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Appendix to Semiannual Technical Report 4

Covering the Period 3 January to 19 June 1966

AD822527

RIOMETER RECORDS OF 18- AND 30-Mc COSMIC NOISE

By: J. C. HODGES

Prepared for:

HEADQUARTERS
U.S. AIR FORCE
AIR FORCE TECHNICAL APPLICATIONS CENTER TD-3
WASHINGTON, D.C. 20333

CONTRACT AF 33(657)-13727
AFTAC Project Authorization
NOVT 5060/ASD(59)
ARPA ORDER NO. 159

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA



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November 1966

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SRI Project 5224

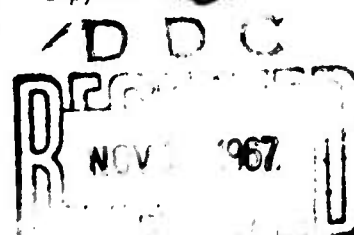
This research was supported by the Project VELA office of the Advanced Research Projects Agency and monitored by the Air Force Technical Applications Center.

Approved: RAY L. LEADABRAND, MANAGER
RADIO PHYSICS LABORATORY

D. R. SCHEUCH, EXECUTIVE DIRECTOR
ELECTRONICS AND RADIO SCIENCES

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ABSTRACT

Riometer record reproductions of 18-Mc and 30-Mc cosmic noise are presented for the period 3 January to 19 June 1966. The riometers were located near San Francisco, California. The riometer and the field site are described briefly, and the use of the data is explained.

CONTENTS

ABSTRACT	111
I INTRODUCTION.	1
II THE RIOMETER.	3
A. General Description.	3
B. Quiet-Day Curve.	4
C. Important Riometer Operating Parameters.	5
III NUFF CREEK SITE	7
A. General Description.	7
B. 30 Mc Riometer	7
C. 18 Mc Riometer	8
IV DATA.	9
A. Chronological Log.	9
1. 30 Mc Riometer Chronology, 3 January to 19 June 1966.	9
2. 18 Mc Riometer Chronology, 3 January to 19 June 1966.	10
B. Chart Records.	11

I INTRODUCTION

As part of the experimental studies of ionospheric variations being conducted at SRI, a riometer station has been operated continuously since 11 June 1963 at Nuff Creek, a ranch located in the hills near Half Moon Bay, California.

The riometer records taken at this station for the period 3 January to 19 June 1966 are reproduced in this volume to make them available to other researchers. These records are useful for comparison with other riometer records or for correlation with other data concerning the sun, the ionosphere, and radio astronomy. The riometer records are also useful as a routine source of information on the activity of the sun.*

*Another source of similar geophysical data is the Monthly CRPL F-series, Part B, "Solar-Geophysical Data," available from the National Bureau of Standards, Boulder, Colorado.

II THE RIOMETER

A. General Description

The word riometer is derived from "relative ionospheric opacity meter." The riometer is an ultrastable receiver system that records the power level of the cosmic noise impinging on the antenna, coming primarily from our galaxy. This radio power, or radio noise, passes through the ionosphere. If the normal ionosphere is bombarded by particles or intense radiations, additional ionization is generated, permitting less cosmic noise to pass through the ionosphere and thus producing a noise-level drop on the riometer recording. A drop of the riometer record (usually referred to as absorption) implies that ionizing radiations, generally from the sun, are present.

Long-term stability of the riometer is achieved by using a servo system rather than a simple receiver. The riometer receiver alternately samples the power available from the antenna and from an internal noise generator (called the servo noise diode) at a sample rate of 340 cps. An electronic servo system continuously adjusts the servo noise diode power output to be equal to the noise power coming from the antenna. The data are recorded on a strip-chart recorder in the form of servo noise diode plate current, which is proportional to the servo noise diode power output. Since this servo noise diode power output is made continuously equal to the antenna noise power, the recording effectively indicates the level of the cosmic signal reaching the antenna.

The noise-power output of a temperature-limited noise diode is directly proportional to the plate current of the diode, which is easily measured or recorded. To convert the plate current to equivalent temperature or power, the following equations are used:

$$T = 5.8 IR + T_r \quad (1)$$

and

$$P = kTB \quad (2)$$

where

T = equivalent temperature in °K

I = noise-diode plate current in mA

R = resistance of the noise-diode load resistor in ohms

T_r = temperature of the noise-diode load resistor in °K,
which is approximately equal to room temperature;
a value of 300°K is usually used.

P = noise power

k = Boltzman's constant

B = receiver bandwidth.

A useful way to express absorption is in terms of decibels. Since the plate current of the noise diode is proportional to the noise-power output, the following equation may be used:

$$dB = 10 \log \frac{I_1}{I_2} \quad (3)$$

where

I_1 = reference current

I_2 = current measured during an absorption event.

B. Quiet-Day Curve

The riometer chart recorder will trace out a sine-like curve each day, representing the cosmic noise distribution as the antenna rotates with the earth. If the conditions are "normal," the curves of several days are used to determine a quiet-day curve. The usual procedure is to operate the riometer for several days, and under "normal" circumstances the daily trace on the chart will repeat that of the previous

day, shifted forward in time by four minutes. The chart repeats itself because the antenna views the same solid angle of the sky at any given time each sidereal day. The daily four-minute shift is the difference between sidereal time and solar time, and amounts to exactly one day each sidereal year.

Finally, the daily records can be compared to the quiet-day curve; if the recorded level is less than the quiet-day level, the ionospheric absorption can be measured quantitatively.

C. Important Riometer Operating Parameters

There are many adjustments on riometers that will affect the data quality. Two of the more important of these are adjustments to the receiver bandwidth and the integration time constant. These can be related to the ability of the riometer to measure a given noise power by:

$$\frac{\Delta P}{P} \propto \frac{1}{\sqrt{BT}} \quad (4)$$

where

ΔP = uncertainty in measuring P

P = measured power

B = receiver bandwidth (predetection)

T = integration time constant (postdetection).

Practically, this means that the wider the bandwidth and the longer the integration time constant, the smaller the uncertainty or trace width. Unfortunately, with wider bandwidths the riometer is more prone to interference; and with long integration time constants, the riometer is not able to respond to fast variations in absorption. In actual operation, a compromise must be made between these conditions. Two typical modern riometers which were used at the Nuff Creek Station and are described herein have the following available bandwidths and integration time constants:

Riometer Bandwidth (kc)	
ARI	EMI
100	60
30	30
15	15
3.5	3.5

Riometer Integration Time Constant (seconds)	
ARI	EMI
2.5	2
6	7
16	20
27	--

The antenna used with the riometer is another important factor. A tilted antenna will see a different portion of the sky from that seen by an antenna looking directly overhead, and will therefore produce a slightly different quiet-day curve. Rotating an antenna with unequal E and H planes will also result in a different quiet-day curve, for the same reason. Finally, the sum of the sidelobes of many antennas can contribute almost as much power as the main lobe of the antenna; and since each lobe looks at a different portion of the sky, much more of the sky is covered than might be expected.

III NUFF CREEK SITE

A. General Description

The Nuff Creek site, operated by SRI, is located in a steep-sided valley near Half Moon Bay, California (lat. $37^{\circ}30.6'N$, long. $122^{\circ}23.8'W$), several miles from any power lines or other sources of interference. The equipment is powered by thermoelectric generators and a stand-by gasoline-powered generator.

The Nuff Creek station is unmanned. A technician services the equipment weekly, spending approximately two hours at the site each visit. During each visit, the technician puts a time mark and calibration on each riometer chart record; this operation is performed manually, usually with the aid of WWV time broadcasts. Errors between time marks and chart time divisions are distributed linearly throughout the chart before the charts are lined up to be photographed.

B. 30 Mc Riometer

The 30 Mc EMI riometer is a standard instrument made by EMI Products, Inc. The load resistor for the Type 5845 servo noise diode is 3320 ohms. The recorder used is an Esterline-Angus pen recorder with a chart speed of 3 inches per hour. Full-scale deflection was adjusted with a shunt until an antenna attenuator was installed. This riometer design was originally the Dorsett riometer. It then became the EMI riometer, next the Western Electrodynamics riometer, and finally the Western Electronics riometer (Loveland, Colorado).

The antenna used with the EMI riometer is a Hygain three-element Yagi with an E-plane half-power beamwidth of 65° and an H-plane half-power beamwidth of 110° . The impedance of the antenna is 47 ohms. The antenna feedline is an RG-8A/U cable with an estimated loss of 1 dB. The antenna polarization is parallel to the valley, $N59^{\circ}E$ true ($N42^{\circ}E$ magnetic).

C. 18 Mc Riometer

The 18 Mc ARI riometer is an Aerospace Research, Inc. (Brighton, Massachusetts) Model 100-A instrument modified to include a 50-ohm servo noise diode load resistor, which requires attenuation in the antenna lead (see the chronological log in Sec. IV). The recorder used is an Esterline-Angus pen recorder with a chart speed of 3 inches per hour; the full-scale deflection is adjusted to 5.0 mA. A 5722 noise diode is used.

The antenna in use with the 18 Mc ARI riometer is a special seven-element ring array designed for low sidelobe response.* The antenna polarization is S147°E true. The beamwidth is approximately circular and 40° between the half-power points. The antenna impedance is 59 ohms. The antenna feedline is an RG-8A/U cable with an estimated loss of 2 dB.

* R. B. Dyce et al., "Cosmic Noise and Ionosphere Studies--Project VELA," Final Report, Part I, Contract AF 49(638)-989, SRI Project 3498, Stanford Research Institute, Menlo Park, California (December 1963).

IV DATA

A. Chronological Log

1. 30 Mc Riometer Chronology, 3 January to 19 June 1966

Bandwidth 30 kc; integration time 2 seconds; frequency sweep OFF; minimum detector OFF; antenna attenuator 6 dB (changed as below).

1966

3 January		First record in this period
3 January	2208	Changed antenna attenuator from 6 to 5 dB
5 January	1000-2355	Series of abrupt rises and drops are equipment problems
7 January	2125	Changed antenna attenuator from 5 to 4 dB
10 January	1850	Changed antenna attenuator from 4 to 5 dB
	2020	Repaired antennae
	2250	Changed antenna attenuator from 5 to 4 dB
13-14 January		Servo noise diode tube going bad; riometer taken to laboratory for repairs
25 January	2155	Riometer back to site, repaired; 4 dB antenna attenuator
29 January	1730-2000	This hash probably due to equipment
31 January	0022	Rise in record due to equipment
	2215	Bandwidth changed from 30 to 15 kc
3-4 February		Abrupt jumps in record probably due to equipment
11 February		Rise at 1430 and fall at 2030 probably interference or due to equipment
13 February		Abrupt drops and rises probably due to equipment
14 February	1745	Reoriented antenna-wind had moved its polarization
	1800	Changed antenna attenuator from 4 to 2 dB.

21 February	1800	Reoriented antenna
28 February	1755	Reoriented antenna
1 March	0310-0320	Abrupt drop probably due to equipment
5 February	1700-1720	Probable equipment problem
12 February	1310-1635	Abrupt rise probably interference or due to equipment
17 March	0400-1400	Abrupt rise and drops probably due to equipment
20 March	0845-1555	Rise in record probably due to interference or equipment
30 March	1510-1750	Rise due to equipment or interference
31 March	0520-0850	Abrupt rises and drops probably due to equipment or interference
1 April	1015-1810	Abrupt rises and drops probably due to equipment or interference
24 April	1410	Abrupt drop probably due to interference or equipment
26-29 April		Abrupt rises and drops probably due to interference
2 May	0130-0150	Abrupt drop probably due to equipment
8-9 May		Riometer limited in amplitude by power supply
11-17 May		Riometer amplitude limited by power supply
17 May	1620-1755	Install new orifices in propane power supply
17-18 May	1800	Servo noise diode going bad, replaced
28-29-30-31 May		Abrupt rises probably due to equipment
2-19 June		Riometer behaving erratically finally taken to laboratory for repairs
10 June		Antenna attenuator changed from 2 to 3 dB
19 June		Last record in this period.

2. 18 Mc Riometer Chronology, 3 January to 19 June 1966

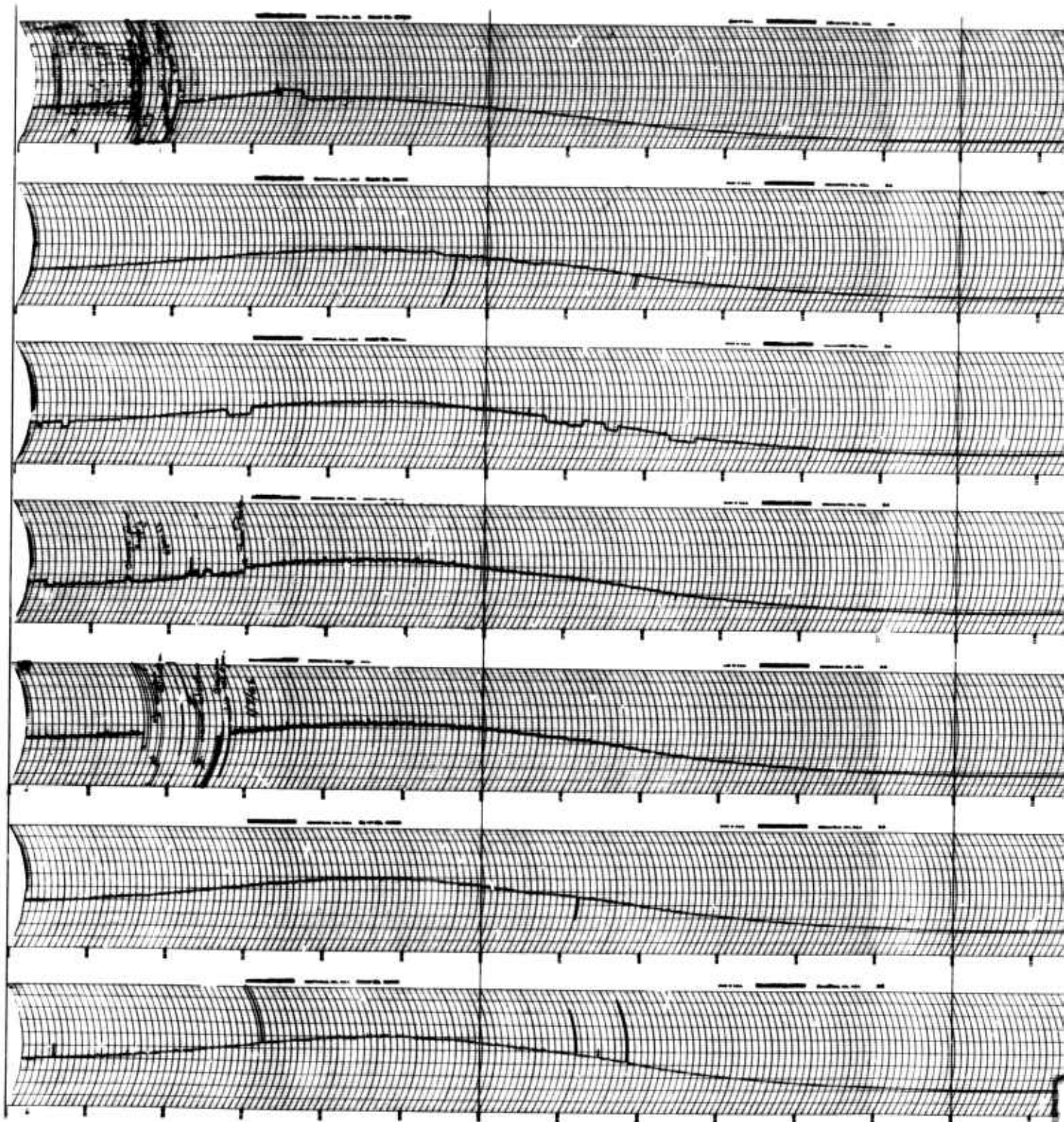
Bandwidth 30 kc; integration time 6 seconds; frequency sweep OFF; minimum detector OFF; antenna attenuator 12 dB.

1966

3 January		First record of this period
9 January	0942	Antenna coaxial lead broken
10 January	2036	Antenna coaxial lead repaired
31 January	2220	Antenna attenuator changed from 12 to 14 dB
28 February	1845	Changed antenna attenuator from 14 to 12 dB
2 March	1800	Changed antenna attenuator from 12 to 13 dB
4 April	1750	Repaired antenna
2-9 May	2130	
	1730	Power-supply problems, abrupt jumps and noise probably due to equipment
14-17 May	0345	More power supply problems, as above
	1720	
17 May	1720	Repaired 2 elements of antenna; one left broken until 18 May
18 May	1800	Repaired antenna; power supply still causing problems, record shows abrupt jumps and drops
19 May to 17 June		Propane generators losing efficiency, need new orifice, cause erratic operation of riometer
2 June	1645	Repaired antenna
10 June	2250	Repaired antenna
17 June	2200	Riometer off air until 15 August
19 June		Last date covered in this period.

B. Chart Records

The chart records appearing on the following pages are reproduced at 20 percent of their original size. The time reads from right to left, and the records begin and end at midnight GMT. The records are in chronological order by frequency; the 30 Mc records are presented first.



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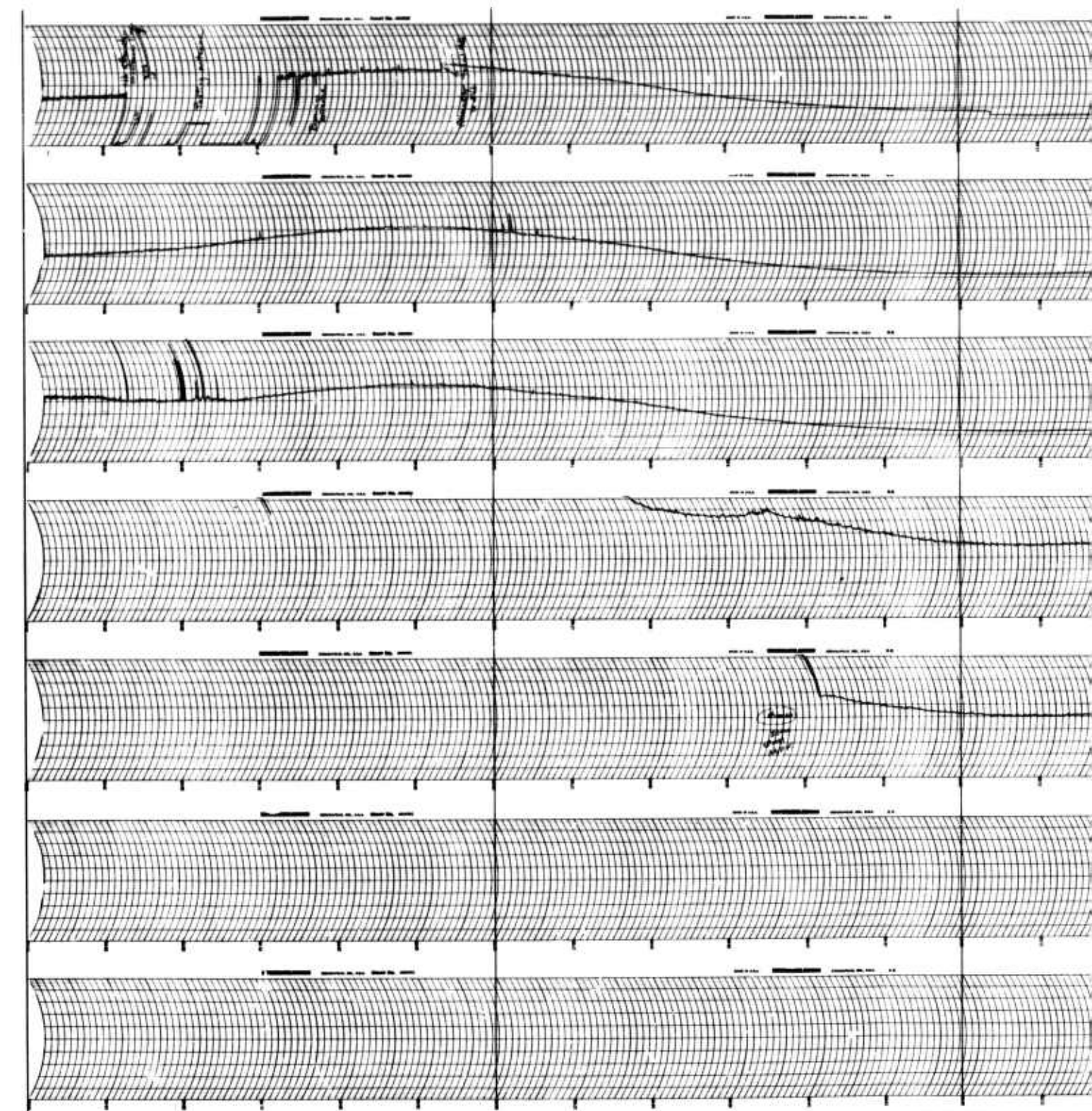
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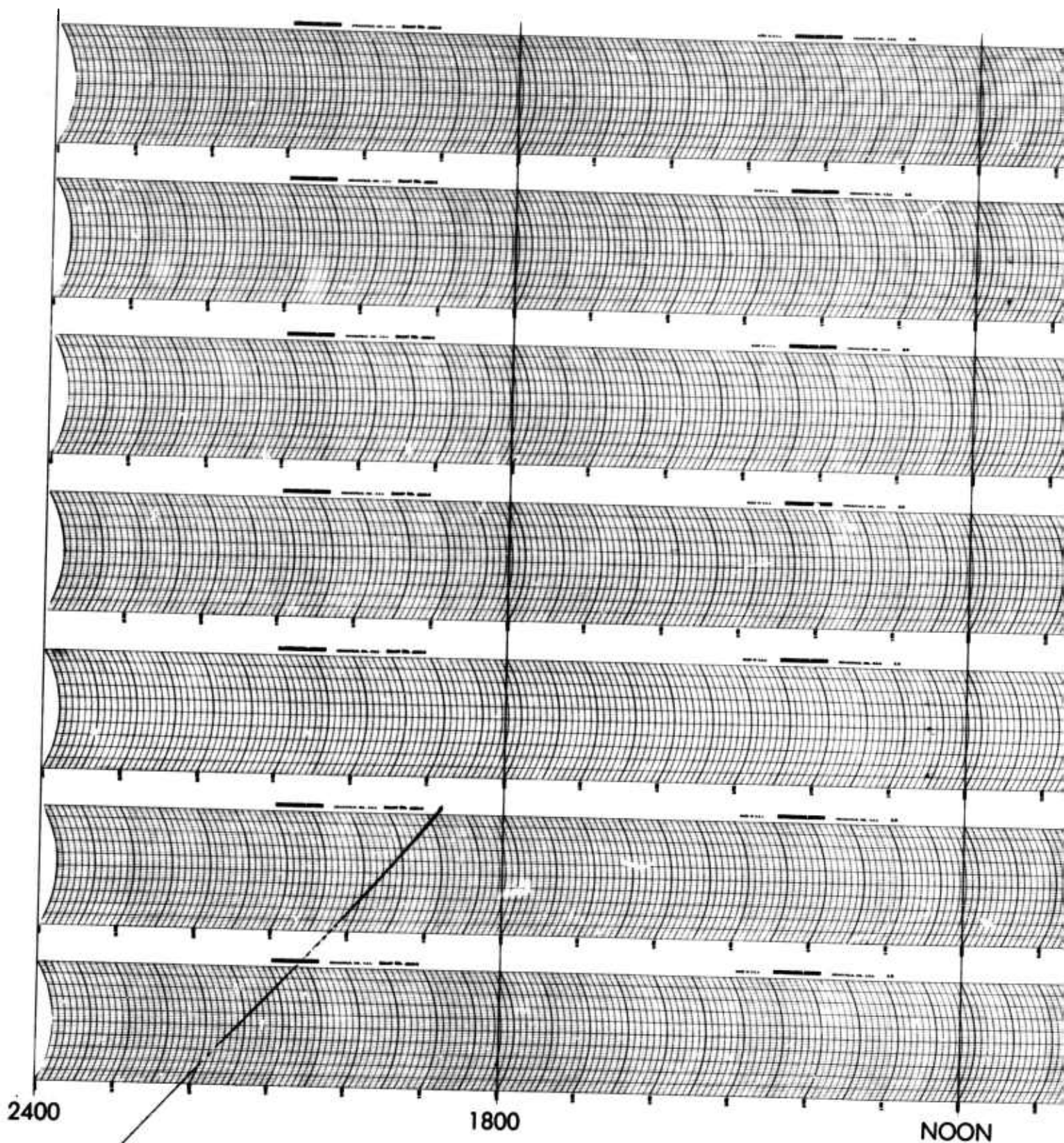
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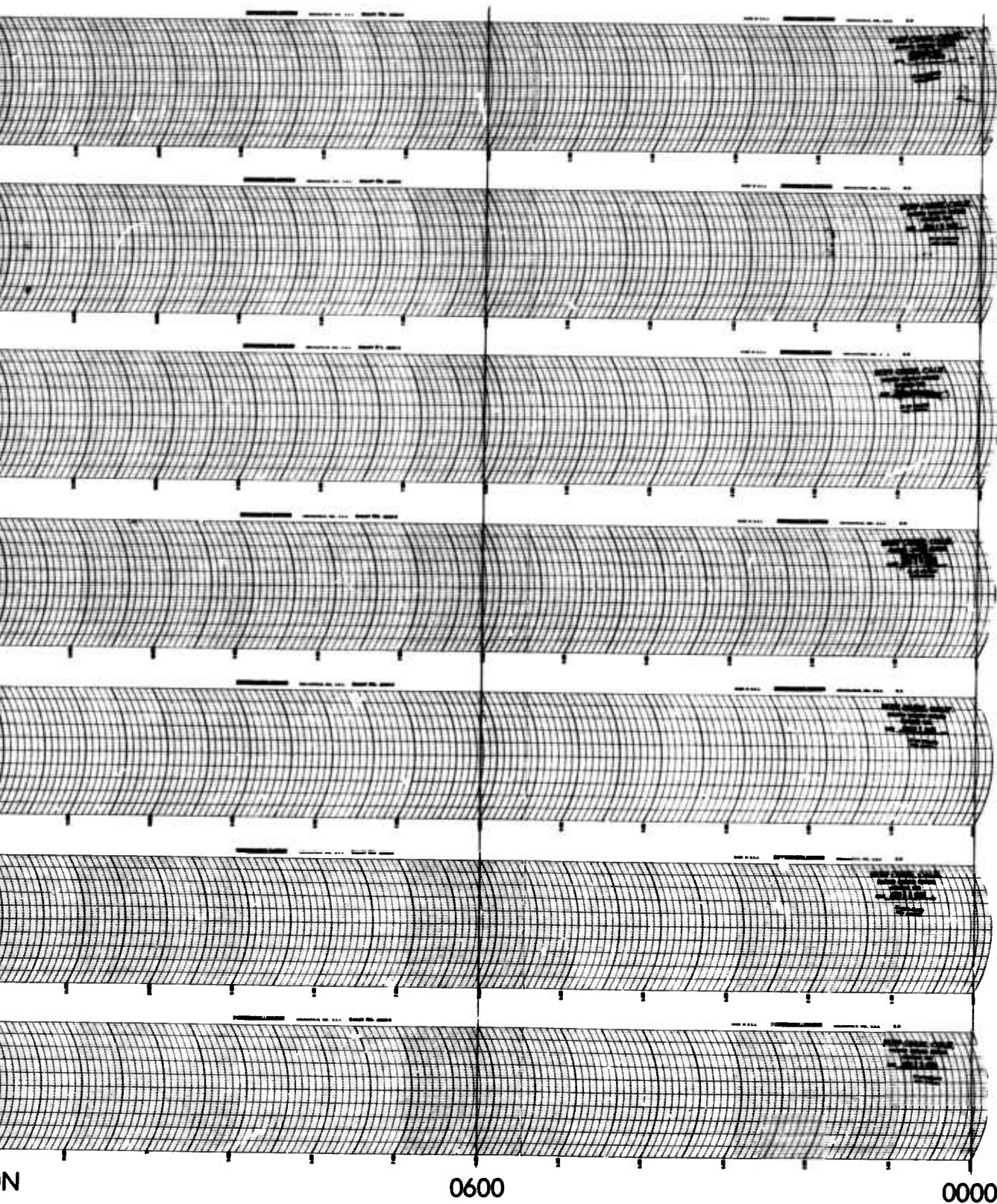
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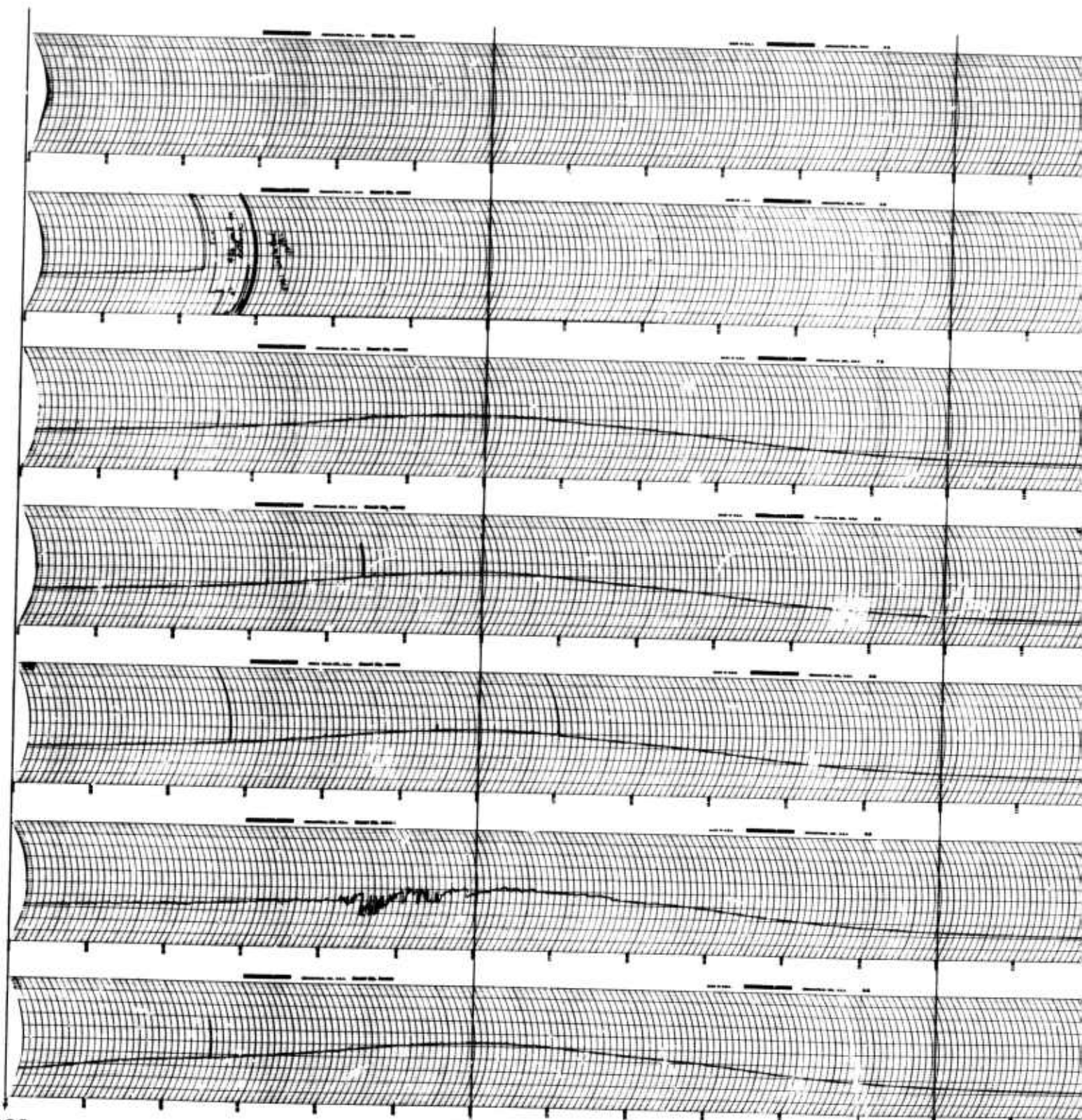
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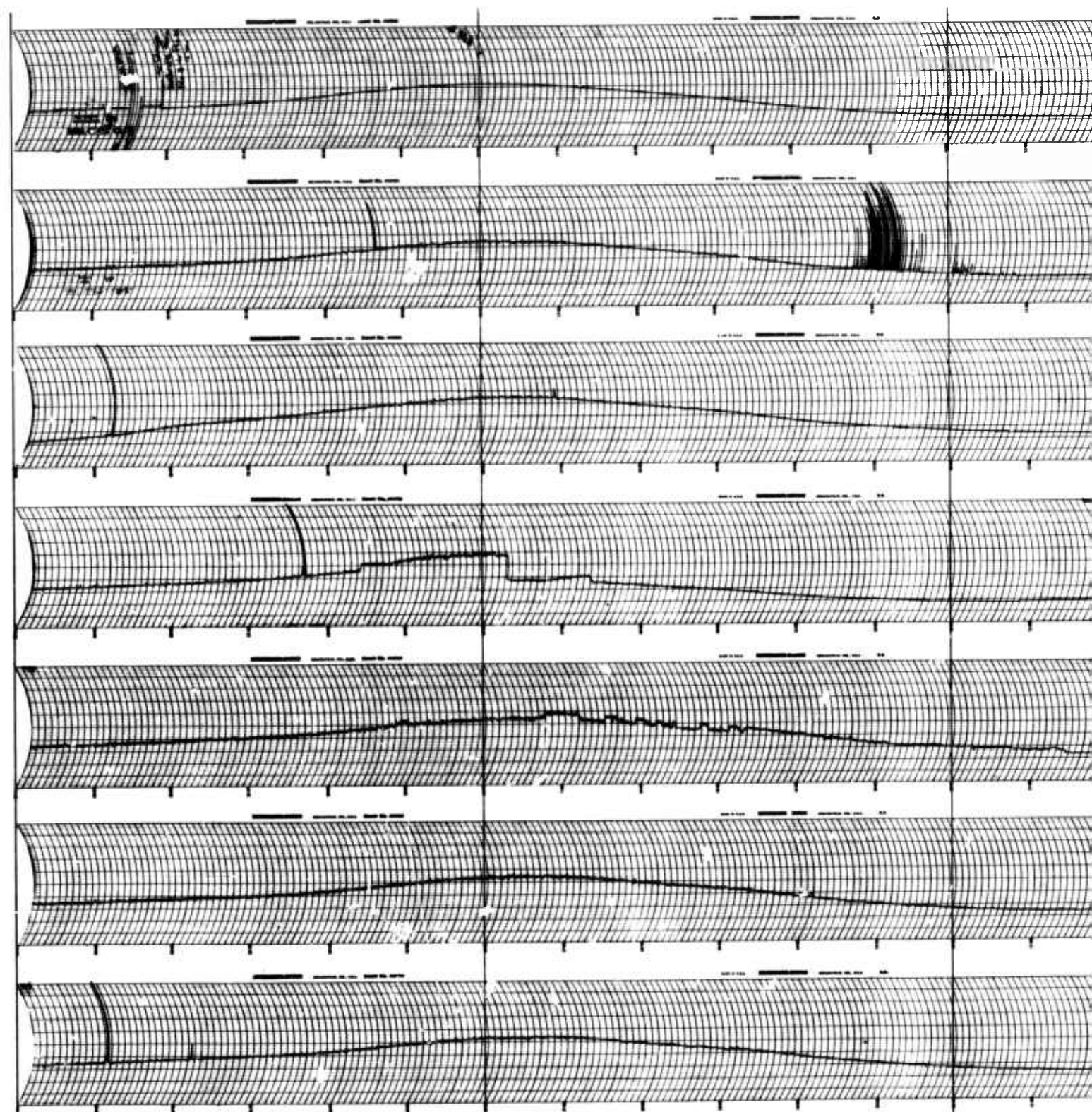
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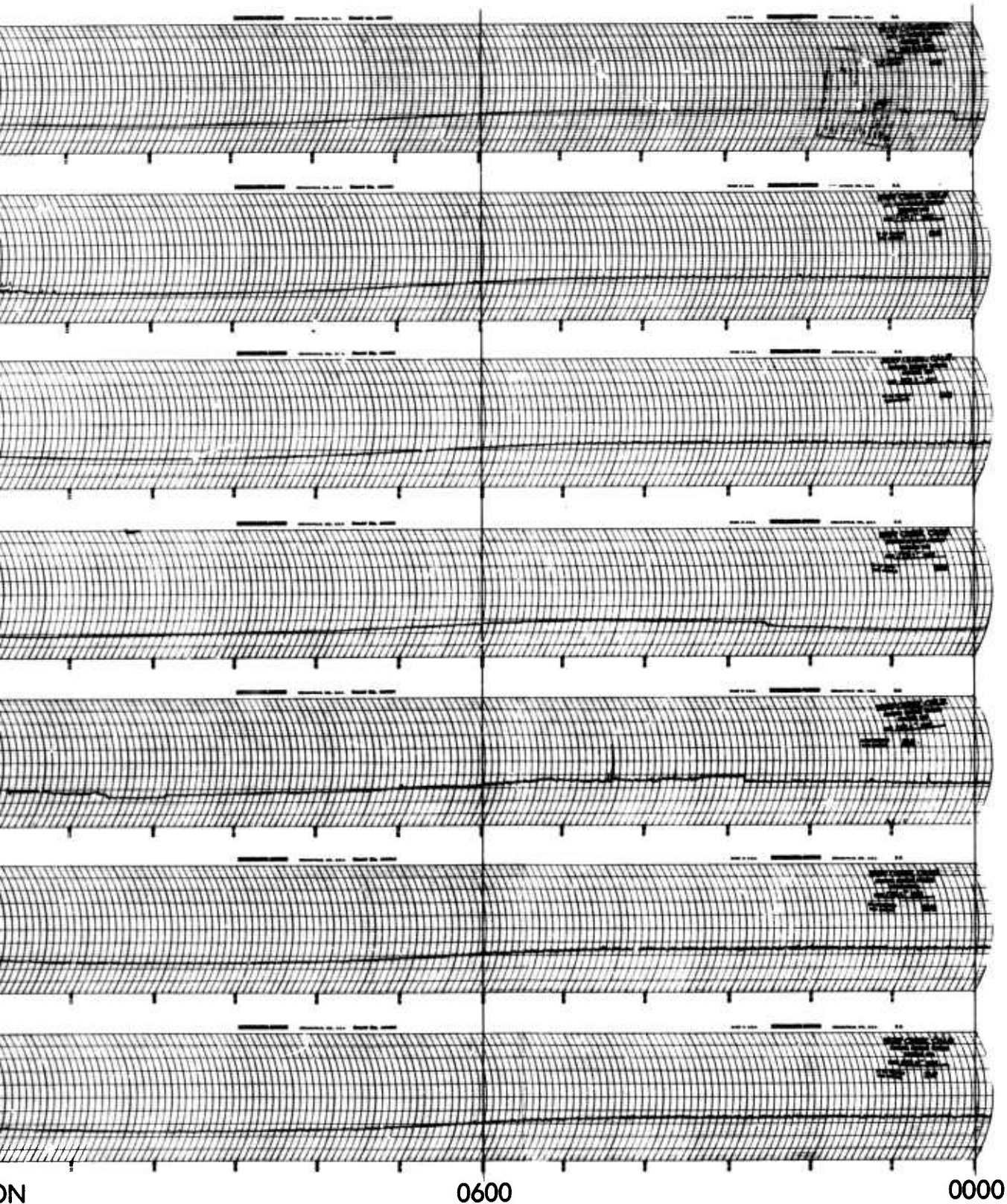
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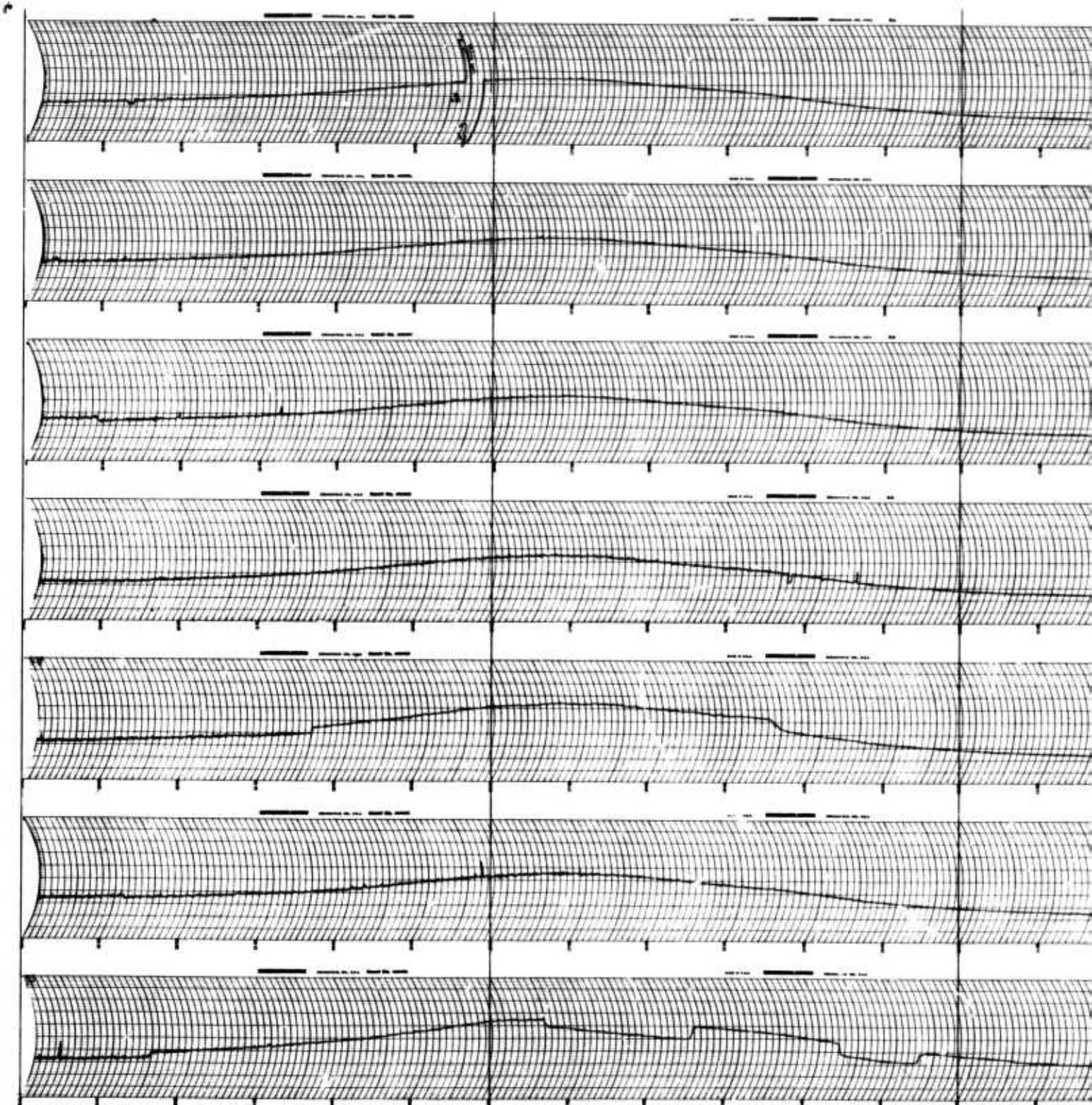
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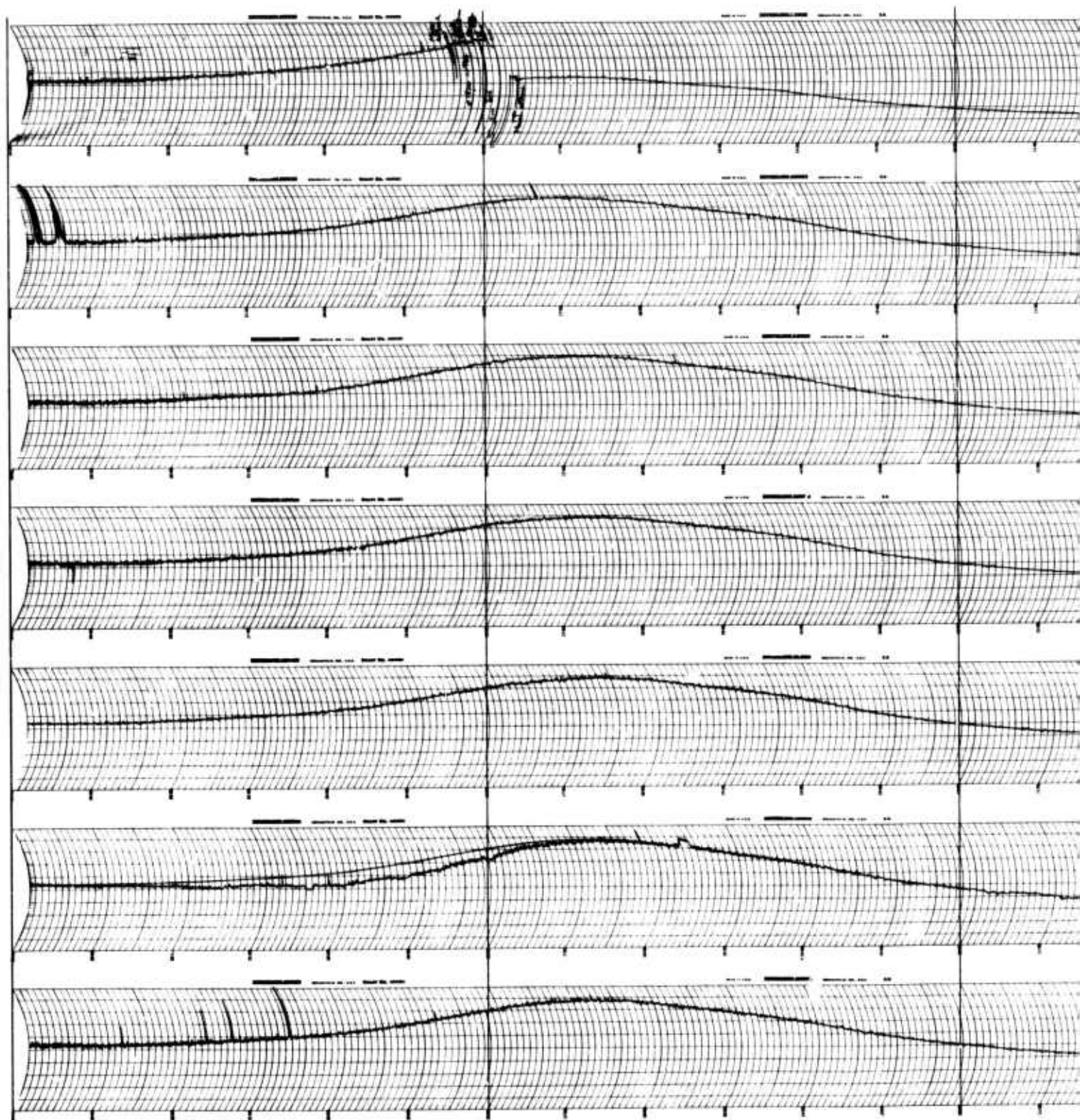
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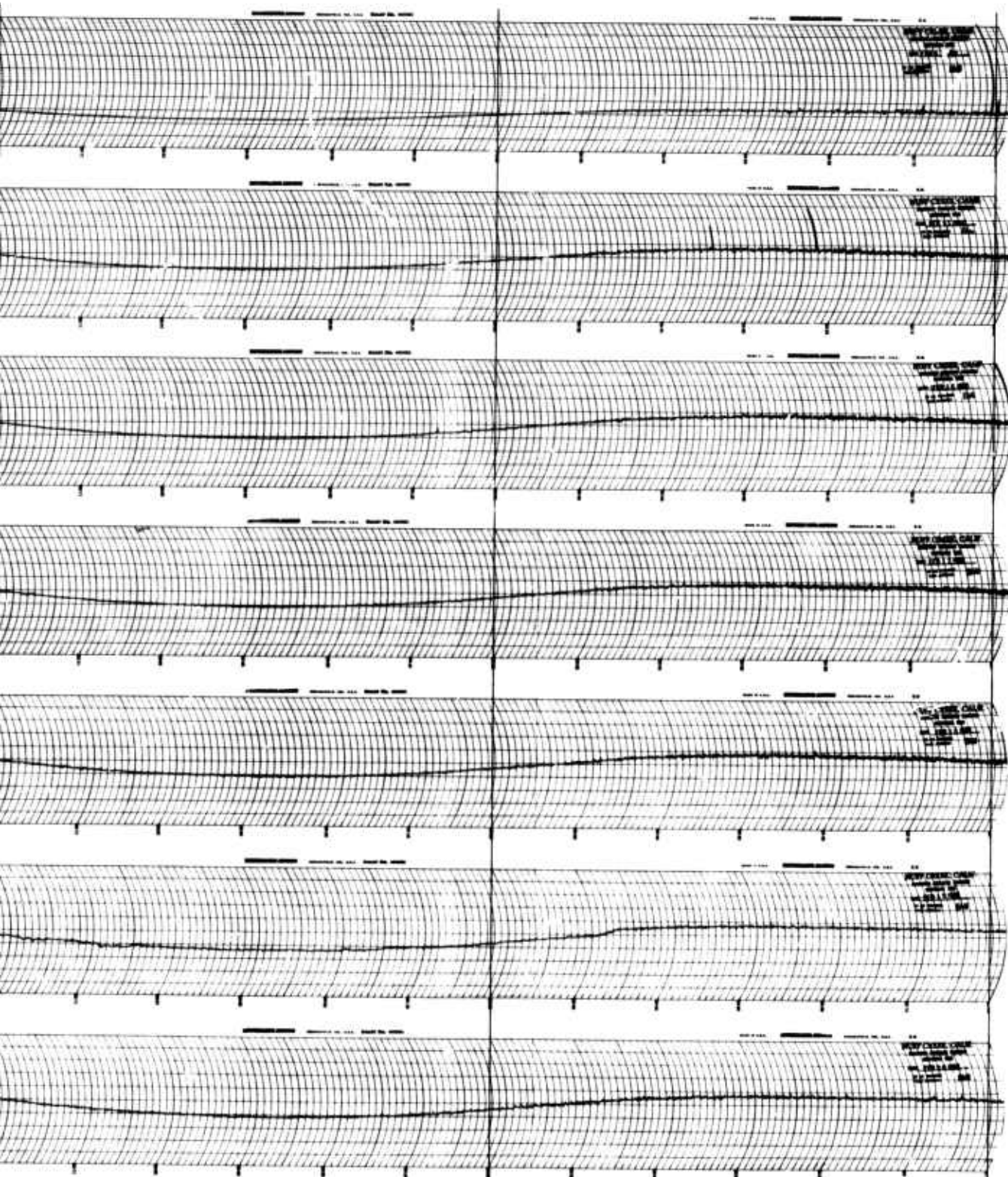
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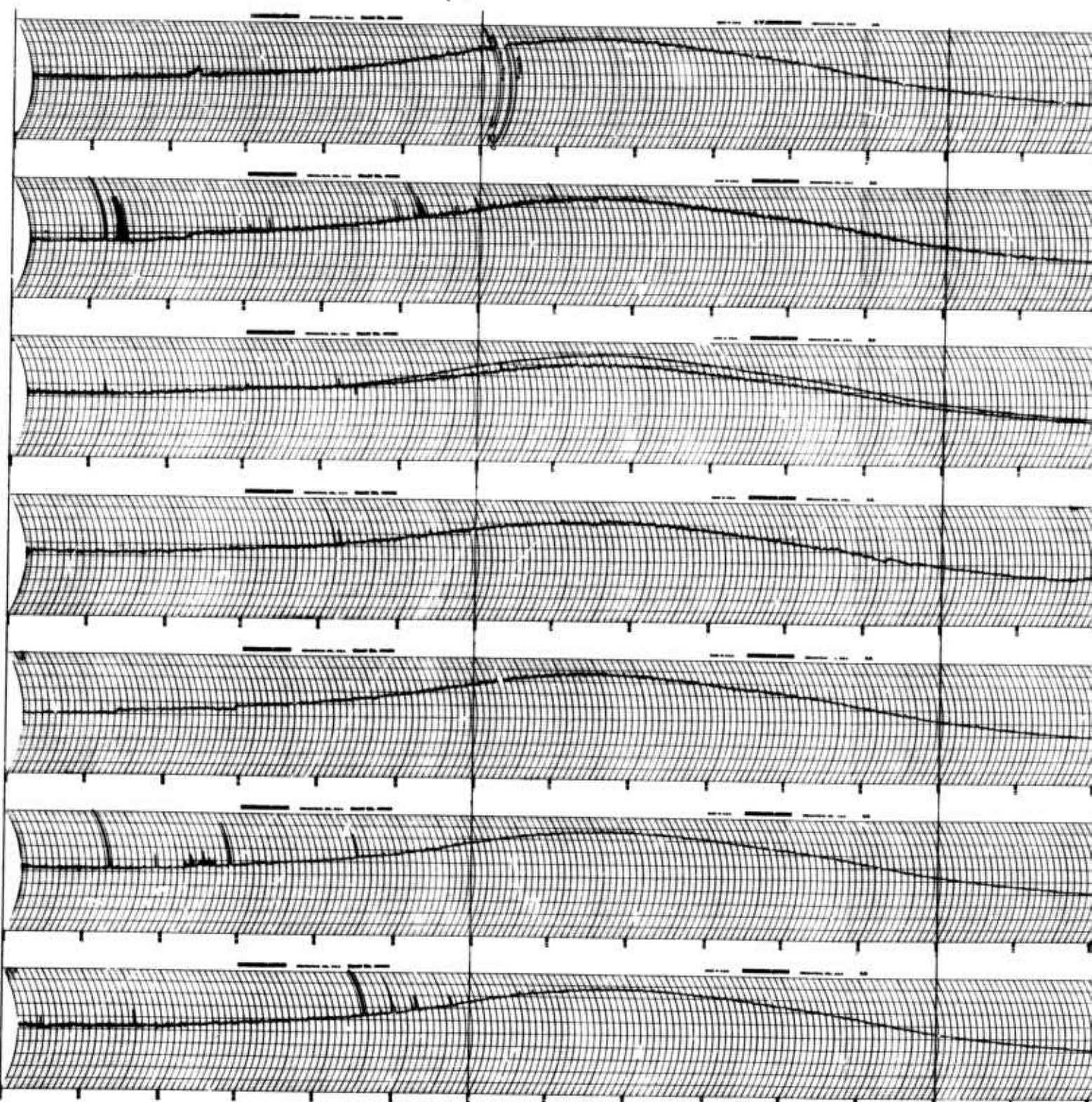
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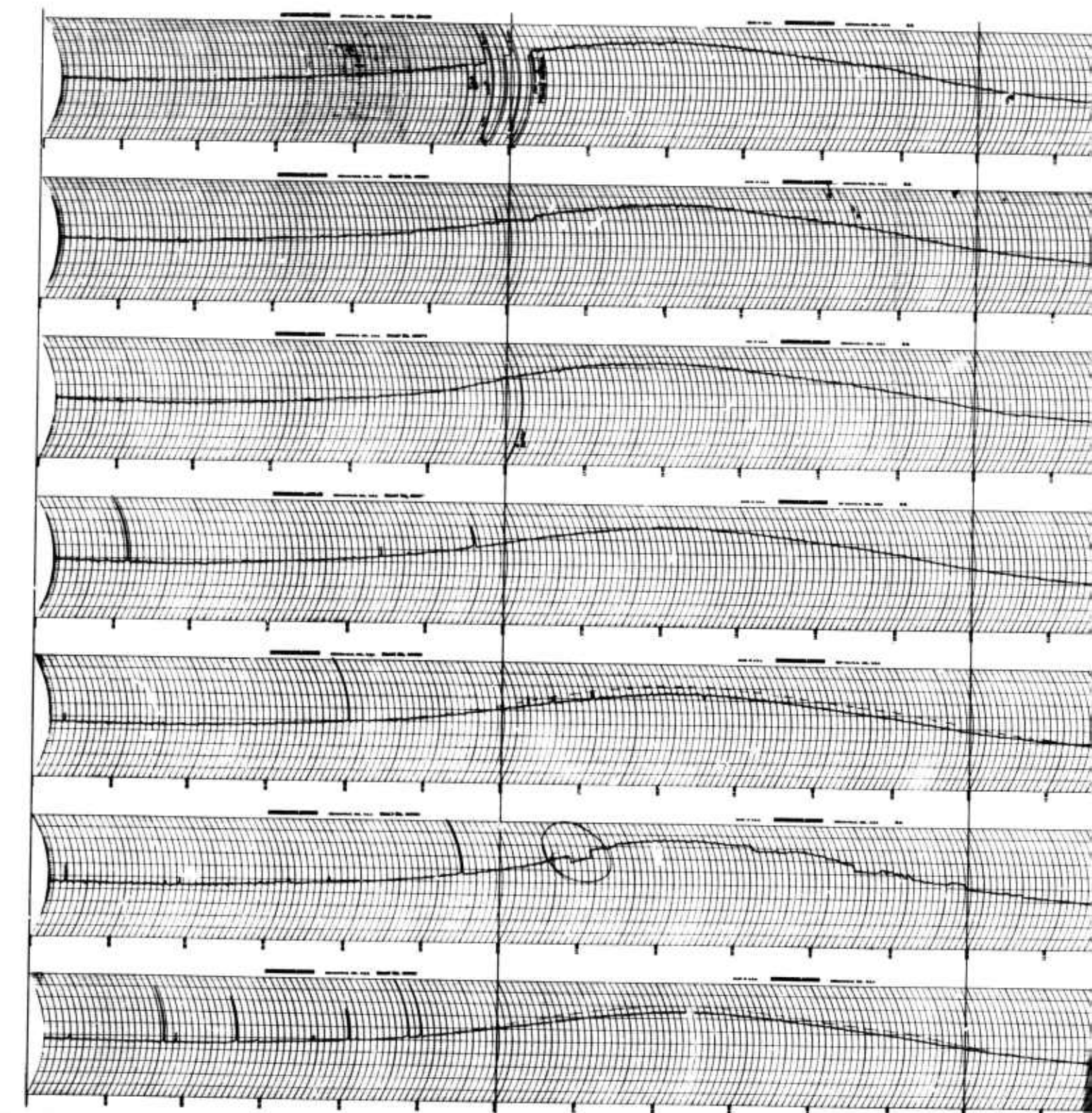
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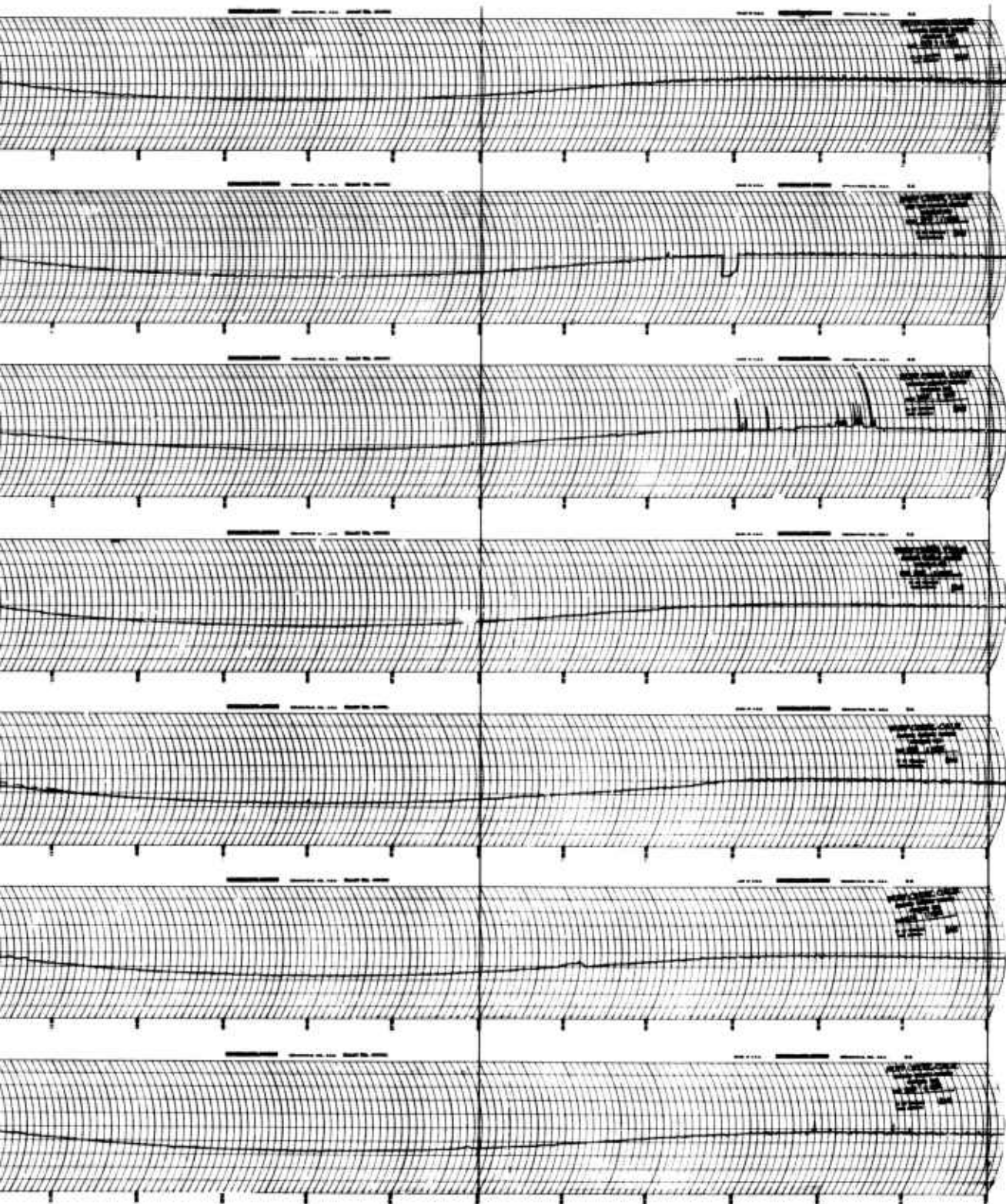
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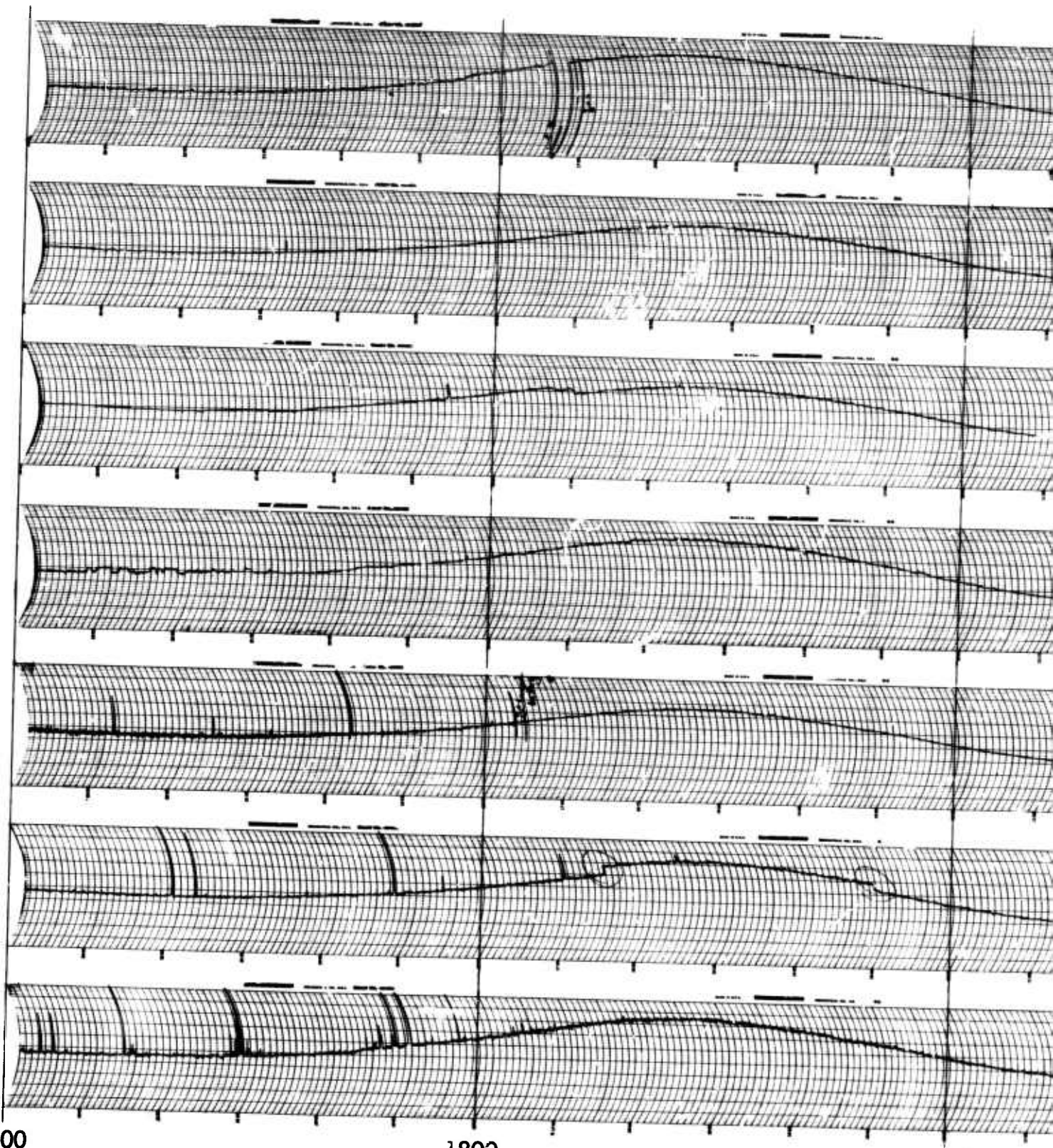
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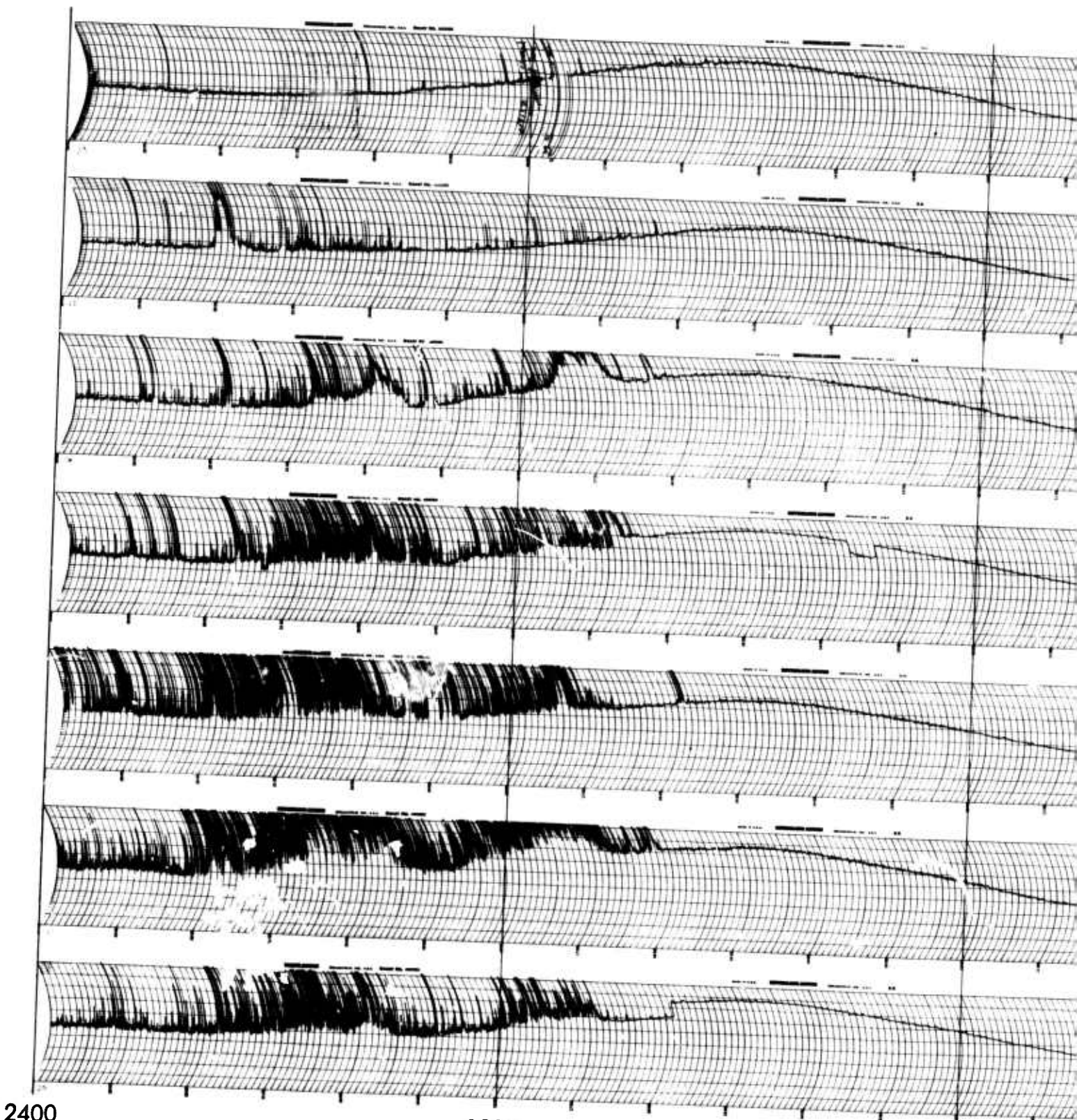
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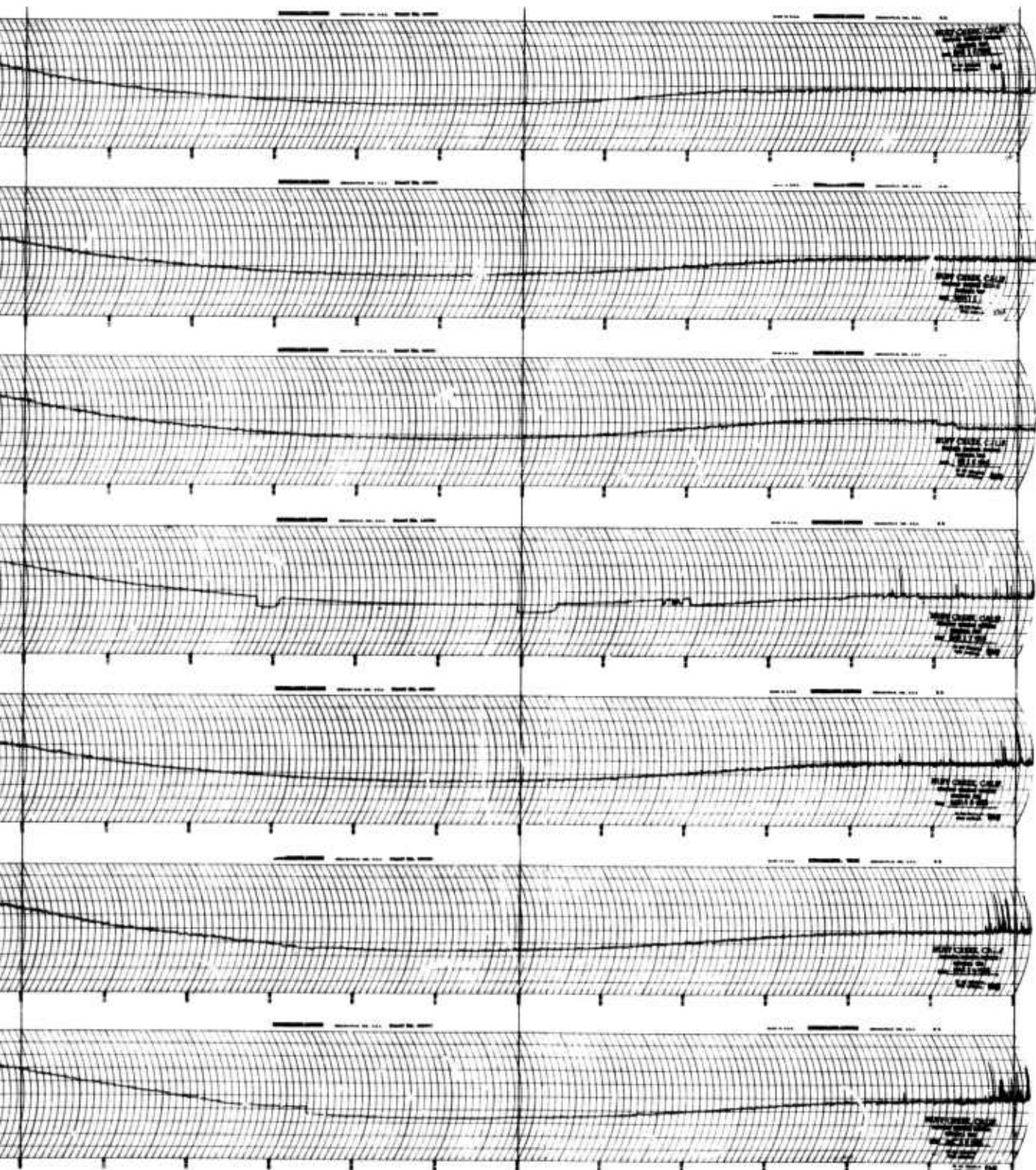
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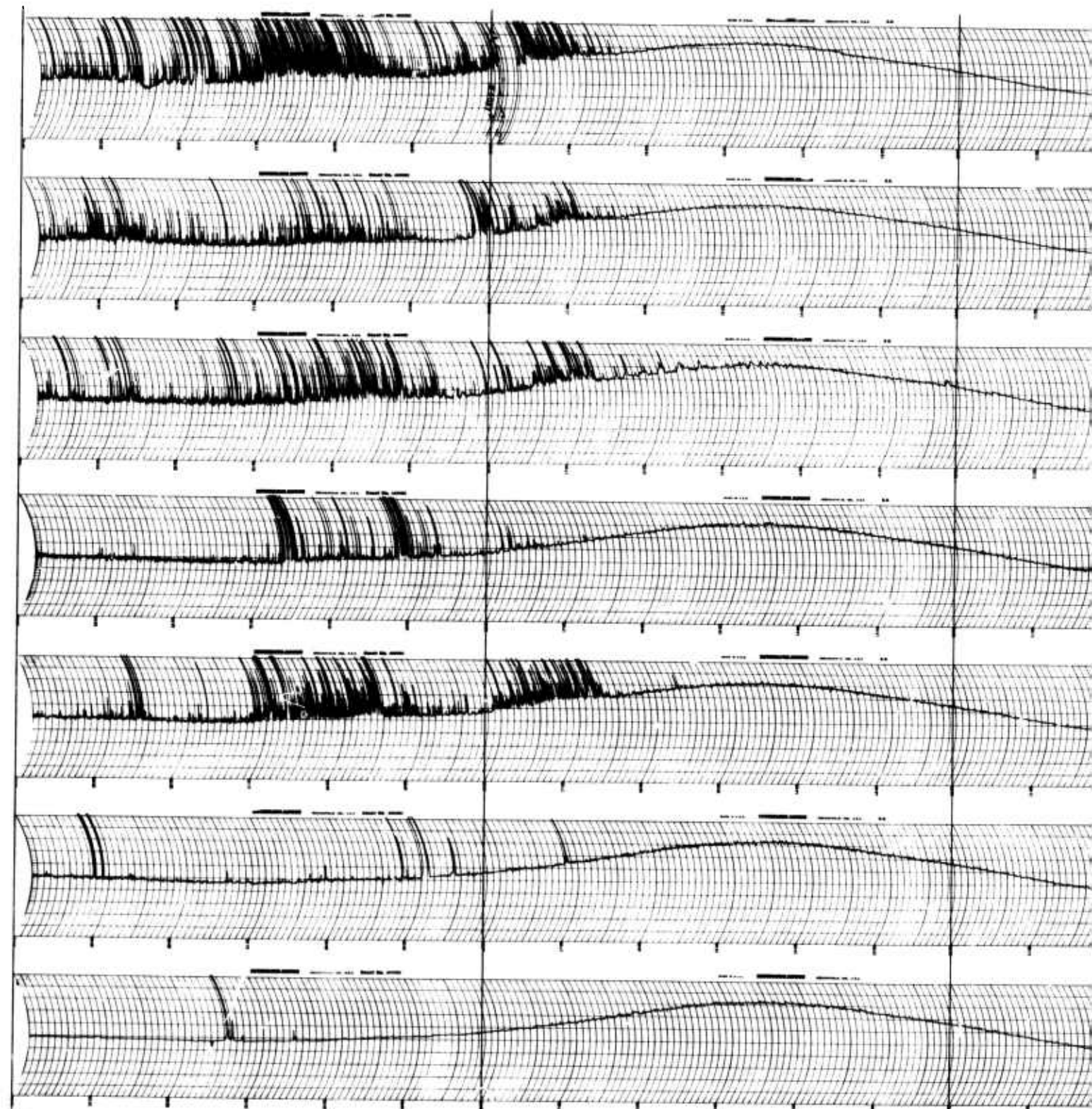
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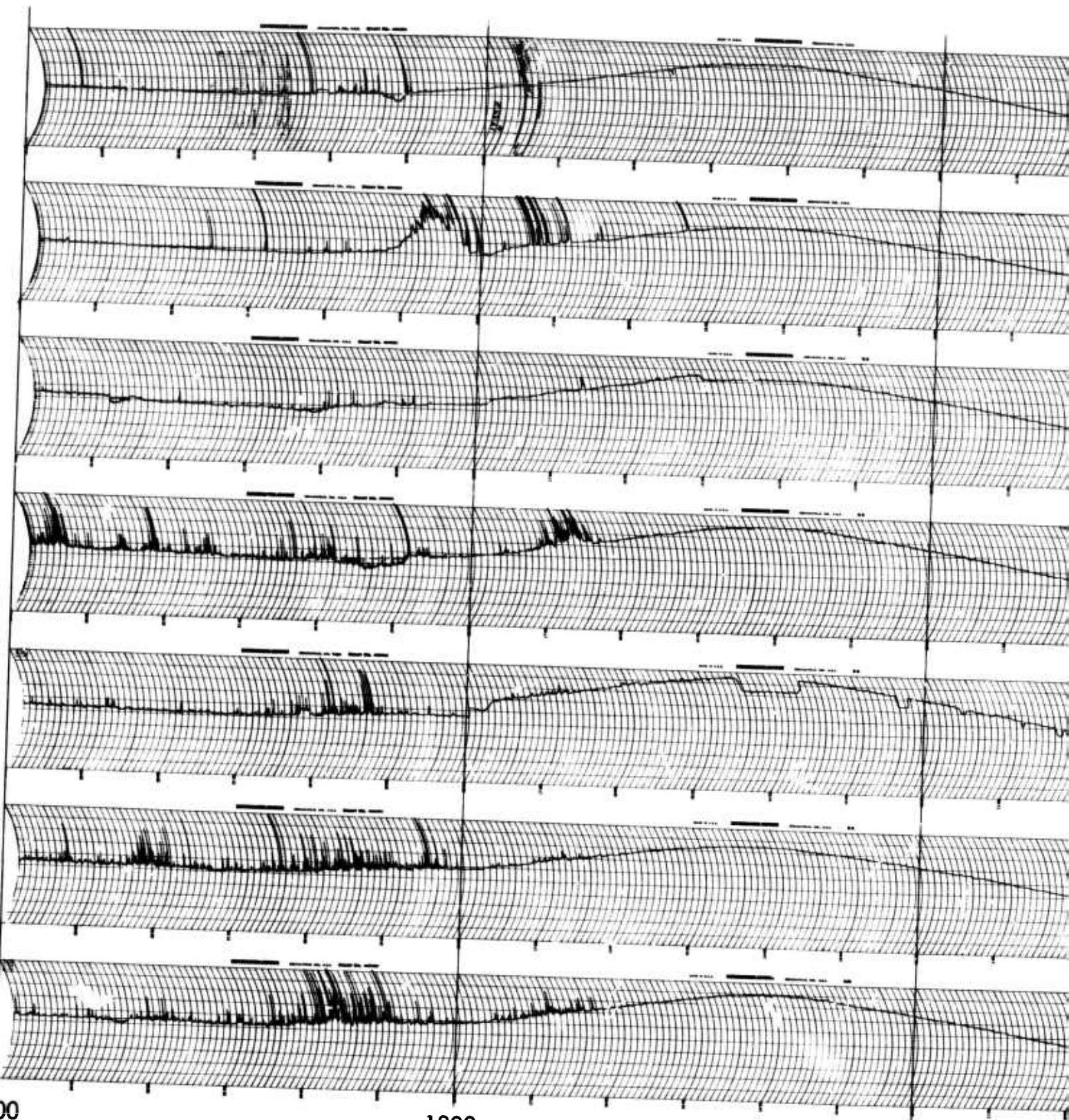
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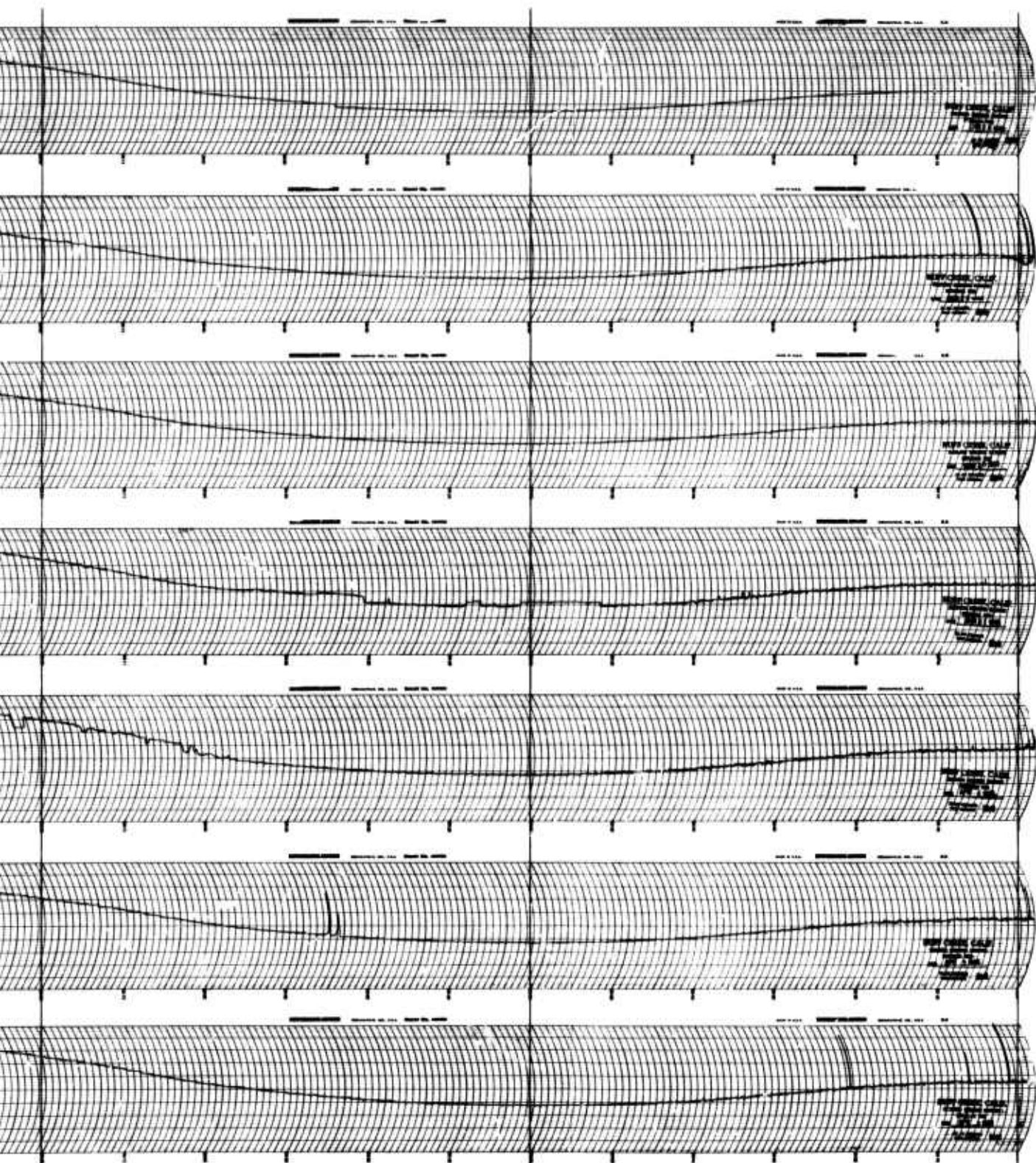
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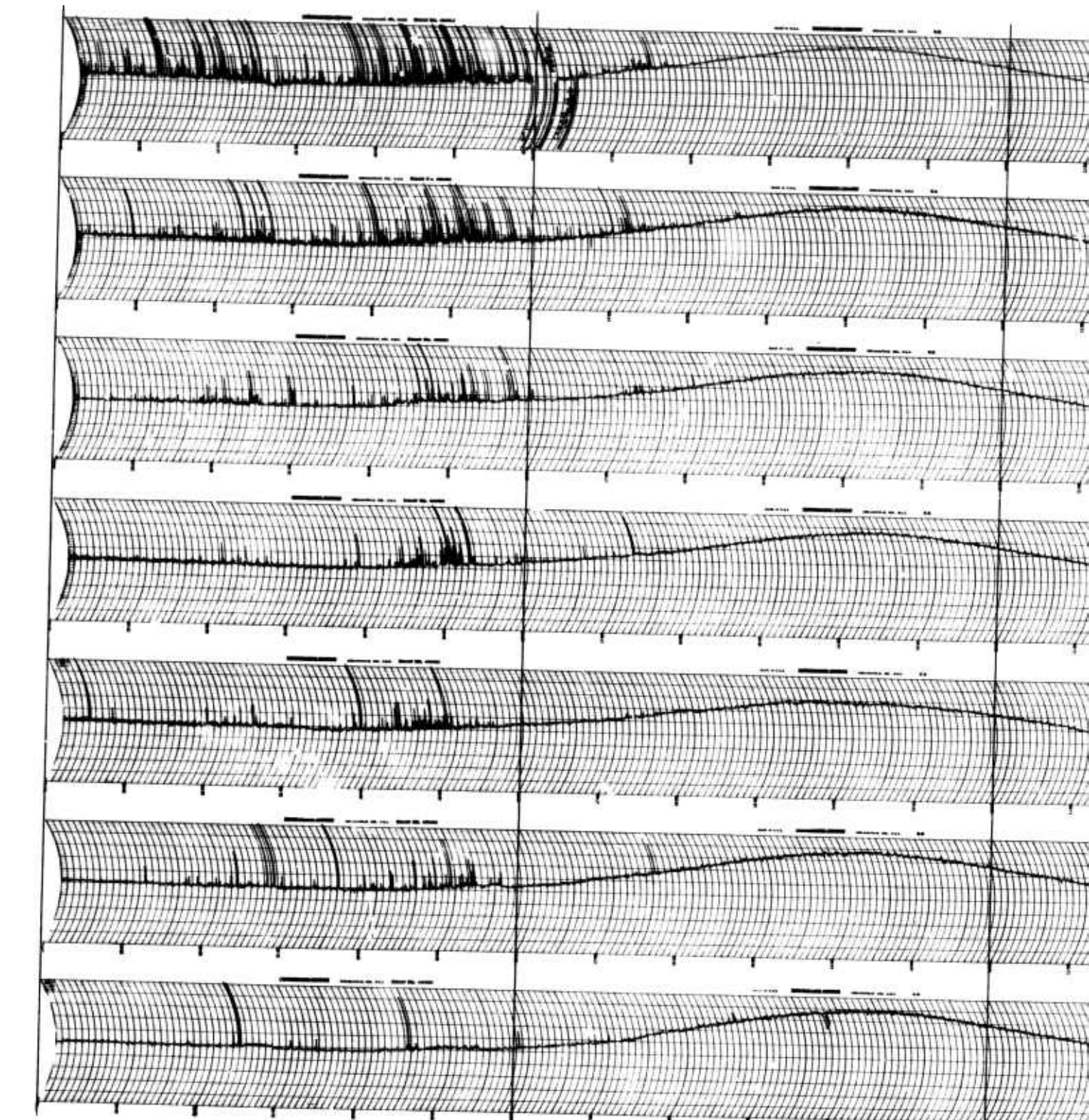
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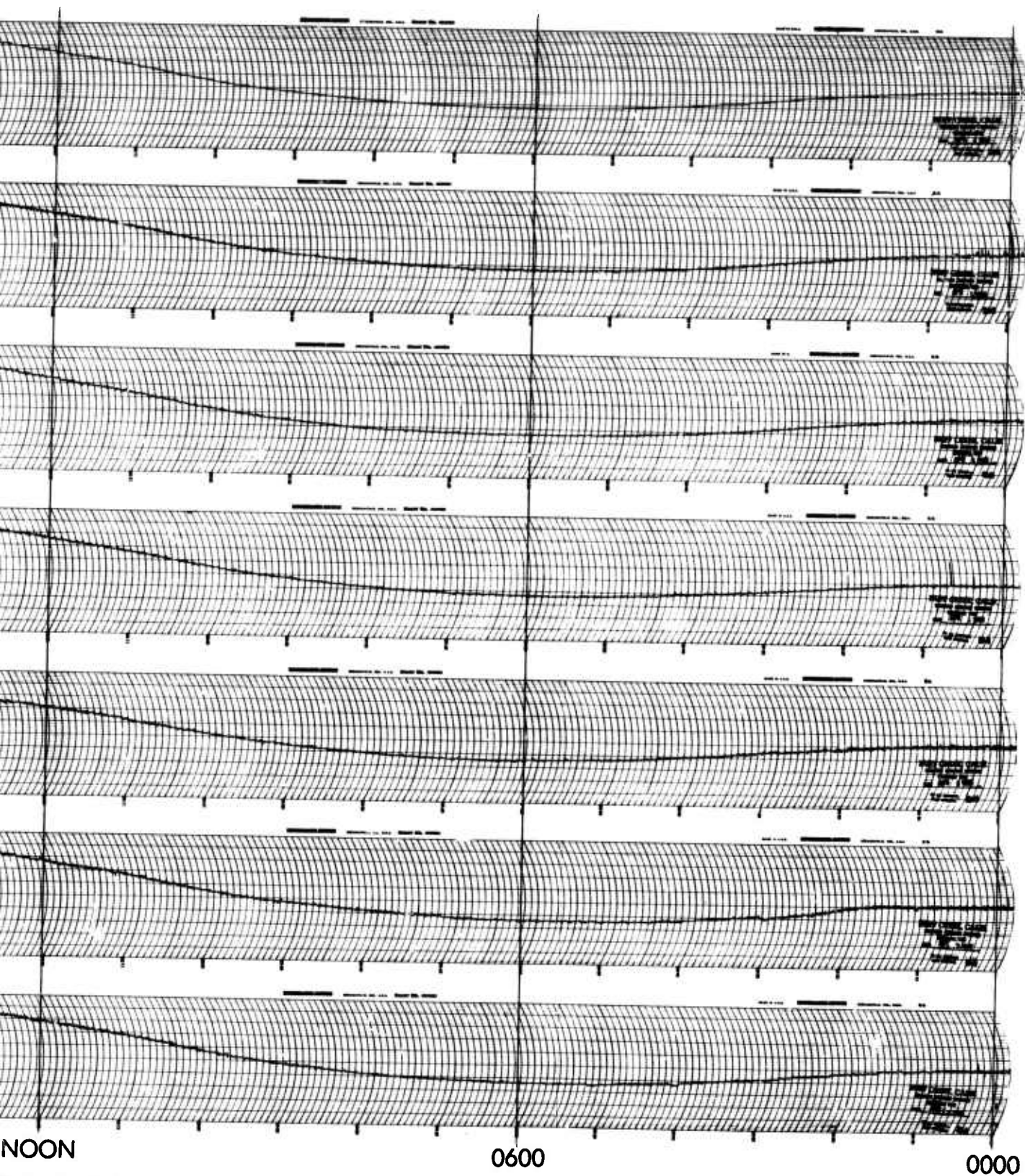
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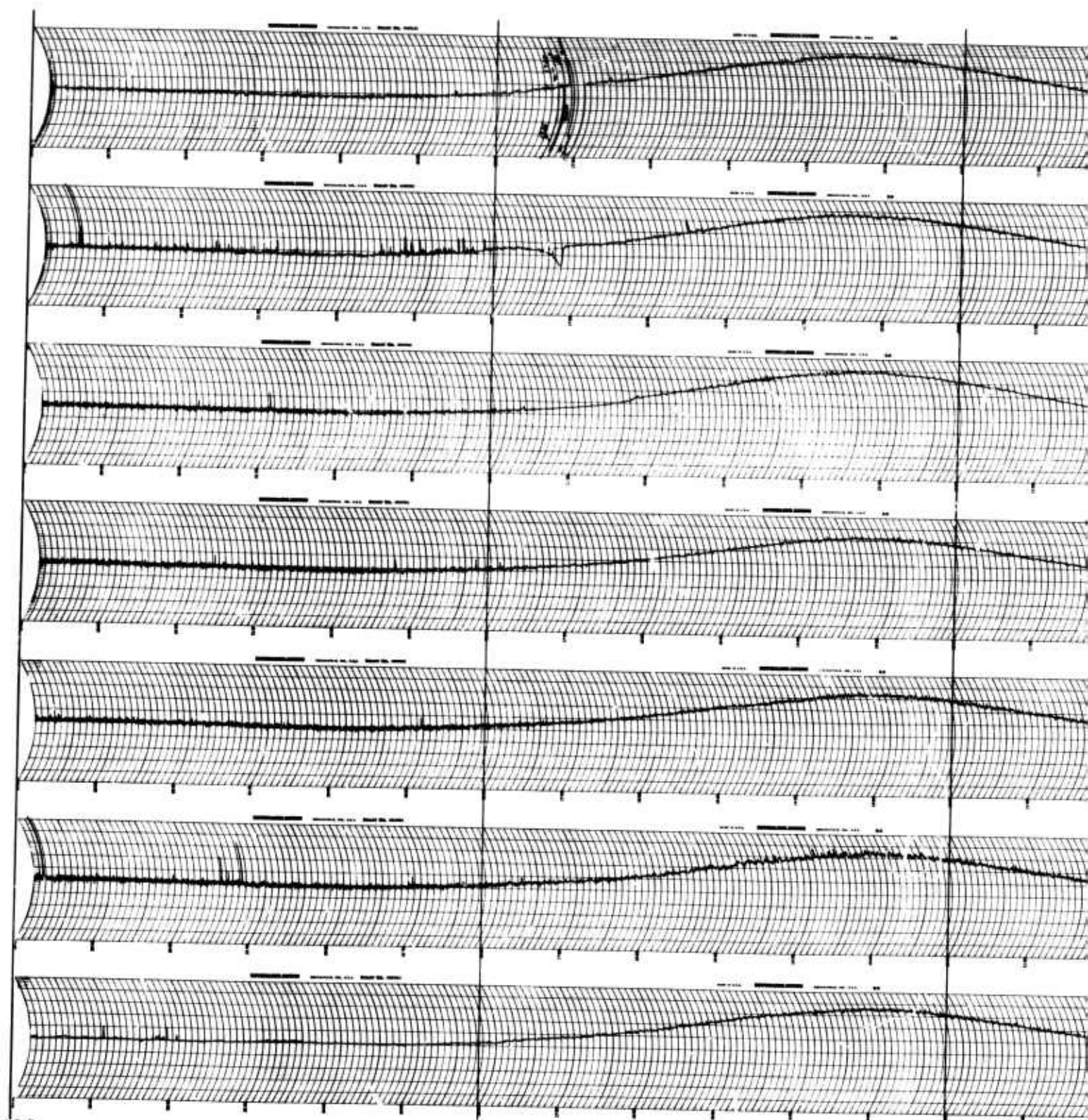
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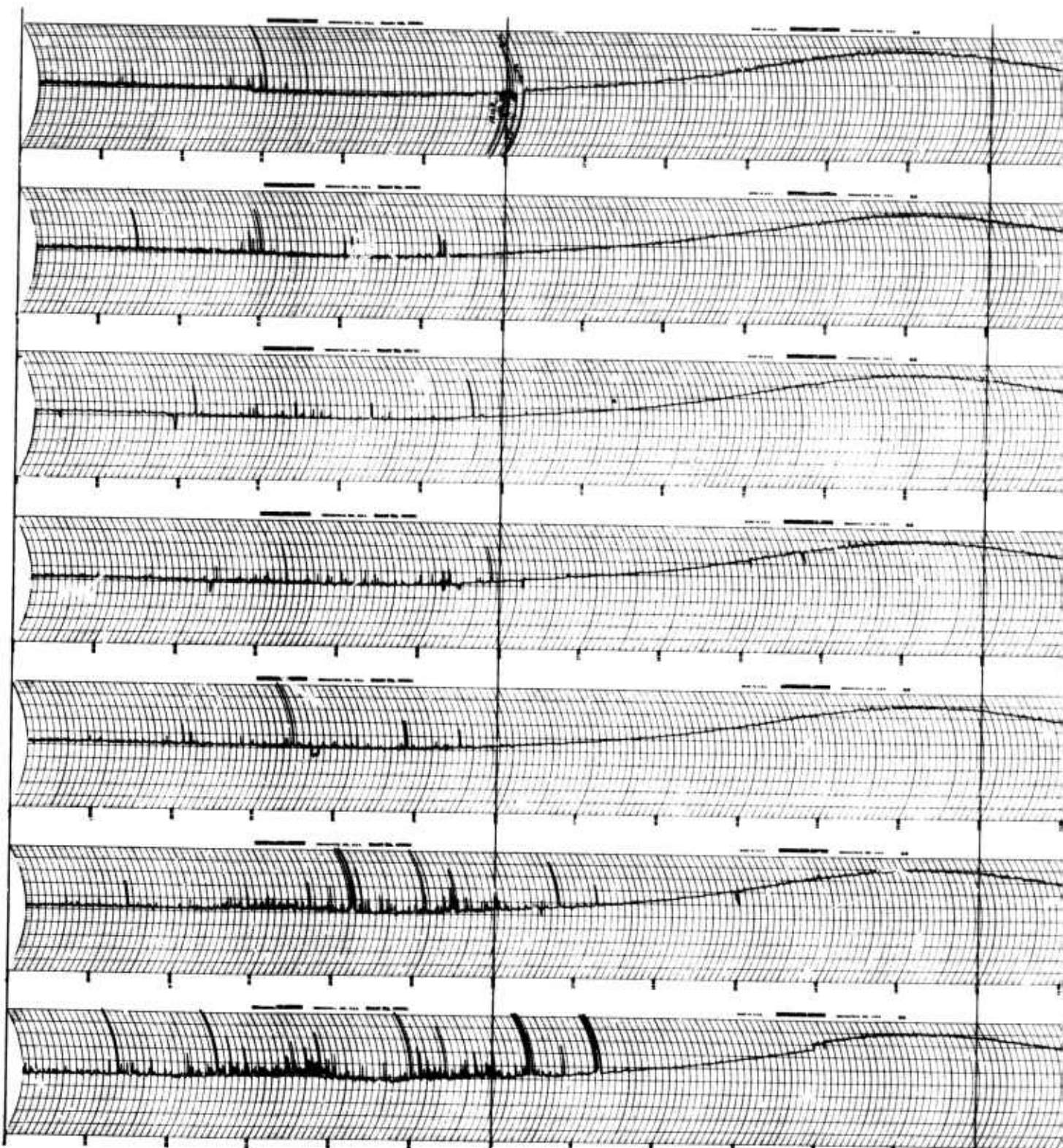
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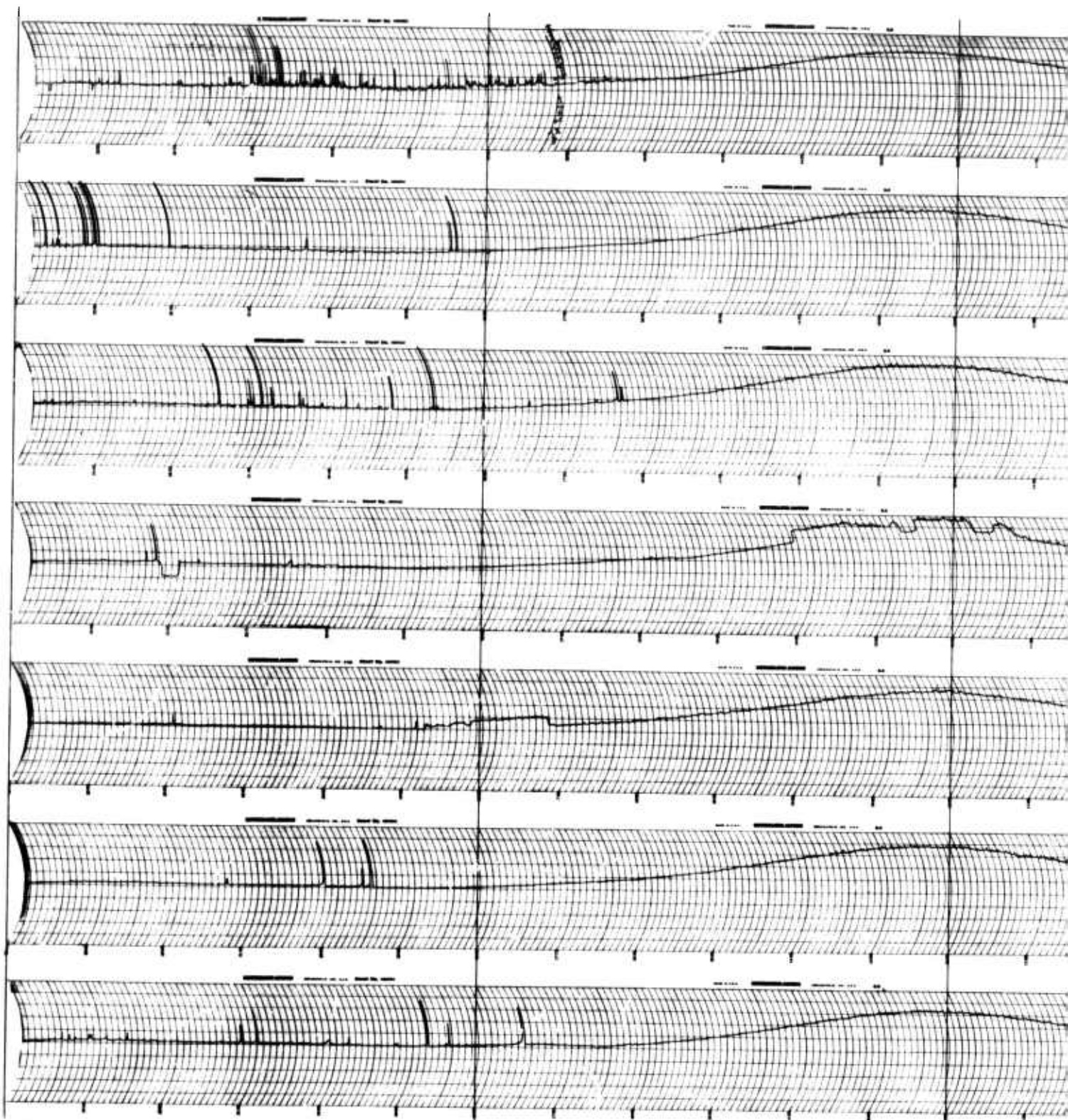
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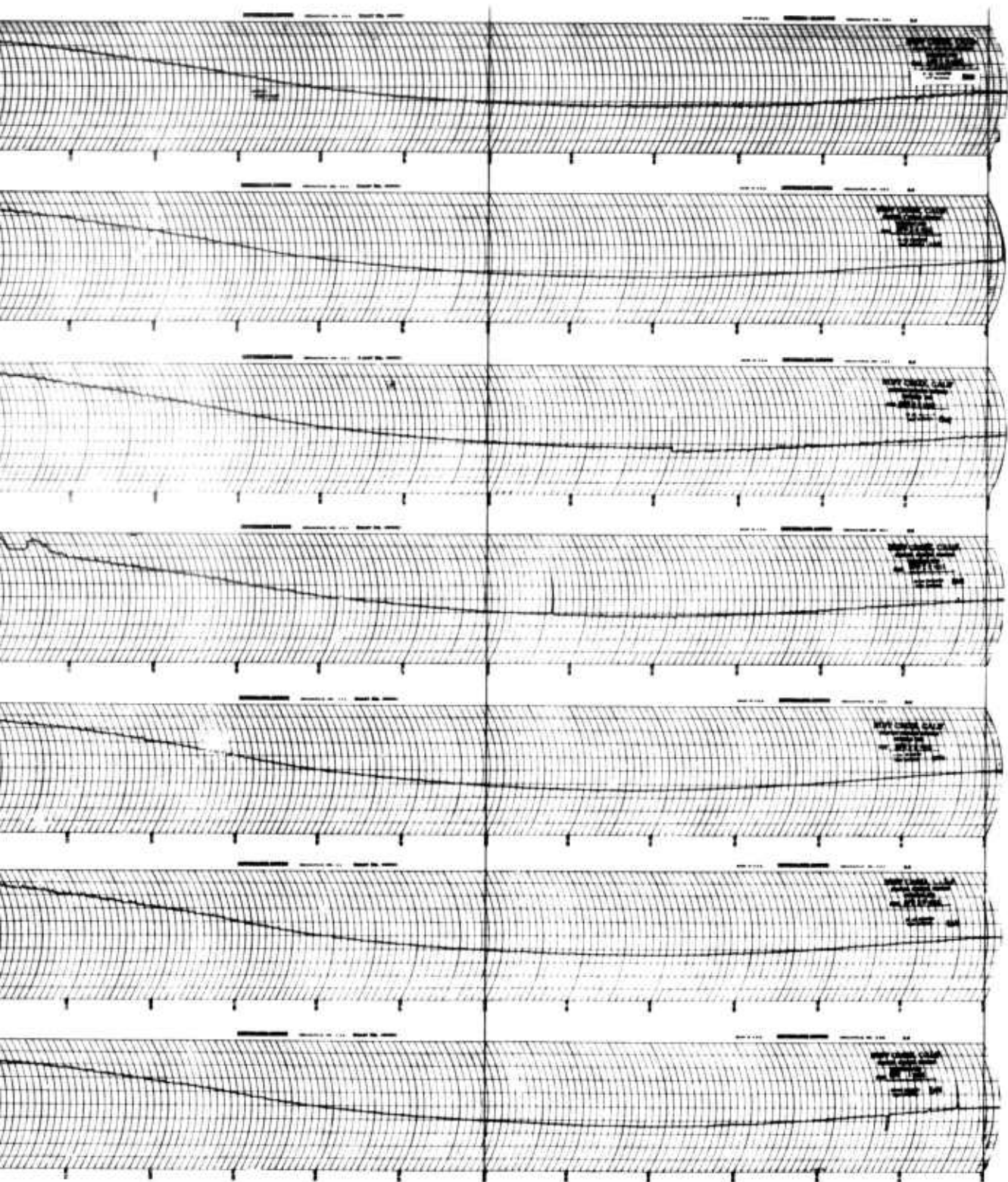
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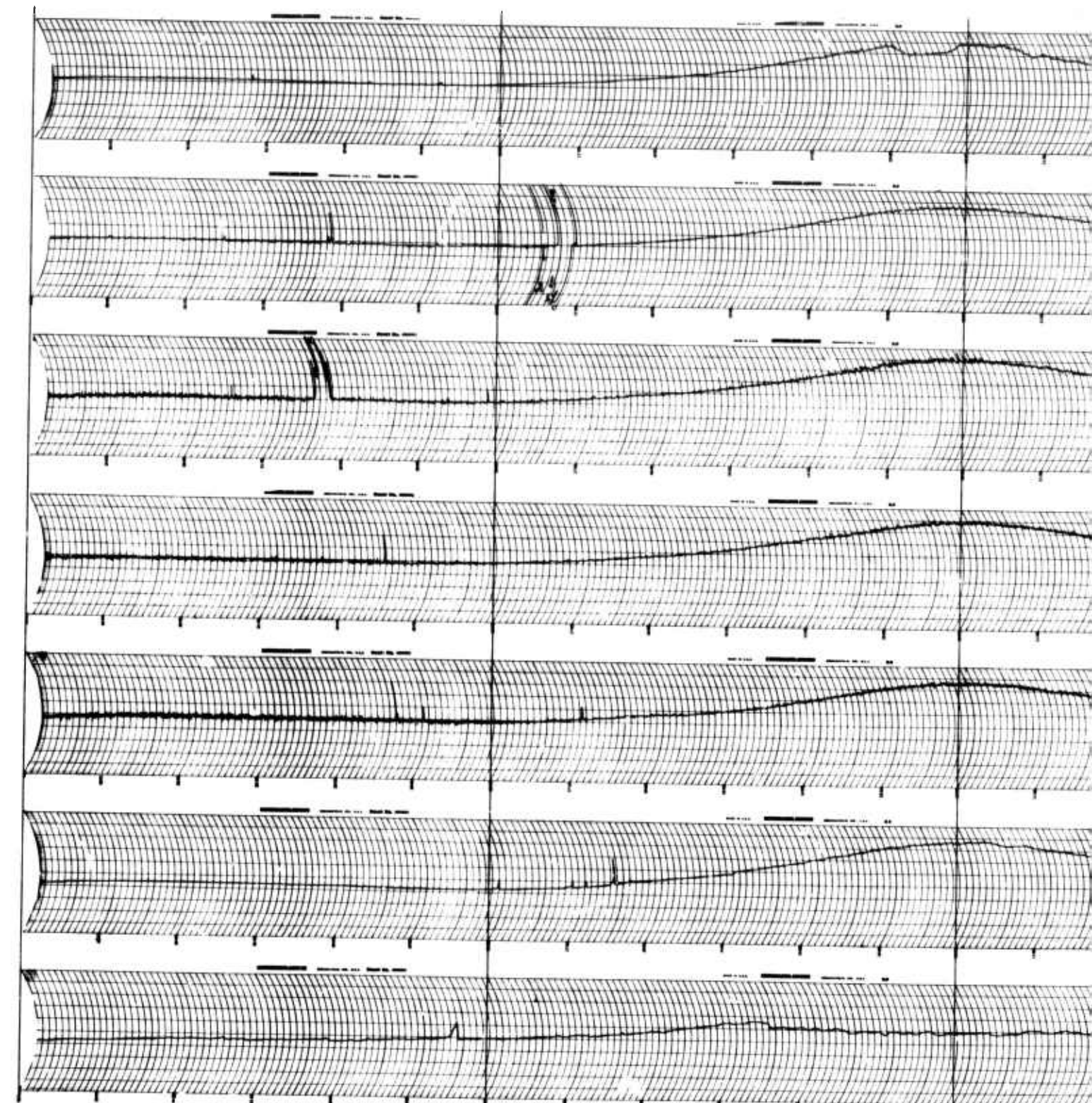


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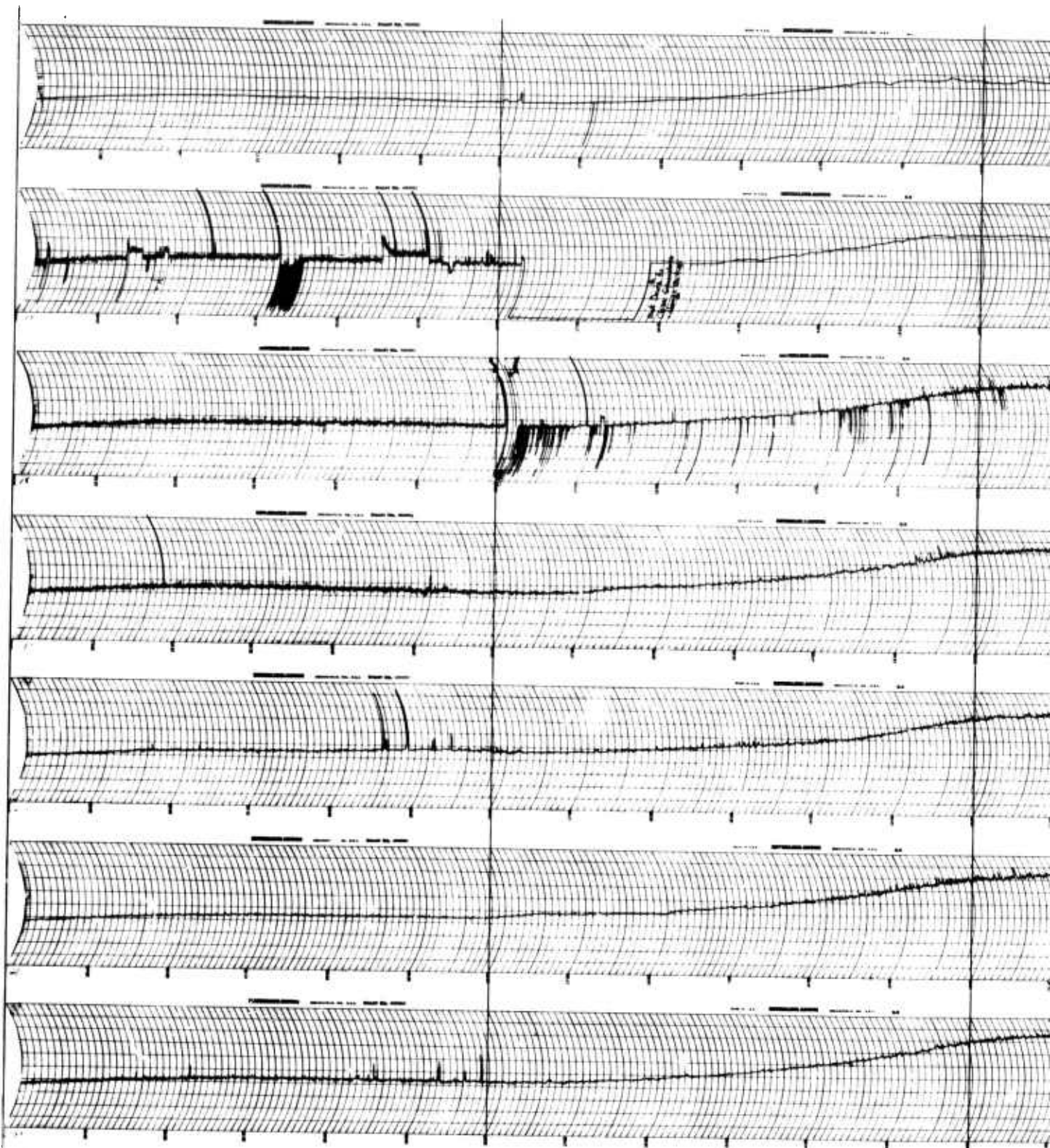
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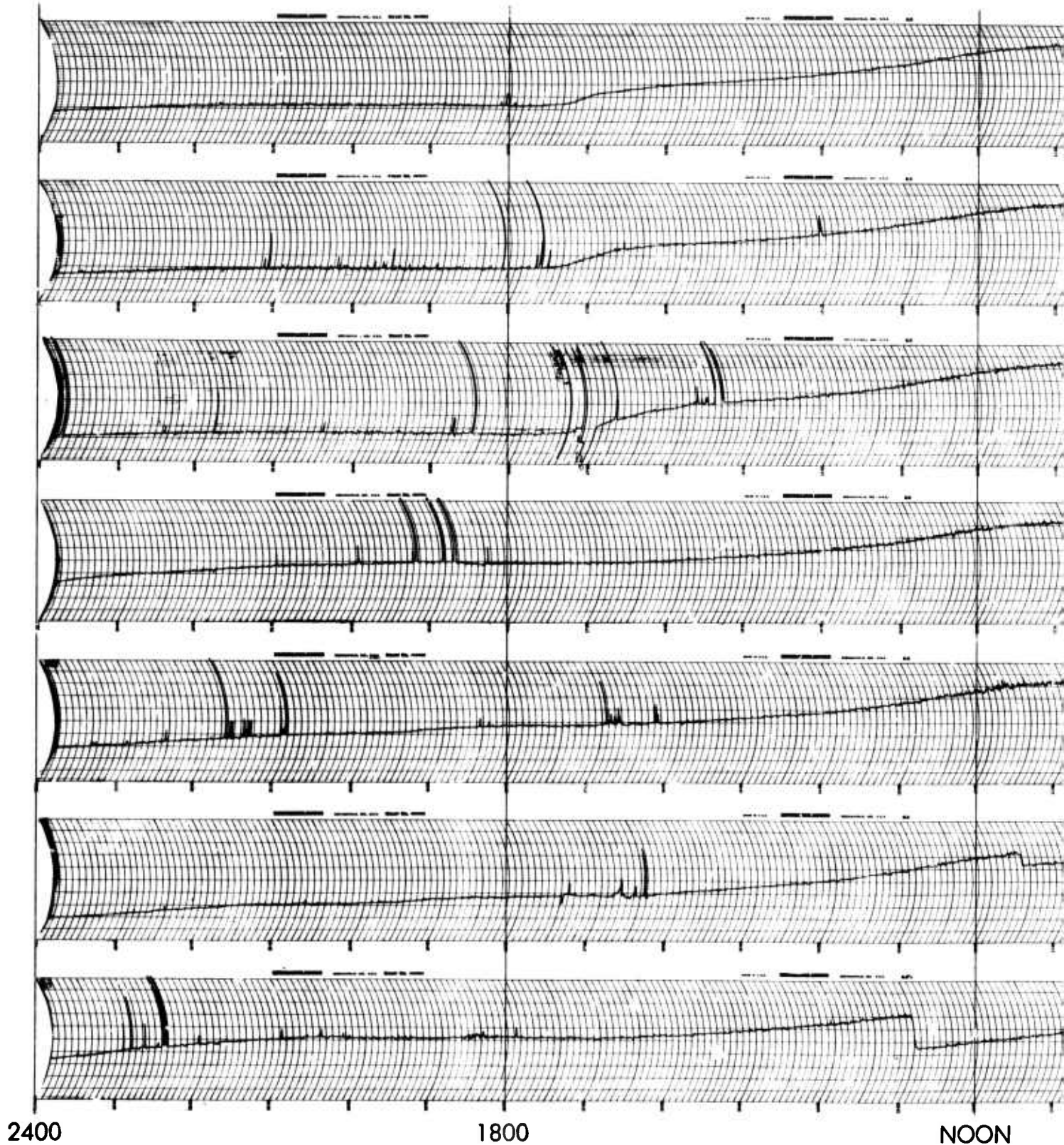
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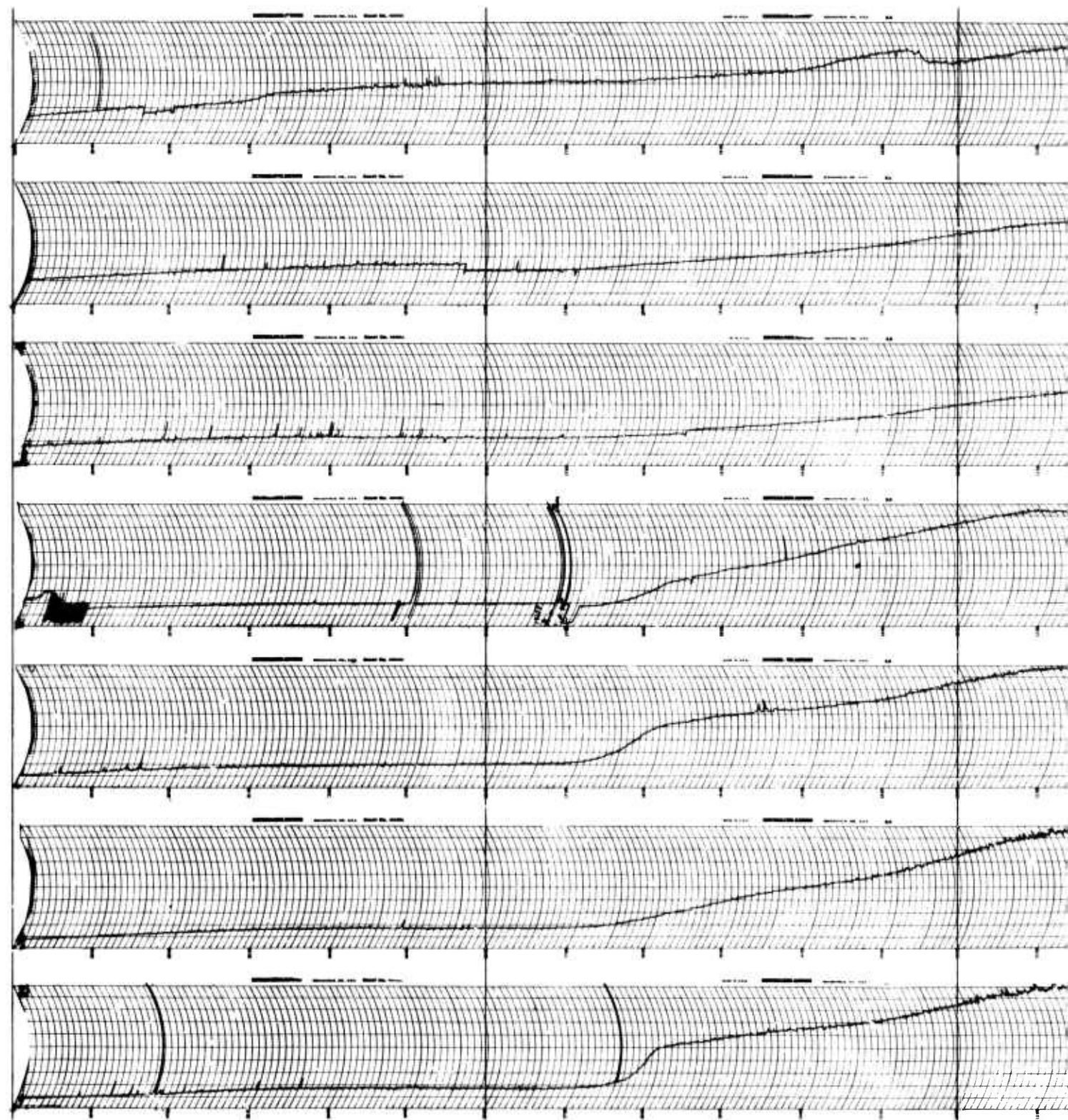
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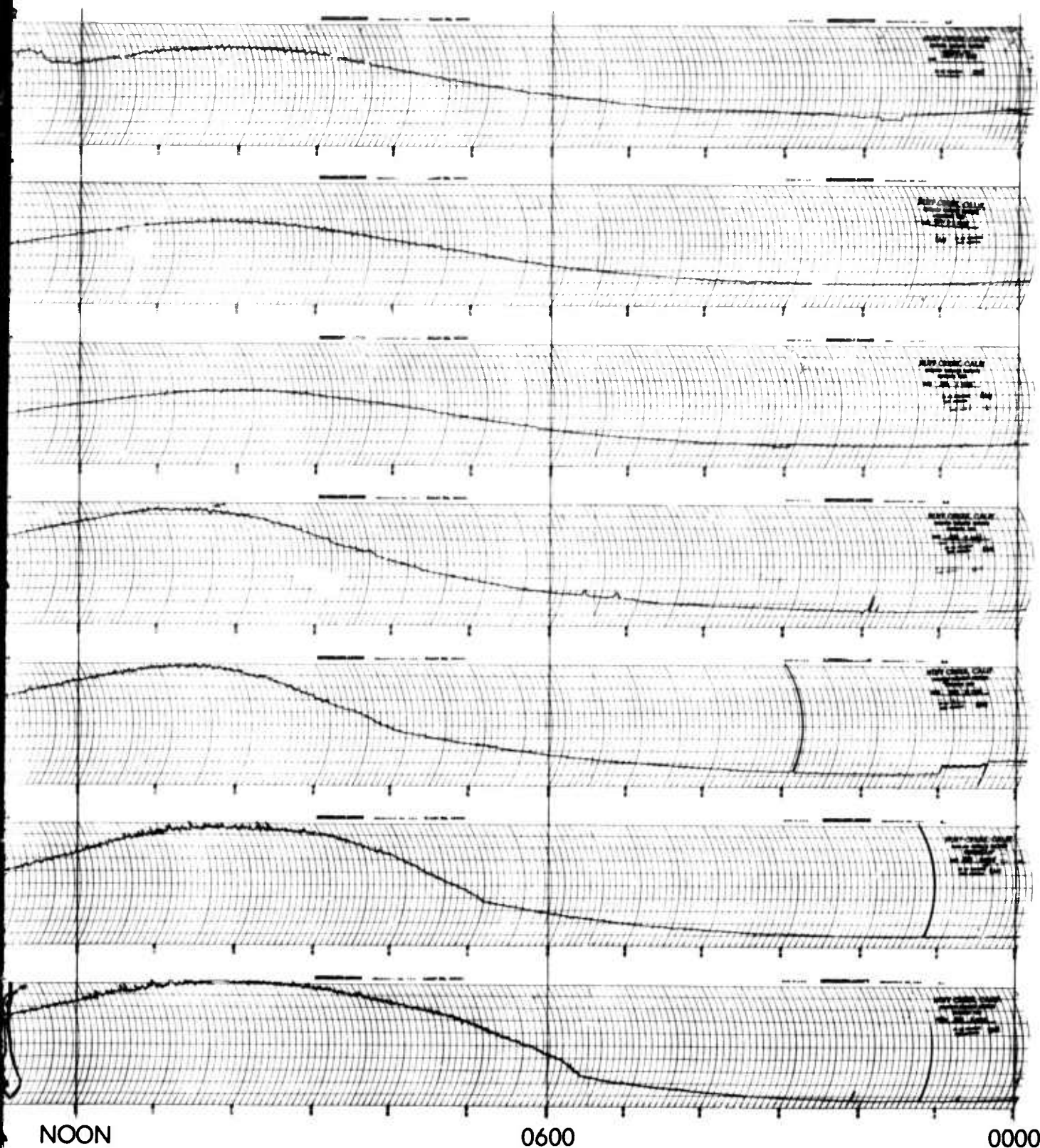
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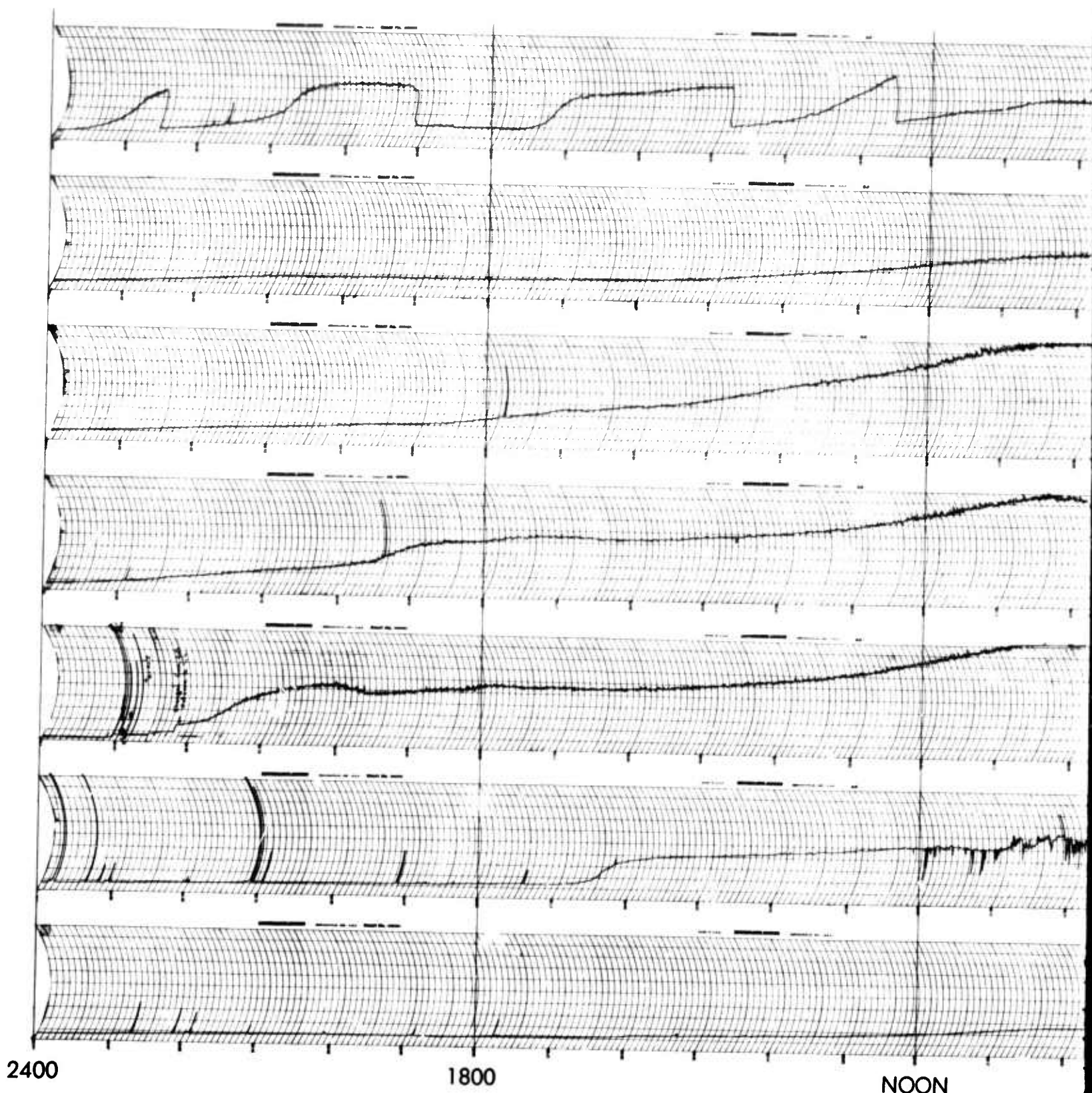
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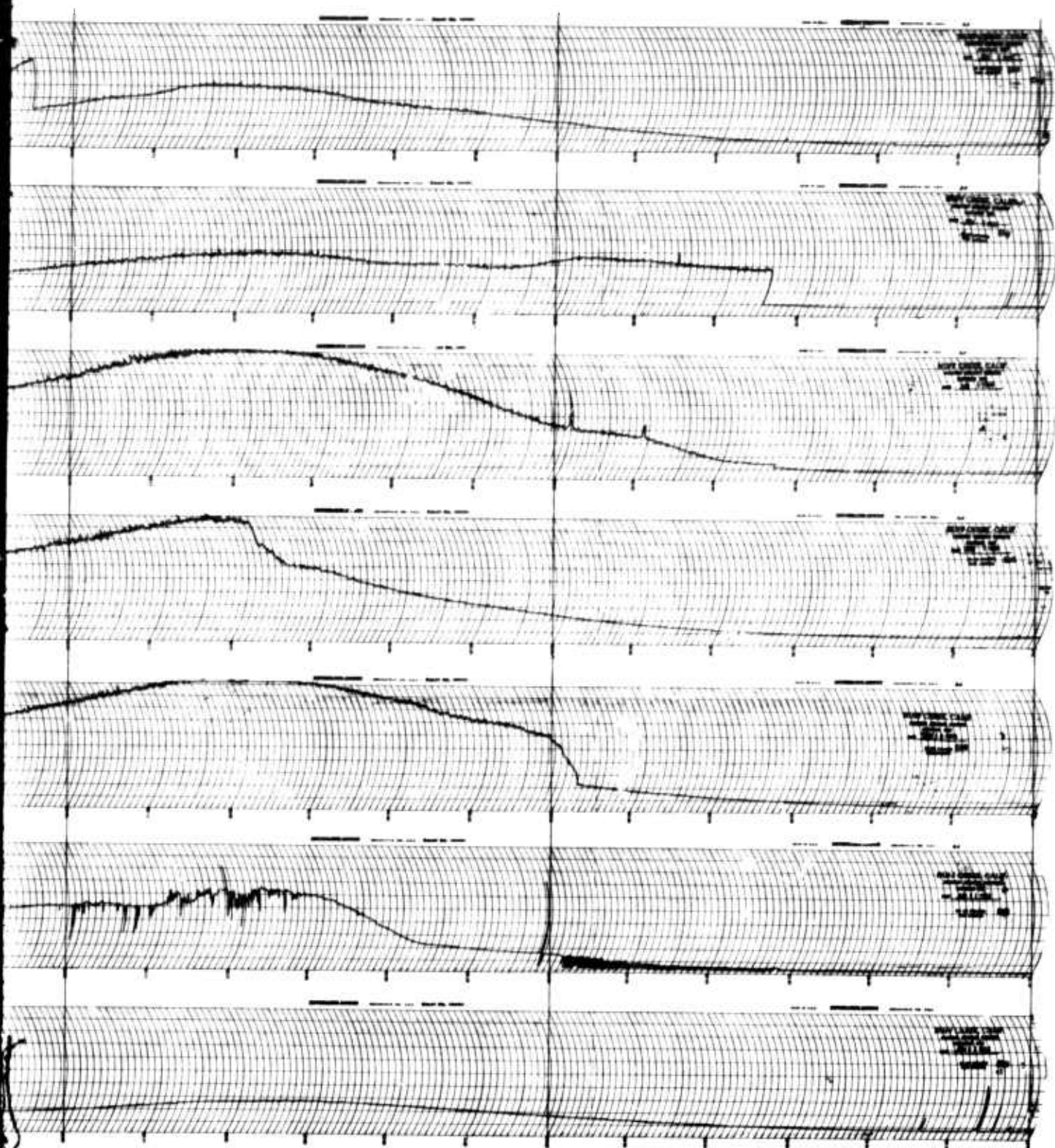
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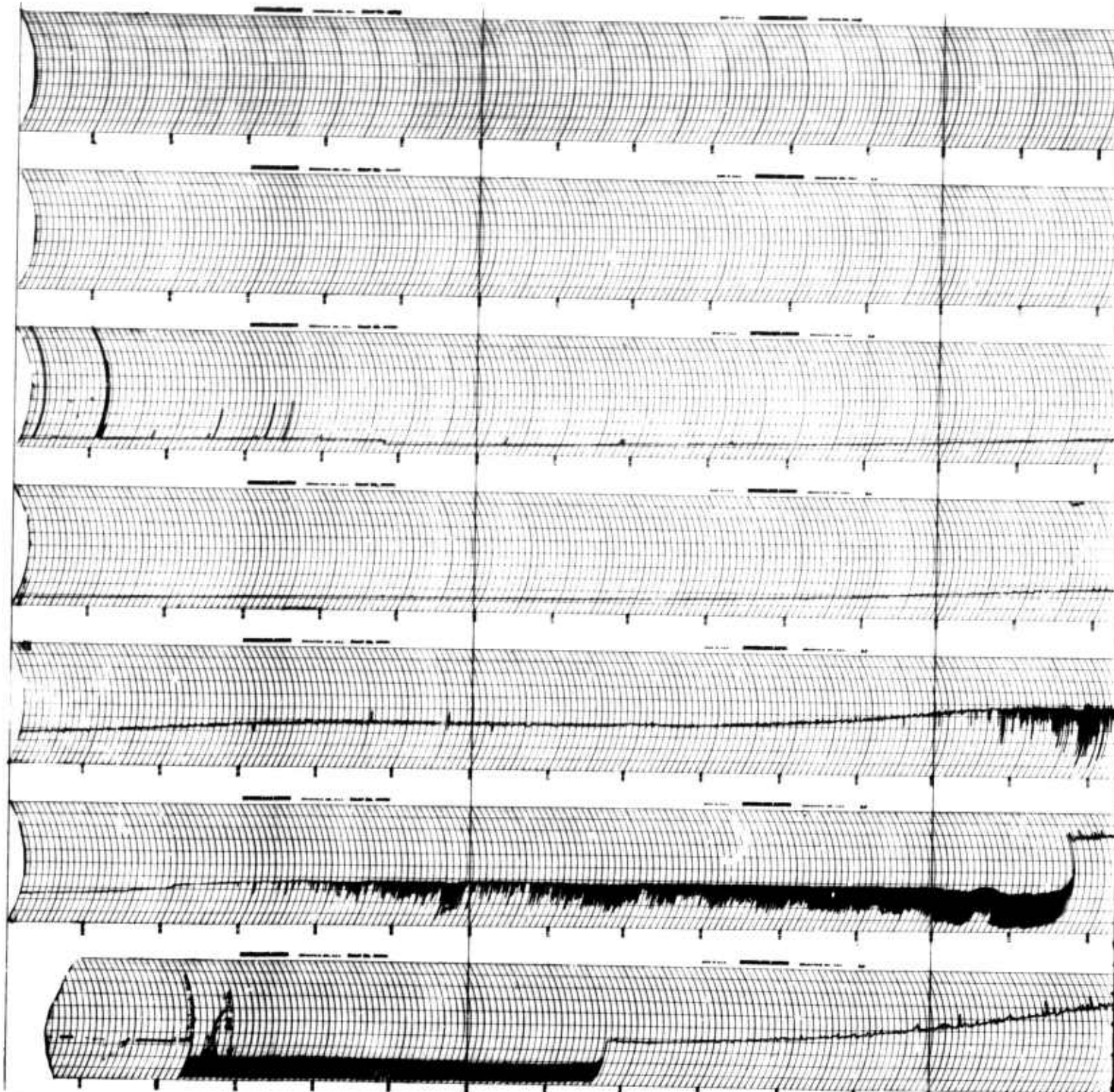
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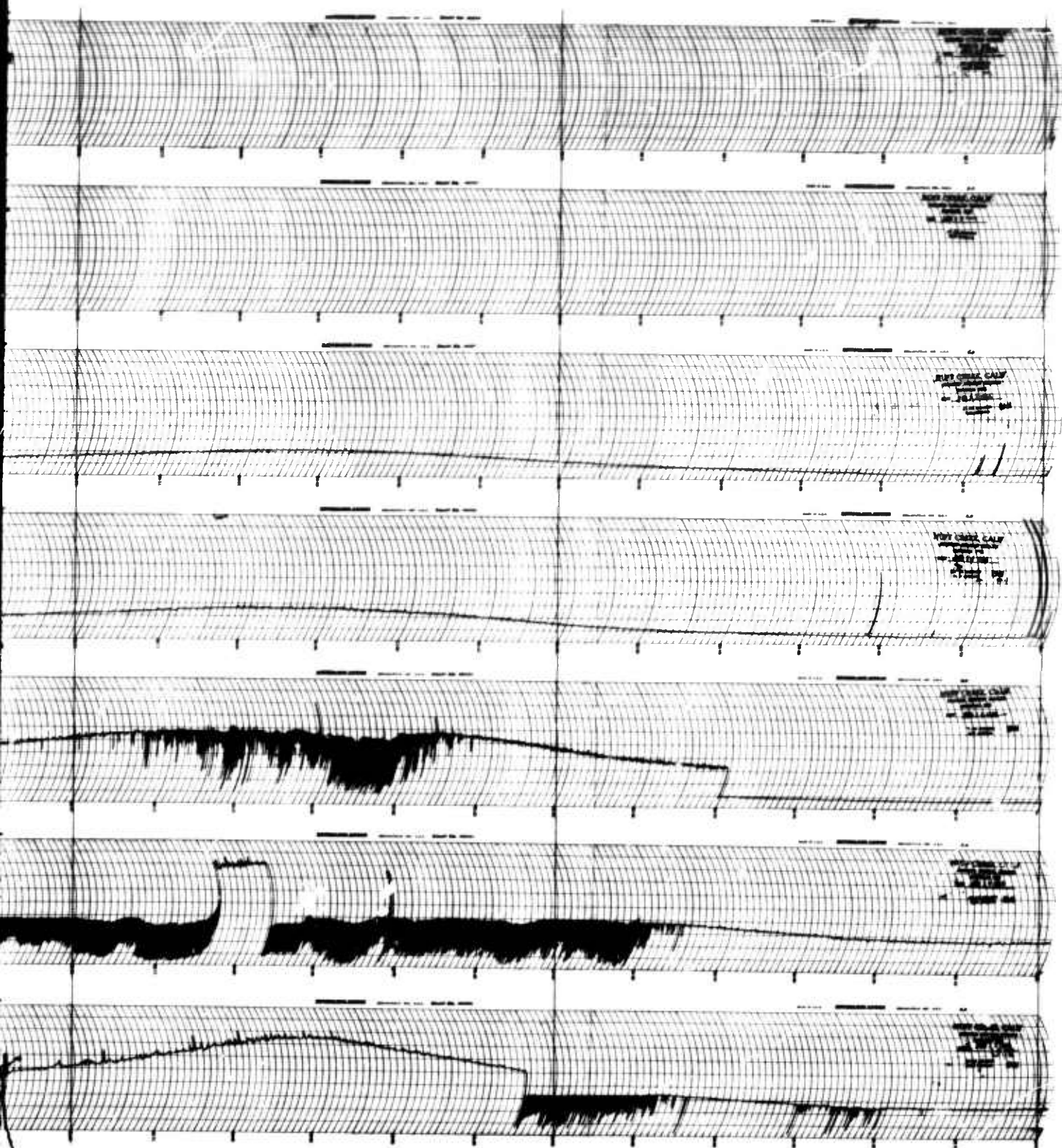
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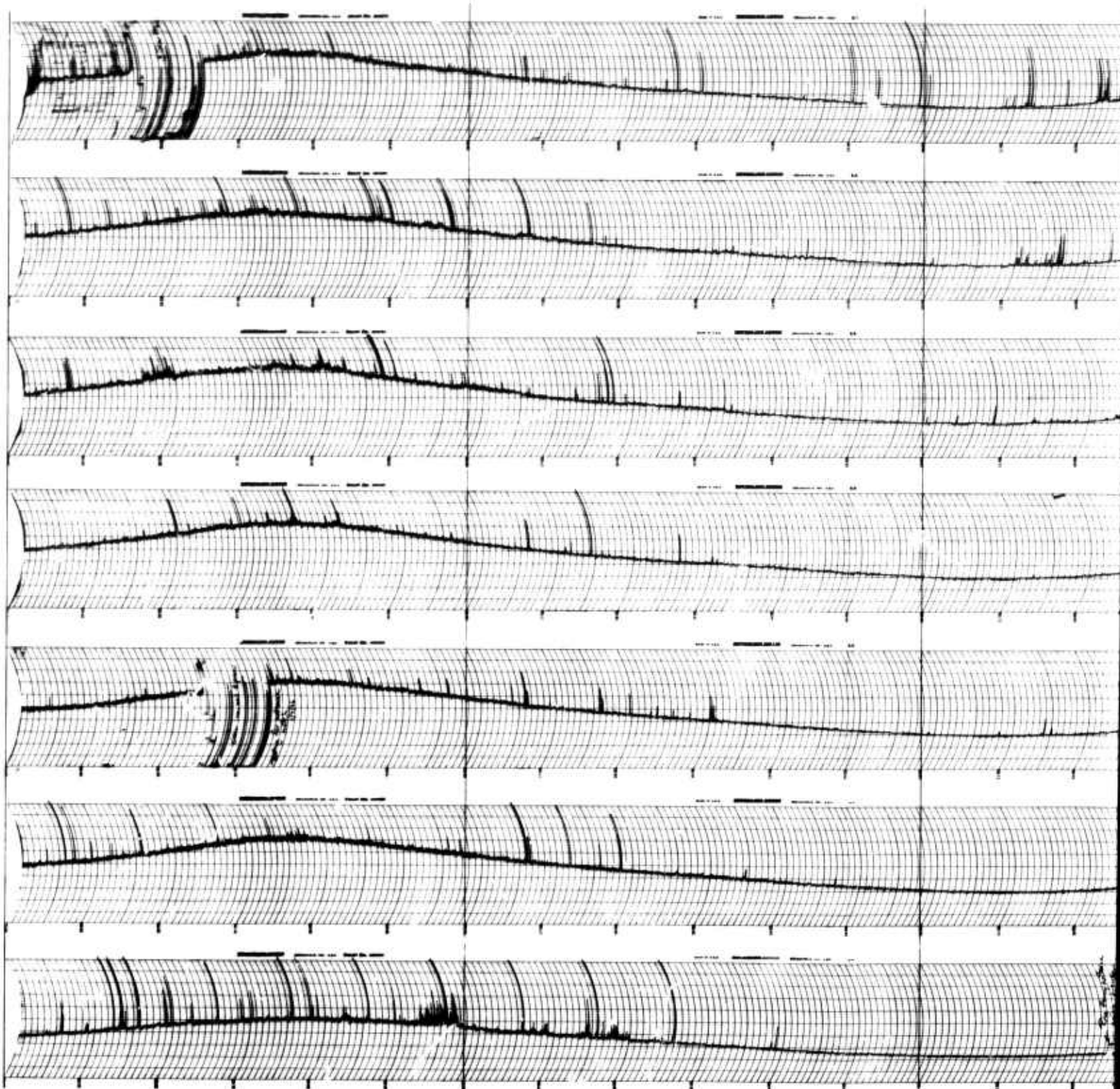
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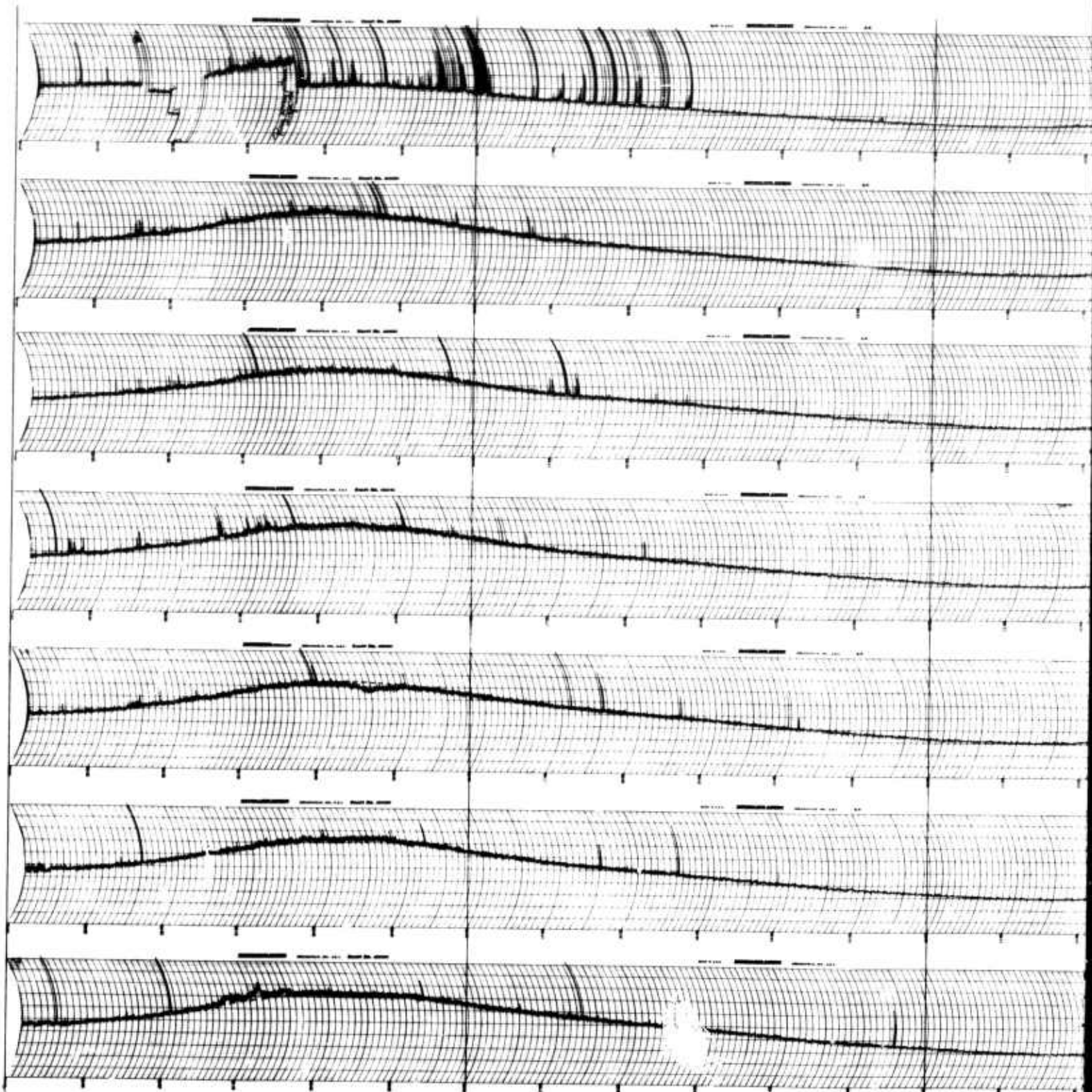
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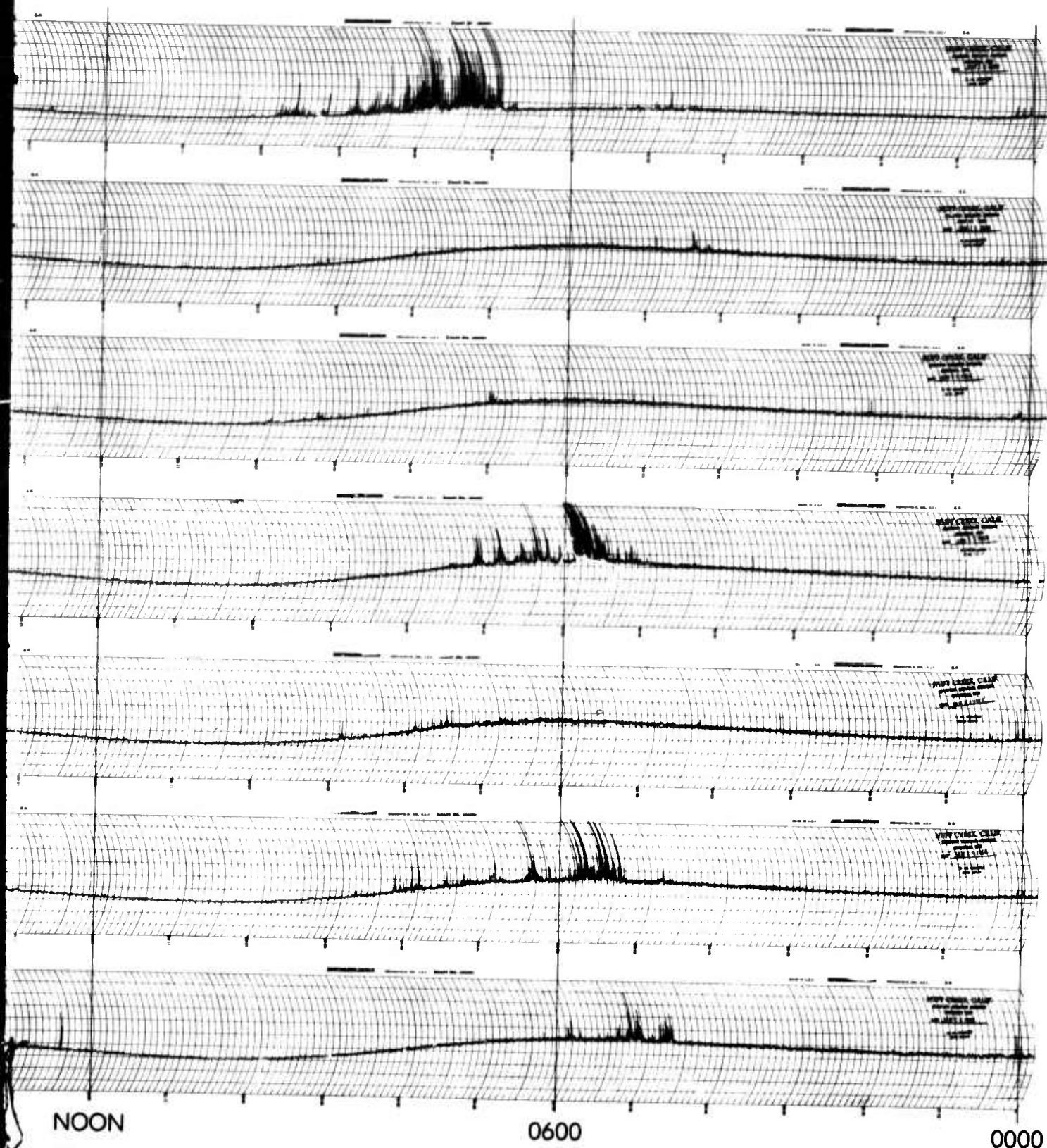
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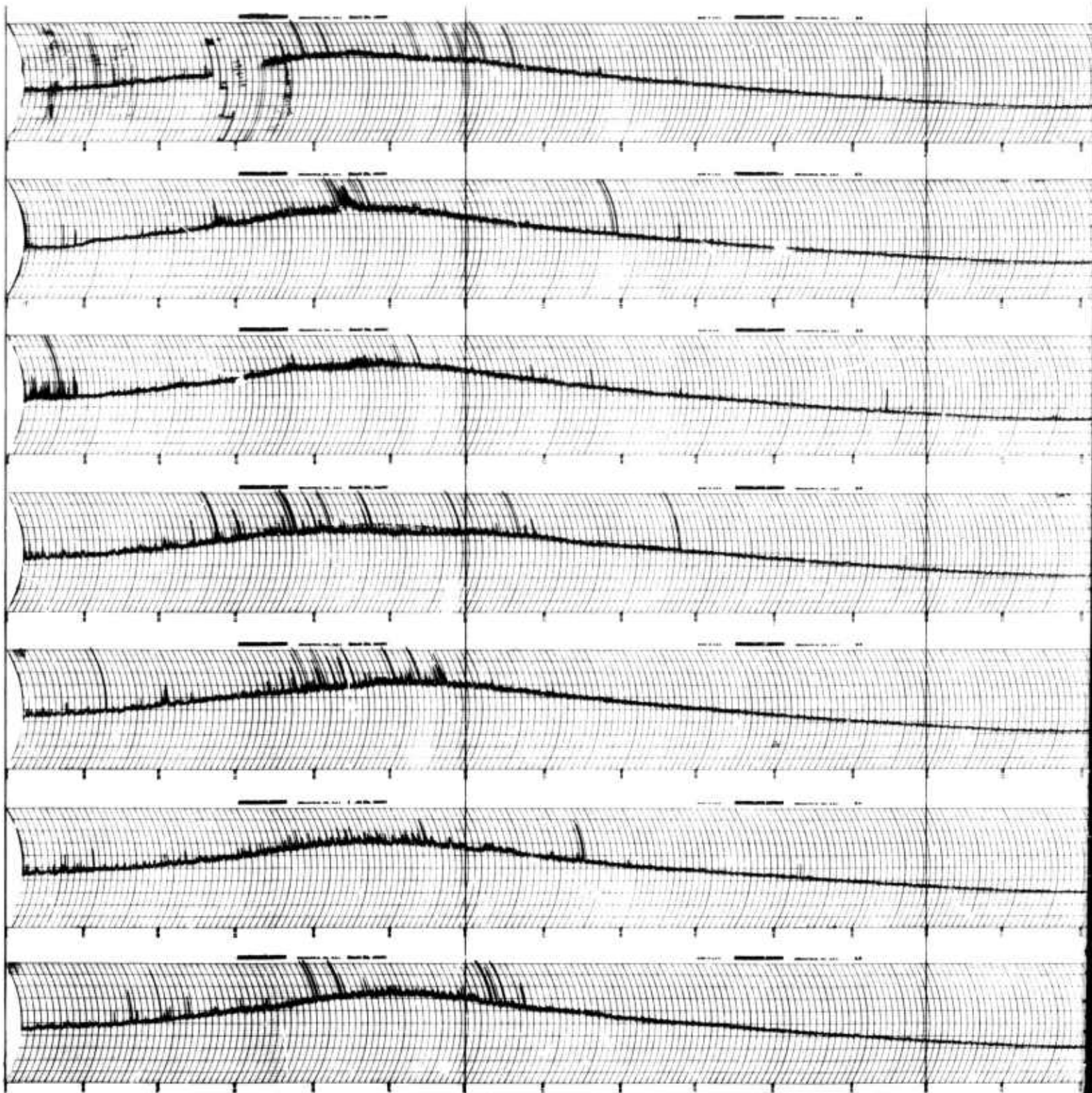
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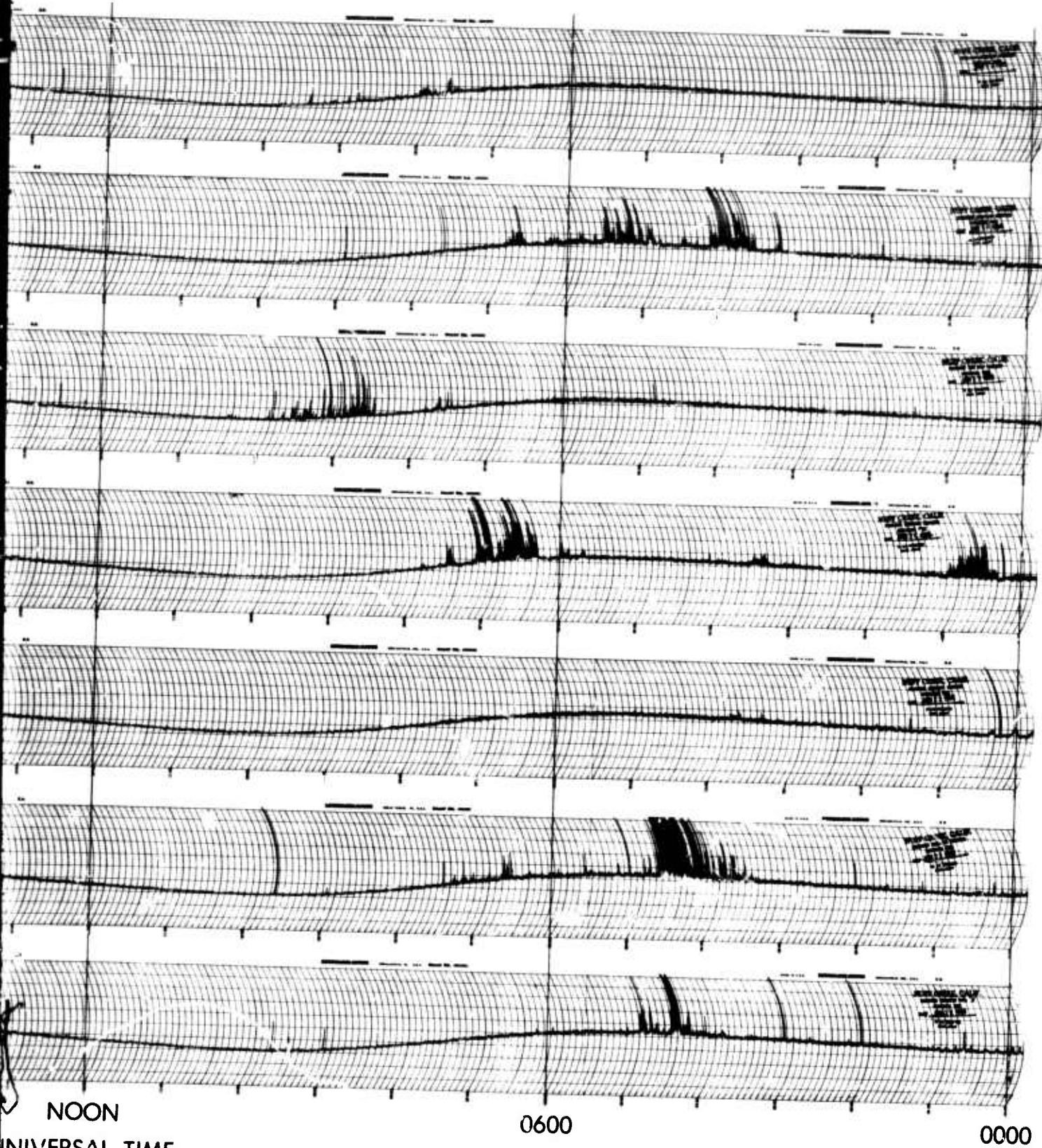
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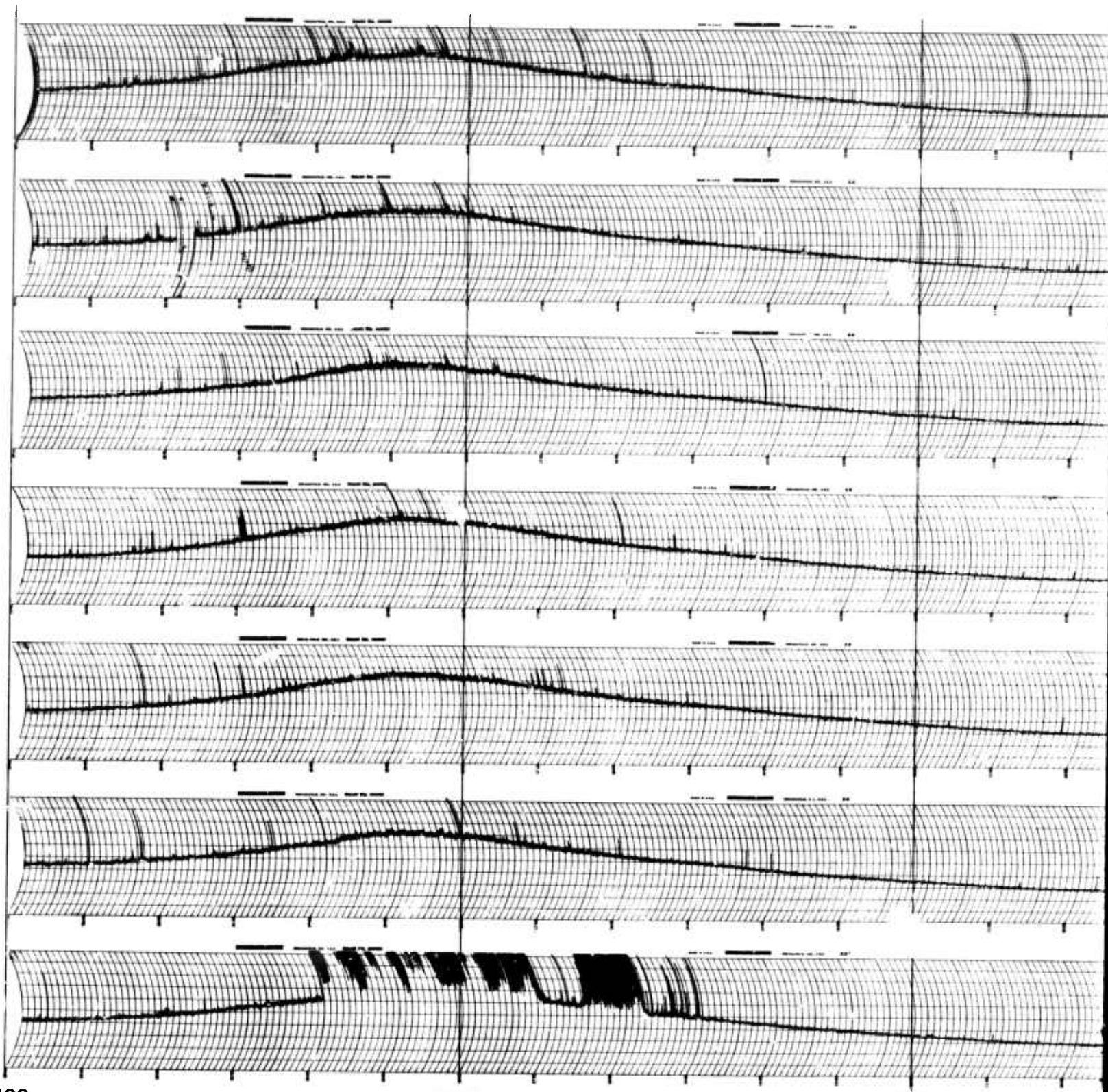
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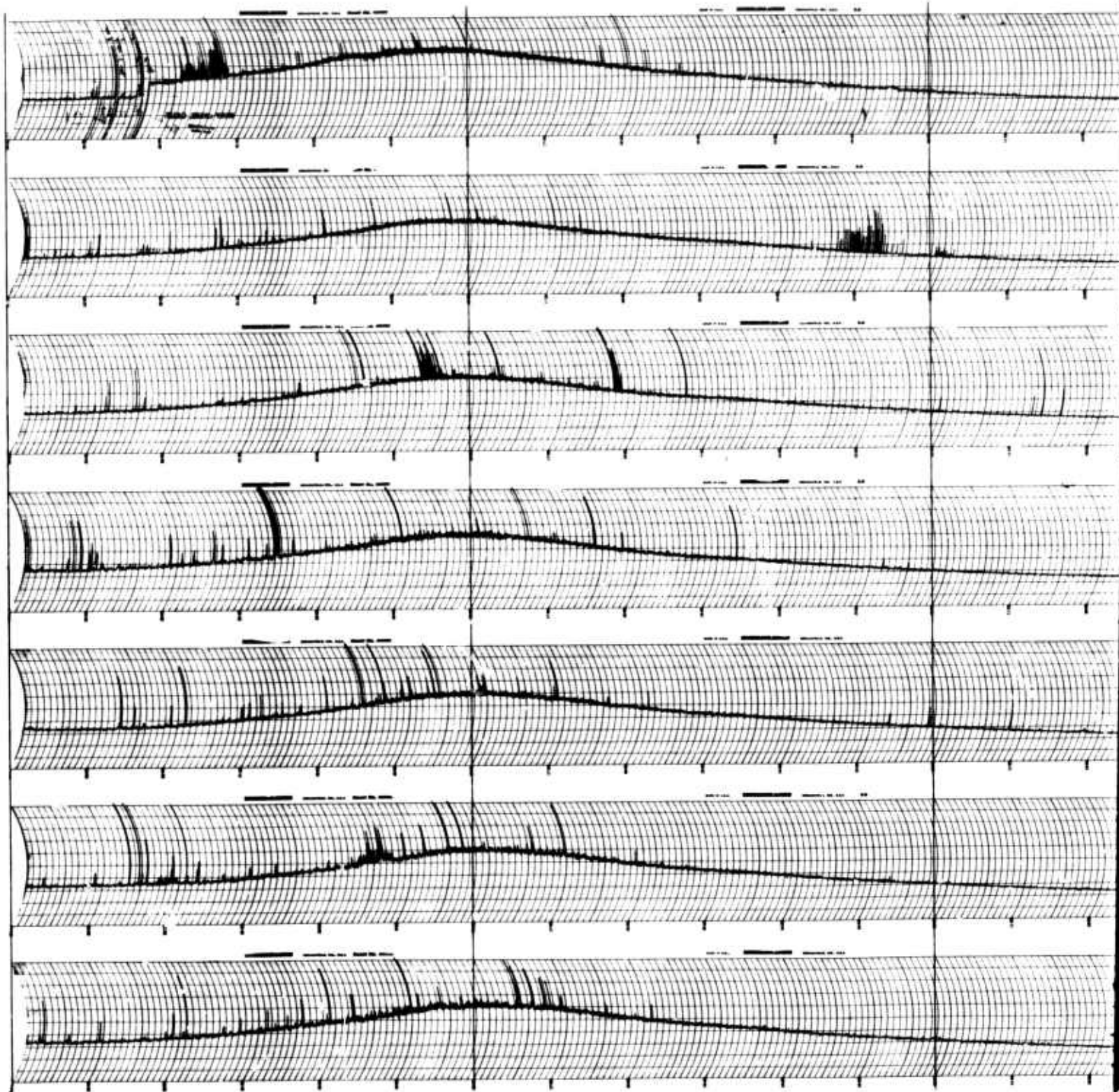
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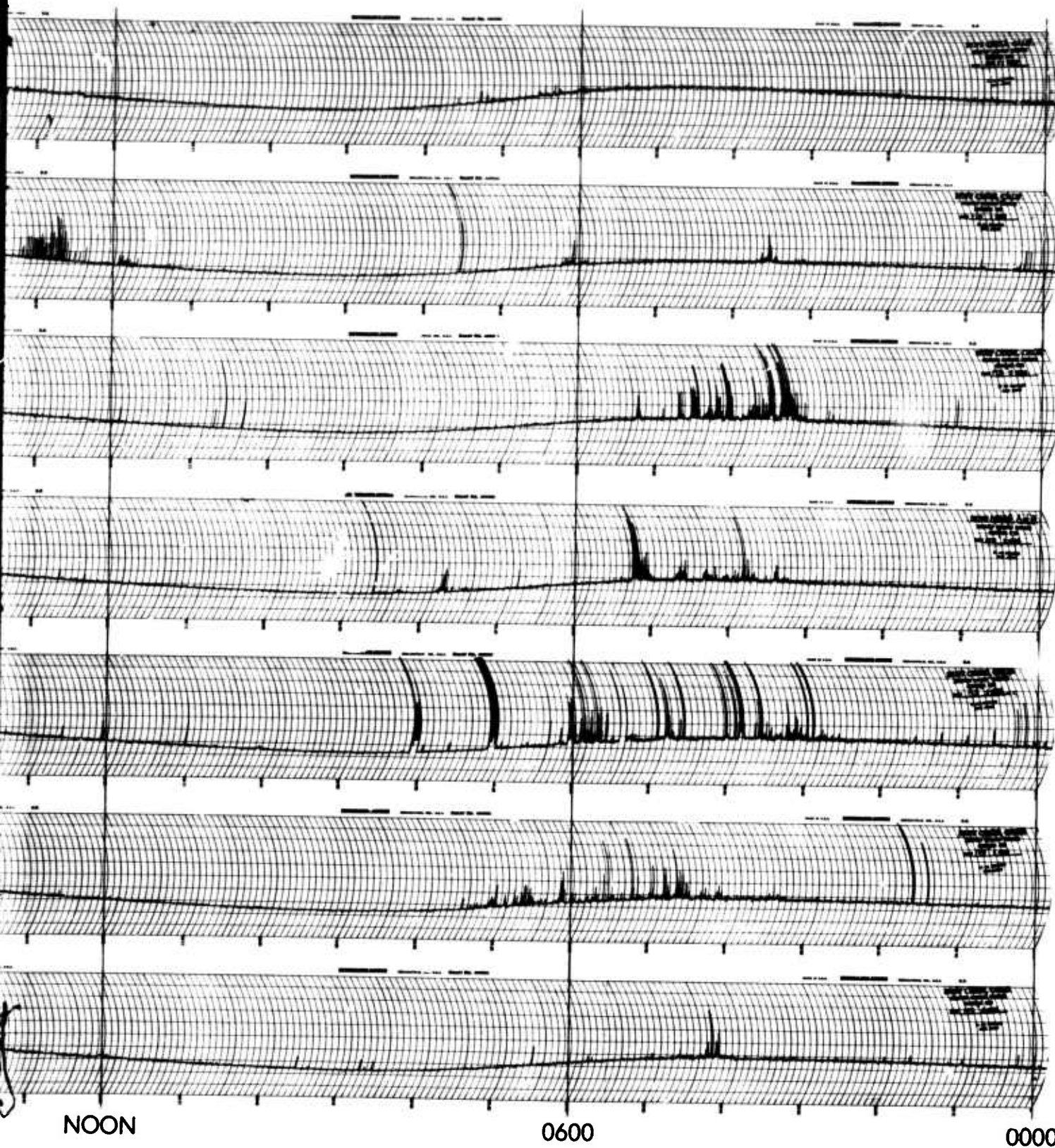
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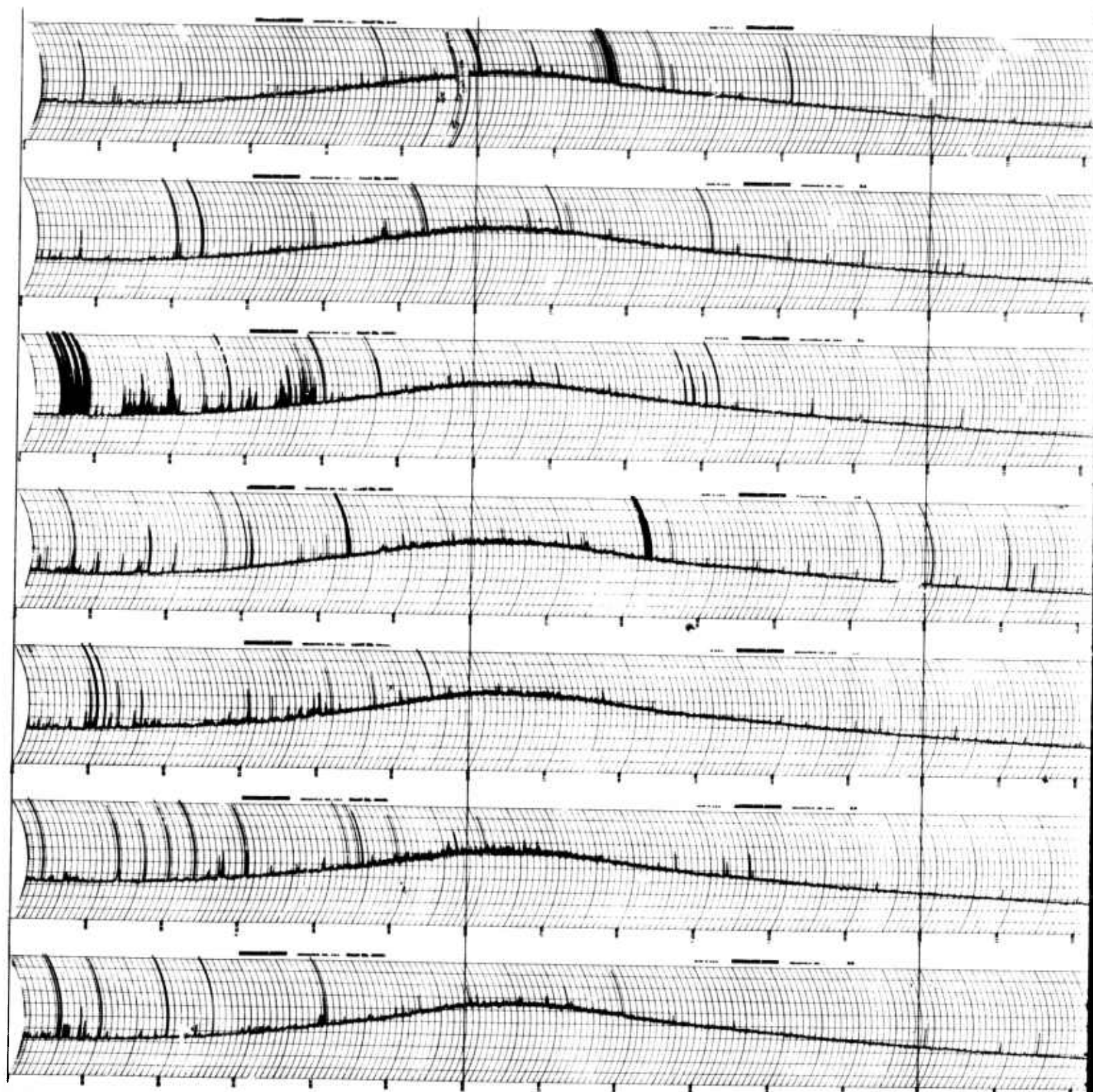
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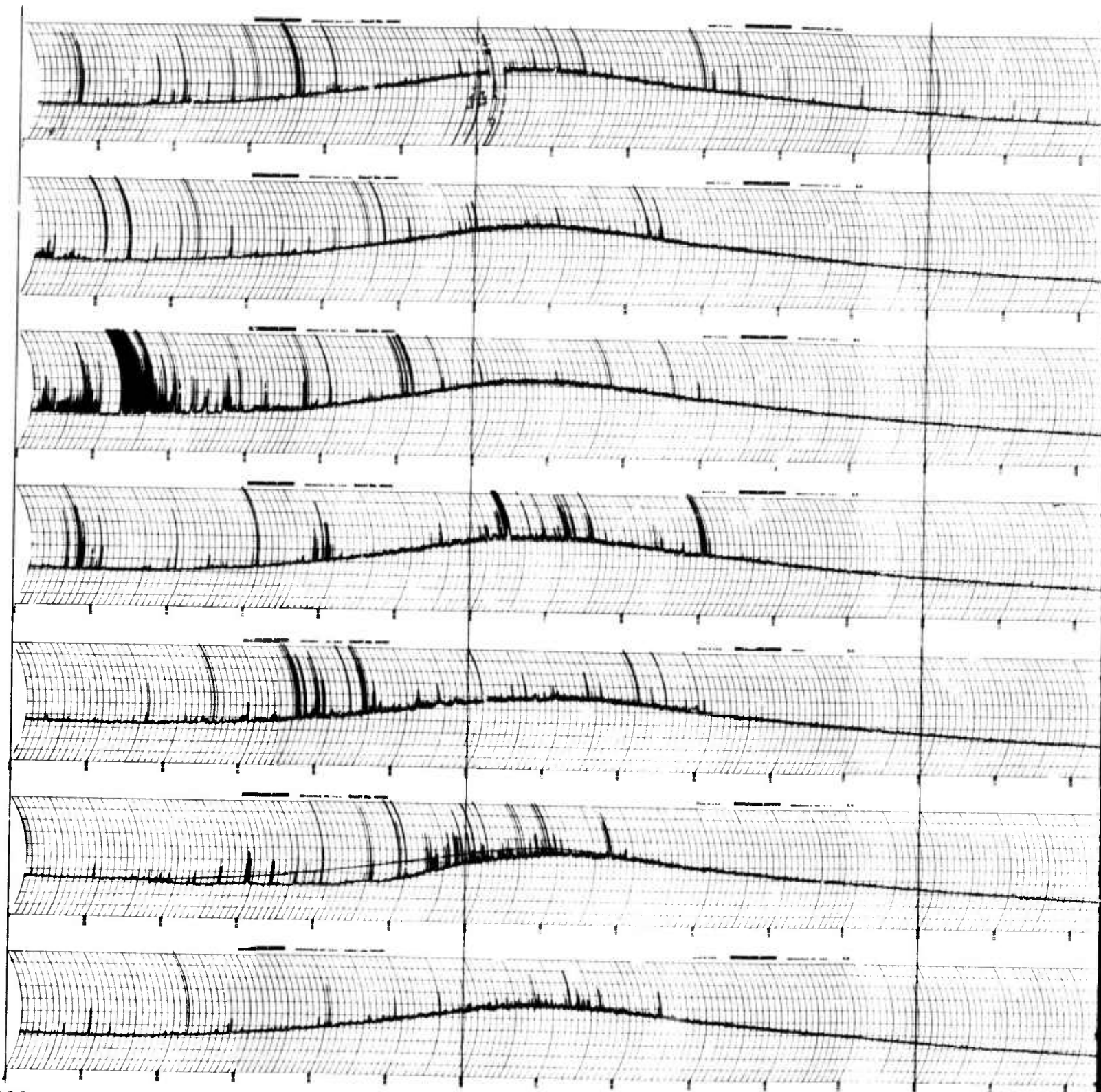
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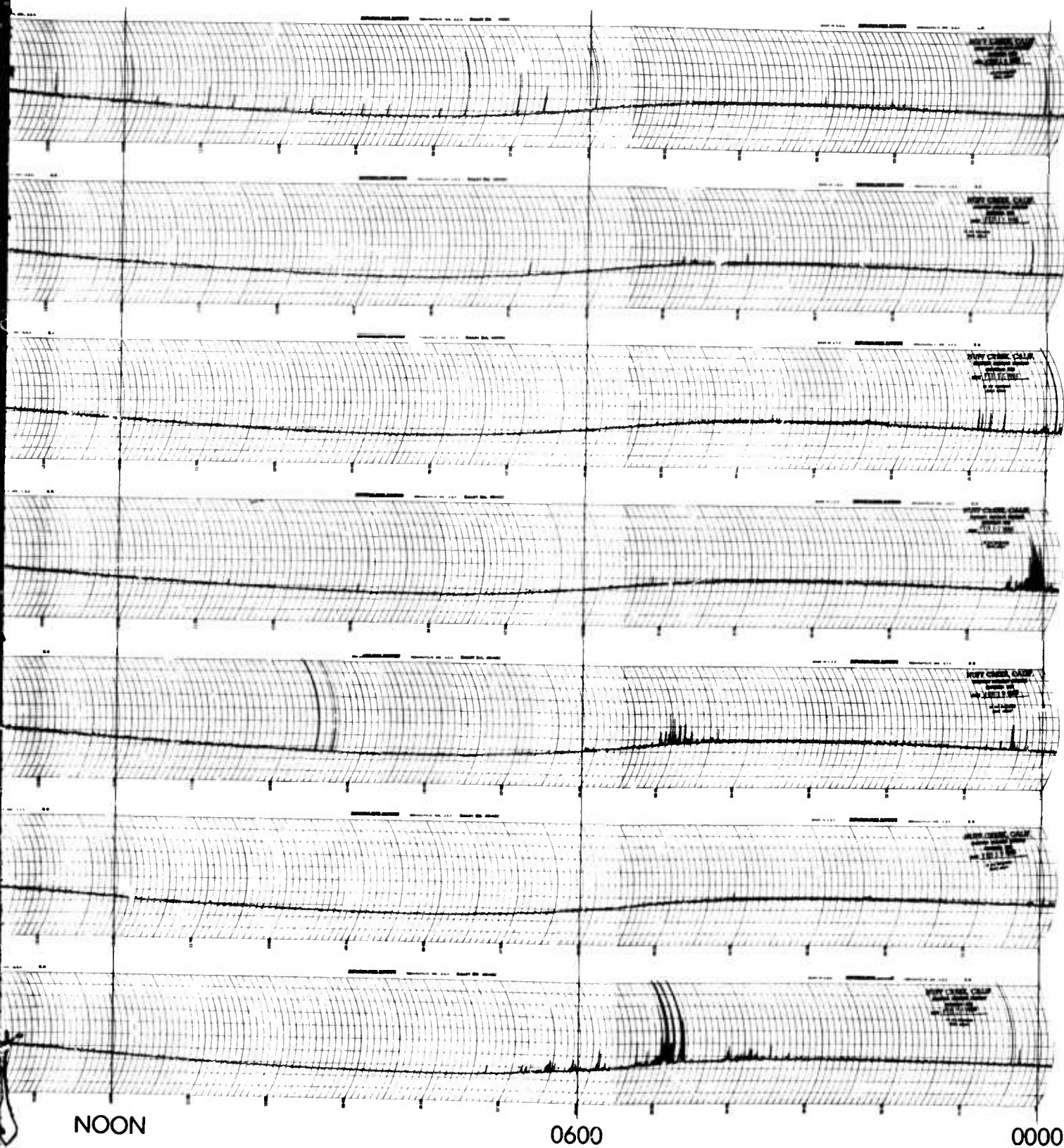
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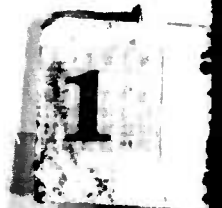
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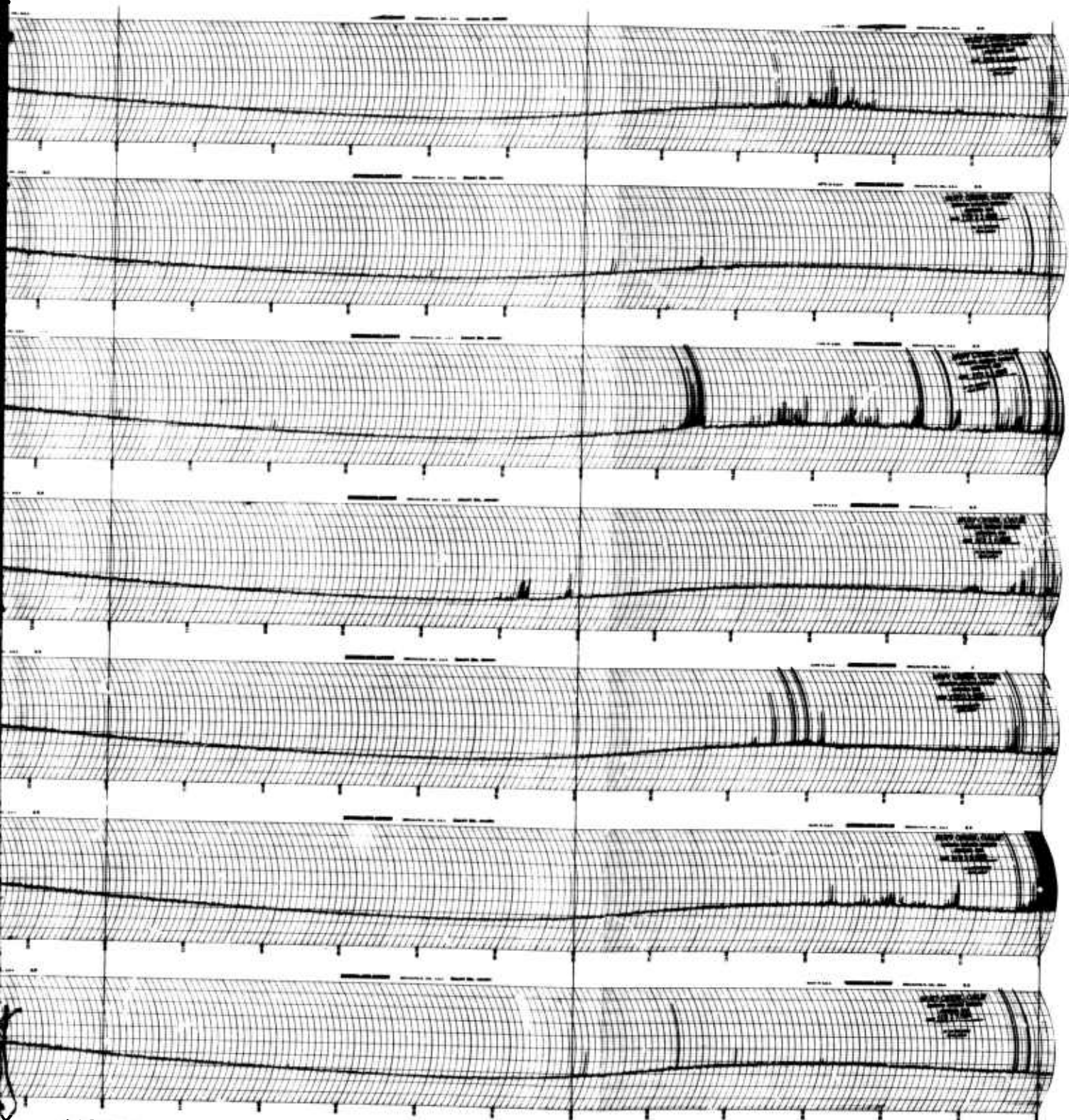
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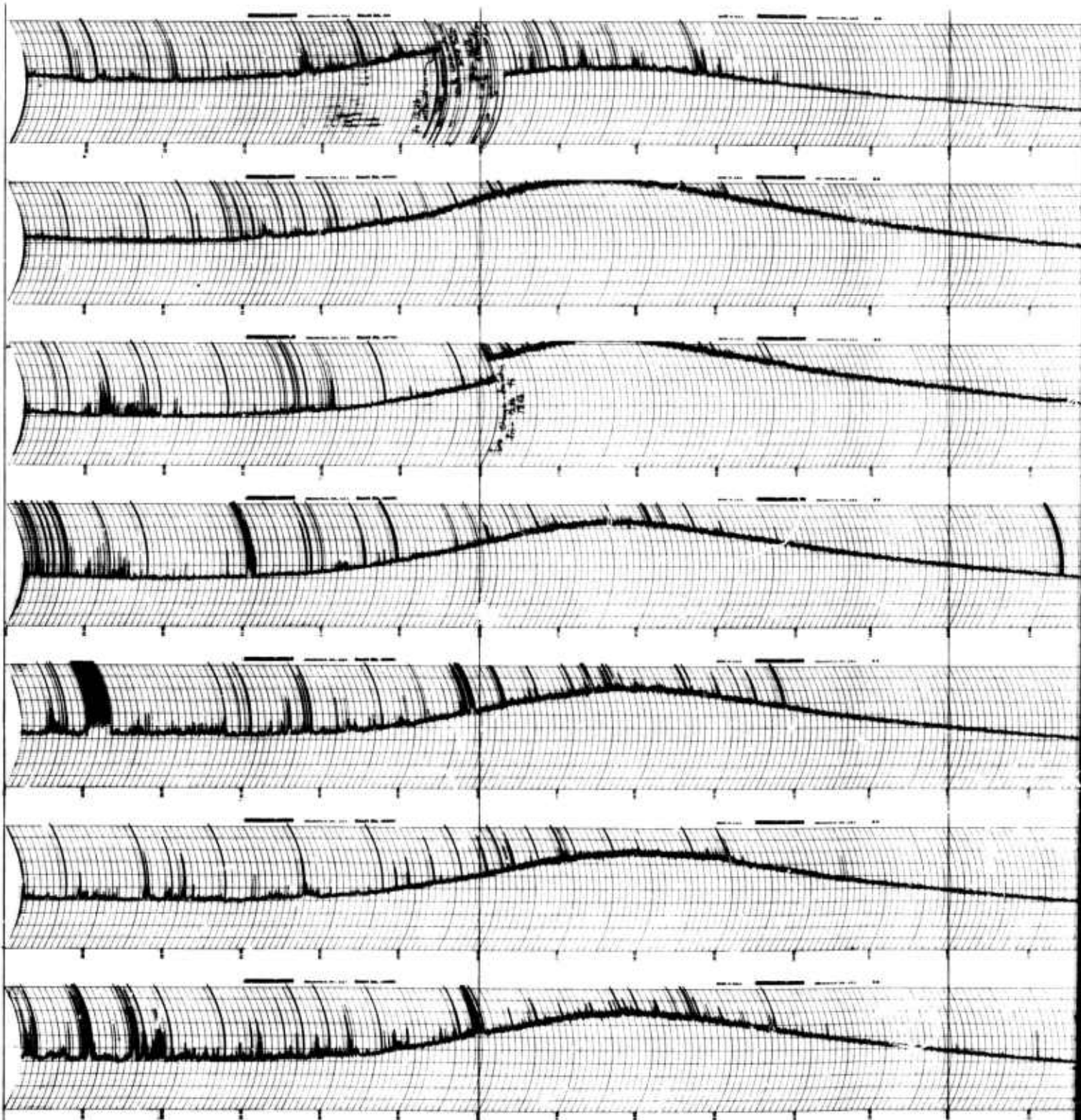
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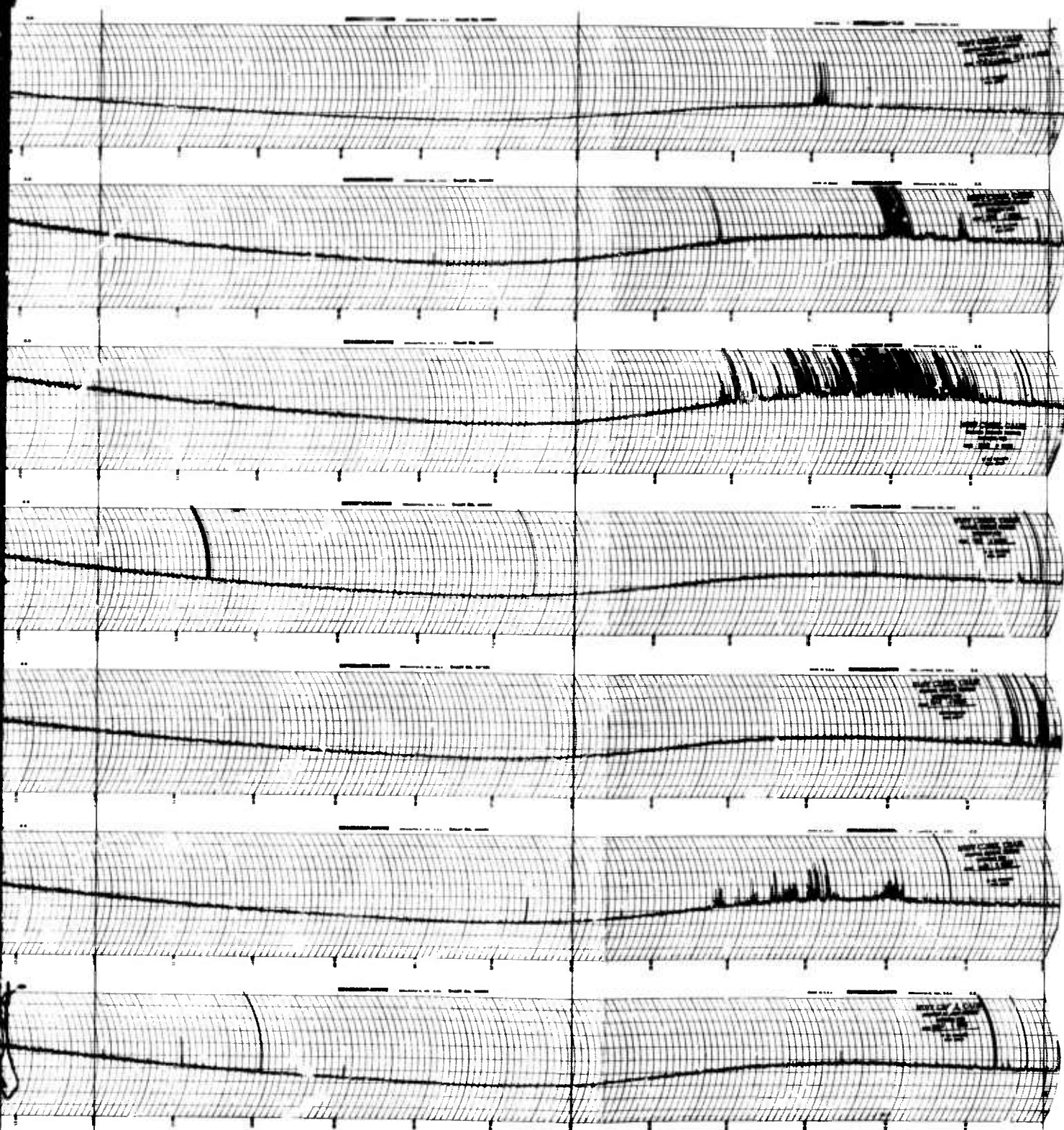
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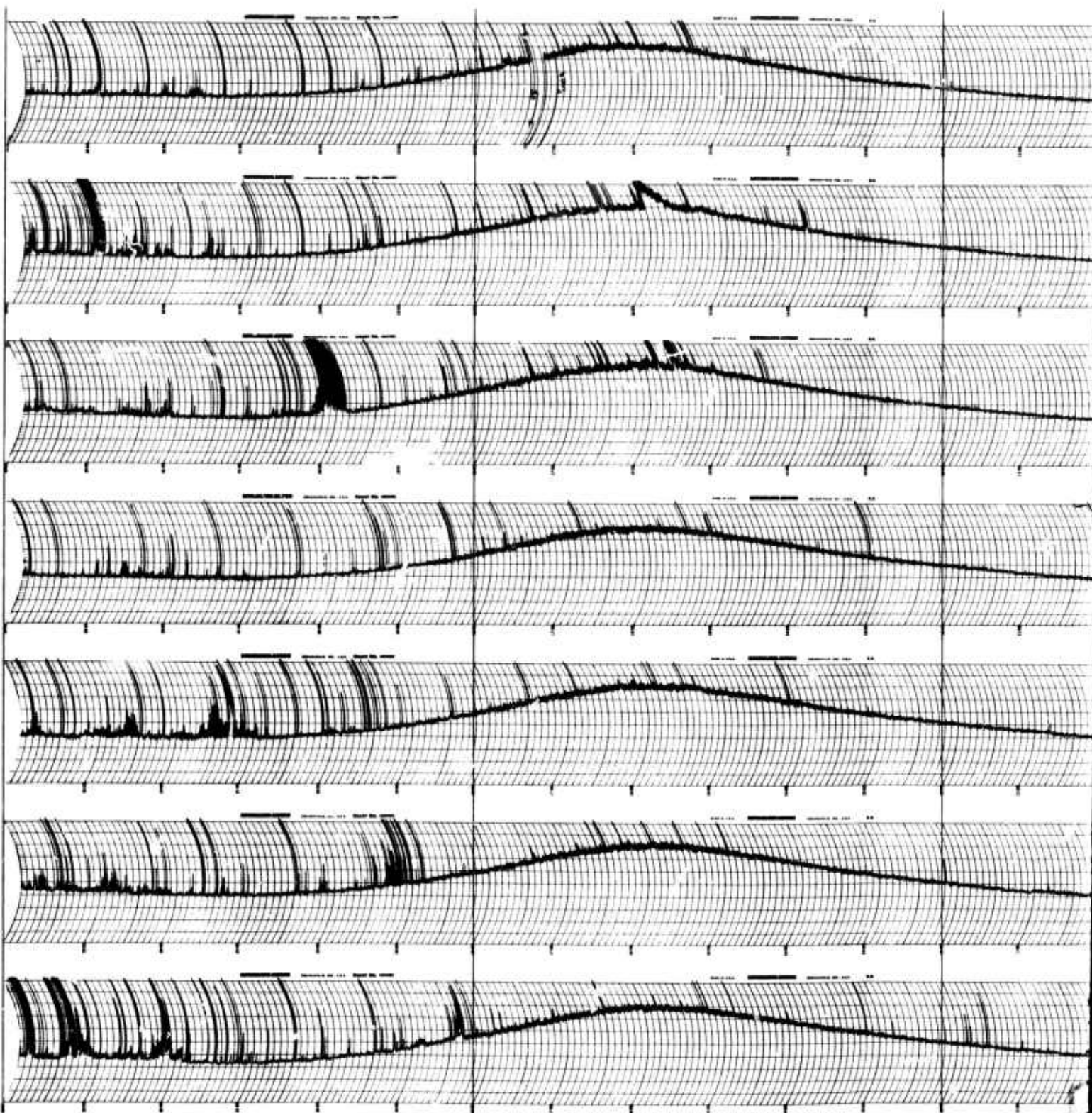
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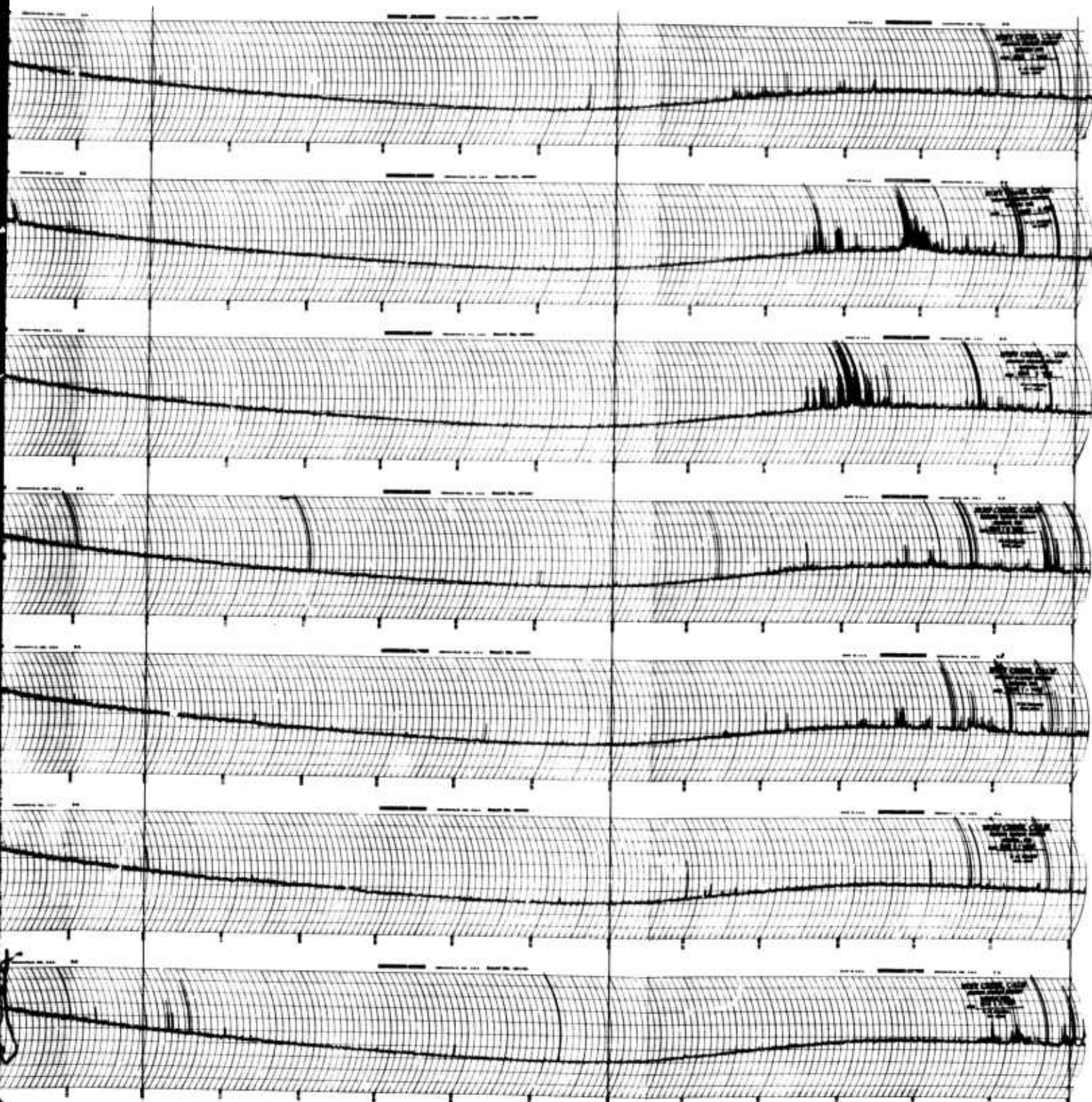
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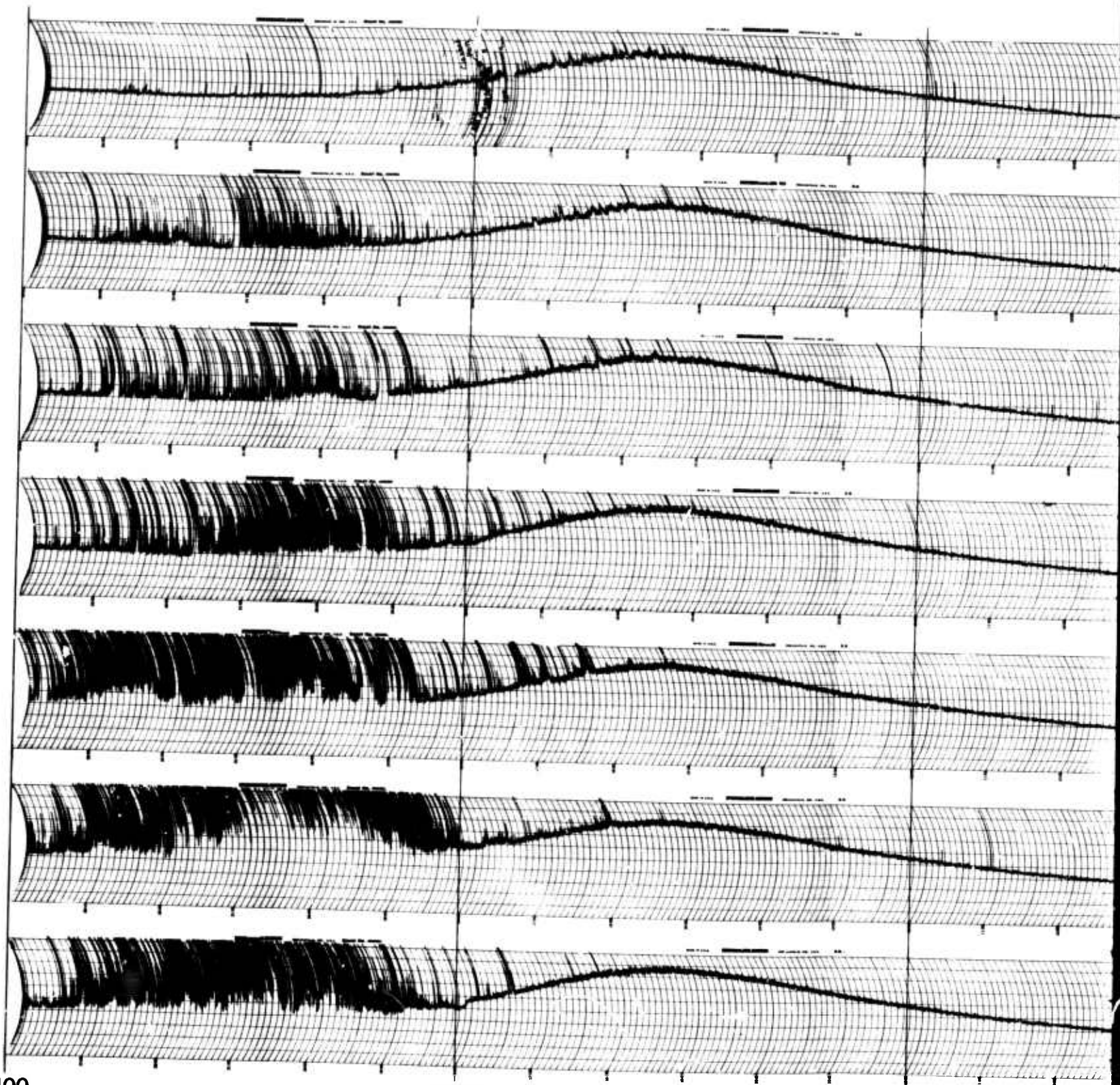
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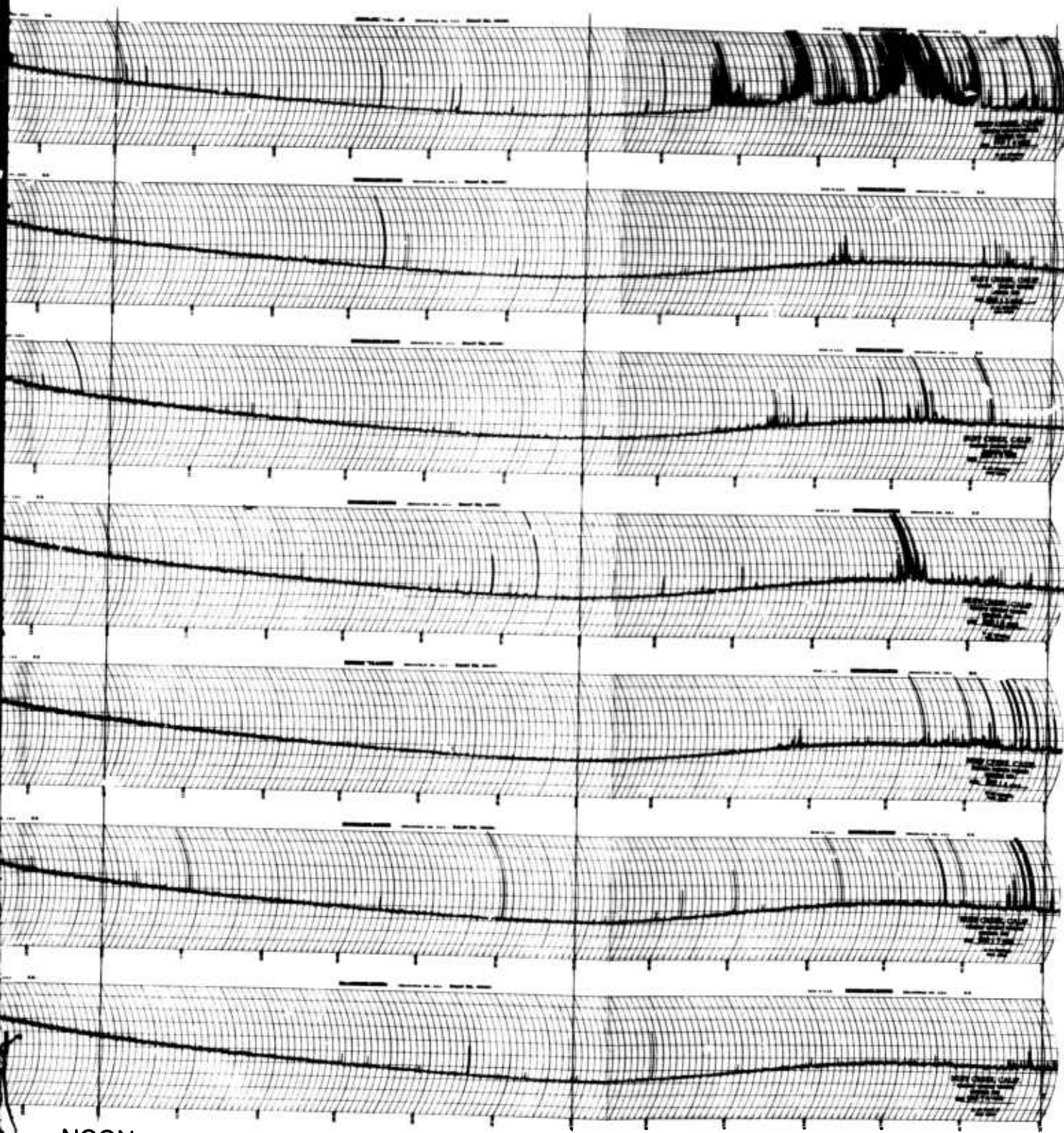
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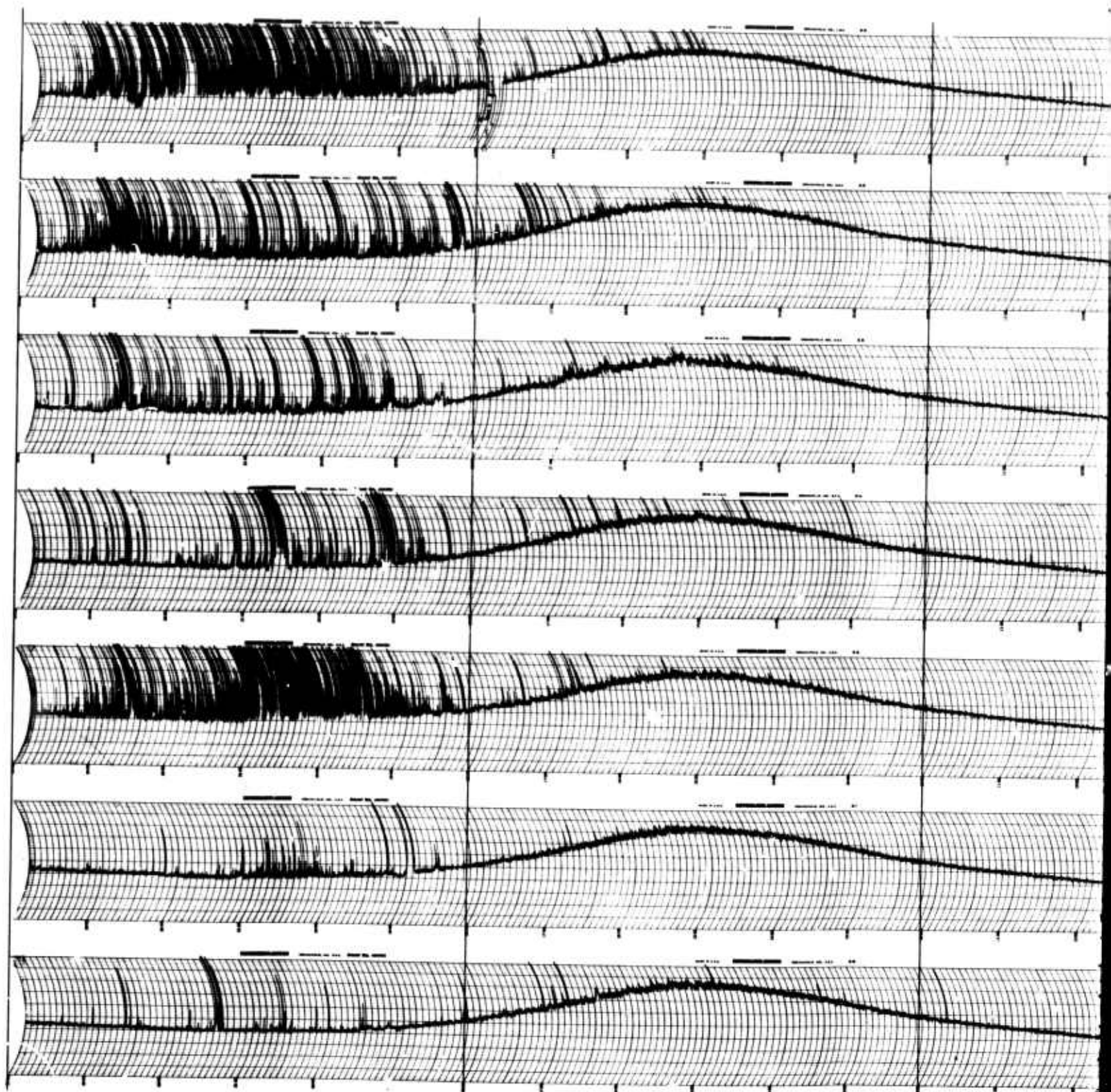
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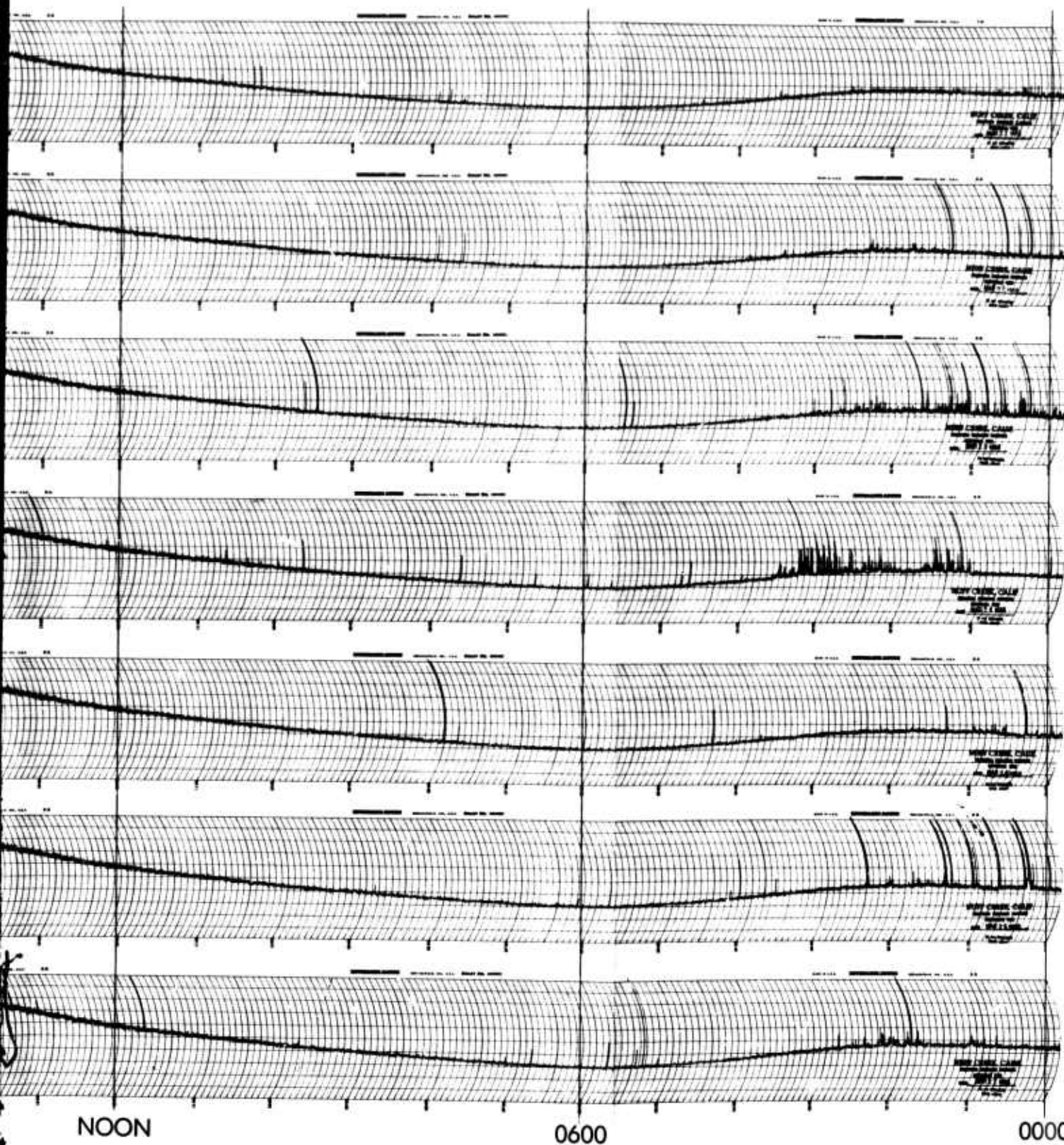
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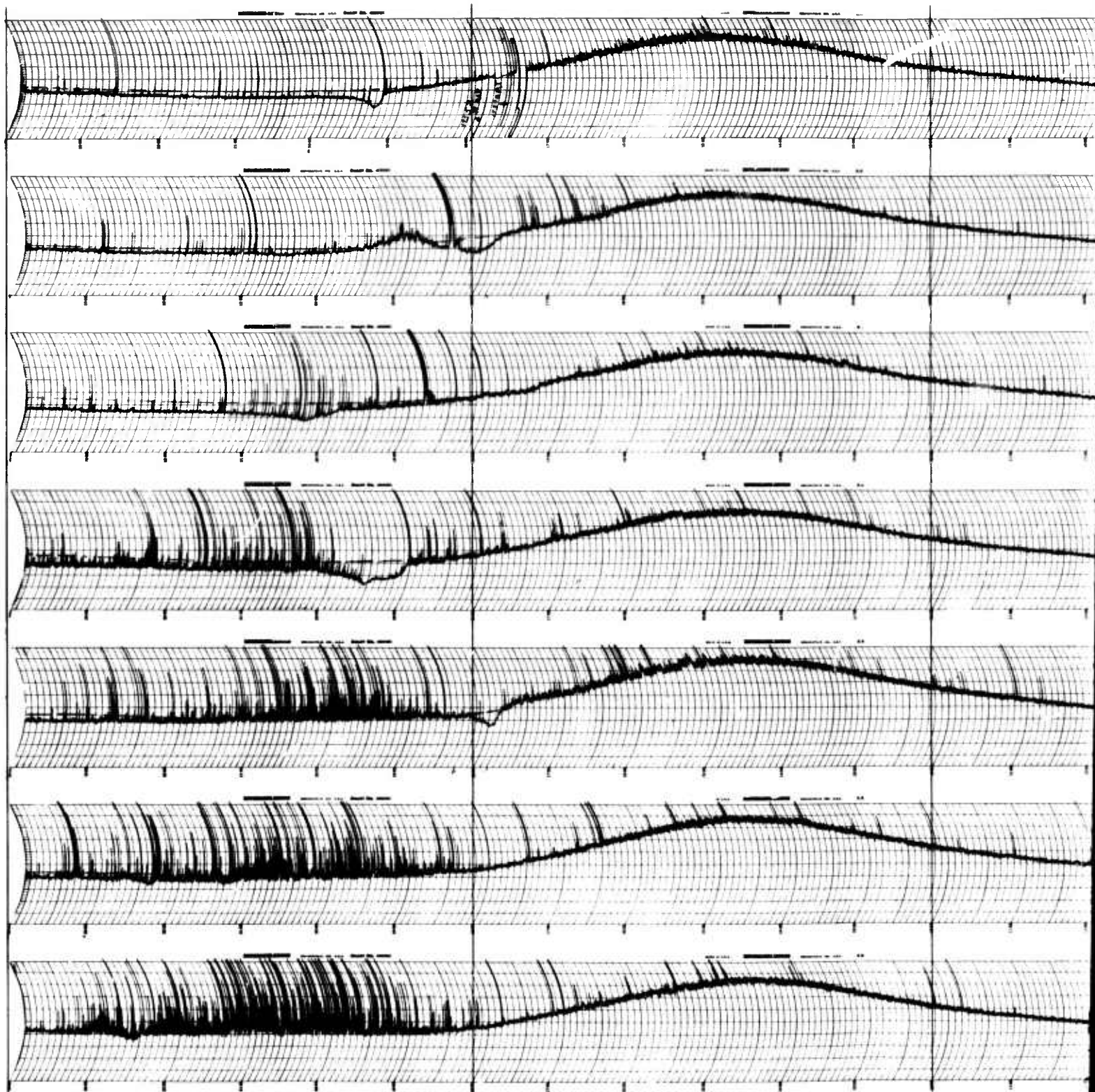
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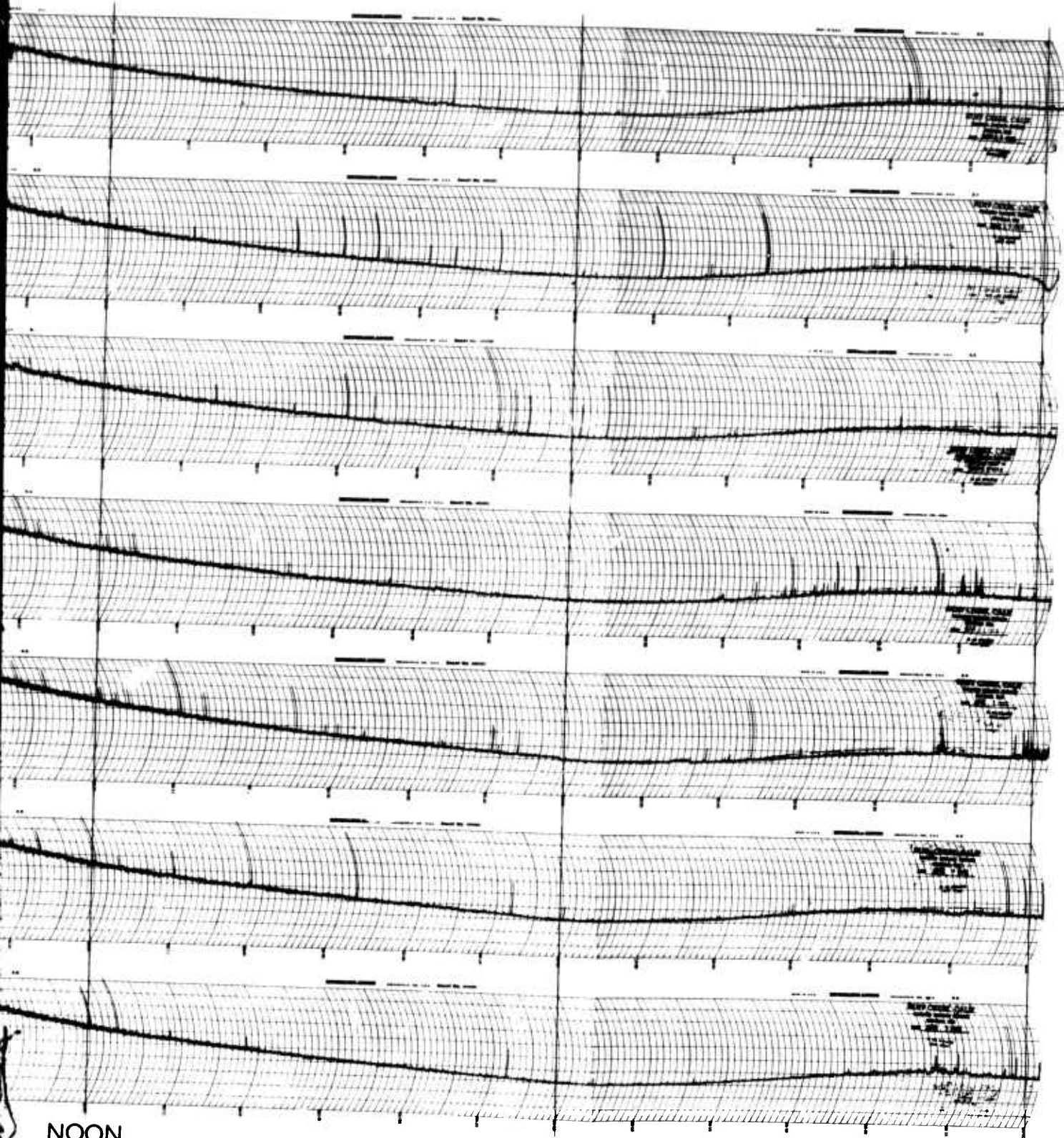
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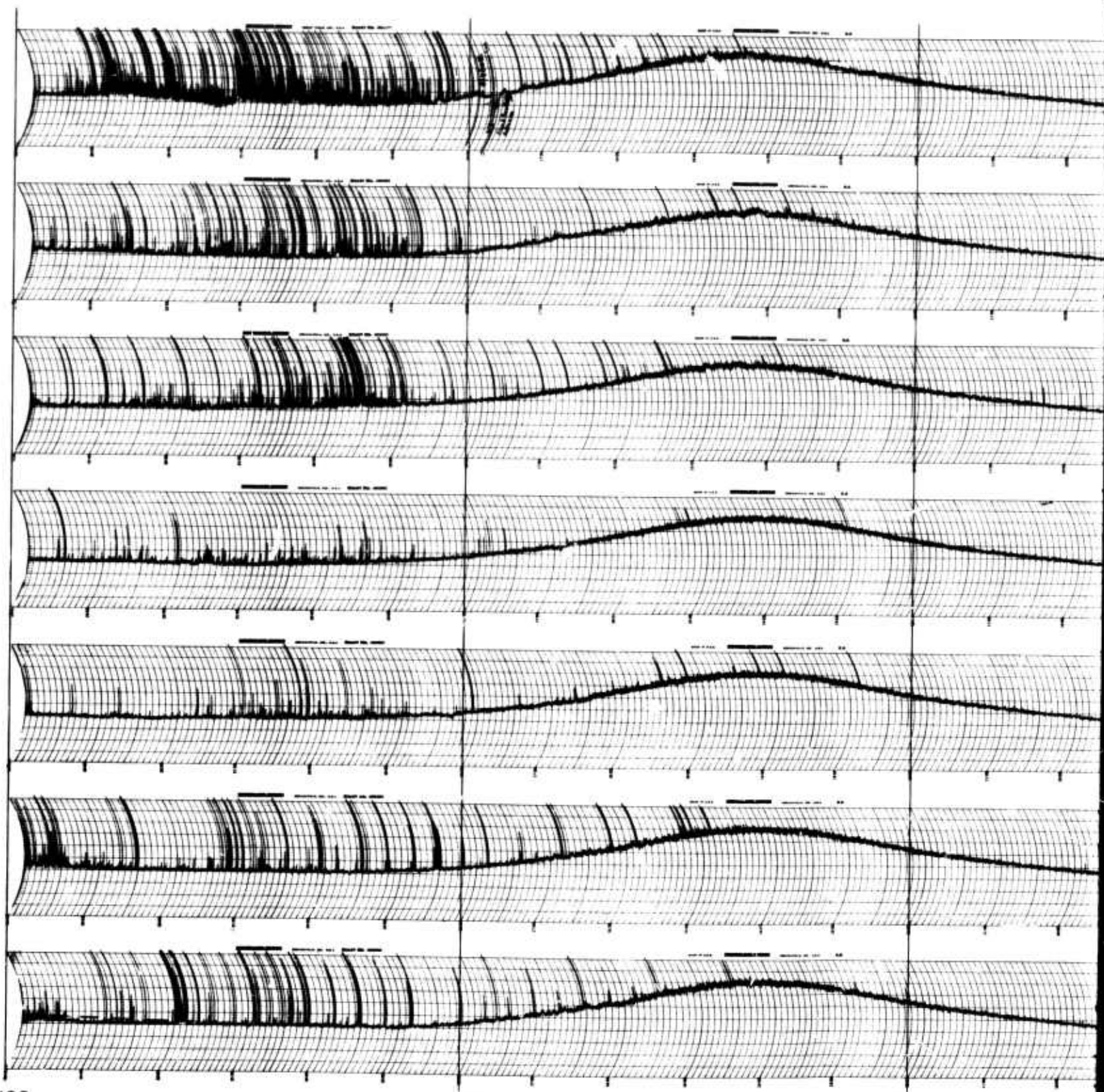
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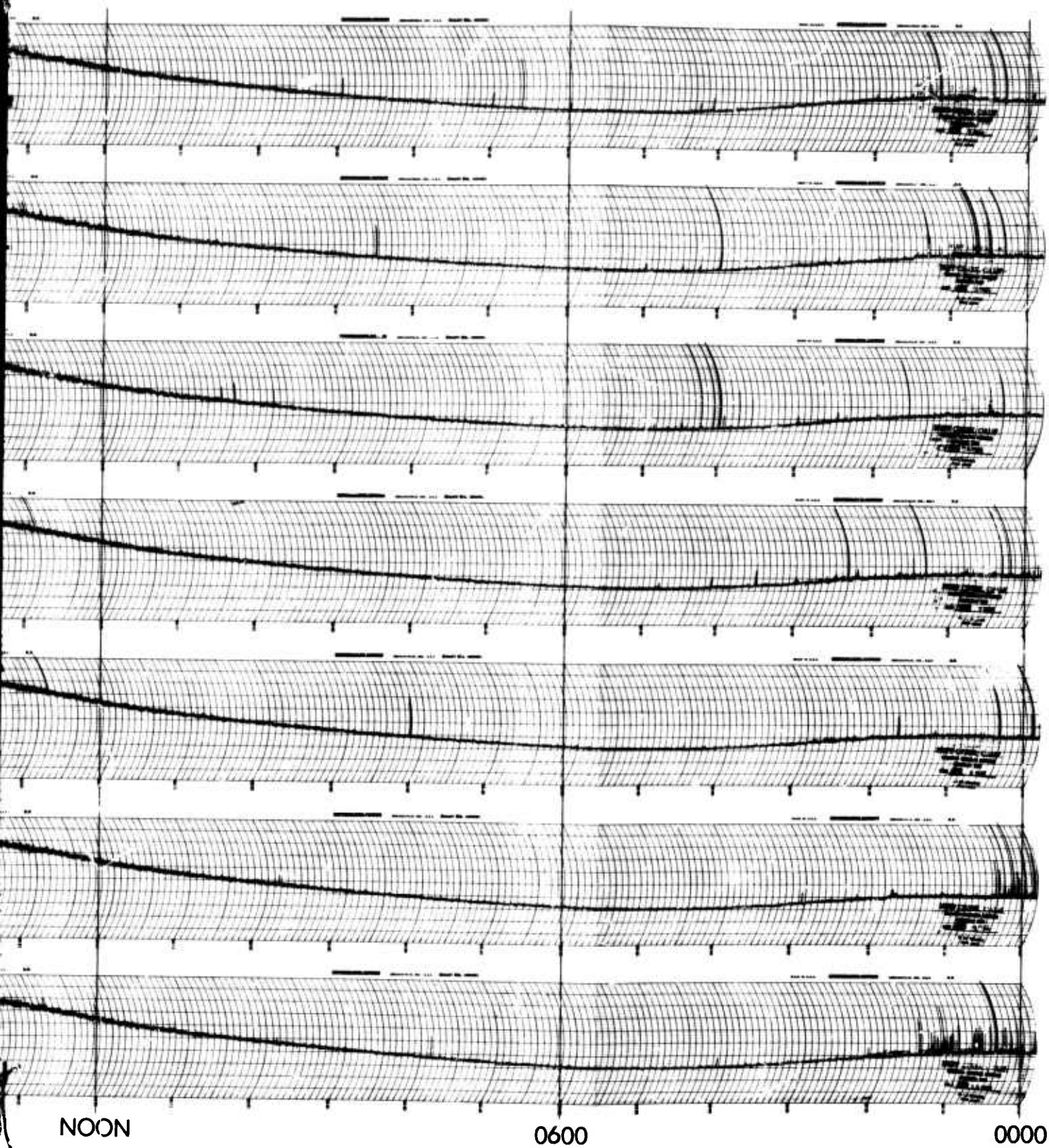
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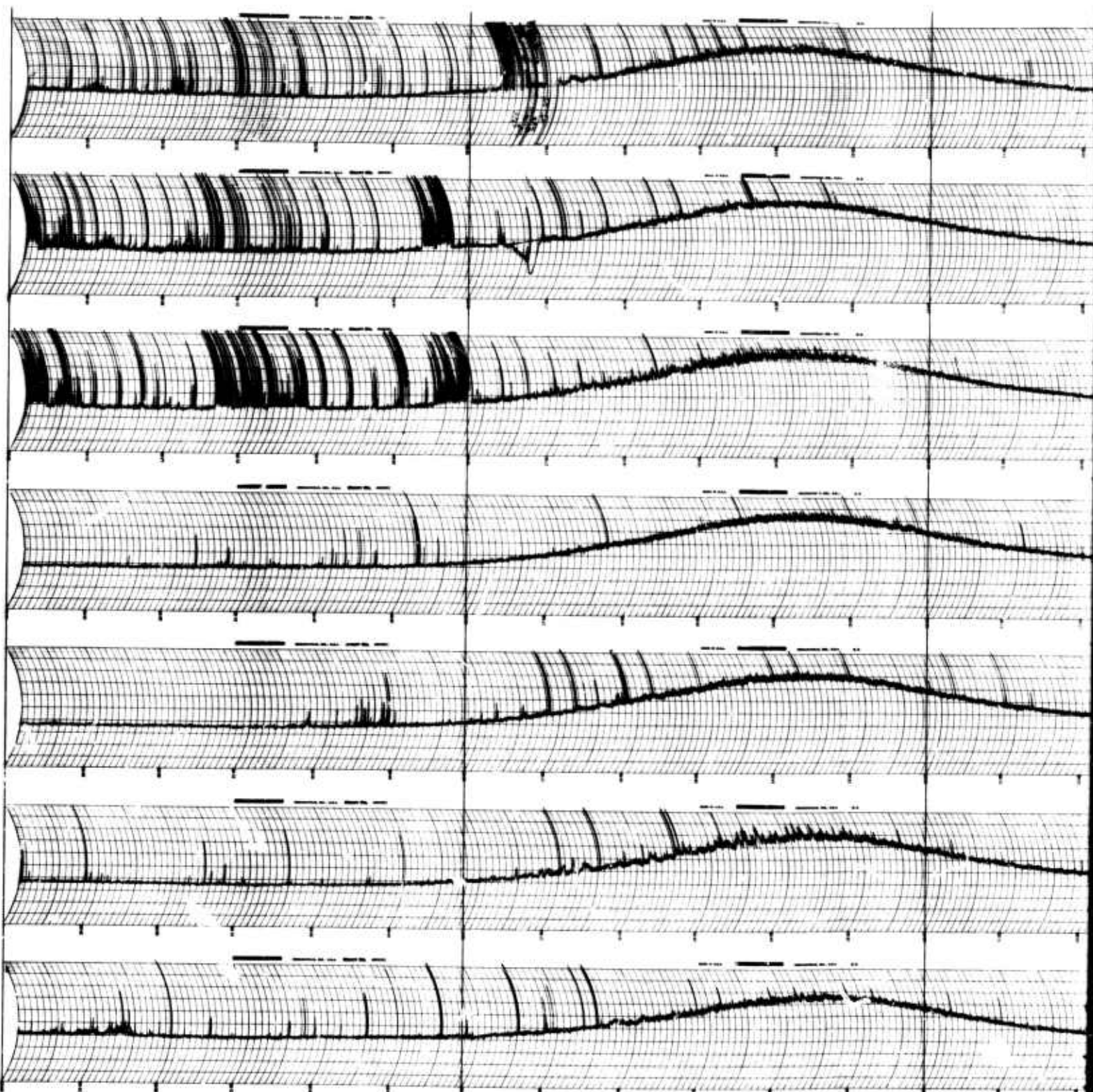
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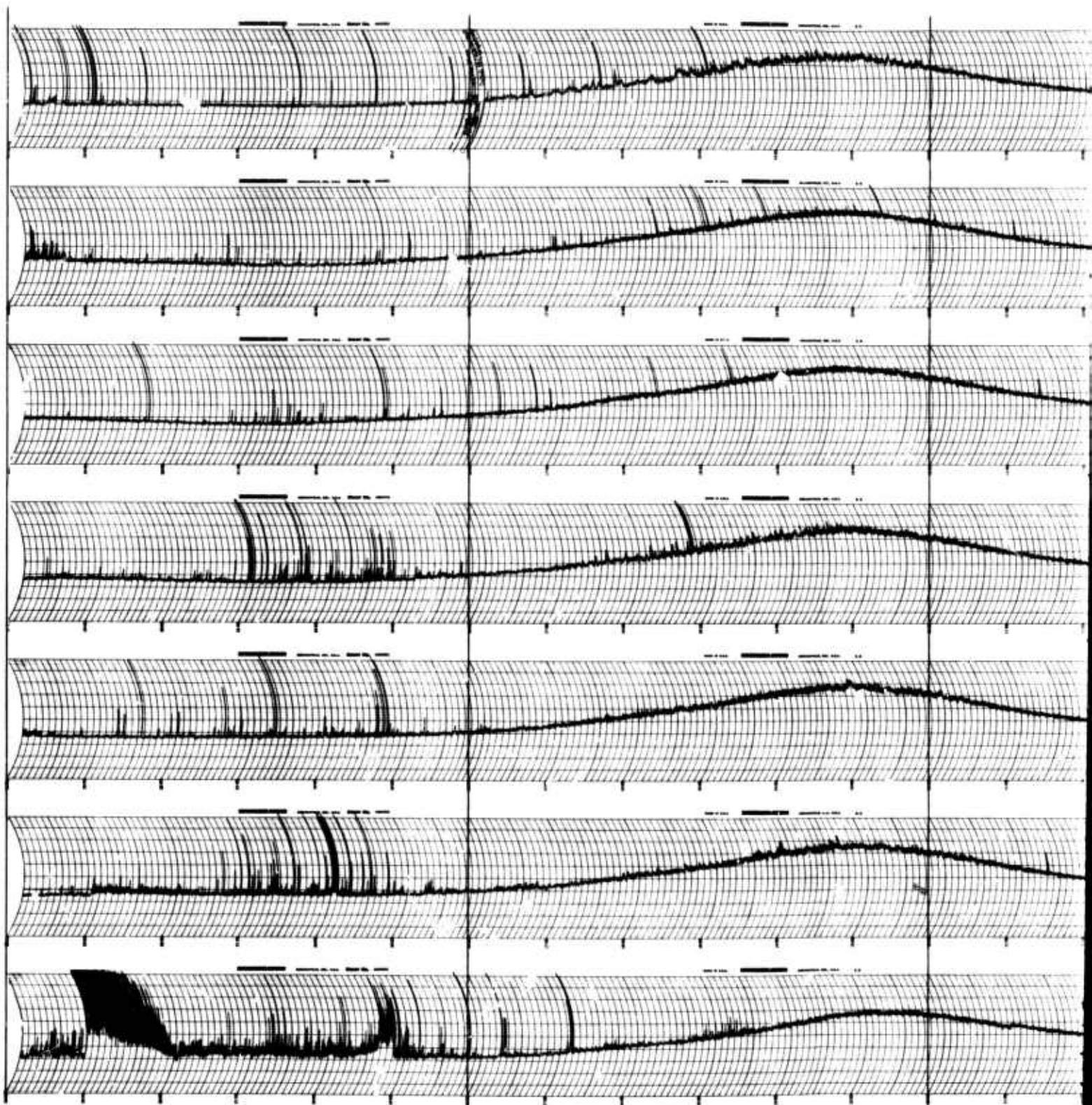
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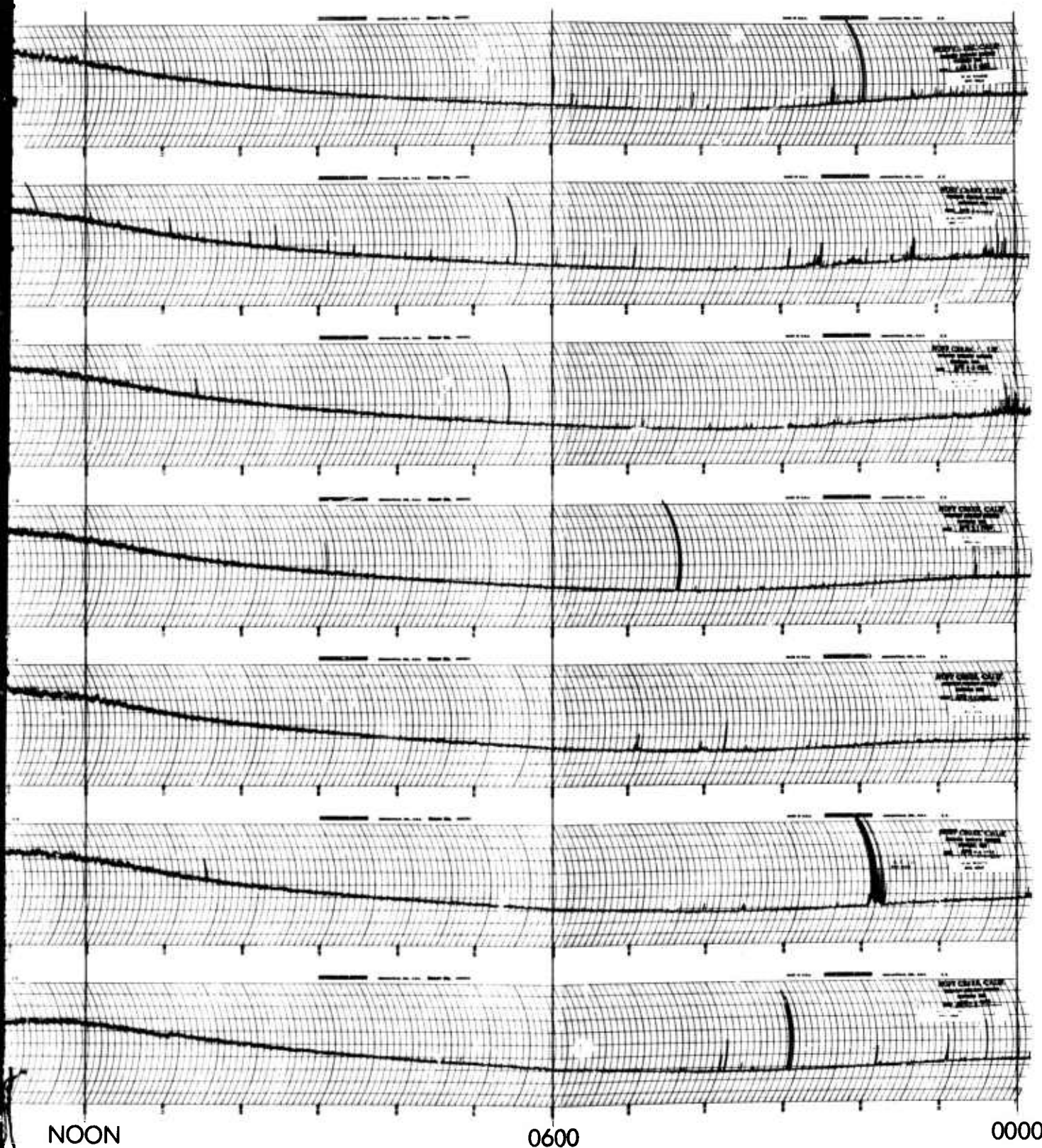
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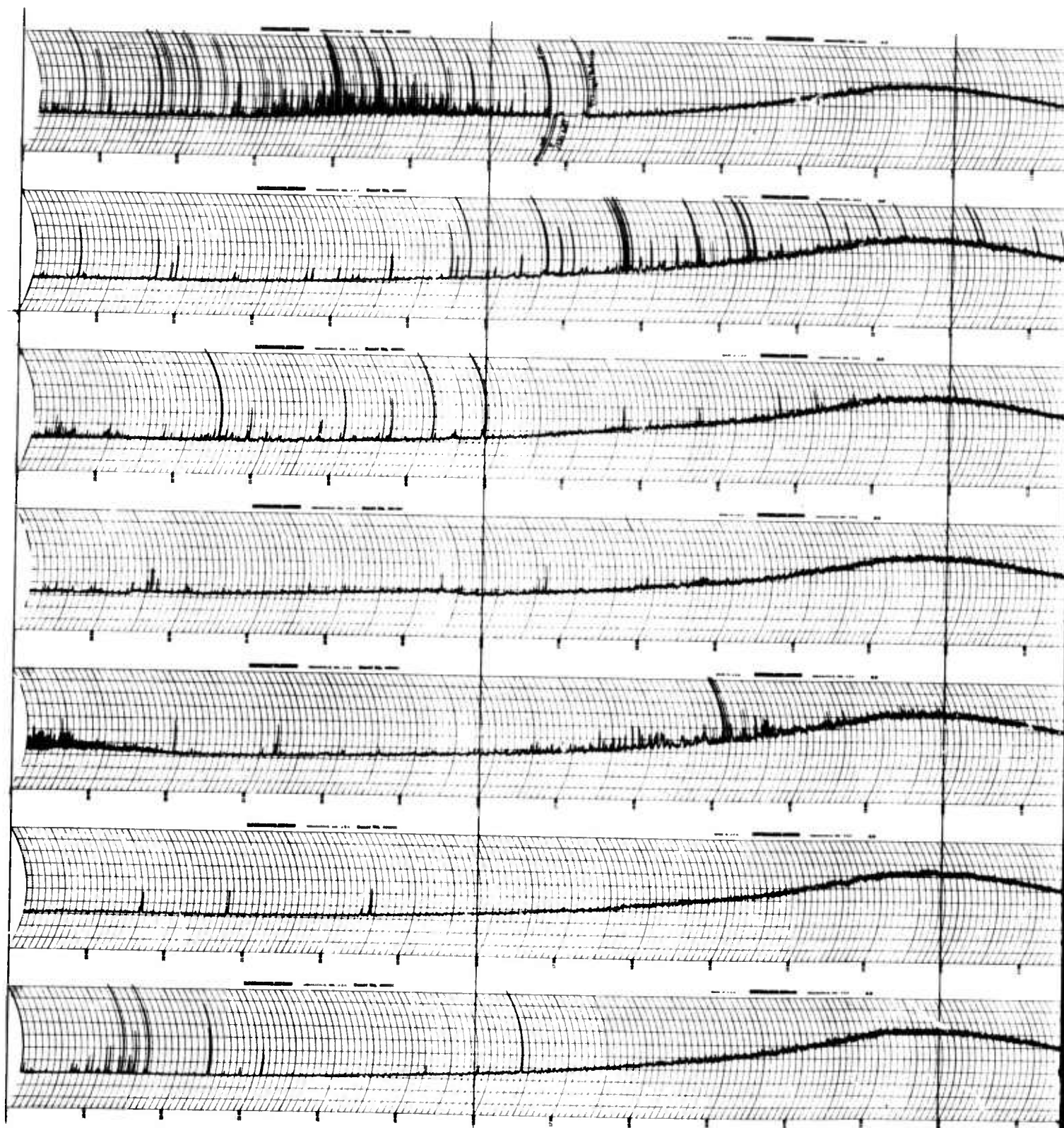
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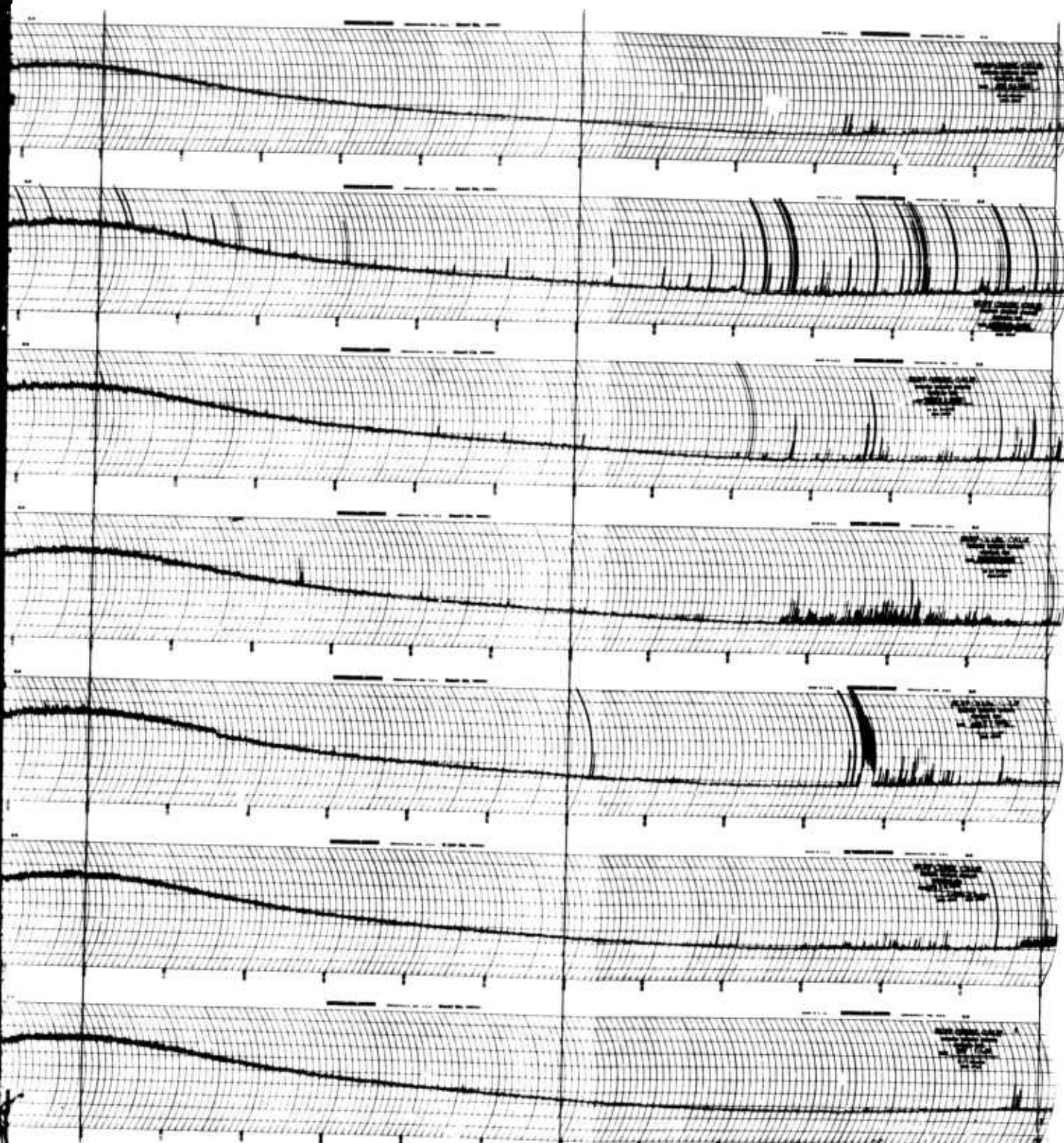
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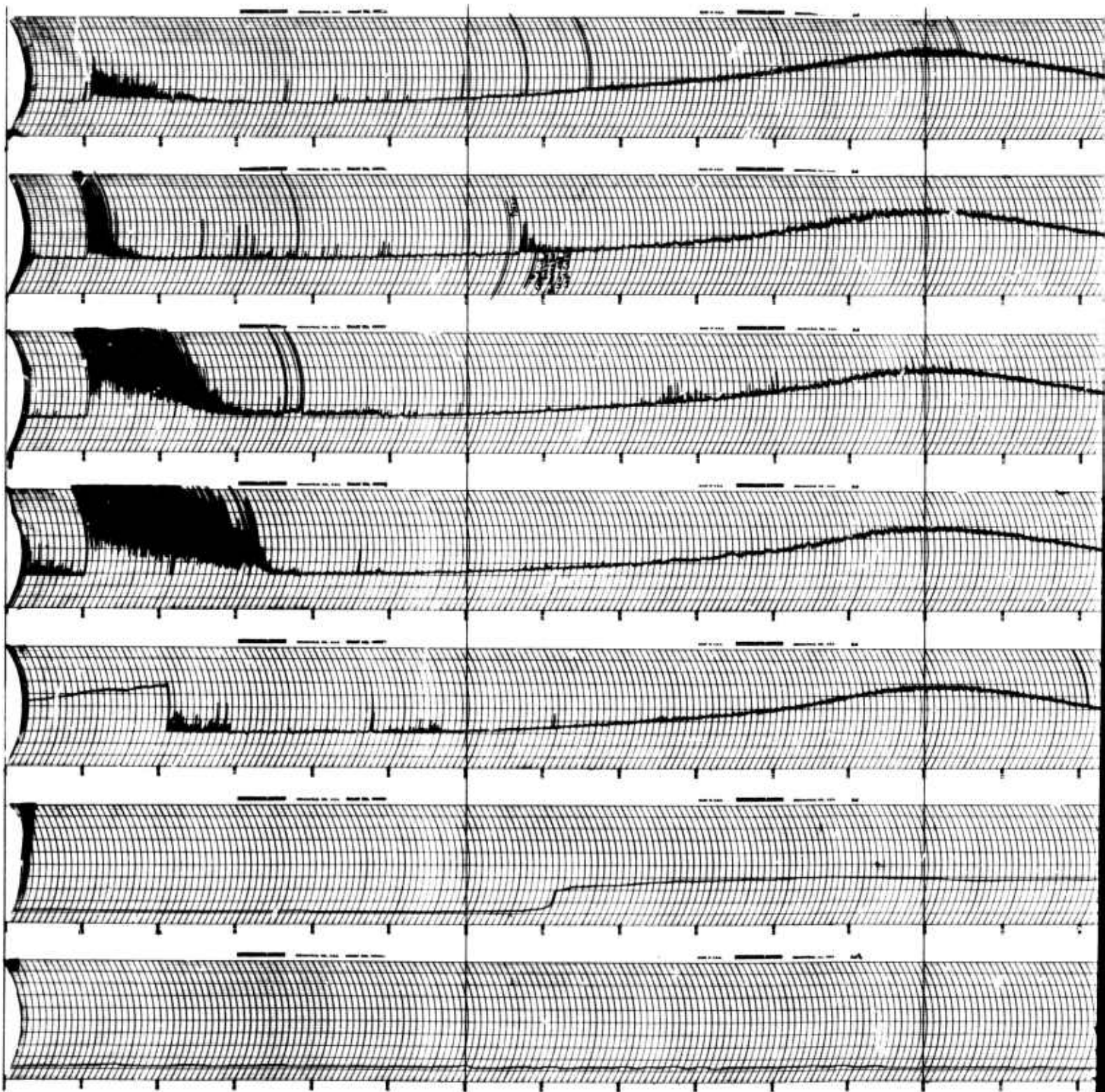
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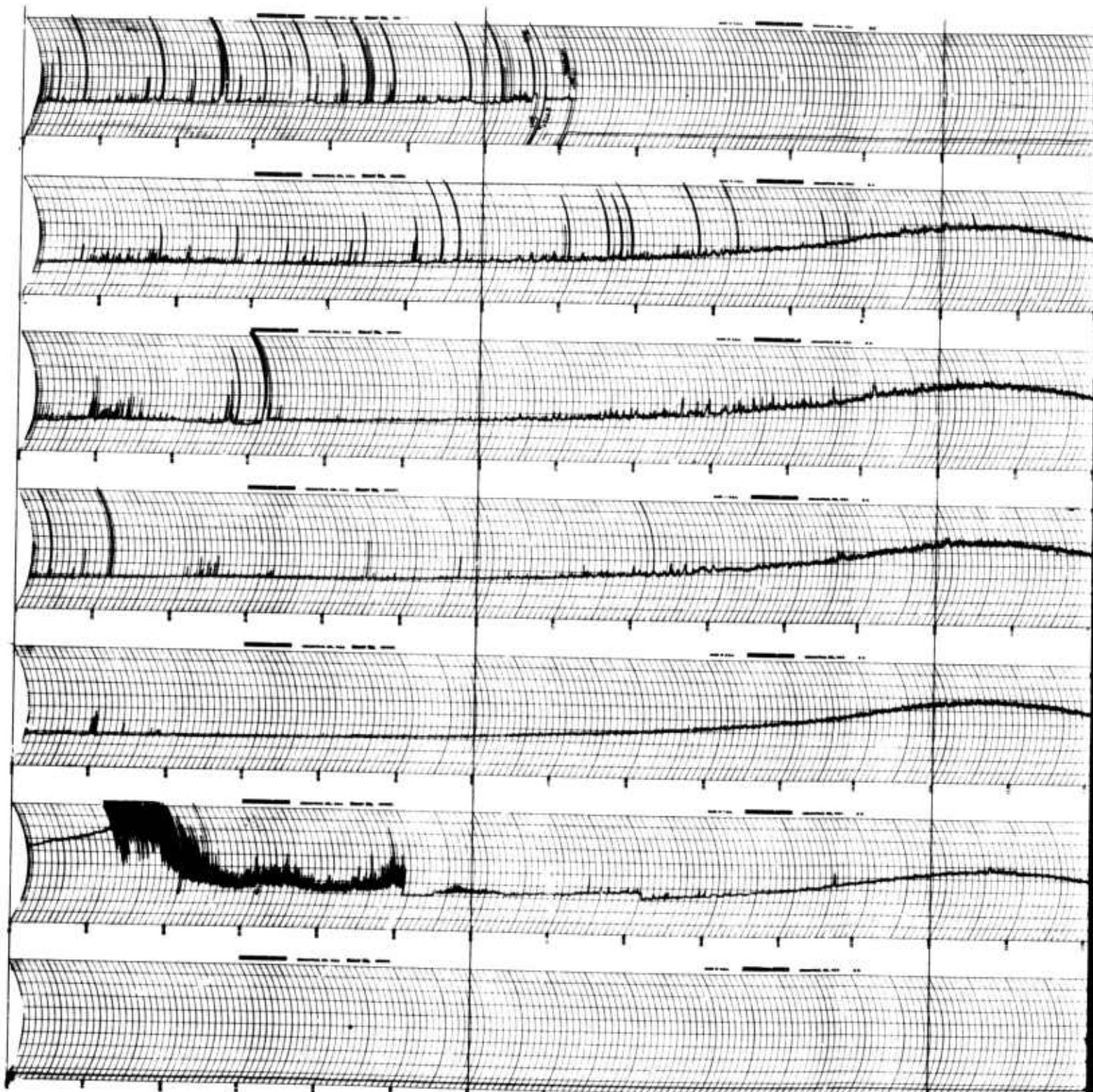
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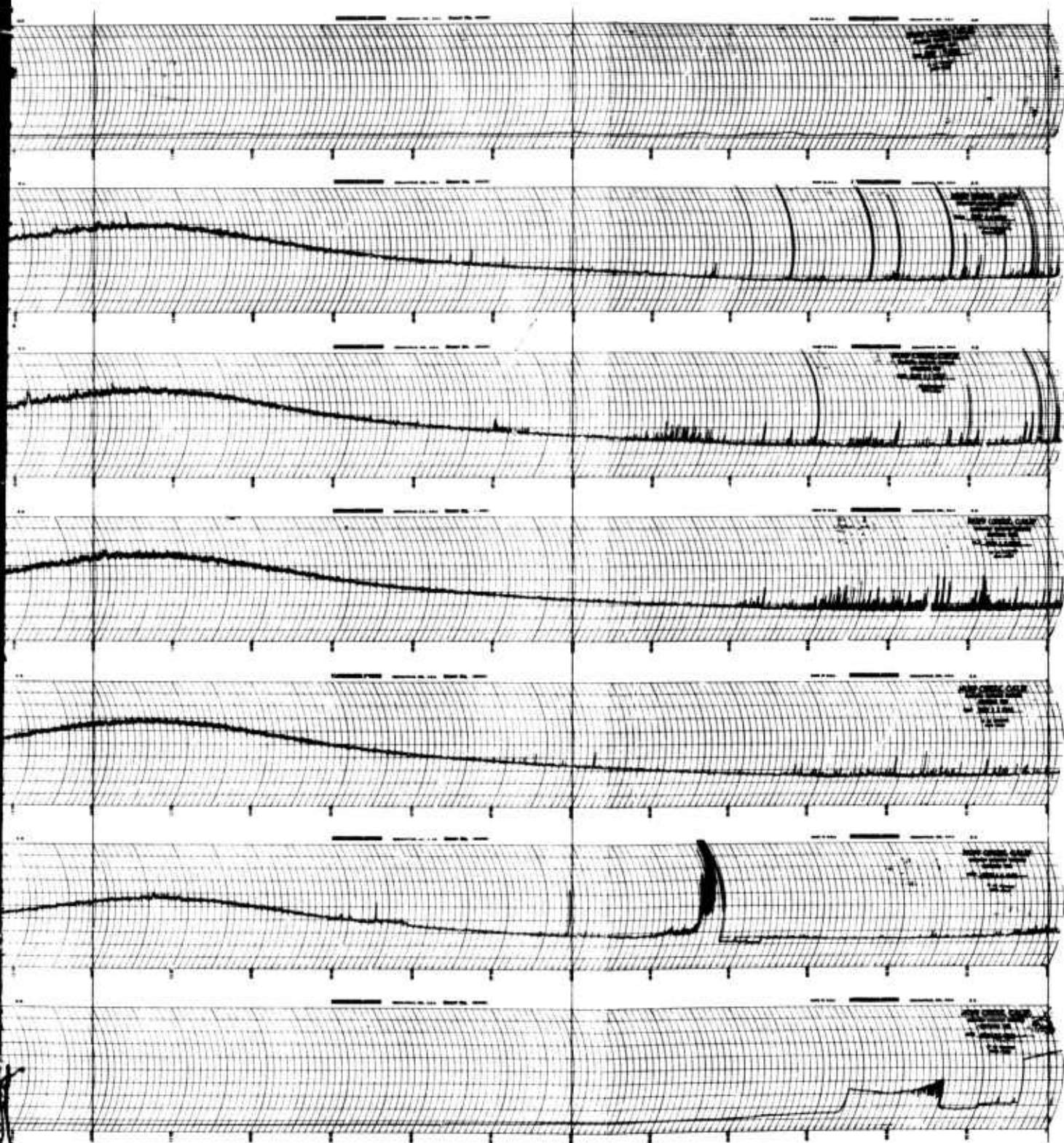
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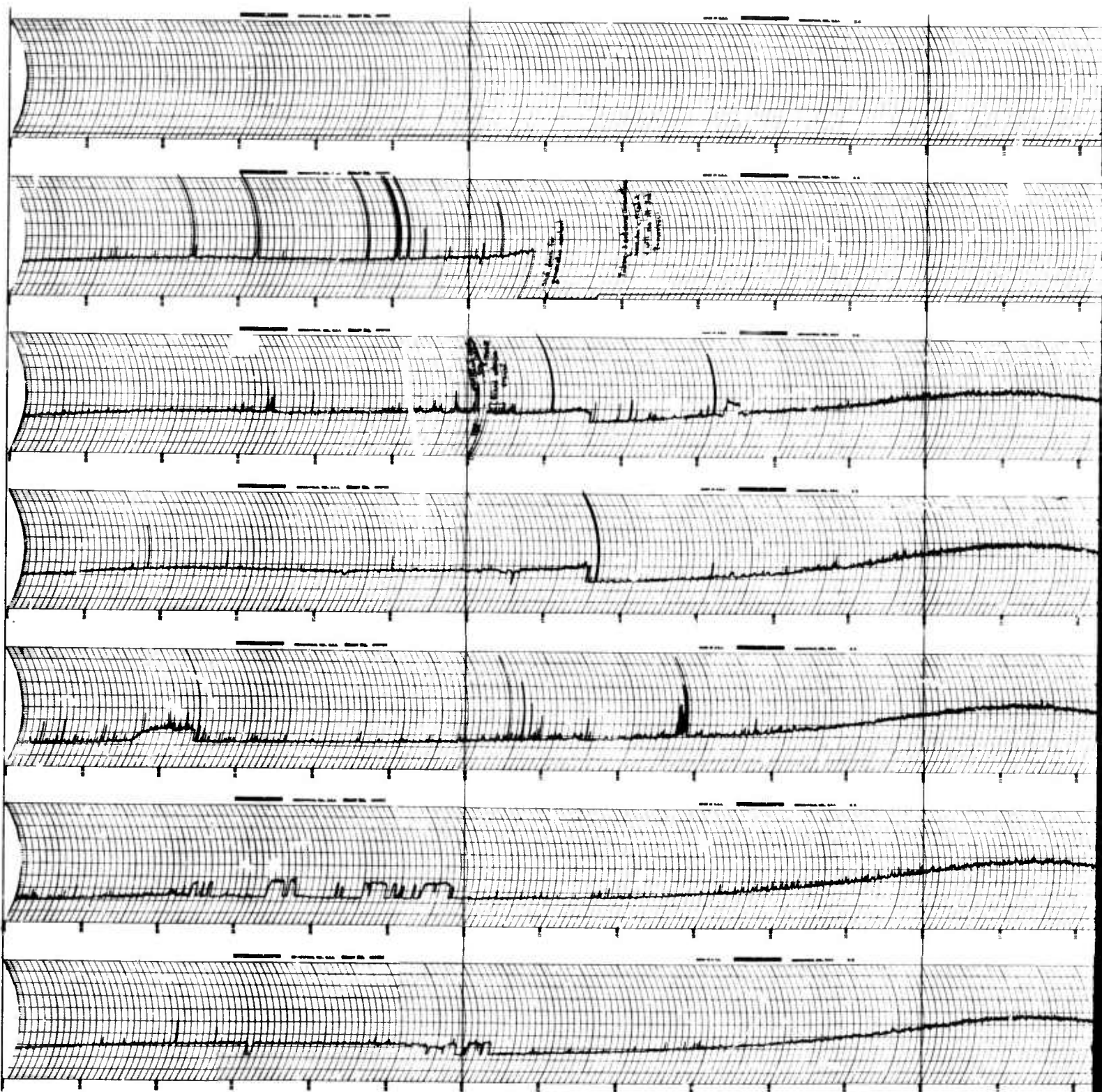
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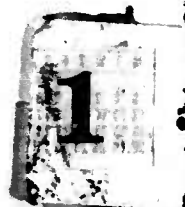
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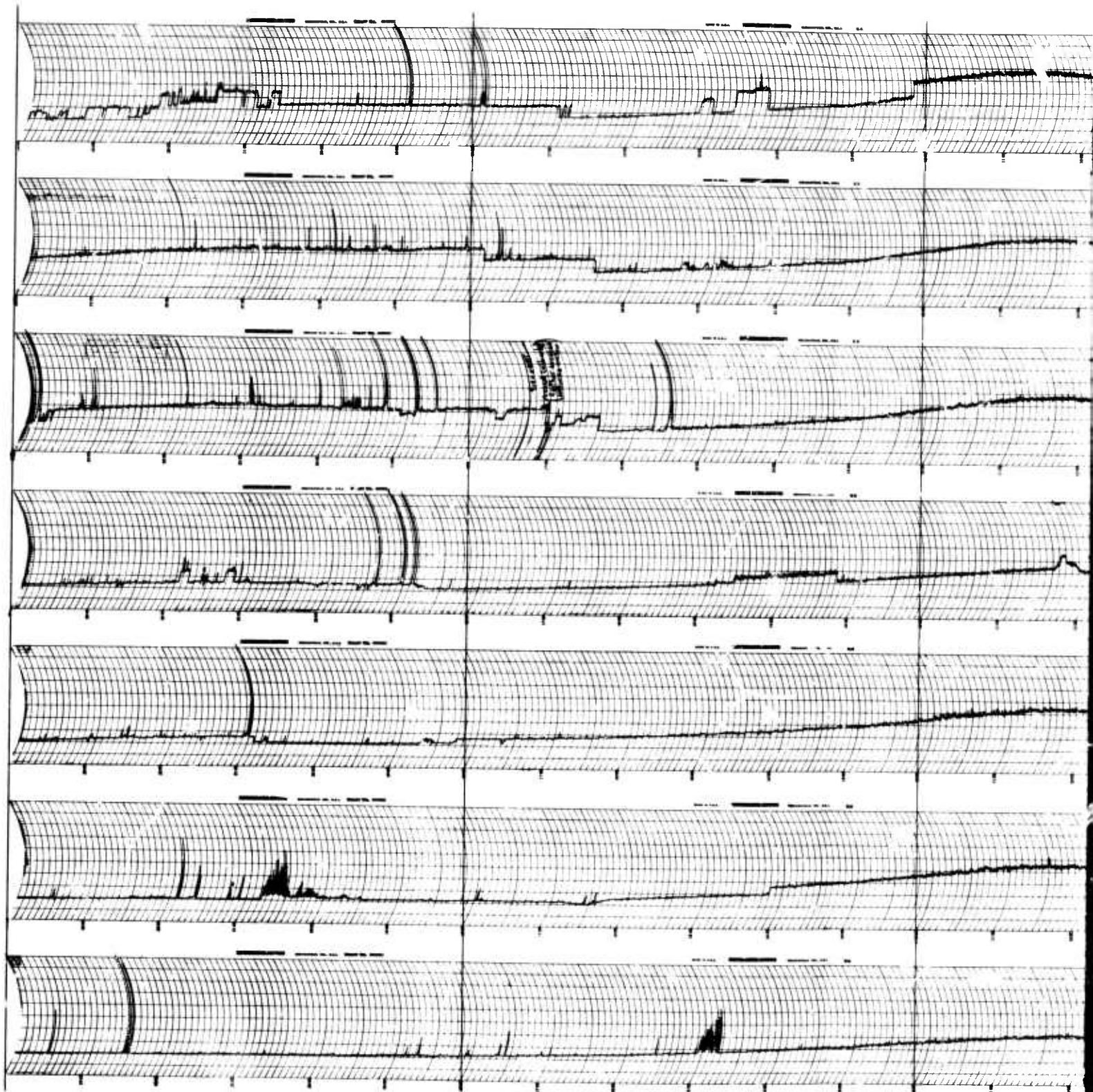
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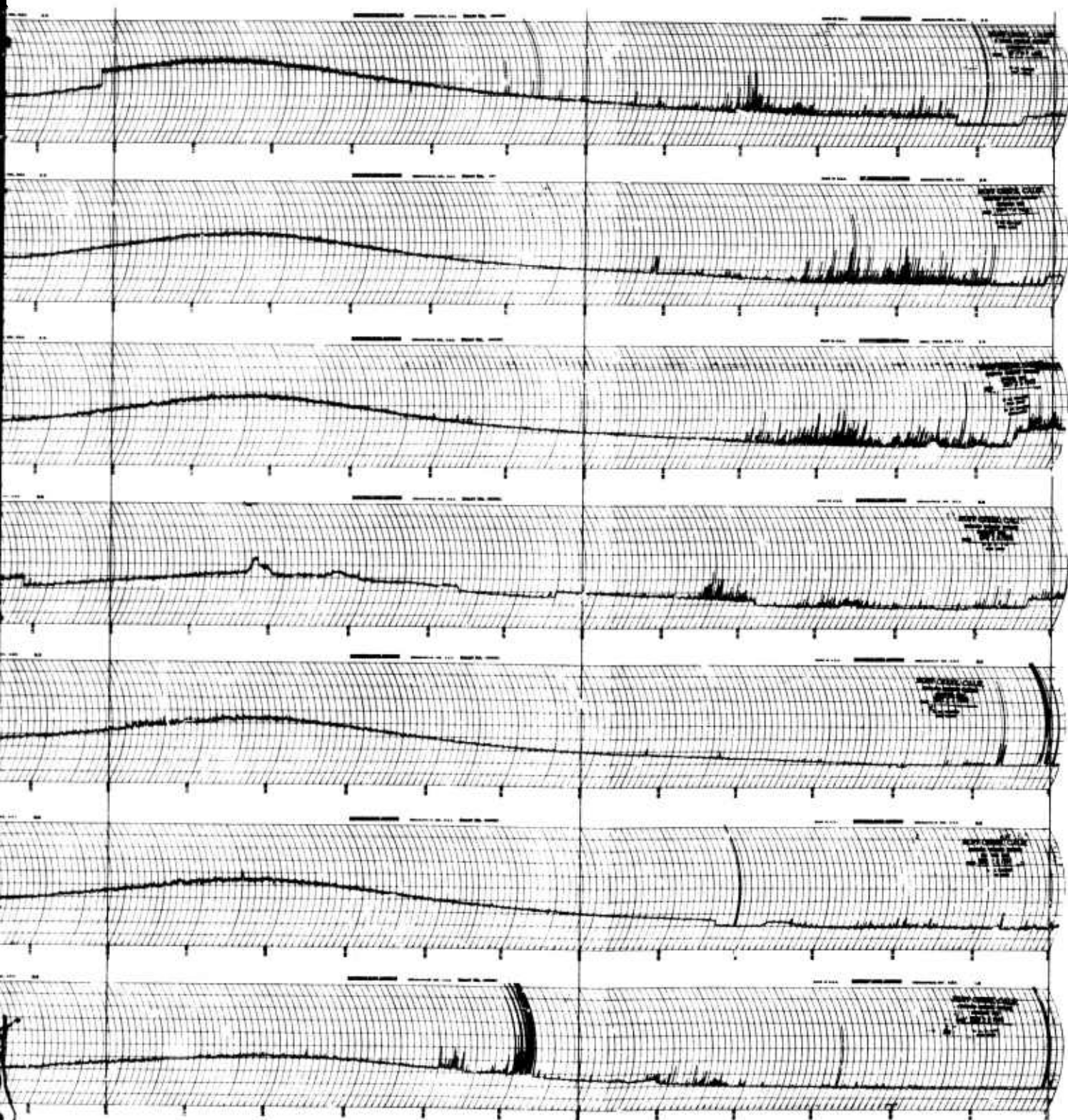
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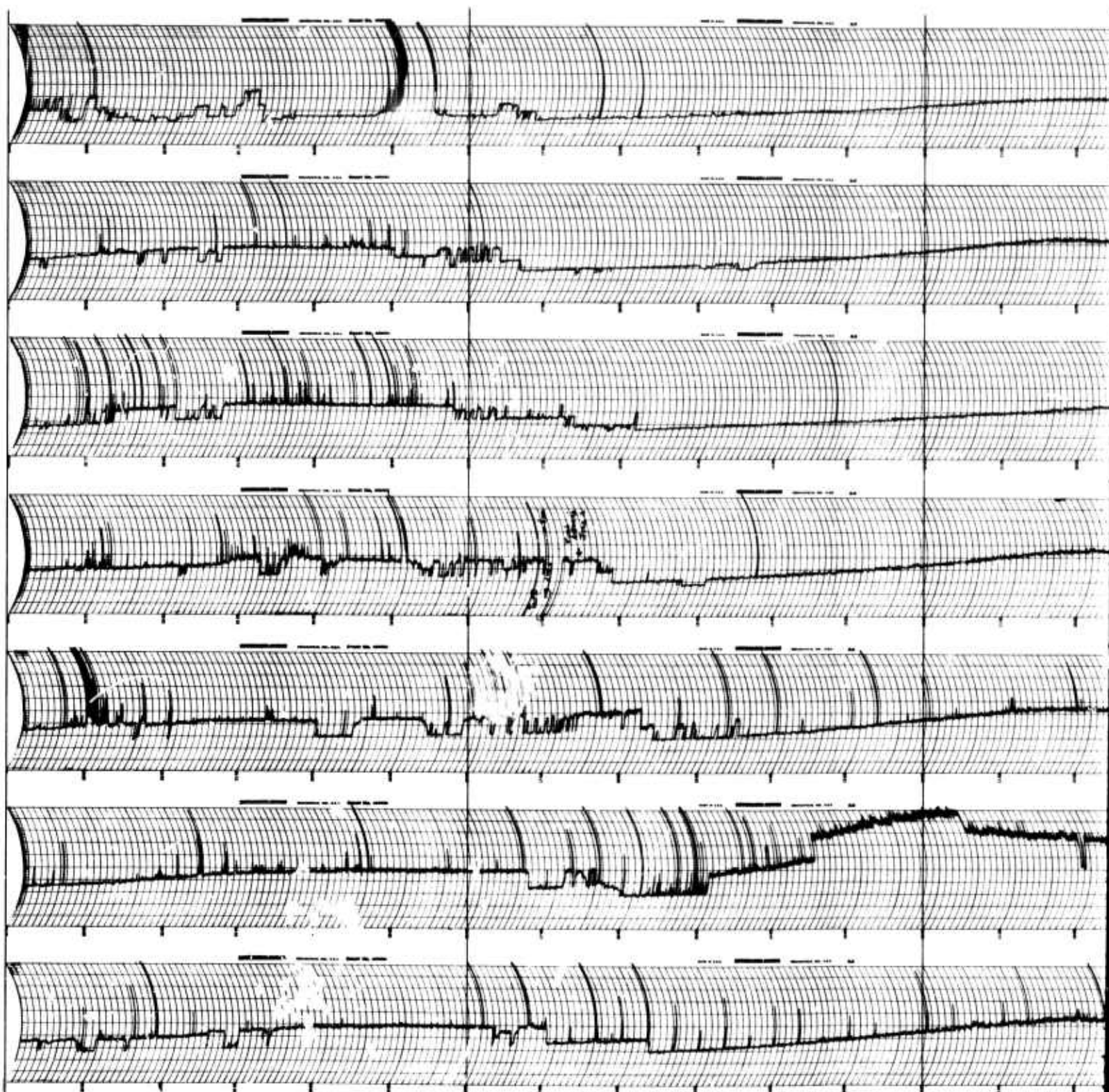
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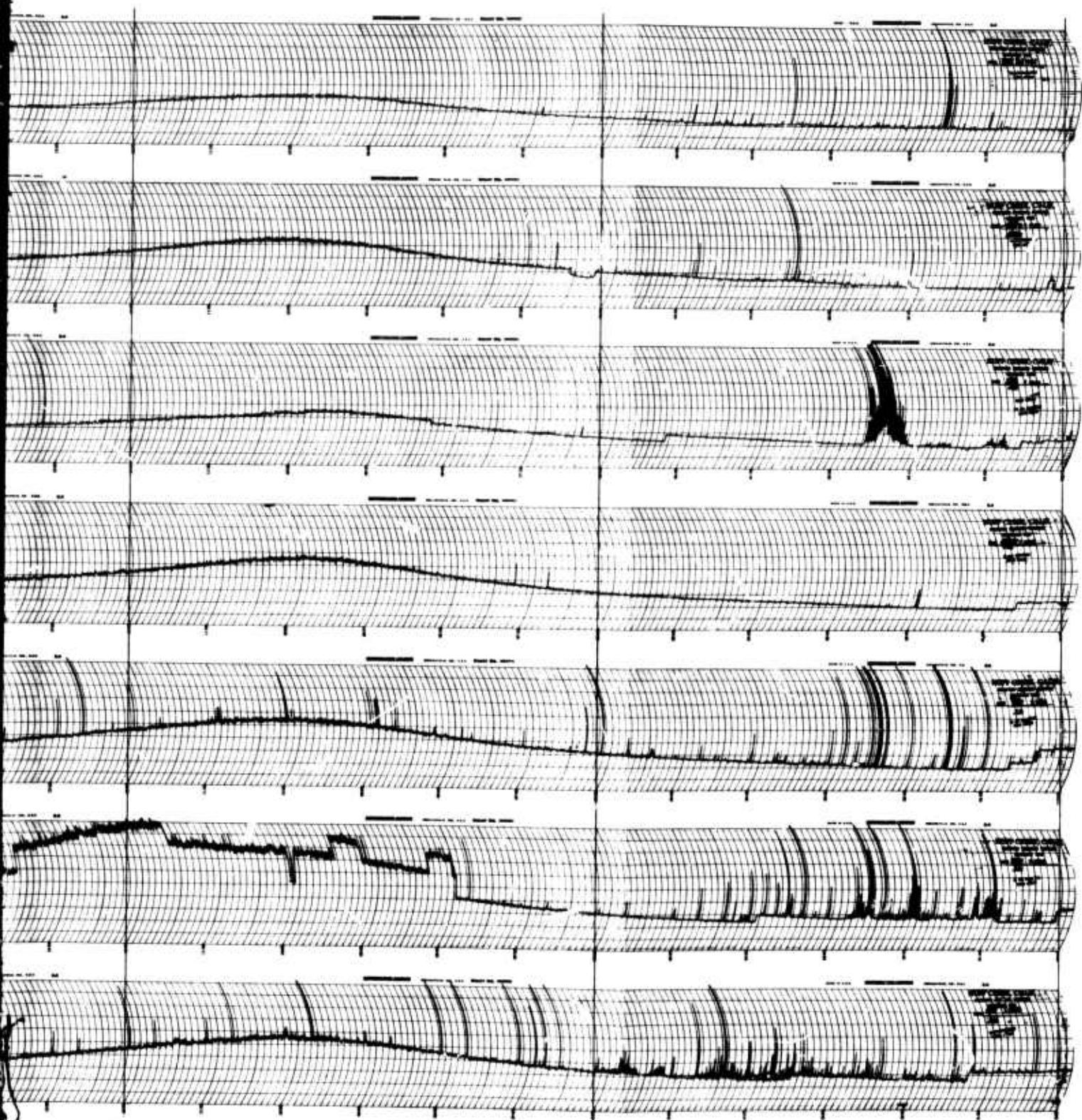
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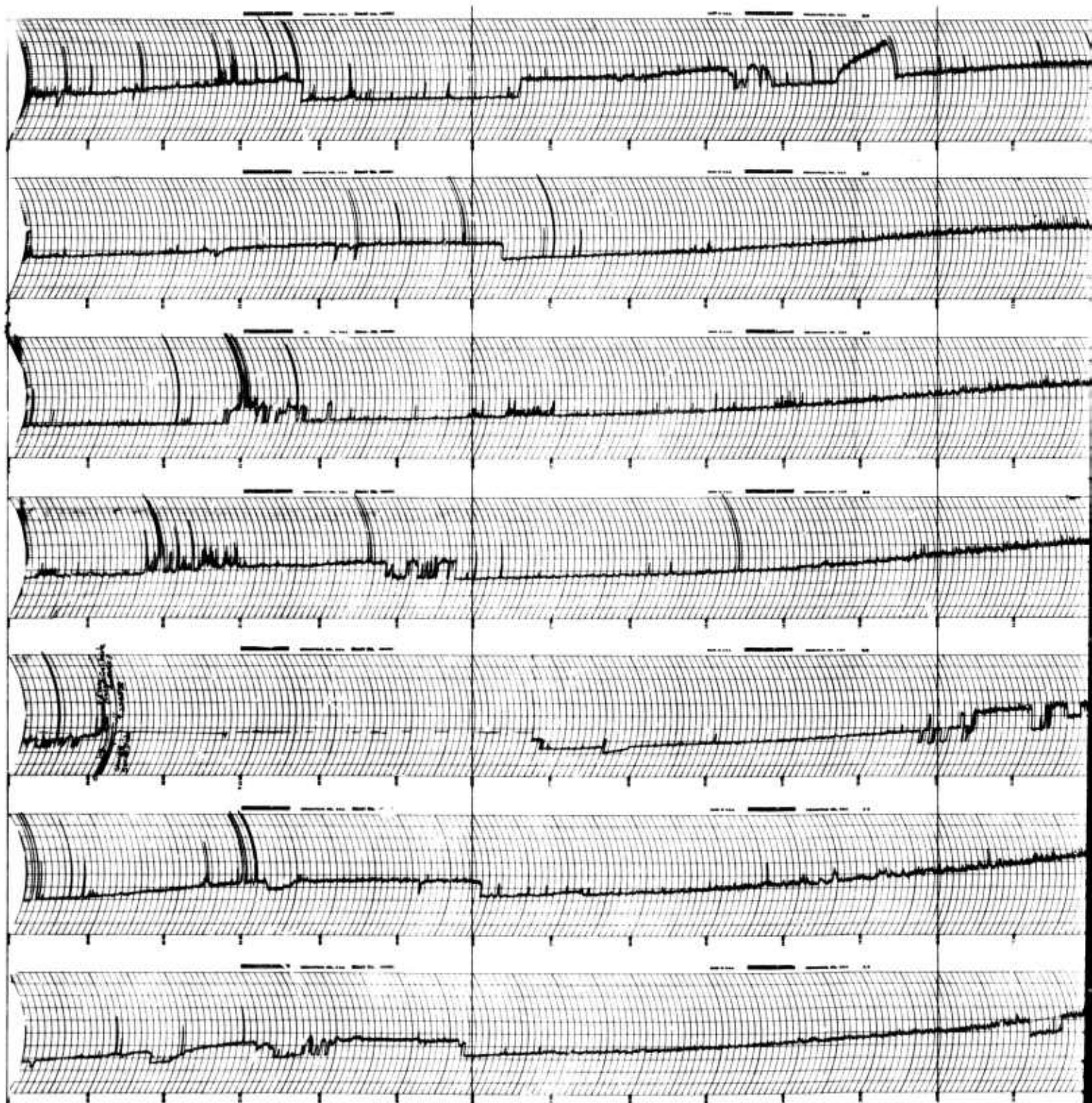
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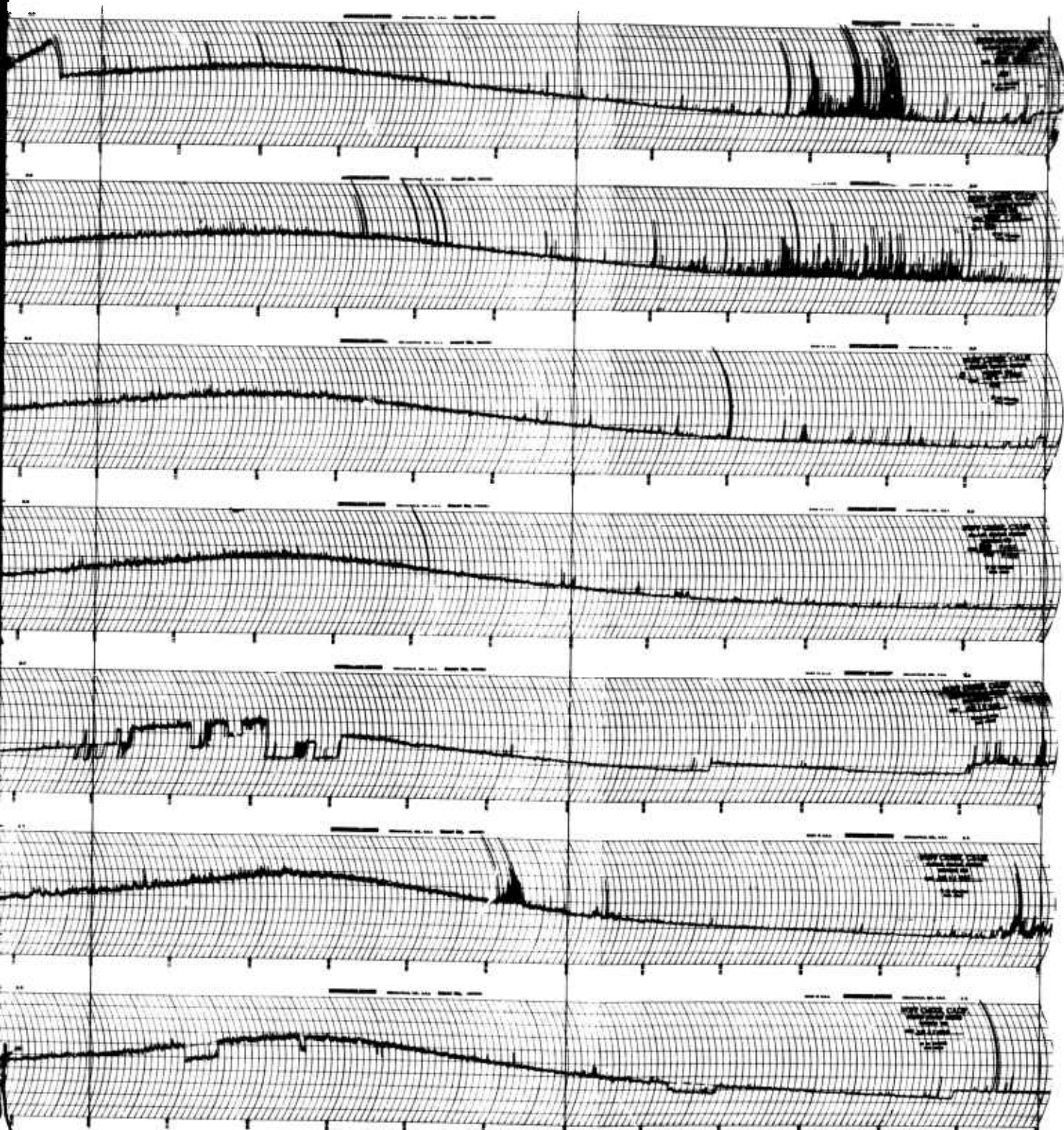
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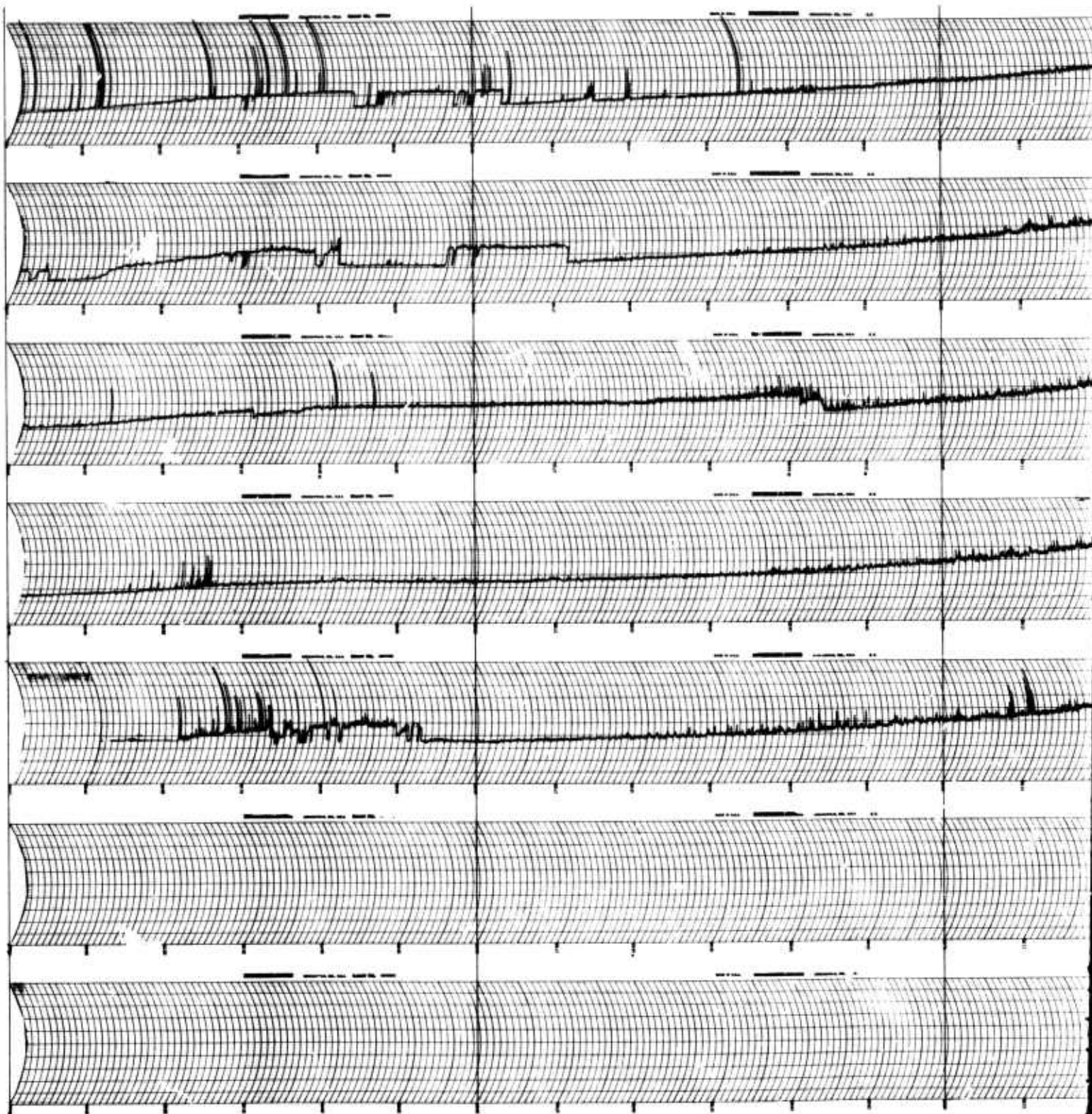
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