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Appendix II to
Semiannual Technical Report I

Covering the Period 29 June 1964
to 3 January 1965

RIOMETER RECORDS OF 18- AND 30-Mc COSMIC NOISE

474940

By: J. C. HODGES

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Prepared for:

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

CONTRACT AF 57)-13727
AFTAC PROJEC AUTHORIZATION
NO. T/5060/ASD 59)
ARPA ORDER NO. 159

STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA

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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 For 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 29 June 1964 to 3 January 1965. 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.

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I INTRODUCTION

As part of the experimental studies of ionospheric variations being conducted at SRI, a riometer station has been operated continuously from 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 29 June 1964 to 3 January 1965 are reproduced in this volume to make them available to other researchers. These records are useful for comparison with other riometer records or correlation with other data concerning the sun, the earth's 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 RIOMETER

A. General Description

The word riometer is derived from "relative ionospheric opacity meter." The riometer is an ultra-stable 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 particles or intense radiations, additional ionization is generated which permits less cosmic noise to pass through the ionosphere, 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 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:

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

and

$$P = KTB \qquad (2)$$

where

T = equivalent temperature in ^{o}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 ^{o}K, which is approximately equal to room temperature. A value of $300^{o}K$ is usually used.

P = noise power

k = Boltzman's constant, and

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:

$$db = 10 \log \frac{I_1}{I_2} \qquad (3)$$

where

I_1 is the reference current, and

I_2 is the 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 prodecure is to operate the riometer for several days, and under "normal" circumstances the daily trace on the chart will reteat 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 4-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:

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

where

ΔP is the uncertainty in measuring P,

P is the measured power,

B is the receiver bandwidth (pre-detection), and

T is the integration time constant (post-detection).

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:

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

Integration Time Constant	
ARI Riometer	EMI Riometer
2.5 sec	2 sec
6 sec	7 sec
16 sec	20 sec
27 sec	-

The antenna used with the riometer is another important factor. If the antenna is tilted it will see a different portion of the sky than an antenna looking directly overhead, thereby producing 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 side lobes 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, a good deal more of the sky is covered than might be expected.

III NUFF CREEK, CALIFORNIA, SITE

A. General Description

The Nuff Creek site, operated by SRI, is located in a steep-sided valley near Half Moon Bay (Lat. 37°30.6'N, Long. 122°[illegible].8'W) several miles from any power lines or other sources of interference. The equipment is powered by batteries and propane thermoelectric generators. The batteries used with the 18-Mc riometer are charged for 1-1/2 days each week by a small gasoline generator and provide adequate power to operate one ARI riometer continuously. Two propane fuel cells will operate two riometers; the fuel consumption is approximately 40 gallons (200 lbs) per month.

The station at Nuff Creek is unmanned. A technician services the equipment weekly, spending approximately two hours at the site each visit. Time marks are placed on the records during the weekly servicing; these time marks are obtained directly from station WWV and have an accuracy of ±1 sec. Errors between the time marks and the chart time divisions are distributed linearly throughout the week unless obvious time errors are detected in the weekly data. Simultaneous interference bursts observed on the two frequencies often allow a crosscheck on the timing accuracy of the two recorders.

B. 30-Mc Riometer

The 30-Mc EMI riometer is a standard EMI Products, Inc.* instrument with a 3320-ohm servo-diode load resistor. The recorder used is an Esterline-Angus pen recorder with a chart speed of 3 in per hour; full-scale deflection is adjusted to be 2.9 ma.

---

* Now Western Electrodynamics, Inc. (WEI).

The antenna used with the EMI riometer is a Hygain three-element Yagi with an E-plane half-power beamwidth of 65 degrees and an H-plane half-power beamwidth of 110 degrees. The impedance of the antenna is 47 ohms. The antenna feedline is RG-8A/U cable with an estimated loss of 1 db. The antenna polarization was either parallel to the valley N59°E true (N42°E magnetic), or perpendicular to the valley as noted in the Chronological Log.

C. 18-Mc Riometer

The 18-Mc ARI riometer is an Aerospace Research Inc. Model 100-A instrument modified to have a 50-ohm servo-diode load resistor, which requires attenuation in the antenna lead (see the Chronological Log below). 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.

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 degrees between the half-power points.* The antenna impedance is 59 ohms. The antenna feedline is RG-8A/U cable with an estimated loss of 2 db.

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* 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 (EMI)

The 30-Mc riometer had a slowly drifting quiet-day curve during this period, at first attributed to the servo diode. In March 1965, however, an examination of the riometer revealed a hidden antenna lead wire within the antenna connector on the RF module, slightly U-shaped and nearly touching the inside surface of the connector. A slight upward change in temperature caused the wire to lengthen and make a poor contact with the inside surface of the connector, producing an unwanted shunt resistance to ground.

A second malfunction was found at this time--a loose ground lug in the diode circuits. This was difficult to find because the actual riometer wiring did not correspond to the circuit diagram.

Since the riometer has been fixed and re-tuned it has performed regularly, but the 5845 diodes continue to have a shorter life than the 5722 diodes used in the ARI riometers.

Time losses were marked on the charts until the recorder was finally set correctly in December.

1964	29 June	Bandwidth 15 kc, integration 2 sec, frequency sweep off, minimum detector off, zero antenna attenuation, antenna polarization N59E true.
	2 July	0500 to 1130. Equipment failure, reason unknown. Quiet-day curve shifts downward slightly.
	7 July	Quiet-day curve shifts back up.
	23 July, 2020 to 31 July, 2235	Downward excursions caused by microphonic noise diode.
	26 Aug, 1314 to 1 Sept, 1525	No record, servo diode burnt out.

	6 Sept	0254 to 1257. Equipmental drop in record, cause unknown.
	22 Sept	1627 to 2634. Equipmental drop in record, cause unknown.
	29 Sept	1627 to 2245. Recorder ran out of paper. Changed noise diode in attempt to cure drifting quiet-day curve.
	10 Oct	Pen running out of ink.
	12 Oct	2040. Pen inked.
	27 Oct	0542 to 2112. Record rises, equipmental problem or local man-made noise.
	30 Oct, 1109 to 2 Nov, 2230	Servo diode burnt out.
	8 Nov	0203 to 1210. Equipmental drop in record.
	16 Nov	2300. Changed servo diode.
	23 Nov	2300. Installed new servo unit. Curve drops.
	28 Nov	0508 to 0517. Equipmental drop in record.
	30 Nov	1130. Changed back to original servo unit.
	7 Dec	0913 to 0920. Equipmental drop in record.
1965	3 Jan	Last record in this volume.

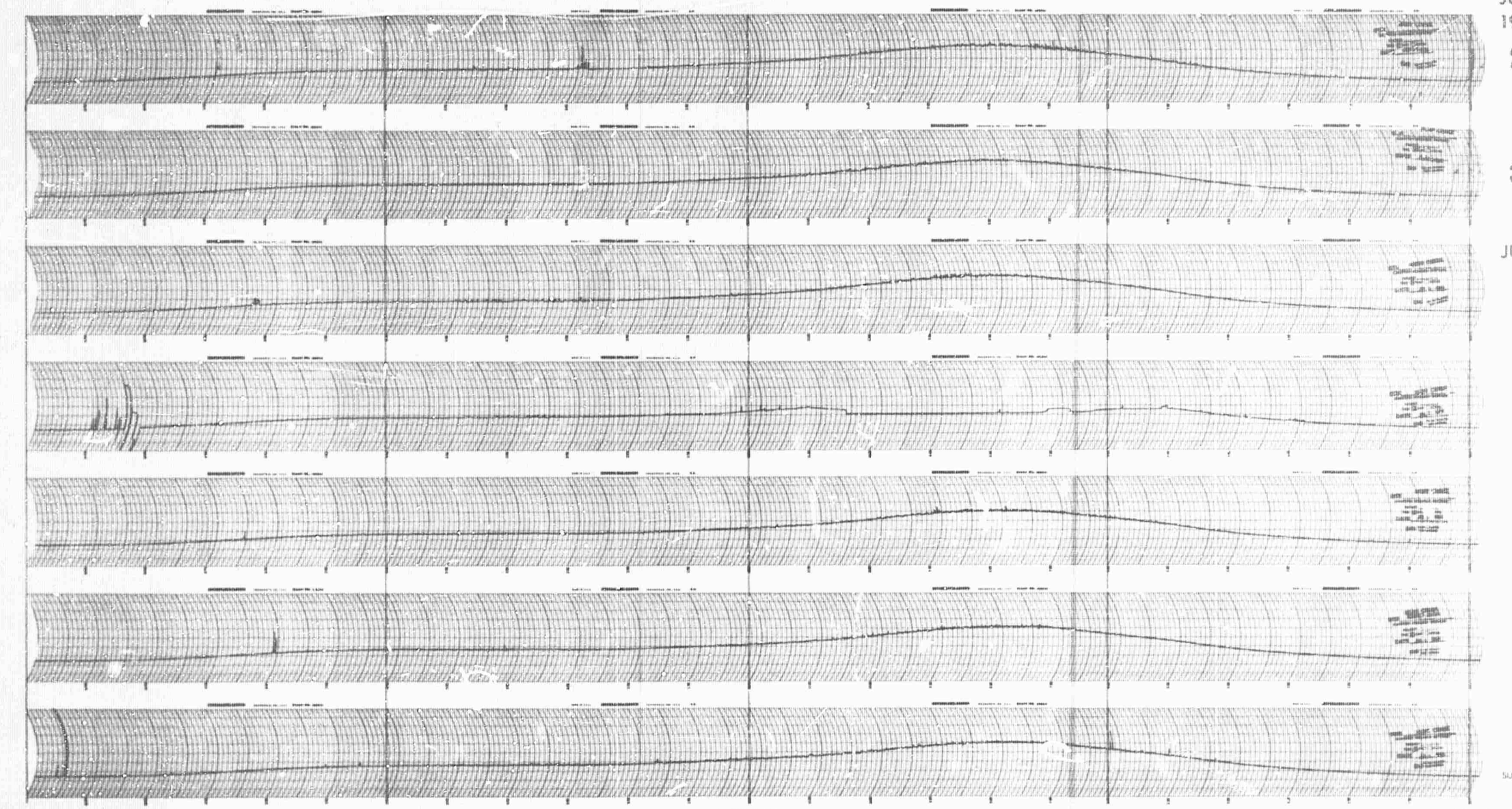
2. 18-Mc Riometer (ARI)

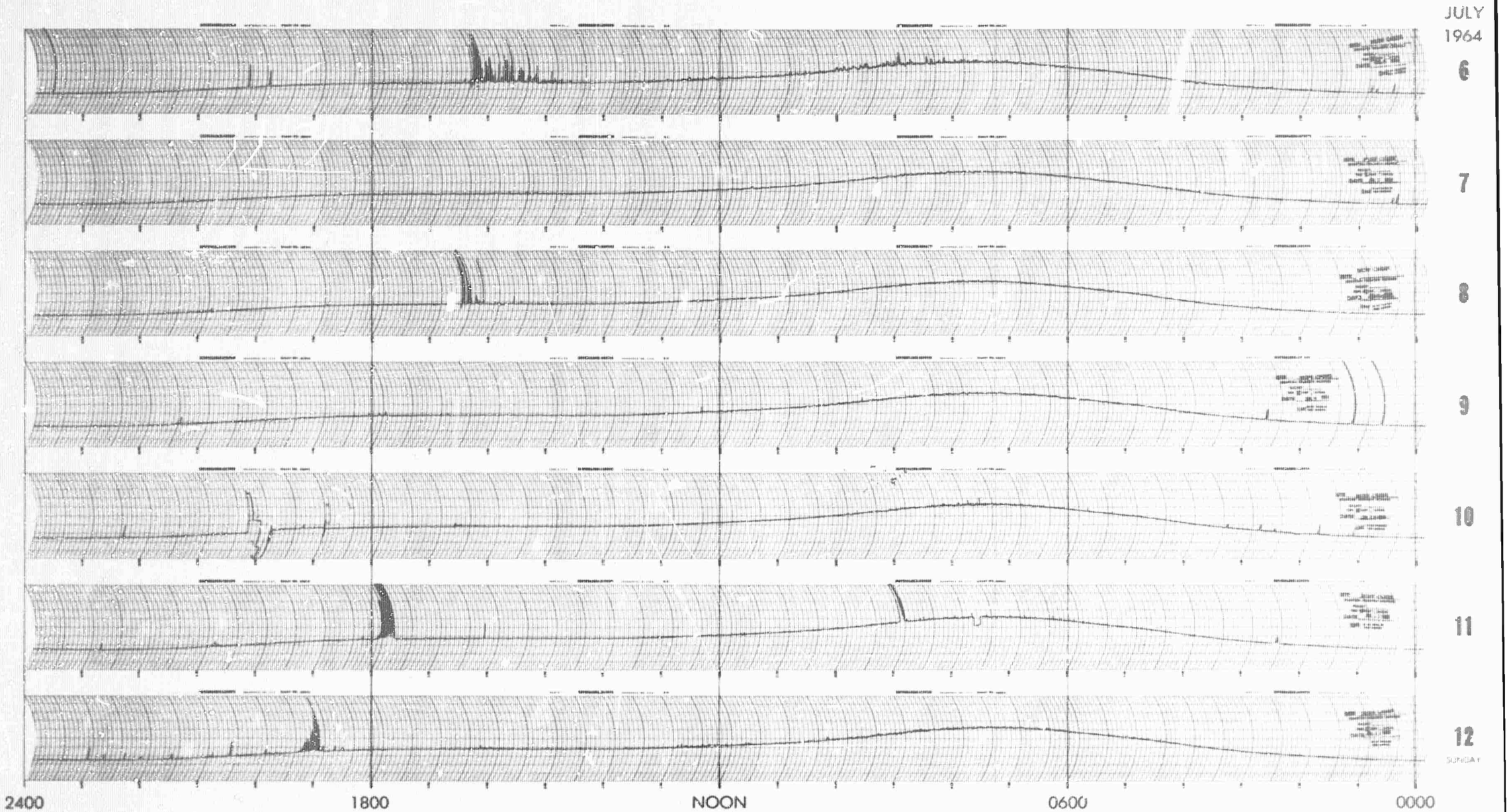
1964	29 June	Bandwidth 30 kc, integration time 6 sec, frequency sweep off, minimum detector off, antenna attenuation 13 db, antenna polarization S147E true.
	31 Aug, 0210 to 1 Sept, 0600	Servo diode burnt out.
	13 Sept, 0830 to 5 Oct, 2115	Generator overhaul, equipment not operating.
	5 Oct to 11 Oct	Man-made noise half of each day.

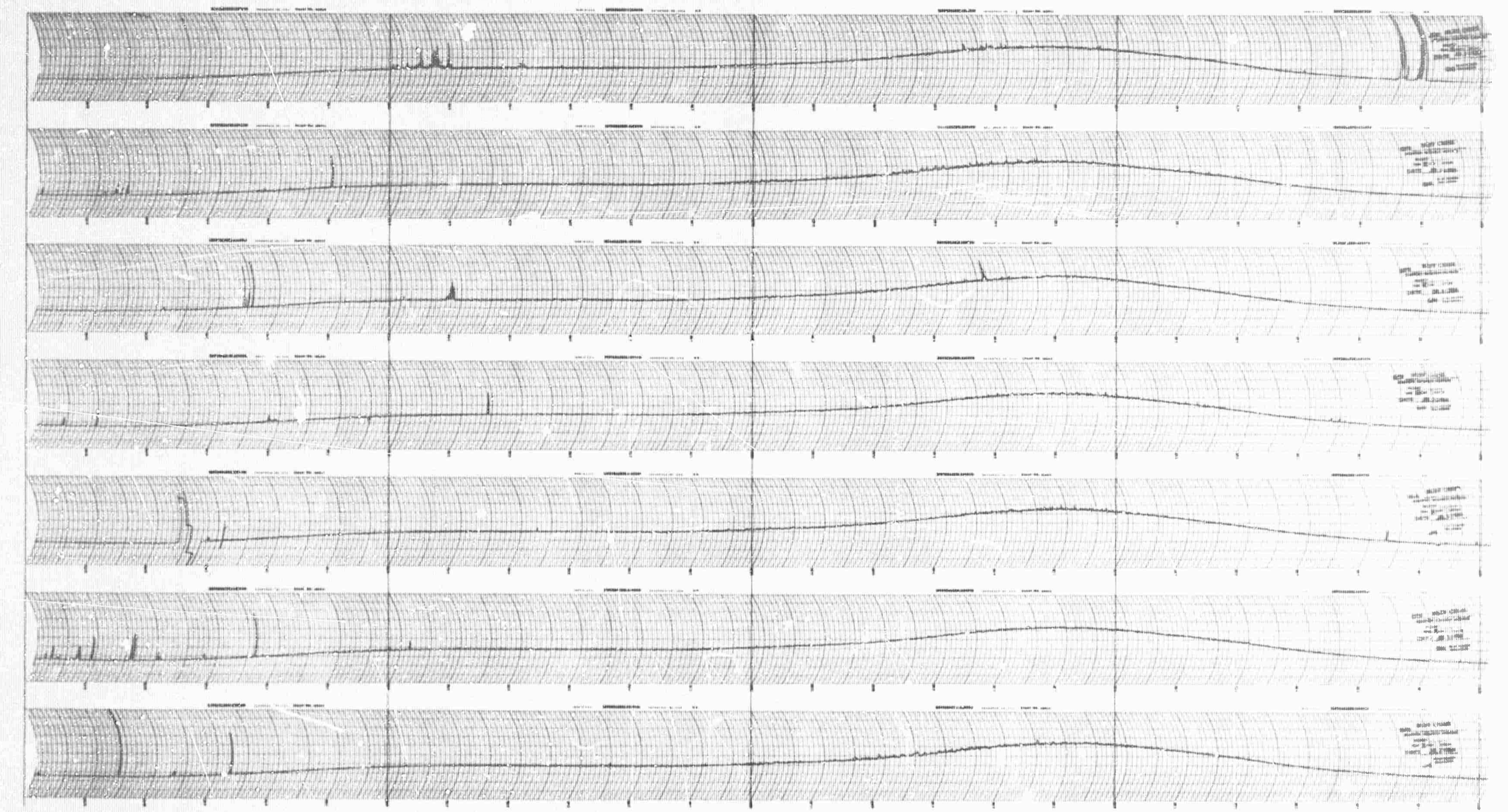
	11 Oct, 1955 to 12 Oct, 2100	Recorder stopped. Changed frequency slightly.
	17 Oct	0300 to 0825. Subtle local noise raises record level.
	24 Oct	0300 to 0605. Subtle local noise raises record level.
	25 Oct	0000 to 0650. Subtle local noise raises record level.
	1 Nov	0130 to 1115. Batteries limiting riometer.
	1 Nov	1115. Batteries die.
	2 Nov	2230. Start again.
	16 Nov to 23 Nov	Chart is 10 minutes/day fast.
	23 Nov to 30 Nov	Chart is 7 minutes/day fast.
	30 Nov to 7 Dec	Chart is 4 minutes/day fast.
	7 Dec to 14 Dec	Chart is 1 1/2 minutes/day fast.
	28 Dec	0730. Batteries die.
	28 Dec	2230. Begin again.
1965	3 Jan	Last record in this volume.

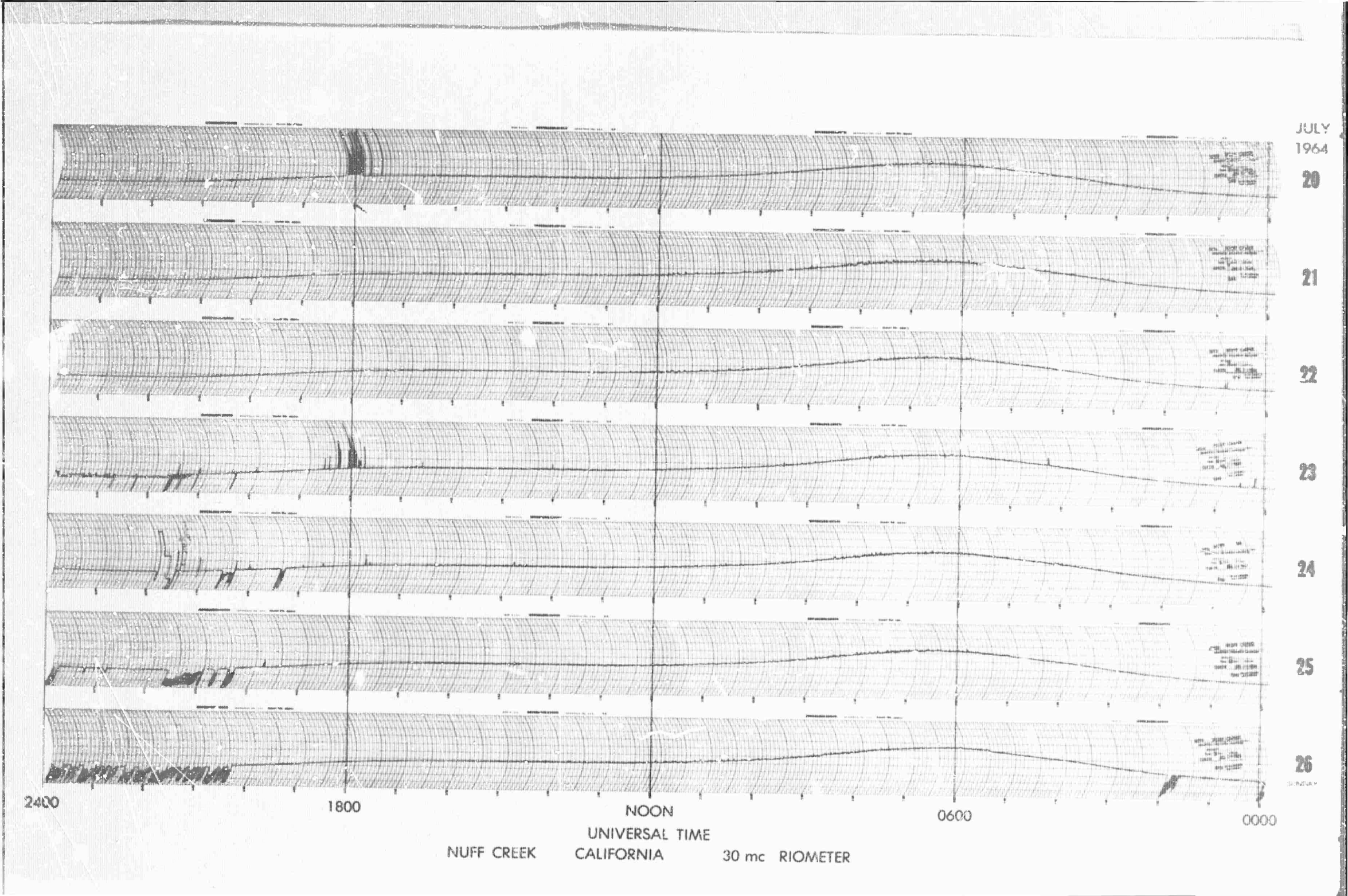
B. Chart Records

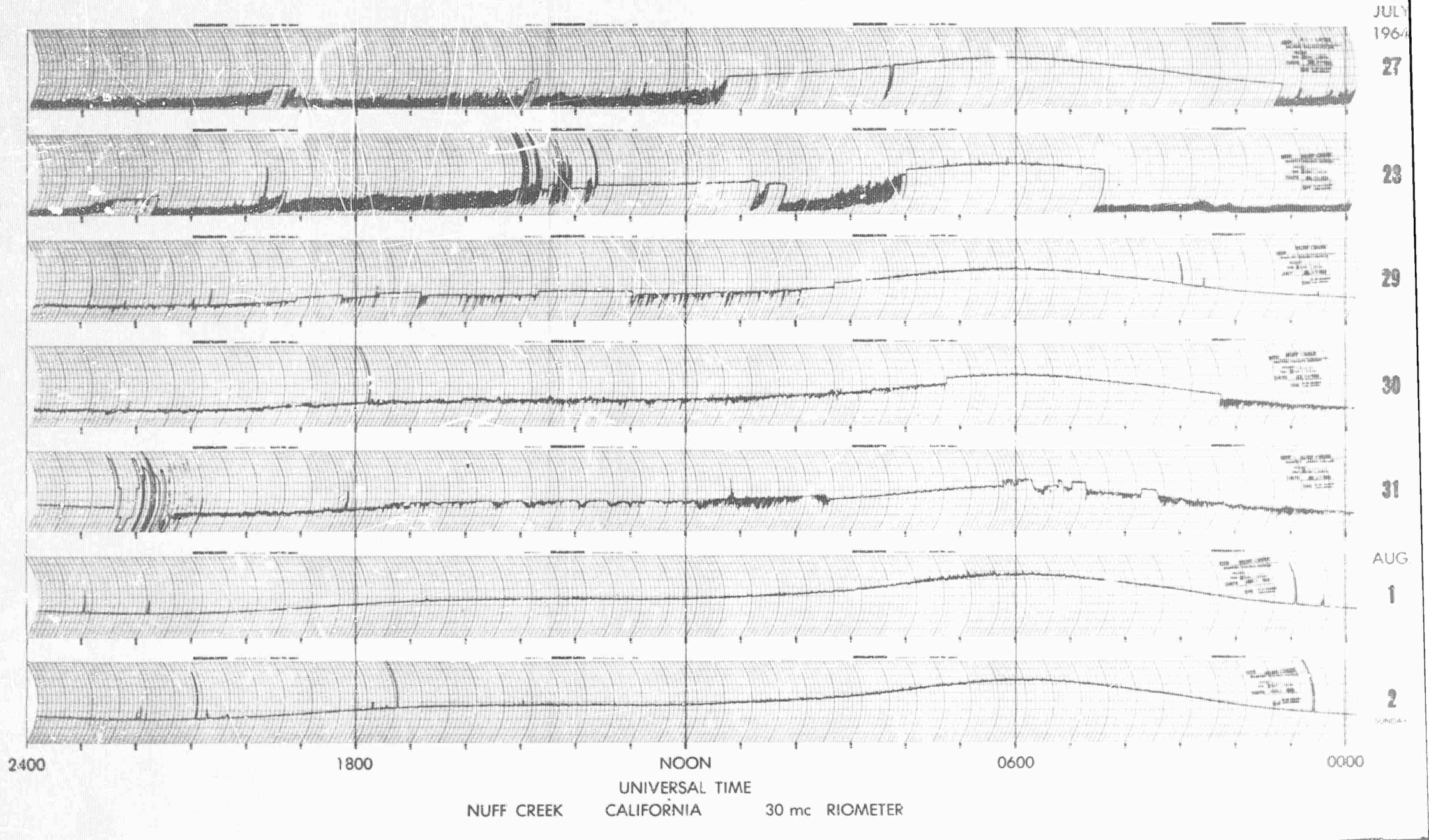
The chart records appearing on the following pages are reproduced at 20 percent of their original size. Time goes from right to left, the records begin and end at midnight GMT. The records are in chronological order by frequency; the 30-Mc records are presented first.

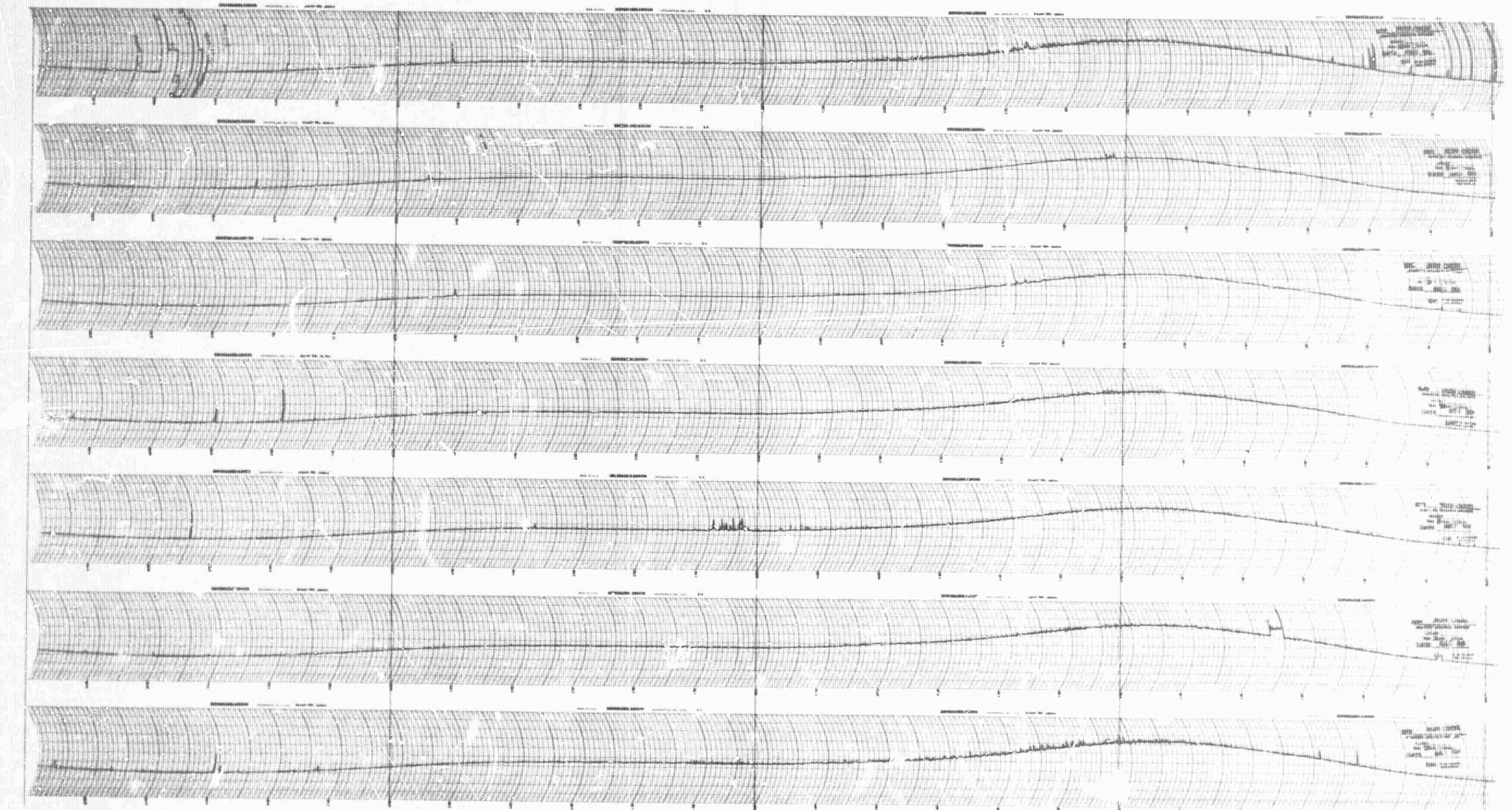

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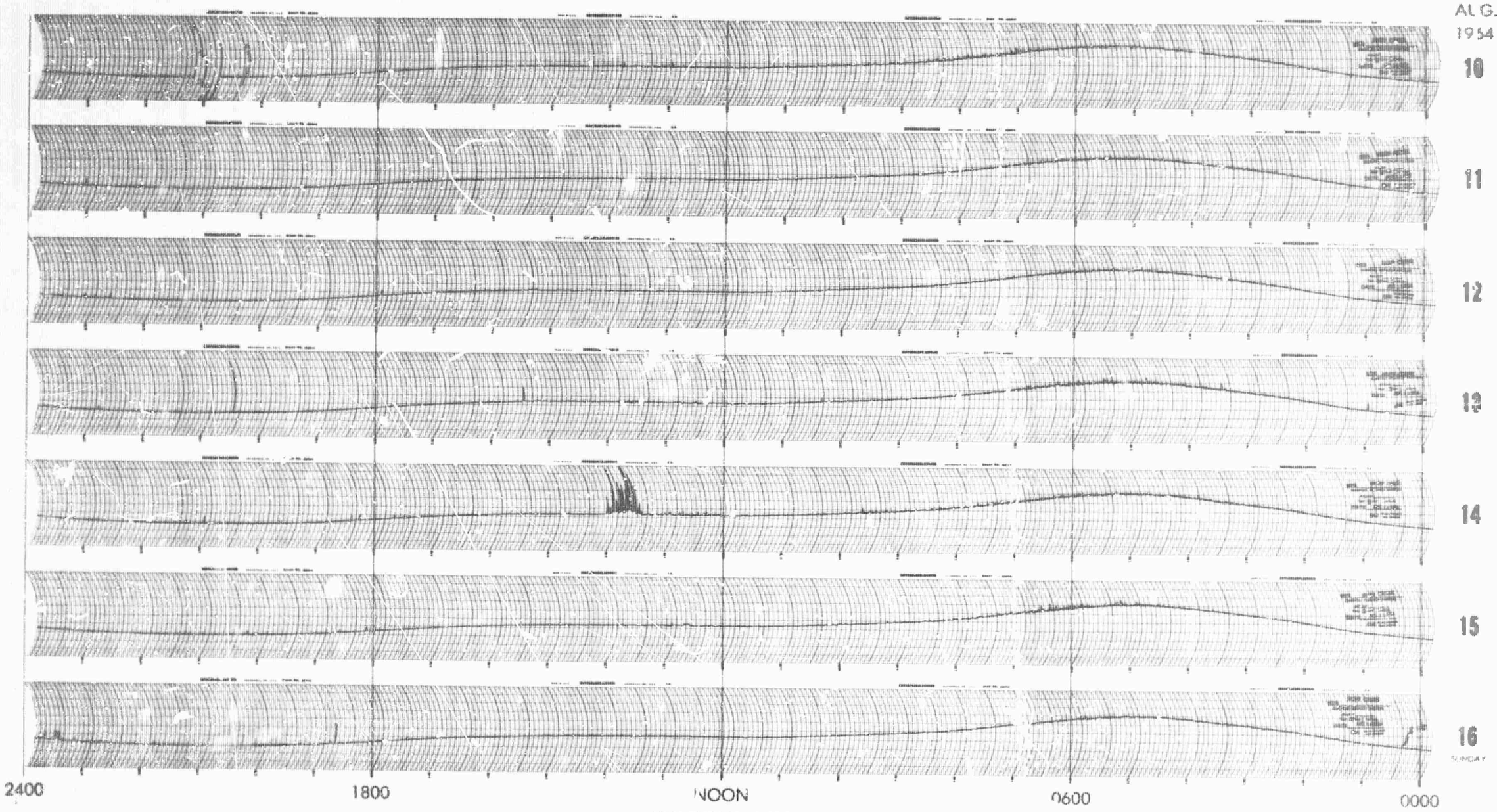

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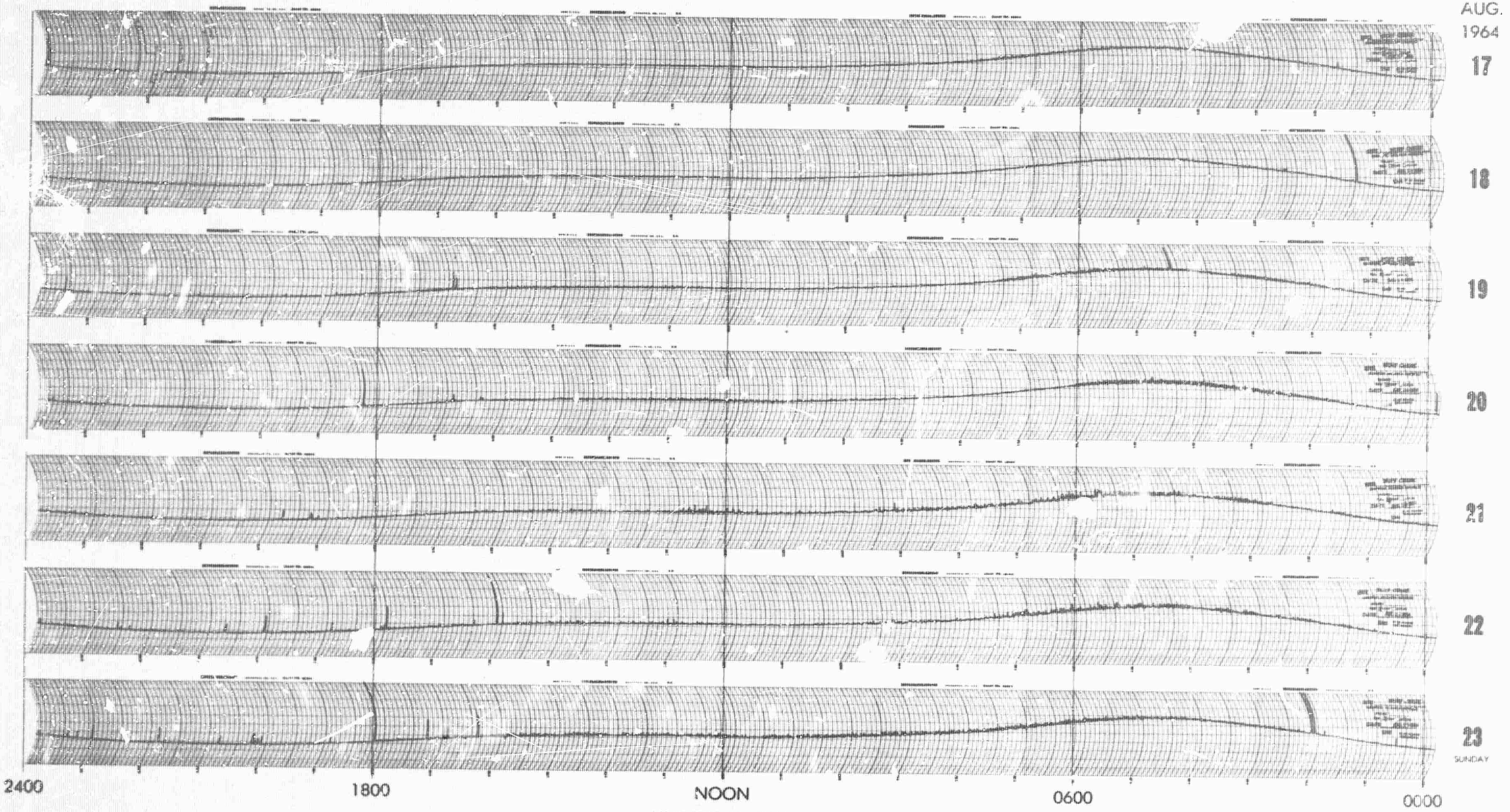

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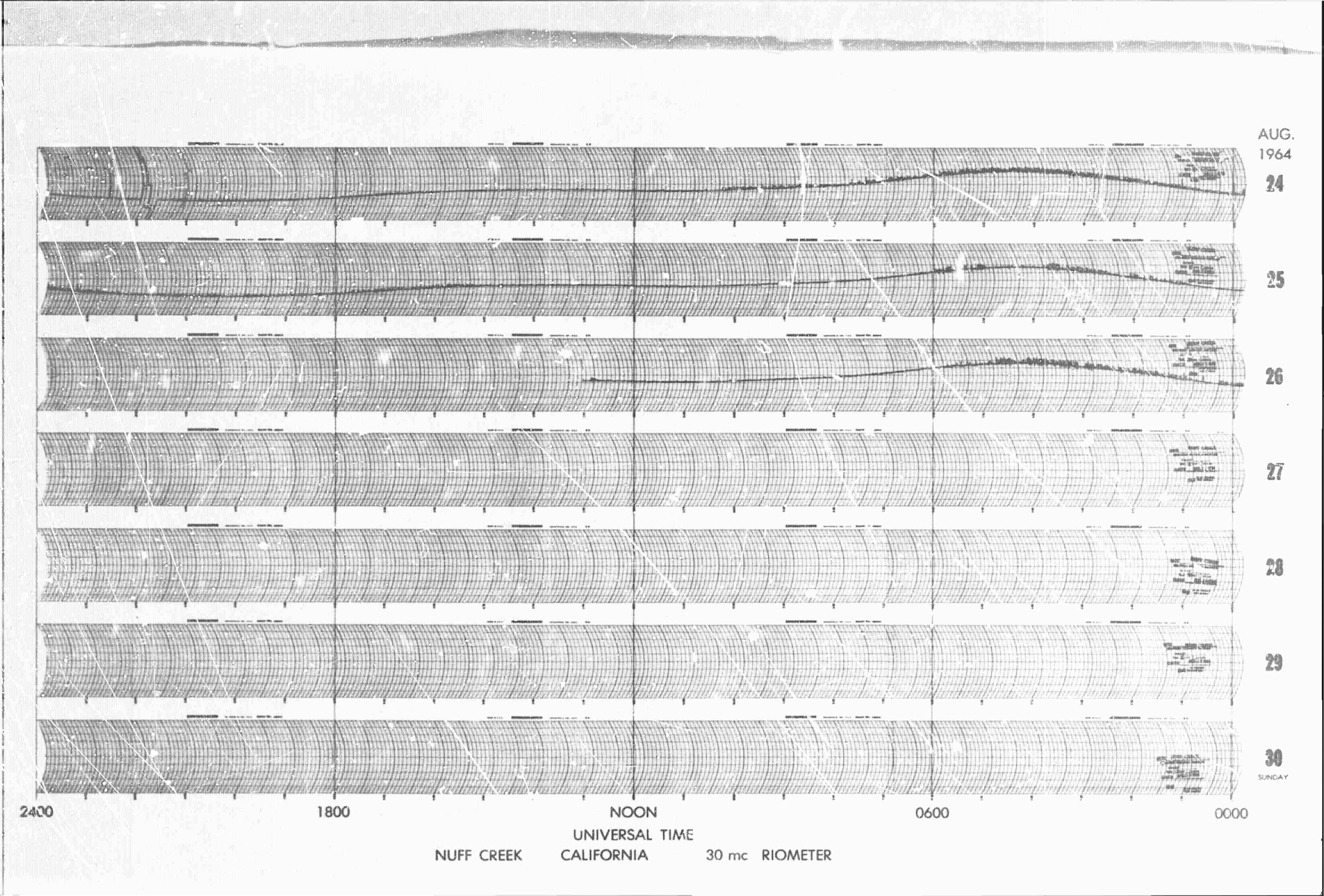

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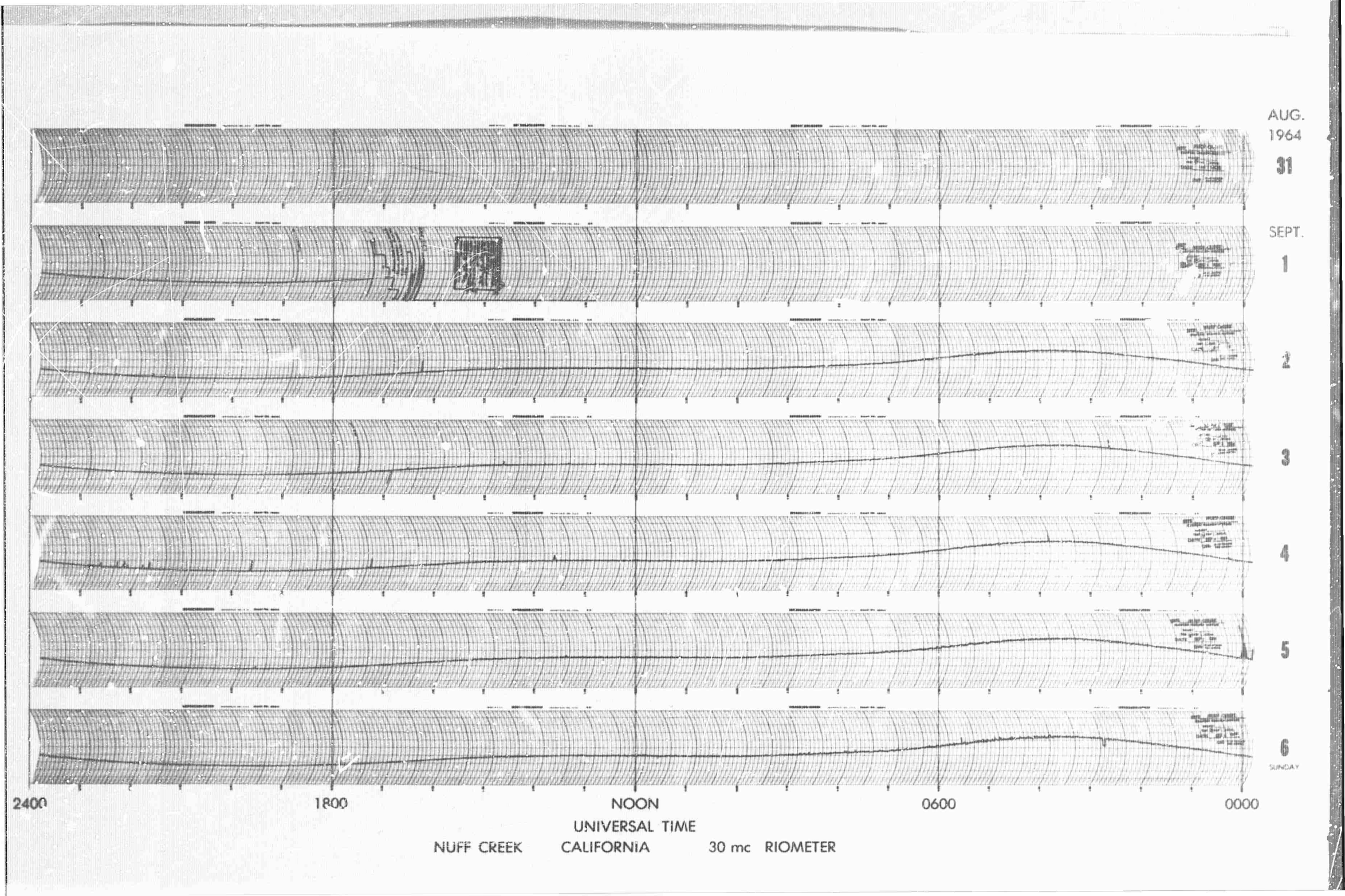

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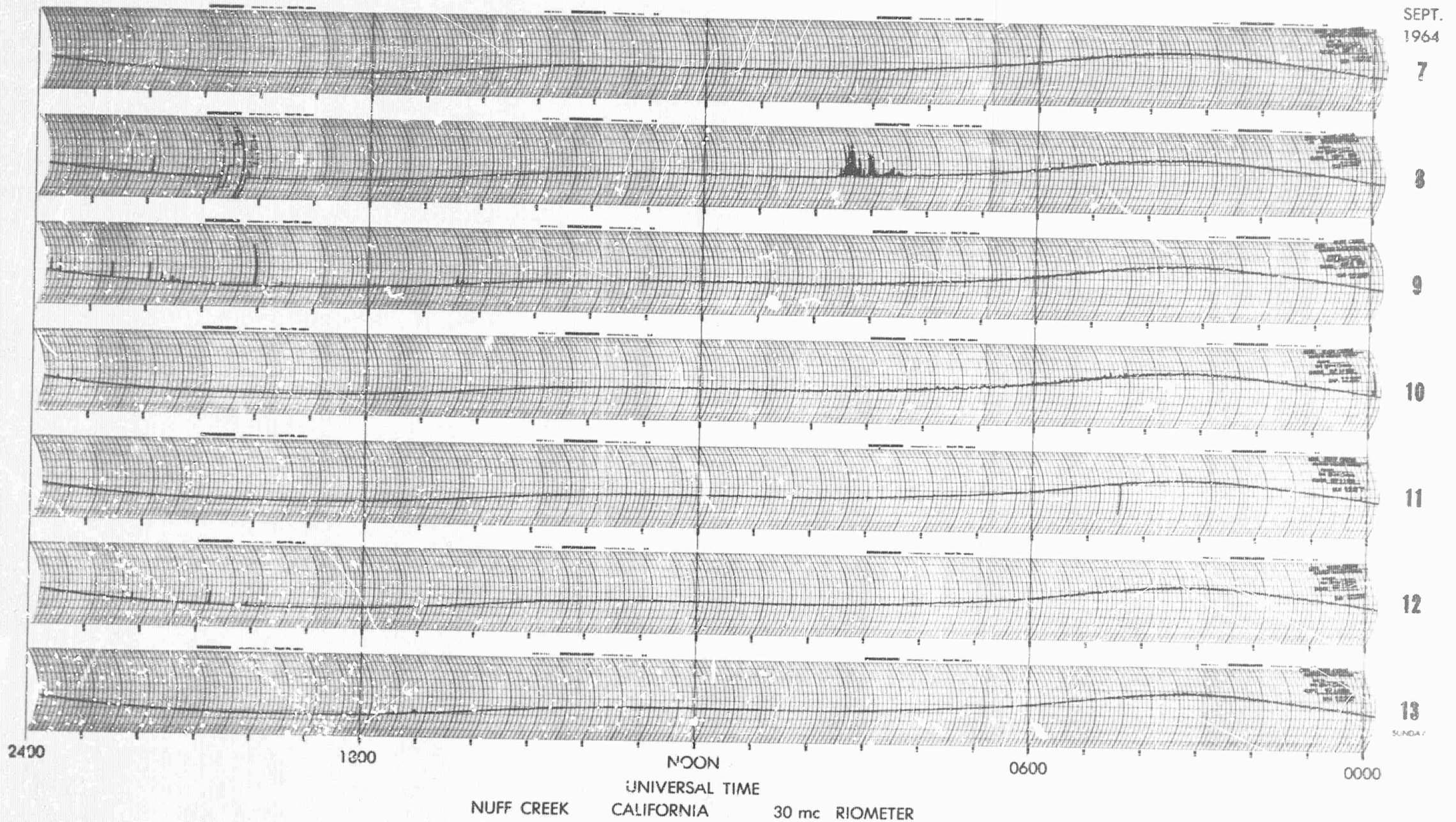

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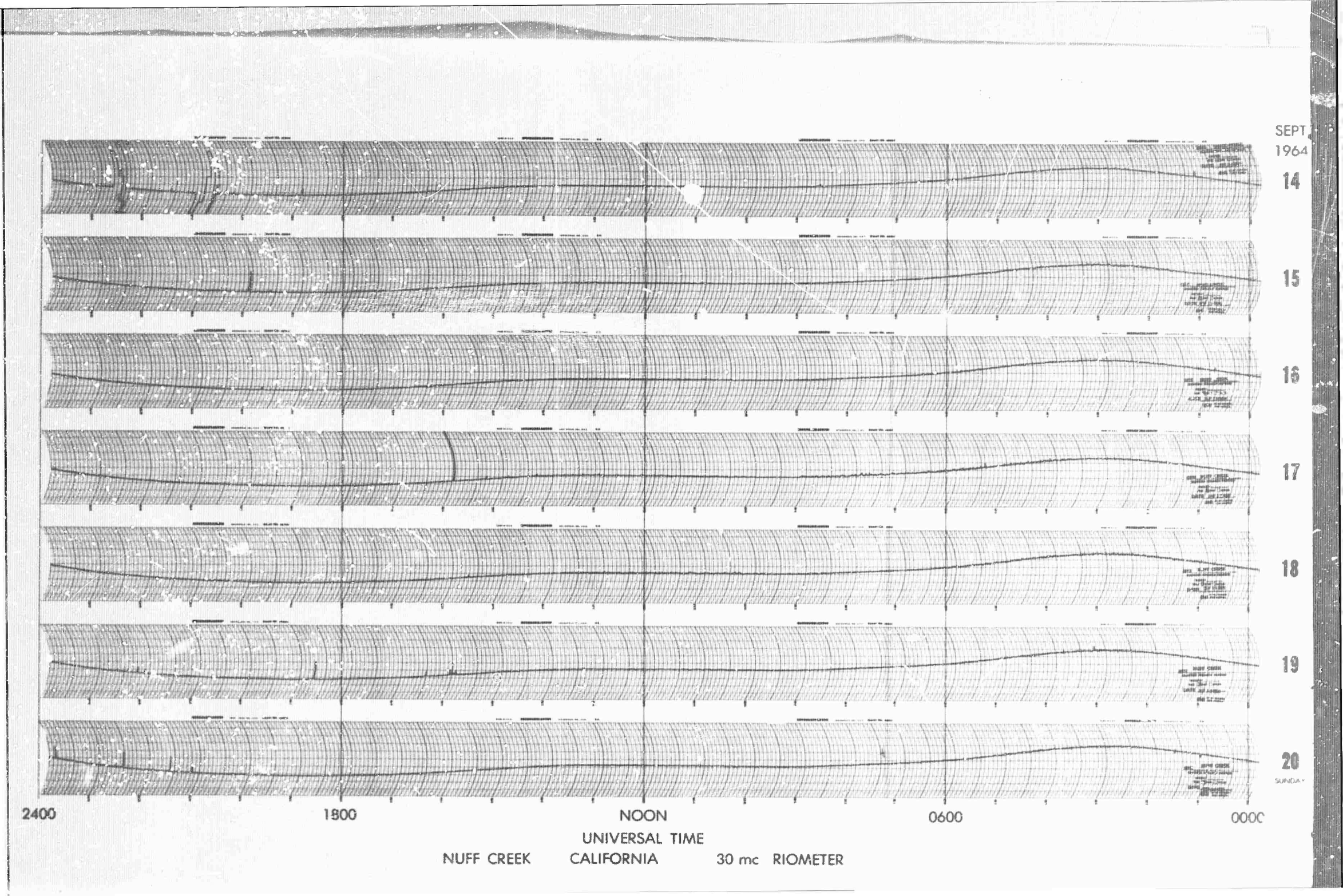

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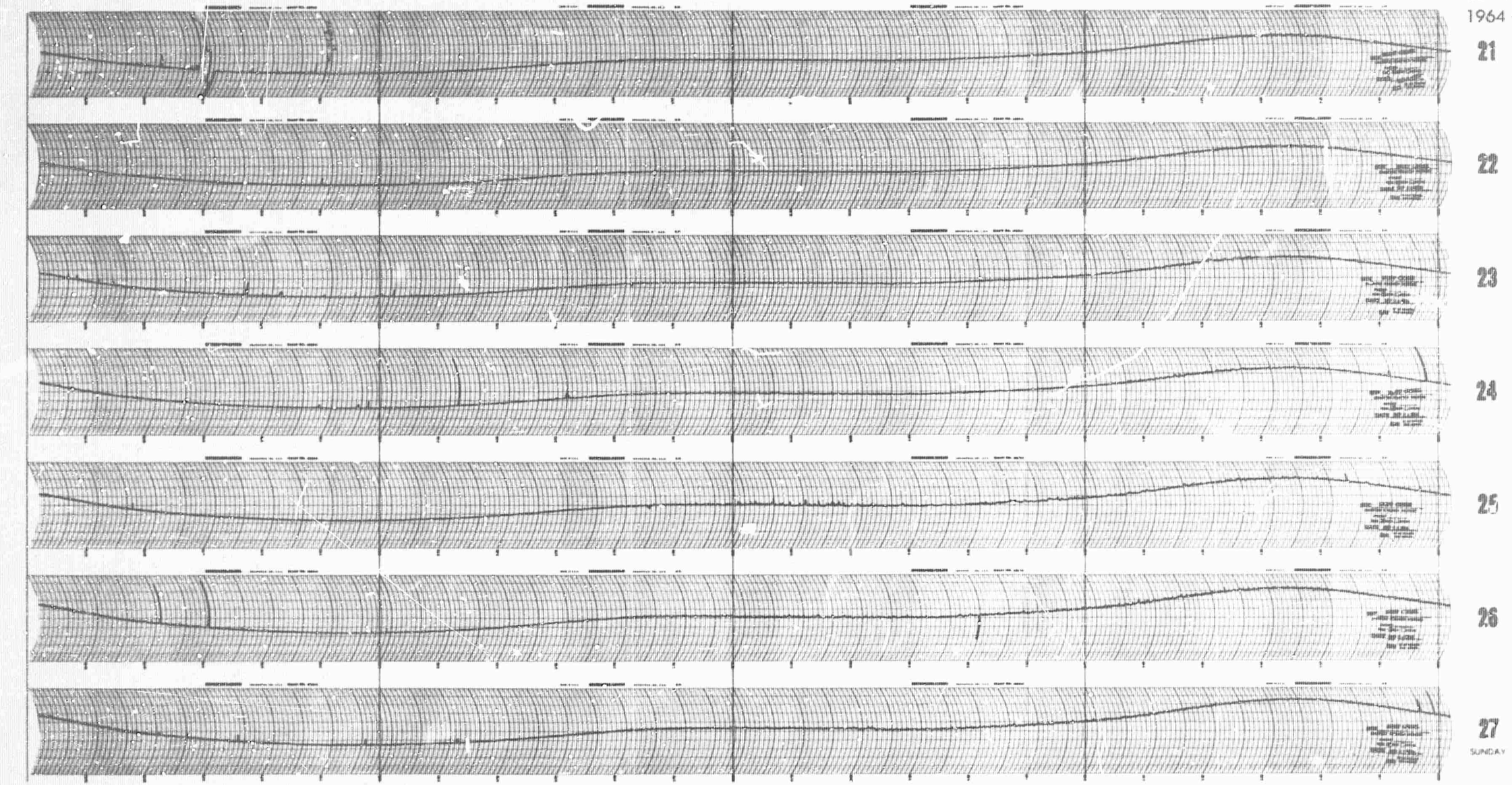

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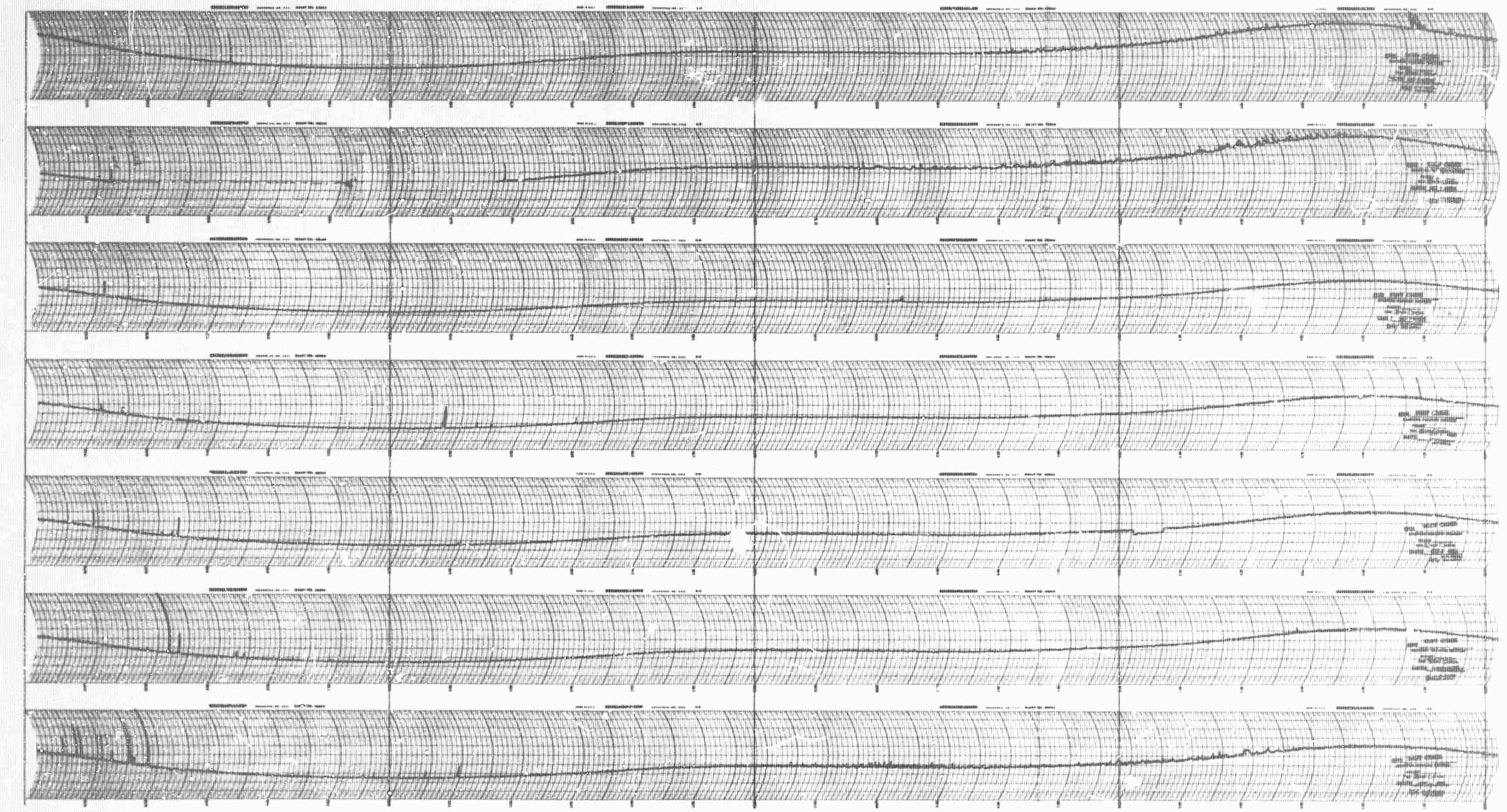

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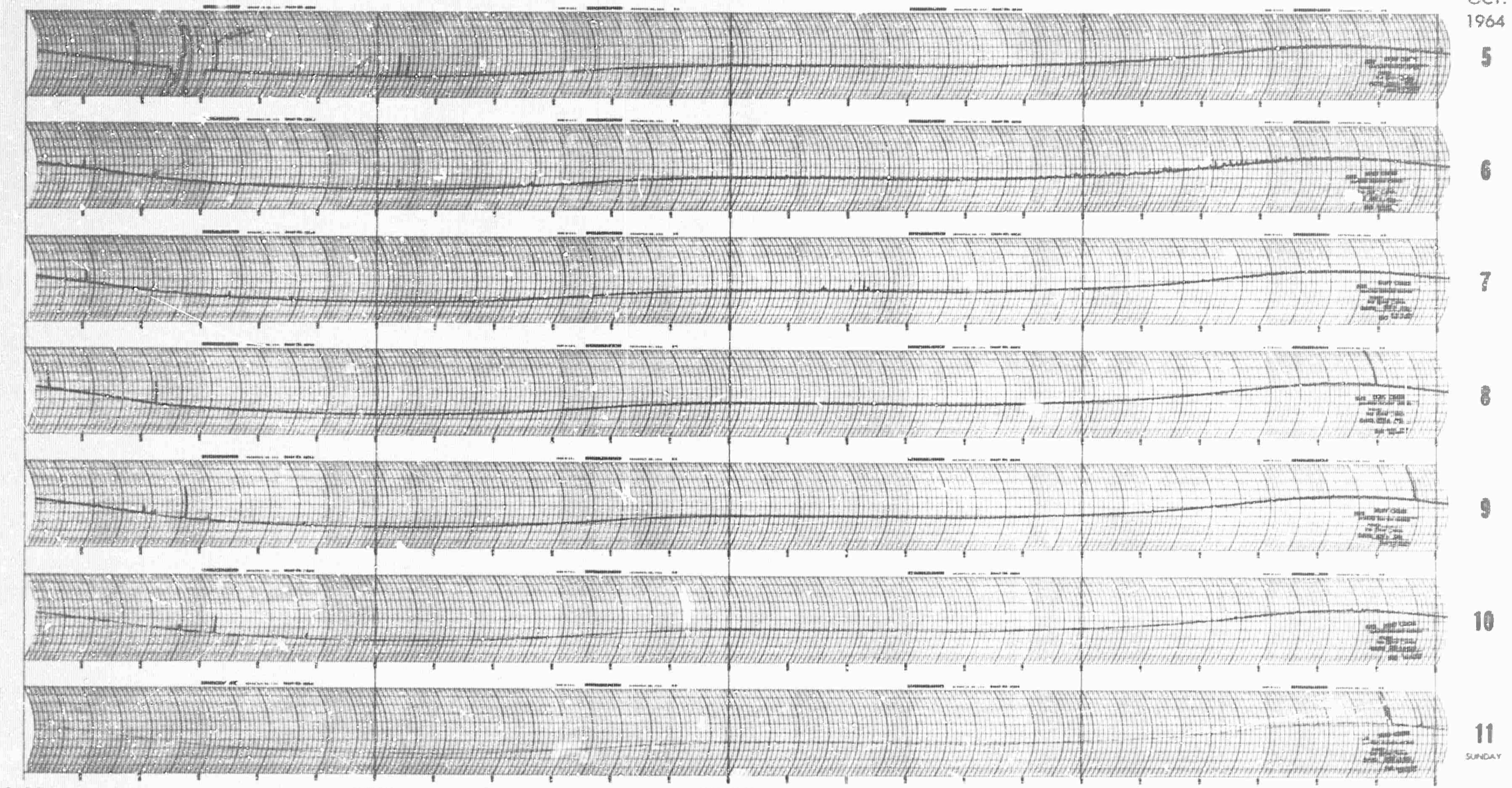

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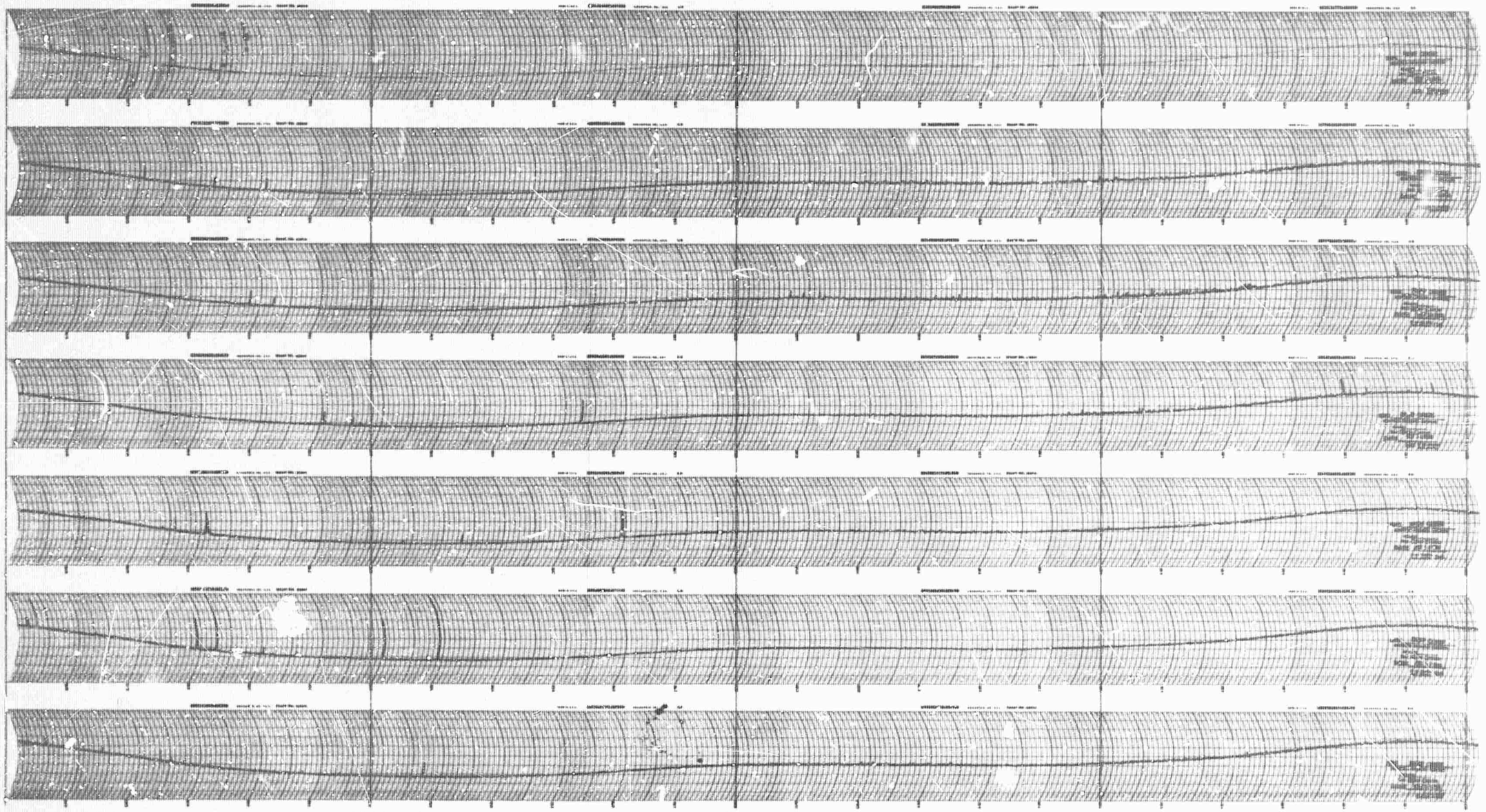

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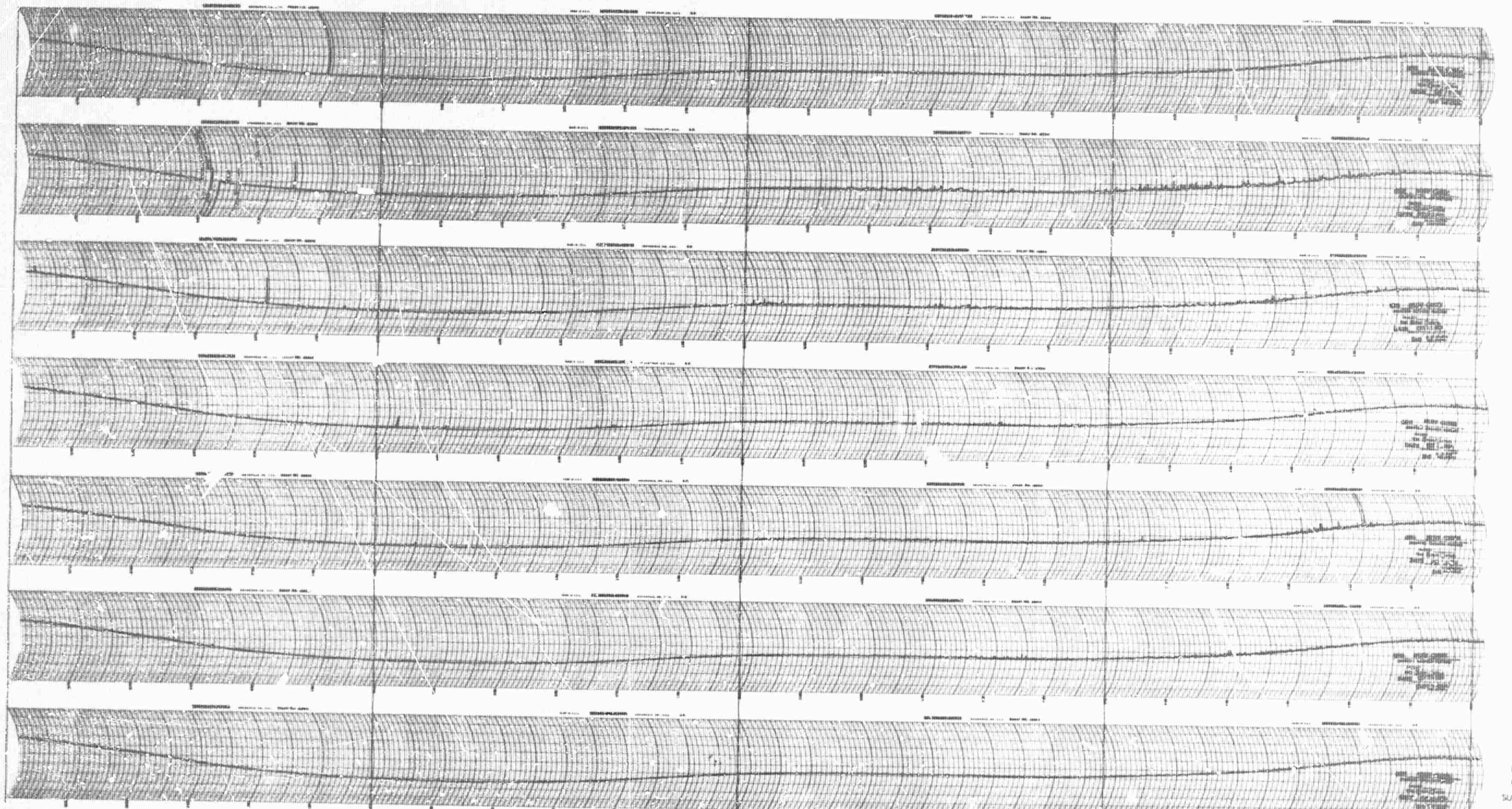

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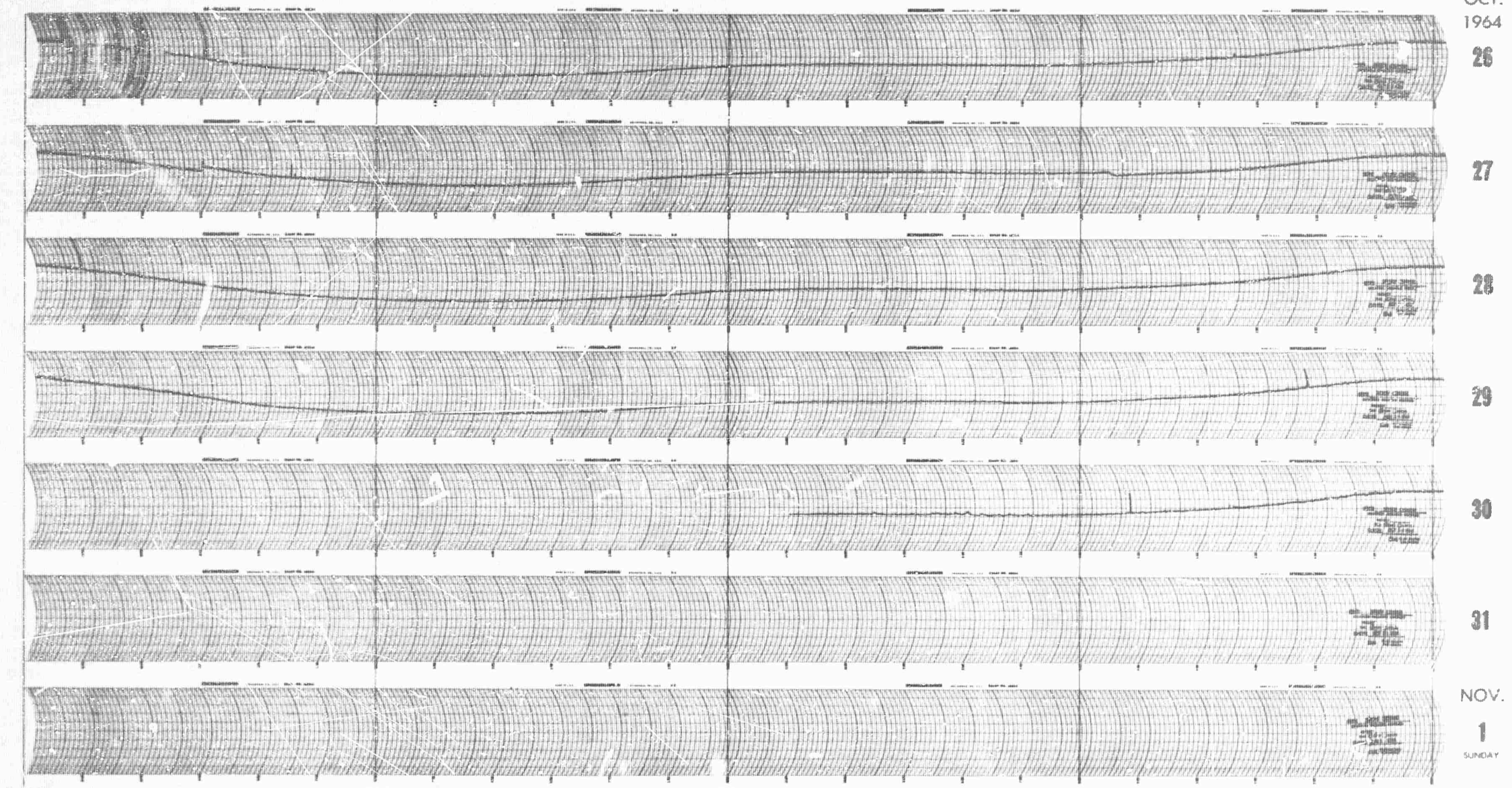

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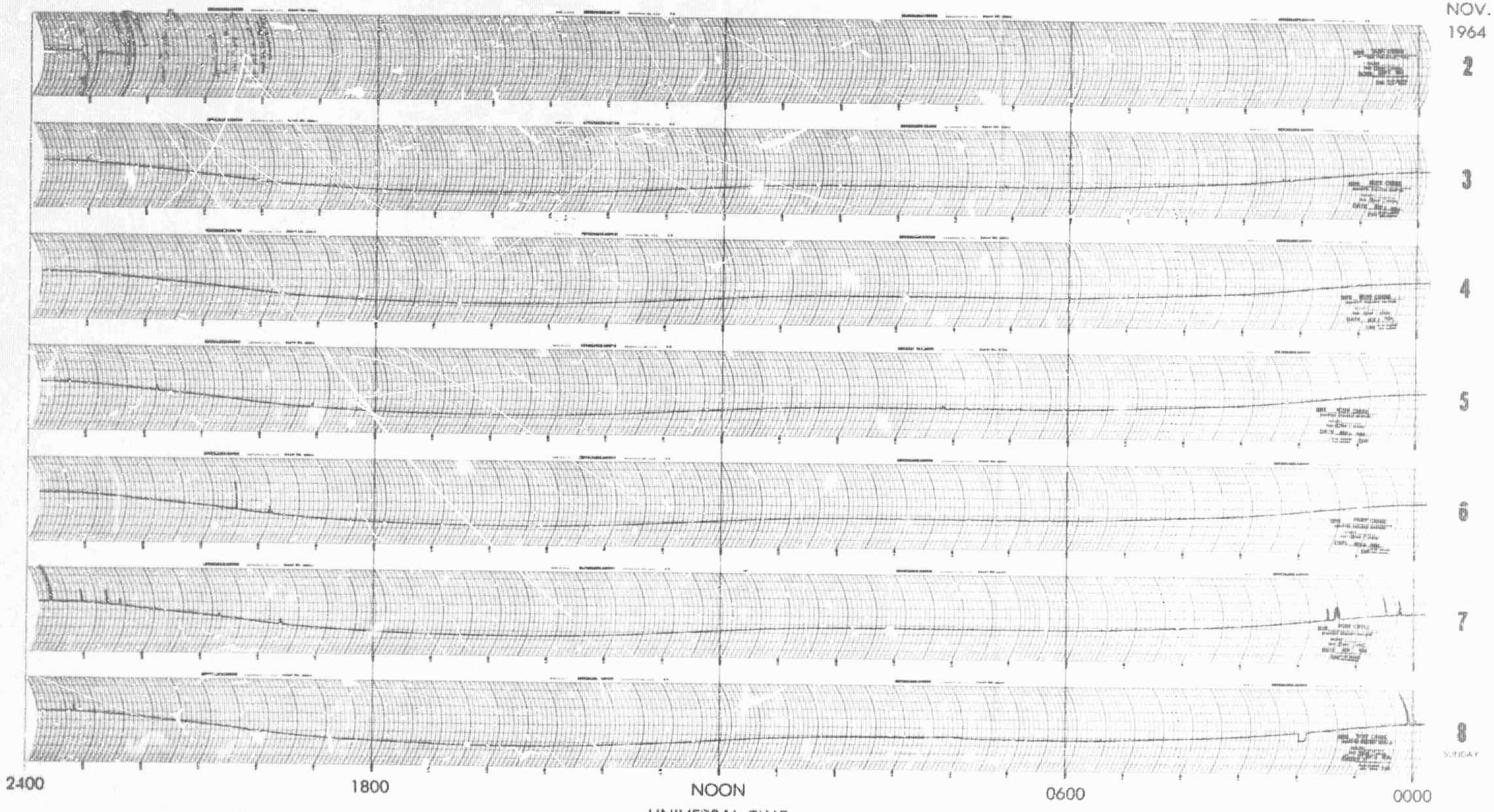

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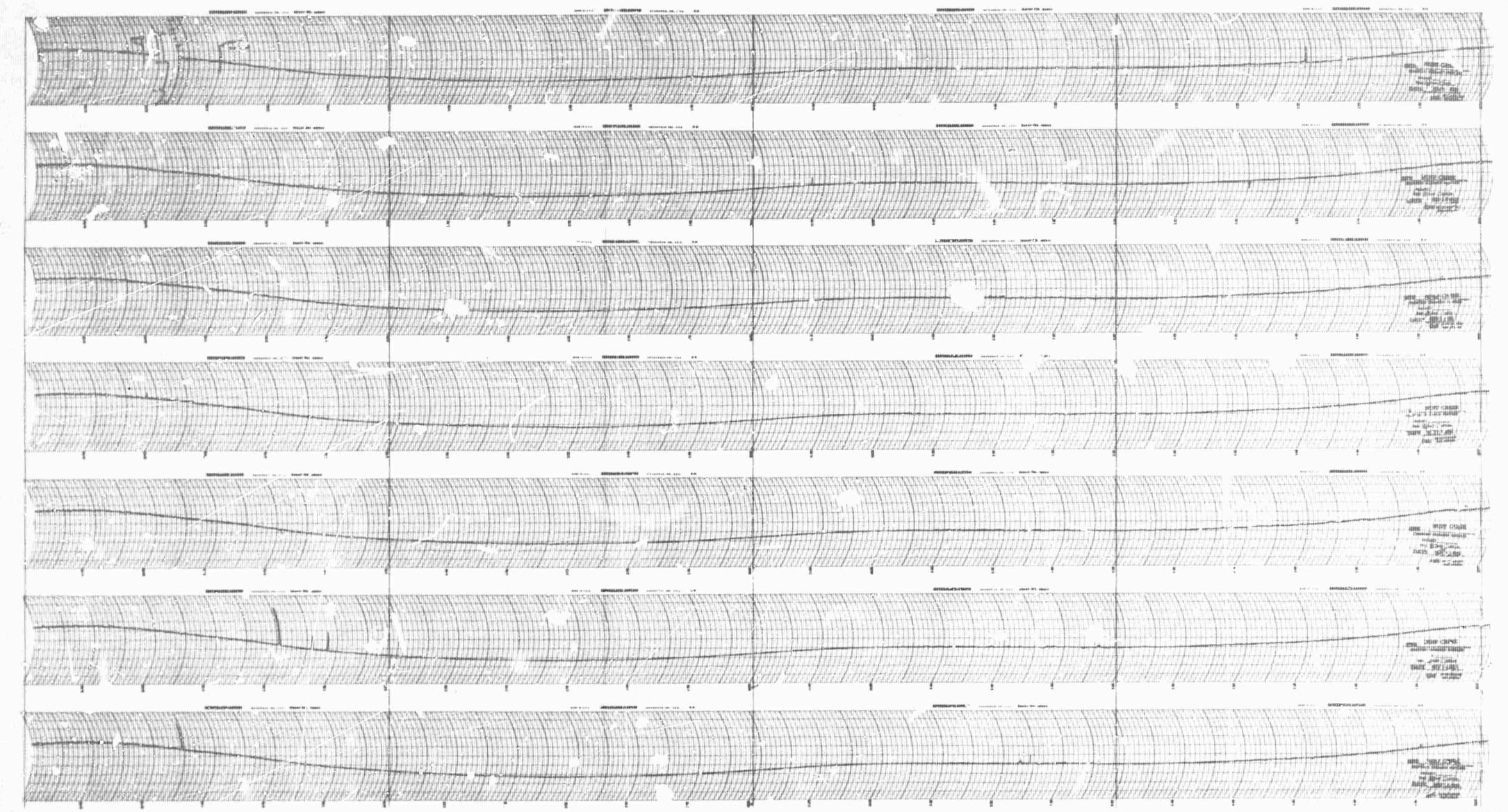

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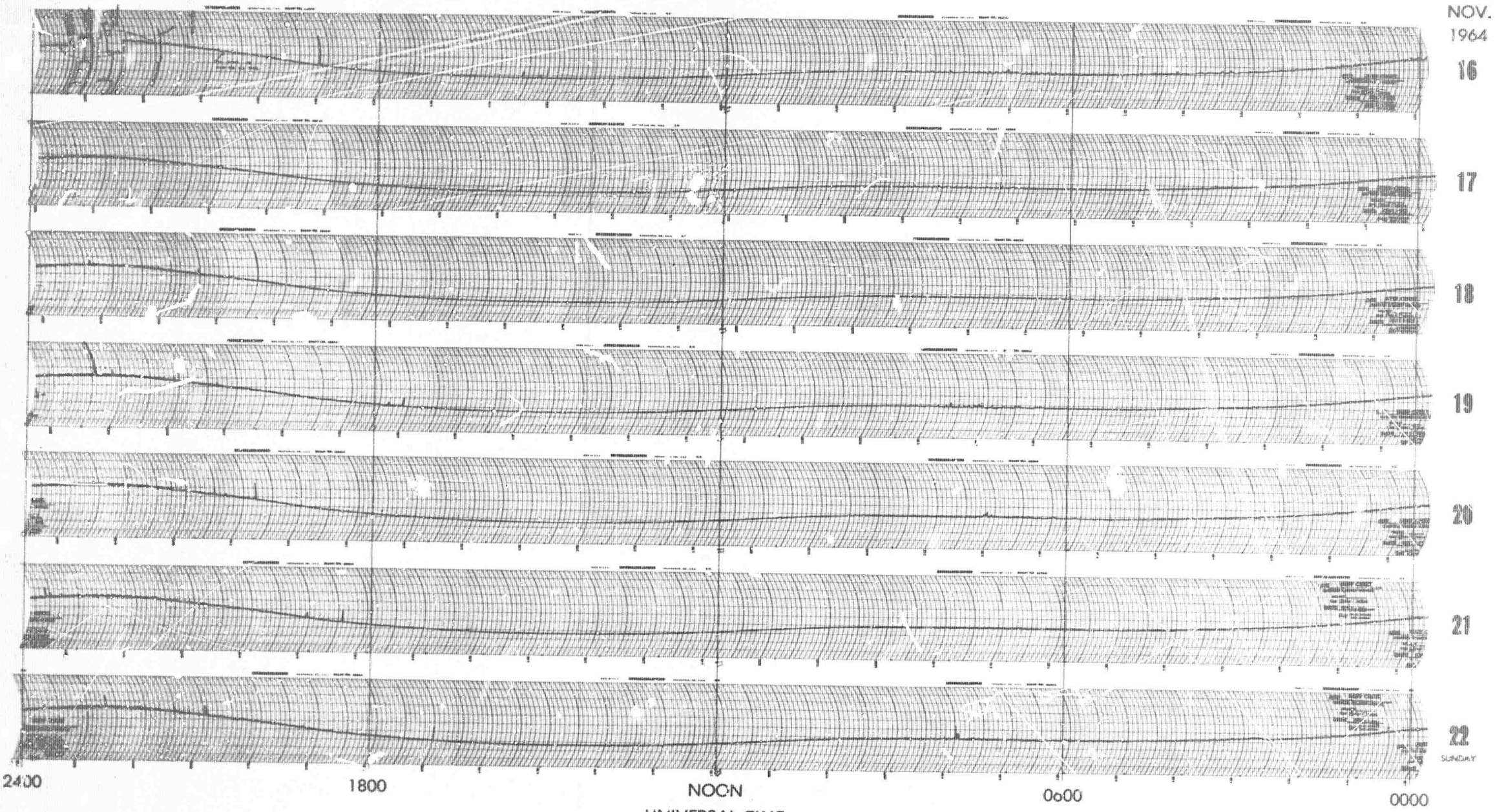

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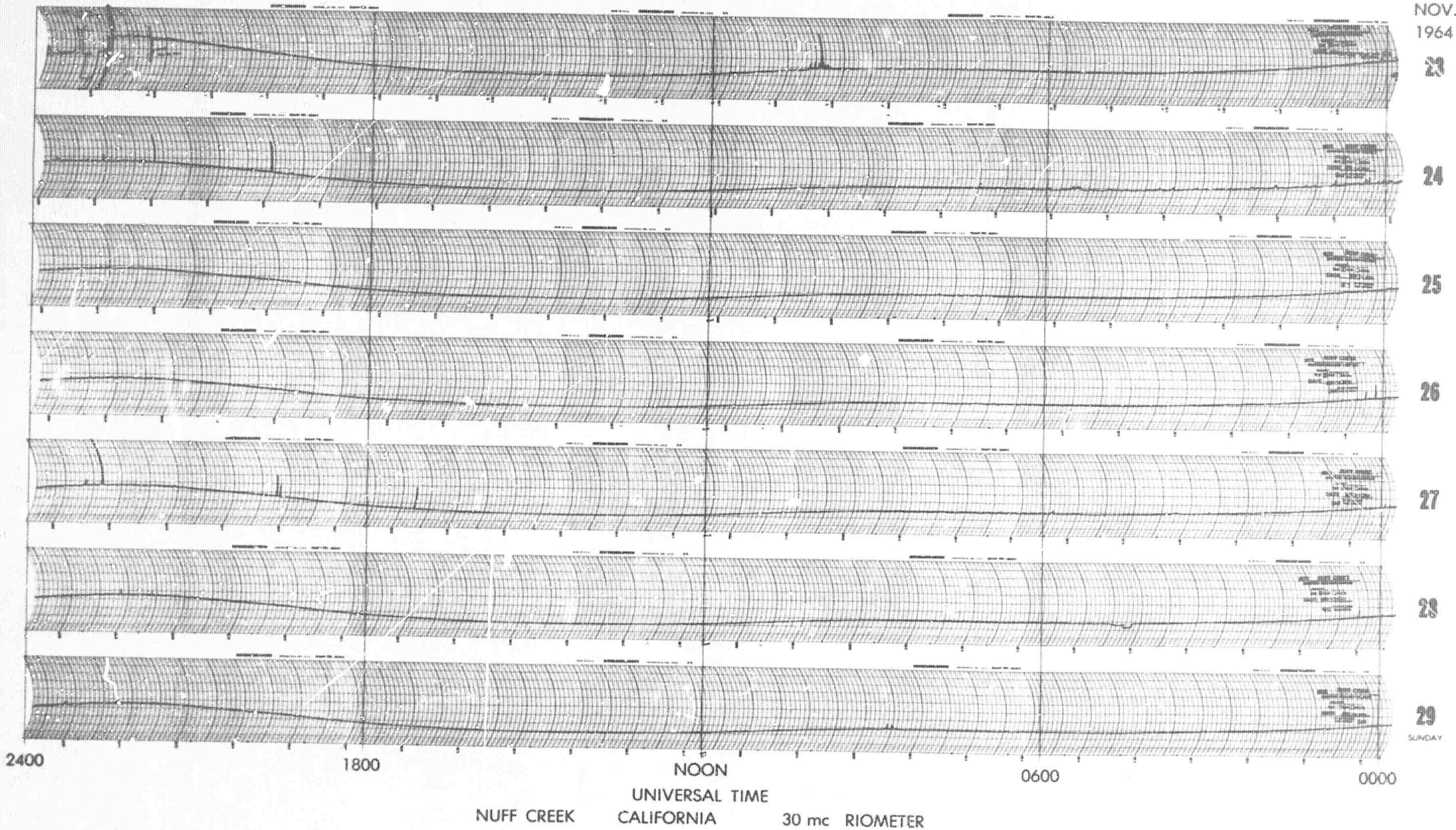

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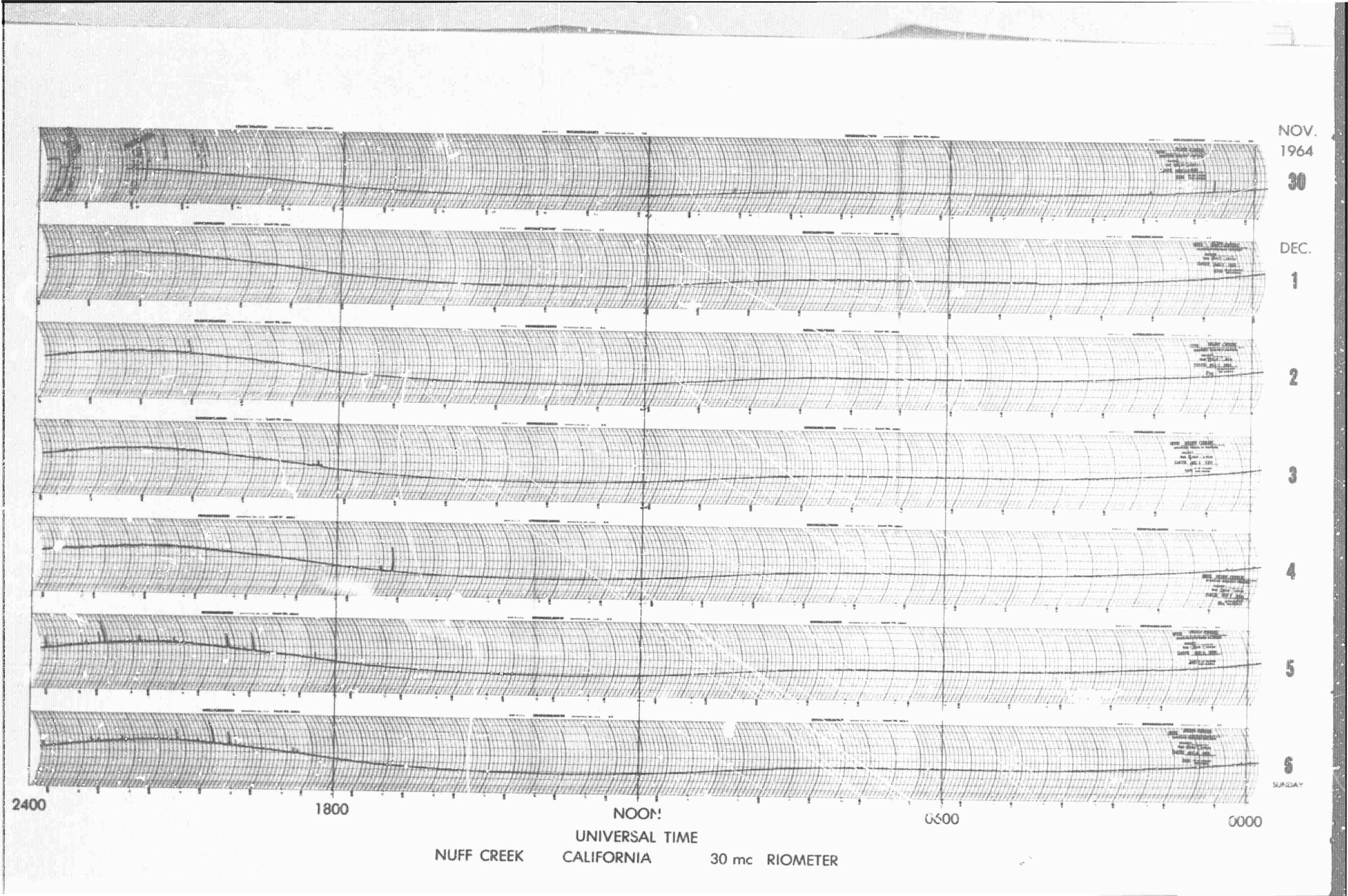

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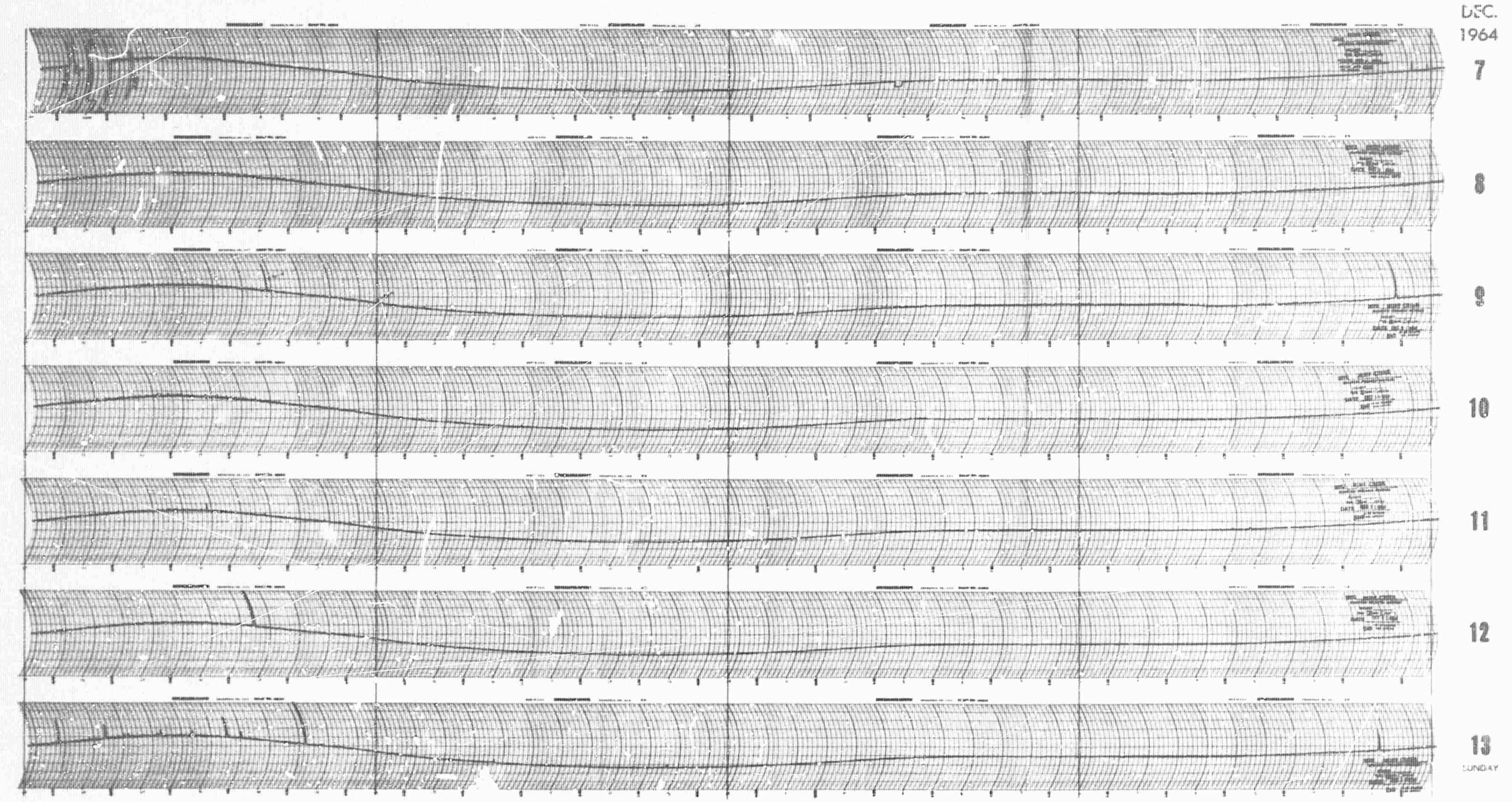

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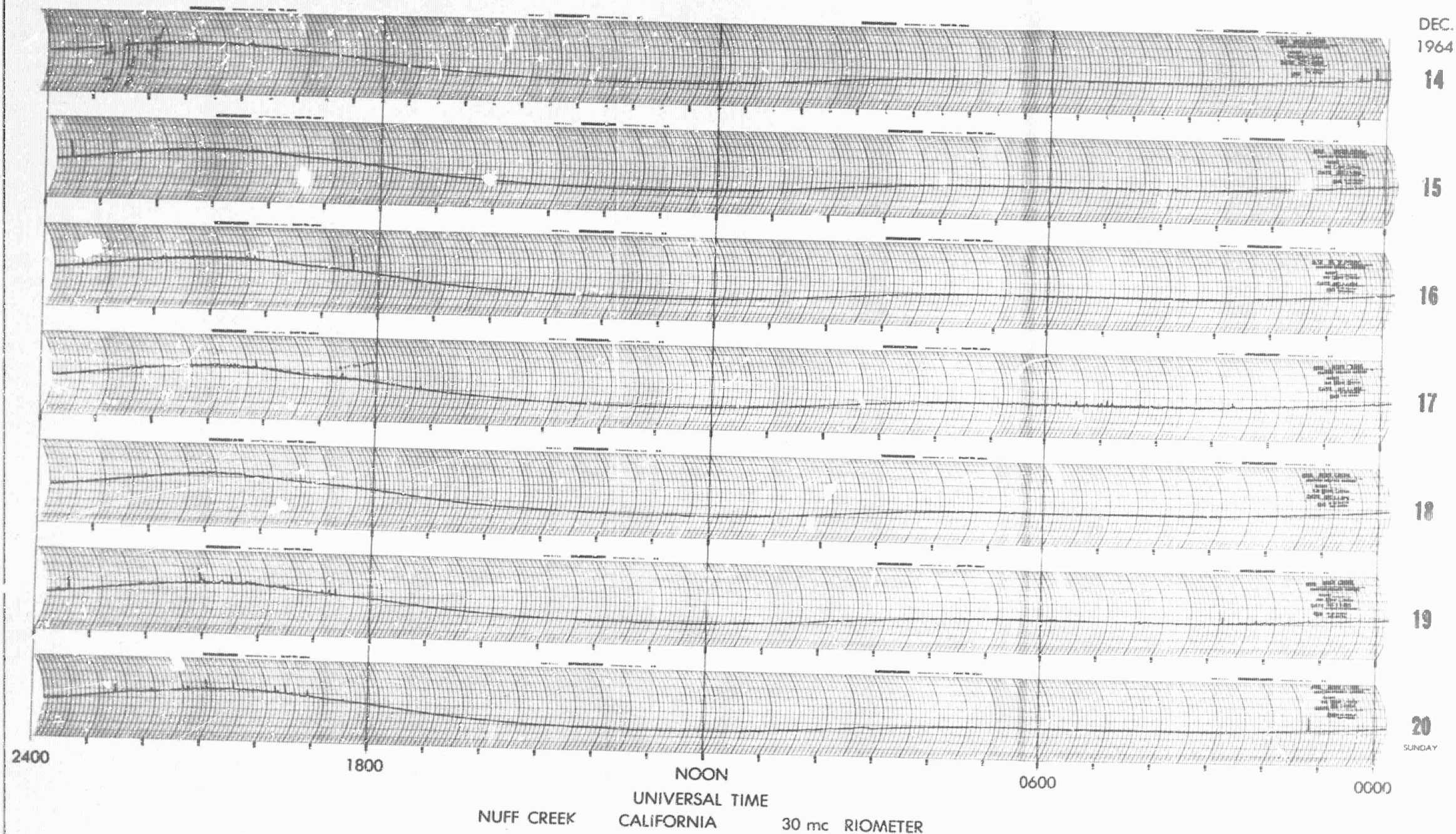

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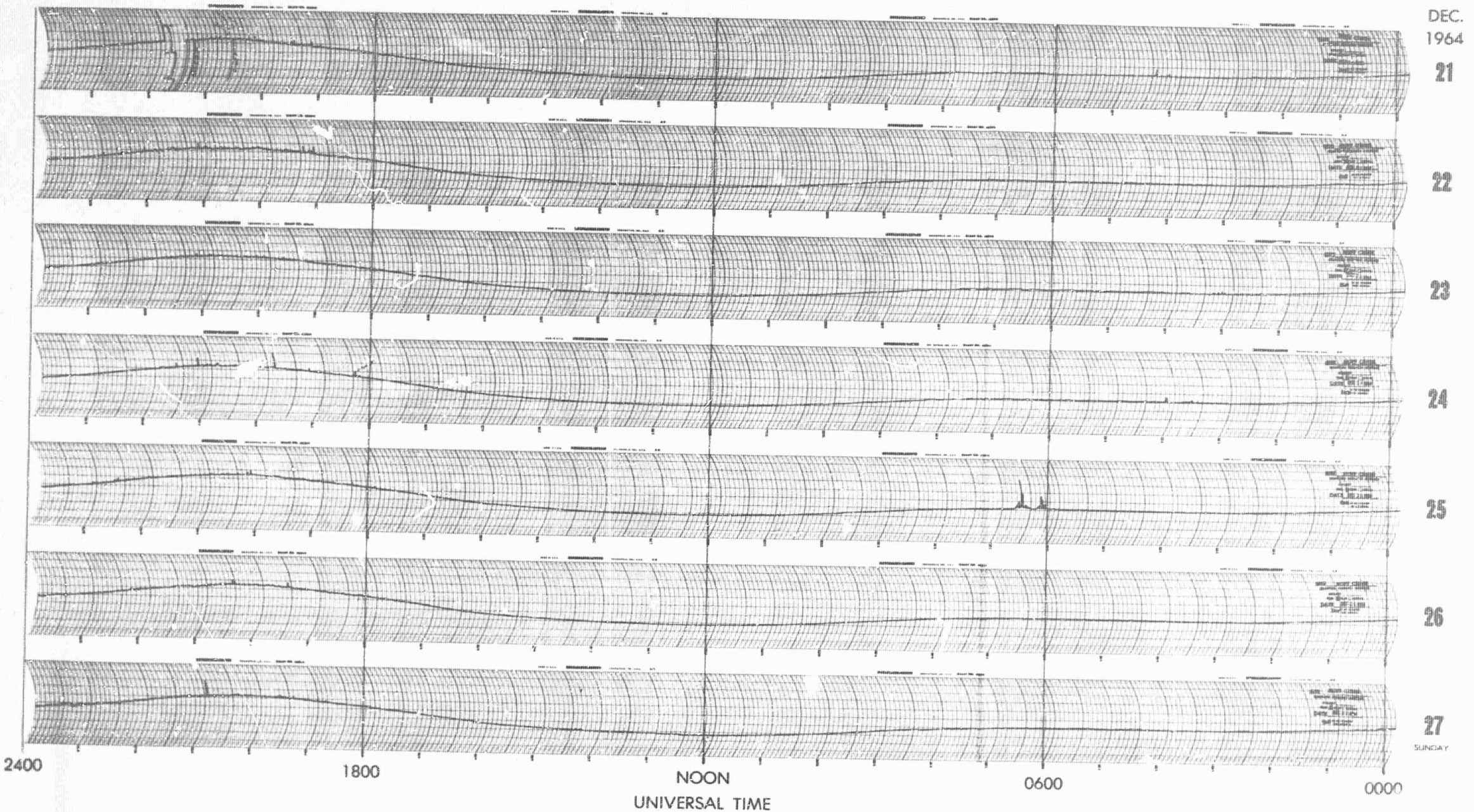

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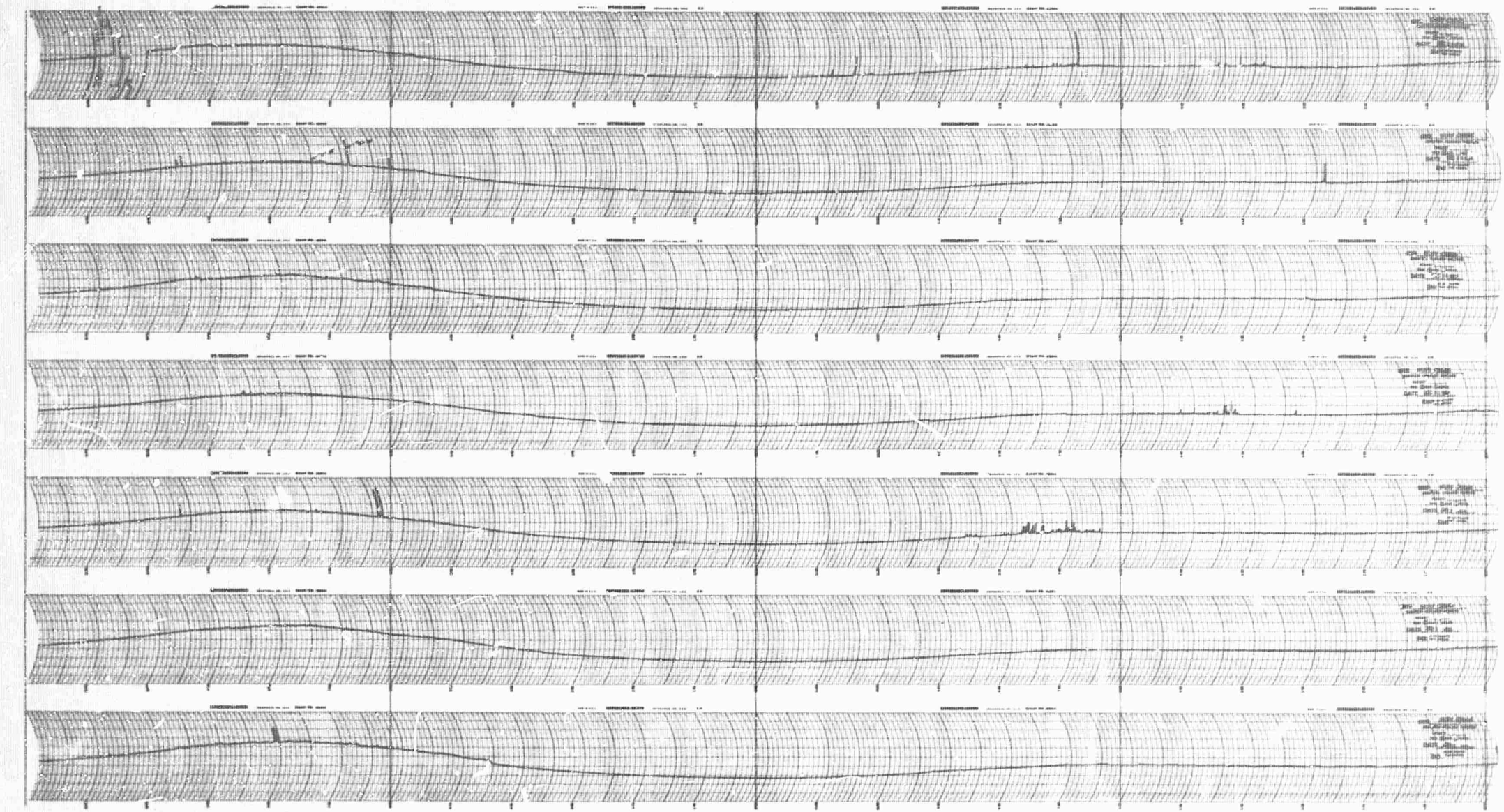

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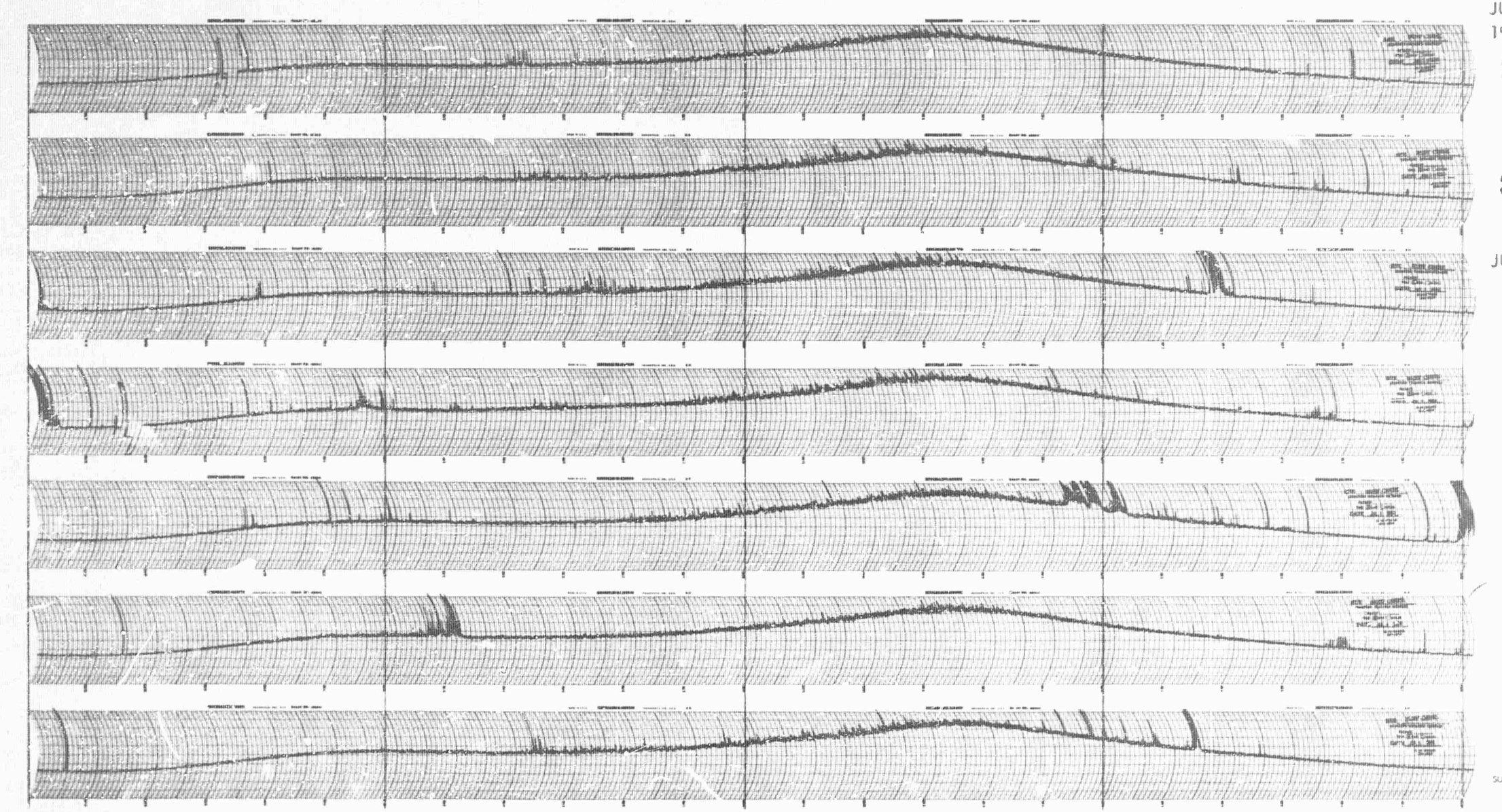

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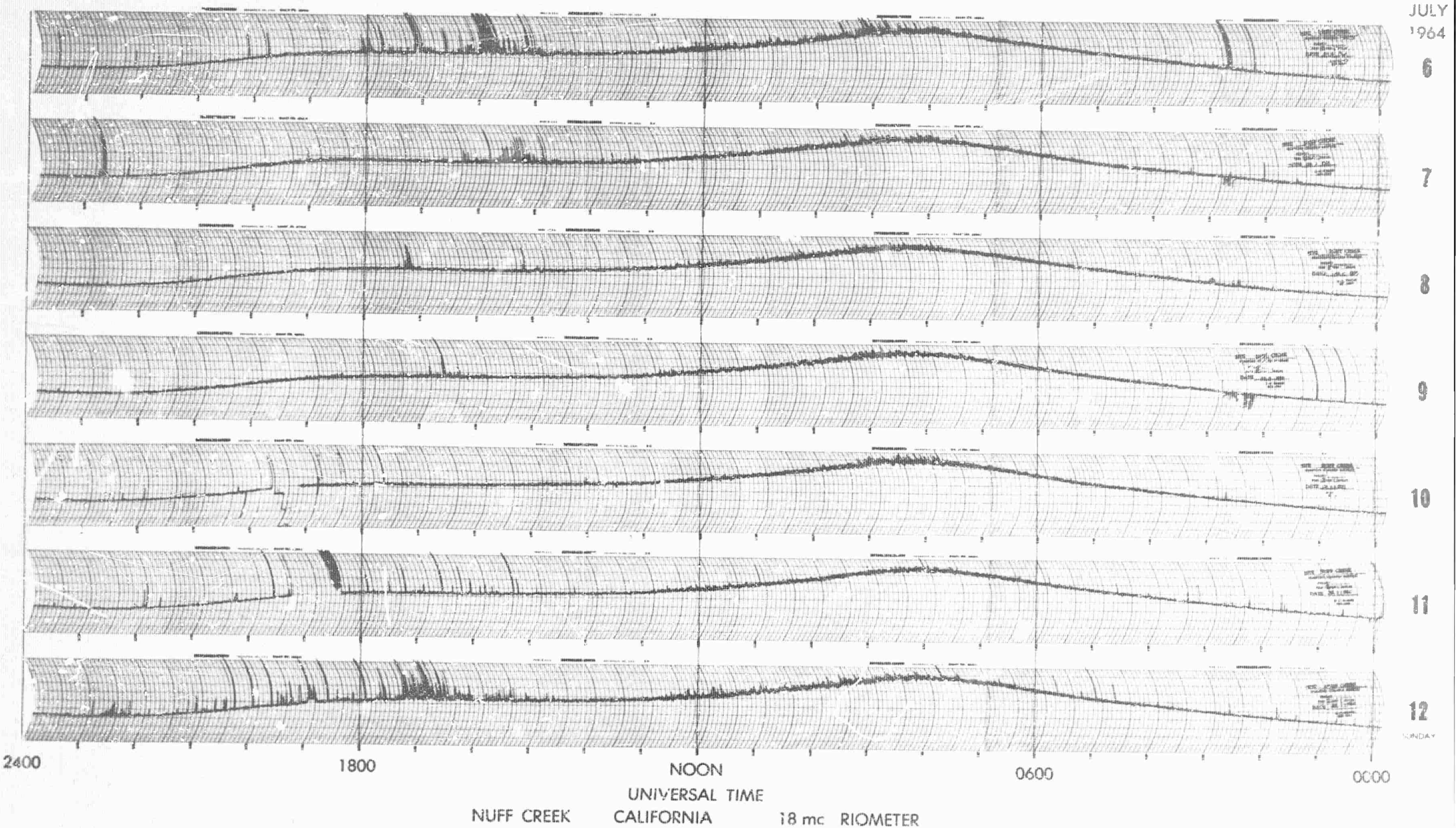

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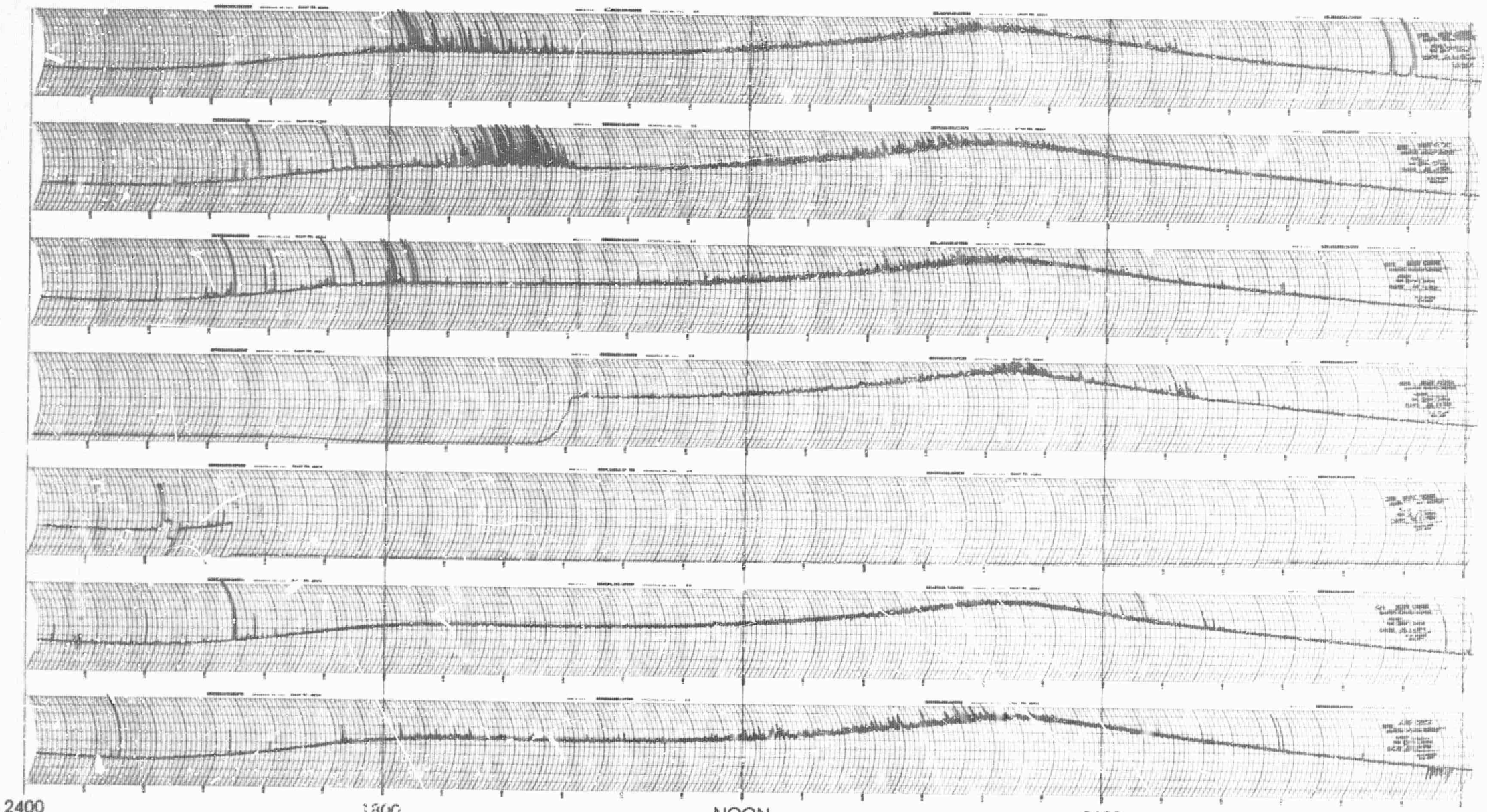

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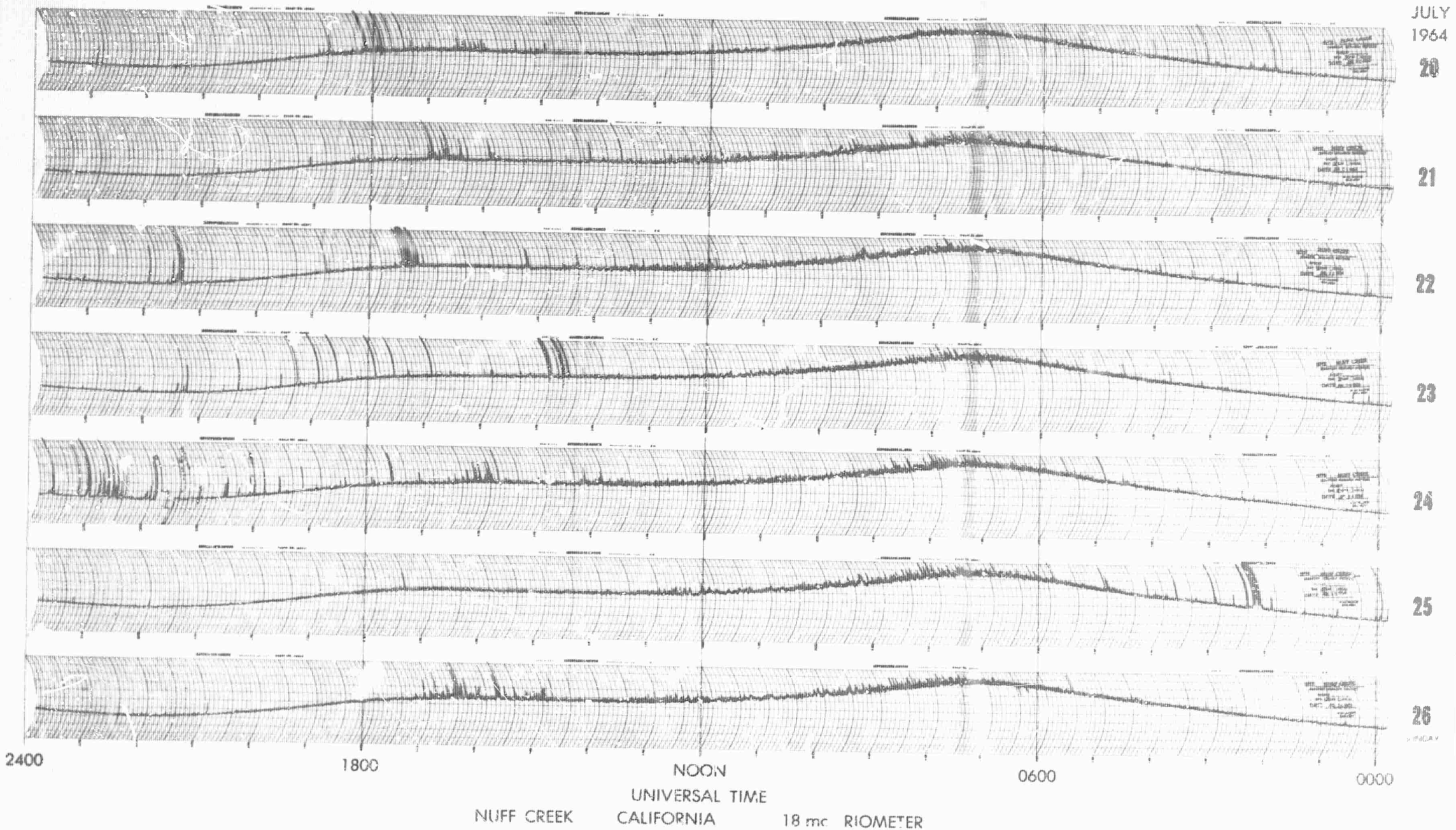

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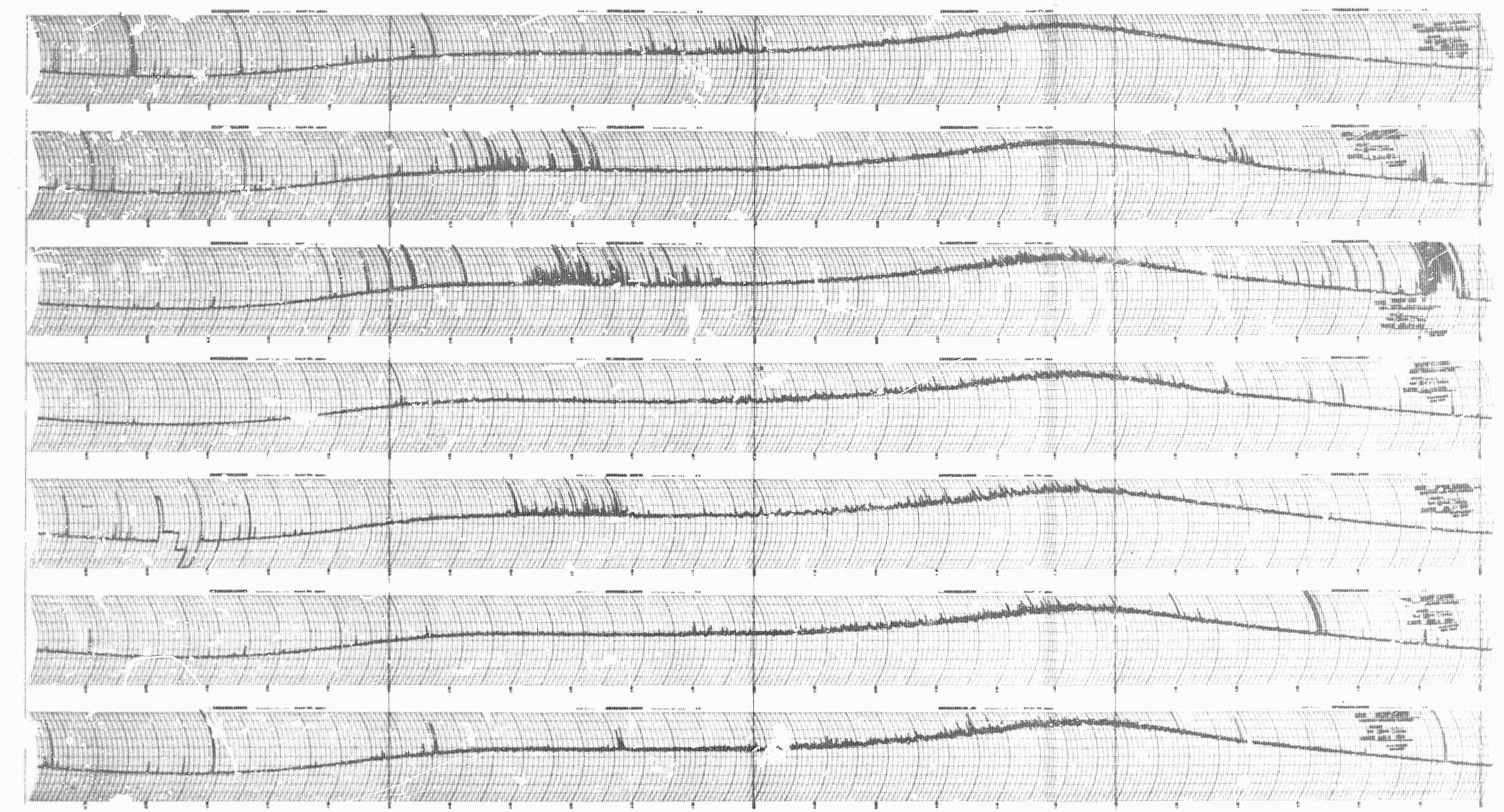

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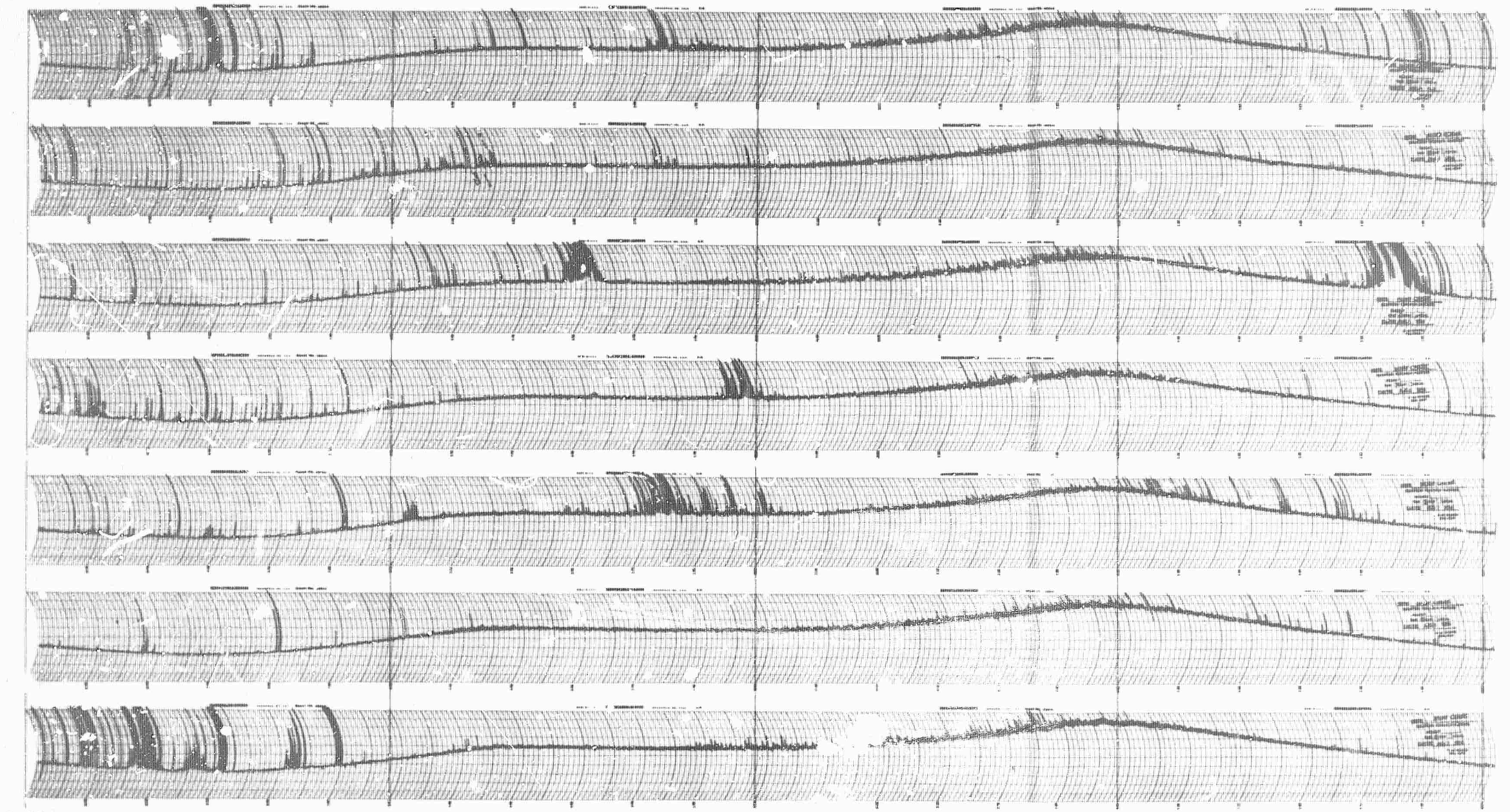

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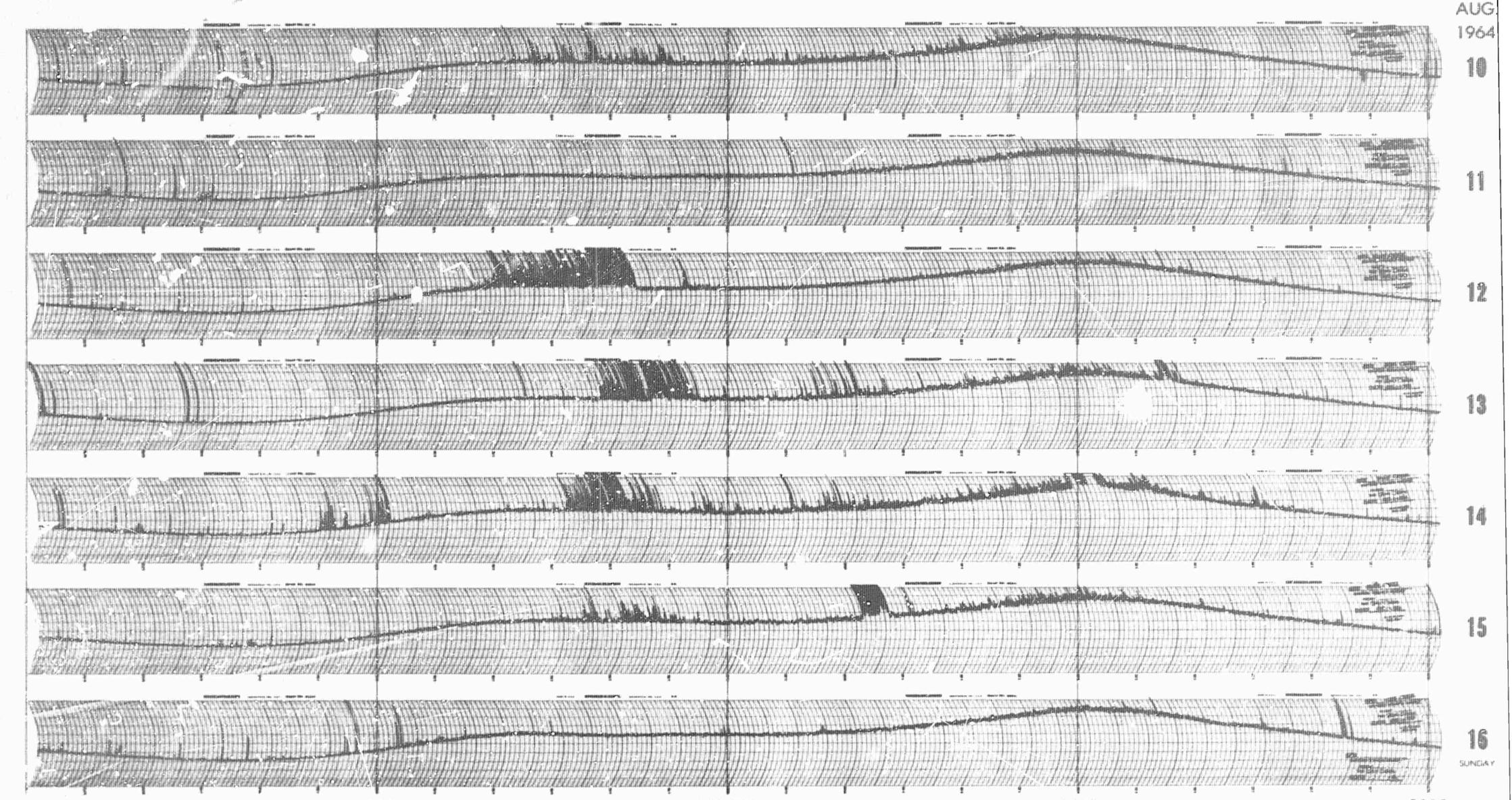

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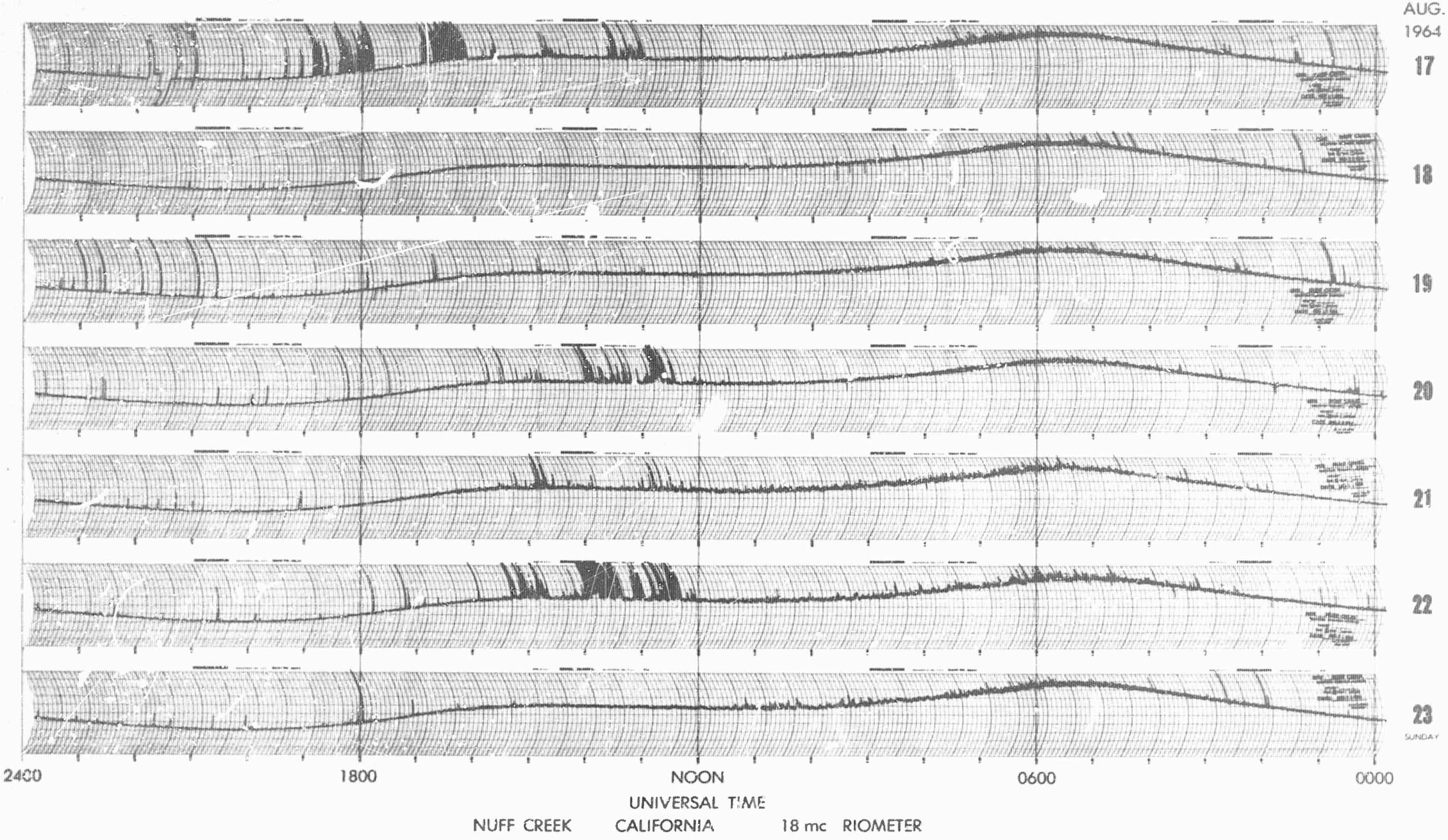

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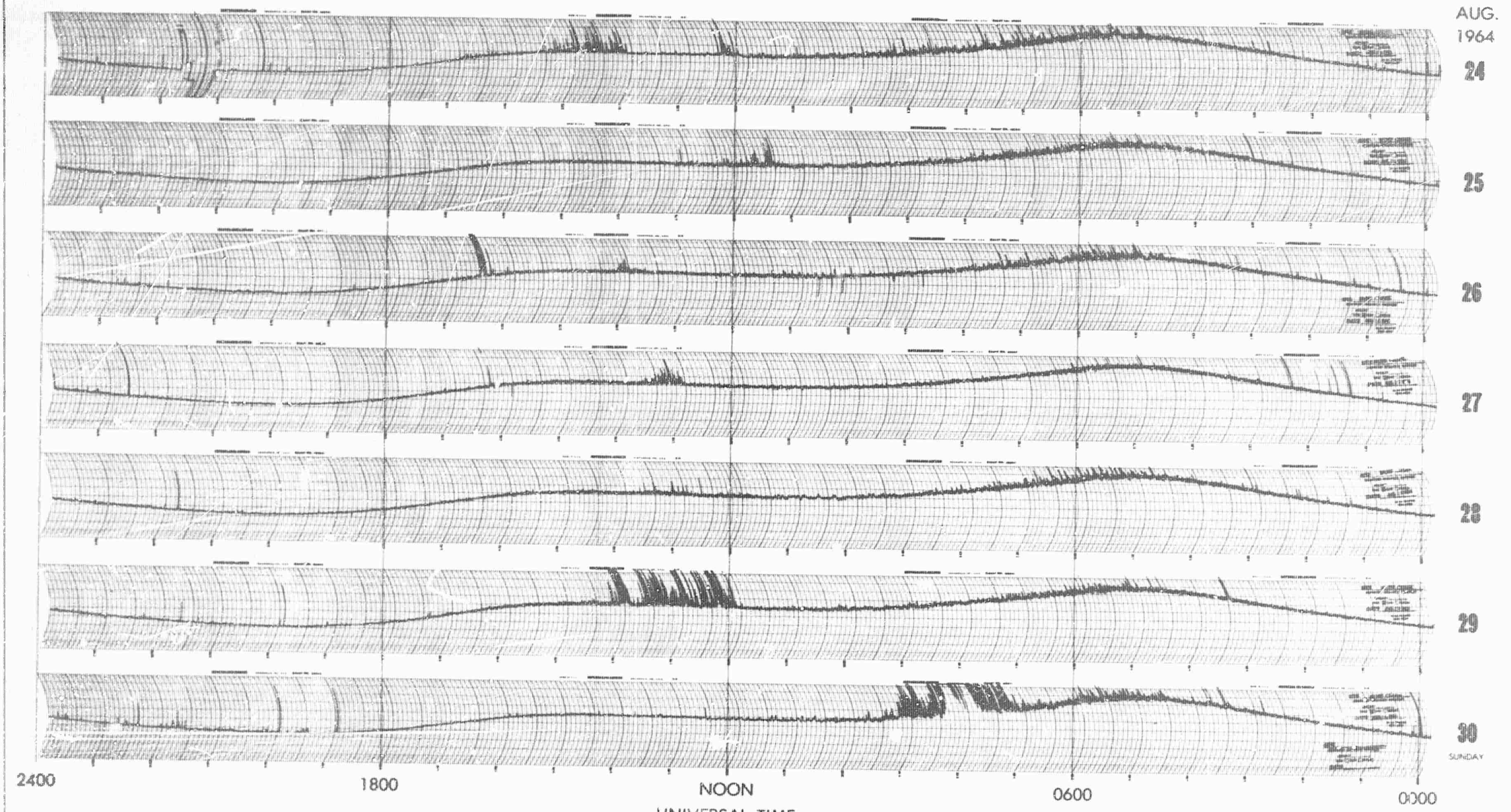

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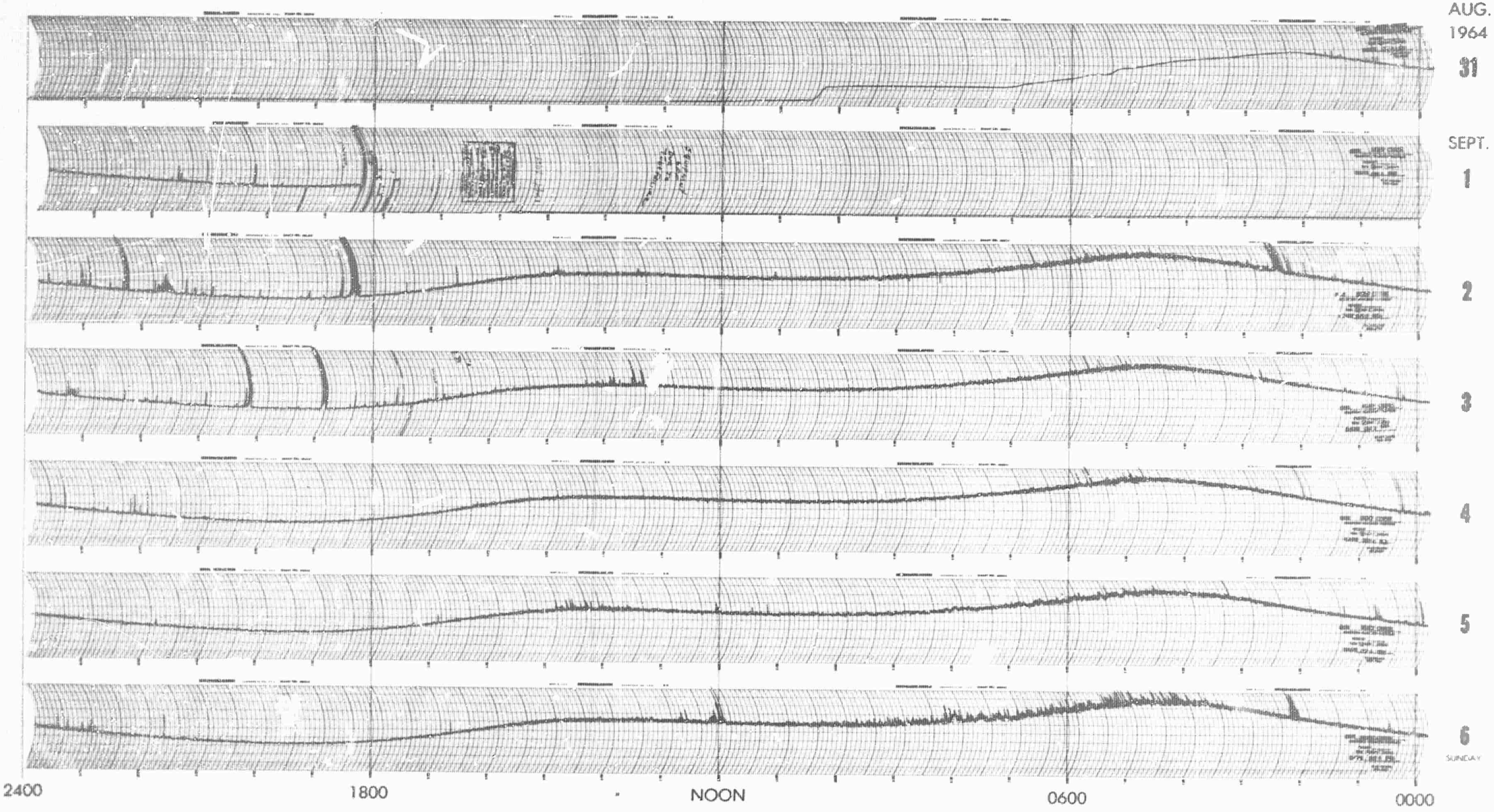

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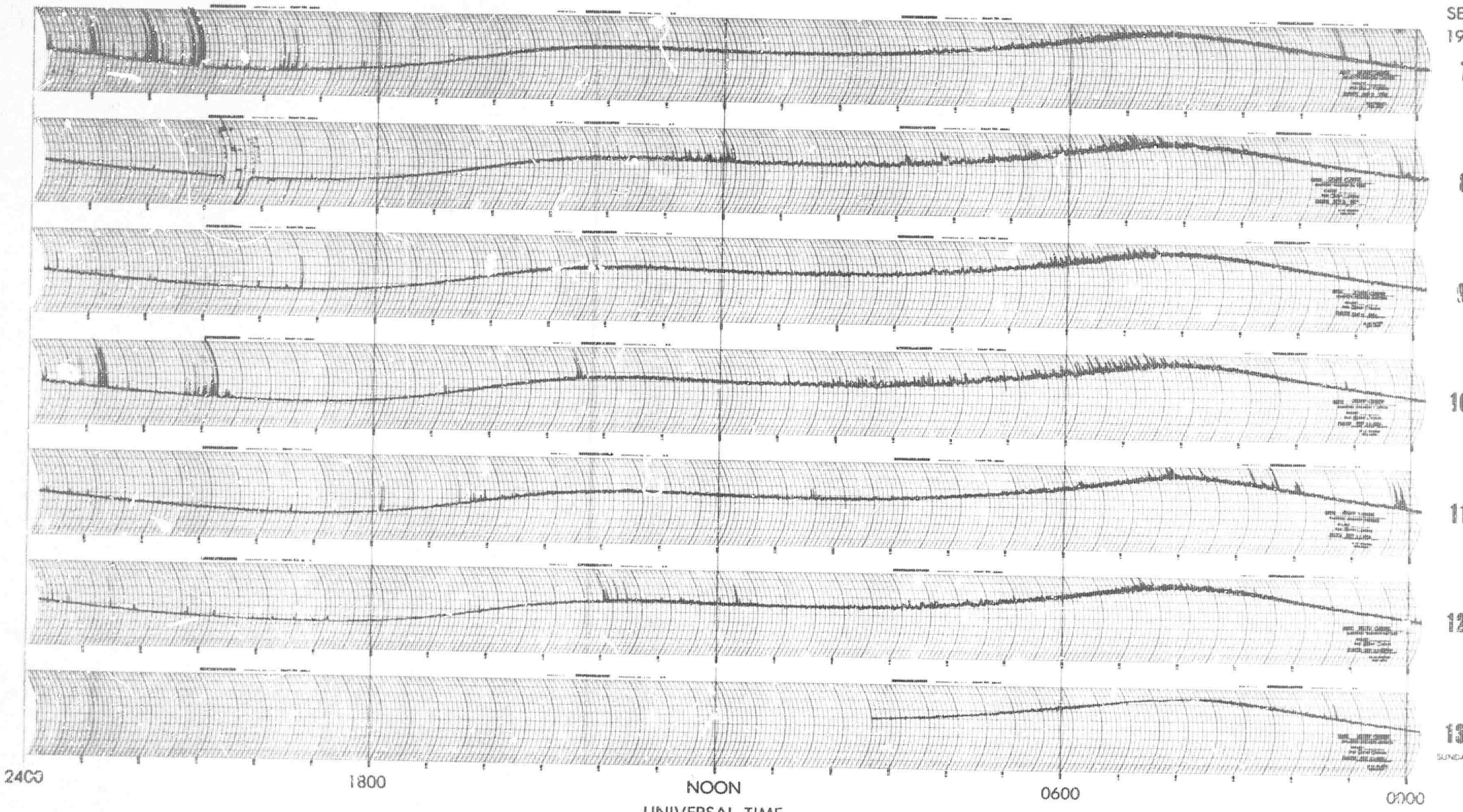

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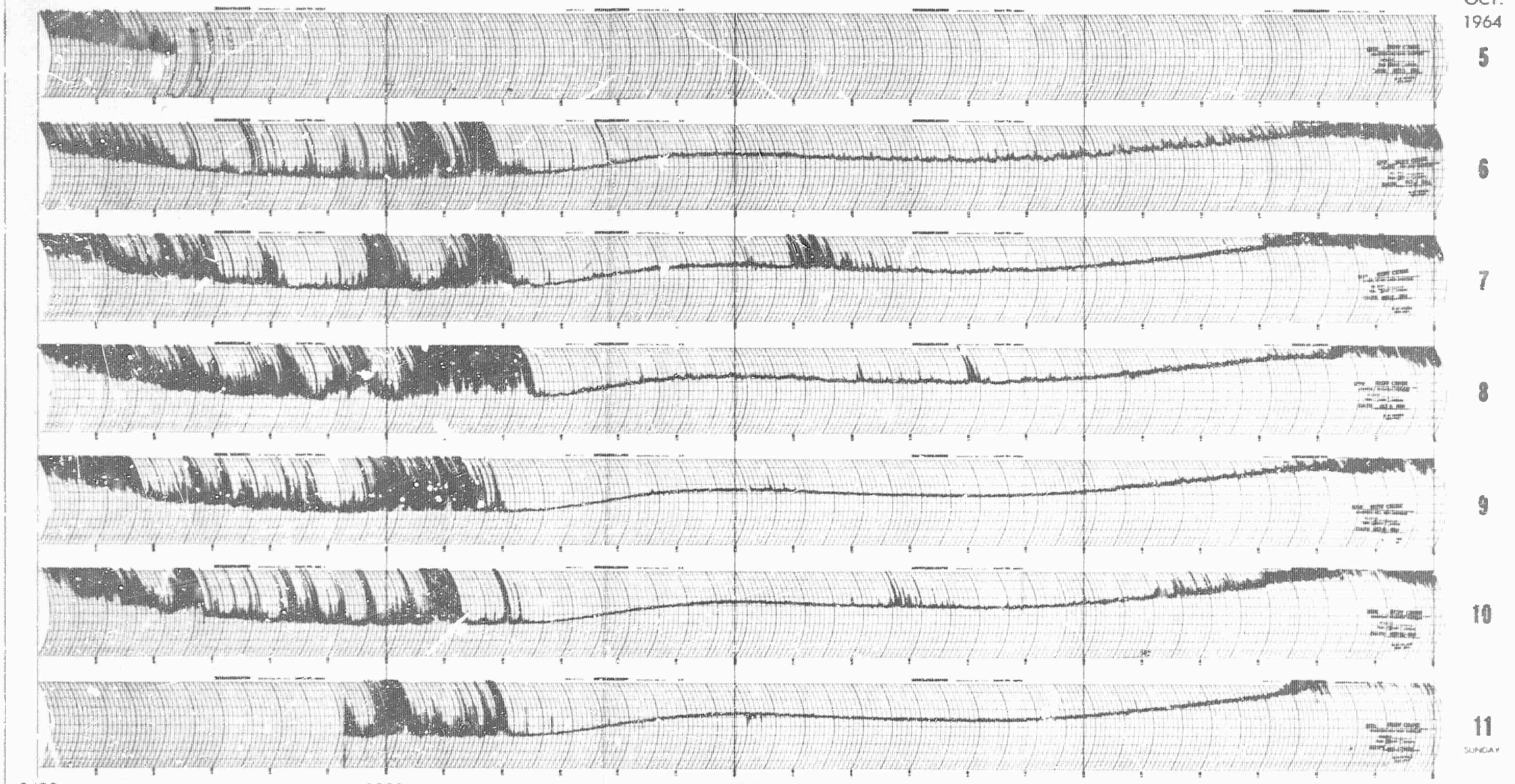

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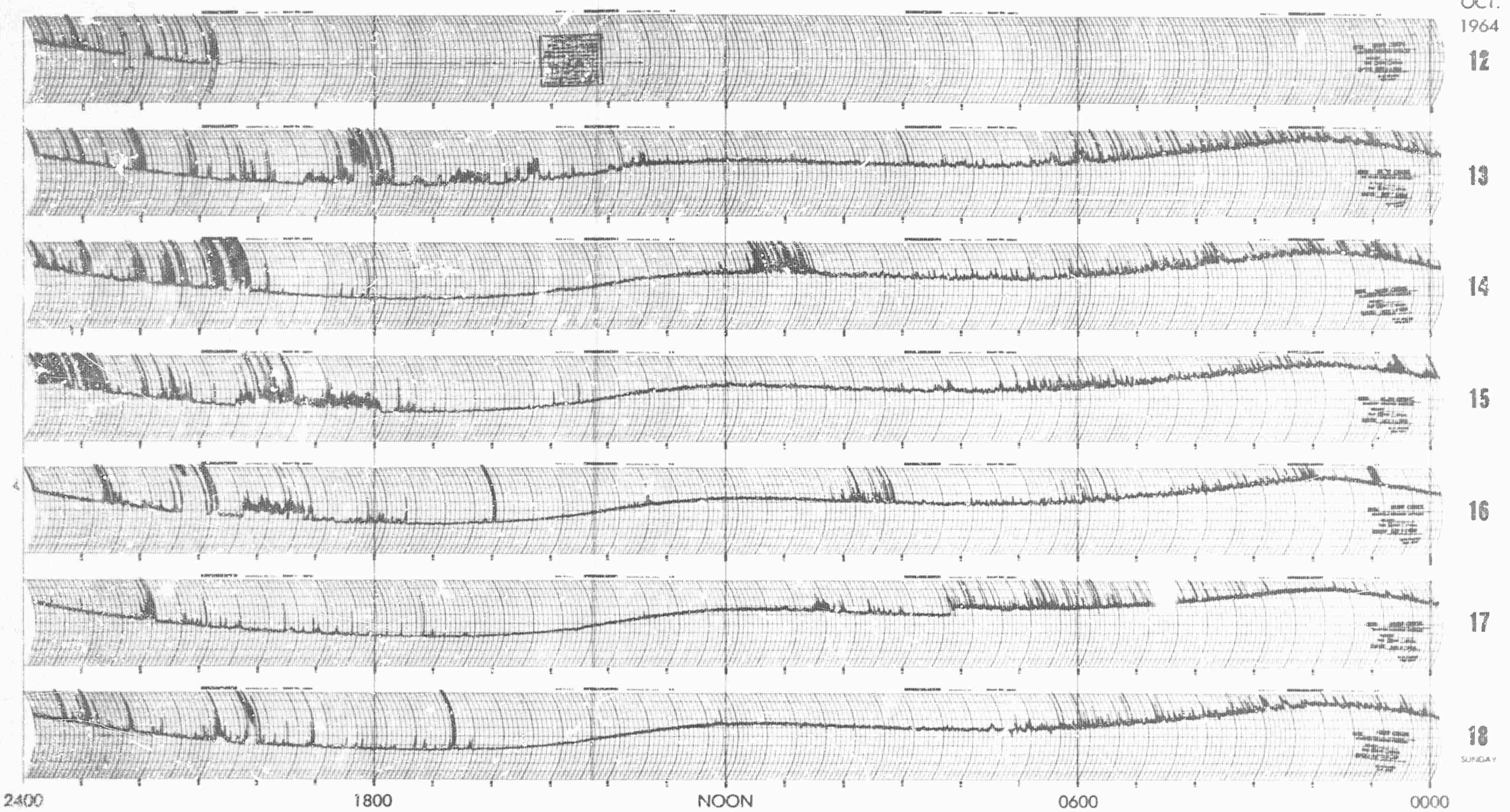

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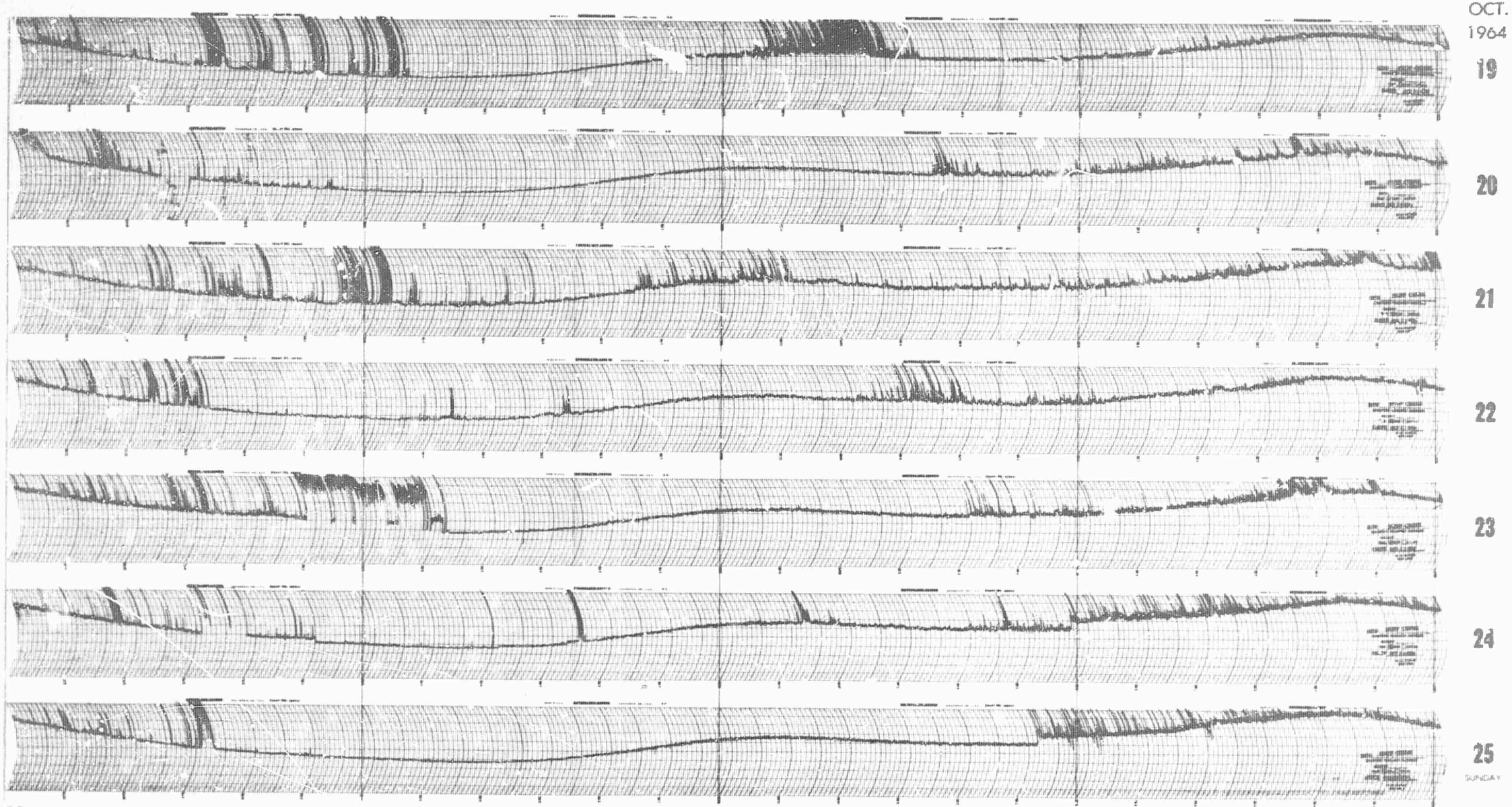

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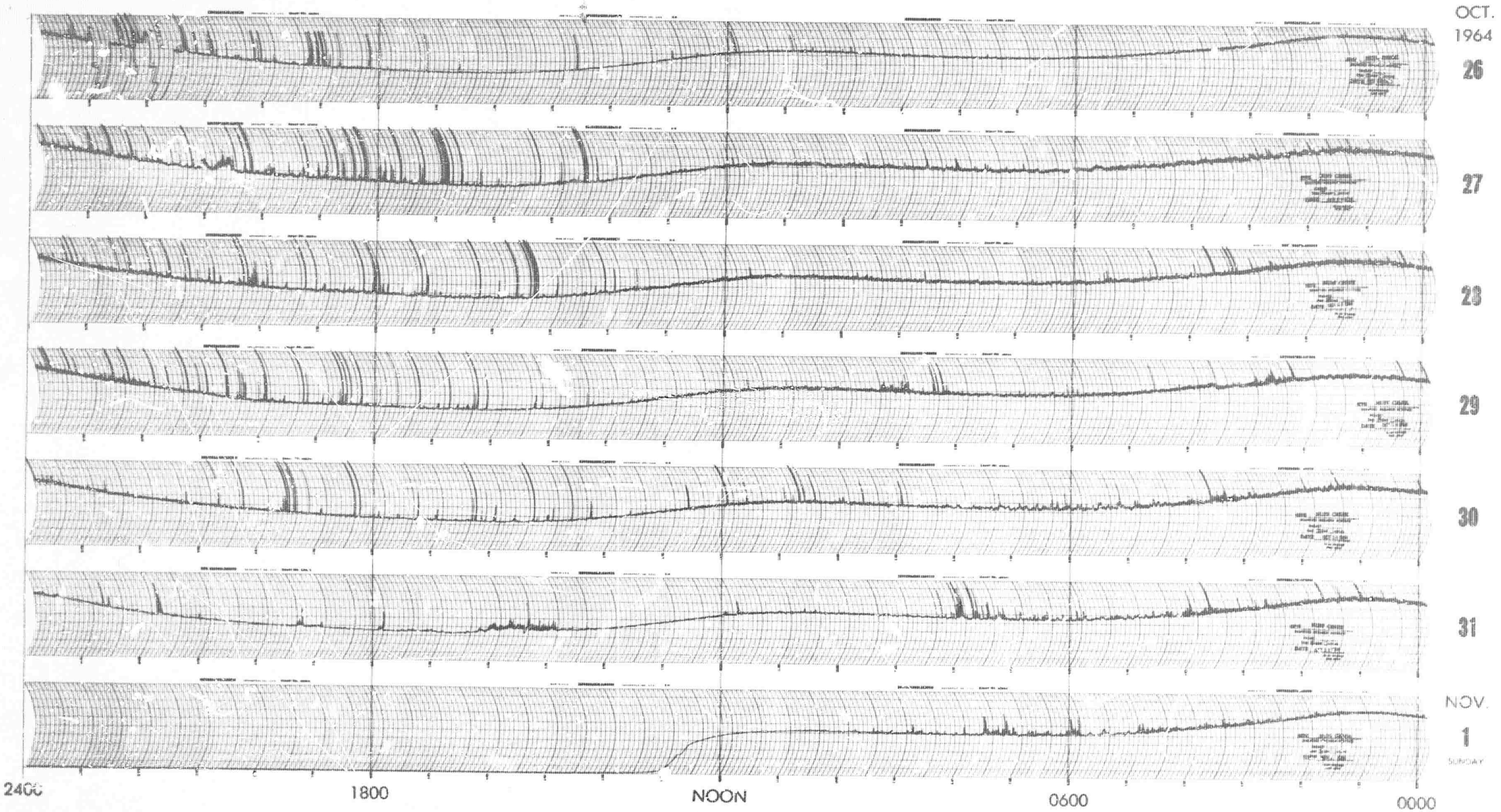

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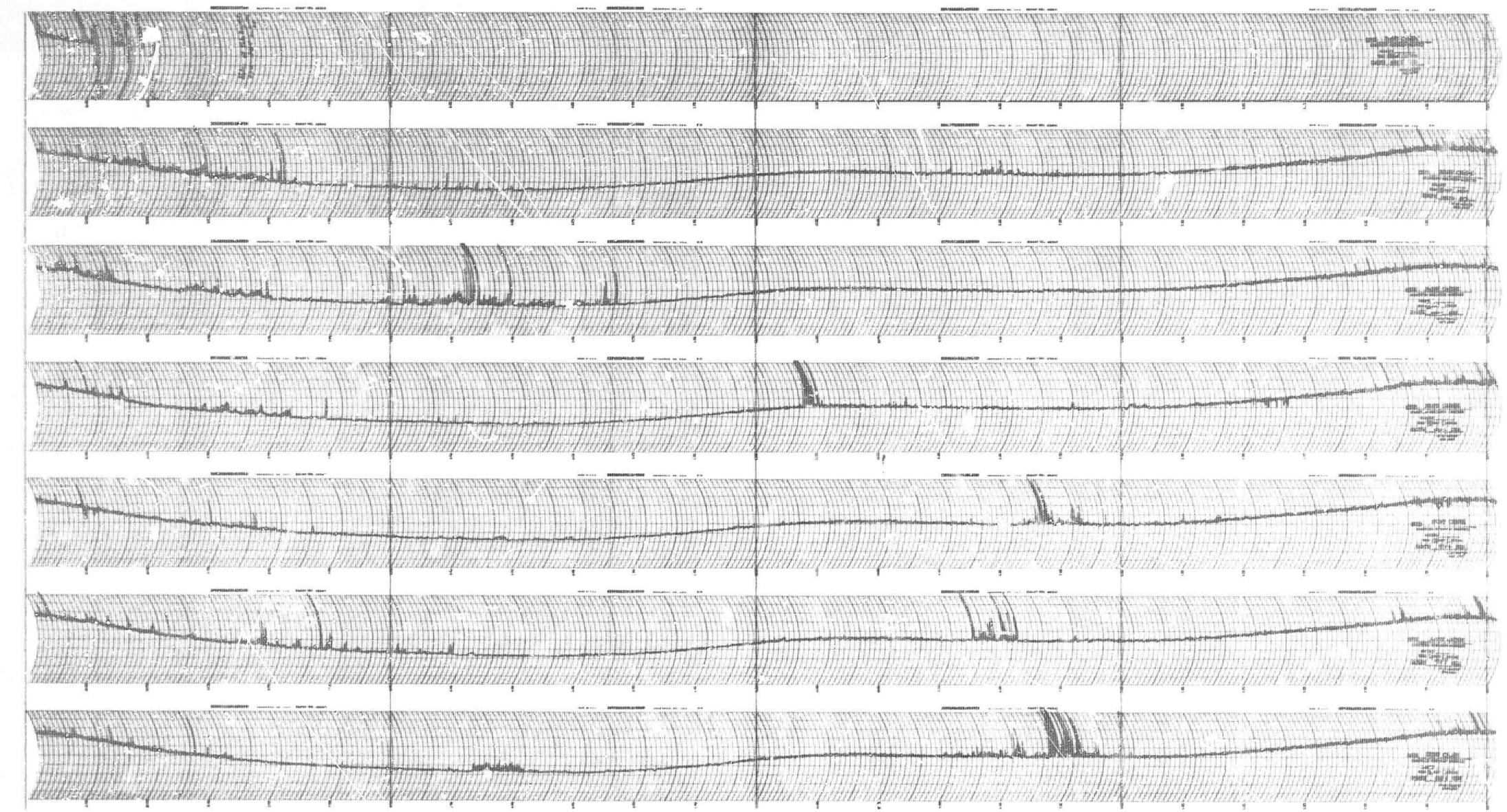

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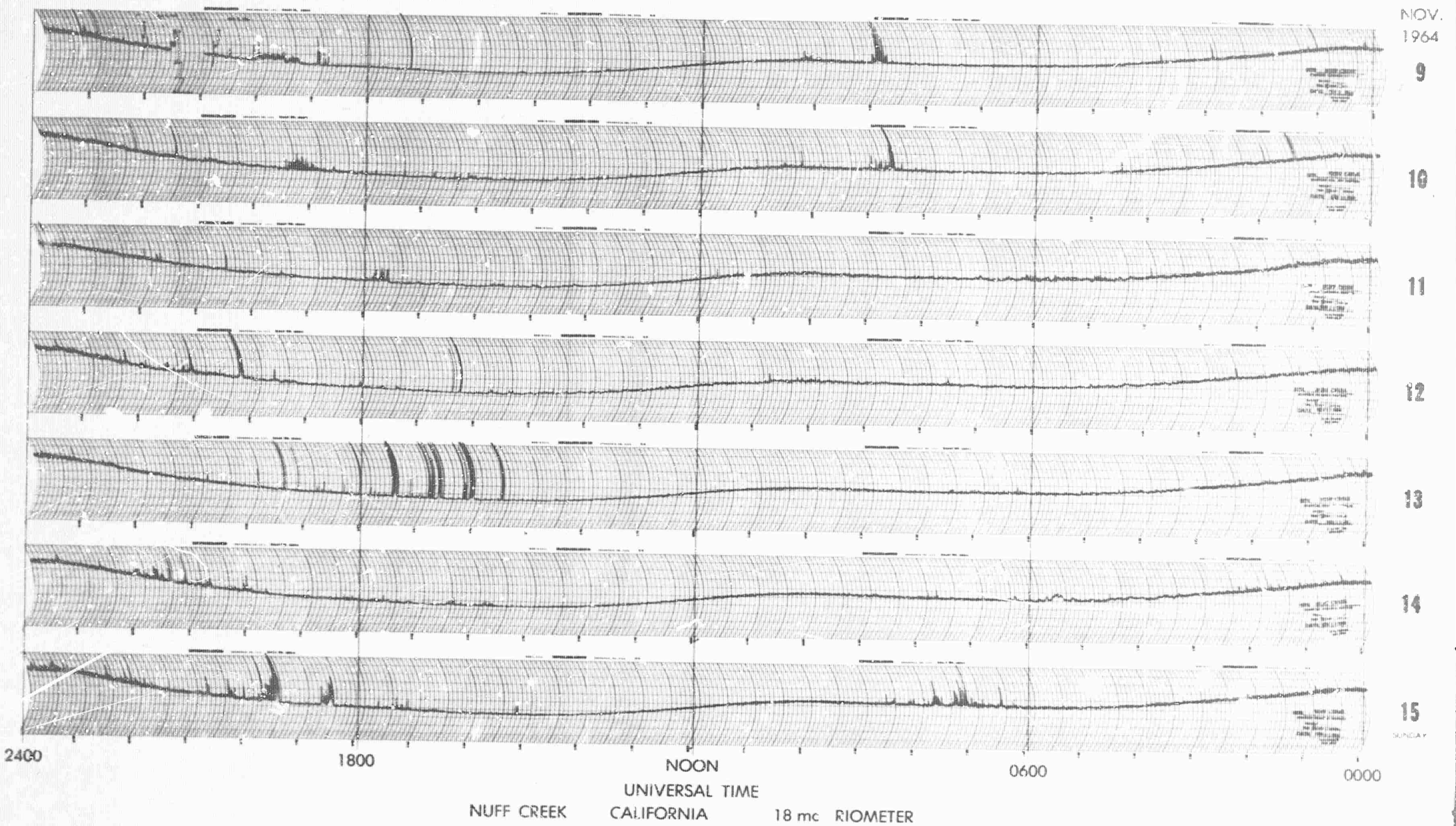

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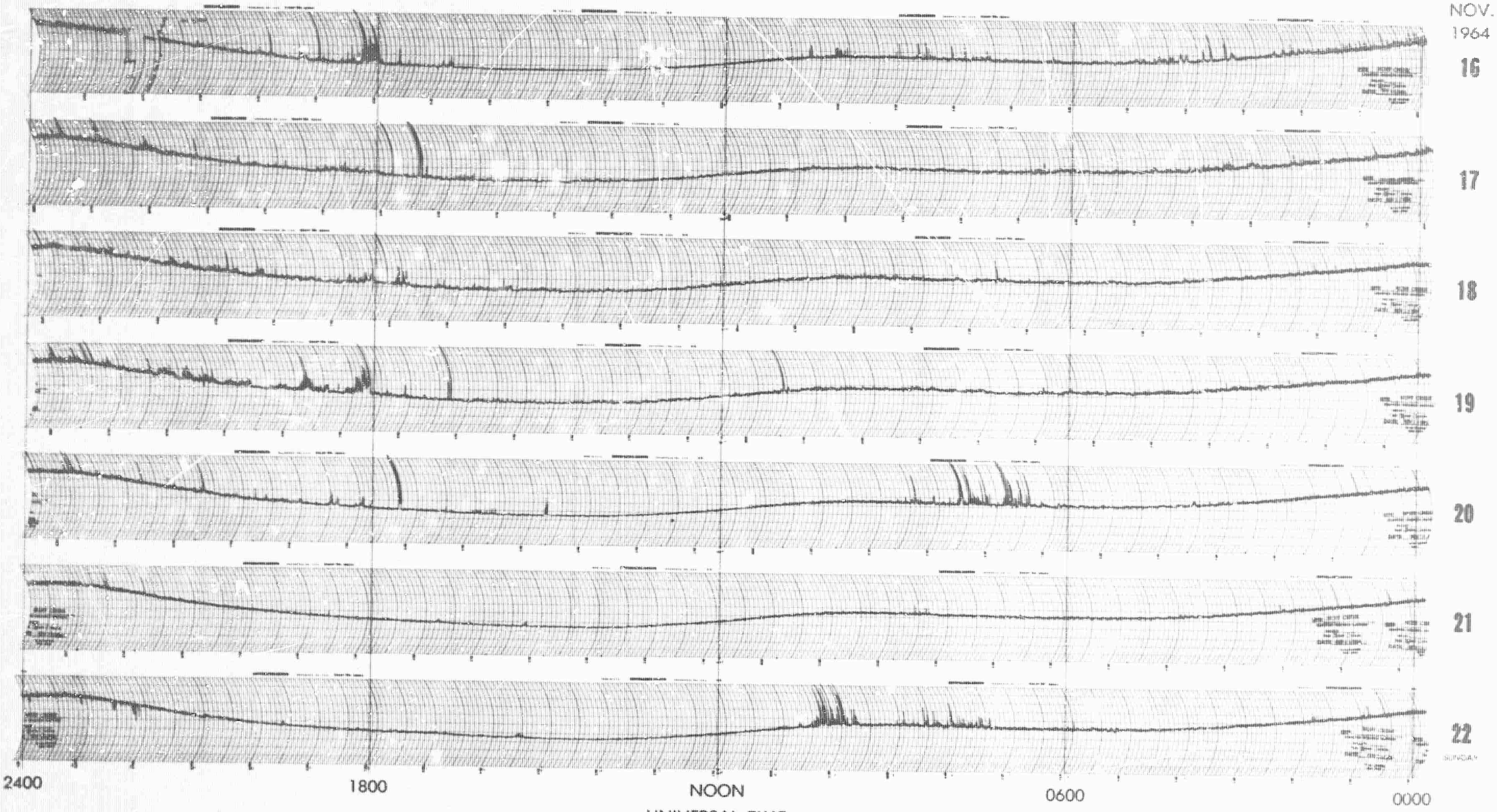

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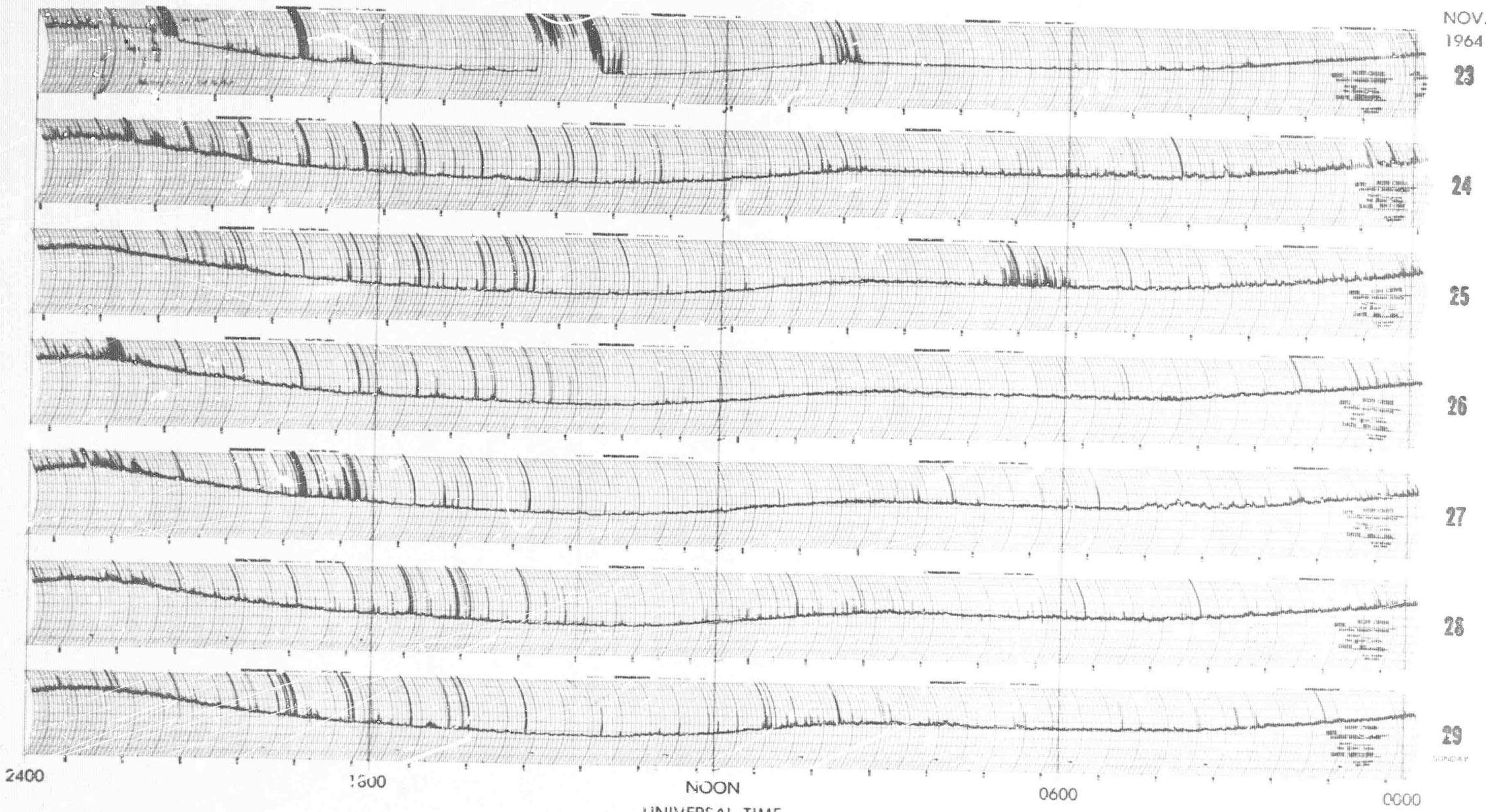

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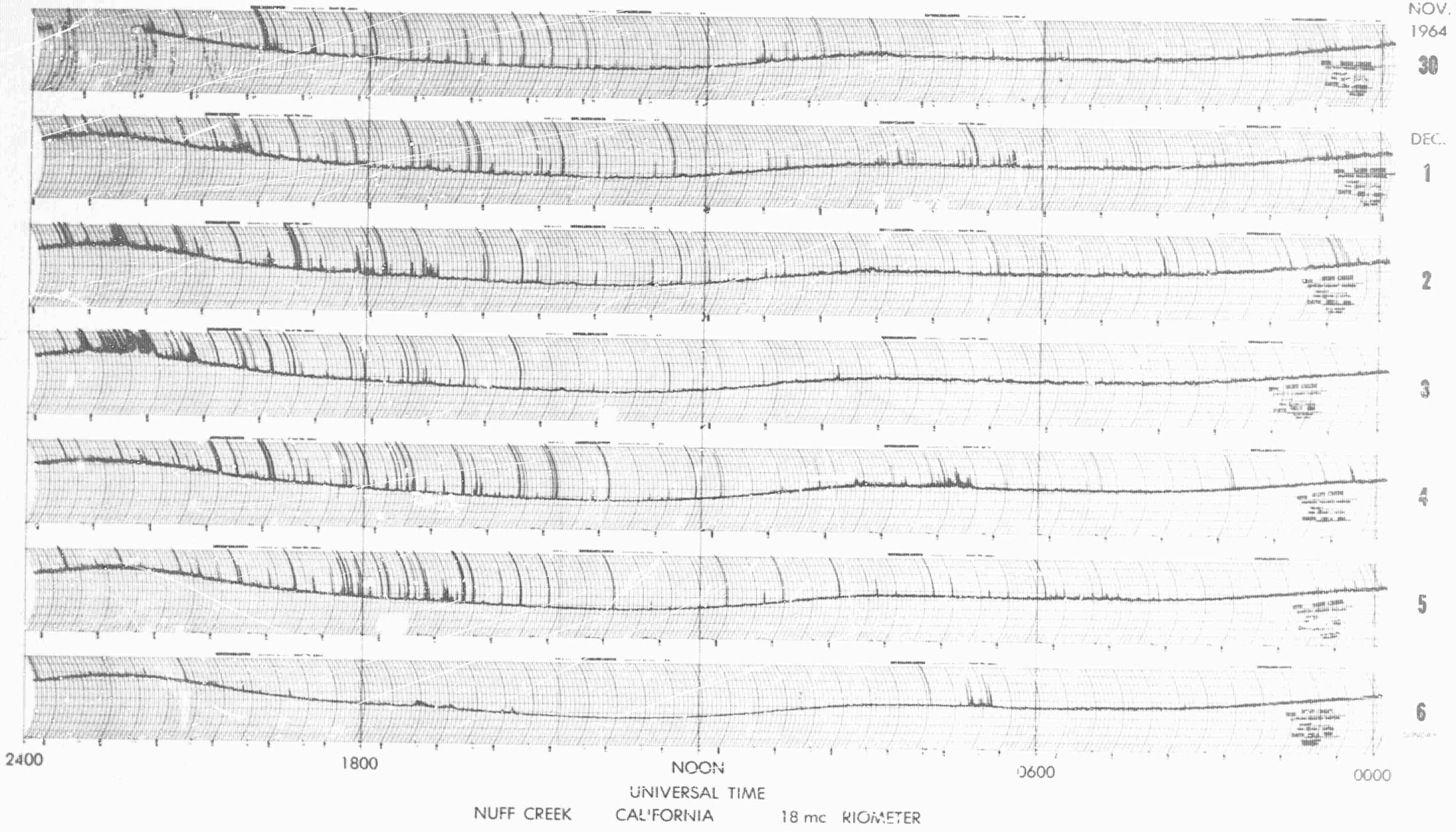

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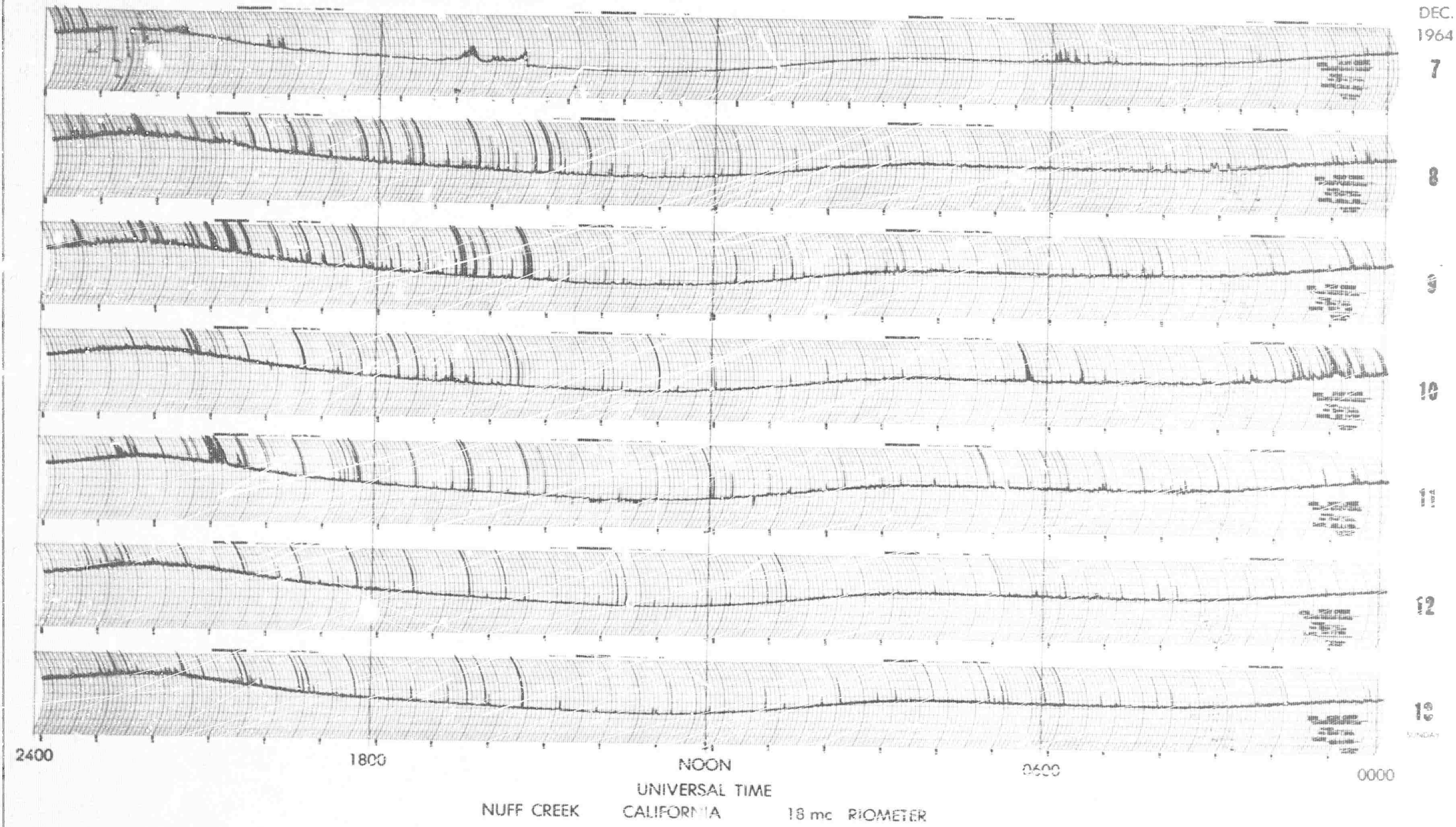

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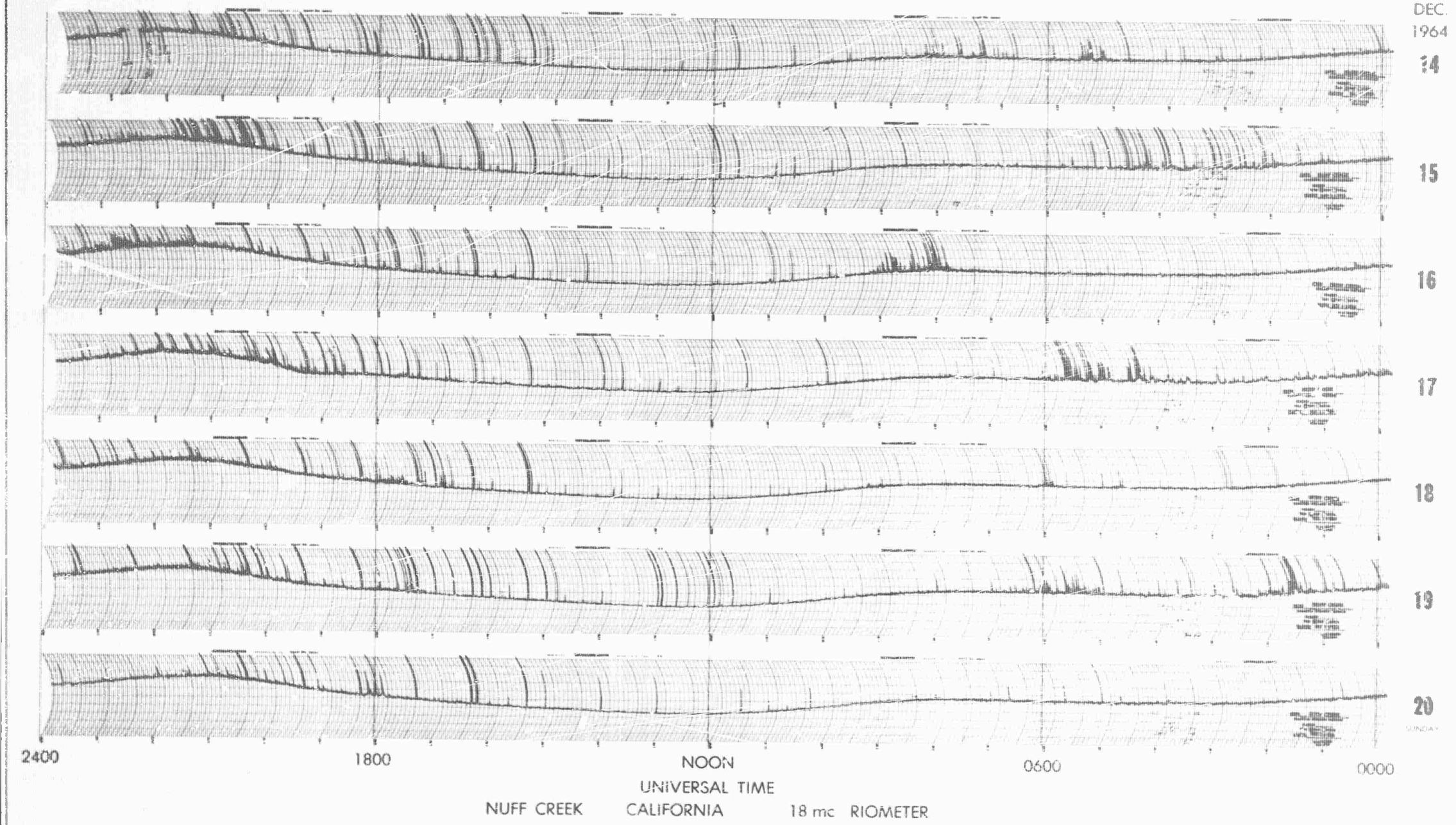

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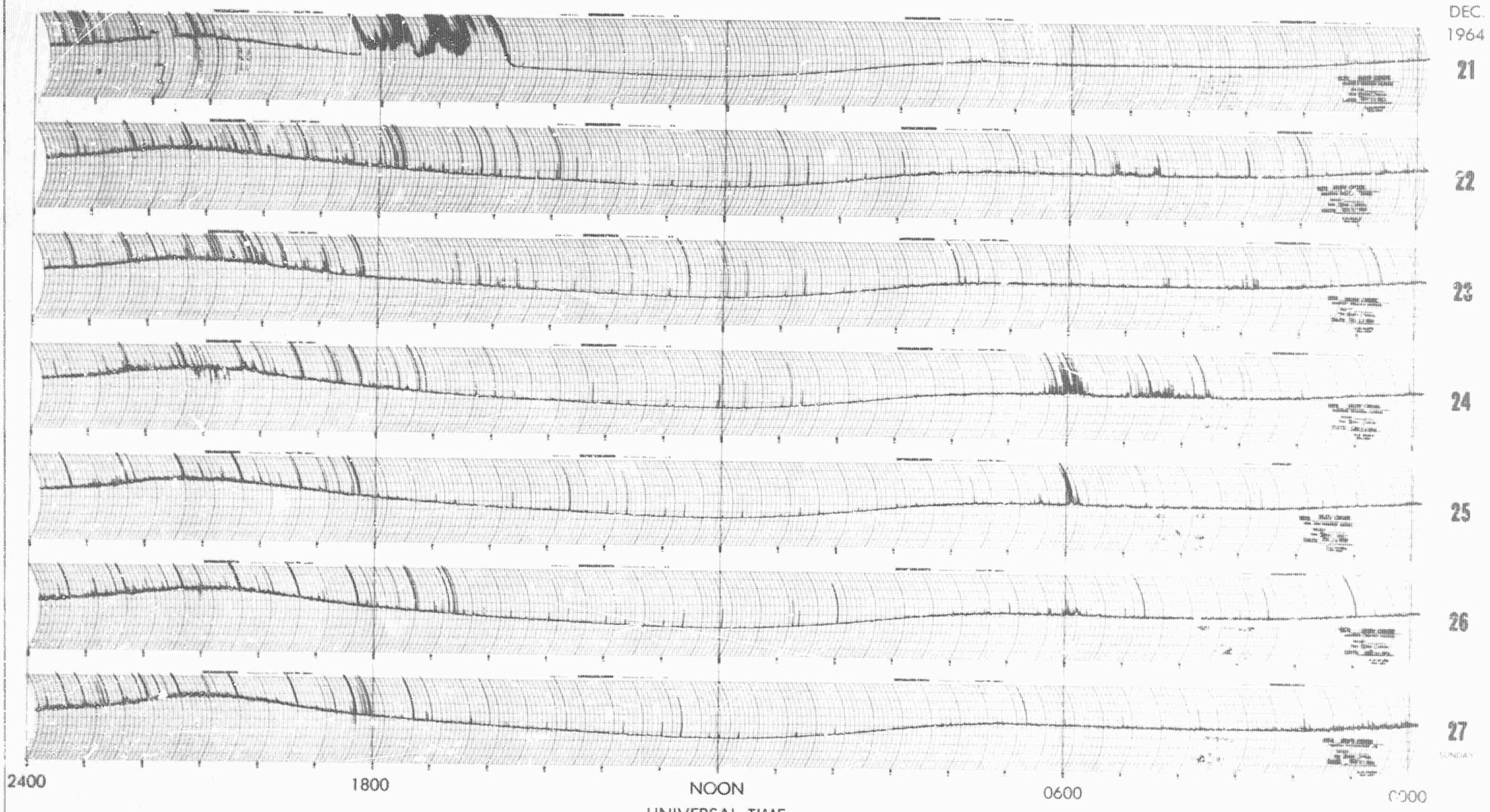

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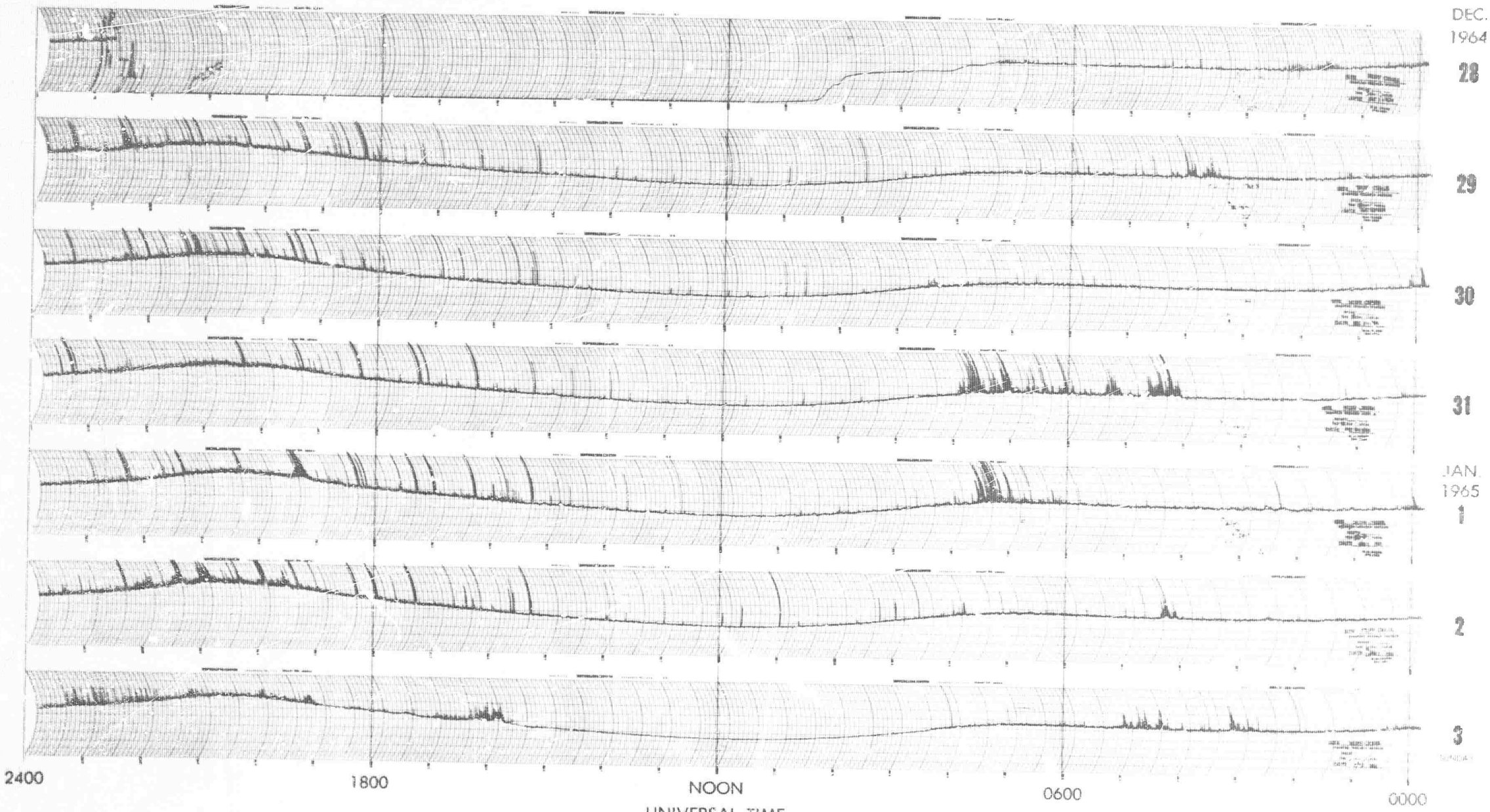

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