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FINAL REPORT: OFFSHORE ALASKA SEISMIC MEASUREMENTS PROGRAM

1 April 1980 - 30 August 1982

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ABSTRACT

This report summarizes the results of 18 deployments of the Texas strong motion ocean bottom seismograph (SM-OBS) which took place between July 1980 and July 1982 offshore of Alaska. From these deployments, 12 instruments were recovered, and 10 recorded data. Some of the instruments were successfully recovered after more than 240 days, longer than any previous OBS deployment that we know of. Two of the instruments apparently recorded data from four different earthquakes. The recorded ground accelerations for these events were in the 10 cm/sec^2 to 20 cm/sec^2 range. Unfortunately, only one earthquake of magnitude larger than 6.0 occurred near the SM-OBS instruments in the July 1980 - July 1982 period, and this was not recorded by the instruments. The main effort of the program was on the development of this new technology. Countless difficult problems encountered during the program were solved, but a few problems remained resulting in some instrumental malfunctions which affected all of the OBS deployments and prevented us from obtaining more data or data of uniformly high quality during this period. This report also evaluates some of these problems and suggests ways to avoid these problems in future SM-OBS programs. Considering the high potential for serious earthquake damage in the offshore Alaska region, it is imperative that the effort to obtain SM-OBS data continues.

HISTORY AND OBJECTIVES OF THE PROGRAM

History_before_1980

In 1978, Exxon Production Research Company (EPR) awarded a contract to the University of Texas (UT) Marine Science Institute to develop a low cost, easily deployable, three-component digital ocean bottom seismograph (OBS) system capable of recording strong motion (SM) of the sea floor. At UT the two scientists principally responsible for this development were Gary Latham and Paul Donoho. Latham had been involved in OBS development for both earthquake and refraction research for many years both at UT and previously at Lamont-Doherty Geological Observatory (e. g., see Latham and Sutton, 1966; Ibrahim and Latham, 1978; and Latham et al., 1978). Donoho is a physicist who designed the microprocessor controlled equipment. At the same time members of the EPR research staff undertook the task of finding an effective way of coupling an OBS instrument to marine sediments (e. g., see Steinmetz et al., 1979).

The National Oceanic and Atmospheric Administration (NOAA) was a third institution involved in this research program. Because of the difficulty of deploying and recovering OBS instruments with small vessels in the remote and dangerous waters offshore of Alaska, NOAA agreed to allow UT to use their research vessels as a platform for this program. In addition, NOAA also provided support for deploying some traditional high-gain OBS instruments in Alaskan waters. These instruments were to monitor and locate precisely background microearthquake activity which would be important for evaluating the significance of any SM data that was obtained.

As a part of the original program supported by Exxon, SM-OBS instruments were deployed in offshore Alaska on three separate occasions (Figure 1 and Table 1) to demonstrate the feasibility of deploying and retrieving these instruments. Three prototype digital SM-OBS instruments were deployed offshore of Kodiak, Alaska in the summer of 1978 and all were successfully recovered after about one month of operation. These stations recorded no seismic events. In the summer of 1979, eight more SM-OBS's were deployed, of which five were recovered in the Fall of 1979. No significant earthquakes occurred while these instruments were deployed and no strong motion data were recorded. The instruments and the field program have been described in some detail by Steinmetz et al. (1980). At this time a network of eleven high gain analog OBS instruments operated near Kodiak. Seven produced usable data including seismograms from about 20 locatable earthquakes. Lawton et al. (1982) have reported the results of the high-gain OBS research. Finally, four SM-OBS instruments were deployed in the Fall of 1979, and all were recovered by early in 1980. These instruments recorded no useful data. Thus by mid-1980 when the period covered by the present report began, a total of 15 SM-OBS instruments had been deployed and 12 had been recovered successfully, but none had recorded any earthquake events.

Objectives_and_History_-_1980_to_1982

In 1980, representatives from UT and from Arco, Chevron, Exxon, Mobil and Shell signed the participants' agreement for the Offshore

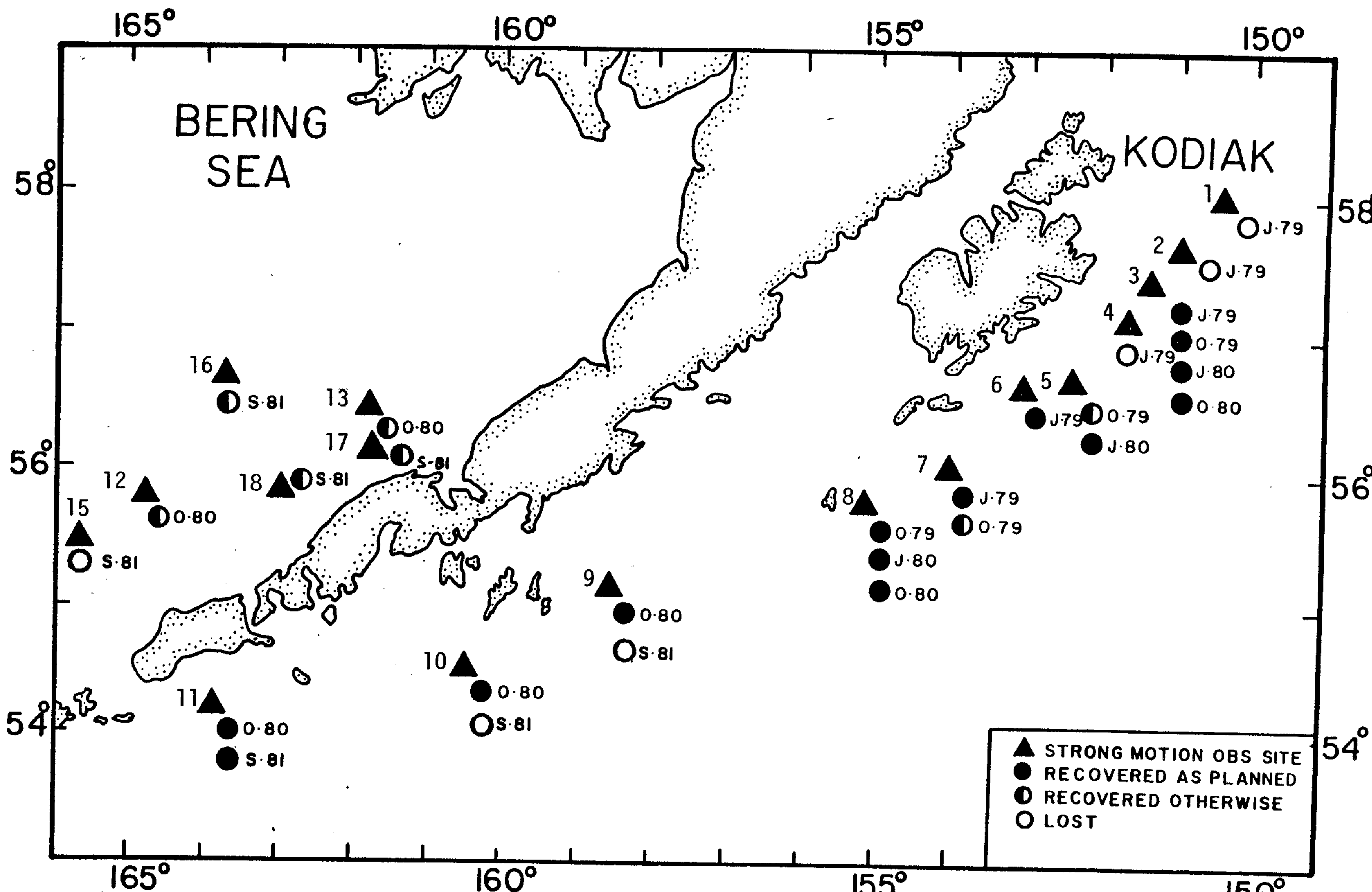


FIGURE 1: Deployment sites for strong motion ocean bottom seismographs, showing degree of success in recovery. Sites labeled "0.79" were deployed in October 1979, "J.80" in July 1980, "0.80" in October 1980, and "S.81" in September 1981.

TABLE 1. Summary of Deployments and Recovery of the SM-OBS

Deployment Number	Station	Lat.	Long.	Water Depth (m)	Deployment Date (GMT)	Recovery Date	Release	Orientation Comp. H1	Orientation Comp. H2	Penetration (inches)
1		-	-	-	8/78	9/78	acoustic	-	-	-
2		-	-	-	8/78	9/78	acoustic	-	-	-
3		-	-	-	8/78	9/78	acoustic	-	-	-
4	1	57°58.3'	150°28.8'	157	6/26/79 1715	Lost	-	42°	132°	-
5	2	57°41.0'	150°58.6'	79	6/26/79 1221	Lost	-	23°	113°	-
6	3	57°25.3'	151°23.3'	172	6/25/79 2202	8/24/79	timed	156°	246°	-
7	4	57°08.5'	151°42.3'	82	6/25/79 1615	Lost	-	341°	71°	-
8	5	56°42.8'	152°27.0'	183	6/25/79 0911	10/79	timed	154°	244°	-
9	6	56°40.1'	153°06.5'	152	6/24/79 2016	8/23/79	timed	146°	236°	-
10	7	56°08.6'	154°03.4'	154	6/24/79 1104	8/23/79	timed	224°	314°	-
11	8	55°47.6'	155°10.1'	117	6/23/79 1722	10/79	timed	214°	304°	-
12	3	57°25.4'	151°23.3'	-	10/14/79	12/6/79	premature	-	-	-
13	4	56°49.9'	153°07.1'	-	10/13/79	3/14/80	timed	-	-	-
14	7	56°05.2'	154°03.3'	-	10/16/79	11/16/79	premature	-	-	-
15	8	55°47.3'	155°10.0'	-	10/12/79	3/13/80	timed	-	-	-
16	3	57°25.1'	151°23.0'	172	7/21/80	10/1/80	acoustic	238°	328°	10"
17	5	56°42.8'	152°27.0'	183	7/21/80	10/2/80	acoustic	36°	126°	10"

TABLE 1. Page 2

Deployment Number	Station	Lat.	Long.	Water Depth (m)	Deployment Date (GMT)	Recovery Date	Release	Orientation Comp. H1	Orientation Comp. H2	Penetration (inches)
18	8	55°47.1'	155°10.8'	117	7/21/80	10/2/80	acoustic	No Record		5"
19	3	57°25.1'	151°23.0'	172	10/2/80 0203	5/30/81 1030	acoustic	40°	130°	10"
20	8	55°47.1'	155°10.8'	117	10/2/80 1800	5/31/81 0220	acoustic	354°	84°	4.5"
21	9	55°09.1'	158°33.8'	190	10/17/80 1000	5/31/81 1339	acoustic	96°	186°	9.25"
22	10	54°30.7'	160°29.9'	146	10/17/80 0240	5/31/81 2250	acoustic	114°	204°	6.5"
23	11	54°14.1'	163°52.4'	97	10/16/80 1555	6/4/81 0206	timed	No Record		-
24	12	55°49.9'	164°47.7'	97	10/80	-	premature	169°	259°	10"
25	13	56°29.0'	161°48.1'	93	10/80	10/81 found on beach	-	250°	340°	4.25"
26	8	55°48.0'	155°10.0'	-	Aborted	-	-	-	-	-
27	9	55°09.17'	158°33.76'	187	9/15/81	Lost	-	-	-	-
28	10	54°30.74'	160°29.92'	146	9/15/81	Lost	-	-	-	-
29	11	54°14.19'	163°51.9'	106	9/16/81	7/9/82	acoustic	-	-	1"
30	15	55°25.08'	115°38.98'	117	9/30/81	Lost	-	-	-	-
31	16	56°42.00'	163°39.98'	74	9/30/81	8/22/83 found in trawler's net	-	-	-	-
32	17	56°13.99'	161°46.92'	62	9/30/81	10/8/81	premature	-	-	-
33	18	55°49.01'	162°58.00'	78	10/1/81	3/82	premature	-	-	-

Alaska Seismic Measurements Program (OASMP), which is the principal subject of this report. In this agreement, UT agreed explicitly to administer the OASMP and to perform several program tasks. Essentially these tasks were:

- To construct 10 to 15 SM-OBS instruments;
- To arrange for the deployment and recovery of these instruments in appropriate sites offshore of Alaska;
- To inform the industrial participants of the results of this program through reports and meetings.

The primary objectives of the program were:

- To perfect the design of a relatively inexpensive but effective OBS instrument package;
- To obtain strong motion records from the ocean floor for relatively large earthquakes occuring in Alaska.

The participants' agreement applied explicitly only to the period from 1980 till 30 August, 1982. However, it was clearly understood that U. S. government assistance and a longer period than two years might be necessary to obtain strong motion records from large earthquakes. In particular, the participants' agreement states:

- "Operation of a 10 to 15 station network of strong-motion OBS stations, coupled with a like number of land stations, will virtually assure acquisition of a meaningful set of strong-motion measurements within this highly active region over a period of three to five years. NOAA vessels operating in this region as part of the Outer Continental Shelf Environmental Shelf Assessment Program will be used to deploy and retrieve the strong-motion OBS stations at no cost to industrial sponsors. In addition, we anticipate that NOAA will continue to sponsor earthquake and refraction studies in the Alaska Zone, using a permanent network of land stations augmented by temporary networks of ocean bottom stations."

Subsequently in 1980 several events took place which were significant for the OASMP. First, three SM-OBS instruments deployed in July of 1980 in Alaska were recovered successfully in October (Figure 1 and Table 1), and then seven more instruments were deployed in October for recovery in 1981.

Second, an OASMP participants' meeting was held in Galveston, Texas on 19 October 1980. This meeting included a review of progress in the OBS program to that date. Most of the information provided at this meeting has been published (Steinmetz et al., 1979; 1981; Lawton et al., 1982). With the exception of a few letters to the industrial participants of the OASMP, the 1980 participants' meeting has been the most recent formal communication between UT scientists and the industrial participants up until the present report.

Third, in October of 1980 Gary Latham, the principal investigator of the OASMP, resigned his post as director of the Galveston Geophysics Laboratory. In January of 1981 Cliff Frohlich was named as principal investigator of the OASMP; however, shortly thereafter Paul Donoho became the principal investigator.

The October 1980 deployments were among the more successful deployments of the entire OASMP. Five of the seven SM-OBS instruments were recovered in the summer of 1981 as planned, one released prematurely and one more was found later on the shores of the Alaskan Peninsula. In contrast, the deployments in the Fall of 1981 were among the most disappointing in the program. Seven instruments were deployed, two returned prematurely, and only one instrument was recovered as planned.

History - 1982 to Present

The participants' agreement of the OASMP promised that the administrator would distribute a final technical report to the industrial participants within 90 days of 30 August, 1982. However, Paul Donoho, the principal investigator of the OASMP, resigned his position at UT in November, 1982. Arther Maxwell, the director of the UT Institute for Geophysics, became the new principal investigator.

At this time, Maxwell asked the authors of the present report to finish analysis of the SM-OBS data and to prepare a final report. This was not a trivial task as none of the data recorded by the SM-OBS instruments had been transferred from the original recording cartridges to any readily accessible medium. This is not to say that this task had been neglected, but simply indicates that other tasks of higher priority, especially the instrumentation, were so formidable. The remainder of this report very briefly describes the instrument and summarizes the results of our analysis of the data, and Appendix IC is a visual presentation of all the data recorded. A 9-track tape with these data in SEG Y format accompanies this report and has been sent to all the industrial participants.

INSTRUMENTATION

We attempt in this section to describe the instrument developed during this program. The description, however, cannot be in detail because neither of the authors of this report was involved in the instrumental development. Certain detailed descriptions of the earlier models, however, have been given by Steinmetz et al. (1979; 1981).

Figure 2, taken from Steinmetz et al. (1979), shows a schematic diagram of the instrument. A triaxial sensor consisting of three 10 Hz geophones senses the ocean-bottom ground motion. Each of the sensor outputs, which is proportional to ground velocity for frequencies above 10 Hz but is proportional to the time derivative of ground acceleration below 10 Hz, is then integrated through a 0.1 Hz, single-pole low-pass filter, giving an output proportional to ground acceleration between 0.1 ahd 10 Hz. Appendix IA gives the precise response.

Each of the output signals is amplified in a binary-gain-ranging amplifier and digitized at a sampling interval of 7.344 msec. The overall sensitivity is approximately 70 DU/(cm/sec^2) (DU = digital unit) at the highest gain. With the gain ranging which permits a dynamic range of over 96 db, acceleration up to 1.0 g can be faithfully detected. The three digitized outputs are then multiplexed and stored continuously in a buffer memory. Up to 120 seconds of data can be stored in the memory at any given time. At the same time, the changes in the signal level are continuously monitored. When these changes satisfy a certain set of predetermined criteria, the data in the buffer memory are transferred onto a tape. These processes are controlled by three microprocessors.

The entire sensor and electronic systems are contained in a 17-inch glass sphere, which fits snugly into a molded plastic cap. The sphere, its contents, the plastic bottom cap and two radio beacons constitute

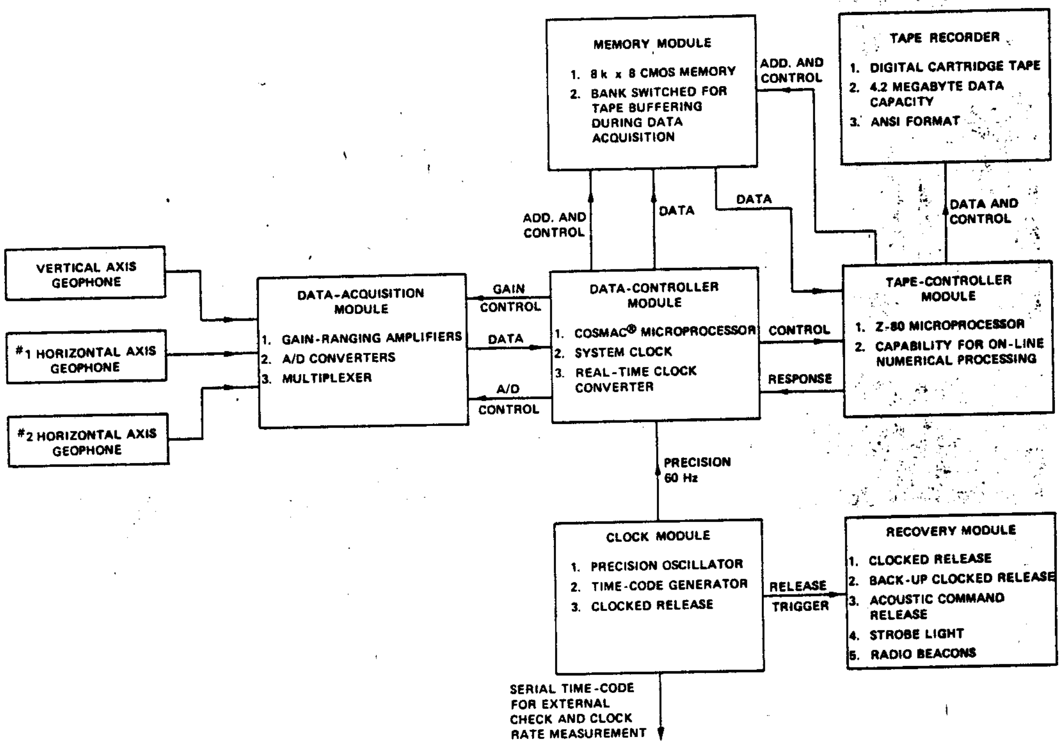


Fig. 2. Schematic of the electronics package.
(from Steinmetz et al., 1979)

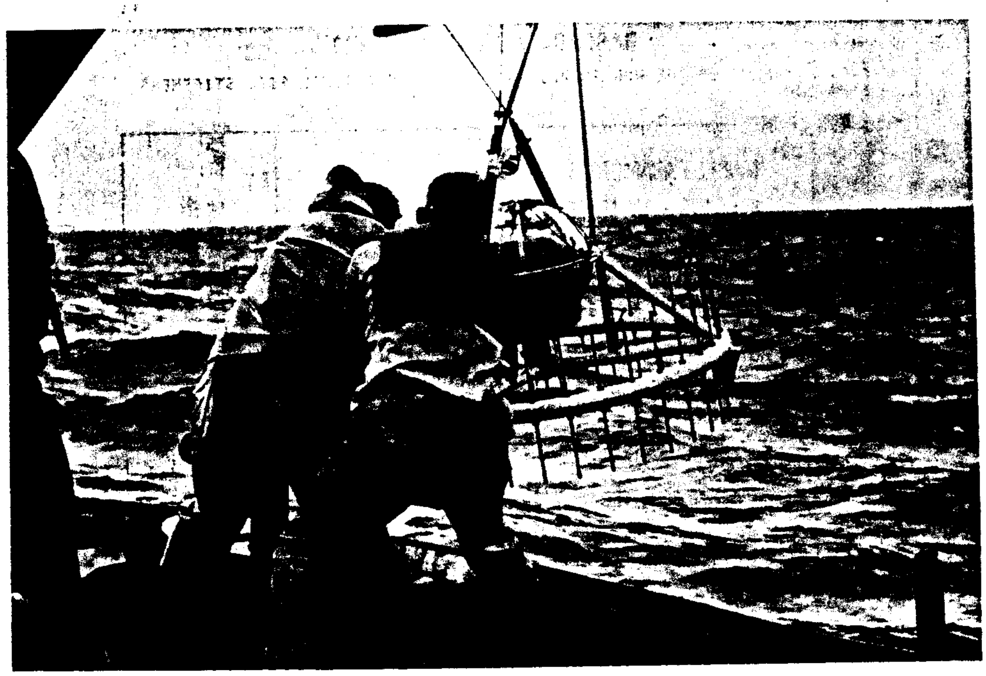


Fig. 3 - Deployment of the SM-OBS system offshore Kodiak Island, Alaska.
(from Steinmetz et al., 1979)

the recovery capsule, the part that is recovered after data collection. On deployment, the recovery capsule is firmly attached to a circular steel frame footing by three stiff elastic straps (Figure 3). Considerable effort had been made to ensure good coupling of the instrument to the ocean floor, as described in detail by Steinmetz et al. (1979; 1981). The release of the recovery capsule from the steel frame is controlled by three subsystems: the acoustic transponder, the main-clock preprogrammed release and the backup-clock preset release. these redundant systems assure successful recovery of the instrument even when two of the three fail for some reason.

RESULTS

The primary data for the OASMP are the records obtained by the SM-OBS instruments deployed in Alaska in deployments 16 to 33, which took place during the 1980-82 period. We have analysed the cartridge records from the twelve SM-OBS instruments which were recovered. This section is a summary of the results of our analysis. In Appendix IB we have listed the information contained in the header records for all SM-OBS data which met the following criteria:

- Whenever three consecutive 16-bit data words are made up of two samples of valid horizontal-component data and a sample of valid vertical-component data as indicated by the presence or absence of the vertical-component flag bit, we accept this 48-bit string of data as a valid string of multiplexed three-component data.

- When a given five-second block of data contains at least 646 (95 per cent) such valid strings out of a possible maximum of 680 sets per block, i. e., when the block contains 95 per cent or more valid data strings, we accept this five-second block of data as valid data.

- If a block of data fails the above test, we shift the entire block by a byte (eight bits) and repeat the test. If it then meets the test, we accept the block as valid data.

In Appendix IC we have also presented each five second record segment in graph form, normalized so that the maximum amplitude of each record is the same. In the remainder of this report, a **block** will refer to a single five-second piece of demultiplexed data from one component of the SM-OBS. Each block is made up of 680 digital samples. An **event segment** is three blocks recorded simultaneously with the first and second block representing data from horizontal seismometers and the third block representing data from the vertical seismometer. An **event group** is two or more adjacent event segments which appear to have been recorded with no time break between adjacent event segments.

Unfortunately, none of the twelve instruments recovered operated exactly as intended, i. e., some recorded only a few event segments, and some recorded "events" with improper block lengths or which were clearly not faithfully representing the output of the seismometers. In addition, all instruments had difficulty in recording the proper times of events, e. g., many "times" consisted of non-digital characters. For this reason, before describing the records of each instrument we include a summary of the results obtained. This summary includes the number of event segments which meet the criteria listed above and the number of "plausible" event times, i. e., those recorded times which were not unrealistic or which we felt we might be able to reconstruct from the recorded time information. Finally, the summary includes the number of event groups which appear similar to earthquake seismograms.

Deployment_16:_21_July_to_1_October,_1980,_Station_3

Summary: 17 event segments recorded; 2 plausible event times; 0 apparent earthquake sequences

Several features of the data suggest that the instrument malfunctioned. Seven of the 17 event segments are identical to one another. None of the events appear to be earthquakes or even to resemble the usual types of background noises observed on seismographs. Two of the event segment times are possibly correct: the headers for events 16001 and 16016 show they occurred on day 202, which corresponds to 20 July, 1980. However, for some reason the hour recorded for event 16016 is earlier than the hour for event 16001.

Deployment_17_-_21_July_to_2_October,_1980,_Station_5

Summary: 363 event segments recorded; 0 possible event times; 2 apparent earthquake sequences

This instrument did record some earthquake-like motions. Two events, beginning at segments 17176 and 17358, appear to be earthquakes, and many of the remaining events are likely to be various types of real ocean bottom signals. Some are similar in character to what might be produced by the passage of nearby ships. One event, beginning at segment 17166 (see Figure 4), looks like one of the possible biological signals described by Buskirk et al (1981; see also Appendix II).

The presumed earthquake events beginning at segments 17176 and 17358 (see Figures 5A and 5B) are quite similar in character. Both have

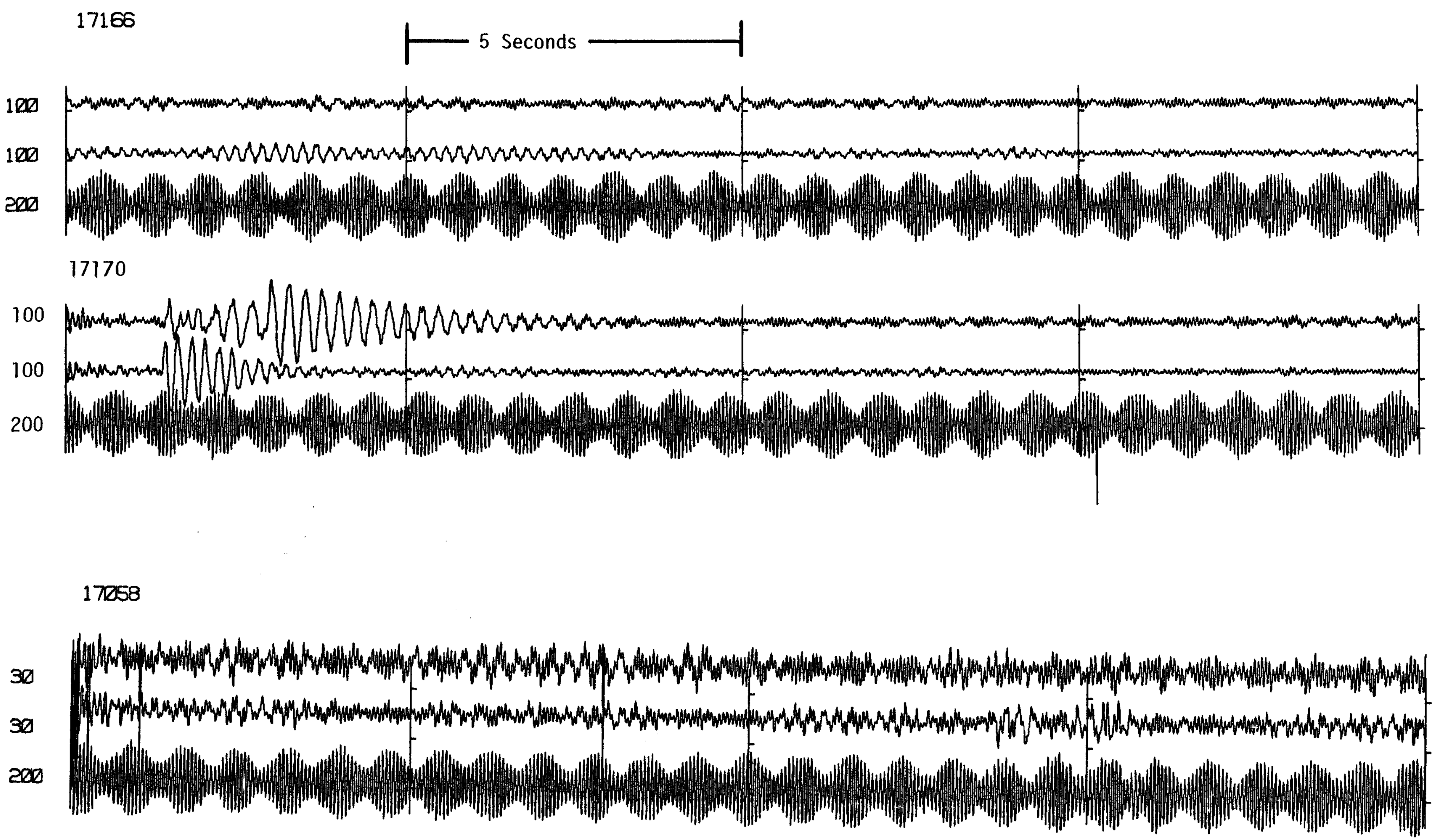
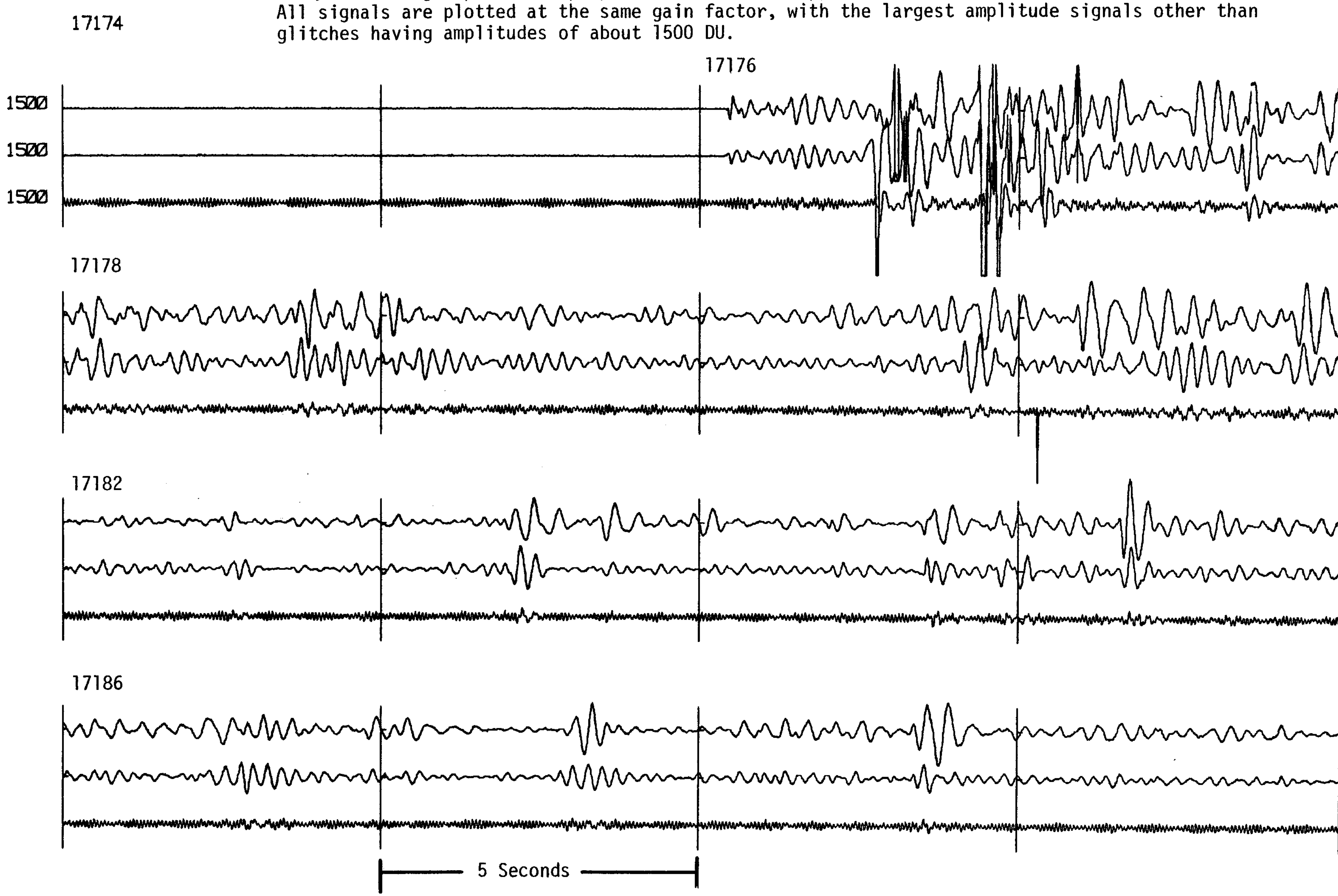


FIGURE 4: Records from deployment 17, which appear to be recorded in groups of four event segments. Event groups beginning with 17166 and 17058 are typical for deployment 17. Note the pronounced high frequency ringing on the third (vertical) component. The event group beginning at 17170 contains a signal similar in character to those that Buskirk et al. (1981) suggested were biological in origin.

FIGURE 5A: Event groups from deployment 17 which are apparently signals produced by earthquakes. All signals are plotted at the same gain factor, with the largest amplitude signals other than glitches having amplitudes of about 1500 DU.



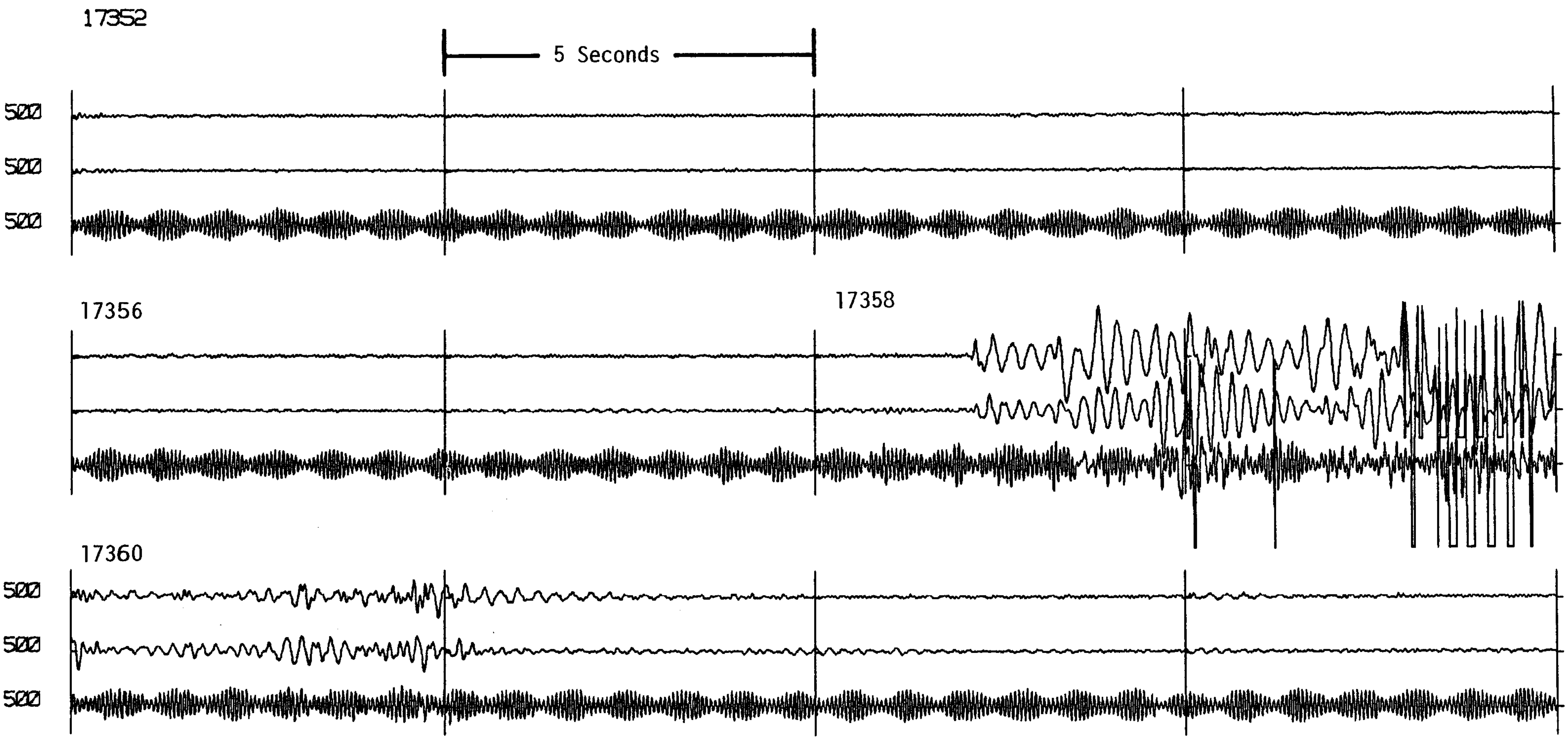


FIGURE 5B: Event groups from deployment 17 which are apparently produced by earthquakes. All signals are plotted at the same gain factor, with the largest amplitude signals other than glitches having amplitudes of about 700 DU.

fairly impulsive onsets, both begin on the third segment of a four segment contiguous group, both possess glitches in the first eight seconds of the record before the gap of unknown length at the end of the four segment group, and both are followed by additional four segment groups which appear to be earthquake-generated. The maximum level for the event beginning at 17176 is about 1500 DU, which corresponds to slightly more than 20 cm/sec^2, or 0.02 g. It occurs at a frequency of approximately 4 Hz. The level for the event beginning at 17358 is about half as large.

Unfortunately the event times were not properly recorded and it is difficult to decide which of the events in Table 2 might be represented in these seismograms. Three of the events which occurred within 600 km and which are within a one-month period following deployment 17 had magnitudes larger than 5.0; these are the events of 1 August 1980 at 2307, 12 August 1980 at 1444, and 23 August 1980 at 0045. Although the epicenters of all these events were more than 350 km from deployment 17, any of them might have produced the observed seismograms as could several other reported events. The only event that occurred nearby to deployment 17 is the event of 6 October 1980, which had a magnitude of 4.6 and a distance of about 40 km. One difficulty with this identification is the frequency content of the detected signal. If proper instrument-ocean bottom coupling was achieved an event at such close distances would be expected to contain more energy at frequencies above 5-10 Hz than is observed on any of these seismograms.

The third (vertical-component) trace on nearly all of the events

TABLE 2: Earthquakes occurring during deployment 17 which were recorded by the National Earthquake Information Service (NEIS) and which occurred within 600 km of the deployment site.

DATE	TIME (GMT)	DEPTH (km)	LATITUDE	LONGITUDE	MAGNITUDE M_b	M_s	DISTANCE FROM 17 (km)
1980 722	22 45 41.7	96	59.756	-152.641	0.00	0.0	338.5
1980 723	23 7 20.7	87	59.448	-152.084	0.00	0.0	304.9
1980 724	19 1 55.0	133	61.511	-152.154	0.00	0.0	533.8
1980 726	13 15 53.4	33	61.029	-147.606	0.00	0.0	554.5
1980 730	4 12 32.3	73	61.253	-150.933	3.70	0.0	512.2
1980 731	11 59 21.3	94	59.386	-152.312	3.70	0.0	297.3
1980 8 1	4 5 38.5	118	59.908	-152.721	0.00	0.0	355.6
1980 8 1	14 39 14.0	121	60.181	-153.147	0.00	0.0	387.7
1980 8 1	23 7 14.7	26	59.617	-148.937	5.40	5.1	382.9
1980 8 2	15 40 29.2	33	59.896	-149.181	0.00	0.0	402.1
1980 8 4	17 31 0.8	96	61.087	-151.870	3.80	0.0	487.5
1980 8 6	9 16 18.9	122	60.148	-152.654	0.00	0.0	382.1
1980 8 9	23 24 39.6	66	58.096	-153.637	4.20	0.0	169.4
1980 811	20 25 45.0	125	59.588	-152.811	0.00	0.0	320.4
1980 812	14 44 28.5	110	59.980	-152.845	5.00	0.0	364.0
1980 812	22 38 44.9	33	58.254	-148.434	0.00	0.0	294.8
1980 813	3 52 55.8	53	59.253	-151.778	4.00	0.0	285.2
1980 820	10 14 48.4	87	60.662	-151.624	3.70	0.0	441.7
1980 822	0 43 48.7	128	61.600	-152.350	4.30	0.0	543.4
1980 823	0 45 54.8	38	55.030	-160.399	5.30	4.4	529.7
1980 823	3 51 0.5	33	59.996	-149.583	0.00	0.0	401.5
1980 824	0 40 52.2	53	55.466	-159.083	4.40	0.0	434.0
1980 824	6 31 34.6	139	60.138	-153.224	0.00	0.0	383.5
1980 824	11 0 37.1	66	60.422	-147.481	0.00	0.0	502.8
1980 825	13 38 24.4	33	59.947	-152.534	4.80	0.0	359.6
1980 830	0 18 21.1	81	59.522	-152.840	4.50	0.0	313.2
1980 9 1	19 46 41.2	33	59.374	-154.805	4.30	0.0	326.7
1980 9 5	5 46 13.0	153	60.160	-153.214	4.00	0.0	385.9
1980 9 5	8 43 27.1	117	61.042	-152.413	0.00	0.0	481.4
1980 9 9	8 25 10.4	33	61.012	-150.905	3.60	0.0	486.2
1980 911	21 25 3.0	33	60.796	-145.934	0.00	0.0	588.8
1980 913	7 24 12.2	100	59.838	-152.249	4.30	0.0	347.7
1980 914	10 10 14.0	33	57.660	-154.894	0.00	0.0	181.0
1980 914	20 14 32.6	31	59.297	-146.457	0.00	0.0	454.9
1980 915	12 34 29.1	69	61.855	-149.972	0.00	0.0	588.7
1980 915	17 7 46.7	125	60.139	-152.860	0.00	0.0	381.7
1980 921	21 0 17.3	130	60.095	-152.932	4.20	0.0	377.1
1980 921	23 47 16.0	83	62.041	-151.451	4.40	0.0	595.1
1980 923	6 14 1.9	89	61.847	-151.049	0.00	0.0	576.4
1980 925	8 7 44.8	52	61.409	-149.962	0.00	0.0	541.1
1980 928	9 10 28.9	33	60.656	-150.695	0.00	0.0	450.0
198010 2	11 17 38.4	33	61.432	-150.065	0.00	0.0	542.0
198010 6	15 15 10.4	33	58.258	-150.067	4.50	0.0	223.1
198010 6	17 51 59.2	33	57.058	-152.716	4.70	0.0	41.6
19801011	12 59 25.5	130	60.261	-152.835	0.00	0.0	395.2
19801011	15 51 25.5	33	54.833	-151.423	4.70	0.0	218.7
19801015	9 20 12.9	24	55.674	-161.130	5.00	0.0	548.9

(e. g. see Figure 4) seemed to be dominated by a high frequency ringing with an amplitude of about 160 digital units (DU). A similar high frequency signal appears on the other two traces but at a much lower amplitude level. Because this ringing exhibits such pronounced beats and such a regular amplitude it seems unlikely that it is caused by mechanical resonance of the OBS frame. Data with a different character were visible on the third trace only when the level significantly exceeded 160 DU. A few of the event segments contain glitches with amplitudes exceeding 10^5 DU.

The apparent beat pattern recorded on the third trace is exceedingly regular in nature. It consists of a signal with amplitude of about 115 DU and a frequency of about 17.8 Hz superimposed on a signal of amplitude about 35 DU and a frequency of either 19.1 Hz or 16.5 Hz, producing beats at the difference frequency of about 1.3 Hz. The event segments occur in groups of four records which apparently cover 20 second uninterupted time intervals. The phase differences of the beat pattern between successive 20 second record groups suggests that successive groups of four records are separated by a regular but unknown time interval and successive groups of eight records are separated by another constant but unknown interval. Only one or possibly two breaks occur in this regular sequence of phase differences in the entire duration of the recorded data. If this interpretation is correct, then all the records from deployment 17 may have been recorded in only two or three time periods.

Deployment_18_-_21_July_to_2_October,_1980,_Station_8

Summary: 130 event segments recorded; 0 plausible event times; 0 apparent earthquake sequences

These data possess a variety of chatter, glitches, high frequency ringing, DC offsets, etc. We doubt the data are related in any simple way to ground motion, more likely the main features of the signal are entirely instrumental in origin.

Deployment_19_-_2_October_1980_to_31_May_1981,_Station_3

Summary: 10 event segments recorded; 4 plausible event times; 0 apparent earthquake sequences

Several of the blocks contain glitch offsets or a slow change in amplitude similar to those in deployment 16 data. The recorded date for event segments 19003, 19005 and 19009 is day 274, which corresponds to 30 September 1980, or two days before the instrument was deployed. Thus if this date is correct these events were probably test events recorded while the SM-OBS was still on board the deployment vessel. When the OBS was recovered, barnacles were found attached to the glass sphere, the plastic sphere container and the radio beacon.

Deployment_20_-_2_October_1980_to_31_May_1981,_Station_8

Summary: 64 event segments recorded; 63 plausible event times; 0 apparent earthquake sequences

Although some of the recorded event-times for deployment 20 were nondigital, the 10's digit for event day contained the sequence 8-9-A-B-C-D-E-F-0-1 etc., suggesting that we could recover the correct day by associating A with 10, B with 11, etc. If so, the first event segment on day 280 was recorded on 6 October 1980, 4 days after deployment, and the last event segment occurred on day 405, or 8 February 1981.

Unfortunately, the quality of the data was not good, and there are not signals with the appearance of earthquakes. Most records contained glitches or hash of various kinds. A few (e. g., 20012, 20020 and 20024) include some signals which strongly resemble signals of short duration seen in other OBS studies which Buskirk et al. (1981, see Appendix II) suggested were of biological origin. If so, these signals might be caused by creatures tapping on or bumping into the OBS sphere with the subsequent ringdown caused due to frame resonance effects.

Deployment_21_-_17_October_1980_to_31_May_1981,_Station_9

Summary: 34 event segments recorded; 18 plausible event times; 0 apparent earthquake sequences

Many of the records from this deployment are dominated by a sawtooth signal with a regular amplitude of about 100 DU and a regular frequency of 5.7 Hz on the x-component, 5.6 Hz on the y-component and 6.2 Hz on the vertical component. Other records contain large amplitude glitches or other signals of short duration with amplitudes exceeding 10^3 DU. None of these signals appear to be related to ground motion. All the plausible event dates are day 288, corresponding to 14 October

1980, three days prior to deployment. If these dates are correct they were probably test events recorded while the OBS was still on the deployment vessel.

When this instrument was recovered, several collections of some kind of "fish eggs" were attached to it. These had been deposited in round patches on the glass sphere, the plastic sphere container and on the radio beacons.

Deployment_22_-_17_October_1980_to_31_May_1981,_Station_10

Summary: 74 event segments recorded; 17 possible event times; 0 apparent earthquake sequences

The event segments recorded on deployment 22 are quite similar in character to the sawtooth signals already mentioned in deployment 21. Occasionally the sawtooth signals are superimposed on large excursions.

The event segments at the beginning are recorded on day 296, or 22 October 1980, several days after deployment. However, event segments recorded later in the sequence are on day 288 or 14 October 1980, which is prior to deployment.

Deployment_23_-_16_October_1980_to_4_June_1981,_Station_11

Summary: 558 event segments recorded; numerous plausible event times; 1 or 2 apparent earthquake sequences

In terms of technical performance, this was probably the most successful of all the SM-OBS deployments. Data were recorded on all four tracks of the cartridge tape, and the visual appearance of nearly all the event segments looks somewhat like OBS data recorded in other experiments. Many of the segments (e. g., 23245 and 23214) are typical specimens of the possible biological events (see Appendix II). The appearance of most of the other event segments is such that it is quite plausible that they represent ocean bottom disturbances of various kinds which are faithfully recorded by the seismometer system. None of the events appear to be an entire earthquake sequence, although one event segment, 23475 (see Figure 6), has the appearance of the coda of an earthquake signal. A number of event segments on this deployment and other deployments having times of 0000 GMT and occurring on days with day numbers divisible by five are not triggered events, but noise signals recorded at regular five-day intervals.

Although many of the recorded event dates possess non-digital characters, we can recover most of the event dates by assuming that non-digital characters represent hexadecimal numbers, and that no carryover occurs from 10's digit to 100's digit. With this interpretation, we find that the SM-OBS still was triggering on events of some kind in January 1981, several months after deployment.

On 4 June 1981 after this instrument was recovered, the hour, minute and second on the OBS clock differed from the real time by only about 45 seconds. However, the date supplied by the clock at this time was 200, and on 5 June 1981 it was 201. We note that there is a discrepancy of exactly one day between the dates determined from our algorithm and those observed upon recovery of the OBS. In particular,

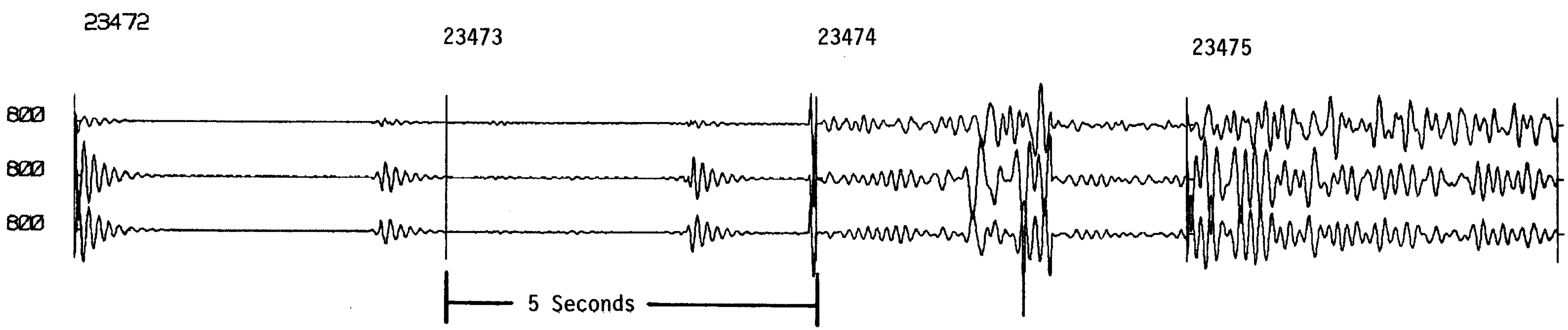


FIGURE 6: Event segments recorded during deployment 23. Earthquakes reported by the National Earthquake Information Service at distances of about 90 km and 180 km from the OBS occurred at the times reported in the headers for event segments 23473 and 23474 (see text). Event segment 23475 more closely resembles typical earthquake coda signals than does any other signal recorded during deployment 23.

our algorithm predicts that 4 June 1981 would correspond to day 201 on the OBS clock, whereas in fact on 4 June 1981 the OBS clock showed day 200. We suspect that the technician who deployed the OBS simply forgot that 1980 was a leap year.

The event times for two event segments, 23473 and 23474, correspond to the times of relatively large nearby earthquakes. In particular, on day 2D2, which our algorithm assigns to 27 November 1980, earthquakes are observed at 0218 and 0637 (see Appendix IB and Figure 6). The National Earthquake Information Service (NEIS) reports earthquakes at 0218 and 0637 on 28 November, 1980. These earthquakes had magnitudes of 4.9 and 5.0 and occurred at distances of about 180 and 90 km from the instrument of deployment 23 (Table 3). It seems highly unlikely that this is a coincidence, particularly since the next recorded event segment, 23475, is the signal which most resembles the coda of an earthquake.

We suspect that the data in event 23475 is associated with one of the two earthquakes mentioned even though the recorded date is different. The software which records dates and events performs these operations at different points in the program sequence, and thus it is possible that the wrong date could be associated with a particular event segment.

The amplitude of event segment 23475 was about 800 DU, which corresponds to ground accelerations of 0.012 g (11 cm/sec^2). None of the other event times recorded by this instrument (Appendix IIB) correspond to the times of events reported by the NEIS (Table 3), and

TABLE 3: Earthquakes occurring during deployment 23 which were recorded by the National Earthquake Information Service (NEIS) and which occurred within 600 km of the deployment site.

DATE	TIME	DEPTH (km)	LATITUDE	LONGITUDE	MAGNITUDE M_b	M_s	DISTANCE FROM 23 (km)
19801016	12 46 20.5	10	55.297	-159.391	4.50	0.0	310.8
19801025	17 16 41.5	33	55.587	-156.913	4.90	0.0	469.4
19801026	22 33 50.7	43	52.486	-169.534	4.80	0.0	422.7
19801030	20 53 9.4	125	57.343	-158.081	4.70	0.0	500.4
19801128	2 18 31.8	33	52.782	-162.735	4.90	0.0	178.0
19801128	6 37 15.3	33	53.408	-163.948	5.00	0.0	91.9
19801129	10 18 54.0	99	53.210	-169.737	4.50	0.0	402.1
1981 112	0 39 29.5	20	54.440	-160.253	4.50	0.0	235.8
1981 112	16 33 23.9	15	52.833	-166.793	5.00	4.6	247.9
1981 112	21 1 25.2	33	52.101	-166.544	4.20	0.0	296.4
1981 114	10 17 27.8	33	52.978	-169.050	4.50	0.0	368.9
1981 114	15 6 43.8	21	52.082	-169.498	4.80	4.5	444.6
1981 118	12 35 5.6	47	55.175	-159.943	4.80	0.0	273.3
1981 119	4 16 30.2	33	54.822	-157.013	4.70	0.0	447.3
1981 129	6 11 5.9	33	53.479	-164.322	4.60	0.0	88.8
1981 2 4	4 42 55.2	33	52.832	-163.510	4.80	0.0	157.6
1981 3 8	0 42 36.8	48	53.797	-164.168	4.40	0.0	52.1
1981 315	7 48 29.2	41	55.581	-160.834	4.80	0.0	245.3
1981 324	18 18 5.0	33	52.413	-167.796	4.50	0.0	329.8
1981 324	18 21 27.9	33	52.673	-168.037	5.50	5.3	325.7
1981 4 4	15 21 4.2	16	53.717	-163.057	4.80	0.0	78.3
1981 411	23 28 25.6	33	52.845	-169.789	4.20	0.0	420.1
1981 414	16 0 42.2	38	52.227	-169.412	4.60	0.0	430.7
1981 427	23 59 46.5	33	52.328	-168.501	4.70	0.0	373.4
1981 430	2 52 13.5	33	53.314	-167.485	4.10	0.0	258.4
1981 510	22 52 43.6	202	56.227	-161.463	4.30	0.0	269.2
1981 517	9 0 2.5	35	53.679	-163.804	4.40	0.0	61.7

none of the other event segments strongly resemble typical earthquake signals as they are usually observed on terrestrial instruments.

Incidently, the instrument of deployment 23 was situated within a few km of Unimak Pass, an area of considerable activity for ship traffic as well as for commercial fishing. Thus it is possible that some of the recorded event segments (e. g., 23472) were stimulated by this activity. However, many of the signals more strongly resemble the supposed biological activity (see Appendix II). Many of the event segments were recorded more than once, with some event segments being recorded as many as five times and one group being recorded eight times (e. g. see 23246-50, 23258-65, 23319-23 and 23391-95).

Deployment_25_-_October_1980,_then_found_on_beach_in__October__1981, Station_13

Summary: 91 event segments recorded; 0 plausible event times; 0 apparent earthquake sequences

Nearly all of these records seem to be dominated by the regular sawtooth 5.6-6.2 Hz signal with amplitude of about 100 DU that was described for deployments 21 and 22. However, on many of the records this signal seems to be recorded along with a different signal as well, often on every other block (e. g., see 25007), giving the signal an uneven character. A few signals also possess the glitches or excursions similar to those observed on several other stations.

Deployment_29_-_16_September_1981_to_9_July_1982,_Station_11

Summary: no data recorded

Deployment_31_-_30_September_1981_to_22_August_1983,_Station_16

Summary: no data recorded

This instrument was found in the net of a pair trawler fishing for the Japanese mother ship **Hoyo Maru**. It was sent to UTIG by Ky Ostergaard, a biological oceanographer stationed on the **Hoyo Maru**. Although the instrument had been on the ocean floor nearly two years, the cassette tape and electronics package were in excellent condition when it was returned to UTIG. However, the cassette tape was detached from the takeup reel, as if it had rewound too far. Subsequent laboratory tests showed that the instrument had failed to surface because there was a defective relay in the release system. Otherwise, the instrument still functioned properly.

Deployment_32_-_30_September_1981_to_8_October_1981,_Station_17

Summary: 21 event segments recorded; 0 plausible event times; 0 apparent earthquake sequences

All the data from this deployment are or poor quality. There is obviously some kind of problem getting data onto the tape.

Deployment_33_-_1_October_1981_to_March_1982,_Station_18

Summary: no data recorded

DISCUSSION

Achievements_of_the_Program

Perhaps the most important achievement of the OASMP has been the development of the SM-OBS instrument itself. Although the Texas OBS is probably the lightest weight OBS available, it is also relatively quite sophisticated, flexible, inexpensive and easy to deploy. It is digital, has large dynamic range, and it is programmable for either short-term or long-term deployments. With only minor changes it has been used successfully on a number of refraction studies. Virtually all the credit for the design and development of electronics for this instrument should go to Paul Donoho. Scientists currently at UT are using an improved instrument very similar in basic design to the SM-OBS for refraction studies. Although the SM-OBS instrument was not intended specifically for refraction, it can be programmed for refraction applications and is appropriate if a few changes in hardware are made. The short-term deployments typical in refraction experiments seem to avoid some of the problems that have occurred in the longer SM deployments. Although the development of a viable refraction instrument was not an explicitly stated objective of the OASMP, it is clear that the program contributed positively to this development.

Several research projects directly and indirectly related to the OASMP were successful enough to lead to publications in scholarly journals. In addition to the papers by Steinmetz et al. (1979; 1981) which were directly concerned with the SM-OBS program, studies by Lawton et al. (1982), Frohlich et al. (1980; 1982) Chen et al. (1982) and Frohlich and Donoho (1982) provided information about systematic problems with the detection and location of earthquakes in Alaska. Finally, Buskirk et al. (1981) completed a study of the character and origins of noise affecting OBS instruments (Appendix II). We have included as Appendix III a complete list of publications resulting from research incorporating data observed with the Texas OBS.

In a limited sense, the tasks outlined in the OASMP were completed. That is, between 1980 and summer 1982 there were 18 SM-OBS deployments offshore of Alaska. Twelve of these instruments were ultimately recovered, and ten recorded at least some "usable" event segments. Indeed, altogether there were more than 1300 5-second records (Appendix I). As many as eight SM-OBS were deployed simulataneously in 1981-82. For the 1980-81 deployment five of the instruments were recovered after being on the ocean floor about 240 days. Four of these instruments were recalled by transmitting a coded acoustic signal to the instruments. The fifth (deployment 23) was released to the surface at a prearranged time after more than 230 days. We are unaware of any other OBS instruments which have been recovered successfully after deployments of this duration.

Finally, two of the instruments deployed in the OASMP actually recorded earthquake signls. The clearest earthquake signals were recorded during deployment 17 in the summer of 1980 (Figure 5). Unfortunately, because the time information was not recorded properly, we have been unable to unequivocally identify the event or events which appear in Figure 5 although several earthquakes which are likely candidates are known to have occurred during the period of deployment

(Table 2). During deployment 23 in the 1980-81 period, two earthquakes of magnitude about 5 at distances of about 90 and 180 km triggered the instrument. All these events produced ground accelerations of about 0.01 g to 0.02 (10 cm/sec^2 to 20 cm/sec^2).

These accelerations are significantly larger than would be calculated from typical formulas relating ground motion to earthquake magnitude. For example, Richter (1958) notes that a Wood-Anderson seismograph with a static magnification of 2800 would record 1.0 mm of motion from a magnitude 3 earthquake at a distance of 100 km. This corresponds to 100 cm of recorded motion from a magnitude 5 earthquake such as the event of 28 November 1980 recorded on deployment 23, or a ground motion of 100 cm/2800 or .0036 cm. At a frequency of about 4 Hz as observed for our data, this would correspond to accelerations of 2.2 cm/sec^2. This is about an order of magnitude smaller than measured by the SM-OBS instruments. For a normal terrestrial observer the observed acceleration of 10-20 cm/sec^2 corresponds to a Modified Mercalli intensity of about V (Richter, 1958), which is strong enough to wake sleeping people and to displace unstable objects. These accelerations observed by the instruments in the OASMP are uniformly higher than predicted by standard terrestrial formulas.

Shortcomings_of_the_Program

By far the most significant shortcoming of the program was its inability to obtain high quality recordings of strong ground motion attributable to earthquake activity. This was partly because there were few large earthquakes in this region during the 1980-1982 period.

Although an event with M_b = 6.1 did occur on 25 January 1982 (53.222° N, 165.719° W, 60 km reported depth, felt at Cold Bay, Dutch Harbor and Unalaska), no other earthquakes with M_b larger than 5.5 occurred between July 1980 and July 1982. It was not unexpected that few large events might occur. The original participants' agreement noted that it might take longer than a two year period to obtain SM measurements.

A second shortcoming was that because of other, more pressing tasks most of the data from the 1980 and 1980-81 deployments was not put into a readily readable form until 1983. For this reason, the fact that identifiable earthquakes were actually recorded in the 1980 and 1980-81 deployments was not discovered until May 1983, although a temporary playback of the latter-period data showed some signals resembling earthquake records. If sufficient time were available to perform a more thorough analysis of the data obtained on each deployment, some of the recurring problems might have been prevented on subsequent deployments.

Reasons for the Shortcomings

We can identify several reasons why the OASMP was not more successful. First, the 1980-82 contract period was an era of administrative confusion for geophysics at UT. After Latham resigned in 1980, Paul Donoho and Jim Dorman quickly became involved in the day-to-day administration of the Galveston Geophysics Laboratory. In 1981 Donoho was forced to take over even more responsibility when Dorman resigned and when the Galveston laboratory was disassociated from the Marine Science Institute. After Donoho resigned in 1982, not a single scientist remained at UT who had been involved with OBS research when the field program for the SM-OBS work began in 1978.

The preload system described by Steinmetz et al. (1979; 1981) and used on some of the deployments ultimately may have contributed to some of the SM-OBS problems. This system employed a weighted collar which was attached to the SM-OBS before deployment. This caused the instrument to fall more quickly to the ocean bottom and at impact drove metal spikes into the ocean bottom. The weighted collar was then removed, leaving the instrument firmly coupled to the ocean bottom by the metal spikes. There were two problems with this system. First, the instrument was designed for clayey bottom sediments and did not always withstand the high impact collision with the ocean floor on rocky or sandy bottom surfaces. This may have been responsible for some of the non-returned instruments, particularly for the Bering Sea deployments. Second, on sandy bottoms the spikes did not always penetrate fully, and thus the instrument was not well coupled to the ocean floor. Because of these problems, the weighted collar described by Steinmetz et al. (1980) was not used during the 1980-81 deployments.

Suggestions_for_SM-OBS_Design

The technical problems associated with obtaining SM-OBS data are difficult ones, and this fact should be kept in mind during any evaluation of the OASMP. The history of OBS research is filled with numerous examples of highly expensive and carefully engineered programs which result in a high proportion of failures.

The OBS problem is difficult because in fact there are three quite different technical problems which must be solved:

- Problem 1: One must design a self-contained seismograph unit complete with power, timing, triggering and data storage.
- Problem 2: This unit must operate underwater, occasionally at considerable depths under high pressures and low temperatures.
- Problem 3: One must be able to recover this unit from the ocean floor

For a SM-OBS, the first problem is compounded because the instrument must operate for long time periods, which is accomplished most easily if it has low power consumption requirements. The record with the Texas SM-OBS system indicates that Problems 2 and 3 were solved effectively. In particular, five SM-OBS instruments were recovered in good condition and as planned in Alaskan waters after about 240 days on the ocean bottom in 1980-1981. This is a significant achievement as OBS systems at other institutions fail most often because of difficulties with Problems 2 and 3. However, this statement is difficult to document since OBS scientists seldom publish statistics concerning the rates or causes of their failures.

Although the record of the Texas SM-OBS is somewhat disappointing, we would recommend that most of the features of the instrument be incorporated into the design of future instruments. In particular, some of the basic design decisions that must be made when building an OBS address the following areas:

1. System weight - The Texas OBS system is the lightest weight of any OBS currently in use. This reduces construction and shipping expenses. However, the most important result is

that the instrument can be deployed or recovered from ships of any size without using cranes. The ability to deploy and recover without cranes is particularly useful during high sea states.

2. Electronics - Digital electronics allows gathering of data amplitudes over a larger dynamic range than is possible with analog recording. In addition, one has the option of utilizing more sophisticated algorithms for discriminating data from noise. However it was problems with the electronics hardware and software which ultimately caused the poor performance of the SM-OBS system in the OASMP.

3. Triggered or continuous operation - For long deployments as is required to obtain SM measurements, triggered recording is a necessity.

4. Pressure vessel - The available glass spheres provide a better strength-to-weight ratio than do other materials. The strength seems to be adequate as Texas OBS have been recovered from depths exceeding 7000 meters (Frohlich et al., 1982). However, spheres restrict the long-term development options for a system more than do metallic cylinders, as it is necessary to completely retool if a larger sphere is used.

5. Recovery system - The Texas OBS used a coded acoustic transponder (backed up by two independent internal clocks) to trigger a circuit which electrolytically dissolved a stainless steel wire, releasing the pressure vessel from a disposable anchor. We had few problems that can be attributed to this system, and recommend it highly.

We would also recommend that any future SM-OBS designer consider carefully the appropriate way to couple the seismometer package to the ocean floor. Quite extensive theoretical and experimental work involving many trials and testing preceeded the present program to ensure good coupling of the instrument to the ocean floor (Steinmetz et al., 1979; 1981). Despite these efforts, problems appear to remain.

Since the Texas SM-OBS was designed, there has been considerable research concerning the response of OBS-sediment systems to ocean bottom motion. Analysis of an extensive series of experiments on several different OBS instruments operated at Lopez Island, Washington, has been published by the University of Hawaii (Sutton et al., 1980), and also reprinted in the journal **Marine Geophysical Researches** (Sutton et al., 1981). Generally, these experiments show that improved performance may be obtained by instruments with a broad base and a low center of mass to minimize the "inverted pendulum" effects which may occur with instruments similar to the Texas design. An alternative design strategy is to place the seismometer in a separate package from the main recording package, and to insure that the density of the seismometer package is nearly equal to the density of the sediments on which it rests.

Suggestions_for_SM-OBS_Deployment

There exists indirect evidence that the high level of fishing activity and other ship traffic in the offshore Alaska area has contributed to the failure of the OASMP. Scientists contemplating future SM-OBS research in this area should consider placing the instrumentation in deeper water or in regions where ship traffic is rare. Several individuals familiar with the Alaskan fishing industry have suggested to us that unintentional interference from fishing trawlers probably contributed to the high failure rate for recovery of SM-OBS instruments. Some expressed surprise that we were able to recover any SM-OBS in the Bering Sea at all because trawling activity was particularly intense in this area, especially in the 1981-82 season. Trawling consists of dragging a large scoop with a width of 10 meters or more along the bottom behind a ship as it steams along in relatively shallow water. The scoop or "trawl" is attached to nets to catch fish as well as crabs or other bottom-dwelling creatures. A trawl which hits an OBS would be likely to destroy or disable it, and the vibration from trawls which passed within a few meters of the OBS would be likely to trigger the instrument. In any future shallow water OBS deployments in Alaskan waters it would be wise to deploy an anchored buoy system nearby similar to those used on crab pots. These highly visible floats and the area near them are generally respected by all fisherman, and trawlers give them a wide berth since they have no interest in fouling their own nets.

Deployment in deeper waters would be likely to reduce unwanted background signals of various kinds. Buskirk et al. (1981) also noted that short-duration non-seismic signals of apparent biological origin became significantly less common as water depth increased.

Need_for_SM-OBS_Measurements

The most disappointing aspect of the OASMP is that duration of the program was not sufficiently long to resolve the fundamental scientific questions that it was created to address. There are many reasons why it is still important to learn about strong motion caused by earthquakes in Alaska. The potential seismic risk in Alaska is as high as any place in the world and many times higher than in any other place in the United States. The 1964 Alaskan Good Friday earthquake (M_w = 9.2) was the second largest earthquake to occur in the world in this century, and earthquakes with magnitudes of 7.0 and greater occur regularly in Alaska. Several large tsunamis caused by earthquakes have occurred in the twentieth century. Since 1964 there has been enormous development in Alaska, both on land and offshore. The cost of a program such as the OASMP is only a small fraction of the cost of building a single offshore drilling and production structure. Clearly information about the effect of strong ground motion on such a structure would be of value. As noted previously, the SM-OBS measurements reported herein suggest that accelerations observed at offshore ocean bottom sites may be somewhat higher than predicted by standard formulas.

Unfortunately, during the 1978-1983 period there is evidence of a significant decline in concern about seismic risk in Alaska. By the end of this period, the NOAA-OCSEAP program had been dismantled, and several of the ships that had been used to deploy SM-OBS instruments had been laid up. Federal funding for this type of research has become difficult to obtain, and thus for a future SM-OBS project a large proportion of the support might have to come from industrial sources.

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APPENDIX IA: Seismometer Response for the SM-OBS

The canonical equation for the output S of a seismograph due to a signal with frequency f and velocity amplitude V is:

$$S = \frac{GR_s}{R_s+R_c} AF \frac{n^2}{((1-n^2)^2+4b^2n^2)^{1/2}} V$$

where: G = transduction constant = 0.6816 volts/(cm/sec) for the SM-OBS

A = amplifier gain, which equals 2048 for the SM-OBS

F = filter response, which equals f_f/f for all $f > f_f = 0.1$ Hz

$n = f/f_o$, where f_o is the fundamental frequency of the seismometer, 10 Hz

b = damping constant, which is 0.7 for the SM-OBS

R_s = shunt resistance = 5400 ohms for the SM-OBS

R_c = coil resistance = 1480 ohms for the SM-OBS

For strong motion analysis the response to accelerations is of more interest than to velocity. Since $\dot{V} = 2\pi fV$ or $V = \dot{V}/2\pi f_o n$ and since $F = f_f/f = (f_f/f_o)/n$ we have:

$$S = \frac{GR_s}{R_s+R_c} \frac{Af_f}{(2\pi f_o^2)((1-n^2)^2+4b^2n^2)^{1/2}} \dot{V} = \frac{0.1744 \text{ volts/(cm/sec}^2)}{((1-n^2)^2+2.8n^2)^{1/2}} \dot{V}$$

Since the denominator is approximately constant (unity) for $f \ll 10$ Hz, this is:

$$S \approx (0.1744 \text{ volts/(cm/sec}^2))\dot{V}$$

In the OASMP SM-OBS instrument, 1 DU = .0025 volts, and thus

$$S \approx (70 \text{ DU/(cm/sec}^2))\ \dot{V}$$

APPENDIX IB:

Catalog of Trace Header Information for all SM-OBS Records on the SEG Y Tape

This includes all records from 12 deployments. Each five-second event segment is recorded on three successive records with the third record being the vertical component data and the first two being horizontal components. In the header catalog listing:

columns 1 and 2 (bythes 1-4 and 5-8) - trace sequence number on the SEG Y tape for the first record in each event segment.

column 3 (bytes 9-12) - event segment identification number. The first two digits are the deployment number and the last three digits are the sequential event segment number for that deployment. Example: 17003 is the third event segment recorded during deployment 17.

columns 4-11 (bytes 181-196) - are header information taken directly from the cartridge tape.

column 9 is event day number

column 10 is event hour and minute

column 11 is event seconds, tenths of seconds and 60ths of seconds.

Example: 1243 is (12.4 +3/60) seconds.

TSN1	TSN2	FRNO	HEADER					DAY	HR-MIN	SEC
1	1	16001	0101	2810	FFFF	FFFF	FFFF	0202	2120	0554
4	4	16002	0002	FFFF	F5F7	FFFF	FFF7	F7F7	FFFF	FFF7
7	7	16003	0003	1C10	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF
10	10	16004	0003	1C10	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF
13	13	16005	0003	1C10	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF
16	16	16006	0003	1610	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF
19	19	16007	0101	1610	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF
22	22	16008	0101	1610	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF
25	25	16009	0101	1610	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF
28	28	16010	0101	1610	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF
31	31	16011	0101	1610	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF
34	34	16012	0101	1610	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF
37	37	16013	0101	1610	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF
40	40	16014	0101	6413	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF
43	43	16015	0003	6413	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF
46	46	16016	0101	2810	FFFF	FFFF	FFFF	0202	1831	4373
49	49	16017	0002	FFFF	F5F7	FFFF	FFF7	F7F7	FFFF	FFF7
52	52	17001	0101	CE1B	FFFF	0205	0000	0001	FFFF	FFFF
55	55	17002	0101	CE1B	FFFF	0205	0000	0001	FFFF	FFFF
58	58	17003	0101	CE1B	FFFF	0205	0000	0001	FFFF	FFFF
61	61	17004	0101	CE1B	FFFF	0205	0000	0001	FFFF	FFFF
64	64	17005	0101	CE1B	FFFF	0205	0000	0001	FFFF	FFFF
67	67	17006	0101	CE1B	FFFF	0205	0000	0001	FFFF	FFFF
70	70	17007	0101	CE1B	FFFF	0205	0000	0001	FFFF	FFFF
73	73	17008	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
76	76	17009	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
79	79	17010	0404	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
82	82	17011	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
85	85	17012	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
88	88	17013	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
91	91	17014	0005	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
94	94	17015	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
97	97	17016	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
100	100	17017	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
103	103	17018	0405	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
106	106	17019	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
109	109	17020	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
112	112	17021	21FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
115	115	17022	0006	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
118	118	17023	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
121	121	17024	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
124	124	17025	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
127	127	17026	0406	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
130	130	17027	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
133	133	17028	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
136	136	17029	F7FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
139	139	17030	0007	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
142	142	17031	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
145	145	17032	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
148	148	17033	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
151	151	17034	0407	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
154	154	17035	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
157	157	17036	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
160	160	17037	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
163	163	17038	0008	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
166	166	17039	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
169	169	17040	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
172	172	17041	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
175	175	17042	0408	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
178	178	17043	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF

181	181	17044	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
184	184	17045	31FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
187	187	17046	0009	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
190	190	17047	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
193	193	17048	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
196	196	17049	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
199	199	17050	0409	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
202	202	17051	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
205	205	17052	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
208	208	17053	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
211	211	17054	000A	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
214	214	17055	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
217	217	17056	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
220	220	17057	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
223	223	17058	040A	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
226	226	17059	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
229	229	17060	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
232	232	17061	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
235	235	17062	000B	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
238	238	17063	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
241	241	17064	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
244	244	17065	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
247	247	17066	040B	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
250	250	17067	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
253	253	17068	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
256	256	17069	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
259	259	17070	000C	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
262	262	17071	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
265	265	17072	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
268	268	17073	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
271	271	17074	040C	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
274	274	17075	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
277	277	17076	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
280	280	17077	31FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
283	283	17078	000D	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
286	286	17079	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
289	289	17080	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
292	292	17081	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
295	295	17082	040D	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
298	298	17083	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
301	301	17084	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
304	304	17085	31FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
307	307	17086	000E	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
310	310	17087	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
313	313	17088	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
316	316	17089	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
319	319	17090	040E	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
322	322	17091	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
325	325	17092	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
328	328	17093	21FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
331	331	17094	000F	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
334	334	17095	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
337	337	17096	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
340	340	17097	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
343	343	17098	040F	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
346	346	17099	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
349	349	17100	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
352	352	17101	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
355	355	17102	0010	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
358	358	17103	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
361	361	17104	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
364	364	17105	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
367	367	17106	0410	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF

370	370	17107	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
373	373	17108	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
376	376	17109	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
379	379	17110	0011	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
382	382	17111	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
385	385	17112	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
388	388	17113	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
391	391	17114	0411	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
394	394	17115	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
397	397	17116	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
400	400	17117	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
403	403	17118	0012	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
406	406	17119	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
409	409	17120	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
412	412	17121	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
415	415	17122	0412	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
418	418	17123	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
421	421	17124	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
424	424	17125	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
427	427	17126	0013	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
430	430	17127	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
433	433	17128	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
436	436	17129	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
439	439	17130	0413	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
442	442	17131	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
445	445	17132	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
448	448	17133	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
451	451	17134	0014	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
454	454	17135	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
457	457	17136	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
460	460	17137	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
463	463	17138	0414	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
466	466	17139	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
469	469	17140	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
472	472	17141	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
475	475	17142	0015	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
478	478	17143	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
481	481	17144	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
484	484	17145	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
487	487	17146	0415	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
490	490	17147	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
493	493	17148	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
496	496	17149	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
499	499	17150	0016	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
502	502	17151	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
505	505	17152	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
508	508	17153	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
511	511	17154	0416	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
514	514	17155	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
517	517	17156	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
520	520	17157	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
523	523	17158	0017	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
526	526	17159	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
529	529	17160	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
532	532	17161	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
535	535	17162	0417	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
538	538	17163	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
541	541	17164	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
544	544	17165	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
547	547	17166	0018	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
550	550	17167	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
553	553	17168	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
556	556	17169	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF

559	559	17170	0418	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
562	562	17171	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
565	565	17172	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
568	568	17173	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
571	571	17174	0019	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
574	574	17175	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
577	577	17176	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
580	580	17177	31FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
583	583	17178	0419	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
586	586	17179	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
589	589	17180	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
592	592	17181	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
595	595	17182	001A	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
598	598	17183	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
601	601	17184	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
604	604	17185	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
607	607	17186	041A	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
610	610	17187	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
613	613	17188	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
616	616	17189	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
619	619	17190	001B	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
622	622	17191	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
625	625	17192	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
628	628	17193	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
631	631	17194	041B	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
634	634	17195	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
637	637	17196	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
640	640	17197	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
643	643	17198	001C	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
646	646	17199	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
649	649	17200	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
652	652	17201	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
655	655	17202	041C	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
658	658	17203	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
661	661	17204	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
664	664	17205	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
667	667	17206	001D	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
670	670	17207	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
673	673	17208	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
676	676	17209	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
679	679	17210	041D	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
682	682	17211	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
685	685	17212	001E	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
688	688	17213	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
691	691	17214	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
694	694	17215	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
697	697	17216	041E	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
700	700	17217	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
703	703	17218	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
706	706	17219	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
709	709	17220	001F	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
712	712	17221	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
715	715	17222	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
718	718	17223	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
721	721	17224	041F	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
724	724	17225	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
727	727	17226	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
730	730	17227	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
733	733	17228	0020	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
736	736	17229	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
739	739	17230	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
742	742	17231	03FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
745	745	17232	0420	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF

748	748	17233	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
751	751	17234	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
754	754	17235	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
757	757	17236	0021	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
760	760	17237	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
763	763	17238	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
766	766	17239	03FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
769	769	17240	0421	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
772	772	17241	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
775	775	17242	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
778	778	17243	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
781	781	17244	0022	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
784	784	17245	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
787	787	17246	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
790	790	17247	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
793	793	17248	0422	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
796	796	17249	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
799	799	17250	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
802	802	17251	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
805	805	17252	0023	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
808	808	17253	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
811	811	17254	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
814	814	17255	31FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
817	817	17256	0423	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
820	820	17257	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
823	823	17258	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
826	826	17259	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
829	829	17260	0024	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
832	832	17261	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
835	835	17262	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
838	838	17263	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
841	841	17264	0424	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
844	844	17265	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
847	847	17266	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
850	850	17267	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
853	853	17268	0025	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
856	856	17269	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
859	859	17270	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
862	862	17271	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
865	865	17272	0425	A6EE	EEEE	EEEE	EEFF	BF01	FFFF	FFFF
868	868	17273	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
871	871	17274	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
874	874	17275	F3FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
877	877	17276	0026	A6EE	EEEE	EEEE	EEFF	BF01	FFFF	FFFF
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883	883	17278	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
886	886	17279	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
889	889	17280	0426	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
892	892	17281	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
895	895	17282	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
898	898	17283	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
901	901	17284	0027	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
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907	907	17286	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
910	910	17287	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
913	913	17288	0427	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
916	916	17289	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
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925	925	17292	0028	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
928	928	17293	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
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937	937	17296	0428	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
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946	946	17299	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
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952	952	17301	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
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958	958	17303	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
961	961	17304	0429	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
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967	967	17306	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
970	970	17307	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
973	973	17308	002A	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
976	976	17309	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
979	979	17310	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
982	982	17311	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
985	985	17312	042A	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
988	988	17313	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
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994	994	17315	07FF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
997	997	17316	002B	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
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1003	1003	17318	027F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
1006	1006	17319	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
1009	1009	17320	042B	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
1012	1012	17321	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
1015	1015	17322	067F	6DEE	EEEE	EEEE	EE77	7777	FF7F	7FFF
1018	1018	17323	FFFF	FFEE	EEEE	EEEE	EEFF	FFFF	FFFF	FFFF
1021	1021	17324	002C	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
1024	1024	17325	01FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
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1033	1033	17328	042C	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
1036	1036	17329	05FF	FFEE	EEEE	EEEE	EEFF	FFFF	FDFF	FFFF
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1045	1045	17332	002D	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
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1117	1117	17356	0030	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
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1129	1129	17360	0430	A6EE	EEEE	EEEE	EEFF	BE01	FFFF	FFFF
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1177	1177	18013	0002	0300	10E8	0000	0000	0200	0001	0001
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1564	1564	20002	000B	0000	0100	0000	0000	0297	1008	3814
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1576	1576	20006	0180	0000	0000	0080	0300	0000	0180	0000
1579	1579	20007	001C	0000	0100	0000	0000	02A7	0613	2065
1582	1582	20008	011E	0000	0100	0000	0000	02B0	0000	0001
1585	1585	20009	0021	0000	0100	0000	0000	02B2	0526	1590
1588	1588	20010	0028	0000	0100	0000	0000	02B5	0509	3393
1591	1591	20011	012A	0000	0100	0000	0000	02C0	0000	0000
1594	1594	20012	002F	0000	0100	0000	0000	02C2	0801	1692
1597	1597	20013	0131	0000	0100	0000	0000	02C2	0823	5390
1600	1600	20014	0131	0000	0100	0000	0000	02C2	0823	5390
1603	1603	20015	0131	0000	0100	0000	0000	02C2	0823	5390
1606	1606	20016	0036	0000	0100	0000	0000	02C2	0924	4353
1609	1609	20017	0138	0000	0100	0000	0000	02C2	0958	0792
1612	1612	20018	0138	0000	0100	0000	0000	02C2	0958	0792
1615	1615	20019	0138	0000	0100	0000	0000	02C2	0958	0792
1618	1618	20020	0045	0000	0100	0000	0000	02C2	1245	3453
1621	1621	20021	0147	0000	0100	0000	0000	02C2	1400	4530
1624	1624	20022	0147	0000	0100	0000	0000	02C2	1400	4530
1627	1627	20023	0147	0000	0100	0000	0000	02C2	1400	4530
1630	1630	20024	004C	0000	0100	0000	0000	02C2	1406	2084
1633	1633	20025	014E	0000	0100	0000	0000	02C2	1407	2485
1636	1636	20026	014E	0000	0100	0000	0000	02C2	1407	2485
1639	1639	20027	0051	0000	0100	0000	0000	02C2	1415	3372
1642	1642	20028	0153	0000	0100	0000	0000	02C2	1556	1270
1645	1645	20029	0153	0000	0100	0000	0000	02C2	1556	1270
1648	1648	20030	0056	0000	0100	0000	0000	02C2	1630	2992
1651	1651	20031	0158	0000	0100	0000	0000	02C5	0000	0001
1654	1654	20032	0158	0000	0100	0000	0000	02C5	0000	0001
1657	1657	20033	0158	0000	0100	0000	0000	02C5	0000	0001
1660	1660	20034	0063	0000	0100	0000	0000	02D7	2210	2070
1663	1663	20035	0165	0000	0100	0000	0000	02D7	2210	3503
1666	1666	20036	006A	0000	0100	0000	0000	02E1	0703	3322
1669	1669	20037	016C	0000	0100	0000	0000	02E2	0452	1050
1672	1672	20038	006D	0000	0100	0000	0000	02E1	0703	3322
1675	1675	20039	016F	0000	0100	0000	0000	02E3	2200	1434
1678	1678	20040	016F	0000	0100	0000	0000	02E3	2200	1434
1681	1681	20041	016F	0000	0100	0000	0000	02E3	2200	1434
1684	1684	20042	0074	0000	0100	0000	0000	02E6	2122	2734
1687	1687	20043	0176	0000	0100	0000	0000	02F0	0000	0000
1690	1690	20044	0079	0000	0100	0000	0000	02F2	2101	0495

1693	1693	20045	017B	0000	0100	0000	0000	02F5	0000	0001
1696	1696	20046	017B	0000	0100	0000	0000	02F5	0000	0001
1699	1699	20047	017B	0000	0100	0000	0000	02F5	0000	0001
1702	1702	20048	0084	0000	0100	0000	0000	0209	1018	1373
1705	1705	20049	0186	0000	0100	0000	0000	0210	0000	0000
1708	1708	20050	0186	0000	0100	0000	0000	0210	0000	0000
1711	1711	20051	0089	0000	0100	0000	0000	0214	0447	5673
1714	1714	20052	018B	0000	0100	0000	0000	0214	0651	5892
1717	1717	20053	008C	0000	0100	0000	0000	0214	0447	5673
1720	1720	20054	018E	0000	0100	0000	0000	0215	0000	0000
1723	1723	20055	018E	0000	0100	0000	0000	0215	0000	0000
1726	1726	20056	018E	0000	0100	0000	0000	0215	0000	0000
1729	1729	20057	0097	0000	0100	0000	0000	0230	2128	0270
1732	1732	20058	0199	0000	0100	0000	0000	0231	2108	2011
1735	1735	20059	0199	0000	0100	0000	0000	0231	2108	2011
1738	1738	20060	0199	0000	0100	0000	0000	0231	2108	2011
1741	1741	20061	00A0	0000	0100	0000	0000	0243	0742	0474
1744	1744	20062	01A2	0000	0100	0000	0000	0245	0000	0001
1747	1747	20063	01A2	0000	0100	0000	0000	0245	0000	0001
1750	1750	20064	01A2	0000	0100	0000	0000	0245	0000	0001
1753	1753	21001	0001	0000	D2DB	D2D3	E6E6	D3CA	D4CA	EAFA
1756	1756	21002	0002	0000	0700	0000	0000	0288	2055	3685
1759	1759	21003	0003	0000	D2DB	D2D3	E6E6	D3CA	D4CA	EAFA
1762	1762	21004	0004	0000	0700	0000	0000	0288	2055	3685
1765	1765	21005	0005	0000	D2DB	D2D3	E6E6	D3CA	D4CA	EAFA
1768	1768	21006	0006	0000	0700	0000	0000	0288	2055	3685
1771	1771	21007	0007	0000	D2DB	D2D3	E6E6	D3CA	D4CA	EAFA
1774	1774	21008	0008	0000	0700	0000	0000	0288	2055	3685
1777	1777	21009	0009	0000	D2DB	D2D3	E6E6	D3CA	D4CA	EAFA
1780	1780	21010	000A	0000	0700	0000	0000	0288	2055	3685
1783	1783	21011	000B	0000	D2DB	D2D3	E6E6	D3CA	D4CA	EAFA
1786	1786	21012	0100	1C10	0700	0000	0000	0288	2058	4170
1789	1789	21013	0001	0000	D2DB	D2D3	E6E6	D3CA	D4CA	EAFA
1792	1792	21014	0002	0000	0700	0000	0000	0288	2058	4170
1795	1795	21015	0003	0000	D2DB	D2D3	E6E6	D3CA	D4CA	EAFA
1798	1798	21016	0004	0000	0700	0000	0000	0288	2058	4170
1801	1801	21017	0006	0000	0700	0000	0000	0288	2058	4170
1804	1804	21018	0100	7C10	0700	0000	0000	0288	2059	1682
1807	1807	21019	0001	0000	D2DB	D2D3	E6E6	D3CA	D4CA	EAFA
1810	1810	21020	0002	0000	0700	0000	0000	0288	2059	1682
1813	1813	21021	0003	0000	D2DB	D2D3	E6E6	D3CA	D4CA	EAFA
1816	1816	21022	0004	0000	0700	0000	0000	0288	2059	1682
1819	1819	21023	0005	0000	D2DB	D2D3	E6E6	D3CA	D4CA	EAFA
1822	1822	21024	0100	5810	0700	0000	0000	0288	2059	4855
1825	1825	21025	0001	0000	C2CB	C2C3	E6E6	C3CA	C4CA	EAFA
1828	1828	21026	0002	0000	0700	0000	0000	0288	2055	0185
1831	1831	21027	0003	0000	C2CB	C2C3	E6E6	C3CA	C4CA	EAFA
1834	1834	21028	0004	0000	0700	0000	0000	0288	2055	0185
1837	1837	21029	0005	0000	C2CB	C2C3	E6E6	C3CA	C4CA	EAFA
1840	1840	21030	0006	0000	0700	0000	0000	0288	2055	0185
1843	1843	21031	0007	0000	C2CB	C2C3	E6E6	C3CA	C4CA	EAFA
1846	1846	21032	0008	0000	0700	0000	0000	0288	2055	0185
1849	1849	21033	0009	0000	C2CB	C2C3	E6E6	C3CA	C4CA	EAFA
1852	1852	21034	0002	0000	0700	0000	0000	0288	2055	5374
1855	1855	22001	0100	1C10	0600	0000	0000	0296	0101	0810
1858	1858	22002	0100	1C10	0600	0000	0000	0296	0101	0810
1861	1861	22003	0100	1C10	0600	0000	0000	0296	0101	0810
1864	1864	22004	0100	1C10	0600	0000	0000	0296	0101	0810
1867	1867	22005	0100	1C10	0600	0000	0000	0296	0101	0810
1870	1870	22006	0100	1C10	0600	0000	0000	0296	0101	0810
1873	1873	22007	0011	0000	0600	0000	0000	02D5	0000	0000
1876	1876	22008	0113	2C1E	0600	0000	0000	02E0	0000	0000
1879	1879	22009	FD8F	0F00	0000	FF8F	0C00	0000	0080	1300

1882	1882	22010	0000	FF8F	0C00	0000	0080	1200	0000	0080
1885	1885	22011	0002	0000	0600	0000	0000	0000	0000	0101
1888	1888	22012	0002	0000	0600	0000	0000	0000	0000	0324
1891	1891	22013	0002	0000	0600	0000	0000	0000	0000	0060
1894	1894	22014	0002	0000	0600	0000	0000	0000	0000	0445
1897	1897	22015	0105	2C18	0600	0000	0000	0000	0000	2700
1900	1900	22016	0002	0000	0600	0000	0000	0000	0000	0061
1903	1903	22017	0002	0000	0600	0000	0000	0288	2050	0373
1906	1906	22018	0004	0000	0600	0000	0000	0288	2050	0373
1909	1909	22019	0006	0000	0600	0000	0000	0288	2050	0373
1912	1912	22020	0001	0000	77FF	6DFB	6FFF	FD6F	5BBF	7F7F
1915	1915	22021	0002	0000	0600	0000	0000	0288	2050	0072
1918	1918	22022	0001	0000	77FF	6DFB	6FFF	FD6F	5BBF	7F7F
1921	1921	22023	0002	0000	0600	0000	0000	0288	2050	1942
1924	1924	22024	0003	0000	77FF	6DFB	6FFF	FD6F	5BBF	7F7F
1927	1927	22025	0004	0000	0600	0000	0000	0288	2050	1942
1930	1930	22026	0005	0000	77FF	6DFB	6FFF	FD6F	5BBF	7F7F
1933	1933	22027	0006	0000	0600	0000	0000	0288	2050	1942
1936	1936	22028	0007	0000	77FF	6DFB	6FFF	FD6F	5BBF	7F7F
1939	1939	22029	0008	0000	0600	0000	0000	0288	2050	1942
1942	1942	22030	0009	0000	77FF	6DFB	6FFF	FD6F	5BBF	7F7F
1945	1945	22031	000A	0000	0600	0000	0000	0288	2050	1942
1948	1948	22032	000B	0000	77FF	6DFB	6FFF	FD6F	5BBF	7F7F
1951	1951	22033	000C	0000	0600	0000	0000	0288	2050	1942
1954	1954	22034	000D	0000	77FF	6DFB	6FFF	FD6F	5BBF	7F7F
1957	1957	22035	000E	0000	0600	0000	0000	0288	2050	1942
1960	1960	22036	0001	0000	FFFF	FFFF	FFFF	FFFE	FFFF	FFFF
1963	1963	22037	0002	0000	0600	0000	0000	0365	2359	0234
1966	1966	22038	0003	0000	FFFF	FFFF	FFFF	FFFE	FFFF	FFFF
1969	1969	22039	0004	0000	0600	0000	0000	0365	2359	0234
1972	1972	22040	0005	0000	FFFF	FFFF	FFFF	FFFE	FFFF	FFFF
1975	1975	22041	0100	5E10	0600	0000	0000	0365	2359	3434
1978	1978	22042	0100	2210	0600	0000	0000	0365	2359	4031
1981	1981	22043	0100	2210	0600	0000	0000	0365	2359	4930
1984	1984	22044	0100	3410	0600	0000	0000	0365	2359	5411
1987	1987	22045	0100	5810	0600	0000	0000	0365	2359	5971
1990	1990	22046	0100	2810	0600	0000	0000	1001	0000	0653
1993	1993	22047	0001	0000	FFFF	FFFF	FFFF	FFFE	FFFF	FFFF
1996	1996	22048	0002	0000	0600	0000	0000	1001	0000	0653
1999	1999	22049	0003	0000	FFFF	FFFF	FFFF	FFFE	FFFF	FFFF
2002	2002	22050	0004	0000	0600	0000	0000	1001	0000	0653
2005	2005	22051	0005	0000	FFFF	FFFF	FFFF	FFFE	FFFF	FFFF
2008	2008	22052	0006	0000	0600	0000	0000	1001	0000	0653
2011	2011	22053	0007	0000	FFFF	FFFF	FFFF	FFFE	FFFF	FFFF
2014	2014	22054	0008	0000	0600	0000	0000	1001	0000	0653
2017	2017	22055	0009	0000	FFFF	FFFF	FFFF	FFFE	FFFF	FFFF
2020	2020	22056	000A	0000	0600	0000	0000	1001	0000	0653
2023	2023	22057	0100	2210	0600	0000	0000	0365	2359	0374
2026	2026	22058	0001	0000	FFFB	FFFF	FFFF	FFFE	FFFF	FFFF
2029	2029	22059	0002	0000	0600	0000	0000	0365	2359	0374
2032	2032	22060	0003	0000	FFFB	FFFF	FFFF	FFFE	FFFF	FFFF
2035	2035	22061	0004	0000	0600	0000	0000	0365	2359	0374
2038	2038	22062	0600	0000	0000	0365	2359	0133	8A0E	2D0F
2041	2041	22063	0001	0000	FFFB	FFFF	FFFF	FFFE	FFFF	FFFF
2044	2044	22064	0100	1C10	0600	0000	0000	0365	2359	1233
2047	2047	22065	0001	0000	FFFB	FFFF	FFFF	FFFE	FFFF	FFFF
2050	2050	22066	0002	0000	0600	0000	0000	0365	2359	1233
2053	2053	22067	0003	0000	FFFB	FFFF	FFFF	FFFE	FFFF	FFFF
2056	2056	22068	0004	0000	0600	0000	0000	0365	2359	1233
2059	2059	22069	0005	0000	FFFB	FFFF	FFFF	FFFE	FFFF	FFFF
2062	2062	22070	0006	0000	0600	0000	0000	0365	2359	1233
2065	2065	22071	0007	0000	FFFB	FFFF	FFFF	FFFE	FFFF	FFFF
2068	2068	22072	0008	0000	0600	0000	0000	0365	2359	1233

2071	2071	22073	0009	0000	FFFB	FFFF	FFFF	FFFE	FFFF	FFFF
2074	2074	22074	000A	0000	0600	0000	0000	0365	2359	1233
2077	2077	23001	0004	0000	0400	0000	0000	0291	1959	5615
2080	2080	23002	0004	0000	0400	0000	0000	0291	1959	5615
2083	2083	23003	0007	0000	0400	0000	0000	0291	2050	4002
2086	2086	23004	0109	1817	0400	0000	0000	0291	2053	0202
2089	2089	23005	000A	0000	0400	0000	0000	0291	2050	4002
2092	2092	23006	000B	0000	0400	0000	0000	0291	2053	0202
2095	2095	23007	000B	0000	0400	0000	0000	0291	2053	0202
2098	2098	23008	000E	0000	0400	0000	0000	0291	2055	0580
2101	2101	23009	0110	1814	0400	0000	0000	0291	2055	2203
2104	2104	23010	0011	0000	0400	0000	0000	0291	2055	0580
2107	2107	23011	0113	6E18	0400	0000	0000	0291	2059	0433
2110	2110	23012	0014	0000	0400	0000	0000	0291	2055	0580
2113	2113	23013	0116	F416	0400	0000	0000	0291	2108	5063
2116	2116	23014	0116	F416	0400	0000	0000	0291	2108	5063
2119	2119	23015	0019	0000	0400	0000	0000	0291	2117	1664
2122	2122	23016	011B	AE11	0400	0000	0000	0291	2117	2714
2125	2125	23017	001C	0000	0400	0000	0000	0291	2117	1664
2128	2128	23018	011E	381B	0400	0000	0000	0291	2237	2351
2131	2131	23019	001F	0000	0400	0000	0000	0291	2117	1664
2134	2134	23020	0121	1619	0400	0000	0000	0291	2239	1120
2137	2137	23021	0121	1619	0400	0000	0000	0291	2239	1120
2140	2140	23022	0121	1619	0400	0000	0000	0291	2239	1120
2143	2143	23023	0026	0000	0400	0000	0000	0291	2256	2843
2146	2146	23024	0128	3614	0400	0000	0000	0291	2321	5745
2149	2149	23025	0029	0000	0400	0000	0000	0291	2256	2843
2152	2152	23026	012B	3212	0400	0000	0000	0292	0246	0984
2155	2155	23027	002C	0000	0400	0000	0000	0291	2256	2843
2158	2158	23028	012E	0A19	0400	0000	0000	0292	0247	1260
2161	2161	23029	012E	0A19	0400	0000	0000	0292	0247	1260
2164	2164	23030	0031	0000	0400	0000	0000	0292	0248	0574
2167	2167	23031	0133	561B	0400	0000	0000	0292	0248	4424
2170	2170	23032	0133	561B	0400	0000	0000	0292	0248	4424
2173	2173	23033	0036	0000	0400	0000	0000	0292	0248	5070
2176	2176	23034	0138	2E16	0400	0000	0000	0292	0251	5732
2179	2179	23035	013B	6A13	0400	0000	0000	0292	0300	0764
2182	2182	23036	013B	6A13	0400	0000	0000	0292	0300	0764
2185	2185	23037	013B	6A13	0400	0000	0000	0292	0300	0764
2188	2188	23038	0040	0000	0400	0000	0000	0292	0320	0761
2191	2191	23039	0142	9416	0400	0000	0000	0292	2050	2535
2194	2194	23040	0043	0000	0400	0000	0000	0292	0320	0761
2197	2197	23041	0145	BC18	0400	0000	0000	0292	2132	0933
2200	2200	23042	0145	BC18	0400	0000	0000	0292	2132	0933
2203	2203	23043	0048	0000	0400	0000	0000	0292	2150	1155
2206	2206	23044	014A	2E16	0400	0000	0000	0293	0105	3093
2209	2209	23045	004B	0000	0400	0000	0000	0292	2150	1155
2212	2212	23046	014D	8615	0400	0000	0000	0293	1849	0701
2215	2215	23047	004E	0000	0400	0000	0000	0292	2150	1155
2218	2218	23048	0150	4C13	0400	0000	0000	0293	1851	2283
2221	2221	23049	0150	4C13	0400	0000	0000	0293	1851	2283
2224	2224	23050	0053	0000	0400	0000	0000	0293	1853	0342
2227	2227	23051	0155	D610	0400	0000	0000	0293	1853	3862
2230	2230	23052	0056	0000	0400	0000	0000	0293	1853	0342
2233	2233	23053	0158	641C	0400	0000	0000	0293	1854	1243
2236	2236	23054	0158	641C	0400	0000	0000	0293	1854	1243
2239	2239	23055	005B	0000	0400	0000	0000	0293	1854	1841
2242	2242	23056	015D	7C19	0400	0000	0000	0293	1858	0602
2245	2245	23057	005E	0000	0400	0000	0000	0293	1854	1841
2248	2248	23058	0160	5615	0400	0000	0000	0293	2004	1173
2251	2251	23059	0160	5615	0400	0000	0000	0293	2004	1173
2254	2254	23060	0063	0000	0400	0000	0000	0293	2005	0181
2257	2257	23061	0165	D61F	0400	0000	0000	0293	2007	1654

2260	2260	23062	0165	D61F	0400	0000	0000	0293	2007	1654
2263	2263	23063	0165	D61F	0400	0000	0000	0293	2007	1654
2266	2266	23064	006A	0000	0400	0000	0000	0293	2014	1135
2269	2269	23065	016C	D811	0400	0000	0000	0293	2018	5651
2272	2272	23066	006D	0000	0400	0000	0000	0293	2014	1135
2275	2275	23067	006E	0000	0400	0000	0000	0293	2018	5651
2278	2278	23068	006F	0000	0400	0000	0000	0293	2014	1135
2281	2281	23069	0070	0000	0400	0000	0000	0293	2018	5651
2284	2284	23070	0071	0000	0400	0000	0000	0293	2014	1135
2287	2287	23071	0072	0000	0400	0000	0000	0293	2018	5651
2290	2290	23072	0073	0000	0400	0000	0000	0293	2014	1135
2293	2293	23073	0074	0000	0400	0000	0000	0293	2018	5651
2296	2296	23074	0075	0000	0400	0000	0000	0293	2014	1135
2299	2299	23075	0076	0000	0400	0000	0000	0293	2018	5651
2302	2302	23076	0077	0000	0400	0000	0000	0293	2014	1135
2305	2305	23077	0179	D41E	0400	0000	0000	0293	2020	4595
2308	2308	23078	007A	0000	0400	0000	0000	0293	2014	1135
2311	2311	23079	007B	0000	0400	0000	0000	0293	2020	4595
2314	2314	23080	007C	0000	0400	0000	0000	0293	2014	1135
2317	2317	23081	007D	0000	0400	0000	0000	0293	2020	4595
2320	2320	23082	007D	0000	0400	0000	0000	0293	2020	4595
2323	2323	23083	0080	0000	0400	0000	0000	0293	2022	1124
2326	2326	23084	0182	6A13	0400	0000	0000	0293	2022	3230
2329	2329	23085	0084	0000	0400	0000	0000	0293	2022	3230
2332	2332	23086	0085	0000	0400	0000	0000	0293	2022	1124
2335	2335	23087	0187	2A14	0400	0000	0000	0293	2022	5354
2338	2338	23088	0088	0000	0400	0000	0000	0293	2022	1124
2341	2341	23089	0089	0000	0400	0000	0000	0293	2022	5354
2344	2344	23090	008A	0000	0400	0000	0000	0293	2022	1124
2347	2347	23091	018C	961A	0400	0000	0000	0293	2023	5175
2350	2350	23092	008D	0000	0400	0000	0000	0293	2022	1124
2353	2353	23093	018F	5615	0400	0000	0000	0293	2024	2840
2356	2356	23094	0090	0000	0400	0000	0000	0293	2022	1124
2359	2359	23095	0192	B018	0400	0000	0000	0293	2025	1602
2362	2362	23096	0192	B018	0400	0000	0000	0293	2025	1602
2365	2365	23097	0095	0000	0400	0000	0000	0293	2027	4954
2368	2368	23098	0096	0000	0400	0000	0000	0293	2025	1602
2371	2371	23099	0097	0000	0400	0000	0000	0293	2027	4954
2374	2374	23100	0199	7016	0400	0000	0000	0293	2028	1153
2377	2377	23101	009A	0000	0400	0000	0000	0293	2027	4954
2380	2380	23102	009B	0000	0400	0000	0000	0293	2028	1153
2383	2383	23103	009C	0000	0400	0000	0000	0293	2027	4954
2386	2386	23104	019E	3218	0400	0000	0000	0293	2028	4403
2389	2389	23105	009F	0000	0400	0000	0000	0293	2027	4954
2392	2392	23106	00A0	0000	0400	0000	0000	0293	2028	4403
2395	2395	23107	00A1	0000	0400	0000	0000	0293	2027	4954
2398	2398	23108	00A2	0000	0400	0000	0000	0293	2028	4403
2401	2401	23109	00A3	0000	0400	0000	0000	0293	2027	4954
2404	2404	23110	00A4	0000	0400	0000	0000	0293	2028	4403
2407	2407	23111	00A5	0000	0400	0000	0000	0293	2027	4954
2410	2410	23112	01A7	6C11	0400	0000	0000	0293	2029	2442
2413	2413	23113	00A8	0000	0400	0000	0000	0293	2027	4954
2416	2416	23114	00A9	0000	0400	0000	0000	0293	2029	2442
2419	2419	23115	00AA	0000	0400	0000	0000	0293	2027	4954
2422	2422	23116	01AC	6A16	0400	0000	0000	0293	2030	4131
2425	2425	23117	01AC	6A16	0400	0000	0000	0293	2030	4131
2428	2428	23118	00AF	0000	0400	0000	0000	0293	2031	1573
2431	2431	23119	00B0	0000	0400	0000	0000	0293	2030	4131
2434	2434	23120	00B1	0000	0400	0000	0000	0293	2031	1573
2437	2437	23121	01B3	7214	0400	0000	0000	0293	2031	3710
2440	2440	23122	00B4	0000	0400	0000	0000	0293	2031	1573
2443	2443	23123	00B5	0000	0400	0000	0000	0293	2031	3710
2446	2446	23124	00B6	0000	0400	0000	0000	0293	2031	1573

2449	2449	23125	00B7	0000	0400	0000	0000	0293	2031	3710
2452	2452	23126	00B8	0000	0400	0000	0000	0293	2031	1573
2455	2455	23127	01BA	1616	0400	0000	0000	0293	2033	0884
2458	2458	23128	00BB	0000	0400	0000	0000	0293	2031	1573
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2464	2464	23130	00BD	0000	0400	0000	0000	0293	2031	1573
2467	2467	23131	01BF	8414	0400	0000	0000	0293	2033	3522
2470	2470	23132	00C0	0000	0400	0000	0000	0293	2031	1573
2473	2473	23133	00C1	0000	0400	0000	0000	0293	2033	3522
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2482	2482	23136	00C4	0000	0400	0000	0000	0293	2031	1573
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2488	2488	23138	00CA	0000	0400	0000	0000	0293	2031	1573
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2494	2494	23140	00CC	0000	0400	0000	0000	0293	2031	1573
2497	2497	23141	00CD	0000	0400	0000	0000	0293	2042	4635
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2503	2503	23143	01D0	EA17	0400	0000	0000	0293	2043	1881
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2512	2512	23146	00D3	0000	0400	0000	0000	0293	2031	1573
2515	2515	23147	01D5	0212	0400	0000	0000	0293	2104	5745
2518	2518	23148	00D6	0000	0400	0000	0000	0293	2031	1573
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2524	2524	23150	01D8	FC14	0400	0000	0000	0293	2110	4851
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2536	2536	23154	01E1	381E	0400	0000	0000	0293	2135	1845
2539	2539	23155	00E2	0000	0400	0000	0000	0293	2130	0950
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2557	2557	23161	00EB	0000	0400	0000	0000	0293	2203	4183
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2566	2566	23164	01F0	1817	0400	0000	0000	0293	2206	5144
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2575	2575	23167	00F5	0000	0400	0000	0000	0293	2208	0731
2578	2578	23168	01F7	601A	0400	0000	0000	0293	2209	4541
2581	2581	23169	00F8	0000	0400	0000	0000	0293	2208	0731
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2587	2587	23171	01FA	4211	0400	0000	0000	0293	2212	1055
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2593	2593	23173	01FF	3014	0400	0000	0000	0293	2221	4165
2596	2596	23174	01FF	3014	0400	0000	0000	0293	2221	4165
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2602	2602	23176	0004	0000	0400	0000	0000	0293	2233	3685
2605	2605	23177	0106	AA15	0400	0000	0000	0293	2233	4862
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2611	2611	23179	0109	1016	0400	0000	0000	0293	2234	2044
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2617	2617	23181	000B	0000	0400	0000	0000	0293	2234	2044
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2623	2623	23183	000D	0000	0400	0000	0000	0293	2234	2044
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2629	2629	23185	0010	0000	0400	0000	0000	0293	2236	1734
2632	2632	23186	0112	C41C	0400	0000	0000	0293	2236	5130
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2644	2644	23190	0019	0000	0400	0000	0000	0293	2237	1022
2647	2647	23191	011B	3812	0400	0000	0000	0293	2244	3023
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2656	2656	23194	001F	0000	0400	0000	0000	0293	2237	1022
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2665	2665	23197	0024	0000	0400	0000	0000	0293	2250	1052
2668	2668	23198	0126	E819	0400	0000	0000	0293	2252	3341
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2674	2674	23200	0129	0E18	0400	0000	0000	0293	2254	5071
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2701	2701	23209	0039	0000	0400	0000	0000	0294	0124	4484
2704	2704	23210	013B	3A10	0400	0000	0000	0294	0124	5491
2707	2707	23211	003C	0000	0400	0000	0000	0294	0124	4484
2710	2710	23212	013E	CA19	0400	0000	0000	0294	0128	5261
2713	2713	23213	013E	CA19	0400	0000	0000	0294	0128	5261
2716	2716	23214	0041	0000	0400	0000	0000	0294	0223	3375
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2725	2725	23217	0146	3218	0400	0000	0000	0294	0351	5611
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2734	2734	23220	014B	3812	0400	0000	0000	0294	1307	2514
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2740	2740	23222	014E	981E	0400	0000	0000	0294	1428	5240
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2746	2746	23224	014E	981E	0400	0000	0000	0294	1428	5240
2749	2749	23225	0053	0000	0400	0000	0000	0294	1445	3162
2752	2752	23226	0155	DC13	0400	0000	0000	0294	1446	2774
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2758	2758	23228	0058	0000	0400	0000	0000	0294	1446	4055
2761	2761	23229	015A	9218	0400	0000	0000	0294	1504	3163
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2767	2767	23231	015D	4E17	0400	0000	0000	0294	1504	4391
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2779	2779	23235	0062	0000	0400	0000	0000	0294	1511	5695
2782	2782	23236	0164	DA1B	0400	0000	0000	0294	1529	0913
2785	2785	23237	0065	0000	0400	0000	0000	0294	1511	5695
2788	2788	23238	0066	0000	0400	0000	0000	0294	1529	0913
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2794	2794	23240	0169	9017	0400	0000	0000	0294	1529	3144
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2809	2809	23245	0070	0000	0400	0000	0000	0294	1545	4593
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2818	2818	23248	0071	0000	0400	0000	0000	0294	1529	3144
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2827	2827	23251	007A	0000	0400	0000	0000	0294	1556	1290
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2836	2836	23254	017F	1A1E	0400	0000	0000	0294	1625	5512
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2845	2845	23257	0084	0000	0400	0000	0000	0294	1635	1820
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2875	2875	23267	0096	0000	0400	0000	0000	0294	1635	3001
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2887	2887	23271	019B	4610	0400	0000	0000	0294	2000	1315
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2893	2893	23273	009E	0000	0400	0000	0000	0294	2001	0841
2896	2896	23274	009F	0000	0400	0000	0000	0294	2000	1315
2899	2899	23275	00A0	0000	0400	0000	0000	0294	2001	0841
2902	2902	23276	01A2	9212	0400	0000	0000	0294	2002	4404
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2911	2911	23279	01A7	C01A	0400	0000	0000	0294	2006	4704
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2917	2917	23281	01A7	C01A	0400	0000	0000	0294	2006	4704
2920	2920	23282	00AE	0000	0400	0000	0000	0294	2013	2672
2923	2923	23283	01B0	1619	0400	0000	0000	0294	2017	2421
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2959	2959	23295	00C3	0000	0400	0000	0000	0295	2100	4294
2962	2962	23296	01C5	5219	0400	0000	0000	0295	2118	2430
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2968	2968	23298	00C8	0000	0400	0000	0000	0295	2123	0414
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2974	2974	23300	00CB	0000	0400	0000	0000	0295	2123	0414
2977	2977	23301	01CD	101F	0400	0000	0000	0295	2230	1461
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3076	3076	23334	0000	0000	0400	0000	0000	0298	1824	0472
3079	3079	23335	0102	FA1F	0400	0000	0000	0298	1959	3612
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3085	3085	23337	0005	0000	0400	0000	0000	0298	2117	4903
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3097	3097	23341	000B	0000	0400	0000	0000	0298	2205	5635
3100	3100	23342	010D	C61A	0400	0000	0000	0298	2213	0911
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3142	3142	23356	0021	0000	0400	0000	0000	0299	0009	5315
3145	3145	23357	0123	F81B	0400	0000	0000	0299	0107	5171
3148	3148	23358	0024	0000	0400	0000	0000	0299	0009	5315
3151	3151	23359	0126	0617	0400	0000	0000	0299	0157	2442
3154	3154	23360	0027	0000	0400	0000	0000	0299	0009	5315
3157	3157	23361	0129	6215	0400	0000	0000	0299	0412	5891
3160	3160	23362	002A	0000	0400	0000	0000	0299	0009	5315
3163	3163	23363	012C	FE12	0400	0000	0000	0299	0431	0321
3166	3166	23364	012C	FE12	0400	0000	0000	0299	0431	0321
3169	3169	23365	002F	0000	0400	0000	0000	0299	0445	0123
3172	3172	23366	0131	5E1C	0400	0000	0000	0299	0451	0454
3175	3175	23367	0131	5E1C	0400	0000	0000	0299	0451	0454
3178	3178	23368	0131	5E1C	0400	0000	0000	0299	0451	0454
3181	3181	23369	0036	0000	0400	0000	0000	0299	0528	0351
3184	3184	23370	0138	2E16	0400	0000	0000	0299	0531	2512
3187	3187	23371	0039	0000	0400	0000	0000	0299	0528	0351
3190	3190	23372	013B	8612	0400	0000	0000	0299	0738	1945
3193	3193	23373	013B	8612	0400	0000	0000	0299	0738	1945
3196	3196	23374	003E	0000	0400	0000	0000	0299	0738	4805
3199	3199	23375	0140	441B	0400	0000	0000	0299	0741	5632
3202	3202	23376	0041	0000	0400	0000	0000	0299	0738	4805

3205	3205	23377	0143	841A	0400	0000	0000	0299	0744	5933
3208	3208	23378	0044	0000	0400	0000	0000	0299	0738	4805
3211	3211	23379	0146	781A	0400	0000	0000	0299	0745	1755
3214	3214	23380	0146	781A	0400	0000	0000	0299	0745	1755
3217	3217	23381	0146	781A	0400	0000	0000	0299	0745	1755
3220	3220	23382	0146	781A	0400	0000	0000	0299	0745	1755
3223	3223	23383	004D	0000	0400	0000	0000	0299	0802	1834
3226	3226	23384	004E	0000	0400	0000	0000	0299	0745	1755
3229	3229	23385	004F	0000	0400	0000	0000	0299	0802	1834
3232	3232	23386	0151	9419	0400	0000	0000	0299	0818	3990
3235	3235	23387	0151	9419	0400	0000	0000	0299	0818	3990
3238	3238	23388	0054	0000	0400	0000	0000	0299	0824	0824
3241	3241	23389	0156	061A	0400	0000	0000	0299	0824	2135
3244	3244	23390	0057	0000	0400	0000	0000	0299	0824	0824
3247	3247	23391	0159	FC1A	0400	0000	0000	0299	0852	1231
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3262	3262	23396	0062	0000	0400	0000	0000	0299	2141	5831
3265	3265	23397	0164	3C1D	0400	0000	0000	02A0	0000	0001
3268	3268	23398	0164	3C1D	0400	0000	0000	02A0	0000	0001
3271	3271	23399	0067	0000	0400	0000	0000	02A0	0026	3340
3274	3274	23400	0169	D013	0400	0000	0000	02A0	0226	3875
3277	3277	23401	0169	D013	0400	0000	0000	02A0	0226	3875
3280	3280	23402	0169	D013	0400	0000	0000	02A0	0226	3875
3283	3283	23403	006E	0000	0400	0000	0000	02A0	1814	4971
3286	3286	23404	0170	0017	0400	0000	0000	02A0	1819	0650
3289	3289	23405	0071	0000	0400	0000	0000	02A0	1814	4971
3292	3292	23406	0173	7C1F	0400	0000	0000	02A0	1939	0912
3295	3295	23407	0074	0000	0400	0000	0000	02A0	1814	4971
3298	3298	23408	0176	F41F	0400	0000	0000	02A0	1940	3900
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3304	3304	23410	007B	0000	0400	0000	0000	02A1	0351	3715
3307	3307	23411	017D	8C18	0400	0000	0000	02A1	1804	0305
3310	3310	23412	007E	0000	0400	0000	0000	02A1	0351	3715
3313	3313	23413	0180	E411	0400	0000	0000	02A1	1919	0690
3316	3316	23414	0081	0000	0400	0000	0000	02A1	0351	3715
3319	3319	23415	0183	8C15	0400	0000	0000	02A1	2009	0911
3322	3322	23416	0183	8C15	0400	0000	0000	02A1	2009	0911
3325	3325	23417	0183	8C15	0400	0000	0000	02A1	2009	0911
3328	3328	23418	0183	8C15	0400	0000	0000	02A1	2009	0911
3331	3331	23419	008A	0000	0400	0000	0000	02A2	2307	2543
3334	3334	23420	018F	B015	0400	0000	0000	02A3	2152	2932
3337	3337	23421	0090	0000	0400	0000	0000	02A2	2307	2543
3340	3340	23422	0192	E01B	0400	0000	0000	02A3	2216	0092
3343	3343	23423	0192	E01B	0400	0000	0000	02A3	2216	0092
3346	3346	23424	0095	0000	0400	0000	0000	02A4	1824	5312
3349	3349	23425	0197	3215	0400	0000	0000	02A4	2152	1605
3352	3352	23426	0098	0000	0400	0000	0000	02A4	1824	5312
3355	3355	23427	019A	6011	0400	0000	0000	02A5	0000	0000
3358	3358	23428	019A	6011	0400	0000	0000	02A5	0000	0000
3361	3361	23429	009D	0000	0400	0000	0000	02A8	0029	1225
3364	3364	23430	019F	841A	0400	0000	0000	02A9	0006	1801
3367	3367	23431	019F	841A	0400	0000	0000	02A9	0006	1801
3370	3370	23432	00A2	0000	0400	0000	0000	02A9	0348	4824
3373	3373	23433	01A4	7A12	0400	0000	0000	02B0	0000	0000
3376	3376	23434	01A4	7A12	0400	0000	0000	02B0	0000	0000
3379	3379	23435	01A4	7A12	0400	0000	0000	02B0	0000	0000
3382	3382	23436	00A9	0000	0400	0000	0000	02B2	1857	3443
3385	3385	23437	01AB	6416	0400	0000	0000	02B5	0000	0001
3388	3388	23438	01AB	6416	0400	0000	0000	02B5	0000	0001
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3394	3394	23440	00B0	0000	0400	0000	0000	02B8	1833	5090
3397	3397	23441	01B2	CA19	0400	0000	0000	02C0	0000	0000
3400	3400	23442	01B2	CA19	0400	0000	0000	02C0	0000	0000
3403	3403	23443	00B5	0000	0400	0000	0000	02C1	1333	2010
3406	3406	23444	01B7	F41C	0400	0000	0000	02C2	1417	0061
3409	3409	23445	01B7	F41C	0400	0000	0000	02C2	1417	0061
3412	3412	23446	00BA	0000	0400	0000	0000	02C3	1903	0235
3415	3415	23447	01BC	5012	0400	0000	0000	02C3	1938	3985
3418	3418	23448	00BD	0000	0400	0000	0000	02C3	1903	0235
3421	3421	23449	01BF	3617	0400	0000	0000	02C4	0229	5011
3424	3424	23450	00C0	0000	0400	0000	0000	02C3	1903	0235
3427	3427	23451	01C2	581C	0400	0000	0000	02C4	0347	3195
3430	3430	23452	00C3	0000	0400	0000	0000	02C3	1903	0235
3433	3433	23453	01C5	0017	0400	0000	0000	02C5	0000	0001
3436	3436	23454	01C5	0017	0400	0000	0000	02C5	0000	0001
3439	3439	23455	00C8	0000	0400	0000	0000	02C5	0041	4261
3442	3442	23456	01CA	B816	0400	0000	0000	02C5	2204	2920
3445	3445	23457	00CB	0000	0400	0000	0000	02C5	0041	4261
3448	3448	23458	01CD	221F	0400	0000	0000	02C5	2345	3482
3451	3451	23459	00CE	0000	0400	0000	0000	02C5	0041	4261
3454	3454	23460	01D0	C21E	0400	0000	0000	02C7	2255	5953
3457	3457	23461	00D1	0000	0400	0000	0000	02C5	0041	4261
3460	3460	23462	01D3	9419	0400	0000	0000	02C8	0026	0411
3463	3463	23463	00D4	0000	0400	0000	0000	02C5	0041	4261
3466	3466	23464	01D6	7C10	0400	0000	0000	02C9	0524	4293
3469	3469	23465	00D7	0000	0400	0000	0000	02C5	0041	4261
3472	3472	23466	01D9	0218	0400	0000	0000	02C9	0821	4950
3475	3475	23467	00DA	0000	0400	0000	0000	02C5	0041	4261
3478	3478	23468	01DC	1010	0000	0000	0002	D000	0000	0004
3481	3481	23469	01DC	1010	0000	0000	0002	D000	0000	0004
3484	3484	23470	00DF	0000	0400	0000	0000	02D1	1448	5551
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3490	3490	23472	00E2	0000	0400	0000	0000	02D1	1448	5551
3493	3493	23473	01E4	EE1F	0400	0000	0000	02D2	0218	1932
3496	3496	23474	01E7	2A1A	0400	0000	0000	02D2	0637	2913
3499	3499	23475	00E8	0000	0400	0000	0000	02D1	1448	5551
3502	3502	23476	01EA	2414	0400	0000	0000	02D4	0240	2233
3505	3505	23477	01EA	2414	0400	0000	0000	02D4	0240	2233
3508	3508	23478	00ED	0000	0400	0000	0000	02D4	0306	0225
3511	3511	23479	01EF	4A12	0400	0000	0000	02D5	0000	0001
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3517	3517	23481	00F2	0000	0400	0000	0000	02D8	2009	1682
3520	3520	23482	01F4	2618	0400	0000	0000	02D8	2126	3241
3523	3523	23483	00F5	0000	0400	0000	0000	02D8	2009	1682
3526	3526	23484	01F7	041C	0400	0000	0000	02D9	0128	1440
3529	3529	23485	00F8	0000	0400	0000	0000	02D8	2009	1682
3532	3532	23486	01FA	F017	0400	0000	0000	02D9	2034	3361
3535	3535	23487	00FB	0000	0400	0000	0000	02D8	2009	1682
3538	3538	23488	01FD	B21F	0400	0000	0000	02E0	0000	0001
3541	3541	23489	01FD	B21F	0400	0000	0000	02E0	0000	0001
3544	3544	23490	0000	0000	0400	0000	0000	02E1	2047	3160
3547	3547	23491	0102	4814	0400	0000	0000	02E1	2243	4743
3550	3550	23492	0003	0000	0400	0000	0000	02E1	2047	3160
3553	3553	23493	0105	1C1C	0400	0000	0000	02E5	0000	0001
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3559	3559	23495	0008	0000	0400	0000	0000	02E5	2322	0763
3562	3562	23496	010A	4418	0400	0000	0000	02E5	2327	4471
3565	3565	23497	000B	0000	0400	0000	0000	02E5	2322	0763
3568	3568	23498	010D	B417	0400	0000	0000	02F0	0000	0000
3571	3571	23499	010D	B417	0400	0000	0000	02F0	0000	0000
3574	3574	23500	0010	0000	0400	0000	0000	02F1	0141	4335
3577	3577	23501	0112	601A	0400	0000	0000	02F1	1643	0532
3580	3580	23502	0013	0000	0400	0000	0000	02F1	0141	4335

3583	3583	23503	0115	1C19	0400	0000	0000	02F1	1915	1444
3586	3586	23504	0016	0000	0400	0000	0000	02F1	0141	4335
3589	3589	23505	0118	C011	0400	0000	0000	02F1	2011	5485
3592	3592	23506	0019	0000	0400	0000	0000	02F1	0141	4335
3595	3595	23507	011B	F014	0400	0000	0000	02F4	0102	2544
3598	3598	23508	001C	0000	0400	0000	0000	02F1	0141	4335
3601	3601	23509	011E	401C	0400	0000	0000	02F5	0000	0000
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3607	3607	23511	011E	401C	0400	0000	0000	02F5	0000	0000
3610	3610	23512	011E	401C	0400	0000	0000	02F5	0000	0000
3613	3613	23513	0025	0000	0400	0000	0000	0200	2112	1514
3616	3616	23514	0127	1A1B	0400	0000	0000	0201	2059	2985
3619	3619	23515	0028	0000	0400	0000	0000	0200	2112	1514
3622	3622	23516	012A	6C1D	0400	0000	0000	0202	1459	5661
3625	3625	23517	002B	0000	0400	0000	0000	0200	2112	1514
3628	3628	23518	012D	6A13	0400	0000	0000	0203	2125	2795
3631	3631	23519	002E	0000	0400	0000	0000	0200	2112	1514
3634	3634	23520	0130	EC12	0400	0000	0000	0204	2249	1641
3637	3637	23521	0031	0000	0400	0000	0000	0200	2112	1514
3640	3640	23522	0133	EE1F	0400	0000	0000	0205	0000	0001
3643	3643	23523	0133	EE1F	0400	0000	0000	0205	0000	0001
3646	3646	23524	0036	0000	0400	0000	0000	0207	2018	1795
3649	3649	23525	0138	7A1B	0400	0000	0000	0208	0127	3864
3652	3652	23526	0138	7A1B	0400	0000	0000	0208	0127	3864
3655	3655	23527	003B	0000	0400	0000	0000	0208	0139	2355
3658	3658	23528	013D	BA11	0400	0000	0000	0208	0334	4870
3661	3661	23529	003E	0000	0400	0000	0000	0208	0139	2355
3664	3664	23530	0140	3C1A	0400	0000	0000	0208	0335	0185
3667	3667	23531	0041	0000	0400	0000	0000	0208	0139	2355
3670	3670	23532	0143	6A1F	0400	0000	0000	0208	0342	2602
3673	3673	23533	0044	0000	0400	0000	0000	0208	0139	2355
3676	3676	23534	0146	E01B	0400	0000	0000	0210	0000	0000
3679	3679	23535	0146	E01B	0400	0000	0000	0210	0000	0000
3682	3682	23536	0146	E01B	0400	0000	0000	0210	0000	0000
3685	3685	23537	004B	0000	0400	0000	0000	0214	2059	0703
3688	3688	23538	014D	A81D	0400	0000	0000	0215	0000	0000
3691	3691	23539	014D	A81D	0400	0000	0000	0215	0000	0000
3694	3694	23540	0050	0000	0400	0000	0000	0217	1913	1722
3697	3697	23541	0152	0A1F	0400	0000	0000	0218	1649	3495
3700	3700	23542	0053	0000	0400	0000	0000	0217	1913	1722
3703	3703	23543	0155	FE12	0400	0000	0000	0218	2027	1125
3706	3706	23544	0056	0000	0400	0000	0000	0217	1913	1722
3709	3709	23545	0158	881F	0400	0000	0000	0218	2028	3601
3712	3712	23546	0059	0000	0400	0000	0000	0217	1913	1722
3715	3715	23547	015B	C614	0400	0000	0000	0219	0012	0732
3718	3718	23548	015B	C614	0400	0000	0000	0219	0012	0732
3721	3721	23549	005E	0000	0400	0000	0000	0219	0046	4773
3724	3724	23550	0160	7019	0400	0000	0000	0220	0000	0000
3727	3727	23551	0160	7019	0400	0000	0000	0220	0000	0000
3730	3730	23552	0063	0000	0400	0000	0000	0222	0036	1143
3733	3733	23553	0165	9A19	0400	0000	0000	0222	0150	5770
3736	3736	23554	0066	0000	0400	0000	0000	0222	0036	1143
3739	3739	23555	0168	0C14	0400	0000	0000	0223	1058	1964
3742	3742	23556	0069	0000	0400	0000	0000	0222	0036	1143
3745	3745	23557	016B	8612	0400	0000	0000	0223	2208	4493
3748	3748	23558	006C	0000	0400	0000	0000	0222	0036	1143
3751	3751	25001	0001	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3754	3754	25002	0003	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3757	3757	25003	0100	9E0F	7A8F	1000	B10F	9B8F	2000	C20F
3760	3760	25004	0005	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
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3766	3766	25006	0007	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
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3778	3778	25010	000B	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
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3784	3784	25012	000B	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3787	3787	25013	BC0F	4300	0580	AC0F	2F00	1980	A90F	1C00
3790	3790	25014	000F	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3793	3793	25015	BC0F	9A0F	1580	B10F	A50F	0780	A90F	B90F
3796	3796	25016	0011	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3799	3799	25017	BC0F	4300	D08F	AC0F	5300	E58F	A90F	6400
3802	3802	25018	BC0F	4300	D08F	AC0F	5300	E58F	A90F	6400
3805	3805	25019	0001	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
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3811	3811	25021	AF0F	5400	EE8F	A70F	6600	FC8F	B70F	5B00
3814	3814	25022	0001	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3817	3817	25023	4A00	0700	1080	5A00	1800	0080	5700	2900
3820	3820	25024	0003	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3823	3823	25025	4B00	1C00	DB8F	5900	0D00	EB8F	5300	FC0F
3826	3826	25026	0005	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3829	3829	25027	5000	BF0F	4180	5D00	D00F	3580	5000	E30F
3832	3832	25028	0007	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3835	3835	25029	5100	6500	B28F	6100	5400	B78F	4E00	4100
3838	3838	25030	0009	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3841	3841	25031	5700	BA0F	3E80	5A00	A90F	4D80	4900	9A0F
3844	3844	25032	000B	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3847	3847	25033	5700	2900	DF8F	5300	3B00	CF8F	4500	4A00
3850	3850	25034	000D	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3853	3853	25035	5C00	0000	1080	5100	F10F	1D80	4500	DD0F
3856	3856	25036	000F	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3859	3859	25037	5E00	E30F	0D80	4E00	F30F	FF8F	4200	0400
3862	3862	25038	0011	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3865	3865	25039	5F00	4200	DD8F	4D00	3300	ED8F	4000	1F00
3868	3868	25040	0013	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3871	3871	25041	5D00	9B0F	4180	4900	AA0F	3580	3C00	BD0F
3874	3874	25042	0001	0000	FFBF	FFFF	FFFF	FFFF	FFBF	FFFF
3877	3877	25043	DD0F	0A00	2480	D00F	FA0F	1480	C20F	EB0F
3880	3880	25044	DD0F	0A00	2480	D00F	FA0F	1480	C20F	EB0F
3883	3883	25045	0241	0000	FFBF	FFBF	FDFF	FDFF	FFBF	FDFF
3886	3886	25046	0001	0000	FFBF	FFBF	FDFF	FDFF	FFBF	FDFF
3889	3889	25047	0005	0000	FFBF	FFBF	FDFF	FDFF	FFBF	FDFF
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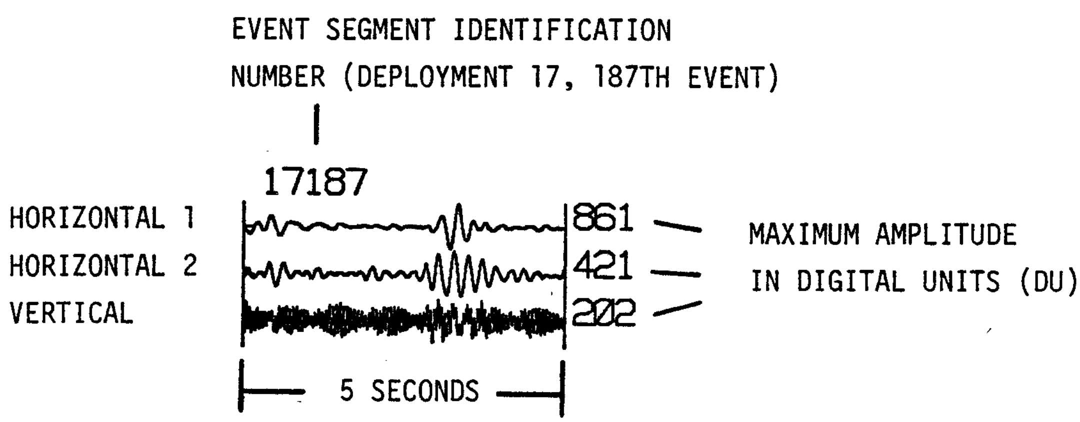
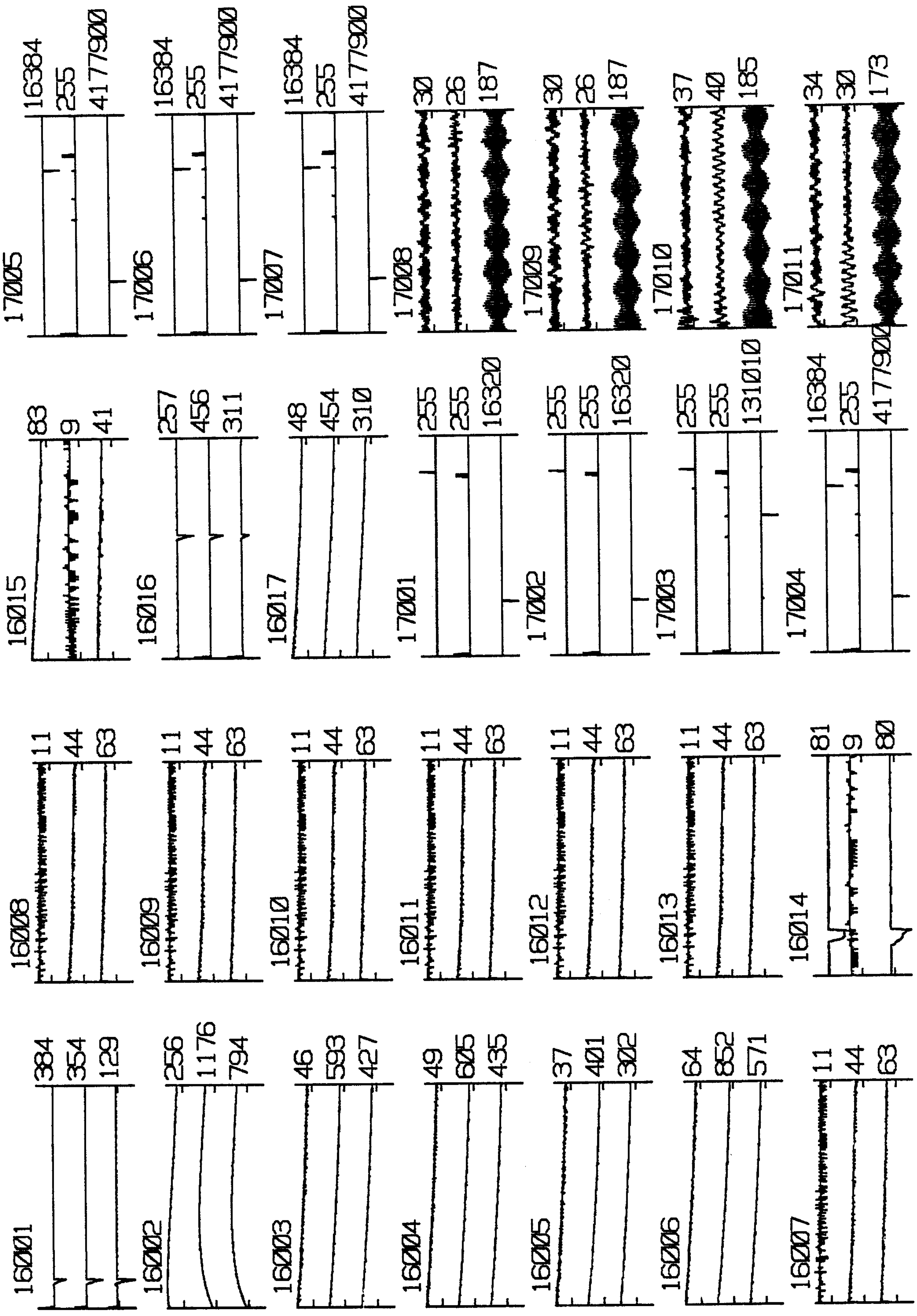
********** END OF FILE REACHED **********

APPENDIX IC: Plots of all SM-OBS records on the SEGY tape. This includes all records from 12 deployments. Each record is normalized on the plot so the maximum amplitude on the component segment is 0.25 inches.

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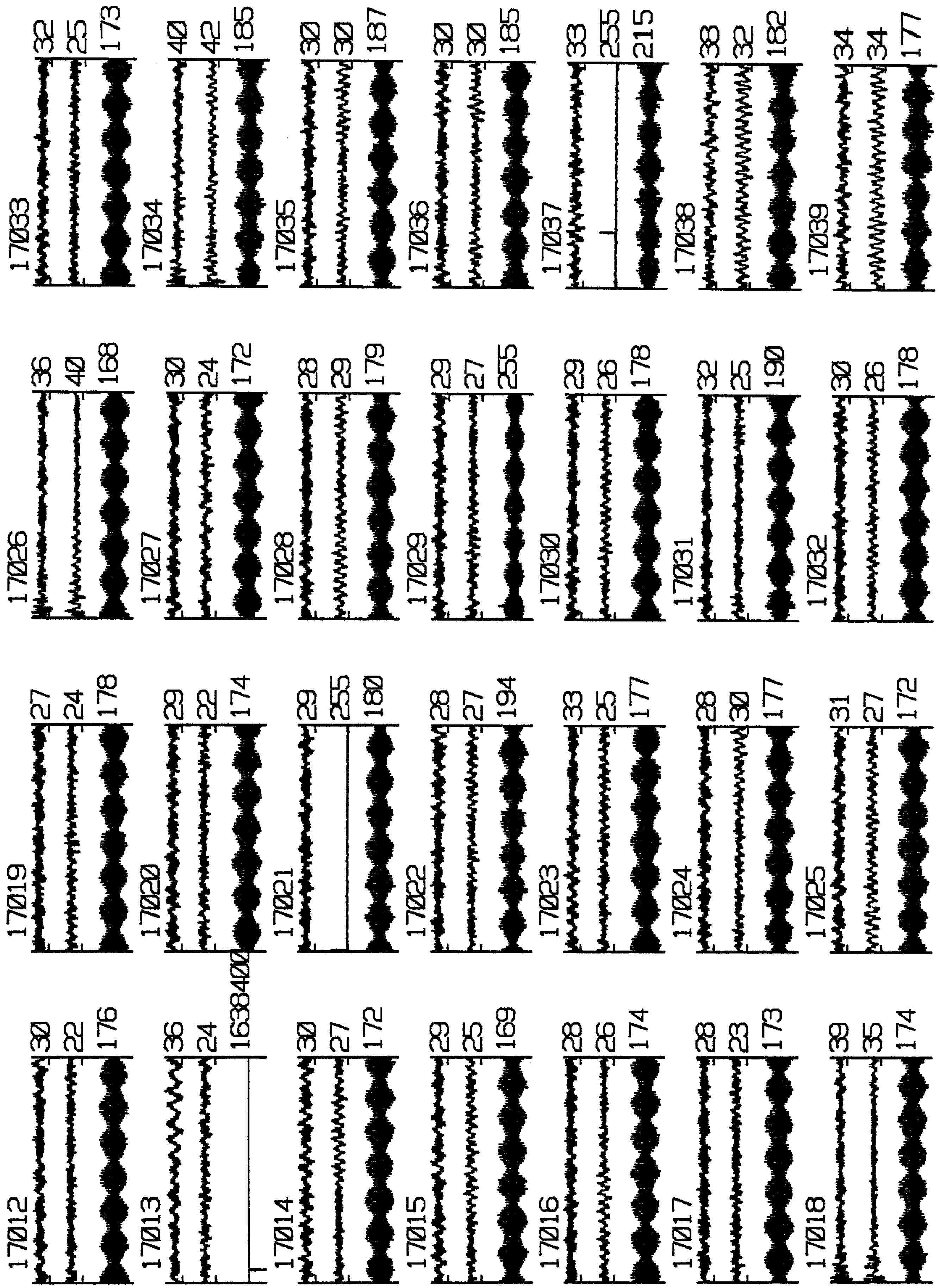
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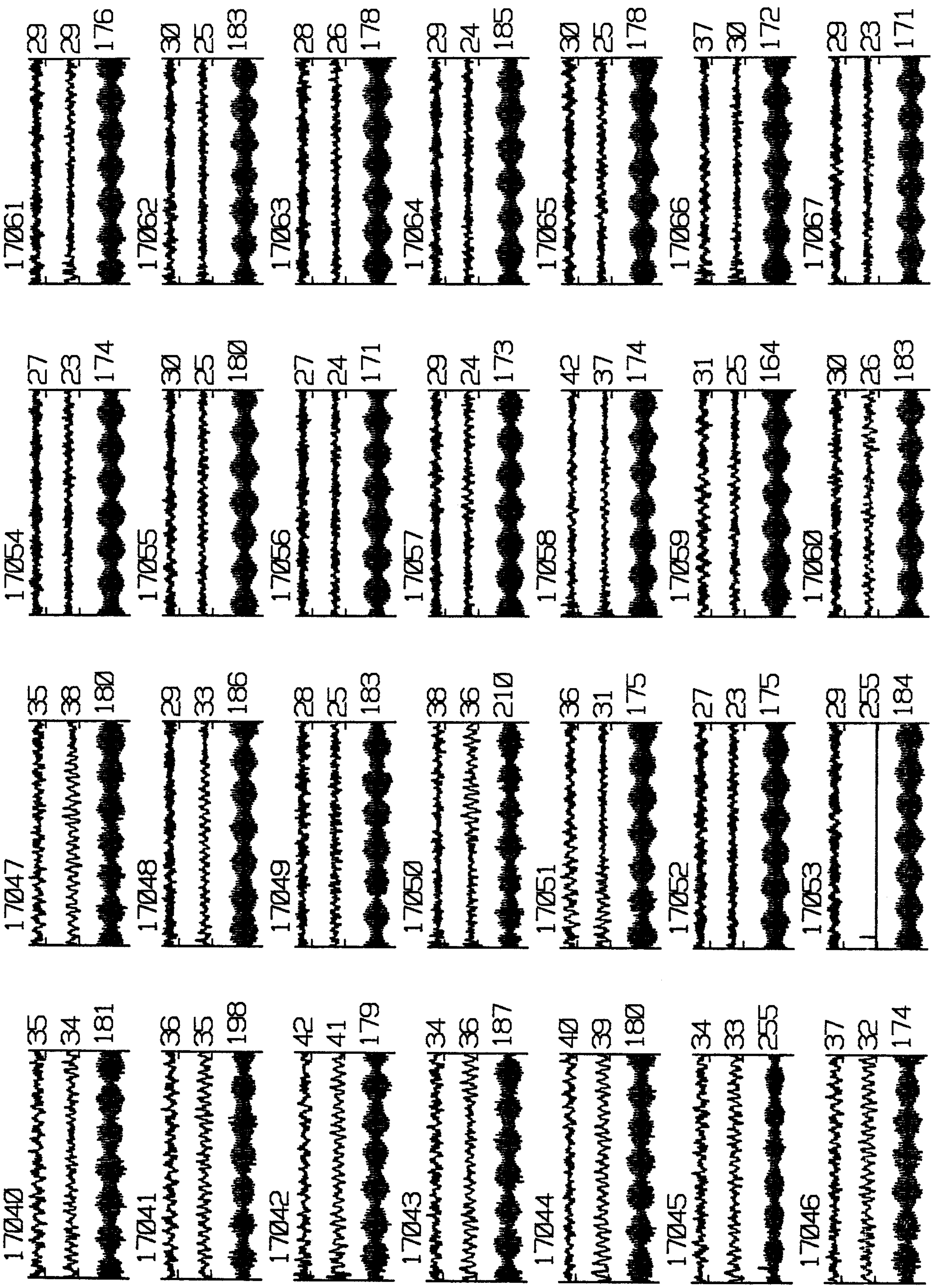
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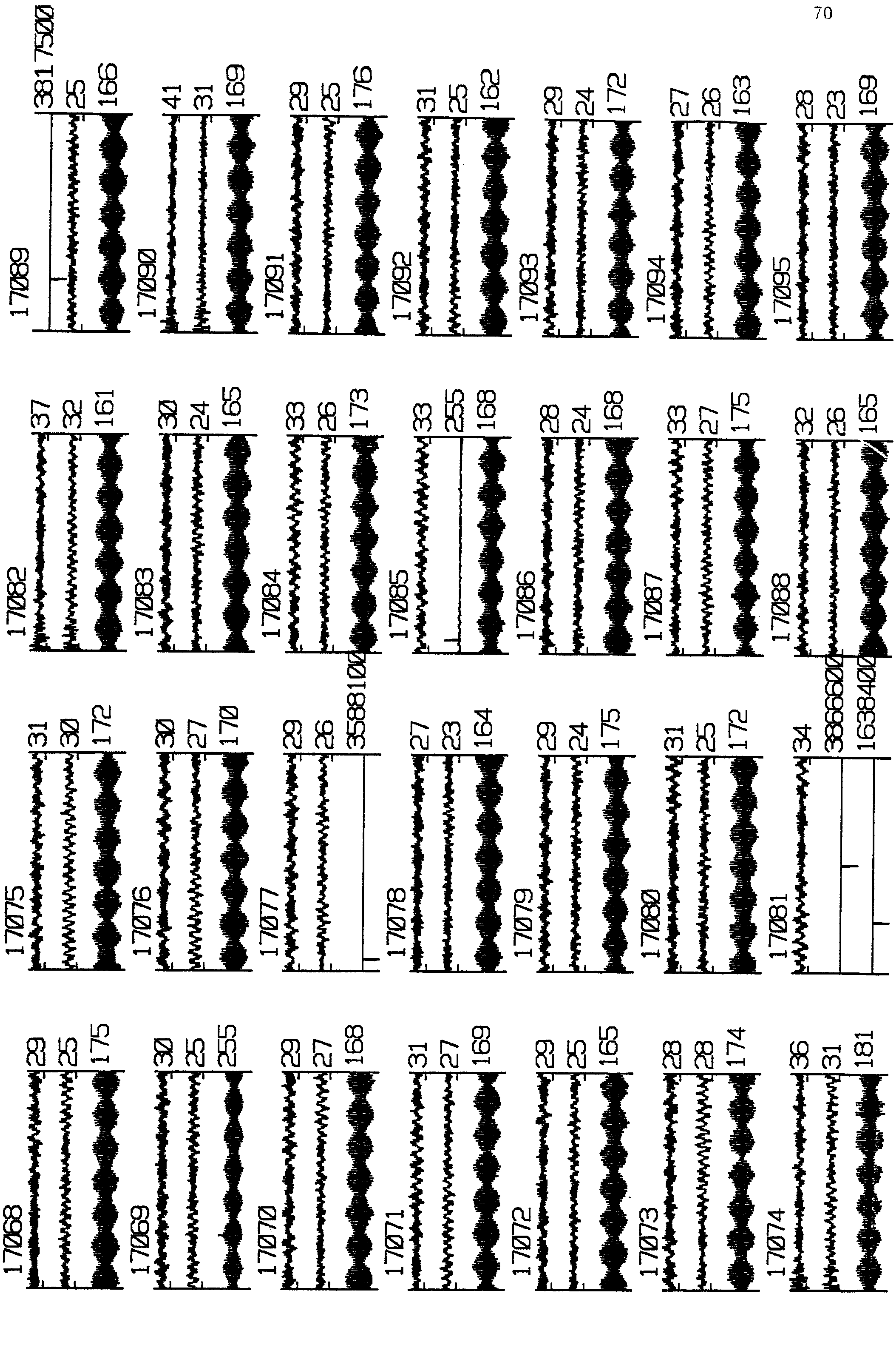
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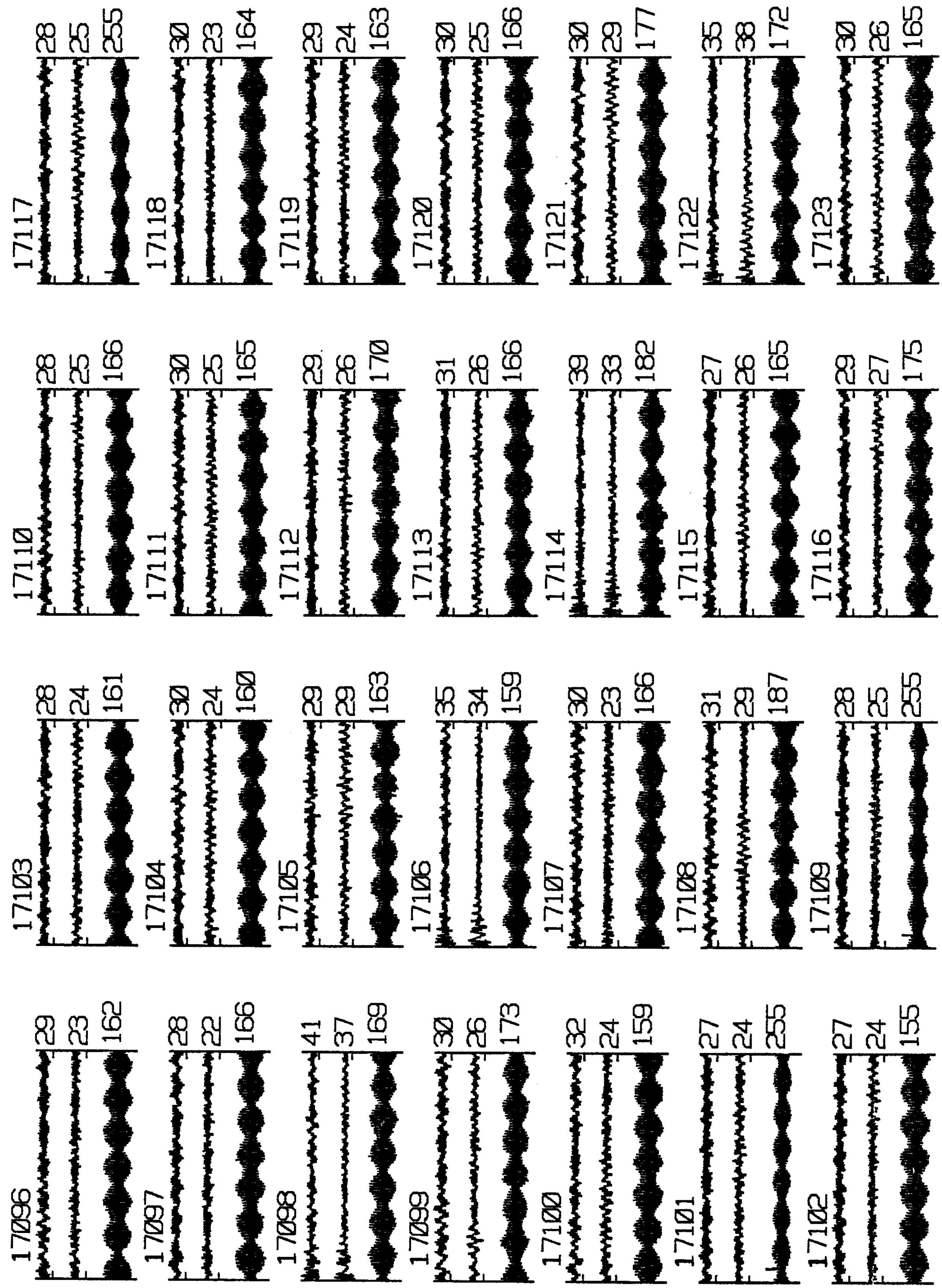
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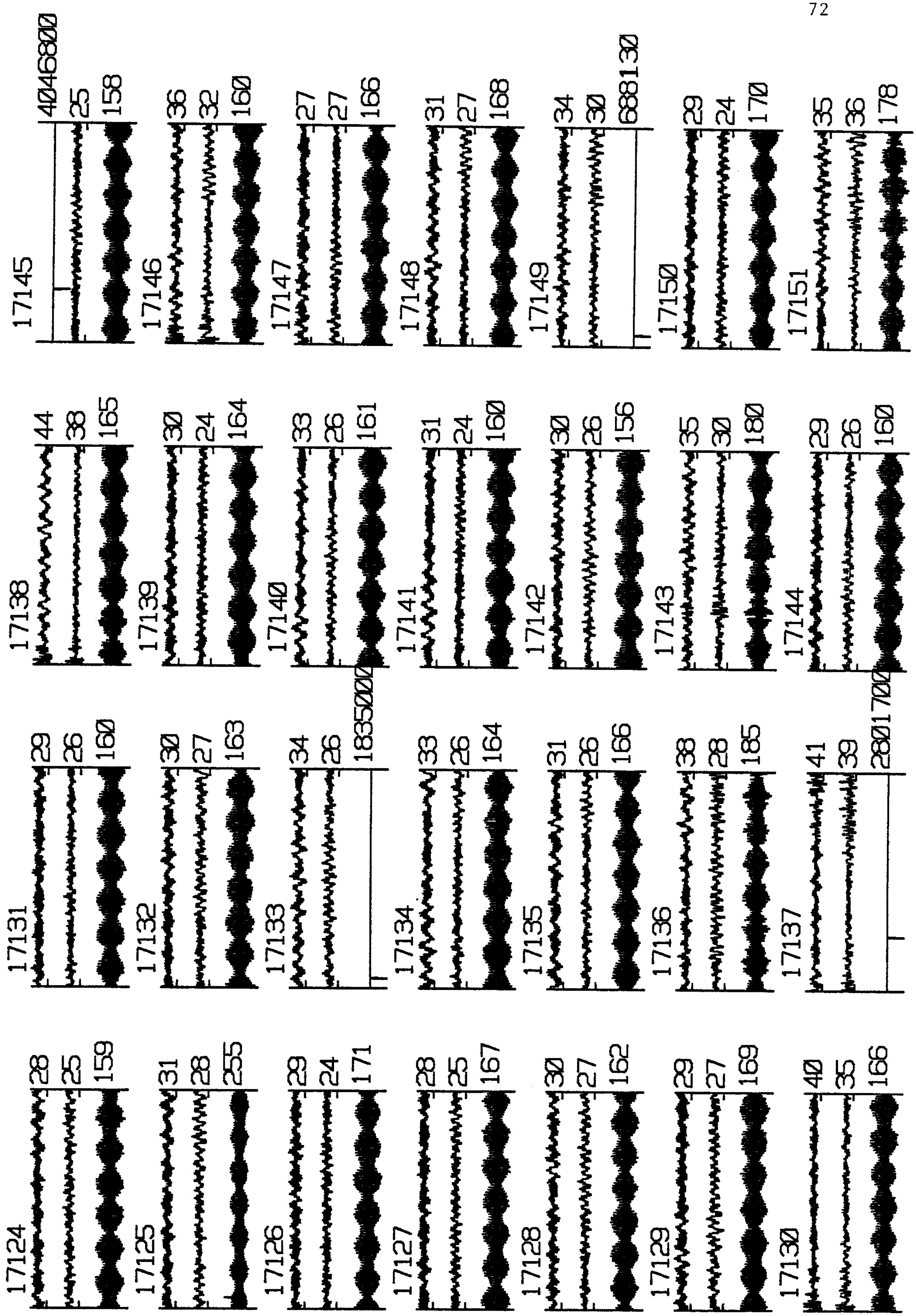
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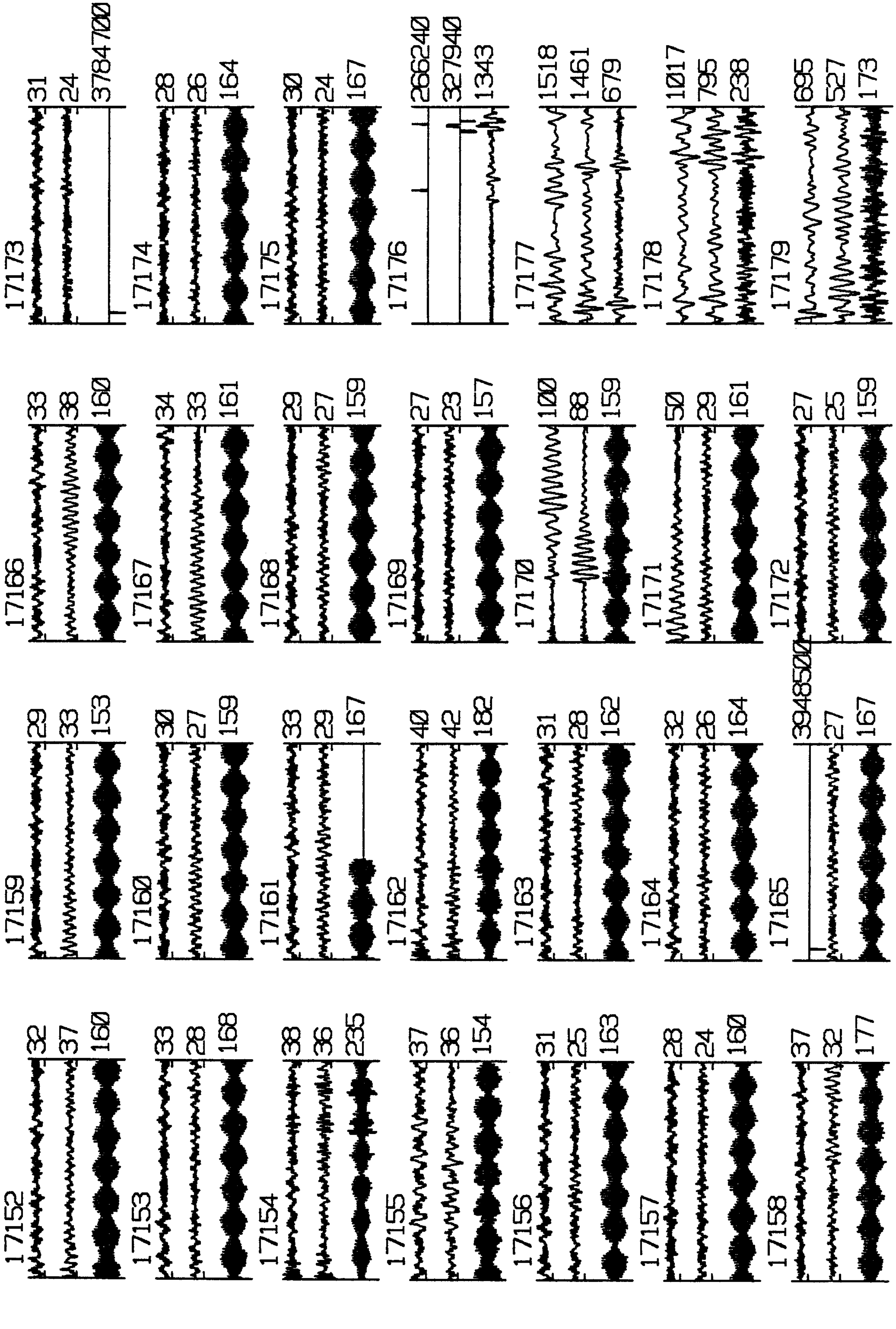
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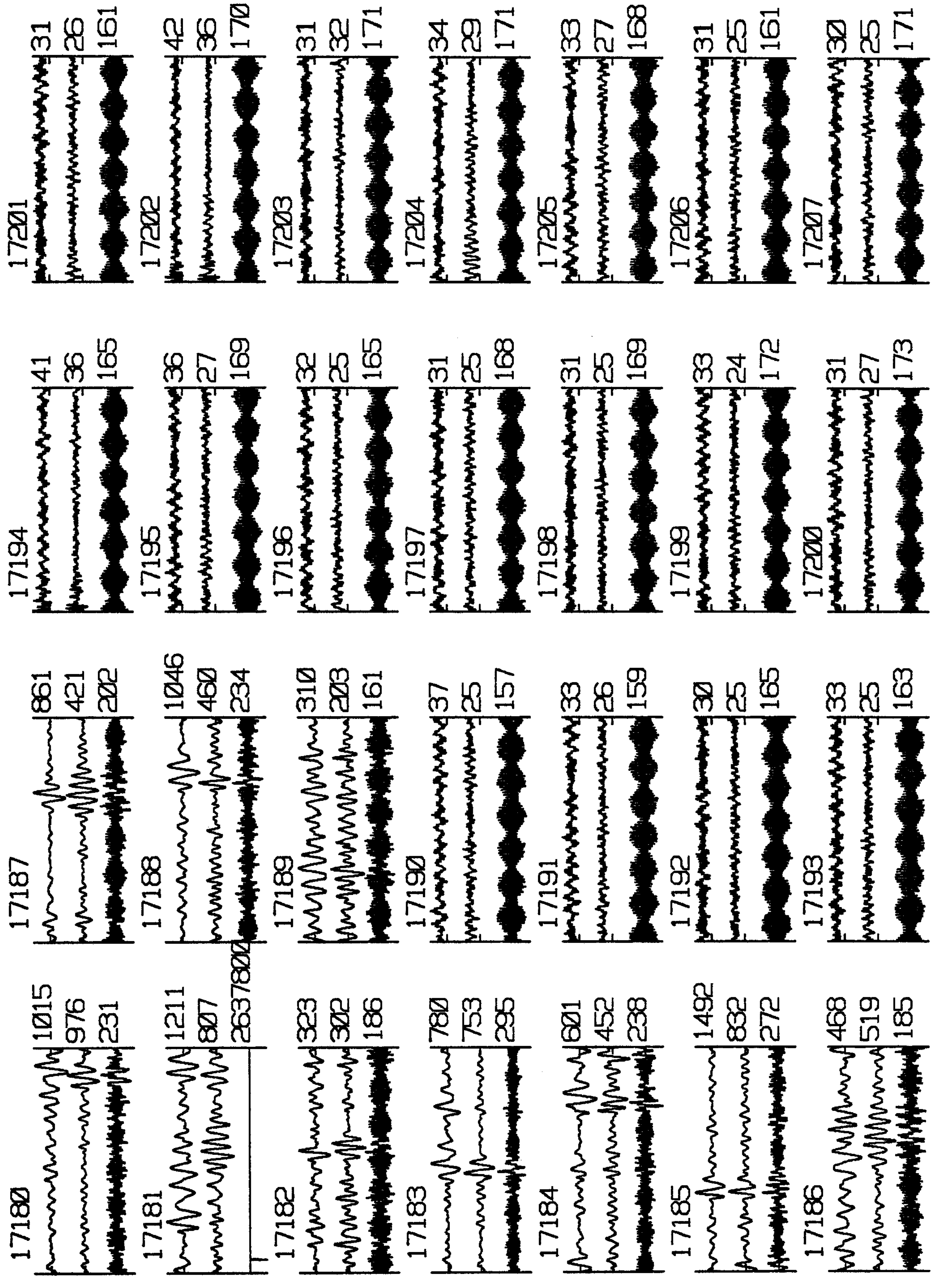
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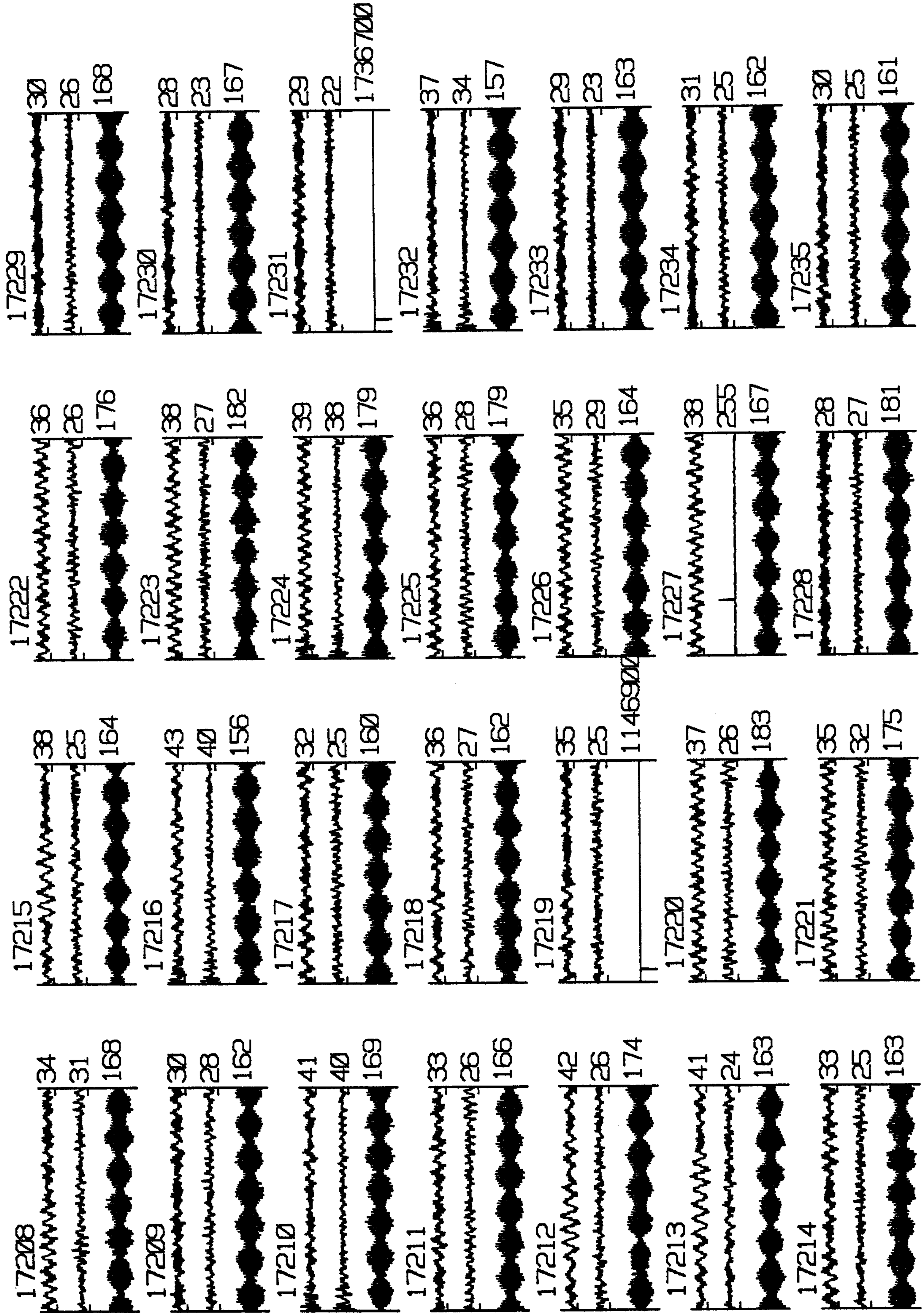
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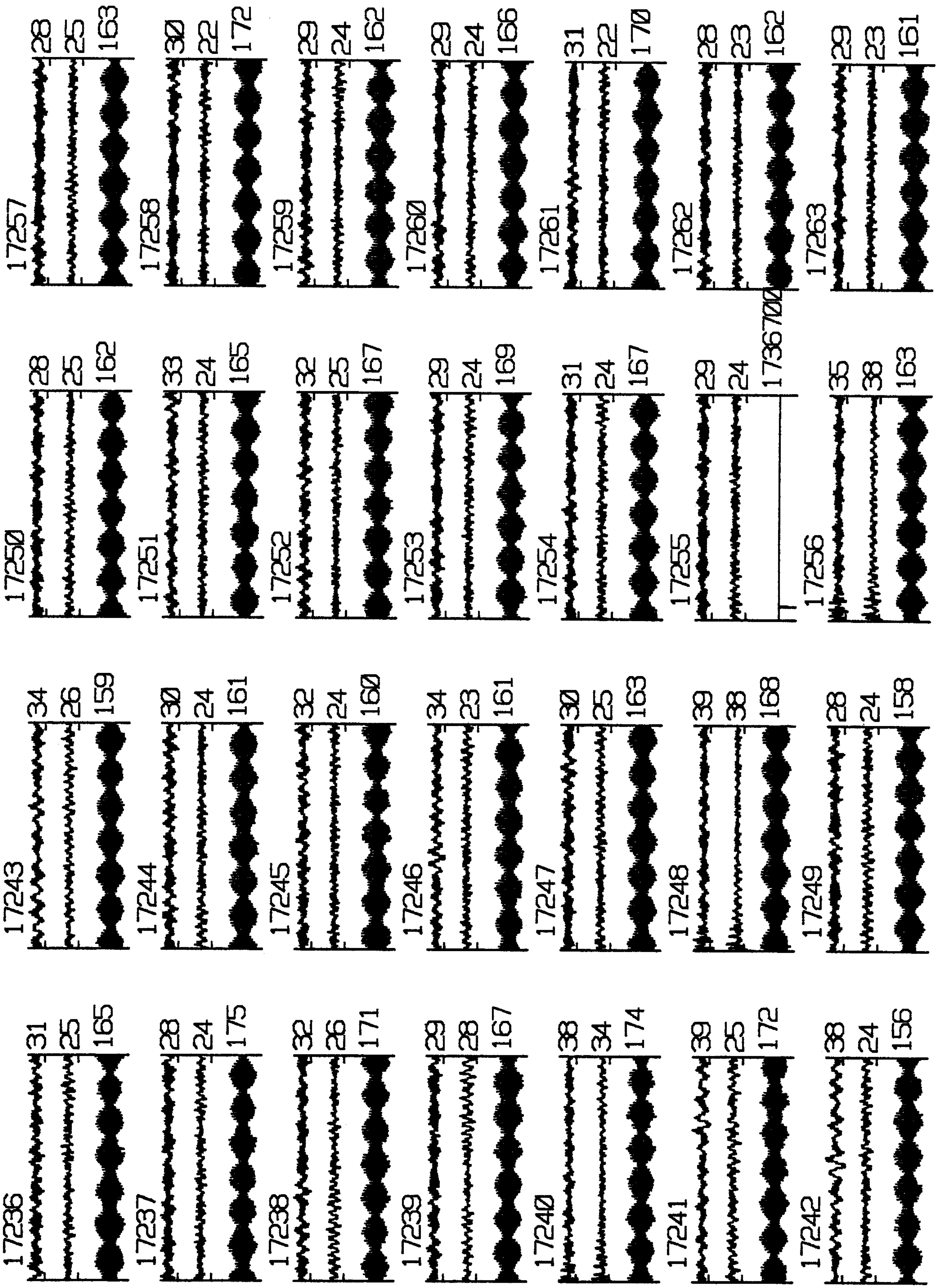
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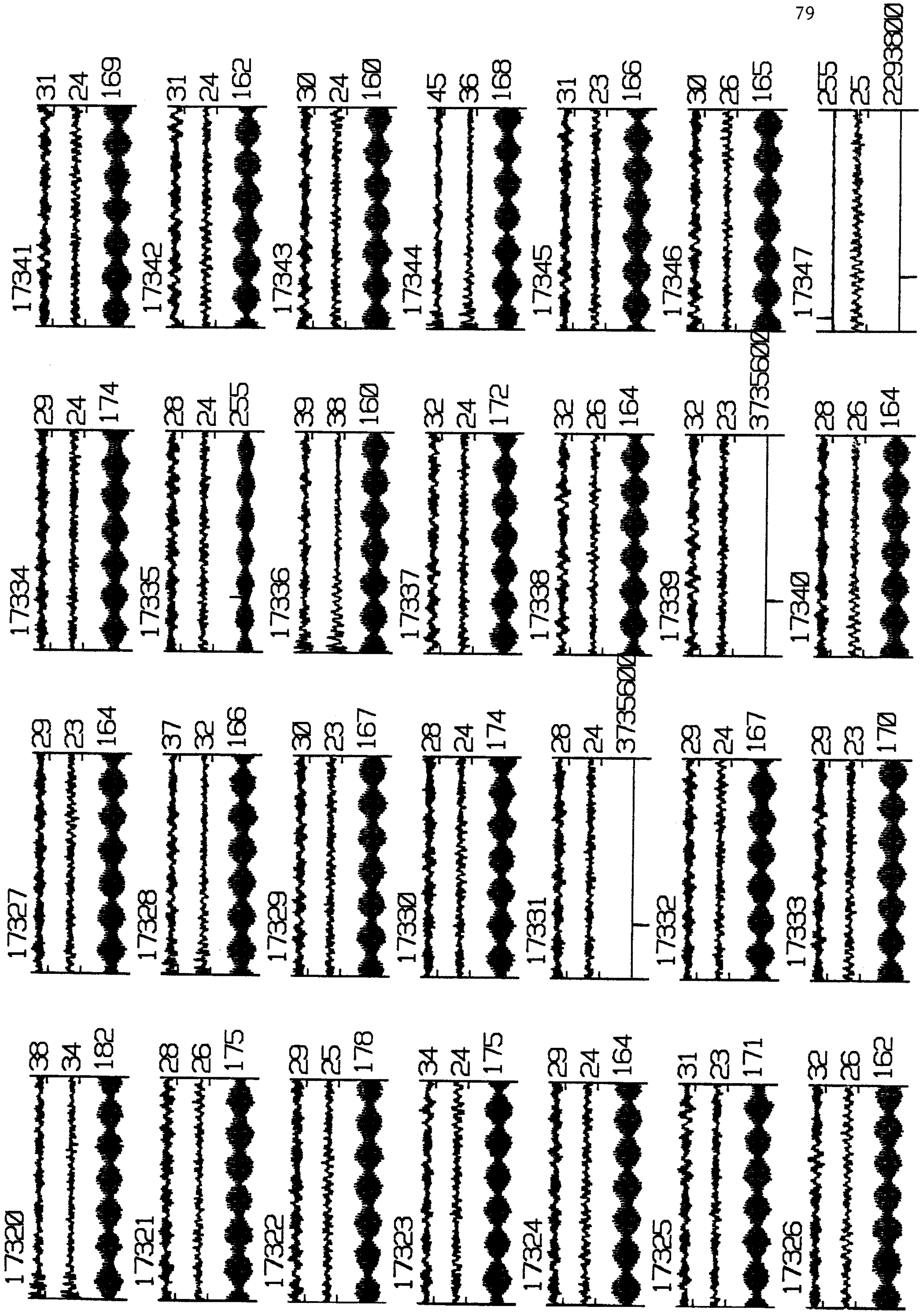
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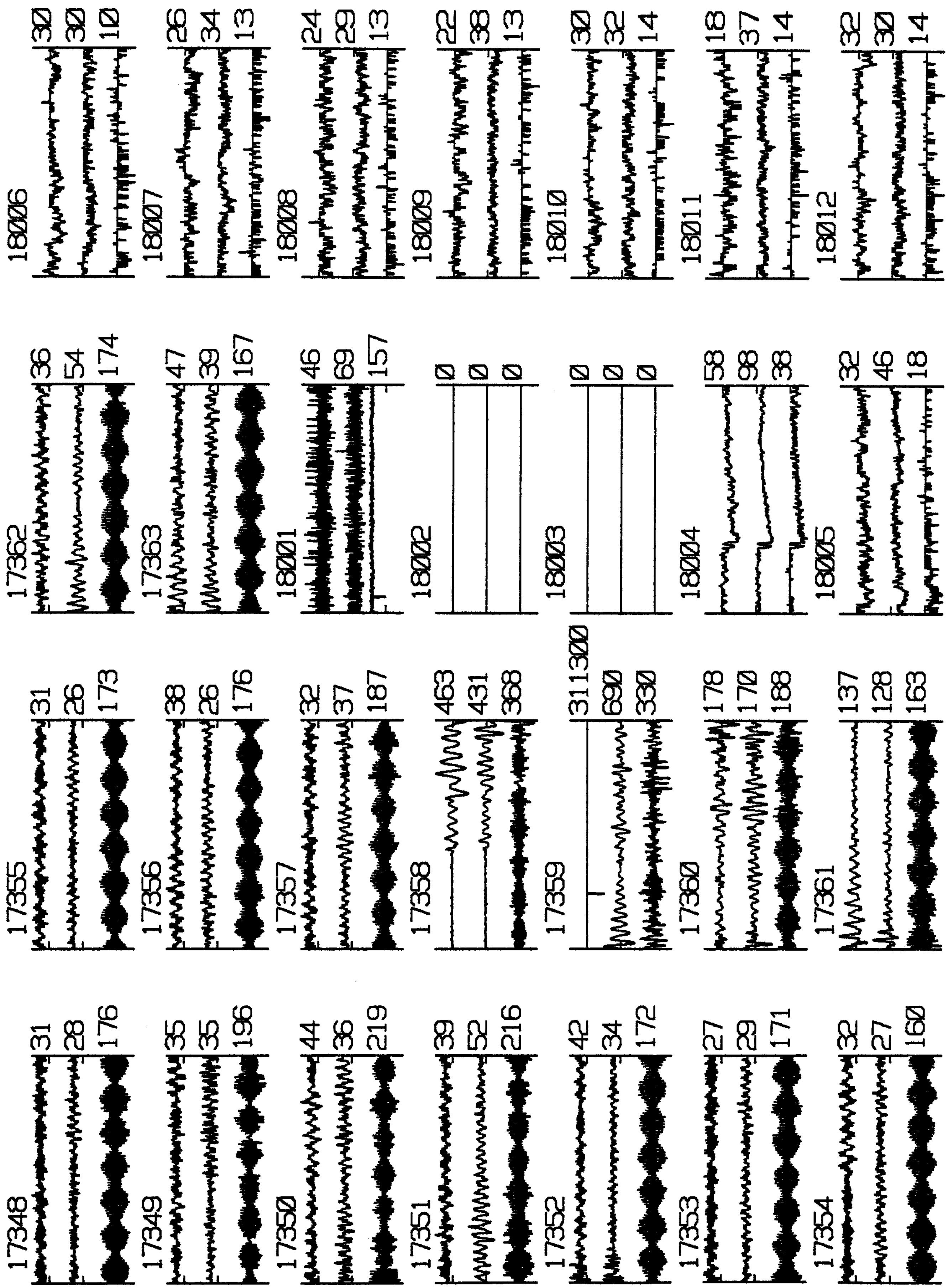
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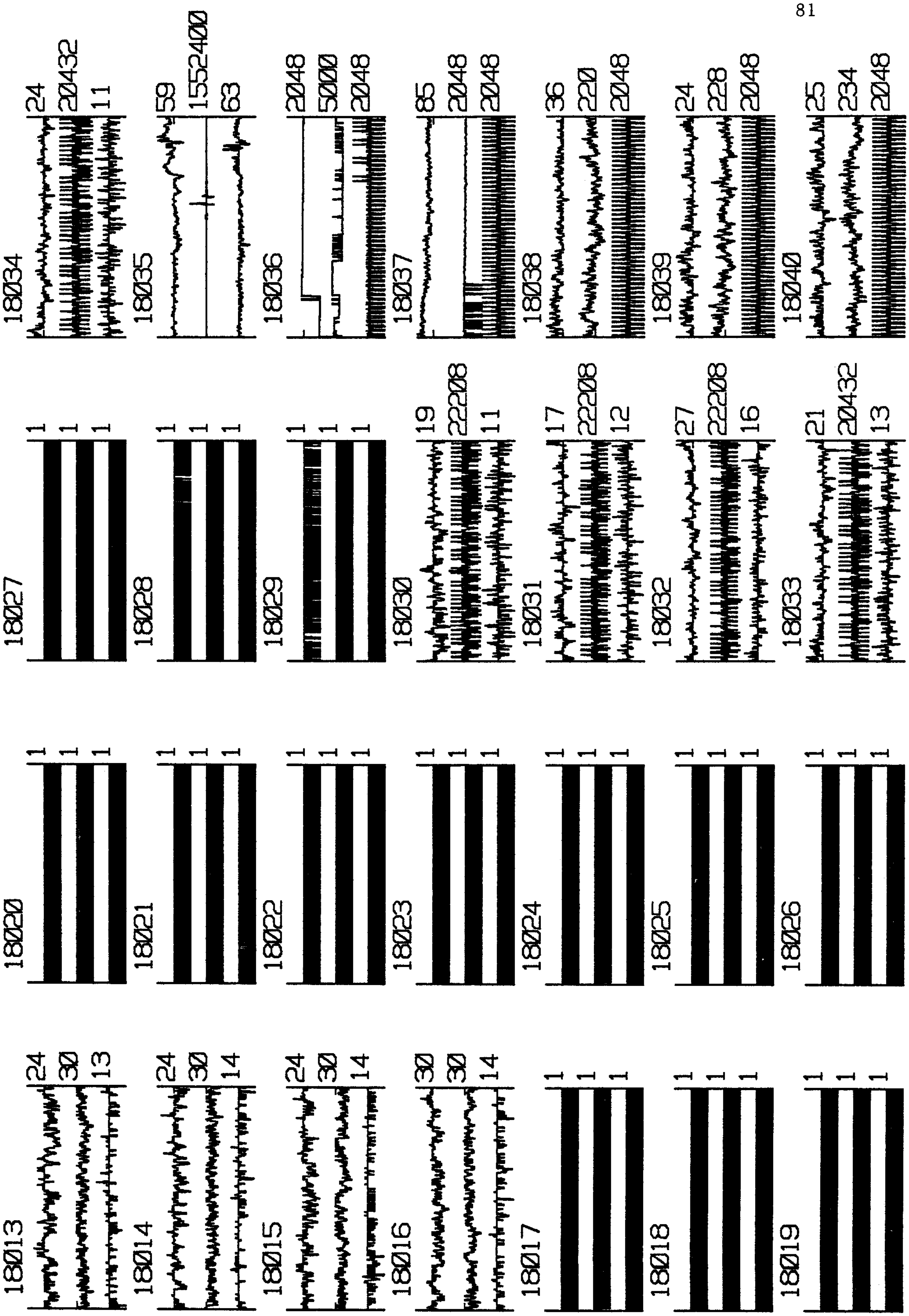
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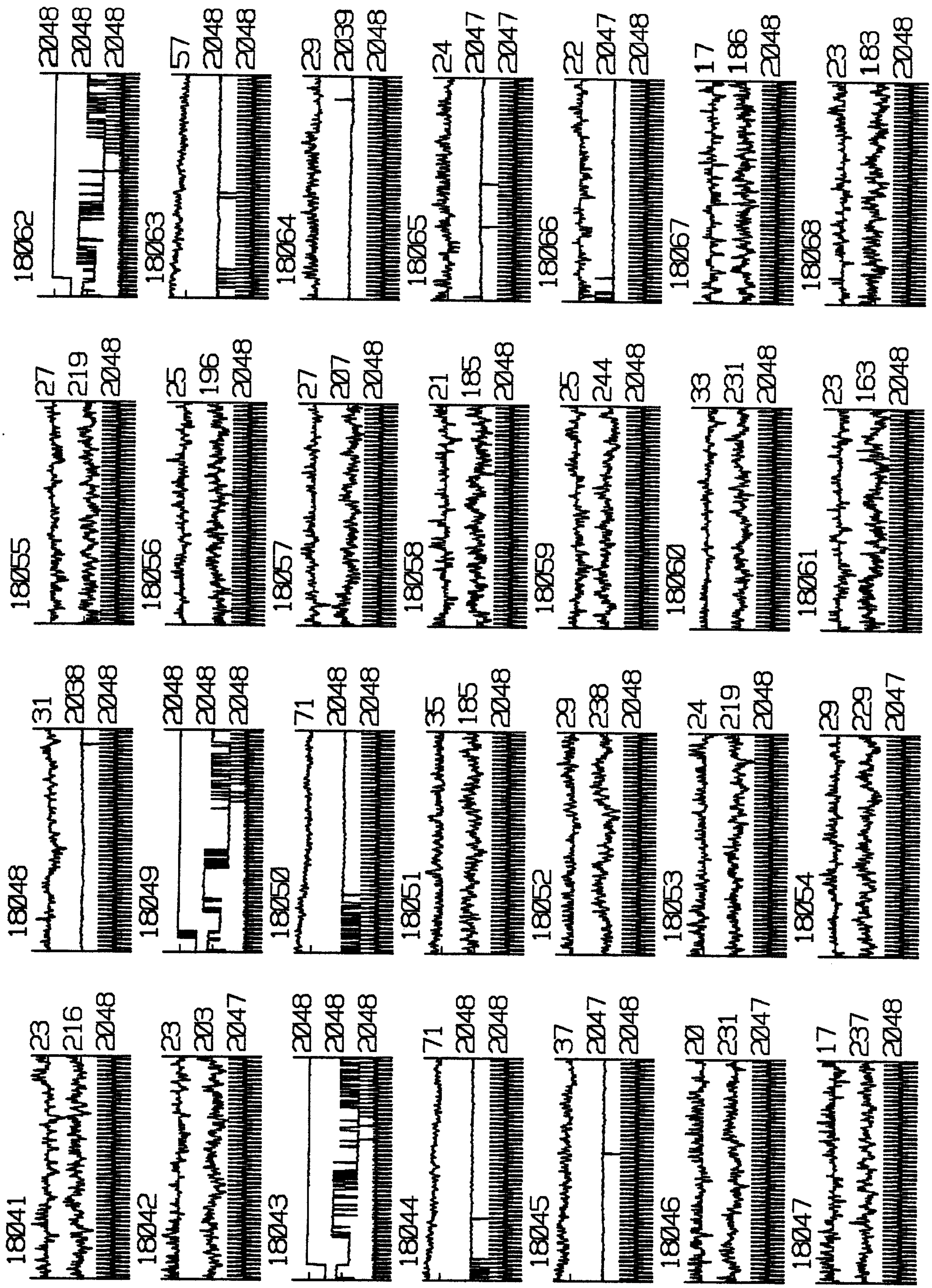
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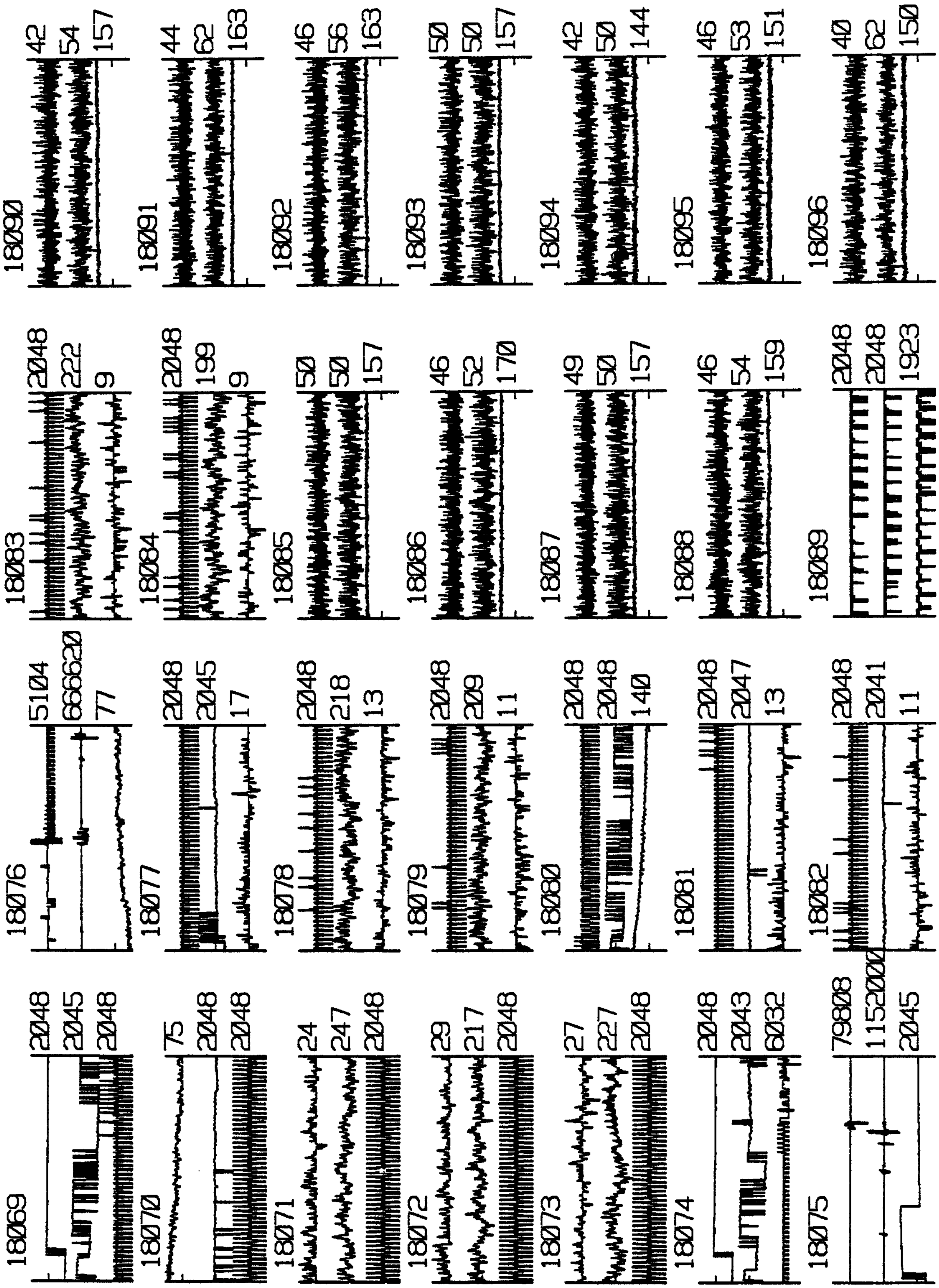

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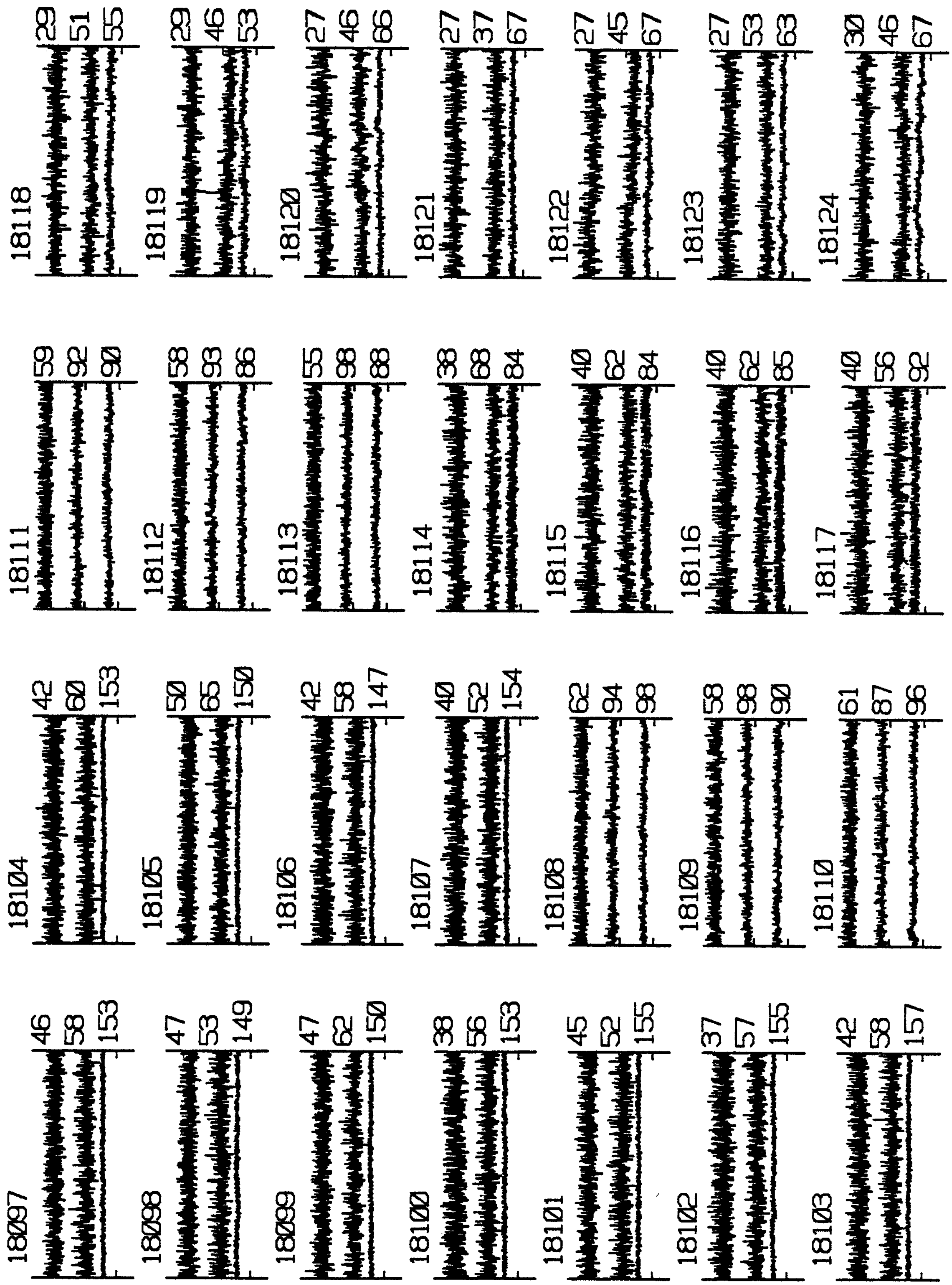
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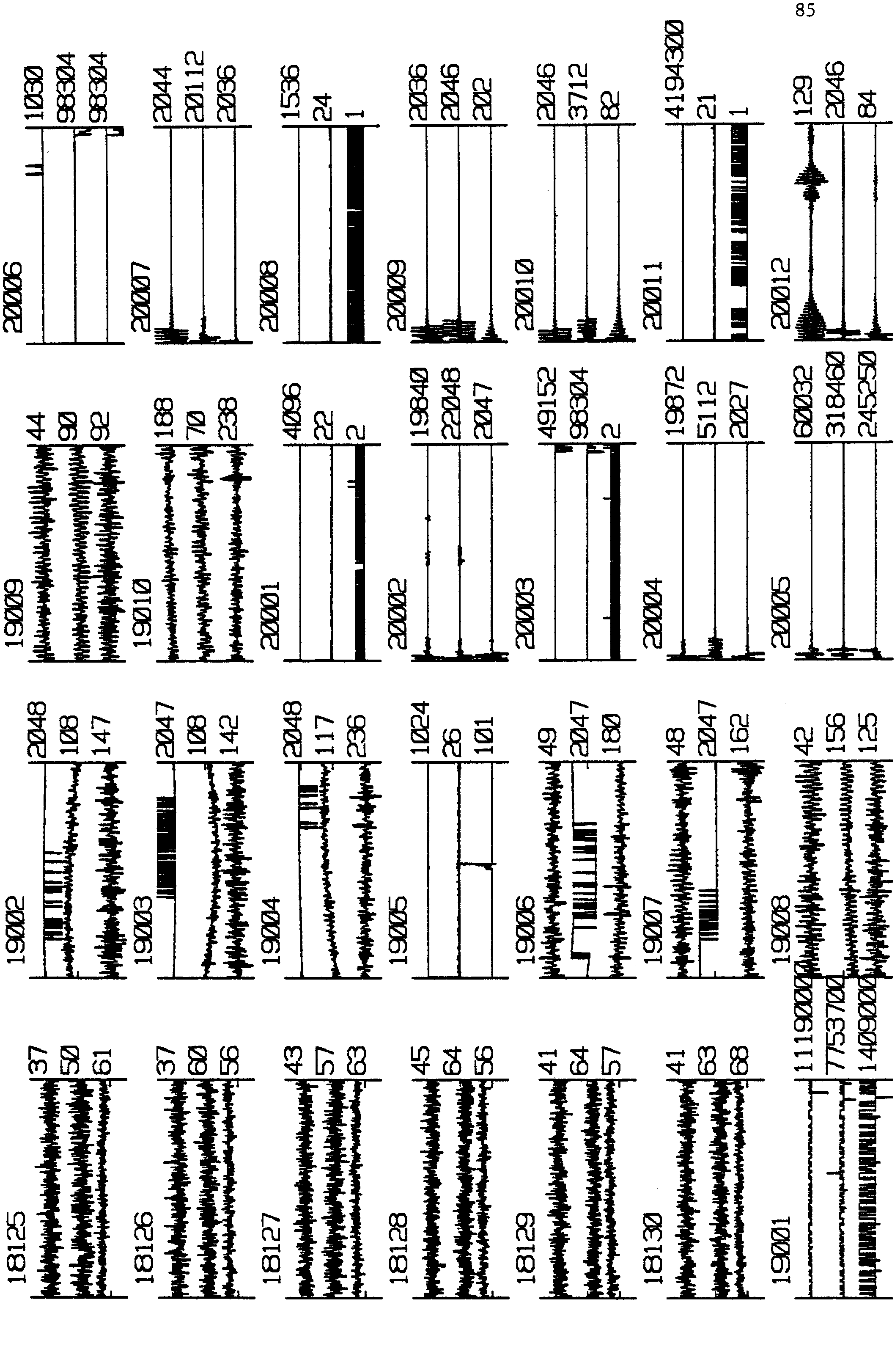
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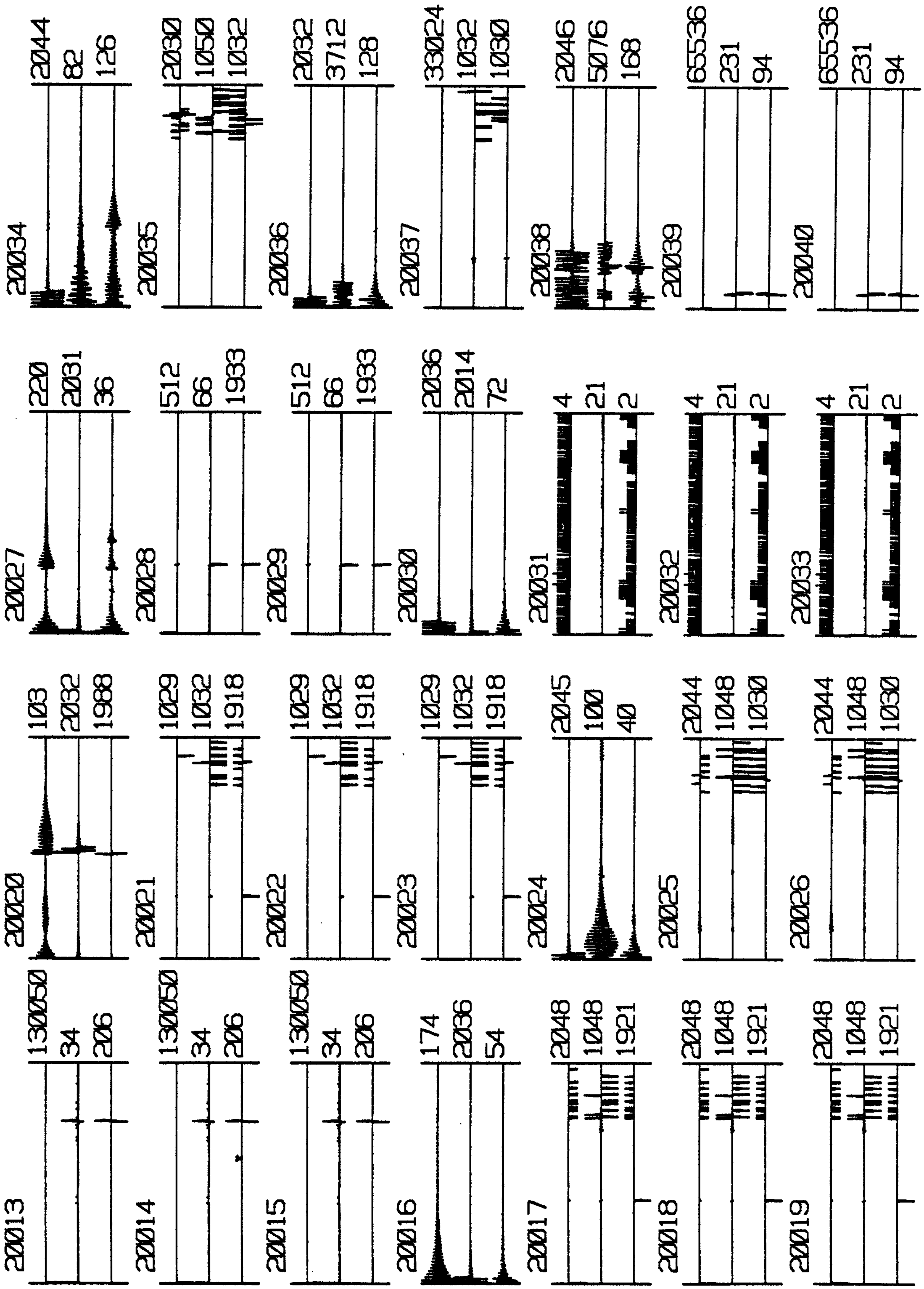
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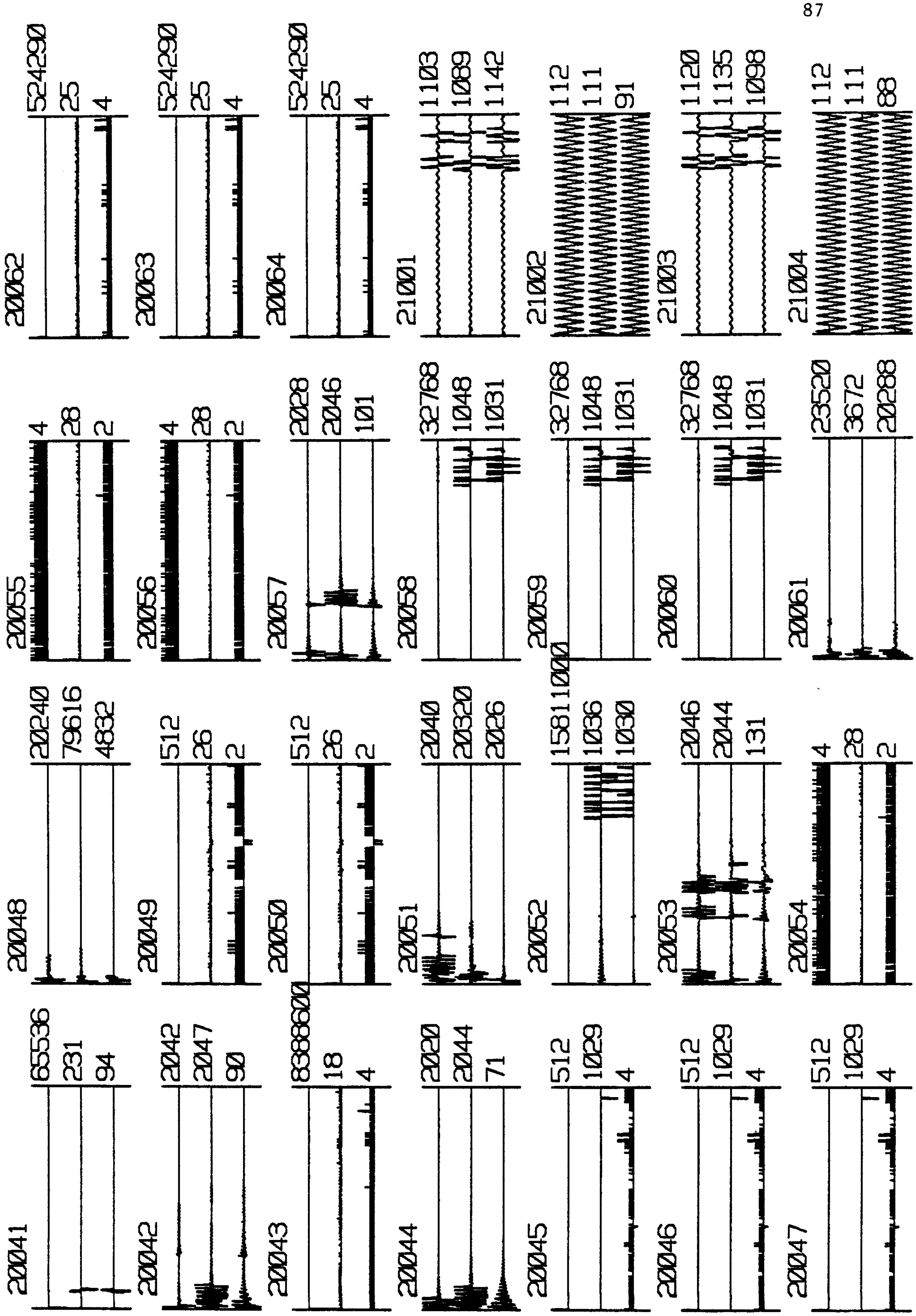
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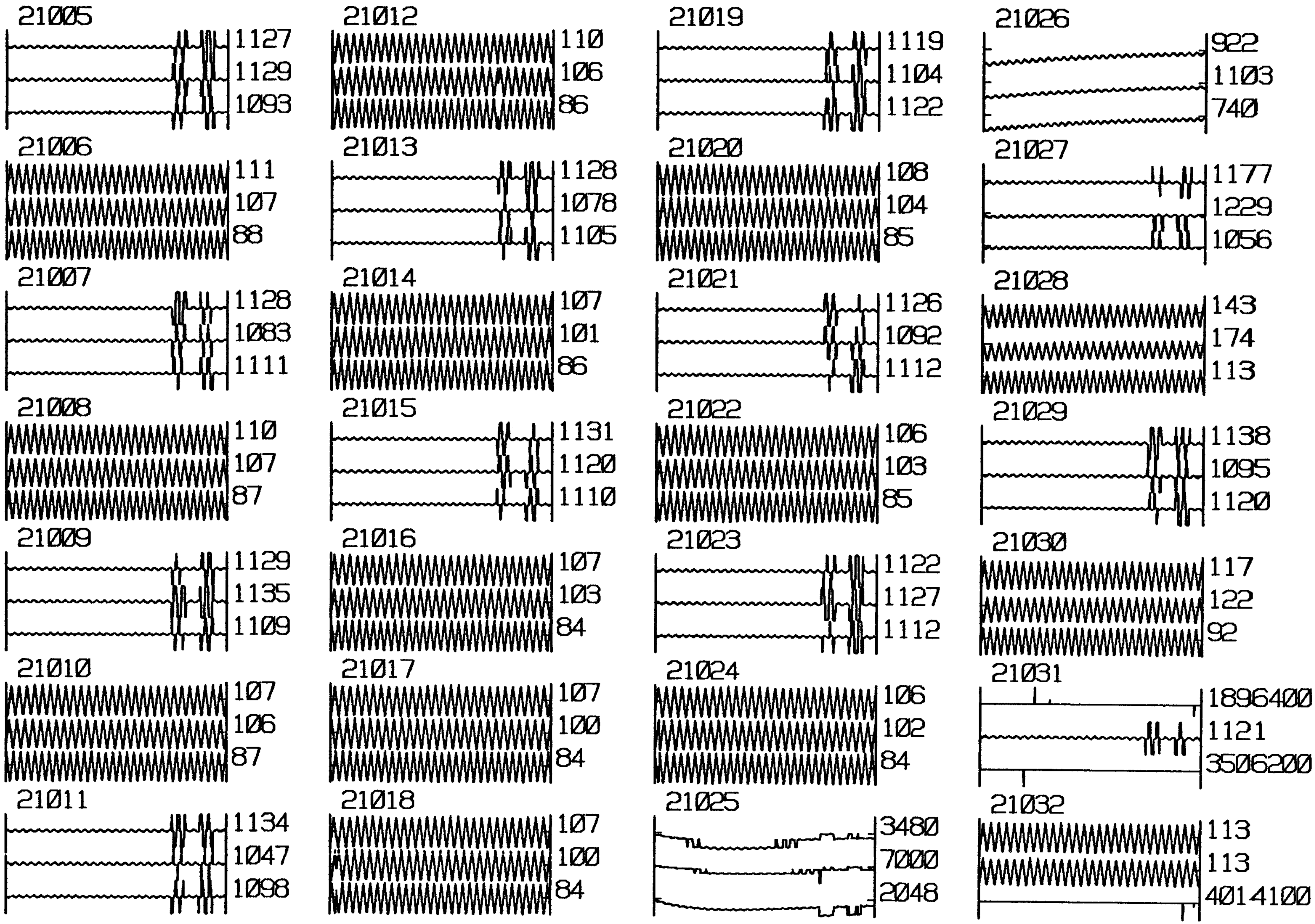
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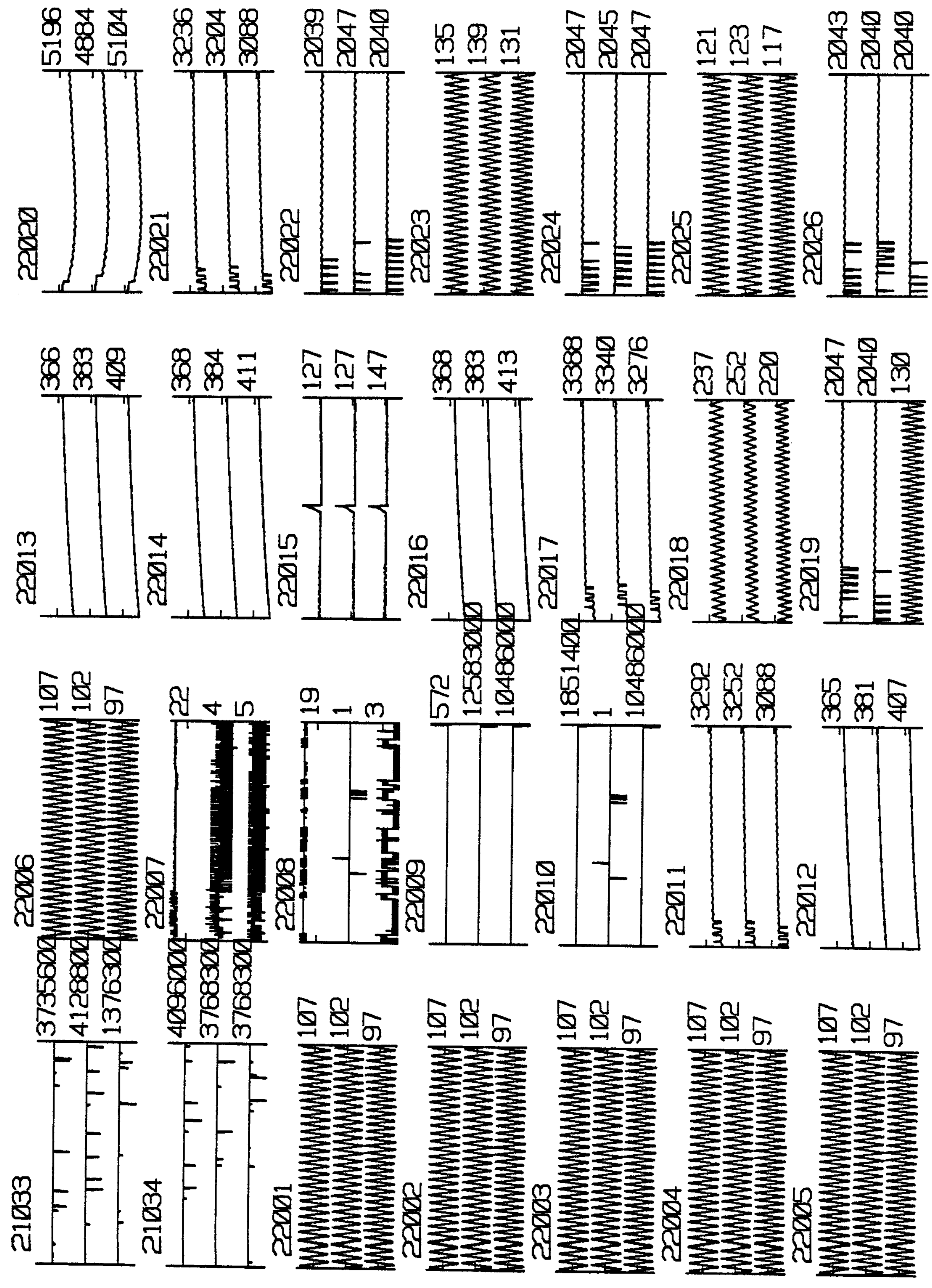

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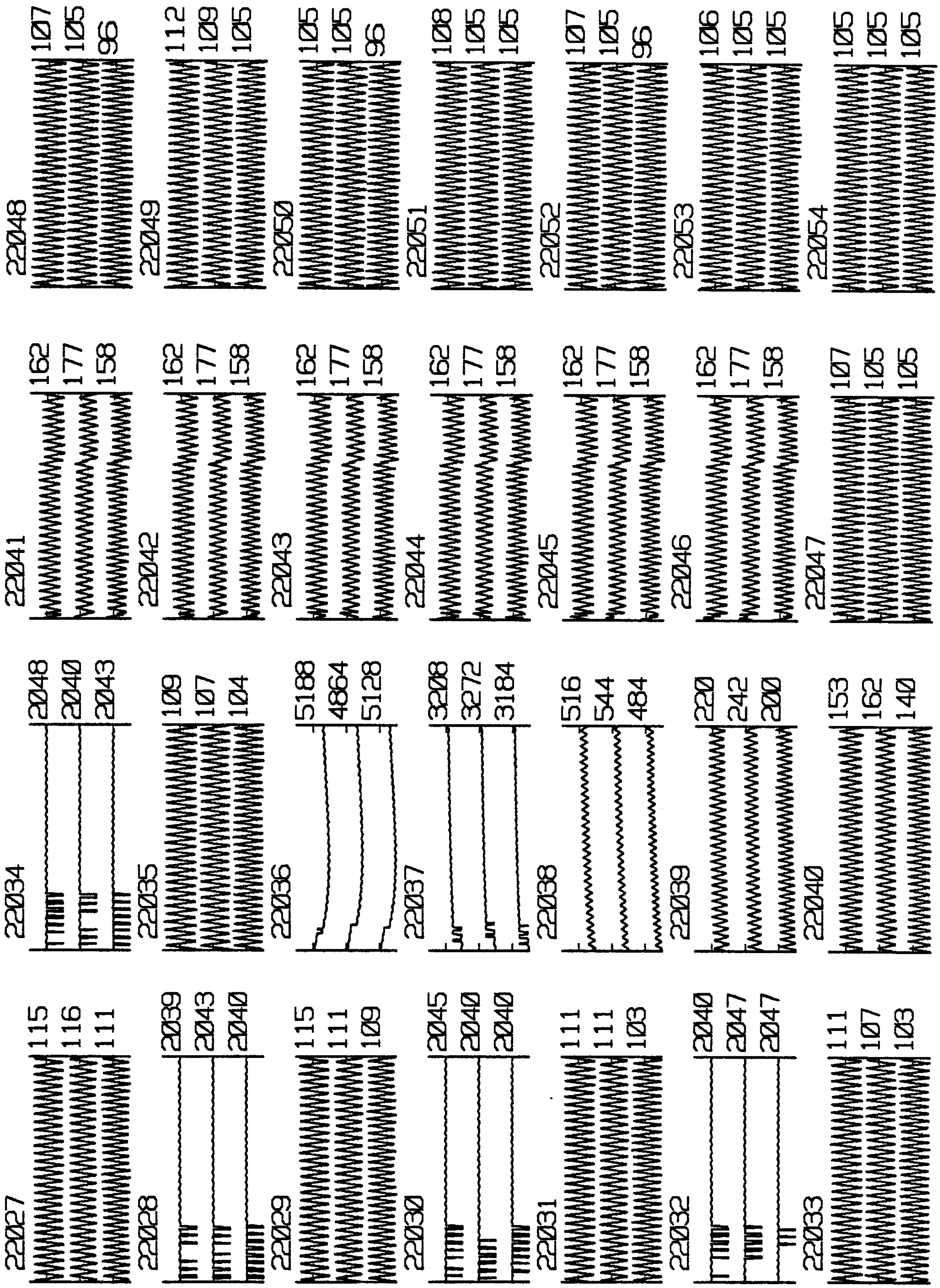
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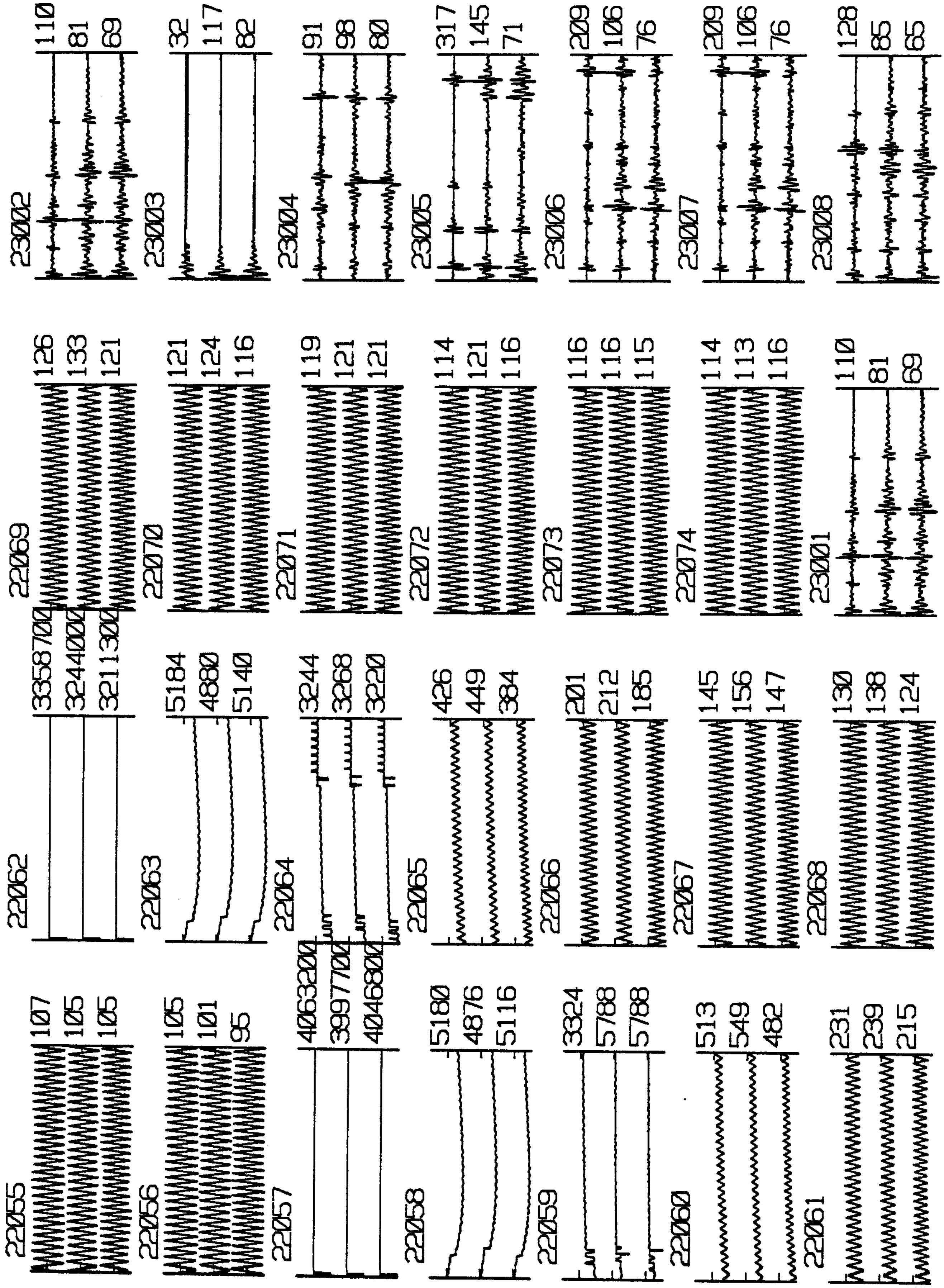
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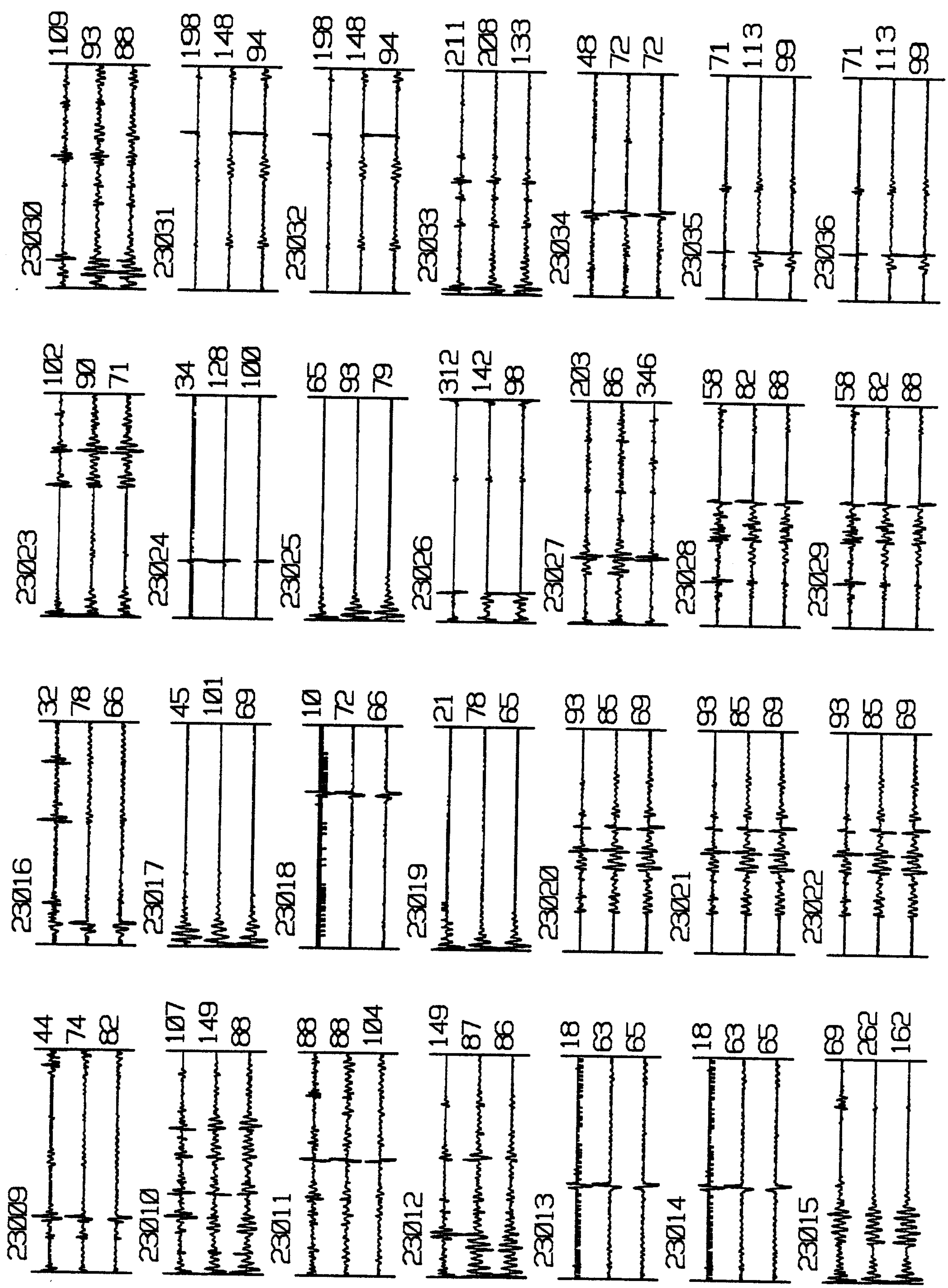
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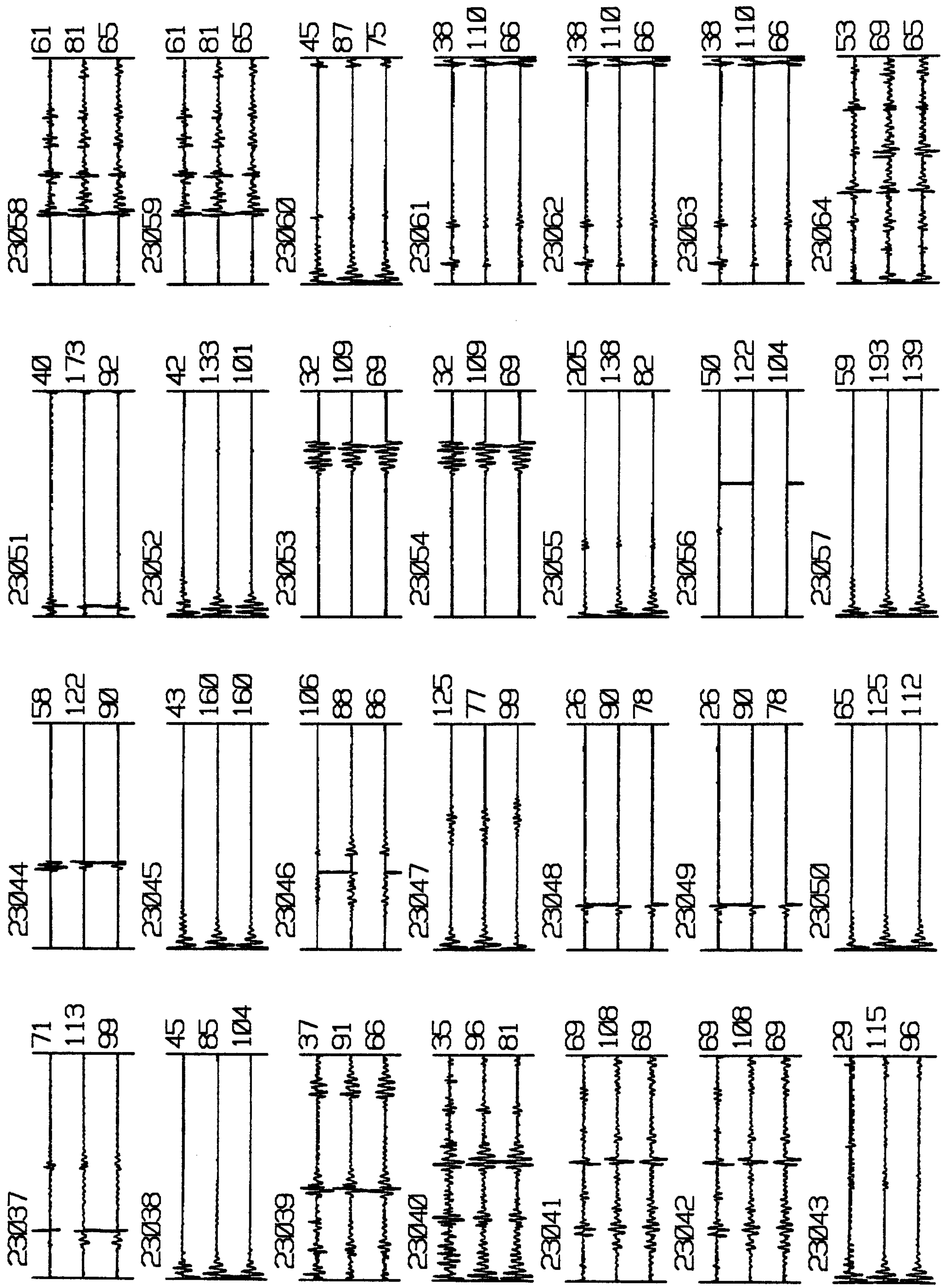

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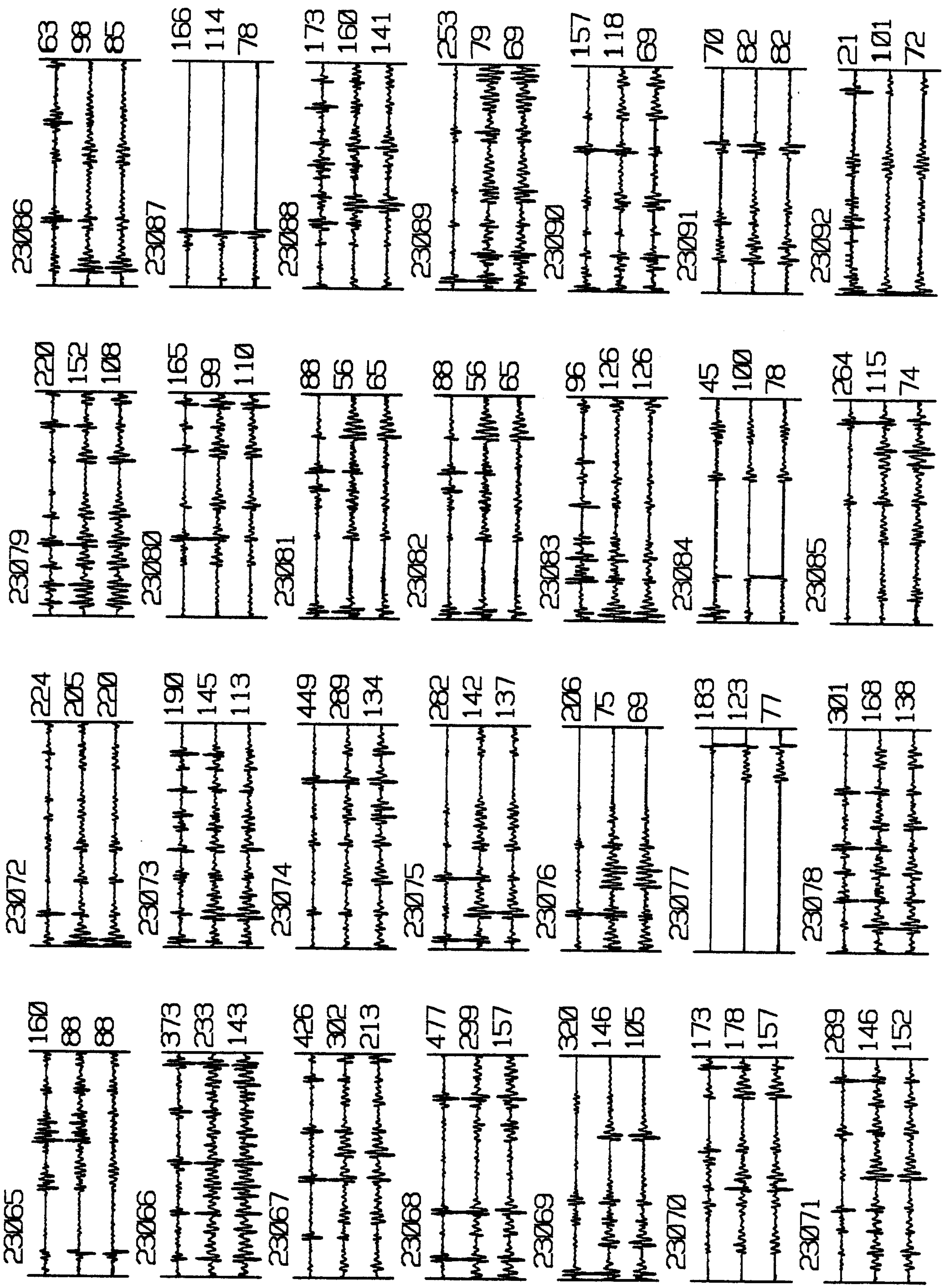
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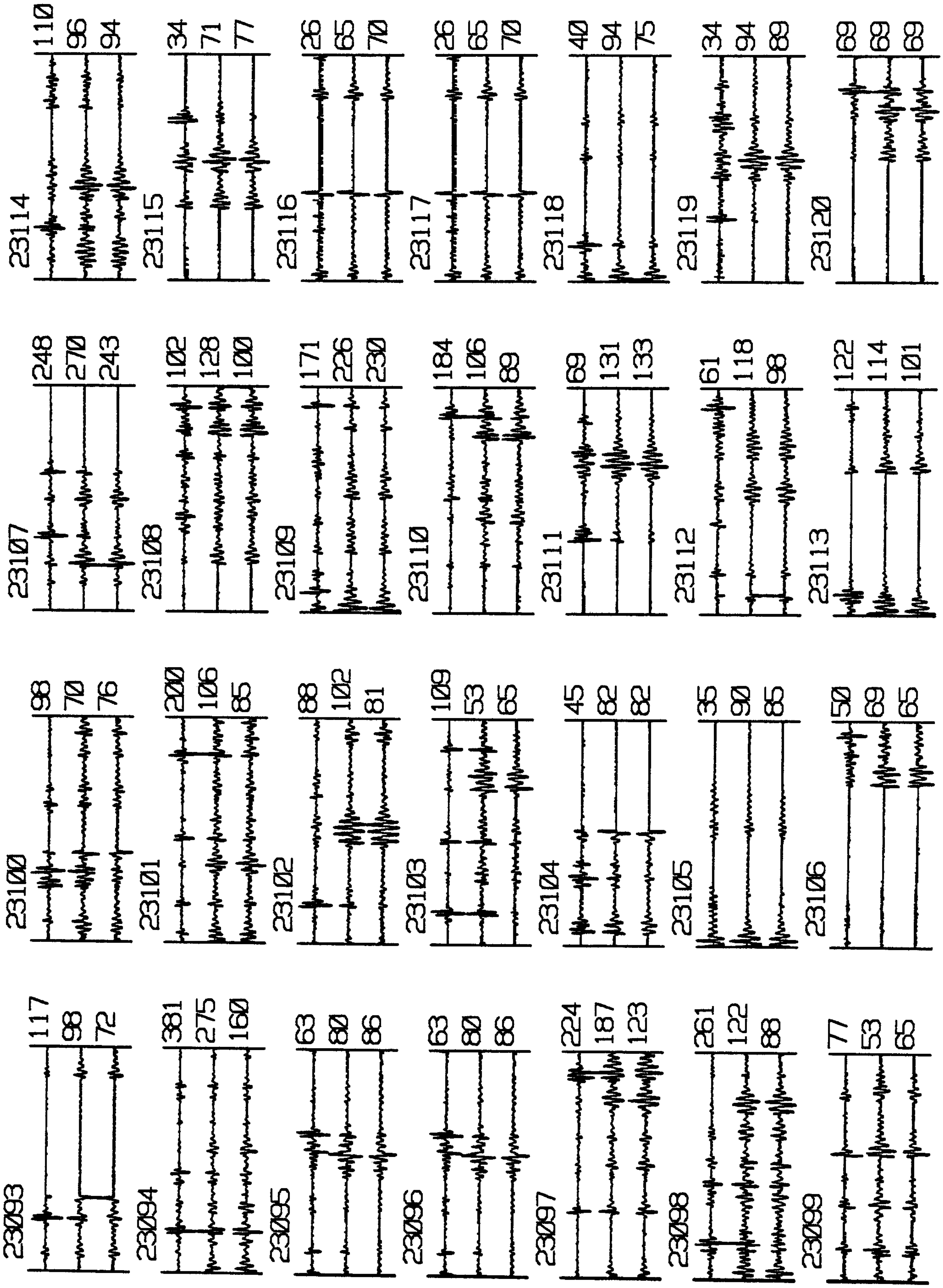
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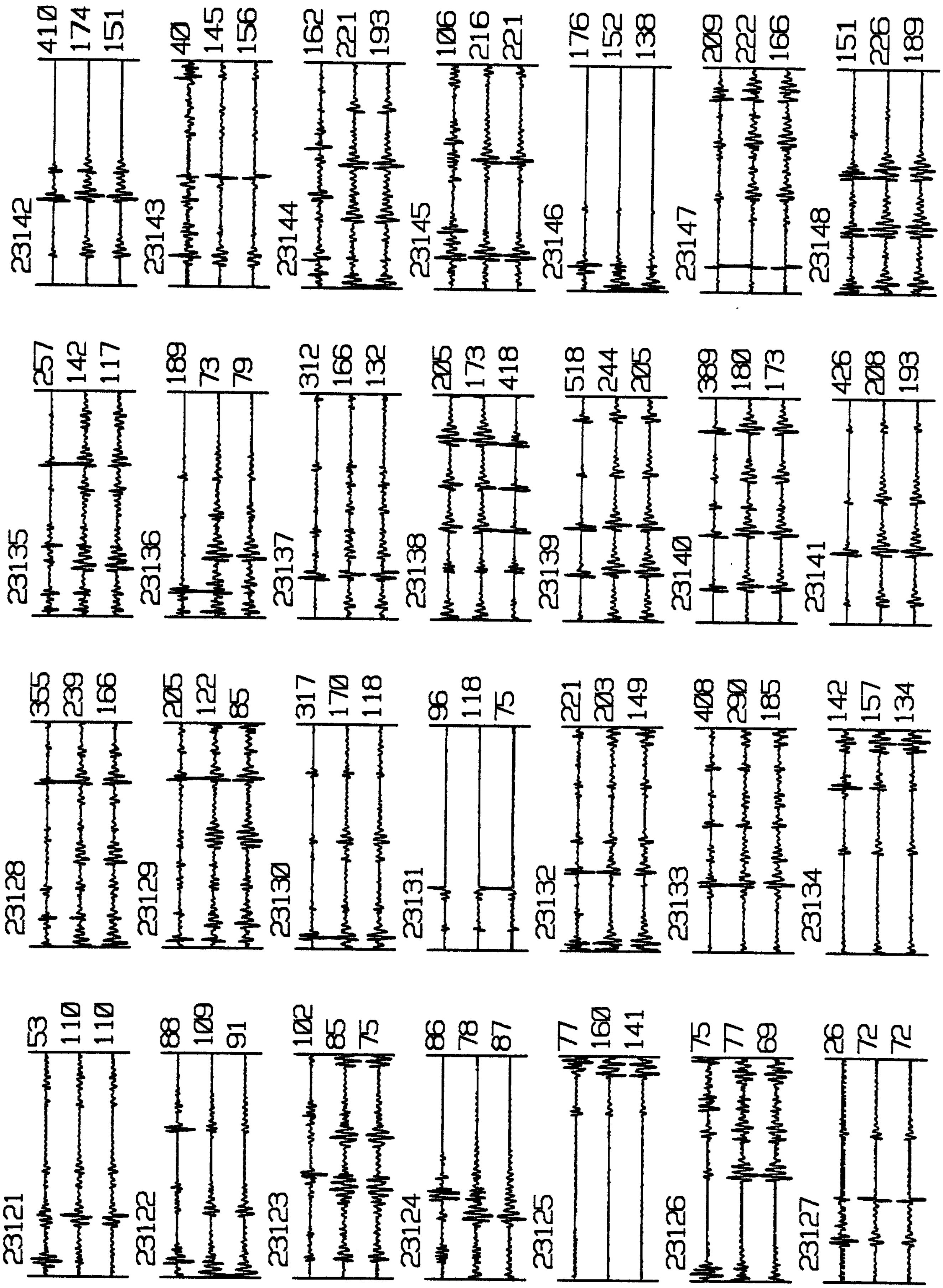
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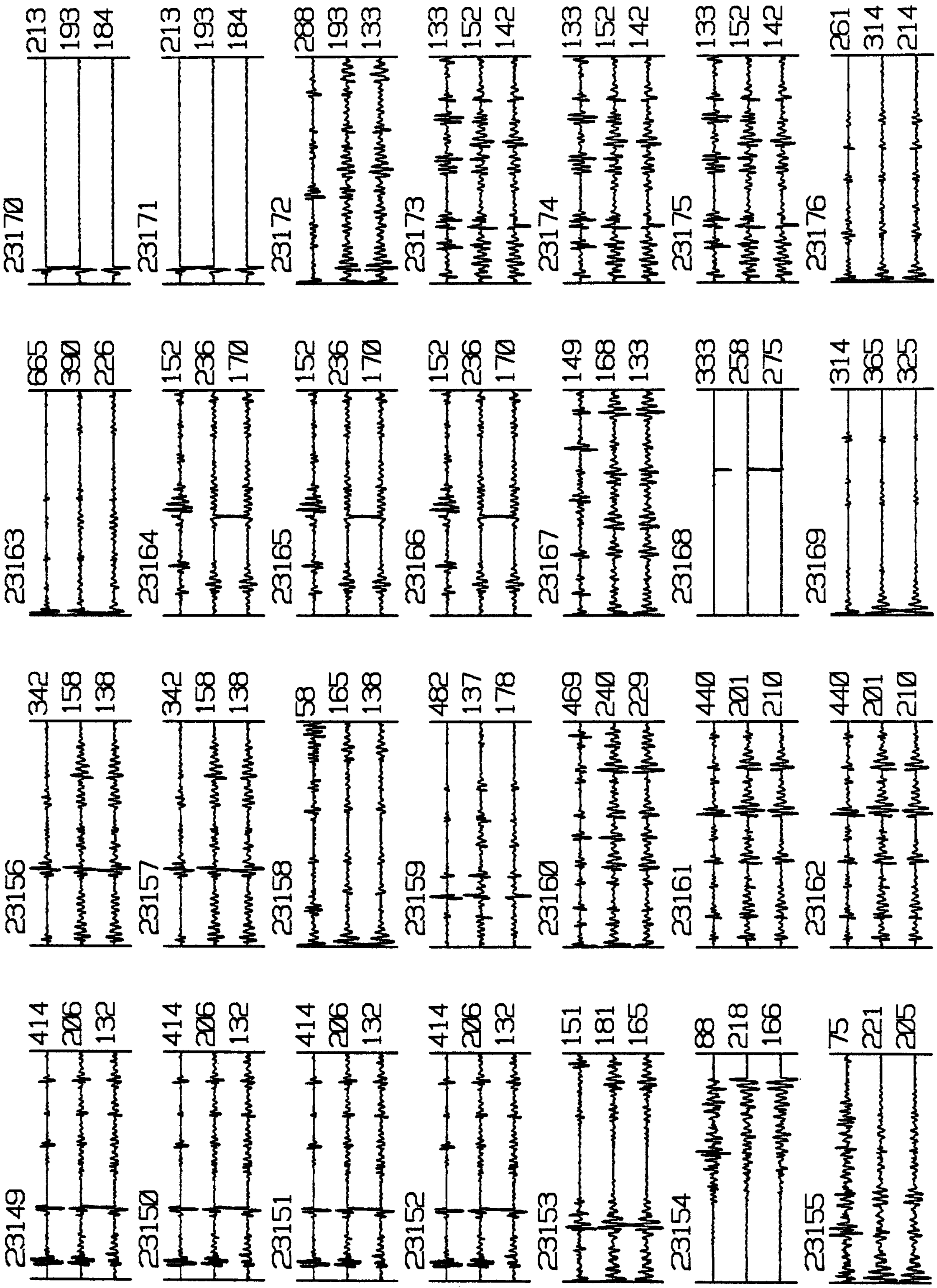
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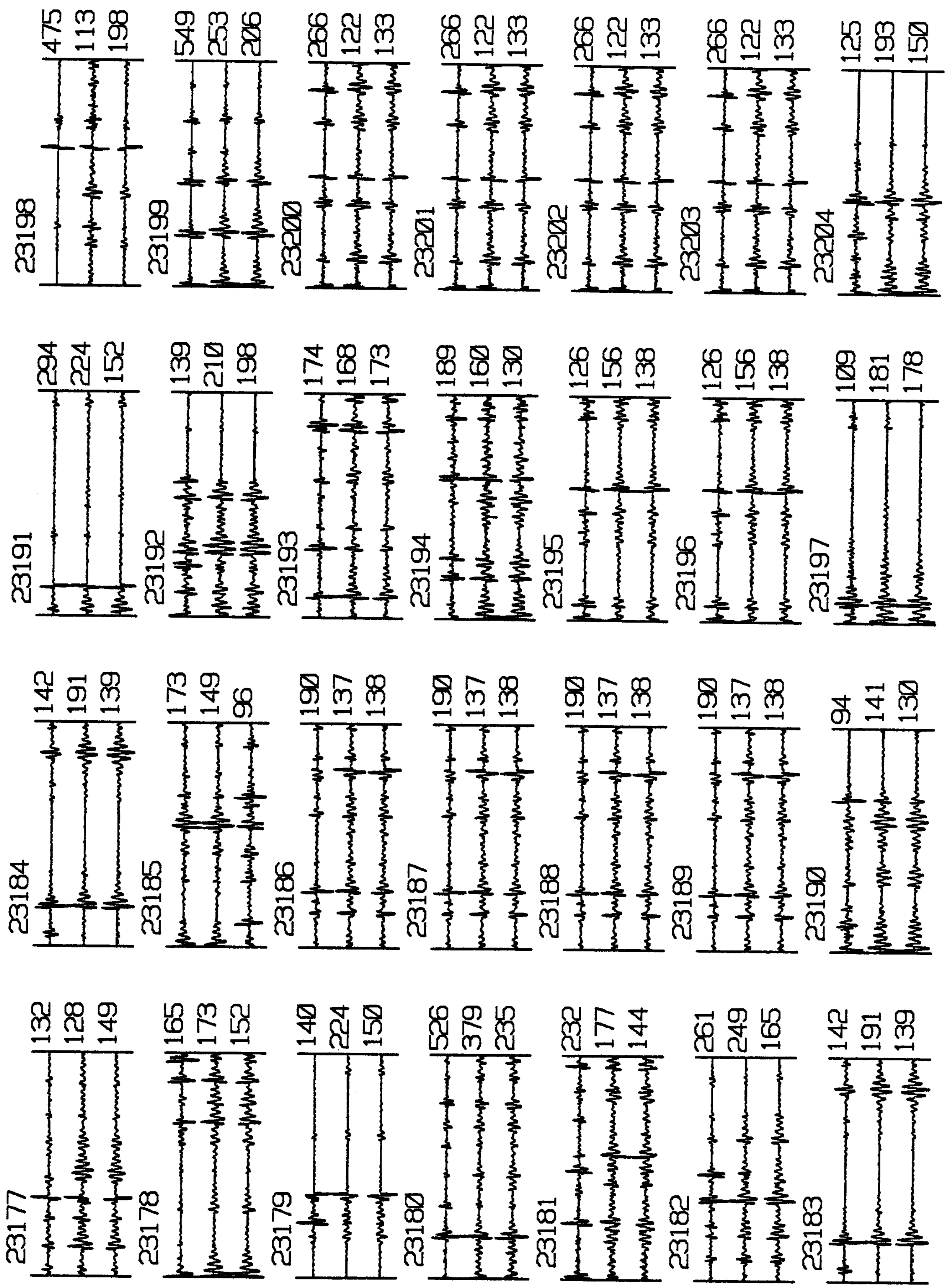
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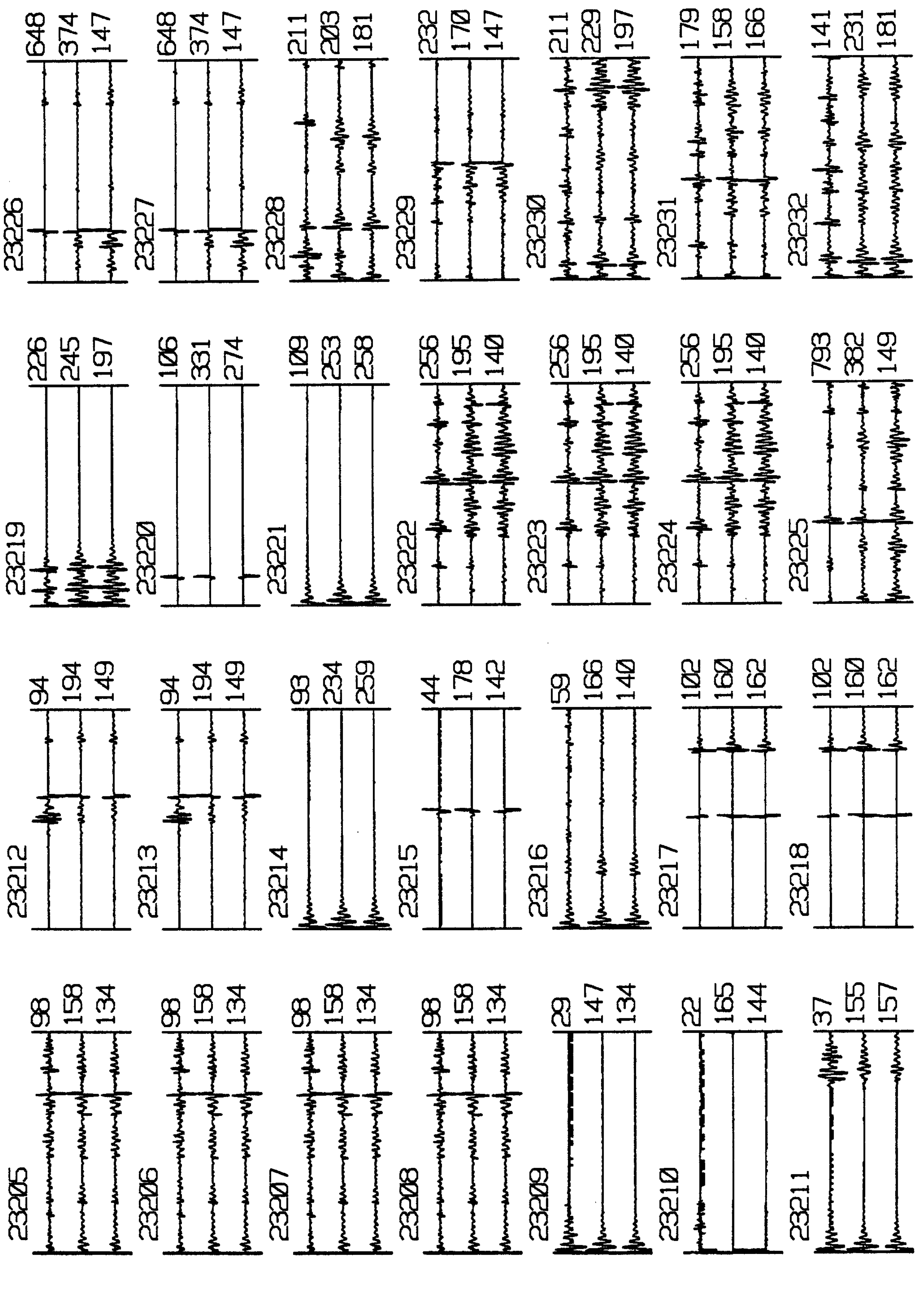
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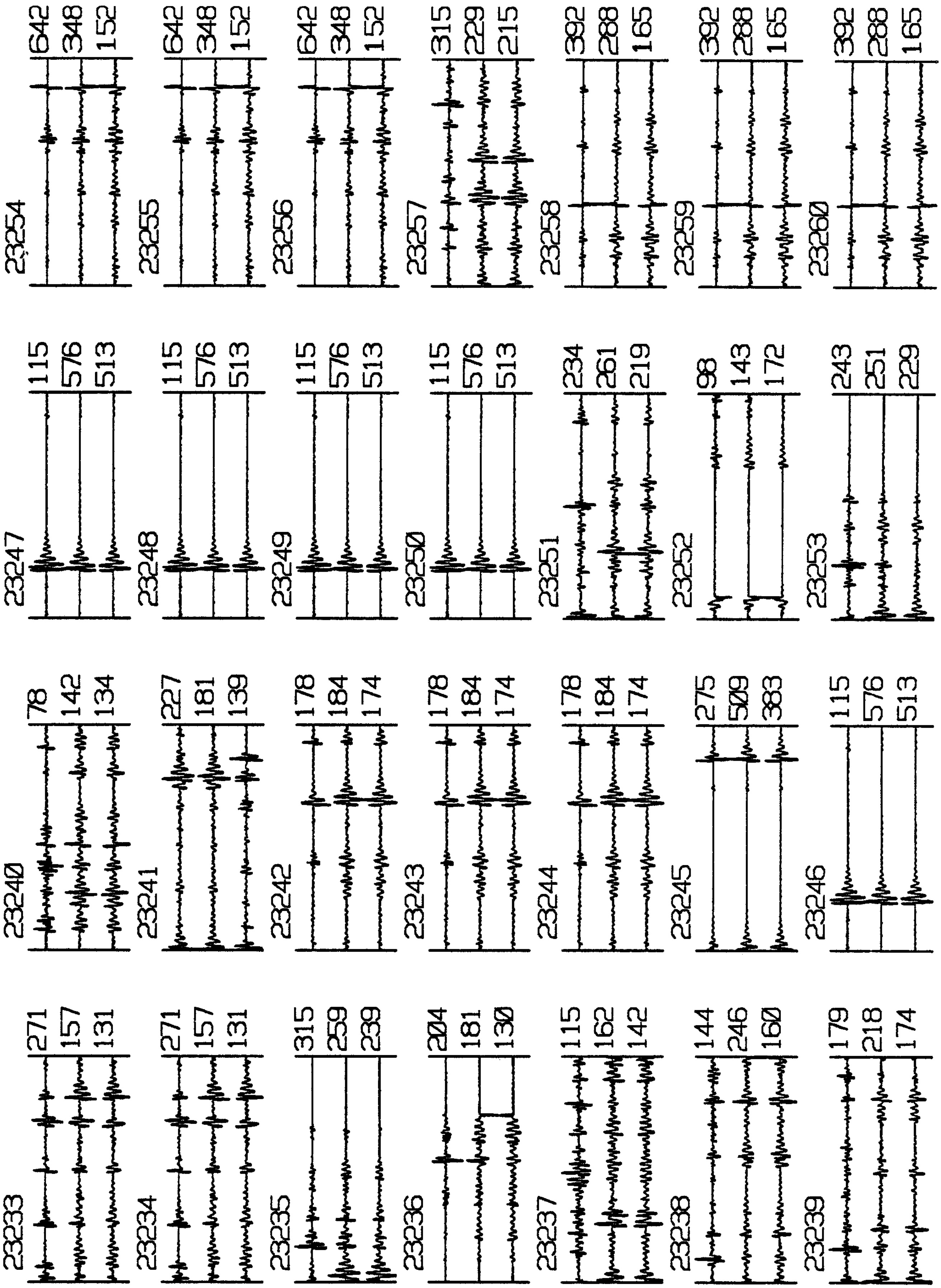
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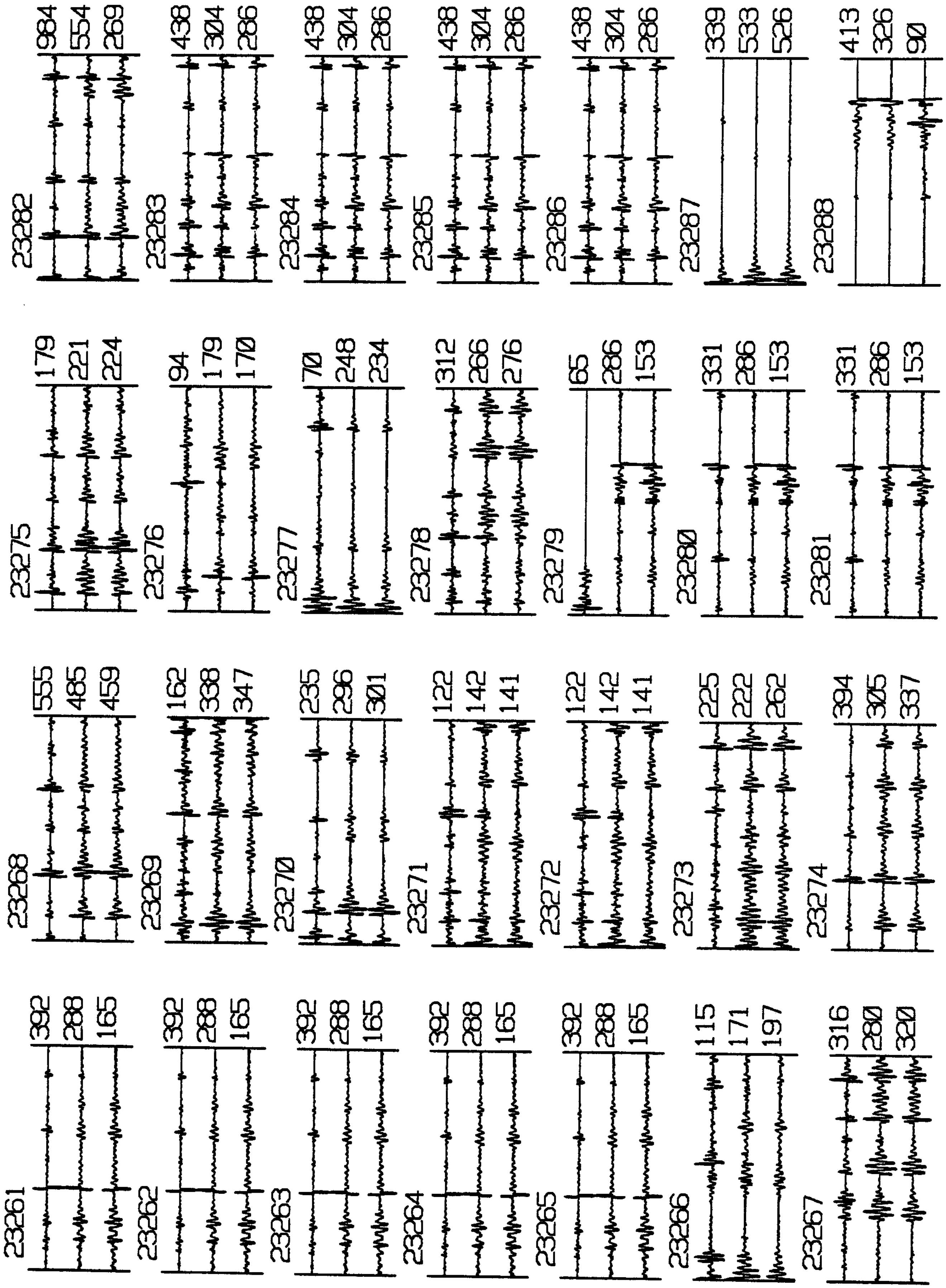
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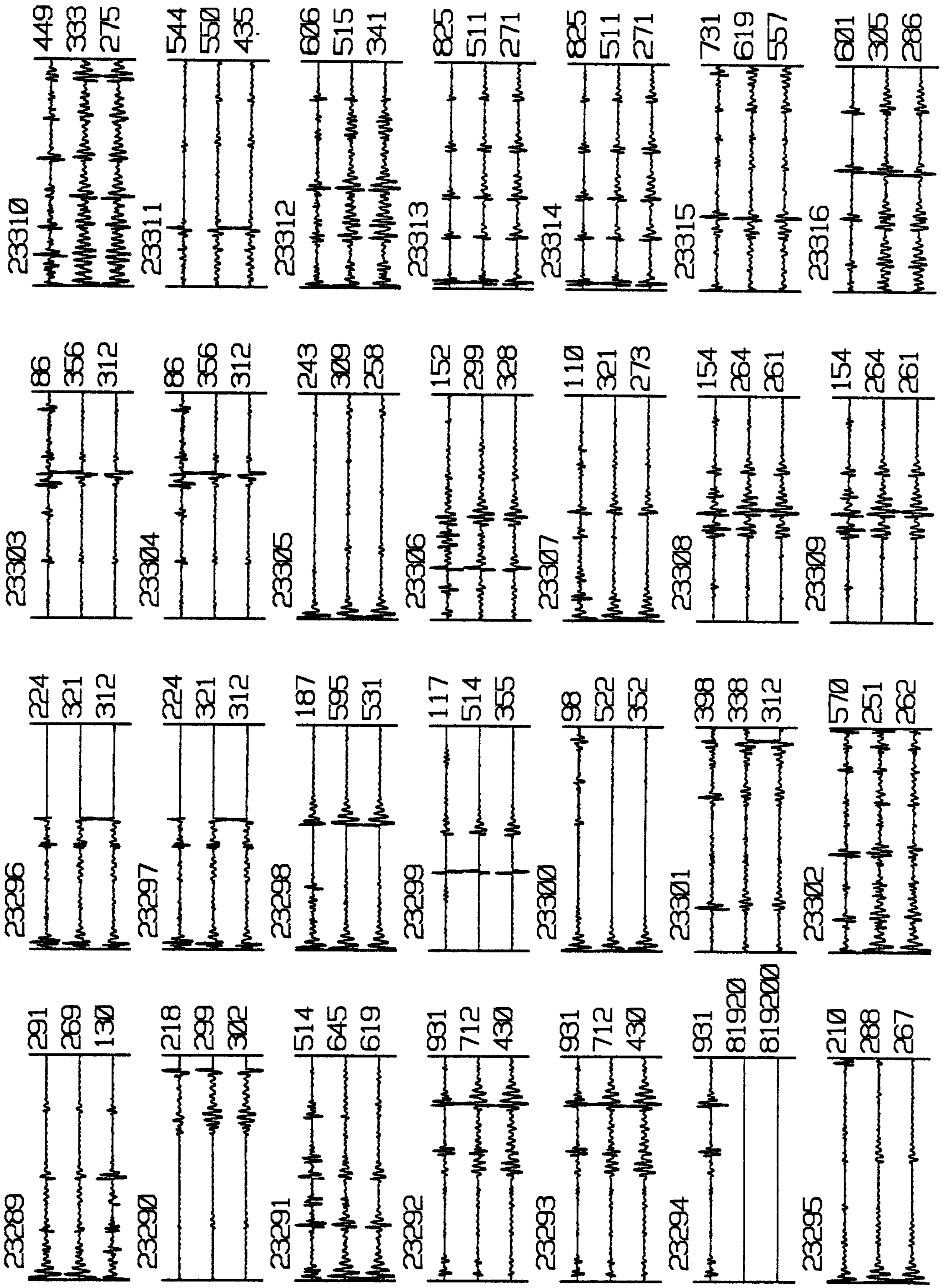

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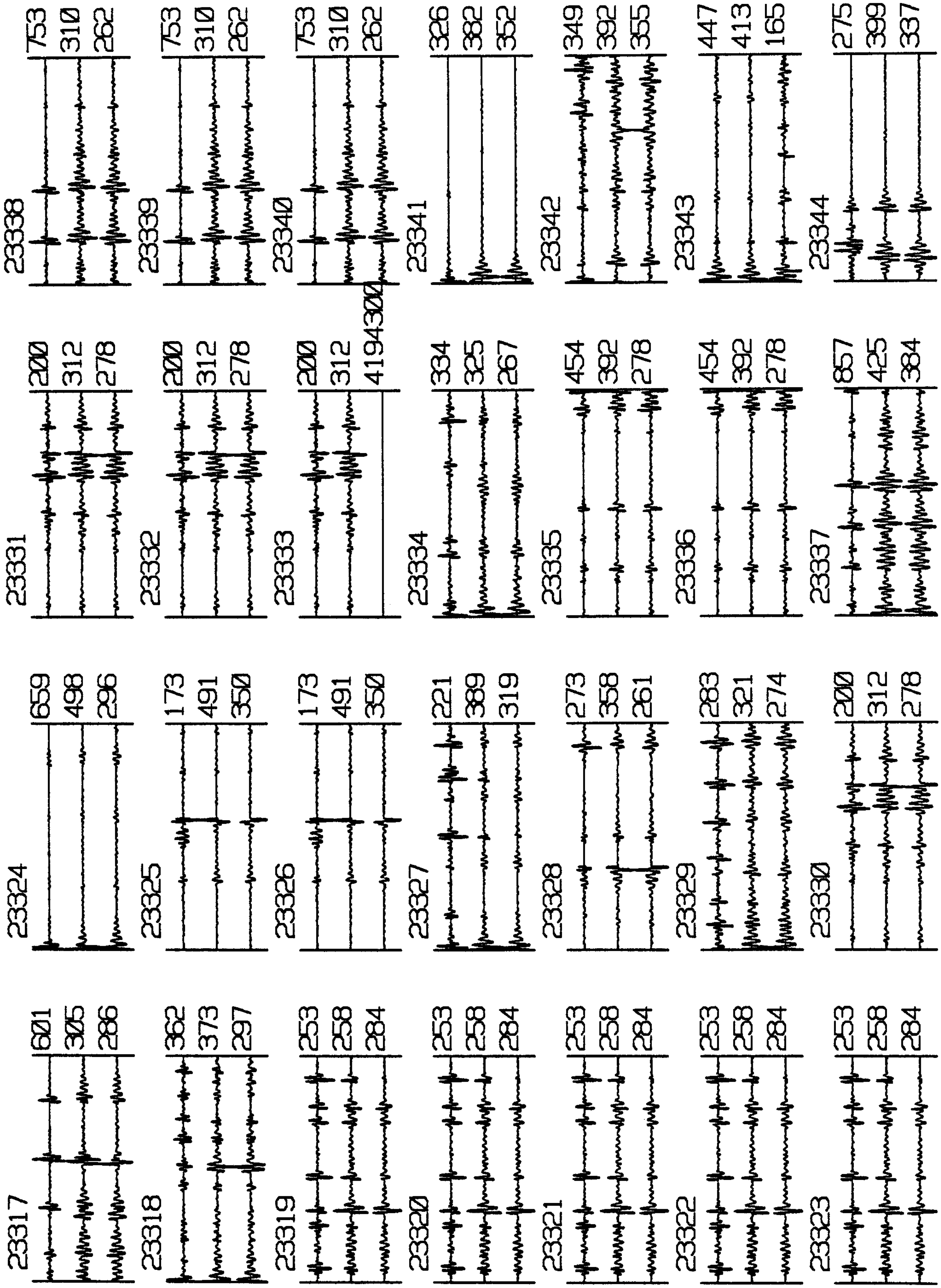
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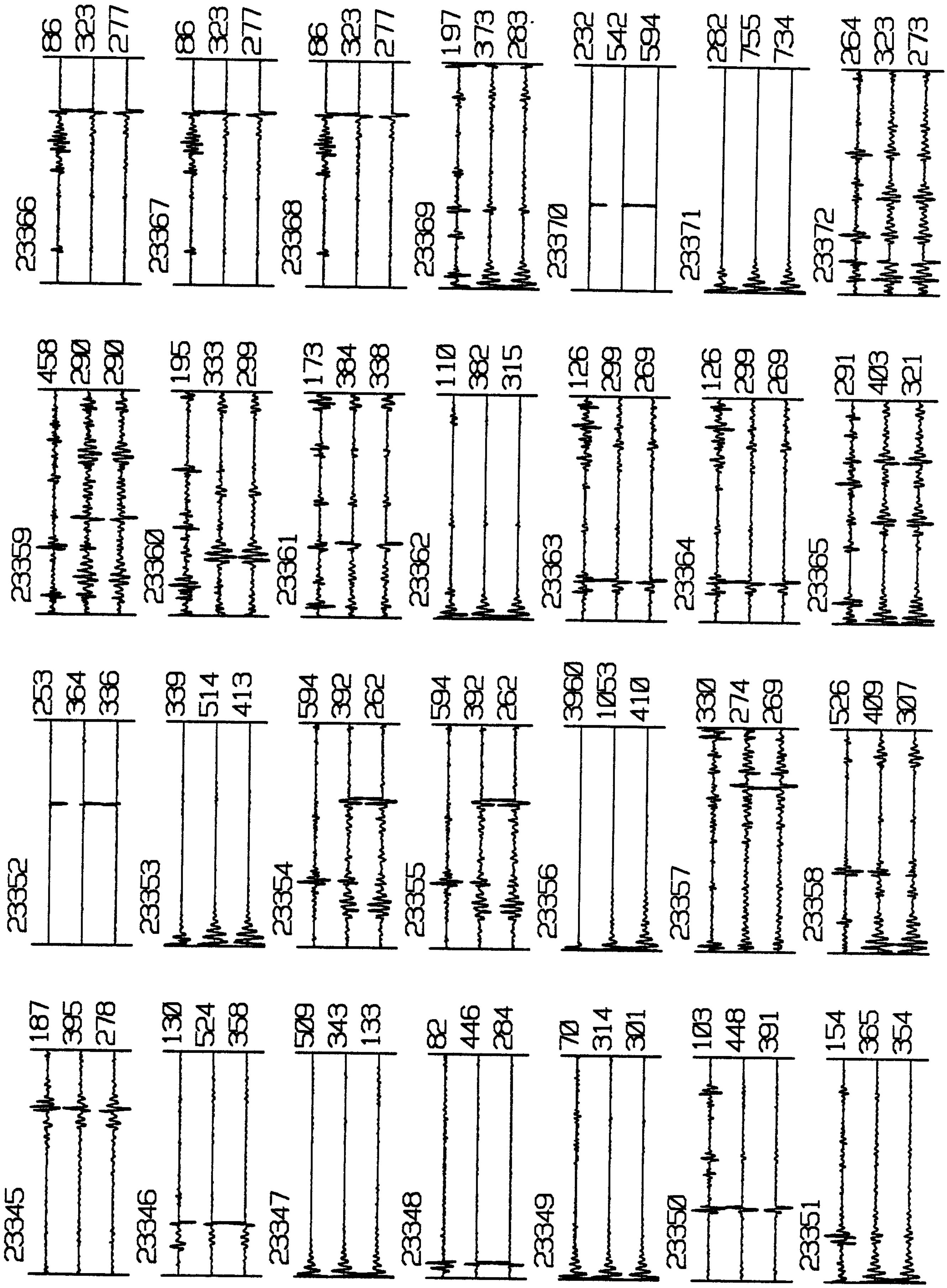
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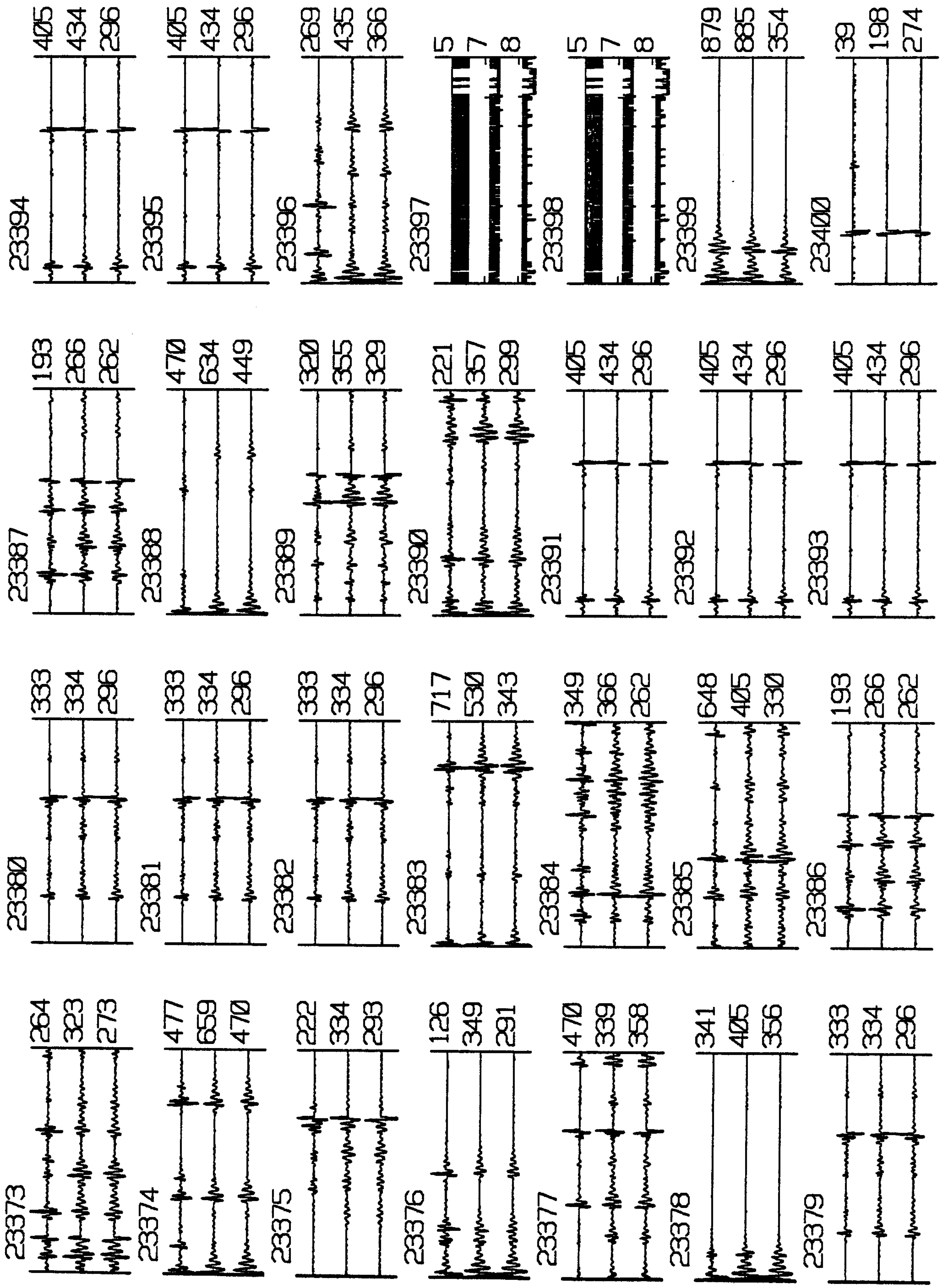

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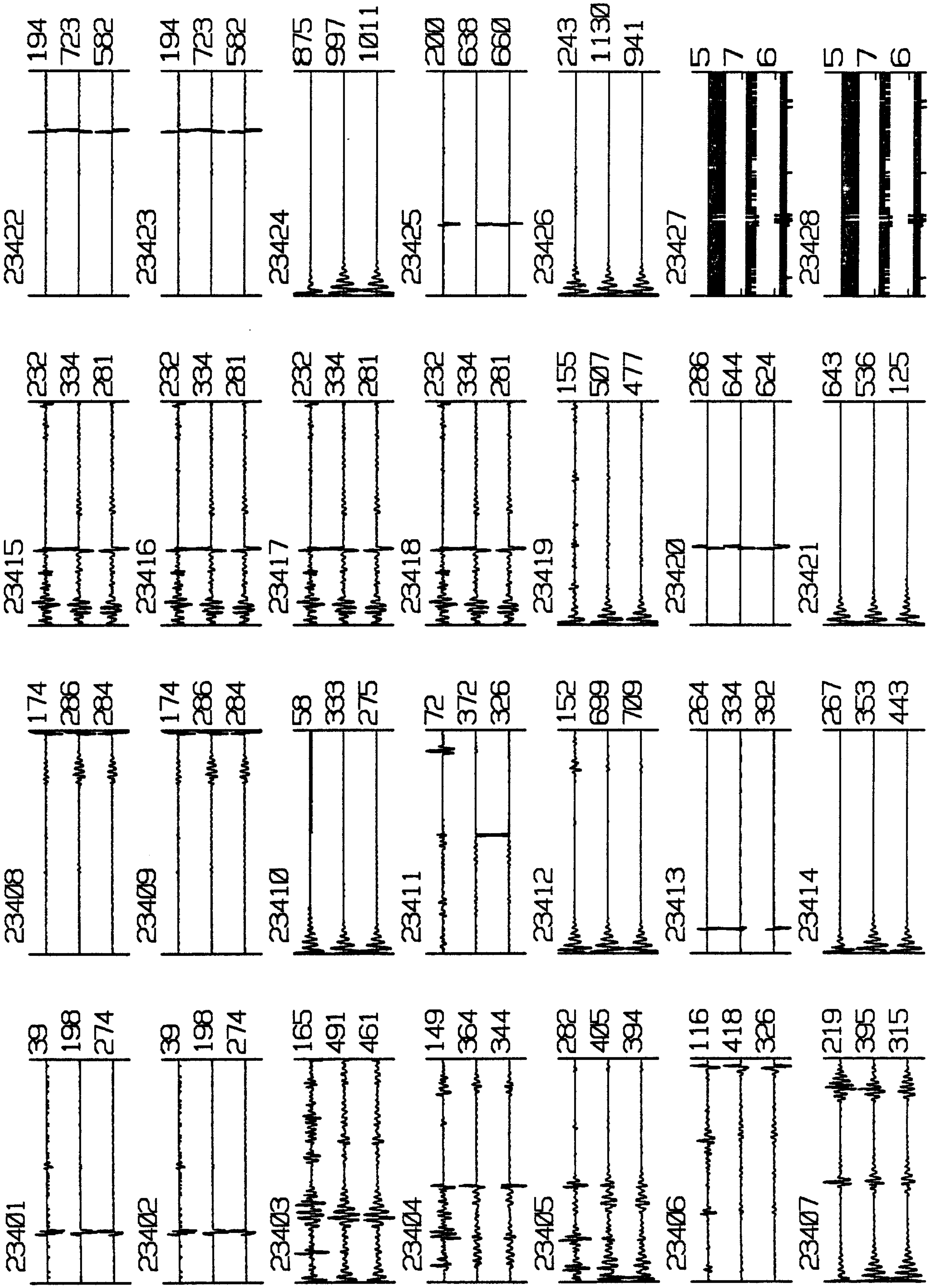
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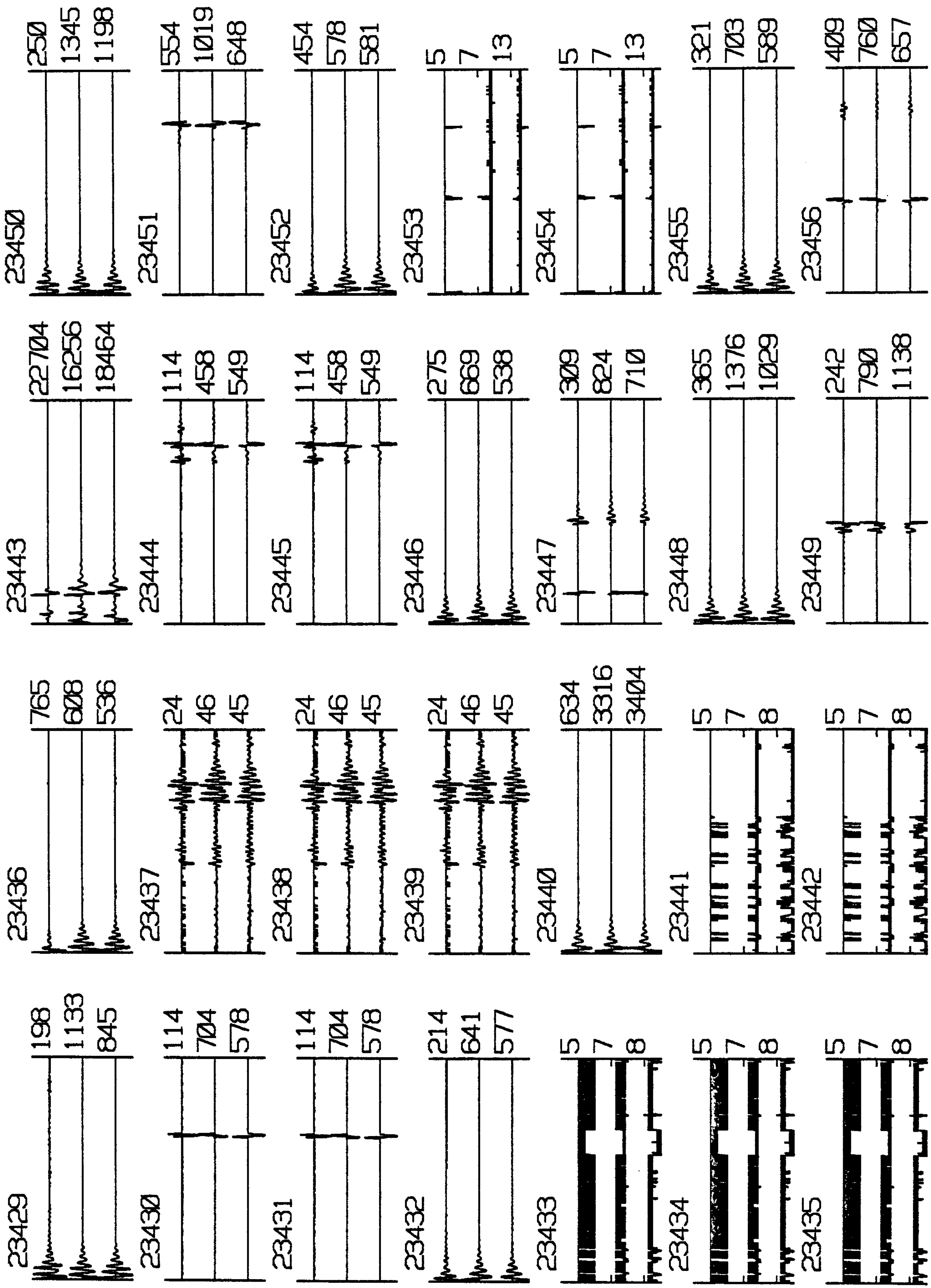
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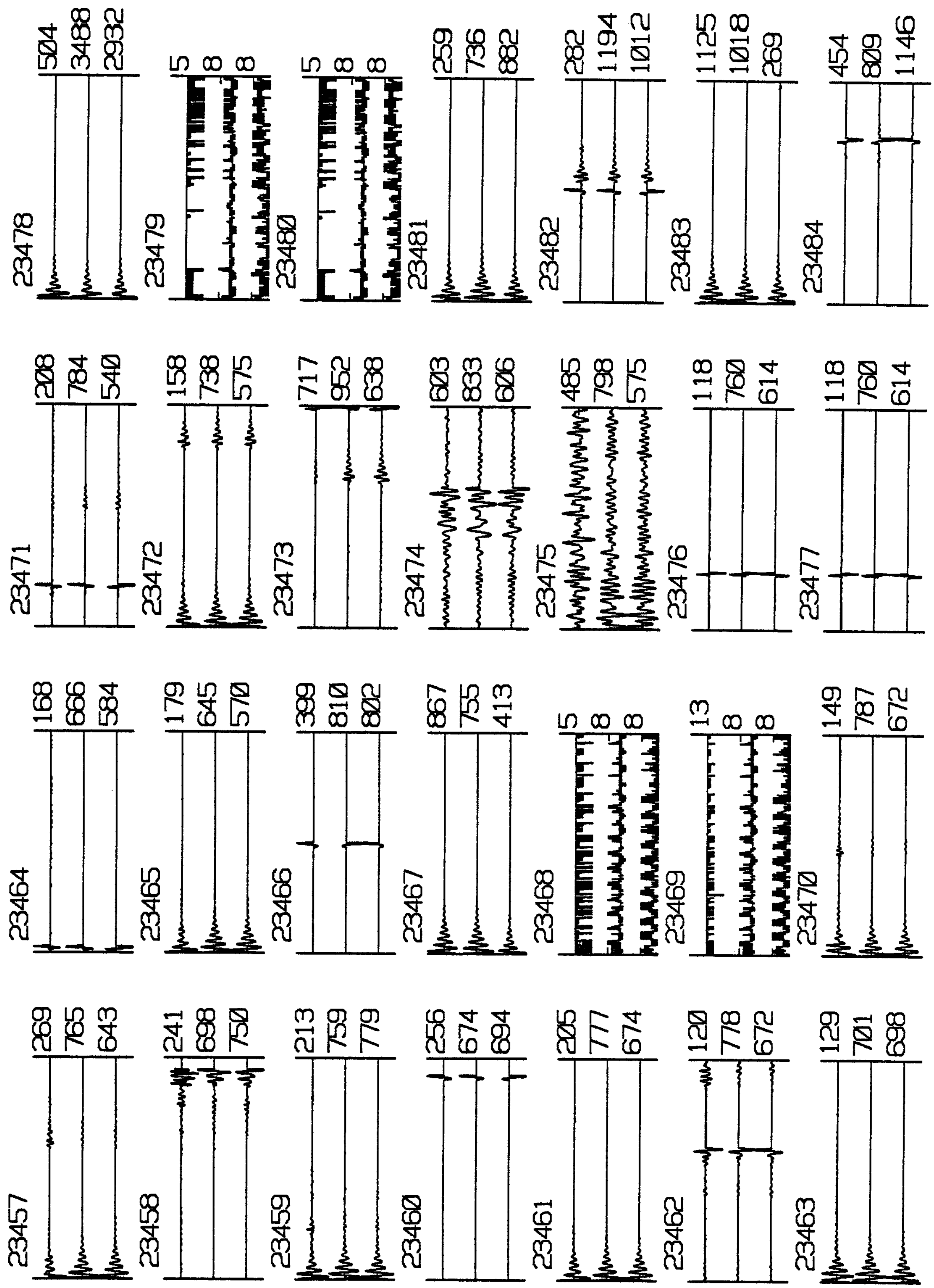
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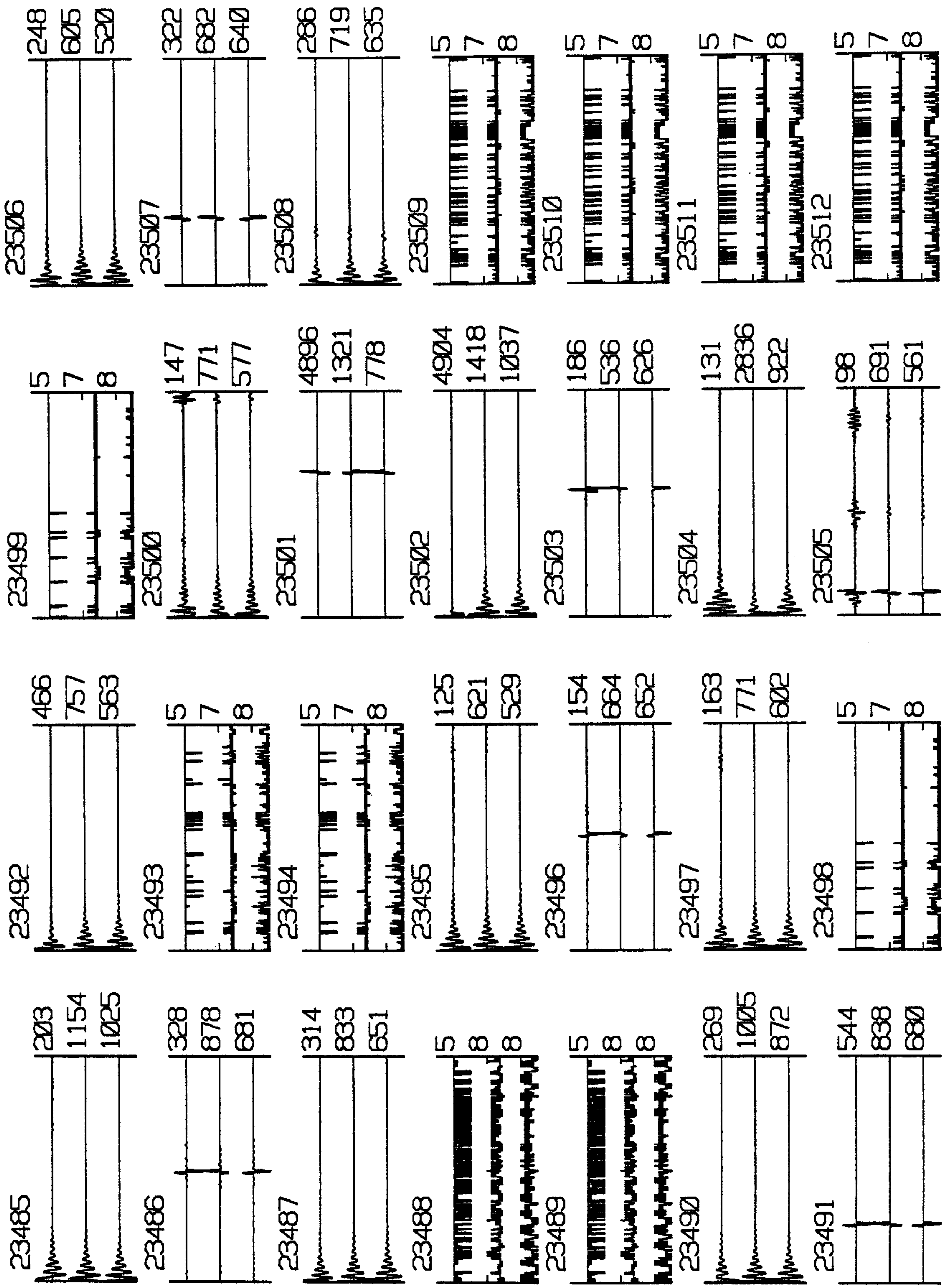
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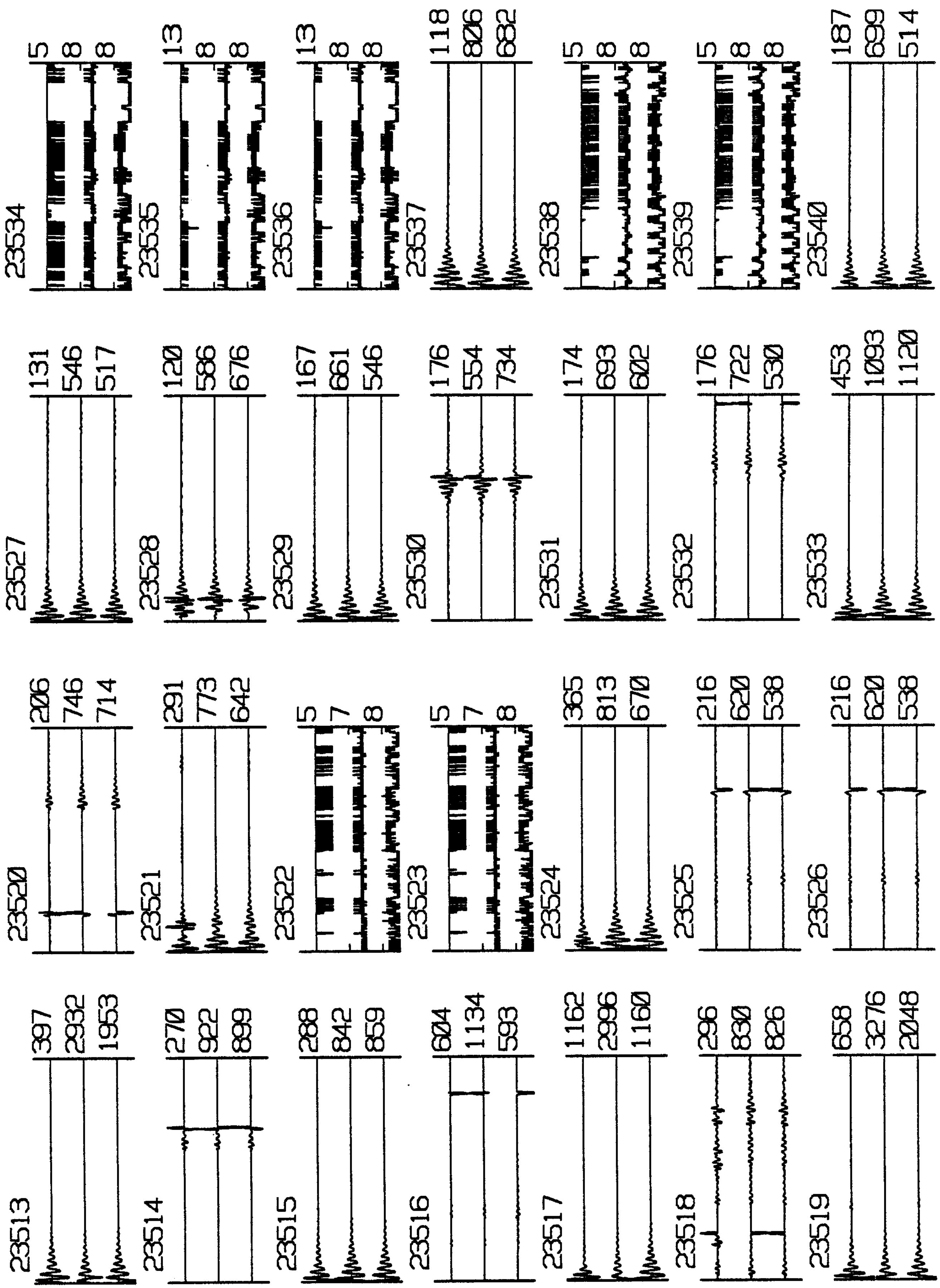

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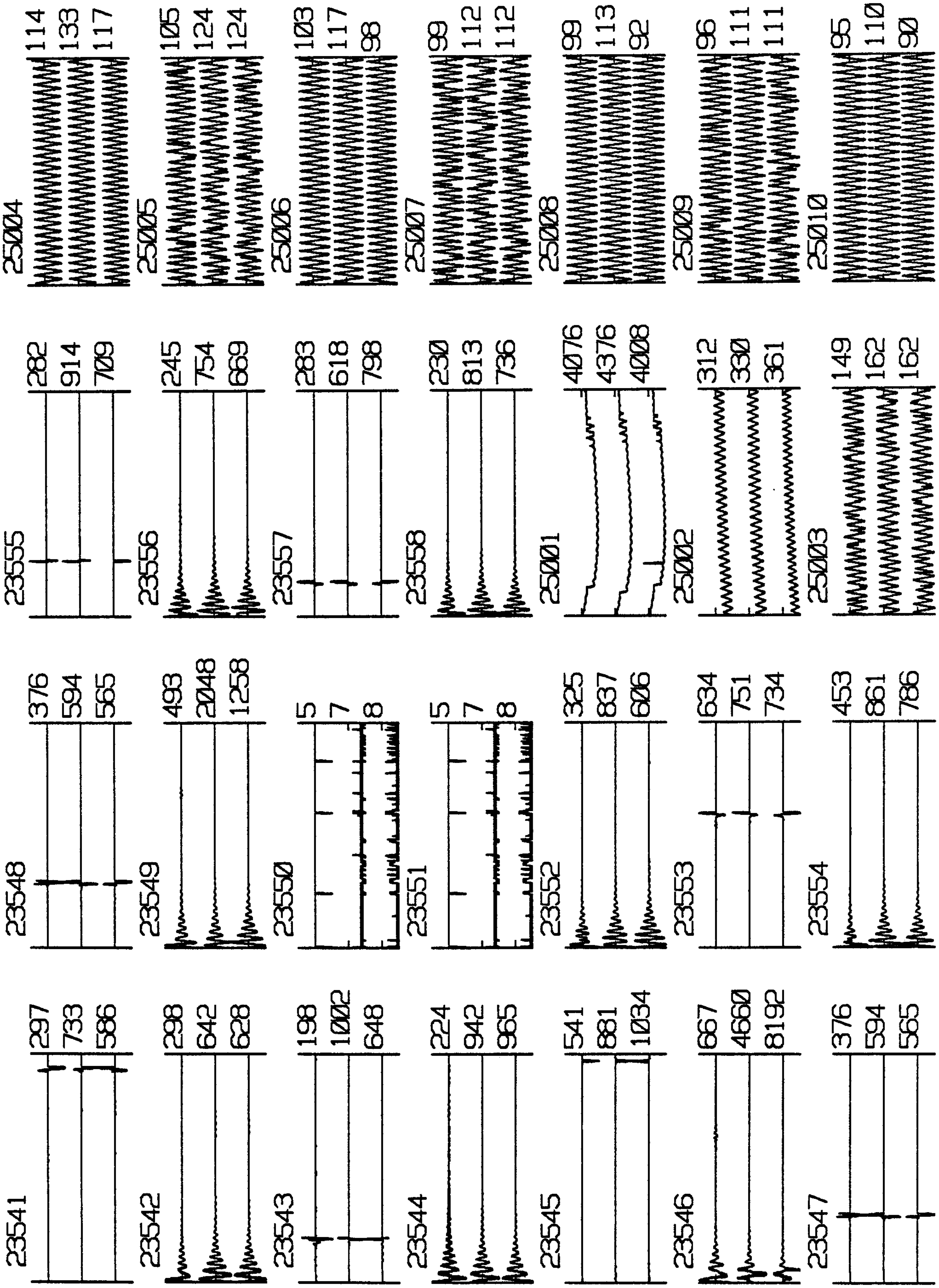
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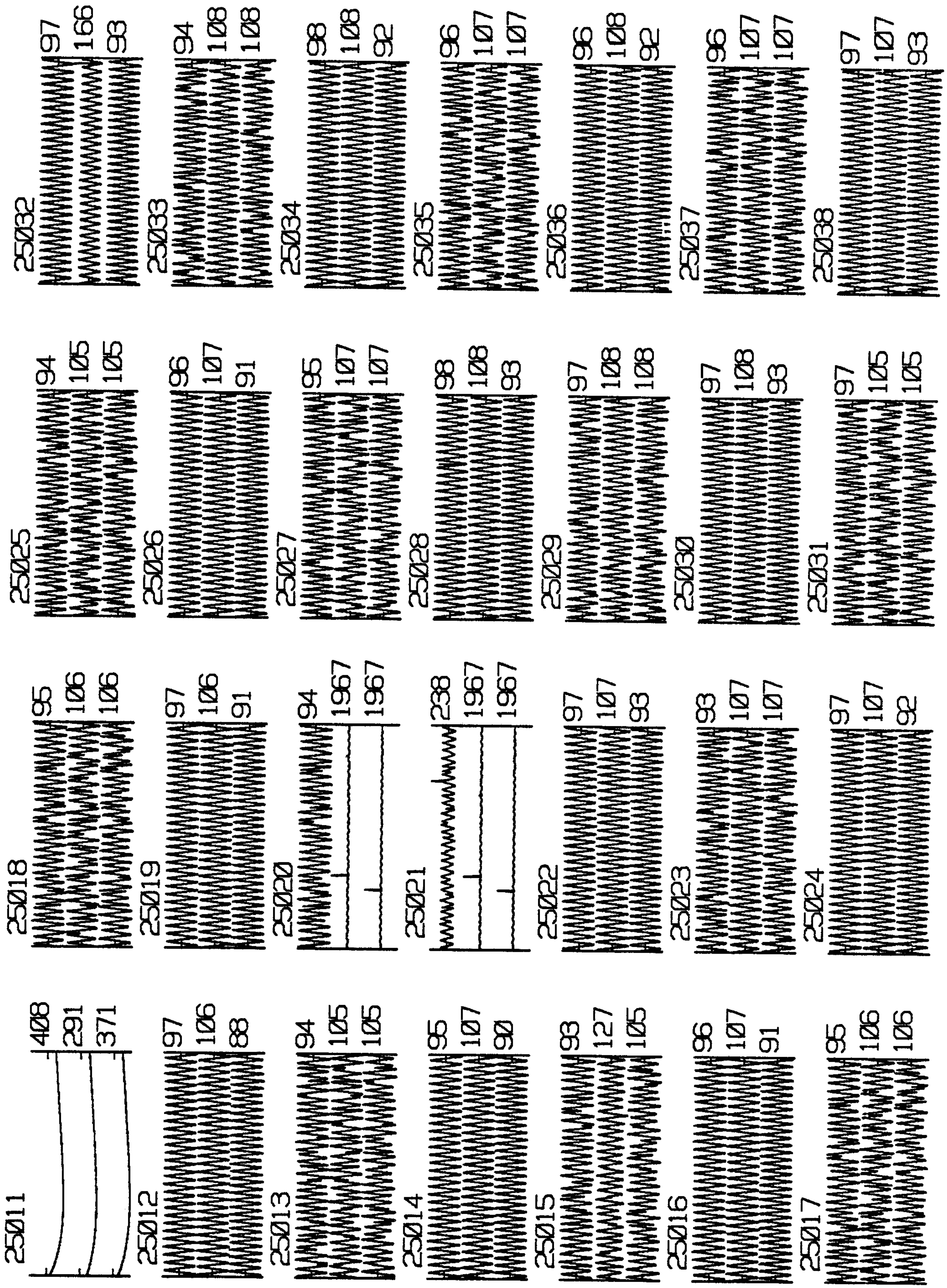
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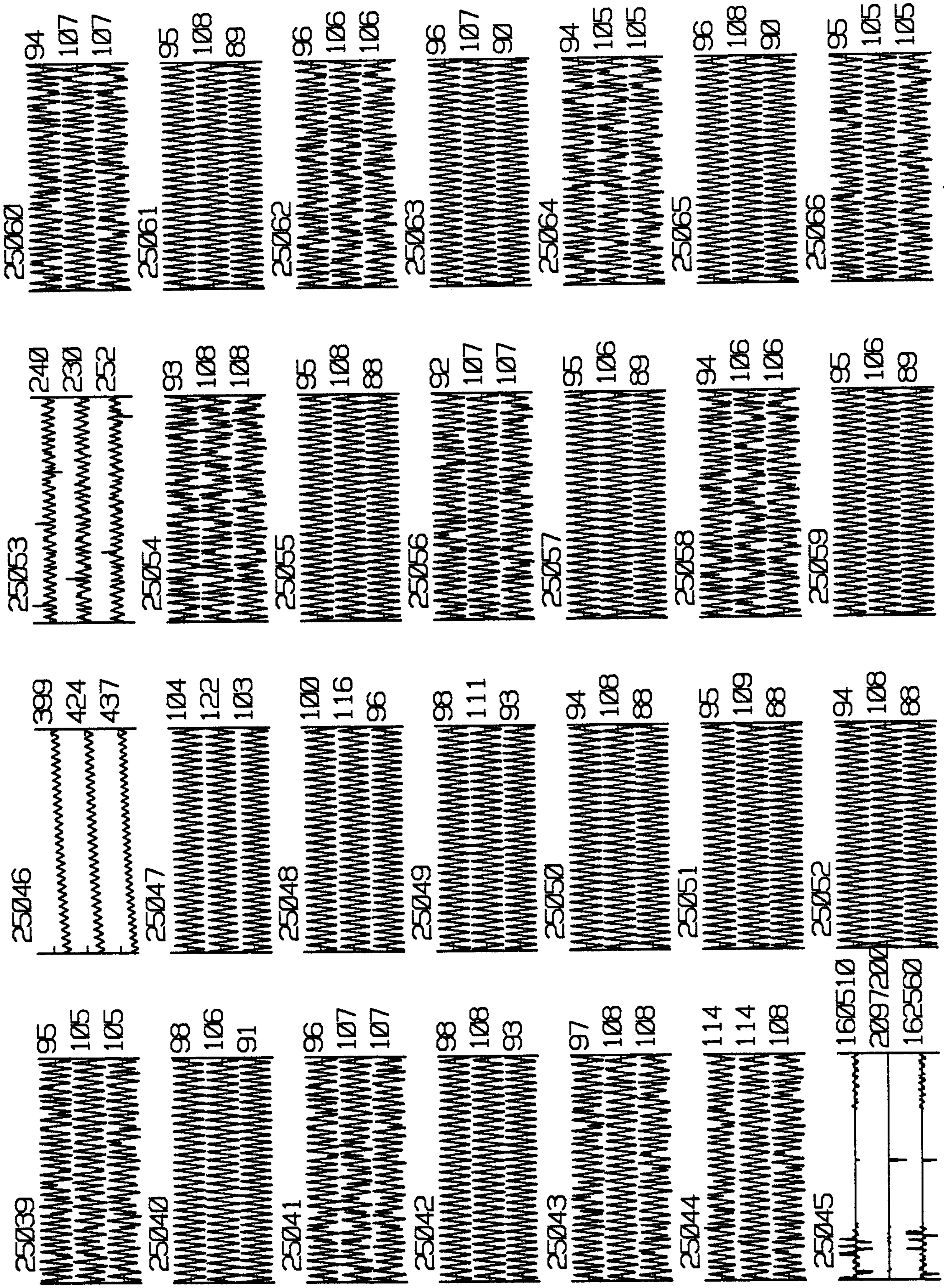
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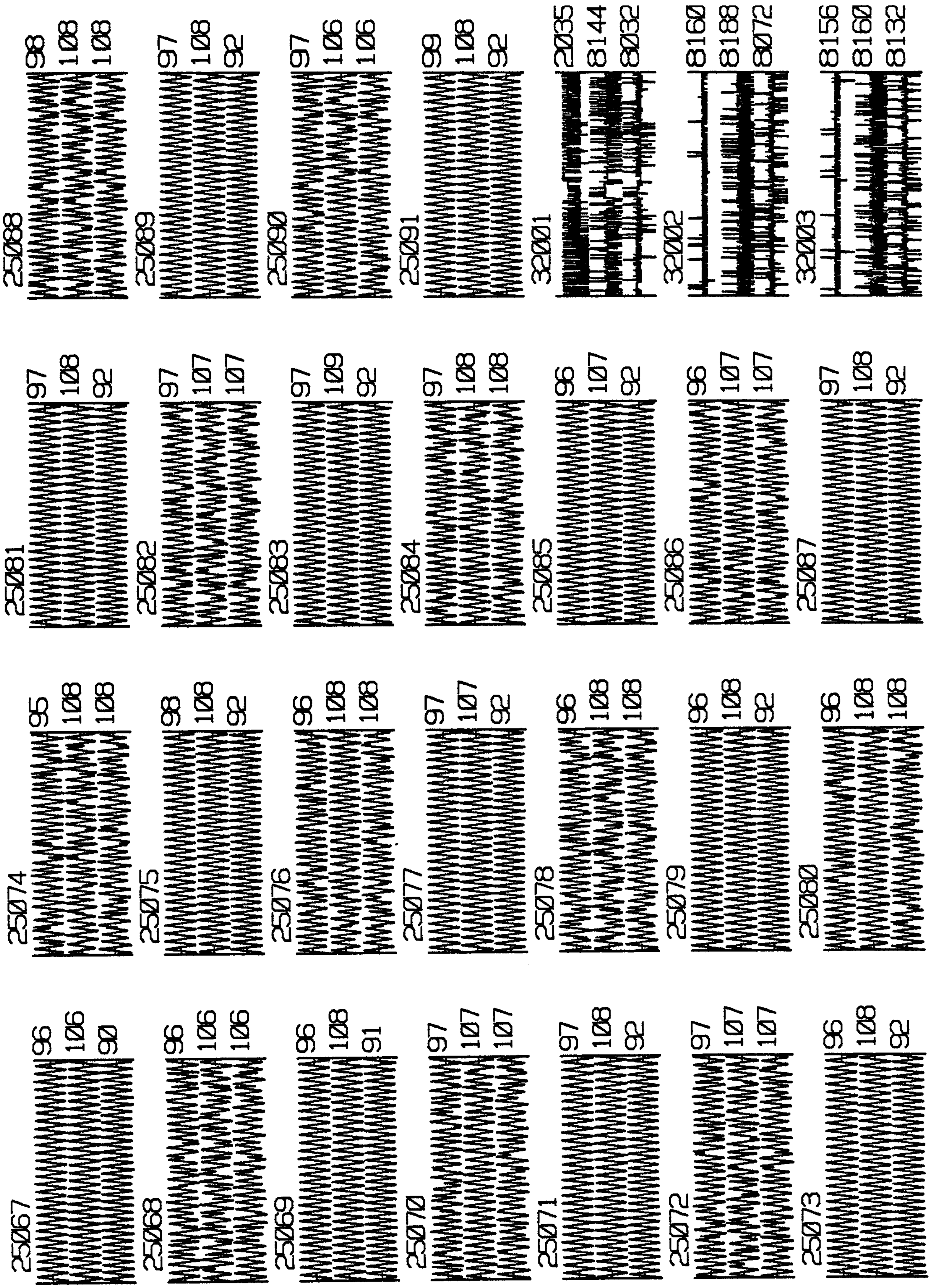
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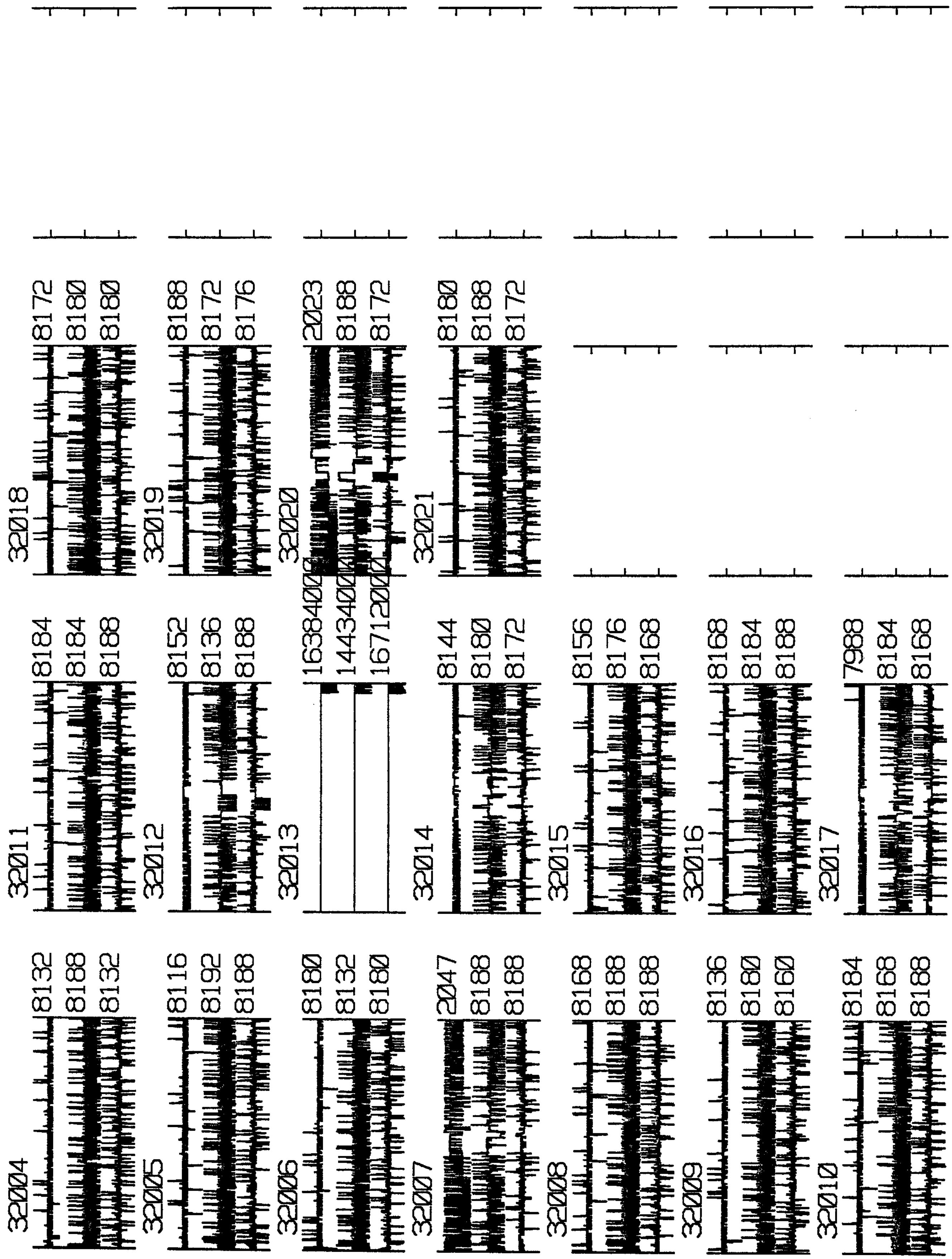
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APPENDIX II:

EVIDENCE THAT BIOLOGICAL ACTIVITY AFFECTS OCEAN BOTTOM SEISMOGRAPH RECORDINGS*

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(Accepted 14 April, 1981)

Abstract. Brief and impulsive signals of uncertain origin appear regularly on records from Ocean Bottom Seismographs (OBS) of several institutions. These signals have been recorded on nearly all deployments of the Texas OBS, including sites at depths greater than 7000 m. At some sites, they account for over 90 % of the events recorded. They are of short duration (usually 0.5–4.0 s) and have a characteristic frequency (usually in the range of 4–18 Hz) that differs from site to site. When networks of OBS instruments are deployed, the signals are not recorded simultaneously by different instruments. Neither the frequency content nor the distribution of durations of these signals is similar to what is observed for known earthquake events.

We present evidence suggesting that the signals are of biological origin, perhaps caused by animals touching the OBS units. (1) The distribution of these signals on instruments deployed at depths shallower than 1000 m shows a 24 h periodicity, while there is a 24 h periodic pattern on instruments deployed at sites deeper than 1000 m (where there is no visible light). (2) The frequency of occurrence of signals is similar to the vertical distribution of biomass in the oceans, i.e., they appear most frequently on OBS instruments deployed at very shallow depths. (3) Biological material has been found attached to several OBS units upon recovery.

1. Introduction

Although the first ocean bottom seismograph was deployed as early as 1937 (Ewing and Ewing, 1961) the stimulus for developing the present equipment occurred only about 20 yr ago when it was thought that the ocean bottom might provide a particularly quiet site for monitoring nuclear explosions (e.g., Ewing and Ewing, 1961; Phillips and McCowan, 1978). Presently, more than a dozen universities in at least six different countries regularly deploy OBS instruments. Several different OBS designs have been developed, with the design choices depending on whether the OBS instruments are intended for shallow or deep water, for long or short term deployment, or for refraction surveys or earthquake monitoring.

Instruments which are designed to monitor earthquakes during deployments lasting more than a few weeks generally use 'triggered' systems which preserve recordings of ground motions only for events with signal amplitudes which are significantly above the level of the average background noise. However, triggered

* University of Texas Institute for Geophysics contribution number 468.

** Now at : Chevron Oil Field Research Co., 3282 Beach Blvd., La Habra, California 90631.

OBS systems are only effective if they are triggered by the events of interest to researchers.

For example, on deployments of the Texas OBS (Latham *et al.*, 1978) we regularly record short impulsive signals of unknown origin (Figure 1). These signals occur in all of the OBS deployments at sites in varying geologic and tectonic settings (Figure 2). These peculiar events made up as many of 90% of the triggers at a site in 160 m of water near Kodiak, Alaska, and as few as 1% of the triggers at a site in 1554 m of water in the New Hebrides. Signals similar in character to those recorded by the Texas OBS are also observed by investigators deploying OBS instruments at all the university groups with which we have communicated. These include the Hawaii Institute of Geophysics (Fred Duennebier, John Sinton, George Sutton, pers. comm.), Kobe University (Toru Ouchi, pers. comm.), Oregon State University (Steve Johnson, pers. comm.), Scripps Institute of Oceanography (John Orcutt, pers. comm.), and the University of California at Santa Barbara (William Prothero, pers. comm.).

There are three reasons why we feel it is necessary to investigate the characteristics of these peculiar signals in detail. First, an important practical reason for studying these events is to devise a triggering scheme which allows us to avoid recording these events in long-term earthquake monitoring or nuclear monitoring studies. For example, instruments designed to record strong motion

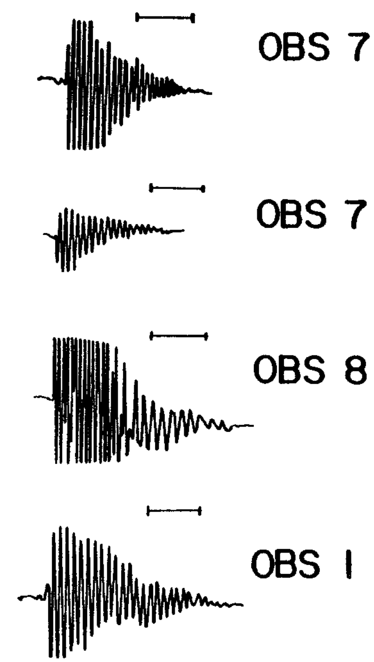

Fig. 1. Examples of signals of uncertain origin recorded on ocean bottom seismographs deployed near Adak, Alaska in 1978. The time bar denotes 1 s.

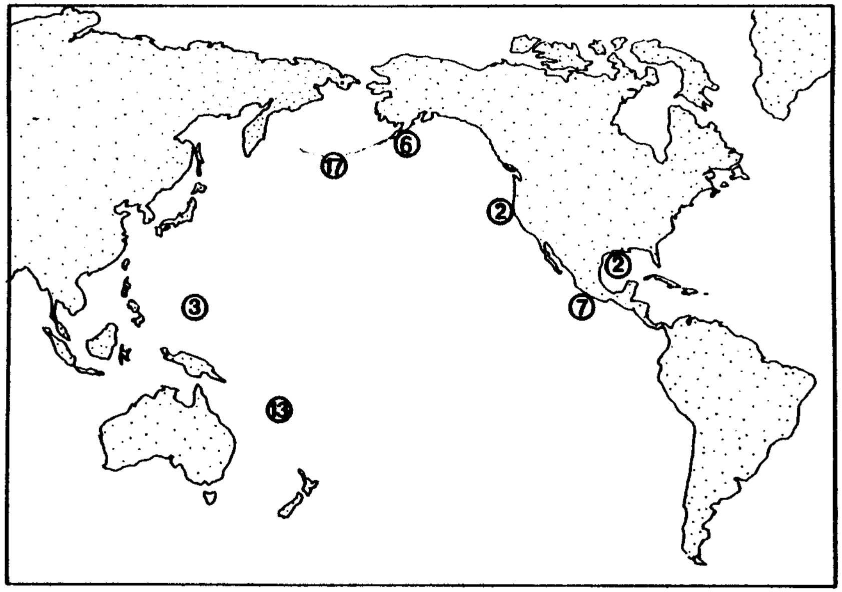

Fig. 2. This world map shows the locations where the Texas OBS has been deployed. The circled number indicates the number of stations for which OBS records were analyzed for this study. The unknown signals were recorded at all stations.

accelerations (Steinmetz *et al.*, 1979 and 1981) are presently deployed in Alaska for periods approaching a year in order to ensure a good chance of measuring a strong local event. Because strong motion events are rare, it is important not to fill up the recording capacity of an OBS instrument entirely with non-seismic signals before a seismic event occurs.

A second reason for studying these events is that although 'fish bumps' have been mentioned in the OBS literature (Francis and Porter, 1973), they have not been described in detail previously, even though they seem to be a ubiquitous form of low frequency noise affecting seismic measurements on the ocean floor. There is an enormous literature concerning noise such as microseisms affecting seismographs situated on land (e.g., see Hasselman, 1963; Haubrich and McCamy, 1969; Rind, 1980; Rind and Donn, 1978). This and other work has considerably improved our understanding of the character and origin of microseism noise, and even showed that it was possible to use microseisms to track storms. However, with some notable exceptions (e.g., Sutton *et al.*, 1980a, b; Zelikovitz and Prothero, 1980; Lewis and Garmany, 1980) there are few studies which concentrate on problems peculiar to OBS recording. We hope that the present paper will stimulate further discussion of the character and significance of these signals affecting OBS instruments.

Finally, we present evidence suggesting that these signals are of biological origin. If this conclusion is correct, then it may be feasible to design instruments similar to OBS instruments which photograph or record activity rates for organisms on the ocean floor. Such observation methods would not rely on the use of lights or food baits to attract animals and would provide non-biased sampling of deep-sea fauna activity.

2. Results

The Texas OBS instruments that recorded the observations reported here are vertical component, self-contained, triggered systems. A digital memory continuously preserves about two minutes of ground motion. When the trigger electronics determine that the short-term average of the signal exceeds the long-term average, the information in the digital memory is recorded permanently onto a cassette tape. Each record includes about two minutes of the ground motion, including several seconds of ground motion prior to the instant that the trigger occurs. The system is described in more detail by Latham *et al.* (1978).

In this section, we describe quantitatively the apparently non-seismic signals observed by the Texas OBS and investigate their rates of occurrence, periodicity, and frequency content for nearly all the Texas OBS experiments that took place between 1977 and 1980. We shall describe the greatest detail records from two experiments, involving 17 stations near Adak, Alaska in 1978 and 1979 (Frohlich *et al.*, 1980 and 1981) and an experiment using 6 stations near Kodiak, Alaska (Lawton *et al.*, 1981).

2.1. Description of Signals

Four criteria distinguish these signals (Figure 1): (1) a sharp, impulsive onset, (2) a frequency spectrum containing one or two very narrow bandwidth peaks, (3) a very regular decrease of amplitude in the signal coda, and (4) a brief duration (less than about 5 s). Because of their regular frequency content and distinctive coda of short duration, these signals differed clearly in appearance from signals produced by known earthquakes recorded by the Texas OBS (e.g., Chen *et al.*, 1981; Frohlich *et al.*, 1981; Lawton *et al.*, 1981). Although most of the signals show an impulsive onset, there is no clear pattern as to the direction of the first motions, as at any one station at least 20% of the signals possess a clear upward deflection and at least 25% possess a clear downward deflection. Signals which are emergent or spindle-shaped were not included in the primary data set, so our conclusions are based on the more numerous impulsive signals.

The signals are brief in duration, usually about two seconds. An analysis of 379 events from the Adak 1978 experiments showed a range of durations from 0.3 to 7.5 s, with most falling between 0.5 and 4.0 s (Figure 3). In spite of their short

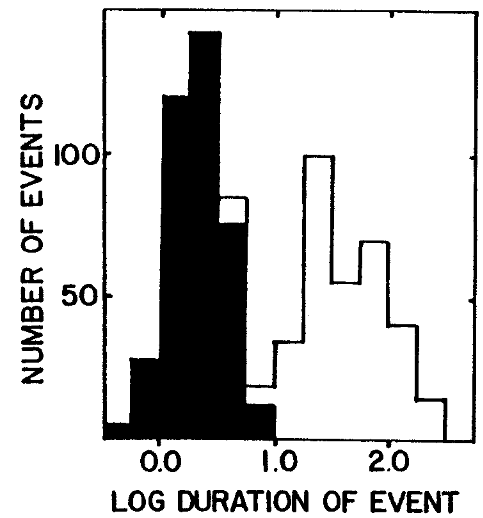

Fig. 3. Histogram of number of events that occur for incremental changes of 0.25 in the $\log_{10}$ of the event duration D, e.g., 120 events occurred with a duration between 1 and 1.7 s ($0 < \log D < 0.25$). Solid bars are signals of the type discussed in this paper (e.g., Figure 1); open bars are known earthquake events. Note the paucity of events with $\log D$ between about 0.75 and 1.25 (about 5 to 15 s). Figure includes all events recorded at OBS station 8 in Adak, Alaska between June 20 and July 20, 1978.

duration, many of these signals have large enough amplitudes to be clipped on the seismograms (i.e., the amplitude of the signals exceeded the maximum range of the recording system during the first few cycles recorded).

One of the most peculiar features of these signals is their extremely regular frequency content. Spectral analysis (fast Fourier transform, uncorrected for instrument response) of a sample of 60 individual unclipped signals (e.g., Figure 4) indicates that all the signals were made up of one or two very narrow bandwidth components superimposed on the background noise spectrum. The peaks of energy are generally in the range of 4 to 20 Hz. At the stations where the signals possessed two narrow bandwidth peaks, the frequency of the higher frequency peak is usually a multiple of approximately two or three times the lower frequency (e.g., see Figure 5).

All signals from an OBS instrument deployed at any particular site have similar spectral content, while the spectral peaks differ for signals recorded at different sites (Figure 5). Because it was impractical to perform spectral analysis to determine the peak frequency for all the signals we observed, for most we determined a predominant frequency by counting zero crossings on the seismograms. For the 60 signals that were analyzed with the Fast Fourier transform, in no case did the spectral peak frequency differ from the predominant frequency determined by counting zero crossings.

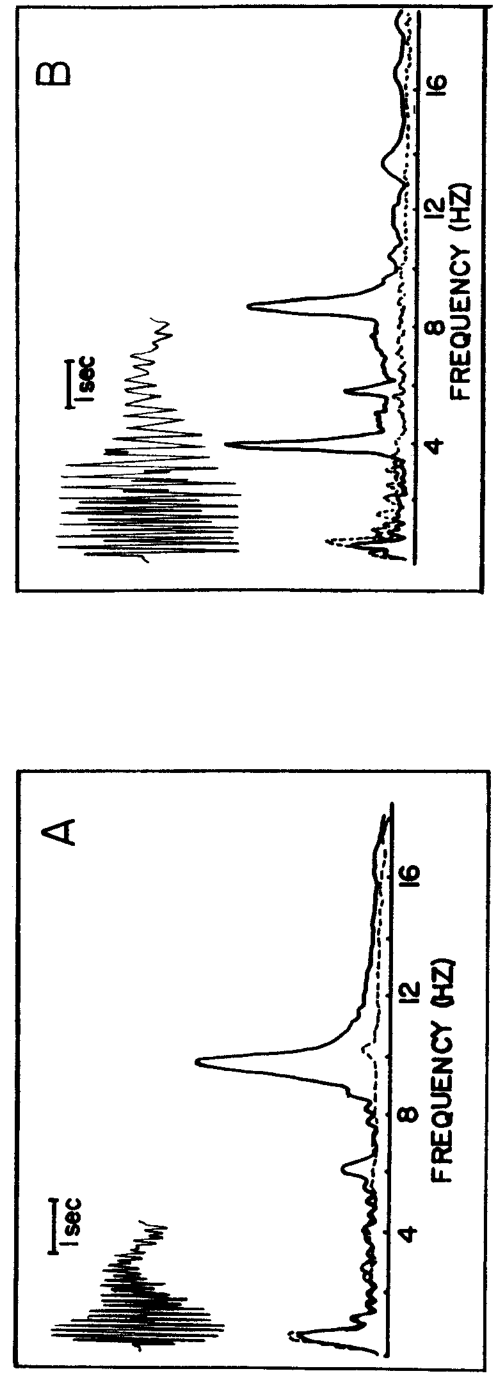

Fig. 4. Signals from the ocean bottom seismogram (above) are presented along with the spectral analysis (below) of the signal (solid line) and a segment of background noise (dashed line). Spectra are fast Fourier transforms of OBS records, uncorrected for instrument response (4.5 Hz geophone). For the signal in 4A (Adak, OBS 7, 22 June 1978 1148 GMT) the predominant frequency is at 10 Hz. Note that nearly all the energy in the peak at 1 Hz is due to the background noise. The signal in 4B (Adak, OBS 6, 22 June 1978 1248 GMT) had two predominant frequency peaks, at 4 Hz and 8.5 Hz, respectively.

Predominant frequencies were determined for all stations from experiments near Adak in 1978 (Frohlich *et al.*, 1980), the Marianas in 1978, the New Hebrides in 1977 and 1978 (Chen *et al.*, 1981), and ROSE in 1979. These signals vary greatly for different OBS stations in any particular experiment (e.g., Figure 5). However, the signals for each individual OBS station are fairly uniform. For example, the predominant frequency ranges for signals on the three OBS units in the Marianas experiment are: (1) 5–6 Hz and 16 Hz (two peaks), (2) 15 Hz (one peak), and (3) 8–9 Hz and 18 Hz (two peaks). Predominant frequencies also differ for seismograms recorded on a single OBS unit when it was deployed at different sites: for example, on Texas OBS unit #32, the predominant frequency occurred at 6 Hz in the New Hebrides 1977 experiment, at 7 and 10 Hz in the Adak 1970 experiment, and at 8 and 16 Hz in the ROSE 1979 data.

2.2. Occurrence of signals

The rate of occurrence of these signals varies greatly at different stations from nearly zero per day to over 160 per day. There is a clear trend suggesting that the frequency of occurrence of these events is related to station depth (Figure 6), as signals generally are more frequent at stations with depths shallower than 2000 m.

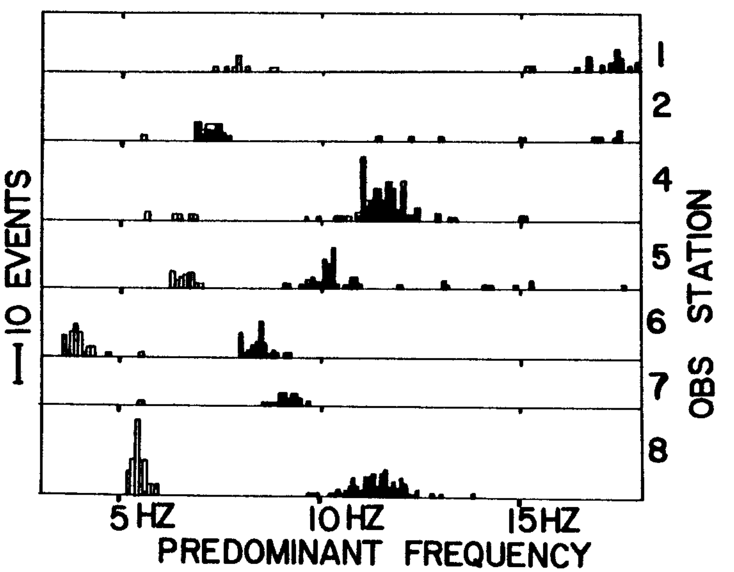

Fig. 5. Histograms showing the distribution of predominant signal frequencies determined by counting zero crossings on ocean bottom seismograms at seven stations in the Adak 1978 experiment. For each signal possessing two predominant frequencies, the second predominant frequency is presented as an open symbol.

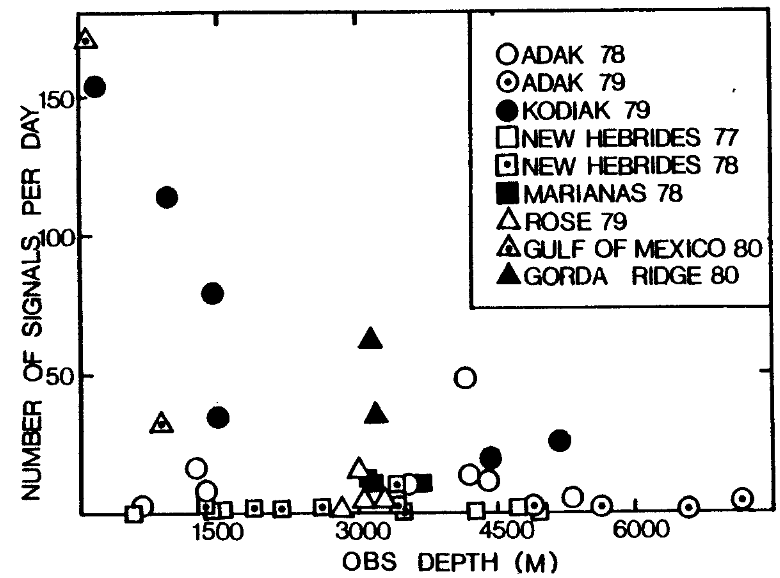

Fig. 6. The relationship between the rate of occurrence of signals and the depth of deployment of the ocean-bottom seismograph at which they were recorded in nine OBS experiments.

This trend is especially apparent in the Kodiak data in which the shallowest station recorded 160 signals per day and the deepest stations observed about 20 per day. In addition, the rates of occurrence are higher at stations deployed offshore of large continental land masses (as in the Kodiak, Gulf of Mexico, and Gorda Ridge experiments), while stations situated near isolated island chains (e.g., as in the Adak, New Hebrides, and Marianas expeirments) tend to record a lower rate of activity.

There was no evidence that any of these signals was recorded on more than one station at a time. In particular, these were no more coincidences (i.e., signals recorded on more than one station within the same minute) than predicted by chance alone. For example, in a time interval of T minutes, if two stations detect N_1 and N_2 signals respectively, we can except that the number C which will occur within one minute of one another will be $C = 2N_1N_2/T$. In the Adak experiment in 1978, stations 4 and 5 operated simultaneously for 24 days. 1172 events were recoded at station 4, 316 events were recorded at station 5, and so the expected number of coincidences would be 21.4. In fact, the observed number of coincidences was 20, not significantly different. Similar results were found for all combinations of stations.

Many of the signals occur in clusters or trains (Table 1). In most experiments, trains for 3 or more signals occurring less than a minute apart account for 20–30%

of the signals. Single events comprised from 30–82% of the records at various stations in the Adak experiments (Table I). Usually the individual signals within such a train are of similar amplitude, but they may vary in duration. Stations with the fewest signals per day have the lowest proportion of signals occurring in trains of multiple signals.

Data from the Kodiak 1979 experiment suggest that the signals at shallow stations are more frequent at certain hours of the day, while signals at stations deeper than 1000 m occur randomly with respect to time of day. The total number of signals per hour of day (all days at a particular station during a single expeirment lumped) is shown in Figure 7. Data for the shallowest station (163 m depth) indicate a lower than average activity rate during the hours around midnight, Kodiak local time. After that low, there is a large increase in activity during the short period of darkness (about 1–3 a.m., in the Alaskan summer). A station at greater depth (928 m) showed small peaks of activity in the hours just before and after darkness.

Other than the 24 h periodicity observed at the shallow station in the Kodiak experiment, statistical tests on the Adak 1978 and Kodiak 1979 data showed no significant temporal pattern in the rate of occurrence of these signals. The rate of signals on a given day on one station was independent from the rate on other stations in the experiment (two-way combination of 5 Adak stations, Spearman Rank Correlations not significant). The daily rate of occurrence of signals at a given station varied randomly during the course of the experiments, i.e., for seven stations at Adak and for five stations at Kodiak, a Chi Square test of the distribution showed no difference from random. In addition, for data from the Kodiak experiment, a Chi Square analysis revealed no significant relationship between the rate of activity and the phase of the tidal cycle.

TABLE I

The table below represents the fraction of signals occuring in temporal groups of different sizes during the 1978 Adak experiment (Frohlich *et al.*, 1981). A signal is counted in a group if it occurs within one minute of another signal.

OBS station	1	2	3	4 or more	Station depth (m)	Number of signals/day
1	0.58	0.21	0.08	0.13	1322	8.7
2	0.63	0.25	0.08	0.04	1218	16.0
3	0.82	0.17	0.01		622	3.3
4	0.30	0.17	0.10	0.43	4159	48.8
5	0.33	0.16	0.12	0.39	4197	13.2
6	0.67	0.13	0.11	0.09	5293	5.0
7	0.60	0.12	0.06	0.22	4389	11.2
8	0.65	0.08	0.05	0.22	3522	10.0

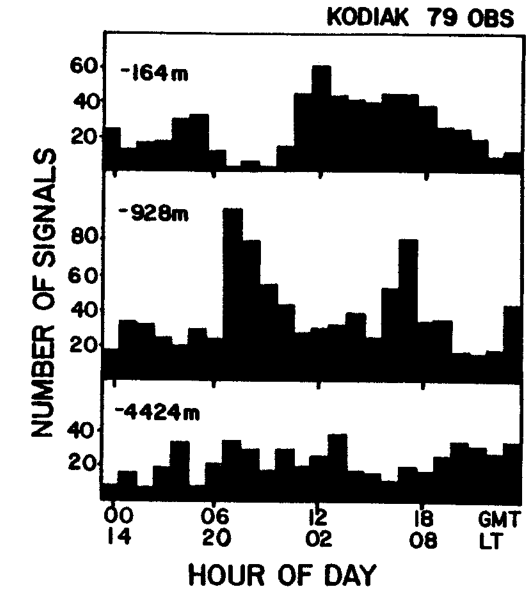

Fig. 7. The number of signals in each hour period recorded on three OBS deployed at different depths near Kodiak, Alaska, in June 1979. Events occurring during each clock hour are lumped for all days during the experiment. The diurnal distribution of signals is random for the deepest OBS (4424 m) but is not random for the units in 164 m of water (Chi square = 264.1).

3. Discussion

The present paper presents the first published description of a particular type of signals of impulsive character and brief duration which are observed on recordings from OBS instruments. This phenomemon appears to be ubiquitous, as it has been observed on all deployments of the Texas OBS instruments. We hope that the description and speculations reported here will encourage other researchers to report their own observations of these signals. Observations recorded by instruments differing in design from the Texas OBS would be particularly useful (e.g., observations from 3-component instruments with hydrophones, or observations from a pair of matched instruments deployed on the ocean bottom and in a borehole).

These signals are an annoyance to most researchers utilizing OBS instruments, as they interfere with recordings of earthquake and refraction signals. They may be a particular problem in studies where large numbers of small unlocatable earthquake events are counted or analyzed statisticaly (e.g., Francis and Porter, 1971). In addition, long term seismic monitoring studies in relatively shallow water can expect to find these events especially troublesome since their rate of occurrence can be remarkably high in shallow coastal areas.

One possible triggering scheme which would discriminate against most of these events would be to record an event in OBS memory only if

(1) The event amplitude exceeded background levels continuously for more than 5 s,

or

(2) The event amplitude exceeded background levels twice within a 20 s period.

The above scheme should permit even small earthquakes to be recorded if both P and S (or surface wave) phases exceeded background levels. For strong motion event monitoring, a system more dependent on event duration than an acceleration level might be more appropriate. For example, one scheme might be to trigger the recorder if :

(1) The event acceleration exceeds some particular level (say, 0.01 g)

and

(2) The event duration exceeds background levels for a specified time (say, 20 s).

This scheme would permit most strong local earthquakes to be recorded

3.1. Relationship to Biological Phenomena

Several lines of evidence support the hypothesis that these signals are of biological origin, possibly caused by animals touching the OBS unit. The pattern, timing, and location of the signals seem to agree with this hypothesis, and indeed, other OBS researchers occasionally refer to them as 'fish bumps' (Francis and Porter, 1973). In the following discussion we present circumstantial evidence that suggest biological phenomena provide a more likely explanation fot these signals than do other possible explanations.

The distribution of occurrence of these signals in the oceans is similar to the distribution of marine life. In particular, the general decrease in rate of occurrence of these signals with depth is similar to the general decrease in the abundance of living organisms with ocean depth. Marine plankton, for which the best sampling data exist, show a drop in biomass by one or two orders of magnitude from the surface to 4000 m depth in both tropical and temperate waters (Zenkevitch, 1963; Marshall, 1971). Similar quantitative measurements of biomass for fish populations do not exist, but since plankton form the base of the food chain, plankton biomass is closely related to fish biomass in an area. Abyssal animals (particularly fish and invertebrates such as holothurians and crustaceans which comprise the bulk of abyssal animal biomass) have reduced body size and sparse populations at depths below 5000 m (Idyll, 1971; Hessler and Jumars, 1974; Grassle *et al.*, 1975). However, these mobile animals are thought to be quite exploratory and opportunistic in feeding habits (Isaacs and Schwartzloze, 1975), and it is quite

possible that they would investigate an OBS dropped into their environment. The signals are more frequent at stations near large continental land masses than those near isolated island chains. Oceanic areas of greatest biological productivity tend to be near continental land masses as well (Walton Smith and Alldridge, 1974).

A second indication that the signals may be of biological origin is the temporal pattern of the signals at stations shallower than about 1000 m. In clear water the presence of sunlight may be detectable by animals only to a depth of about 1000 to 1200 m, and there are diurnal vertical migrations of plankton down to 800 or 900 m or deeper (Marshall, 1971). If the activity of animals causes the signals, we might expect to find a 24 h periodicity at stations shallower than 1000 m and a lack of such a pattern at stations below 1000 m, as observed in the Kodiak experiment (Figure 7). Some of the more obvious changes in activity in the Kodiak data occur at about the time darkness is falling in the Alaskan summer when the experiments were conducted. If biological activity is responsible for the temporal variations in signal activity observed in Figure 7, then these data suggest that during twilight hours the species responsible avoid contact with OBS units at depths like 163 m, and are more active at depths like 928 m.

Perhaps the most convincing evidence that animals can affect OBS instruments is that biological material has been found on OBS units upon recovery (Figure 8).

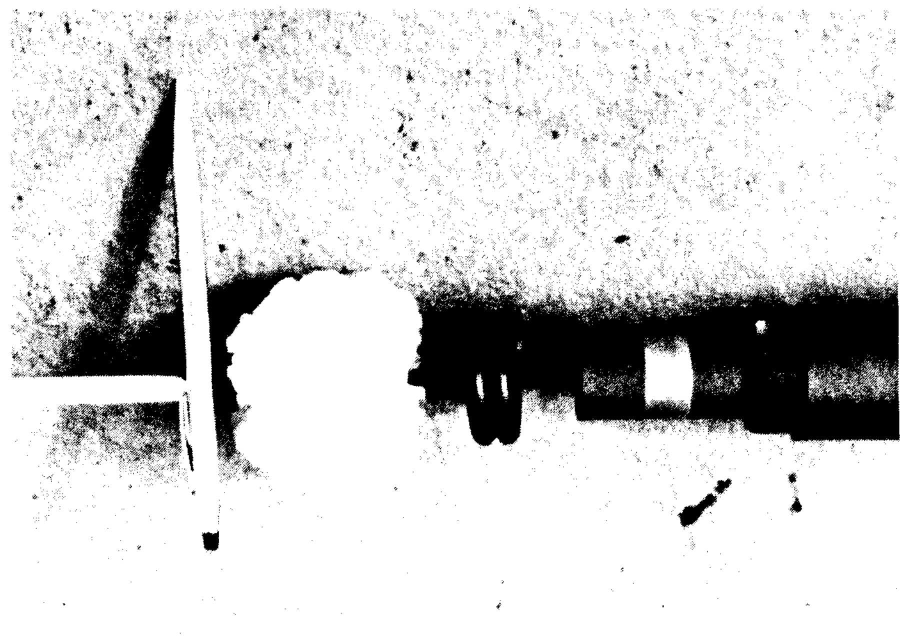

Fig. 8. Photograph of unidentified gelatinous eggs found attached to the radio beacon antenna of an ocean bottom seismograph recovered in the Aleutians near Adak in August 1979. The OBS was deployed in 795 m of water and was recovered 61 days after deployment.

Eggs, apparently from an invertebrate, were found attached to two Texas OBS units which had been deployed for several weeks offshore of Alaska, at depths of 182 and 795 m, respectively. The biological material was attached to the antenna (which is above water during recovery operation) of one instrument and to the glass sphere of the other. Because the instruments rested on the ocean floor except for a few minutes while they were sinking during deployment, and for a few minutes while they were surfacing during recovery, the eggs most likely were deposited by a deep water organism. Unfortunately, the species of the animal producing the eggs could not be identified. Eggs have also been reported on OBS instruments deployed and recovered in 2200 m of water by scientists at the Pacific Geoscience Center in Canada (M. Bone, pers. comm.).

The idea that these signals are records of a tapping or touching movement is strengthened by the impulsive nature of the signals. Their frequency pattern closely resembles that of impulse tests on the Texas OBS (see Figure 9) conducted during Project Lopez (Sutton *et al.*, 1980b). In addition, the signal also resembles the impulse generated by the tape recorder when the tape head shifts into position to begin recording information stored in the digital memory. However, the signals generated by the tape head at any station are all virtually identical, whereas the supposedly biological signals differ from one another in duration, first motion, etc. It is possible that external impulses can cause various signals with complicated features such as bimodal frequency spectrum, because impulses at different points on the OBS might stimulate different resonant frequencies in OBS frames. As discussed below, probably varying sediment thicknesses and properties at different OBS sites contribute to the variations in signals observed at different OBS sites.

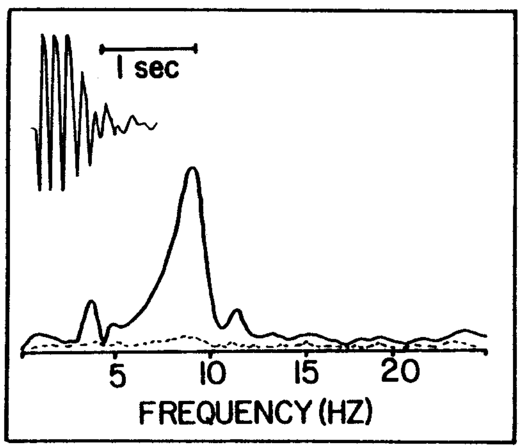

Fig. 9. An impulse response signal from the ocean bottom seismogram (above) is presented along with the spectral analyses (below) of the signal (solid line) and a segment of background noise (dashed line). Spectra are fast Fourier transform of OBS records uncorrected for instrument response. The event was a vertical impulse test recorded on a vertical geophone (4.5 Hz) during the Lopez Island Intercomparison Experiment (Sutton *et al.*, 1980b).

The signals do not appear to be recordings of animal vocalizations for several reasons. Sounds produced by marine fish and mammals have an irregular or emergent pattern rather than an impulsive nature, and they generally have a complex, mixed frequency content with most energy in the range of about 100 Hz or above (Sebeok, 1979 ; Tavolga, 1964). Even the pure tone (about 20 Hz) sounds that have been recorded from finback whales (Tavolga, 1964) have an emergent character and unlike our signals are repeated regularly at intervals from 12 to 25 times per minute.

3.2. Alternative explanations

The unknown signals possible could be caused by small earthquakes. Certain sections of a few earthquakes recorded on Texas OBS units have a similar appearance, and some examples of the signals seem to have a small arrival before the large impulsive arrival. In addition, signals that resemble the signals discussed here have been recorded by the Wake Island Hydrophone array on instruments situated on the ocean bottom at a depth of 5.5 km and in the SOFAR channel at a depth of 1.0 km (George Suttun, pers. comm.). Presumably a hydrophone would not record a transient displacement impulse. However, the vast majority of our clearly recorded signals resemble those in Figure 1 and differ distinctly from recordings of known earthquakes because they exhibit a sharply impulsive onset, a regular exponential decay in a coda amplitude, a regular frequency spectrum, and a brief duration. No known earthquake signals recorded on an OBS exhibit all of these features.

In addition, the signals occur even more frequently in the Gulf of Mexico, a generally aseismic area (Frohlich and Dumas, 1980) than in the New Hebrides, one of the most seismically active areas on earth. The signals are detected on only one instrument, so that earthquakes producing these signals would have to be quite small, local events. There are no distinct *S* waves following the initial impulsive arrivals, and the events are more uniform in amplitude and duration than would be expected for earthquakes. If these signals are caused by earthquakes, they may be occurring so close to the OBS that they differ distinctly in appearance from other more distant events. In particular, for a nearby event occurring in the uppermost sediments beneath the OBS, the *P* and *S* phases could arrive nearly simultaneously, and most of the energy would be in trapped waves travelling in these sedimentary layers. However, we do not believe that these signals are caused by earthquakes, because there appears to be no relationship between the seismo-tectonic setting in which the signals are recorded and their frequency of occurrence, their signal polarity, or their duration. Incidentally, in one study by scientists at the Hawaii Institute of Geophysics using both OBS and borehole seismometers, numerous small signals resembling those we discuss here were observed on the OBS instruments, but not on the borehole instruments (Fred Duennebier, pers. comm.). This observation is difficult to explain if the signals are caused by earthquake activity.

Another possible explanation for these signals is that they are caused by changes in the OBS frame or in the sediments under the instrument as the OBS settles on the ocean floor, adjusts to the ambient temperatures and adjusts to the extreme hydrostatic pressures found on the ocean floor (e.g., see Solomon *et al.*, 1977). This explanation seems unlikely since the rate of occurrence of signals observed on the Texas OBS does not increase with depth. In addition, there is no observed change in the rate of occurrence of signals during the course of OBS experiments. In particular, there was no evidence of a high initial rate of occurrence followed by a marked decrease in the rate.

3.3. Possible Applications

Unlike microseisms recorded on land seismographs, activity of these signals at one OBS station does not seem to be related to their activity at nearby stations. The signals appear to be purely local, responding to a phenomenon occuring in the immediate vicinity of the OBS instrument.

If the signals are of biological origin as we suggest, a possible useful application of these signals would be to facilitate observations of deep-sea life. The biogeographical zone below 1000 m depth in the ocean is very poorly studied, and the animals there are strikingly different from those living at shallower oceanic sites. There is a major change in the relative abundance of different animal groups with depth (Marshall, 1971; Zenkevitch, 1963). In addition, studies of bottom samples (Dayton and Hessler, 1972; Hessler and Jumars, 1974) suggest deep-sea fauna may have different nutritional strategies and reproductive patterns.

Since little is known about deep-sea animals, objective information which could be provided by an OBS triggered system would be special interest to biologists. For example, a camera or tape recorder deployed with and triggered by an OBS could provide pictures or sound recordings of living deep-sea animals, many of which are known only from dead specimens taken in trawls. An OBS triggered system would have several advantages over baited time-lapse cameras (Isaacs and Schwartzlose, 1975) and manned submersibles (Grassle *et al.*, 1975; Busby, 1976), which often are restricted in depth of operation, are expensive to operate, are limited to relatively short duration studies, and excite or disturb the animals during their operation.

It is also possible that these signals would be used by OBS researchers to calibrate their instruments *in situ*. Since OBS instruments are usually deployed on sediments with low mechanical strength, the impulse response of the OBS/sediment system is generally quite unlike the impulse response of the seismometer alone (Sutton *et al.*, 1980a; Zelikovitz and Prothero, 1980). In particular, for most OBS designs in current use, the bouncing or rocking resonant modes of the OBS on the elastic sediments have frequencies in the same range as seismic signals. It is likely that the predominant frequencies observed in the coda

of signals discussed in this paper (Figure 5) are the frequencies of resonant modes of the OBS/sediment system, which are excited by an impulsive source.

For vertical motion, Sutton *et al.*, (1980b) and Zelikovitz and Prothero (1980) have calculated the impulse response of the OBS systems in terms of quantities such as the effective mass and radius of the OBS system and the shear modulus of the sediments beneath the OBS. However, to date there has been little research concerning the effects of horizontal impulses and of coupling between various horizontal and vertical modes (Lewis and Garmany, 1980). If these problems are resolved, it may be possible to determine the effect on seismic signals of the sediments at a particular OBS site from an analysis of one or more of the peculiar signals discussed in this paper.

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APPENDIX III:

PUBLICATIONS REPORTING RESEARCH WITH THE TEXAS OBS

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