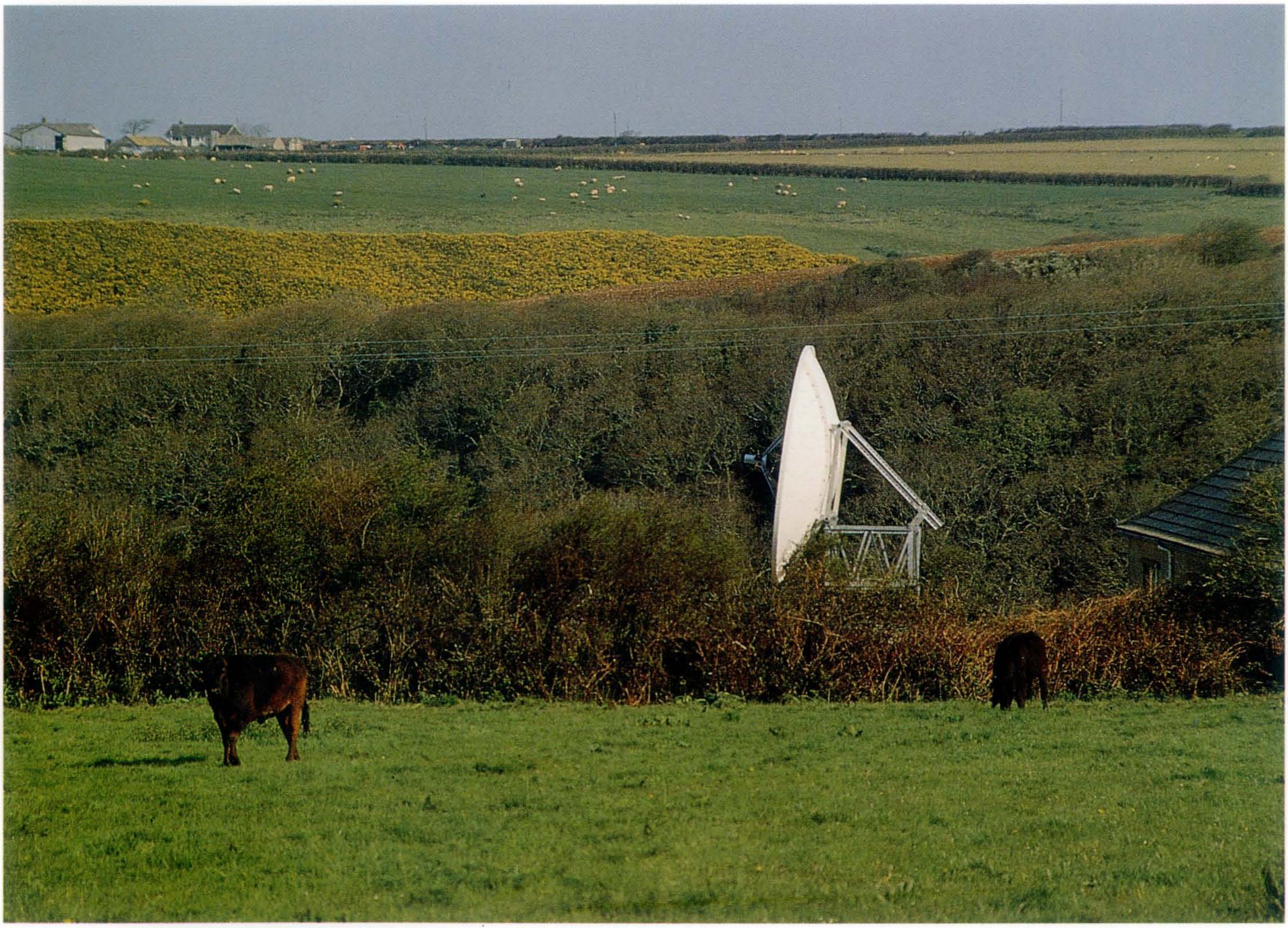
BRITISH GEOLOGICAL SURVEY

GEOMAGNETIC BULLETIN 20

Magnetic Results 1990

LERWICK, ESKDALEMUIR AND HARTLAND OBSERVATORIES



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Lerwick, Eskdalemuir and Hartland observatories

Compilers

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GEOMAGNETISM GROUP REPORT 1990

Magnetic Observatory Operations

The ideal magnetic observatory produces high-accuracy data (absolute values) in real-time. In 1990 progress was made towards this ideal for the UK observatories through developments in instrumentation, communications, and data processing software. A new instrument for vector field measurements, comprising a proton magnetometer mounted in a two-axis coil system, has been designed and built and is under test. The instrument is designed to measure total field intensity and (changes in) declination and inclination, and will replace the equipment currently used to make baseline reference measurements. The new instruments will be installed during 1991 and the data provided will enable corrections to the observatory fluxgate variometer values, previously made months in arrears, to be applied hourly. Data transmission is now handled by a dedicated IBM-PC which telephones each observatory every three hours, seven days a week, retrieving and transferring the latest data to the BGS Edinburgh Vax computer. Within minutes, in a fully automated procedure, the data are passed through stringent quality control procedures, and data derivatives, including a forecast of geomagnetic activity, are produced. These data products are immediately available to customers on the Geomagnetism Information and Forecast Service (GIFS), accessible over the UK JANET computer network.

Using the experience gained in automating the UK observatories, BGS is now building state-of-the-art magnetic observatory systems for sale. The Automatic Remote Geomagnetic Observatory (ARGO), is the latest design. Controlled by an IBM-PC, ARGO will operate in a wide range of environments, storing data locally on floppy disk or transmitting the values to a collection site using telephone, radio or satellite links. An ARGO system has been ordered by for installation at Sopron observatory, Hungary, and interest has been shown by institutions in other European countries intending to modernise their observatories.

Computer generation of K indices

During 1990 a method for computer generation of K indices was developed which was adopted by BGS on 1 January 1991 to produce K indices from the three UK geomagnetic observatories. In the past the scaling of K indices has been performed by hand, a time-consuming and subjective task. There are three main reasons for producing K indices by computer. Firstly, a standard algorithm for K scaling eliminates differences introduced in the bias of K indices by a change of handscaler at an observatory. Secondly, the time spent on handscaling K indices can be used for more productive purposes. Thirdly, digital processing techniques raise the possibility that indices such as **aa** and Kp (derived from K indices measured at a worldwide network of observatories) can be produced in real time if the required communications are established. At present there may be a delay of a few weeks in producing Kp, but there are many users in science and commerce who would benefit from a real time index of disturbance in the geomagnetic field.

The main problem in scaling K indices is the recognition of the solar regular (S_r) variation. A handscaler uses experience and knowledge of the shape of the quiet day (S_q) variation to estimate the S_r variation. The computer algorithm adopted by BGS fits a curve to the H and D minute mean values in a 24 hour period, but limits the curvature of the fitted curve if any disturbance is present. This is similar to a handscaler seeing a disturbed period in the trace and sketching a smooth curve through it. If the disturbance is greater than a certain level then no S_r variation is estimated and the maximum-minimum range is used for scaling the K index. This fulfils the condition for handscaling K indices that if the S_r variation cannot be readily identified then no S_r variation should be assumed.

The algorithm has been tested by comparing the computed K indices with the handscaled K indices for the years 1986-90. The agreement was studied as a function of handscaled K index, Universal Time and season. The overall levels of agreement achieved are typically 83% at Lerwick, 82% at Eskdalemuir and 76% at Hartland. If differences in index values of ± 1 are ignored the agreement is greater than 99% at all three observatories. It was shown that a different bias in the errors was obtained when comparing the computed K indices with the indices scaled by different handscalers. The years 1986-90 include a solar minimum and a solar maximum year, but no appreciable affect on the bias of the errors was seen which could be attributed to the solar cycle.

Automatic baseline reference measurements

Throughout 1990 the practice of making a baseline reference measurement (BRM) once per working day under operator control from Edinburgh continued. However, in order to use BRMs to correct the ARGOS fluxgate measurements to absolute values in real time an automatic system for making BRMs every hour is needed, and the necessary changes to the ARGOS software were made. Automatic hourly measurements commenced in August and continued for the rest of the year. As from 1 January 1991 automatic BRMs are normal practice and manual BRMs have been discontinued. The automatic BRMs differ from the manual BRMs because no independent measurement of Z is made. Serson's method is used to measure H and ΔD, and Z is calculated from the measured values of F and H. The Z measurements made by this method agreed closely with the Z measurements made manually using Nelson's method.

Figure 1 shows that hourly BRMs give excellent time resolution for fluxgate drift caused by a temperature change in the ARGOS variometer chamber. The bottom panel shows the hourly measurements of the variometer chamber temperature at Hartland in September. The top three panels show the difference between the hourly BRMs and the ARGOS fluxgate measurements in D, H and Z. The sudden rise in temperature on 13 September was caused by a failure of the heating controller. The heating was switched off at about midday on 14 September and a new heating controller was installed on 17 September. The drifts in the fluxgate measurements due to this temperature variation are obvious and these measurements were used to determine the perturbations to the allocated zero-field corrections shown in Figure 7 of the bulletin. Under the manual system only one measurement would have been made on each of 13,14 and 17 September, so it would not have been possible to estimate the fluxgate drifts to the same precision.

The automatic BRMs have performed well at Lerwick and Hartland, but there has been a temperature related diurnal variation detected at Eskdalemuir with amplitude of a few nanotesla in H and D. This is thought to be due to thermal effects in the coil system and tests are being carried out to eliminate this variation. It is planned that from 1 January 1992 automatic BRMs will be used to correct the fluxgate measurements in real time.

The Geomagnetism Information and Forecast Service (GIFS)

GIFS continued to be maintained as a service to science and commerce in 1990. Updating of records from the UK observatories, including computer-generated K indices, and of the geomagnetic activity forecast was automated as part of the work carried out on automation of data processing for the observatories. Academic users of GIFS can access the following information on-line:

a) Hourly mean values and one-hour and three-hour range indices from the three UK observatories. The records are maintained on GIFS for a year and are updated daily.

b) Geomagnetic activity indices and measures of solar activity:

i. Handscaled and computer generated K indices for the UK observatories

ii. The planetary activity indices Kp, ap, Cp and C9

iii. The daily International Sunspot Number and the 10.7 cm radio flux.

c) Spot values of the geomagnetic field computed using the International Geomagnetic Reference Field model.

d) Annual mean values from the international network of geomagnetic observatories. A total of 511 observatories are represented (about 170 are currently in operation). The earliest value is for 1813 at Hackney Wick, UK.

e) A forecast of geomagnetic activity for the next 27 days. The forecast, which is updated daily, is based on the statistics of magnetic activity and measures of solar activity.

Most commercial users of GIFS are interested in recent data from the UK observatories and in the expected degree of disturbance in the near-future. On GIFS they can list the activity forecast and the one-minute data from the UK observatories. These data files are maintained for three days. Commercial customers do not have access to the extensive historical data sets made available to academic users.

A three-component fluxgate magnetometer has been installed 25 km south of Edinburgh and transmits data to BGS headquarters in Edinburgh by radio link. The data are plotted in real time on an analogue chart recorder. Each working data the chart recording is examined at regular intervals and when there is evidence of the onset of magnetic disturbance an alert is issued on GIFS. Some commercial customers subscribe to a seperate activity monitoring service in which alerts are sent by fax and detailed analyses of disturbance levels are carried out anu supplied to them the following day.

Modelling

BGS collects geomagnetic data from sources worldwide to use in the computation of global geomagnetic field models. Models have been produced for the World Magnetic Charts, the navigational charts published by the British and American naval authorities, and for the International Geomagnetic Reference Field (IGRF), widely used in science and commerce. The accuracy of global field models depends heavily on the worldwide network of magnetic observatories. In many third-world countries observatories are under threat of closure due to lack of funds, and in others equipment is becoming unserviceable. A consortium of companies in the oil industry, the IGRF Users Group, recognising the importance of data from third-world observatories to the accuracy of global field models, is funding a programme to equip some of them with systems built by BGS. In 1991 equipment, similar to the ARGO system, will be deployed in Nigeria and Kenya.

An important application of global field models is in directional drilling for oil production. The output of a magnetometer, located in a down-well tool in a special non-magnetic section of the drill-string, is recorded as it moves along the well. The path of the well can be traced, provided the geomagnetic field at the drill site is known accurately. The field value is computed using a global model. The industry leaders are pressing all operators to adopt a standard geomagnetic field model for use in the North Sea, and the UK Department of Energy is supporting the modelling activities of BGS.

Global models do not account for magnetic fields due to the magnetisation of local rocks, (the crustal anomaly field), the regular daily variations, or geomagnetic field disturbances. Oil industry users are demanding the highest accuracy in magnetic reference and have contracted BGS to study methods of modelling these phenomena in order to improve upon the field estimates provided by global models. It has been demonstrated that for the North Sea region the daily variation can be modelled accurately, taking into account seasonal changes, except during periods of moderate and severe disturbance. At any particular time accuracy can be further improved using the detailed information on field changes recorded at the UK observatories.

Aeromagnetic surveys over the UK and the North Sea provide plentiful data on the crustal anomaly field down to wavelengths of about 1 km, but only in field intensity, not direction. A study of theoretical methods for transforming total intensity anomalies to vector field anomalies has been undertaken. Case studies for areas near Edinburgh and in East Anglia, regions with quite different geology, have been carried out. The results of applying a transformation procedure to the aeromagnetic data were compared with vector measurements over dense networks in the two areas, made specially for the study. There is very good agreement between the theoretical results and the observations, and the method has now been used to produce charts showing short-wavelength detail in compass heading over the Gulf of Mexico.

Results from the study carried out over an area of 55x55 km centred on Bathgate near Edinburgh are presented in Figure 2.

The UK Magnetic Survey

A network of 47 repeat stations has been established in the UK, and full three-component geomagnetic field measurements are made at each station every 3 to 5 years. The station names, the dates on which they have been occupied and their geographical locations are listed in Table 1. The station positions are also shown in Figure 3.

Observing practice in the survey has been integrated with that at the UK observatories employing the same absolute instruments, a fluxgate-theodolite for declination and inclination measurements and a proton precession magnetometer to measure total field intensity. True north is determined using a gyro-attachment for the theodolite.

Each station is occupied for approximately 8 hours and the data collected are corrected for diurnal variations and for moderate disturbances using the records from the two closest UK observatories. In 1990, 10 repeat stations were re-occupied. In addition measurements were made at 20 sites in East Anglia in support of the theoretical work on crustal anomaly modelling.

In 1990 polynomial models of declination, inclination and total intensity for epoch 1990.0 were produced based on the data from the UK network, supplemented by measurements made in magnetic surveys in France and Ireland.

Geomagnetic Disturbance Forecasting

The Sun continuously emits charged particles into space forming the solar wind. Eruptive events on the Sun inject high-speed material into the solar wind which may cause geomagnetic disturbances on reaching the Earth. Magnetic storms occurring close to solar maximum are often isolated events because the solar disturbances responsible for them are intense but short-lived. During the declining phase of the solar cycle longer-lived solar structures, coronal holes, become important sources of geomagnetic activity. As these co-rotate with the Sun they are responsible for a tendency for high levels of geomagnetic activity to recur with the solar rotation period of 27 days, a helpful property for prediction.

The maximum in the current solar cycle has now been passed, but both solar and geomagnetic activity remain high. The Geomagnetism Group issues daily geomagnetic activity forecasts, making use of the most recent information on solar activity, and operates a real-time geomagnetic disturbance monitoring service for commercial customers.

In many commercial applications the geomagnetic field is used for directional reference with field values for a particular location computed using a global or regional field model. During magnetic storms the geomagnetic field can differ very widely from the modelled value; compass heading may change by several degrees, for example. In other applications there are more direct physical effects. Rapid field changes cause induced currents to flow in power distribution networks which can, in extreme cases lead to loss of supply. Oil pipelines are subject to corrosion where induced currents flow between the pipes and earth. Short-wave radio communications are disrupted and the positional accuracy obtainable from satellite navigation systems is degraded because of the disturbed state of the ionosphere. During magnetic storms the intense electrical currents flowing in the upper atmosphere cause heating, leading to atmospheric expansion and increased drag on low-altitude spacecraft. Spacecraft electronics systems are vulnerable to damage by high-energy charged particles and are at risk during storms. The European Space Agency has commissioned BGS to produce long-term forecasts of solar and geomagnetic activity to use in mission planning, and short-term forecasts for day-to-day management of spacecraft operations.

INTERMAGNET

INTERMAGNET is a programme for international exchange of data from a worldwide network of observatories using satellite communications. The initial trials conducted in 1989 and funded by a research contract from the Air Weather Service of the US Air Force were successful. Data from the three UK observatories were transmitted to the US Geological Survey in Golden, Colorado, and to the Geological Survey of Canada in Ottawa every 12 minutes via the GOES-East satellite. Data were received from US and Canadian observatories at Hartland where a 5 m satellite receiving dish was installed in May 1989.

During 1990 the trials were suspended because of problems with the GOES-East satellite which is now unable to maintain its position in geostationary orbit above the Gulf of Mexico. Reliable transmission of data will not be possible again until a new satellite is launched. Data exchange between the US and the UK continues on a temporary basis using electronic mail. In May 1990 meetings of the INTERMAGNET Executive and Technical Committees were held at BGS Edinburgh.

In 1991 a METEOSAT receiver will be installed at BGS Edinburgh and transmitters will be installed at each of the UK observatories. METEOSAT will allow exchange of data within the Afro-European sector. Stations in Finland, France, Spain and Hungary, and equipment installed in Africa with the support of Finland, France and the IGRF Users Group will be among the first contributors to INTERMAGNET in this region. BGS Edinburgh will act as a Geomagnetic Information Node (GIN) for the Afro-European sector, exchanging data with other GINs in the US and Japan, and disseminating data to the user communities.

Institutions in twelve countries, representing more than 50 geomagnetic observatories, have now signed the INTERMAGNET protocol. Further information on the INTERMAGNET programme can be obtained from:

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BGS Technical Report Series

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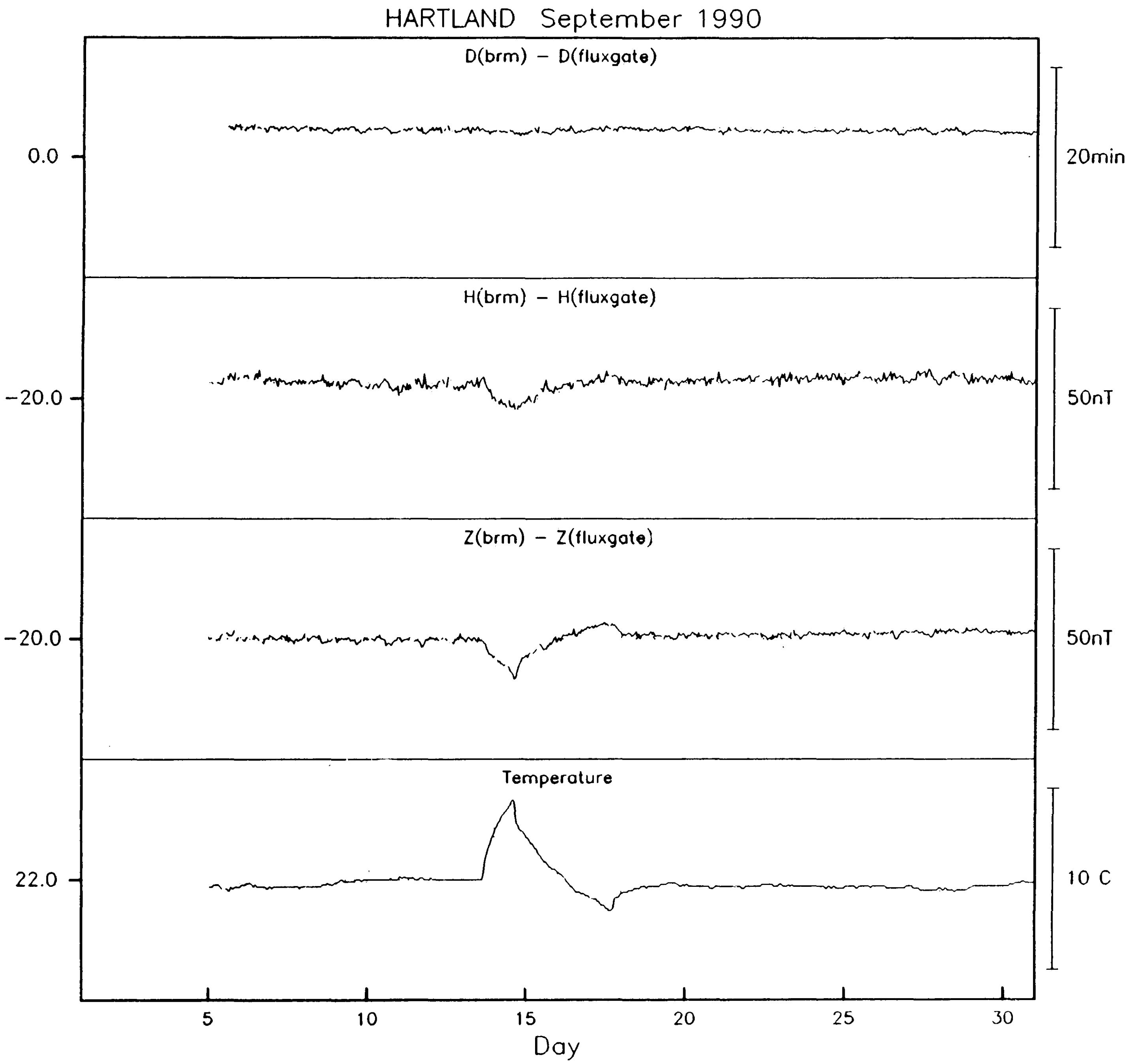
Figure Captions

Figure 1. Comparison of ARGOS fluxgate and baseline reference measurements at Hartland observatory in September 1990 when a fault developed in the heating system in the variometer chamber. The drift in the fluxgate values caused by the temperature changes (particularly in the horizontal and vertical intensities) could be corrected accurately because baseline reference measurements were made hourly.

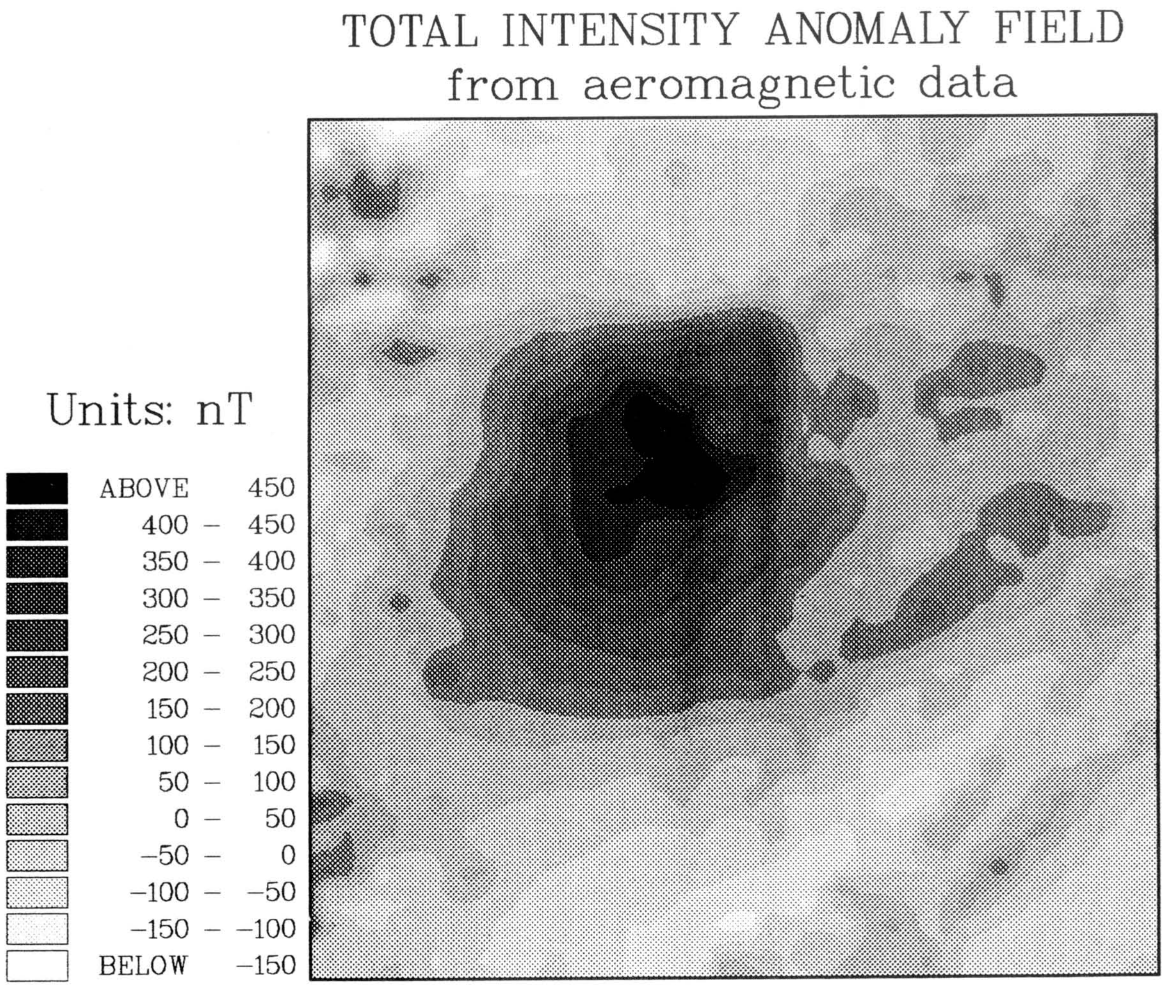
Figure 2. The upper diagram shows anomalies in total field intensity over an area of 55x55km centred on Bathgate near Edinburgh, with values ranging from -200 nT to 500 nT. The result of transforming these data to estimates of the vector anomaly field is illustrated in the lower diagram where compass heading (declination) is shown, varying from 7.9 degrees to 6.7 degrees west of true north. Vector measurements made on a 36-point grid in the area have confirmed that the theoretical results are a good representation of the actual anomaly field.

Figure 3. The positions of the UK magnetic survey repeat stations. These are also listed in Table 1.



HARTLAND September 1990
D(brm) – D(fluxgate)
0.0
20min
H(brm) – H(fluxgate)
–20.0
50nT
Z(brm) – Z(fluxgate)
–20.0
50nT
Temperature
22.0
10 C
5
10
15
20
25
30
Day

Figure 1.


TOTAL INTENSITY ANOMALY FIELD
from aeromagnetic data
Units: nT
ABOVE 450
400 – 450
350 – 400
300 – 350
250 – 300
200 – 250
150 – 200
100 – 150
50 – 100
0 – 50
–50 – 0
–100 – –50
–150 – –100
BELOW –150

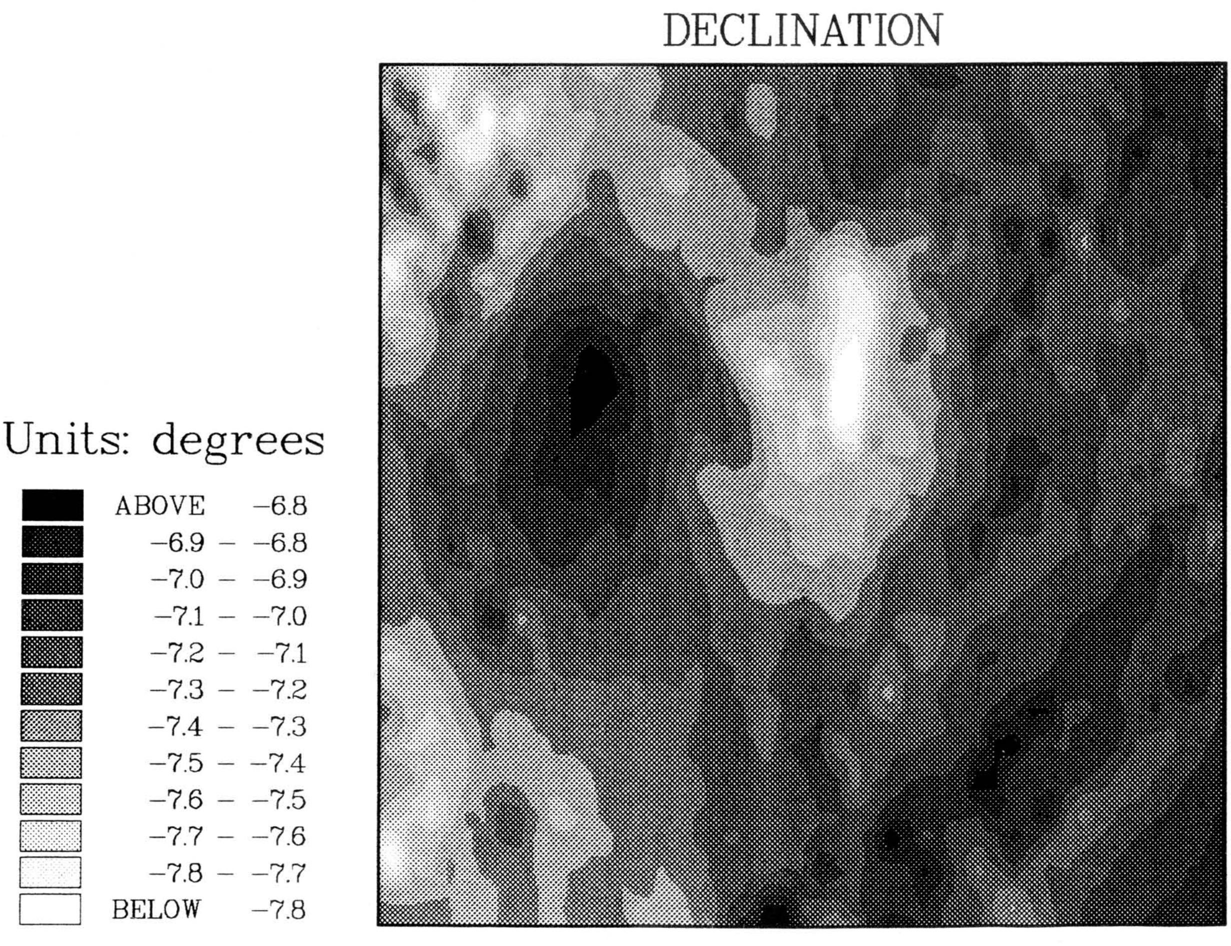

DECLINATION
Units: degrees
ABOVE –6.8
–6.9 – –6.8
–7.0 – –6.9
–7.1 – –7.0
–7.2 – –7.1
–7.3 – –7.2
–7.4 – –7.3
–7.5 – –7.4
–7.6 – –7.5
–7.7 – –7.6
–7.8 – –7.7
BELOW –7.8

Figure 2.

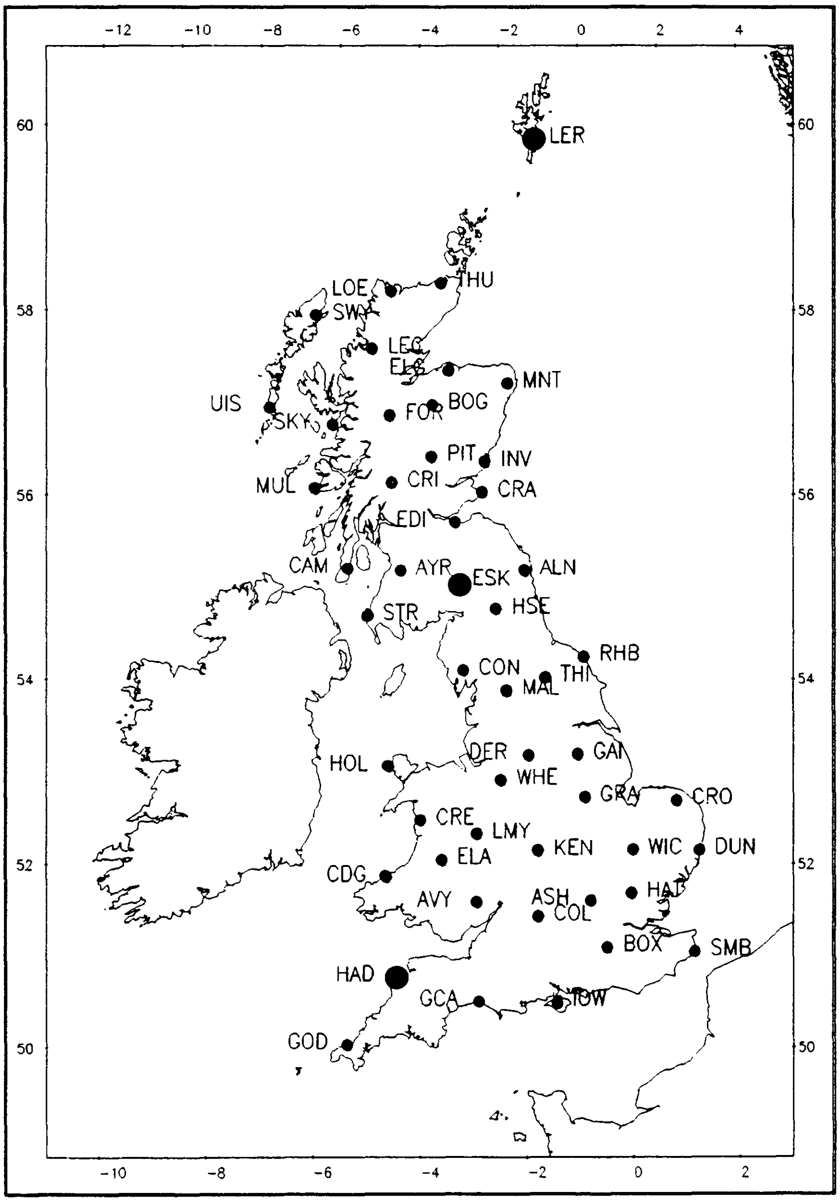

-12
-10
-8
-6
-4
-2
0
2
4
60
58
56
54
52
50
LER
THU
LOE
SWY
LEG
ELS
MNT
UIS
SKY
FOR
BOG
PIT
INV
MUL
CRI
CRA
EDI
CAM
AYR
ESK
ALN
STR
HSE
RHB
CON
THI
MAL
HOL
DER
GAI
WHE
GRA
CRO
CRE
LMY
KEN
WIC
DUN
CDG
ELA
AVY
ASH
COL
HAT
BOX
SMB
HAD
GCA
IOW
GOD

Figure 3.

	Station name	Code	Date 1	Date 2	Lat	Long	Alt
1	Elgin	ELG	13/05/1985	05/06/1989	57 37.9 N	3 19.6 W	28 m
2	Thurso	THU	15/05/1985	03/07/1989	58 35.3 N	3 29.9 W	60 m
3	Loch Eriboll	LOE	16/05/1985	04/07/1989	58 29.8 N	4 39.9 W	8 m
4	Pitlochry	PIT	27/05/1985	08/06/1989	56 41.6 N	3 43.8 W	120 m
5	Boat of Garten	BOG	29/05/1985	06/07/1989	57 15.5 N	3 42.9 W	213 m
6	Mintlaw	MNT	30/05/1985	06/06/1989	57 28.6 N	1 59.9 W	70 m
7	Alnwick	ALN	03/06/1985	18/07/1990	55 25.2 N	1 43.7 W	82 m
8	Wheelock	WHE	17/06/1985	06/08/1990	53 07.9 N	2 19.7 W	68 m
9	Gainsborough	GAI	19/06/1985	07/08/1990	53 23.0 N	0 44.6 W	30 m
10	Thirsk	THI	20/06/1985		54 14.1 N	1 21.2 W	38 m
11	Edinburgh	EDI	25/07/1985	28/06/1990	55 57.9 N	3 12.9 W	25 m
12	Kenilworth	KEN	12/08/1985	23/08/1990	52 21.2 N	1 36.7 W	100 m
13	Cardigan	CDG	15/08/1985	21/08/1990	52 05.3 N	4 39.9 W	55 m
14	Holyhead	HOL	16/08/1985	20/08/1990	53 17.8 N	4 38.3 W	20 m
15	Godrevy Point	GOD	13/05/1986	04/09/1990	50 14.1 N	5 23.4 W	15 m
16	Stonebarrow Hill	GCA	15/05/1986	06/09/1990	50 43.7 N	2 51.3 W	91 m
17	Robin Hood's Bay	RHB	02/06/1986		54 26.6 N	0 31.6 W	137 m
18	Coniston	CON	04/06/1986		54 20.2 N	3 04.2 W	50 m
19	Housesteads	HSE	06/06/1986	19/07/1990	55 00.1 N	2 21.4 W	229 m
20	Hatfield Forest	HAT	16/06/1986		51 50.4 N	0 12.6 E	85 m
21	Box Hill	BOX	17/06/1986		51 16.1 N	0 18.7 W	137 m
22	St Margarets Bay	SMB	19/06/1986		51 09.5 N	1 23.9 E	61 m
23	Grantham	GRA	30/06/1986		52 54.9 N	0 38.1 W	61 m
24	Derwent Estate	DER	02/07/1986		53 24.0 N	1 45.9 W	305 m
25	Malham	MAL	04/07/1986		54 06.2 N	2 10.4 W	400 m
26	Cregennan	CRE	01/09/1986		52 42.4 N	3 58.9 W	278 m
27	Long Mynd	LMY	03/09/1986		52 33.4 N	2 50.5 W	472 m
28	Ashridge	ASH	29/09/1986		51 47.3 N	0 36.2 W	183 m
29	Coleshill	COL	01/10/1986		51 38.4 N	1 39.3 W	100 m
30	Elan Village	ELA	18/05/1987		52 16.6 N	3 33.3 W	213 m
31	Abergavenny	AVY	19/05/1987		51 48.6 N	2 52.1 W	91 m
32	Newport (IOW)	IOW	21/05/1987		50 42.2 N	1 20.4 W	30 m
33	Crianlarich	CRI	14/09/1987		56 24.2 N	4 37.5 W	190 m
34	Lechmelm	LEC	16/09/1987		57 51.8 N	5 05.5 W	10 m
35	Stornoway	SWY	18/09/1987		58 12.6 N	6 23.7 W	15 m
36	Campbeltown	CAM	31/05/1988		55 27.0 N	5 32.8 W	15 m
37	Ayr	AYR	01/06/1988		55 26.3 N	4 25.1 W	122 m
38	Stranraer	STR	02/06/1988		54 56.1 N	5 07.2 W	105 m
39	Fort Augustus	FOR	14/06/1988		57 08.5 N	4 40.8 W	25 m
40	Inverkeilor	INV	16/06/1988		56 37.7 N	2 31.8 W	15 m
41	Crail	CRA	17/06/1988		56 17.4 N	2 37.1 W	10 m
42	Mull	MUL	27/06/1988		56 19.1 W	6 19.3 W	30 m
43	South Uist	UIS	29/06/1988		57 11.4 N	7 24.7 W	5 m
44	Skye	SKY	01/07/1988		57 01.7 N	5 57.6 W	20 m
45	Cromer	CRO	19/09/1988		52 48.7 N	1 13.4 E	30 m
46	Dunwich Heath	DUN	20/09/1988		52 15.3 N	1 37.3 E	15 m
47	Wicken Fen	WIC	22/09/1988		52 18.6 N	0 17.6 E	4 m

Date 1 : date of the first occupation
Date 2 : date of the second occupation
Latitudes and longitudes are given in degrees and decimal minutes
Altitudes are in metres above sea-level

Table 1. UK Magnetic Survey Repeat stations

Magnetic Results 1990: Lerwick, Eskdalemuir and Hartland Observatories.

1 INTRODUCTION

This bulletin is a report of the measurements made between 1 January and 31 December 1990 at the UK geomagnetic observatories operated by the British Geological Survey (BGS) at Lerwick, Eskdalemuir and Hartland.

The three observatory sites are described, with notes of any changes made during the year. A description is given of the Automatic Remote Geomagnetic Observatory System (ARGOS), deployed at each observatory since 1st January 1987 (Riddick *et al.* 1990). The method of collecting the data from each observatory, the quality control procedures and the method of reducing the data to absolute values are also outlined.

The presentation of the data in this bulletin is principally in graphical form, with plots of daily and hourly mean values for each year, and complete sets of daily magnetograms derived from minute values. An IBM diskette containing the hourly mean values has been produced as a companion to this volume and is available on request.

An annual report of the work carried out by the Geomagnetism Group during the year is given at the end of the bulletin. This describes development work carried out during the year on instrumentation and data processing techniques. Some examples are also given of the use of geomagnetic data in commerce and science.

2 DESCRIPTIONS OF THE OBSERVATORIES

The locations of the UK magnetic observatories are shown on the front cover of the bulletin. The history of the current UK geomagnetic observatories, and of other observatories that have operated in the British Isles, is described by Robinson (1982).

Lerwick (Shetland, Scotland)

Lerwick observatory is situated on a ridge of high ground about 2.5 km to the SW of the port of Lerwick. The surrounding countryside is moorland comprising peat bog, heather and outcropping rock. The observatory is operated by the Meteorological Office as a meteorological station carrying out routine synoptic observations and upper-air measurements. Other work includes detection of thunderstorms, measurement of solar radiation, ozone and atmospheric pollution levels, and chemical sampling. BGS uses Lerwick as a seismological station, recording data from a local three-component seismometer set and, via radio link, from the Shetland seismic array.

Lerwick was established as a meteorological site in 1919 and geomagnetic measurements began in 1922. Responsibility for the magnetic observations passed from the Meteorological Office to BGS in 1968. There are no members of BGS staff stationed at Lerwick.

Figure 1 is a site diagram of Lerwick observatory. During 1990 no major changes were made at the site. Routine maintenance work was carried out on the observatory buildings.

The observatory coordinates are:

	Geographic	Geomagnetic
Latitude	60°08′N	62°08′N
Longitude	358°49′E	89°14′E
Height above *msl*	85 m	

(Geomagnetic coordinates used in this report are relative to a geomagnetic pole position of 79°11′N, 70°59′W, computed from the 5th generation International Geomagnetic Reference Field at epoch 1990.0.)

Eskdalemuir (Dumfries & Galloway, Scotland)

Eskdalemuir observatory is situated on a rising shoulder of open moorland in the upper part of the valley of the river White Esk in the southern uplands of Scotland. It is surrounded by moorland and young conifer forest with hills rising to nearly 700 m to the NW. The observatory is 100km from Edinburgh and the closest towns are Langholm and Lockerbie.

Eskdalemuir is a synoptic meteorological station involved in measurement of solar radiation, levels of atmospheric pollution, and chemical sampling. The observatory operates a US standard seismograph and an International Deployment Accelerometer Program (IDAP) long-period sensor. BGS has a three-component seismometer set installed at the observatory and records data from four remote sites transmitted to the observatory by radio link. The observatory opened in 1908. It was built because of disruption to geomagnetic measurements at Kew observatory (London) following the advent of electric tramcars at the beginning of the 20th century. BGS took over responsibility for magnetic observations from the Meteorological Office in 1968.

Mr W E Scott, Mr C R Pringle and Mrs H Middleton, who are responsible for the general maintenance of the observatory, are now the only members of BGS staff stationed at Eskdalemuir.

Figure 2 is a site diagram of Eskdalemuir observatory. Following a power failure to the absolute hut and the variometer chamber, rewiring was carried out at these locations in March.

The observatory coordinates are:

	Geographic	Geomagnetic
Latitude	55°19′N	58°00′N
Longitude	356°48′E	83°49′E
Height above *msl*	245 m	

Hartland (Devon, England)

Hartland observatory is situated on the NW boundary of Hartland village. The site is the southern half of a large meadow which slopes steeply northward into a wooded valley. The sea (Bristol Channel) is about 3 km to both the north and west of Hartland. BGS operates a three-component seismometer set and a LF microphone at the observatory, and data from a seismic outstation in South Wales is transmitted to the observatory by radio link.

The observatory was purpose-built for magnetic work, and continuous operations began in 1957, the International Geophysical Year (IGY). Hartland is the successor to Abinger and Greenwich observatories. The moves from Greenwich to Abinger and then to Hartland were made necessary as electrification of the railways progressed, making accurate geomagnetic measurements impossible in SE England. BGS took control of Hartland observatory, from the Royal Greenwich Observatory, in 1968.

Since June 1987 Mr K E Johns (caretaker) has been the only member of BGS staff stationed at Hartland.

Figure 3 is a site diagram of Hartland observatory. Routine maintenance was carried out on all the observatory buildings during 1990. On 4 September a proportional temperature controller was installed in the variometer chamber to improve the response of the heating system to temperature variations.

The observatory coordinates are:

	Geographic	Geomagnetic
Latitude	51°00′N	54°08′
Longitude	355°31′E	80°06′
Height above *msl*	95 m	

3 INSTRUMENTATION

3.1 Absolute observations

At each observatory absolute measurements are made in a single Absolute Hut (see the site diagrams). On 1st January 1990 a new observatory standard reference point was adopted at each observatory. The need for this change arose from a new procedure for making absolute measurements. In 1989 measurements were made at two separate pillars: declination (D) was determined by fluxgate theodolite on the "D" pillar, the total, horizontal and vertical intensities (F, H & Z) were determined by Proton Vector Magnetometer (PVM) on the "PVM" pillar. Inclination (I) was calculated from the measurements made on the PVM pillar and referred to that pillar. However, the geographic North component (X) and East component (Y) calculated from H and D were hybrid values which were not referred to any physical reference point.

From 1st January 1990 F has been measured on the PVM pillar, with D and I being measured by fluxgate-theodolite on the D pillar. Measurements of the site difference in F between the two pillars are made during quarterly service visits, which enable F measurements at the PVM pillar to be corrected to the D pillar. Thus, values of D, I and F are obtained at the D pillar, and the calculated values of H, Z, X and Y are all referred to that point. For continuity with previous records the differences between the new and old standards are quoted in the tables of annual mean values in the sense (new standard - old standard) for all elements of the geomagnetic field. Thus annual mean values prior to 1990.5 can be referred to the new standard by adding the site difference to the old standard values. A detailed account of the change in absolute measurement reference is given by Kerridge and Clark (1991).

The instruments used at each observatory are given below.

	Fluxgate-theodolite	**PVM**
Lerwick	ELSEC 810	ELSEC 8801 Proton precession magnetometer mounted in ELSEC 5920 coils
Eskdalemuir	Bartington MAG 01H	ELSEC 8801 Proton precession magnetometer mounted in ELSEC 5920 coils
Hartland	ELSEC 810	ELSEC 8801 Proton precession magnetometer mounted in ELSEC 5920 coils

3.2 ARGOS: Variometer Measurements

Figure 4 is a block diagram showing the equipment in each ARGOS system.

The essential components of the ARGOS systems are a three-component fluxgate magnetometer (EDA FM100C), two proton magnetometers (ELSEC 820M), and a Digital Equipment Corporation PDP 11/23 processor which controls the operation of the system. The fluxgate sensors measure the X, Y and Z components of the geomagnetic field. The fluxgate magnetometer is operated in 'full field' mode, providing an analogue output of 5 V in a field of 50,000 nT. The three fluxgate sensors are located in a temperature-controlled variometer chamber, on a large single pier, with individual mountings separated by about 1.5 m. Each sensor is mounted inside a calibration coil. The temperature of the variometer chamber is monitored continuously. The proton magnetometers are sited in non-magnetic huts, mounted inside coils which can be used to apply bias or back-off fields. A Time Electronics 9818 programmable current supply is used to supply a precisely controlled current to the coils when required.

A Thaler Corporation VRE 105CA precision reference supply is used to generate a reference signal of 5 V. In routine operation the analogue outputs from the three channels of the fluxgate magnetometer, the temperature sensor and the voltage reference are switched in turn, by a

Hewlett-Packard HP3488A scanner, to the input of a Datron 1061A digital voltmeter and the five signals are measured. At the same time the PDP 11/23 processor triggers one of the proton magnetometers (P1) which performs an F (total intensity) measurement. (The second proton magnetometer (P2) is routinely inhibited.) This measurement sequence is repeated every 10 seconds, with the timing reference provided by a CMOS digital clock connected to the PDP 11/23 through a parallel interface. Communications between the PDP 11/23 processor and the other instruments and peripherals are via an IEEE instrument bus and RS232 serial ports.

A 7-point cosine filter is applied to the 10-second samples to produce minute values, centred on the minute, (Green, 1985). At the end of each hour the 60 minute values of X, Y, Z and F are written to a DC100 data cartridge together with hourly mean values, one-hour and three-hour activity indices based on the range in the X-component, the temperature of the variometer chamber, the reference voltage, and items of "housekeeping" information. An hour's data is written, in ASCII, as two 512 byte blocks. The cartridge drive is a TU58 dual drive. The system program is loaded from tape on drive 0, and data are written to the tape mounted on drive 1. The tape capacity is sufficient to store up to ten days' data. At each observatory the data collected are displayed on a VDU, and updated every minute, to enable the status of ARGOS to be monitored locally. A printer, normally disabled, can be switched on to obtain hard-copy of the display.

A British Telecom Datel 4122 modem (operating at 1200 baud) allows remote communication with the ARGOS systems via the public switched telephone network (PSTN). Each working day the ARGOS data from each observatory, up to the most recent complete hour, are retrieved to BGS, Edinburgh, using the Processing and Remote Interrogation System (PARIS), based on a PDP 11/23 computer. The operator in Edinburgh can examine the system status and control a number of other ARGOS functions which include making baseline reference measurements (see Section 3.3), resetting the system clock, repositioning the data tape, and restarting ARGOS in the event of a system failure.

Each ARGOS system is supported by a 500 VA Merlin-Gerin SX500 Uninterruptible Power Supply which has internal batteries capable of powering the full system for 30 minutes in the event of mains failure. Each observatory also has a stand-by diesel generator designed to start automatically within two minutes of loss of mains power. In the event of a sustained mains break and failure of the stand-by generators a further battery supply will maintain power to the fluxgates and the system clock for up to 7 days. This avoids deterioration in data quality due to drifts which are almost always severe when a fluxgate magnetometer is switched on after being powered down. The time from the system clock is essential for restarting ARGOS remotely when power is restored.

3.3 ARGOS: Baseline Reference Measurements

A consequence of the automation of the observatories was the removal of on-site staff, and so the loss of the guaranteed supply of regular absolute observations made by experienced BGS observers. Baseline reference measurements (BRMs) are designed to compensate for this change in observatory practice, enabling the standards achieved with manned operation to be maintained with an automated system.

BRMs are 'almost' absolute measurements carried out under the control of the PARIS operator in Edinburgh, normally once every working day. Measurements of H and Z are made using proton magnetometer P1, interrupting the 10-second cycling of the magnetometer for the routine measurement of F. P1 is mounted in a coil with the magnetic axis approximately (magnetic) north-south. The Z measurement is made by cancelling the horizontal field H (Nelson's method). The approximate value of H is calculated from the ARGOS fluxgate X and Y values and, by using the known coil constant, the current needed to cancel H is computed and then supplied to the coil. The Serson method is used to measure H. Measurements are made firstly with a bias field of approximately 1.5H applied in the same direction as H and then with the bias field reversed. The two measurements of the resultant intensity and a measurement of F (with no bias field) enable H to be determined.

Magnetic declination (D) is measured by proton magnetometer P2 which is mounted in a coil with the magnetic axis approximately (magnetic) east-west. If the magnetic axis is truly magnetic east-west then the measurements of the resultant fields made with bias fields east-west and then west-east will be equal. This is how the coil is set up initially, and an absolute determination of D is made at that time. At a later date, if D has changed, the resultant fields will no longer be equal and from the two measurements, and an F measurement, the change in D can be determined.

Full PVM absolute observations require a sequence of measurements to be made with the coil rotated into positions which enable errors due to imperfect alignment of its magnetic axis to be eliminated. In a BRM the coil cannot be rotated, so the measurement is not error-free. If the mechanical stability of the coil system is good, and the pier on which it is mounted does not tilt, then the error is (practically) constant. Comparisons of BRM results with measurements made by the ARGOS fluxgates then show up short-term drifts in the fluxgate magnetometers which would not be detected by comparisons made with the less frequent absolute measurements. In effect, BRMs provide a means for interpolating between absolute observations.

The H and Z measurements at all three observatories are made in coils wound on a marble former. At Lerwick the D measurement is made in a similar coil; at Eskdalemuir and Hartland the D measurement is made using Braunbeck coils which have a Tufnol former. All the marble coils are supported by Tufnol saddles.

In September 1990 a system was developed to make automatic BRMs every hour. Averaging 24 BRMs in each day reduces the scatter in the measurements compared with making one manual BRM once per working day. This has become standard practice for 1991. A description of the automatic BRMs is given in the annual report at the end of this bulletin.

3.4 Summary of Technical Specifications of the ARGOS Equipment

The specifications quoted here are those given by the manufacturers of the equipment.

a) FM100C fluxgate magnetometer

Sensitivity:	0.1 mV/nT
Dynamic range:	±100,000 nT
Temperature coefficient:	(in the range) 0.1 - 1 nT/°C

b) ELSEC 820M proton precession magnetometer

Resolution:	0.1 nT
Accuracy:	±1 nT
Measurement range:	14,000-90,000 nT

c) System clock

Accuracy:	1 second per week

d) Datron 1061A digital voltmeter

Accuracy:	1 part in 10^7
Temperature coefficient:	0.2 μV/°C

e) Time Electronics 9818 programmable current supply

Maximum current:	1 A
Accuracy:	1 μA

f) Thaler Corporation VRE 105CA precision reference supply

Reference voltage:	5V
Accuracy:	±0.4 mV
Temperature coefficient:	0.6 ppm/°C

3.5 Back-up Systems

At each observatory an EDA FM 100B three-axis fluxgate magnetometer, completely independent of ARGOS, is maintained to provide back-up data in the event of a total ARGOS failure. The fluxgate sensors are aligned in the H, D (magnetic east-west) and Z directions. The analogue outputs of the magnetometer are input to a 12-bit A/D converter and sampled every 10 seconds. The 10-second samples are written to a DC300XL cartridge tape to ECMA 46 standard. The cartridge is changed every 14 days and sent by post to BGS, Edinburgh, for transcription. The dynamic range of the magnetometers at Lerwick is ±2000 nT, at Eskdalemuir and Hartland it is ±1000 nT.

3.6 Calibration of geomagnetic measurements

The physical measurements made by ARGOS are of the analogue DC voltage output from the fluxgate sensors and the frequency from the polarised sample in the proton precession magnetometer (PPM).

Provided drift in the voltage reference used by the DVM is less than that of the fluxgate sensors, long term changes in the measurement of the magnetic field are only due to drift in the sensors. The DVM is calibrated once per year by the manufacturers to comply with National Physical Laboratory (NPL) standards, and its accuracy is quoted as 1 part in 10^7. Every three months it is checked by measuring the voltage of a standard cell which has been calibrated according to NPL standards. A check of the fluxgate sensitivity is also carried out by applying a bias field to the sensor. This is done by passing a known current through Helmholtz coils with an accurately known coil constant. The current is supplied by a constant current power supply which is calibrated by measuring the voltage across a standard resistor using the DVM. The change in the applied magnetic field can then be related to the change in voltage output from the sensor.

The PPM measures the frequency of emitted radiation from a sample of proton rich fluid, which is related to the ambient magnetic field the proton gyromagnetic ratio. The conversion from frequency to magnetic field value carried out by the PPM is checked by irradiating the sensor with a signal of known frequency from an oscillator. The frequency of this signal is determined by comparing it with an accurate frequency standard transmitted from Rugby. This check on the PPM is carried out every three months at each observatory.

4 DATA PROCESSING

Each working day the PARIS operator in Edinburgh retrieves data from the observatory ARGOS systems by telephone link. The data files are then transferred to the BGS Edinburgh mainframe computer (a Vax 6410) for processing.

The data files are first sorted into Universal Time (UT) day files. Subsequent data processing is carried out on these day files by a single FORTRAN program on the Vax which uses subroutines to generate various data products and derivatives. The data in each day file are first put through a quality control routine which checks for a range of possible errors. The data products then generated each day are:

a) Magnetograms, to both fixed and variable scale.
b) A formatted list of minute values of all the geomagnetic elements.
c) Hourly mean values and range indices.
d) A forecast of geomagnetic activity for the next 27 days.
e) Hourly and daily ranges in each geomagnetic element.
f) A comparison of total field computed from ARGOS X, Y and Z and total field measured by the ARGOS proton magnetometer P1.
g) A list of missing data.

The magnetograms are examined to identify any erroneous values not detected by the quality control routine, and are used for hand-scaling of K indices.

The prompt retrieval of data from the three UK observatories, made possible by ARGOS, immediately generated scientific and commercial demand for rapid access to the data. The Vax is connected to the UK Joint Academic Network (JANET) which enables transfer to academic users worldwide; commercial users can access the Vax using a British Telecom X25 gateway or dial-up modem. The Geomagnetism Information and Forecasting Service (GIFS) was created in 1988 to provide a 'user-friendly' interface between enquirers and the data sets, (Kerridge and Harris, 1988). GIFS, originally set up for academic users, now has separate academic and commercial sections. The data sets on GIFS derived from UK observatory data are updated daily.

At the end of each month any gaps in the ARGOS data are filled using data from the back-up magnetometers. The 10-second back-up data are filtered in the same way as the ARGOS raw samples to produce minute values. The resulting complete day files are archived on magnetic tape (two copies) on the Vax and also on data cartridge. The (unfiltered) back-up data are maintained as a high time-resolution data set. A monthly bulletin is issued for each observatory which includes magnetograms (with gaps filled), lists of K indices, the results of absolute observations and BRMs made during the month, tables of hourly mean values of H, D and Z, and a list of events associated with solar activity.

The number of missing minute values during 1990 at each observatory, resulting from failure of the ARGOS and back-up systems during the same periods of time, were as follows:

	No. of missing minute values	Date
Lerwick	0	-
Eskdalemuir	0	-
Hartland	73	20 Feb
	35	5 Sep

5 CORRECTION OF FLUXGATE VARIOMETER DATA TO ABSOLUTE VALUES

Where variometer records are made photographically a physical mark, a baseline, is made on the photographic paper. Absolute observations are used to allocate a value to the baseline using the sensitivity of the magnetometer (the scale value, usually expressed in nT/mm), to relate the offset of the trace at the time of an absolute observation (the ordinate) to the baseline. For a fluxgate magnetometer a baseline value may be taken to be the value of the geomagnetic field at an arbitrary output voltage of the magnetometer. An alternative view is that the fluxgate magnetometer sensitivity (usually expressed in mV/nT) is used to, in effect, deduce the magnetometer output in zero magnetic field. The absolute observations enable corrections to be made for any such zero-field offset, (which is likely to vary with time), and the site difference between the location of the fluxgate sensor and the appropriate absolute pier.

The zero-field offset corrections allocated for each observatory for 1990 are shown in the upper panel of Figures 5-7. (The results for each observatory are discussed in detail below.) The symbols show differences between absolute values and values derived from the ARGOS fluxgate magnetometers in the sense (absolute value - ARGOS value). The full line shows the correction adopted, derived from polynomial fits to the observed values computed using the method of least squares. In deriving the polynomials the points immediately before the beginning and after the end of the year were used, but are not shown in the plots. This ensured that unrealistic discontinuities were not introduced at the year boundaries. The plots of the polynomial fits are stepped because the values computed from the polynomials have been rounded to the nearest nT or 0.1 min.

The differences between BRMs and ARGOS fluxgate values are also shown in the middle panel of Figures 5-7 plotted in the sense (BRM value - ARGOS value), for comparison with the zero-field corrections derived from absolute observations. The daily mean temperature of the variometer chamber is also shown in the bottom panel of Figures 5-7 in order to reveal any temperature related effects. The Z component measured by the fluxgate sensor is most affected by temperature changes as the temperature dependence is proportional to the intensity of the field being measured.

Lerwick

The upper panel of Figure 5 shows that the H and D measurements made by the fluxgate sensors were very stable. An annual variation is evident for the Z component which appears to be coincident with the slight rise in temperature in the variometer chamber in the latter part of the year.

The D and Z BRMs agree well with the absolute measurements, but there is a drift in the H BRMs during the summer months. This is being investigated further. The temperature range in the variometer chamber was kept to within 2°C throughout the year.

The table below lists the *rms* differences of the observed zero field corrections from the allocated values. The *rms* differences for 1987-89 are also listed. The number of observations of each element in each year is given in brackets.

Year	H(nT)		D(min)		Z(nT)	
1987	2.76	(34)	0.96	(27)	1.03	(34)
1988	2.59	(31)	0.50	(23)	1.38	(30)
1989	2.97	(19)	0.48	(18)	1.57	(19)
1990	1.69	(25)	0.37	(24)	1.95	(25)

Eskdalemuir

The upper panel of Figure 6 shows that the H and Z measurements from the fluxgates are fairly stable when compared with the absolute measurements. There is a slight variation in the comparison for D, but the amplitude of the variation of the allocated zero-field offset corrections is less than 3 arc-minutes. The scatter in the absolute observations appears to be greater than at Lerwick or Hartland: this will be investigated.

The H and D BRMs show long-term drifts which are not apparent in the absolute measurements. Such drifts are most likely caused by slow tilting of the magnetometer coil mountings. The coils for the D BRMs developed a fault in November 1990 and have been replaced in February 1991.

The temperature range in the variometer chamber throughout the year was kept to within 2°C.

The table below lists the *rms* differences of the observed zero field corrections from the allocated values. The *rms* differences for 1987-89 are also listed. The number of observations of each element in each year is given in brackets.

Year	H(nT)		D(min)		Z(nT)	
1987	1.93	(31)	0.28	(29)	1.38	(33)
1988	2.32	(26)	0.85	(21)	0.95	(27)
1989	1.77	(15)	0.61	(21)	1.06	(15)
1990	2.63	(38)	0.81	(38)	1.59	(38)

Hartland

The upper panel of Figure 7 shows that the D measurements from the fluxgate sensors are very stable when compared with the absolute measurements. For the first half of the year the measurements from the ARGOS Z fluxgate sensor were very stable, but at about day 193 the temperature in the variometer chamber started to rise during a heat wave. The effect can be seen in the comparison of the absolute measurements and fluxgate measurements for the Z component. It was decided to maintain the temperature in the variometer chamber at about 21°C so that similar heat waves would not cause deviations in the zero field corrections. On day 247 a new heating controller was installed and the temperature raised. Towards the end of the year it became apparent that there was not enough heating to maintain this temperature in the winter so the temperature dropped and the Z fluxgate comparison with the absolute measurements drifted back to the value of earlier in the year. More heating capacity will be installed to enable the temperature range to be kept to within 2°C.

On day 257 a fault in the controller resulted in the temperature rising to 25°C before the heating was switched off. The deviations in the allocated zero field corrections were made using the experimental automatic BRMs which were being made every hour. These are described fully in the annual report at the end of the bulletin.

The apparent annual variation in the H component is mainly due to the rise in temperature in the variometer chamber in the second half of the year.

The D BRMs are stable. The high level of scatter in the H BRMs improved after the proton precession magnetometer was changed on day 249. The drift in the Z fluxgate sensor due to the higher temperature in the second half of the year is seen in the comparison with the Z BRMs.

The table below lists the *rms* differences of the observed zero field corrections from the allocated values. The *rms* differences for 1987-89 are also listed. The number of observations of each element in each year is given in brackets. The apparently larger values for 1990 are due mainly to the less stable temperature in the variometer chamber which will be improved in the future.

Year	H(nT)	D(min)	Z(nT)
1987	0.71 (51)	0.15 (38)	1.39 (51)
1988	0.67 (50)	0.18 (8)	1.02 (50)
1989	1.24 (44)	0.24 (5)	1.03 (44)
1990	1.88 (55)	0.49 (57)	1.11 (56)

6 PRESENTATION OF RESULTS

The data are organised by observatory in the order Lerwick, Eskdalemuir and Hartland. The results presented for each observatory are:

a) Daily magnetograms of H, D and Z.
b) Plots of hourly mean values of H, D and Z.
c) Plots of daily mean values of H, D and Z.
d) Plots of annual mean values and secular variation for H, D, and Z.
e) Tables of monthly and annual mean values of all geomagnetic elements.
f) Tables of hand-scaled K indices.

The daily magnetograms of H, D and Z are plotted 16 to a page, the data for days 1 to 16 of each month on one page, and the data for the remaining days of the month on the facing page. The D trace is plotted positive (east) upwards. The absolute level in each plot is indicated by the value shown to the left of the plots, in degrees for D and in nanotesla for H and Z. The magnetogram scale values, shown to the right of the plots, are varied (by multiples of two) where necessary, and when changes are made this is indicated at the top of the magnetogram. This accounts for the occasional discontinuities in the traces at day boundaries.

The hourly mean data are plotted at a constant scale in 27-day batches, according to the Bartels rotation number. These plots show a number of features of geomagnetic field variations including diurnal variation, and seasonal changes in its magnitude, and periods of geomagnetic disturbance. By plotting the data in 27-day batches recurrent disturbances caused by active regions on the Sun which persist for more than one solar rotation are highlighted. Changes due to secular variation at the UK observatories over the course of a year are small compared to diurnal variations and disturbances. However, the gradual drift eastwards in D is discernible in the plots. In the plots of daily mean values secular variation is quite clear in H, D and Z, as shorter period variations are attenuated by the averaging. The reference values shown on the left sides of the daily mean plots are the annual mean values.

ARGOS data are corrected using BRMs and absolute observations to produce a series of absolute minute values of H, D and Z centred on the minute. Hourly mean values, centred on the UT half-hour, are computed from minute values, daily mean values from hourly means, and monthly mean values from daily means. (Hourly means are not computed if there are more than six minute values missing; daily means are not computed if there are more than two hourly means missing.) Annual mean values are calculated from the monthly mean values weighted according to the number of days in the month. At each stage of processing the remaining mean values of the geomagnetic elements are calculated from the corresponding mean values of H, D and Z. The monthly mean and annual mean values for all the geomagnetic elements are tabulated. Declination and inclination are expressed in degrees and decimal minutes, the units of all the other elements are nanotesla.

The K index summarises geomagnetic activity at an observatory by assigning a code, an integer from 0 to 9, to each 3-hour Universal Time (UT) interval. The index values are determined from the ranges in H and D (scaled into nT), with allowance made for the regular diurnal variation.

The K index has a local time (LT) and seasonal dependence associated with the geographic and geomagnetic coordinates of the observatory. The hand-scaled K indices for each of the UK observatories are tabulated.

A number of 3-hour geomagnetic indices are computed by combining K indices from networks of observatories to characterise global activity levels and to eliminate LT and seasonal effects. K indices from each of the three UK observatories are used in deriving the planetary geomagnetic activity indices Kp, Kn and Km, sanctioned by the International Association of Geomagnetism and Aeronomy (IAGA). The K indices from Hartland and Canberra (approximately antipodal to Hartland) are used to produce the aa index, a further planetary activity index. (Definitive values of the indices recognised by IAGA are published by the International Service for Geomagnetic Indices, Paris.) Daily mean, monthly mean and annual mean values of the aa index are listed following the tables of K indices for Hartland. The derivation of the geomagnetic activity indices mentioned here is described in great detail by Mayaud (1980).

The annual mean values at each observatory since operations began are tabulated. Declination and inclination are expressed in degrees and decimal minutes, the units of all the other elements are nanoteslas. Plots of the annual mean values of H, D, Z and F, and of first differences of the annual means, representing secular variation at the observatories are presented. In the case of Hartland, annual mean values from Abinger observatory for 1925.5-56.5 have been included in the table. The plots for Hartland also include values from Abinger, taking into account the site differences between the two observatories determined during 1957 when both observatories operated simultaneously for a period of time.

7 DATA AVAILABILITY

Hourly mean values of H, D, Z and F for each observatory for the years 1987-1989 are available on an IBM-compatible 3.5" (or 5.25") diskette. The diskette contains a file 'README' which explains the content and format of each file on the diskette. Other data included in this bulletin can be obtained in digital form by application to:

Data Services
Geomagnetism Group
British Geological Survey
Murchison House
West Mains Road — ☎: 031 667 1000
Edinburgh EH9 3LA — Fax: 031 668 4368
Scotland UK — Telex: 727343 SEISED G

8 GEOMAGNETISM GROUP STAFF LIST 1990

Edinburgh

Group Manager (Grade 7)	Dr W F Stuart
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SSO	Dr D J Kerridge J C Riddick
HSO	T D G Clark T J Harris Dr S Macmillan E M Reader
SO	S Anderson (finished contract May 1990) S Flower (started Sep 1990)
ASO	E Clarke
Craftsman	J McDonald

Eskdalemuir

Industrial Craftsman	C R Pringle
	W E Scott
Cleaner	Mrs H Middleton

Hartland

PGS E	K G Johns

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Forbes, A J. 1987. General Instrumentation, in *Geomagnetism* Vol.1, edited by J A Jacobs, chapter 2, pp.51-142. (London: Academic Press Limited.)

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Kerridge, D J 1988. Theory of the fluxgate-theodolite. *British Geological Survey Technical Report*, WM/88/14.

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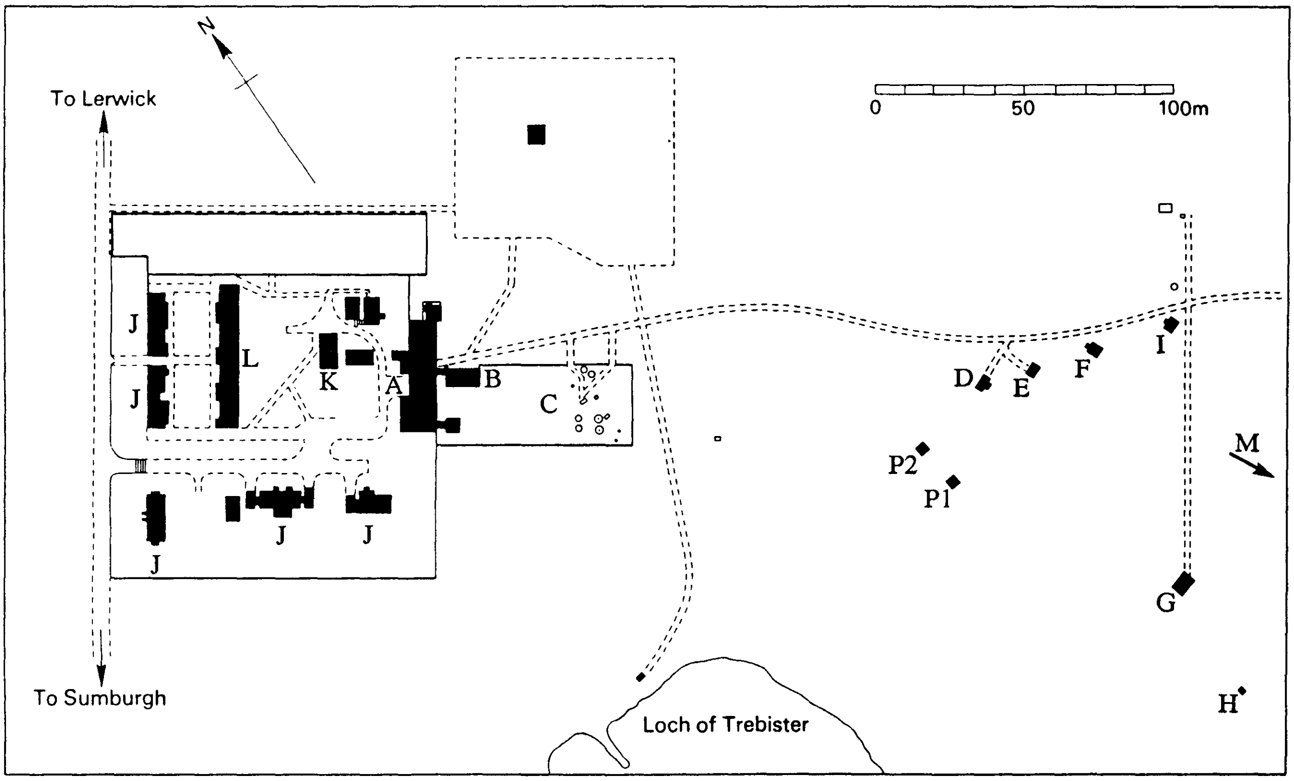
Lerwick Observatory



Observatory Layout

A Main observatory building
B BGS office, seismic recorders
C Meteorological instrument enclosure
D Absolute Hut
E Instrument Hut
F Variometer House
G West Hut
H Azimuth mark
I Back-up fluxgate data-logger
J Staff houses
K Standby generator
L Staff hostel
M To position of GOES-East satellite transmitter
P1 ARGOS Proton magnetometer 1
P2 ARGOS Proton magnetometer 2

Instrument Deployment

Absolute Hut
PVM (used for H/Z/F measurements)
D/I Fluxgate Theodolite

The fixed mark (azimuth 8° 38' 02" E of S) is viewed through a small sliding panel in the hut door.

Instrument Hut
PVM electronics
ARGOS electronics
ARGOS uninterruptible power supply (UPS)

Variometer House
ARGOS fluxgate sensors (X,Y,Z)
Back-up fluxgate sensors (H,D,Z)

The Variometer House is constructed from non-magnetic concrete and has internal dimensions of 4.9 by 3 metres. The roof is semi-circular in cross section. The temperature of the house is controlled to a diurnal range of ± 1°C. The meridian at the time of construction is defined on the north and south walls.

Previous descriptions

Harper W.G. 1950. Lerwick Observatory. *Meteorological Magazine, Vol.79, 309-314.*
Tyldesley, J.B. 1971. Fifty years of Lerwick Observatory. *Meteorological Magazine, Vol.100. 173-179.*

Figure 1. Lerwick observatory site diagram

Eskdalemuir Observatory

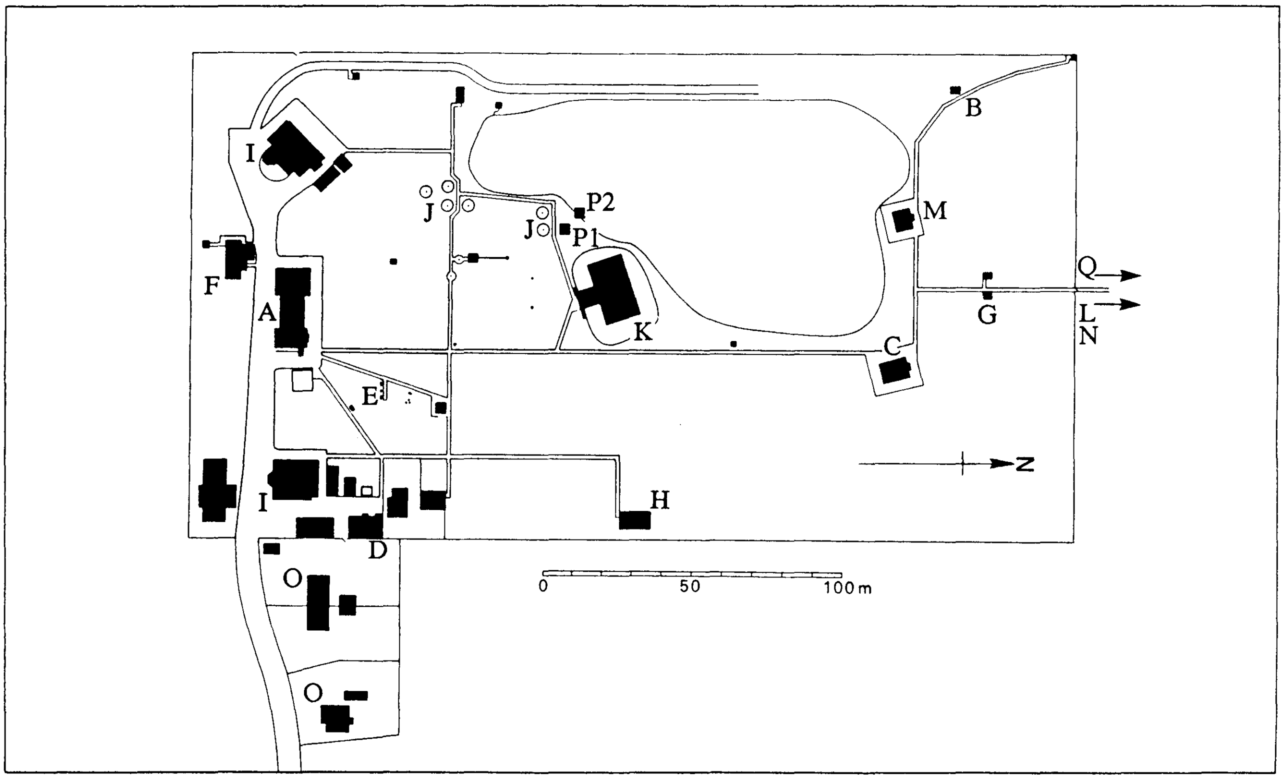


Figure 2. Eskdalemuir observatory site diagram

Observatory Layout

A Main observatory building

B Atmospheric pollution sampling

C East Absolute Hut

D Garage and standby generator

E Meteorological instruments

F Seismic laboratory, seismic recorders, offices, electronics laboratory

G Hut G

H Non-magnetic laboratory

I Staff accommodation

J Rain gauges

K Underground variometer chamber, instrument room containing data loggers

L Seismic vault, 280 metres from boundary wall

M West Absolute Hut

N Chemical sampling by Warren Spring Laboratory, 75 metres from boundary wall

O Private houses, formerly housing observatory staff

P1 ARGOS Proton magnetometer 1

P1 ARGOS Proton magnetometer 2

Q GOES-East satellite transmitter, 300 metres from boundary wall

Instrument Deployment

Hut G contains the PVM electronics, the digital clock and the printer used to record values during absolute observations.

East Absolute Hut
PVM (used for H/Z/F measurements)
D/I Fluxgate Theodolite

The fixed mark (azimuth 8° 12' 35" W of S) is viewed through a shutter on the south wall of the hut.

Underground Variometer Chamber
ARGOS fluxgate sensors (X,Y,Z)
Back-up sensors (H,D,Z)

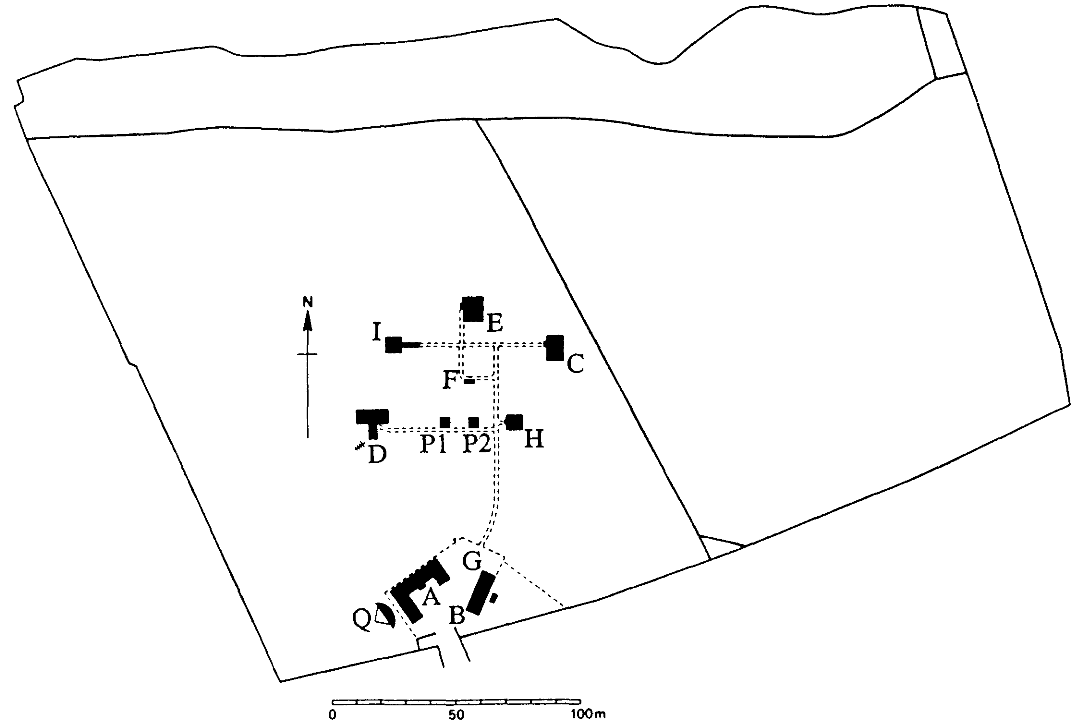
The variometer chamber comprises two separate rooms inside a domed chamber covered with a thick layer of earth to form a mound. The instruments and the greater part of the rooms are thus below the level of the surrounding ground. The temperature of the chamber is controlled to a diurnal range of ±0.5°C. The instrument room has been created by extending the former porch back into the stairwell and entrance, leaving a compartment under the floor for standby batteries. The entrance to the room is protected by an external porch.

West Absolute Hut
The hut contains three instrument piers. The fixed mark is viewed through a shutter in the south wall of the hut.

Non-Magnetic Laboratory
The laboratory is used for instrument development and testing. It contains two rooms, a sensor room with three piers and a larger instrument room with a single pier.

Previous descriptions
Blackwell, M.J 1958. Eskdalemuir Observatory - the first 50 years. *Meteorological Magazine, London Vol. 87, 129.*
Crichton, J. 1950. Eskdalemuir Observatory. *Meteorological Magazine, London, Vol.79, 337.*

Hartland Observatory



Observatory Layout

A Main observatory building,

B Caretakers house

C Absolute Hut

D Non-Magnetic laboratory, GOES-East satellite transmitter

E Variometer House

F Instrument Hut

G Garage

H Test 2 Hut

I Test 1 Hut

P1 ARGOS Proton magnetometer 1

P2 ARGOS Proton magnetometer 2

Q GOES-E Satellite receiver

Instrument Deployment

Absolute Hut

PVM (used for H/Z/F measurements)
D/I Fluxgate Theodolite

The fixed mark (azimuth 11° 27' 54" E of N) is viewed through a window in the north wall of the hut.

Non-Magnetic Laboratory

The laboratory was built in 1972 to provide accommodation for a rubidium-vapour magnetometer digital recording system. It comprises an instrument room and a sensor room with five instrument piers. At present, a 3-component fluxgate (H,D,Z) is in operation. This is connected to a data collection platform transmitting data to the GOES-East satellite.

Variometer House

ARGOS fluxgate sensors (X,Y,Z)
Back-up sensors (H,D,Z)

The Variometer House comprises an entrance porch and a main room, which contains two separate internal rooms, each divided into three compartments. The temperature of the house is controlled to a diurnal range of ±0.5°C. Two cable ducts connect the Variometer House to the Instrument Hut.

Instrument Hut

PVM electronics
ARGOS electronics
Standby batteries and ARGOS uninterruptible power supply (UPS)

Test Hut 1

The hut contains an orthogonal coil system and its power supplies. The inner coil, a vertical-axis square coil, was previously used for BMZ calibration. Two additional 2 metre square coils, for creating horizontal fields parallel and normal to the meridian, were added in 1983 to create a near zero field facility for investigating the magnetic signature of the AMPTE satellite.

Test Hut 2

Auxilliary measurement position

The fixed mark (azimuth 12° 52'33" E of N) is viewed through a window in the north wall.

Previous descriptions

Finch, H.F. 1960. Geomagnetic measurement. *Journal of the Royal Naval Scientific Service. Vol.15, No.1, 26-31*

Figure 3. Hartland observatory site diagram

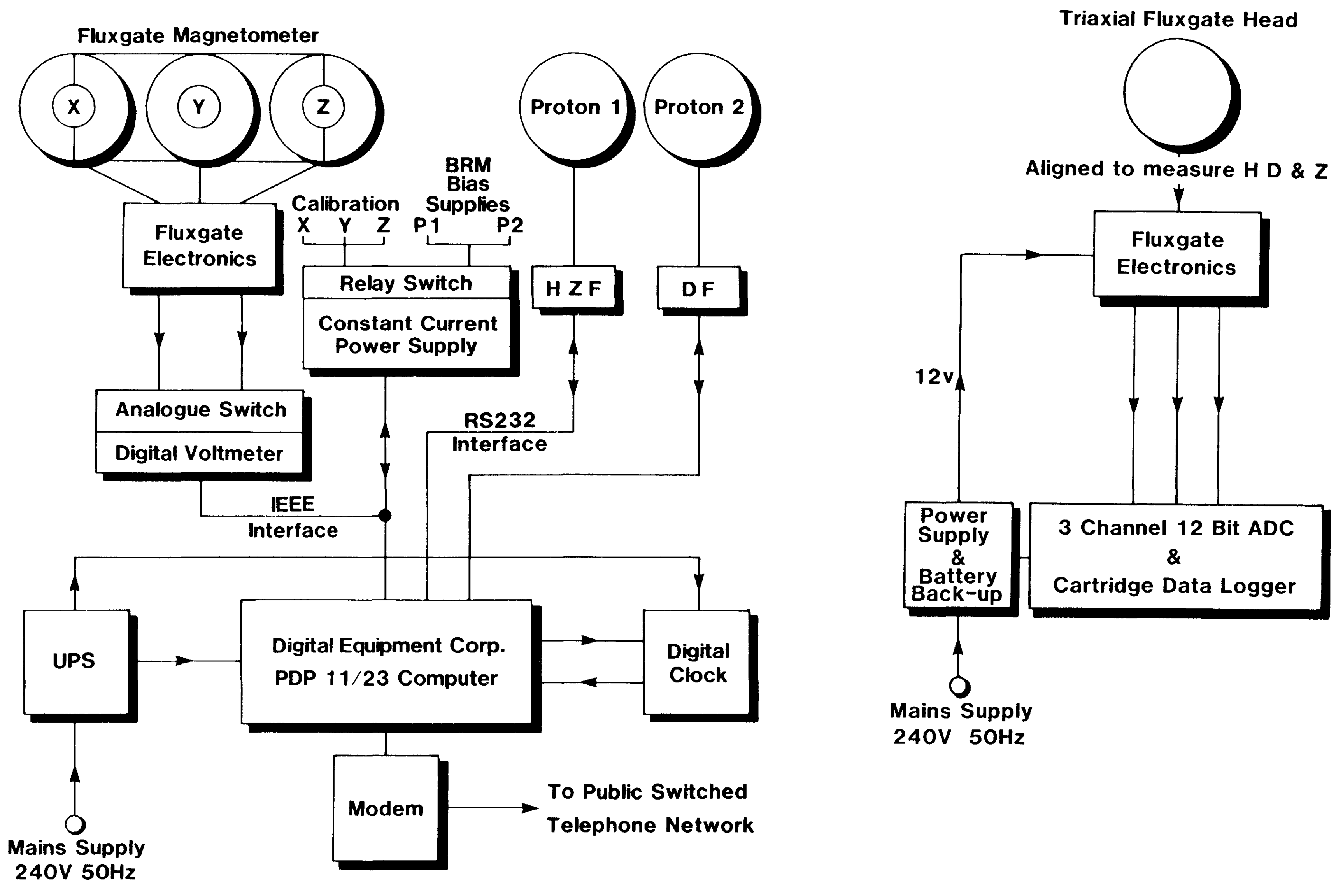
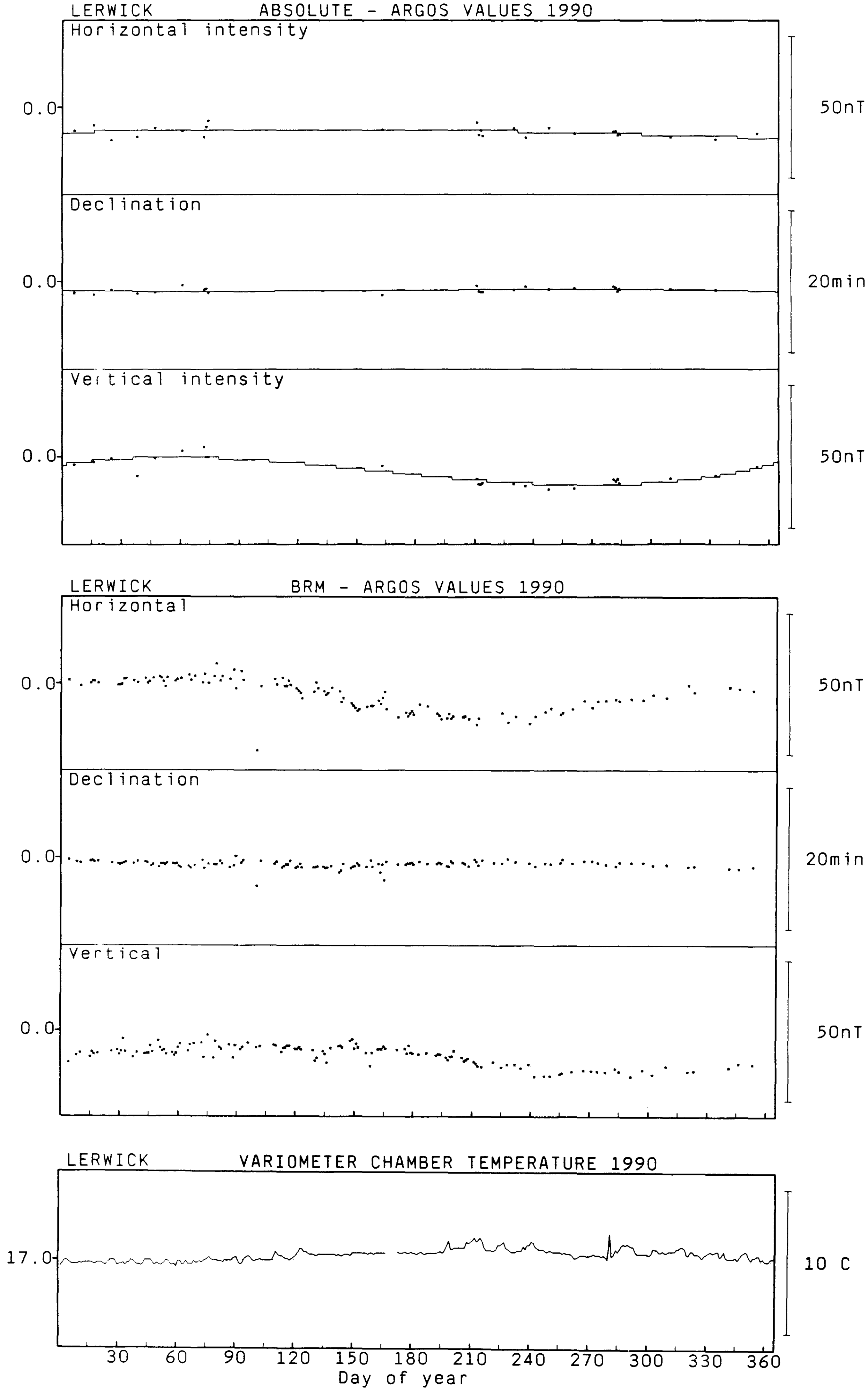


Figure 4. Block diagram of ARGOS and backup system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ABSOLUTE - ARGOS VALUES 1990
Horizontal intensity
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Declination
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Vertical intensity
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50nT
LERWICK
BRM - ARGOS VALUES 1990
Horizontal
0.0
50nT
Declination
0.0
20min
Vertical
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LERWICK
VARIOMETER CHAMBER TEMPERATURE 1990
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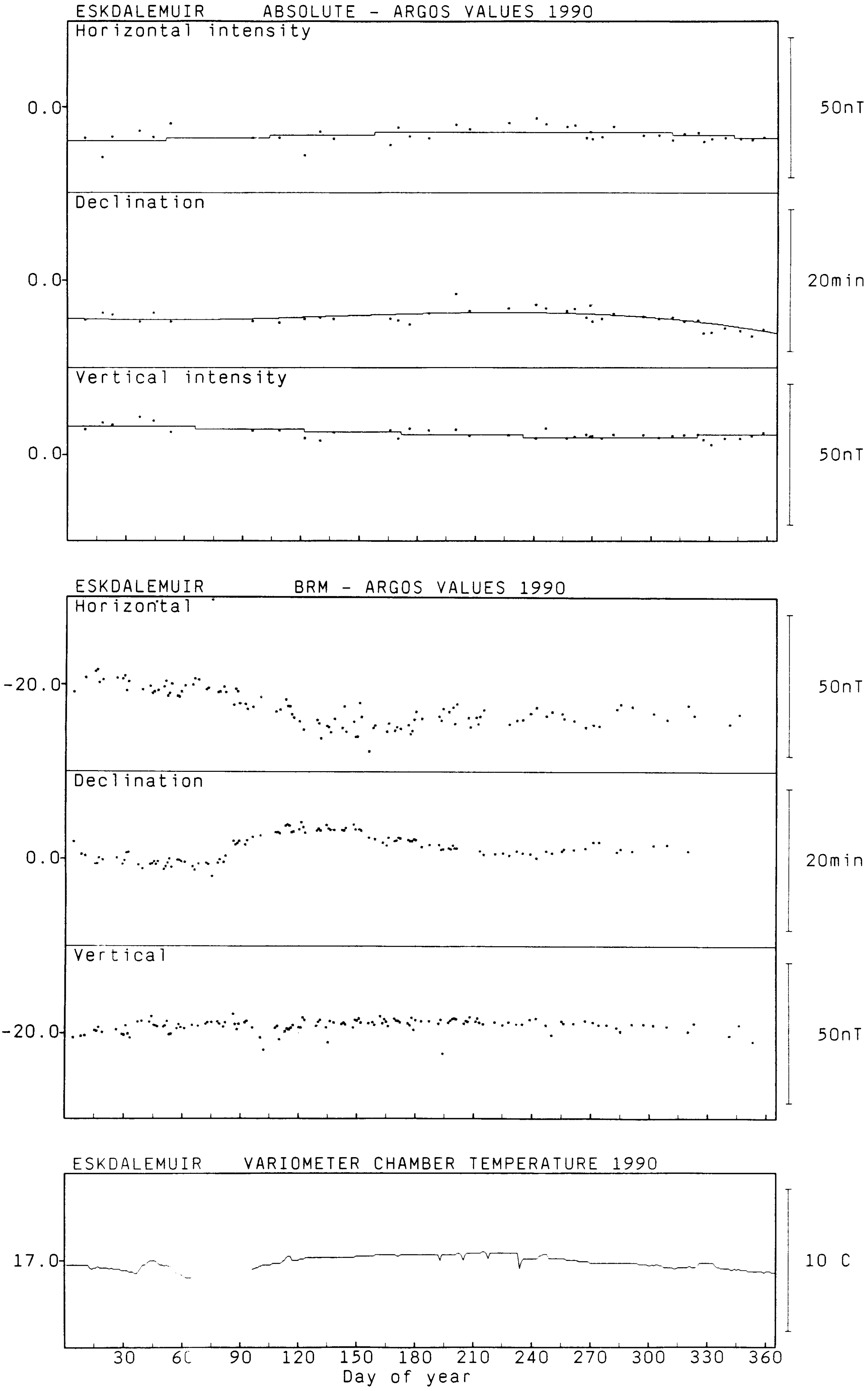
Day of year

Figure 5.


ESKDALEMUIR ABSOLUTE - ARGOS VALUES 1990
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ESKDALEMUIR BRM - ARGOS VALUES 1990
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ESKDALEMUIR VARIOMETER CHAMBER TEMPERATURE 1990
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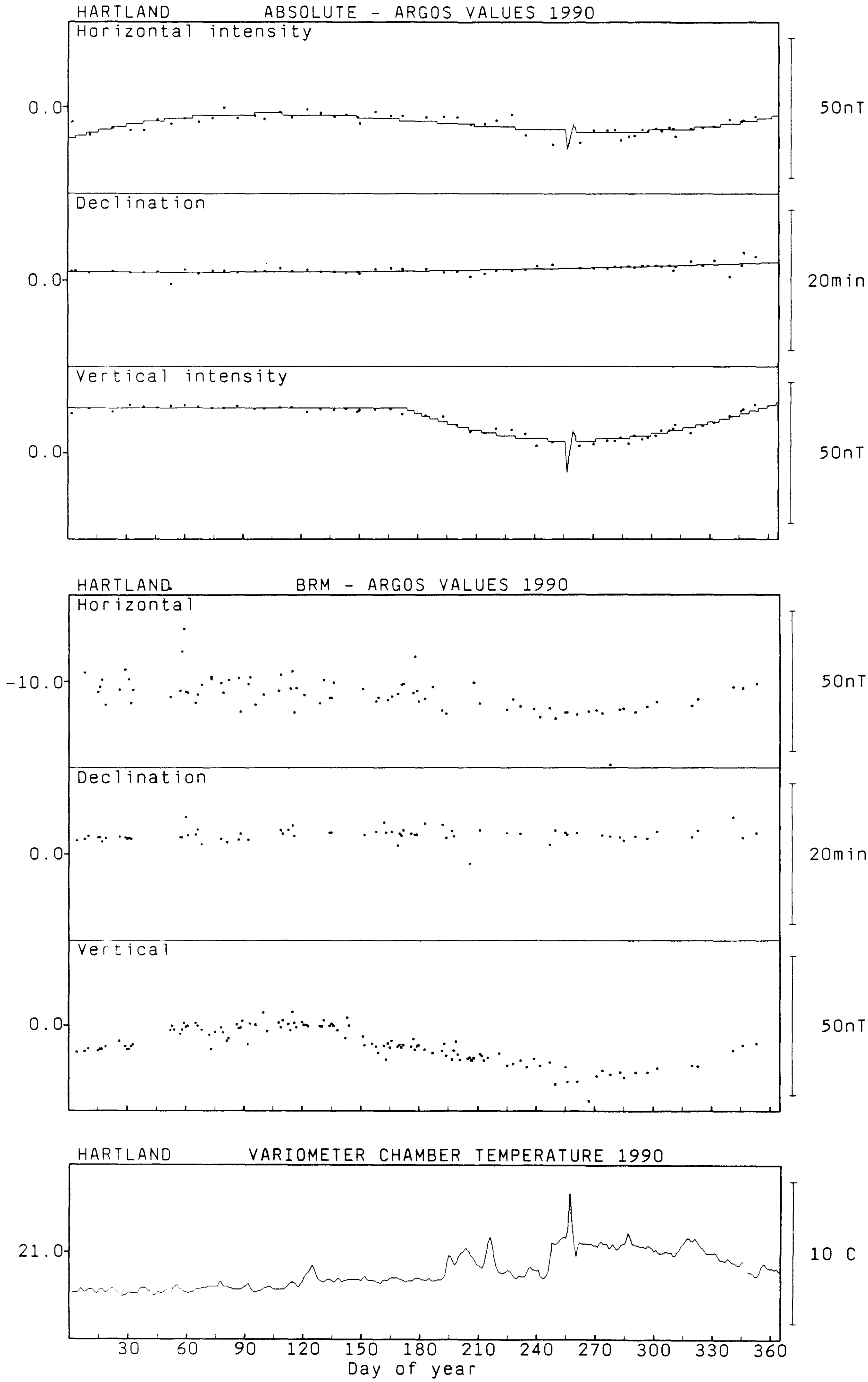
Day of year

Figure 6.



HARTLAND ABSOLUTE - ARGOS VALUES 1990
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HARTLAND BRM - ARGOS VALUES 1990
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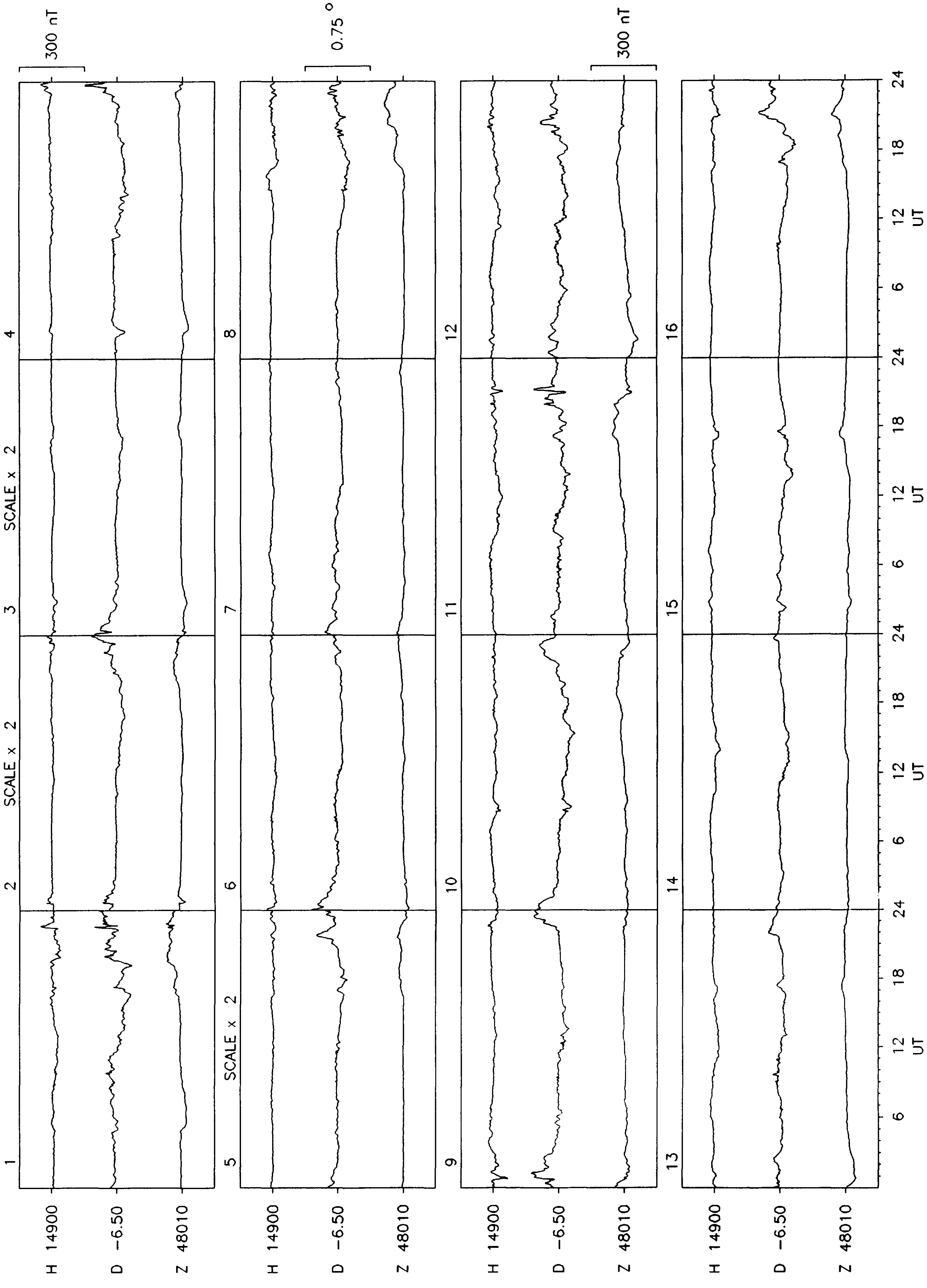
Day of year

Figure 7.

Lerwick 1990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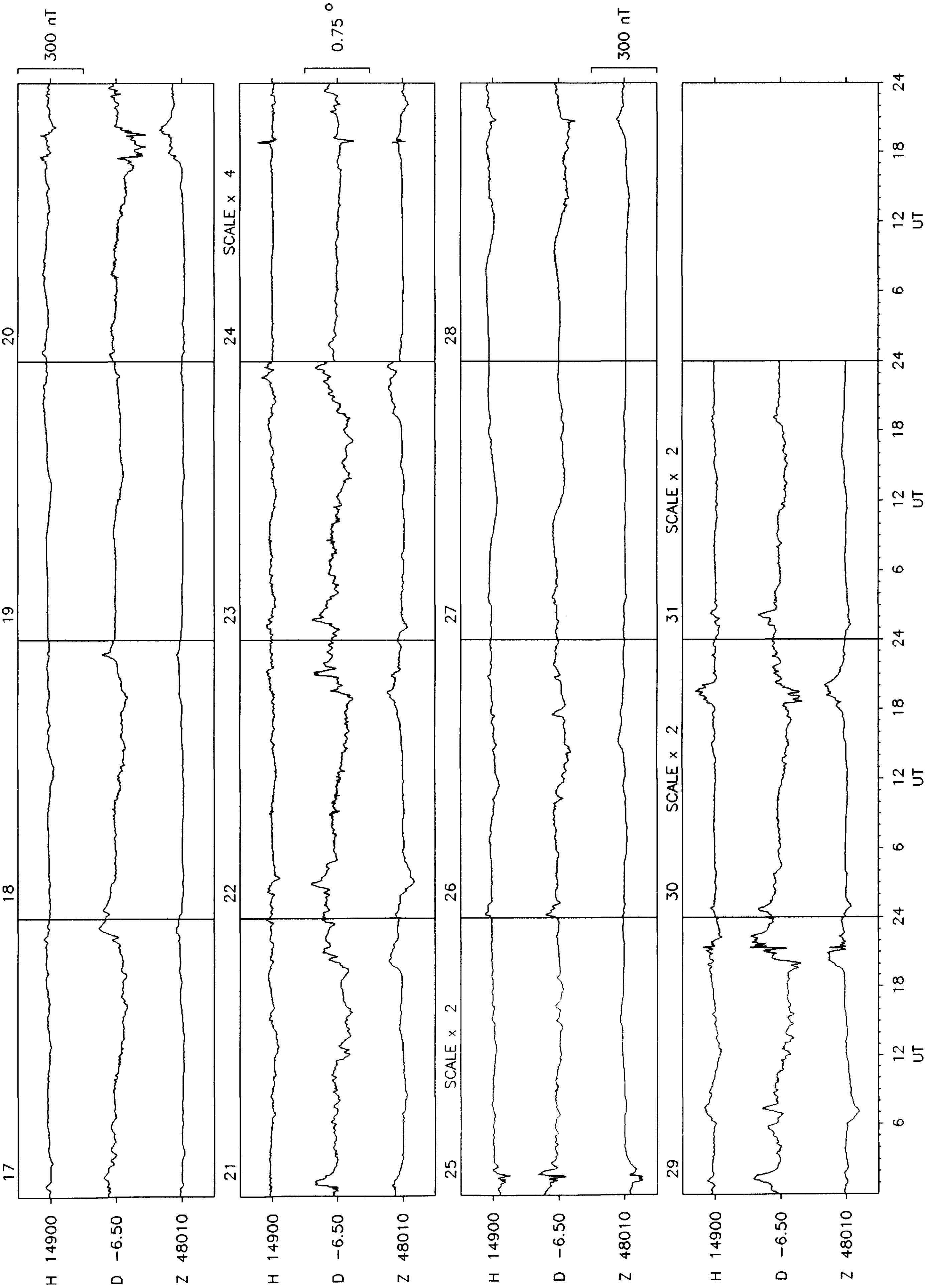
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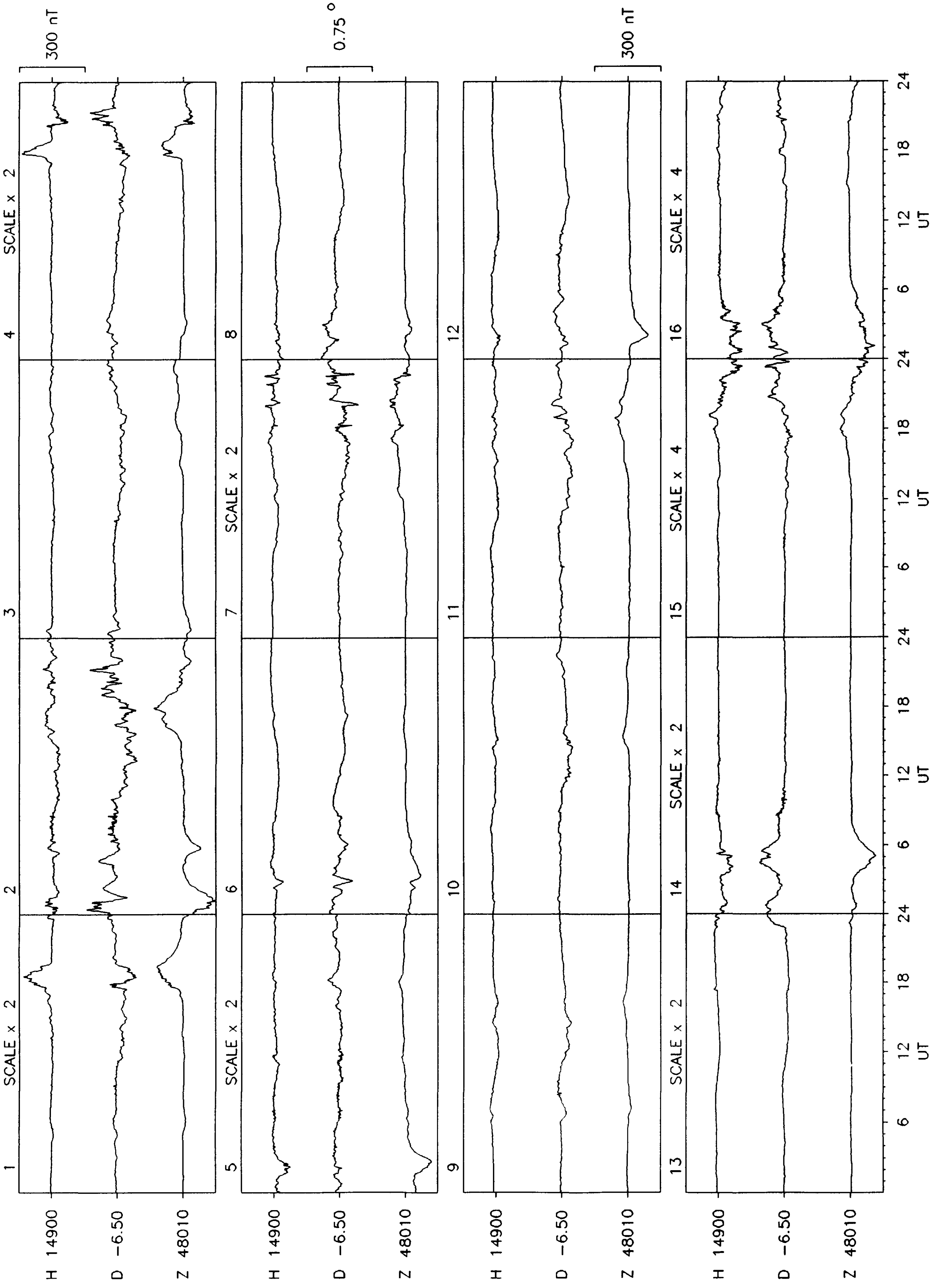
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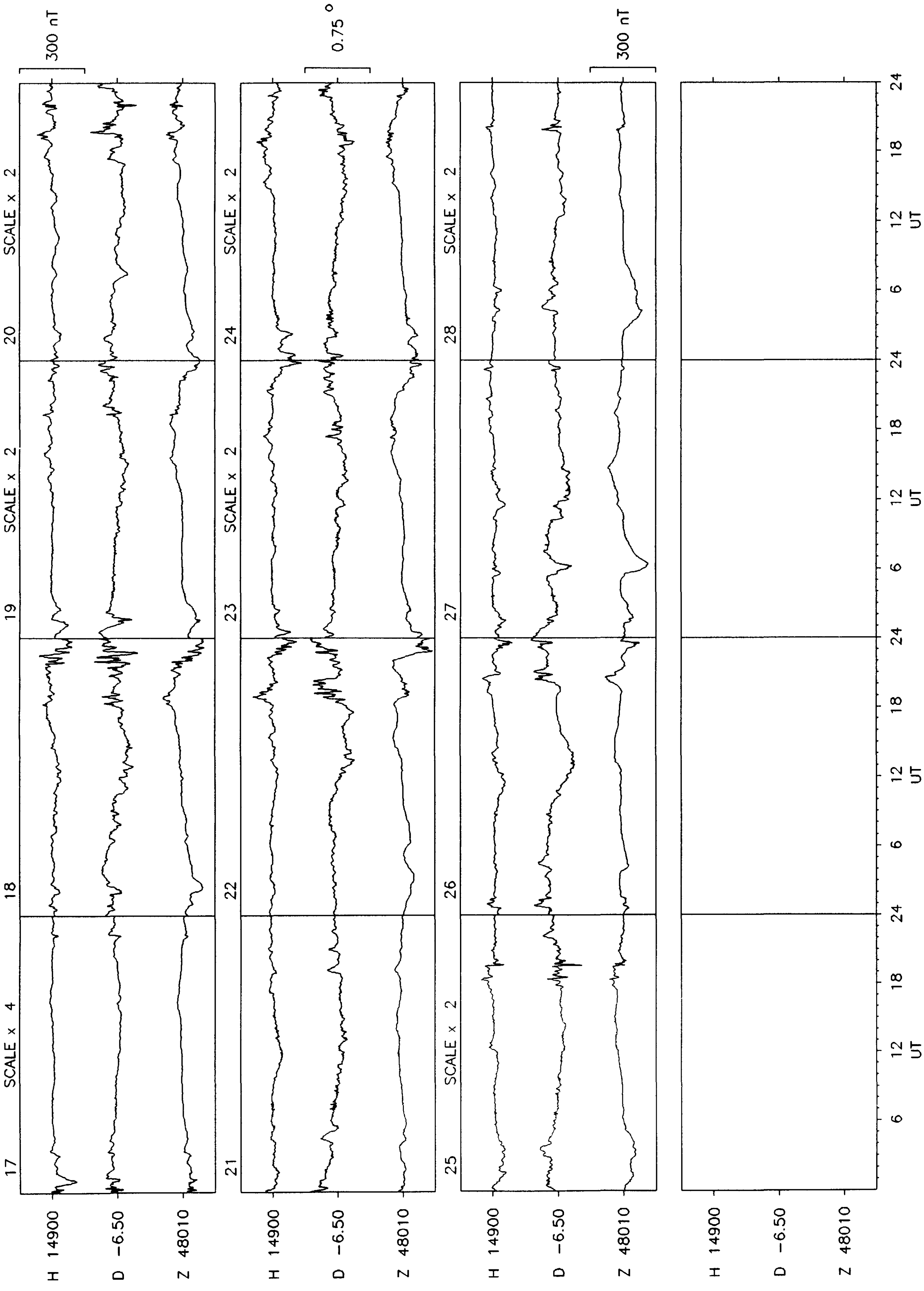

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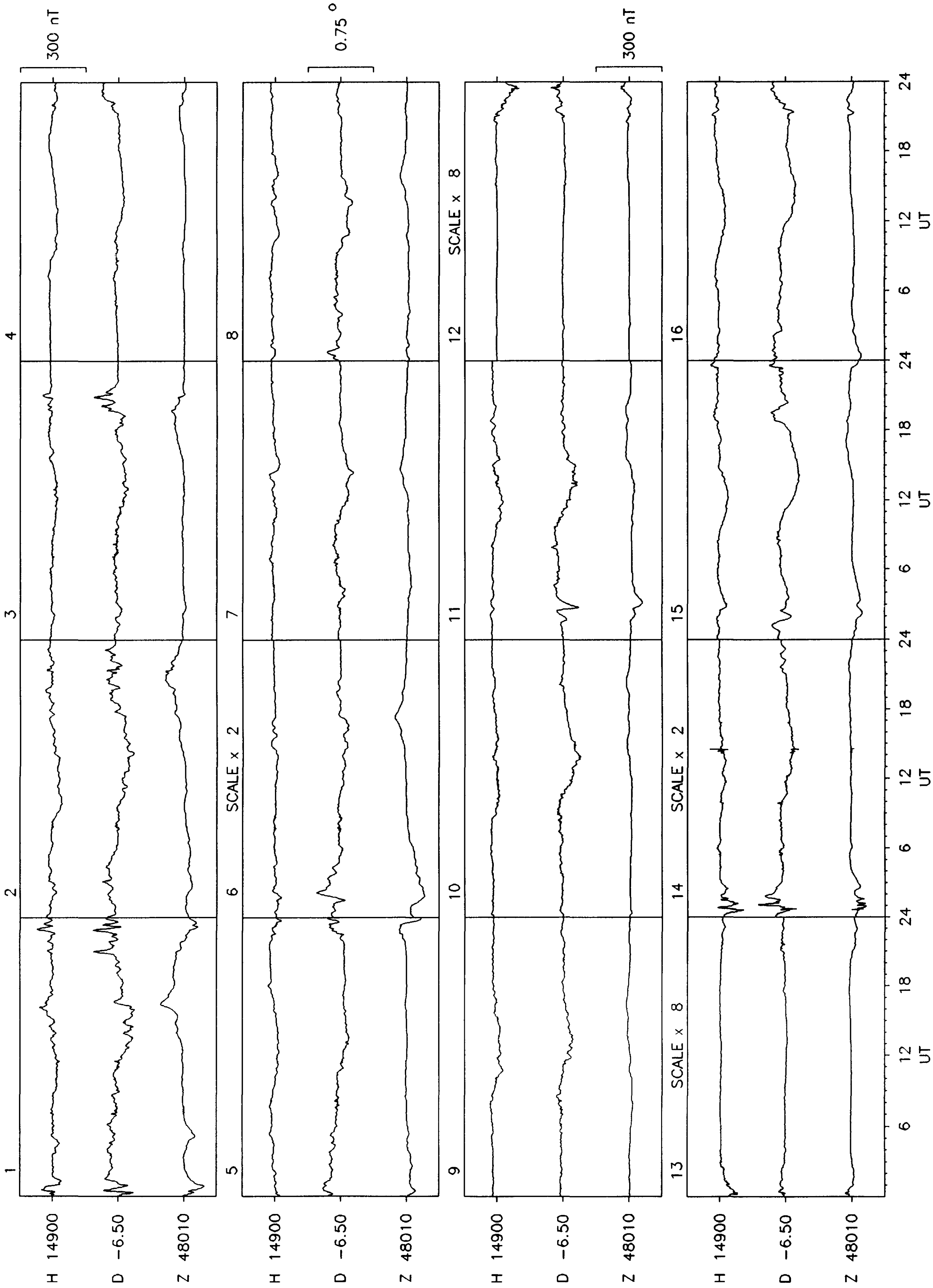

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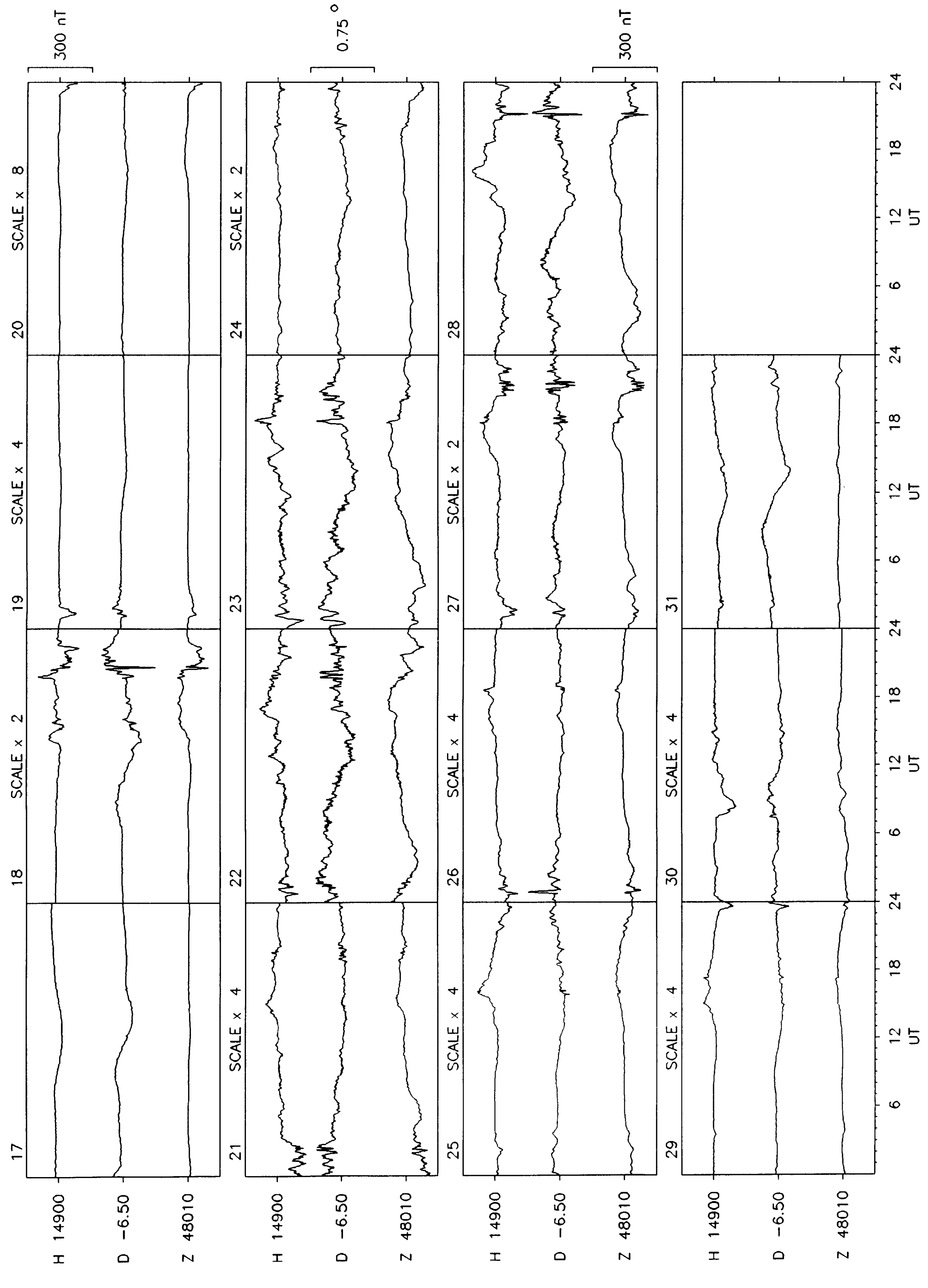
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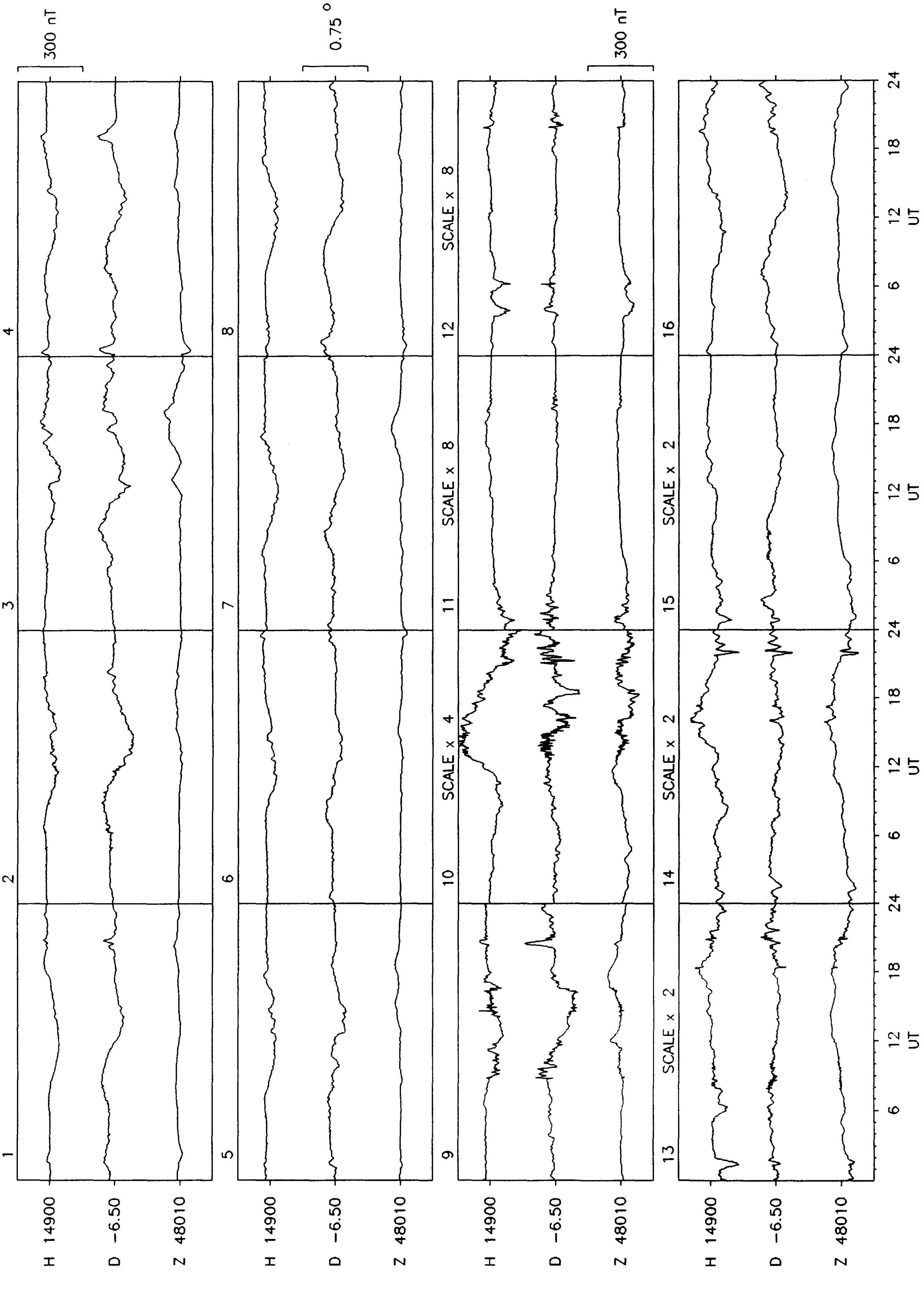

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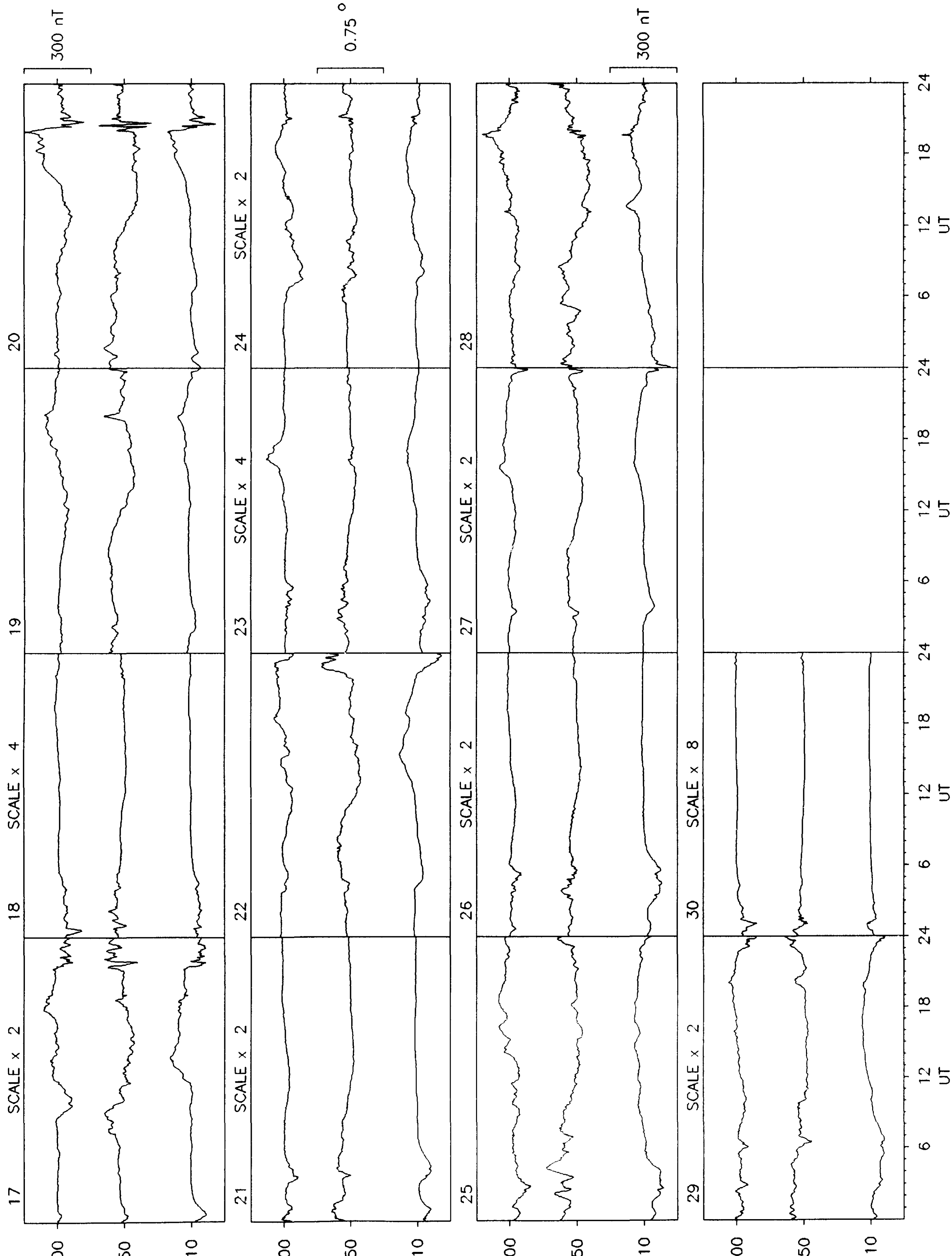
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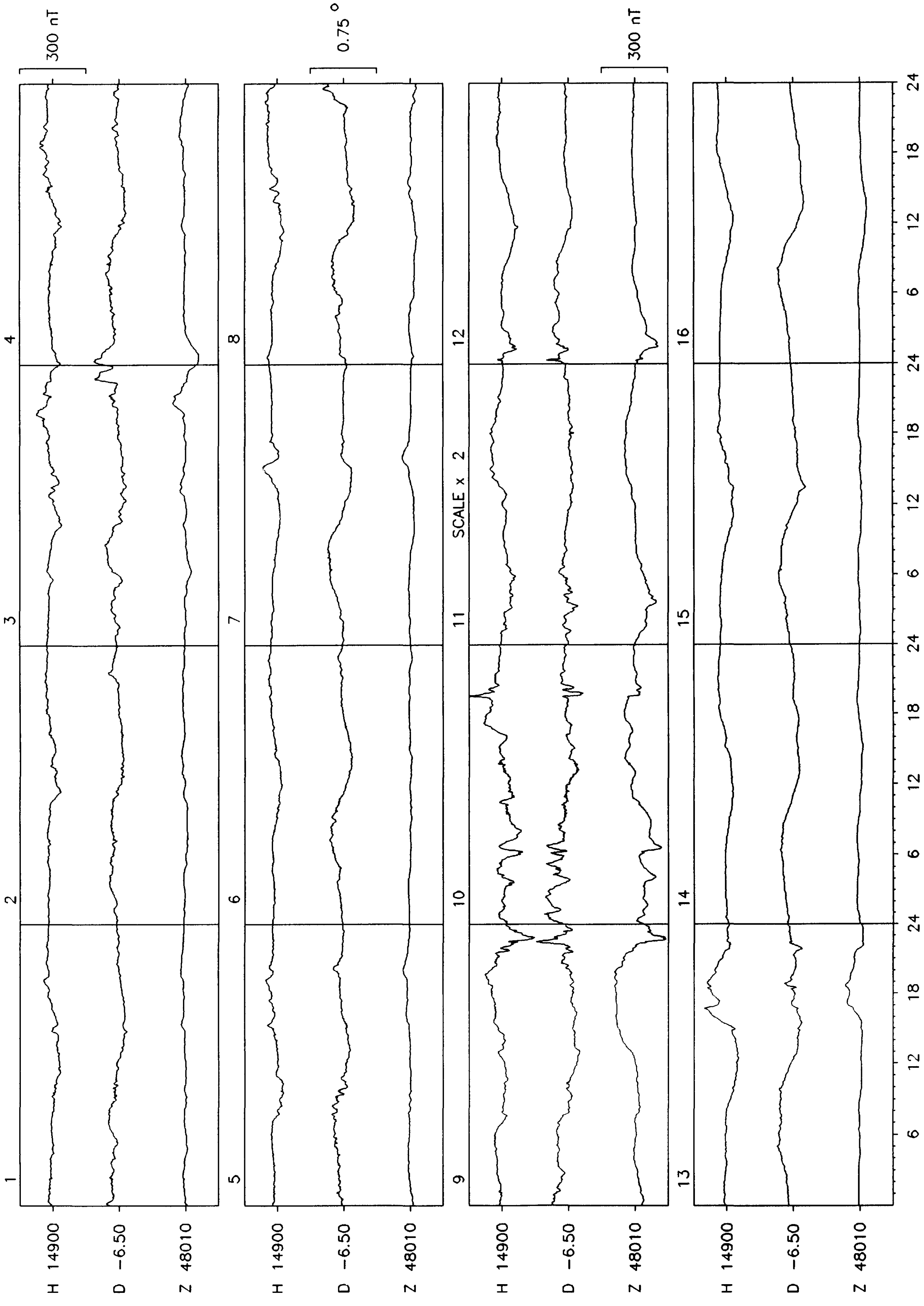
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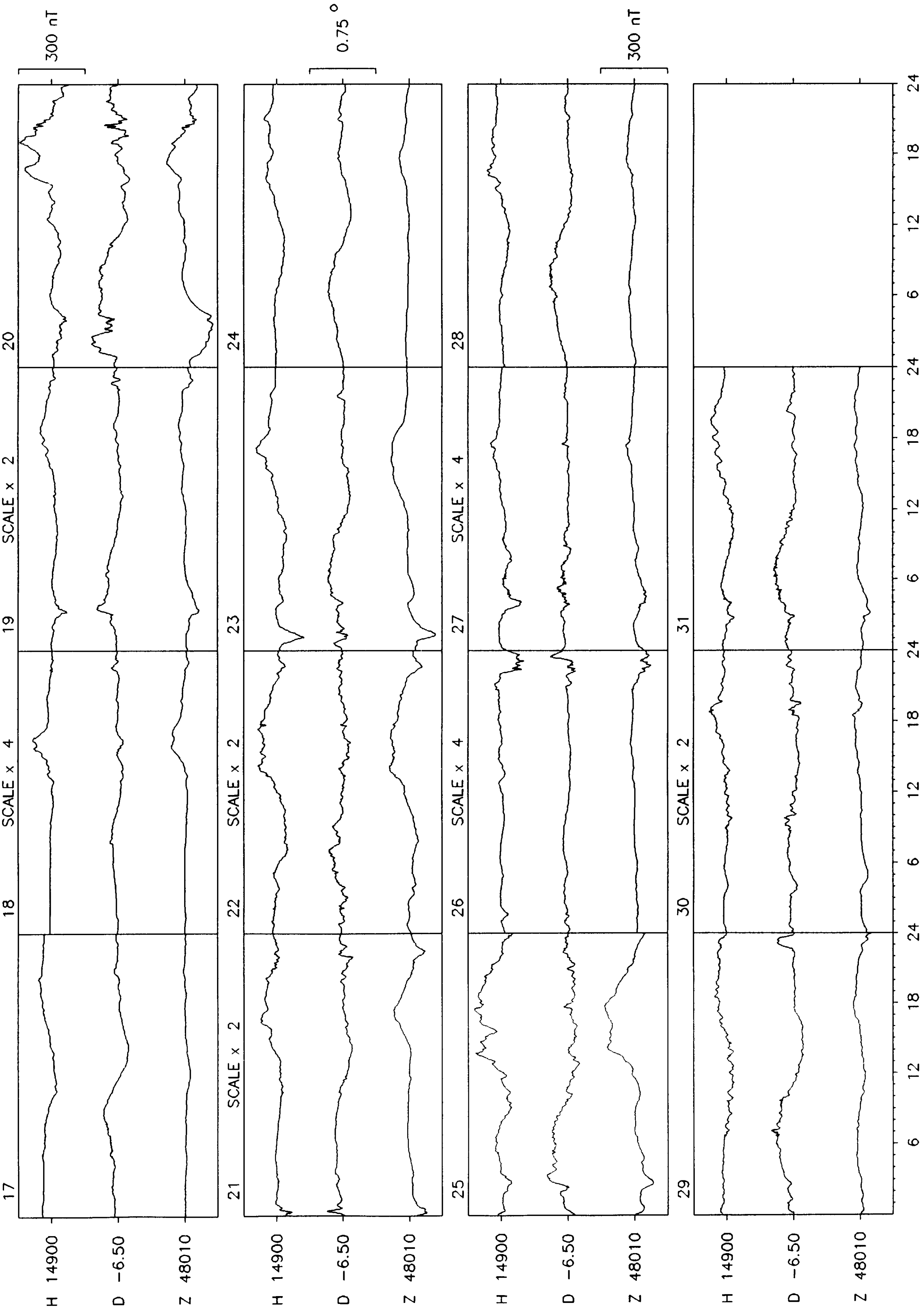
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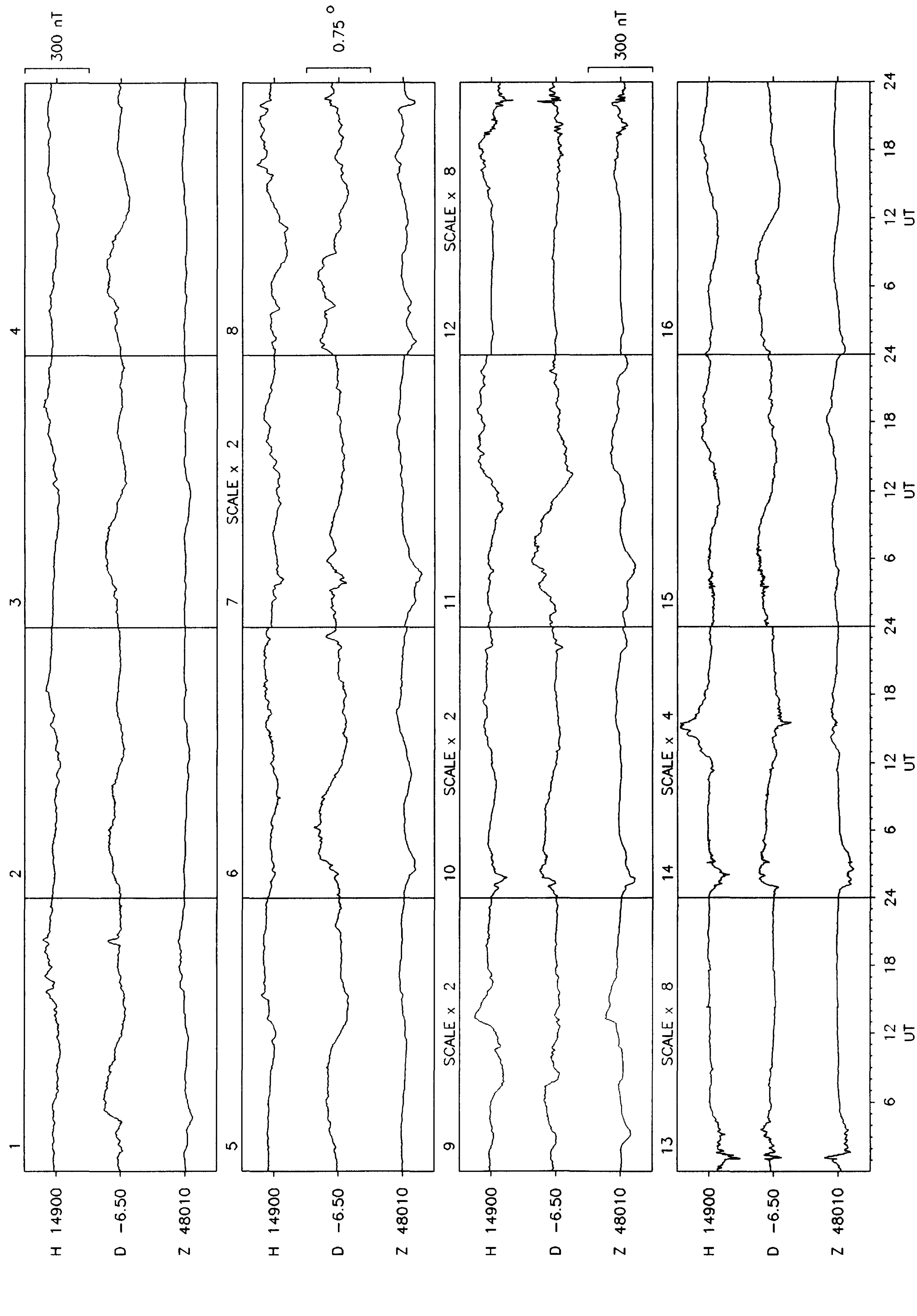
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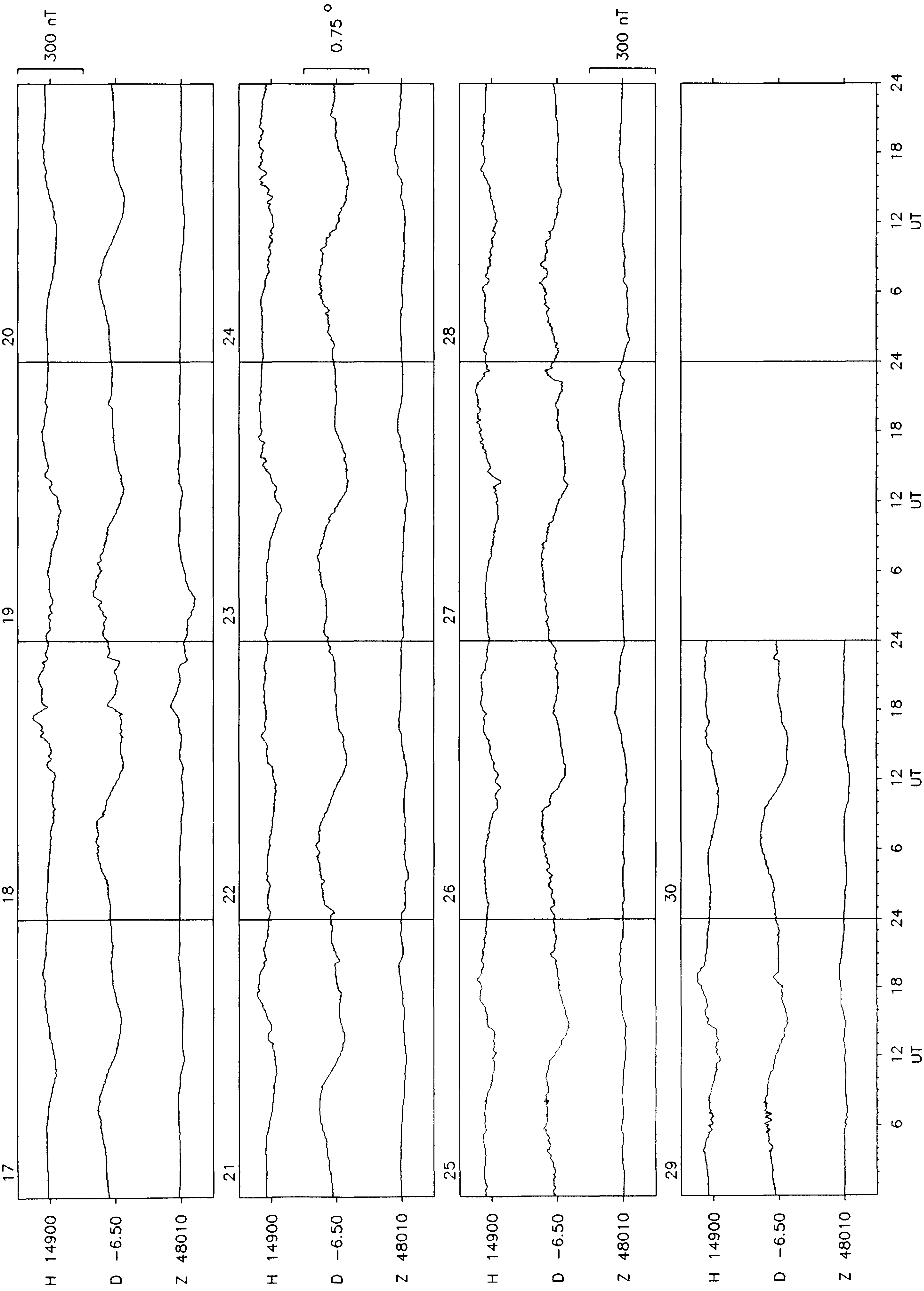
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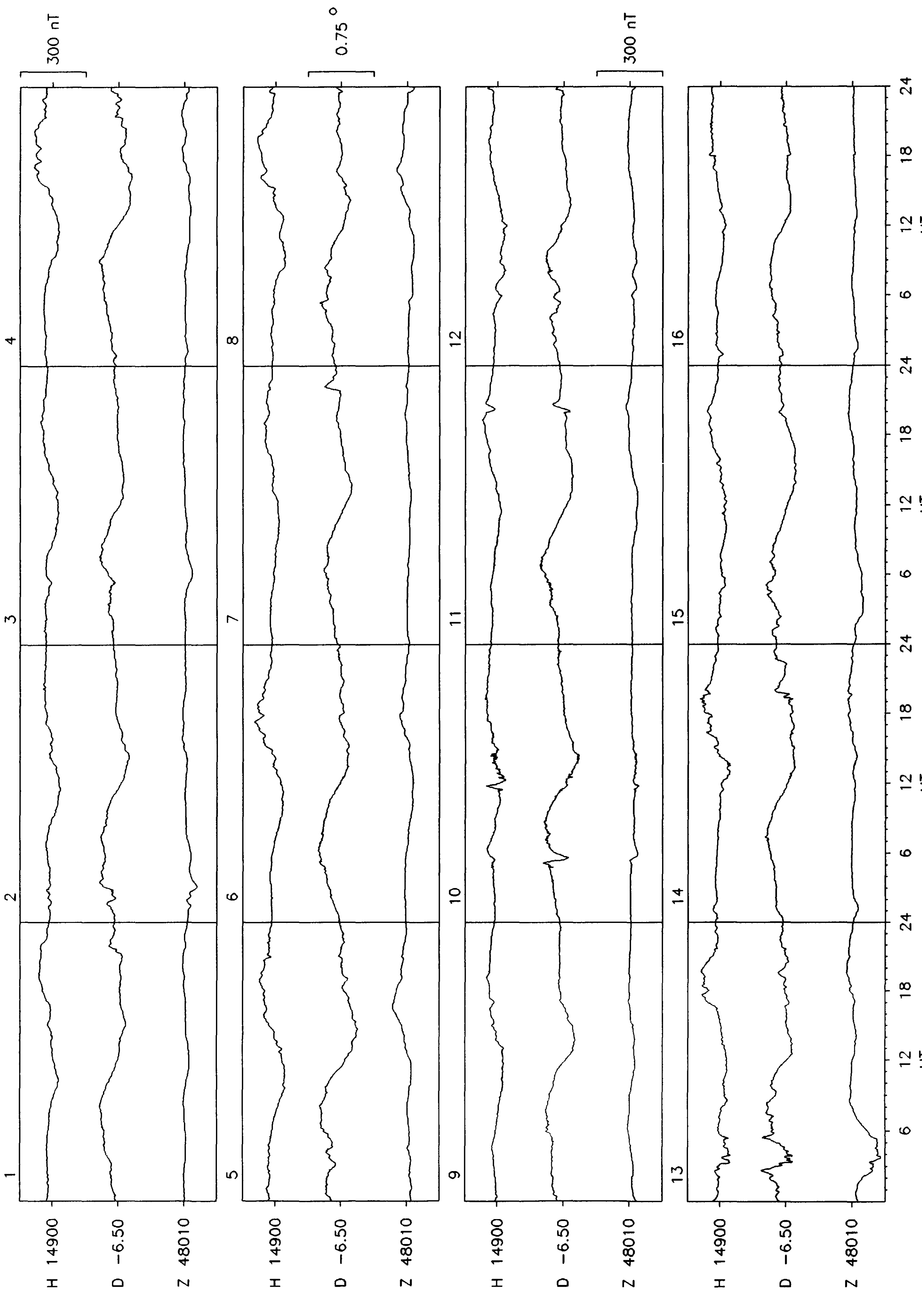
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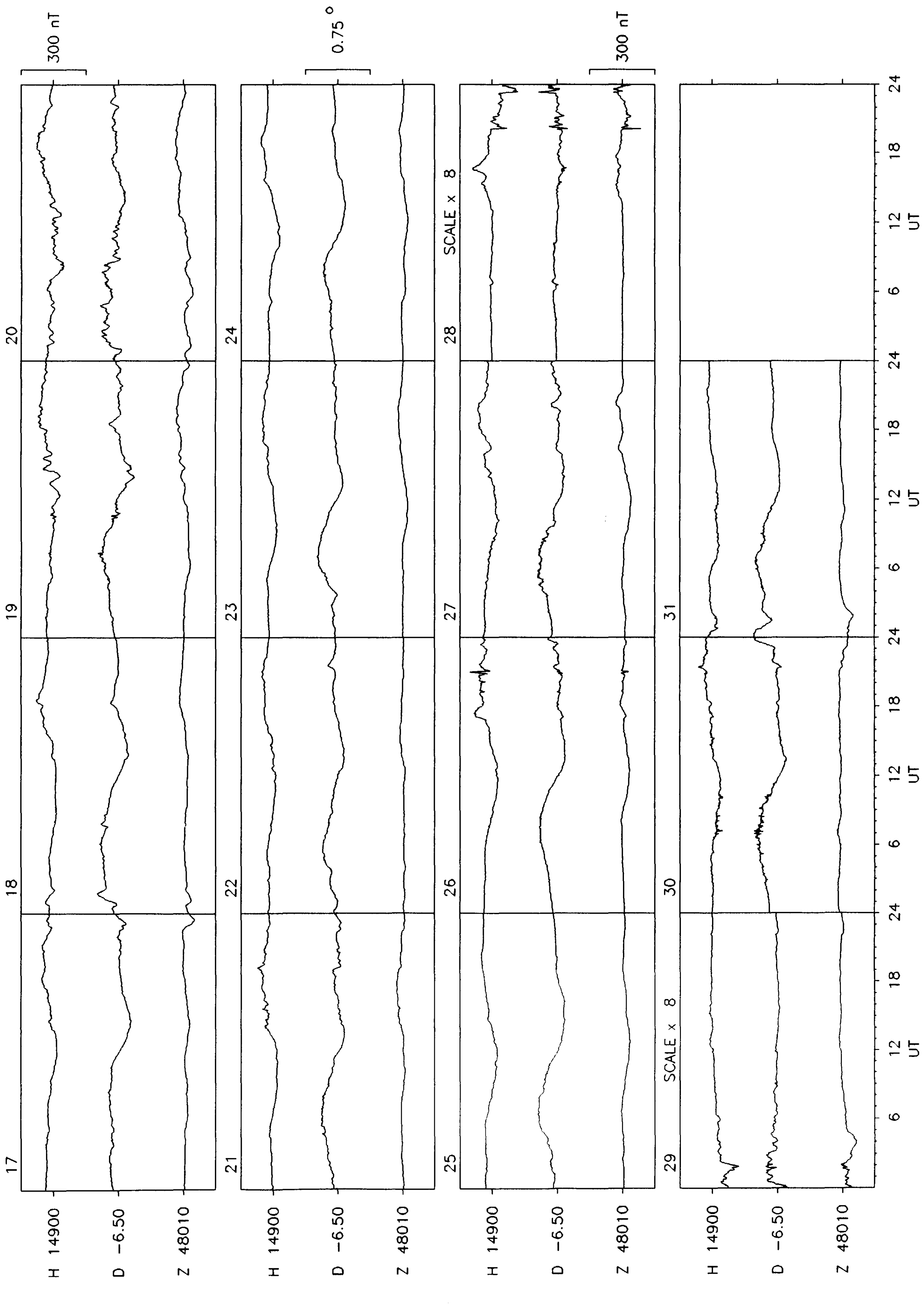

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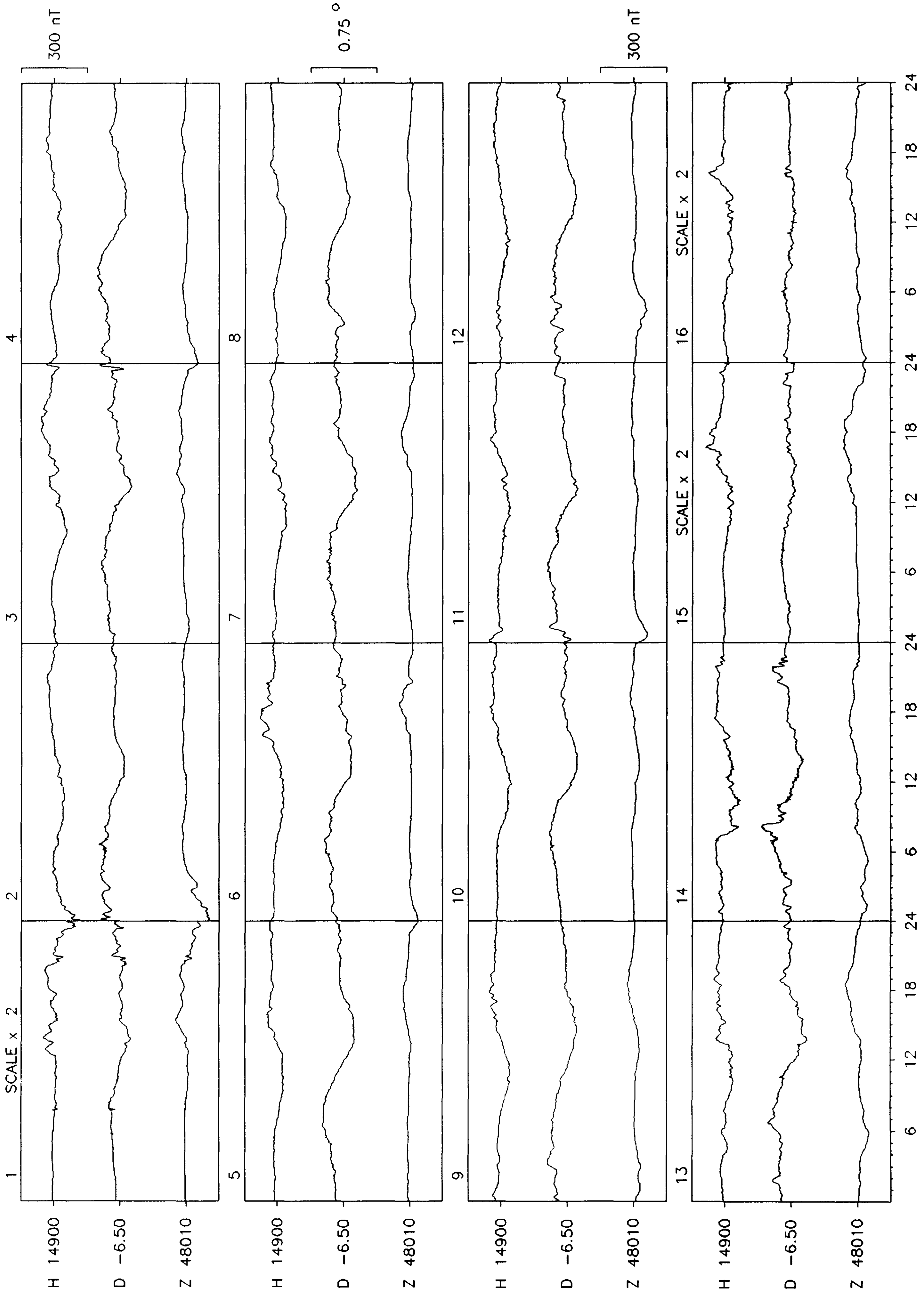
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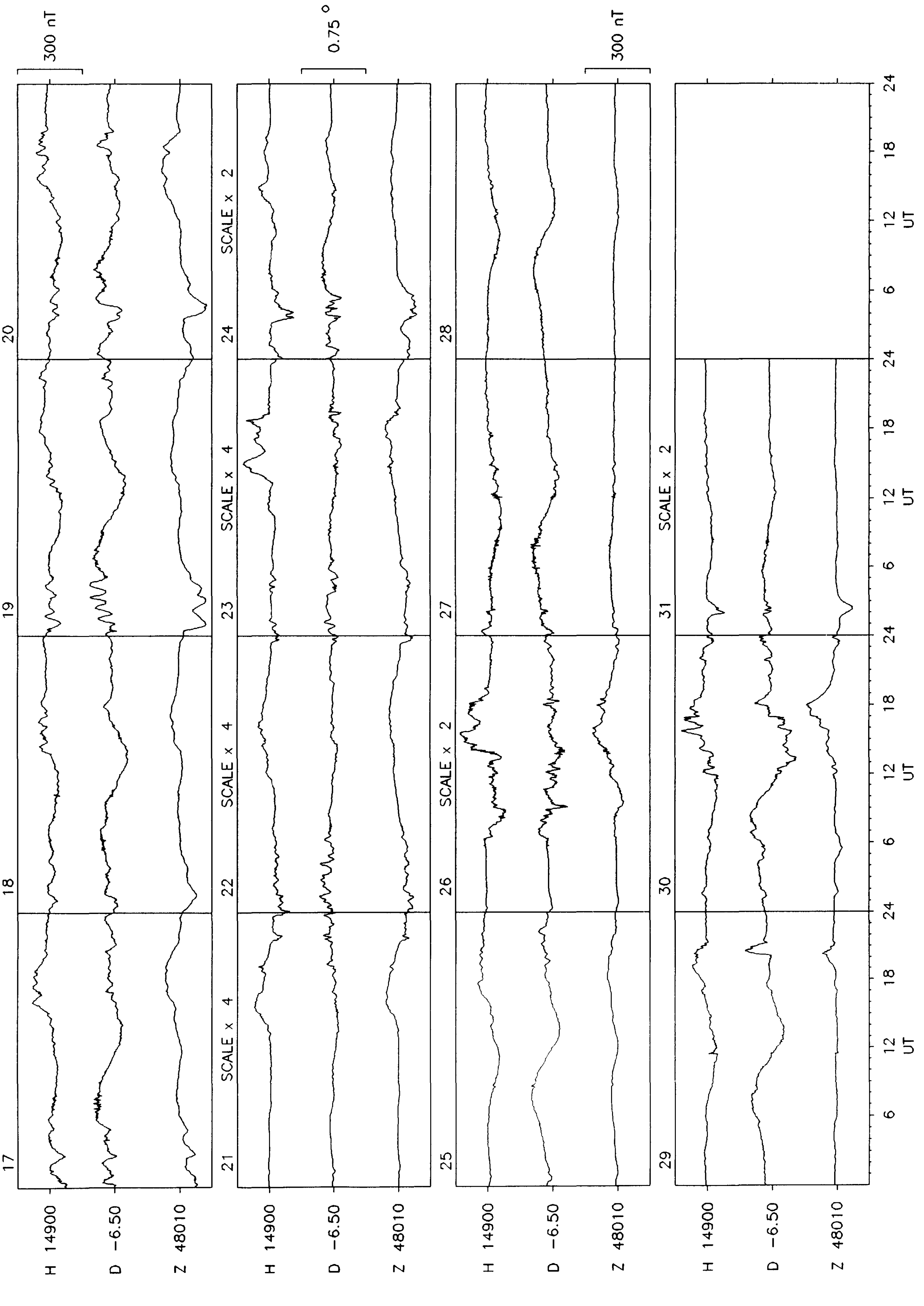
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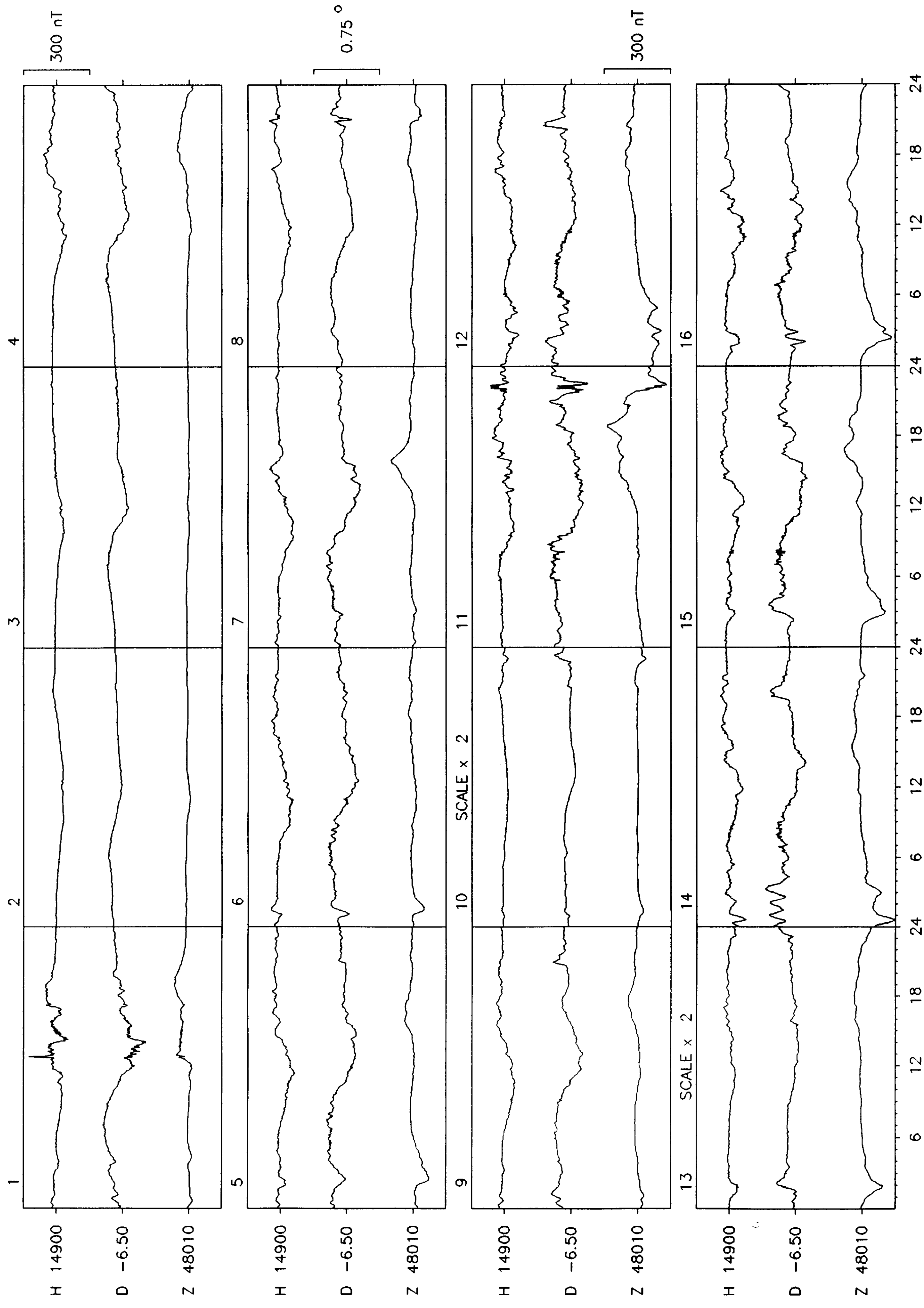
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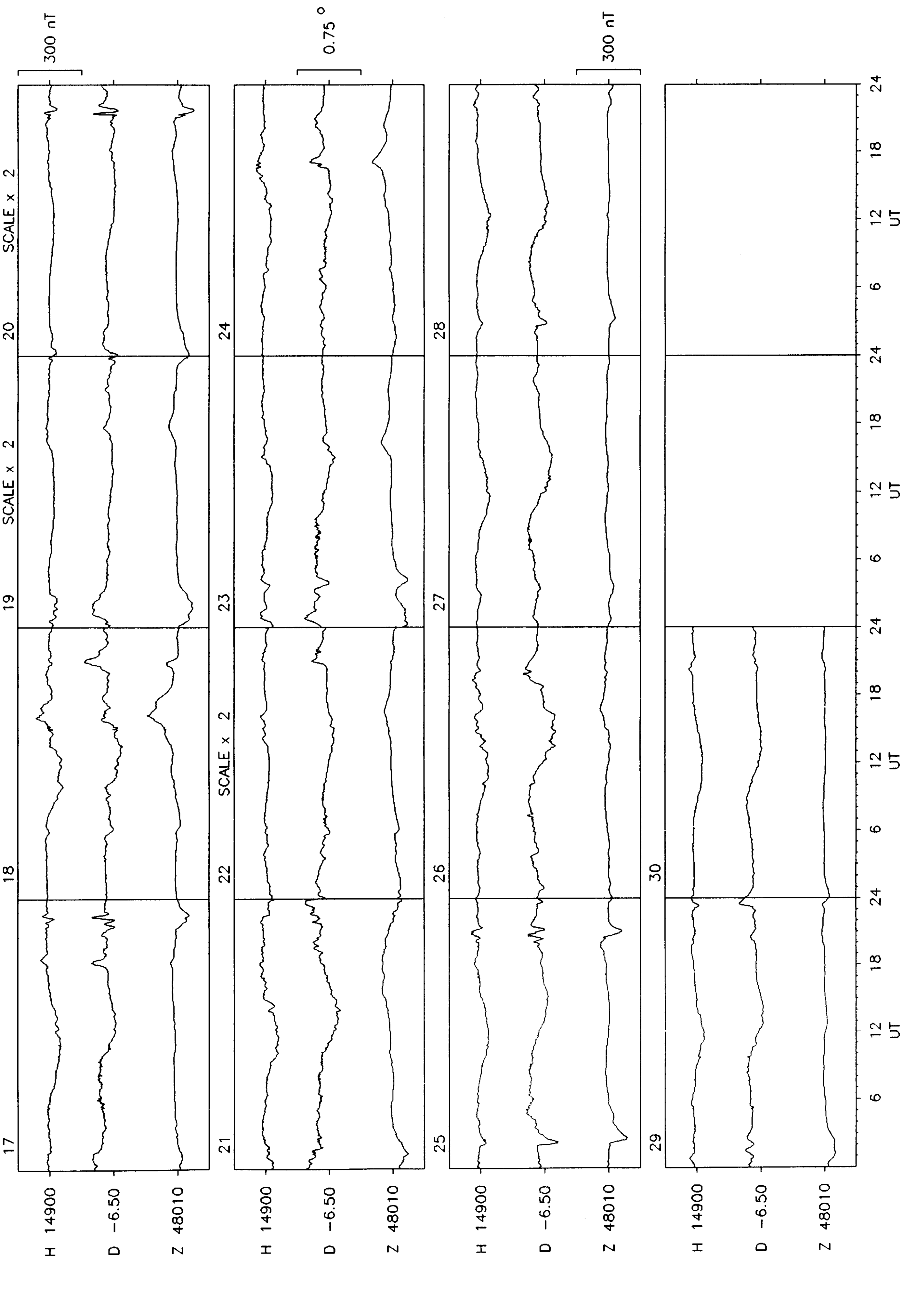
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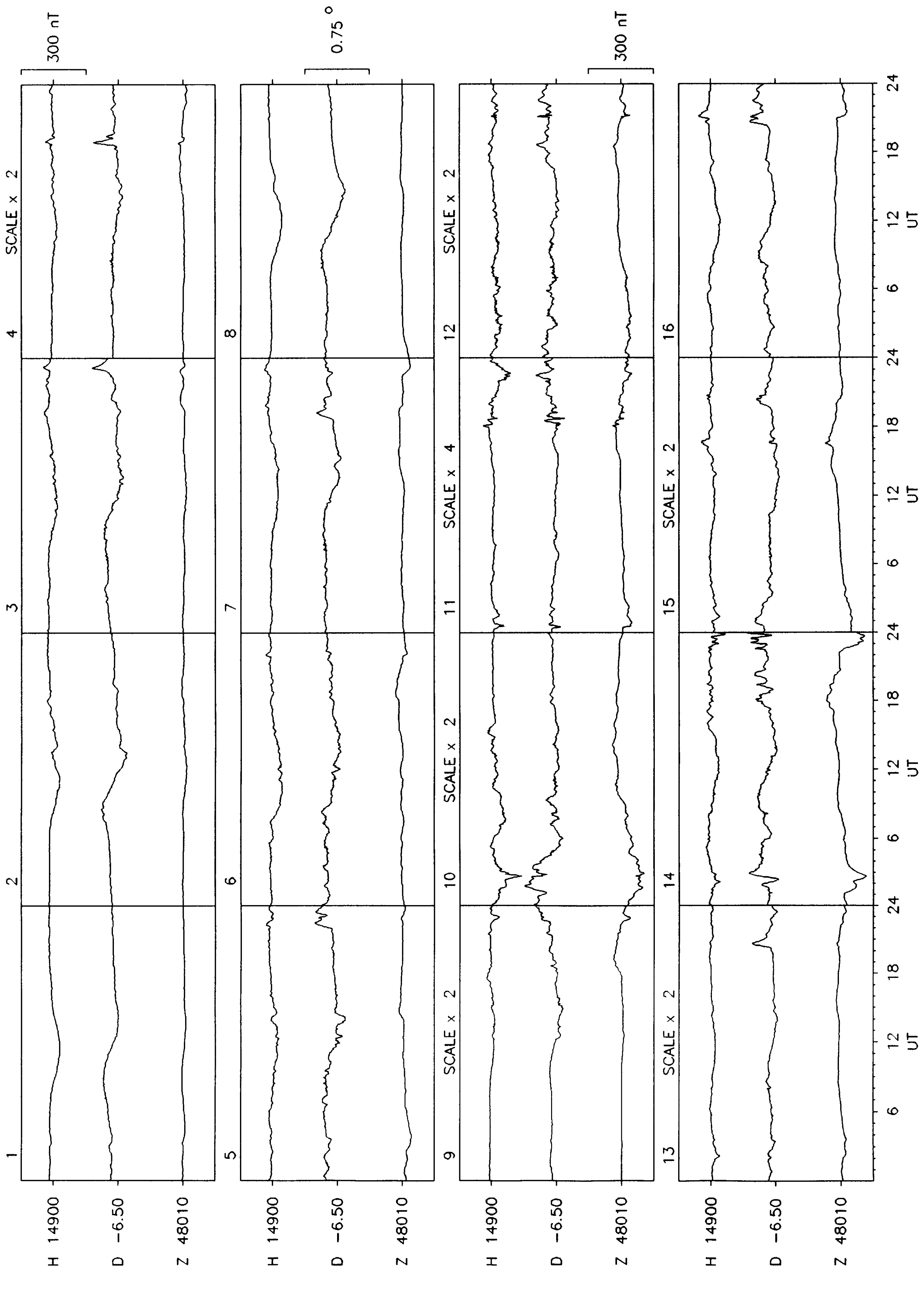
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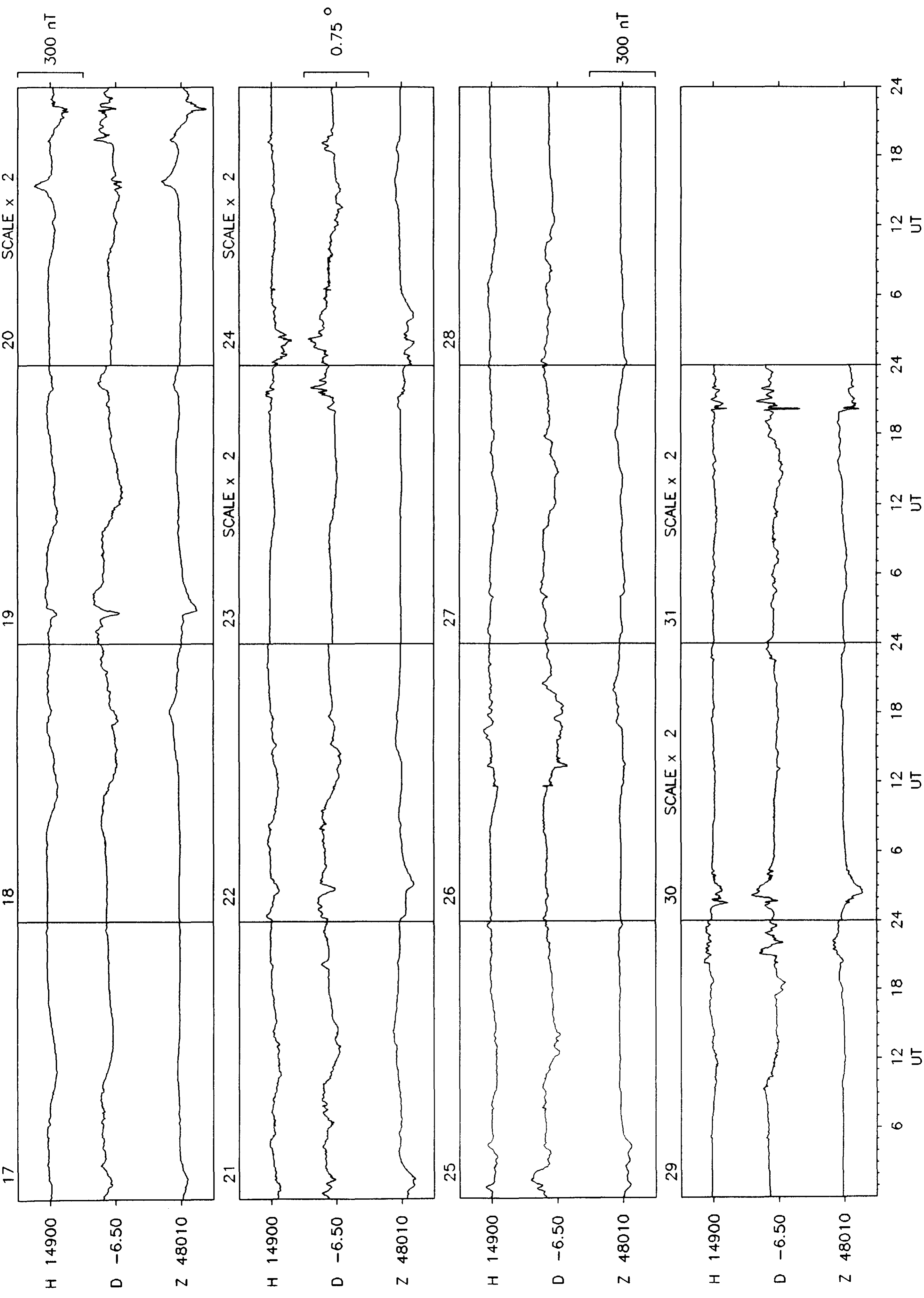

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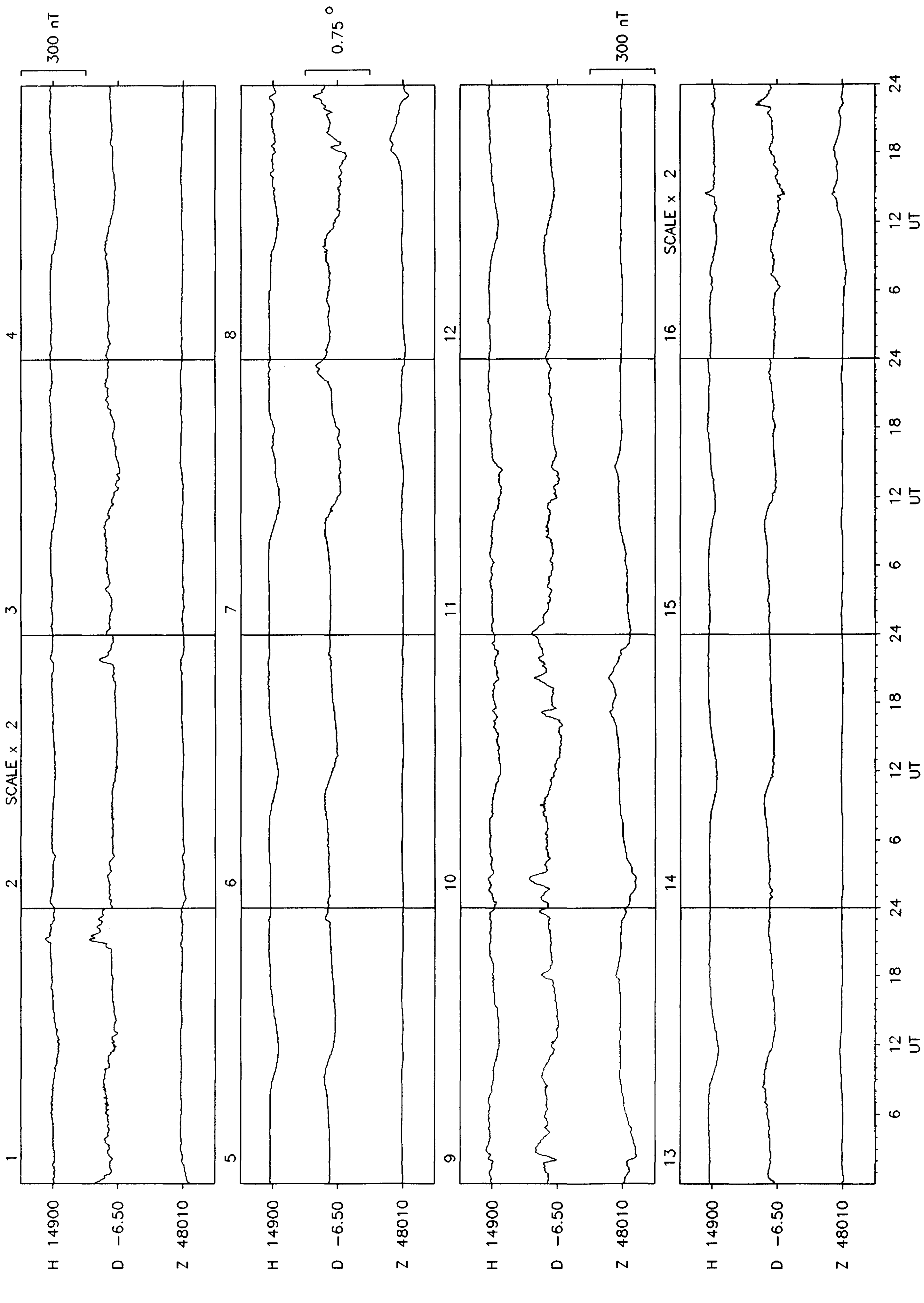
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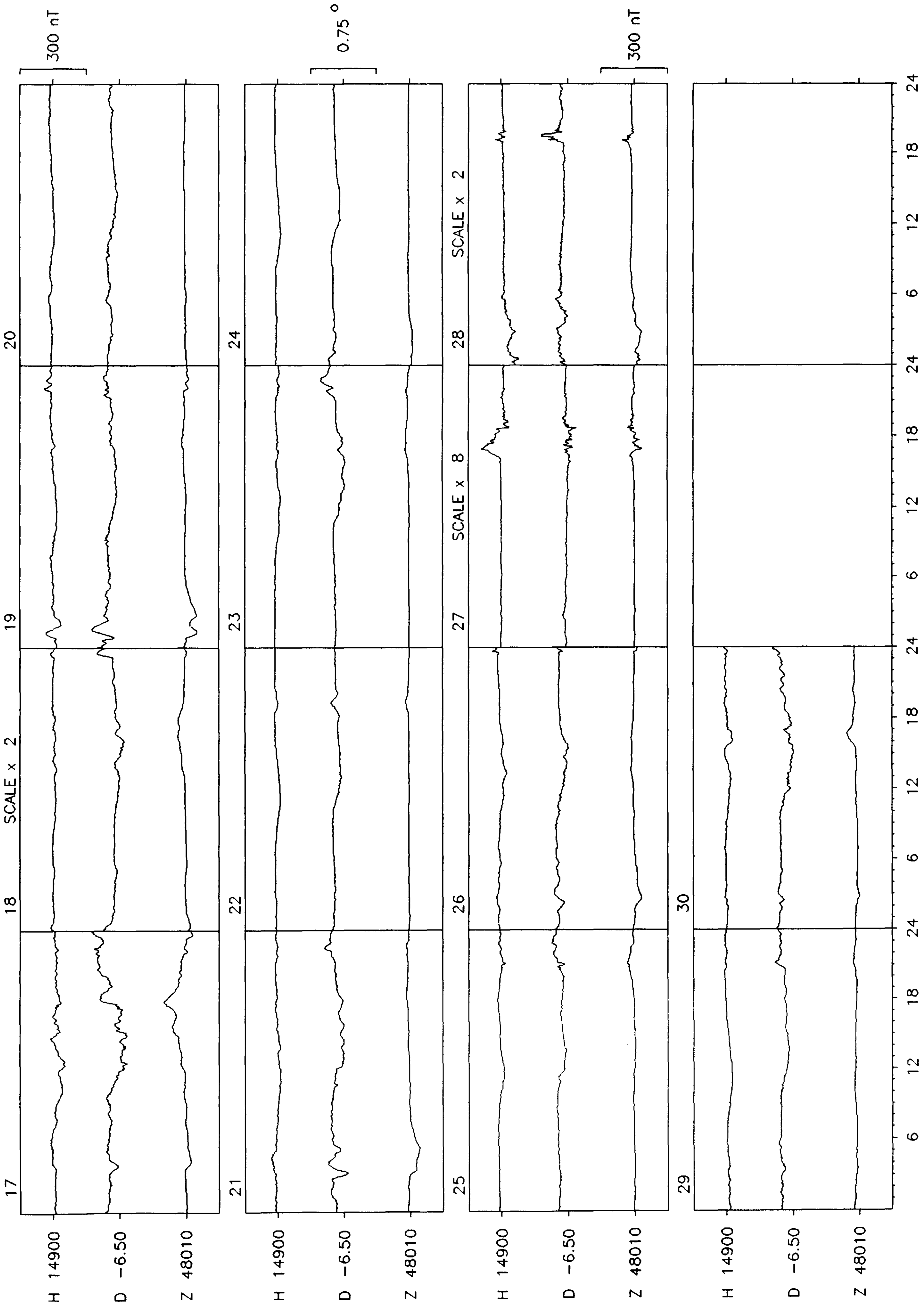
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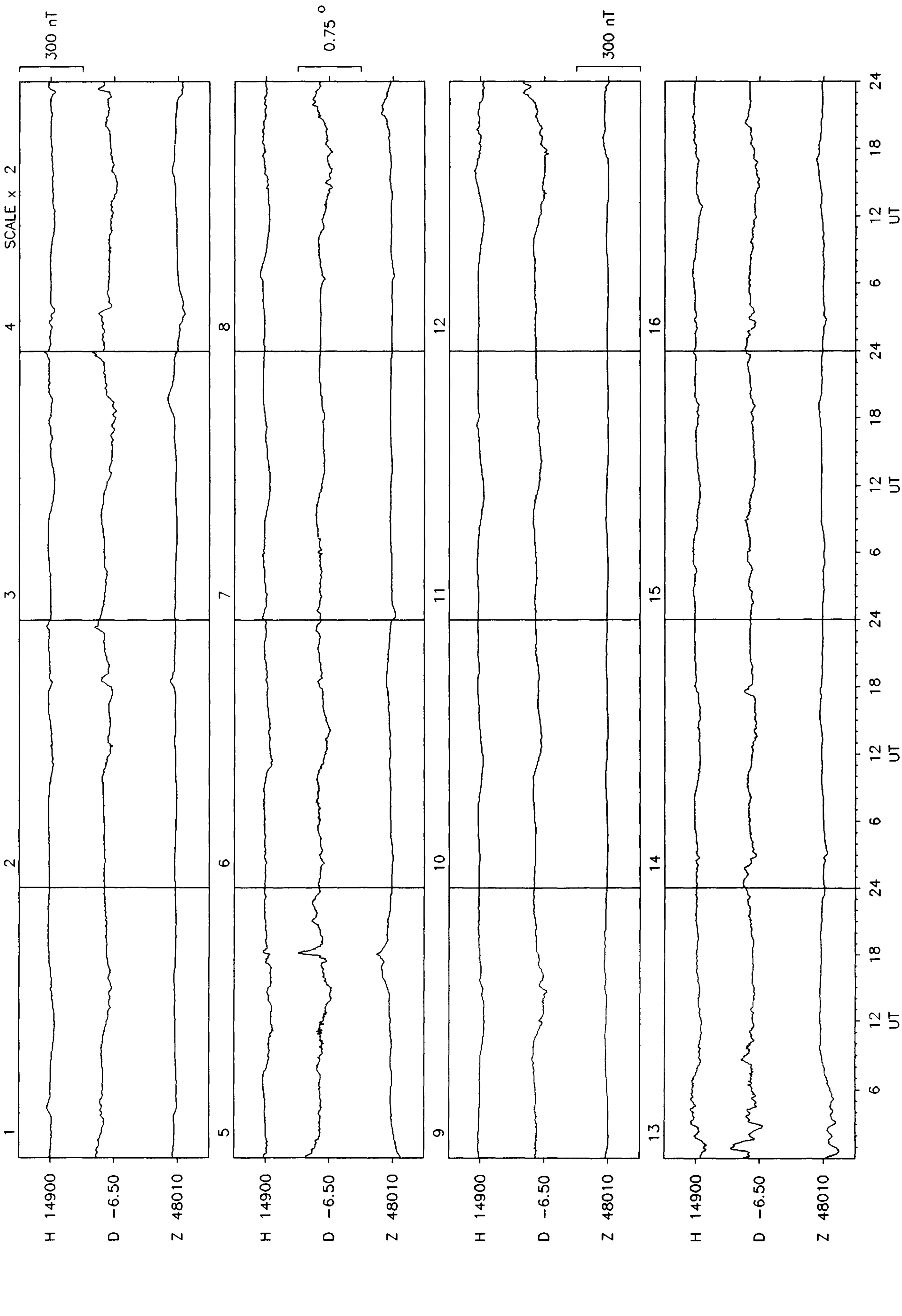
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300 nT
0.75 °
300 nT
H 14900
D −6.50
Z 48010
UT
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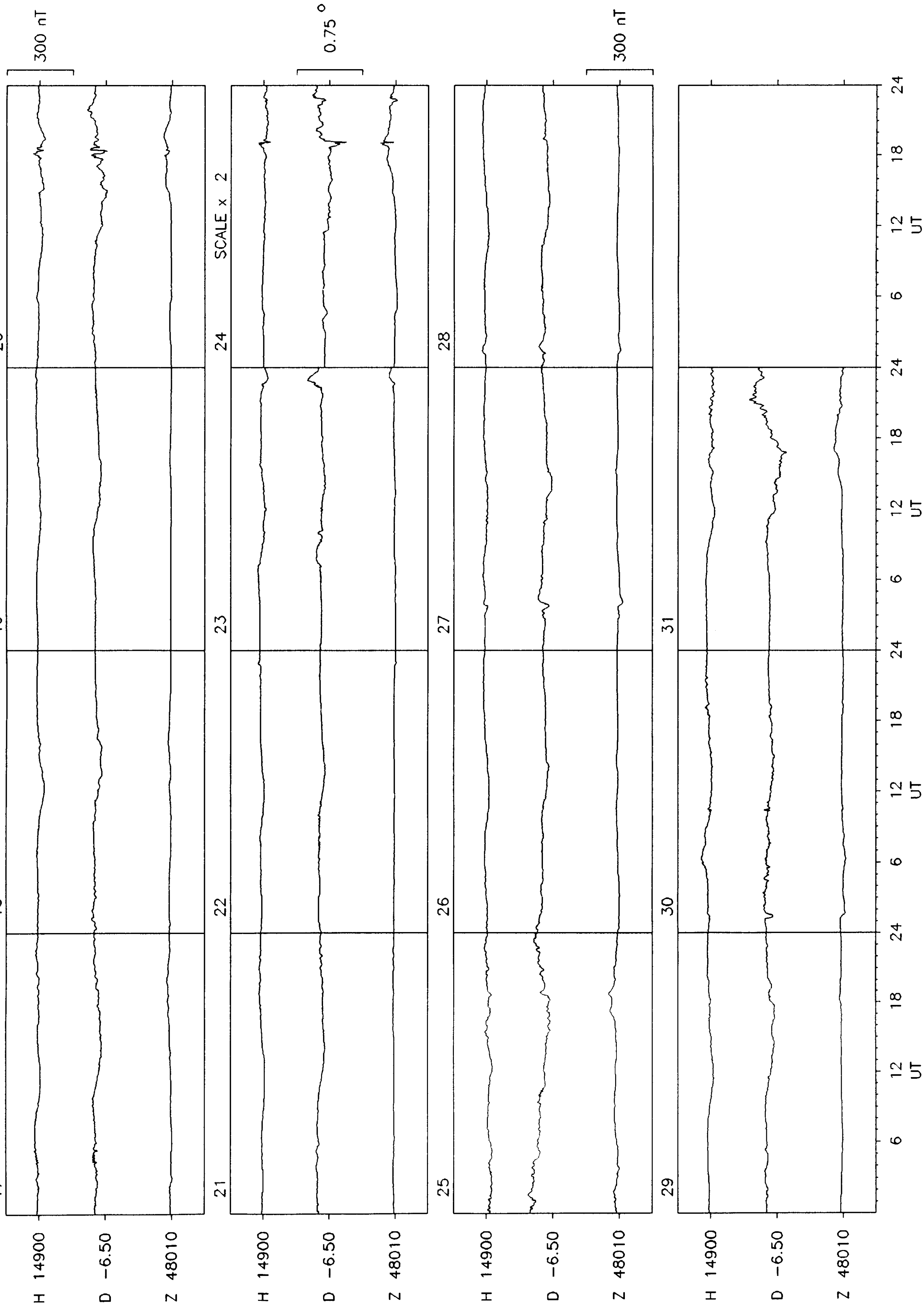
300 nT
0.75 °
300 nT
SCALE x 2
17
18
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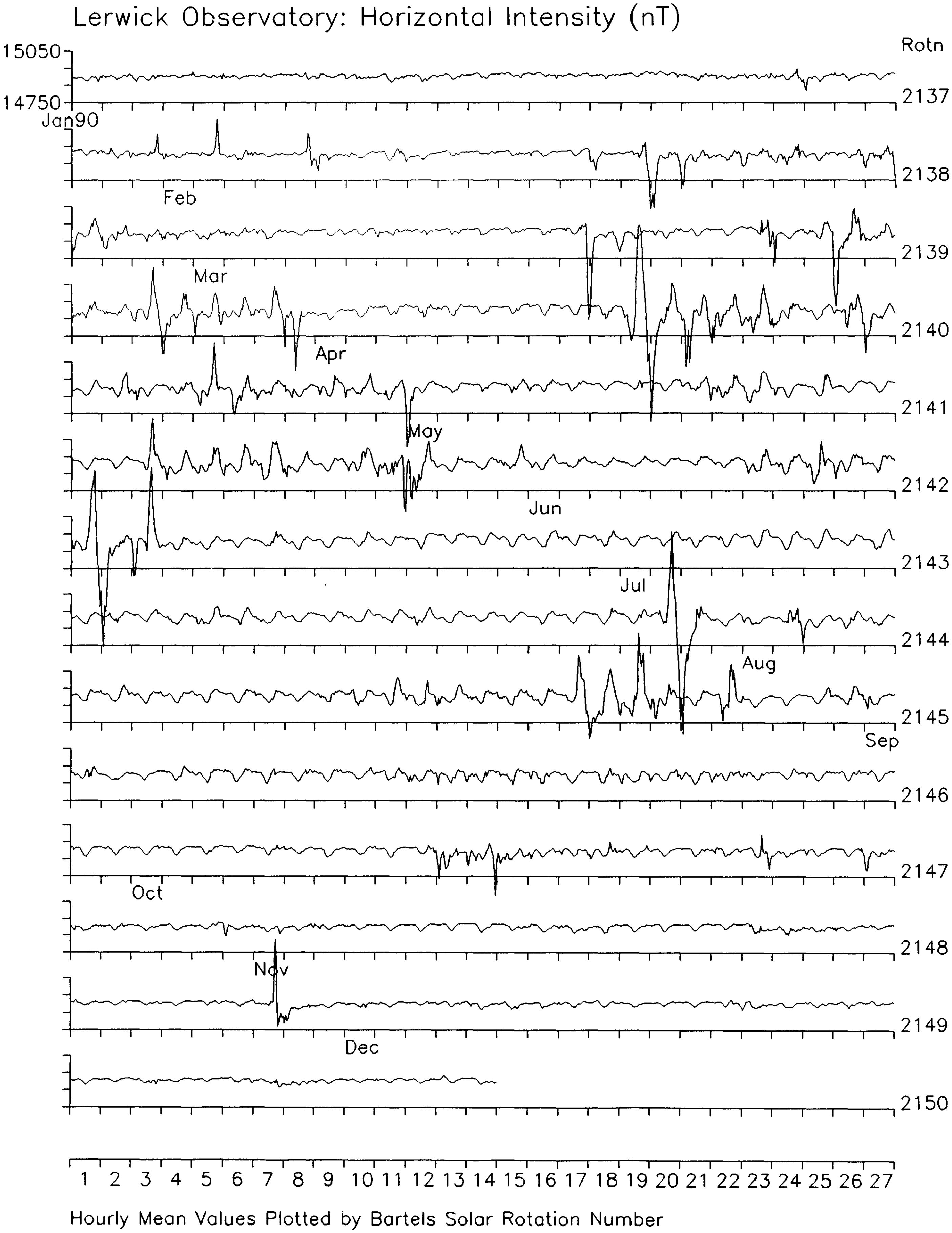
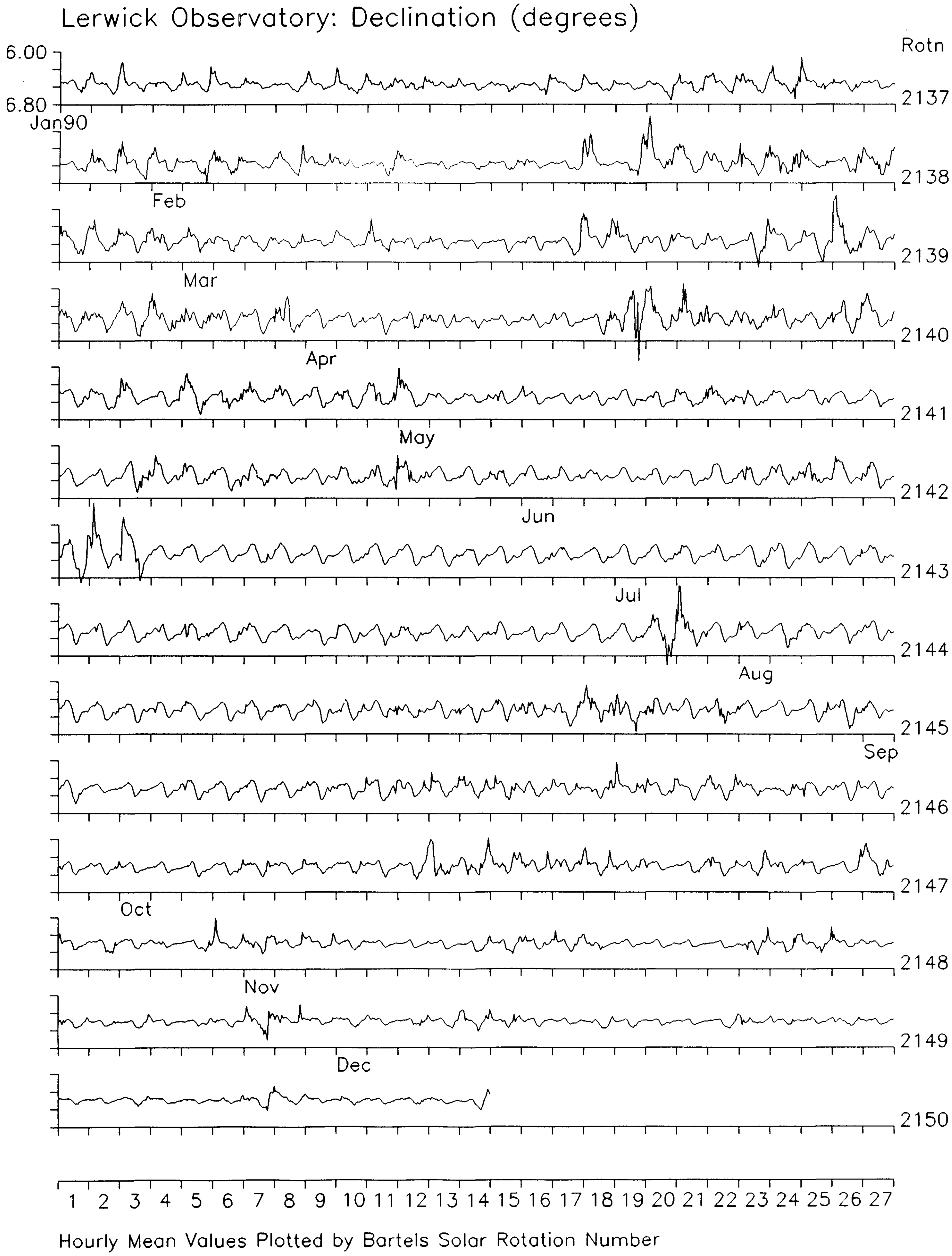
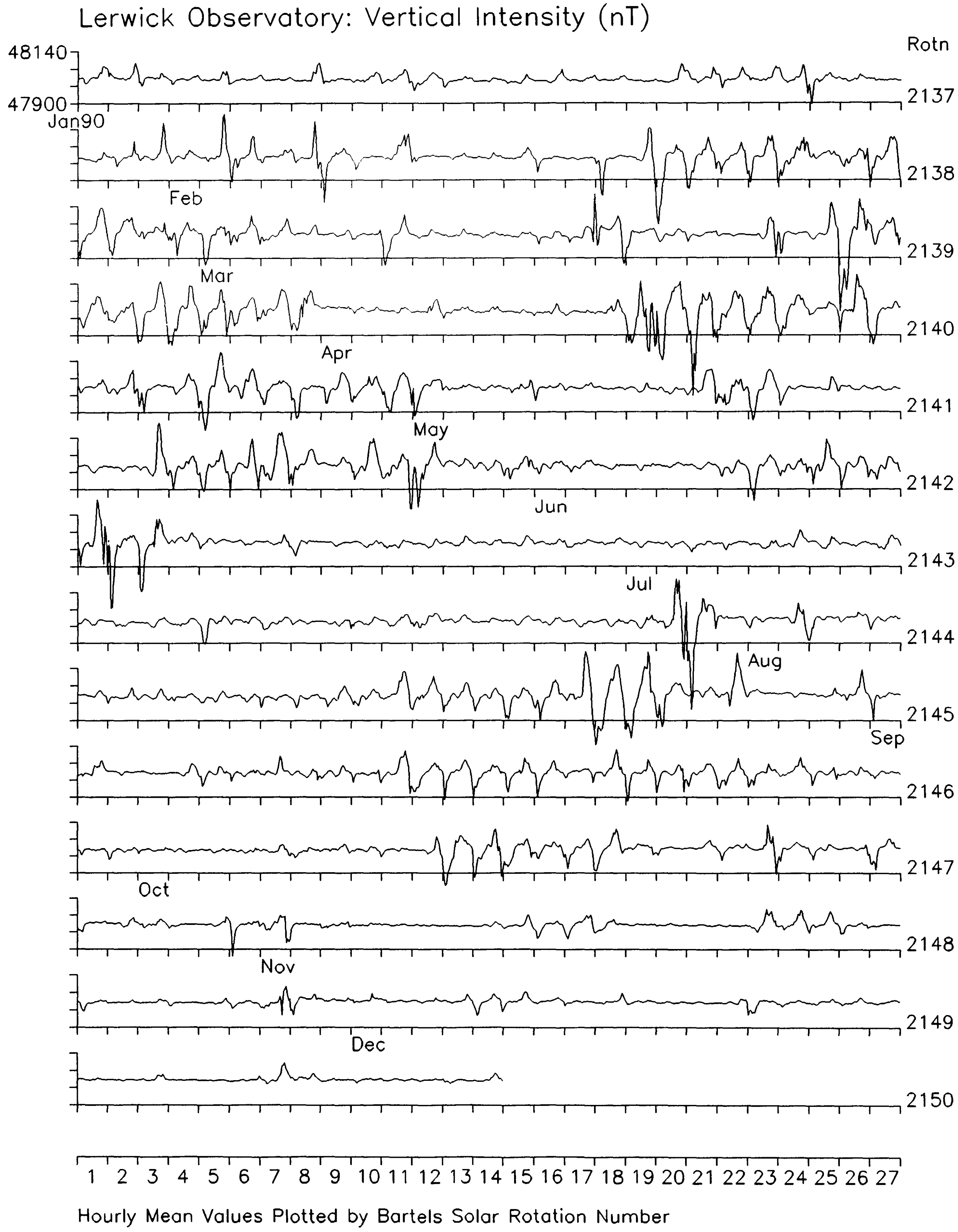
H 14900
D −6.50
Z 48010
UT
6
12
18
24



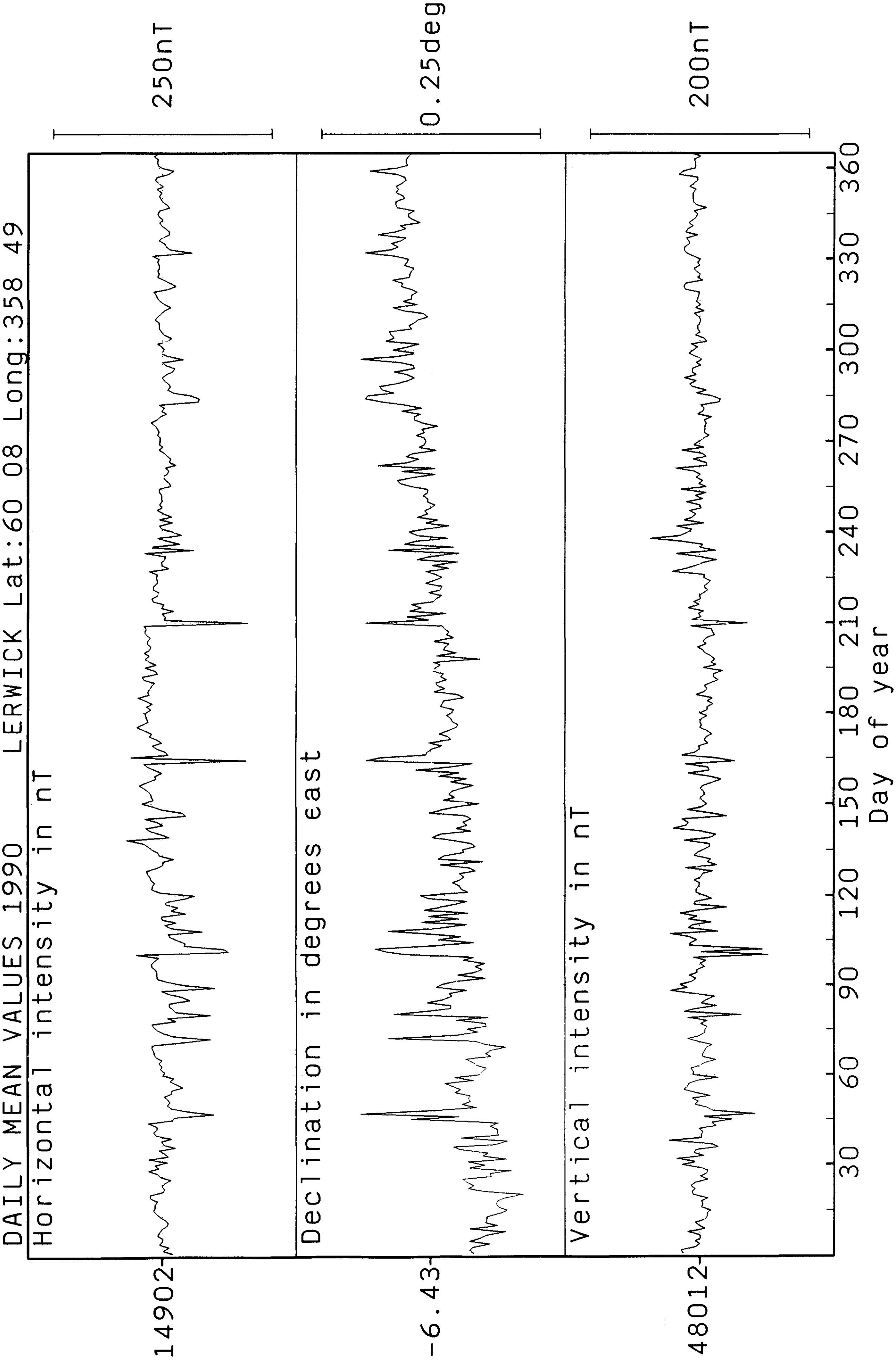
Lerwick Observatory: Horizontal Intensity (nT)
15050
14750
Rotn
Jan90
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted by Bartels Solar Rotation Number



Lerwick Observatory: Declination (degrees)
Rotn
6.00
6.80
Jan90
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted by Bartels Solar Rotation Number



Lerwick Observatory: Vertical Intensity (nT)
48140
47900
Rotn
Jan90
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted by Bartels Solar Rotation Number



DAILY MEAN VALUES 1990 LERWICK Lat:60 08 Long:358 49
Horizontal intensity in nT
Declination in degrees east
Vertical intensity in nT
250nT
0.25deg
200nT
14902
-6.43
48012
30
60
90
120
150
180
210
240
270
300
330
360
Day of year

Monthly and annual mean values for Lerwick 1990

Month	D	H	I	X	Y	Z	F
Jan	-6 29.9	14900	72 45.3	14804	-1686	48002	50261
Feb	-6 28.6	14891	72 45.8	14796	-1680	47998	50255
Mar	-6 28.2	14889	72 46.0	14794	-1678	48000	50256
Apr	-6 27.1	14886	72 46.2	14792	-1673	47999	50254
May	-6 27.9	14906	72 44.9	14811	-1678	48000	50261
Jun	-6 26.9	14908	72 44.7	14814	-1674	47997	50259
Jul	-6 26.7	14909	72 44.5	14815	-1674	47992	50254
Aug	-6 26.0	14898	72 45.5	14804	-1669	48004	50263
Sep	-6 25.3	14896	72 45.6	14803	-1666	48003	50261
Oct	-6 24.0	14892	72 45.8	14799	-1660	48000	50257
Nov	-6 24.3	14898	72 45.5	14805	-1662	48005	50264
Dec	-6 24.0	14899	72 45.5	14806	-1661	48007	50266
Annual	-6 26.6	14898	72 45.4	14804	-1672	48001	50260

D and I are given in degrees and decimal minutes
H, X, Y, Z and F are given in nanotesla

LERWICK OBSERVATORY K INDICES 1990

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	1212 1344	1222 2563	4222 2334	1010 1121	2221 2220	1321 1321	0102 1212	1131 4355	2213 5330	0000 0000	3111 1123	2200 0000
2	3102 1235	4322 2344	3222 2223	0122 2221	1112 2212	2122 2221	2201 2210	4221 2013	0000 0000	0001 2211	2211 1114	0001 1122
3	4310 1221	2001 1222	2111 1243	1132 3332	2223 3233	1211 2122	1220 2111	2113 3323	0001 2100	0111 1123	1201 1121	1000 1123
4	2102 2124	3311 2665	0011 0113	3221 3230	3112 3221	1211 2111	1011 1322	2221 2220	0012 2323	1122 3252	1000 0000	3412 2224
5	3212 2334	5323 2332	2211 1213	2012 2310	1122 1221	1001 2201	2211 2131	0100 3211	3212 3211	1211 2103	0000 0001	3112 2332
6	3110 1012	3321 0100	4221 3310	1012 2202	0111 2011	2223 2223	1111 2331	1121 2332	3122 2221	2122 2112	0000 0000	1111 1011
7	2210 1001	1122 3455	1211 3201	2121 2312	1210 3301	3433 3333	0010 1123	2212 3222	2222 3311	1111 1132	0001 1123	2110 0100
8	0000 2323	3210 0000	3212 2201	2111 2212	2211 3213	2333 3323	0222 2332	1310 2201	2111 2333	1010 1100	1011 1233	0011 2222
9	3211 2103	0020 2100	0112 1101	1233 4443	2122 2235	3343 5422	1200 2210	2101 2221	2212 3232	1101 2334	3312 1222	0001 1100
10	3132 1223	0011 1212	1111 2111	4356 7777	3443 3442	5323 3223	0323 3210	0011 2122	2120 1124	6544 3322	3211 1332	0000 0000
11	2122 2234	1111 1231	3322 2220	7544 4562	3442 4243	2322 3222	1110 1132	3121 2312	2233 3434	6332 3366	3122 2111	0000 0100
12	2322 2232	2211 0000	2212 2458	4884 5566	4211 1111	4233 5688	1221 1112	2212 1112	4322 2332	4342 2334	1100 0000	0000 1223
13	2112 1212	0000 0204	8323 3334	5453 3455	0110 2433	8754 5443	3422 1332	2222 3222	4212 2324	3321 2144	2011 0000	4222 1011
14	2101 2112	4532 2201	5323 5212	4344 5446	1000 1111	6524 7743	2011 3332	2243 2323	4322 3332	4321 1333	1000 0000	3210 1210
15	2111 2210	0122 3467	3311 2133	5422 4321	0100 2210	1211 2212	2211 2222	1213 4544	3322 4332	4312 3443	0000 1100	1110 0111
16	0001 0243	6632 3345	2110 1113	2122 3133	0010 1110	2010 1121	2101 2121	3233 3524	3333 4322	2221 1233	1232 4324	2111 2120
17	2111 1113	7522 3335	2010 0000	3145 3445	0112 1111	0010 0010	0110 2223	4322 2332	2112 2133	2110 0000	1212 3332	1100 0111
18	2101 2123	3222 3235	0022 4465	6421 2323	2233 5634	0111 2332	3120 1331	3222 4321	0222 3433	0001 1222	3201 2324	1001 1100
19	0000 1012	5312 3344	6211 2212	2101 2233	4422 2433	2211 3120	1222 3322	3321 3323	4321 1323	3201 1002	3111 0112	0000 0000
20	2121 1342	4243 3455	3222 4338	2121 3463	3322 3444	0000 1110	3232 3232	3332 3331	4111 2235	1111 4545	1111 0001	0101 1332
21	3122 2232	3321 2232	6545 6553	4421 2111	5212 4434	0000 2322	1100 3231	3132 5556	3112 3223	2222 2121	2301 2112	0000 0000
22	3322 2143	2121 2244	4223 3433	1221 3324	3444 5344	2110 2202	2200 1212	6545 4445	3331 3344	3221 2200	0000 0020	0000 0001
23	4222 2233	5233 3446	4333 4343	4433 4633	4213 2322	1002 3200	1201 1211	5535 7675	3322 3210	0001 1134	0000 1213	0011 1103
24	4222 2365	5322 4454	3222 3343	1254 4454	1111 2233	2211 2222	0111 1220	4533 4430	1221 2322	5332 3230	2000 0000	0212 2253
25	5222 2322	4422 3354	5322 4656	4432 3323	3333 4434	1111 2222	1111 2100	1010 1312	3211 1133	3311 1002	0001 1012	2101 1222
26	3112 2222	3212 3244	6433 4453	3421 2112	5333 4347	1112 2212	0000 2343	1255 6553	2222 3232	1002 3331	2101 1102	1000 0000
27	0100 0110	3343 3123	5332 3465	2321 4325	4653 4533	1011 3223	1212 2322	3222 3211	2212 2201	1201 1211	4332 3874	0201 1000
28	0000 1132	2441 3342	3332 3445	3321 3343	1111 3321	2121 1211	2454 6788	1011 2100	2201 2012	2121 0000	4421 1142	2000 0010
29	4332 2144		2322 5546	4343 1235	1122 2223	0221 3231	8554 4433	0113 2232	2111 2013	0001 1233	1100 0012	0100 0110
30	4321 2253		5365 5321	7422 2223	2323 3343	0001 2201	0132 2223	2223 3433	2000 1121	5411 2113	1101 2312	2211 1121
31	4322 2230		2111 2212		3312 2222		3221 0001	5223 2221		3222 2464		0001 1323

Annual Values of Geomagnetic Elements

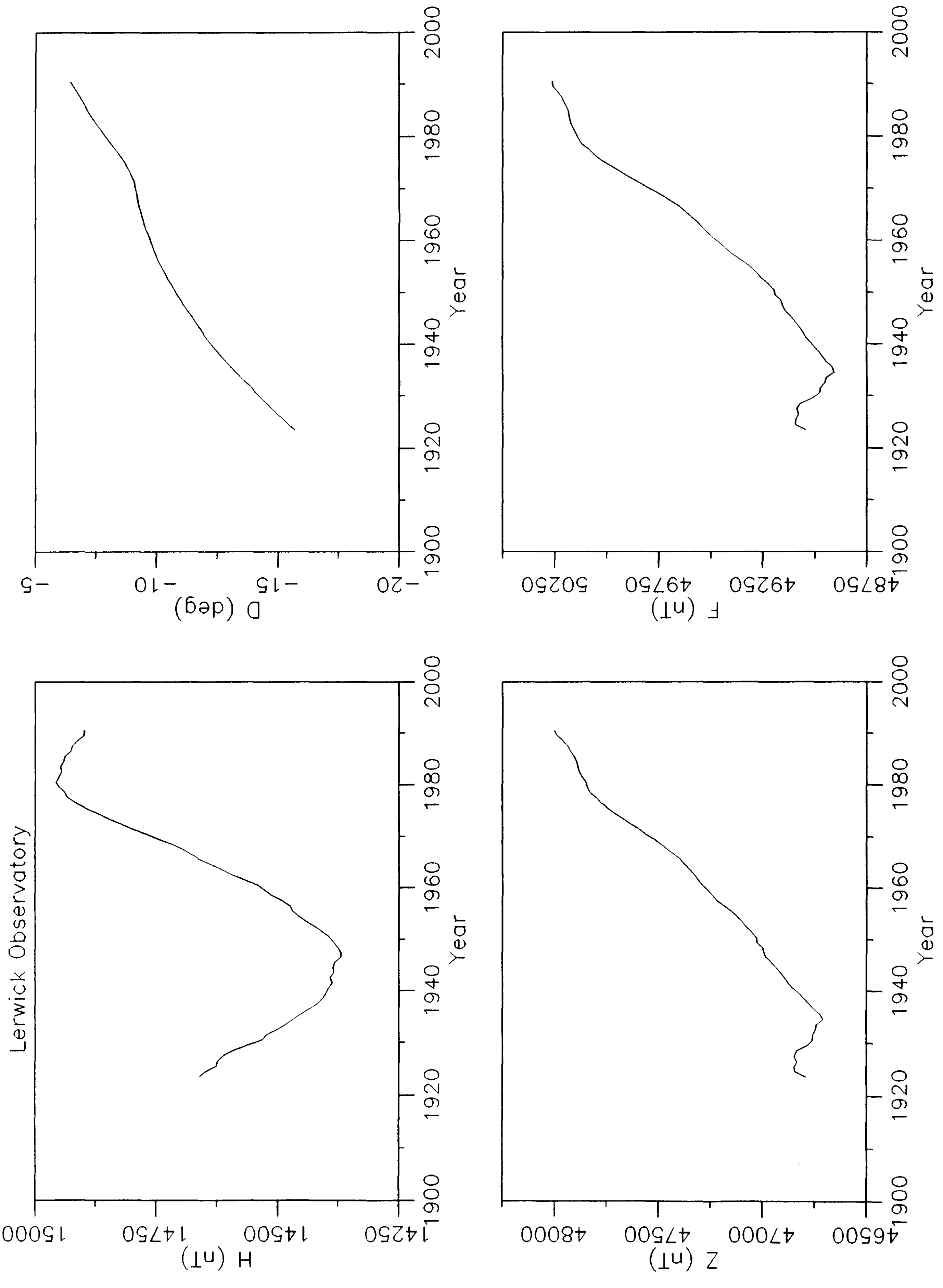
Lerwick

	Year	D	H	I	X	Y	Z	F
	1923.5	-15 40.3	14655	72 33.7	14111	-3959	46655	48902
	1924.5	-15 26.5	14642	72 35.7	14113	-3899	46708	48950
	1925.5	-15 13.5	14621	72 37.2	14108	-3840	46713	48948
	1926.5	-14 58.6	14618	72 37.1	14121	-3778	46699	48933
	1927.5	-14 45.7	14607	72 38.1	14125	-3722	46713	48944
	1928.5	-14 32.9	14585	72 39.4	14117	-3664	46702	48926
	1929.5	-14 19.4	14556	72 40.3	14104	-3601	46651	48869
	1930.5	-14 7.0	14527	72 41.6	14088	-3543	46624	48835
	1931.5	-13 55.4	14517	72 42.3	14090	-3493	46623	48830
	1932.5	-13 41.9	14495	72 43.5	14083	-3433	46608	48809
	1933.5	-13 29.8	14477	72 44.6	14077	-3379	46605	48802
Note 1		0 0.0	0	0 3.0	0	0	144	138
	1934.5	-13 17.7	14462	72 48.0	14074	-3326	46716	48903
	1935.5	-13 5.3	14445	72 49.4	14070	-3271	46730	48911
	1936.5	-12 53.6	14428	72 51.2	14064	-3220	46763	48938
	1937.5	-12 42.4	14411	72 52.8	14058	-3170	46785	48955
	1938.5	-12 31.6	14401	72 54.0	14058	-3123	46809	48974
	1939.5	-12 21.4	14394	72 54.9	14061	-3080	46833	48995
	1940.5	-12 11.1	14389	72 55.8	14065	-3037	46860	49019
	1941.5	-12 1.0	14382	72 56.8	14067	-2994	46884	49040
	1942.5	-11 52.5	14386	72 56.8	14078	-2960	46899	49056
	1943.5	-11 43.5	14378	72 57.8	14078	-2922	46919	49073
	1944.5	-11 35.1	14380	72 58.1	14087	-2888	46940	49093
	1945.5	-11 26.3	14376	72 58.8	14090	-2851	46963	49114
	1946.5	-11 17.1	14363	73 0.2	14085	-2811	46989	49135
	1947.5	-11 8.7	14363	73 0.5	14092	-2776	47002	49148
	1948.5	-11 0.9	14371	73 0.1	14106	-2746	47009	49157
	1949.5	-10 53.1	14378	73 0.2	14119	-2715	47037	49185
	1950.5	-10 45.5	14388	72 59.5	14135	-2686	47039	49190
	1951.5	-10 37.7	14402	72 59.1	14155	-2656	47061	49215
	1952.5	-10 29.9	14417	72 58.6	14176	-2627	47087	49245
	1953.5	-10 22.8	14435	72 57.8	14199	-2601	47106	49268
	1954.5	-10 15.6	14450	72 57.3	14219	-2574	47129	49294
	1955.5	-10 9.2	14464	72 56.9	14237	-2550	47156	49324
	1956.5	-10 2.8	14469	72 57.3	14247	-2524	47191	49359
	1957.5	-9 57.5	14486	72 56.8	14268	-2505	47225	49397
	1958.5	-9 52.7	14507	72 55.8	14292	-2489	47246	49423
	1959.5	-9 48.1	14523	72 55.3	14311	-2472	47271	49452
	1960.5	-9 43.4	14538	72 54.9	14329	-2455	47299	49483
	1961.5	-9 39.1	14565	72 53.5	14359	-2442	47318	49509
	1962.5	-9 33.3	14591	72 52.1	14389	-2422	47336	49534
	1963.5	-9 28.5	14610	72 51.3	14411	-2405	47359	49561
	1964.5	-9 24.4	14634	72 50.2	14437	-2392	47382	49590
	1965.5	-9 21.1	14656	72 49.2	14461	-2382	47403	49617
	1966.5	-9 17.8	14672	72 48.7	14479	-2370	47431	49648
	1967.5	-9 14.2	14688	72 48.3	14498	-2358	47464	49685
	1968.5	-9 12.1	14712	72 47.4	14523	-2353	47496	49722
	1969.5	-9 10.3	14740	72 46.2	14552	-2349	47531	49764
	1970.5	-9 7.9	14766	72 45.4	14579	-2343	47573	49812
	1971.5	-9 5.2	14796	72 44.1	14610	-2337	47607	49853
	1972.5	-8 59.5	14820	72 43.3	14638	-2316	47646	49898
	1973.5	-8 53.6	14844	72 42.4	14666	-2295	47680	49937
	1974.5	-8 46.5	14866	72 41.8	14692	-2268	47719	49981
	1975.5	-8 38.4	14890	72 40.9	14721	-2237	47753	50021
	1976.5	-8 29.9	14911	72 40.1	14747	-2204	47780	50053
	1977.5	-8 20.9	14927	72 39.5	14769	-2167	47803	50079
	1978.5	-8 10.1	14933	72 39.8	14782	-2122	47835	50112
	1979.5	-8 0.3	14944	72 39.3	14798	-2081	47850	50129
	1980.5	-7 50.4	14952	72 39.0	14812	-2039	47858	50139
	1981.5	-7 40.9	14946	72 39.7	14812	-1998	47875	50154
	1982.5	-7 31.6	14940	72 40.4	14812	-1957	47890	50166
	1983.5	-7 22.6	14942	72 40.4	14818	-1918	47895	50172

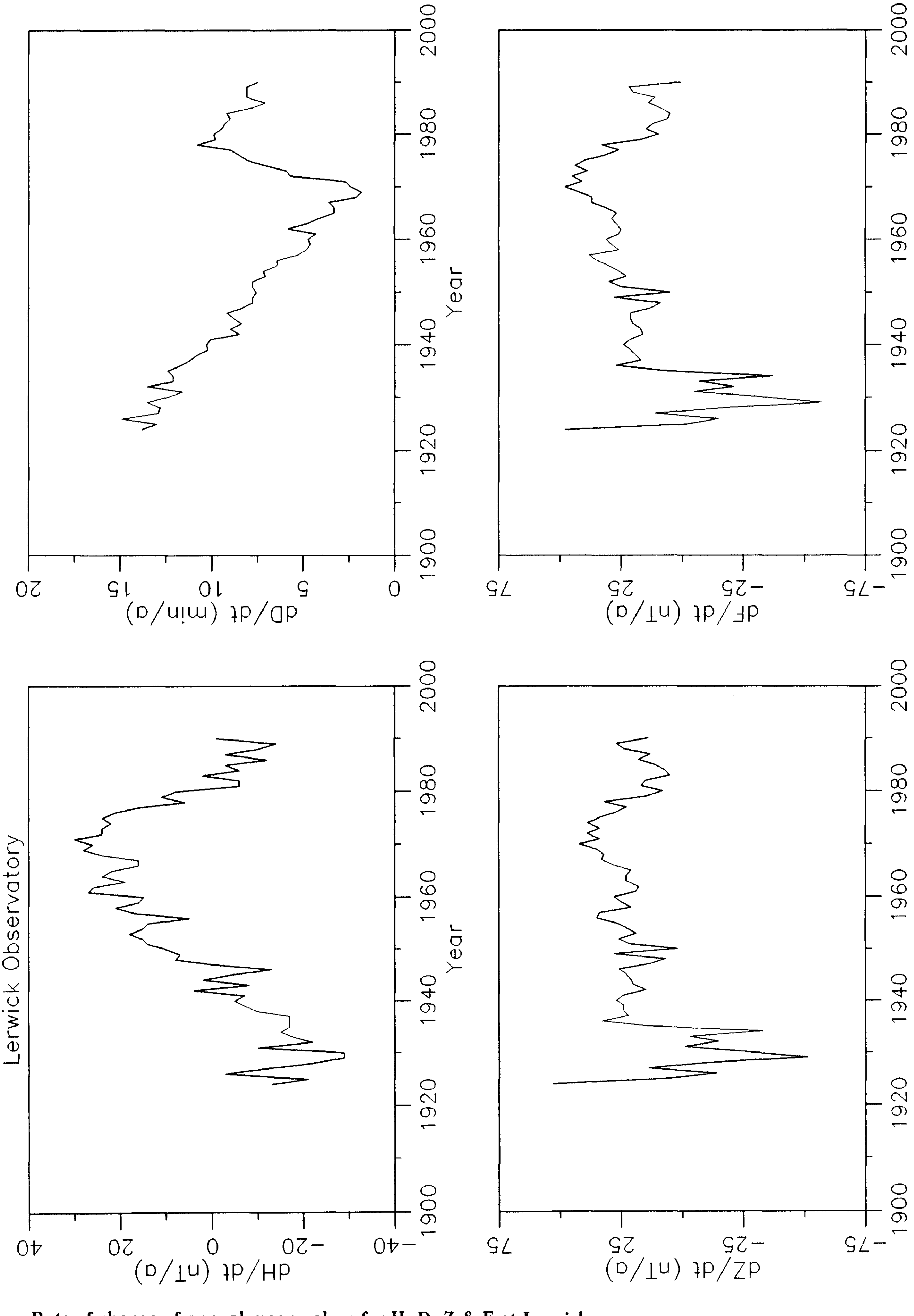
	Year	D	H	I	X	Y	Z	F
	1984.5	-7 13.4	14936	72 40.9	14818	-1878	47902	50177
	1985.5	-7 5.5	14933	72 41.3	14819	-1844	47913	50186
	1986.5	-6 58.4	14921	72 42.5	14811	-1811	47931	50200
	1987.5	-6 50.3	14918	72 43.0	14812	-1776	47944	50211
	1988.5	-6 42.2	14908	72 44.1	14806	-1740	47968	50231
	1989.5	-6 34.1	14894	72 45.6	14796	-1704	47995	50253
Note 2		0 0.0	5	0 -0.5	5	-1	-8	-6
	1990.5	-6 26.6	14898	72 45.4	14804	-1672	48001	50260

1 Site differences 1 Jan 1934 (new value - old value)
2 Site differences 1 Jan 1990 (new value - old value)

D and I are given in degrees and decimal minutes
All other elements are in nanotesla

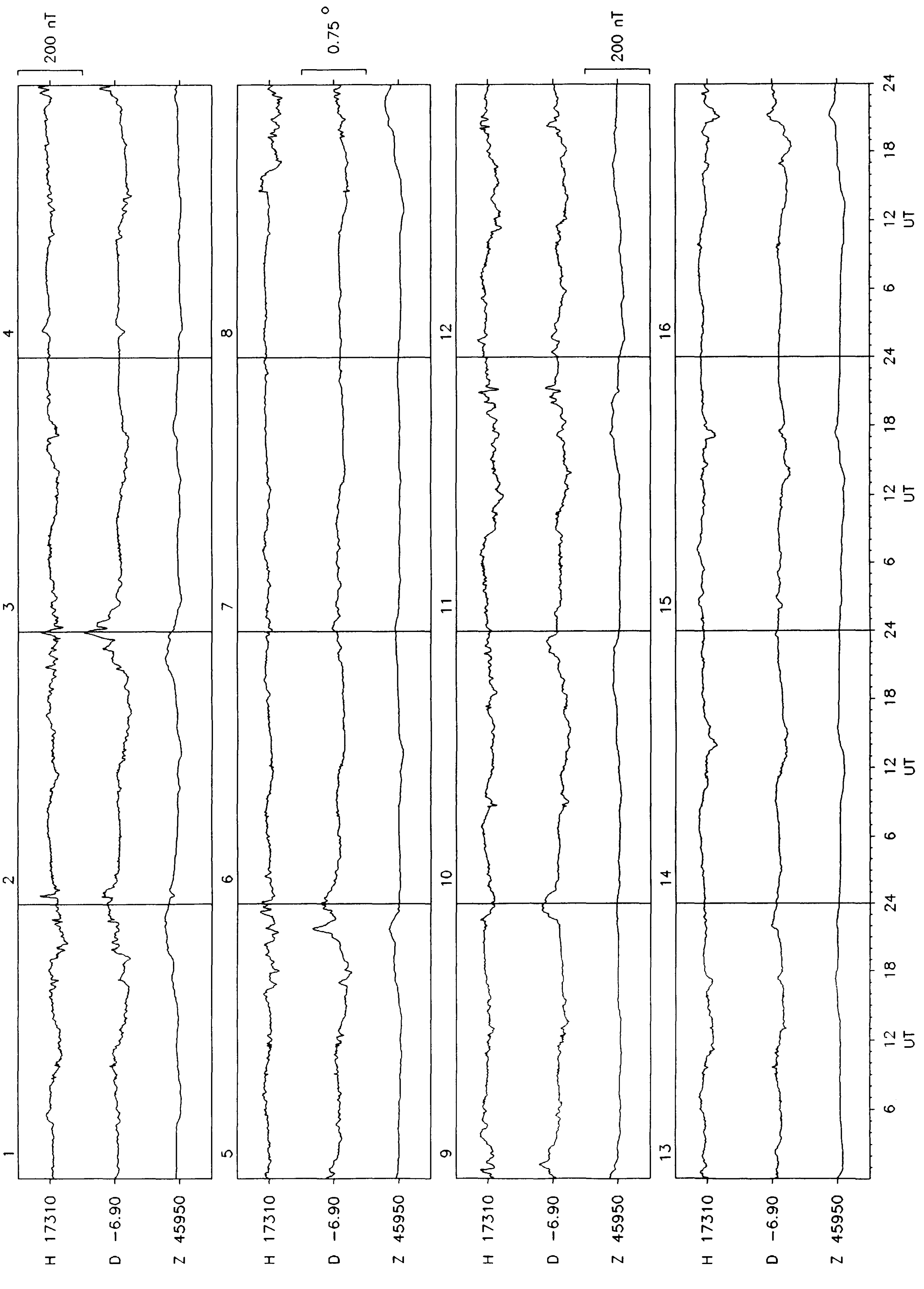


Annual mean values of H, D, Z & F at Lerwick



Rate of change of annual mean values for H, D, Z & F at Lerwick

Eskdalemuir 1990


200 nT
0.75 °
200 nT
H 17310
D −6.90
Z 45950
1
2
3
4
5
6
7
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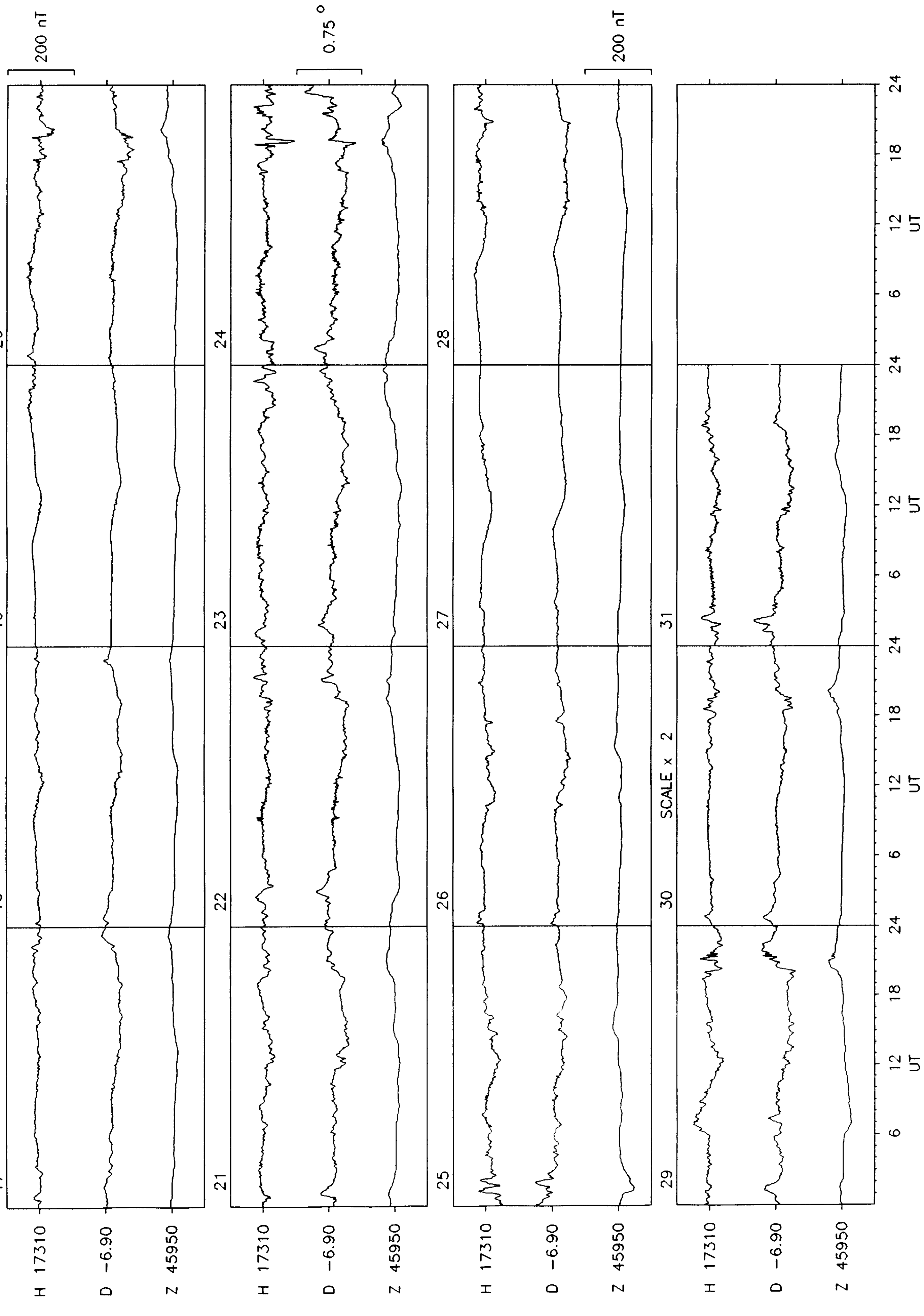
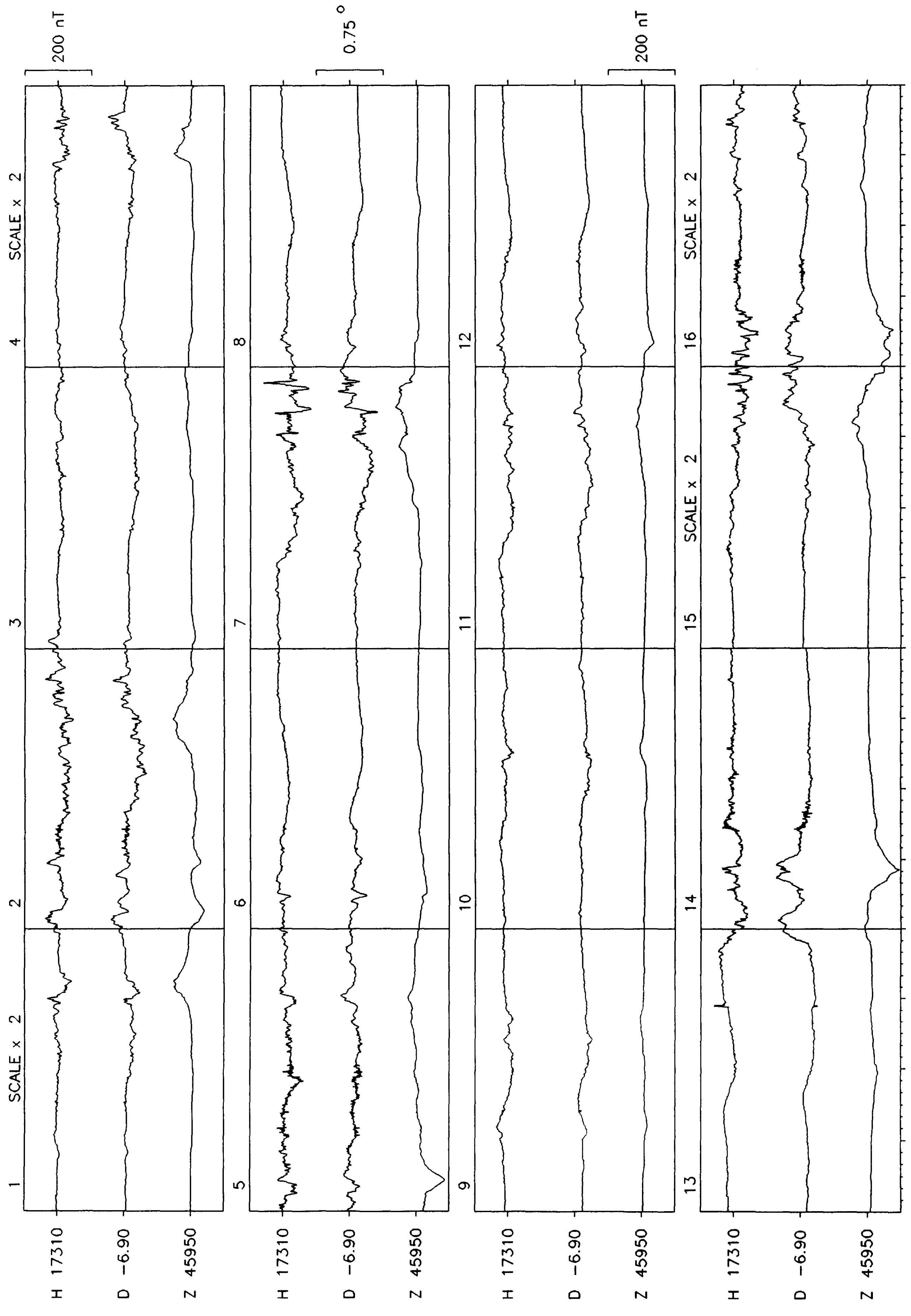
9
10
11
12
13
14
15
16
6
12
18
24
UT


200 nT
0.75 °
200 nT
H 17310
D −6.90
Z 45950
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
SCALE x 2
6
12
18
24
UT


H 17310
D −6.90
Z 45950
SCALE x 2
200 nT
0.75 °
UT
1
2
3
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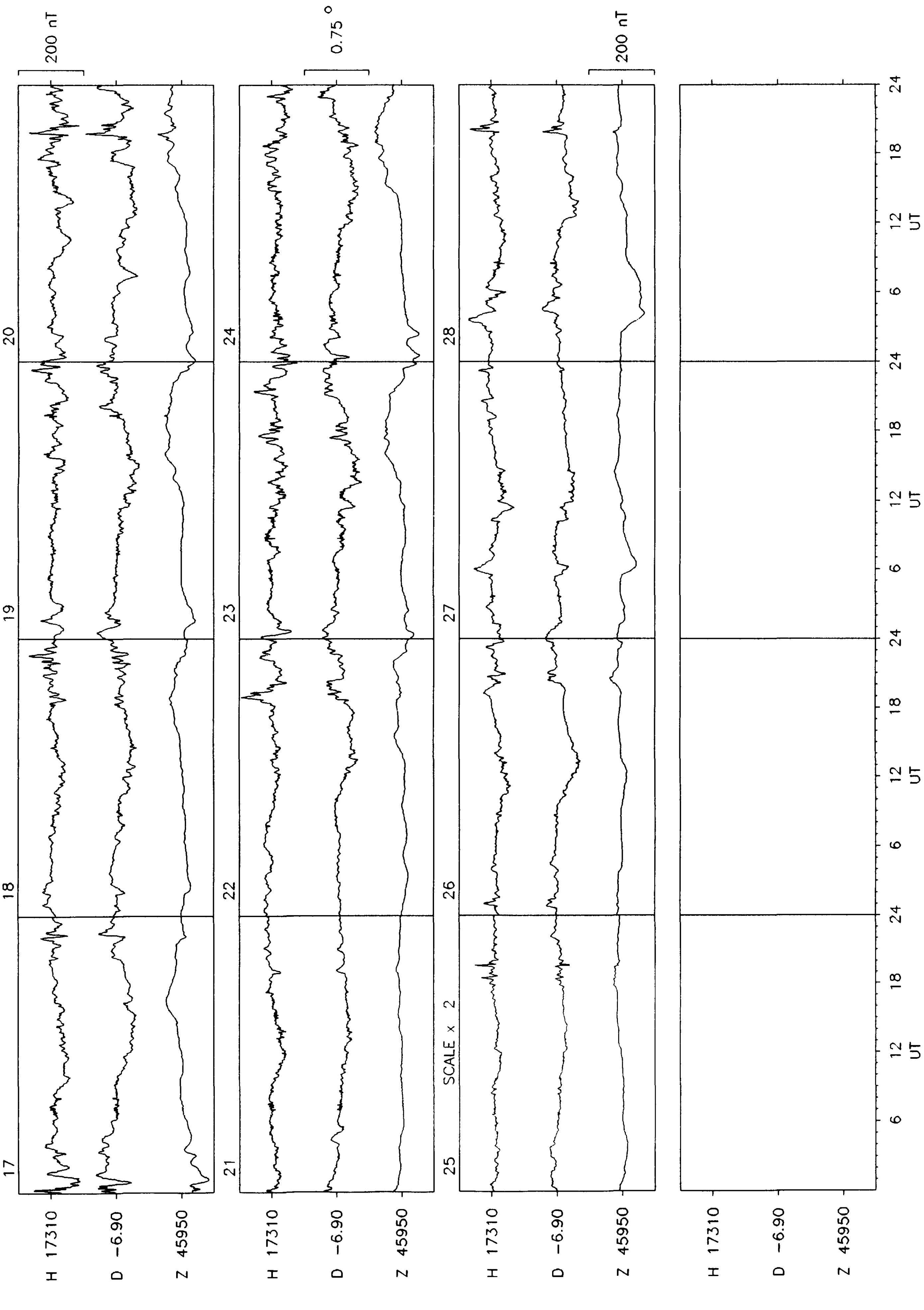
200 nT
0.75 °
200 nT
17
18
19
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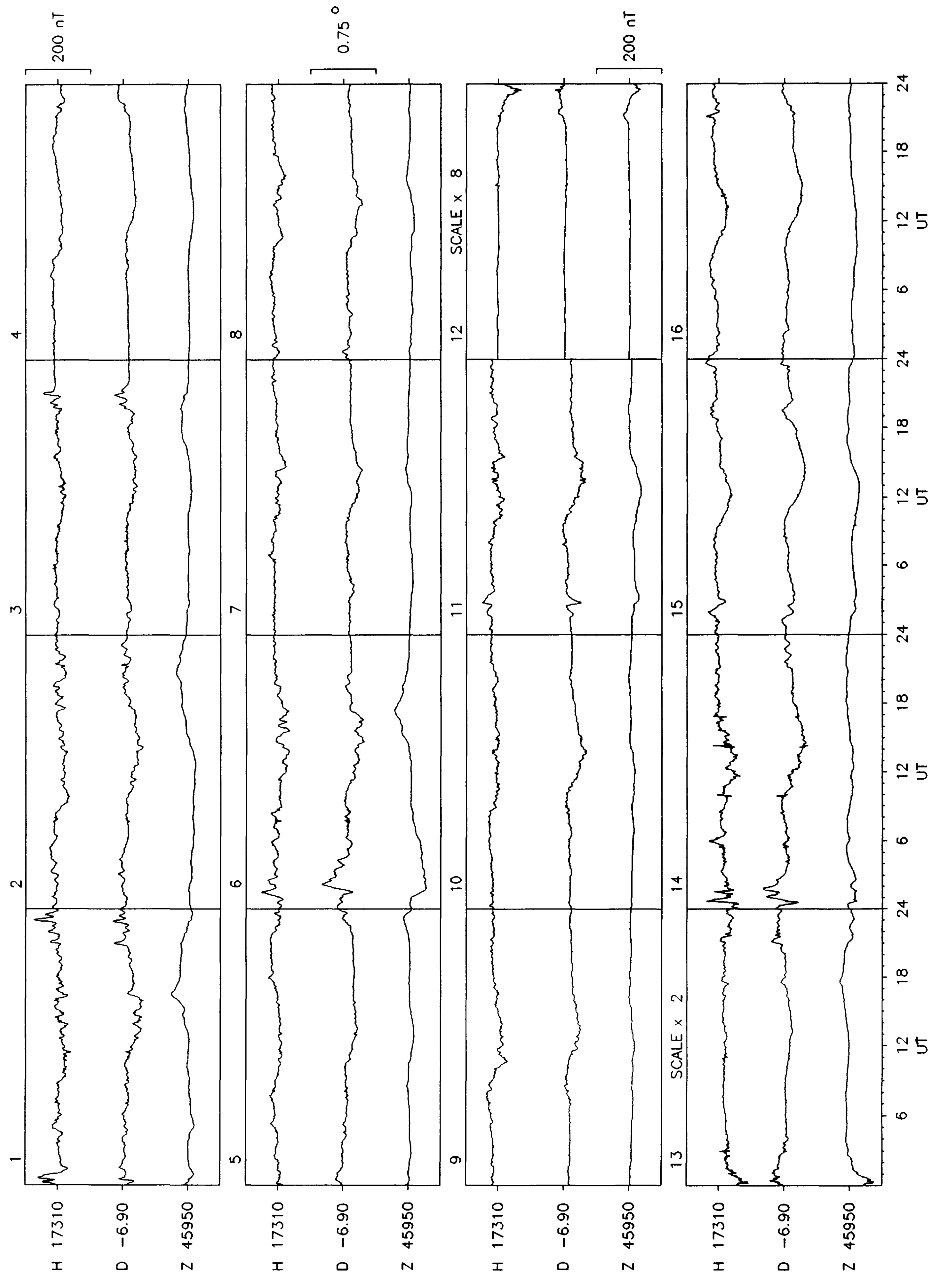
25
26
27
28
SCALE x 2
H 17310
D −6.90
Z 45950
6
12
18
24
UT



H 17310
D −6.90
Z 45950
200 nT
0.75 °
200 nT
SCALE x 8
SCALE x 2
1
2
3
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5
6
7
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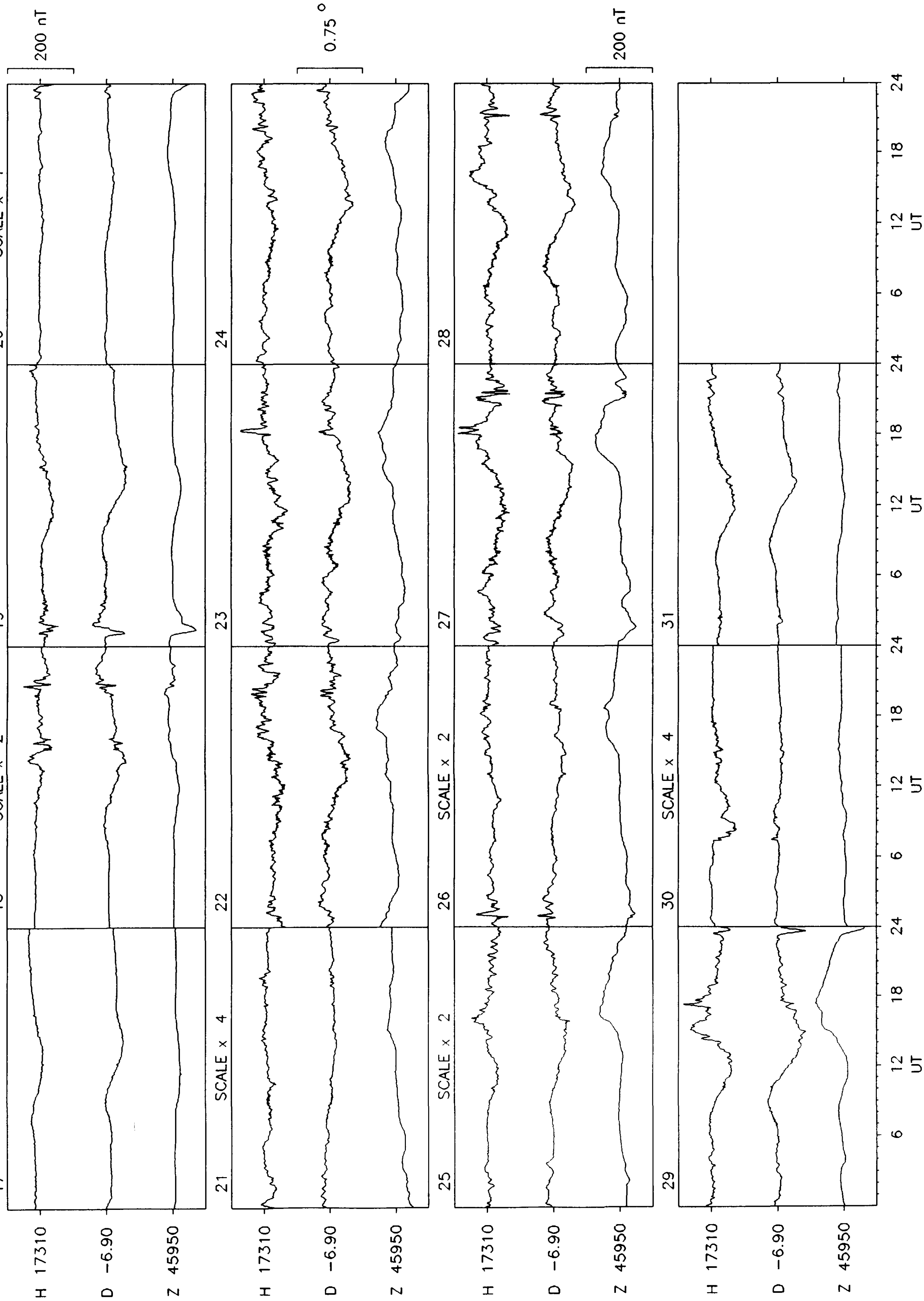
9
10
11
12
13
14
15
16
6
12
18
24
UT


200 nT
0.75 °
200 nT
SCALE x 4
SCALE x 2
SCALE x 4
SCALE x 2
SCALE x 2
SCALE x 4
17
18
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20
21
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31
H 17310
D −6.90
Z 45950
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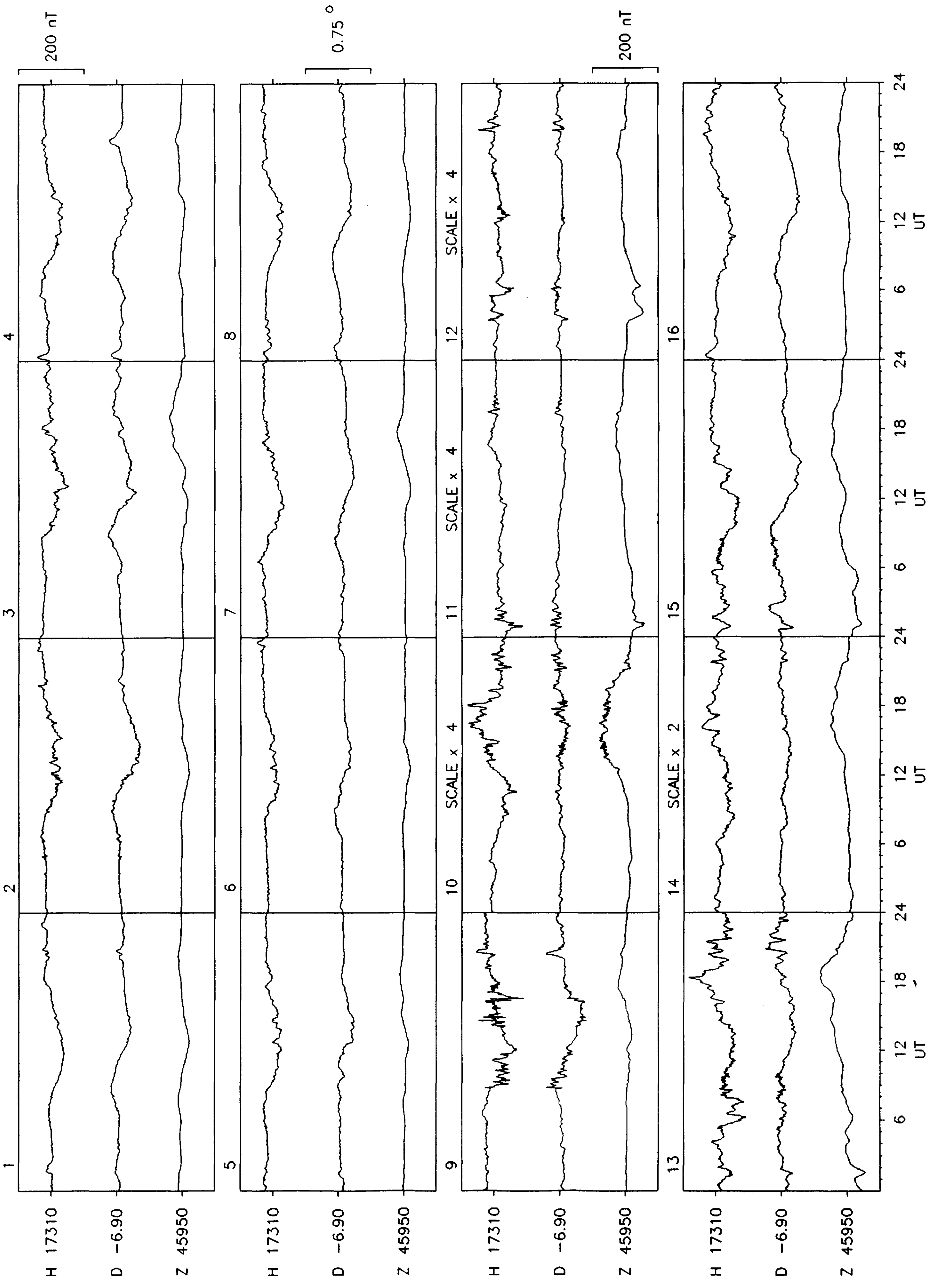
UT


200 nT
0.75 °
200 nT
1
2
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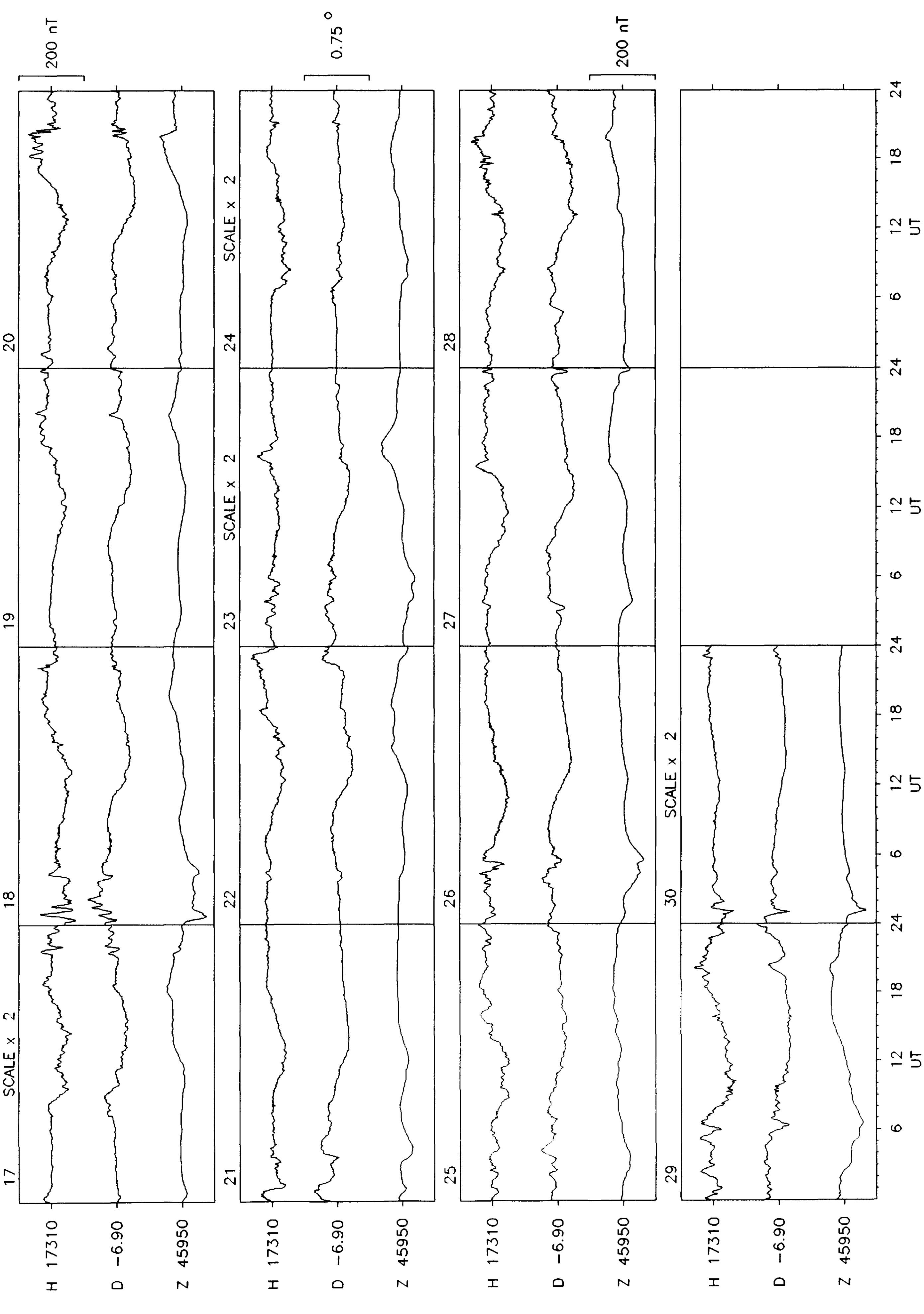
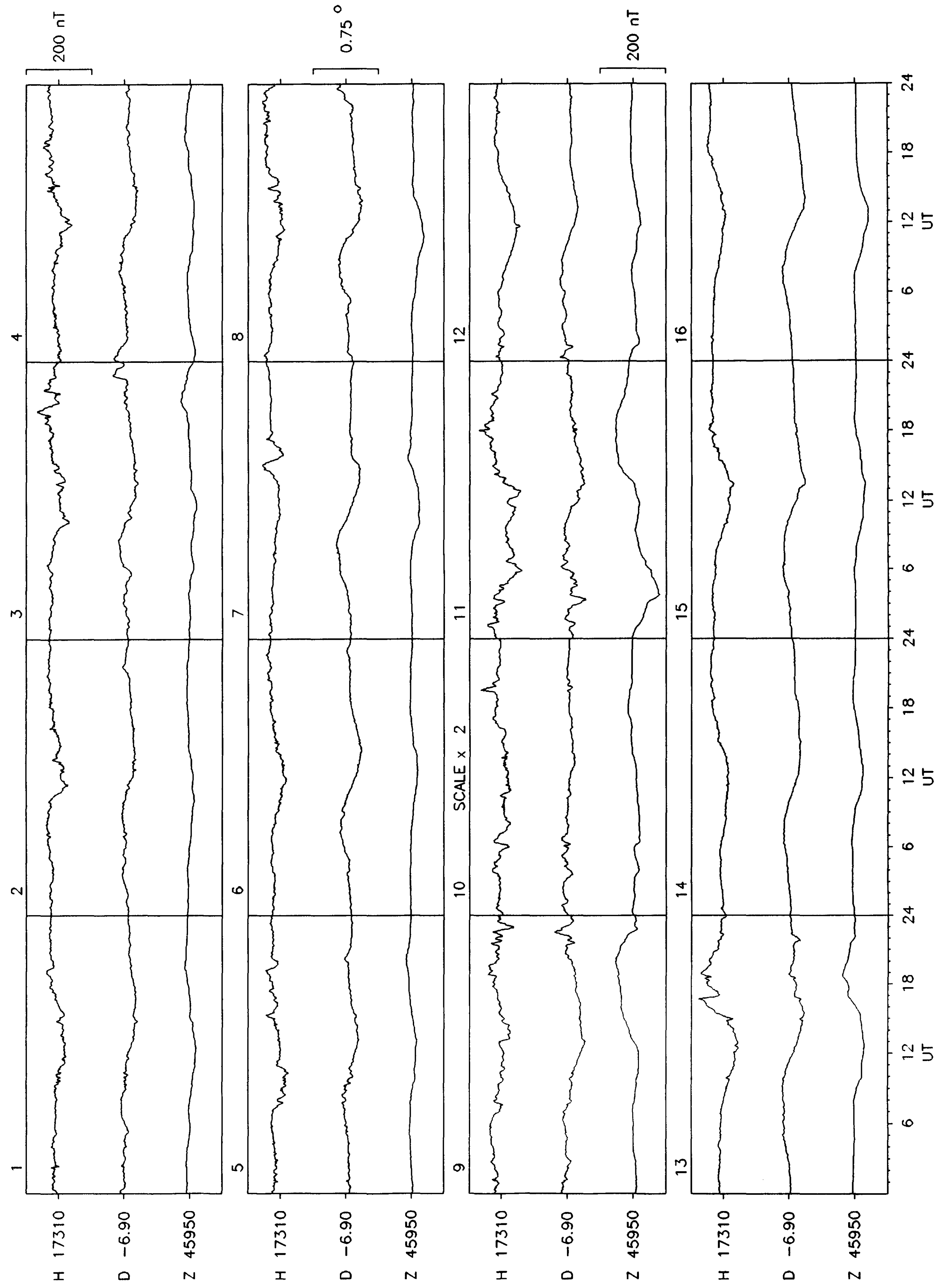
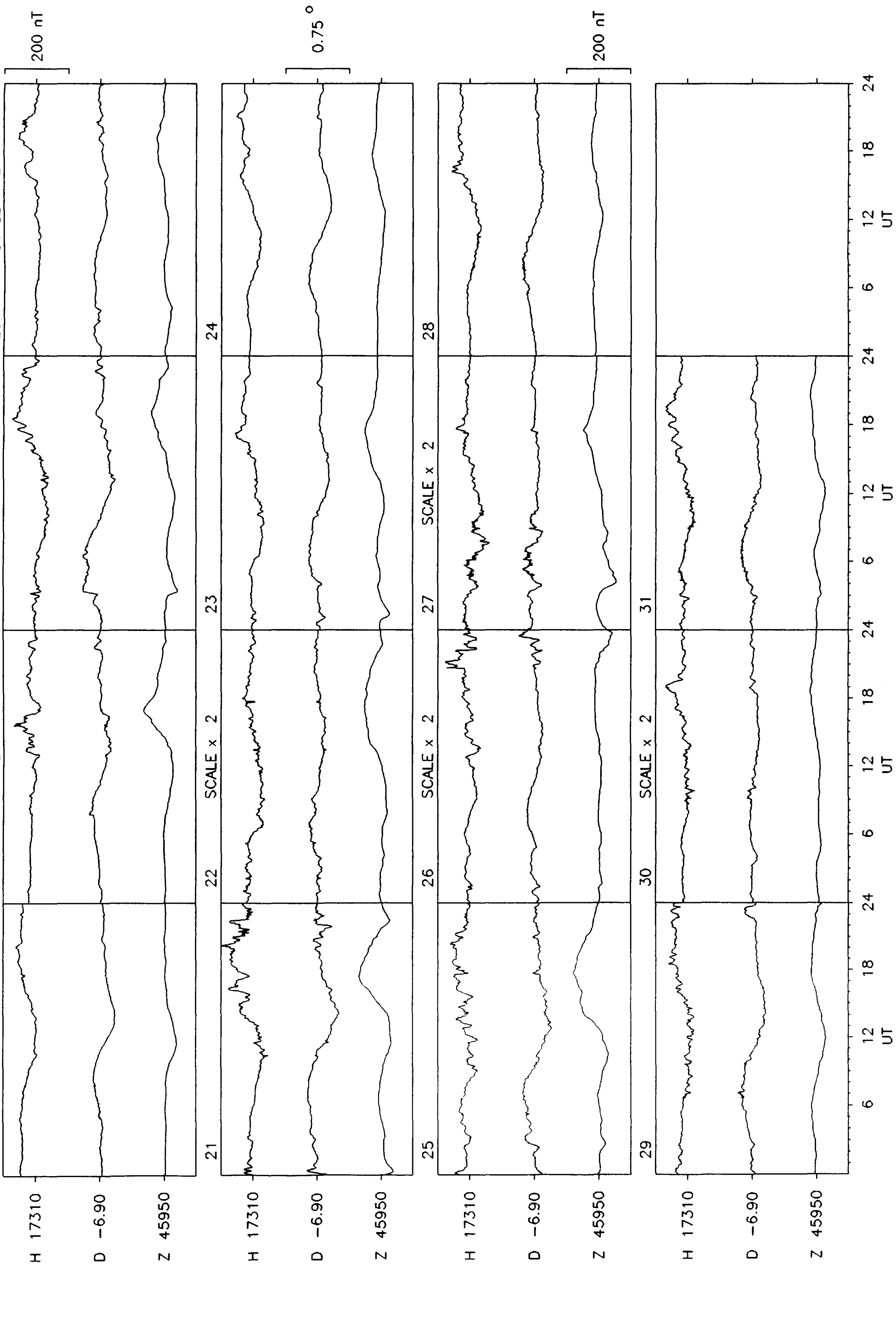
4
5
6
7
8
9
10
11
12
13
14
15
16
SCALE x 4
SCALE x 4
SCALE x 4
SCALE x 2
H 17310
D −6.90
Z 45950
6
12
18
24
UT



200 nT
0.75 °
200 nT
SCALE x 2
17
18
19
20
21
22
23
24
25
26
27
28
29
30
H 17310
D −6.90
Z 45950
6
12
18
24
UT


200 nT
0.75 °
200 nT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
SCALE x 2
H 17310
D -6.90
Z 45950
6
12
18
24
UT



H 17310
D −6.90
Z 45950
200 nT
0.75 °
200 nT
SCALE x 2
21
22
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26
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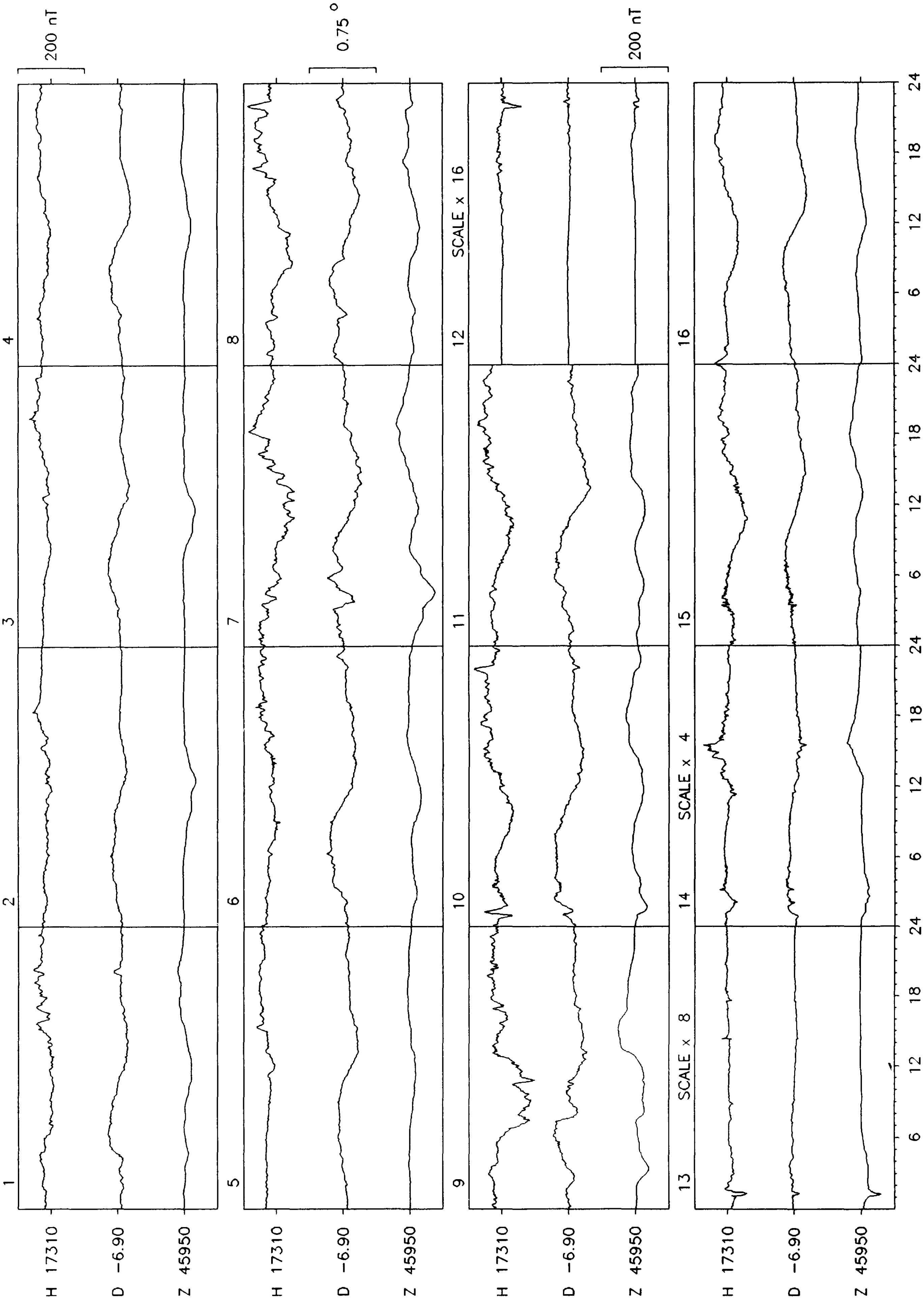
29
30
31
UT


200 nT
0.75 °
200 nT
H 17310
D -6.90
Z 45950
SCALE x 16
SCALE x 4
SCALE x 8
UT
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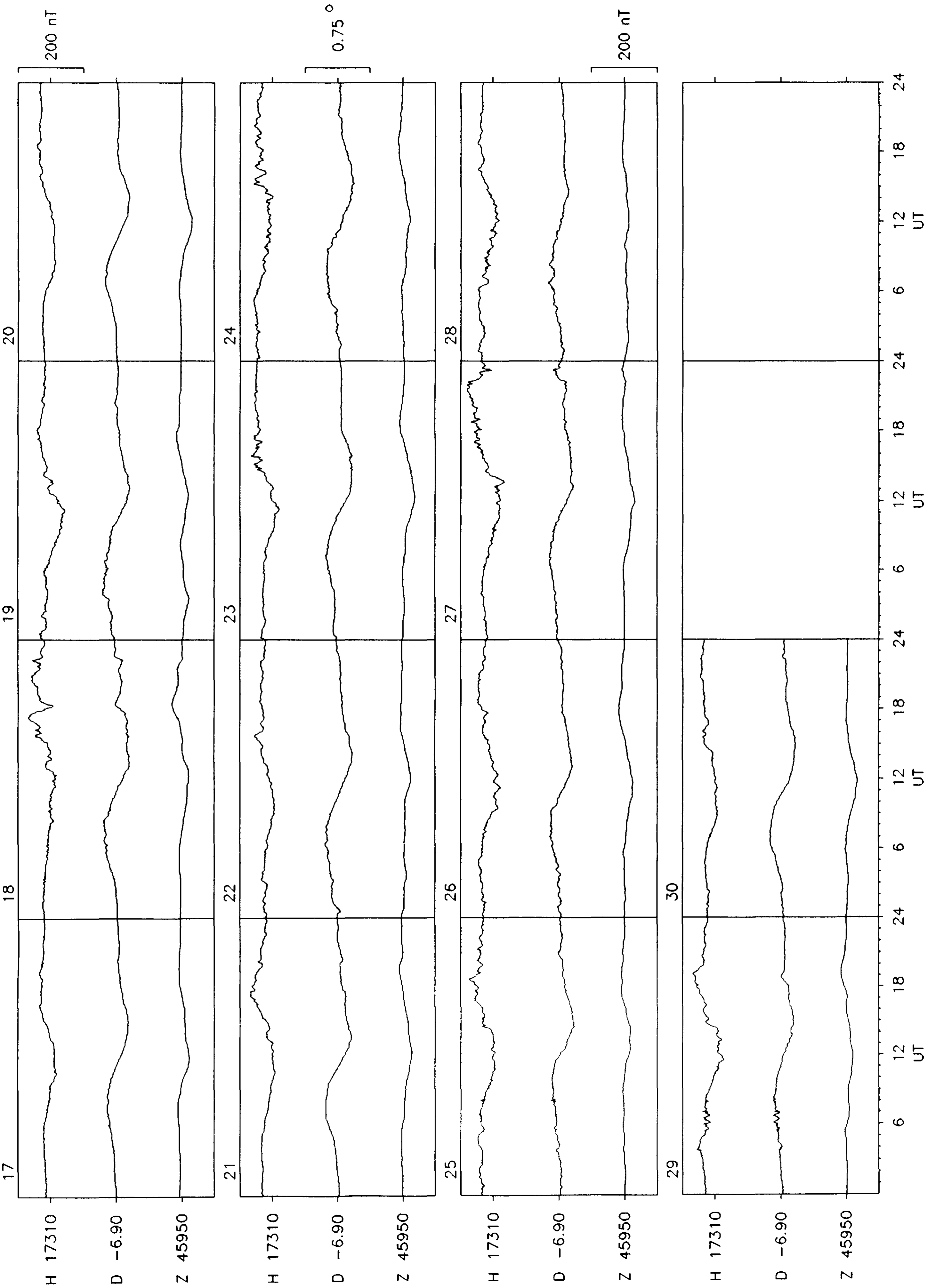
16


200 nT
0.75 °
200 nT
17
18
19
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21
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23
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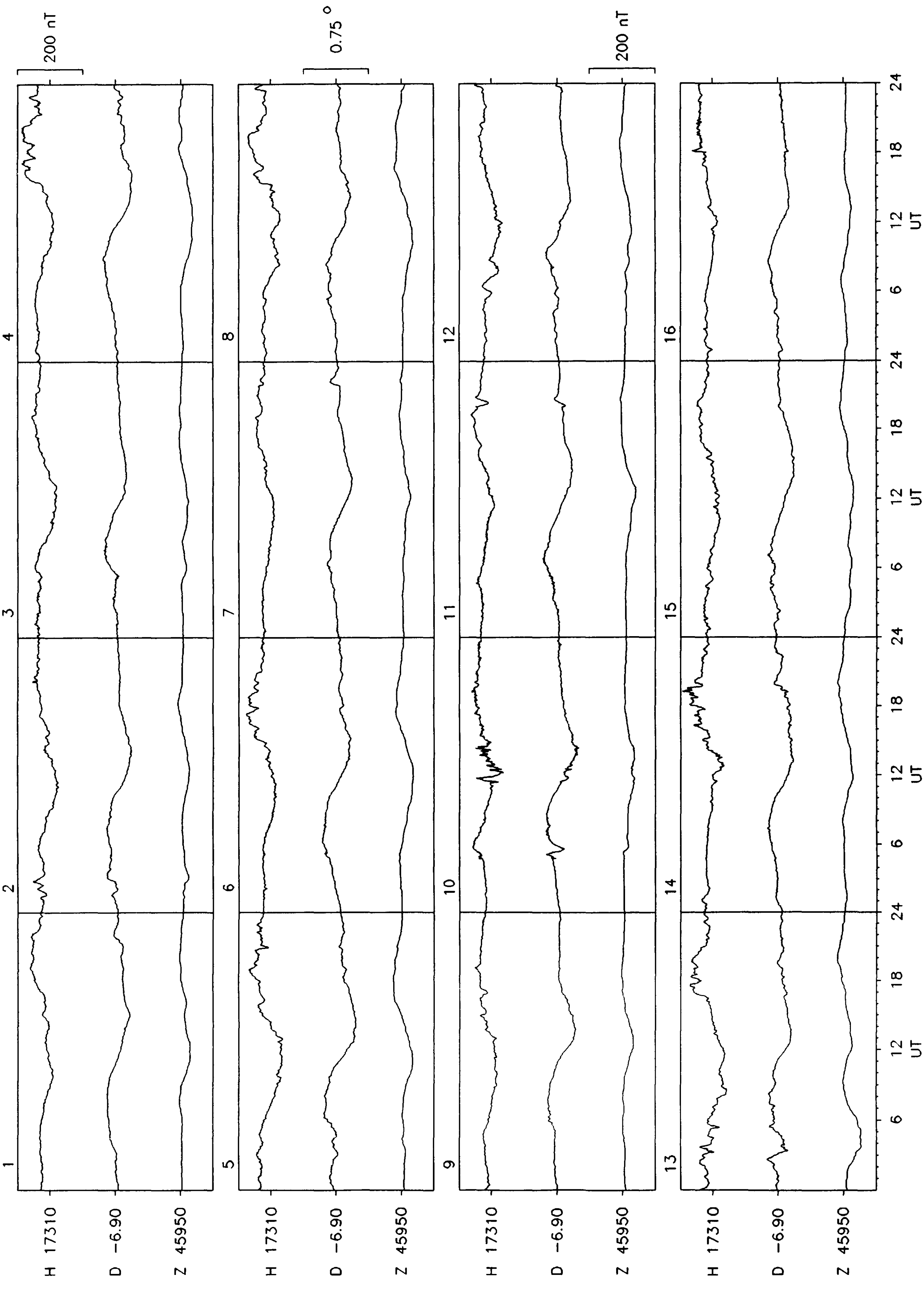
26
27
28
29
30
H 17310
D −6.90
Z 45950
6
12
18
24
UT


200 nT
0.75 °
200 nT
H 17310
D −6.90
Z 45950
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12
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14
15
16
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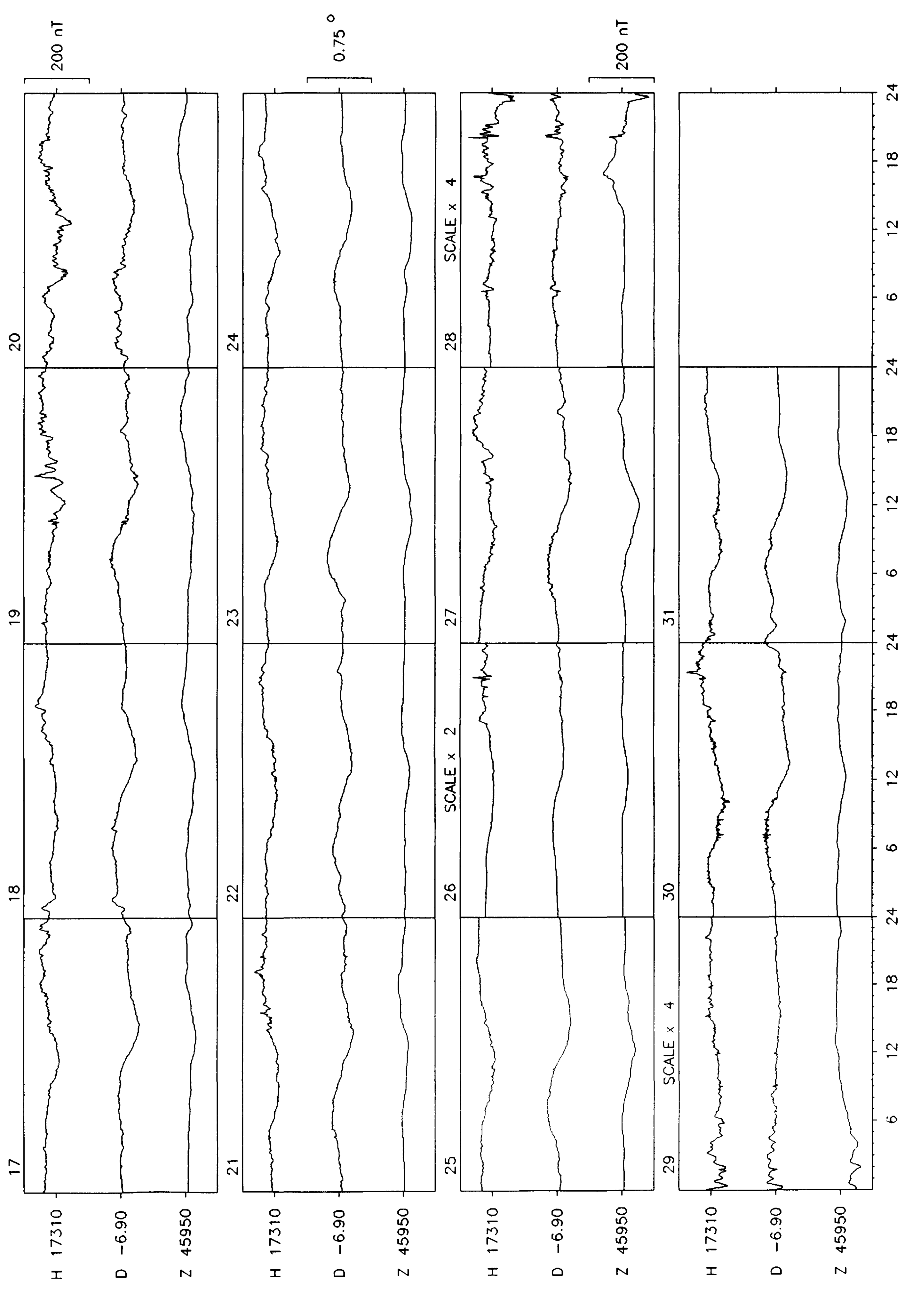
12
18
24
UT



200 nT
0.75 °
200 nT
17
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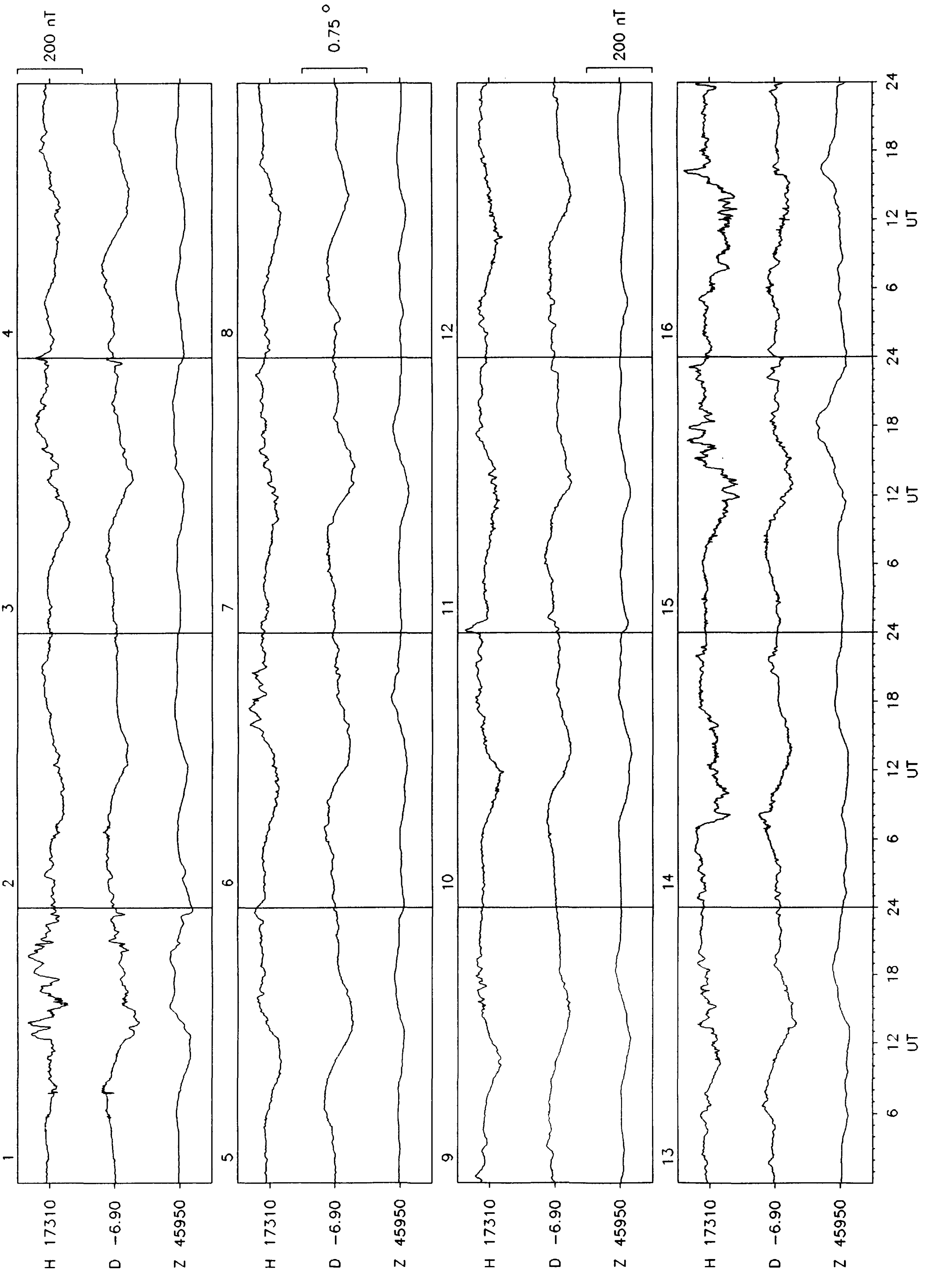
29
30
31
SCALE x 2
SCALE x 4
SCALE x 4
H 17310
D −6.90
Z 45950
H 17310
D −6.90
Z 45950
H 17310
D −6.90
Z 45950
H 17310
D −6.90
Z 45950
6
12
18
24
UT


200 nT
0.75 °
200 nT
H 17310
D −6.90
Z 45950
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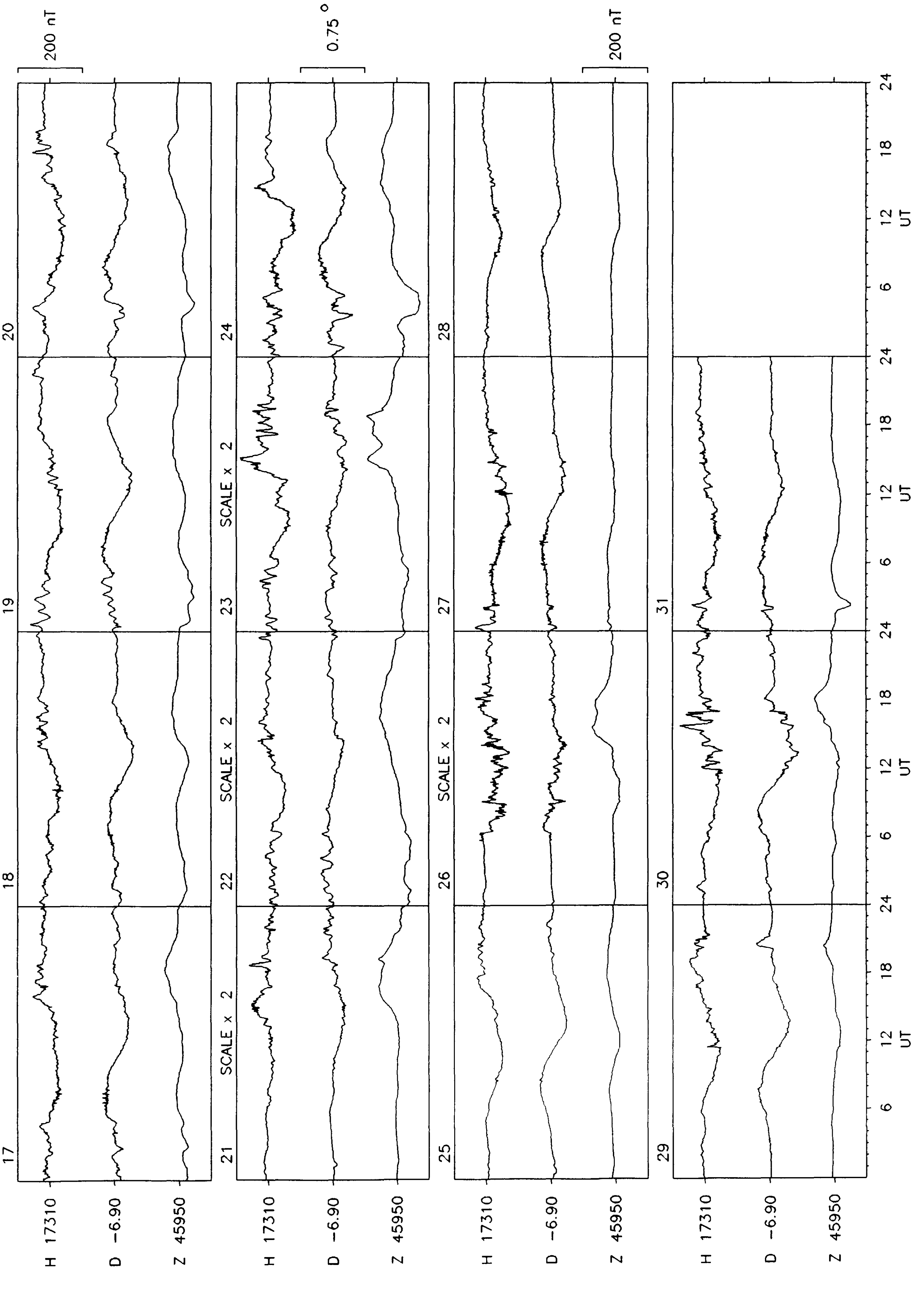
UT


200 nT
0.75 °
200 nT
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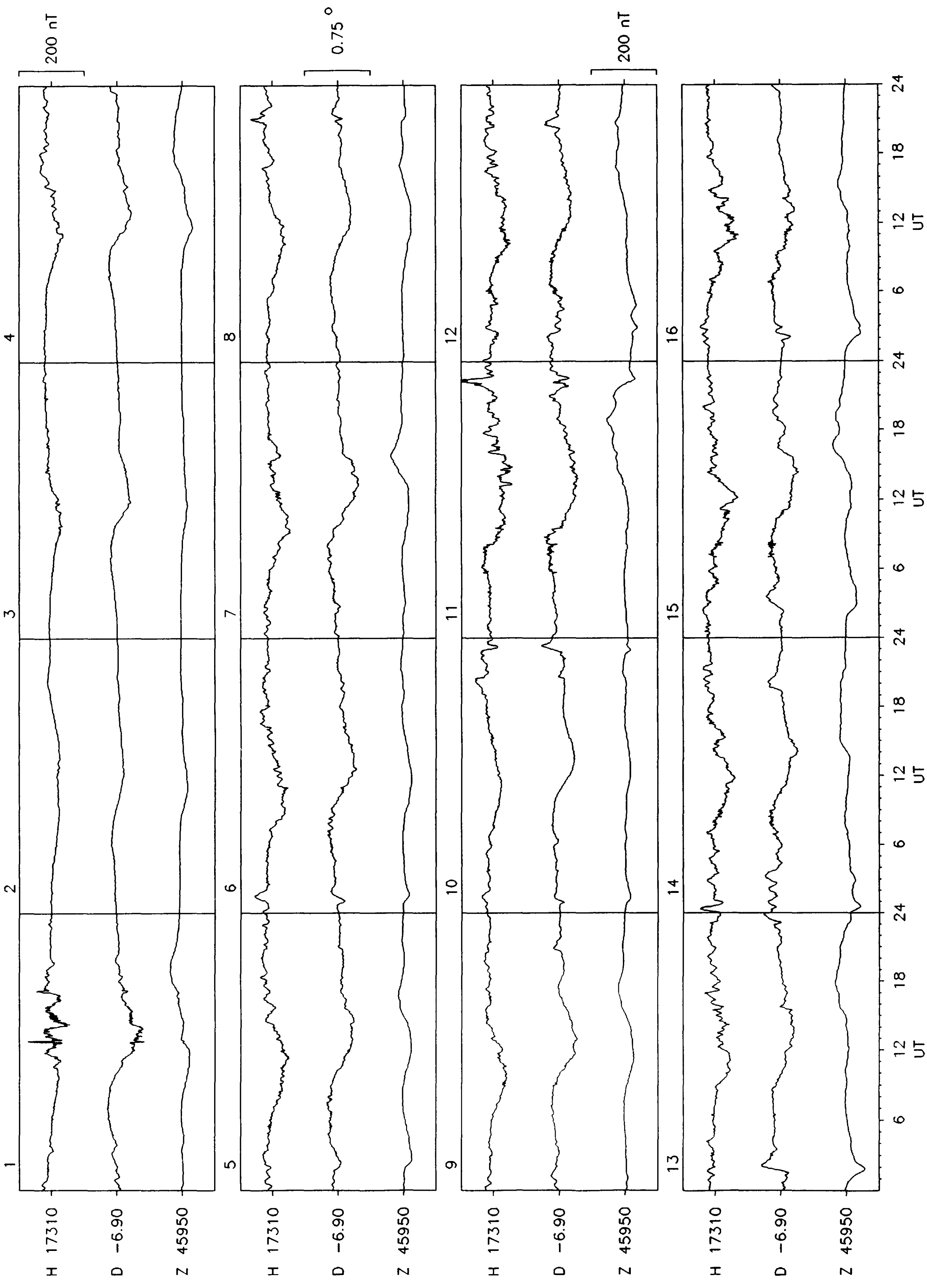
31
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
H 17310
D −6.90
Z 45950
H 17310
D −6.90
Z 45950
H 17310
D −6.90
Z 45950
H 17310
D −6.90
Z 45950
6
12
18
24
UT



200 nT
0.75 °
200 nT
H 17310
D −6.90
Z 45950
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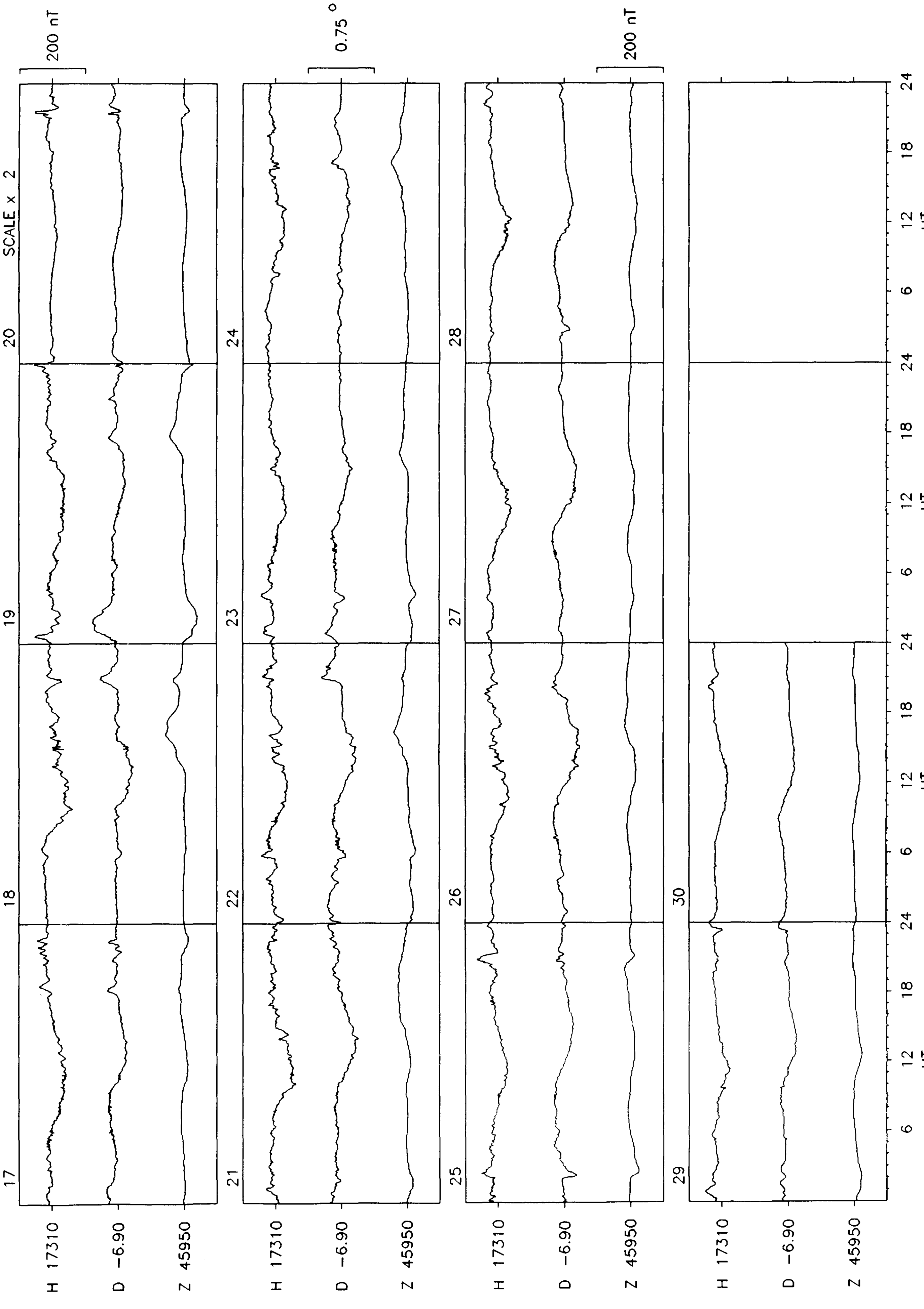
UT



SCALE x 2
200 nT
0.75 °
200 nT
17
18
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H 17310
D −6.90
Z 45950
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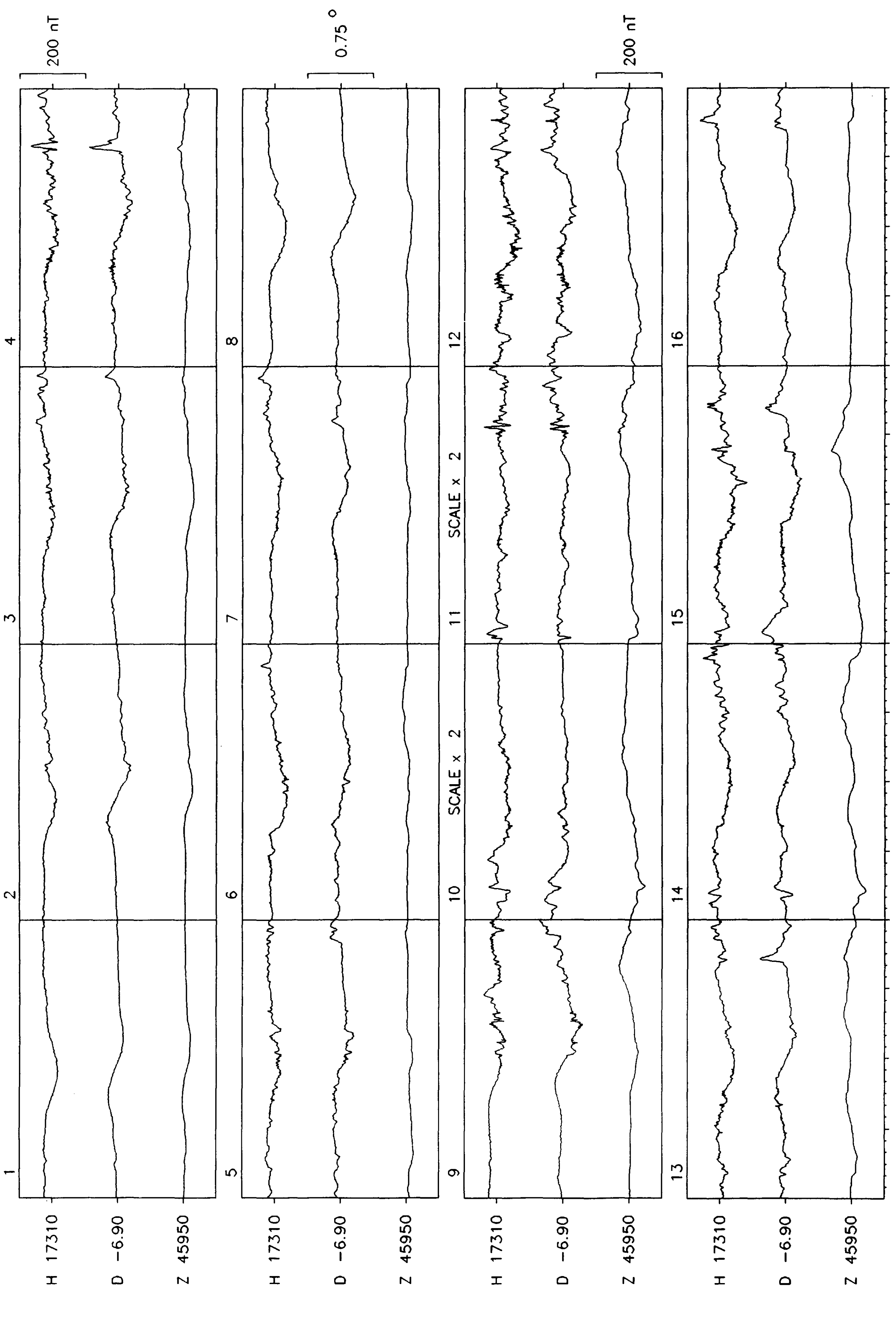
UT


200 nT
0.75 °
200 nT
SCALE x 2
SCALE x 2
1
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H 17310
D −6.90
Z 45950
6
12
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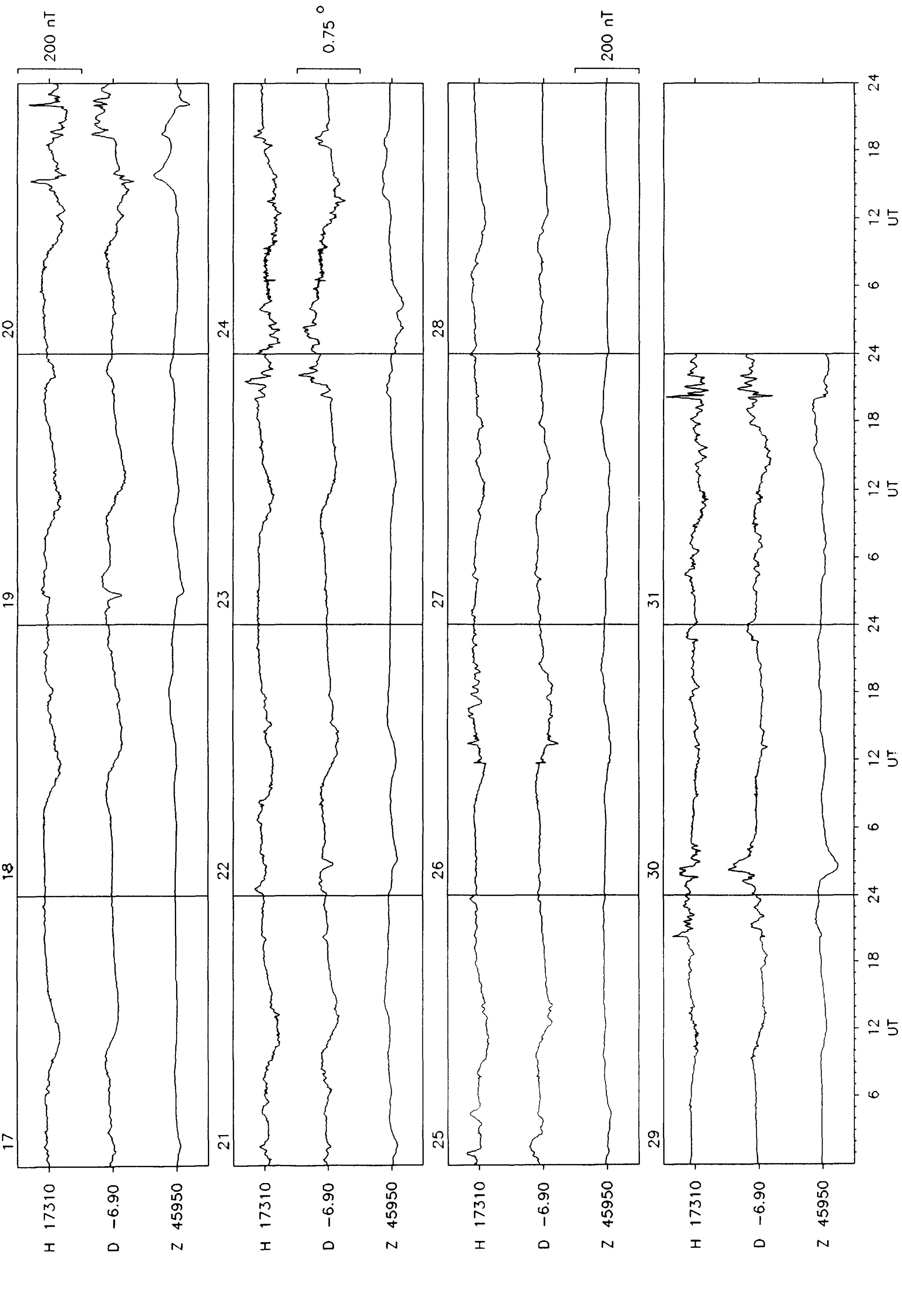
UT


200 nT
0.75 °
200 nT
17
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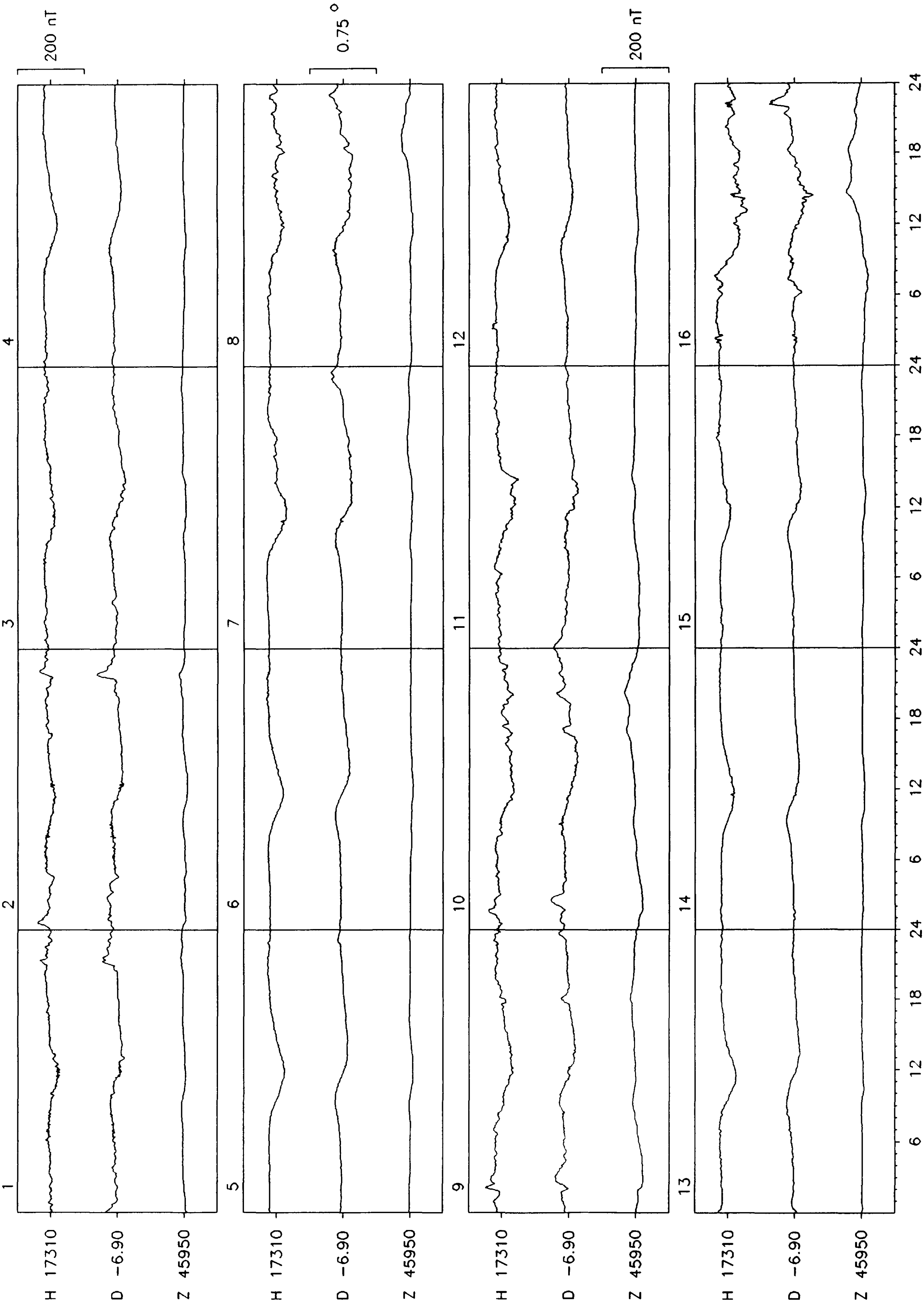
H 17310
D −6.90
Z 45950
6
12
18
24
UT


200 nT
0.75 °
200 nT
H 17310
D -6.90
Z 45950
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16
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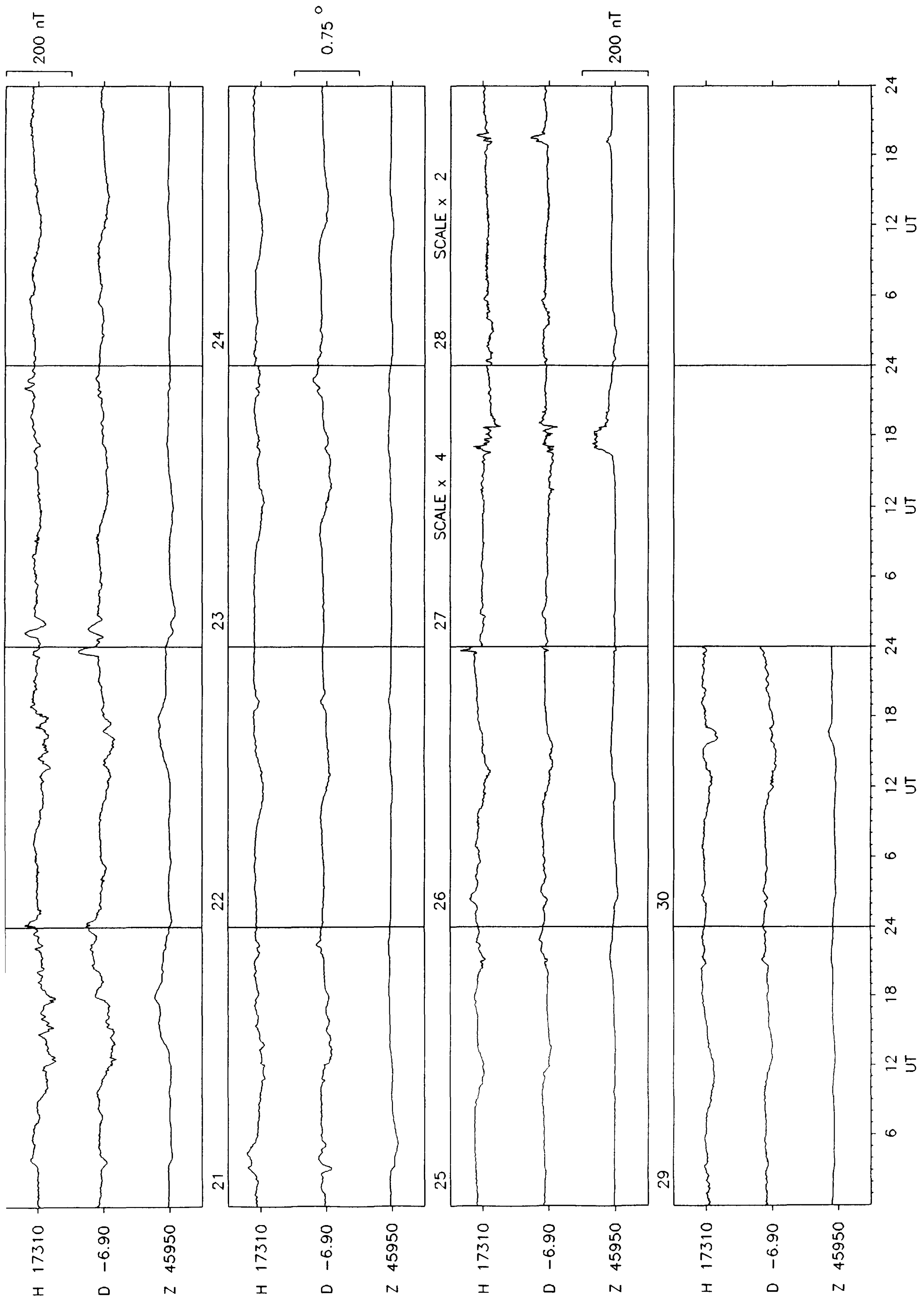
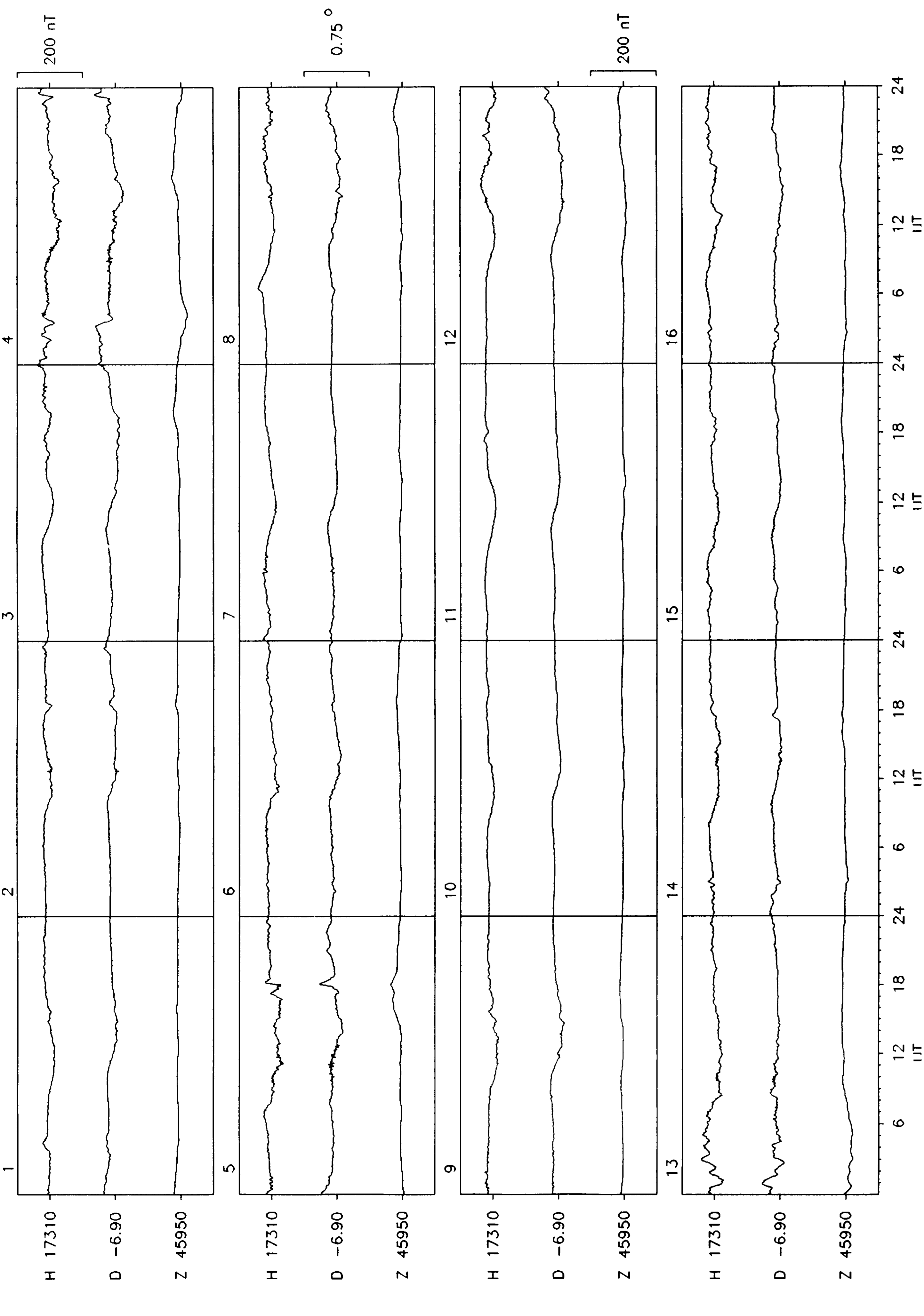
24
UT


200 nT
0.75 °
200 nT
SCALE x 2
SCALE x 4
21
22
23
24
25
26
27
28
29
30
6
12
18
24
UT
H 17310
D −6.90
Z 45950


200 nT
0.75 °
200 nT
1
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4
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6
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10
11
12
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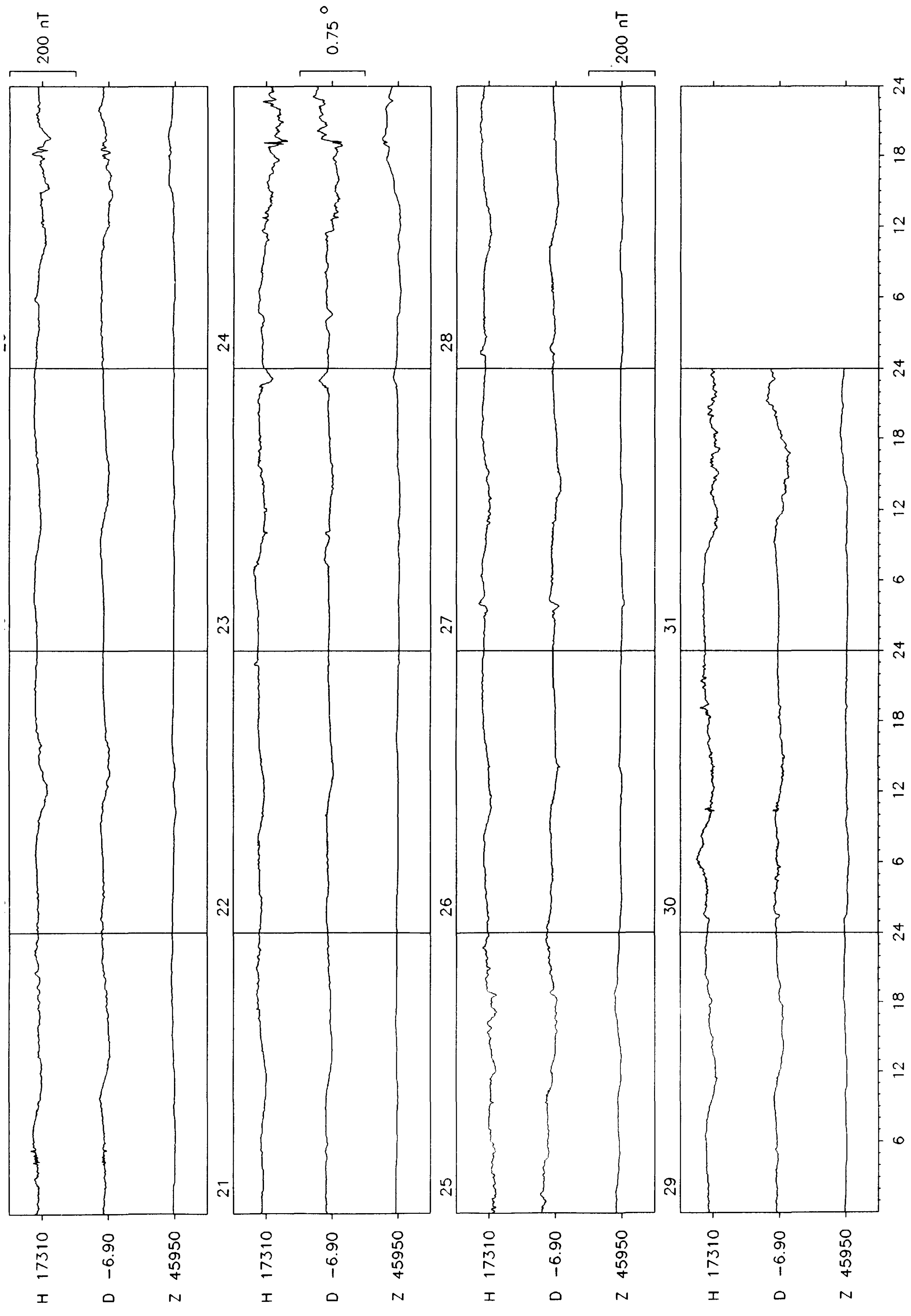
14
15
16
H 17310
D -6.90
Z 45950
6
12
18
24
UT


200 nT
0.75 °
200 nT
H 17310
D −6.90
Z 45950
21
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12
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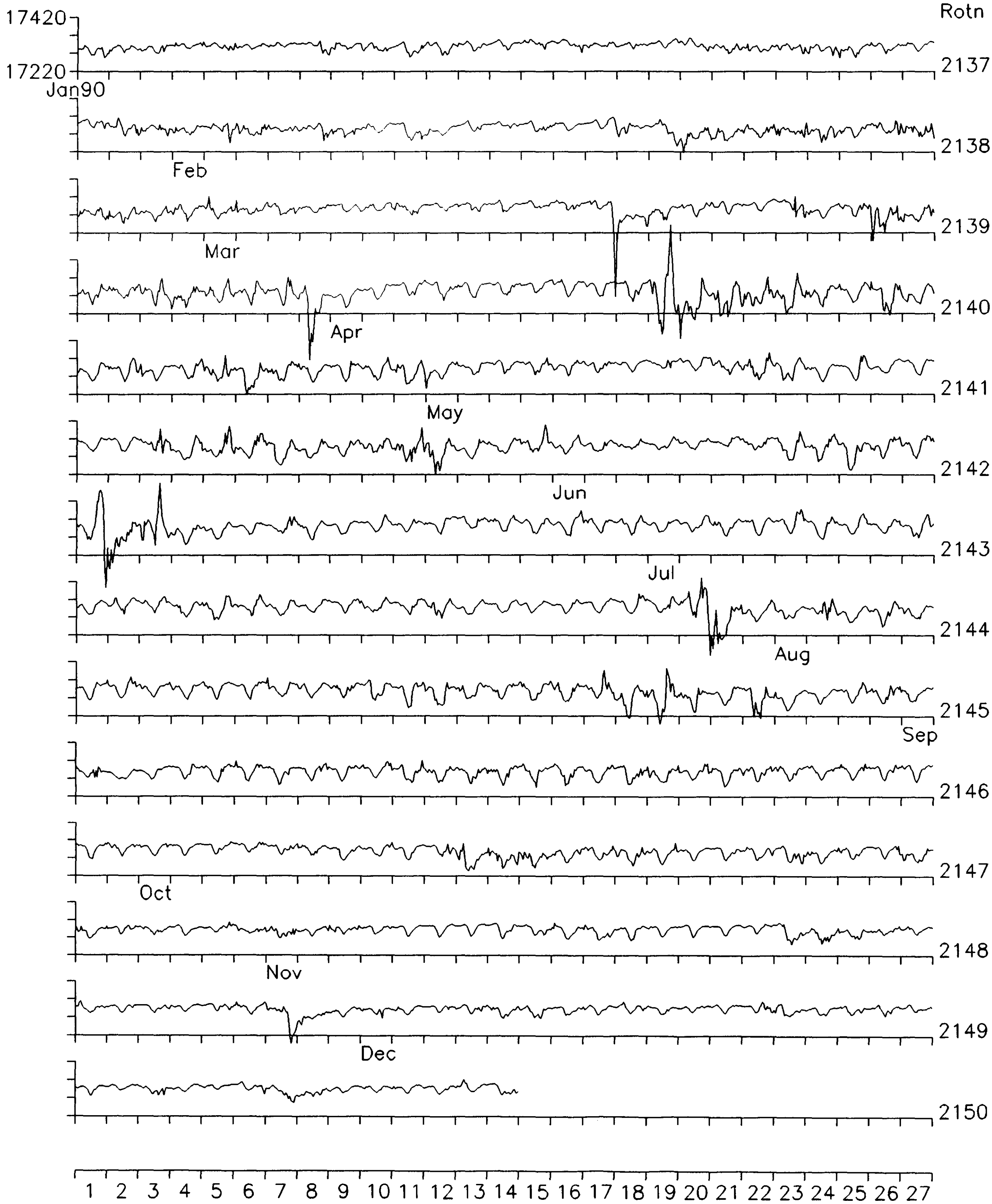
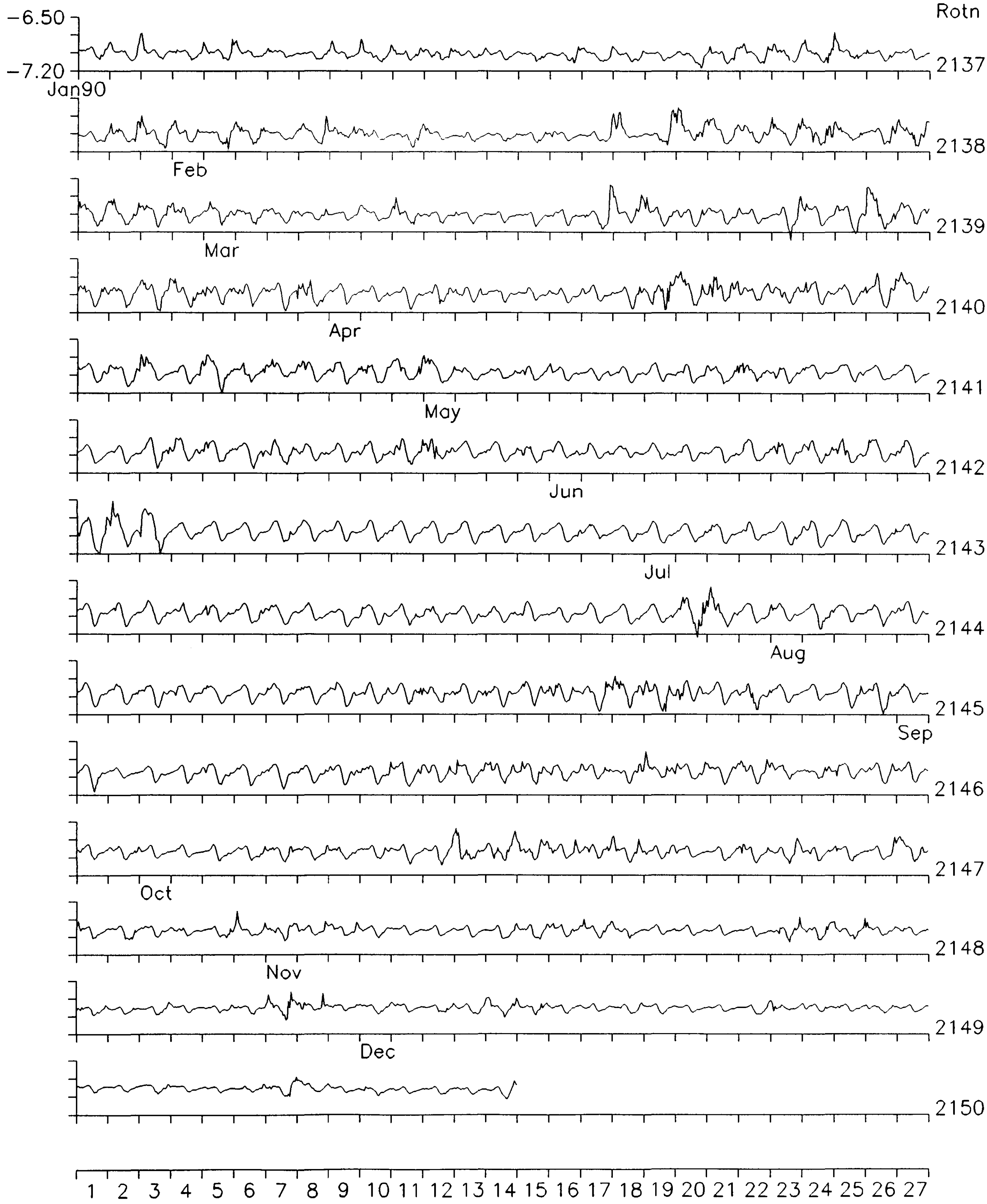
24
UT

Eskdalemuir Observatory: Horizontal Intensity (nT)

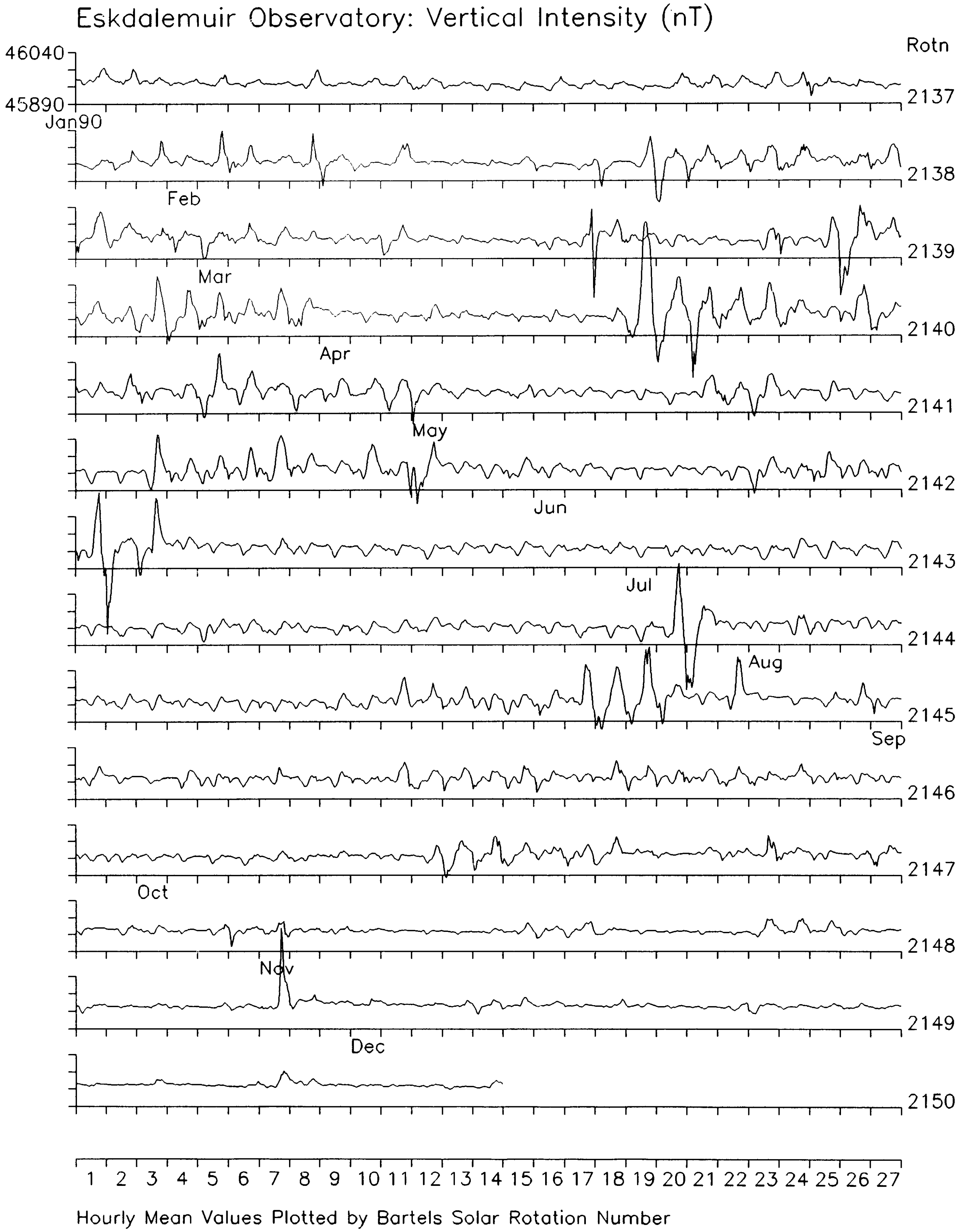


Hourly Mean Values Plotted by Bartels Solar Rotation Number

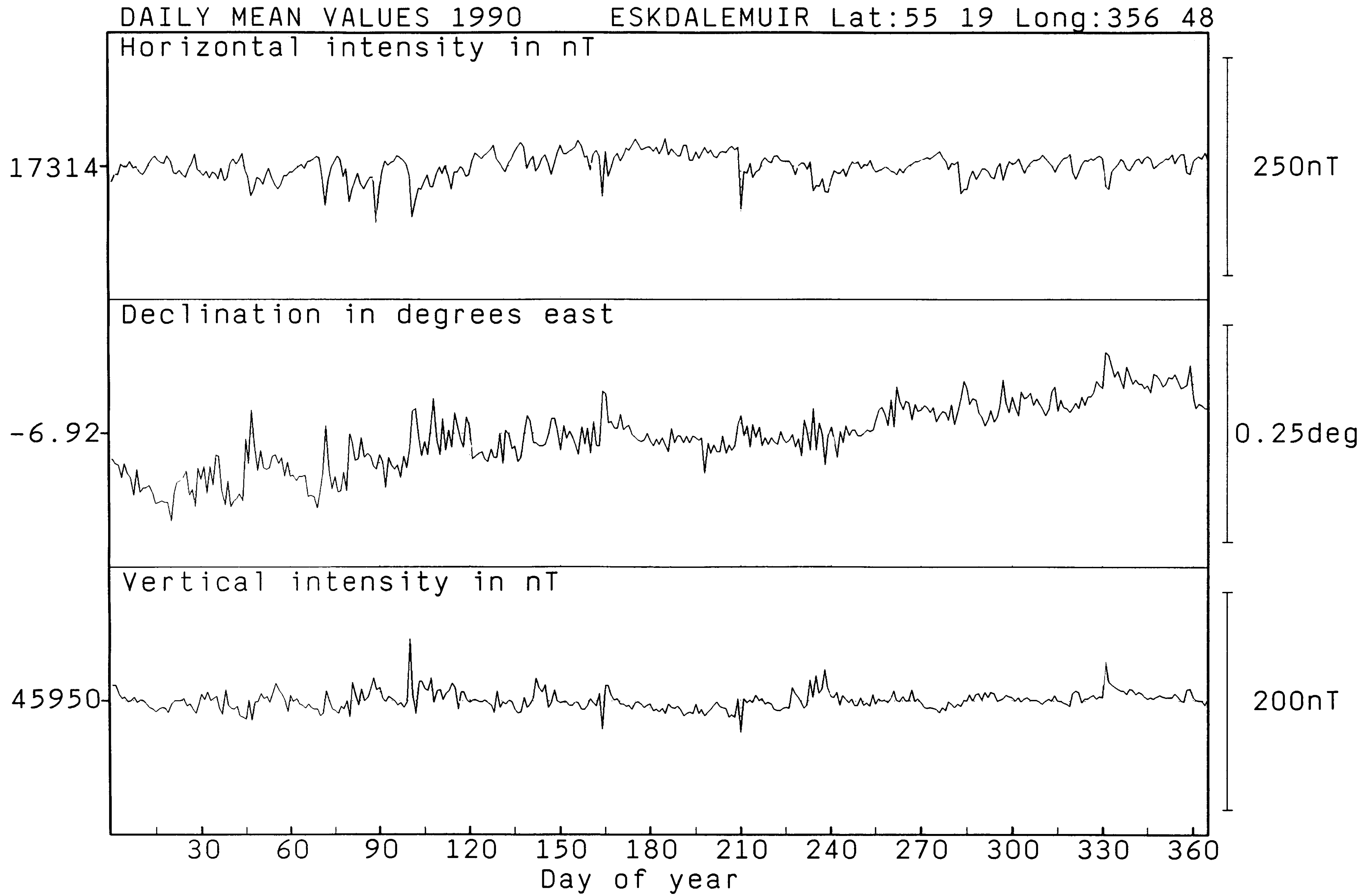
Eskdalemuir Observatory: Declination (degrees)



Hourly Mean Values Plotted by Bartels Solar Rotation Number



Eskdalemuir Observatory: Vertical Intensity (nT)
46040
45890
Rotn
Jan90
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted by Bartels Solar Rotation Number


DAILY MEAN VALUES 1990 ESKDALEMUIR Lat:55 19 Long:356 48
Horizontal intensity in nT
Declination in degrees east
Vertical intensity in nT
17314
-6.92
45950
250nT
0.25deg
200nT
30 60 90 120 150 180 210 240 270 300 330 360
Day of year

Monthly and annual mean values for Eskdalemuir 1990

Month	D	H	I	X	Y	Z	F
Jan	-6 58.6	17312	69 21.3	17184	-2103	45949	49102
Feb	-6 57.6	17304	69 21.8	17176	-2097	45948	49098
Mar	-6 57.7	17304	69 21.8	17176	-2097	45949	49099
Apr	-6 55.7	17304	69 22.0	17178	-2087	45956	49106
May	-6 55.7	17323	69 20.6	17197	-2090	45950	49107
Jun	-6 55.0	17328	69 20.2	17202	-2087	45948	49107
Jul	-6 55.6	17327	69 20.2	17201	-2090	45942	49101
Aug	-6 55.4	17310	69 21.5	17184	-2087	45952	49104
Sep	-6 54.0	17314	69 21.2	17189	-2080	45950	49104
Oct	-6 53.2	17311	69 21.4	17186	-2076	45950	49103
Nov	-6 52.4	17316	69 21.2	17192	-2072	45954	49108
Dec	-6 51.7	17320	69 20.9	17196	-2069	45955	49111
Annual	-6 55.2	17314	69 21.2	17188	-2086	45950	49104

D and I are given in degrees and decimal minutes
H, X, Y, Z and F are given in nanoteslas

ESKDALEMUIR OBSERVATORY K INDICES 1990

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	1222 3343	1222 3453	4322 3344	2120 2222	2222 2320	2322 3332	1112 2223	1132 4443	2203 5421	0101 0001	3212 2123	2200 2100
2	4112 2335	4333 3344	2223 3333	1222 3322	1223 3222	2122 2221	3211 2221	3222 2113	0001 1010	1012 2111	3321 1224	0001 2222
3	5211 2322	3101 2222	2211 2243	1132 3332	2233 3243	1211 2132	2221 2222	2123 3333	0002 3211	1112 2233	1211 1121	2000 2223
4	2102 2124	3322 3455	3112 1113	3222 3231	3223 4332	1321 2122	1011 2333	3211 2221	0012 2323	1222 3353	1011 1000	3322 3323
5	3222 2334	3334 2332	2221 1313	2112 2321	2223 2331	1212 2212	2212 3243	1101 3222	3222 3322	1212 3213	0000 0001	3122 2332
6	3111 1122	4331 0111	5432 3321	1122 2212	1211 2222	2323 2333	1211 2331	2221 3332	3233 3322	2232 2223	0000 0001	2112 1121
7	2221 2001	1132 3455	1222 3201	2122 2312	1211 3401	3433 4343	1110 2123	2212 2222	2223 2312	1112 2233	0011 2223	2210 1010
8	1101 3433	3311 0100	2212 2311	3111 3212	2222 3323	3333 3434	1222 2333	2310 2311	2212 2334	1111 2211	2011 2333	0021 2222
9	3222 2214	0121 2201	1123 1211	2234 5542	3222 3234	2344 4332	2211 3220	2212 2321	2223 3332	1101 3334	3311 2332	1001 2210
10	3233 2223	1112 2222	2122 2221	4466 6776	3444 3452	4223 3324	0424 4321	1112 3222	3221 2134	5544 4322	3211 1333	0000 1010
11	2232 3333	1122 2232	3322 3321	7444 3552	3432 4332	2322 3332	1221 1232	4222 2312	2233 3434	5343 3355	3222 3111	0000 0110
12	3323 2342	3221 0100	2322 2448	4664 6564	3222 1112	3343 5669	1232 2223	2212 2212	3323 3333	4333 3343	1101 2111	0000 2323
13	2222 2212	0001 1314	5323 3434	3443 3454	0211 3433	8553 6543	3432 2332	2223 3332	4213 3334	2232 2243	1010 0000	4332 1121
14	2111 3211	4443 3312	5333 4322	3344 4544	1000 2111	5535 6743	2112 3343	2343 3323	4333 4332	4322 2334	1001 0000	3211 1210
15	2121 2310	1232 3455	3222 3133	4322 3321	1111 2320	2311 2233	2222 2322	2223 4444	4333 4332	4322 3443	0000 1111	1211 1121
16	1112 1343	5533 3344	3121 2213	3122 2223	0000 1210	3110 1121	2112 2131	3333 4424	3234 4323	2221 2234	2232 3334	2101 3221
17	2211 1223	5432 3334	2010 1100	3244 4445	1112 1221	0111 1110	1111 2223	3322 2332	2222 2233	2111 0001	2222 3332	1200 1121
18	2112 3223	3233 3344	1132 4554	5422 3324	2233 4534	0222 3343	3121 2331	3223 3322	1233 3343	0011 1222	3211 3334	1001 1200
19	1000 1122	4323 3445	5211 2212	2111 2343	2322 2433	2212 3220	2223 4332	4332 3333	4321 2333	3212 1112	4222 1213	0000 0100
20	3222 2342	4343 4455	3223 3336	3222 3443	3322 3444	0000 2110	3342 4332	3432 3431	4112 2235	1212 3545	2211 1111	0101 2232
21	3223 3232	3322 3332	6445 4454	4421 2212	4213 3434	0001 2332	1211 2332	3223 5554	3123 3223	3232 2121	2311 2112	0100 0111
22	3422 2243	2221 3254	3223 3344	1221 2324	3443 3433	2211 2211	2211 2222	4444 5434	3332 3343	3221 2211	0000 1020	1011 0002
23	3322 3234	4233 4445	3333 3443	4443 3533	3323 1312	1112 3321	1302 1211	4544 6653	3322 3312	1111 2134	0000 2213	0022 1103
24	4323 3355	4333 3344	3232 3233	1353 3333	1211 2333	2222 2322	1111 1220	3433 5330	2222 3322	4333 3331	2100 0001	0213 2343
25	4232 3321	3433 3354	3323 4544	2333 3323	3333 3333	1221 3232	1111 1110	1110 1322	3322 2233	3321 2112	0001 2122	2201 2322
26	3112 3321	3222 3243	6433 3443	3431 3221	4343 4456	1212 2212	1011 1454	2355 5553	3222 3332	1003 3332	2211 2103	1000 1000
27	0100 1110	3444 3233	4333 3454	2322 3323	3554 3433	1111 3334	1212 2332	4233 4221	2212 3211	2211 2322	4332 4663	0301 2110
28	0011 2233	2542 3342	2332 3334	2332 3343	1121 3321	2222 2211	3454 5677	2112 2211	3312 3012	2121 0000	3322 2252	2001 1010
29	4333 3244		2222 5434	4443 2334	2222 2323	1322 3231	6644 5544	1113 3333	3212 2023	0002 2243	1100 1022	0001 1120
30	4322 3353		3365 5532	5322 2323	2334 3453	1001 2211	2223 1234	2223 4533	2011 1122	4412 2223	2101 2322	2322 2122
31	4323 2231		2122 2222		3322 3332		3222 1111	4323 3222		3332 3454		0001 2323

Annual Values of Geomagnetic Elements

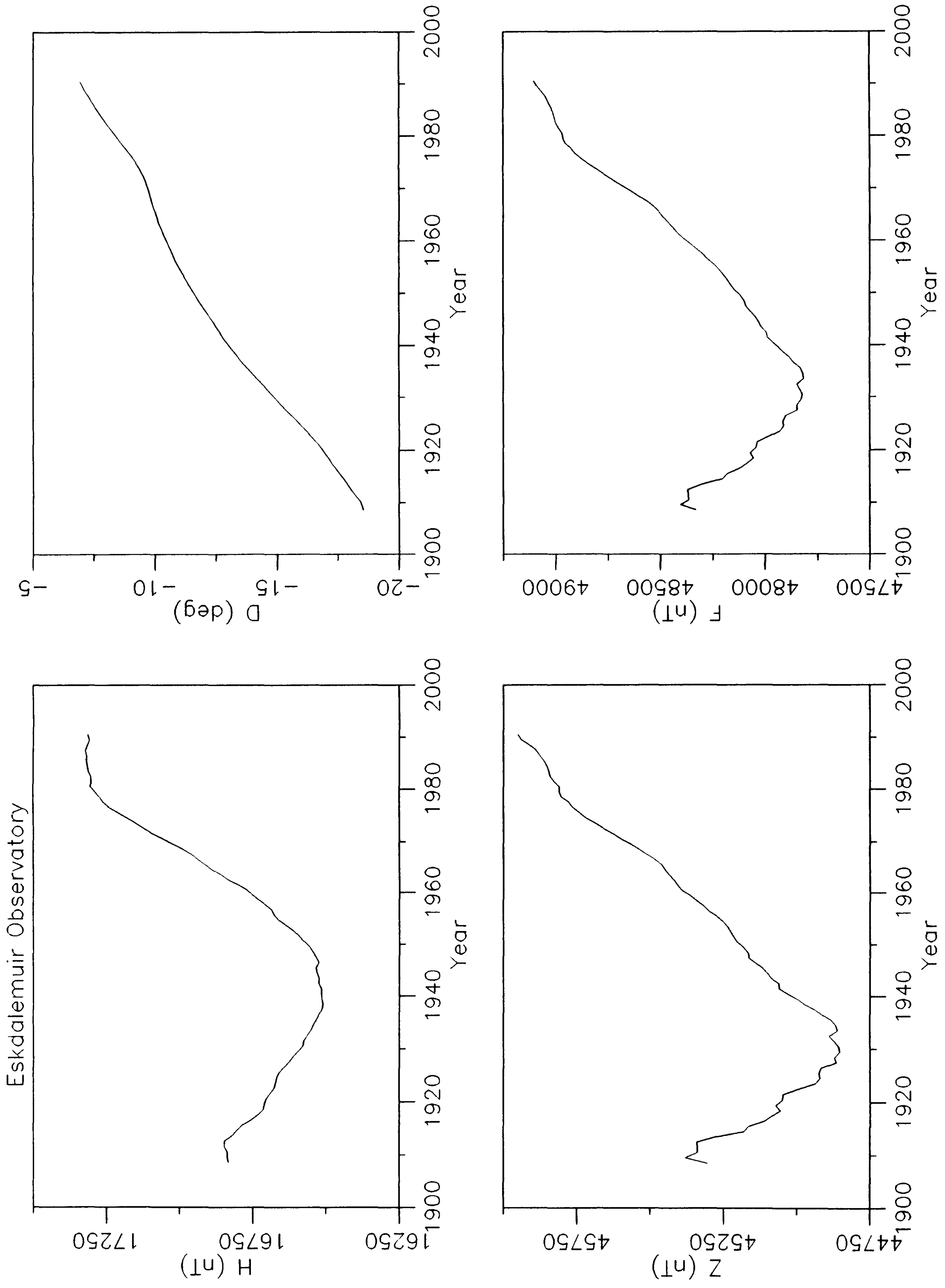
Eskdalemuir

Year	D	H	I	X	Y	Z	F
1908.5	-18 33.3	16821	69 37.3	15947	-5353	45283	48306
1909.5	-18 30.1	16826	69 38.9	15956	-5339	45360	48380
1910.5	-18 23.3	16826	69 37.8	15967	-5308	45317	48340
1911.5	-18 12.4	16836	69 37.1	15993	-5260	45317	48343
1912.5	-18 3.9	16836	69 37.2	16006	-5221	45318	48344
1913.5	-17 54.9	16811	69 37.3	15996	-5171	45254	48276
1914.5	-17 45.3	16793	69 36.1	15993	-5121	45159	48180
1915.5	-17 35.9	16775	69 36.9	15990	-5072	45142	48158
1916.5	-17 26.1	16744	69 37.6	15975	-5017	45088	48097
1917.5	-17 17.1	16720	69 38.6	15965	-4968	45061	48063
1918.5	-17 8.1	16703	69 39.0	15962	-4921	45034	48032
1919.5	-16 58.7	16700	69 39.6	15972	-4877	45049	48045
1920.5	-16 49.6	16693	69 39.5	15978	-4832	45026	48021
1921.5	-16 37.2	16681	69 40.3	15984	-4771	45025	48016
1922.5	-16 25.8	16666	69 40.0	15985	-4714	44974	47963
1923.5	-16 13.8	16661	69 38.8	15997	-4657	44915	47906
1924.5	-16 1.2	16657	69 38.7	16010	-4597	44898	47889
1925.5	-15 48.4	16650	69 39.3	16020	-4535	44902	47890
1926.5	-15 35.3	16632	69 40.3	16020	-4469	44896	47878
1927.5	-15 22.7	16615	69 40.2	16020	-4406	44843	47822
1928.5	-15 10.5	16602	69 41.2	16024	-4346	44849	47823
1929.5	-14 58.8	16586	69 41.9	16022	-4287	44832	47802
1930.5	-14 47.1	16568	69 43.2	16019	-4228	44834	47797
1931.5	-14 34.8	16565	69 43.7	16032	-4170	44850	47812
1932.5	-14 23.7	16553	69 45.0	16033	-4115	44867	47823
1933.5	-14 12.1	16539	69 45.2	16033	-4058	44839	47792
1934.5	-14 0.6	16531	69 45.9	16039	-4002	44845	47795
1935.5	-13 48.8	16520	69 47.0	16042	-3944	44861	47806
1936.5	-13 37.4	16512	69 48.4	16047	-3889	44894	47834
1937.5	-13 26.9	16501	69 49.8	16049	-3837	44920	47855
1938.5	-13 17.1	16499	69 50.7	16057	-3791	44953	47885
1939.5	-13 7.3	16502	69 51.1	16071	-3746	44977	47909
1940.5	-12 57.9	16503	69 51.8	16082	-3703	45008	47938
1941.5	-12 48.2	16503	69 52.5	16093	-3657	45037	47965
1942.5	-12 39.8	16513	69 51.9	16111	-3620	45039	47971
1943.5	-12 31.2	16511	69 52.7	16118	-3579	45064	47994
1944.5	-12 23.0	16518	69 52.5	16134	-3542	45076	48007
1945.5	-12 14.5	16522	69 52.6	16146	-3503	45093	48025
1946.5	-12 5.9	16512	69 54.0	16145	-3461	45120	48046
1947.5	-11 57.1	16520	69 53.9	16162	-3421	45140	48068
1948.5	-11 48.9	16532	69 53.2	16182	-3385	45144	48076
1949.5	-11 40.9	16544	69 52.8	16201	-3350	45158	48093
1950.5	-11 33.2	16564	69 52.0	16228	-3317	45180	48121
1951.5	-11 25.5	16581	69 51.1	16252	-3284	45193	48139
1952.5	-11 18.0	16601	69 50.0	16279	-3253	45203	48155
1953.5	-11 11.0	16625	69 48.7	16309	-3224	45213	48173
1954.5	-11 3.4	16647	69 47.6	16338	-3193	45228	48194
1955.5	-10 56.3	16665	69 46.9	16362	-3162	45250	48221
1956.5	-10 49.7	16674	69 47.0	16377	-3132	45277	48250
1957.5	-10 43.6	16695	69 46.0	16403	-3107	45296	48275
1958.5	-10 38.0	16719	69 45.0	16432	-3085	45320	48306
1959.5	-10 32.1	16742	69 44.1	16460	-3061	45344	48336
1960.5	-10 26.3	16761	69 43.5	16484	-3037	45370	48367
1961.5	-10 20.9	16792	69 41.8	16519	-3016	45385	48392
1962.5	-10 15.7	16825	69 39.8	16556	-2997	45396	48414
1963.5	-10 10.2	16850	69 38.6	16585	-2975	45413	48438
1964.5	-10 5.3	16880	69 36.9	16619	-2957	45427	48462
1965.5	-10 0.8	16907	69 35.5	16649	-2940	45440	48483
1966.5	-9 56.4	16928	69 34.6	16674	-2922	45460	48509
1967.5	-9 52.1	16949	69 33.8	16698	-2905	45486	48541
1968.5	-9 48.6	16979	69 32.5	16731	-2893	45514	48578
1969.5	-9 45.4	17013	69 31.0	16767	-2883	45542	48616

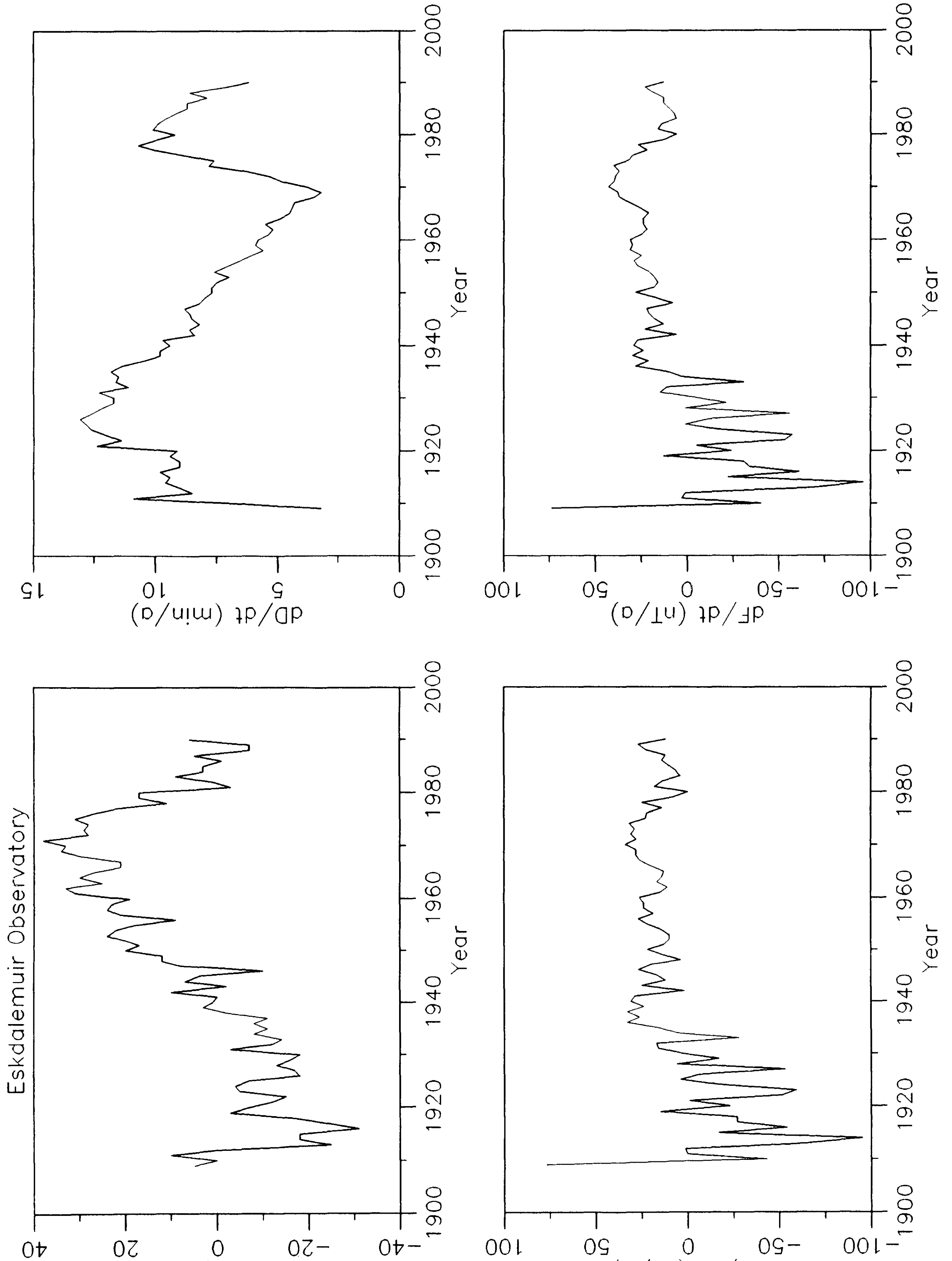
	Year	D	H	I	X	Y	Z	F
	1970.5	-9 41.6	17046	69 29.6	16803	-2870	45576	48659
	1971.5	-9 36.8	17084	69 27.8	16844	-2853	45604	48699
	1972.5	-9 31.5	17112	69 26.7	16876	-2832	45635	48738
	1973.5	-9 25.2	17141	69 25.5	16910	-2805	45664	48775
	1974.5	-9 17.4	17169	69 24.5	16944	-2772	45696	48815
	1975.5	-9 9.8	17200	69 23.0	16981	-2739	45719	48847
	1976.5	-9 1.1	17227	69 21.8	17014	-2700	45741	48877
	1977.5	-8 51.2	17249	69 20.6	17044	-2655	45755	48899
	1978.5	-8 40.5	17260	69 20.5	17063	-2603	45780	48926
	1979.5	-8 30.5	17277	69 19.6	17087	-2556	45788	48939
	1980.5	-8 21.3	17294	69 18.5	17110	-2513	45788	48945
	1981.5	-8 11.2	17291	69 19.2	17114	-2462	45806	48961
	1982.5	-8 1.3	17292	69 19.4	17123	-2413	45820	48975
	1983.5	-7 51.7	17301	69 18.9	17138	-2366	45824	48981
	1984.5	-7 42.5	17304	69 18.9	17147	-2321	45830	48988
	1985.5	-7 33.8	17307	69 18.9	17156	-2278	45840	48998
	1986.5	-7 25.1	17306	69 19.4	17161	-2234	45854	49011
	1987.5	-7 17.2	17311	69 19.3	17171	-2196	45866	49024
	1988.5	-7 8.6	17304	69 20.4	17170	-2152	45889	49043
	1989.5	-7 1.4	17297	69 21.5	17167	-2115	45916	49066
Note 1		0 0.0	11	0 -0.2	11	-1	22	25
	1990.5	-6 55.2	17314	69 21.2	17188	-2086	45950	49104

1 Site differences 1 Jan 1990 (new value - old value)

D and I are given in degrees and decimal minutes
All other elements are in nanotesla

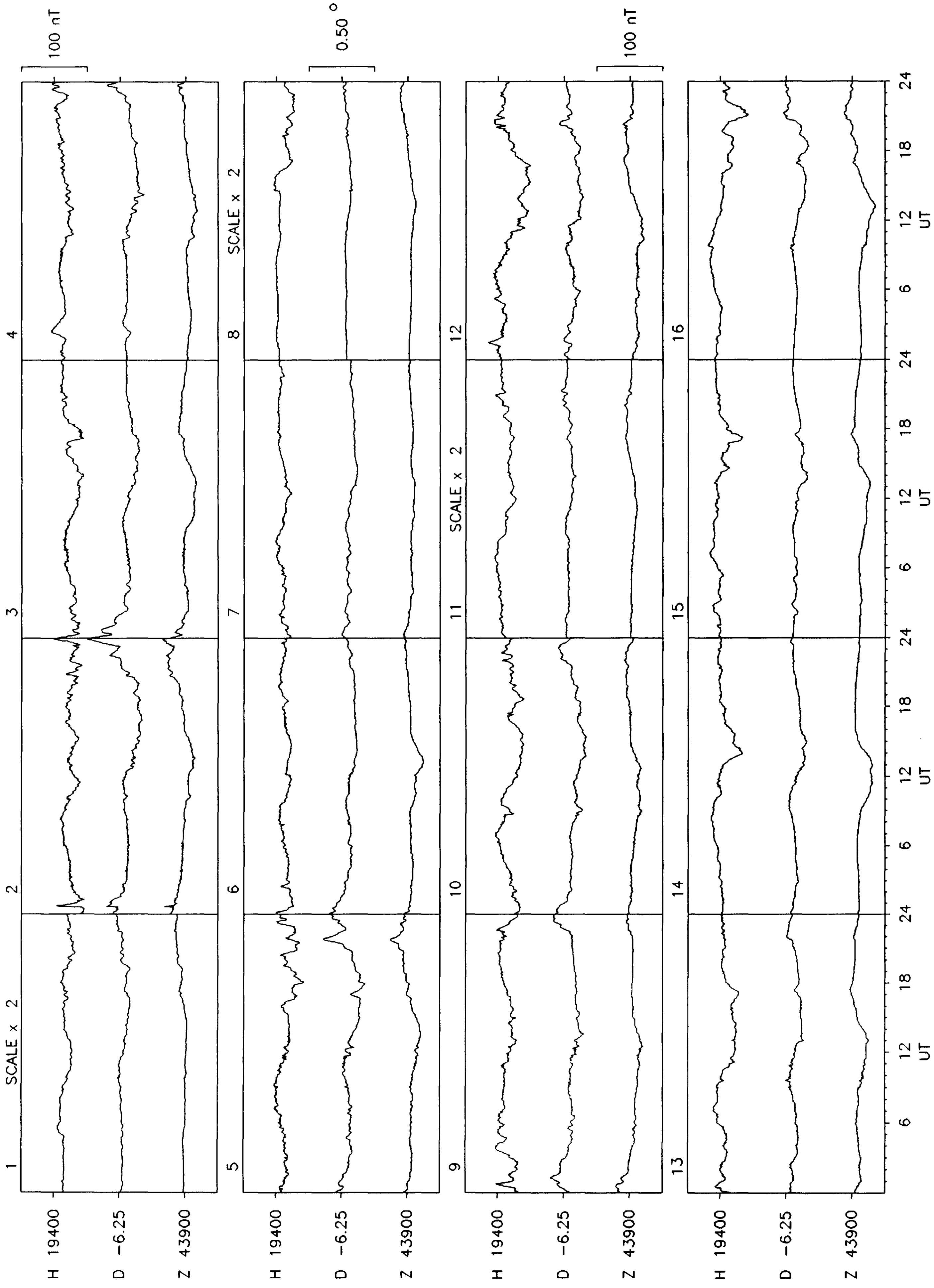


Annual mean values of H, D, Z & F at Eskdalemuir



Rate of change of annual mean values for H, D, Z & F at Eskdalemuir

Hartland 1990



100 nT
0.50 °
100 nT
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
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H 19400
D −6.25
Z 43900
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18
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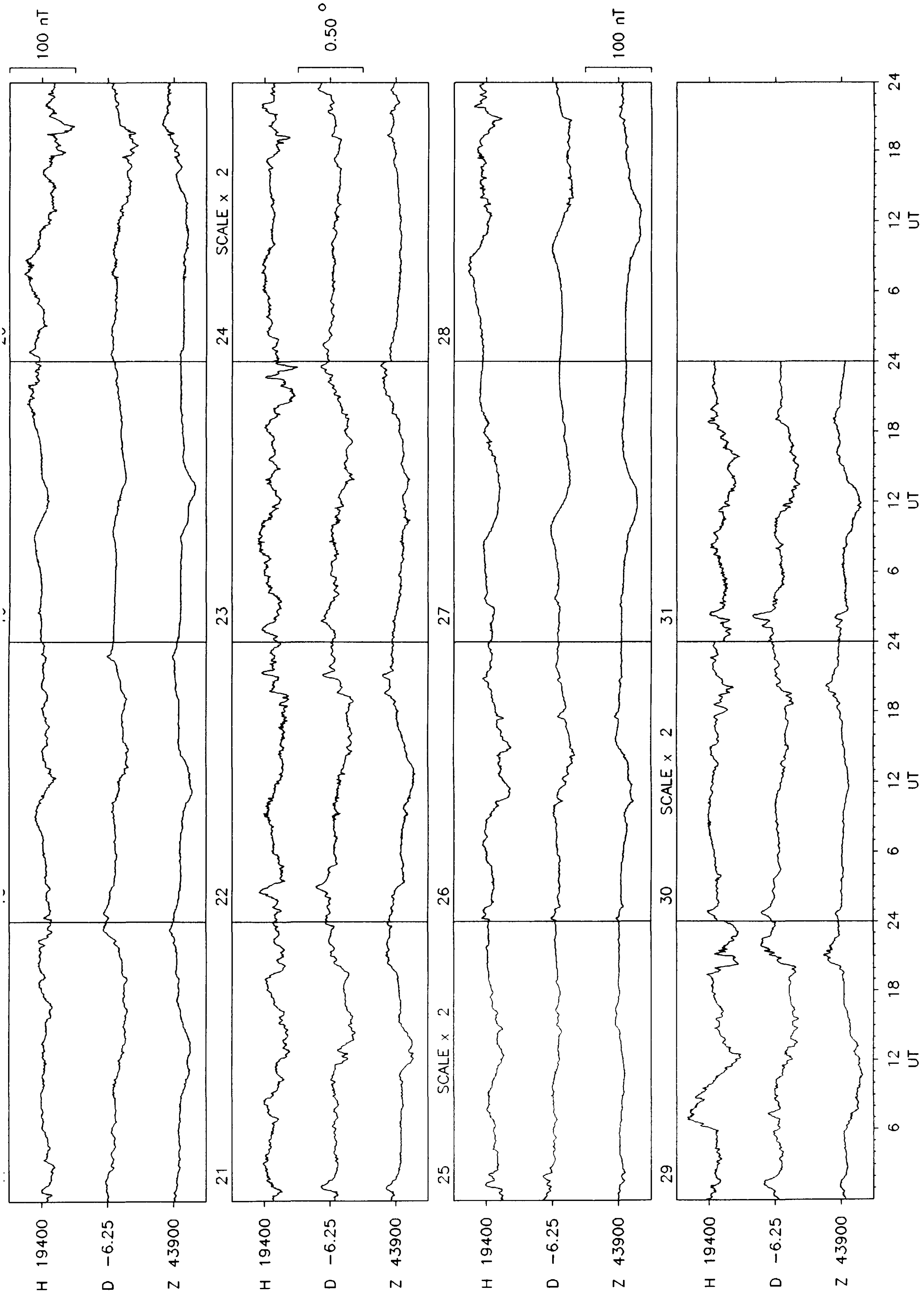
UT



H 19400
D −6.25
Z 43900
100 nT
0.50 °
SCALE x 2
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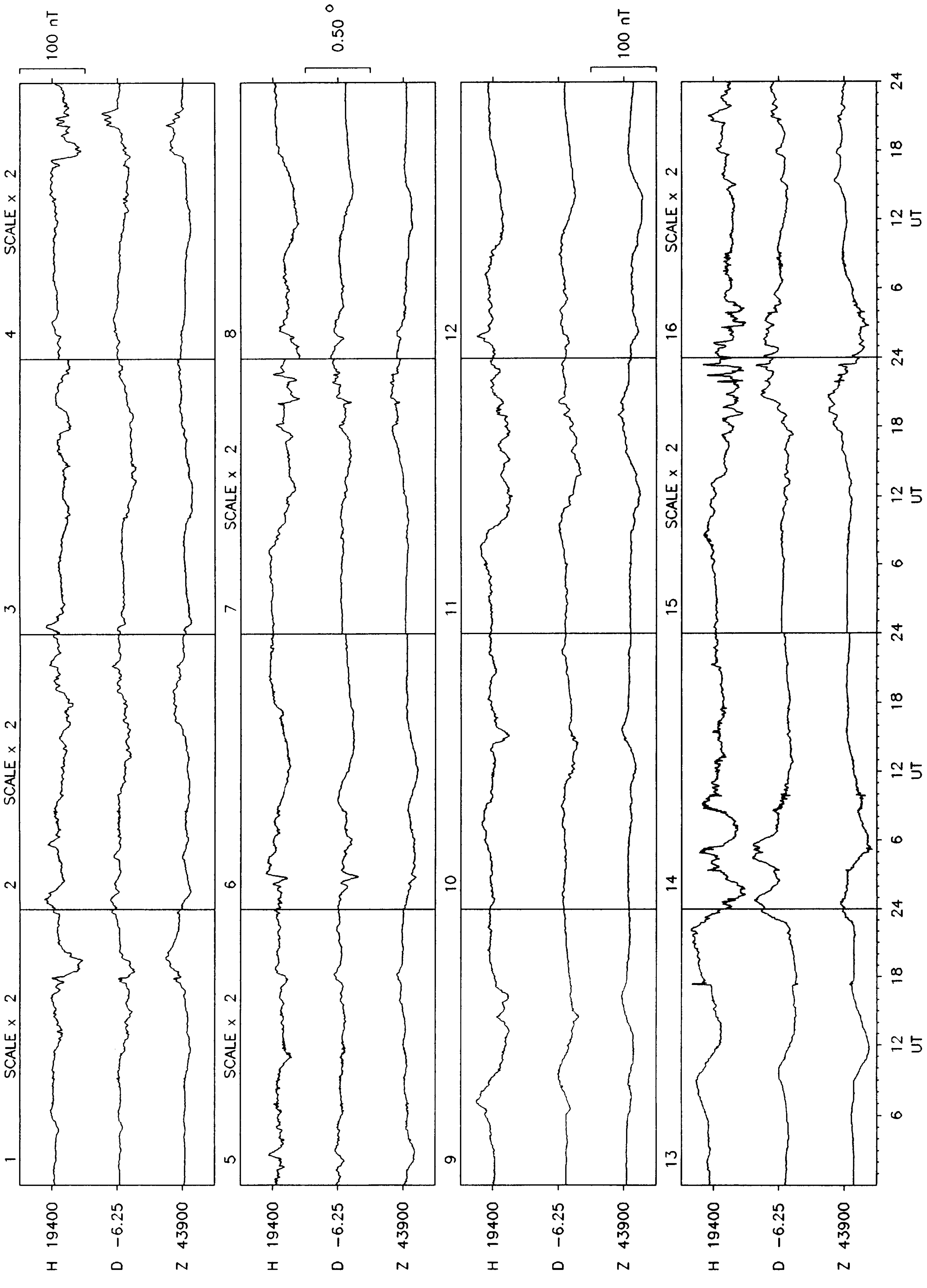
100 nT
0.50 °
100 nT
SCALE x 2
H 19400
D −6.25
Z 43900
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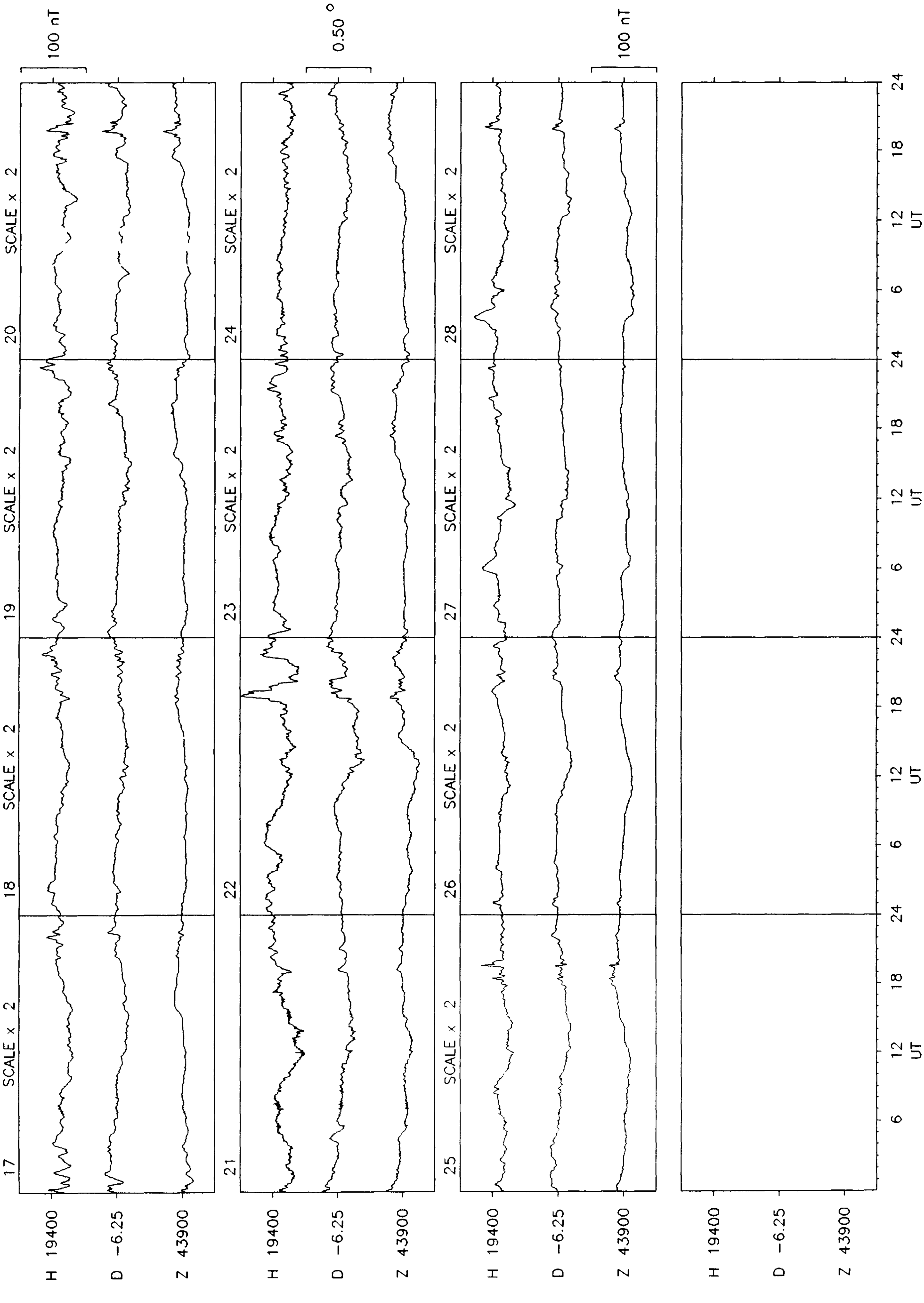
UT


100 nT
0.50 °
100 nT
SCALE x 2
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H 19400
D −6.25
Z 43900
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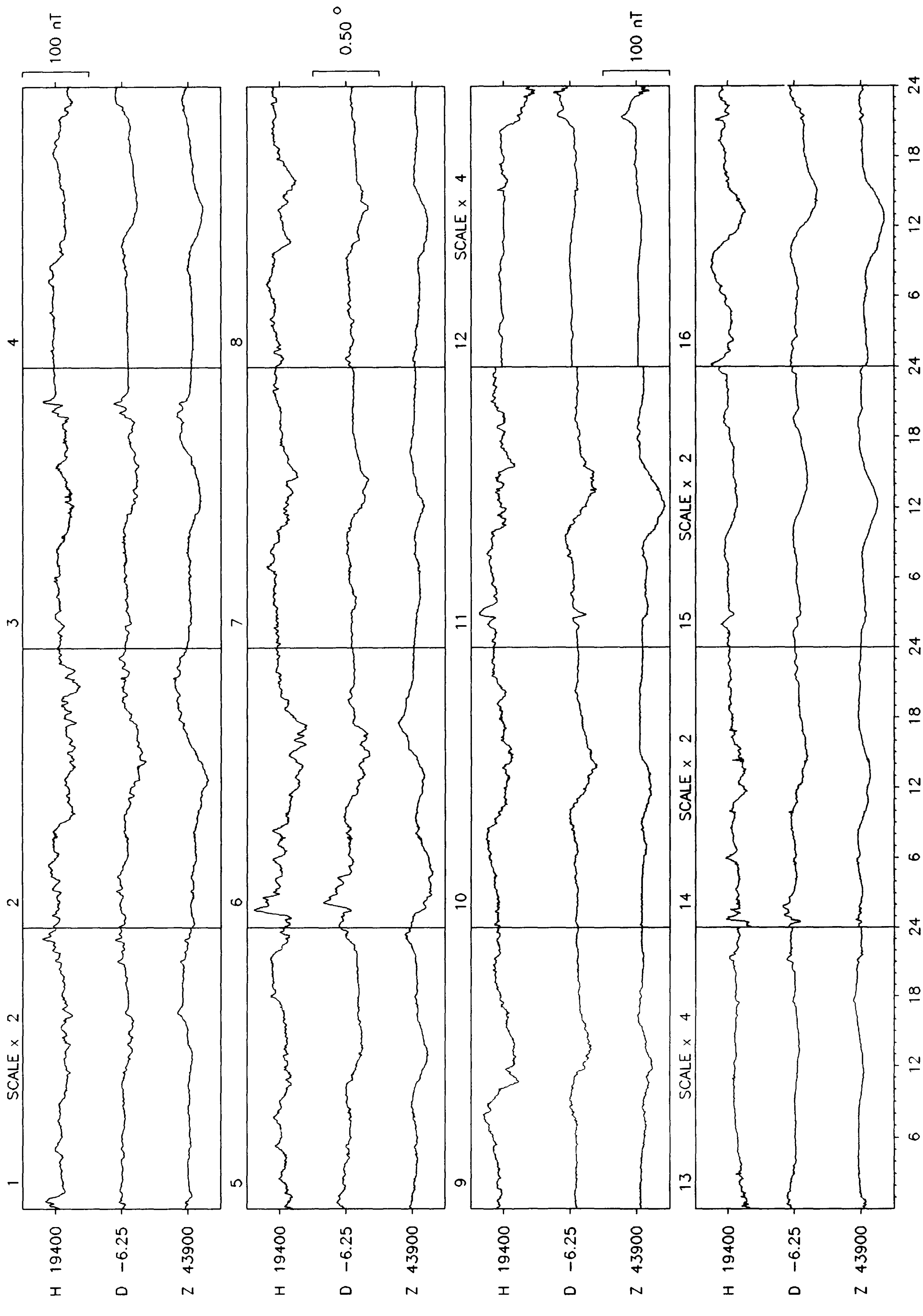
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SCALE x 2
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SCALE x 4
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SCALE x 2
SCALE x 4
H 19400
D −6.25
Z 43900
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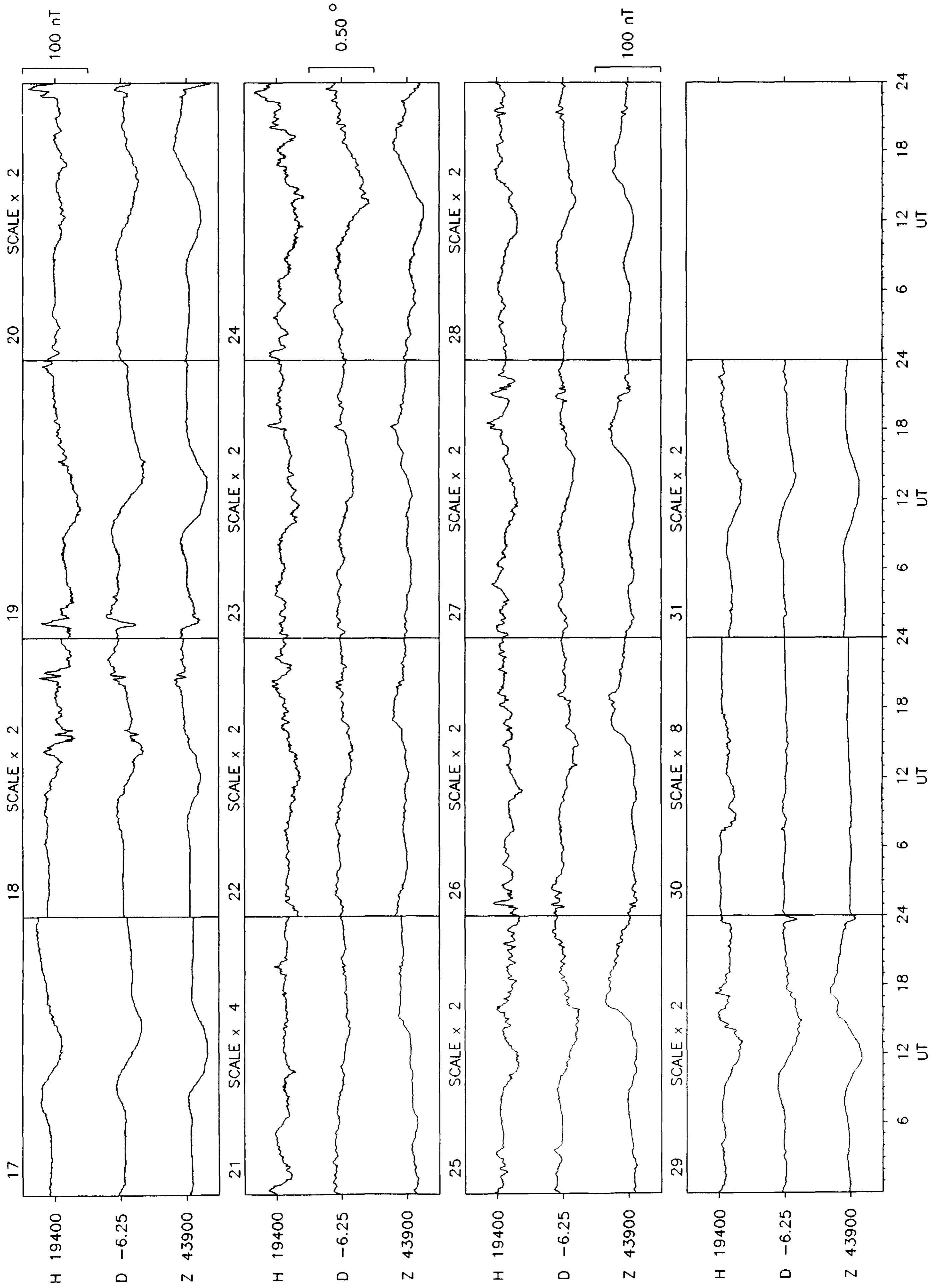

100 nT
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100 nT
H 19400
D −6.25
Z 43900
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SCALE x 2
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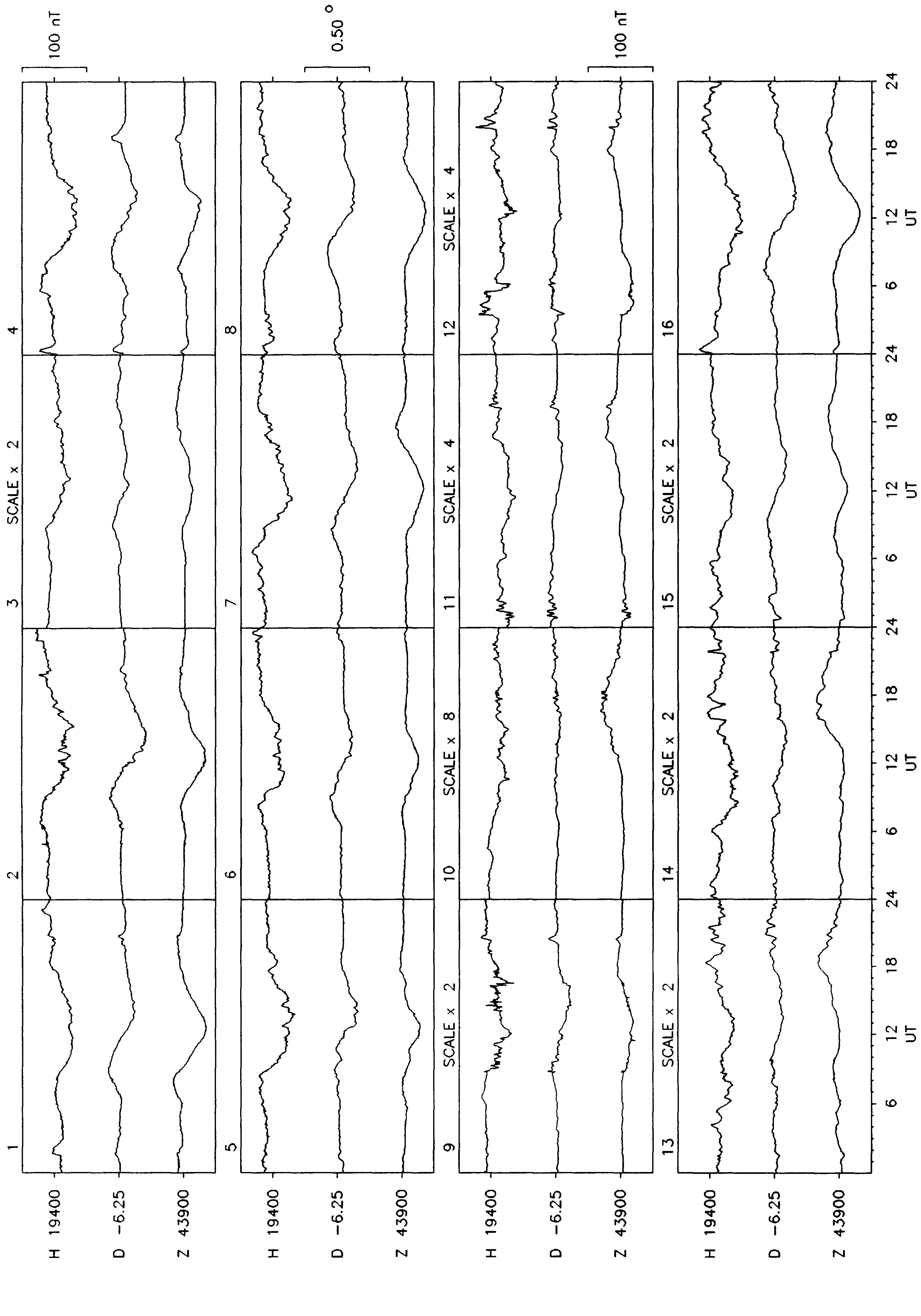

100 nT
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100 nT
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H 19400
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H 19400
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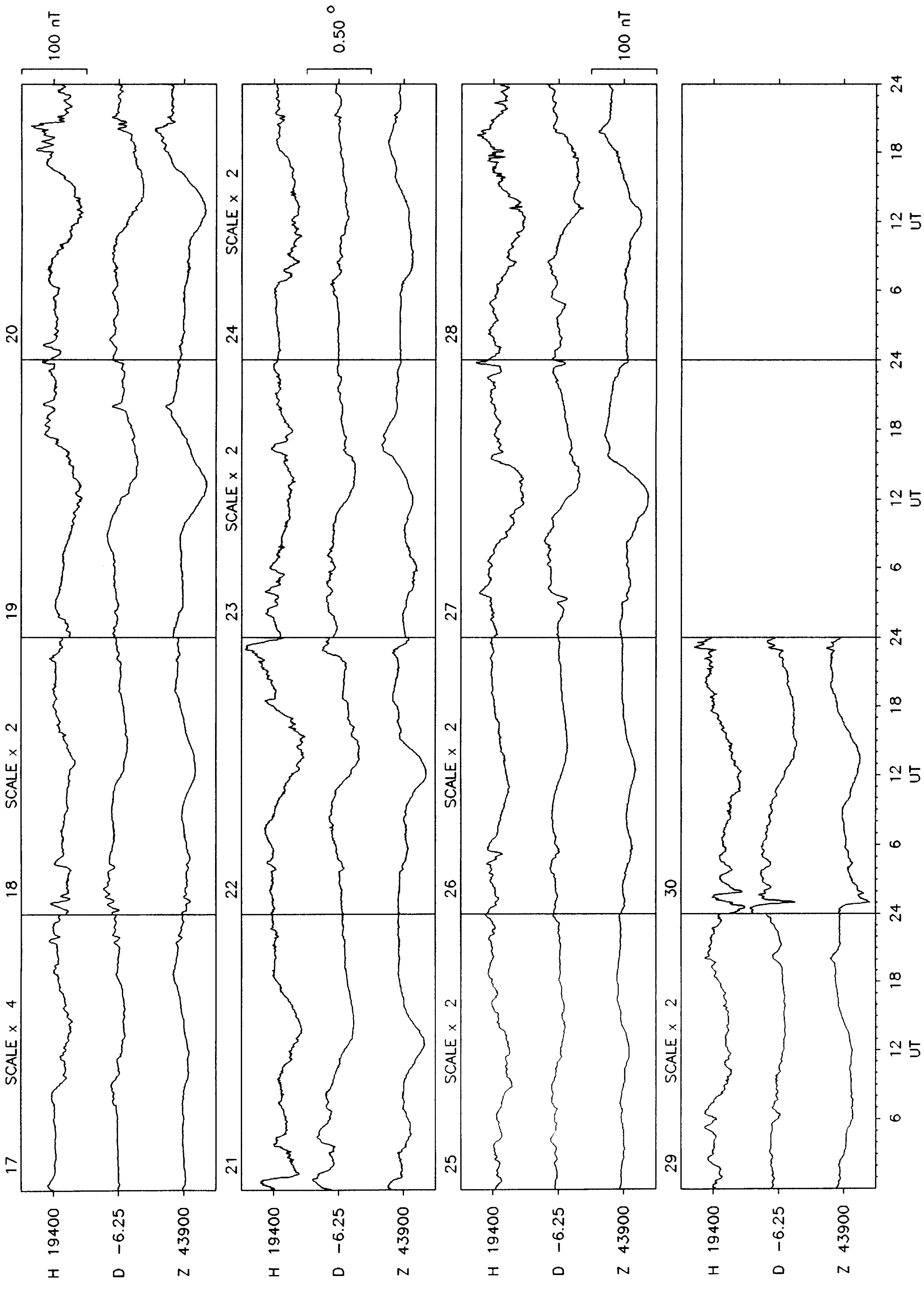
H 19400
D −6.25
Z 43900
100 nT
0.50 °
100 nT
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SCALE x 2
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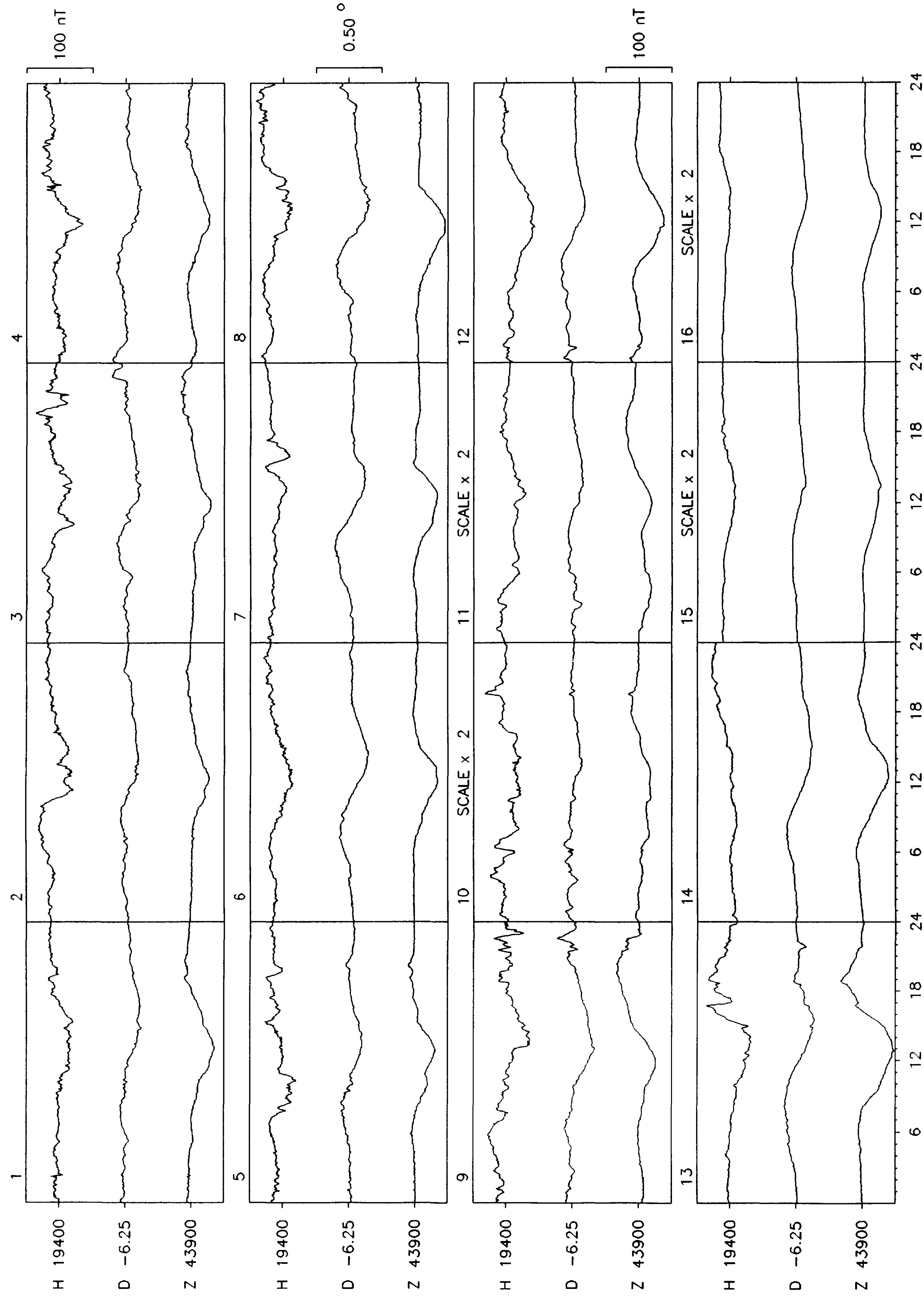
H 19400
D -6.25
Z 43900
100 nT
0.50 °
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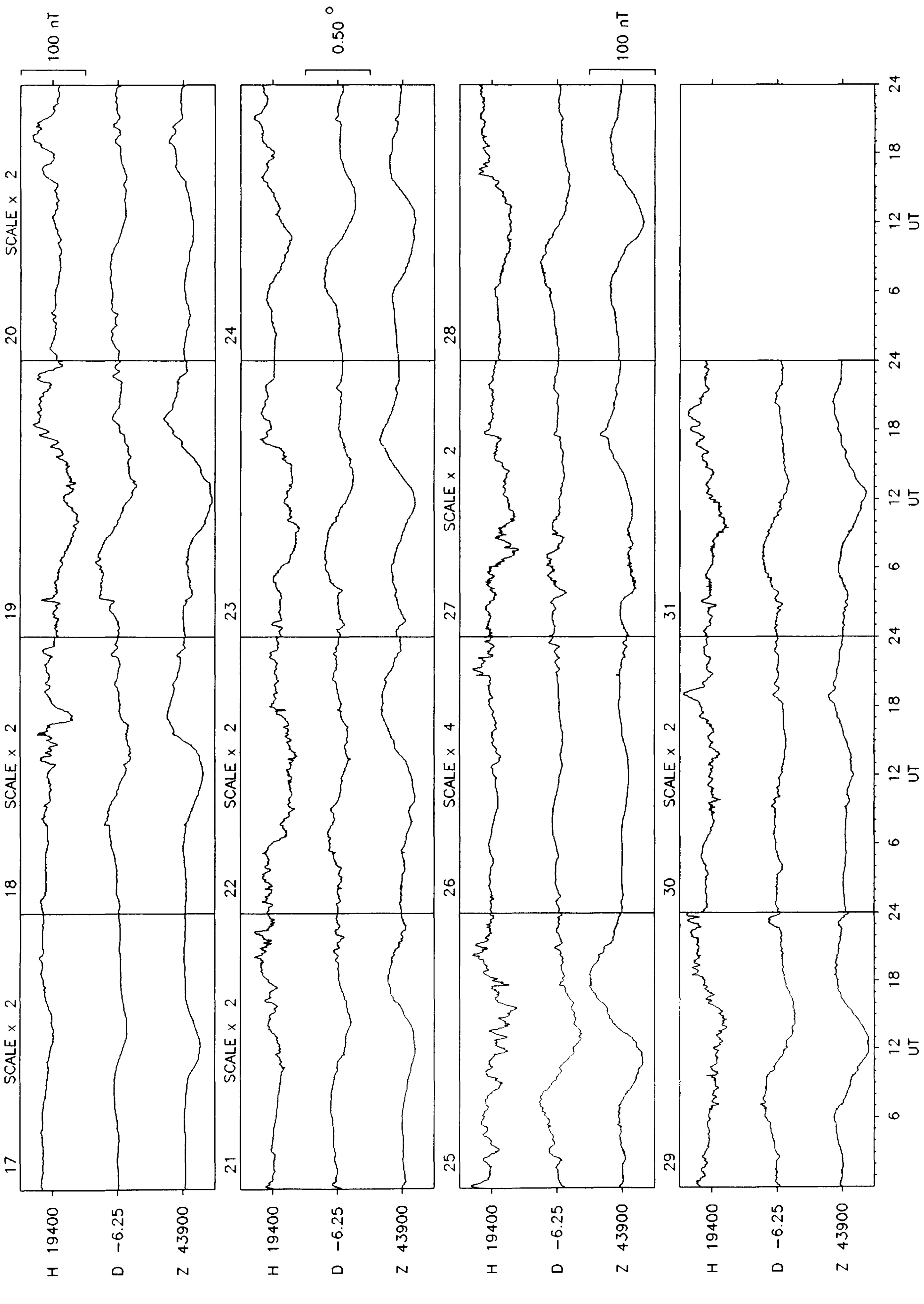
H 19400
D −6.25
Z 43900
100 nT
0.50 °
SCALE x 2
SCALE x 4
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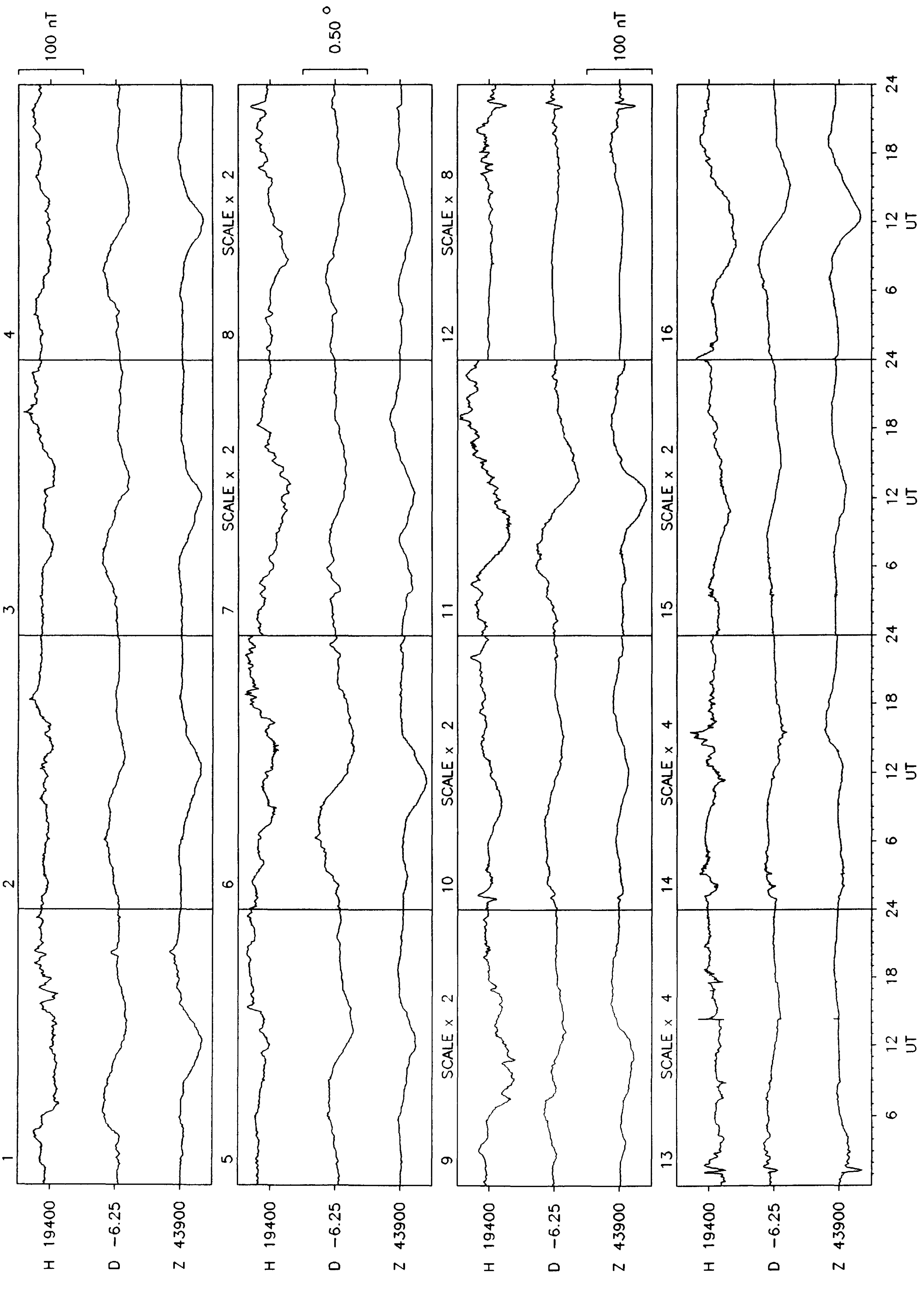
100 nT
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SCALE x 2
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SCALE x 4
SCALE x 2
H 19400
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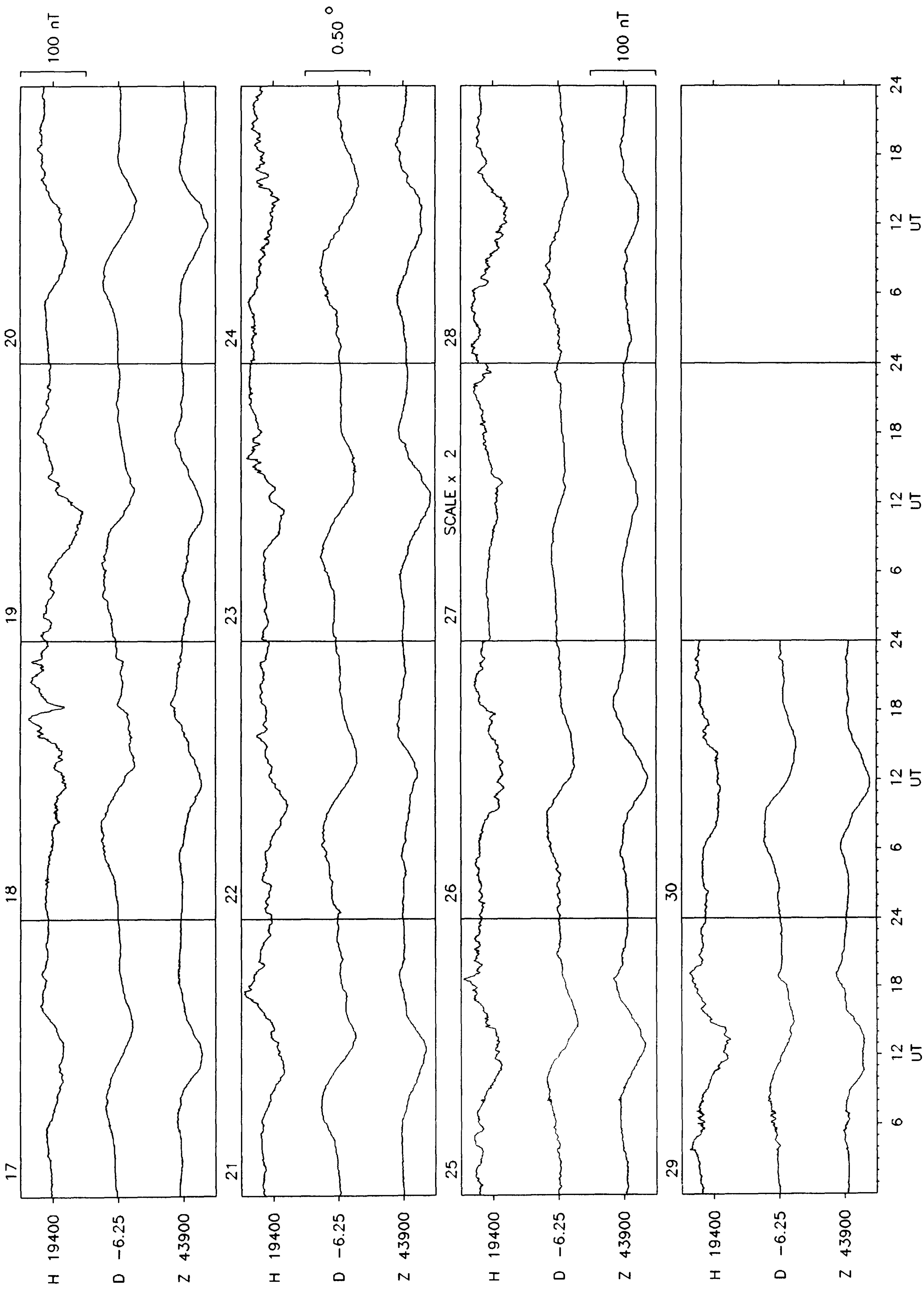
100 nT
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100 nT
SCALE x 2
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H 19400
D −6.25
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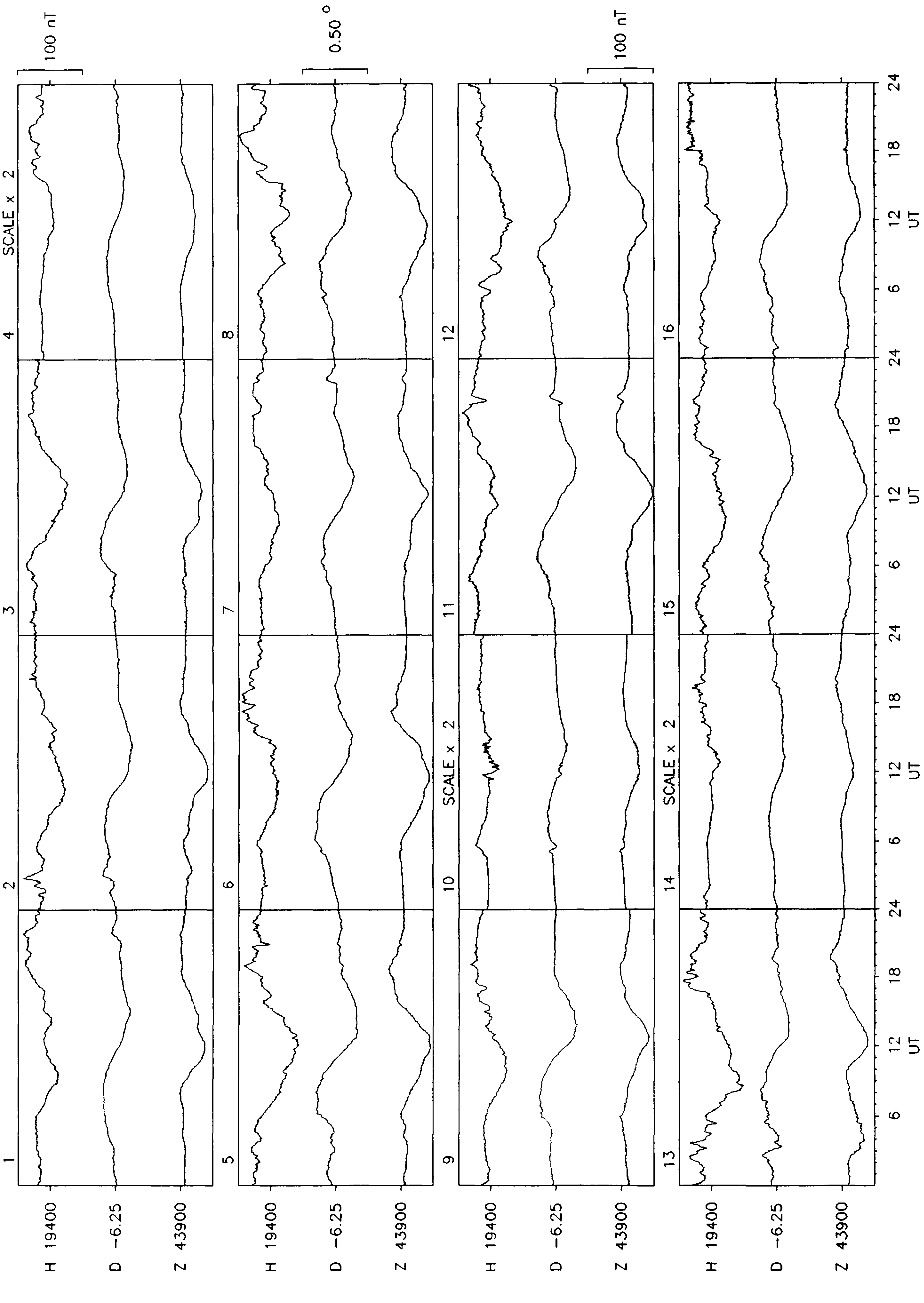
H 19400
D −6.25
Z 43900
100 nT
0.50 °
SCALE x 2
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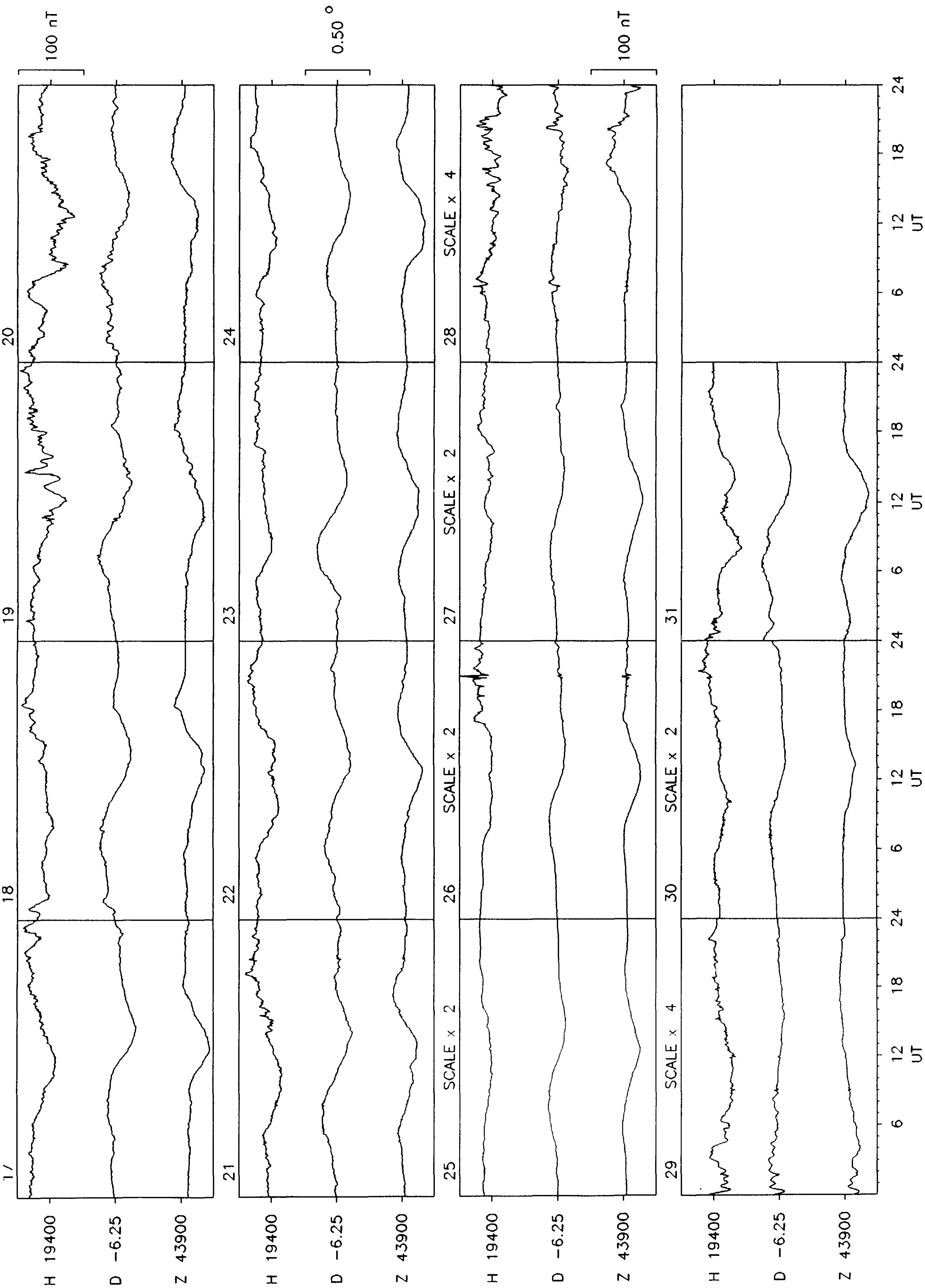
100 nT
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D −6.25
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SCALE x 2
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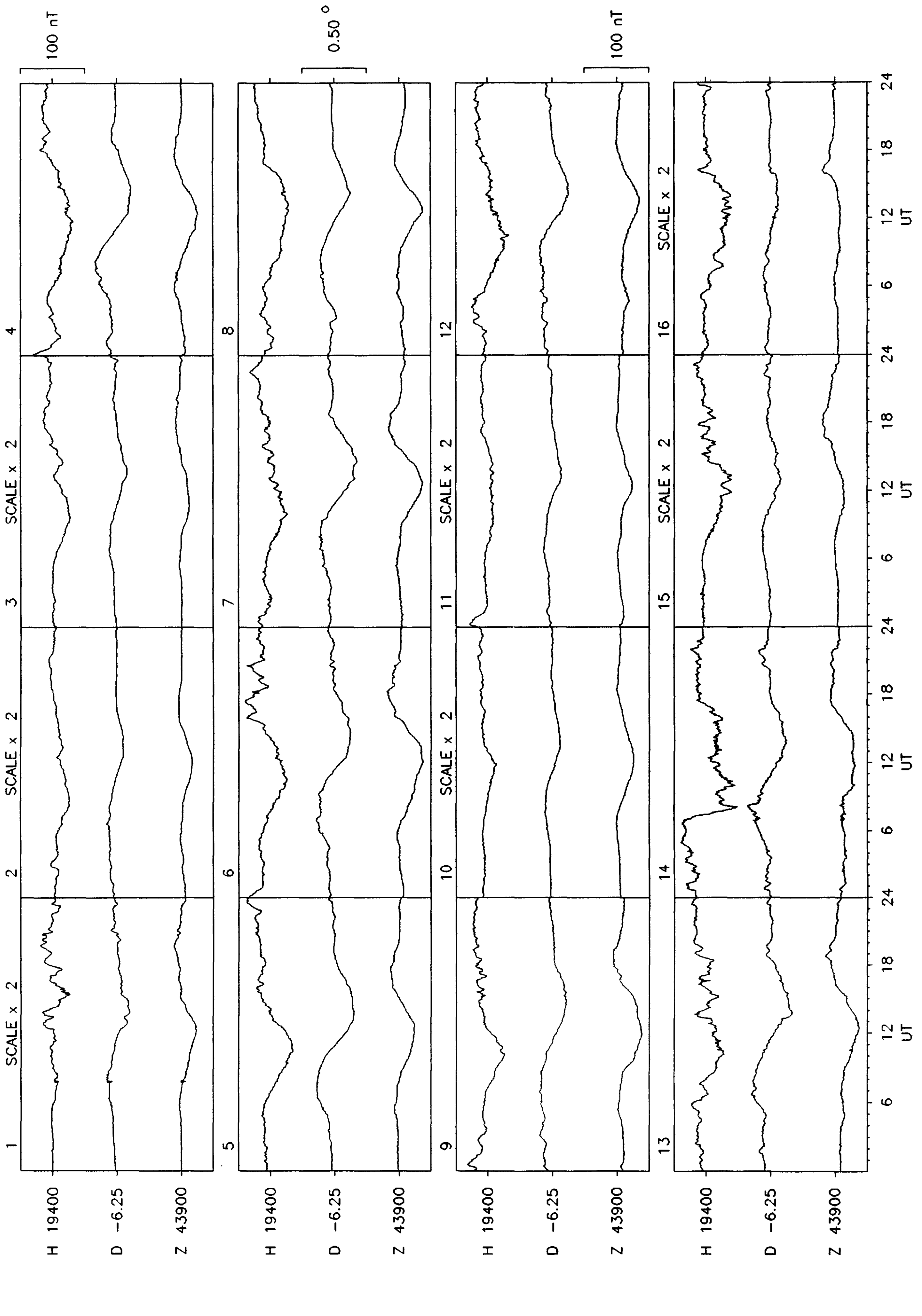
100 nT
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100 nT
H 19400
D -6.25
Z 43900
SCALE x 2
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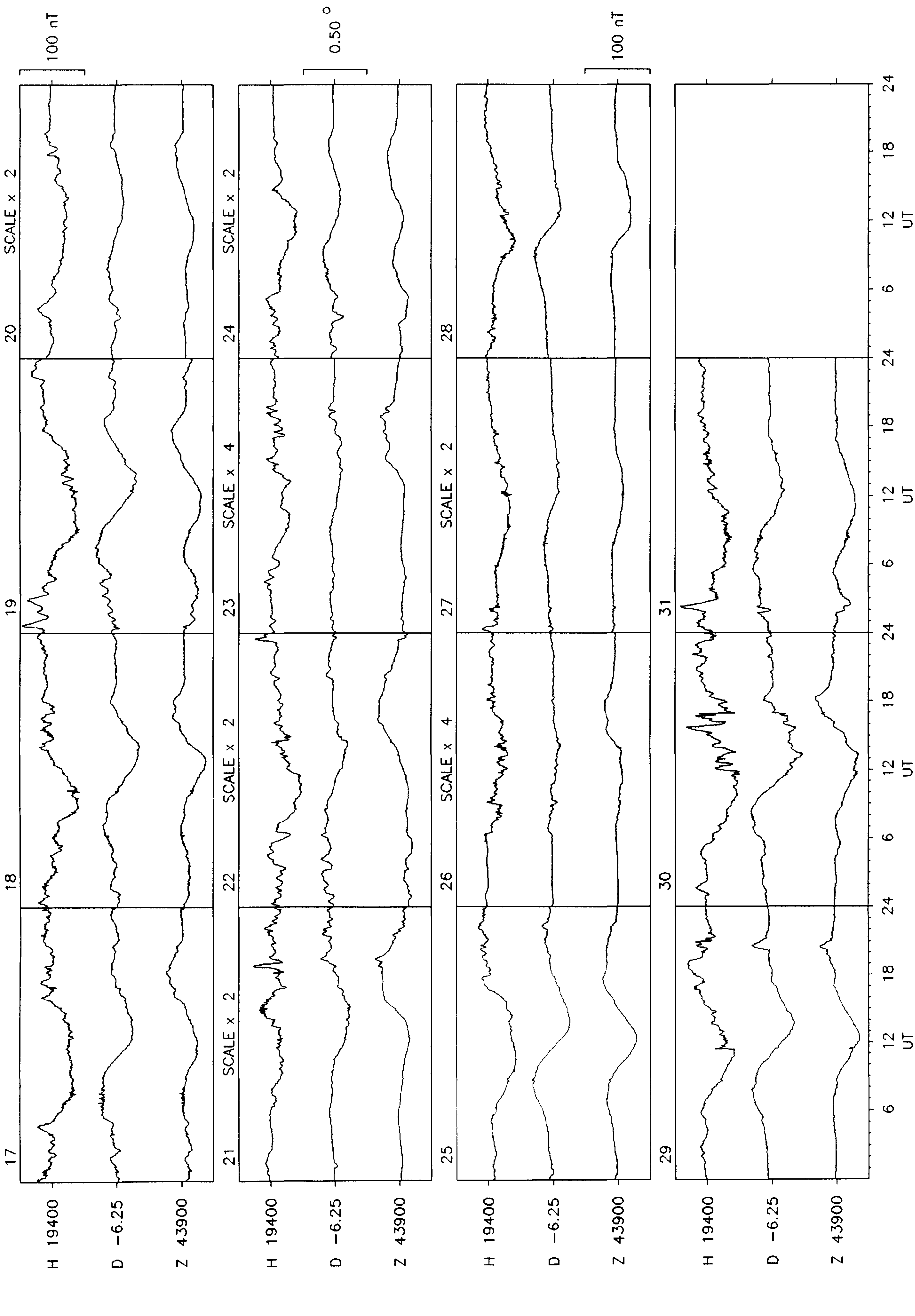
100 nT
0.50 °
100 nT
SCALE x 2
SCALE x 4
H 19400
D −6.25
Z 43900
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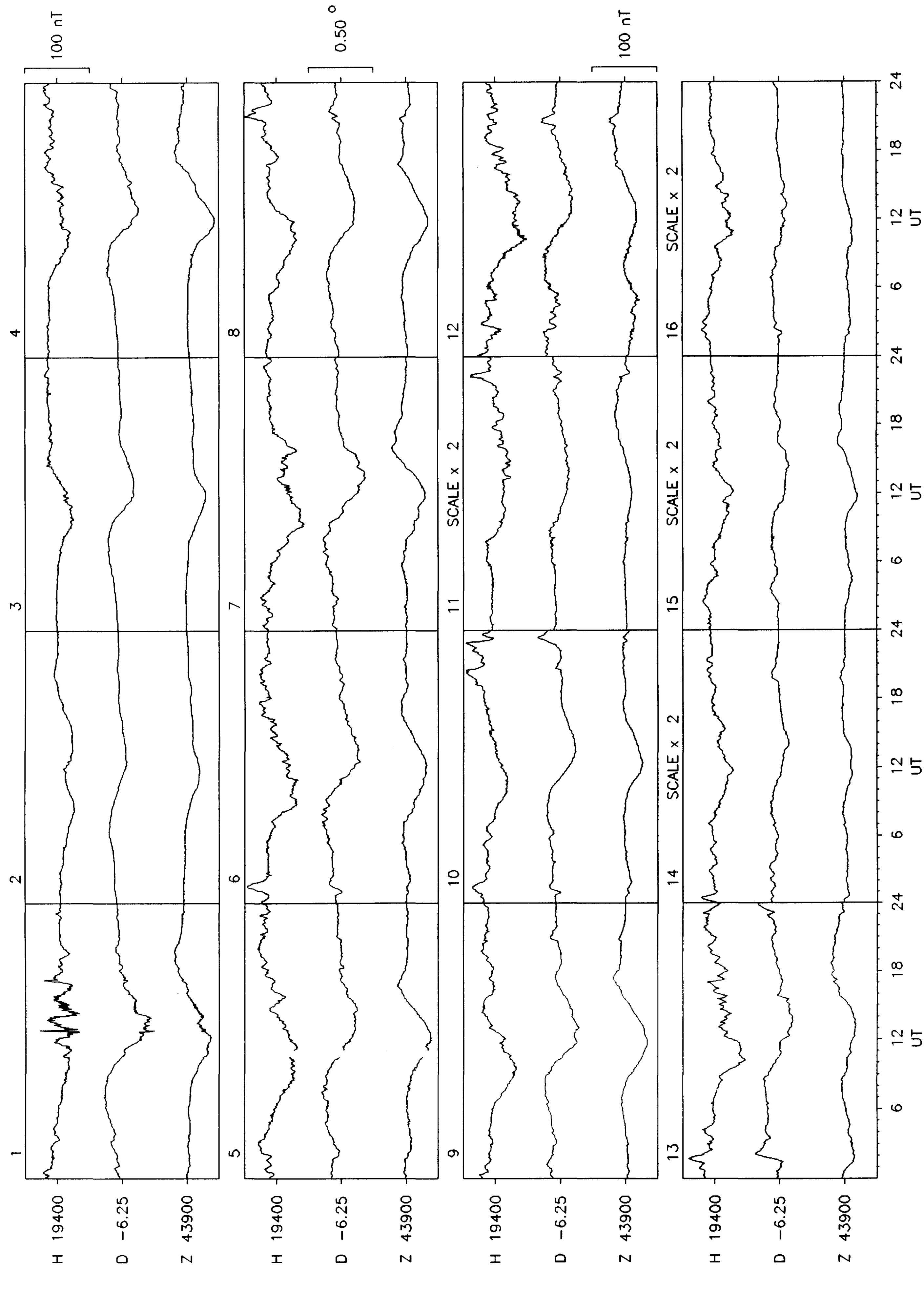
100 nT
0.50 °
100 nT
H 19400
D −6.25
Z 43900
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SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
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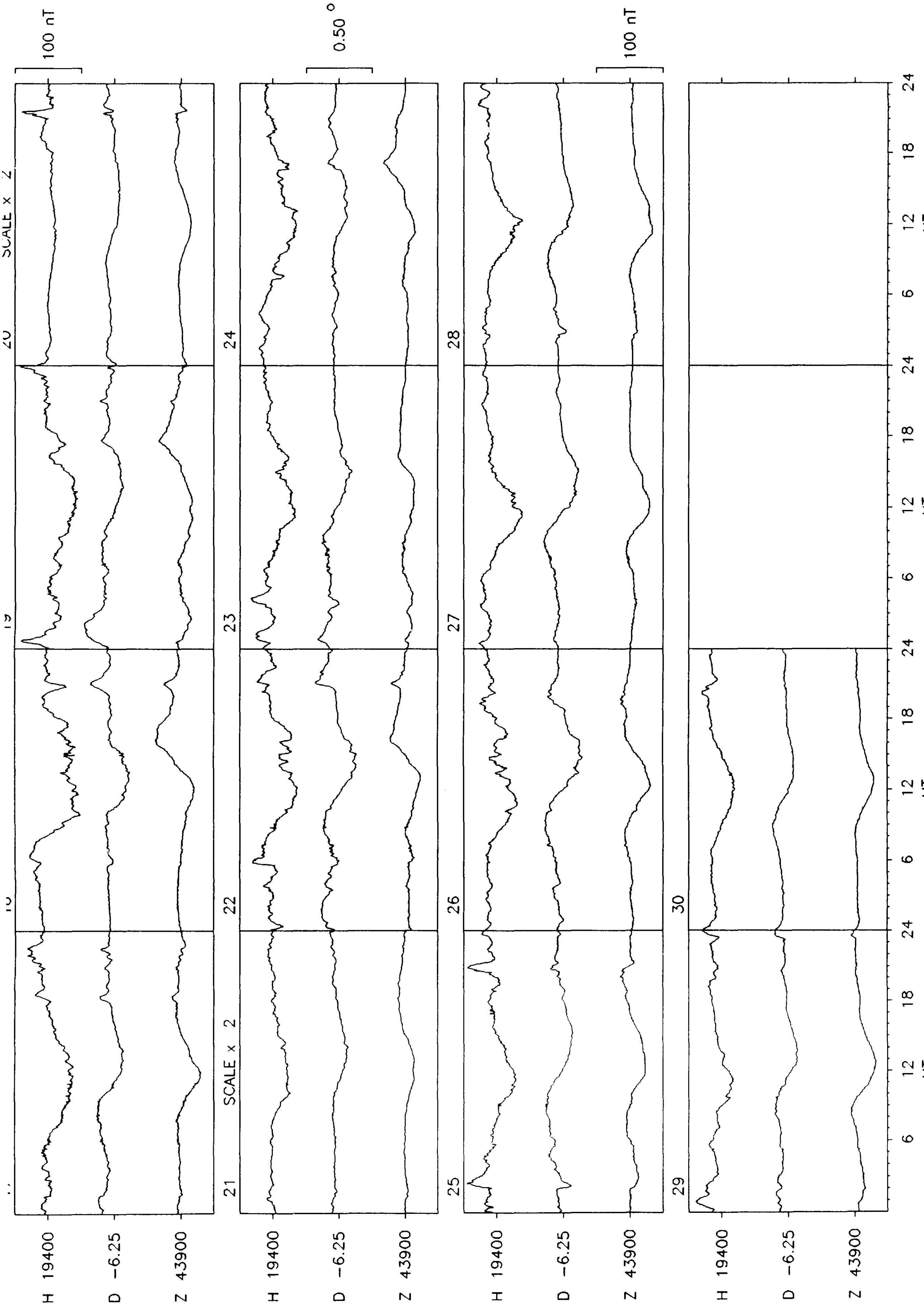
UT



H 19400
D −6.25
Z 43900
100 nT
0.50 °
SCALE x 2
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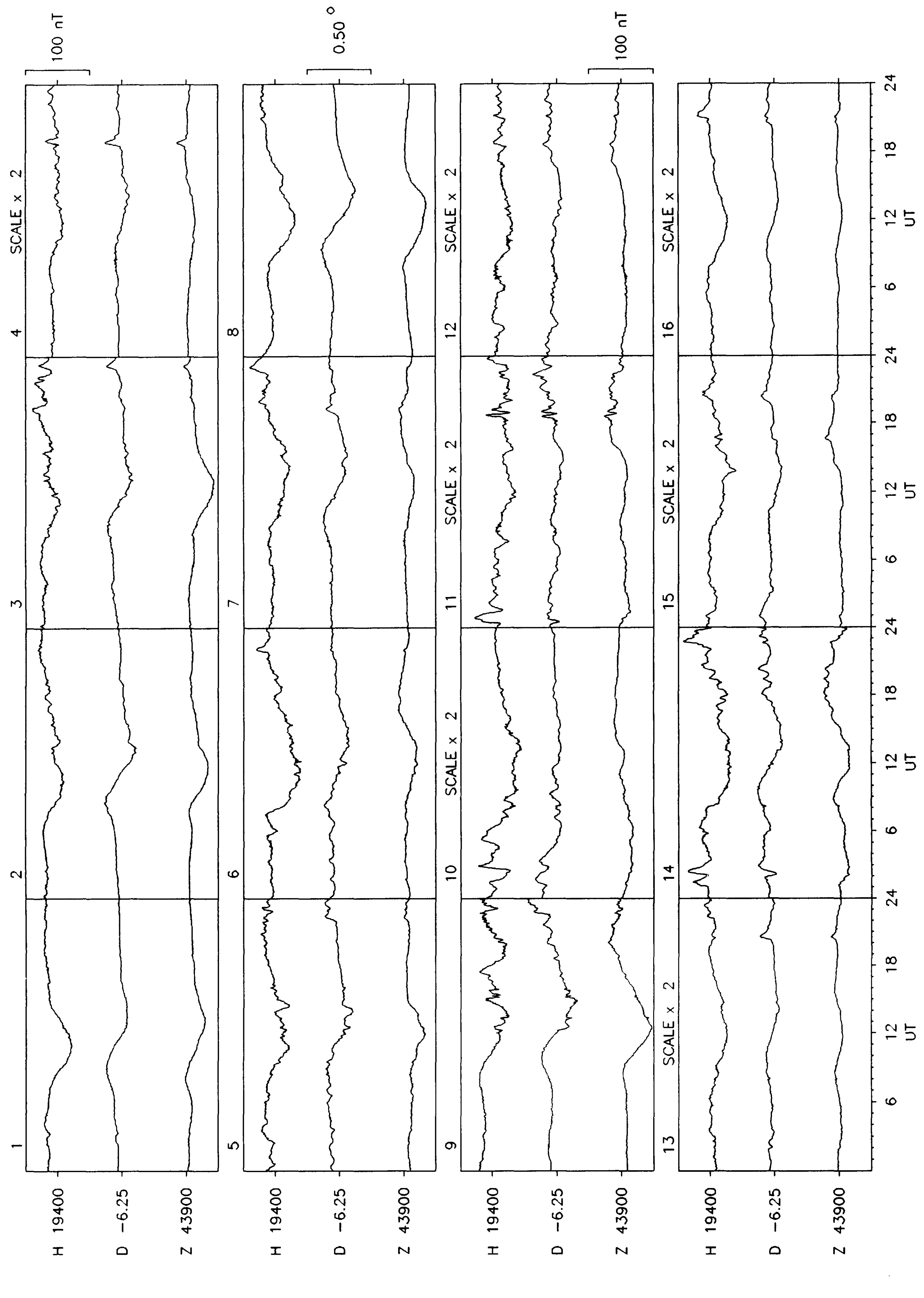
UT



100 nT
0.50 °
100 nT
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
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16
H 19400
D -6.25
Z 43900
6
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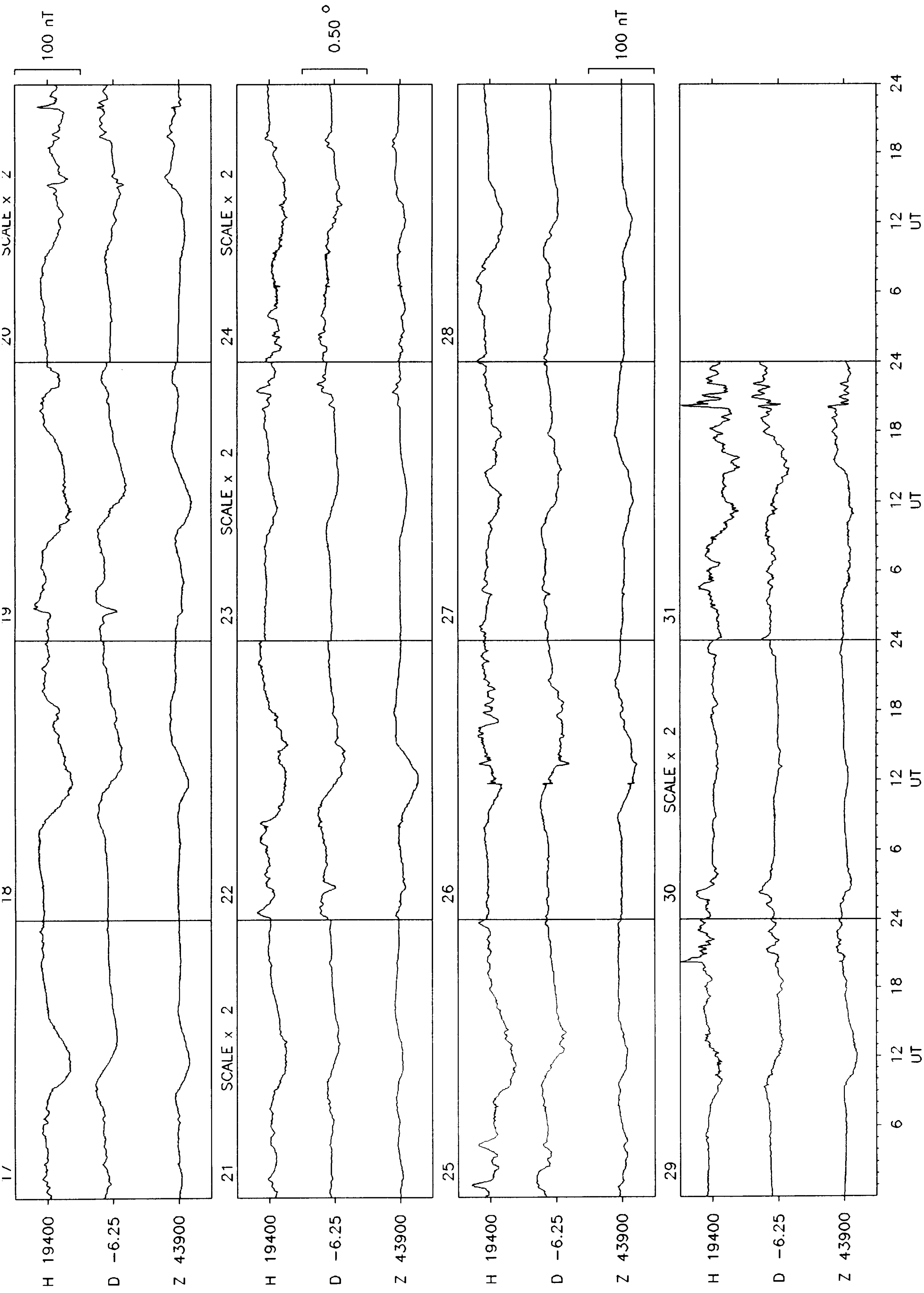
UT


100 nT
0.50 °
100 nT
H 19400
D −6.25
Z 43900
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SCALE x 2
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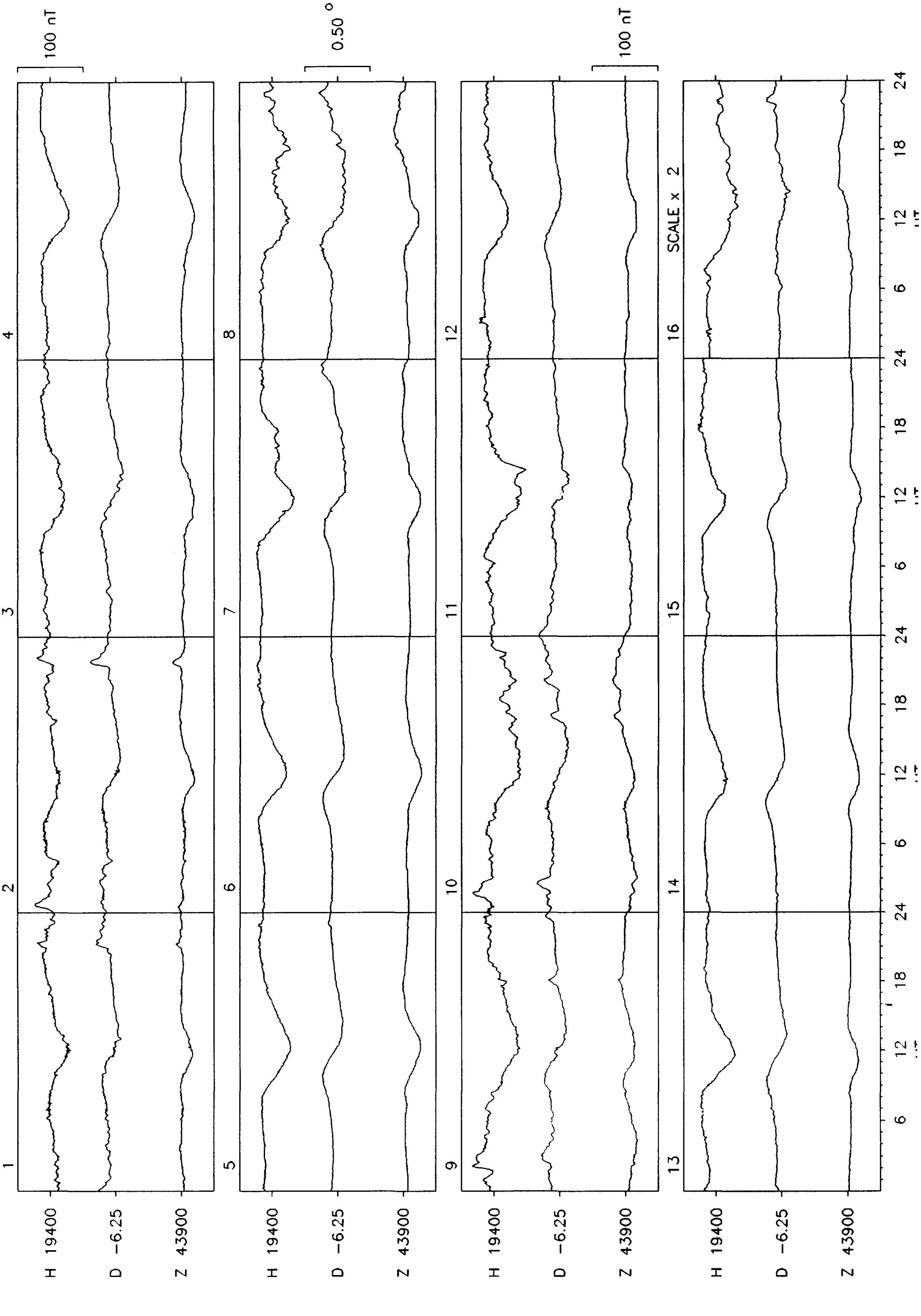
UT


100 nT
0.50 °
100 nT
SCALE x 2
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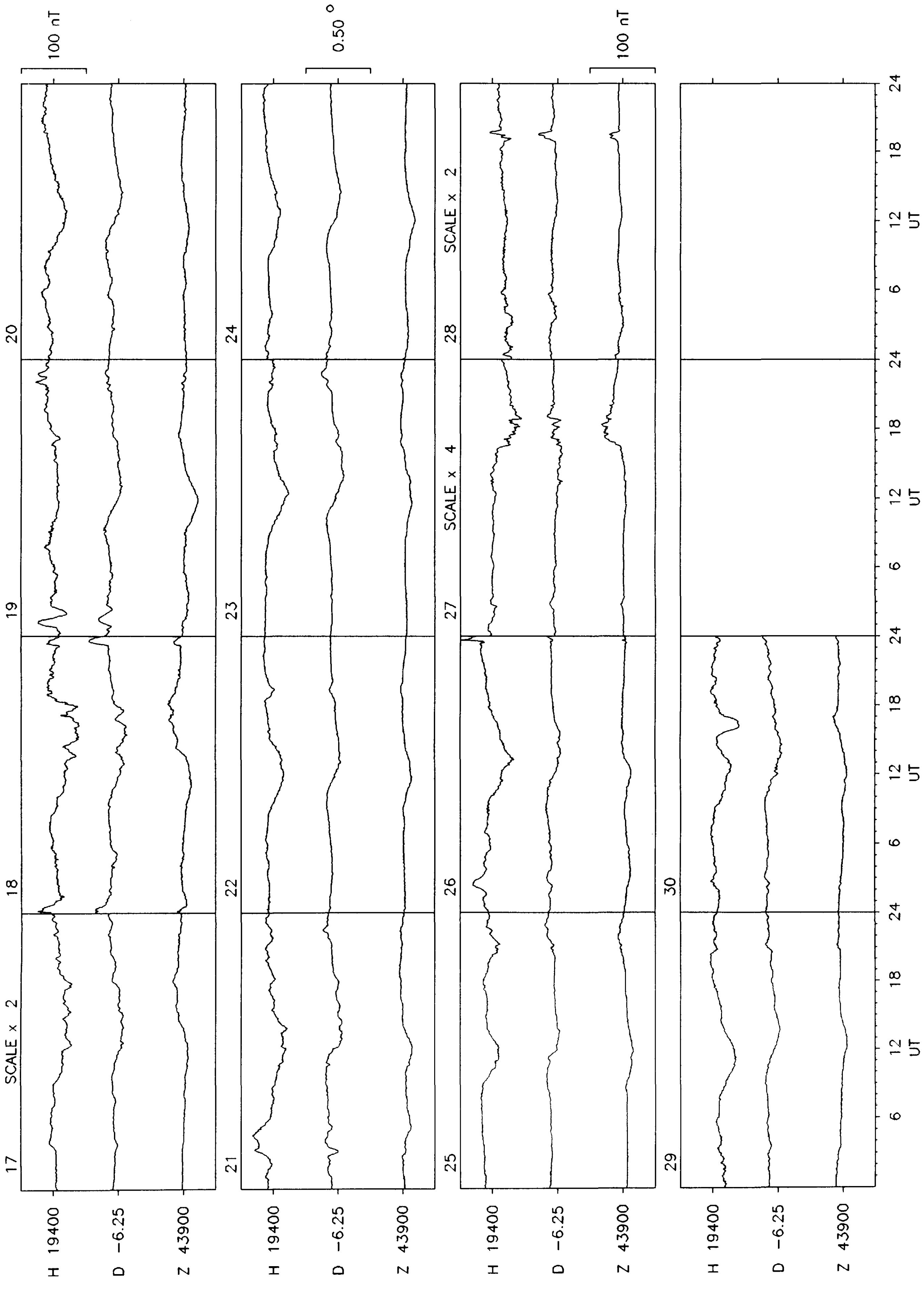
H 19400
D −6.25
Z 43900
6
12
18
24



100 nT
0.50 °
100 nT
SCALE x 2
SCALE x 4
SCALE x 2
17
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H 19400
D −6.25
Z 43900
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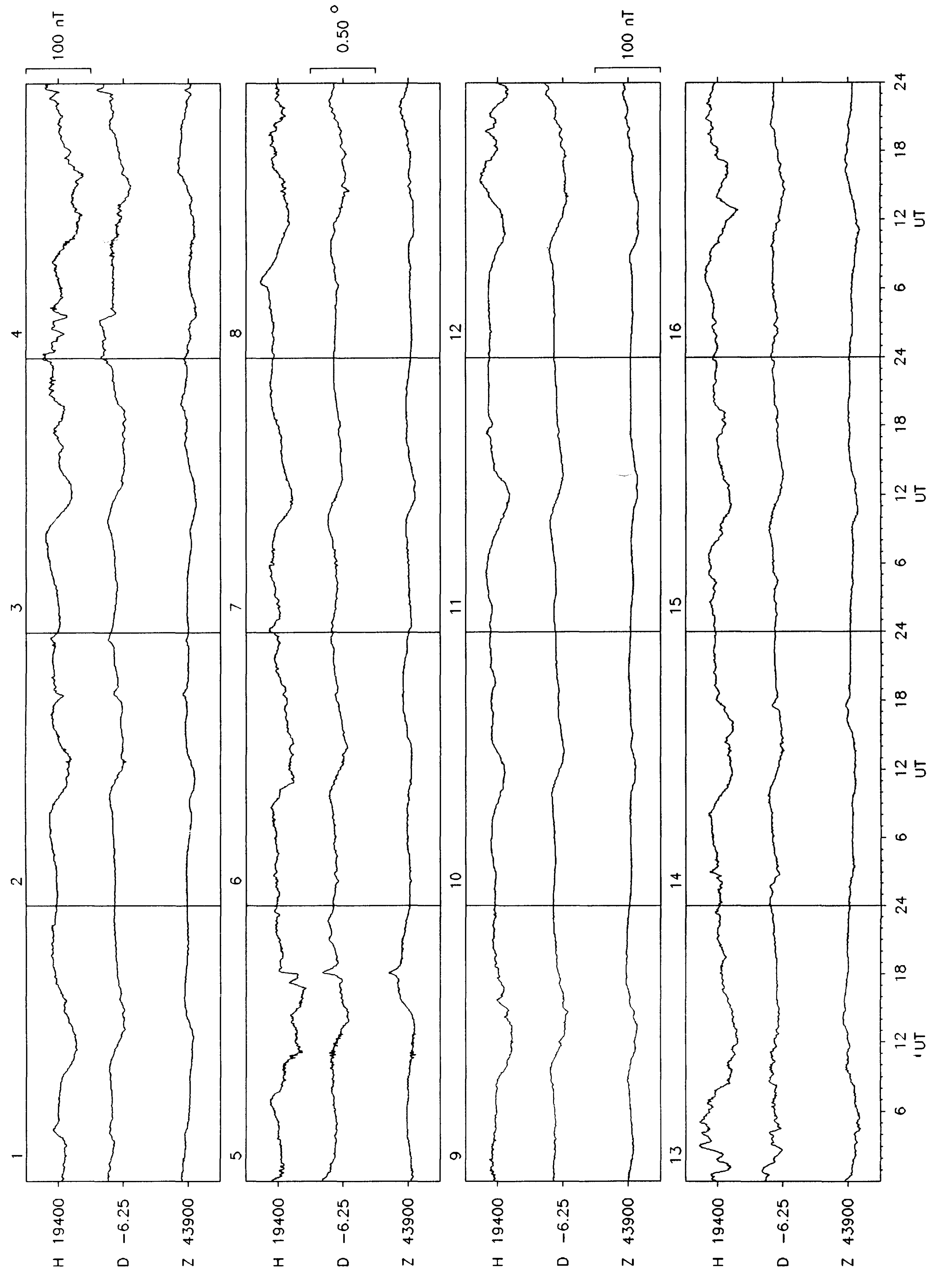
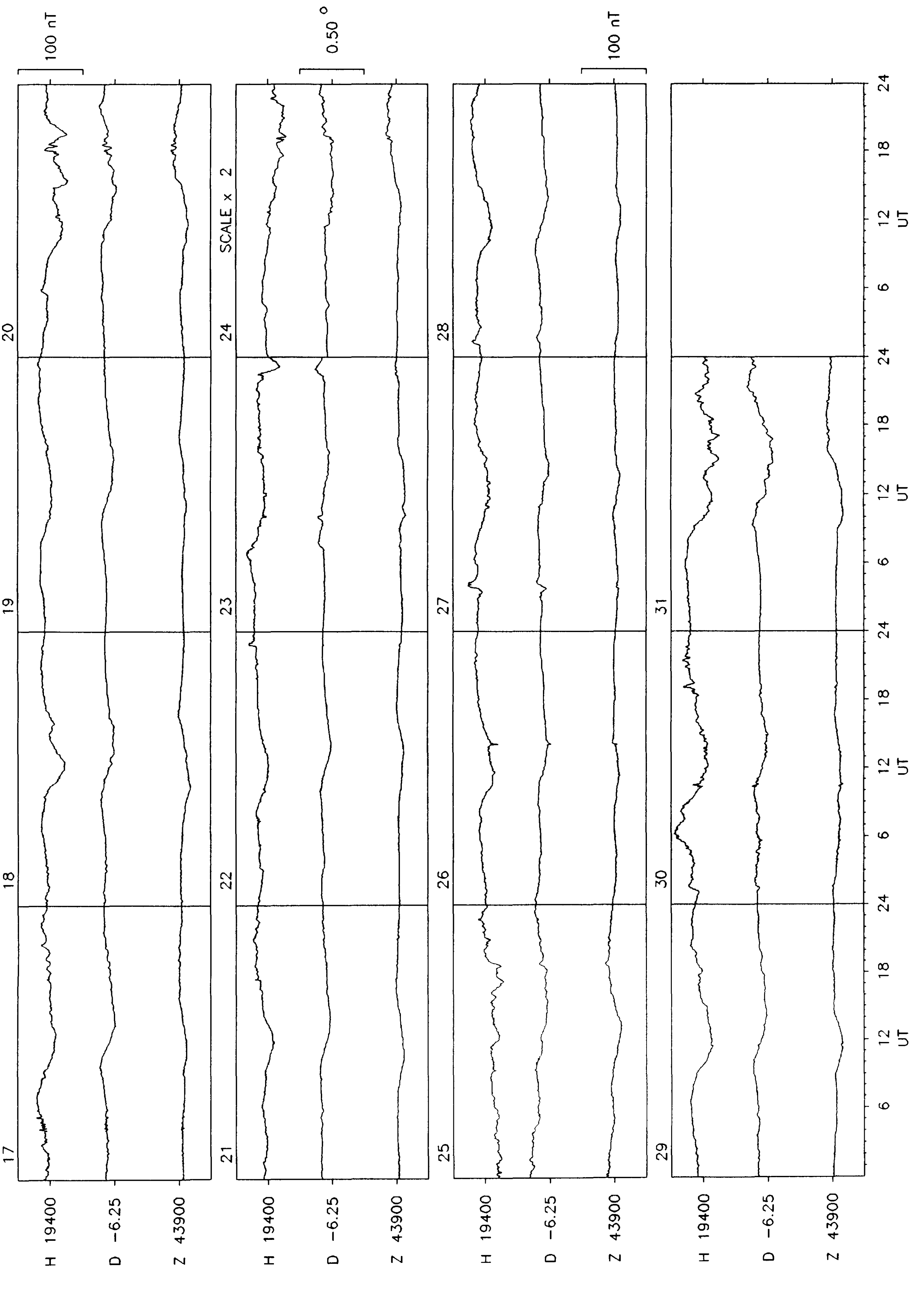
UT


100 nT
0.50 °
100 nT
H 19400
D −6.25
Z 43900
UT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
6 12 18 24


H 19400
D −6.25
Z 43900
100 nT
0.50 °
SCALE x 2
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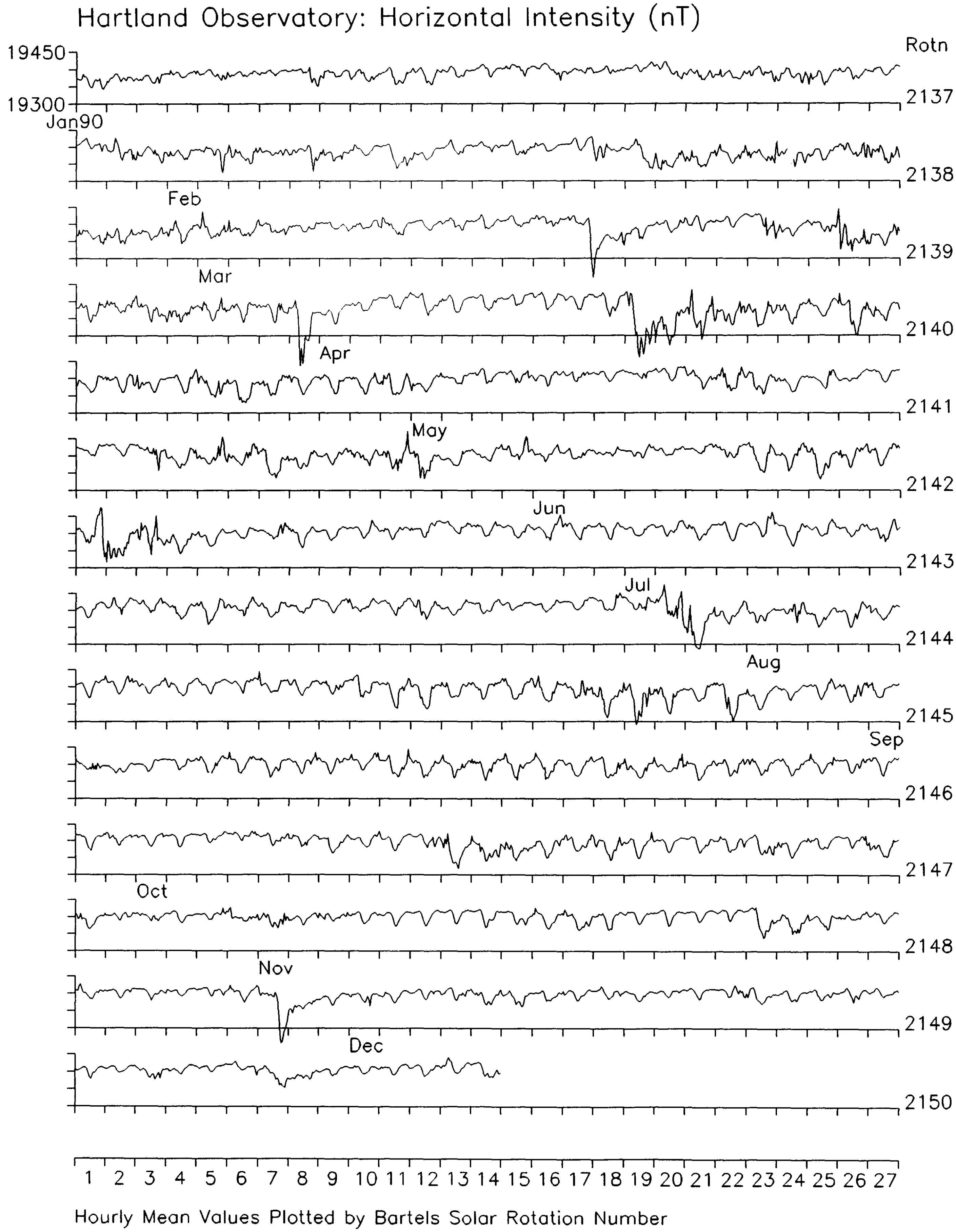
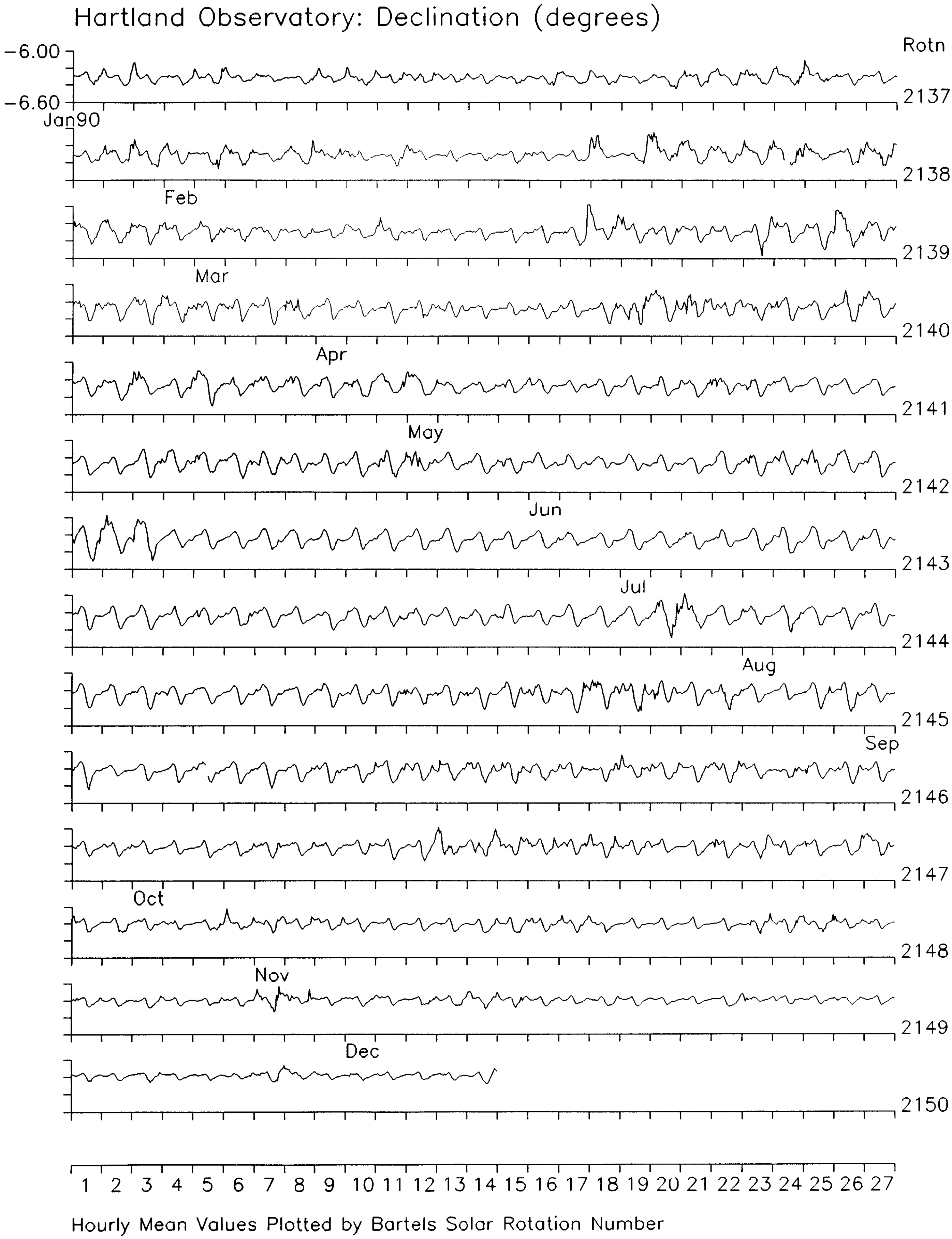
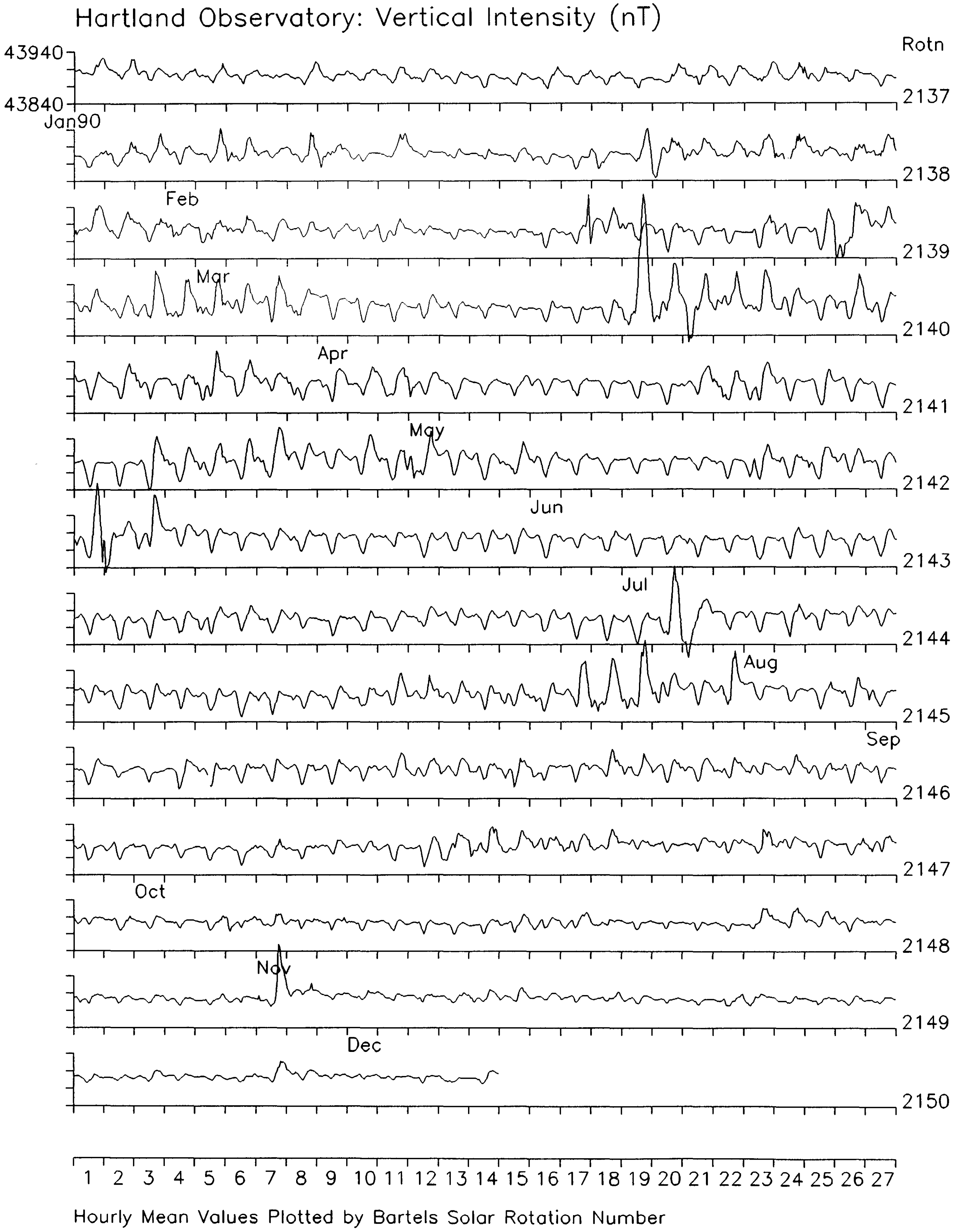
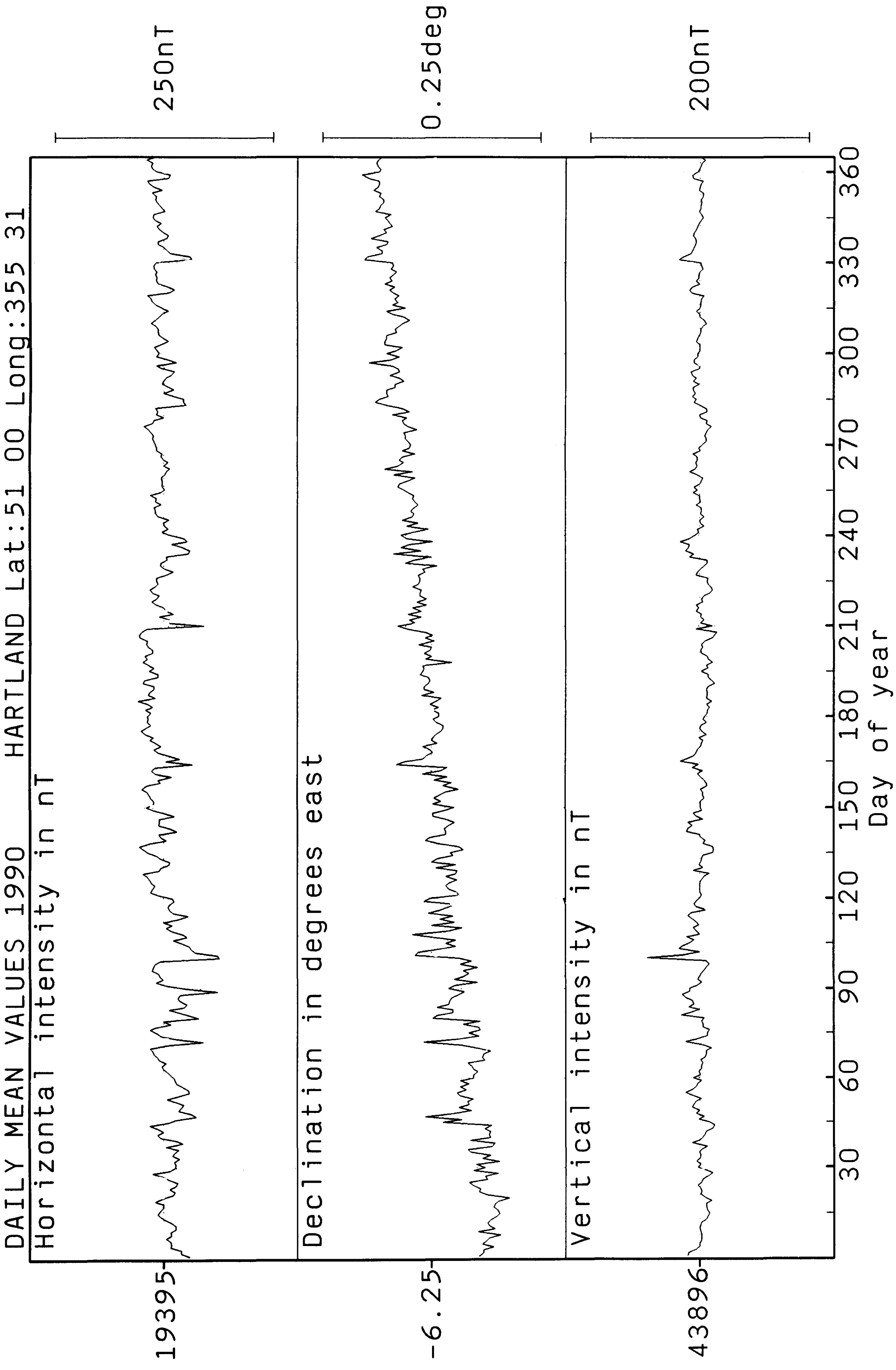
UT


Hartland Observatory: Horizontal Intensity (nT)
19450
19300
Rotn
Jan90
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted by Bartels Solar Rotation Number


Hartland Observatory: Declination (degrees)
−6.00
−6.60
Rotn
Jan90
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted by Bartels Solar Rotation Number


Hartland Observatory: Vertical Intensity (nT)
Rotn
43940
43840
Jan90
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted by Bartels Solar Rotation Number



DAILY MEAN VALUES 1990 HARTLAND Lat:51 00 Long:355 31
Horizontal intensity in nT
Declination in degrees east
Vertical intensity in nT
250nT
0.25deg
200nT
19395
-6.25
43896
30
60
90
120
150
180
210
240
270
300
330
360
Day of year

Monthly and annual mean values for Hartland 1990

Month	D	H	I	X	Y	Z	F
Jan	-6 18.9	19388	66 10.1	19270	-2133	43894	47985
Feb	-6 17.8	19382	66 10.6	19265	-2126	43896	47985
Mar	-6 17.3	19386	66 10.4	19269	-2123	43897	47987
Apr	-6 16.2	19383	66 10.7	19267	-2117	43901	47990
May	-6 16.0	19403	66 9.2	19287	-2118	43895	47992
Jun	-6 15.3	19405	66 9.1	19289	-2114	43895	47993
Jul	-6 14.7	19409	66 8.6	19294	-2111	43889	47989
Aug	-6 14.0	19393	66 9.9	19278	-2106	43896	47989
Sep	-6 13.3	19399	66 9.5	19285	-2102	43896	47991
Oct	-6 12.5	19396	66 9.7	19282	-2098	43897	47991
Nov	-6 12.3	19398	66 9.6	19284	-2097	43898	47993
Dec	-6 11.5	19402	66 9.3	19289	-2093	43897	47994
Annual	-6 15.0	19395	66 9.7	19280	-2111	43896	47990

D and I are given in degrees and decimal minutes
H, X, Y, Z and F are given in nanoteslas

HARTLAND OBSERVATORY K INDICES 1990

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	2323 3343	1322 3454	4322 3444	2130 2332	2222 2321	2432 2332	1112 2223	1233 4443	3314 4421	1110 0001	3222 2123	2301 2211
2	4122 2335	4433 3444	2322 3333	1232 3333	2223 3222	2222 2221	3311 1331	3323 3223	1112 2110	1021 3121	3321 2224	0111 2222
3	5222 2331	3112 2332	2222 2343	2243 3333	2333 2344	1222 2232	2321 1122	2222 3434	0112 3211	2212 2233	2211 2212	2111 2233
4	3202 3224	3322 3355	1112 1123	3332 2330	3223 4332	2321 2222	2112 1433	4221 2321	0013 3323	2232 3353	2111 0010	3423 3334
5	3223 3344	4333 2442	3222 2214	2123 3321	2233 2332	2222 2212	3321 3243	1201 2223	3323 3322	2222 3213	0000 0001	3123 2332
6	4221 2123	4331 1111	5432 3331	1032 2312	1221 2222	2333 3333	2111 2331	3321 2332	3233 3322	2233 2223	1000 0011	2112 2121
7	3221 2101	1133 3455	1222 2311	2232 2322	2221 3311	3533 4333	1221 2223	3212 2223	2333 3312	1112 2233	0012 2133	2221 1011
8	1111 2443	3321 2200	3223 3312	3111 2212	2322 3324	3443 3434	1222 2333	2321 2311	2212 3344	2111 1111	2022 2333	0121 3232
9	4322 3214	0131 2211	1123 2221	2244 5542	3232 3334	3454 3432	2311 2220	3212 1221	3213 3332	1111 4334	3322 2333	1112 2210
10	4233 2333	1112 3322	1122 3221	4466 6666	4553 3443	4333 3324	1433 4321	1121 3222	3221 1134	5554 4323	3322 1333	0000 2010
11	3233 3343	1222 3232	3332 3321	5434 3552	4433 3333	2333 3333	1222 2231	4211 2323	2343 3445	5444 3455	3223 3221	0000 2110
12	3333 2342	3321 0000	3333 3456	4655 5565	3221 1212	3343 4668	2233 2223	3212 2212	3333 3343	4333 3444	1211 1111	0000 3323
13	3222 2222	1111 1315	5332 2434	3433 3344	1212 2433	6554 6543	3432 2432	2332 3332	5323 3334	3233 2354	1111 0000	4332 1122
14	3121 3211	4443 2312	5434 4322	3354 4444	1101 1111	5535 5633	3112 3343	3353 3323	4443 4442	4321 2344	1011 0000	3211 2310
15	2221 3321	2233 4466	3321 2233	4332 3321	1211 2220	2322 2333	2232 2321	2323 5444	3333 4433	4323 4343	1101 1111	1211 2221
16	1212 2343	5533 3454	3121 2223	3232 2233	1110 1211	3121 2111	2221 2232	3343 3424	4334 4323	2232 2234	2232 3334	2212 3222
17	3221 2224	5433 3344	2011 1101	4245 4435	1111 1221	0111 1210	1211 2223	3322 2323	3223 3233	3221 0011	2322 3433	2201 1122
18	2222 3233	4233 3344	1133 4555	5432 3334	2333 4534	1322 2343	3222 2331	3233 3322	1243 3344	0011 1232	4211 3344	1101 3210
19	0011 2122	4323 3355	5222 2212	3221 2343	3333 3333	2222 3221	2223 4333	4422 3433	4322 2434	4322 1223	4221 1213	0001 1110
20	3222 2342	4333 4665	4233 3435	3222 2343	4323 3444	0001 2210	3342 3332	3432 3431	4211 1235	2222 3445	2221 1111	1211 2332
21	4233 4333	4322 3332	6445 4354	4421 2212	4223 3344	0111 2332	2311 2332	3233 4554	3223 3333	3232 2122	2312 3123	1100 0112
22	3423 3243	2322 3254	4333 3444	1321 2334	3443 3433	3212 1212	2322 2212	4443 4435	3332 3444	4221 2311	1000 2020	1111 1002
23	3333 3344	4234 4544	4333 3444	4443 3443	2423 2422	1122 3321	1310 0211	4554 6553	3332 2322	1112 1235	0000 2223	0022 1213
24	4333 3345	4323 3444	3332 3333	1343 3333	1222 2333	2322 2222	1221 1120	3433 5331	2232 3432	4333 3341	2100 0001	1213 3344
25	4233 3322	3433 3354	4433 4544	3333 3323	3333 3333	2222 2232	1211 1210	2111 1323	3322 2243	4311 2212	1002 2133	2312 2332
26	3213 3321	3323 3343	5434 4443	3431 2212	4443 4456	2212 1222	1121 2454	2355 5544	3232 3342	1113 3332	3212 3213	2111 2011
27	1211 0220	4444 3233	4433 3445	2422 3323	3554 3423	1112 3334	1223 3332	4233 4322	2232 3321	2212 3322	4433 4664	1312 2211
28	0111 2233	3532 4342	3343 3334	3322 3343	1121 3322	2222 2211	3564 5566	2112 2111	3322 3112	2122 0000	3422 2252	2111 1111
29	4334 3343		3233 4435	4443 2345	2322 2333	1223 3231	6654 5434	1223 2243	3221 1023	0112 2243	2211 0122	1111 1121
30	4321 3453		3465 4532	5332 2324	2334 3453	1111 2212	2323 2234	3233 3543	3111 1122	5421 3223	2212 3323	2323 2232
31	4333 2331		2131 3222		3313 2332		3333 2211	4323 2222		3333 3454		1112 3233

DAILY aa INDICES

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	31	39	34	14	16	23	11	37	36	4	17	11
2	34	49	23	22	23	12	14	17	6	11	21	10
3	26	21	19	35	31	13	11	25	8	19	12	15
4	23	43	10	17	23	12	17	14	19	31	5	32
5	32	38	19	19	22	11	22	10	22	20	3	23
6	18	16	33	15	11	26	12	17	25	23	4	13
7	12	46	16	18	12	34	12	14	27	16	14	9
8	27	14	20	11	19	35	17	12	22	7	21	18
9	27	14	18	46	31	49	9	10	19	25	23	12
10	34	21	14	134	47	31	25	11	21	70	23	4
11	35	21	24	72	32	24	14	20	44	60	20	5
12	30	11	51	102	10	98	16	13	33	42	13	18
13	18	18	45	48	19	80	25	30	35	33	5	25
14	15	48	42	55	6	79	23	35	39	29	3	16
15	19	65	20	30	9	20	16	43	45	40	7	11
16	22	63	15	22	6	9	12	35	35	20	34	19
17	23	54	6	56	8	5	10	24	21	10	29	13
18	20	40	53	37	47	20	16	19	34	9	31	10
19	10	51	25	20	28	12	29	25	28	19	18	6
20	33	66	46	27	31	5	29	31	26	34	12	17
21	37	28	86	22	36	10	14	47	26	20	21	7
22	35	37	41	26	48	12	13	58	34	18	7	10
23	44	55	42	52	20	16	8	88	22	21	10	20
24	48	41	28	39	12	14	9	30	26	35	5	32
25	30	43	51	30	30	14	8	12	20	15	12	20
26	22	33	55	19	56	15	23	71	23	19	21	9
27	7	41	47	24	59	19	18	28	16	15	77	13
28	15	40	33	33	13	16	117	10	18	9	30	9
29	46		40	48	20	16	83	20	14	21	10	7
30	47		83	30	36	8	25	39	9	38	18	37
31	31		13		19		14	25		46		21
Monthly mean value	27.4	37.8	33.9	37.4	25.2	24.6	21.6	28.1	25.1	25.1	17.6	15.2

Annual Mean Value for 1990 = 26.5

Annual Values of Geomagnetic Elements

Abinger

Year	D	H	I	X	Y	Z	F
1925.5	-13 22.7	18597	66 35.2	18092	-4303	42946	46800
1926.5	-13 10.4	18581	66 36.3	18092	-4234	42947	46794
1927.5	-12 58.4	18575	66 36.2	18101	-4170	42932	46778
1928.5	-12 47.0	18564	66 37.2	18104	-4108	42941	46782
1929.5	-12 35.8	18555	66 37.2	18108	-4047	42918	46758
1930.5	-12 24.6	18542	66 38.2	18109	-3985	42924	46757
1931.5	-12 13.7	18543	66 38.1	18122	-3928	42923	46757
1932.5	-12 2.6	18536	66 39.1	18128	-3868	42940	46770
1933.5	-11 51.7	18532	66 39.4	18136	-3809	42942	46770
1934.5	-11 41.1	18533	66 39.7	18149	-3754	42955	46782
1935.5	-11 30.3	18527	66 40.9	18155	-3695	42981	46805
1936.5	-11 20.0	18524	66 41.8	18163	-3640	43007	46827
1937.5	-11 10.4	18522	66 42.7	18171	-3589	43031	46848
1938.5	-11 1.4	18522	66 43.2	18180	-3542	43050	46865
1939.5	-10 51.9	18528	66 43.5	18196	-3492	43074	46890
1940.5	-10 43.0	18533	66 43.9	18210	-3446	43099	46915
1941.5	-10 33.8	18539	66 44.3	18225	-3399	43128	46944
1942.5	-10 24.8	18554	66 43.9	18248	-3354	43146	46966
1943.5	-10 16.2	18556	66 44.5	18259	-3308	43172	46991
1944.5	-10 7.8	18566	66 44.3	18277	-3265	43189	47010
1945.5	-9 59.5	18573	66 44.3	18291	-3223	43207	47030
1946.5	-9 51.1	18569	66 45.4	18295	-3177	43235	47054
1947.5	-9 43.1	18577	66 45.2	18310	-3136	43246	47067
1948.5	-9 35.4	18593	66 44.4	18333	-3098	43255	47082
1949.5	-9 27.5	18607	66 44.0	18354	-3058	43273	47104
1950.5	-9 19.7	18628	66 43.0	18382	-3019	43288	47126
1951.5	-9 12.2	18648	66 42.1	18408	-2983	43305	47149
1952.5	-9 4.7	18670	66 41.0	18436	-2946	43316	47168
1953.5	-8 57.5	18695	66 39.5	18467	-2911	43321	47183
1954.5	-8 50.9	18720	66 38.1	18497	-2879	43332	47203
1955.5	-8 43.6	18738	66 37.4	18521	-2843	43348	47225
1956.5	-8 36.8	18750	66 37.4	18539	-2808	43376	47255
1957.1	-8 32.9	18755	66 37.6	18547	-2788	43394	47274

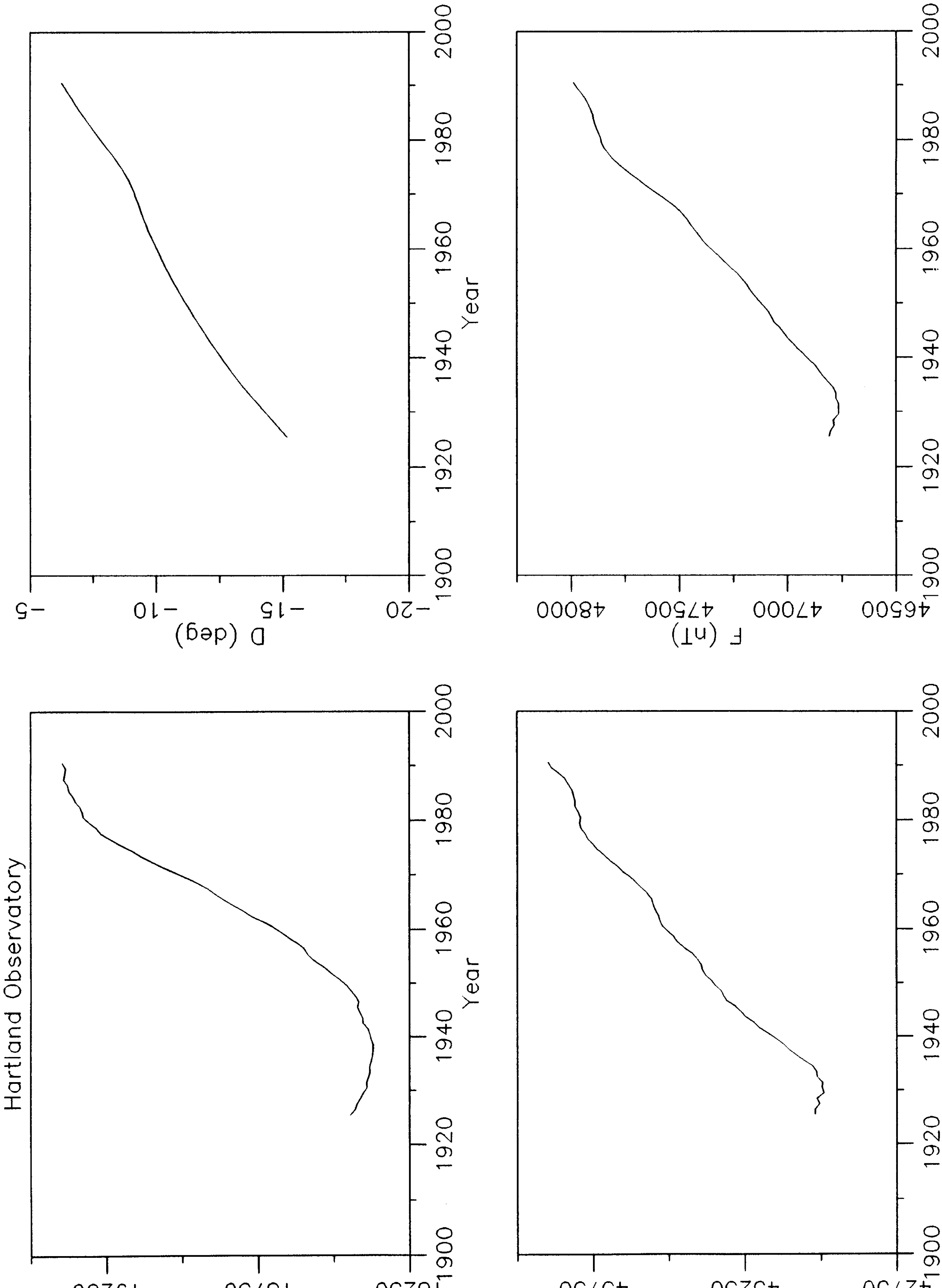
Hartland

	Year	D	H	I	X	Y	Z	F
Note 1		-1-46.6	-146	0 11.4	-247	-542	56	-6
	1957.5	-10 17.2	18627	66 47.7	18328	-3326	43451	47275
	1958.5	-10 11.0	18655	66 46.3	18361	-3298	43465	47299
	1959.5	-10 5.0	18681	66 45.1	18392	-3271	43484	47327
	1960.5	-9 58.8	18707	66 43.9	18424	-3242	43504	47356
	1961.5	-9 53.0	18744	66 41.7	18466	-3217	43512	47378
	1962.5	-9 46.9	18779	66 39.5	18506	-3190	43517	47396
	1963.5	-9 40.6	18807	66 37.9	18539	-3161	43528	47417
	1964.5	-9 35.2	18840	66 36.0	18577	-3138	43535	47437
	1965.5	-9 30.1	18872	66 34.0	18613	-3115	43540	47454
	1966.5	-9 25.1	18897	66 32.7	18642	-3092	43554	47477
	1967.5	-9 20.3	18923	66 31.5	18672	-3071	43573	47505
	1968.5	-9 15.5	18956	66 29.9	18709	-3050	43592	47535
	1969.5	-9 11.1	18994	66 27.9	18750	-3032	43611	47568
	1970.5	-9 6.5	19033	66 26.1	18793	-3013	43636	47606
	1971.5	-9 1.1	19075	66 23.8	18839	-2990	43655	47640
	1972.5	-8 55.3	19110	66 22.1	18879	-2964	43676	47674
	1973.5	-8 48.2	19144	66 20.5	18918	-2930	43697	47707
	1974.5	-8 40.4	19175	66 19.1	18956	-2892	43719	47739
	1975.5	-8 32.3	19212	66 17.0	18999	-2852	43733	47767
	1976.5	-8 23.1	19240	66 15.7	19034	-2806	43749	47793
	1977.5	-8 13.7	19271	66 13.9	19073	-2758	43758	47813
	1978.5	-8 03.6	19286	66 13.3	19095	-2704	43773	47833
	1979.5	-7 53.5	19309	66 12.0	19127	-2651	43778	47847
Note 2		0 0.0	0	0 -0.2	0	0	-6	-5
	1980.5	-7 43.8	19330	66 10.3	19154	-2600	43768	47846

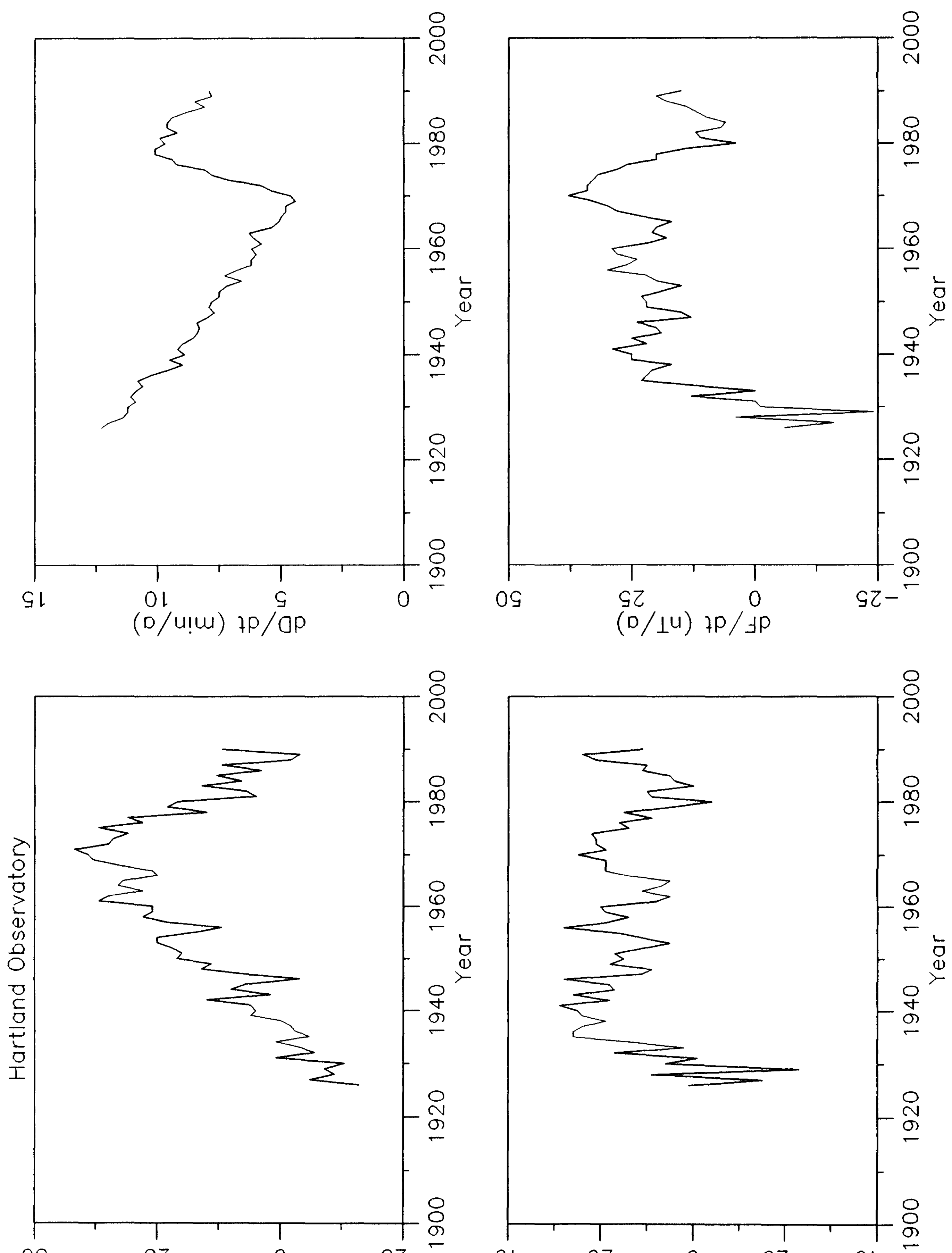
	Year	D	H	I	X	Y	Z	F
	1981.5	-7 33.9	19335	66 10.2	19167	-2546	43777	47857
	1982.5	-7 24.7	19342	66 10.1	19180	-2495	43787	47869
	1983.5	-7 15.1	19358	66 9.0	19203	-2443	43787	47876
	1984.5	-7 5.5	19366	66 8.6	19218	-2391	43791	47882
	1985.5	-6 56.1	19379	66 7.9	19237	-2340	43796	47892
	1986.5	-6 47.3	19383	66 8.0	19247	-2291	43807	47904
	1987.5	-6 39.2	19395	66 7.4	19264	-2247	43817	47918
	1988.5	-6 30.7	19393	66 8.2	19267	-2199	43838	47936
	1989.5	-6 22.9	19389	66 9.1	19269	-2155	43862	47956
Note 3		0 0.0	-6	0 1.1	-6	1	23	19
	1990.5	-6 15.0	19395	66 9.7	19280	-2111	43896	47990

1 Site differences 1 Jan 1957 (Hartland value - Abinger value)
2 Site differences 1 Jan 1980 (new value - old value)
3 Site differences 1 Jan 1990 (new value - old value)

D and I are given in degrees and decimal minutes
All other elements are in nanotesla



Annual mean values of H, D, Z & F at Hartland



Rate of change of annual mean values for H, D, Z & F at Hartland

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The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Overseas Development Administration.

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Cover photos

Intermagnet satellite communications installed at Hartland observatory

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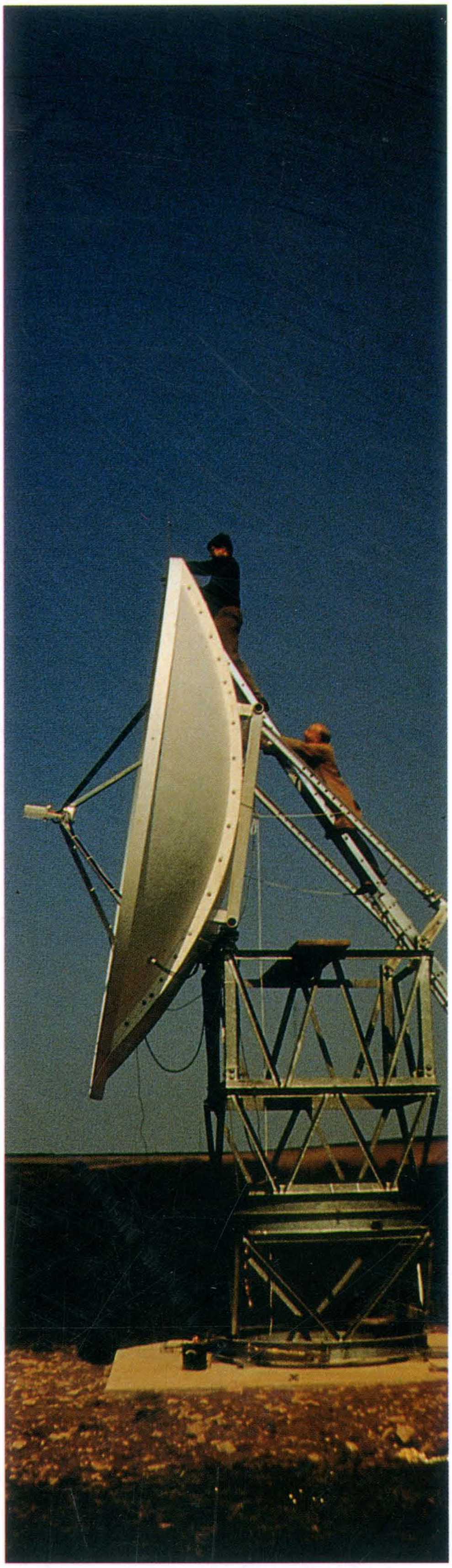

GEOMAGNETIC BULLETINS

1 Hartland Observatory magnetic results 1965, 1966 and 1967

2 Magnetic results 1968, Eskdalemuir, Hartland and Lerwick observatories

3 Magnetic results 1969. Eskdalemuir, Hartland and Lerwick observatories

4 Magnetic results 1970. Eskdalemuir, Hartland and Lerwick observatories

5 Magnetic results 1971. Eskdalemuir, Hartland and Lerwick observatories

6 Annual mean values of the geomagnetic elements since 1941

7 Magnetic results 1972. Eskdalemuir, Hartland and Lerwick observatories

8 Spherical harmonic models of the geomagnetic field

9 Magnetic results 1973–77. Eskdalemuir, Hartland and Lerwick observatories

10 Annual mean values of the geomagnetic elements

11 Magnetic results 1978–79. Eskdalemuir, Hartland and Lerwick observatories

12 A bibliographic guide to the production of local and regional magnetic charts

13 Magnetic results 1980. Eskdalemuir, Hartland and Lerwick observatories

14 Magnetic results 1981. Eskdalemuir, Hartland and Lerwick observatories

15 Magnetic results 1982. Eskdalemuir, Hartland and Lerwick observatories

16 Magnetic results 1983, 1984. Eskdalemuir, Hartland and Lerwick observatories

17 Magnetic results 1985. Eskdalemuir, Hartland and Lerwick observatories

18 Magnetic results 1986. Eskdalemuir, Hartland and Lerwick observatories

19 Magnetic results 1987–89. Lerwick, Eskdalemuir and Hartland observatories

20 Magnetic results 1990. Lerwick, Eskdalemuir and Hartland observatories

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