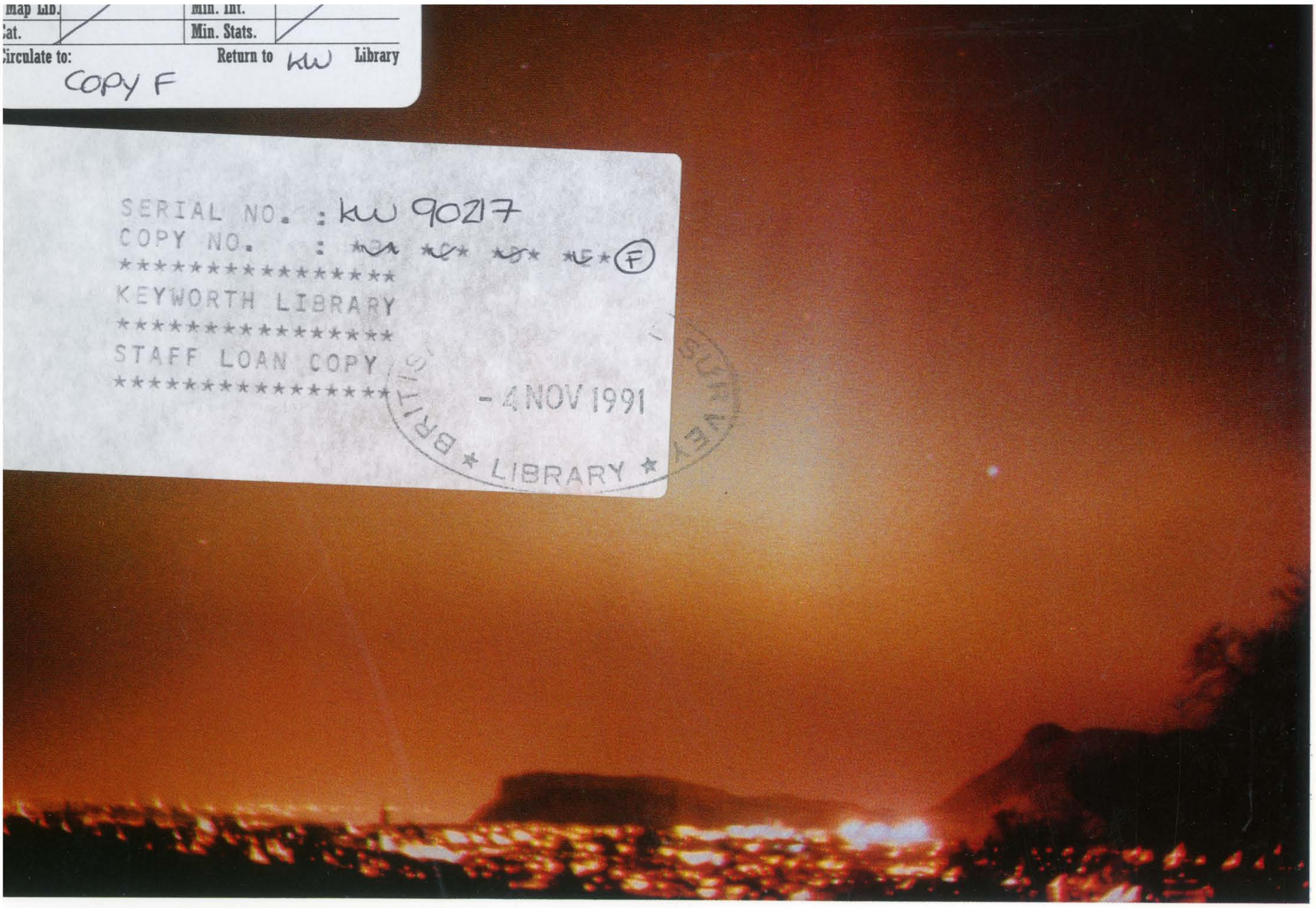
BRITISH GEOLOGICAL SURVEY

GEOMAGNETIC BULLETIN 19

Magnetic Results 1987–89

LERWICK, ESKDALEMUIR AND HARTLAND OBSERVATORIES



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Compilers

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Bibliographical reference

Kerridge, D J, Clark, T D G, and Harris, T J (compilers). 1991. Magnetic results 1987–89: Lerwick, Eskdalemuir and Hartland observatories. *British Geological Survey Geomagnetic Bulletin* 19.

Printed in England for the British Geological Survey by Derry and Sons Limited, Nottingham

First published 1991

ISBN 0 85272 197 8

Edinburgh British Geological Survey 1991

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Geomagnetism Group Report 1989

Magnetic Results 1987-89: Lerwick, Eskdalemuir and Hartland Observatories.

1 INTRODUCTION

This bulletin is a report of the measurements made at the UK geomagnetic observatories operated by the British Geological Survey (BGS) at Lerwick, Eskdalemuir and Hartland in the years 1987, 1988 and 1989.

Following successful trials during 1986, the Automatic Geomagnetic Observatory Systems (ARGOS), designed by A J Forbes and J C Riddick, were adopted as the primary instrument and recording systems at the three observatories on 1 January 1987. The results presented here are from the first three years of automated observatory operation. The description of the ARGOS equipment and operation in this bulletin closely follows that given by Riddick et al. (1990). Previous Geomagnetic Bulletins have largely consisted of tables of hourly mean values. 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.

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 south-west 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 1987-89 no major changes were made at the site. Routine maintenance work was carried out on the observatory buildings. Satellite transmission equipment was installed in 1988 to enable transmission of data from Lerwick to the US Geological Survey (USGS) in Golden, Colorado, via the GOES-East satellite, as part of the INTERMAGNET project.

The observatory coordinates are:

	Geographic	Geomagnetic
Latitude	60°08'N	62°08'N
Longitude	358°49'E	89°14'E
Height above mean sea level		85m

(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 700m to the north-west. 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. During 1987 the condition of the underground chamber at Eskdalemuir deteriorated because of ingress of water. In 1988 a new floor was laid in the west variometer room and this largely cured the problem, though there remains some seepage through the walls of the chamber. A proportional-control thermostatic heating system was installed in the underground chamber in 1988. Routine maintenance was carried out on the Absolute Hut, and repairs were made to the roof of the West Hut. Satellite transmission equipment was installed in 1988 to enable transmission of data from Eskdalemuir to the USGS, as part of the INTERMAGNET project.

The observatory coordinates are:

	Geographic	Geomagnetic
Latitude	55°19'N	58°00'N
Longitude	356°48'E	83°49'E
Height above mean sea level		245m

Hartland (Devon, England)
Hartland observatory is situated on the north-west 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 are 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 1987-89. Satellite transmission equipment was installed in 1988 to enable transmission of data from Hartland to the USGS, as part of the INTERMAGNET project. In April 1989 a 5m diameter satellite dish was erected 10m from the north-west corner of the main observatory building, facing due west. This enables receipt of INTERMAGNET data from the USGS and from the Geological Survey of Canada via the GOES-East satellite.

The observatory coordinates are:

	Geographic	**Geomagnetic**
Latitude	51°00'N	54°08'
Longitude	355°31'E	80°06'
Height above mean sea level		95m

3 INSTRUMENTATION

3.1 Absolute observations

At each observatory absolute measurements are made in a single Absolute Hut (see the site diagrams).

Lerwick
In 1987 absolute measurements of the horizontal intensity (H) and the vertical component (Z) were made by a proton vector magnetometer (PVM), an ELSEC 8801 proton precession magnetometer with the sensor mounted in ELSEC 5920 coils. The coils allow back-off fields to be applied in either a horizontal or a vertical plane (approximately). Nelson's method (Hurwitz and Nelson, 1960), in which Z is measured by applying a back-off field to annul H, and H is measured by applying a back-off field to annul Z, was used.

(Forbes (1987) has reviewed the use of a proton magnetometer and a coil system to make vector measurements.) Magnetic declination (D) was measured using a standard Kew-pattern declinometer. Absolute values of D thus referred to the pillar, absolute values of H and Z to the adjacent PVM pillar.

Absolute observations in 1988 were carried out using the same instruments as in 1987 until September 1988 when the observatory declinometer was replaced by an ELSEC 810 fluxgate-theodolite. The declination pillar remained the same. The operation and measurement procedures for the fluxgate-theodolite are described by Kerridge (1988).

In March 1989 the PVM observations of H and Z were supplemented by total intensity (F) measurements, made using the PVM, and inclination (I) observations made using the fluxgate-theodolite. By making both sets of observations over the rest of 1989 the corrections required to adjust the values of H and Z calculated from the F and I measurements to the PVM pillar were determined.

During the period 1987-89 observations were carried out every 2-3 weeks by the senior meteorologist, Mr A Gair until February 1989, when Mr C Clarke took over his duties, and by BGS staff on three-monthly service visits.

Eskdalemuir

In 1987 absolute measurements were made using equipment similar to that at Lerwick. Absolute observations in 1988 were carried out using the same instruments until, December when the observatory declinometer was replaced by a Bartington MAG 01H fluxgate-theodolite. The declination pillar remained the same. In December 1989 the PVM observations of H and Z were supplemented by total intensity (F) measurements, made using the PVM, and inclination (I) observations made using the fluxgate-theodolite.

During 1987-89 observations were carried out by BGS staff every two weeks.

Hartland

In 1987 and 1988 absolute measurements of H and Z were made using a PVM, similar to that used at Eskdalemuir and Lerwick observatories. Declination was measured by a hybrid instrument using a theodolite to view a suspended Kew-pattern magnet.

In September 1989 the observatory declinometer was replaced by an ELSEC 810 fluxgate-theodolite. The declination pillar remained the same.

Weekly absolute observations were made until June 1987 by Mr E M Reader. Mr K E Johns was trained in observing practice in 1987 and has made weekly observations of H and Z by PVM since July 1987, and measurements of D, by fluxgate-theodolite since September 1989. Additional observations were made on three-monthly service visits.

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 (north), Y (east) and Z (vertical) components of the geomagnetic field. The fluxgate magnetometer is operated in 'full field' mode, providing an analogue output of 5 volts in a field of 50000nT. The three fluxgate sensors are located in a temperature-controlled variometer chamber, on a large single pier, with individual mountings separated by about 1.5m. 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 volts . 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 one-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 minute values are displayed on a VDU to enable the status of ARGOS to be monitored locally. A printer, normally disabled, can be switched on to obtain hard copy of the same information.

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 standby 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 resulting from 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

Baseline Reference Measurements (BRMs) are a new and important part of the UK observatory operations. 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. 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 first 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 are no longer 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 Aluxgate 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.

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: ±100000 nT
Temperature coefficient: (in the range) 0.1-1 nT/°C

b ELSEC 820M proton proton precession magnetometer

Resolution: 0.1 nT
Accuracy: ±1 nT
Measurement range: 14000-90000 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 ±2000nT and at Eskdalemuir and Hartland it is ±1000nT.

4 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 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, to be made.

The zero-field offset corrections allocated for each observatory for each year are shown in Figures 5-13. (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. The corrections for 1987 were derived by hand by Mr A C J Greenwood, following the practice of previous years. The corrections for 1988 and 1989 were 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 Figures 5-13, for comparison with the zero-field corrections derived from absolute observations, plotted in the sense (BRM value - ARGOS value). The daily mean temperature of the variometer chamber is also shown in order to reveal any temperature related effects.

Lerwick

Plots of the zero-field corrections for the three years 1987, 1988 and 1989 are presented in the upper panels of Figures 5, 6 and 7 respectively. The results of the comparisons between BRM's and ARGOS values are shown in the middle panels, and the daily mean temperature of the variometer chamber is plotted in the bottom panel of each figure.

In 1987 the agreement between the absolute observation and BRM comparisons was good for D and Z. The abrupt changes in the BRM comparisons for H at about days 180 and 240 were caused by relevelling of the H (and Z) coil during service visits. The effect on the Z BRMs is less marked, but can be seen in the plot. The results for 1988 are similar to those for 1987. The D BRM coil was re-levelled on about day 190 in 1988. The agreement between the absolute observations and BRMs is good for D and Z, but the BRM comparisons for H show a long-term change not apparent in the absolute-value comparisons. Similar remarks apply to 1989 although far fewer absolute observations were made and BRMs were lost for about 3 months following a lightning strike at the observatory.

A consistent feature of the Z plots is an annual variation for both the absolute value and BRM comparisons. This is strong evidence for an annual cycle of drift, caused by temperature changes, in the ARGOS Z-component fluxgate. The level of noise in the D BRM comparisons at Lerwick appears to be less than at either Eskdalemuir or Hartland (see below). This is probably because of the stability of the marble coil in which D BRMs are made at Lerwick.

In the plots of variometer chamber temperature for 1989 there are three prominent peaks corresponding to times of unusually high ambient temperatures. The thermal control system can maintain the variometer chamber temperature above the outside temperature, but cannot cool the chamber.

The rms deviations of the observed zero-field corrections from the allocated values are tabulated below. The rms values for 1984-86 (based on less irregular observations than in 1987-89) are also listed. There is apparently some deterioration in the scatter of the values compared to the earlier years. This can be attributed in part to measurements made by relatively inexperienced observers. In the absolute value comparison for H for 1989, for example, there are two outlying points between days 60 and 90 which contribute substantially to the overall rms value. The points do not, however, bias the final correction, which lies much closer to the observations carried out by more experienced observers on service visits to the observatory.

Year	H(nT)	D(min)	Z(nT)
1984	1.07	0.47	1.20
1985	0.89	0.29	0.70
1986	1.64	0.63	0.55
1987	2.76	0.96	1.03
1988	2.59	0.50	1.38
1989	2.97	0.48	1.57

Eskdalemuir

Plots of the zero-field corrections for the three years 1987, 1988 and 1989 are presented in the upper panels of Figures 8, 9 and 10 respectively. The results of the comparisons between BRMs and ARGOS values are shown in the middle panels, and the daily mean temperature of the variometer chamber is plotted in the bottom panel of each figure.

In 1987 the agreement between the absolute observation and BRM comparisons was good for D, H and Z. The severe changes in the allocated corrections in H resulted from changes made to the ARGOS X- and Y-component fluxgate electronics. In 1988 the absolute value comparisons for H showed much less change over the year. The agreement between the absolute value and BRM comparisons for H and D was poorer than in 1987. A plot of daily mean values of D for 1988 with the data corrected on the basis of the polynomial fit to the point values in Figure 9 showed anomalous values at the start of the year and between days 90 and 120. That the values were anomalous was confirmed by examination of similar plots for Lerwick and Hartland, which both displayed close correspondence in detailed features with the Eskdalemuir plot, except during these two periods.

The discrepancies were eliminated by using the short-term variations in the BRM comparisons at Eskdalemuir at these times to derive the modifications to the polynomial fit shown in Figure 9. In both 1988 and 1989 there were apparent drifts between the BRM and ARGOS measurements which are not evident in the comparisons with the absolute observations, particularly in H and D. At Eskdalemuir the variometer chamber temperature excursions seen at Lerwick during 1989 do not appear. This is in part due to the improved thermal control system installed at Eskdalemuir in 1988, and also to the thermal inertia of the underground vault. For all three years the scatter in the comparisons with BRM H measurements appears to be worse than for either D or Z. This problem has been traced to the tuning of the proton magnetometer, which had not been properly optimised for the Serson H measurement.

The table below lists the rms deviations of the observed zero-field corrections from the allocated values. The rms values for 1984-85 (based on more regular observations than in 1987-89) are also listed.

Year	H(nT)	D(min)	Z(nT)
1984	1.24	0.24	0.73
1985	2.08	0.29	1.85
1986	-----	-----	-----
1987	1.93	0.28	1.38
1988	2.32	0.85	0.95
1989	1.77	0.61	1.06

Hartland

Plots of the zero-field corrections for the three years 1987, 1988 and 1989 are presented in the upper panels of Figures 11, 12 and 13 respectively. The results of the comparisons between BRMs and ARGOS values are shown in the middle panels, and the daily mean temperature of the variometer chamber is plotted in the bottom panel of each figure.

In 1987 the agreement between the absolute observation and BRM comparisons was good for D and Z; for H the BRM comparisons after day 210 showed changes following relevelling of the coils on a service visit. In 1988 the absolute value and BRM comparisons are in good agreement for D, H and Z, although the noise level on the BRM results increased in the second half of the year. An intermittent fault on the Y-component fluxgate magnetometer electronics was traced and corrected in April 1988. There were very few absolute observations of D, but the BRM H results indicate that the correction based on the absolute measurements is reliable. In 1989 the quality of the BRM H comparisons deteriorated further; the absolute value comparisons indicate that the ARGOS fluxgates were not responsible for this. Again, few absolute measurements of D were made. The change in the BRM D comparisons between days 120 and 240 was not supported by the absolute observations made during that period, so no change to the corrections based on the absolute observations alone was made. The agreement between the Z absolute value and BRM comparisons was good and clearly showed temperature-related effects. The initial zero-field correction, based on a polynomial fit, was adjusted to take account of these effects. As at Lerwick there is a clear annual variation in the Z comparisons.

The variometer chamber temperature variations at Lerwick during 1989 were matched by those at Hartland, with additional short-term excursions earlier in the year. The rms deviations of the observed zero-field corrections from the allocated values are tabulated below. The rms values for 1984-86 (based on more regular observations than in 1987-89) are also listed.

Year	H(nT)	D(min)	Z(nT)
1984	0.57	0.29	0.98
1985	0.62	0.13	0.90
1986	0.45	0.13	-----
1987	0.71	0.15	1.39
1988	0.67	0.18	1.02
1989	1.24	0.24	1.03

5 DATA PROCESSING

Each working day the PARIS operator in Edinburgh retrieves data from the observatory ARGOS systems by telephone link. The data files received contain the measurements recorded since the previous call-up. In the first stage of processing the data are organised into Universal Time (UT) day files (24 kbytes). In 1987 and 1988 subsequent processing was carried out on the PARIS PDP 11/23 computer. Since May 1989 the day files have been transferred to the BGS Edinburgh mainframe computer (a VAX 6410) for processing.

The set of FORTRAN programs used for processing the ARGOS day files on the PDP 11/23 has been superseded 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 BRM's 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, resulting from failure of the ARGOS and back-up systems during the same periods of time, for each observatory and for each year, were as follows:

	1987	**1988**	**1989**
Lerwick	8	11	1693
Eskdalemuir	420	13	1140(H only) 422(H D Z)
Hartland	1501(H only) 148(H D Z)	0	0

6 PRESENTATION OF RESULTS

The data are organised by year and then by observatory in the order Lerwick, Eskdalemuir and Hartland. The results presented for each observatory for each year 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 Tables of monthly and annual mean values of all geomagnetic elements.
e 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 nT 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 more than six one-minute values are missing; daily means are not computed if more than two hourly means are 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 nanoteslas.

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).

Following the results for 1989 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. Annual mean values from Abinger observatory for 1925.5-56.5 have been included in the Hartland 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 1987-89 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
Edinburgh EH9 3LA
Scotland UK

Telephone: 031-667 1000
Fax: 031-668 4368
Telex: 727343 SEISED G

8 GEOMAGNETISM GROUP STAFF LIST (1st January 1990)

Edinburgh

Group Manager (Grade 7)	Dr W F Stuart
PSec	M Milne (from January 1989)
Grade 7	D R Barraclough Dr D Beamish
SSO	Dr D J Kerridge J C Riddick
HSO	T D G Clark (from January 1990) T J Harris Dr S Macmillan (from October 1989) E M Reader
ASO	E Clarke (from April 1989)
Craftsman	J McDonald

Eskdalemuir

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

Hartland

PGS E	K G Johns

There were a number of staff changes during 1987-89.

Edinburgh

Mr A J Forbes, who was in charge of the UK observatory operations, and who had been previously stationed at Lerwick observatory, retired in March 1987.

Mr P R Robinson, a former superintendent at Eskdalemuir observatory, retired in May 1987.

Mr A C J Greenwood died in service in November 1988. Mr Greenwood had been stationed at both Hartland and Eskdalemuir observatories during his career with BGS.

Miss K Dyson retired in August 1989.

Hartland

Mr A M Allen retired in January 1987 after 20 years service at Hartland observatory.

Mr E M Reader transferred from Hartland to Edinburgh in June 1987.

REFERENCES

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

Green, C A. 1985. Geomagnetic hourly average and minute values from digital data. *BGS Geomagnetism Research Group Report 85/19.*

Hurwitz, L, and Nelson, J H. 1960. Proton vector magnetometer. *Journal of Geophysical Research*, Vol.65, 1759-1765.

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

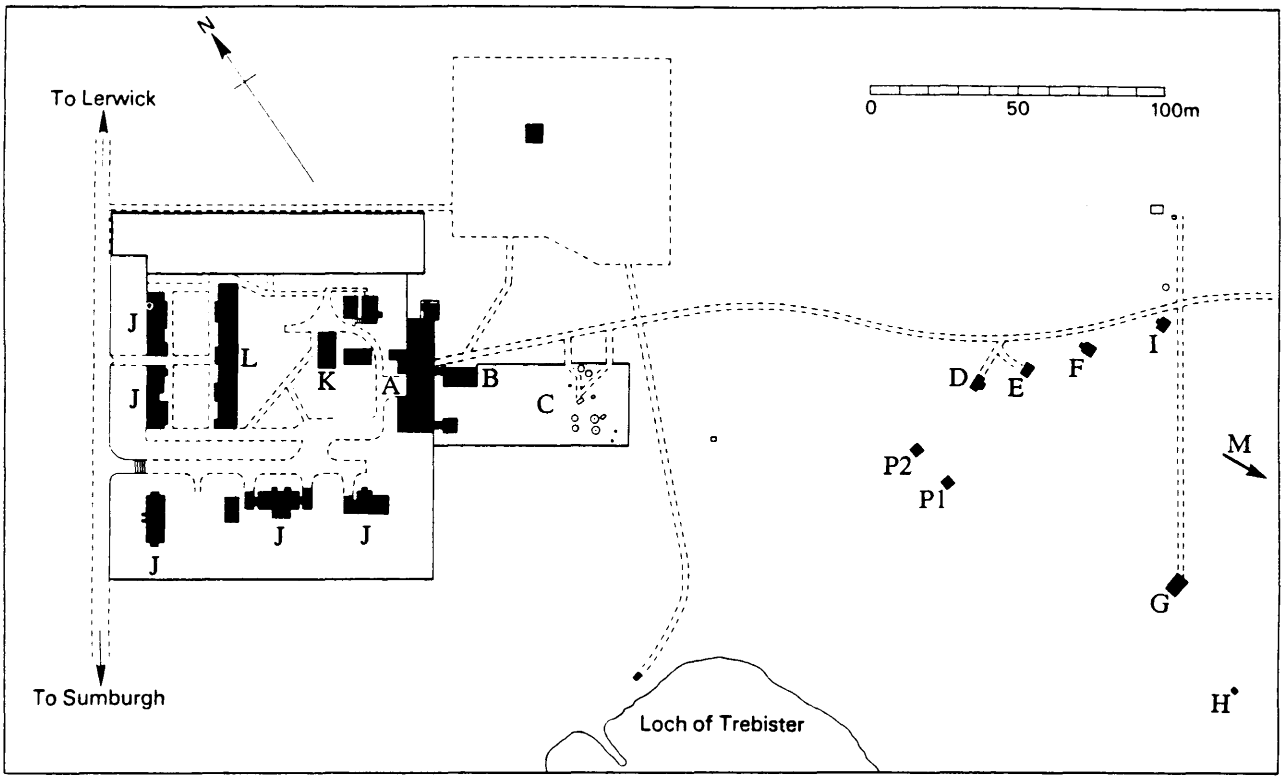
Kerridge, D J, and Harris, T J. 1988. GIFS: the Geomagnetism Information and Forecast Service. *British Geological Survey Technical Report*, WM/88/16.

Mayaud, P N. 1980. Derivation, meaning, and use of geomagnetic indices. *American Geophysical Union, Geophysical Monograph 22.* (Washington DC: American Geophysical Union.) 154pp.

Riddick, J R, Greenwood, A C, and Stuart, W F. 1990. The automatic geomagnetic observatory system (ARGOS) operated in the UK by the British Geological Survey. *Physics of the Earth and Planetary Interiors*, Vol.59, 29-44.

Robinson, P R. 1982. Geomagnetic observatories in the British Isles. *Vistas in Astronomy*, Vol.26, 347-367.

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)

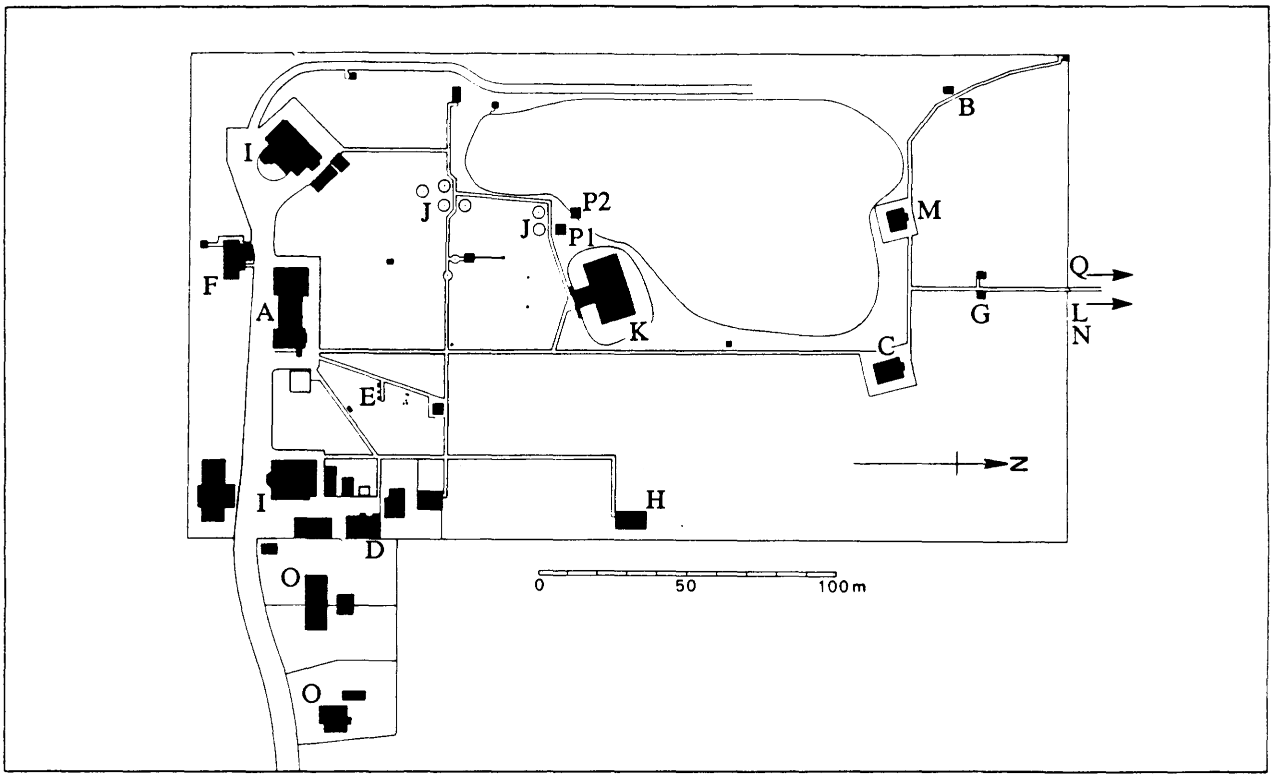
The Variometer House is constructed from non-magnetic concrete and has internal dimensions of 4.9 by 3 metres. The roof is semi-circular in cross section. The temperature of the house is controlled to a diurnal range of ±1°C. The meridian at the time of construction is defined on the north and south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



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.

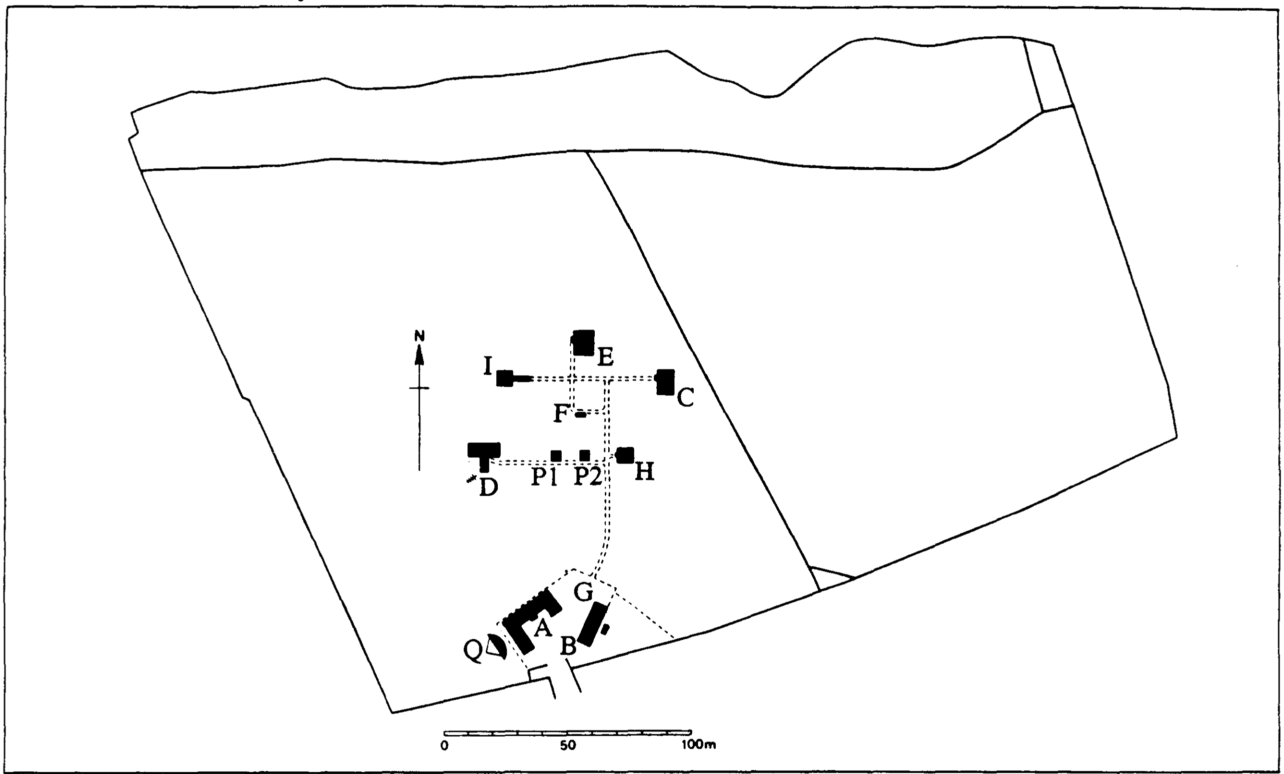
Previous descriptions

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.*

Figure 2. Eskdalemuir observatory site diagram

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

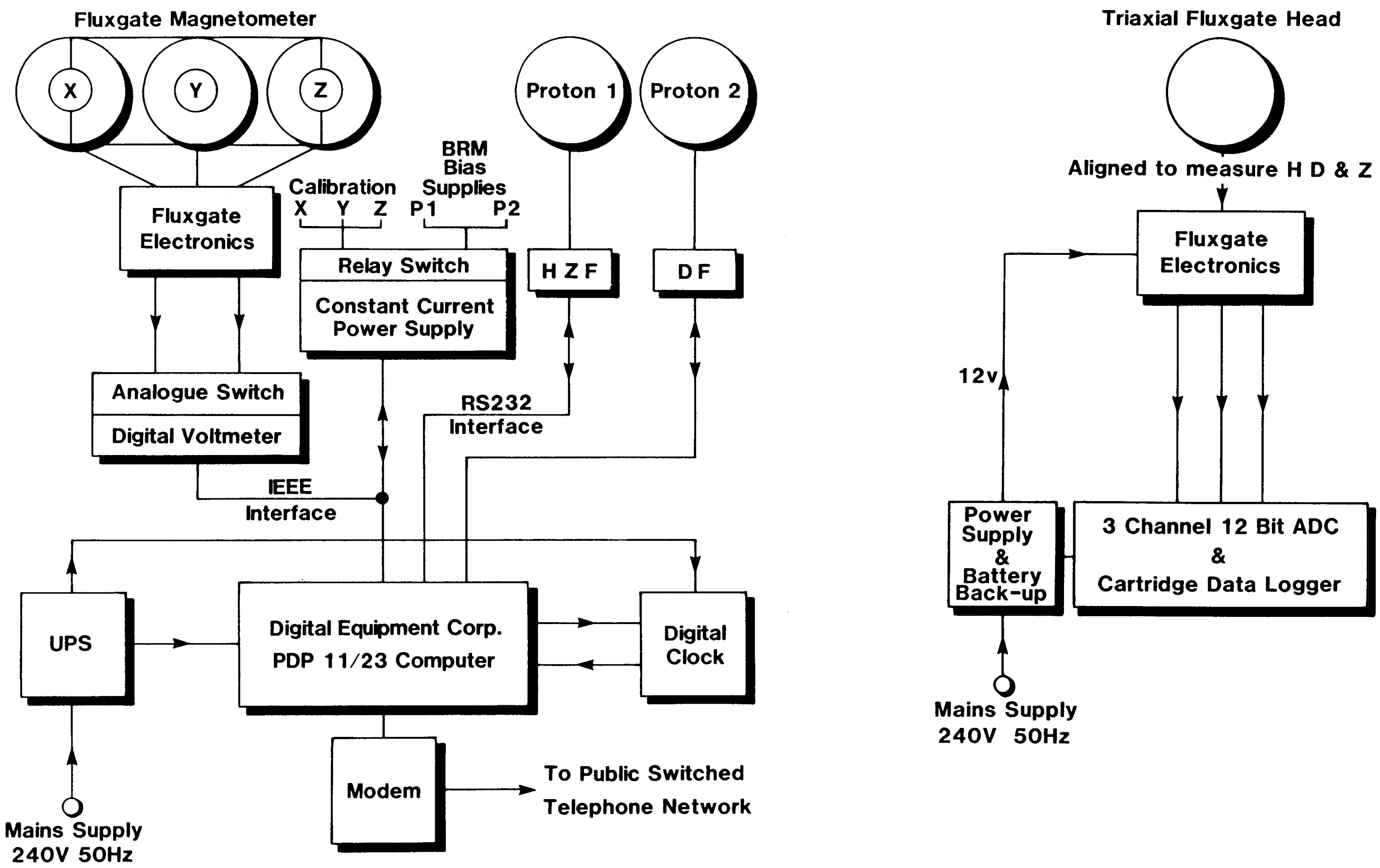


Figure 4. Block diagram of the ARGOS and back-up system

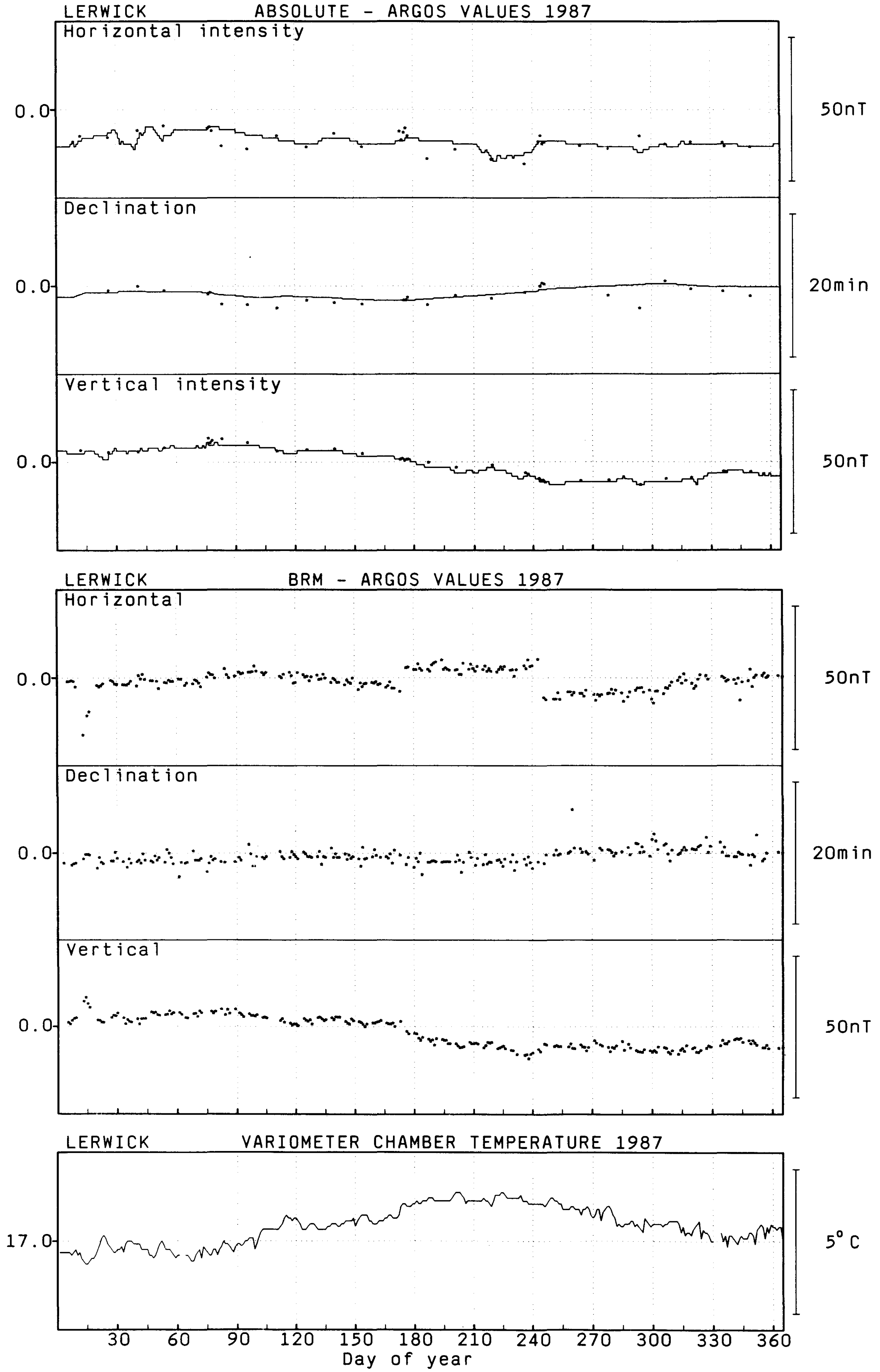

LERWICK ABSOLUTE - ARGOS VALUES 1987
Horizontal intensity
0.0
50nT
Declination
0.0
20min
Vertical intensity
0.0
50nT
LERWICK BRM - ARGOS VALUES 1987
Horizontal
0.0
50nT
Declination
0.0
20min
Vertical
0.0
50nT
LERWICK VARIOMETER CHAMBER TEMPERATURE 1987
17.0
5° C
30 60 90 120 150 180 210 240 270 300 330 360
Day of year

Figure 5.

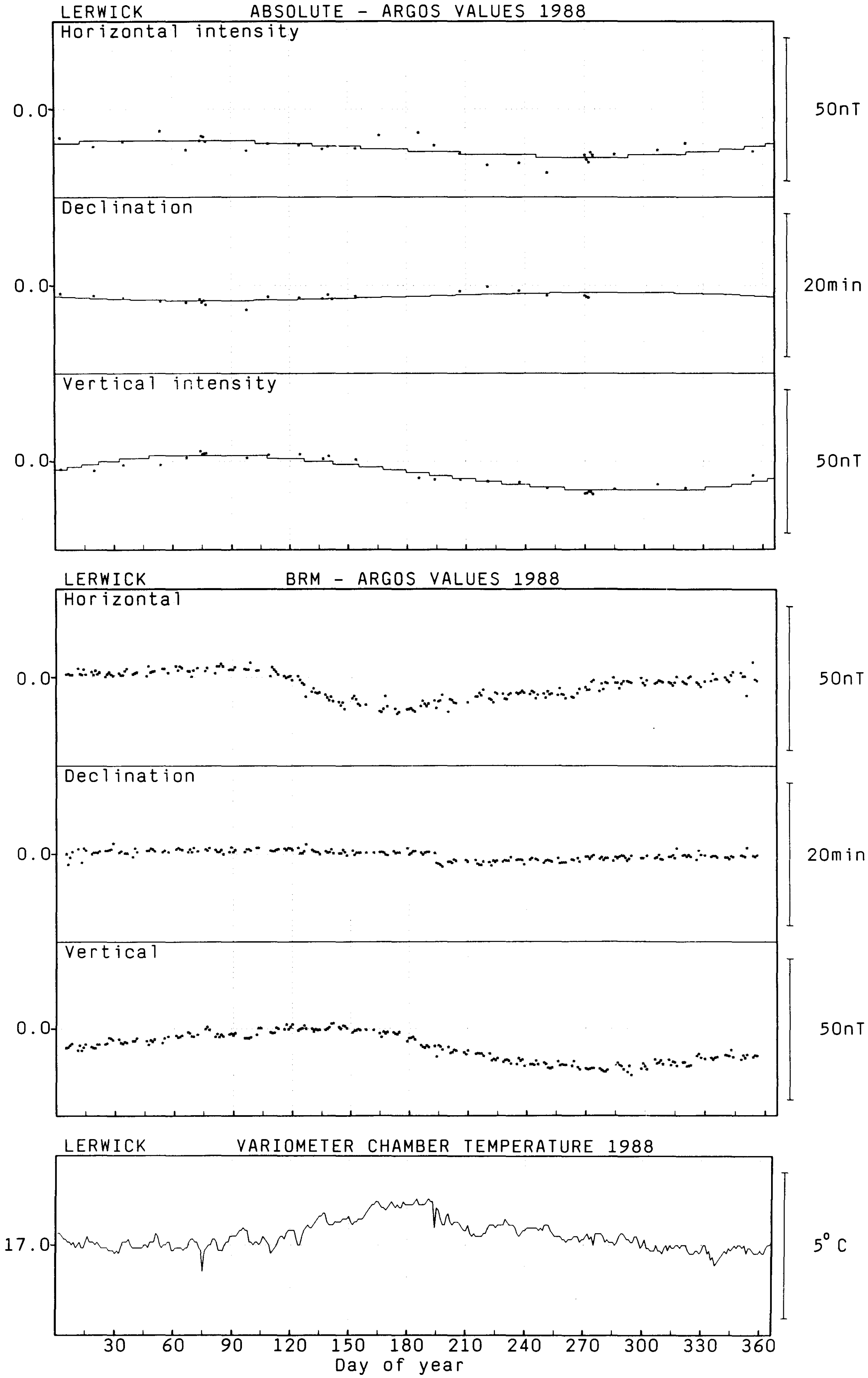

LERWICK ABSOLUTE - ARGOS VALUES 1988
Horizontal intensity
0.0
50nT
Declination
0.0
20min
Vertical intensity
0.0
50nT
LERWICK BRM - ARGOS VALUES 1988
Horizontal
0.0
50nT
Declination
0.0
20min
Vertical
0.0
50nT
LERWICK VARIOMETER CHAMBER TEMPERATURE 1988
17.0
5° C
30 60 90 120 150 180 210 240 270 300 330 360
Day of year

Figure 6.

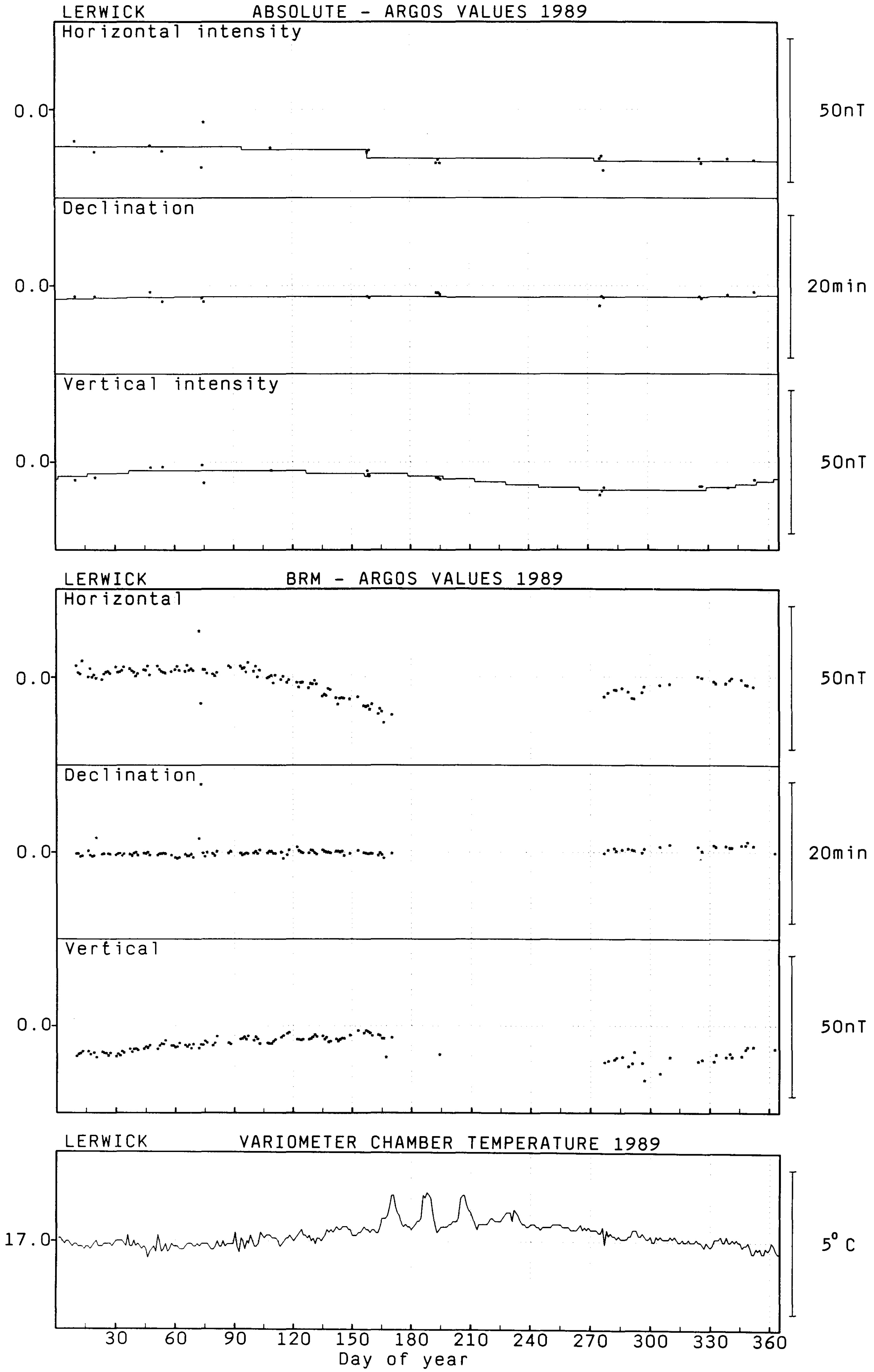

LERWICK
ABSOLUTE - ARGOS VALUES 1989
Horizontal intensity
0.0
50nT
Declination
0.0
20min
Vertical intensity
0.0
50nT
LERWICK
BRM - ARGOS VALUES 1989
Horizontal
0.0
50nT
Declination
0.0
20min
Vertical
0.0
50nT
LERWICK
VARIOMETER CHAMBER TEMPERATURE 1989
17.0
5° C
30
60
90
120
150
180
210
240
270
300
330
360
Day of year

Figure 7.

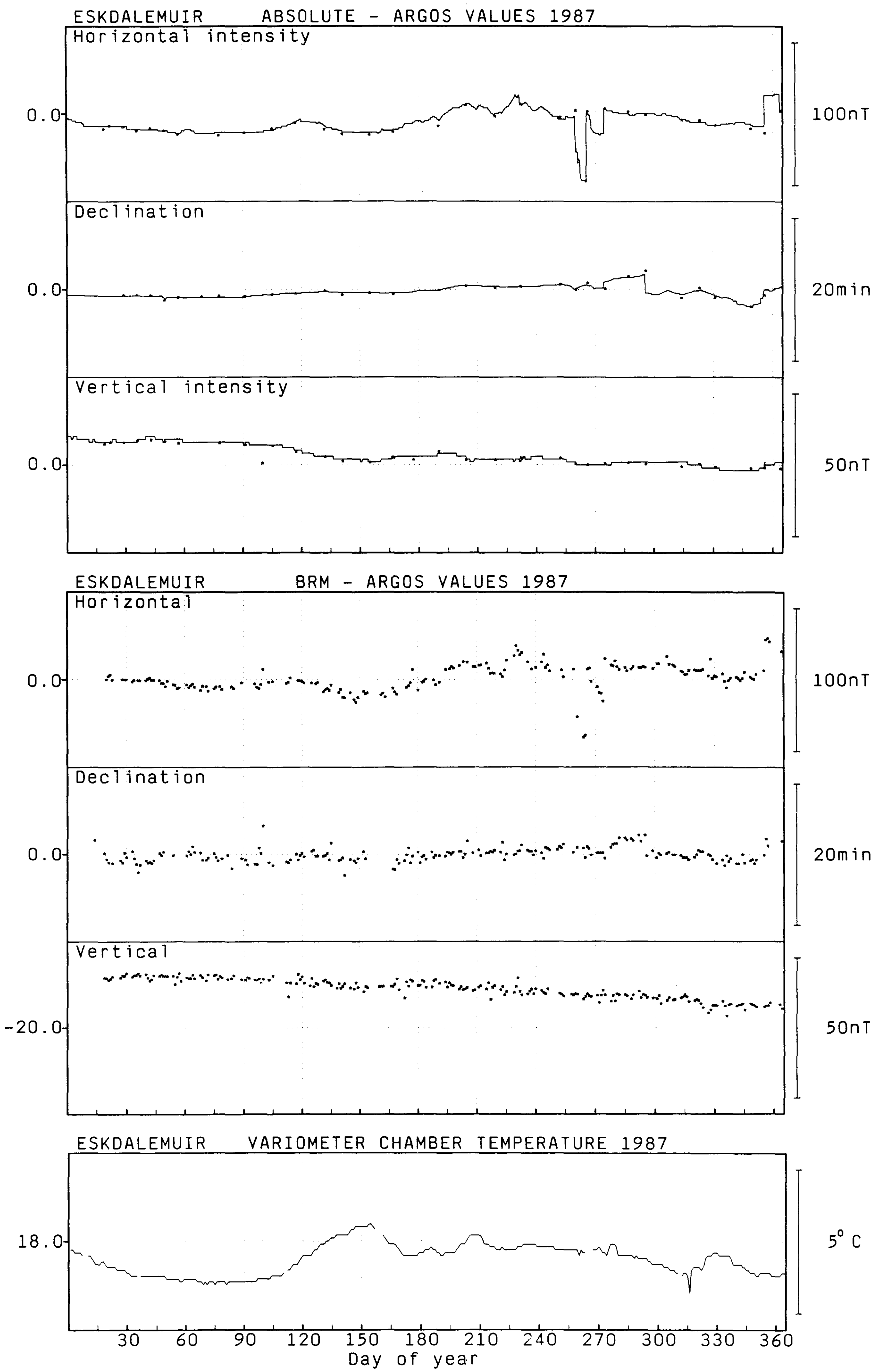

ESKDALEMUIR ABSOLUTE - ARGOS VALUES 1987
Horizontal intensity
0.0
100nT
Declination
0.0
20min
Vertical intensity
0.0
50nT
ESKDALEMUIR BRM - ARGOS VALUES 1987
Horizontal
0.0
100nT
Declination
0.0
20min
Vertical
-20.0
50nT
ESKDALEMUIR VARIOMETER CHAMBER TEMPERATURE 1987
18.0
5° C
30 60 90 120 150 180 210 240 270 300 330 360
Day of year

Figure 8.

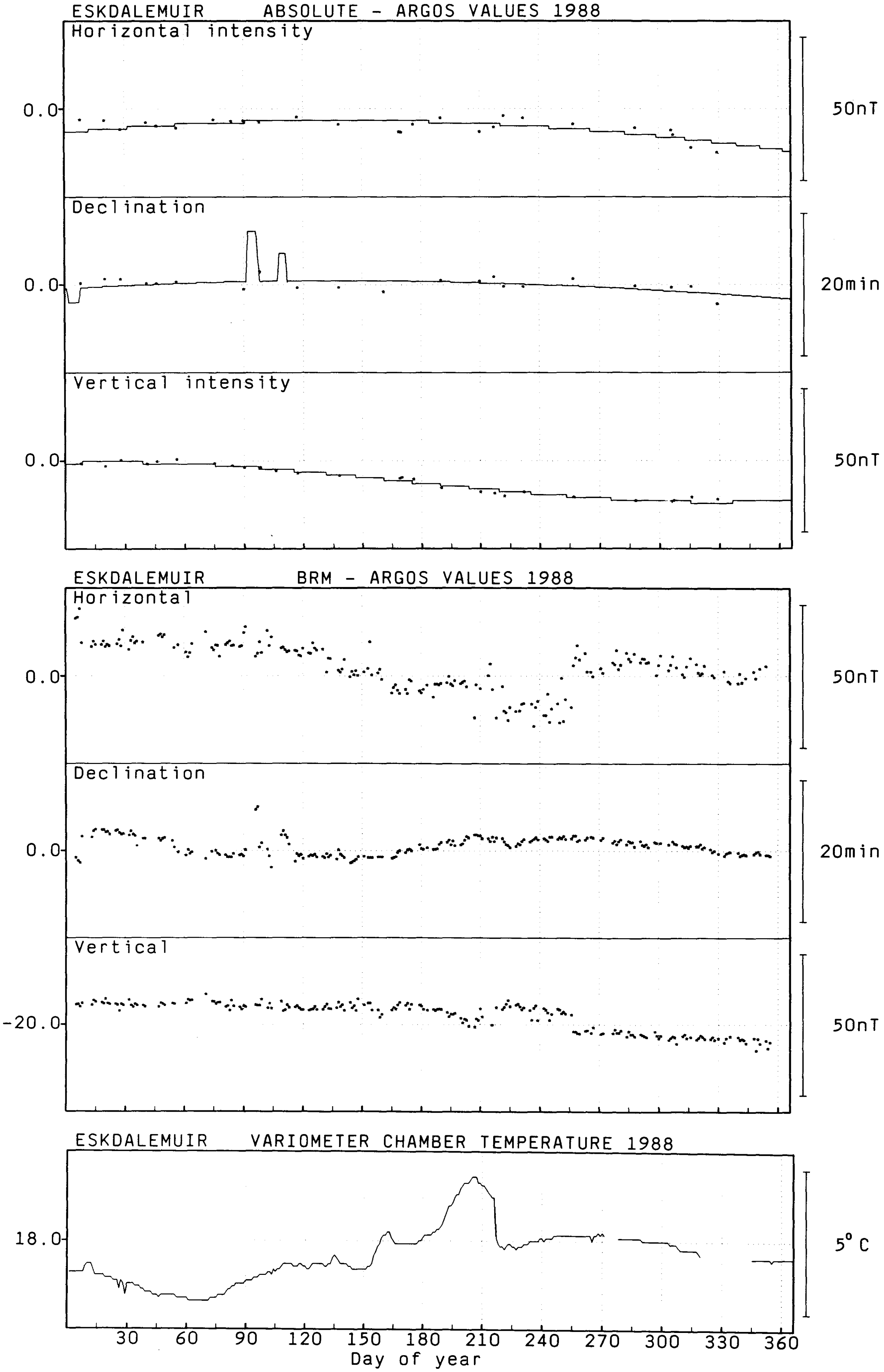
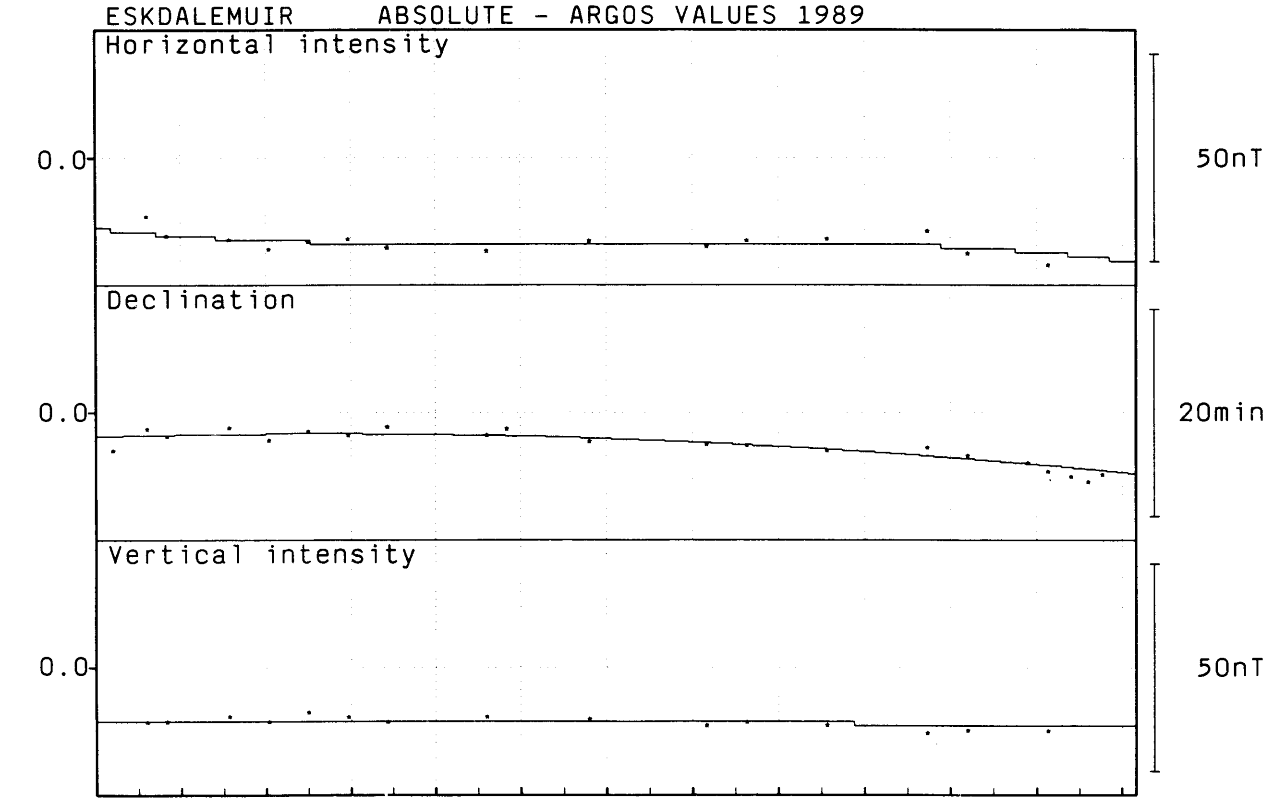

ESKDALEMUIR ABSOLUTE - ARGOS VALUES 1988
Horizontal intensity
0.0
50nT
Declination
0.0
20min
Vertical intensity
0.0
50nT
ESKDALEMUIR BRM - ARGOS VALUES 1988
Horizontal
0.0
50nT
Declination
0.0
20min
Vertical
-20.0
50nT
ESKDALEMUIR VARIOMETER CHAMBER TEMPERATURE 1988
18.0
5° C
30 60 90 120 150 180 210 240 270 300 330 360
Day of year

Figure 9.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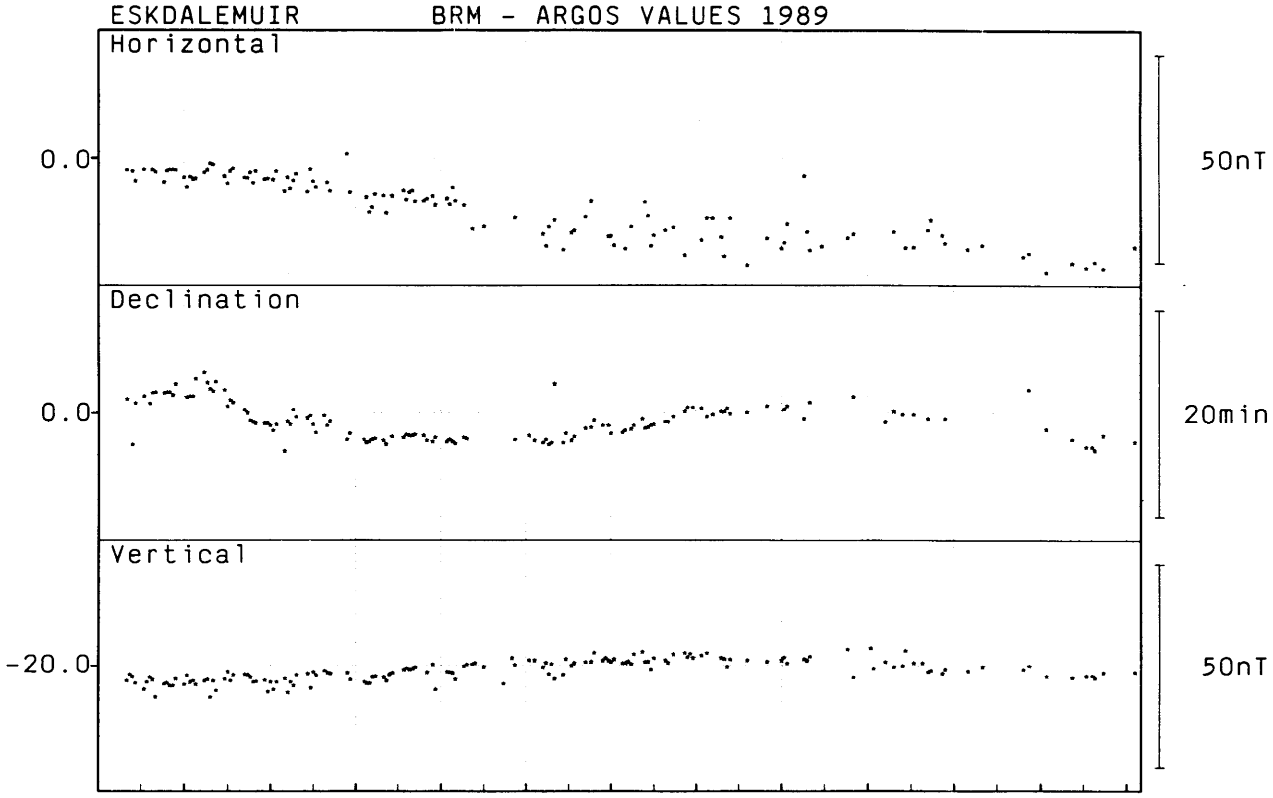
Horizontal intensity
0.0
50nT
Declination
0.0
20min
Vertical intensity
0.0
50nT


ESKDALEMUIR BRM - ARGOS VALUES 1989
Horizontal
0.0
50nT
Declination
0.0
20min
Vertical
-20.0
50nT

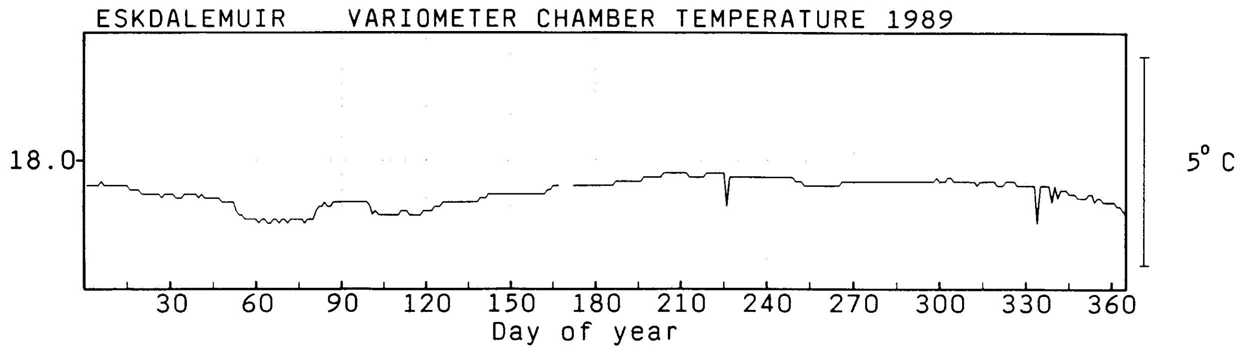
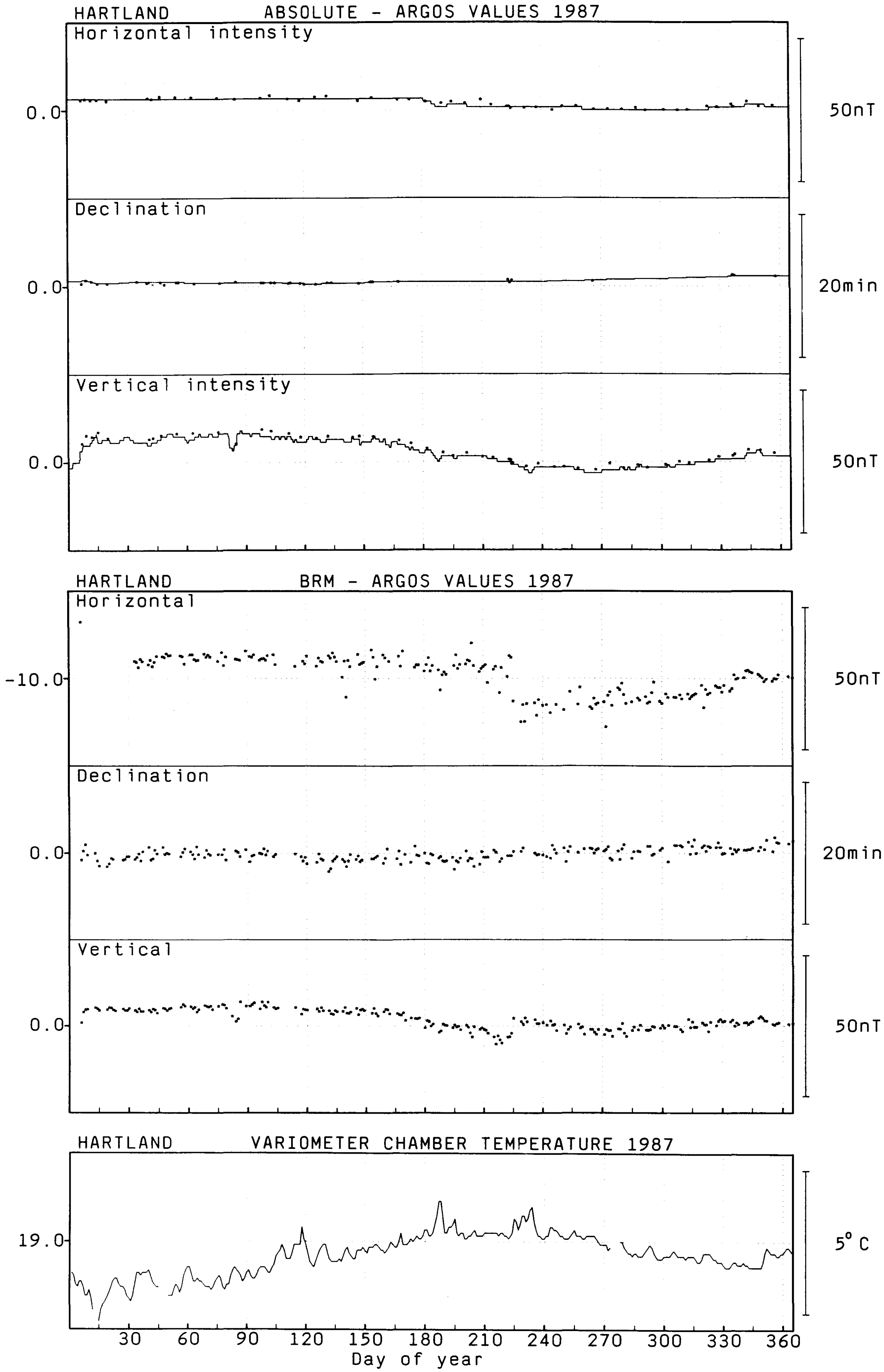

ESKDALEMUIR VARIOMETER CHAMBER TEMPERATURE 1989
18.0
5° C
30 60 90 120 150 180 210 240 270 300 330 360
Day of year

Figure 10.



HARTLAND ABSOLUTE - ARGOS VALUES 1987
Horizontal intensity
0.0
50nT
Declination
0.0
20min
Vertical intensity
0.0
50nT
HARTLAND BRM - ARGOS VALUES 1987
Horizontal
-10.0
50nT
Declination
0.0
20min
Vertical
0.0
50nT
HARTLAND VARIOMETER CHAMBER TEMPERATURE 1987
19.0
5° C
30 60 90 120 150 180 210 240 270 300 330 360
Day of year

Figure 11.

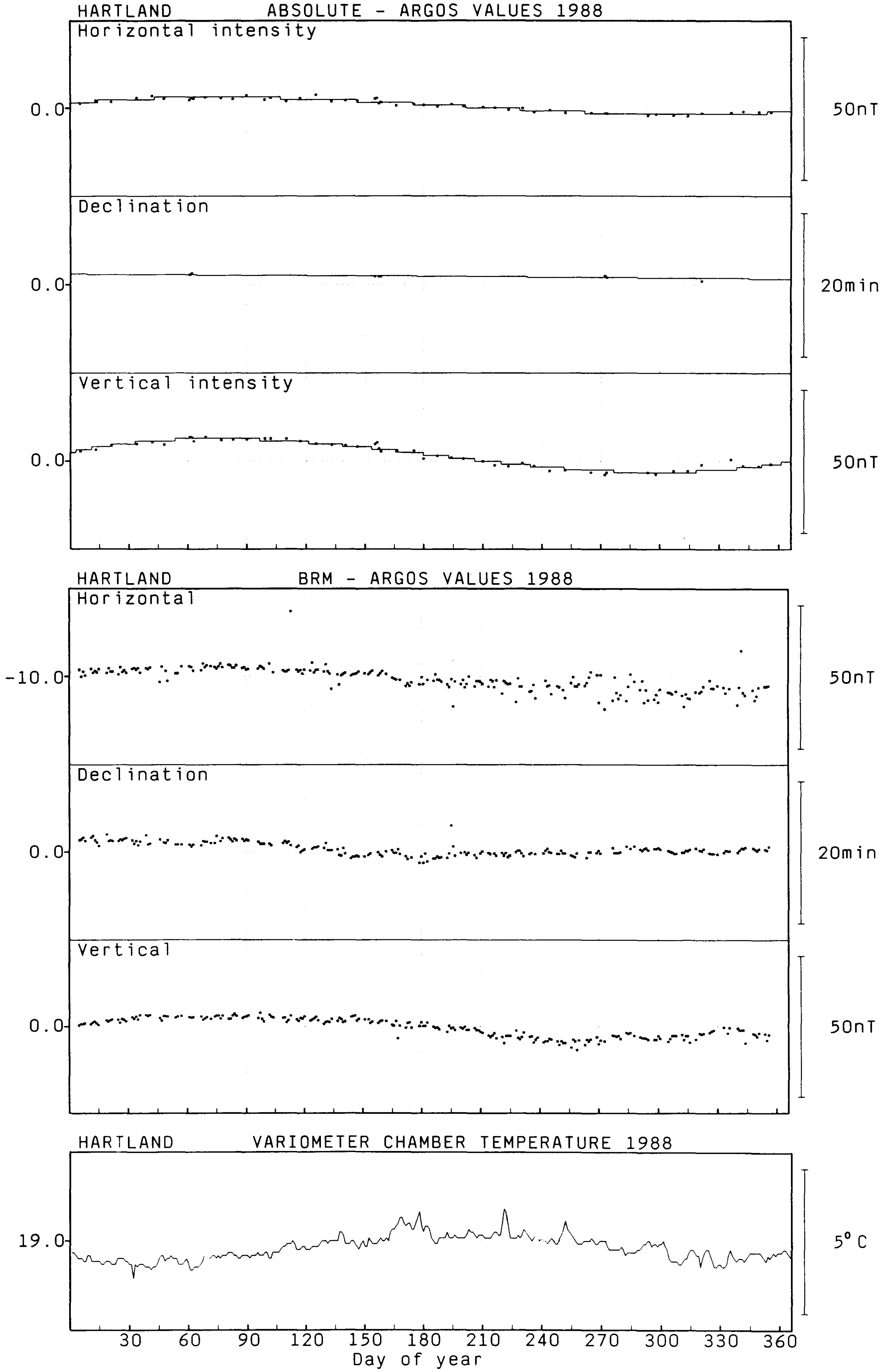
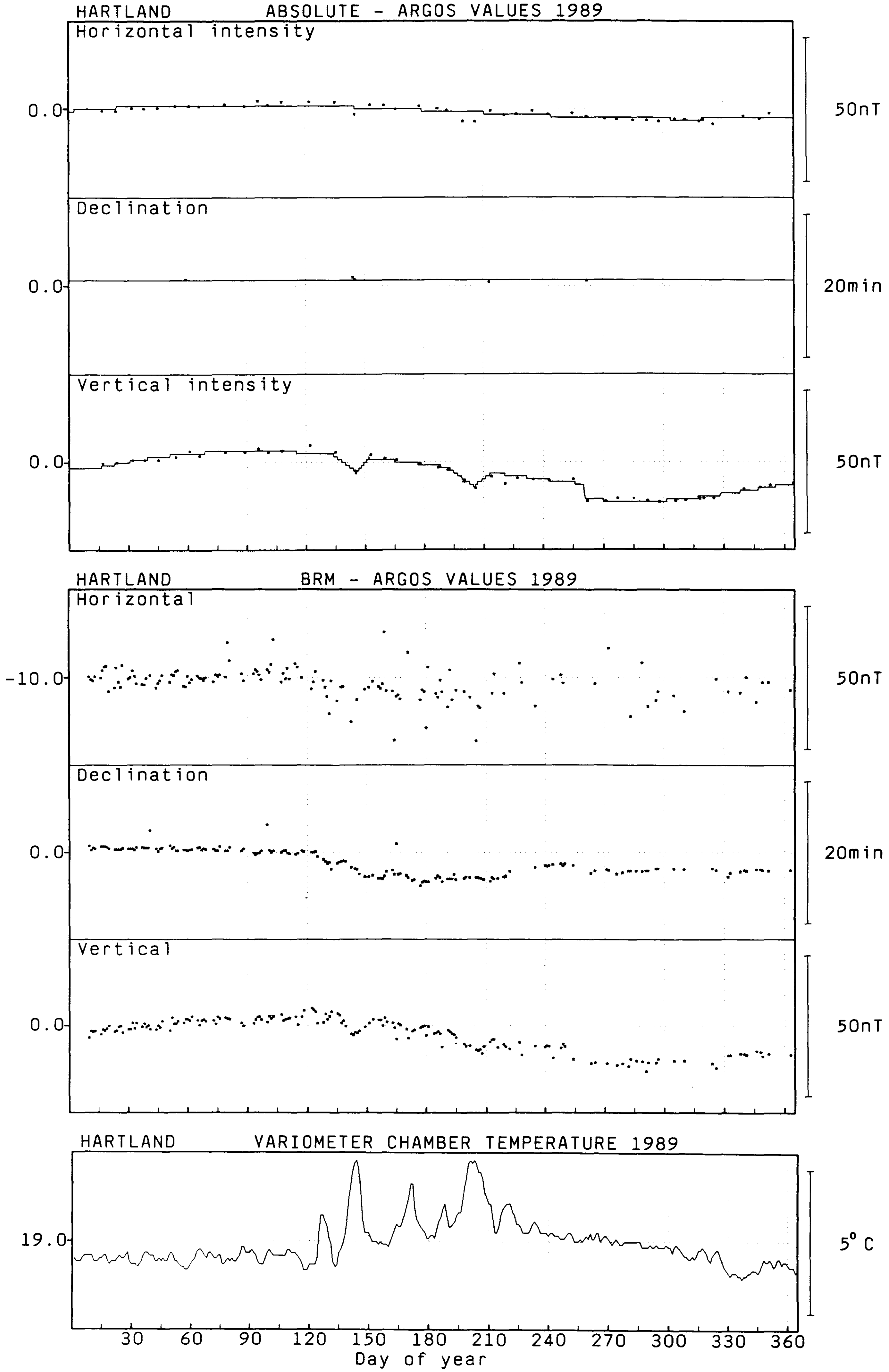

HARTLAND ABSOLUTE - ARGOS VALUES 1988
Horizontal intensity
0.0
50nT
Declination
0.0
20min
Vertical intensity
0.0
50nT
HARTLAND BRM - ARGOS VALUES 1988
Horizontal
-10.0
50nT
Declination
0.0
20min
Vertical
0.0
50nT
HARTLAND VARIOMETER CHAMBER TEMPERATURE 1988
19.0
5° C
30 60 90 120 150 180 210 240 270 300 330 360
Day of year

Figure 12.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0.0
50nT
Declination
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20min
Vertical intensity
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50nT
HARTLAND BRM - ARGOS VALUES 1989
Horizontal
-10.0
50nT
Declination
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Vertical
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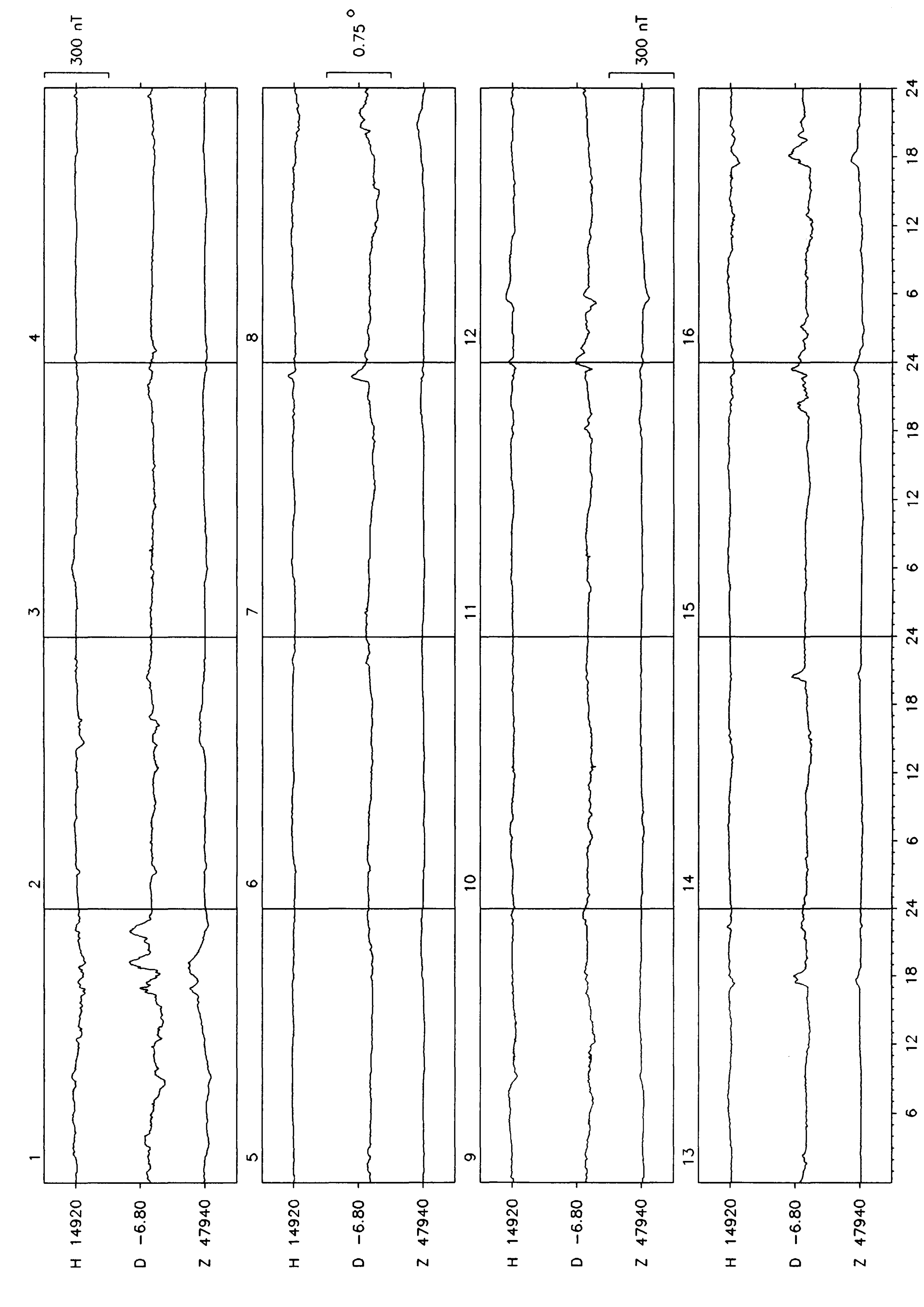
HARTLAND VARIOMETER CHAMBER TEMPERATURE 1989
19.0
5° C
30 60 90 120 150 180 210 240 270 300 330 360
Day of year

Figure 13.

LERWICK 1987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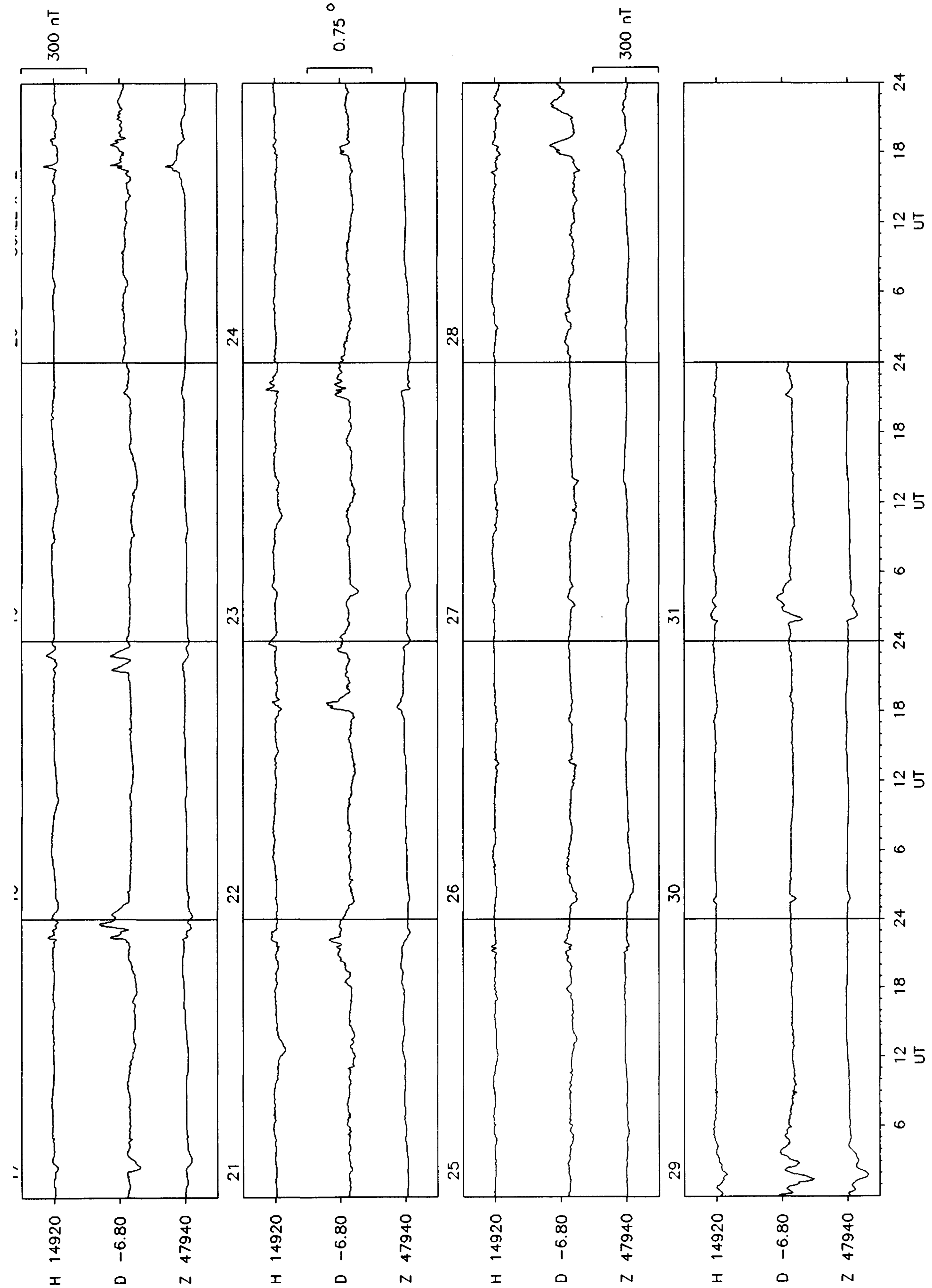
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300 nT
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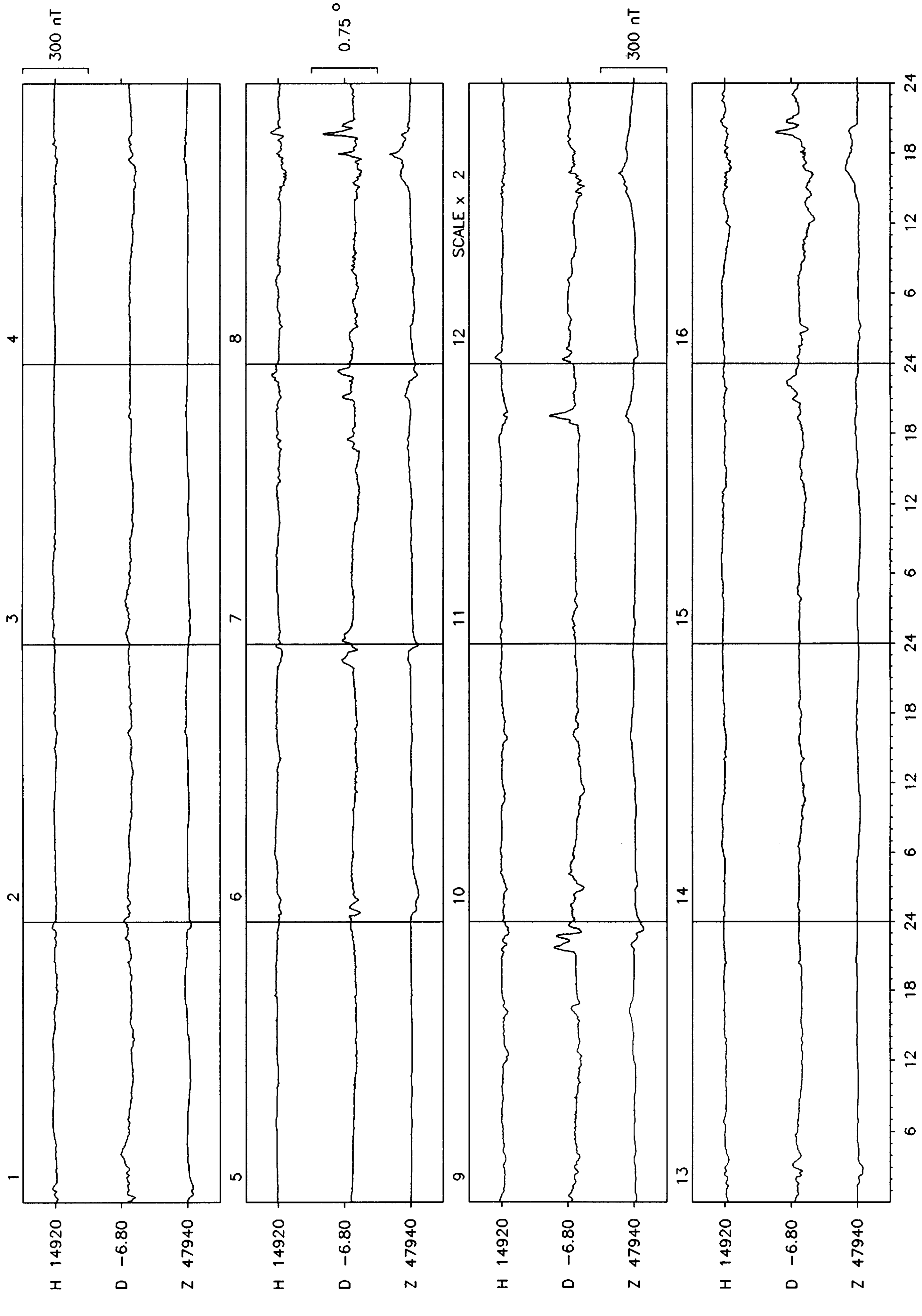
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D −6.80
Z 47940
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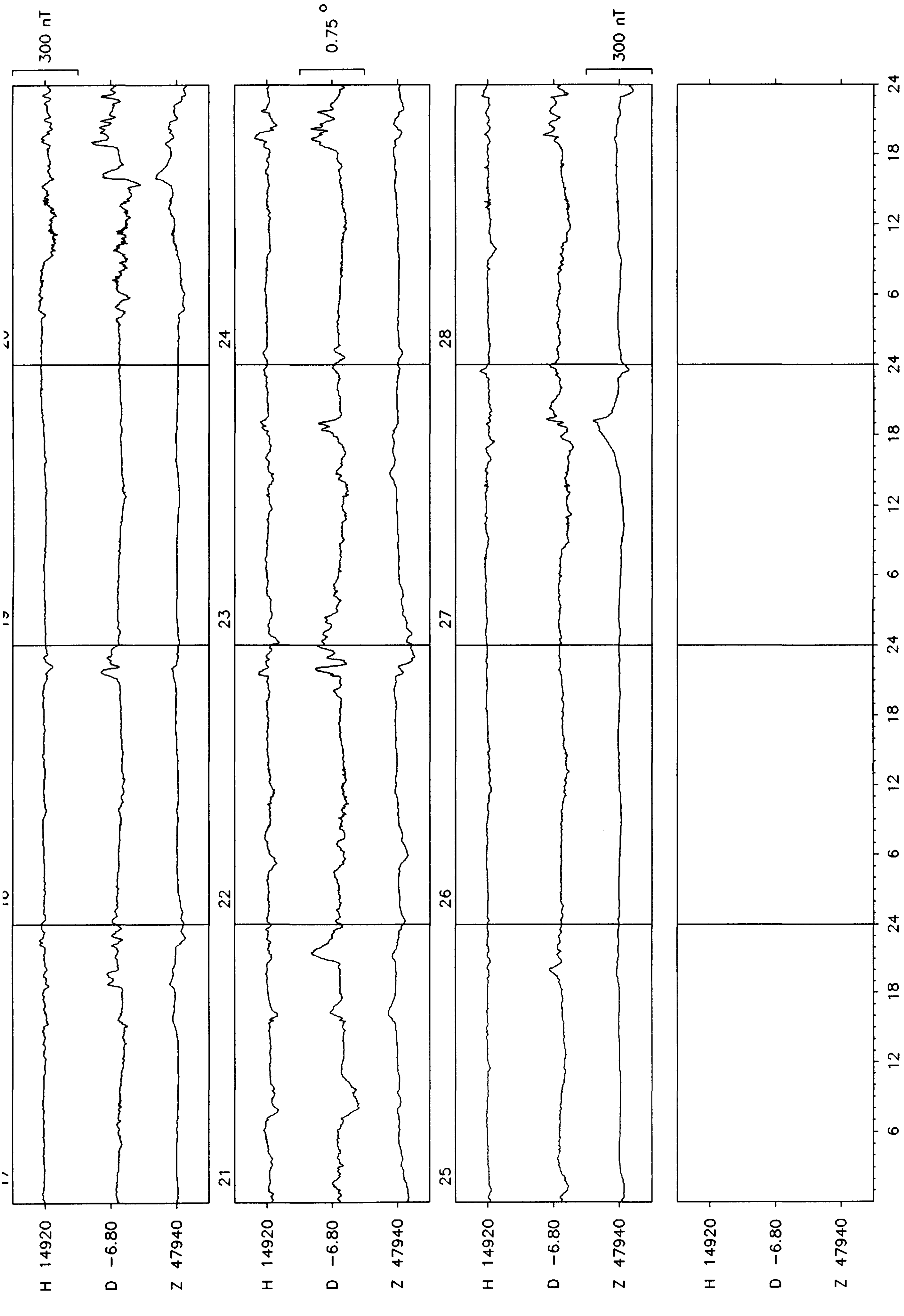
24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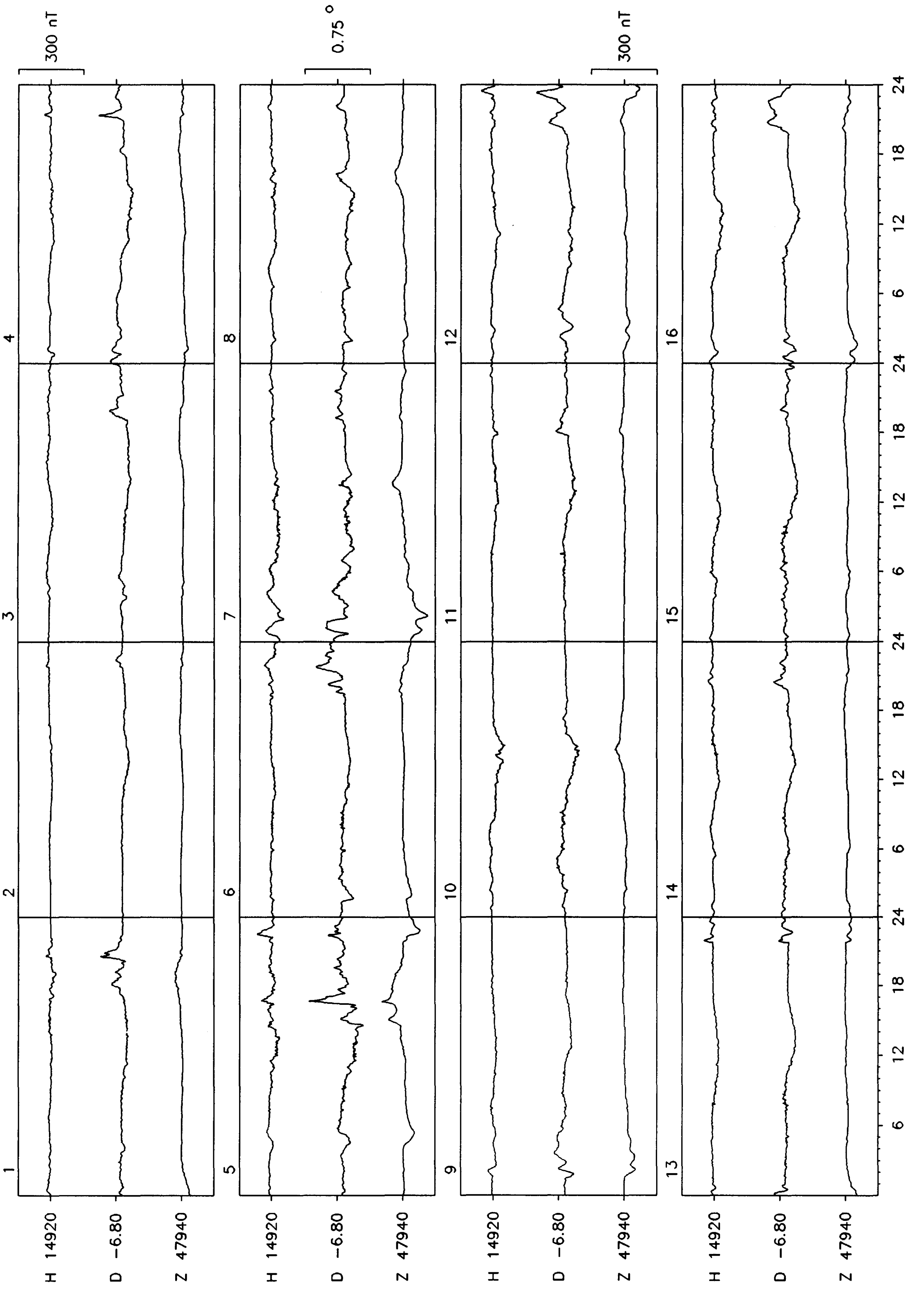
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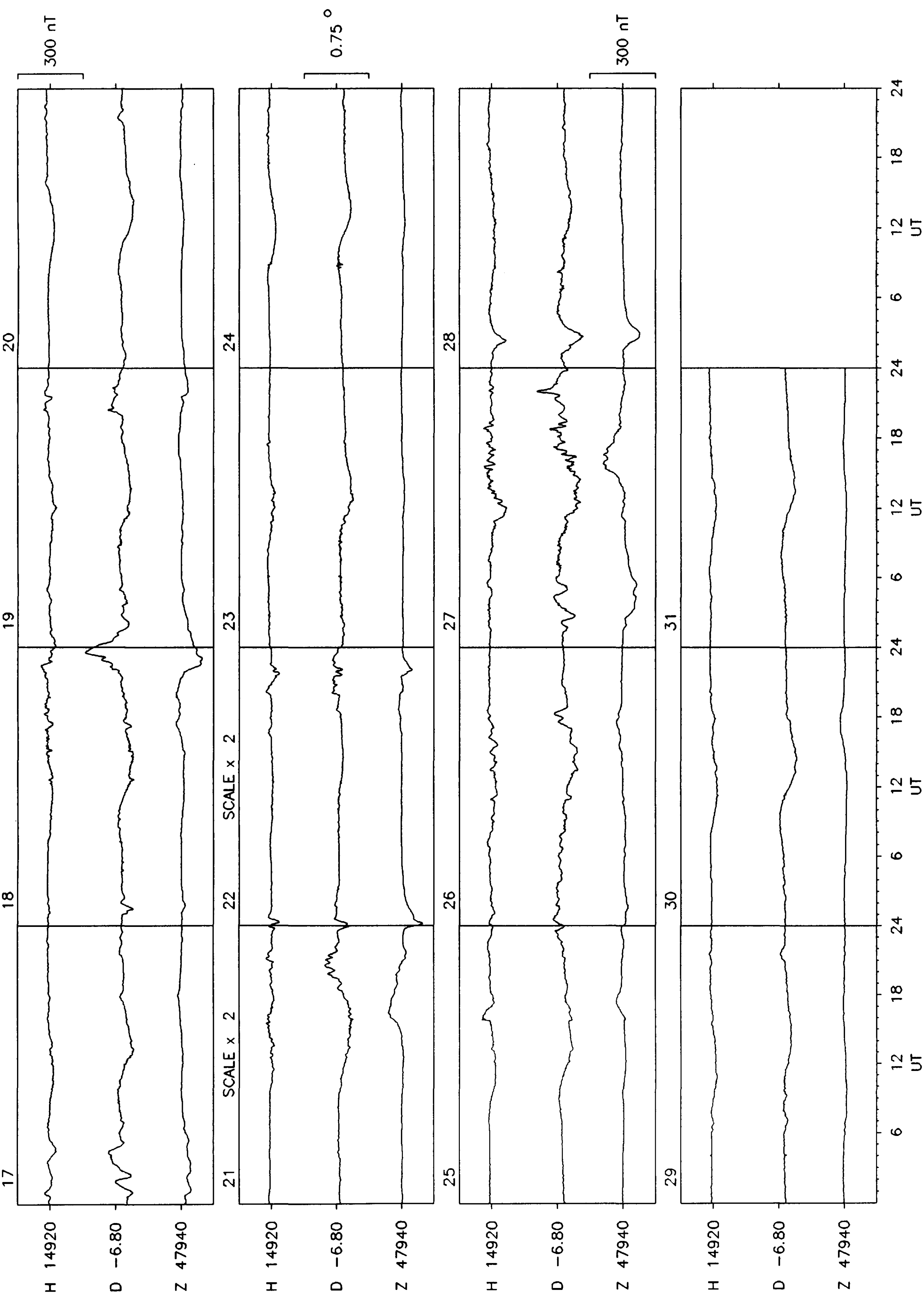

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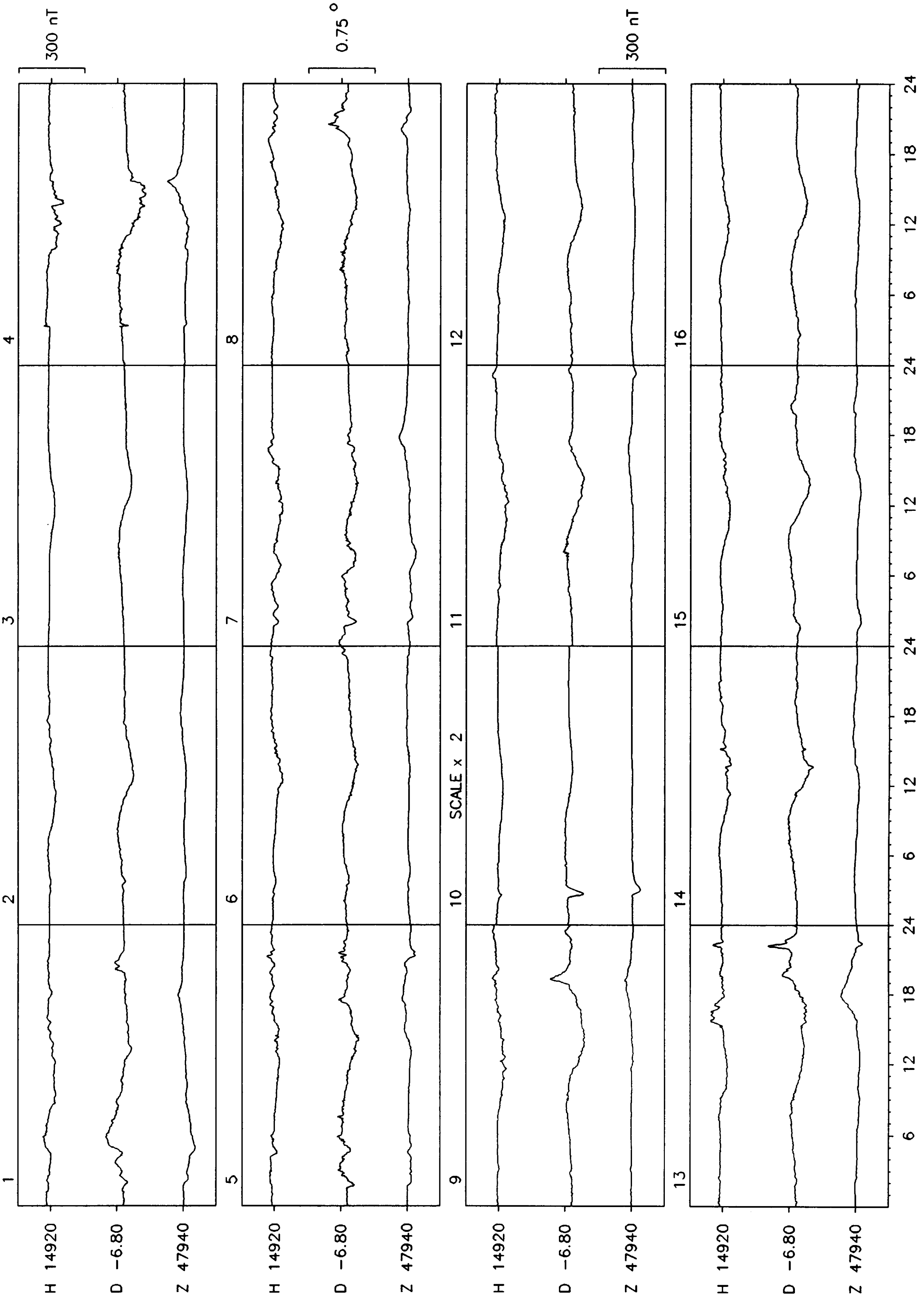
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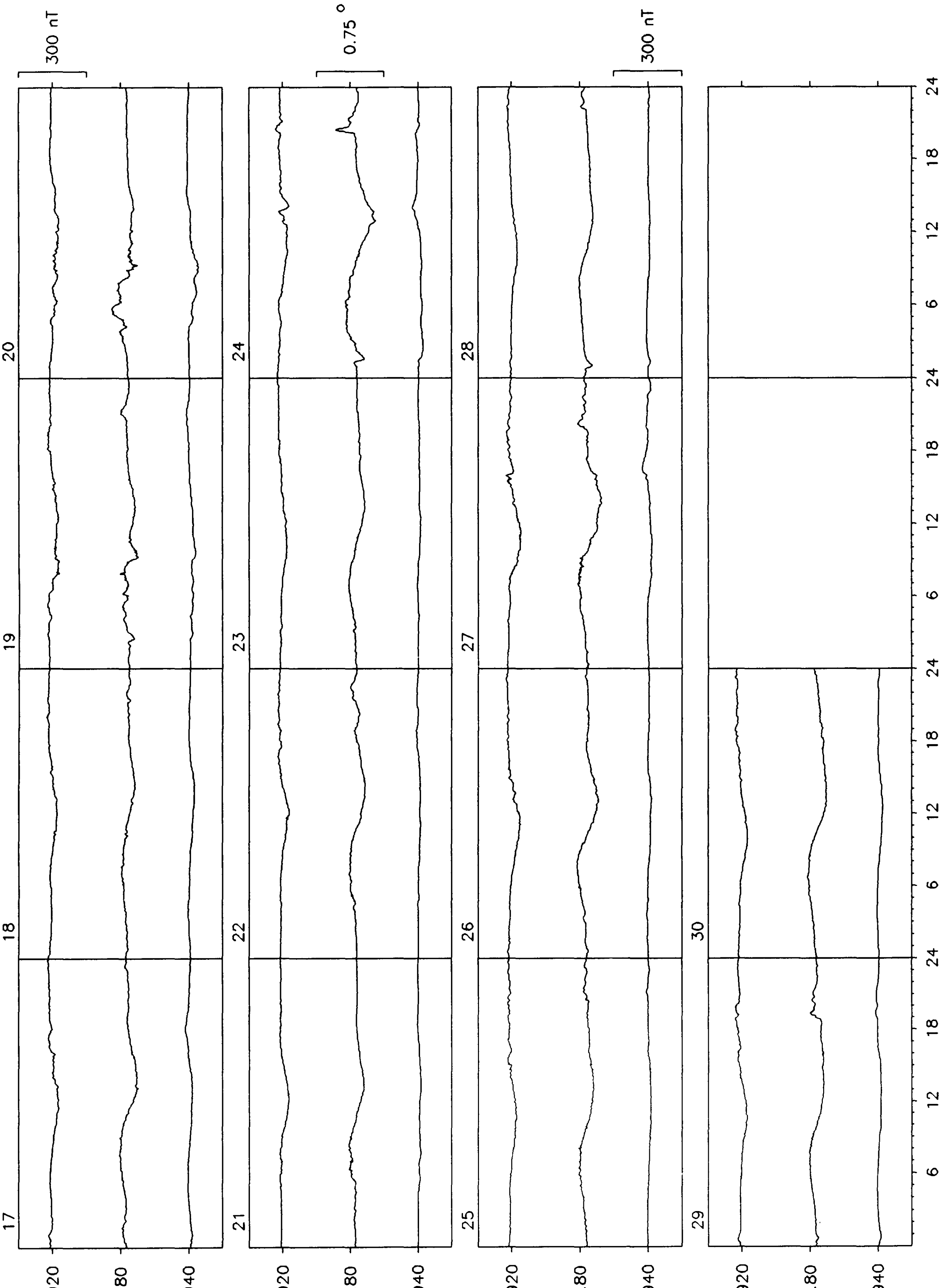
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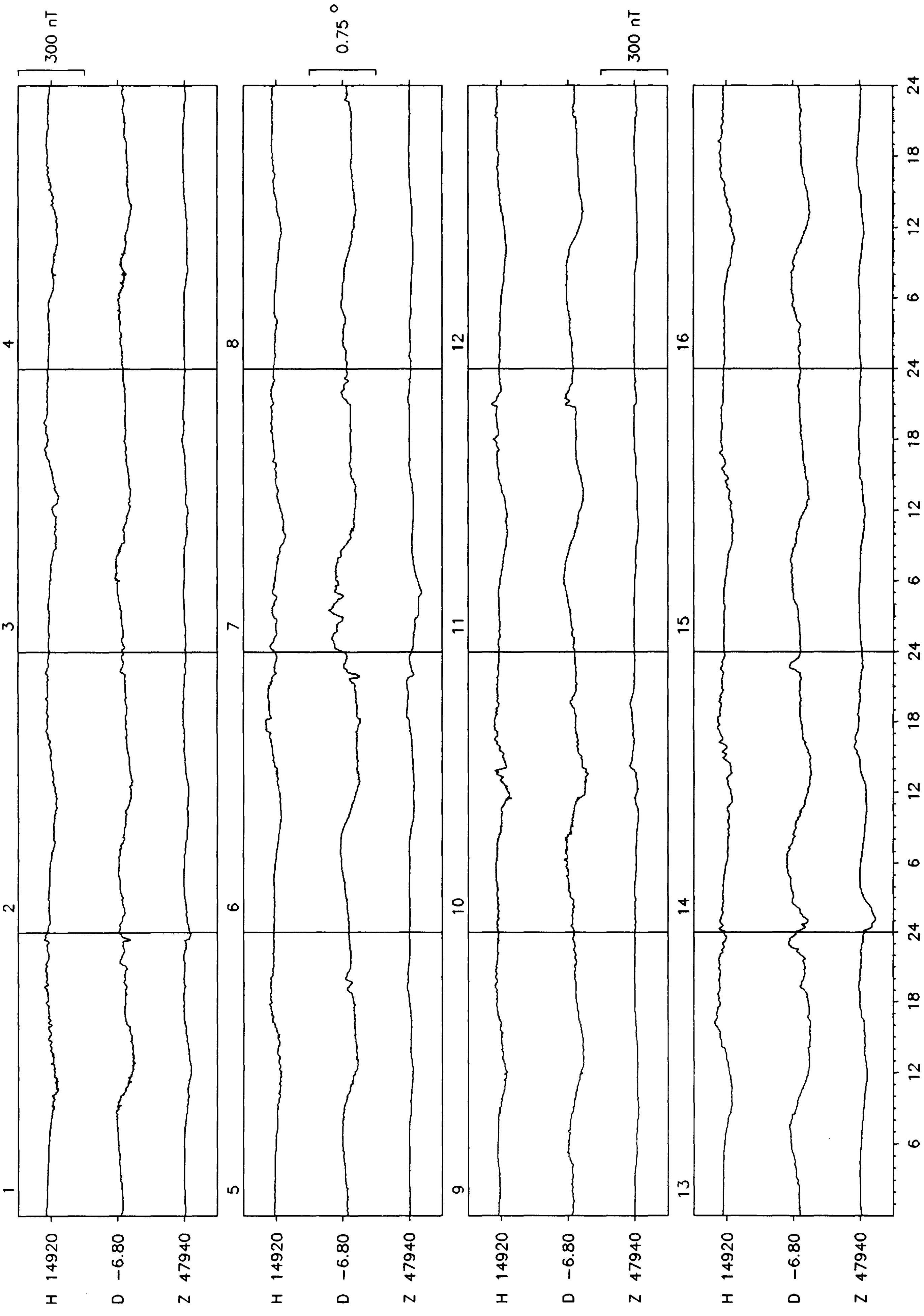
300 nT
0.75 °
300 nT
H 14920
D −6.80
Z 47940
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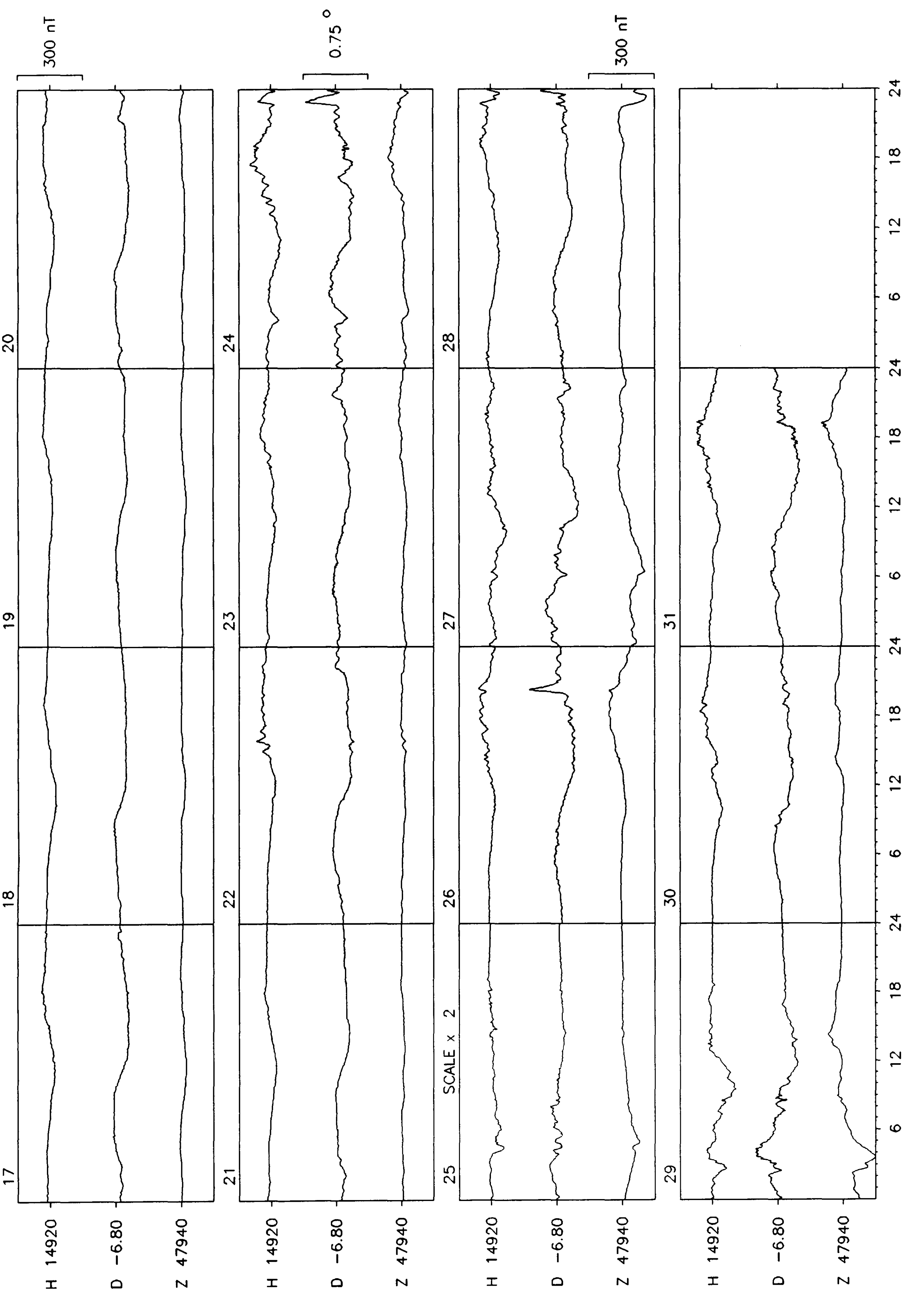
H 14920
D −6.80
Z 47940
300 nT
0.75 °
300 nT
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SCALE x 2
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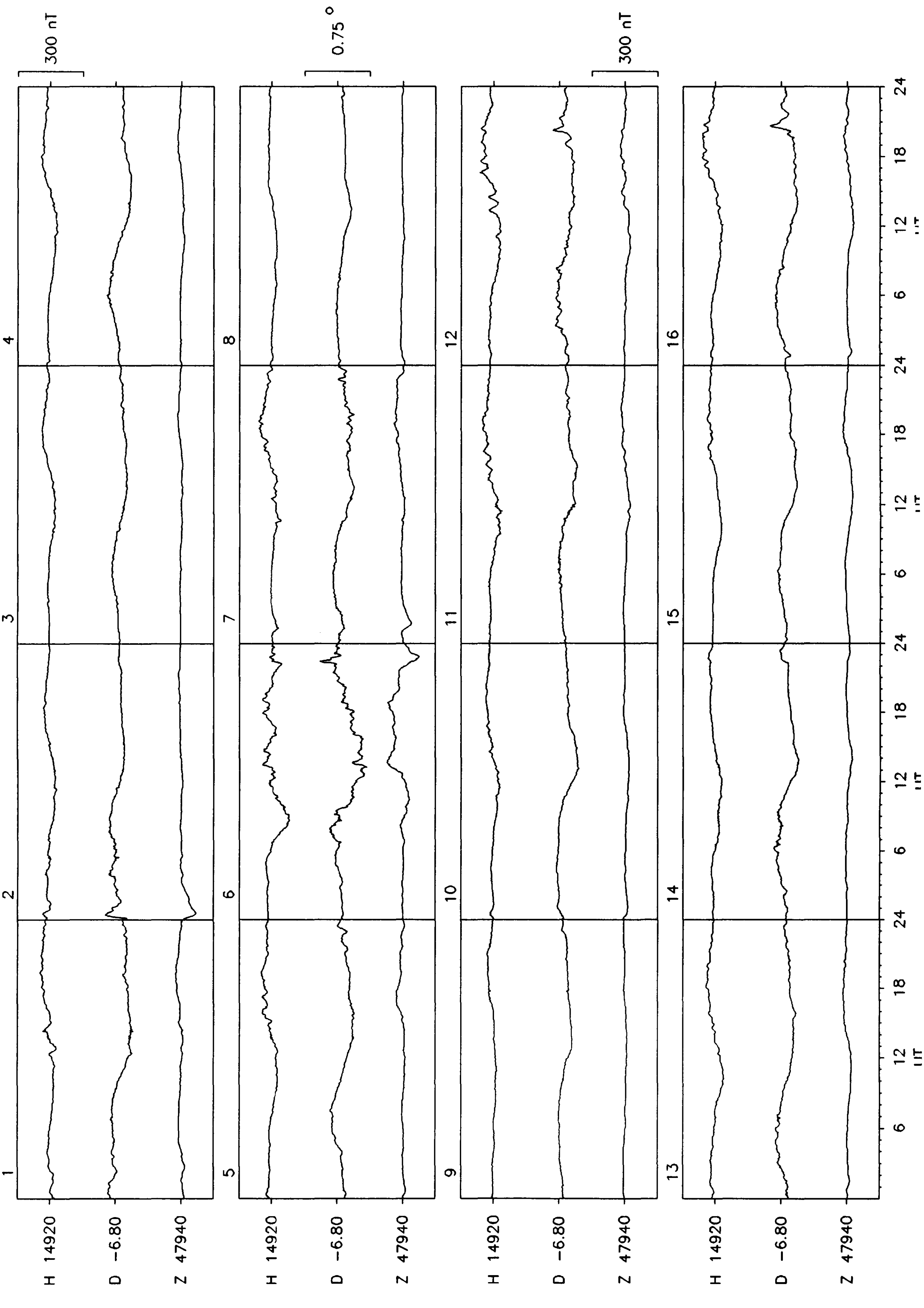
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0.75 °
300 nT
H 14920
D −6.80
Z 47940
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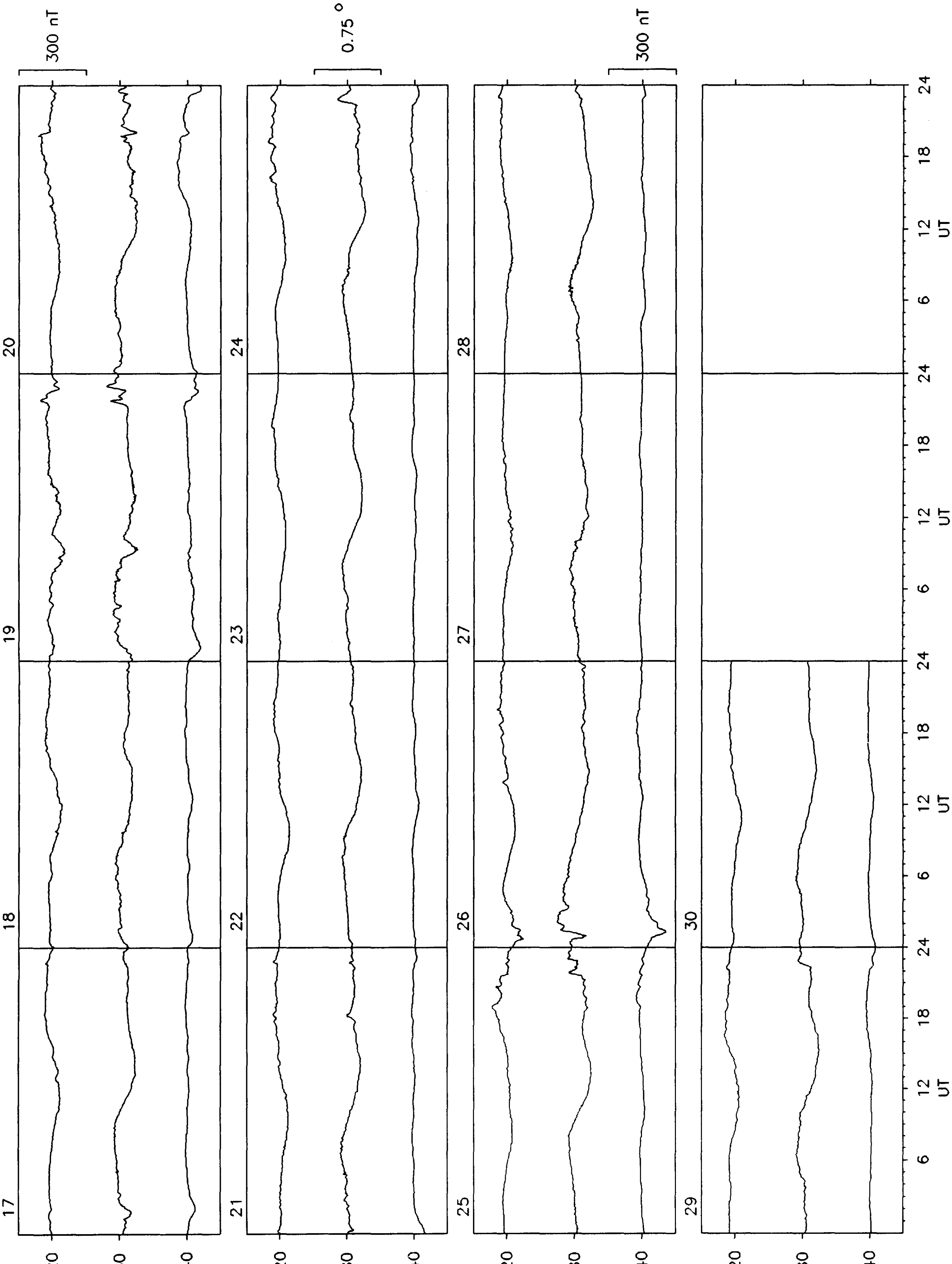
300 nT
0.75 °
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H 14920
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Z 47940
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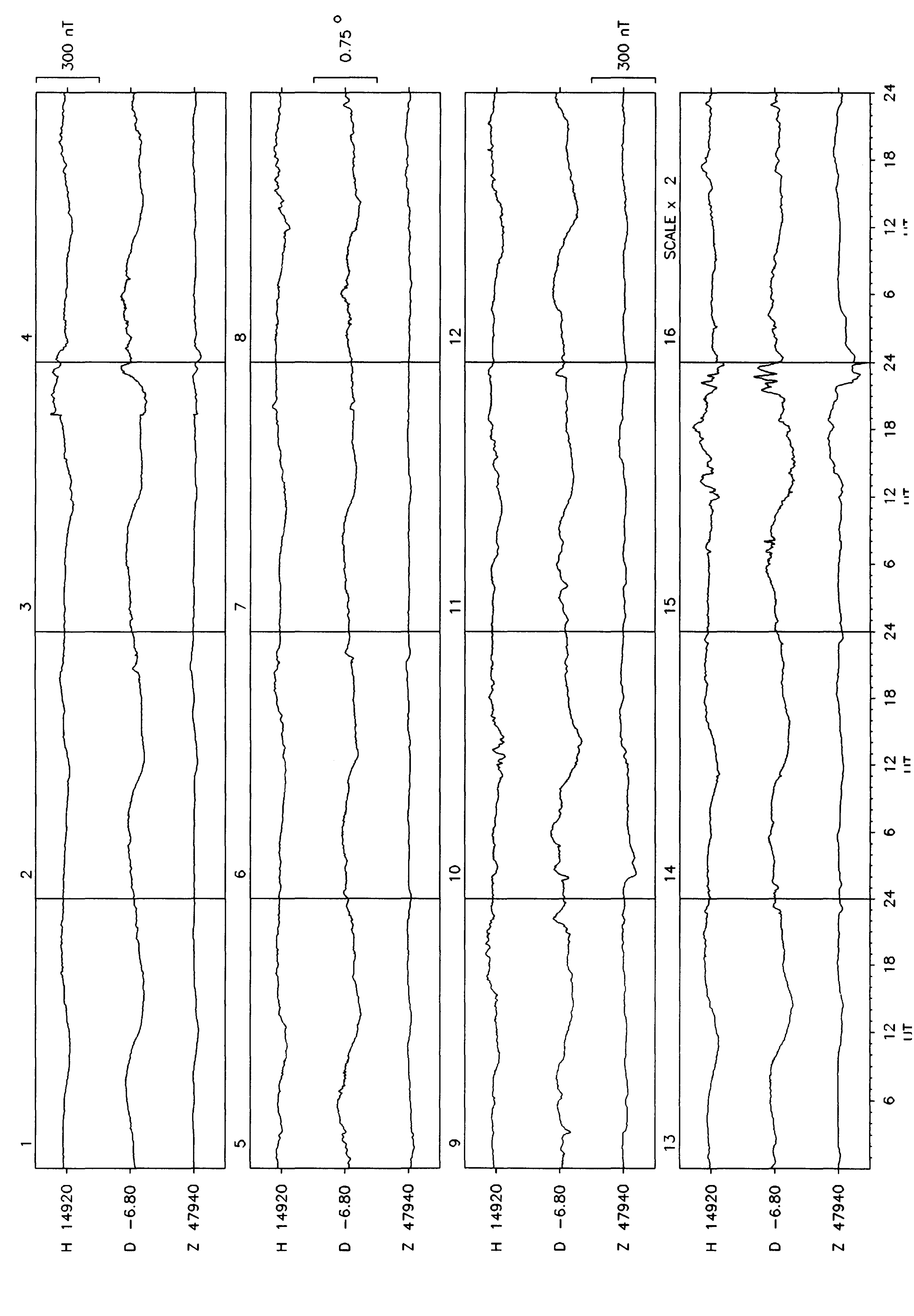
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0.75 °
300 nT
SCALE x 2
H 14920
D −6.80
Z 47940
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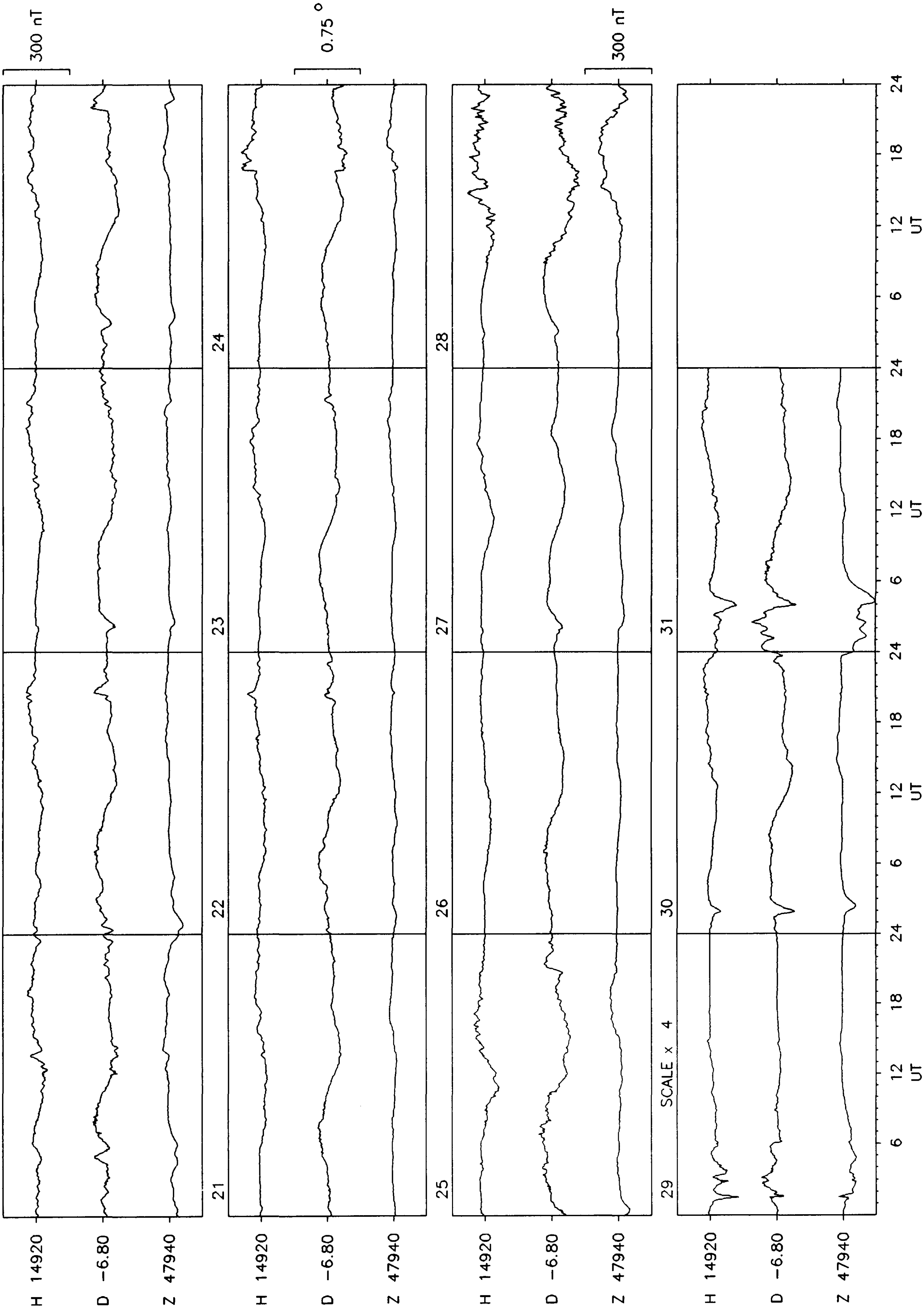
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H 14920
D −6.80
Z 47940
300 nT
0.75 °
300 nT
SCALE x 4
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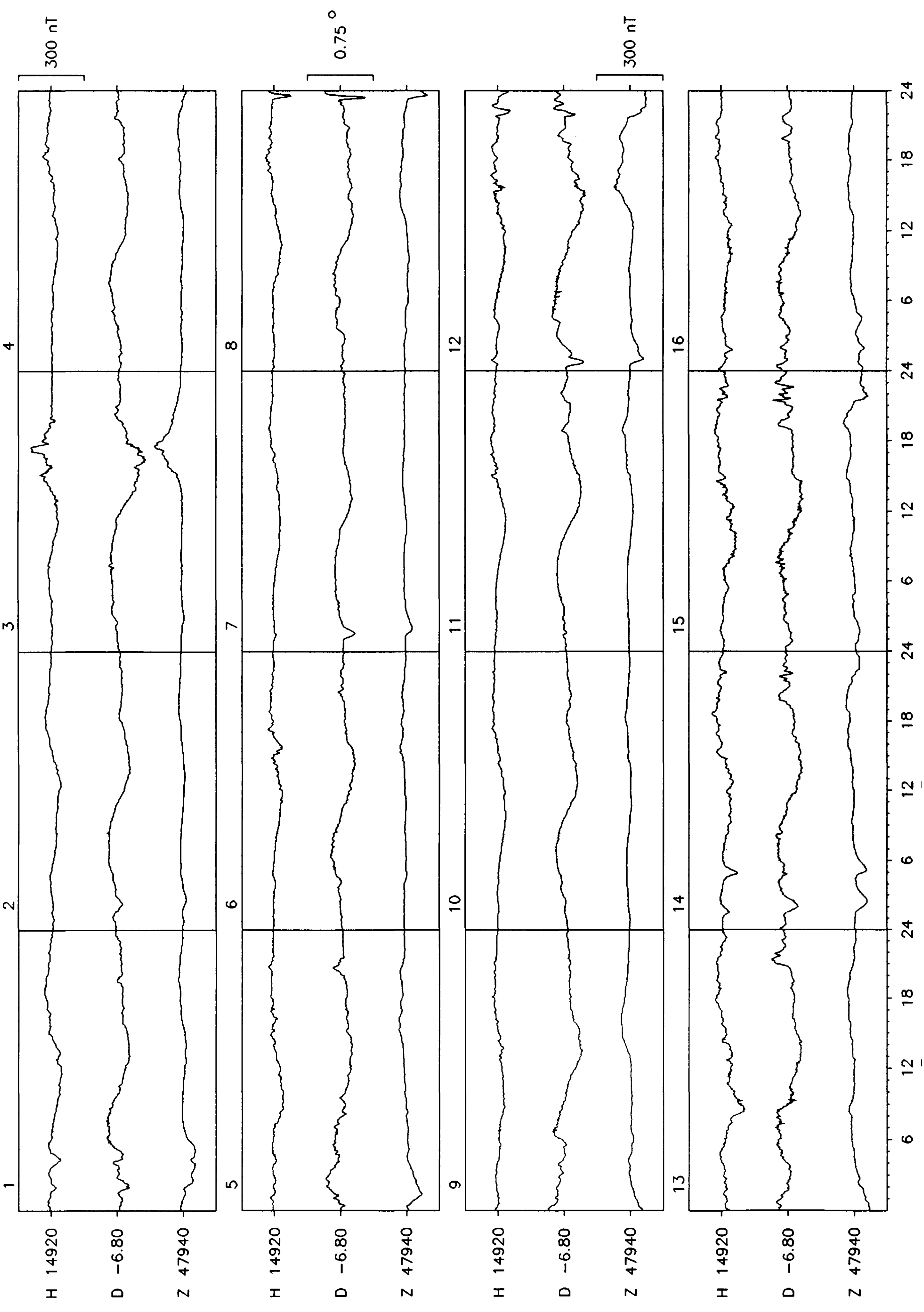

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300 nT
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D −6.80
Z 47940
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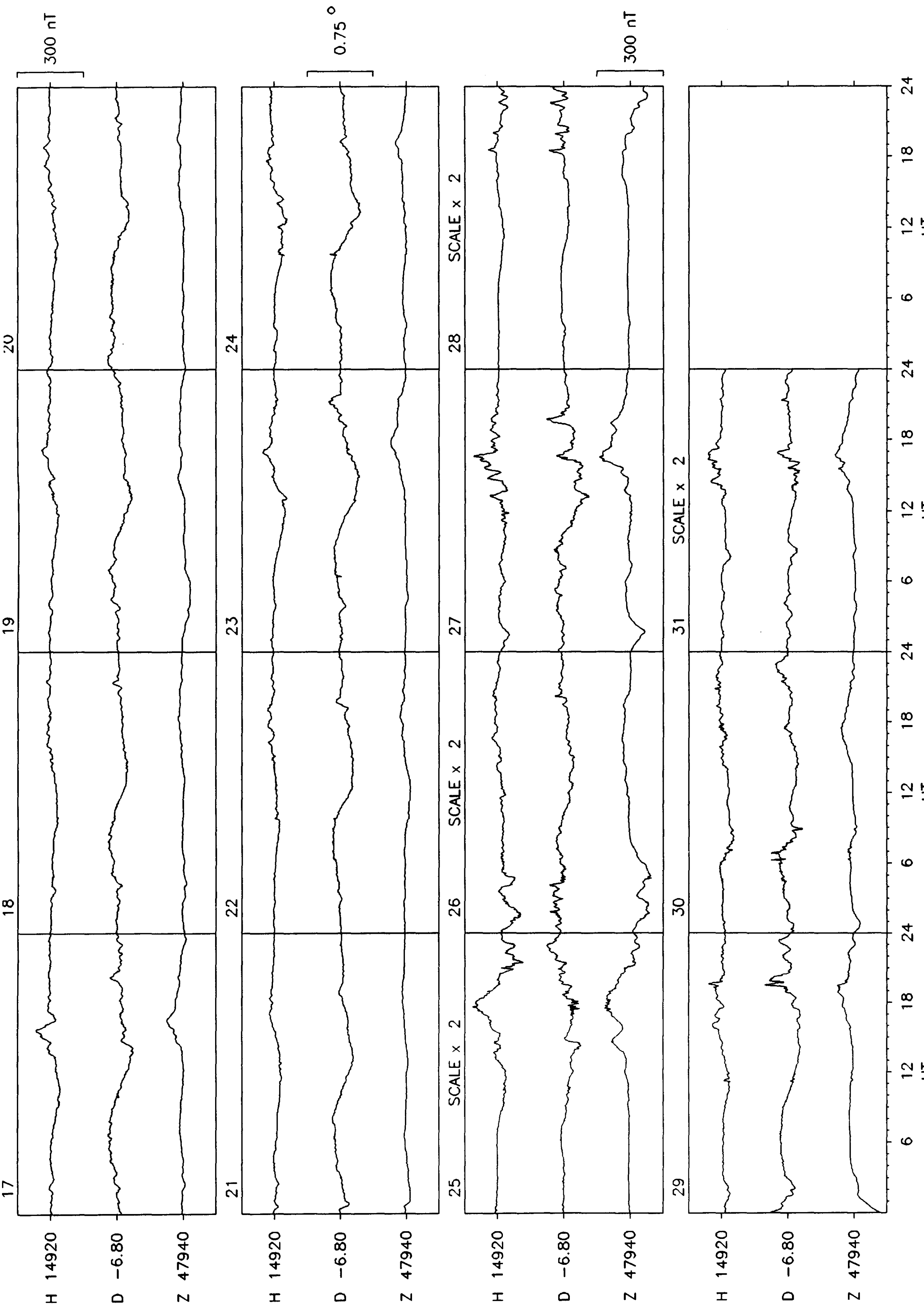

300 nT
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300 nT
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H 14920
D −6.80
Z 47940
SCALE x 2
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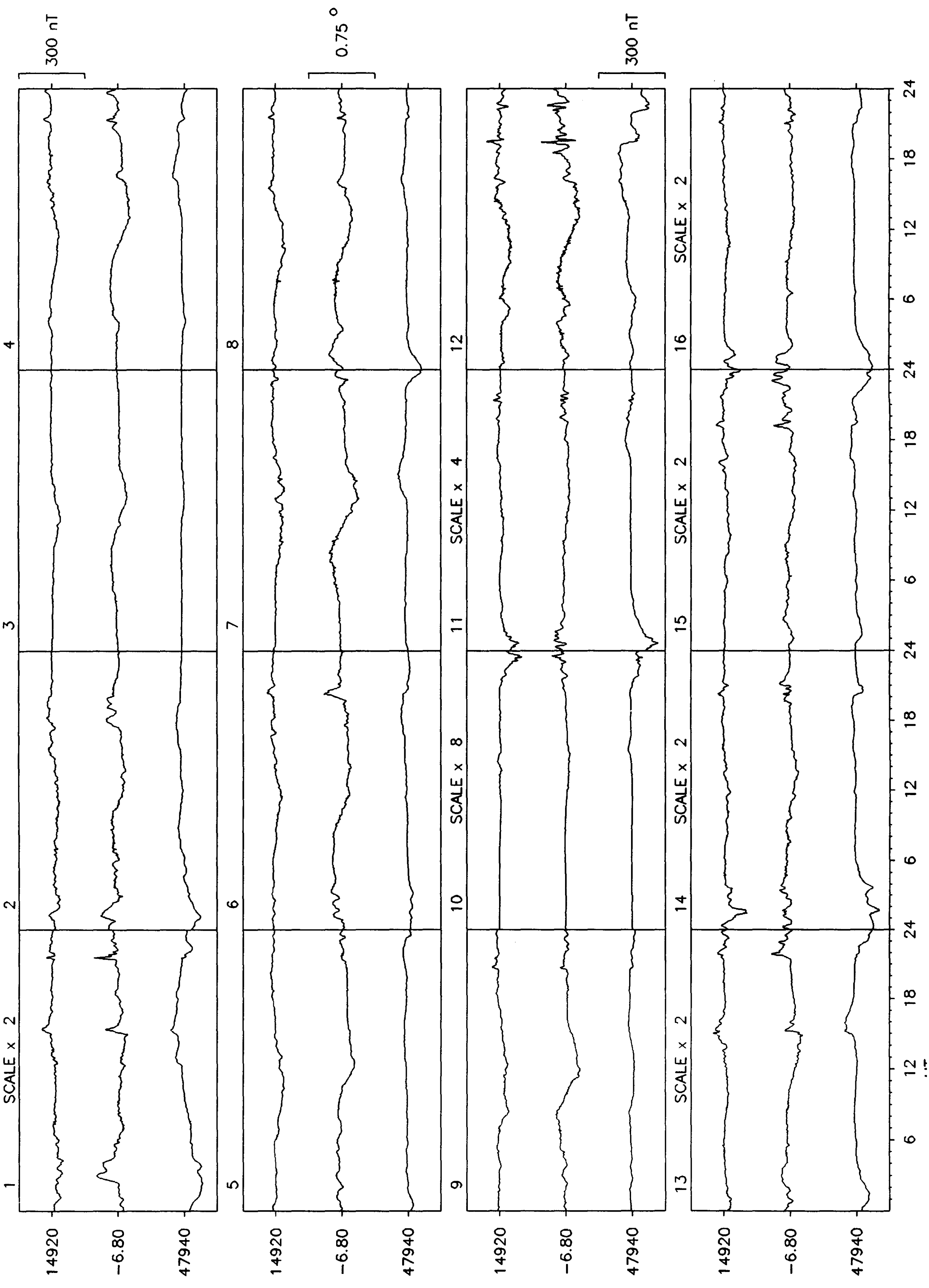
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H 14920
D −6.80
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SCALE x 2
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SCALE x 4
SCALE x 2
SCALE x 2
SCALE x 2
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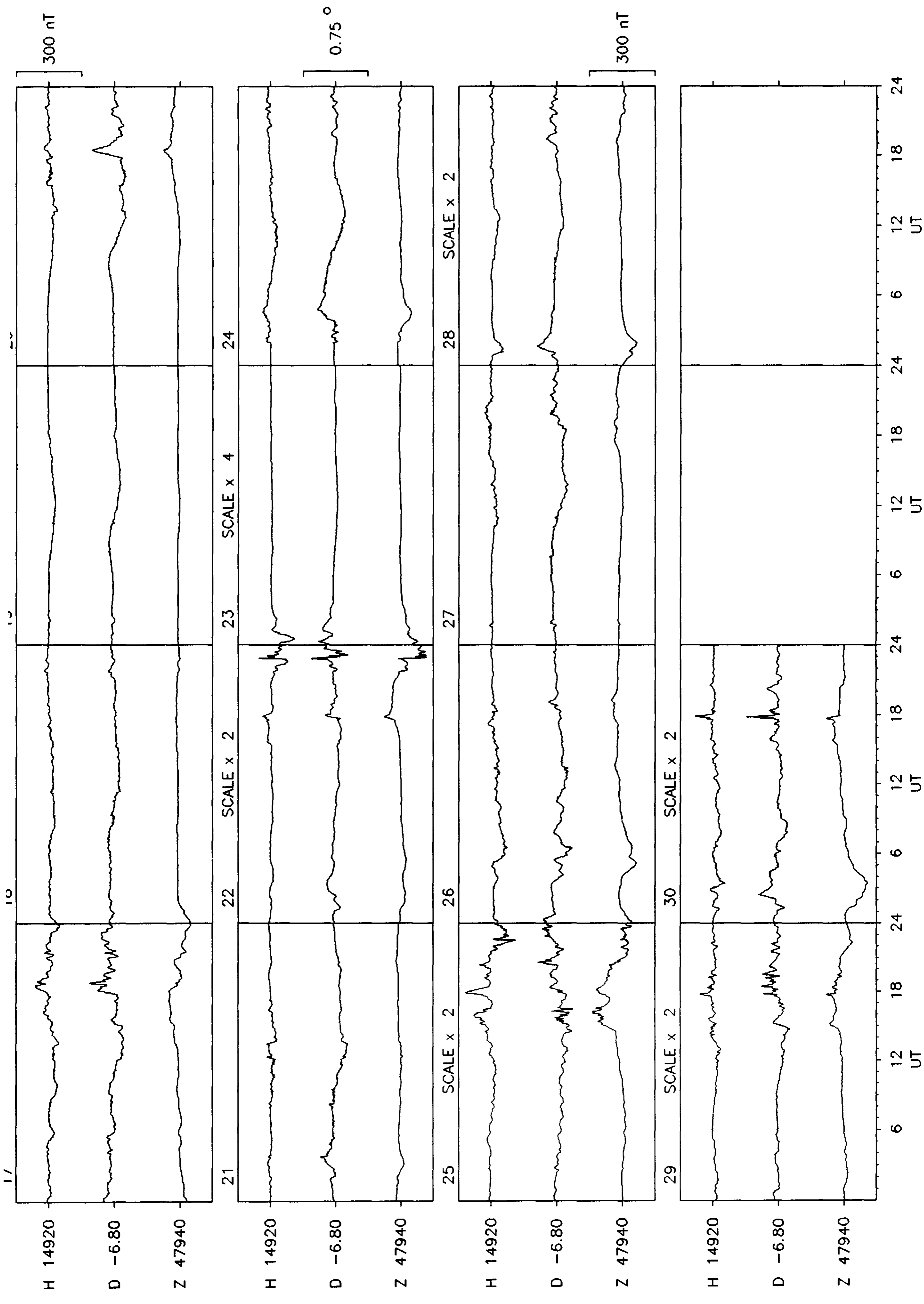

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0.75 °
300 nT
H 14920
D −6.80
Z 47940
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SCALE x 2
SCALE x 4
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SCALE x 2
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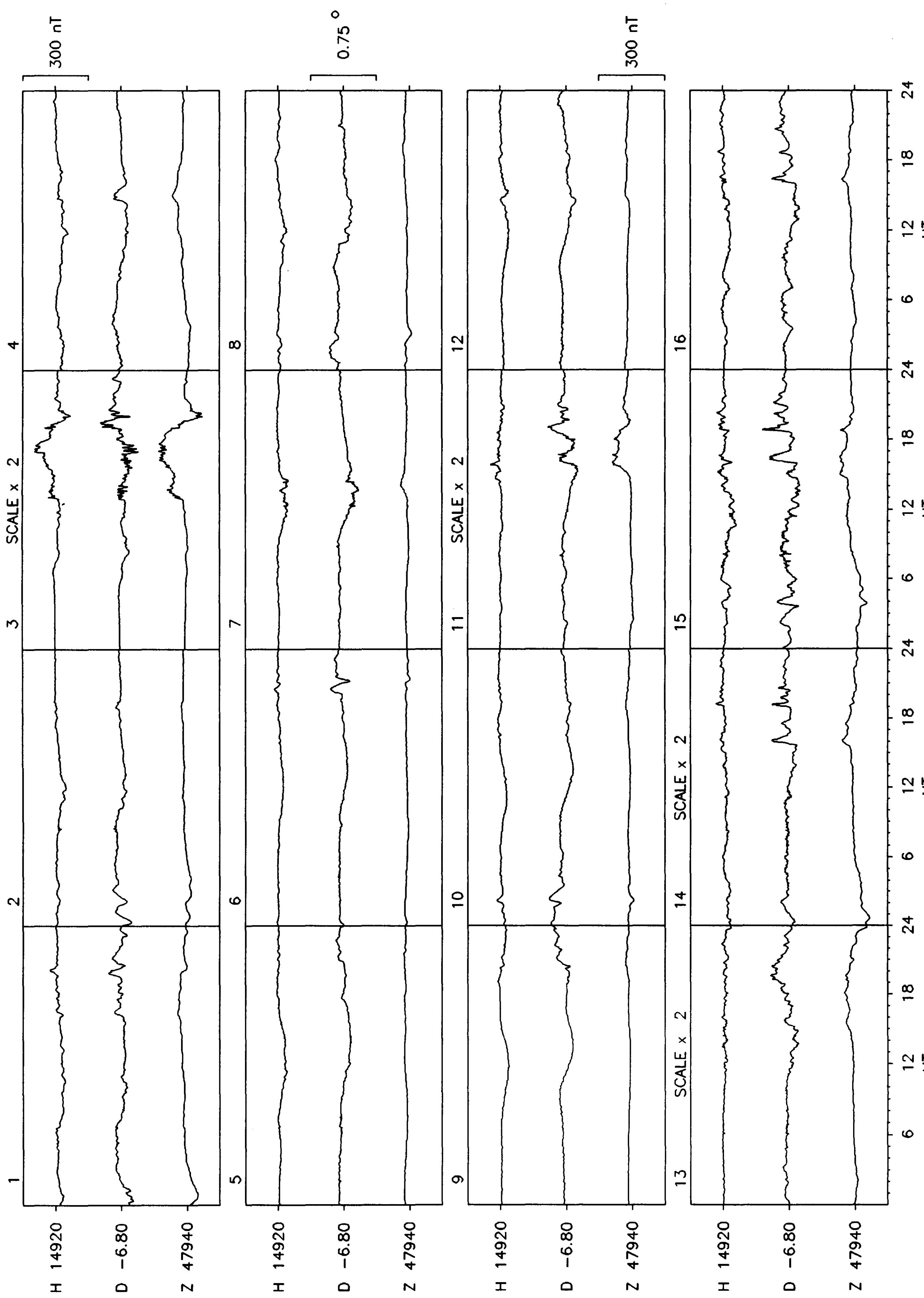
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0.75 °
300 nT
SCALE x 2
H 14920
D −6.80
Z 47940
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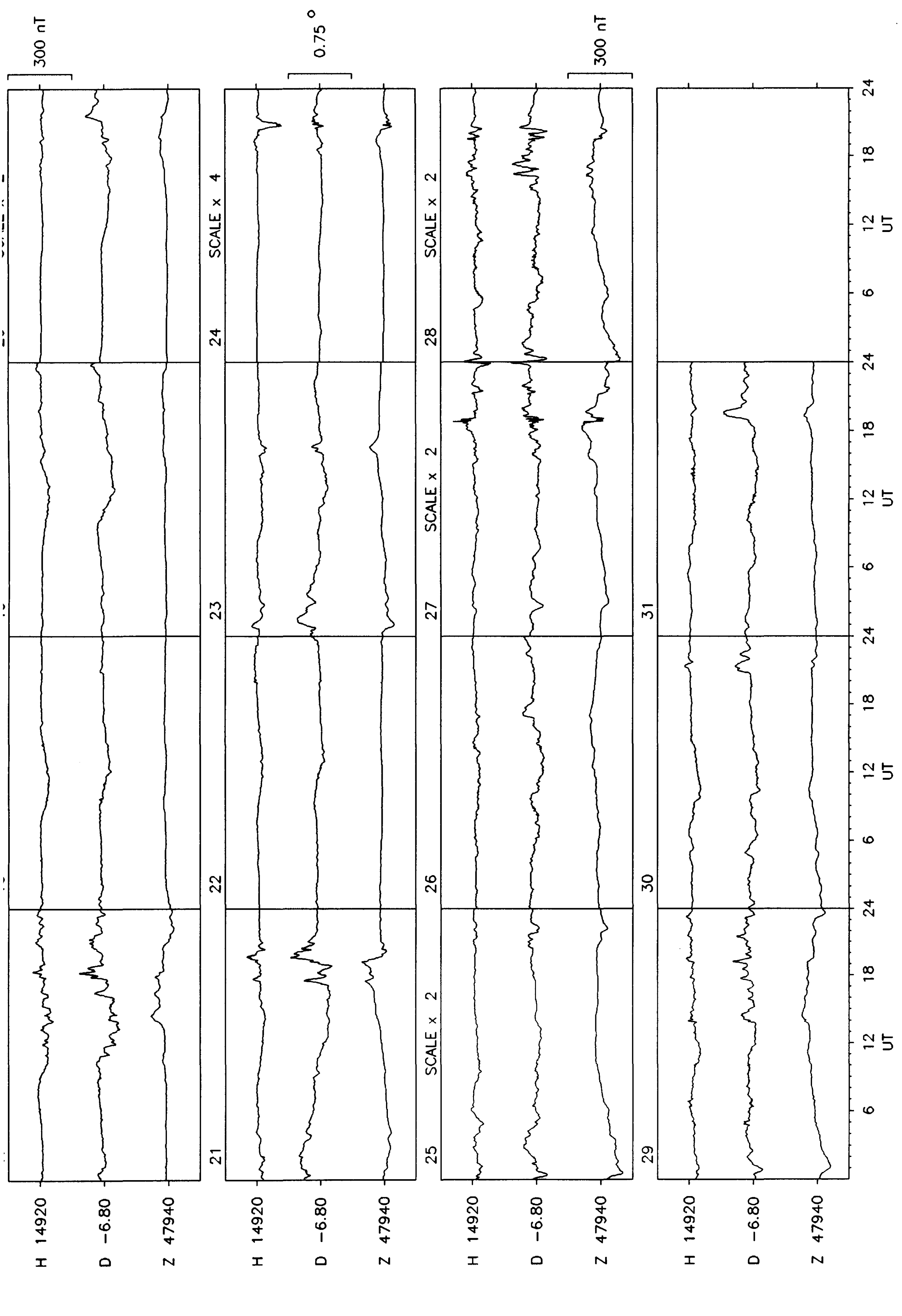
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SCALE x 2
H 14920
D −6.80
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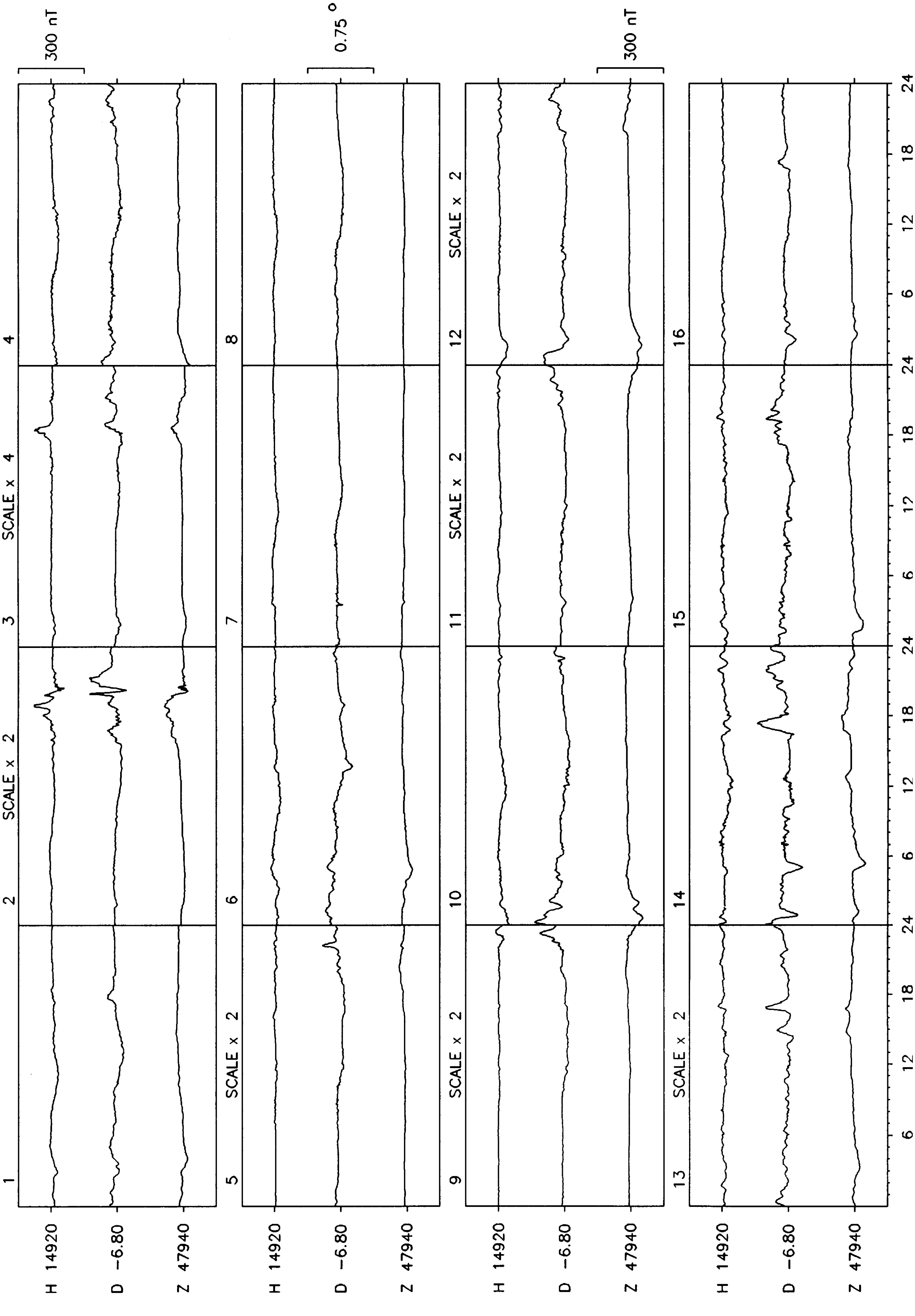
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300 nT
H 14920
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Z 47940
SCALE x 2
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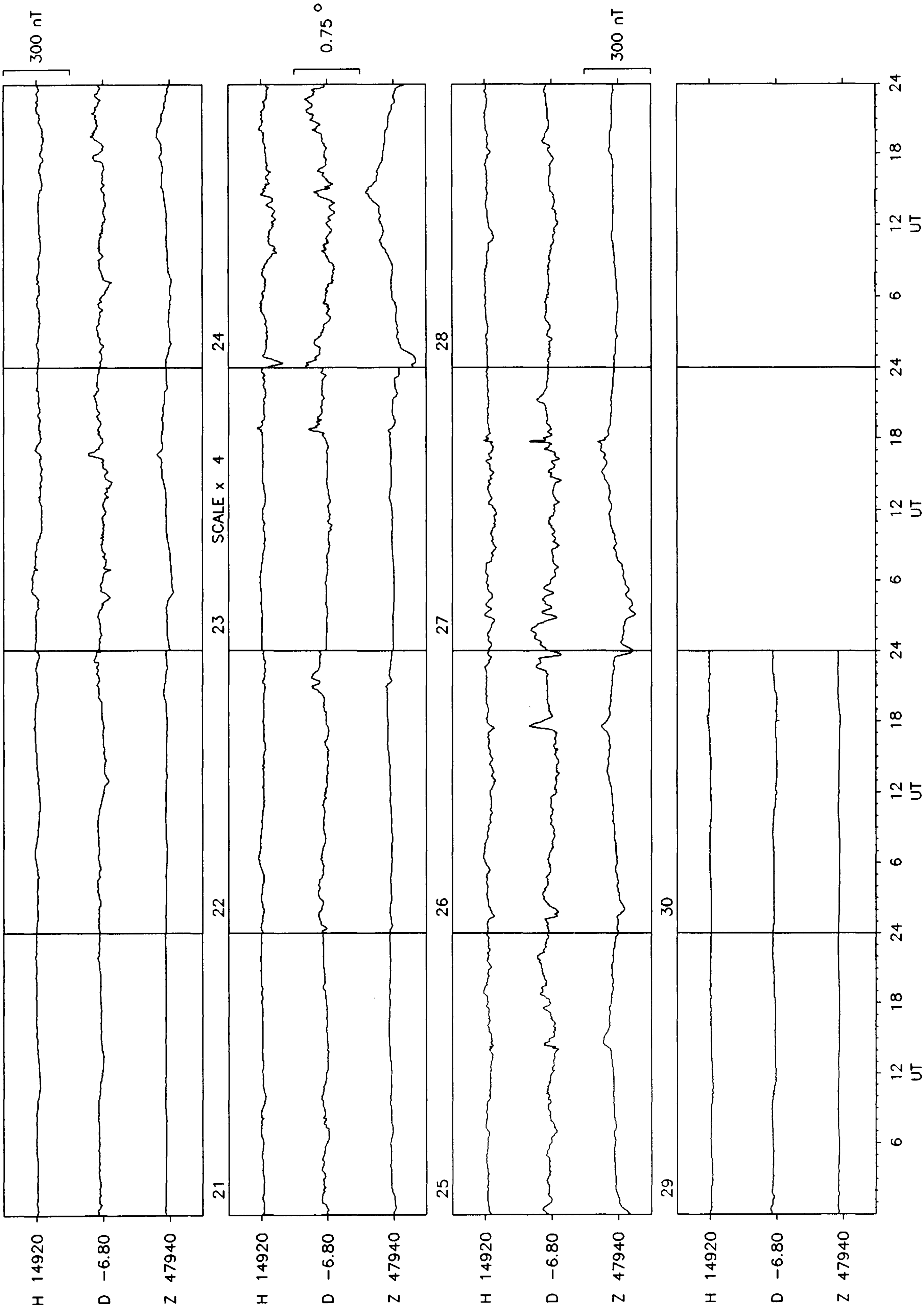

300 nT
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300 nT
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SCALE x 4
H 14920
D −6.80
Z 47940
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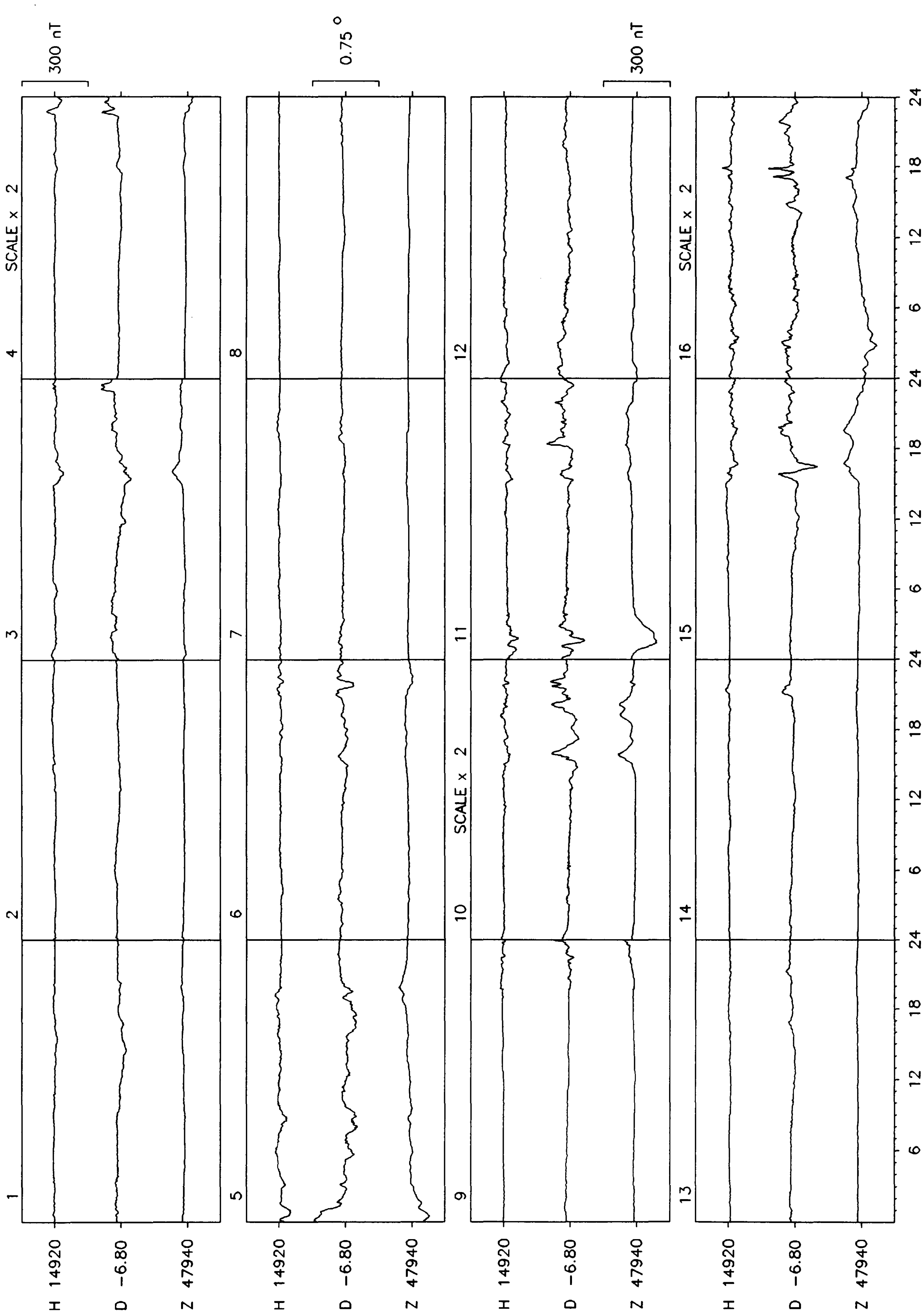
300 nT
0.75 °
300 nT
SCALE x 2
SCALE x 2
SCALE x 2
H 14920
D −6.80
Z 47940
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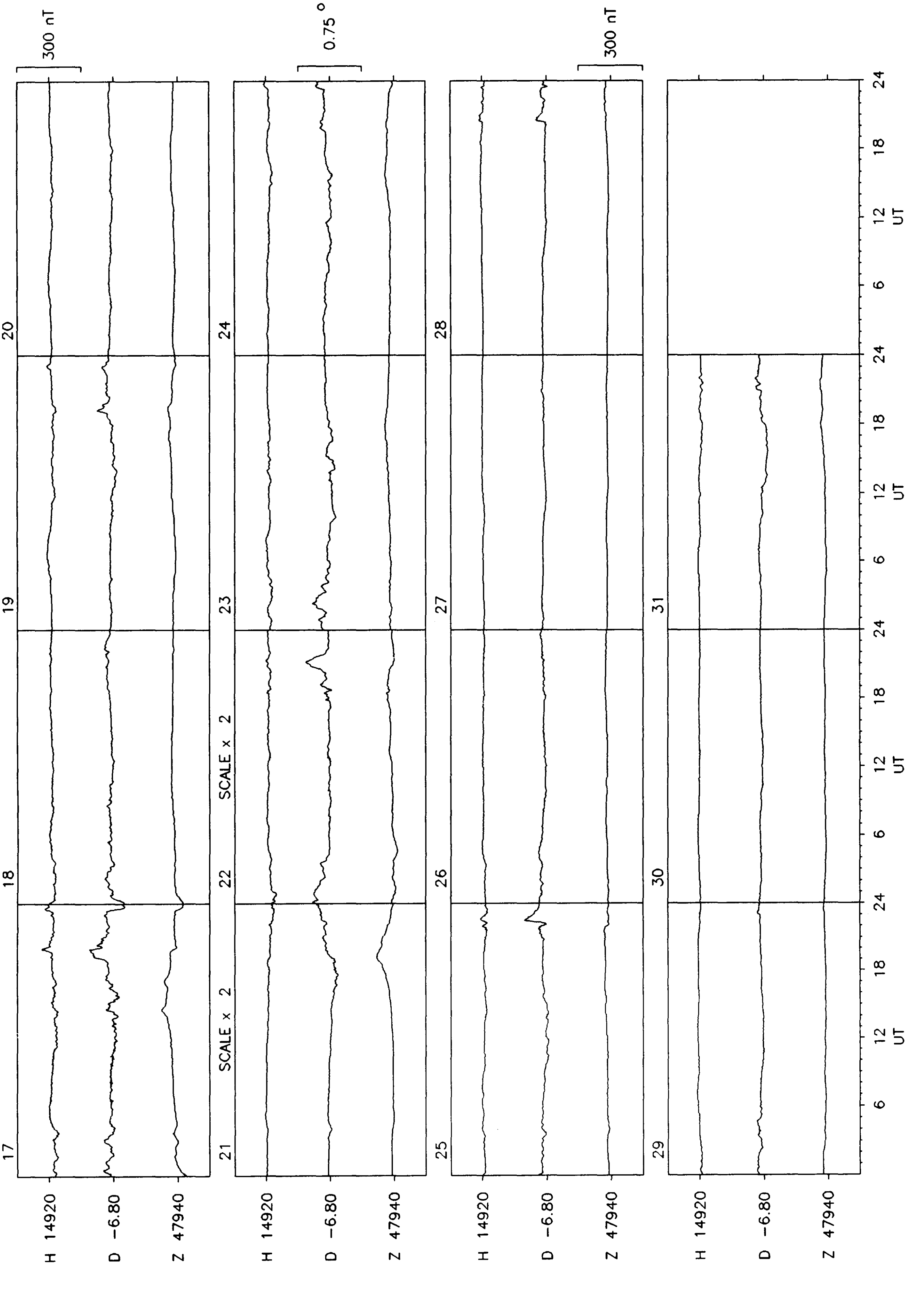
H 14920
D −6.80
Z 47940
300 nT
0.75 °
300 nT
SCALE x 2
SCALE x 2
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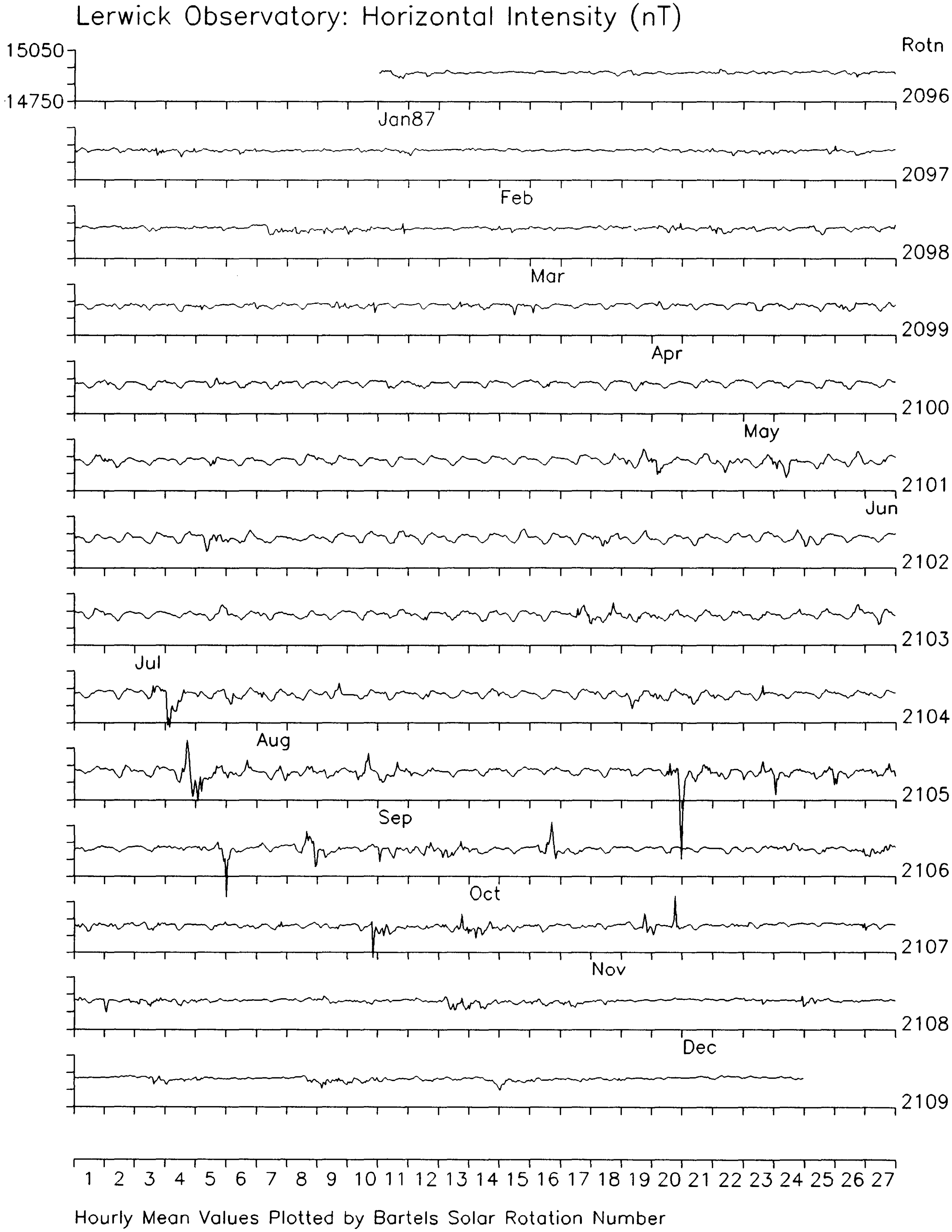
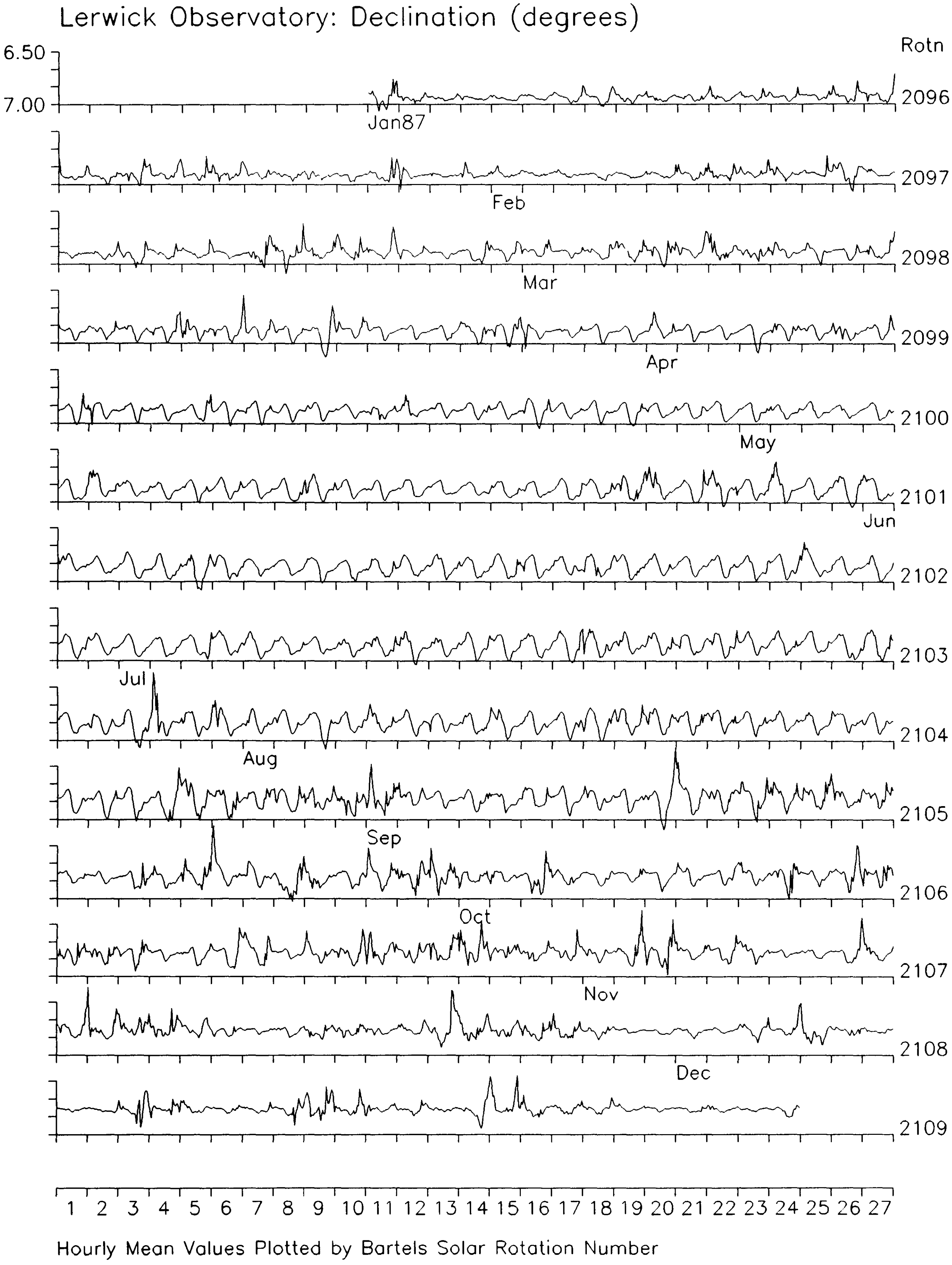
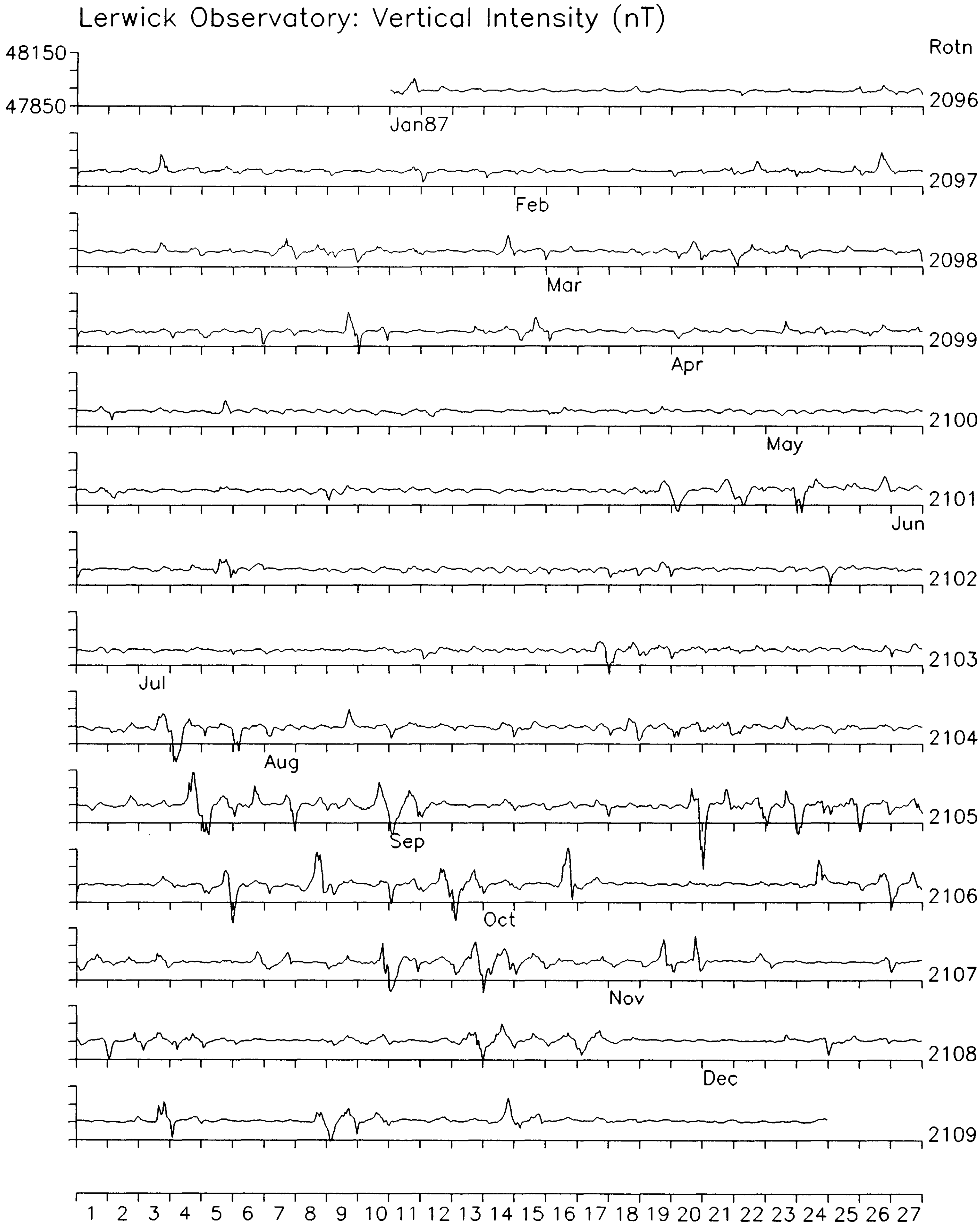
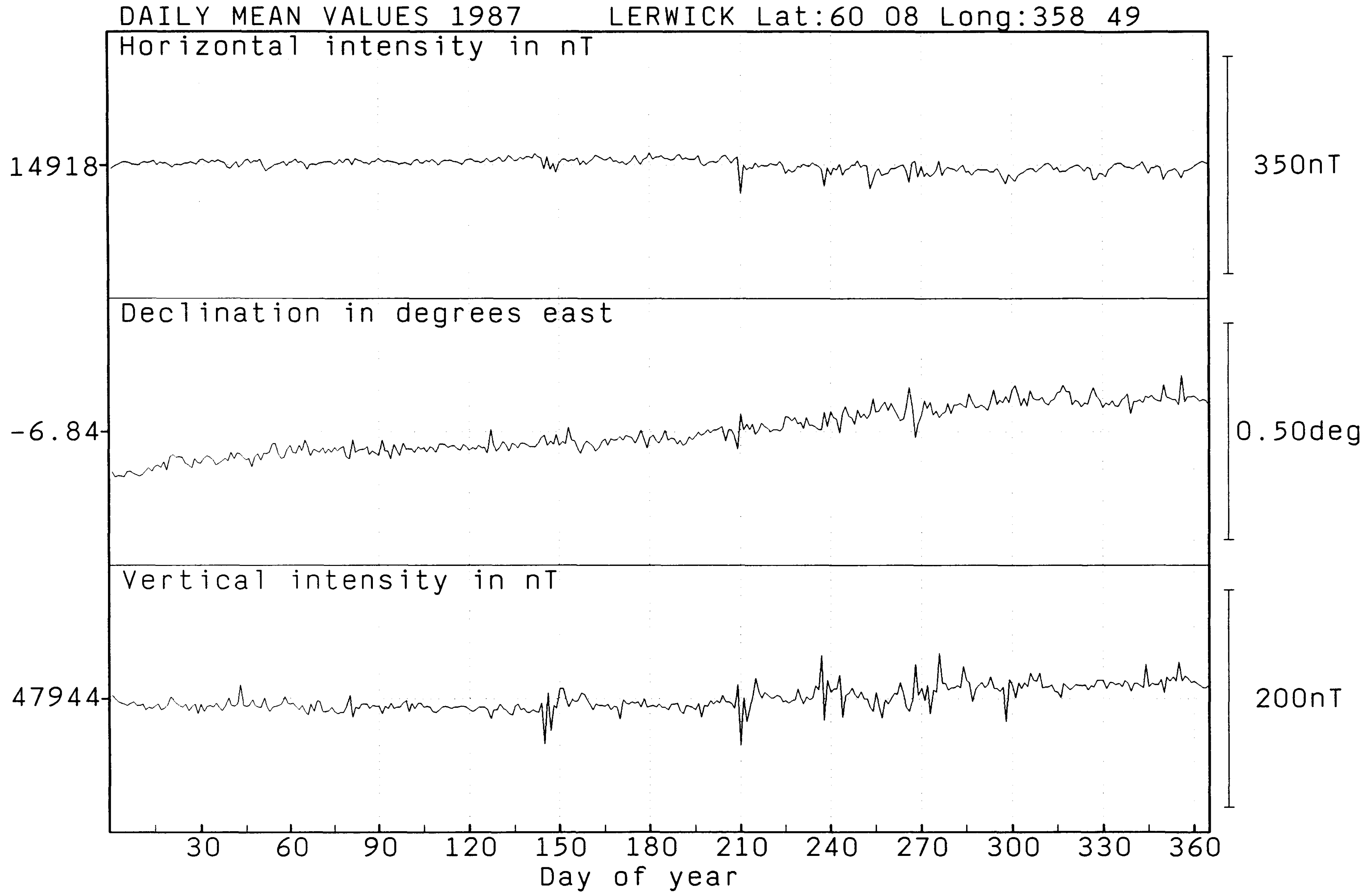

Lerwick Observatory: Horizontal Intensity (nT)
15050
14750
Rotn
2096
Jan87
2097
Feb
2098
Mar
2099
Apr
2100
May
2101
Jun
2102
2103
Jul
2104
Aug
2105
Sep
2106
Oct
2107
Nov
2108
Dec
2109
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted by Bartels Solar Rotation Number



Lerwick Observatory: Declination (degrees)
6.50
7.00
Rotn
2096
Jan87
2097
Feb
2098
Mar
2099
Apr
2100
May
2101
Jun
2102
2103
Jul
2104
Aug
2105
Sep
2106
Oct
2107
Nov
2108
Dec
2109
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



Hourly Mean Values Plotted by Bartels Solar Rotation Number


DAILY MEAN VALUES 1987 LERWICK Lat:60 08 Long:358 49
Horizontal intensity in nT
14918
350nT
Declination in degrees east
-6.84
0.50deg
Vertical intensity in nT
47944
200nT
30
60
90
120
150
180
210
240
270
300
330
360
Day of year

Monthly and annual mean values for Lerwick 1987

Month	D	I	H	X	Y	Z	F
	° ′	° ′	nT	nT	nT	nT	nT
Jan	-6 55.2	72 42.7	14921	14812	-1798	47938	50206
Feb	-6 53.7	72 42.7	14920	14812	-1791	47939	50207
Mar	-6 52.9	72 42.5	14923	14815	-1788	47936	50205
Apr	-6 52.6	72 42.5	14923	14816	-1787	47936	50205
May	-6 52.1	72 42.2	14926	14819	-1785	47934	50204
Jun	-6 51.6	72 42.3	14926	14819	-1783	47939	50209
Jul	-6 50.8	72 42.4	14925	14819	-1779	47937	50207
Aug	-6 49.3	72 43.3	14914	14808	-1771	47948	50214
Sep	-6 47.5	72 43.6	14909	14804	-1763	47945	50210
Oct	-6 46.4	72 43.9	14907	14803	-1758	47956	50219
Nov	-6 45.8	72 43.7	14911	14807	-1756	47957	50222
Dec	-6 45.8	72 43.5	14914	14810	-1756	47959	50224
Annual	-6 50.3	72 43.0	14918	14812	-1776	47944	50211

LERWICK OBSERVATORY K INDICES 1987

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	1222 2343	2200 0112	1101 1233	2321 2221	0012 2222	2101 3211	0000 1101	2311 3121	5432 3425	3121 1233	2201 1210	1100 0110
2	0111 2211	2000 0100	0000 0102	0101 1100	1011 1211	3221 1210	0100 0121	2110 2210	3221 1321	3112 2110	1121 2464	1000 0100
3	0111 0001	1100 0010	0201 1132	0000 1000	0111 2210	0001 1211	0001 1133	0111 3431	0101 2101	0132 4553	3202 3564	2111 1313
4	1000 0001	0000 0110	2101 2113	0213 3300	1122 2211	1111 2211	3111 1211	1111 2222	1101 2222	1212 3211	3210 2022	1000 0224
5	1000 0000	0000 0101	0312 3433	3221 2322	0002 2320	1211 2322	1111 2111	3222 2221	2112 2112	0011 1222	1012 1224	4332 1220
6	0100 0001	2100 1103	3112 1033	0101 2202	0001 2233	0133 3333	1101 1212	0211 2321	2112 2231	1001 0123	1211 2111	0100 1223
7	0000 0013	2001 1223	4332 2122	3222 2310	2322 1212	2002 2322	0000 1120	3101 1210	0112 3213	1123 3311	1111 0000	1010 0010
8	1001 1122	1221 1341	2122 2312	1022 2233	1100 1101	1000 1000	1222 3222	1221 2224	3221 2212	2112 2121	0001 1100	0000 0000
9	1021 1101	2111 2204	3211 1000	0001 2231	0101 2111	0000 0102	1211 1323	2220 2111	1232 2121	0000 0022	0001 1224	0000 0013
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12	2311 0101	3222 3431	2312 1134	0110 1101	0000 1111	1212 3332	0211 2222	3221 3334	2222 3343	1000 2212	5122 1133	2211 1111
13	1001 1222	1200 0010	2011 1003	1002 0334	0010 2223	2111 2211	1000 1112	2343 3333	3212 4414	2222 3344	3322 4534	0000 0101
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17	2211 1124	0110 1232	3311 1101	1000 2210	1100 1211	2101 2202	2321 3223	2111 3421	2221 2343	2013 3333	1000 0000	2311 2333
18	3101 0103	1001 1013	2010 2324	0001 1111	0000 1110	2111 2210	3211 2232	0211 2212	2112 1212	1002 2110	1100 1110	3211 0001
19	1011 1111	0000 1001	4212 2132	2122 1122	0000 1111	3233 2114	2101 2223	1221 2312	1011 1100	1001 2222	1222 2311	0111 1132
20	1122 2442	0333 3443	1000 1101	1232 1100	1001 2102	2101 2232	1311 2223	2112 2221	0001 2342	1000 1234	1131 0222	0001 1010
21	1011 2022	2233 0334	1102 3344	0110 0000	1100 1110	2111 1122	1111 2211	2110 1210	1312 3210	2212 1342	1111 0010	0201 1233
22	2110 1132	1322 1124	4111 1234	0101 1111	0101 3312	1001 1110	2222 2232	0002 1221	3311 2436	0001 1112	2111 1122	3321 2244
23	2202 1123	3212 2232	1011 2100	0000 1000	1111 1222	1100 1111	1102 2222	1210 3322	7221 1211	3211 1200	2233 3253	3211 1210
24	1100 0221	2011 1244	0021 1110	2111 3132	2322 3334	0011 1223	1110 2333	1102 3221	2321 2122	2212 2176	4223 3333	1100 0001
25	0110 1212	2001 1021	0000 1312	0110 2111	3432 3330	0001 1233	3223 4222	2112 4665	2232 4656	5433 3223	2121 3222	1101 1113
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27	0101 1000	121 1233	3313 3334	0022 2221	2233 3222	1012 1000	2211 2210	3223 4431	1002 2231	3232 2356	3232 2422	0000 0000
28	1111 1333	2112 2233	3321 1110	2000 0001	1111 1224	0111 1102	1212 4434	1201 2244	4212 3233	5434 3553	1112 1121	0000 0022
29	4311 1000		0011 0001	1001 1121	3333 3210	0101 1212	7644 4201	3102 2342	2222 4543	3222 3333	1001 0000	1110 0001
30	1000 0110		0001 1110	0001 0111	0012 2221	1101 1100	3110 3213	1131 2222	5443 3532	1222 2133	0000 0110	0000 0000
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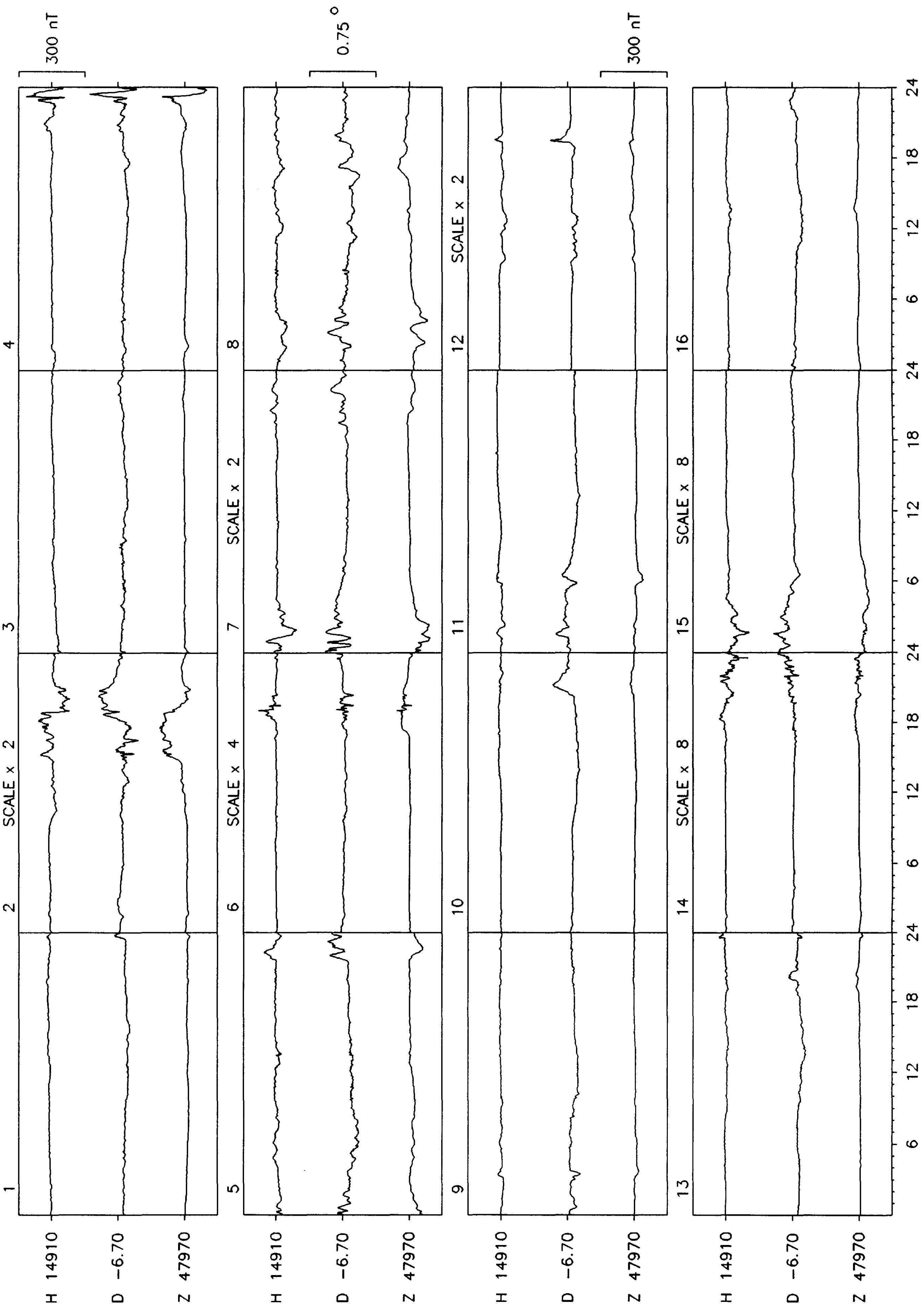
LERWICK 1988



300 nT
0.75 °
300 nT
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SCALE x 2
SCALE x 4
SCALE x 2
SCALE x 2
SCALE x 8
SCALE x 8
H 14910
D −6.70
Z 47970
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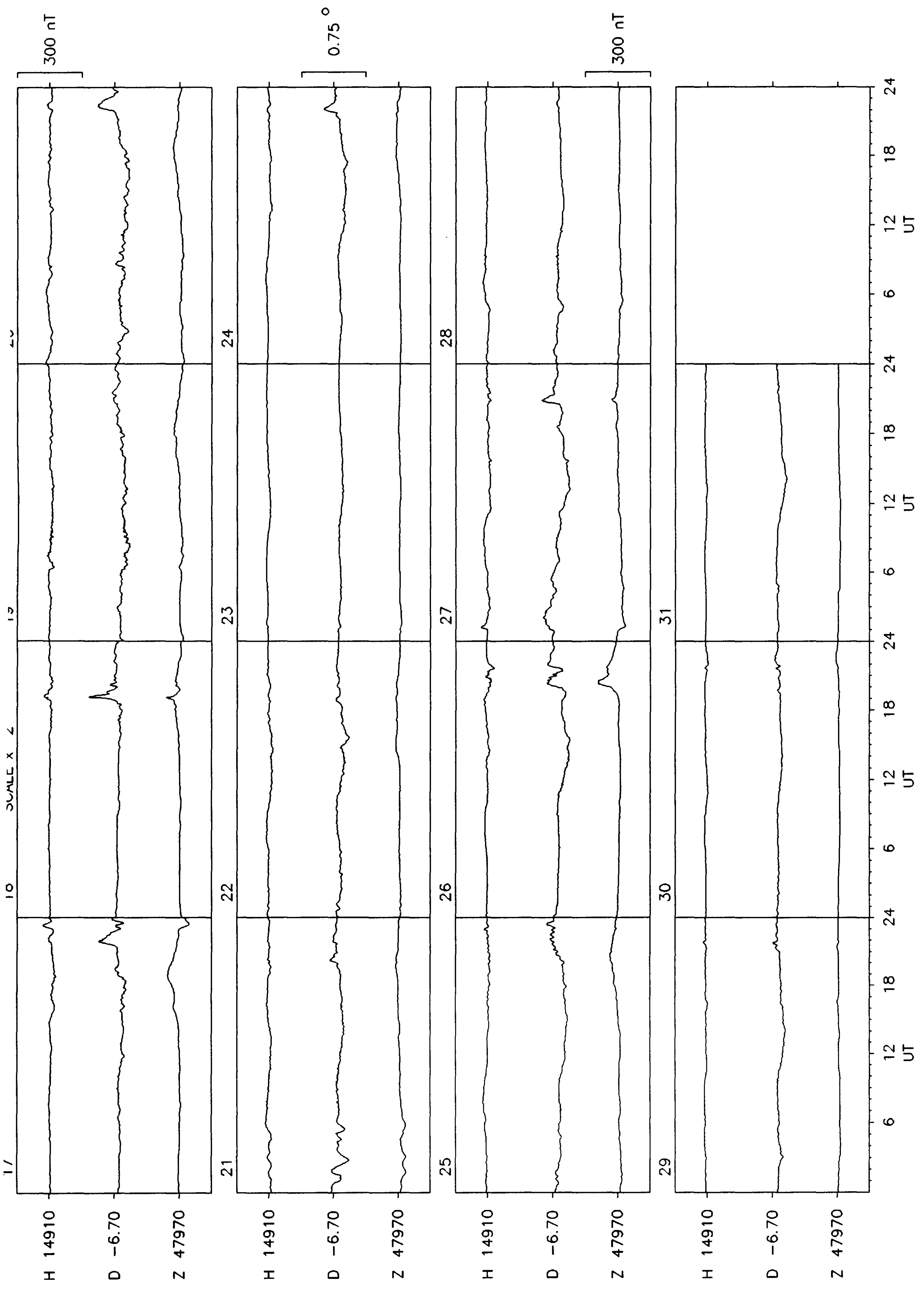
300 nT
0.75 °
300 nT
SCALE x 2
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H 14910
D −6.70
Z 47970
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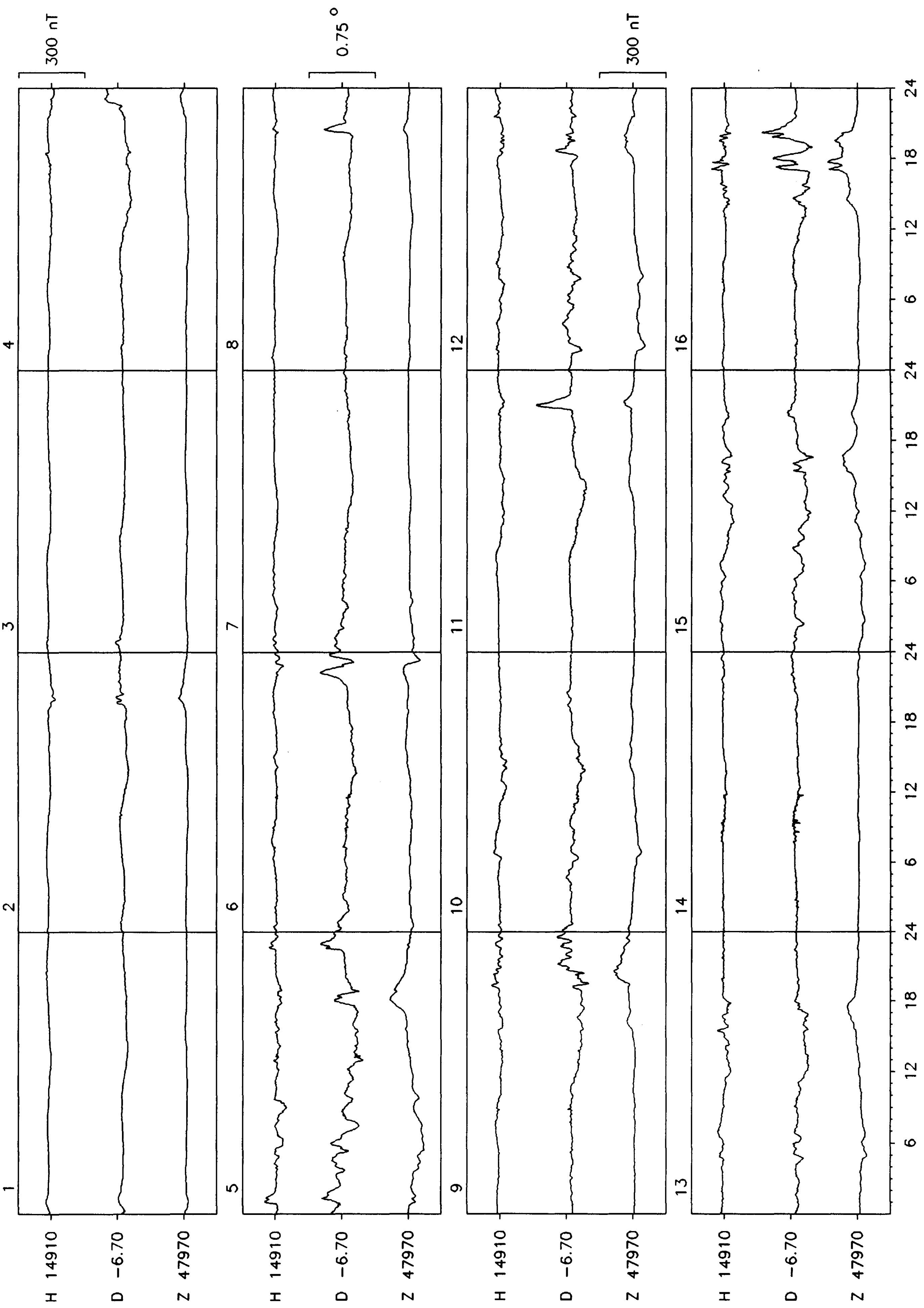
300 nT
0.75 °
300 nT
H 14910
D −6.70
Z 47970
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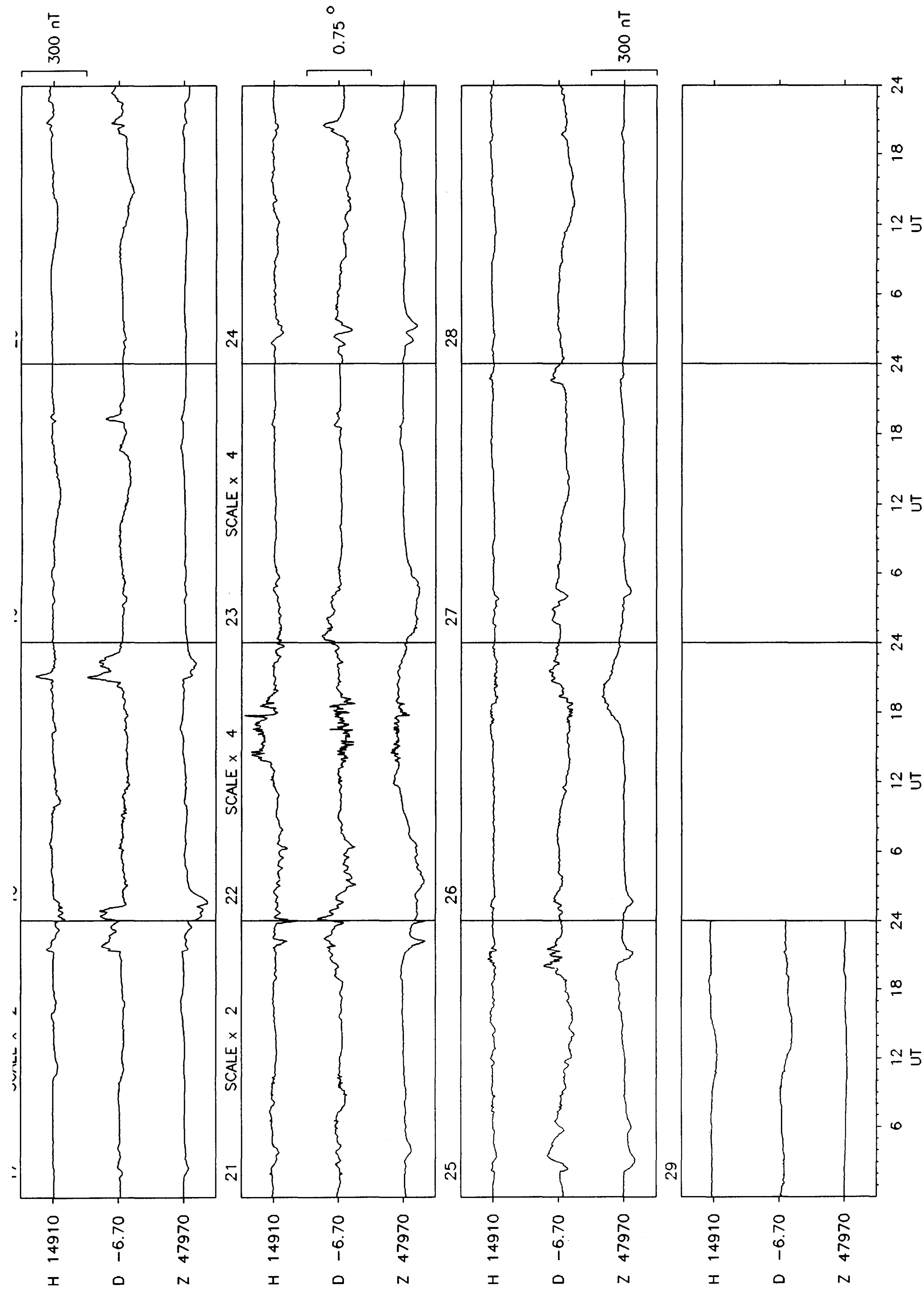
300 nT
0.75 °
300 nT
SCALE x 2
SCALE x 4
SCALE x 4
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H 14910
D −6.70
Z 47970
UT
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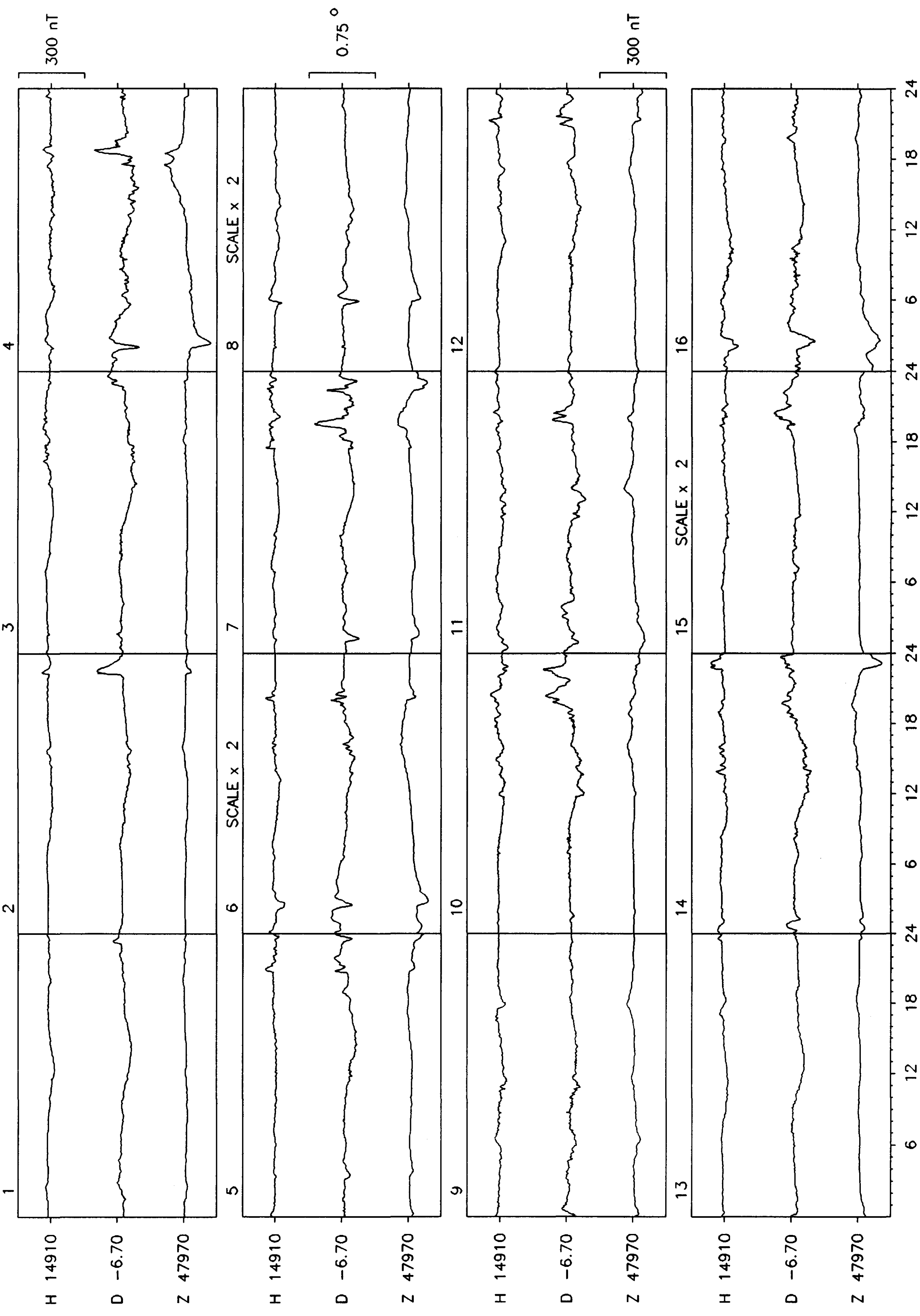
300 nT
0.75 °
300 nT
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SCALE x 2
SCALE x 2
SCALE x 2
H 14910
D −6.70
Z 47970
H 14910
D −6.70
Z 47970
H 14910
D −6.70
Z 47970
H 14910
D −6.70
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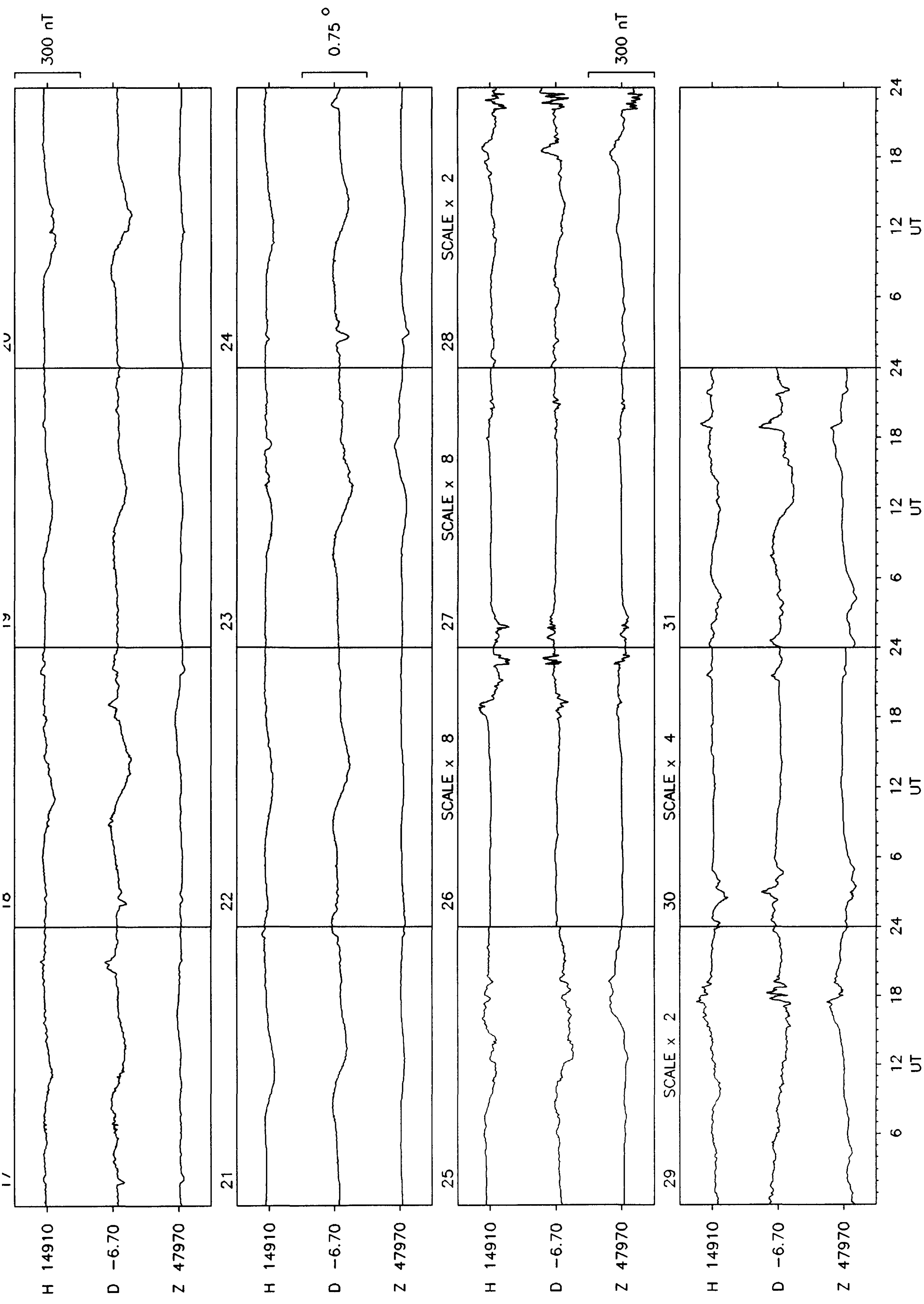

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300 nT
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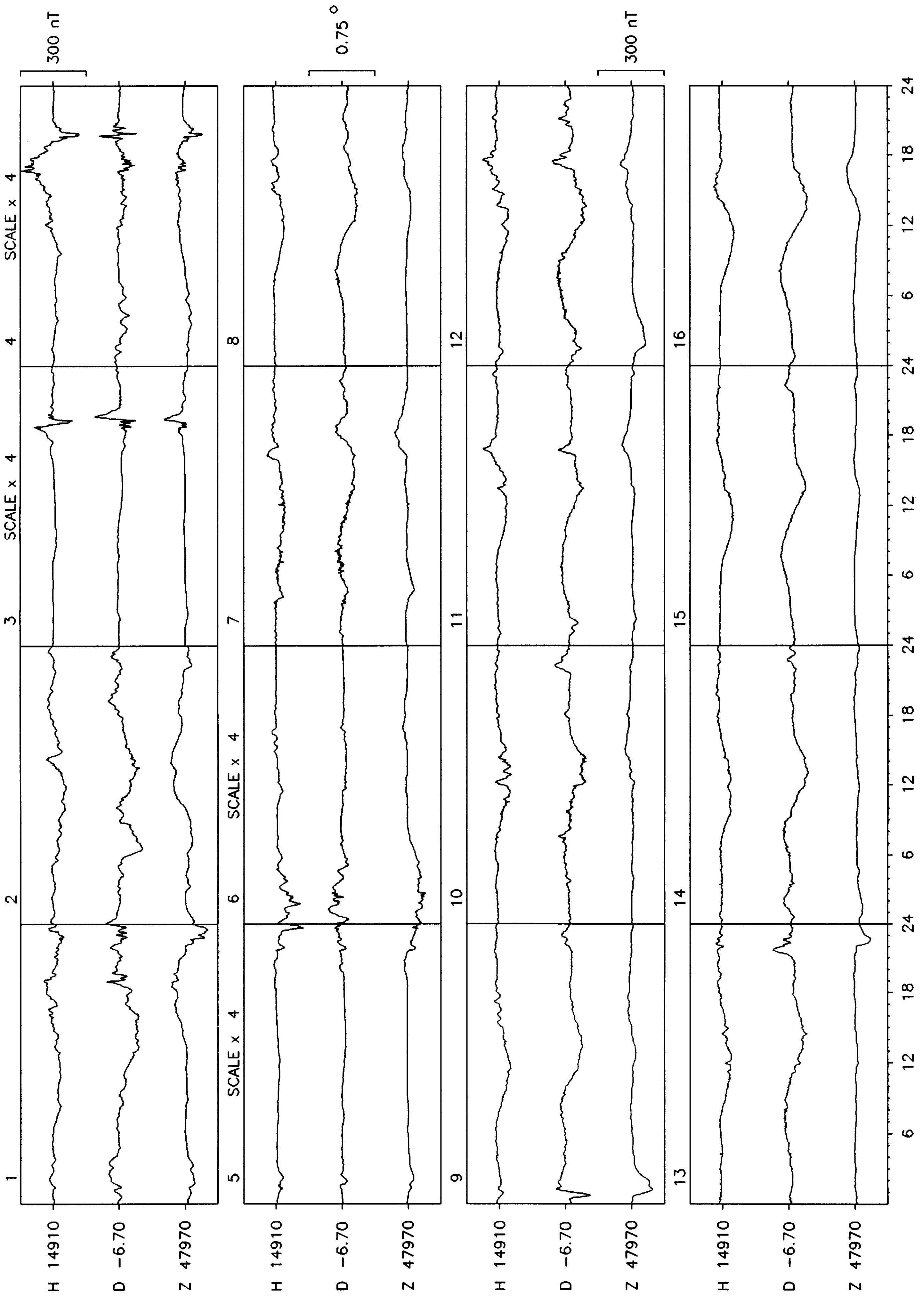
UT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D −6.70
Z 47970
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0.75 °
SCALE x 4
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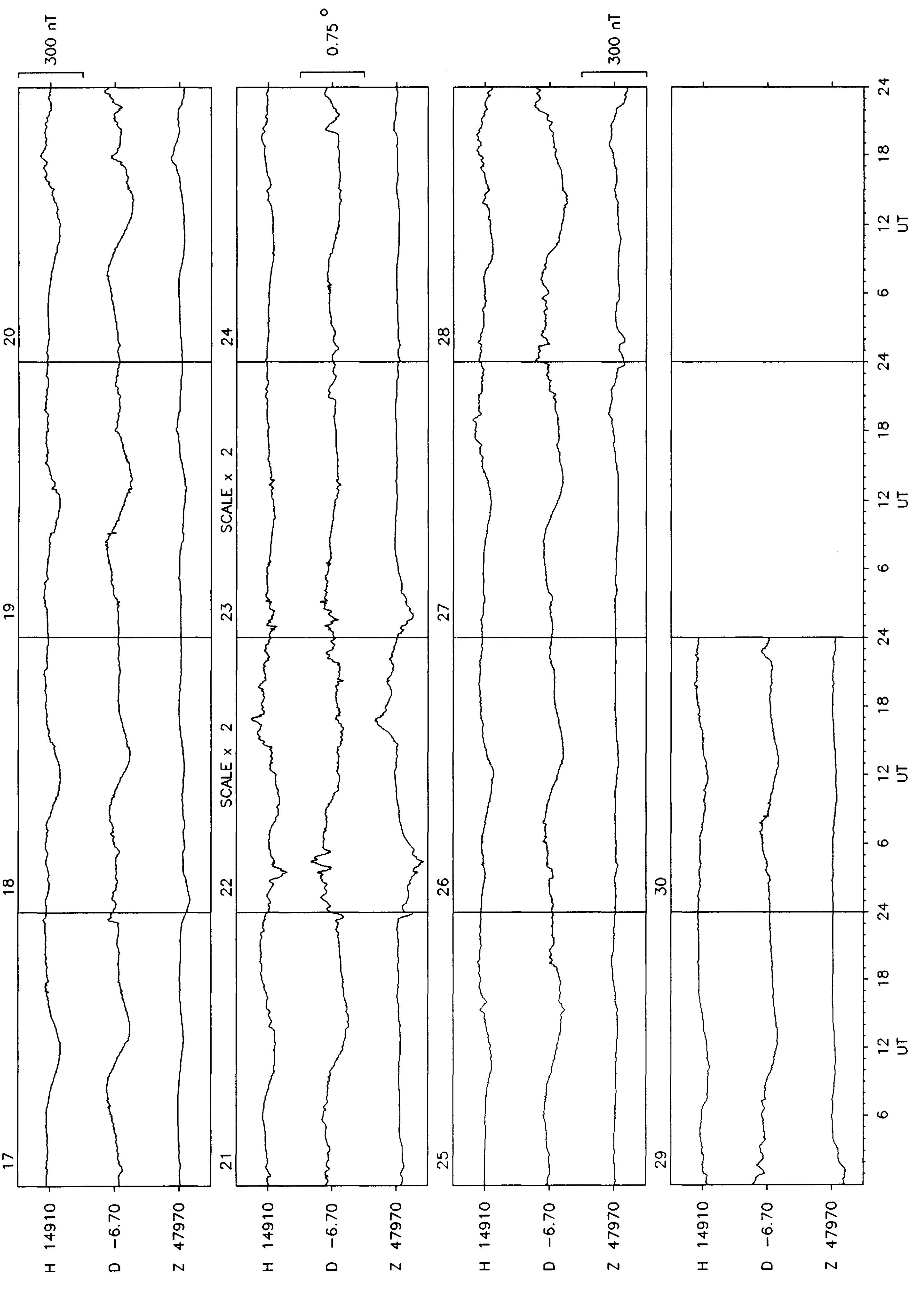

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0.75 °
300 nT
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D −6.70
Z 47970
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29
30
SCALE x 2
SCALE x 2
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12
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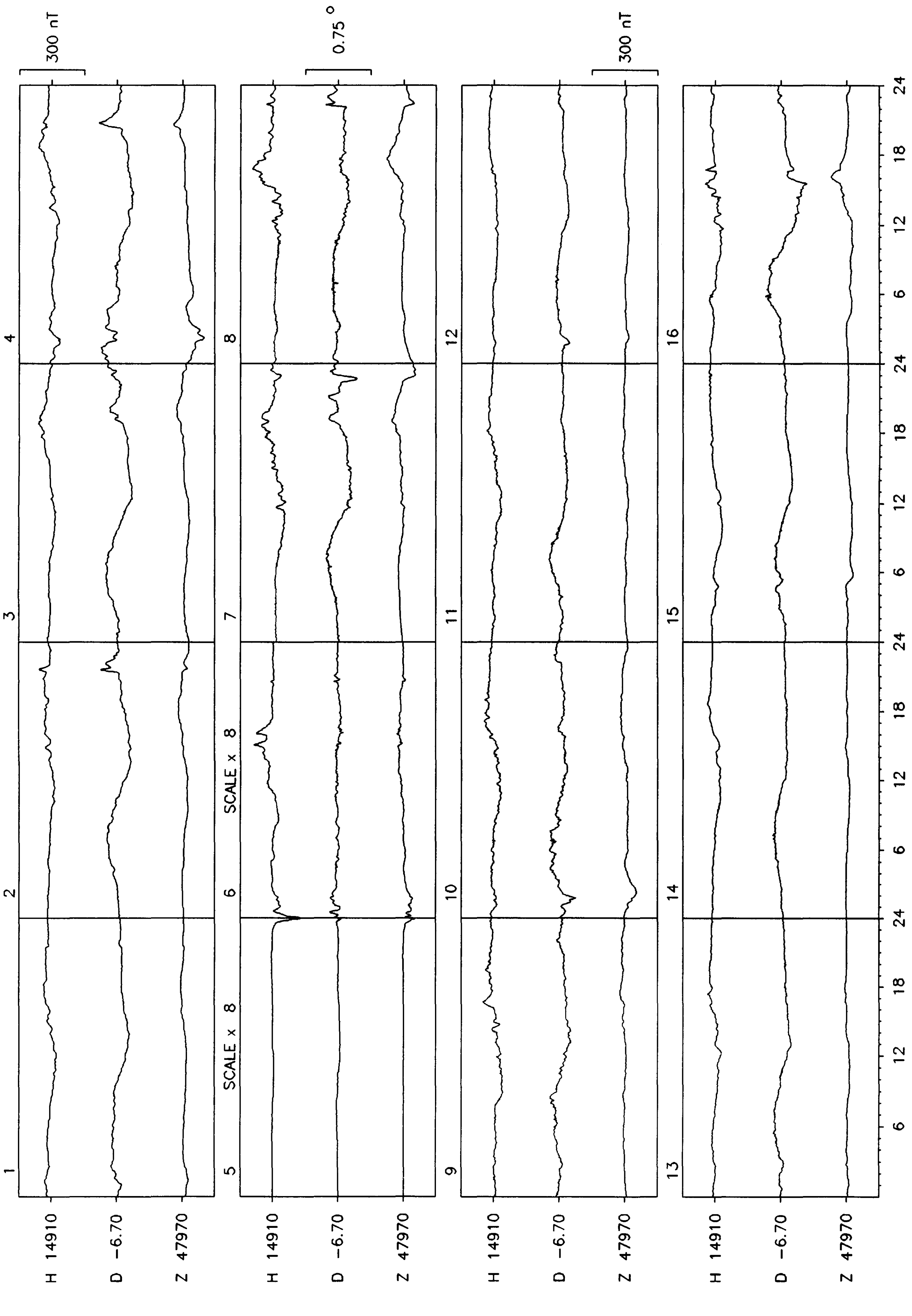
UT



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300 nT
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D −6.70
Z 47970
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SCALE x 8
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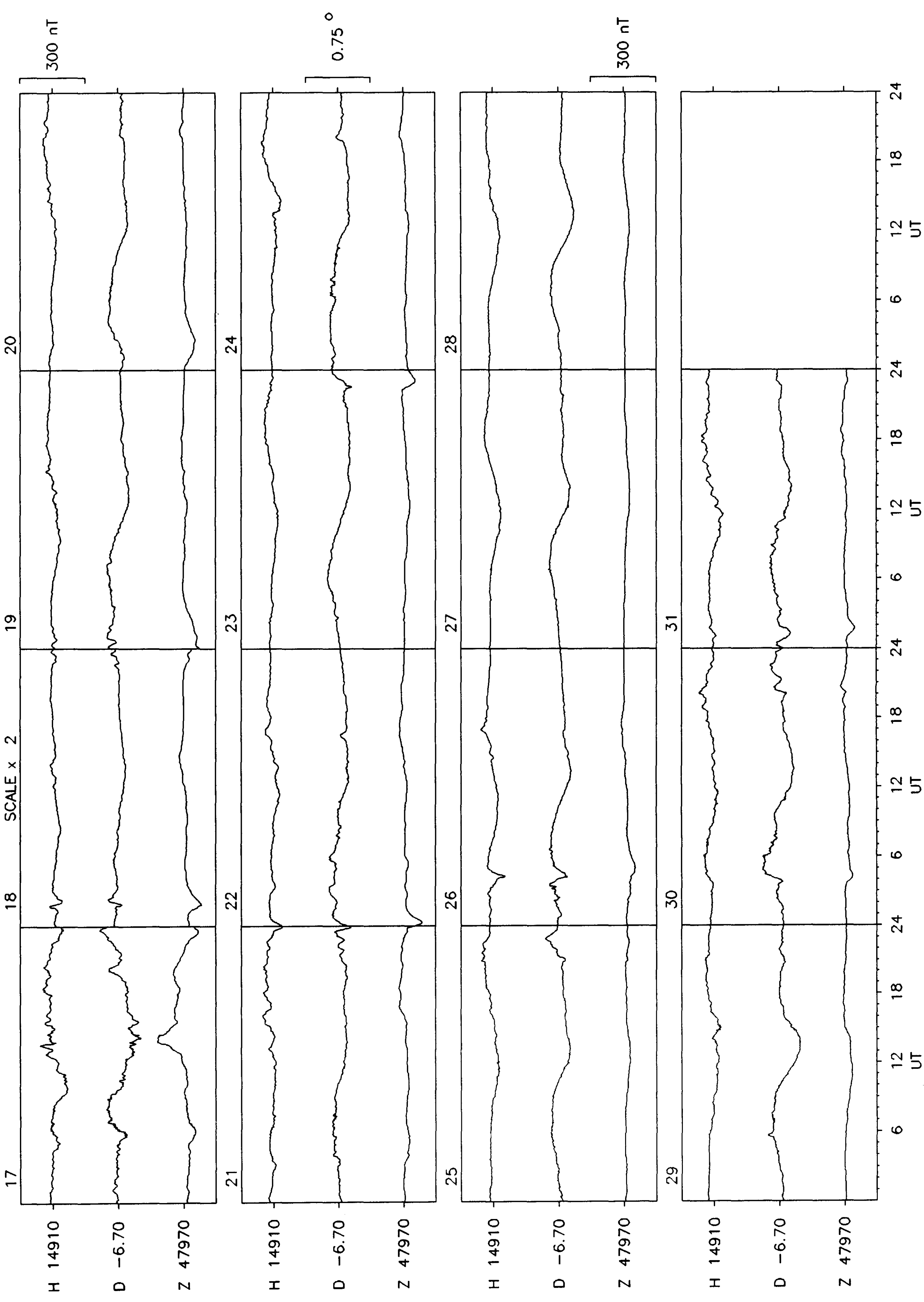

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300 nT
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D −6.70
Z 47970
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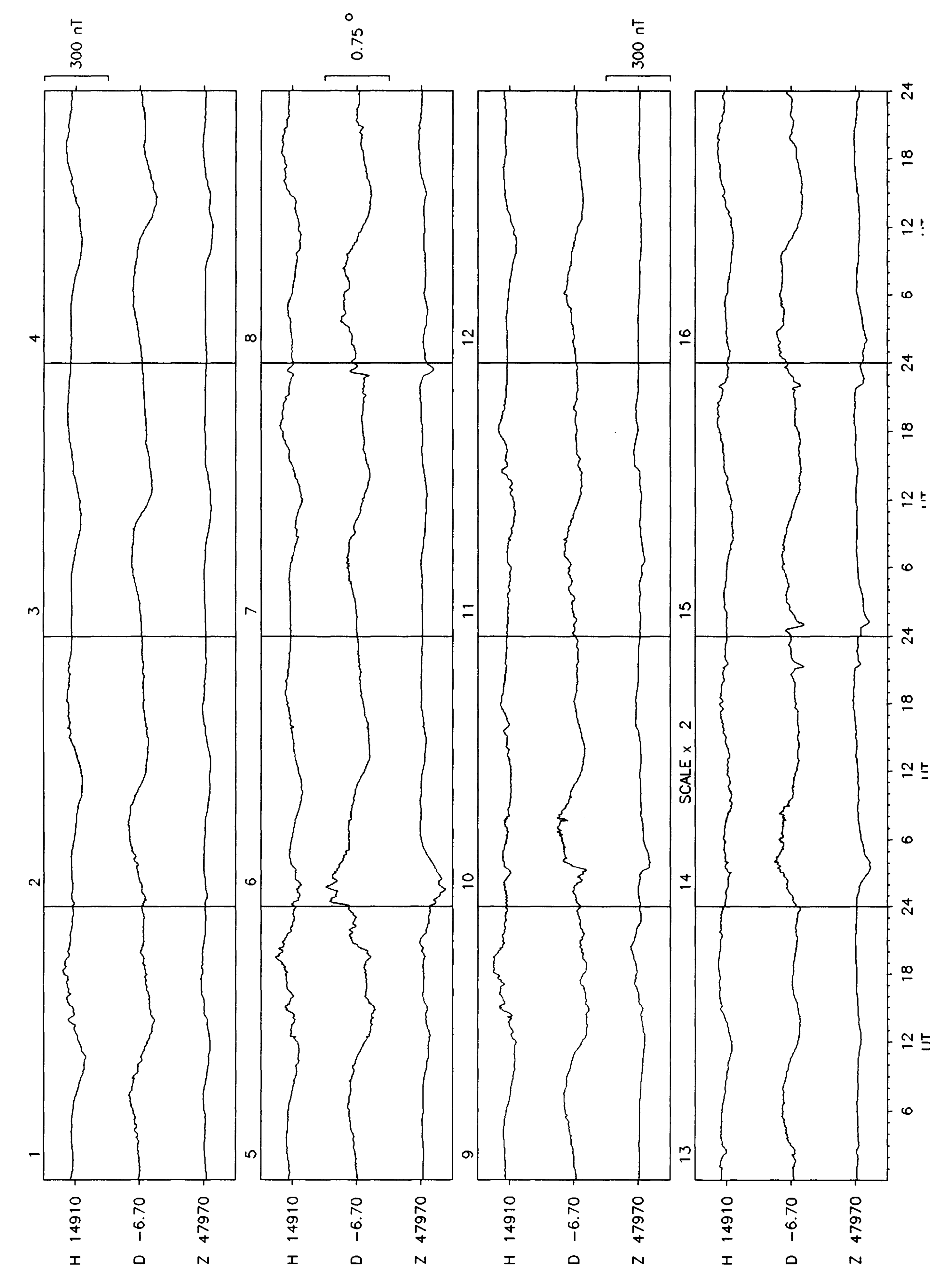
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Z 47970
SCALE x 2
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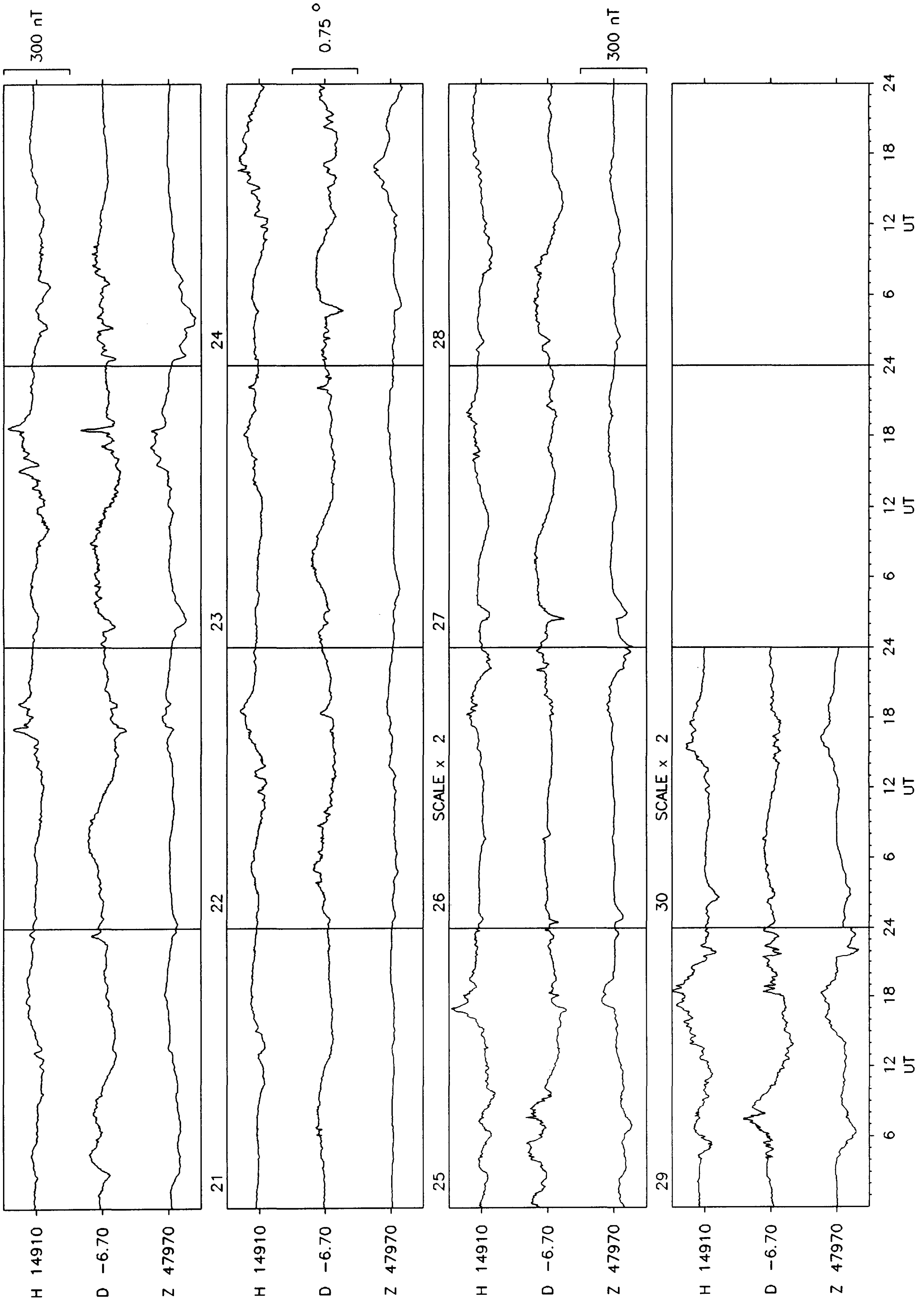
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SCALE x 2
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D −6.70
Z 47970
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Z 47970
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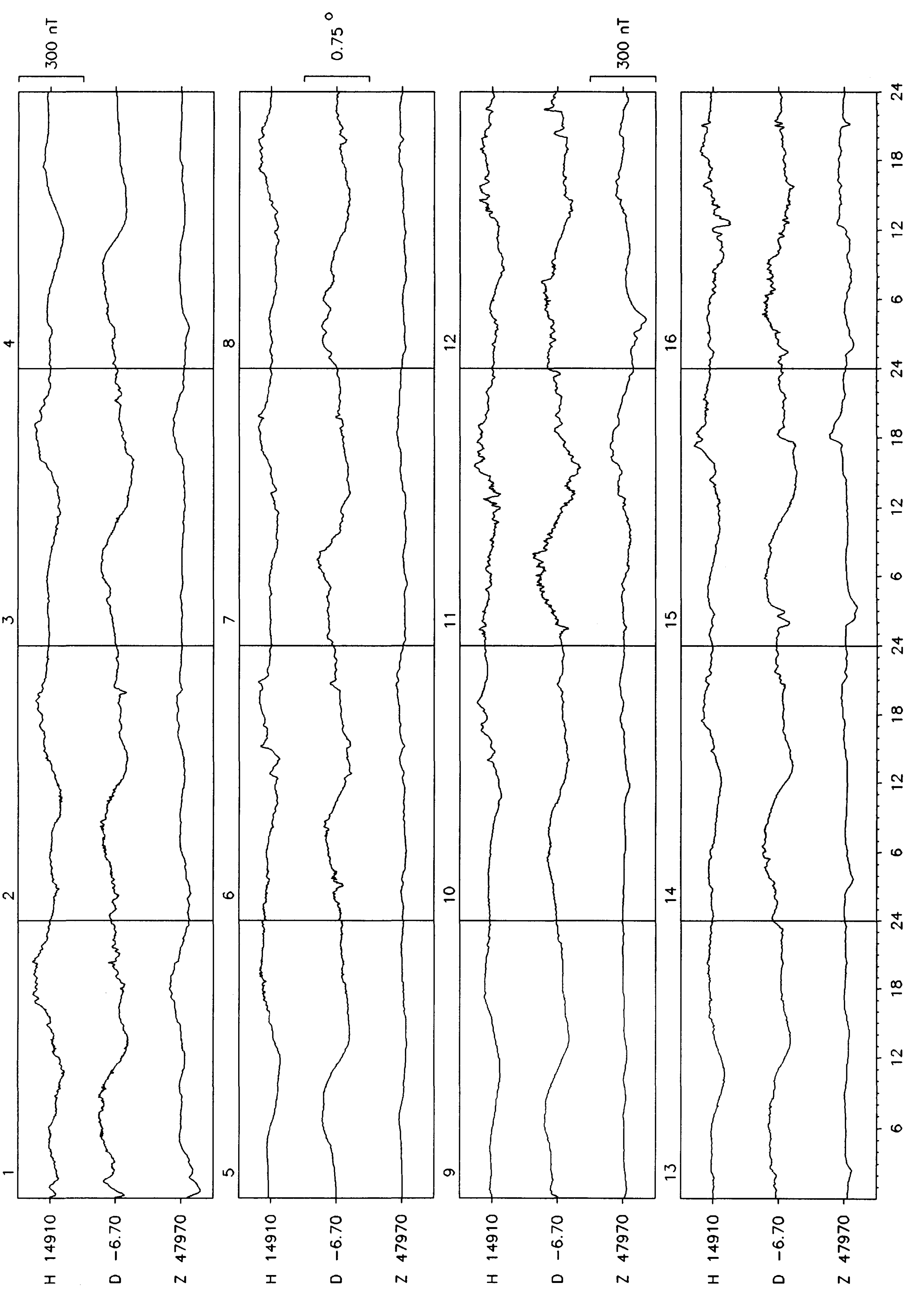
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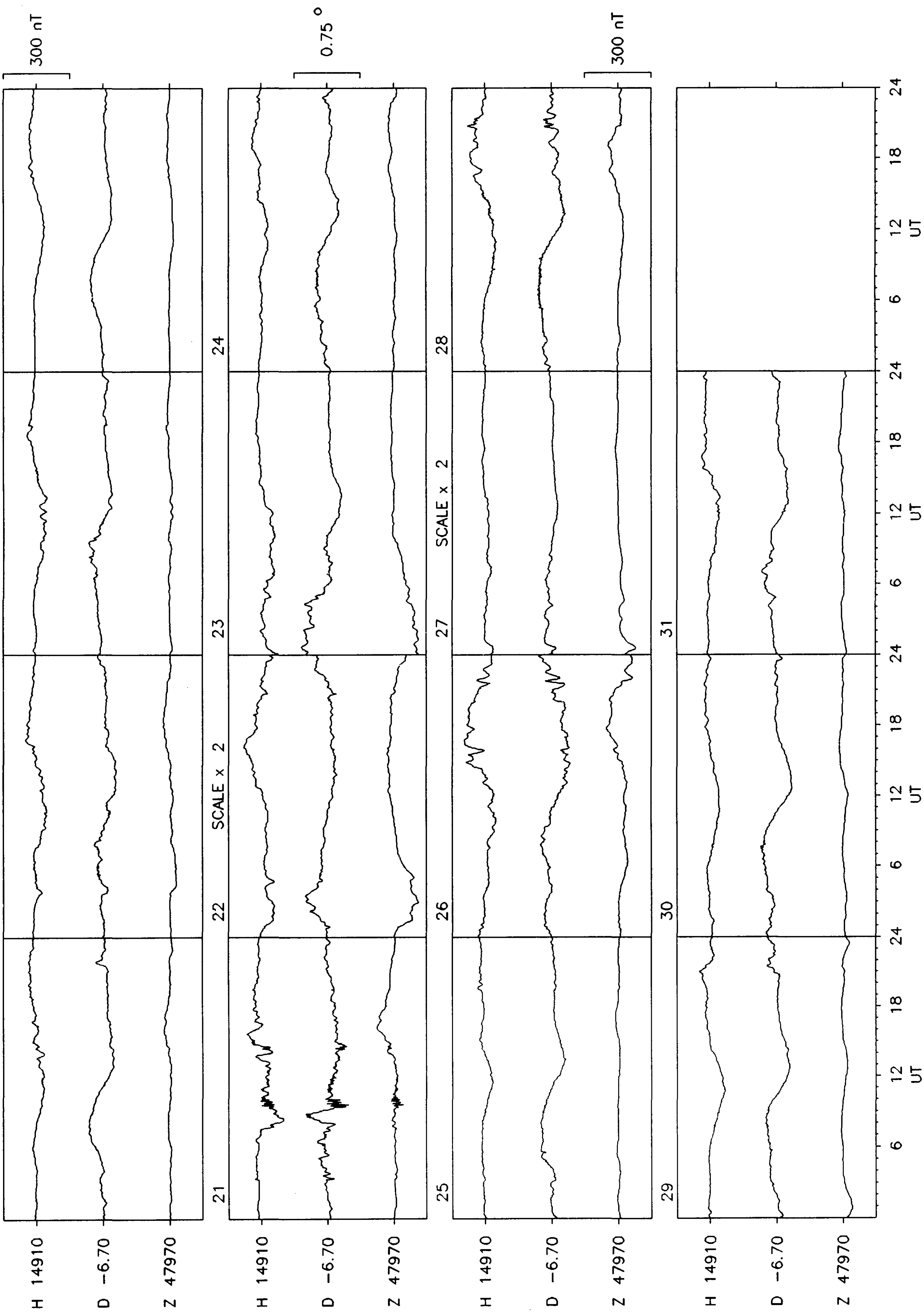

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Z 47970
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300 nT
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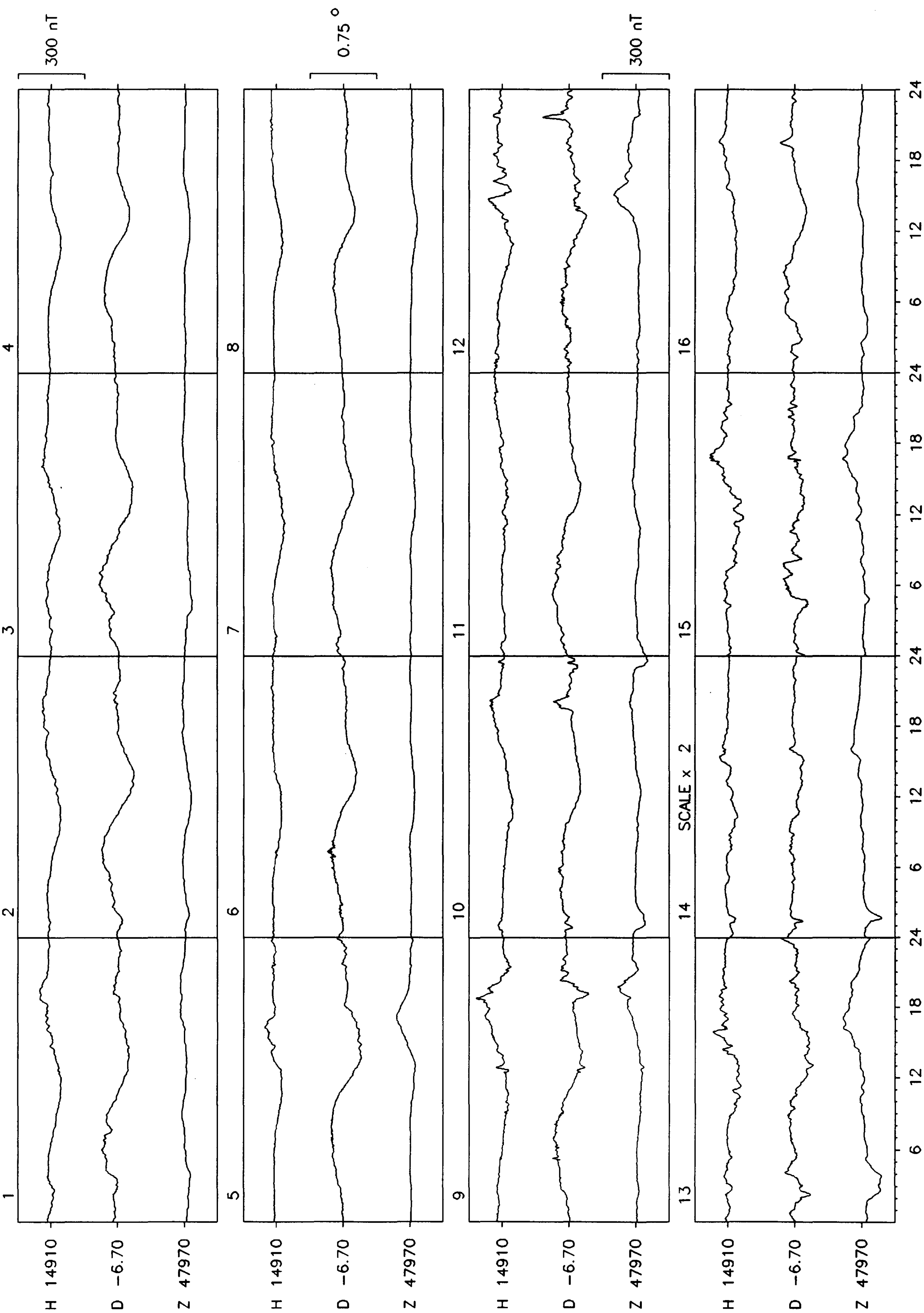
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Z 47970
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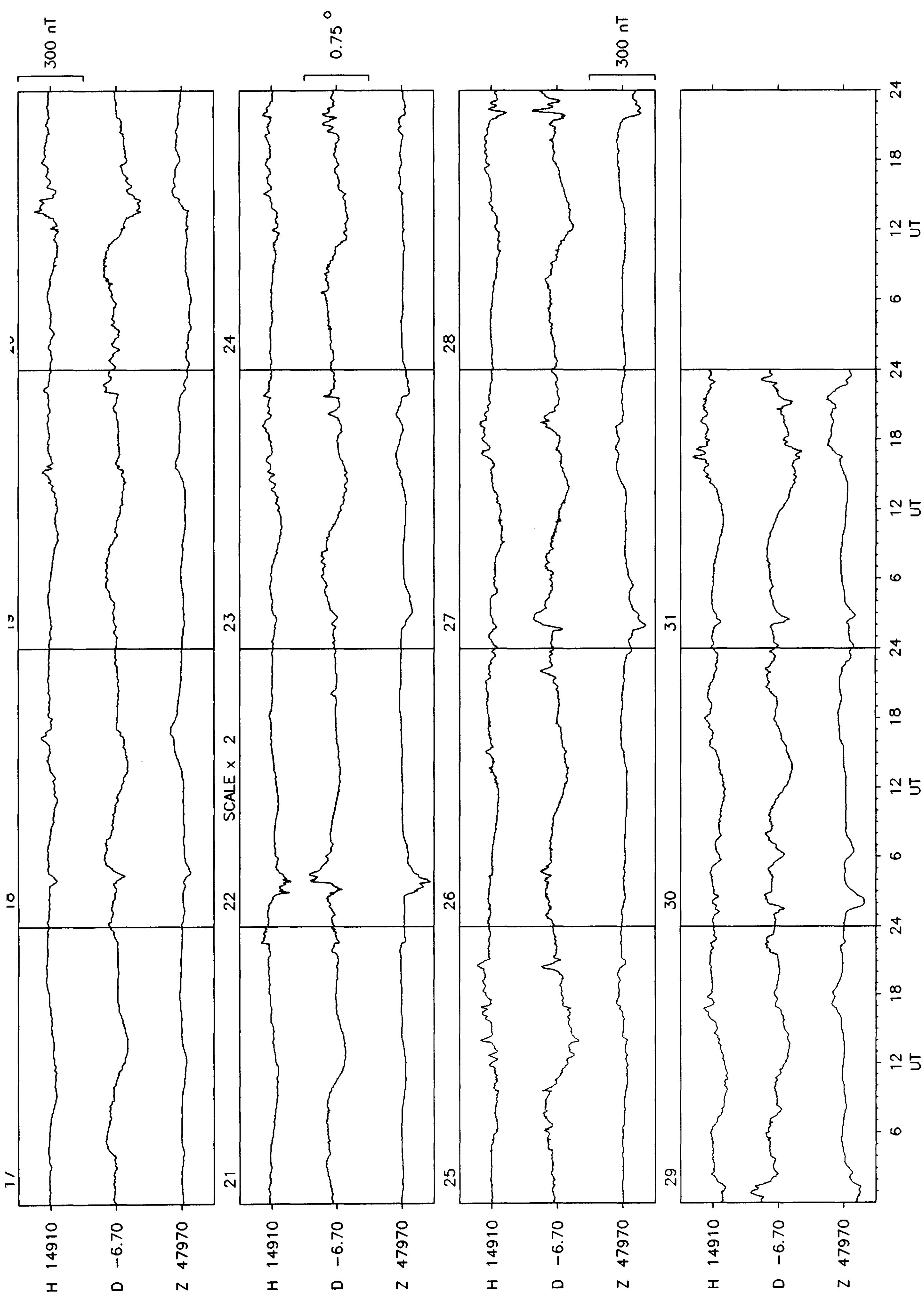
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Z 47970
300 nT
0.75 °
SCALE x 2
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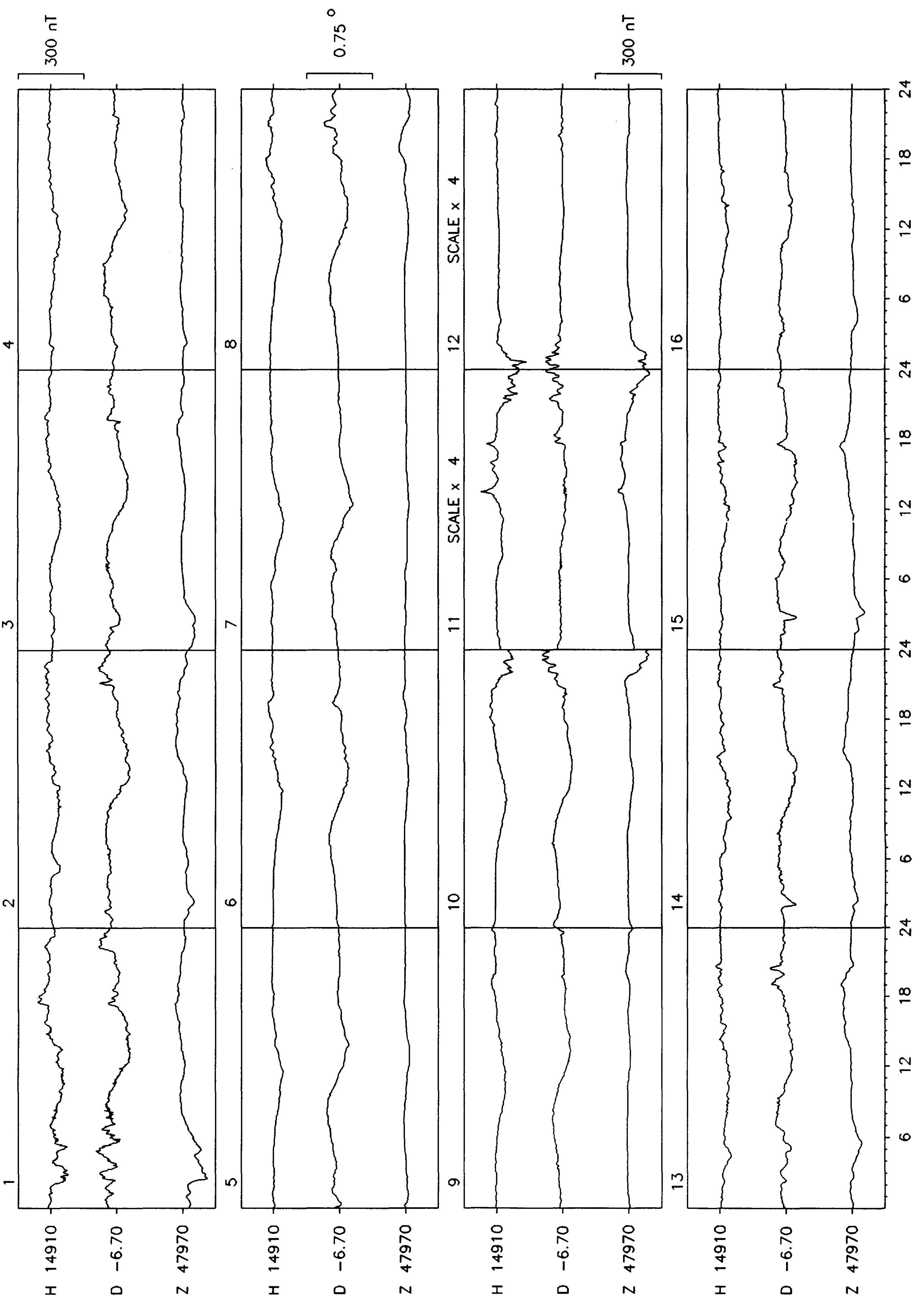
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300 nT
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H 14910
D −6.70
Z 47970
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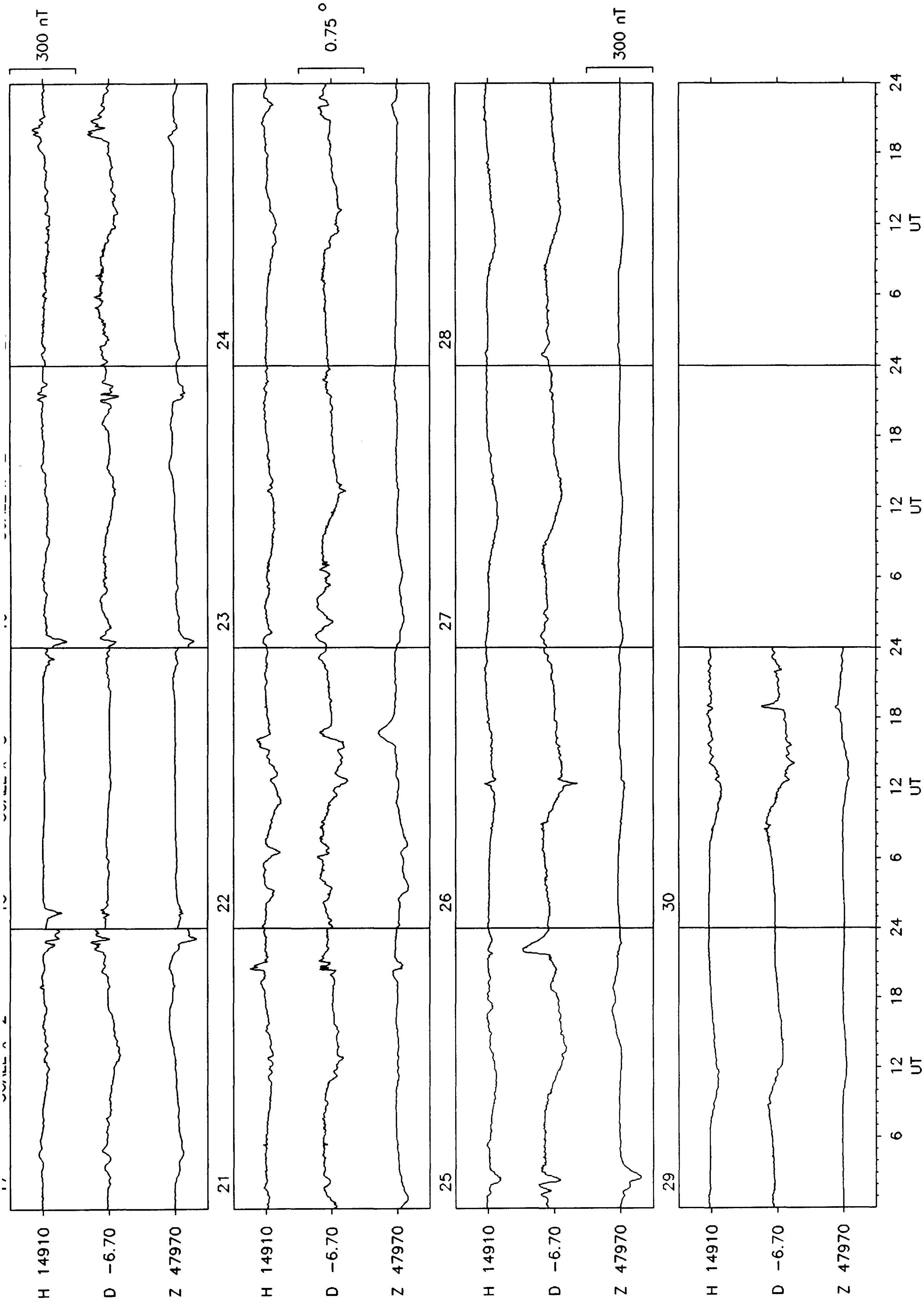

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300 nT
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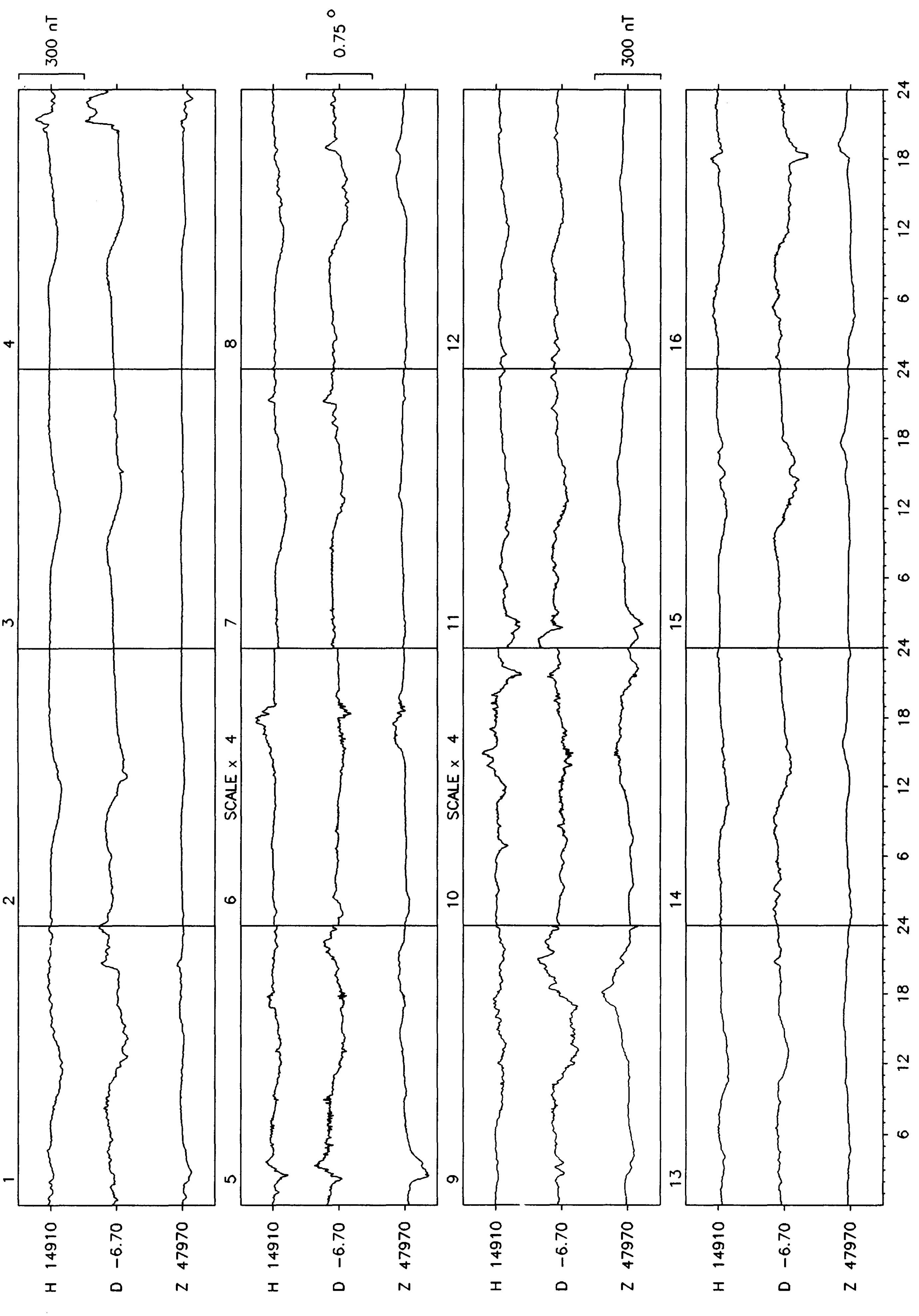
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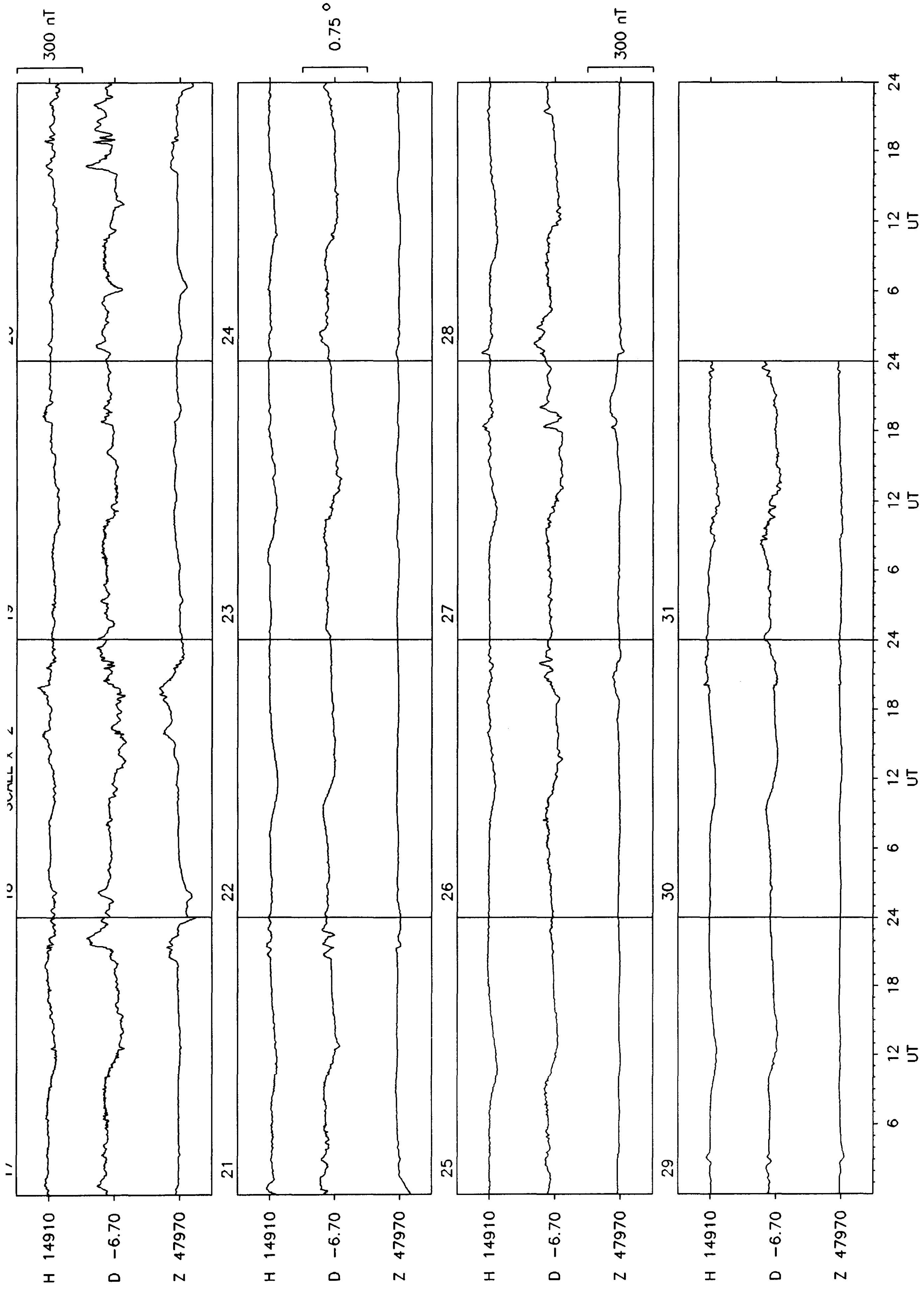
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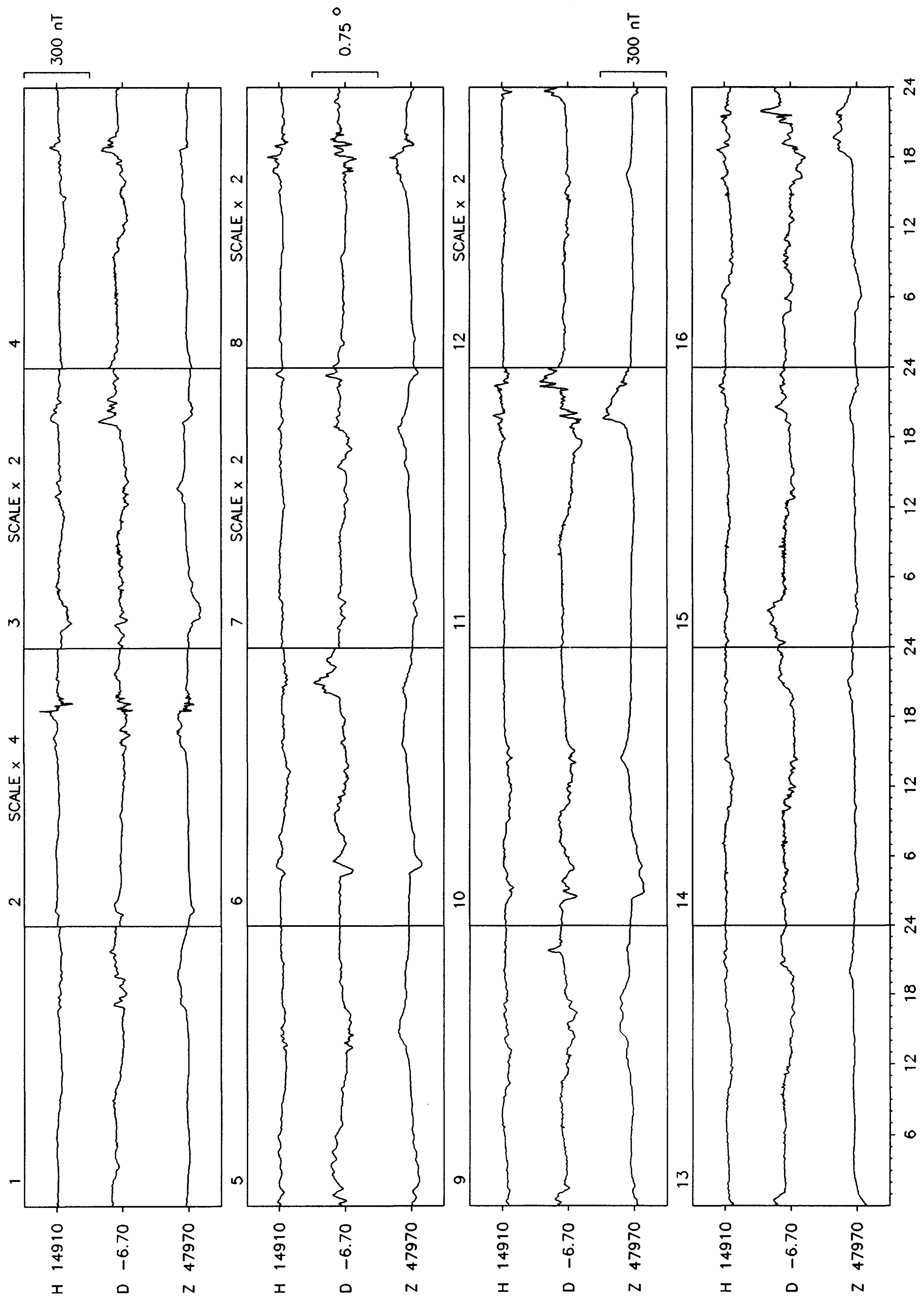
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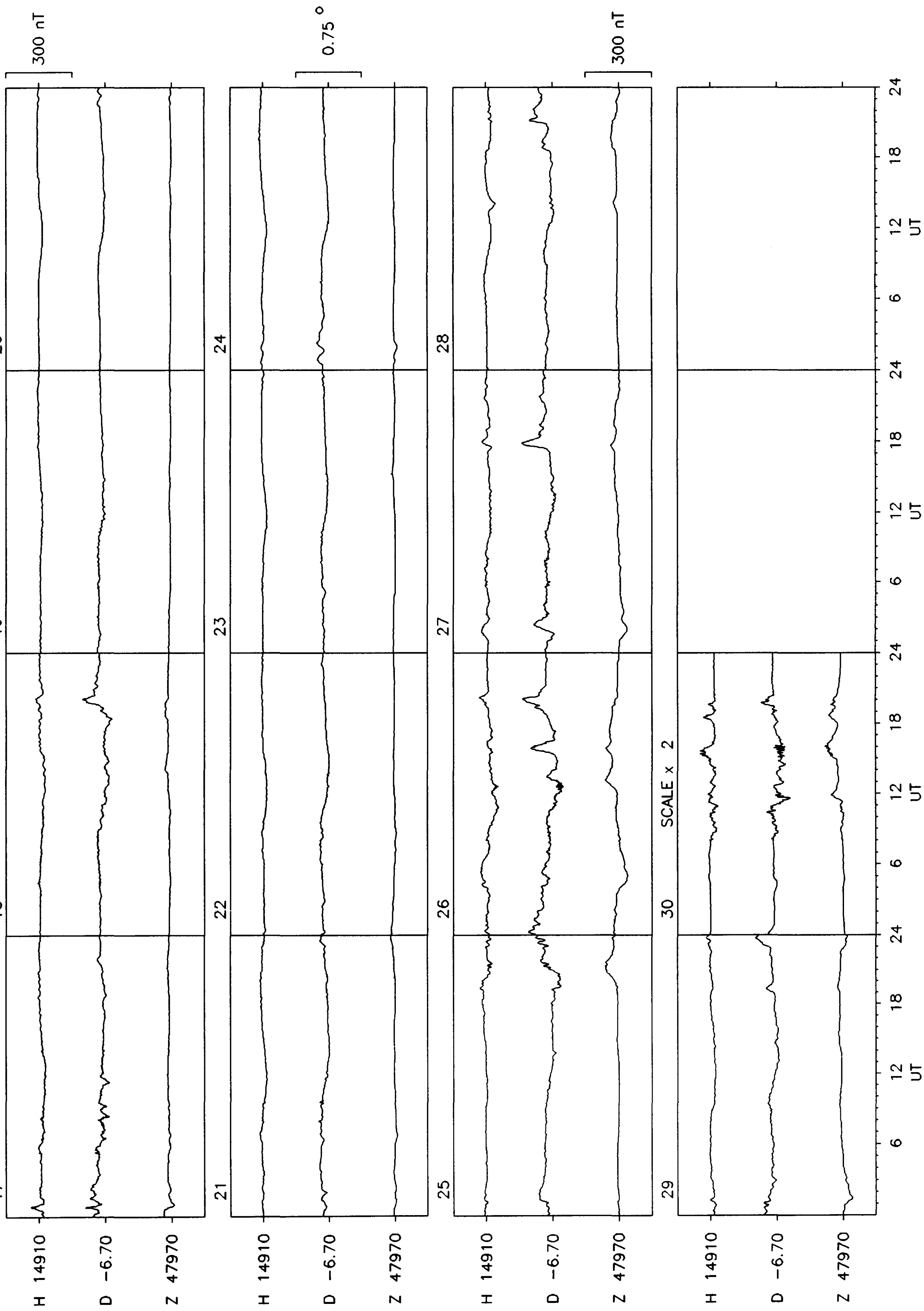

300 nT
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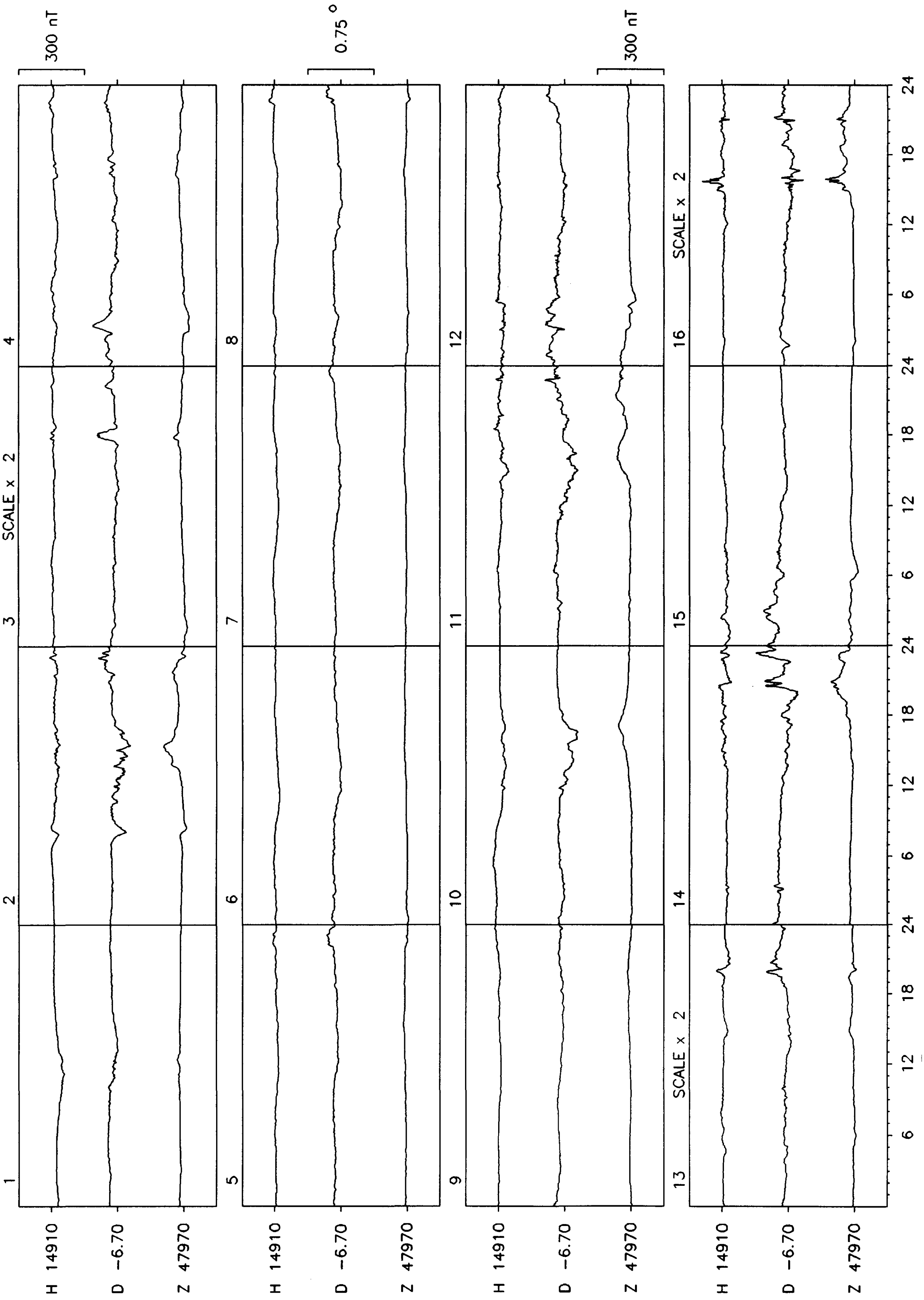
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D −6.70
Z 47970
300 nT
0.75 °
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SCALE x 2
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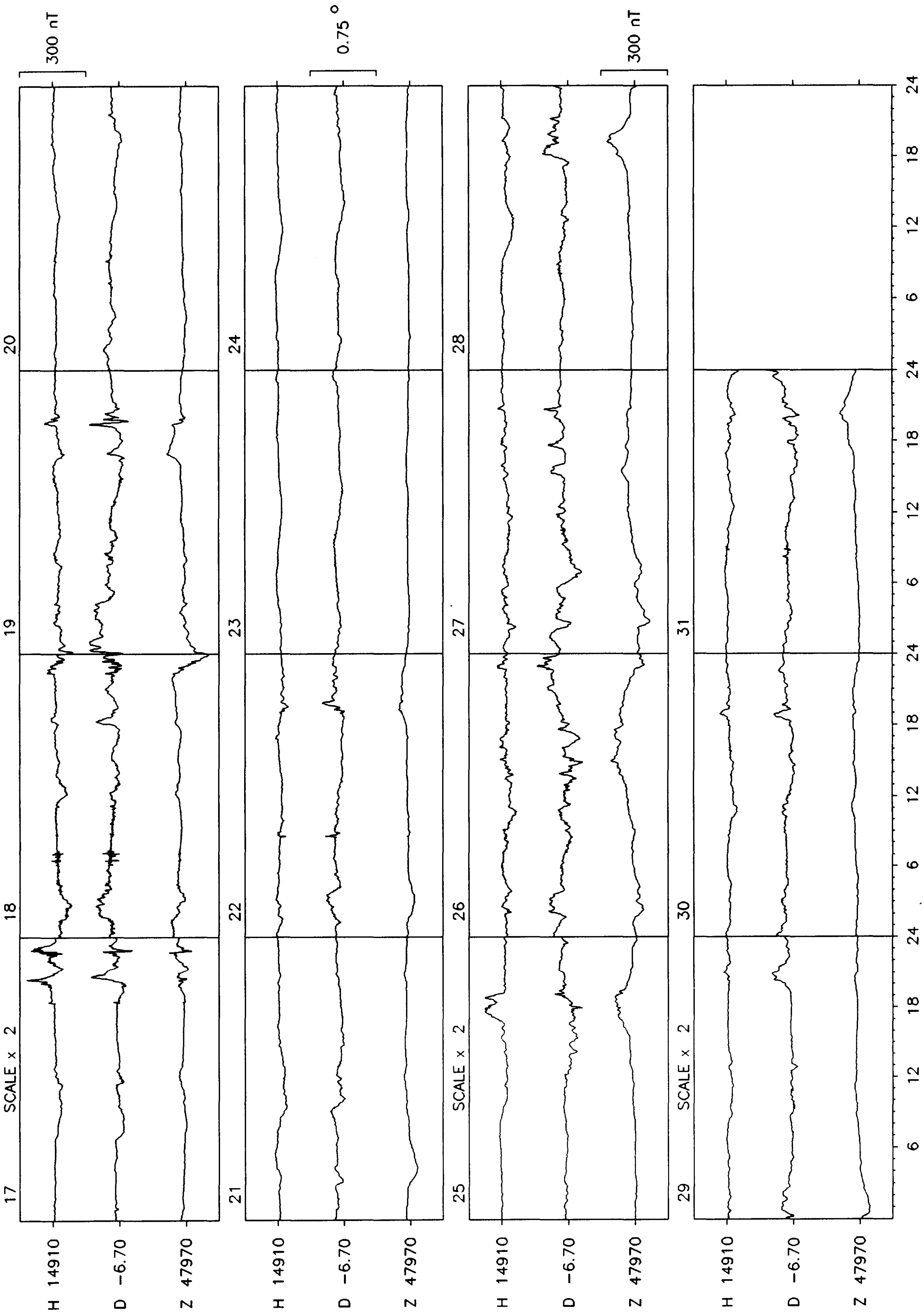
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SCALE x 2
H 14910
D −6.70
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H 14910
D −6.70
Z 47970
H 14910
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H 14910
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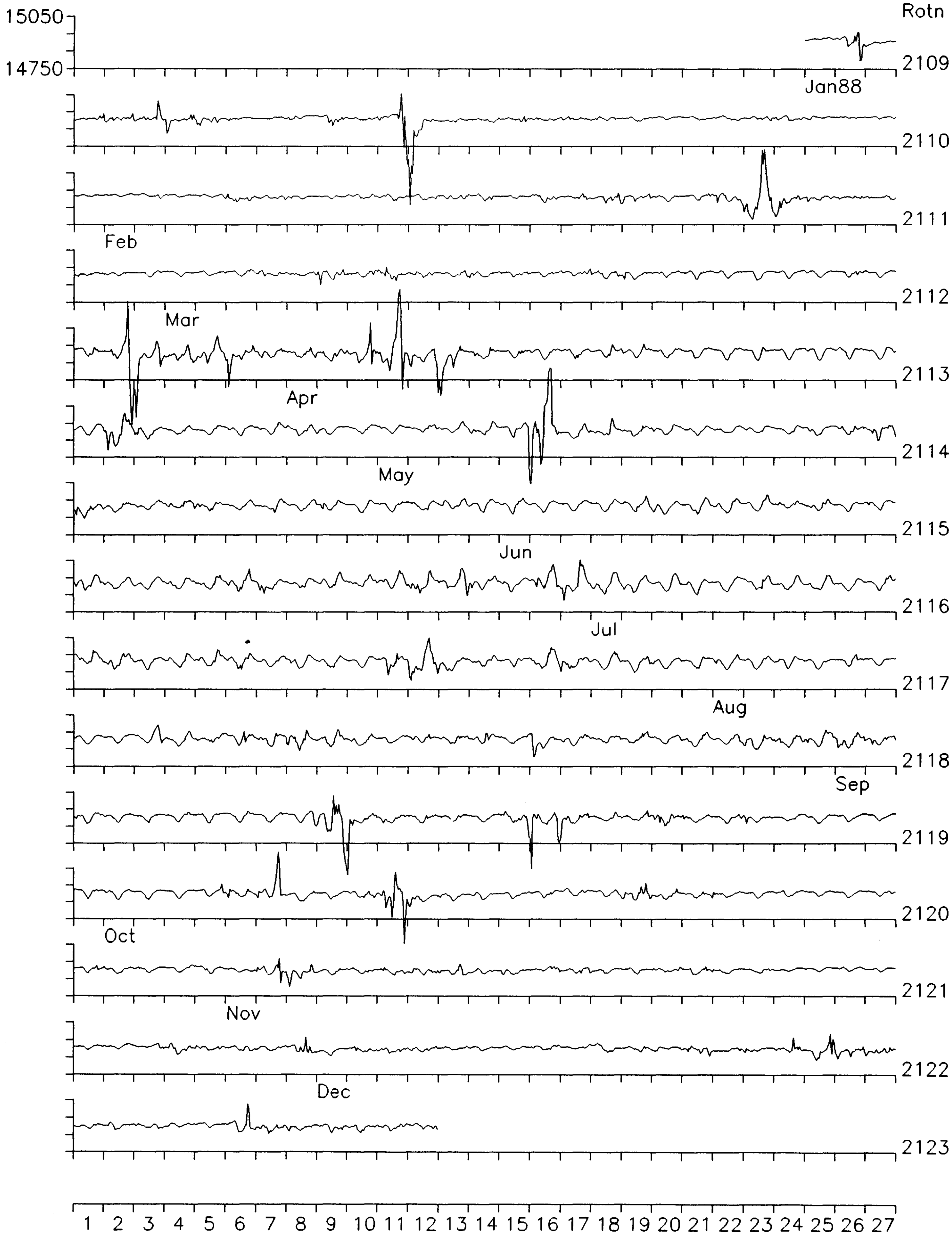
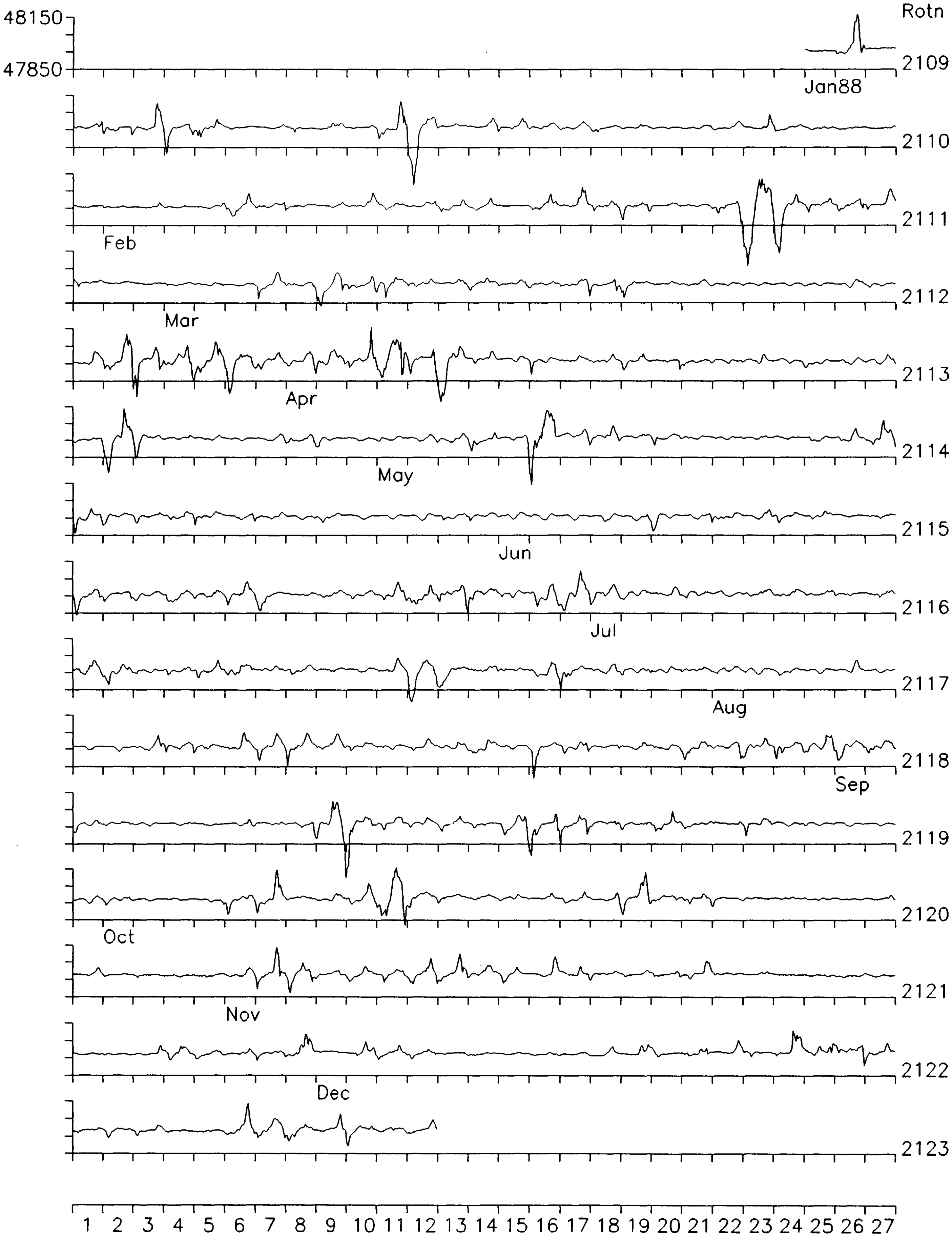
Lerwick Observatory: Horizontal Intensity (nT)



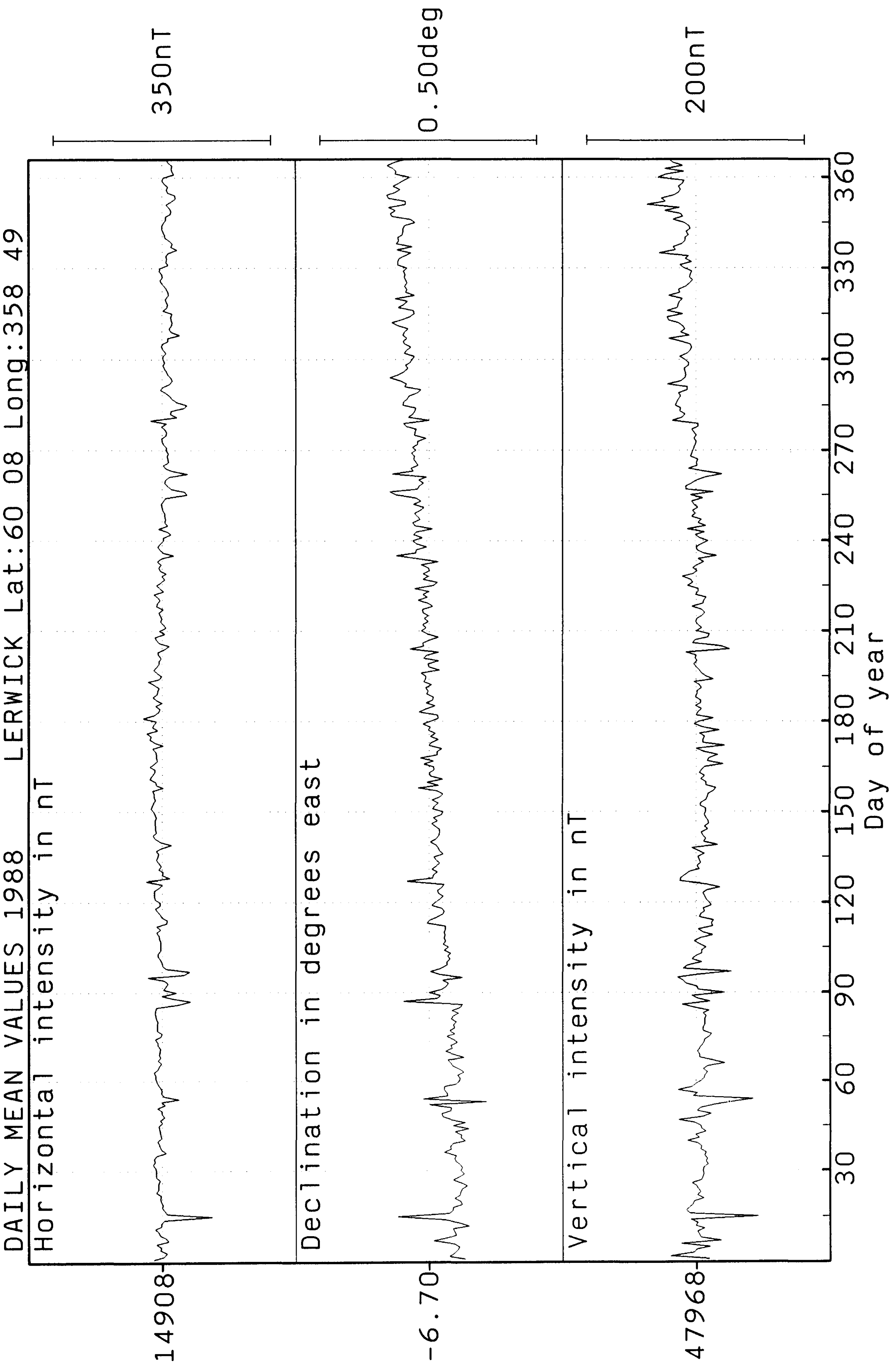
Hourly Mean Values Plotted by Bartels Solar Rotation Number

Lerwick Observatory: Declination (degrees)
6.50
7.00
Rotn
2109
Jan88
2110
2111
Feb
2112
Mar
2113
Apr
2114
May
2115
Jun
2116
Jul
2117
Aug
2118
Sep
2119
2120
Oct
2121
Nov
2122
Dec
2123
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)



Hourly Mean Values Plotted by Bartels Solar Rotation Number



DAILY MEAN VALUES 1988 LERWICK Lat:60 08 Long:358 49
Horizontal intensity in nT
Declination in degrees east
Vertical intensity in nT
350nT
0.50deg
200nT
14908
-6.70
47968
30
60
90
120
150
180
210
240
270
300
330
360
Day of year

Monthly and annual mean values for Lerwick 1988

Month	D	I	H	X	Y	Z	F
	° ′	° ′	nT	nT	nT	nT	nT
Jan	-6 45.8	72 44.1	14908	14804	-1756	47965	50228
Feb	-6 45.5	72 43.8	14911	14807	-1755	47962	50226
Mar	-6 45.2	72 43.8	14910	14807	-1753	47961	50225
Apr	-6 44.1	72 44.0	14909	14806	-1748	47964	50228
May	-6 43.2	72 43.5	14916	14814	-1745	47963	50229
Jun	-6 42.8	72 43.1	14921	14819	-1744	47959	50227
Jul	-6 42.0	72 43.6	14914	14812	-1740	47964	50229
Aug	-6 41.4	72 43.9	14910	14808	-1737	47966	50230
Sep	-6 40.3	72 44.7	14899	14798	-1731	47967	50228
Oct	-6 39.5	72 44.8	14900	14800	-1728	47978	50238
Nov	-6 38.8	72 44.9	14901	14801	-1725	47982	50243
Dec	-6 38.1	72 45.1	14899	14799	-1721	47986	50246
Annual	-6 42.2	72 44.1	14908	14806	-1740	47968	50231

LERWICK OBSERVATORY K INDICES 1988

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0000 1112	1000 0000	2000 0012	2221 2333	2001 2211	0112 3221	3222 3333	2221 2220	4332 3333	2222 2232	1101 0222	0001 2000
2	2213 3463	1000 0021	0000 1203	3233 3322	0211 2223	1101 2121	2222 3221	2211 2211	2322 3213	3111 2000	4233 2474	0032 3313
3	1111 0001	2000 0000	1110 2223	2132 2483	1111 1233	0001 2100	0211 2332	2221 2211	3211 2232	0000 1110	4422 3243	2111 1443
4	1100 1135	0000 1113	4322 2342	4446 5782	3211 3343	0000 2211	1200 0110	0100 1101	2112 2111	0010 1124	2012 2231	2311 1202
5	2221 2003	3333 3333	2101 1133	4222 2237	0123 3229	1111 3333	0100 1221	0001 2312	2101 1110	3322 2322	3211 2210	0000 0002
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7	6321 2134	2101 1001	3122 1344	1322 2321	0113 3334	0112 2223	1132 2222	2111 2210	0111 1000	1111 1112	3312 2444	0000 0001
8	3312 2332	1000 1041	3443 3212	0010 3221	2222 3433	1221 3221	3222 2322	0001 1011	0101 2232	1001 1131	3212 2452	1100 0102
9	2211 0000	0011 1233	3223 2320	4112 2212	1122 2321	0110 3232	2000 0201	2221 3343	0000 1122	2223 3333	3012 2213	2000 0011
10	0000 0033	2122 2210	1012 3244	0123 3223	3222 2322	2321 1211	0101 3331	2112 2232	1011 1123	3355 7667	3312 2200	1101 2310
11	3221 1000	0011 1144	3312 3231	2111 3312	1222 2211	1121 3220	3233 3332	2112 2221	3243 6556	3222 1112	0011 1234	1111 3233
12	0013 3250	3232 1132	2011 1233	3212 3422	2011 1201	0111 2101	2222 4233	2222 4424	7321 2233	2111 1110	2112 2324	2311 1112
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25	1110 0122	2321 2233	0012 2221	1001 1220	1111 2123	2333 2532	1212 2221	1123 3332	3211 1224	1111 0001	2000 1032	2222 3553
26	1001 1133	2111 0132	2232 3487	1111 2101	2421 2300	3131 2444	2222 4433	2210 3213	0102 3212	0011 1133	3222 3330	3323 3333
27	2112 1132	2311 0003	7422 3464	1100 2223	0001 1011	3321 2231	4332 2212	4322 2332	2111 1101	1112 1231	3221 1431	3232 2331
28	1211 0000	1011 1021	3223 2345	2222 2323	0100 2111	2132 2211	2122 3333	1122 2224	2111 1211	3212 1100	0011 2032	1111 2332
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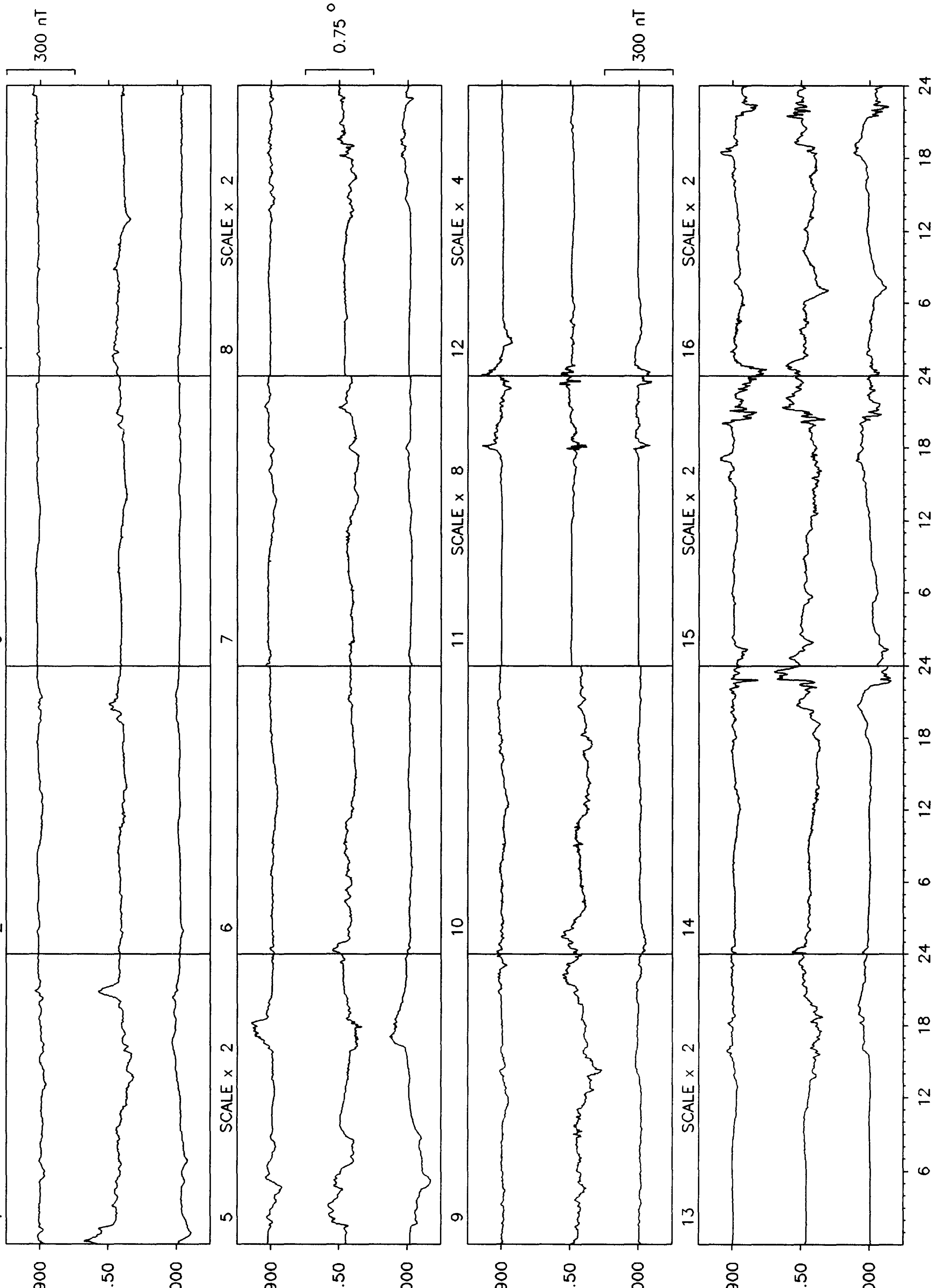
LERWICK 1989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SCALE x 2
SCALE x 8
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SCALE x 2
SCALE x 2
SCALE x 2
H 14900
D -6.50
Z 48000
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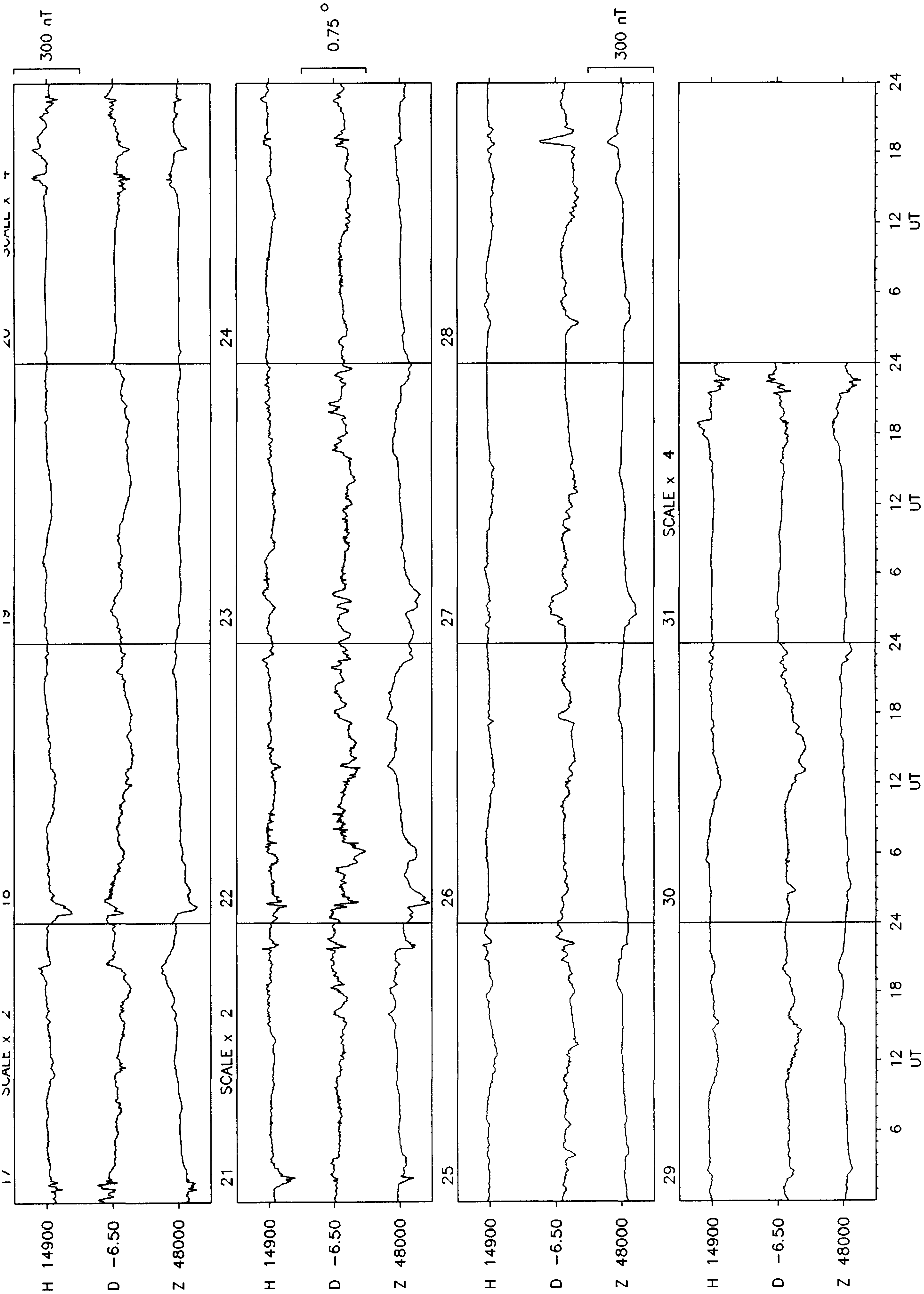
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300 nT
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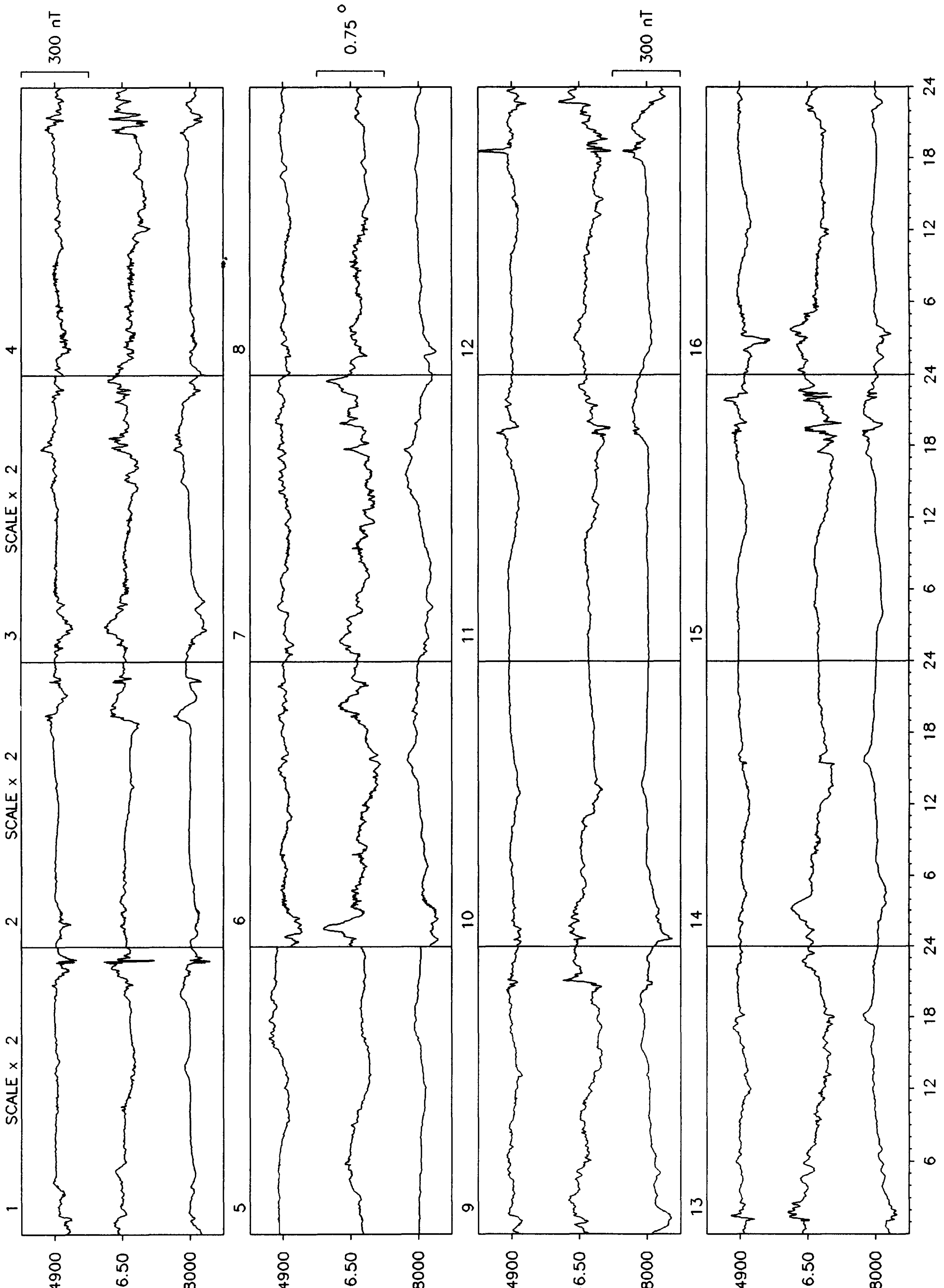
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D −6.50
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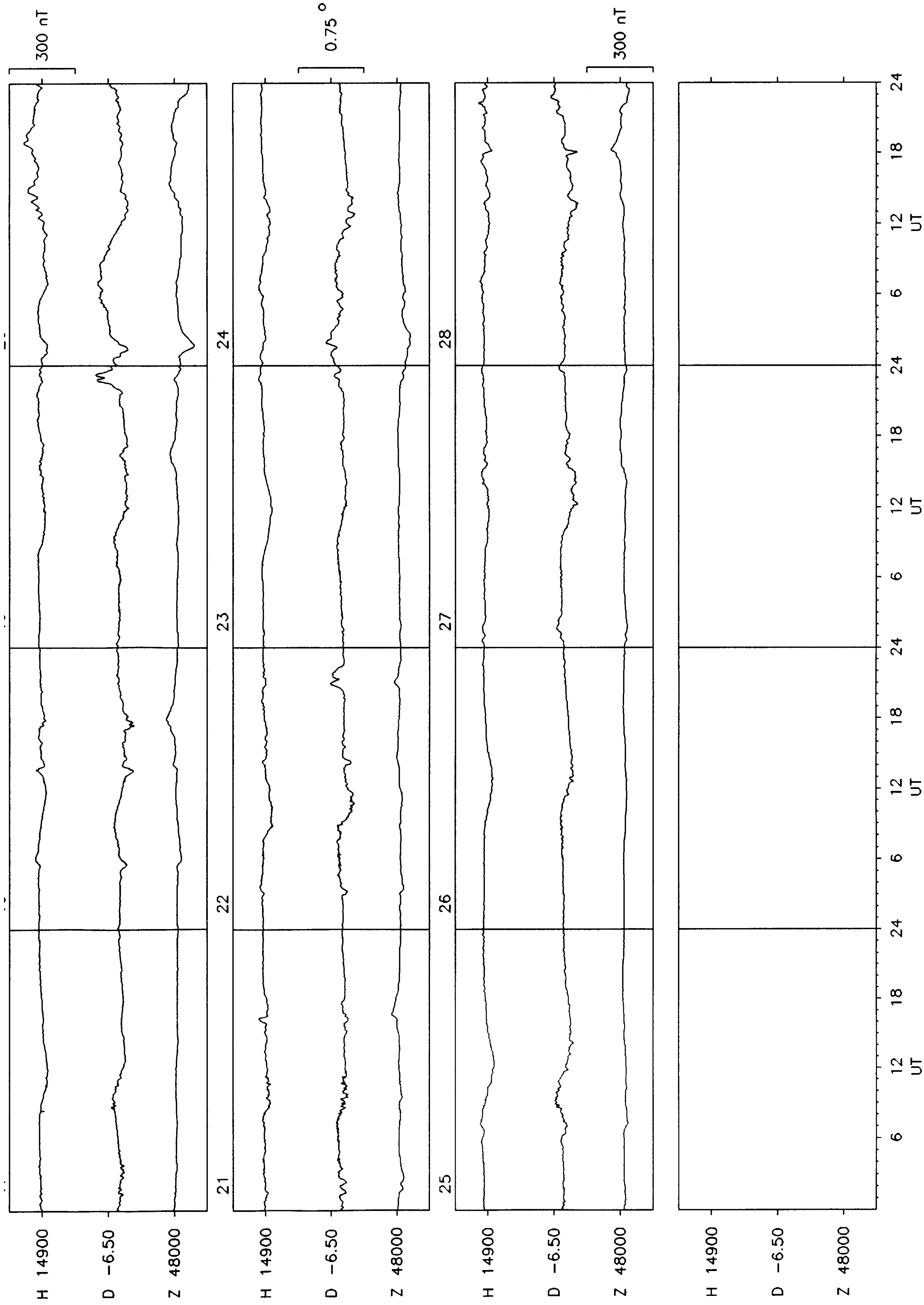
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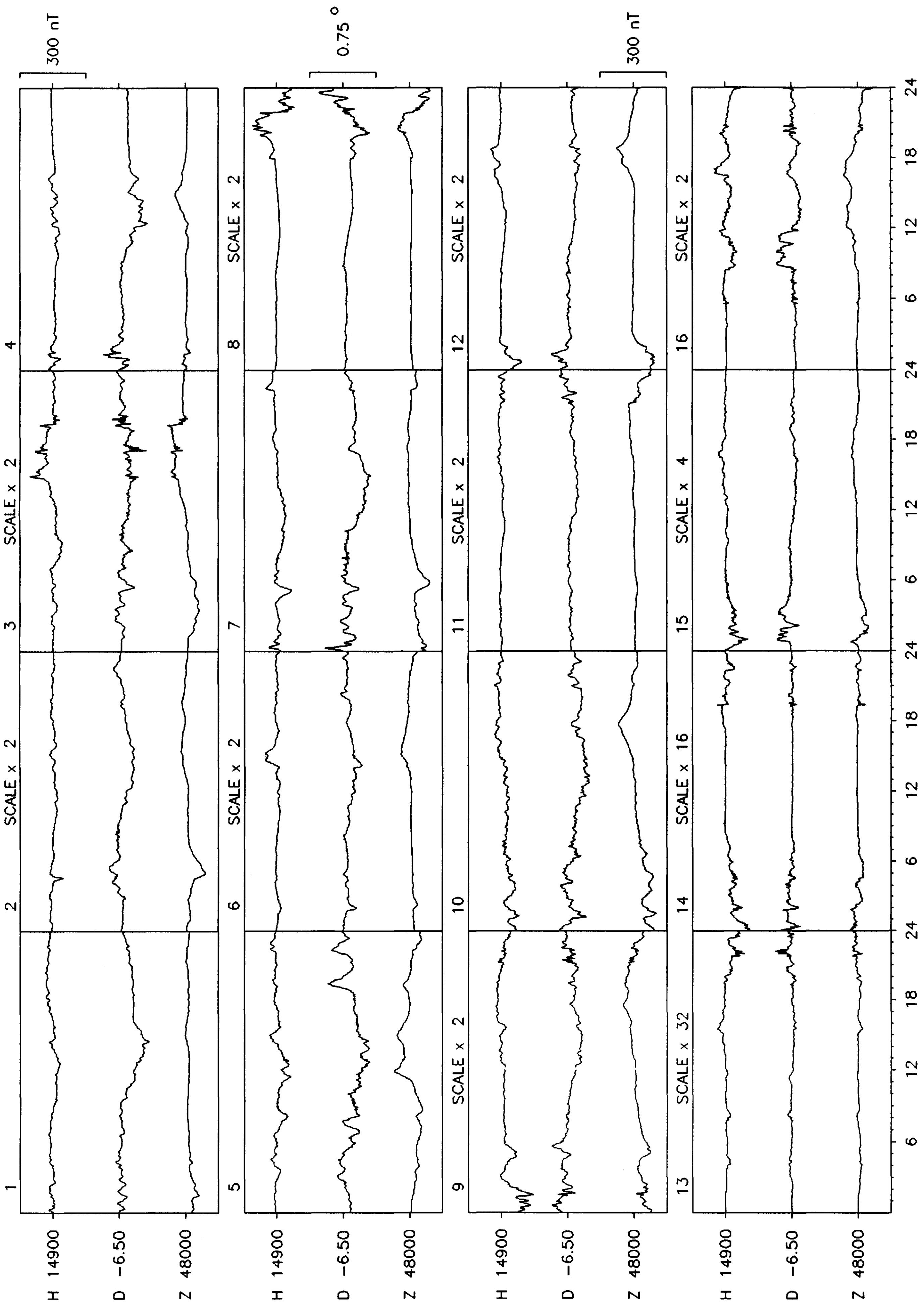
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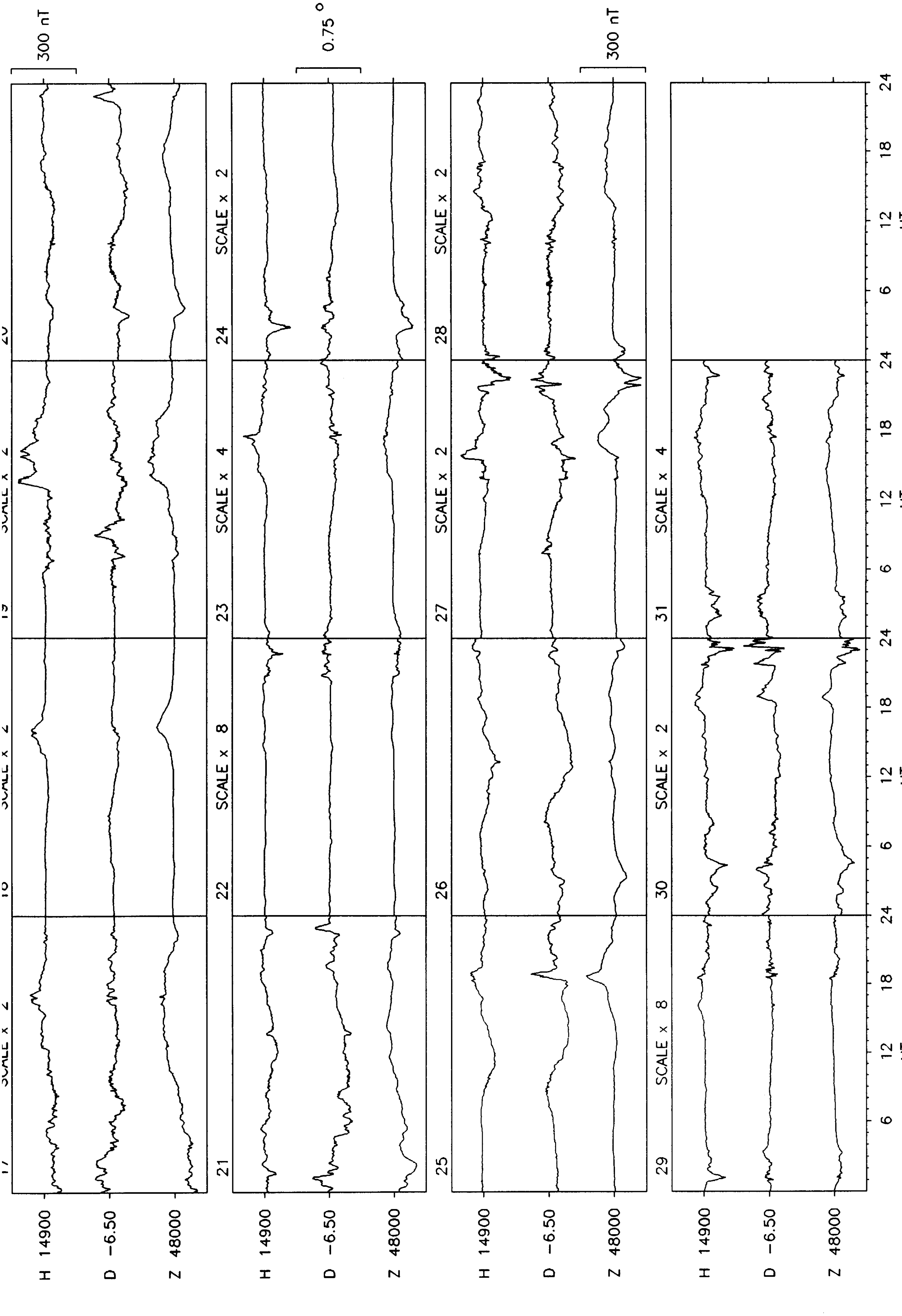

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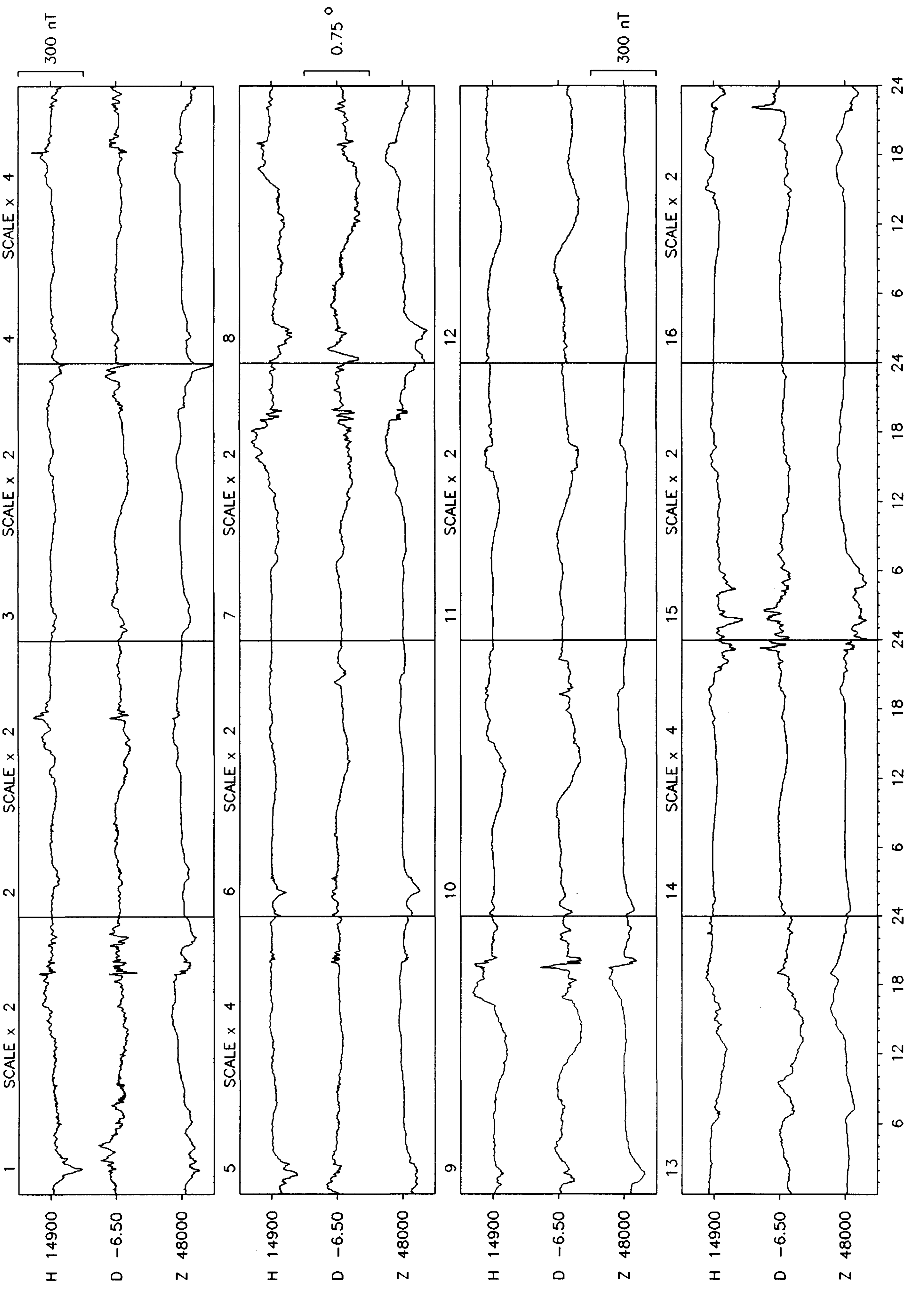
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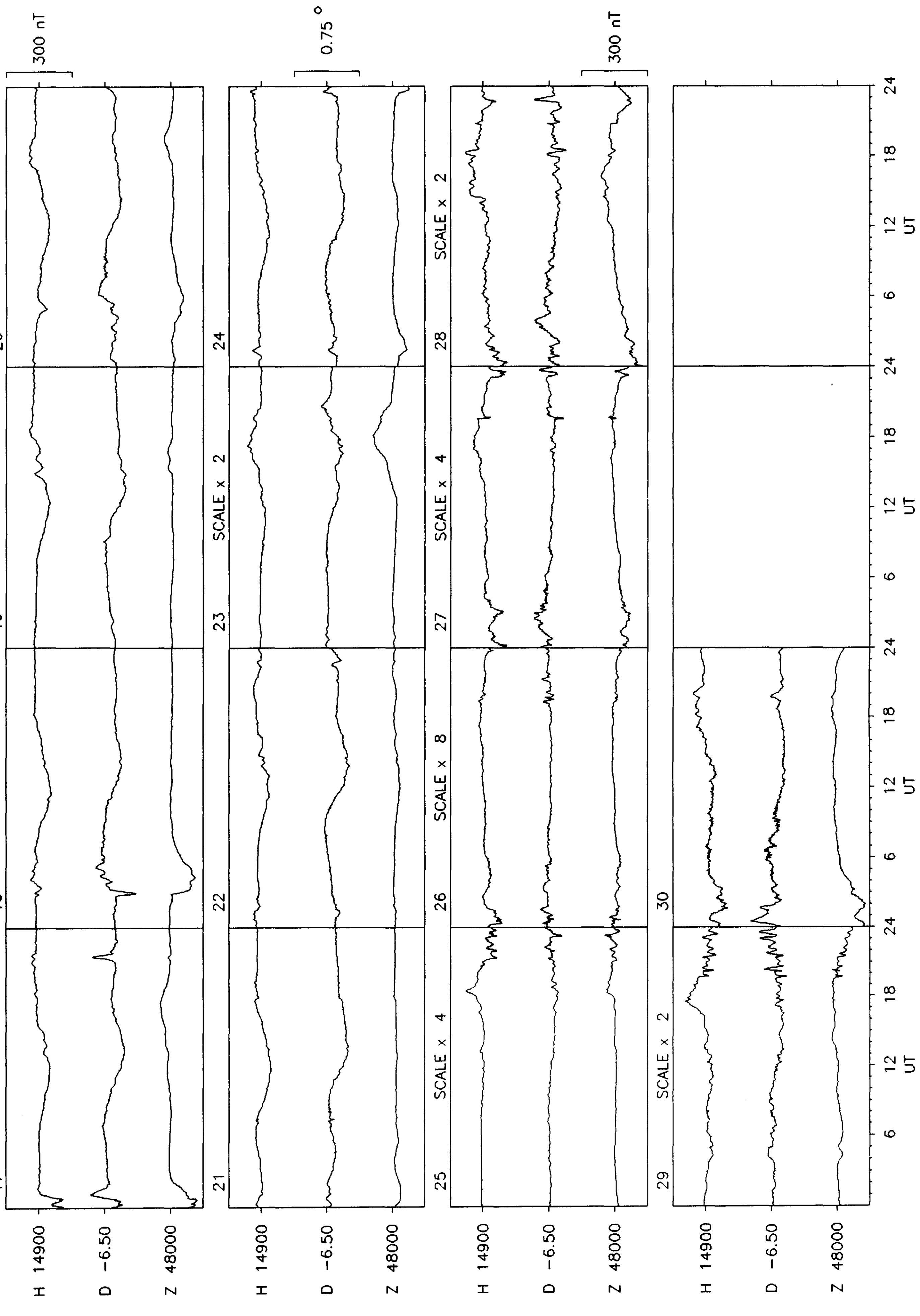

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0.75 °
300 nT
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SCALE x 8
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SCALE x 2
H 14900
D −6.50
Z 48000
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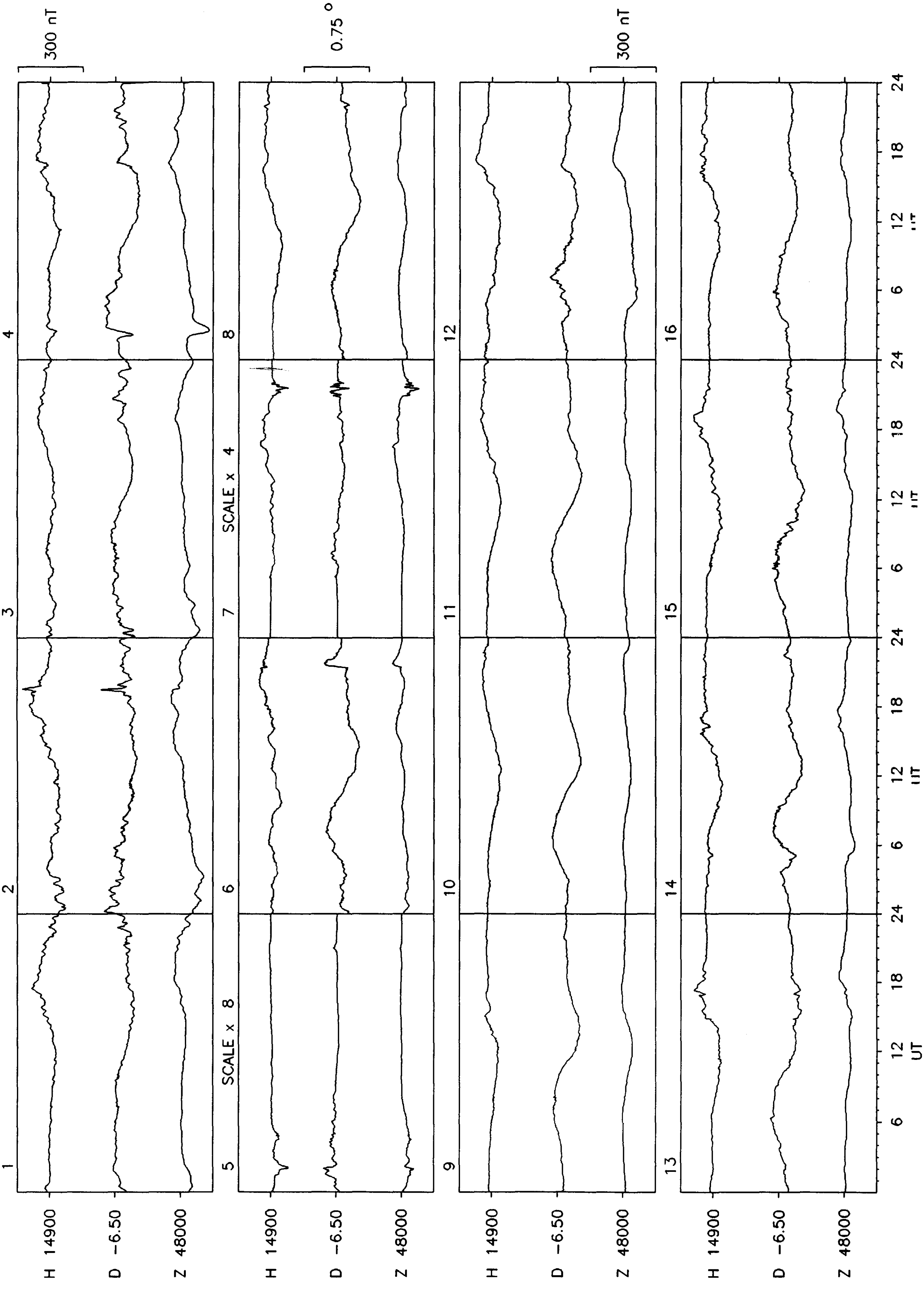
UT


300 nT
0.75 °
300 nT
1
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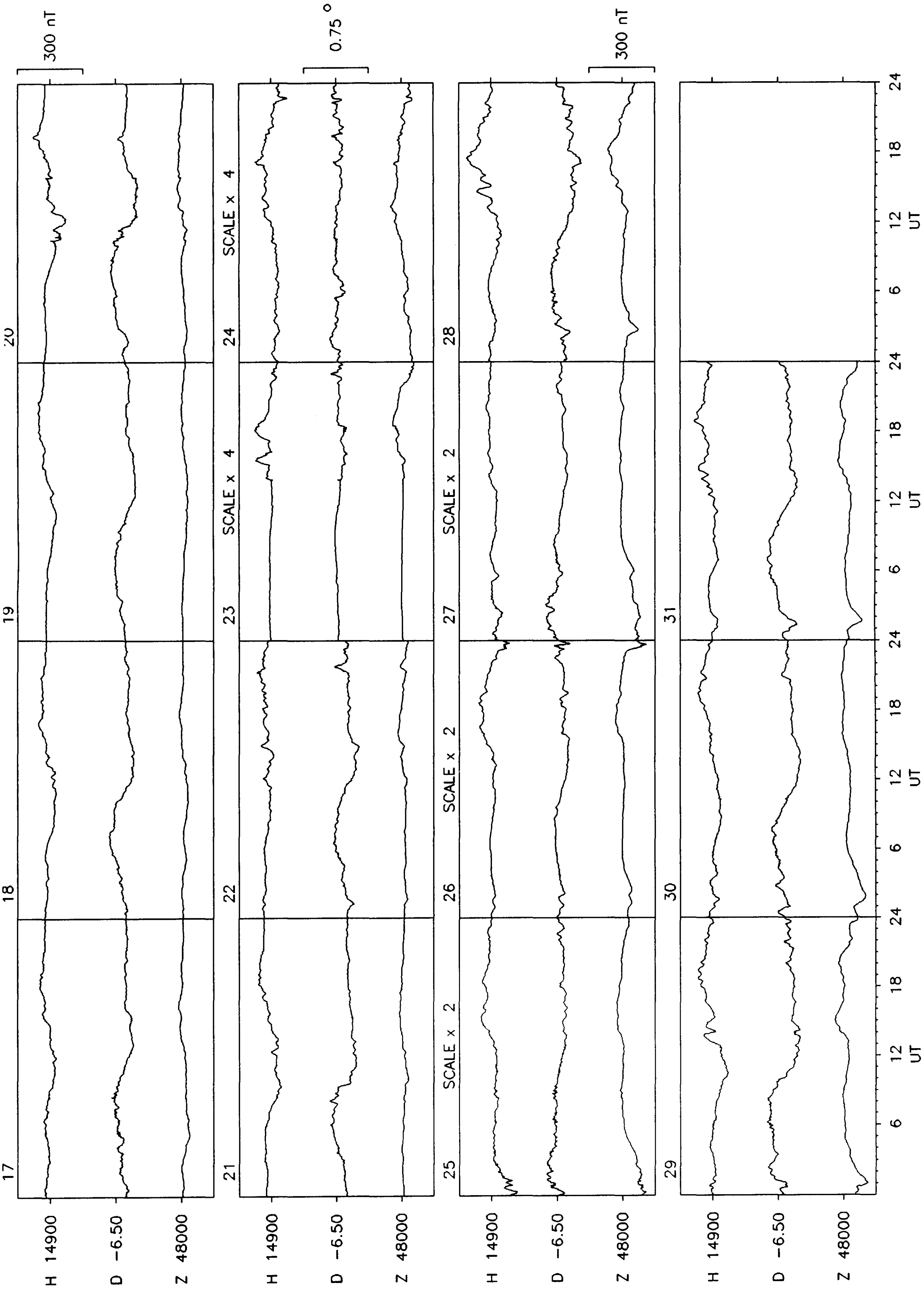
15
16
SCALE x 8
SCALE x 4
H 14900
D −6.50
Z 48000
6
12
18
24
UT



300 nT
0.75 °
300 nT
17
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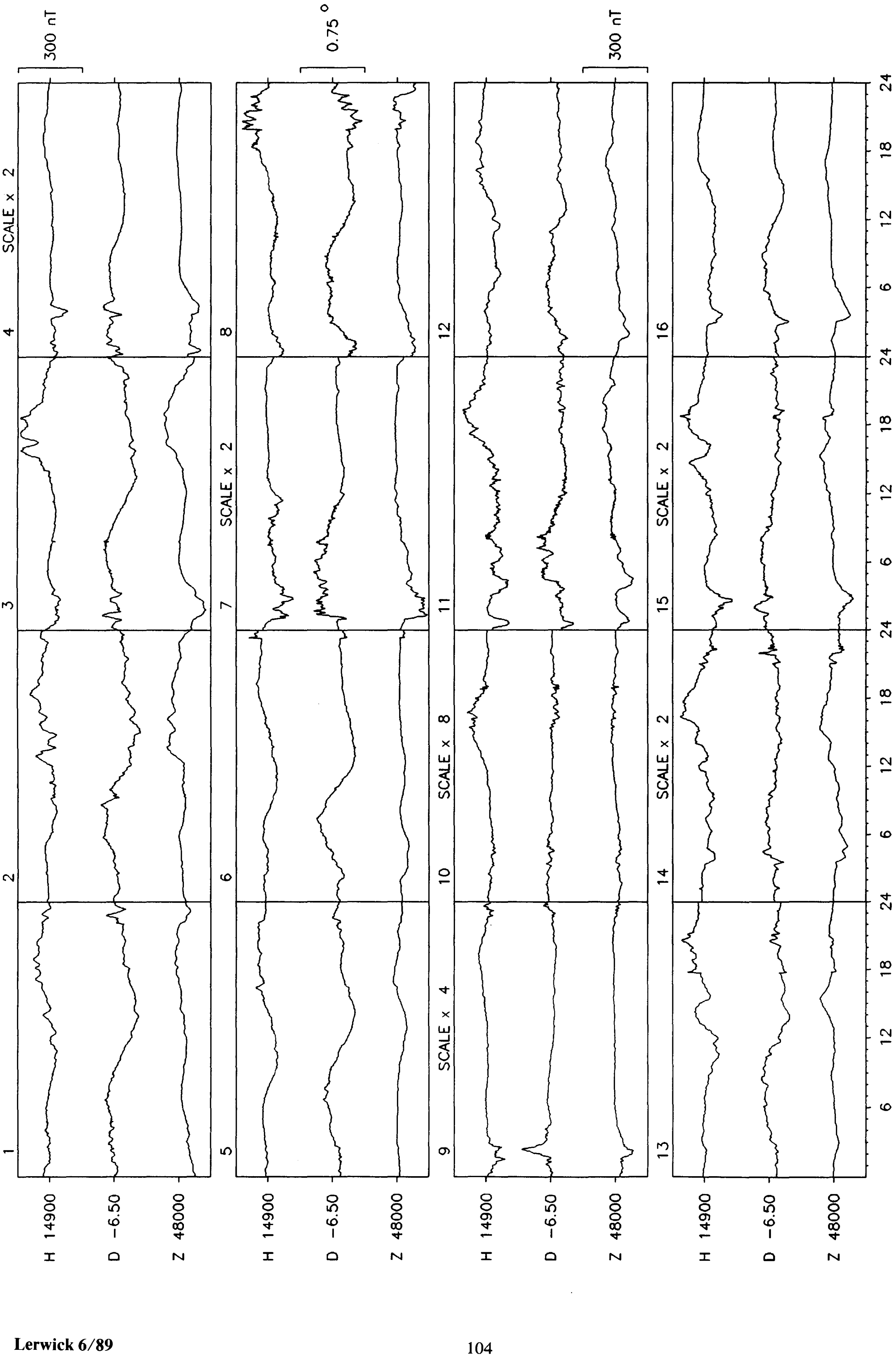
28
29
30
31
SCALE x 4
SCALE x 4
SCALE x 2
SCALE x 2
SCALE x 2
H 14900
D −6.50
Z 48000
6
12
18
24
UT



300 nT
0.75 °
300 nT
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SCALE x 2
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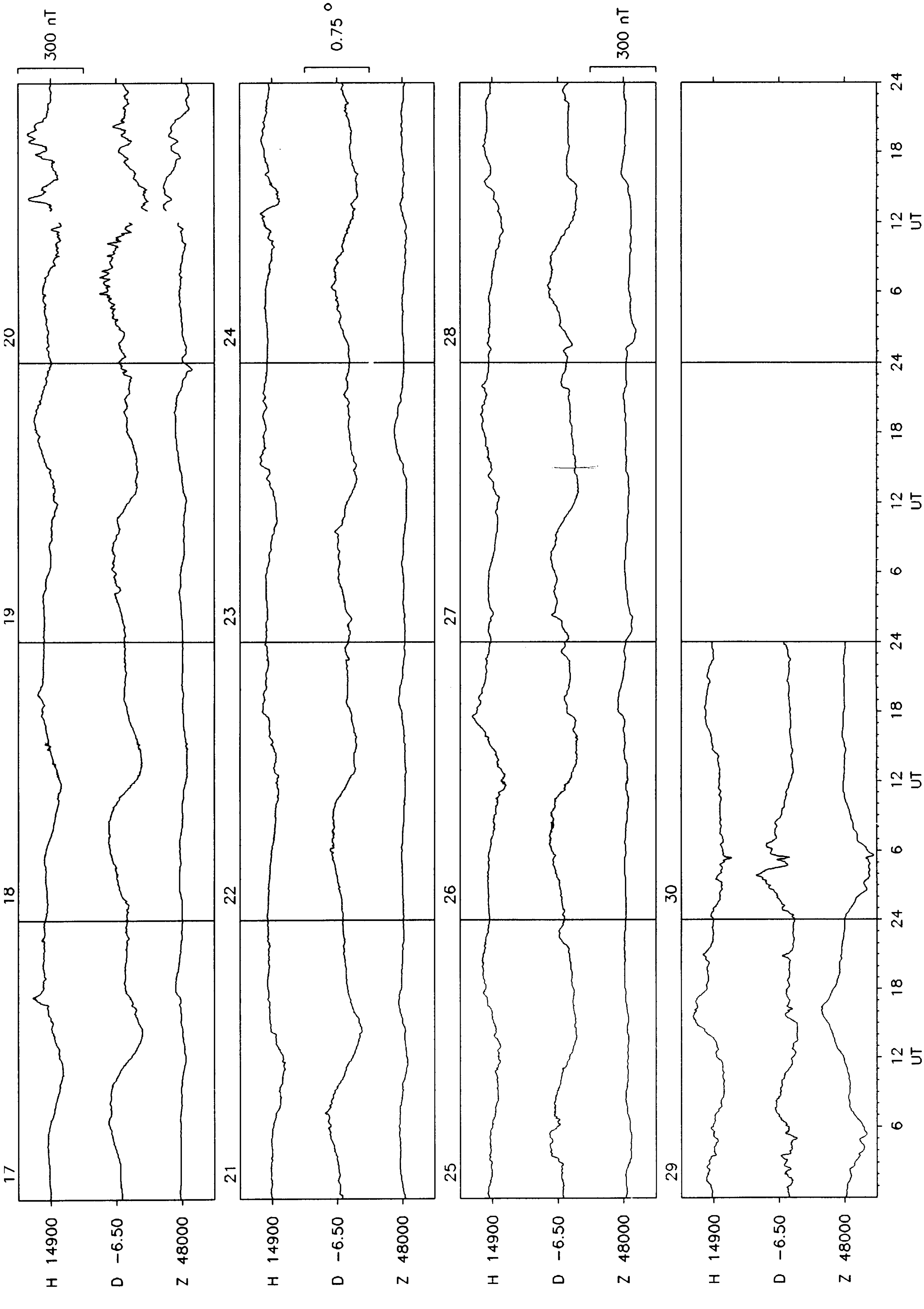
8
SCALE x 2
9
10
11
12
SCALE x 4
SCALE x 8
13
14
15
16
SCALE x 2
SCALE x 2
H 14900
D -6.50
Z 48000
6
12
18
24
UT



H 14900
D −6.50
Z 48000
300 nT
0.75 °
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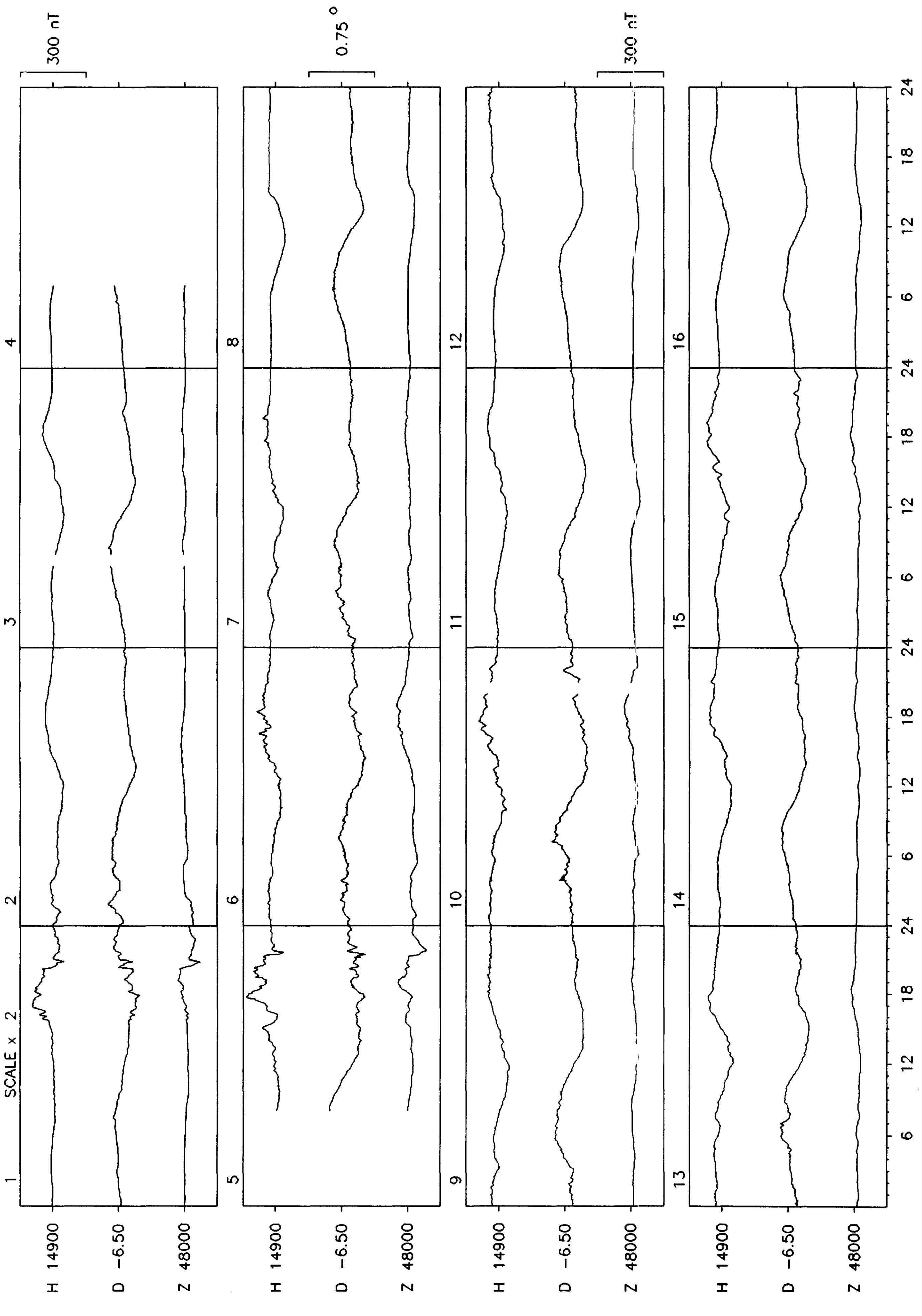
UT


300 nT
0.75 °
300 nT
SCALE x 2
H 14900
D −6.50
Z 48000
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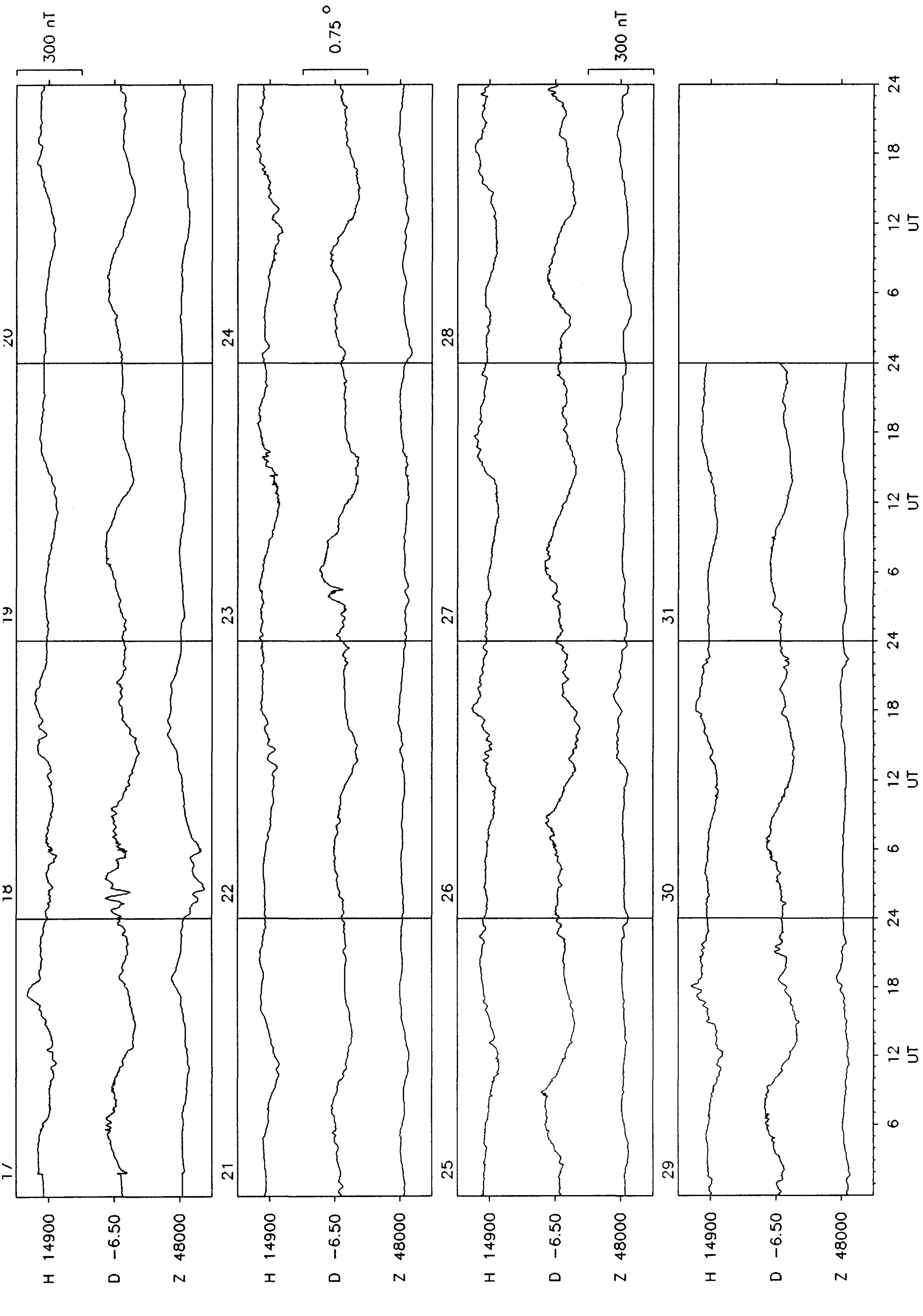
24


300 nT
0.75 °
300 nT
H 14900
D −6.50
Z 48000
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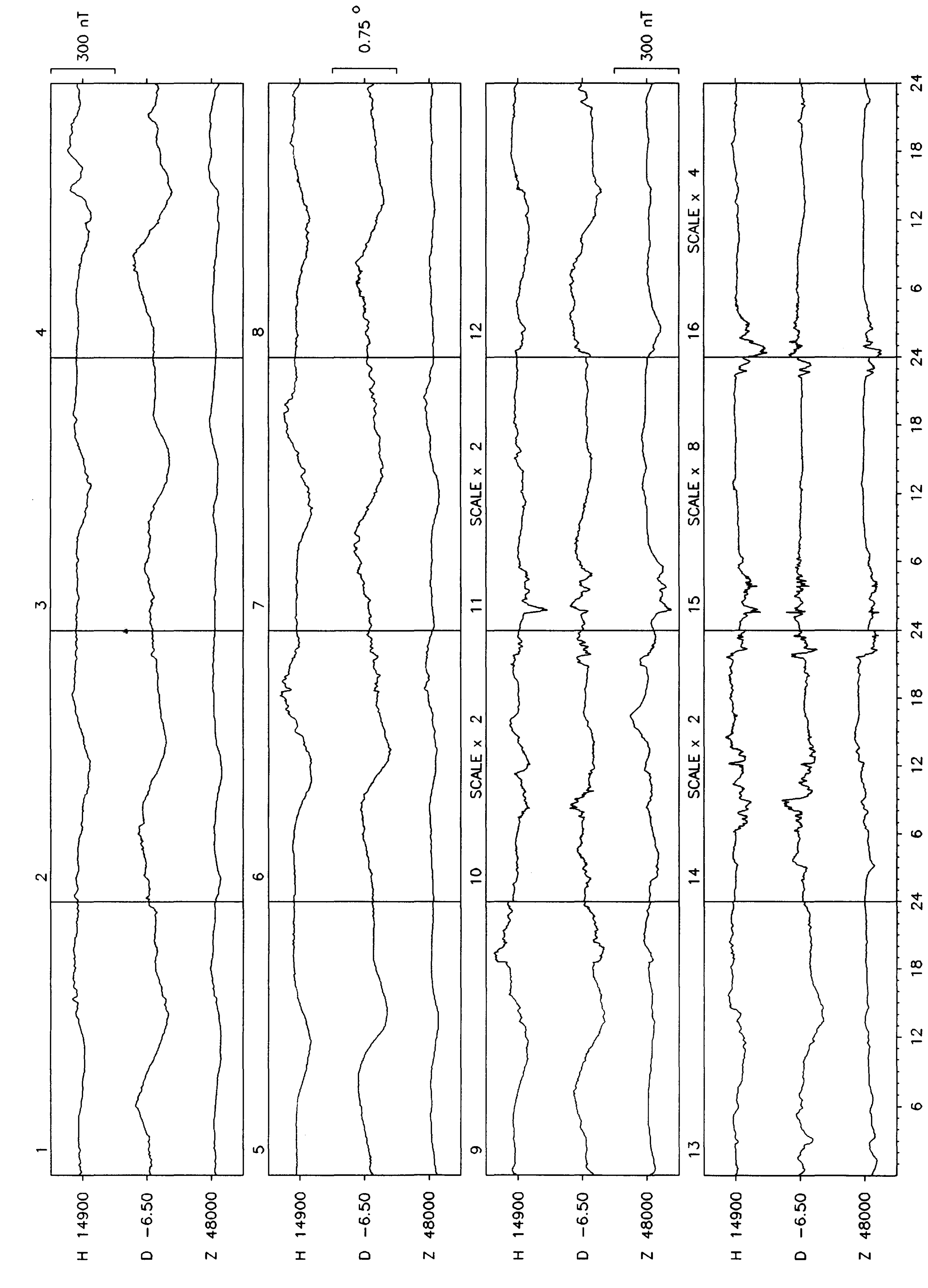
UT


300 nT
0.75 °
300 nT
H 14900
D −6.50
Z 48000
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SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 8
SCALE x 4
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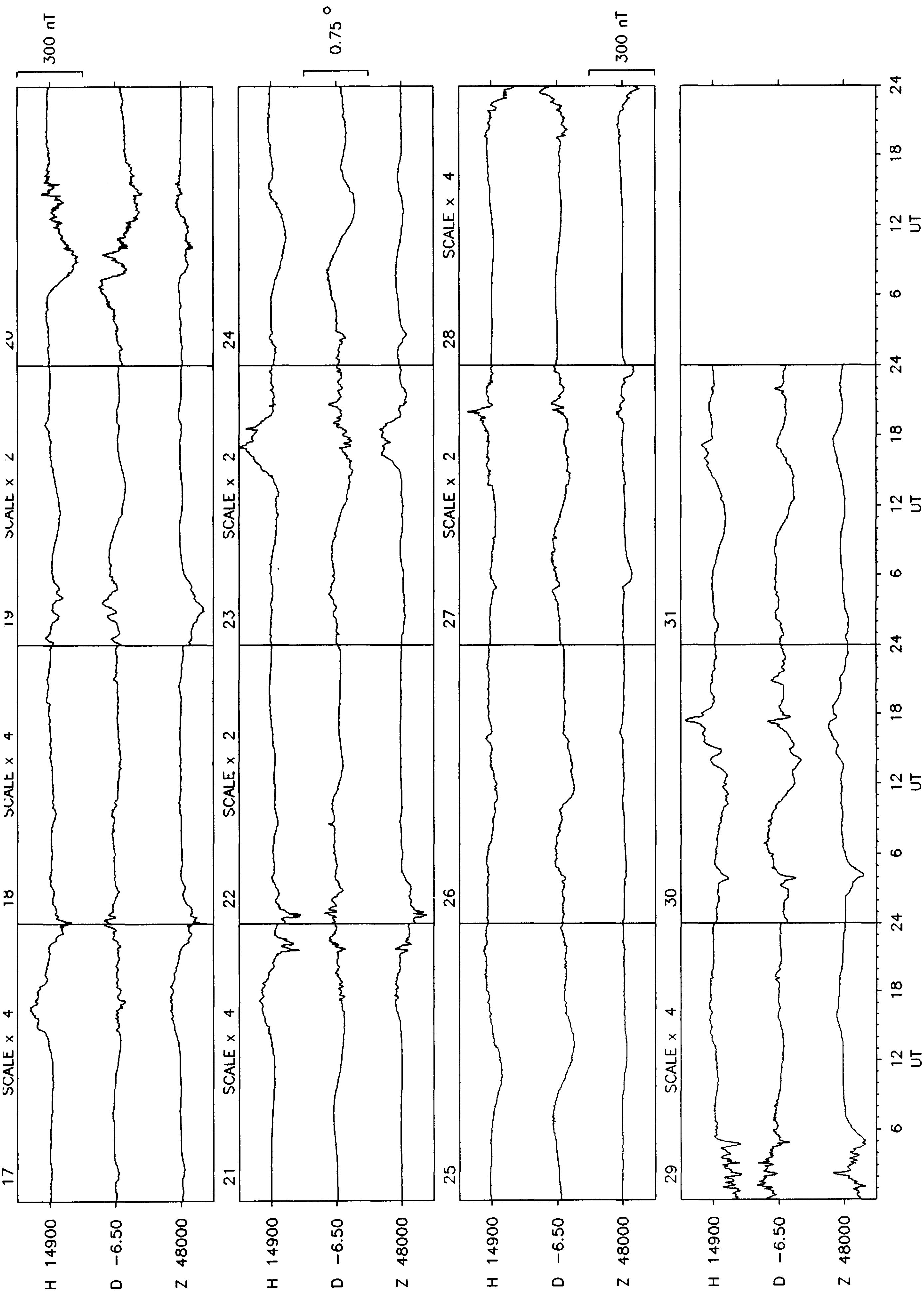
300 nT
0.75 °
300 nT
H 14900
D −6.50
Z 48000
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31
SCALE x 4
SCALE x 2
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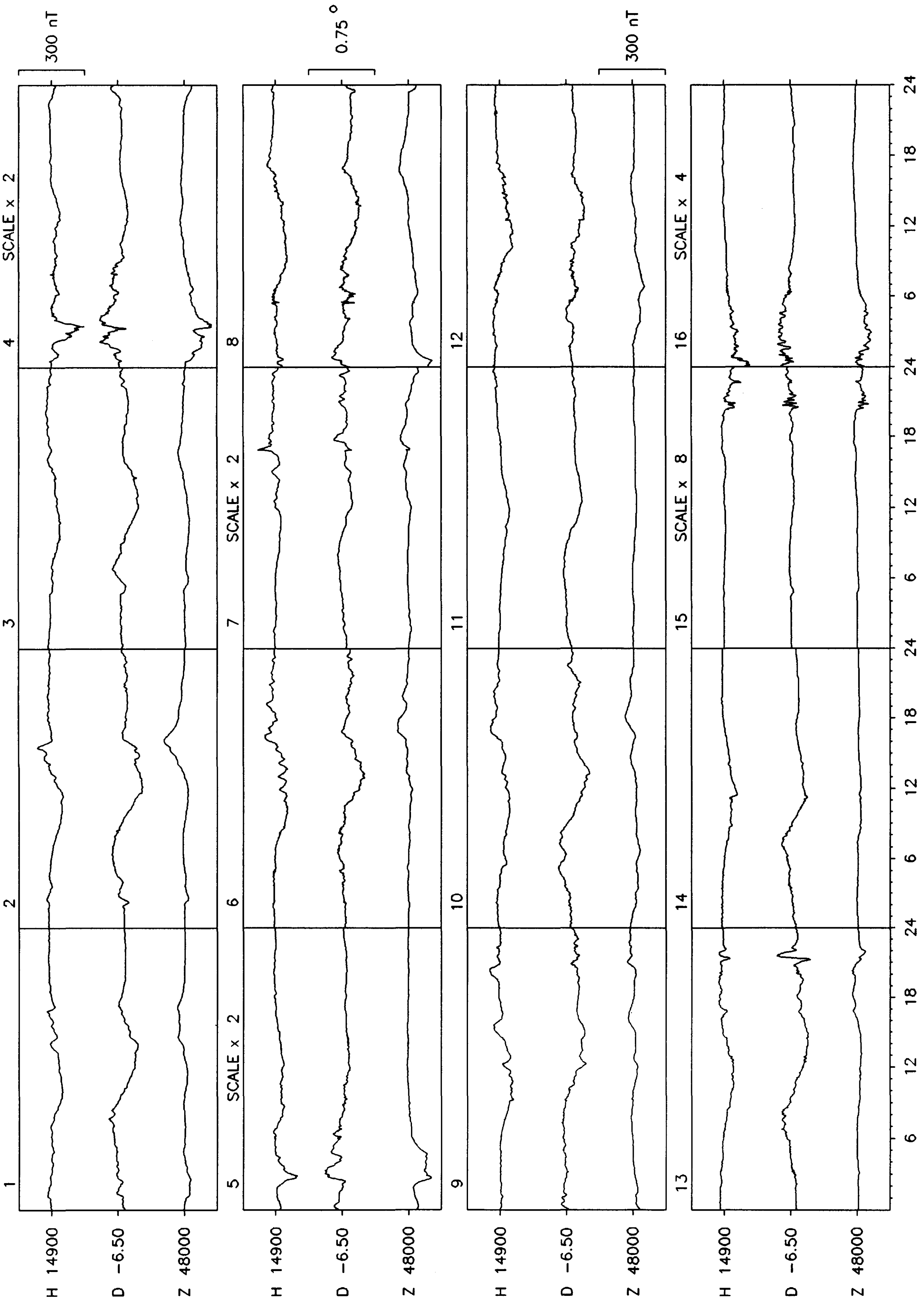
UT


300 nT
0.75 °
300 nT
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 8
SCALE x 4
H 14900
D −6.50
Z 48000
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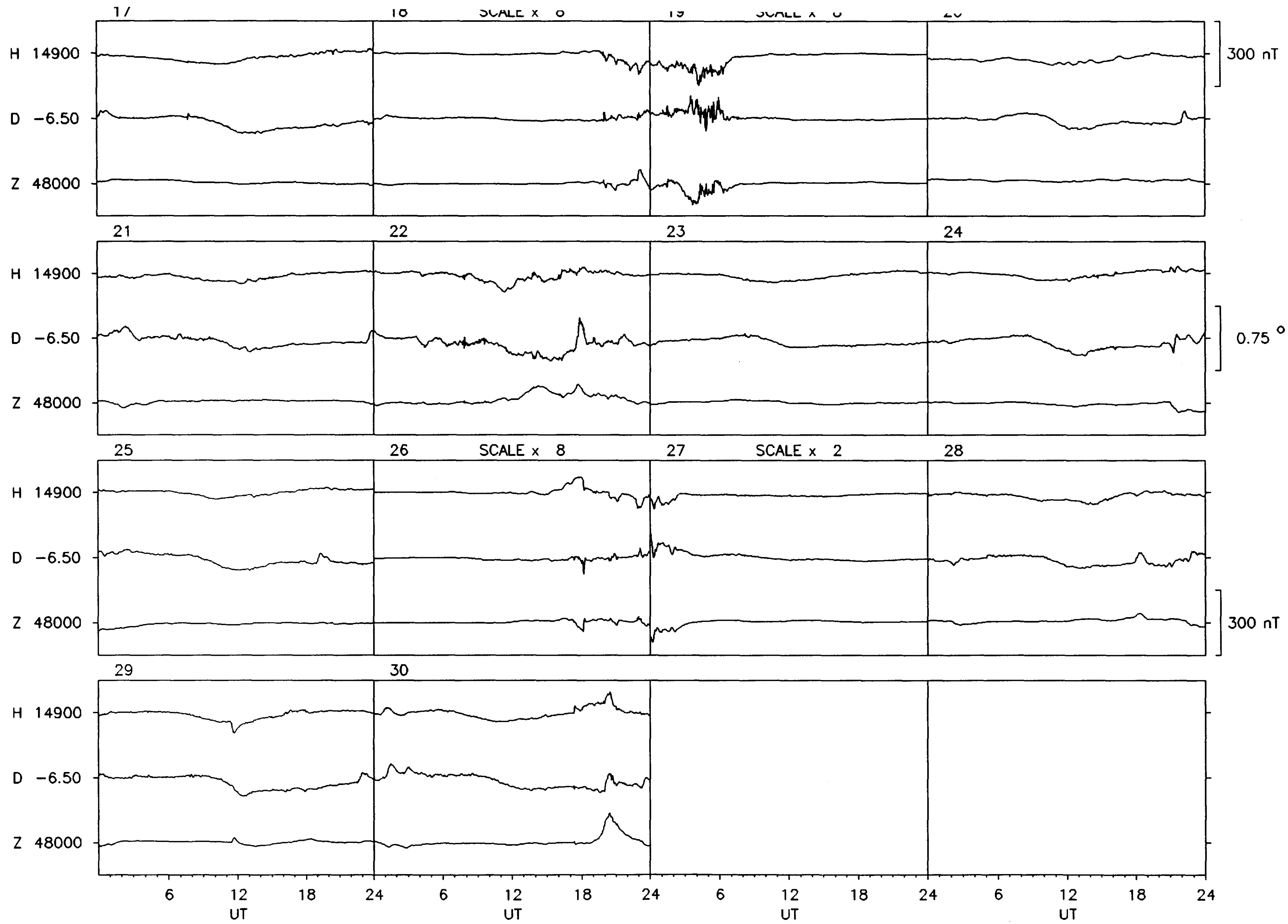
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26
SCALE x 8
27
SCALE x 2
28
29
30
H 14900
D -6.50
Z 48000
300 nT
0.75 °
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12
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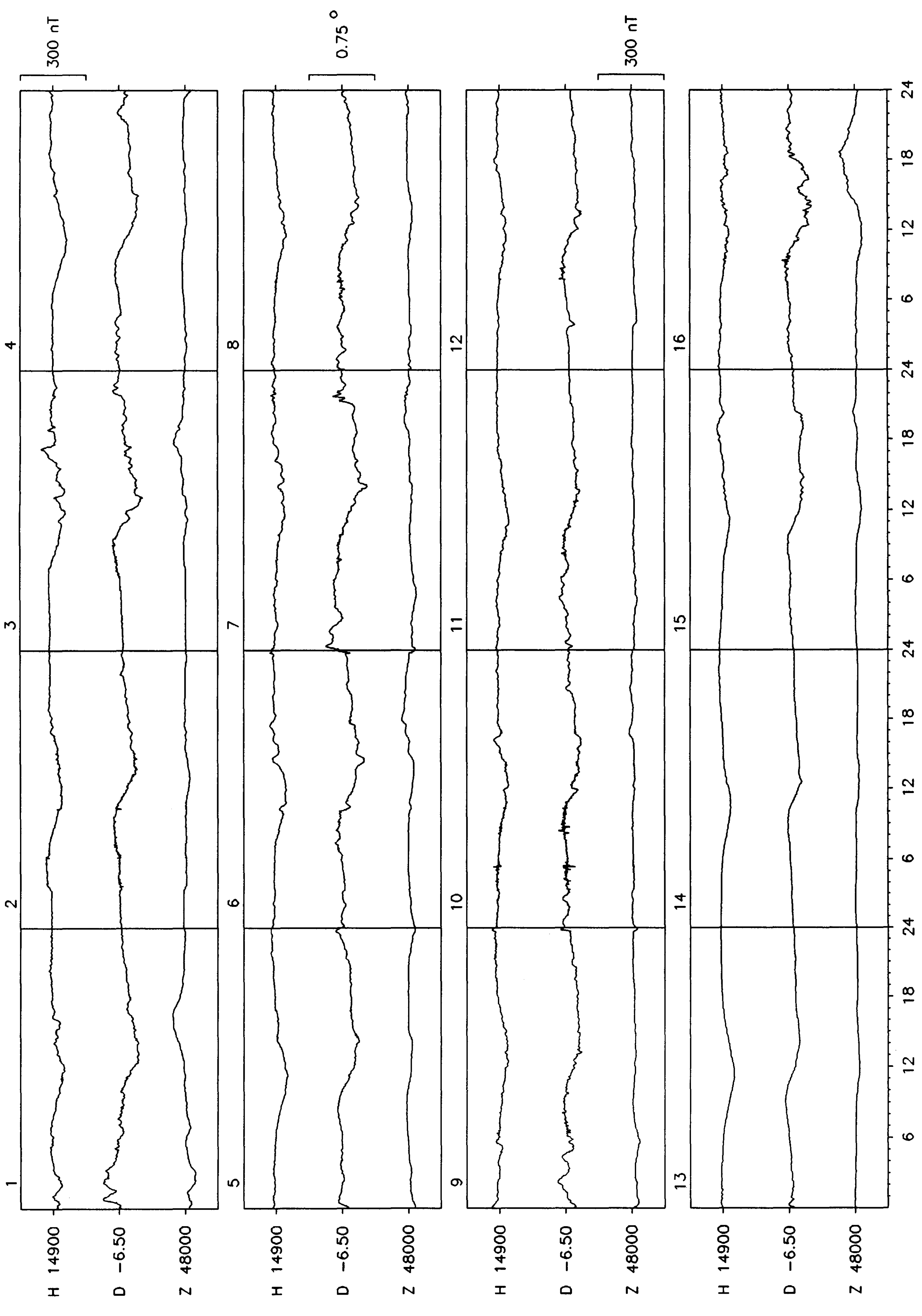
24
UT


300 nT
0.75 °
300 nT
H 14900
D −6.50
Z 48000
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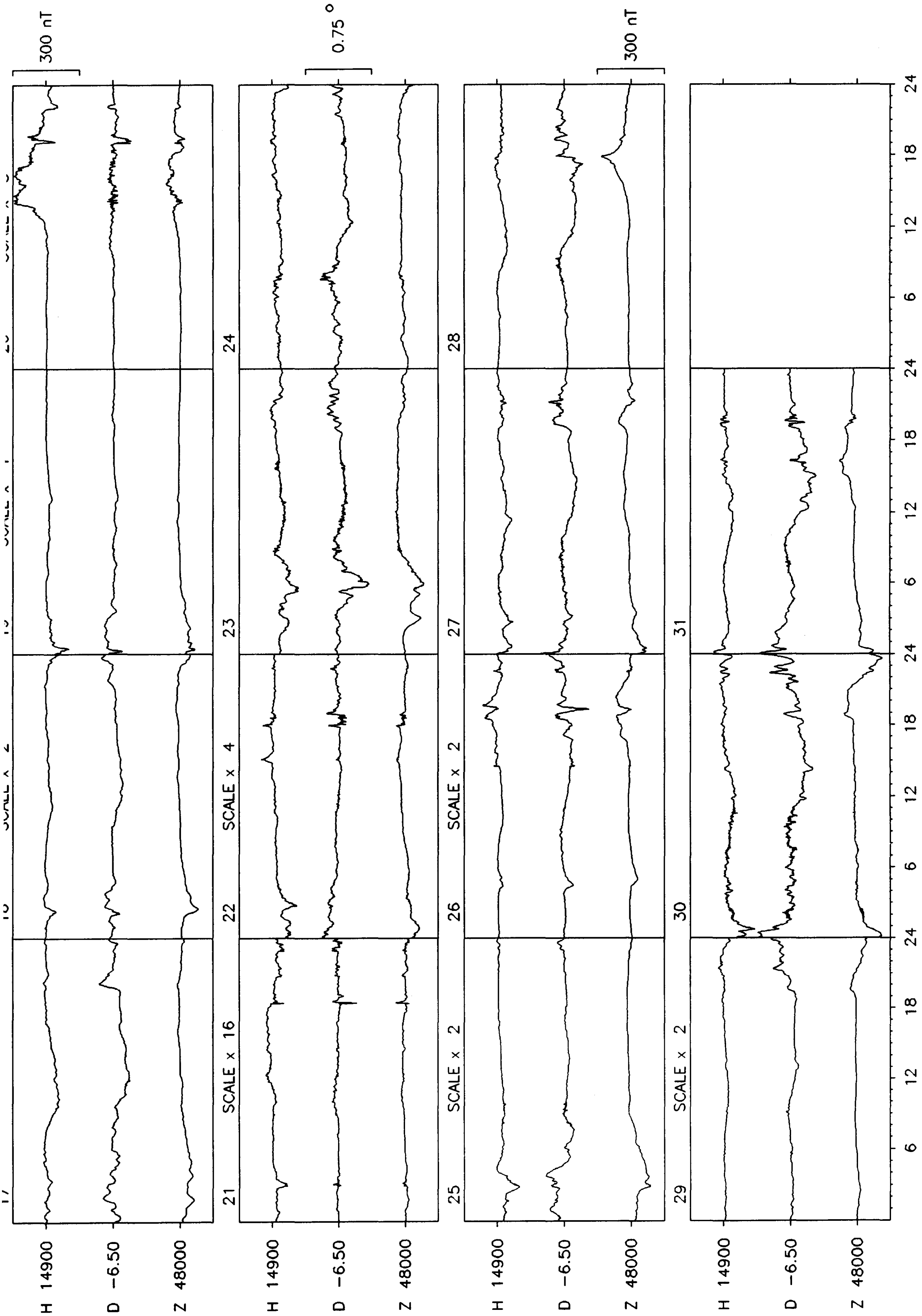

300 nT
0.75 °
300 nT
H 14900
D −6.50
Z 48000
21
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31
SCALE x 16
SCALE x 4
SCALE x 2
SCALE x 2
SCALE x 2
6
12
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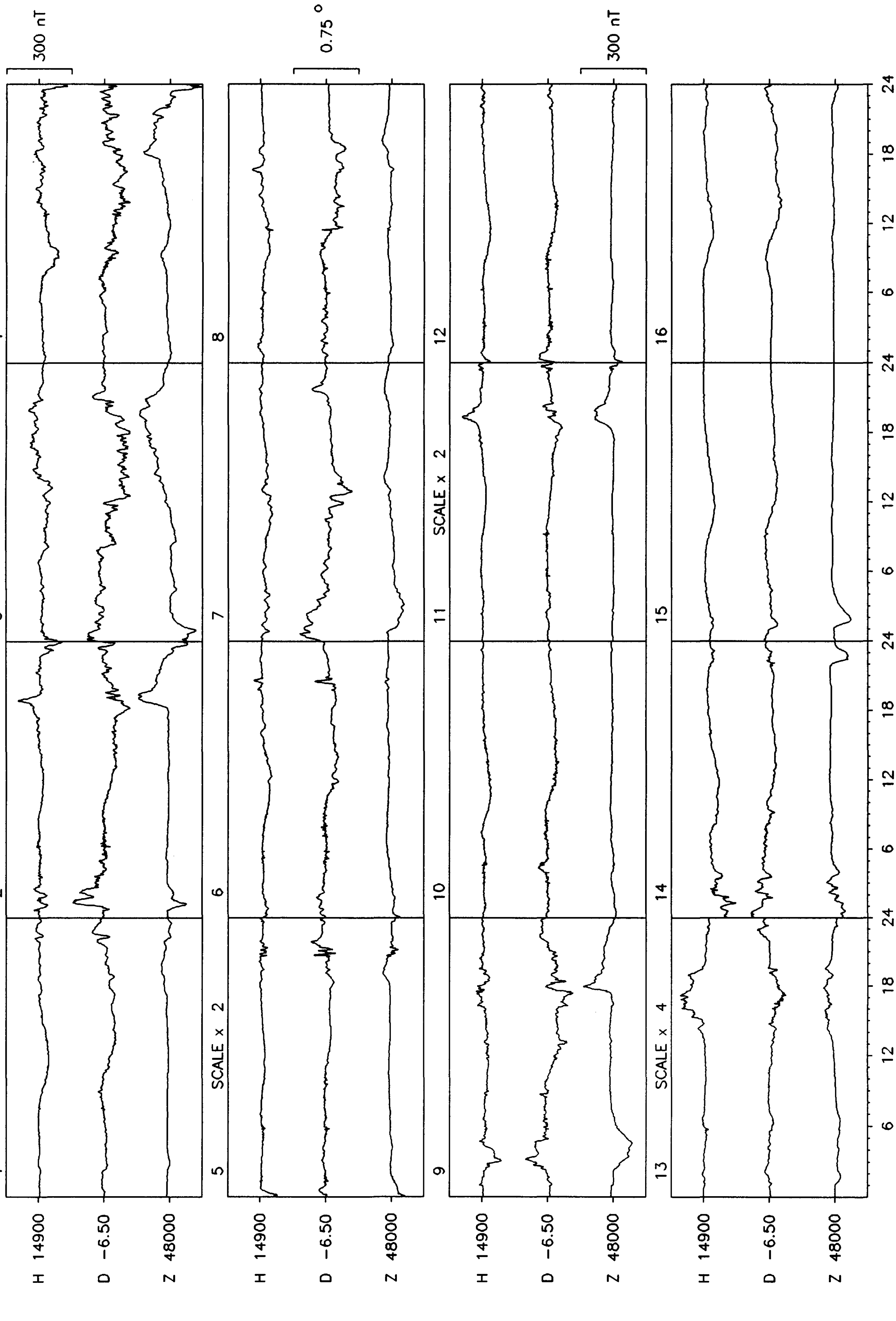
24
UT


300 nT
0.75 °
300 nT
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16
SCALE x 2
SCALE x 2
SCALE x 4
H 14900
D −6.50
Z 48000
H 14900
D −6.50
Z 48000
H 14900
D −6.50
Z 48000
H 14900
D −6.50
Z 48000
6
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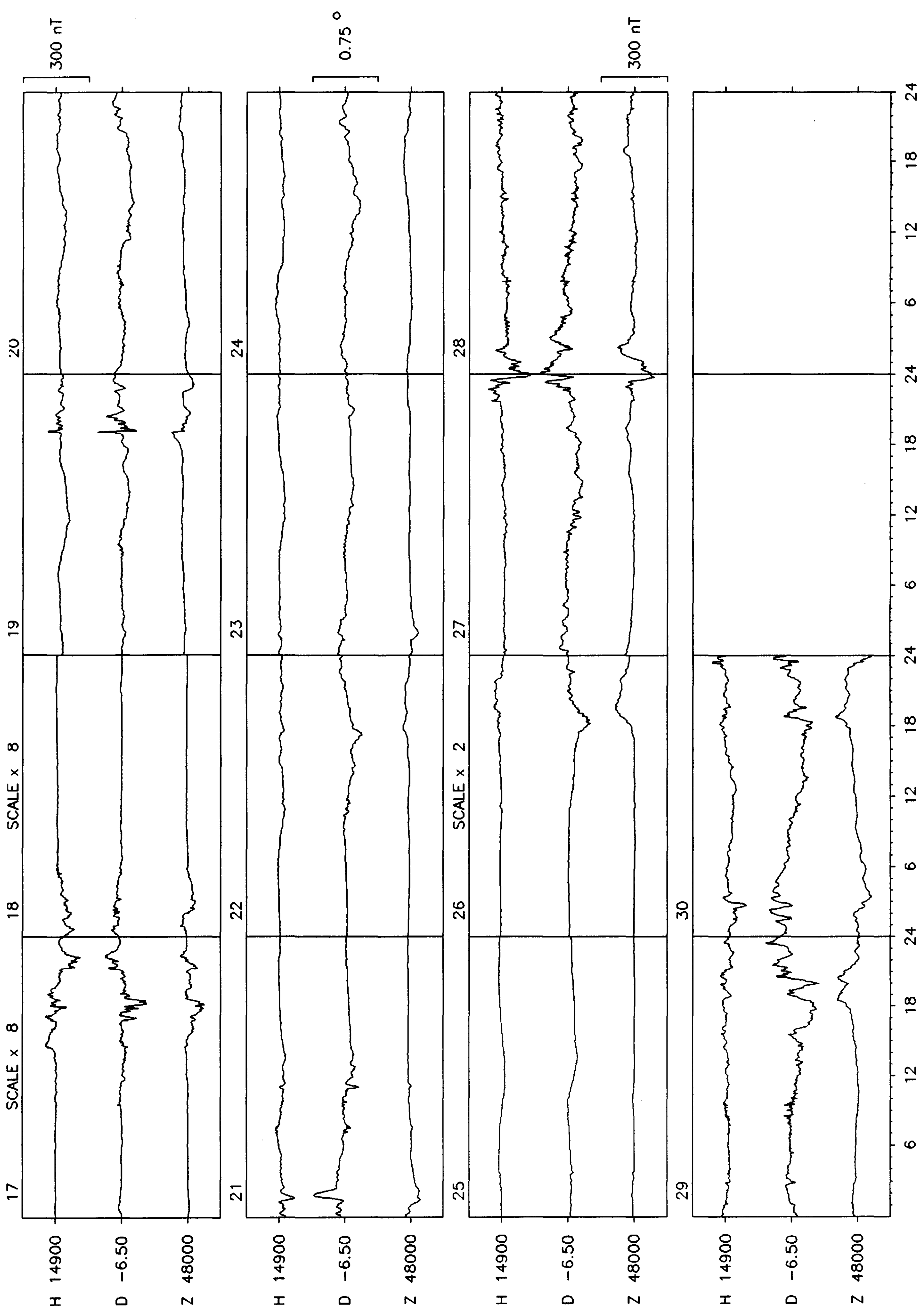
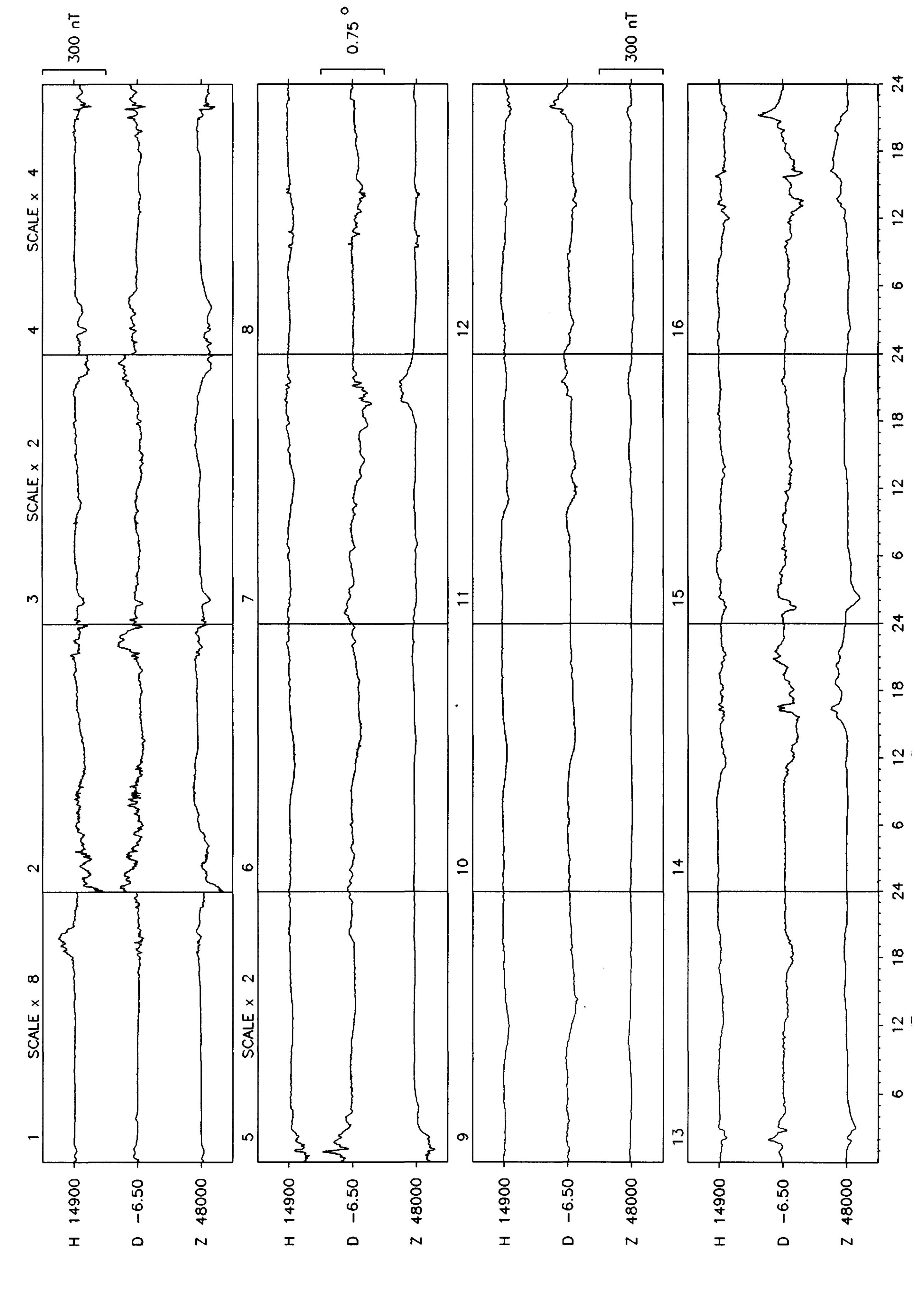
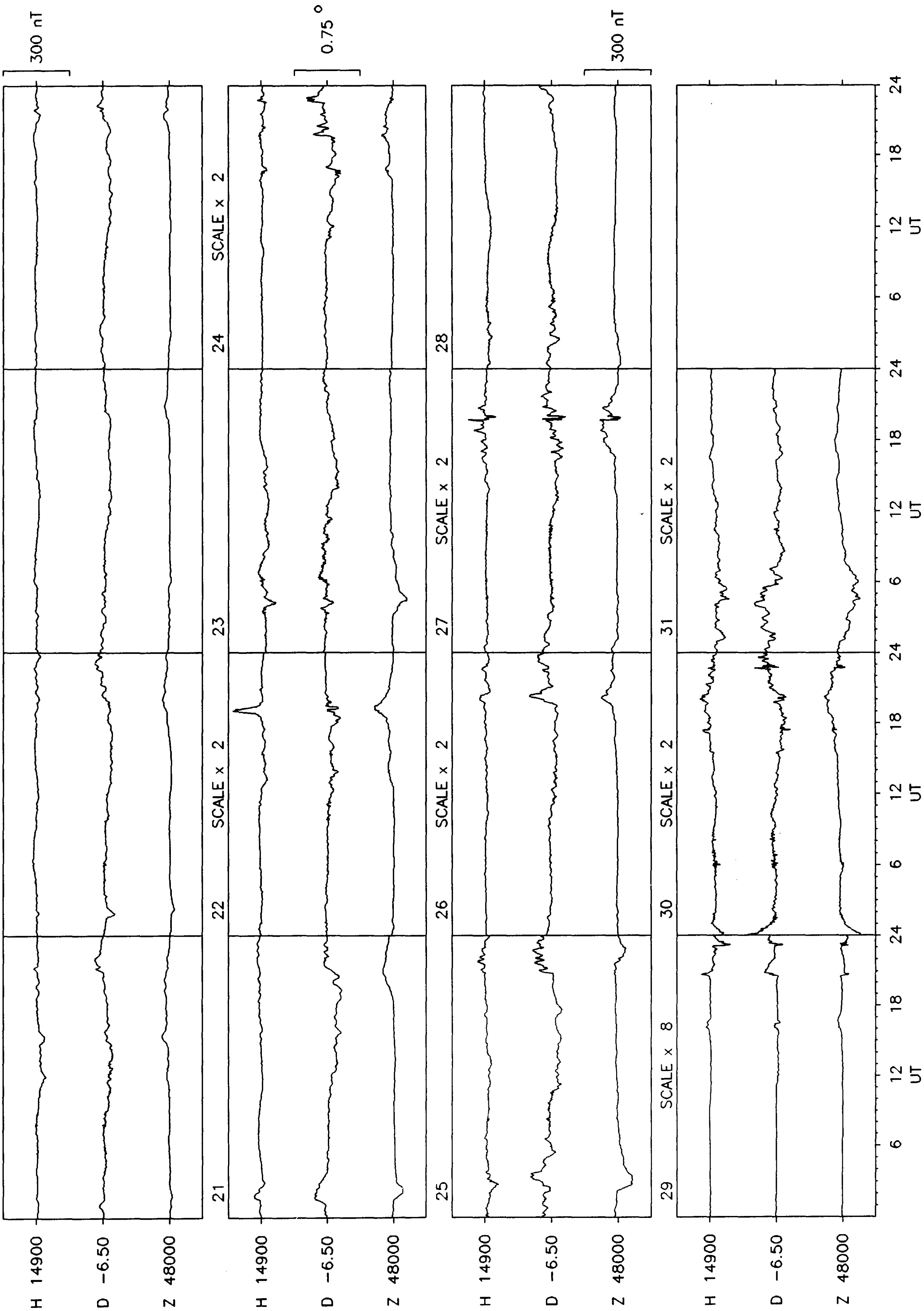
24



300 nT
0.75 °
300 nT
17
SCALE x 8
18
SCALE x 8
19
20
21
22
23
24
25
26
SCALE x 2
27
28
29
30
H 14900
D −6.50
Z 48000
6
12
18
24
UT


300 nT
0.75 °
300 nT
SCALE x 8
SCALE x 2
SCALE x 4
SCALE x 2
H 14900
D −6.50
Z 48000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
6 12 18 24



300 nT
0.75 °
300 nT
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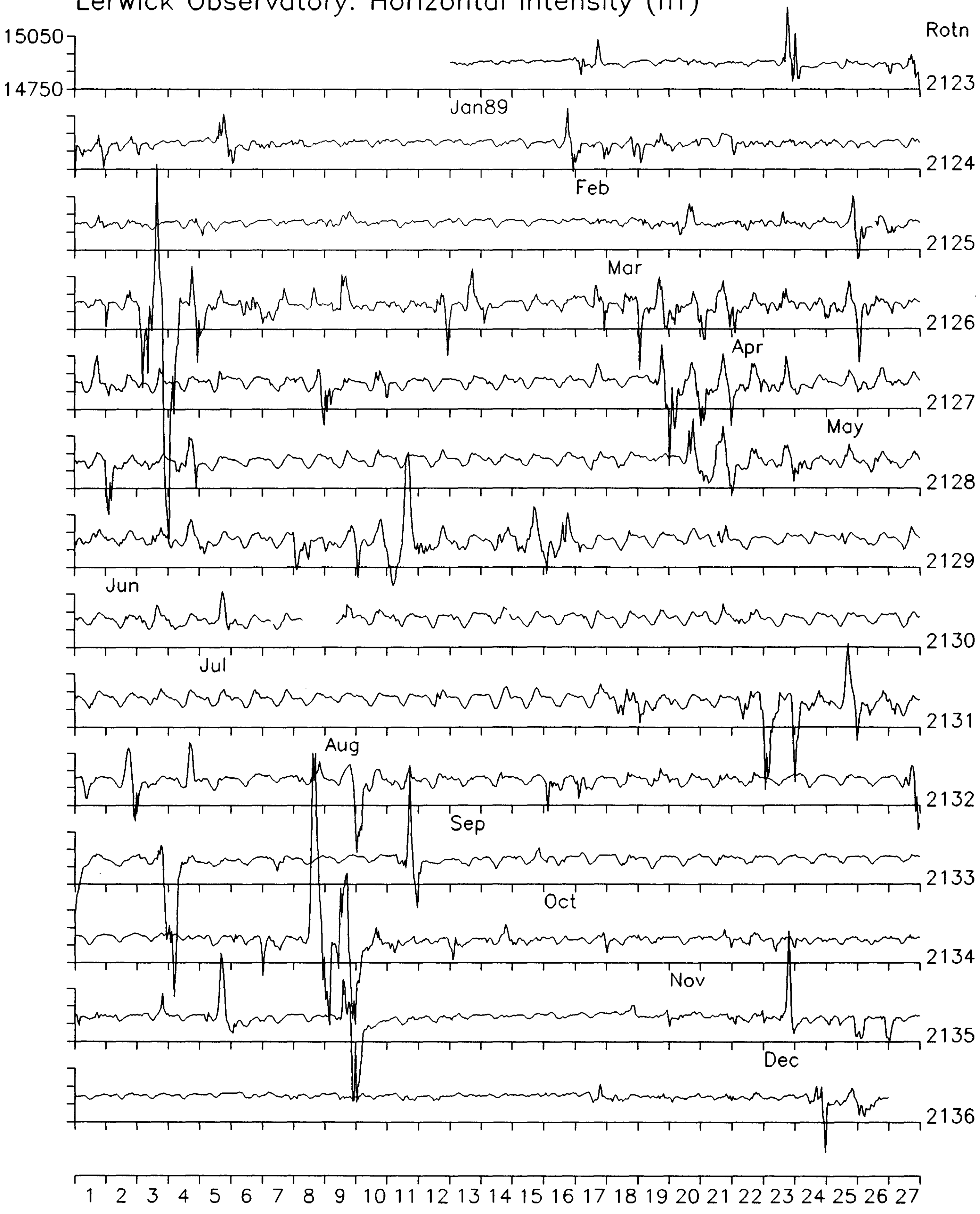
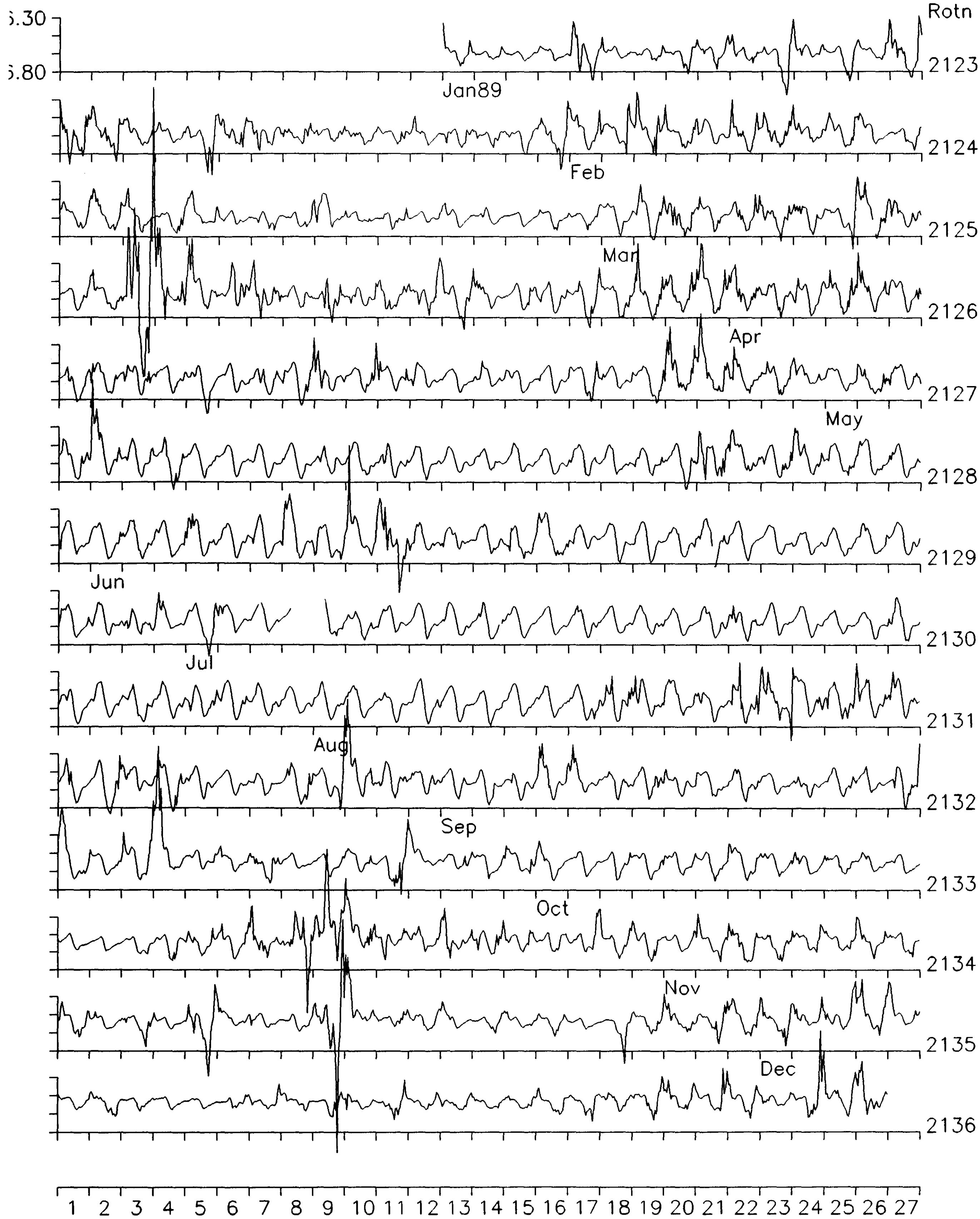
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 8
SCALE x 2
SCALE x 2
H 14900
D −6.50
Z 48000
6
12
18
24
UT

Lerwick Observatory: Horizontal Intensity (nT)



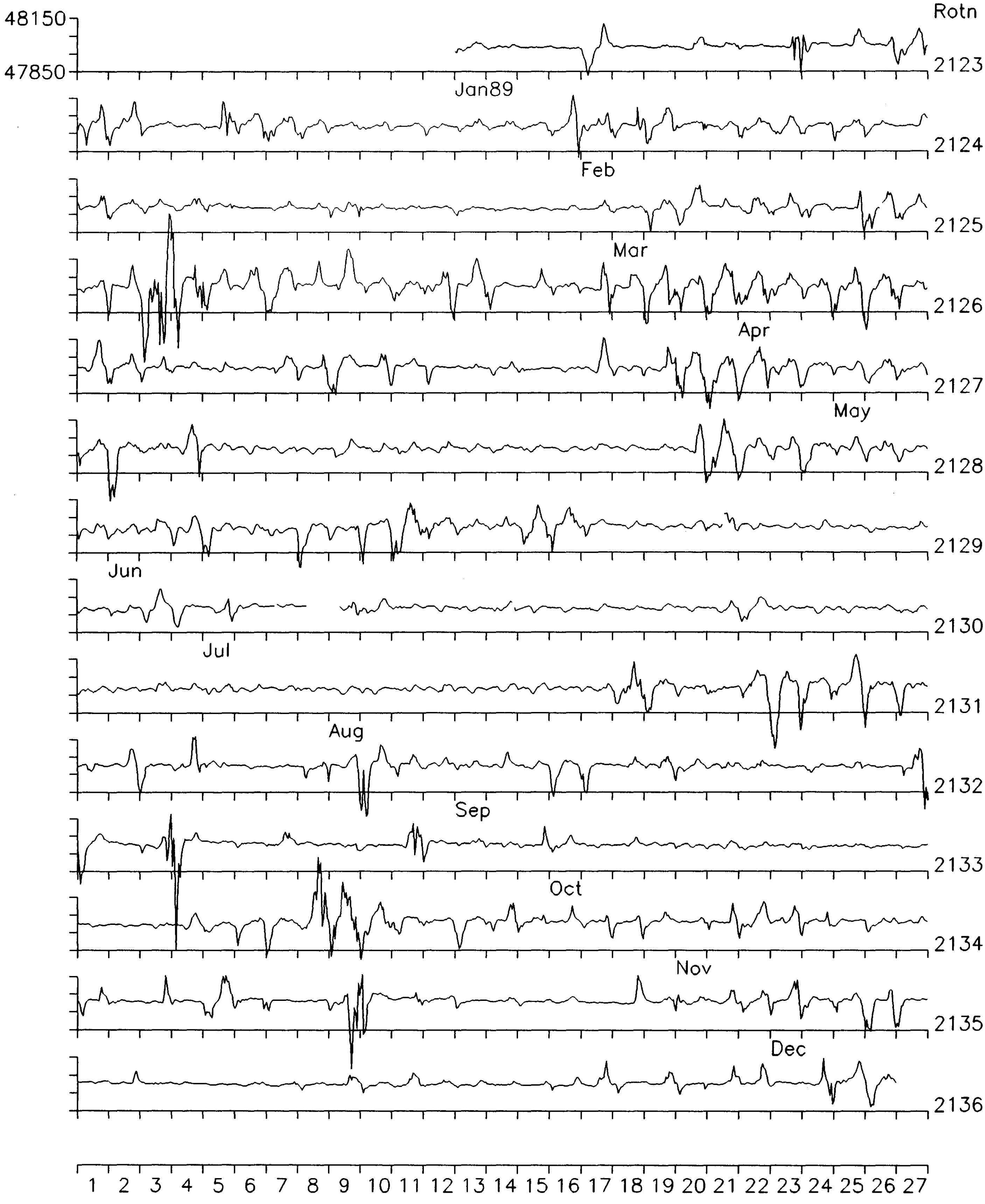
Hourly Mean Values Plotted by Bartels Solar Rotation Number

Lerwick Observatory: Declination (degrees)

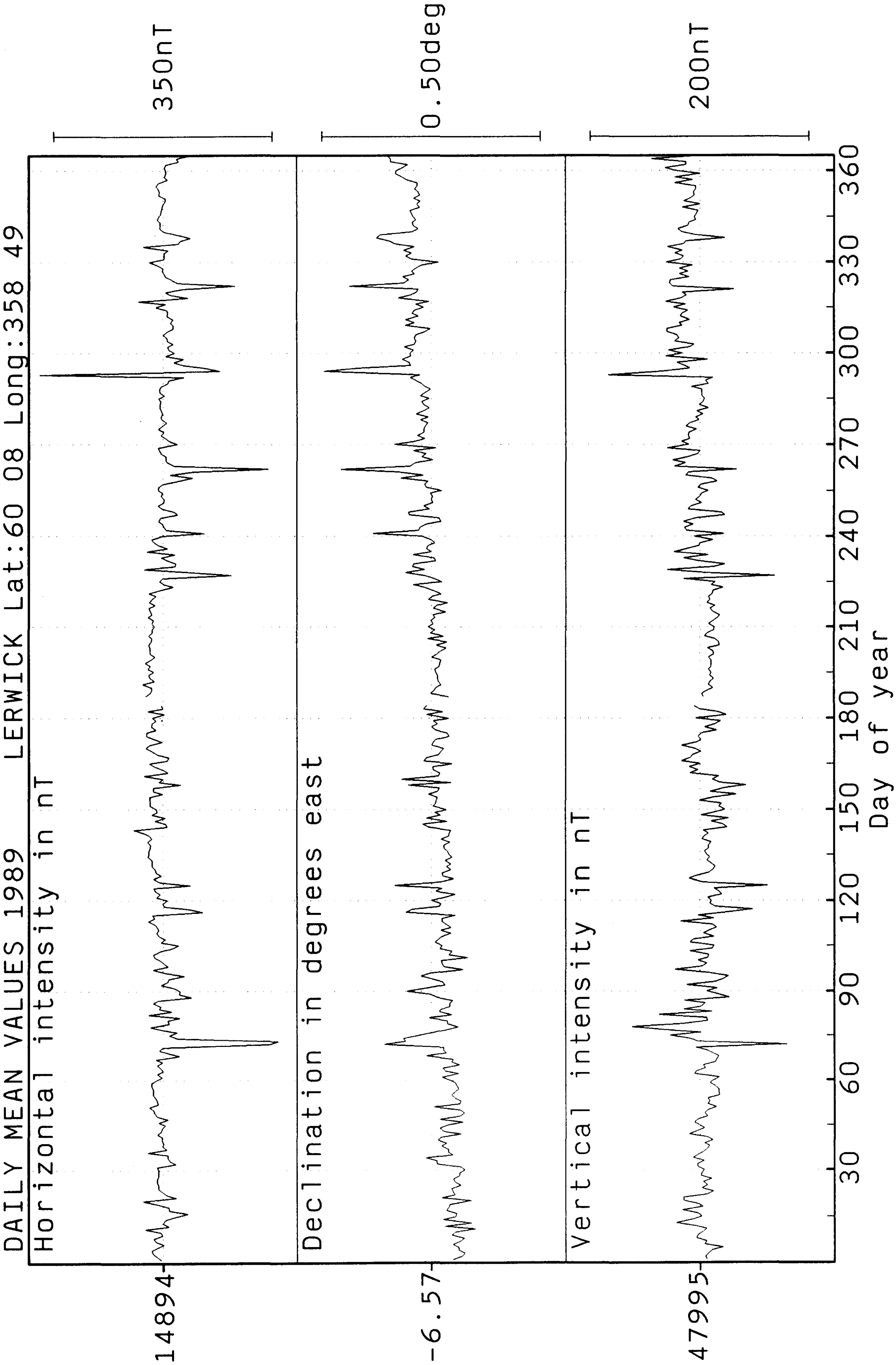


Hourly Mean Values Plotted by Bartels Solar Rotation Number

Lerwick Observatory: Vertical Intensity (nT)



Hourly Mean Values Plotted by Bartels Solar Rotation Number



DAILY MEAN VALUES 1989 LERWICK Lat:60 08 Long:358 49
Horizontal intensity in nT
350nT
14894
Declination in degrees east
0.50deg
-6.57
Vertical intensity in nT
200nT
47995
30
60
90
120
150
180
210
240
270
300
330
360
Day of year

Monthly and annual mean values for Lerwick 1989

Month	D	I	H	X	Y	Z	F
	° ′	° ′	nT	nT	nT	nT	nT
Jan	-6 37.6	72 45.4	14897	14797	-1719	47994	50253
Feb	-6 36.6	72 45.1	14900	14801	-1715	47990	50250
Mar	-6 35.1	72 46.5	14879	14781	-1706	47994	50247
Apr	-6 35.4	72 45.6	14892	14794	-1709	47988	50246
May	-6 35.6	72 44.5	14907	14808	-1712	47984	50246
Jun	-6 34.6	72 44.7	14905	14807	-1707	47989	50250
Jul	-6 34.8	72 44.2	14913	14815	-1709	47986	50250
Aug	-6 33.5	72 45.5	14893	14796	-1701	47989	50247
Sep	-6 32.6	72 46.4	14882	14785	-1696	47999	50253
Oct	-6 31.7	72 46.0	14891	14794	-1693	48004	50261
Nov	-6 31.5	72 46.5	14885	14789	-1691	48012	50266
Dec	-6 30.7	72 46.1	14890	14794	-1689	48006	50262
Annual	-6 34.1	72 45.6	14894	14796	-1704	47995	50253

LERWICK OBSERVATORY K INDICES 1989

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	4221 2233	4413 3136	2211 3211	6543 4454	2111 1333	2212 3333	1111 1563	1100 1212	2111 2200	3211 2211	1011 1123	5321 3475
2	1011 1022	4310 2155	2422 3323	3422 4532	3332 3342	2222 4332	3211 1000	1111 1011	2101 3301	0221 1211	4220 1244	4332 1124
3	0000 1111	5532 3544	3443 6453	4321 3335	3222 1232	3321 3443	0000 1210	1211 1210	1221 1212	0012 3	3233 4342	4233 2234
4	2010 1012	3323 2244	3102 3200	4333 3565	4222 2324	4512 2211	00	0011 4322	5643 3113	1 2212	1133 3334	5522 2256
5	4532 2552	3322 2334	2333 4343	6444 4344	7643 3344	1111 2312	2 3544	0000 1100	5542 2221	2001 2102	5322 1144	5310 1022
6	3211 0011	4232 3333	4222 4433	4211 2233	2222 2233	2210 1123	2211 3331	0000 3322	0112 3332	1012 3212	2112 2232	1100 1011
7	2111 1222	3323 3444	4322 2323	1133 4463	0343 5566	6444 3114	2221 2221	1122 2331	2113 3533	3211 2223	3223 3123	2111 1222
8	0111 3342	3222 2212	1120 0356	4332 2433	1011 2212	3222 2244	0000 2000	1221 1122	3231 2212	2221 2002	2213 2330	0002 2101
9	2222 2223	3322 2233	6533 3434	3221 2442	0010 2201	6422 3345	2211 1011	2101 2232	2102 3332	3221 2112	4421 2433	0000 1000
10	3222 1221	3212 2000	3322 2223	2001 2232	1000 1002	5545 7774	1222 2323	3344 4434	1211 2322	2222 2321	1211 1111	0000 0000
11	1000 3787	0012 2243	2212 2224	1221 4321	0000 1212	4432 3432	1001 1110	6422 3321	0001 0001	2221 1100	2212 2253	0001 2111
12	7521 1122	2201 2254	5222 2343	1110 1111	2232 1321	2322 3221	00 12	3111 3112	1222 2201	0221 2221	3110 1012	2100 1023
13	0001 2343	4322 2323	5787 7999	1132 3222	1111 3321	1122 4433	1221 2211	3311 3221	0121 2224	1000 0000	4432 4765	3200 1210
14	3000 2234	3321 2300	9764 4588	3221 2346	1322 2312	3435 4555	0000 2222	2445 5335	0022 1000	0000 1000	4322 1002	0001 2332
15	4322 3466	0101 0344	6533 4433	6532 3322	1122 2332	5444 5553	0002 3322	8853 5337	1422 4577	0001 1120	3100 0000	3211 1011
16	6443 3355	4412 2112	1345 4545	0000 4435	1211 2321	3321 1200	0100 0000	7522 3333	6532 2223	1112 2221	0001 1012	1112 3333
17	4233 3352	1111 0000	4443 4533	4000 1113	2221 2220	0001 2311	2222 2332	3221 6556	2010 1121	3222 1132	3225 7878	1111 2212
18	4223 2112	0210 3220	0111 3411	3411 0100	1111 2211	1001 2220	3322 3321	6333 3233	4222 2477	4302 2115	7732 1122	2011 1122
19	2211 0012	1011 2213	0355 6542	1001 3221	1112 2211	0211 2122	1010 1000	4411 2230	6884 3231	6433 3222	1011 0242	1110 0110
20	3111 4666	2222 2342	1322 2214	2321 2322	2113 4230	2323 4442	1100 0221	1244 4310	0111 2212	1224 9887	2111 1122	1100 0122
21	5323 3445	2122 1310	3332 3232	2220 1210	1222 3210	1011 2001	1111 1111	1001 4567	2211 2102	8957 7697	41 1000	3200 1222
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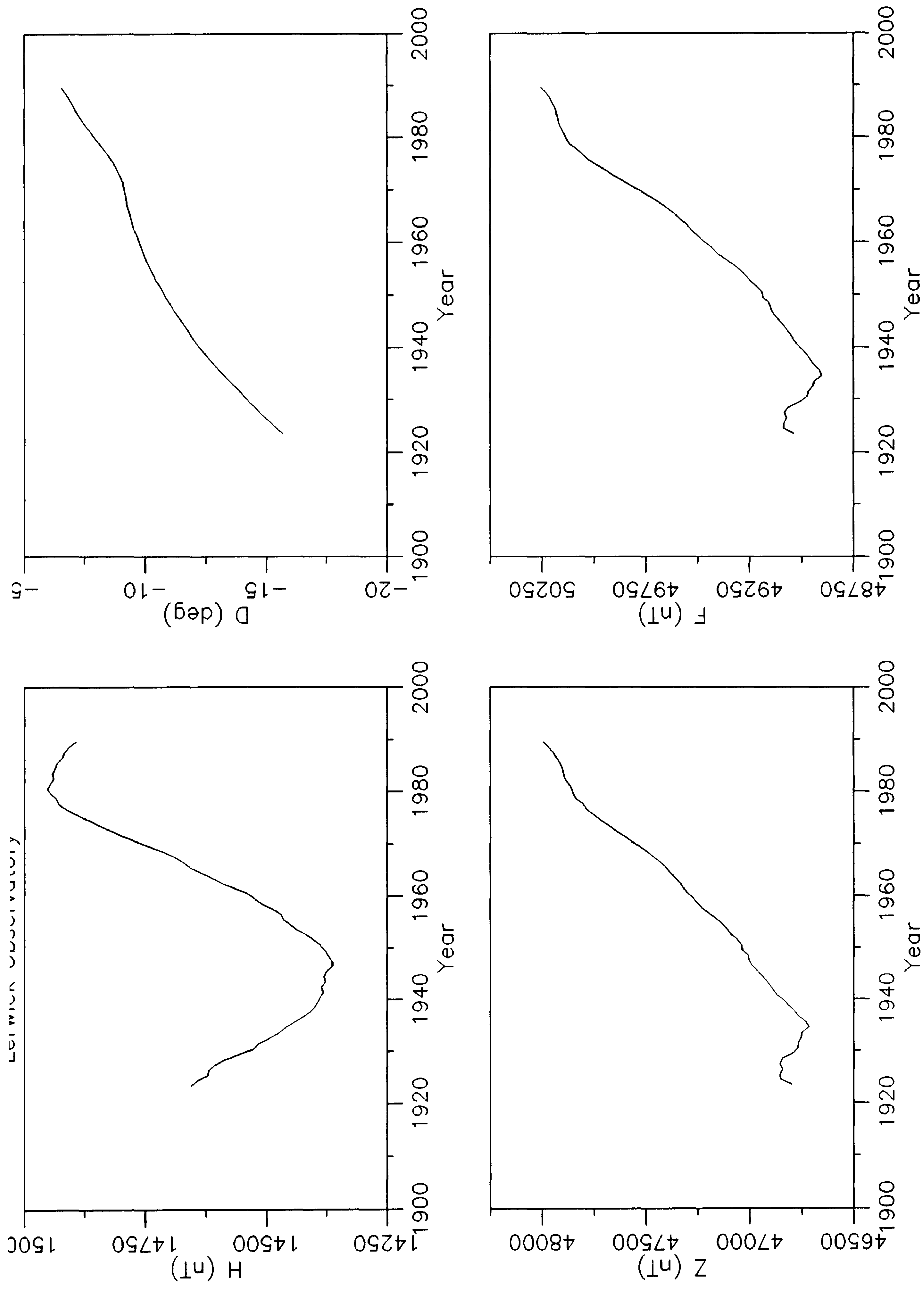
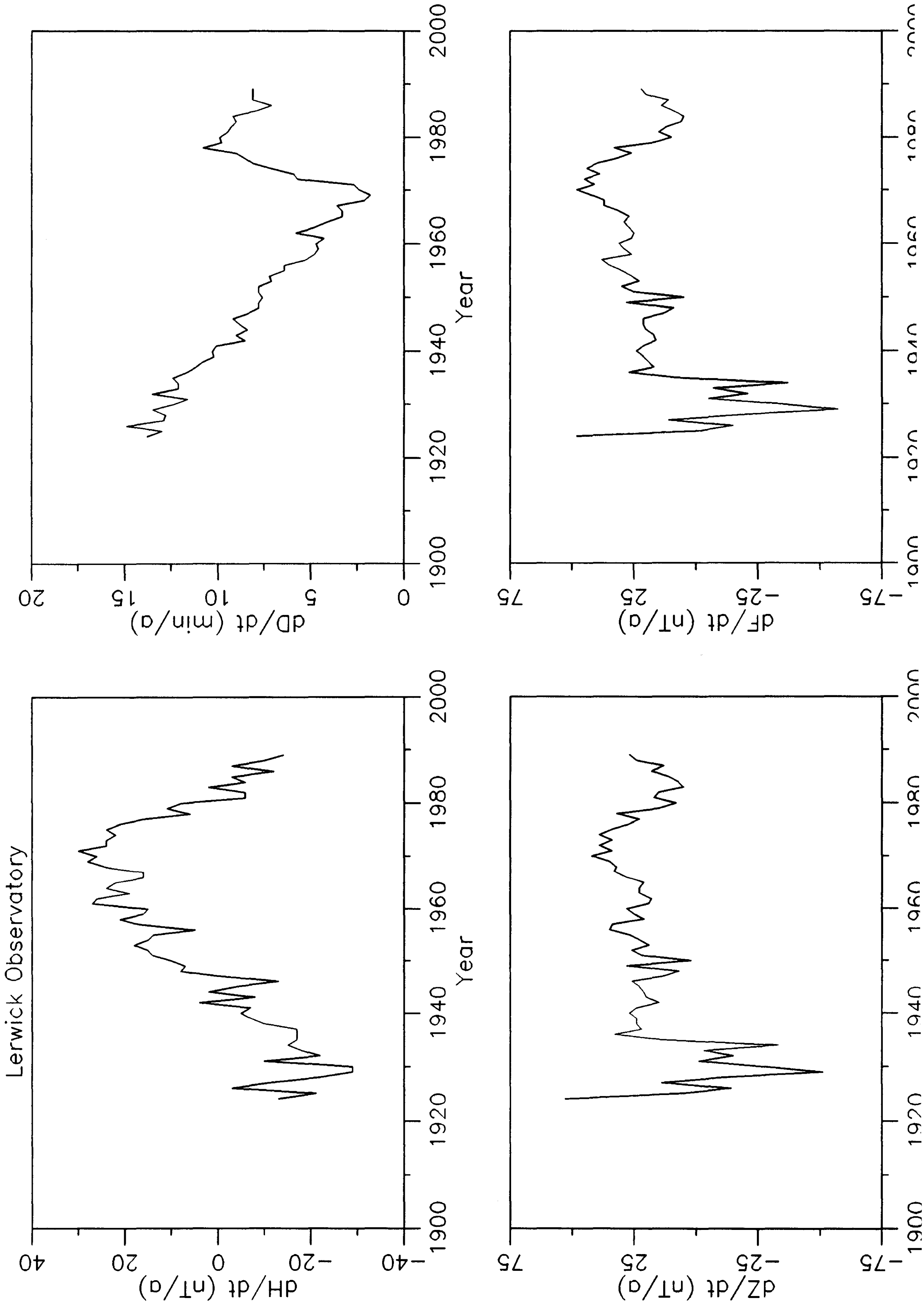
23	3332 2333	0000 1112	4223 5645	2011 2442	1212 4665	1011 2211	2321 3221	2312 5563	1011 0101	3442 2233	2100 1112	0332 2221
24	2111 1232	2222 2000	5531 1210	3111 1213	5454 5556	1113 4211	2122 3222	2110 3211	1001 2113	2231 2223	2111 2212	1112 3444
25	2212 2123	0022 1000	0011 2242	1222 4566	5332 4333	1222 2212	1212 2112	0011 2111	1001 1120	5532 0103	0000 0000	3322 1233
26	2112 2321	0001 1000	2321 3222	8544 3566	3222 4345	0112 2212	2122 3432	0211 2200	0033 4787	1311 3354	0001 1344	2112 2254
27	3322 2200	1000 2211	2132 4546	6643 4567	4432 3322	2111 2112	2211 3212	1322 3353	5211 1110	4312 1133	2112 2235	33 63
28	1311 1241	1121 2233	5234 5423	5433 5355	2212 4433	2112 2211	2311 2233	2001 2247	2101 2233	0111 1332	5333 2222	3210 1013
29	2011 2221		8533 4576	2333 3555	3212 3322	2322 3222	2112 3332	6733 4332	1013 3212	1111 2134	2222 2443	212 3568
30	2211 2222		4542 2346	4322 3331	3211 1233	2421 2112	1211 2222	1322 3532	3211 1242	4322 2134	4312 2244	5332 3445
31	3221 2567		6633 4556		3121 3332		2110 1102	2100 2312		4211 2331		4543 3222

LERWICK

Year	D	I	H	X	Y	Z	F
1923	−15 40.3	72 33.7	14655	14111	−3959	46655	48902
1924	−15 26.5	72 35.7	14642	14113	−3899	46708	48950
1925	−15 13.5	72 37.2	14621	14108	−3840	46713	48948
1926	−14 58.6	72 37.1	14618	14121	−3778	46699	48933
1927	−14 45.7	72 38.1	14607	14125	−3722	46713	48944
1928	−14 32.9	72 39.4	14585	14117	−3664	46702	48926
1929	−14 19.4	72 40.3	14556	14104	−3601	46651	48869
1930	−14 7.0	72 41.6	14527	14088	−3543	46624	48835
1931	−13 55.4	72 42.3	14517	14090	−3493	46623	48830
1932	−13 41.9	72 43.5	14495	14083	−3433	46608	48809
1933	−13 29.8	72 44.6	14477	14077	−3379	46605	48802
1934	−13 17.7	72 48.0	14462	14074	−3326	46716	48903
1935	−13 5.3	72 49.4	14445	14070	−3271	46730	48911
1936	−12 53.6	72 51.2	14428	14064	−3220	46763	48938
1937	−12 42.4	72 52.8	14411	14058	−3170	46785	48955
1938	−12 31.6	72 53.9	14401	14059	−3124	46809	48973
1939	−12 21.4	72 54.9	14394	14061	−3080	46833	48995
1940	−12 11.1	72 55.8	14389	14065	−3037	46960	49018
1941	−12 1.0	72 56.8	14382	14067	−2994	46884	49040
1942	−11 52.5	72 56.8	14386	14078	−2960	46899	49056
1943	−11 43.5	72 57.8	14378	14078	−2922	46919	49073
1944	−11 35.1	72 58.1	14380	14087	−2888	46940	49093
1945	−11 26.3	72 58.8	14376	14090	−2851	46963	49114
1946	−11 17.1	73 0.2	14363	14085	−2811	46989	49135
1947	−11 8.7	73 0.5	14363	14092	−2776	47002	49148
1948	−11 0.9	73 0.1	14371	14106	−2746	47009	49157
1949	−10 53.1	73 0.2	14378	14119	−2715	47037	49185
1950	−10 45.5	72 59.5	14388	14135	−2686	47039	49190
1951	−10 37.7	72 59.1	14402	14155	−2656	47061	49215
1952	−10 29.9	72 58.6	14417	14176	−2627	47087	49245
1953	−10 22.8	72 57.8	14435	14199	−2601	47106	49268
1954	−10 15.6	72 57.3	14450	14219	−2574	47129	49294
1955	−10 9.2	72 56.9	14464	14237	−2550	47156	49324
1956	−10 2.8	72 57.3	14469	14247	−2524	47191	49359
1957	−9 57.5	72 56.8	14486	14268	−2505	47225	49397
1958	−9 52.7	72 55.8	14507	14292	−2489	47246	49423
1959	−9 48.1	72 55.3	14523	14311	−2472	47271	49452
1960	−9 43.4	72 54.9	14538	14329	−2455	47299	49483
1961	−9 39.1	72 53.5	14565	14359	−2442	47318	49509
1962	−9 33.3	72 52.1	14591	14389	−2422	47336	49534
1963	−9 28.5	72 51.3	14610	14411	−2405	47359	49561
1964	−9 24.4	72 50.2	14634	14437	−2392	47382	49590
1965	−9 21.1	72 49.2	14656	14461	−2382	47403	49617
1966	−9 17.8	72 48.7	14672	14479	−2370	47431	49648
1967	−9 14.2	72 48.3	14688	14498	−2358	47464	49685
1968	−9 12.1	72 47.4	14712	14523	−2353	47496	49722
1969	−9 10.3	72 46.2	14740	14552	−2349	47531	49764
1970	−9 7.9	72 45.4	14766	14579	−2343	47573	49812
1971	−9 5.2	72 44.1	14796	14610	−2337	47607	49853
1972	−8 59.5	72 43.3	14820	14638	−2316	47646	49898
1973	−8 53.6	72 42.4	14844	14666	−2295	47680	49937
1974	−8 46.5	72 41.8	14866	14692	−2268	47719	49981
1975	−8 38.4	72 40.9	14890	14721	−2237	47753	50021
1976	−8 29.9	72 40.1	14911	14747	−2204	47780	50053
1977	−8 20.9	72 39.5	14927	14769	−2167	47803	50079
1978	−8 10.1	72 39.8	14933	14782	−2122	47835	50112
1979	−8 0.3	72 39.3	14944	14798	−2081	47850	50129
1980	−7 50.4	72 39.0	14952	14812	−2039	47858	50139
1981	−7 40.9	72 39.7	14946	14812	−1998	47875	50154
1982	−7 31.6	72 40.4	14940	14812	−1957	47890	50166
1983	−7 22.6	72 40.4	14942	14818	−1918	47895	50172
1984	−7 13.4	72 40.9	14936	14818	−1878	47902	50177
1985	−7 5.5	72 41.3	14933	14819	−1844	47913	50186
1986	−6 58.4	72 42.5	14921	14811	−1811	47931	50200
1987	−6 50.3	72 43.0	14918	14812	−1776	47944	50211
1988	−6 42.2	72 44.1	14908	14806	−1740	47968	50231
1989	−6 34.1	72 45.6	14894	14796	−1704	47995	50253



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



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

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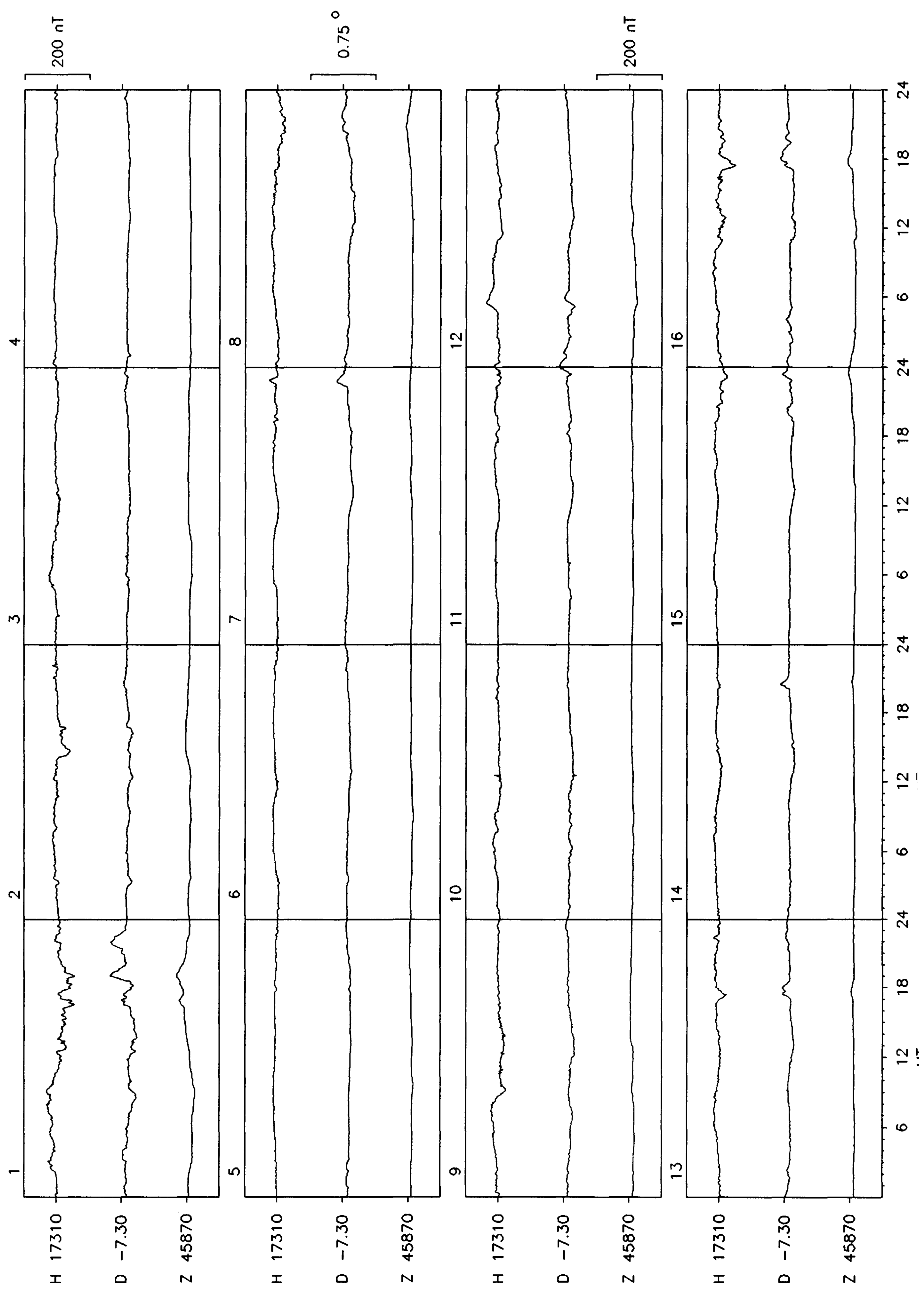
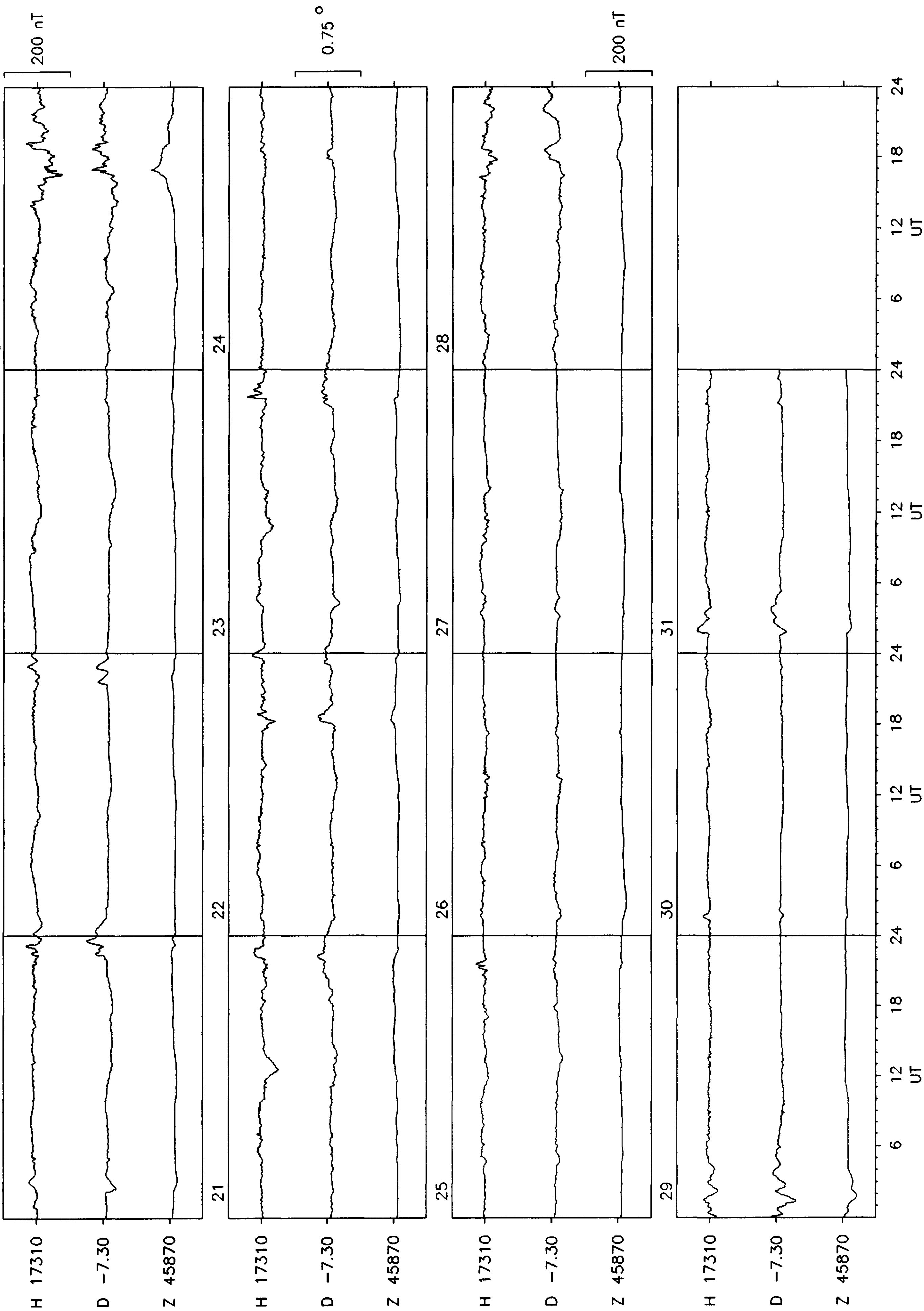


H 17310
D −7.30
Z 45870
200 nT
0.75 °
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
6 12 18 24



H 17310
D −7.30
Z 45870
200 nT
0.75 °
200 nT
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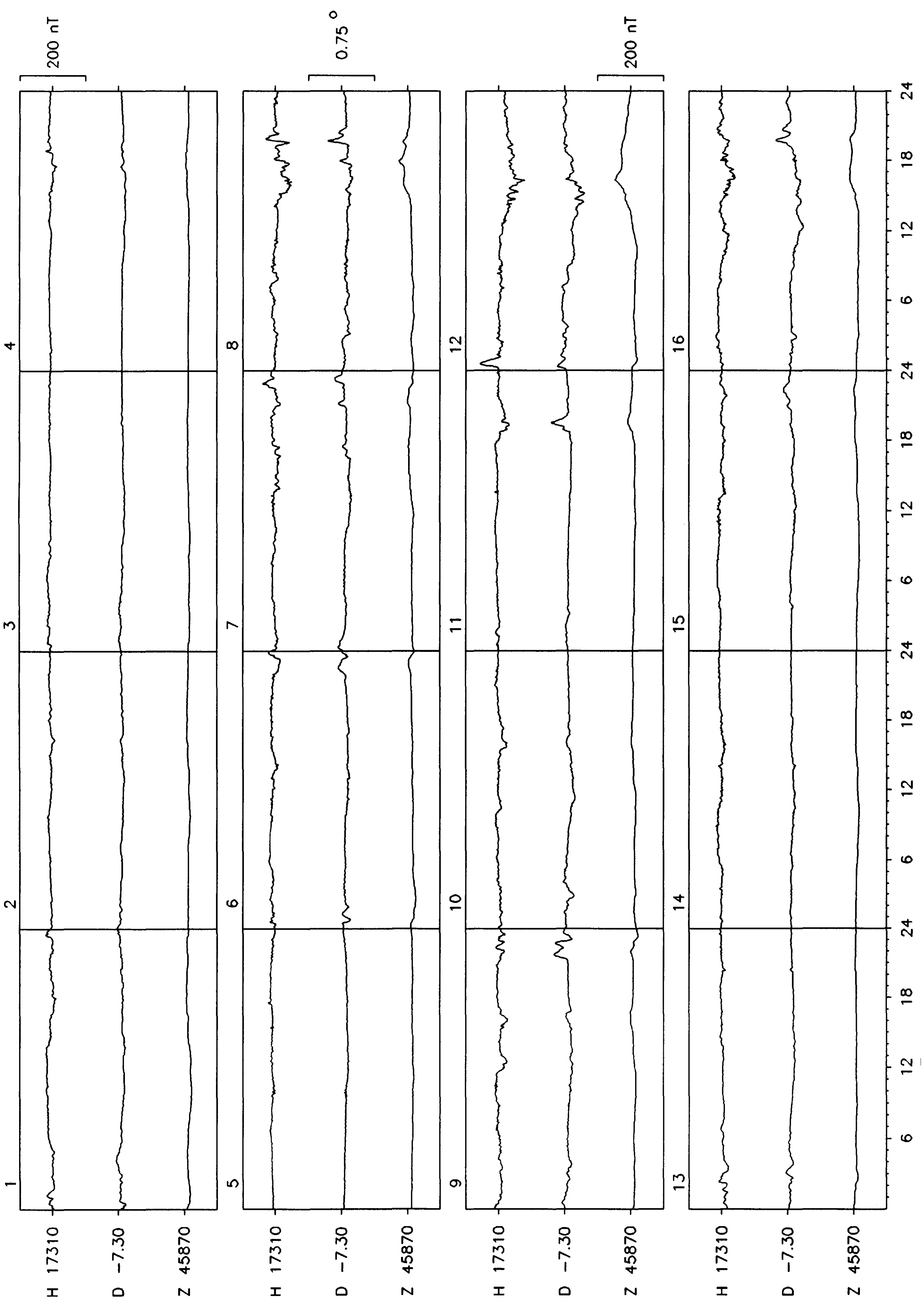
UT


200 nT
0.75 °
200 nT
H 17310
D −7.30
Z 45870
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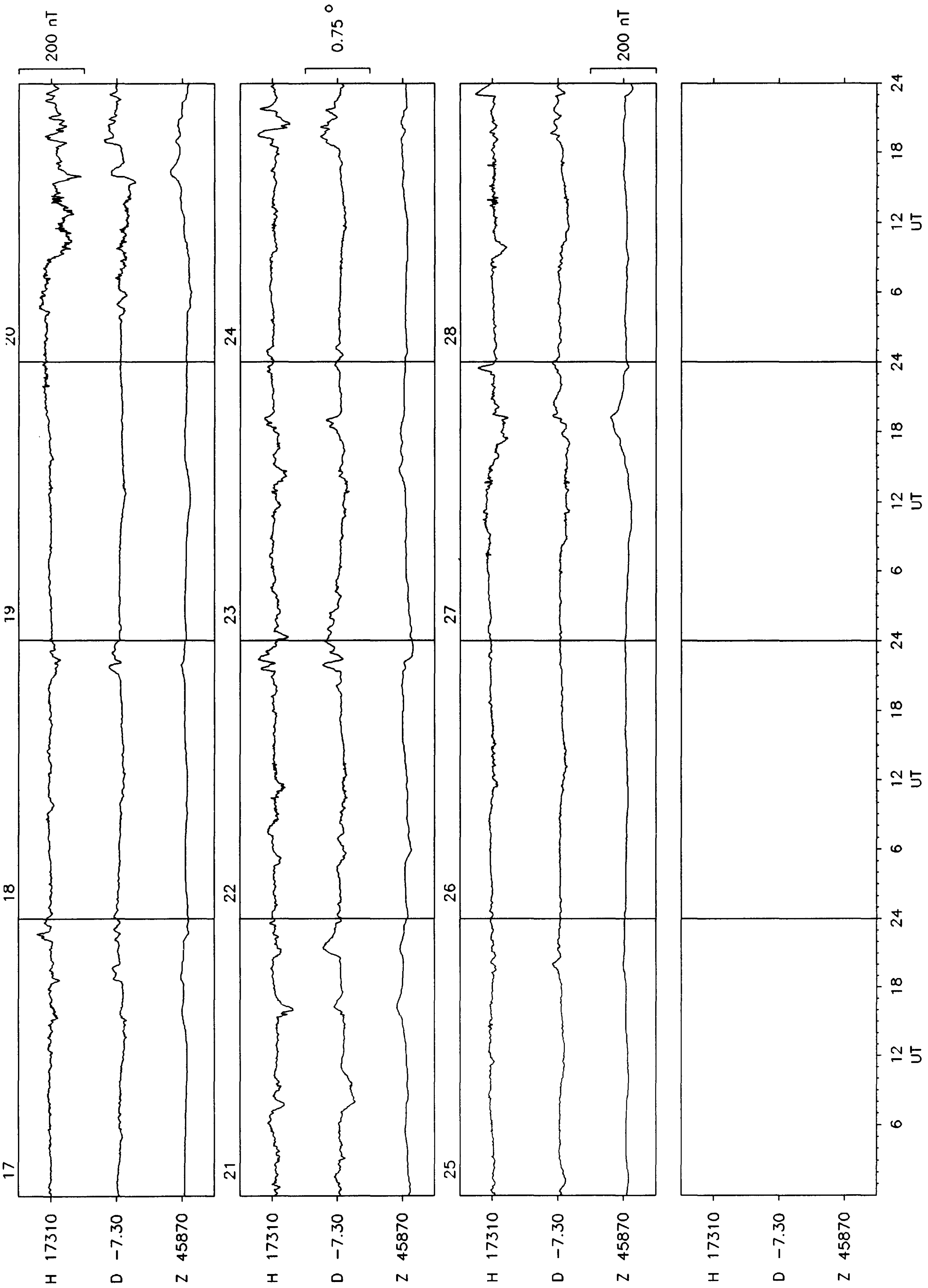

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200 nT
0.75 °
200 nT
H 17310
D −7.30
Z 45870
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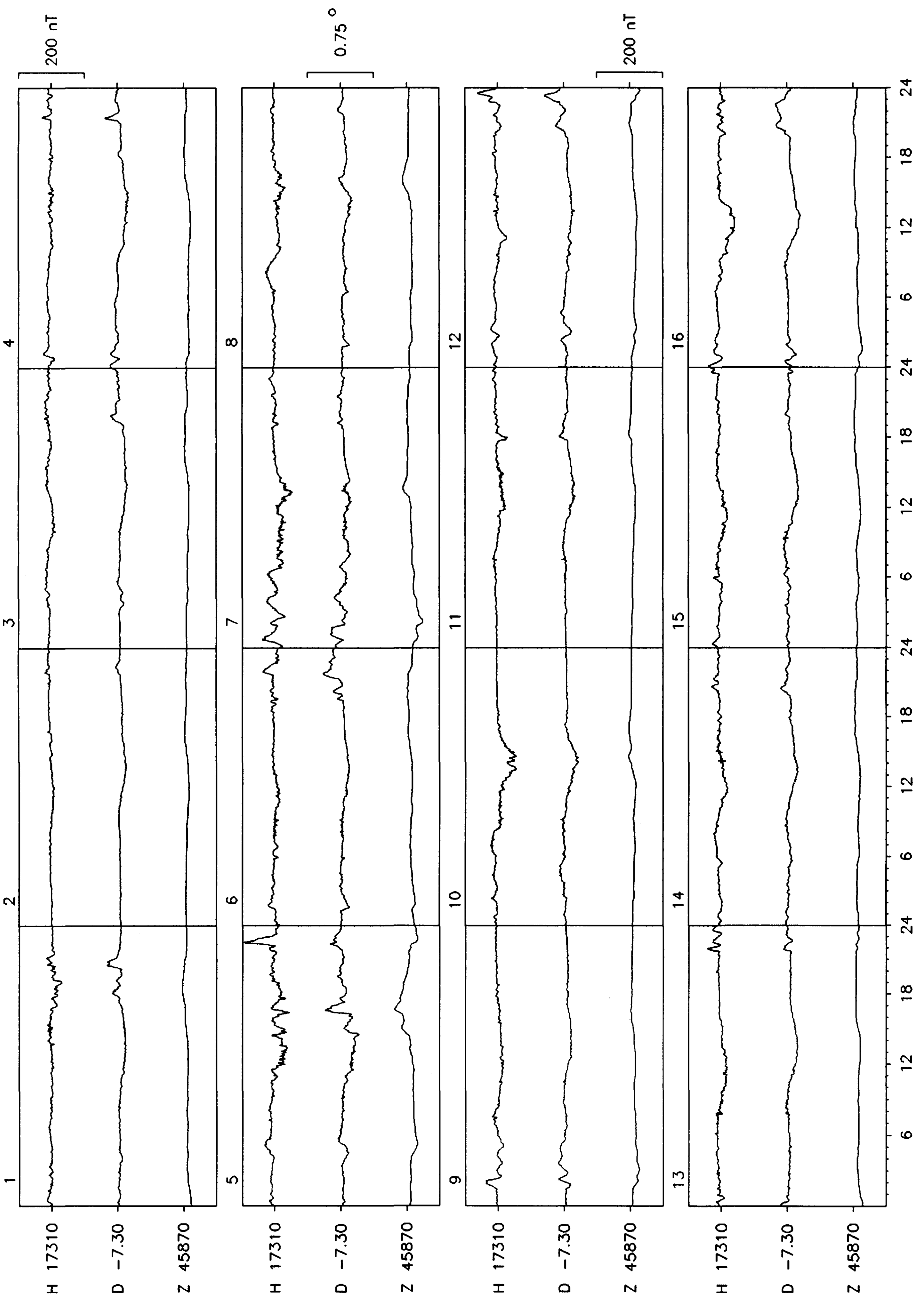
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0.75 °
200 nT
H 17310
D −7.30
Z 45870
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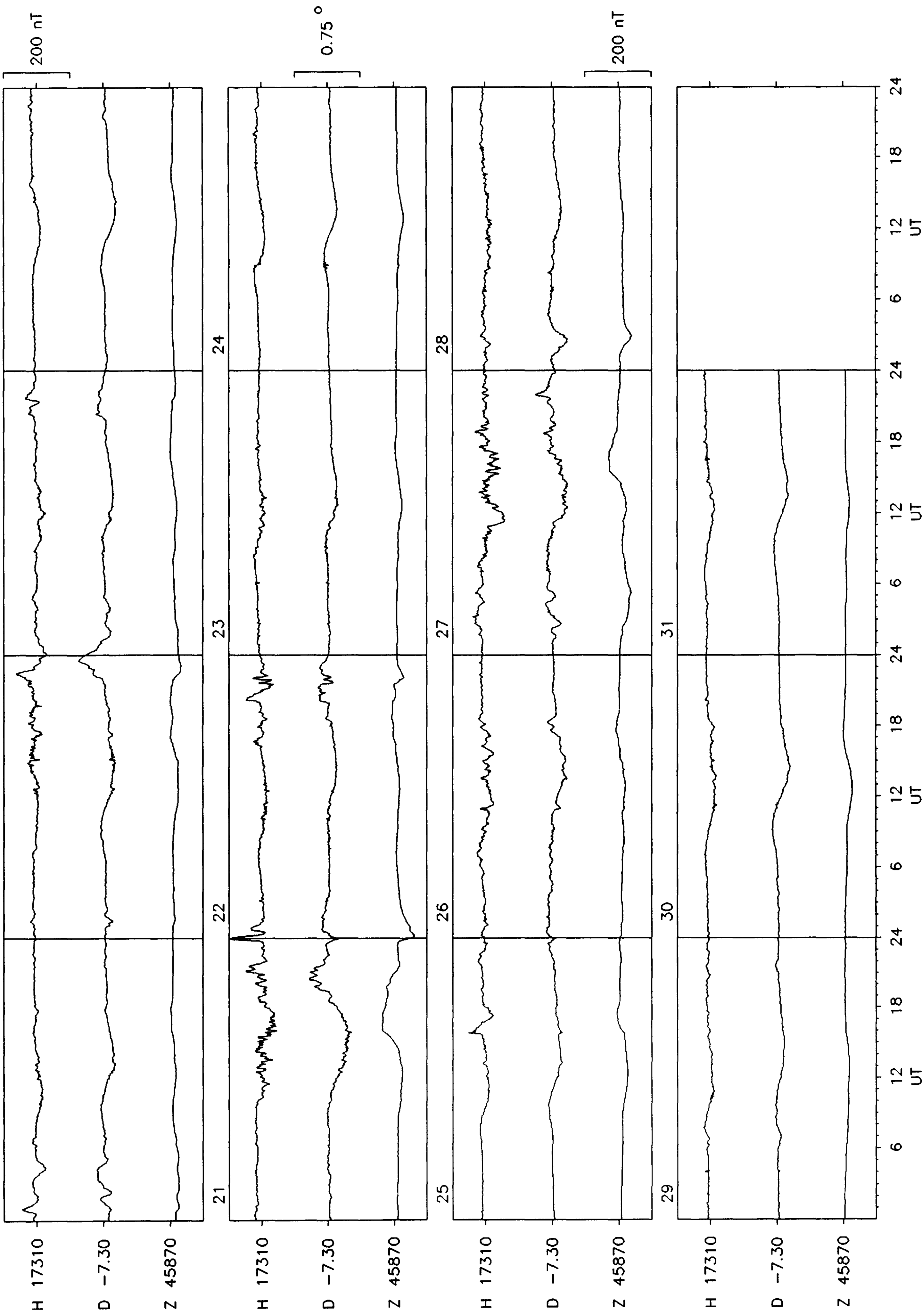
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0.75 °
200 nT
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H 17310
D −7.30
Z 45870
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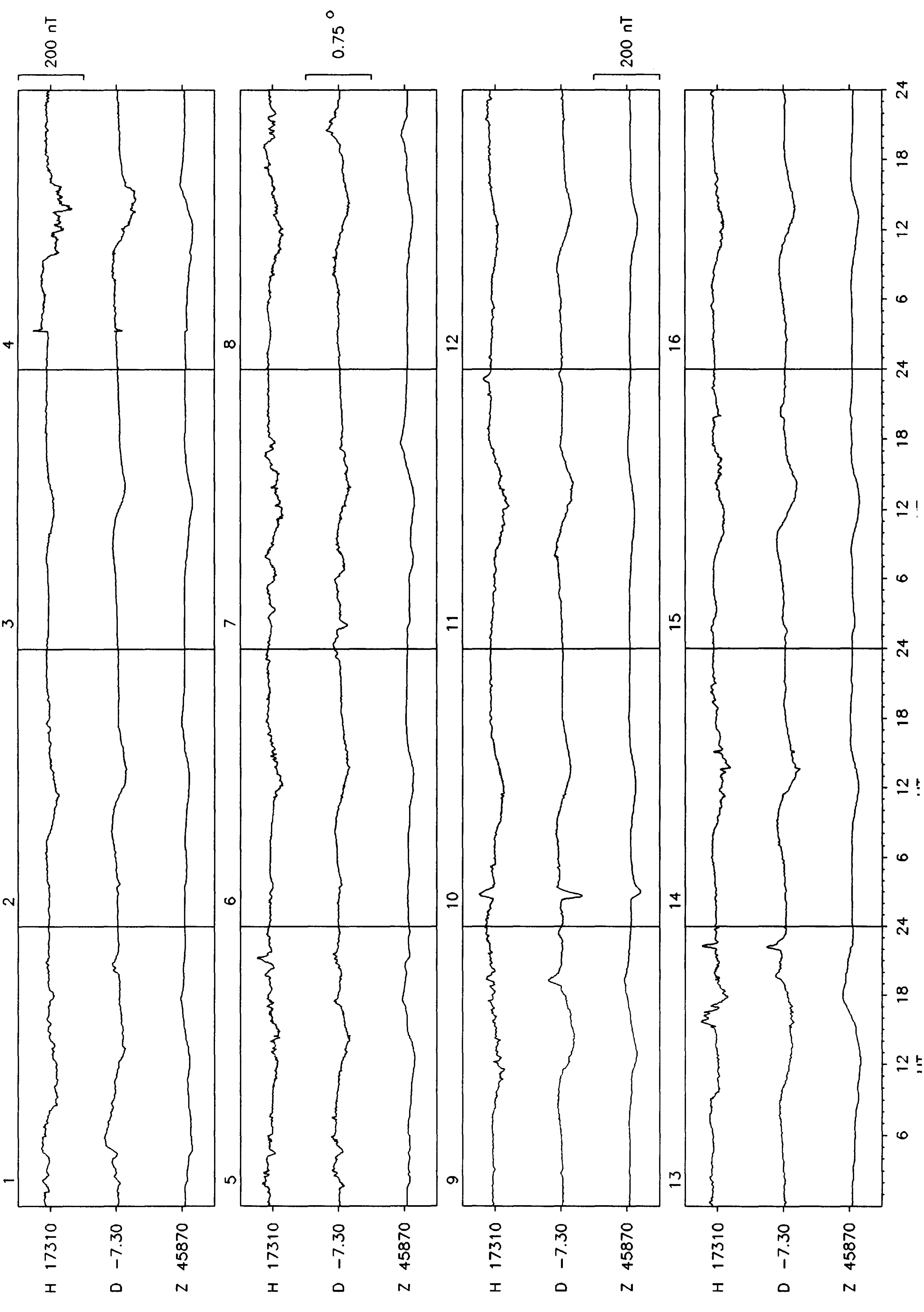
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200 nT
H 17310
D -7.30
Z 45870
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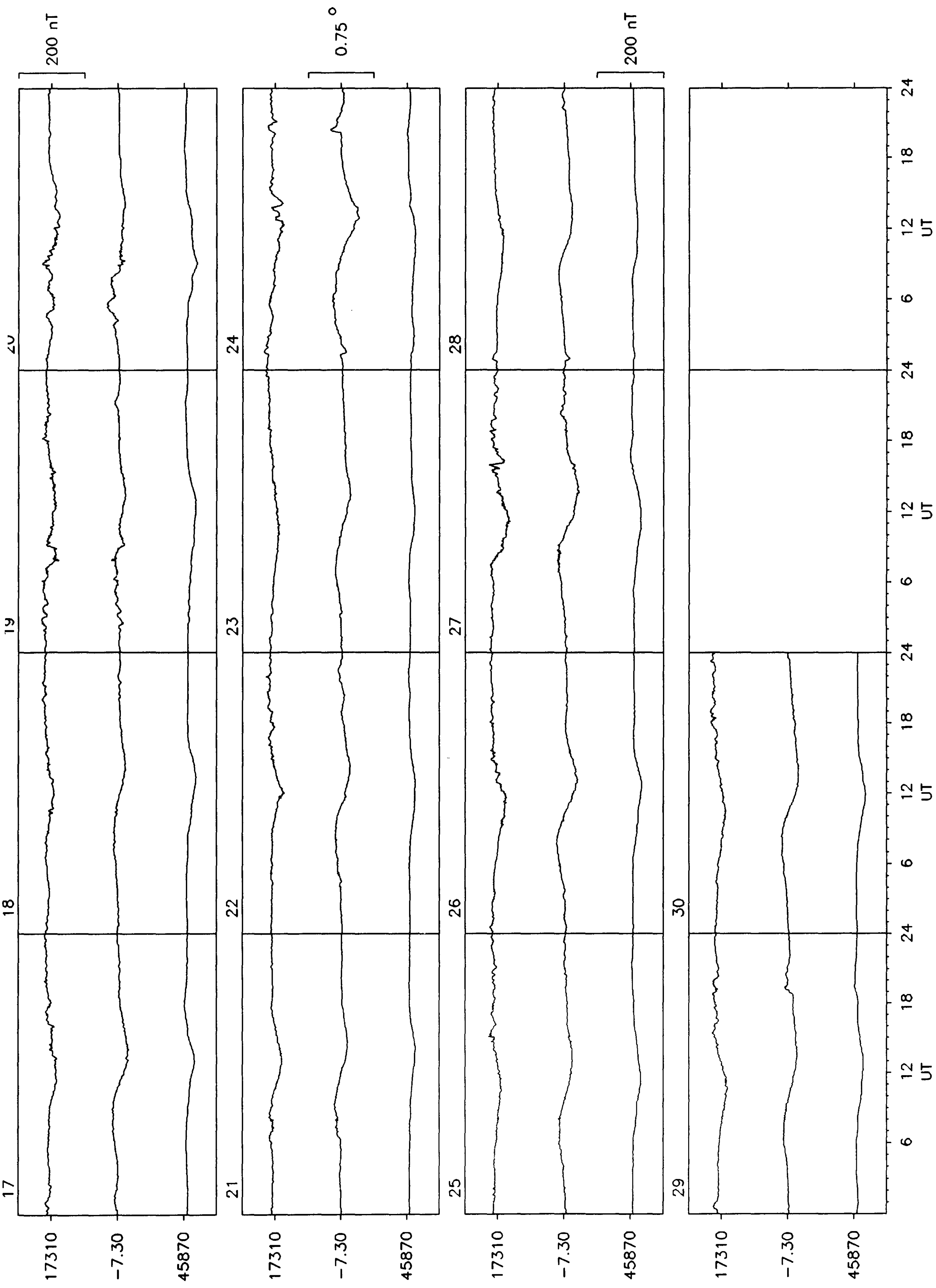
200 nT
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H 17310
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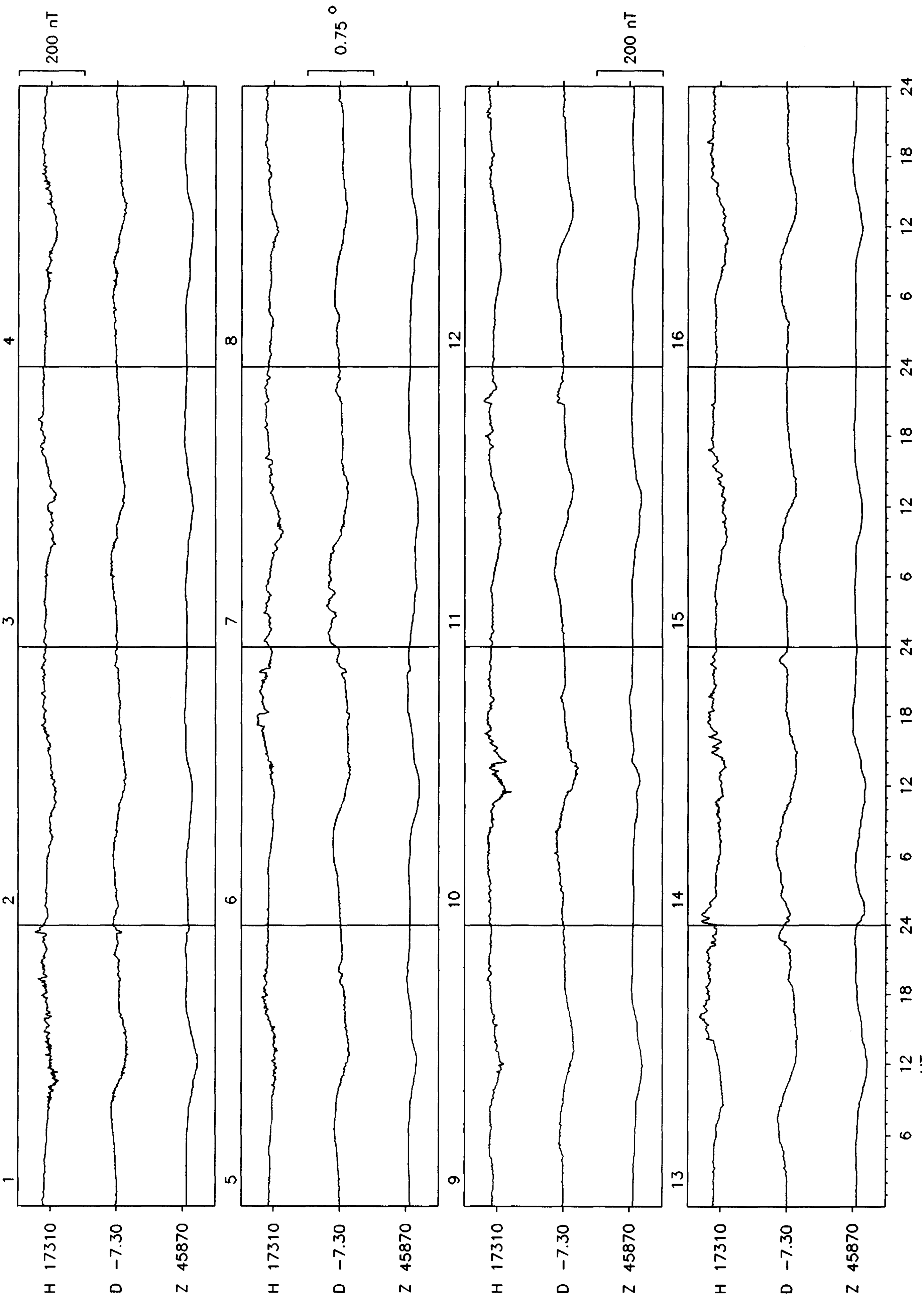
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200 nT
H 17310
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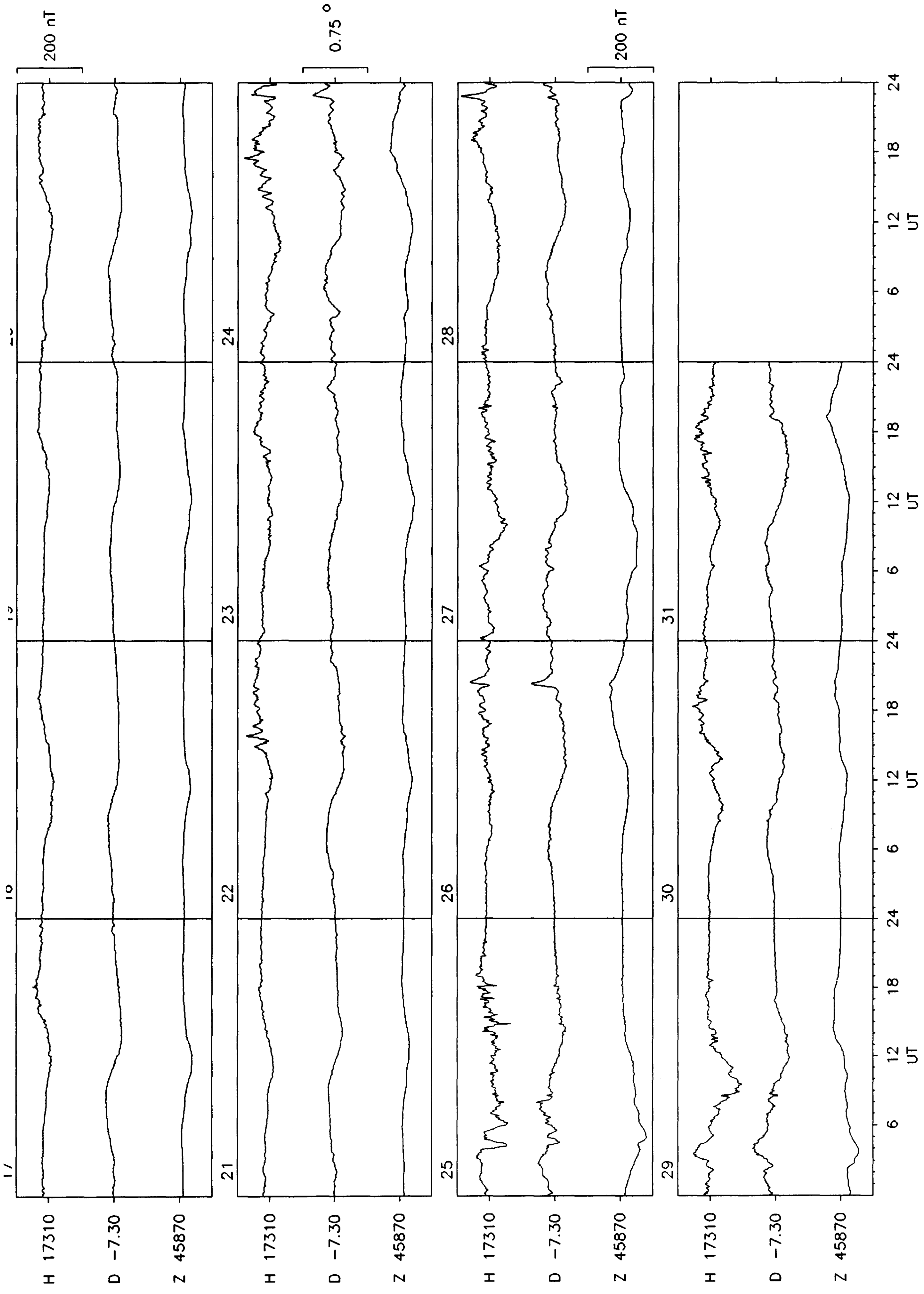
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0.75 °
200 nT
H 17310
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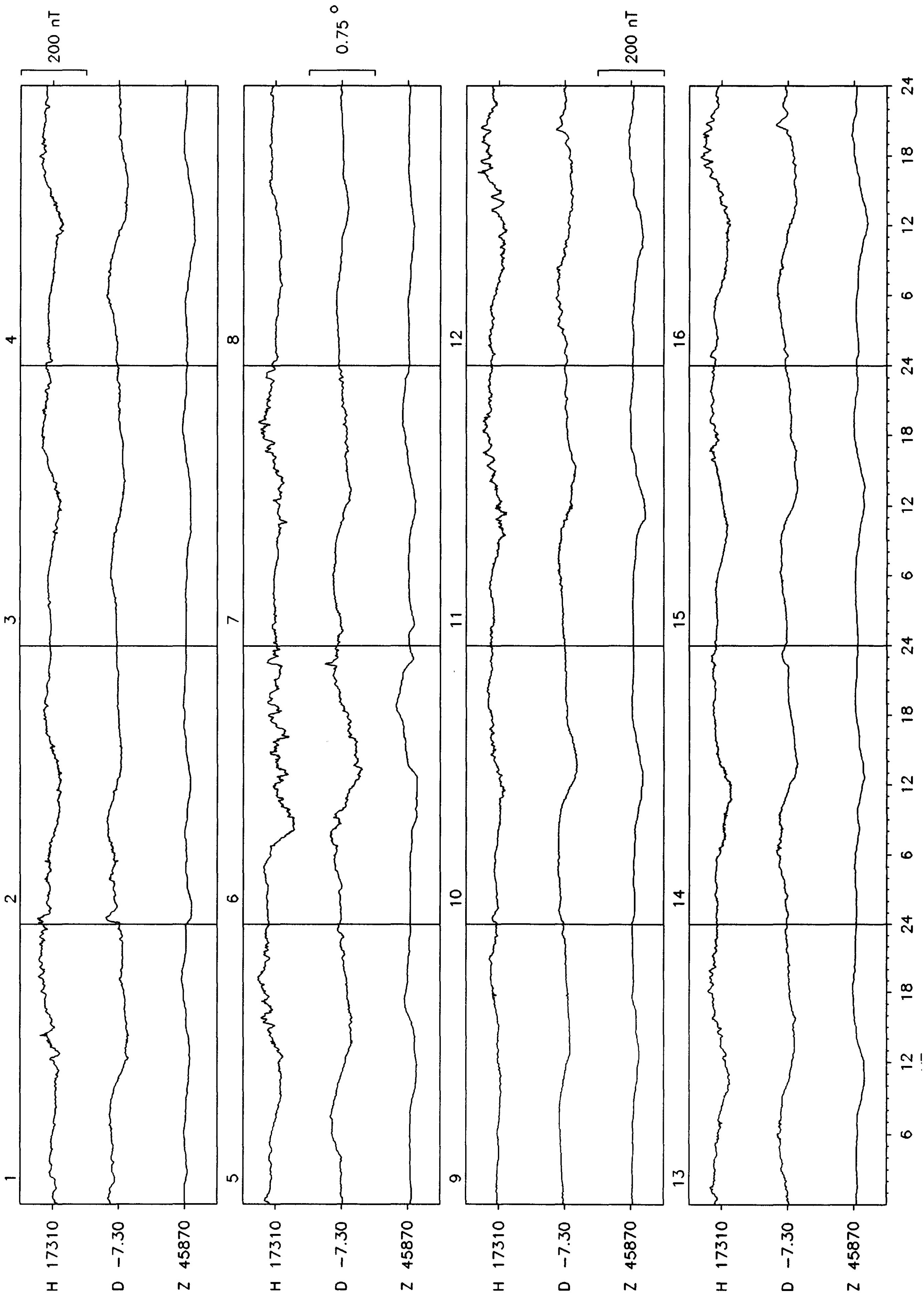
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200 nT
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D −7.30
Z 45870
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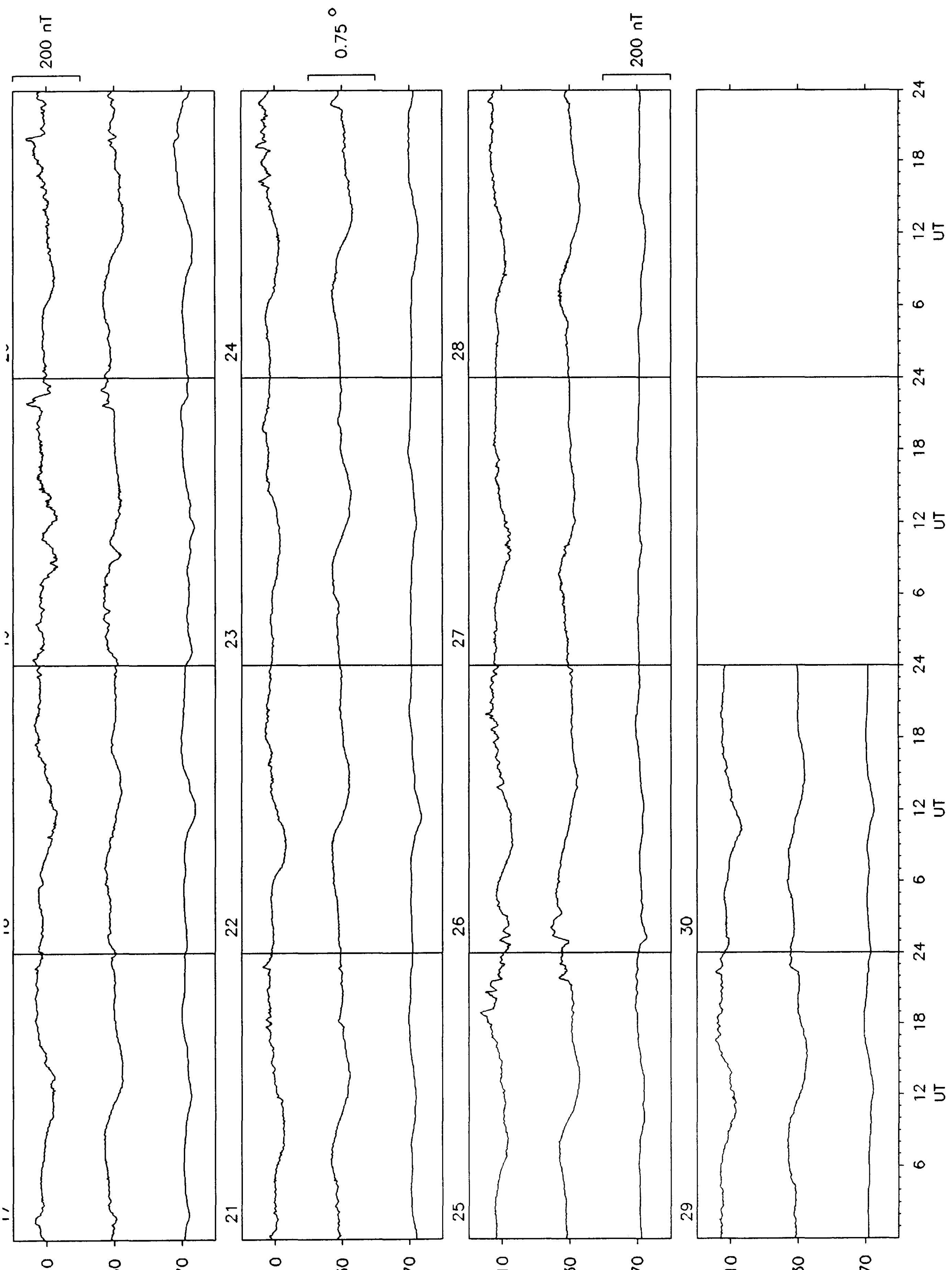
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0.75 °
200 nT
H 17310
D −7.30
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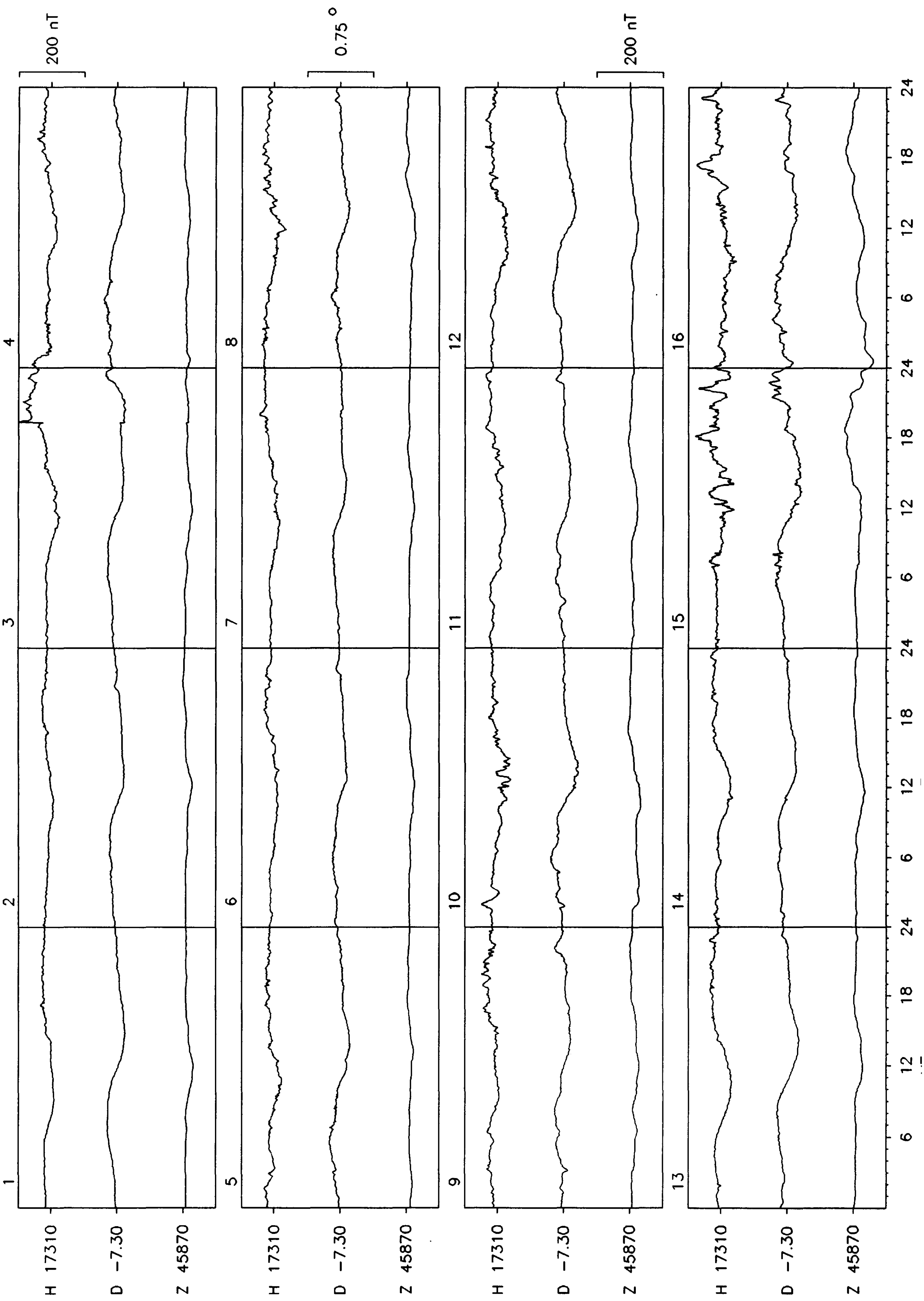
200 nT
0.75 °
200 nT
H 17310
D −7.30
Z 45870
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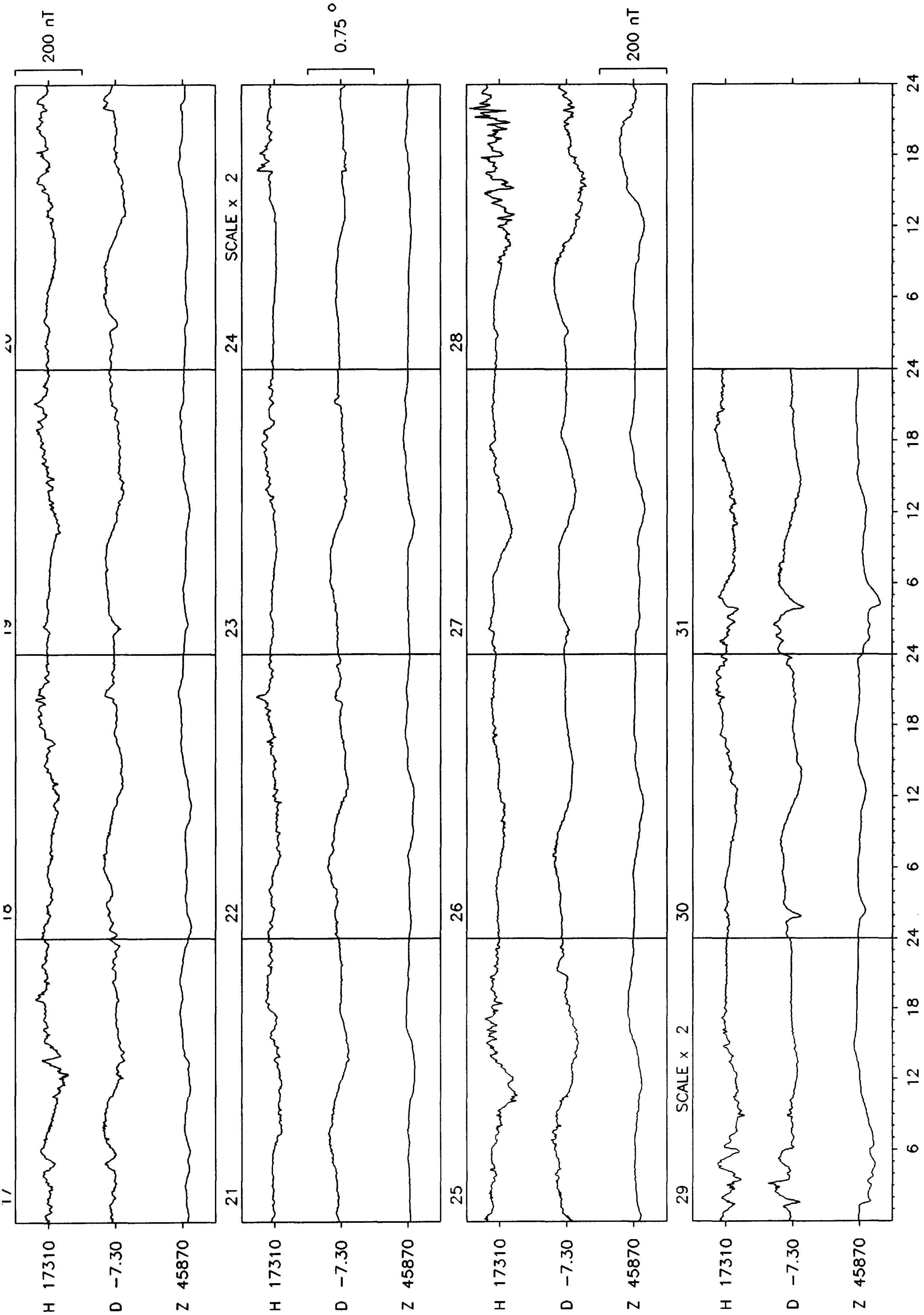
200 nT
0.75 °
200 nT
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SCALE x 2
H 17310
D −7.30
Z 45870
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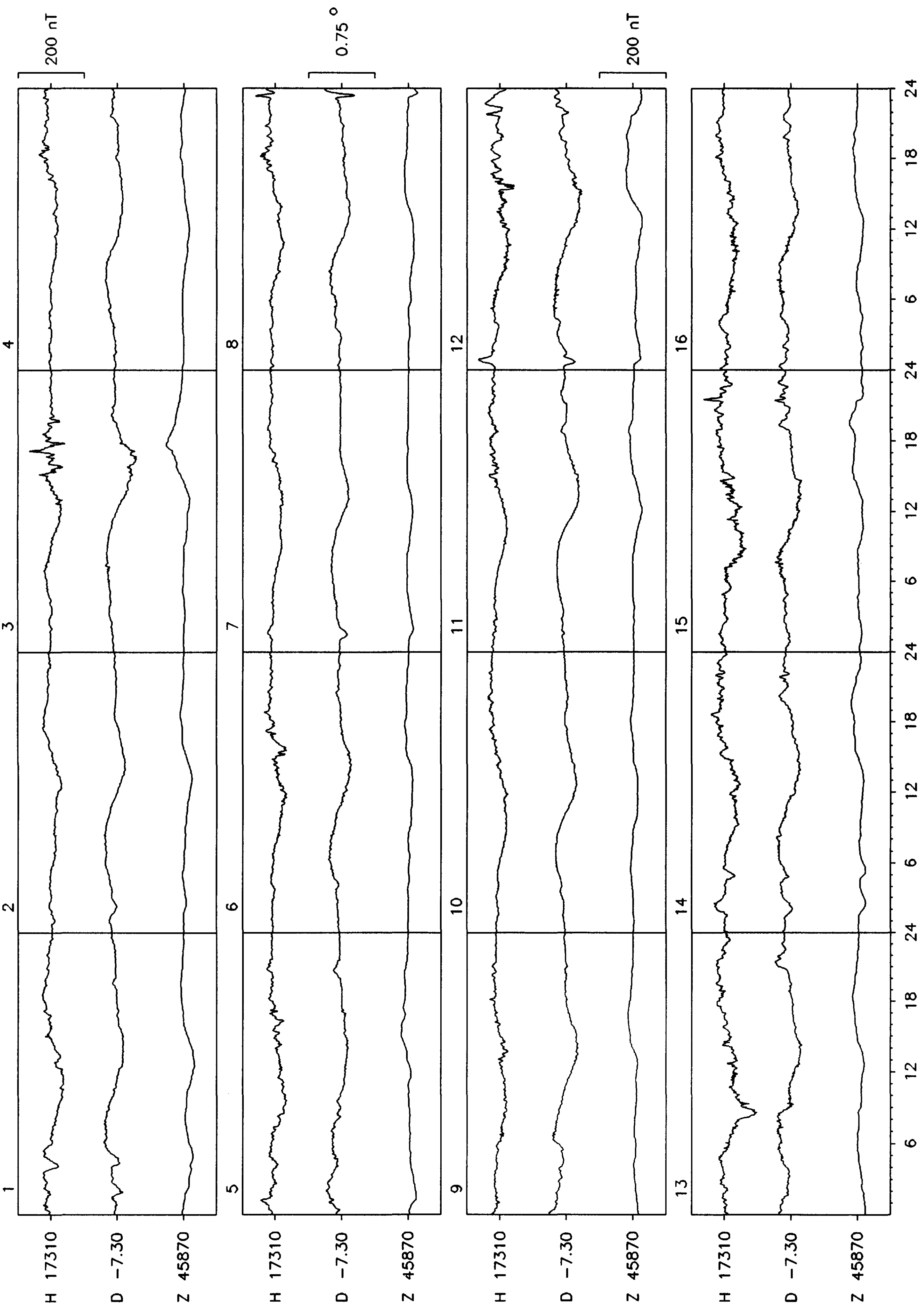
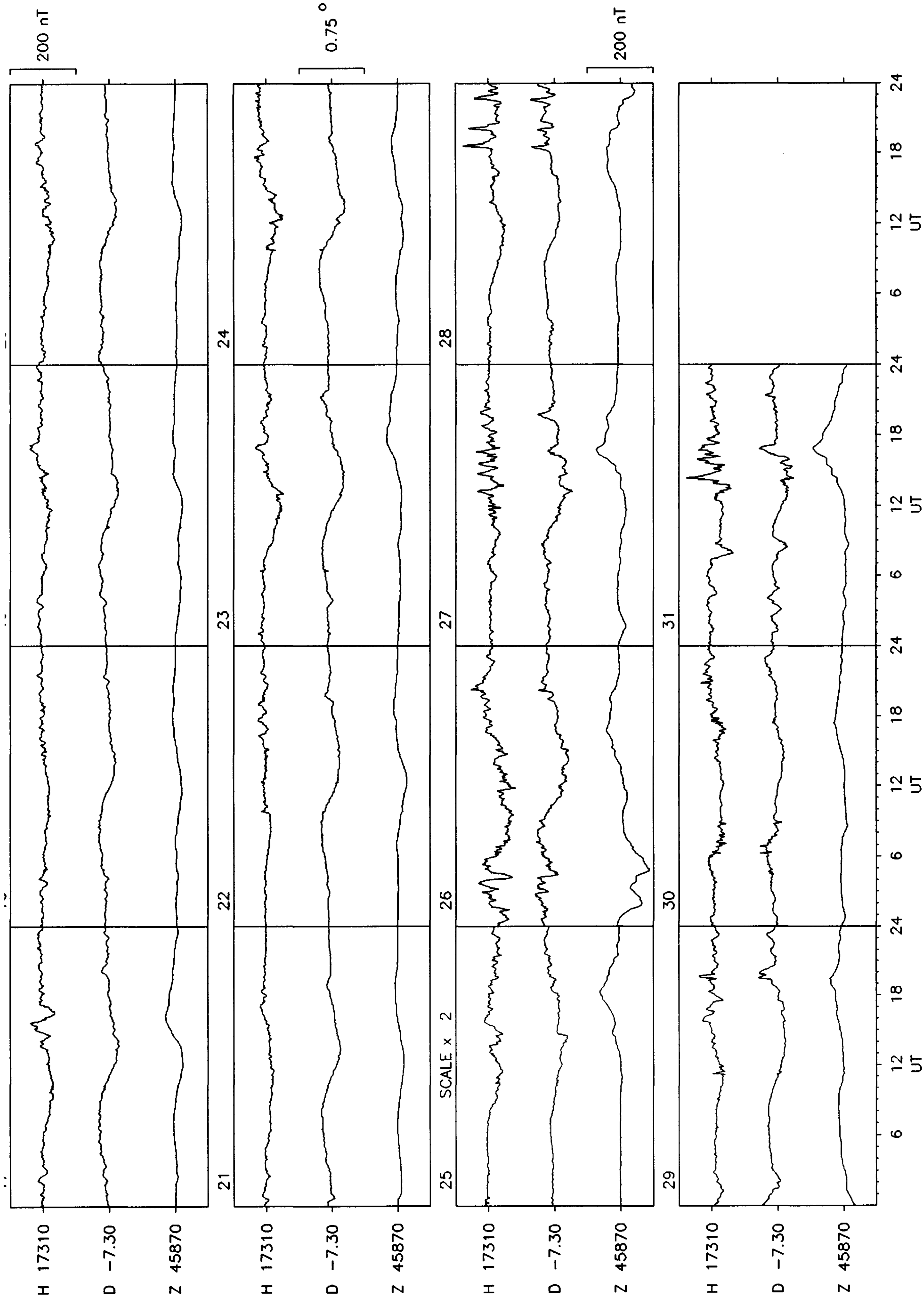

200 nT
0.75 °
H 17310
D -7.30
Z 45870
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
6 12 18 24


200 nT
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200 nT
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D −7.30
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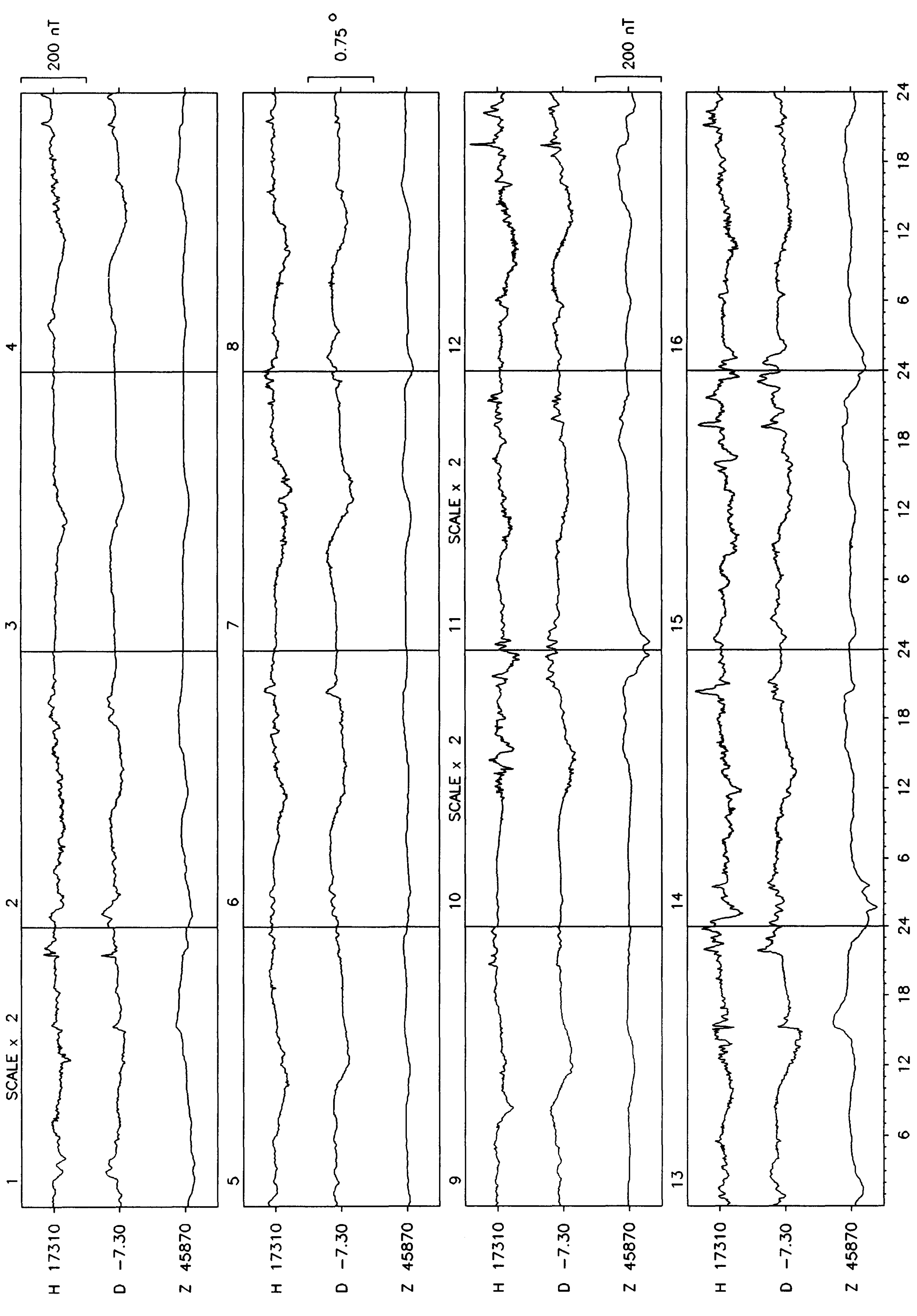
200 nT
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200 nT
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SCALE x 2
SCALE x 2
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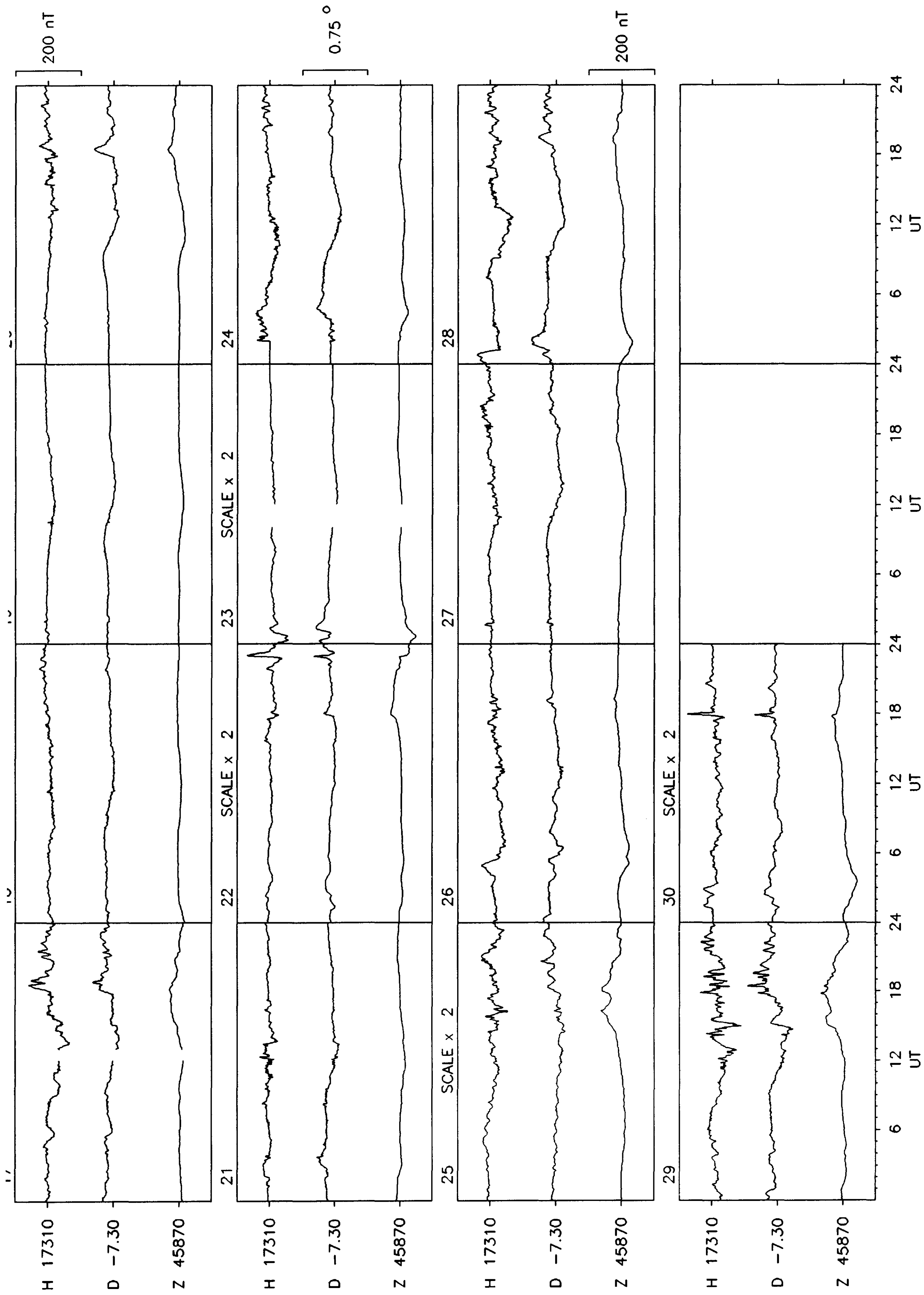
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D −7.30
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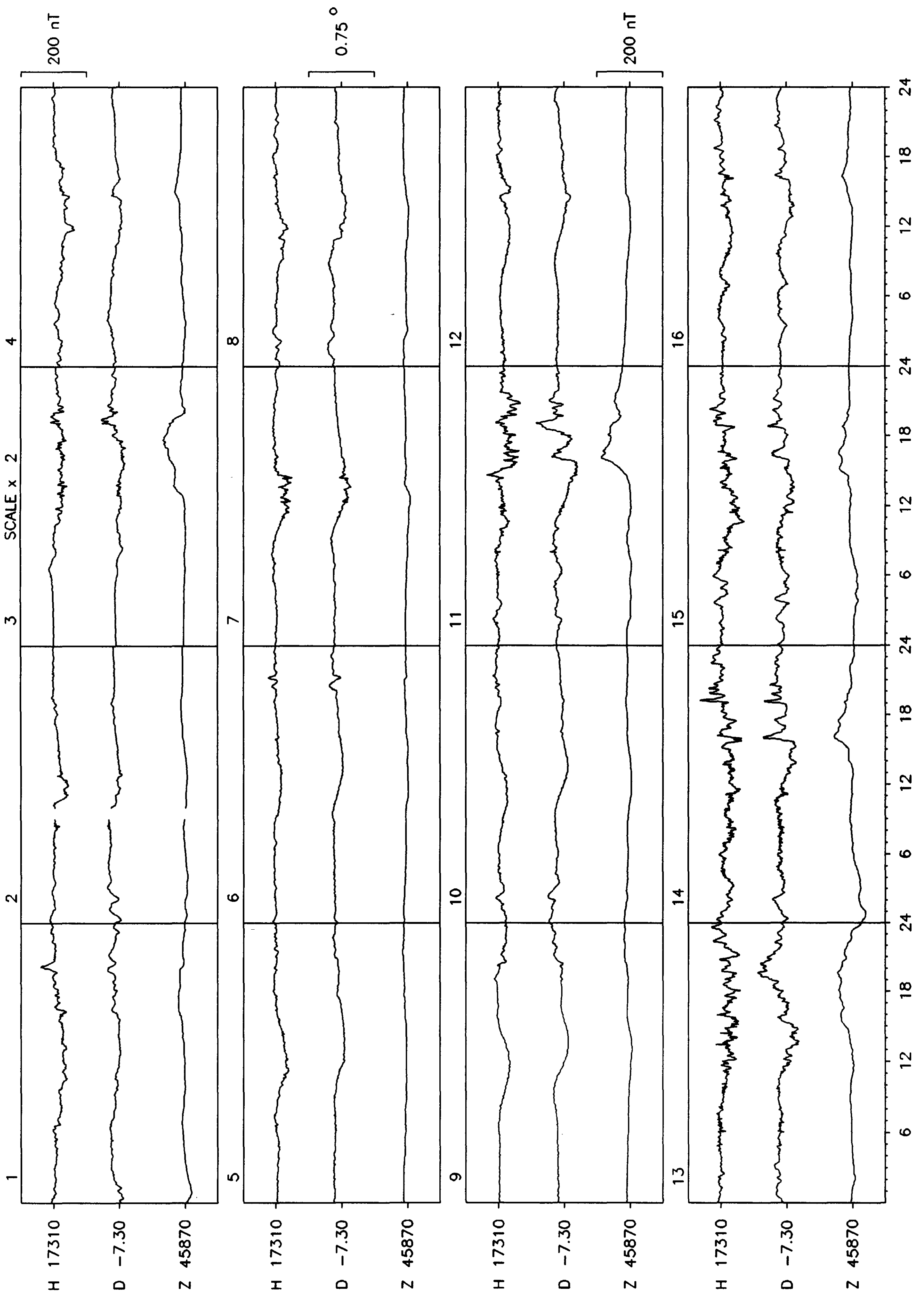
200 nT
0.75 °
200 nT
SCALE x 2
H 17310
D −7.30
Z 45870
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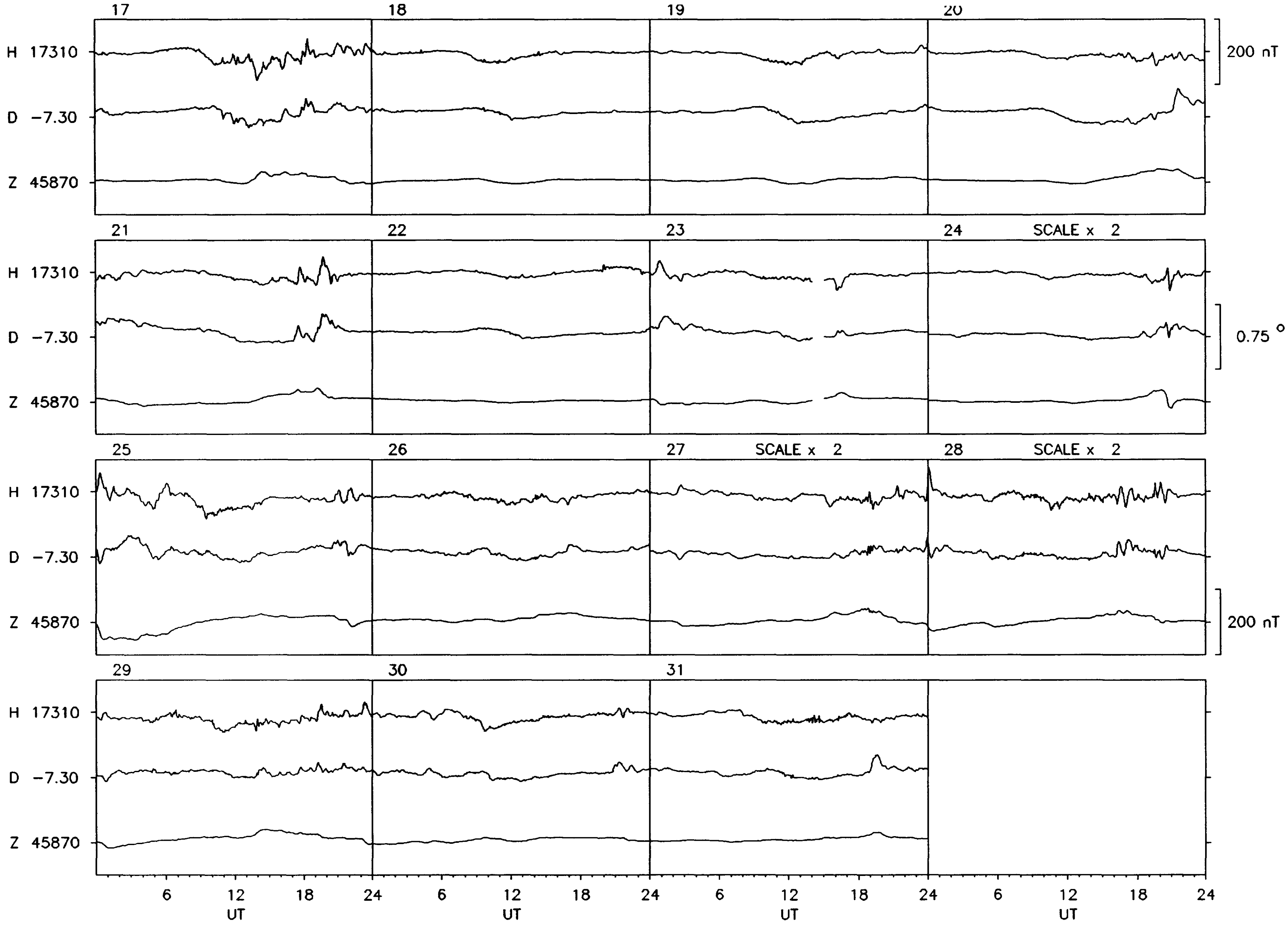
H 17310
D −7.30
Z 45870
200 nT
0.75 °
SCALE x 2
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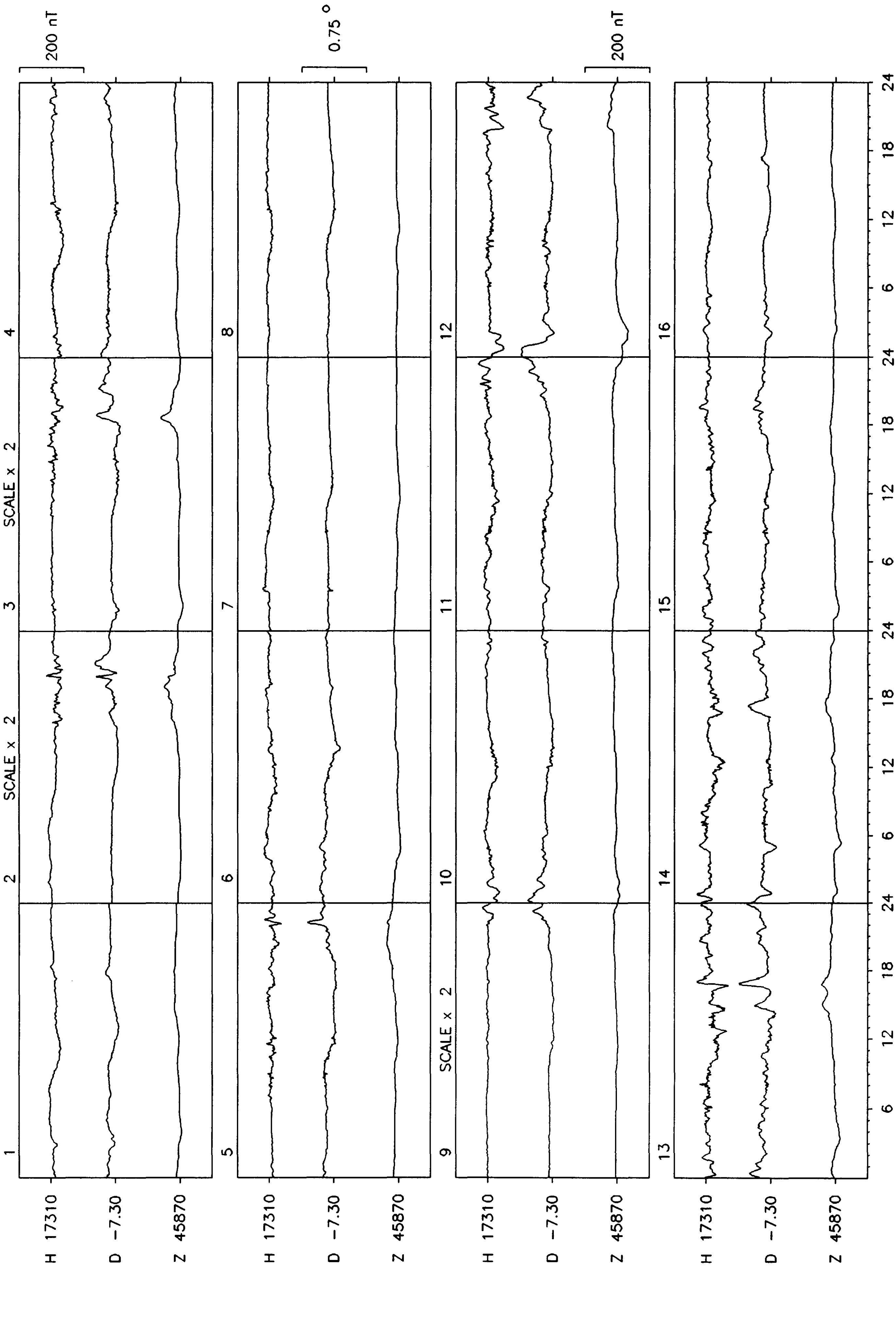
200 nT
0.75 °
200 nT
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SCALE x 2
SCALE x 2
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D −7.30
Z 45870
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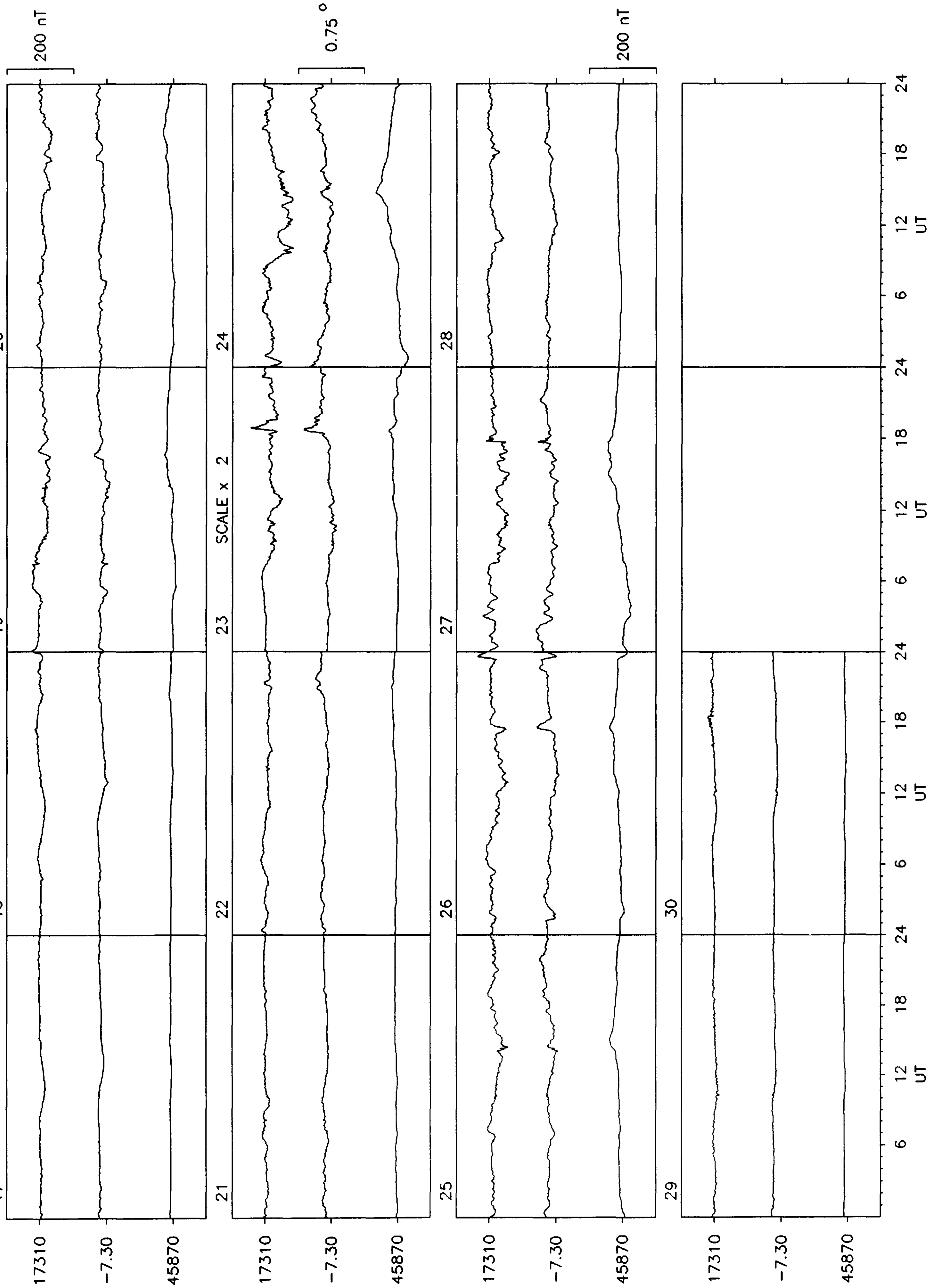
200 nT
0.75 °
200 nT
SCALE x 2
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H 17310
D −7.30
Z 45870
UT
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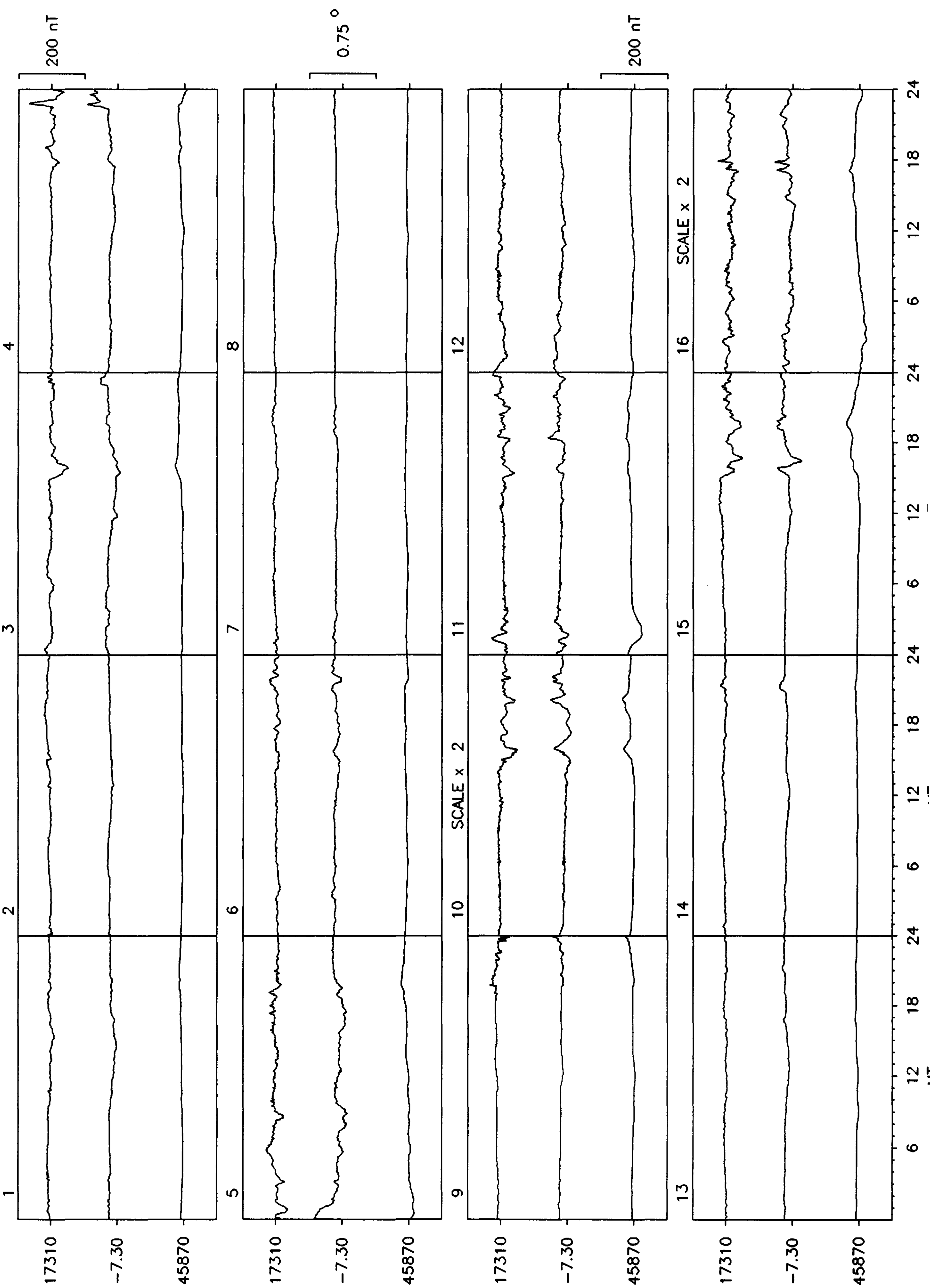
200 nT
0.75 °
200 nT
H 17310
D −7.30
Z 45870
SCALE x 2
SCALE x 2
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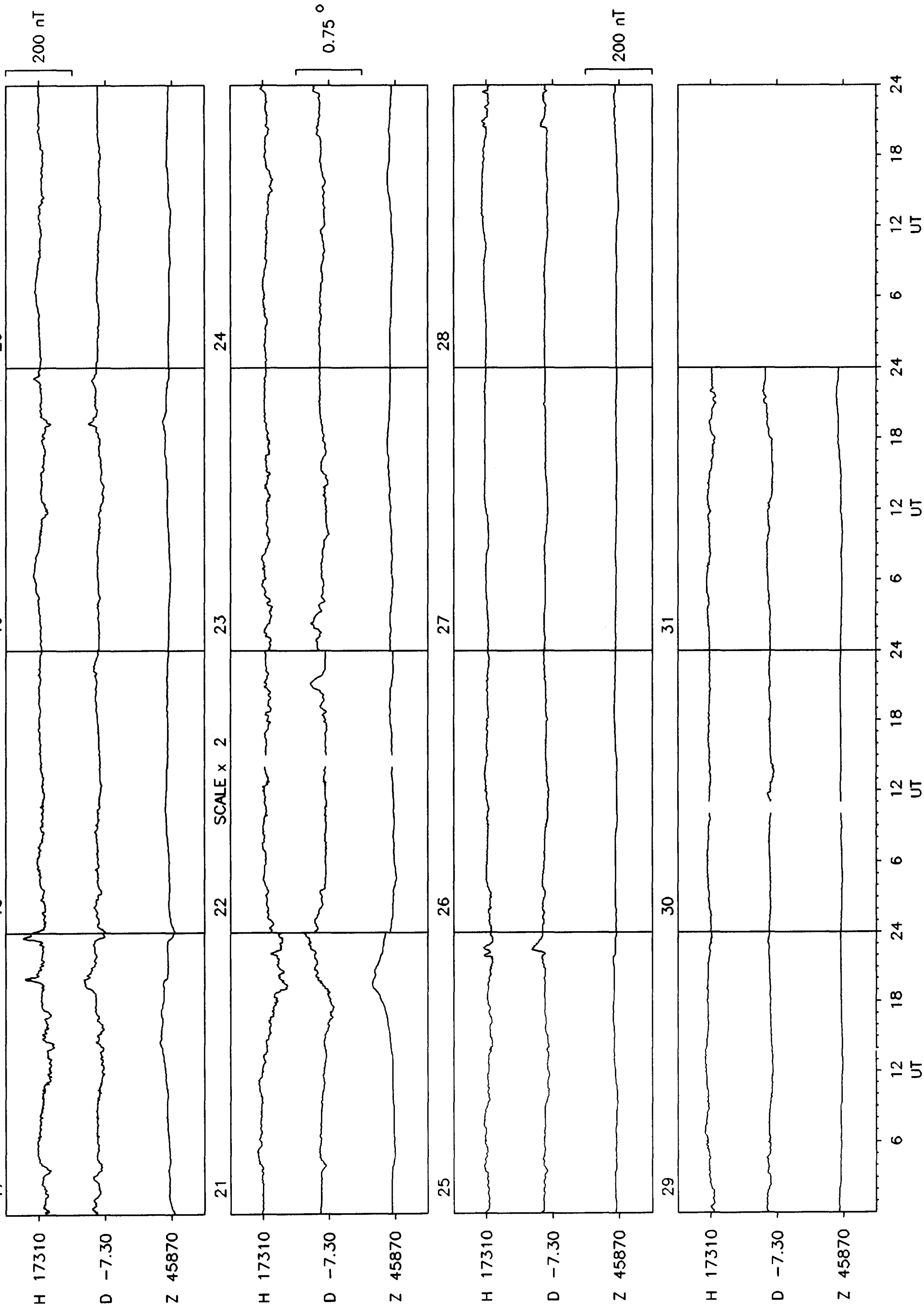
200 nT
0.75 °
200 nT
17
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27
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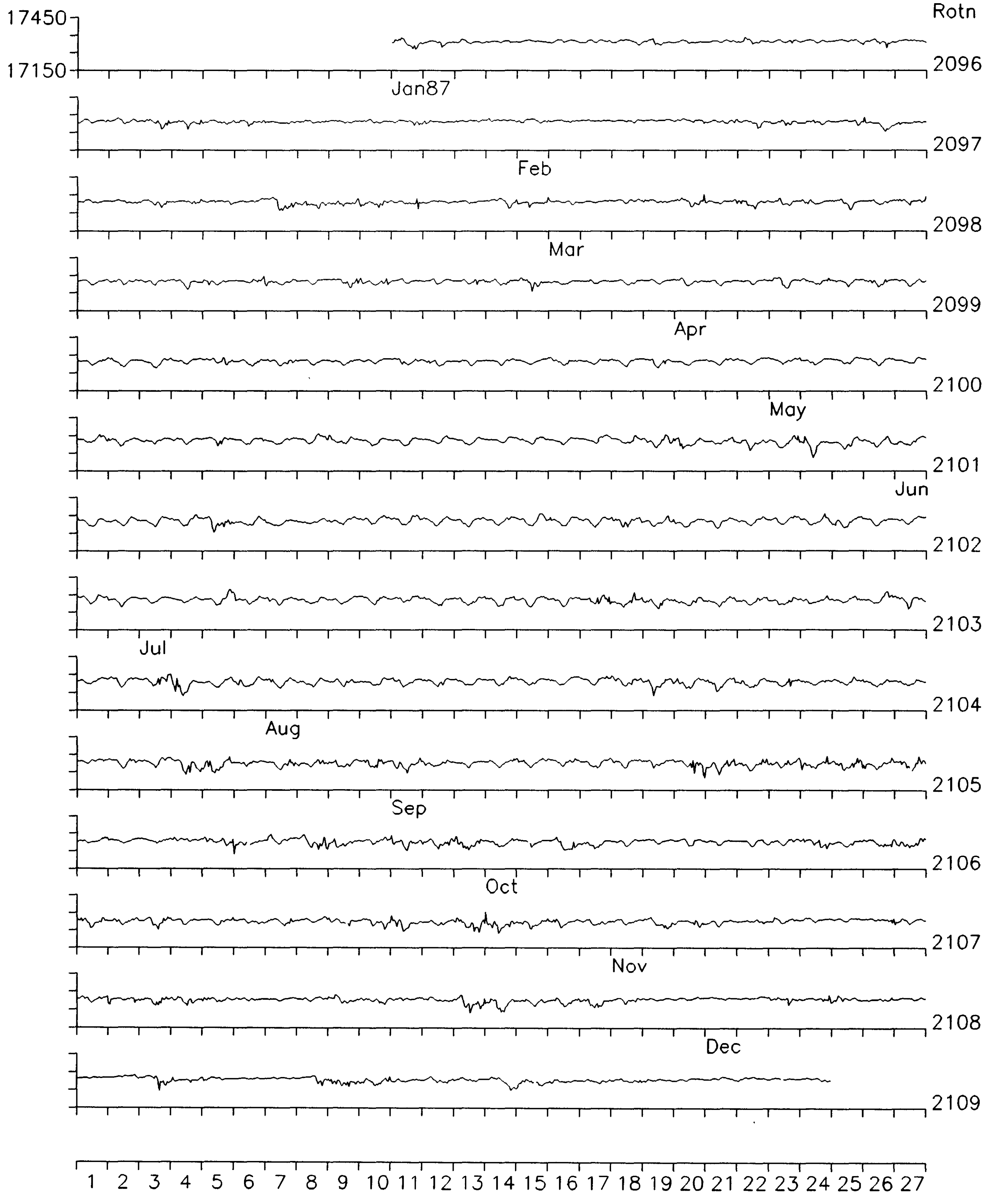
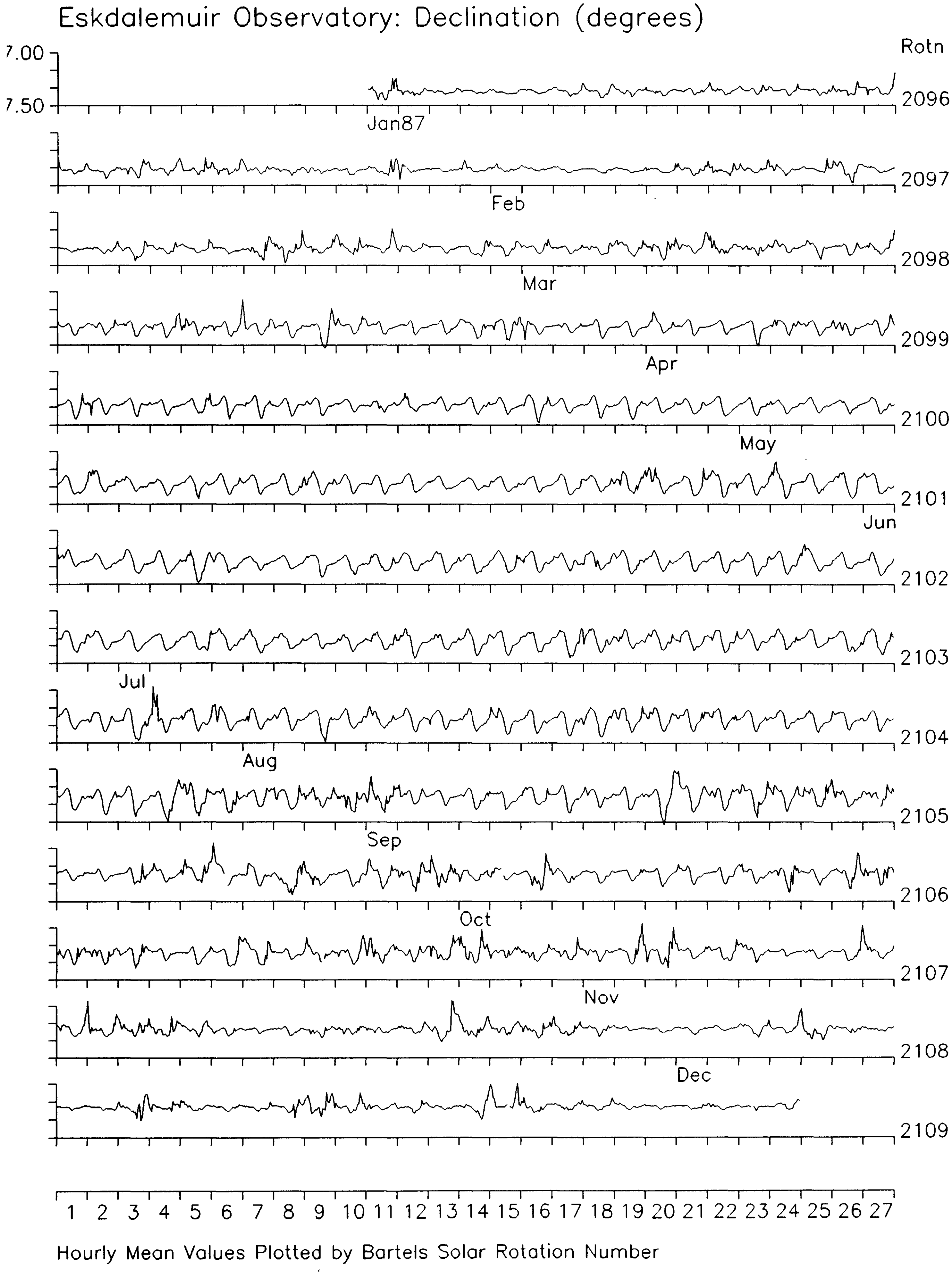
29
30
31
SCALE x 2
H 17310
D −7.30
Z 45870
6
12
18
24
UT

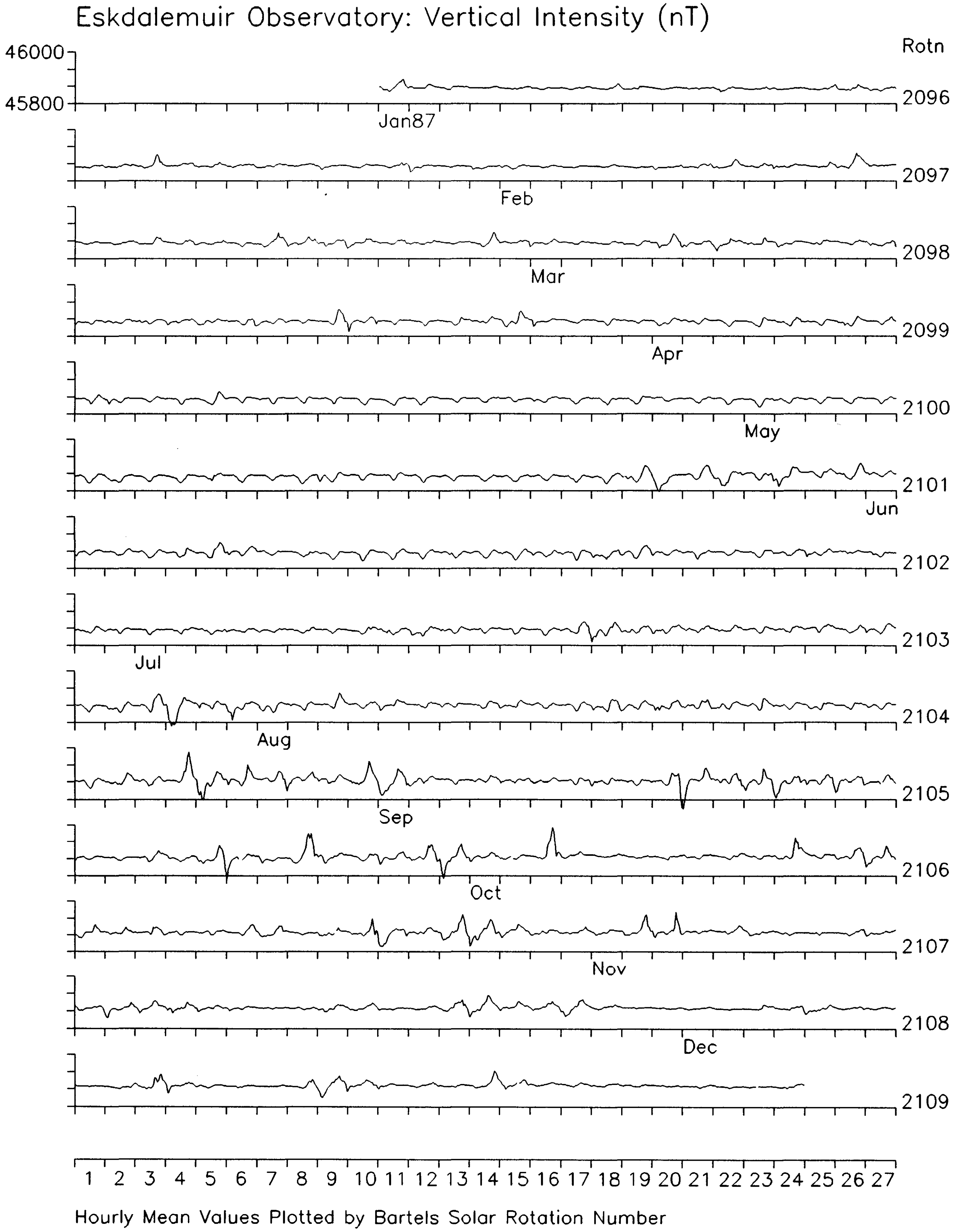
Eskdalemuir Observatory: Horizontal Intensity (nT)



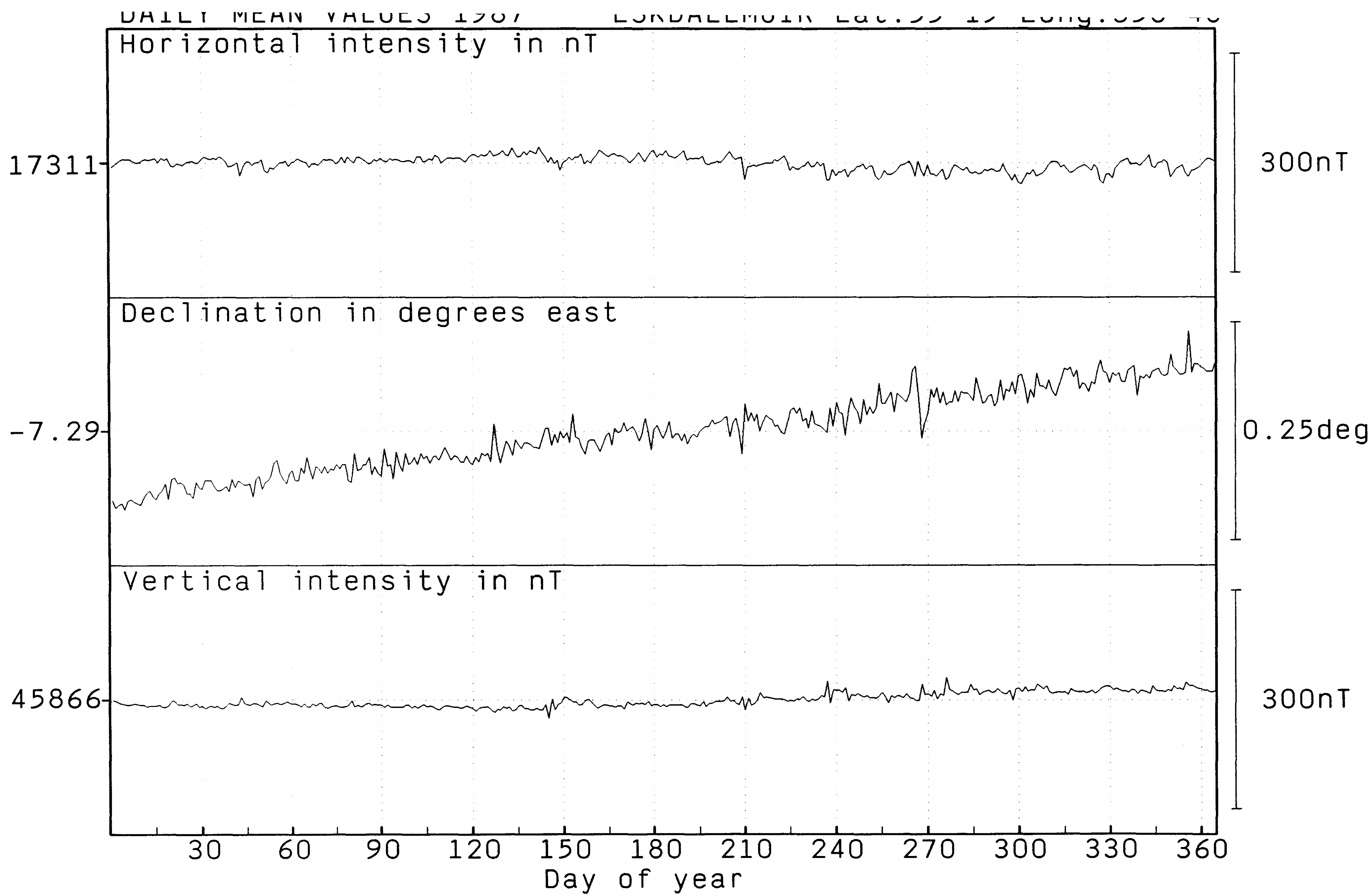
Hourly Mean Values Plotted by Bartels Solar Rotation Number



Eskdalemuir Observatory: Declination (degrees)
7.00
7.50
Rotn
2096
Jan87
2097
Feb
2098
Mar
2099
Apr
2100
May
2101
Jun
2102
2103
Jul
2104
Aug
2105
Sep
2106
Oct
2107
Nov
2108
Dec
2109
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



Eskdalemuir Observatory: Vertical Intensity (nT)
46000
45800
Rotn
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
Jan87
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
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


Horizontal intensity in nT
17311
300nT
Declination in degrees east
-7.29
0.25deg
Vertical intensity in nT
45866
300nT
30
60
90
120
150
180
210
240
270
300
330
360
Day of year

Monthly and annual mean values for Eskdalemuir 1987

Month	D	I	H	X	Y	Z	F
	° ′	° ′	nT	nT	nT	nT	nT
Jan	-7 21.5	69 19.0	17313	17170	-2217	45859	49018
Feb	-7 20.7	69 19.2	17310	17168	-2213	45860	49018
Mar	-7 19.9	69 19.0	17314	17172	-2209	45859	49019
Apr	-7 19.1	69 18.8	17316	17175	-2206	45857	49017
May	-7 18.2	69 18.4	17321	17180	-2202	45856	49018
Jun	-7 17.5	69 18.6	17320	17180	-2198	45860	49022
Jul	-7 17.0	69 18.8	17317	17177	-2195	45861	49022
Aug	-7 16.5	69 19.7	17307	17168	-2192	45870	49026
Sep	-7 15.2	69 20.1	17301	17163	-2184	45871	49025
Oct	-7 14.6	69 20.5	17298	17160	-2181	45878	49031
Nov	-7 13.7	69 20.2	17302	17164	-2177	45879	49033
Dec	-7 13.0	69 19.9	17308	17171	-2174	45880	49036
Annual	-7 17.2	69 19.3	17311	17171	-2196	45866	49024

ESKDALEMUIR OBSERVATORY K INDICES 1987

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	2223 2343	2210 1122	2111 2333	2331 2221	1013 2223	2112 3322	0100 2201	3321 3222	5432 4435	3122 2333	2211 2210	1101 0110
2	1212 3212	2001 0210	0001 1102	0111 1110	2112 2222	3321 2221	1101 1221	2210 2211	4222 2321	3123 3120	2222 2455	2000 1111
3	1221 1011	2111 0001	0212 2232	0001 1000	1122 2220	0102 2212	1102 2143	1122 3531	0112 2101	0133 4453	4212 3454	2122 1312
4	1000 0011	0000 1221	3112 2213	0313 3311	0021 2110	2212 3222	4222 2221	1211 2322	1201 2223	2223 3211	3222 3012	1100 0235
5	1000 0111	0001 1201	1313 3435	3321 2333	0001 1220	2211 3332	2222 3221	3232 2321	2112 2222	0112 2112	1023 2234	4333 2232
6	0101 1001	2101 2113	3222 1034	1101 3212	0000 1223	1244 3333	1211 2222	1222 2431	2222 2232	1111 1133	2322 3122	0211 2223
7	1100 0112	2111 2223	4332 3122	3232 3320	2311 1102	2012 3332	1112 2220	3111 1211	1123 3313	0112 3111	1211 1001	2110 1110
8	1111 1222	2221 2341	2132 2312	1122 2333	1202 2101	2111 2111	2323 3222	1221 2334	3222 3213	2112 2121	1111 2100	0000 0000
9	1132 2111	2212 2204	3221 1110	1012 2232	0212 2211	0011 0212	1321 2323	3222 3221	2232 2222	0000 0022	0011 2225	0000 1023
10	1122 2010	2312 1211	2222 3300	4311 2110	1123 3321	2012 2211	3322 3321	1111 2221	2103 5545	3211 1111	3212 2112	2223 3554
11	0111 1123	1100 1141	0022 2331	0122 2212	1101 2223	1113 2321	2321 2322	2111 3232	4334 3444	2232 3453	1322 2234	3211 2333
12	3312 1211	4222 3421	3312 2134	1111 1112	0100 1111	2222 3432	1222 3223	3222 3434	2332 3354	1010 2322	5222 2244	3222 1211
13	2111 1322	2210 1010	3122 1113	1112 1434	0110 2323	2212 2222	1111 2112	3343 3333	3323 3424	2222 3344	3233 4534	0001 1111
14	1110 2130	1111 1100	2122 2232	0112 3221	3212 3323	1222 3112	2212 2222	3323 3333	4333 3343	4333 3542	4323 3433	1011 1122
15	0101 1123	0101 2122	2222 2122	2101 2221	0112 2210	1001 1321	1233 4444	2233 4334	3333 3444	2333 3442	3222 2232	0001 1432
16	2212 2331	2212 2342	3022 3133	0111 2101	0211 2221	2121 2332	3323 2434	3223 3322	4133 2333	2332 3332	2211 1211	3433 4534
17	3211 1124	1111 2333	3312 2201	2001 2221	1101 2221	2101 2212	2333 4233	2222 3422	2322 3343	2113 4333	1000 0001	2312 3334
18	3212 1113	2112 2123	2011 3334	1012 2212	0011 0110	2212 2321	3222 3332	1211 2222	2122 1222	2112 2110	1111 1123	3222 1102
19	1122 2111	1011 1122	4212 2133	2232 2221	0001 1211	3233 3224	2212 2233	1222 2322	1012 1110	1012 3222	2322 2322	0122 2132
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21	1122 3123	2233 0334	1112 3345	0110 1100	1101 1210	2212 1222	1221 2221	2111 1220	2322 3211	2212 2342	2122 1010	0211 1233
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23	2213 2123	3222 3232	1122 2110	0101 1111	2122 1323	1211 2121	1201 2232	2221 3333	5322 2221	4222 2301	1243 4354	3322 2210
24	2111 1222	2112 2244	0022 1111	2212 3132	2322 3444	0111 2333	1111 3443	1103 3232	3322 2232	2222 2254	3323 3333	0111 2222
25	0211 1223	2112 1121	0011 2412	0211 2211	3432 4341	0111 1233	3233 4332	2133 4443	2333 4555	4443 3223	2121 3222	1111 1113
26	2111 2110	1002 1111	2123 3321	1201 3111	0112 2342	3311 2232	1111 1211	4433 3343	2332 2331	1122 3312	3222 3423	1201 1111
27	1202 2000	1122 2333	3323 4434	1122 2322	3233 2333	1122 2210	2111 2210	2223 4 42	2112 2232	3332 3456	3332 3422	0000 0000
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29	4210 1000		1122 0111	2011 1221	3343 3220	1111 2223	5553 4321	4013 2443	3232 5543	3223 3333	1001 0000	1111 0001
30	2000 0111		0011 2120	0011 1221	0113 3331	1111 1110	3111 2223	2241 2333	4443 3642	2223 2133	0001 0121	0001 1010
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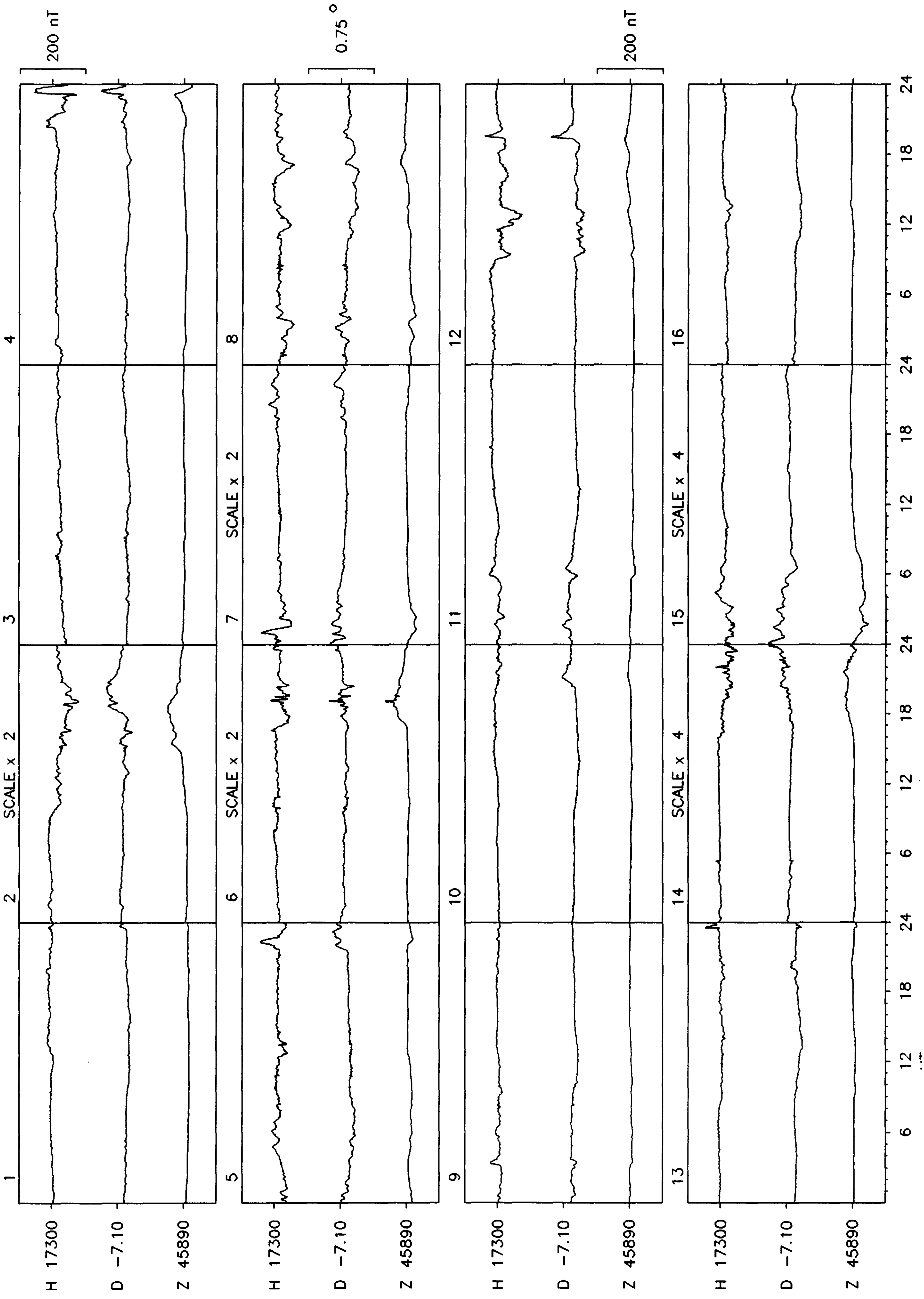
ESKDALEMUIR 1988


200 nT
0.75 °
200 nT
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 4
SCALE x 4
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H 17300
D −7.10
Z 45890
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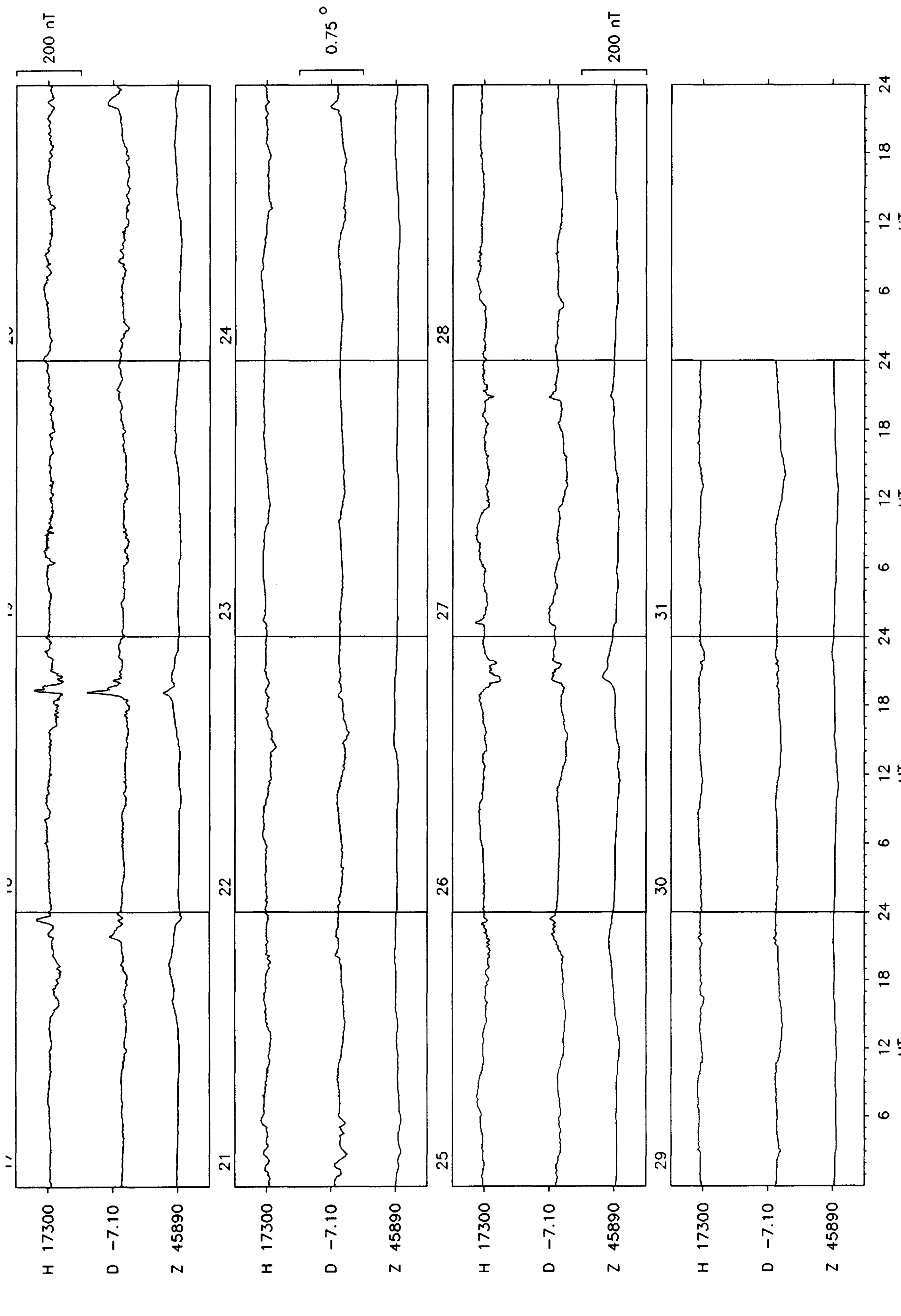
200 nT
0.75 °
200 nT
H 17300
D −7.10
Z 45890
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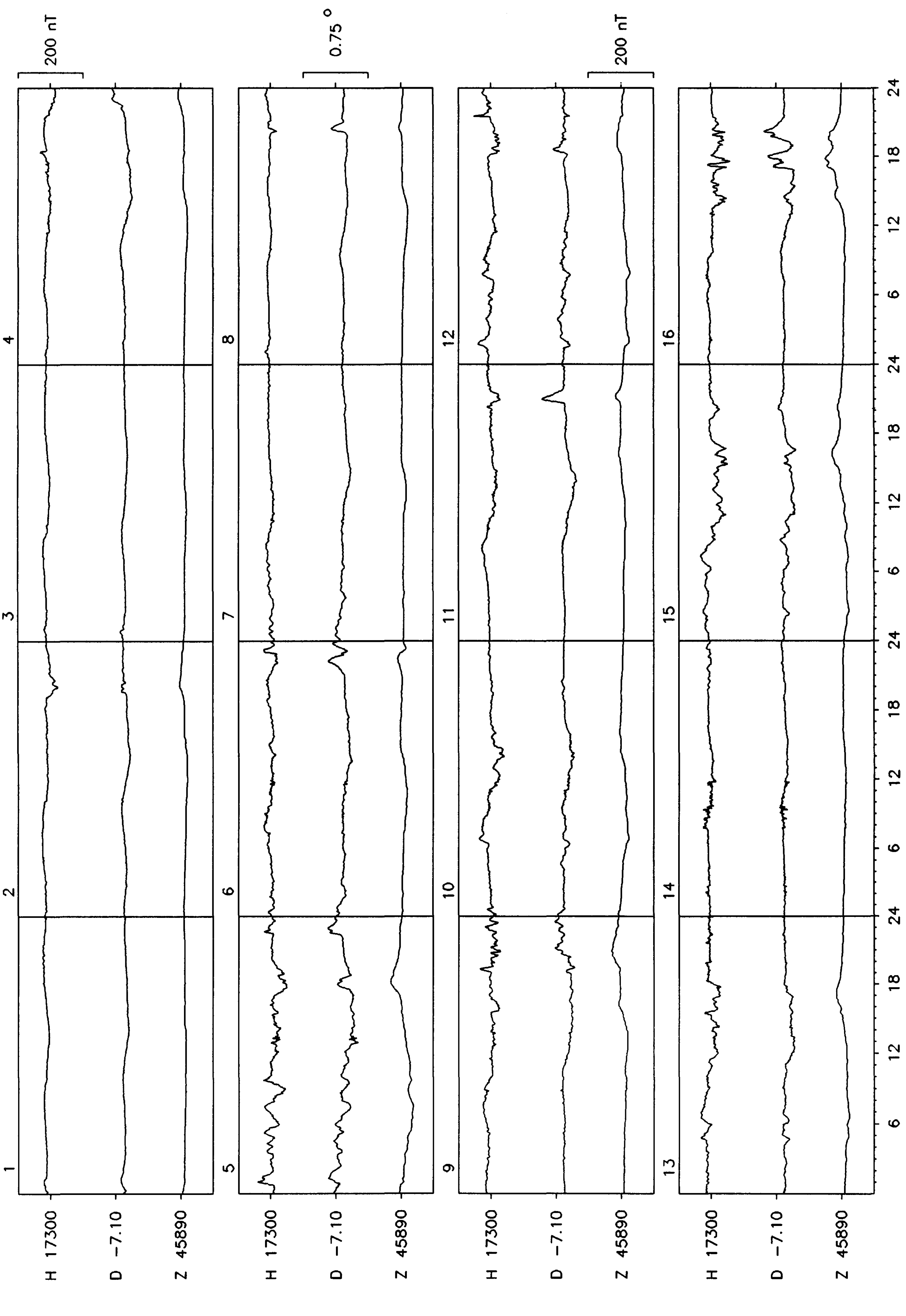
200 nT
0.75 °
200 nT
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H 17300
D −7.10
Z 45890
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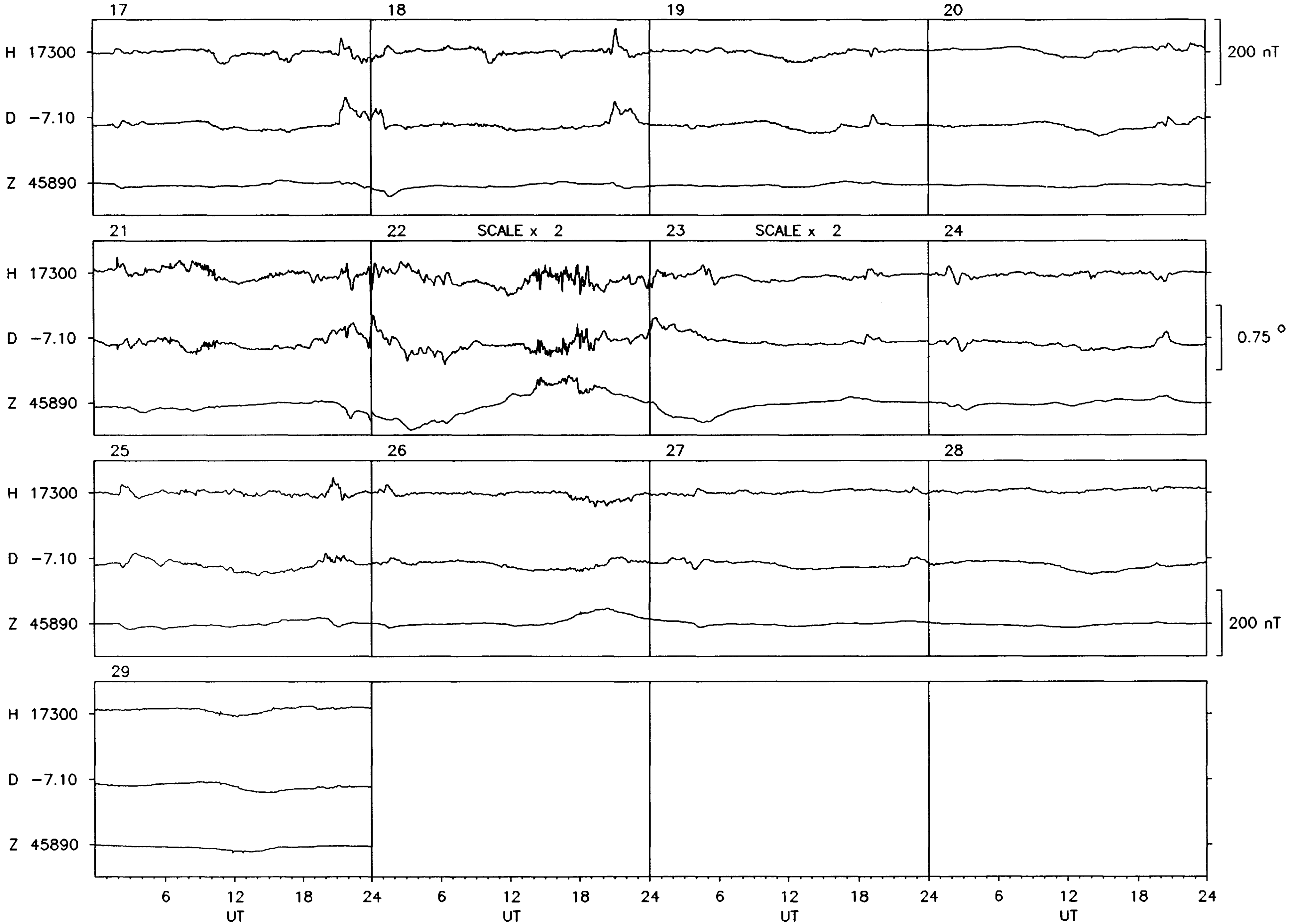
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SCALE x 2
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SCALE x 2
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H 17300
D −7.10
Z 45890
200 nT
0.75 °
200 nT
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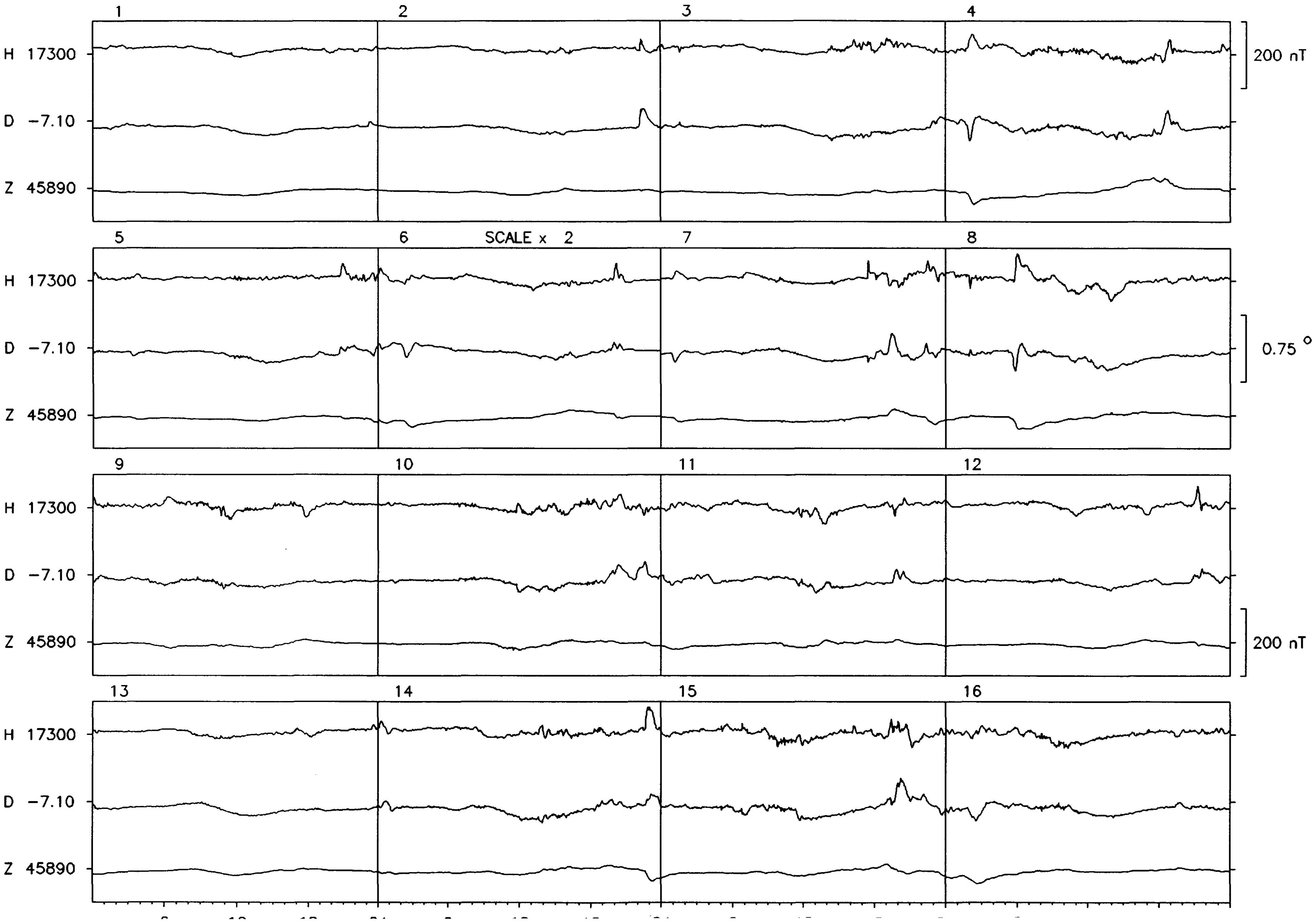

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SCALE x 2
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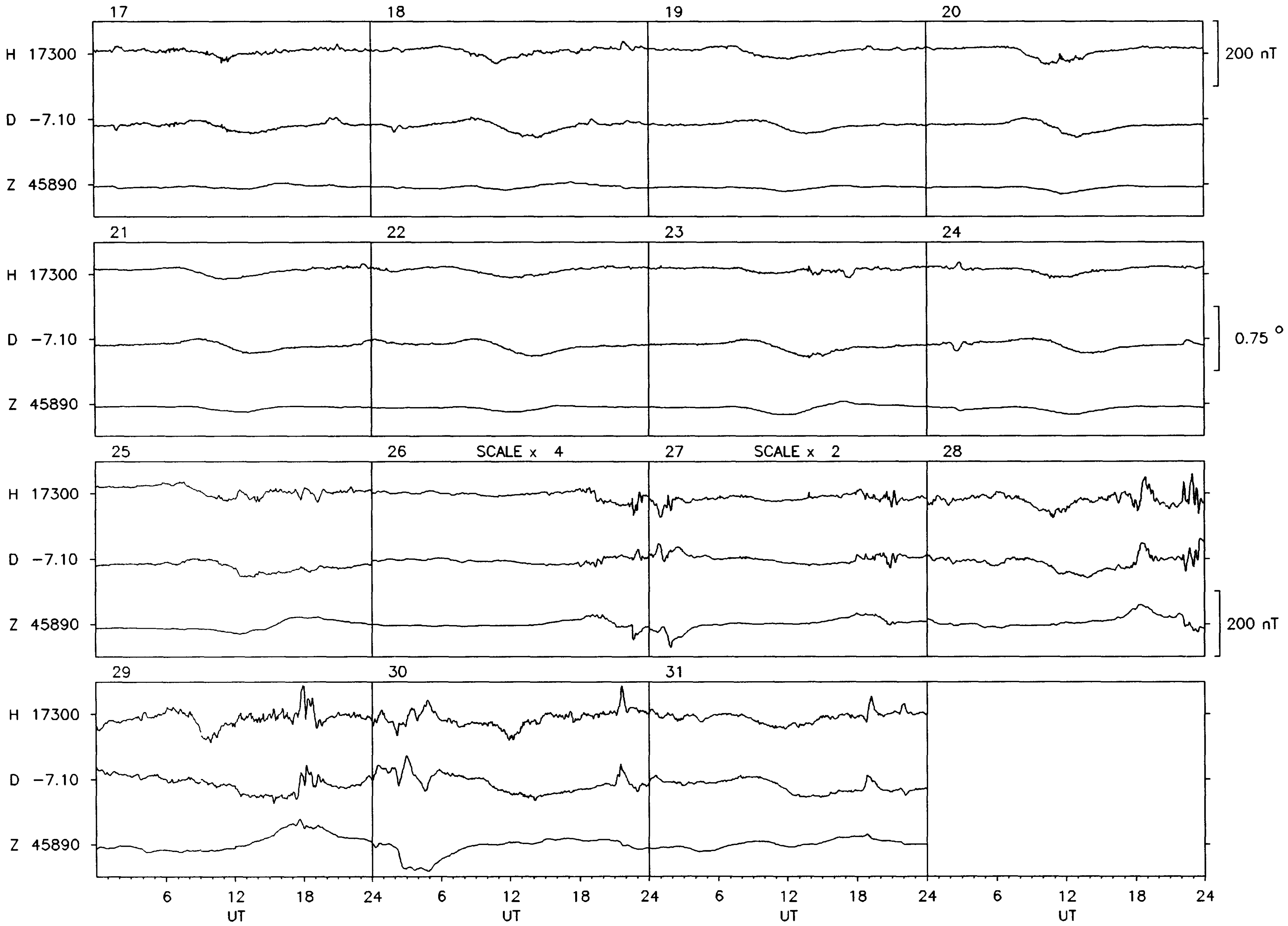
H 17300
D −7.10
Z 45890
200 nT
0.75 °
200 nT



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SCALE x 2
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H 17300
D −7.10
Z 45890
200 nT
0.75 °
200 nT
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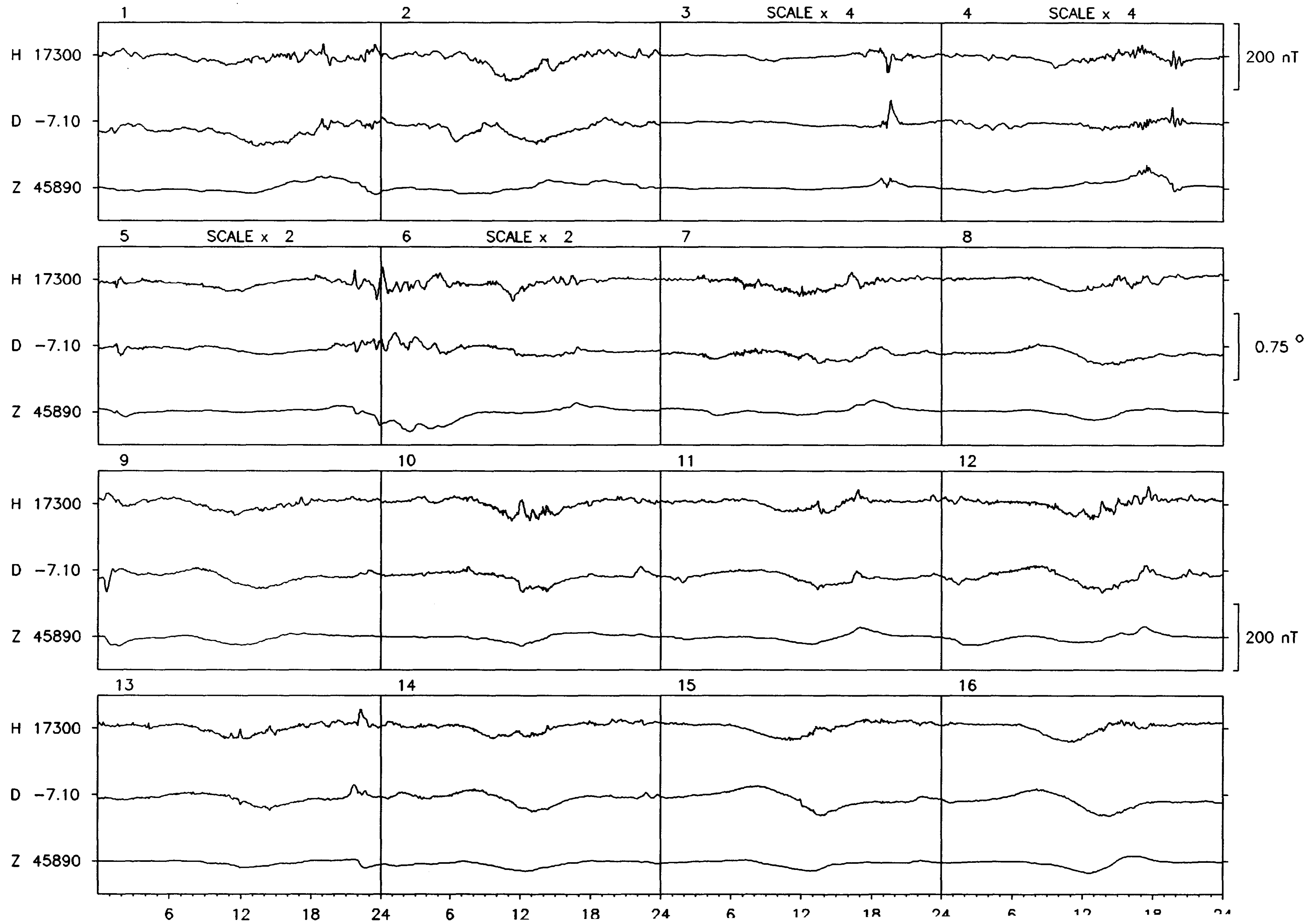
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SCALE x 2
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SCALE x 2
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H 17300
D -7.10
Z 45890
200 nT
0.75 °
200 nT
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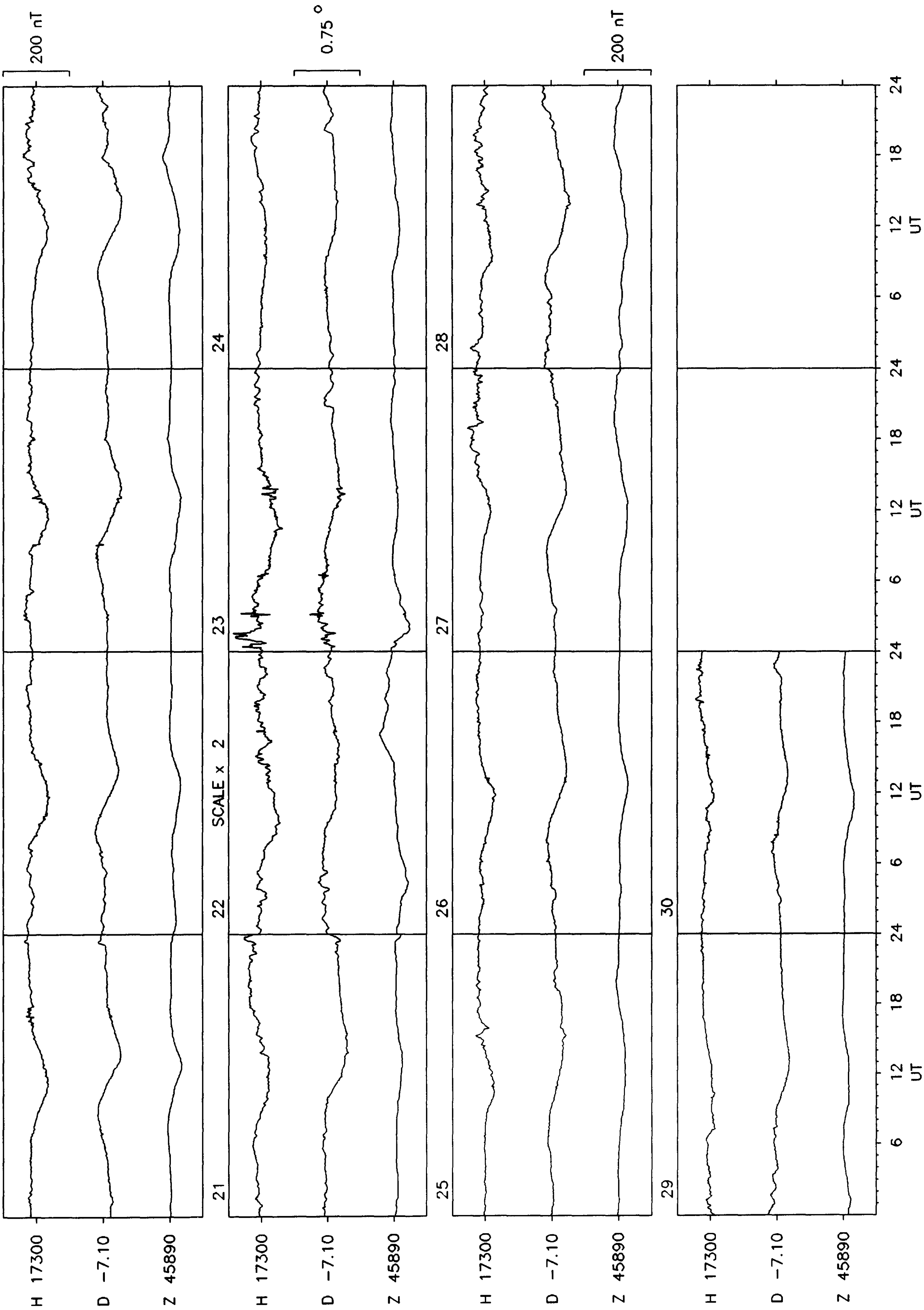
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Z 45890
200 nT
0.75 °
SCALE x 2
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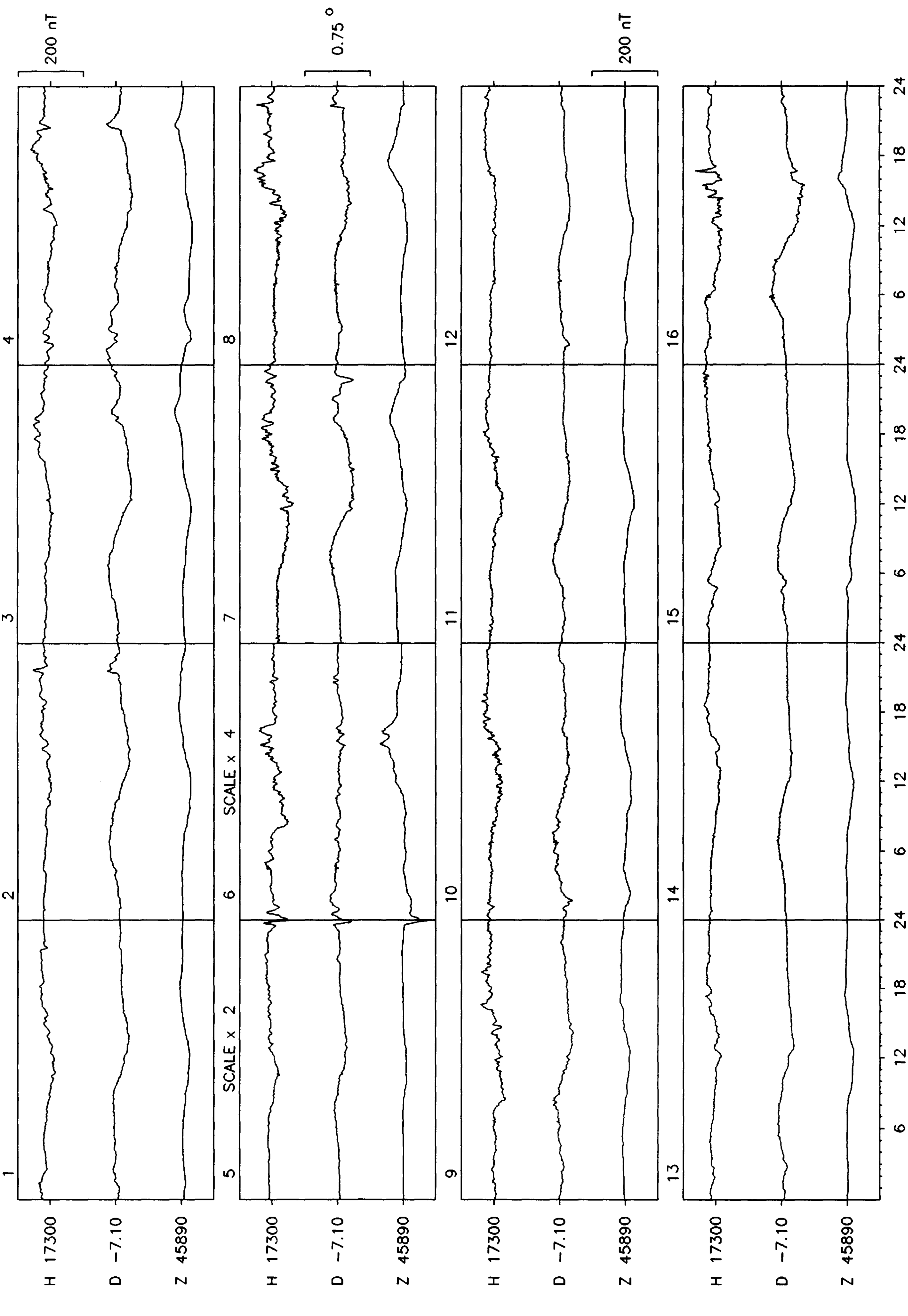
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D −7.10
Z 45890
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SCALE x 2
SCALE x 4
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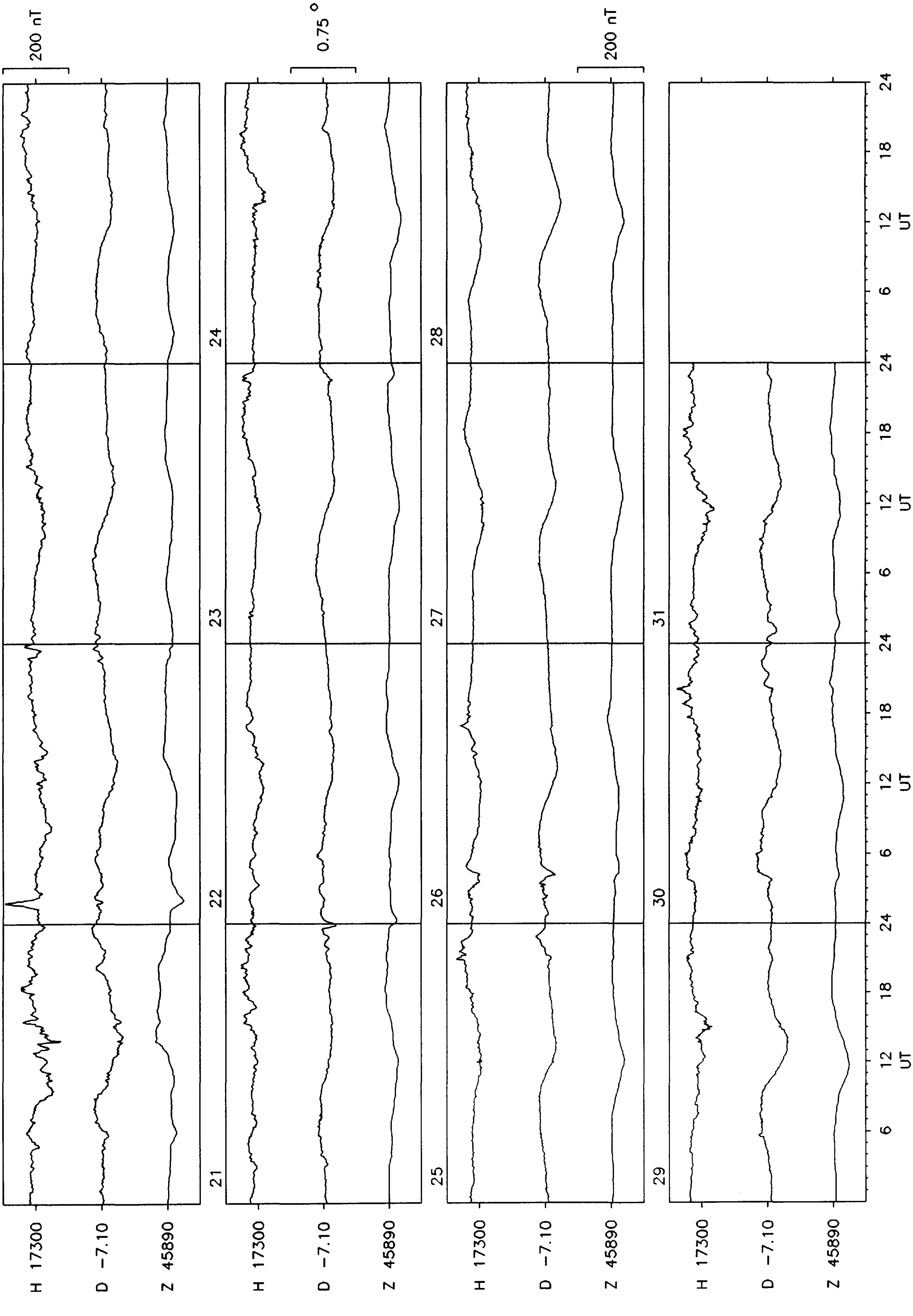
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0.75 °
200 nT
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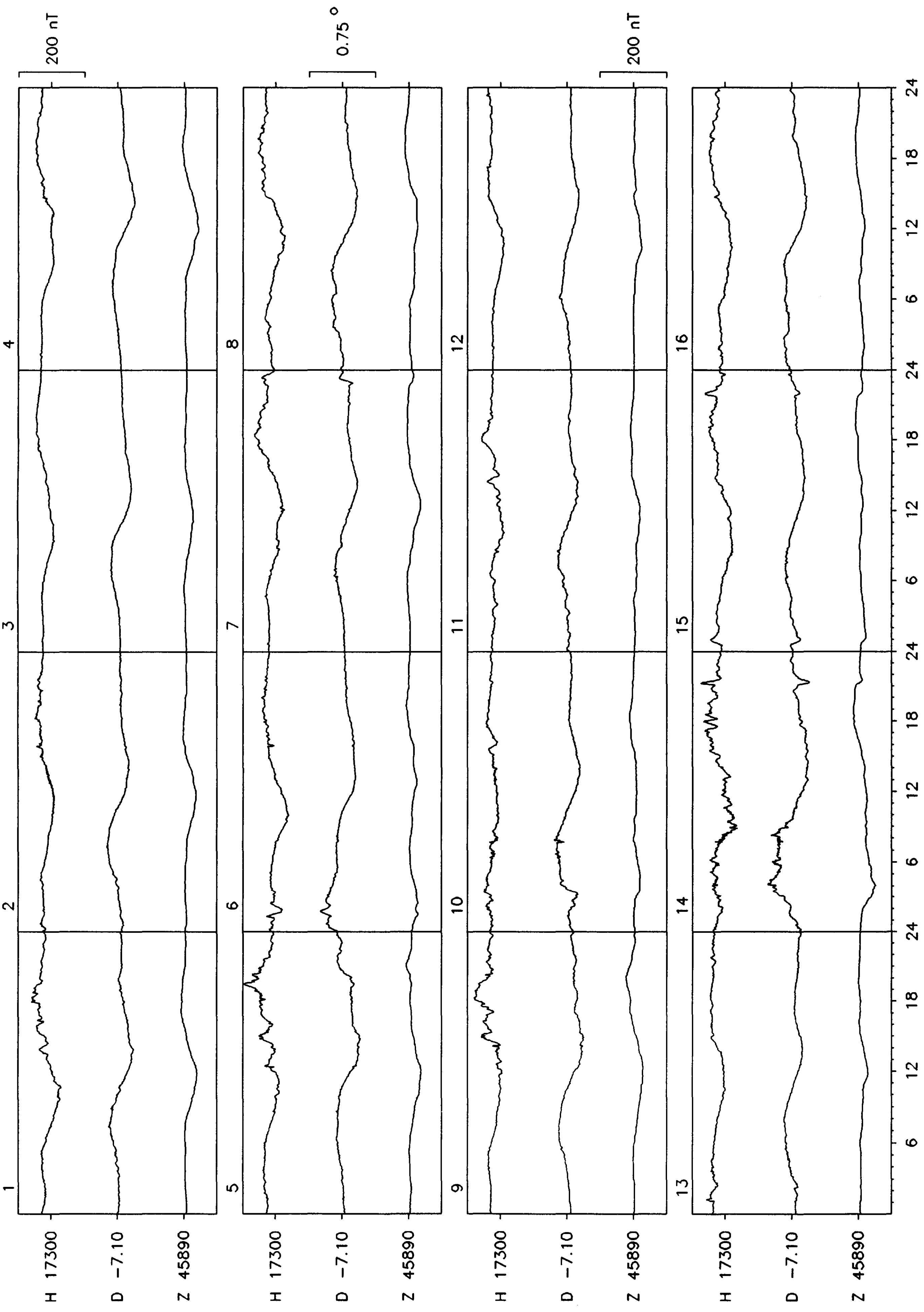
H 17300
D −7.10
Z 45890
200 nT
0.75 °
200 nT
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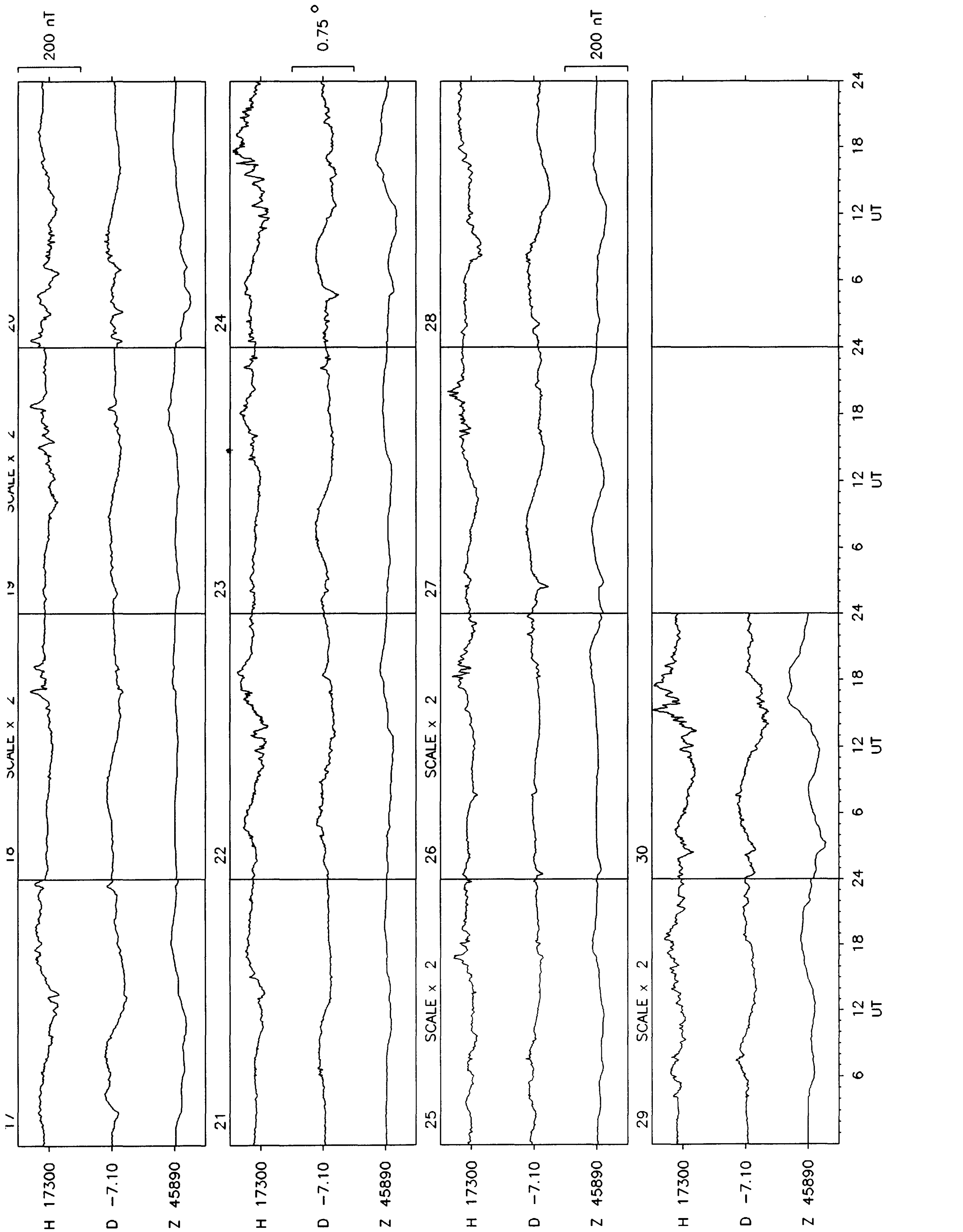

H 17300
D −7.10
Z 45890
200 nT
0.75 °
SCALE x 2
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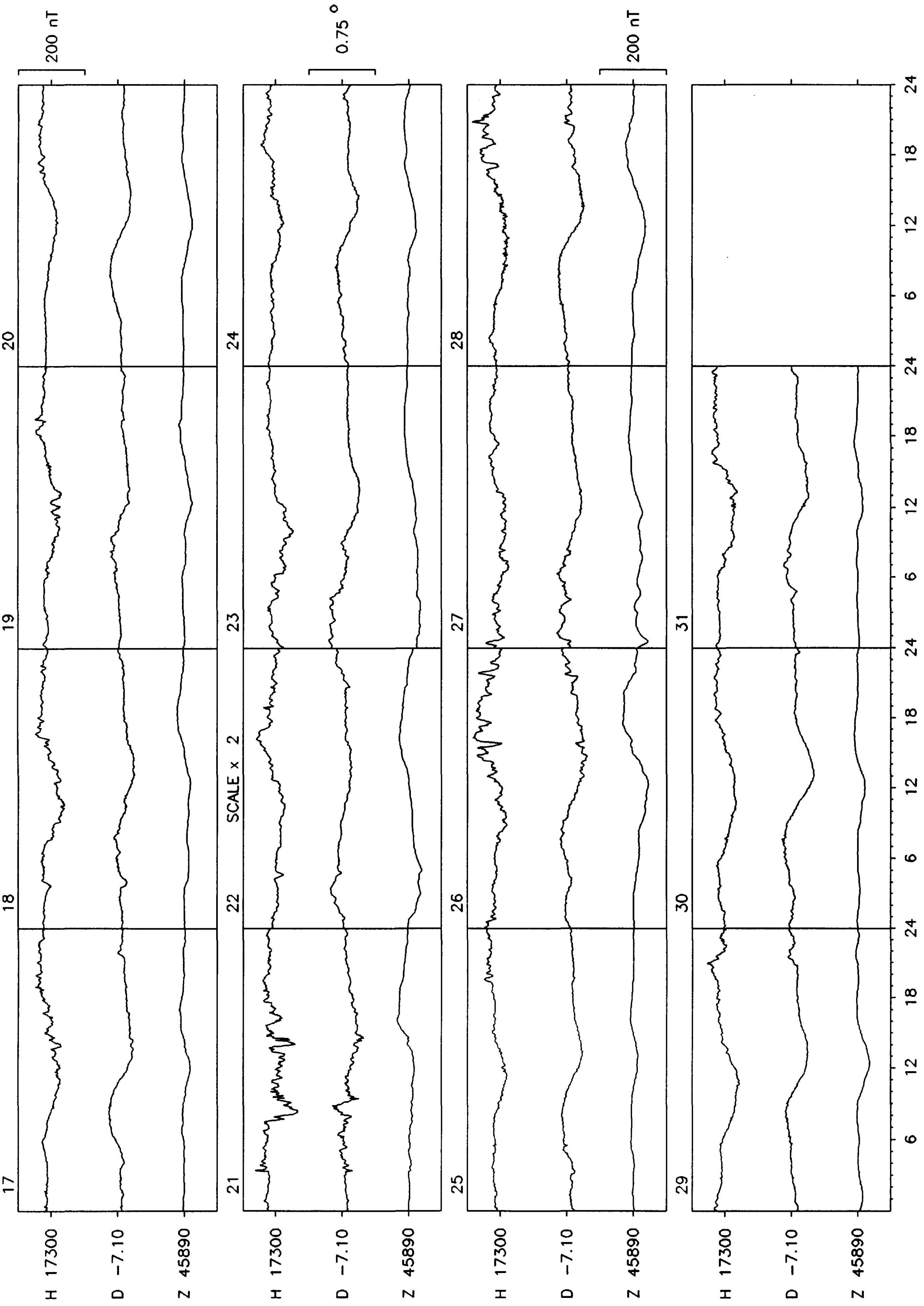
200 nT
0.75 °
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D −7.10
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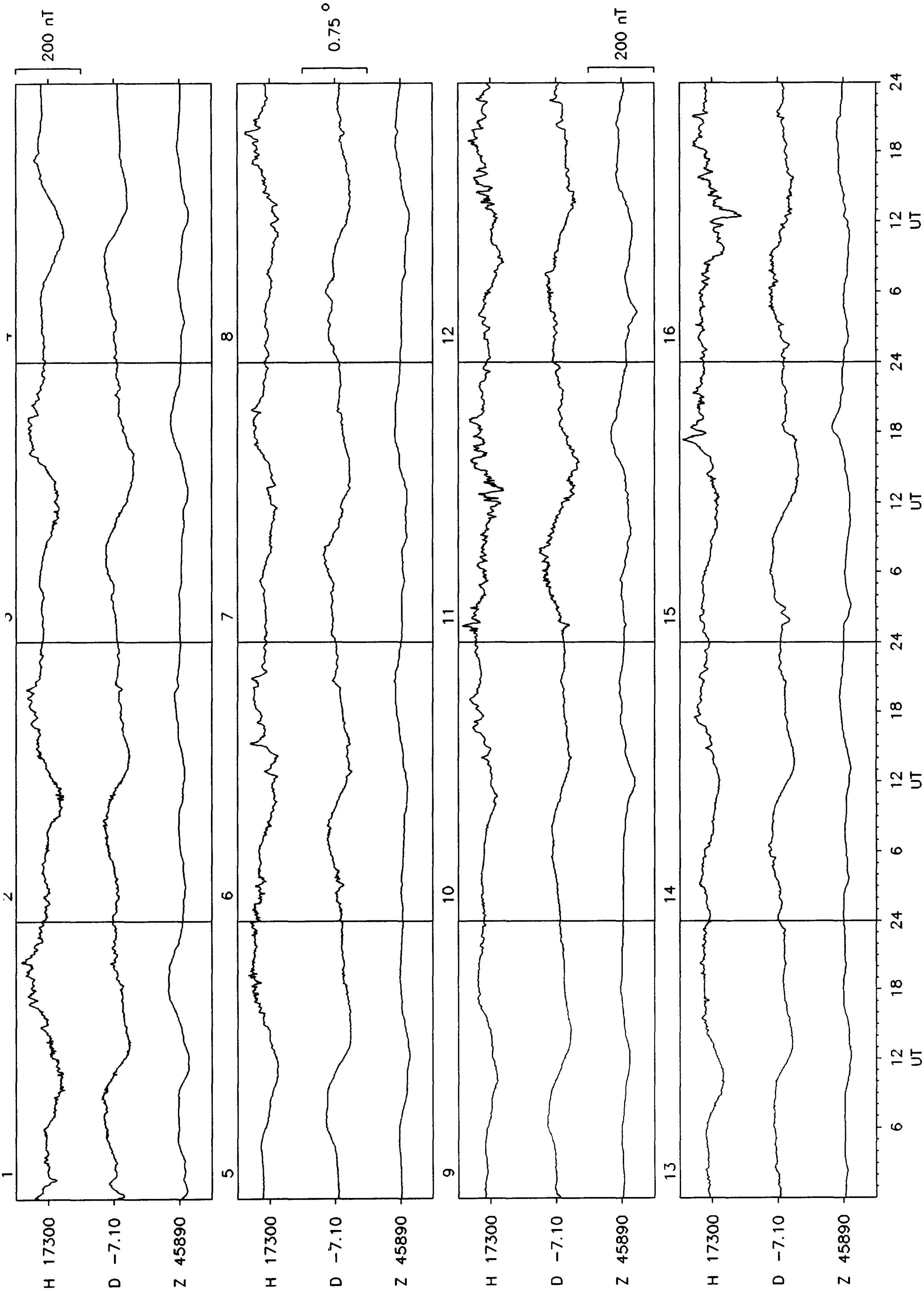
H 17300
D −7.10
Z 45890
200 nT
0.75 °
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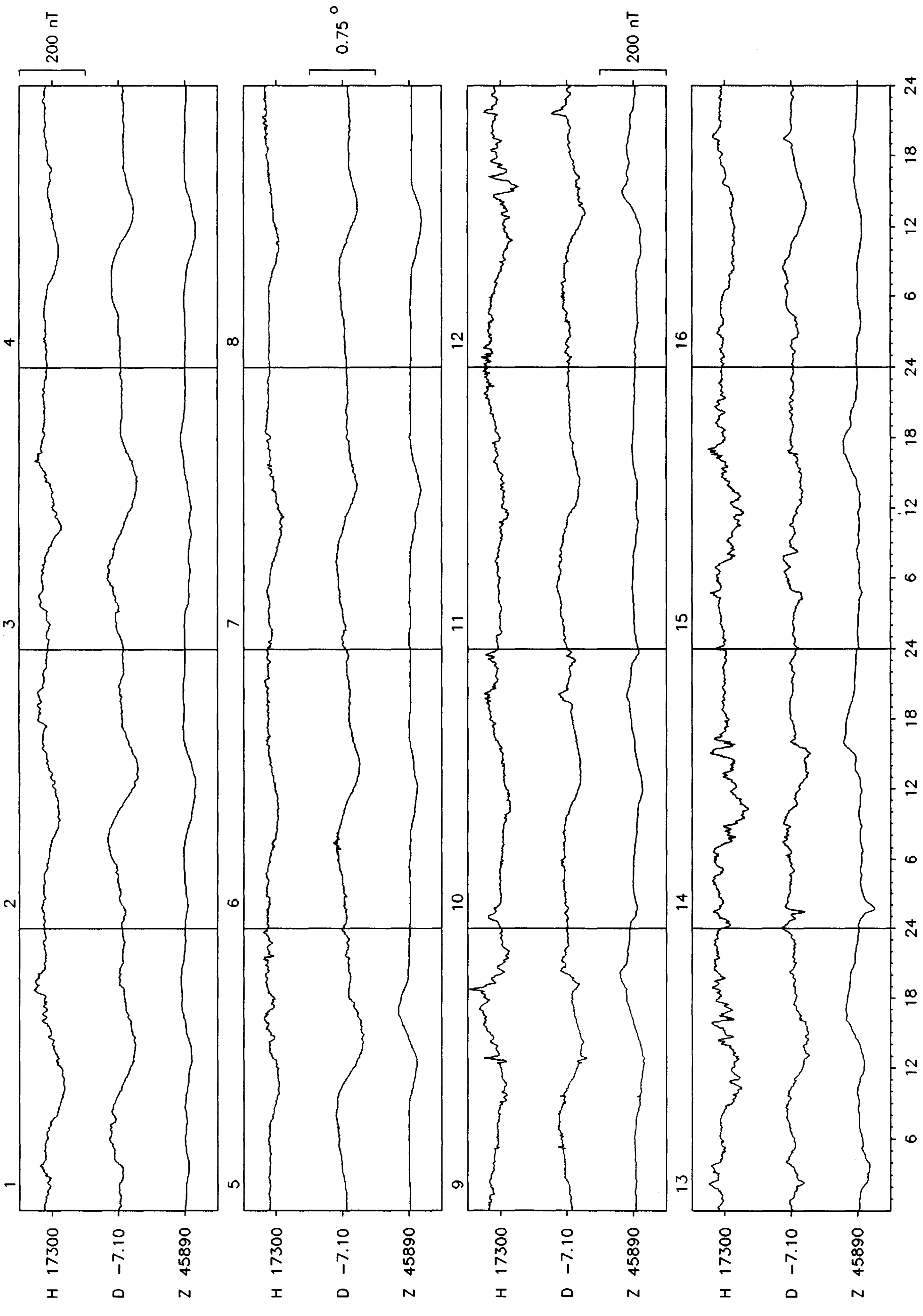
H 17300
D −7.10
Z 45890
200 nT
0.75 °
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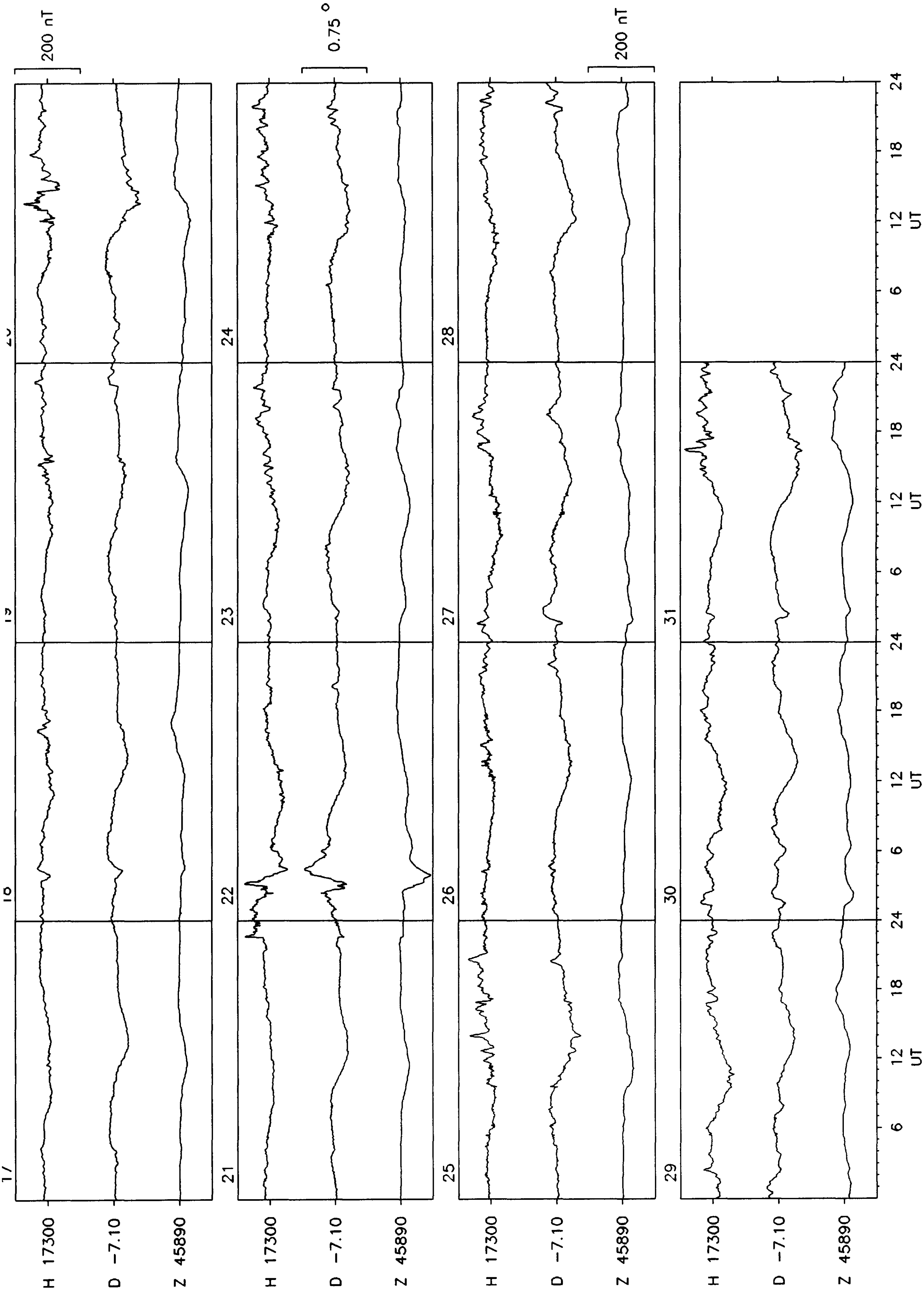

200 nT
0.75 °
200 nT
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H 17300
D −7.10
Z 45890
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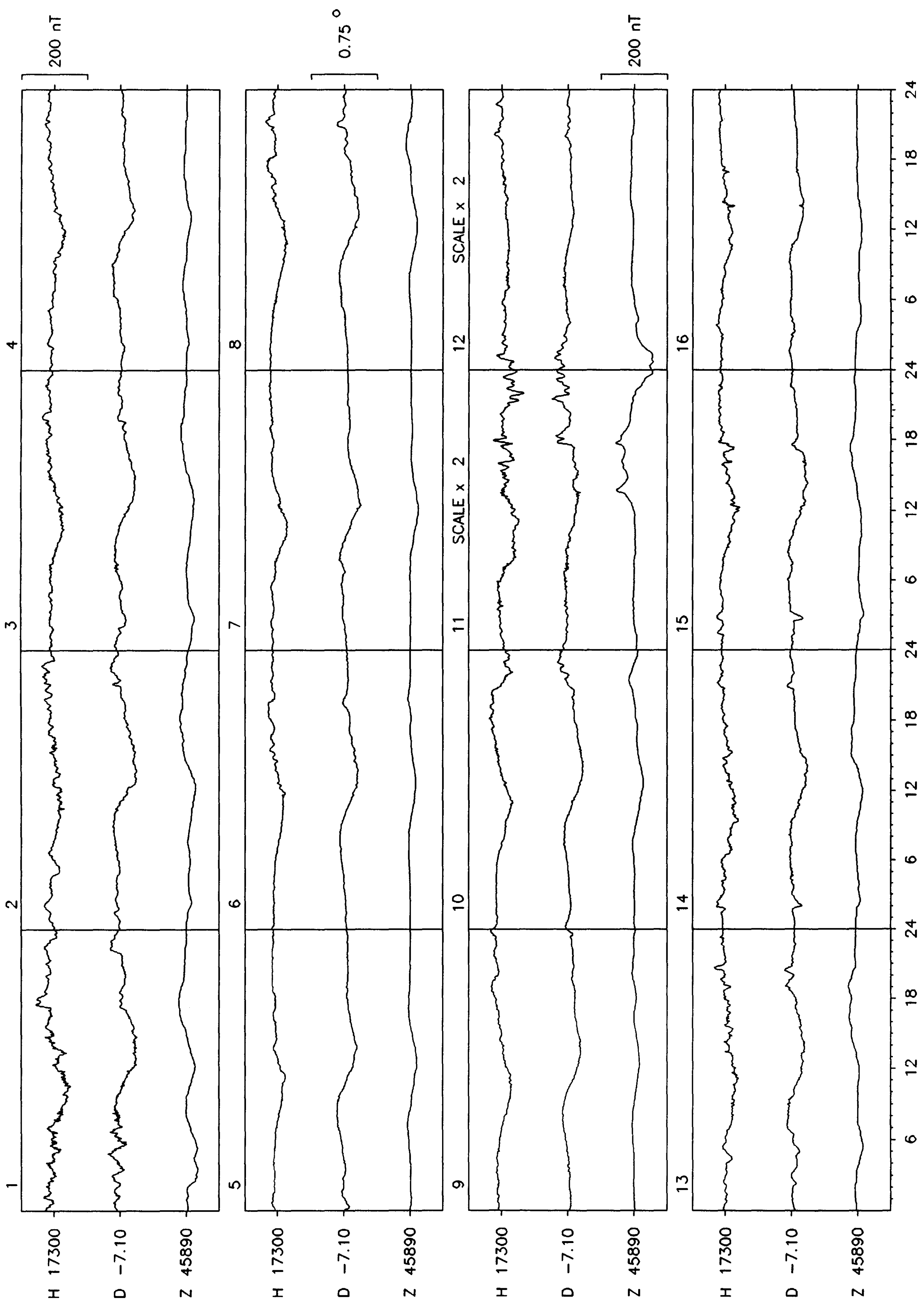
UT



200 nT
0.75 °
200 nT
SCALE x 2
SCALE x 2
H 17300
D −7.10
Z 45890
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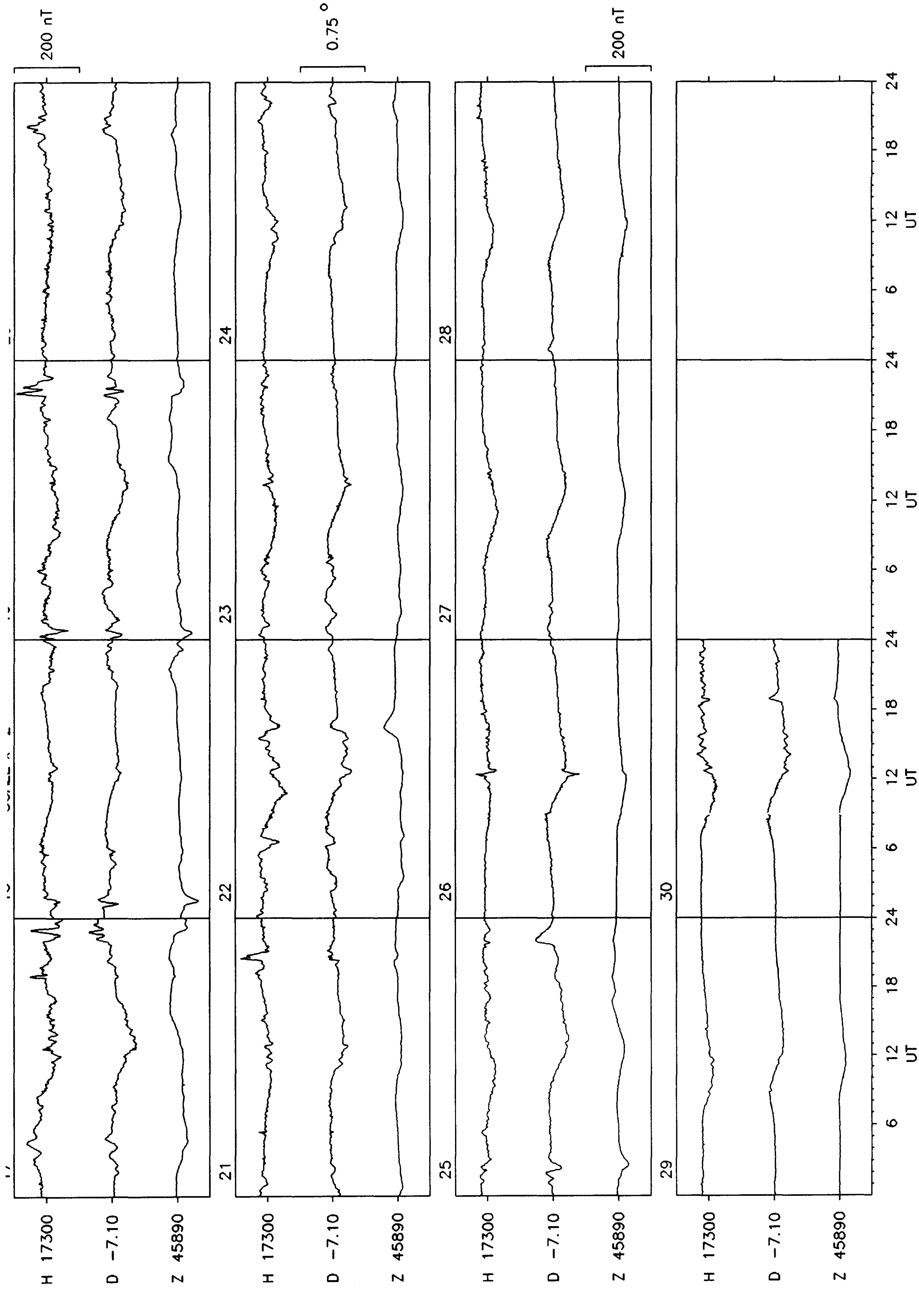
200 nT
0.75 °
200 nT
H 17300
D −7.10
Z 45890
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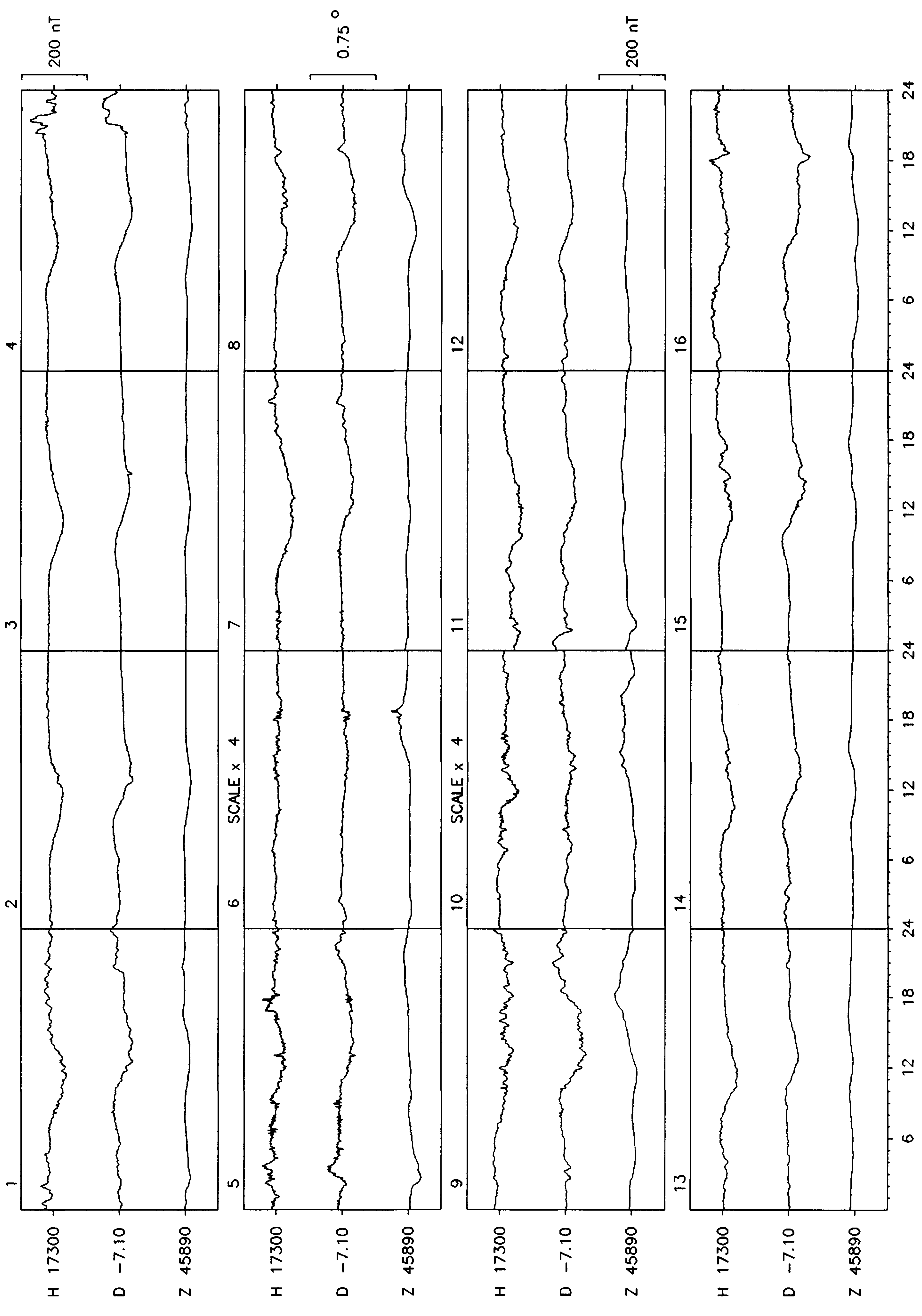
200 nT
0.75 °
200 nT
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SCALE x 4
SCALE x 4
H 17300
D −7.10
Z 45890
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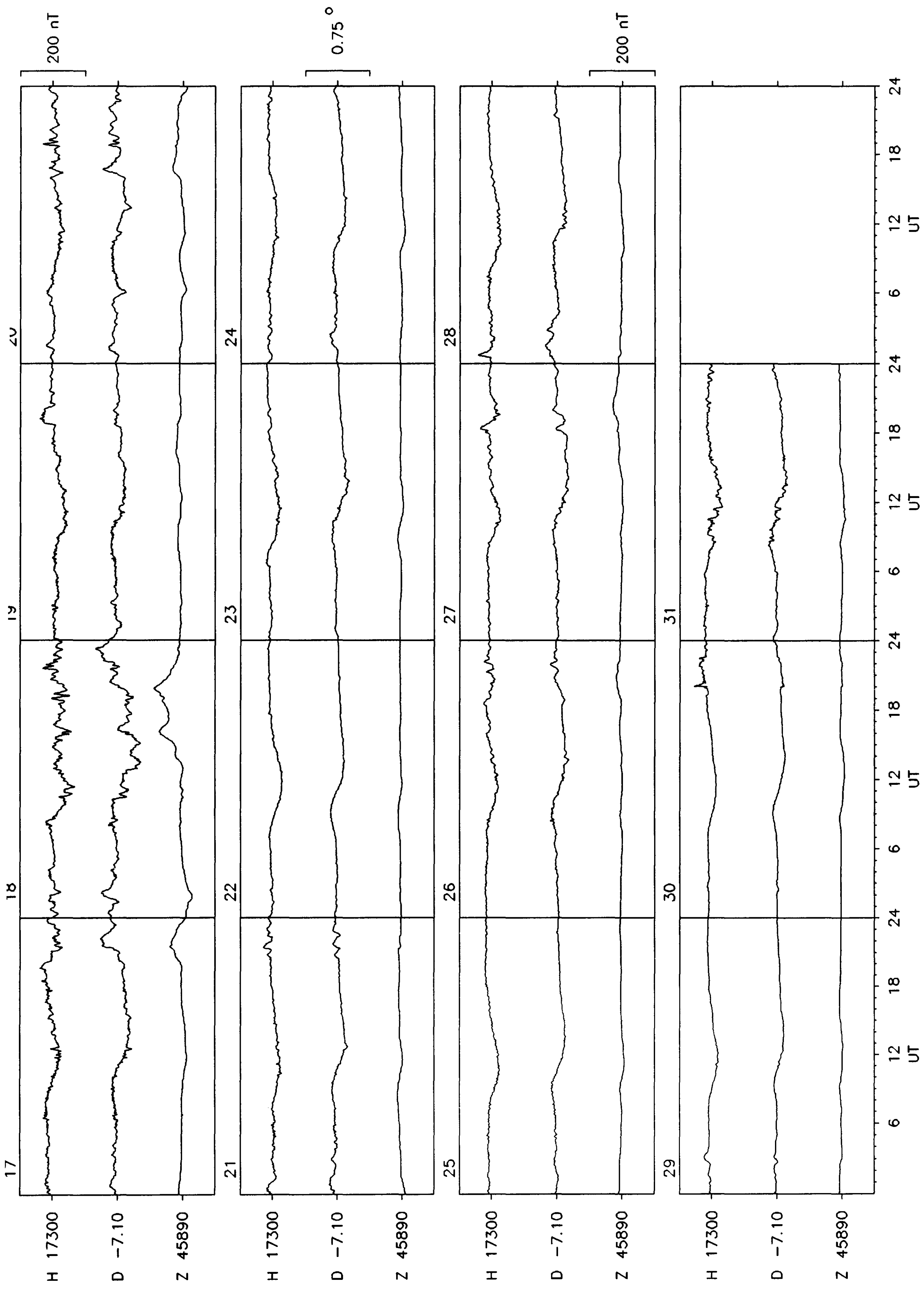
H 17300
D −7.10
Z 45890
200 nT
0.75 °
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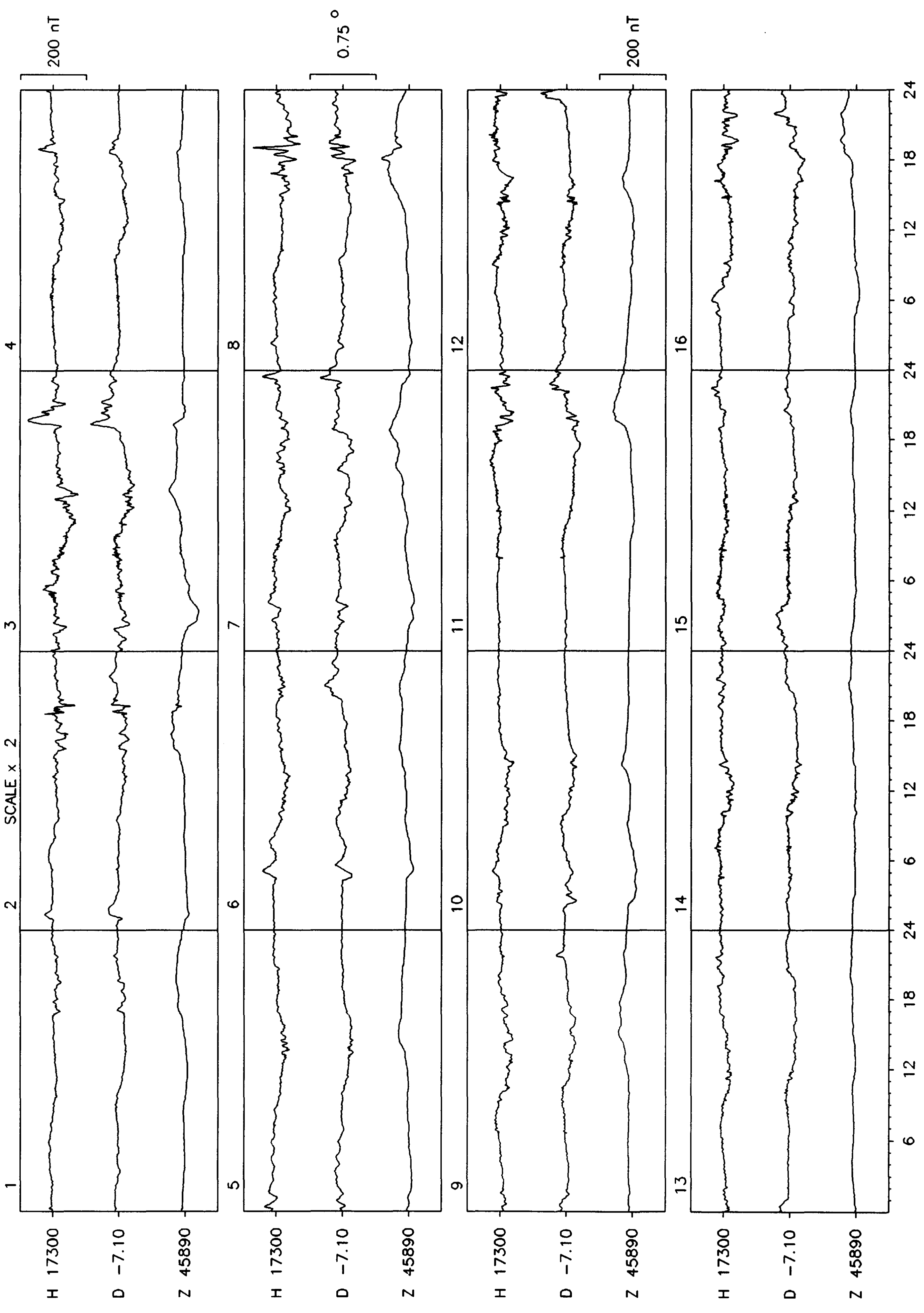
200 nT
0.75 °
200 nT
SCALE x 2
H 17300
D −7.10
Z 45890
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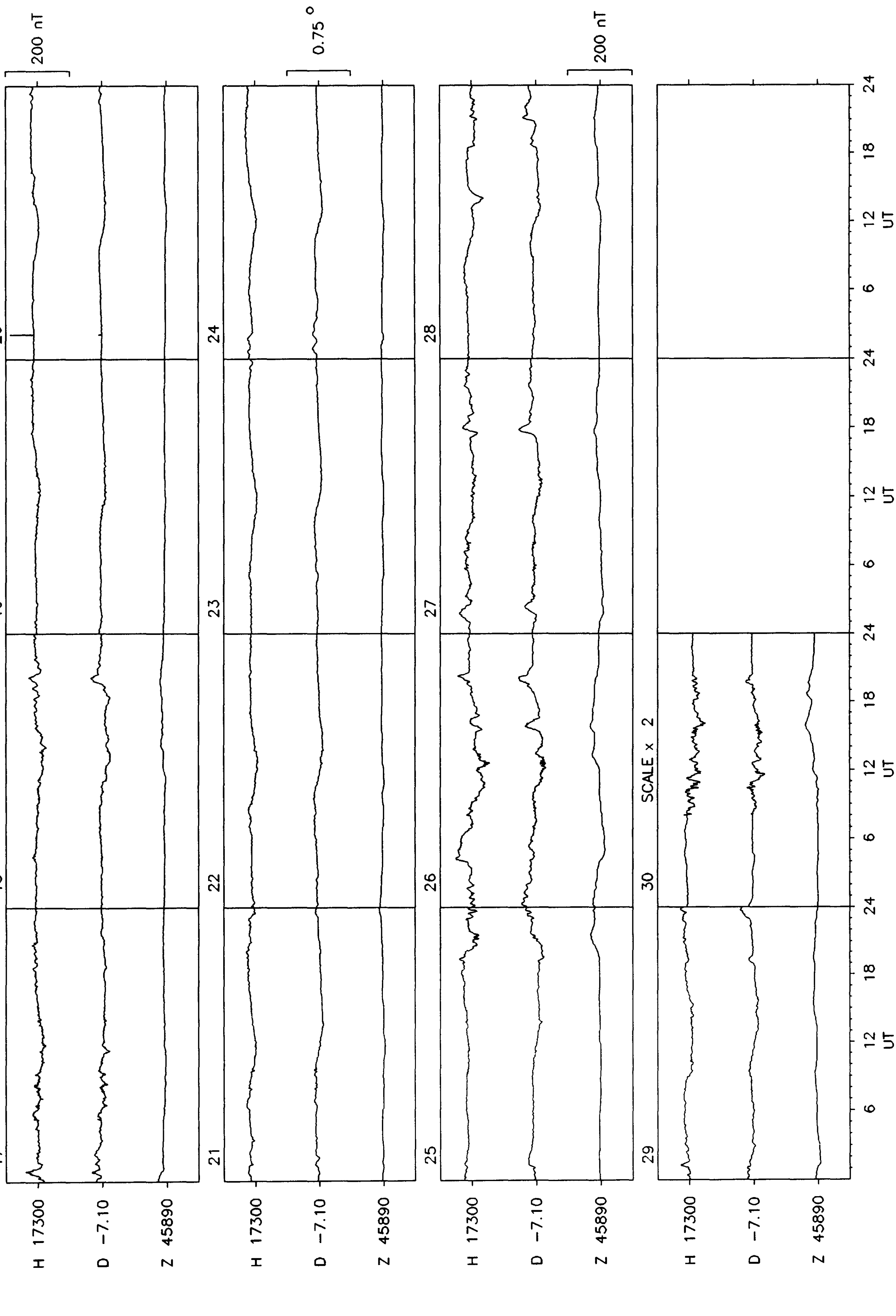
200 nT
0.75 °
200 nT
H 17300
D −7.10
Z 45890
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SCALE x 2
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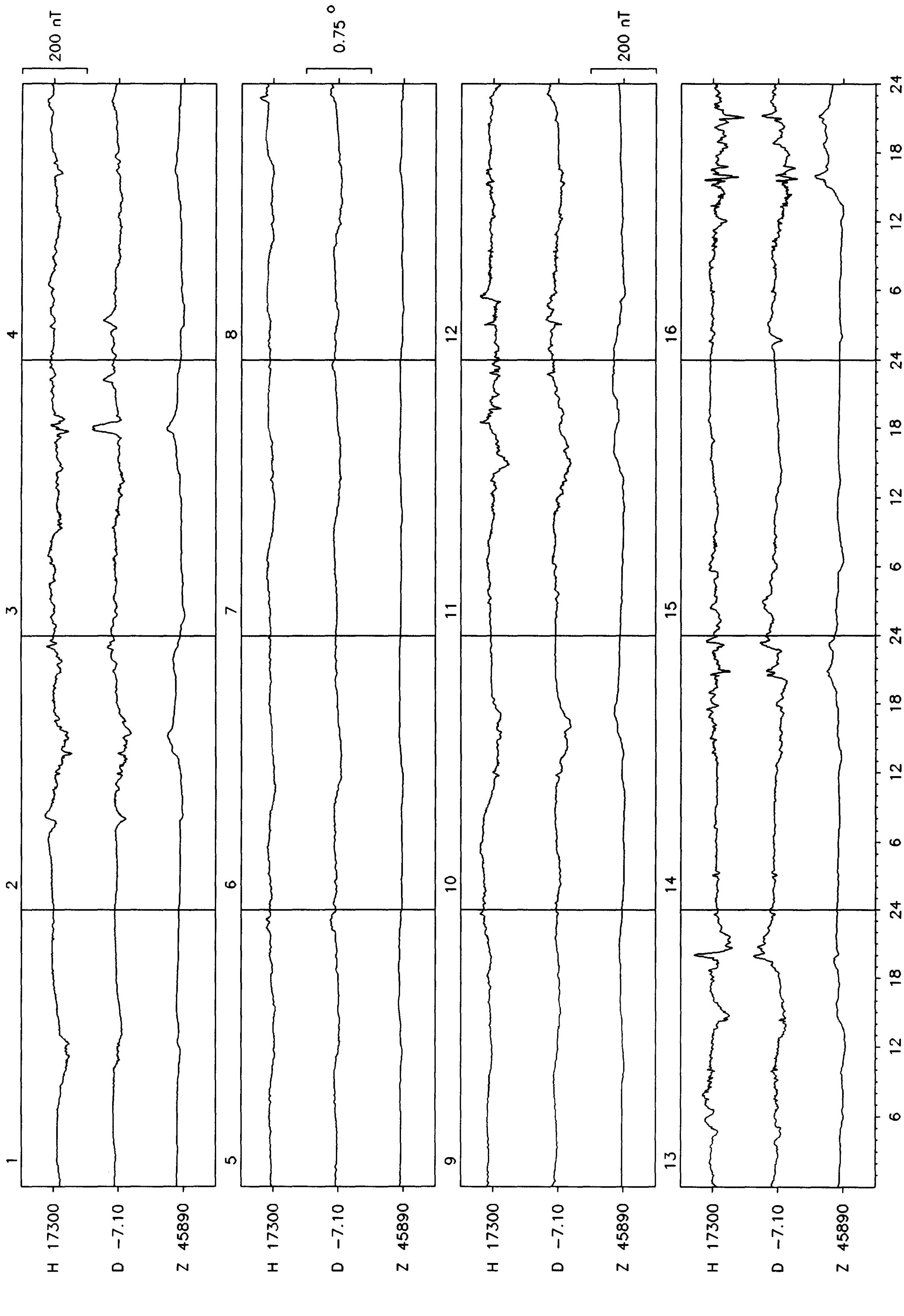
UT


200 nT
0.75 °
200 nT
H 17300
D −7.10
Z 45890
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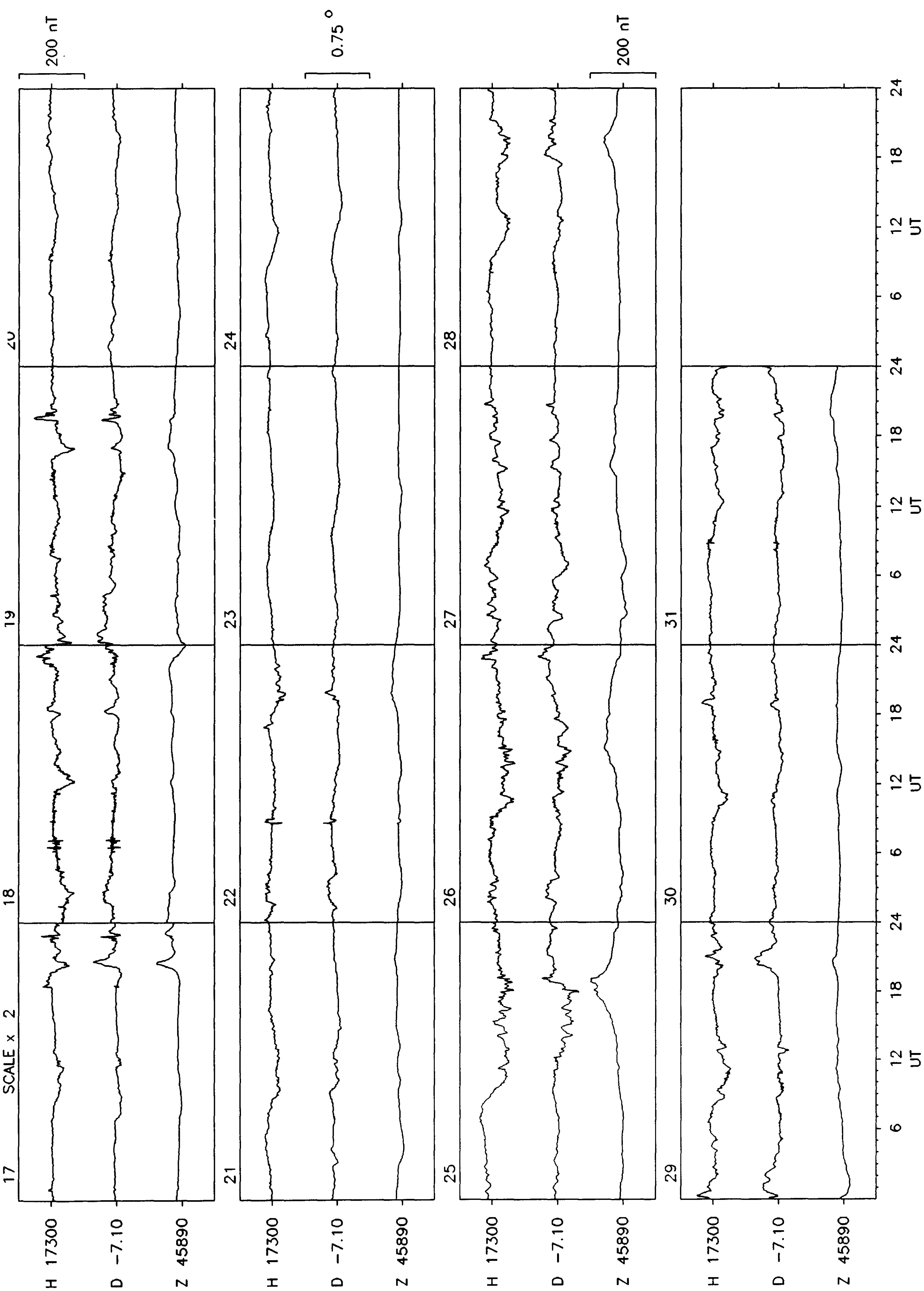
UT


SCALE x 2
200 nT
0.75 °
200 nT
H 17300
D −7.10
Z 45890
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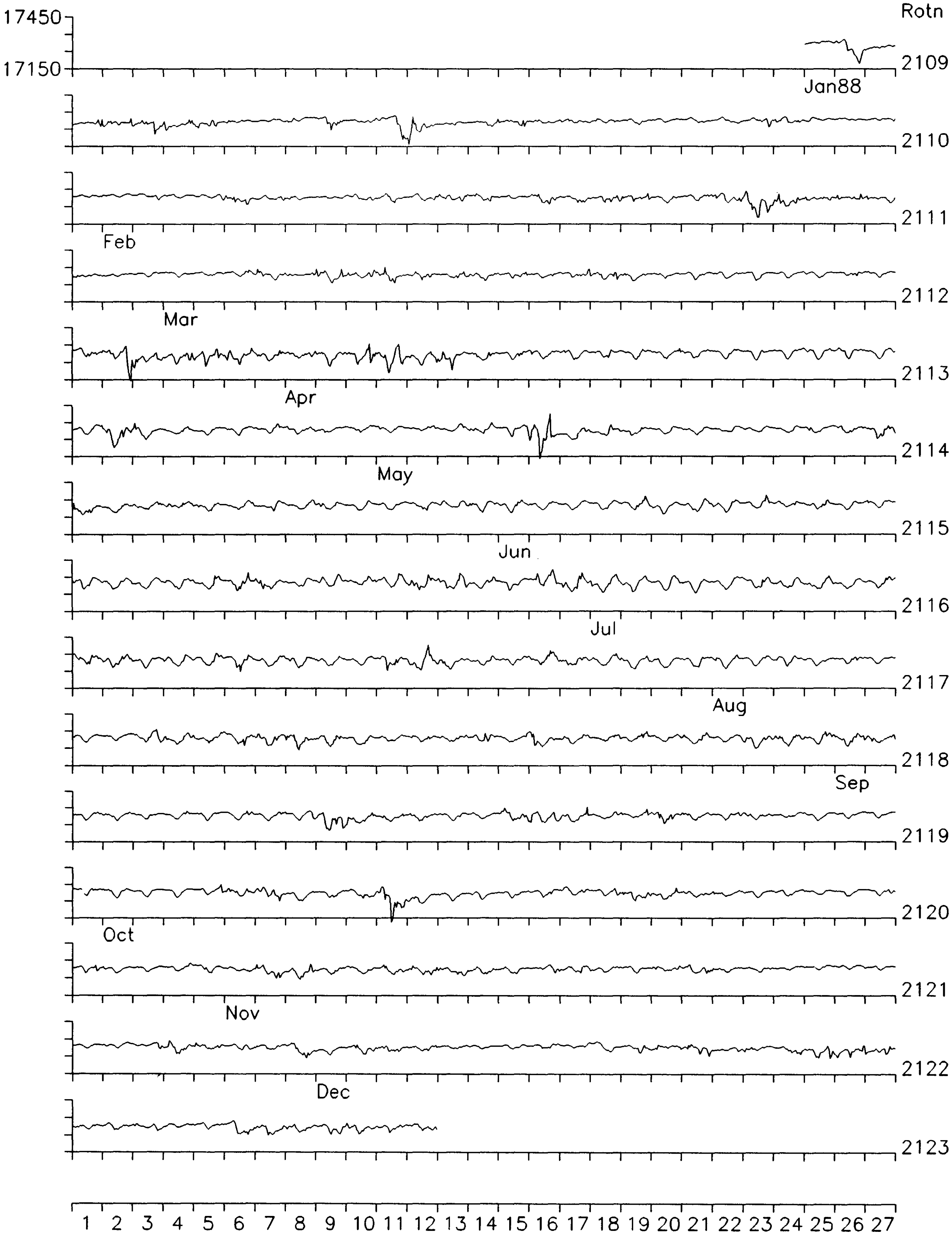
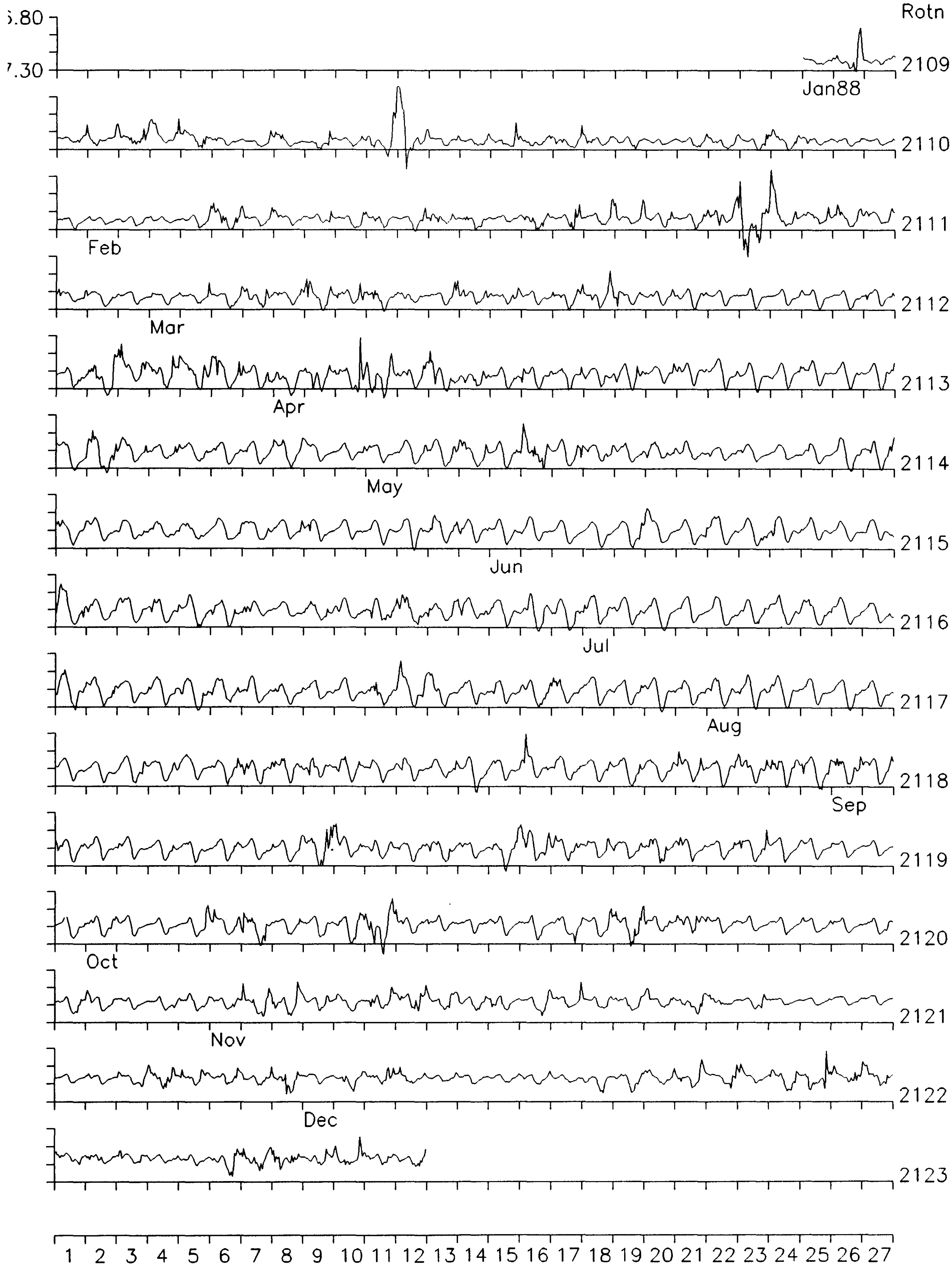
UT

Eskdalemuir Observatory: Horizontal Intensity (nT)

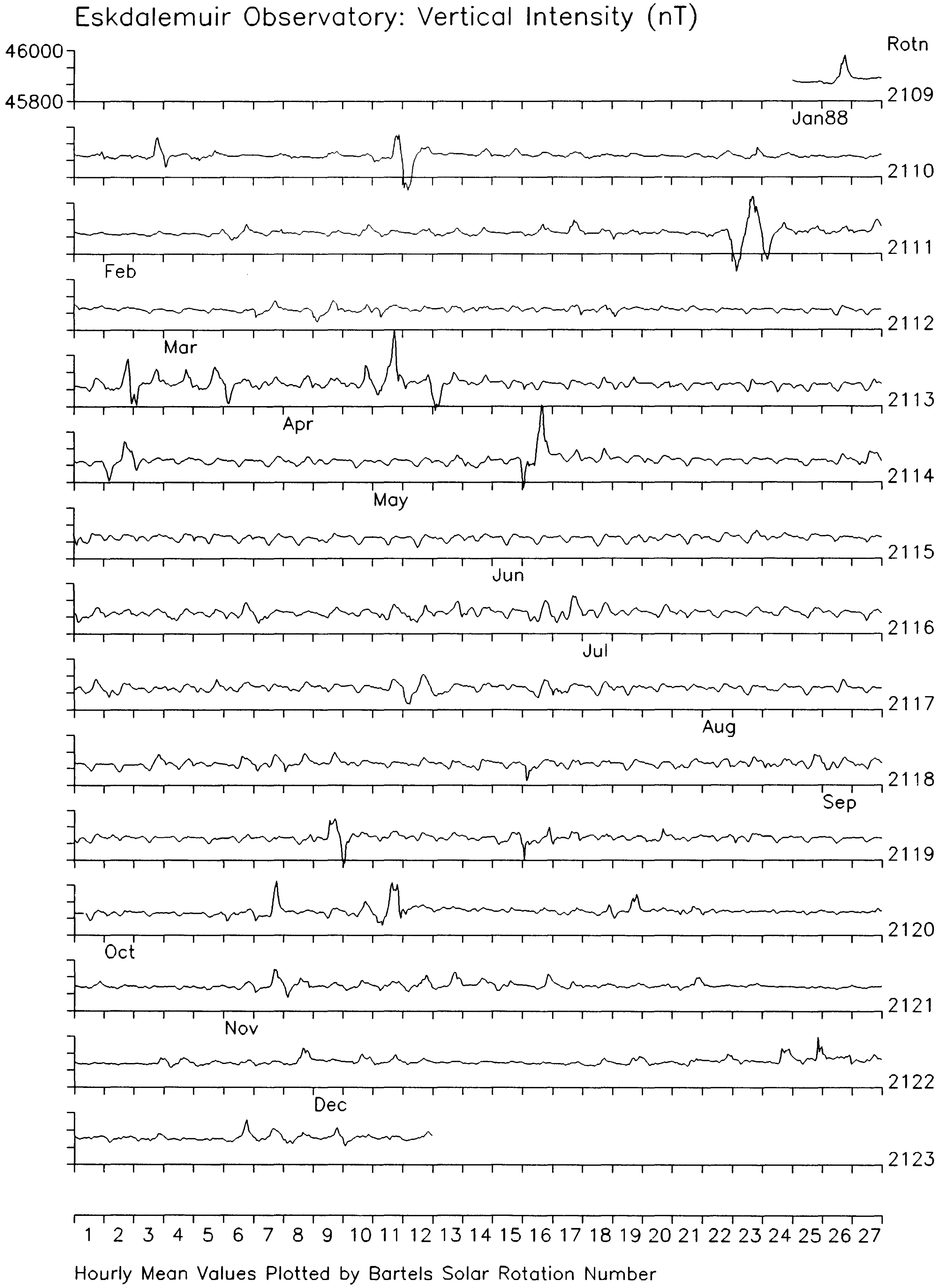


Hourly Mean Values Plotted by Bartels Solar Rotation Number

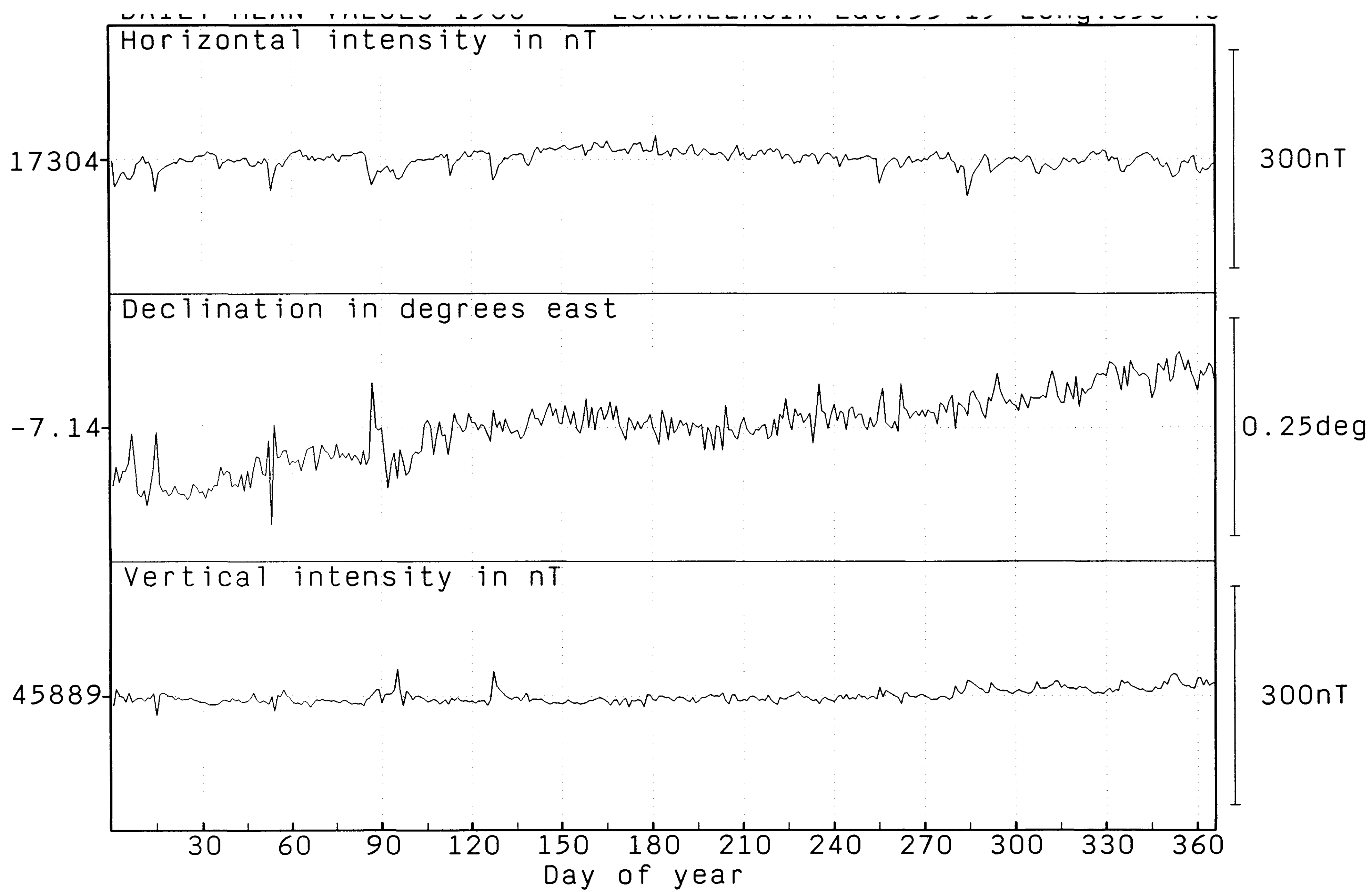
Eskdalemuir Observatory: Declination (degrees)



Hourly Mean Values Plotted by Bartels Solar Rotation Number



Eskdalemuir Observatory: Vertical Intensity (nT)
Rotn
46000
45800
2109
Jan88
2110
2111
Feb
2112
Mar
2113
Apr
2114
May
2115
Jun
2116
Jul
2117
Aug
2118
Sep
2119
2120
Oct
2121
Nov
2122
Dec
2123
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


Horizontal intensity in nT
17304
300nT
Declination in degrees east
-7.14
0.25deg
Vertical intensity in nT
45889
300nT
30 60 90 120 150 180 210 240 270 300 330 360
Day of year

Monthly and annual mean values for Eskdalemuir 1988

Month	D	I	H	X	Y	Z	F
	° ′	° ′	nT	nT	nT	nT	nT
Jan	-7 12.5	69 20.9	17295	17158	-2170	45886	49037
Feb	-7 11.7	69 20.5	17300	17164	-2167	45883	49036
Mar	-7 10.3	69 20.2	17304	17169	-2160	45883	49038
Apr	-7 9.7	69 20.6	17300	17165	-2157	45887	49040
May	-7 8.3	69 19.9	17310	17176	-2151	45886	49042
Jun	-7 8.2	69 19.1	17320	17186	-2152	45882	49042
Jul	-7 8.7	69 19.7	17313	17179	-2153	45886	49044
Aug	-7 8.1	69 20.0	17309	17175	-2150	45886	49042
Sep	-7 7.8	69 20.5	17302	17168	-2148	45888	49041
Oct	-7 6.9	69 20.9	17298	17165	-2143	45896	49048
Nov	-7 5.8	69 20.8	17301	17168	-2137	45899	49051
Dec	-7 4.8	69 21.1	17298	17166	-2132	45904	49055
Annual	-7 8.6	69 20.4	17304	17170	-2152	45889	49043

ESKDALEMUIR OBSERVATORY K INDICES 1988

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0001 2122	2000 0001	2101 1012	3222 2343	2112 2222	1122 3331	4332 3333	2331 3231	3433 4333	3222 3232	1111 1222	1002 2000
2	2214 3454	1101 1132	0011 1204	2243 3323	0212 2223	2201 2222	2223 3231	2212 2222	3322 2223	2121 2110	4233 3464	1132 3323
3	1122 1111	2001 0100	2111 2333	2143 2473	1221 1333	0011 1210	0212 3332	2322 2311	3222 3232	0011 1210	3333 4243	2222 2443
4	2110 1235	1011 1223	4332 2342	5445 5563	3221 3342	0001 3211	1112 1210	1111 1101	2222 2222	0011 2234	2122 2232	2321 2212
5	2222 3014	3334 3333	2211 1133	4322 3235	0223 3226	1122 3343	0110 2232	0121 2323	2111 2110	3333 3323	3212 2211	0000 0112
6	3123 2554	3222 2214	4332 3352	5535 4422	6565 6654	3322 2212	3322 3322	1221 1112	1001 2221	5344 4452	0322 2143	1001 0011
7	6322 2244	2212 1001	3122 1444	1233 3322	1223 3334	1122 2323	1232 2322	2112 2221	1122 2111	2122 2223	3322 3344	0000 1101
8	3323 3432	2000 1132	3443 3222	1021 3331	2222 3433	1222 3221	2222 3332	0111 1221	0111 3232	1012 2231	3222 1453	1101 1203
9	2322 1011	1122 2243	3323 2331	4222 1312	2132 3332	0111 3332	2111 1212	2222 4342	0111 2222	2223 3333	3113 2223	2000 1112
10	1000 1133	2233 3210	1123 3344	1223 4323	3222 2322	3331 1311	1112 2332	3212 1333	2022 2233	4356 6444	3322 2210	2112 2310
11	3321 1101	0022 2144	3322 3232	2112 3312	2222 2321	1222 3321	3334 4333	2122 1233	3343 4545	4223 2212	0022 1344	1212 3343
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13	0011 1123	1323 2322	2011 1222	2213 3223	2211 2220	3211 3112	2021 2222	3333 3433	2222 3232	1212 2111	3112 1222	2332 3353
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16	1011 2102	1112 3442	3323 1222	1111 3211	2323 3412	2212 3222	3333 4333	2322 2231	1212 3211	2222 1342	0232 3333	3223 3434
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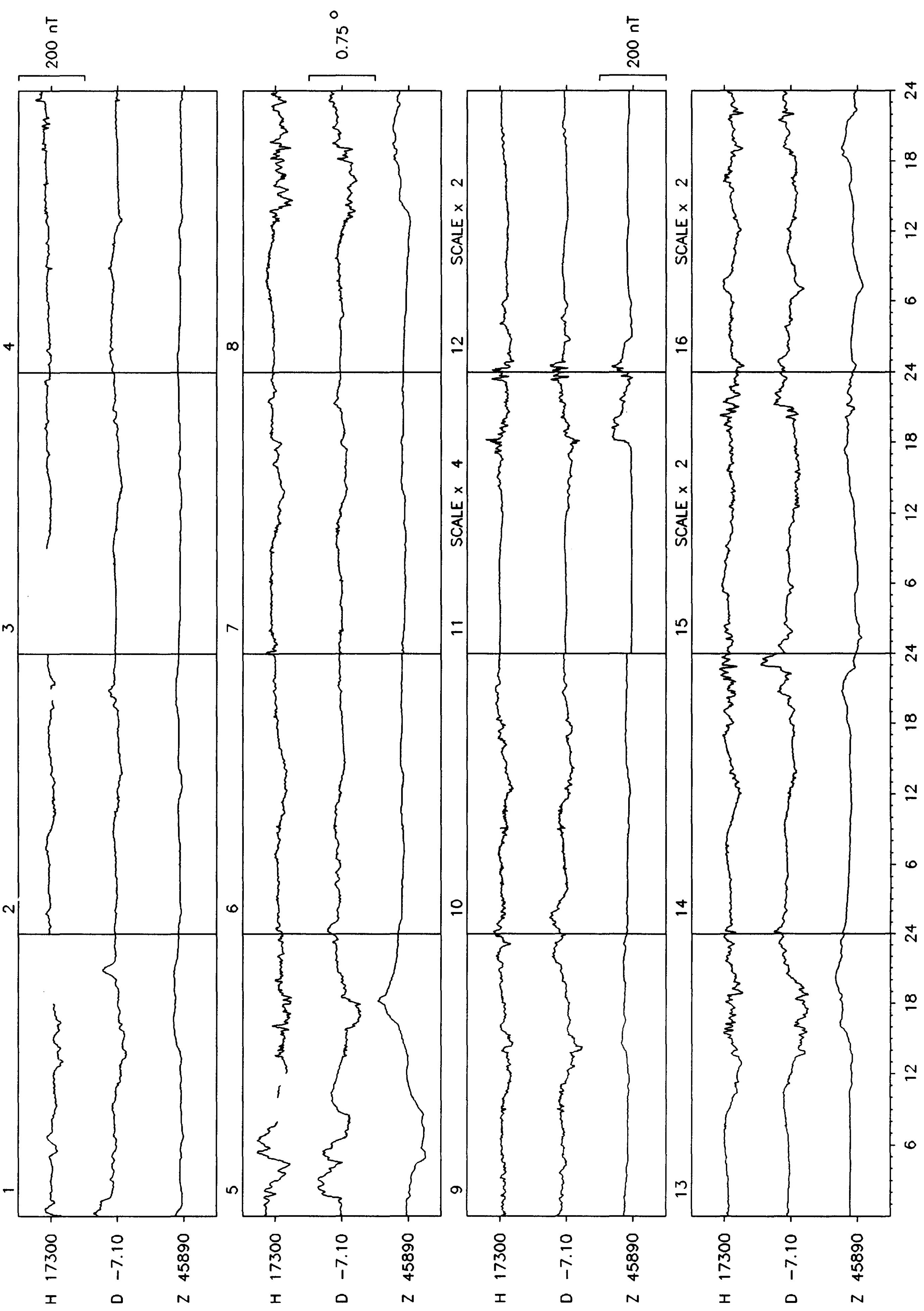
22	2112 2221	6554 6655	2110 1111	3443 4444	3322 2320	2323 3332	4423 4444	4532 3221	3333 3422	2011 1110	1011 1100	3332 1232
23	1001 1000	5532 3341	1011 2221	4432 3233	1101 2223	2312 3333	3333 3112	2222 2233	3332 3122	1122 2210	0100 0001	1101 1011
24	0011 2113	3311 2131	3111 2102	2112 2233	1122 3321	3423 3433	2222 3222	1123 3333	1113 3223	2122 1112	2100 0000	1010 1012
25	1122 1122	3322 2243	0122 3332	0101 3331	1112 1233	3333 3543	2322 3122	1223 4332	3212 2224	1111 1111	2000 1133	2223 3353
26	1001 1243	3111 1332	3333 3466	2221 3111	2320 2310	4232 3453	3223 4434	2211 3323	1123 4222	0122 2132	3333 3331	3324 3333
27	3223 2232	2311 1113	5322 3454	1201 2233	0101 1221	4212 2331	3332 3322	4322 2332	2011 2201	1122 2242	3222 2432	3333 2332
28	1211 0000	1011 1121	3233 3355	3222 3333	1110 2121	2133 2321	2222 3343	1123 2223	2111 2221	3323 2112	0111 3132	1122 3332
29	1101 0201	0001 1110	3343 3553	2221 1001	1222 3322	1343 4443	2111 2233	3232 3323	1012 1000	2211 1000	2111 1223	4233 3144
30	0000 0012		4523 4324	1222 2222	2332 1333	3333 4432	2221 1222	3332 2223	0022 3232	0000 1132	3245 3331	2213 2132
31	0100 1100		3222 3243		3223 3232		1321 2312	3111 3434		2123 3222		1121 2233

ESKDALEMUIR 1989


H 17300
D −7.10
Z 45890
200 nT
0.75 °
SCALE x 4
SCALE x 2
SCALE x 2
SCALE x 2
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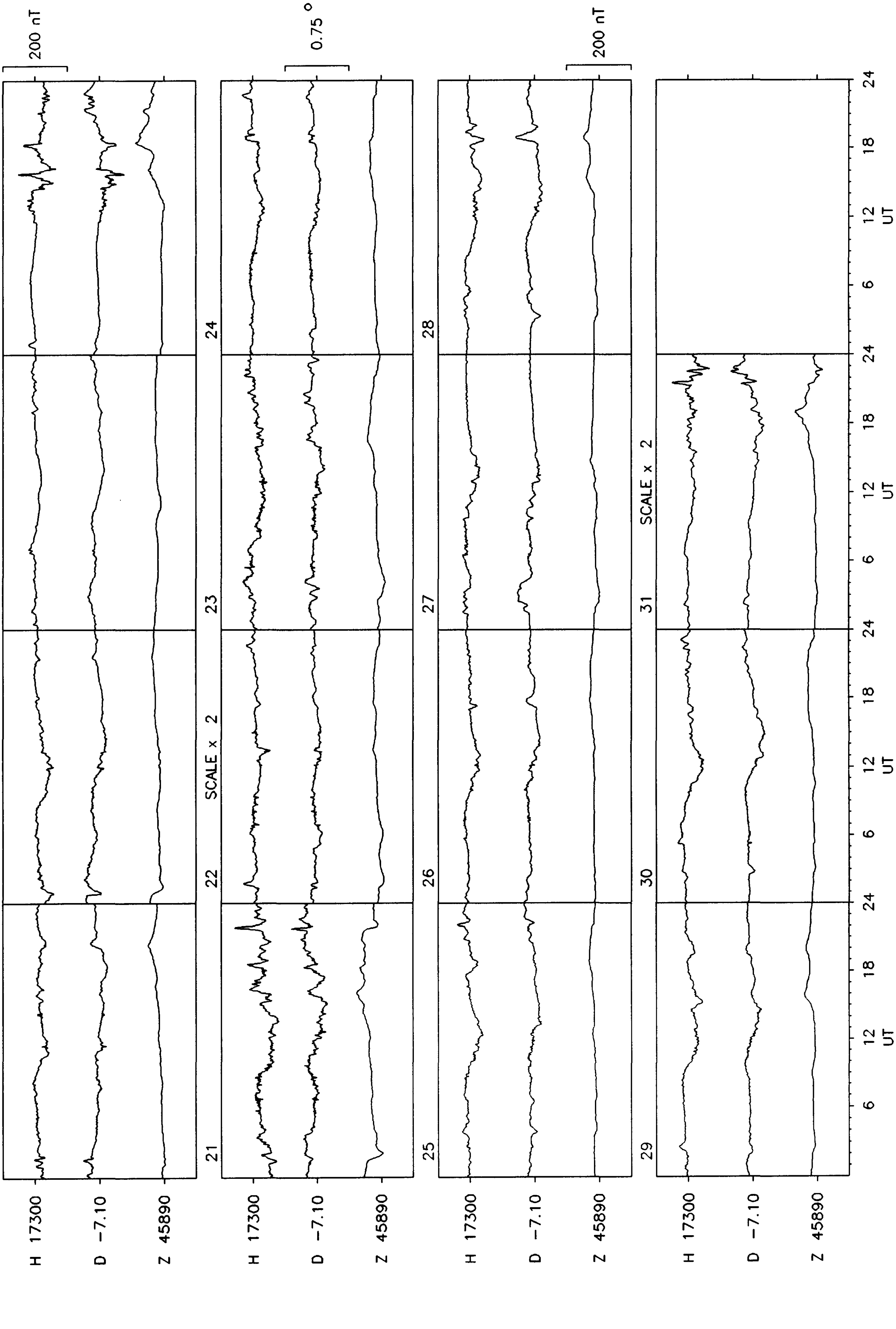
200 nT
0.75 °
200 nT
H 17300
D −7.10
Z 45890
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SCALE x 2
SCALE x 2
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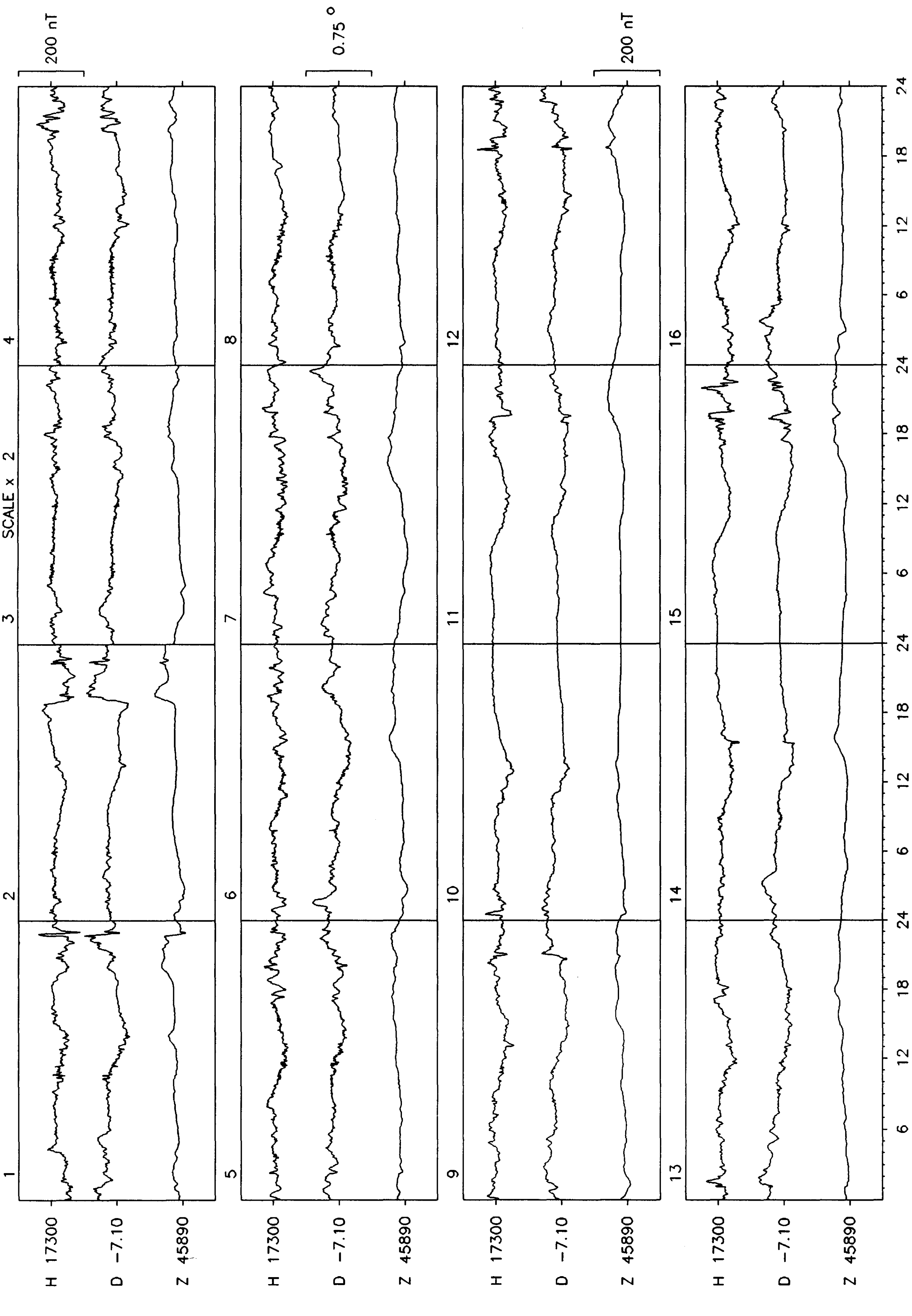
UT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0.75 °
200 nT
SCALE x 2
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H 17300
D −7.10
Z 45890
6
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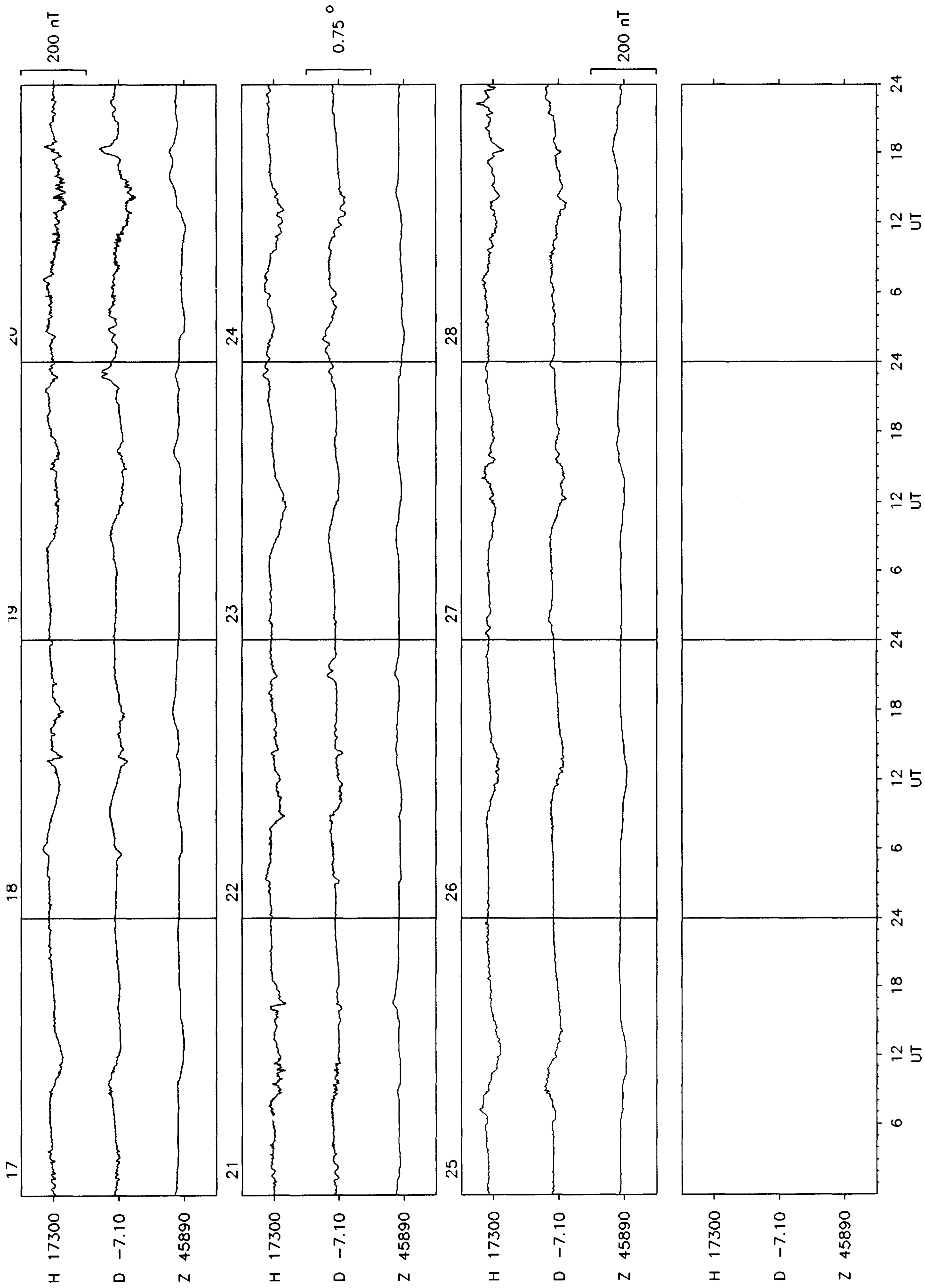
18
24



200 nT
0.75 °
200 nT
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H 17300
D −7.10
Z 45890
H 17300
D −7.10
Z 45890
H 17300
D −7.10
Z 45890
H 17300
D −7.10
Z 45890
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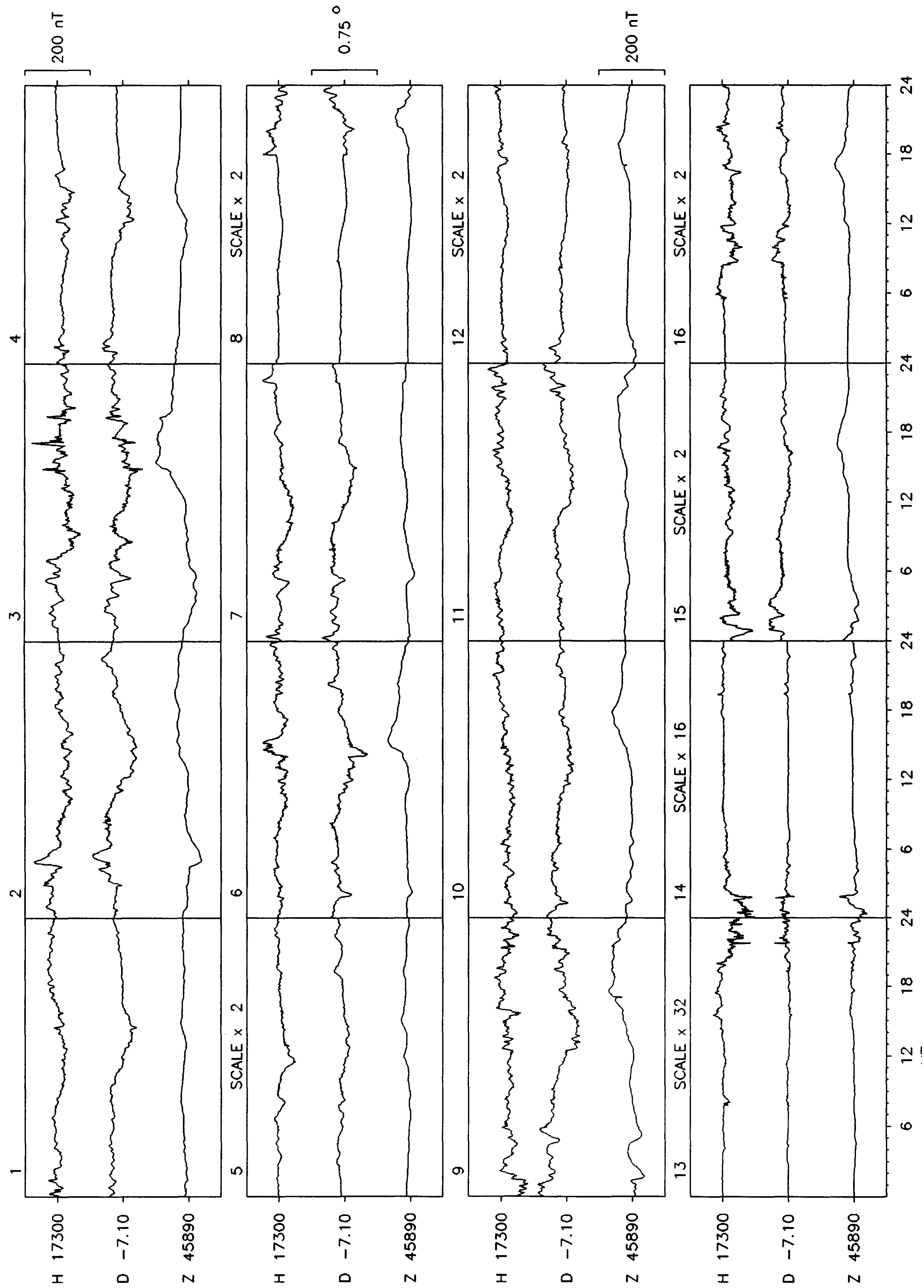
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0.75 °
200 nT
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Z 45890
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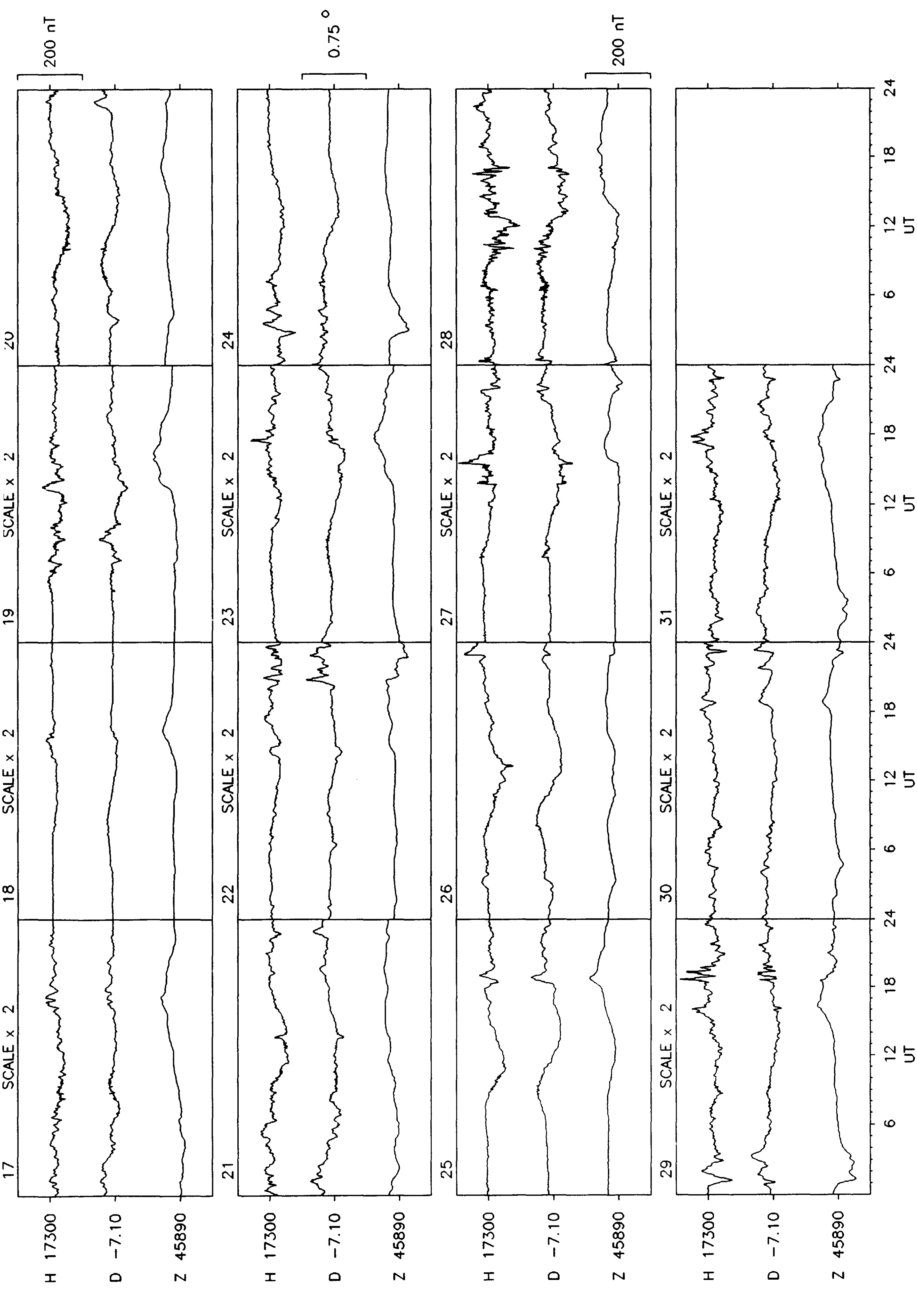
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 16
SCALE x 32



200 nT
0.75 °
200 nT
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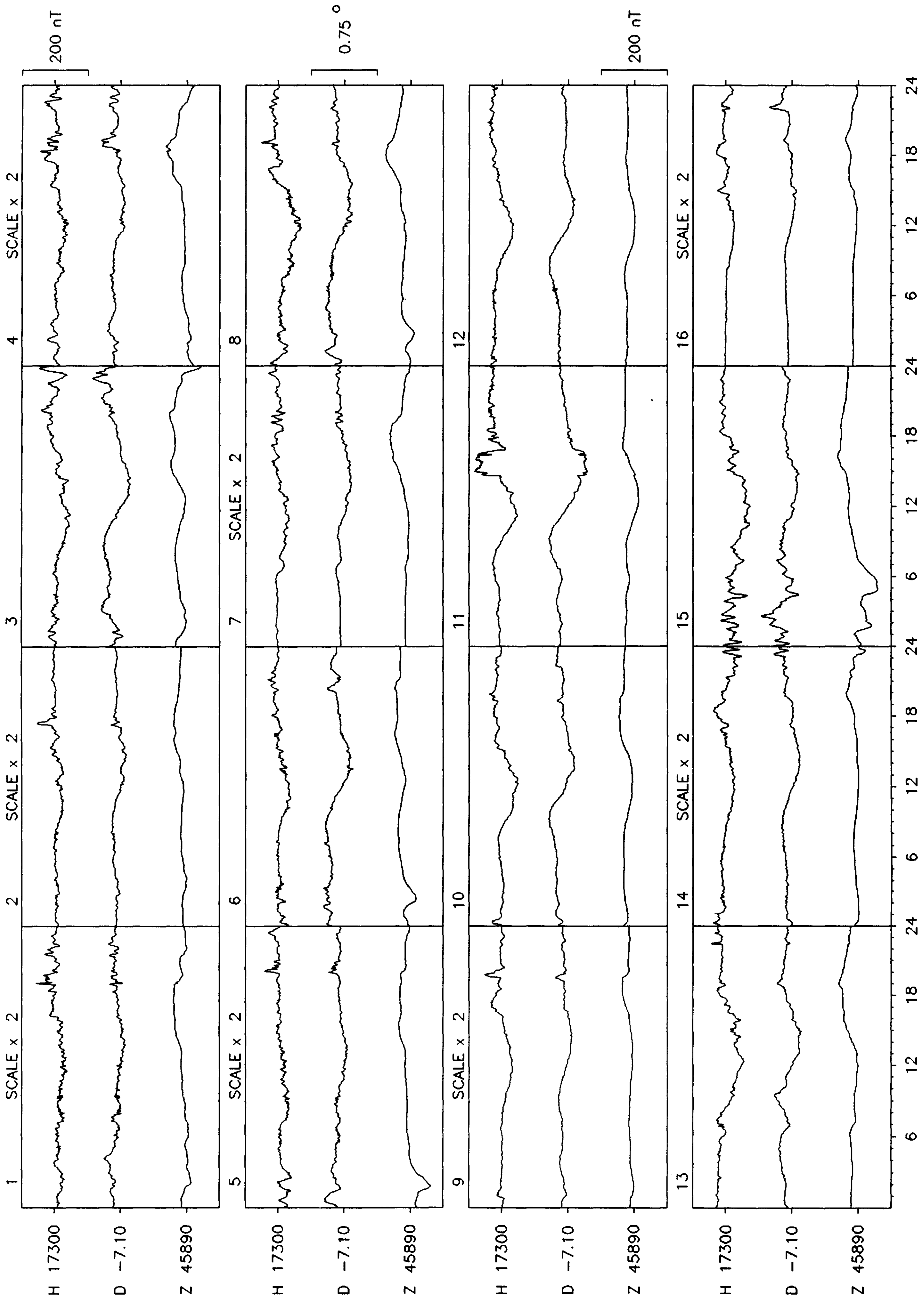
SCALE x 2
H 17300
D −7.10
Z 45890
6
12
18
24
UT



200 nT
0.75 °
200 nT
SCALE x 2
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16
H 17300
D -7.10
Z 45890
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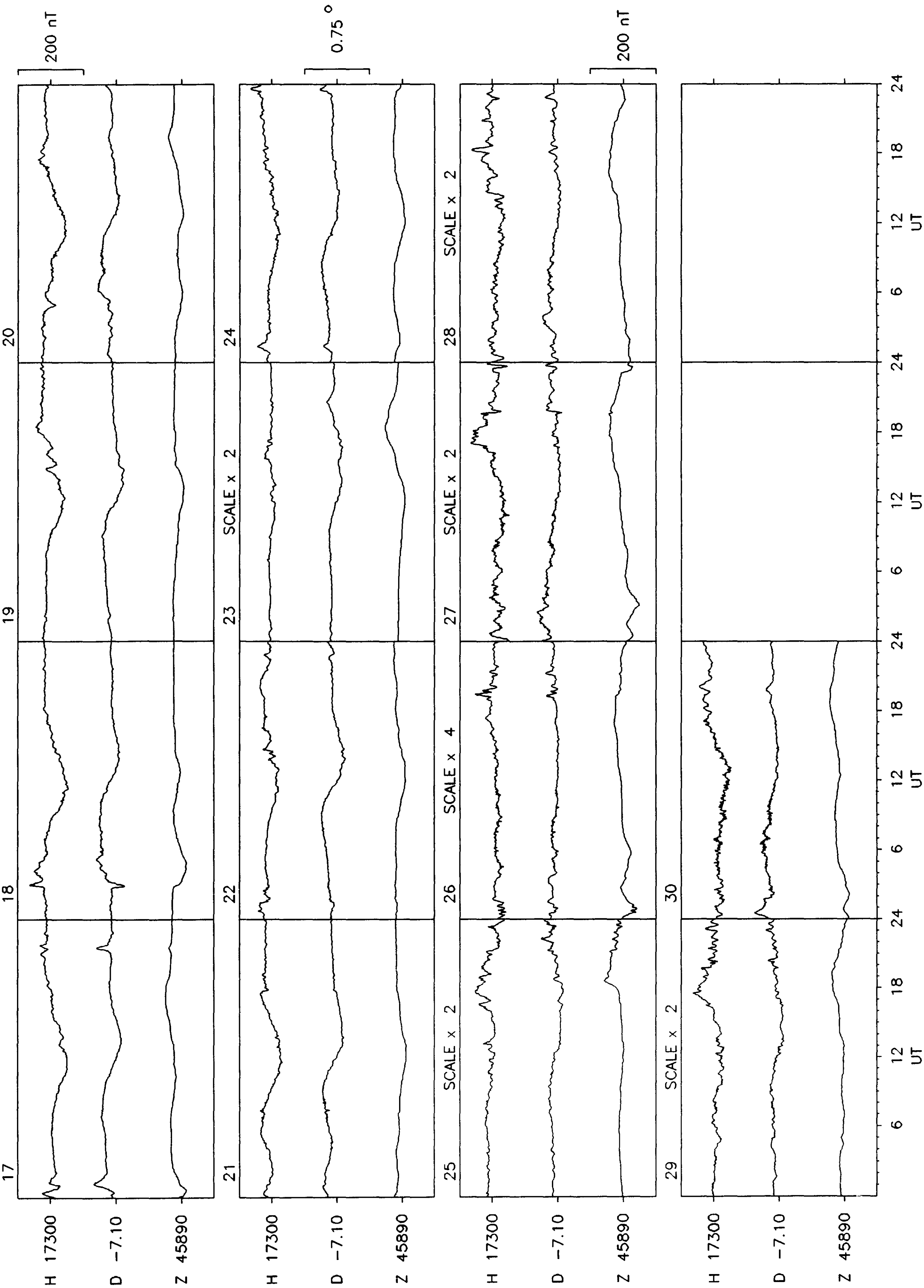
UT


200 nT
0.75 °
200 nT
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SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 4
SCALE x 2
SCALE x 2
H 17300
D −7.10
Z 45890
6
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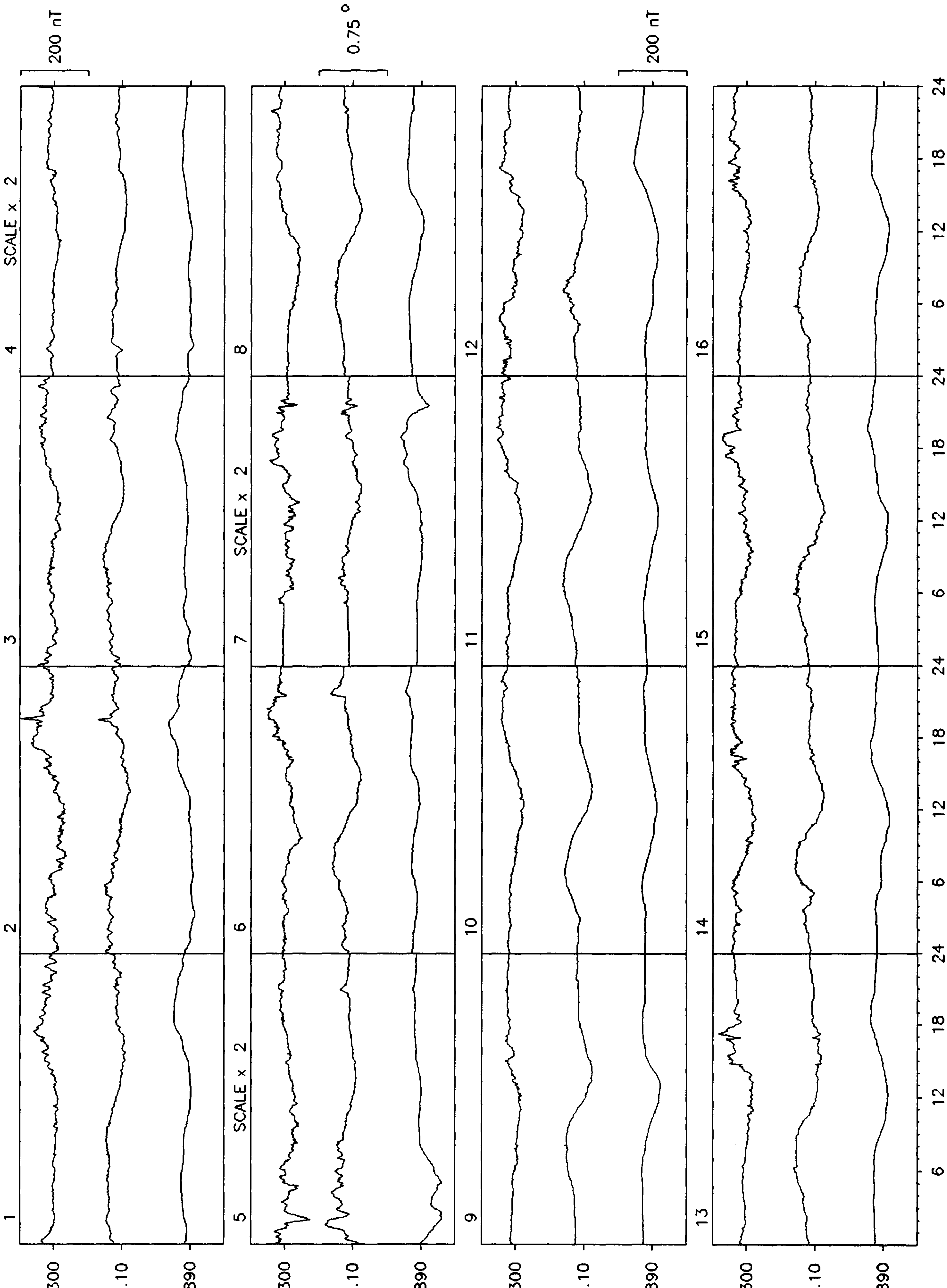
24
UT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0.75 °
200 nT
SCALE x 2
SCALE x 2
SCALE x 2
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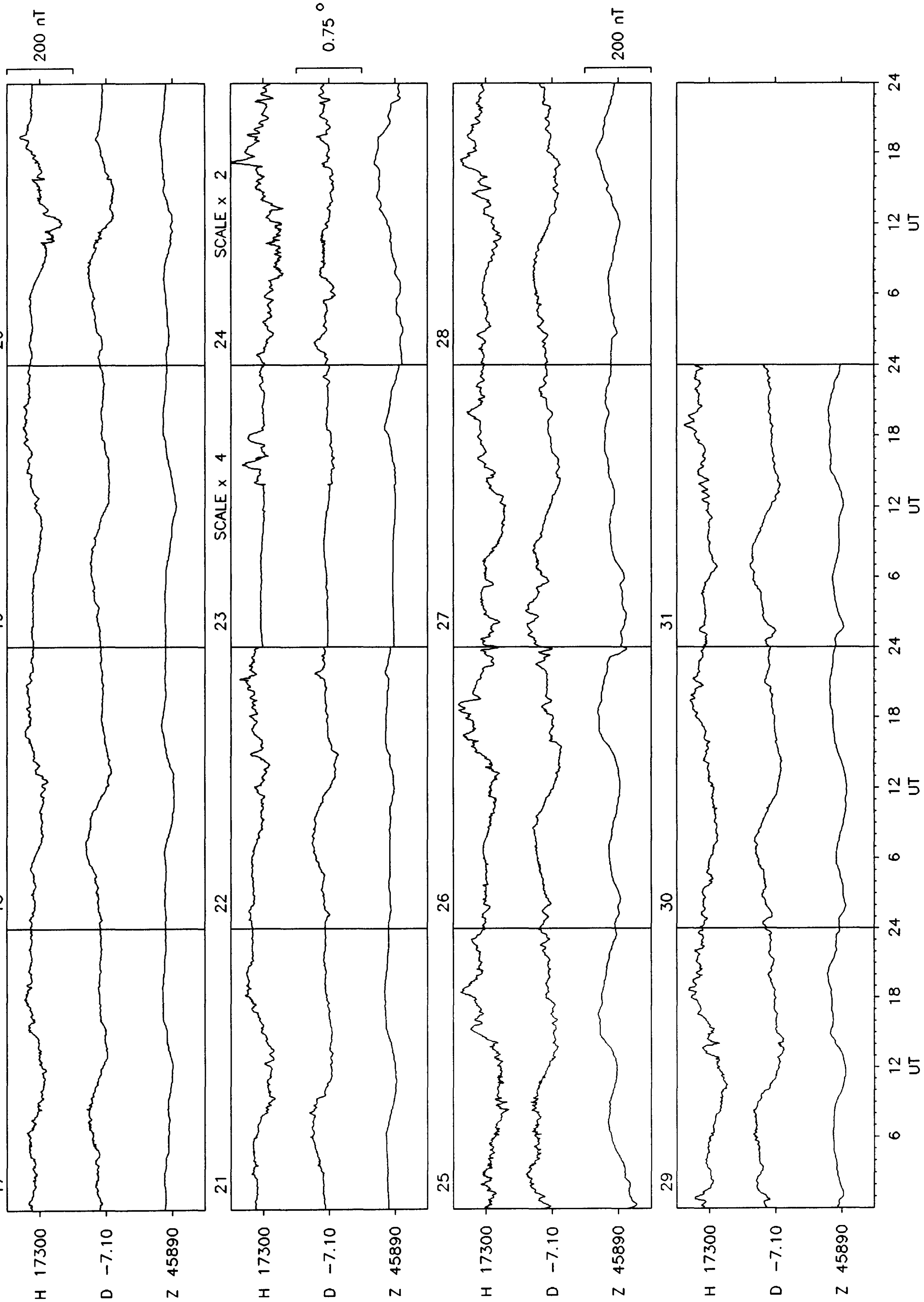
200 nT
0.75 °
200 nT
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SCALE x 4
SCALE x 2
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D −7.10
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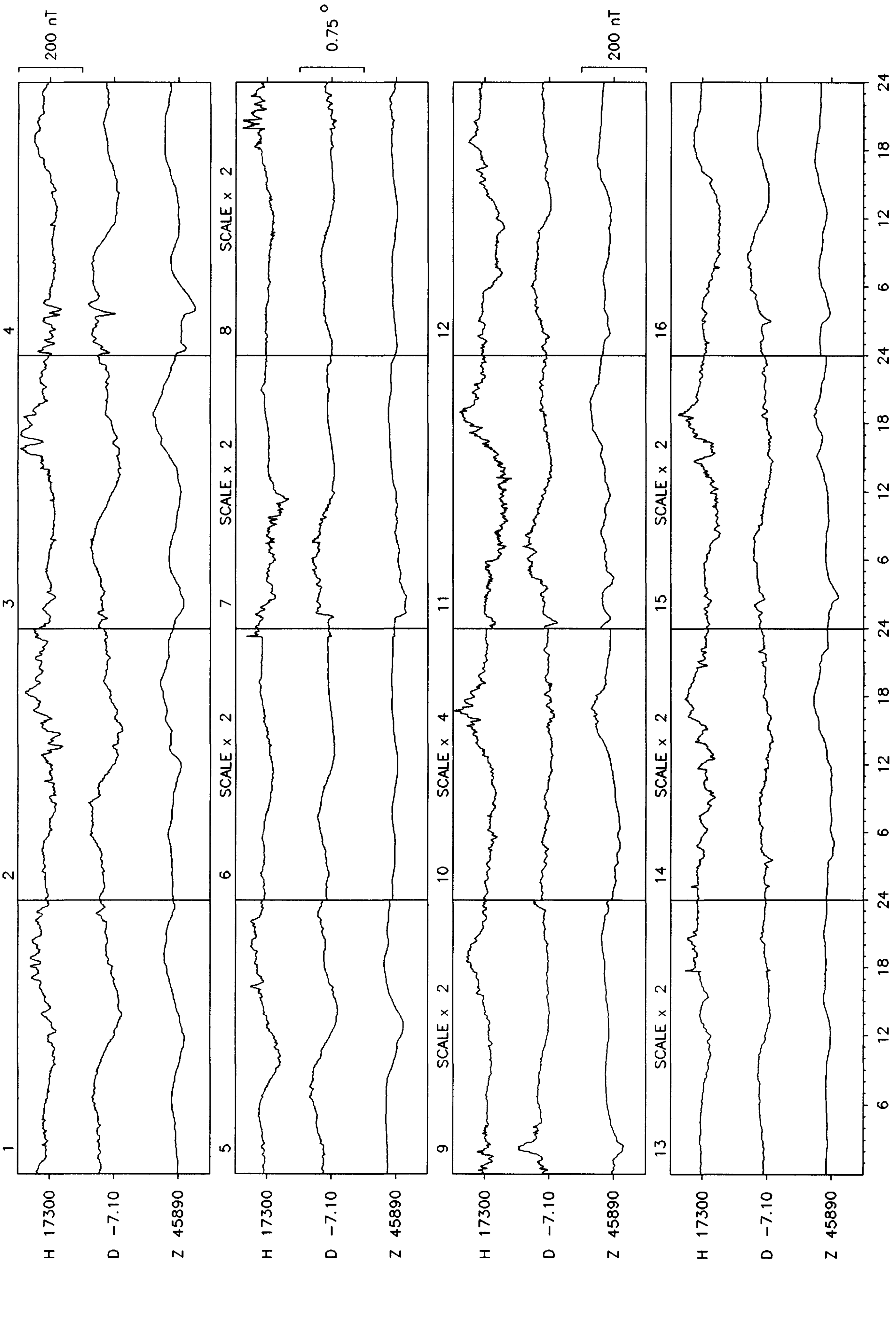
200 nT
0.75 °
200 nT
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SCALE x 2
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SCALE x 2
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SCALE x 4
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SCALE x 2
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SCALE x 2
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D -7.10
Z 45890
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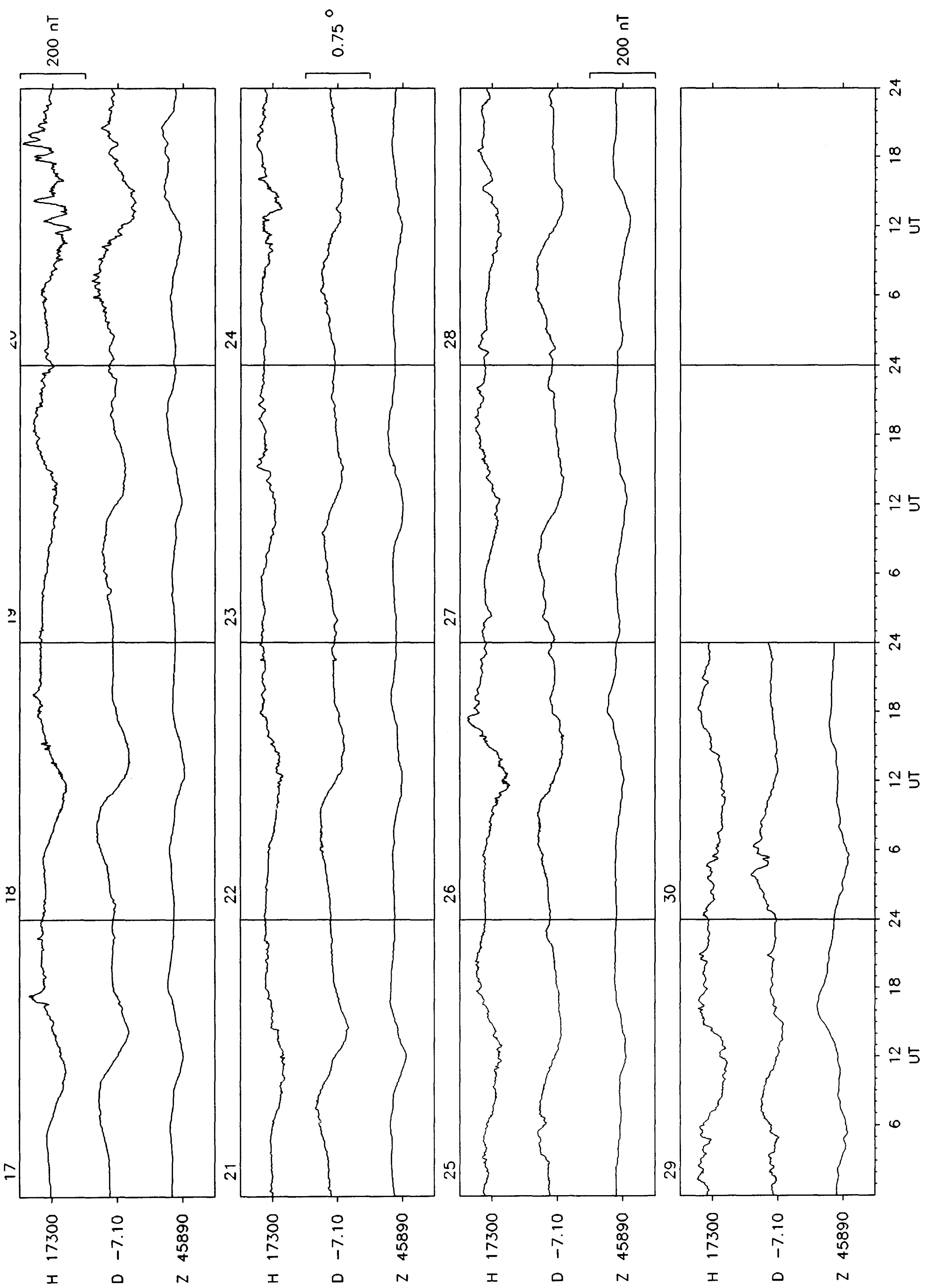
H 17300
D −7.10
Z 45890
200 nT
0.75 °
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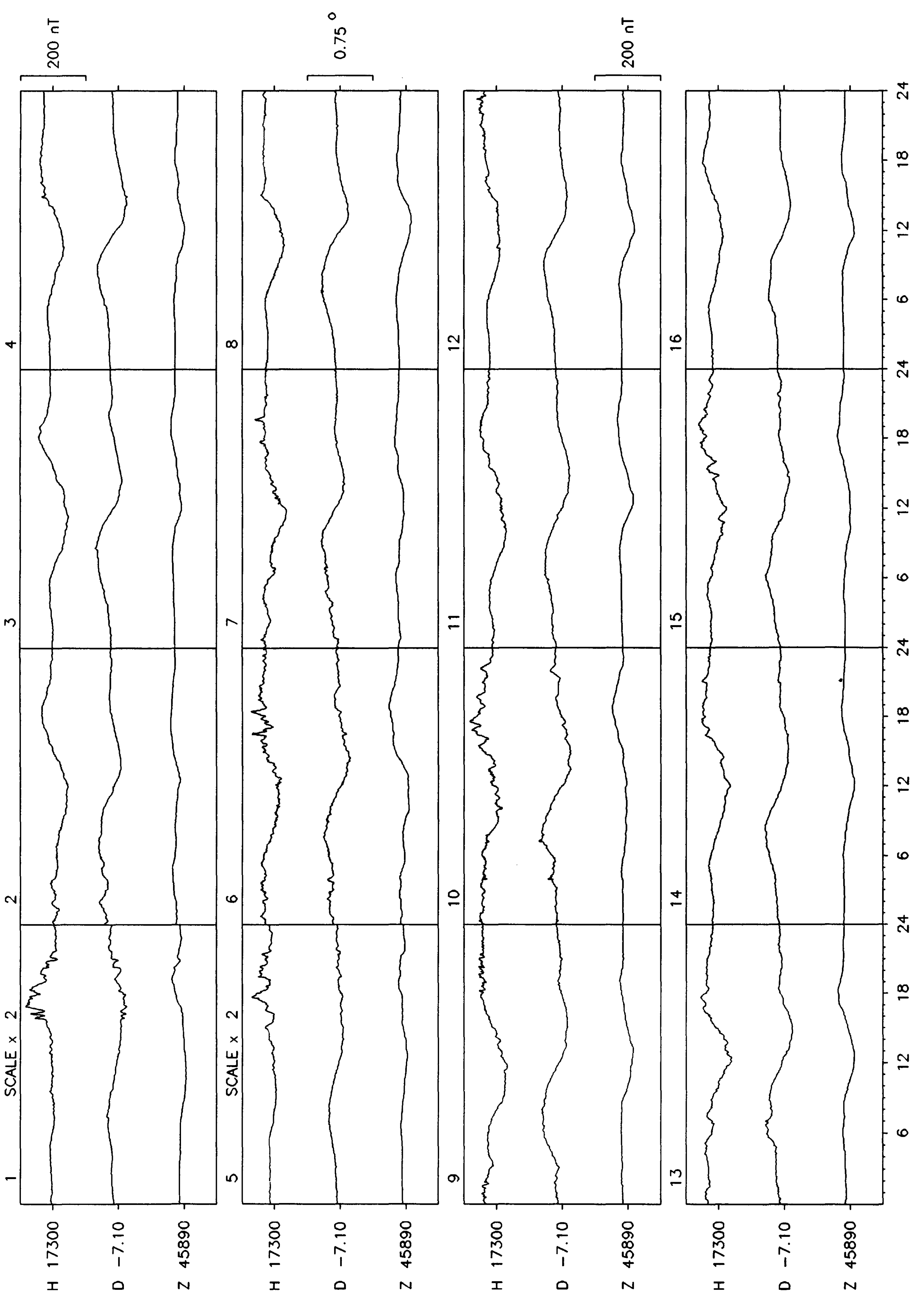
200 nT
0.75 °
200 nT
SCALE x 2
SCALE x 2
H 17300
D −7.10
Z 45890
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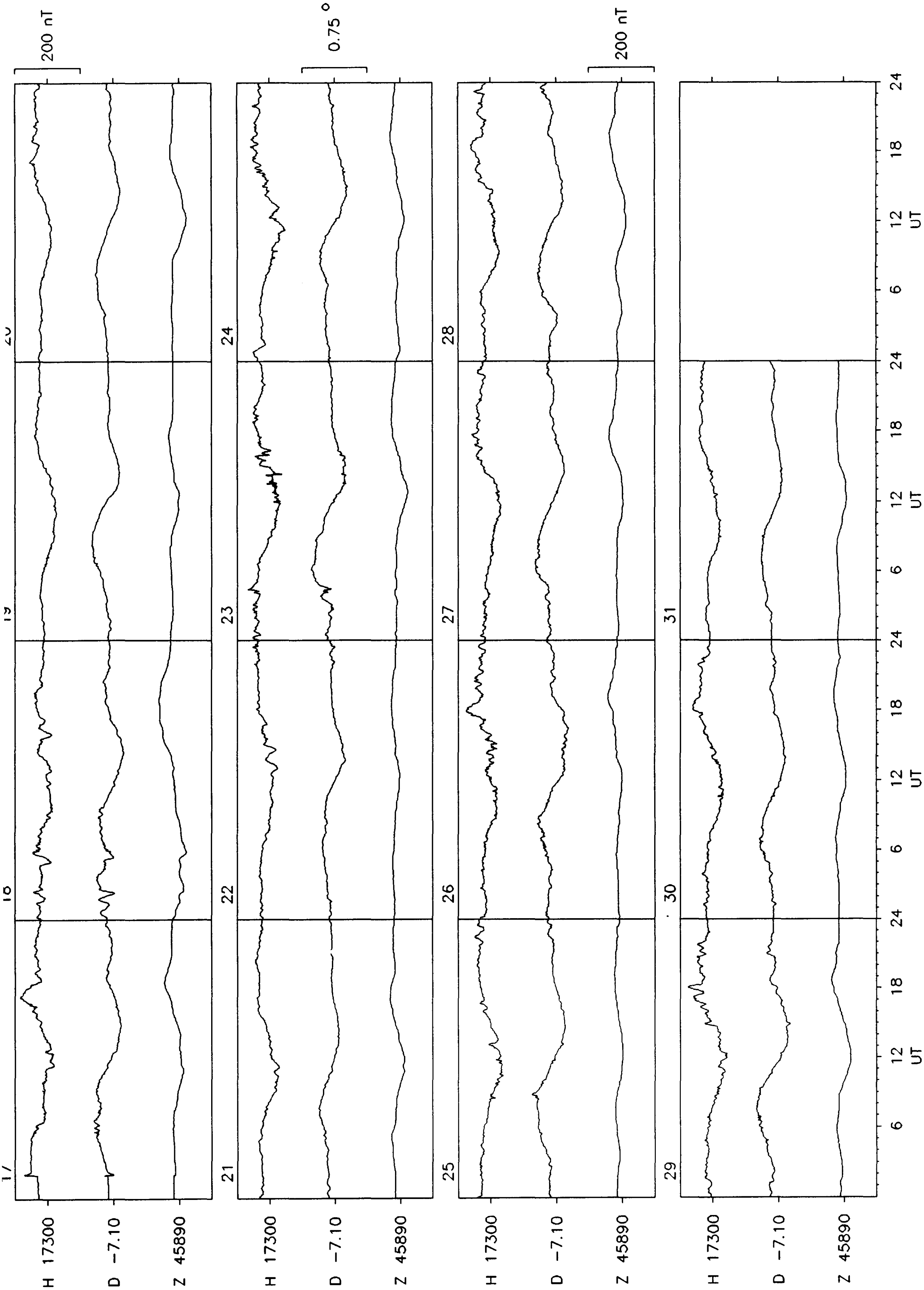
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200 nT
H 17300
D −7.10
Z 45890
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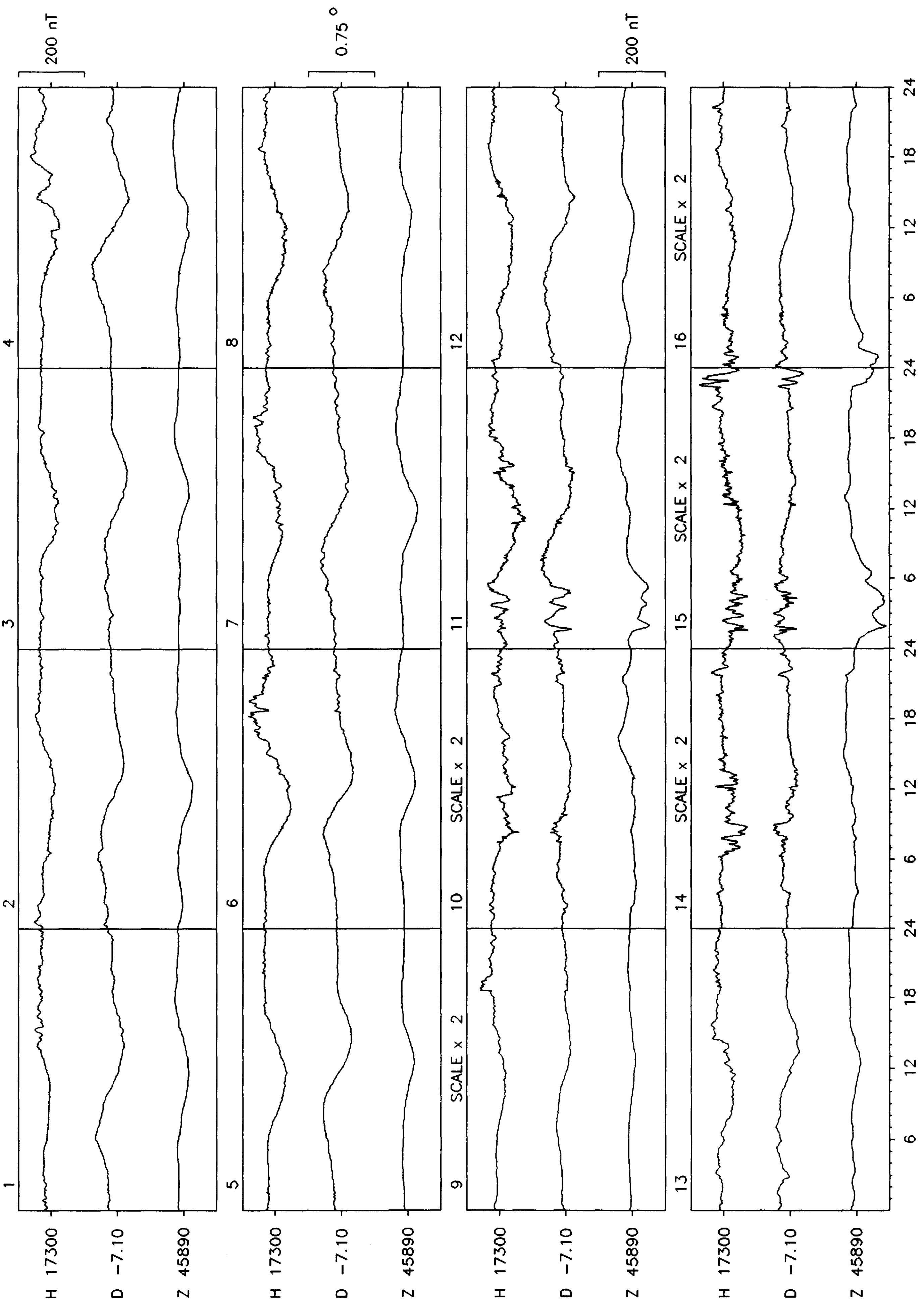
UT



H 17300
D −7.10
Z 45890
200 nT
0.75 °
200 nT
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SCALE x 2
SCALE x 2
SCALE x 2
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SCALE x 2
SCALE x 2
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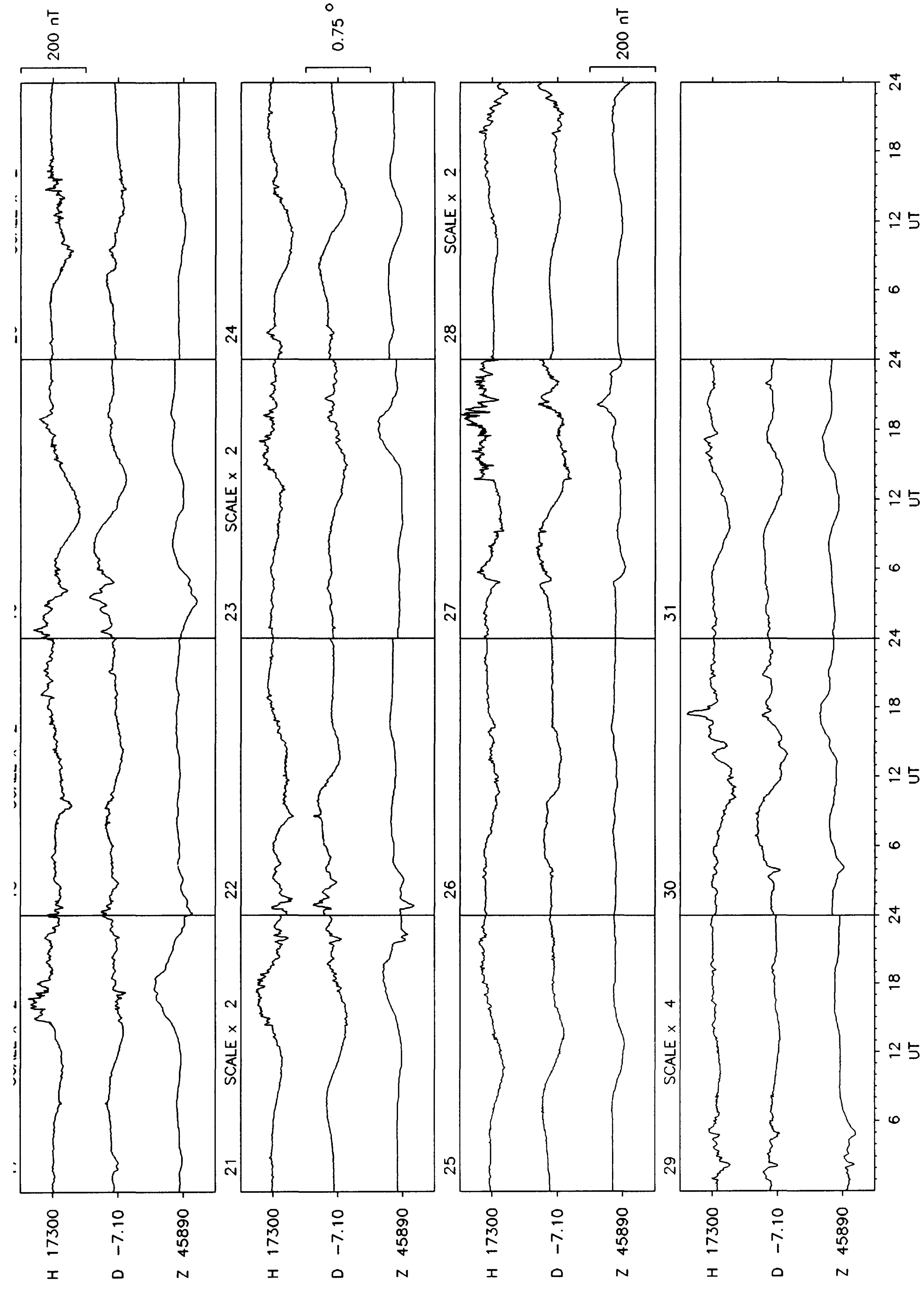
200 nT
0.75 °
200 nT
H 17300
D −7.10
Z 45890
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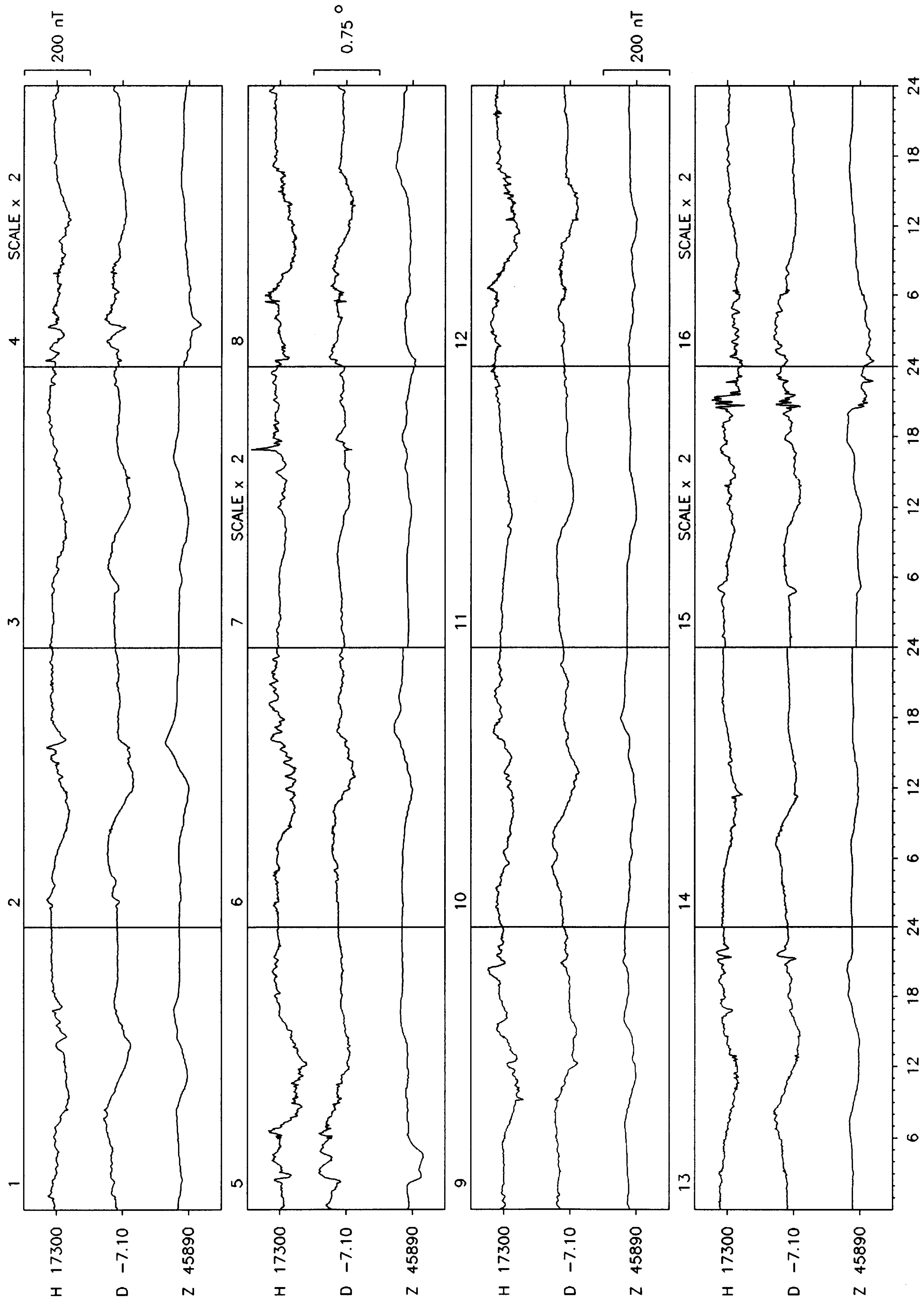
200 nT
0.75 °
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SCALE x 2
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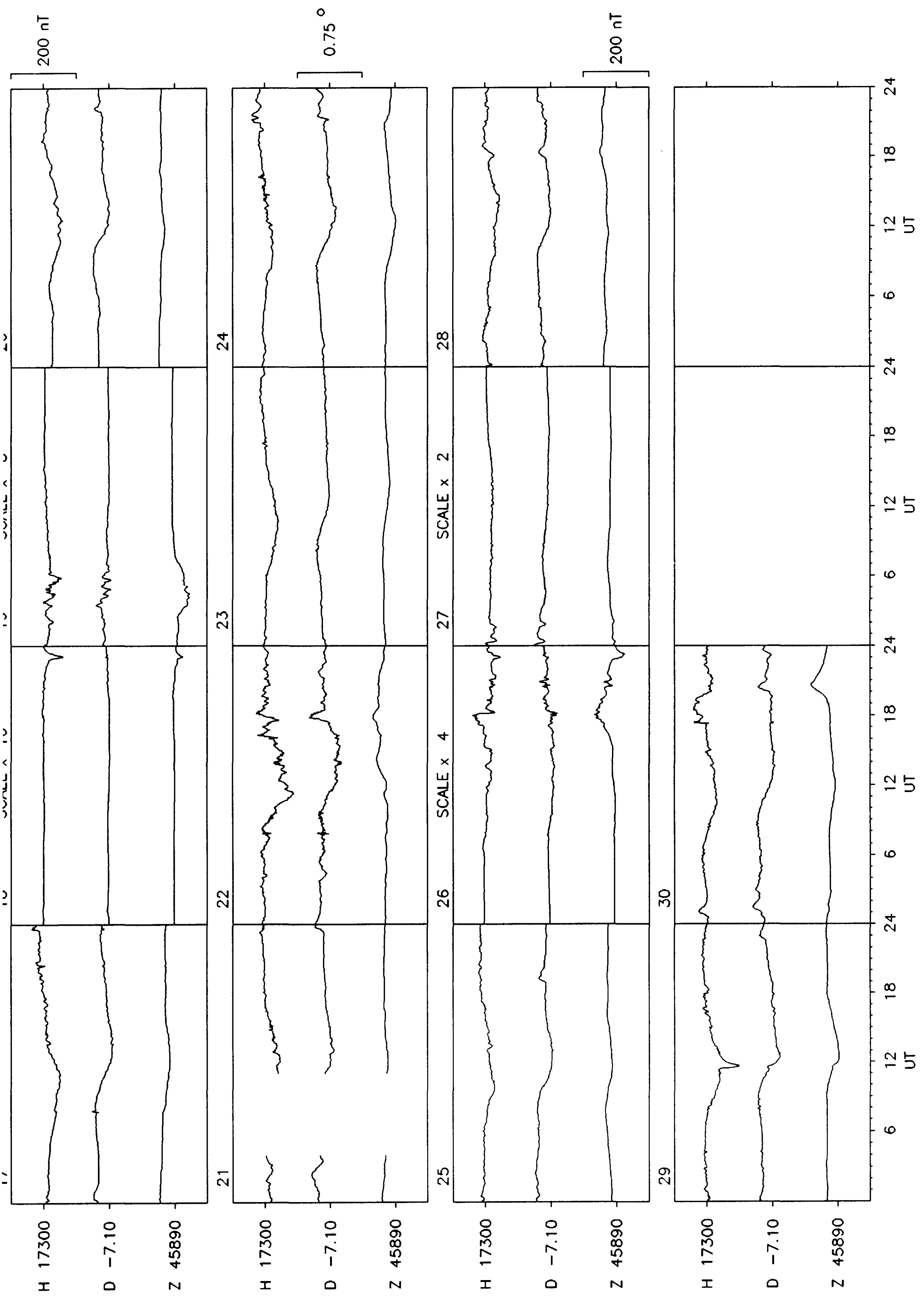

200 nT
0.75 °
200 nT
SCALE x 4
SCALE x 2
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H 17300
D −7.10
Z 45890
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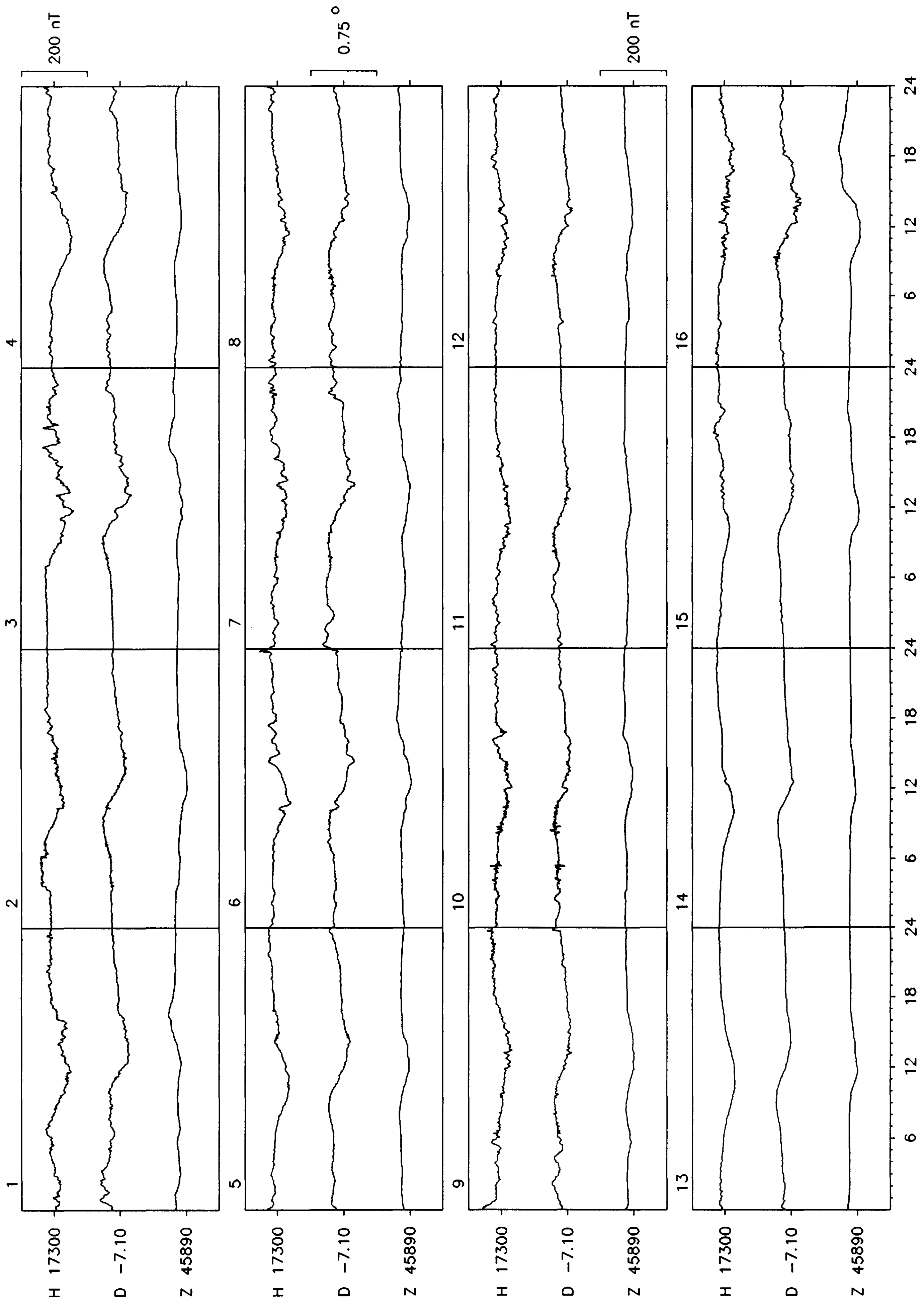
UT


200 nT
0.75 °
200 nT
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H 17300
D −7.10
Z 45890
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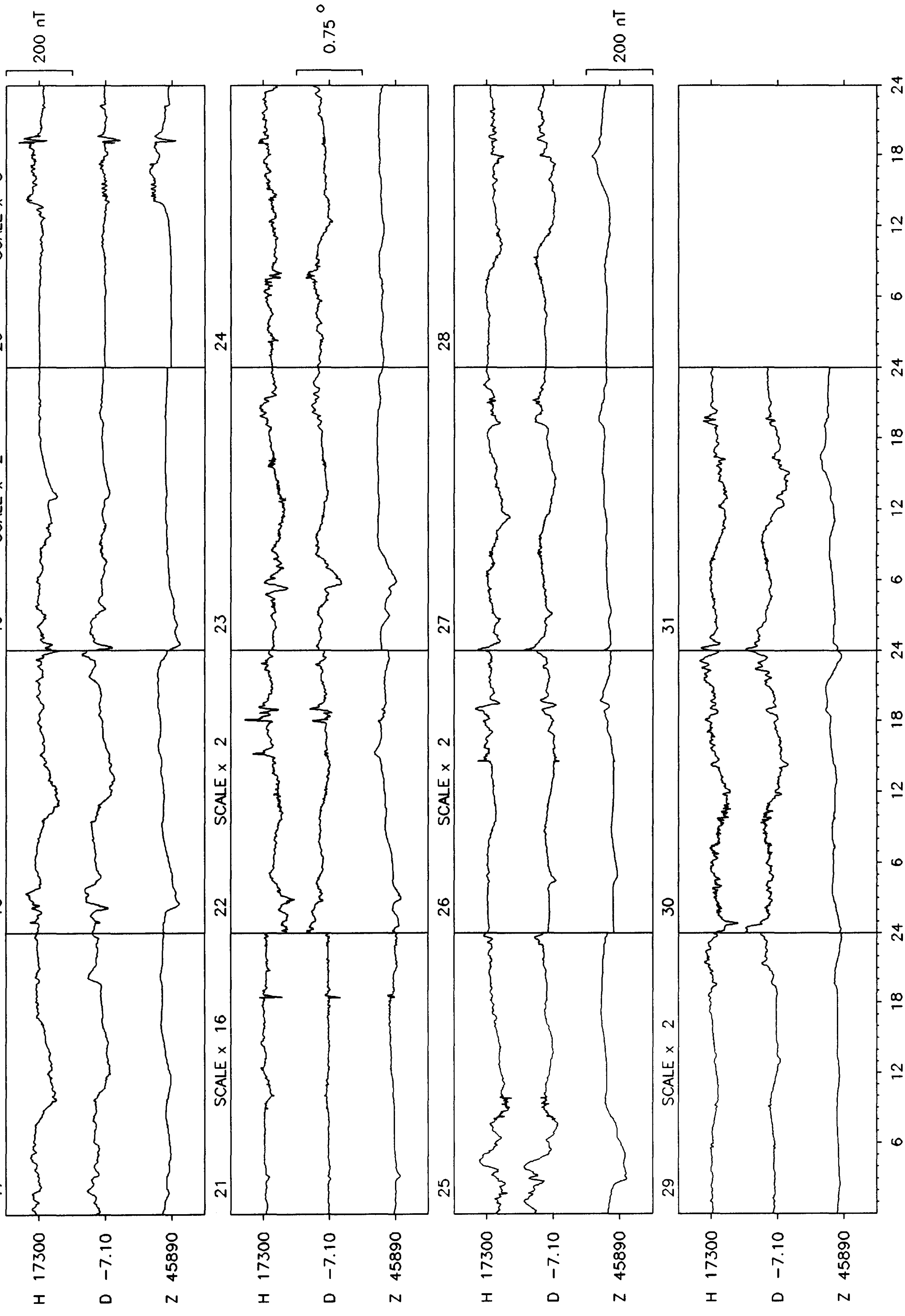
200 nT
0.75 °
200 nT
SCALE x 8
SCALE x 2
SCALE x 16
SCALE x 2
SCALE x 2
SCALE x 2
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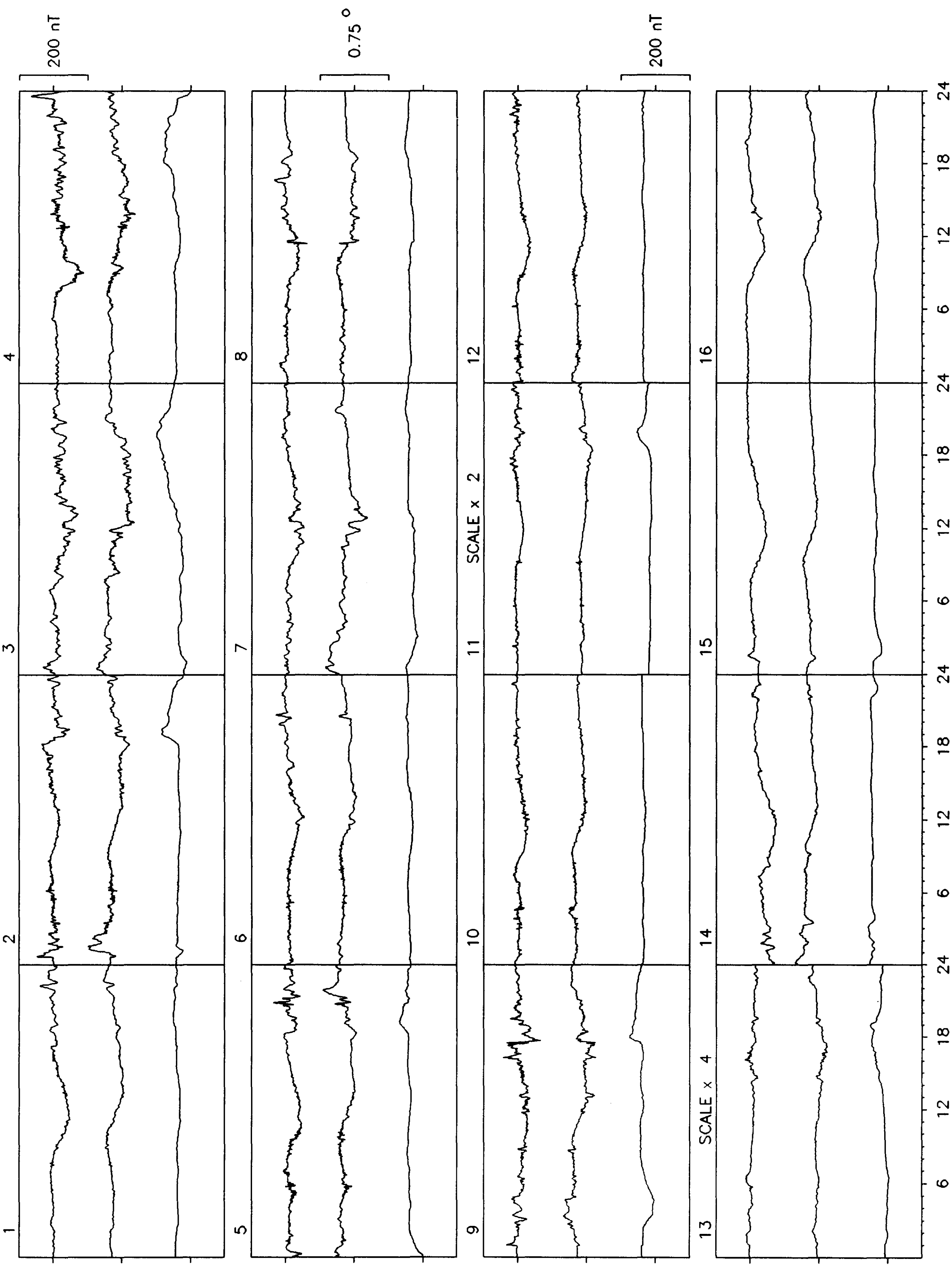
Z 45890
UT


200 nT
0.75 °
200 nT
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SCALE x 2
SCALE x 4
H 17300
D -7.10
Z 45890
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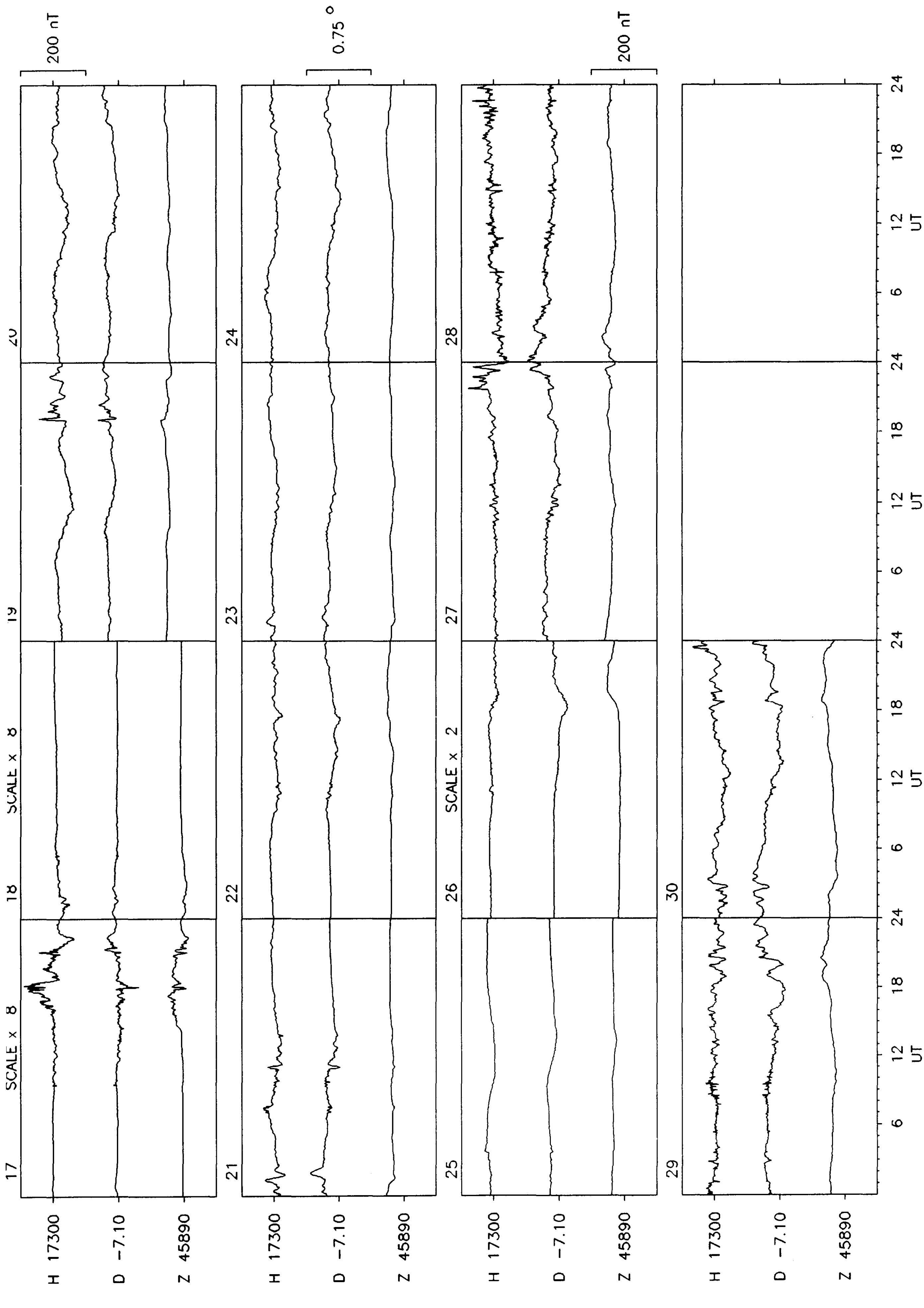
UT


200 nT
0.75 °
200 nT
SCALE x 8
SCALE x 8
SCALE x 2
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H 17300
D −7.10
Z 45890
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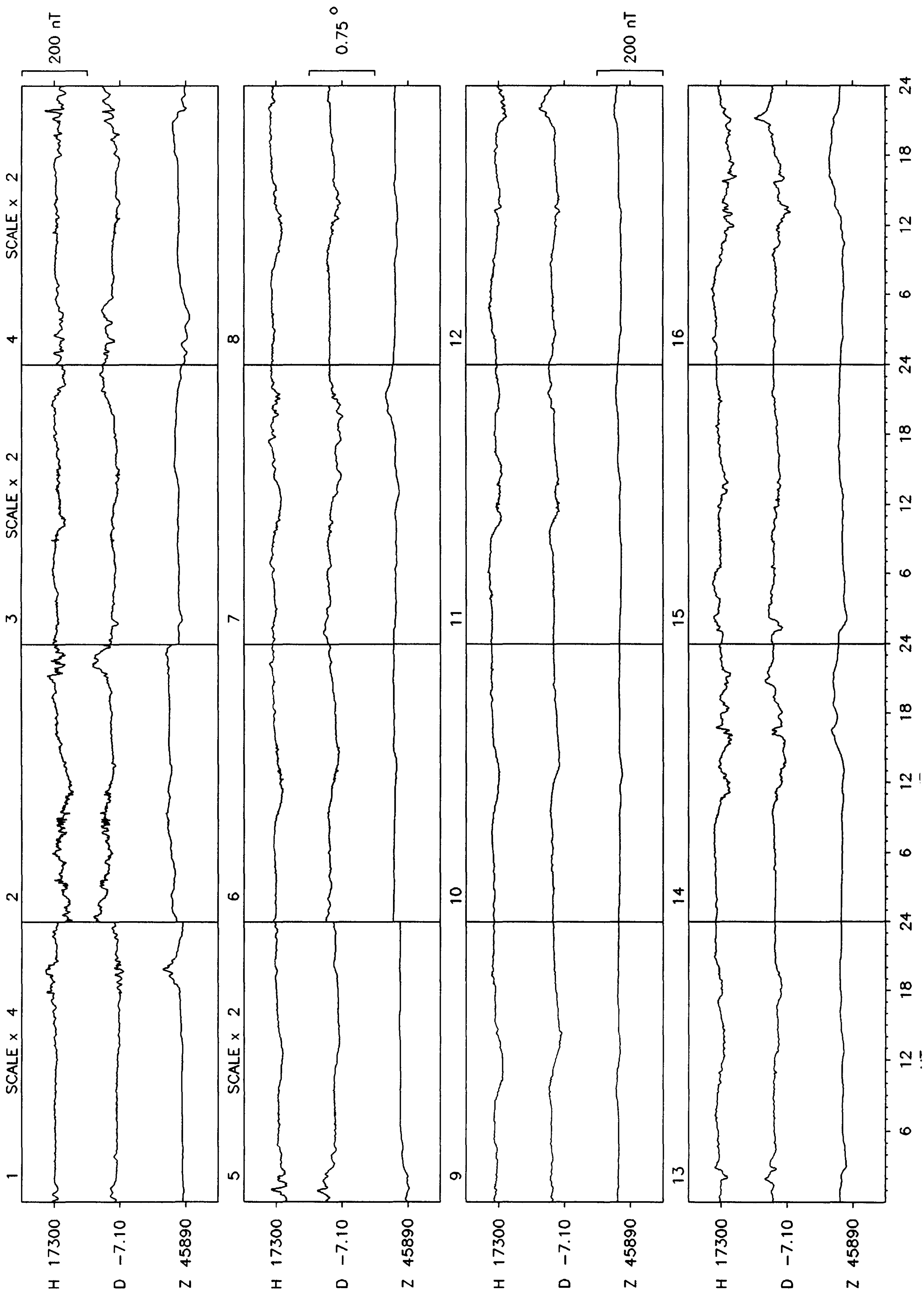
200 nT
0.75 °
200 nT
SCALE x 4
SCALE x 2
SCALE x 2
SCALE x 2
H 17300
D −7.10
Z 45890
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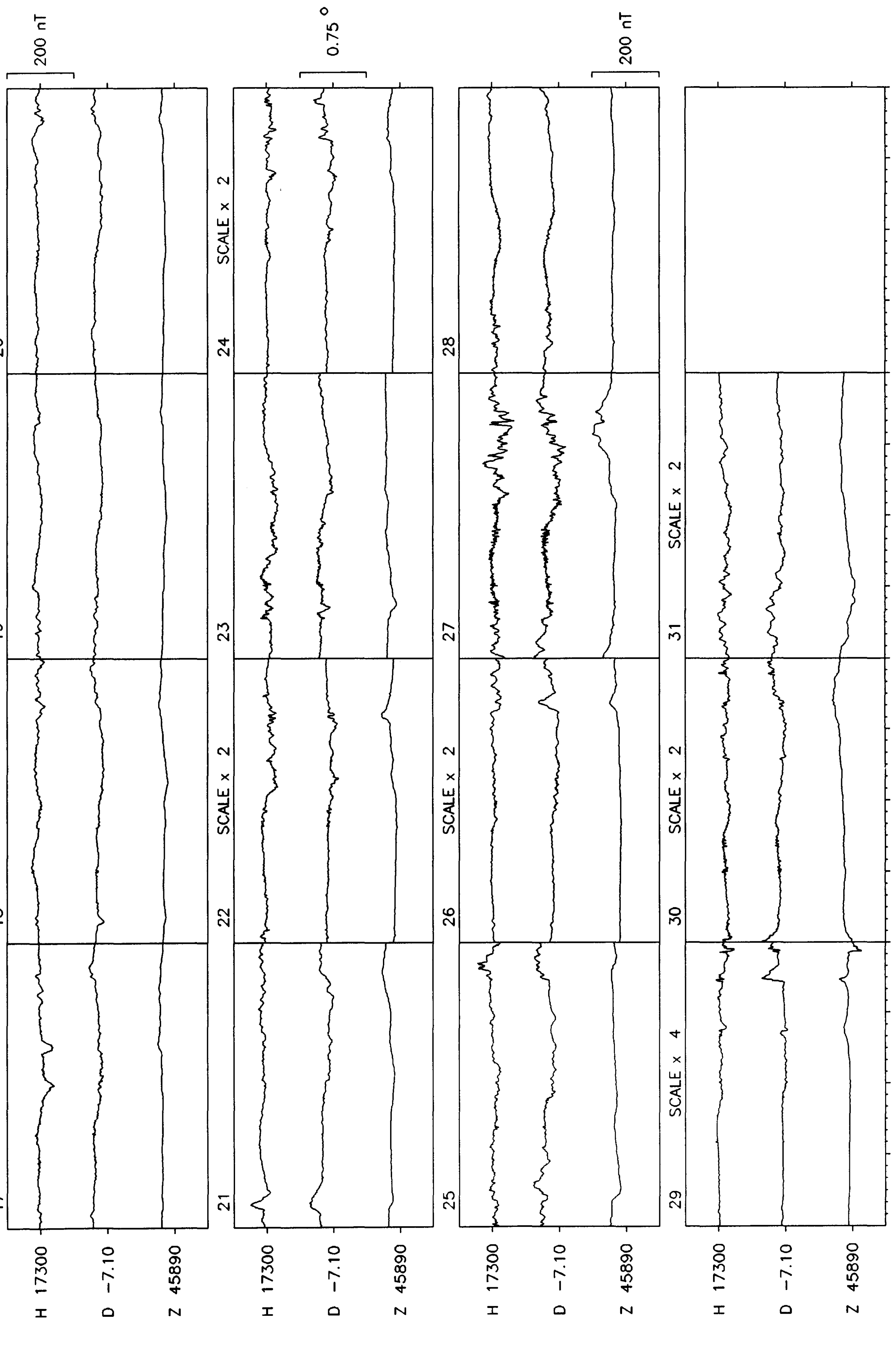
H 17300
D −7.10
Z 45890
200 nT
0.75 °
200 nT
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30
31
SCALE x 2
SCALE x 2
SCALE x 2
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SCALE x 4
SCALE x 2
SCALE x 2
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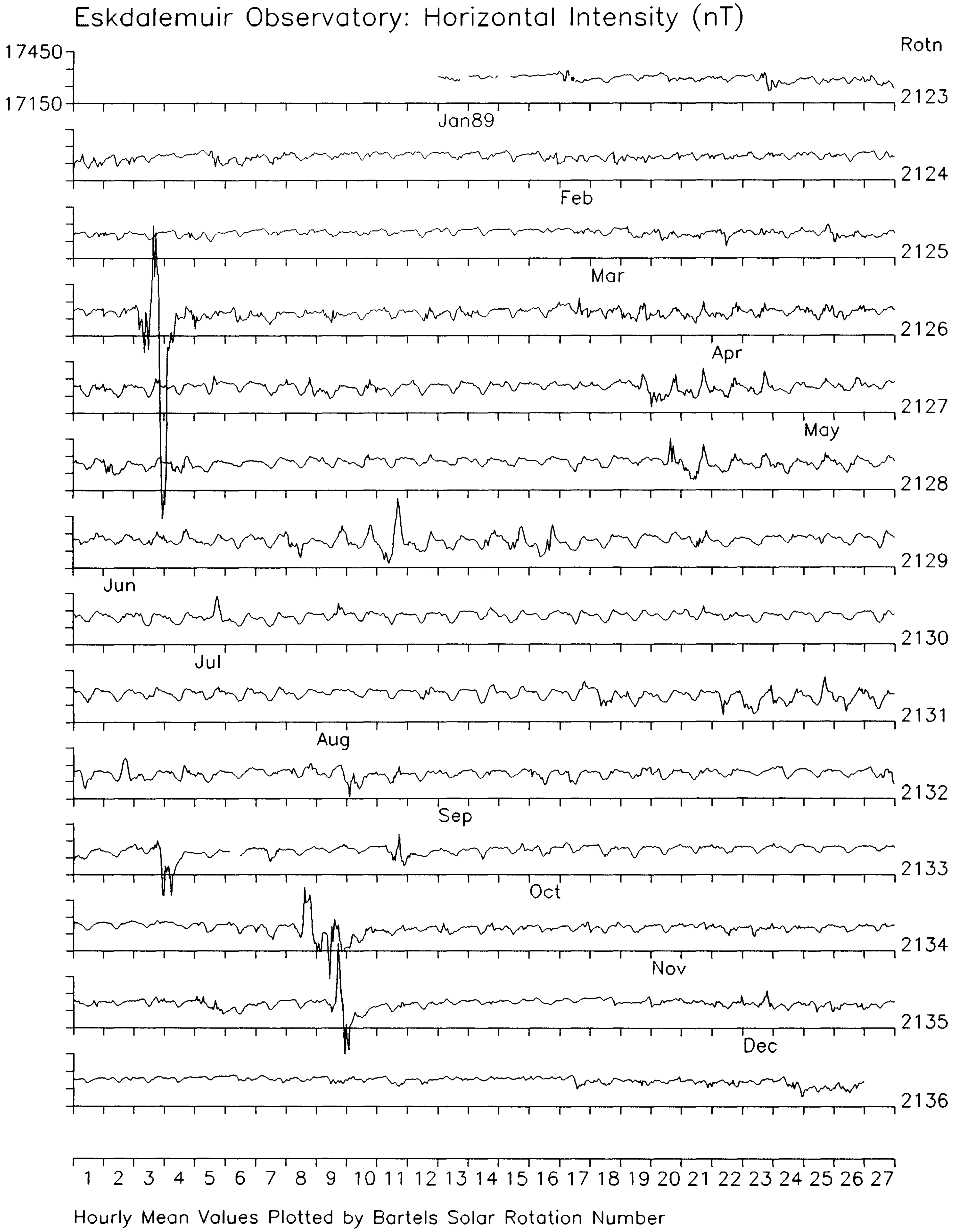
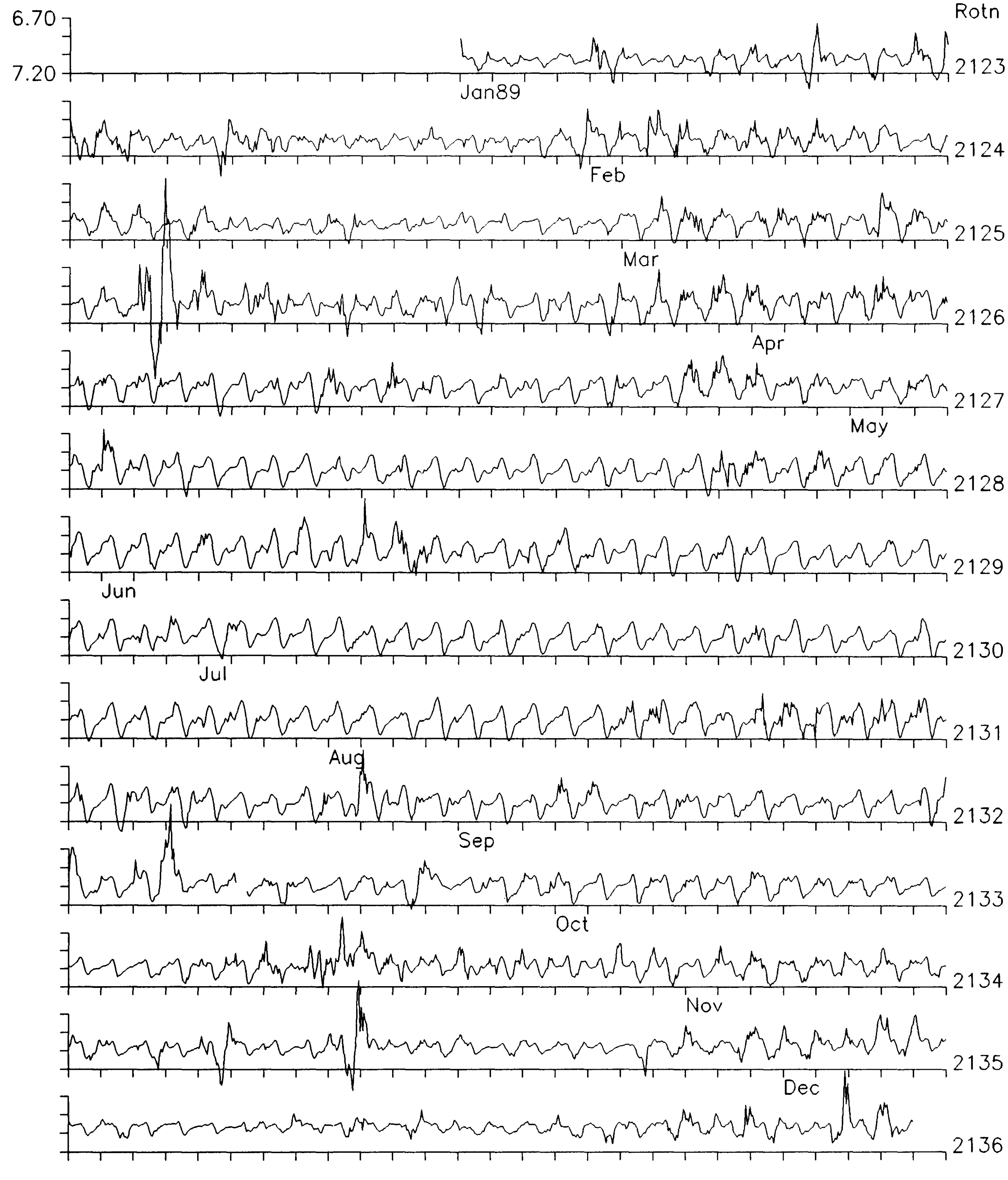
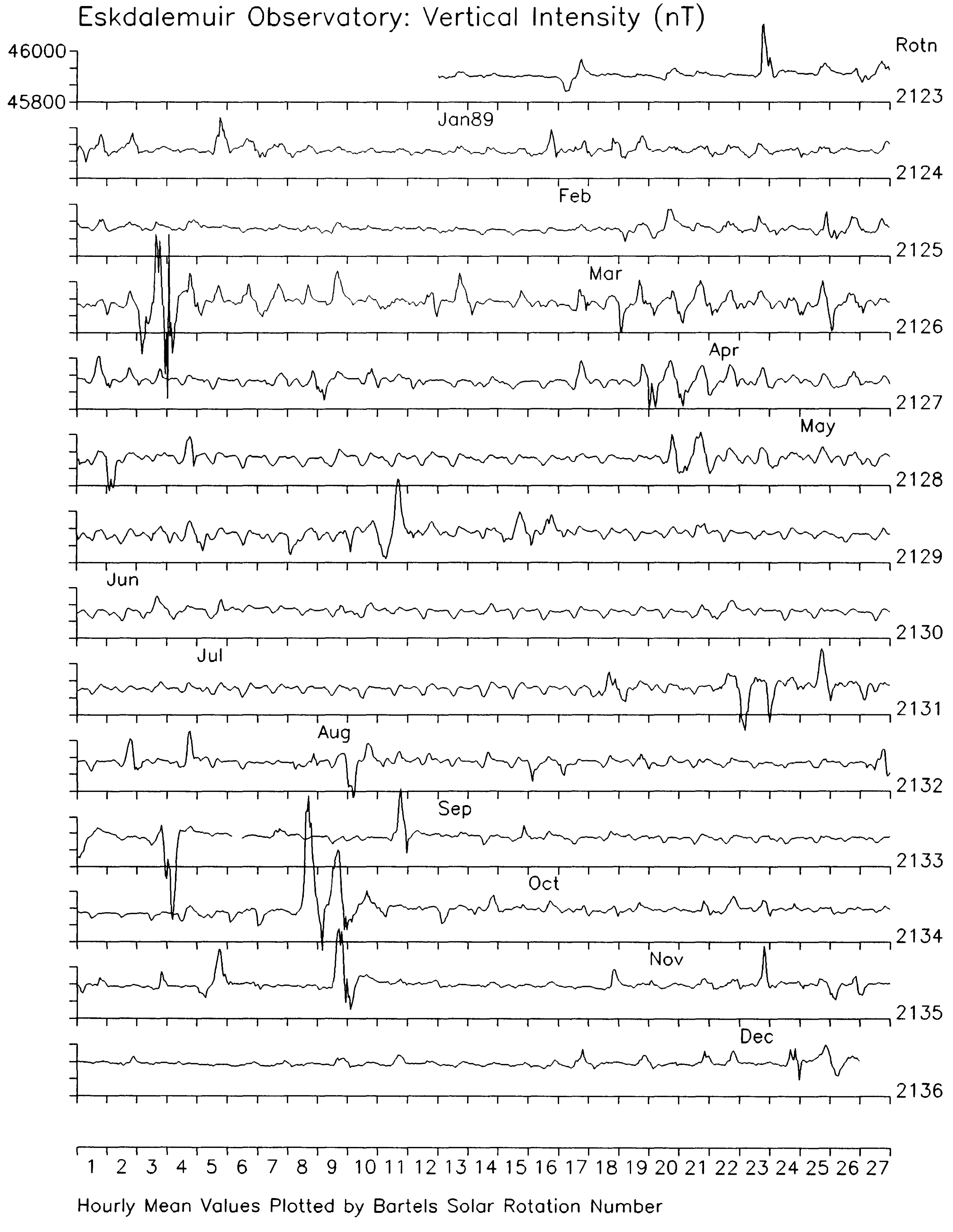
12
18
24
UT

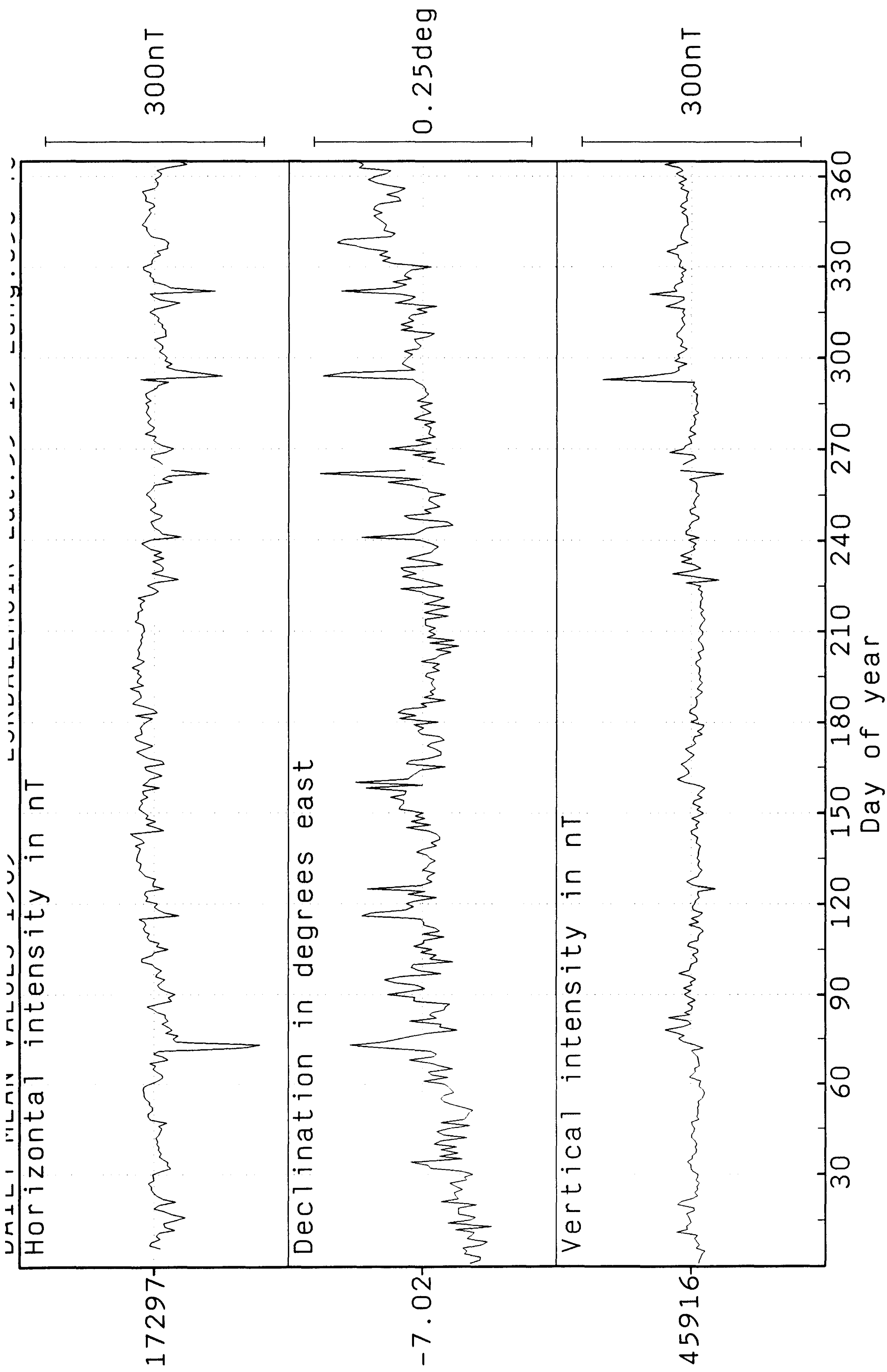

Eskdalemuir Observatory: Horizontal Intensity (nT)
17450
17150
Rotn
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
Jan89
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted by Bartels Solar Rotation Number

Eskdalemuir Observatory: Declination (degrees)



Hourly Mean Values Plotted by Bartels Solar Rotation Number


Eskdalemuir Observatory: Vertical Intensity (nT)
46000
45800
Rotn
2123
Jan89
2124
Feb
2125
Mar
2126
Apr
2127
May
2128
2129
Jun
2130
Jul
2131
Aug
2132
Sep
2133
Oct
2134
Nov
2135
Dec
2136
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



Horizontal intensity in nT
Declination in degrees east
Vertical intensity in nT
300nT
0.25deg
300nT
17297
-7.02
45916
30
60
90
120
150
180
210
240
270
300
330
360
Day of year

Monthly and annual mean values for Eskdalemuir 1989

Month	D		I		H	X	Y	Z	F
	°	'	°	'	nT	nT	nT	nT	nT
Jan	-7	4.4	69	21.8	17290	17158	-2129	45912	49060
Feb	-7	3.3	69	21.4	17295	17164	-2124	45909	49059
Mar	-7	1.6	69	22.8	17278	17148	-2114	45918	49061
Apr	-7	1.1	69	21.5	17296	17166	-2113	45912	49062
May	-7	1.5	69	20.4	17310	17180	-2117	45907	49062
Jun	-7	1.0	69	20.7	17308	17178	-2114	45913	49067
Jul	-7	2.0	69	20.0	17316	17186	-2120	45906	49063
Aug	-7	1.5	69	21.1	17300	17170	-2116	45910	49061
Sep	-7	1.2	69	21.8	17291	17161	-2113	45914	49062
Oct	-7	0.9	69	22.1	17291	17162	-2112	45924	49071
Nov	-7	0.3	69	22.4	17290	17161	-2109	45933	49079
Dec	-6	58.3	69	21.9	17296	17168	-2099	45929	49078
Annual	-7	1.4	69	21.5	17297	17167	-2115	45916	49066

ESKDALEMUIR OBSERVATORY K INDICES 1989

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	4222 2233	4423 3235	3222 3322	3443 3454	3111 2333	3212 3333	1122 2553	1201 2222	2121 3310	3322 2322	1122 2223	4322 3554
2	1011 1022	3321 3254	3433 3323	2333 4522	3332 3343	2323 4333	3210 1111	2221 1221	2211 2411	132 321	4321 2343	3333 3224
3	0001 1122	4433 3554	3443 4543	4322 3334	3222 2123	3222 3443	0011 1211	2222 2220	1221 1212	0013 3332	3233 4342	4333 3334
4	2121 2123	4323 3244	3112 3301	4333 4455	4222 2324	4412 2221	0100 3100	0123 4432	5533 3213	1221 3212	2244 3334	4423 3355
5	4443 3342	3333 3343	3344 3243	5444 4344	6543 3344	1122 2323	1012 3544	1001 0211	4343 3322	2101 3213	3322 2244	5321 2122
6	3222 1112	4333 3343	4233 4433	3222 2233	2222 2333	2221 2224	2222 3431	1111 3343	2222 3332	2123 3323	2222 3232	2111 1112
7	3112 2222	3333 3434	3332 3323	1233 4344	0343 4545	5445 3133	2222 3231	2222 2332	2113 4633	3222 3323	3323 3223	2121 2223
8	0122 4343	3323 2213	2120 1445	3222 3433	1112 1223	3222 3254	0011 3211	2222 2122	3332 3312	2221 2113	3223 3331	4444 2212
9	2222 3223	3322 3333	4432 3434	3221 3452	1111 3201	6422 3444	2211 1121	2211 2343	2113 3332	3322 2213	3322 3533	1101 1010
10	3223 2222	4212 2000	4332 3323	3111 3323	1111 1112	4554 6764	2332 3323	3354 4334	2222 3322	2332 3322	2221 2222	0000 1011
11	1110 3566	0012 2343	2223 3334	1231 5422	1110 1323	3433 3433	1102 1221	4433 4422	0001 0002	2222 2201	3323 2343	0112 2211
12	5422 2122	2212 3244	4232 3433	2120 3222	2232 2321	3222 2331	0001 2212	3212 3223	3232 3312	1222 2222	3221 2013	2110 2123
13	0001 3343	4322 2333	5697 8799	2133 3333	2212 4421	1112 4543	2221 2221	3322 3222	1121 3324	1000 0000	4443 4545	3211 1220
14	3111 3334	3322 2311	9755 5576	4222 2445	2322 2322	3445 5554	1101 2322	3454 5334	1123 2100	0001 1000	3322 2212	0002 3333
15	4333 3355	1111 2345	6533 4433	4432 3322	1222 2332	4343 5553	0112 3322	5543 4446	2423 4456	1002 1230	3111 1100	3222 2121
16	4343 4444	2413 3223	2455 3543	1010 4435	1312 2332	3421 2310	0100 1100	4423 3434	4332 322	2112 3222	0001 2122	1112 3334
17	4234 3354	2211 2011	3443 3433	4001 2123	2232 2221	0001 2412	3223 2432	3232 5545	22 2122	3222 1232	4235 6899	1123 3322
18	3323 3212	1210 3321	0221 3312	3411 2111	2221 3211	1111 2220	3332 3321	5334 3344	4233 3459	4313 3224	6543 2332	2111 2122
19	2221 1122	1121 2223	1355 5432	1011 3322	1112 2221	1212 2223	1111 1111	3421 2231	6753 4321	5433 4221	1111 2243	2210 1121
20	3112 5654	3232 3442	1332 3224	2331 2322	2123 4330	2333 4442	1101 1222	2245 5421	0111 2122	2234 7686	2222 2222	1111 1132
21	3333 3444	2233 2321	3333 3333	2321 2210	2222 3221	1021 2111	1112 1211	2111 4355	2 2203	5667 6596	4233 2001	3200 1222
22	4343 5423	1232 2132	2242 4465	3101 3222	2213 3333	1111 2322	2111 3322	4232 1321	2233 3432	5533 4564	0002 1322	3222 4342
23	3333 3333	1011 2122	4233 4544	2112 3342	2212 5754	1111 2321	2322 3322		1111 1112	2442 2233	2201 1112	1332 2222
24	2222 2233	2222 2111	4332 2211	3112 2223	4444 5655	1113 4321	3122 3322		1111 2223	3232 2233	2211 2122	2223 3444
25	2222 3233	1132 2111	1012 2243	2223 4545	4332 4343	2222 2212	2222 3212	0011 2222	1011 2221	4433 1213	1100 0000	2322 2234
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31	3223 3446		4433 4544		3222 3332		2111 2212	1100 2322		4222 3331		4443 3332

ESKDALEMUIR

Year	D	I	H	X	Y	Z	F
1908	−18 33.3	69 37.3	16821	15947	−5353	45283	48306
1909	−18 30.1	69 38.8	16826	15956	−5339	45360	48380
1910	−18 23.3	69 37.8	16826	15967	−5307	45317	48340
1911	−18 12.4	69 37.1	16836	15993	−5260	45317	48343
1912	−18 3.9	69 37.2	16836	16006	−5221	45318	48344
1913	−17 54.9	69 37.3	16811	15996	−5171	45254	48276
1914	−17 45.3	69 36.1	16793	15993	−5121	45159	48180
1915	−17 35.9	69 36.9	16774	15990	−5072	45142	48158
1916	−17 26.1	69 37.6	16744	15975	−5017	45088	48097
1917	−17 17.1	69 38.6	16720	15965	−4968	45061	48063
1918	−17 8.1	69 39.0	16703	15962	−4921	45034	48032
1919	−16 58.7	69 39.6	16700	15972	−4877	45049	48045
1920	−16 49.6	69 39.5	16693	15978	−4832	45026	48021
1921	−16 37.3	69 40.3	16681	15984	−4771	45025	48016
1922	−16 25.8	69 40.0	16666	15985	−4714	44974	47963
1923	−16 13.8	69 38.8	16661	15997	−4657	44915	47906
1924	−16 1.2	69 38.7	16657	16010	−4597	44898	47889
1925	−15 48.4	69 39.3	16650	16020	−4535	44902	47890
1926	−15 35.3	69 40.3	16632	16020	−4469	44896	47878
1927	−15 22.7	69 40.2	16615	16020	−4406	44843	47822
1928	−15 10.5	69 41.2	16602	16024	−4346	44849	47823
1929	−14 58.9	69 41.9	16586	16022	−4287	44832	47802
1930	−14 47.1	69 43.2	16568	16019	−4228	44834	47797
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1932	−14 23.7	69 45.0	16553	16033	−4115	44867	47823
1933	−14 12.1	69 45.2	16539	16033	−4058	44839	47792
1934	−14 0.6	69 45.9	16531	16039	−4002	44845	47795
1935	−13 48.8	69 47.0	16520	16042	−3944	44861	47806
1936	−13 37.4	69 48.4	16512	16047	−3889	44894	47834
1937	−13 26.9	69 49.8	16501	16049	−3837	44920	47855
1938	−13 17.1	69 50.7	16499	16057	−3791	44953	47885
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1940	−12 57.9	69 51.8	16503	16082	−3703	45008	47938
1941	−12 48.2	69 52.5	16503	16093	−3657	45037	47965
1942	−12 39.8	69 51.9	16513	16111	−3620	45039	47971
1943	−12 31.2	69 52.7	16511	16118	−3579	45064	47994
1944	−12 23.0	69 52.5	16518	16134	−3542	45076	48007
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1952	−11 18.0	69 50.0	16601	16279	−3253	45203	48155
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1962	−10 15.7	69 39.8	16825	16556	−2997	45396	48414
1963	−10 10.2	69 38.6	16850	16585	−2975	45413	48438
1964	−10 5.3	69 36.9	16880	16619	−2957	45427	48462
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1967	−9 52.1	69 33.8	16949	16698	−2905	45486	48541
1968	−9 48.6	69 32.5	16979	16731	−2893	45514	48578
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1983	−7 51.7	69 18.9	17301	17139	−2366	45824	48981
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1986	−7 25.1	69 19.4	17306	17161	−2234	45854	49011
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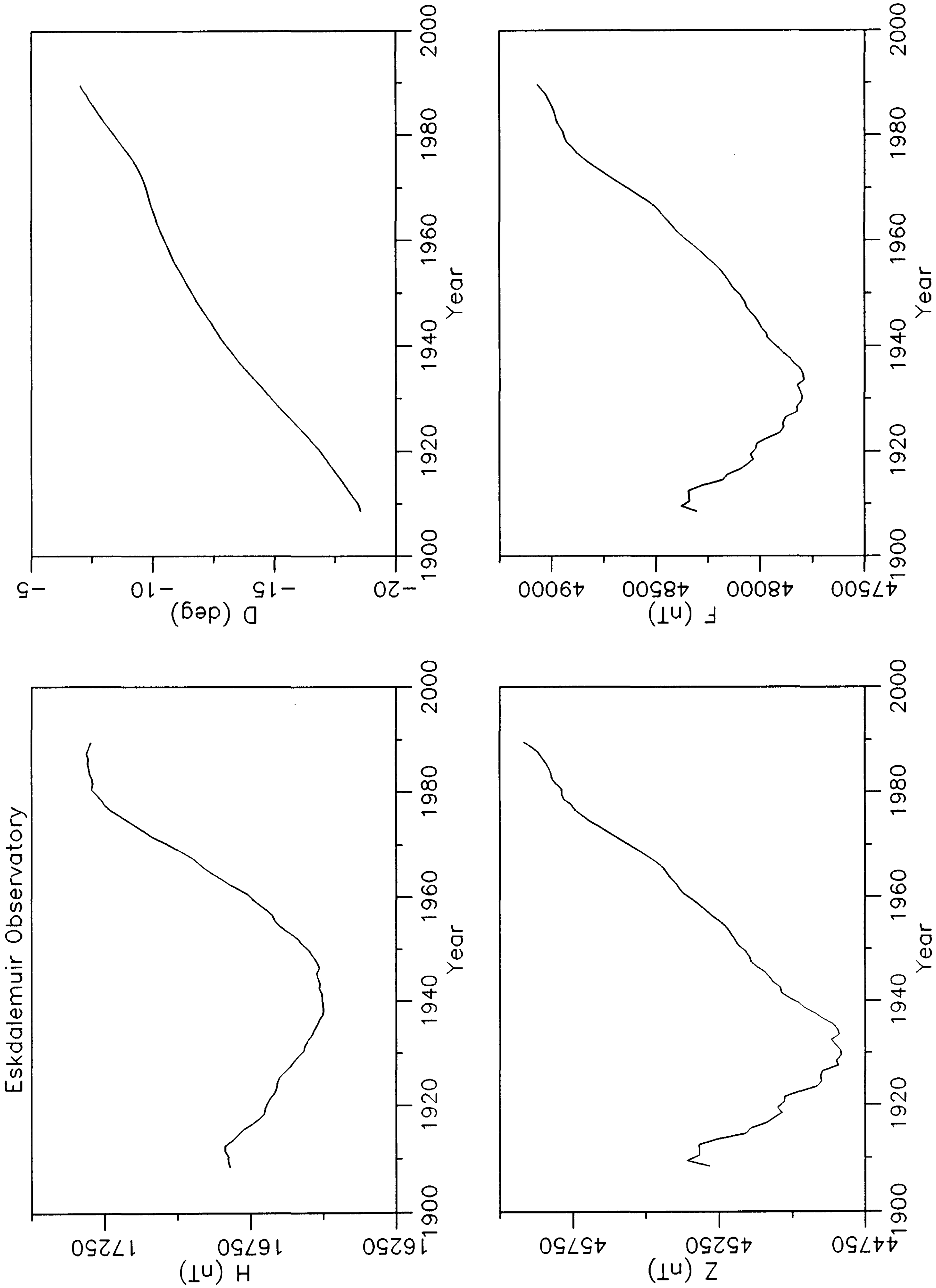
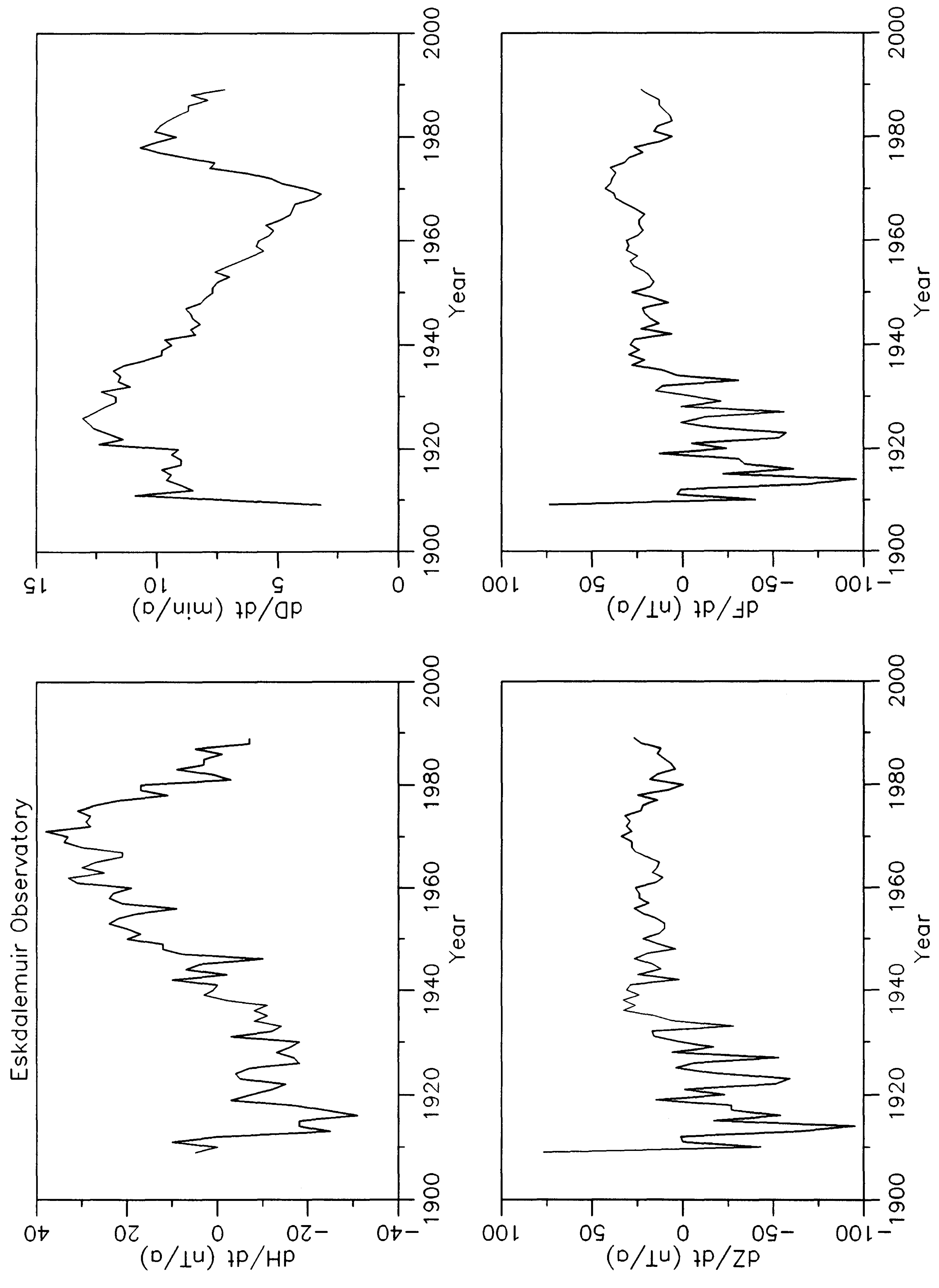
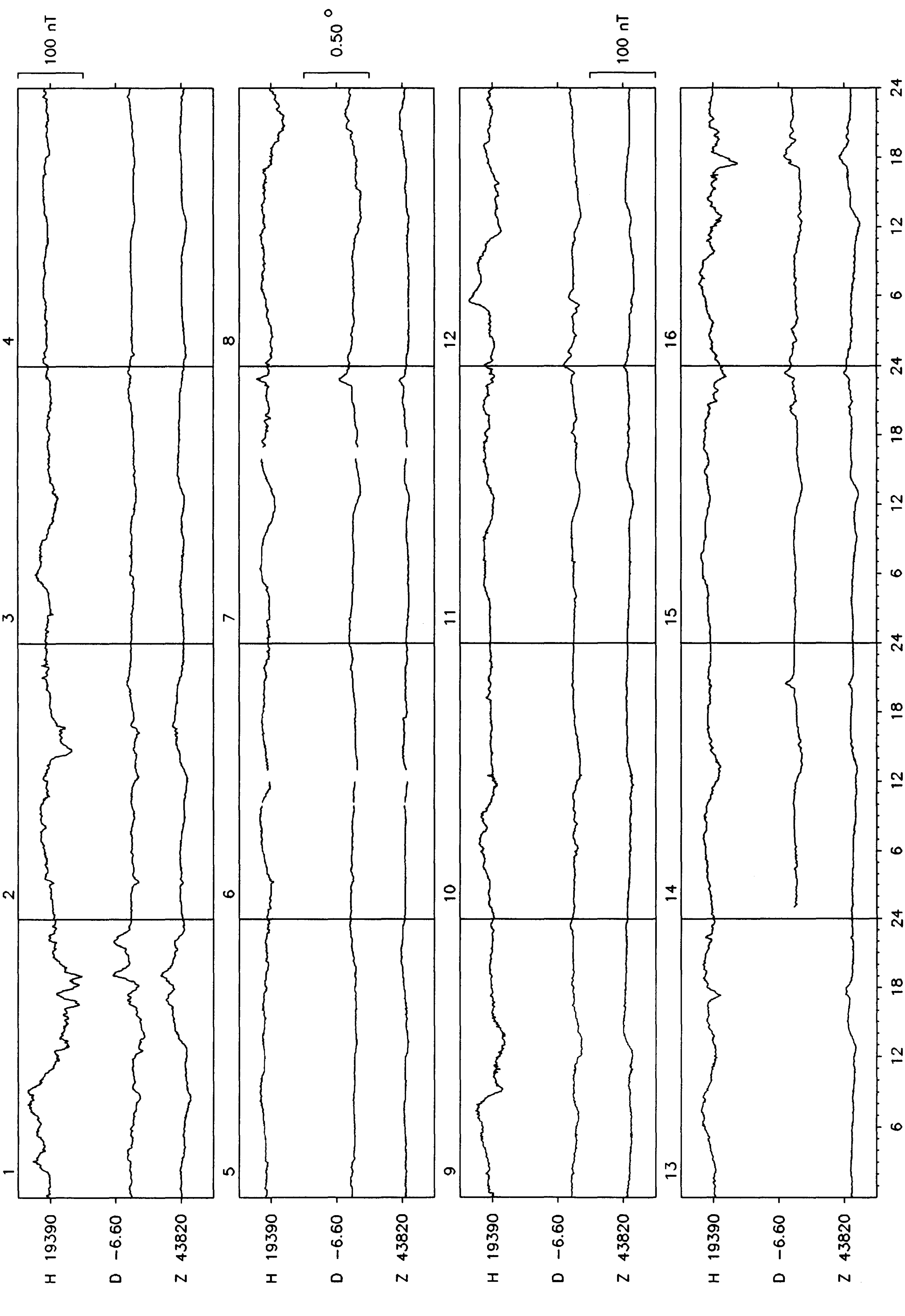


Annual mean values of H, D, Z & F at Eskdalemuir



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

HARTLAND 1987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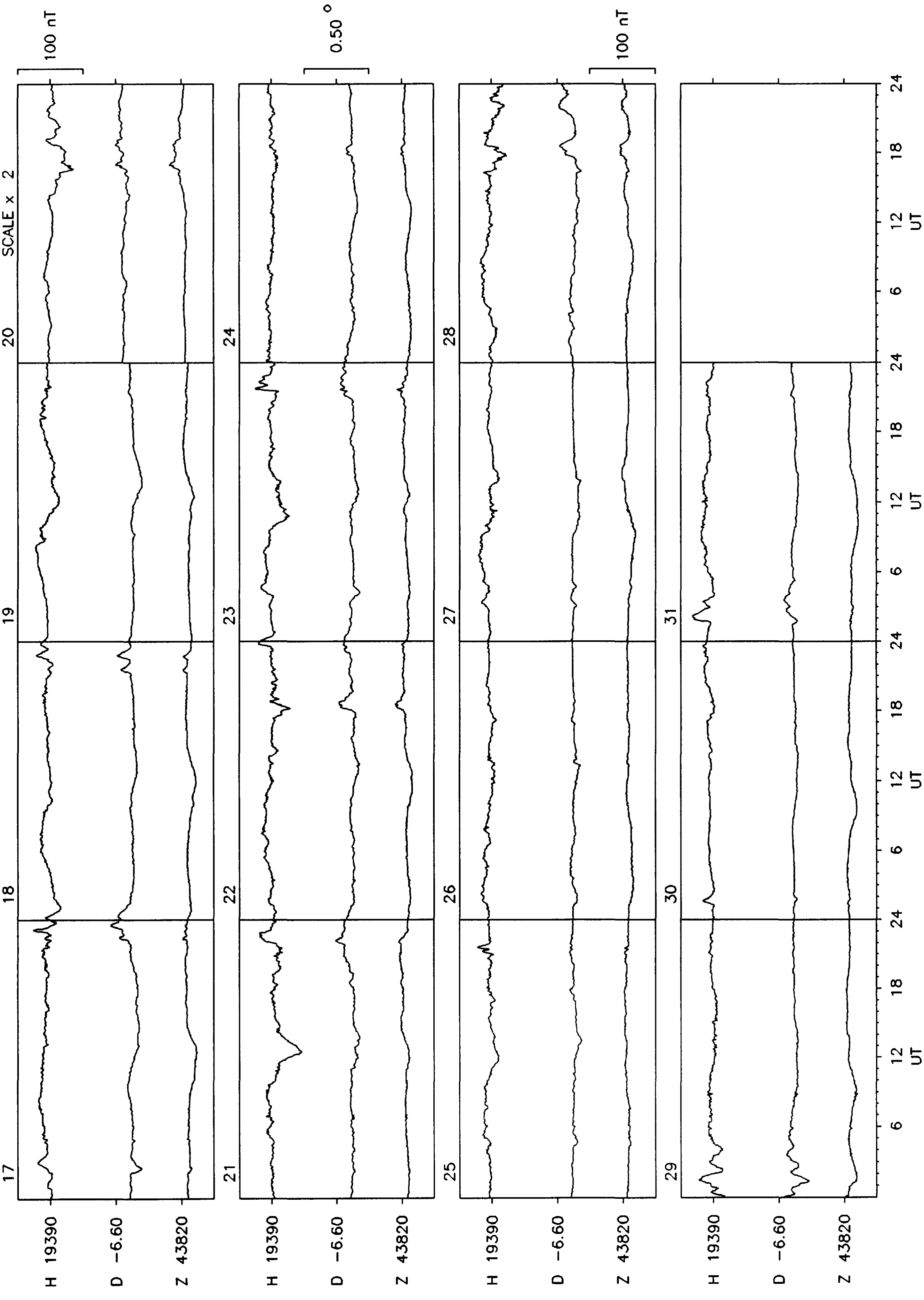

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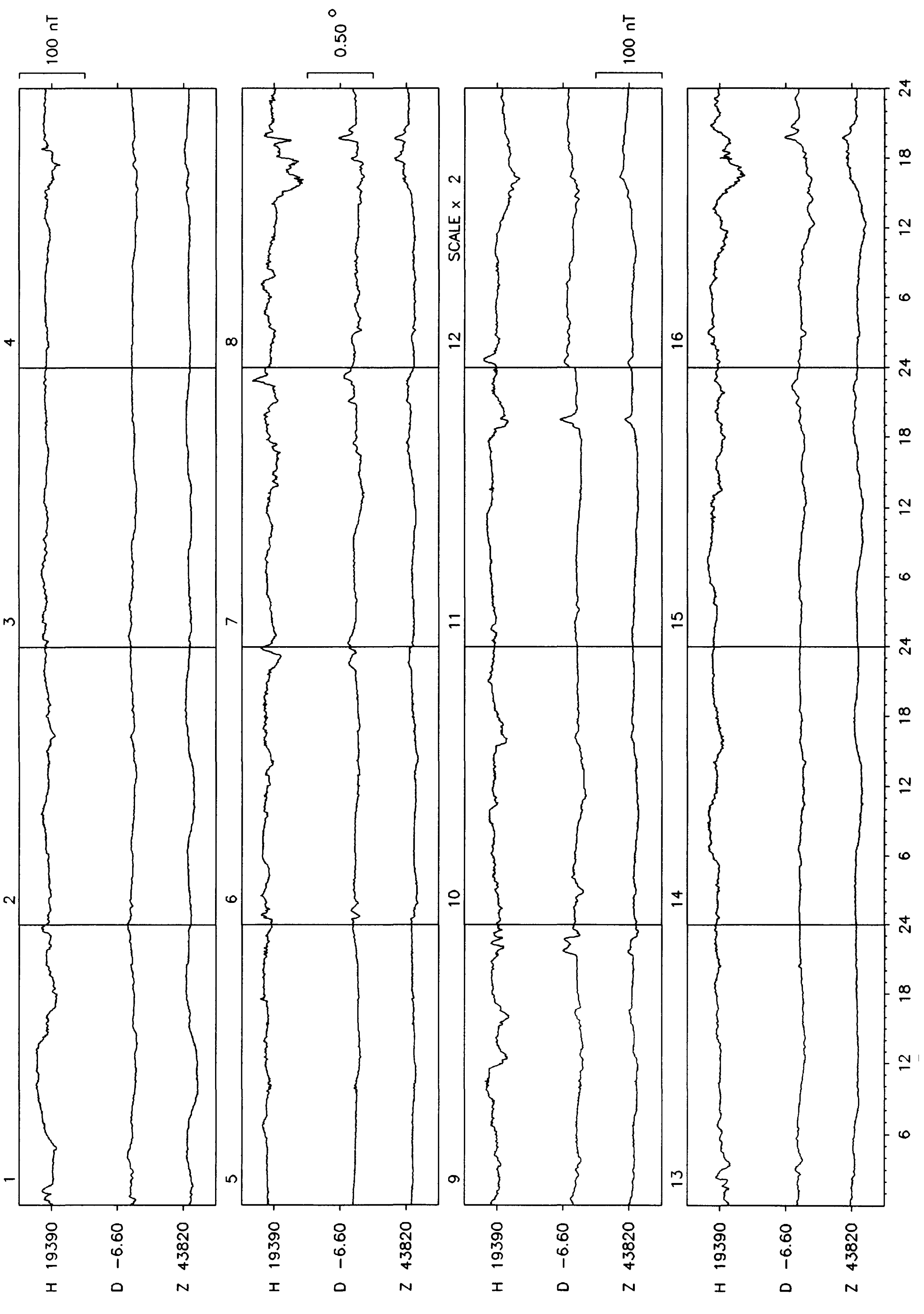
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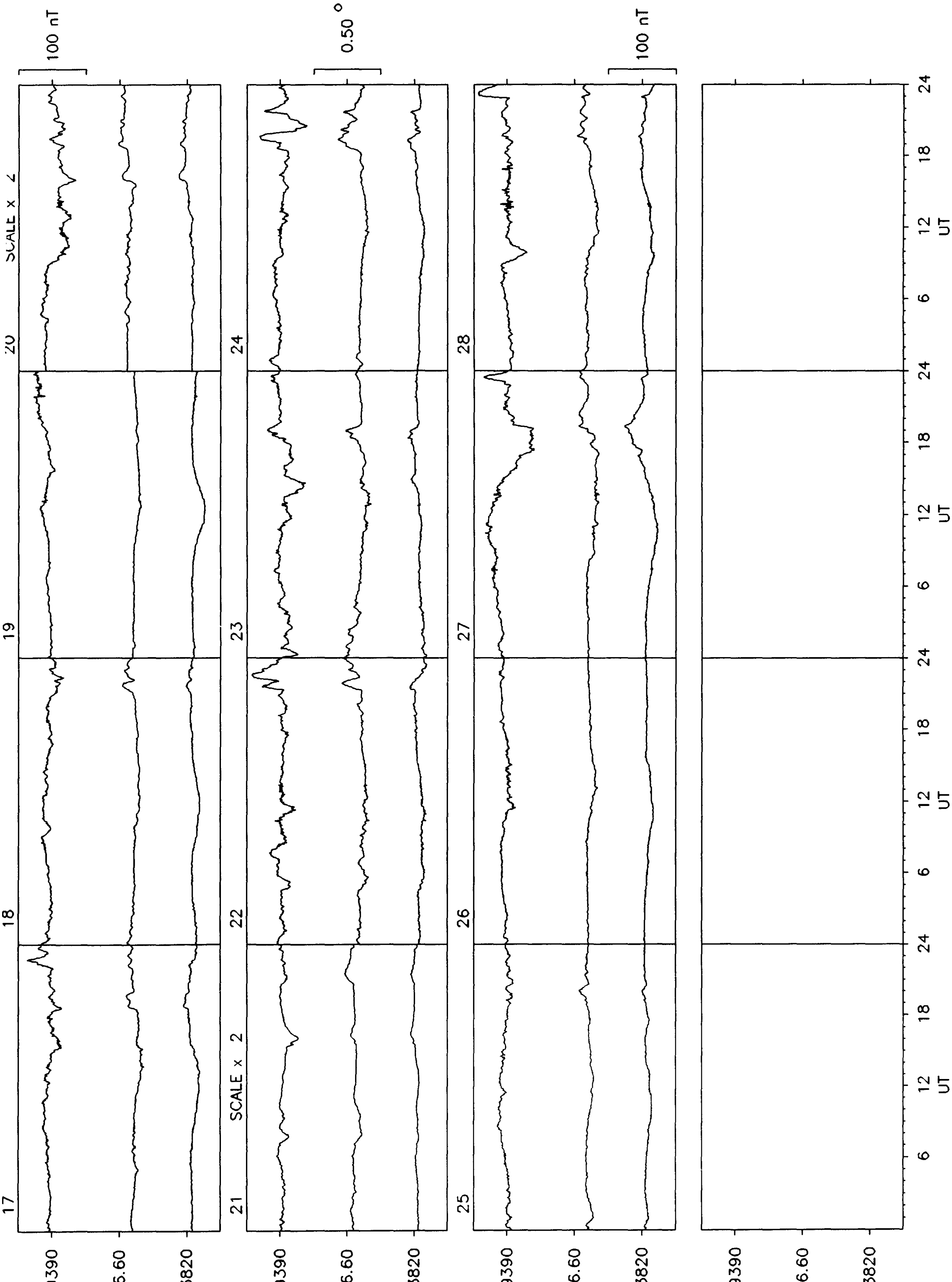
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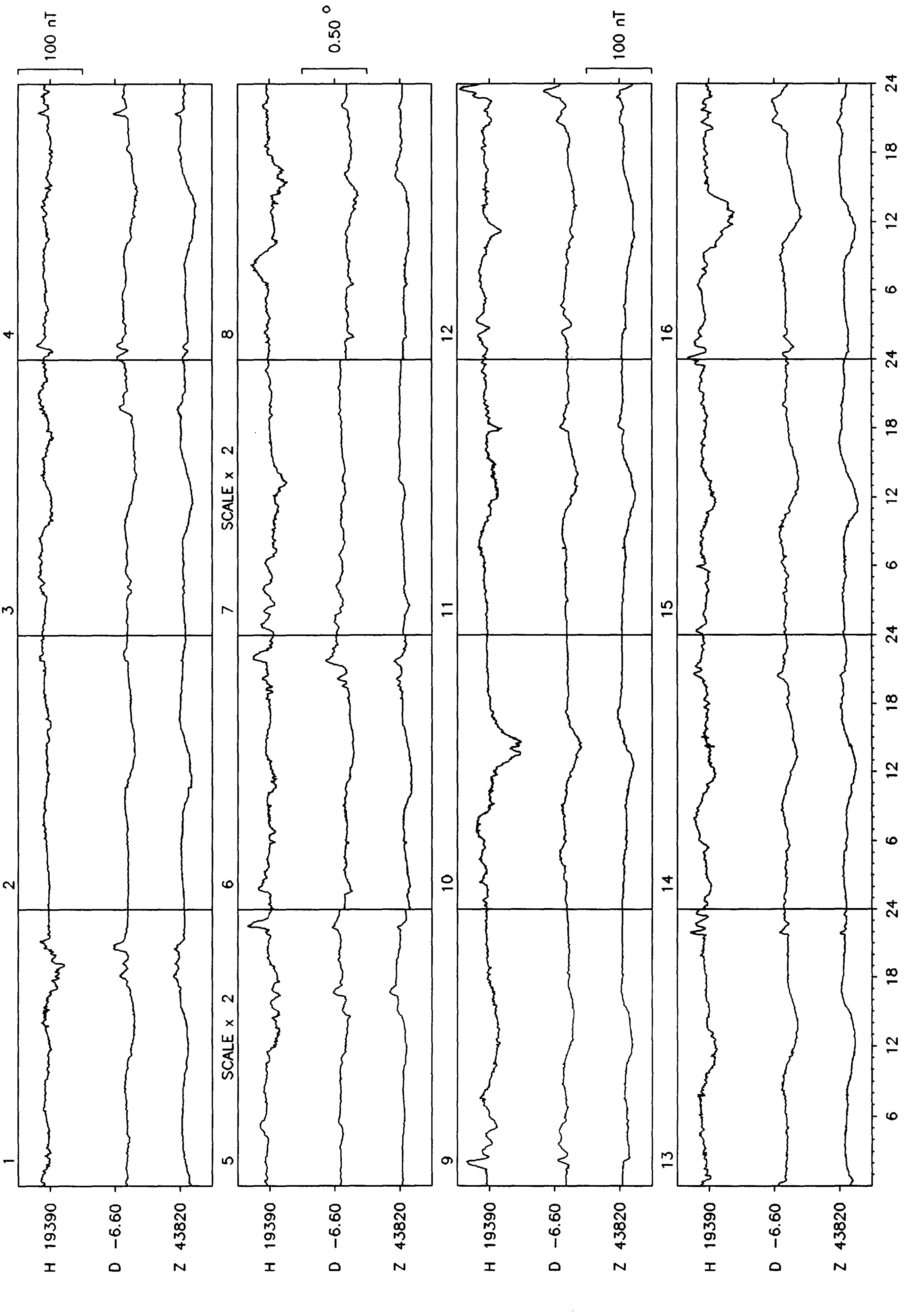
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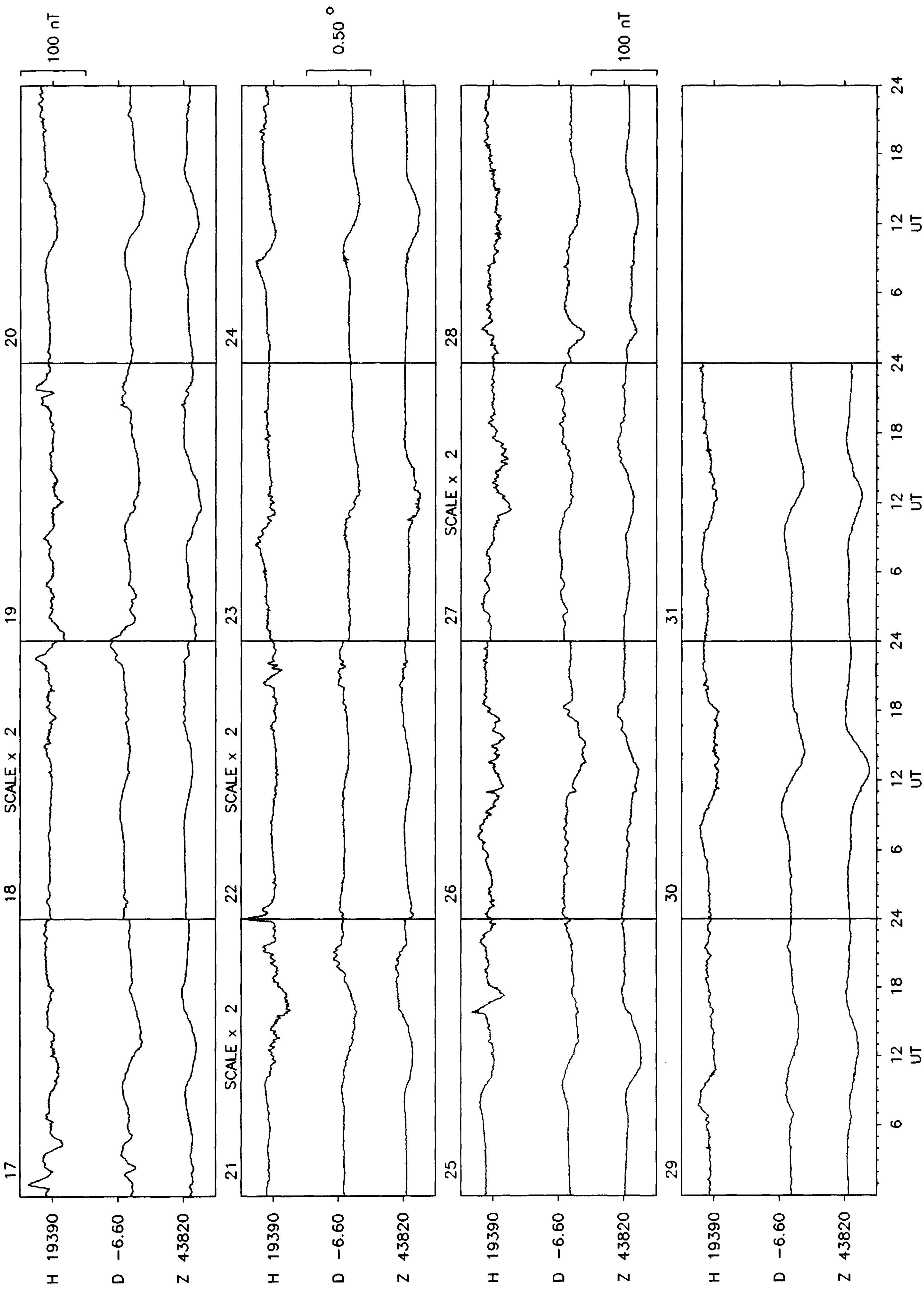
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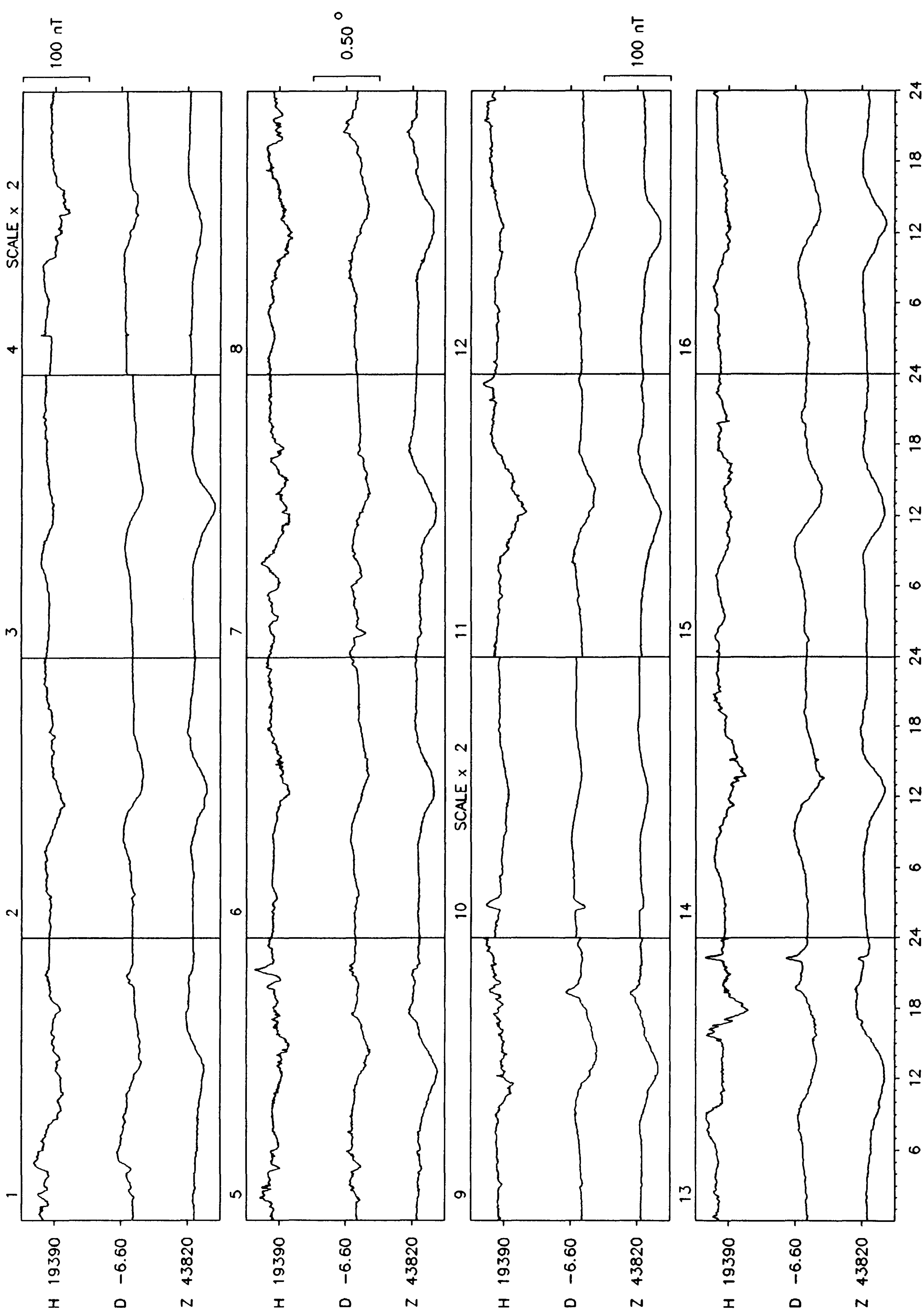
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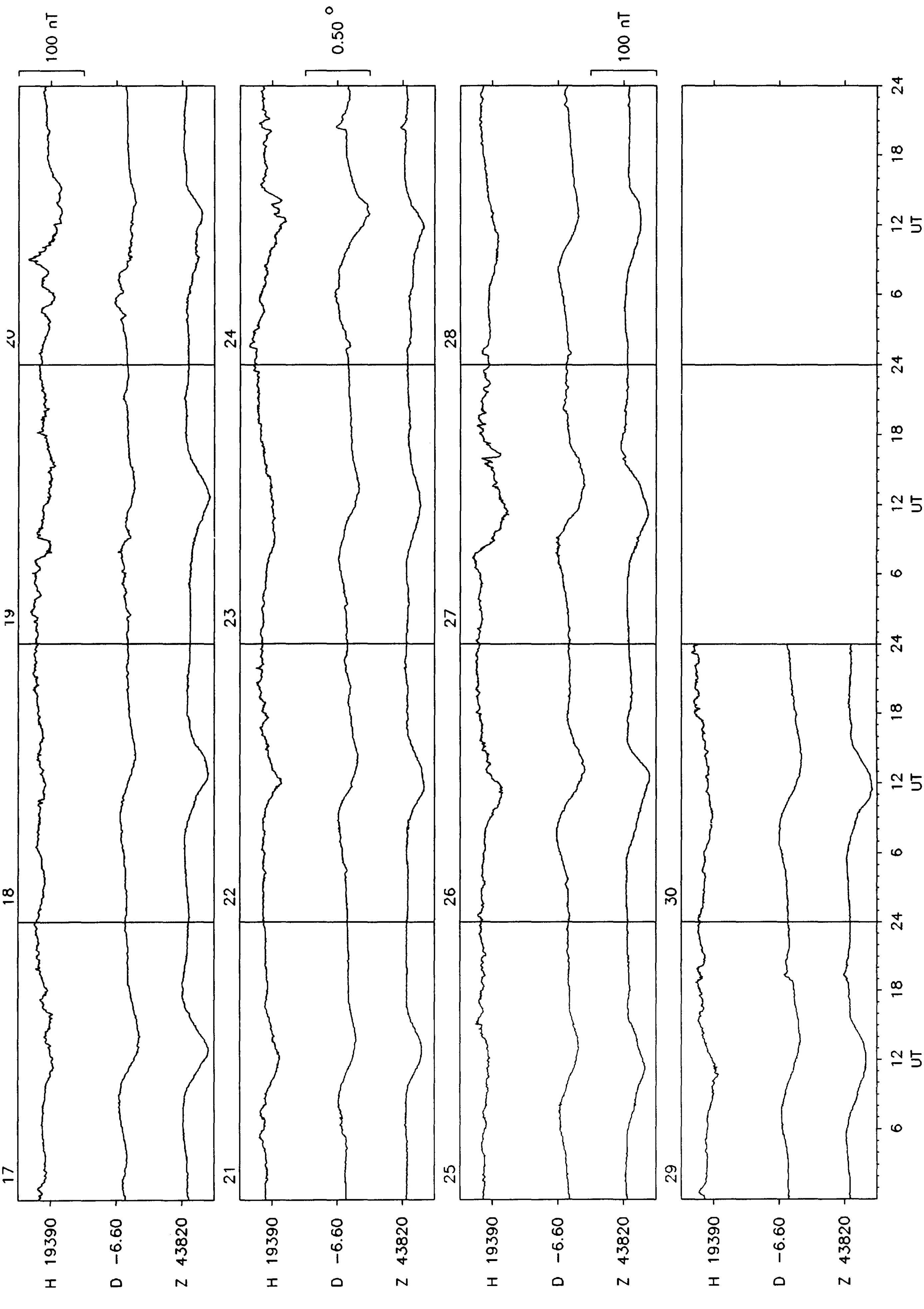

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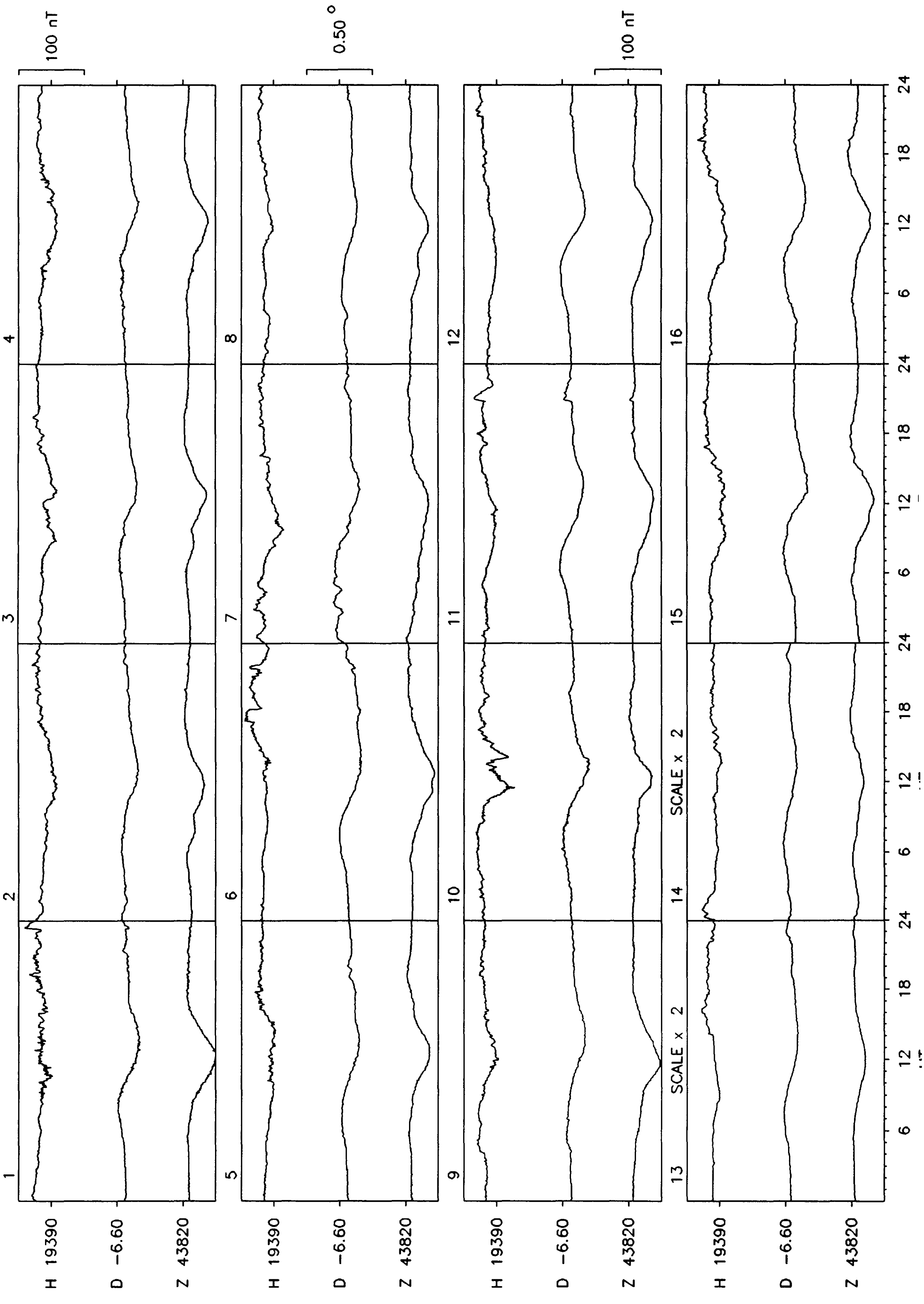
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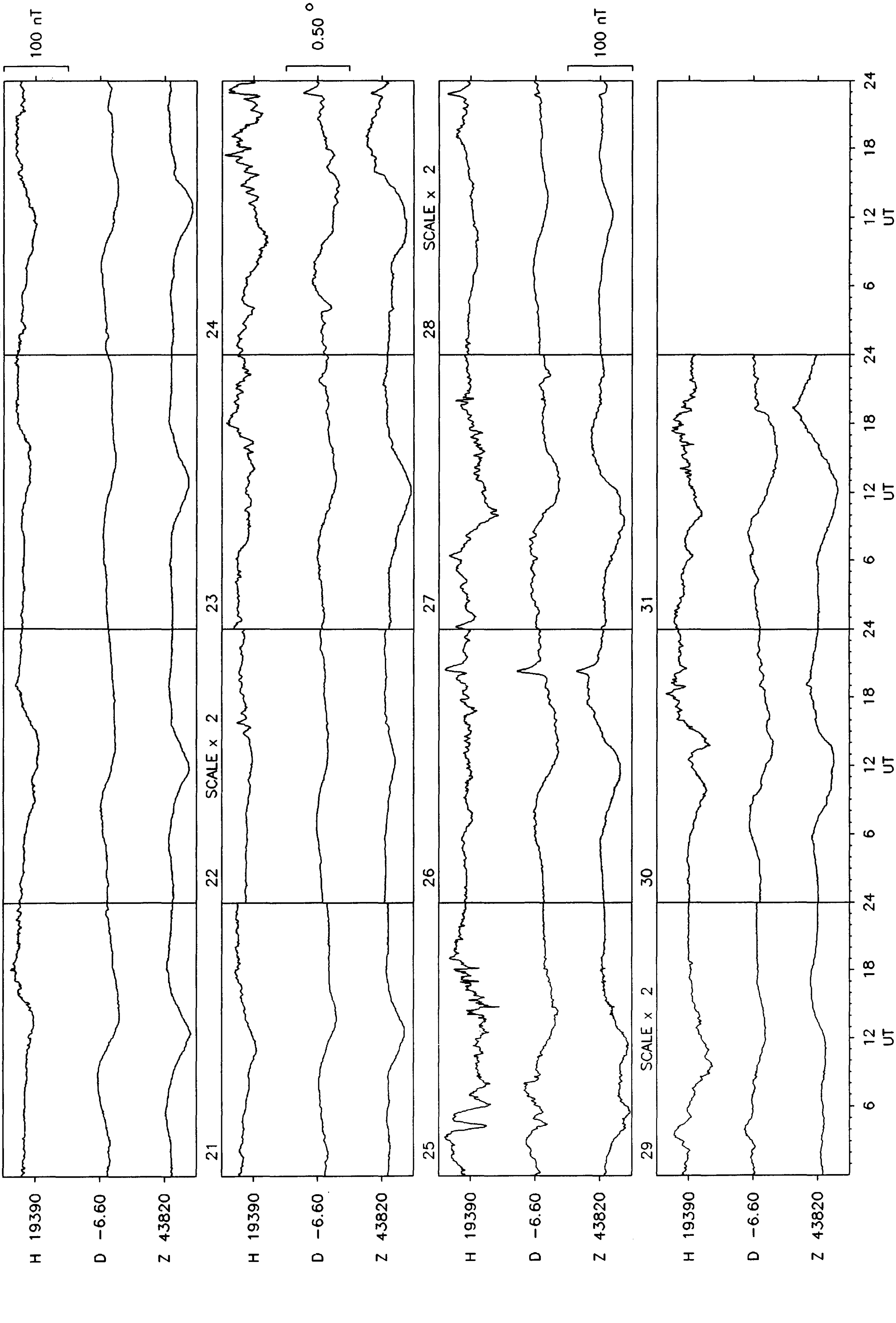

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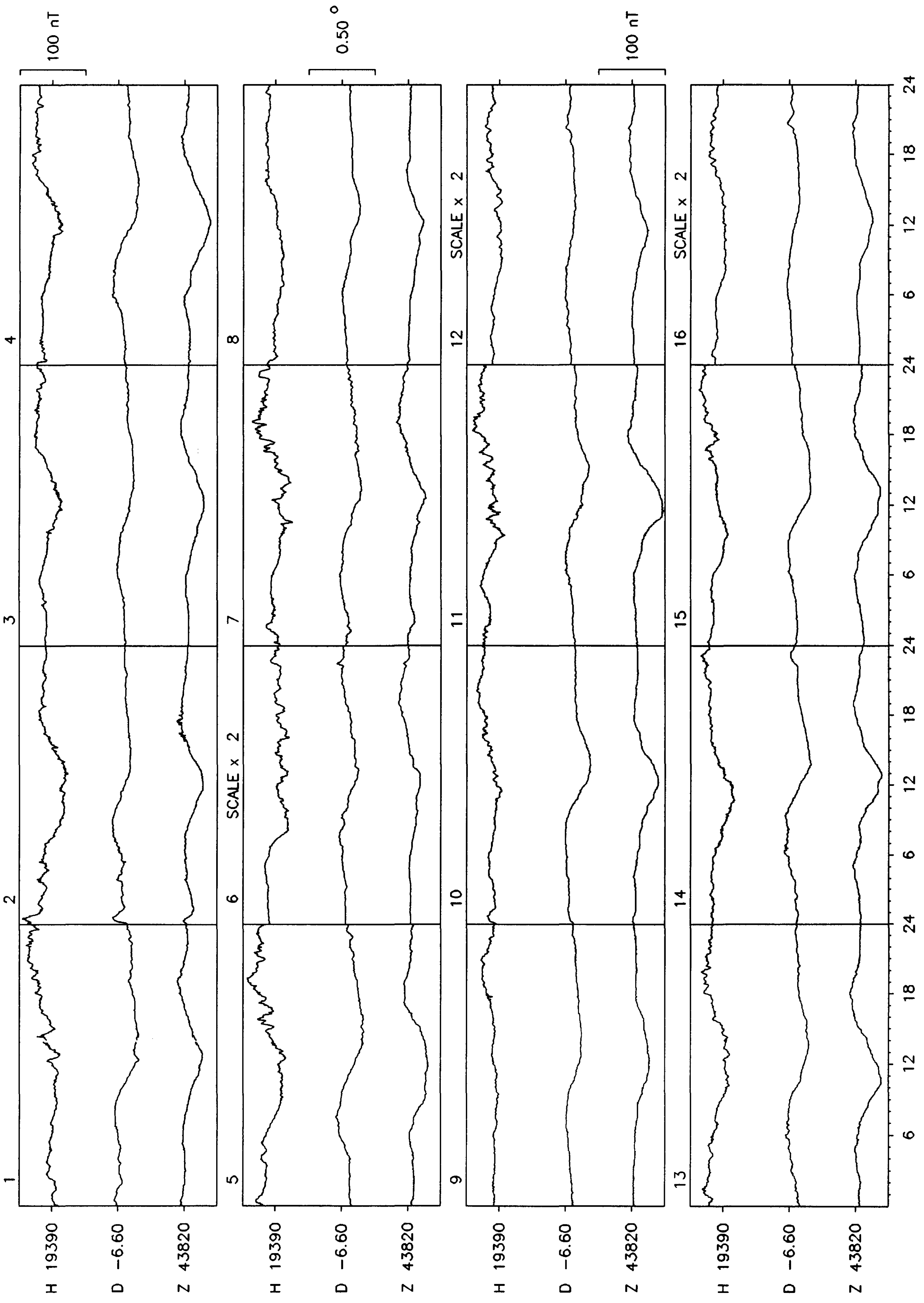

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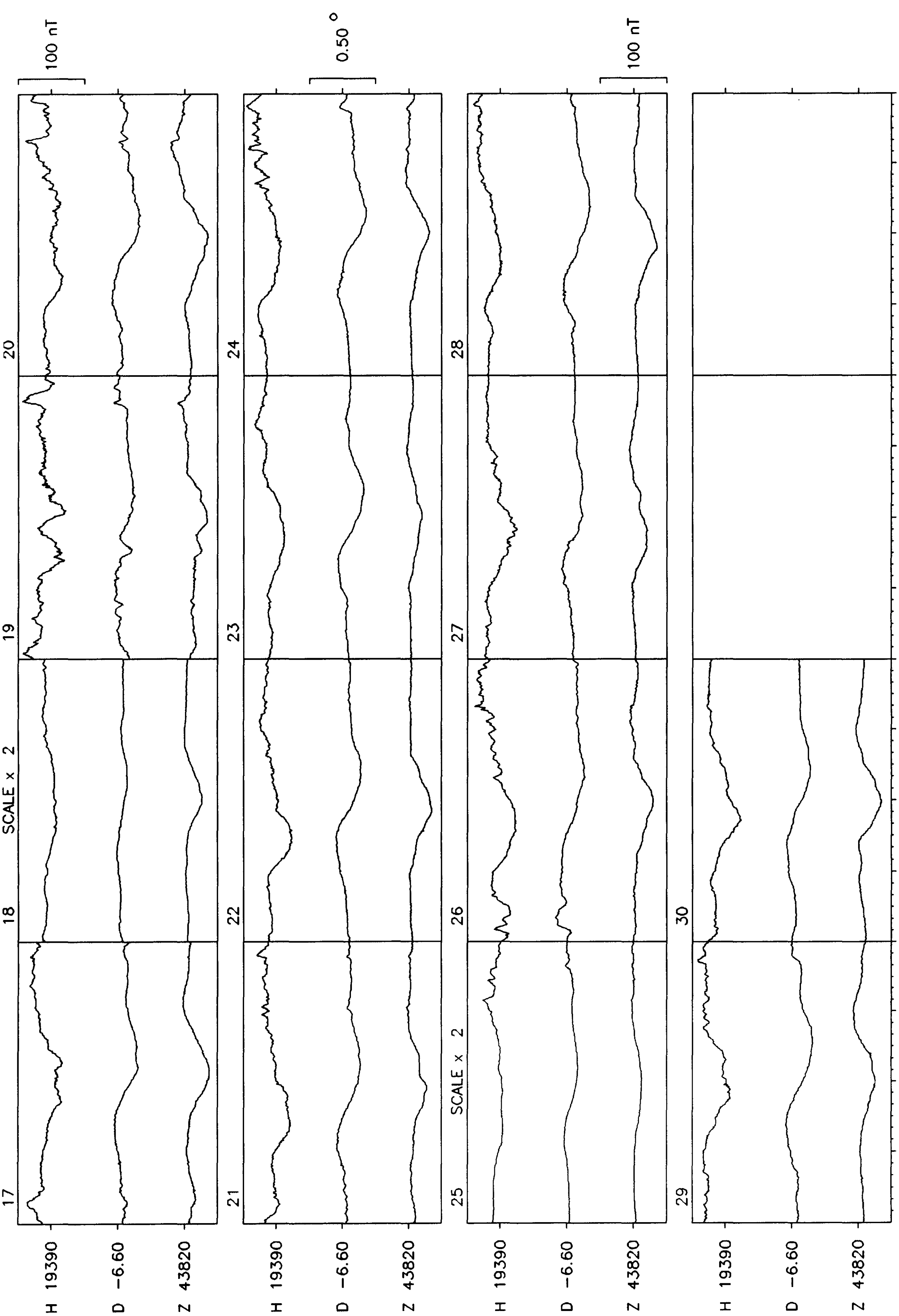

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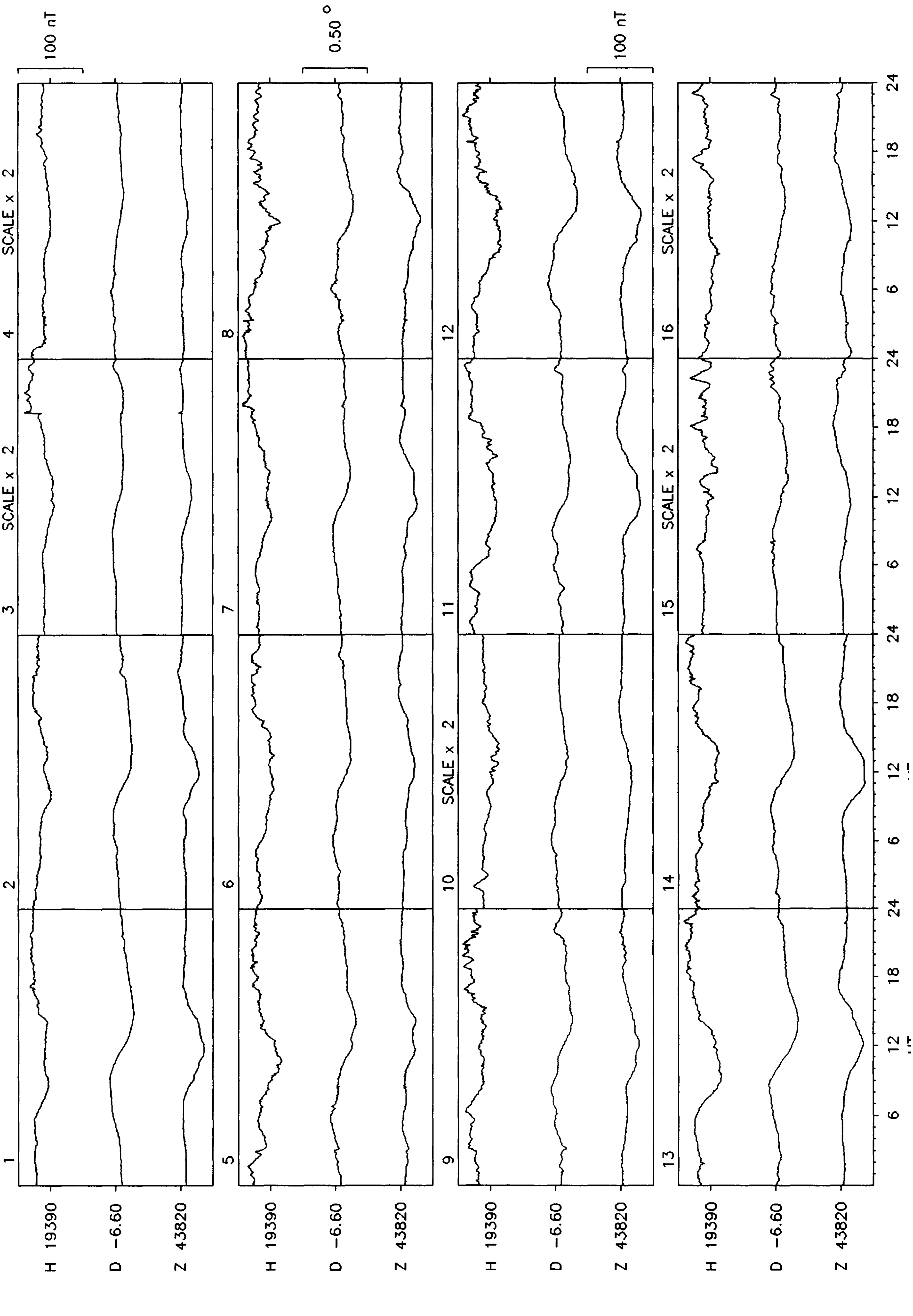

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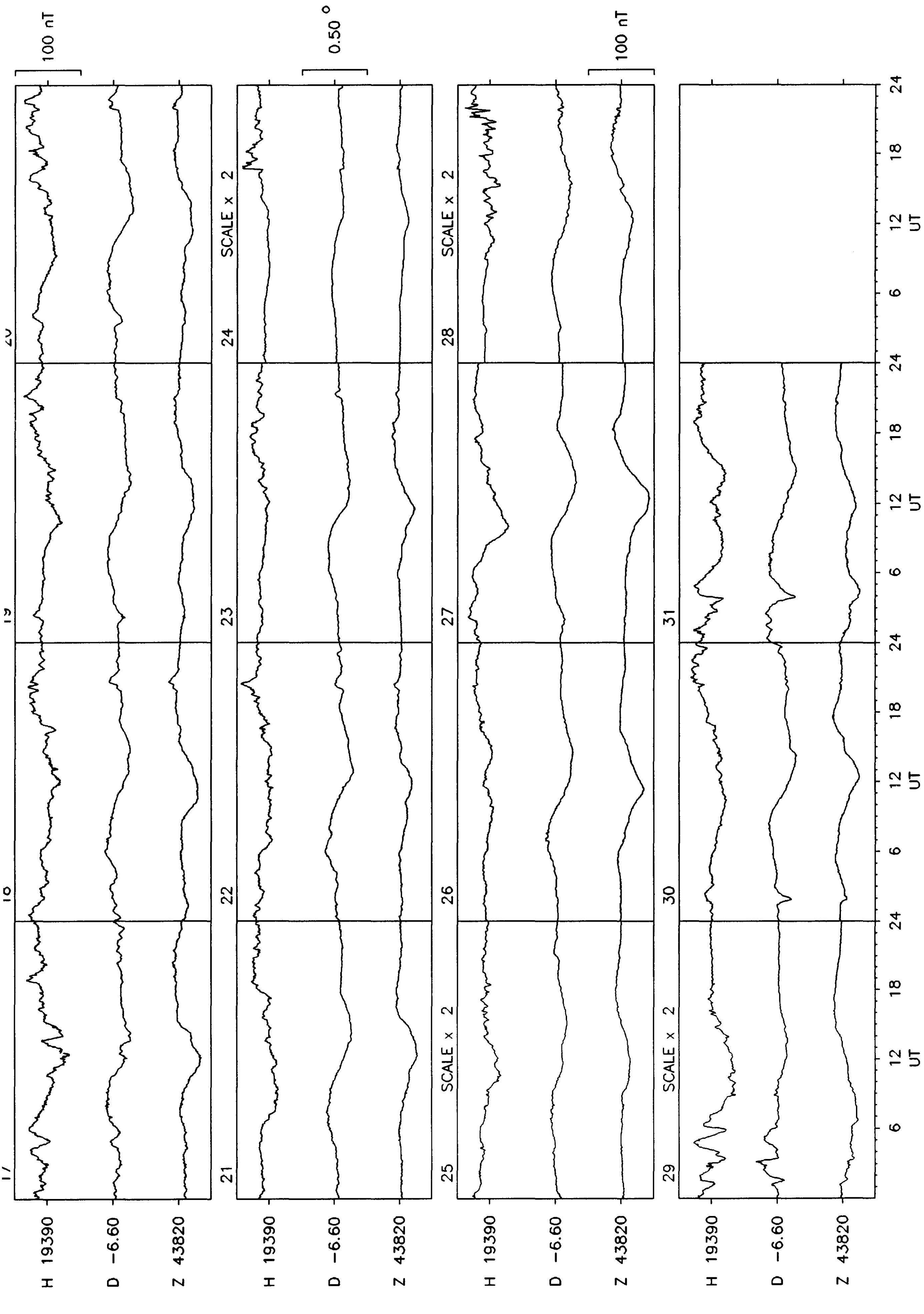
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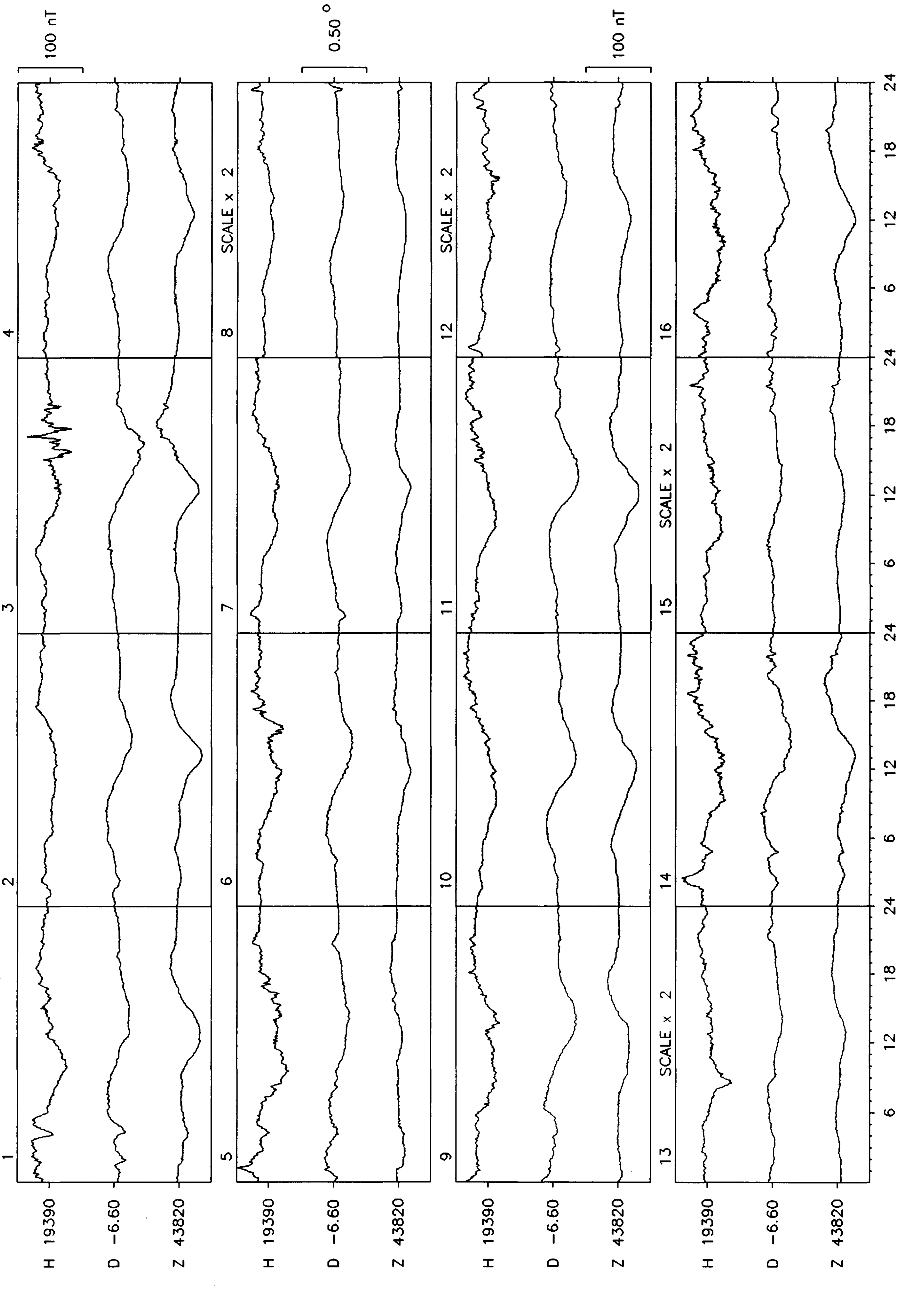

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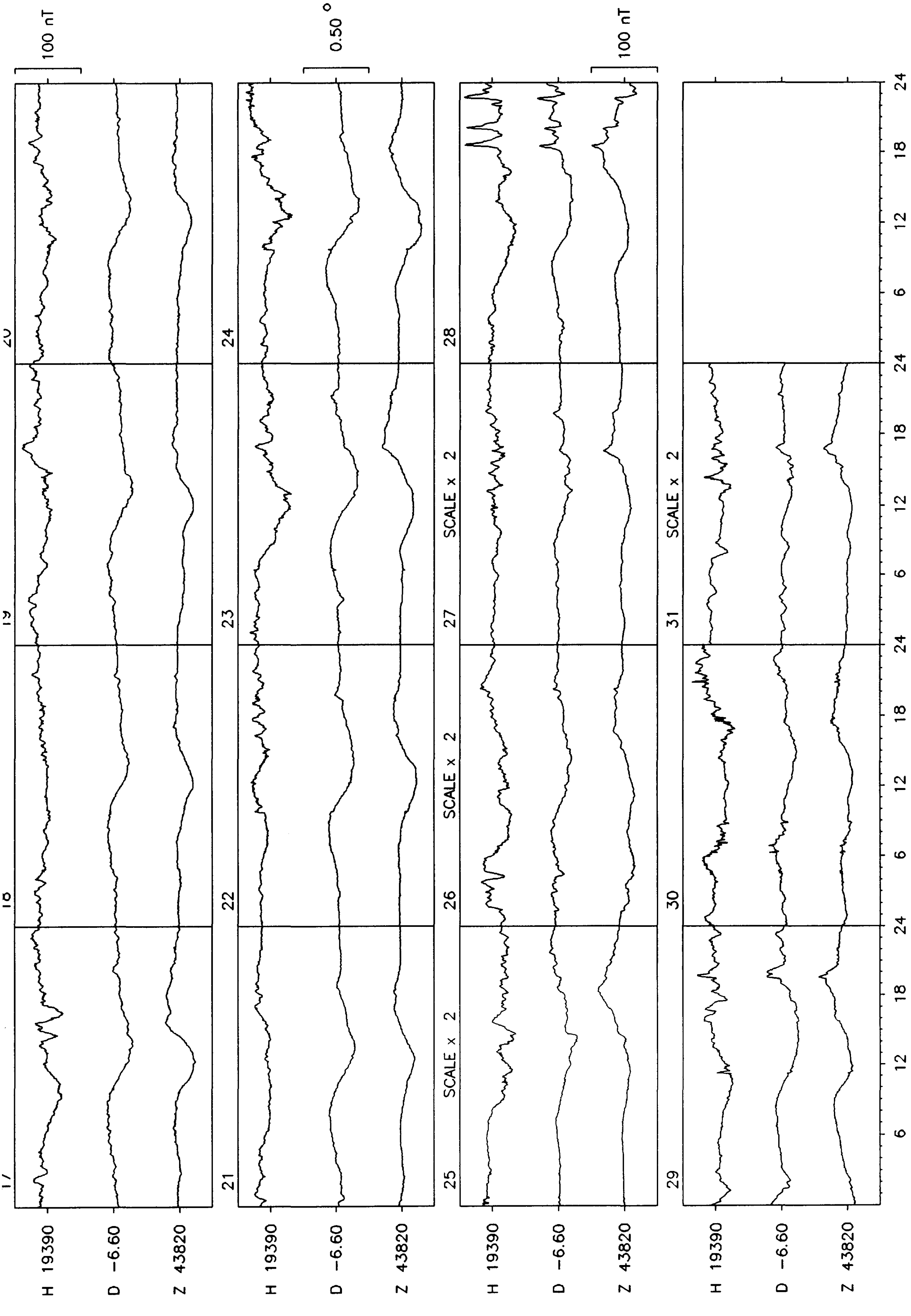
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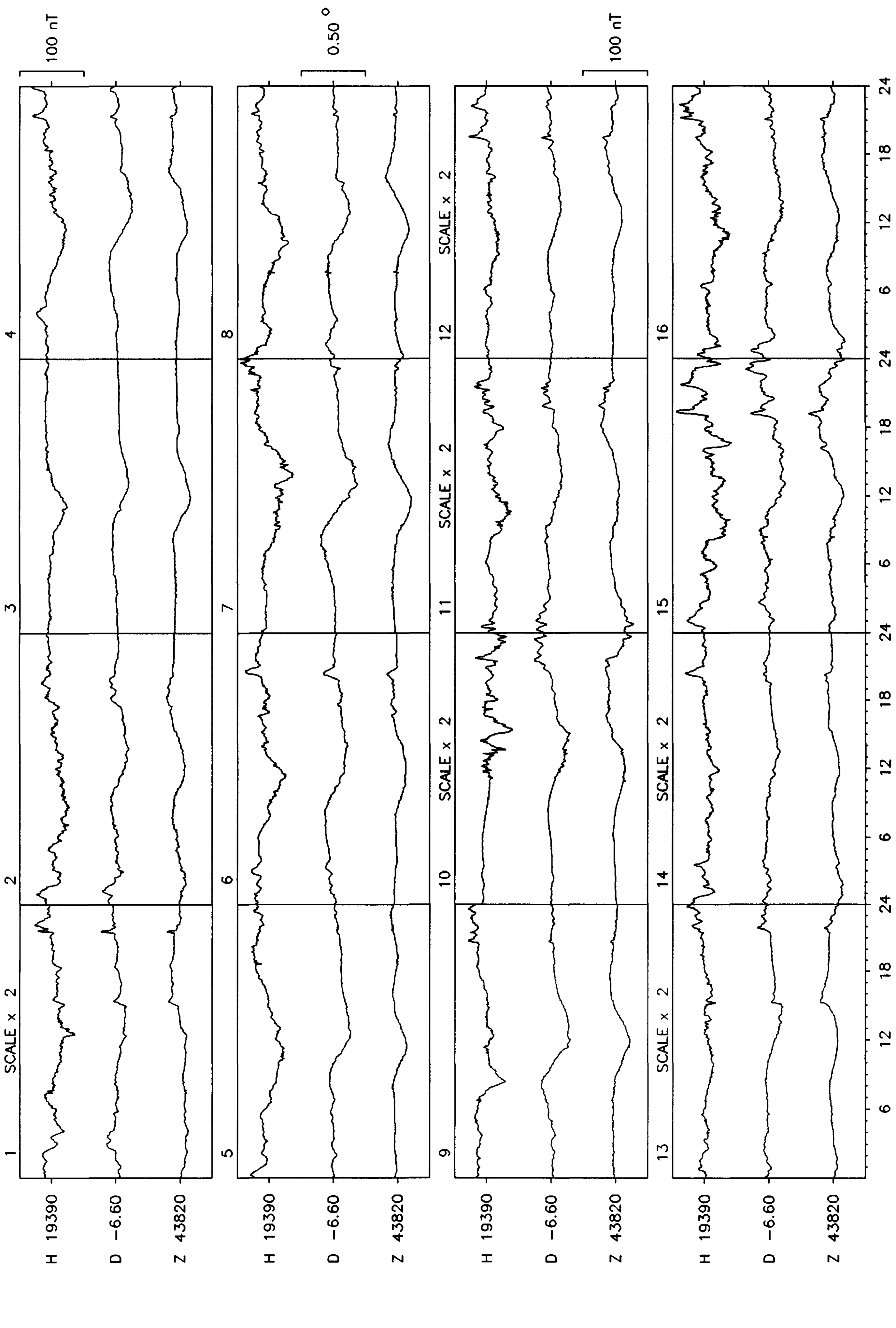

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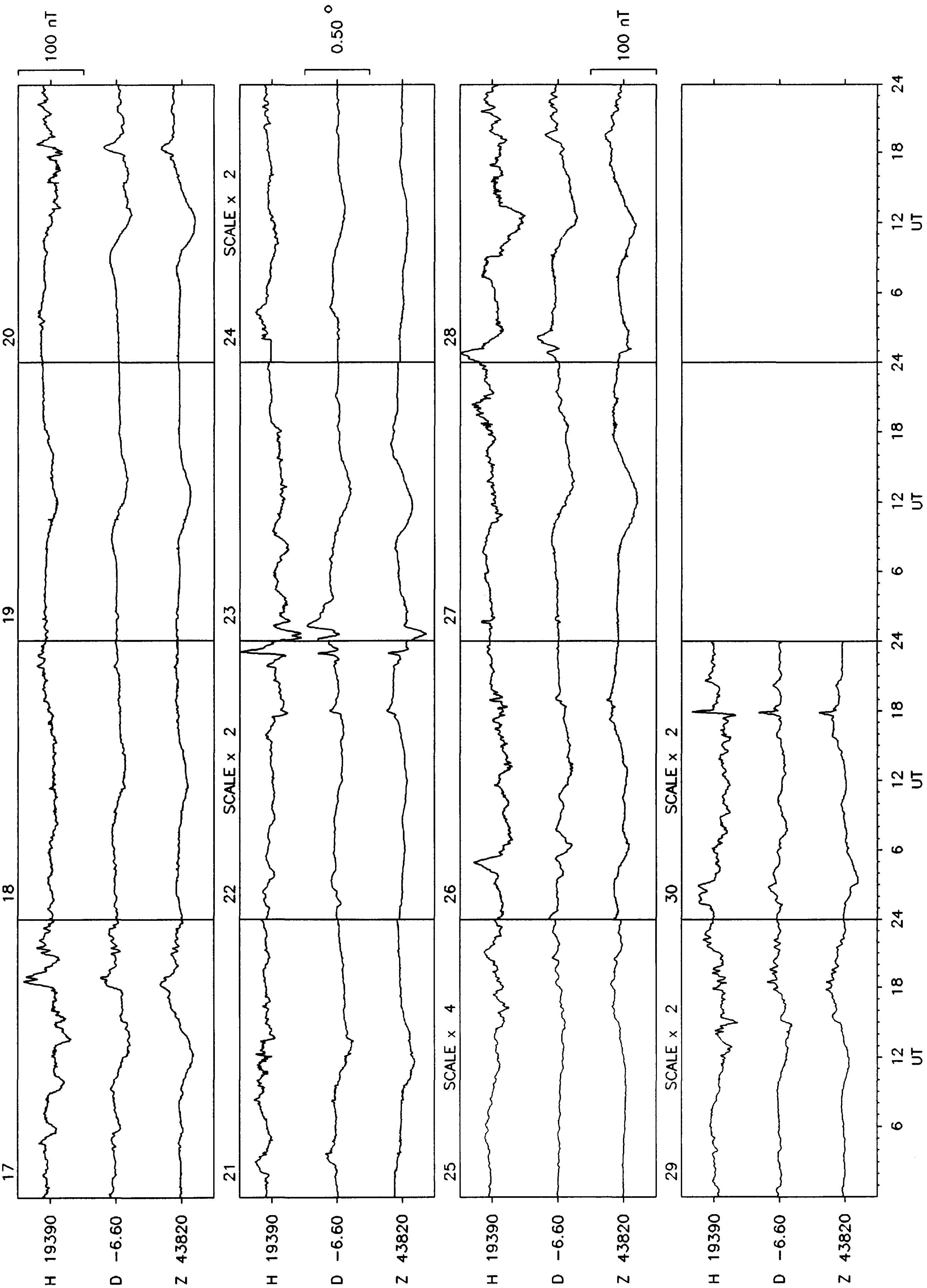
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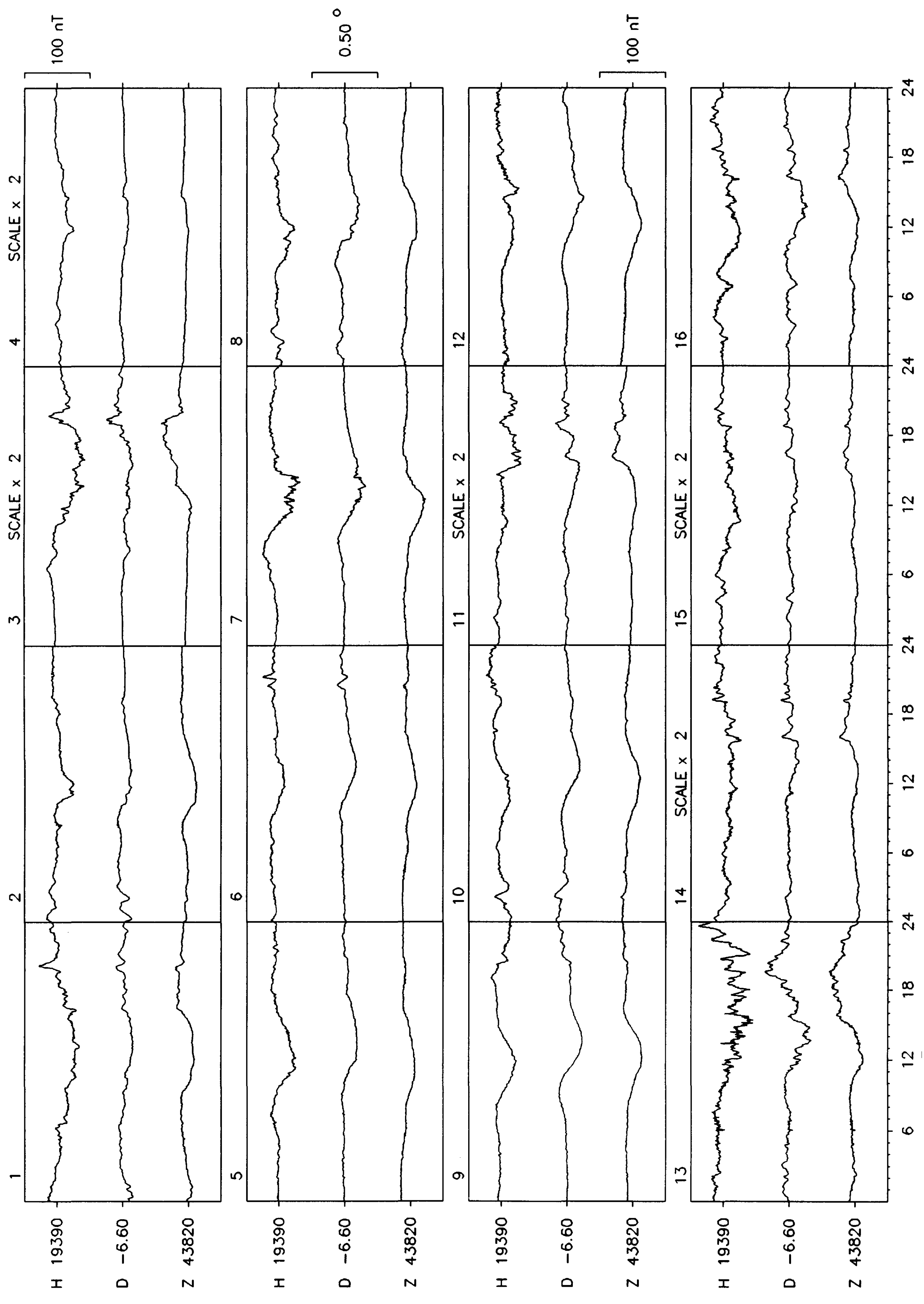

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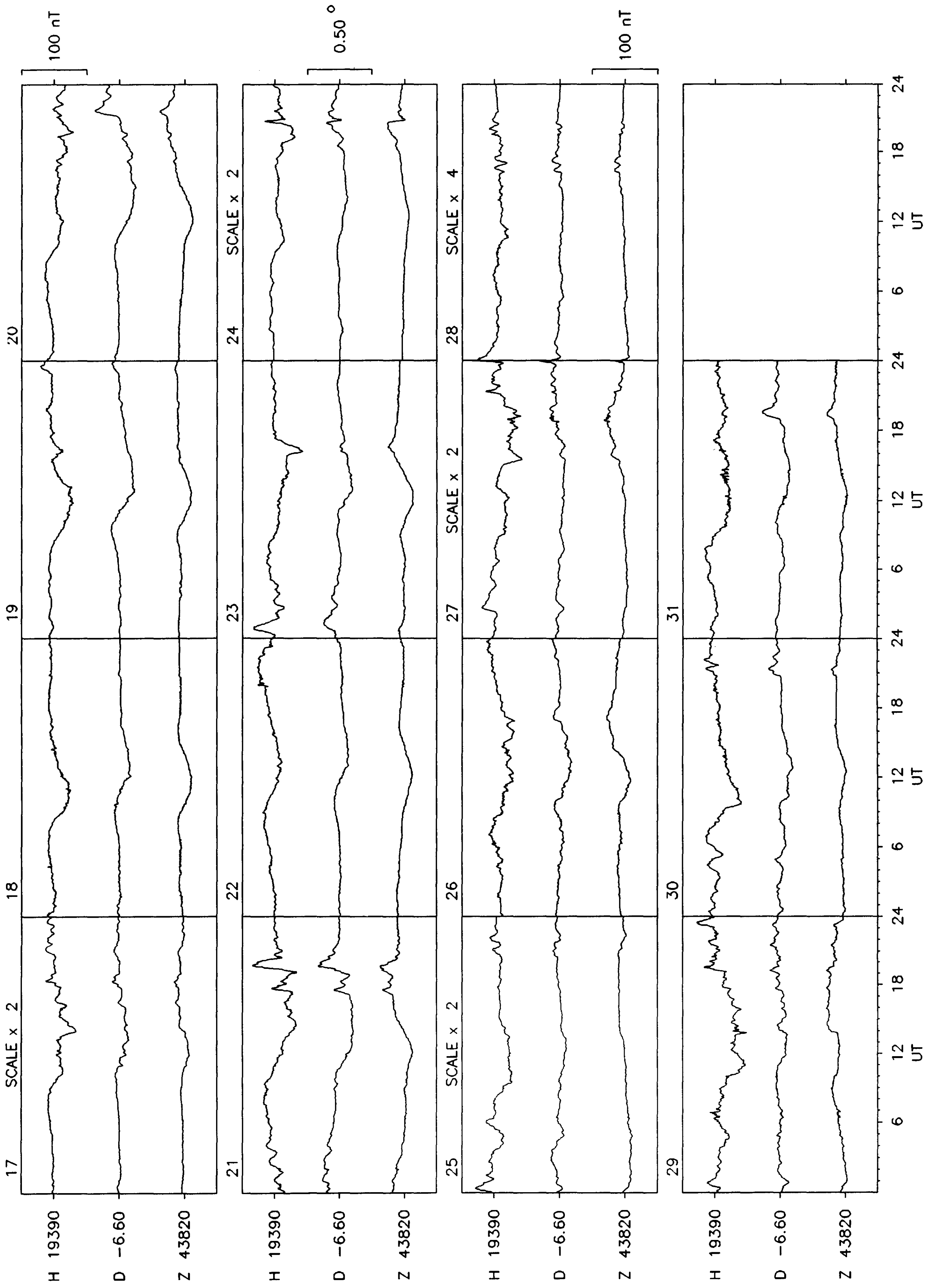
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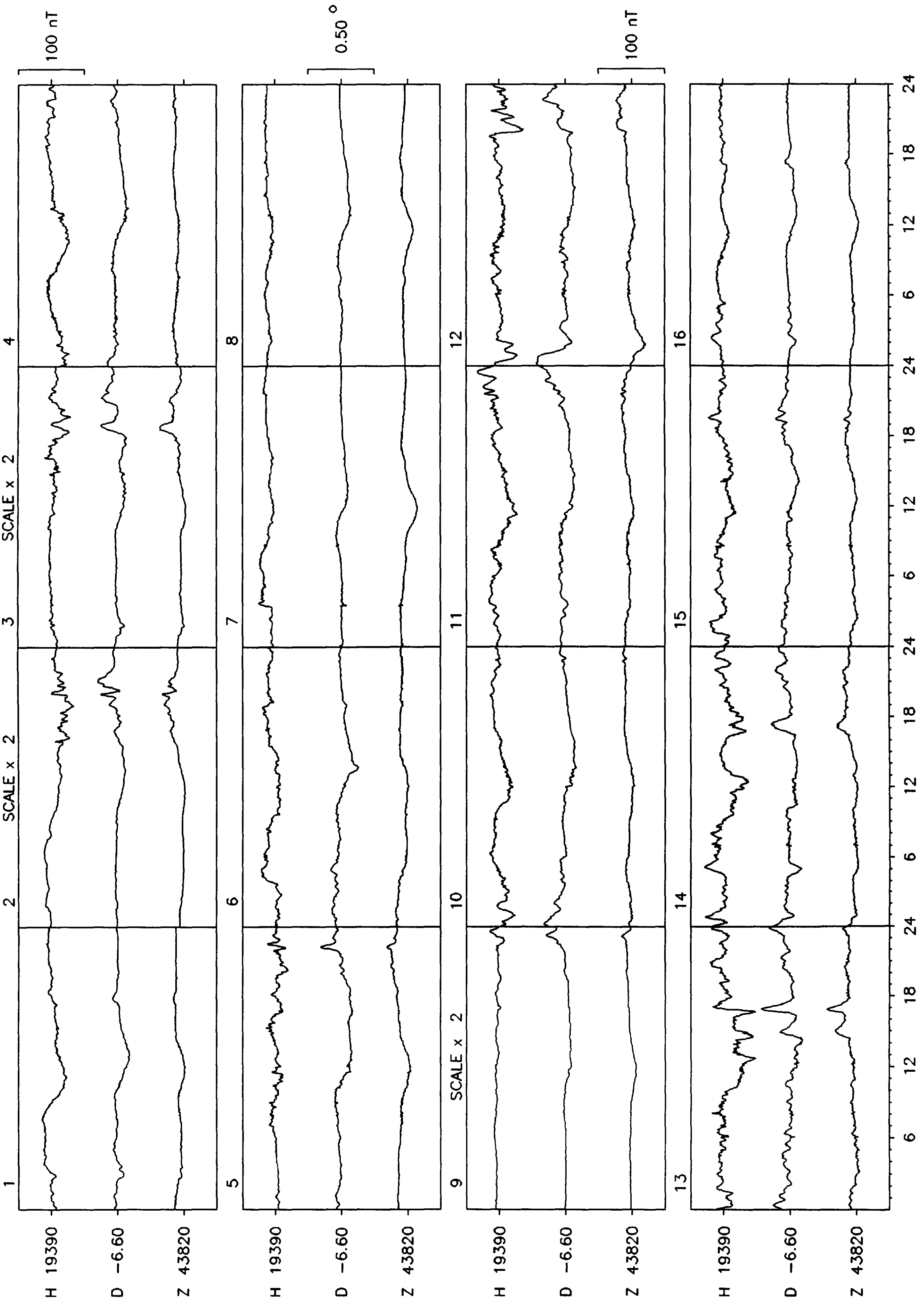
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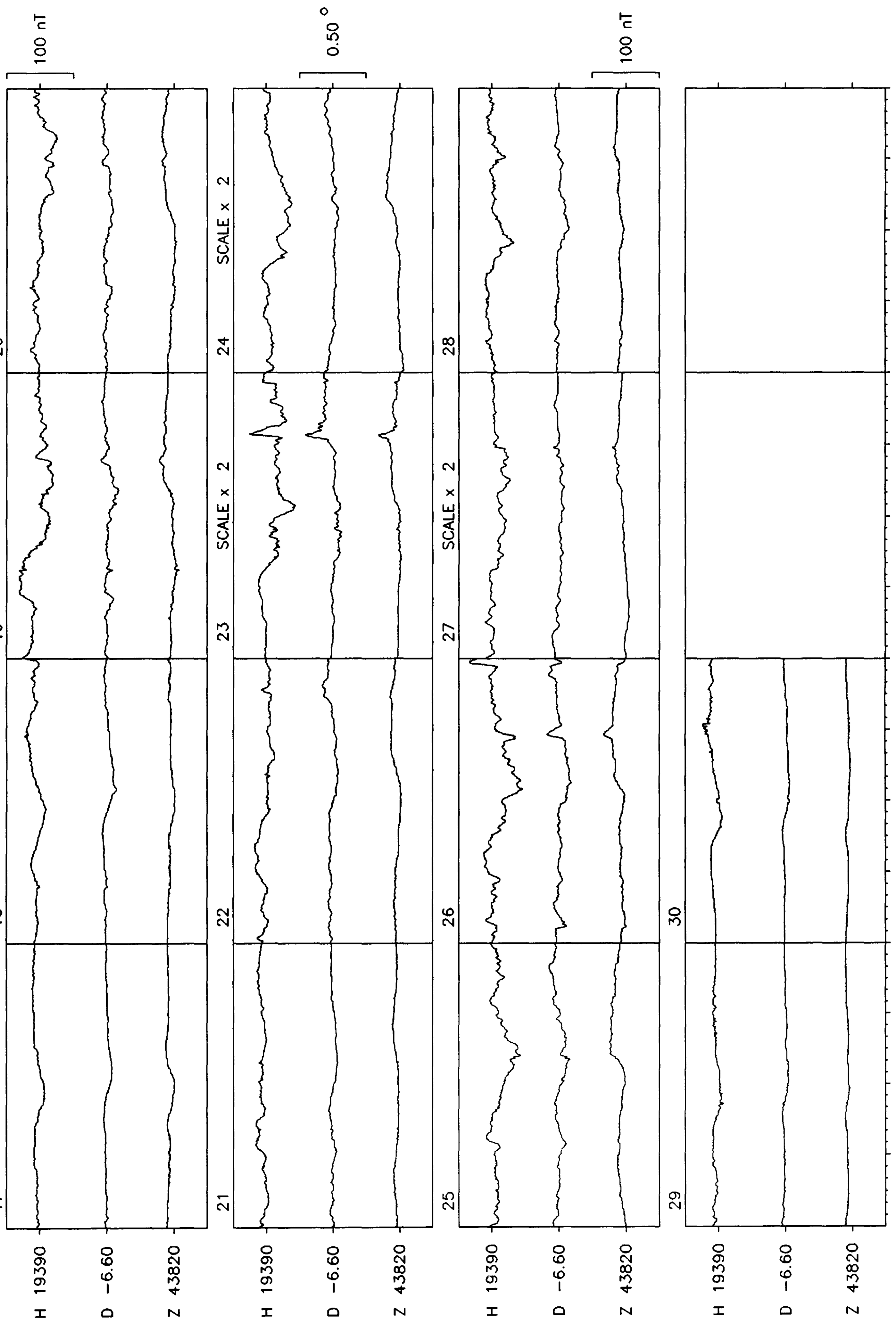
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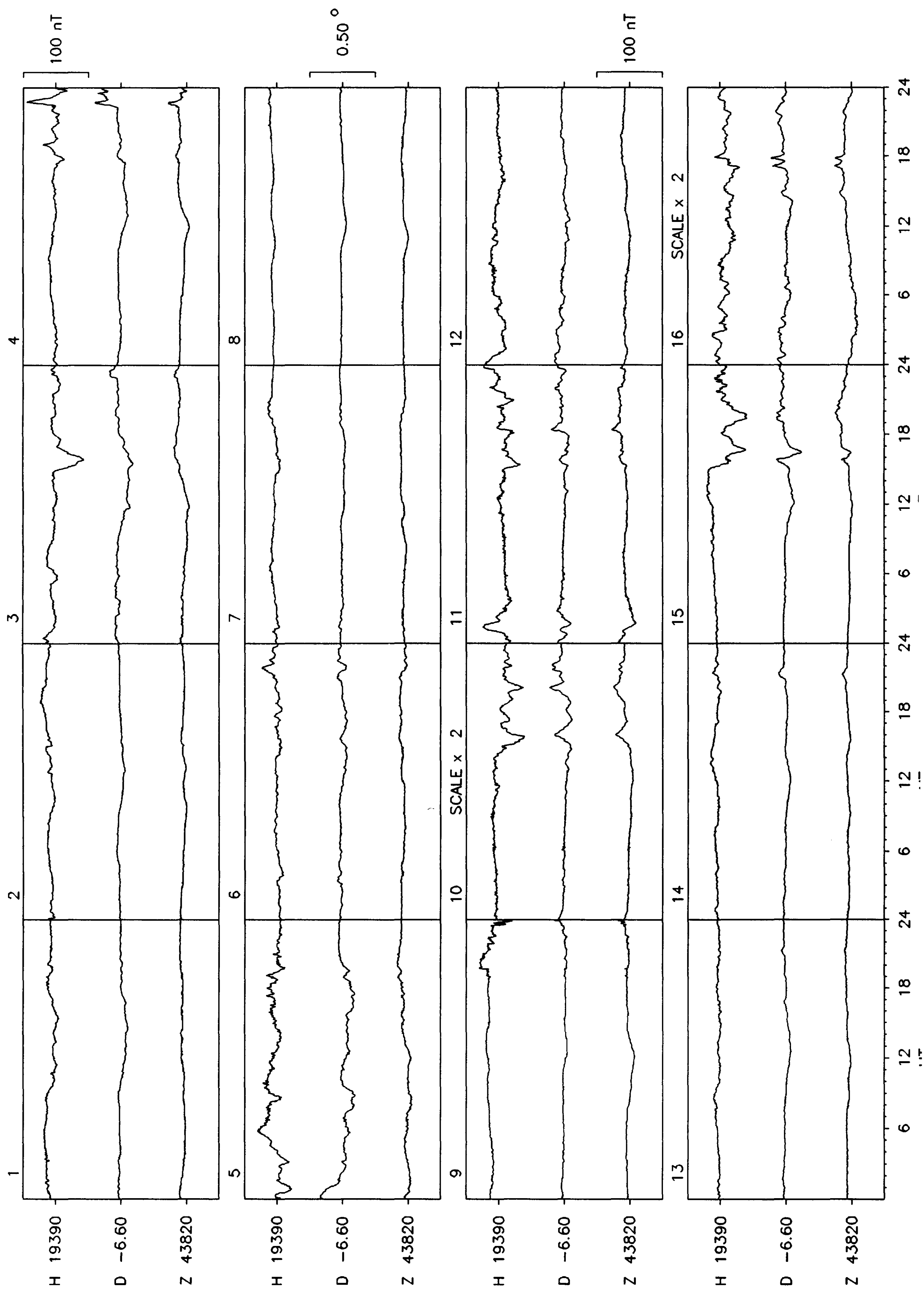
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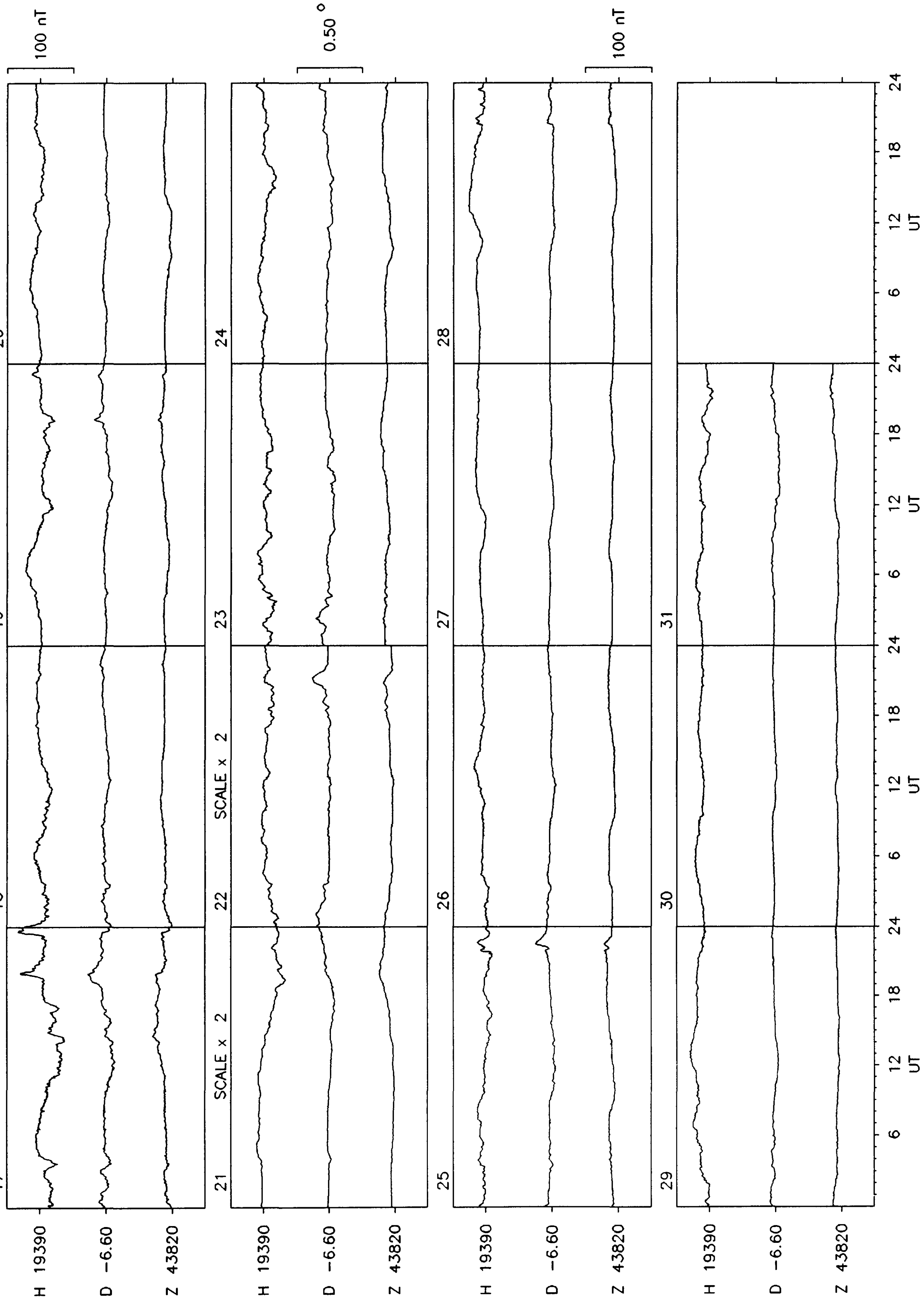

100 nT
0.50 °
100 nT
H 19390
D −6.60
Z 43820
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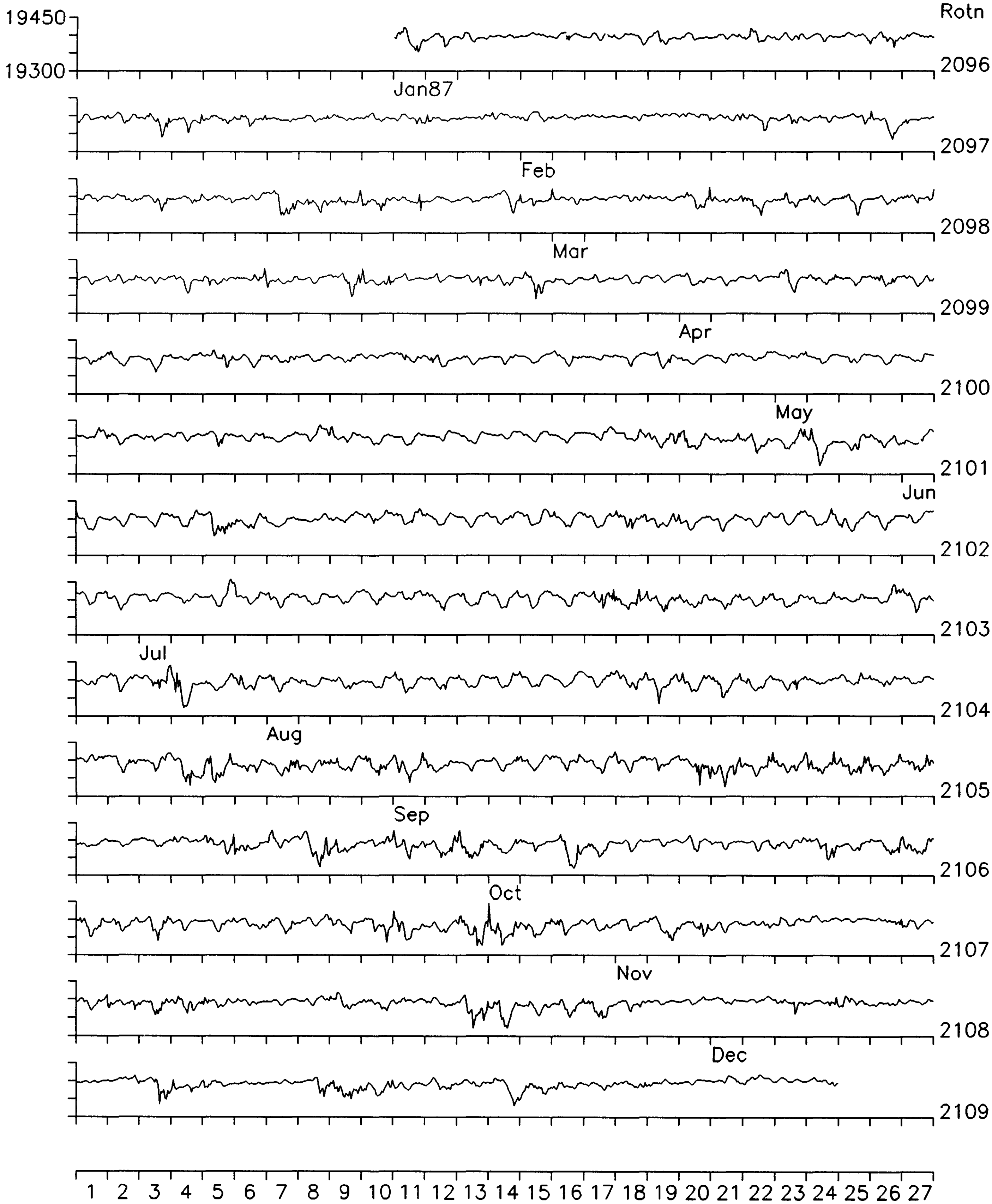
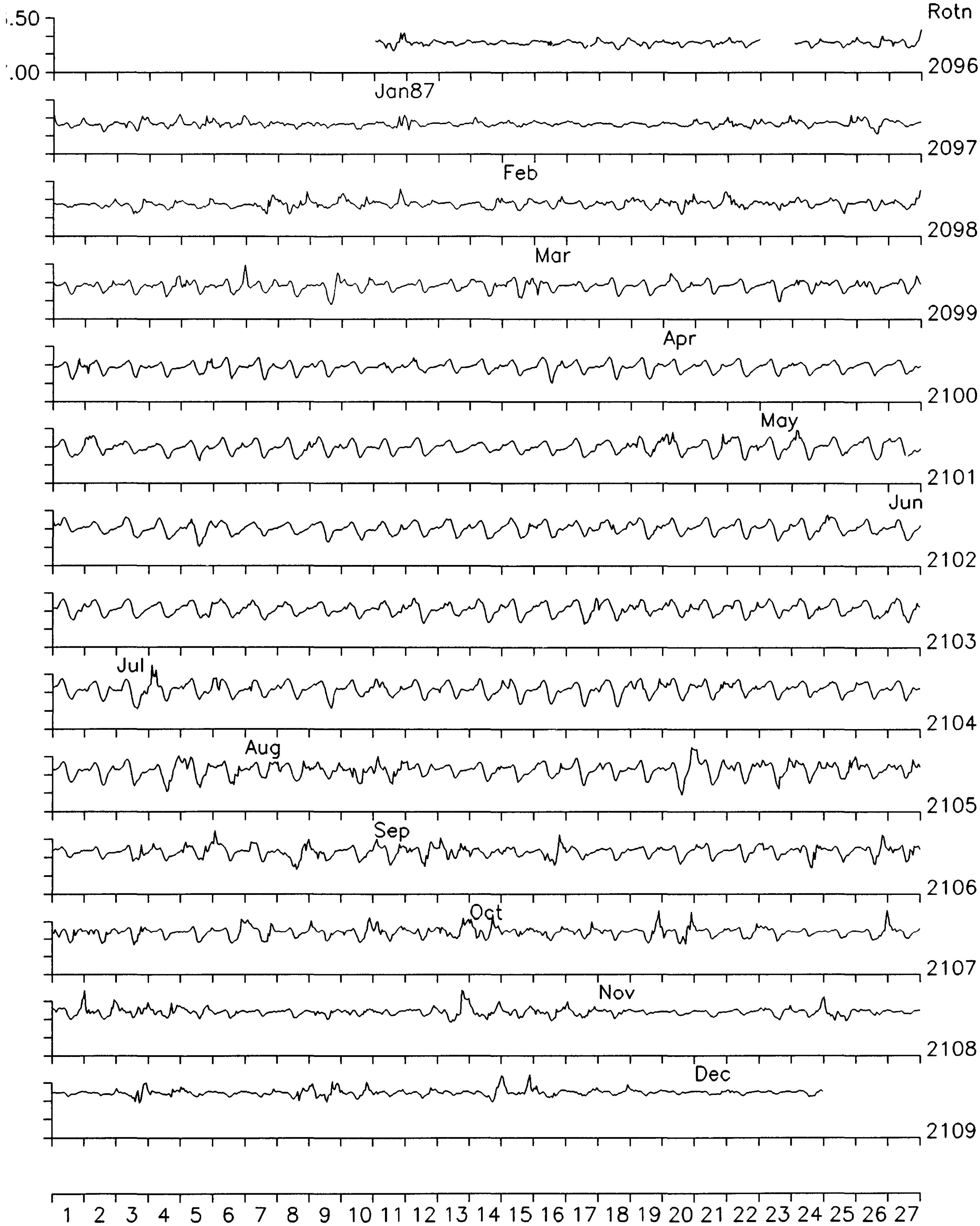
Hartland Observatory: Horizontal Intensity (nT)

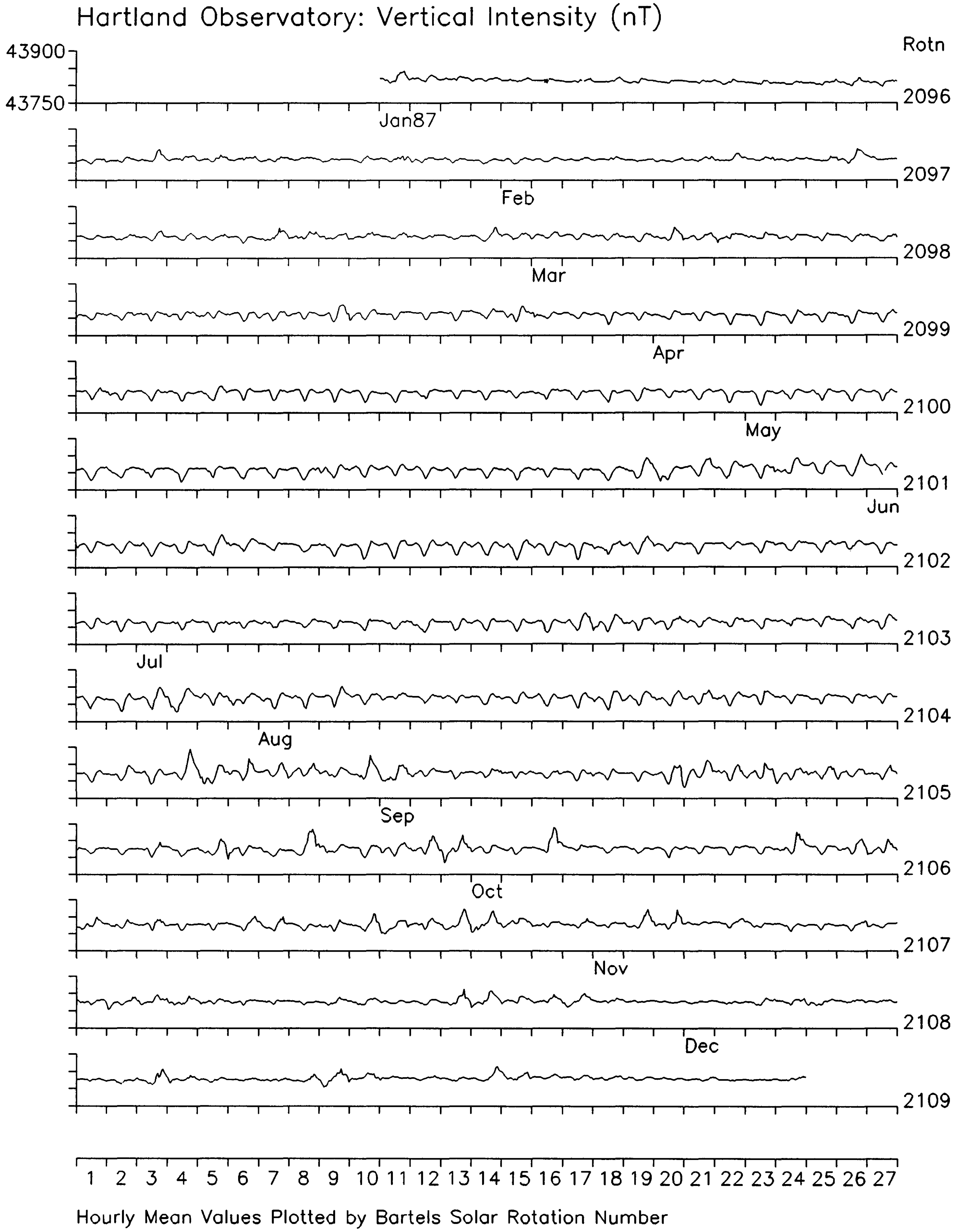


Hourly Mean Values Plotted by Bartels Solar Rotation Number

Hartland Observatory: Declination (degrees)



Hourly Mean Values Plotted by Bartels Solar Rotation Number


Hartland Observatory: Vertical Intensity (nT)
43900
43750
Rotn
2096
Jan87
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2100
May
2101
Jun
2102
2103
Jul
2104
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2108
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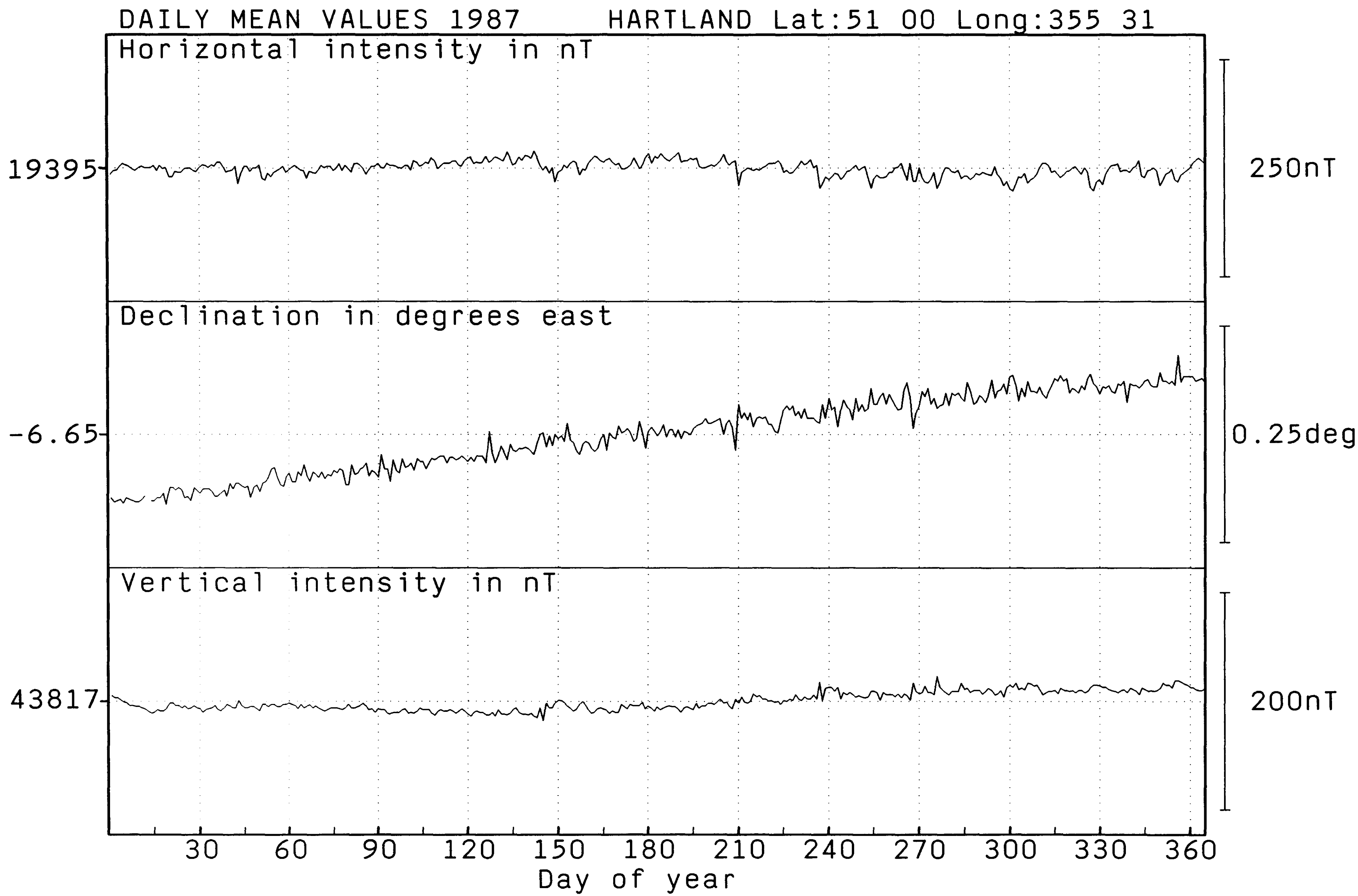
2109
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Hourly Mean Values Plotted by Bartels Solar Rotation Number


DAILY MEAN VALUES 1987
HARTLAND Lat:51 00 Long:355 31
Horizontal intensity in nT
19395
250nT
Declination in degrees east
-6.65
0.25deg
Vertical intensity in nT
43817
200nT
30
60
90
120
150
180
210
240
270
300
330
360
Day of year

Monthly and annual mean values for Hartland 1987

Month	D	I	H	X	Y	Z	F
	° ′	° ′	nT	nT	nT	nT	nT
Jan	-6 43.5	66 7.4	19394	19261	-2271	43812	47913
Feb	-6 42.8	66 7.4	19393	19260	-2267	43812	47912
Mar	-6 42.0	66 7.3	19395	19263	-2263	43811	47912
Apr	-6 41.2	66 6.9	19399	19267	-2259	43808	47911
May	-6 40.2	66 6.7	19402	19271	-2254	43807	47911
Jun	-6 39.5	66 6.9	19401	19270	-2250	43811	47915
Jul	-6 38.7	66 6.9	19402	19272	-2245	43813	47917
Aug	-6 38.0	66 7.6	19394	19264	-2240	43821	47921
Sep	-6 37.0	66 8.1	19388	19259	-2234	43823	47920
Oct	-6 36.4	66 8.4	19385	19256	-2230	43827	47923
Nov	-6 35.9	66 8.2	19389	19261	-2228	43828	47925
Dec	-6 35.6	66 7.9	19393	19265	-2227	43829	47928
Annual	-6 39.2	66 7.4	19395	19264	-2247	43817	47918

HARTLAND OBSERVATORY K INDICES 1987

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	3334 3344	2211 2222	2111 2333	2321 2232	1013 2223	2112 3322	0100 2111	3422 2322	5432 4435	3122 2343	3322 2321	1101 1210
2	1322 4322	2010 1210	0011 1212	0221 2110	2111 2222	3321 2211	1011 1121	2221 2311	4322 2321	3123 2121	2222 2455	2101 1211
3	2221 1011	1111 0010	0212 2233	0010 1010	1222 3221	0102 2213	1112 2144	1121 2431	0112 2101	0134 4453	4213 3464	3223 1423
4	2000 0112	0001 1320	3112 2213	1323 3322	1122 2211	2312 2222	4321 1232	1212 2322	1222 2323	2223 3221	3222 2122	2100 1334
5	1000 0111	0012 1201	2323 3435	3321 2333	0102 2321	2221 3332	2222 2222	3332 2332	3222 2222	1112 2212	2123 2334	4433 2332
6	0100 1001	3201 2113	3222 1134	1201 3212	0201 2333	1244 3343	1221 1322	1322 2431	2223 3242	1111 2133	3312 3222	1211 2233
7	1100 0123	2111 2323	4332 4222	4232 3320	3322 2212	3213 3332	1112 1120	3211 1221	1223 3313	0011 3100	1321 1101	2111 2120
8	2111 1223	2231 2342	3133 3313	1122 2243	1212 1211	2111 1211	2333 3222	1222 2334	4323 3322	3223 3221	1121 2100	0000 1010
9	1132 2111	2214 2314	3321 1211	1112 2242	0212 2111	0011 1112	1331 2323	3332 3221	2333 2222	0011 1132	0112 2235	0001 1024
10	1122 2011	3312 1211	2232 3300	4421 2110	1223 3321	2112 2211	4333 3321	1211 1222	2123 5545	3211 1122	4223 3212	3223 3554
11	0120 1123	1100 1042	1122 2331	0122 3312	2212 1233	2123 2322	2321 2233	2111 2332	5344 3444	2233 3554	2323 2234	4211 2334
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13	2011 2332	2210 1011	3122 2113	2113 1434	1221 2323	2212 1221	2223 3213	3344 3333	4323 3424	3233 3455	4333 4534	1011 1211
14	1110 2130	0111 1210	2222 2232	1112 3221	3222 3323	1222 2212	2222 2222	3323 3333	5433 3343	4333 3543	4323 4433	1110 1122
15	0000 0133	0111 2222	2323 2123	2111 2222	0112 1211	1112 1332	1333 4444	3343 3334	4333 3454	3334 3442	3223 2332	0001 2432
16	2212 3431	2212 2342	3122 3134	1111 1101	1211 1221	2221 2342	3333 2434	3333 2332	4133 3333	2332 2332	3211 2310	4434 4534
17	3211 1124	1211 2333	3322 2212	2111 2221	1101 1222	3112 2212	2333 4233	3323 3432	2323 3343	2124 4333	1001 1101	3312 3334
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19	1122 2122	1001 1222	4322 2233	2232 2222	0100 1202	3333 3224	3212 2333	2222 3323	1012 1210	1112 3222	2333 3321	1212 2232
20	1233 3443	1334 4443	1000 1111	2334 2200	2111 1112	2222 2233	1322 2333	2213 3331	1112 2343	2111 2234	2232 2332	1101 2120
21	1222 3233	2243 1334	1112 3335	0221 1100	2101 1110	3212 1222	1222 2222	2211 1220	2322 3221	3212 2452	2121 1110	0312 2343
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26	2121 2110	1012 2111	2223 3331	1201 2111	1222 2352	3311 2232	1222 1212	4544 3443	3443 3332	1233 2323	3322 3424	1202 1111
27	1212 2000	1122 2444	3334 4434	1132 2322	3233 2333	1122 2210	2232 2221	2233 4442	2113 2233	4332 4445	3333 3423	0001 0010
28	2222 2343	2123 2234	4322 1111	2011 1002	2222 2234	1211 1212	1323 4445	2211 3344	4224 4343	6445 3553	2222 2332	0001 1122
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30	2000 0121		0111 2120	1111 1212	1113 3331	1101 0110	4121 2233	2341 2333	5443 3642	2333 2133	0002 1221	1111 1010
31	3311 1112		0101 2210		2222 2332		3422 3321	3343 5433		2222 2342		0111 2121

DAILY aa INDICES

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	39	14	19	18	12	14	5	19	50	22	14	9
2	22	7	7	10	10	13	6	10	21	16	38	9
3	11	7	14	3	13	10	16	20	7	44	46	25
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5	7	9	37	19	10	14	13	26	13	11	21	35
6	6	15	16	12	11	46	11	19	19	11	17	14
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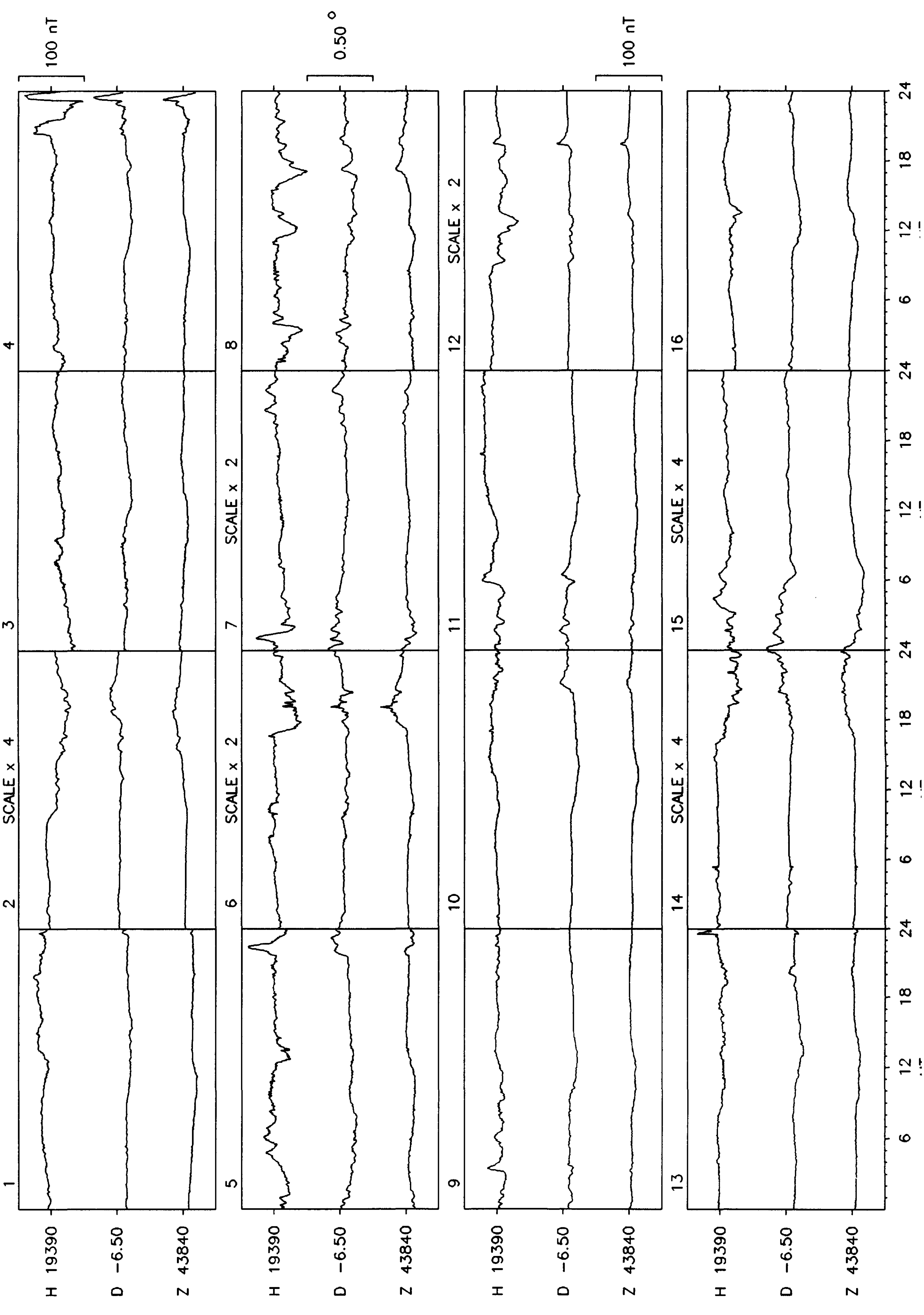
31	13		7		22		23	44		21		9
MONTHLY MEAN VALUE	**14.9**	**16.8**	**17.8**	**13.0**	**14.8**	**13.3**	**19.3**	**24.3**	**30.7**	**25.8**	**22.4**	**16.0**

YEARLY MEAN VALUE FOR 1987 = 19.1

HARTLAND 1988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100 nT
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SCALE x 2
SCALE x 4
SCALE x 4
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D −6.50
Z 43840
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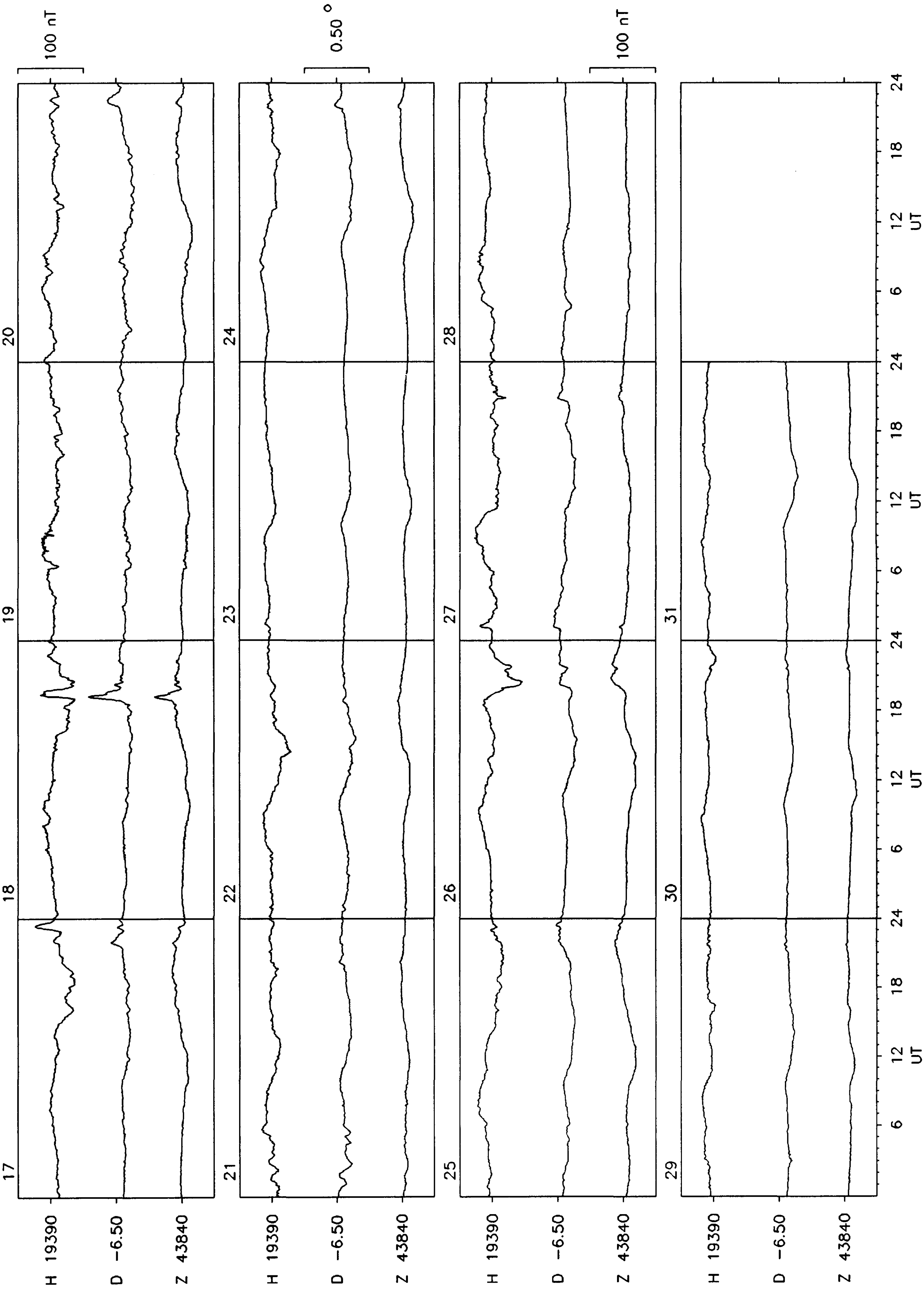
100 nT
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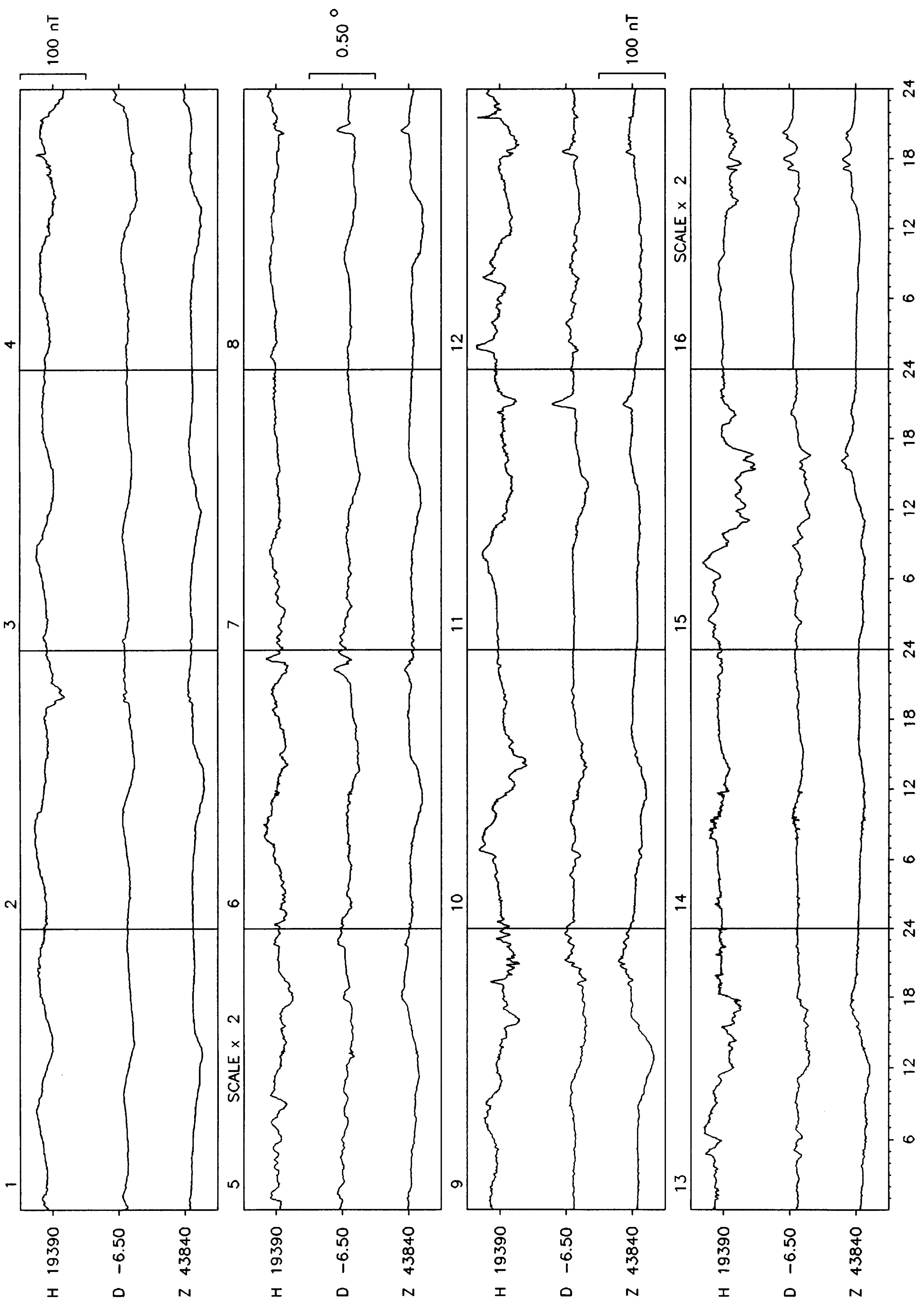

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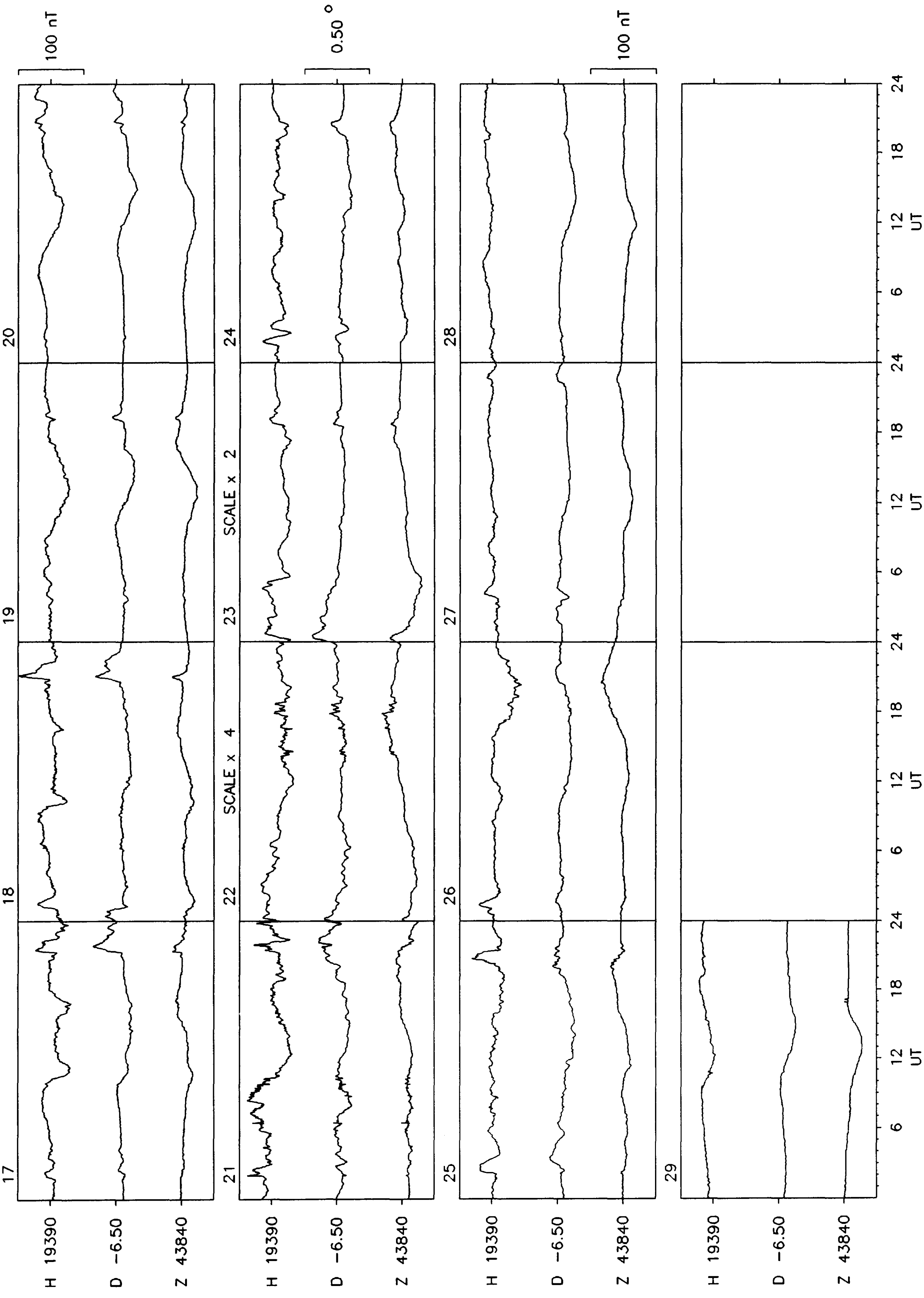
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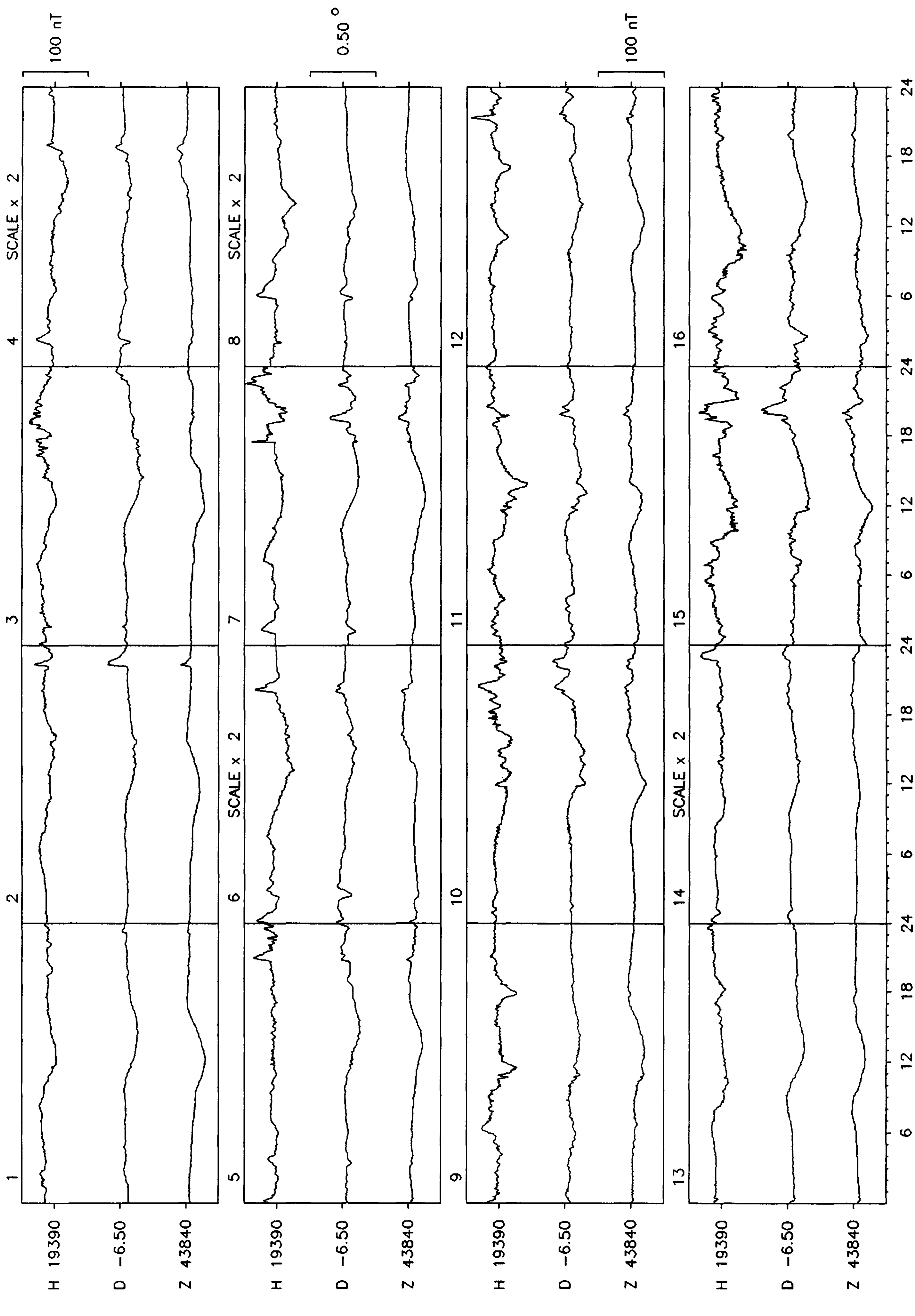

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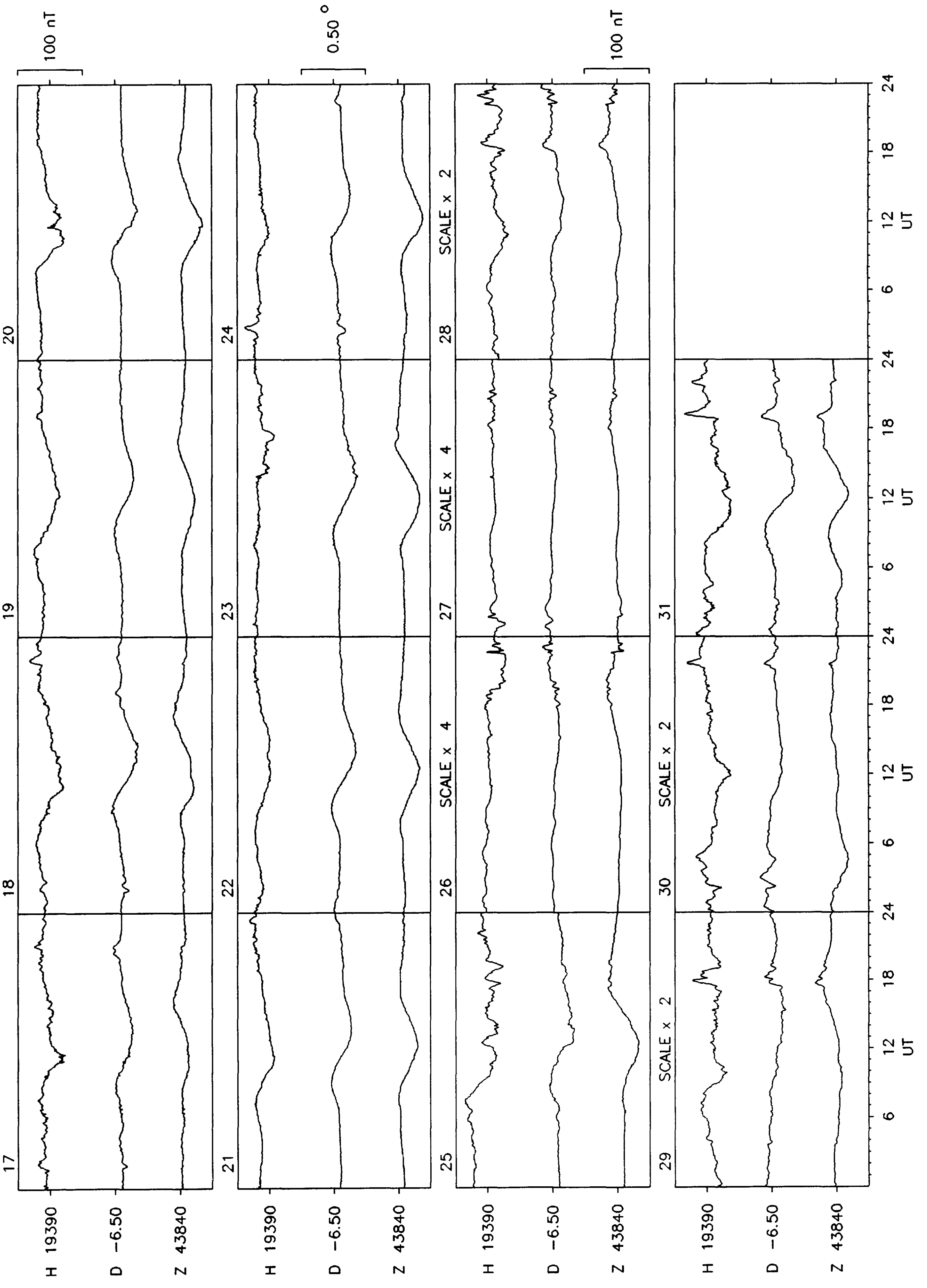
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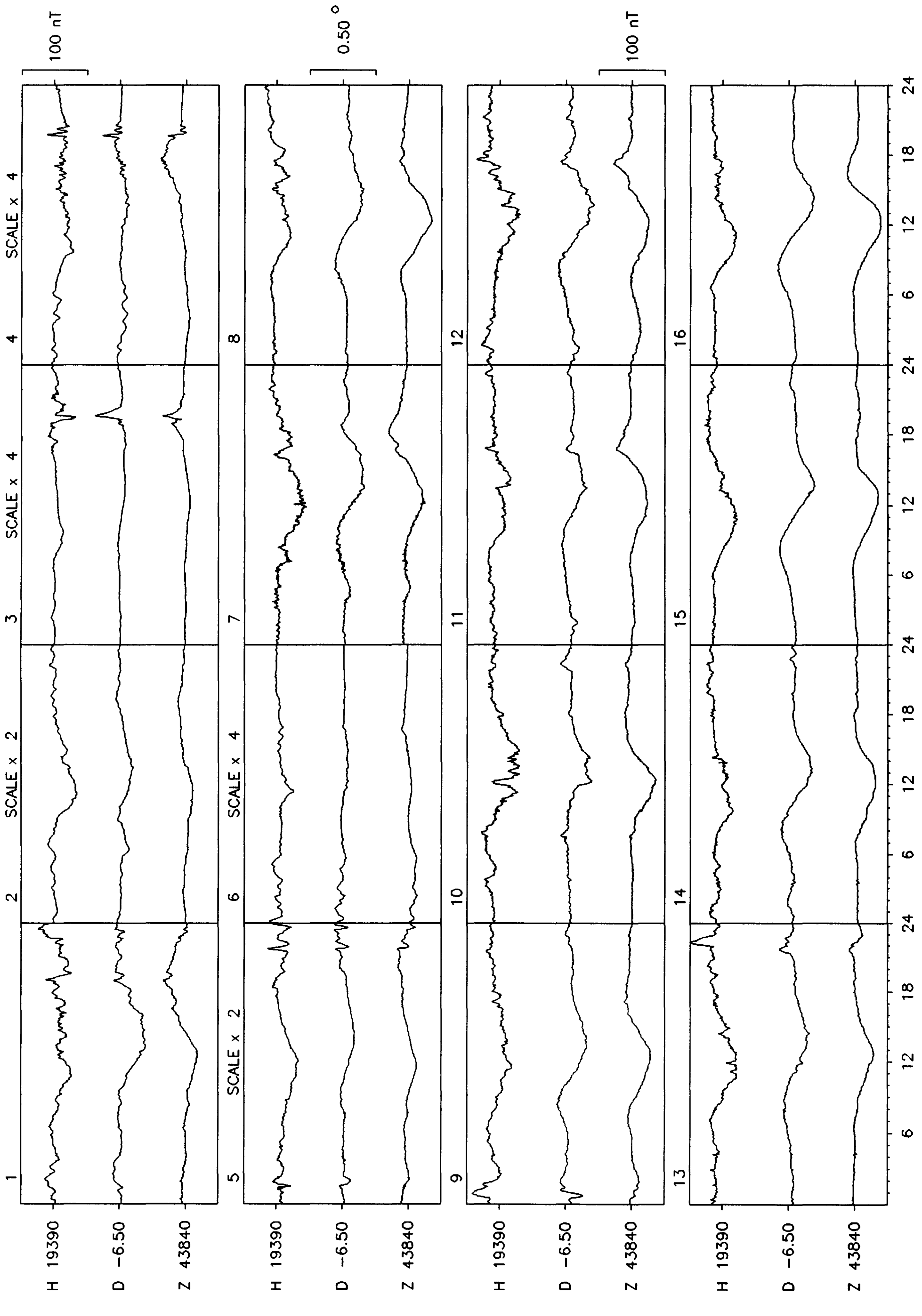

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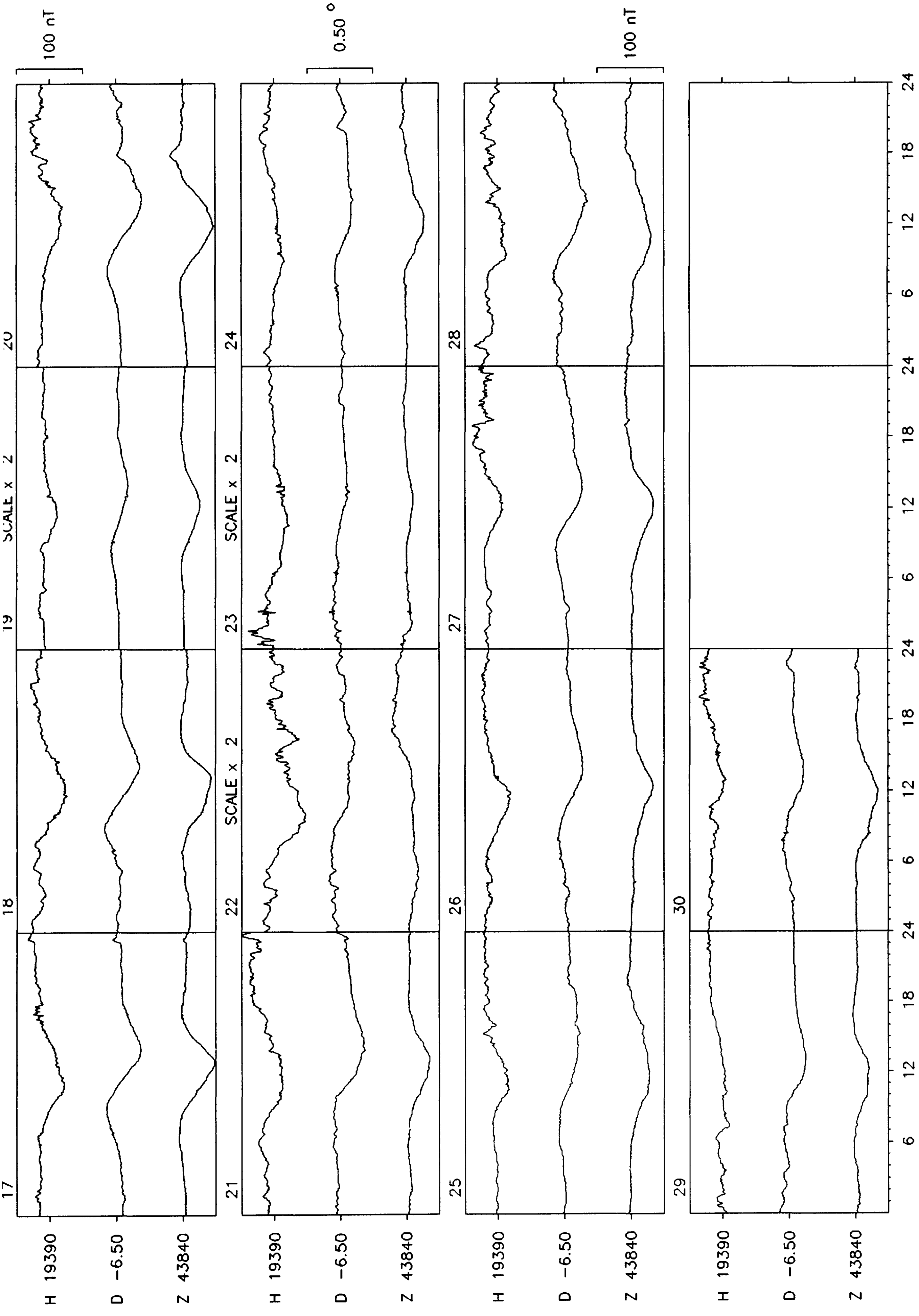

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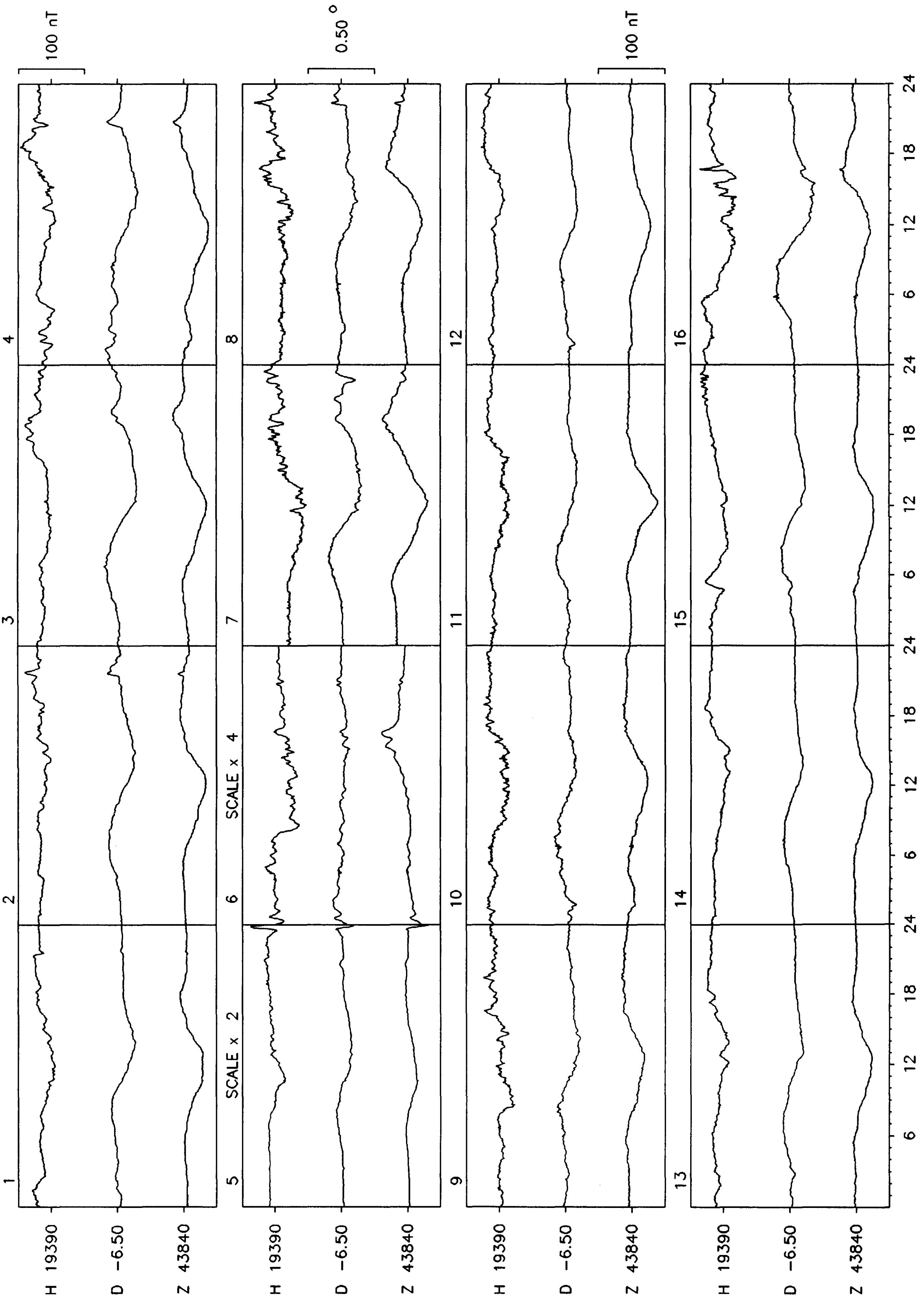
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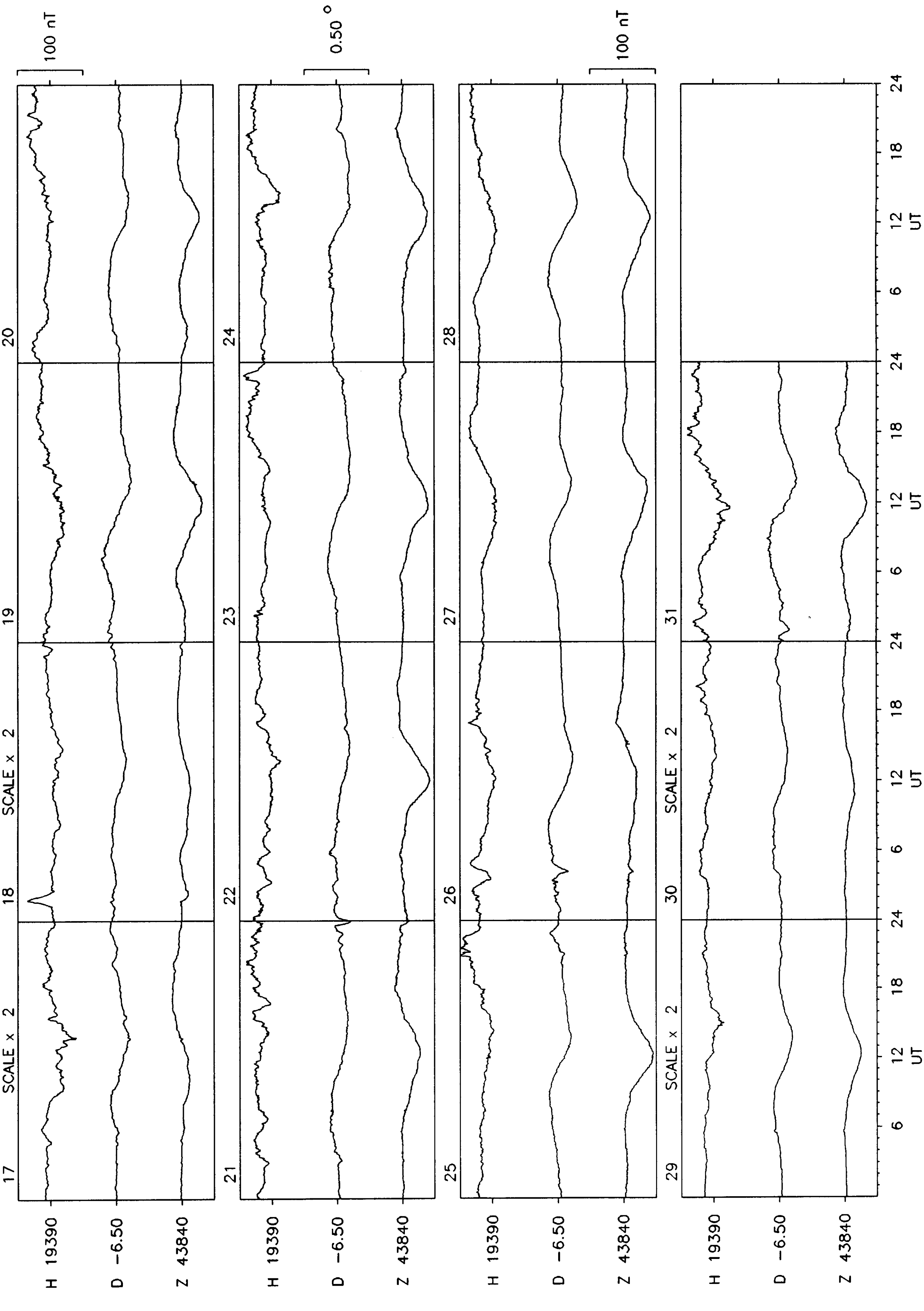
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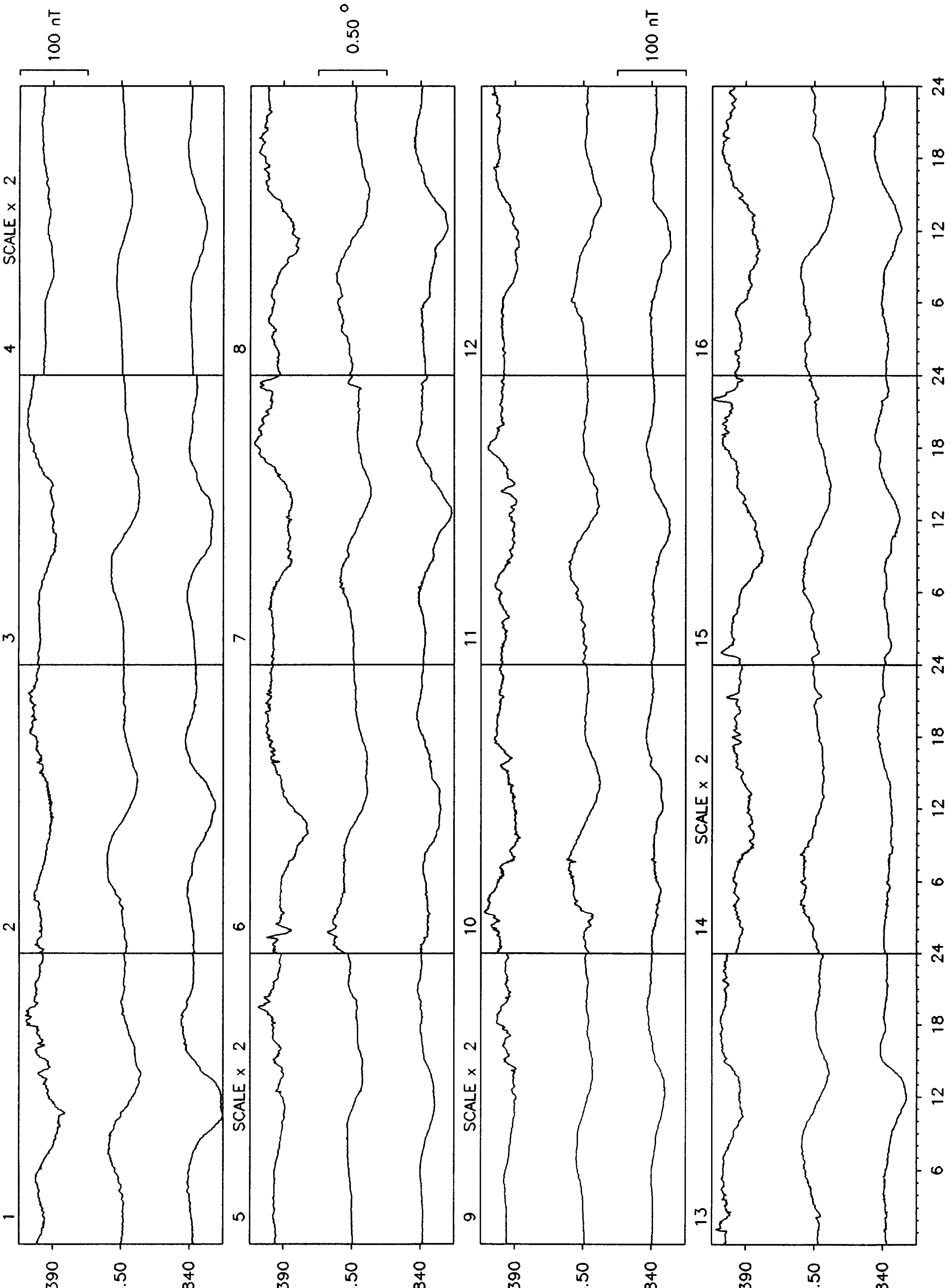

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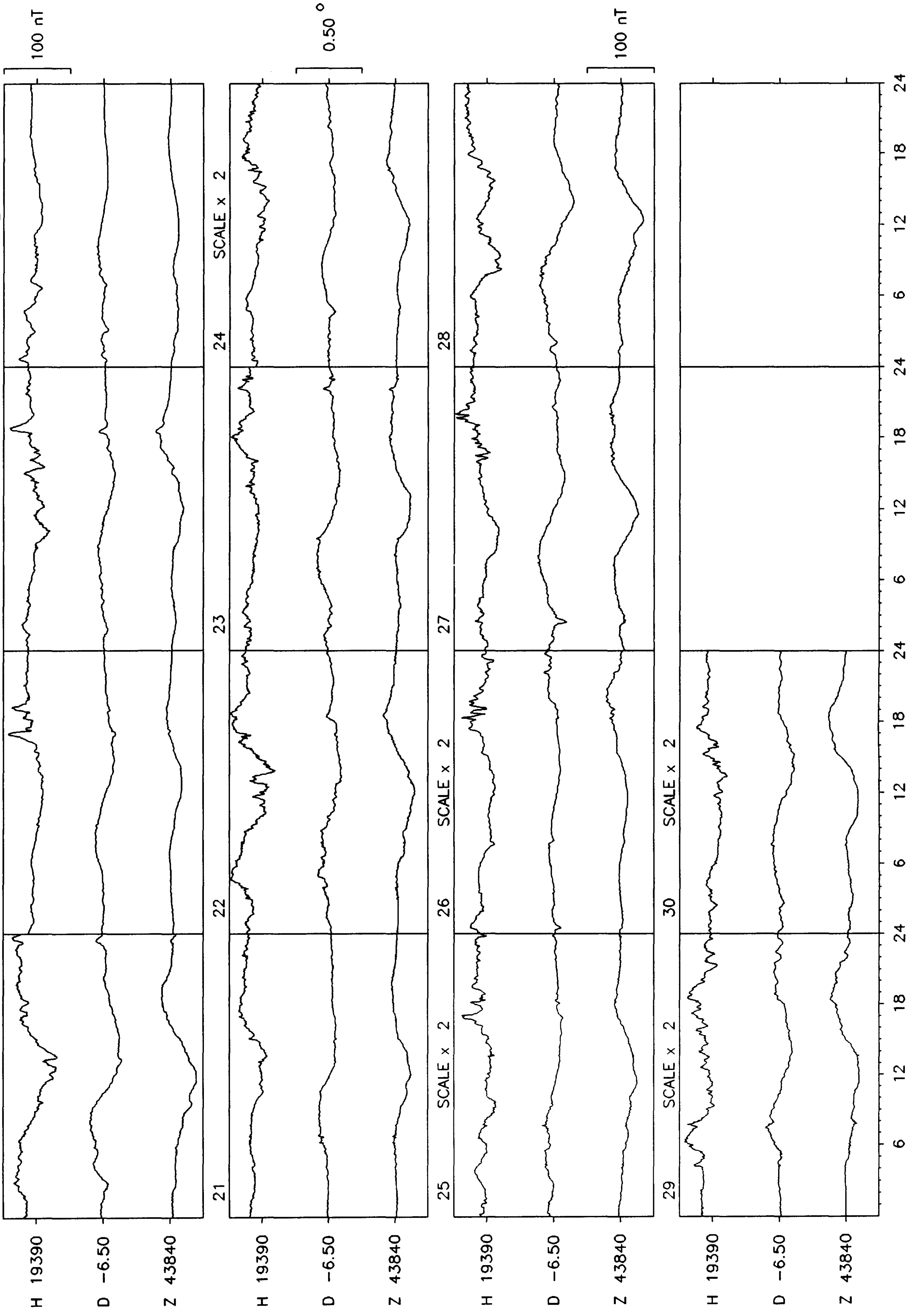

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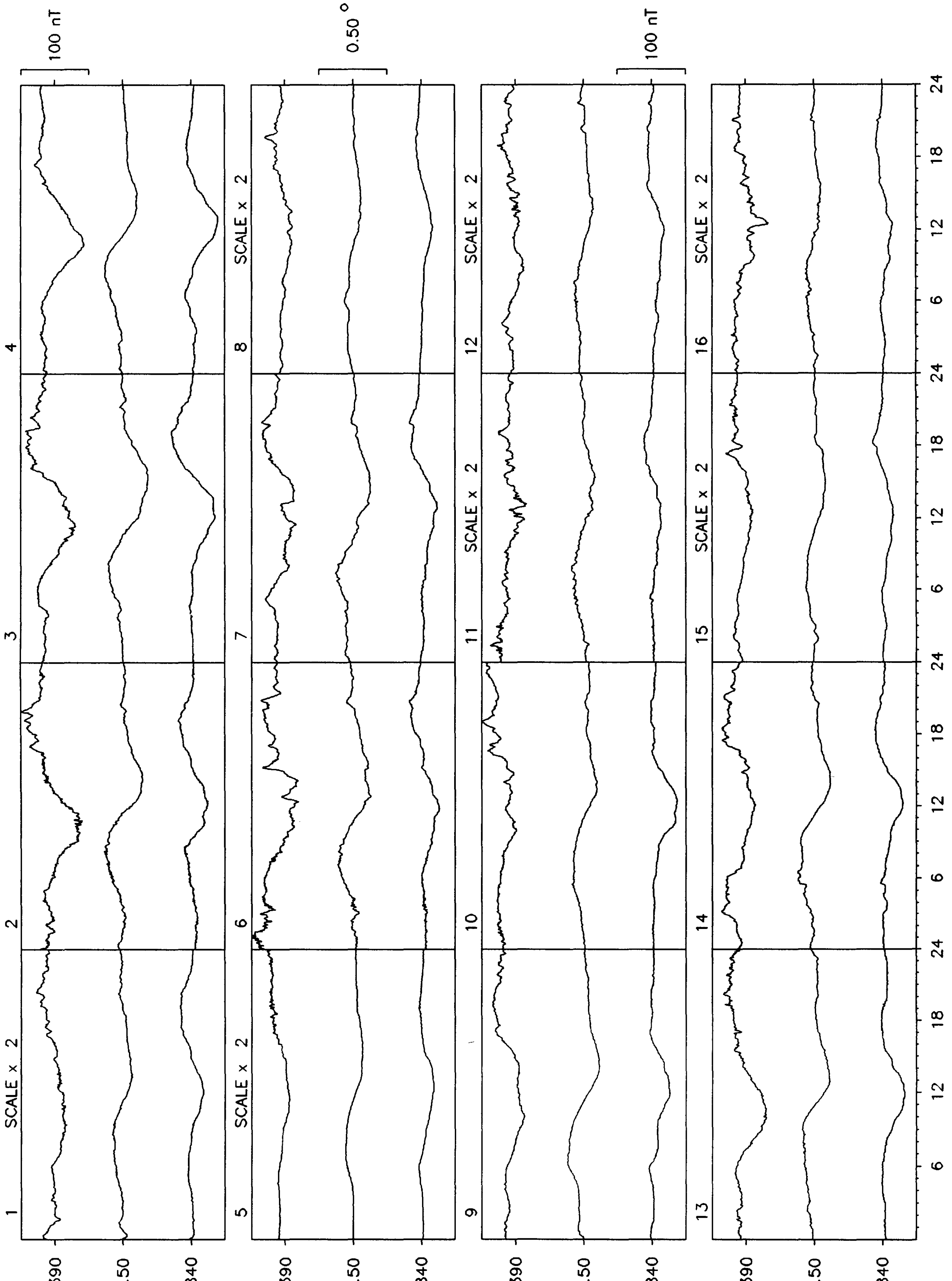
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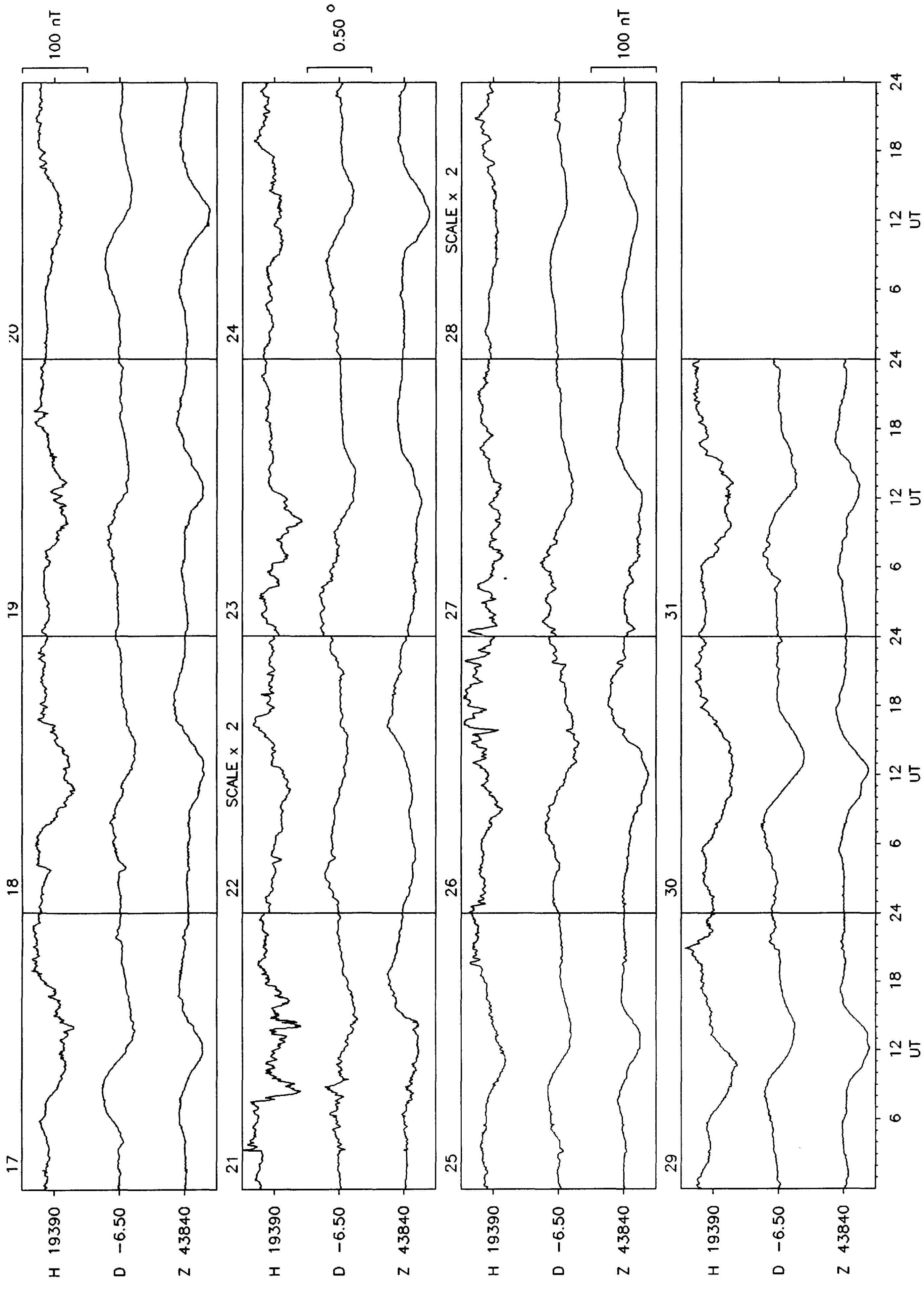

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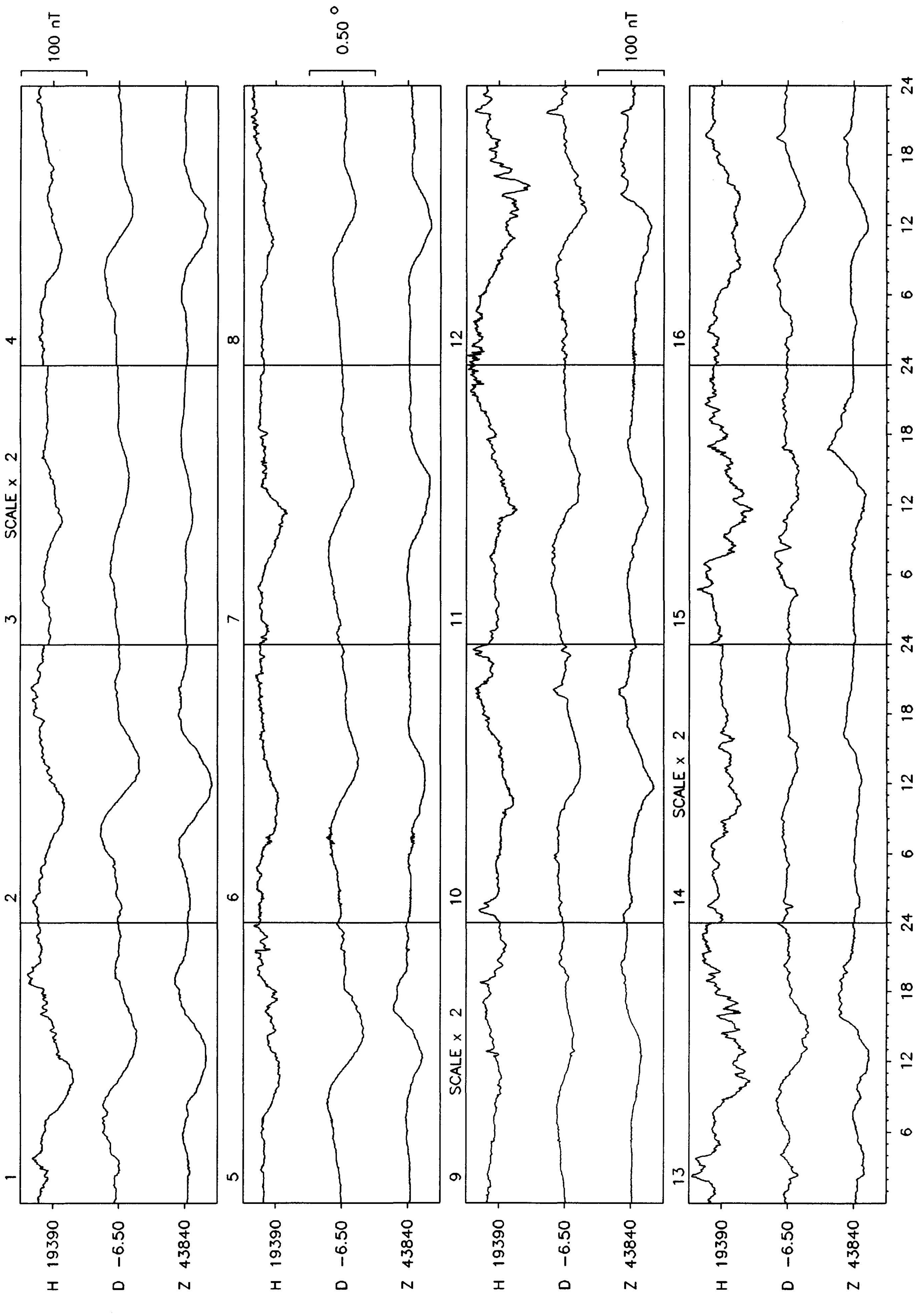
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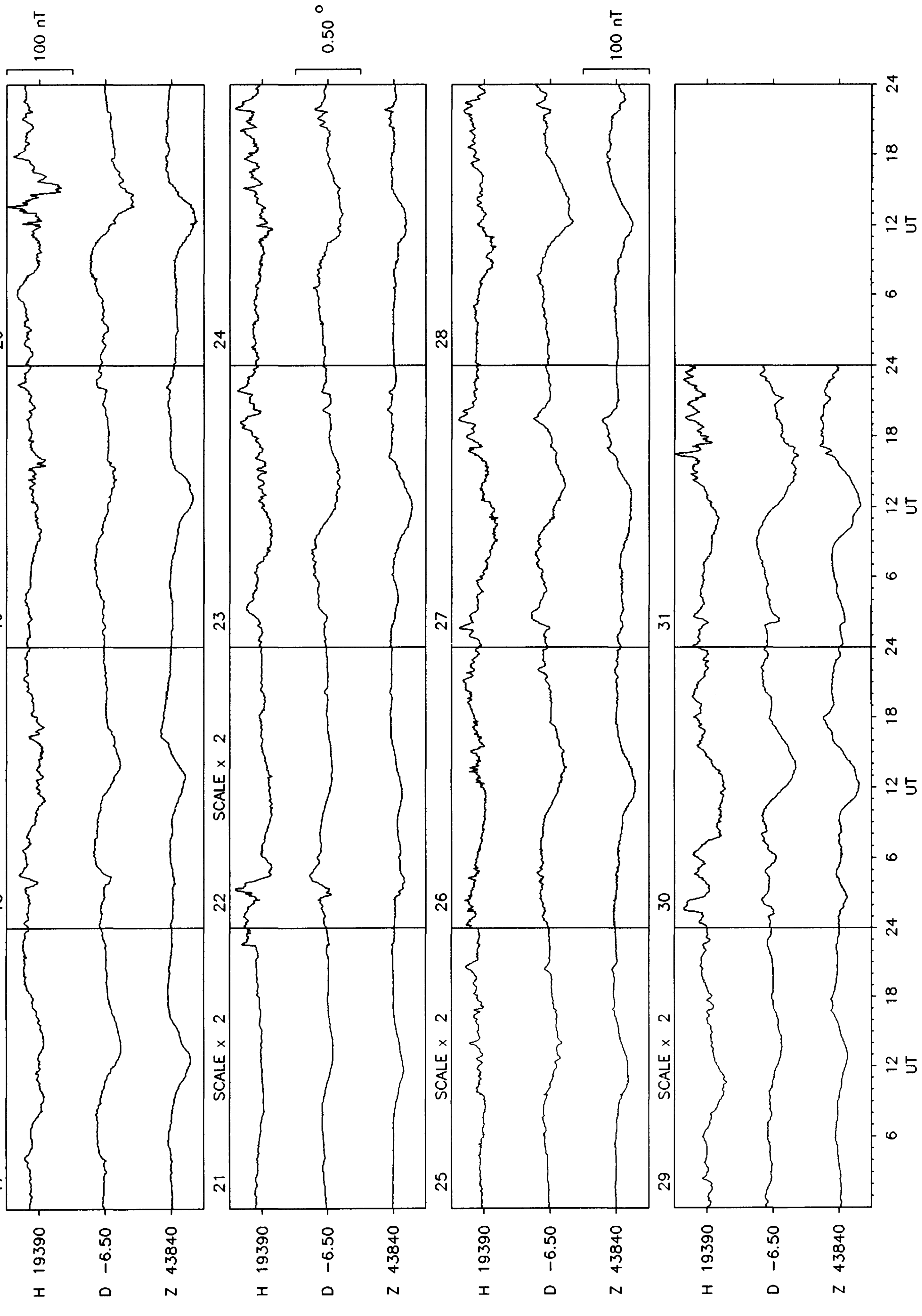

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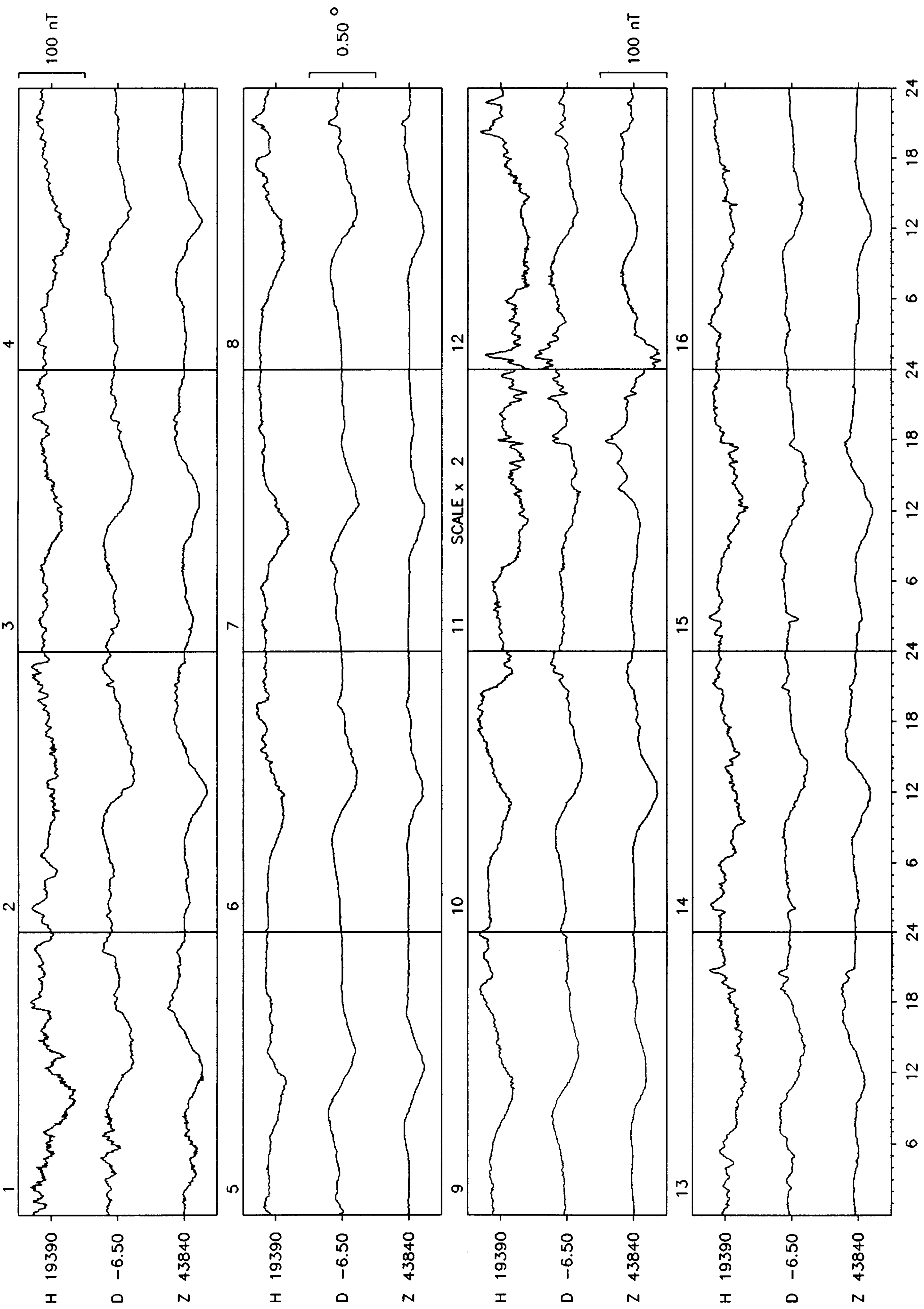
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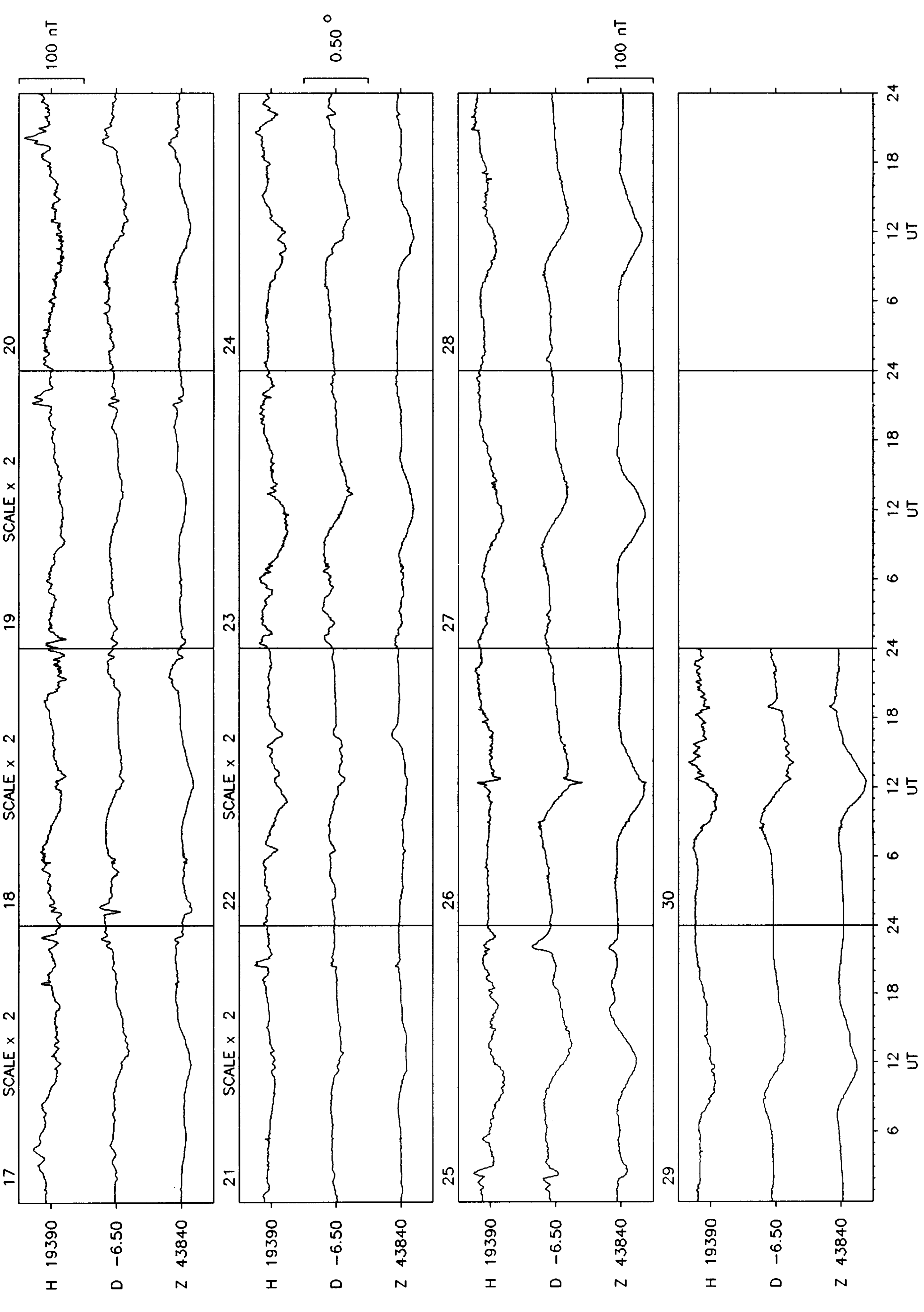
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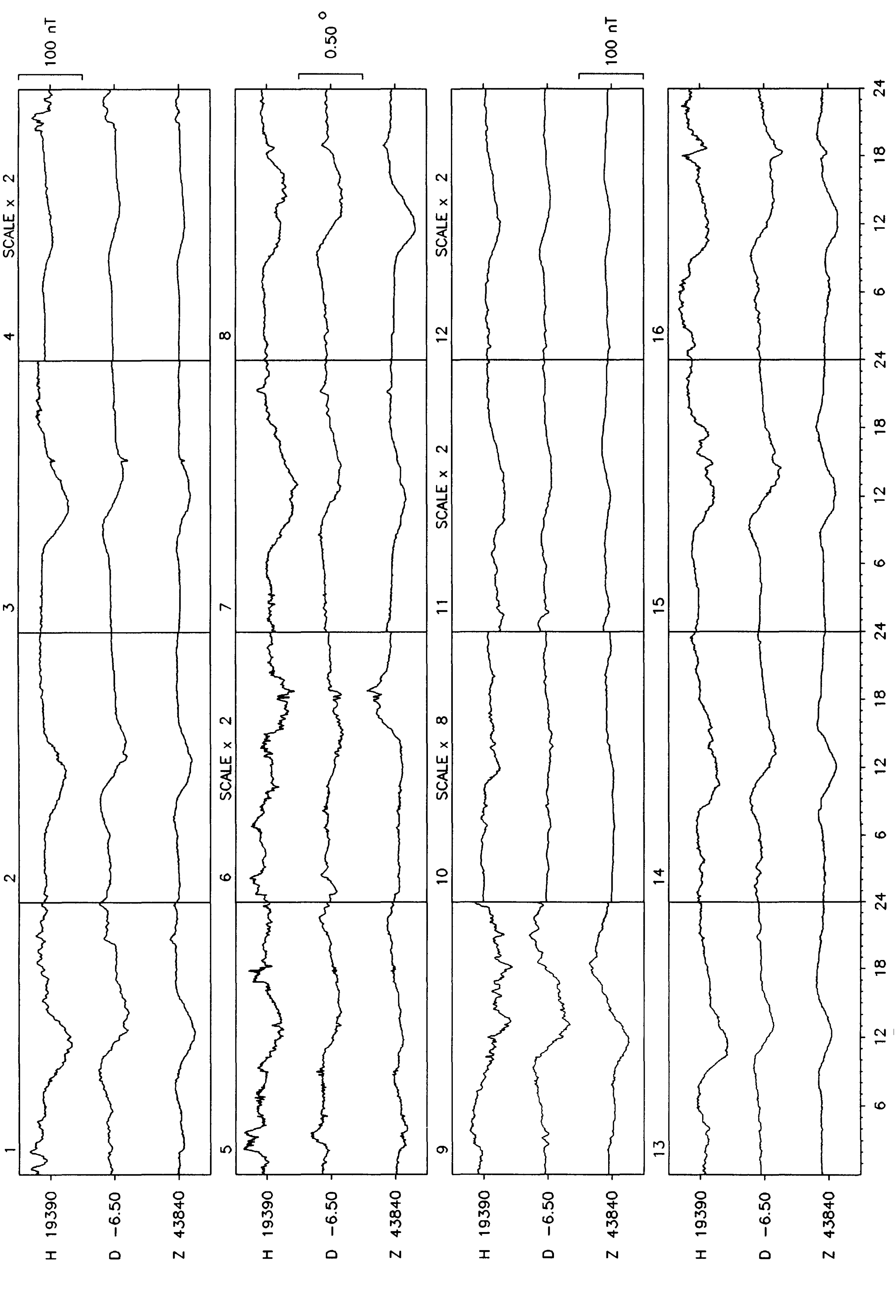
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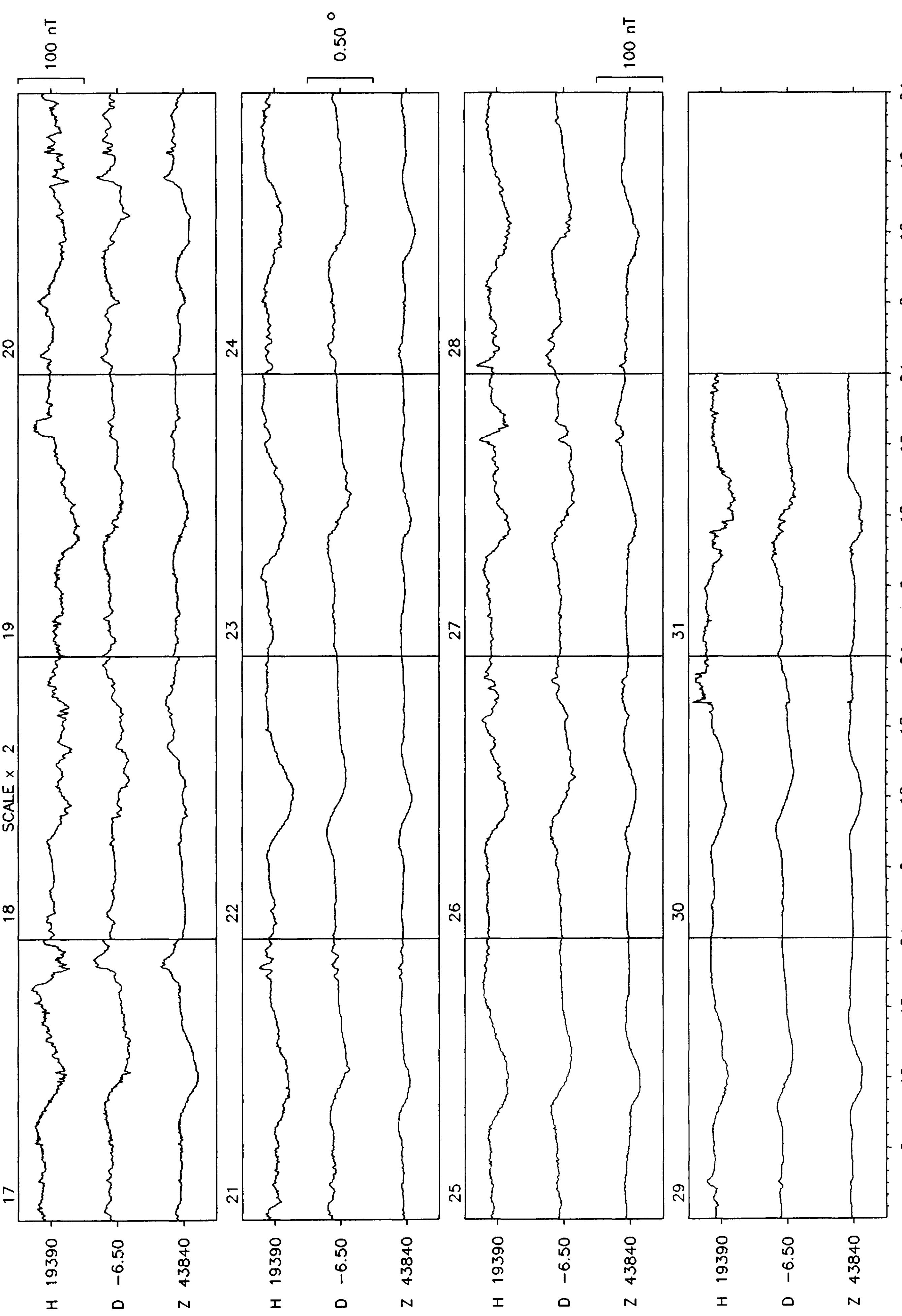
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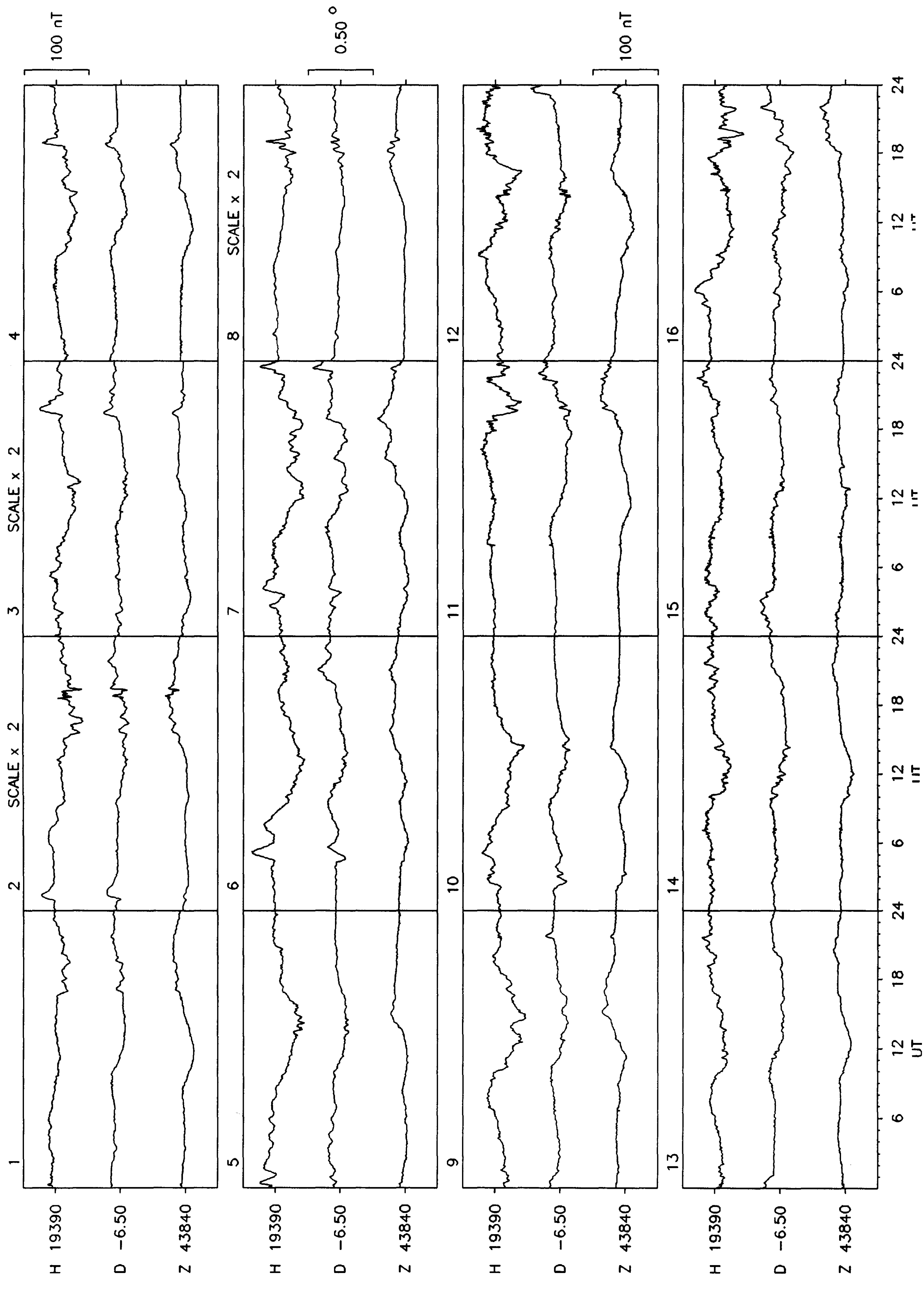
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D −6.50
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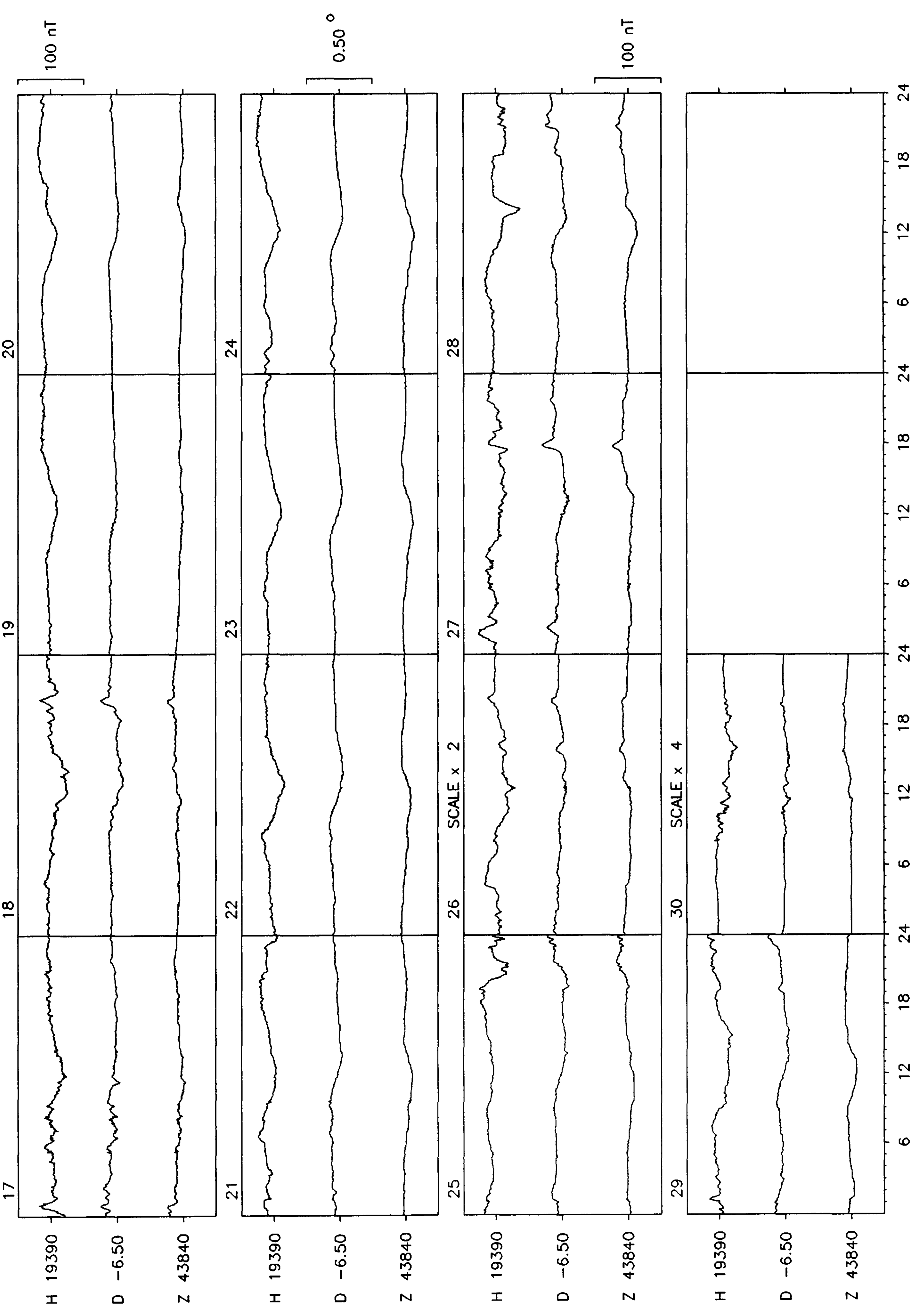
100 nT
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SCALE x 2
SCALE x 4
H 19390
D −6.50
Z 43840
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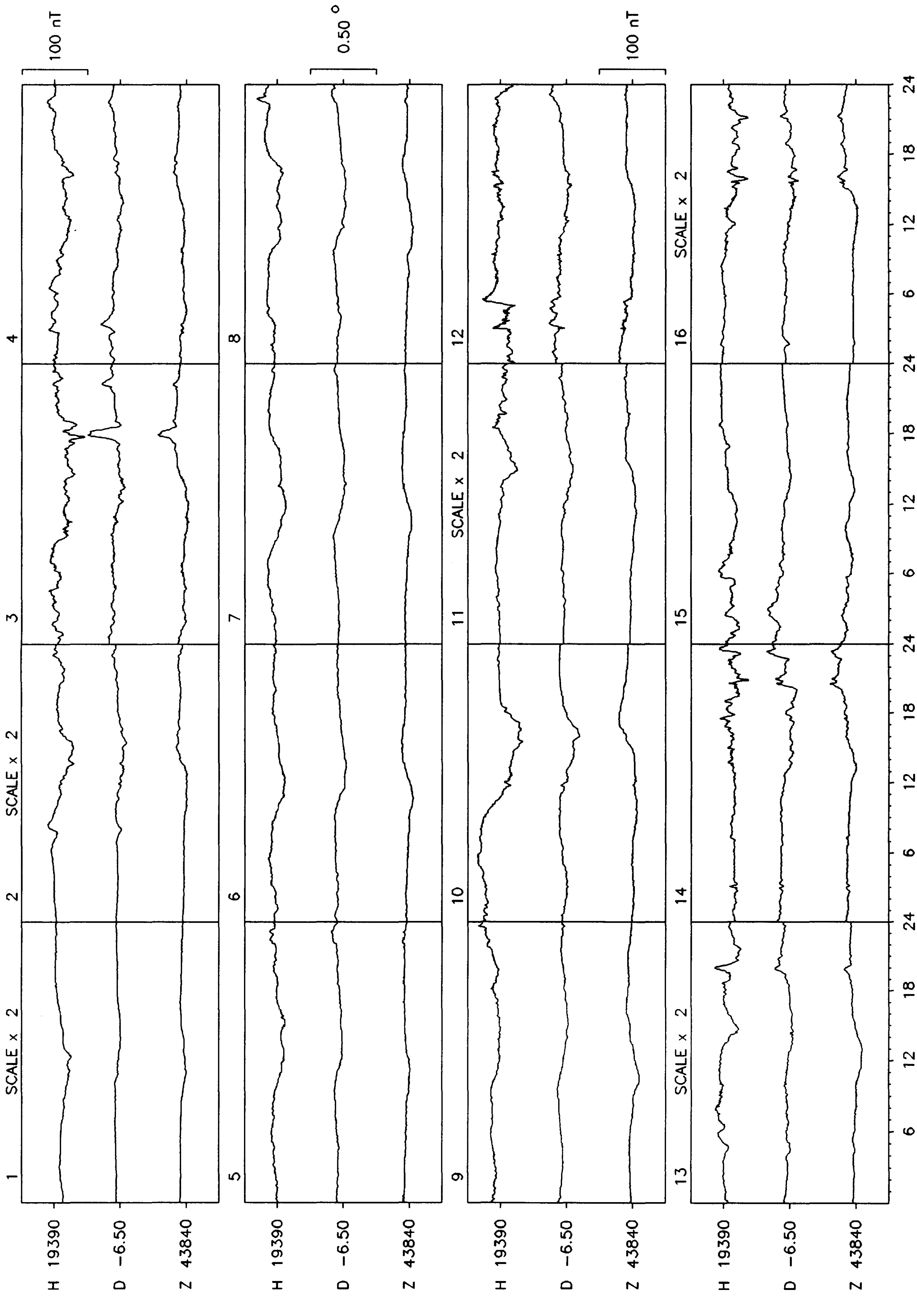

100 nT
0.50 °
100 nT
H 19390
D −6.50
Z 43840
SCALE x 2
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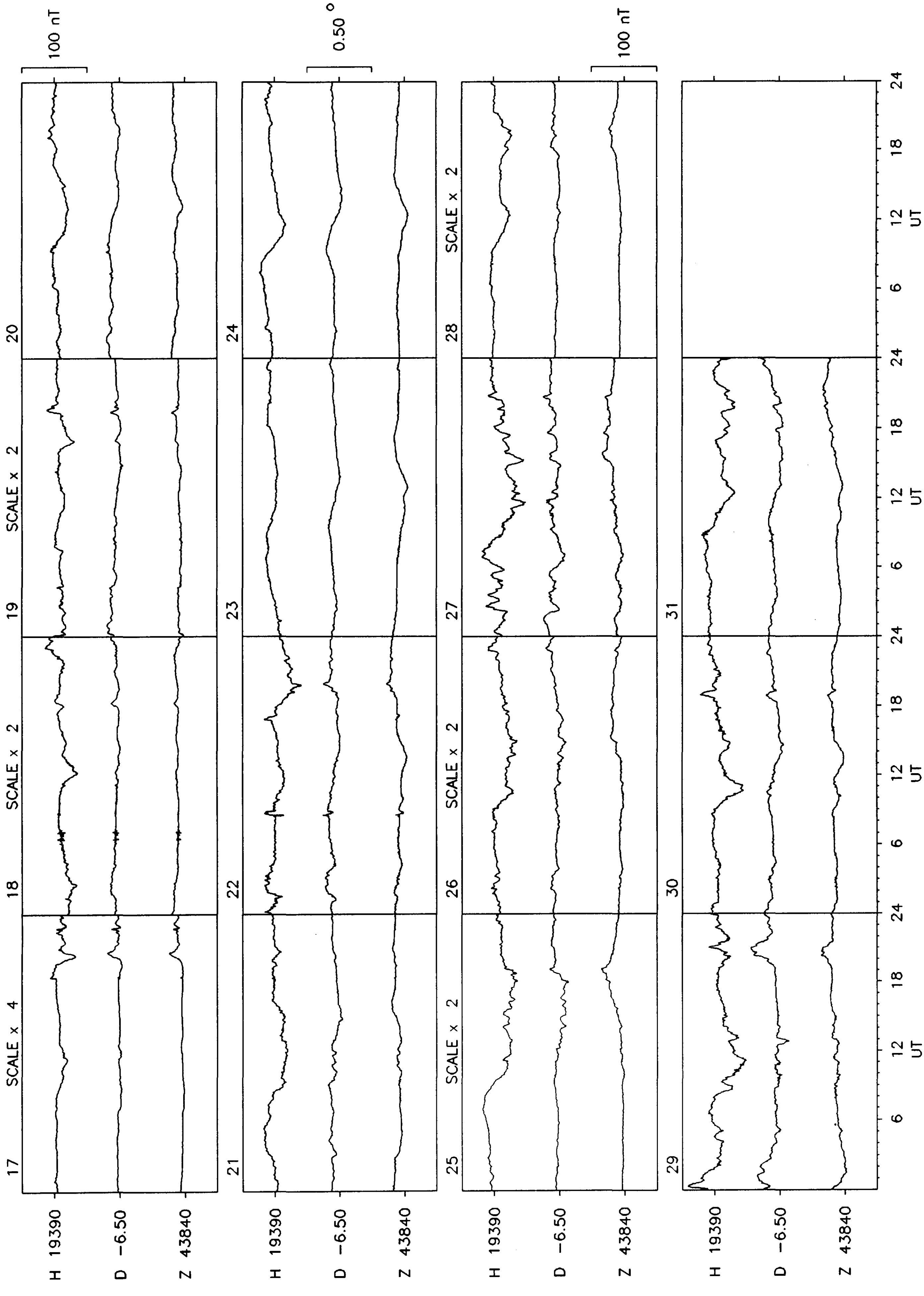
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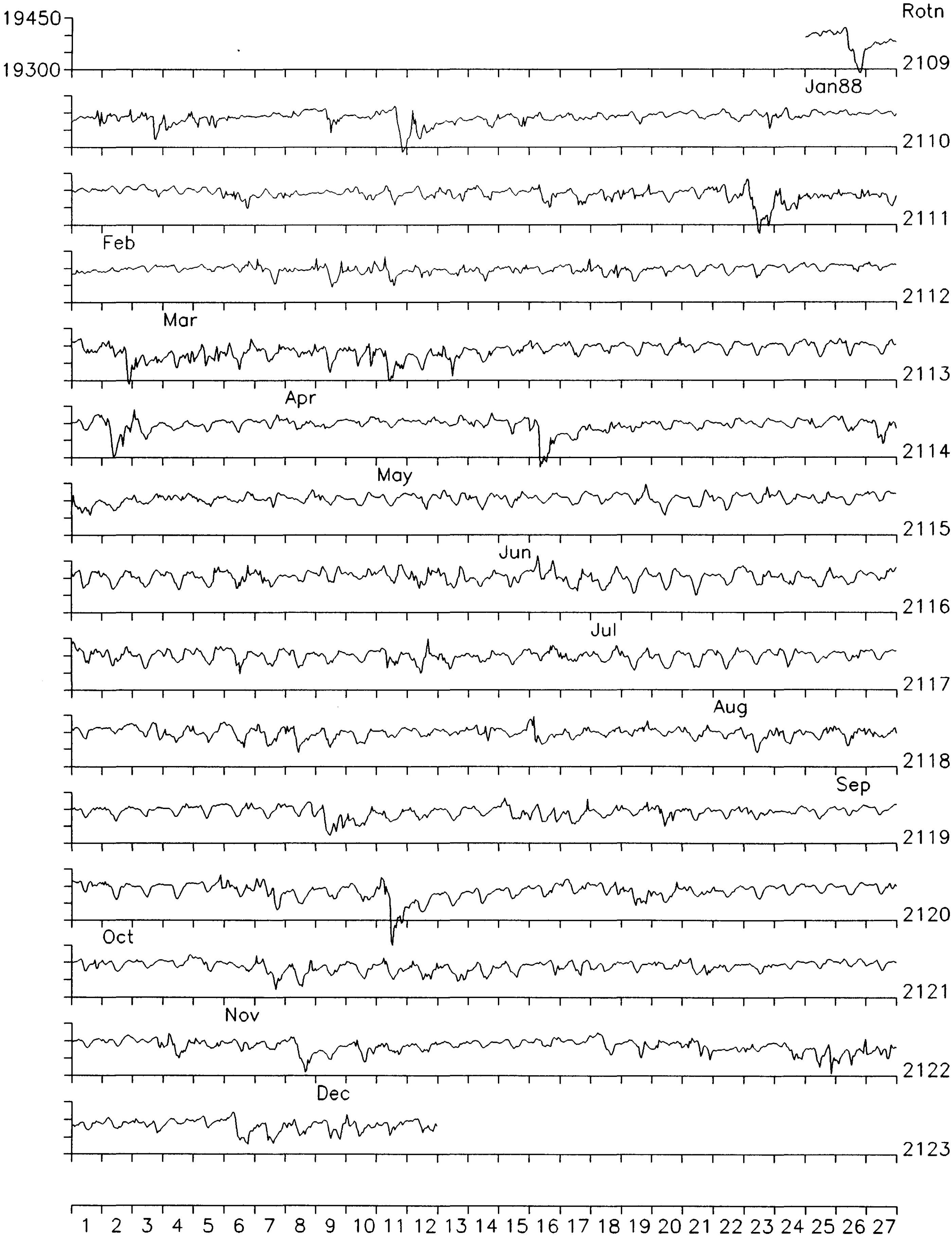
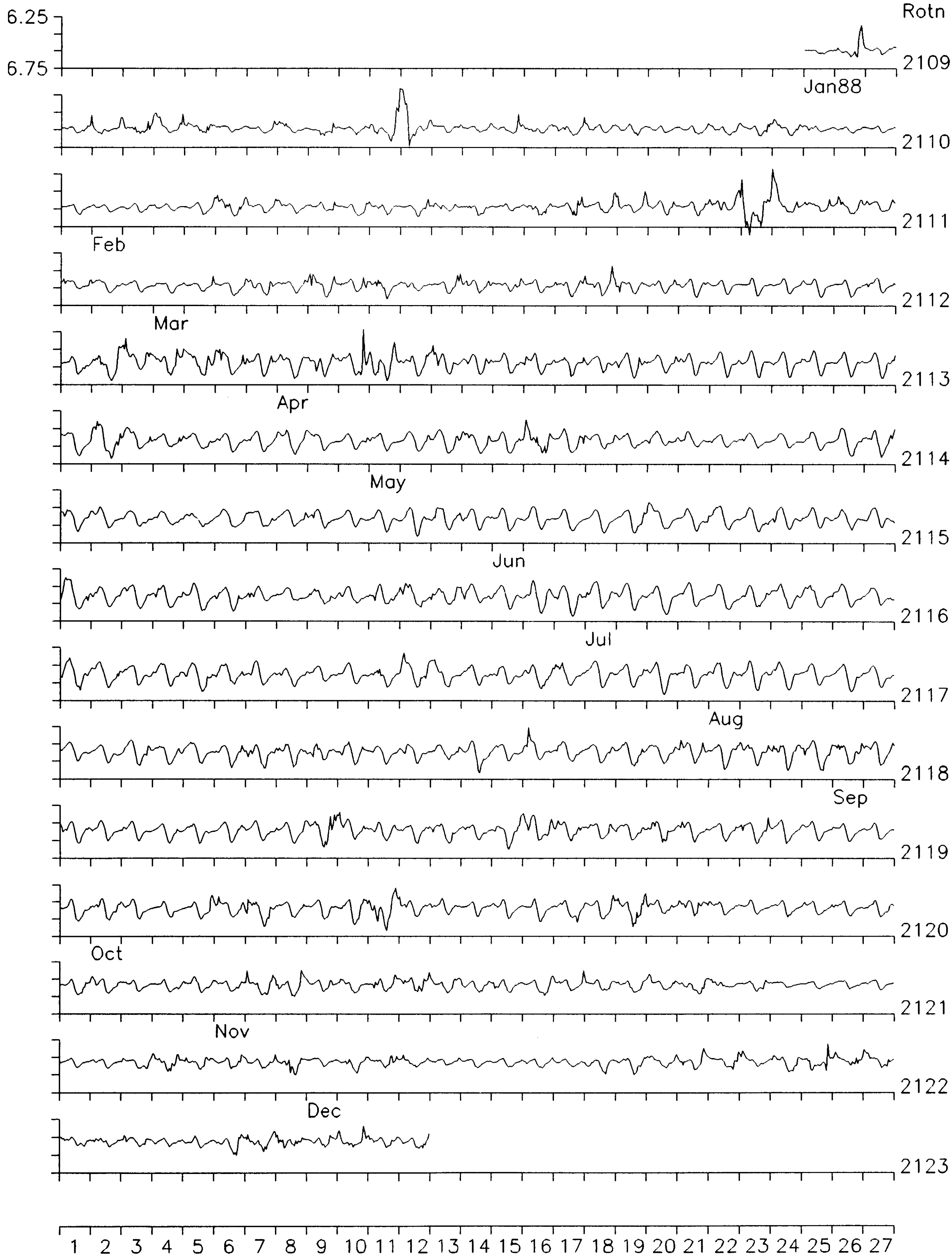
Hartland Observatory: Horizontal Intensity (nT)



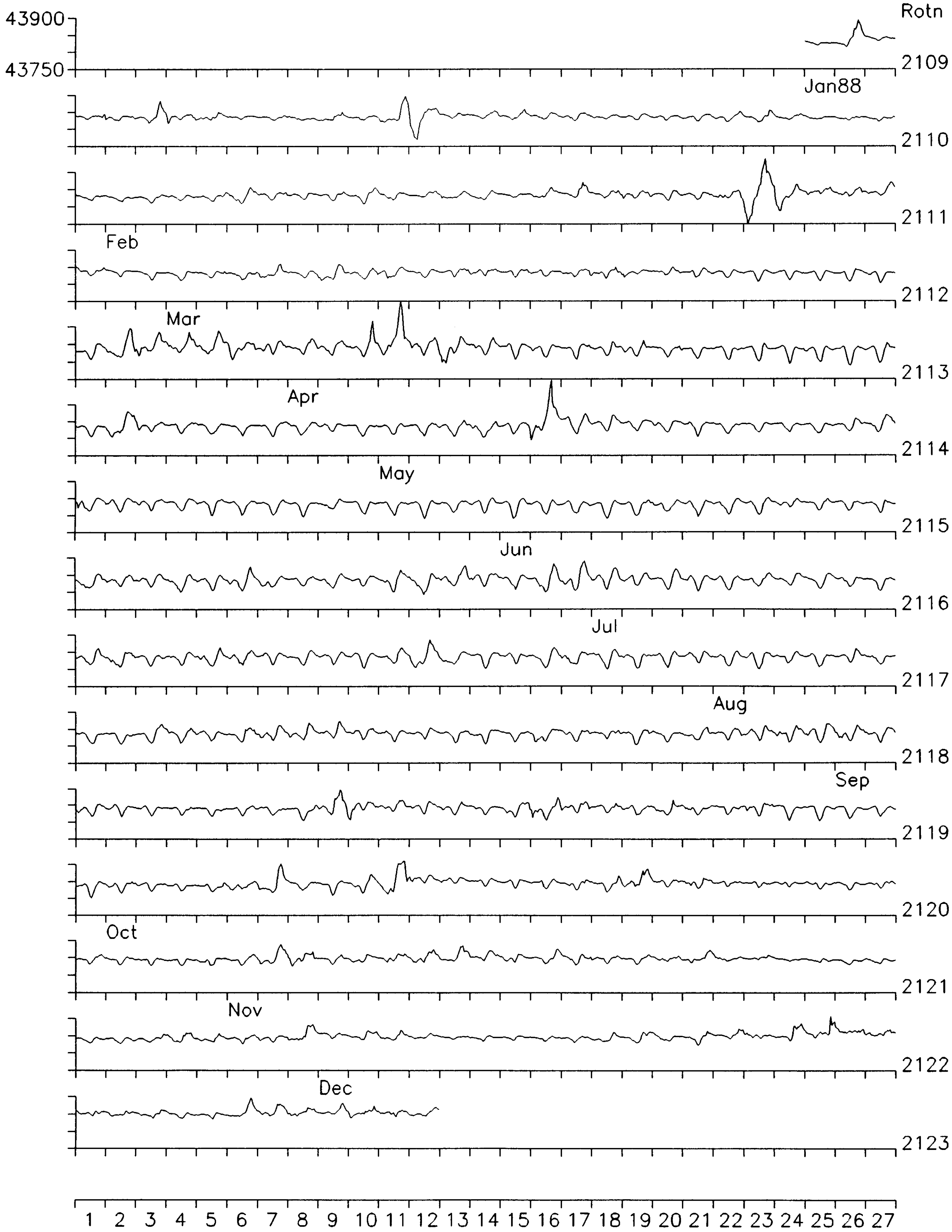
Hourly Mean Values Plotted by Bartels Solar Rotation Number

Hartland Observatory: Declination (degrees)

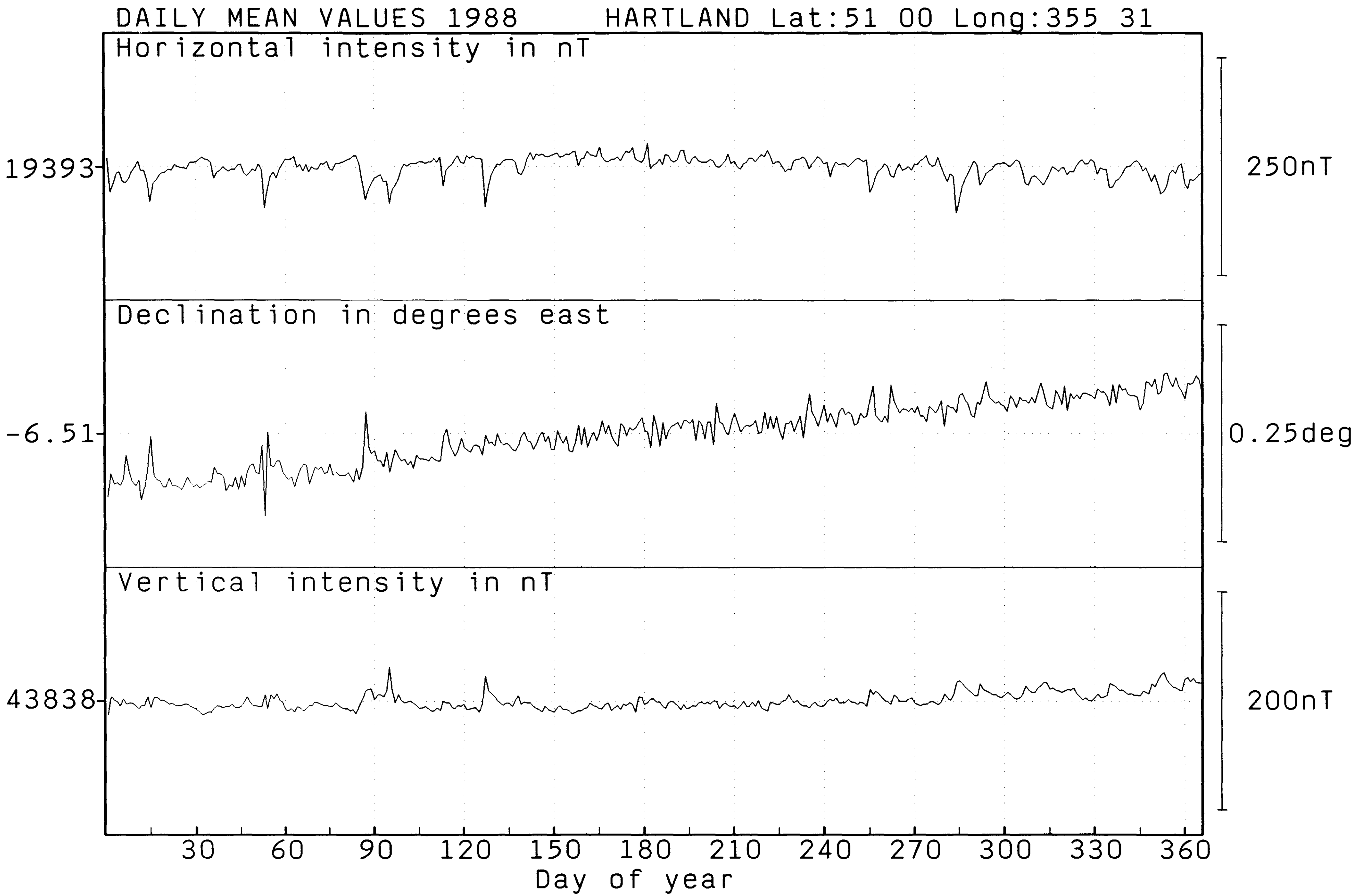


Hourly Mean Values Plotted by Bartels Solar Rotation Number

Hartland Observatory: Vertical Intensity (nT)



Hourly Mean Values Plotted by Bartels Solar Rotation Number


DAILY MEAN VALUES 1988 HARTLAND Lat:51 00 Long:355 31
Horizontal intensity in nT
19393
250nT
Declination in degrees east
-6.51
0.25deg
Vertical intensity in nT
43838
200nT
30 60 90 120 150 180 210 240 270 300 330 360
Day of year

Monthly and annual mean values for Hartland 1988

Month	D		I		H	X	Y	Z	F
	°	′	°	′	nT	nT	nT	nT	nT
Jan	-6	34.0	66	8.5	19387	19260	-2217	43835	47931
Feb	-6	33.5	66	8.3	19389	19262	-2215	43834	47931
Mar	-6	33.1	66	8.2	19392	19265	-2213	43835	47933
Apr	-6	32.2	66	8.3	19391	19265	-2207	43837	47934
May	-6	31.3	66	7.8	19398	19272	-2203	43836	47936
Jun	-6	30.8	66	7.3	19405	19280	-2201	43833	47936
Jul	-6	30.2	66	7.6	19400	19275	-2197	43835	47936
Aug	-6	29.9	66	7.7	19399	19274	-2195	43836	47937
Sep	-6	29.2	66	8.2	19393	19269	-2191	43839	47937
Oct	-6	28.7	66	8.8	19387	19263	-2187	43844	47939
Nov	-6	28.2	66	8.8	19387	19264	-2185	43846	47941
Dec	-6	27.6	66	9.2	19383	19260	-2181	43851	47944
Annual	-6	30.7	66	8.2	19393	19268	-2199	43838	47936

HARTLAND OBSERVATORY K INDICES 1988

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0101 2122	2000 1101	2111 0112	3222 2343	2112 2212	1222 2322	4333 3333	2322 2231	3433 4333	3233 3333	2122 0332	1012 3101
2	3214 3454	1102 1132	1011 1214	3344 3333	1211 2223	2201 2222	3333 2331	2222 2222	3322 3233	3122 3210	5233 3454	1132 3323
3	2222 2111	2011 0100	2121 2333	3243 2474	1221 1333	1112 1210	1222 2332	2323 2311	3222 2232	0011 1310	3333 4353	2222 2553
4	2110 1235	1112 3223	4332 3342	5444 4574	3321 3343	1011 2211	2111 2210	1211 1111	2232 2222	0121 2134	2122 2232	2322 2212
5	3332 3114	3344 3433	3212 2233	4333 3245	1223 3335	1222 3343	0211 1332	0111 2333	2112 2210	4433 2323	3222 2321	1111 1112
6	3233 3554	3222 2224	5332 3452	5545 4432	6564 5554	4312 2211	3322 3332	2231 1112	1011 2231	5344 4452	0433 2243	2111 1111
7	5322 2244	3212 2111	3222 1444	1233 3332	1224 3334	1232 2333	2232 3321	2112 3121	1122 2111	2212 2222	3323 3344	1101 2202
8	3423 3432	2011 1142	3444 4332	1021 2332	2222 3433	2322 3221	3332 3332	0112 1221	0112 2233	2112 2331	3222 2353	1202 2212
9	2322 1011	1123 2343	3334 1331	4233 2212	2233 2322	0212 3342	2211 1212	2222 3343	1111 1222	2224 3344	3123 3323	2100 0122
10	1001 2133	2233 3221	1123 3344	1233 4333	3322 2323	3431 2311	2212 2332	3212 1233	2022 2233	4457 6554	3222 3210	2212 2310
11	3331 2101	0123 2244	3323 3232	3212 3312	2322 2311	2232 3331	3334 4333	2223 2233	3343 4555	4233 2322	1122 2344	1223 4443
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13	0111 2233	1333 2332	2021 0222	2223 3224	2212 2220	3212 2112	2122 2222	3333 3333	2333 2332	1223 2222	3122 2232	2333 4353
14	3422 3467	2023 1111	3122 3234	2232 3222	0211 1010	4433 3334	3332 2323	4343 3423	3232 2332	2222 2211	2223 3233	2210 2344
15	6654 3334	2234 2431	2233 3354	1111 2222	2332 2222	3332 2224	3411 2433	3244 3333	3323 3422	1022 3322	3422 3233	3331 2110
16	2012 2112	1122 3552	3323 2222	1121 2221	2323 3422	2222 2222	3333 4333	2332 2331	2212 3211	2222 2342	1343 2344	3333 3444
17	1112 1233	2213 2325	2223 2223	1122 1213	2343 4443	2322 3323	2312 3322	2222 1212	3333 3344	3223 3334	3233 2121	3233 3265
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22	2111 2331	7565 5655	2100 1110	3444 4544	3331 2321	2333 3332	4423 3444	4532 3221	3333 3422	2111 2200	1011 1111	3332 2332
23	1012 1100	5533 3342	1021 3212	5432 3233	2212 2323	2313 2333	3333 3212	3222 2233	3332 3222	2122 2221	0110 0001	2112 2112
24	1011 1123	4322 3242	3211 1022	2122 1233	1122 3331	3433 3433	2222 2232	2223 3333	1123 3223	3122 2212	2210 0011	2122 1012
25	2122 1223	3323 2243	0132 3332	1112 3231	1211 1233	3343 3543	2312 2232	1234 4332	3222 2224	2122 1111	2011 2143	2223 3353
26	2012 2243	3112 1333	3343 4465	2221 2112	2421 2310	4242 3453	3233 3434	2211 3323	1123 4222	1123 3232	3433 4441	3334 4334
27	3233 2232	2321 1003	5433 3454	1211 2233	0111 2221	4322 2332	4332 2222	4323 2342	2122 2211	1123 3242	3222 2432	4333 3331
28	1312 1101	1011 1121	3334 3355	3232 3333	0211 1221	3243 3322	3222 2344	1223 2223	2121 2222	3323 2212	1111 3132	1122 3332
29	1211 1212	1001 1110	3344 3553	2232 1101	1322 3322	2454 3444	2222 2233	3333 2333	1122 1110	2211 1100	3111 1223	4233 3144
30	1011 1012		5534 4235	1223 2223	2433 2333	3324 4432	2221 1322	3343 3333	0033 3332	1111 1133	3245 4541	2213 2232
31	0111 1111		3223 2343		3323 3332		2332 2322	3222 3434		2233 3323		1122 2234

DAILY aa INDICES

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	12	6	8	26	10	13	29	15	32	25	14	9
2	50	10	12	37	16	9	19	12	23	11	47	29
3	15	6	21	72	16	6	13	14	16	7	41	31
4	23	14	30	78	25	6	8	6	15	14	15	17
5	28	39	17	35	32	18	10	17	7	32	21	9
6	60	20	37	56	110	13	22	12	9	62	26	8
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12	34	26	21	25	11	9	33	35	34	15	36	26
13	15	23	9	19	9	12	10	32	22	13	18	39
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21	14	40	4	16	19	10	39	14	22	12	12	21
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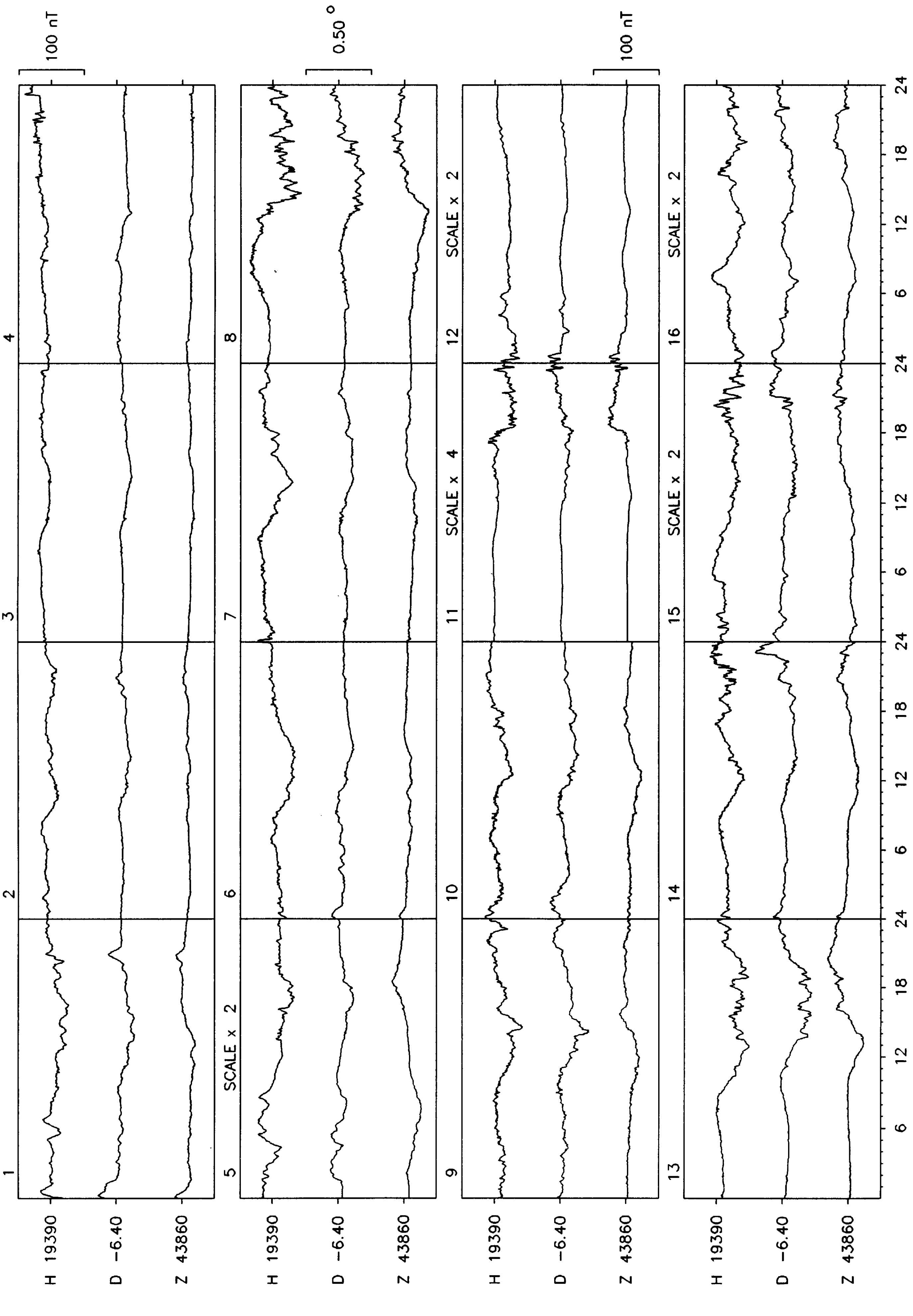
30	6		56	14	23	33	10	28	18	14	63	17
31	6		25		20		18	25		29		24
MONTHLY MEAN VALUE	22.5	23.4	24.9	25.2	20.5	20.0	20.2	20.6	21.3	23.2	23.3	25.6

YEARLY MEAN VALUE FOR 1988 = 22.6

HARTLAND 1989



H 19390
D -6.40
Z 43860
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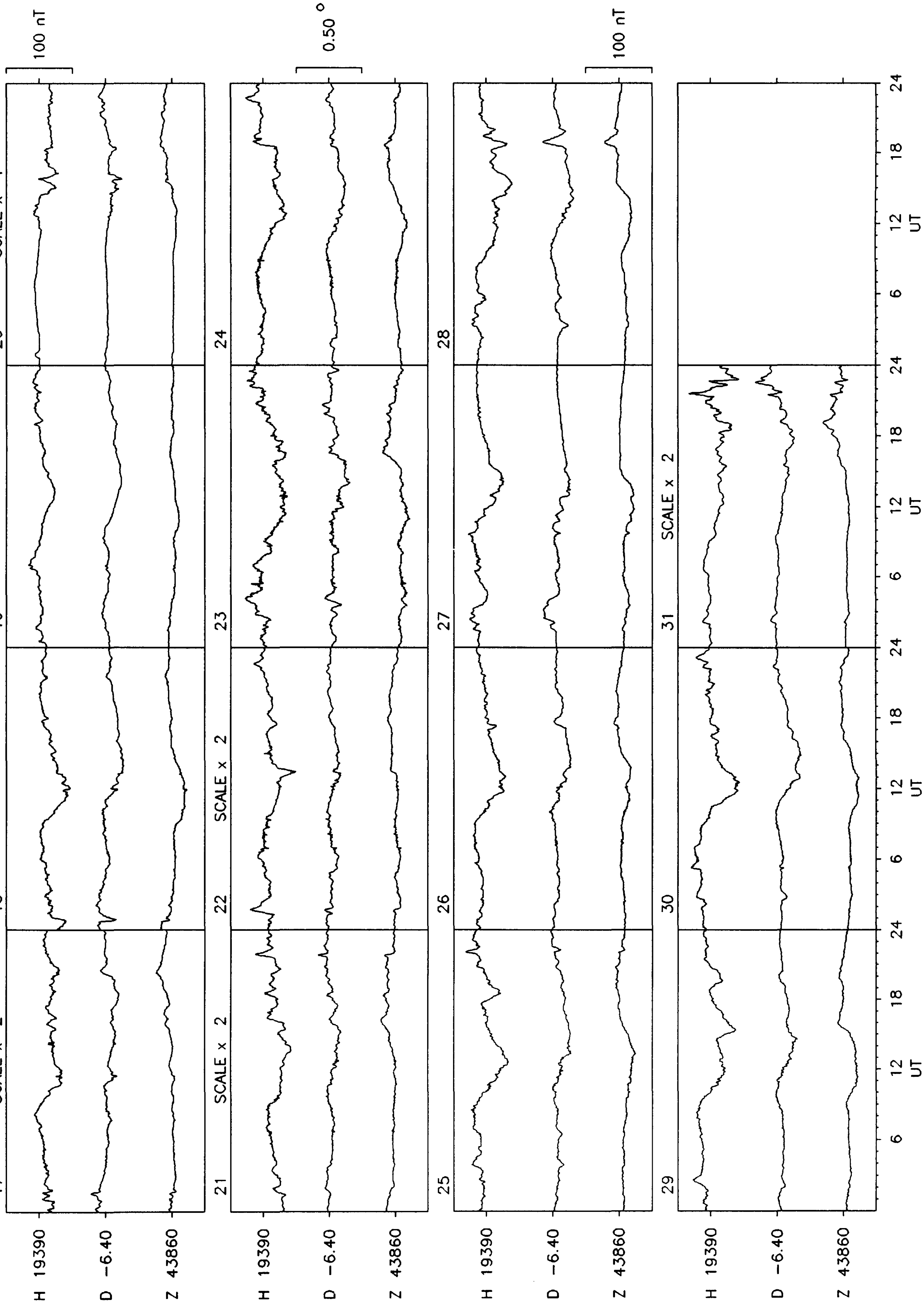

100 nT
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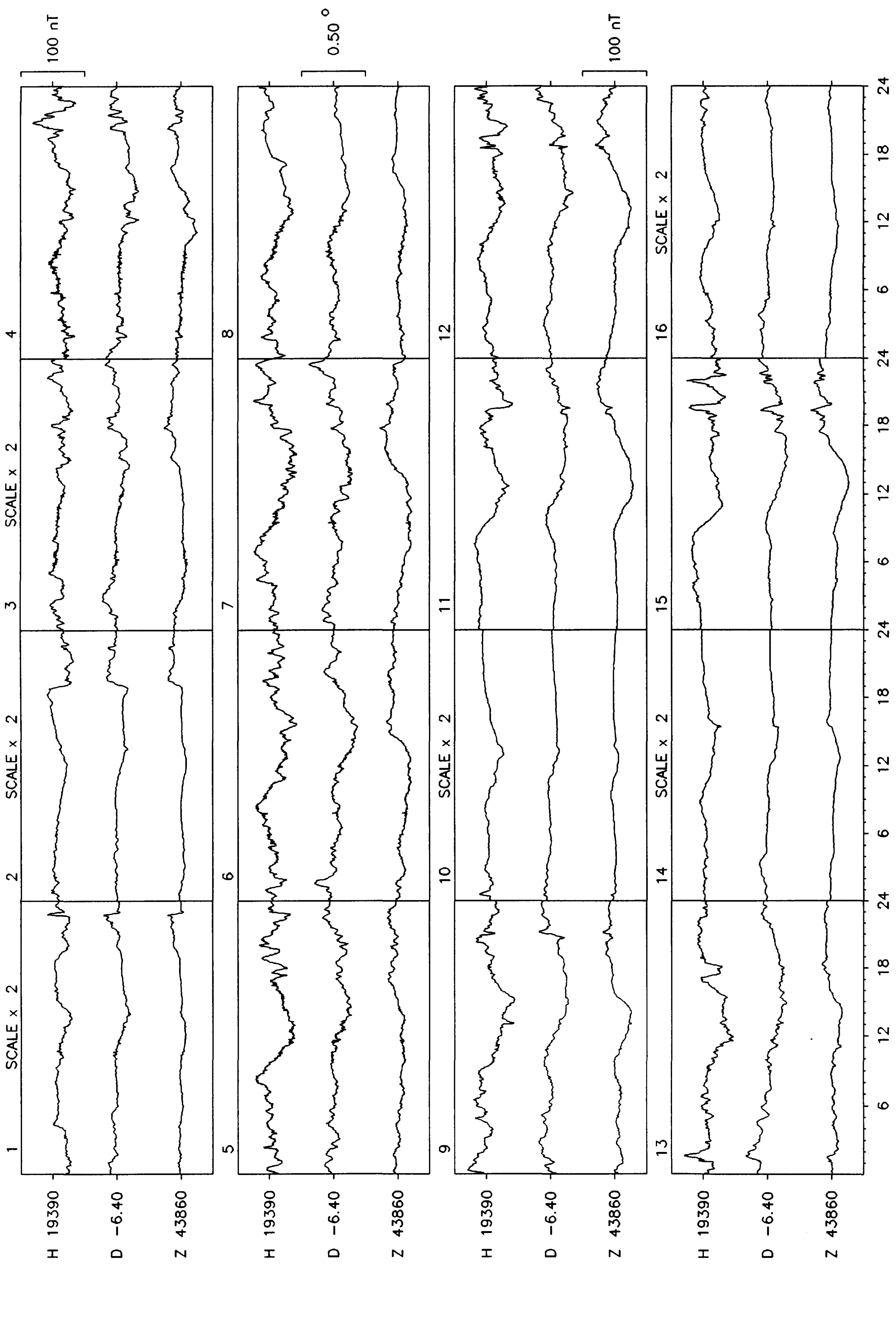

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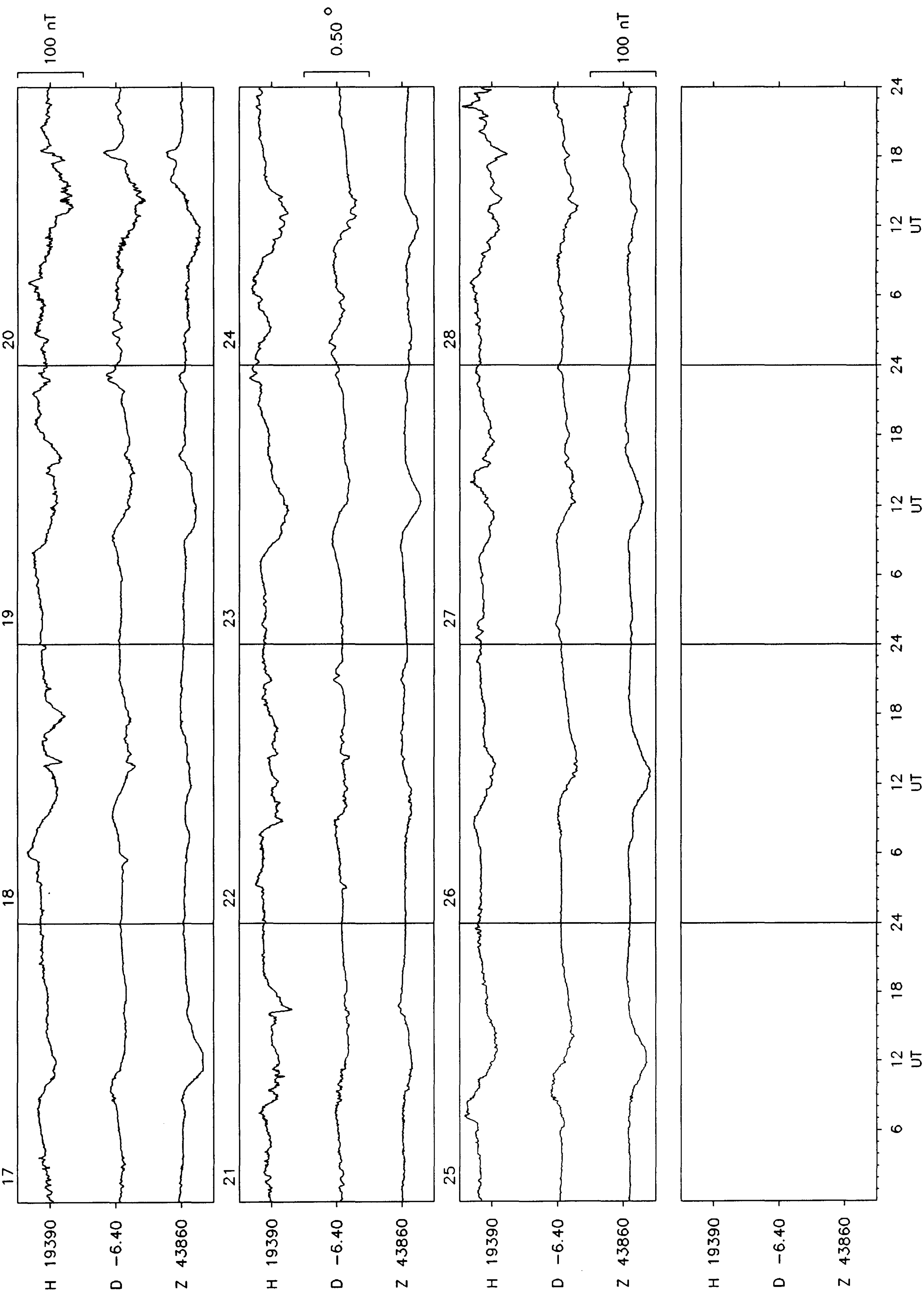
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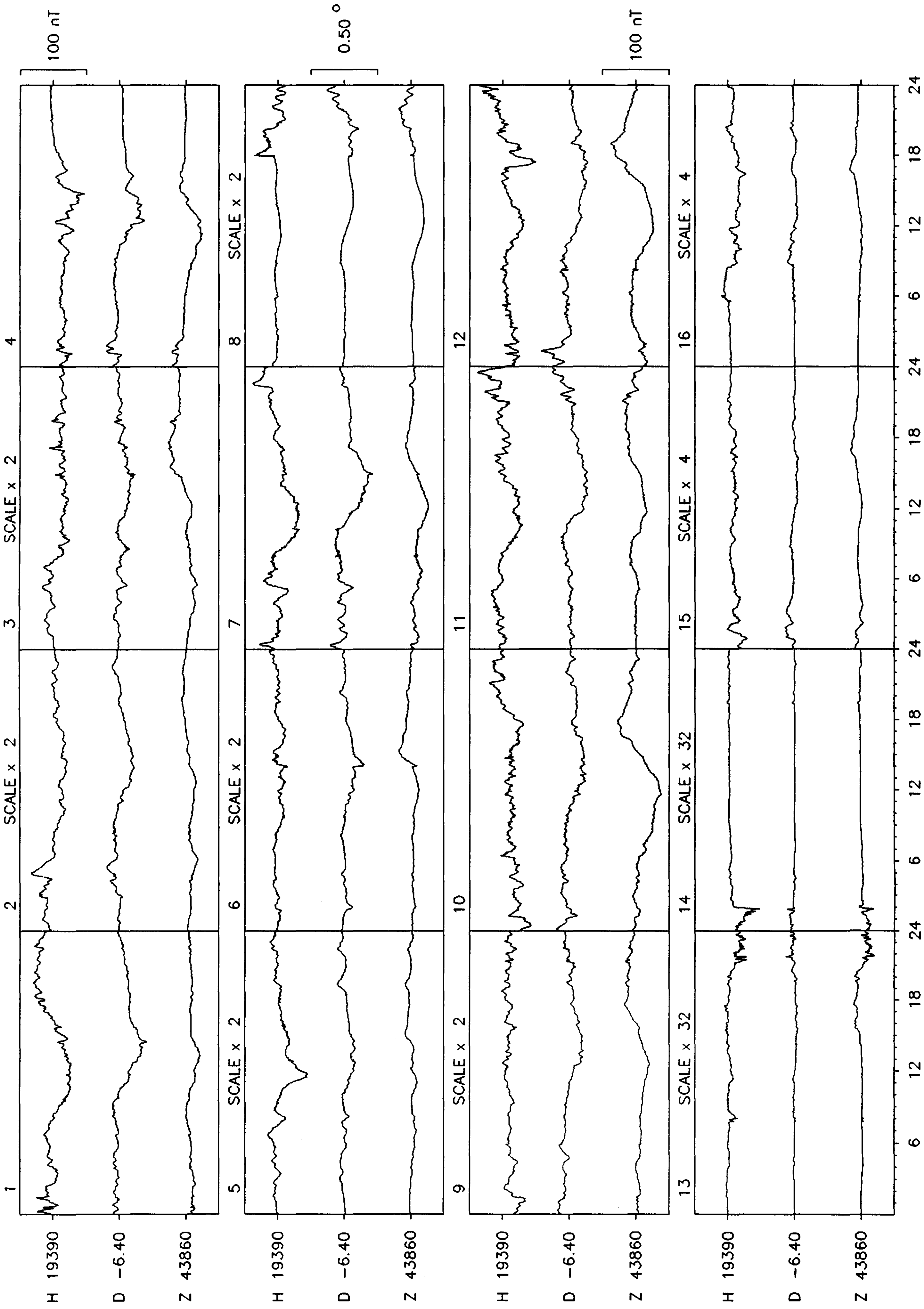
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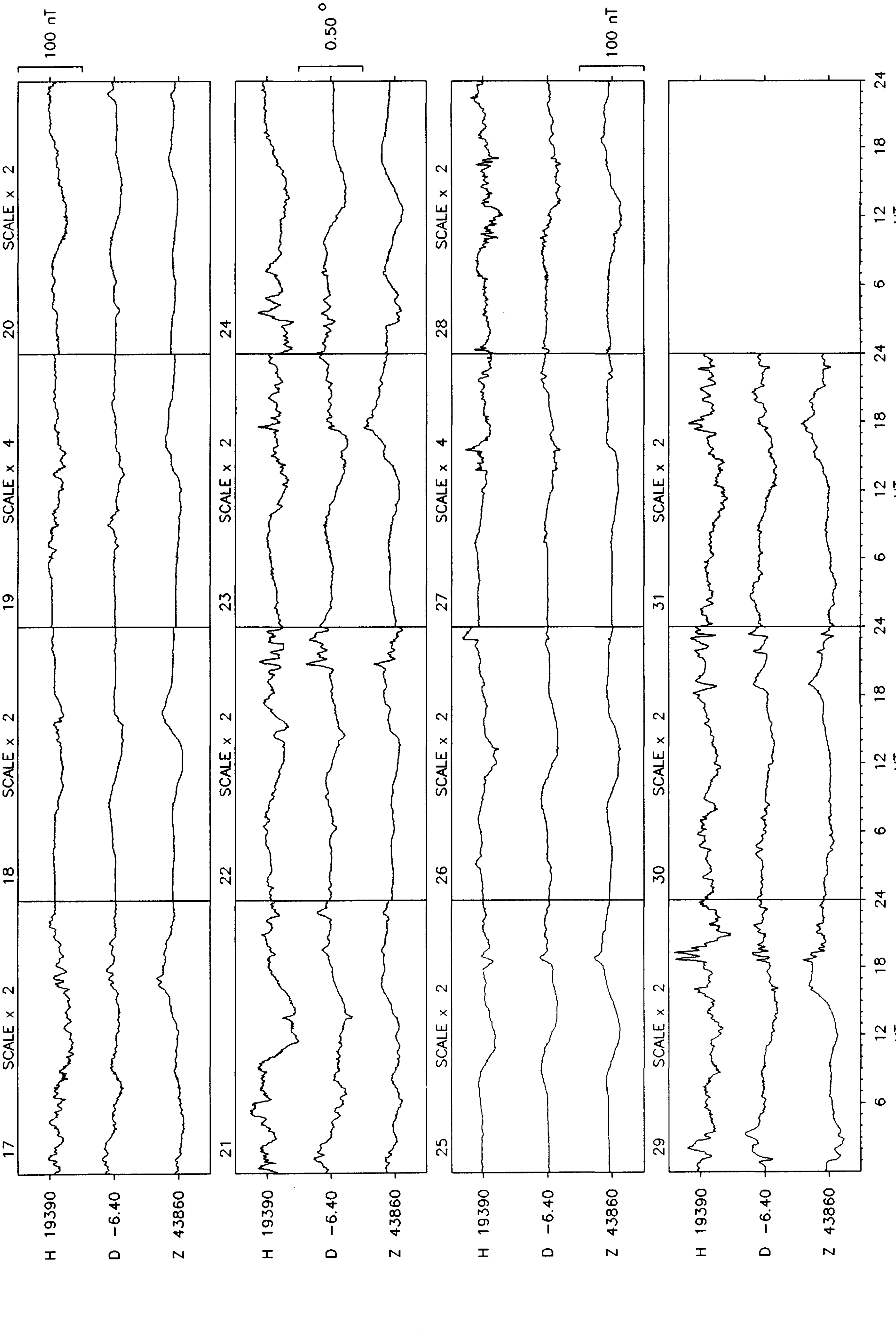
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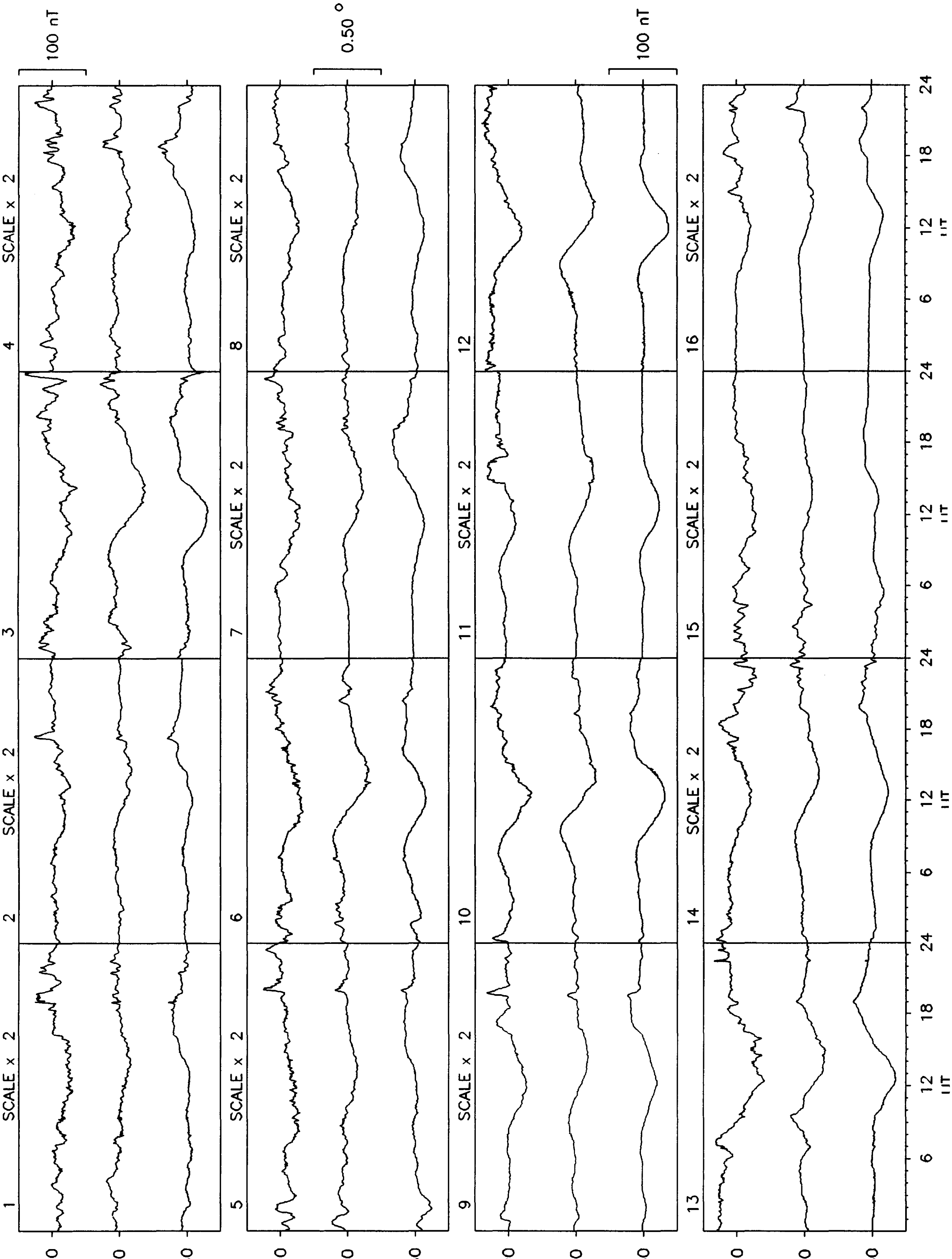
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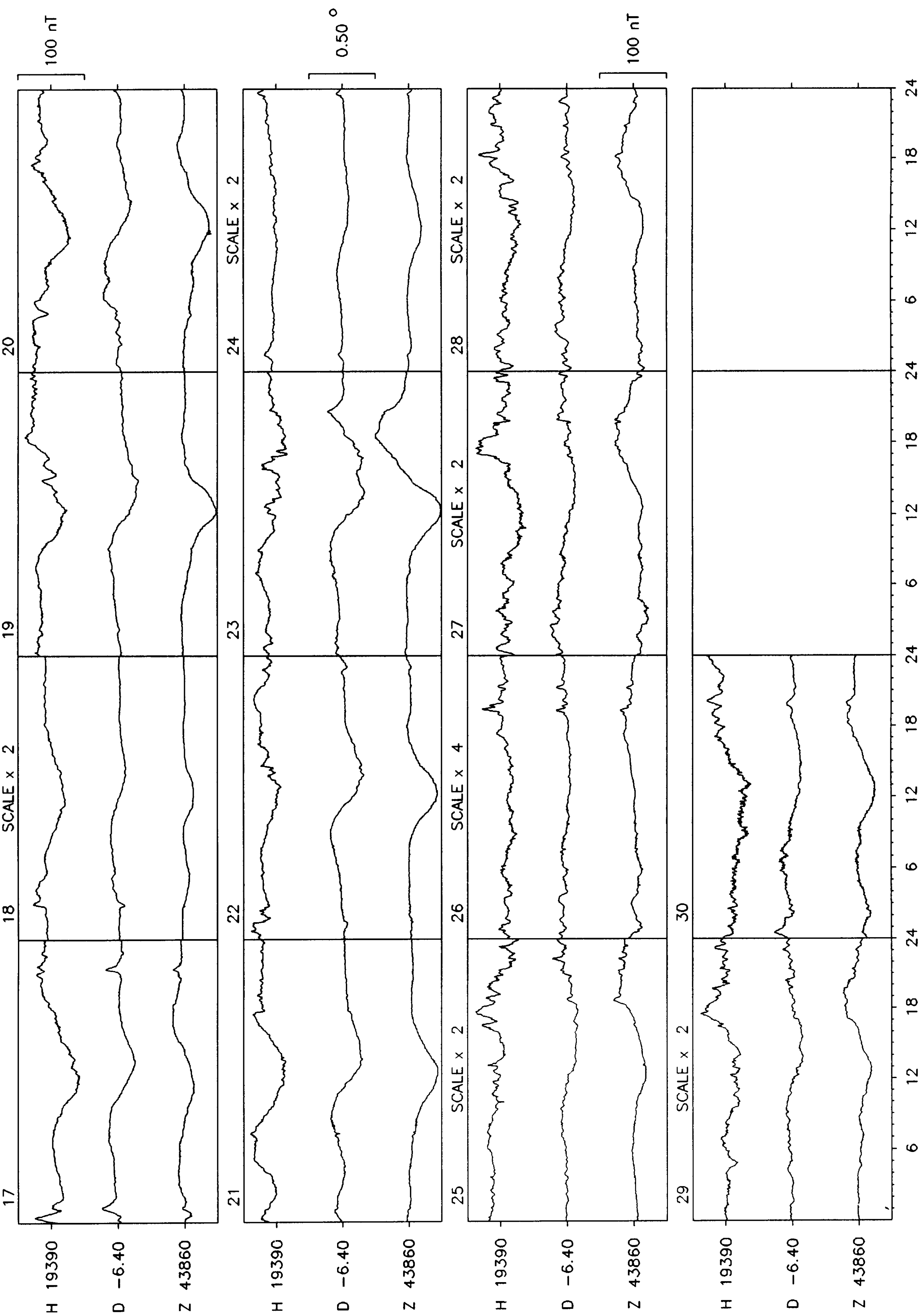
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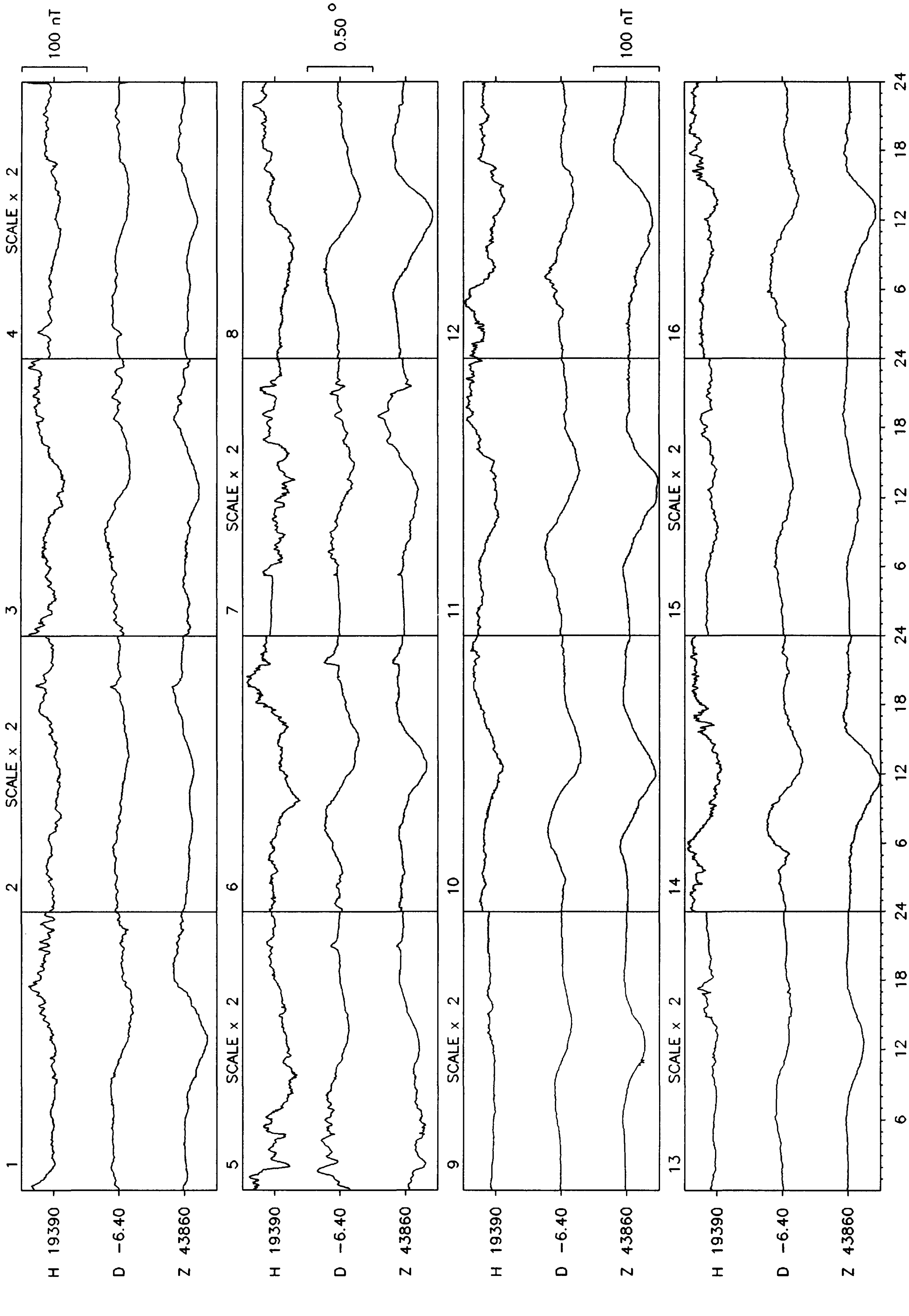
100 nT
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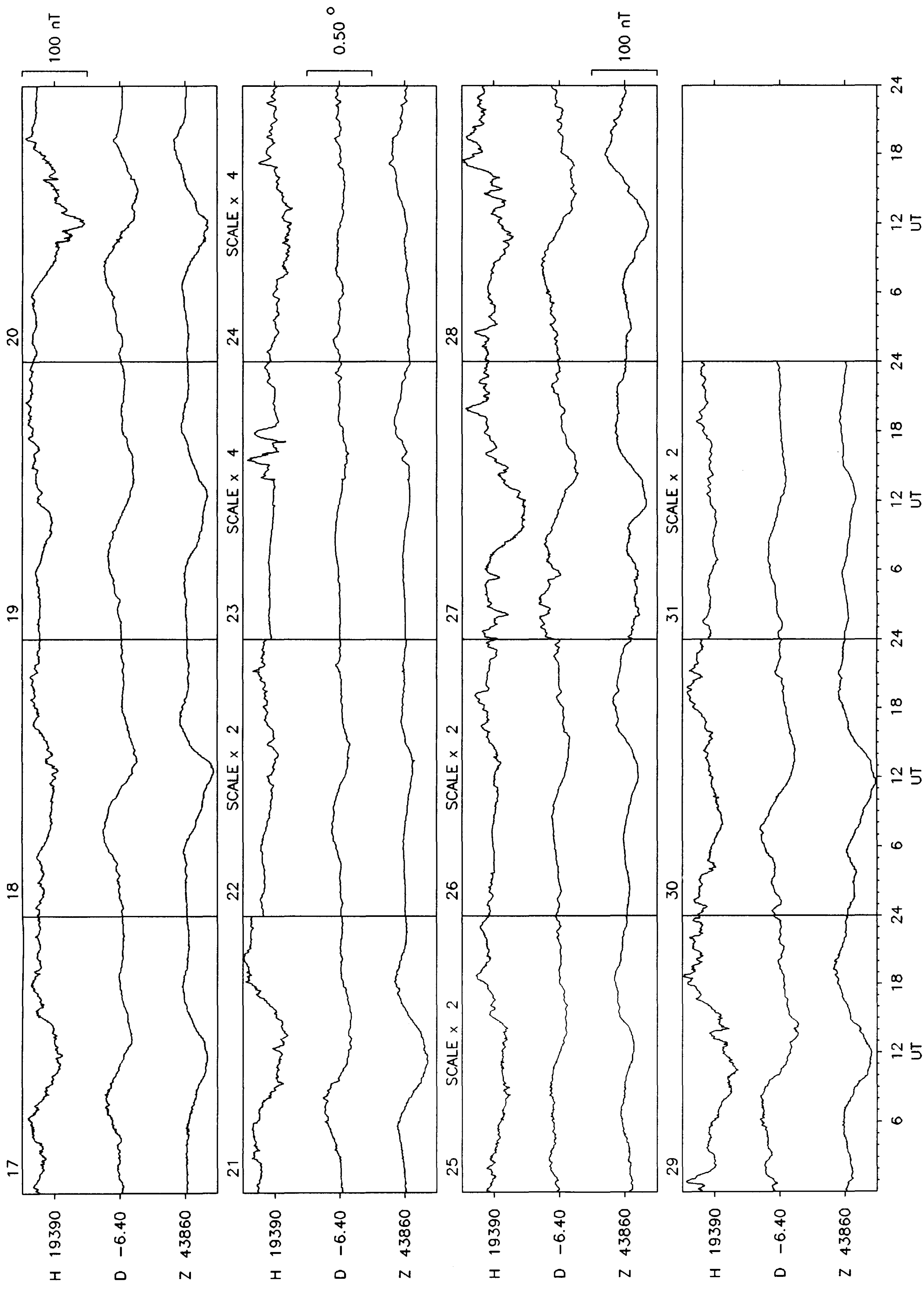

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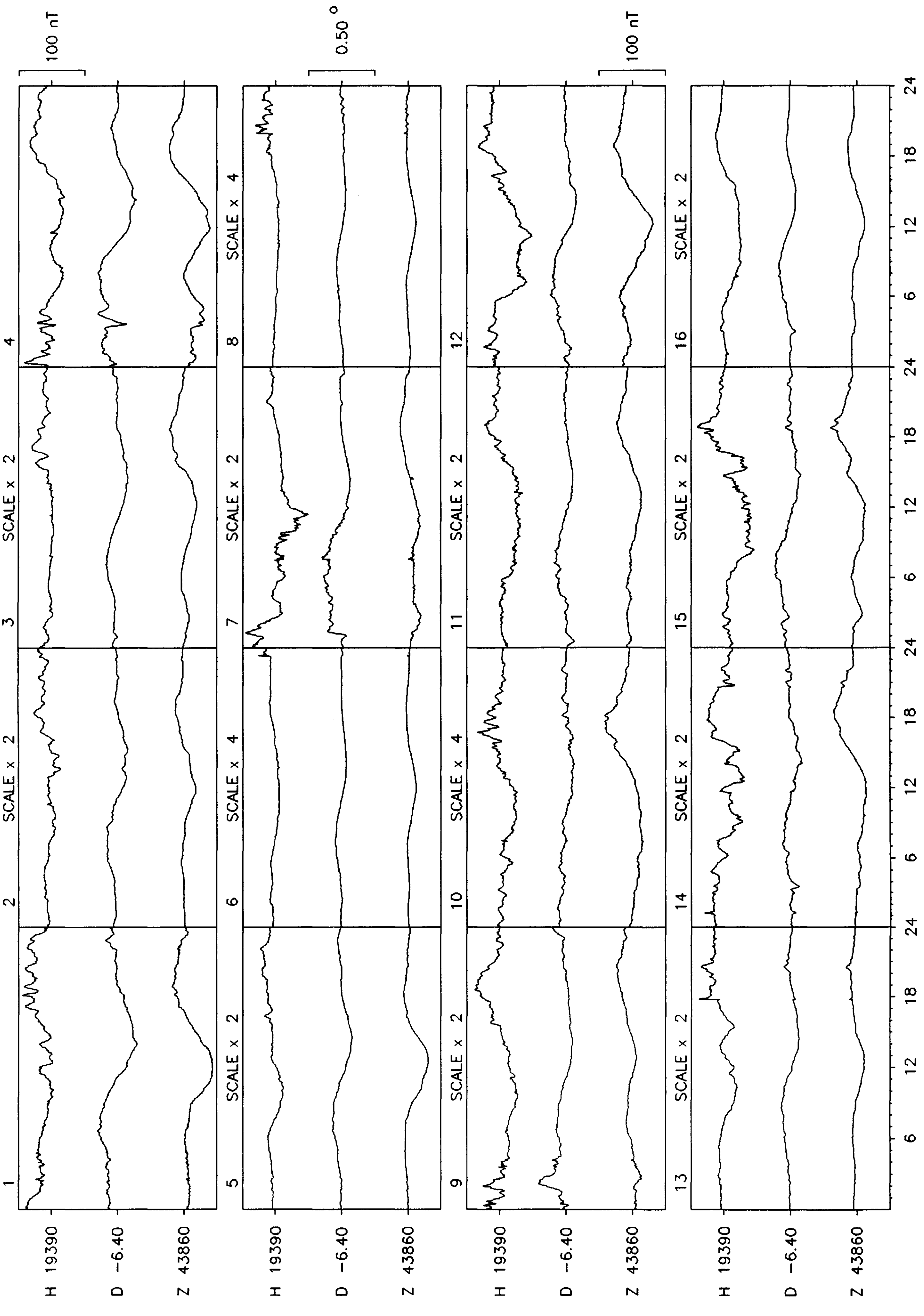
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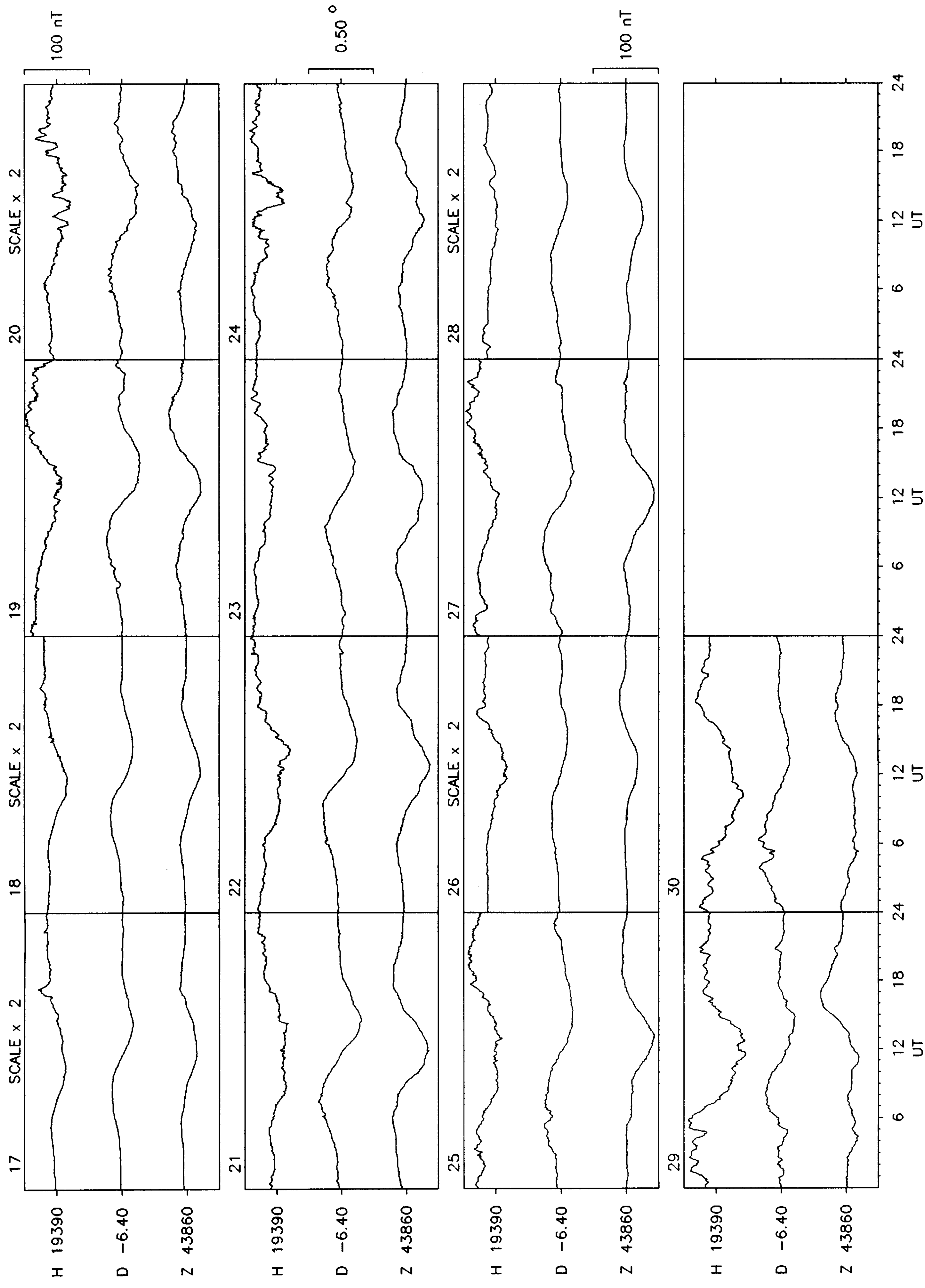
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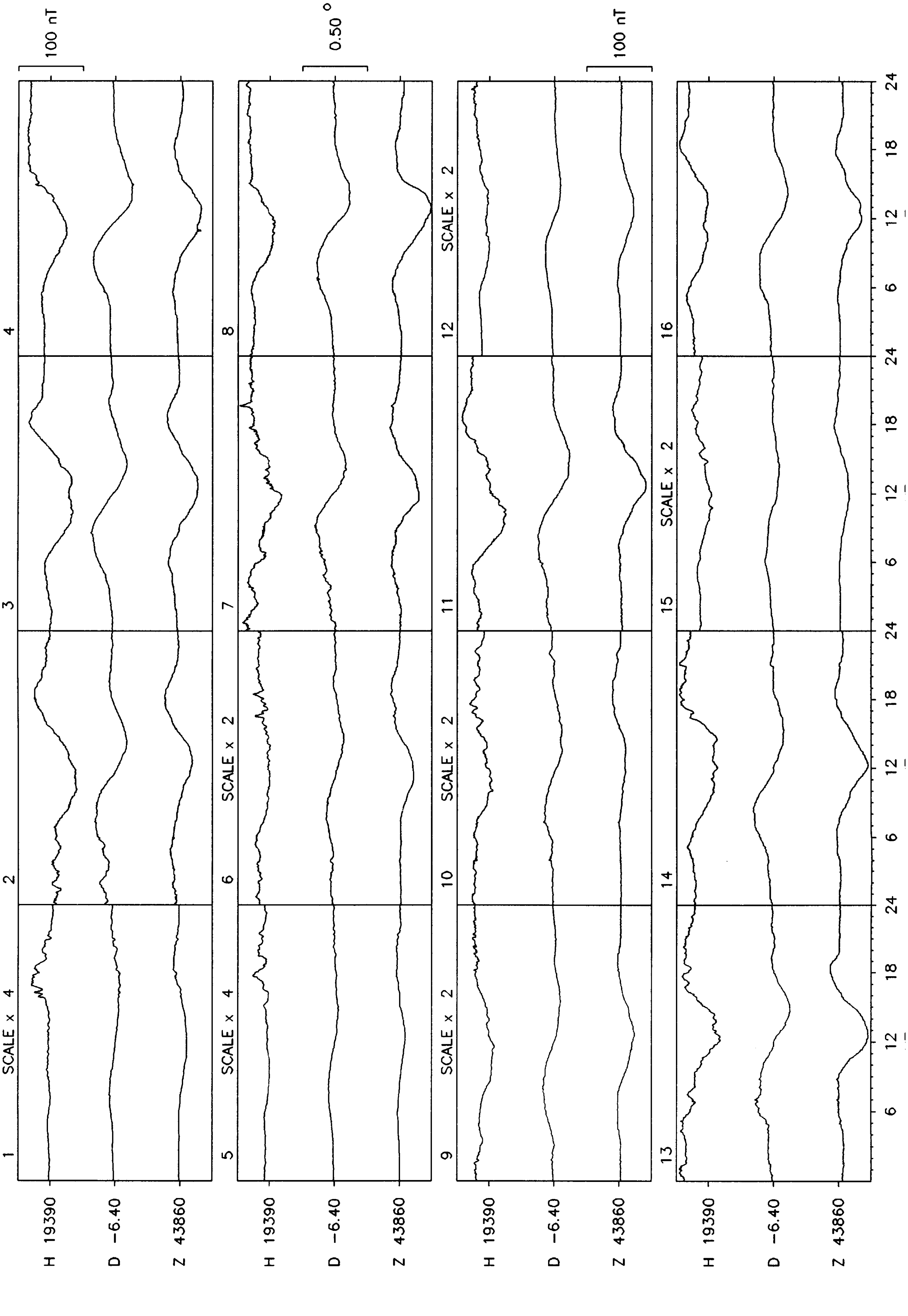
100 nT
0.50 °
100 nT
H 19390
D −6.40
Z 43860
SCALE x 4
SCALE x 2
1
2
3
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10
11
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14
15
16
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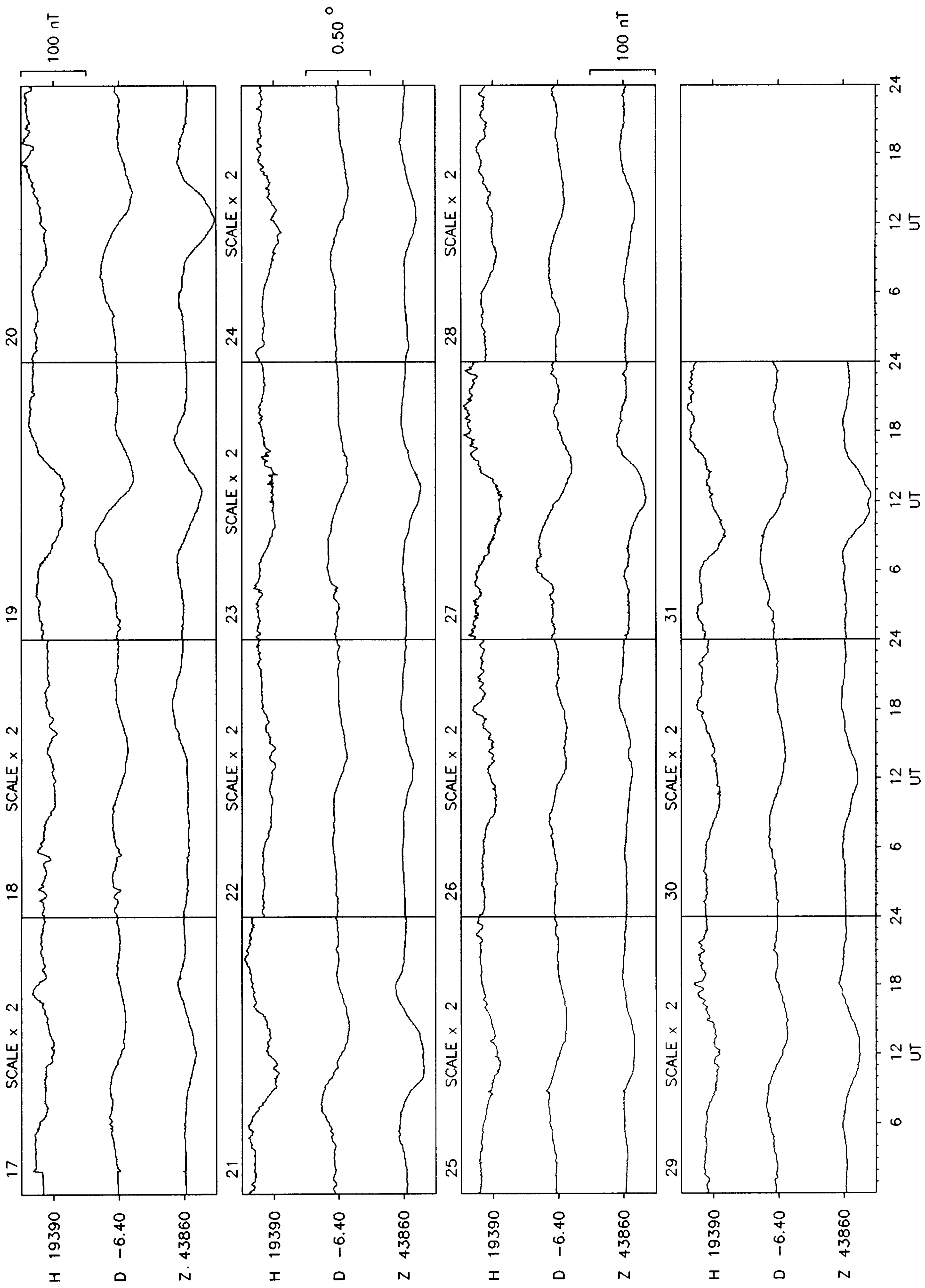
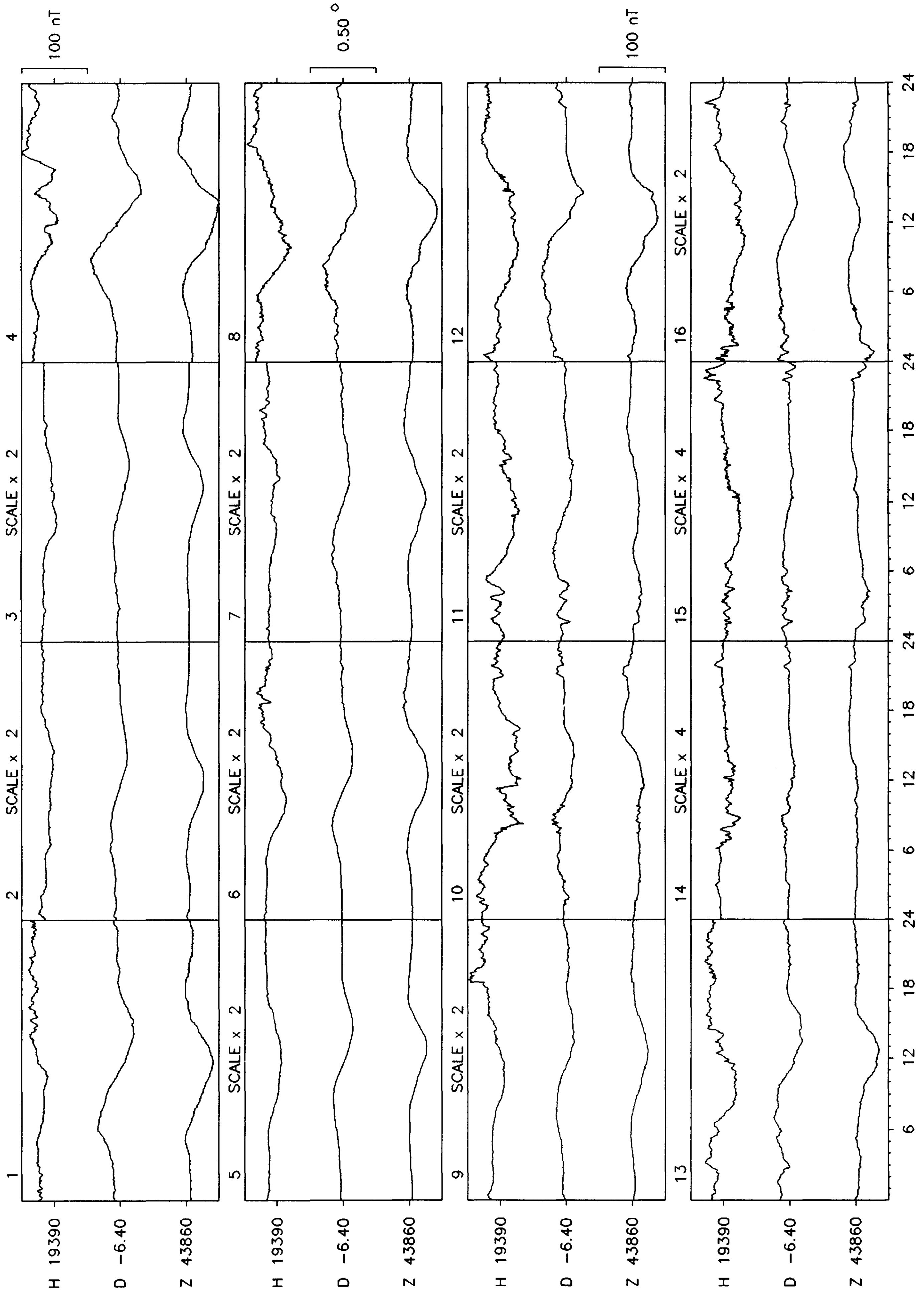
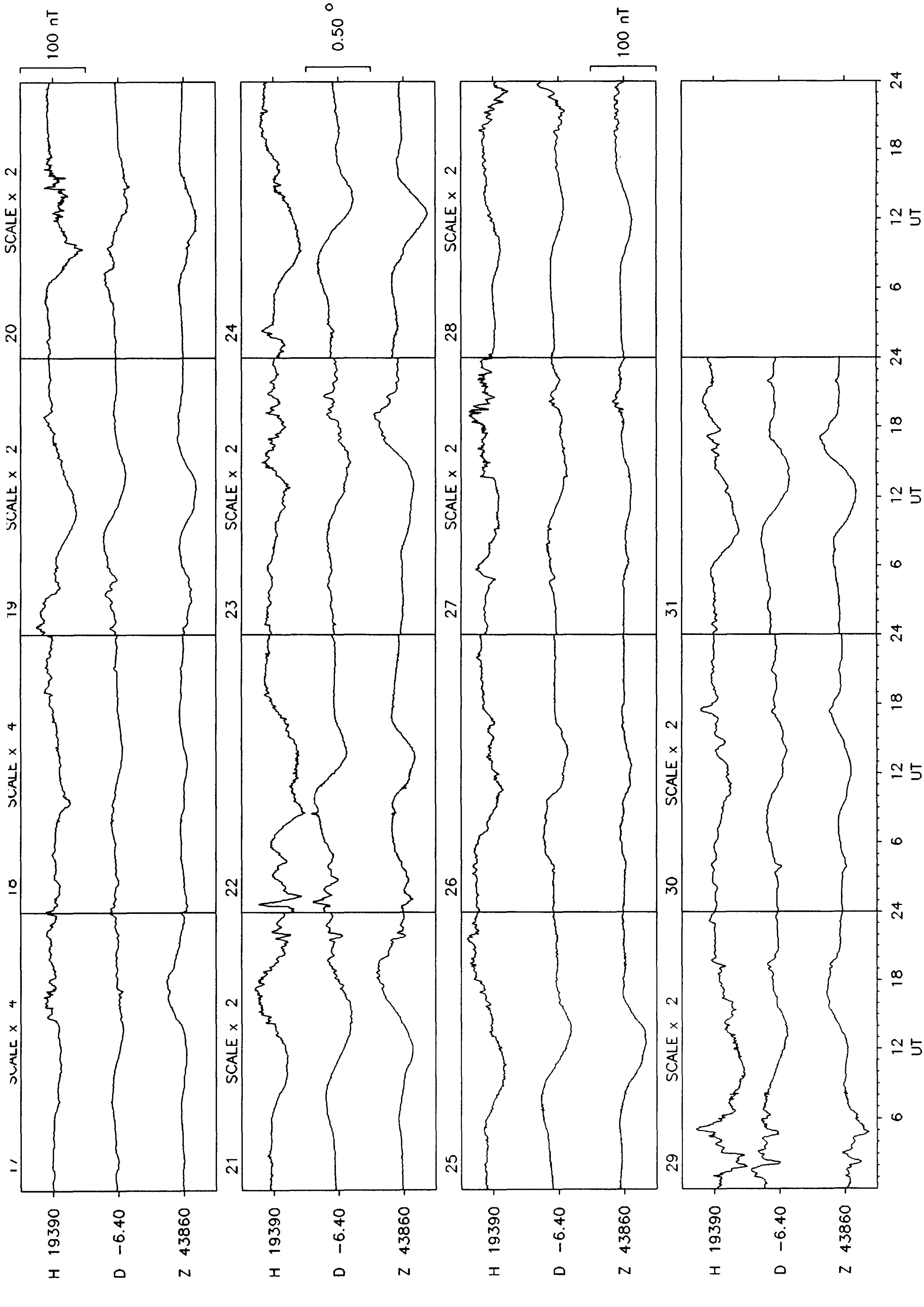
12
18
24



100 nT
0.50 °
100 nT
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
SCALE x 2
H 19390
D −6.40
Z 43860
UT
6
12
18
24



100 nT
0.50 °
100 nT
H 19390
D −6.40
Z 43860
SCALE x 2
SCALE x 4
6
12
18
24



100 nT
0.50 °
100 nT
H 19390
D −6.40
Z 43860
17
SCALE x 4
18
SCALE x 4
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SCALE x 2
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SCALE x 2
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SCALE x 2
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SCALE x 2
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SCALE x 2
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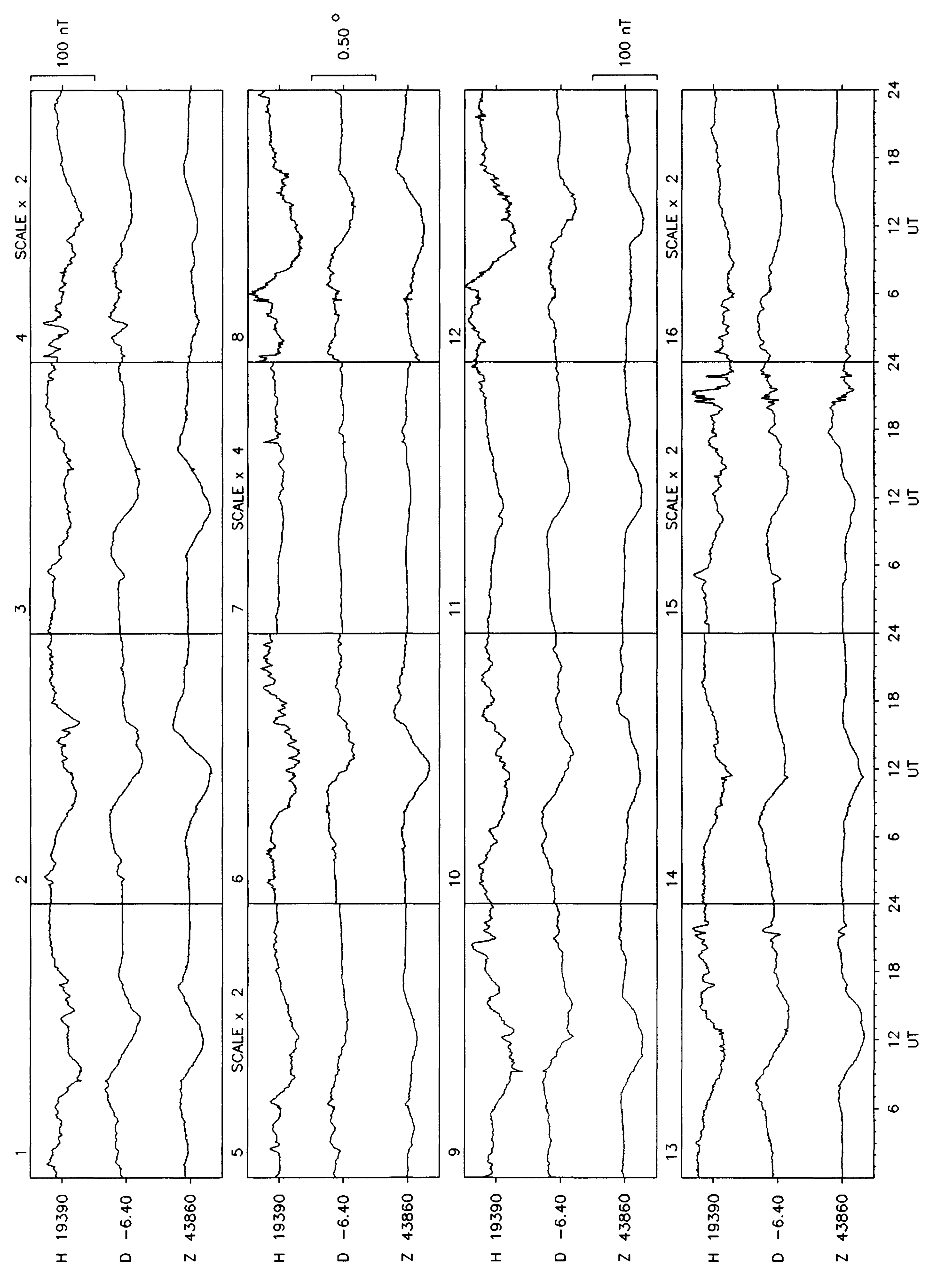
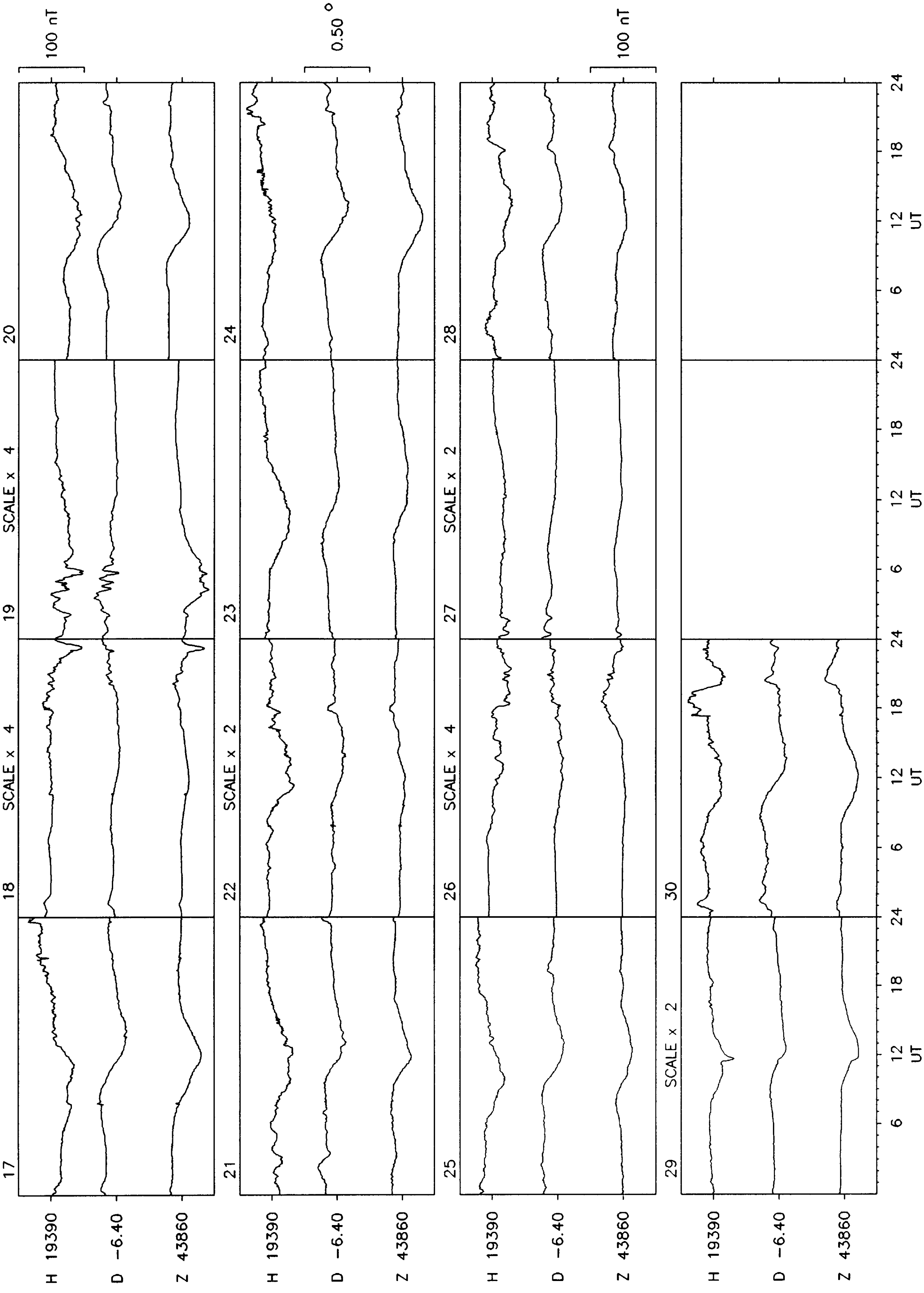
SCALE x 2
29
SCALE x 2
30
SCALE x 2
31
6
12
18
24
UT



100 nT
0.50 °
100 nT
SCALE x 2
SCALE x 4
SCALE x 2
SCALE x 2
H 19390
D −6.40
Z 43860
1 2 3 4
5 6 7 8
9 10 11 12
13 14 15 16
6 12 18 24
UT


H 19390
D −6.40
Z 43860
100 nT
0.50 °
17
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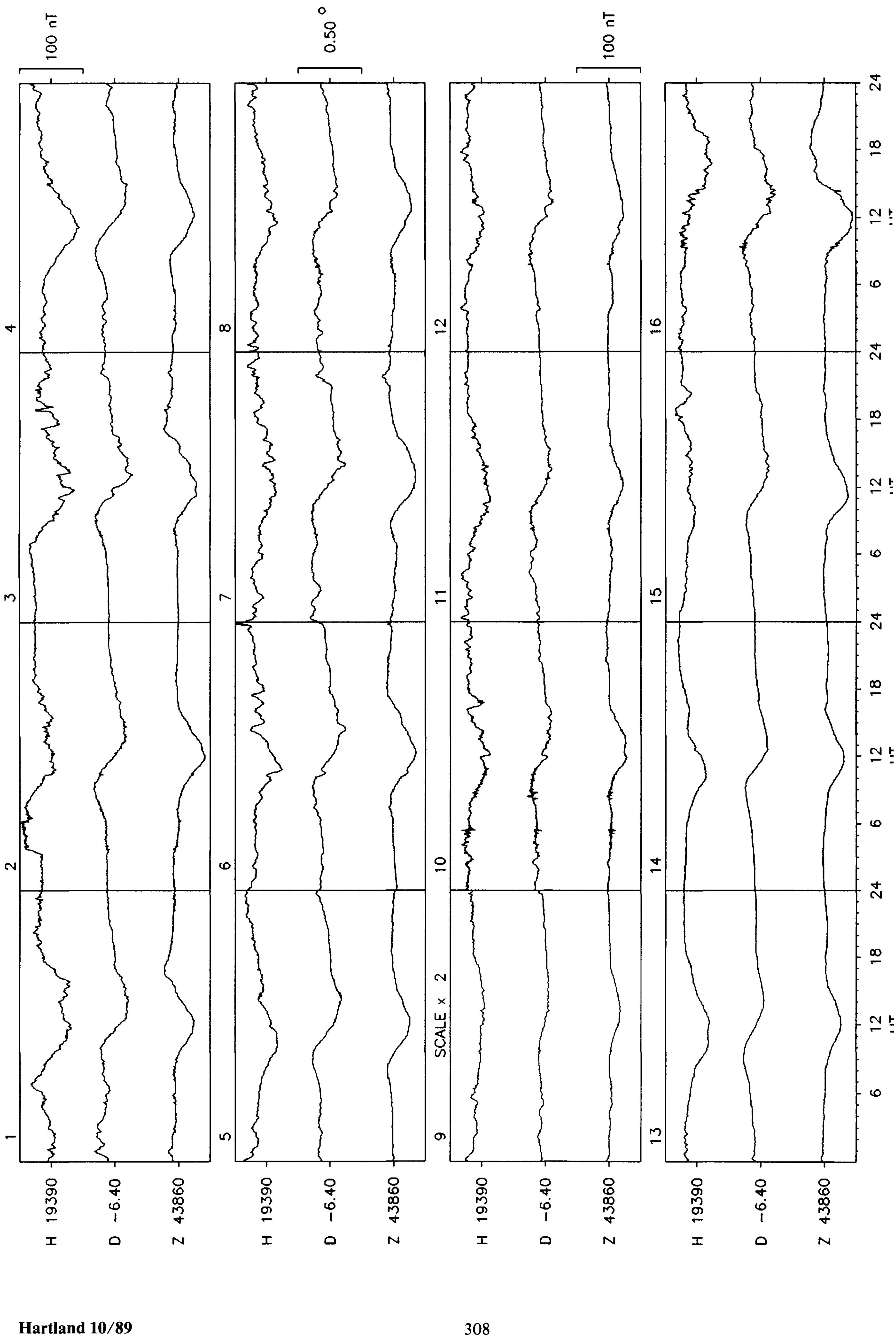
27
28
29
30
SCALE x 4
SCALE x 4
SCALE x 2
SCALE x 4
SCALE x 2
SCALE x 2
6
12
18
24
UT



100 nT
0.50 °
100 nT
H 19390
D −6.40
Z 43860
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16
SCALE x 2
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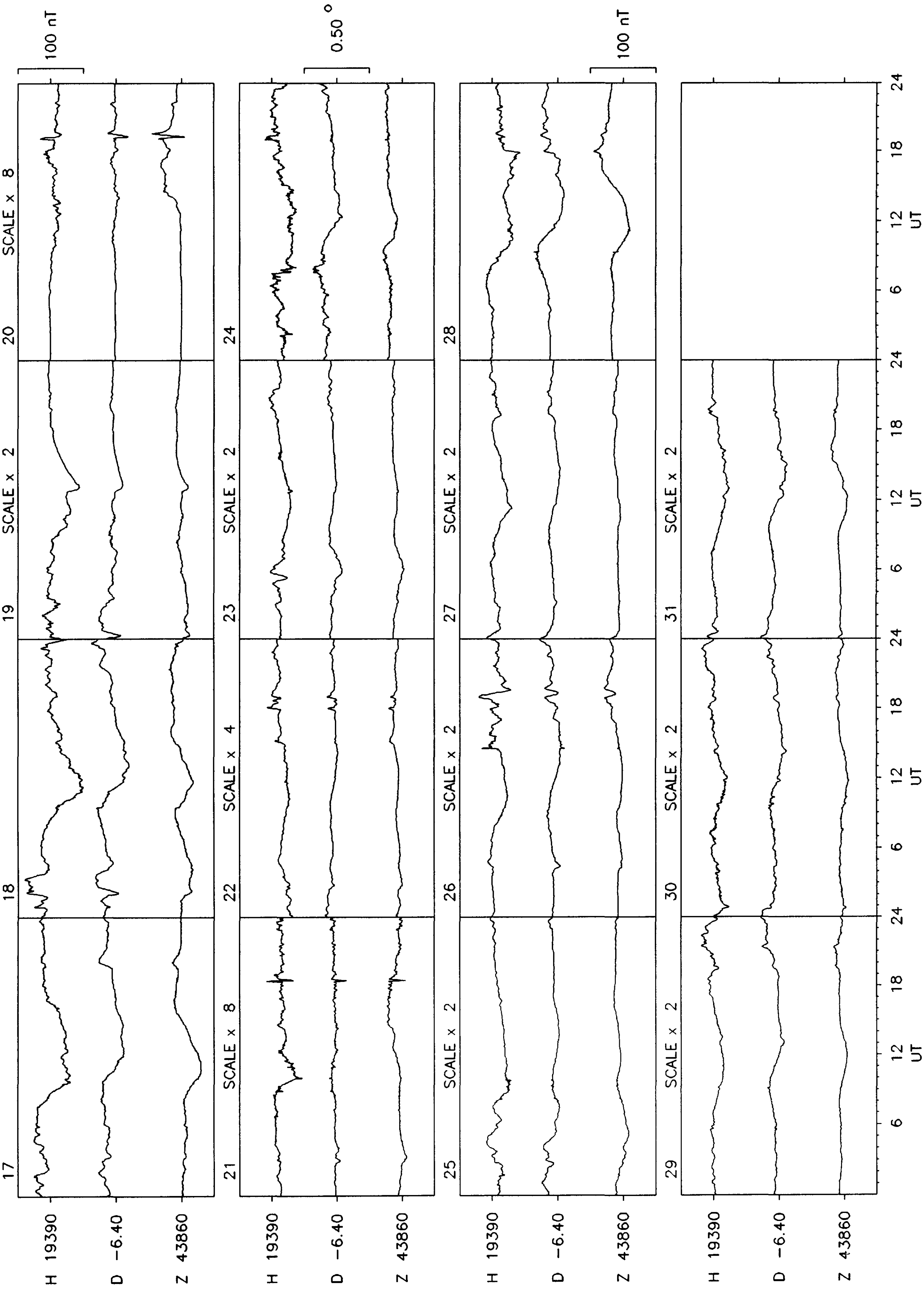
12
18
24
UT


100 nT
0.50 °
100 nT
17
18
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26
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28
29
30
31
SCALE x 8
SCALE x 2
SCALE x 4
SCALE x 8
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
H 19390
D −6.40
Z 43860
H 19390
D −6.40
Z 43860
H 19390
D −6.40
Z 43860
H 19390
D −6.40
Z 43860
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12
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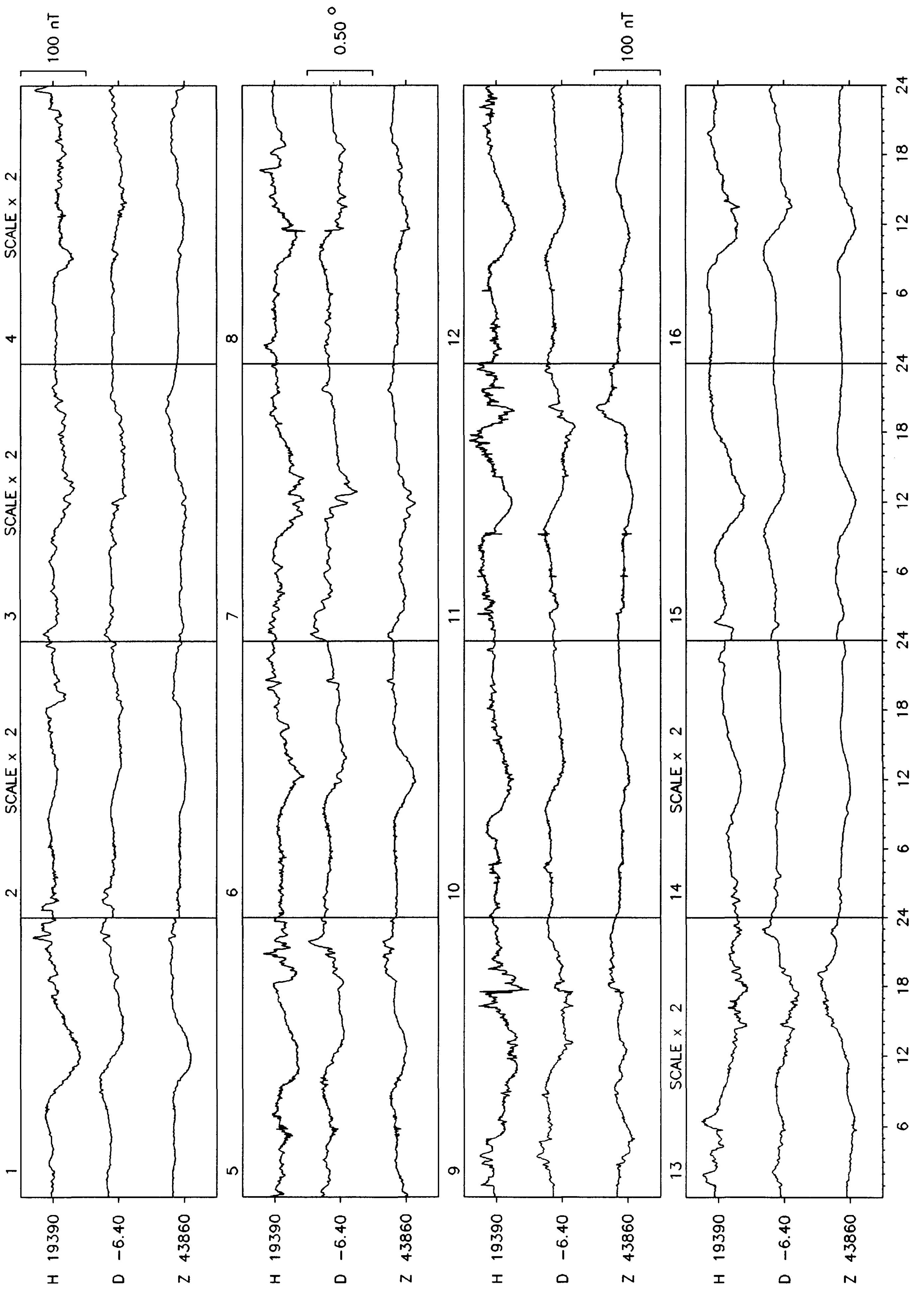
24
UT


100 nT
0.50 °
100 nT
SCALE x 2
H 19390
D −6.40
Z 43860
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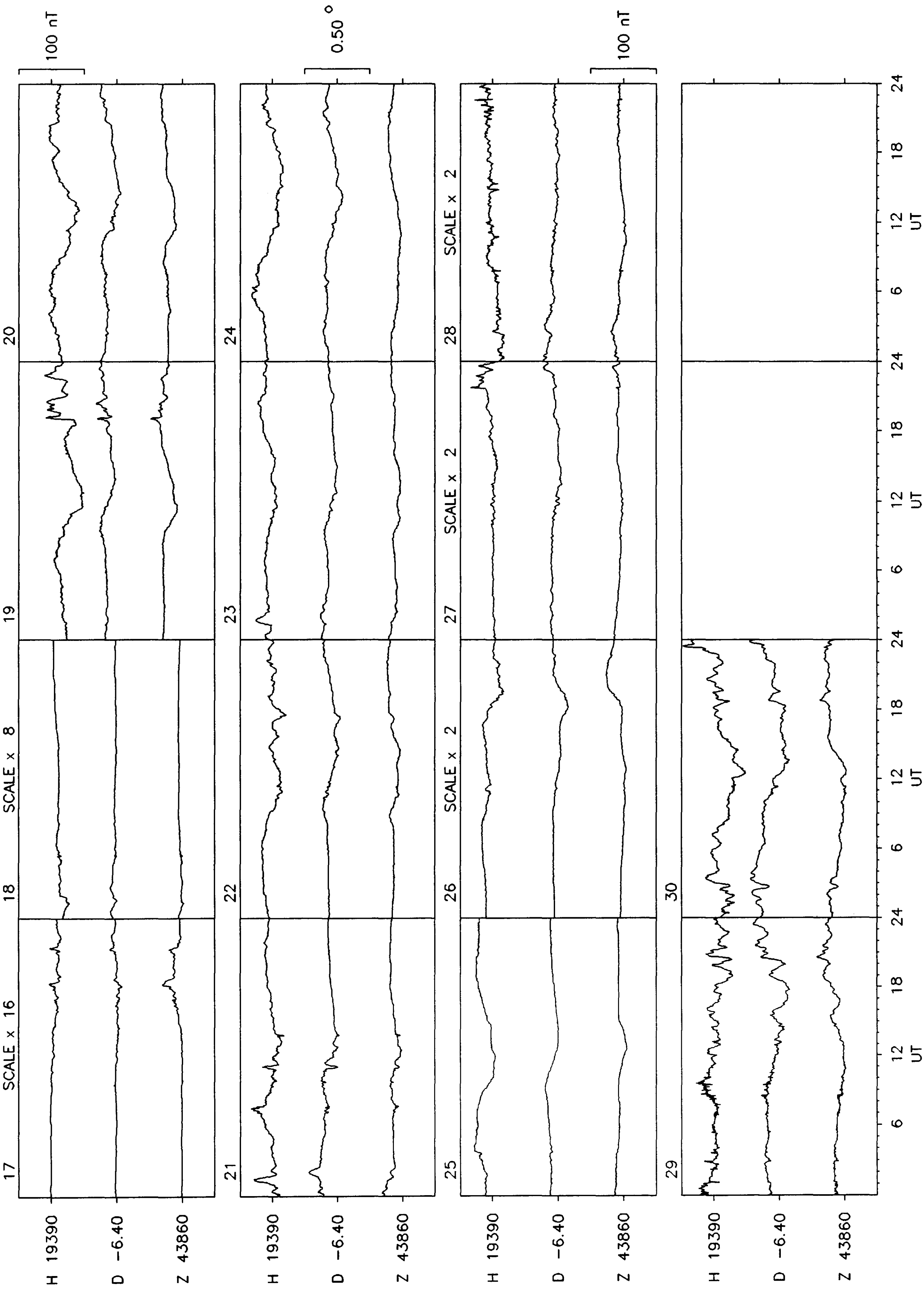
UT


100 nT
0.50 °
100 nT
H 19390
D −6.40
Z 43860
SCALE x 16
SCALE x 8
SCALE x 2
17
18
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21
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26
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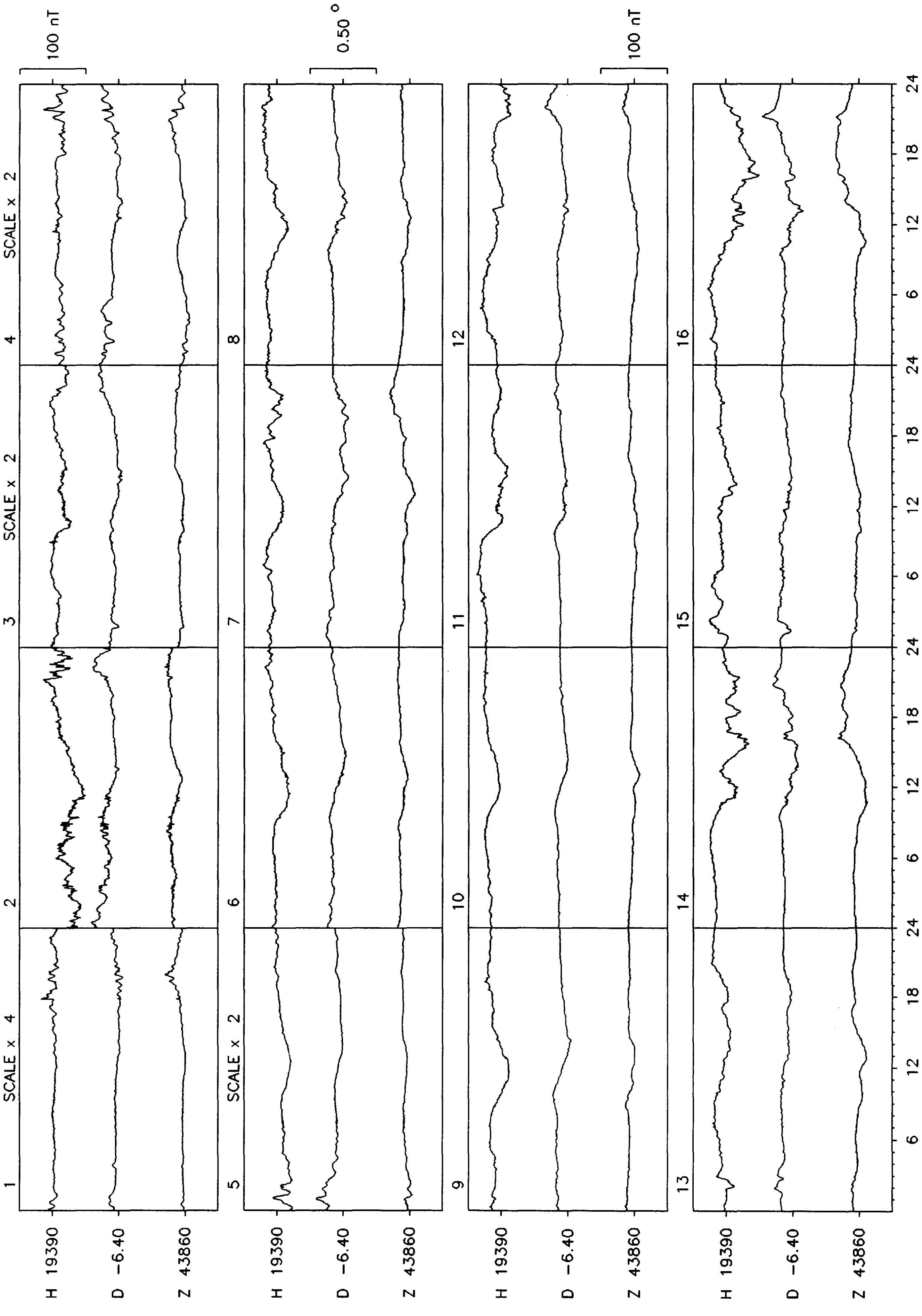
30
6
12
18
24
UT



H 19390
D −6.40
Z 43860
100 nT
0.50 °
100 nT
SCALE x 4
SCALE x 2
SCALE x 2
SCALE x 2
1
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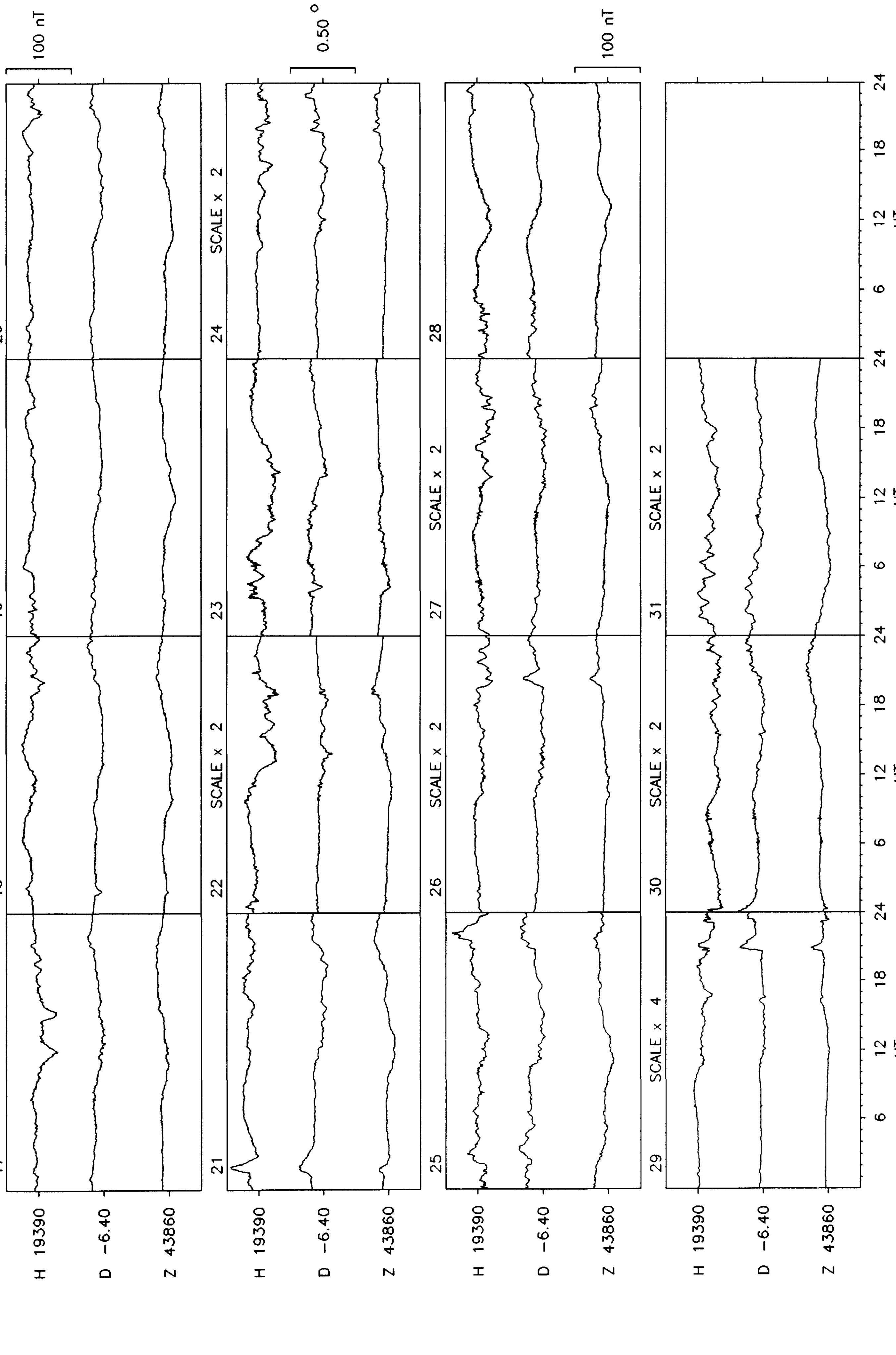
UT


100 nT
0.50 °
100 nT
17
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26
27
28
29
30
31
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 2
SCALE x 4
SCALE x 2
SCALE x 2
H 19390
D −6.40
Z 43860
H 19390
D −6.40
Z 43860
H 19390
D −6.40
Z 43860
H 19390
D −6.40
Z 43860
6
12
18
24
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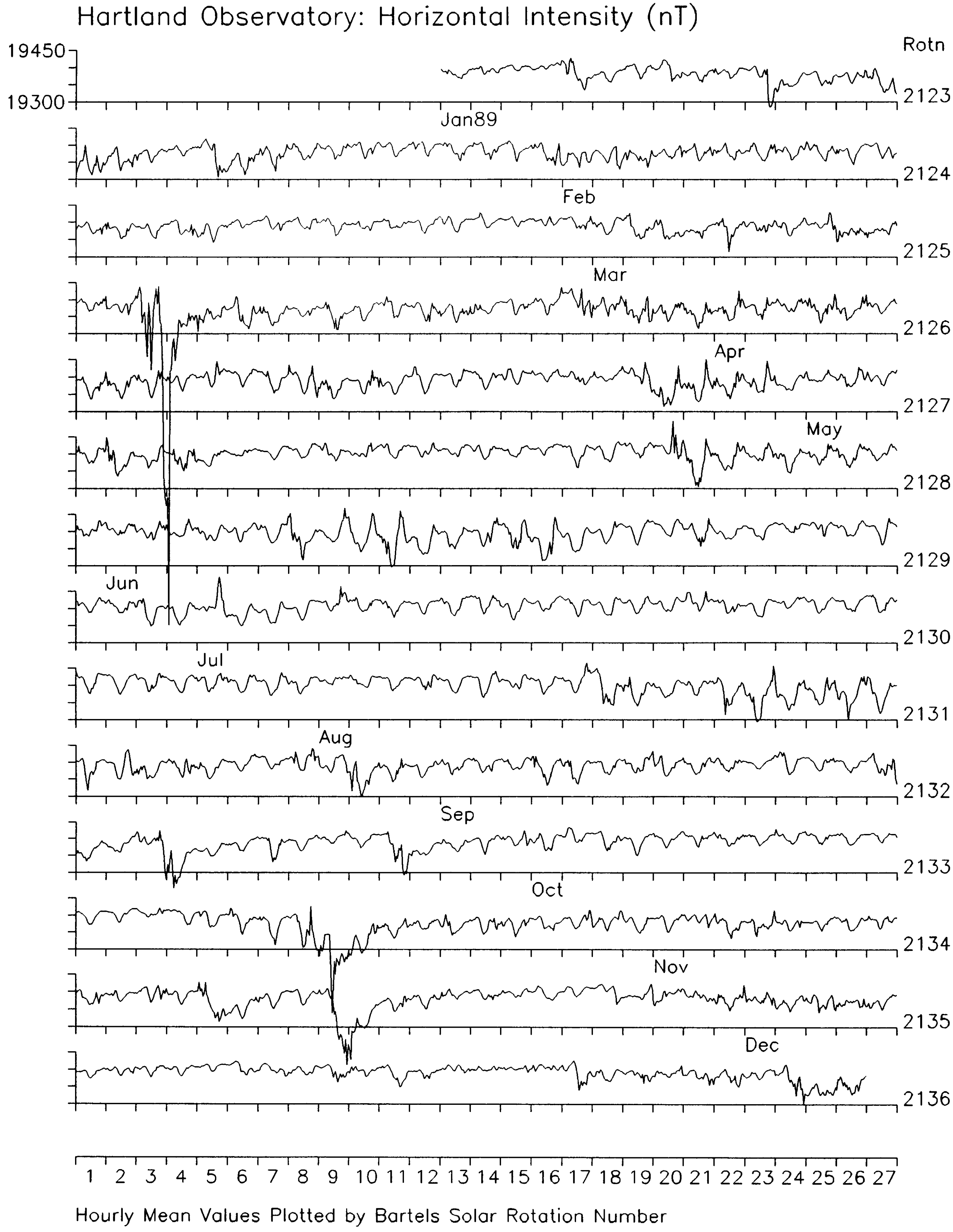
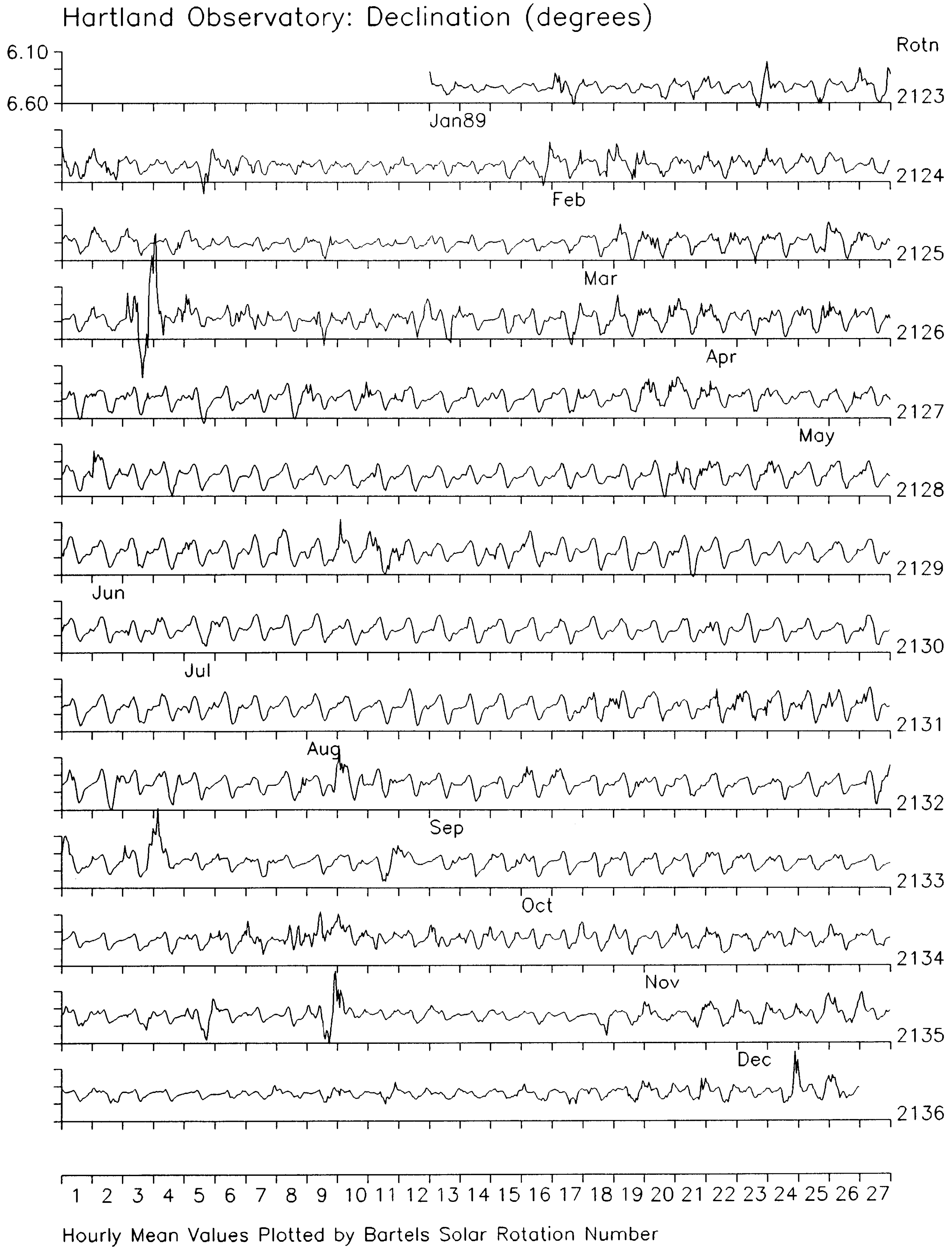
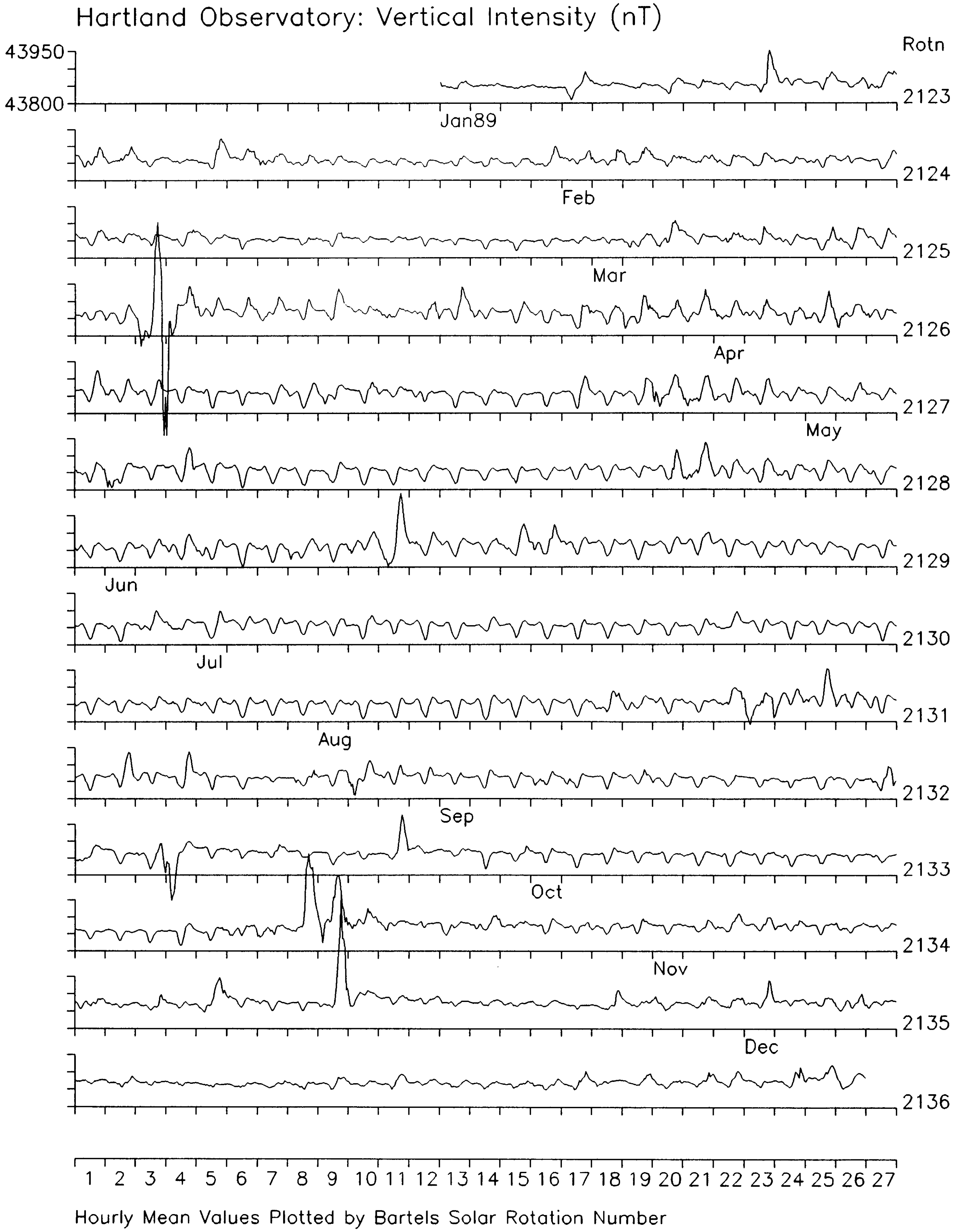
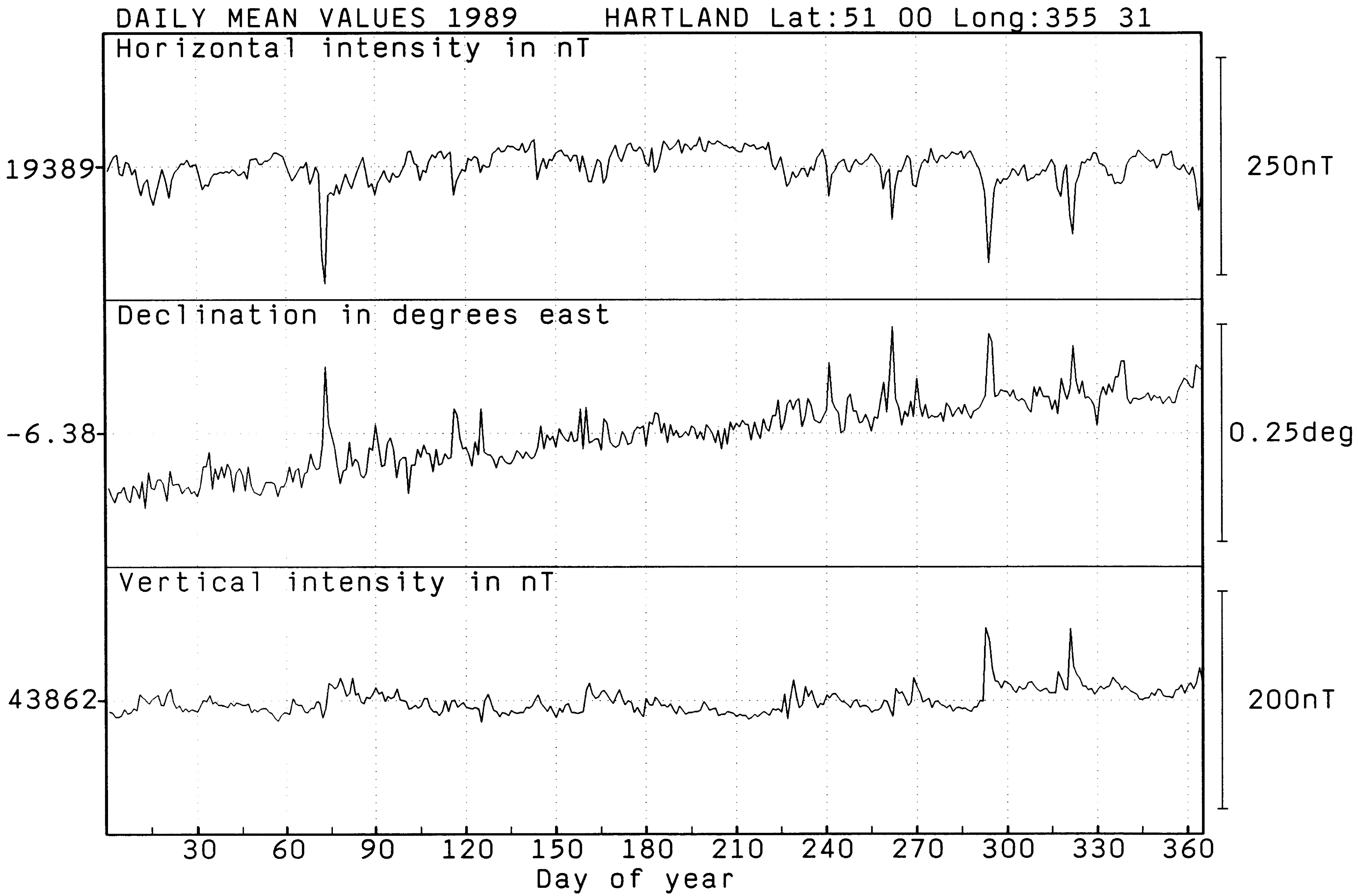
24
6
12
18
24
UT
UT
UT
UT


Hartland Observatory: Horizontal Intensity (nT)
19450
19300
Rotn
2123
Jan89
2124
Feb
2125
Mar
2126
Apr
2127
May
2128
2129
Jun
2130
Jul
2131
Aug
2132
Sep
2133
Oct
2134
Nov
2135
Dec
2136
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)
6.10
6.60
Rotn
2123
Jan89
2124
Feb
2125
Mar
2126
Apr
2127
May
2128
2129
Jun
2130
Jul
2131
Aug
2132
Sep
2133
Oct
2134
Nov
2135
Dec
2136
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)
43950
43800
Rotn
2123
Jan89
2124
Feb
2125
Mar
2126
Apr
2127
May
2128
2129
Jun
2130
Jul
2131
Aug
2132
Sep
2133
Oct
2134
Nov
2135
Dec
2136
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 1989
HARTLAND Lat:51 00 Long:355 31
Horizontal intensity in nT
Declination in degrees east
Vertical intensity in nT
19389
-6.38
43862
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 Hartland 1989

Month	D	I	H	X	Y	Z	F
	° ′	° ′	nT	nT	nT	nT	nT
Jan	-6 26.8	66 9.6	19380	19257	-2176	43857	47948
Feb	-6 26.1	66 9.1	19387	19265	-2173	43856	47950
Mar	-6 24.7	66 10.5	19369	19248	-2163	43864	47950
Apr	-6 24.3	66 9.2	19387	19266	-2163	43860	47954
May	-6 24.1	66 8.1	19402	19281	-2163	43854	47954
Jun	-6 23.1	66 8.6	19397	19277	-2157	43860	47958
Jul	-6 22.7	66 7.5	19410	19290	-2156	43854	47957
Aug	-6 21.7	66 8.8	19393	19274	-2149	43858	47954
Sep	-6 21.1	66 9.3	19386	19267	-2145	43861	47954
Oct	-6 20.7	66 9.6	19385	19266	-2142	43868	47960
Nov	-6 20.3	66 10.1	19381	19263	-2140	43877	47967
Dec	-6 19.9	66 9.5	19388	19270	-2138	43871	47964
Annual	-6 22.9	66 9.1	19389	19269	-2155	43862	47956

HARTLAND OBSERVATORY K INDICES 1989

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	4232 2243	4423 4345	3223 3322	3443 3454	3112 2323	3323 2333	1222 2553	1100 2221	2233 3210	3332 2322	2122 2223	4332 3554
2	2122 2132	3311 3254	3533 4333	3333 4532	2332 2443	2223 3433	3321 2111	3121 1111	2211 2321	0322 2221	4331 3343	3333 3224
3	0012 1122	5533 4545	3343 3443	4322 3334	3222 2233	3222 2433	0111 2321	2212 2110	1221 2112	0023 4333	4343 4342	4334 3334
4	2121 2223	4323 4344	3223 4311	4444 4454	4322 2435	4522 2222	0110 2110	1122 2422	5543 3213	2221 3312	2244 4335	5433 3355
5	4544 3442	3333 4344	3345 4344	5443 3354	6554 3344	2122 2323	1112 3554	1000 0101	4343 3322	3102 2113	3333 2244	5321 3232
6	3223 2223	4333 3343	4333 4343	3321 2333	2333 1334	3321 2225	3322 2332	1011 2242	2223 2332	2123 3323	2222 3232	2111 1212
7	3123 3232	3334 3445	4433 3423	1333 4444	4343 4545	5445 3033	3322 3331	2223 3332	3213 3643	3321 3324	3323 4123	2221 2233
8	1223 4343	4333 2313	2131 2456	3332 3433	1122 2213	3232 2354	0011 2111	2222 2222	4442 3313	2222 2113	3234 3331	1112 2212
9	3333 4333	4333 3333	4433 4444	3222 3442	1111 2211	6422 2444	2321 2222	2211 2243	2113 3332	3321 2223	3332 3543	1111 2021
10	3223 3222	4323 3210	4332 2333	3111 3223	2101 1112	4554 5654	2232 3323	3354 3433	2322 3323	2332 2322	2321 2222	0010 0011
11	2121 3566	1122 2343	2234 3324	2231 5432	2211 1323	4432 3443	1112 2111	4433 3422	1001 0002	2222 2211	3323 2344	0112 2222
12	5322 2232	3322 3244	5232 3433	2221 2222	3332 2322	3332 2331	0112 2212	3221 2222	3343 3312	1222 2222	3221 2123	2211 2223
13	0012 3343	4333 3433	5688 7789	2133 2333	2222 3422	1123 4542	1222 2211	3222 3122	1221 3324	2000 1000	4443 5445	3221 1231
14	3111 3345	3422 3421	9764 4566	4222 3454	2332 2322	3445 4553	1111 1212	3465 5334	1223 2110	0001 2100	3322 1212	0003 3343
15	5433 3355	1221 2344	6544 3443	4533 3323	1333 3332	4443 5543	1112 2322	5554 5446	2433 4456	1002 1231	3211 1 11	3222 2122
16	4444 4445	3423 3223	2455 4454	1111 4445	2312 3322	3431 1321	0201 1100	4322 3234	4432 2223	2222 3222	1111 2222	2223 3334
17	4334 4453	2222 1111	4443 3443	4111 2124	2332 2221	0001 2412	3233 2332	3232 4545	2122 2123	3222 1232	4346 6687	2112 3322
18	4323 3222	1221 3331	0221 2412	4422 2211	2211 2211	2101 2221	4422 2321	5334 3344	523 3466	4423 3224	6542 2332	3121 2233
19	3222 2223	1122 2324	1355 5532	1012 3322	1213 1222	1212 2233	2120 2111	3421 1231	5754 4332	5443 4322	1122 2243	2221 1121
20	3222 6664	3333 3442	2332 2324	2331 2322	2123 4331	2433 4443	1211 2222	2244 5411	11 1 2223	2235 5686	3222 2222	1211 1133
21	3333 3444	2233 2321	4333 3333	3321 2311	2332 3222	1121 2212	1222 1211	2111 3345	3221 2 13	5567 5575	3233 2001	4301 2223
22	5443 5434	2333 3232	2243 4565	3101 3223	2323 3334	1211 2222	2112 3212	4332 1221	2335 3543	5433 3554	1012 2322	4323 4453
23	3433 3433	1111 2122	4233 4534	2122 3443	2322 5664	2111 2231	2422 3322	3333 5453	2121 1122	4441 3233	3212 2212	1332 3322
24	2222 2233	3333 3101	4332 2221	3122 2224	5454 5644	1123 4321	3132 3322	3111 2222	2121 2223	3232 2233	2222 2222	2224 3455
25	2223 3233	1133 2111	1022 2243	3233 4544	4332 4343	2231 2322	2222 2213	0111 2222	2111 2221	4443 1213	1200 0000	3423 2234
26	2213 3321	1011 2101	2323 4224	5554 3565	3222 3343	1122 2322	2222 3332	1223 2211	1144 4465	1432 4355	0112 2453	3223 3354
27	3423 3210	2002 3322	2243 5655	4443 4554	4431 3333	2111 2223	2321 2222	2433 4354	4321 2211	5323 2333	2223 3235	3333 3443
28	2322 3342	2122 3344	4234 4534	4443 4454	3223 3433	3212 2322	2222 2233	2103 2246	3211 1233	1122 2332	4443 3334	3322 2223
29	3122 3331		5543 4465	3333 3544	4223 3333	3332 3222	2212 2333	6543 3443	2124 3222	2232 3244	3233 3443	2234 3576
30	2223 3333		3443 3355	4332 3233	3331 2332	2422 1122	2221 2222	2423 3433	3221 2343	5333 3334	4323 3344	5333 2344
31	3223 3456		4433 3554		3322 3333		2211 2222	1111 2323		4222 3431		4444 3342

DAILY aa INDICES

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	28	49	27	53	18	22	38	9	15	22	17	66
2	14	32	48	42	26	31	10	10	16	20	39	40
3	10	63	48	32	17	22	8	9	11	25	51	46
4	21	37	24	61	33	21	5	18	40	14	51	51
5	65	35	48	49	62	14	30	3	34	11	37	24
6	23	38	35	19	25	19	20	13	22	20	25	11
7	23	45	31	44	64	50	17	18	35	23	30	19
8	36	25	43	29	11	30	6	14	34	17	27	13
9	34	33	52	25	9	41	12	17	18	20	46	10
10	23	21	30	14	8	80	19	53	22	18	22	5
11	61	22	31	28	14	33	8	41	5	14	39	14
12	25	26	38	13	22	19	8	15	25	18	19	17
13	22	40	348	29	18	29	12	18	19	4	70	14
14	32	26	208	36	18	57	10	66	12	5	20	25
15	66	26	74	37	24	49	11	83	56	8	12	19
16	64	32	70	32	15	15	6	32	28	20	13	30
17	46	12	48	18	15	10	25	48	12	19	175	20
18	24	18	25	16	11	7	23	41	73	33	58	20
19	18	19	75	13	11	15	7	16	73	38	18	16
20	85	34	21	15	26	41	8	39	12	128	17	18
21	44	20	31	18	19	9	9	33	17	158	23	21
22	51	22	55	15	24	9	12	19	45	61	13	69
23	37	9	53	30	54	11	20	47	9	34	11	38
24	21	18	24	17	74	17	18	11	15	30	19	51
25	22	13	20	46	37	15	12	10	9	28	7	41
26	21	7	27	77	25	14	22	12	76	43	28	39
27	22	14	67	59	29	10	15	43	14	31	34	41
28	26	29	54	55	26	13	16	35	16	20	44	20
29	23		79	42	26	26	16	65	17	26	40	78
30	25		61	38	18	15	13	29	23	39	40	52
31	58		66		23		9	12		28		46
MONTHLY MEAN VALUE	**34.5**	**27.3**	**60.1**	**33.4**	**25.8**	**24.8**	**14.3**	**28.3**	**26.8**	**31.4**	**34.7**	**31.3**

YEARLY MEAN VALUE FOR 1989 = 31.1

ABINGER

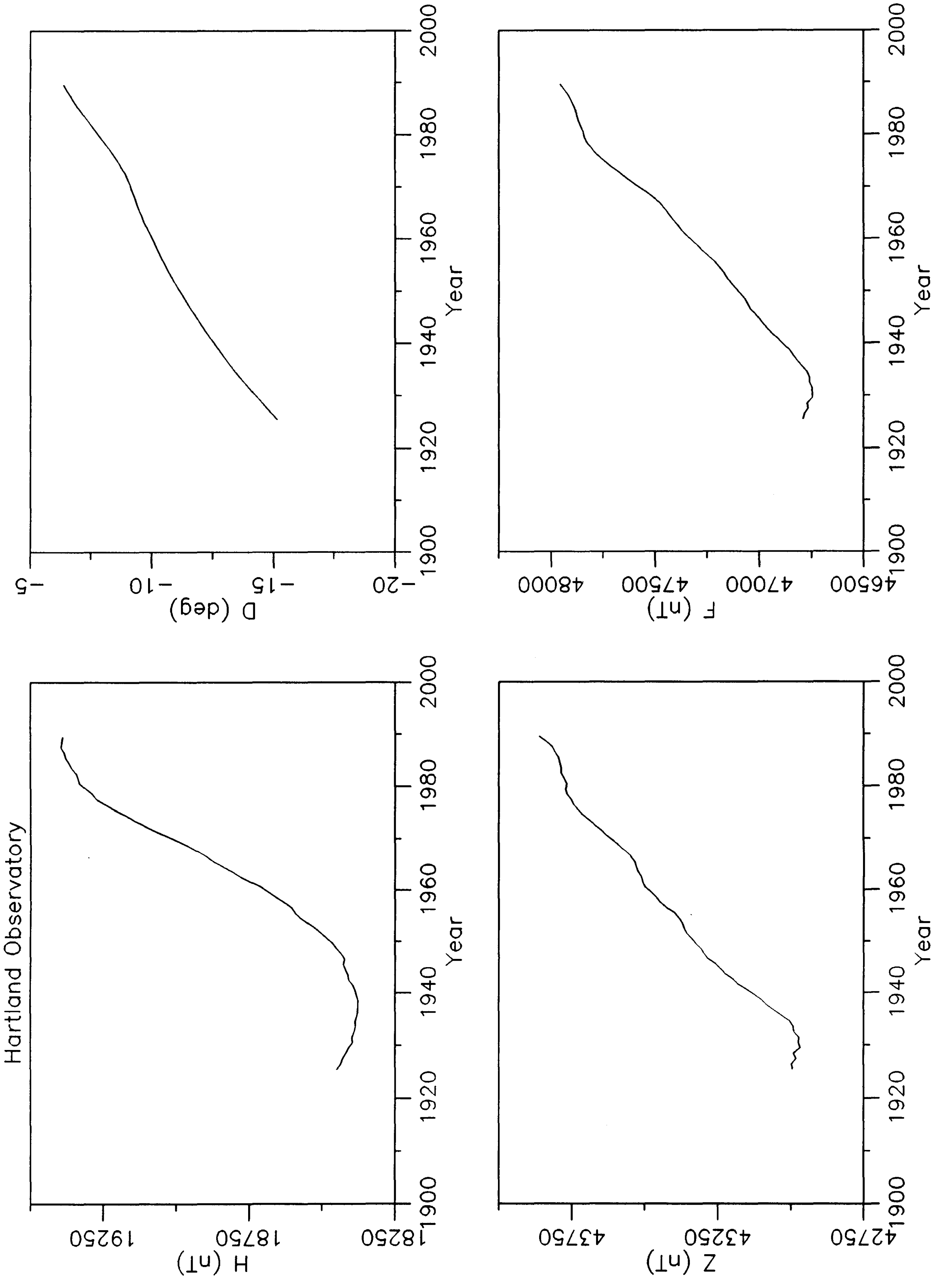
Year	D	I	H	X	Y	Z	F
1925	−13 22.7	66 35.1	18597	18092	−4303	42946	46801
1926	−13 10.4	66 36.3	18581	18092	−4234	42947	46794
1927	−12 58.4	66 36.2	18575	18101	−4170	42932	46777
1928	−12 47.0	66 37.2	18564	18104	−4108	42941	46782
1929	−12 35.8	66 37.2	18555	18108	−4047	42918	46758
1930	−12 24.6	66 38.2	18542	18109	−3985	42924	46757
1931	−12 13.7	66 38.1	18543	18122	−3928	42923	46756
1932	−12 2.6	66 39.1	18536	18128	−3868	42940	46770
1933	−11 51.7	66 39.4	18532	18136	−3809	42942	46770
1934	−11 41.1	66 39.7	18533	18149	−3754	42955	46782
1935	−11 30.3	66 40.9	18527	18155	−3695	42981	46805
1936	−11 20.0	66 41.8	18524	18163	−3640	43007	46827
1937	−11 10.4	66 42.7	18522	18171	−3589	43031	46848
1938	−11 1.4	66 43.2	18522	18180	−3542	43050	46865
1939	−10 51.9	66 43.5	18528	18196	−3492	43074	46890
1940	−10 43.0	66 43.9	18533	18210	−3446	43099	46915
1941	−10 33.8	66 44.3	18539	18225	−3399	43128	46944
1942	−10 24.8	66 43.9	18554	18248	−3354	43146	46966
1943	−10 16.2	66 44.5	18556	18259	−3308	43172	46991
1944	−10 7.8	66 44.3	18566	18277	−3265	43189	47010
1945	−9 59.5	66 44.3	18573	18291	−3223	43207	47030
1946	−9 51.1	66 45.4	18569	18295	−3177	43235	47054
1947	−9 43.1	66 45.2	18577	18310	−3136	43246	47067
1948	−9 35.4	66 44.4	18593	18333	−3098	43255	47082
1949	−9 27.5	66 44.0	18607	18354	−3058	43273	47104
1950	−9 19.7	66 43.0	18628	18382	−3019	43288	47126
1951	−9 12.2	66 42.1	18648	18408	−2983	43305	47149
1952	−9 4.7	66 41.0	18670	18436	−2946	43316	47168
1953	−8 57.5	66 39.5	18695	18467	−2911	43321	47183
1954	−8 50.9	66 38.1	18720	18497	−2879	43332	47203
1955	−8 43.6	66 37.3	18738	18521	−2843	43348	47225
1956	−8 36.8	66 37.4	18750	18539	−2808	43376	47255

HARTLAND

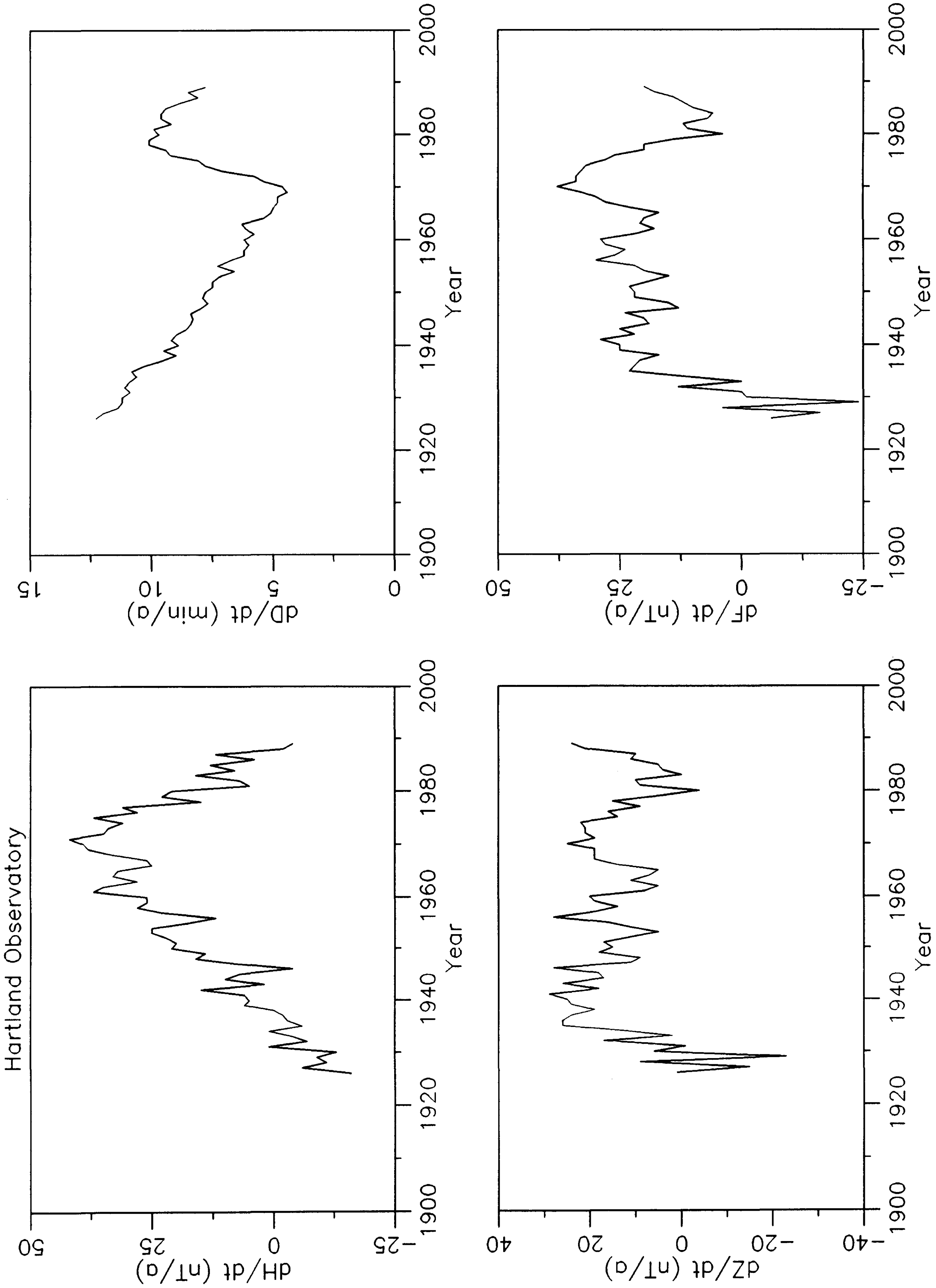
Year	D	I	H	X	Y	Z	F
1957	−10 17.2	66 47.8	18627	18328	−3326	43451	47275
1958	−10 11.0	66 46.3	18655	18361	−3298	43465	47299
1959	−10 5.0	66 45.1	18681	18392	−3271	43484	47327
1960	−9.58.8	66 43.9	18707	18424	−3242	43504	47356
1961	−9 53.0	66 41.7	18744	18466	−3217	43512	47378
1962	−9 46.9	66 39.5	18779	18506	−3190	43517	47396
1963	−9 40.6	66 37.9	18807	18539	−3161	43528	47417
1964	−9 35.2	66 35.9	18840	18577	−3138	43535	47437
1965	−9 30.1	66 33.9	18872	18613	−3115	43540	47454
1966	−9 25.1	66 32.7	18897	18642	−3092	43554	47477
1967	−9 20.3	66 31.6	18923	18672	−3071	43573	47505
1968	−9 15.5	66 29.9	18956	18709	−3050	43592	47535
1969	−9 11.1	66 27.9	18994	18750	−3032	43611	47568
1970	−9 6.5	66 26.1	19033	18793	−3013	43636	47606
1971	−9 1.1	66 23.8	19075	18839	−2990	43655	47640
1972	−8 55.3	66 22.1	19110	18879	−2964	43676	47674
1973	−8 48.2	66 20.5	19144	18918	−2930	43697	47707
1974	−8 40.4	66 19.1	19175	18956	−2892	43719	47739
1975	−8 32.3	66 17.0	19212	18999	−2852	43733	47767
1976	−8 23.1	66 15.7	19240	19034	−2806	43749	47793
1977	−8 13.7	66 13.9	19271	19073	−2758	43758	47813
1978	−8 3.6	66 13.3	19286	19095	−2704	43773	47833
1979	−7 53.5	66 12.0	19309	19127	−2651	43778	47847
*							
1980	−7 43.8	66 10.3	19330	19154	−2600	43768	47848
1981	−7 33.9	66 10.2	19335	19167	−2546	43777	47857
1982	−7 24.7	66 10.1	19342	19180	−2495	43787	47869
1983	−7 15.1	66 9.0	19358	19203	−2443	43787	47876
1984	−7 5.5	66 8.6	19366	19218	−2391	43791	47882
1985	−6 56.1	66 7.9	19379	19237	−2340	43796	47892
1986	−6 47.3	66 8.0	19383	19247	−2291	43807	47904
1987	−6 39.2	66 7.4	19395	19264	−2247	43817	47918
1988	−6 30.7	66 8.2	19393	19268	−2199	43838	47936
1989	−6 22.9	66 9.1	19389	19269	−2155	43862	47956

* When Hartland adopted the proton magnetometer as the observatory standard on 1 January 1980, this involved a change in the point of observation. The measured site differences are (new pillar minus old pillar):

H −0.5 nT; Z −6.0 nT.



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



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

Geomagnetism Group Report 1989

In 1989 the Geomagnetism Group (GG) obtained a number of commissions. The successful operation of the ARGOS systems at the UK observatories, enabling data retrieval in near real-time, and the ability to process and make the data accessible to users by means of the Geomagnetism Information and Forecast Service (GIFS), proved to be key factors in the marketing of GG services to industry. The commissions required the expertise developed by GG in its scientific programme, and provided support in areas of high scientific priority.

GIFS

In 1989, GIFS, originally set up as a service to academic users of geomagnetic data, was extended to include a separate section catering for commercial users. The information available for academic users of GIFS is as follows:

a Hourly mean values and one-hour and three-hour range indices from the UK observatories. Records are maintained on GIFS for twelve months and the data sets are updated daily.

b Catalogues of geomagnetic activity indices and measures of solar activity:

 i Hand-scaled K indices for the UK observatories,

 ii Planetary activity indices: Kp, Ap, Cp and C9,

 iii International Sunspot Number and 10.7 cm radio flux data.

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

d Annual mean values from geomagnetic observatories worldwide. A total of 511 observatories are represented (about 170 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.

Commercial users of GIFS do not have access to such extensive data sets. Users can list the activity forecast and minute values from the UK observatories. The minute-value files are maintained for three days.

Geomagnetic activity monitoring

Several commissions related to geomagnetic activity. This reflects the increasing appreciation by commercial interests of the significance of geomagnetic disturbance, and the need to take action either in advance of periods of activity or to make corrections retrospectively.

The geomagnetic field is still widely used for navigation by sea and air both by amateurs and professionals, but magnetic reference is unreliable during periods of geomagnetic activity, increasing risk. Radio navigation systems use magnetic reference as a convenient standard for calibration. Gyro compasses use a magnetic compass for stabilisation, and Inertial Navigation systems are initialised and periodically checked against magnetic reference. All modern military and civil aircraft have a geomagnetic field algorithm in their flight deck computers and carry a magnetic compass as a fail-safe instrument.

Navigation, in a broader sense, has also found more modern applications, for example in directional drilling and in determining the orientation of hydrophone and seismometer arrays in oil production and exploration. Costly and dangerous mistakes may be made if work is carried out during a magnetic storm, when the direction of the field may change by several degrees over a few hours.

In 1989, companies working in the North Sea oil industry placed contacts with BGS to supply data from the UK observatories and provide an activity forecast via GIFS. GG also provides a monitoring service, and alerts are issued directly to geophysical survey ships operating in the North Sea when disturbances are expected. A number of companies used the facilities at the UK observatories to calibrate geophysical survey instruments.

Geomagnetic disturbances arise from the interaction of the charged particles comprising the solar wind, and the interplanetary magnetic field transported by it, with the main geomagnetic field generated in the Earth's core. The field is compressed on the sunward side and stretched on the anti-sunward side creating a cavity in the solar wind, the magnetosphere, in which the Earth's field is wholly contained (see Figure 1). The magnetosphere acts as a buffer between the solar wind and the terrestrial atmosphere, controlling the transfer of particles and energy into the upper atmosphere. Geomagnetic activity can thus be viewed as a measure of the condition of 'space weather'.

The space weather has direct effects on satellites in low-altitude orbits. During magnetic storms the ohmic dissipation resulting from the intense currents flowing in the auroral zones when charged particles are channelled into the upper atmosphere via the magnetosphere, heats the upper atmosphere. The atmosphere expands in response to the heating, causing increases in density of up to 40% at satellite altitudes. The resulting increase in atmospheric drag slows spacecraft, which then lose altitude. These effects are critical in determining when and where spacecraft and debris near the end of their life finally re-enter the lower atmosphere and burn up, with fragments possibly returning to Earth. The lifetime of all low-altitude satellites depends on the integrated effect of such disturbances.

During magnetic storms a satellite may be engulfed in a cloud of electrostatic charge blocking radio communication with it. Electrical components, especially those used in modern computers, may be damaged because of the electric fields caused by the charging of the spacecraft. Energetic charged particles can penetrate the microchips in on-board computer systems possibly causing false commands to be triggered. The enhanced radiation in a magnetic storm represents a significant hazard to astronauts aboard spacecraft.

The European Space Operations Centre (ESOC) placed contracts with BGS to carry out a study on forecasting long-term (years) levels of solar and geomagnetic activity. The forecasting scheme devised is now in use at ESOC in planning and managing space missions, specifically for the European Retrievable Carrier (EURECA) programme.

The Global Positioning System (GPS) constellation of satellites provides positional information of great accuracy on the Earth's surface by transmitting precisely timed radio signals to ground receivers. The satellites are high-altitude and so not subject to disturbances caused by atmospheric heating. However, changes in the state of the ionosphere during a magnetic storm can introduce phase delays in the transmitted signals leading to major degradation in positional accuracies.

Ground-to-ground radio and radar communications use the ionosphere to reflect signals in order to 'see' over the horizon. The position of the ionosphere changes during a magnetic storm, and it may become transparent to signals normally reflected. The signal at a receiving site may fade or be completely lost during a storm. Complex ionospheric structure during magnetic disturbance can result in multiple reflections which, in the case of radar, appear as false signals.

During a magnetic storm, the rapid changes in the geomagnetic field induce electric currents in the Earth's crust and in large man-made electrical conductors such as electricity power supply lines, gas and oil pipelines, and telephone and cable networks. Induced currents in power lines can overload transformers and trip safety cut-outs. Pipelines suffer corrosion, and equipment used to protect against corrosion in 'normal' conditions can be damaged. Work was carried out by GG for a company involved in maintenance of oil pipelines.

The various effects of magnetic disturbances were vividly illustrated by the great magnetic storm of 13-14 March 1989, by some measures the largest magnetic storm ever recorded. At Lerwick observatory, declination changed by almost 8° in a few hours. In the upper panel of Figure 2 the records of declination, horizontal intensity and vertical intensity at Lerwick during the storm are plotted. (The 'quiet' level of declination at around the time of the storm was about 6.7°W.) In the lower panel of Figure 2 the respective rates of change are shown. At the height of the storm declination was changing by over a degree per minute and the horizontal and vertical intensities by several hundred nT per minute. The storm was so intense that the aurora was seen clearly in the south of England and, in Edinburgh, the Northern Lights became the Southern Lights! Auroral sightings were reported from as far south as Mexico.

In Canada more than six million people in Quebec and Montreal lost electricity supplies for several hours following the failure of compensation devices to counteract the effects of currents induced in the power grid. There were smaller-scale power failures in Sweden. Radio communication and navigation systems were disrupted worldwide. Numerous satellite anomalies, requiring emergency interventions from ground control stations were reported. Over 6000 objects in space were 'lost' by tracking stations as their orbits changed because of increased drag. Geophysical exploration companies using magnetic reference reported 'impossible' conditions.

The general level of magnetic activity was high in 1989 because of the vigour of the current solar cycle which began in September 1986. Long-term averages of solar and geomagnetic activity, characterised by sunspot numbers and the aa index respectively, are shown in Figure 3 for the last few solar cycles. Forecasts of activity levels for the remainder of the current cycle (number 22) are included in the plots. The plots show that magnetic activity is greatest during the declining part of the solar cycle, rather than at sunspot maximum, so activity monitoring will become even more important in the next few years. Fortunately, during the declining phase of the solar cycle geomagnetic activity becomes more predictable!

The International Geomagnetic Reference Field Users Group

In applications of geomagnetism that fall into the area of navigation most users rely upon a global model of the main (undisturbed) geomagnetic field to compute magnetic declination. The models include a prediction of secular variation, the changes in the geomagnetic field on time-scales of months to years, to allow the model to be used up to (typically) five years into the future. The accuracy of the predicted secular variation is heavily dependent on good accuracy data from magnetic observatories in developing countries where funding is low and in many cases under threat. A group of North Sea oil production companies who are users of the International Geomagnetic Reference Field (IGRF) has accepted the principle of supporting such observatories, through a scheme which BGS will administer, in return for a global model developed by GG. This will help to ensure that the accuracy of future models will not deteriorate because of loss of data from vital areas. The agreement has enabled GG to start a programme for design of instruments for operation in third-world countries. The programme builds on the successful technical developments made in the ARGOS automatic observatory systems, and the experience gained in communications, data processing and quality control.

Three systems are being designed. The first is a full observatory system for sites with trained local technical and scientific staff, good standard accommodation for equipment, and a reliable power supply. The system will include computing facilities to enable local staff to carry out detailed analysis of the data collected. The second-level system will have less sophisticated data analysis capabilities, but will require local support for general maintenance of the equipment, and limited data processing and quality control. The third and simplest system will provide data which will be sent to BGS for processing. All three systems will transmit data via satellite to Edinburgh as part of the INTERMAGNET programme (see below). The first system is due to be deployed in Nigeria in 1991.

Diurnal variation and crustal field modelling

The standards of accuracy now demanded of magnetic reference by commercial users are higher than ever before as their instruments and measurement techniques become more sophisticated. The estimate of the geomagnetic field at a particular location provided by a global geomagnetic field model is likely to be inadequate because of disturbances, diurnal changes and fields due to crustal magnetisation.

GG is carrying out commissioned work to find ways to correct for these sources of error in magnetic reference. The spatial dependence of diurnal variation over the North Sea has been modelled as a function of the level of geomagnetic activity. A theoretical study to investigate the possiblity of deriving directional information from total-field aeromagnetic data over the UK is under way, supported by observations on a dense network over the Bathgate anomaly near Edinburgh, carried out as part of the UK magnetic survey. If successful this study could be of great value in defining short wavelength variations in declination over the North Sea where there are high-resolution total-intensity aeromagnetic data sets, but no vector measurements.

The characteristics of geomagnetic field behaviour are very dependent on position. Disturbances recorded at one observatory may appear quite different at another. In scientific terms, mapping the currents flowing in the magnetosphere and ionosphere, in both disturbed and quiet conditions, which is essential to advancing understanding of solar-terrestrial interactions, requires global data. In commercial terms, a geophysical survey company may need to know the level of disturbance at a particular time anywhere in the world. Data retrieval, processing and dissemination facilities similar to those developed by BGS are not, at present, available worldwide, but there is a demand for them, both academic and commercial.

INTERMAGNET

INTERMAGNET is a proposed global network of geomagnetic observatories exchanging digital data in real-time using satellite communications. BGS has taken a lead in the INTERMAGNET programme and, during 1988, installed equipment at each of the UK observatories to enable transmission of data via the GOES-East satellite (a US meteorological satellite), to the US and Canada. In May 1989 a satellite receiving disk was commissioned at Hartland observatory to allow reception of data transmitted from the US and Canada.

The initial trials for INTERMAGNET in 1989, funded by a research contract from the Air Weather Service of the US Air Force, were successful. Every twelve minutes, data from the UK observatories were transmitted to the United States Geological Survey in Golden, Colorado. Data from six US observatories, were received at Hartland and transferred to Edinburgh. During the same period UK data were exchanged with data transmitted from three Canadian observatories, operated by the Geological Survey of Canada, Ottawa.

During 1991 a METEOSAT receiver will be installed at BGS Edinburgh, and transmitters will be sited at each of the UK observatories. This will enable exchange of data within the Afro-European sector. Stations set up in Finland, France, Spain and Hungary, and equipment installed in Africa with the support of Finland and France and the IGRFUG, will be the beginning of coverage for this area.

BGS Edinburgh, will act as the Afro-European Geomagnetic Information Node (GIN) for INTERMAGNET and GG will be responsible for collecting and processing data from participating observatories, exchanging data with other GINs in the US and Japan, and for disseminating data to the user communities.

By January 1990 twelve countries, representing more than 50 geomagnetic observatories, had signed the INTERMAGNET protocol. Transmission of data from these observatories is expected to start in the next 2-3 years.

All geomagnetic observatories are encouraged to join the INTERMAGNET network. Details of the operation of INTERMAGNET and the equipment needed to participate in the programme can be obtained from:

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Telephone: 031-667 1000
Fax: 031-668 4368
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GEOMAGNETISM GROUP PUBLICATIONS 1989

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Captions for illustrations

Figure 1. The Earth's main field is distorted by the solar wind to form the magnetosphere.

Figure 2. The upper diagram shows magnetic declination and the horizontal and vertical intensity of the geomagnetic field during the great storm of March 13-14 1989.

The lower diagram shows the rate of change of the field over the same period. When the field changes rapidly electrical currents are induced in conductors such as power lines and oil pipelines with detrimental effects.

Figure 3. Diagram of the aa index to indicate magnetic activity and of sunspot numbers to illustrate solar activity

The upper panel shows magnetic activity over recent solar cycles characterised by 13-month averages of the aa index, a measure of geomagnetic activity. The lower panel shows a similar average for sunspot numbers. Both diagrams include predictions for the remainder of the current solar cycle. The peak in magnetic activity is generally during the declining part of the solar cycle rather than at solar maximum.

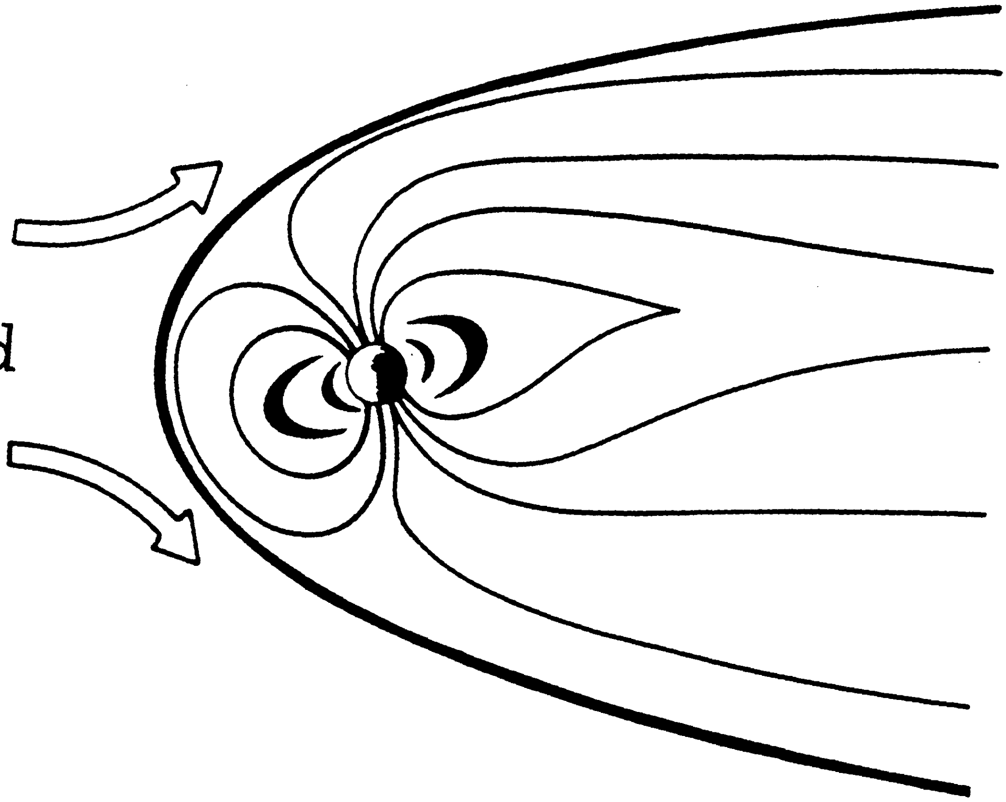
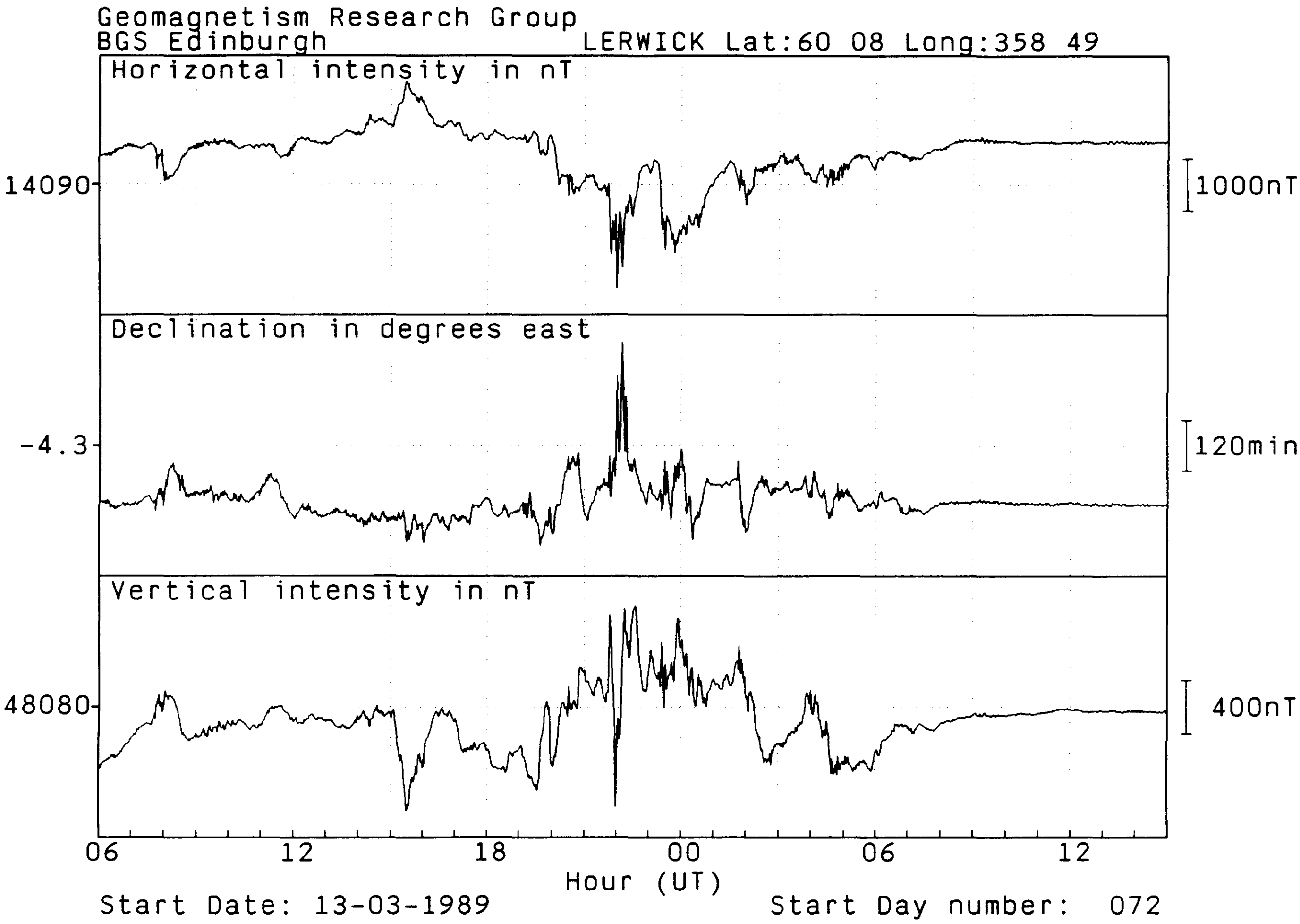


Figure 1.


Geomagnetism Research Group
BGS Edinburgh
LERWICK Lat:60 08 Long:358 49
Horizontal intensity in nT
14090
1000nT
Declination in degrees east
-4.3
120min
Vertical intensity in nT
48080
400nT
06
12
18
00
06
12
Hour (UT)
Start Date: 13-03-1989
Start Day number: 072

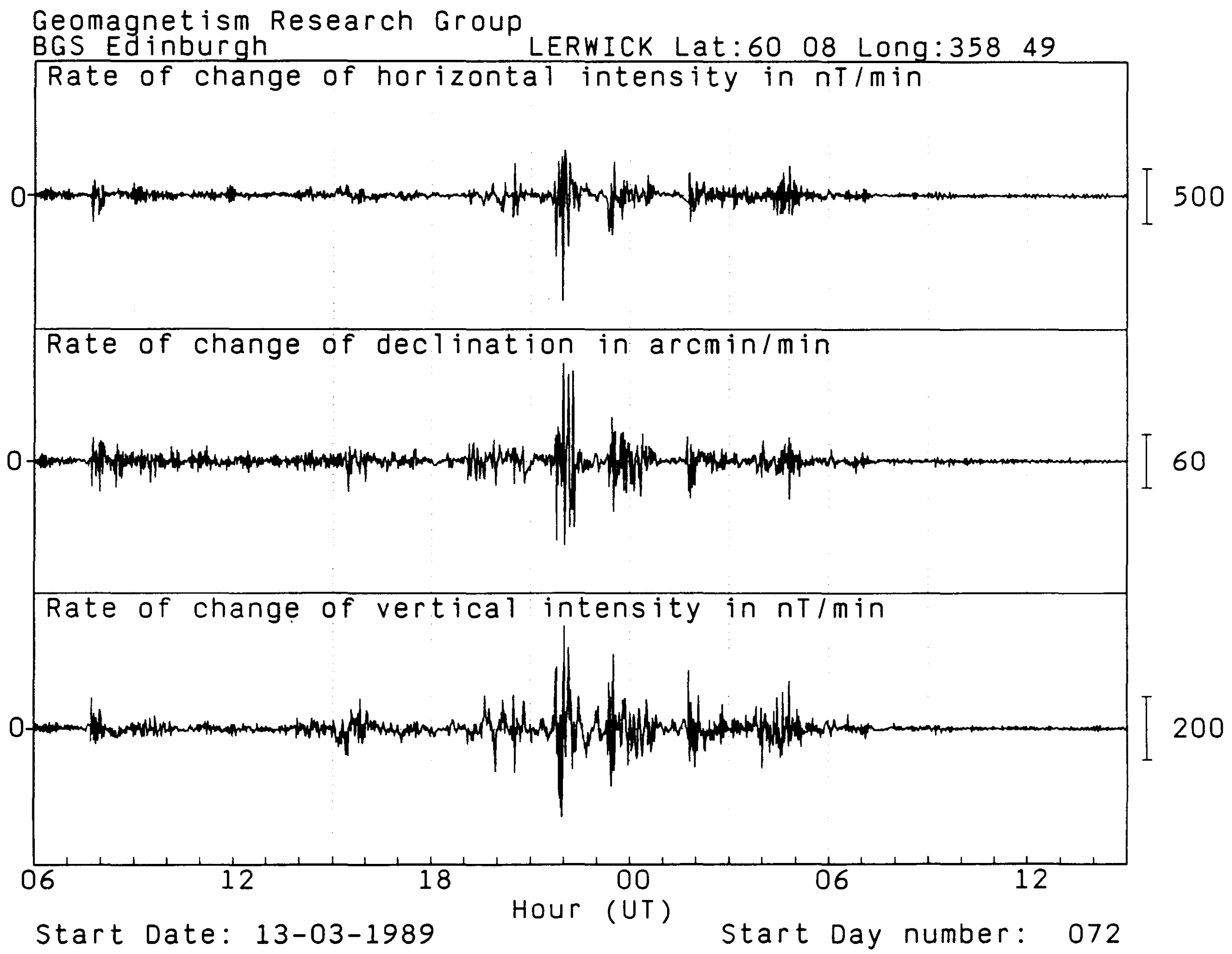

Geomagnetism Research Group
BGS Edinburgh
LERWICK Lat:60 08 Long:358 49
Rate of change of horizontal intensity in nT/min
0
500
Rate of change of declination in arcmin/min
0
60
Rate of change of vertical intensity in nT/min
0
200
06
12
18
00
06
12
Hour (UT)
Start Date: 13-03-1989
Start Day number: 072

Figure 2.

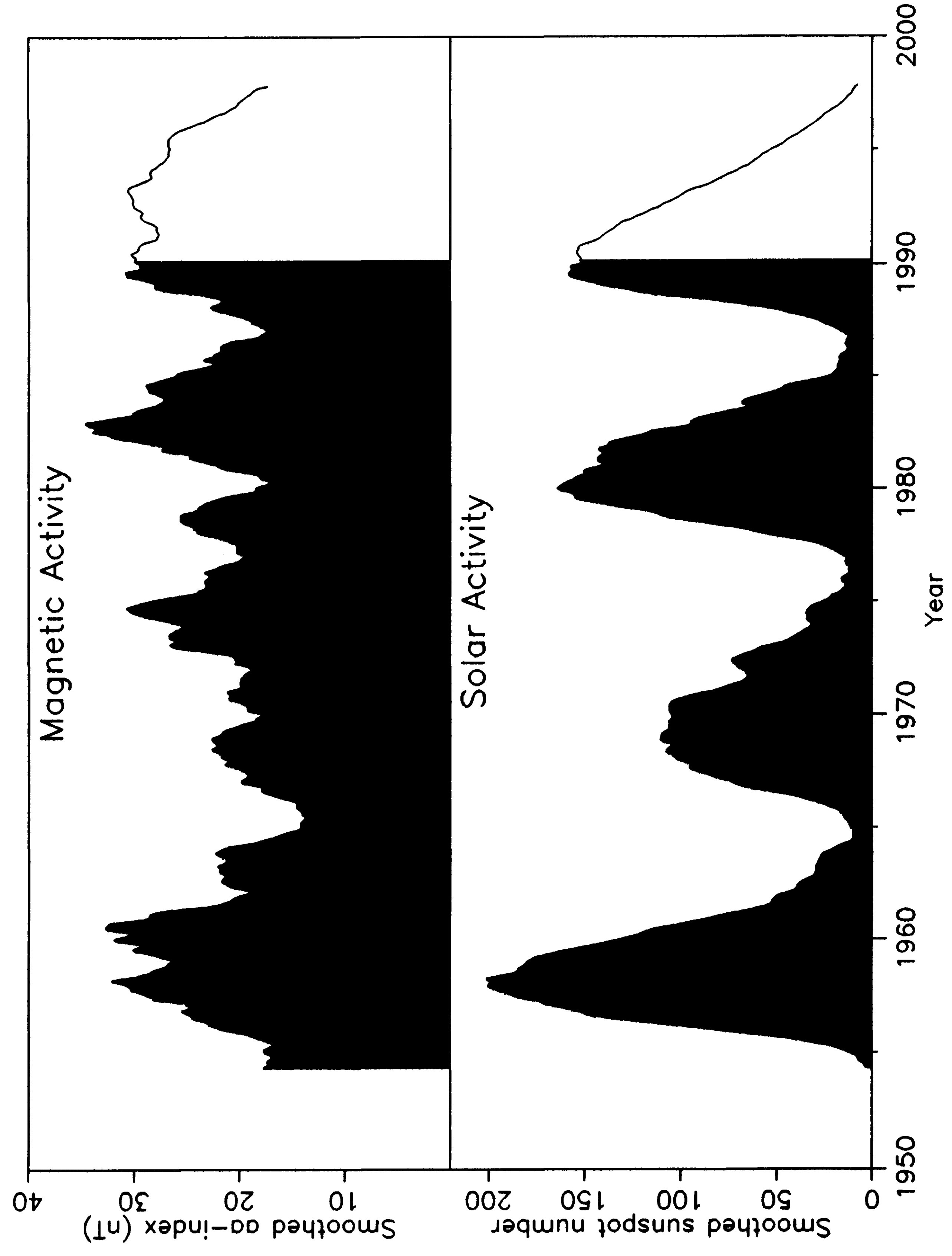

Magnetic Activity
Solar Activity
Smoothed aa-index (nT)
Smoothed sunspot number
Year
0
10
20
30
40
50
100
150
200
1950
1960
1970
1980
1990
2000

Figure 3.

BRITISH GEOLOGICAL SURVEY

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The full range of Survey publications is available through the Sales Desks at Keyworth and at Murchison House, Edinburgh, and in the BGS London Information Office in the Natural History Museum Earth Galleries. The adjacent bookshop stocks the more popular books for sale over the counter. Most BGS books and reports are listed in HMSO's Sectional List 45, and can be bought from HMSO and through HMSO agents and retailers. Maps are listed in the BGS Map Catalogue and the Ordnance Survey's Trade Catalogue, and can be bought from Ordnance Survey agents as well as from BGS.

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.

The British Geological Survey is a component body of the Natural Environment Research Council.

Cover photos

Both pictures are of the aurora borealis over Edinburgh. The front cover picture was taken from Blackford Hill looking north. (*Duncan Waldron, ABIPP*)

ISBN 0 85272 197 8

GEOMAGNETIC BULLETINS

Natural Environment Research Council