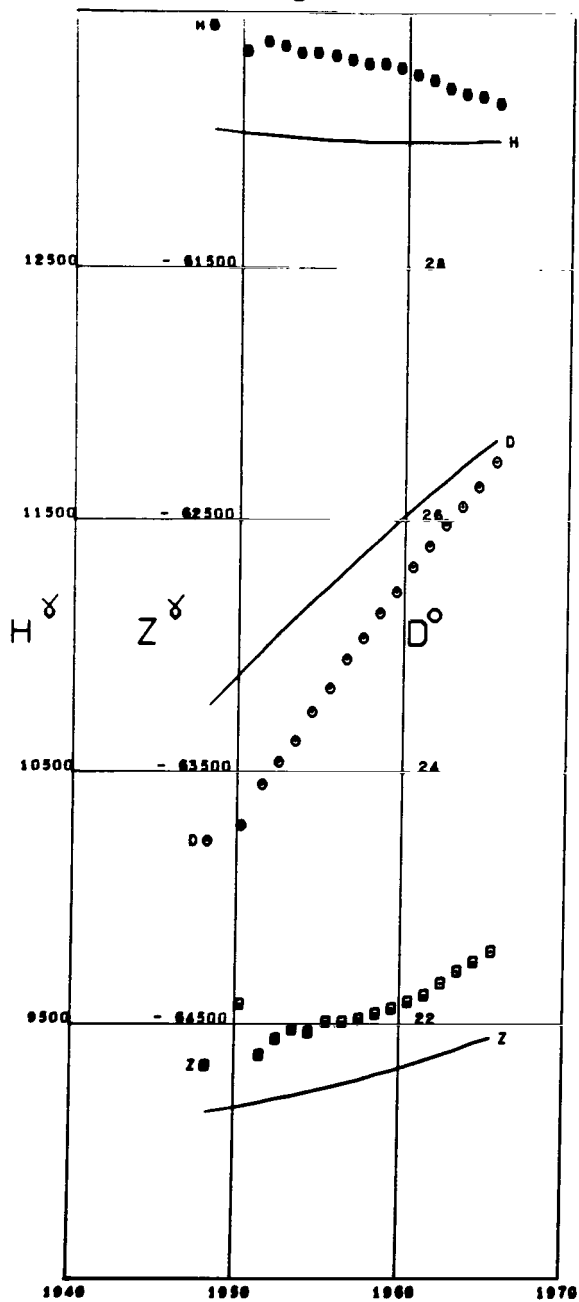


Figure A105

MAHNAY  
 Lat 50.29 Long 5.68

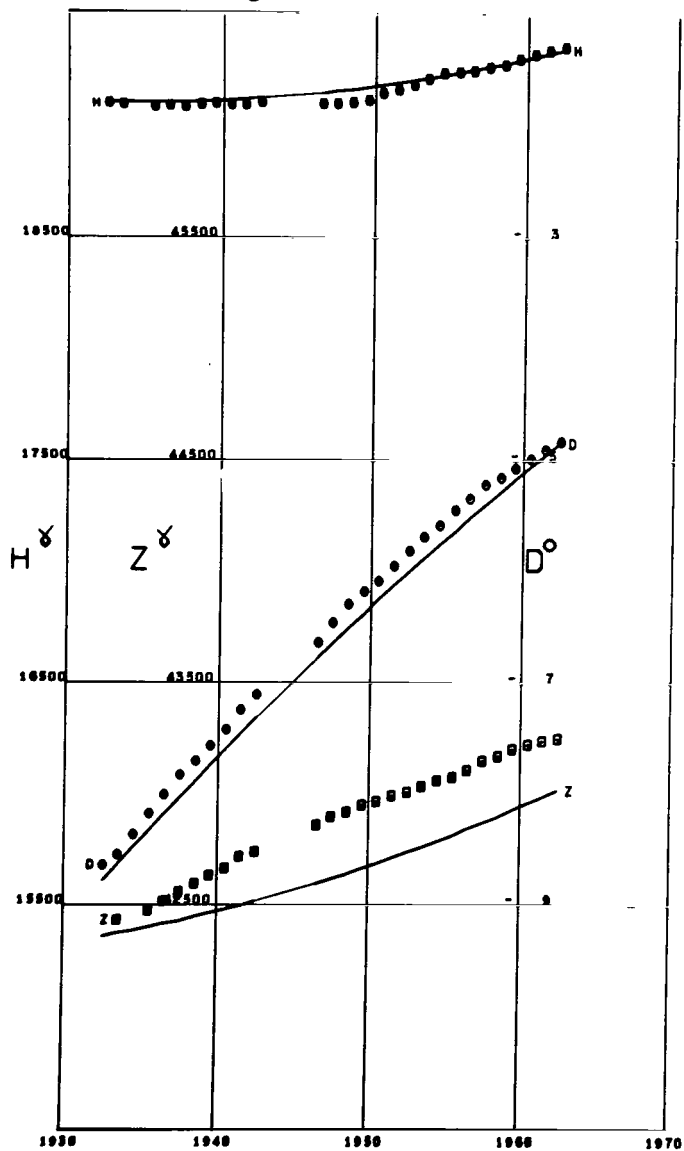


Figure A106

MAISACH

Lat 48.20 Long 11.26 Alt 0.57

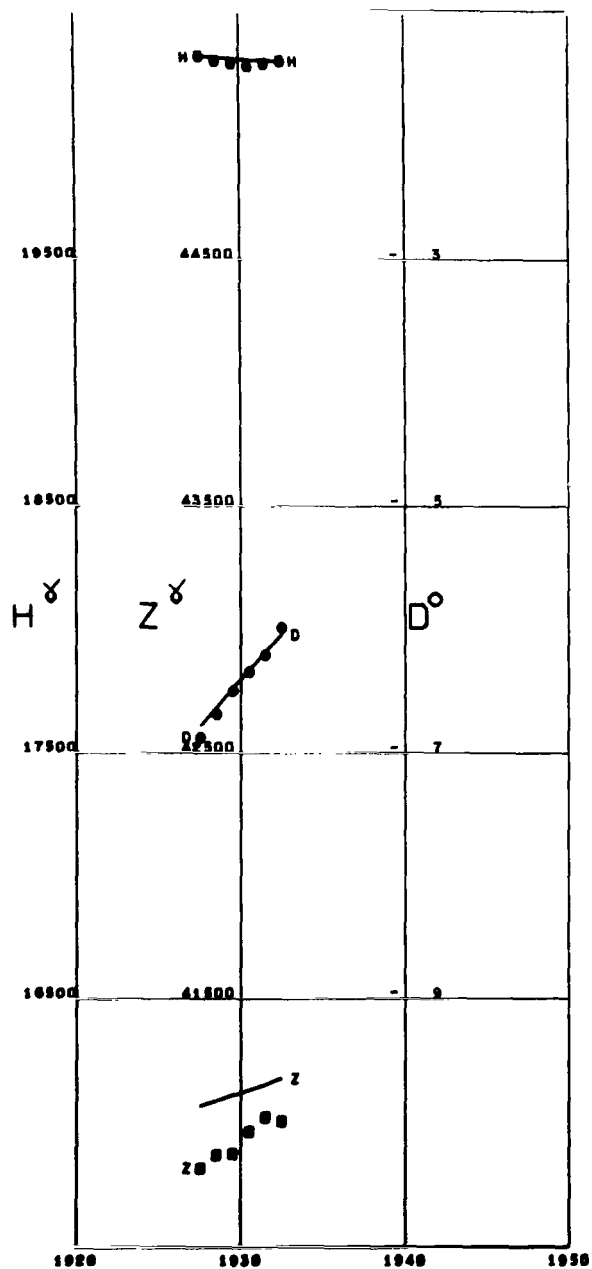


Figure A107

MAITUN

Lat 43.25 Long 132.33

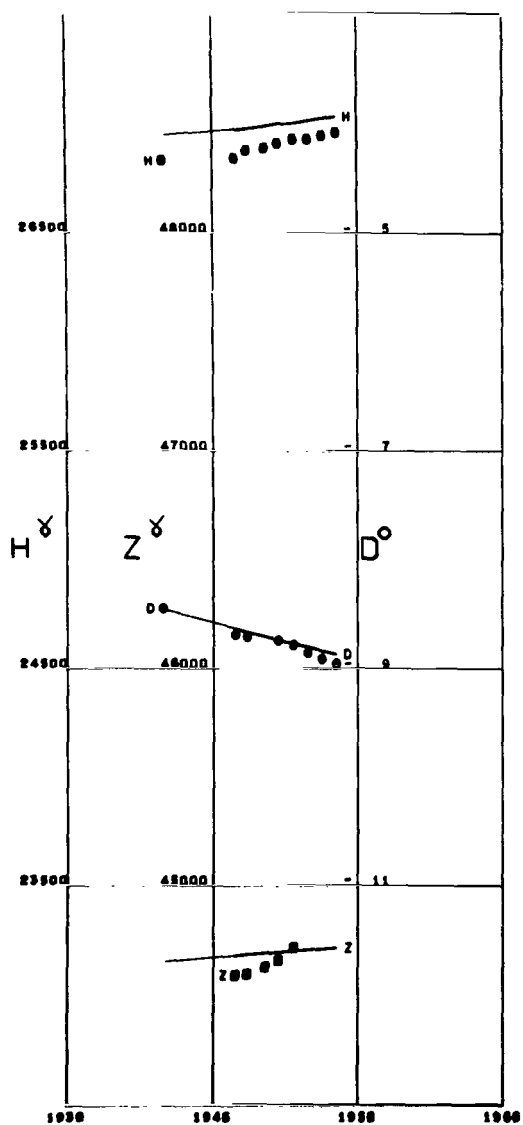


Figure A108

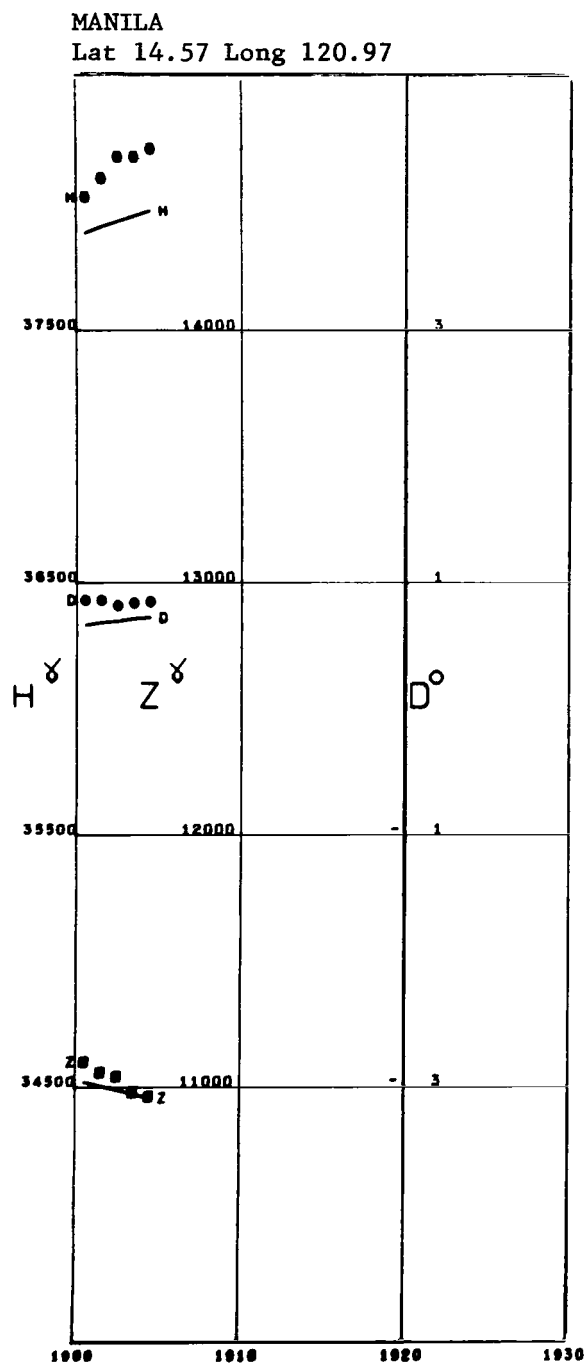


Figure A109

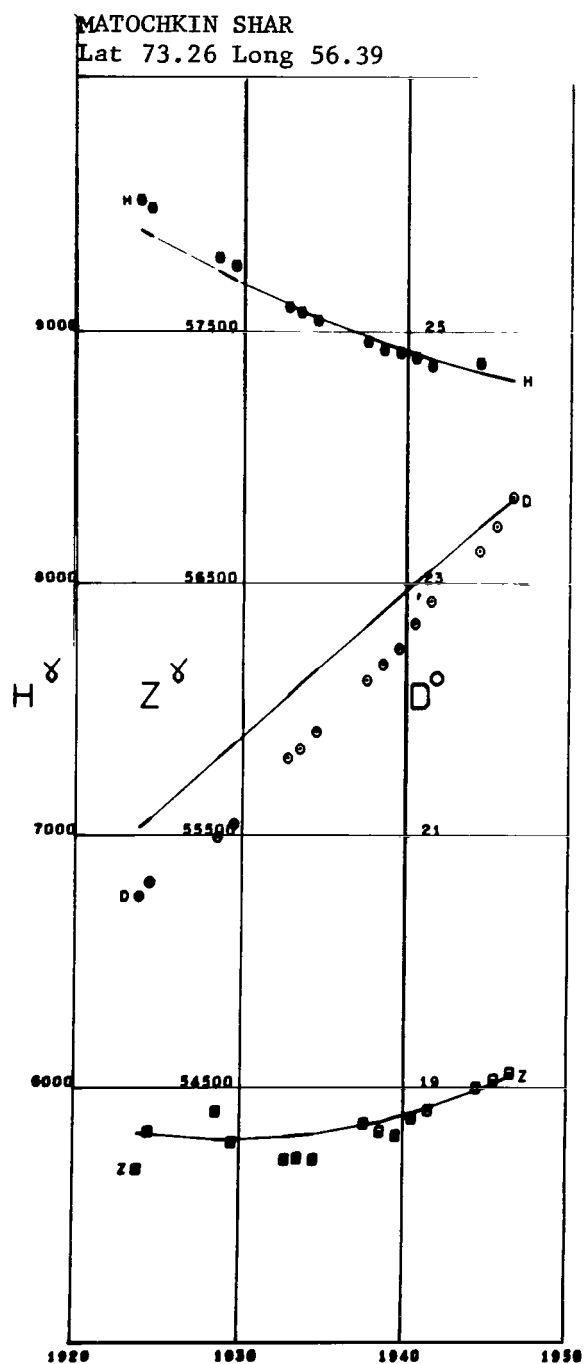


Figure A110



MAURITIUS  
 Lat -20.09 Long 57.55

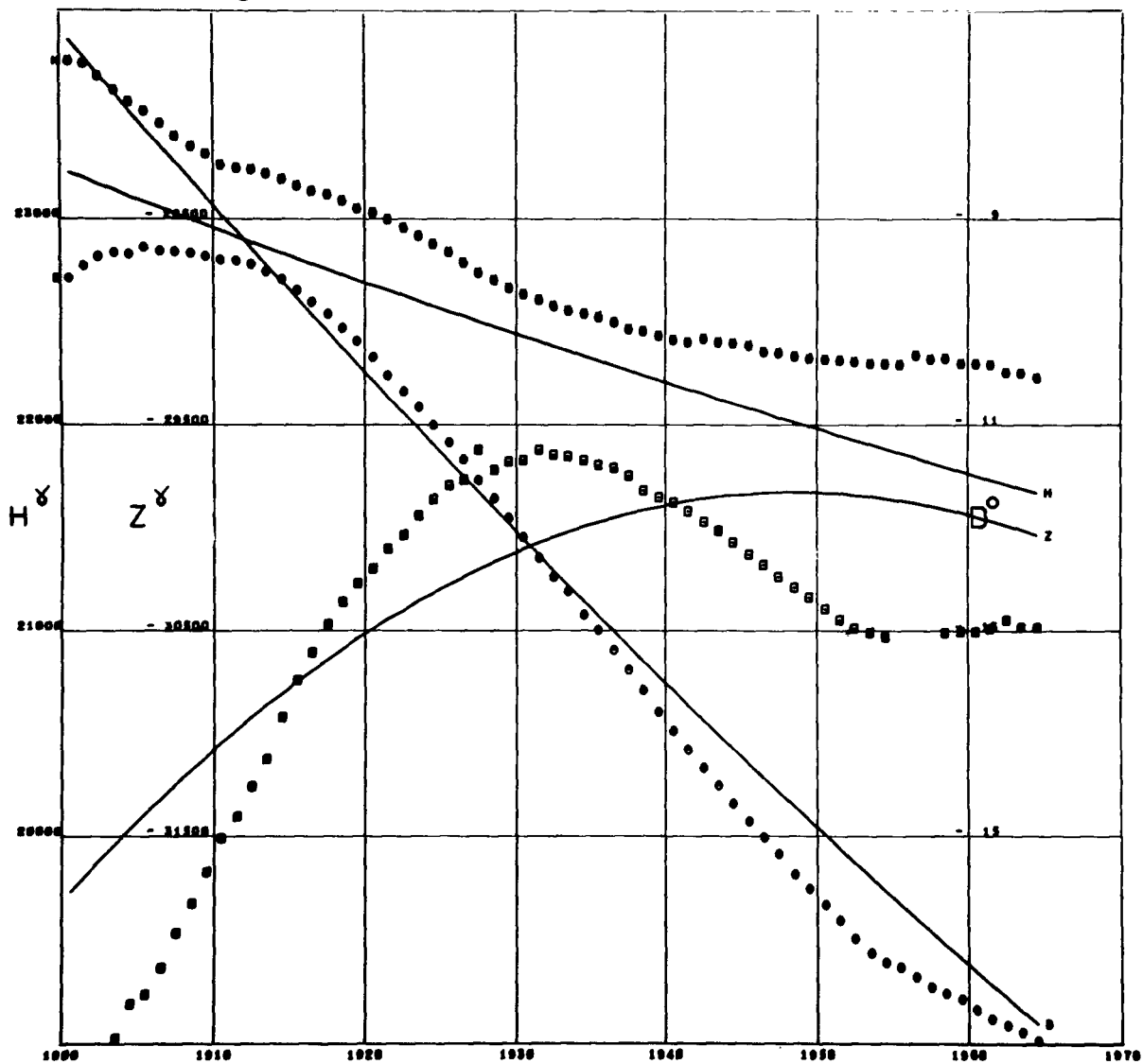


Figure A111

MAWSON  
 Lat -67.60 Long 62.88

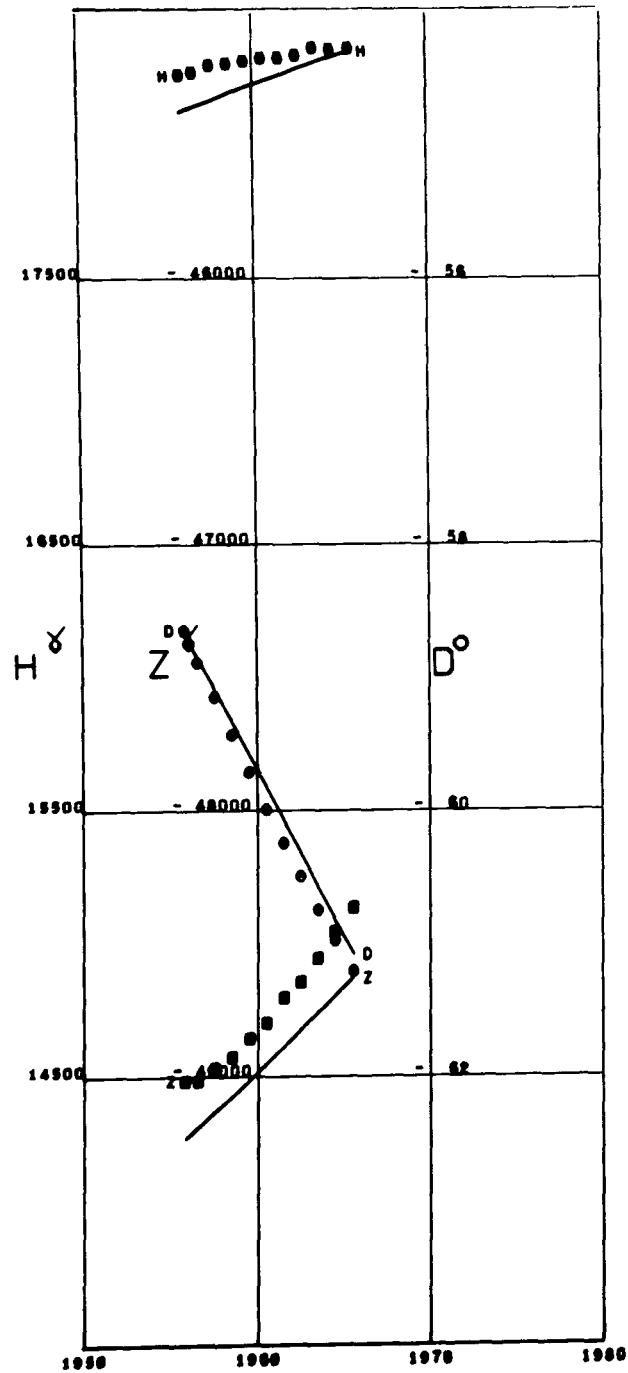


Figure A112

MEANOOK

Lat 54.61 Long -113.33 Alt 0.68

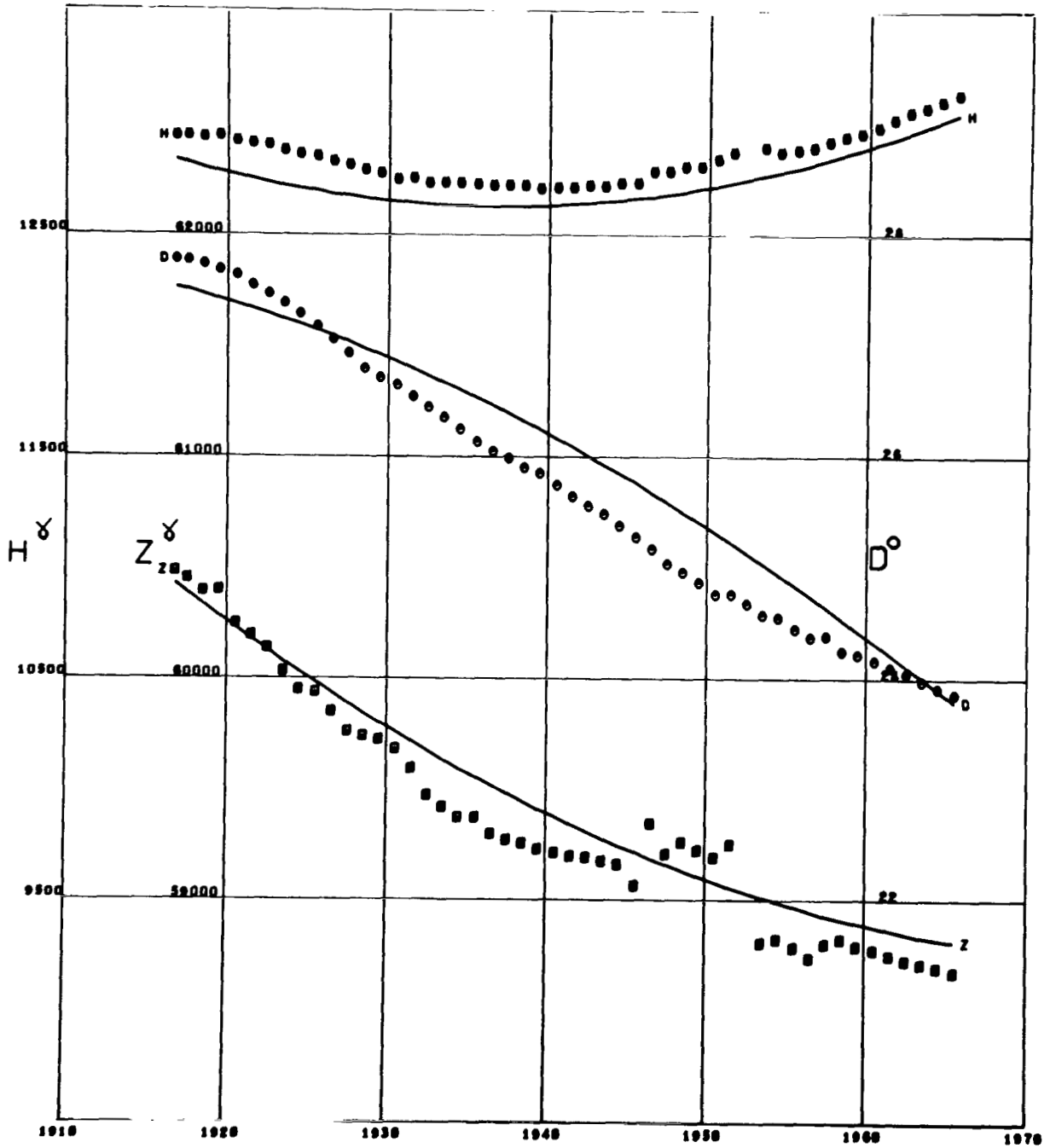


Figure A113

MELBOURNE  
 Lat -37.83 Long 144.97

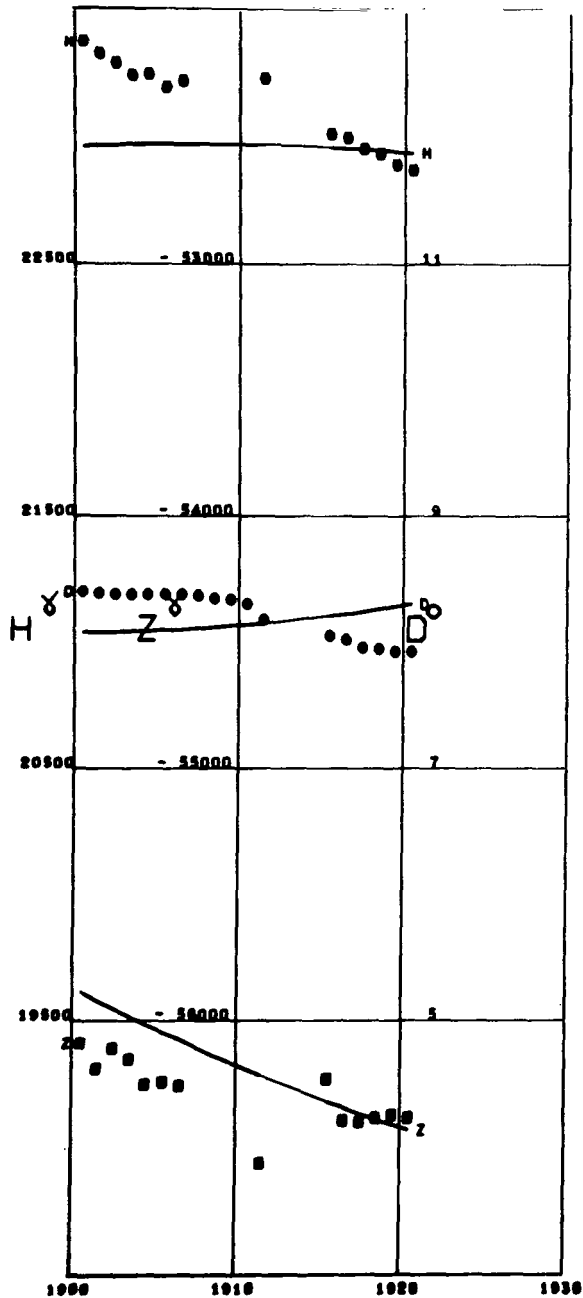


Figure A114

MEMAMBETSU  
 Lat 43.90 Long 144.19 Alt 0.04

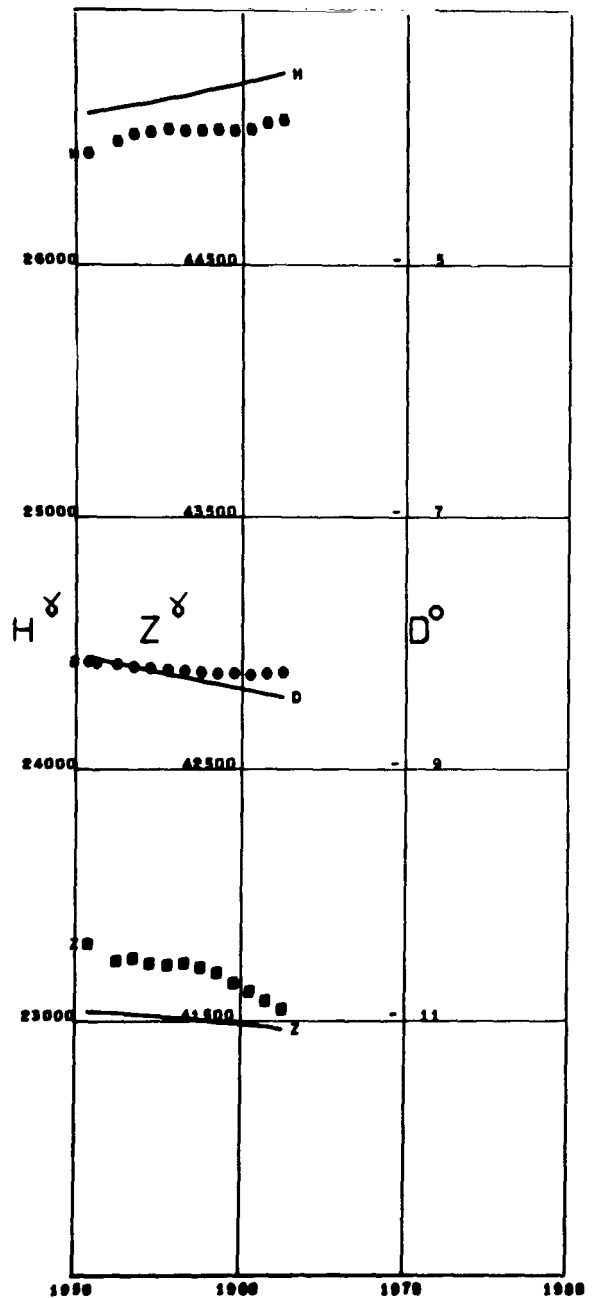


Figure A115

MIRNY  
 Lat -66.55 Long 93.01

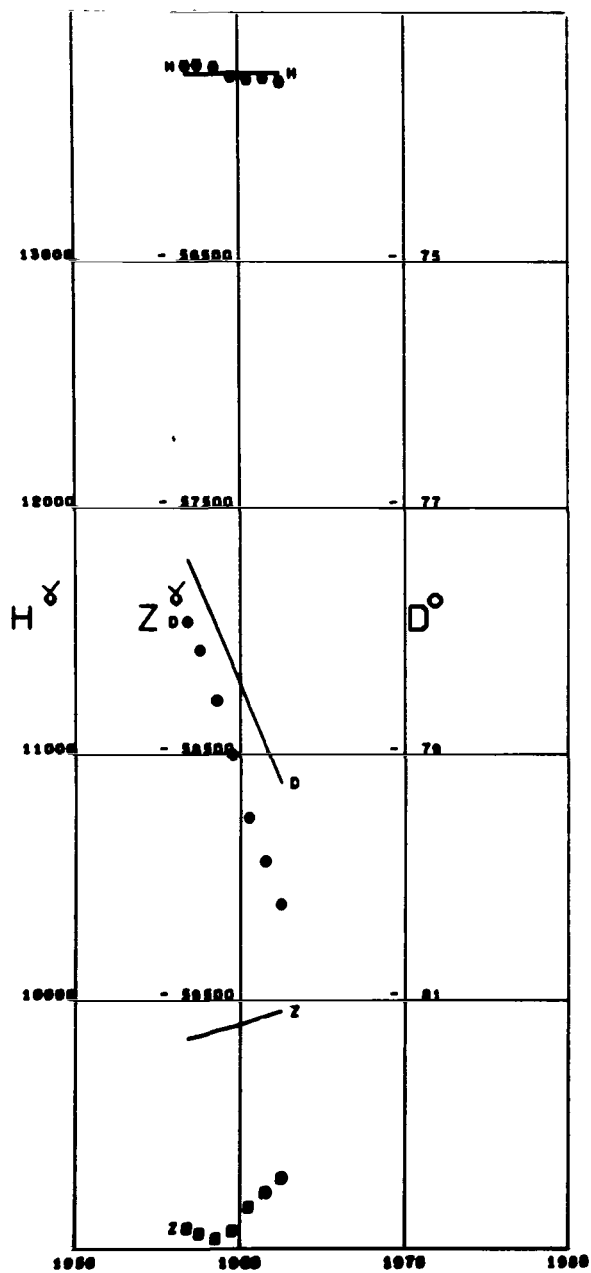


Figure A116

MISALLAT  
 Lat 29.51 Long 30.89 Alt 0.12

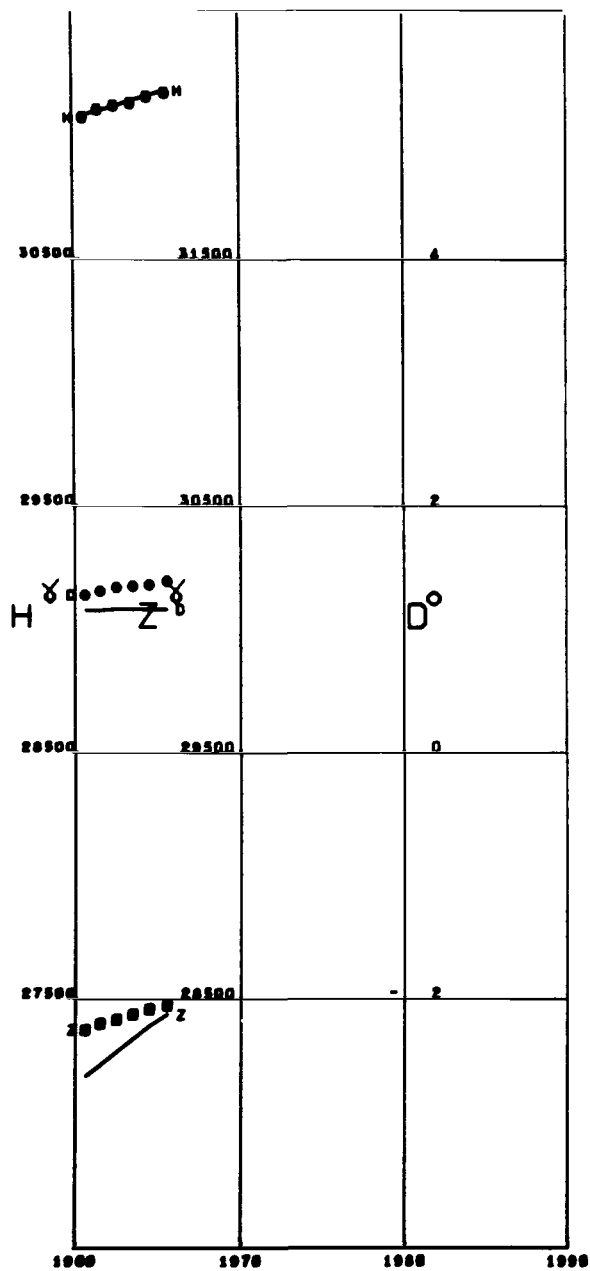


Figure A117

MOCA

Lat 3.34 Long 8.66 Alt 1.35

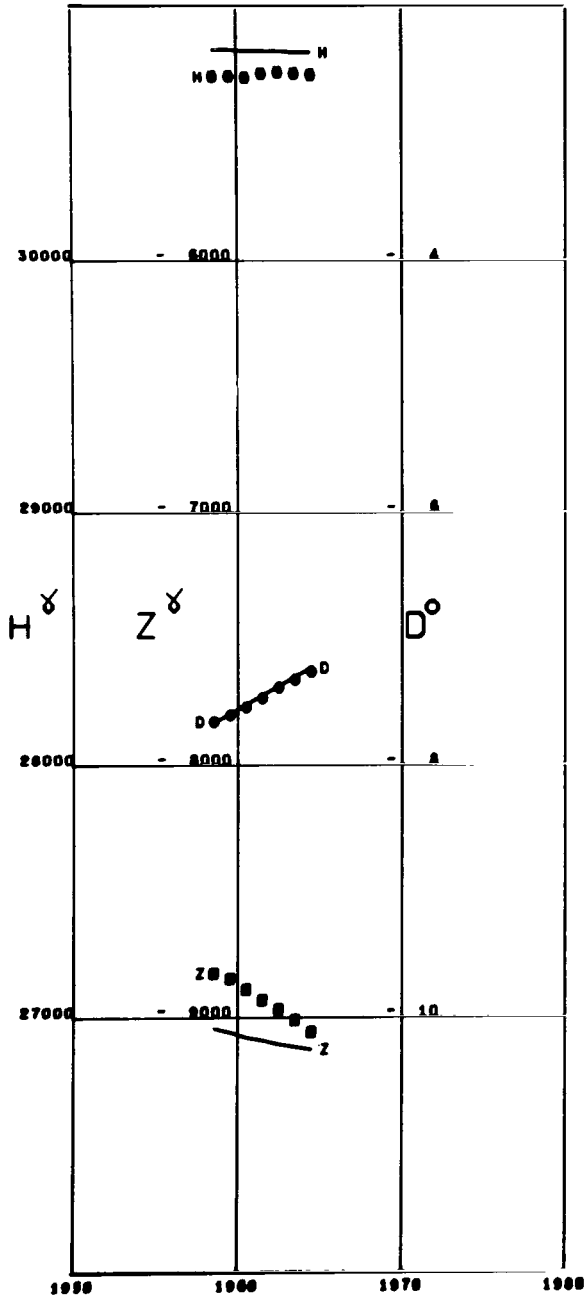


Figure A118

MONTE CAPPELLINO

Lat 44.55 Long 8.95

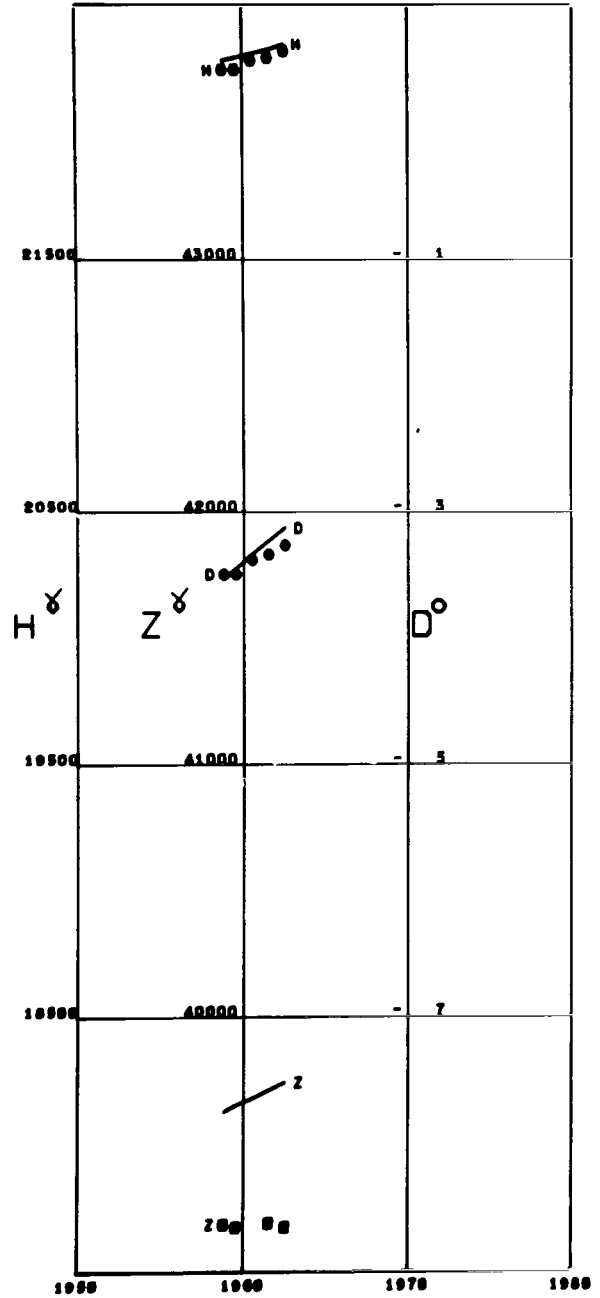


Figure A119

MUNICH  
Lat 48.14 Long 11.60

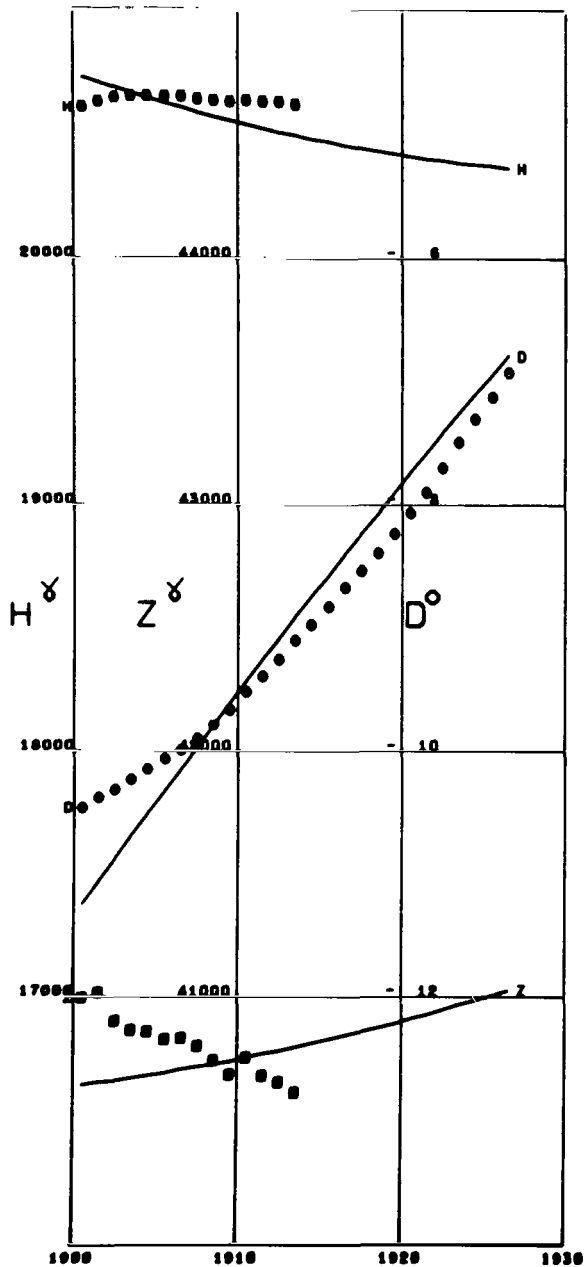


Figure A120

MUNTINLUPA  
Lat 14.37 Long 121.01 Alt 0.06

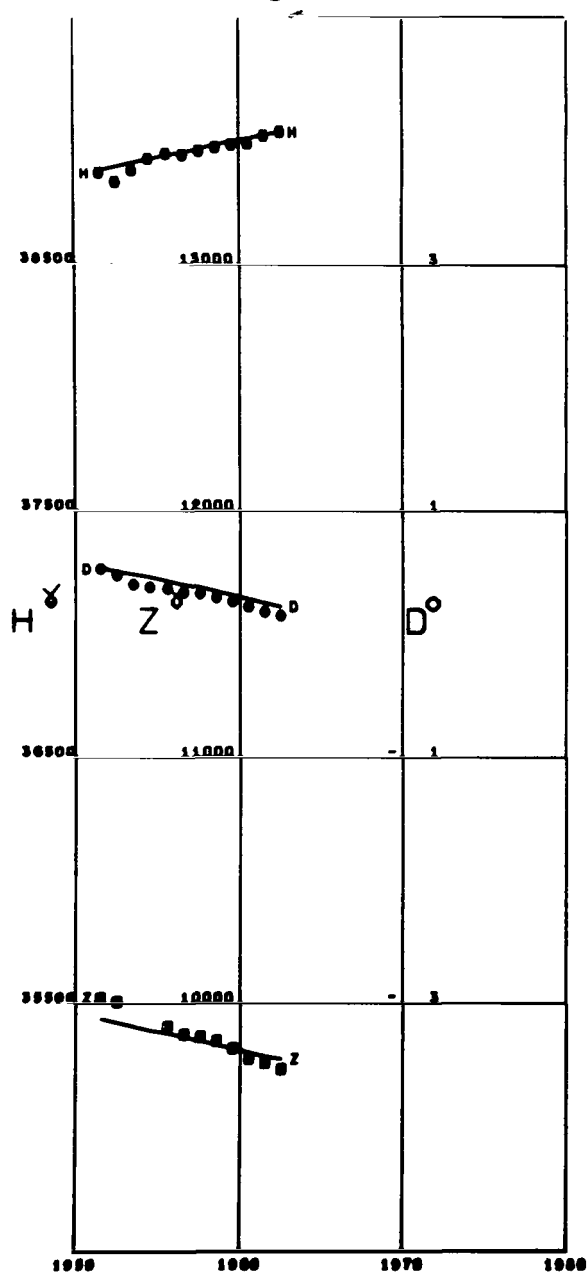


Figure A121

# NANTES

Lat 47.24 Long -1.56

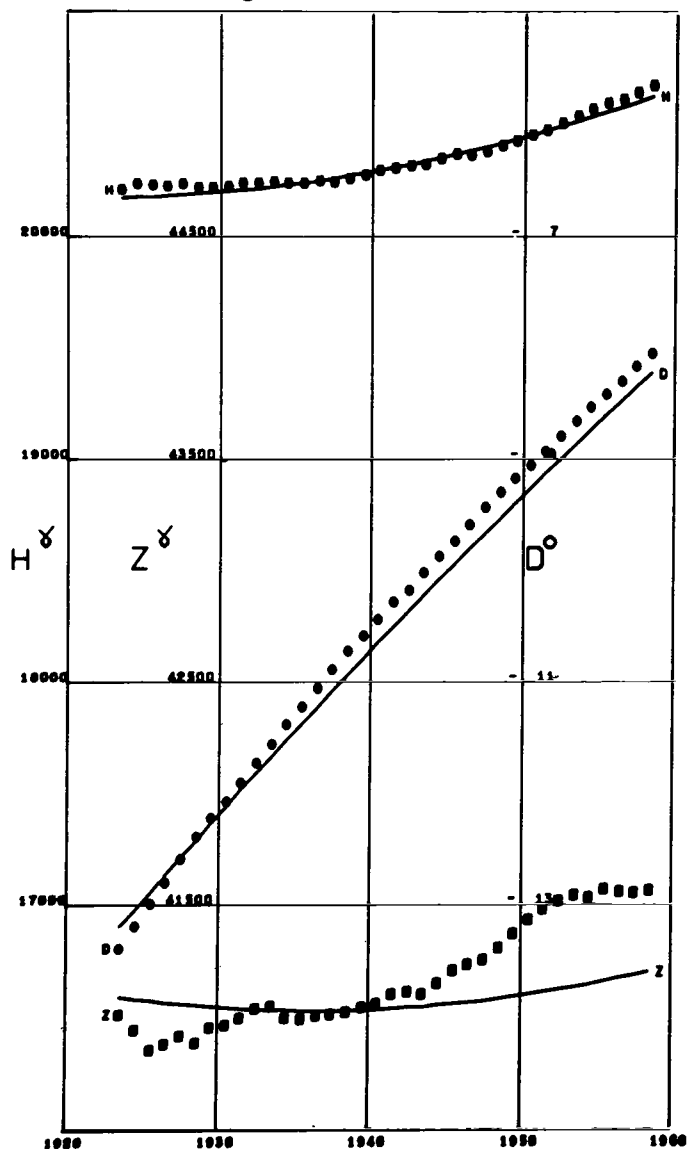


Figure A122

# NEW YEARS ISLAND

Lat -54.65 Long -64.15

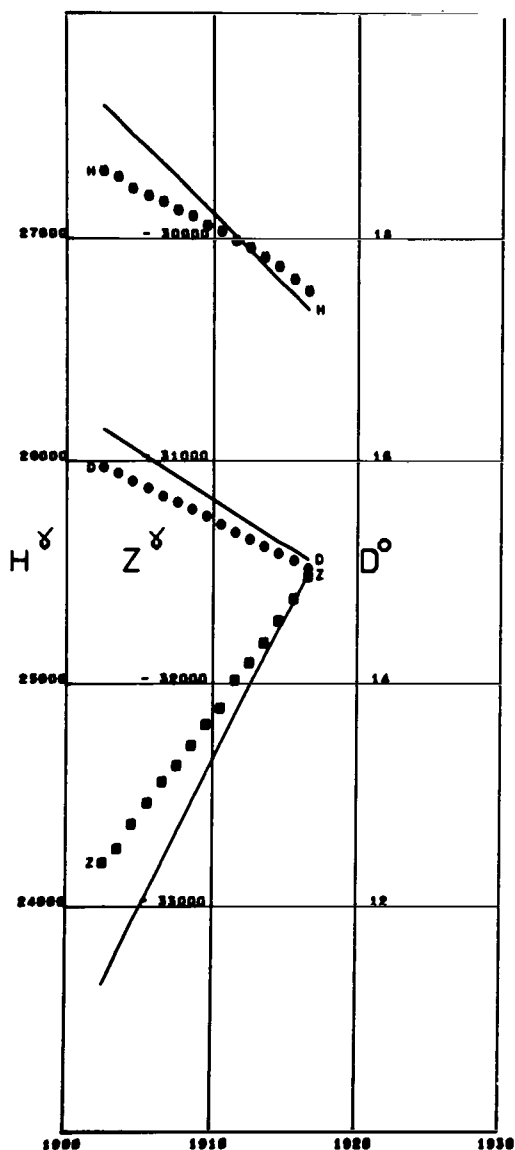


Figure A123



NIEMECK  
Lat 52.07 Long 12.67

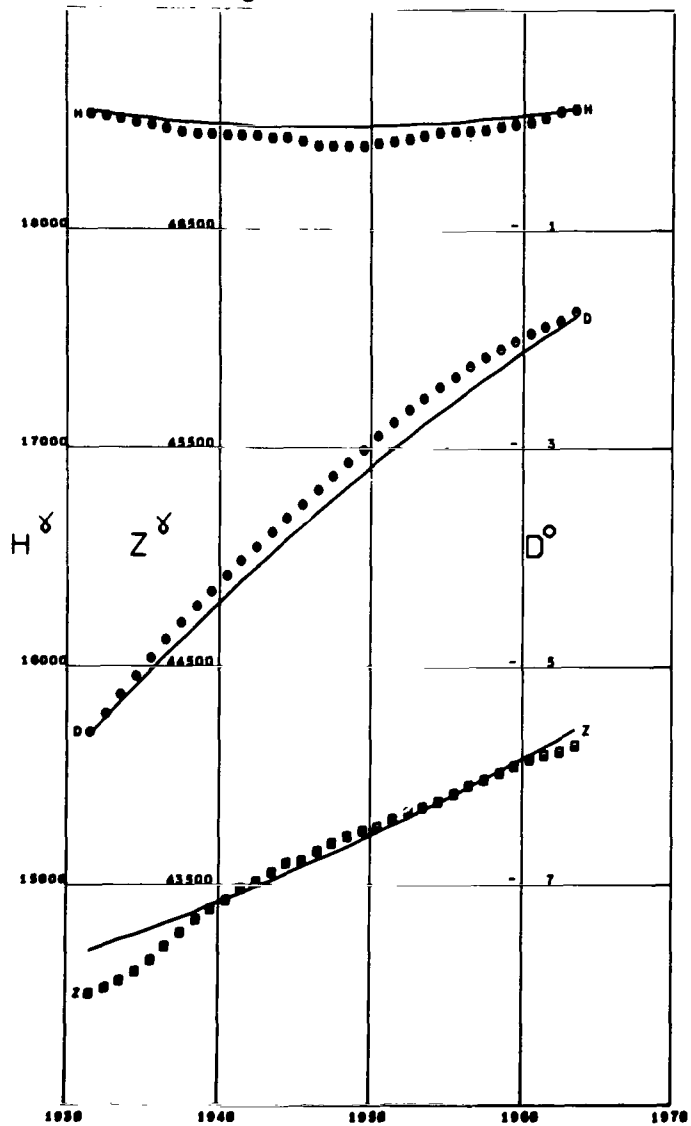


Figure A124

NIZHNEDEVISTSK  
Lat 51.51 Long 38.36

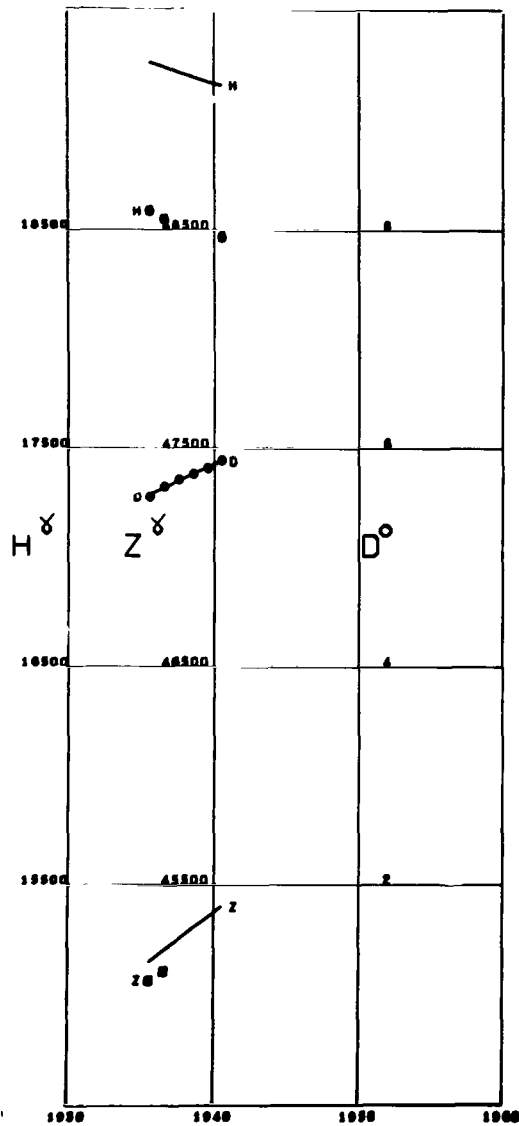


Figure A125

NURMIJARVI  
 Lat. 60.50 Long 24.65 Alt 0.11

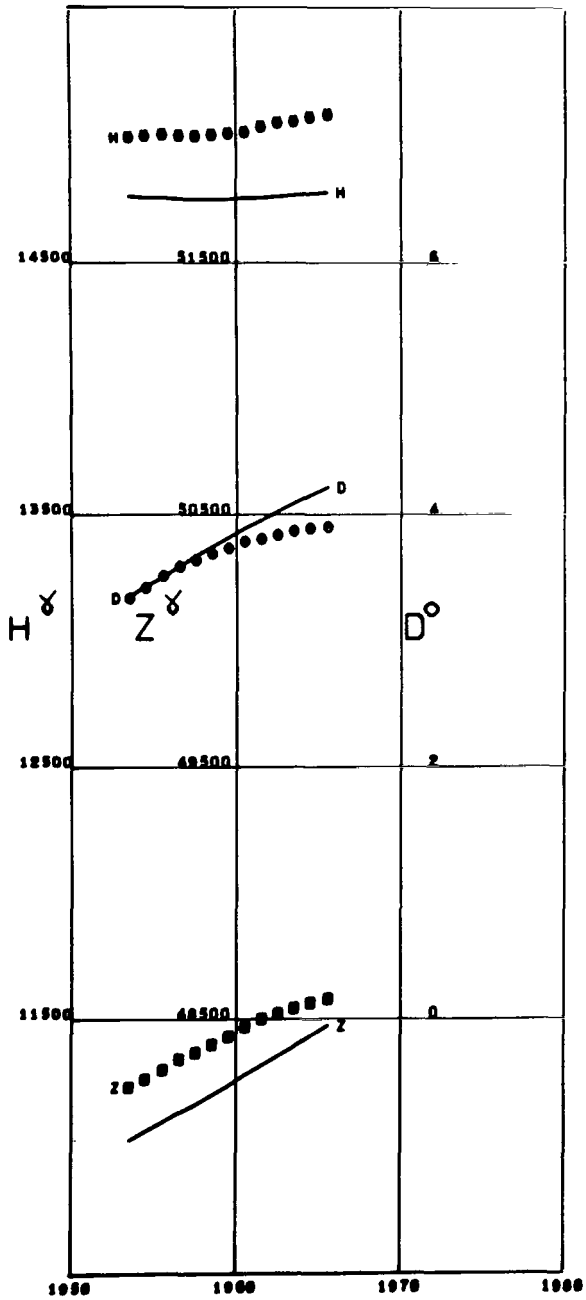


Figure A126

O GYALLA PESTH  
 Lat 47.87 Long 18.19

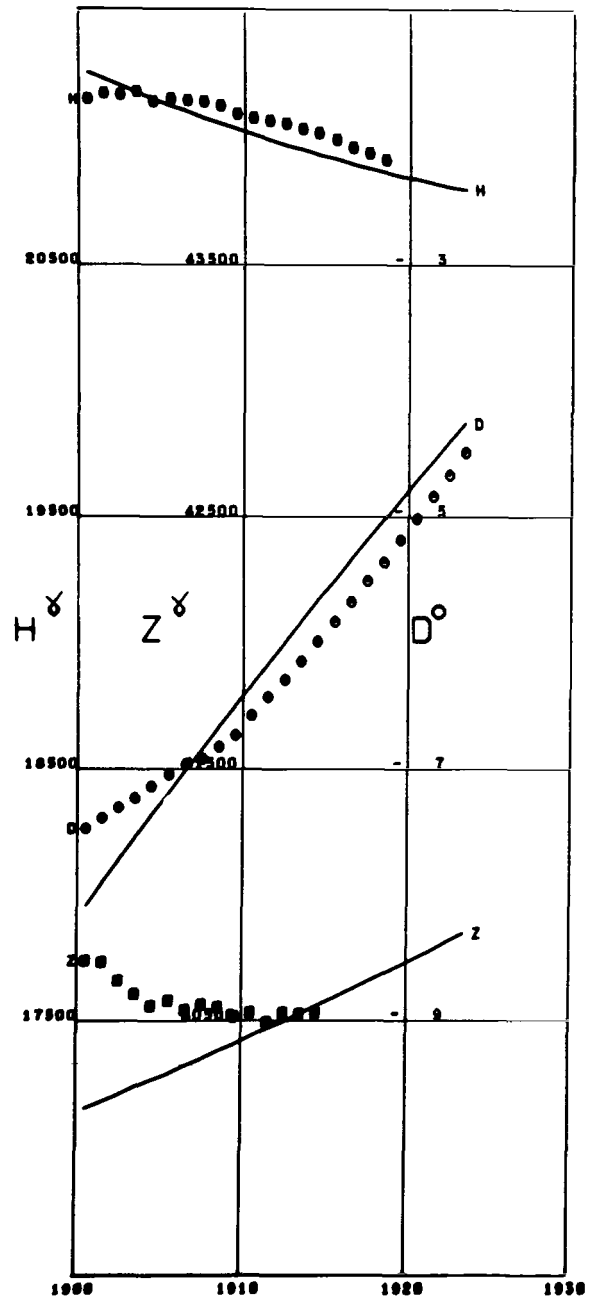


Figure A127

ODESSA  
Lat 46.66 Long 30.77

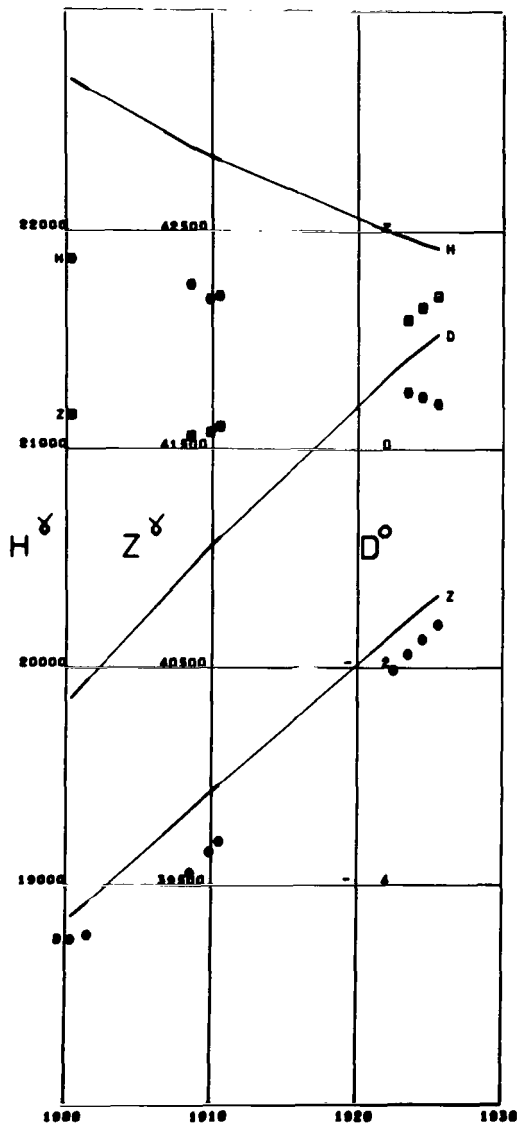


Figure A128

OSLO  
Lat 59.91 Long 10.72

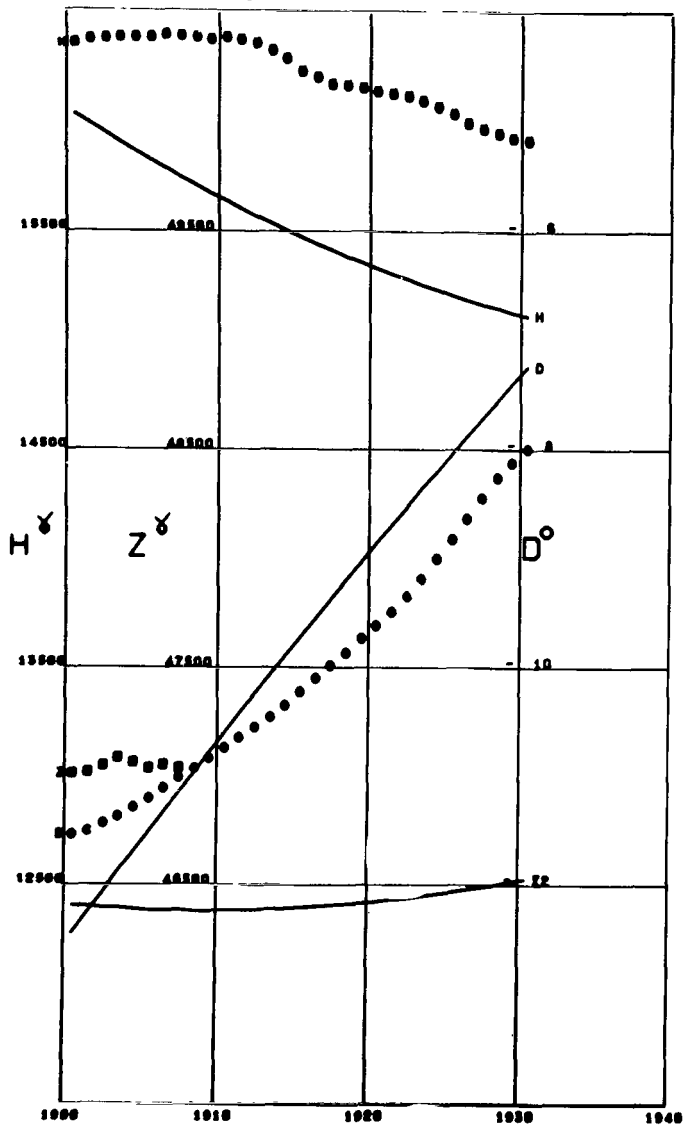


Figure A129

OTOMARI  
Lat 46.65 Long 142.76

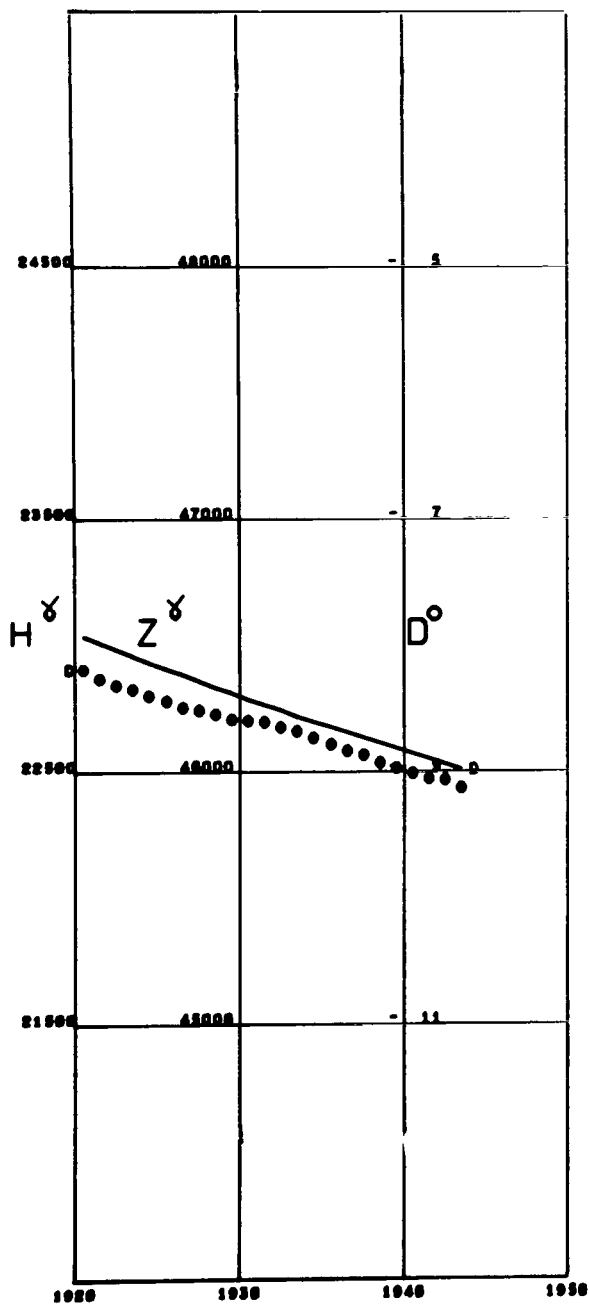


Figure A130

PALAU  
Lat 7.33 Long 134.48

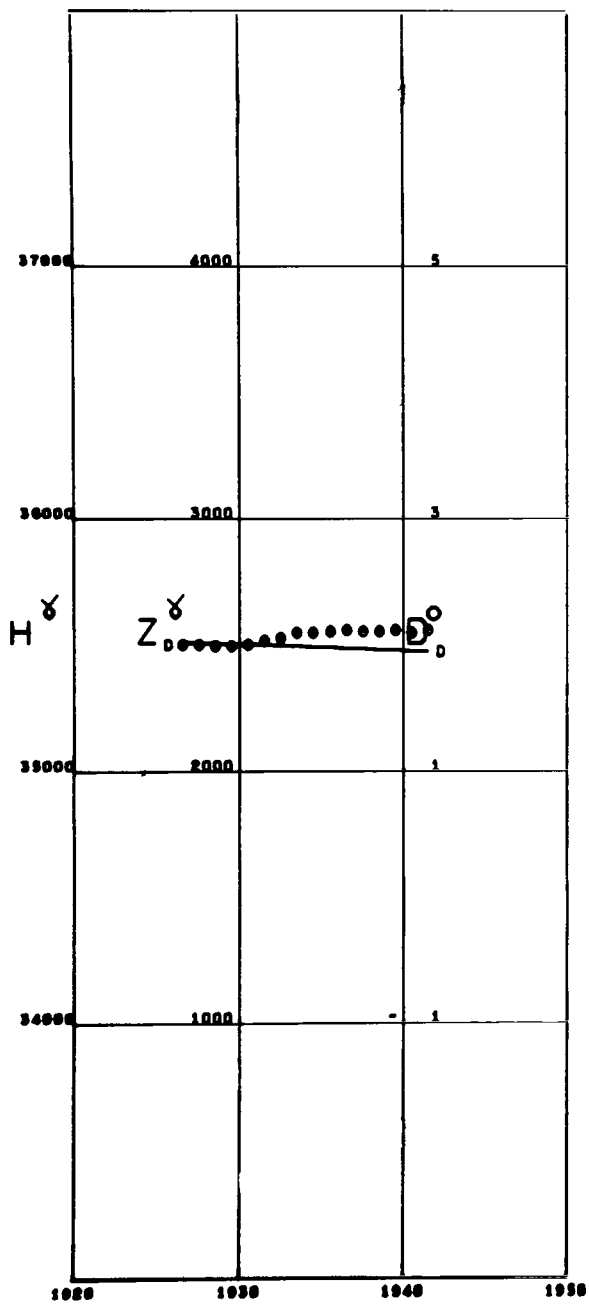


Figure A131

PANAGYURISHTE  
Lat 42.51 Long 24.18

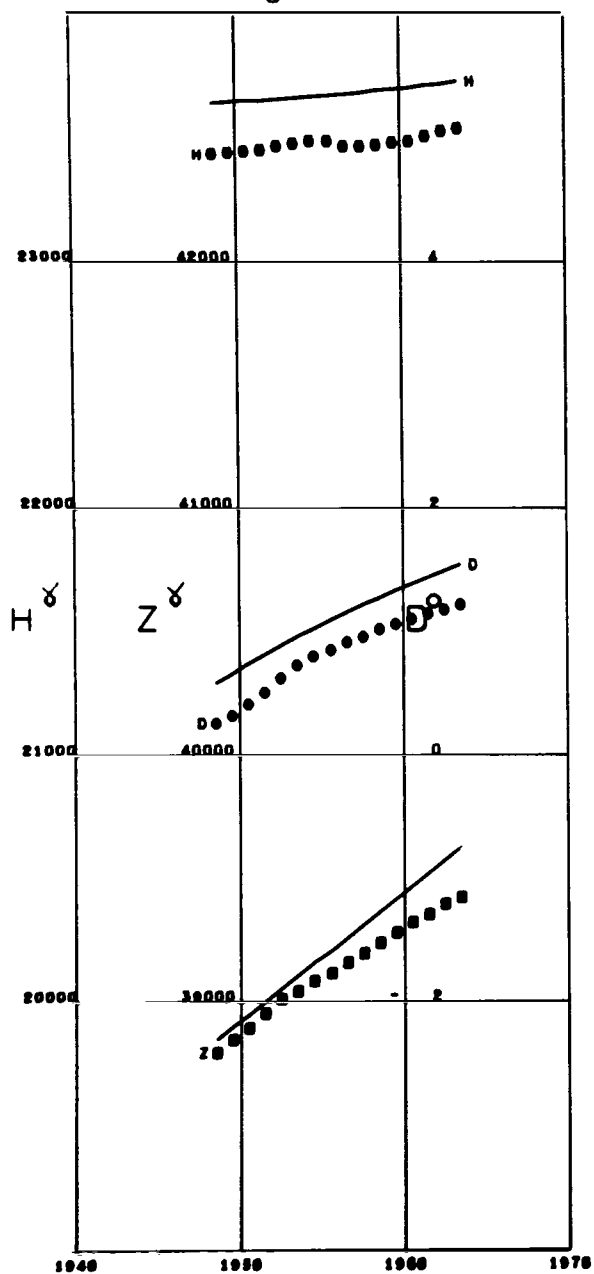


Figure A132

PARAMARIBO  
Lat 5.81 Long -55.22 Alt 0.10

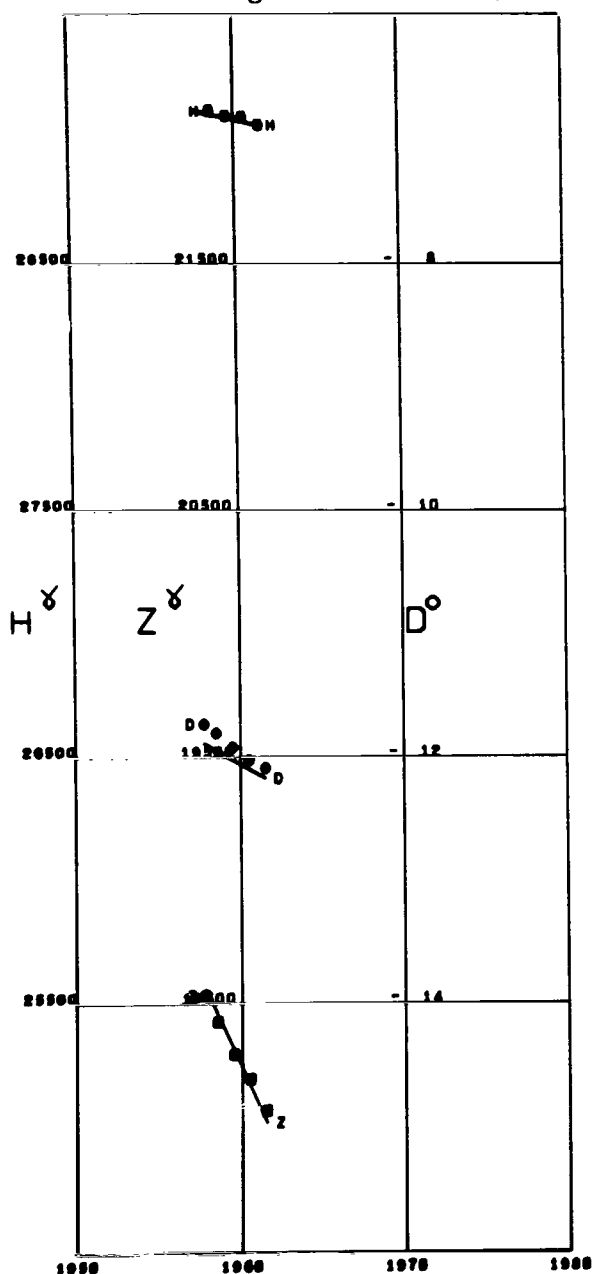


Figure A133

PATRONY  
 Lat 52.16 Long 104.45 Alt 0.76

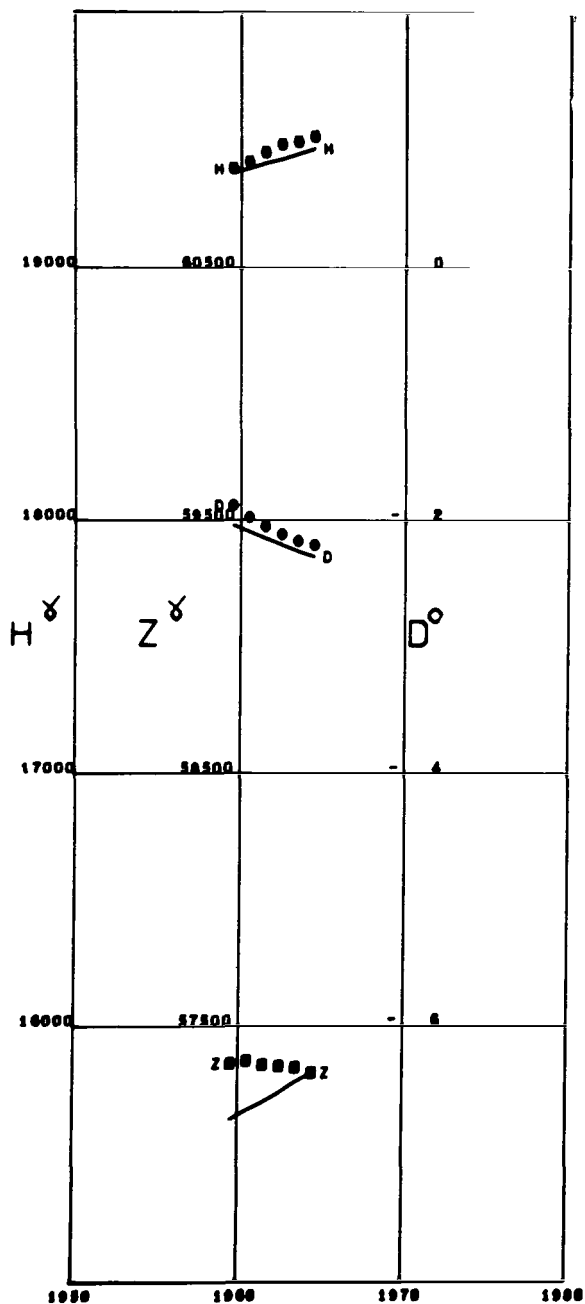


Figure A134

PERPIGNAN  
 Lat 42.70 Long 2.88

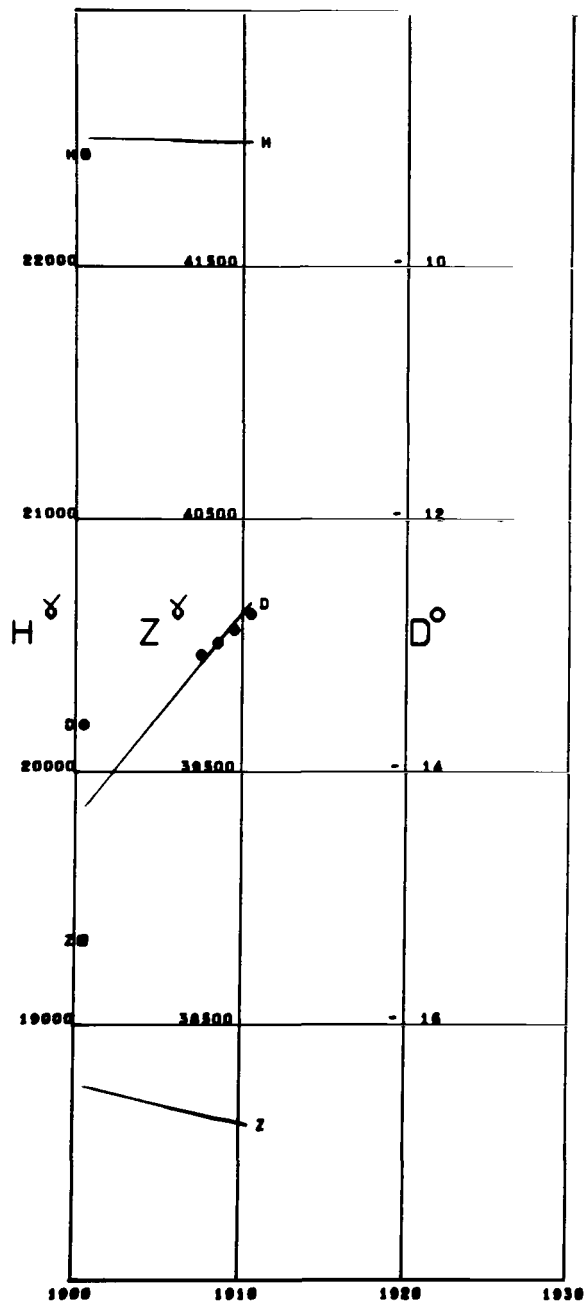


Figure A135

PILAR

Lat -31.66 Long -63.88 Alt 0.34

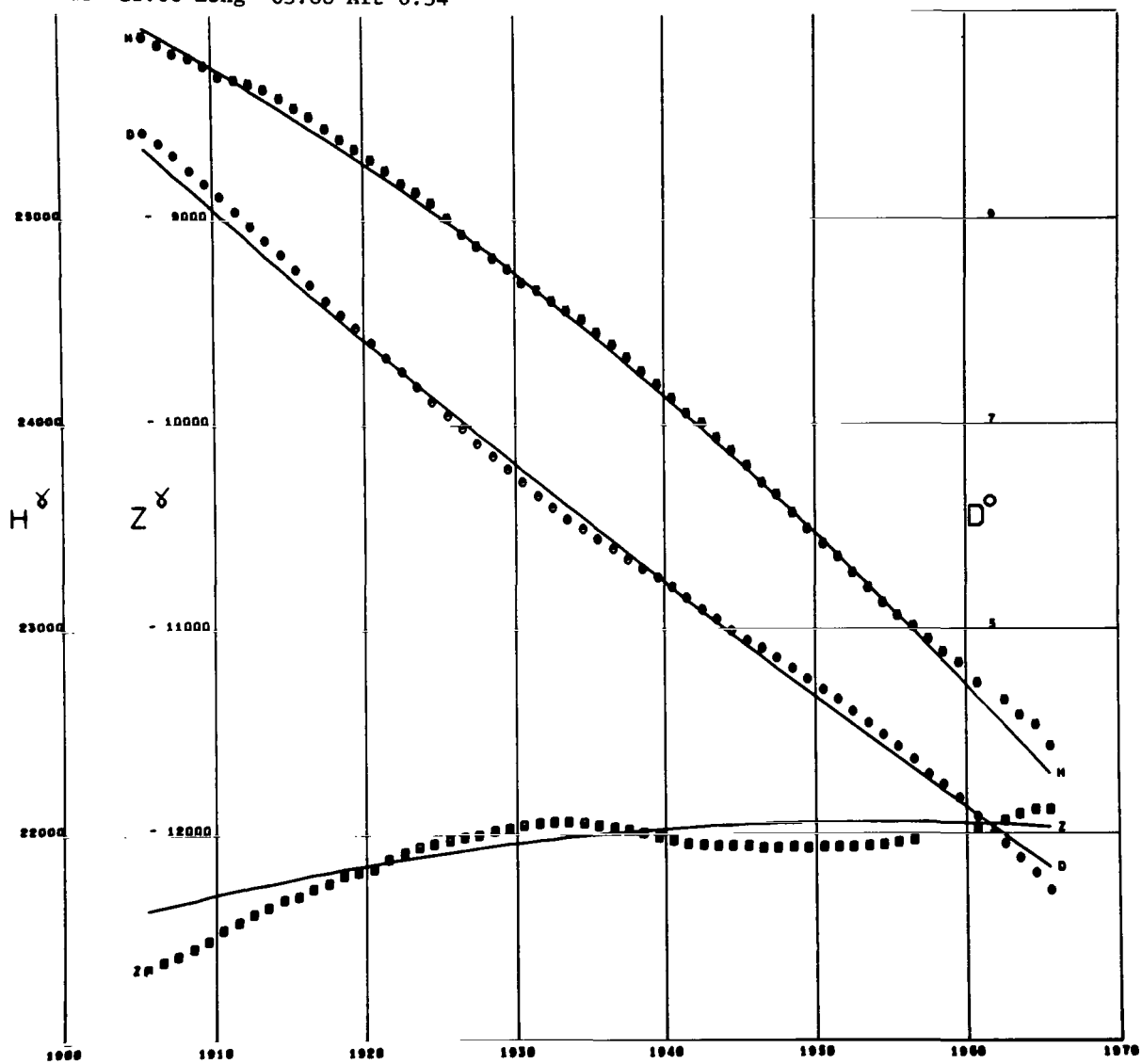
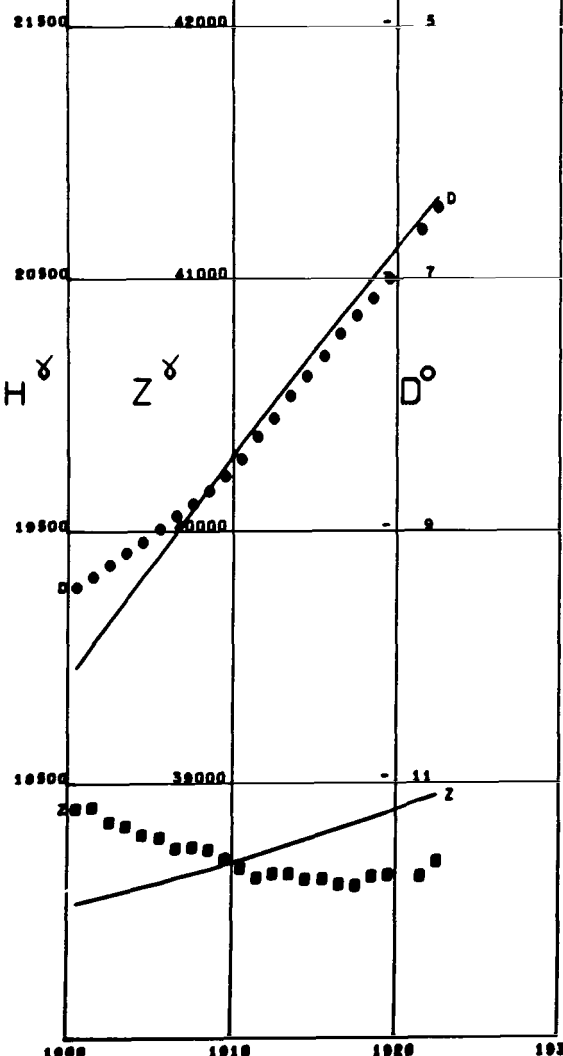


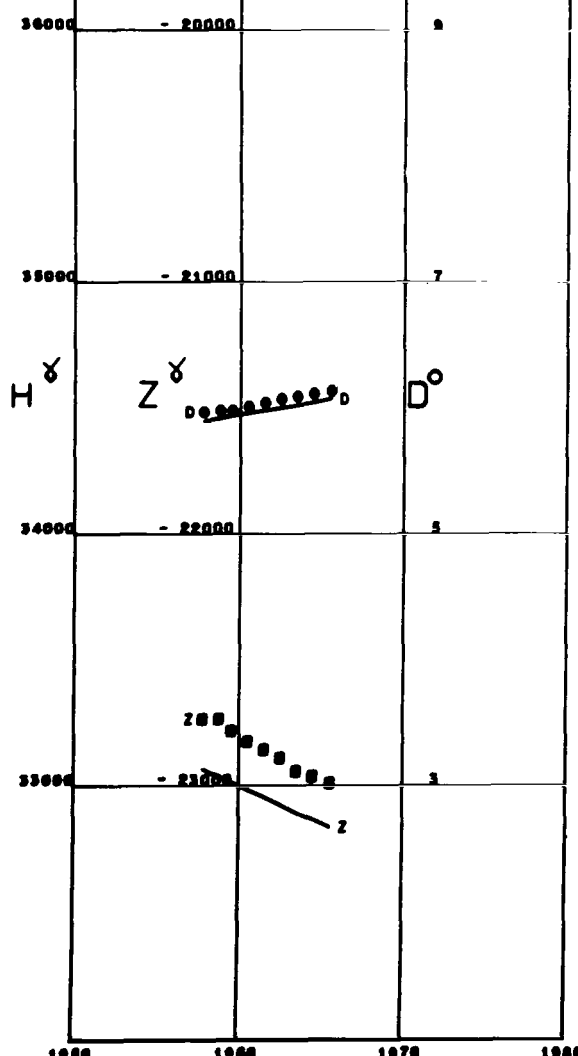
Figure A136

Lat 44.86 Long 13.84



**Figure A137**

Lat -9.40 Long 147.15 Alt 0.08



**Figure A138**



POTSDAM  
Lat 52.38 Long 13.06

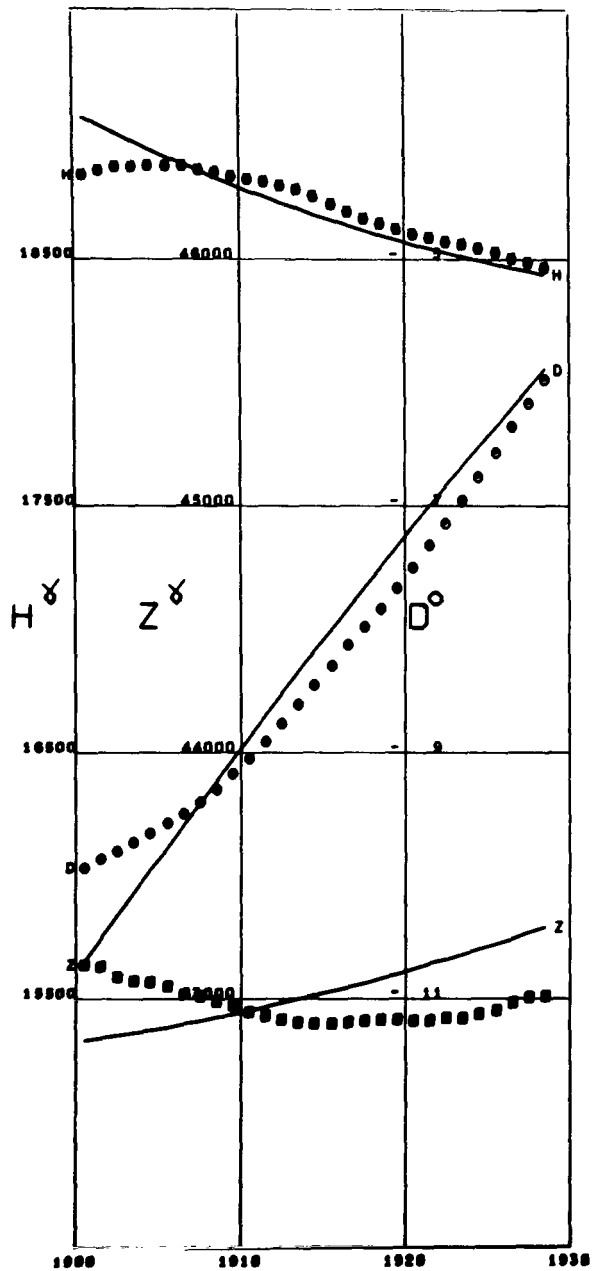


Figure A139

PRAGUE  
Lat 50.08 Long 14.41

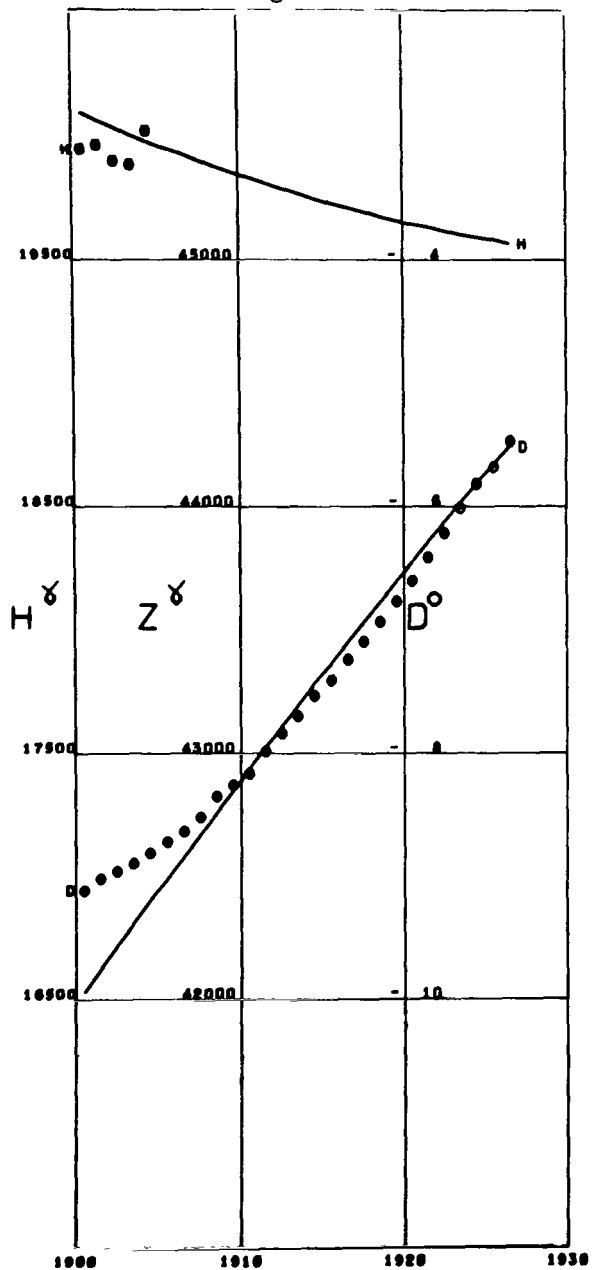


Figure A140

PRUHONICE  
Lat 49.99 Long 14.54

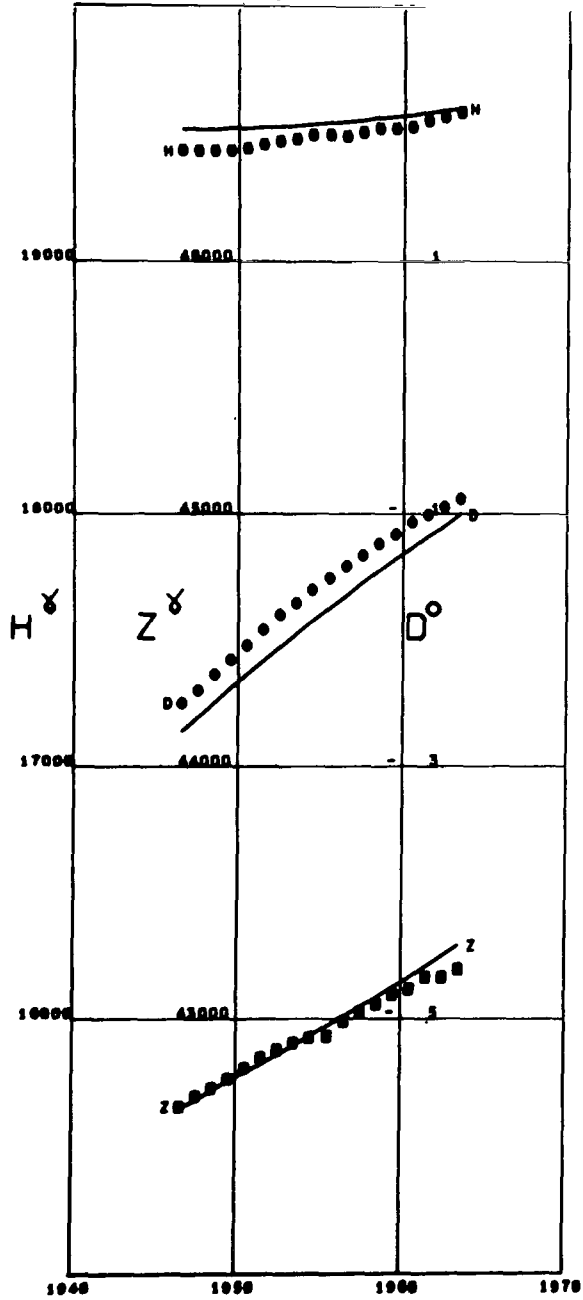


Figure A141

QUETTA  
Lat 30.18 Long 66.95

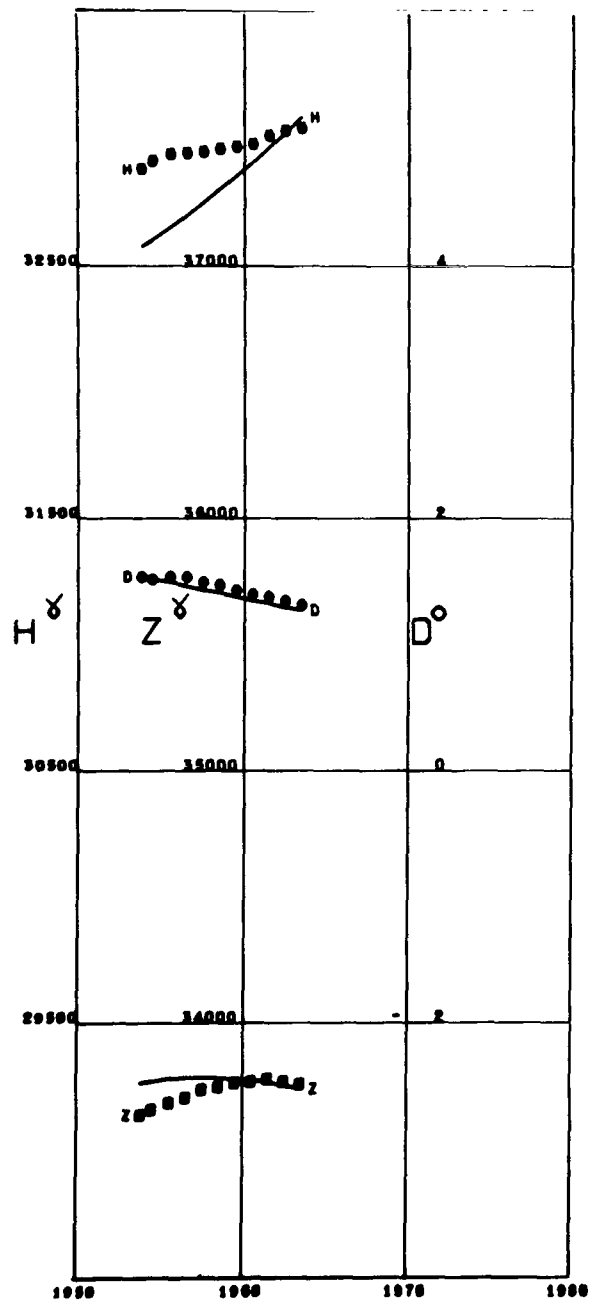


Figure A142

QUIACA  
 Lat -22.10 Long -65.60

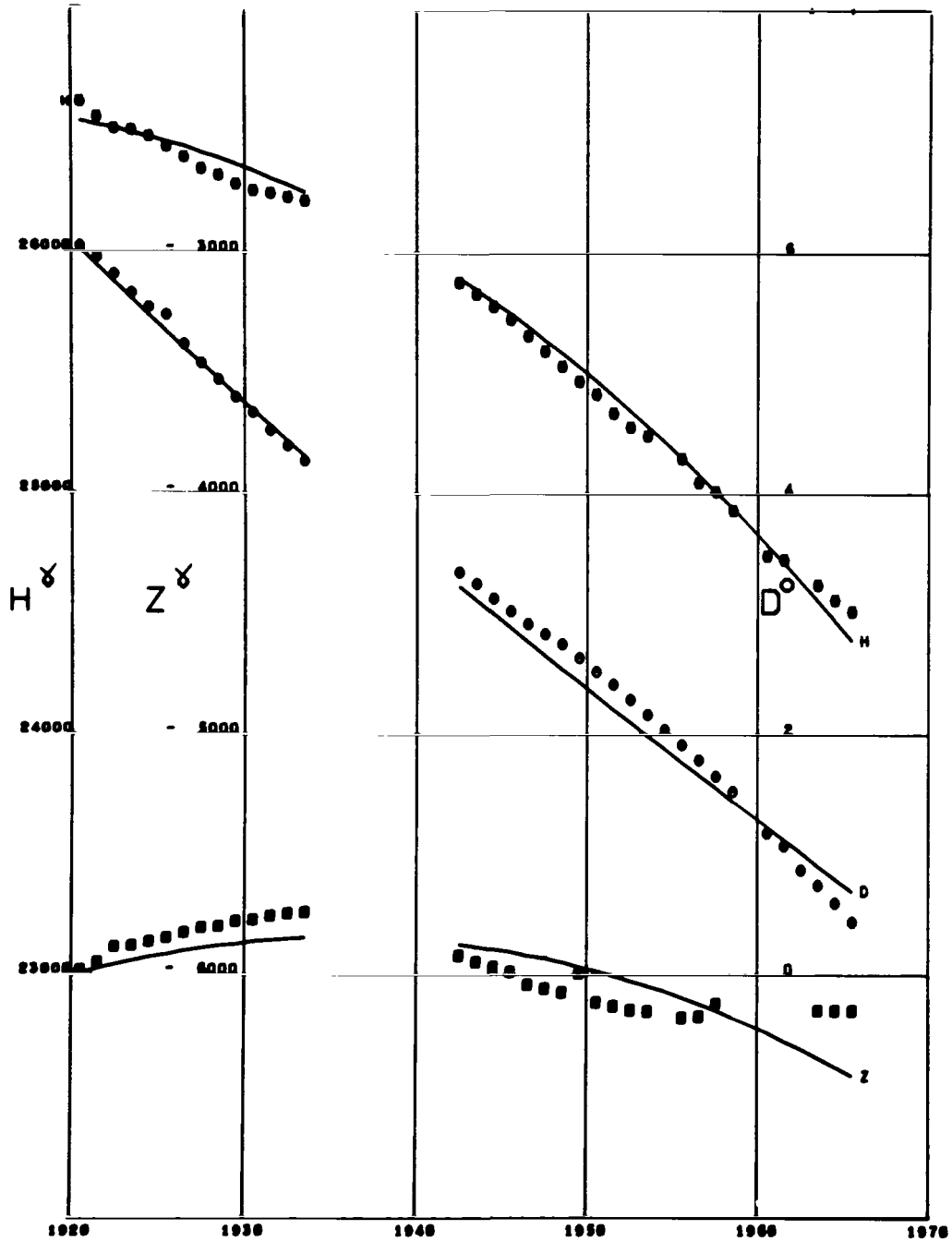


Figure A143

REGENSBURG  
Lat 47.48 Long 8.44

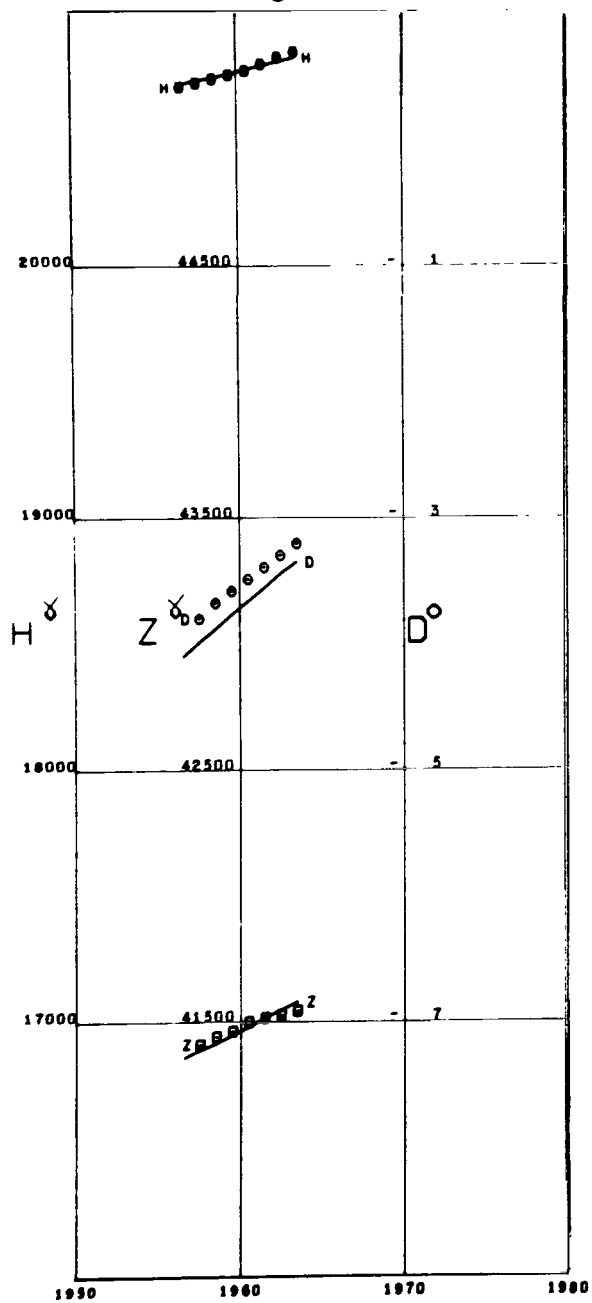


Figure A144

RIO DE JANEIRO  
Lat -22.90 Long -43.17

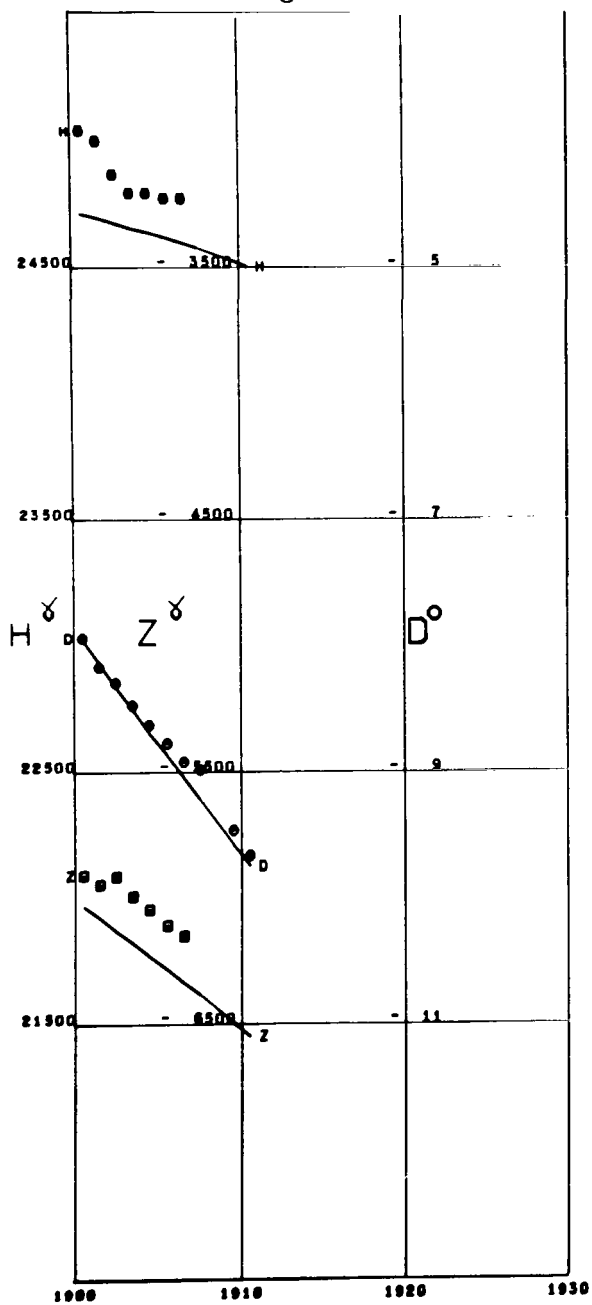


Figure A145

RUDE SKOV  
 Lat 55.84 Long 12.45 Alt 0.05

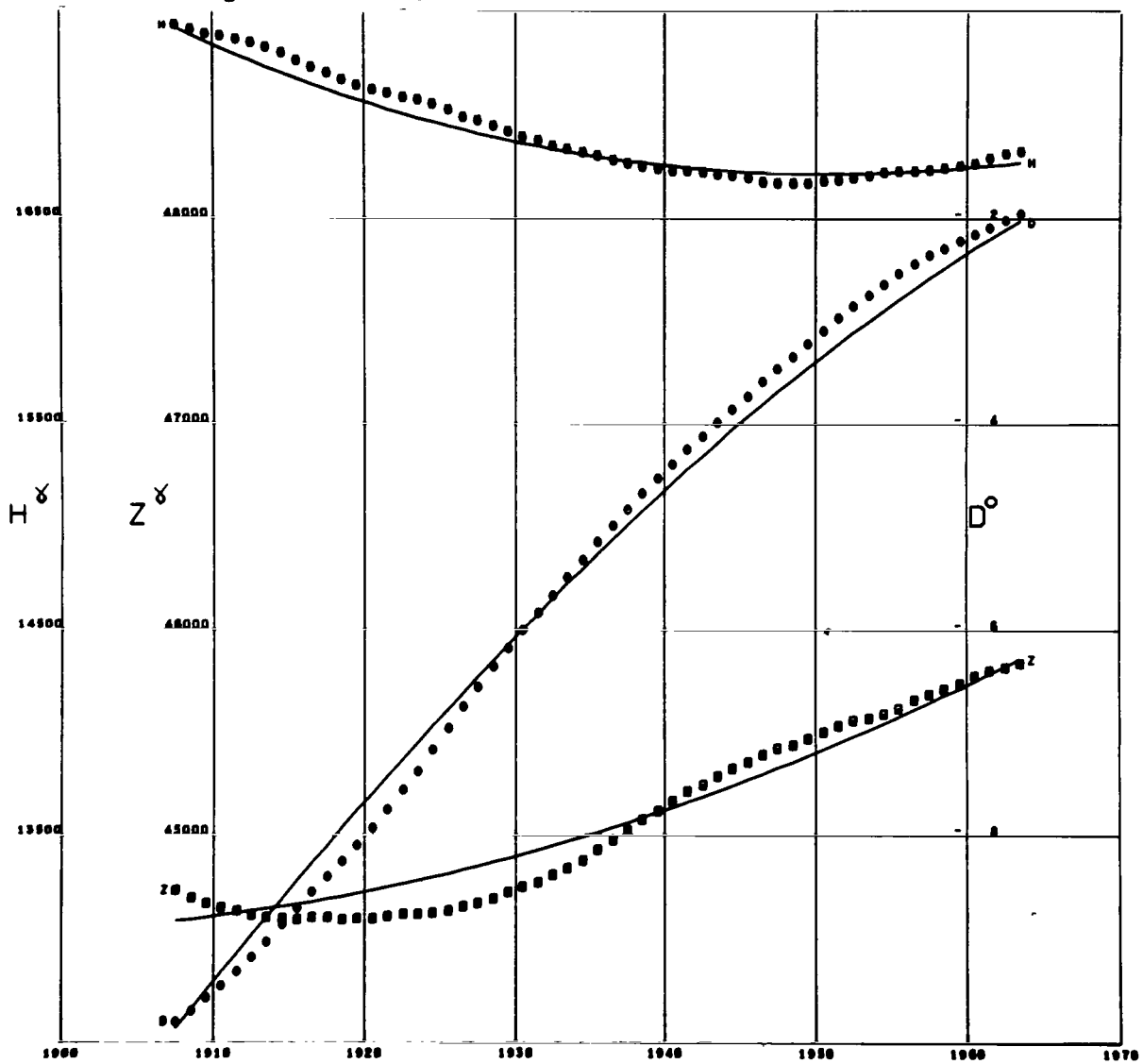


Figure A146

SAN FERNANDO  
 Lat 36.46 Long -6.20

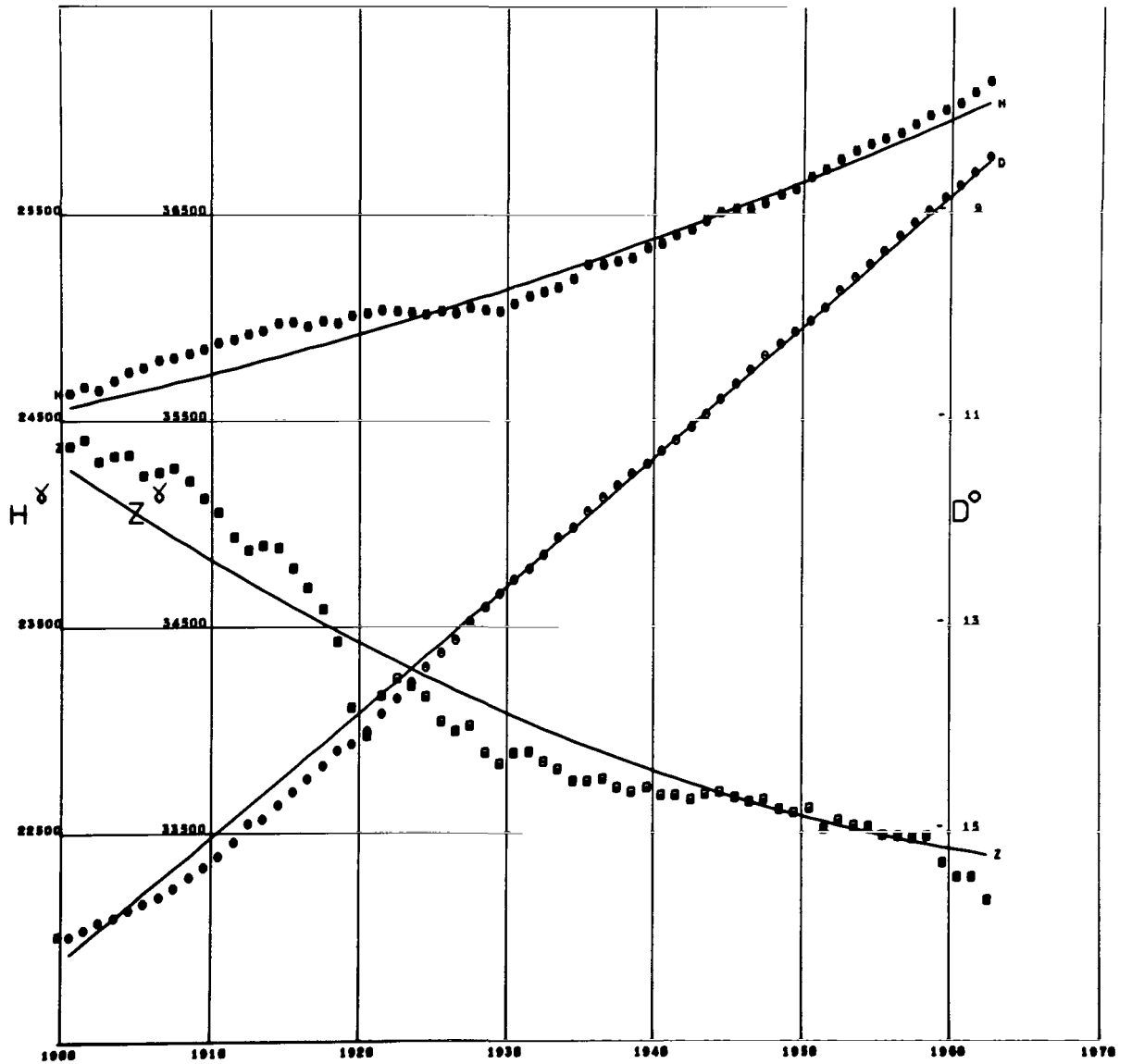


Figure A147

SAN JUAN  
 Lat 18.11 Long -66.15 Alt 0.40

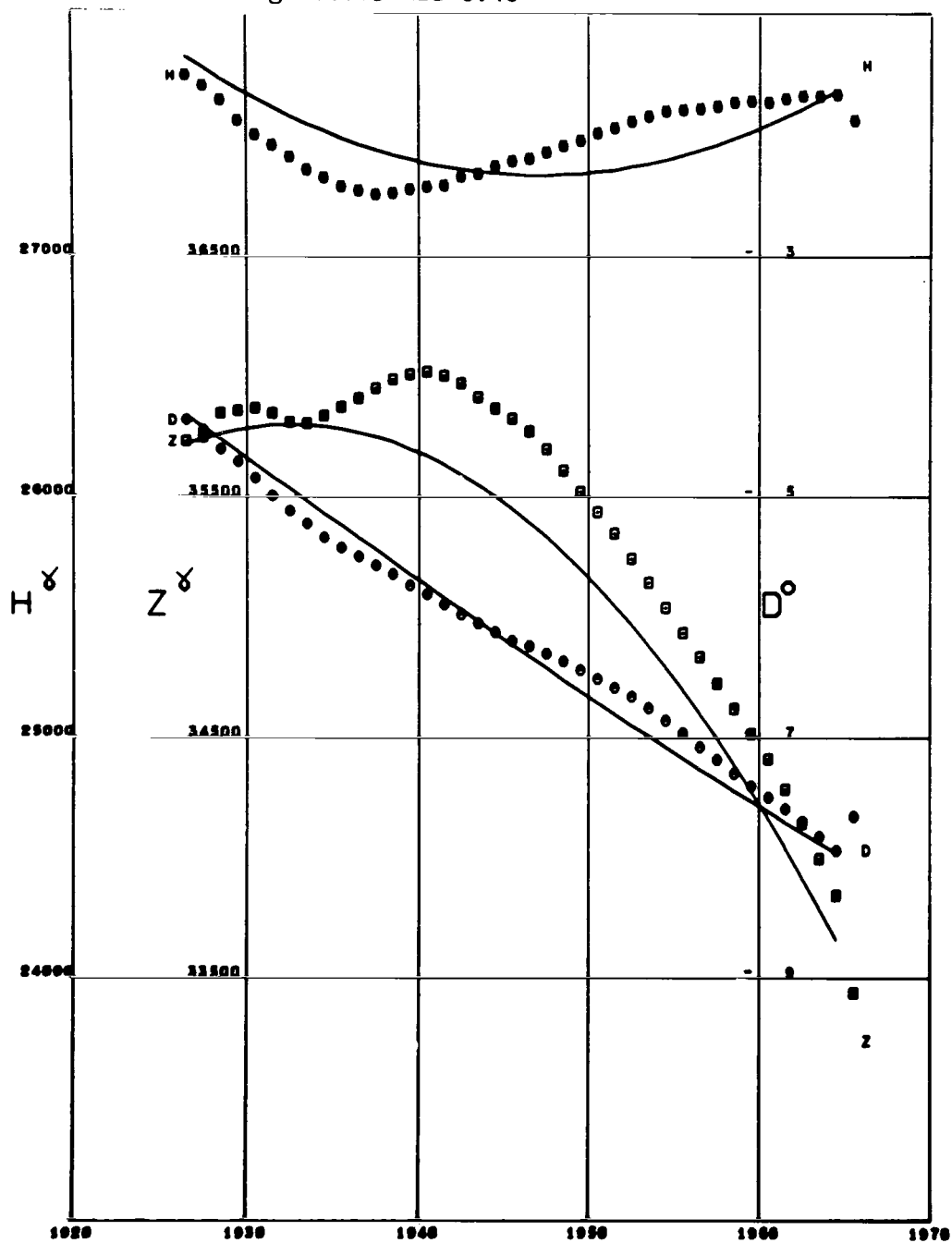


Figure A148

SAN MIGUEL  
 Lat 37.76 Long -25.65

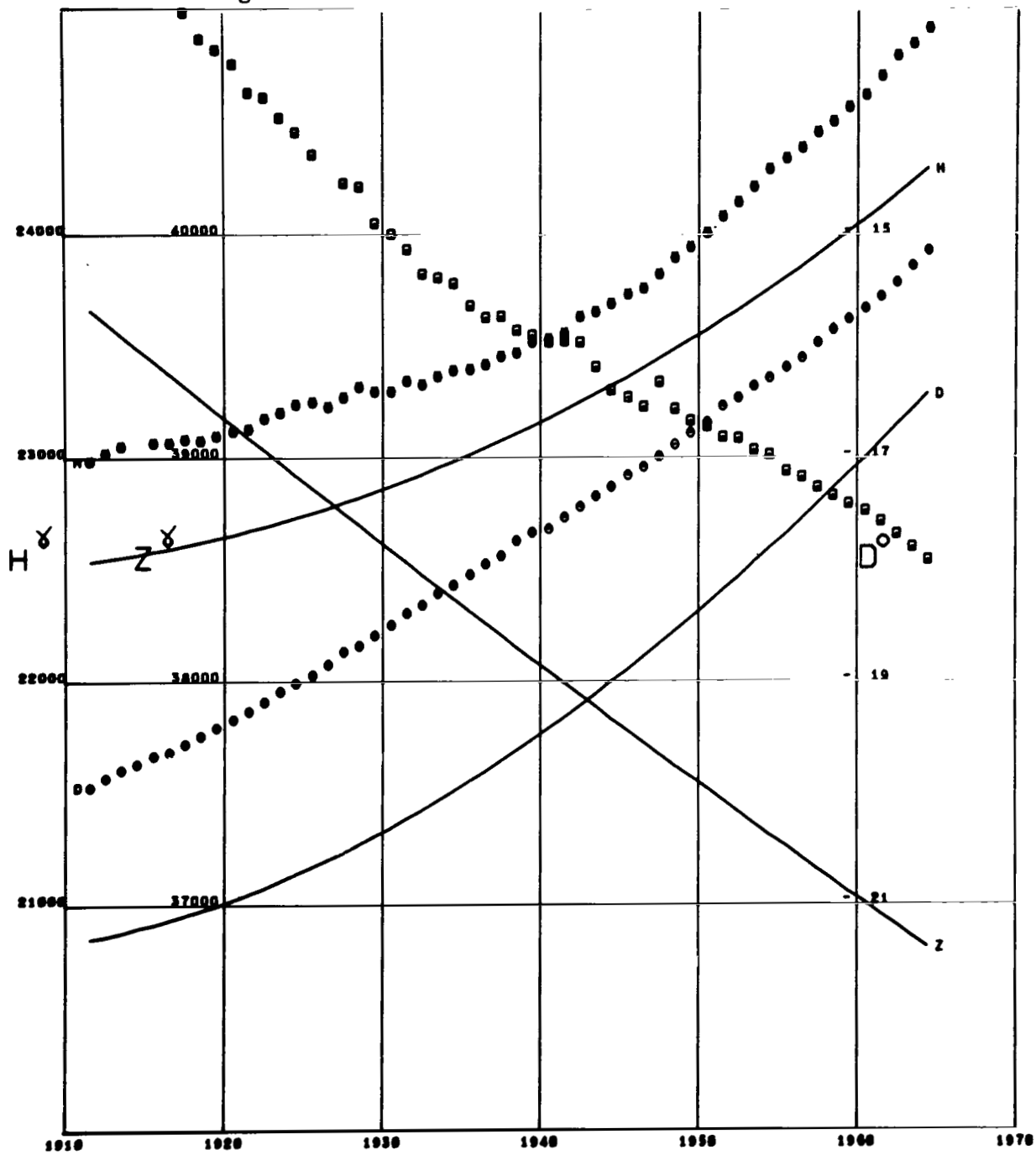


Figure A149



SANTIAGO  
Lat -33.45 Long -70.70

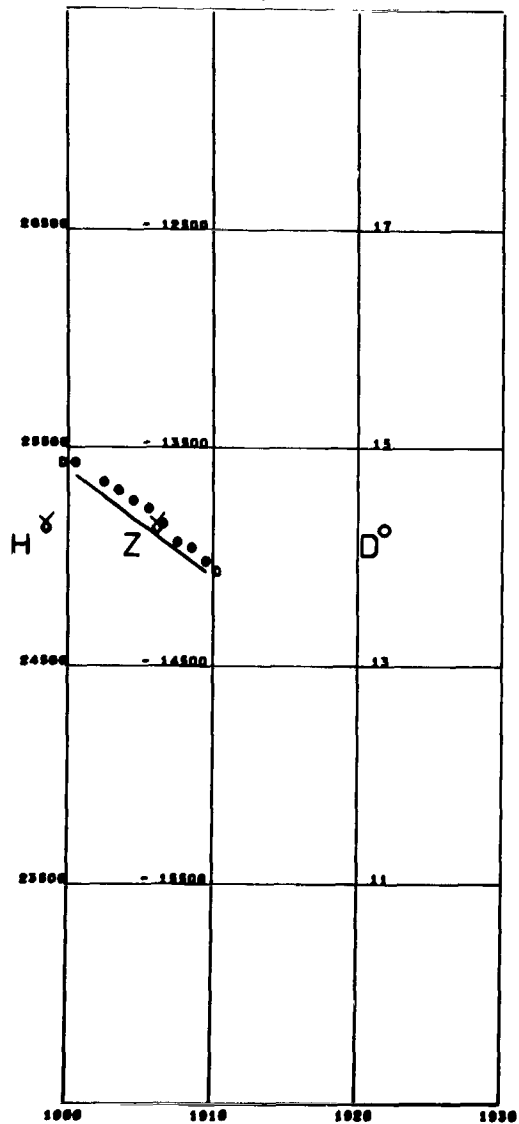


Figure A150

SEDDIN  
Lat 52.27 Long 13.01

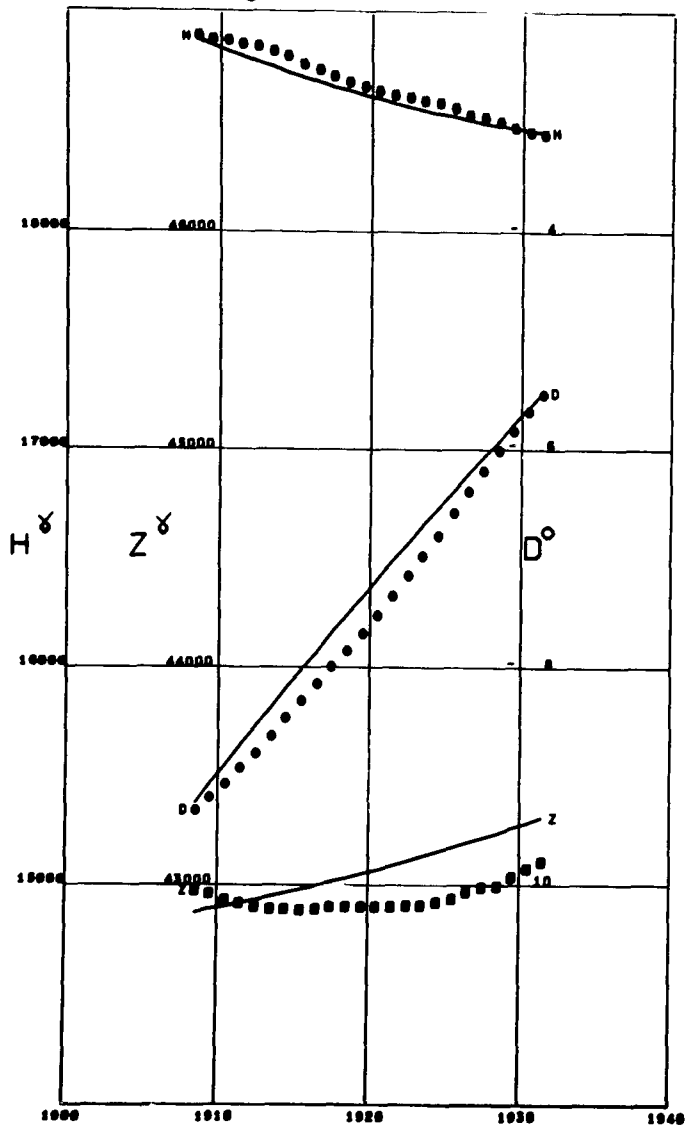


Figure A151

SIMOSATO  
 Lat 33.57 Long 135.94

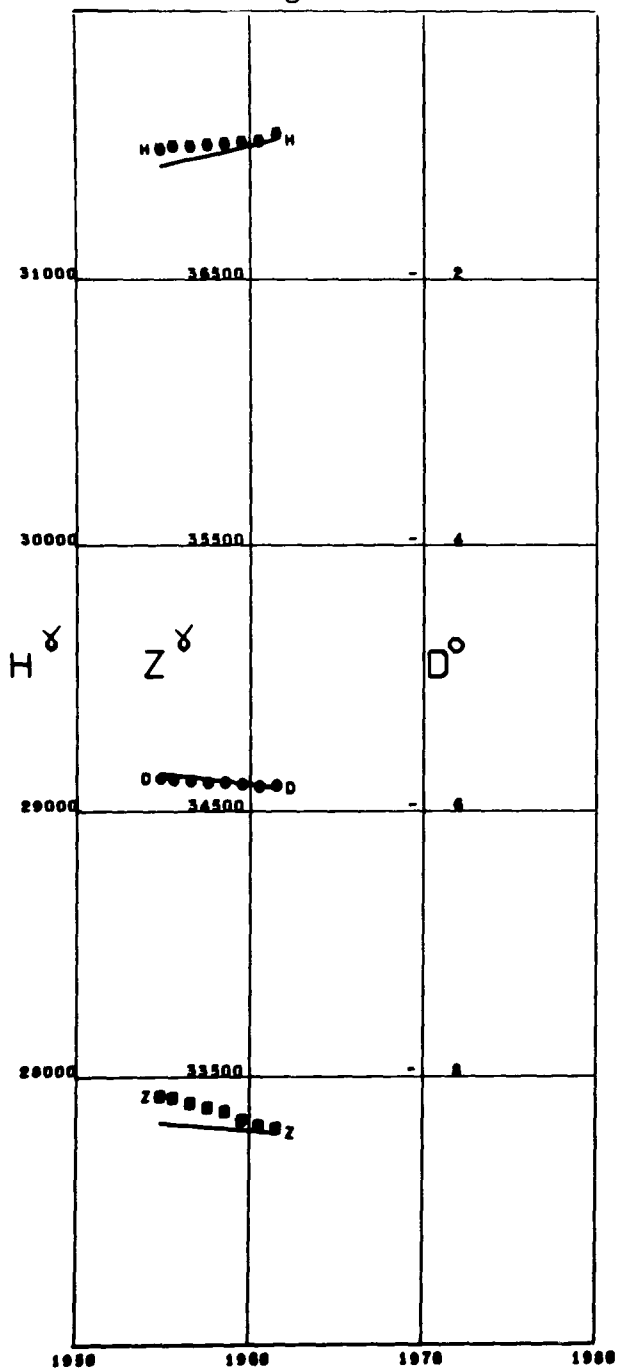


Figure A152

SITKA  
 Lat 57.05 Long -135.32 Alt 0.02

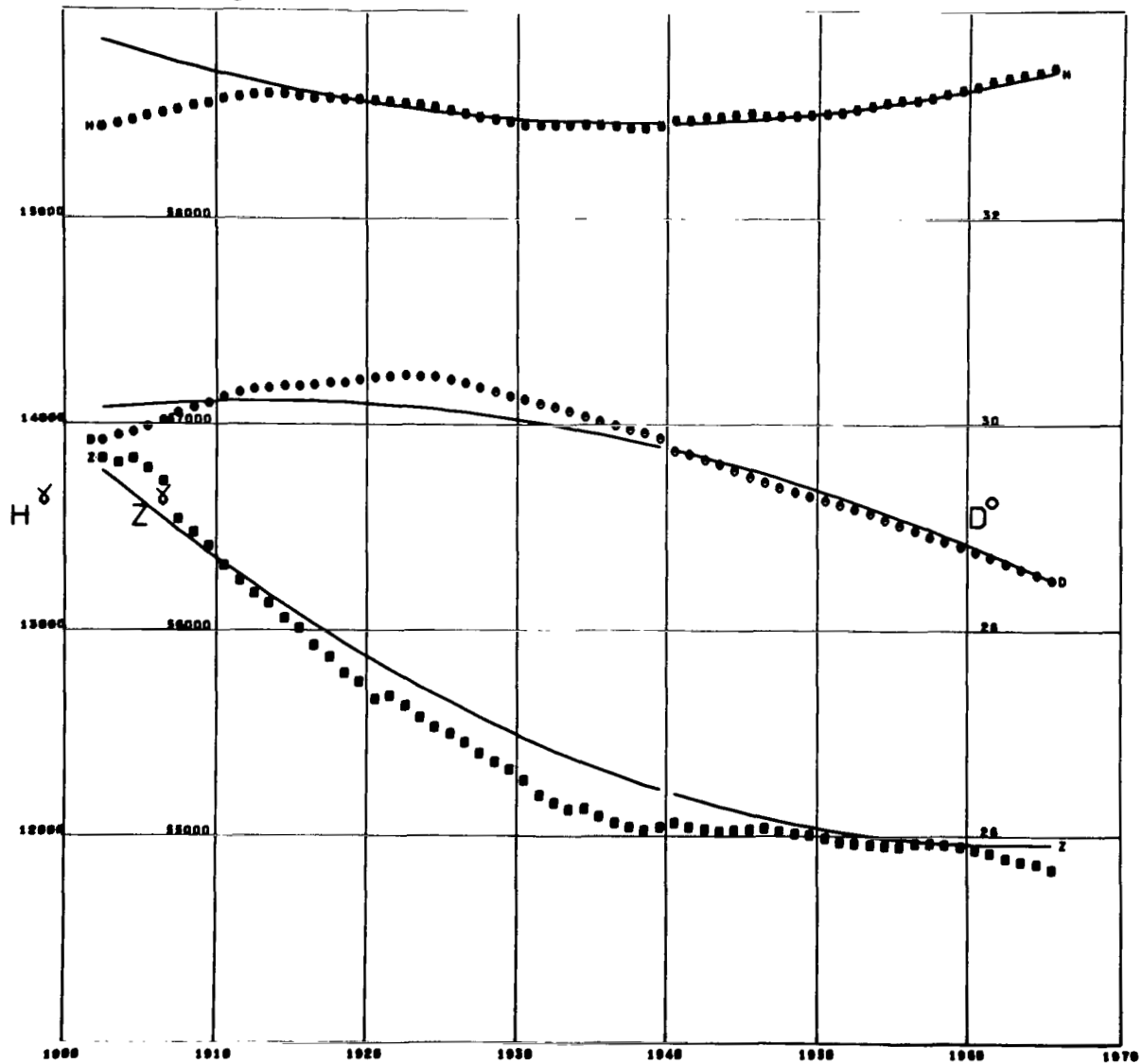


Figure A153

SLUTZK  
Lat 59.68 Long 30.48

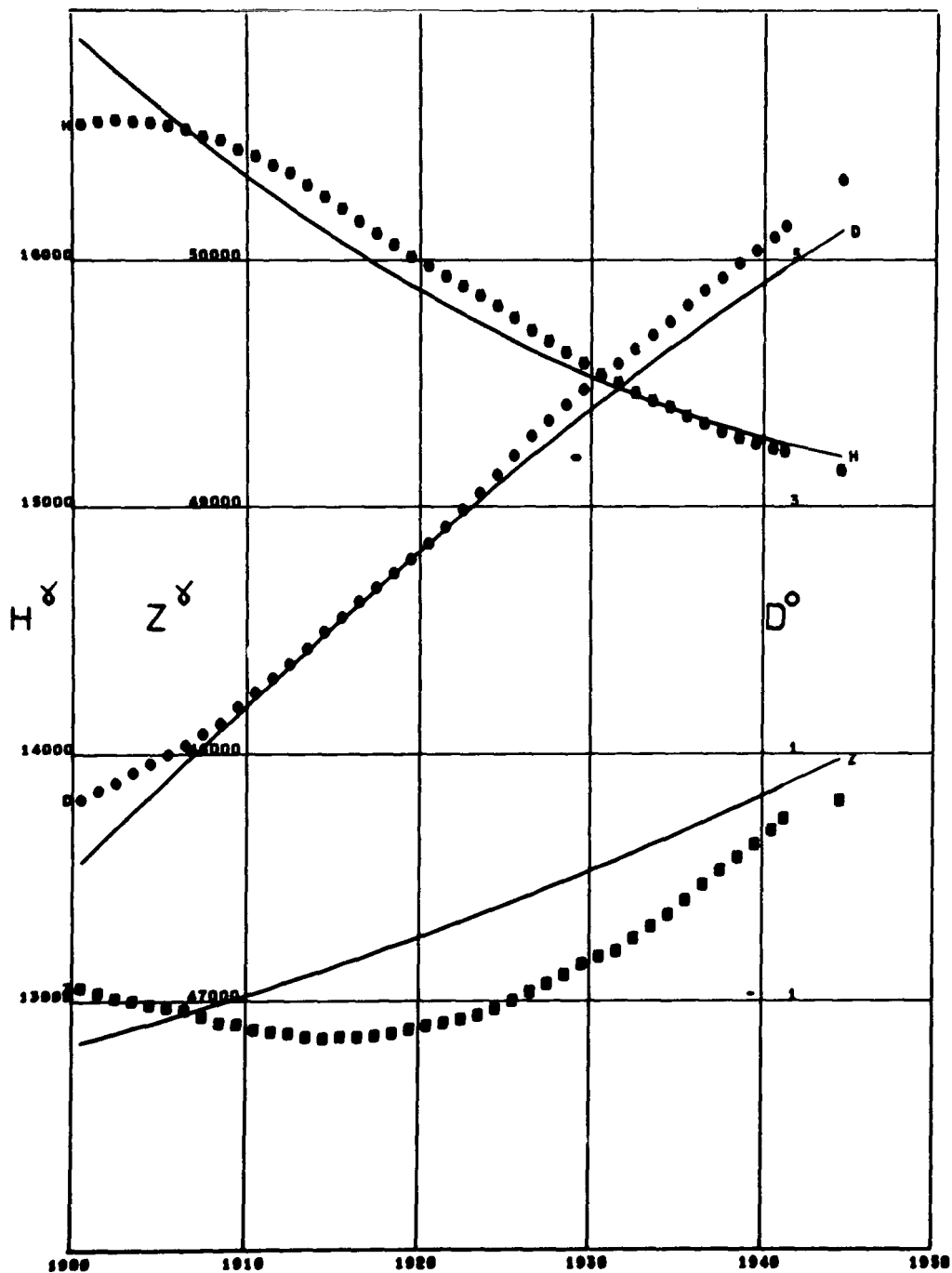


Figure A154

SODANKYLA  
 Lat 67.36 Long 26.63

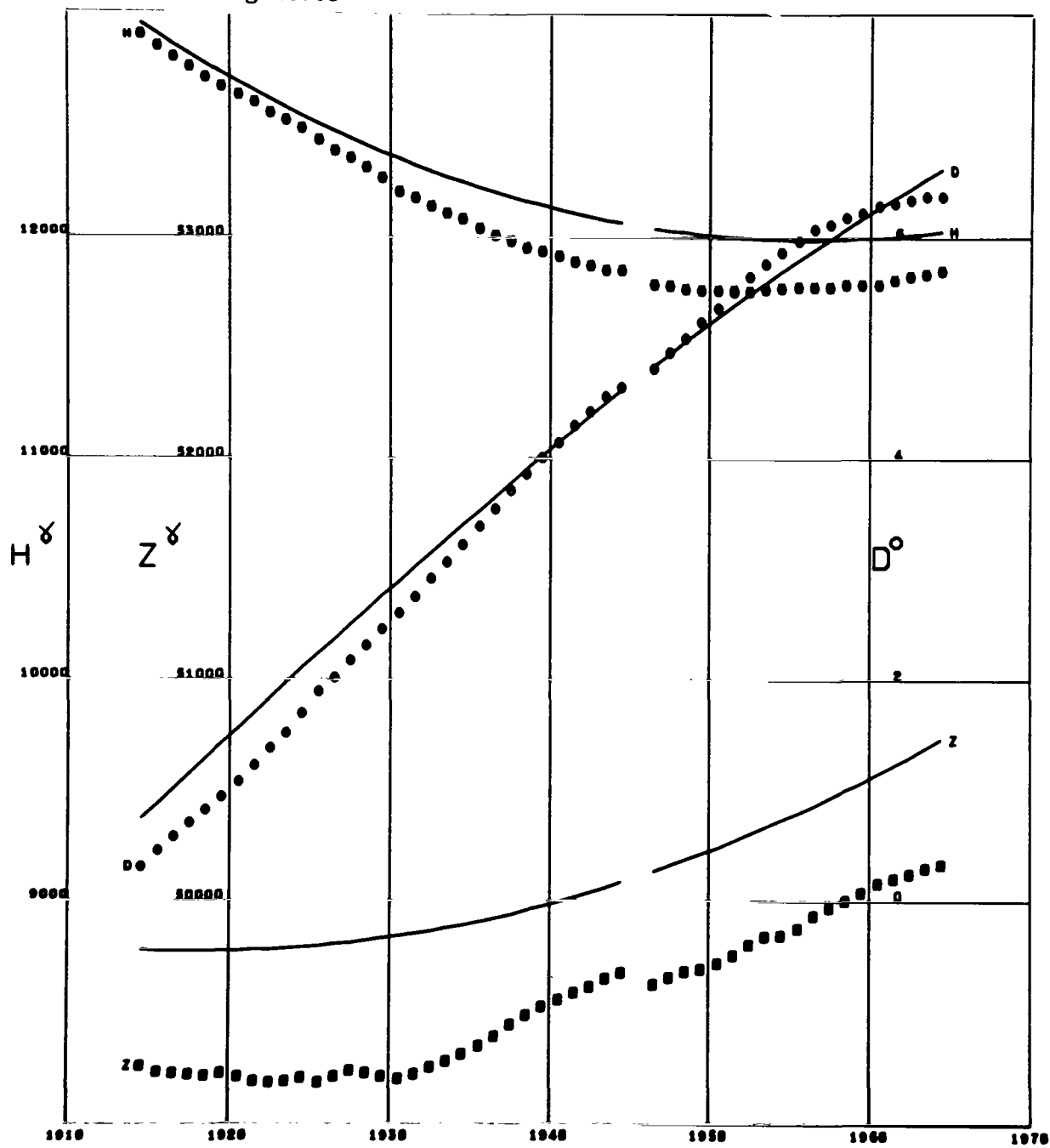


Figure A155

SOUTH POLE  
Lat -89.99 Long -13.32 Alt 2.80

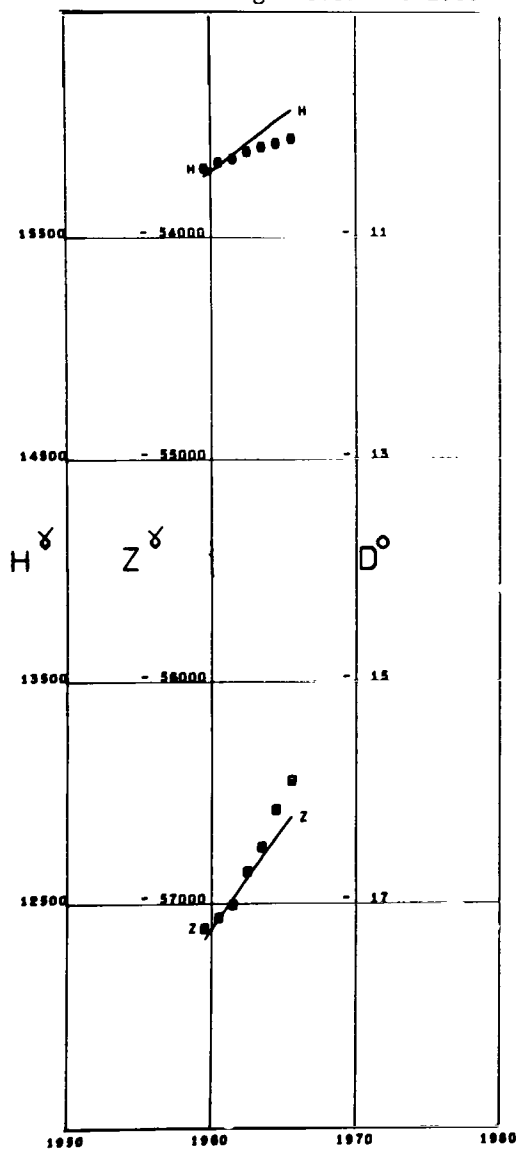


Figure A156

SREDNIKAN  
Lat 62.44 Long 152.31

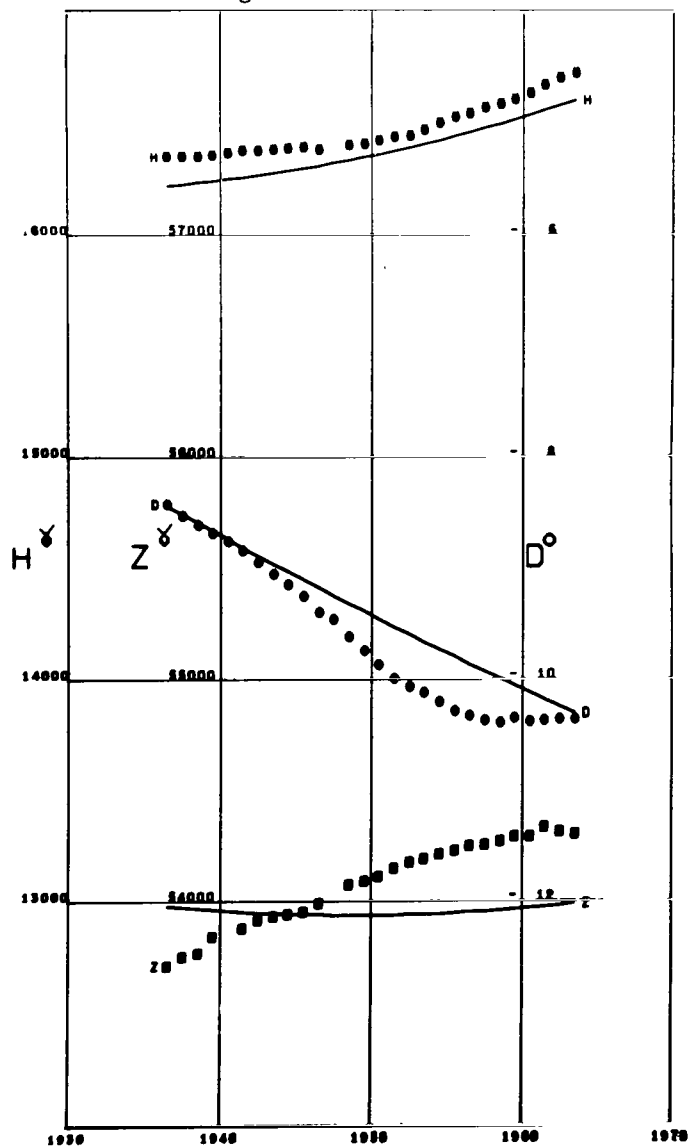


Figure A157

# ST. HELIER

Lat 49.19 Long -2.09

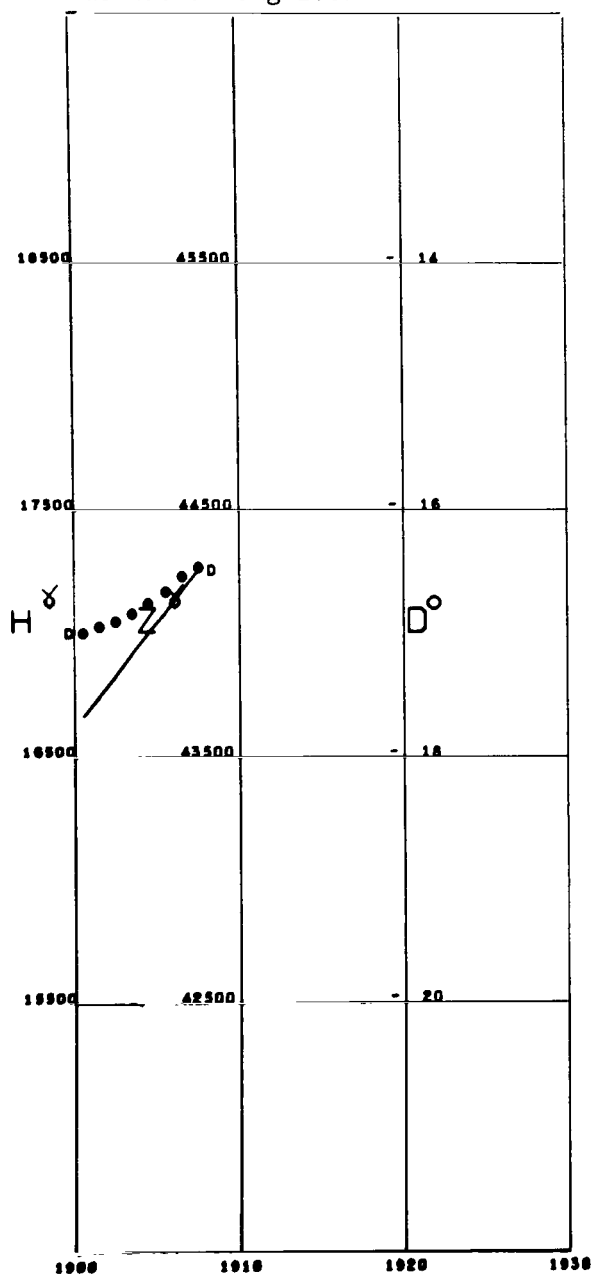


Figure A158

# STARA DALA

Lat 47.87 Long 18.19

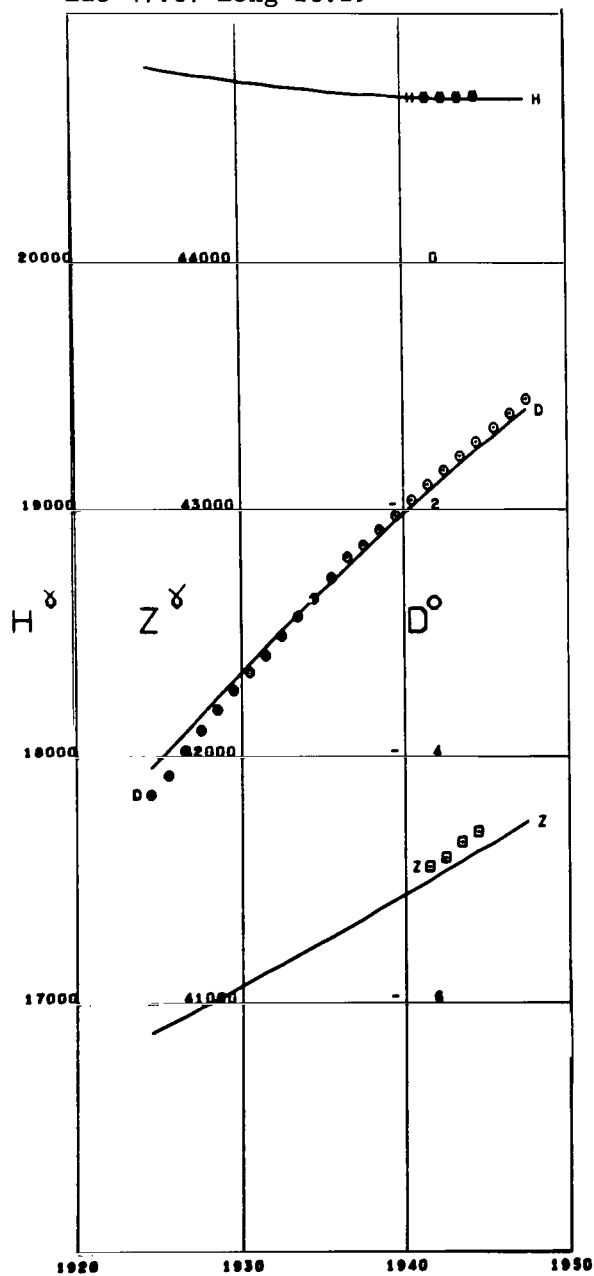


Figure A159

STEPANOVKA

Lat 46.78 Long 30.88 Alt 0.14

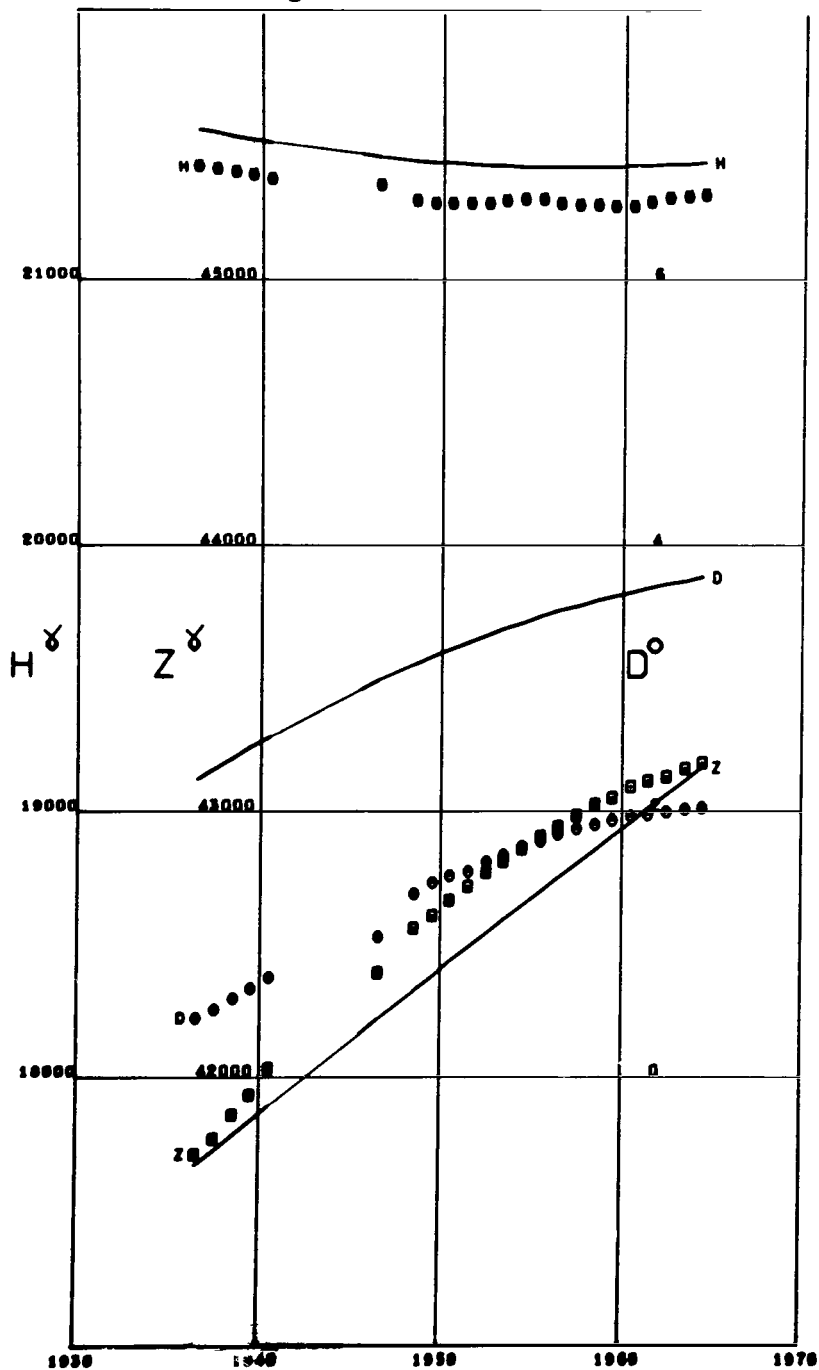


Figure A160



STONYHURST  
 Lat 53.84 Long -2.47

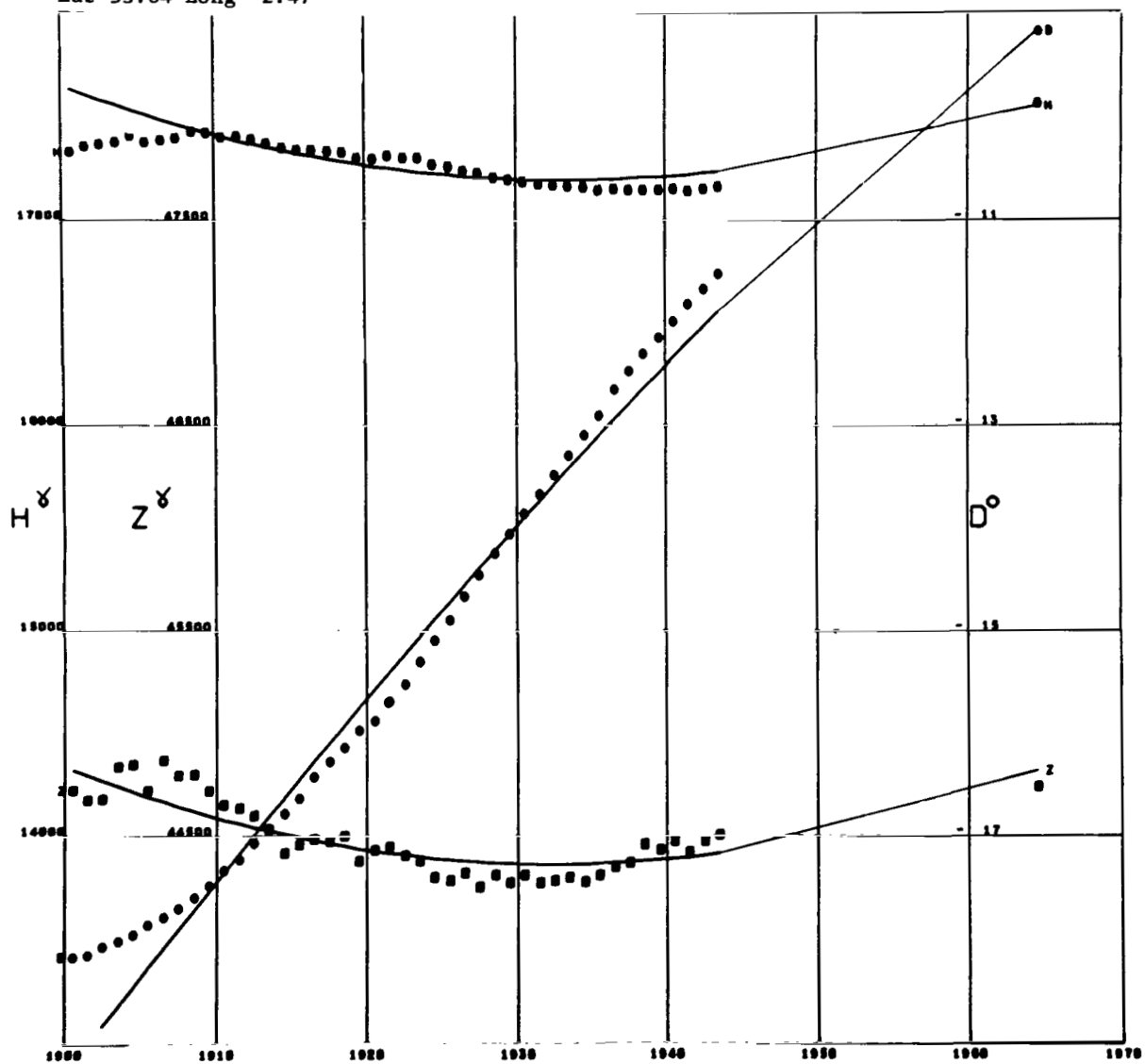


Figure A161

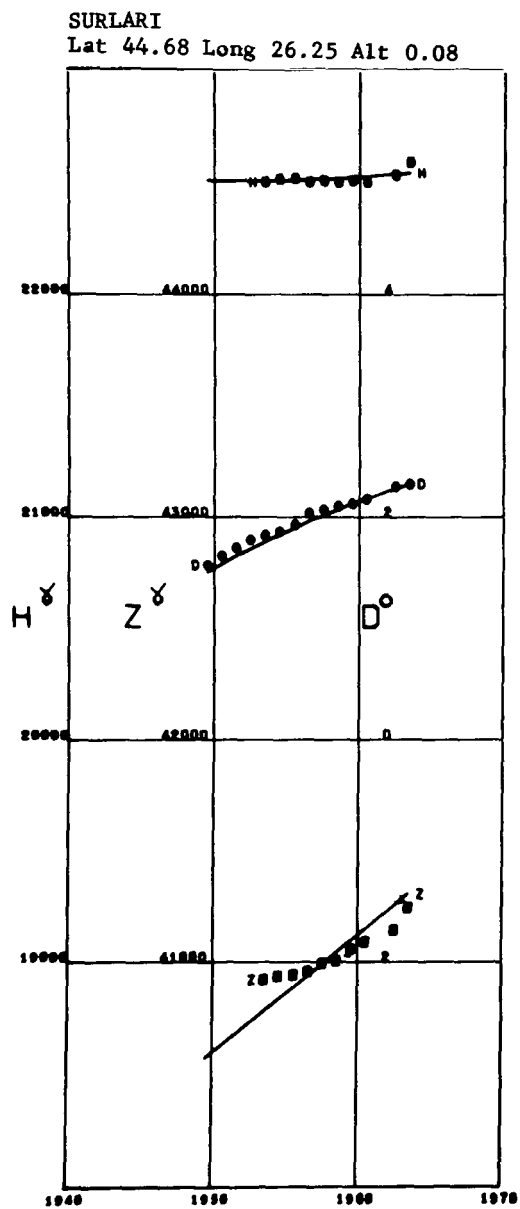


Figure A162

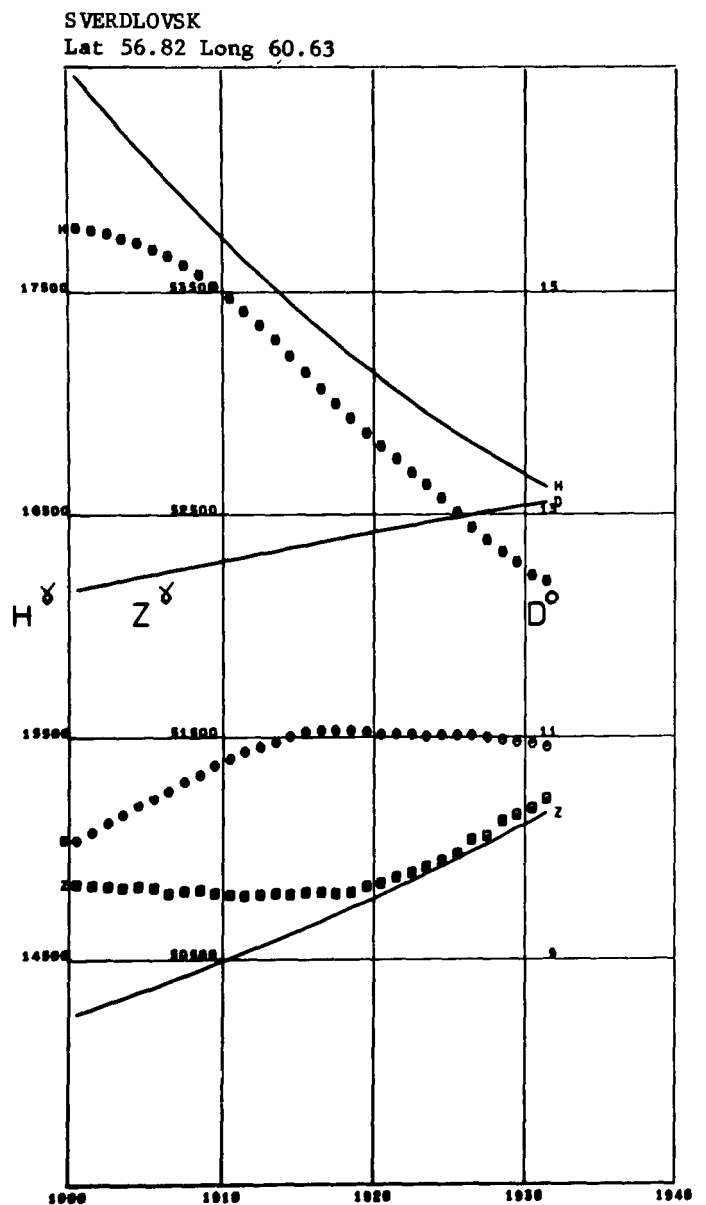


Figure A163

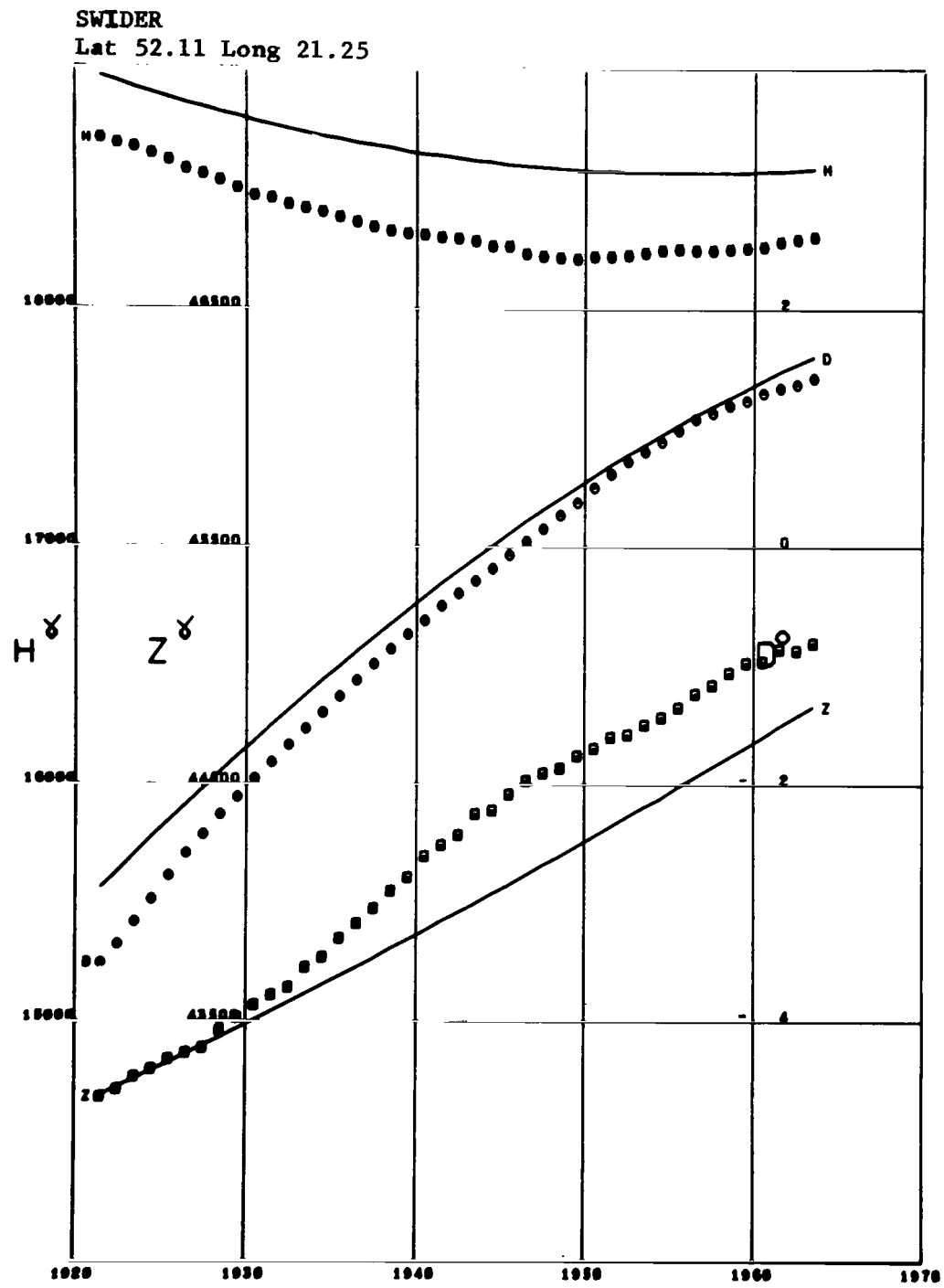


Figure A164

TAIPEI  
Lat 25.03 Long 121.51

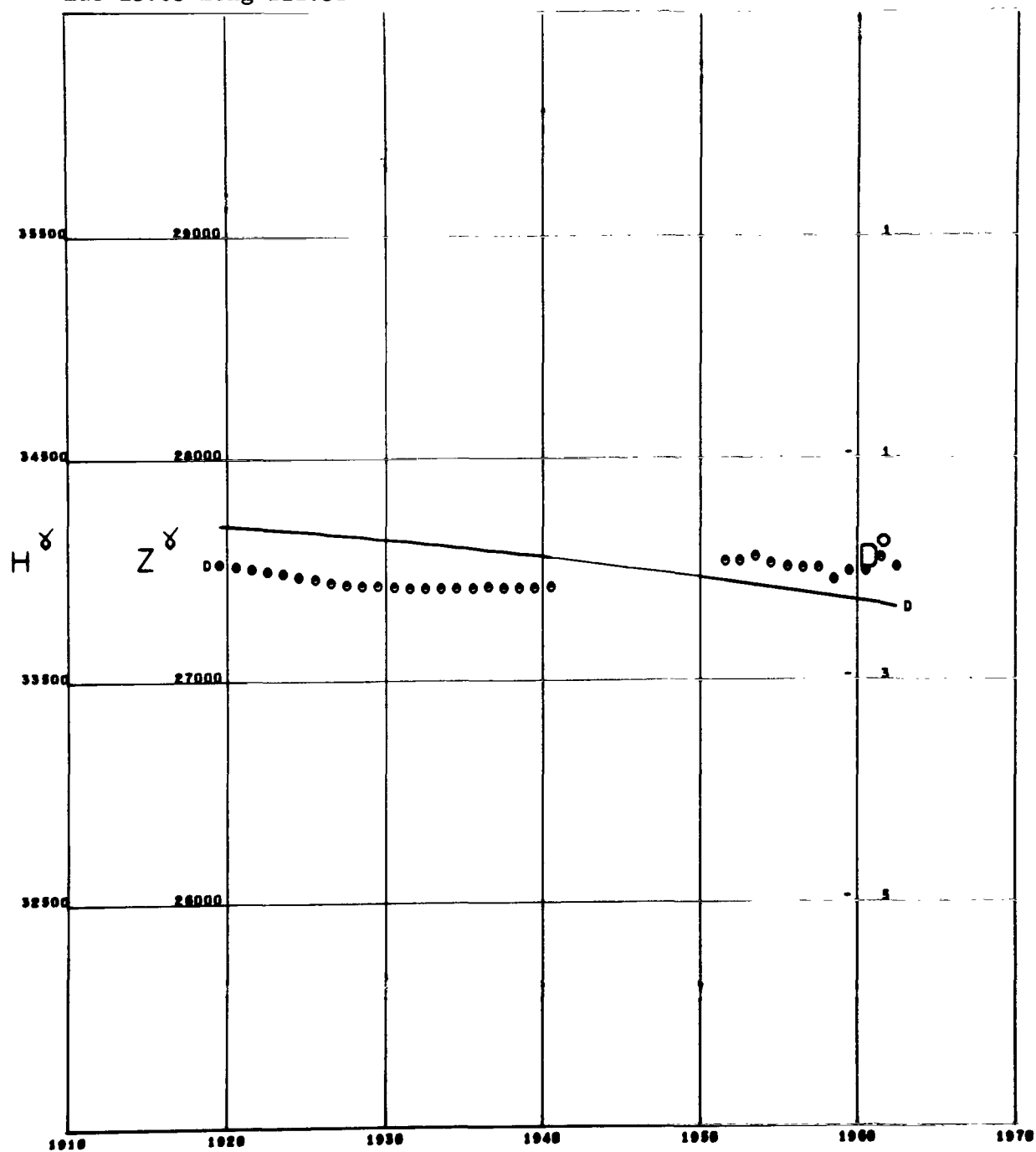


Figure A165

TAMANRASSET  
 Lat 22.79 Long 5.52

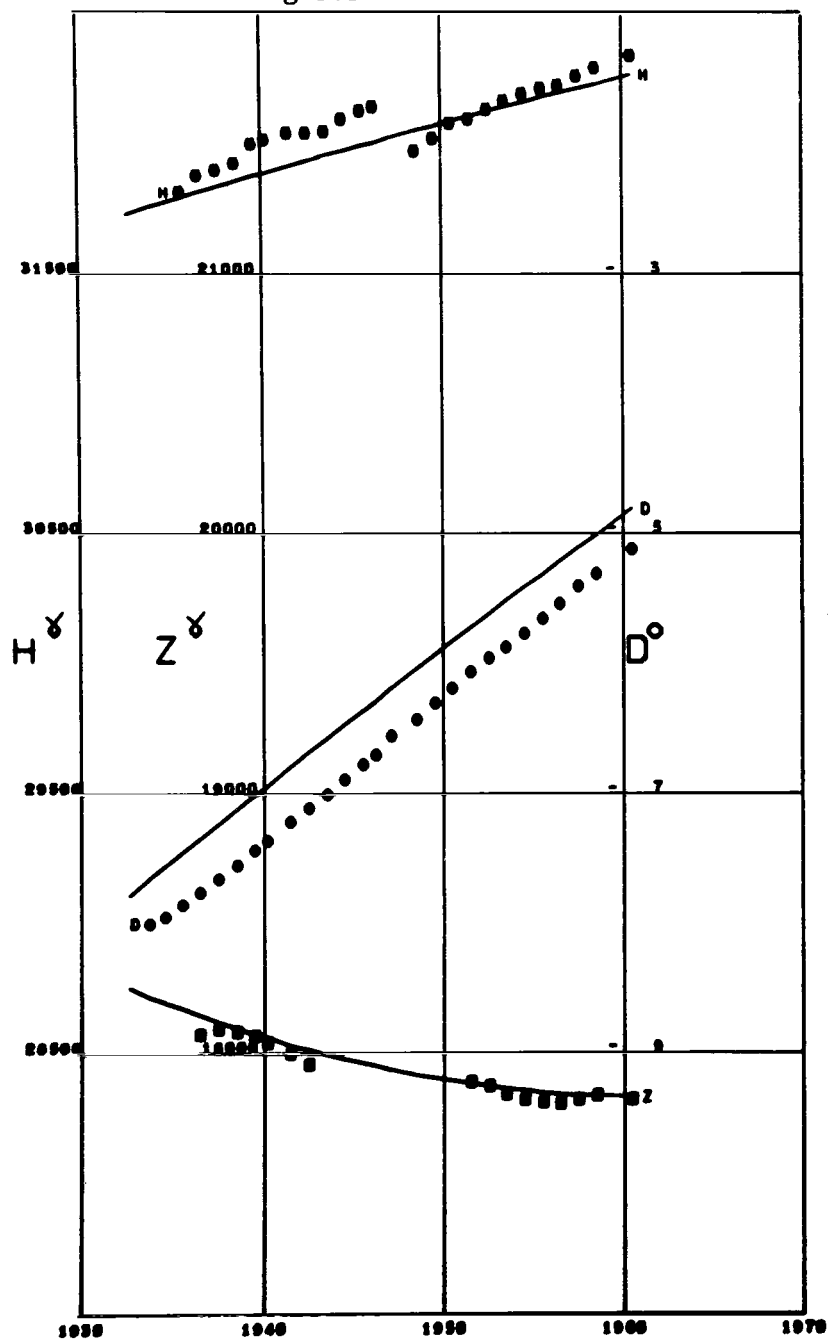


Figure A166

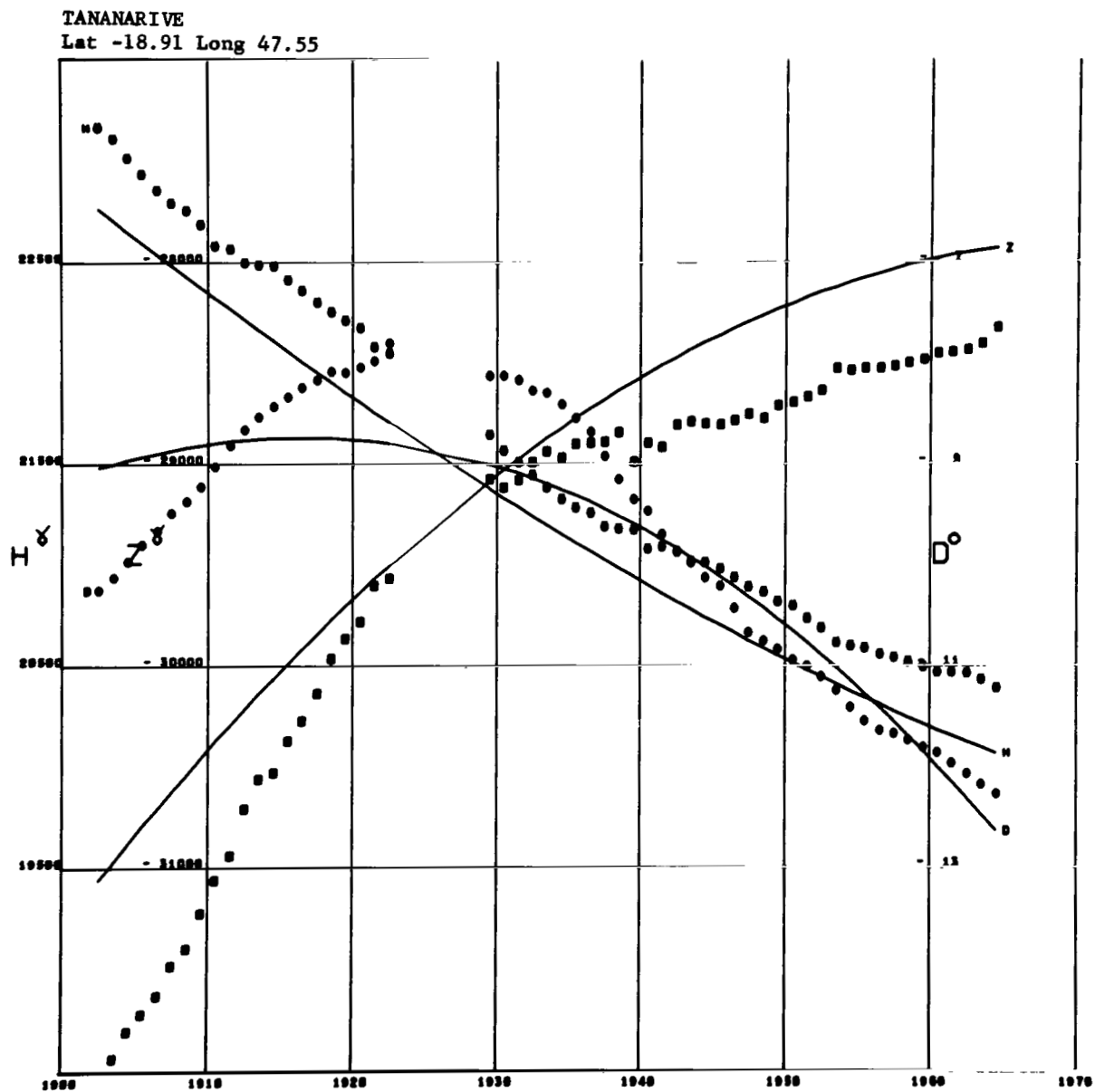


Figure A167

TASHKENT  
 Lat 41.33 Long 69.30

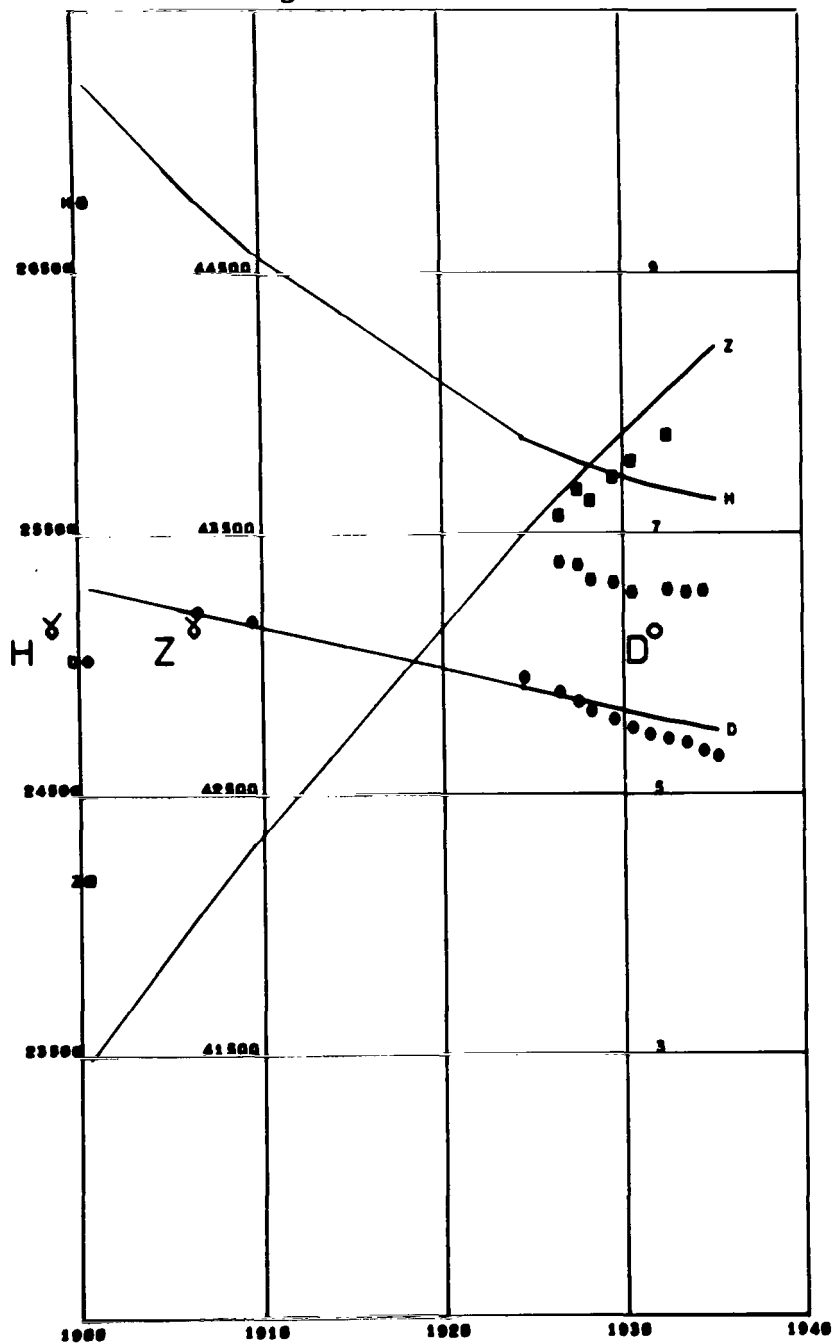


Figure A168

TATUOCA  
 Lat -1.20 Long -48.51

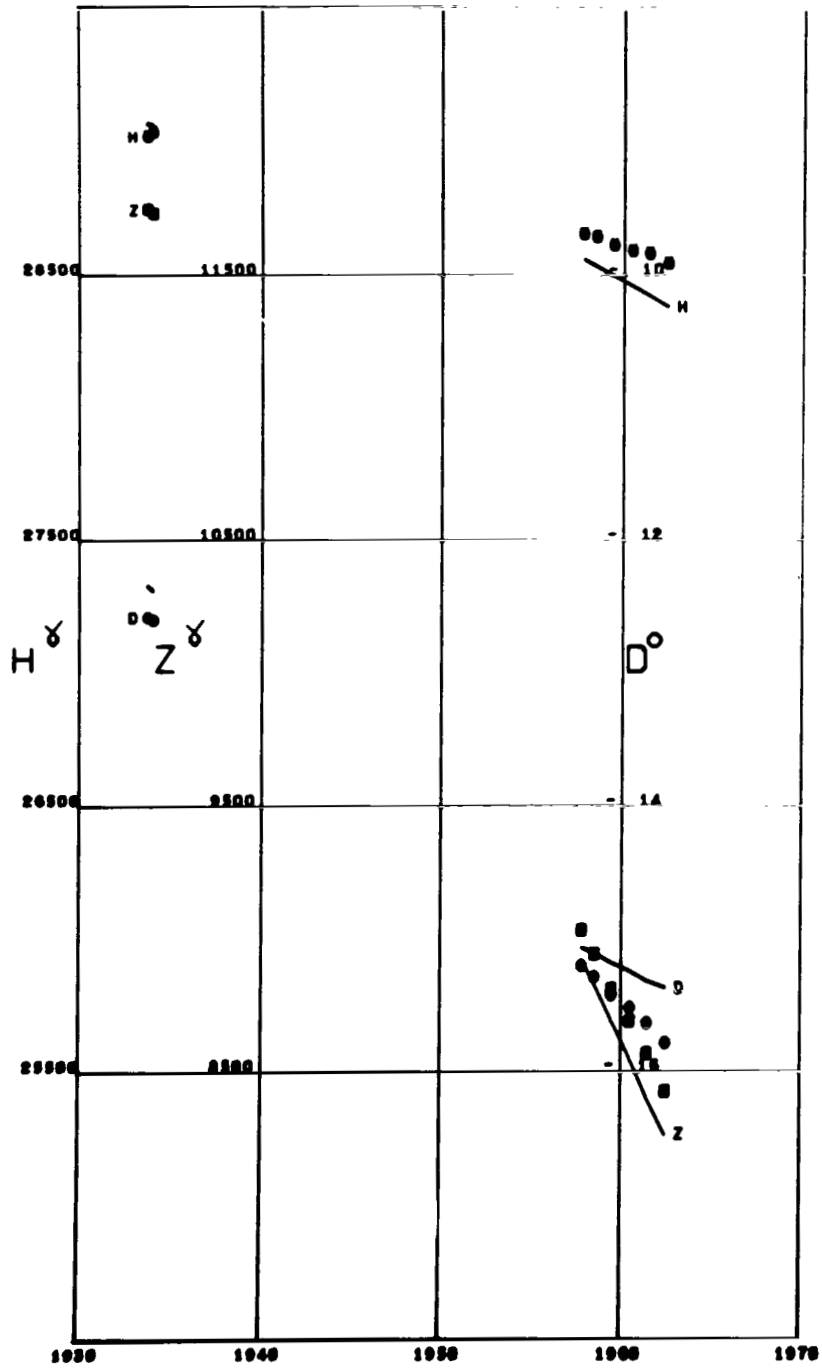


Figure A169



# TBILISI

Lat 41.71 Long 44.79

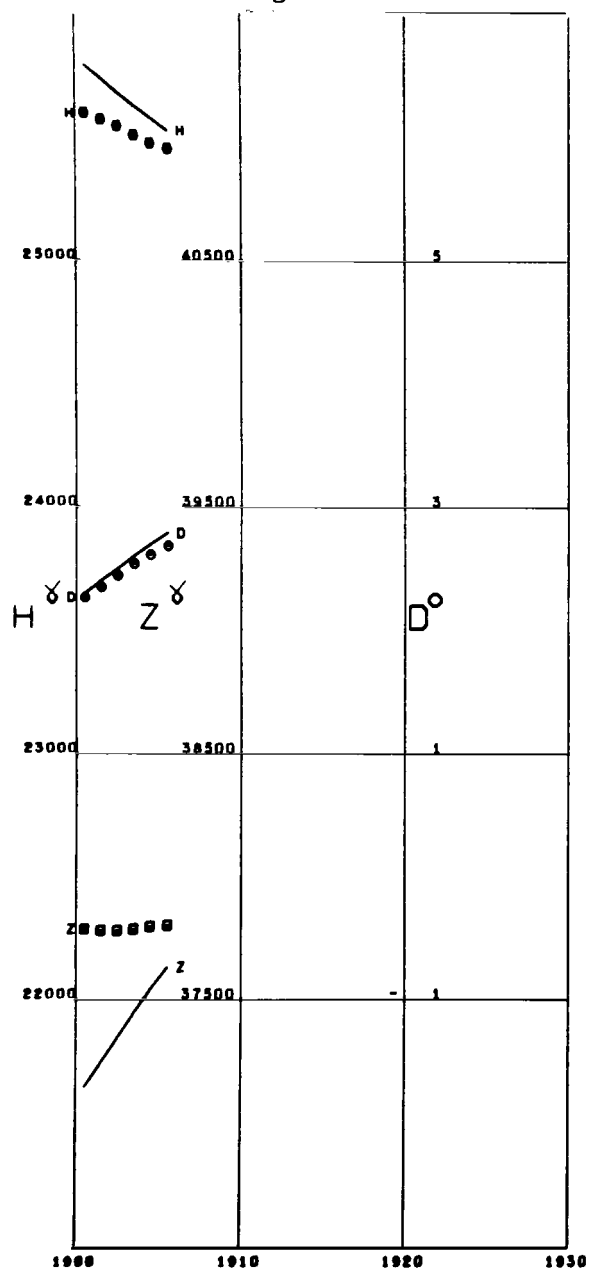


Figure A170

# TEHRAN

Lat 35.73 Long 51.38

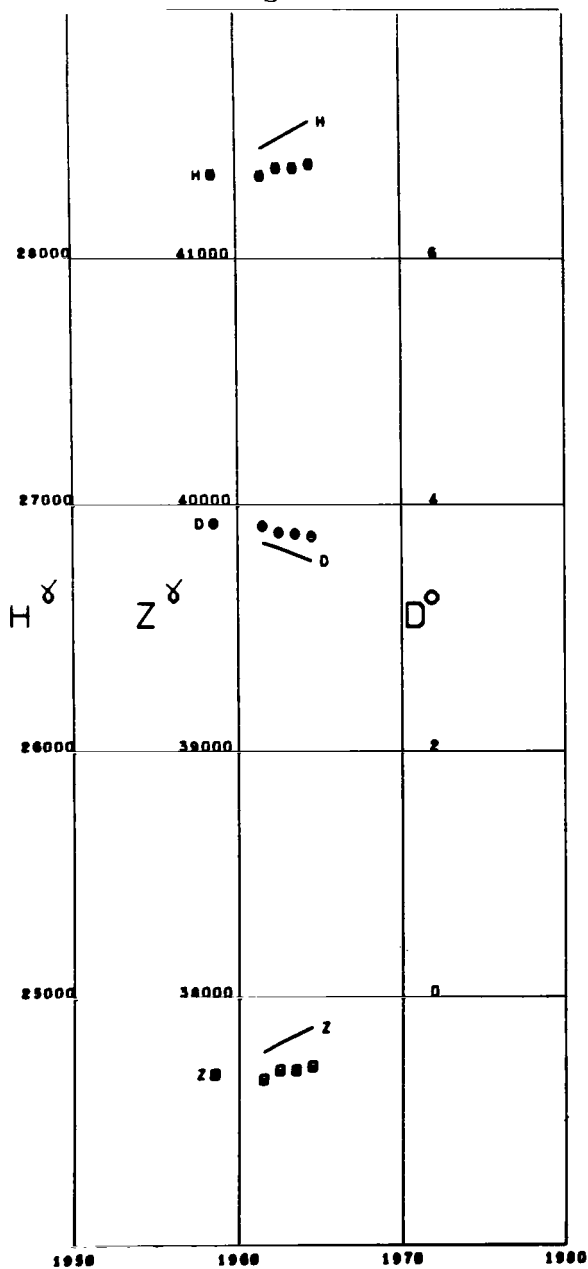


Figure A171

TENERIFE  
 Lat 28.47 Long -16.27 Alt 0.40

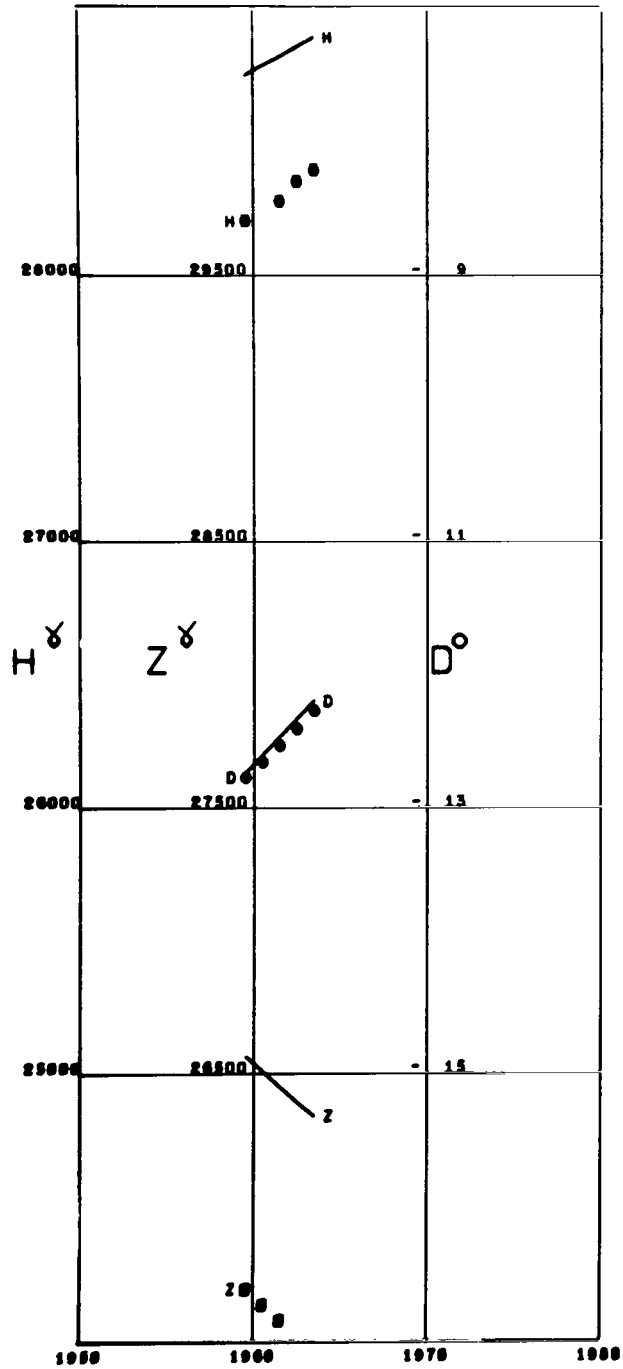


Figure A172

TEOLOYUCAN  
 Lat 19.74 Long -99.18

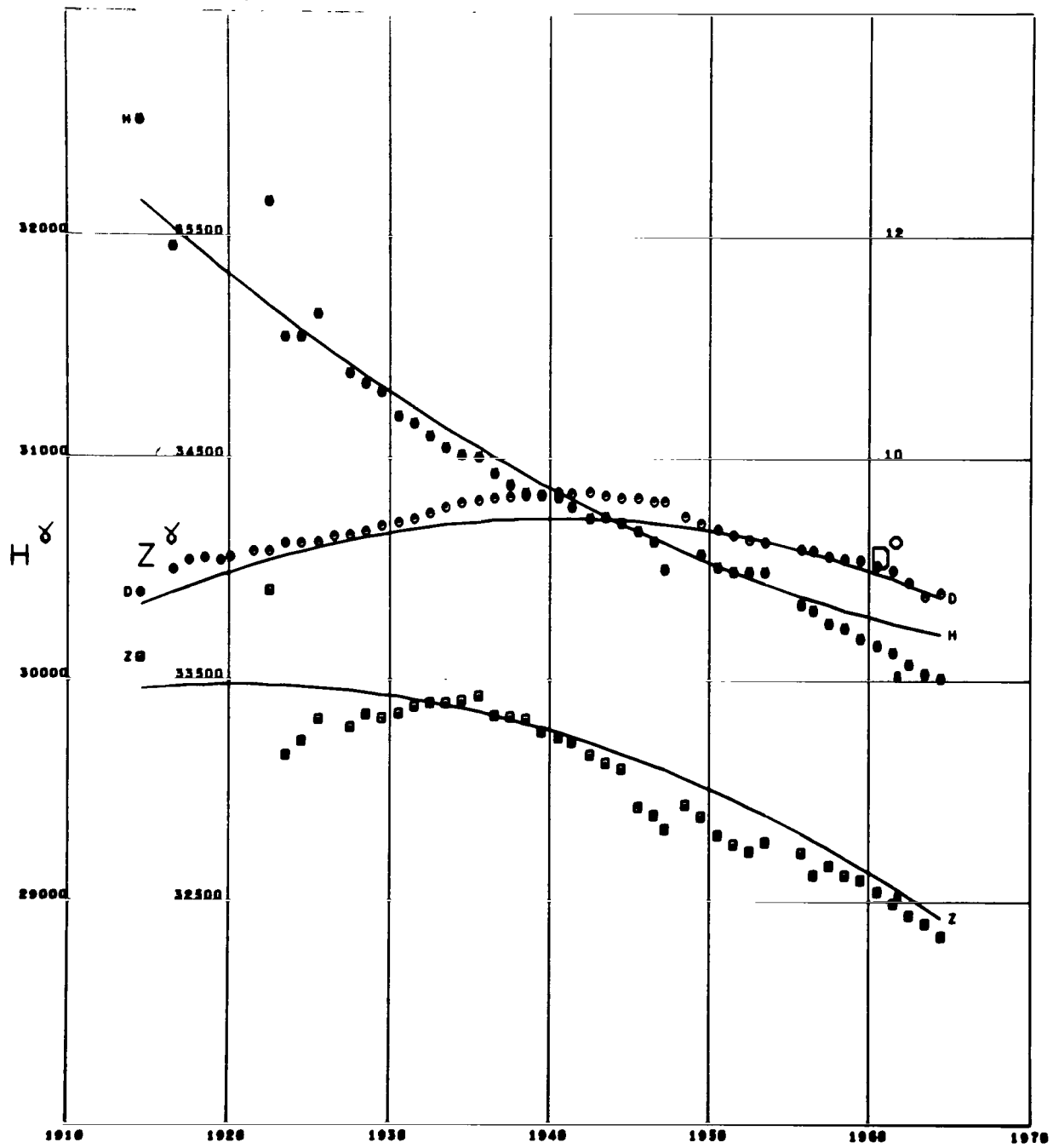


Figure A173

THULE II  
 Lat 77.48 Long -69.16

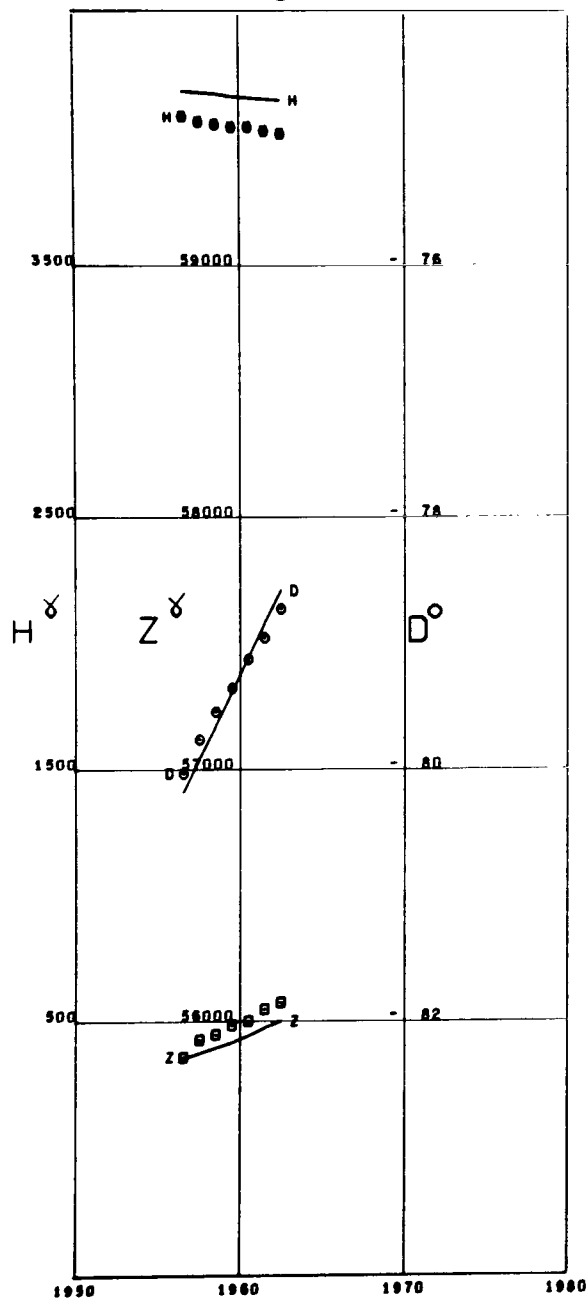


Figure A174

TIHANY  
 Lat 46.90 Long 17.89

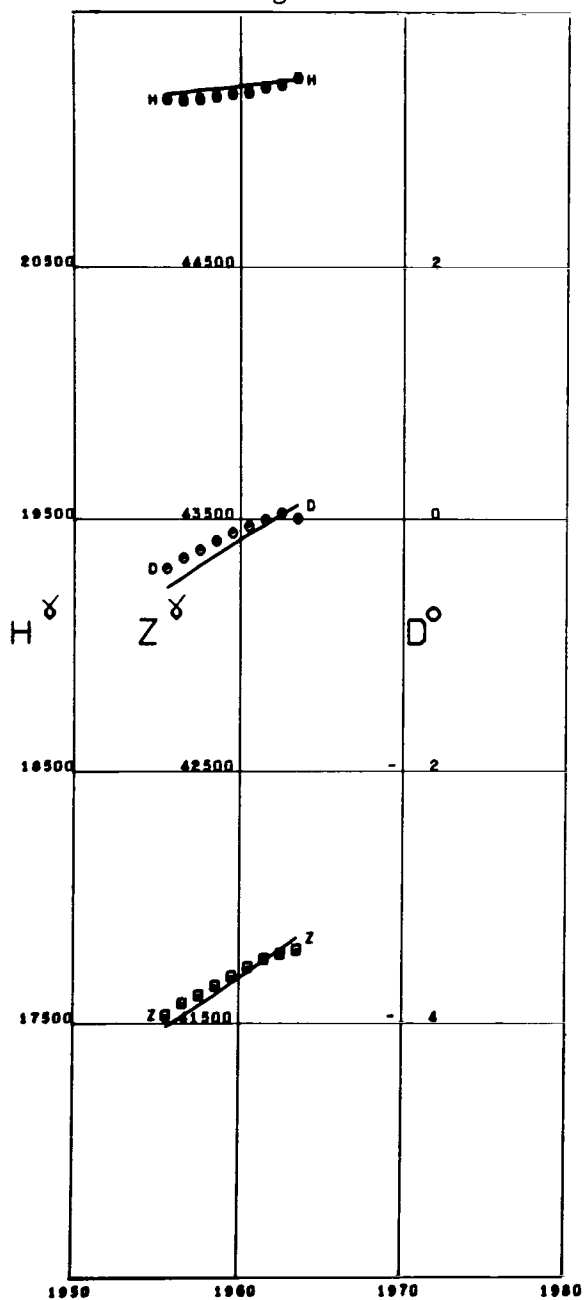


Figure A175

TIKHAYA BAY  
Lat 80.33 Long 52.80

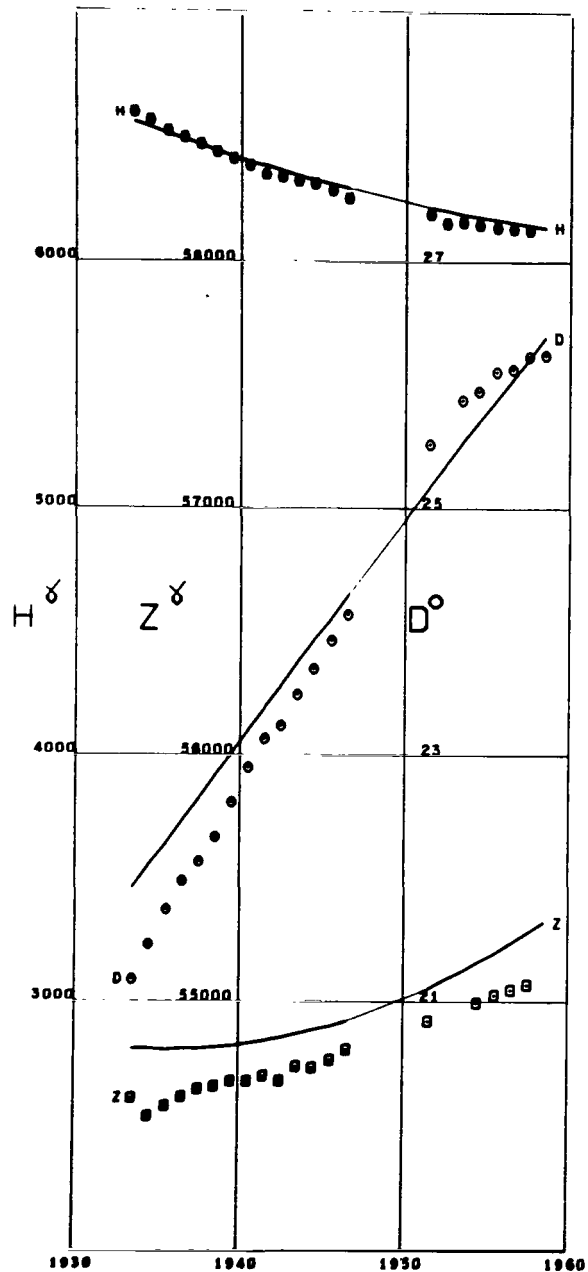


Figure A176

TIKSI  
Lat 71.58 Long 129.00

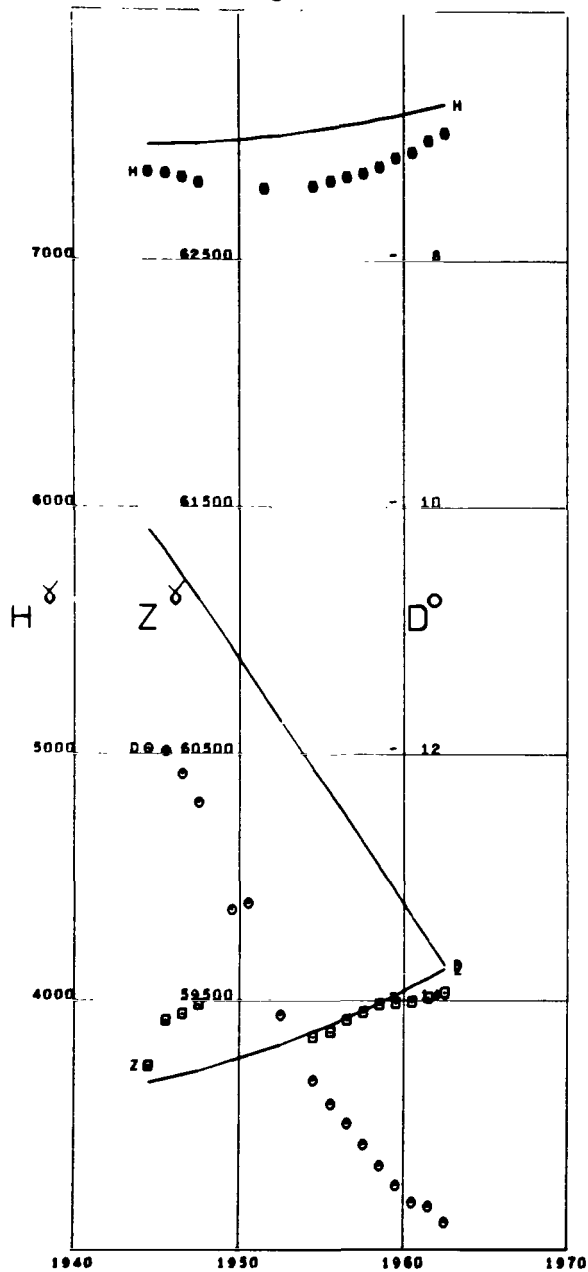


Figure A177

TOKYO  
Lat 35.68 Long 139.75

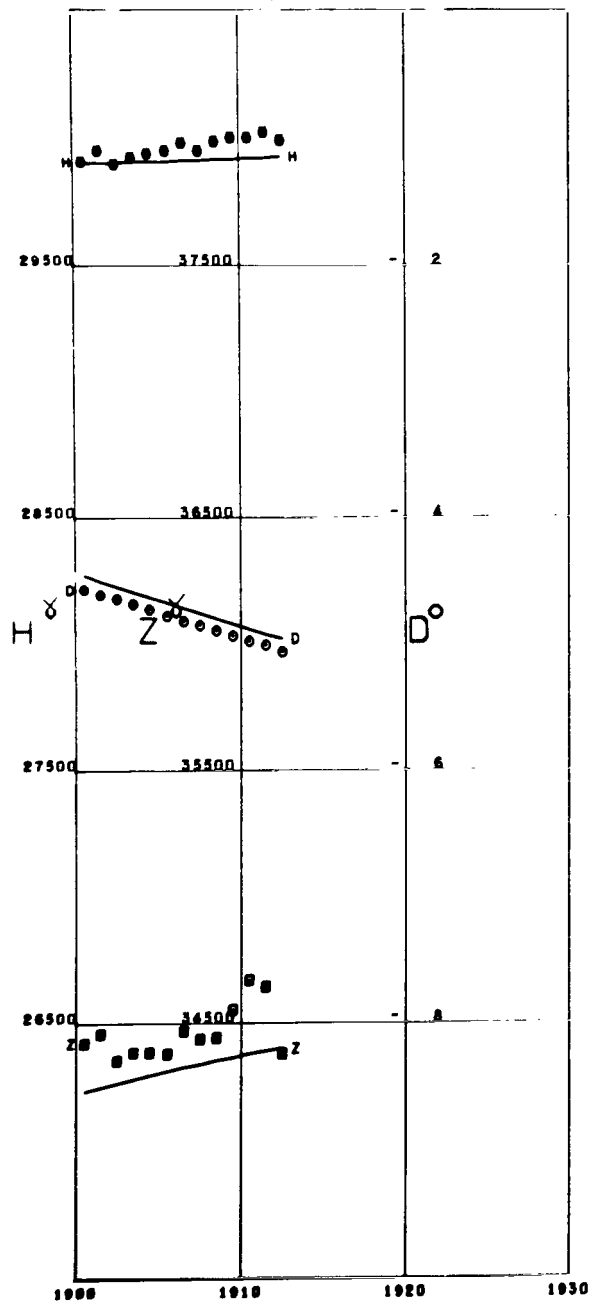


Figure A178

TOLEDO  
Lat 39.88 Long -4.04 Alt 0.50

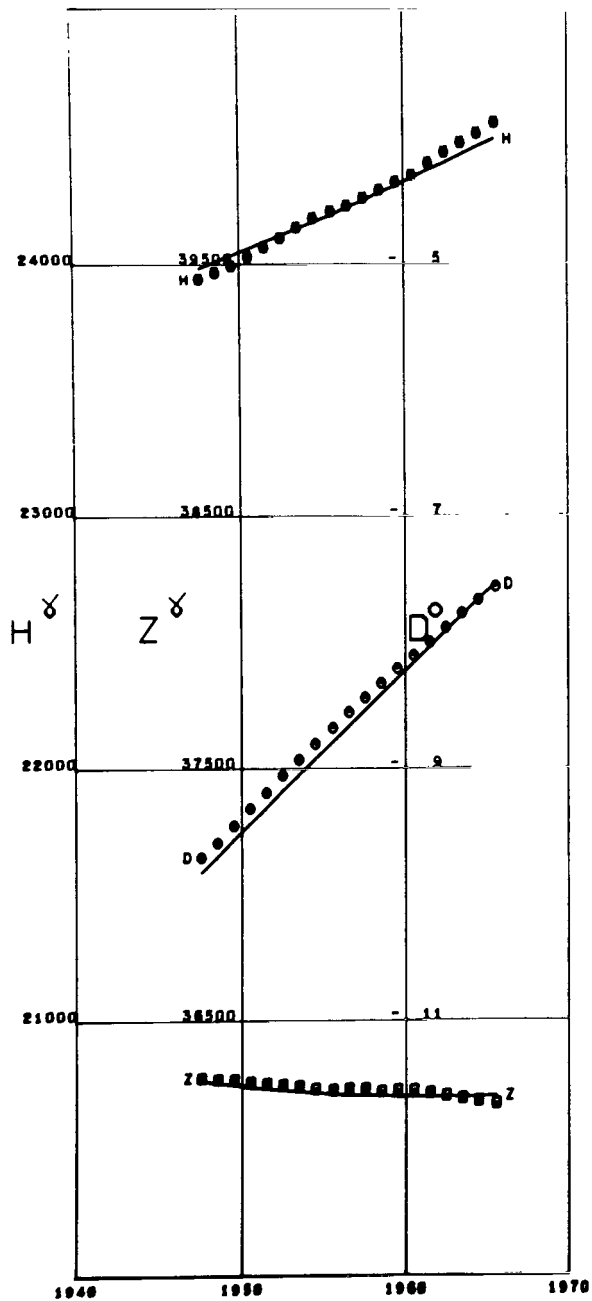


Figure A179

TOOLANGI

Lat -37.53 Long 145.46 Alt 0.48

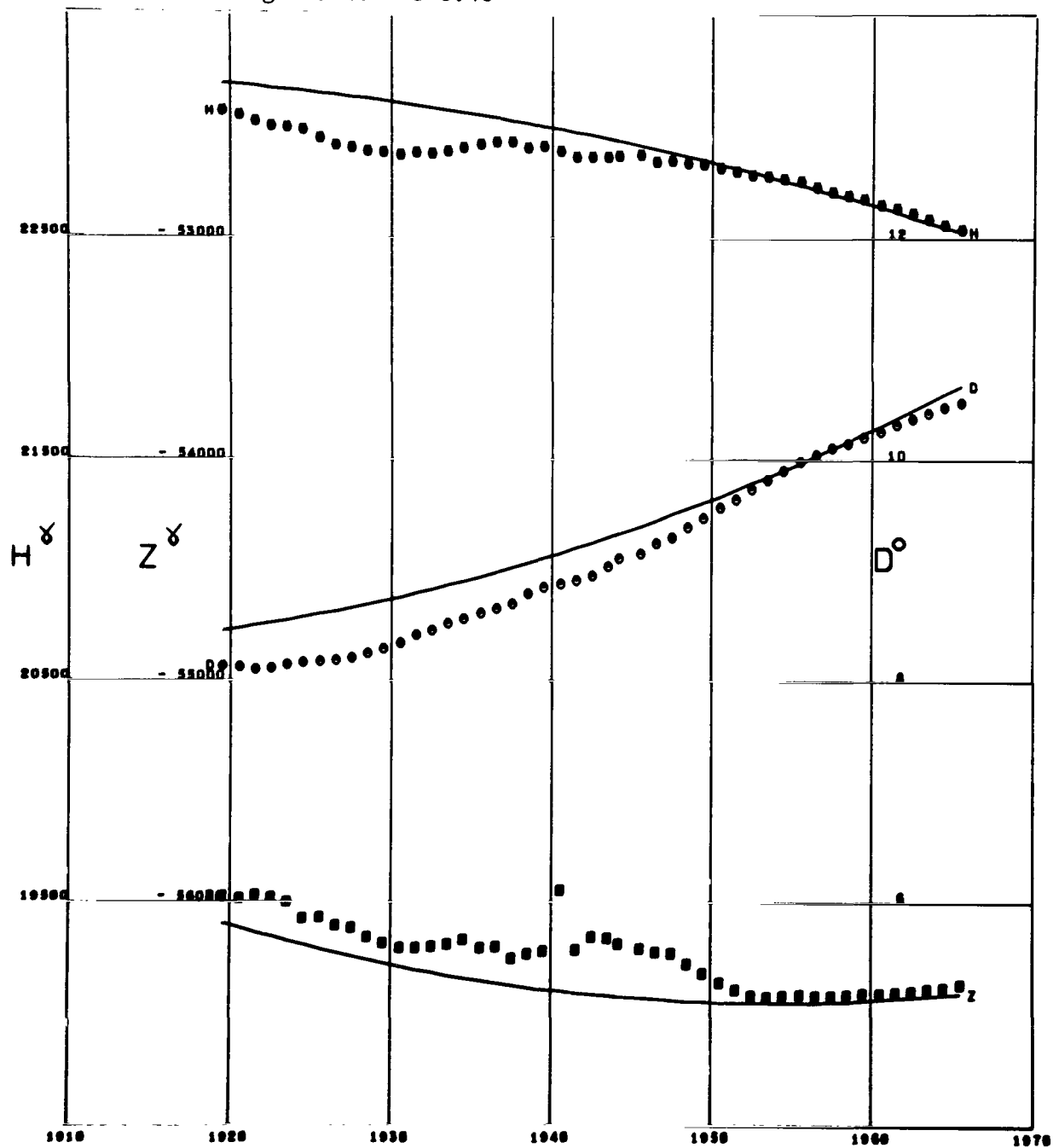


Figure A180

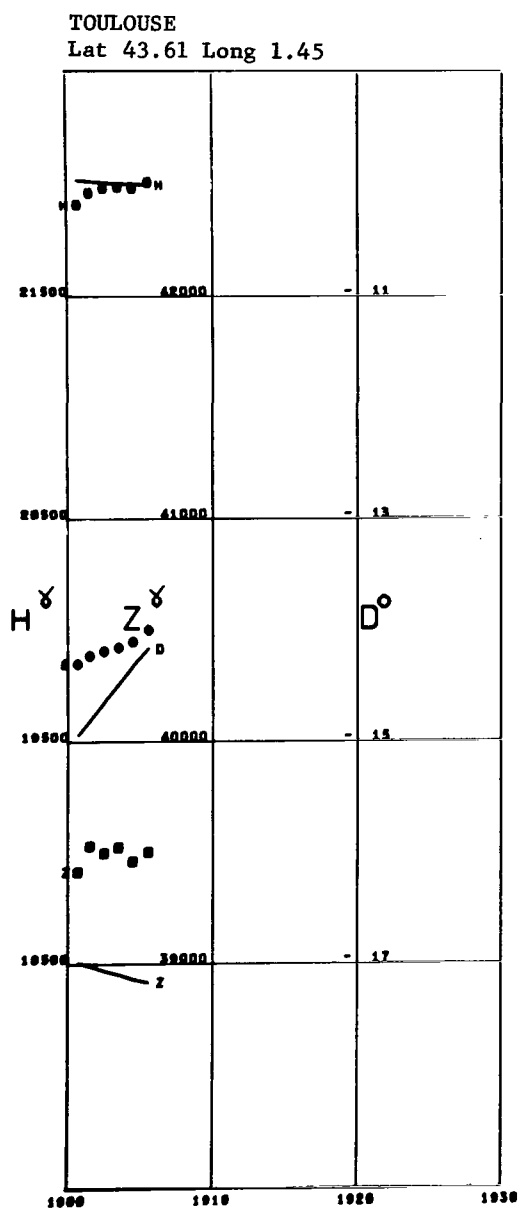


Figure A181

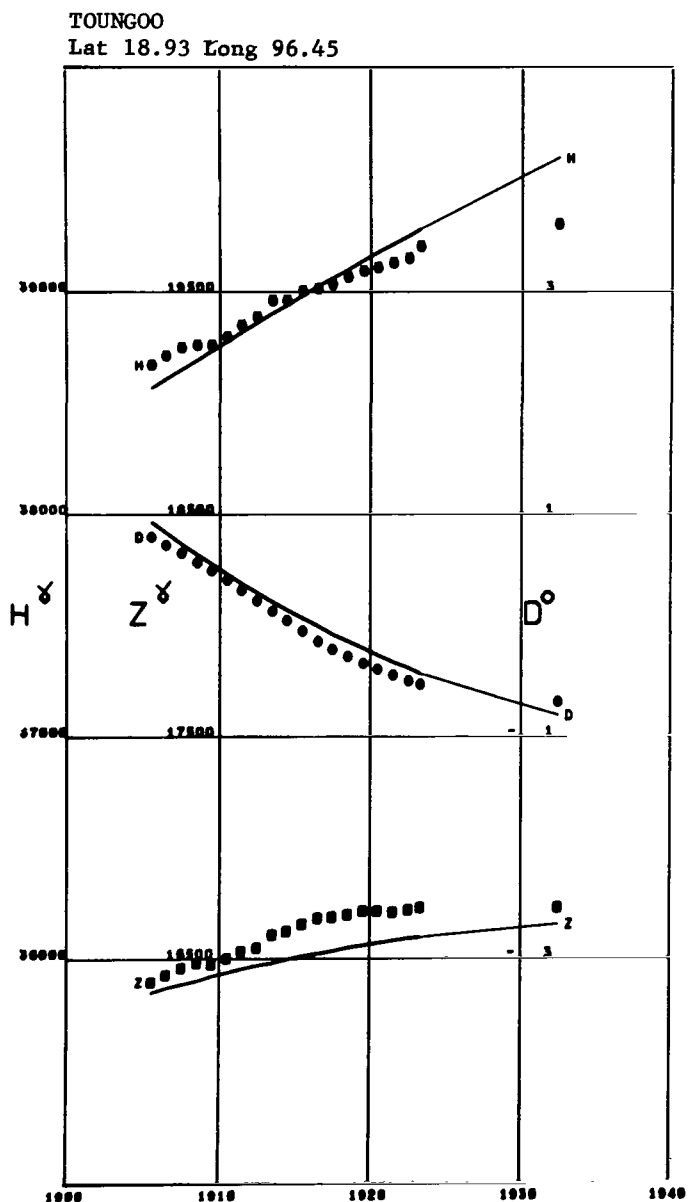


Figure A182



TOYOHARA

Lat 46.94 Long 142.74

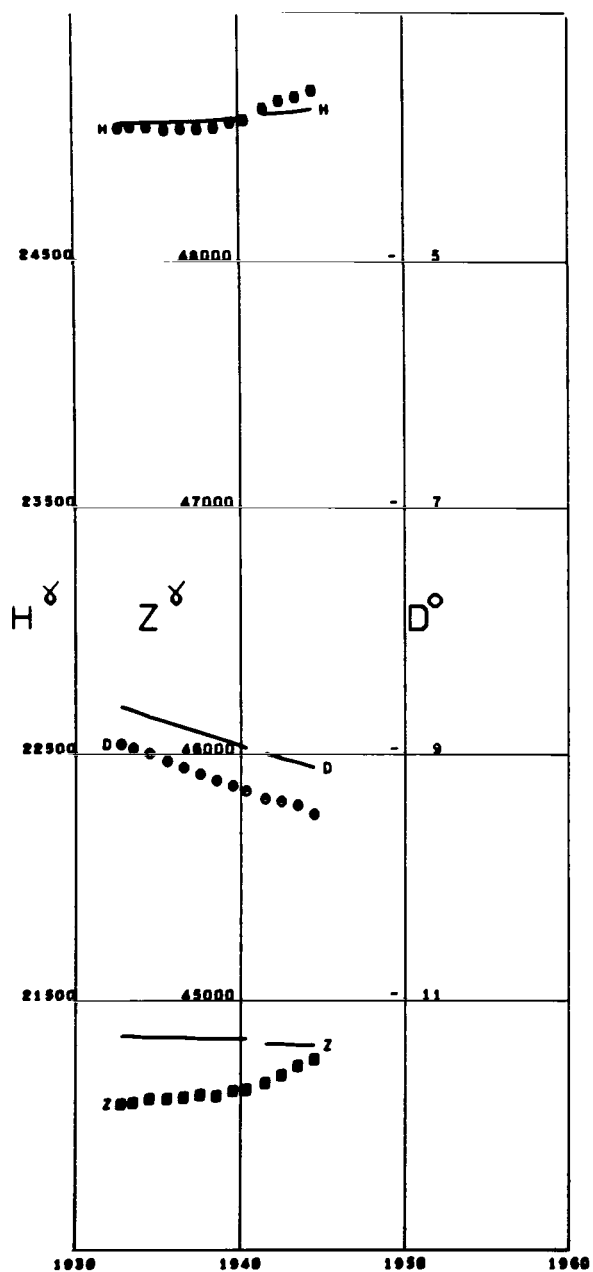


Figure A183

TRELEW

Lat -43.24 Long -65.31 Alt 0.03

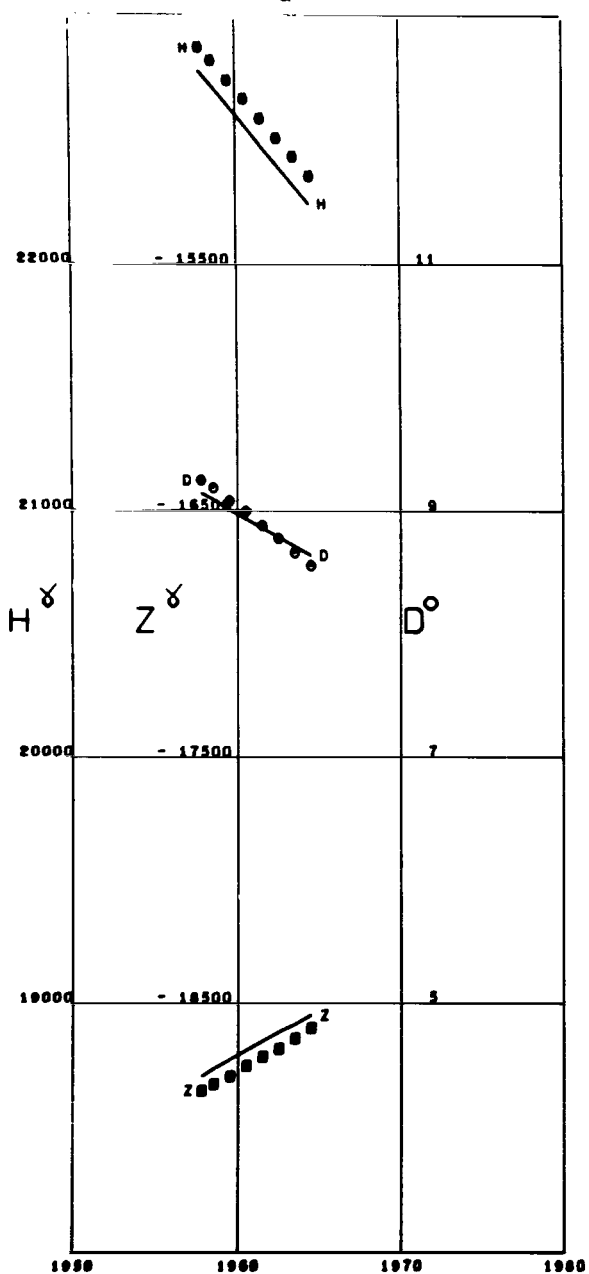


Figure A184

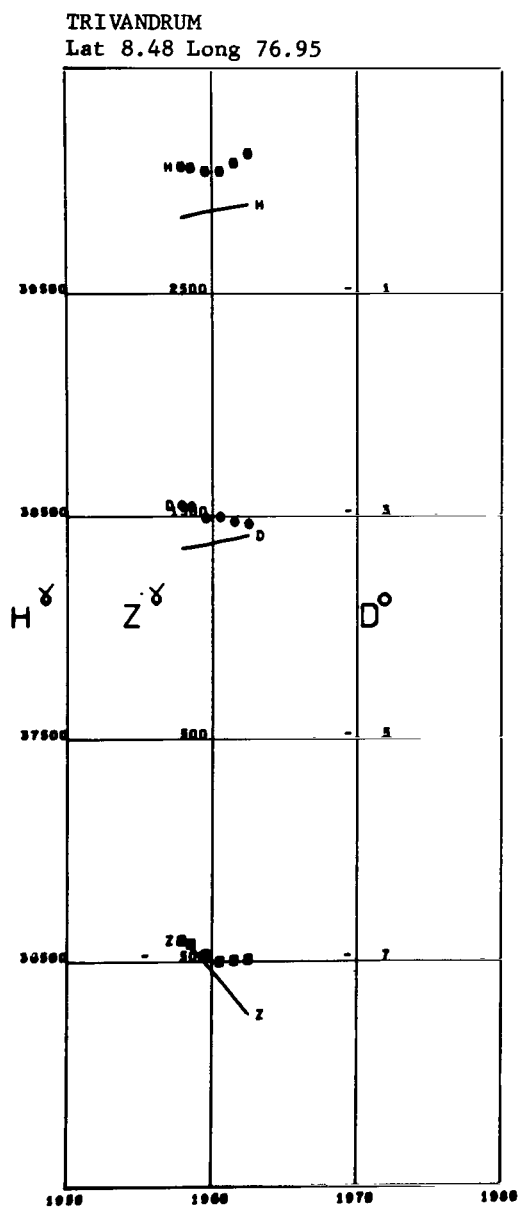


Figure A185

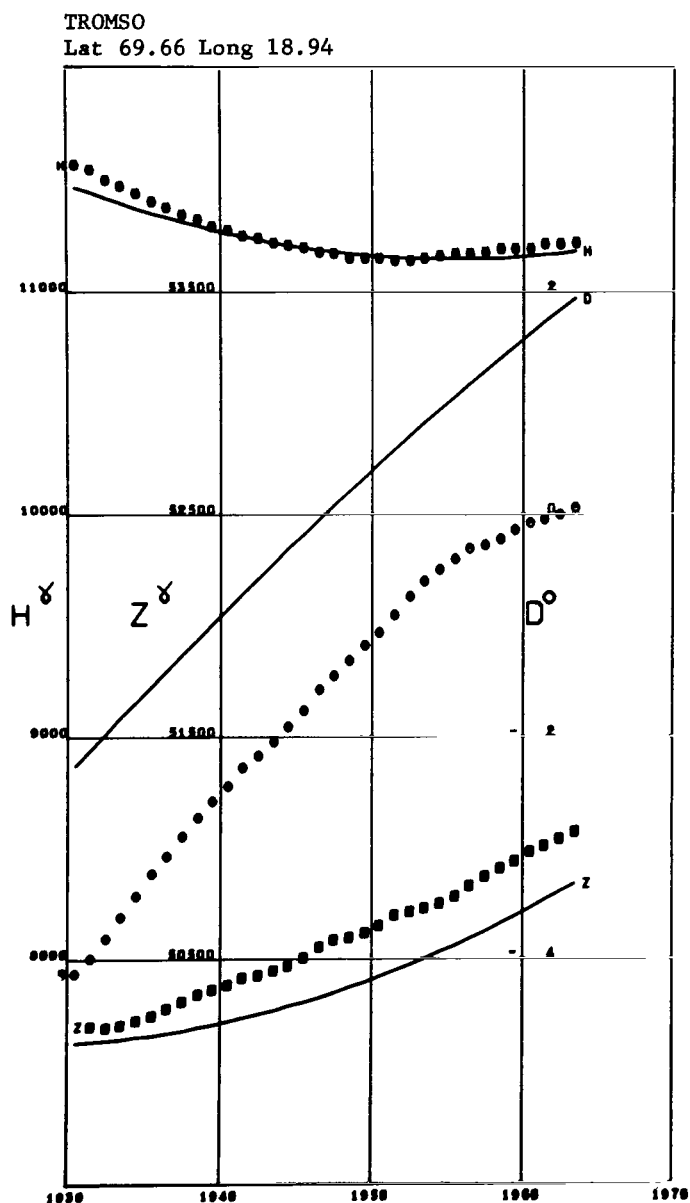


Figure A186

TSINGTAO  
 Lat 36.07 Long 120.32

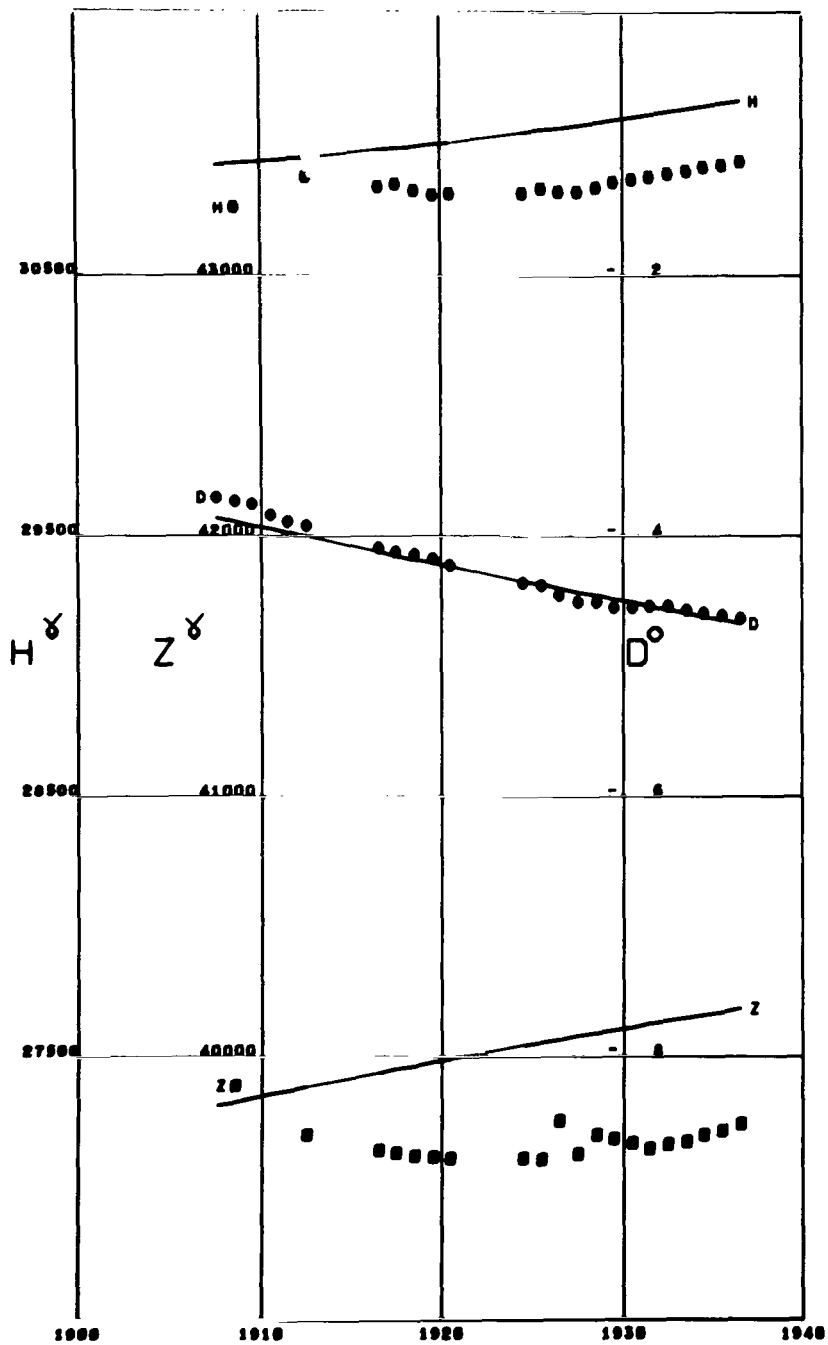


Figure A187

TUCSON

Lat 32.24 Long -110.83 Alt 0.77

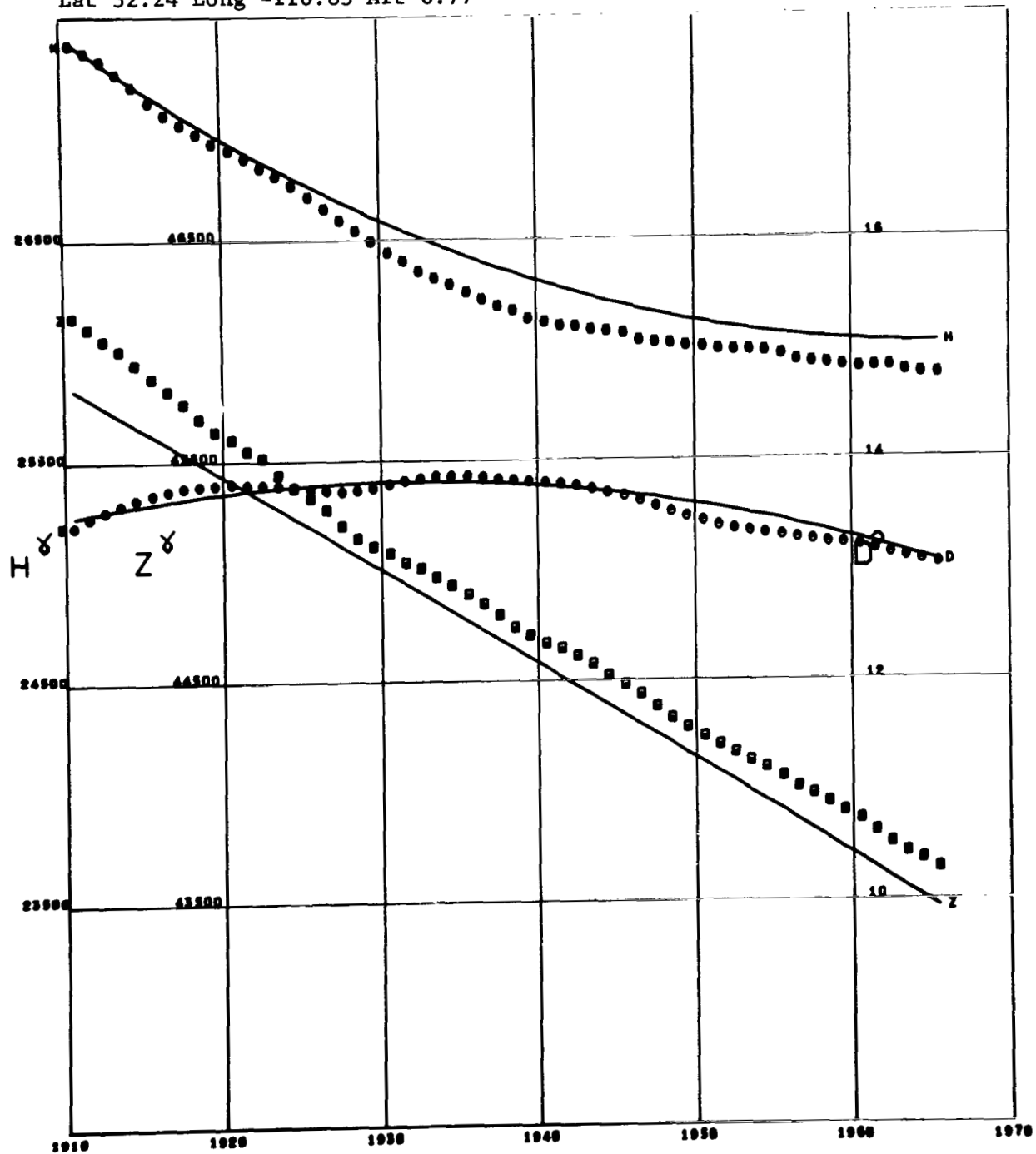


Figure A188

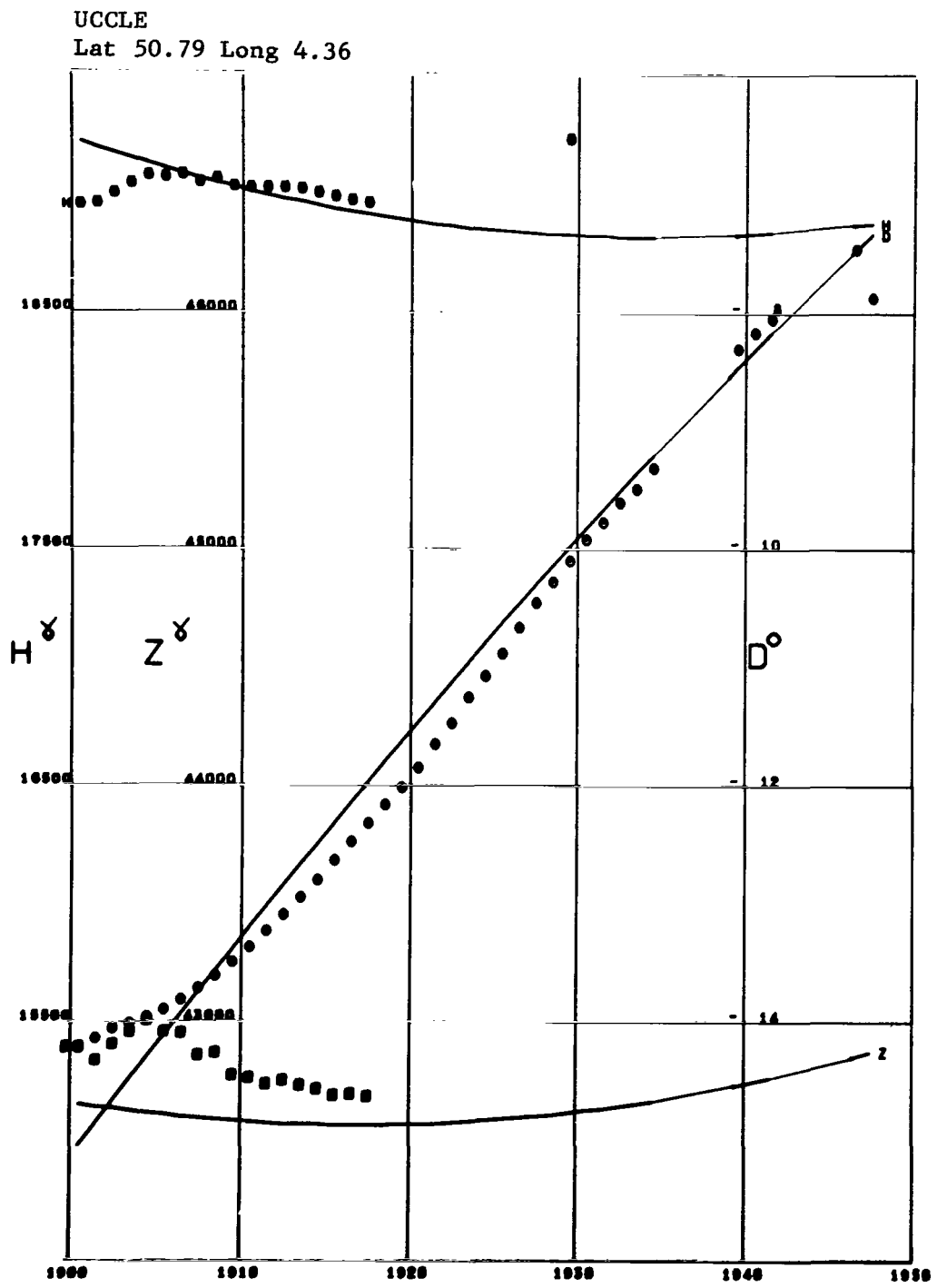


Figure A189

UELEN  
 Lat 66.16 Long -169.83

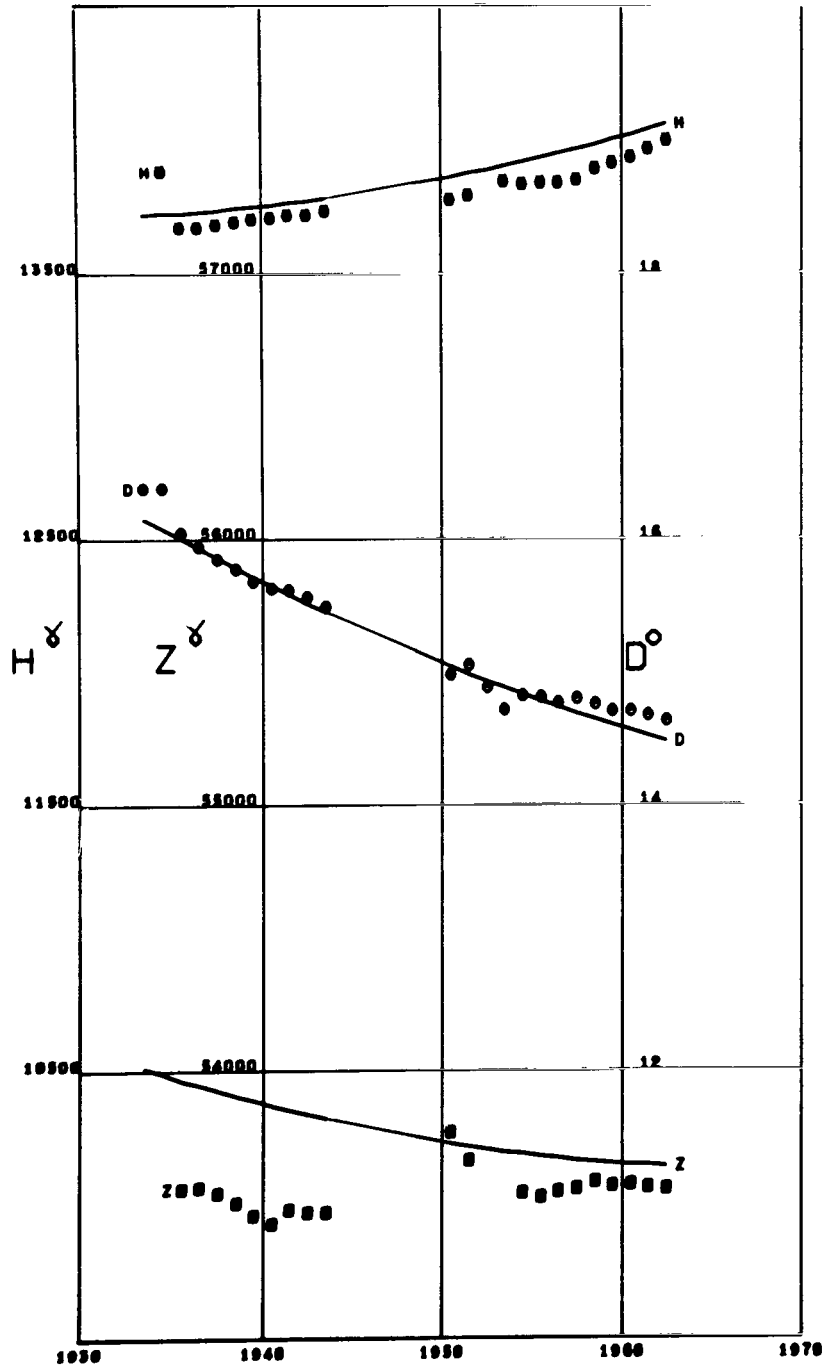


Figure A190

VAL JOYEUX  
 Lat 48.82 Long 2.01

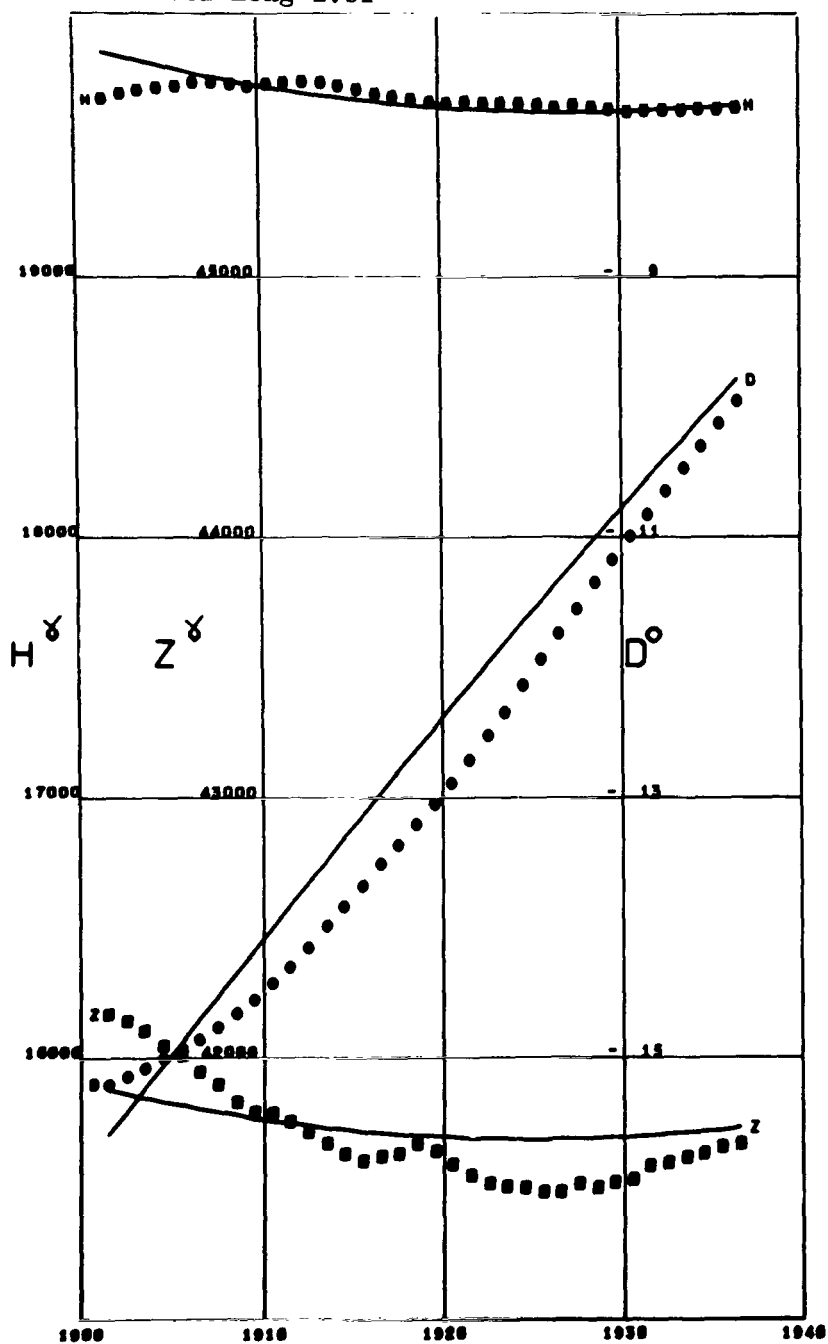


Figure A191

VALENTIA  
 Lat 51.93 Long -10.25

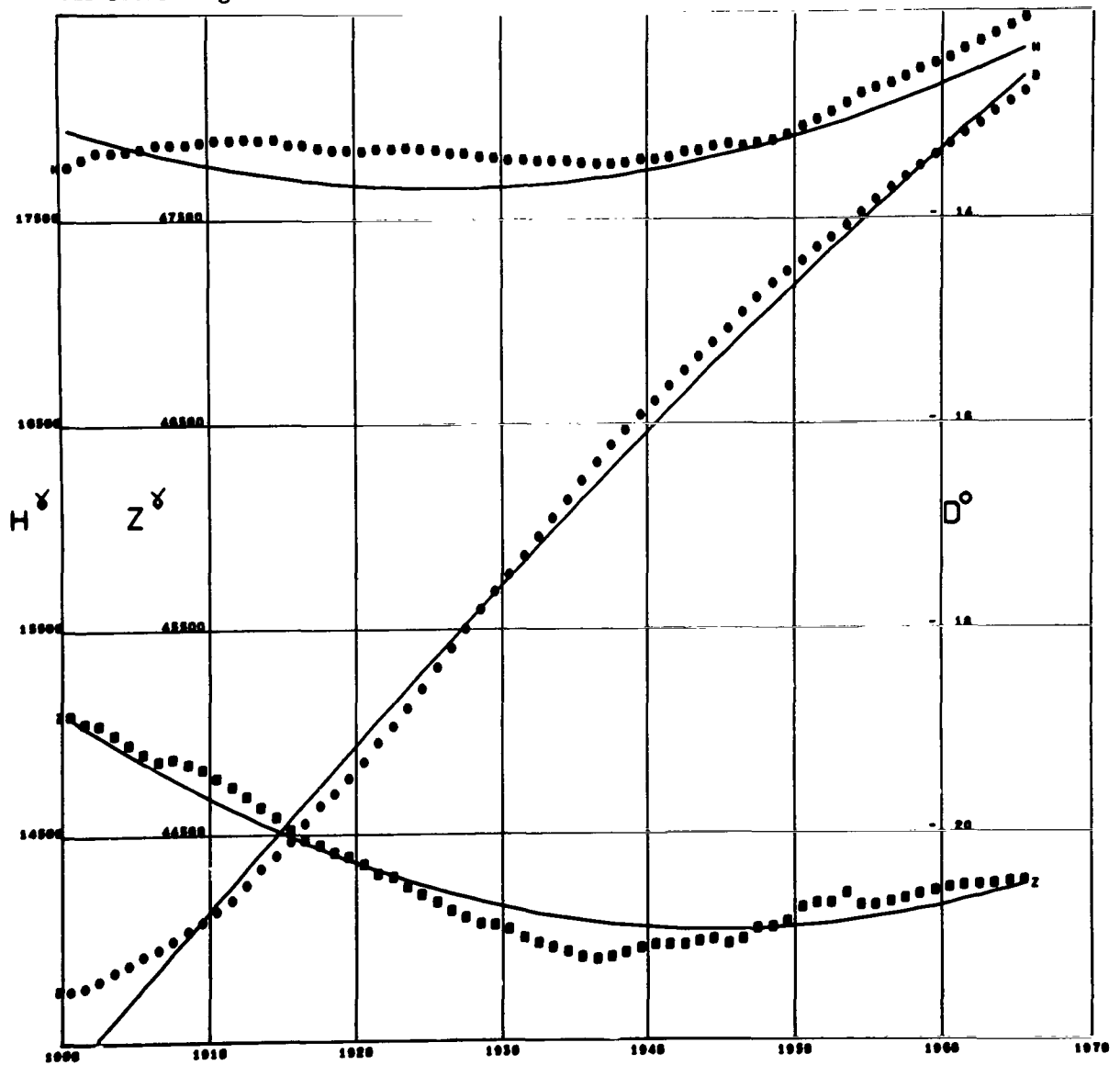


Figure A192



VASSOURAS

Lat -22.40 Long -43.65 Alt 0.46

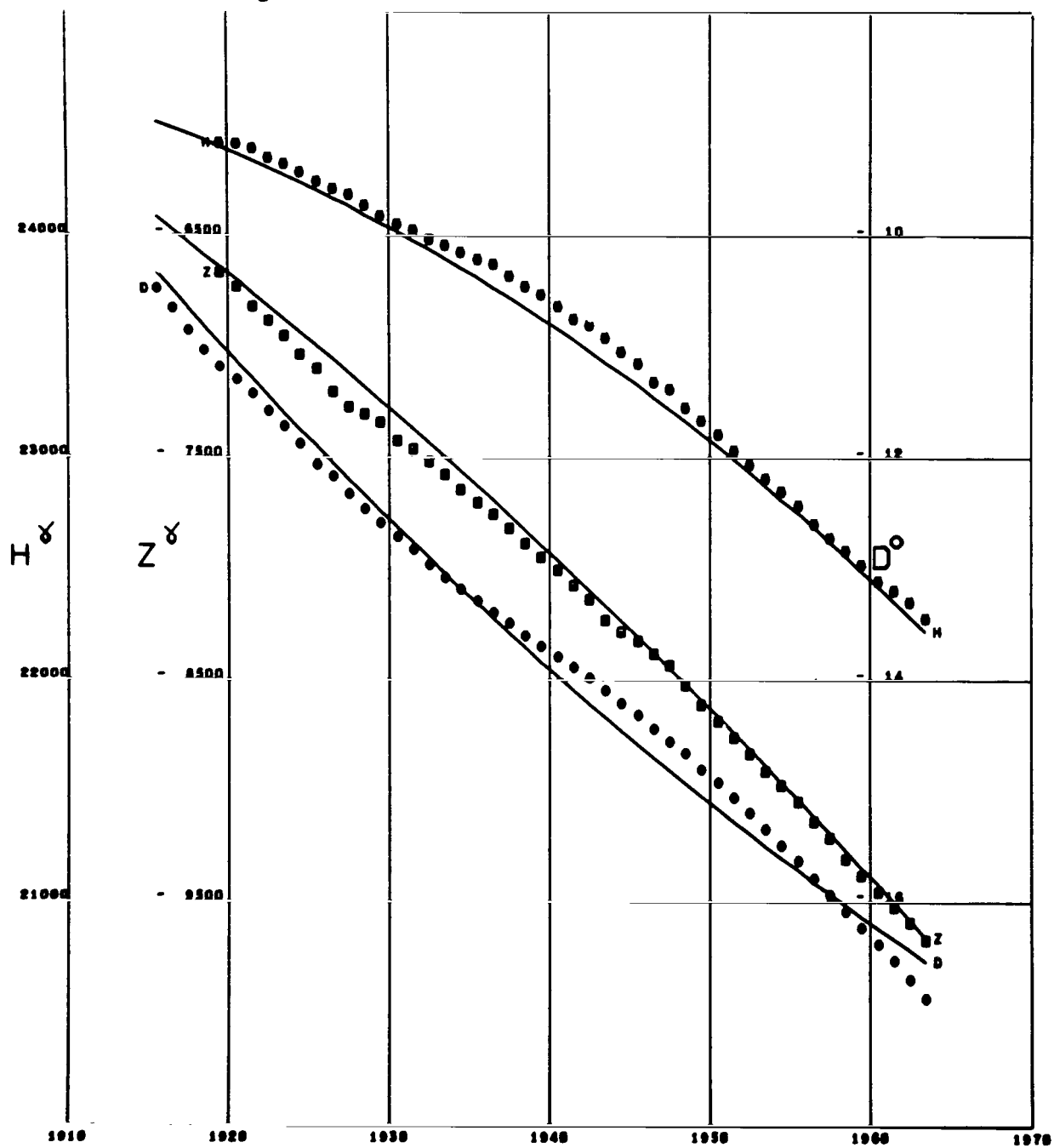


Figure A193

VYKHODNOY  
 Lat 73.23 Long 56.73

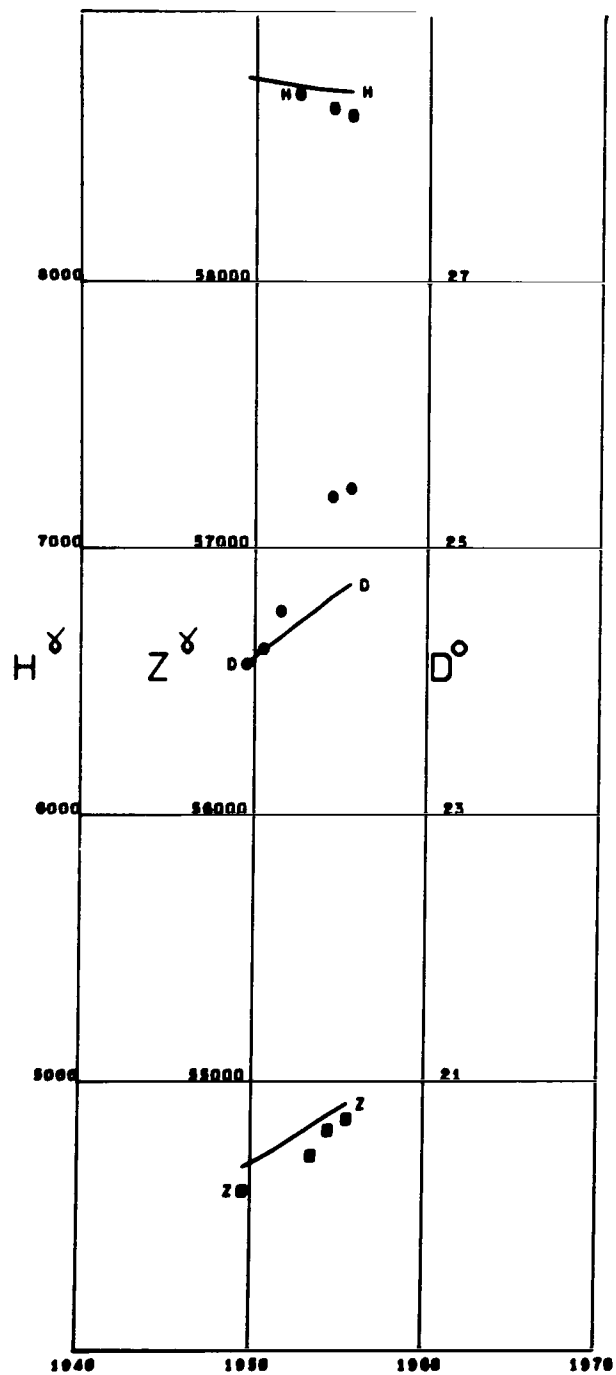


Figure A198

VYSOKAYA DUBRAVA  
 Lat 56.73 Long 61.06 Alt 0.29

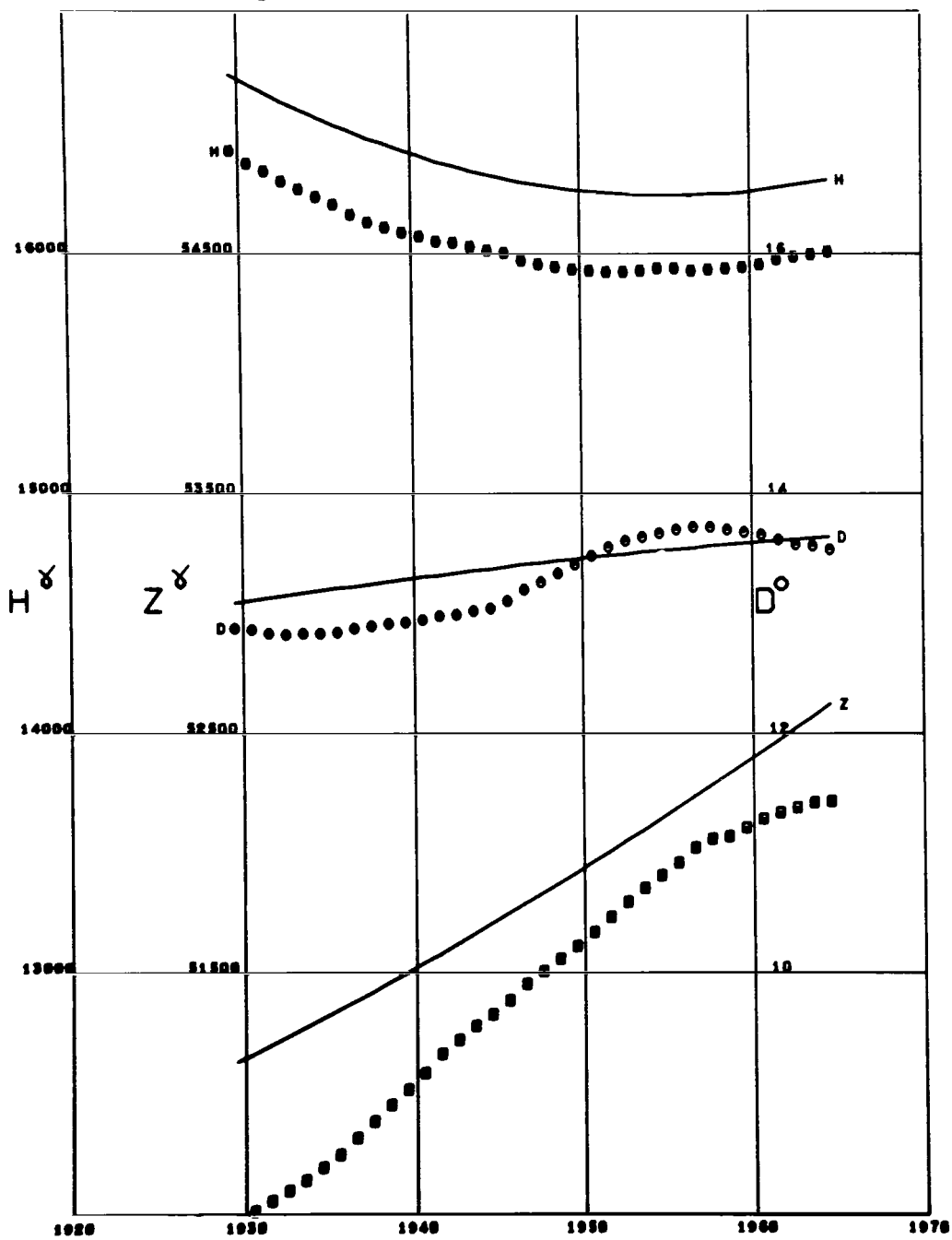


Figure A199

WATHEROO  
 Lat -30.31 Long 115.87

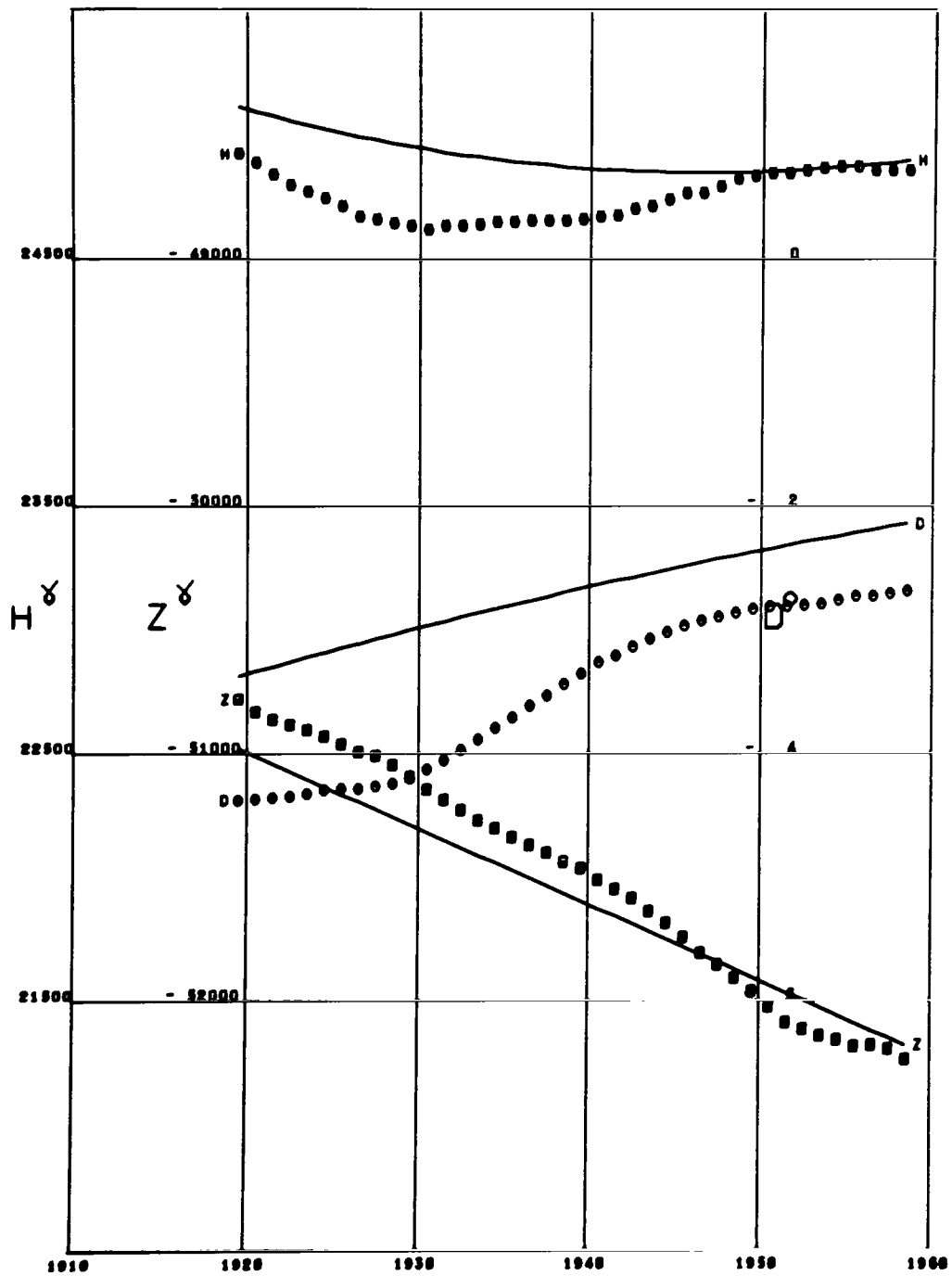


Figure A200

WIEN AUHOF  
Lat 48.20 Long 16.23

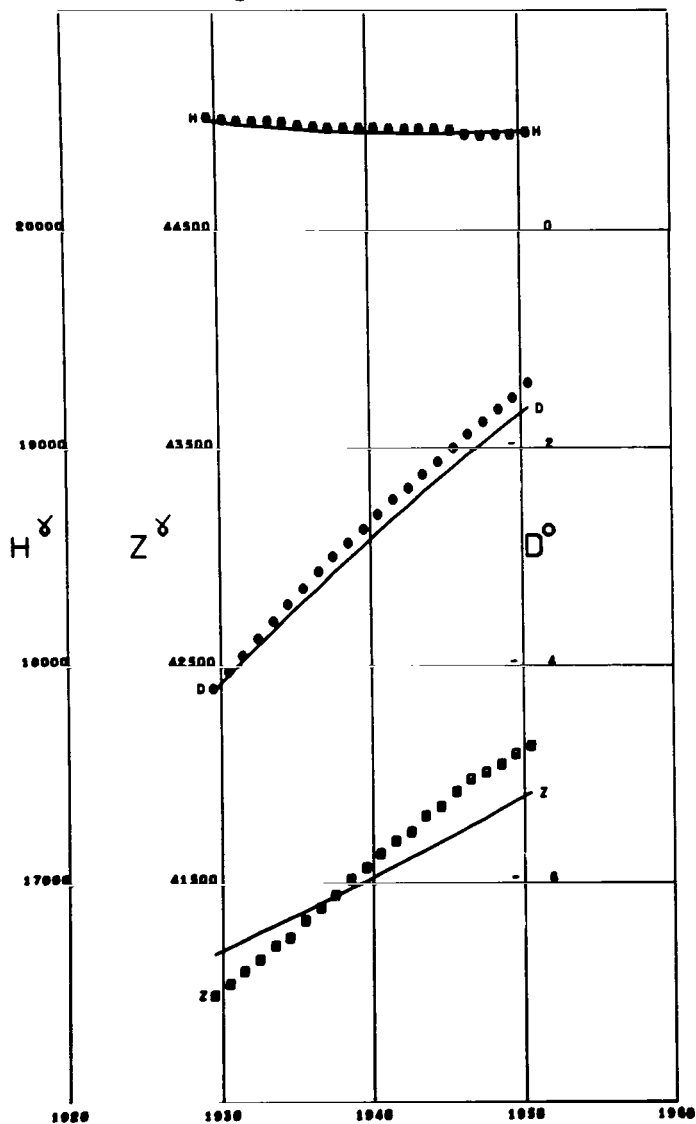


Figure A201

WIEN KOBENZL  
Lat 48.26 Long 16.31

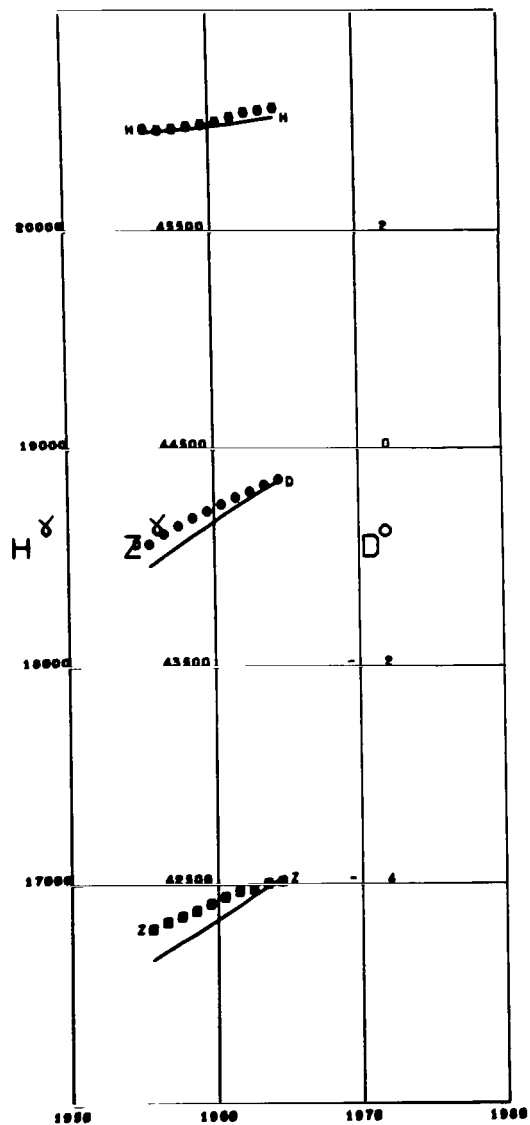


Figure A202

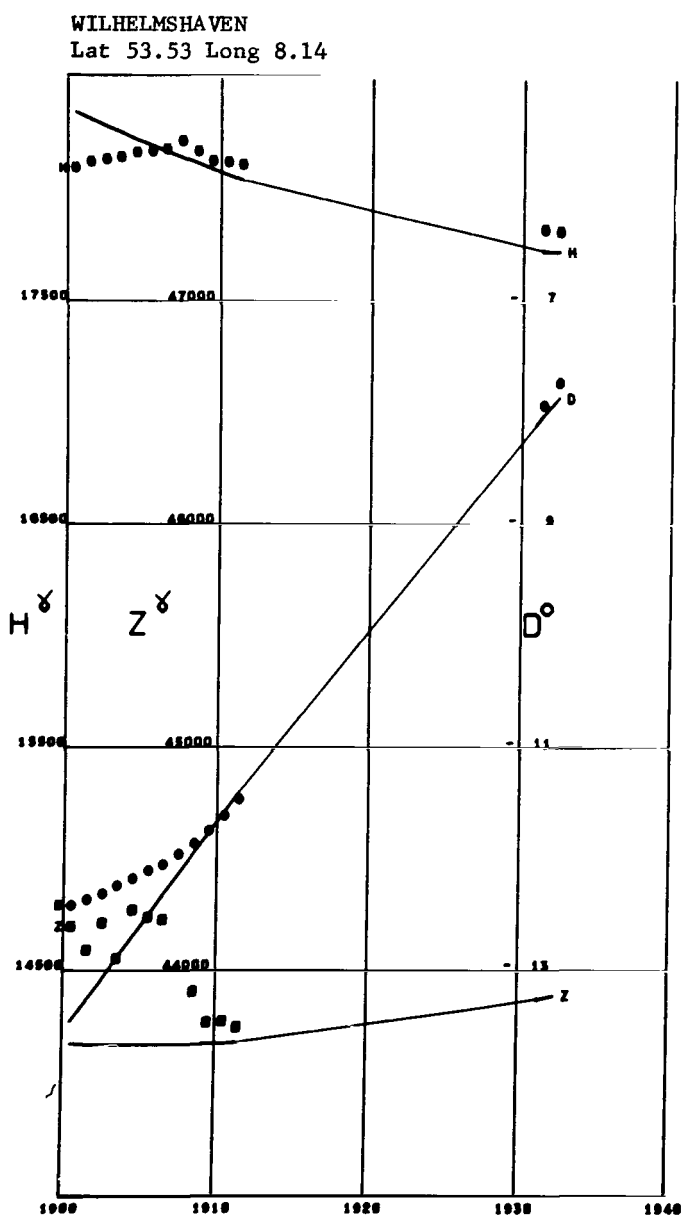


Figure A203

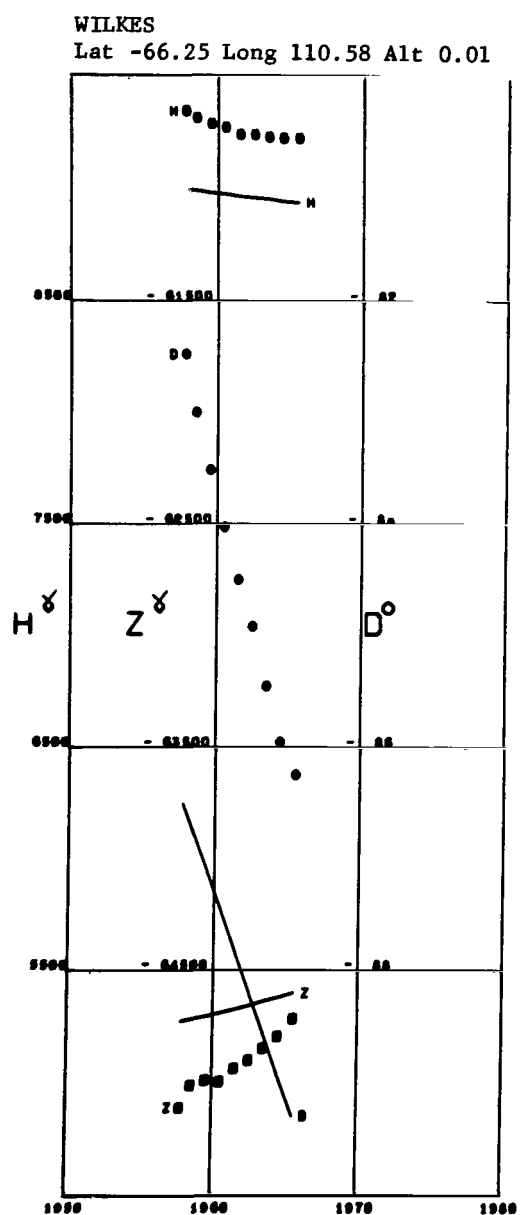


Figure A204

WINGST  
 Lat 53.74 Long 9.07

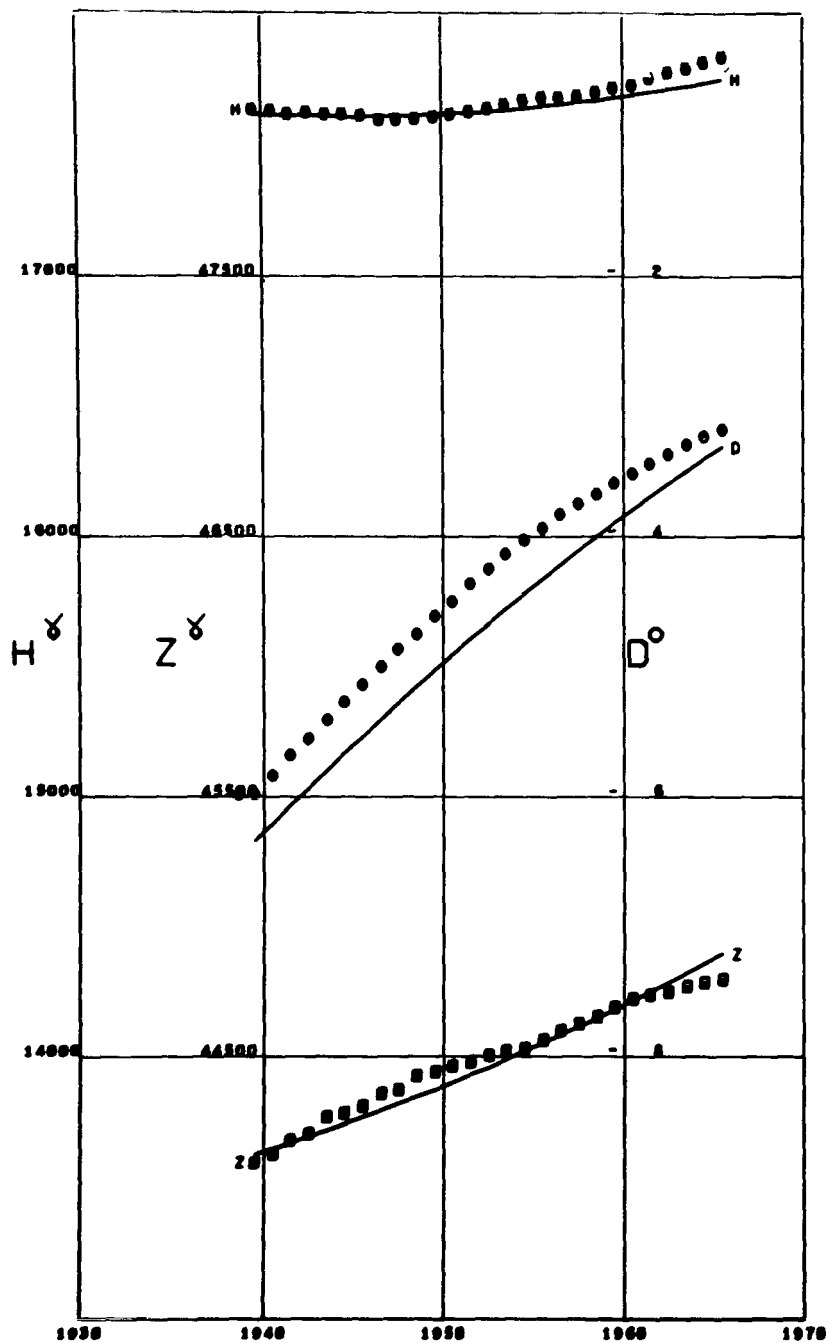


Figure A205

WITTEVEEN  
 Lat 52.81 Long 6.66

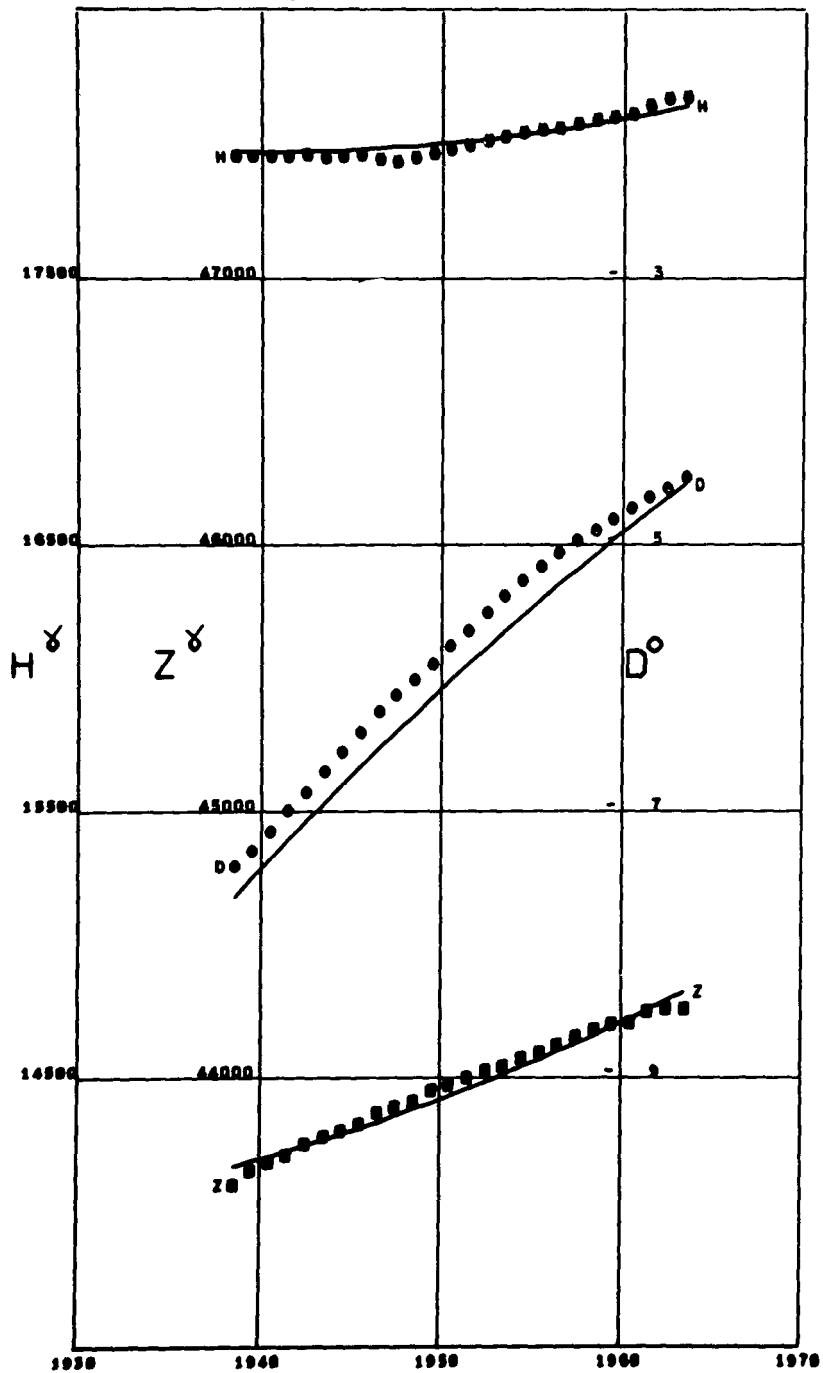


Figure A206



YAKUTSK  
Lat 62.01 Long 129.71 Alt 0.10

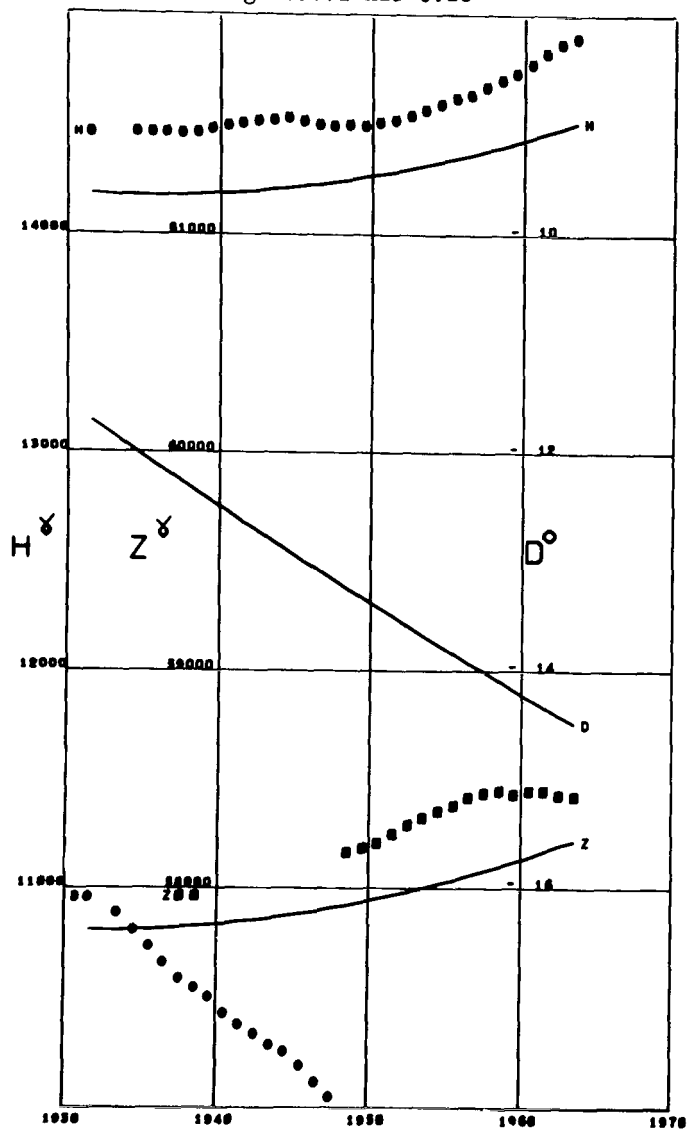


Figure A207

YUZHNO SAKHALINSK  
Lat 46.95 Long 142.71

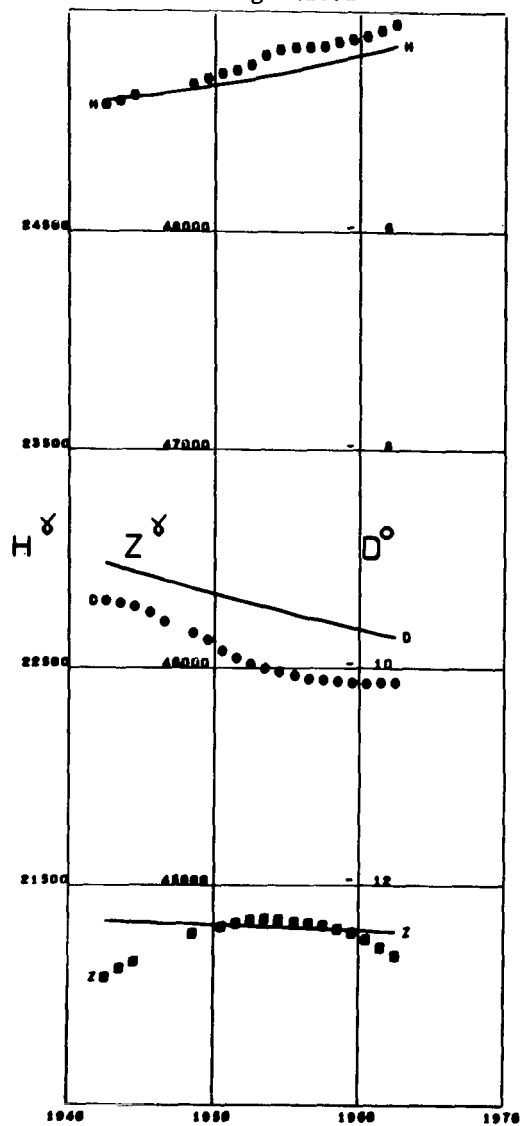


Figure A208

ZAYMISHCHE  
 Lat 55.83 Long 48.85

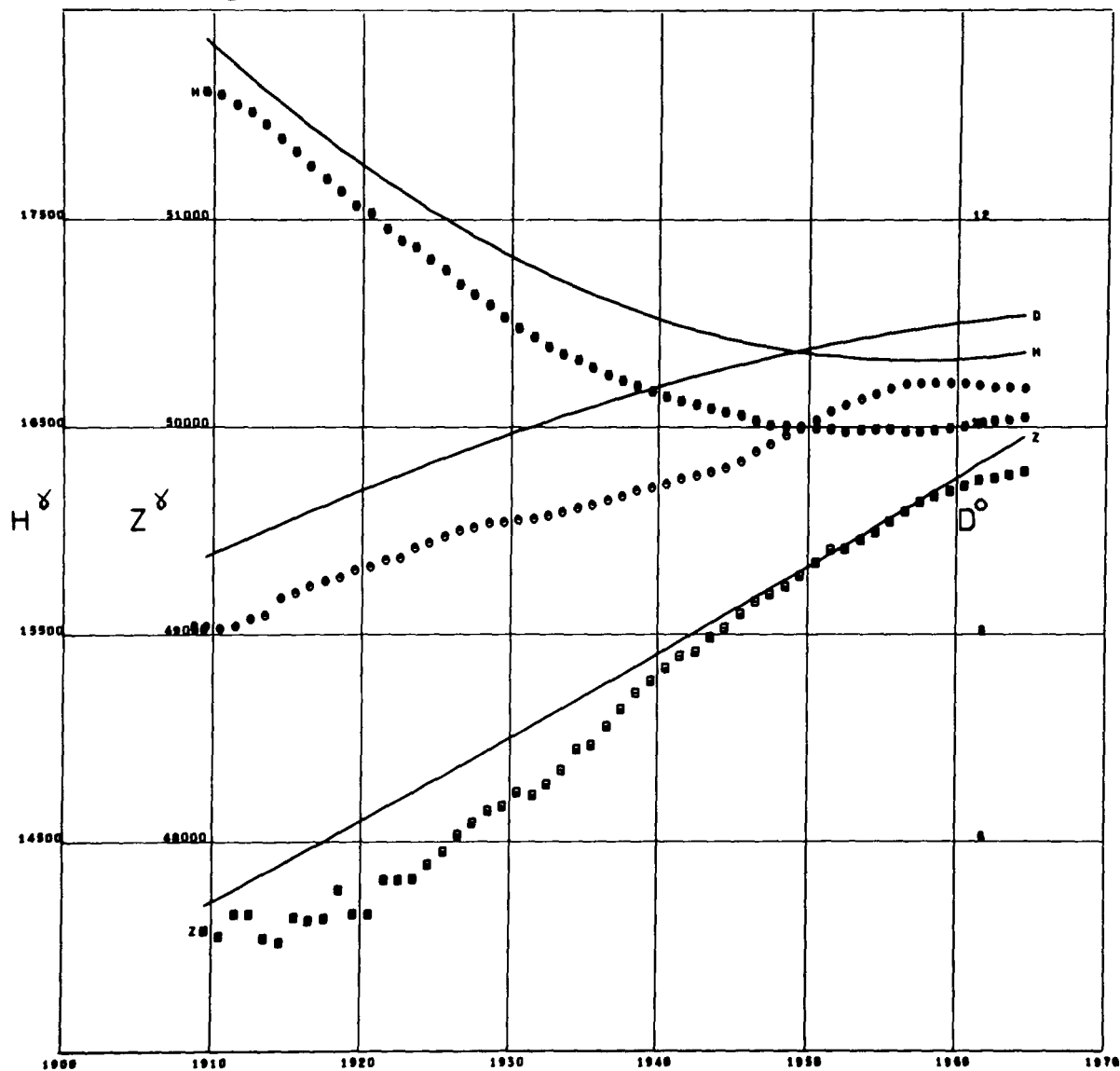


Figure A209

ZIKAWEI  
Lat 31.20 Long 121.43

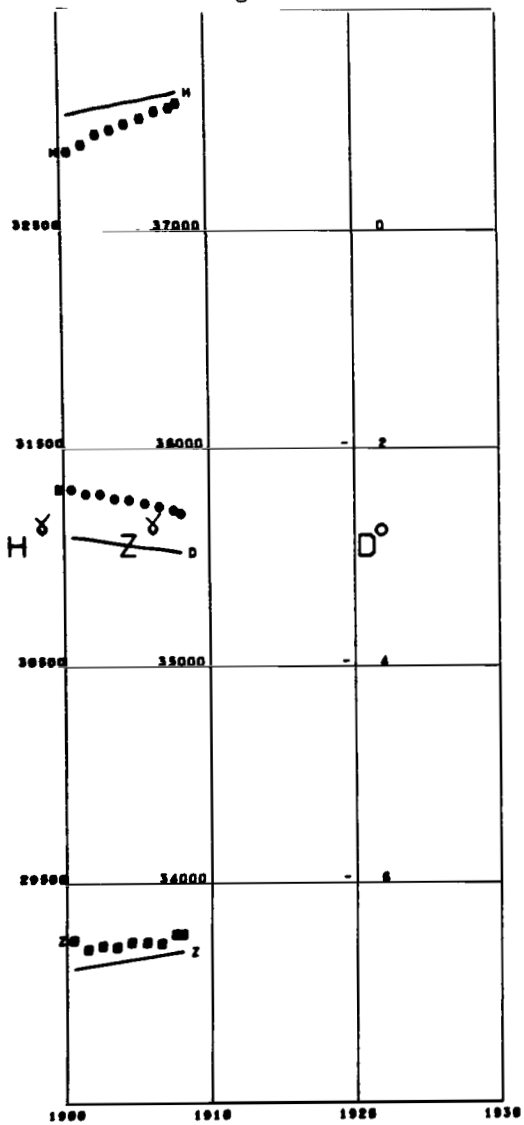


Figure A210

ZINSEN  
Lat 37.47 Long 126.62

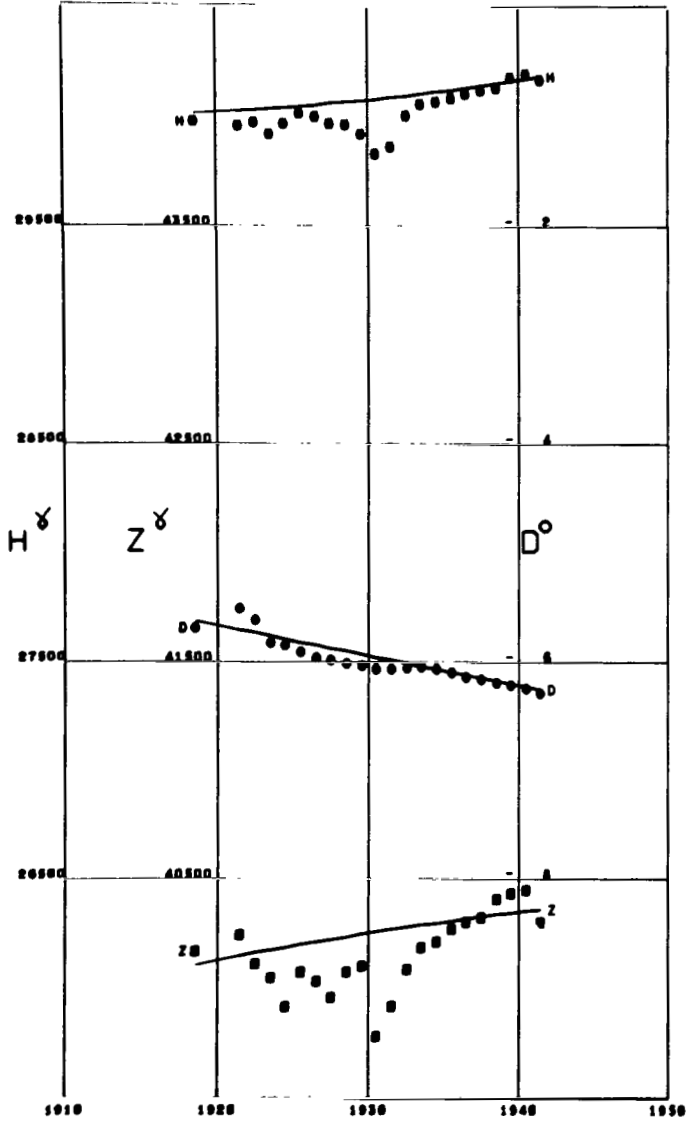


Figure A211

ZO SE  
 Lat 31.09 Long 121.18

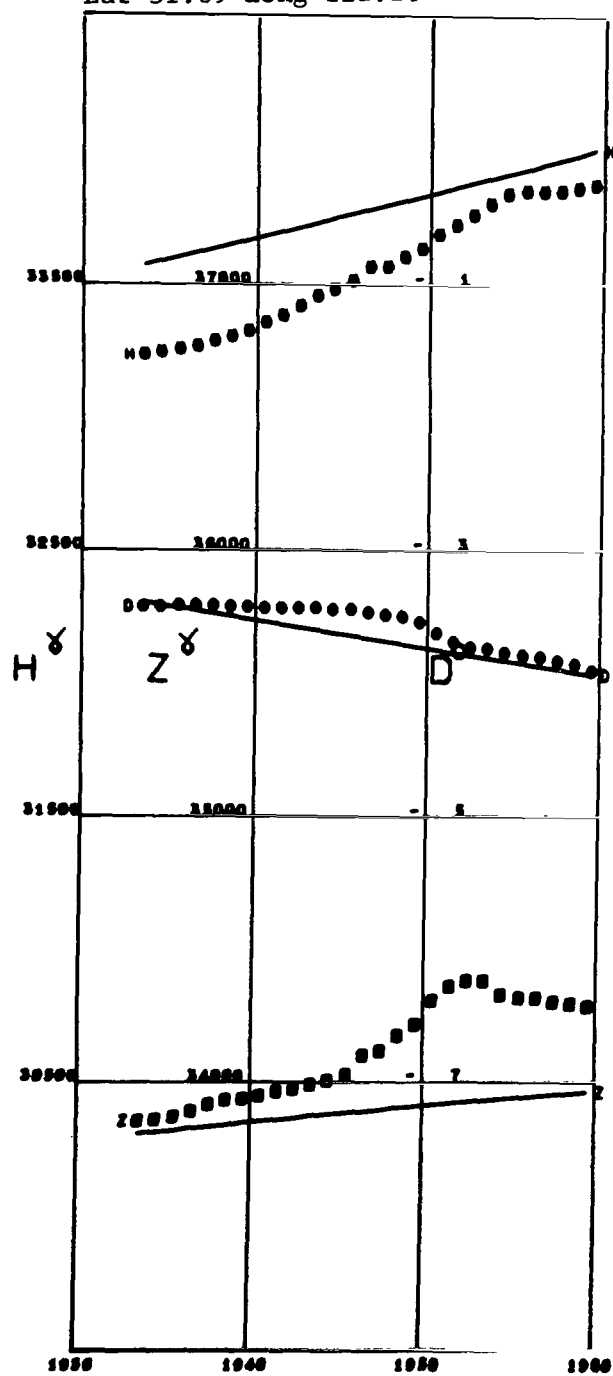


Figure A212

ZUY  
 Lat 52.46 Long 104.03

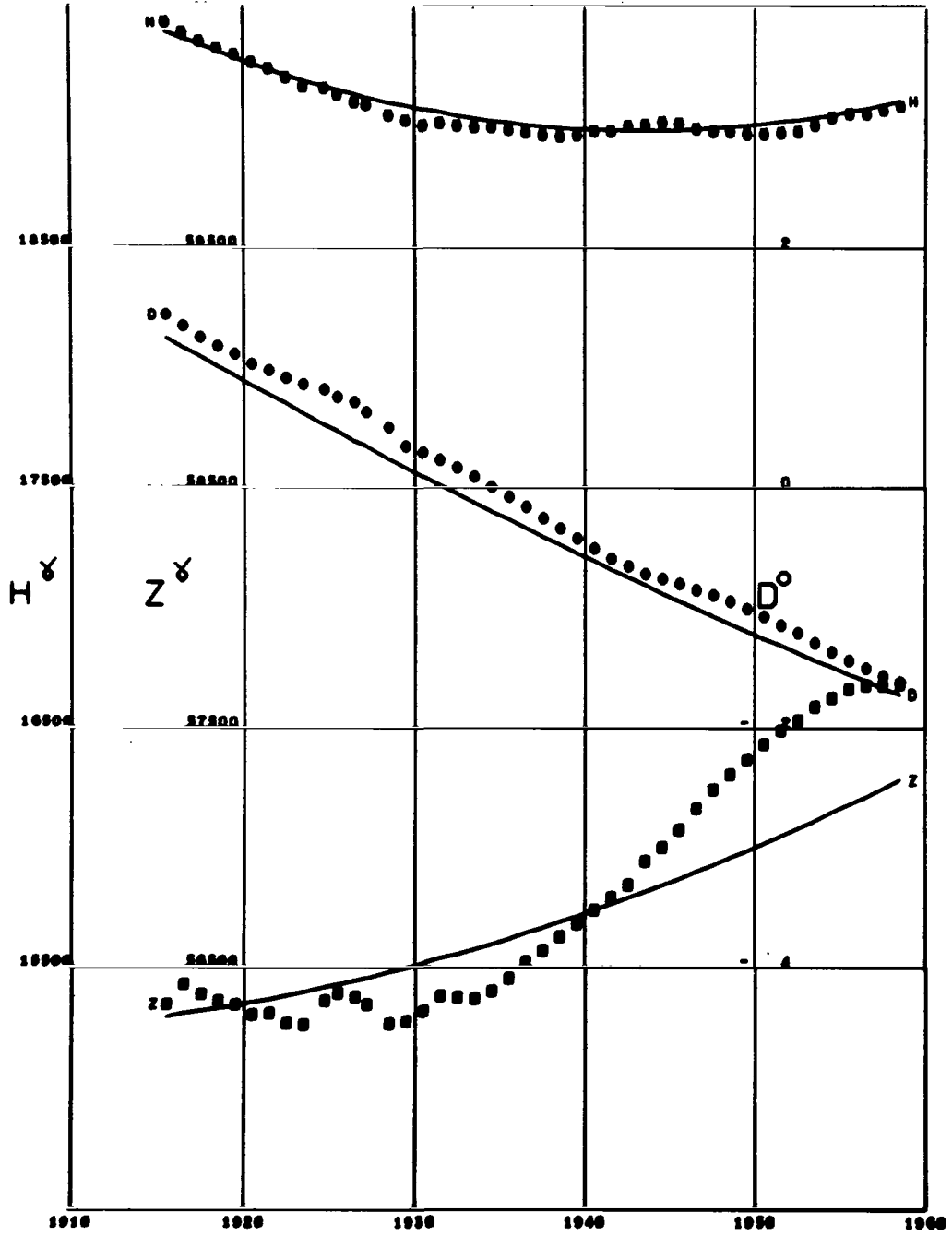


Figure A213



Appendix B

**Comparison of Isoporic Charts (1912-1942) From GSFC (12/66)  
With Those From Vestine et al. (1947)**

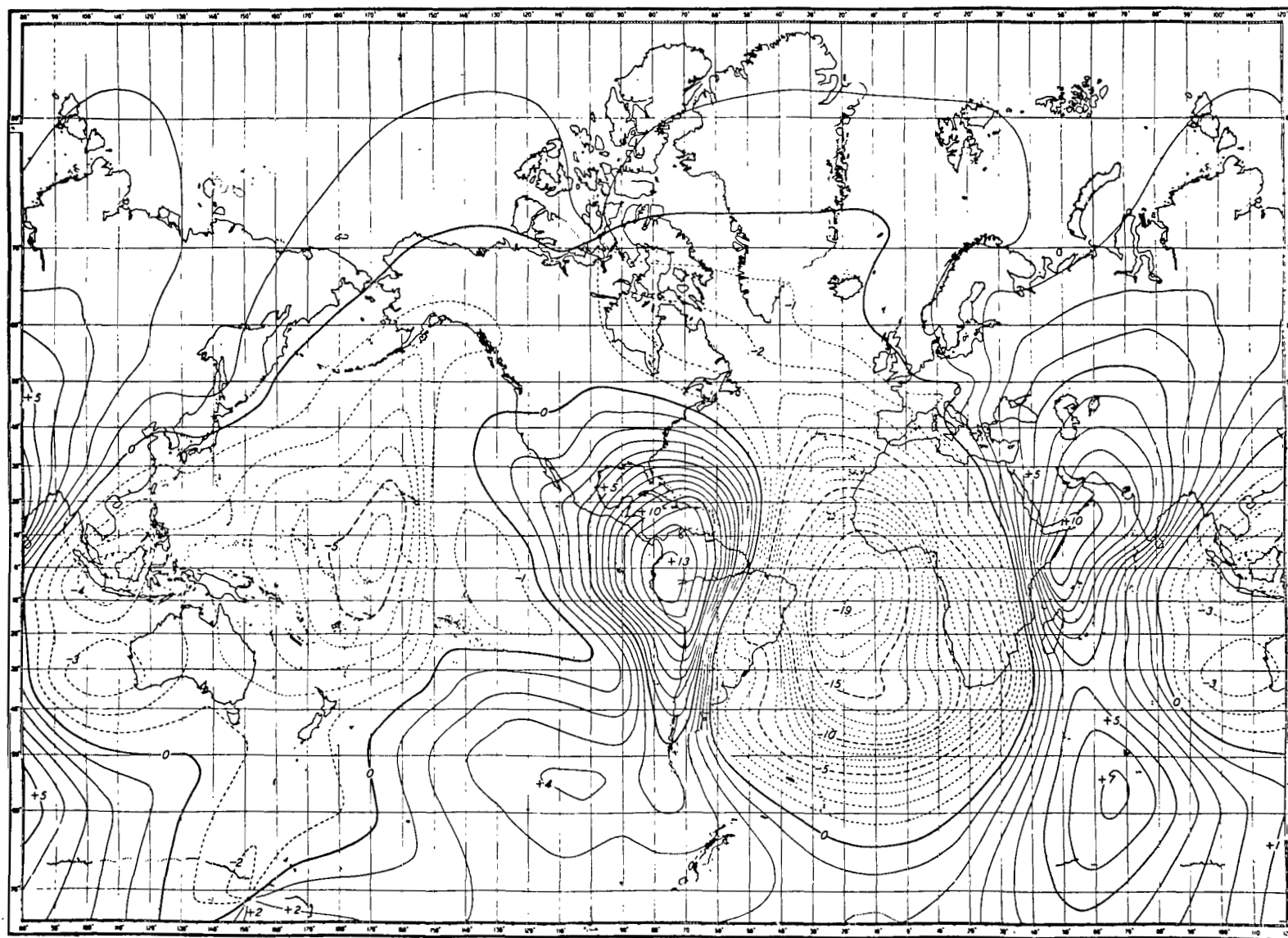


Figure B1-Geomagnetic secular change in minutes per year, inclination, epoch 1912.5. Vestine et al. (1947).



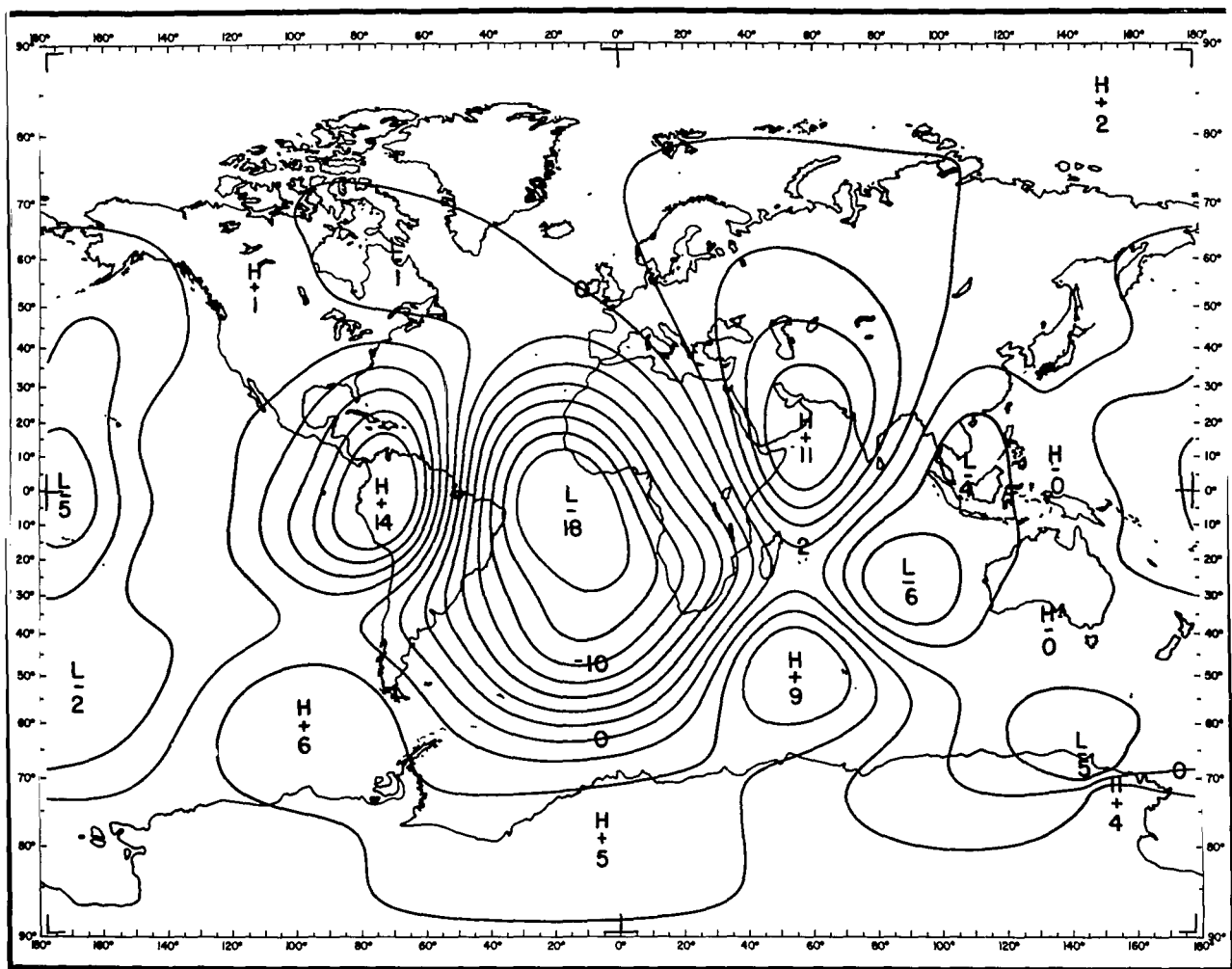


Figure B2—Geomagnetic secular change in minutes per year, inclination, epoch 1912.5. GSFC (12/66).

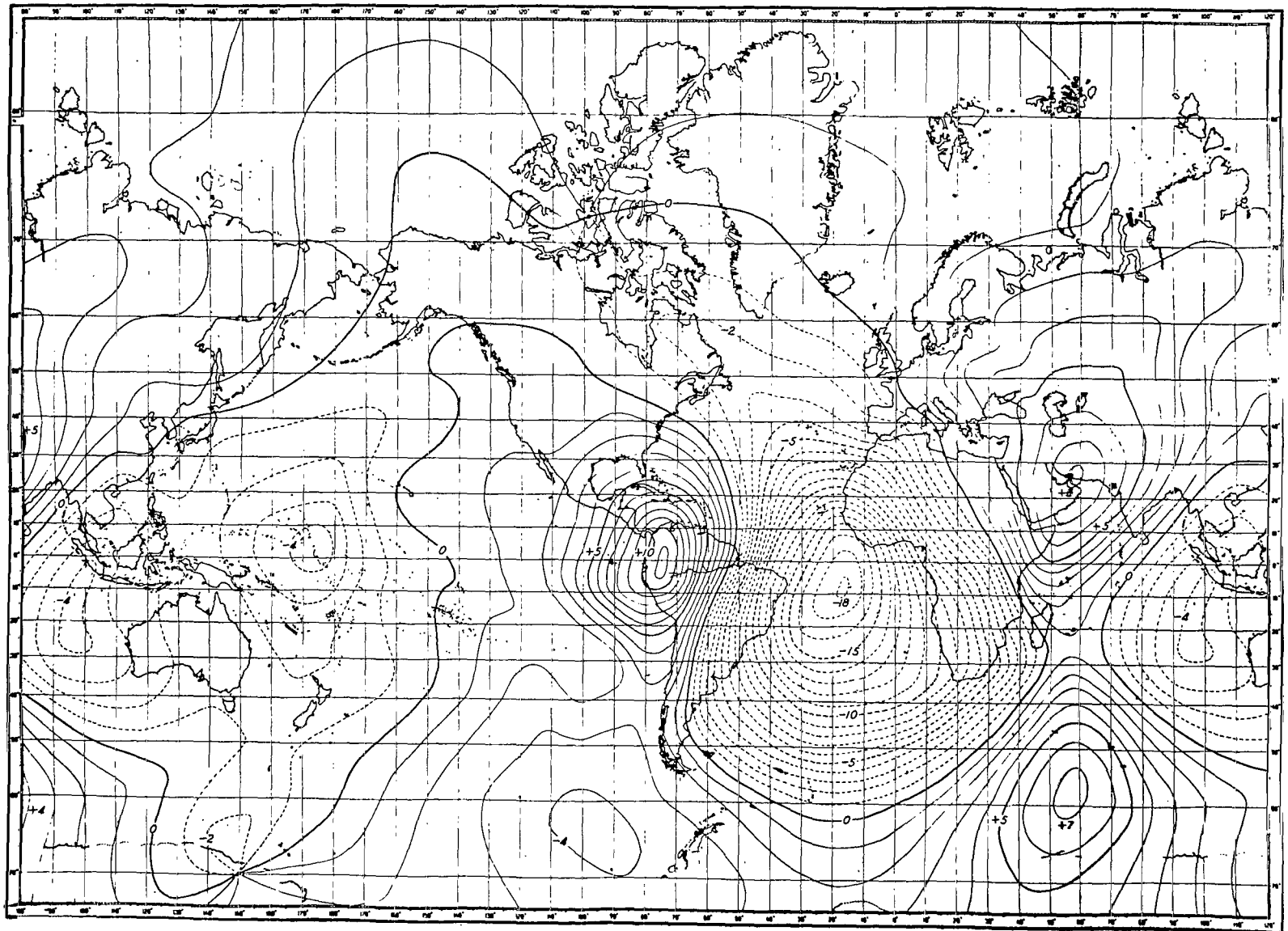


Figure B3-Geomagnetic secular change in minutes per year, inclination, epoch 1922.5. Vestine et al. (1947).

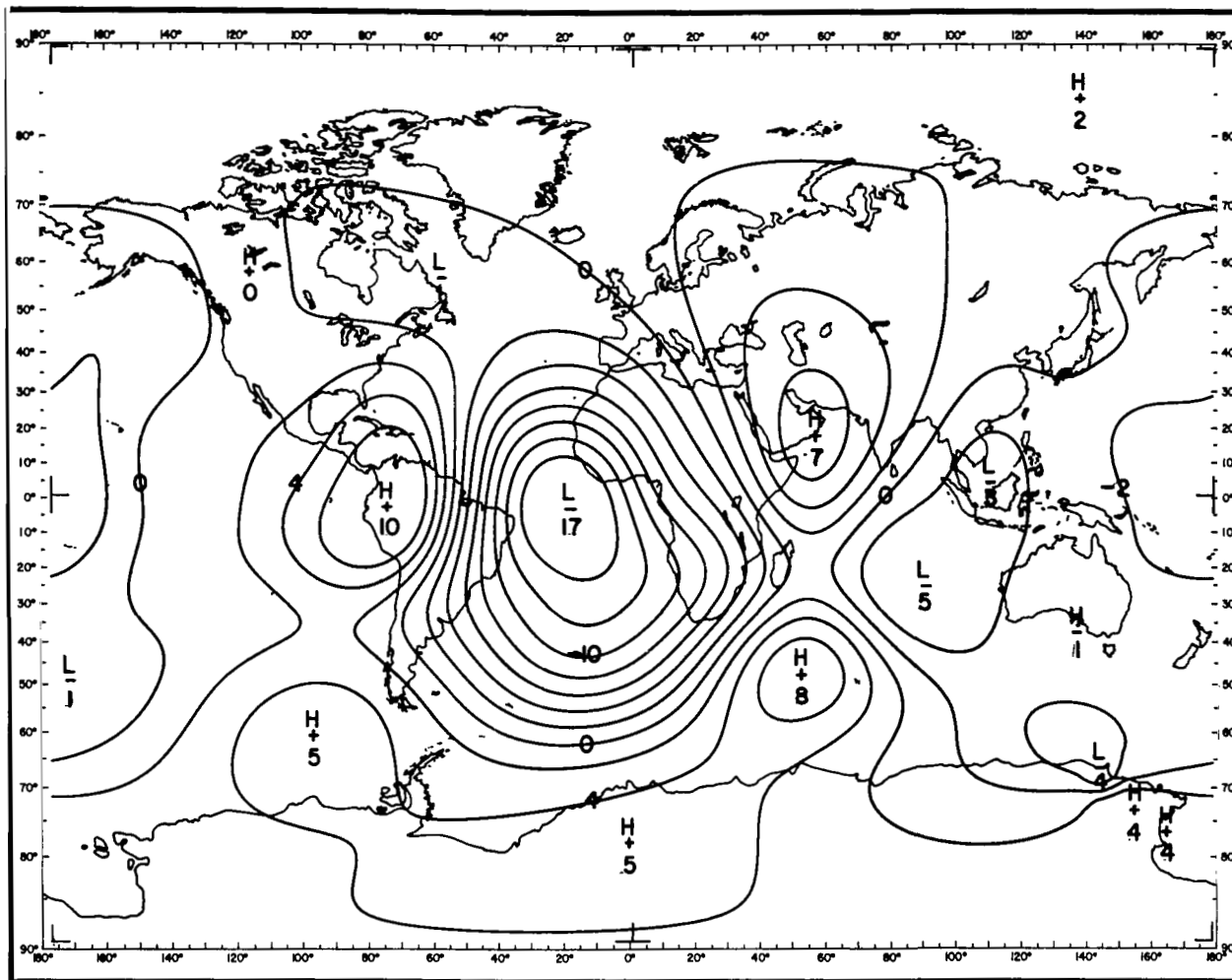


Figure B4—Geomagnetic secular change in minutes per year, inclination, epoch 1922.5. GSFC (12/66).

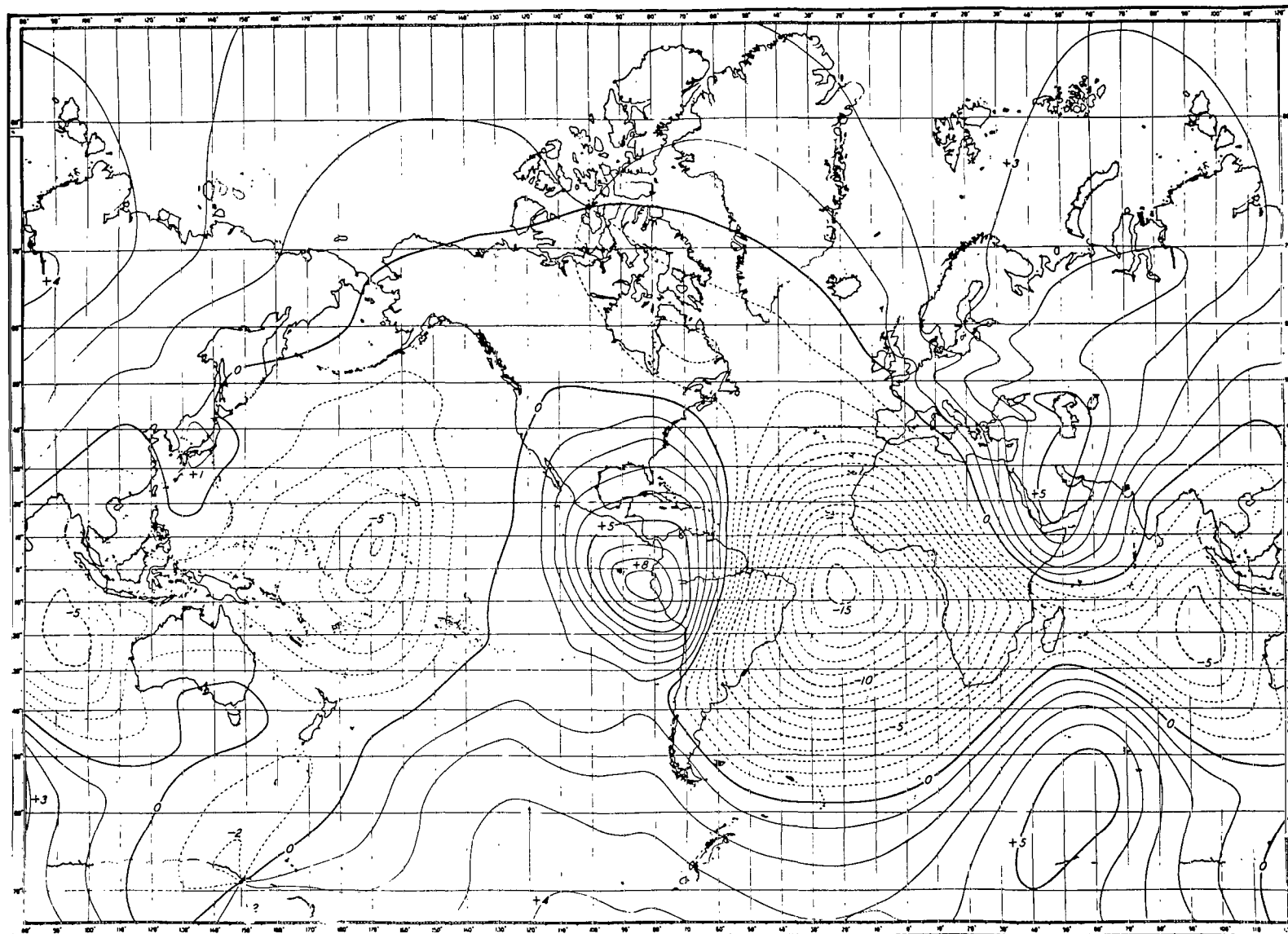


Figure B5—Geomagnetic secular change in minutes per year, inclination, epoch 1932.5. Vestine et al. (1947).

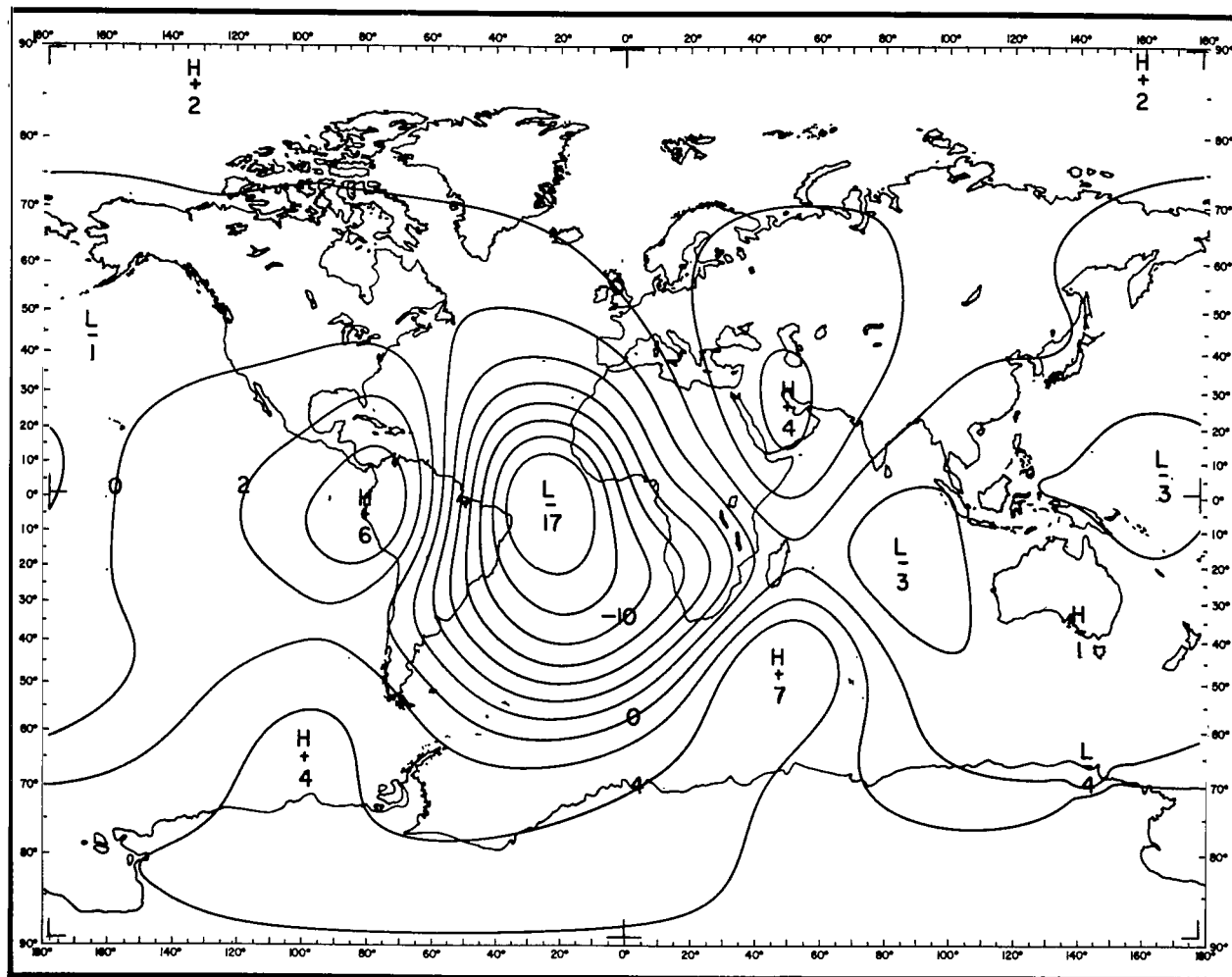


Figure B6—Geomagnetic secular change in minutes per year, inclination, epoch 1932.5. GSFC (12/66).

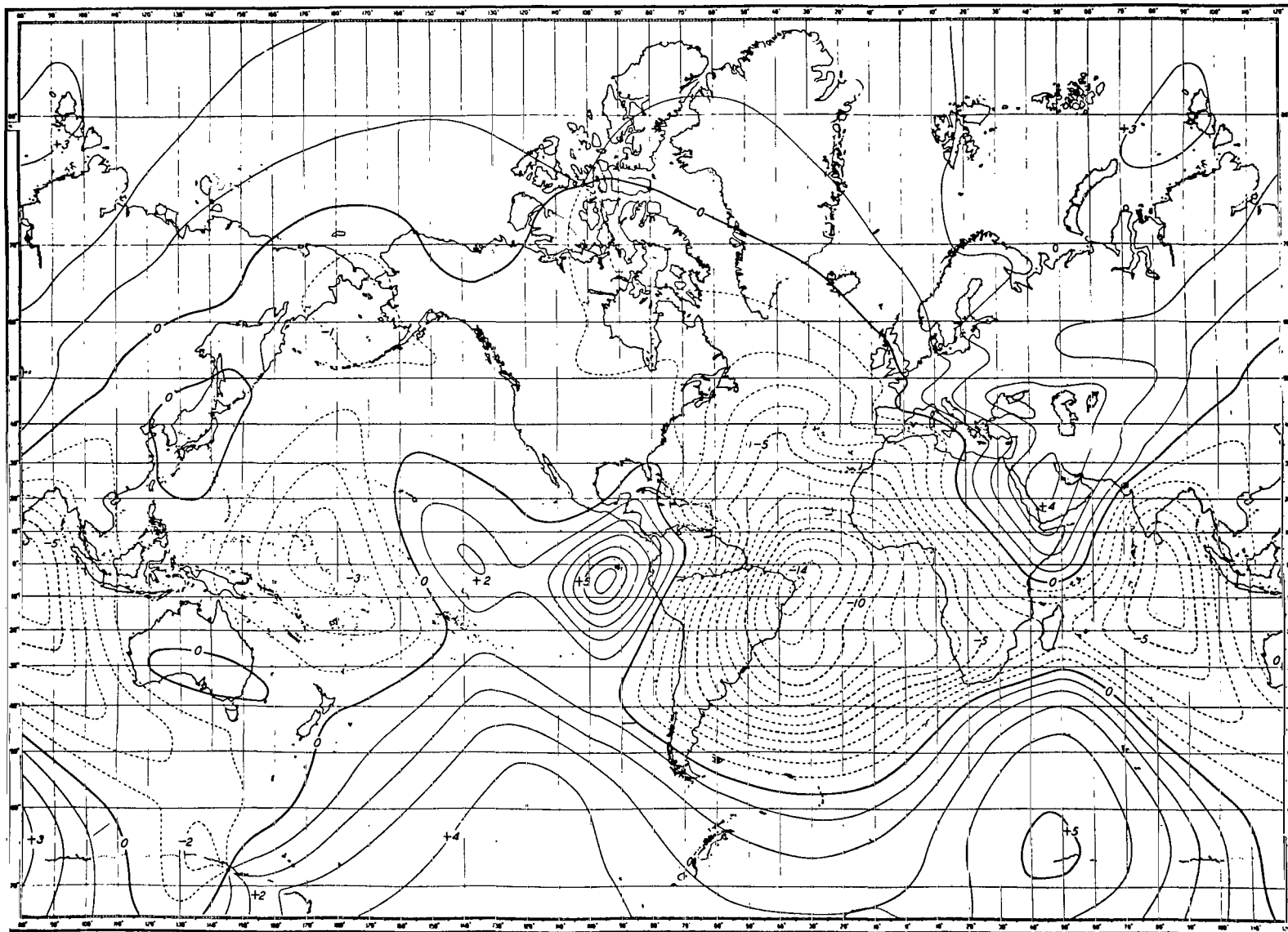


Figure B7-Geomagnetic secular change in minutes per year, inclination, epoch 1942.5. Vestine et al. (1947).

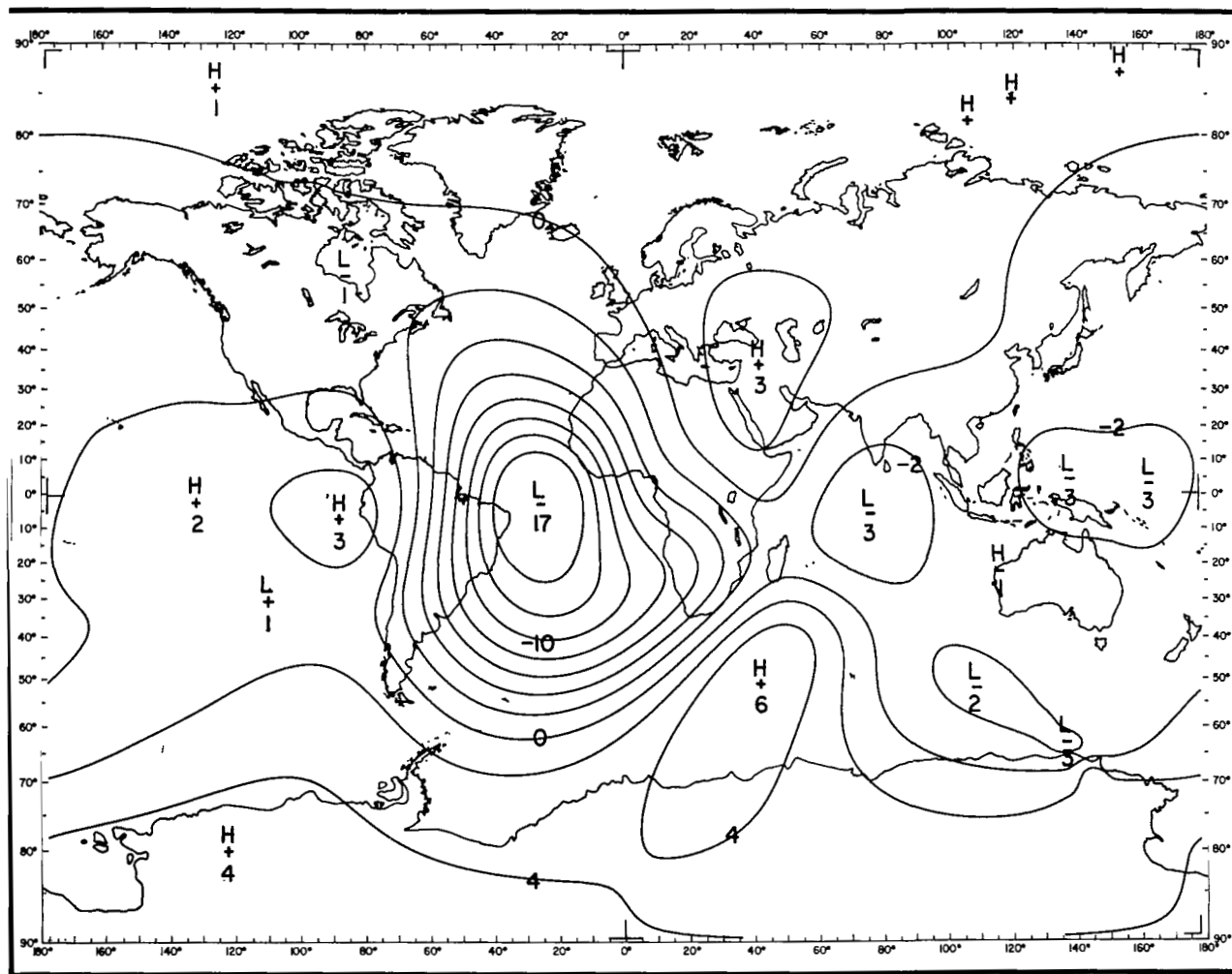


Figure B8—Geomagnetic secular change in minutes per year, inclination, epoch 1942.5. GSFC (12/66).

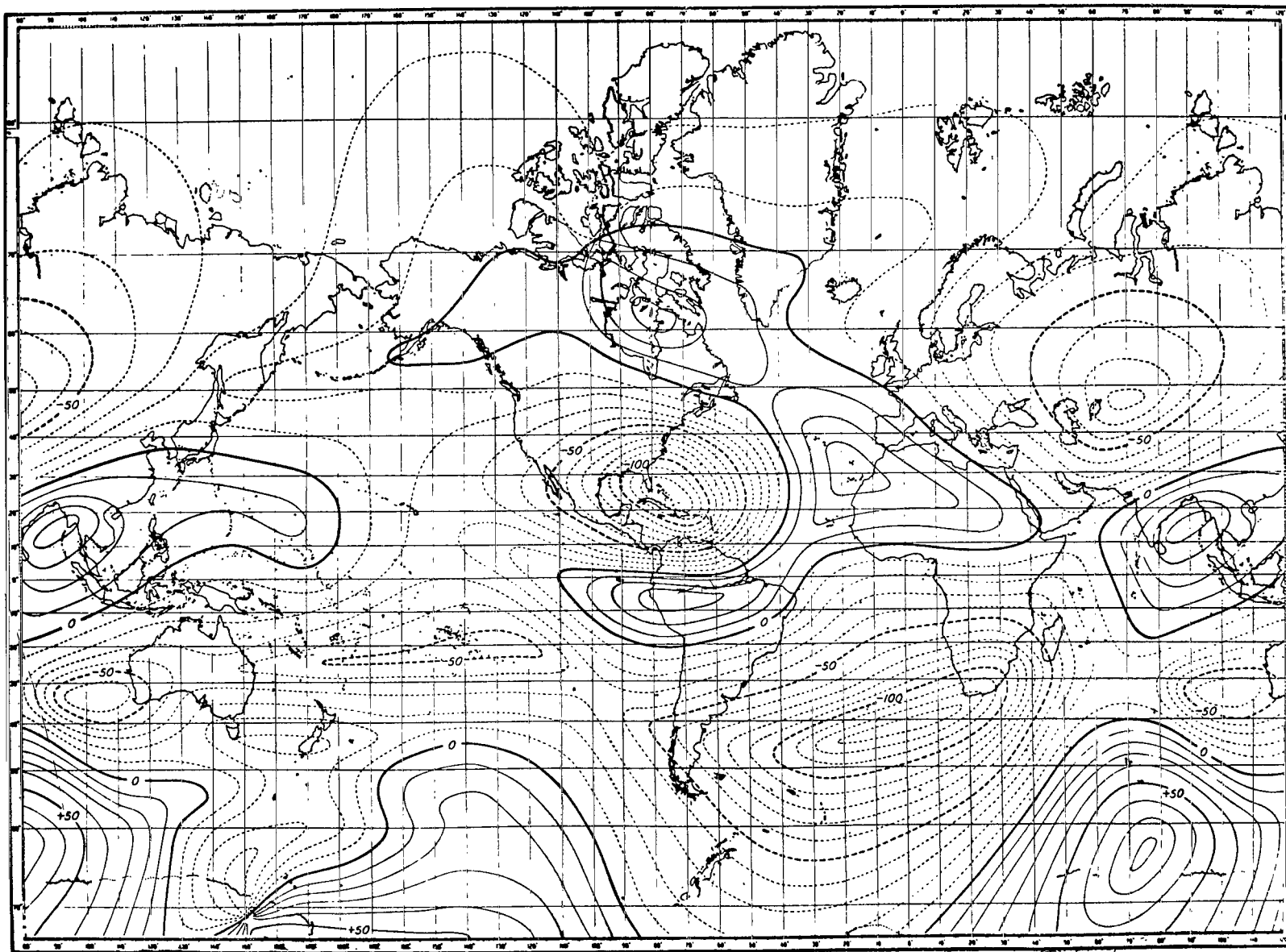


Figure B9-Geomagnetic secular change in gammas per year, horizontal component, epoch 1912.5. Vestine et al. (1947).



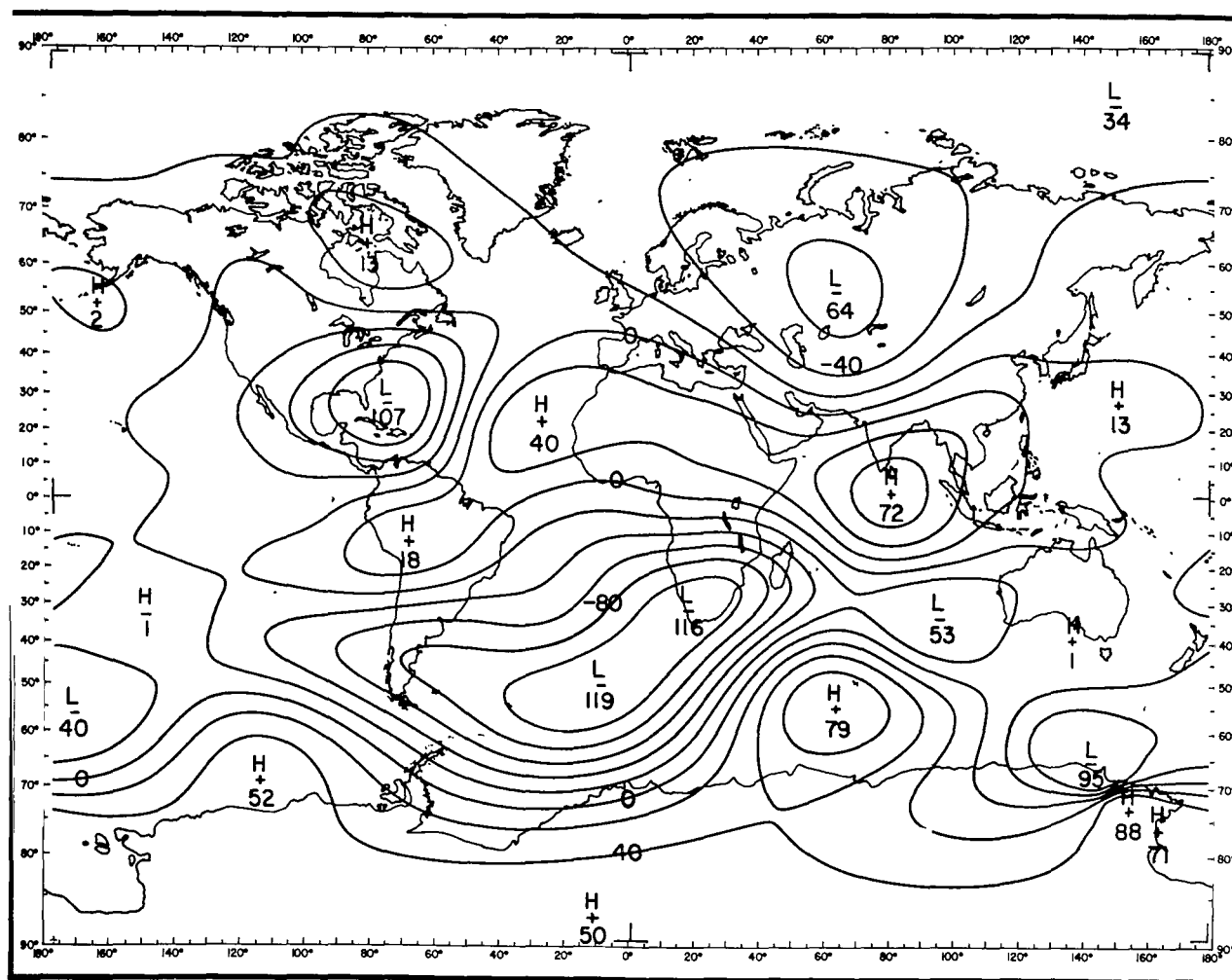


Figure B10—Geomagnetic secular change in gammas per year, horizontal component, epoch 1912.5.  
GSFC (12/66).

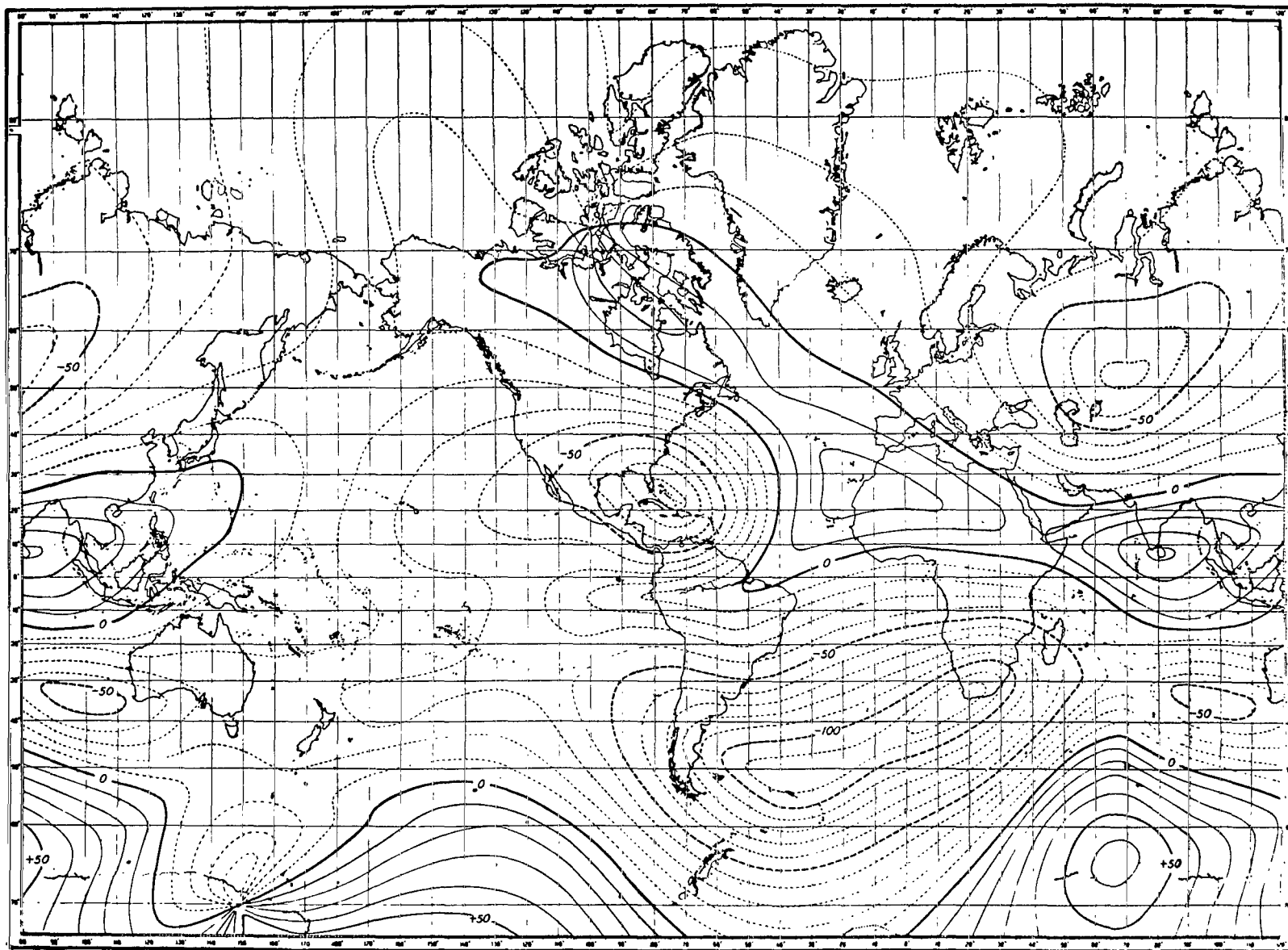


Figure B11-Geomagnetic secular change in gammas per year, horizontal component, epoch 1922.5. Vestine et al. (1947).

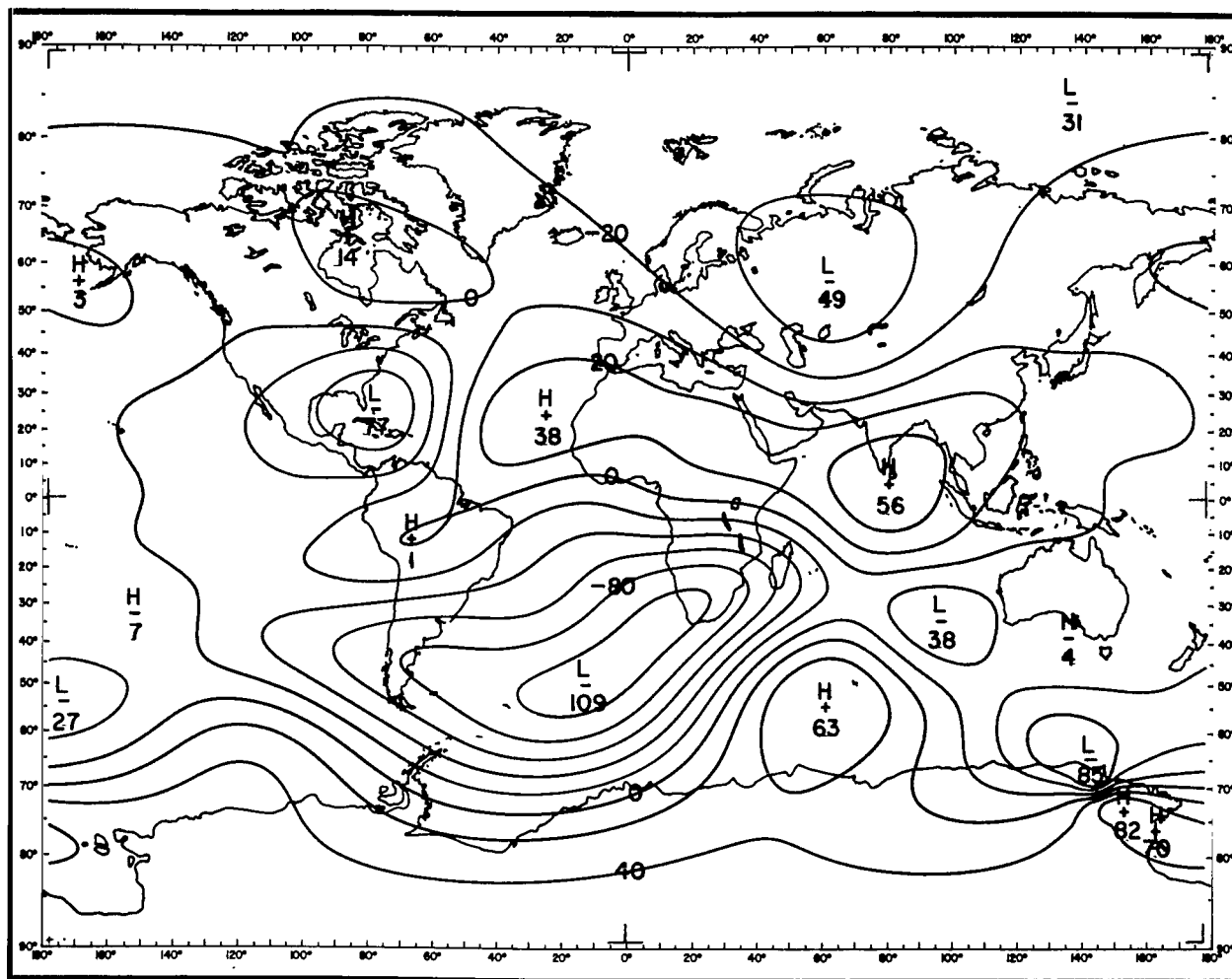


Figure B12—Geomagnetic secular change in gammas per year, horizontal component, epoch 1922.5. GSFC (12/66).

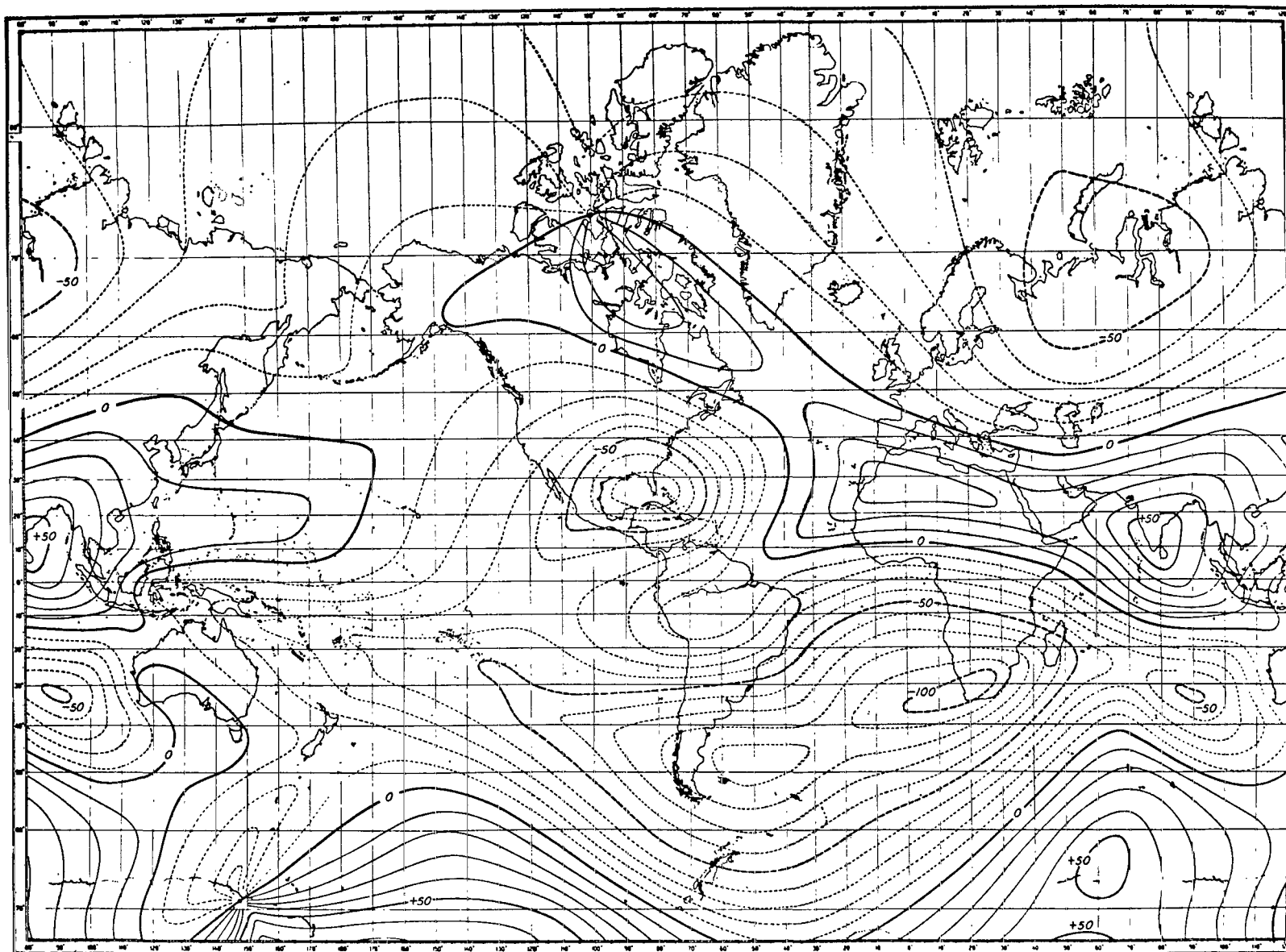


Figure B13—Geomagnetic secular change in gammas per year, horizontal component, epoch 1932.5. Vestine et al. (1947).

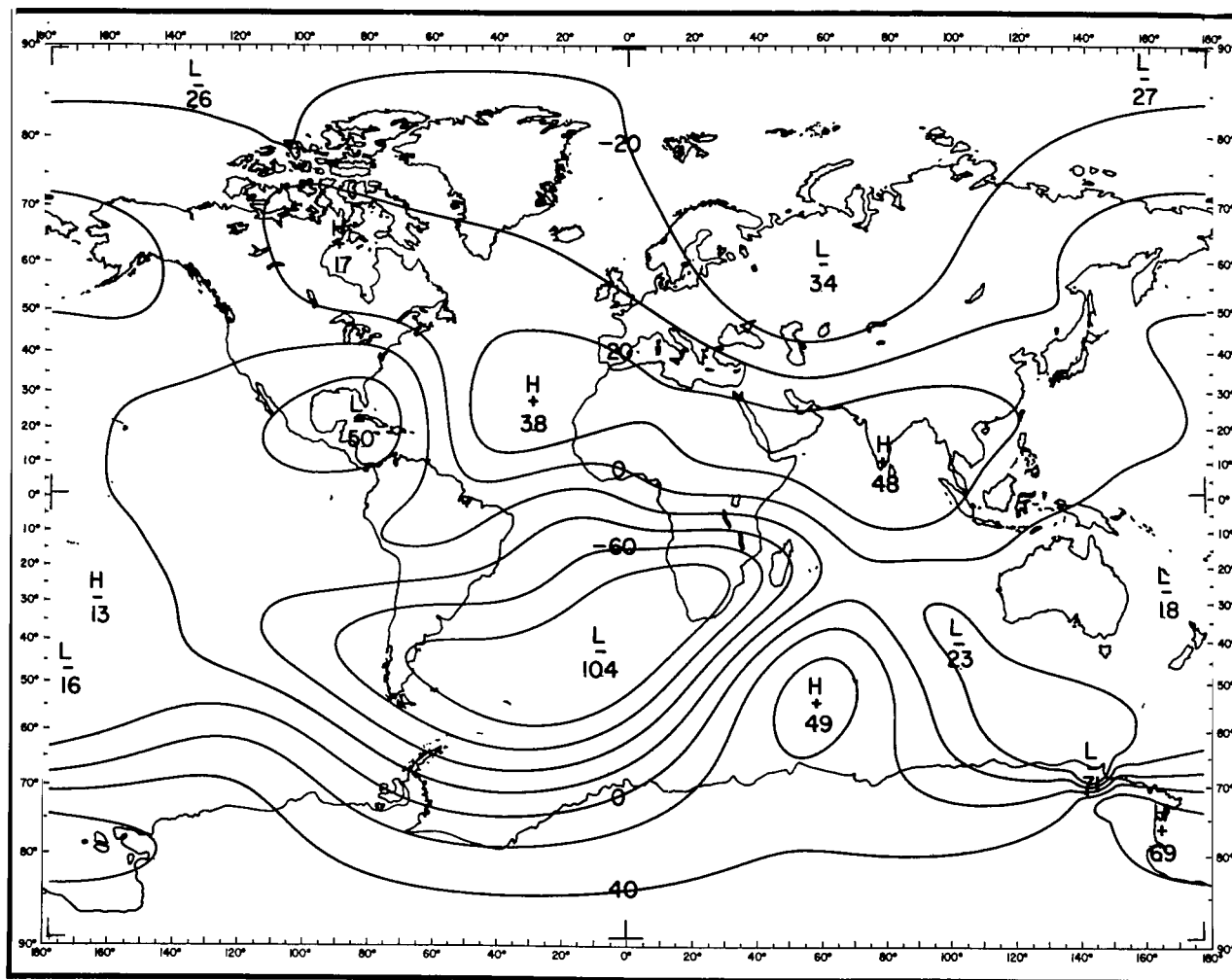


Figure B14—Geomagnetic secular change in gammas per year, horizontal component, epoch 1932.5. GSFC (12/66).

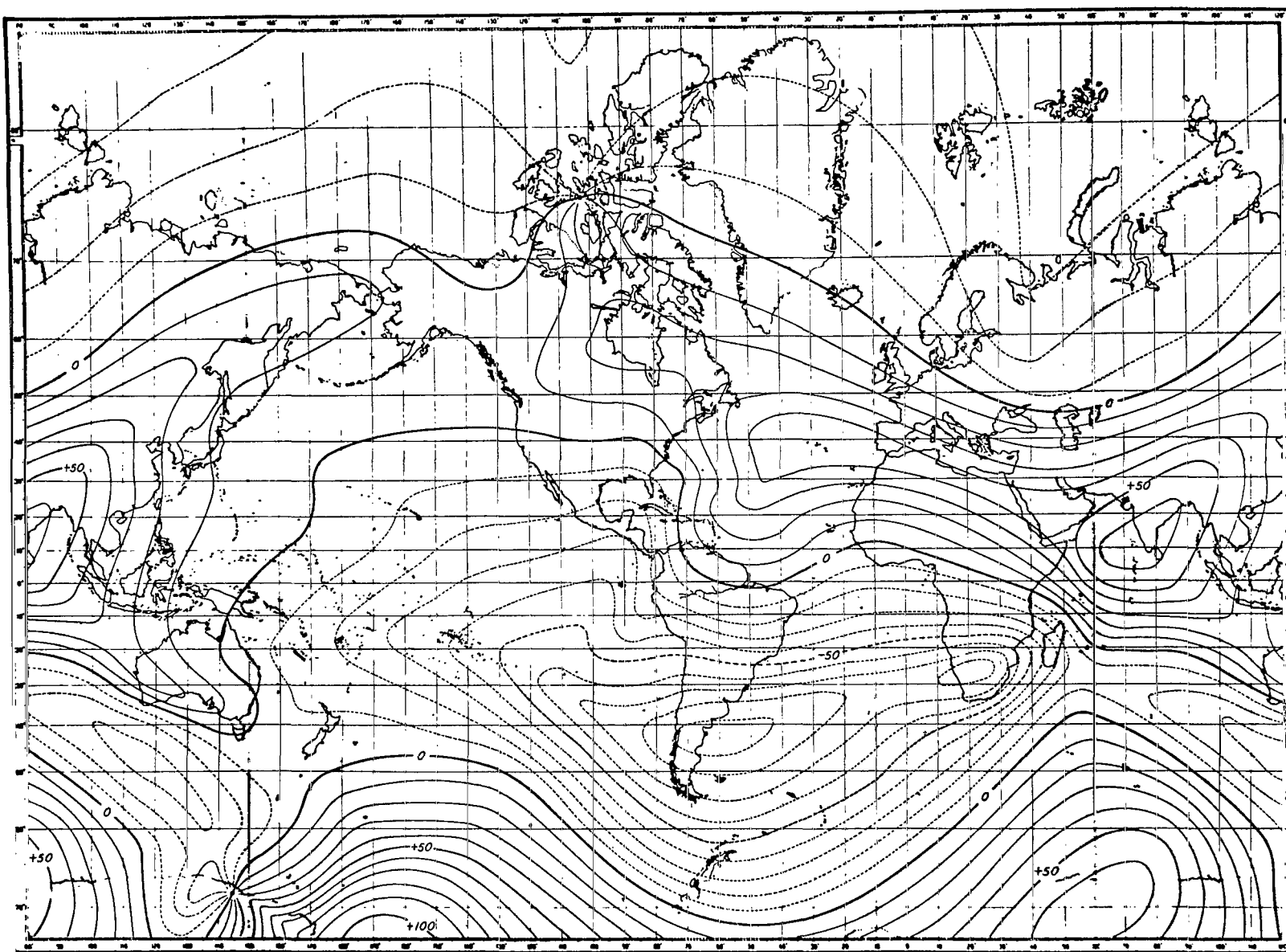


Figure B15-Geomagnetic secular change in gammas per year, horizontal component, epoch 1942.5. Vestine et al. (1947).

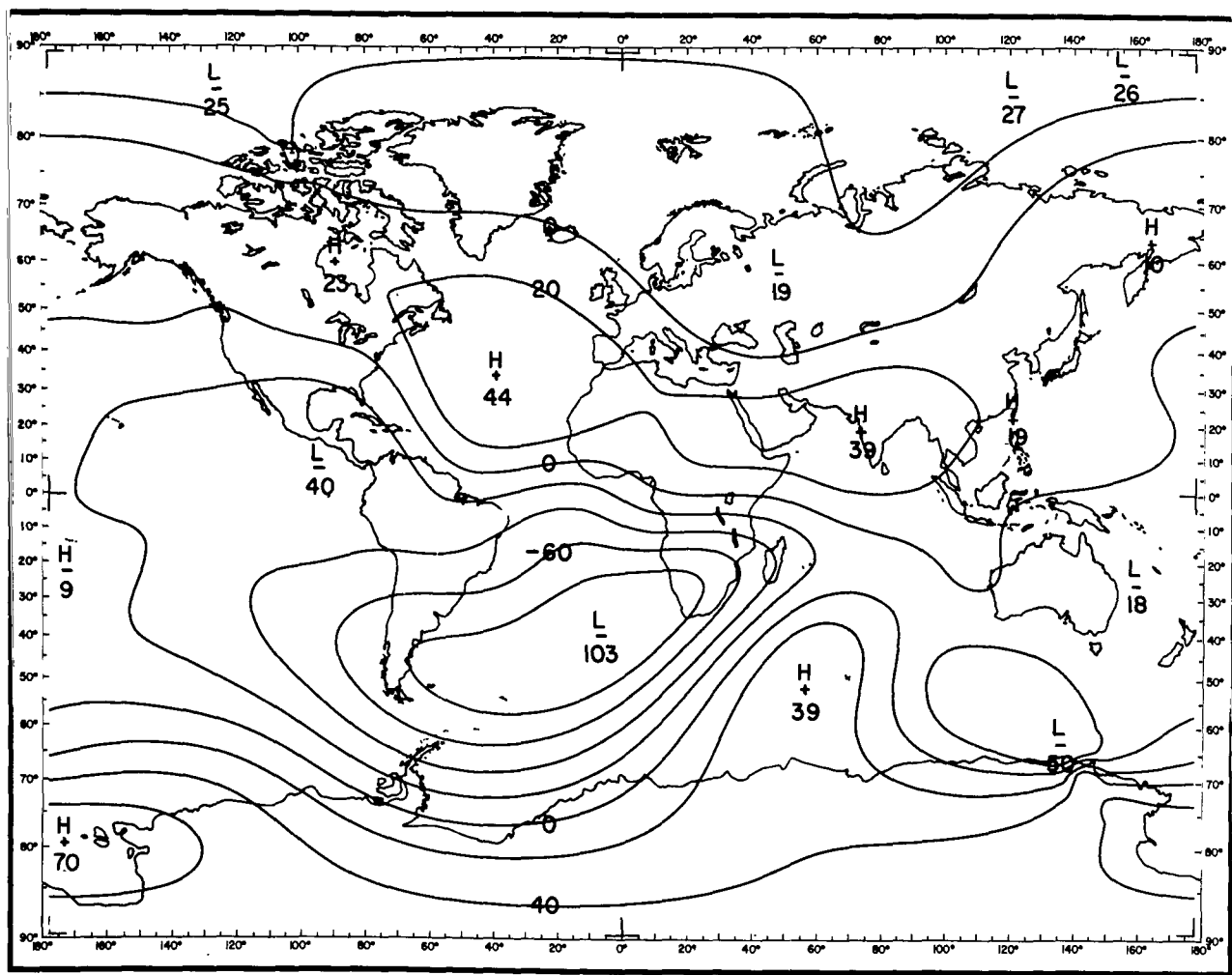


Figure B16—Geomagnetic secular change in gammas per year, horizontal component, epoch 1942.5. GSFC (12/66).

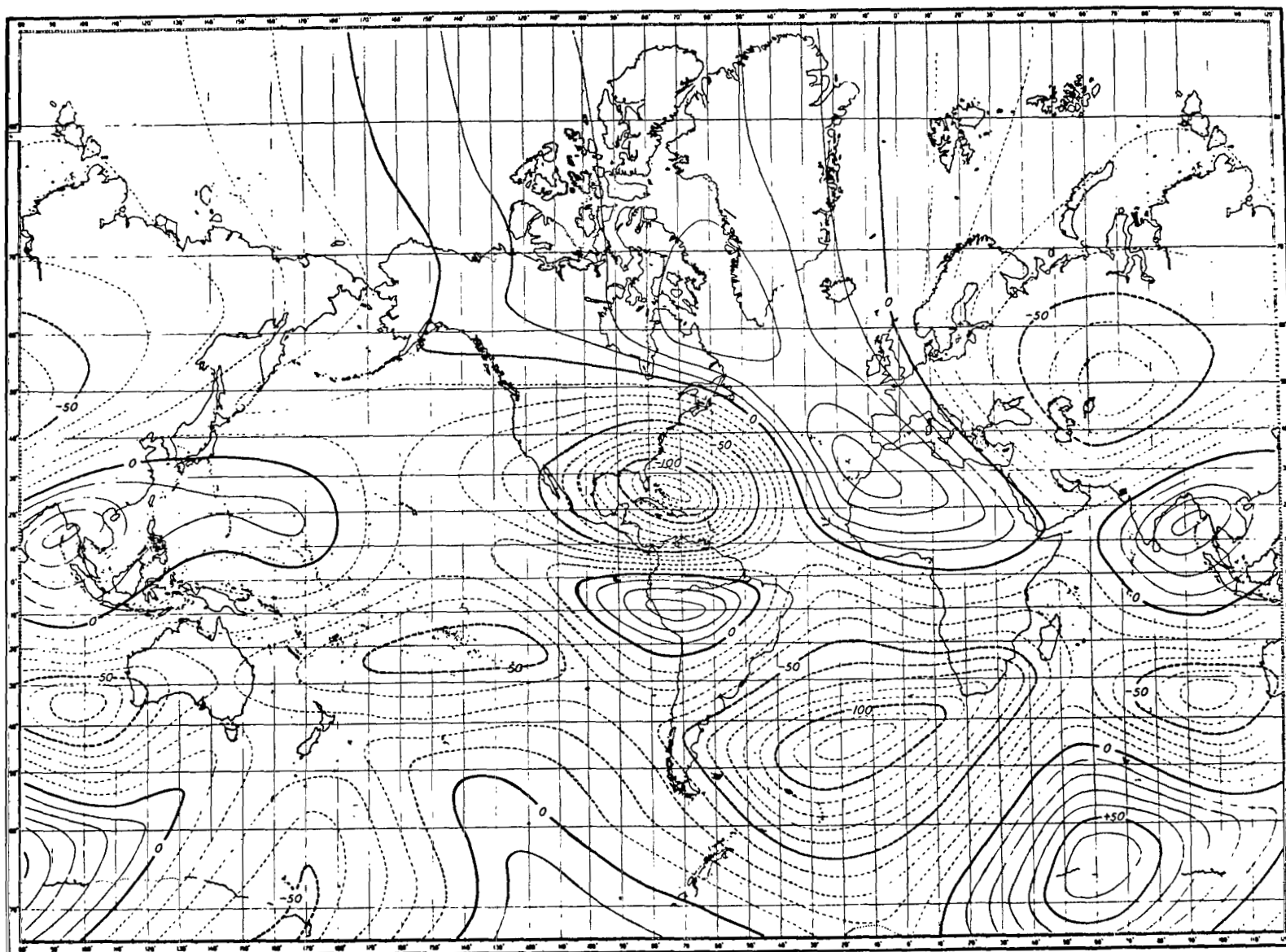


Figure B17-Geomagnetic secular change in gammas per year, north component, epoch 1912.5. Vestine et al. (1947).



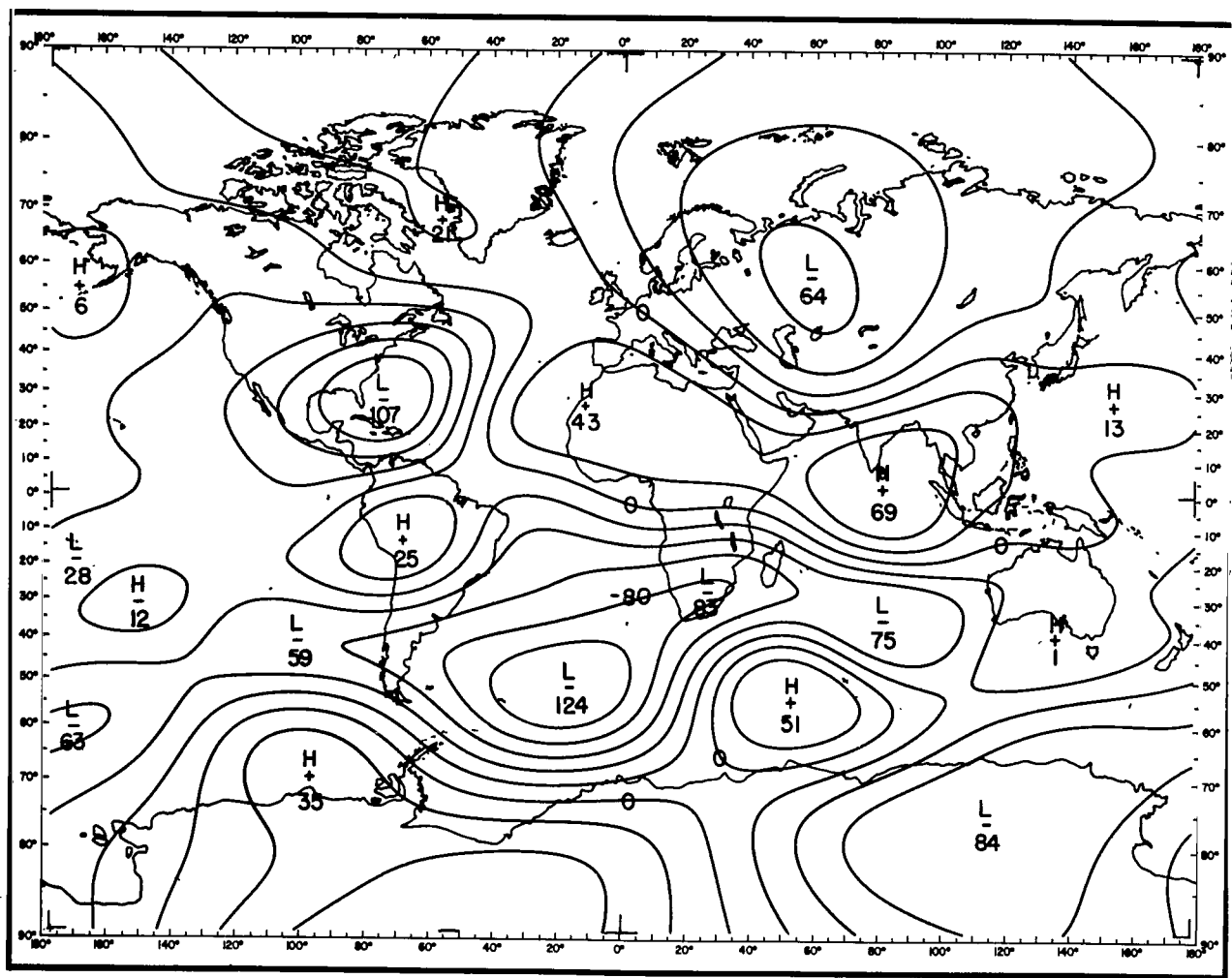


Figure B18—Geomagnetic secular change in gammas per year, north component, epoch 1912.5. GSFC (12/66).

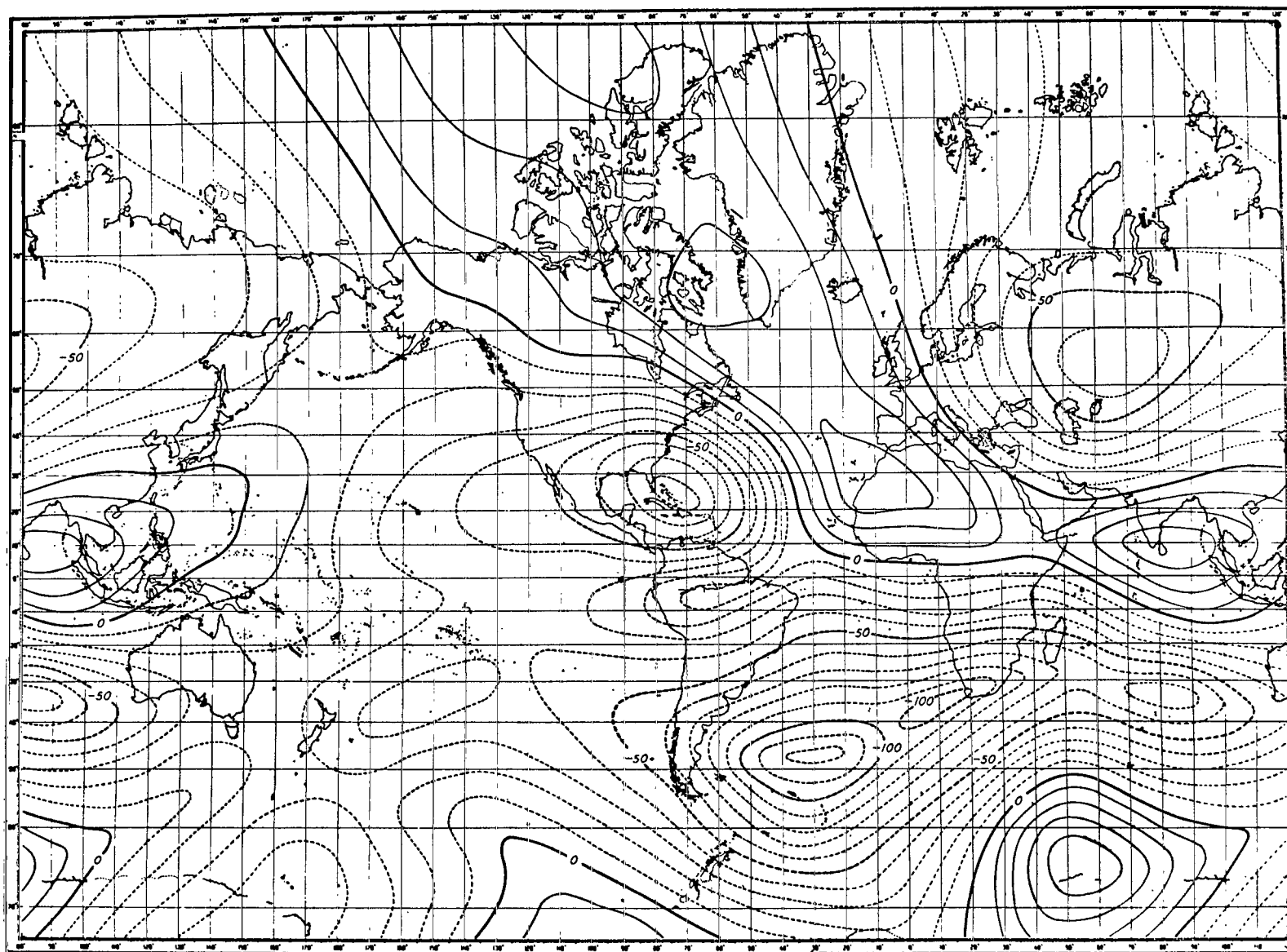


Figure B19-Geomagnetic secular change in gammas per year, north component, epoch 1922.5. Vestine et al. (1947).

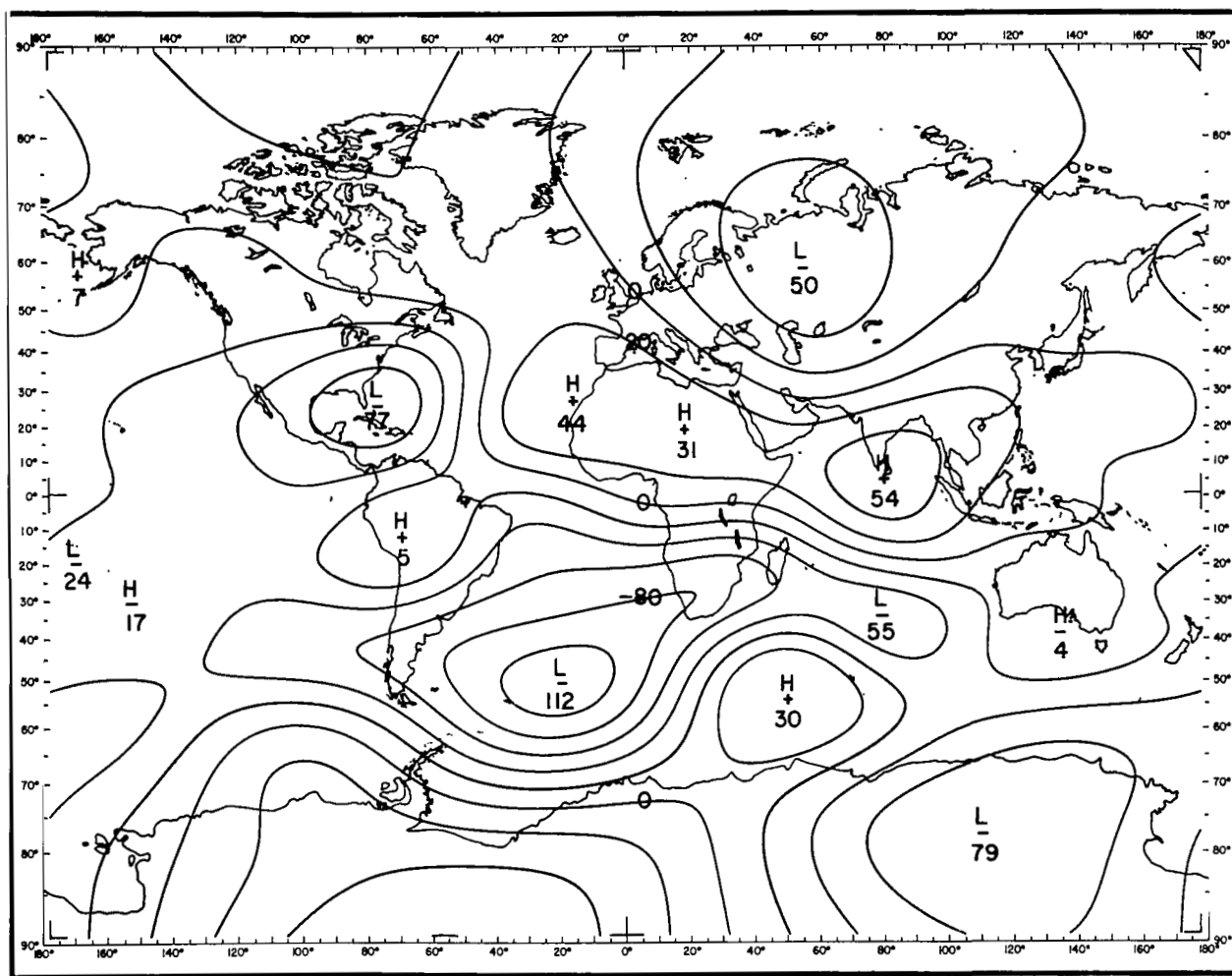


Figure B20—Geomagnetic secular change in gammas per year, north component, epoch 1922.5. GSFC (12/66).

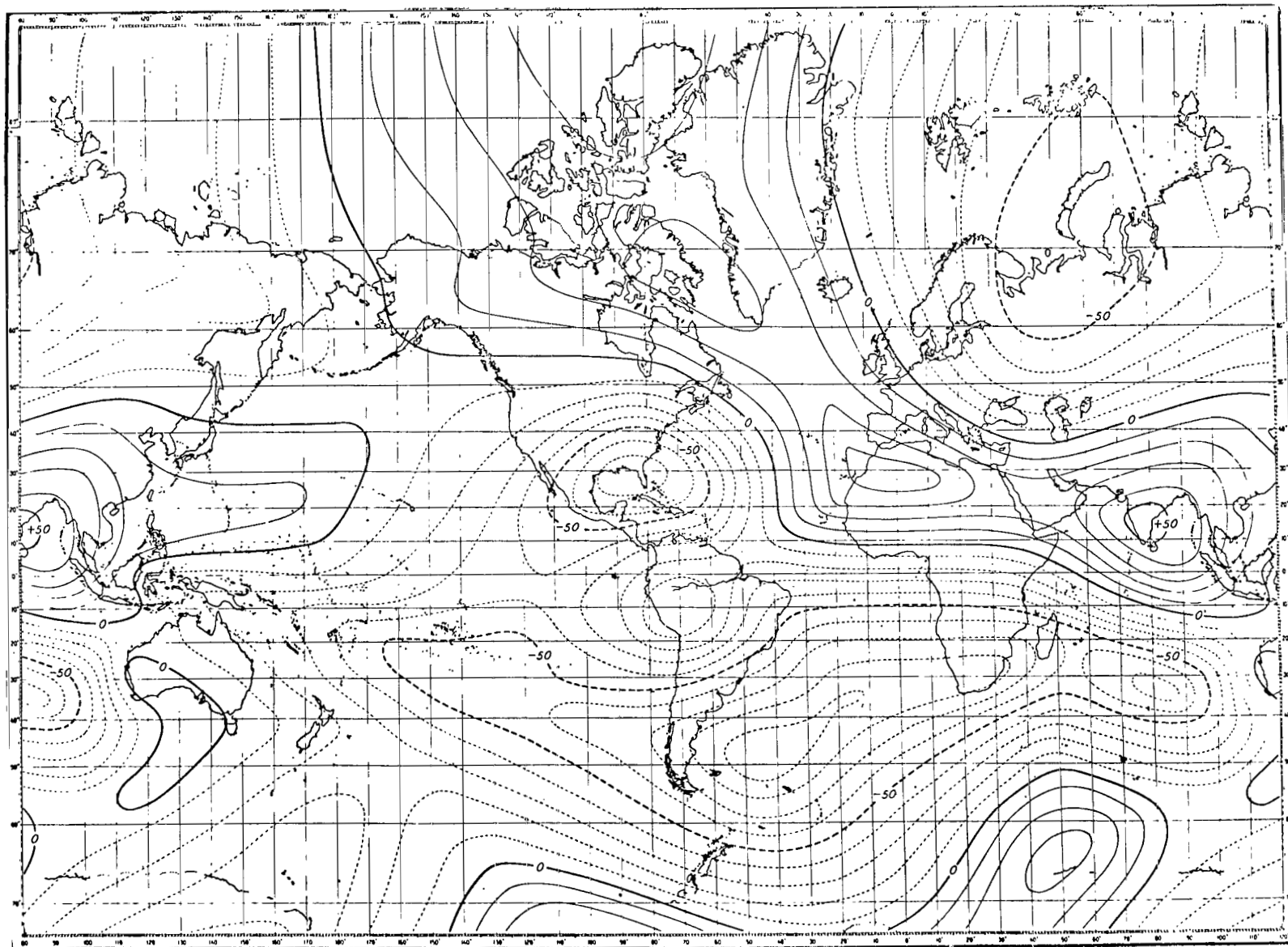


Figure B21—Geomagnetic secular change in gammas per year, north component, epoch 1932.5. Vestine et al. (1947).



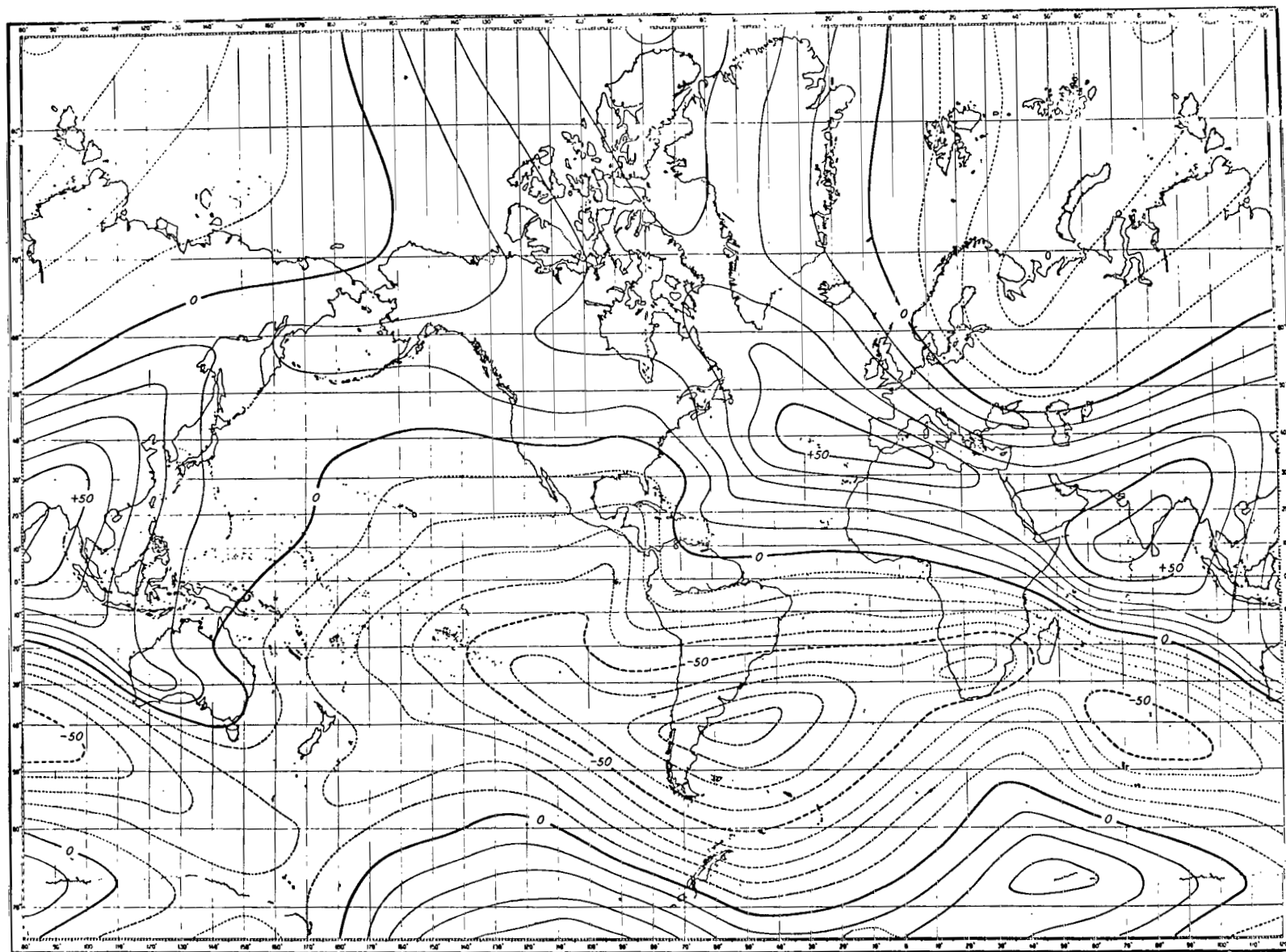


Figure B23—Geomagnetic secular change in gammas per year, north component, epoch 1942.5. Vestine et al. (1947).

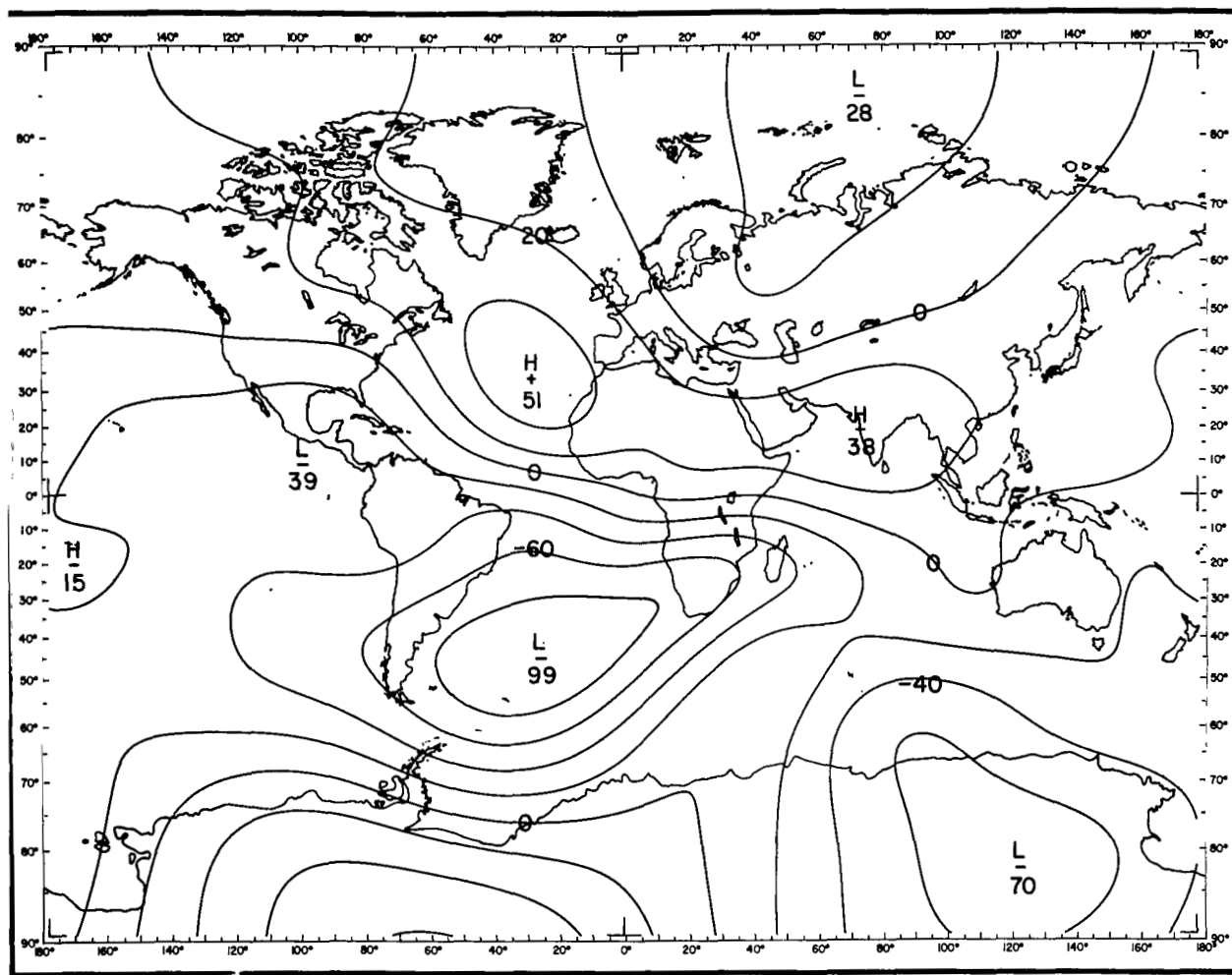


Figure B24—Geomagnetic secular change in gammas per year, north component, epoch 1942.5. GSFC (12/66).

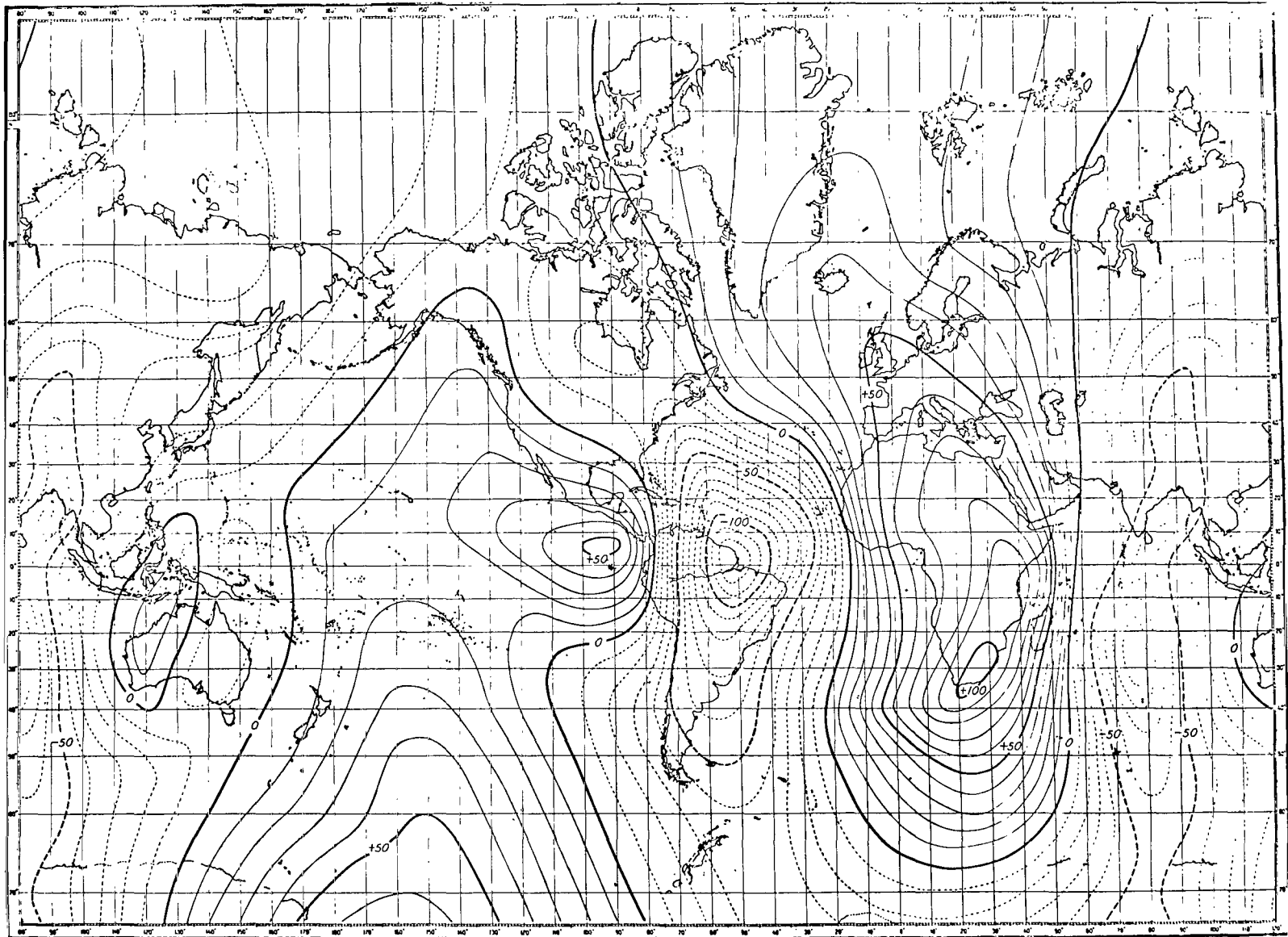


Figure B25-Geomagnetic secular change in gammas per year, east component, epoch 1912.5. Vestine et al. (1947).



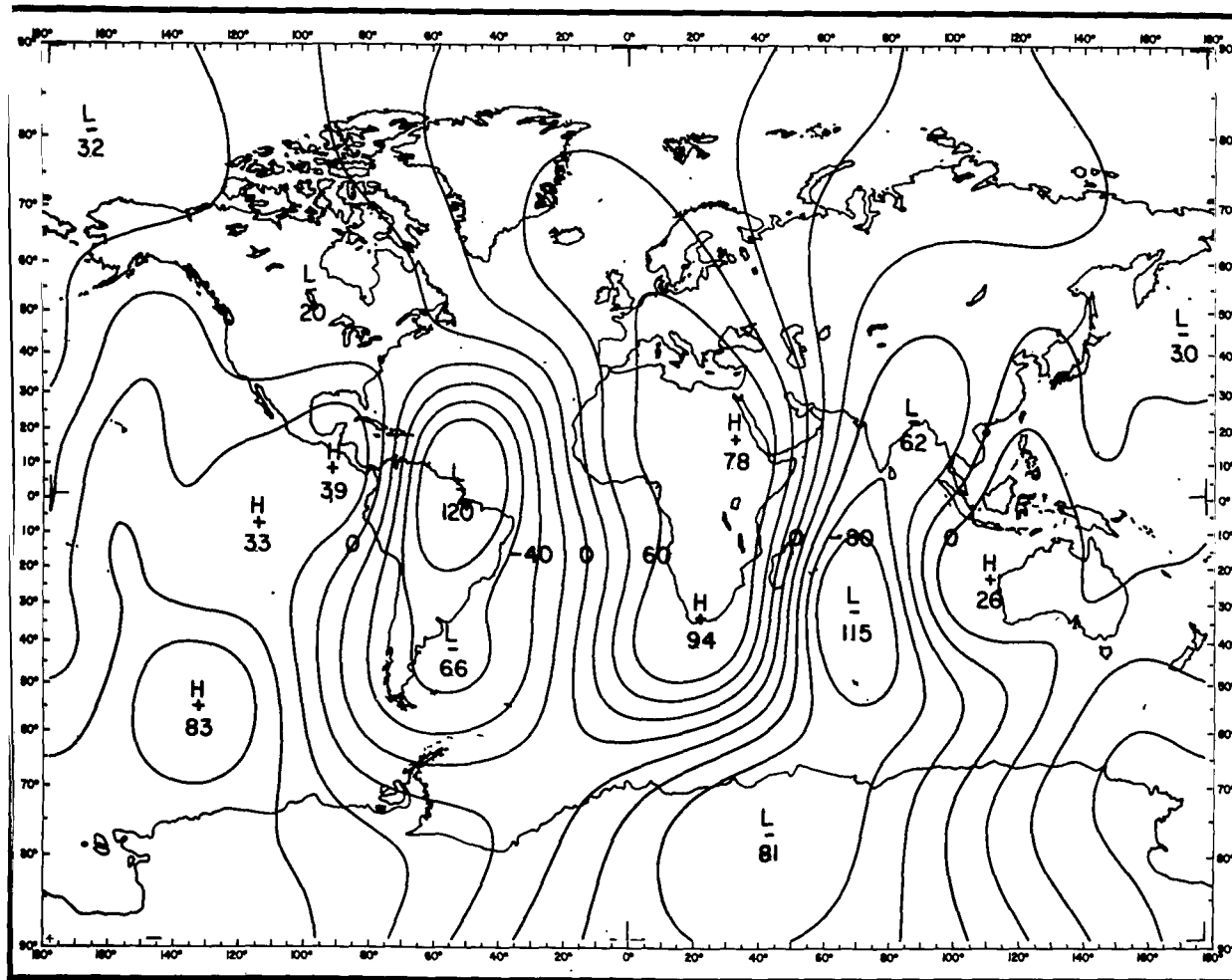


Figure B26—Geomagnetic secular change in gammas per year, east component, epoch 1912.5. GSFC (12/66).

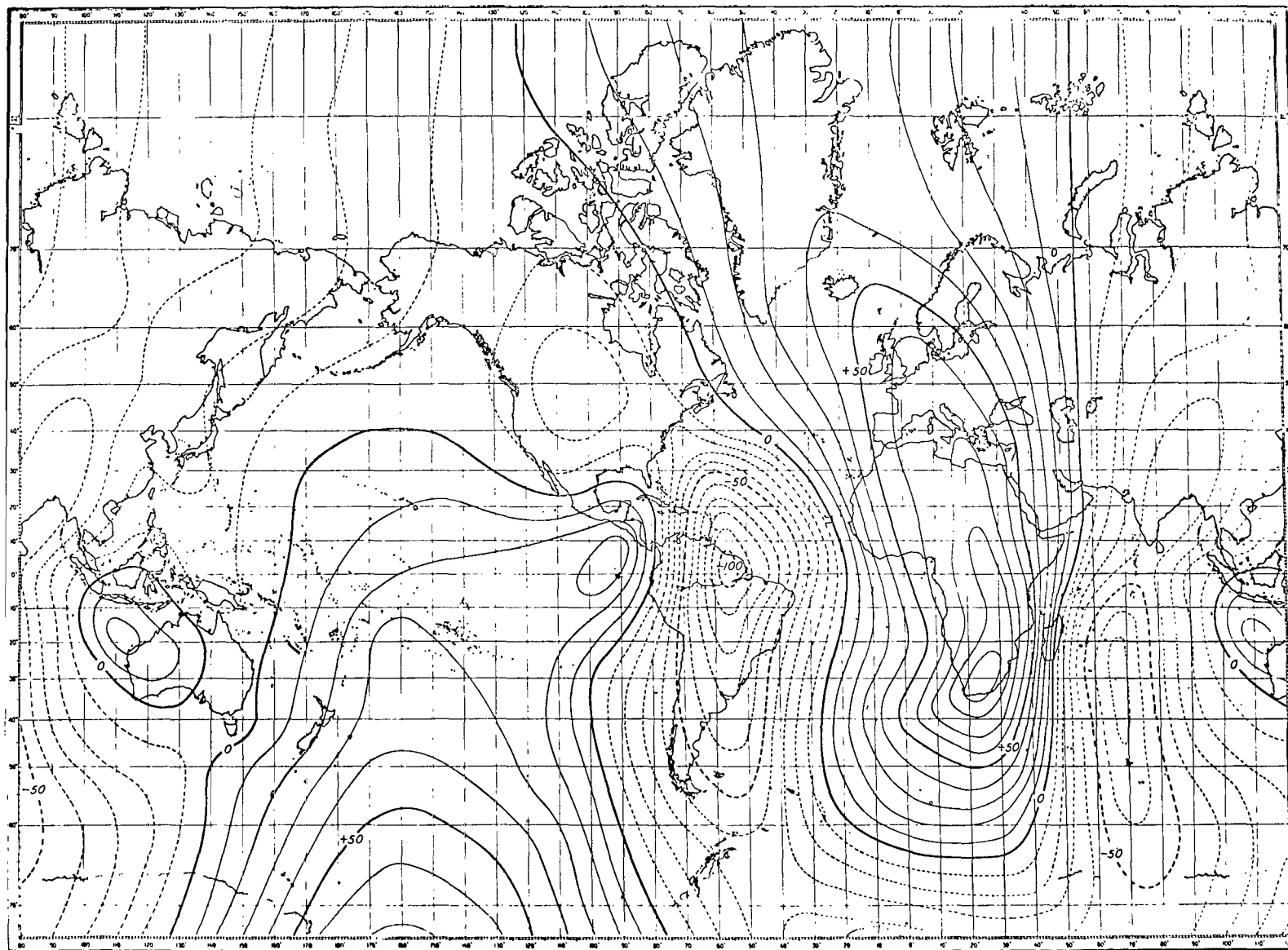


Figure B27-Geomagnetic secular change in gammas per year, east component, epoch 1922.5. Vestine et al. (1947).

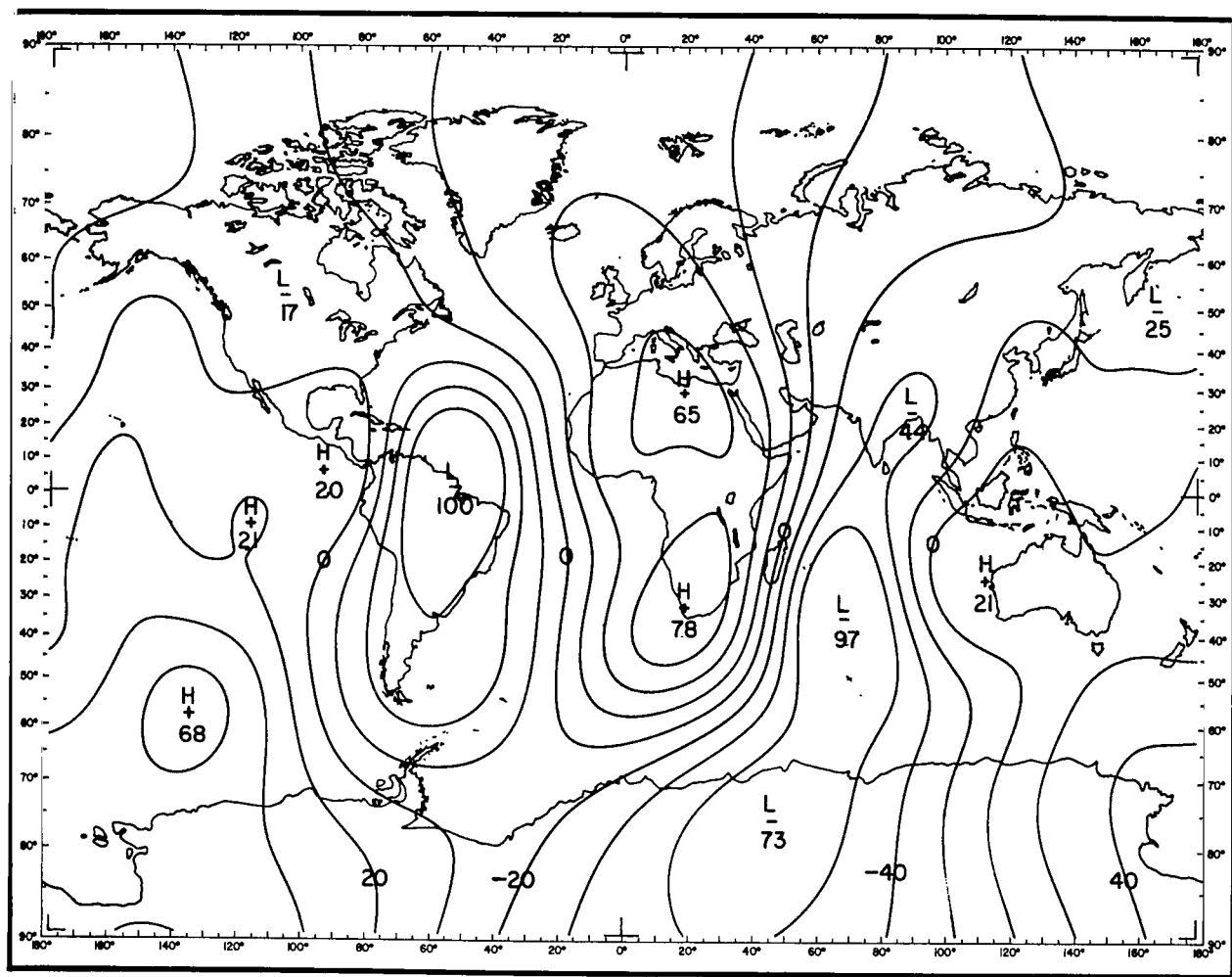


Figure B28—Geomagnetic secular change in gammas per year, east component, epoch 1922.5. GSFC (12/66).

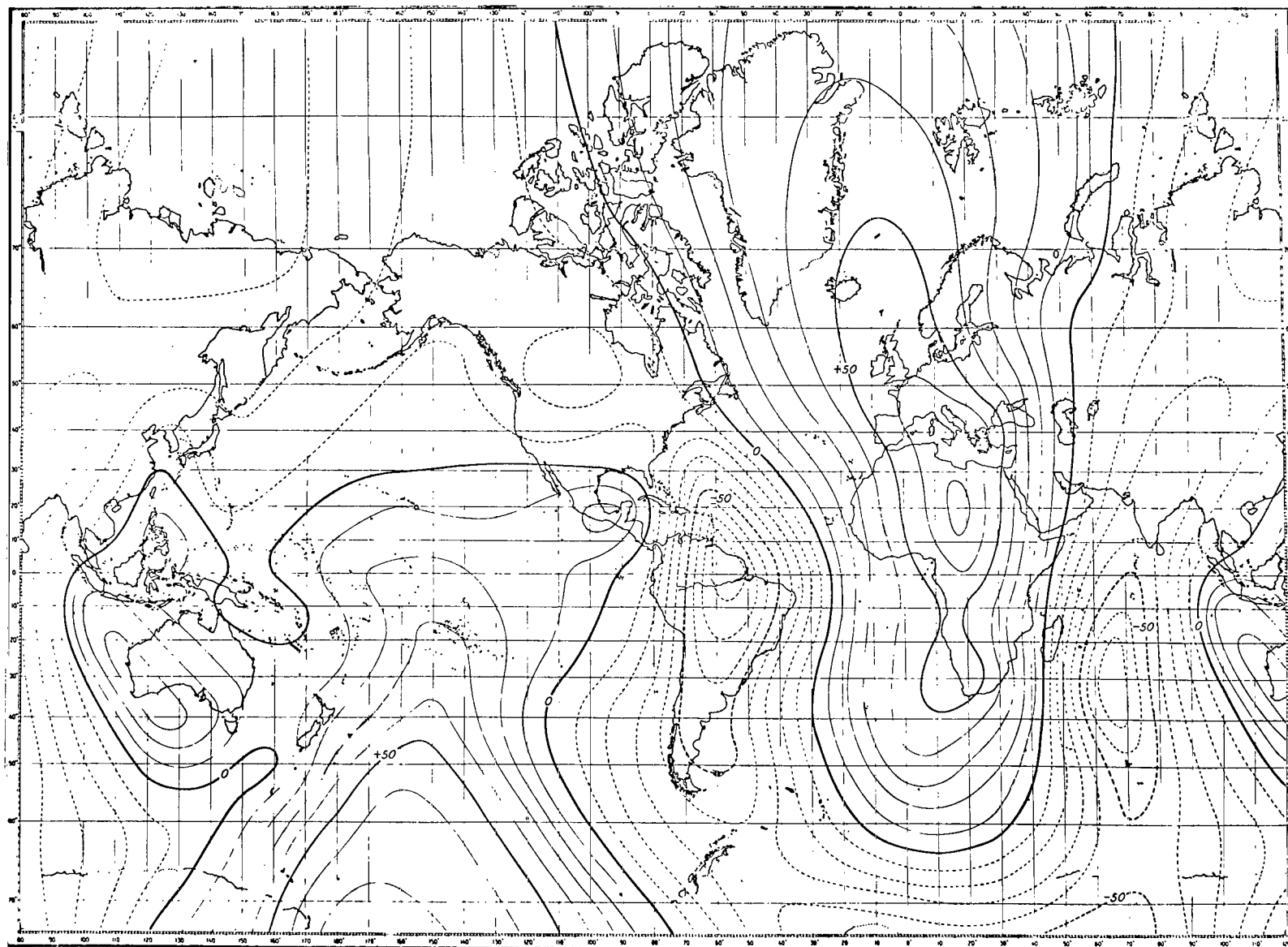


Figure B29—Geomagnetic secular change in gammas per year, east component, epoch 1932.5. Vestine et al. (1947).

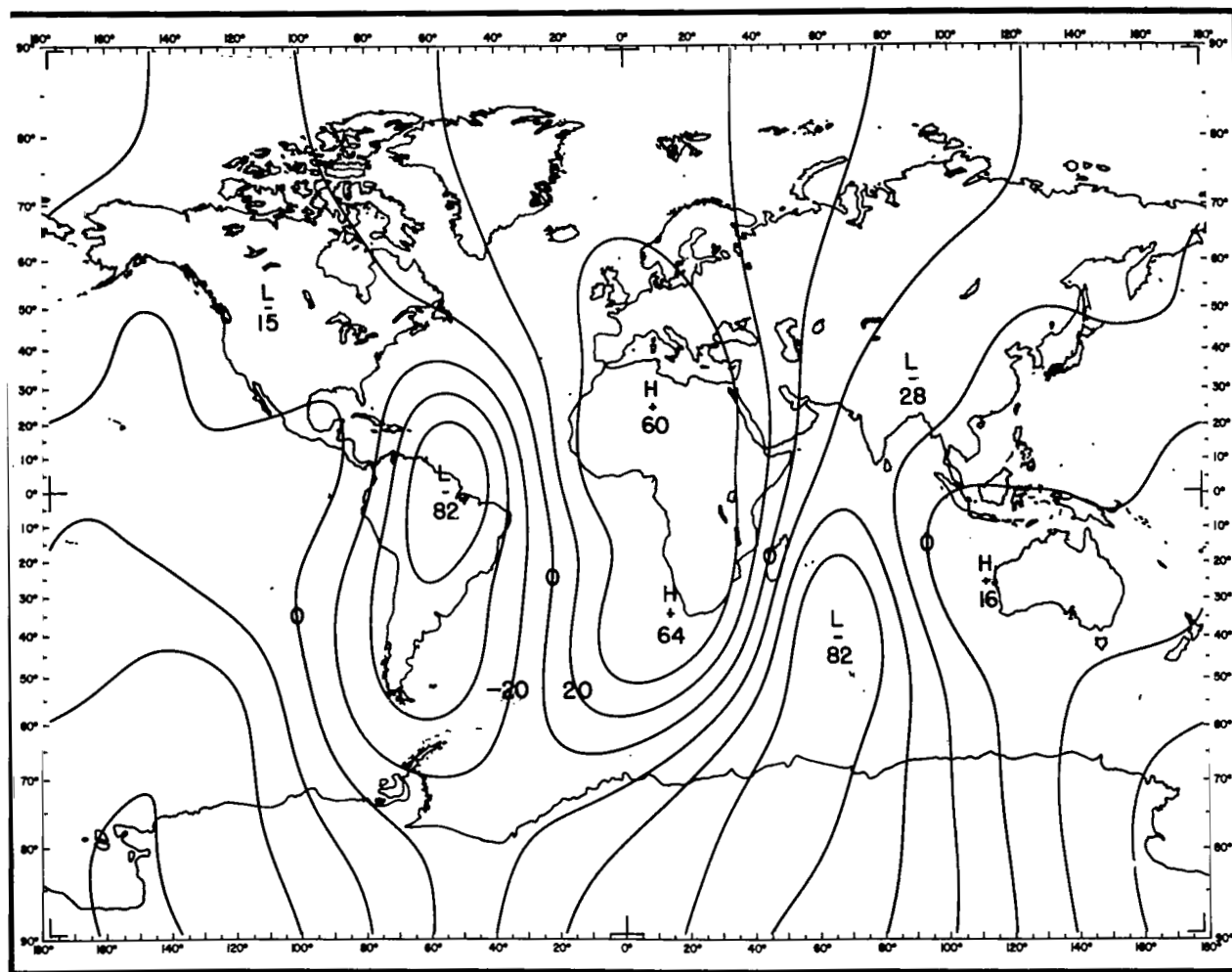


Figure B30—Geomagnetic secular change in gammas per year, east component, epoch 1932.5. GSFC (12/66).

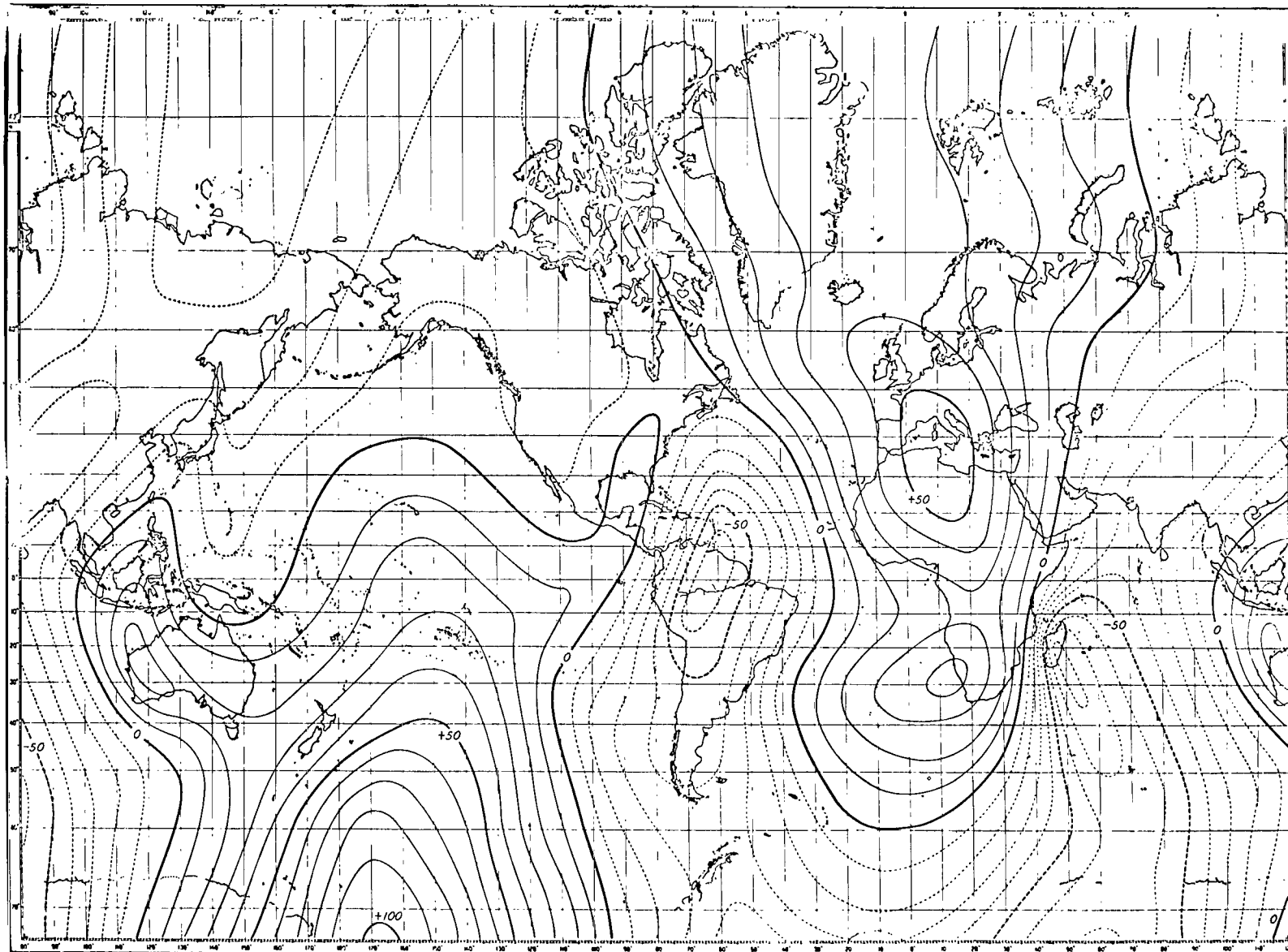


Figure B31—Geomagnetic secular change in gammas per year, east component, epoch 1942.5. Vestine et al. (1947).

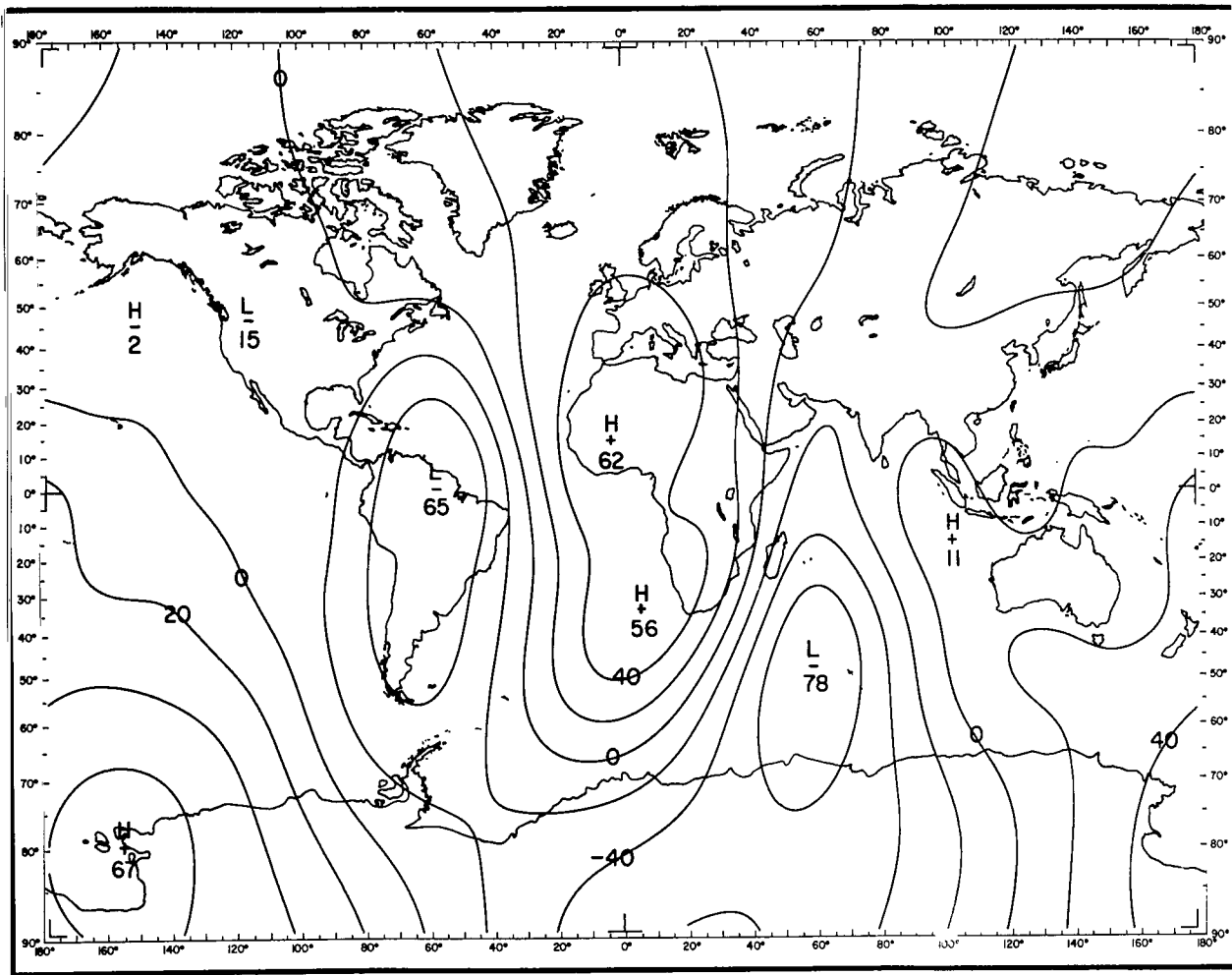


Figure B32—Geomagnetic secular change in gammas per year, east component, epoch 1942.5. GSFC (12/66).

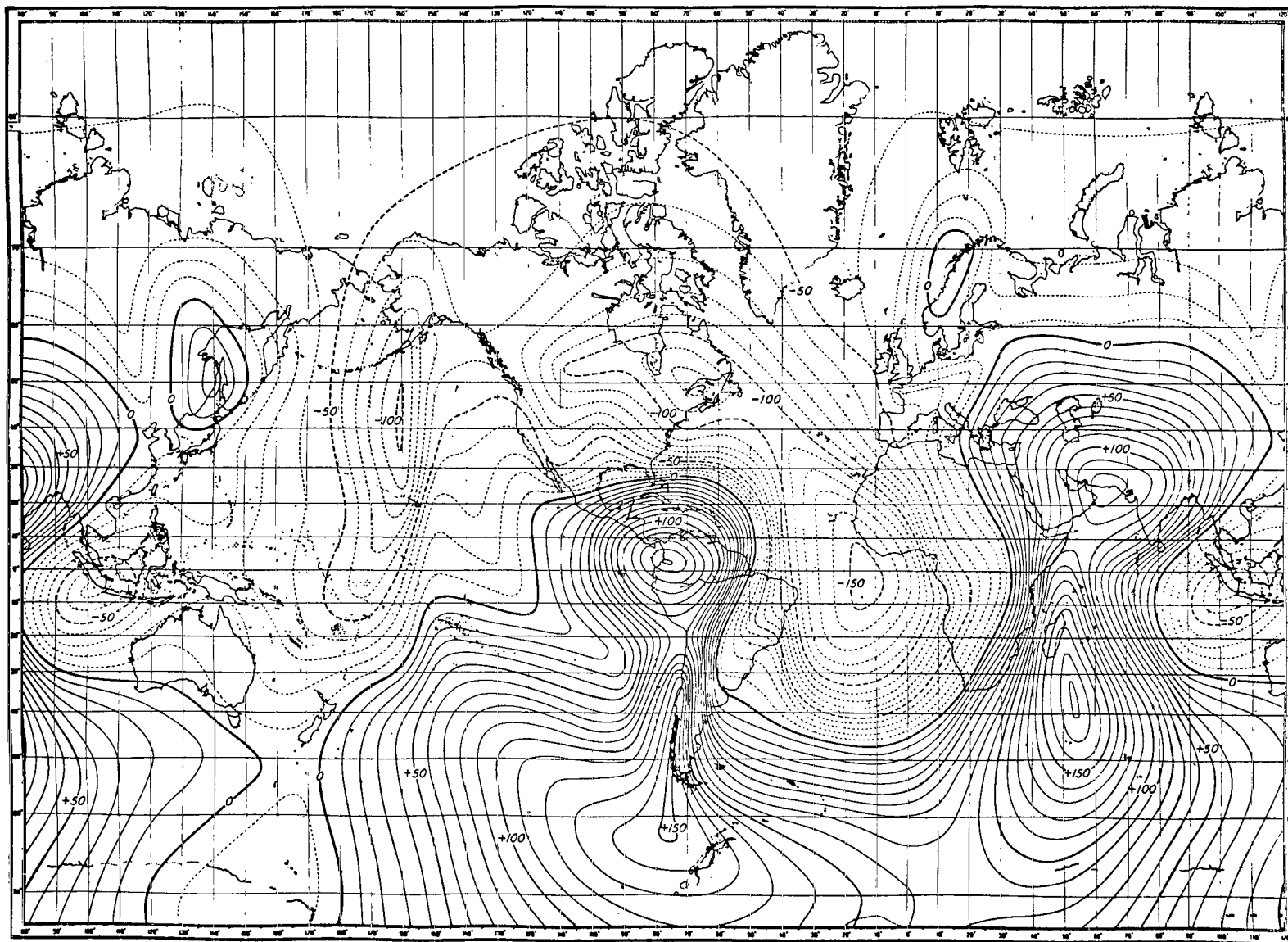


Figure B33—Geomagnetic secular change in gammas per year, vertical component, epoch 1912.5. Vestine et al. (1947).



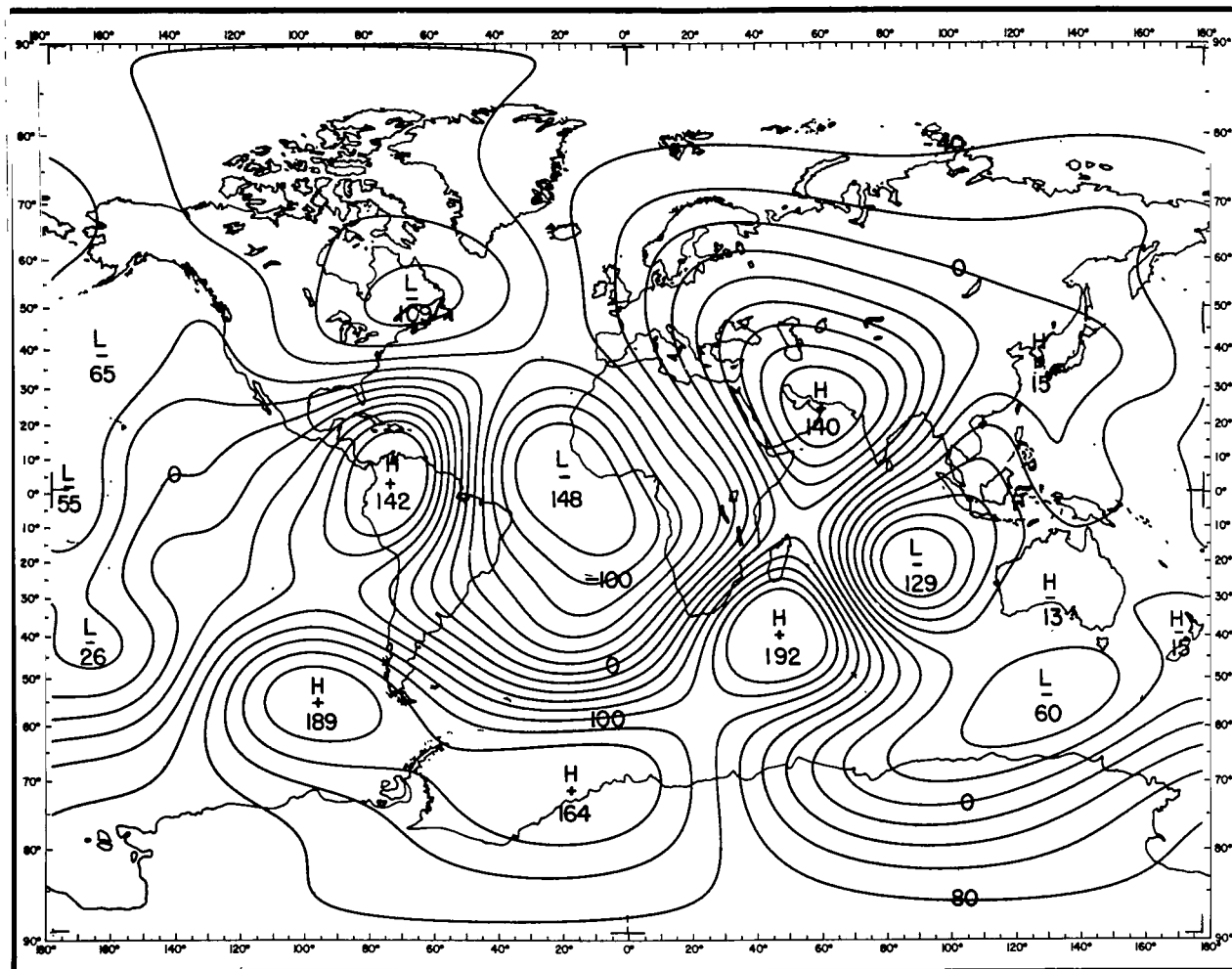


Figure B34—Geomagnetic secular change in gammas per year, vertical component, epoch 1912.5. GSFC (12/66).

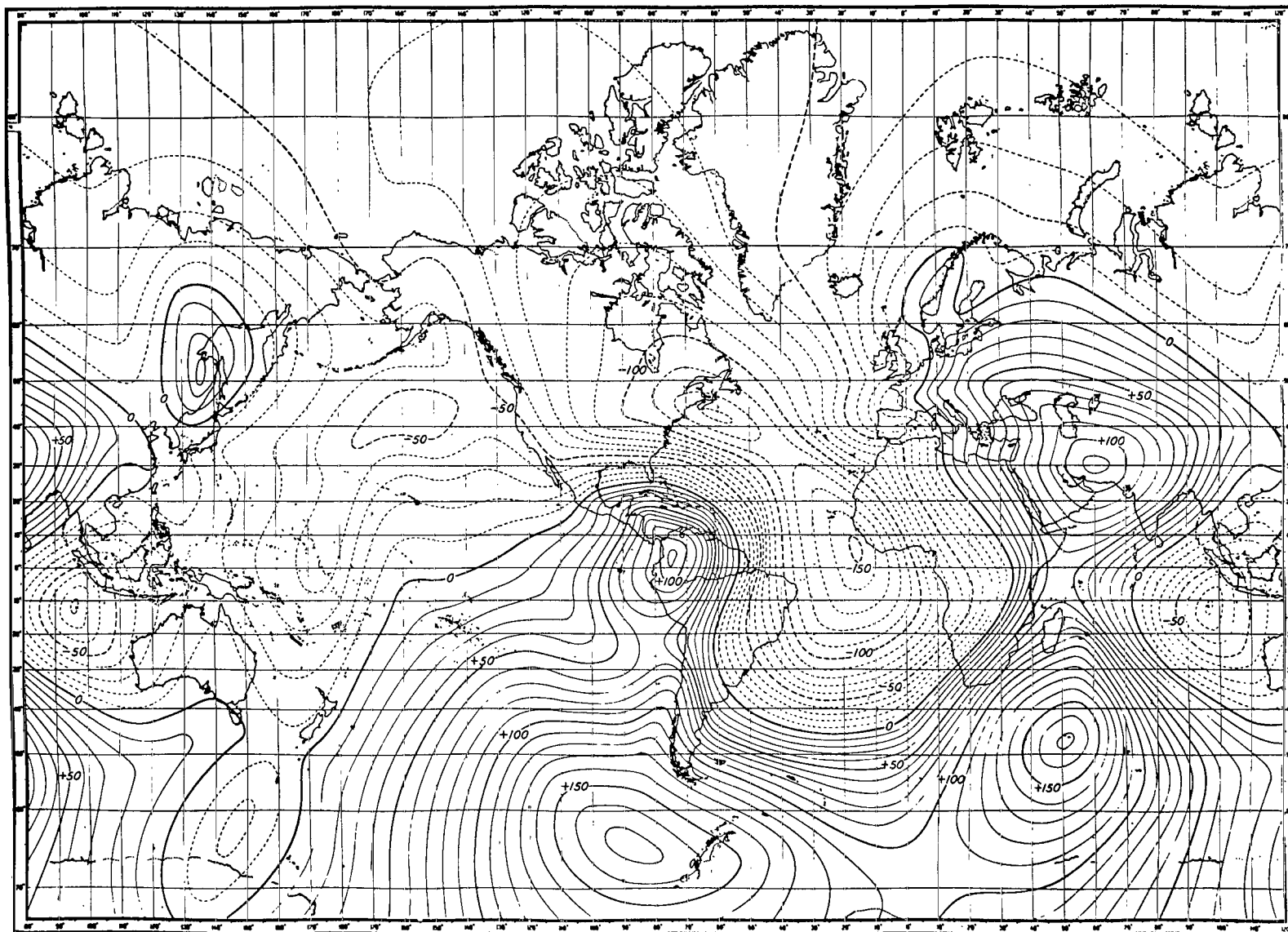


Figure B35-Geomagnetic secular change in gammas per year, vertical component, epoch 1922.5. Vestine et al. (1947).

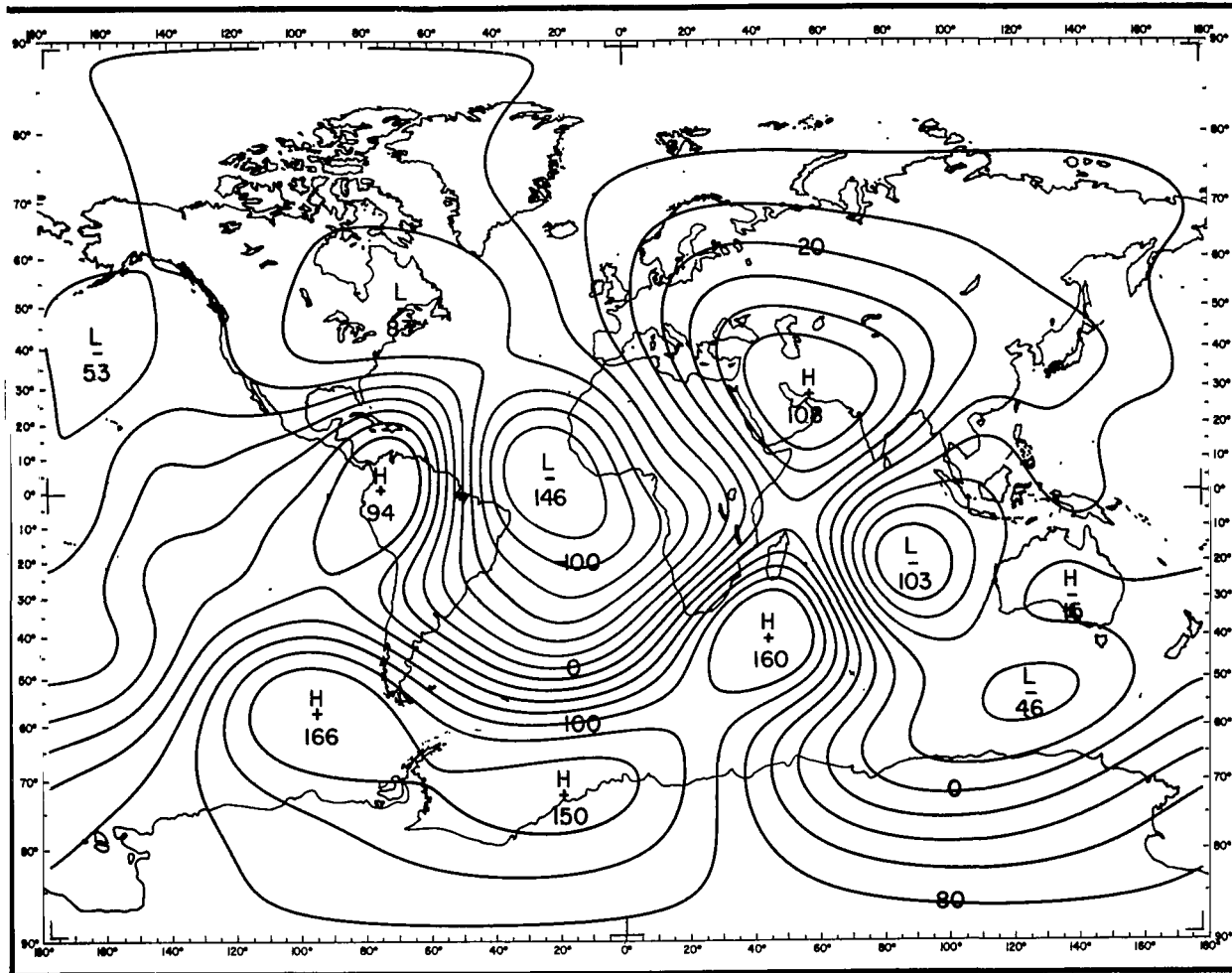


Figure B36—Geomagnetic secular change in gammas per year, vertical component, epoch 1922.5. GSFC (12/66).

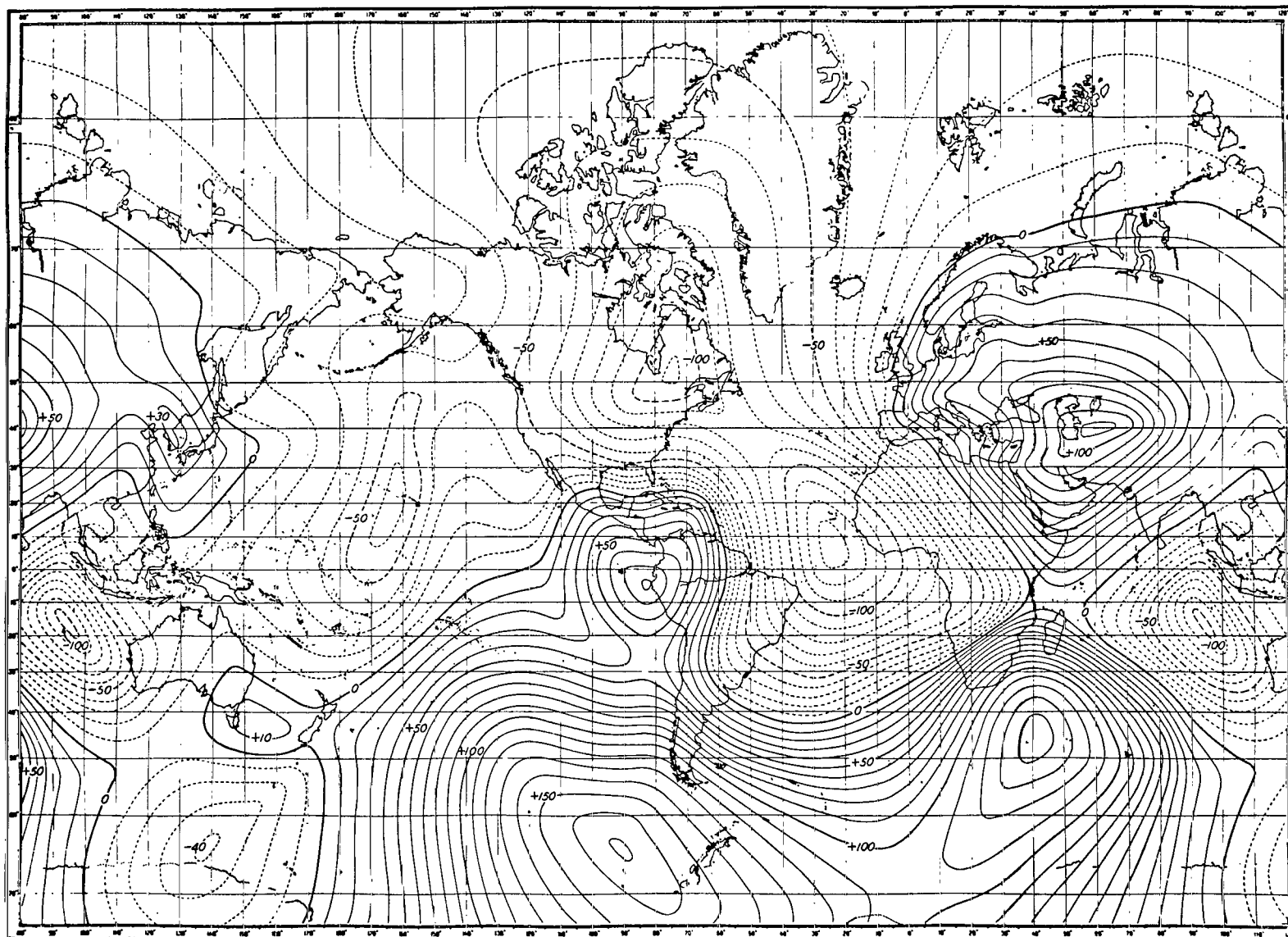


Figure B37—Geomagnetic secular change in gammas per year, vertical component, epoch 1932.5. Vestine et al. (1947).

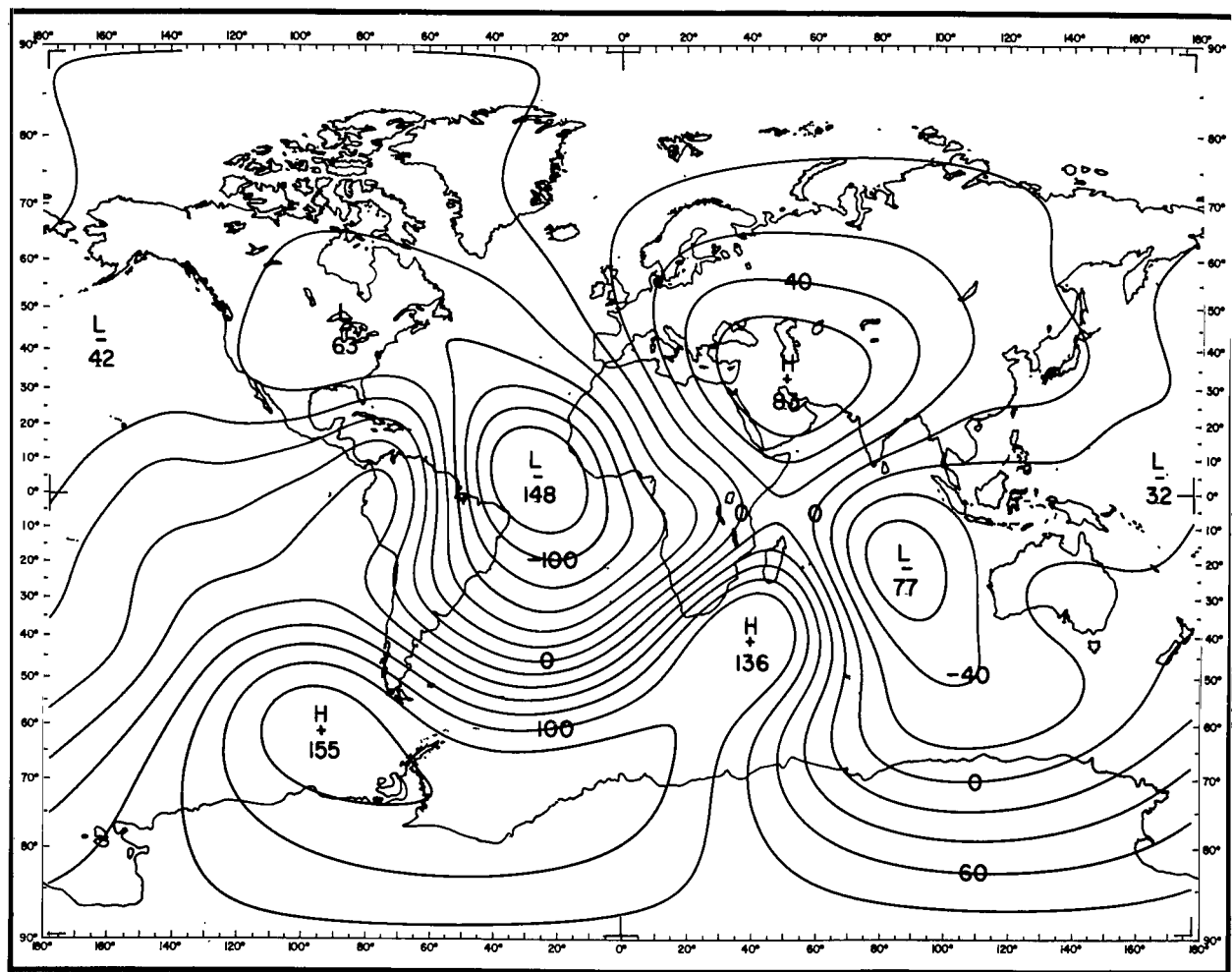


Figure B38—Geomagnetic secular change in gammas per year, vertical component, epoch 1932.5. GSFC (12/66).

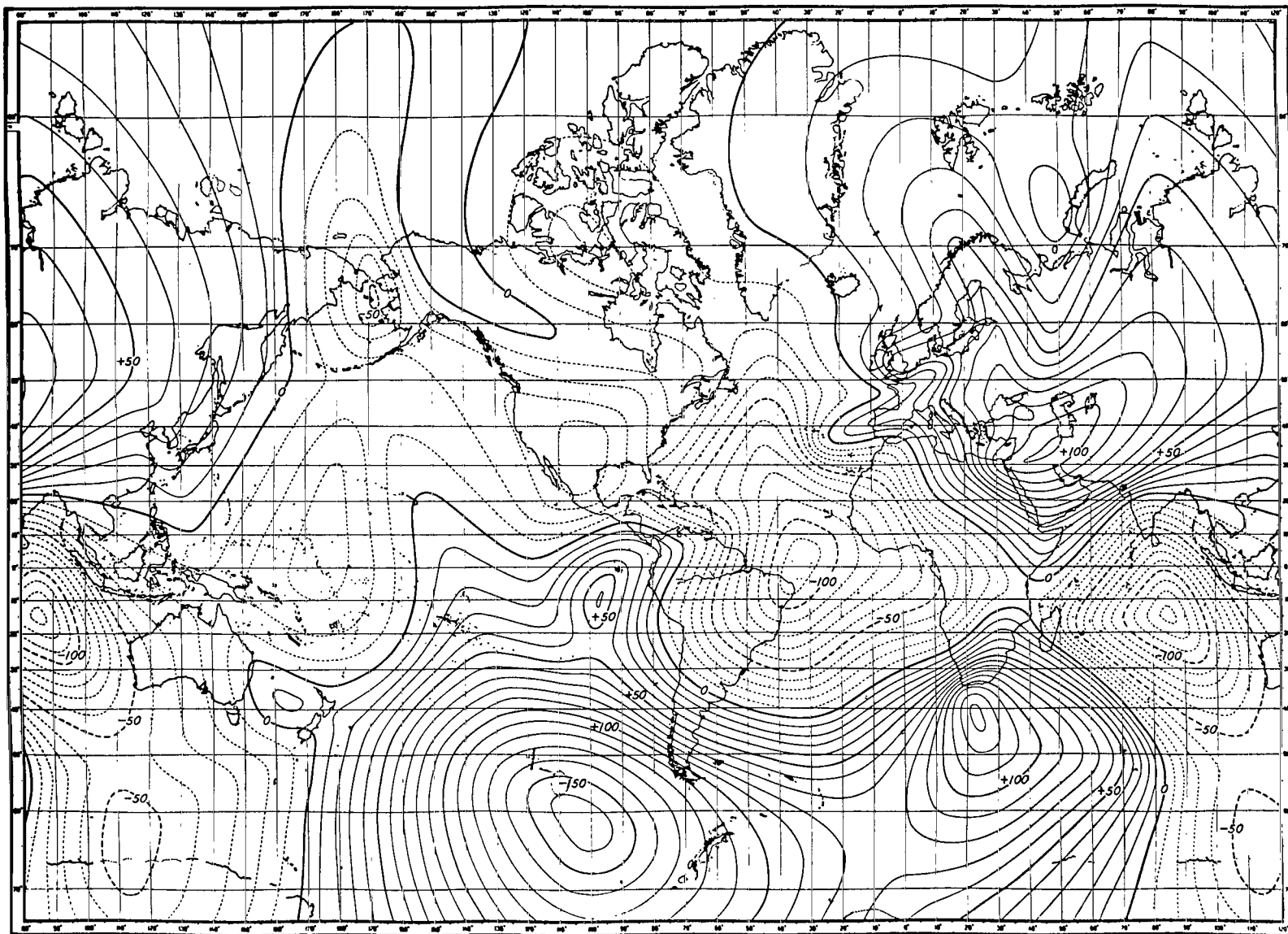


Figure B39-Geomagnetic secular change in gammas per year, vertical component, epoch 1942.5. Vestine et al. (1947).

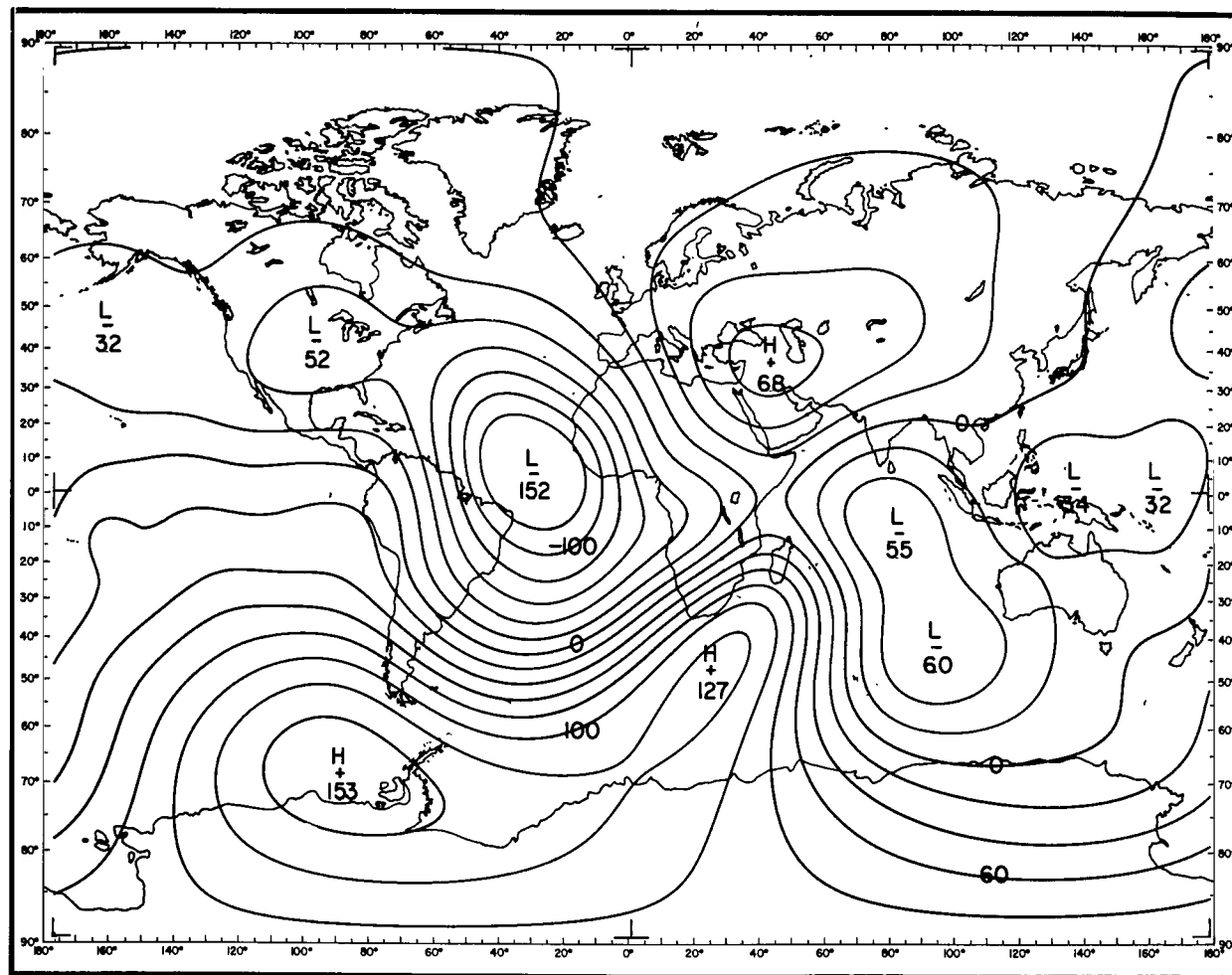


Figure B40—Geomagnetic secular change in gammas per year, vertical component, epoch 1942.5. GSFC (12/66).

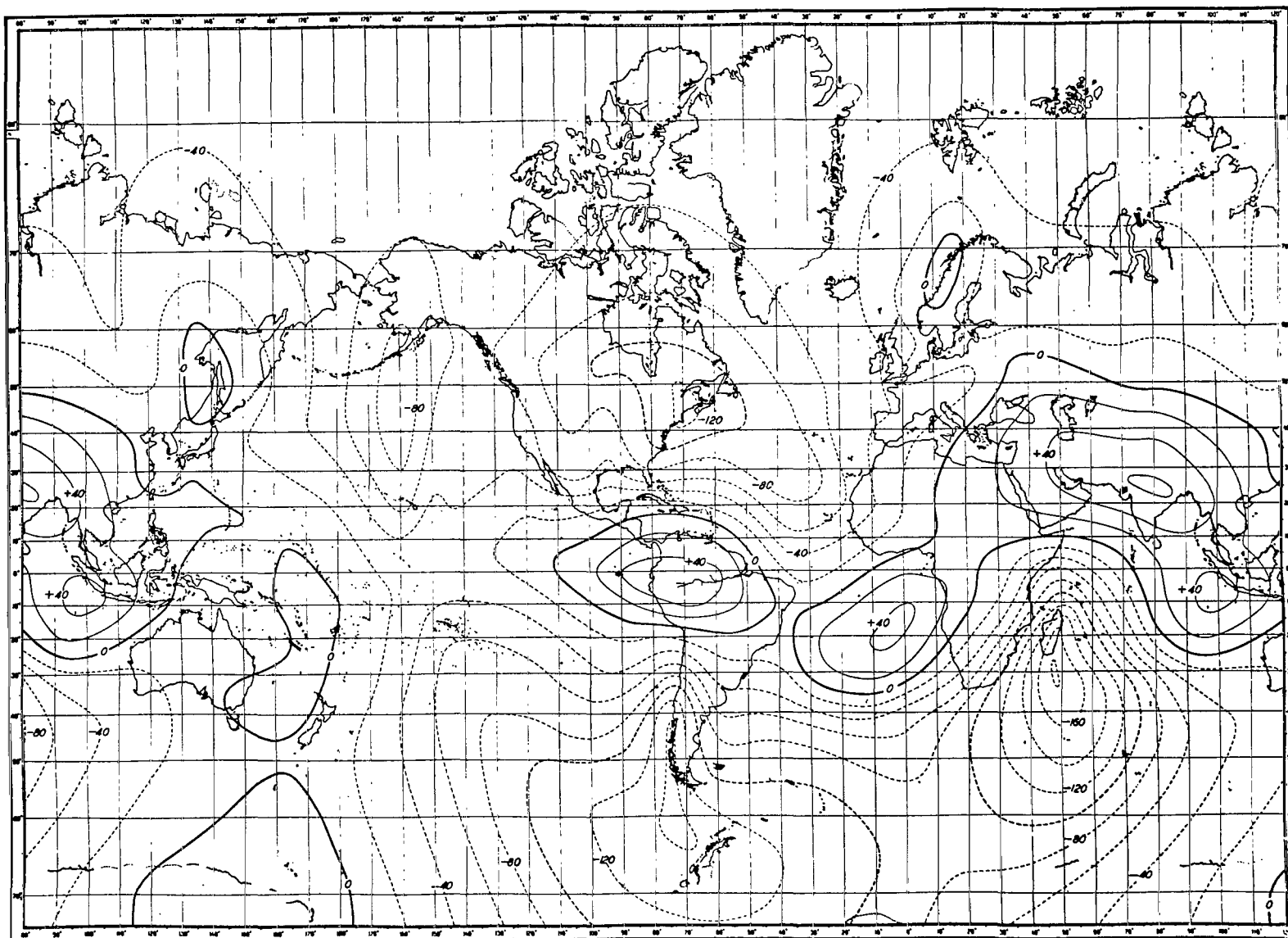


Figure B41—Geomagnetic secular change in gammas per year, total intensity, epoch 1912.5. Vestine et al. (1947).



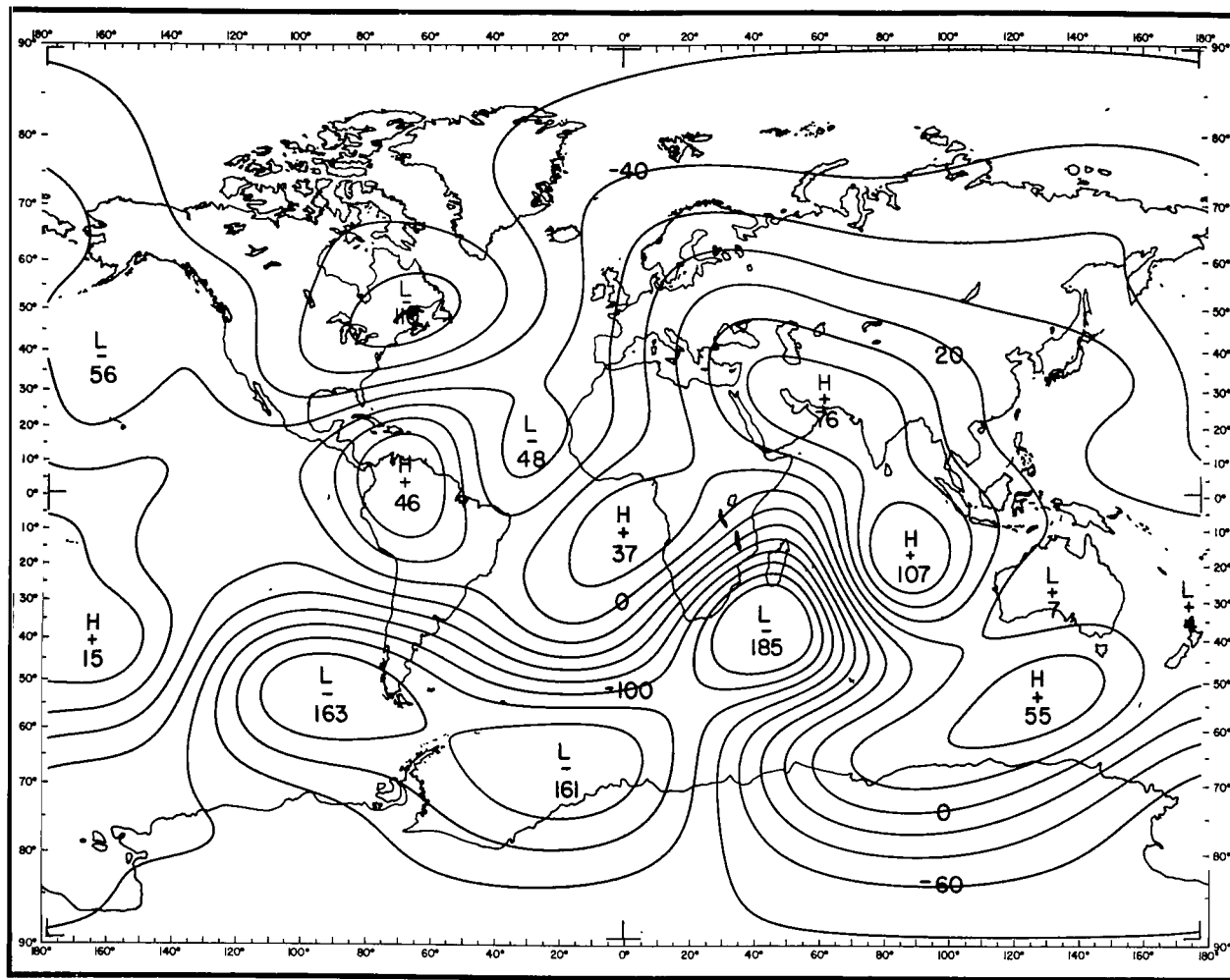


Figure B42—Geomagnetic secular change in gammas per year, total intensity, epoch 1912.5. GSFC (12/66).

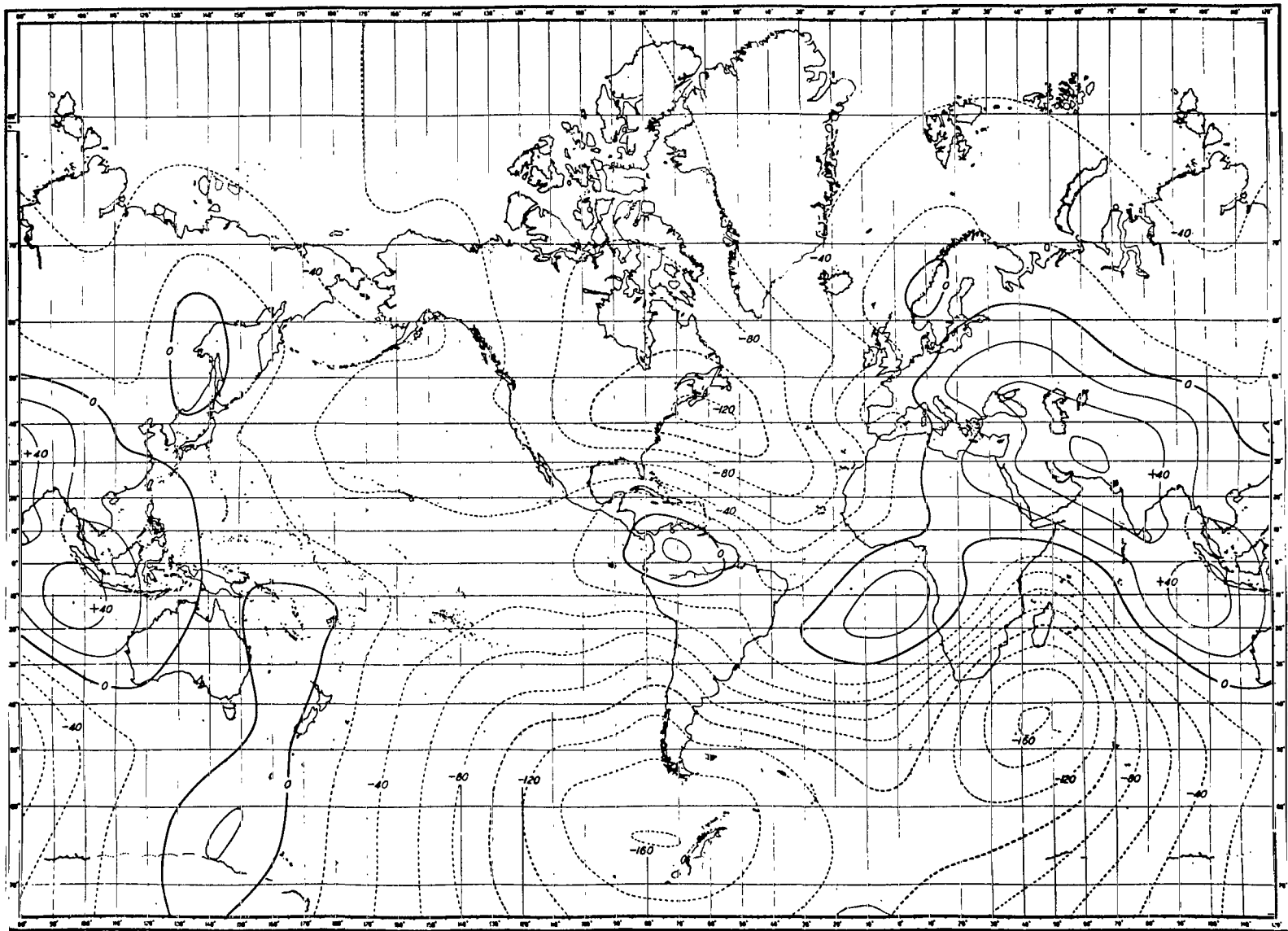


Figure B43—Geomagnetic secular change in gammas per year, total intensity, epoch 1922.5. Vestine et al. (1947).

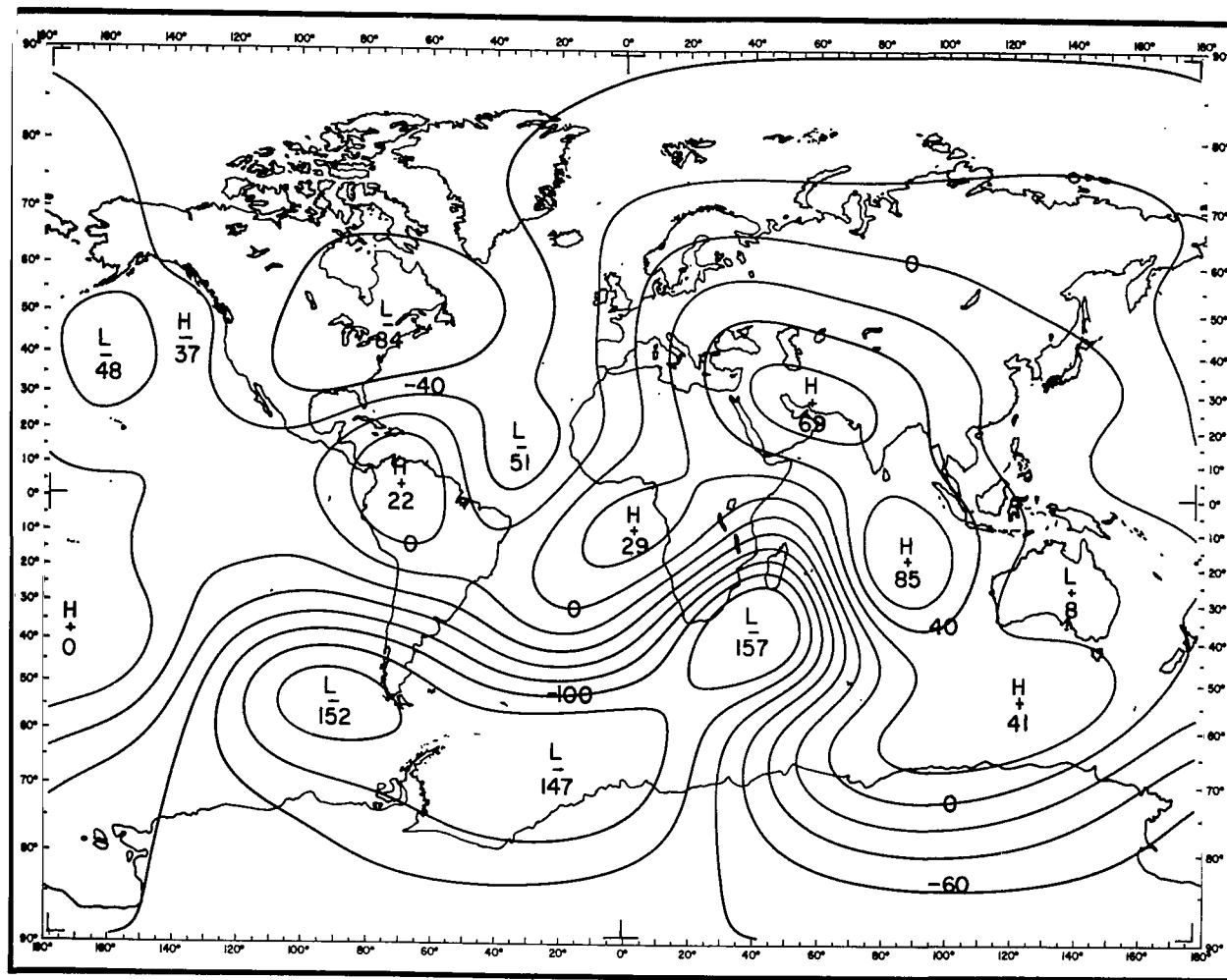


Figure B44—Geomagnetic secular change in gammas per year, total intensity, epoch 1922.5. GSFC (12/66).

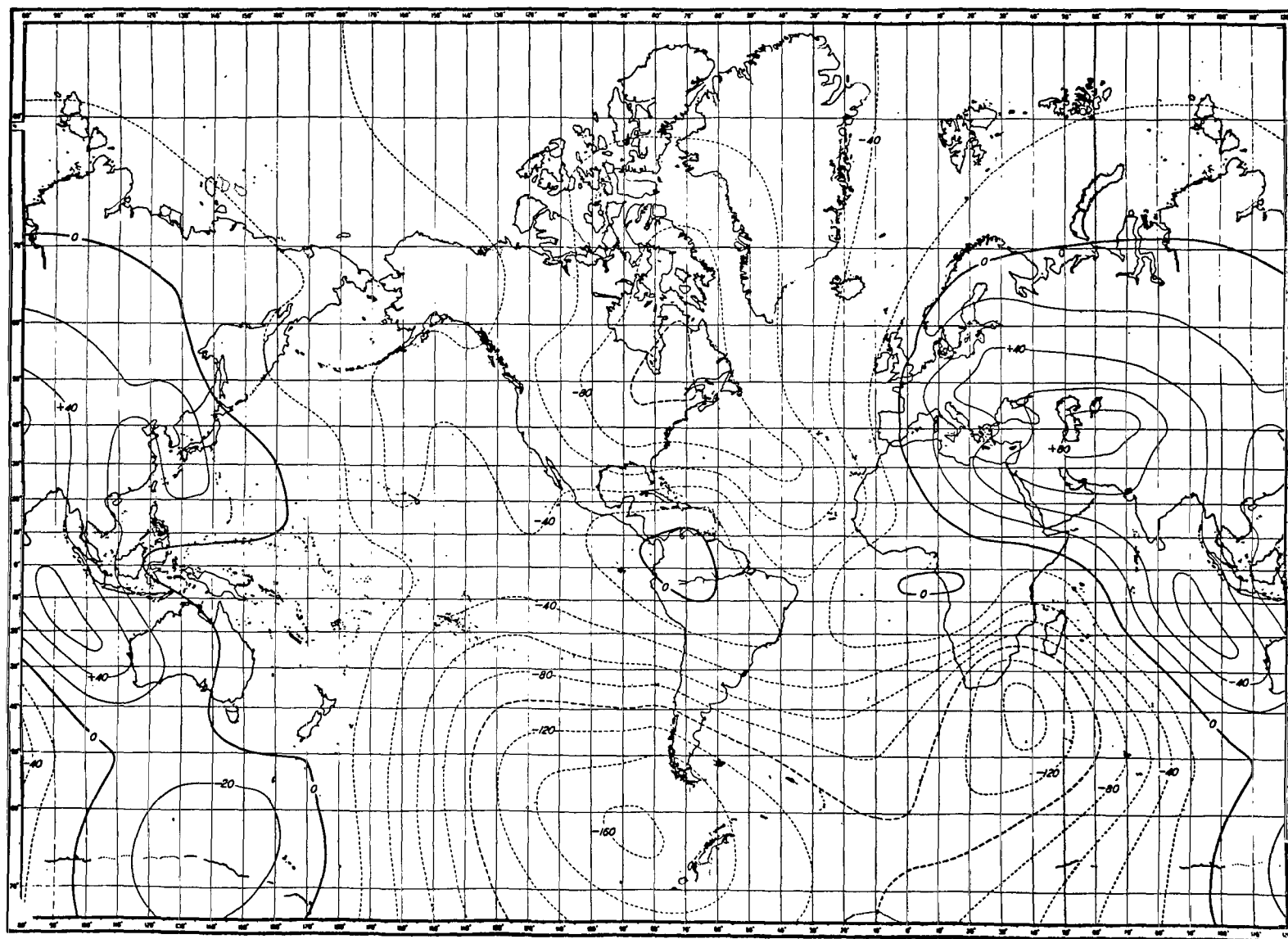


Figure B45-Geomagnetic secular change in gammas per year, total intensity, epoch 1932.5. Vestine et al. (1947).

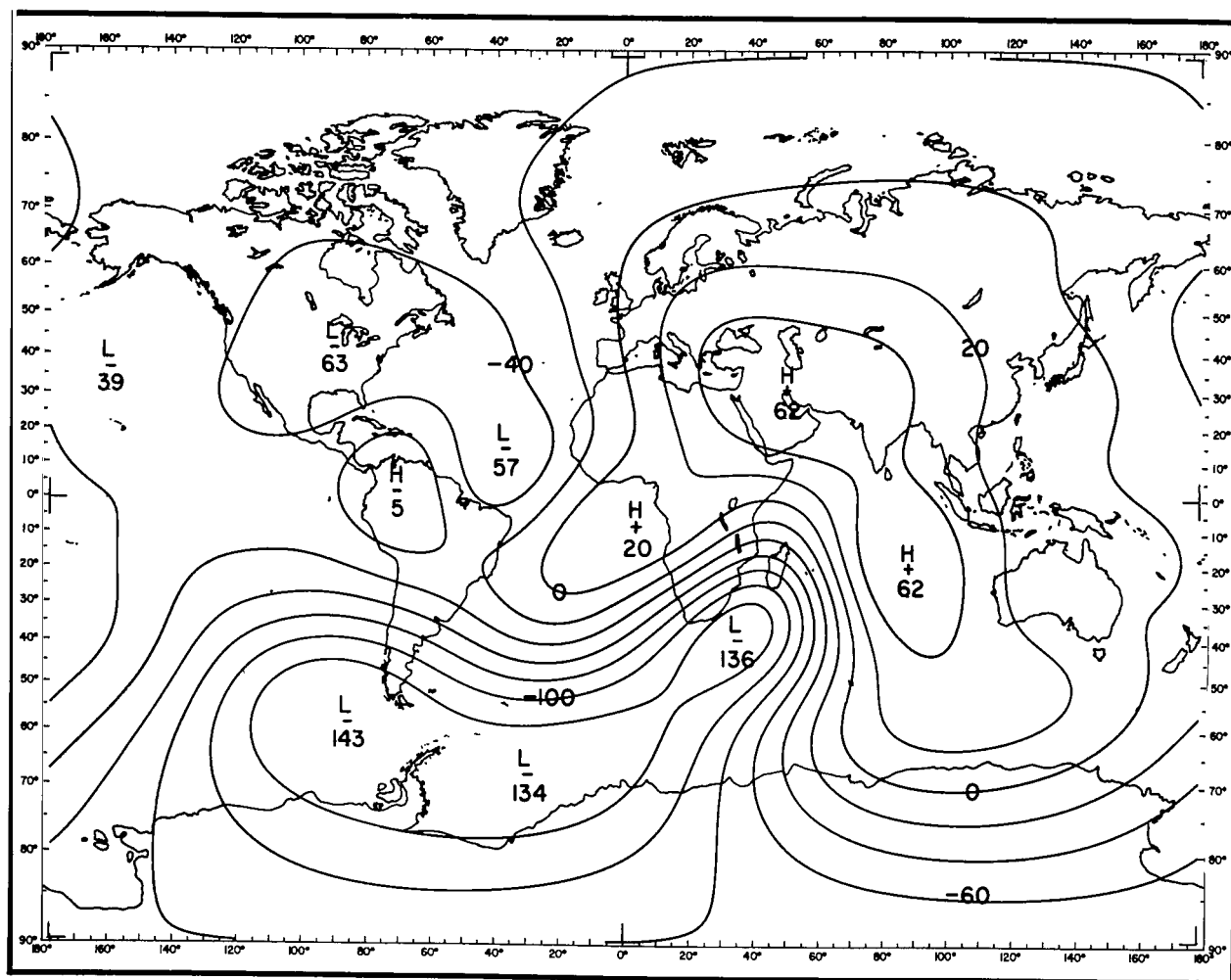


Figure B46—Geomagnetic secular change in gammas per year, total intensity, epoch 1932.5. GSFC (12/66).

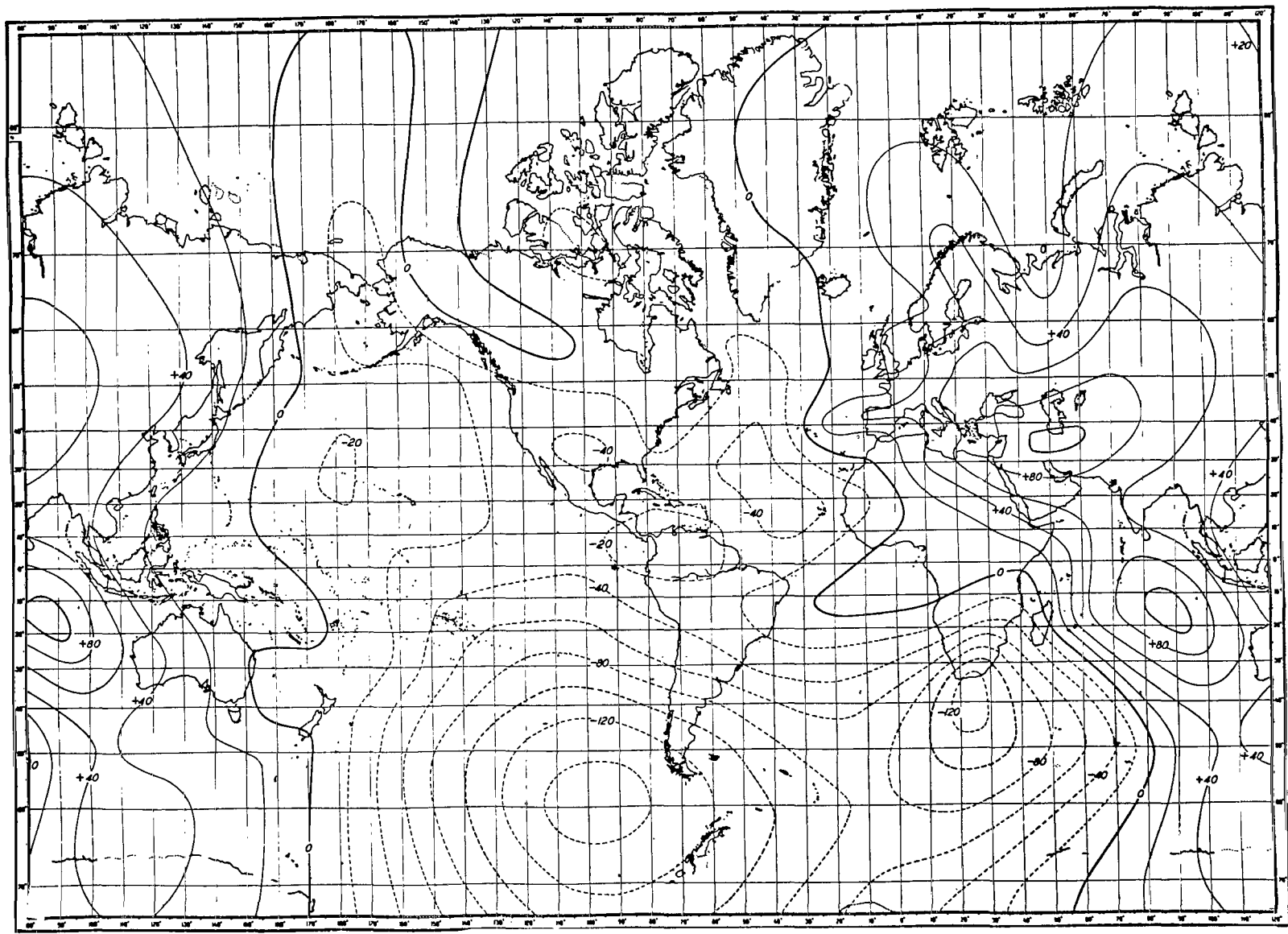


Figure B47—Geomagnetic secular change in gammas per year, total intensity, epoch 1942.5. Vestine et al. (1947).







Appendix C

**Main Field Component and Isoporic Charts Computed From  
GSFC (12/66) for 1965.0 at the Earth's Surface**





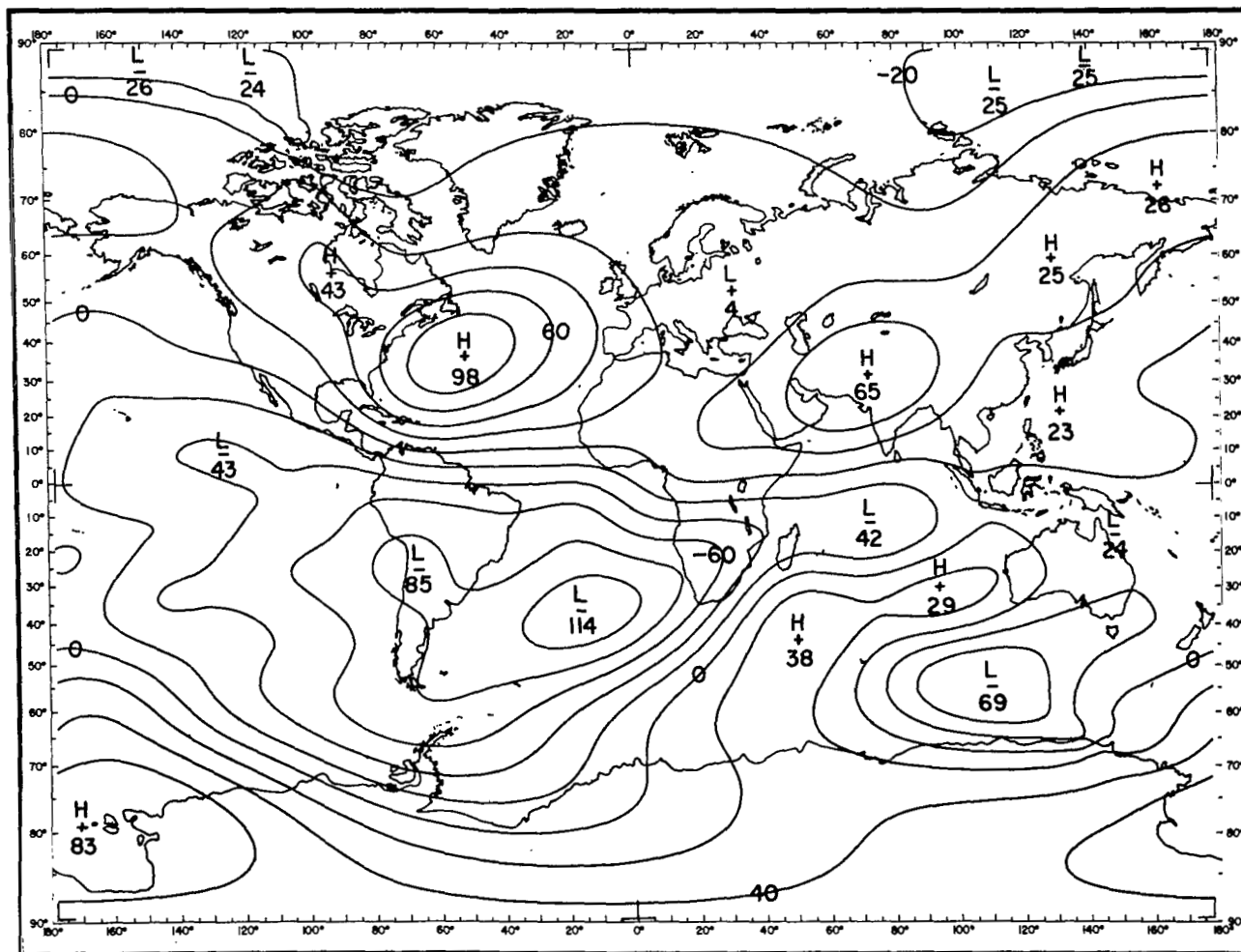


Figure C2—Geomagnetic secular change in gammas per year, horizontal component, epoch 1965.0. GSFC (12/66).

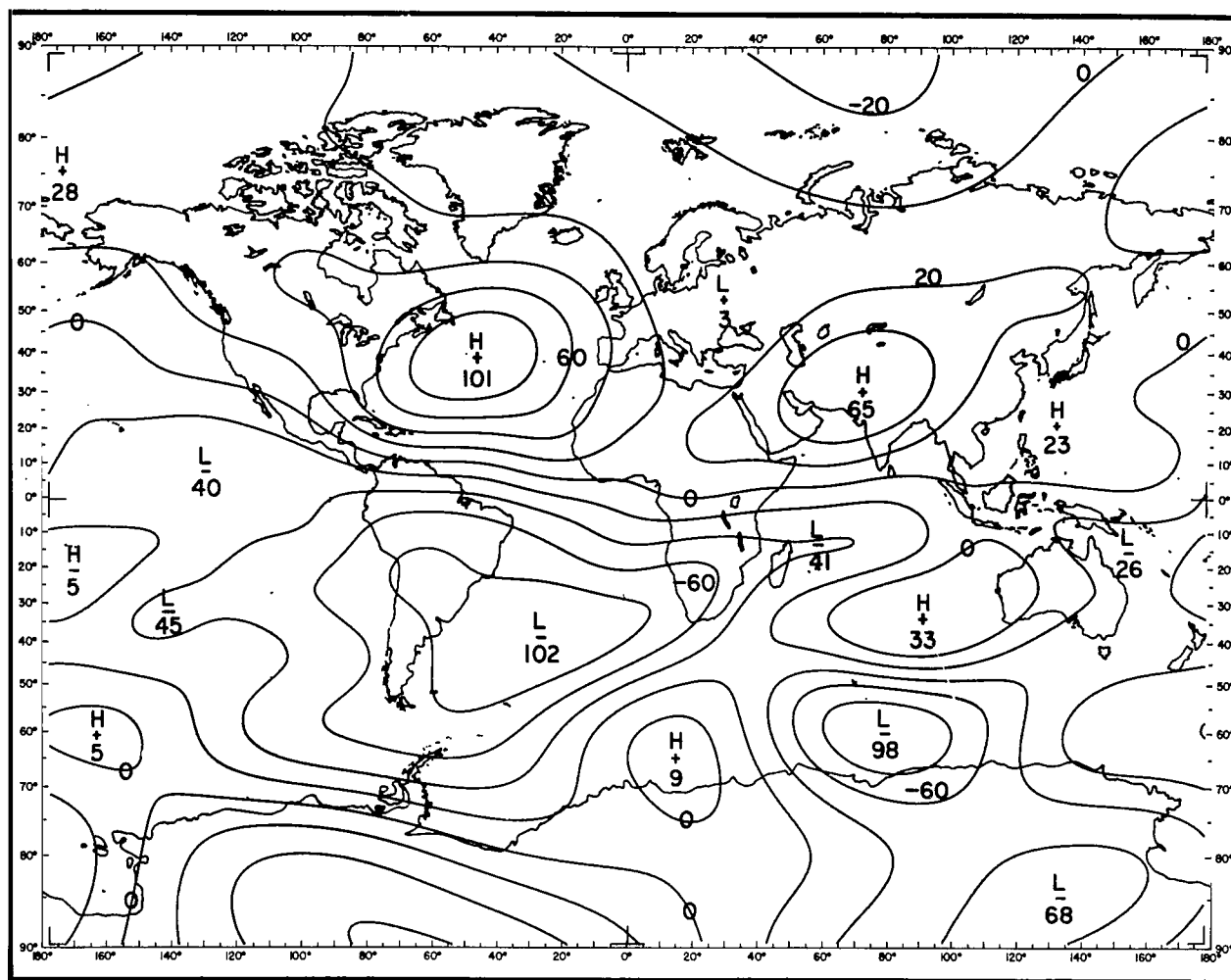


Figure C3—Geomagnetic secular change in gammas per year, north component, epoch 1965.0. GSFC (12/66).

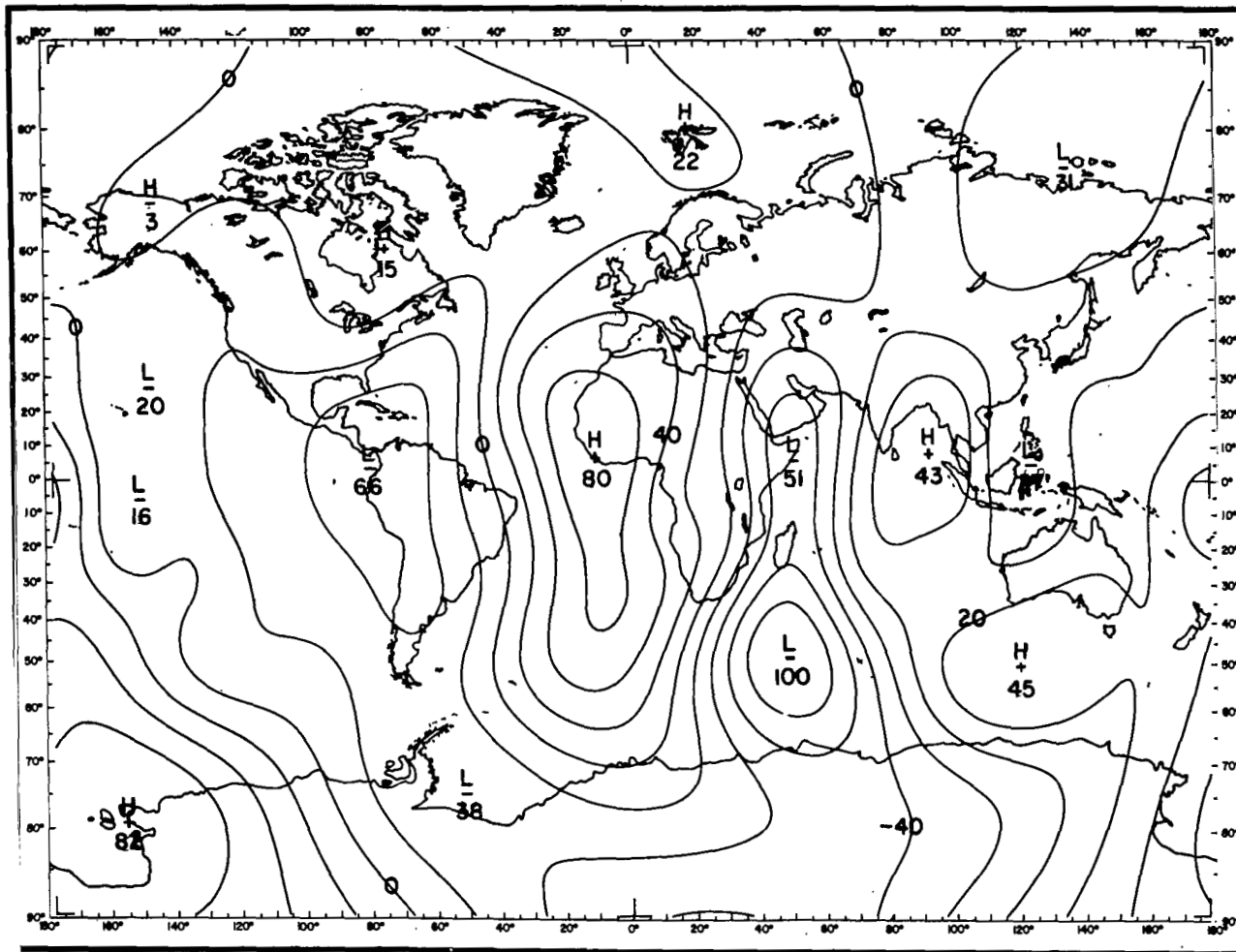


Figure C4—Geomagnetic secular change in gammas per year, east component, epoch 1965.0. GSFC (12/66).

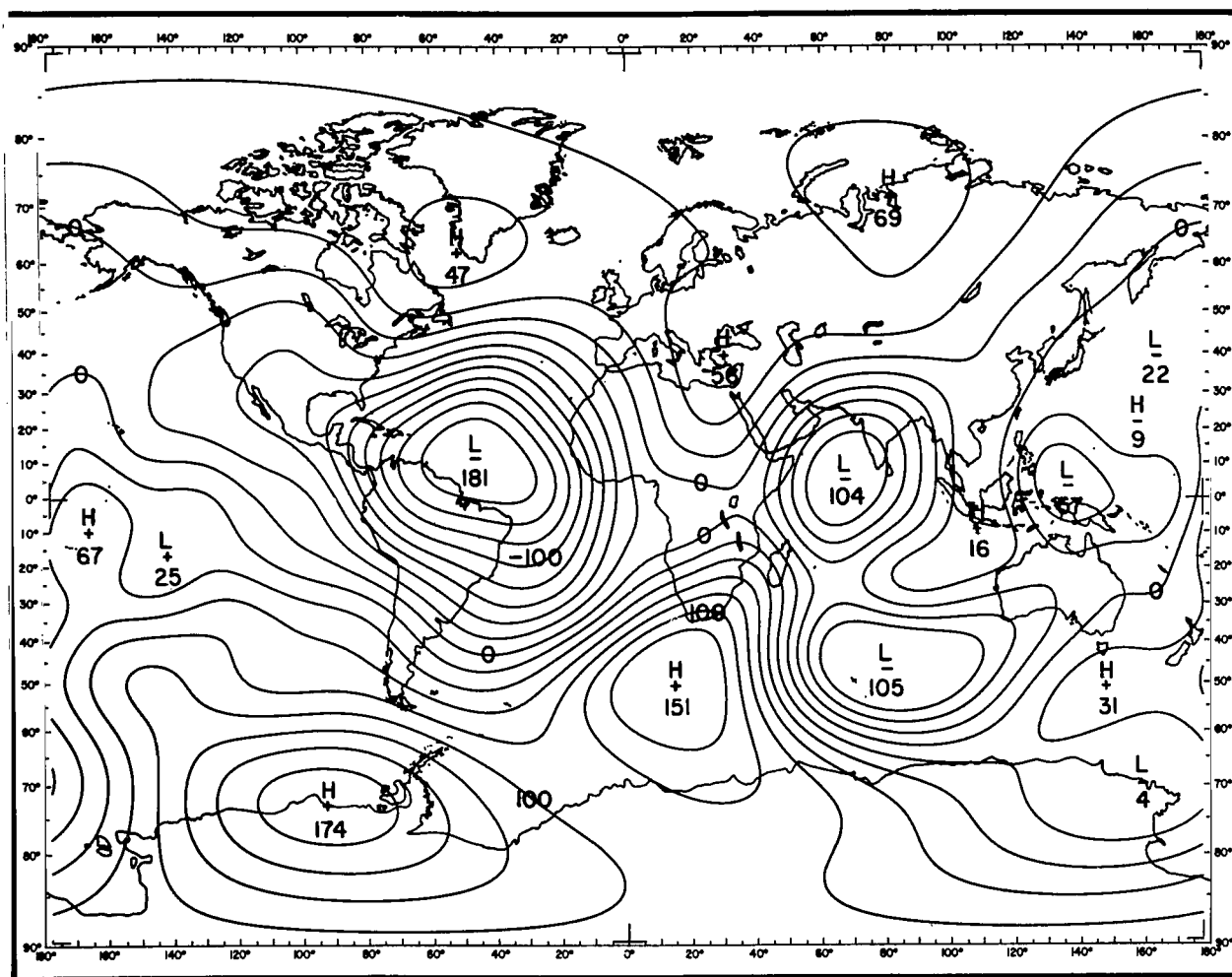


Figure C5—Geomagnetic secular change in gammas per year, vertical component, epoch 1965.0. GSFC (12/66).

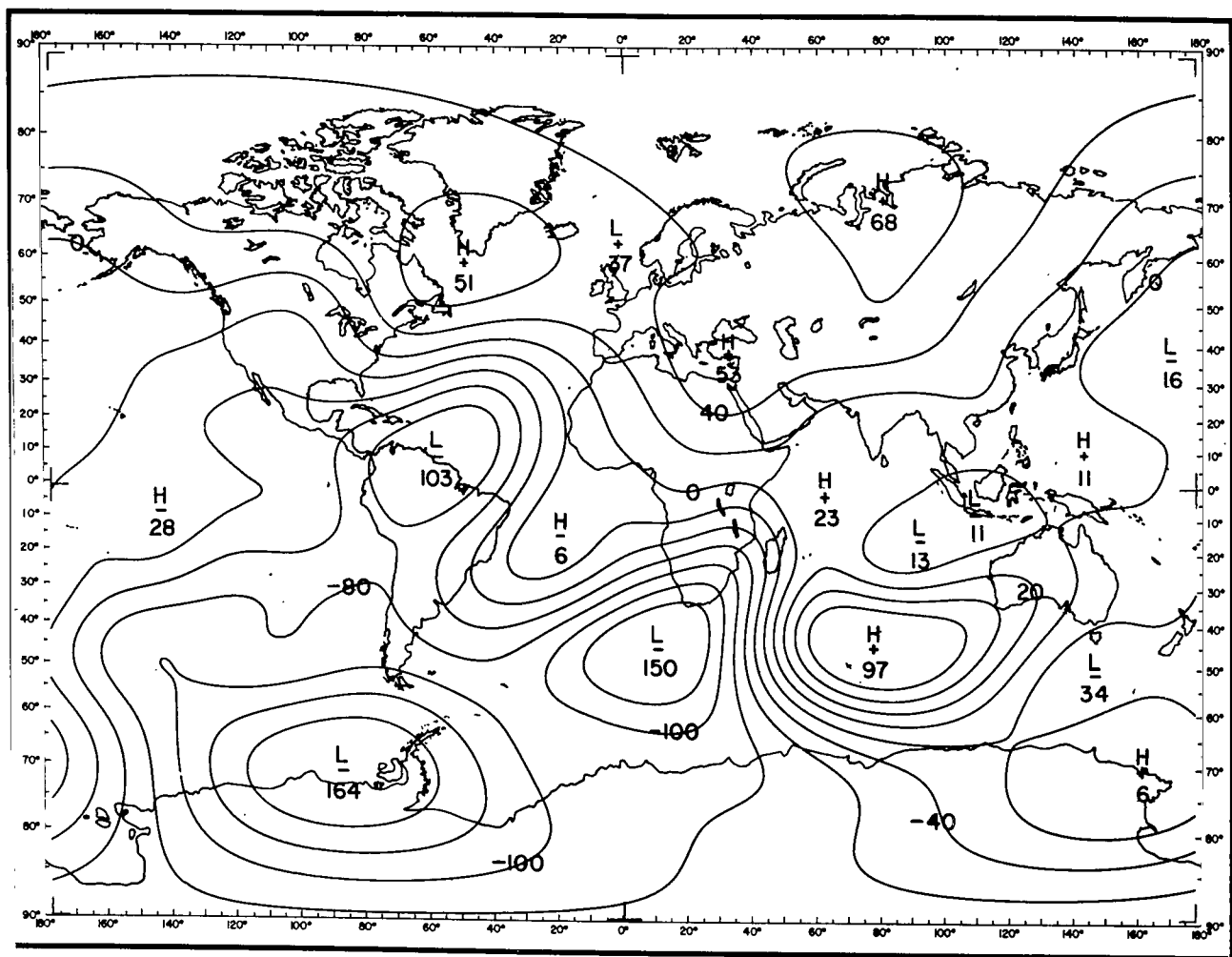


Figure C6—Geomagnetic secular change in gammas per year, total intensity, epoch 1965.0. GSFC (12/66).



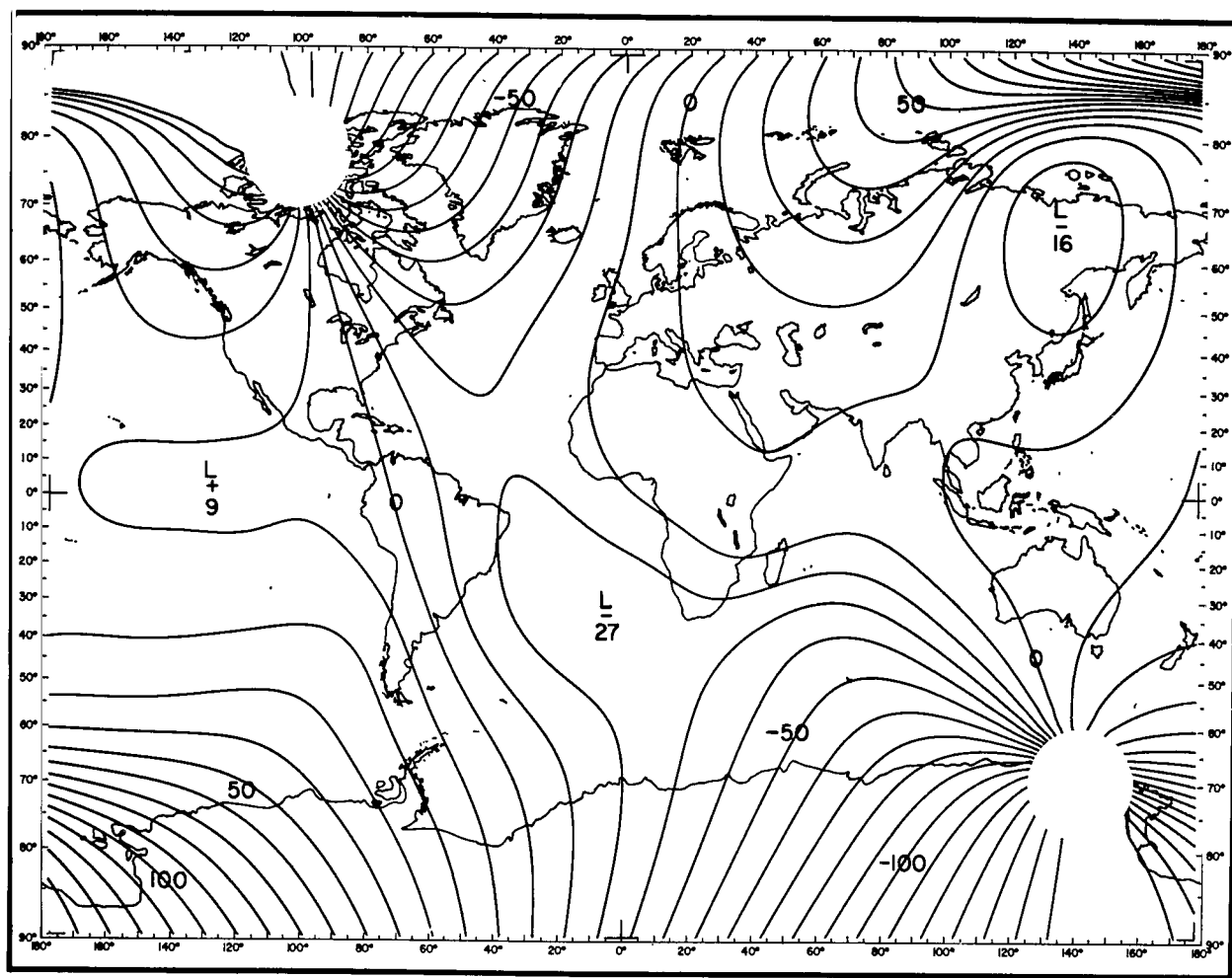


Figure C7-D in degrees, epoch 1965.0. GSFC (12/66).

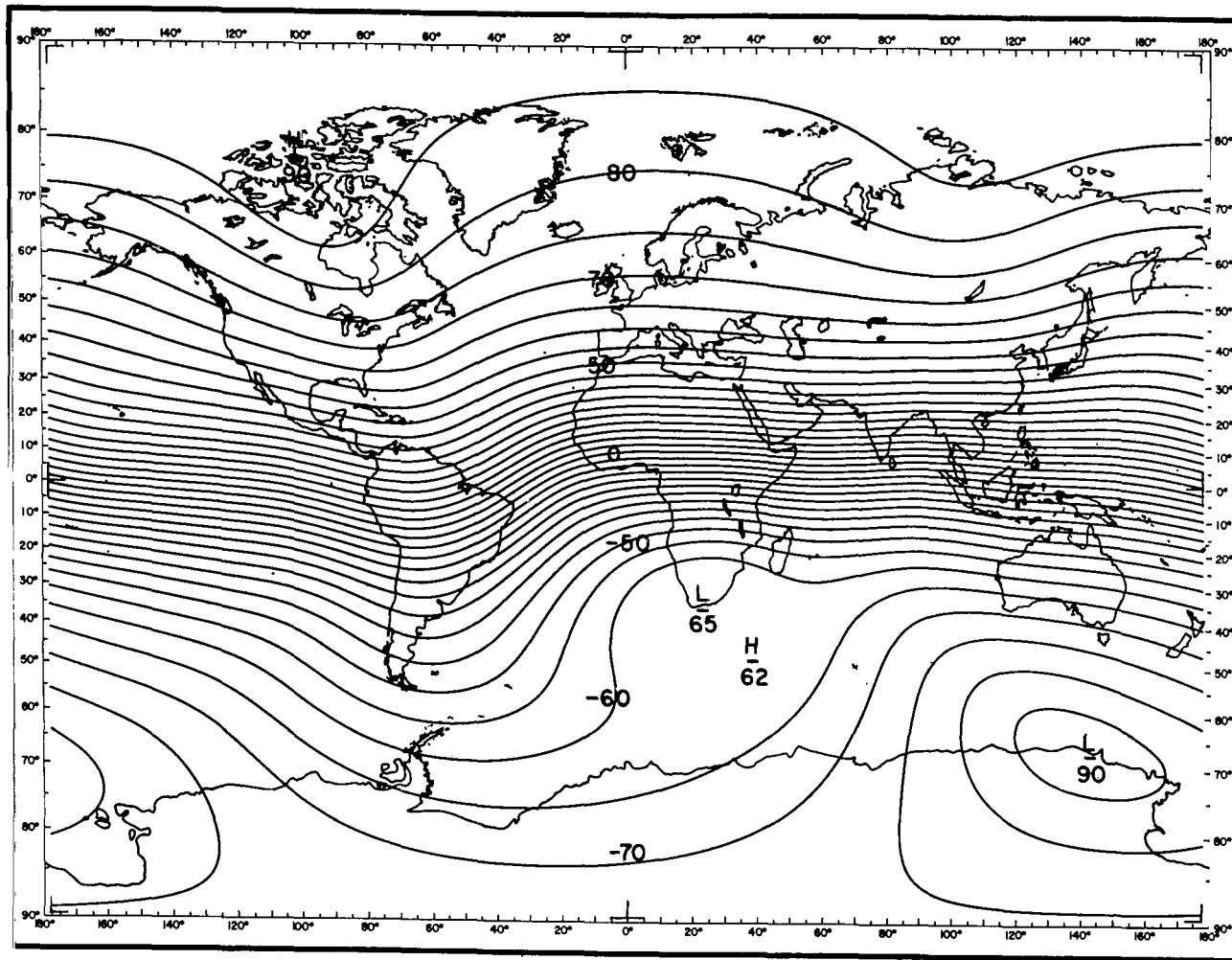


Figure C8-1 in degrees, epoch 1965.0. GSFC (12/66).

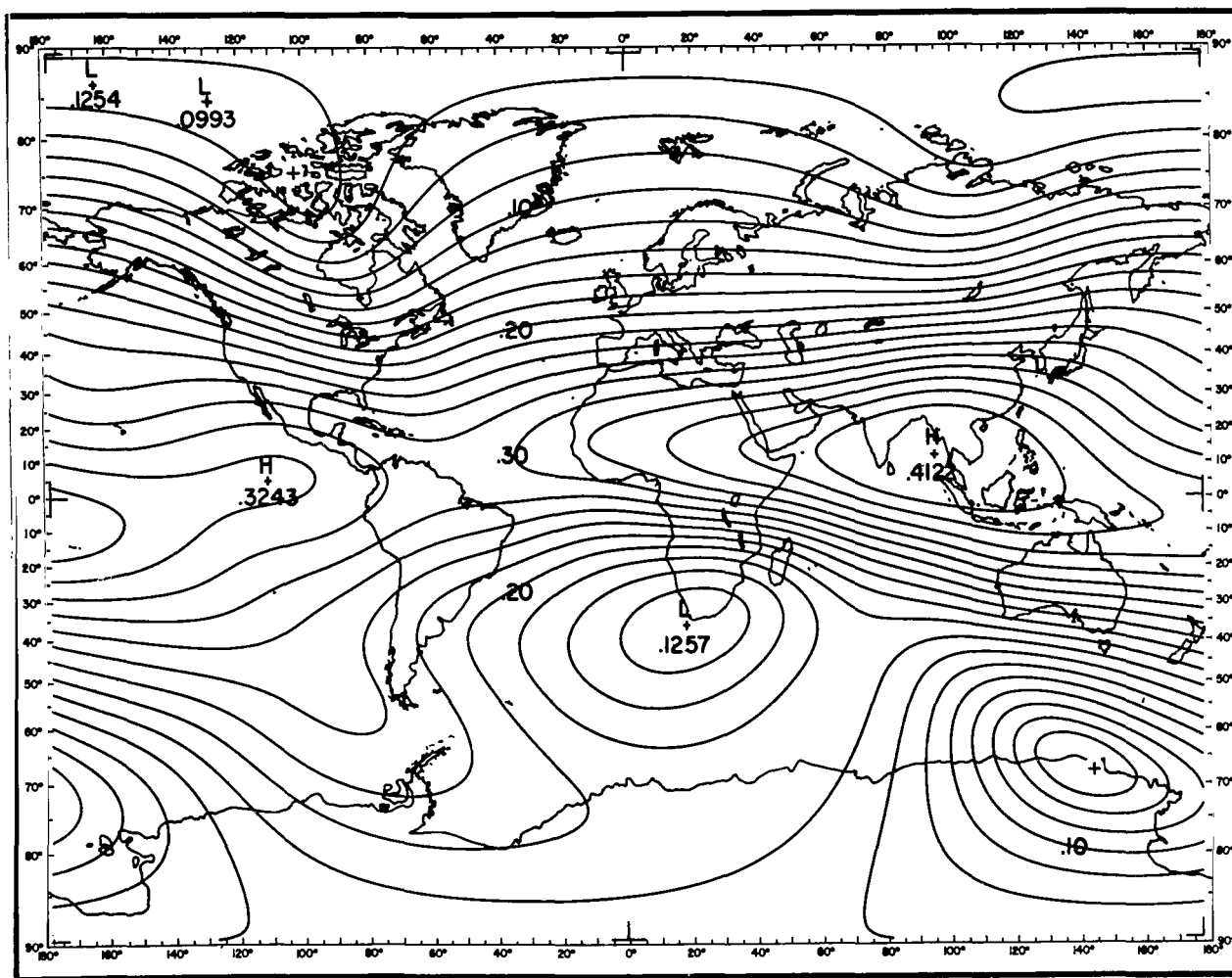


Figure C9-H in gauss, epoch 1965.0. GSFC (12/66).

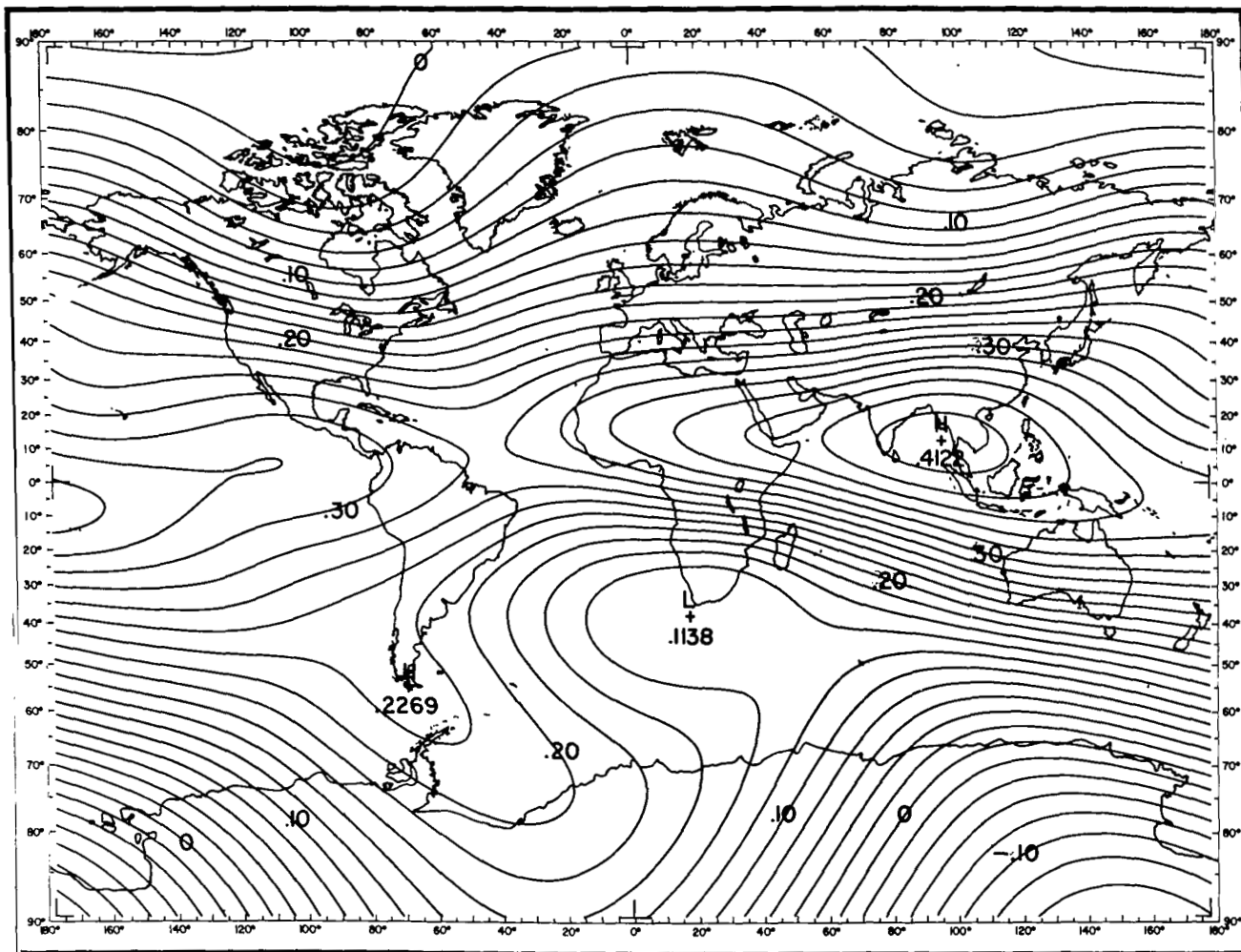


Figure C10-X in gauss, epoch 1965.0. GSFC (12/66).

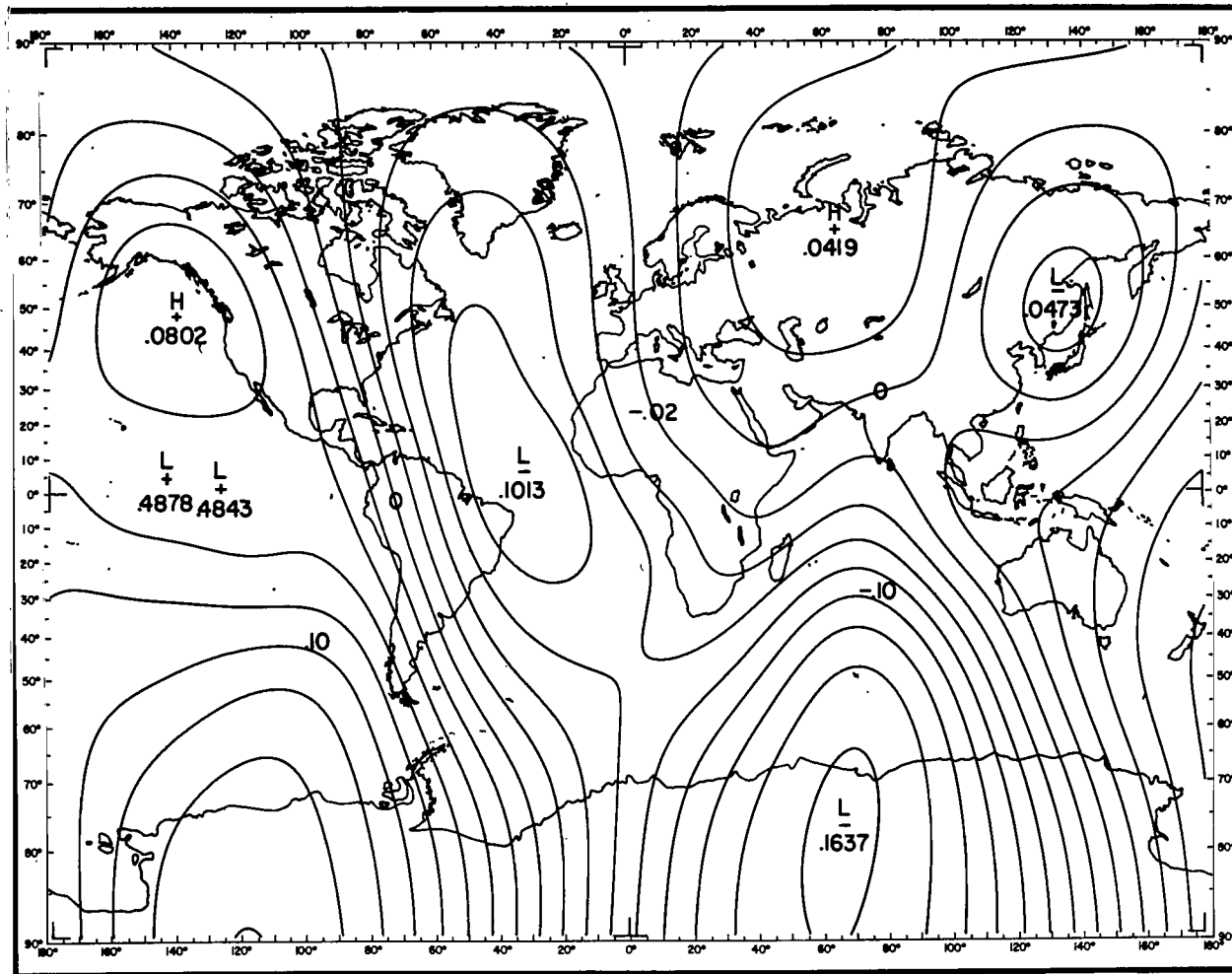


Figure C11-Y in gauss, epoch 1965.0. GSFC (12/66).

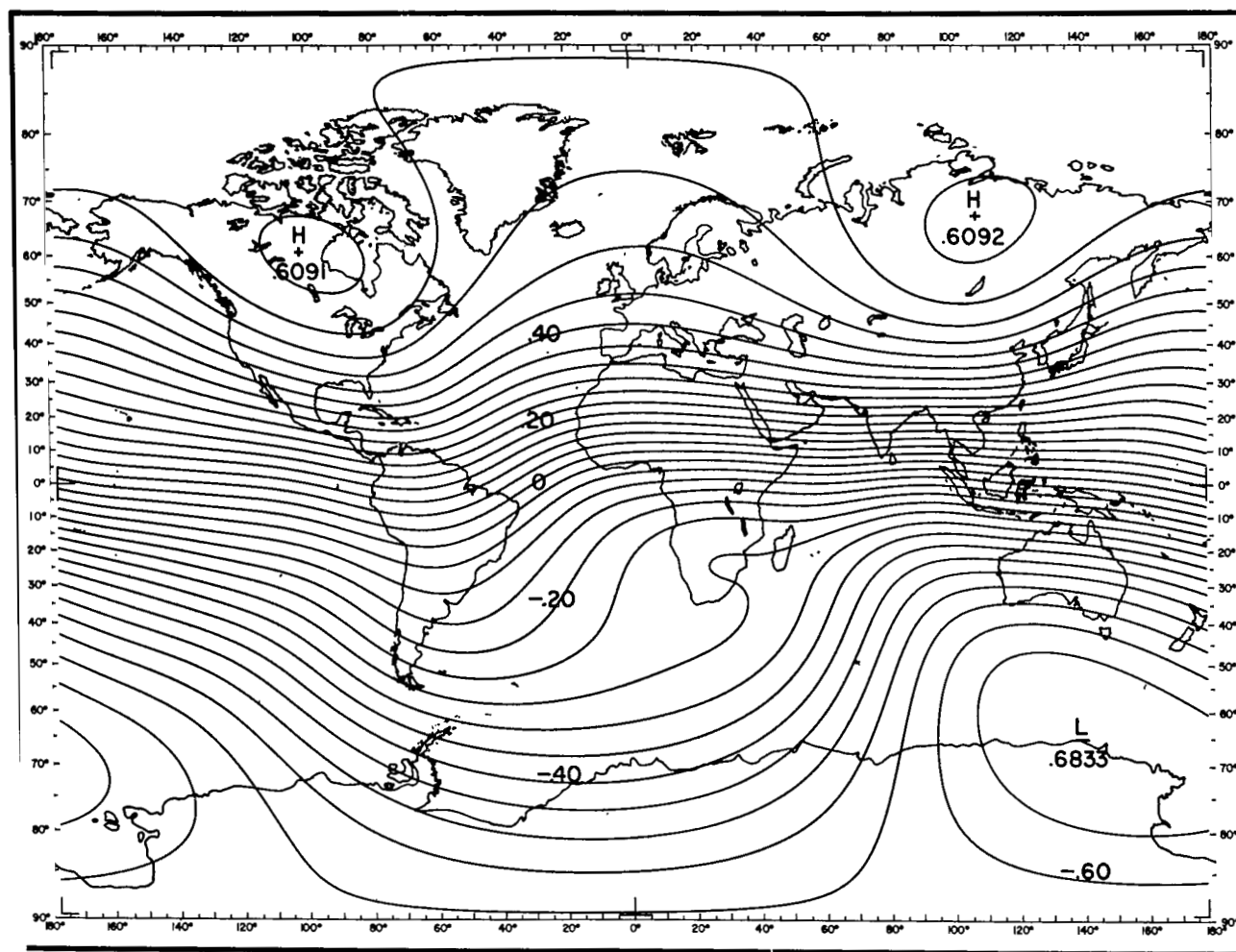


Figure C12-Z in gauss, epoch 1965.0. GSFC (12/66).

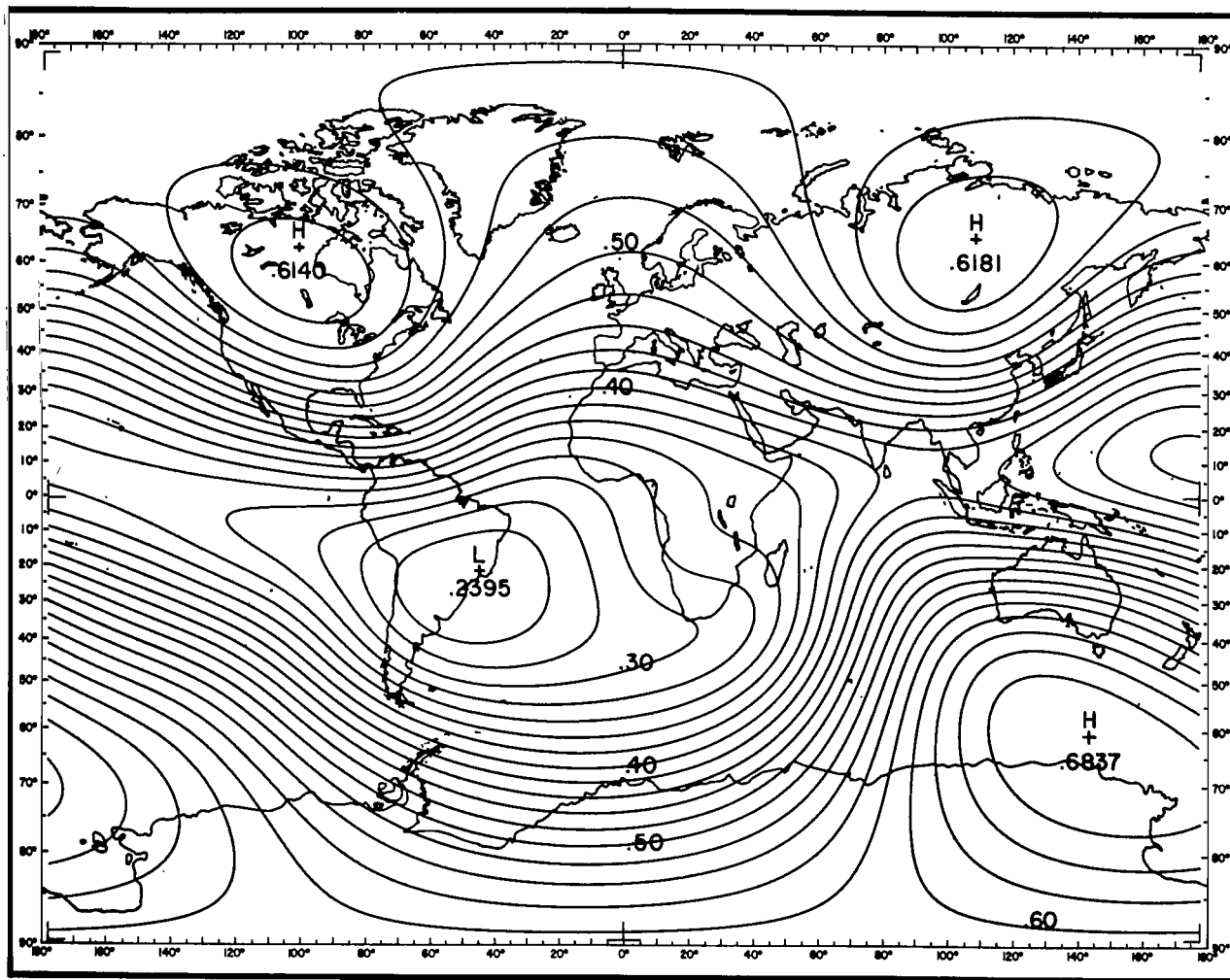


Figure C13-F in gauss, epoch 1965.0. GSFC (12/66).

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