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The IOSDL Towed Thermistor Spar on
Challenger Cruise 18, September 1987

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ABSTRACT

This report describes the performance of the IOSDL Towed Thermistor Spar over the shelf break in the Bay of Biscay during September 1987.

Although problems were encountered with the electronics, the resulting data set provides useful information, and both averaged and high resolution plots are presented. The data supports the conjecture that internal tides are responsible for significant mixing of the thermocline in two regions near the continental shelf break in the Bay of Biscay.

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	PRICE

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1. A DESCRIPTION OF THE TOWED THERMISTOR SPAR

The thermistor spar is designed to measure small scale thermal structures between 1 and 10 m below the sea surface with a resolution of 0.5 mK and a sampling rate of 4Hz. A 2 m x 2 m catamaran is towed in undisturbed water ahead of the ship's wake by an armoured conducting cable attached to a point on one of the catamaran's hulls and taken to a point well forward on the towing vessel, figure 1. A 10 m long, hollow streamlined spar is suspended between the hulls of the catamaran. This spar has an 82 kg weight attached to its bottom. The coupling between the spar and the catamaran is via a universal joint and swivel, thus allowing the spar to remain nearly vertical and pointing into the local flow, decoupled from the angular motions of the catamaran.

There are twelve thermistors fitted along the length of the spar's leading edge, one noise monitoring resistor, a pressure transducer and a forward looking 1 MHz sonar transducer to detect bubble clouds, figure 1. Two inclinometers are also fitted to the top plate of the spar. Wires from these sensors run internally up the spar and are taken to two 6" diameter pressure cases containing the electronics mounted in a compartment in each hull. A shipboard 16 bit ADC (analogue to digital converter) digitises the sonar signal at two fixed range points together with the other 16 channels. The data is stored via a Sea Data digital cassette recorder and is the direct output of the ADC. The decimal output for each channel is in the range 0 to 65536 and is in uncalibrated, non-engineering units ("counts"). A real time graphical display and hard copy is produced by a BBC microcomputer for monitoring.

2. THE PERFORMANCE OF THE SPAR ON CHALLENGER CRUISE 18

There were three tows with the thermistor spar during this cruise in September 1987, two in the Bay of Biscay over La Chapelle Bank and the third in the Porcupine Sea-Bight area as summarised in Table 1 below and indicated in Figure 2.

TABLE 1

Run	Area	Tides	Start	Lat.	Long.	Stop	Lat.	Long.
1	Biscay	Neaps	246/2000	47°51'	6°24'	247/0317	47°27'	6°35'
2	Biscay	Springs	253/1730	47°45'	6°32'	254/0245	47°07'	6°44'
3	Porcupine	Neaps	262/1900	51°33'	11°24'	263/0300	51°22'	12°02'

On the first run the data collected was of reasonably good quality but at 0247 the catamaran capsized in 5-6 m swell after completing about two thirds of its planned track. The catamaran righted itself over a period of minutes, and on recovery the spar was found to be undamaged apart from the severance of the inclinometer cable. Some damage was also sustained by the towing cable near the towing point. On the second run the spar was towed over nearly the same track as run 1 so that Spring-Neap differences could be investigated. The data was generally more noisy (in terms of spikes) than that collected during the first tow. The third run was carried out over the Porcupine Sea-Bight and, after about the first hour of the tow (during which data of high quality was obtained), the data became badly contaminated with noise spikes. This was due to an open circuit which developed in a Marsh and Marine underwater connector.

Generally, thermistors 1 (at the top of the spar), 3, 6, 8, 9, 11 and 12 (at the bottom) were found to be noticeably contaminated with white noise, as compared with the other thermistors. After the cruise, this was diagnosed as being due to unintentional reversal of the screen and core of the wires used for these particular sensors, and this fault has now been corrected. The other significant fault in the data was that the sonar channels, thermistors 1, 3, 5, 7 and 9, and RX and PX, were often simultaneously contaminated with large spikes. This fault seems to be apparent in every second channel logged (and so, because of the order of logging, does not appear in, for example, thermistor 11), and may result from an intermittent fault with the sonar or the analogue multiplexer, which logs each channel in quick succession, but in a definite order. This fault was totally eliminated for tow 2 when the sonar signal output was disconnected at the ship unit (at 0025h on day 254; the spikes at 0120h were during a short test reconnection of the sonar).

Finally, during run 1, all the thermistors, and RX, were intrinsically more noisy than during the other tows and on previous deployments. This probably resulted from a poor Sea Earth condition.

3. DATA PROCESSING ROUTE

The processing involved firstly transferring the data from ten Sea Data tapes to three 9-track 1600 BPI magnetic tapes using the IOSDL Digidata system and Sea Data model 12B reader, one 9 track tape for each thermistor spar run, as detailed in Table 2.

TABLE 2

Data Processing

Sea Data tape number	Run number	Magnetic tape number
CHALL8701	1	CH188701
CHALL8702	1	
CHALL8703	1	
CHALL8704	2	CH188702
CHALL8705	2	
CHALL8706	2	
CHALL8707	2	
CHALL8708	3	CH188703
CHALL8709	3	
CHALL8710	3	

For each Sea Data tape the following operations were carried out:-

(i) A data file was created in which each successive 100 records had been averaged together, and a plot of this averaged data was produced which showed the general trend of the information on the tape.

(ii) A detailed plot of the raw data was obtained, showing every data point. These plots, and subsequent spectral analysis, showed that some thermistors were typically contaminated with white noise, and others with occasional large spikes, as already described.

(iii) A low-pass filter with a cut-off at 0.5 Hz was applied to all the thermistor data and significantly reduced the general noise levels. In addition, the large spikes were listed and then individually removed from the data file.

(iv) Finally a high resolution plot was produced of the filtered, despiked thermistor data. It was found necessary to only plot every second point (0.5 second spacing), and this was consistent with the choice of the filter. In these plots, the noise monitoring resistor, RX, shows the raw data, and so has been neither filtered nor despiked.

This report contains averaged plots for all ten Sea Data tapes, but high resolution plots for the first eight tapes only, the last two being too badly contaminated to allow the presentation of any useful results. A description of the numerical programs used in the data analysis is given in Appendix 1.

4. A DESCRIPTION OF THE AVERAGED PLOTS

The 100-point averaged plots are presented as Appendix 2 and show data averaged over successive 100 record sections (25 seconds). The upper twelve traces displayed show the individual thermistor channels, T1 being at the top of the spar, T12 at the bottom, and an approximate 1 K scale is indicated. Temperature increases towards the top of the figure. Immediately below the thermistors is the noise monitoring resistor, labelled RX with a 10 mK scale, and next comes the "total" angle, TOT, scale in degrees. This is the angle of the spar from the vertical and is calculated from the inclinometer angles. The individual inclinometer angles (F.A. for the Fore-Aft, P.S. for Port-Starboard) are shown with a positive number representing AFT and STARBOARD. Finally, the output from the pressure transducer, converted to metres and labelled PX, and the depth, labelled DEP, are shown. DEP is the depth (in metres) of the pressure transducer calculated from the inclinometer angles. It is a check on the attitude of the spar in the water. On tapes 9 and 10 DEP provides the only depth information since the pressure sensor output had become unreliable. The tick marks on the time axes at the bottom of the plots are at intervals of 15 minutes and every hour. The only useful sonar information is shown on the plot for tape 5 (S_1 range 3.4 m, S_2 range 9.2 m), and on this plot, and that for tape 6, TOT is shown at the top of the figure.

5. A DESCRIPTION OF THE HIGH RESOLUTION PLOTS

These plots (originally 2m long) have been divided into overlapping sections and photo-reduced to enable them to be included in this report. They are presented as Appendix 3. The twelve thermistor channels are T1 to T12 from top to bottom, and these have been despiked, filtered and only every second point is plotted. The despiking leaves a gap in the data. The vertical scales for each successive thermistor are in counts, with about 4000 counts corresponding to 1 K. Temperature again increases towards the top of the figure. After the horizontal record count scale, the raw data from the high-stability resistor RX is shown, giving an indication of the electronic noise levels (scale again in counts). The spikes were only removed from the resistor when they were large enough to over-plot the thermistor data. Finally, the time scale (GMT, and Julian day) is indicated. Tick marks are at intervals of 1, 10 and 60 minutes. Note that, because of the increased activity, the vertical scale for the second tow, tapes 4, 5, 6, 7 is one half of that for tapes 1, 2, 3 and 8. Also, about 1 minute of data near 0000/254, tape 6, for T12 is off scale, and tapes 9 and 10 were not plotted because of the poor quality of the data.

6. CALIBRATIONS OF THE SPAR

A pre-cruise laboratory calibration was performed for the first time for this instrument (thermistors plus wires) during August 1987. However, thermistors 1, 3, 6, 8, 9, 11 and 12 were contaminated with noise and this, coupled with the fact that two thermistors were replaced before the cruise, meant that this calibration was of little use.

A post-cruise calibration was then carried out in March 1988. Having effectively eliminated the noise contamination problem, this exercise was much more successful, but applying the calibration coefficients so obtained to isothermal sections of the actual cruise data revealed that thermistors 1, 3, 5, 7 and 9 were low by typically 50-60 mK. However, by marginally adjusting the calibration coefficients it was possible to ensure that all 12 thermistors gave the same temperature to within about 5 mK for isothermal sections of the cruise data covering the range 15°C to 19°C. The calibration coefficients finally chosen are listed in table 3 (where the temperature of the nth thermistor is $a_n \times T_n + b_n$, where T_n is in counts), but plots of isotherms have not yet been obtained and so cannot be presented here.

TABLE 3

Calibration coefficients

Thermistor	**$a_n \times 10^4$**	**b_n**
1	2.51798	6.30887
2	2.51119	6.37546
3	2.55525	6.11259
4	2.52819	6.21015
5	2.53678	6.21279
6	2.50769	6.30036
7	2.53493	6.20946
8	2.58124	6.14156
9	2.53084	6.27164
10	2.51880	6.29418
11	2.50306	6.37783
12	2.52962	6.11780

Whilst preparing the spar for use in another cruise (the ARE IF88 trial), it was observed that the output from thermistors 1, 3, 5, 7 and 9 was altered when the 1 MHz sonar power supply was connected. Since the sonar was not connected during the March 1988 calibration, this may partially explain the above problem for these thermistors. The reason for this effect is not known, but the above calibration, giving an acuracy of about 5 mK, is good enough for most purposes.

7. CONCLUSIONS

Tows 1 and 2 in the Bay of Biscay reveal striking differences in the amounts of small scale activity (SSA) between Neap (tow 1) and Spring (tow 2) tides, with far more activity at Spring tides. Maximum SSA, indicative of the upward mixing of cool water, seems to occur near 0000/247 on tow 1 and at 1830/253 and 0000/254 on tow 2. The first two of these locations are about 20km onto the shelf from the break, the third about 20km into the ocean, and coincide approximately with where internal tidal energy, emanating from the shelf break, is predicted to reach the ocean surface.

Tow 3 is interesting by way of contrast and reveals the relative absence of high activity mixing regions in the Porcupine Sea-Bight. This might have been anticipated from recent work on internal tidal generation and mixing.

It is intriguing to conjecture that small-scale activity resulting from mixing in or near the thermocline, as opposed to wind-wave mixing, may only occur at certain locations on the Continental slopes around the British Isles, where internal tidal generation is large. It seems likely that mixing events such as those presented here are responsible for the production of the region of cool surface water over the shelf break in the Bay of Biscay, often observed in the literature. The temperature anomaly may be in excess of 1°C at Spring tides, extend for hundreds of km along the break, and be up to 50 km in width. The data presented here will enable a detailed investigation of the mixing regions to be conducted (the subject of a future report), but the rich variety of thermal structure, and the usefulness of the towed thermistor spar, are already apparent.

ACKNOWLEDGEMENTS

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Fig 1. The Towed Thermistor Spar

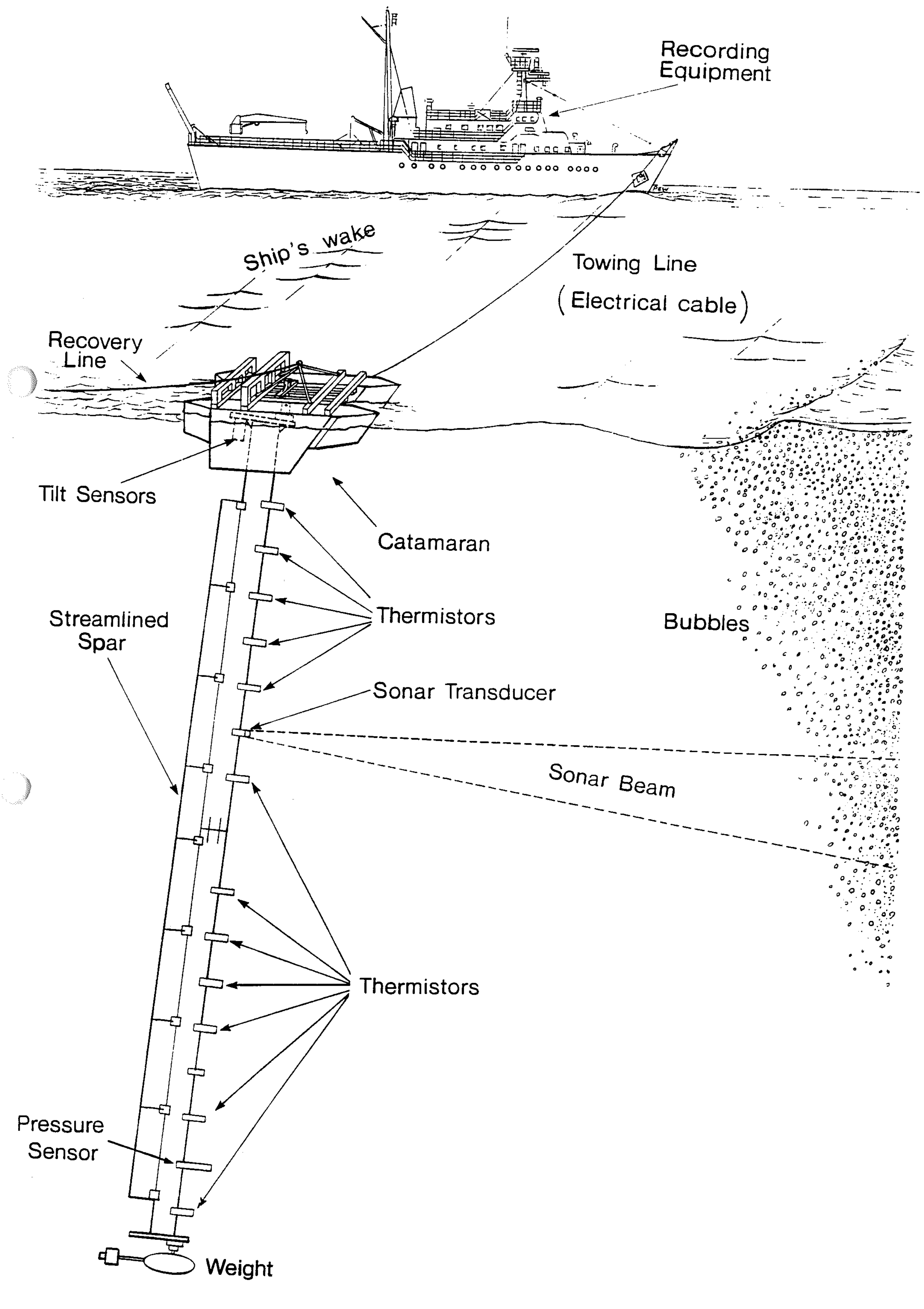
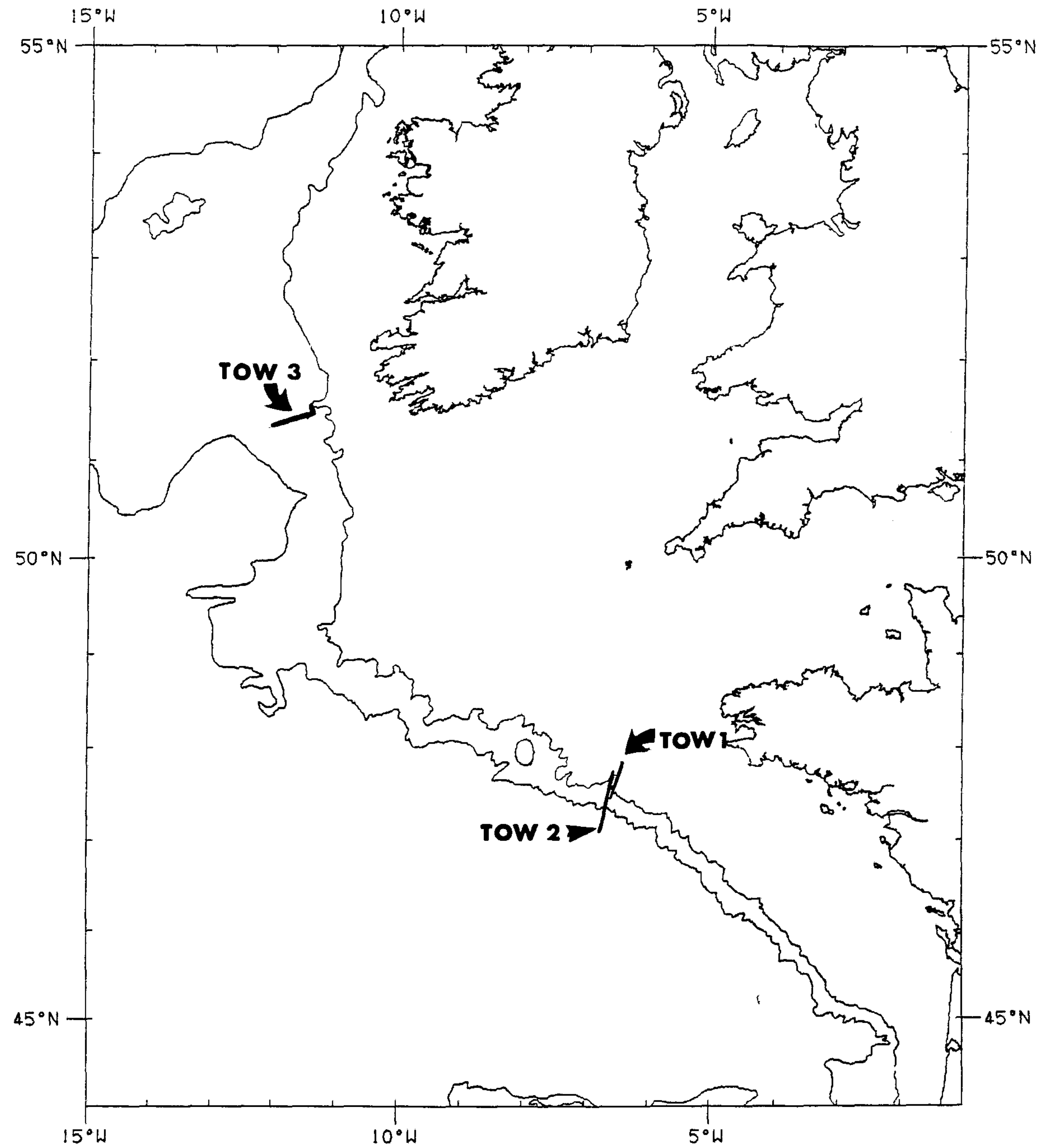


Figure 2.



Plot of Thermistor Spar runs
RVS Challenger cruise 18

APPENDIX 1

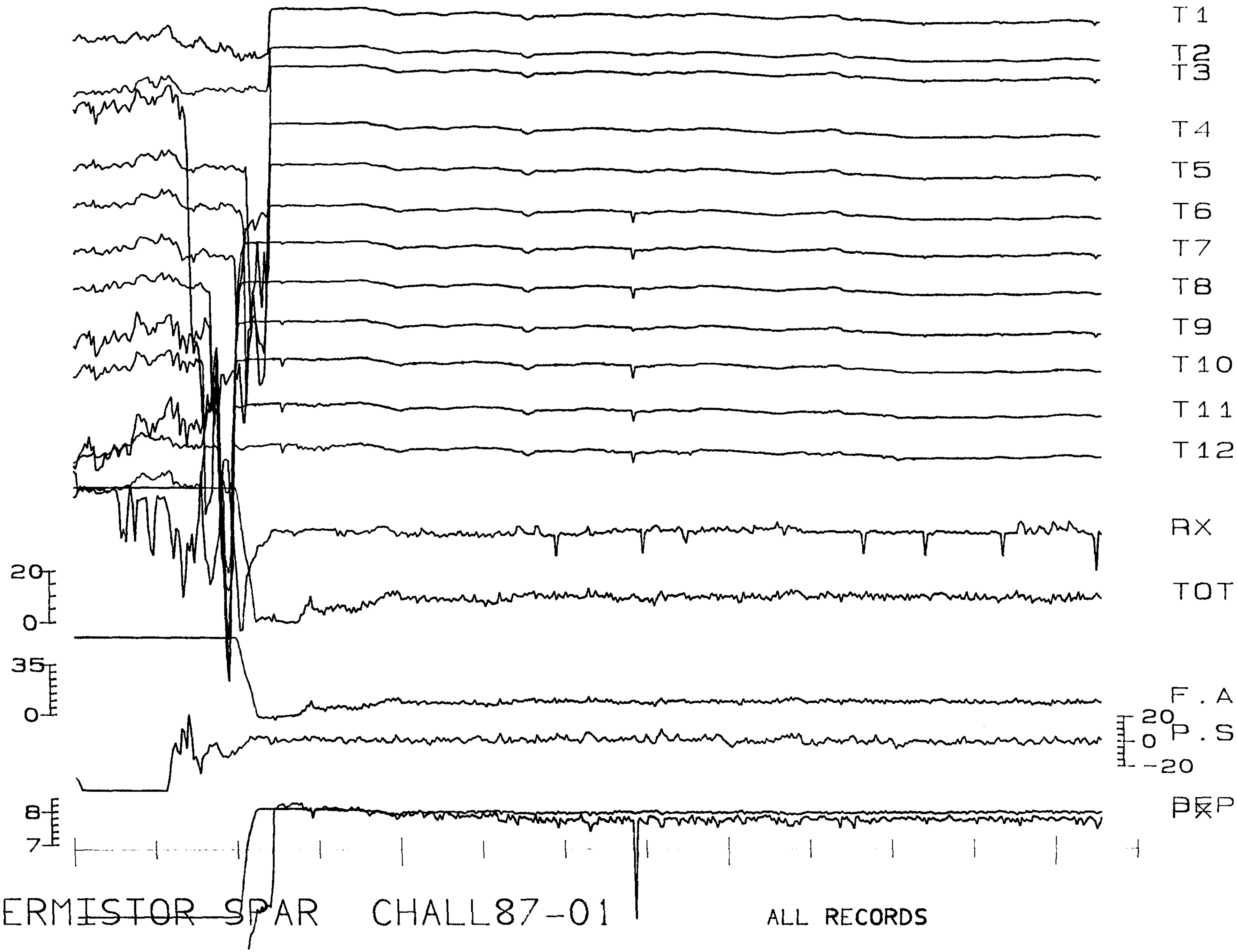
Computer Program List

The computer programs used in the processing of the thermistor spar data are listed below. All programs are written in Fortran 77 and were, with the exception of SPARAV and SPARPLOT, developed during the current financial year specifically for use on the new NERC IBM at Wallingford.

TREAD FORTRAN -	A program to read 9 track 1600 BPI magnetic tapes in the format created by the IOSDL DIGIDATA SYSTEM.
SPARAV FORTRAN -	An averaging program to create a data file for the averaged plots.
SPARPLOT FORTRAN -	A program to plot the averaged data.
LPLOT FORTRAN -	A program to produce a 3 m long plot containing every point on a Sea Data tape.
SPIKE FORTRAN -	This program lists the record numbers of the large spikes.
LPASS FORTRAN -	A program to low-pass filter the data with a cut off frequency of 0.5 Hz.
SELDEL FORTRAN -	A program to selectively delete particular data spikes.
FPLOT FORTRAN -	A program to create a filtered, despiked plot of every 2nd point in the data file.

APPENDIX 2

Averaged Plots



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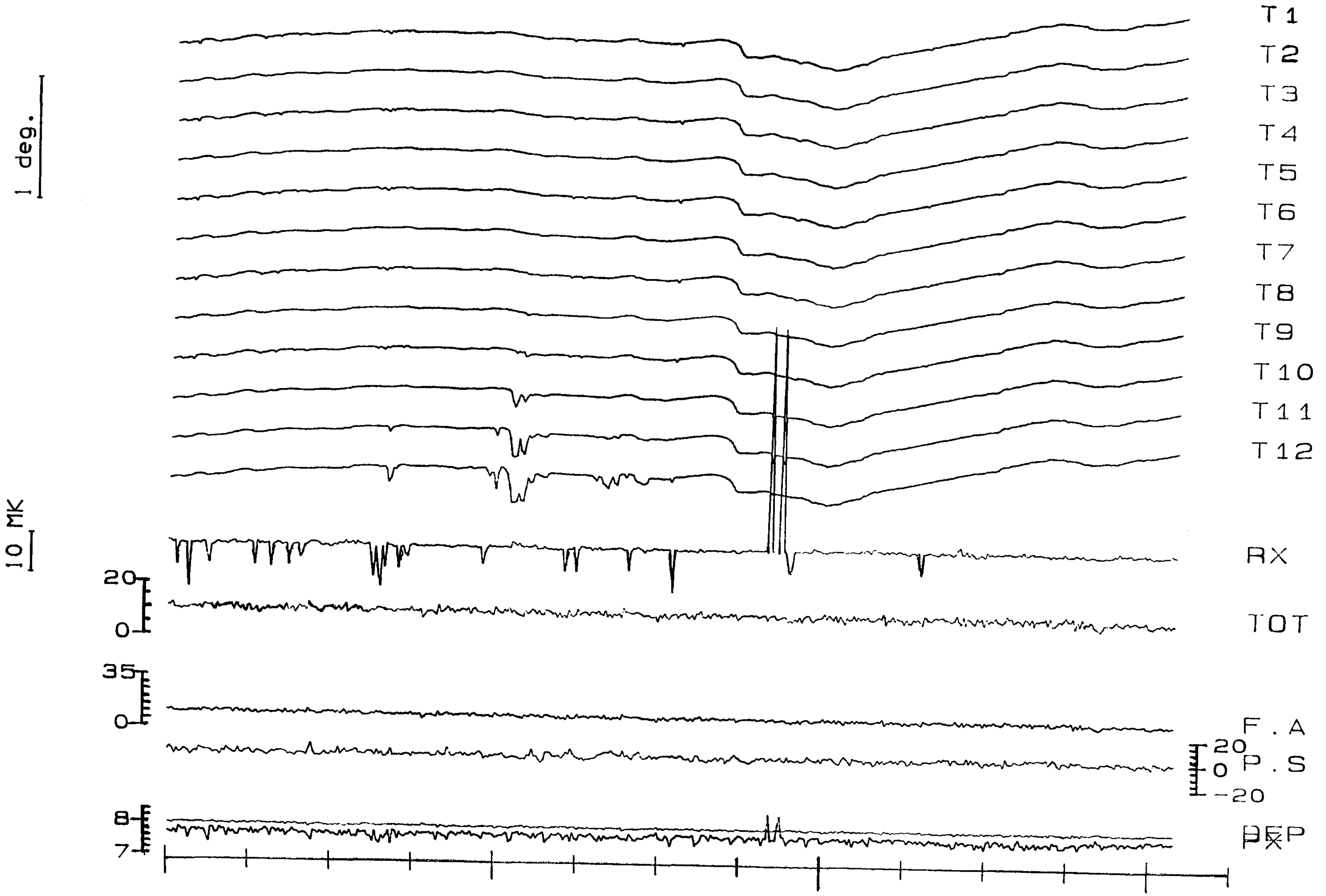
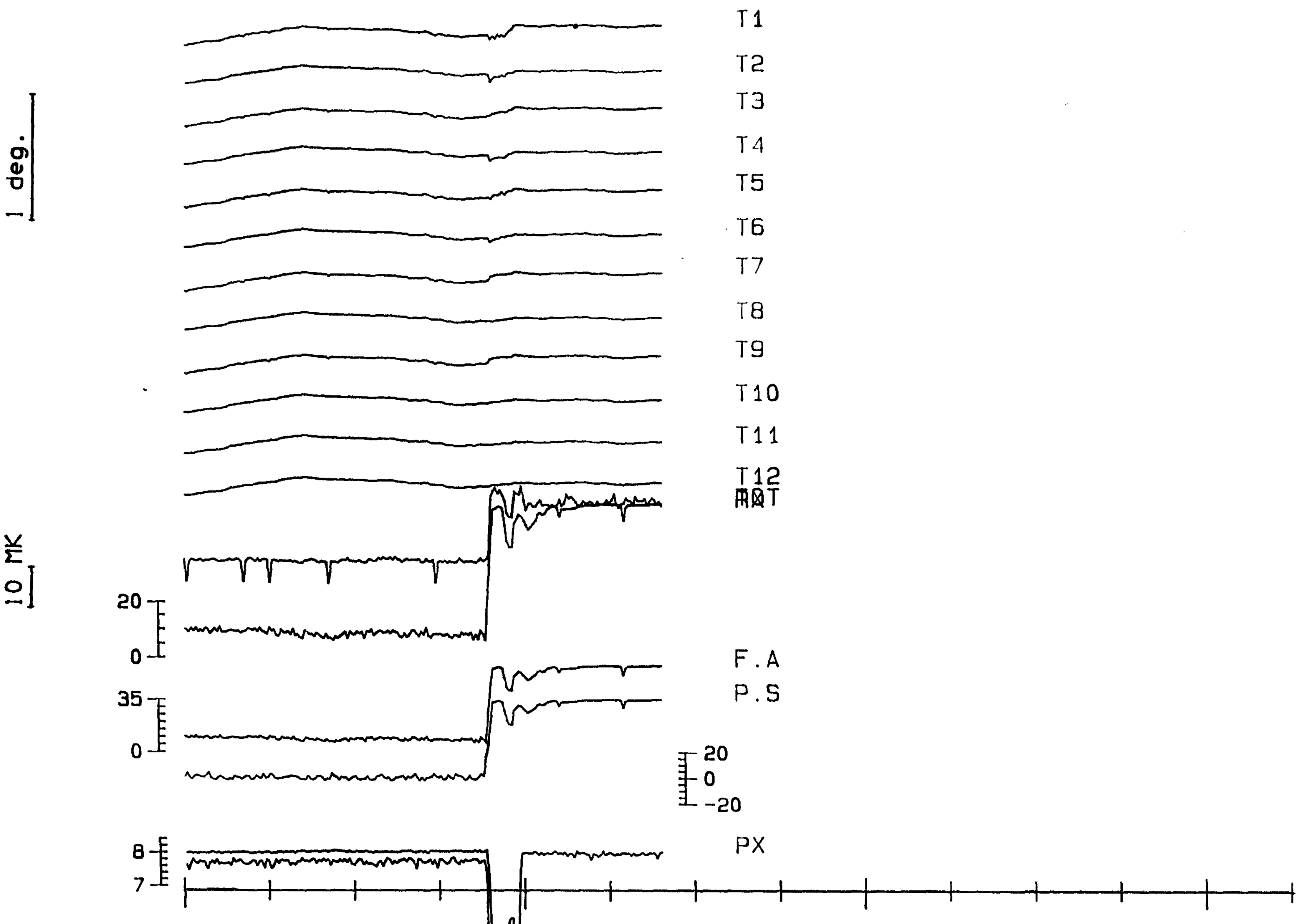
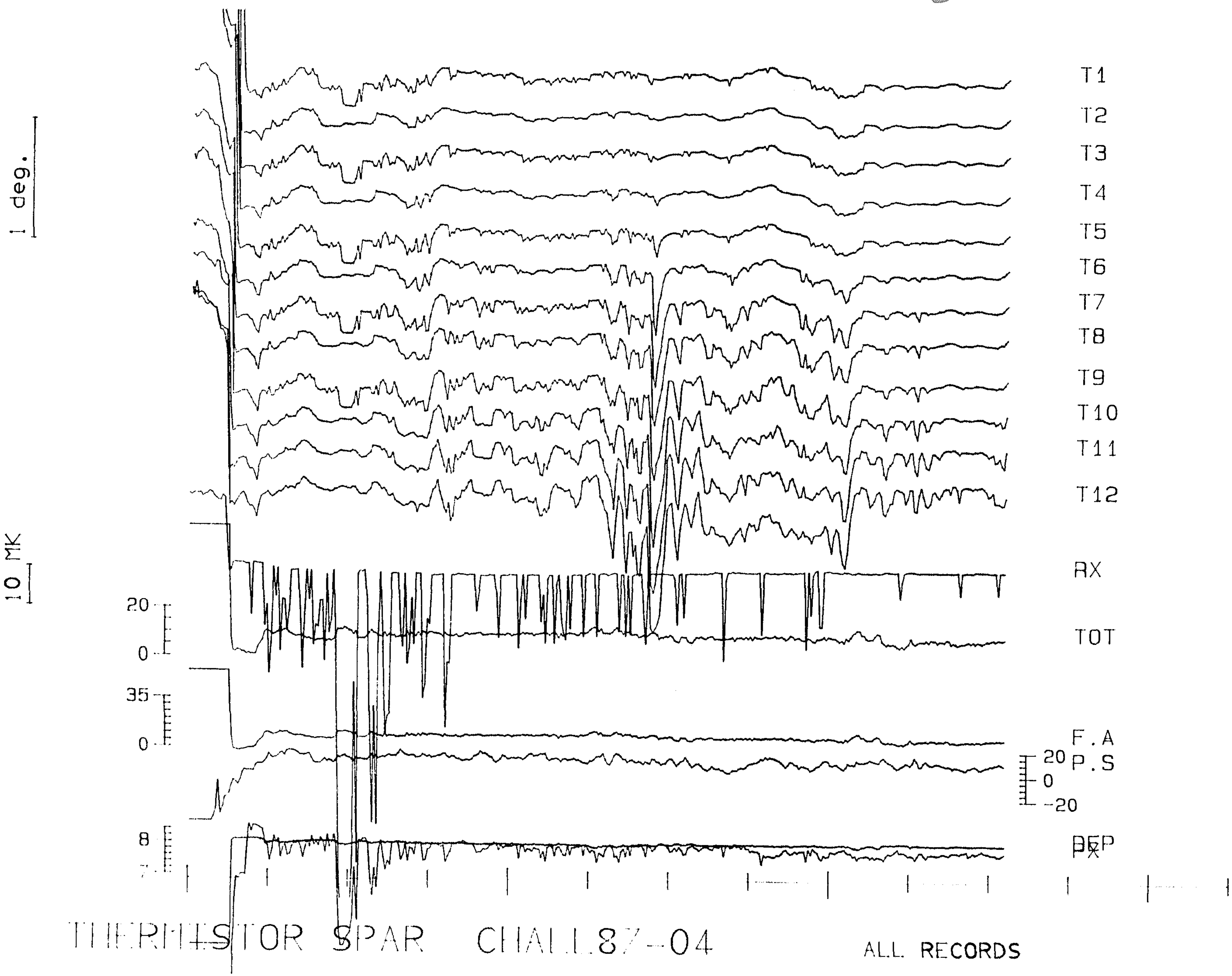


THERMISTOR SPAR CHALL87-02

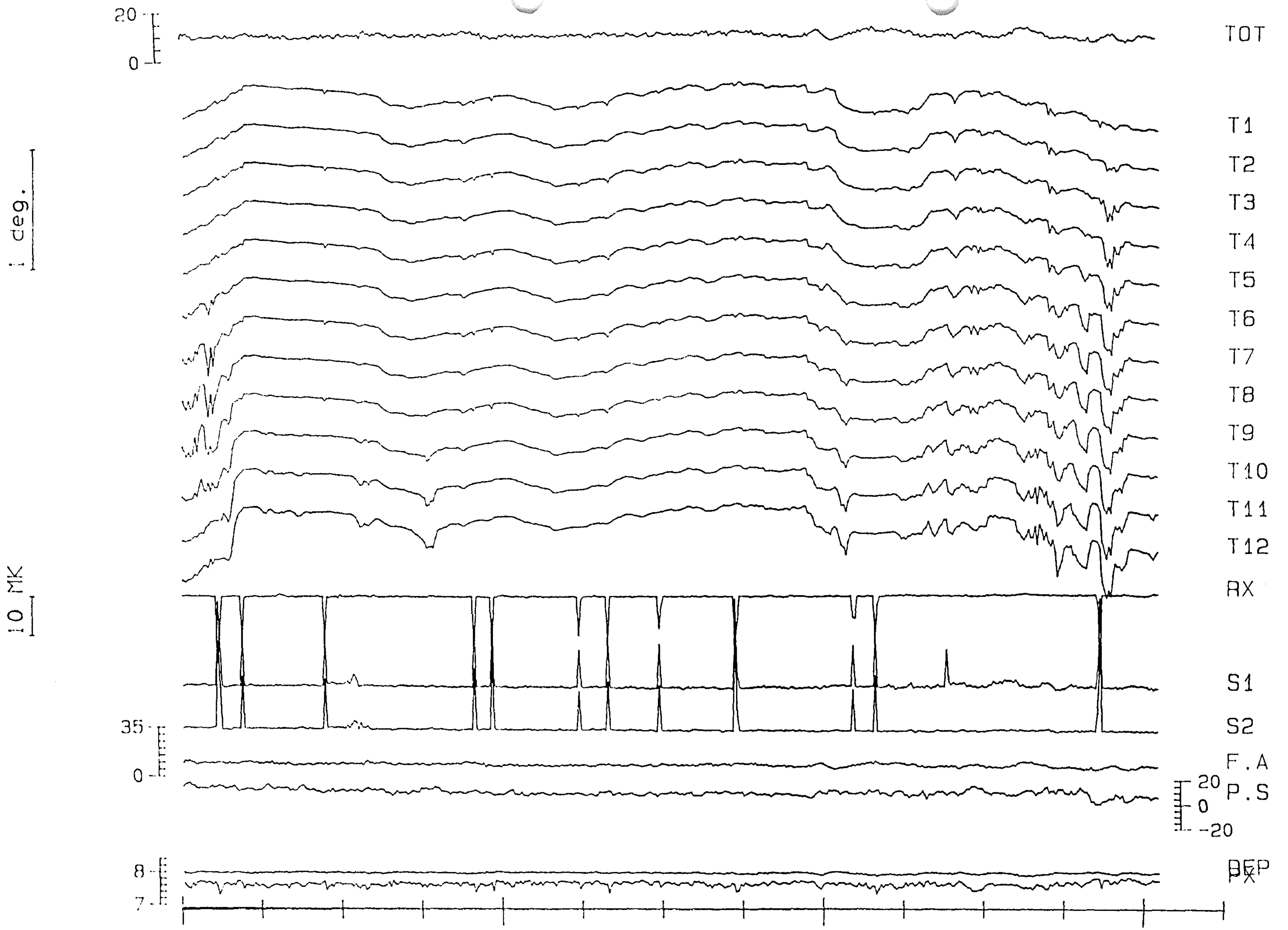
ALL RECORDS



THERMISTOR SPAR CHALL87-03 ALL RECORDS

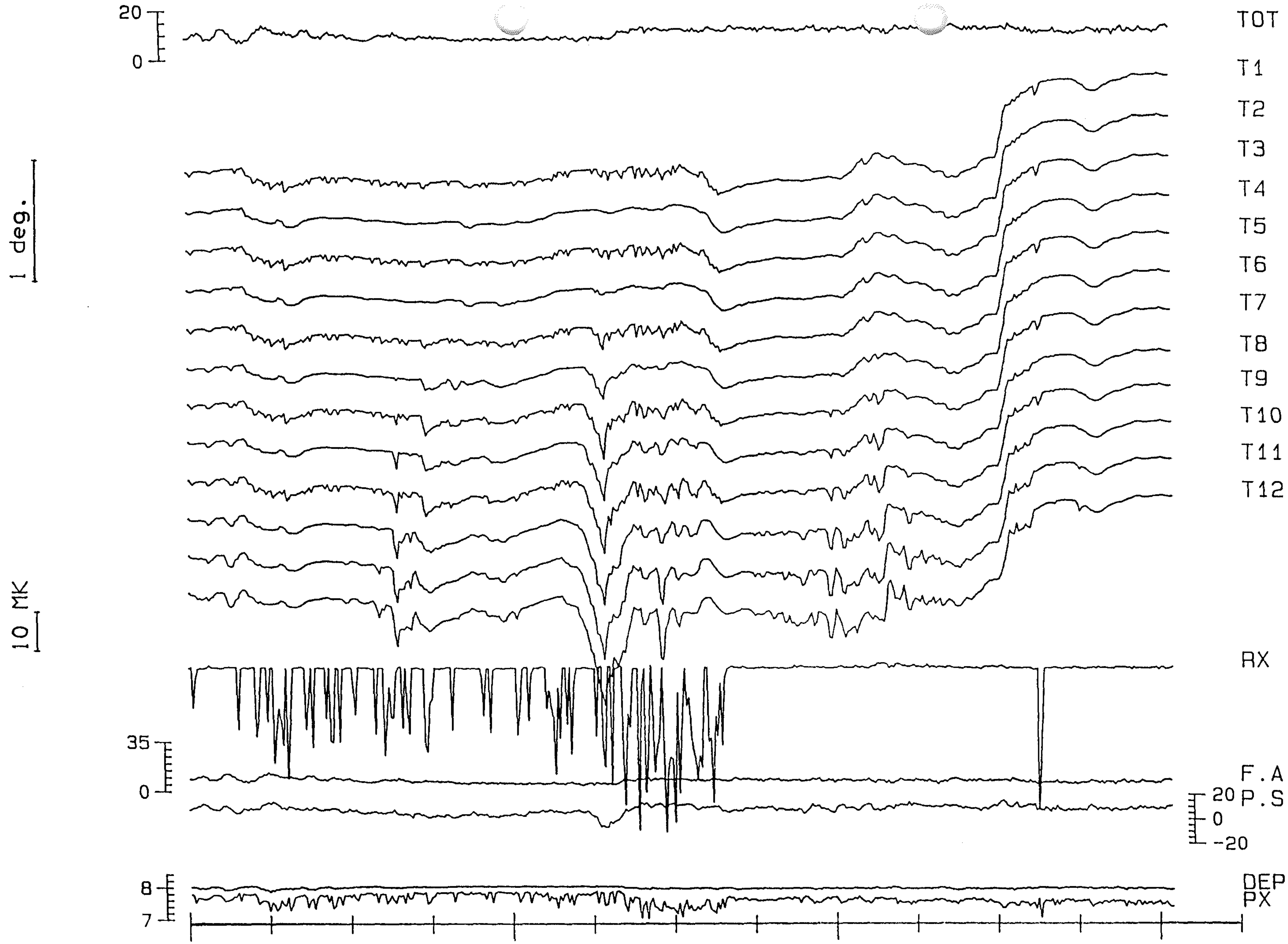


THERMISTOR SPAR CHALL87-04 ALL RECORDS

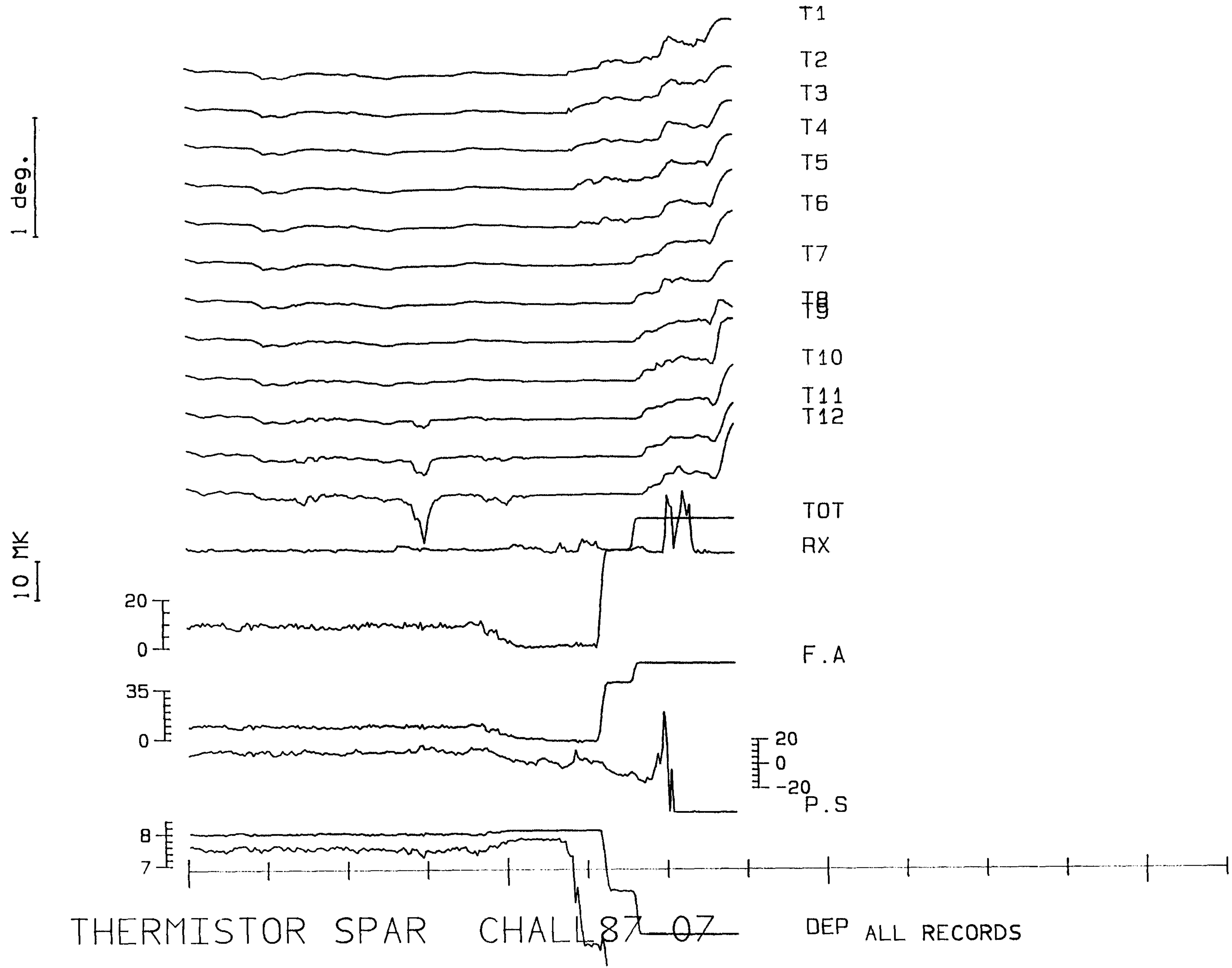


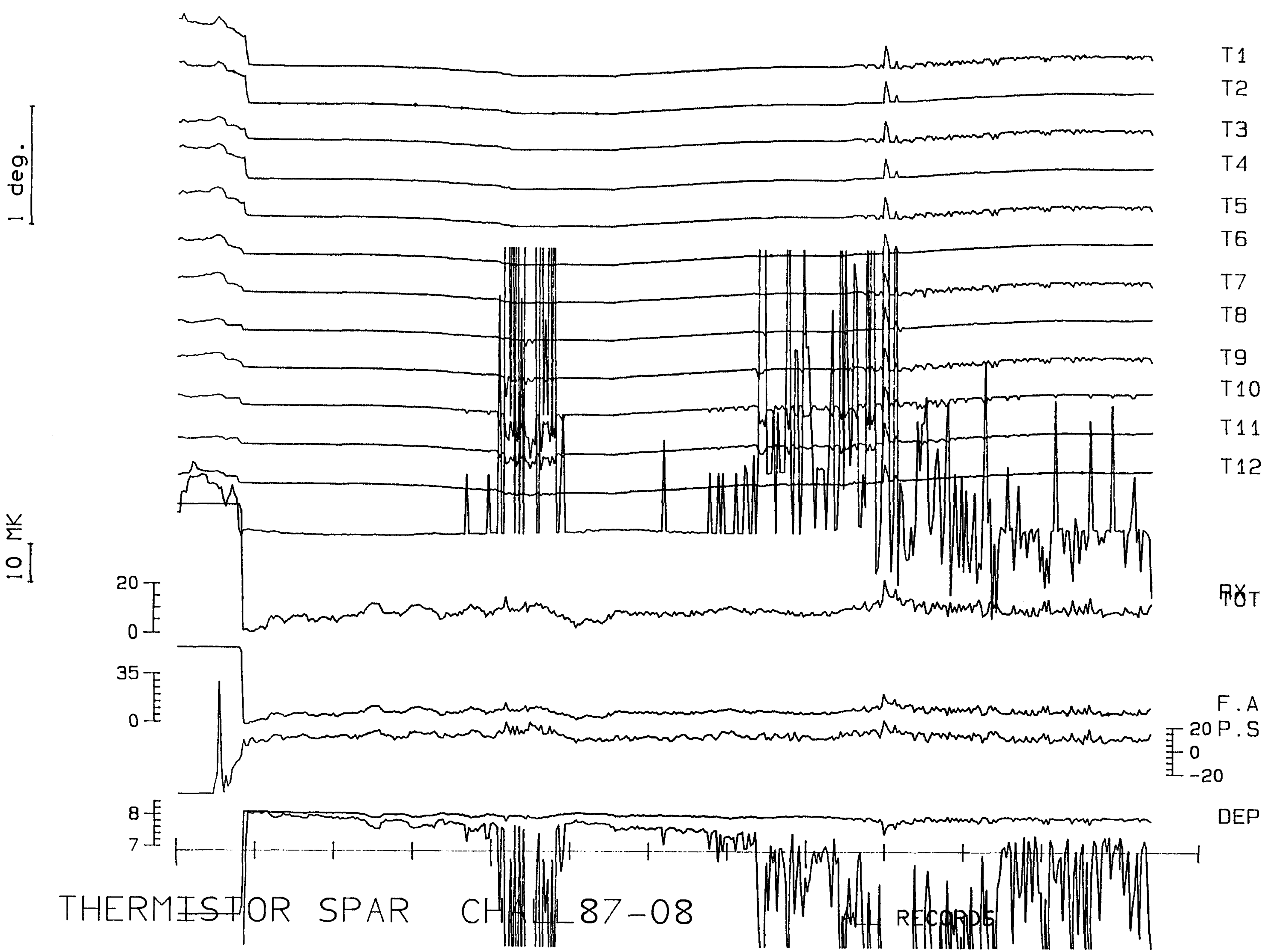
THERMISTOR SPAR CHALL87-05

ALL RECORDS



THERMISTOR SPAR CHALL87-06 ALL RECORDS


T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
TOT
RX
F.A
P.S
1 deg.
10 MK
20
0
35
0
20
0
-20
8
7
THERMISTOR SPAR CHALL87-07
DEP ALL RECORDS



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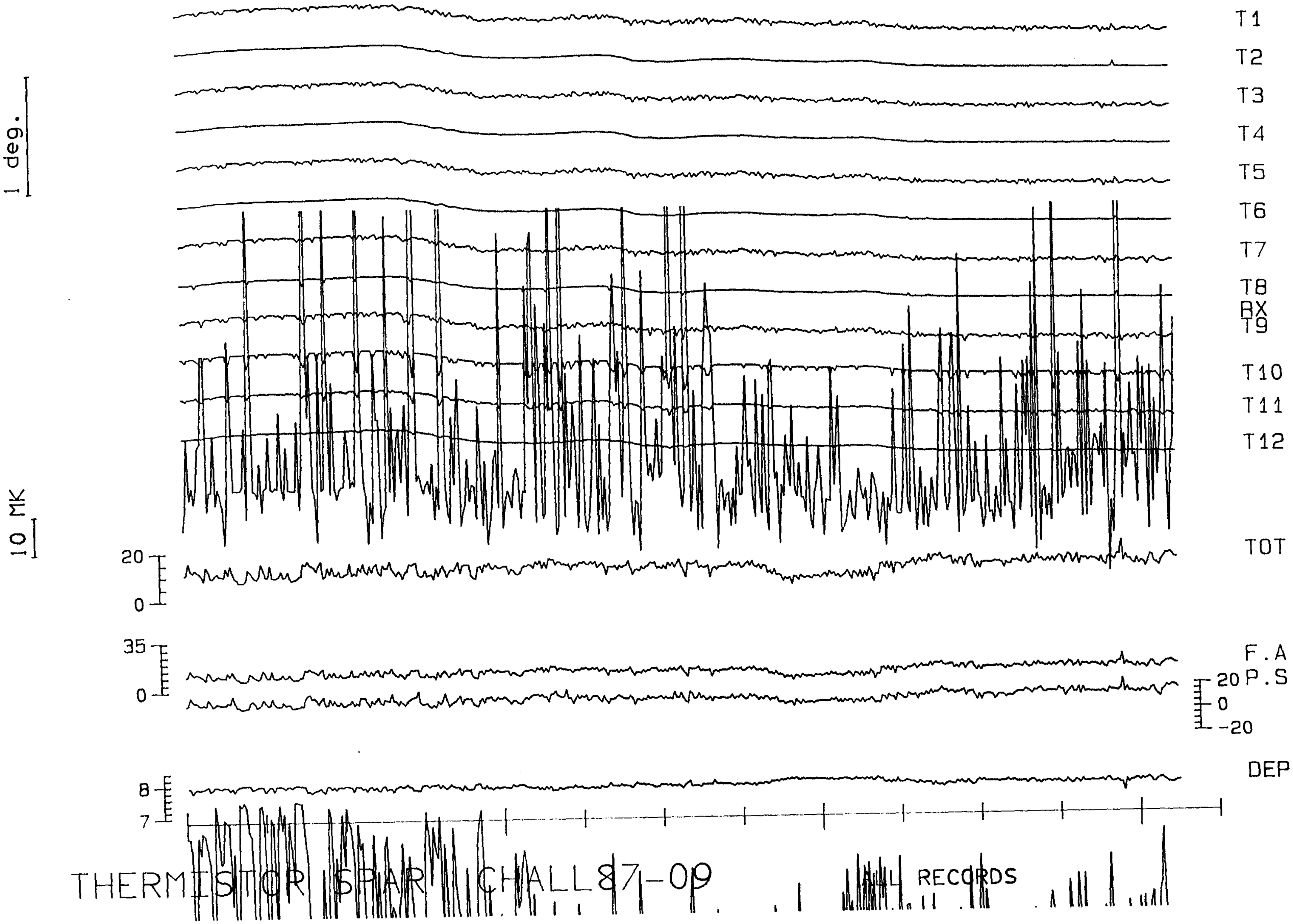
T1
T2
T3
T4
T5
T6
T7
T8
RX
T9
T10
T11
T12
TOT
F.A
P.S
DEP
1 deg.
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20
0
35
0
20
0
-20
8
7
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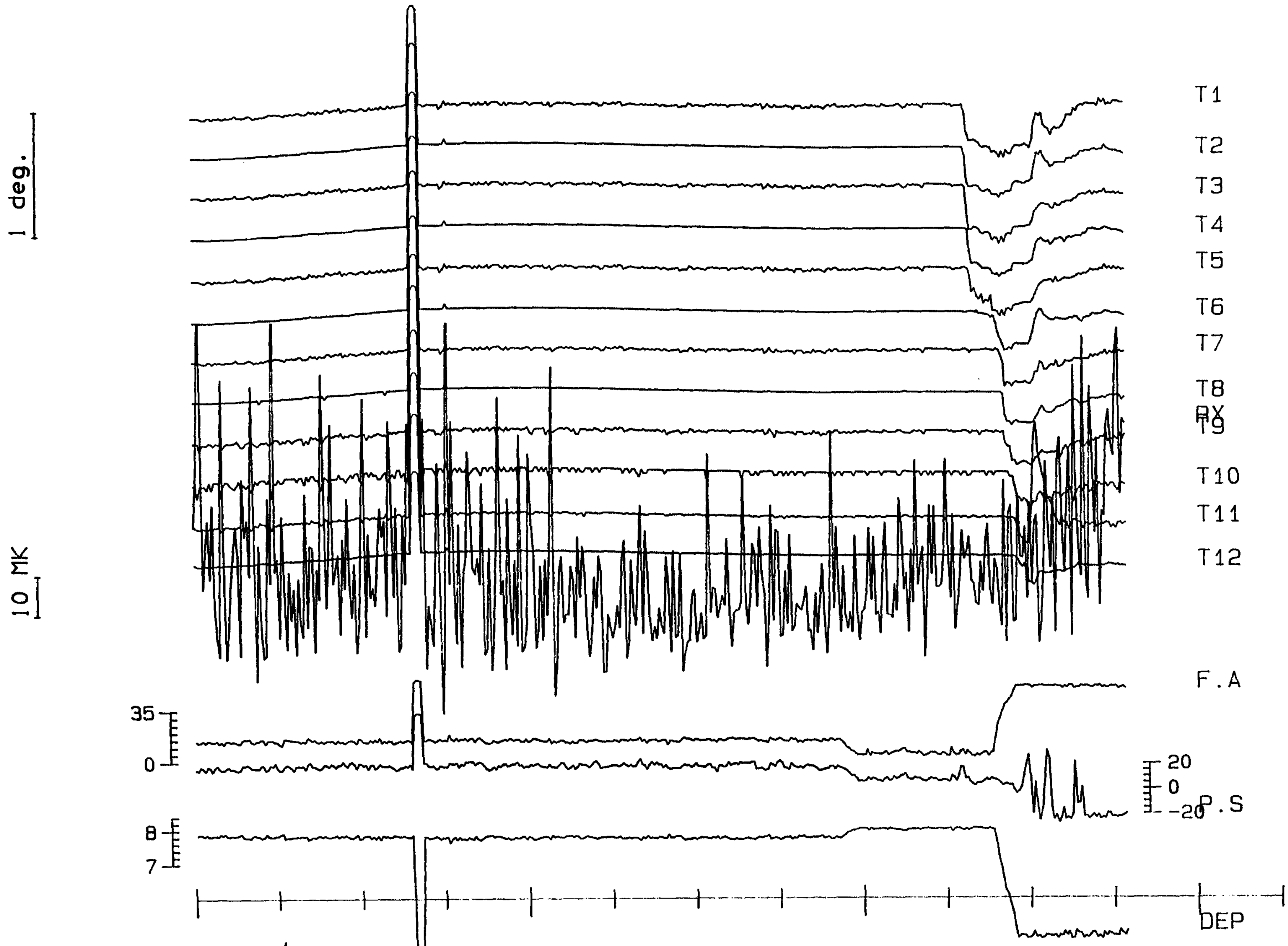
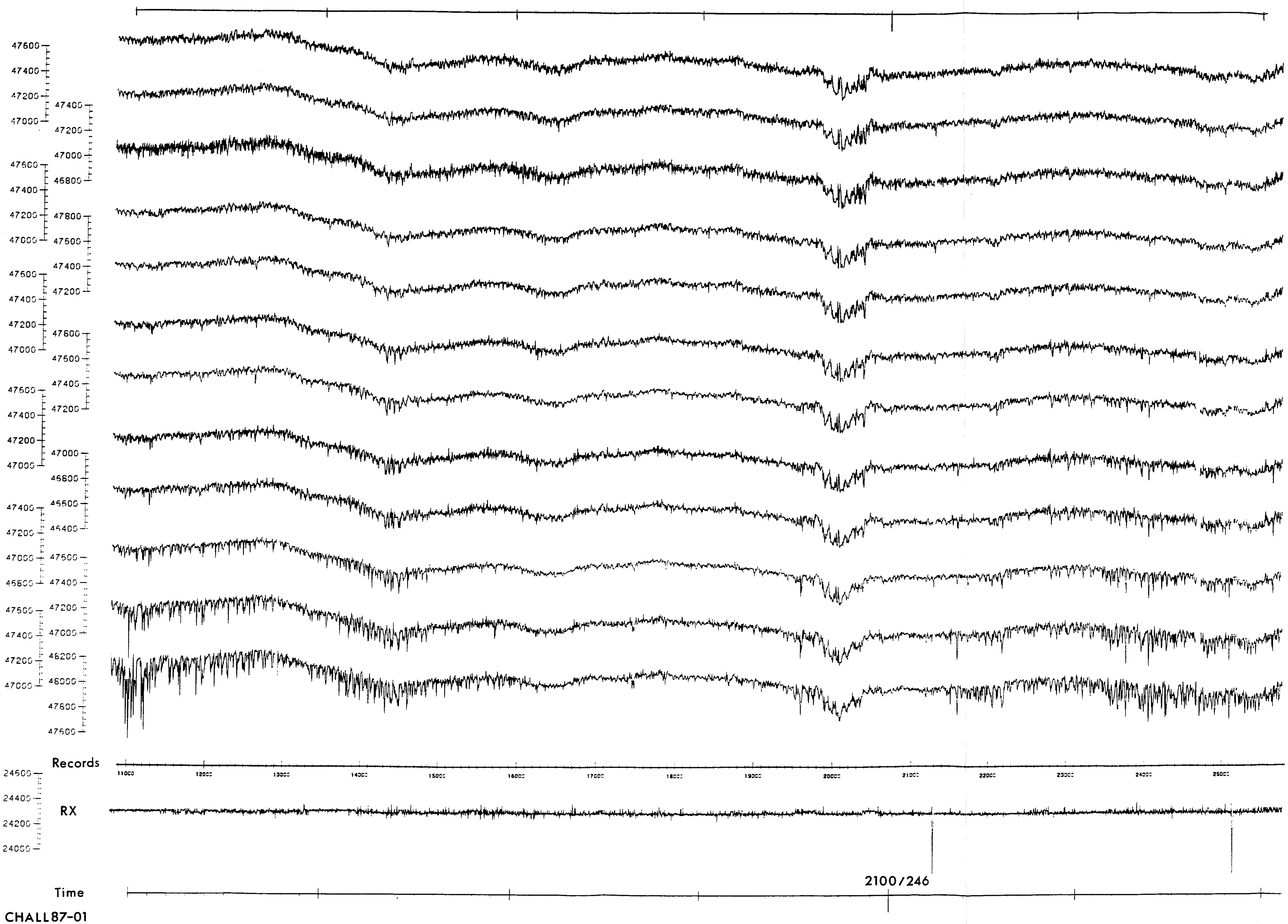
ALL RECORDS



THERMISTOR SPAR CHALL87-10 ALL RECORDS

APPENDIX 3

High Resolution Plots



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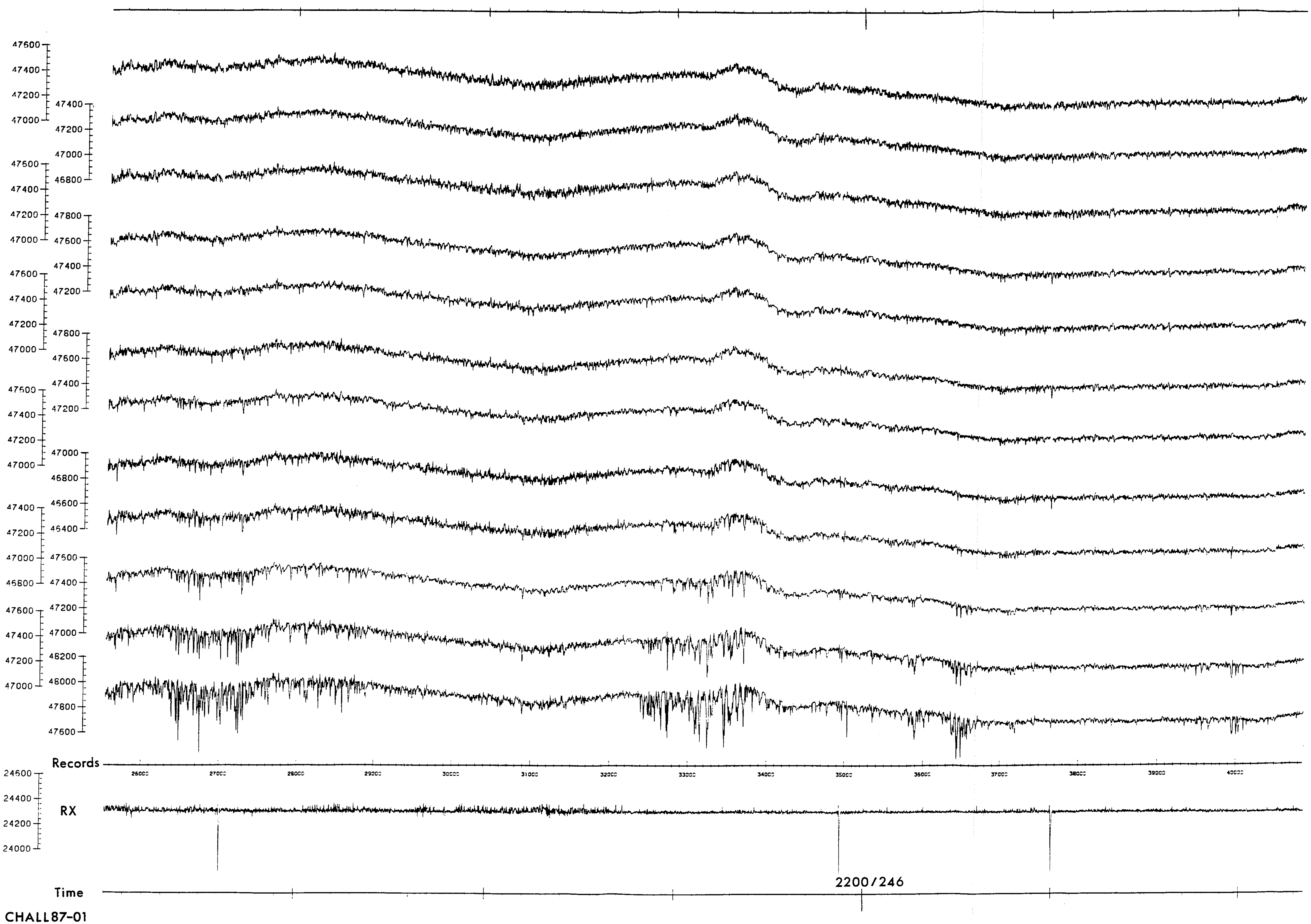
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40000
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Time
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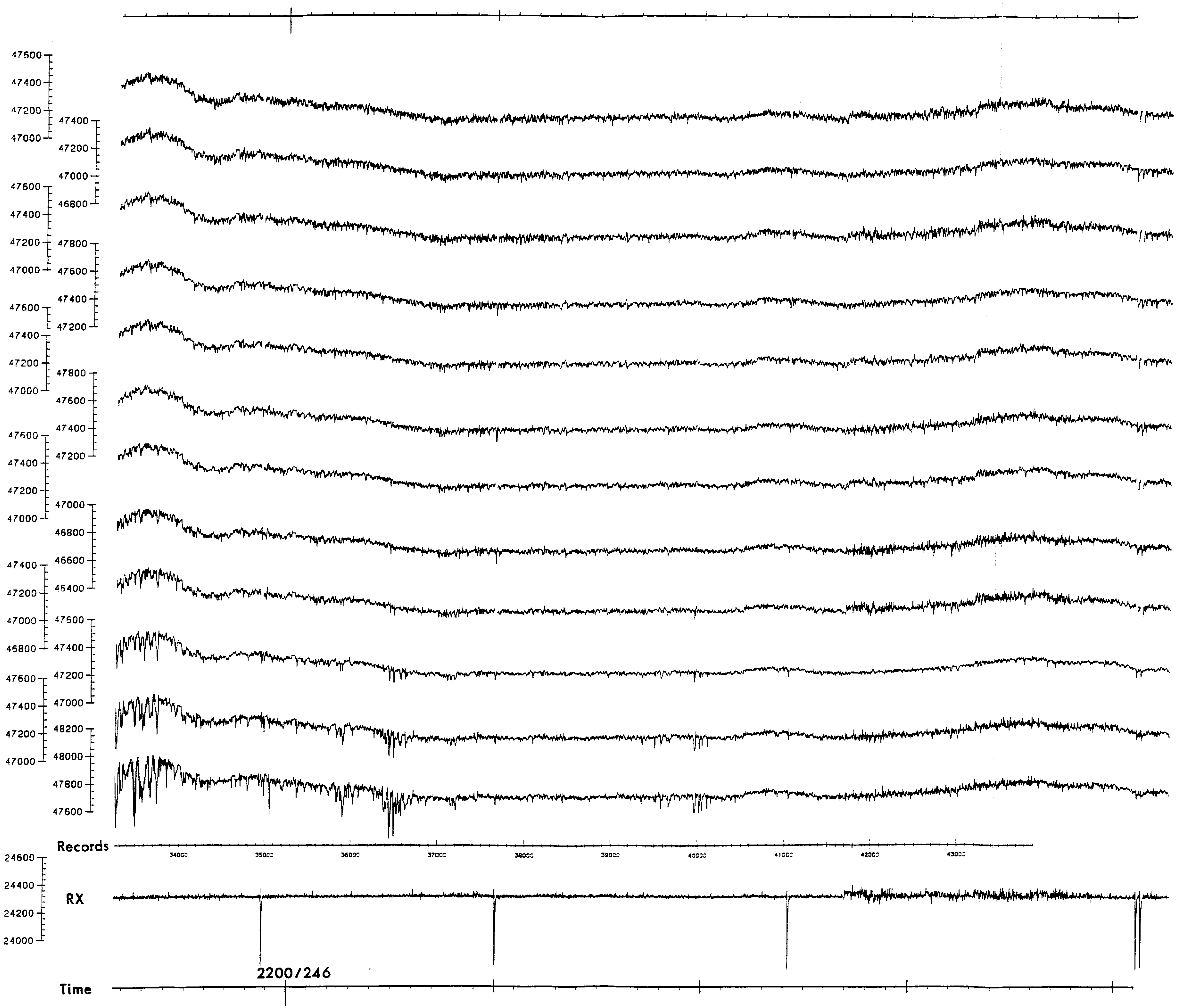

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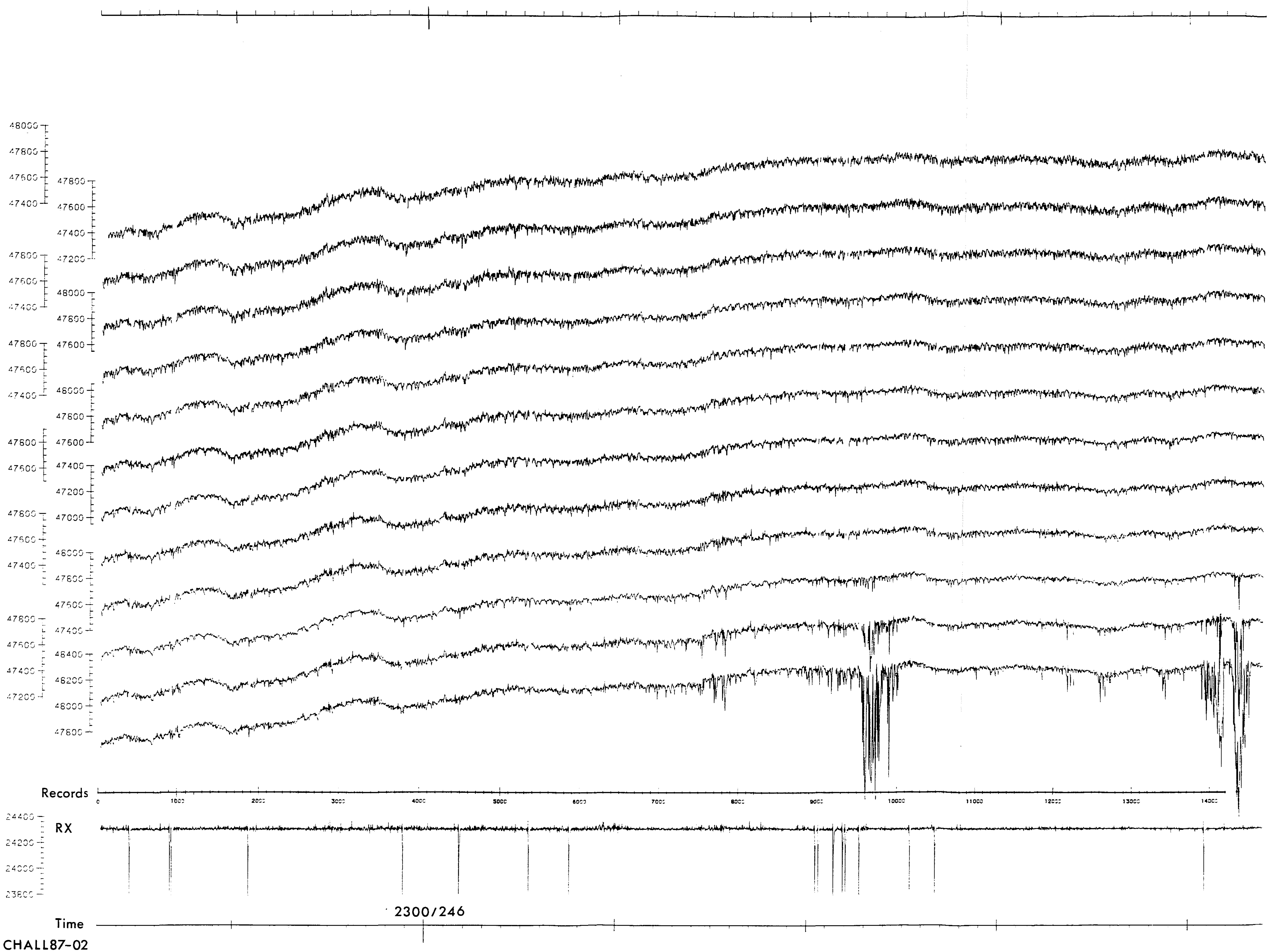

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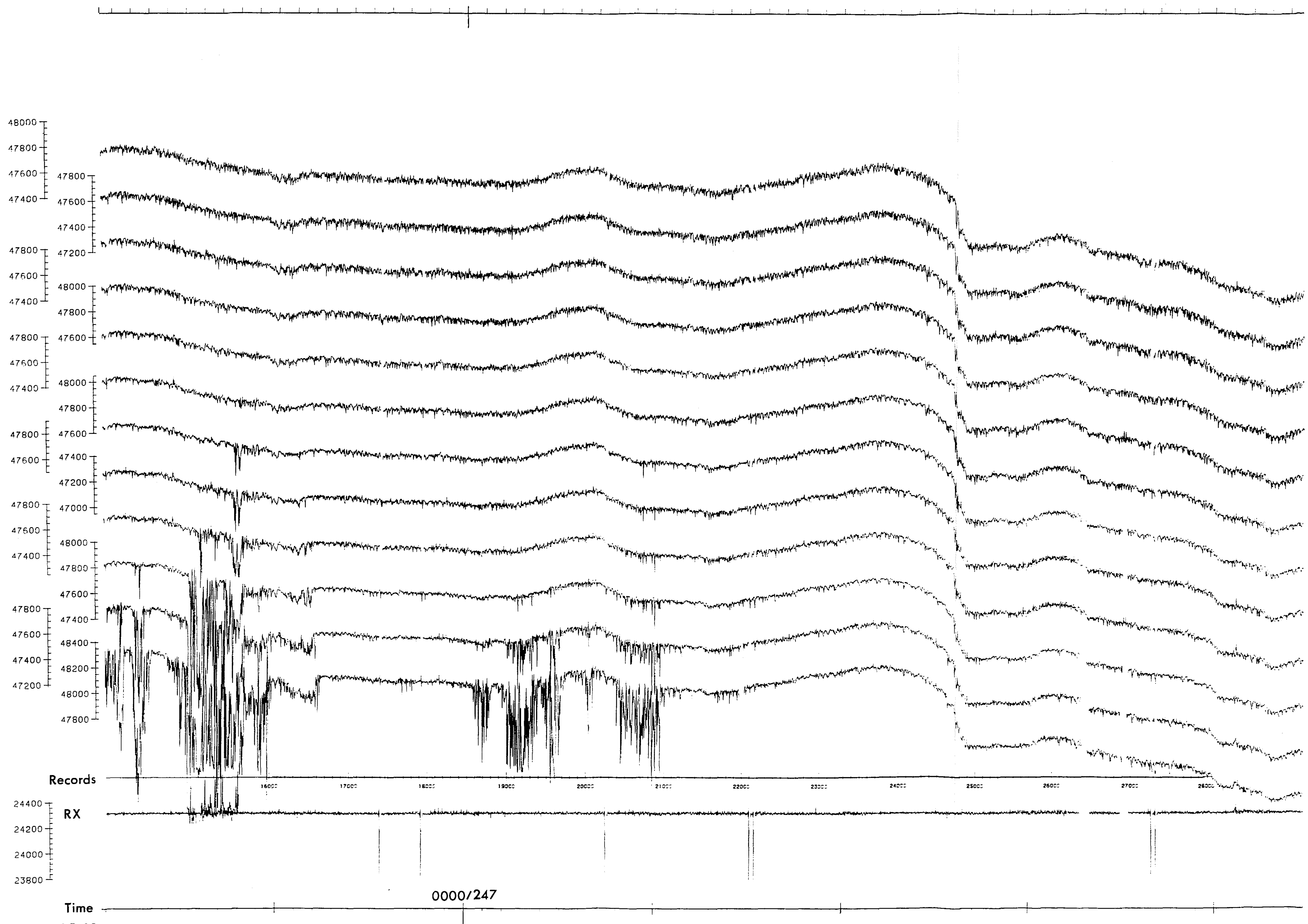
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0000/247
Time

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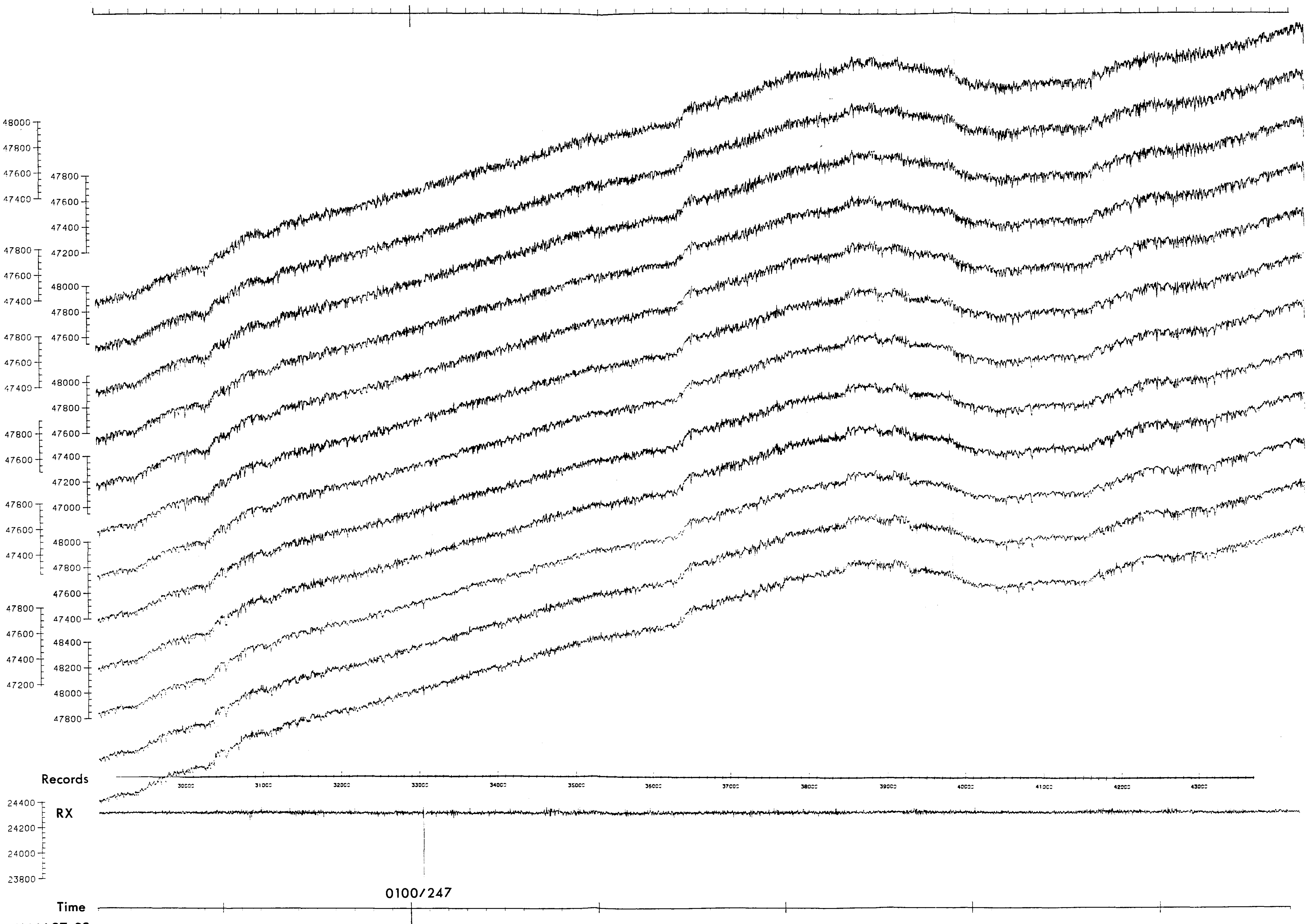

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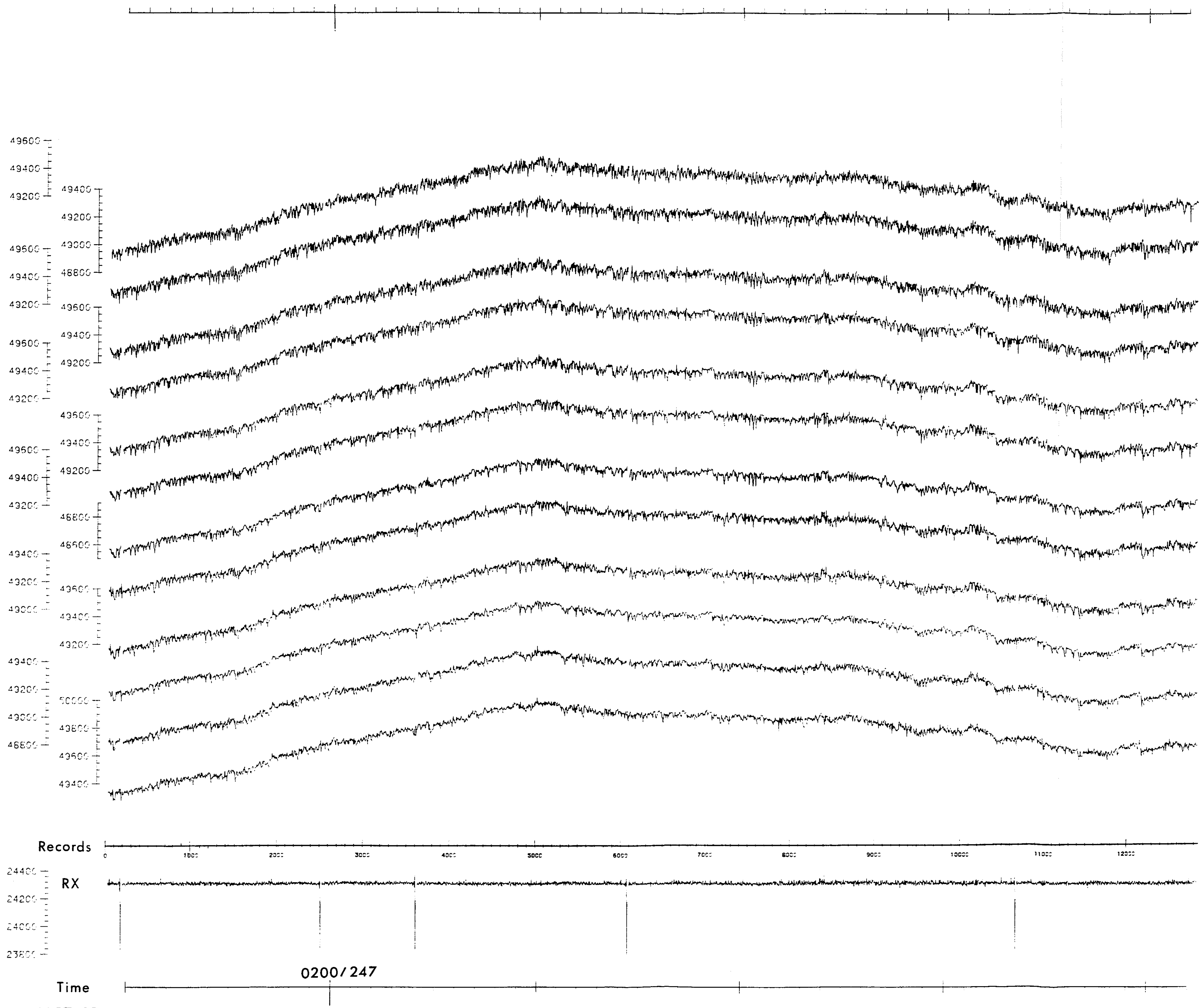
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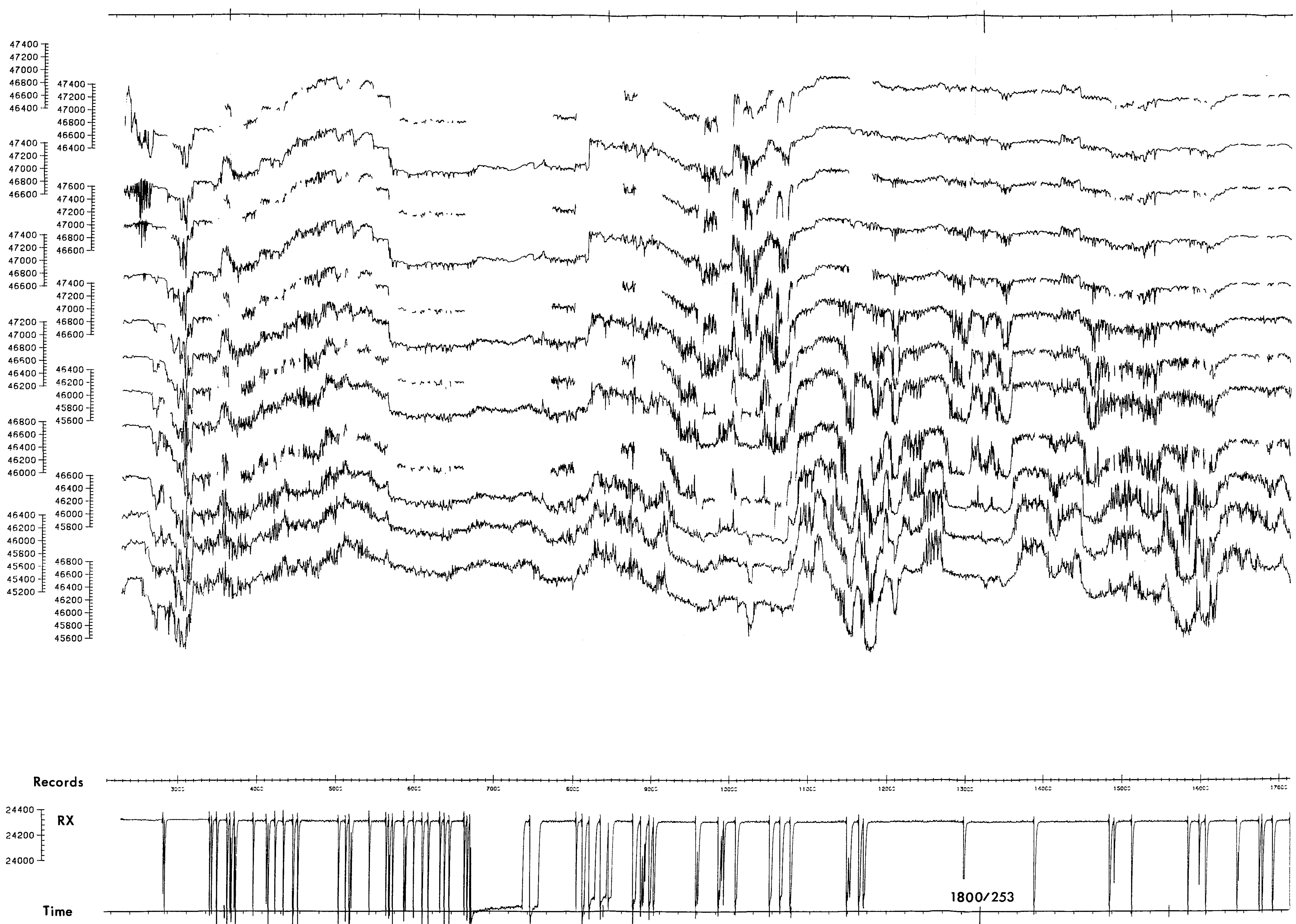

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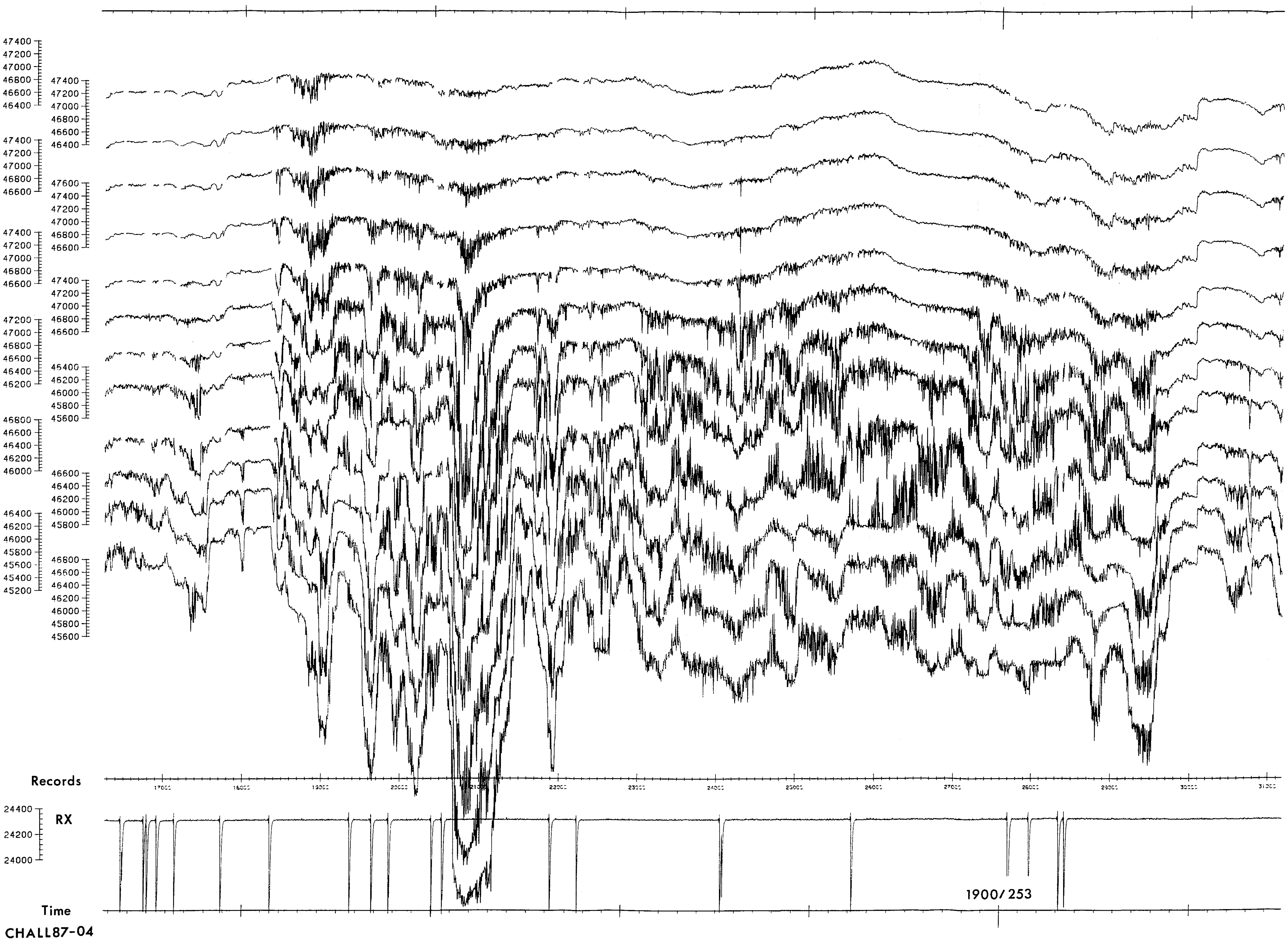
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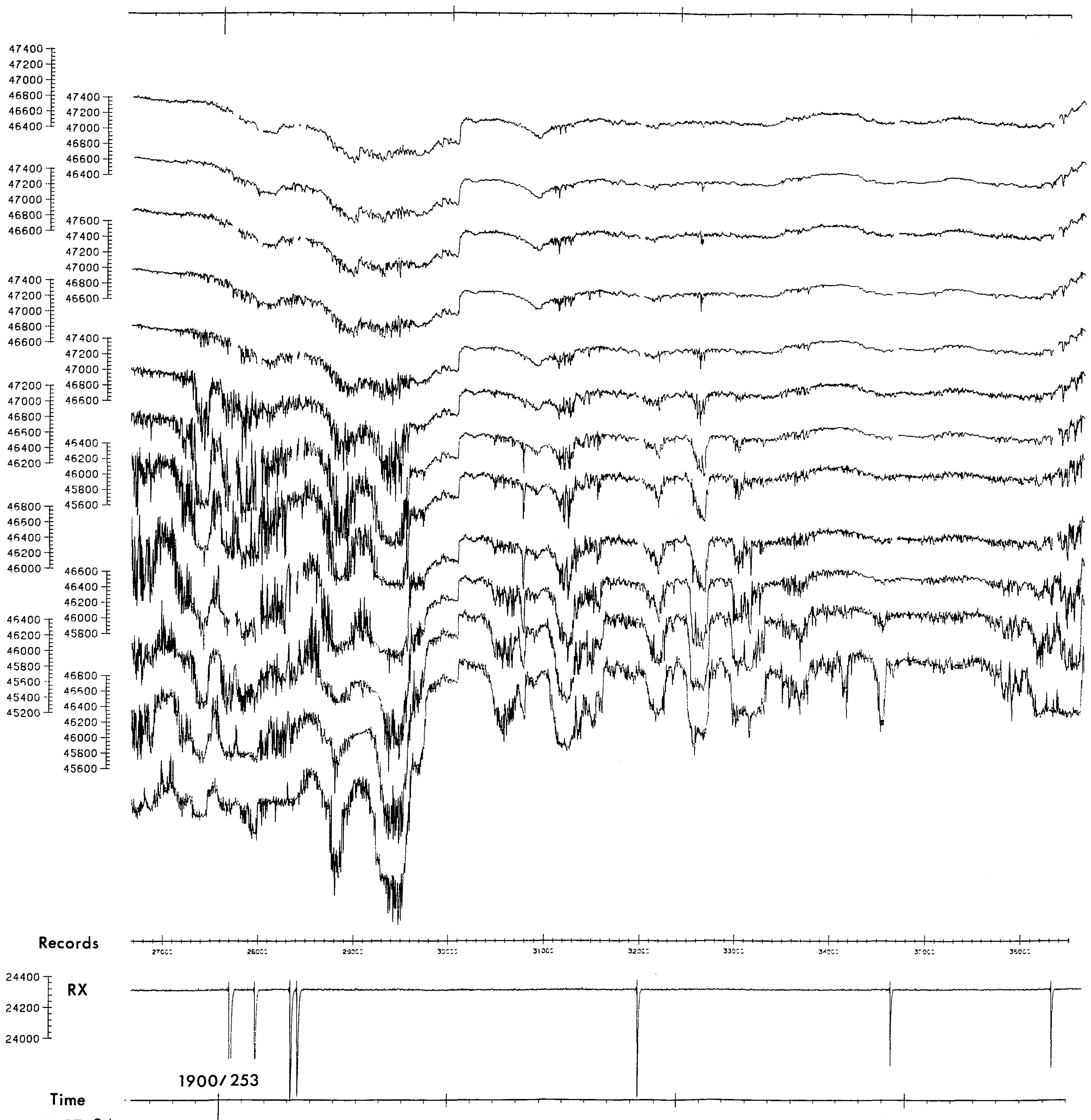

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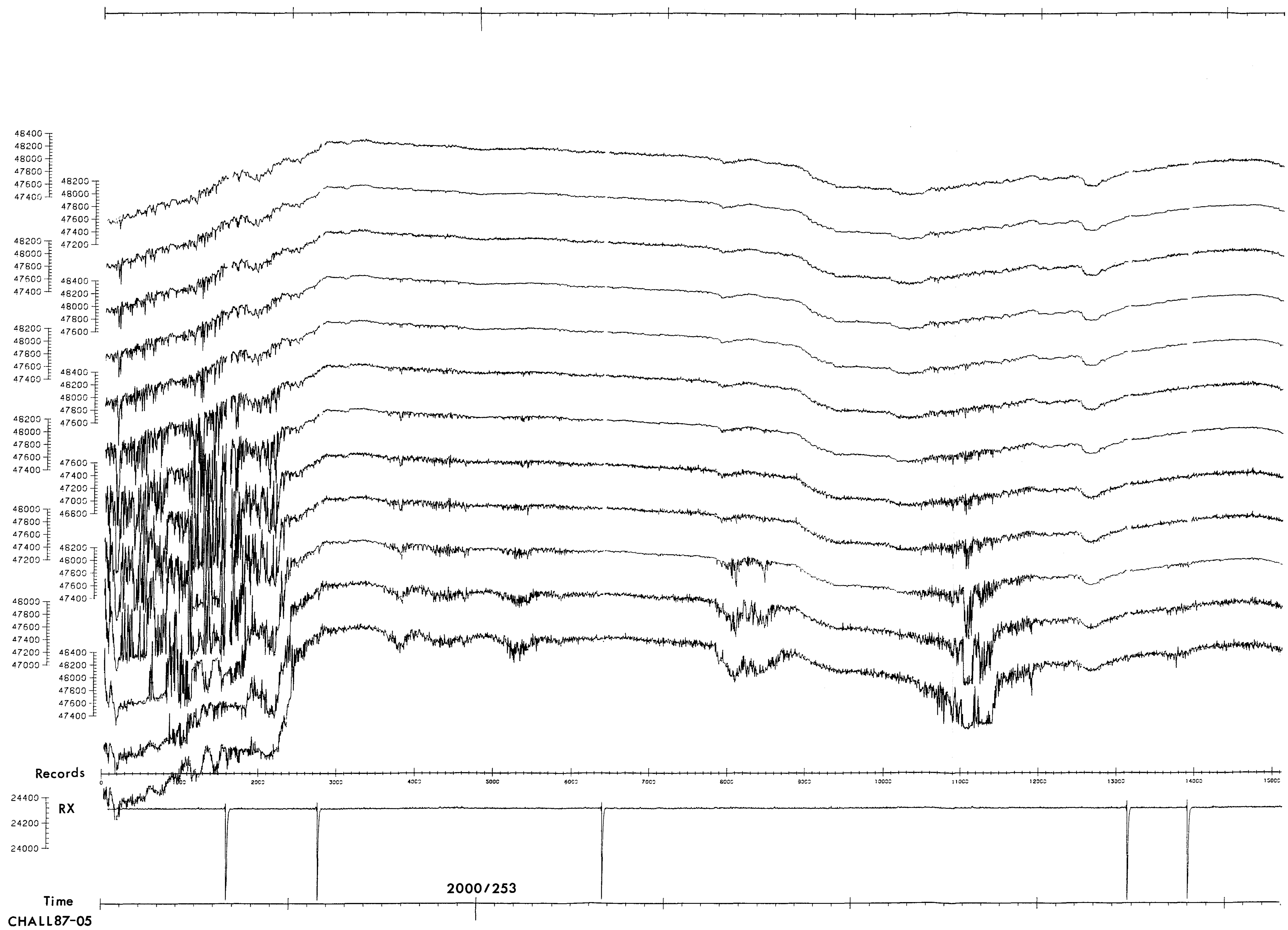
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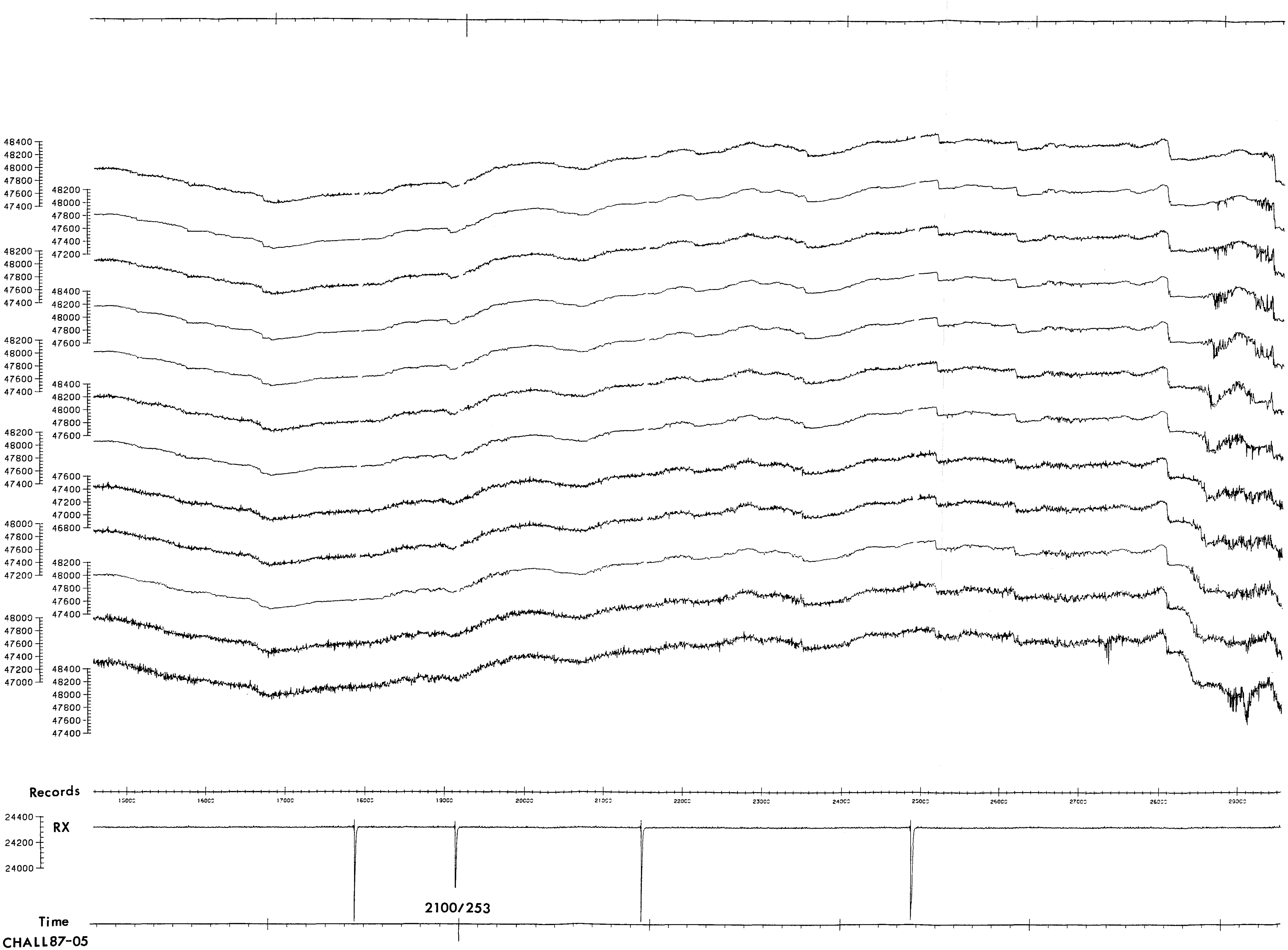
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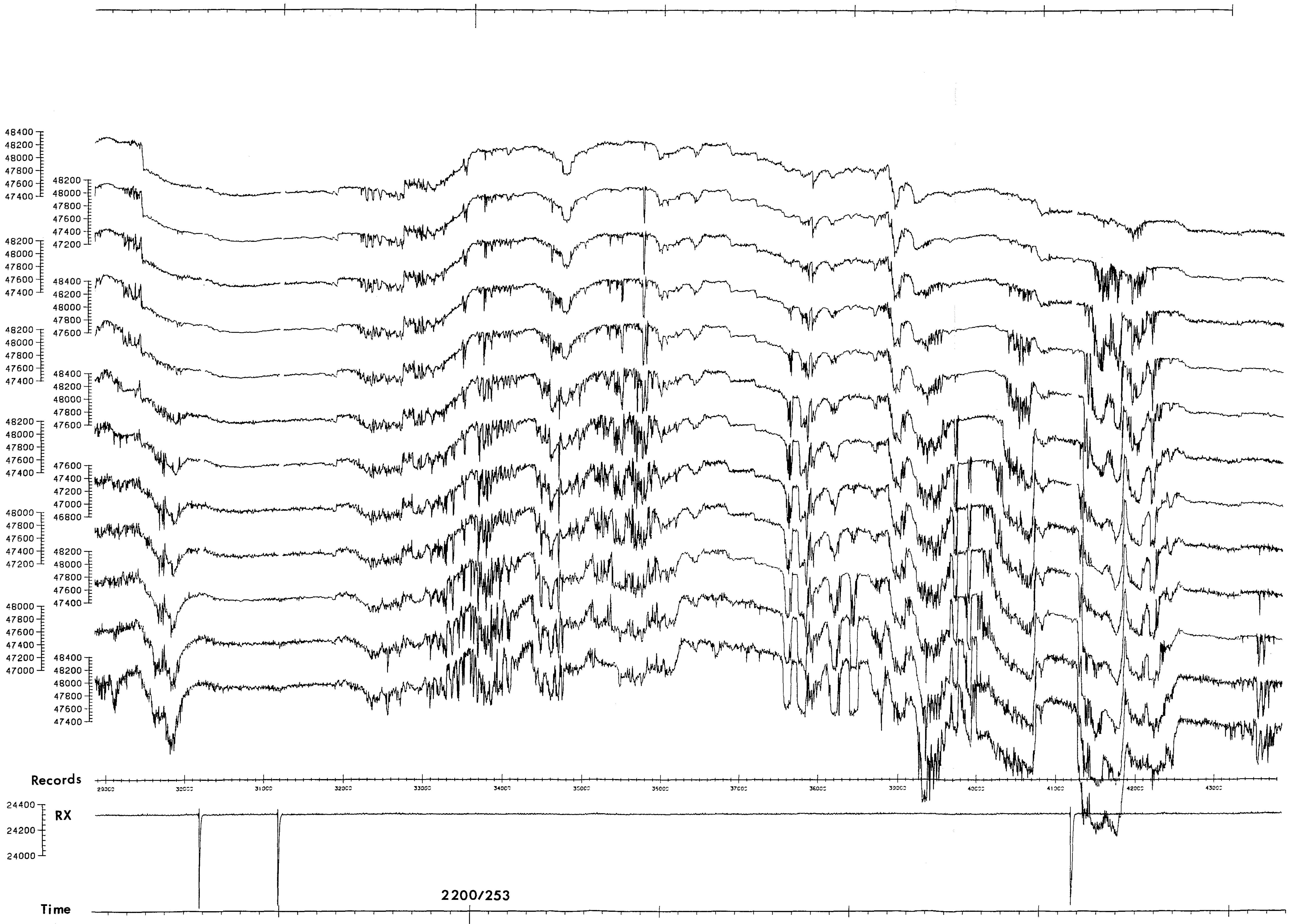

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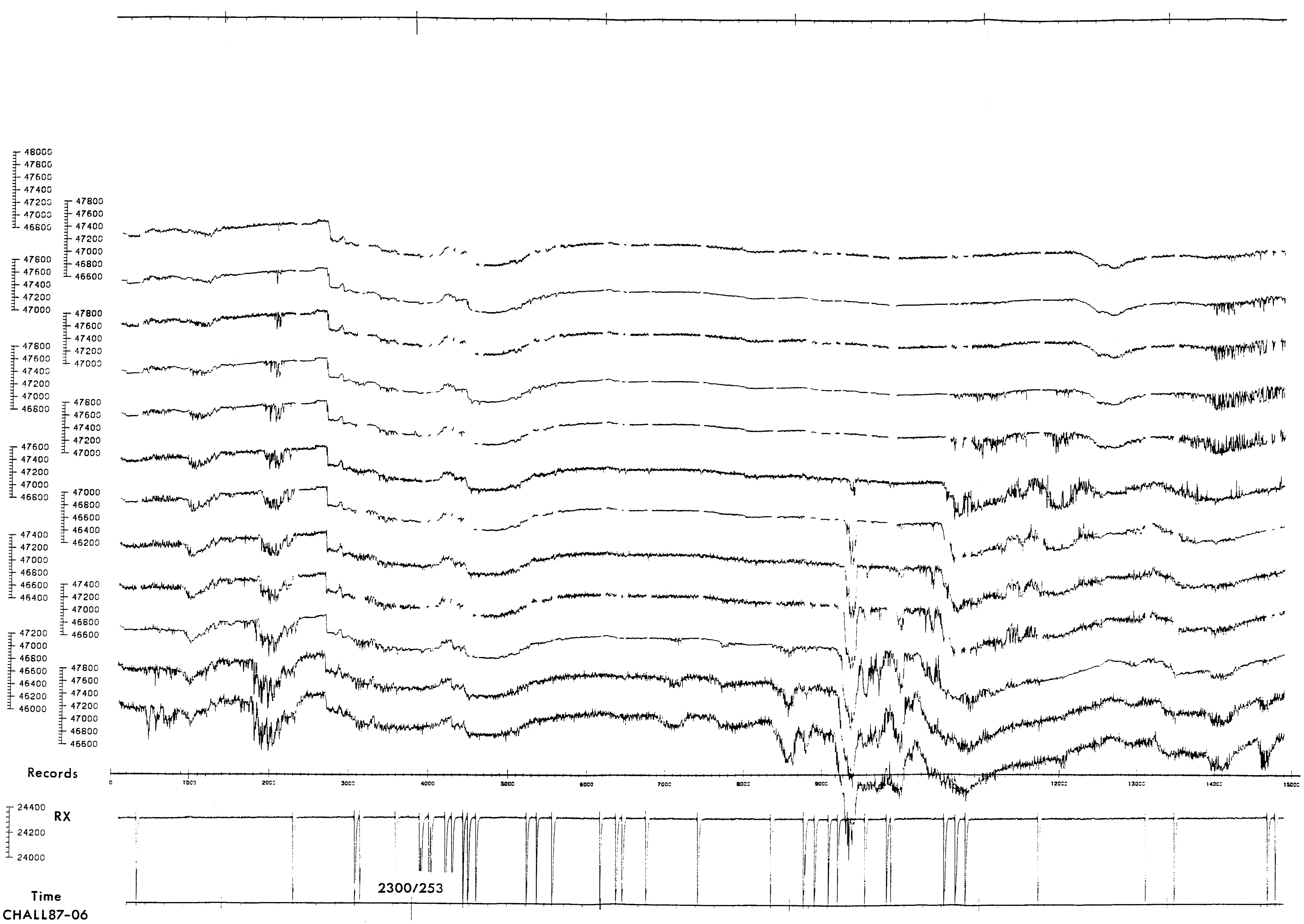

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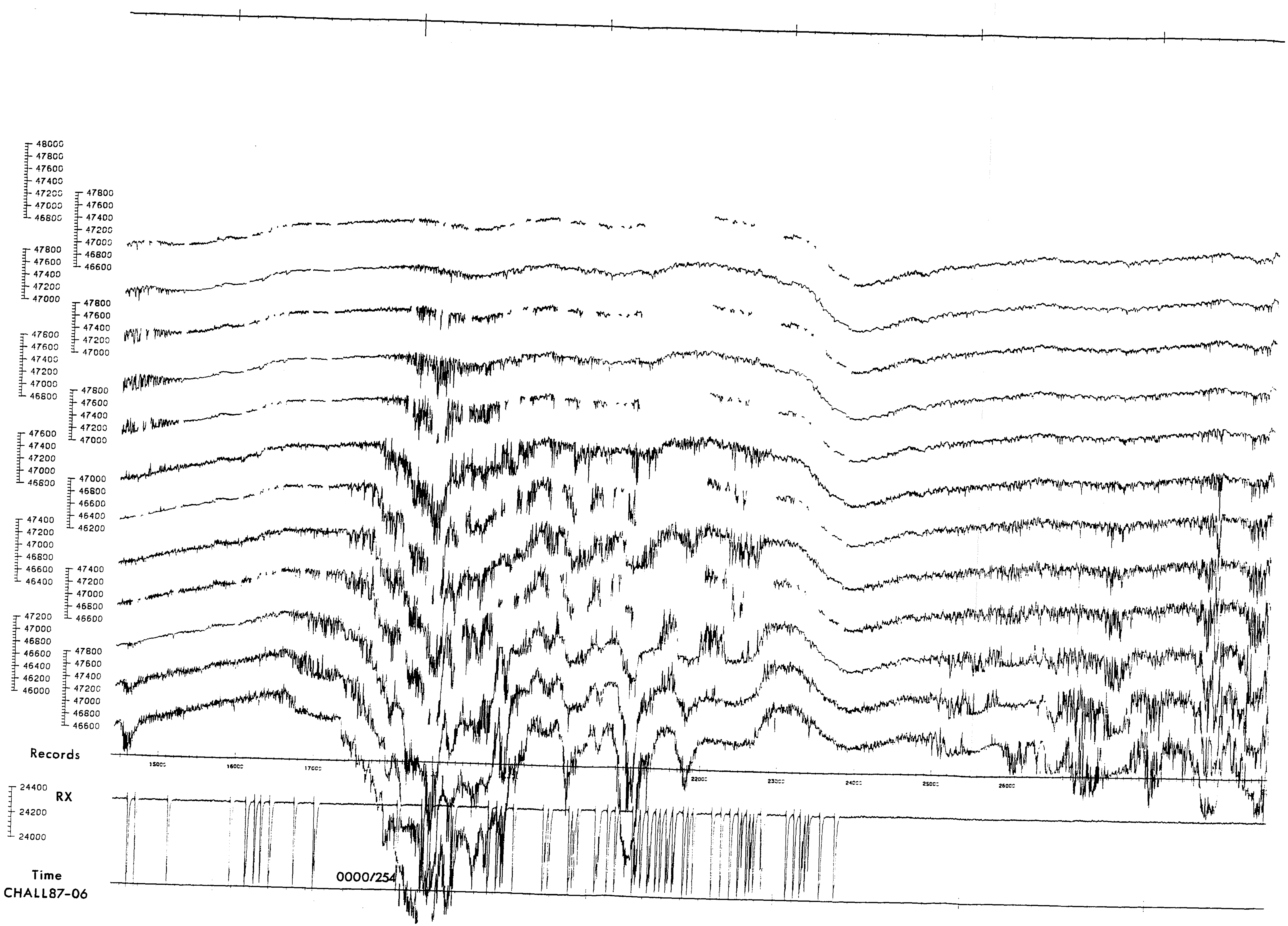

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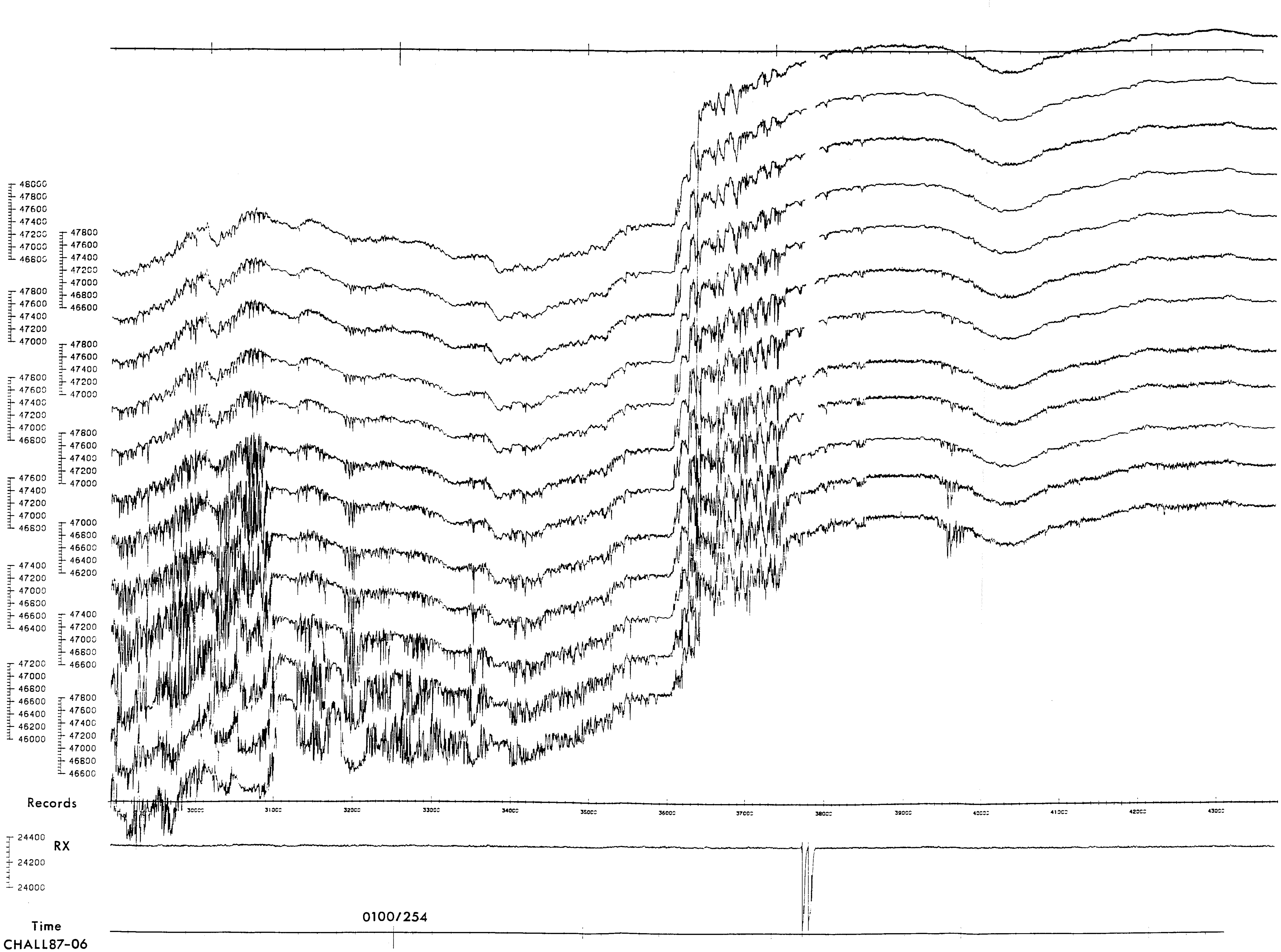
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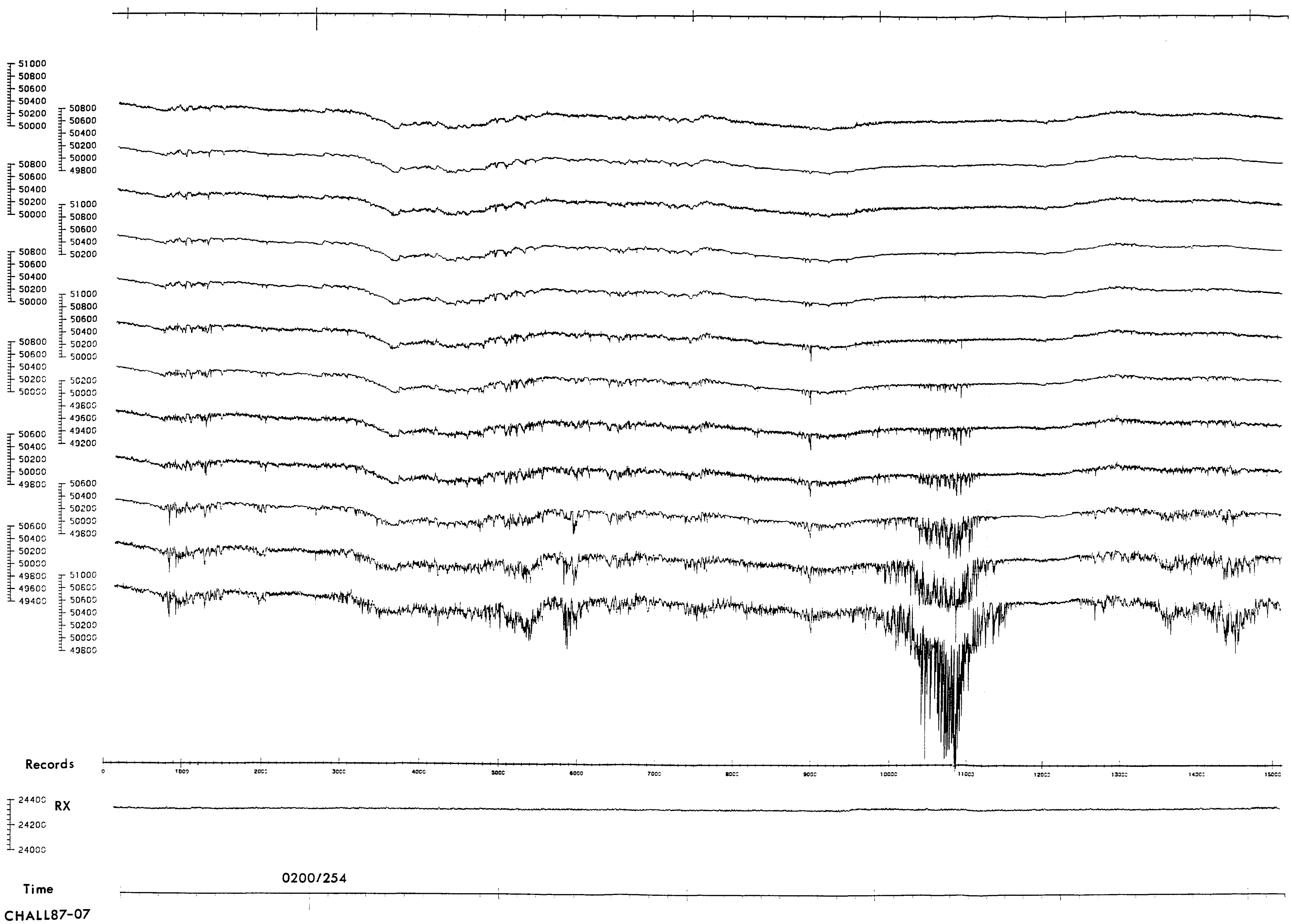
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RX
Time
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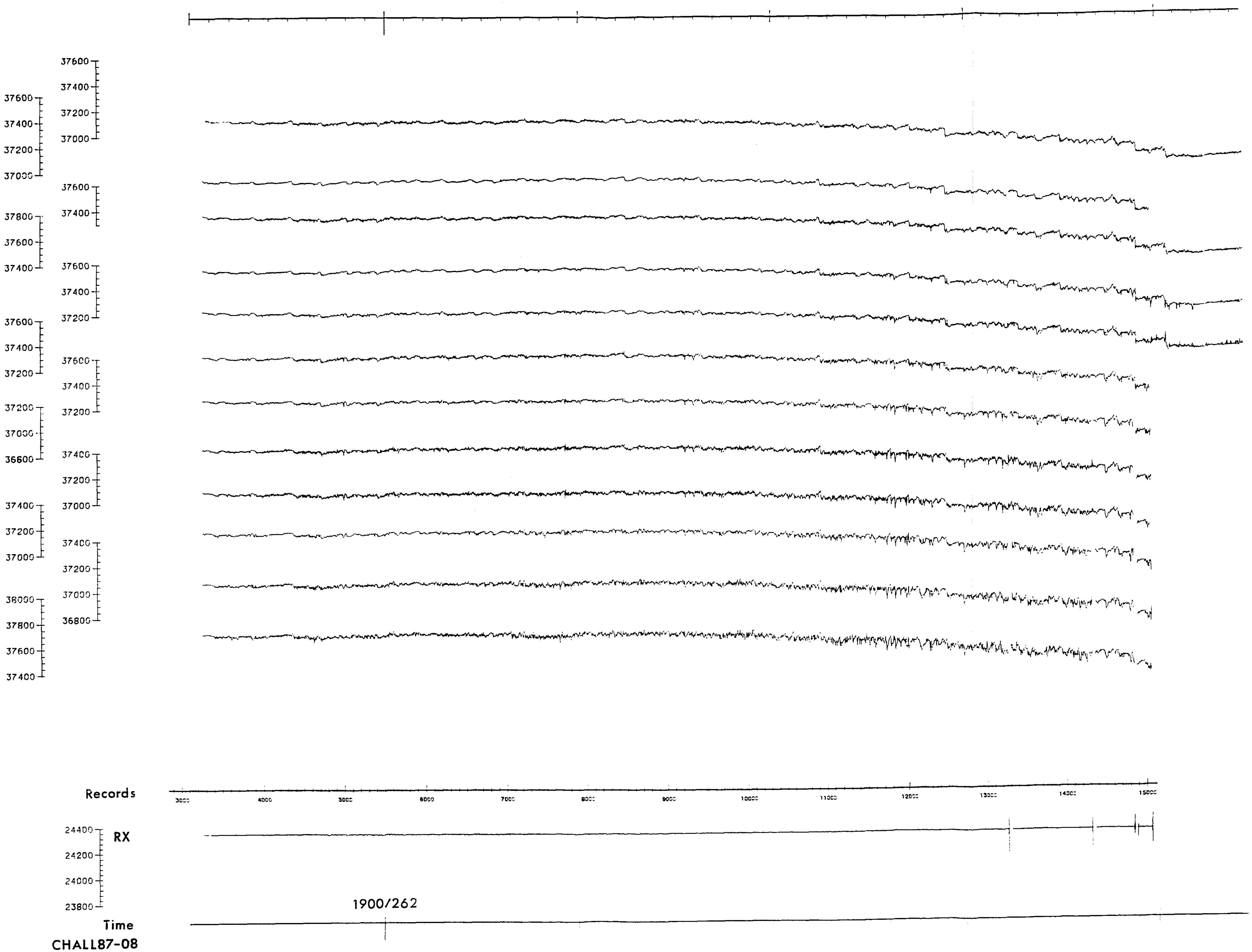
CHALL87-07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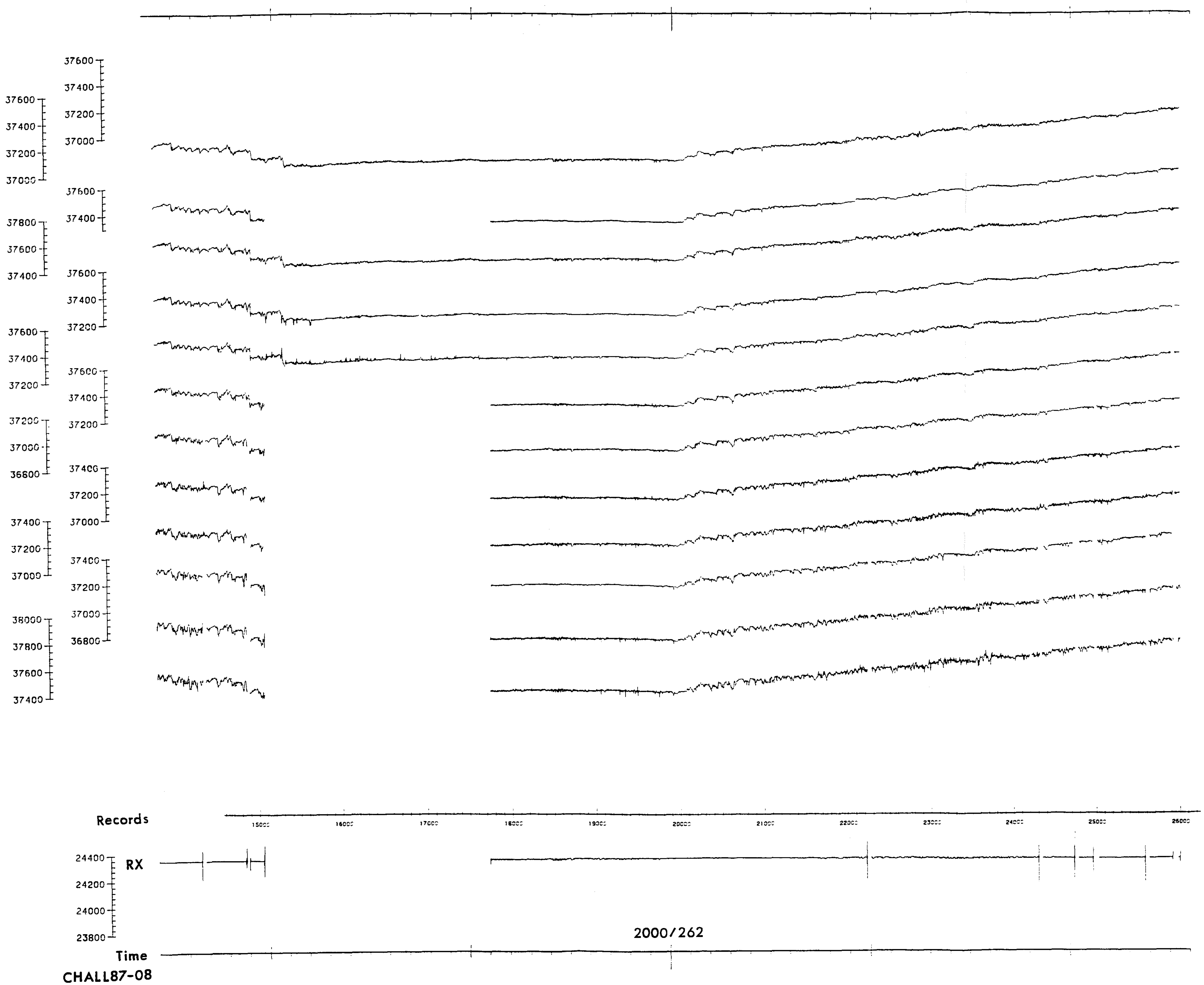
Time
CHALL87-08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2000/262
Time
CHALL87-08