High Resolution Seismic Reflection Survey near SPR Surface Collapse Feature at Weeks Island, Louisiana

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Introduction

This supplemental report is in response to questions and concerns raised at the Seismic Review Committee Meeting in Albuquerque, New Mexico, on November 9, 1994. Clyde Lee from Sytech was critical of the acquisition and processing of the Weeks Island, Louisiana, shallow high resolution reflection data. Mr. Lee suggested the data were acquired with inappropriate parameters and equipment and the processing flow and parameters were based on inaccurate analysis and event identification. Mr. Lee's observations concerning the validity and accuracy of these data were in error. This report includes several intermediate analysis steps and reprocessed CDP stacked sections primarily intended to reinforce the overall data quality and structural interpretations presented in previous reports. All previous event identifications made by the University of Kansas/Kansas Geological Survey (UK/KGS) were extrapolations based on available ground truth at that time (i.e., VSP in borehole BH-5 and water table measurement taken during the drilling of the angle borehole).

Acquisition and Field Data Quality

First and foremost, the statement that all near-offset traces were saturated with ground roll and direct wave, and were therefore unusable, is false. It was suggested this data could not be salvaged because the seismograph (15-bit, floating point) lacked sufficient dynamic range, the analog low-cut filters were too low, and the source produced too much ground roll and direct wave. It was implied that the only interpretable reflections were at long offsets where the reflection arrivals become asymptotic to the refraction (effectively wide-angle). Near-offset reflections on processed field files presented at the November 9th meeting were suggested to be somehow misleading because AGC (automatic gain control) and digital filtering artificially enhanced near-offset coherency. Unless the raw data were converted from SEG2 to Sytech processing format in a manner that truncated or otherwise changed the data, it is unclear what prevented the enhancement and easy identification of near-offset reflections on the majority of the data files.

Field files or shot gathers conclusively demonstrate the quality of reflections in this data set (Appendix A). Appendix A1 contains all field files from lines 1 and 4, digitally filtered and scaled (AGC). Over 70% of the field files have a reflection hyperbola that can be confidently interpreted to within 12 ft of the source (extremely near-offset). Appendix A2, which includes all field files from lines 1 and 4 with no

enhancements, clearly supports the level of QA/QC provided individual shot records and confirms bad shots were not recorded if second attempts to acquire improved data quality. Without a good understanding of the site conditions and constraints it is impossible to truly critique the QA/QC or shot consistency. We feel the data presented in Appendix A are more than sufficient evidence to support our acquisition parameters, equipment, and on-site QA/QC.

Coherent reflections on CDP stacked sections are not strongly influenced by long offset (wide-angle) traces. Comparison of stacked sections with all traces to ones using only traces with offsets less than about 100 ft show conclusively the shape and trend of the reflections interpreted on previous reports accurately represent two-way travel times for zero offset reflections (Appendix B). The processing of these CDP stacked sections was identical to that in the final report with the exception of the severe digital filter (Table 1). With the obvious similarity in the apparent structures and reflection arrival times between a stacked section with no long offsets to one containing all offsets, it would be extremely difficult to support that long offset interference resulted in artifacts on the stacked section.

Near-Surface Interference

Most apparent structures on coherent CDP stacked reflection sections are not artifacts of near-surface static anomalies. Careful analysis and planning of data processing steps based on first arrivals as well as the reflection energy is essential to stacked-reflection accuracy with minimal near-surface interference. Processing shallow reflection data with one strong reflection and very few and sometimes no other confidently interpretable reflections is not uncommon for shallow reflection data sets, but is highly unusual for high resolution petroleum data sets.

During initial processing of this data set extra care was taken to insure that structures interpreted on the stacked sections were not artifacts of elevation or near-surface velocity anomalies. Asymmetric reflection hyperbola with no hint of irregularities in the direct or refracted arrivals are commonplace on this data set (Appendix A). To verify that no shallow (< 20 ft) velocity anomalies have manifested themselves as apparent structure on the CDP stacked sections, we provide common offsets gathers at two offset distances (Appendix C). The subtle, consistent change in refracted arrivals evident during examination of unprocessed field files (Appendix A2) can be directly attributed to elevation change and the associated decrease in low velocity (weathered) material. Elevation effects were minimized through several previously described datum correction steps. It is

evident from both the common-offset gathers and field files that the shallow near-surface had little or no effect on the apparent structural irregularity of the stacked reflection.

Water Table Interpretation

The suggestion in previous UK/KGS reports that the coherent reflection interpreted on stacked data could be water table was based on three criteria: 1) the drill data available at the time, 2) the strong acoustic contrast represented by a saturated/dry unconsolidated material contrast, and 3) documented evidence at other locations of water table/saturated boundary reflections (Hunter et al., 1984; Birkelo et al., 1987; Merey et al., 1992, Miller et al., 1994). It is not at all uncommon to obtain reflections from the water table interface when profiling shallow unconsolidated environments. Contrary to the experience of many present at the meeting, reflections from water table in the Houston area and many other coastal settings is not at all uncommon (Miller et al., 1994). Drill and well data obtained after the preparation of our final report sheds doubt on the interpretation of the strong reflection as the water table but does not provide evidence for other possible explanations, such as intra-alluvial age discontinuities.

Conclusions and Recommendations

The supplemental analysis of the Weeks Island seismic data substantiates the data acquisition and processing of UK/KGS as detailed in both the preliminary and final reports. Careful study of the raw and severely digital filtered data reveals reflections at extremely close offsets on more than 70% of the shot gathers (Appendix A). Reflections that on many unprocessed field files are obscured by source noise were enhanced by straightforward digital filtering. Shot gathers with asymmetric reflection hyperbolae, indicative of velocity or structure changes, had very uniform first arrivals with symmetric refraction cross-overs and refraction/direct wave velocity structures (Appendix A). This perfect symmetry in first arrivals coincident with extreme asymmetry in the reflection hyperbola sheds doubt on claims that most observed irregularities on stacked sections are the result of near-surface anomalies. Minimal static anomalies were observed on common-offset gathers, suggesting a relatively acoustically uniform shallow near-surface (< 10-20 ft) (Appendix C). Comparisons of full fold with low fold, close-offset CDP stacked sections were intended to determine if longer offset reflections were producing any artifacts (Appendix B). Apparent structural features are consistent both horizontally

or vertically, independent of the presence or absence of longer offset traces. It is also obvious that reflections were recorded from offsets less than 100 ft and stacked coherently.

The critique of this data set during the November 9, 1994 meeting was at best incomplete. The unfounded and unsubstantiated suggestions that the data acquisition phase was misplanned and improperly executed, the processed data was misleading, and the stacked sections were not representative of the imaged reflector were incorrect. We believe most miscues were based on incomplete and inaccurate analysis and a lack of experience in the acquisition, processing, and interpretation of seismic reflection data targeting interfaces shallower than 200 ft. It is the intention of this document to verify the validity of our previously presented data.

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TABLE 1

Processing Flow

Primary Processing
format from SEG2 to KGSEGY
preliminary editing (automatic bad trace edit with 10 msec noise window)
trace balancing (150 msec window)
first arrival muting (direct wave and refraction)
surgical muting (removal of groundroll based on trace-by-trace arrival)
assign geometries (input source and receiver locations)
elevation correction to multiple, floating datums
sort into CDPs (re-order traces in common midpoints)
velocity analysis (whole data set analysis on 100 ft/sec increments)
spectral analysis (frequency vs amplitude plots)
NMO correction (station dependent ranging from 1350 to 2500 ft/sec)
correlation statics (2 msec max shift, 7 pilot traces, 100 msec window)
digital filtering (bandpass 70-140 280-420)*
secondary editing (manual review and removal of bad or noisy traces)
CDP stack
amplitude normalization (whole trace with 40 msec delay)
display

* THIS SEVERE DIGITAL FILTER WAS USED TO ENHANCE THE REFLECTIONS ON NEAR-OFFSET TRACES AT THE EXPENSE OF NARROWING THE BAND–WIDTH TO A POINT THE REFLECTIONS APPEAR RINGY.

Table 1. Processing flow for CDP stacked data. Parameters were determined by analysis for each prior step as well as through iterative analysis of particular operations.

Appendix Captions

Appendix A1, Line 1. All field files recorded from line 1 filtered and AGC scaled. The reflection is evident at very close offsets on most files. The filter used on these files is much more severe than that used on stacked section included in previous reports. This severe low-cut filter was used as a means of 'uncovering' or enhancing reflections suggested not to be present by Mr. Lee–files such as 37, which has reflection on close offset traces. File 65 displays the reflection coherently across all traces with the exception of Morton Road which is evident on traces 12 and 13. The change in elevation and near-surface materials is evident on file 113. Files from about 90 to the end of the line have an increased amount of noise. Even with this high percentage of noise, reflections on near-offset traces can be easily interpreted as far as file 135. Beyond 135 the survey lines moved into a wooded area with a very disturbed near-surface. Source-generated energy is very difficult to separate from noise on the last 25% of this line. The reduction in data quality at the southern end of line 1 has not been masked or hidden by overprocessing and is obvious on the CDP stacked sections presented in this and previous reports. As an added bonus, the reflection from the top of salt is extremely evident on several files near the start of line 1, especially file 9 at about 180 msec.

Appendix A1, Line 4. All field files recorded from line 4, filtered and AGC scaled. The reflection is evident at very close offsets on most files. The filter used on these files is much more severe than that used on stacked section included in previous reports. As with line 1, this severe low-cut filter was used as a means of 'uncovering' or enhancing reflections suggested not to be present by Mr. Lee–files such as 4055. File 4100 displays the reflection coherently across all traces except in very close proximity to the sinkhole evident in the middle portion of the spread. Also evident are the diffraction or "bow tie" effect obvious on the CDP stacked section of line 4. The asymmetric nature of the reflection as evident on file 4148 is indicative of structure. The dead or excessively noisy traces 18-22 on file 4148 are the effects of Advanced Products Road. Even on the extreme west end of line 4, such as file 4171, the reflection can be interpreted on traces with less than 8 ft of source offset. This extremely high low-cut filter increases the ratio of high frequency noise present pre-first arrival and on longer offsets. This increase in noise is actually a result of a decrease in the lower spectral components of the source generated energy. Source generated energy is very difficult to separate from noise on the last 25% of this line. Occasionally a file like 4131 with no apparent reflection energy can be observed, but these low- to minimal-signal files represent less than 20% of the total data set and are usually in the proximity of much higher signal-to-noise ratio files, such as in this case. Files 4129, 4132, and 4133 all have easily identifiable reflections on a dozen or better traces less than 100 ft from the source. As on line 1, an added bonus is an easily interpretable reflection from the top of salt which is extremely evident on several files near

the start of line 4, especially files 4058 and 4060 at about 150 msec. The reflection hyperbola is highlighted on several field files.

Appendix A2, Line 1

From first arrival analysis of field files, no near-surface layers appear to have manifested themselves as structural artifacts on the stacked sections. Field file 64 clearly displays an easily interpretable asymmetric reflection beneath a perfectly symmetric uniform first arrival. Refraction statics would not correct the velocity/structural feature as indicated by the distorted reflection hyperbola. Assuming, for the moment, that the asymmetry were the result of a near-surface heterogeneity, a localized velocity anomaly with more than a 50% change in average velocity over less than 50 ft would be implied with the entire change occurring between the top of the reflecting surface and about 50 ft of depth. If it is an artifact, the structural/ velocity anomaly above the reflection (interfering with the reflection arrival) would also have to be very abrupt. Both possible explanations are probably outside the realm of possibility at this site. The reflection becomes relatively symmetric again at field file 76, with little apparent dip. A refraction begins to appear about 81. The reflection is very asymmetric with an elevation change apparent near center of line. Stacking velocity drops drastically with no localized irregularities at or above refracting surface based on first arrivals. File 115 has drop in elevation and is down at level of fill hole, with a refraction now present and uniform on right, with the left side of the file still on the hillside. It is obvious that some structure seems to be present on or about traces 11-15 on file 115 with no indications of near-surface irregularities in the first arrivals.

After reviewing all field files, nowhere is an apparent regularity in the reflection directly traceable to the first arrival/refraction. It is also clear that the refracting event represents a surface that is fairly uniform and approaches the surface as the elevation decreases.

Appendix A2, Line 4

The first 40 or so field files were acquired over fill/rubble hauled in for road base. Once the shot passed beyond the fill, refractions for the most part are very uniform, consistent, and identifiable. Files 4057, 4058, and 4059 possess very symmetric refractions with little or no trace to trace irregularities. The reflection hyperbola, however, possesses significant asymmetry. Based on the arrival patterns on these files the structure/velocity irregularity is most likely representative of the reflector surface and not the shallow near surface. A bonus on these files is the apparent deeper reflection interpretable at about 140 msec that could possibly be from the salt surface. A fairly significant change occurs west of Advanced Products Road, as evident in the dramatic change in refraction arrivals. The reflection event is very weak to non-existent probably as a result of fill, old driveways, building foundations, etc., present at or near the ground surface in this area. The change in reflection curvature is particularly evident on file 4170. The reflection hyperbola are

compelling evidence (especially when compared to the entire field file) in support of structural irregularities on the reflector surface.

Appendix B, Line 1. These two CDP stacked sections of line 1 have the same severe digital filter used on the field files in Appendix 1A. Line 1a represents a stacked section with all traces possessing a source-to-receiver offset from 4 to 384 ft with good S/N. Line 1a is a CDP stacked section with the same traces Mr. Lee suggested only produced coherent events from long offset reflection wavelets. Line 1b is a 12-fold CDP stack of line 1 with only traces possessing source-to-receiver offsets from 4 to 104 ft. For a 90 to 100 ft target these traces would be classified as mid- to close-offset. Mr. Lee strongly suggested no reflections were recorded on close offset traces and therefore stacked sections presented in previous reports represented structures altered by refraction interference and wide angle effects. Comparison of lines 1a and 1b clearly refutes the statement that all reflections on stacked sections are only from long offsets and therefore apparent structures are influenced by refractions and wide angle offsets. Contrasting the close-offset stacked section (line 1b) with the stacked section containing all traces (line 1a), and considering the raypaths as a function of time/depth, the lack of a horizontal shift in apparent structural features minimizes the possibility that an extremely variable near-surface was responsible for the apparent structural features. This comparison also suggests refraction statics should not significantly alter the interpretation of coherent reflections on this stacked section.

Appendix B, Line 4. The two CDP stacked sections of line 4 have the same severe digital filter used on the field files in Appendix A1. Line 4a represents a stacked section with all traces possessing a source-to-receiver offset from 4 to 384 ft and acceptable S/N. Line 4a is a CDP stacked section with the same traces Mr. Lee suggested only produced coherent events from long offset reflection wavelets. Line 4b is a 12-fold CDP stack of line 1 with only traces possessing source-to-receiver offsets from 4 to 104 ft. For a 90 to 100 ft target these traces would be classified as mid- to close-offset. Mr. Lee strongly suggested no reflections were recorded on close offset traces and therefore stacked sections, as presented in previous reports, represented structures altered by refraction interference and wide angle effects. Comparison of line 4a and 4b clearly refutes the statement that all reflections on stacked sections are only from long offsets and therefore apparent structures are artifacts. (Note: It is understood that everyone agrees the structure associated with the sinkhole is real.) Contrasting the close-offset stacked section (line 4b) with the stacked section containing all traces (line 4a), and considering the refraction, reflections, and direct wave raypaths, the lack of a horizontal offset in apparent structural features minimizes the possibility that an extremely variable near-surface was responsible for the apparent structural features. This comparison also suggests refraction statics would not significantly alter interpretation of coherent events on this stacked section.

Appendix C, Line 1. Unfiltered, common-offset gathers of traces north of the source (negative and up dip direction) with a source-to-receiver offset of 12 ft and 102 ft. Without the appropriate digital filter (a severe filter would have enhanced the reflection at the expense of accurate first arrival information) the reflections from 12 ft are difficult to interpret, however, the reflections on the 102 ft common offset panel are evident with no processing. The purpose of these common-offset gathers is to allow inspection of the first arrivals. Flat relatively uniform first arrivals are indicative of consistent source time zero and a very consistent near-surface velocity structure. Based on initial walkaway testing there does not appear to be a refracting interface within the upper 100 or so feet at the start of line 1. Near the end of line 1 the reflection becomes shallow enough in time to interfere with the direct wave arrivals. If a refraction were produced from an interface on the order of 20 ft deep, the 102 ft common-offset section should possess evidence of a cross-over near the south end of the section. No apparent cross-over can be interpreted. The first arrivals on the 102 ft offset clearly display the effects of elevation change (an effect that is removed during normal datum corrections), but with the exception of the last 25% (southernmost end) no indication of a cross-over is present. Based on a strong lack of consistency between the first arrival undulations and the reflection interpretable on the 102 ft common-offset panel it is very unlikely any structure interpreted on line 1 is present purely as a result of uncompensated or improperly corrected near-surface static.

Appendix C, Line 4. Unfiltered, common-offset gathers of traces east of the source with a source-to-receiver offset of 12 ft and 102 ft. Without the appropriate digital filter the reflections from 12 ft are difficult to interpret; however, the reflection on the 102 ft common offset panel is evident with no processing. The purpose of these common-offset gathers is to allow inspection of the first arrivals. Flat relatively uniform first arrivals are indicative of consistent source time zero and a consistent near-surface velocity structure.

Appendix A1, Line 1

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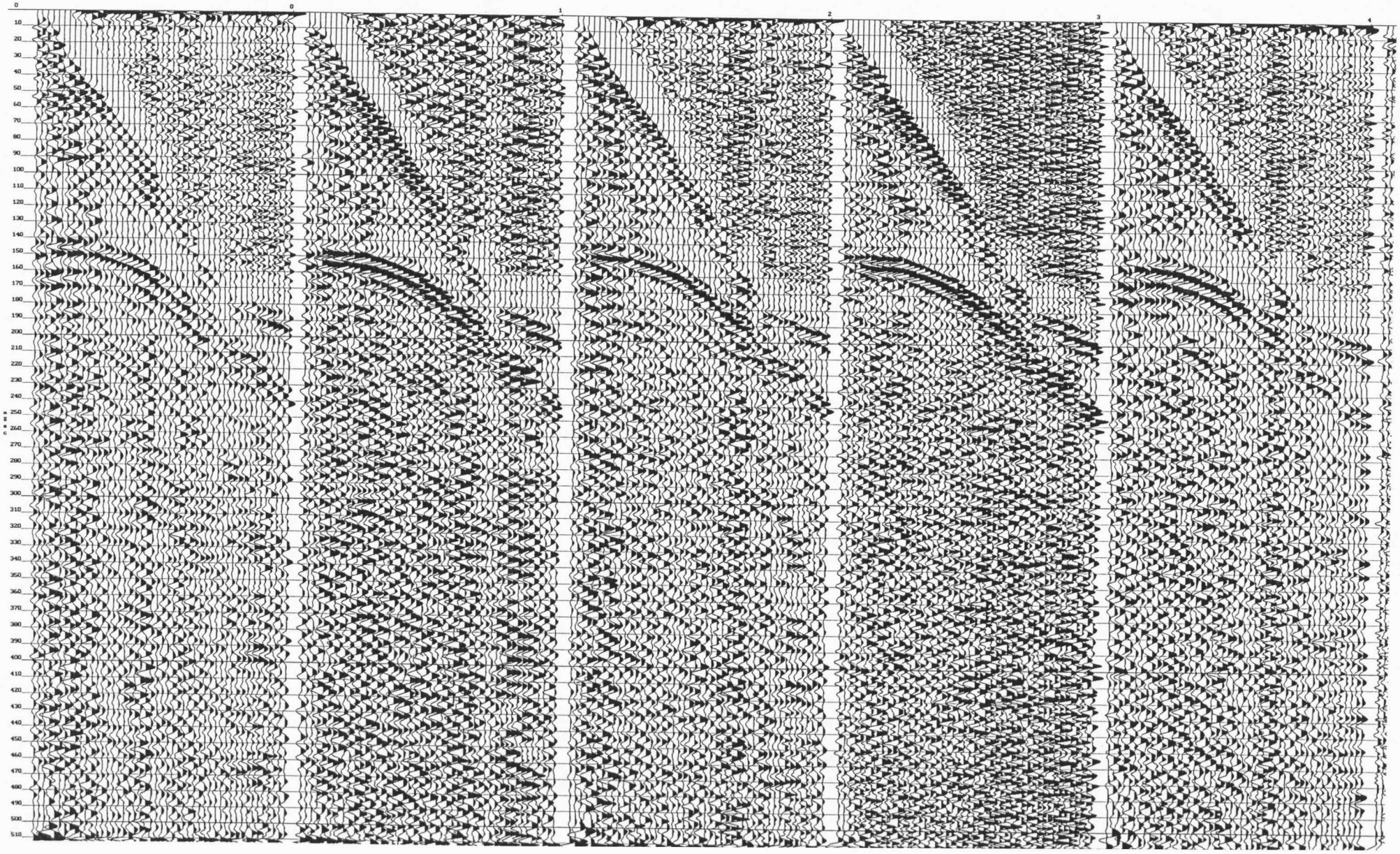
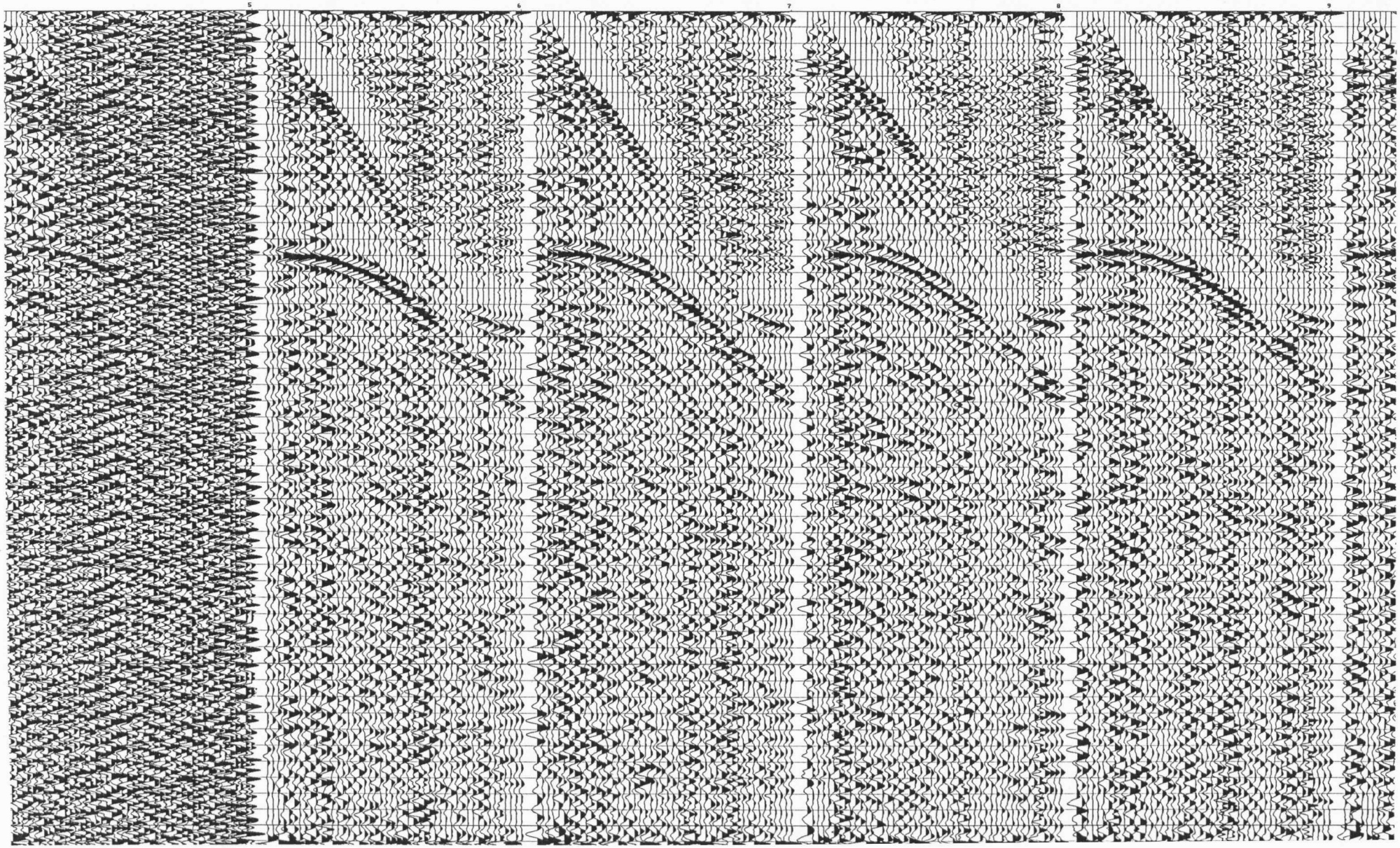
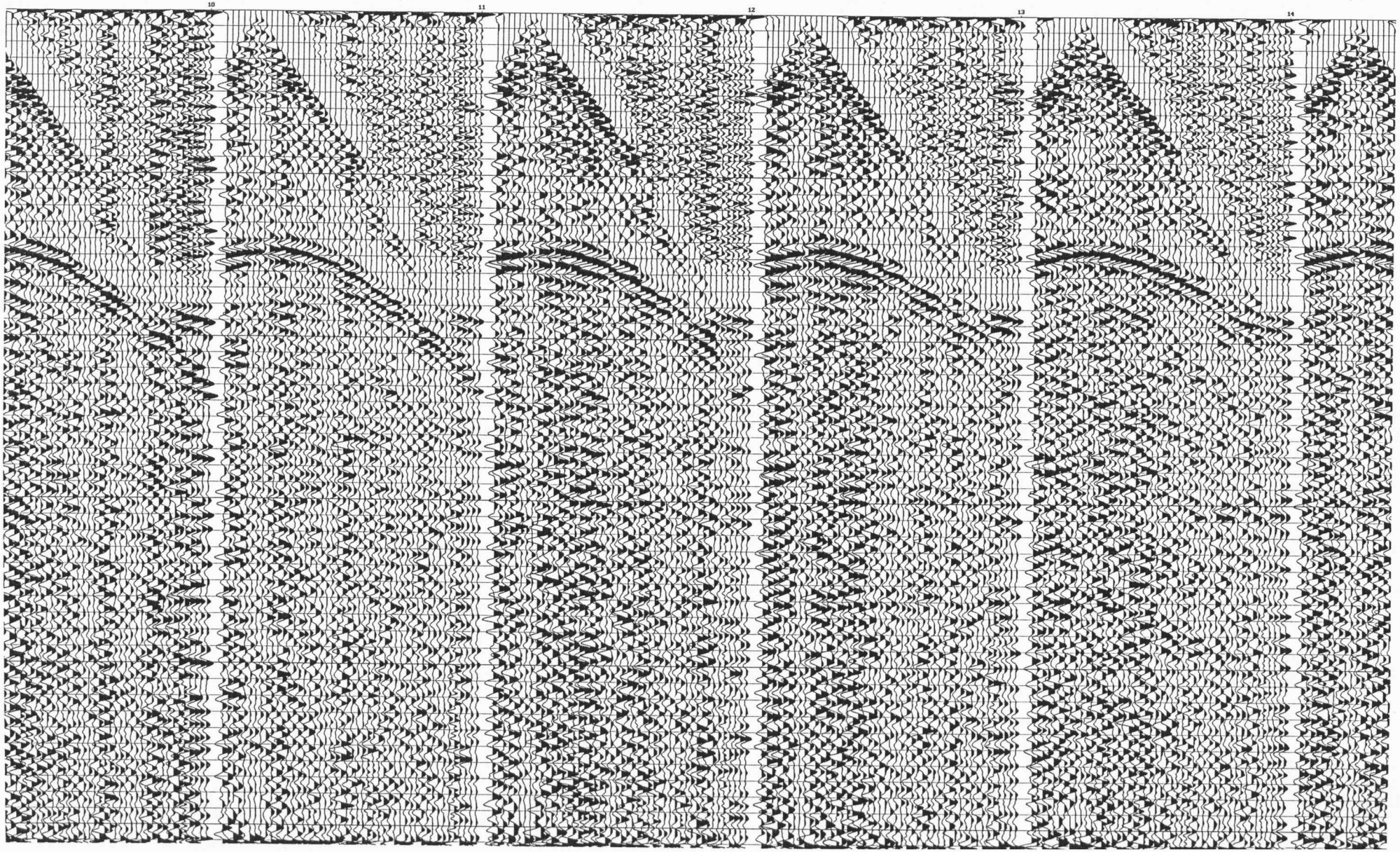


Salt reflection

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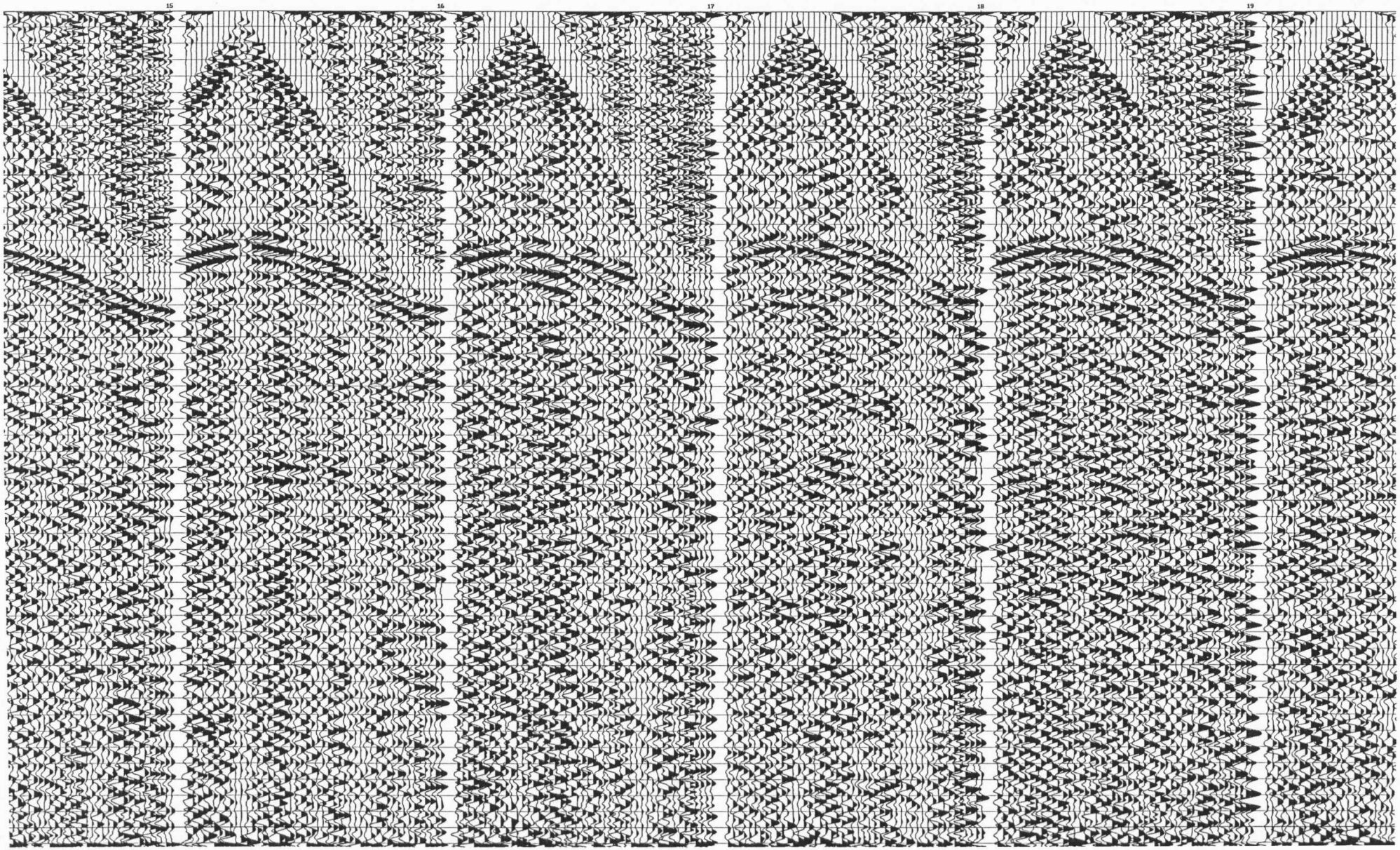
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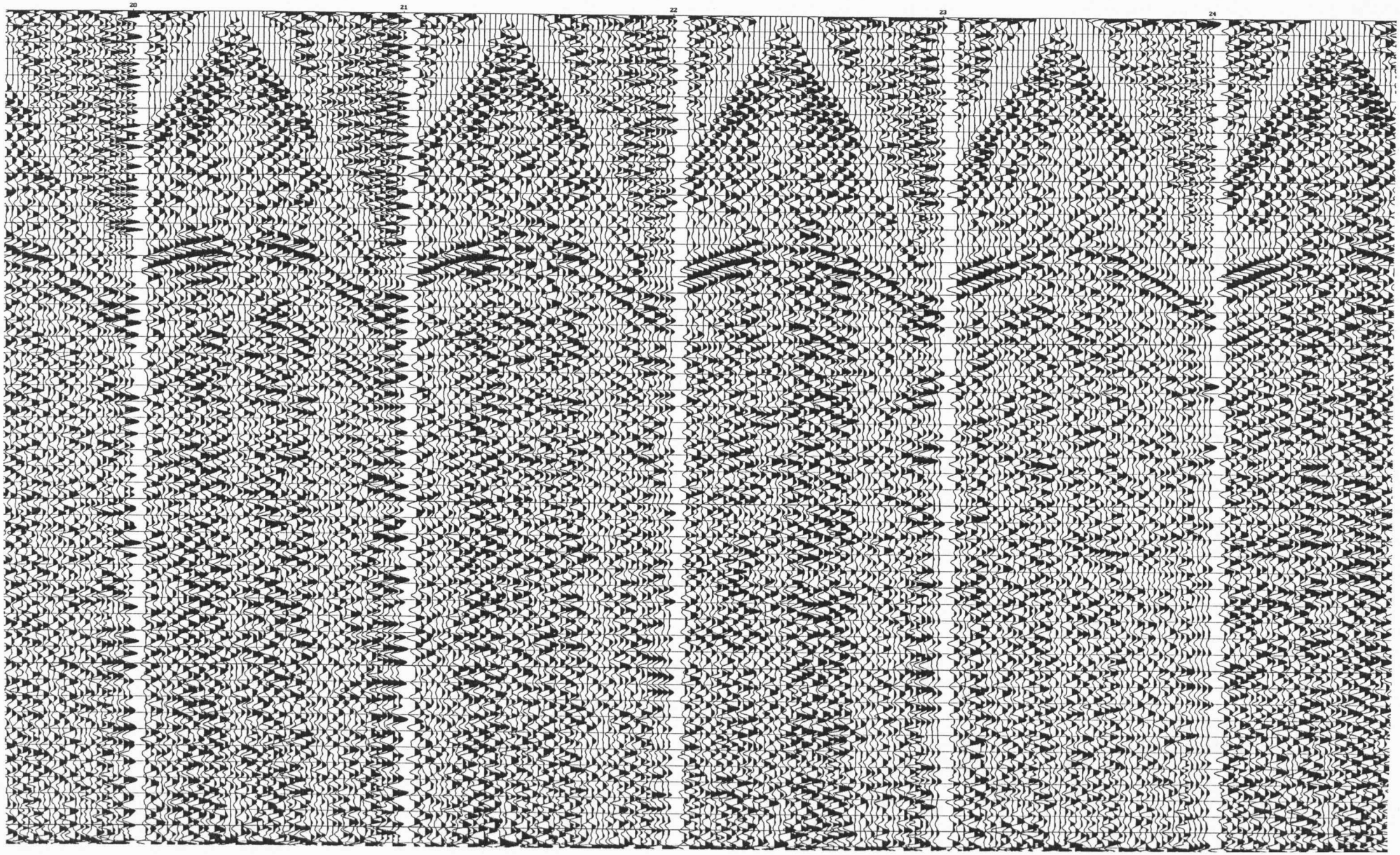
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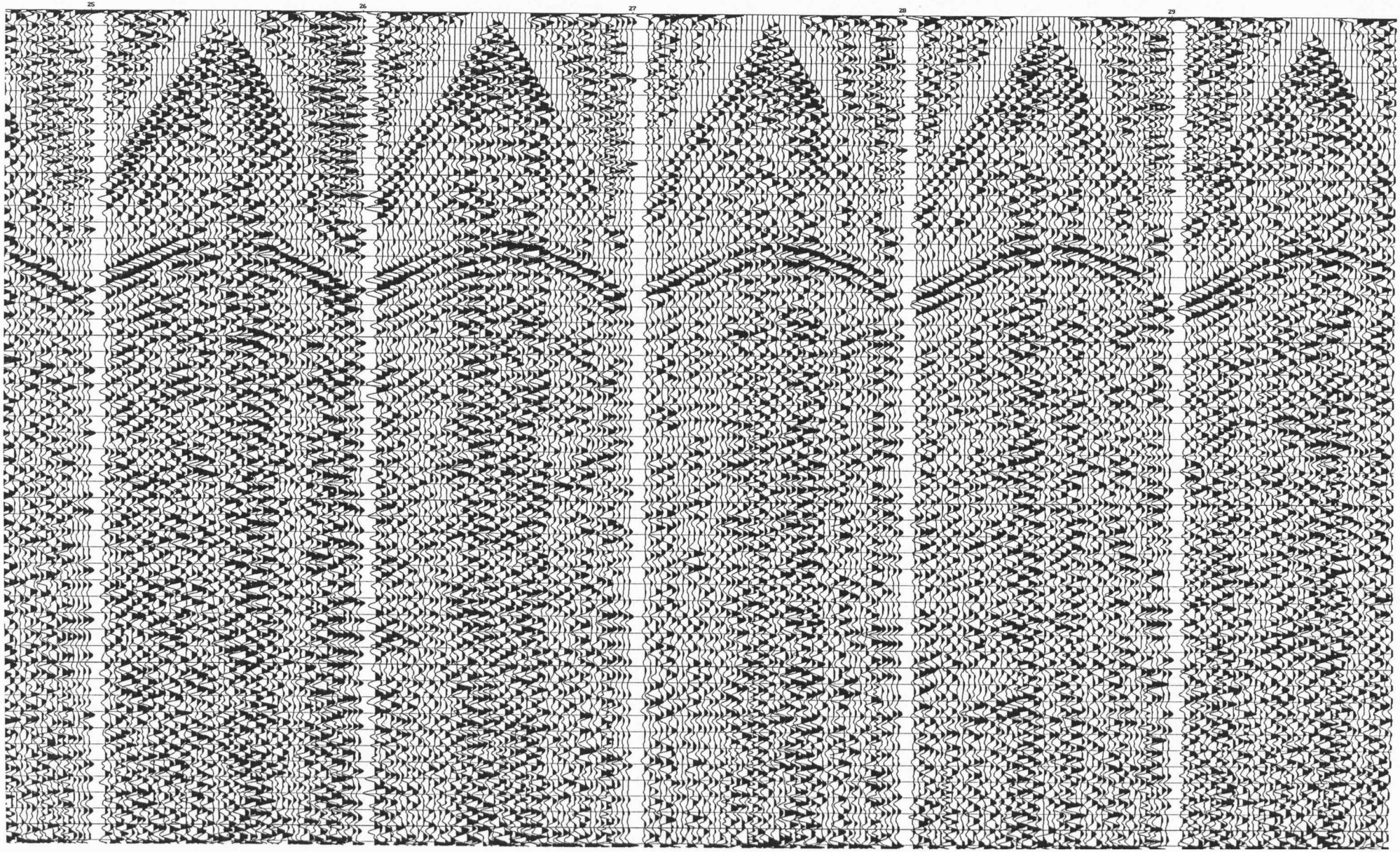
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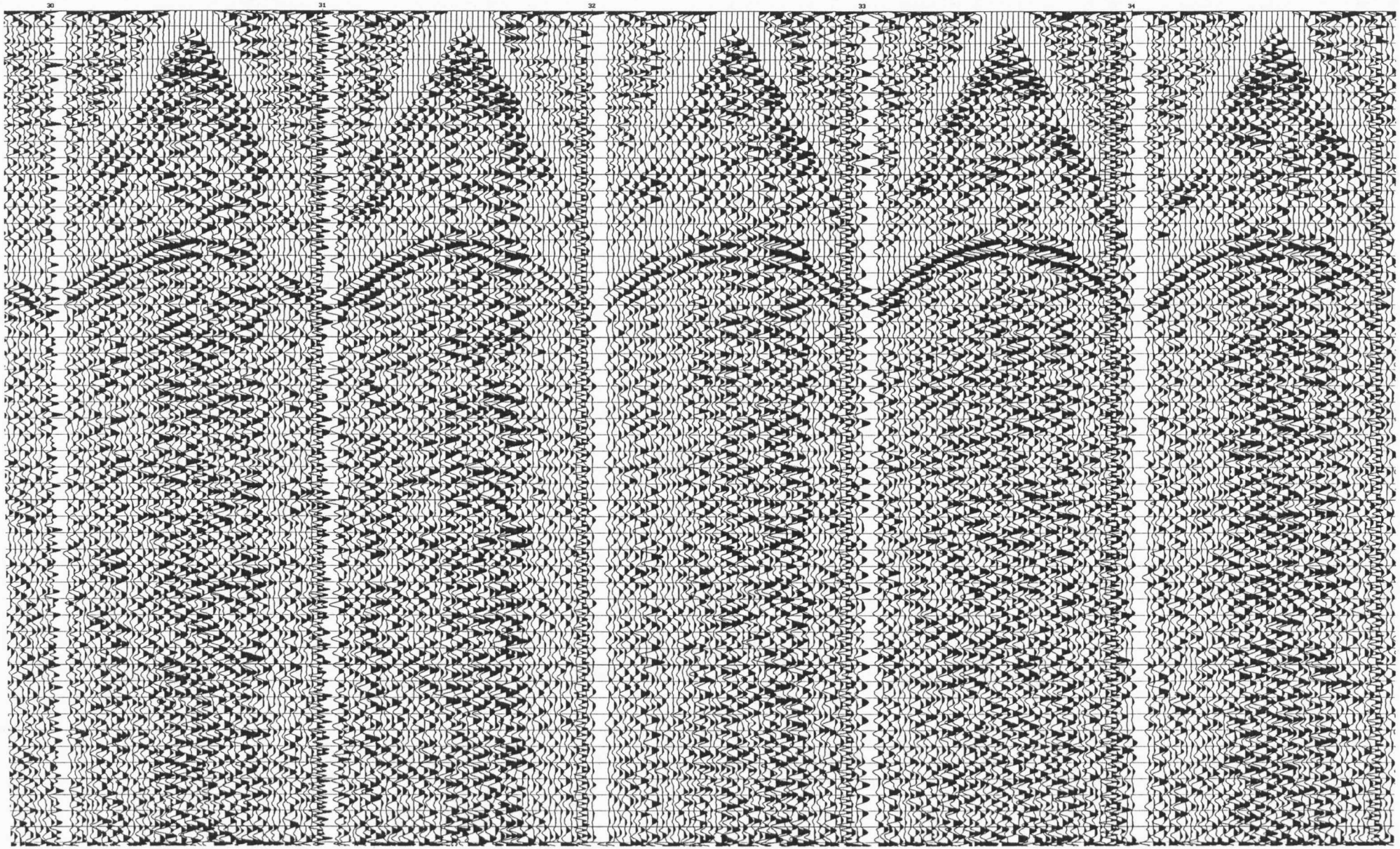
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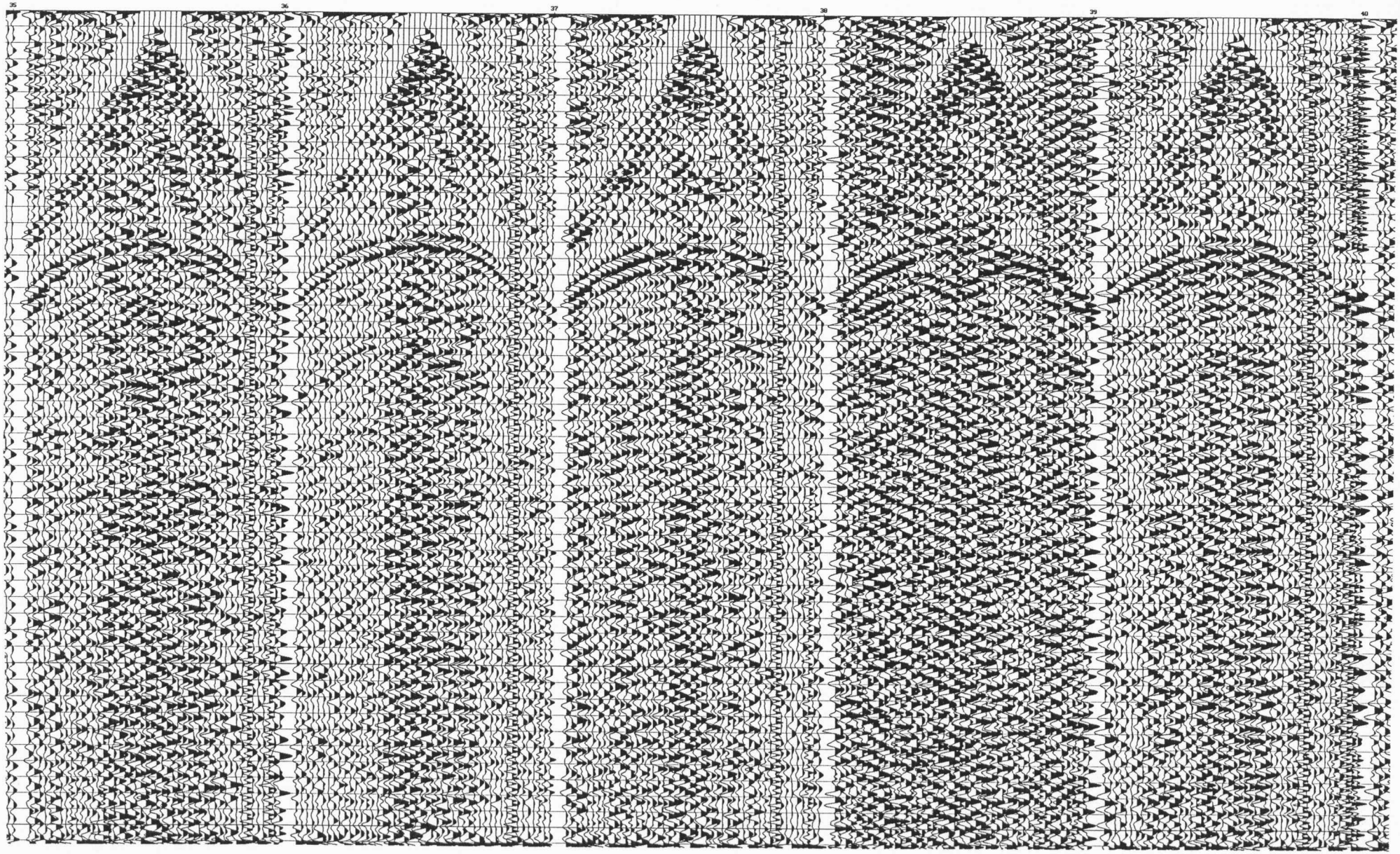
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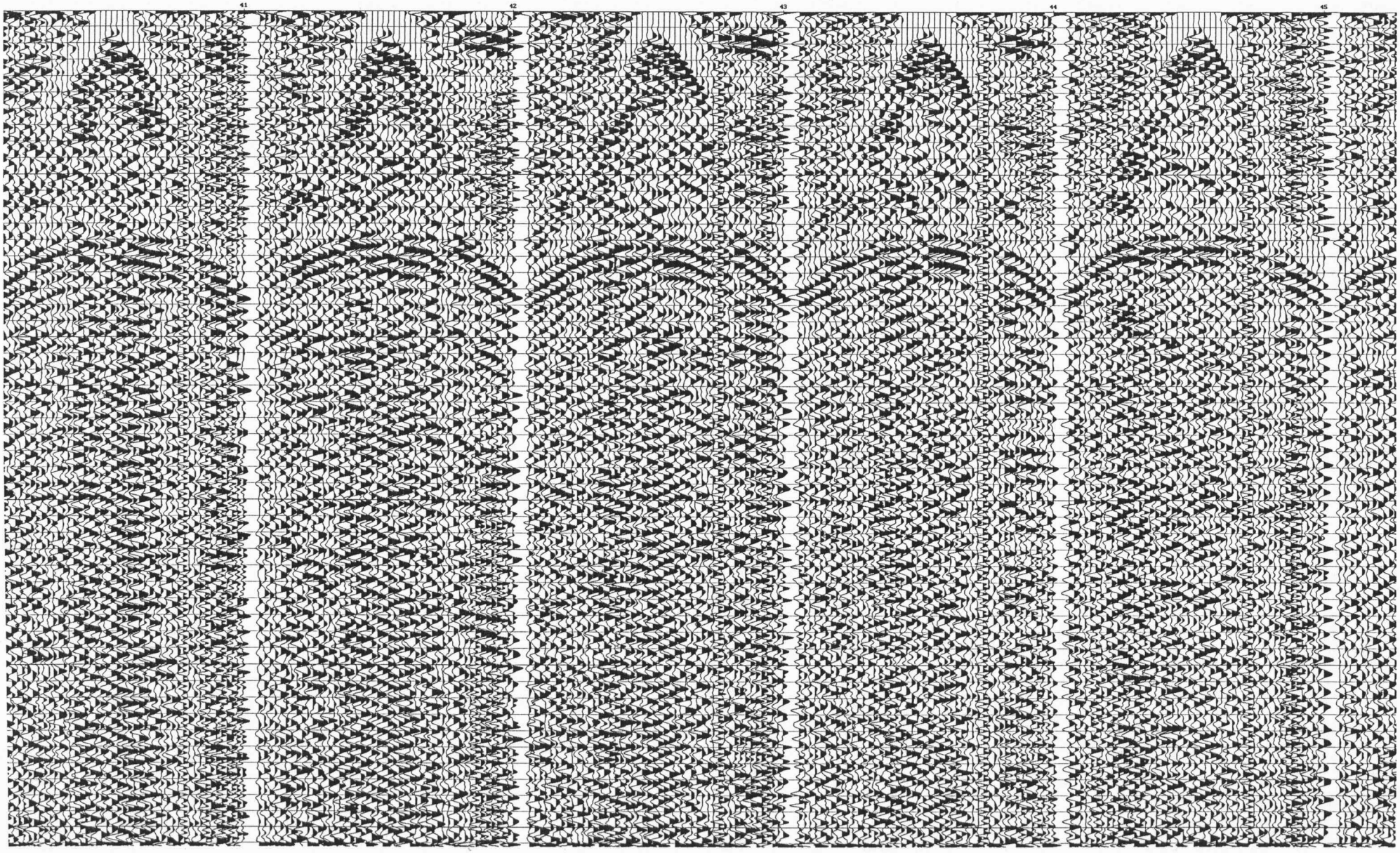
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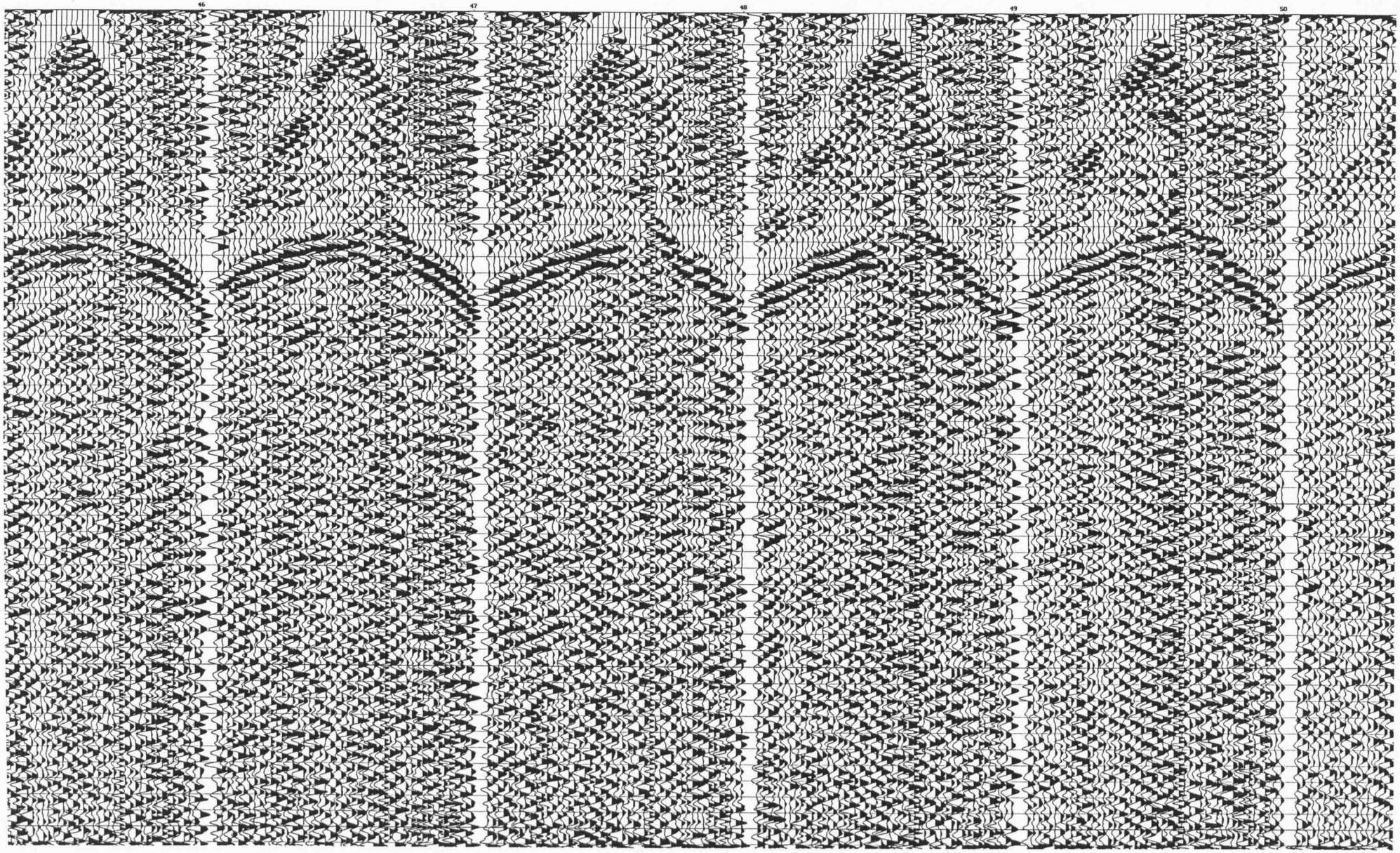
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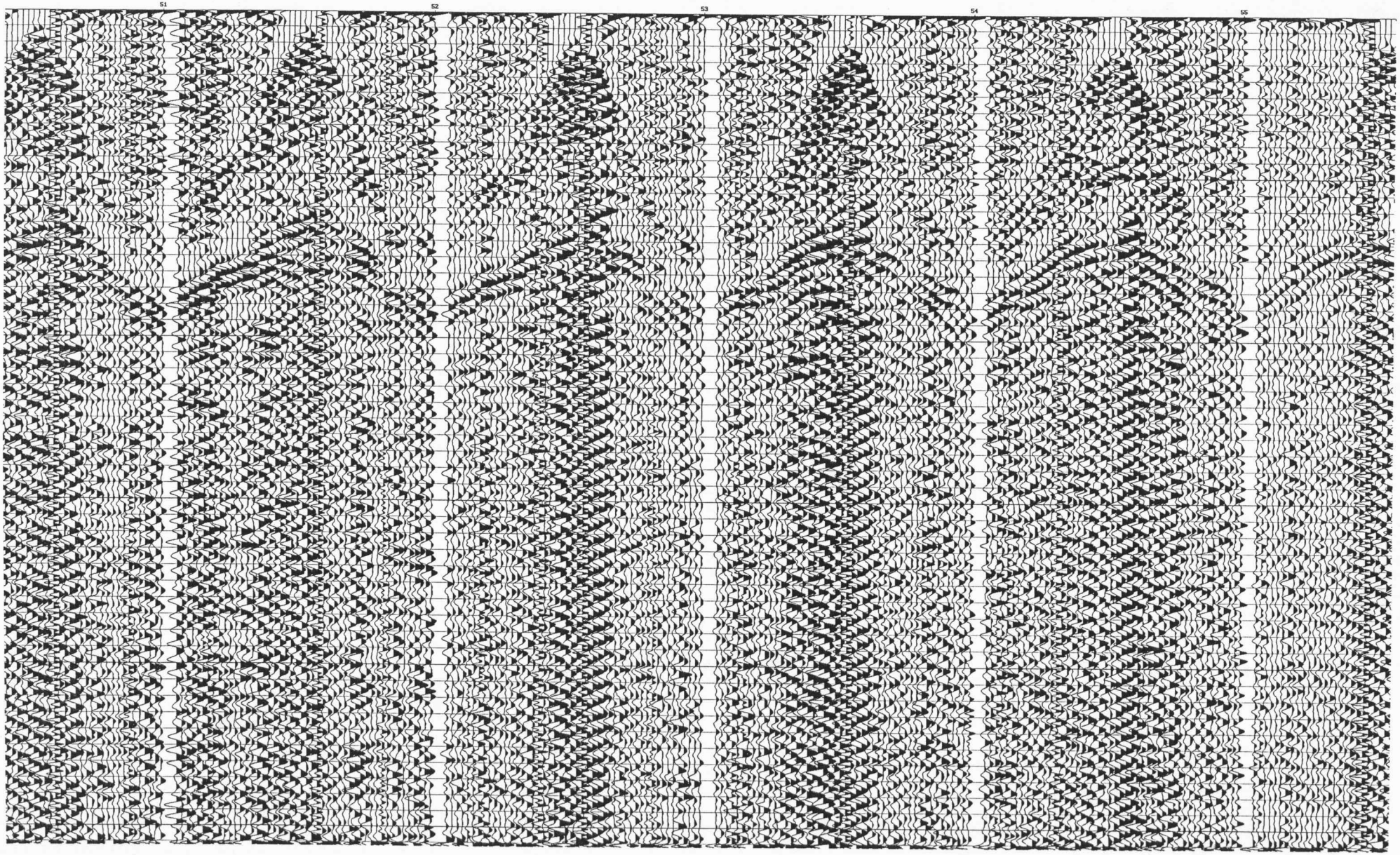
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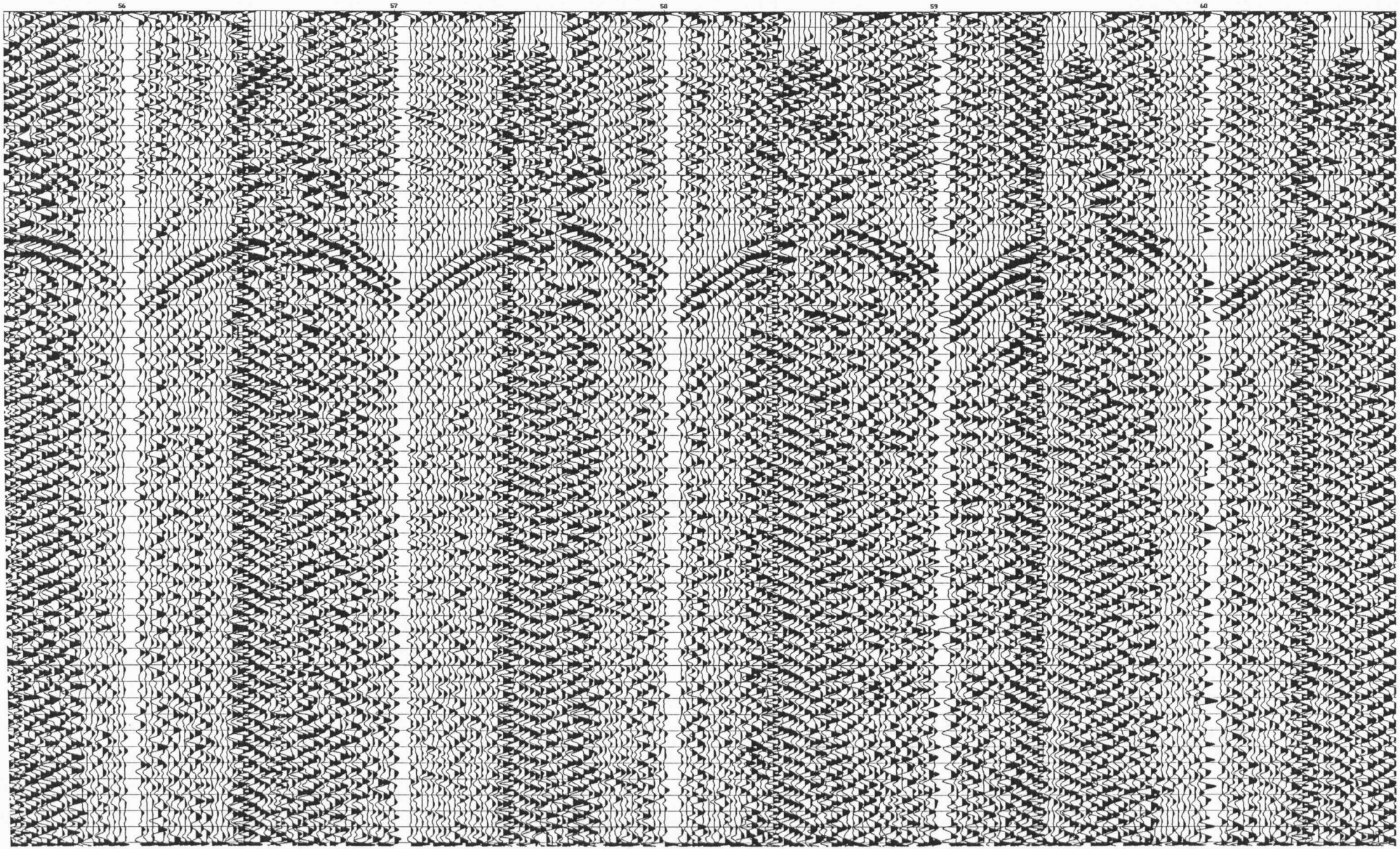
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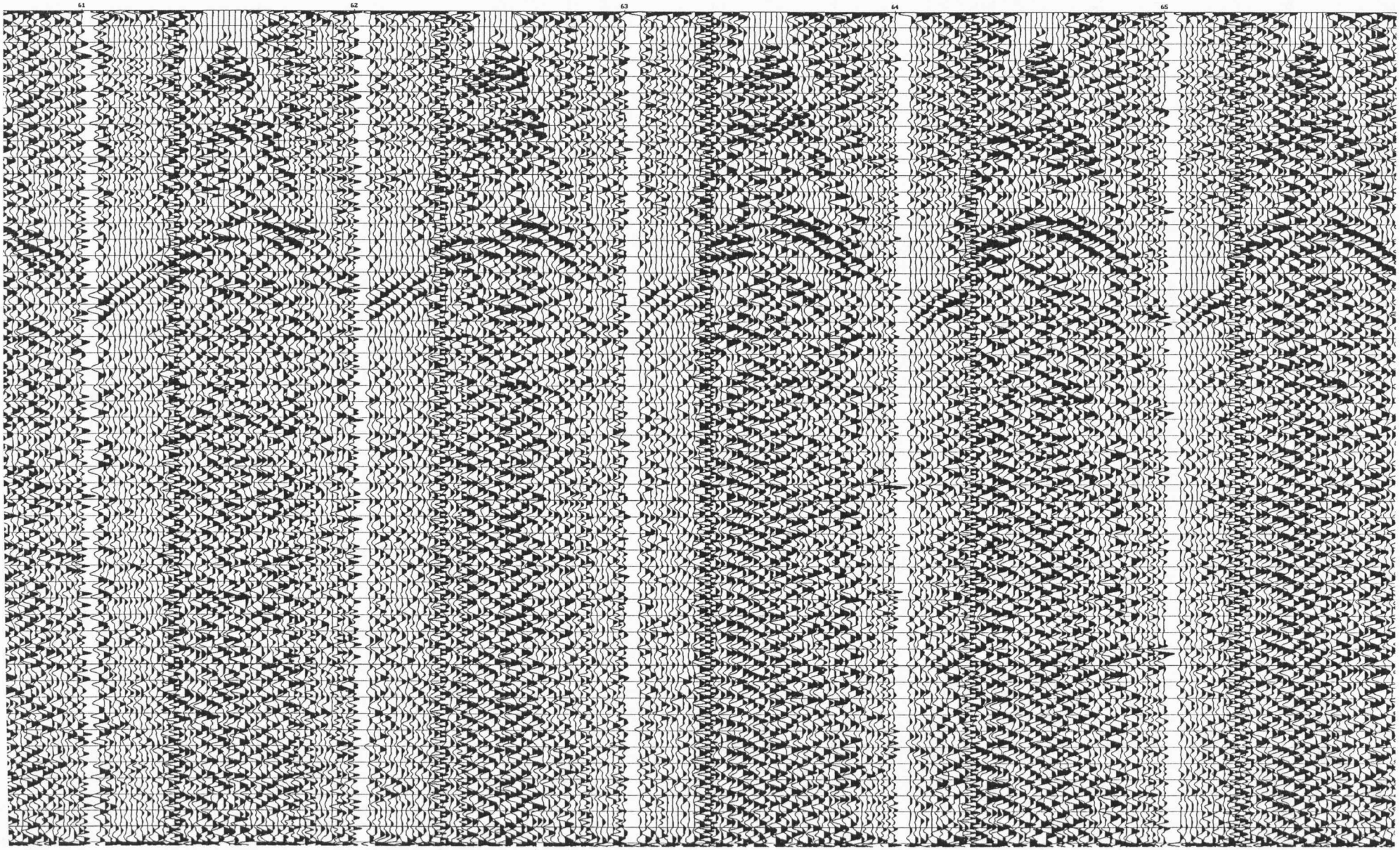
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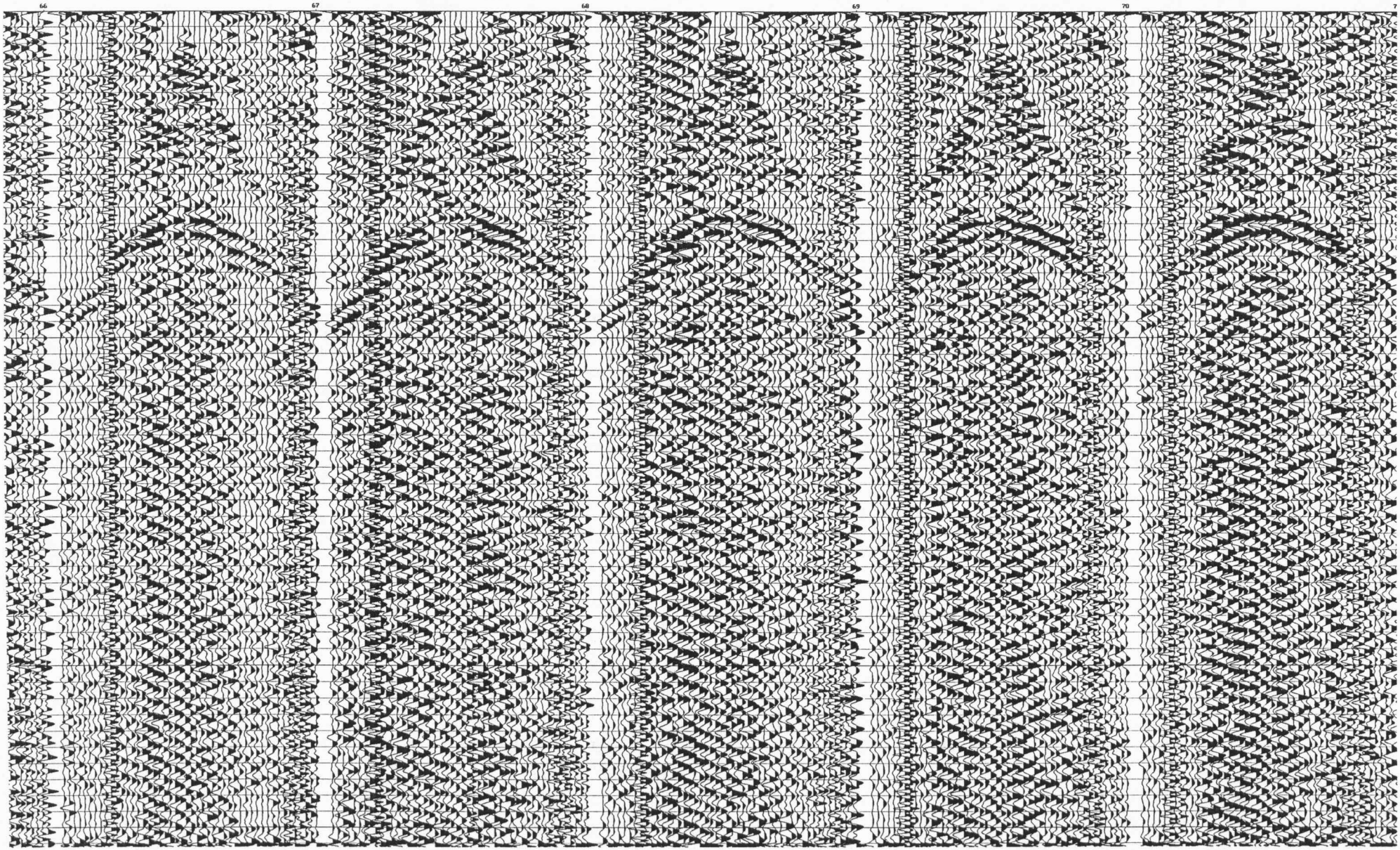
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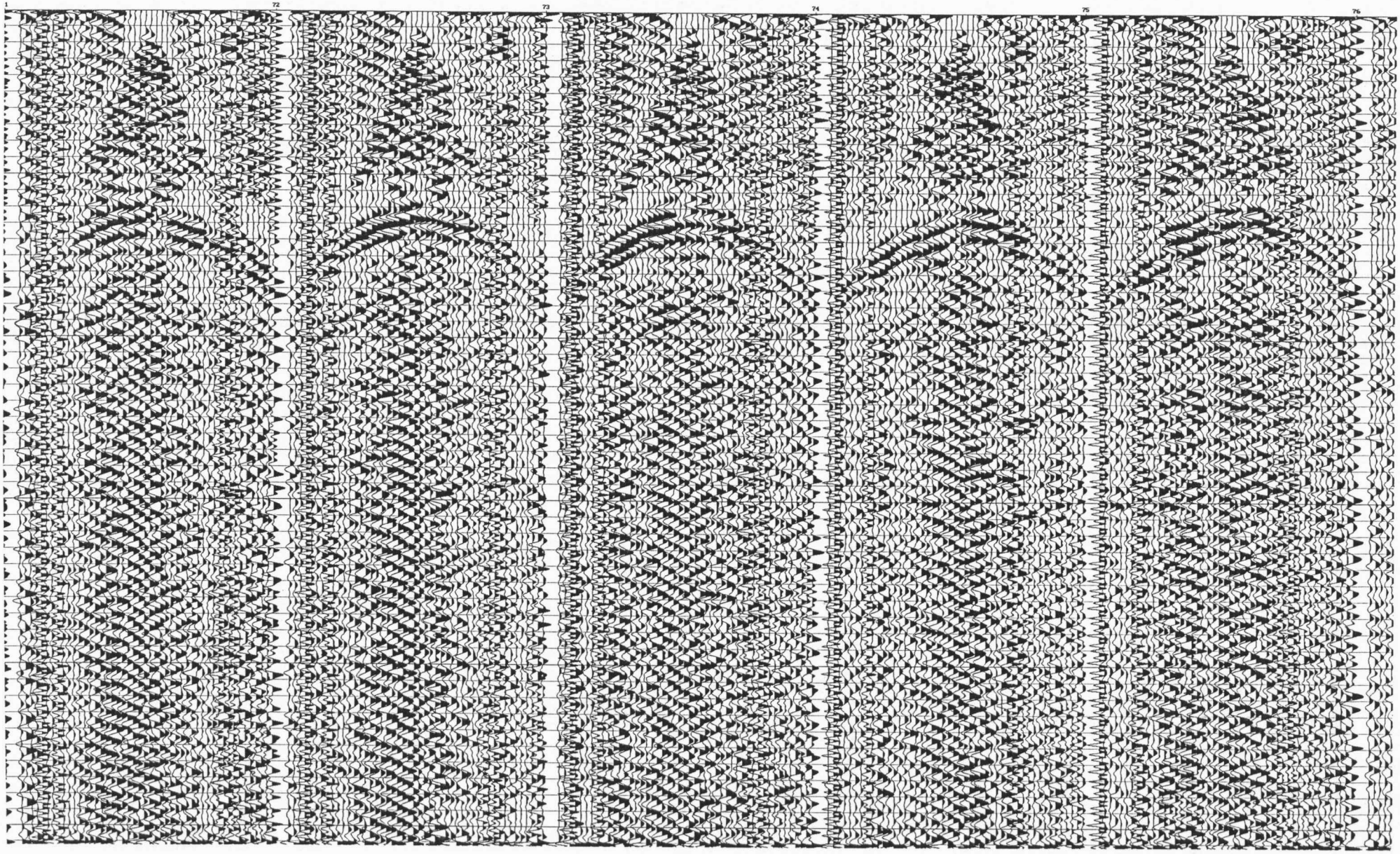
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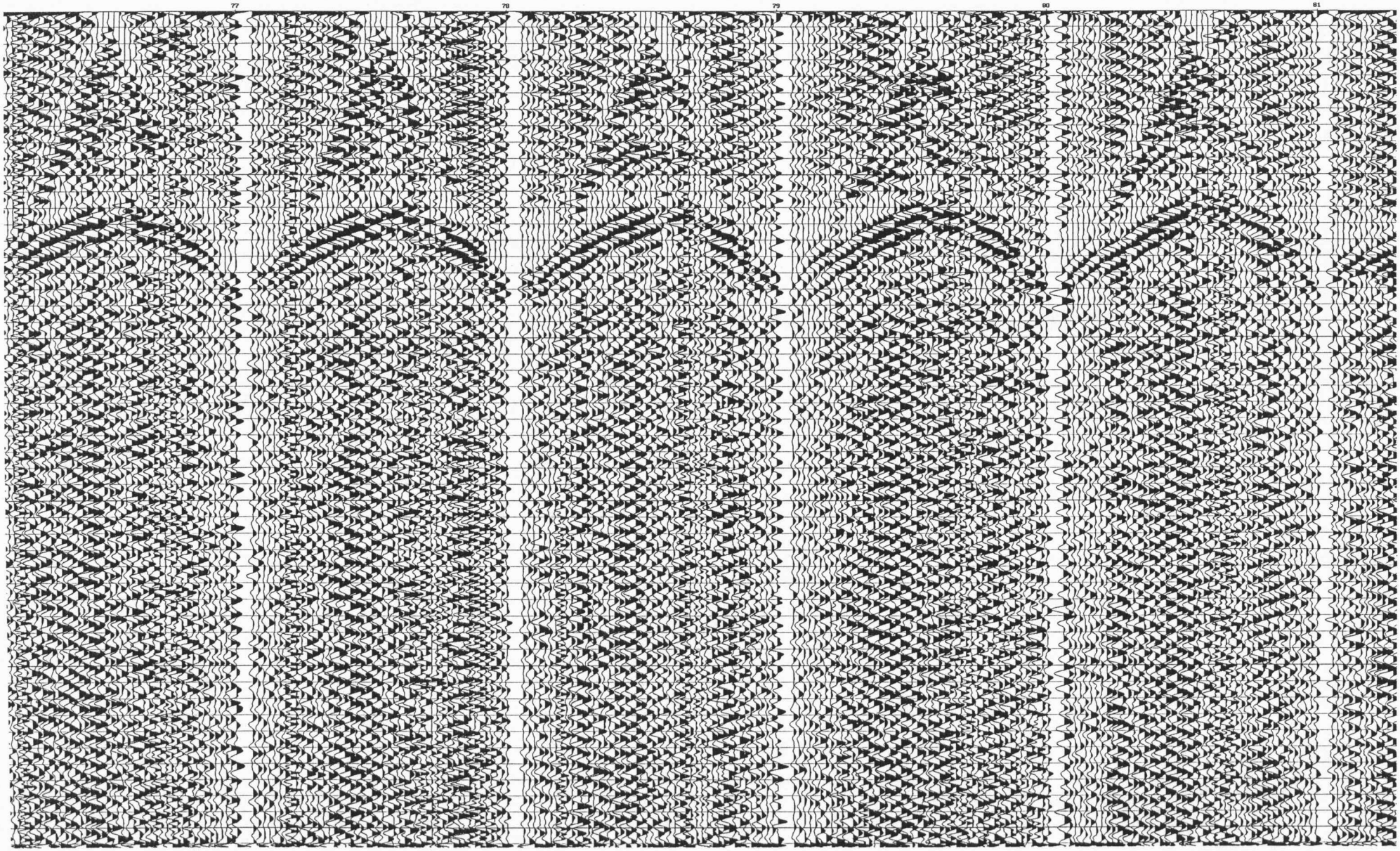
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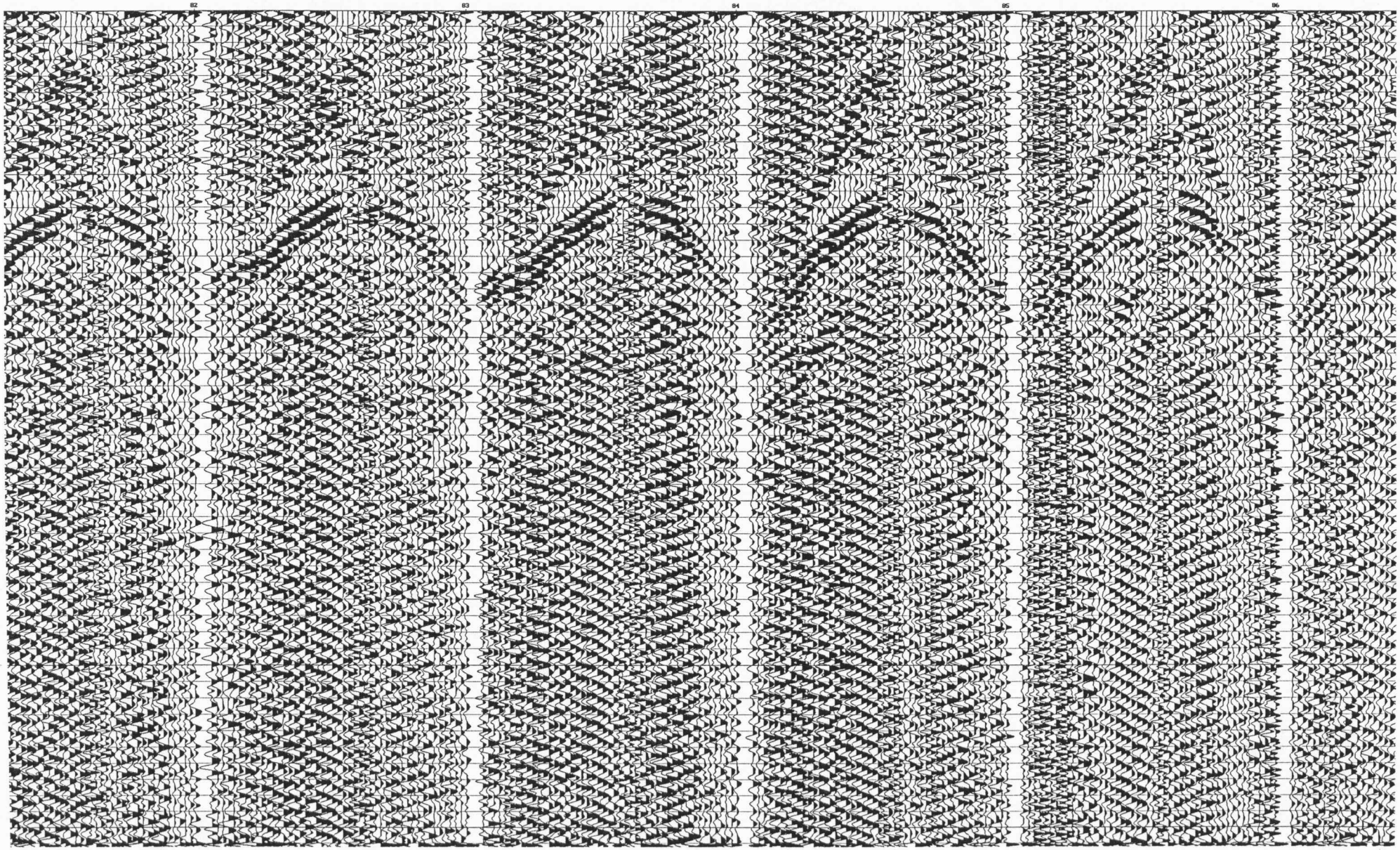
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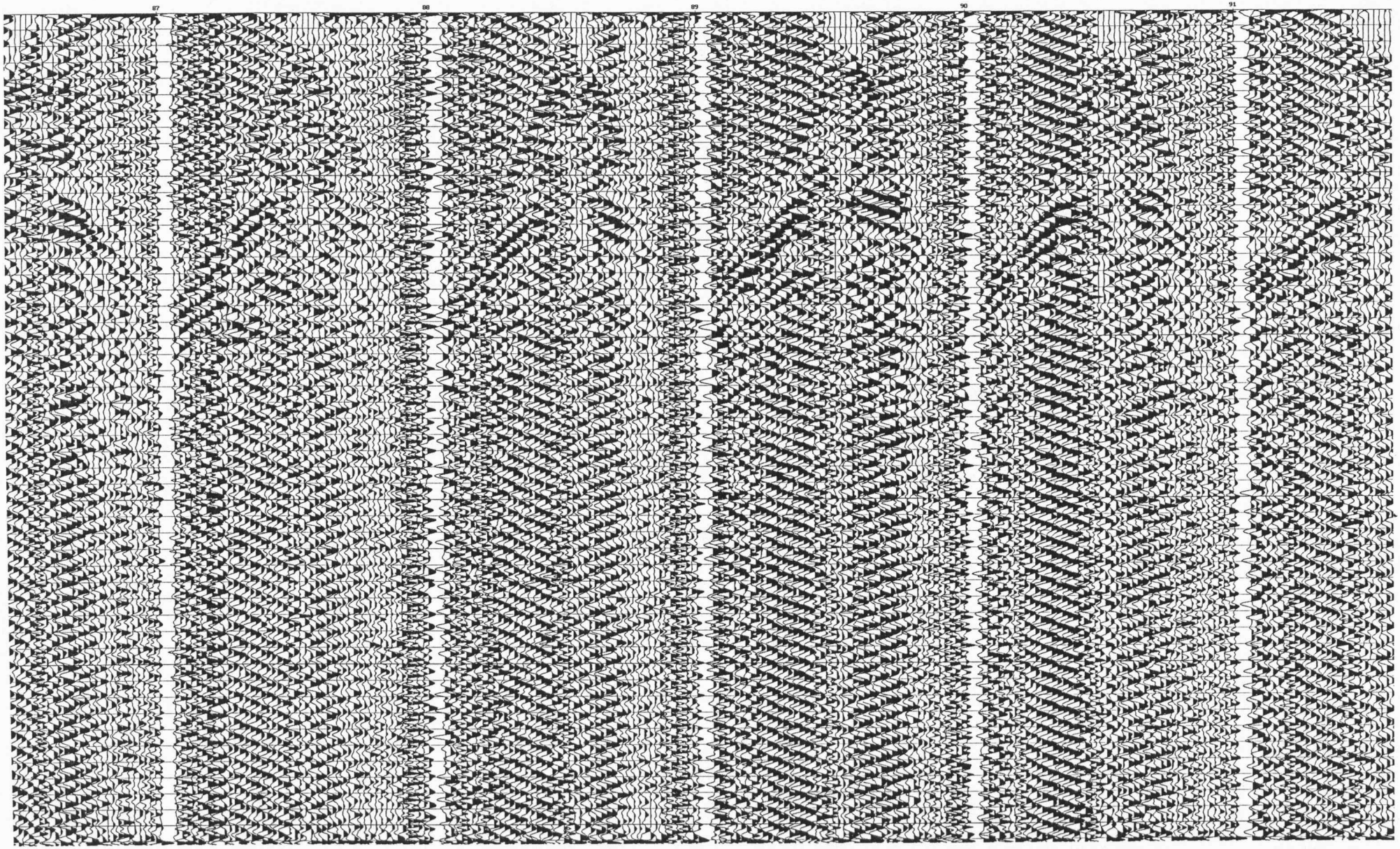
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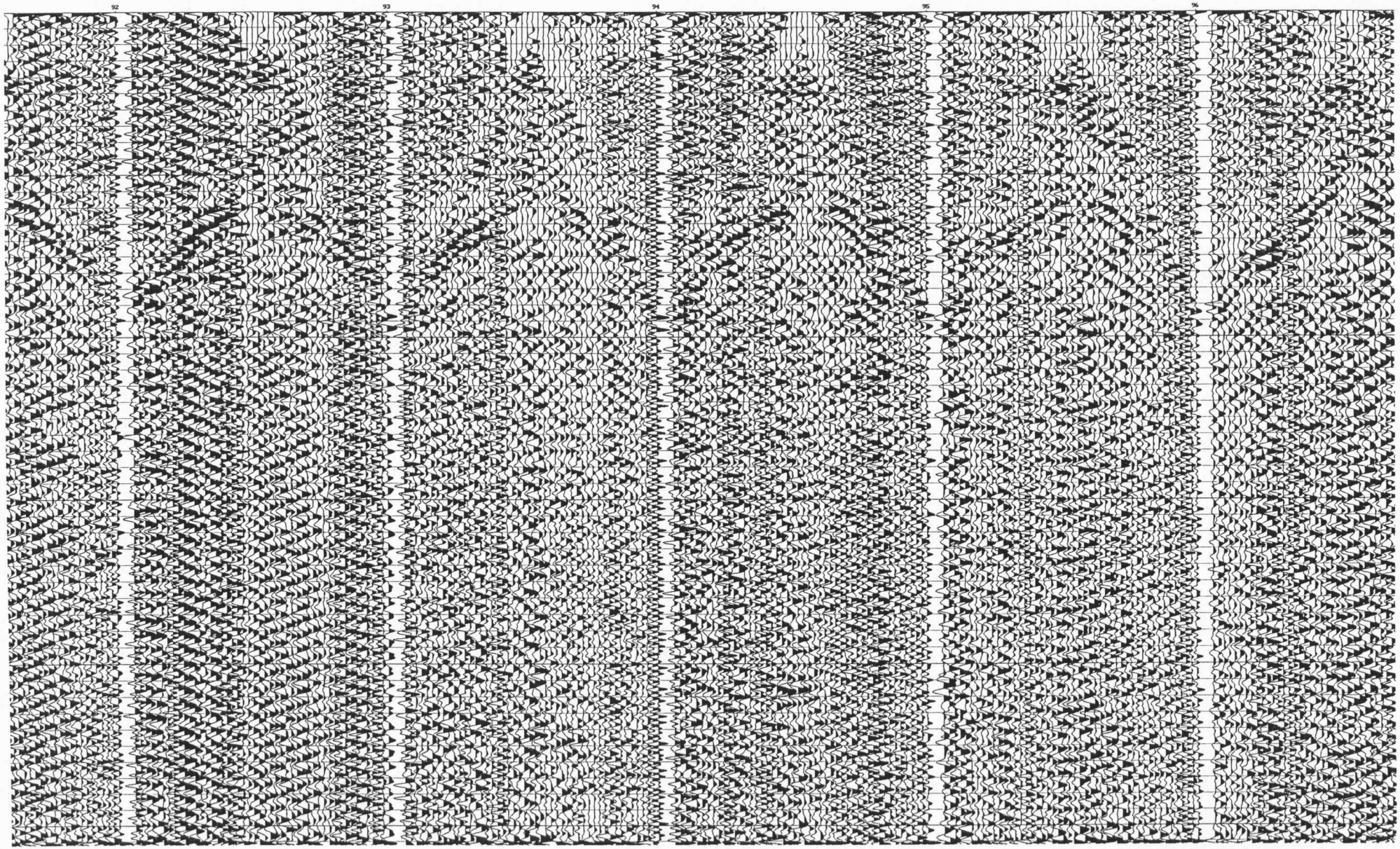
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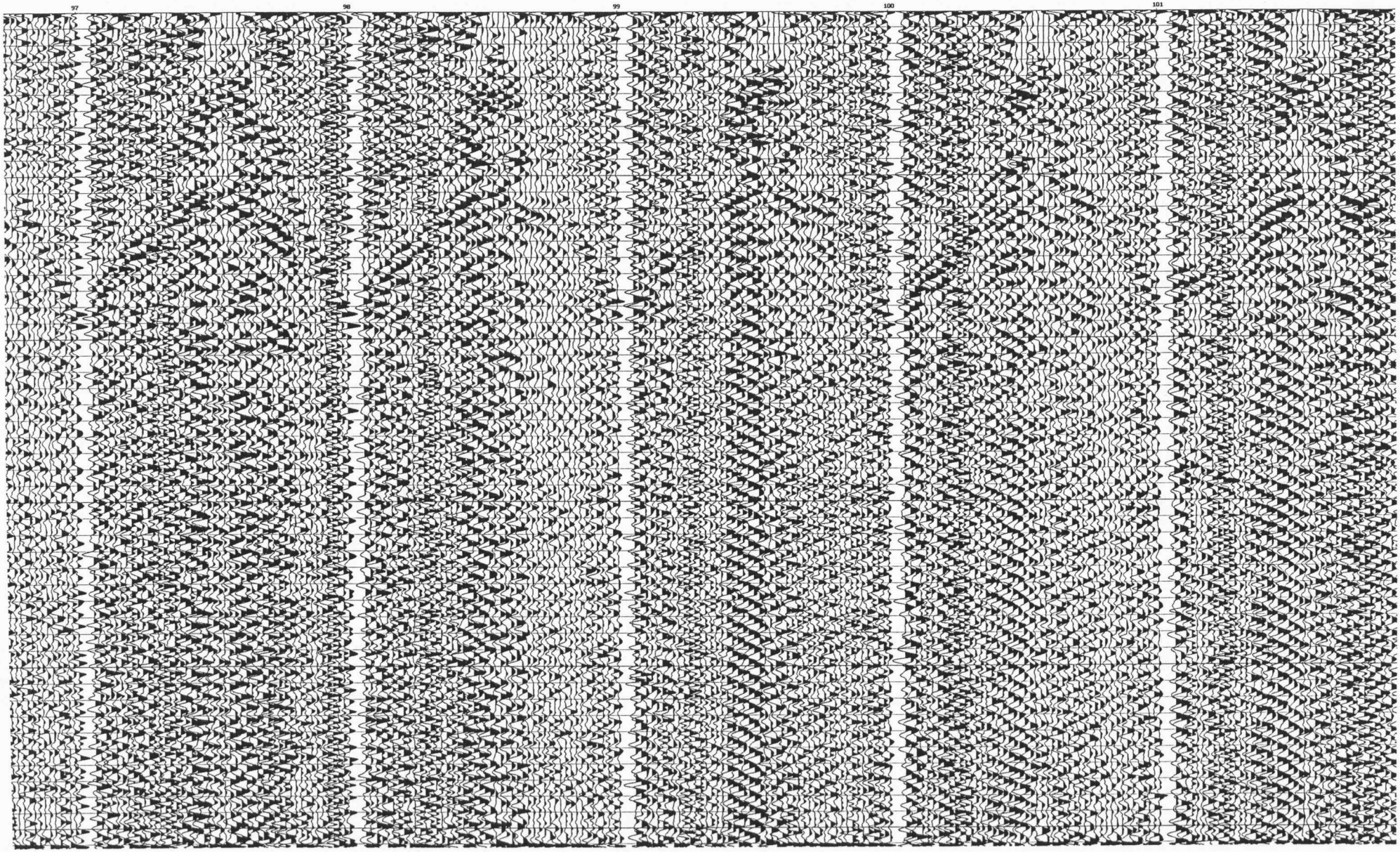
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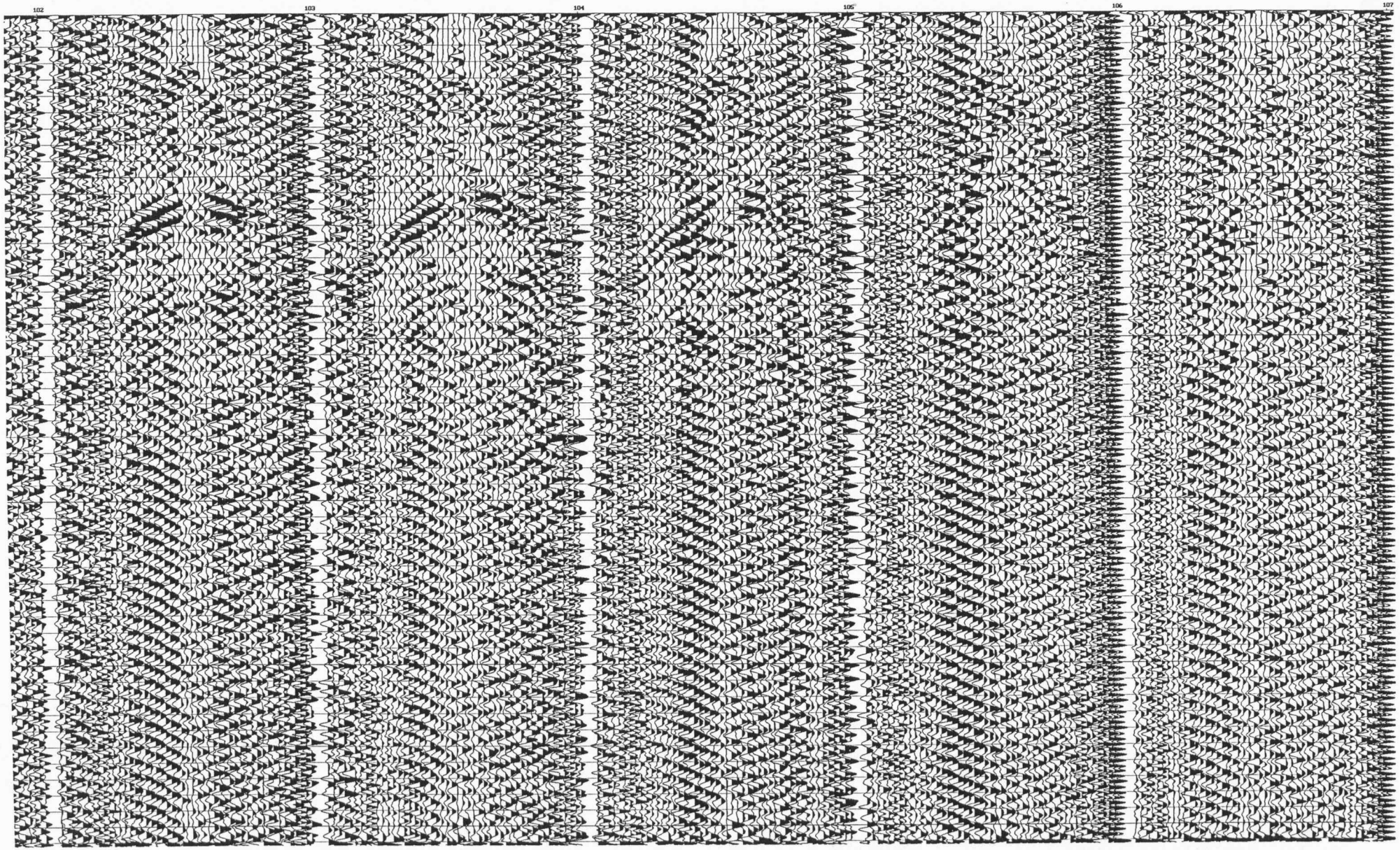
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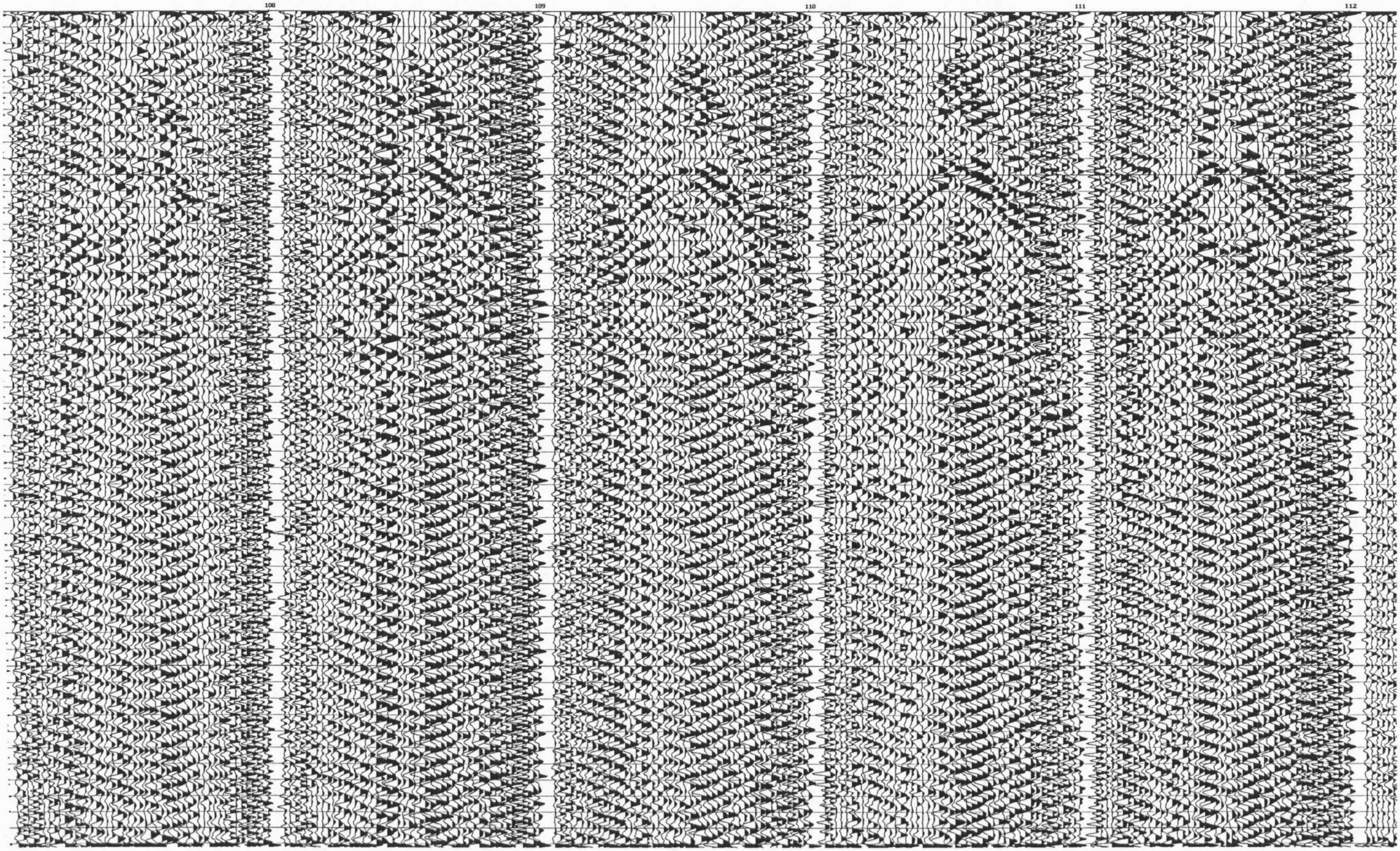
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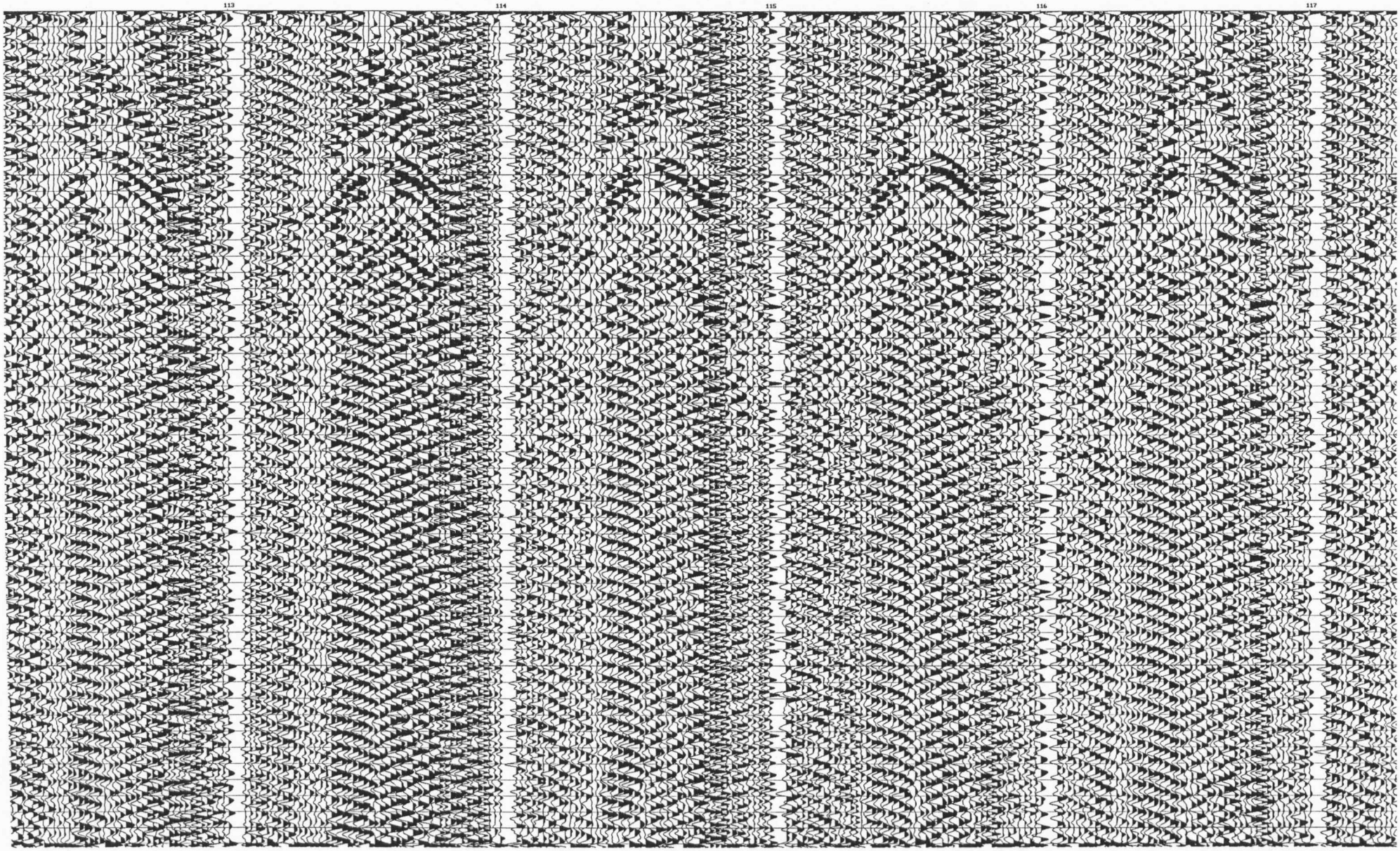
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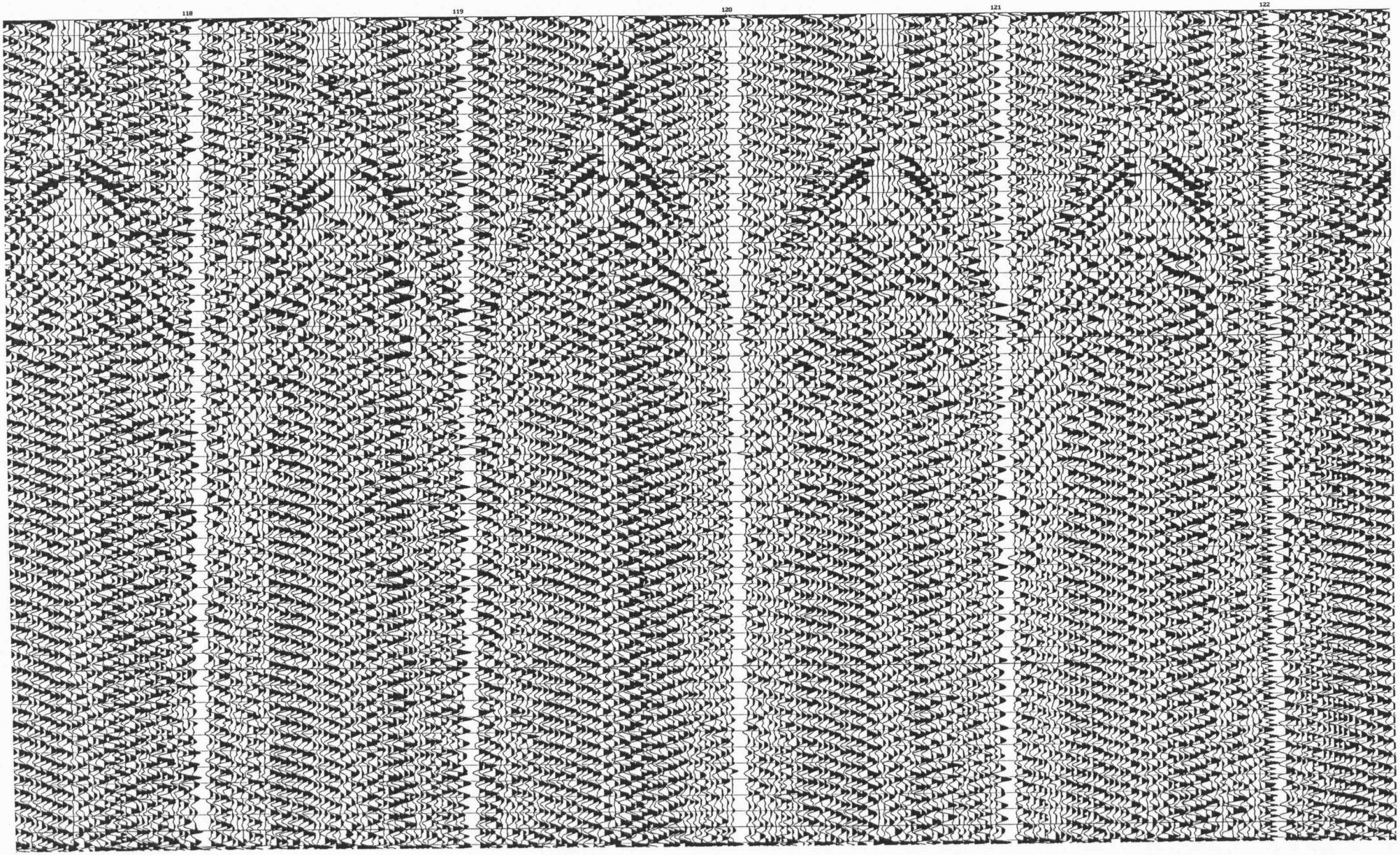
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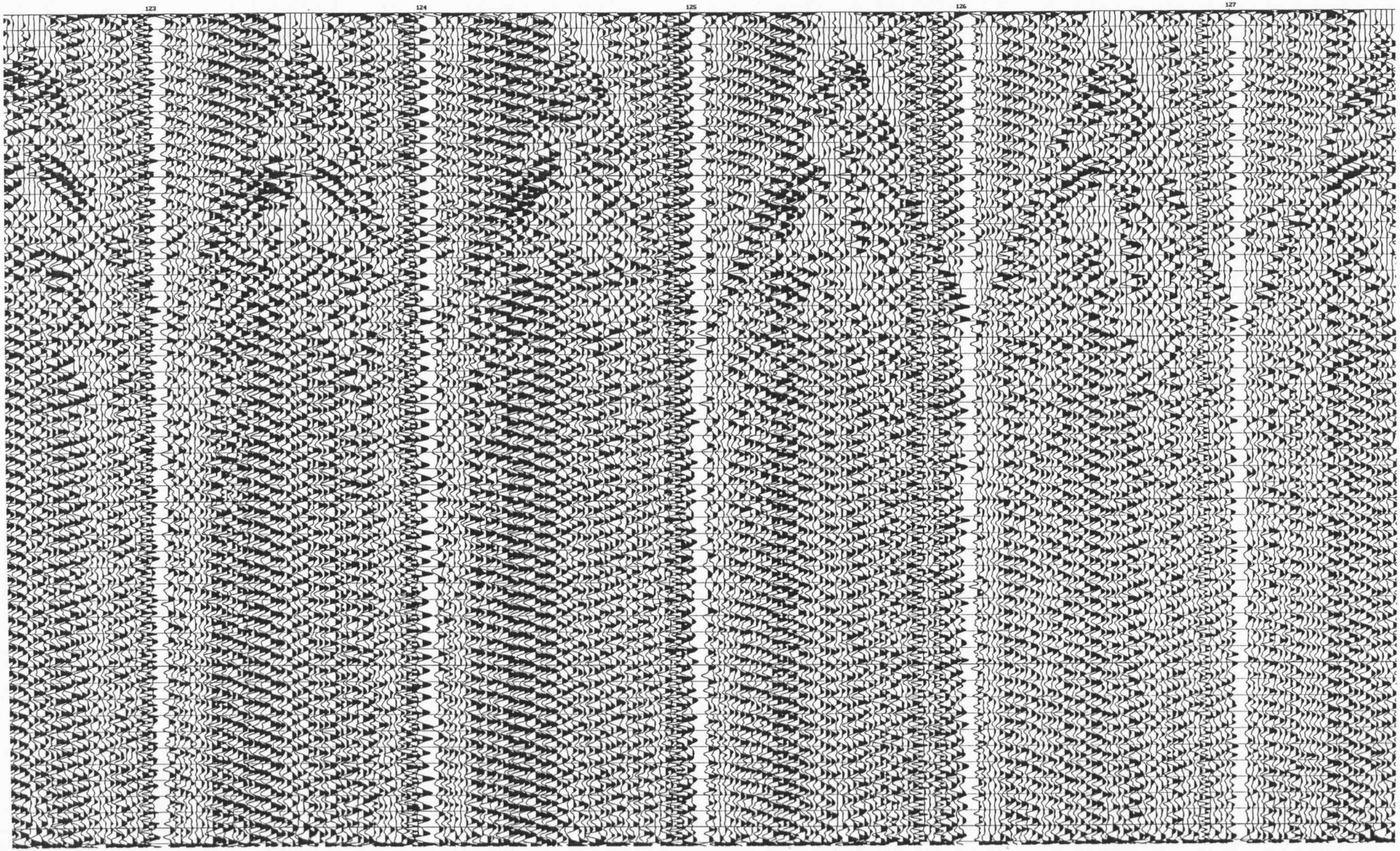
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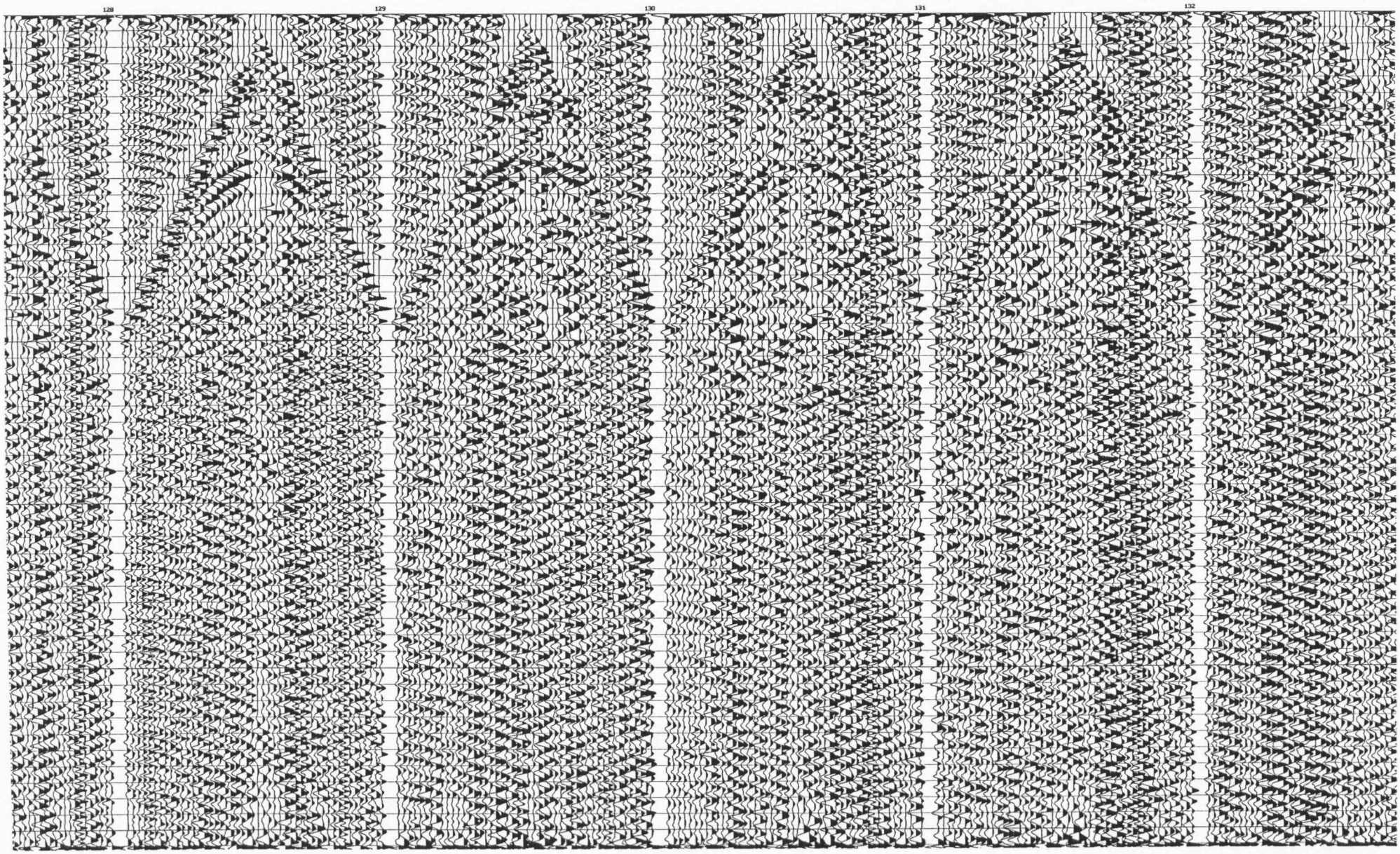
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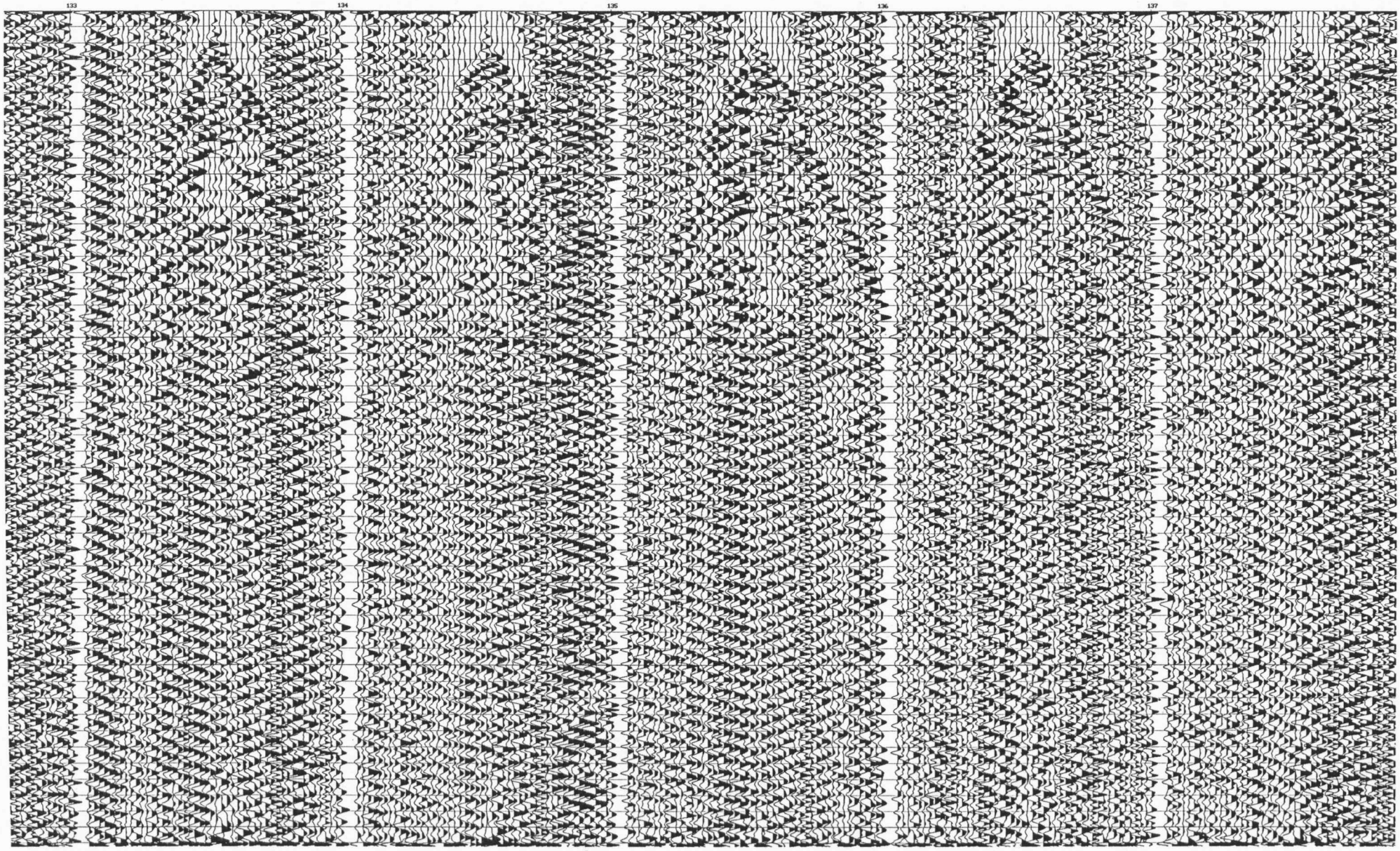
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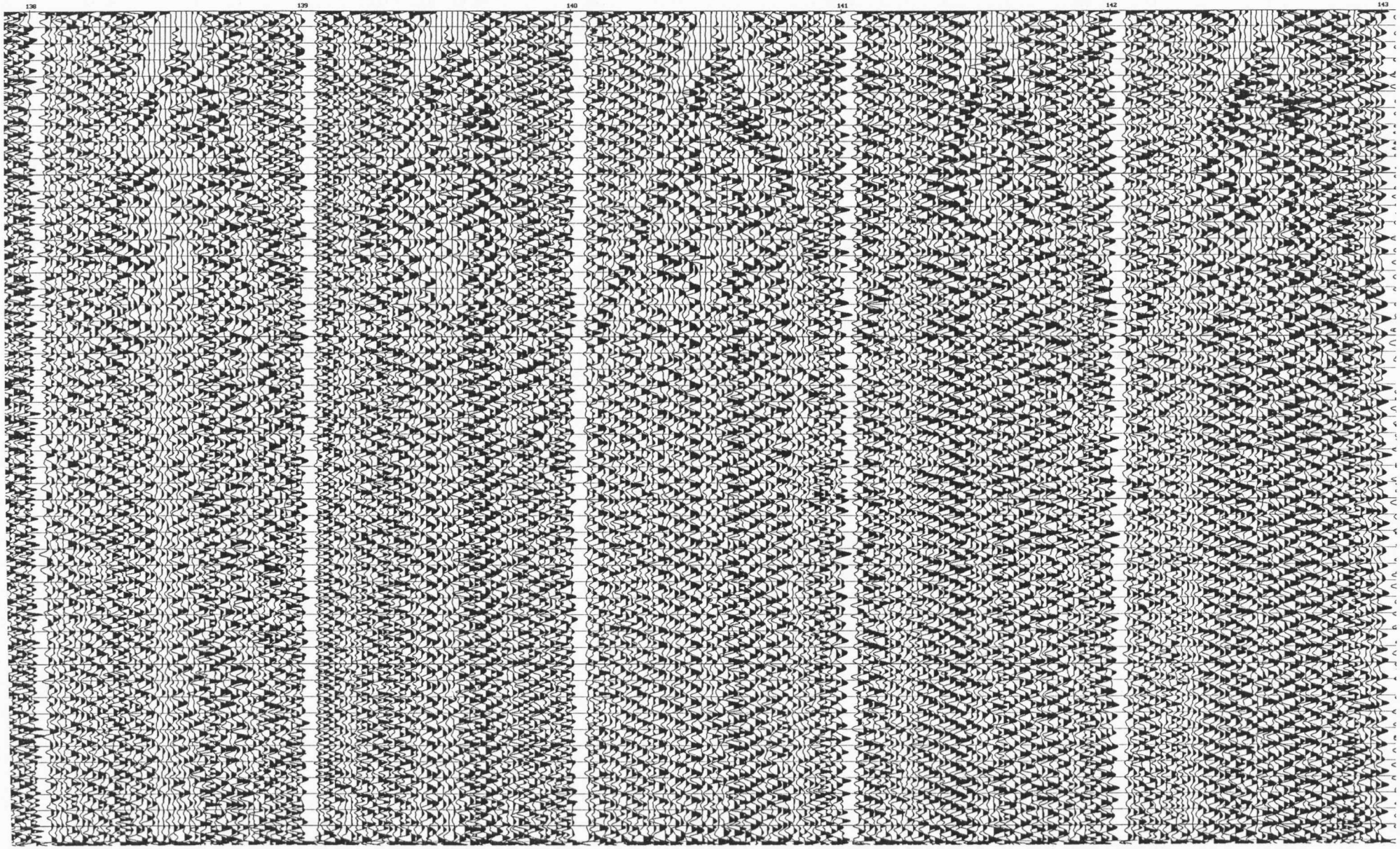
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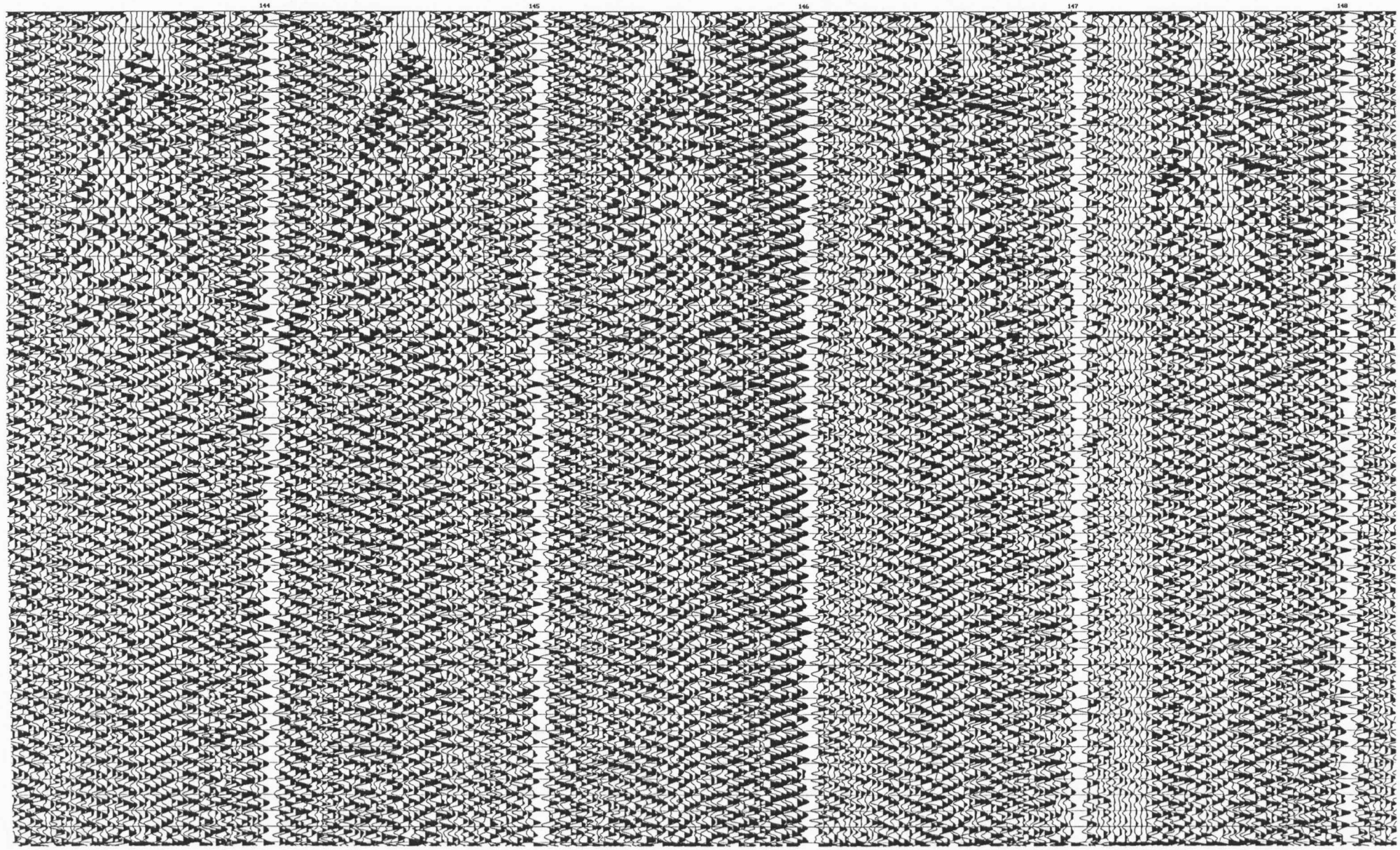
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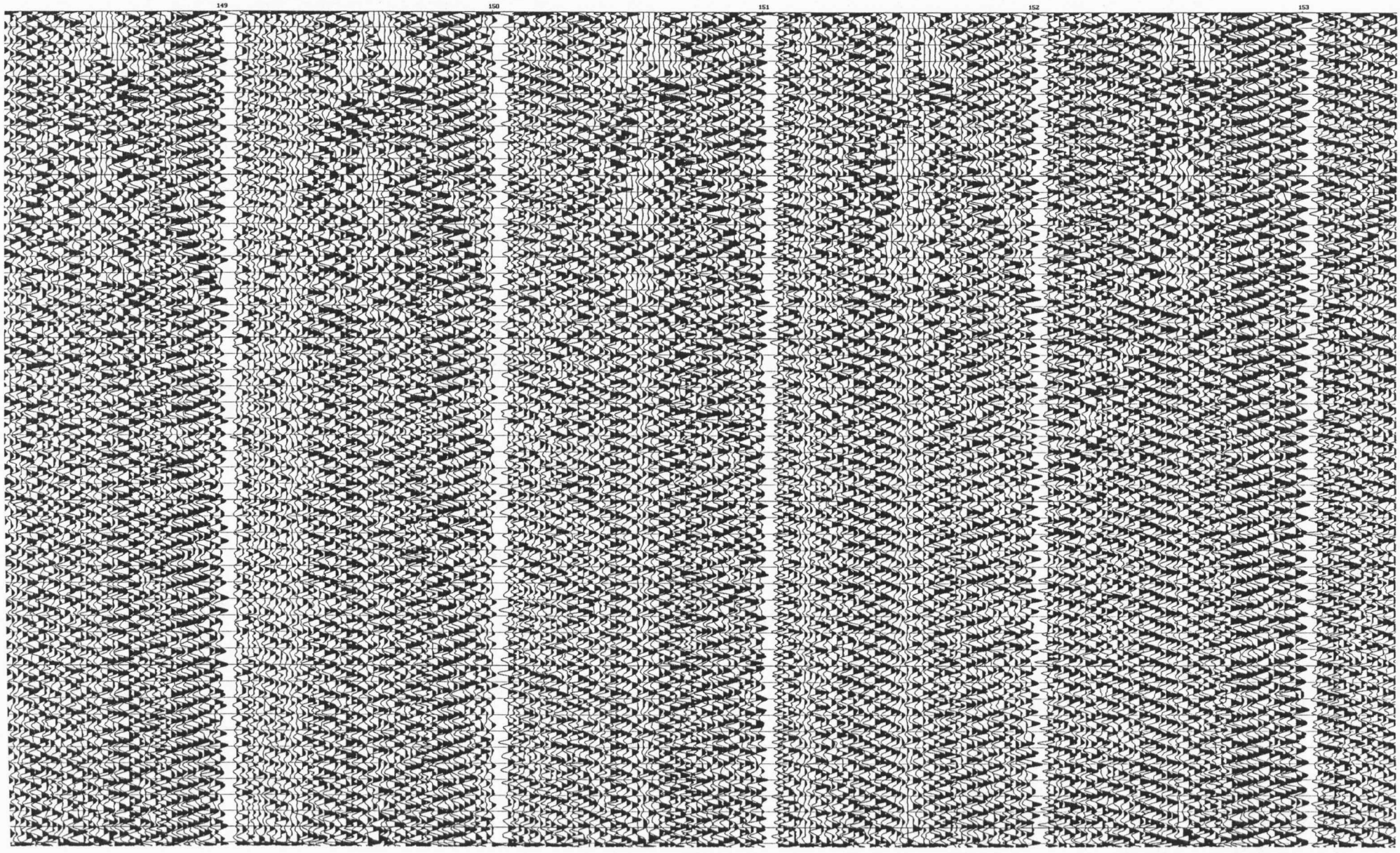
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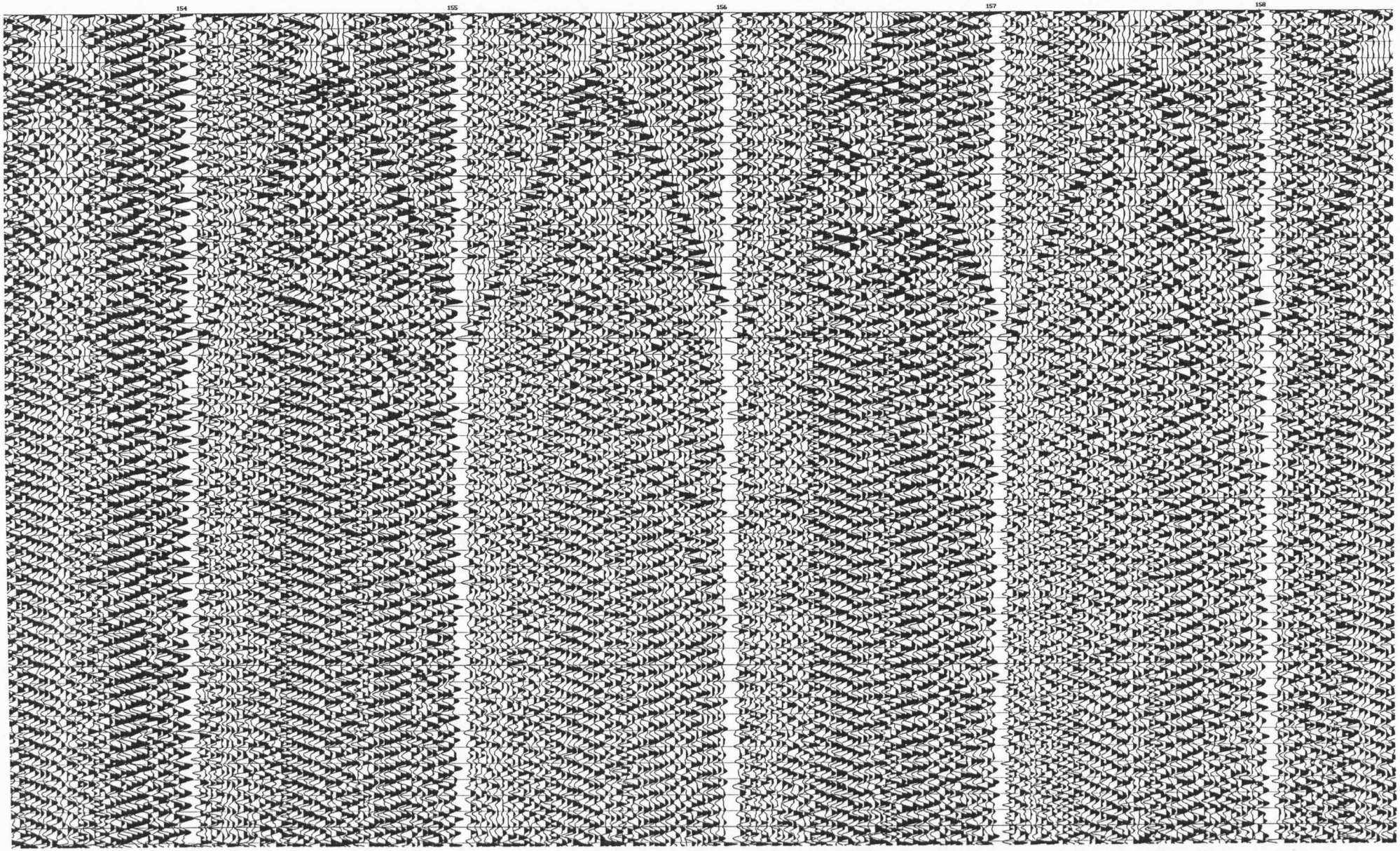
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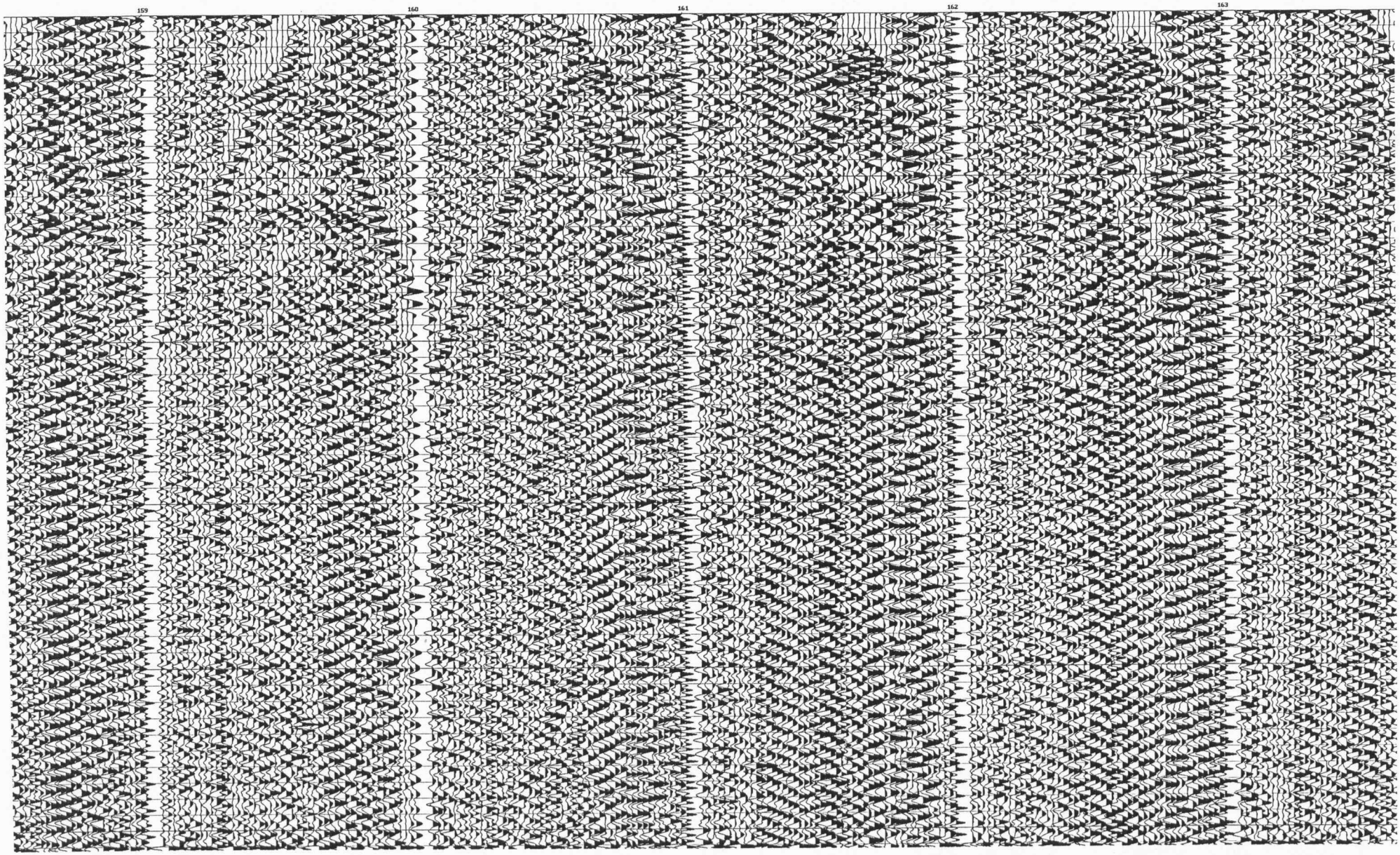
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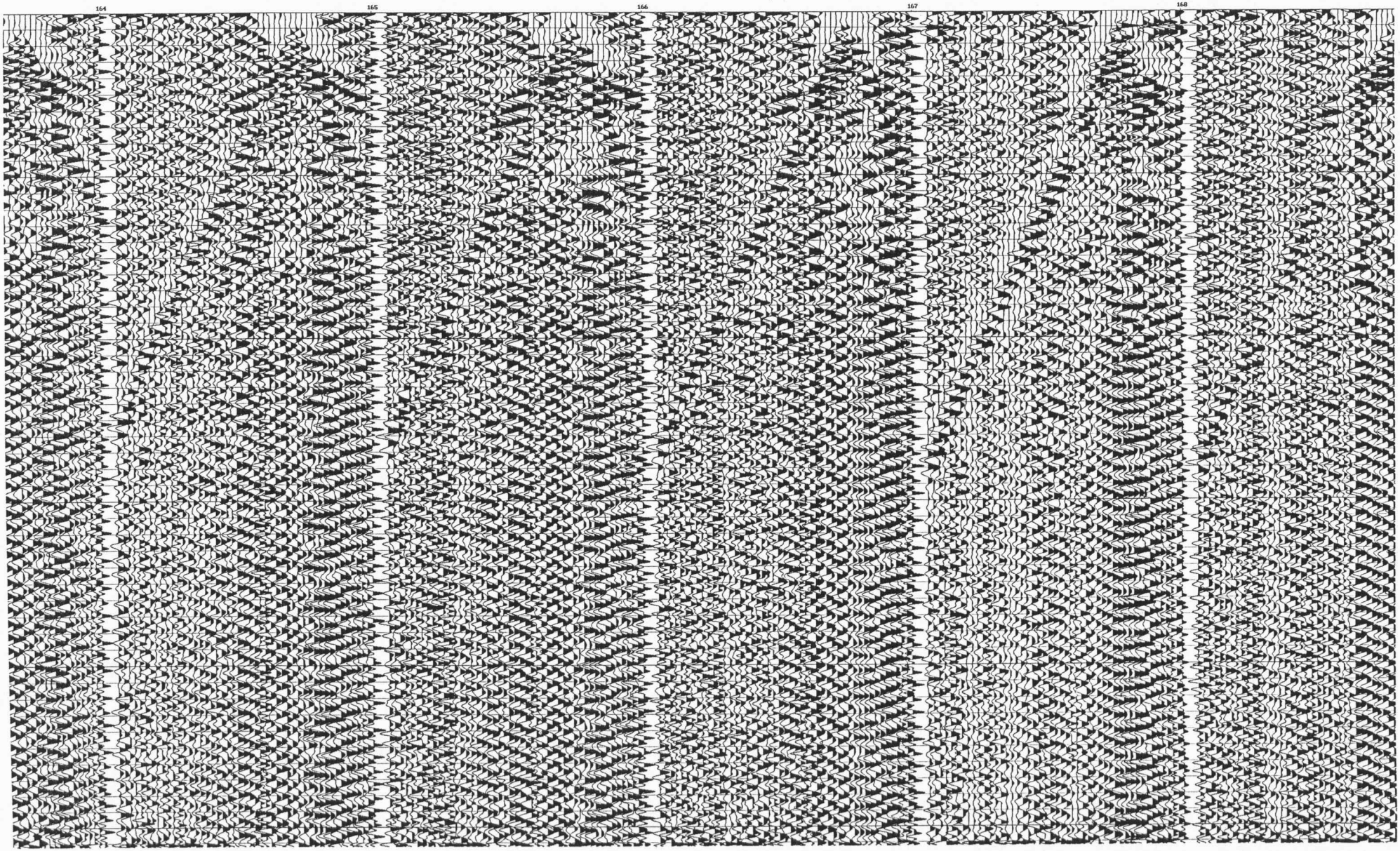
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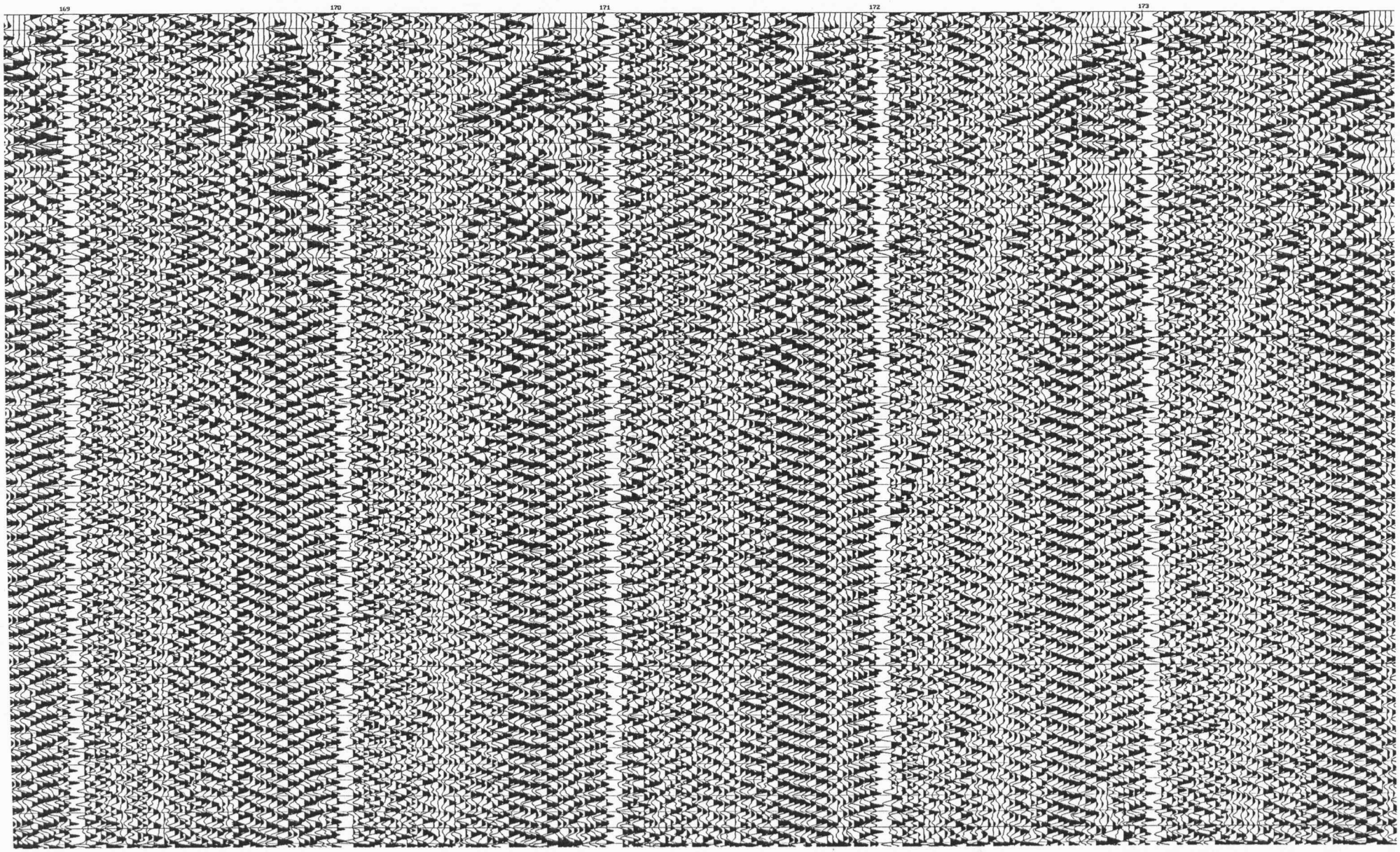
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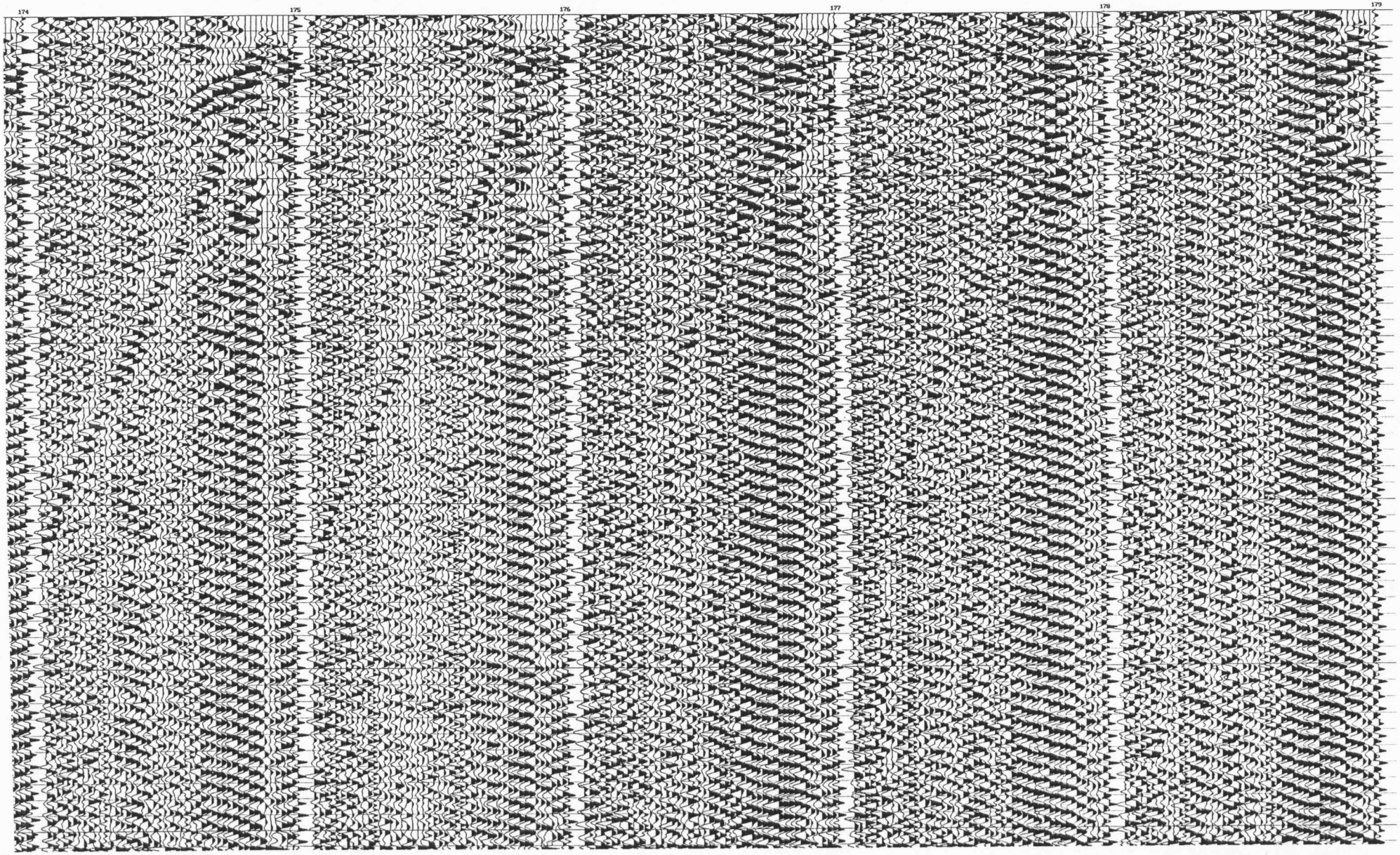
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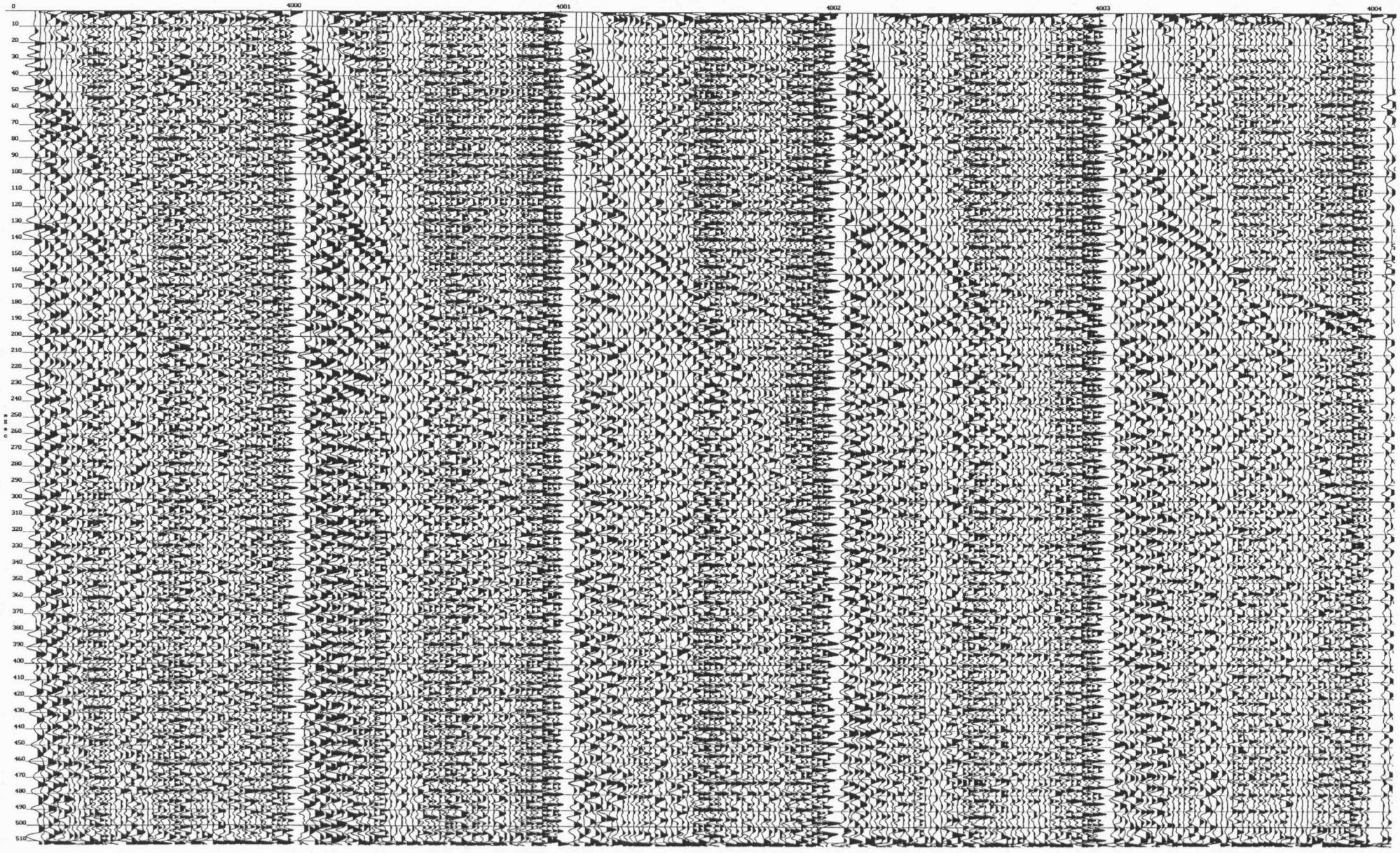

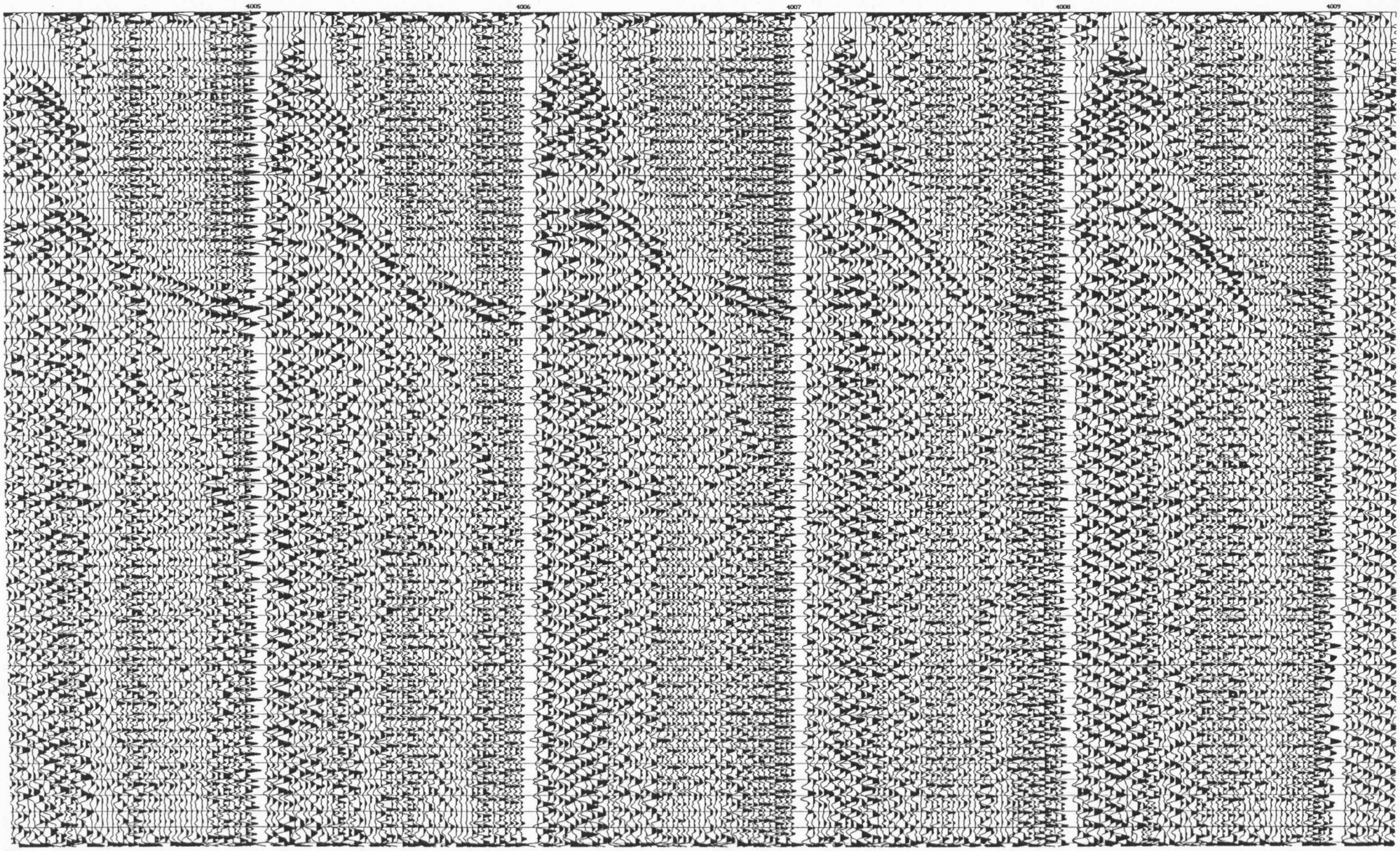
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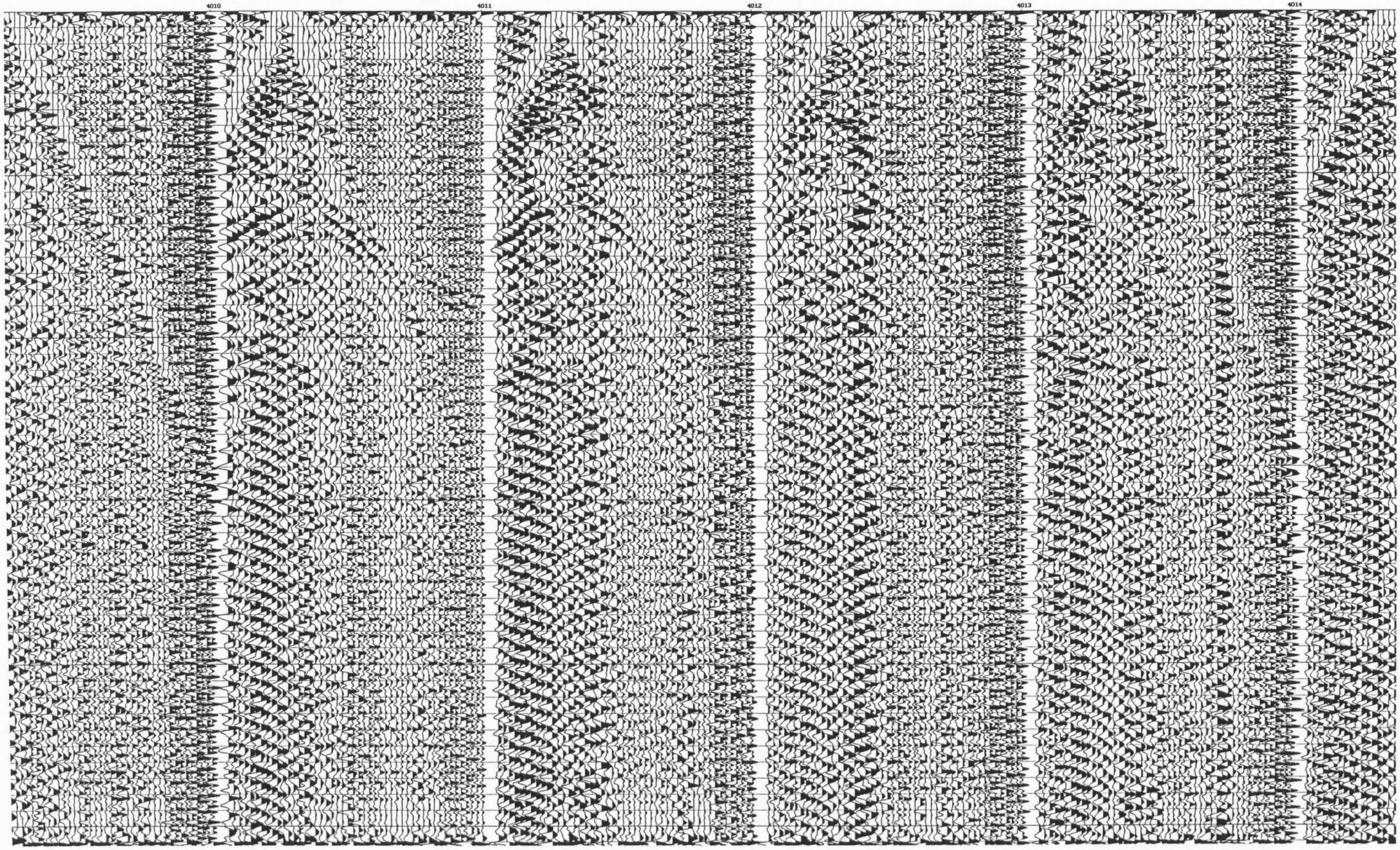
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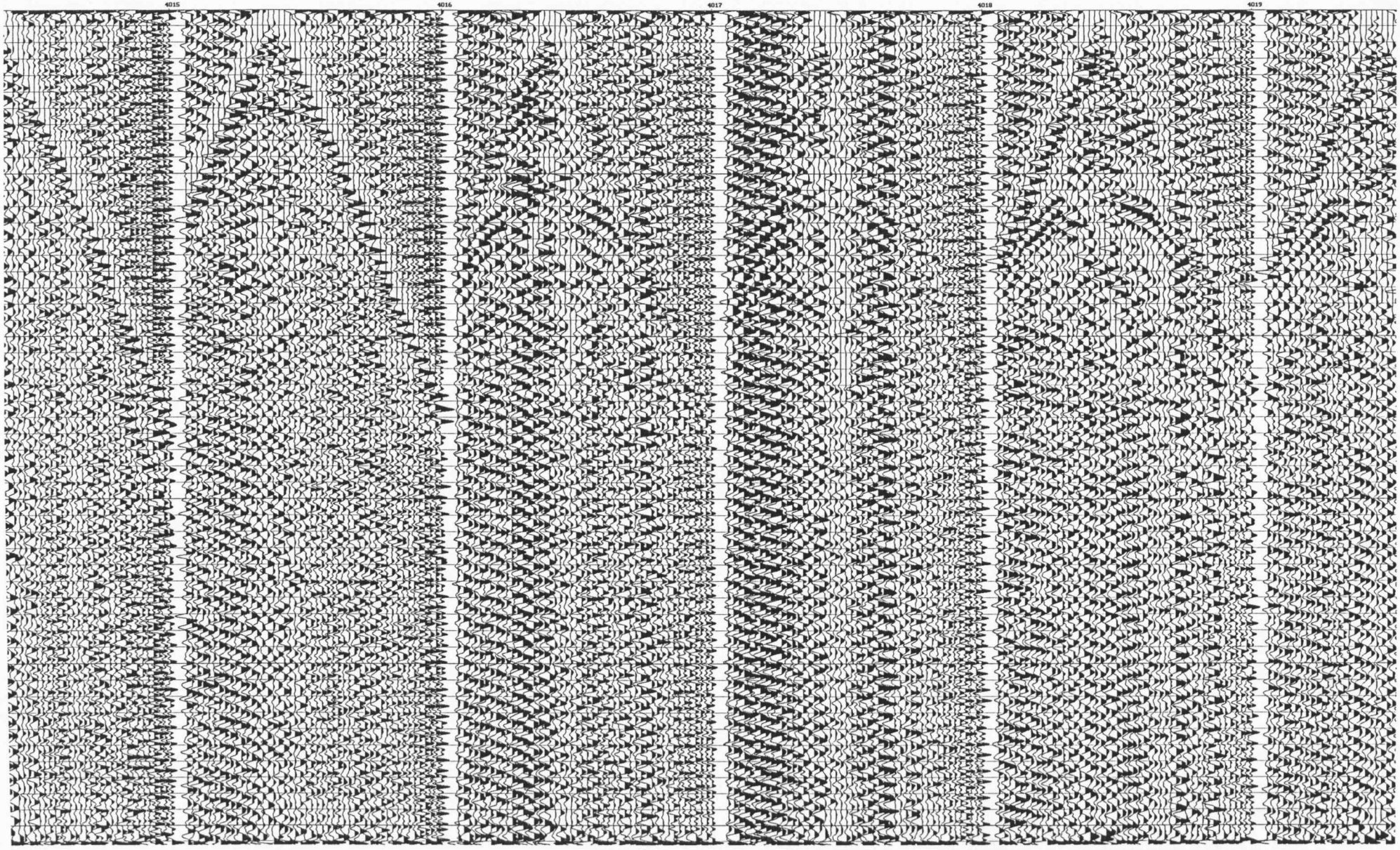
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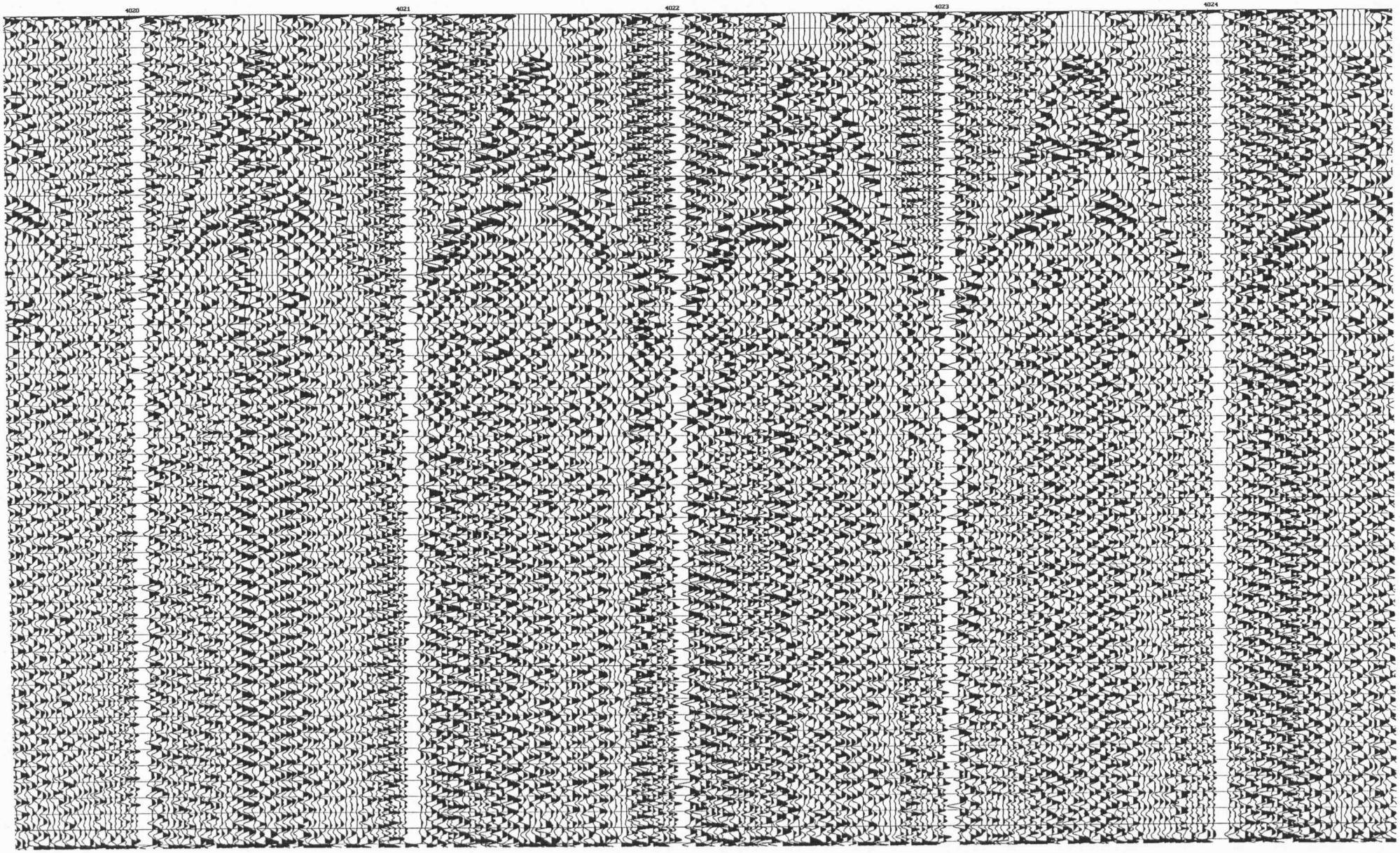
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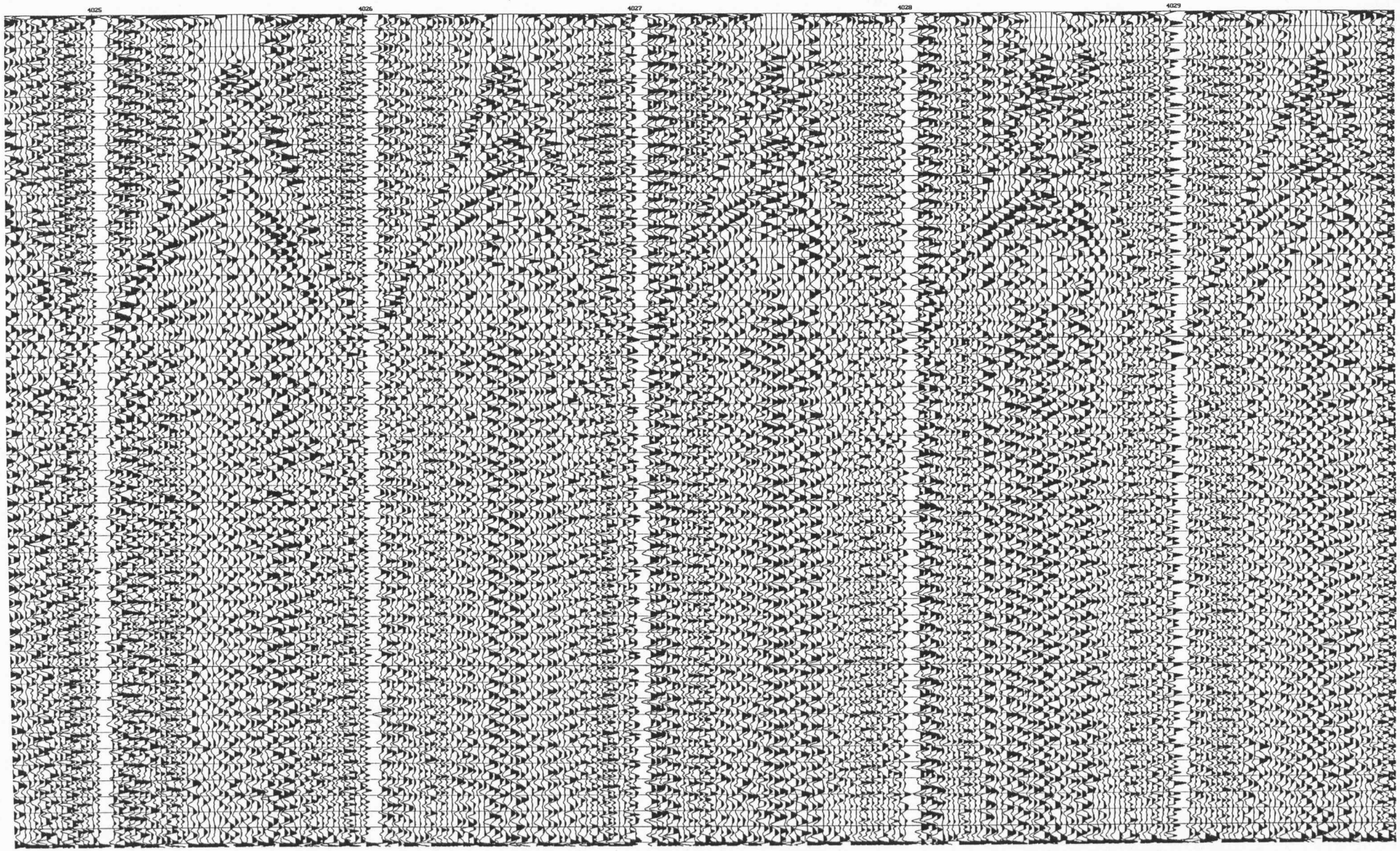
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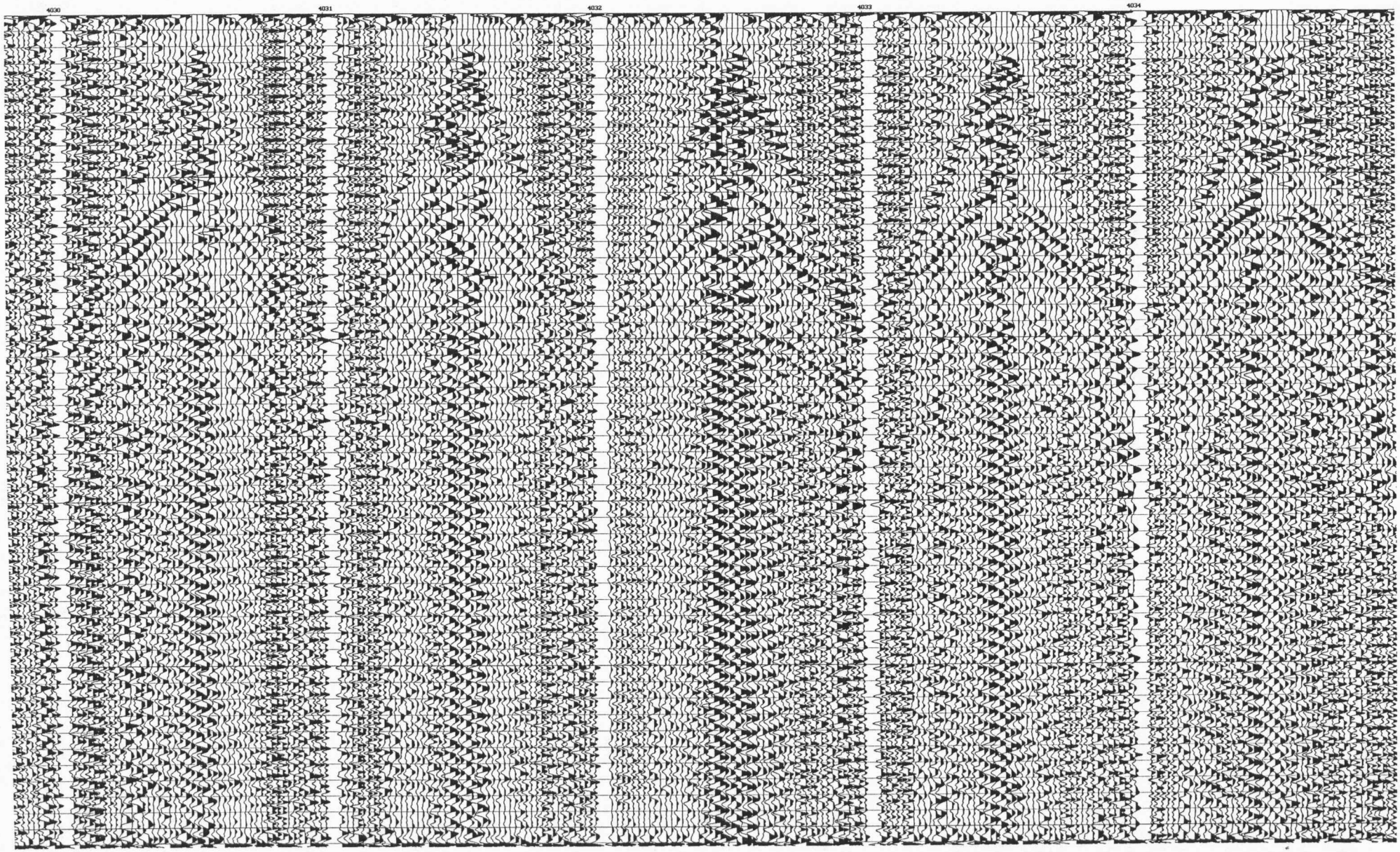
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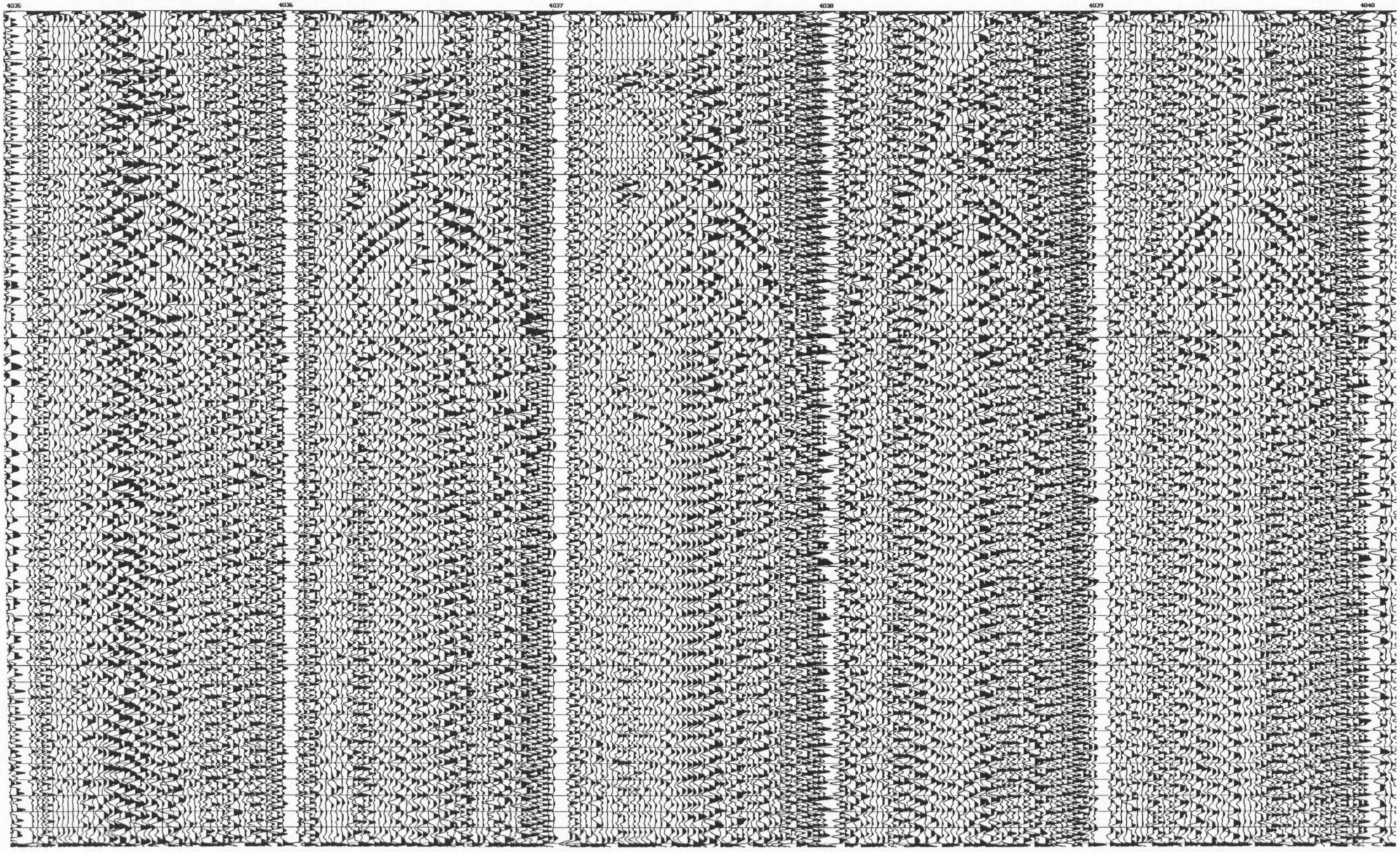
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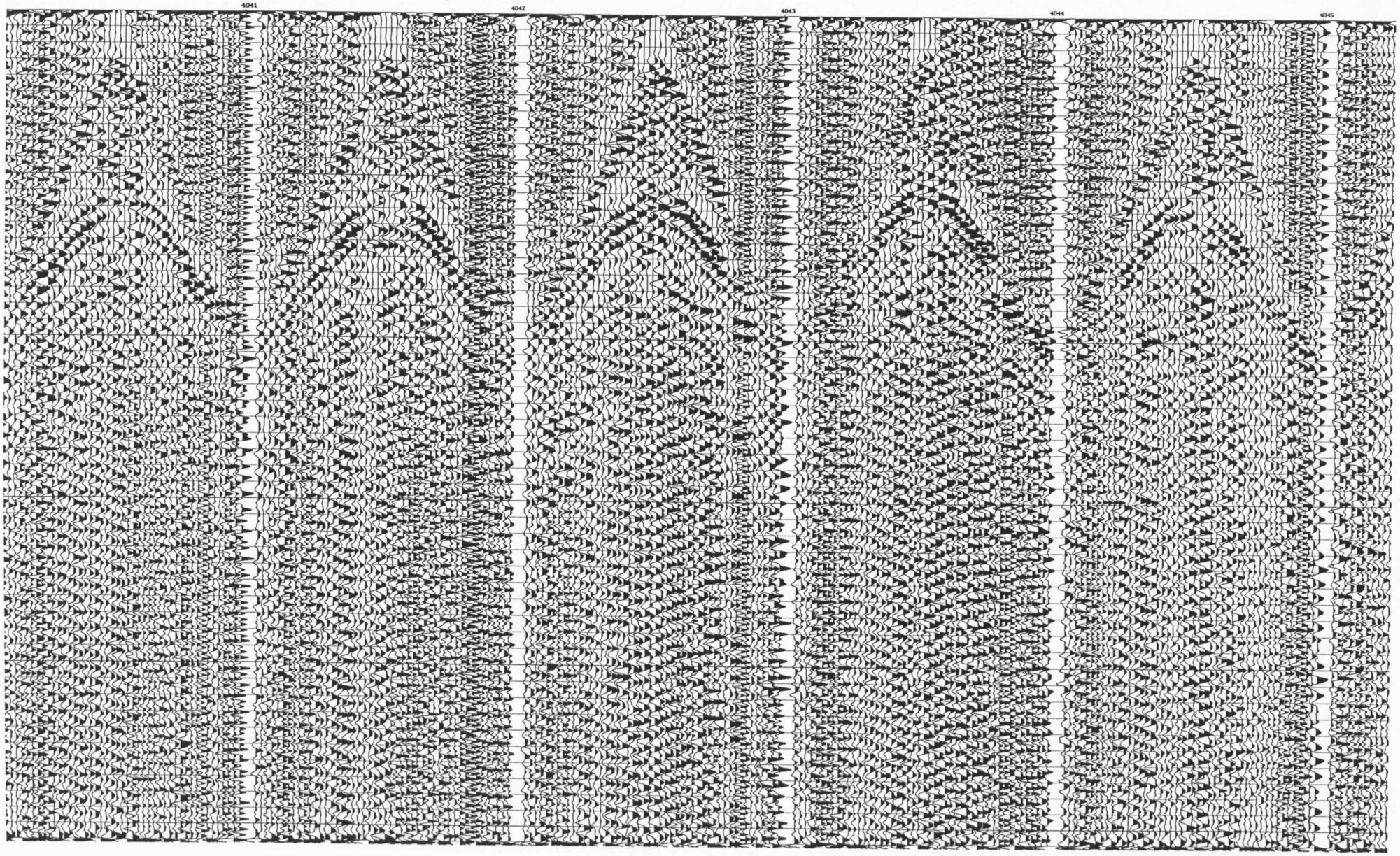
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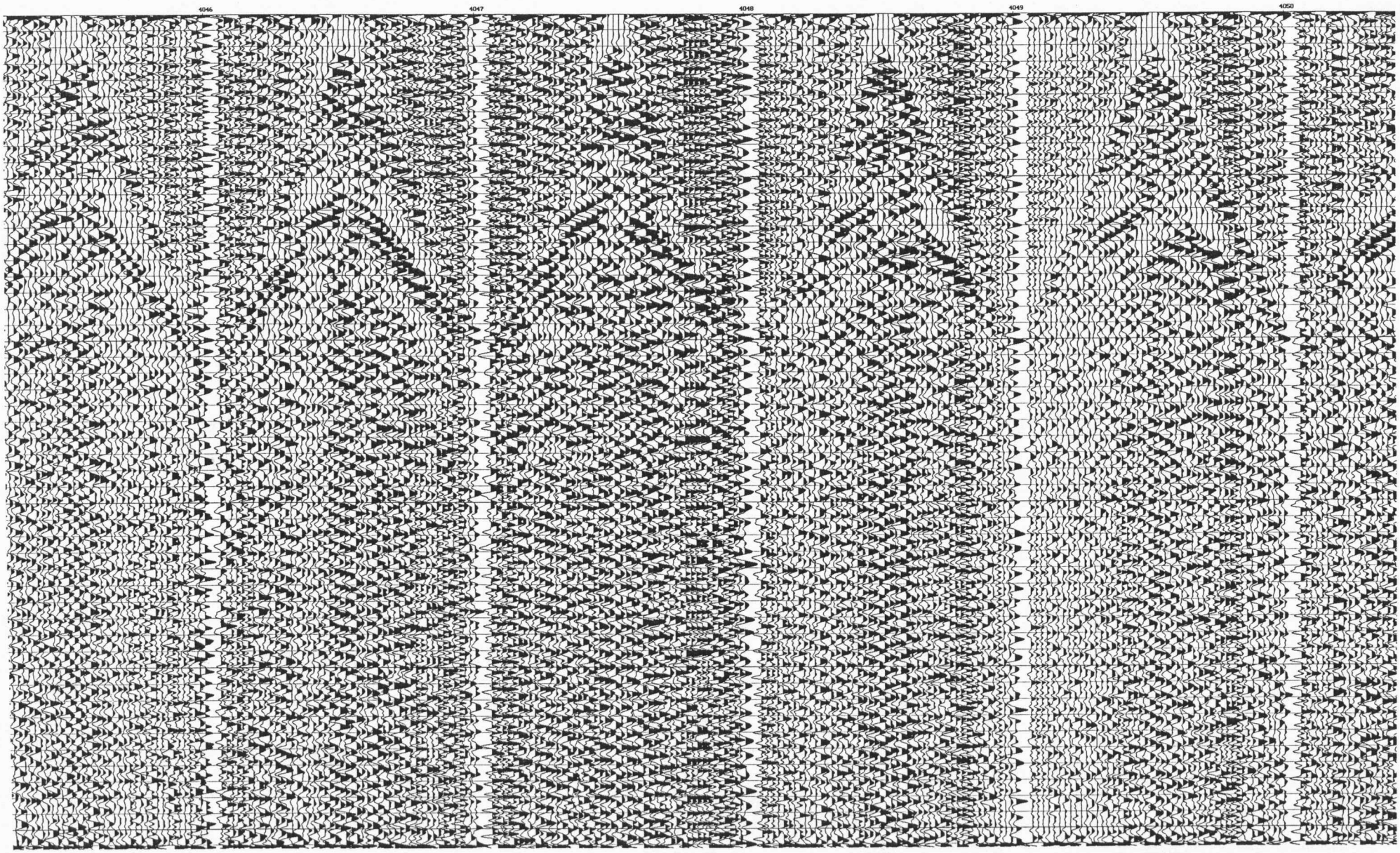
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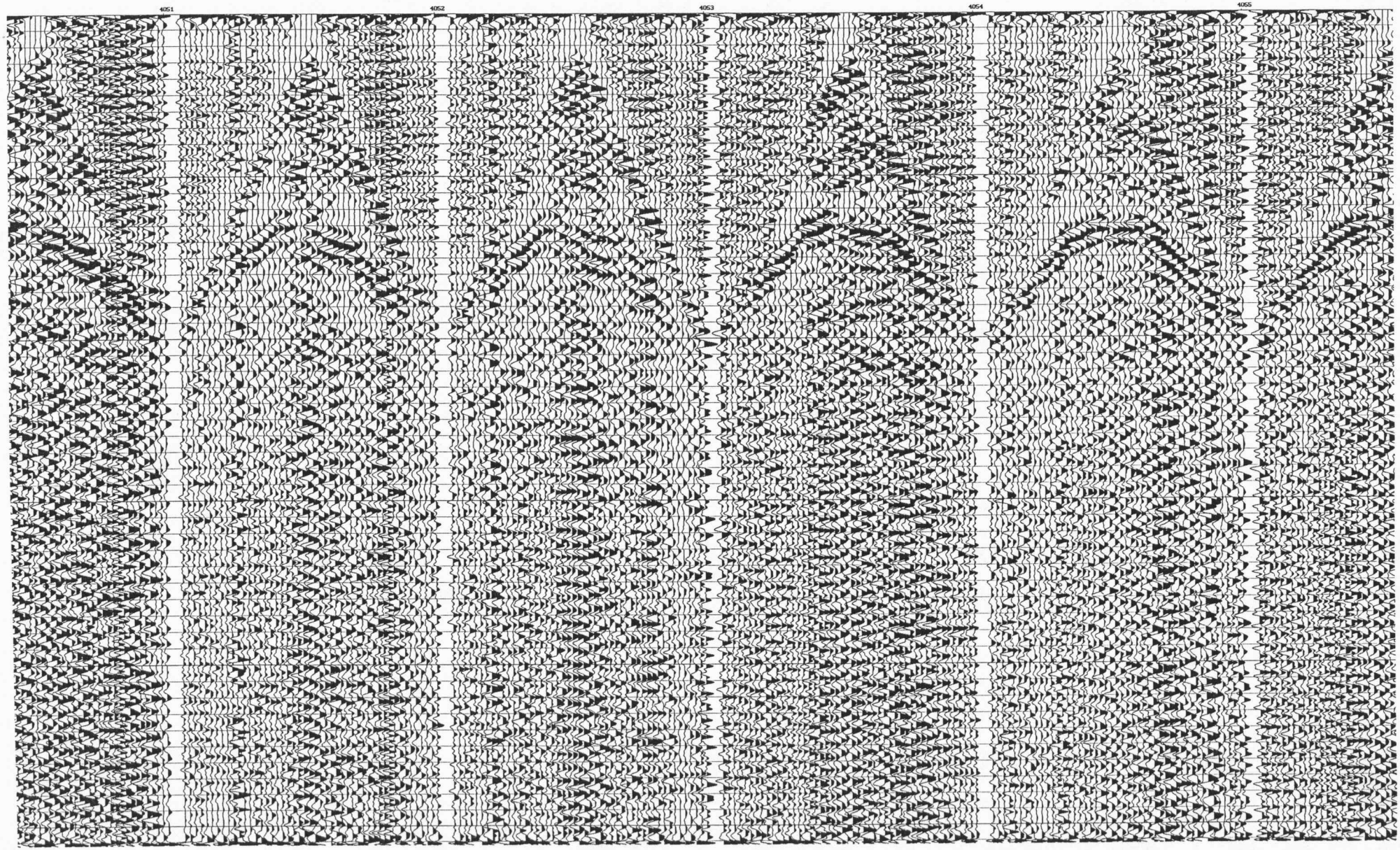
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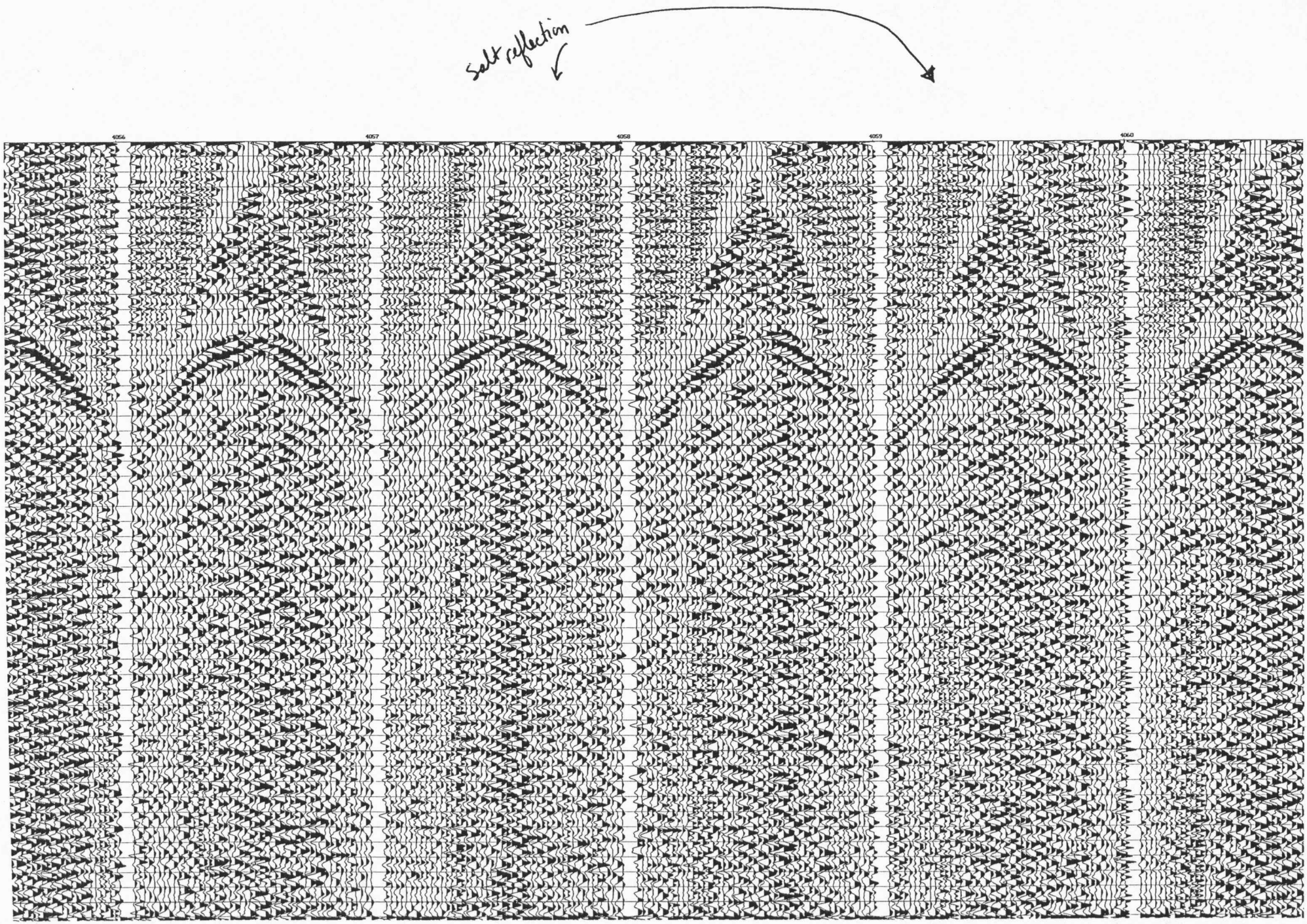
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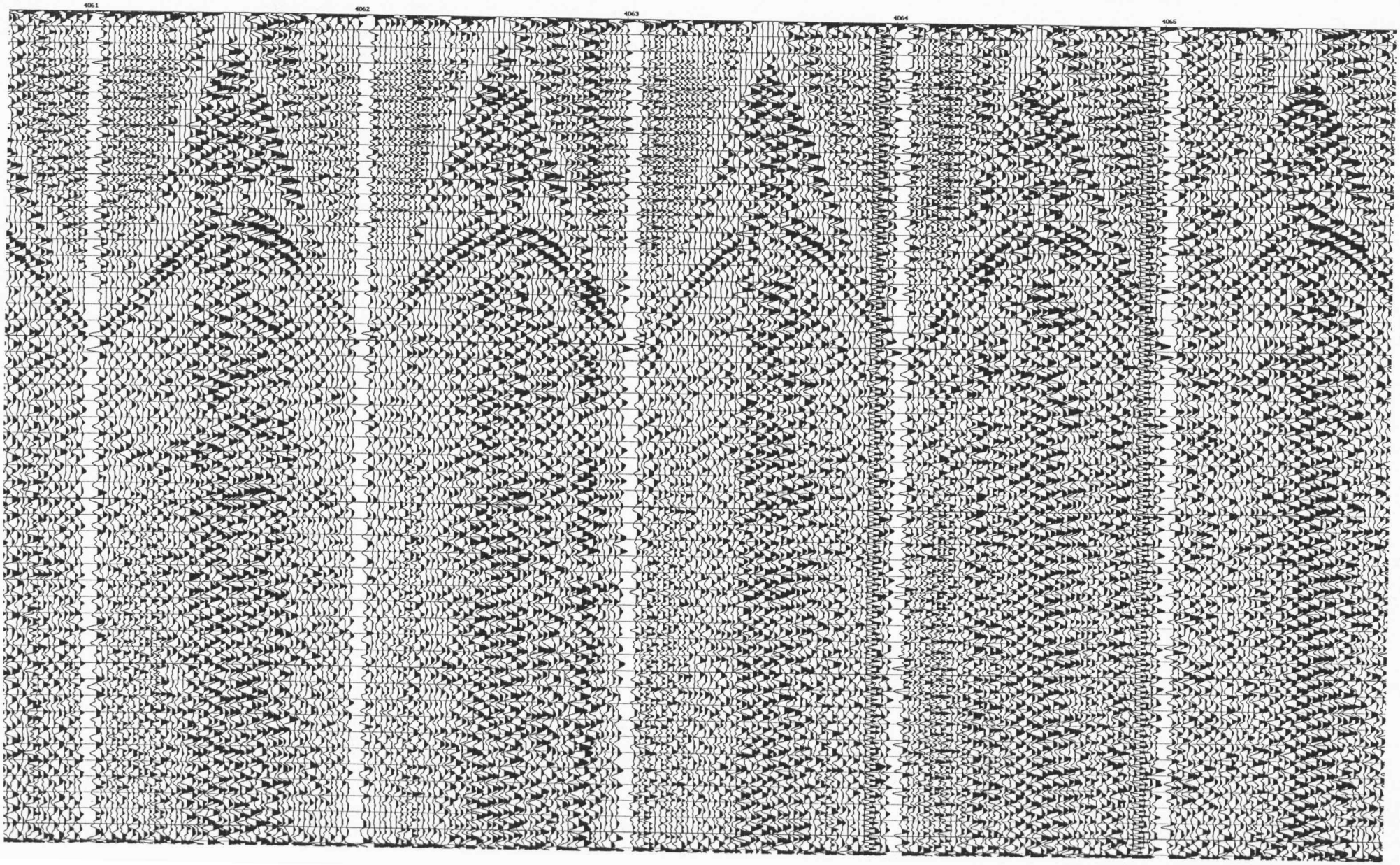
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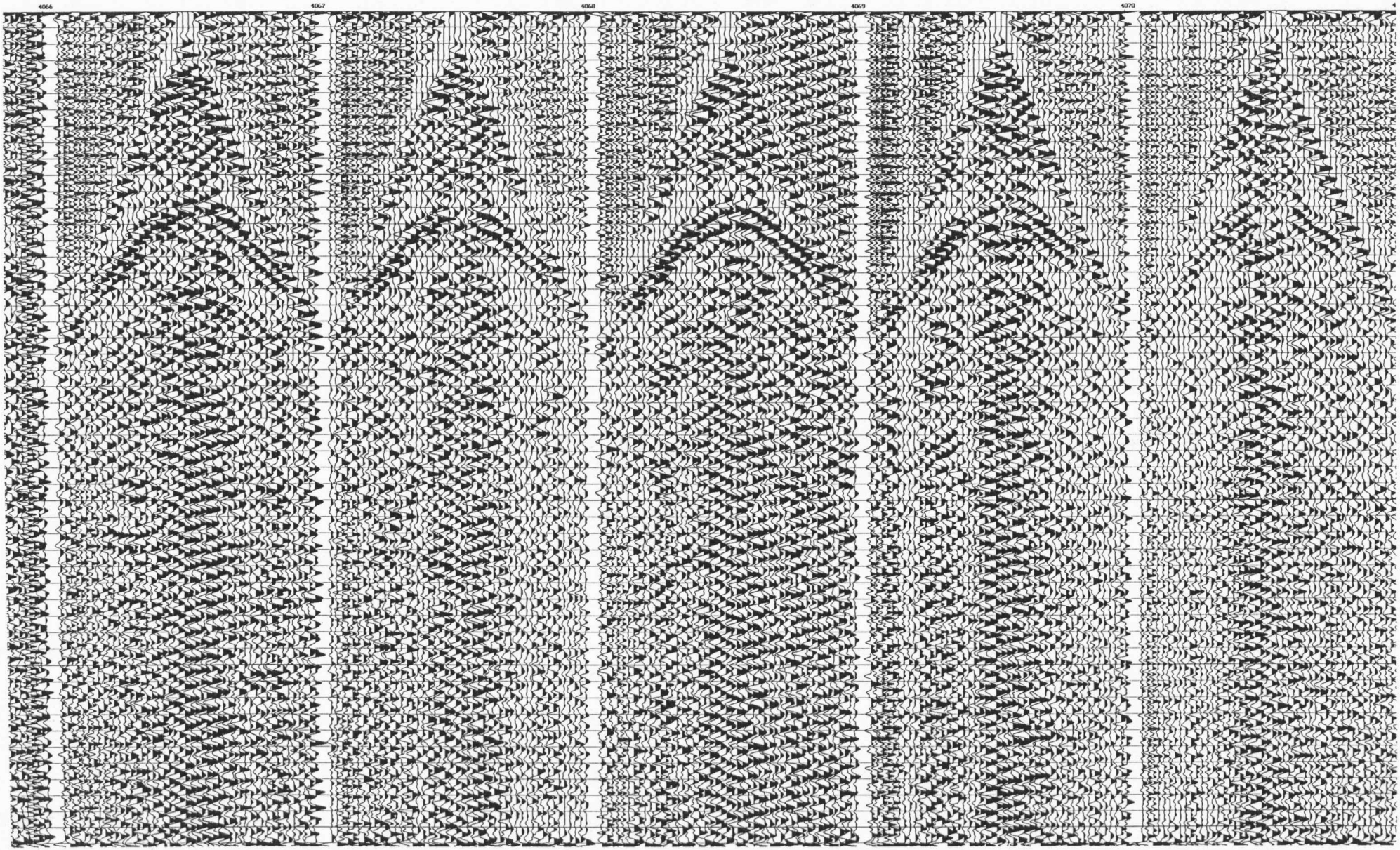
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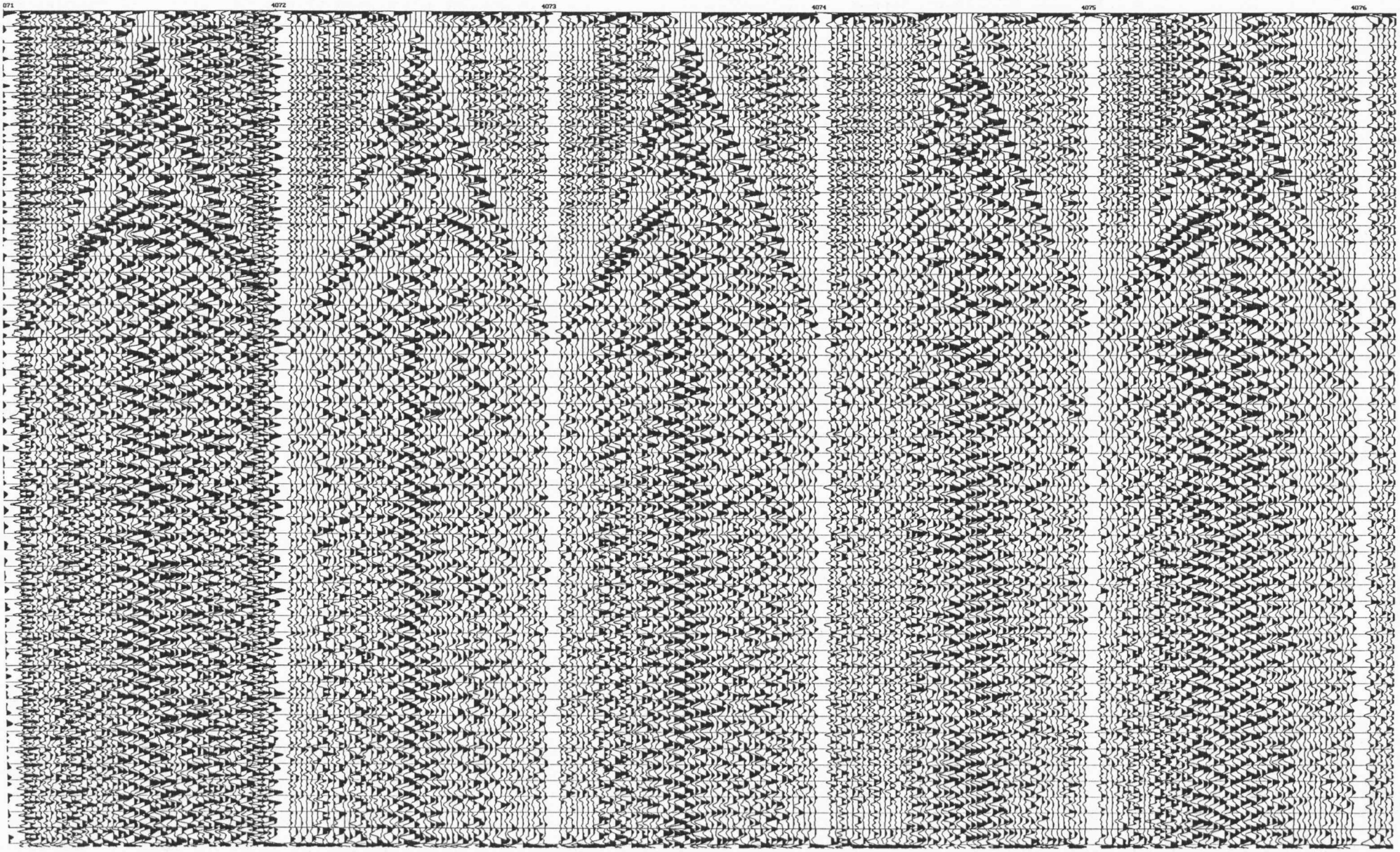
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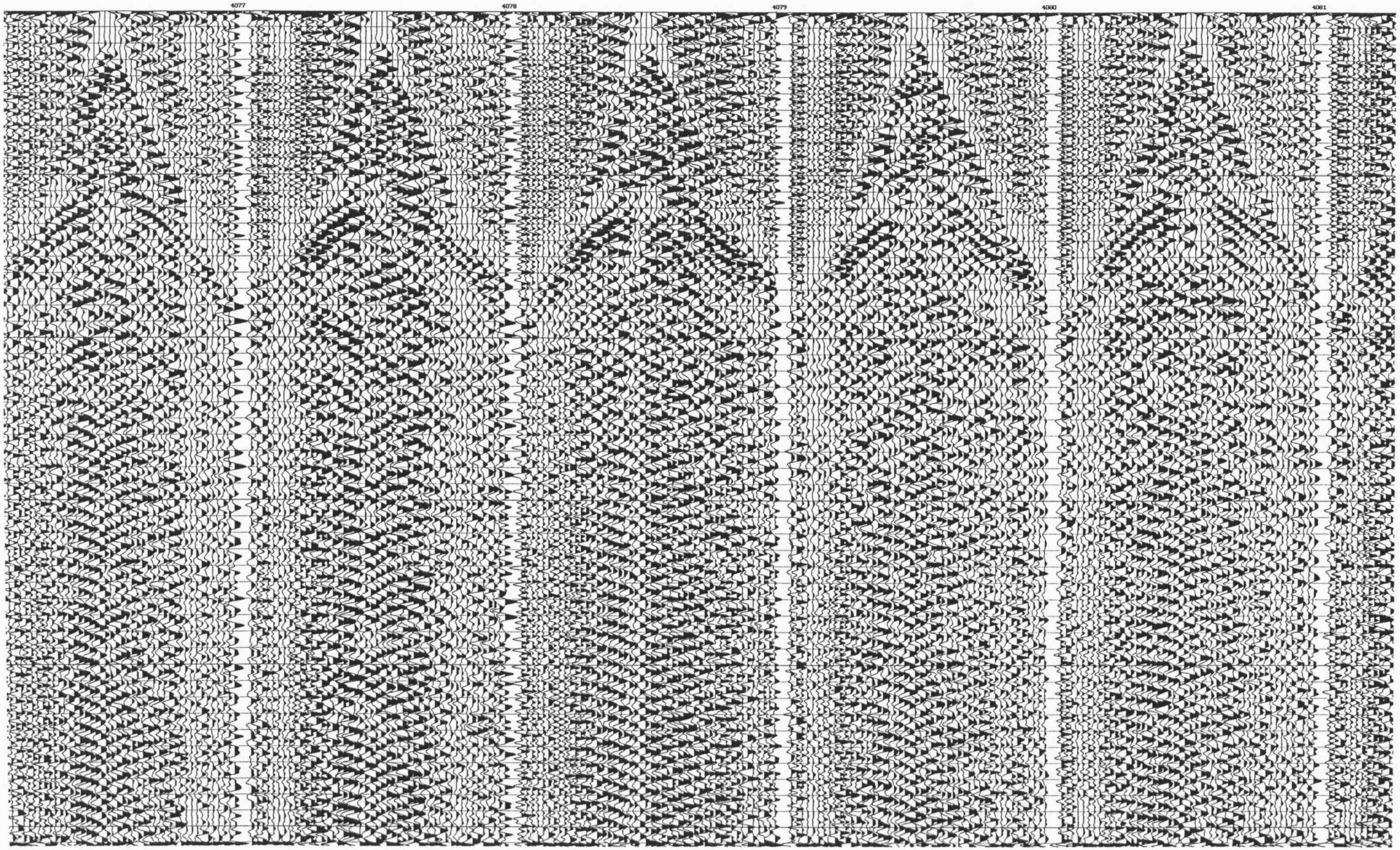
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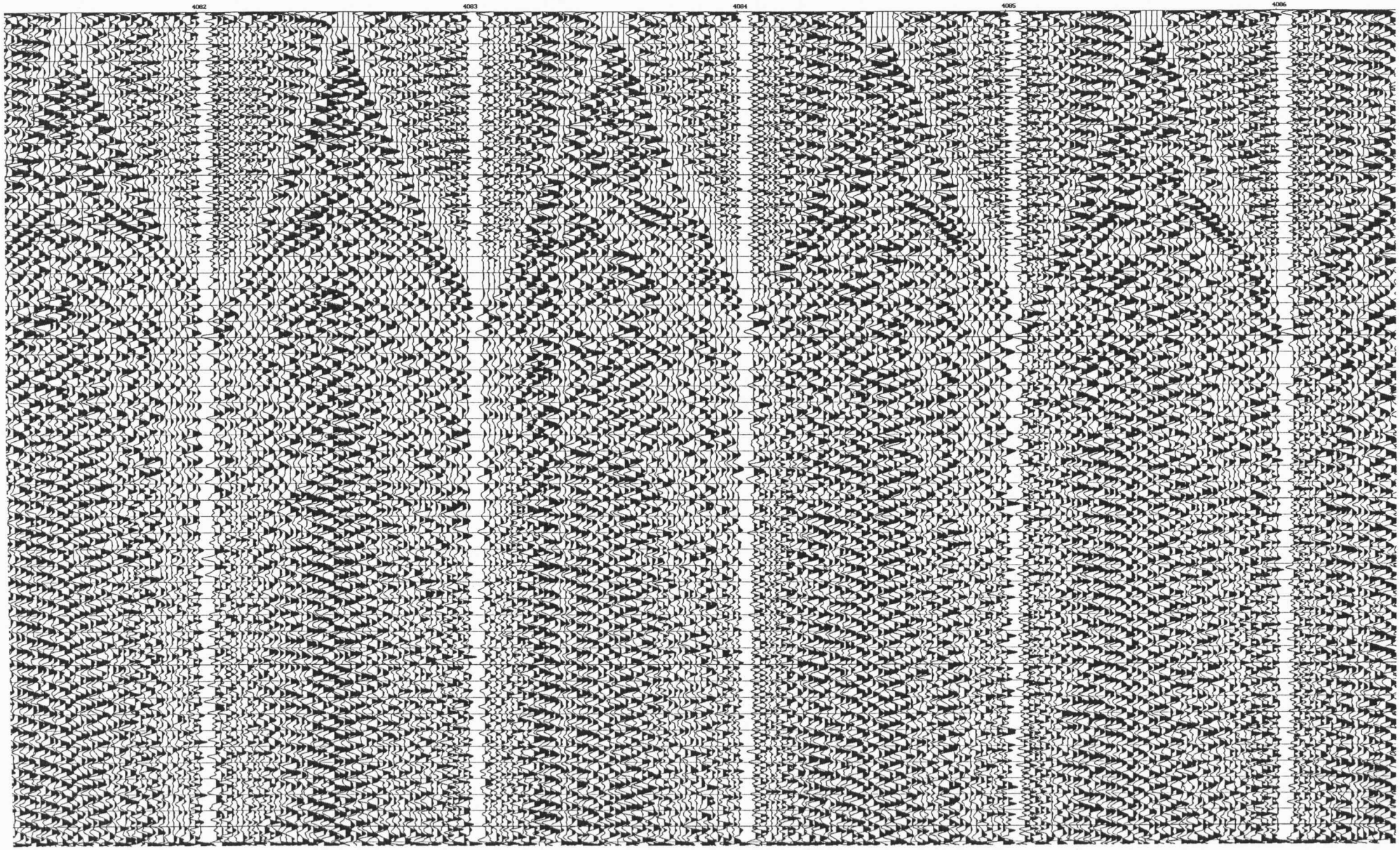
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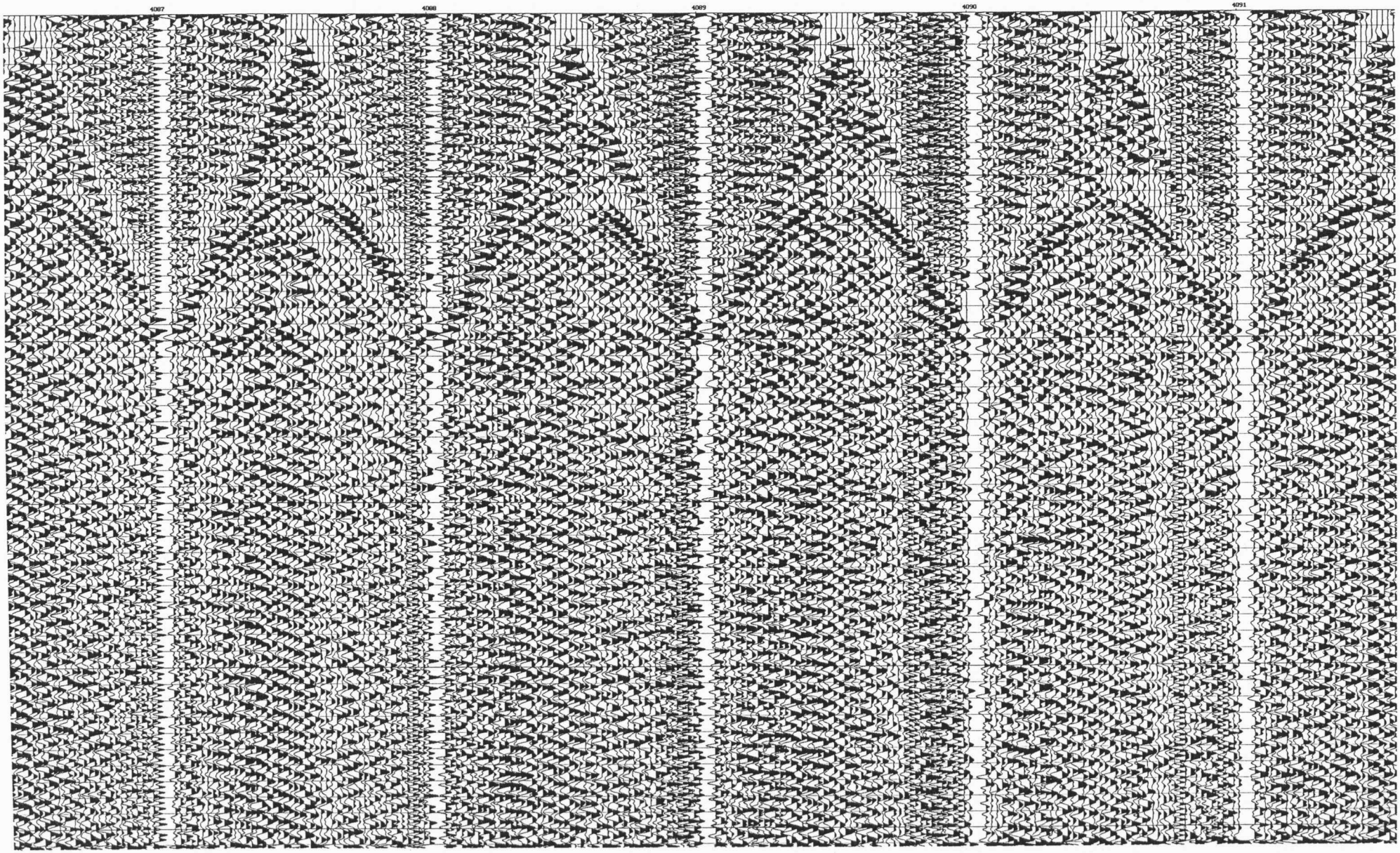
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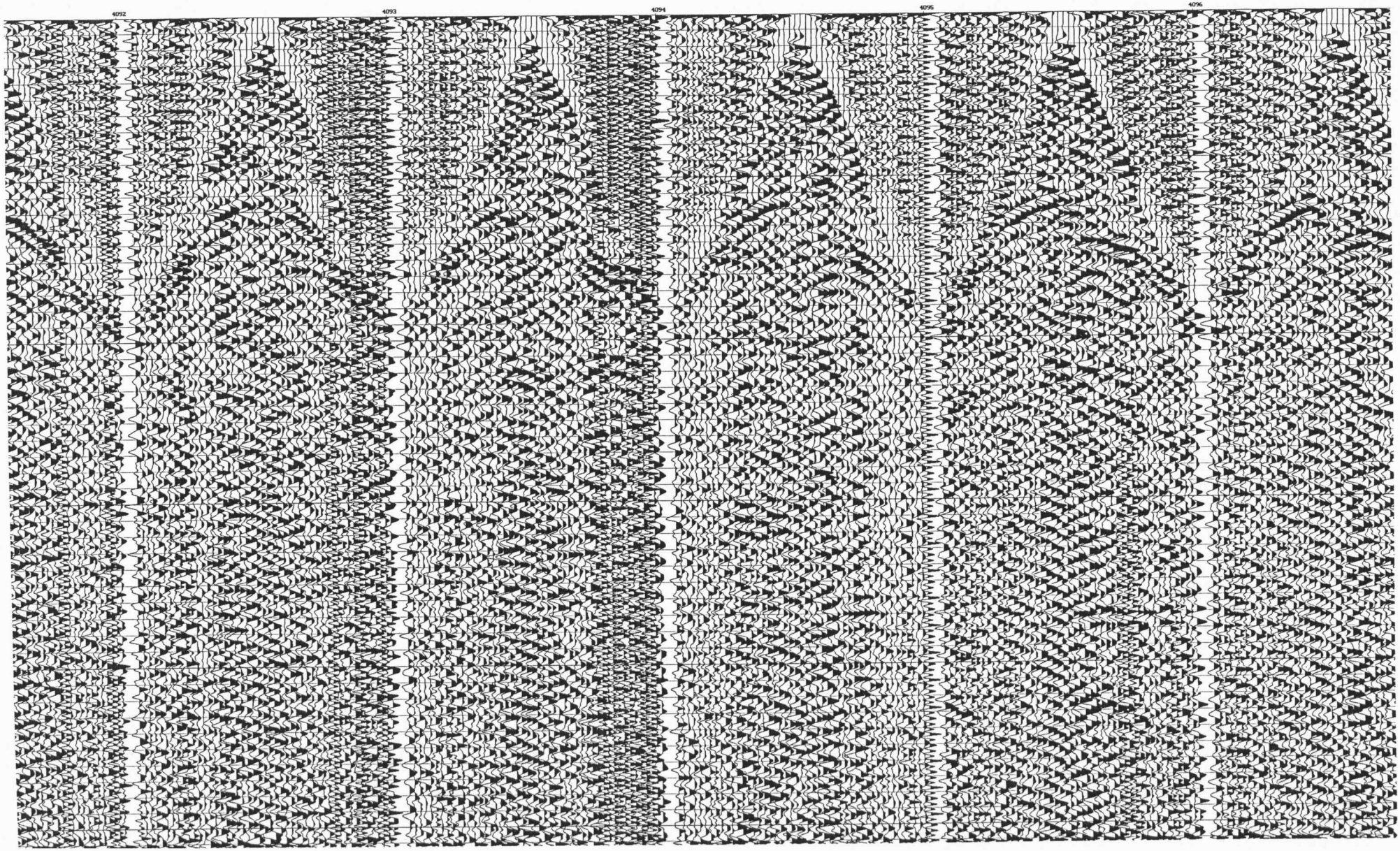
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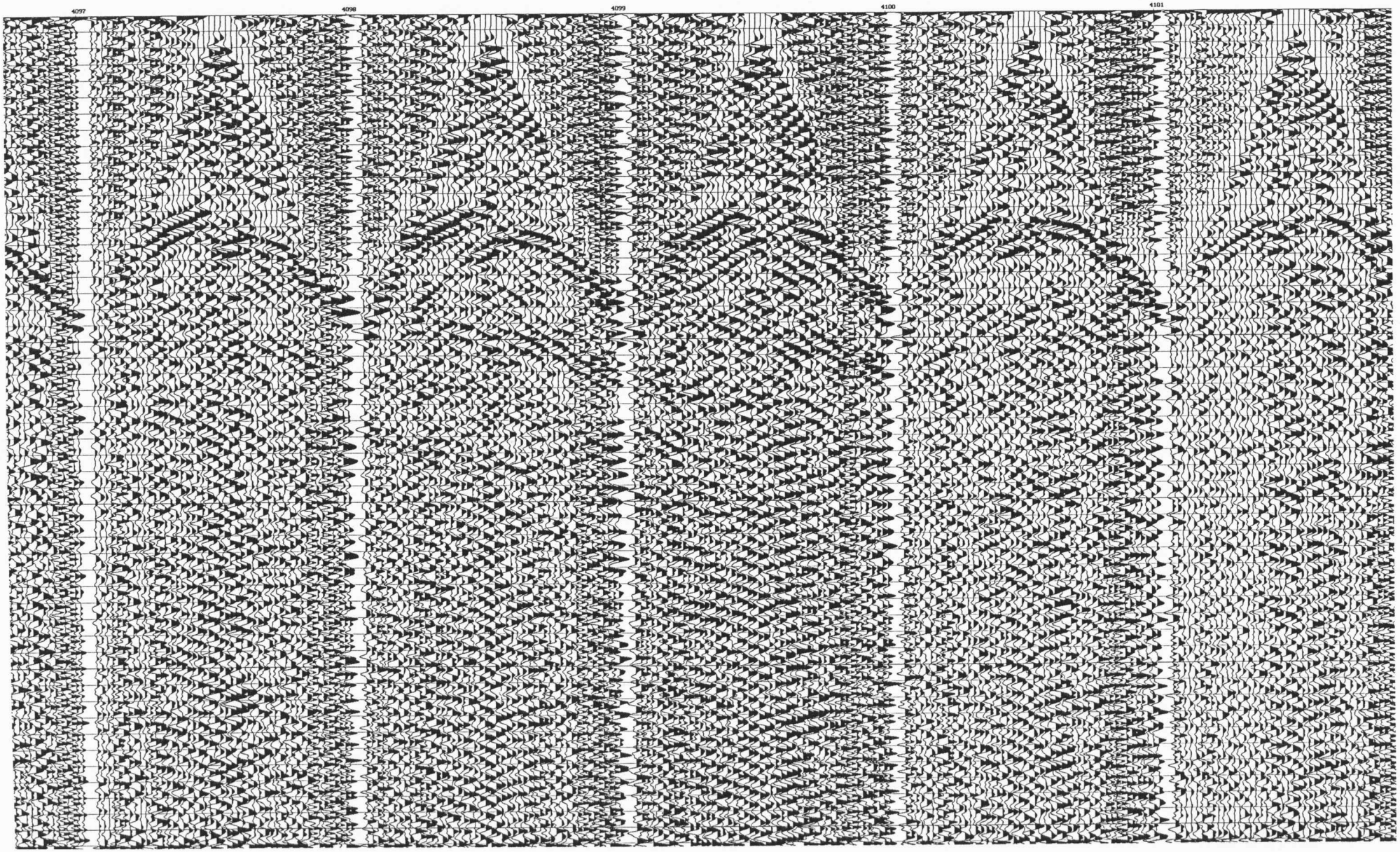
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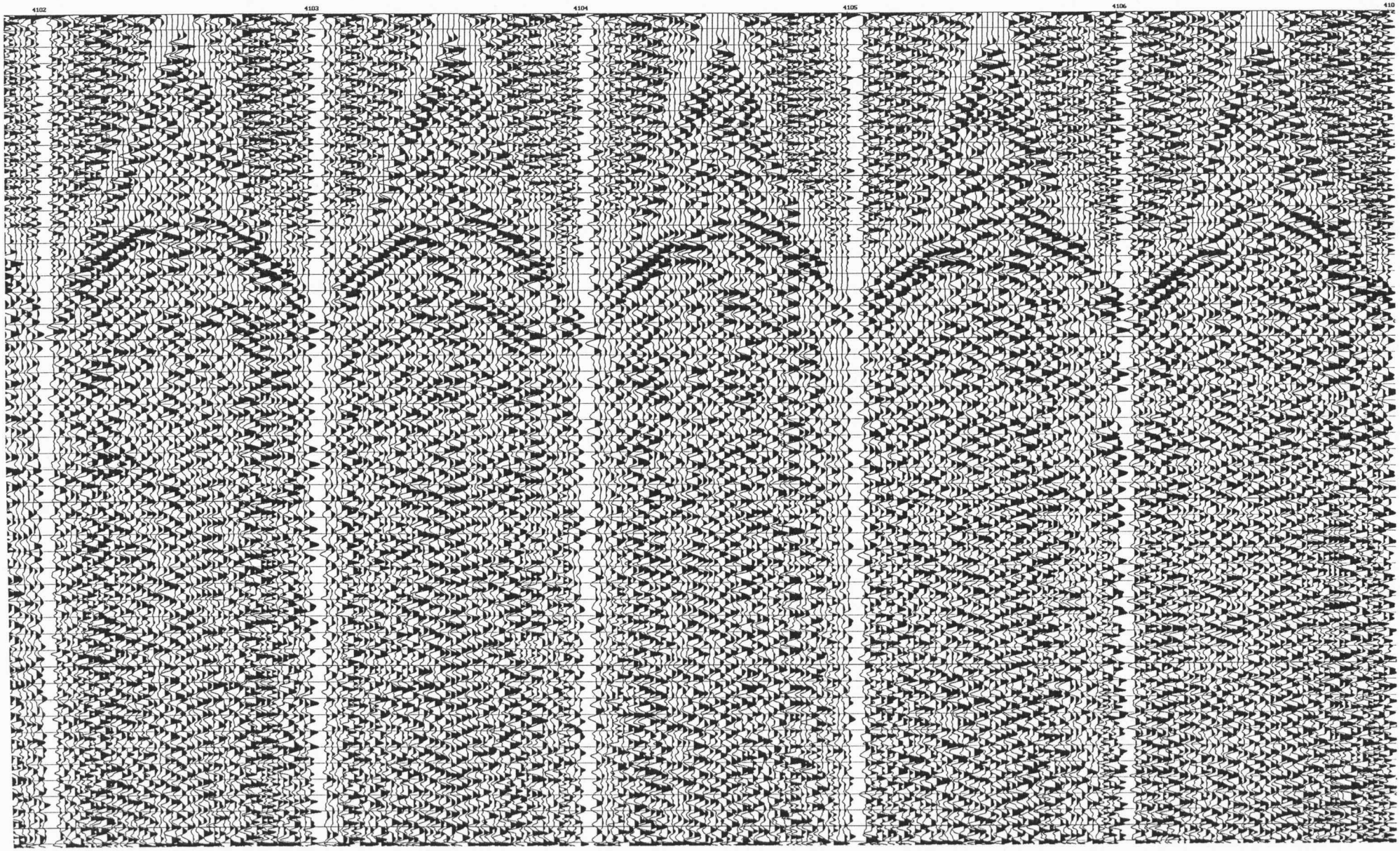
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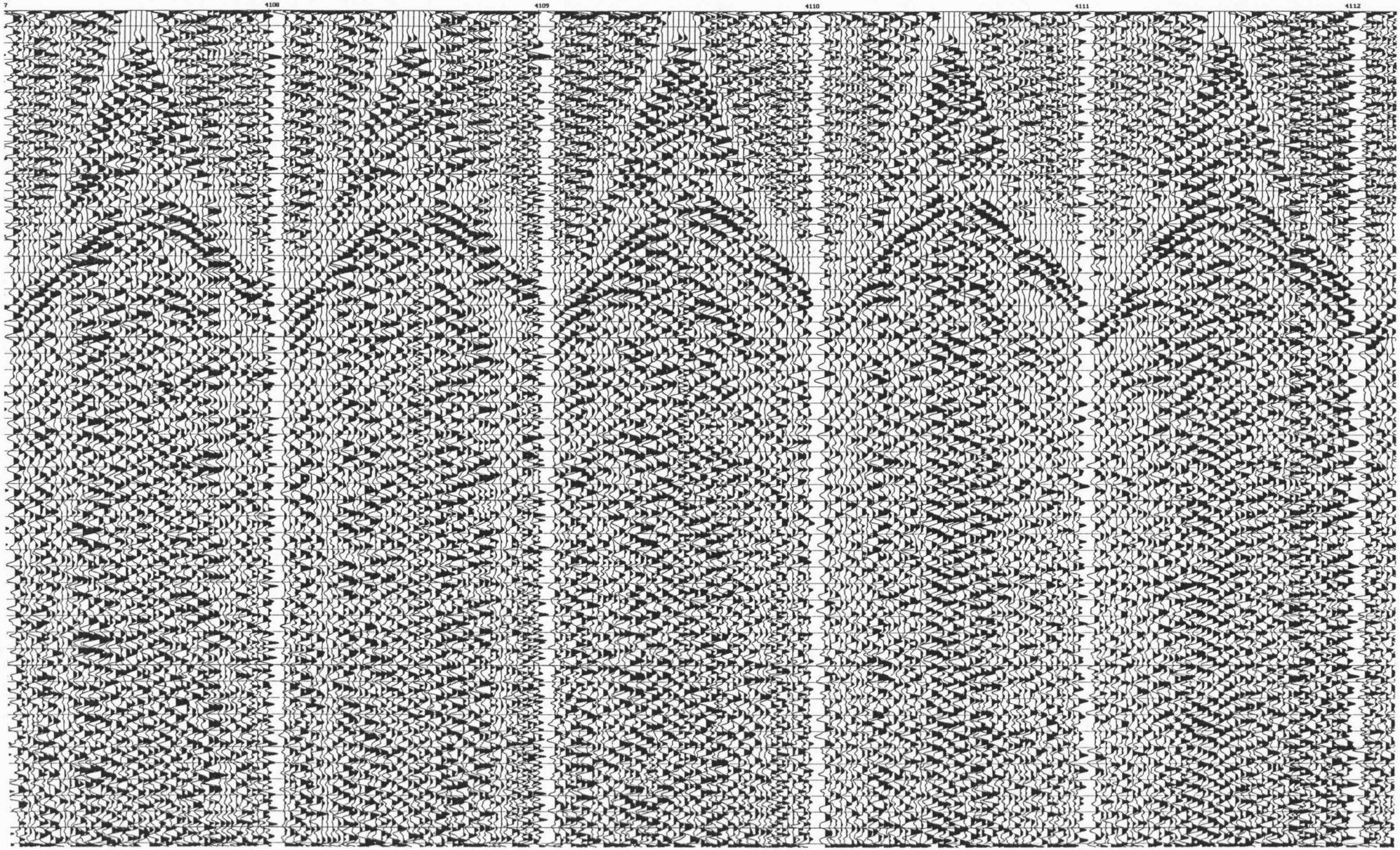
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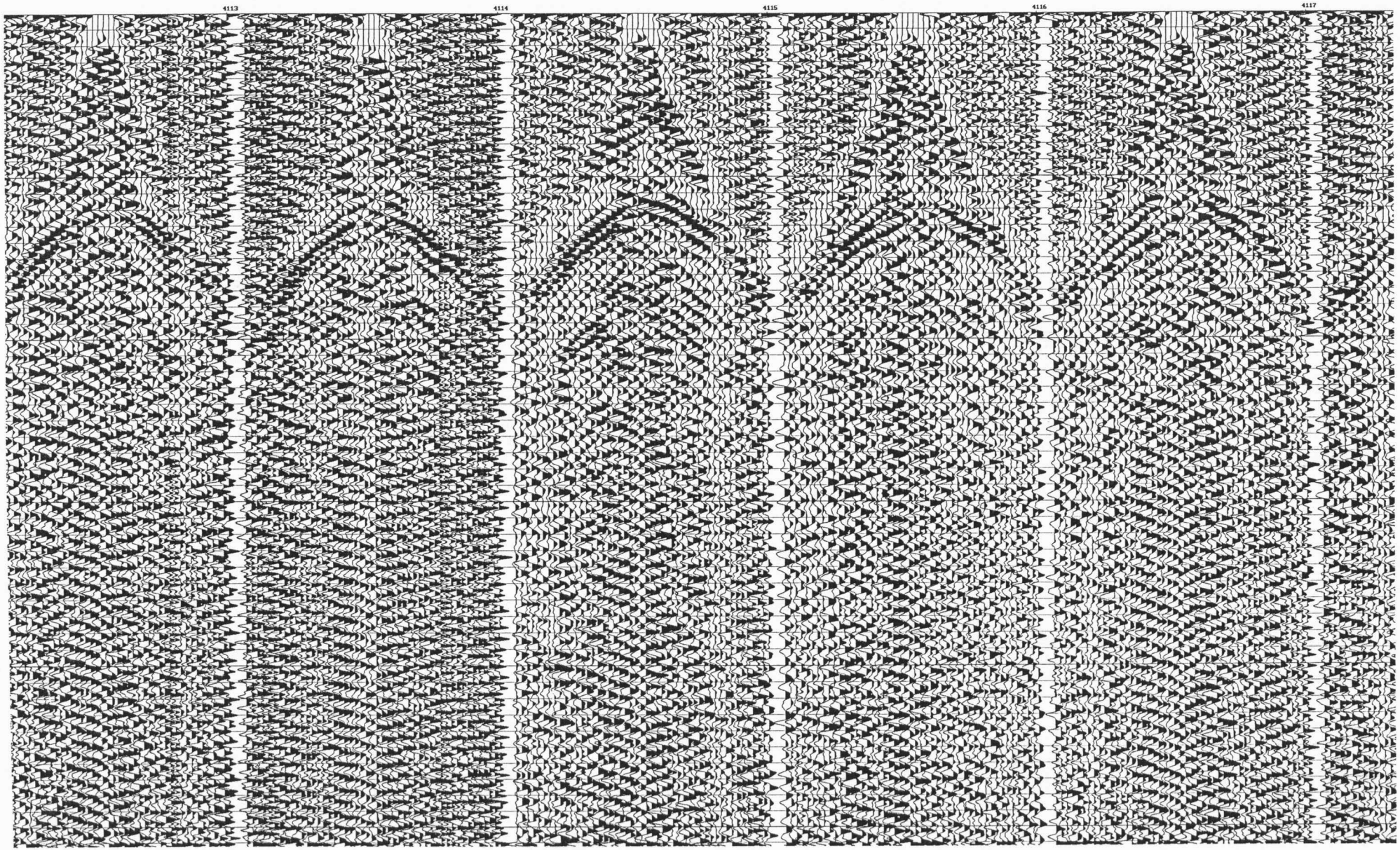
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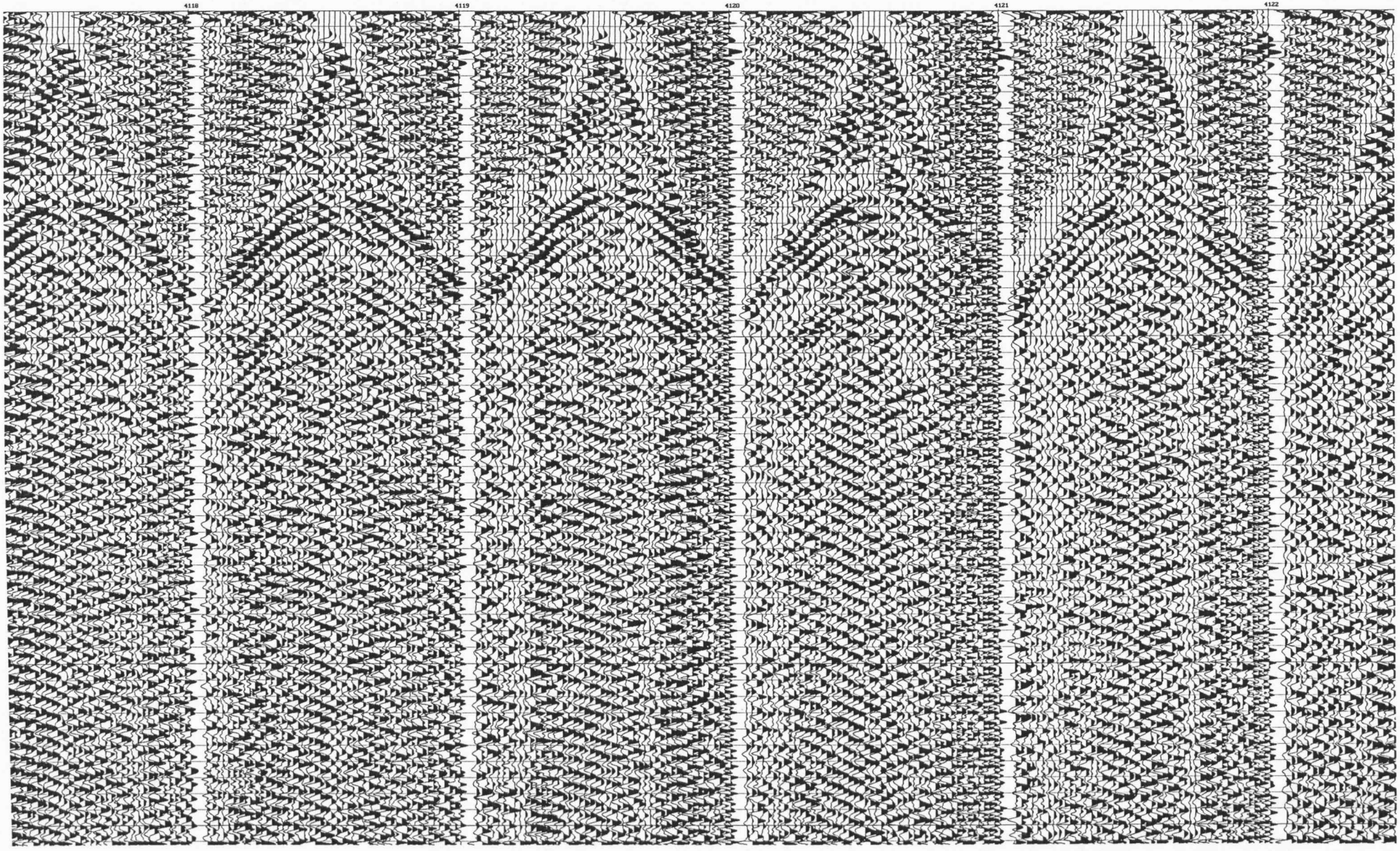
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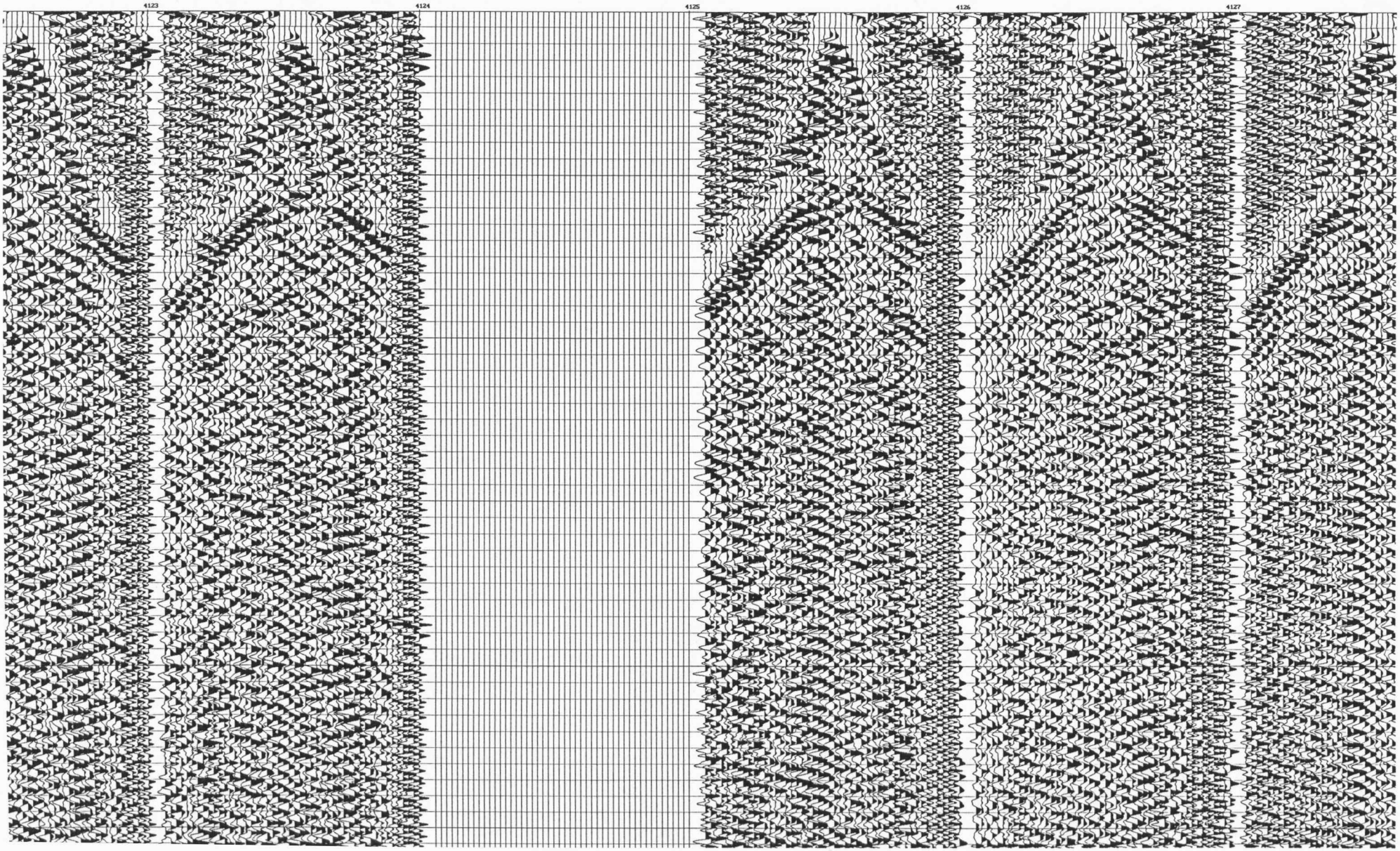
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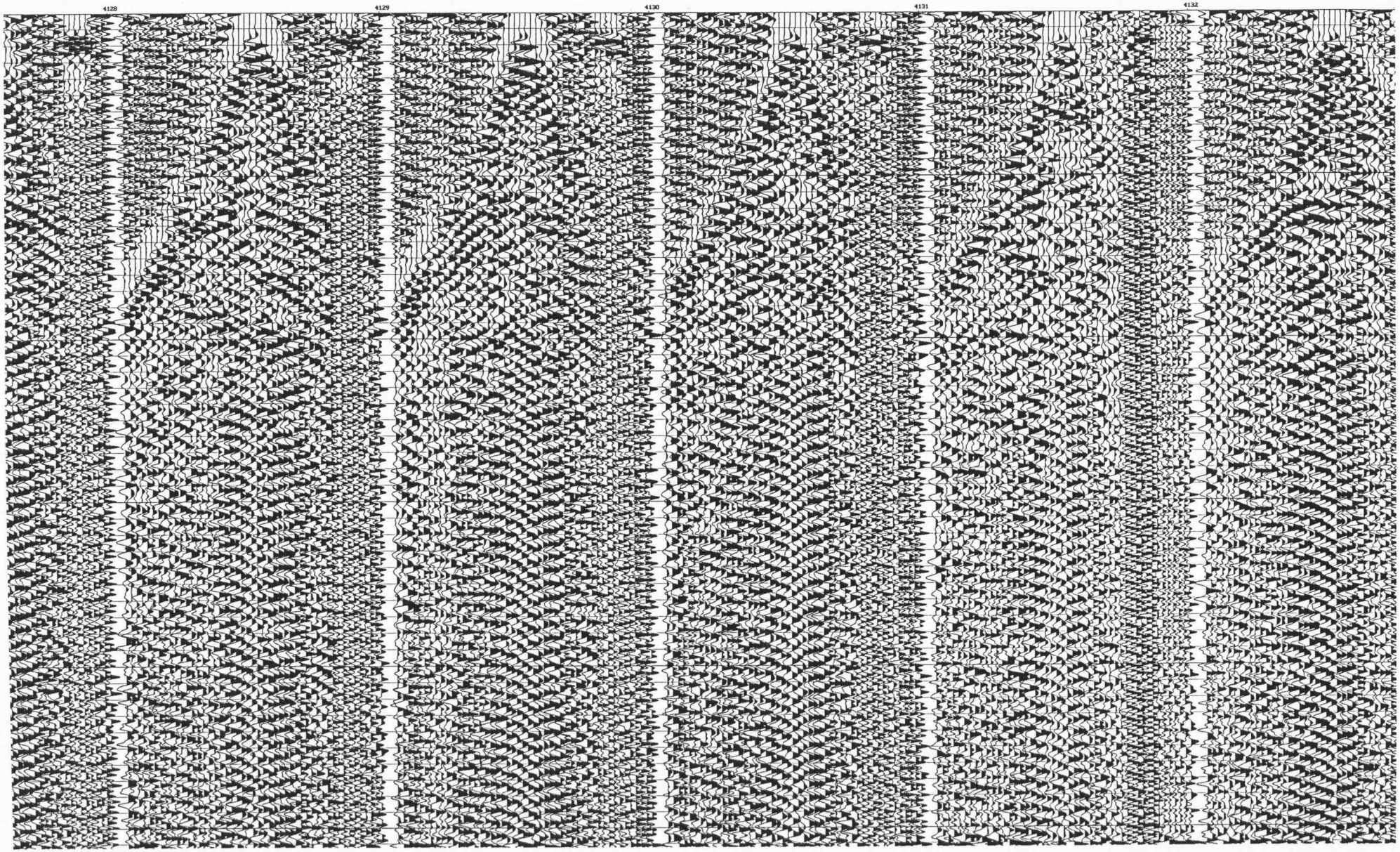
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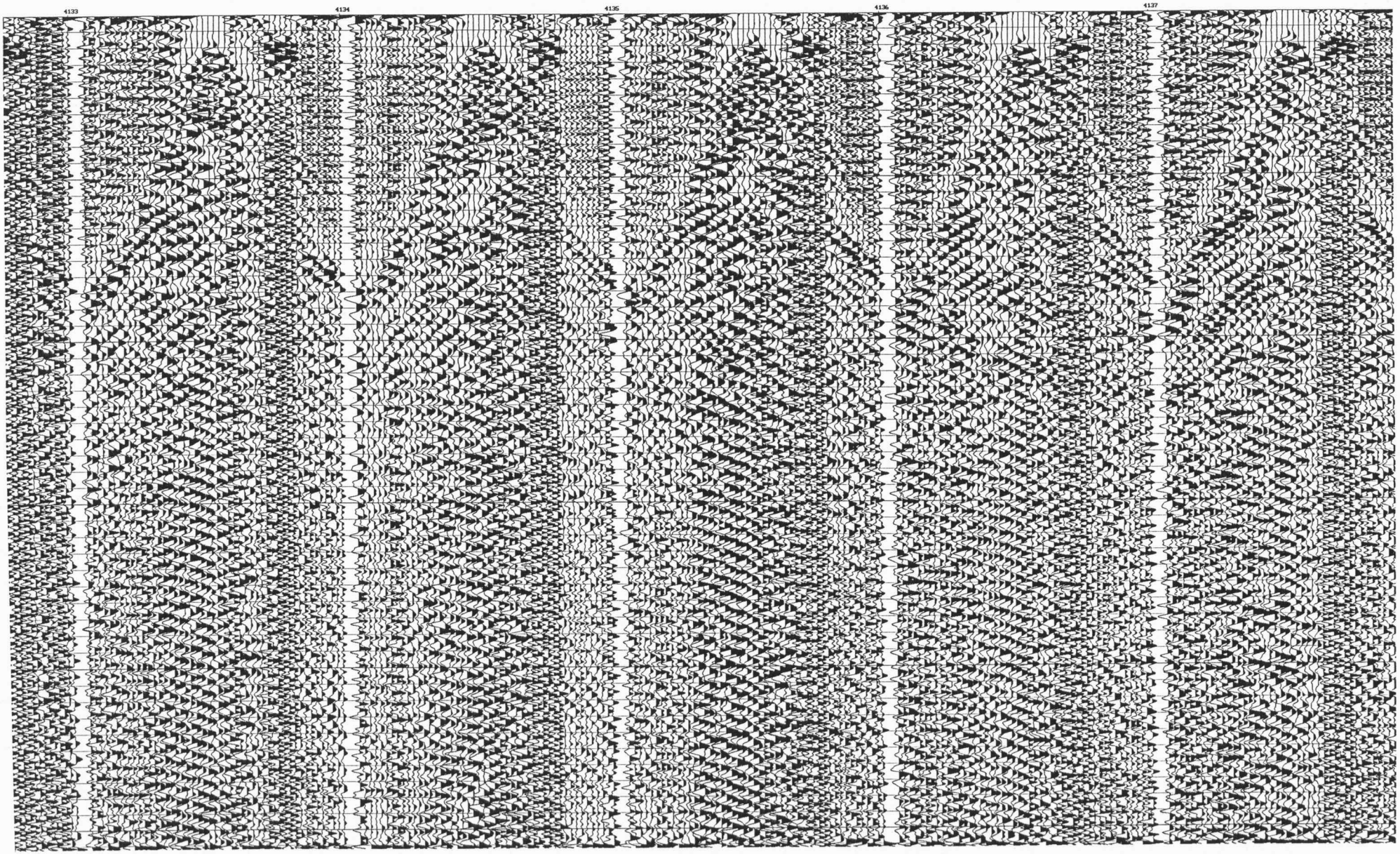
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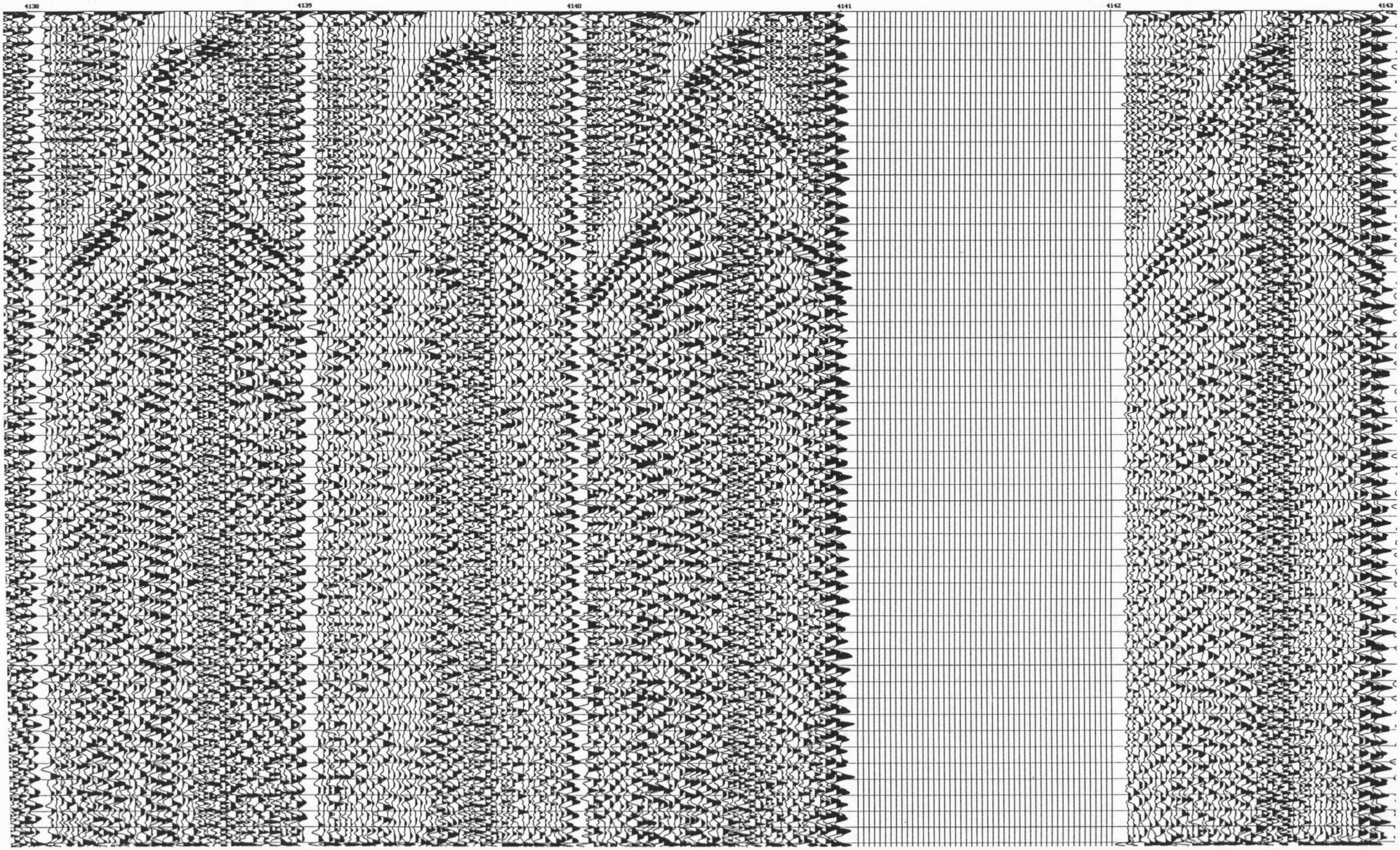
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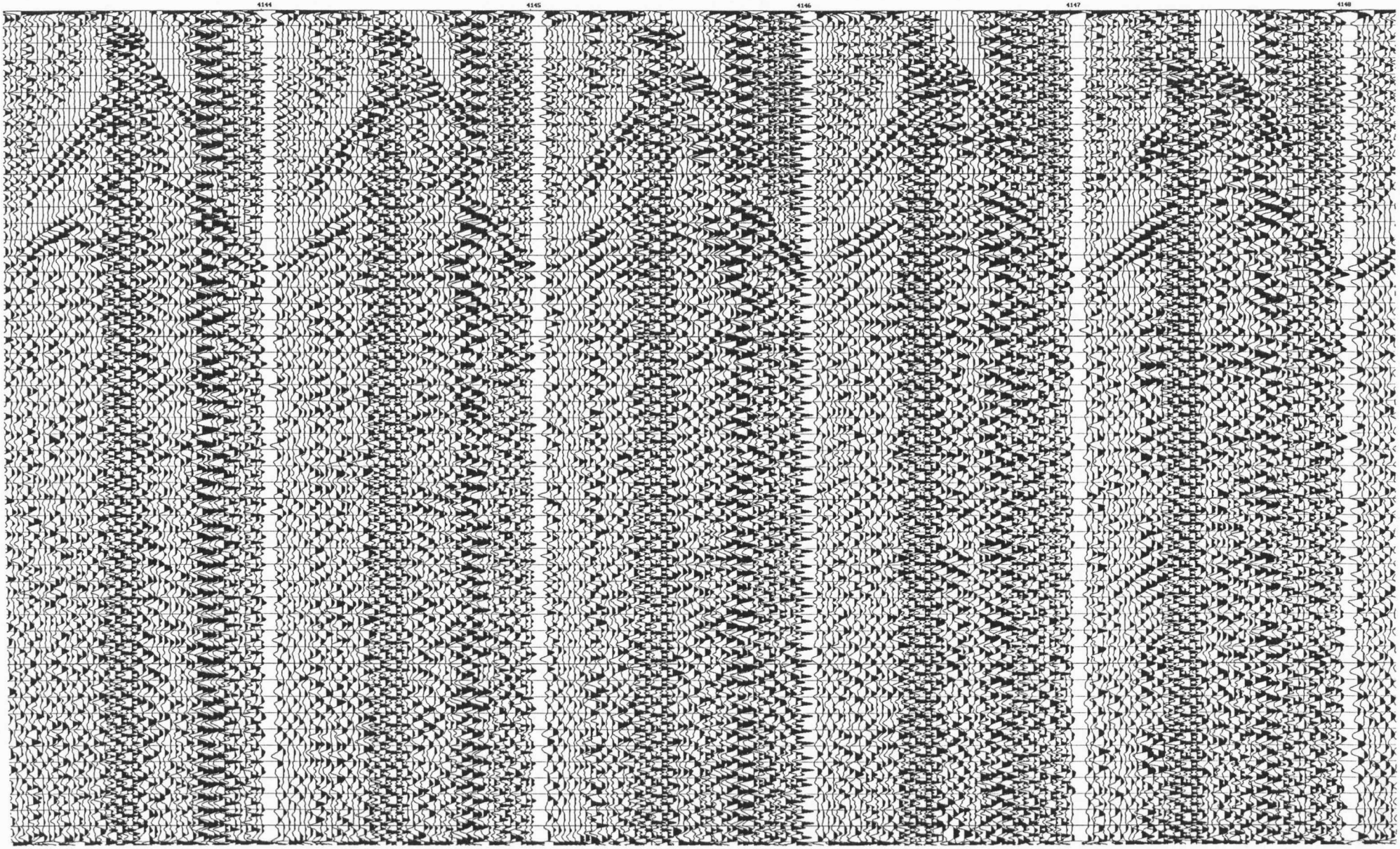
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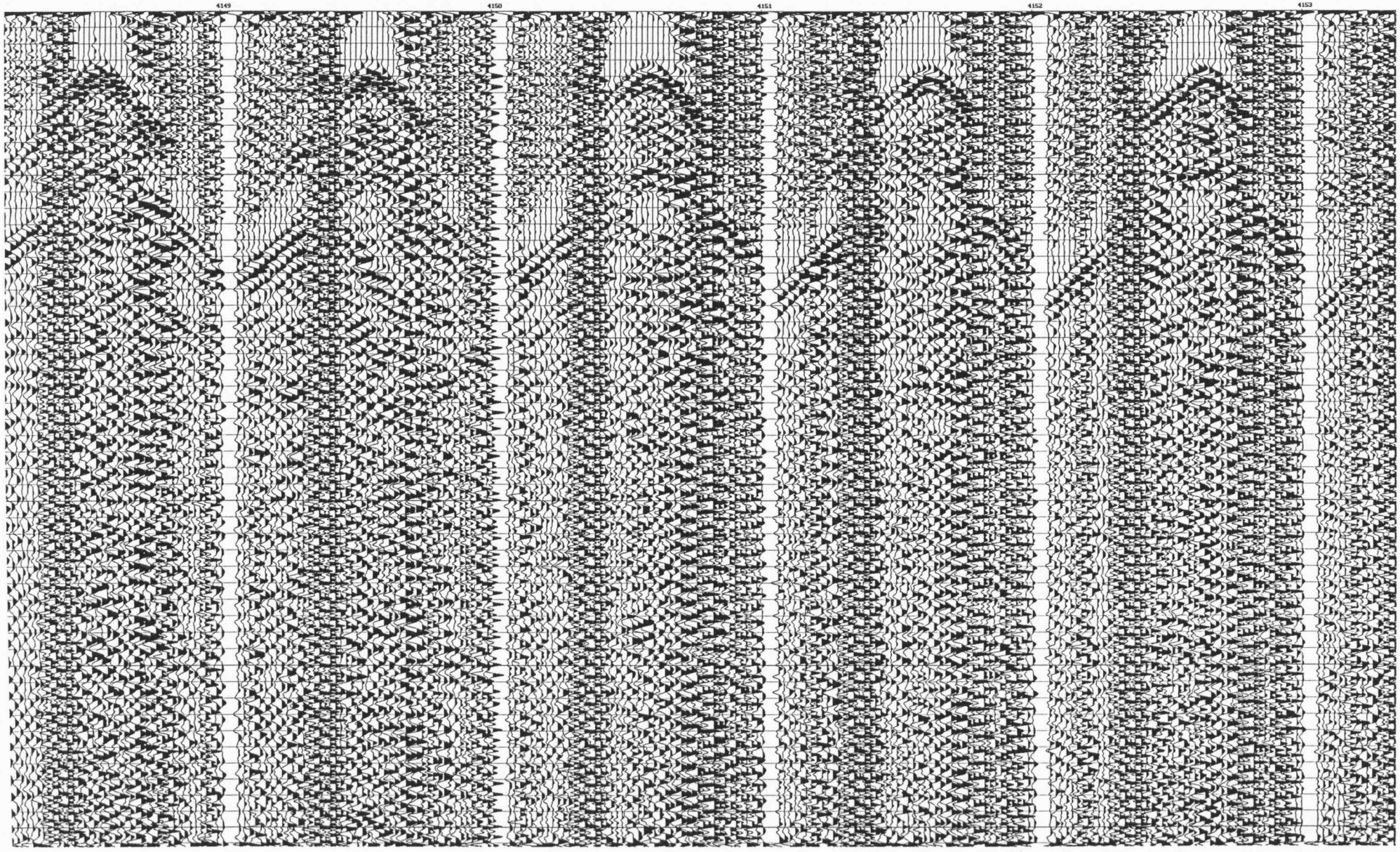
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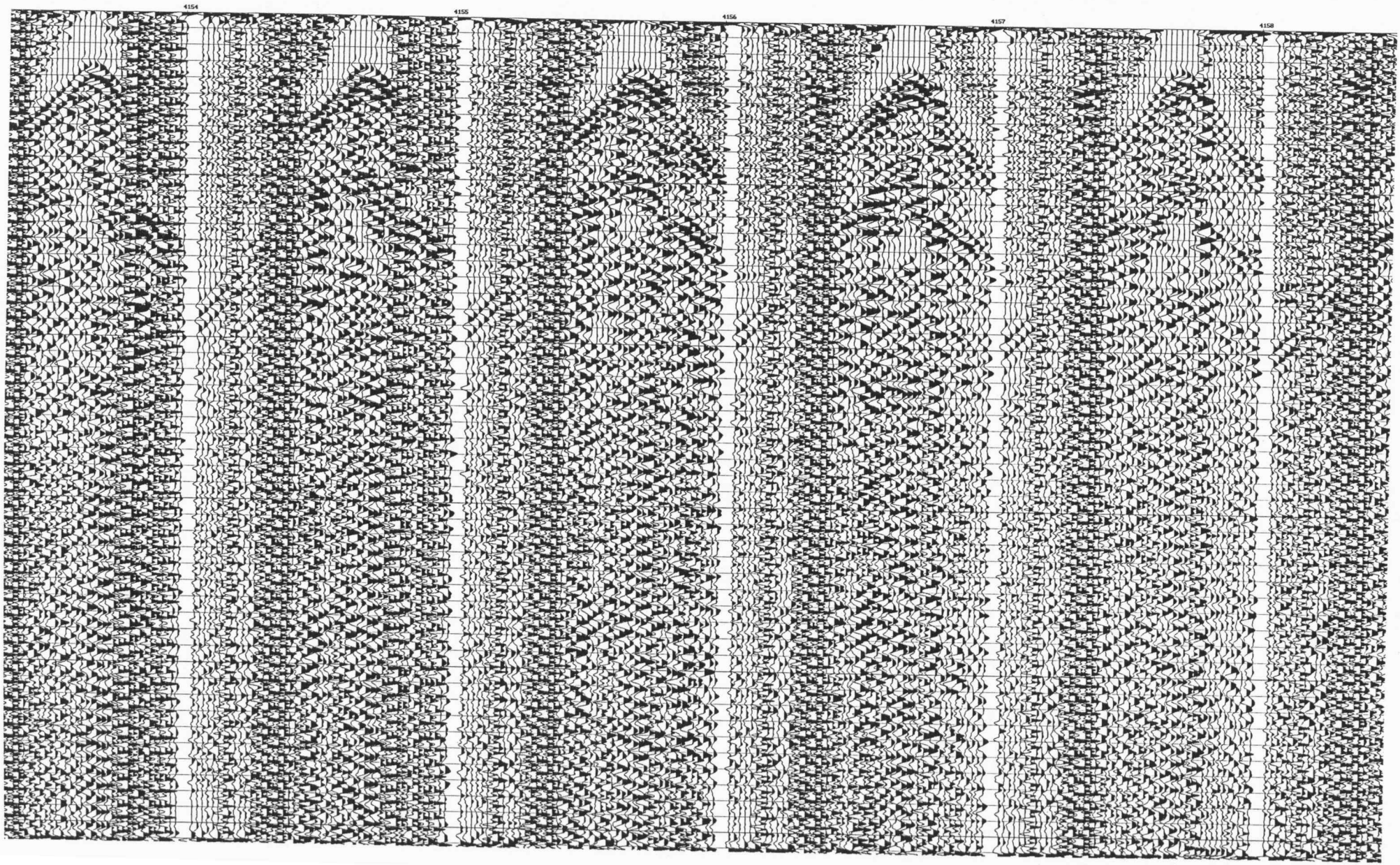
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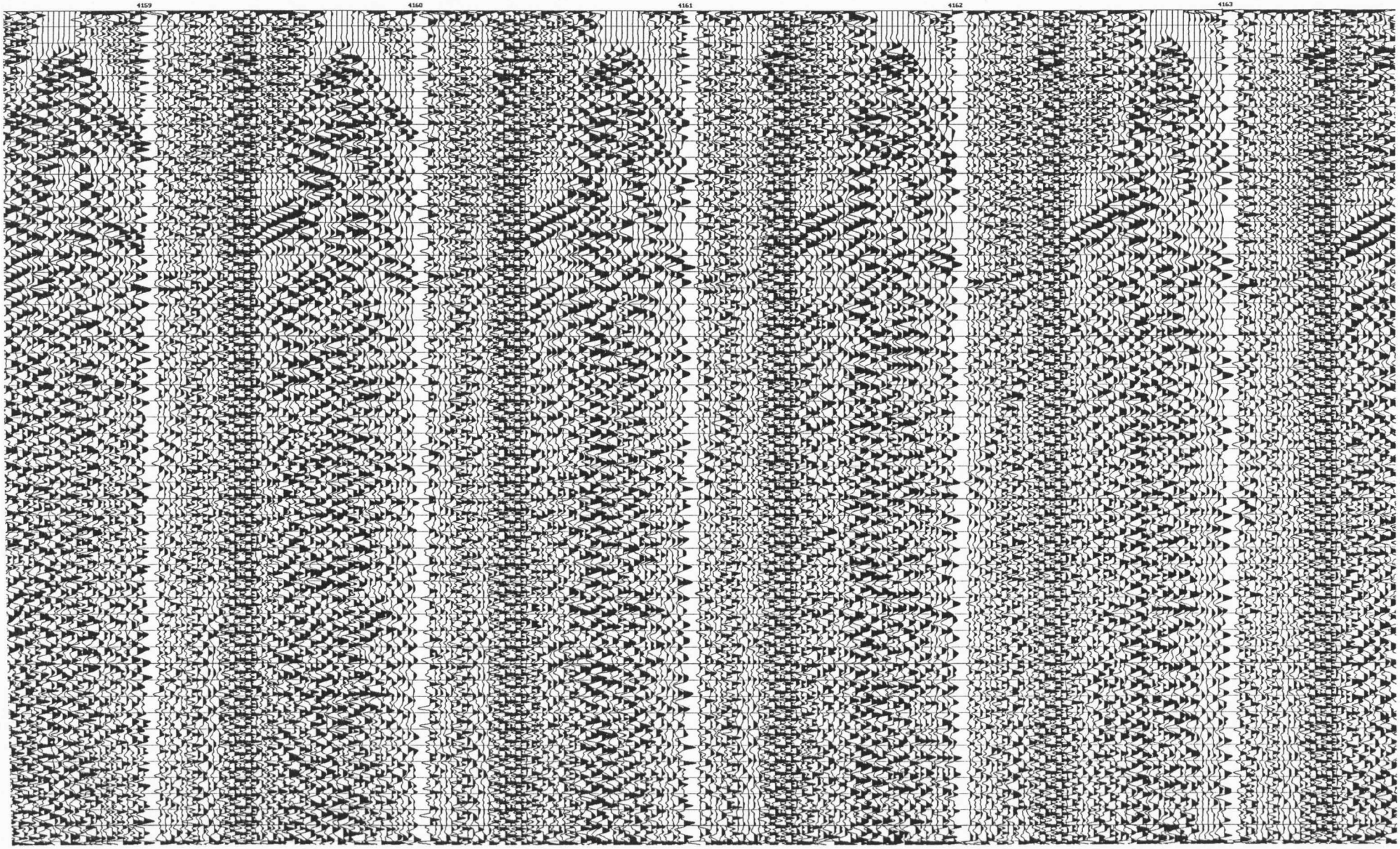
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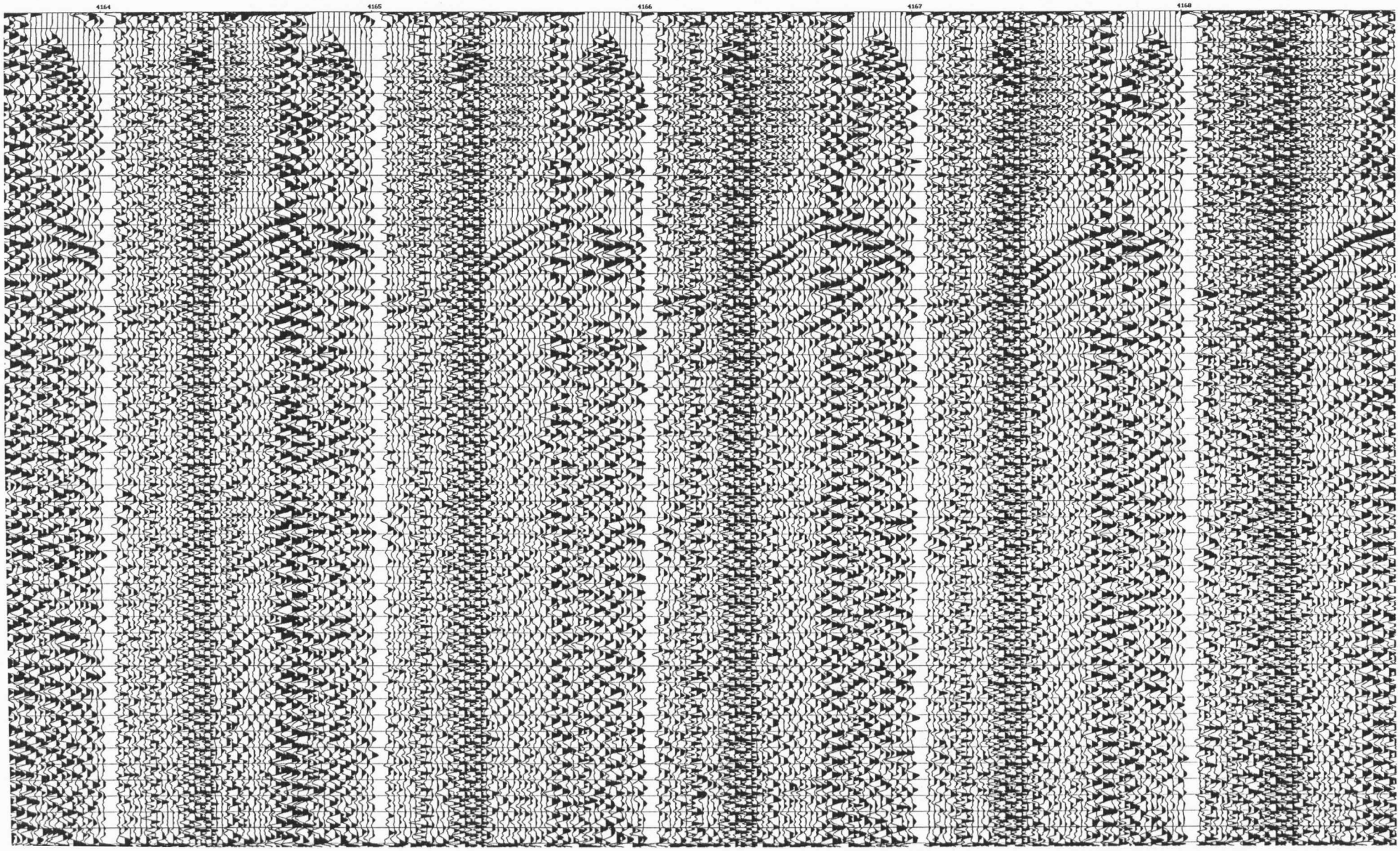
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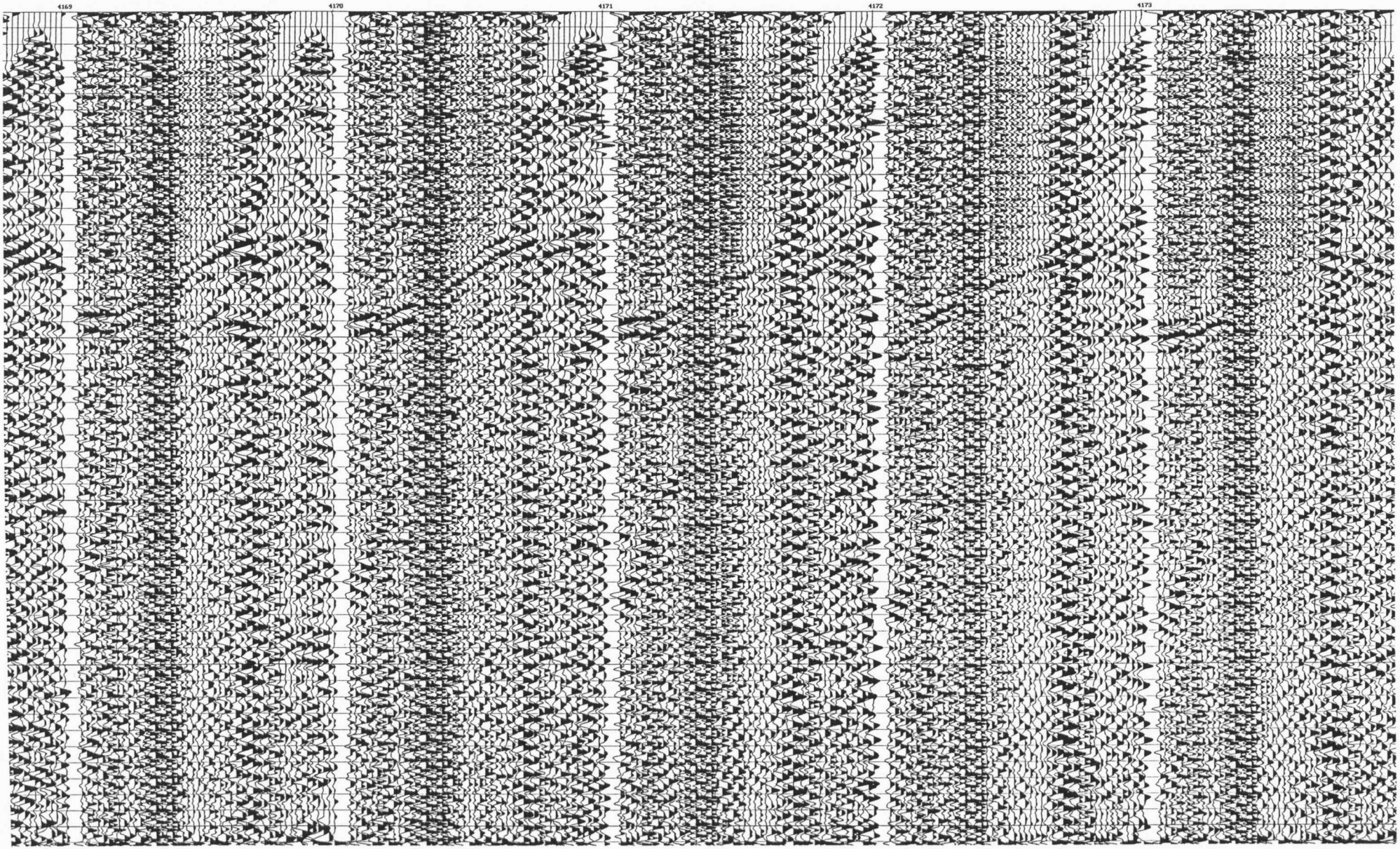
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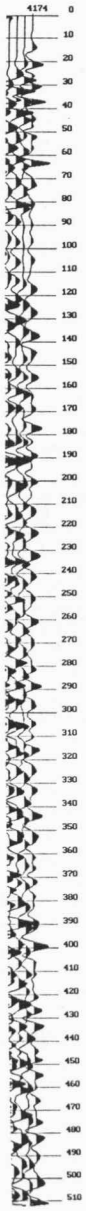

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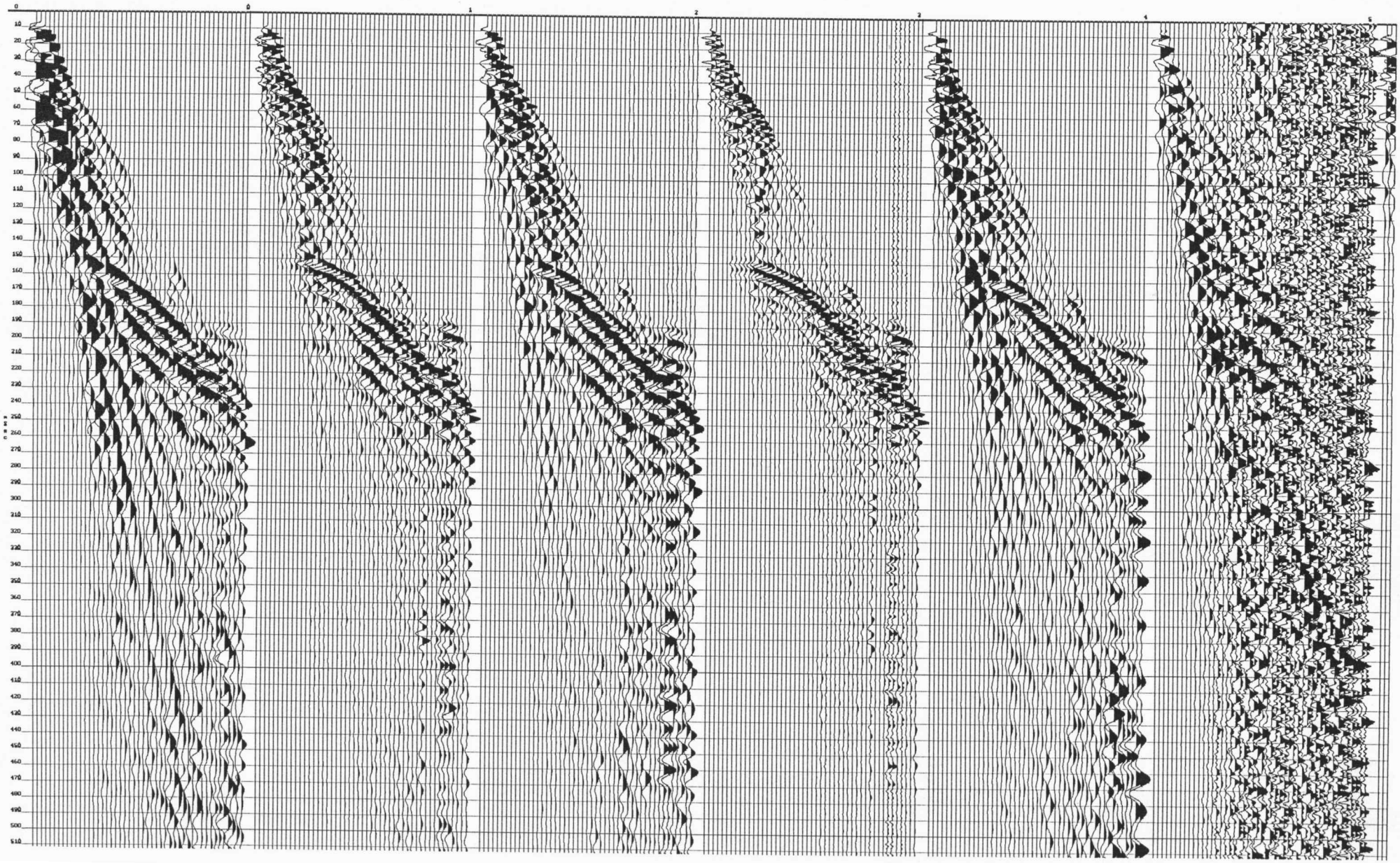

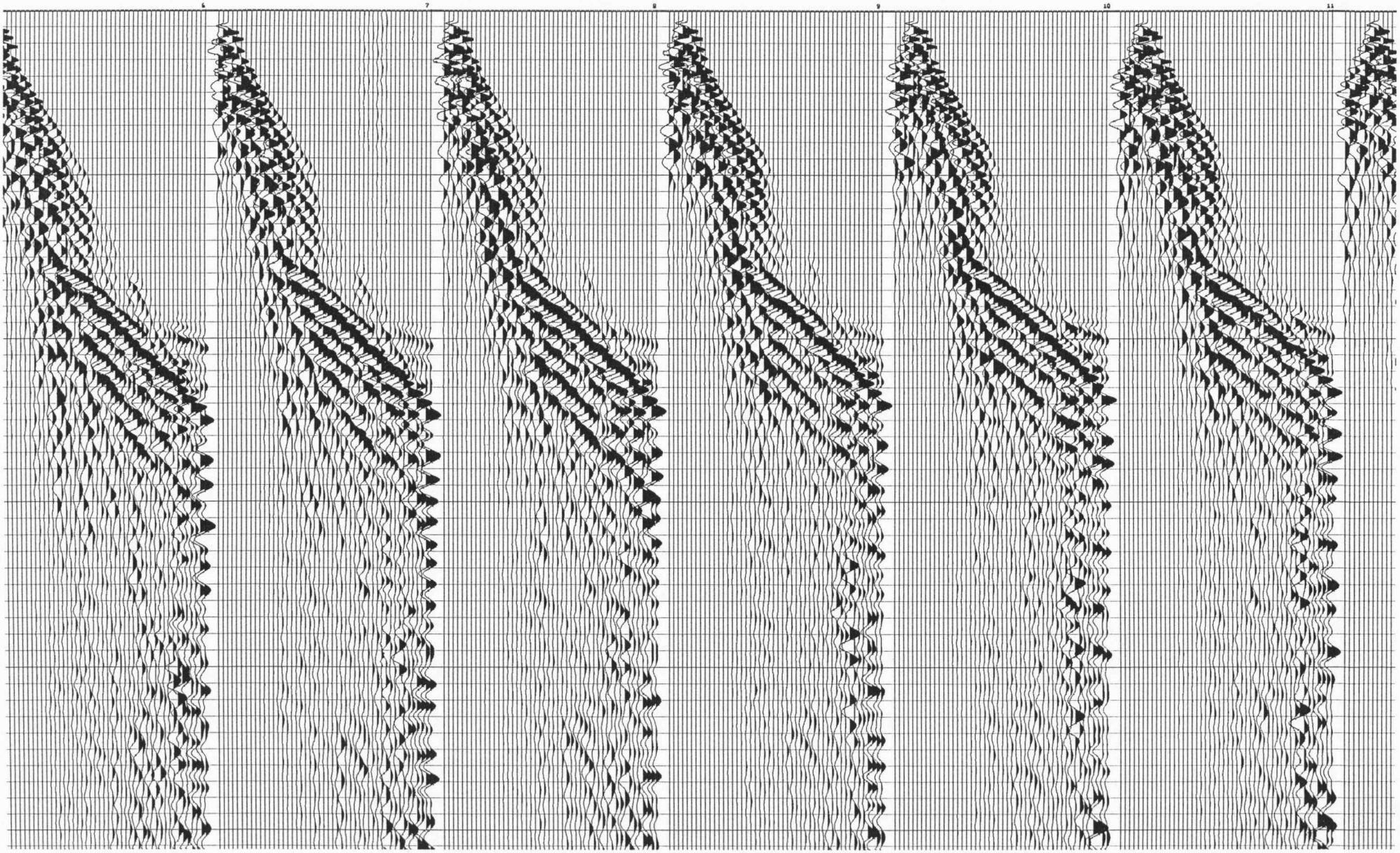
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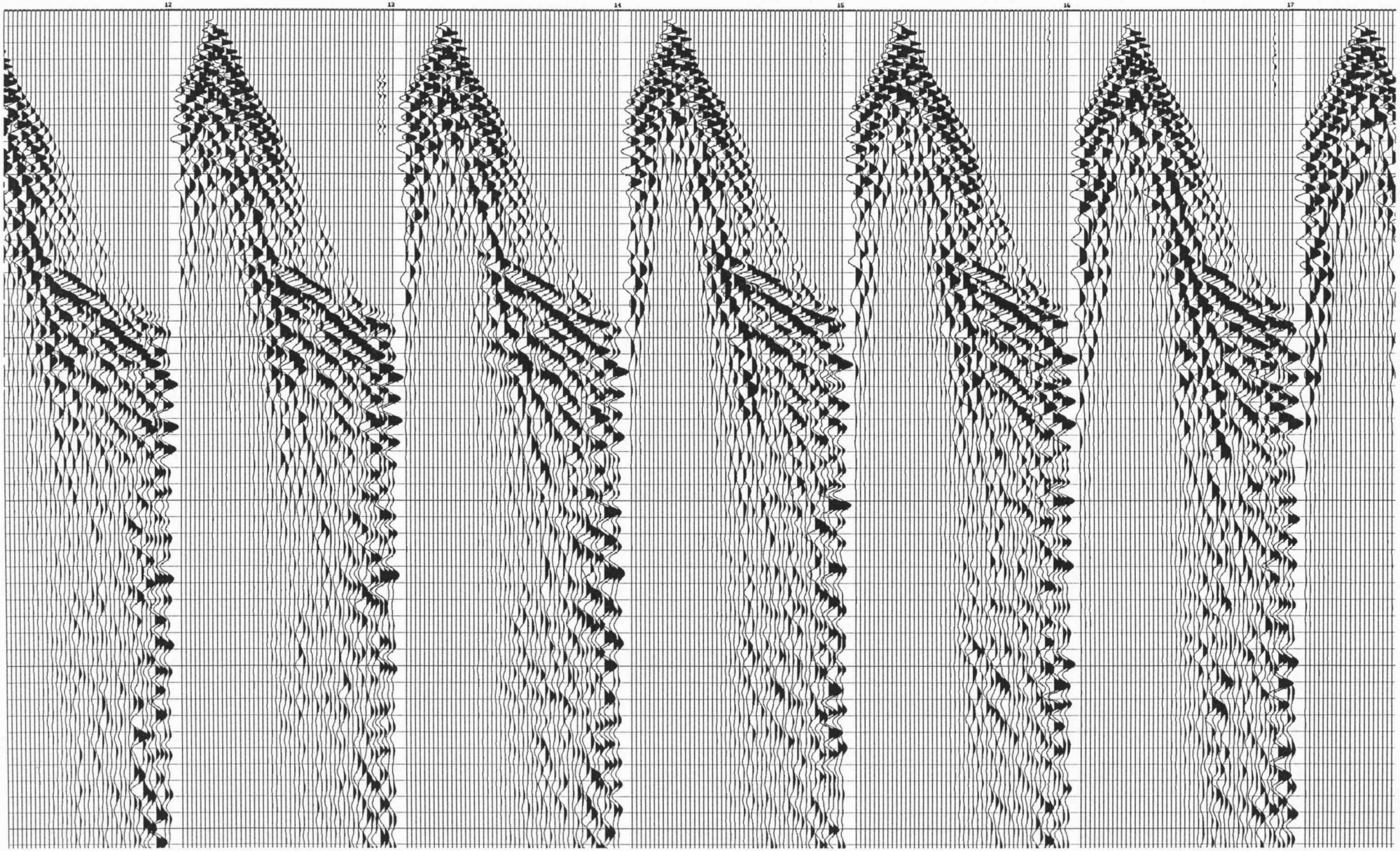
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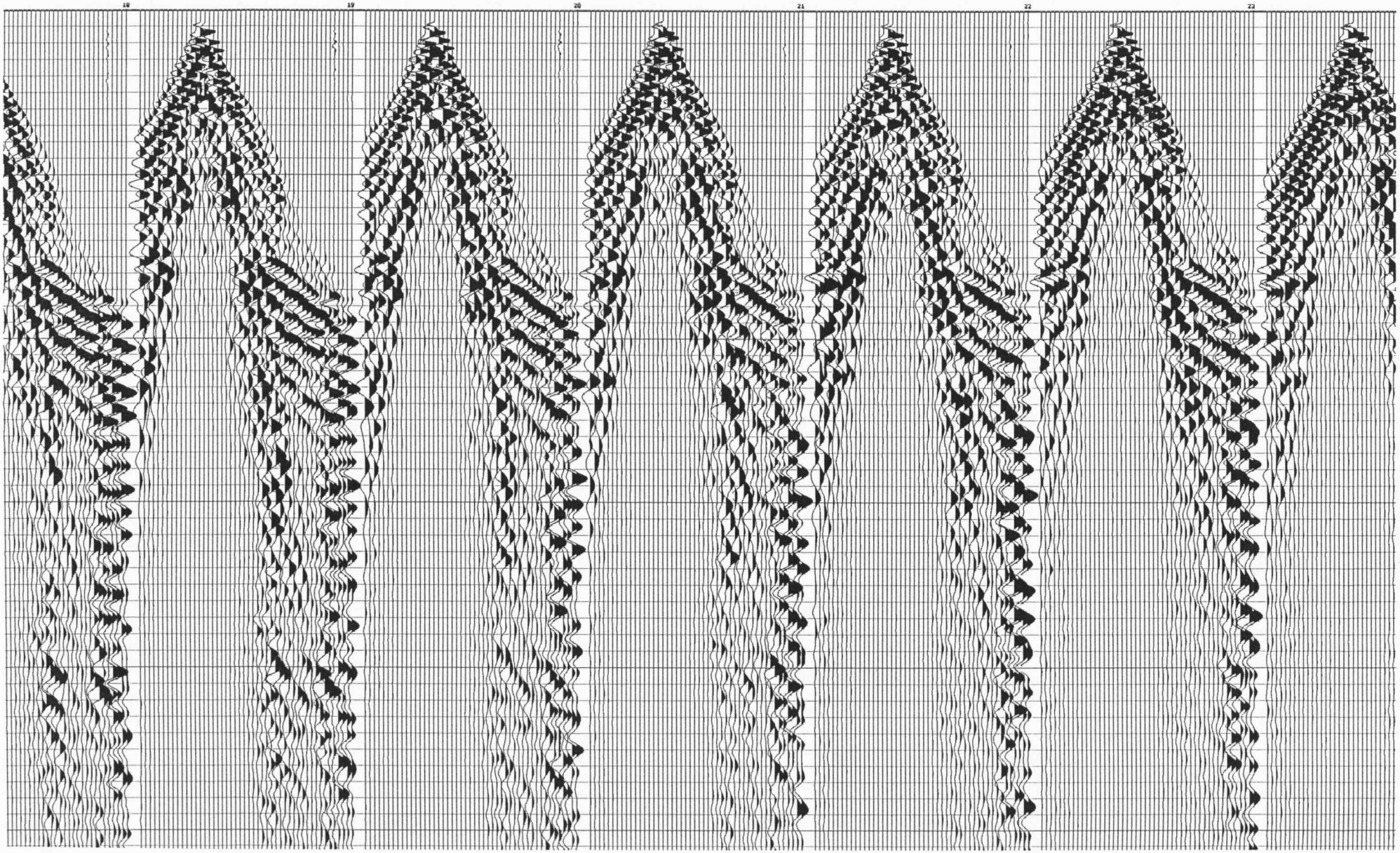
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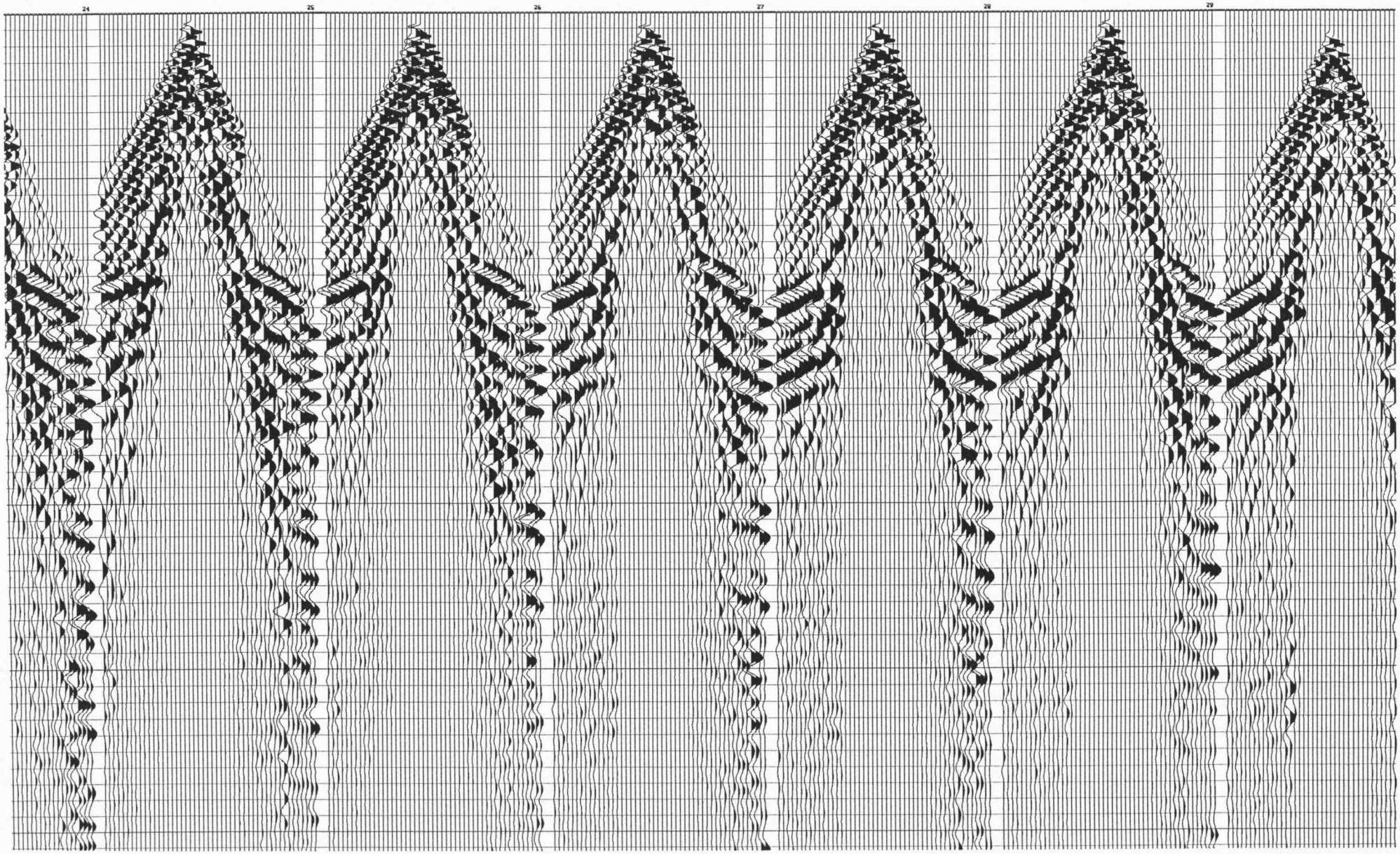
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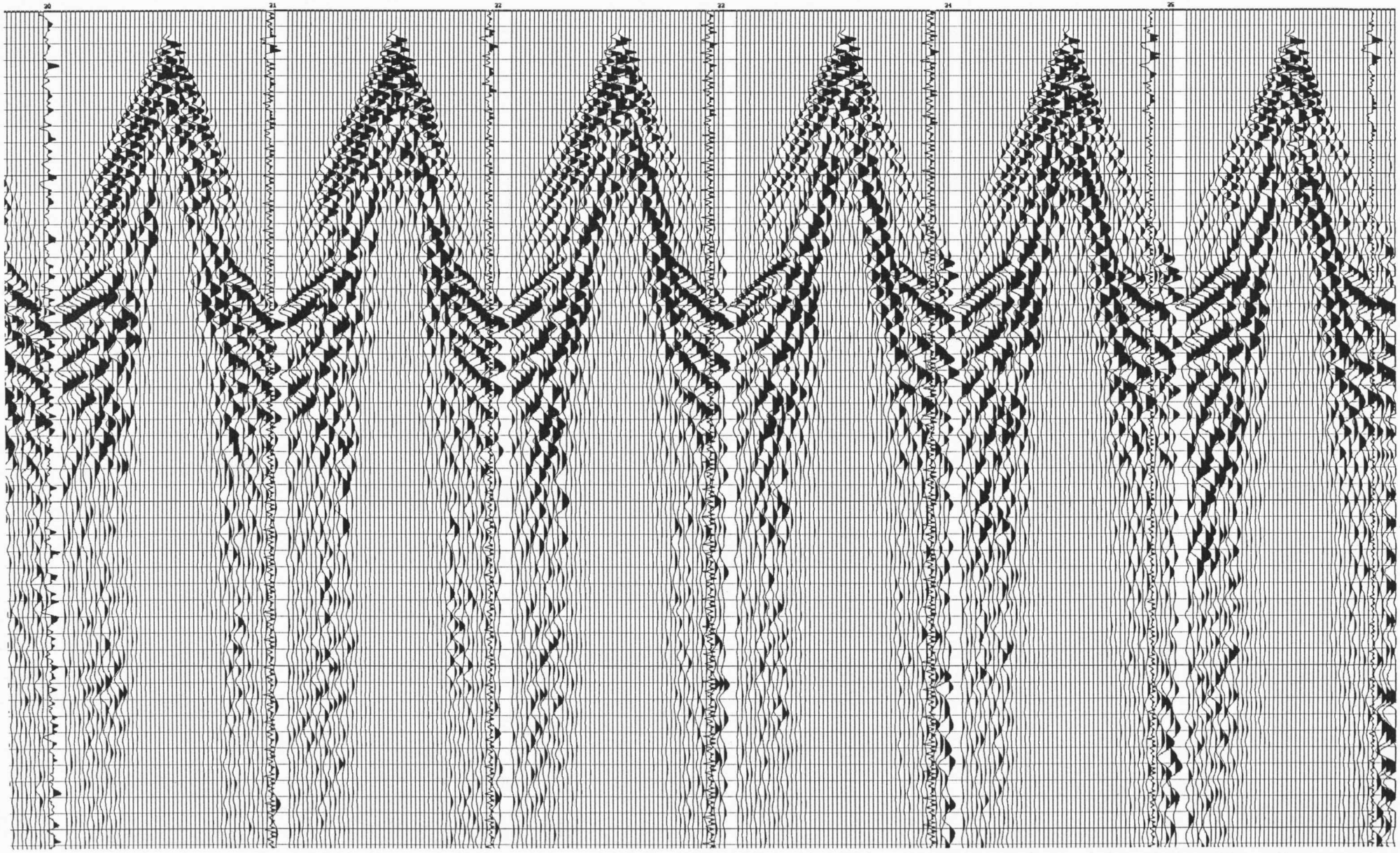
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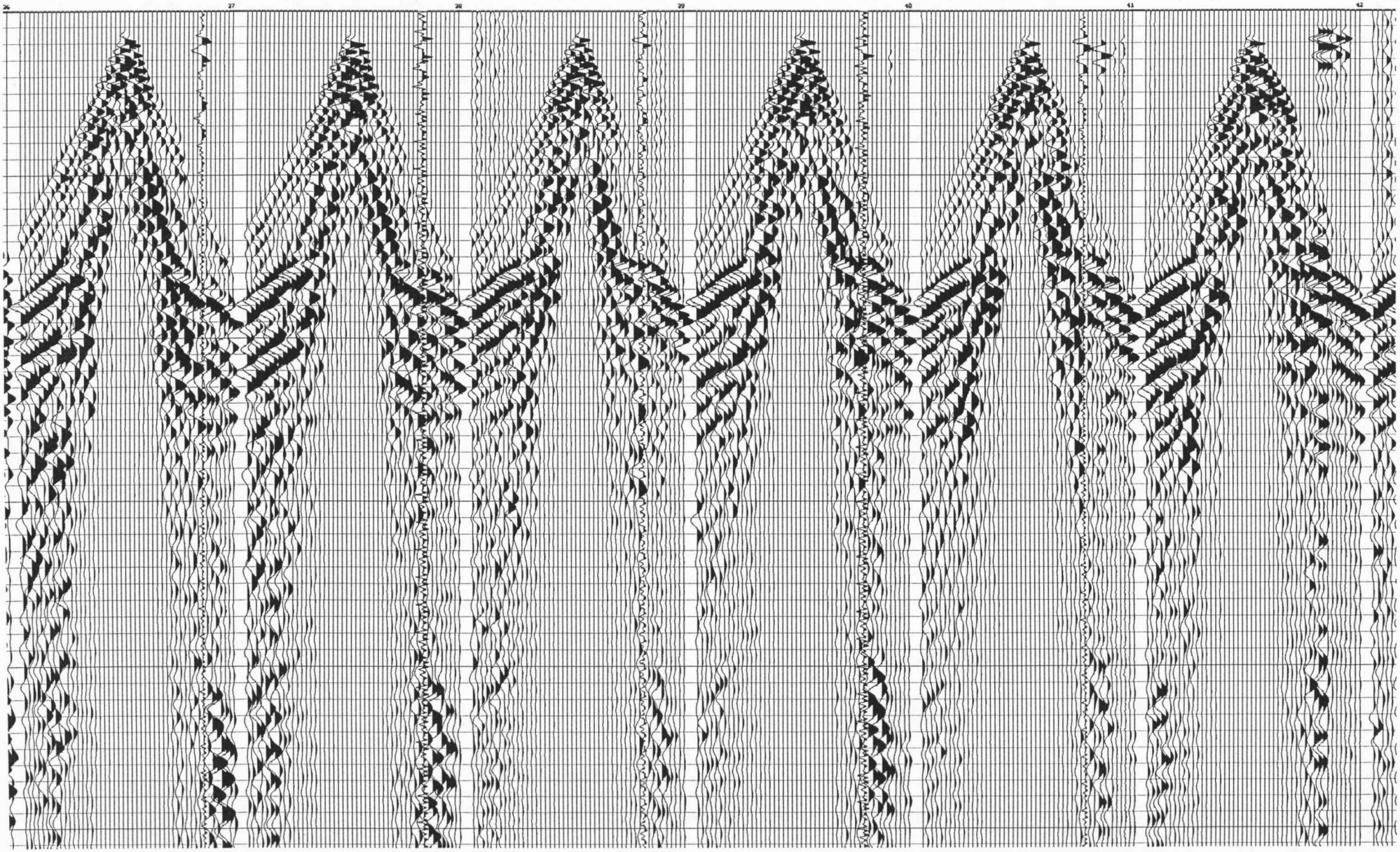
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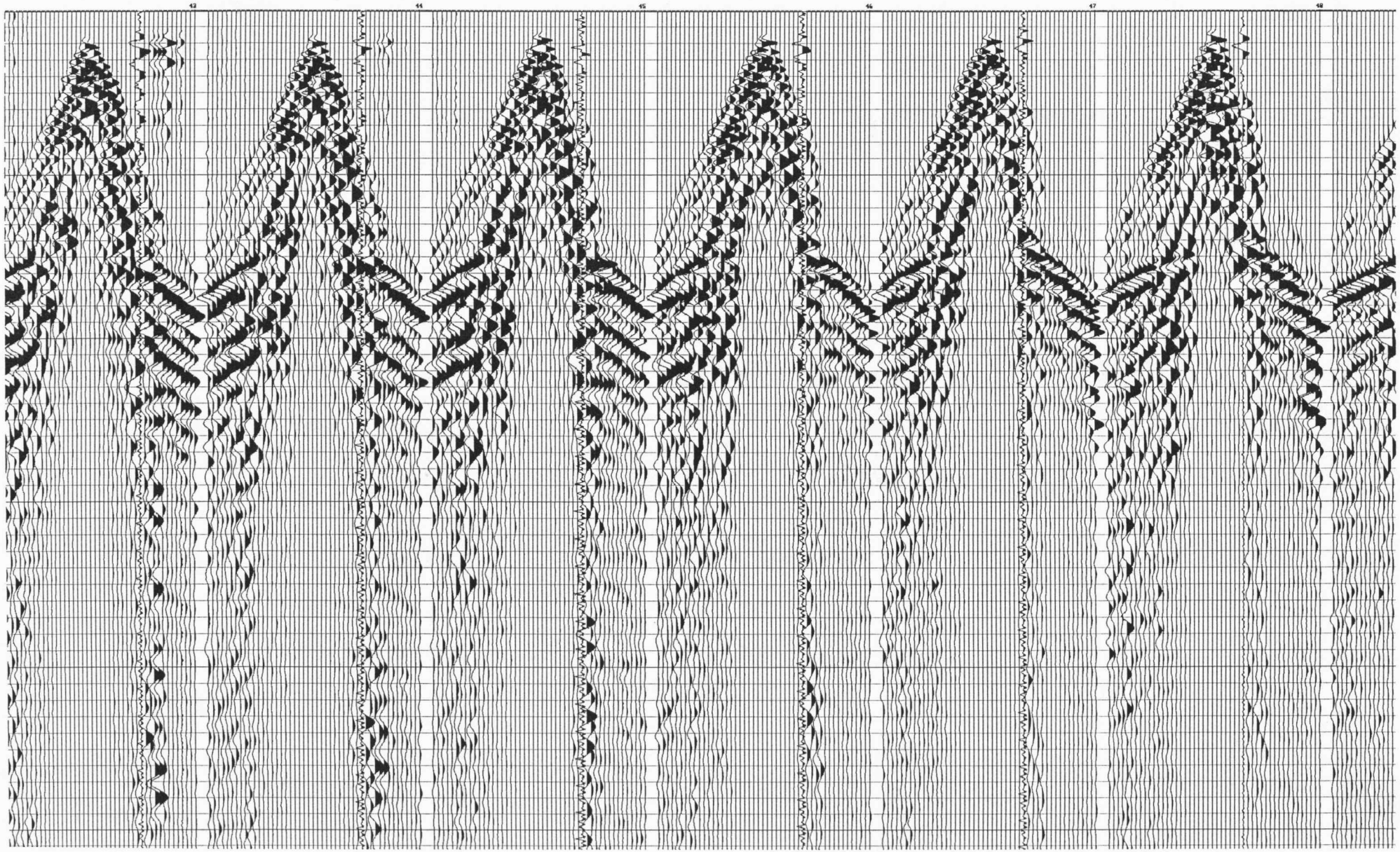
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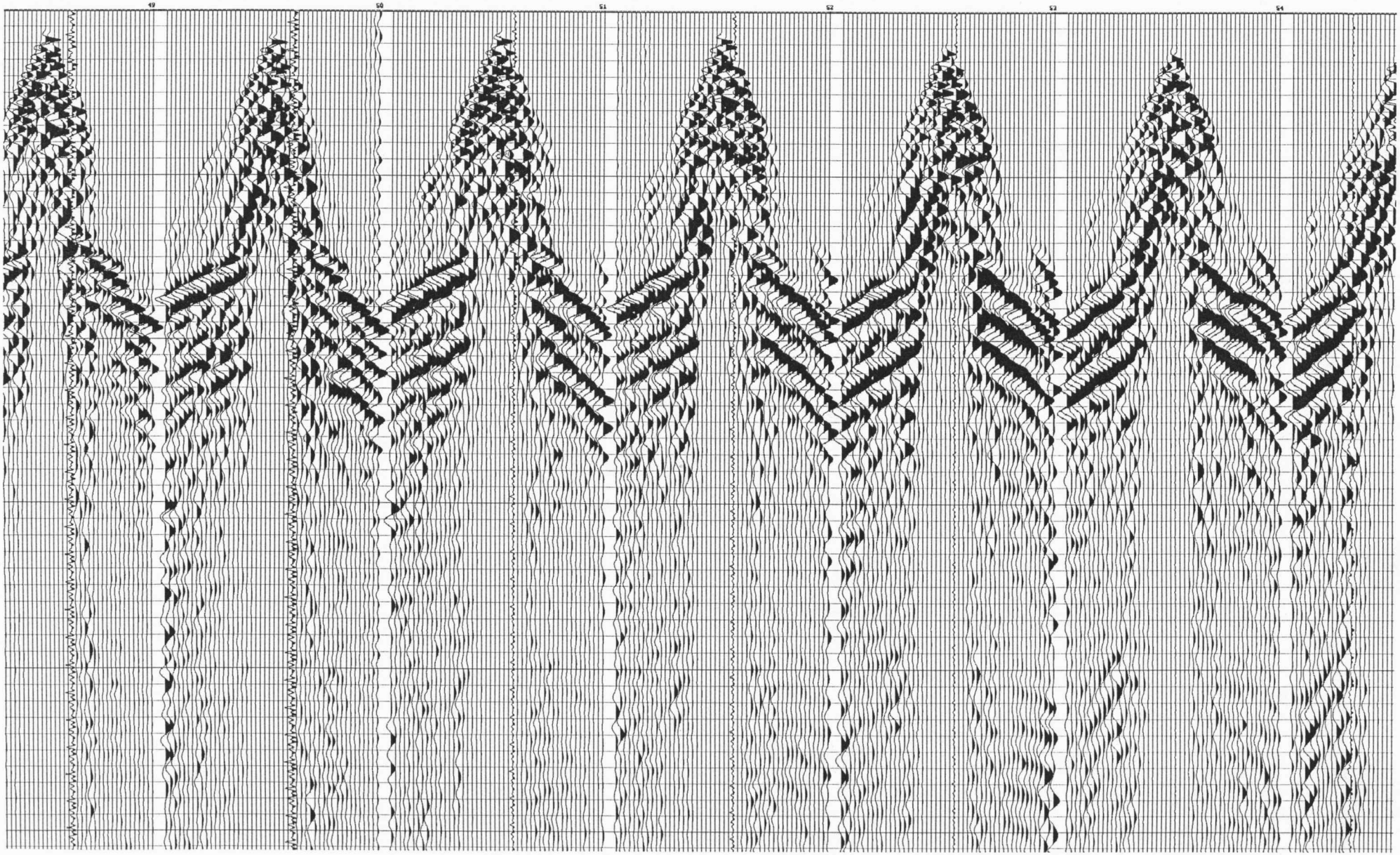
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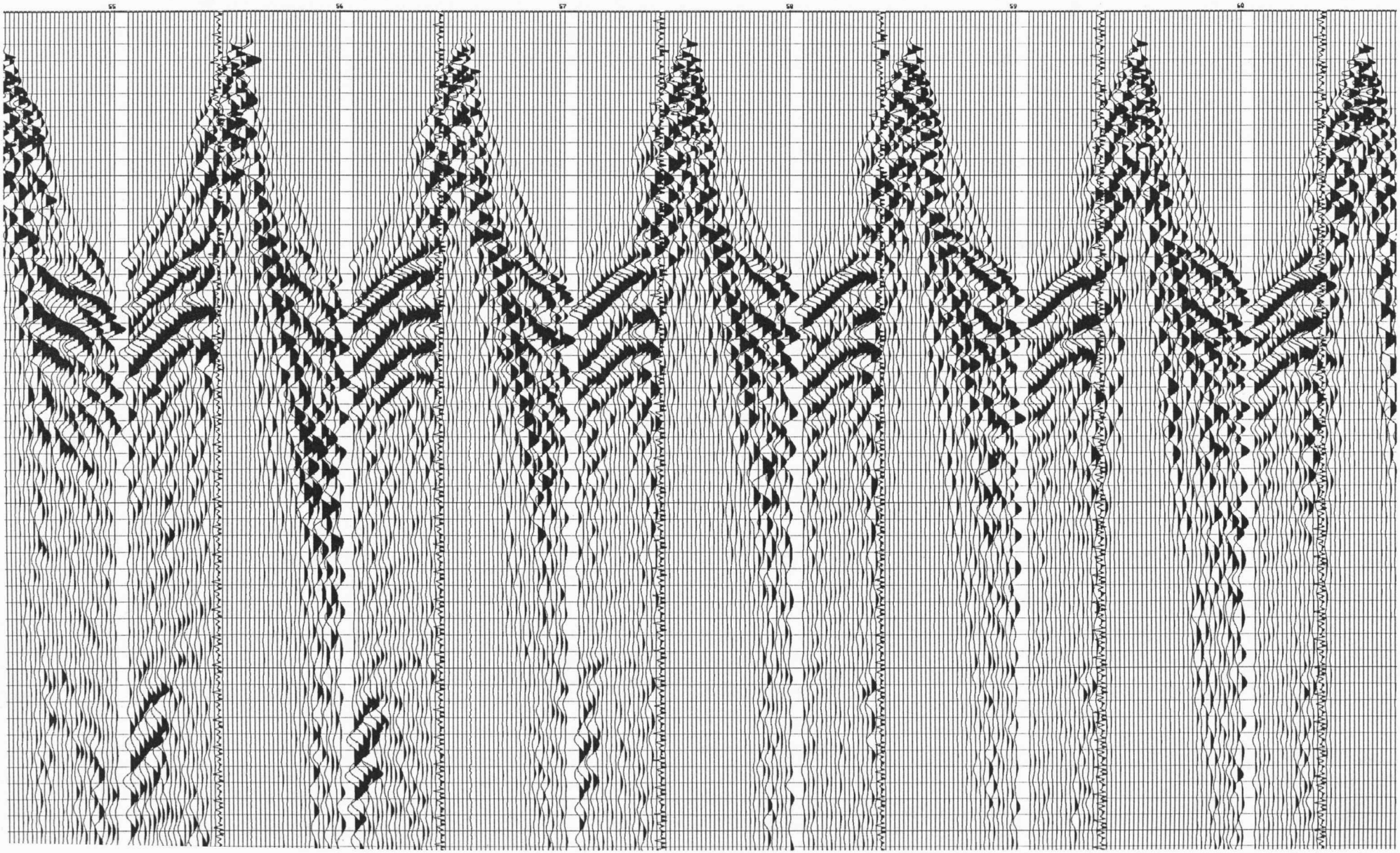

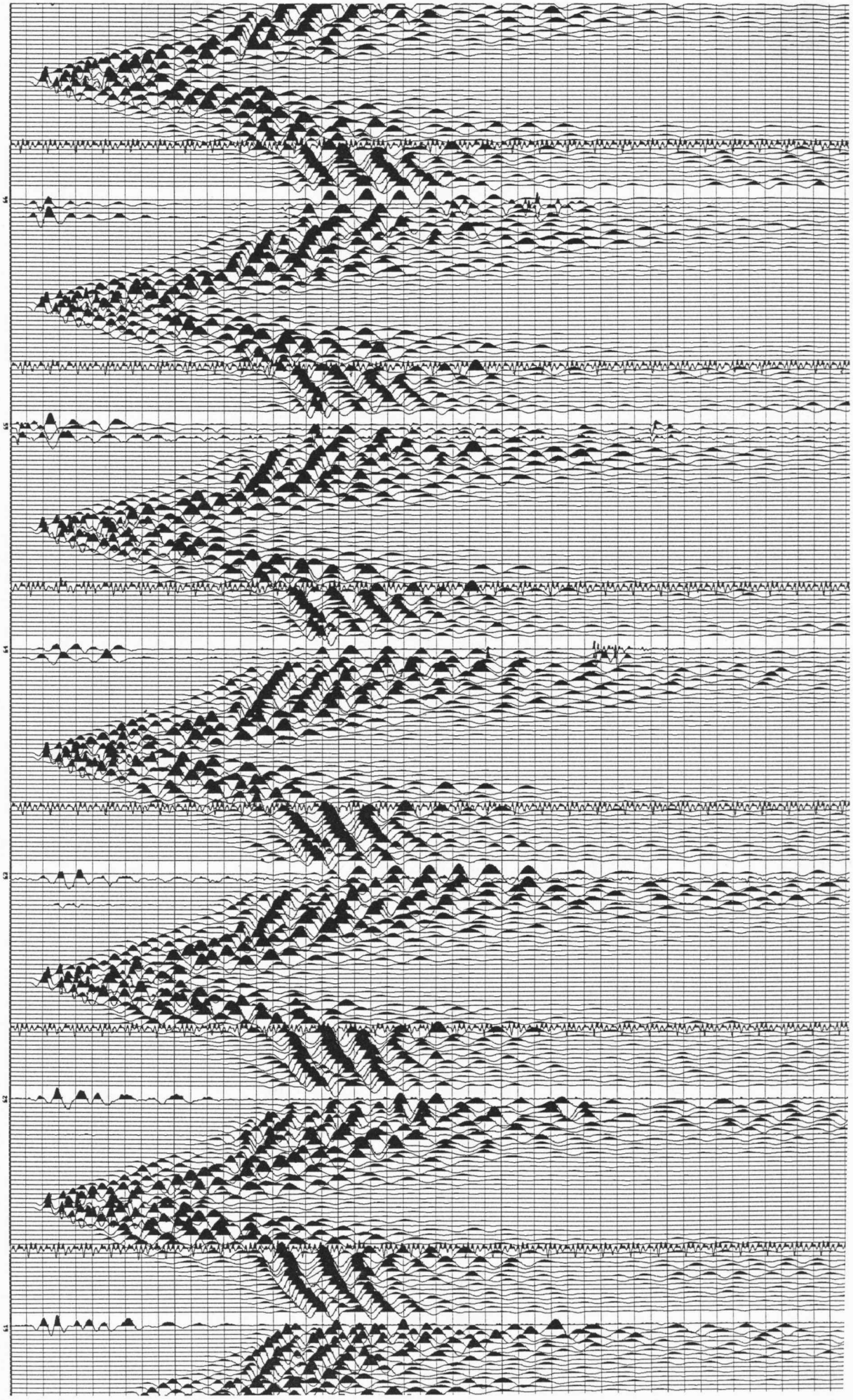
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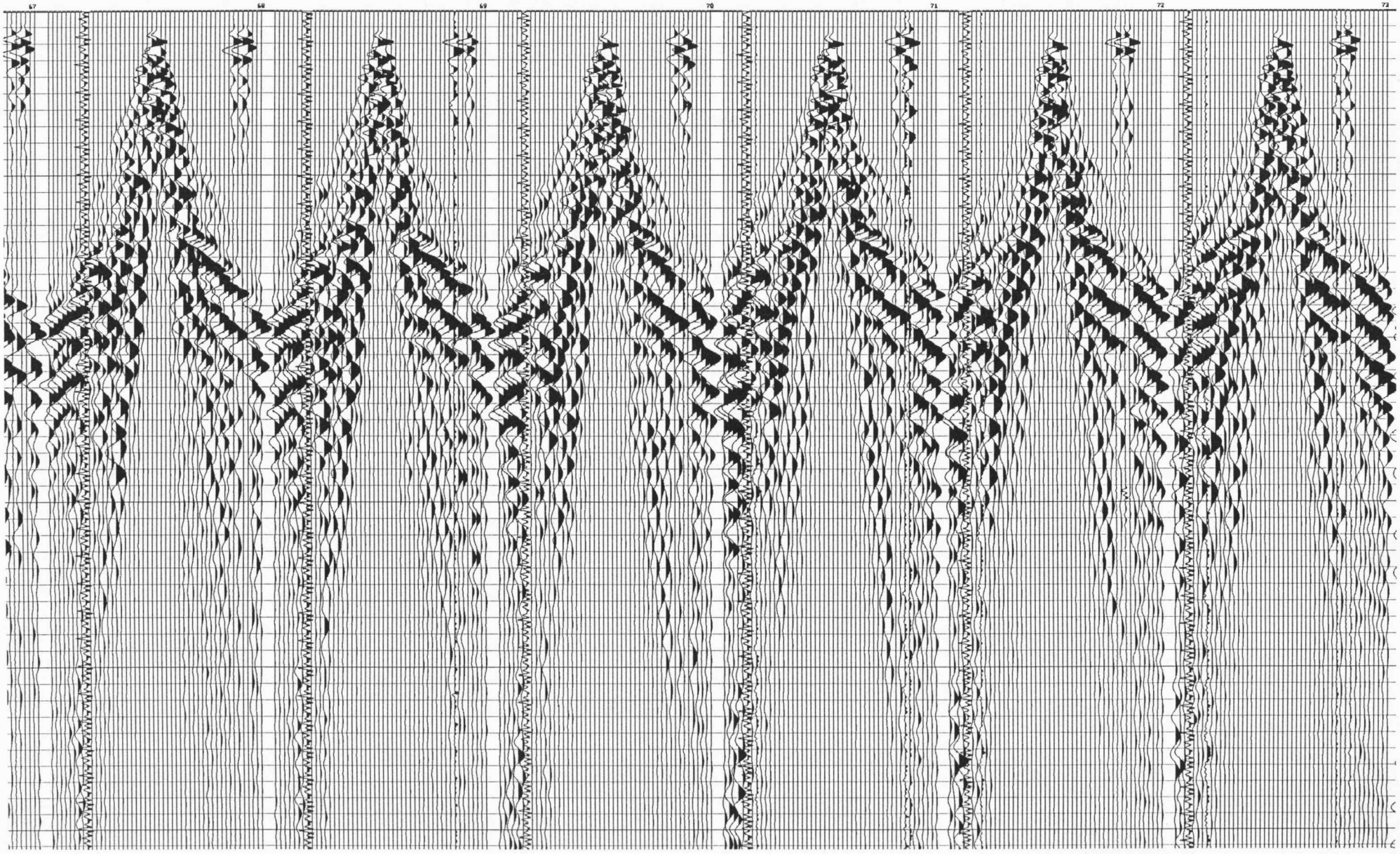
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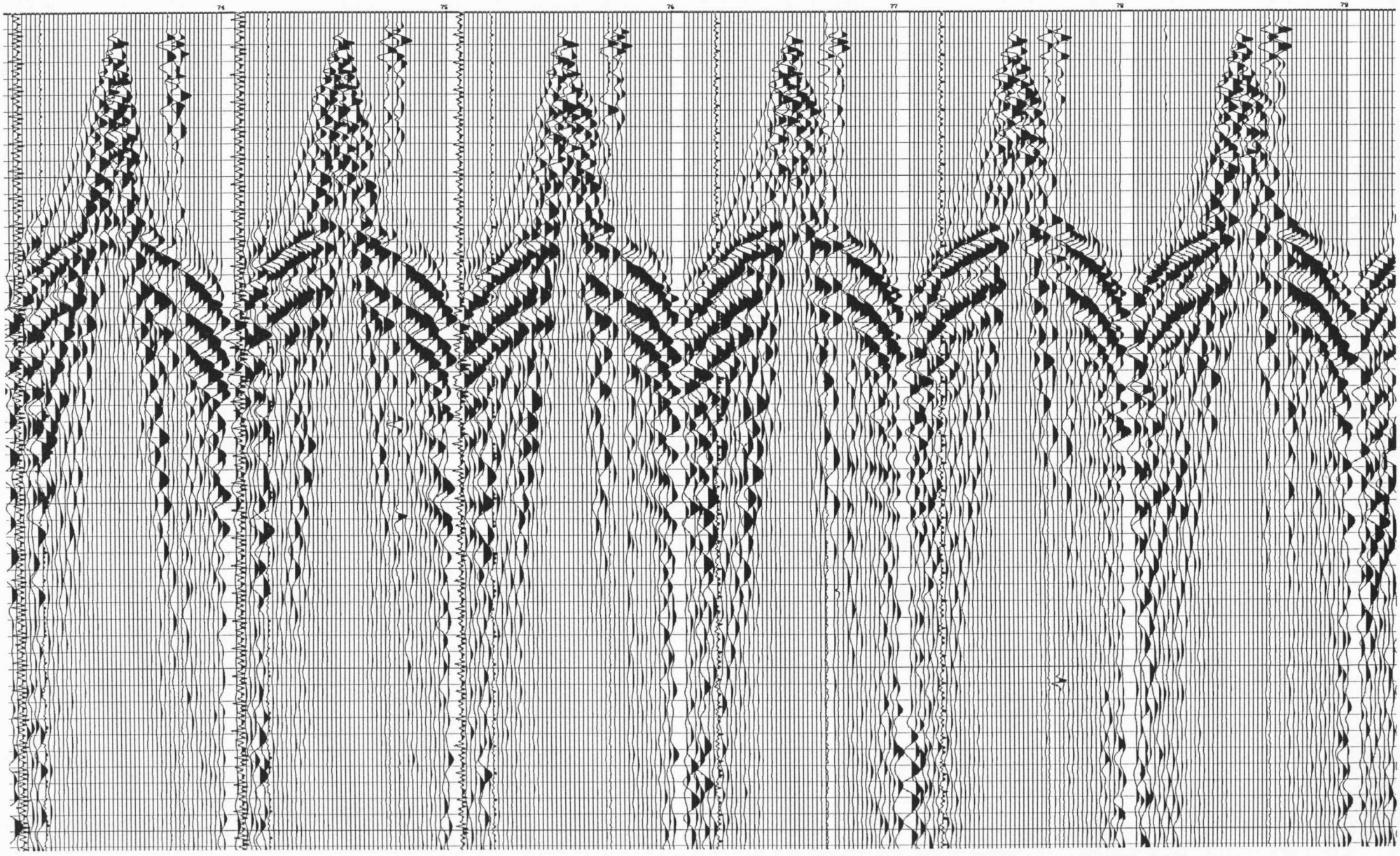

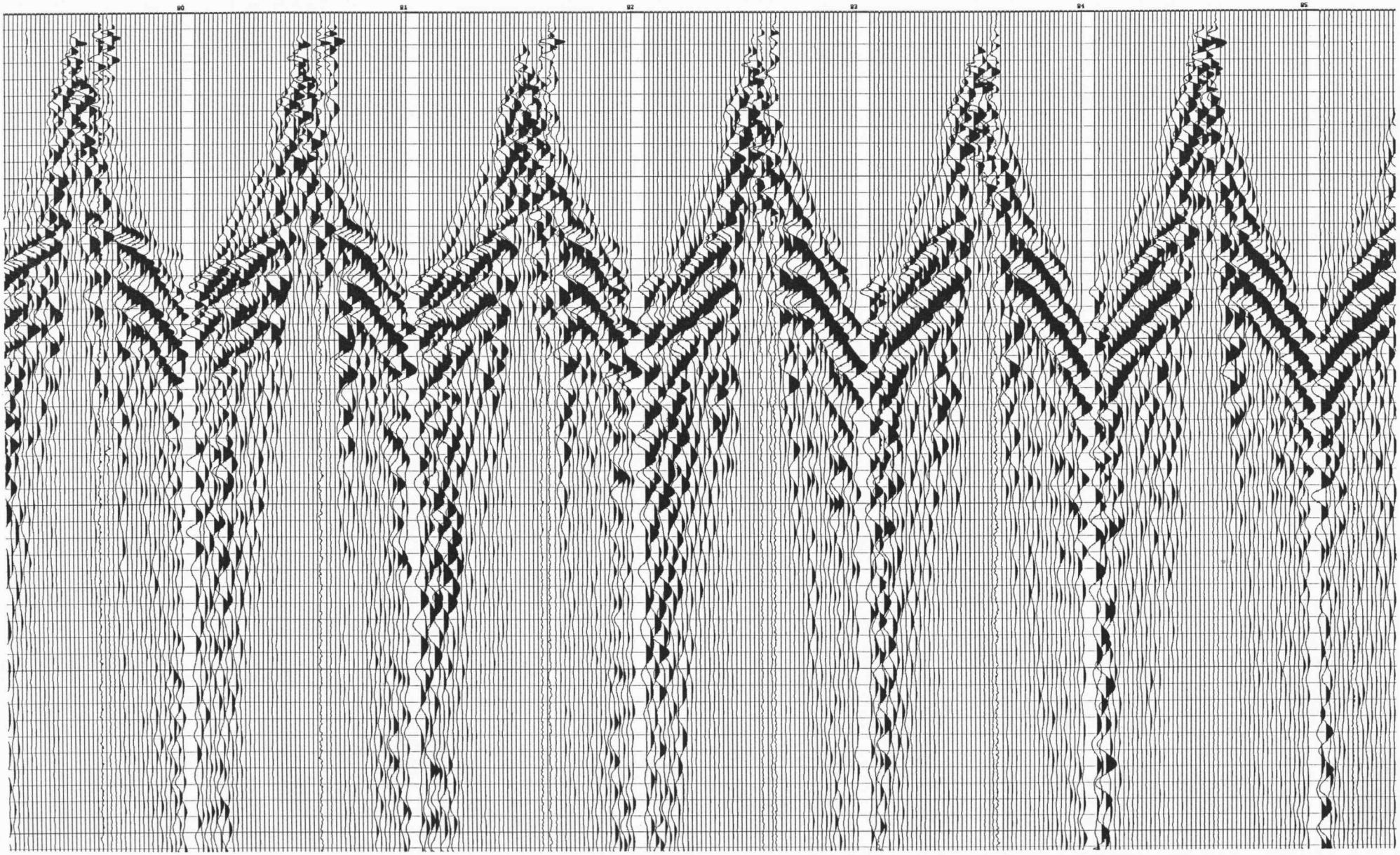
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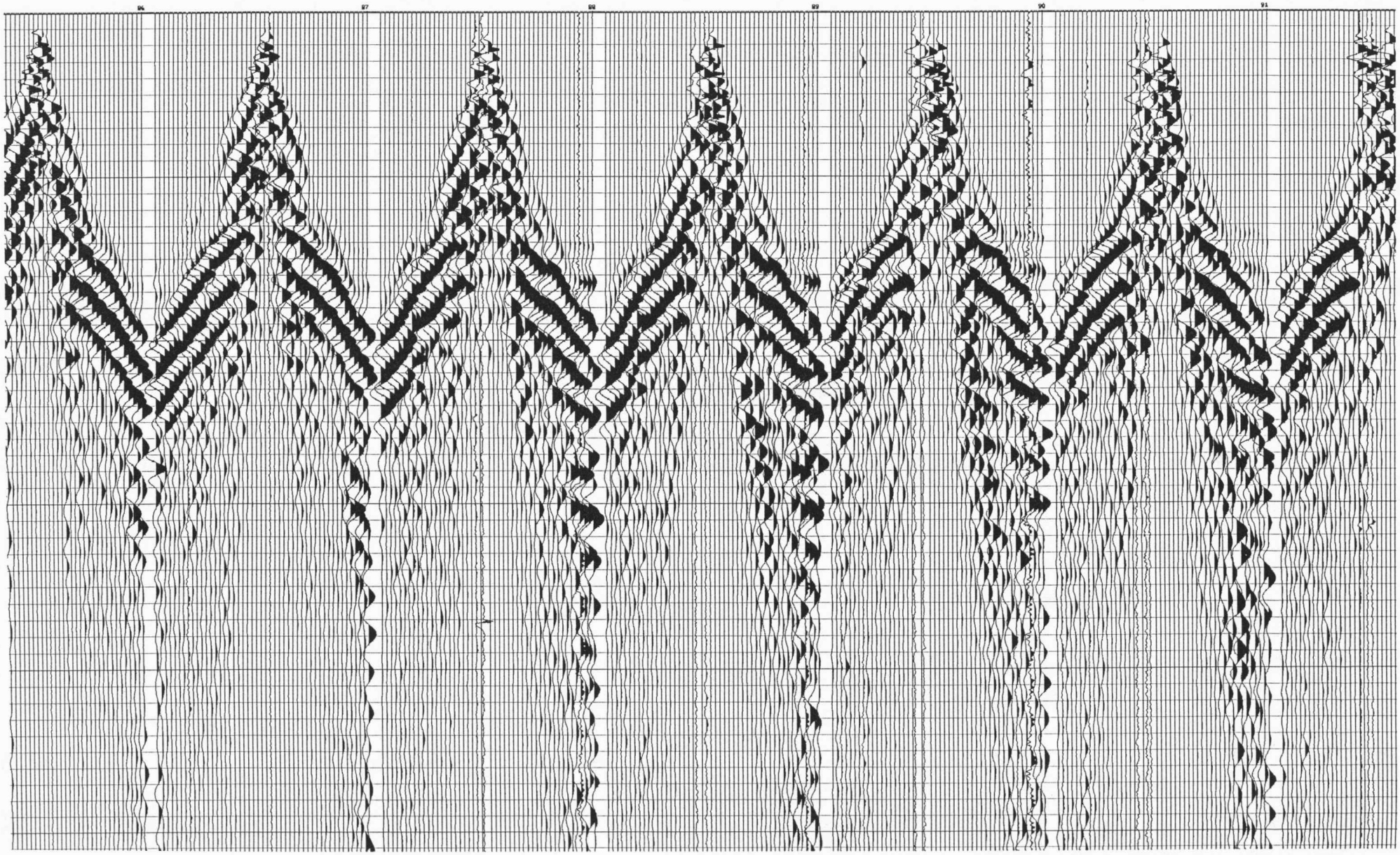
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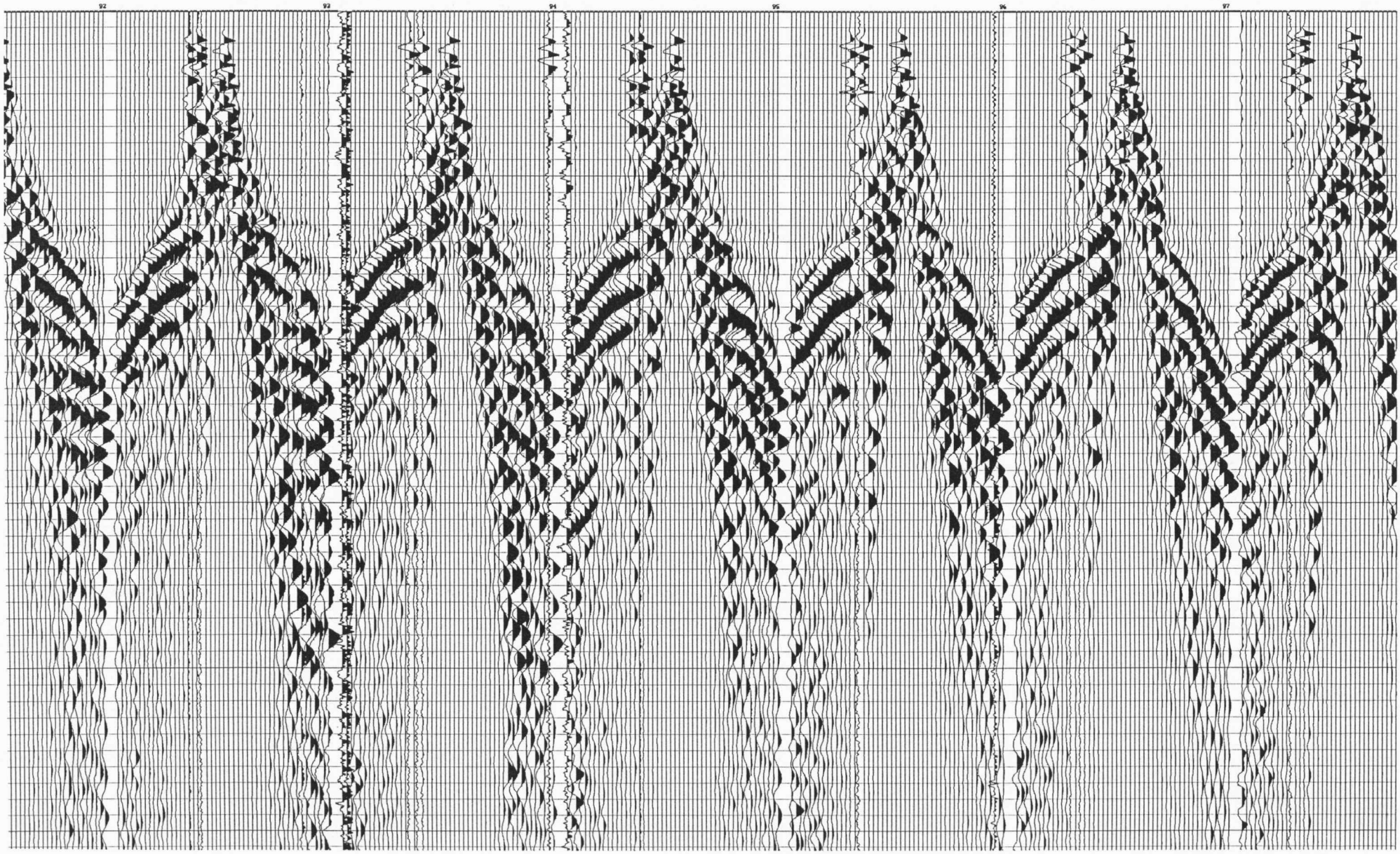
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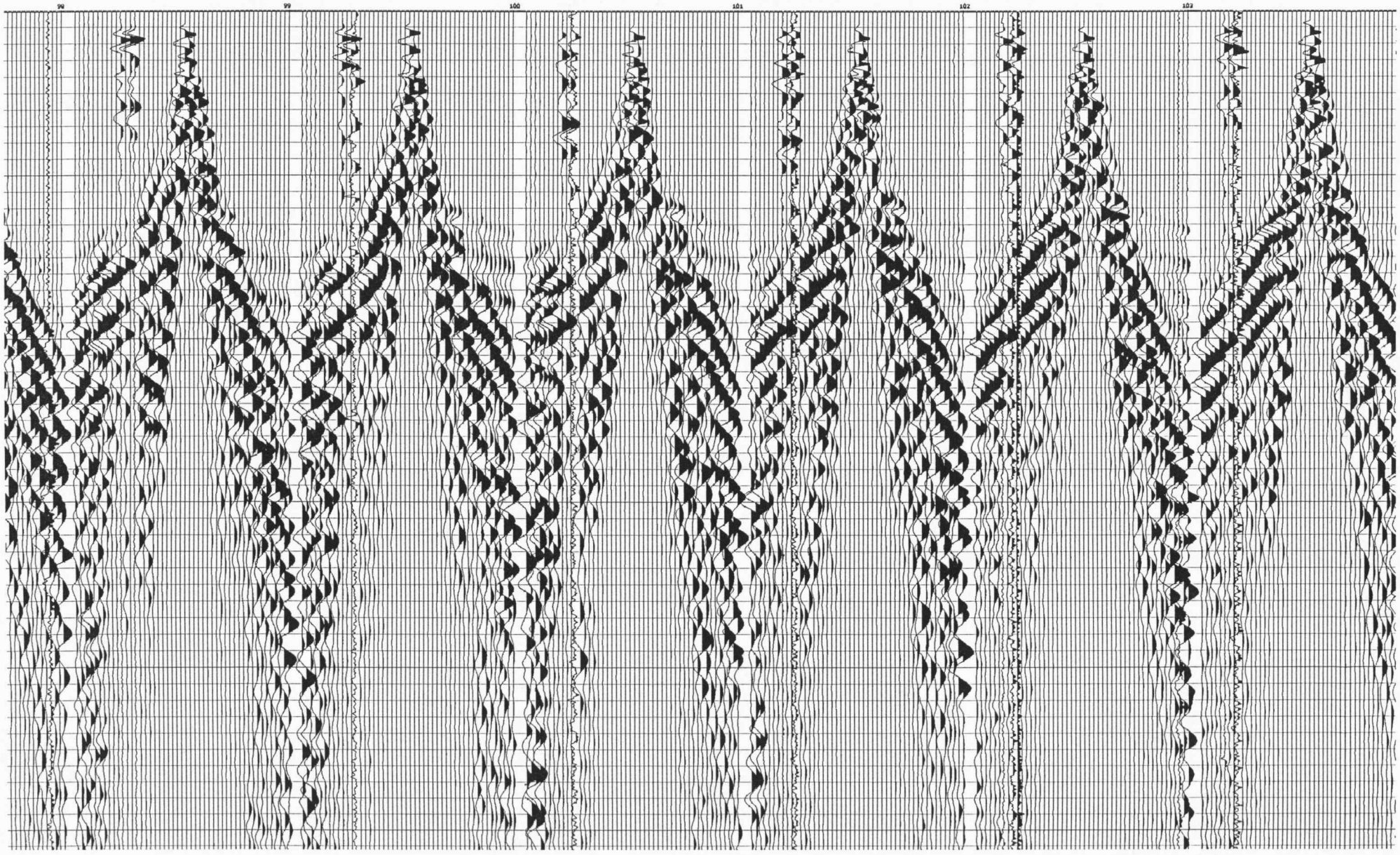
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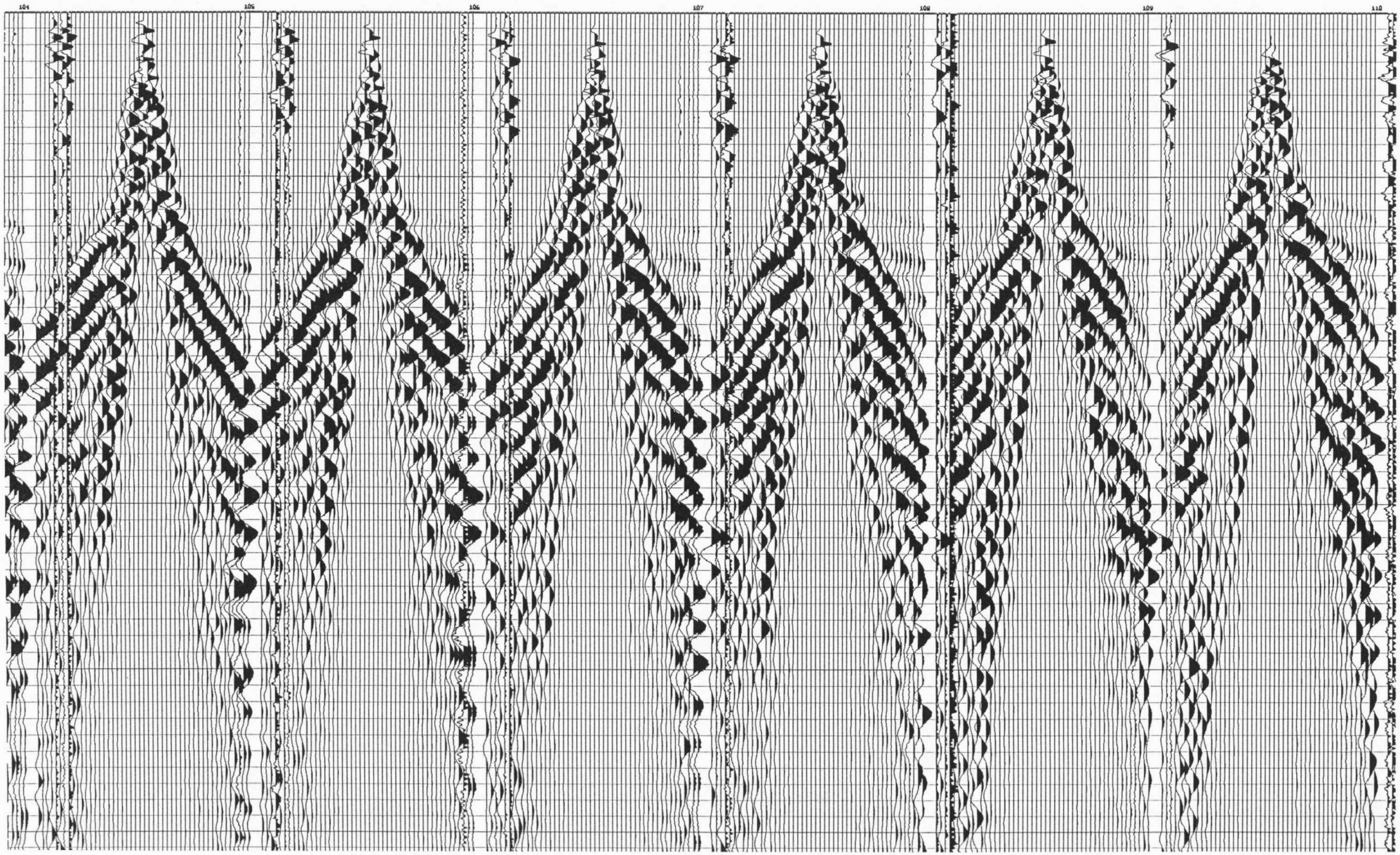
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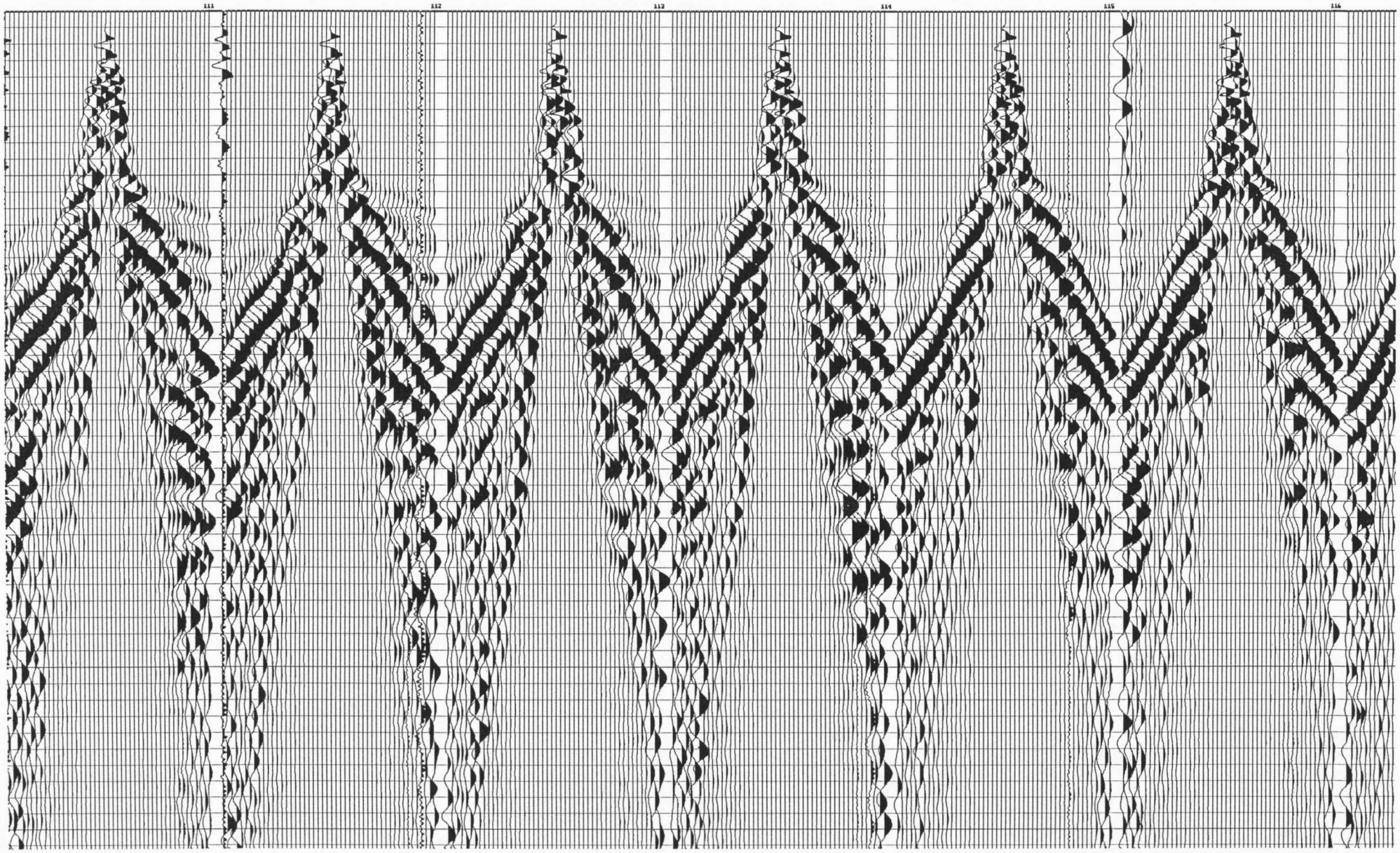
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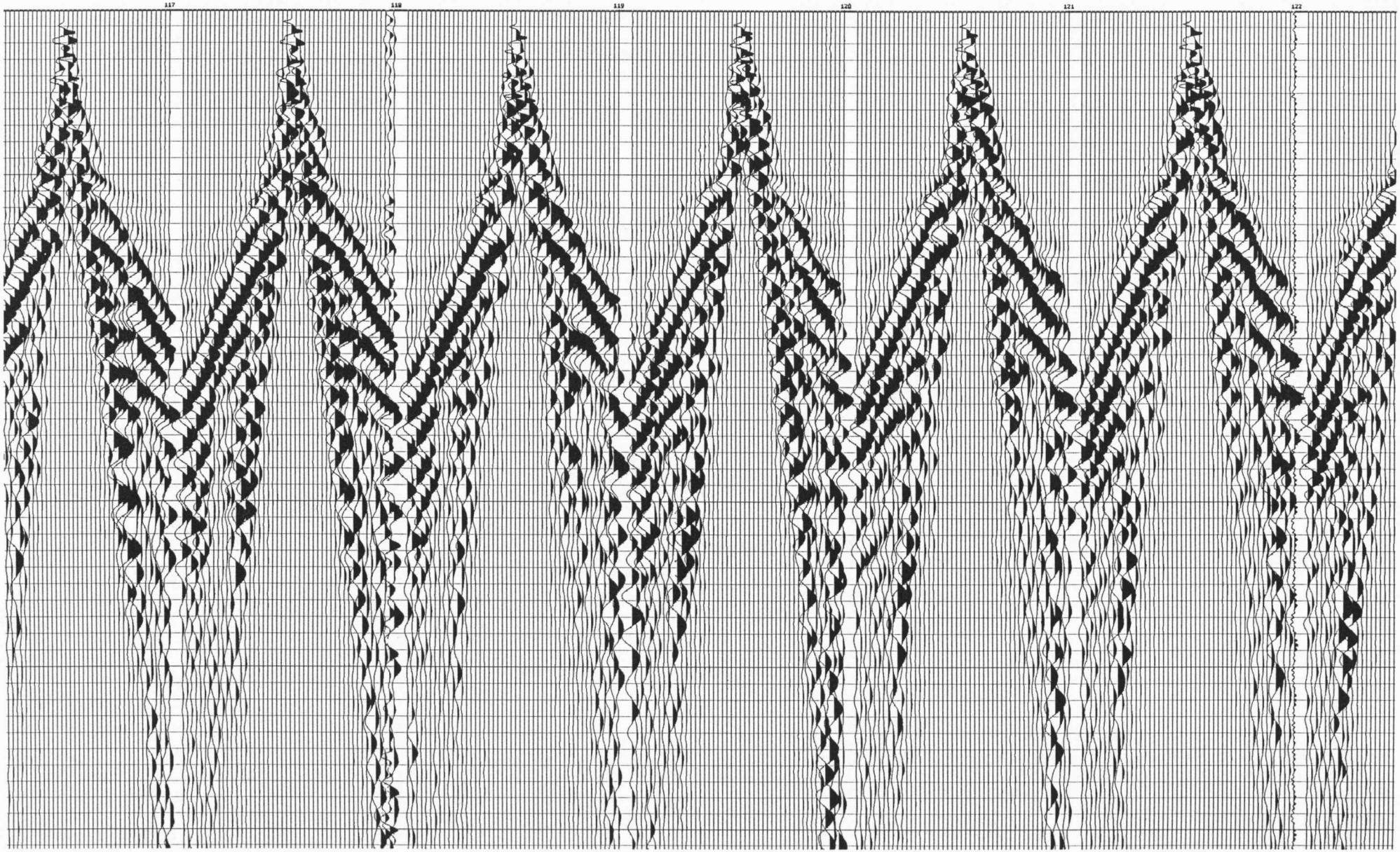
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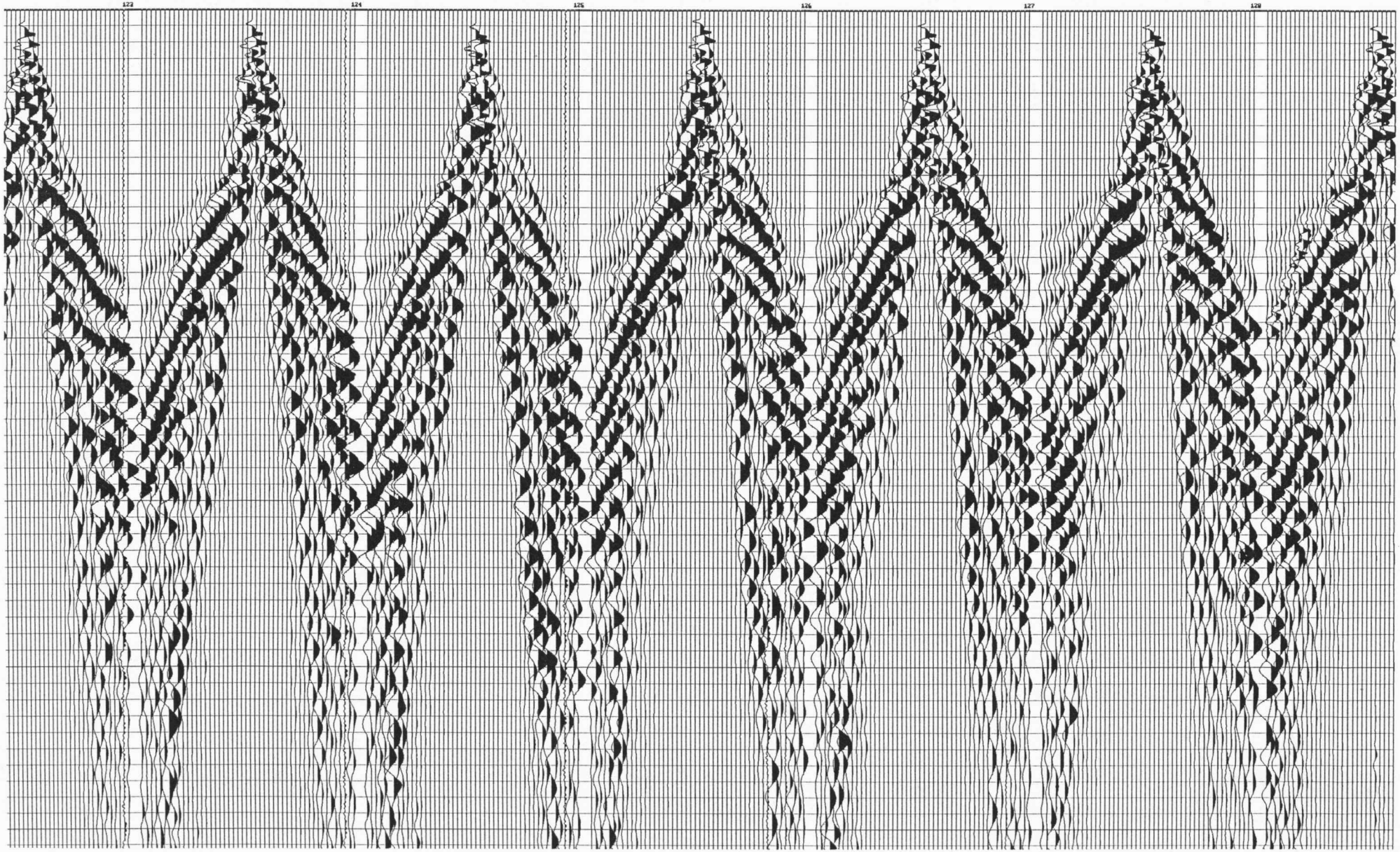
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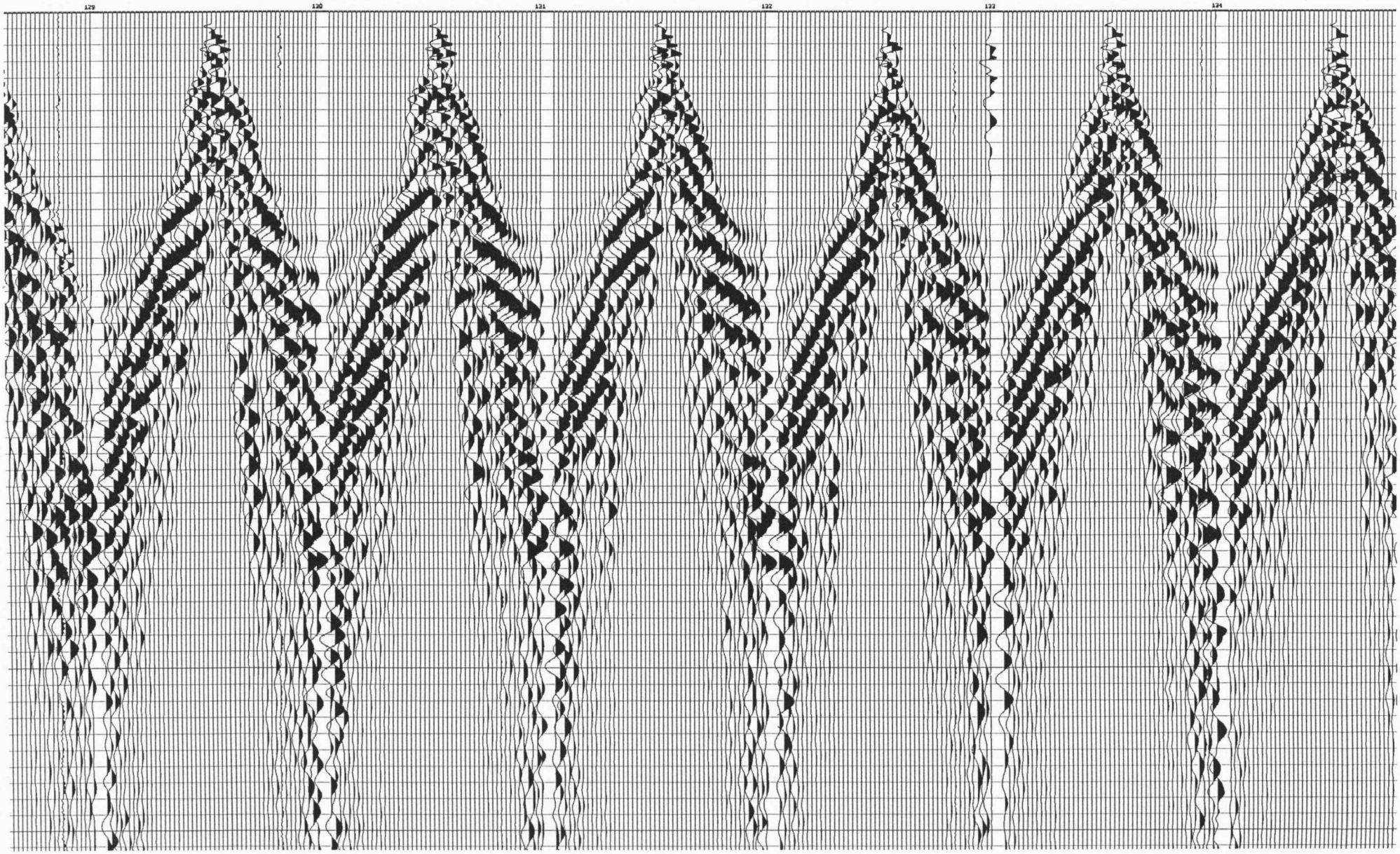
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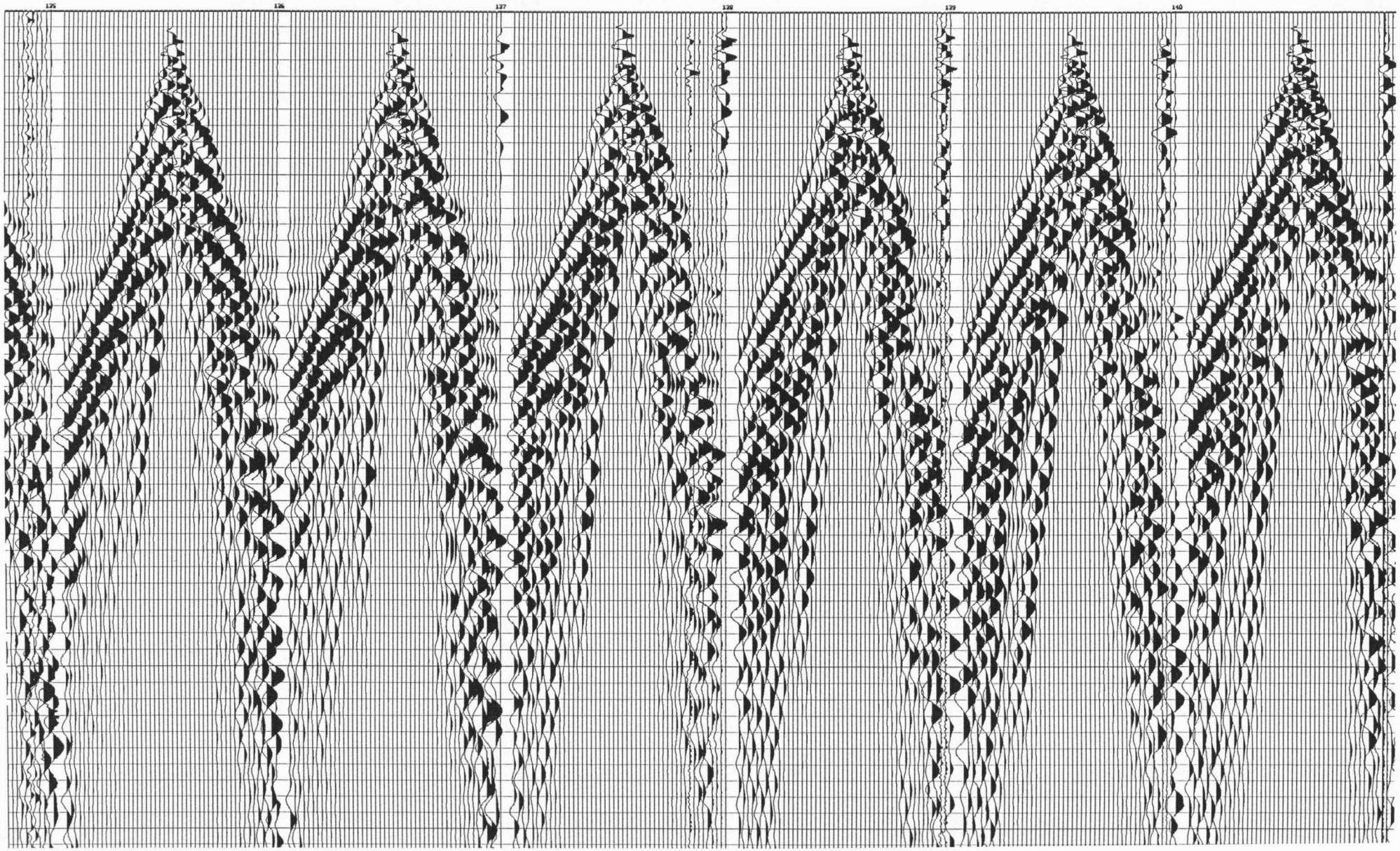
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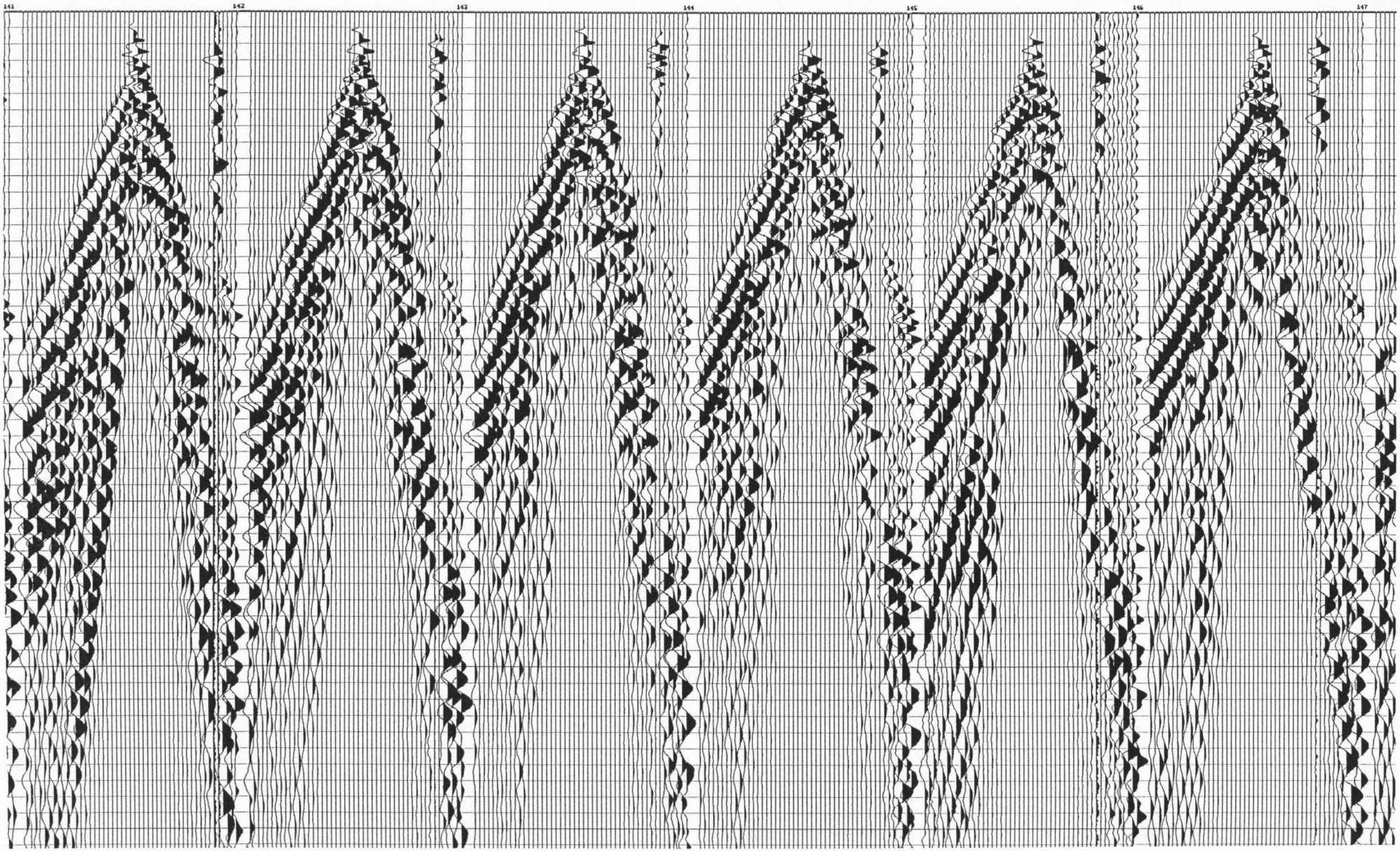
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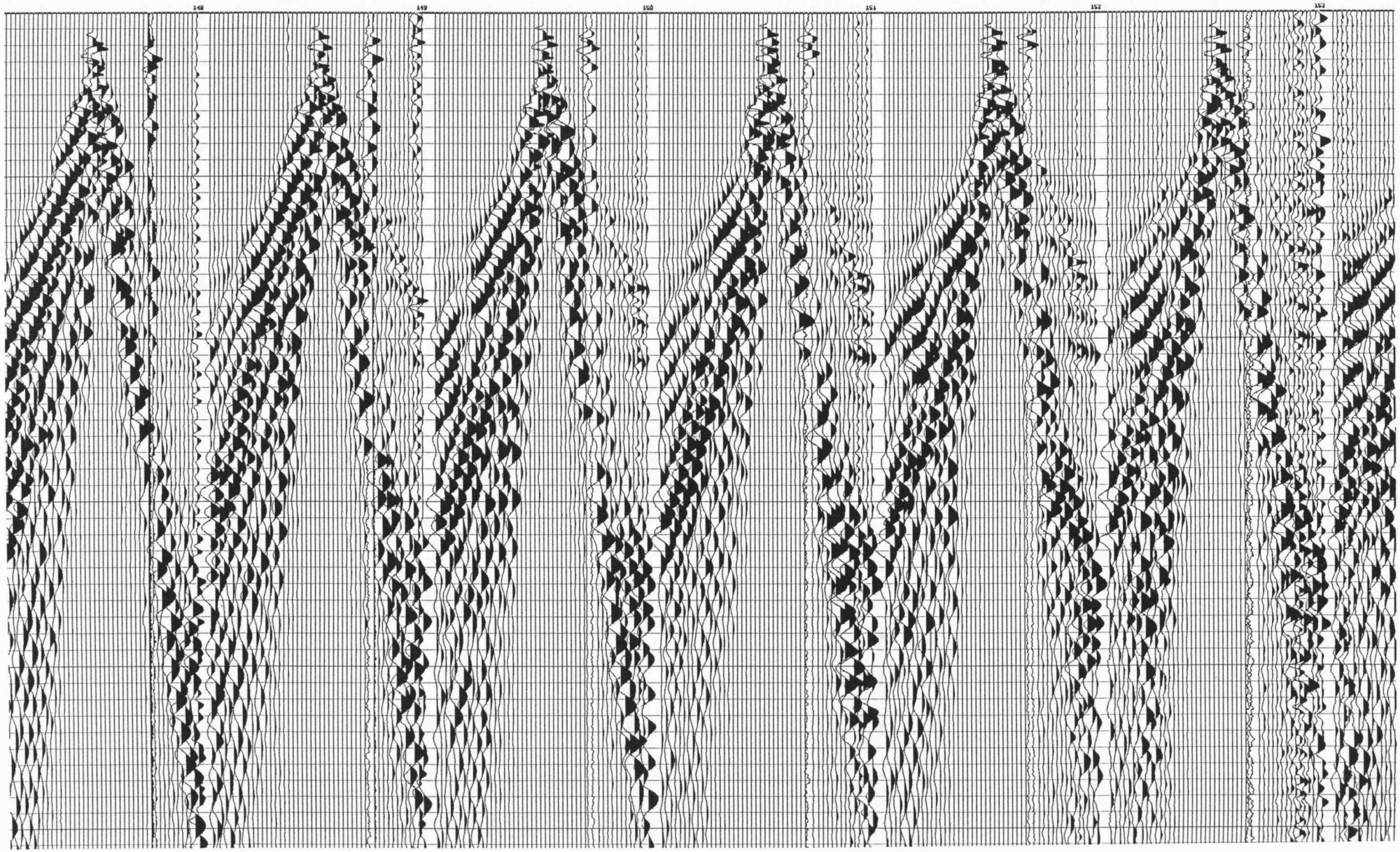
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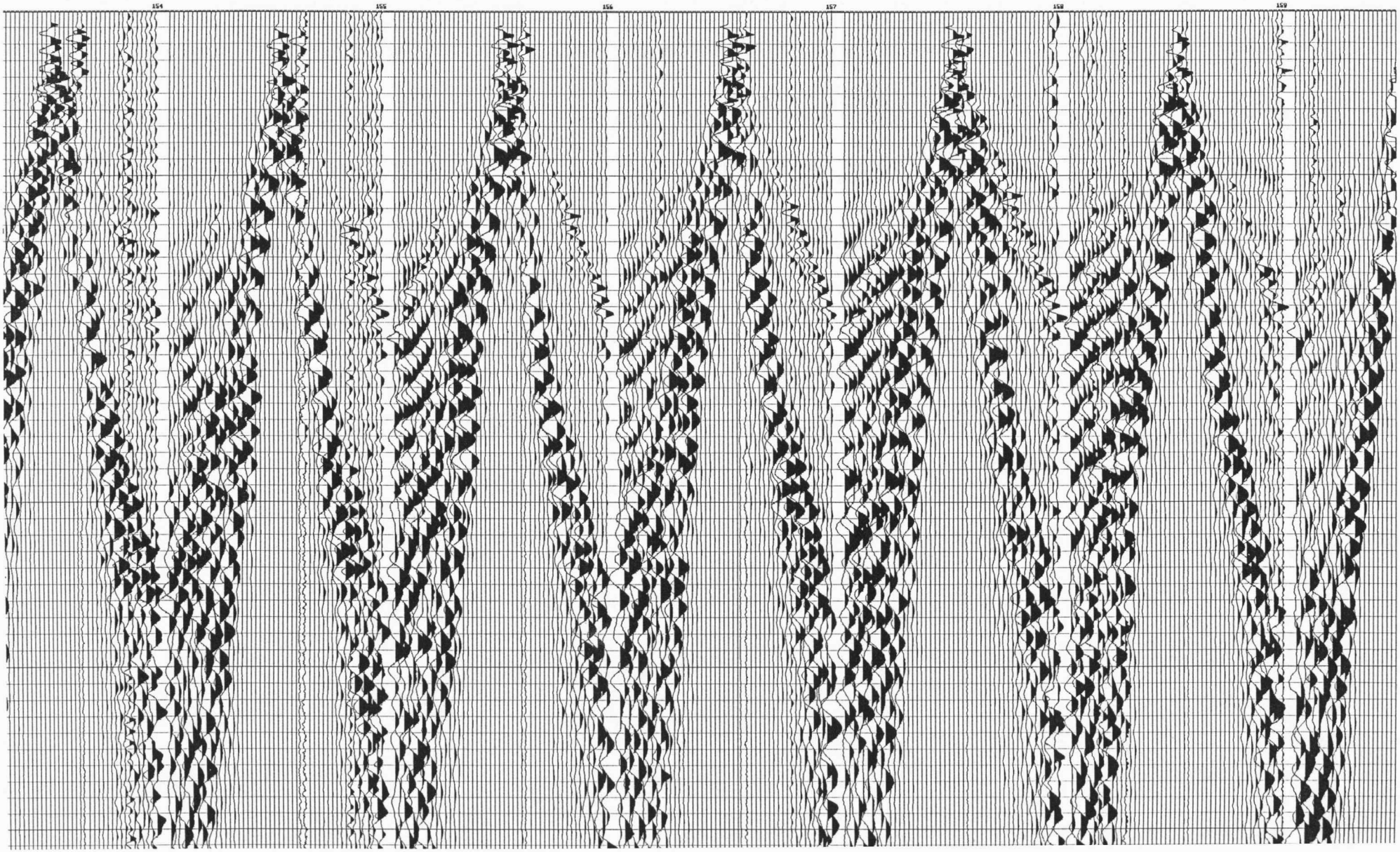
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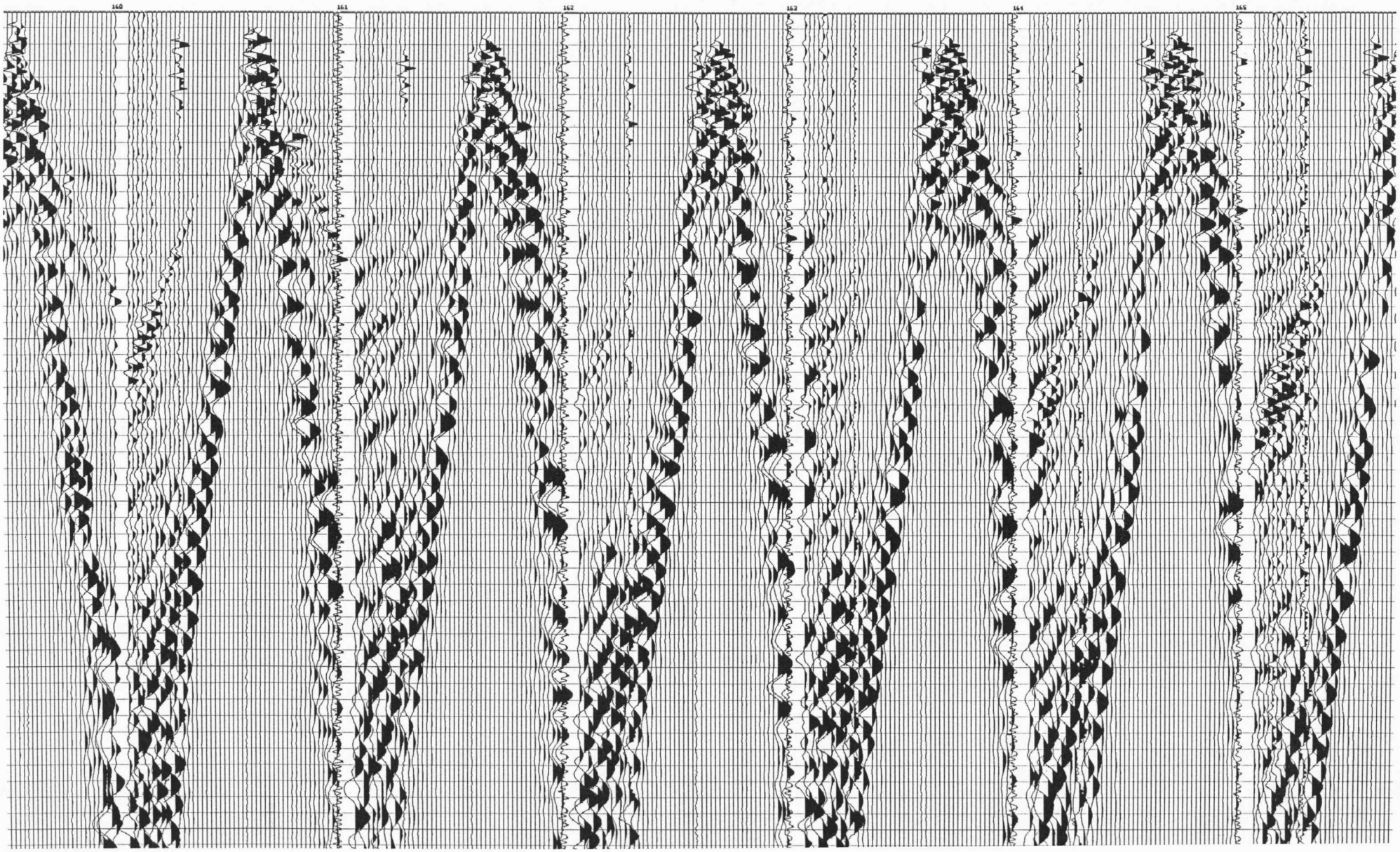
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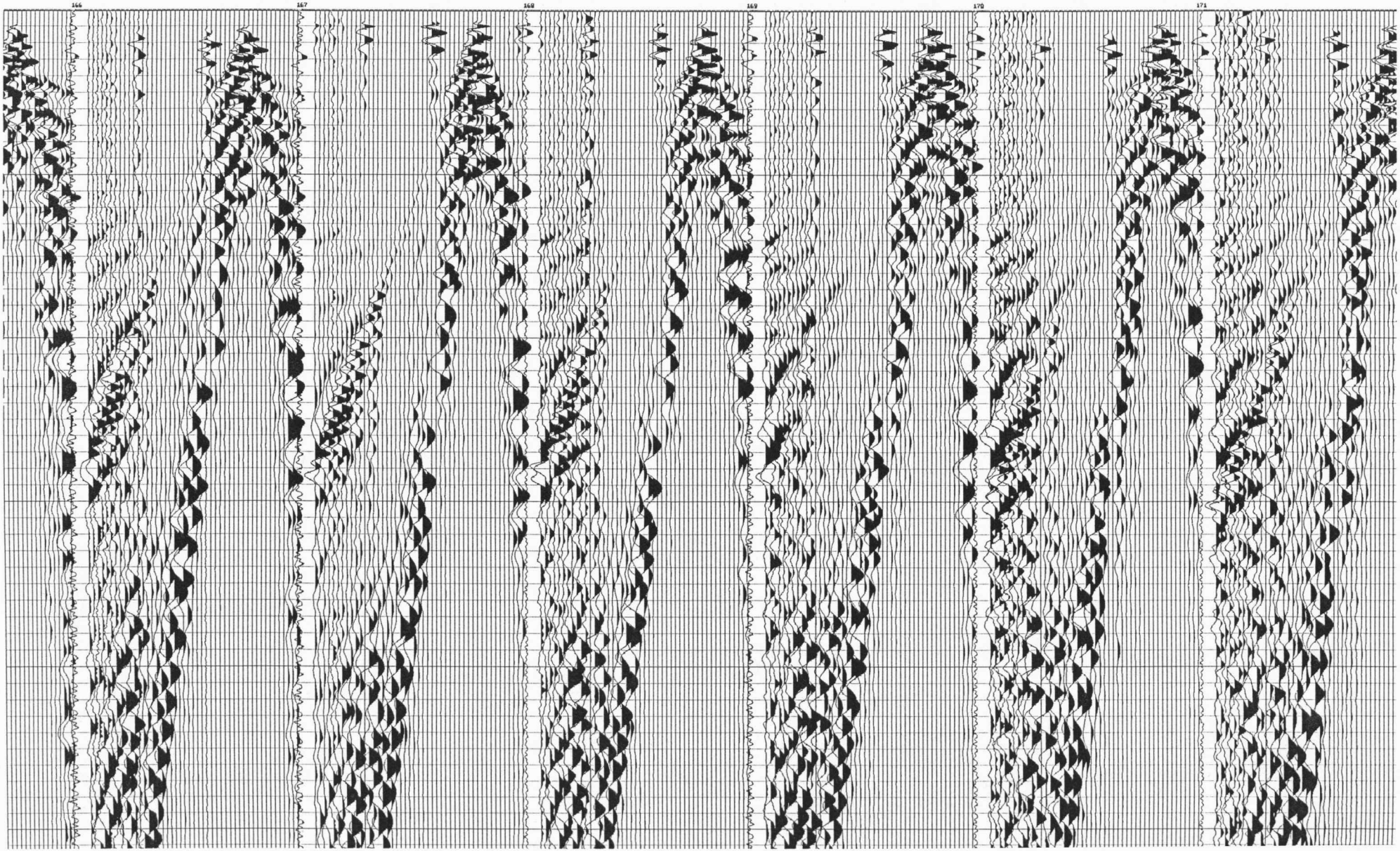
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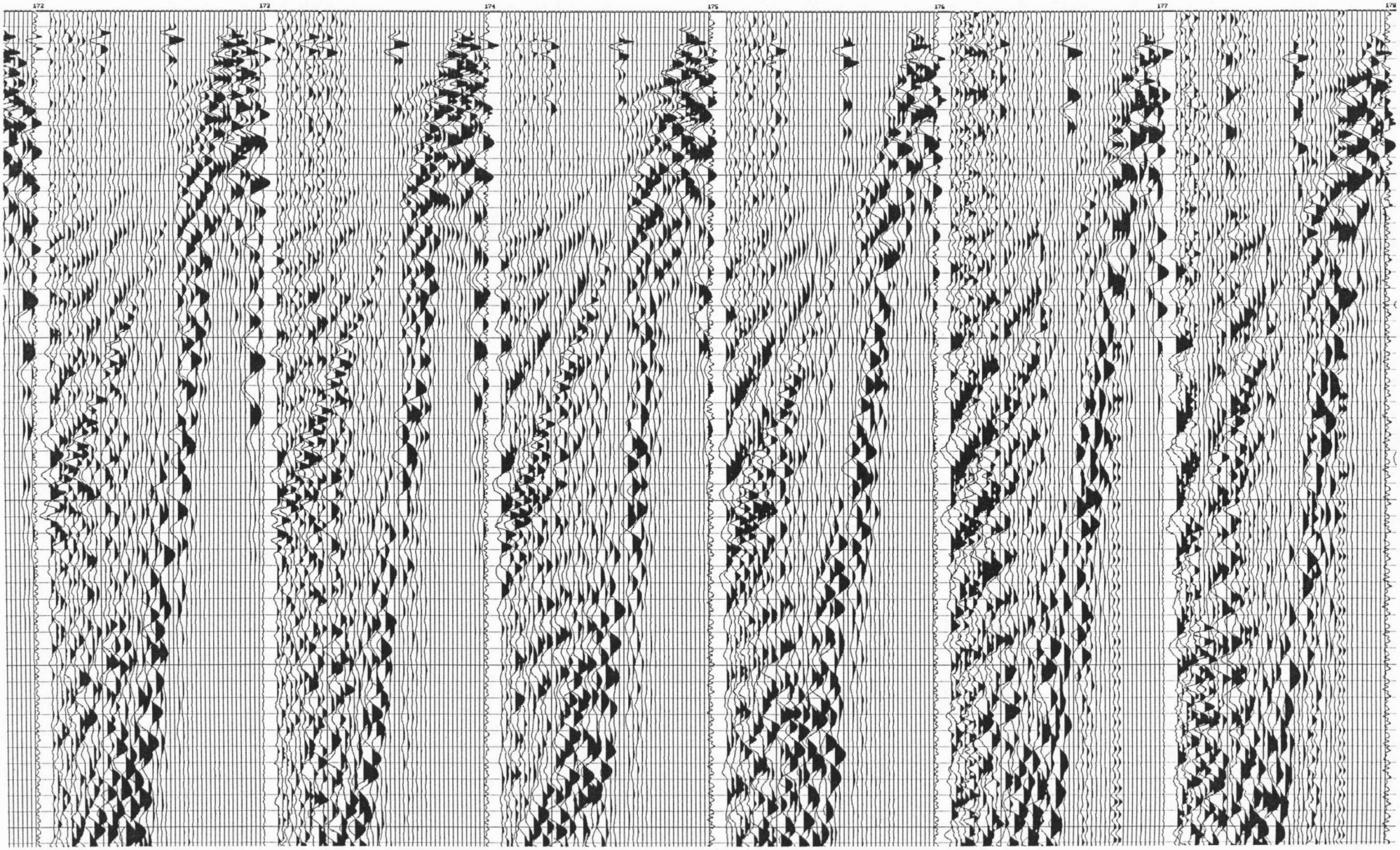
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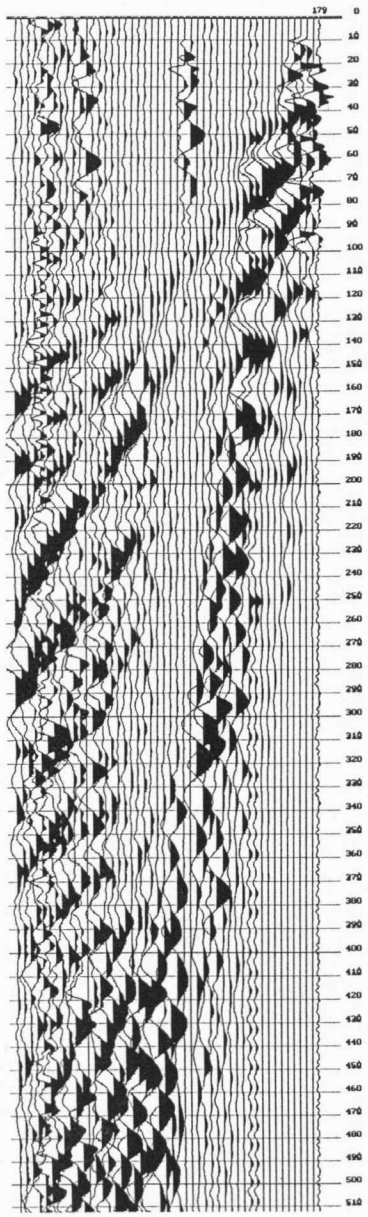
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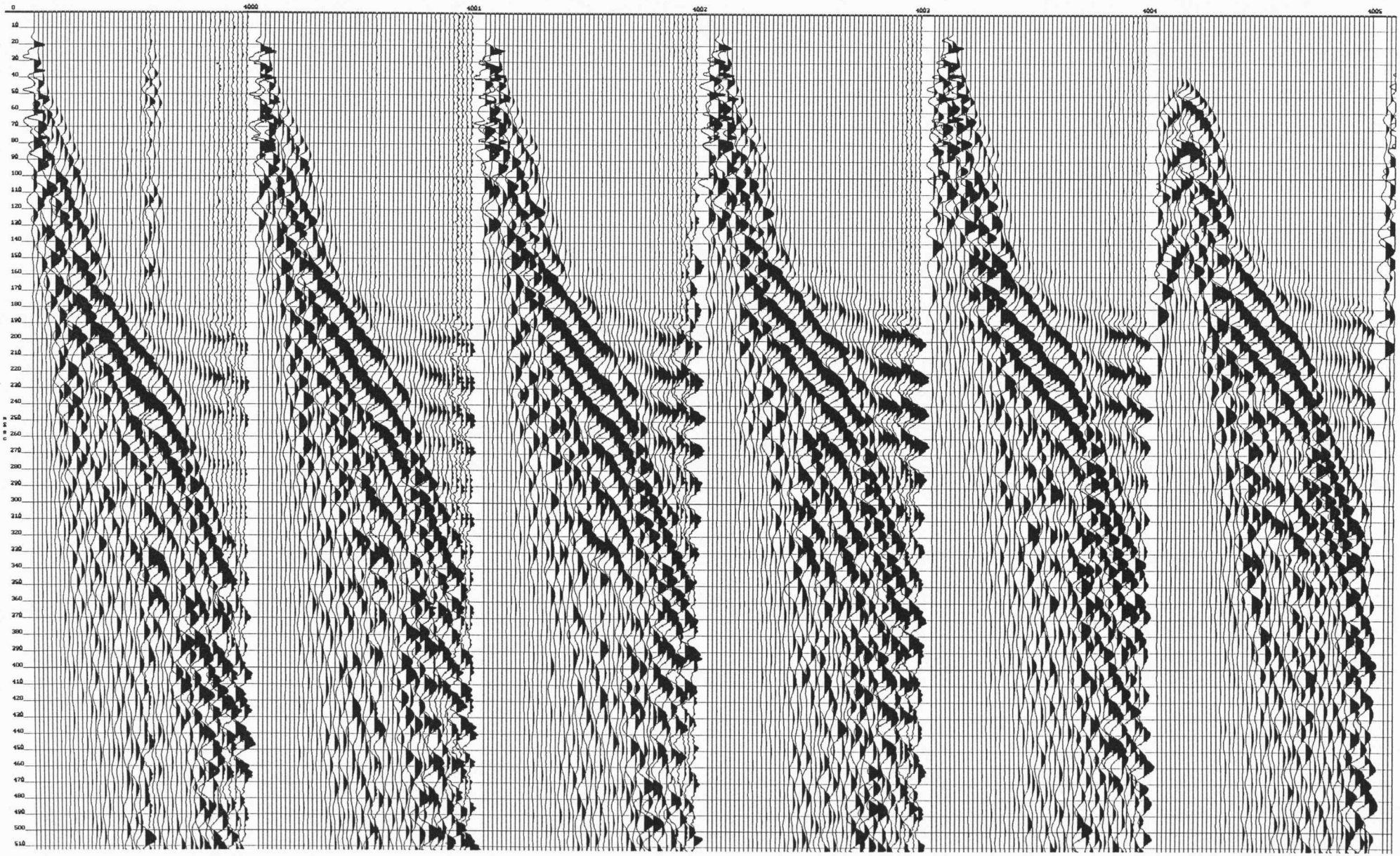
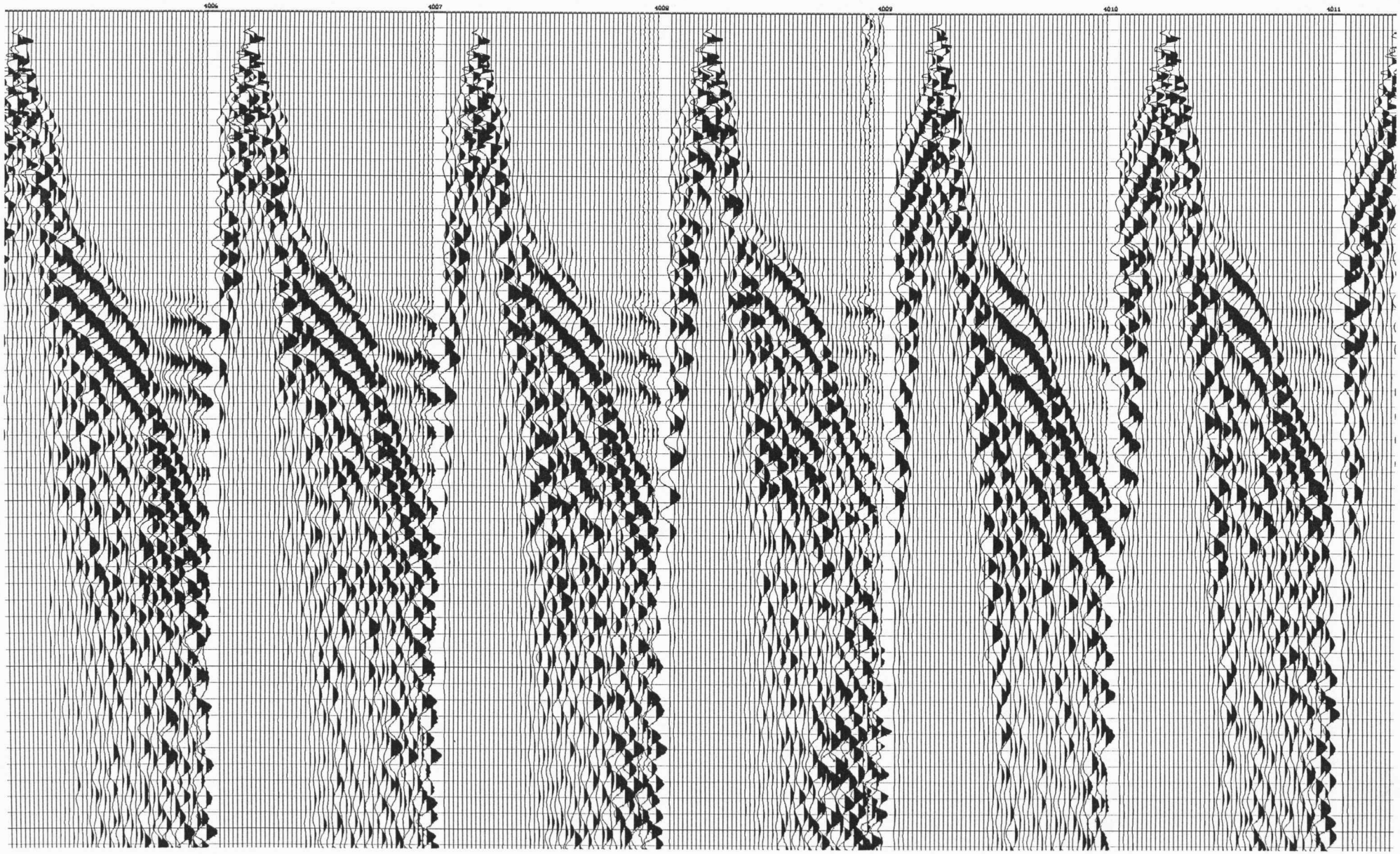
Appendix A2, Line 4

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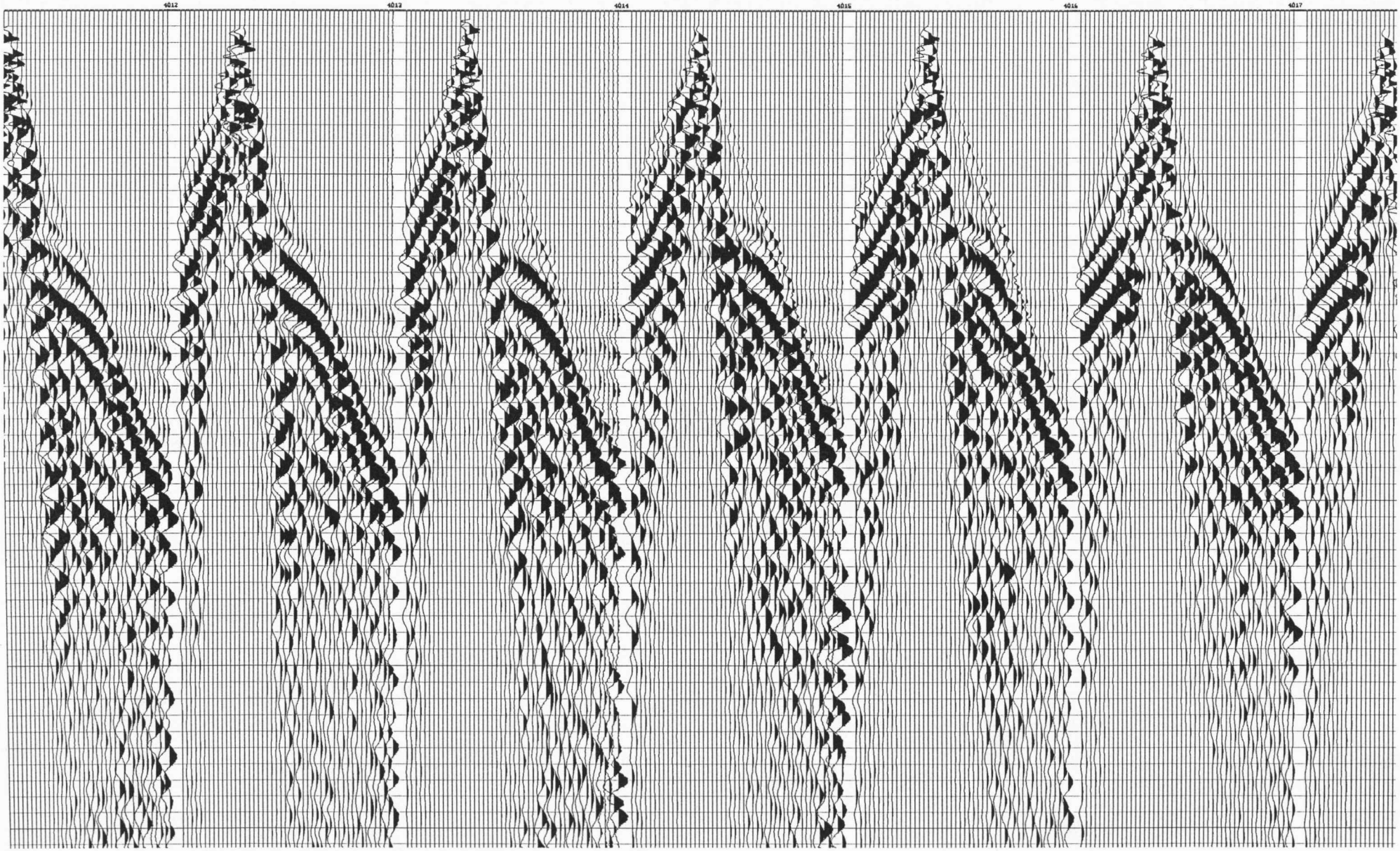
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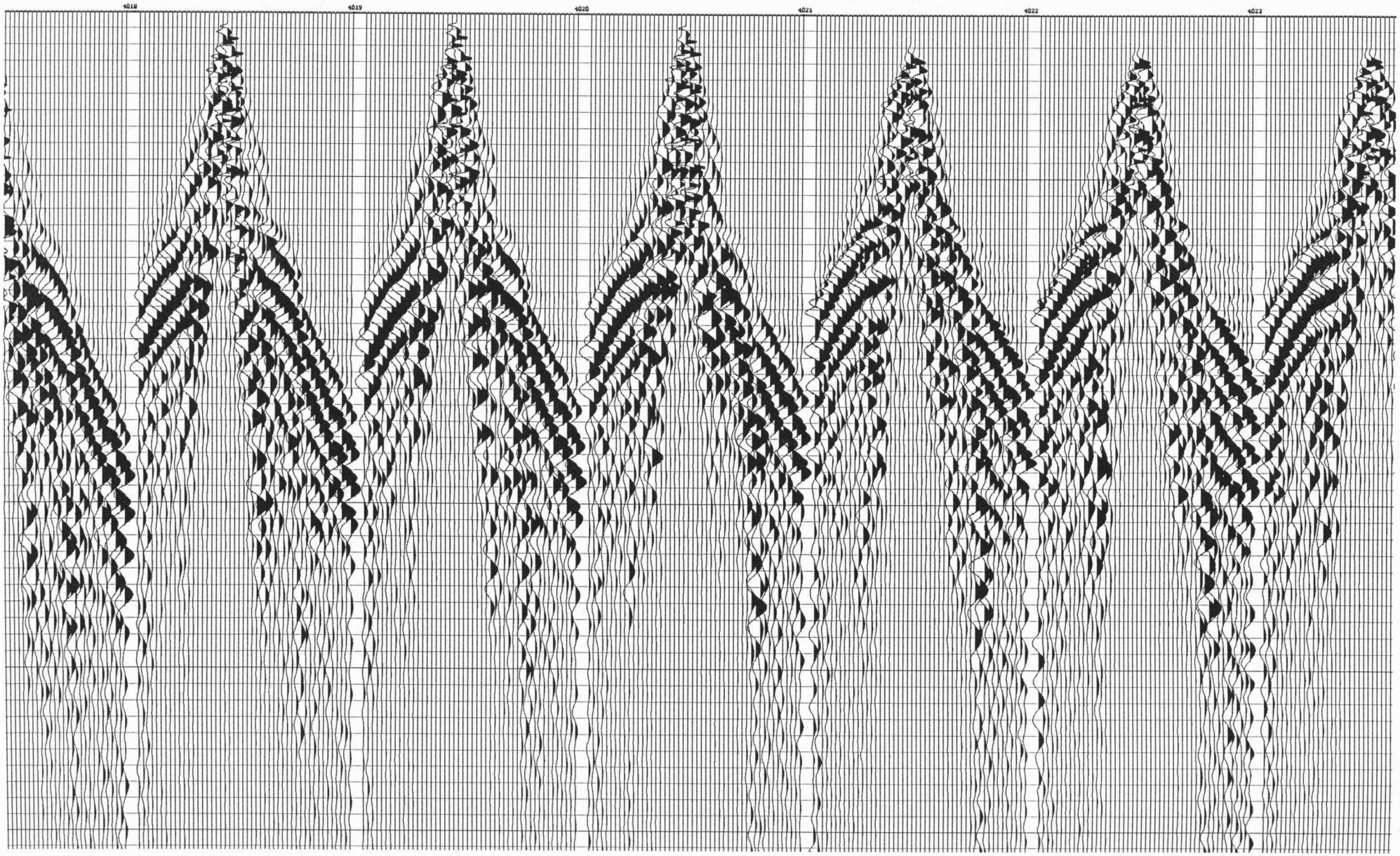
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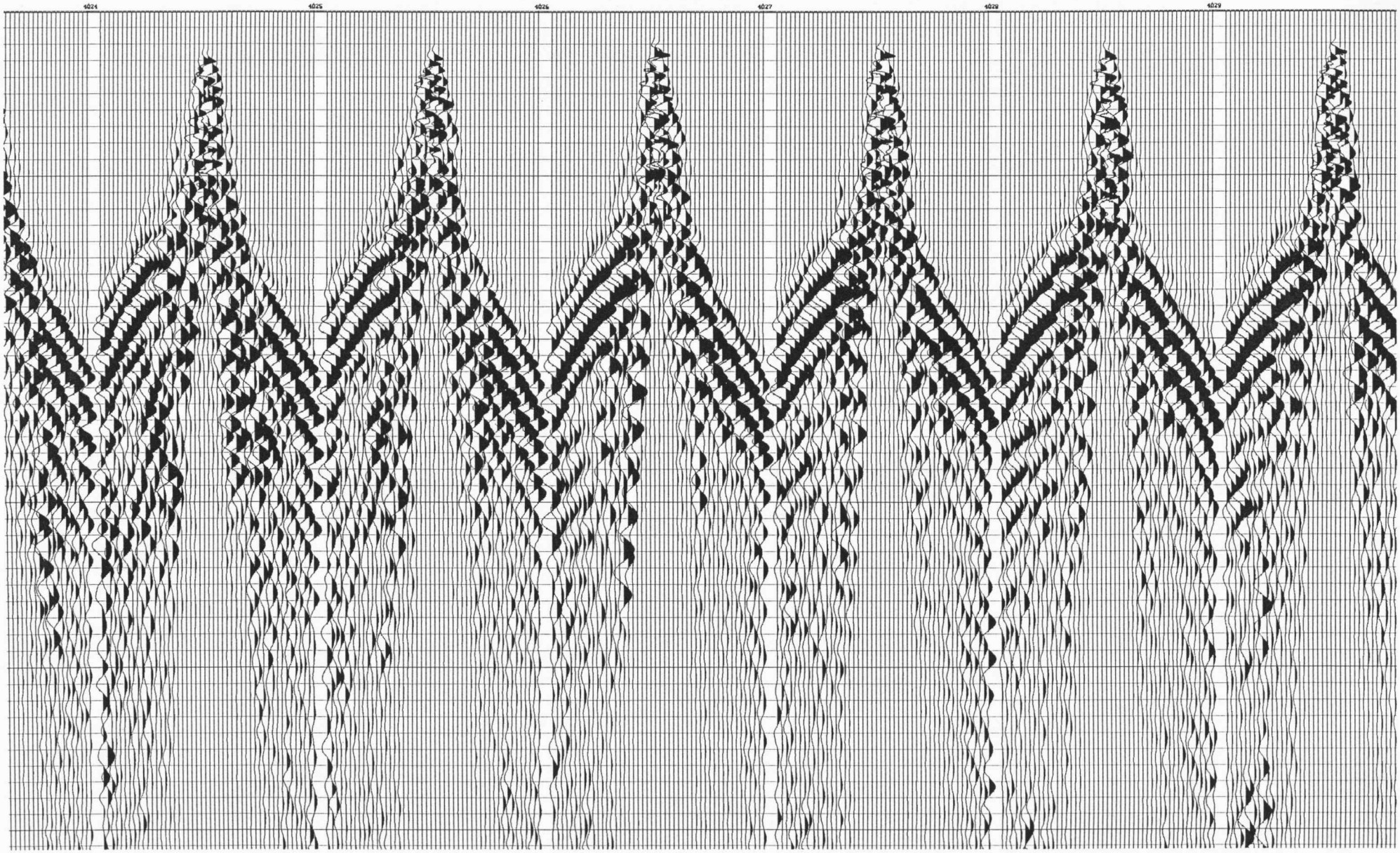
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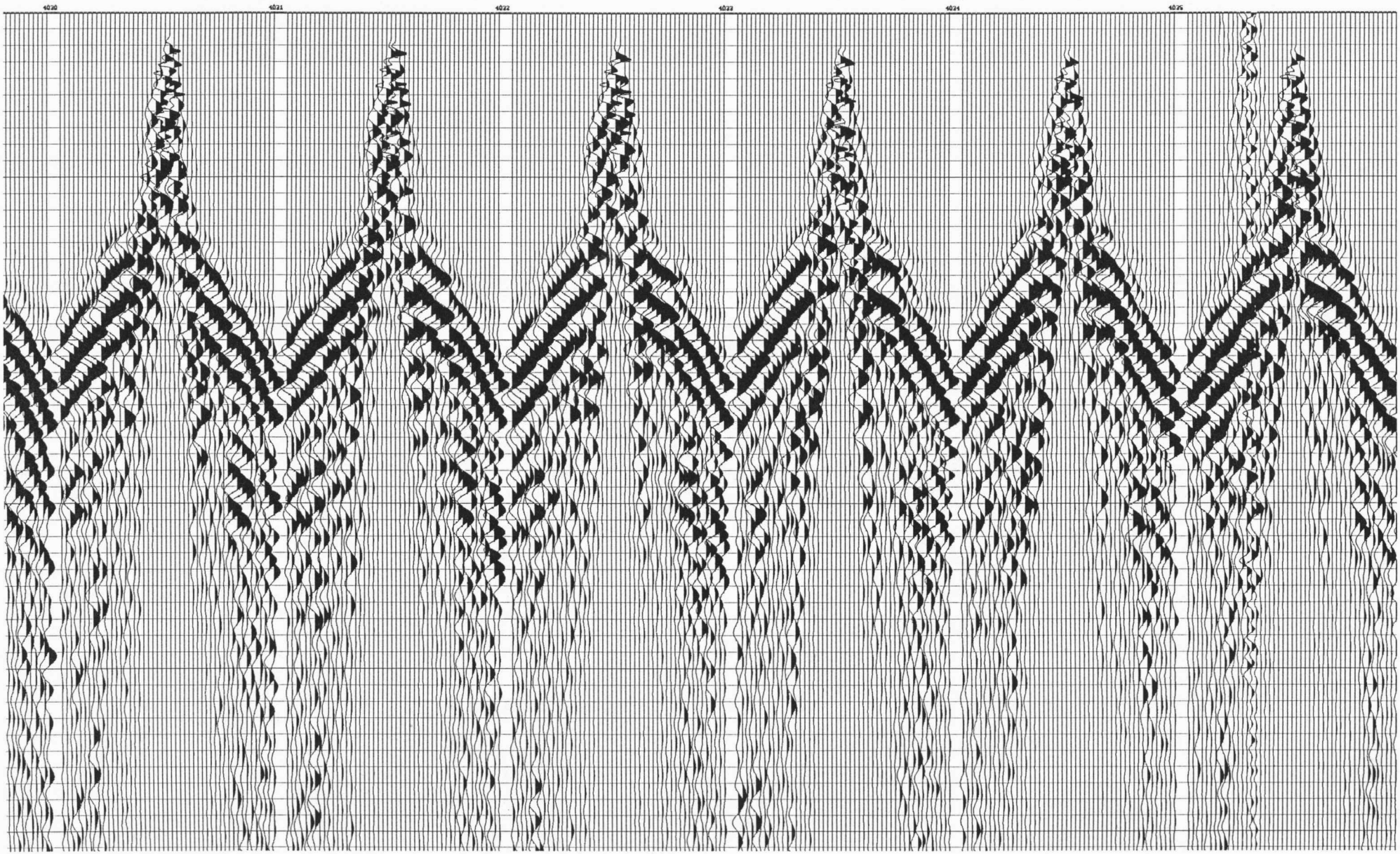
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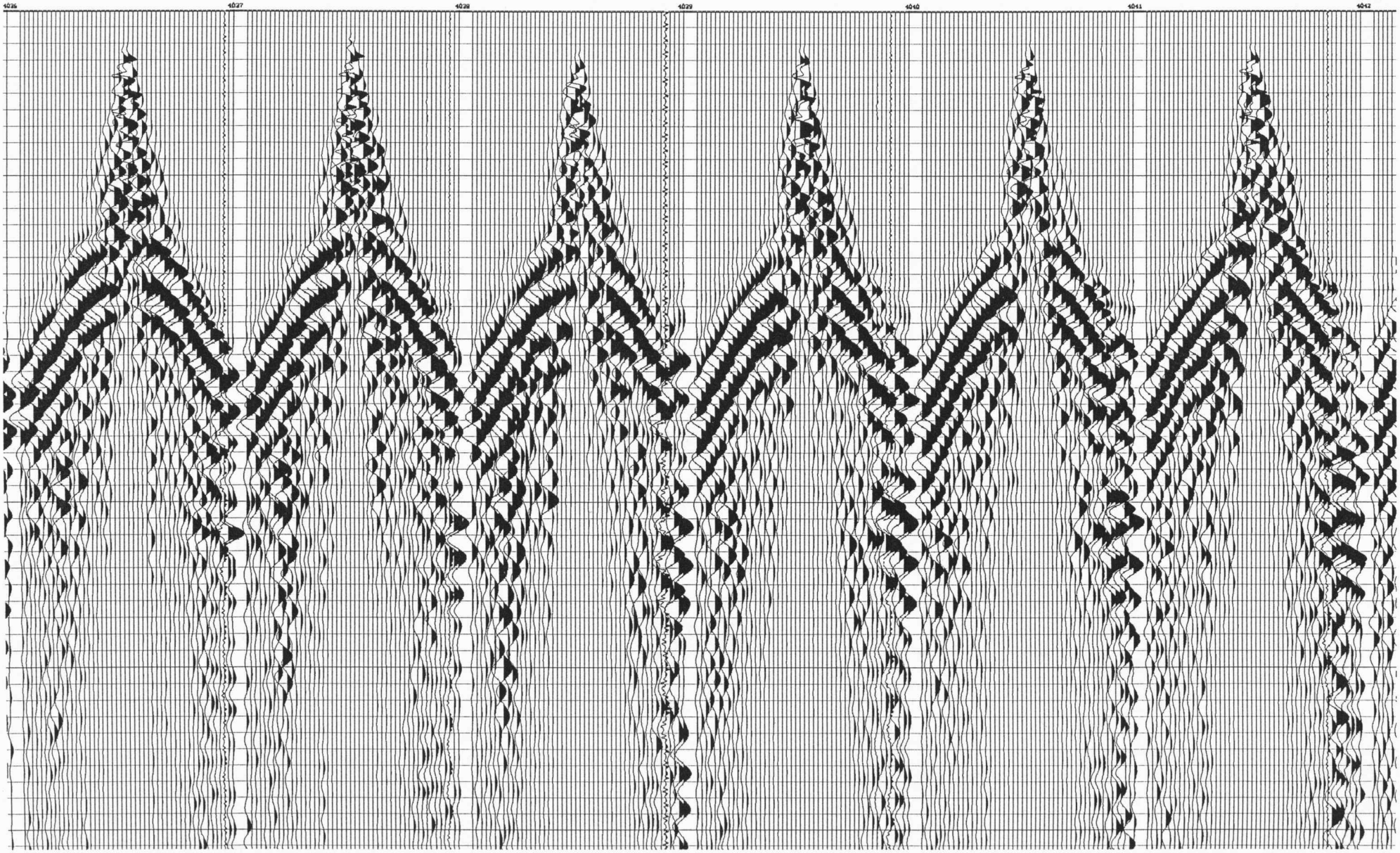
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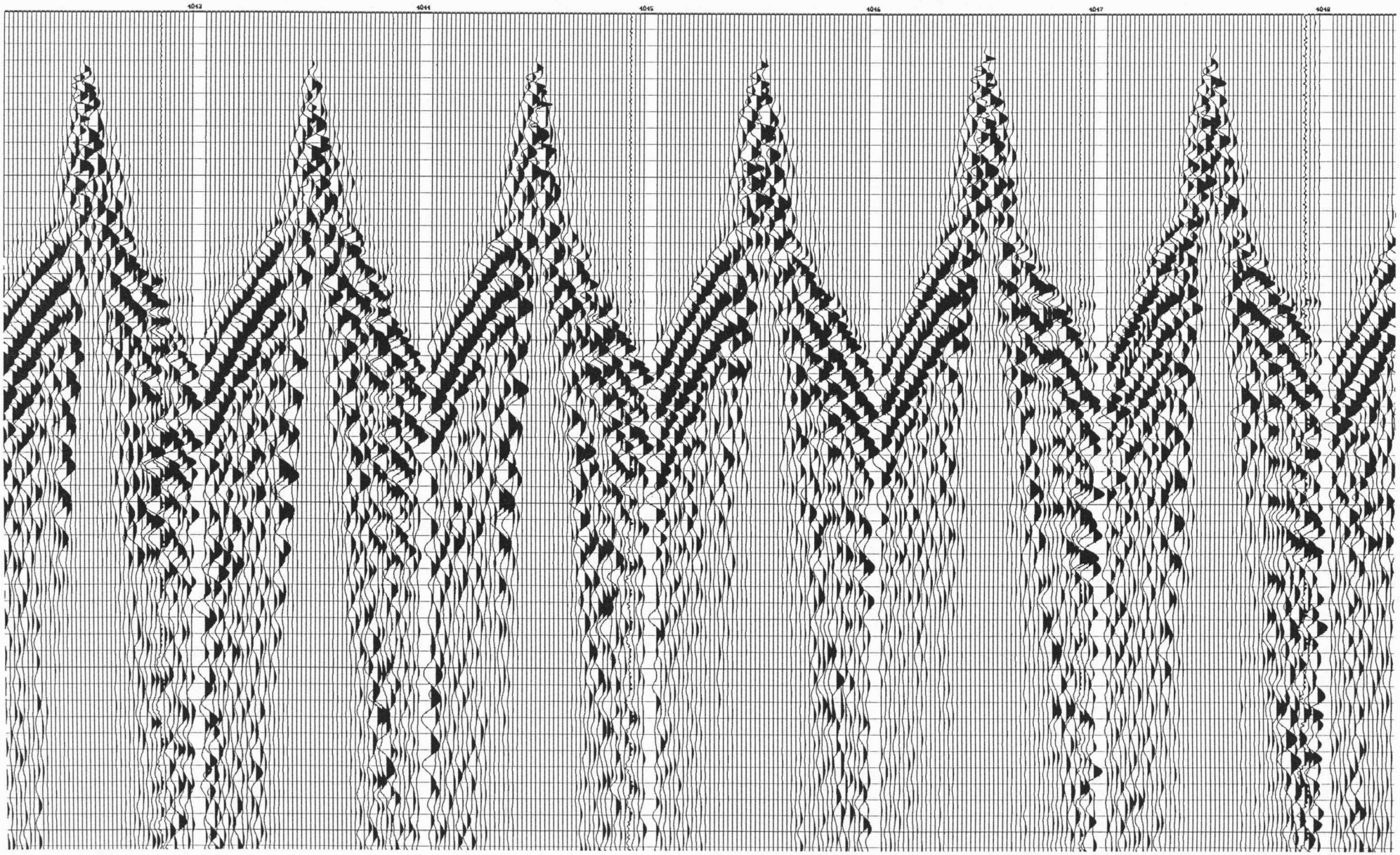
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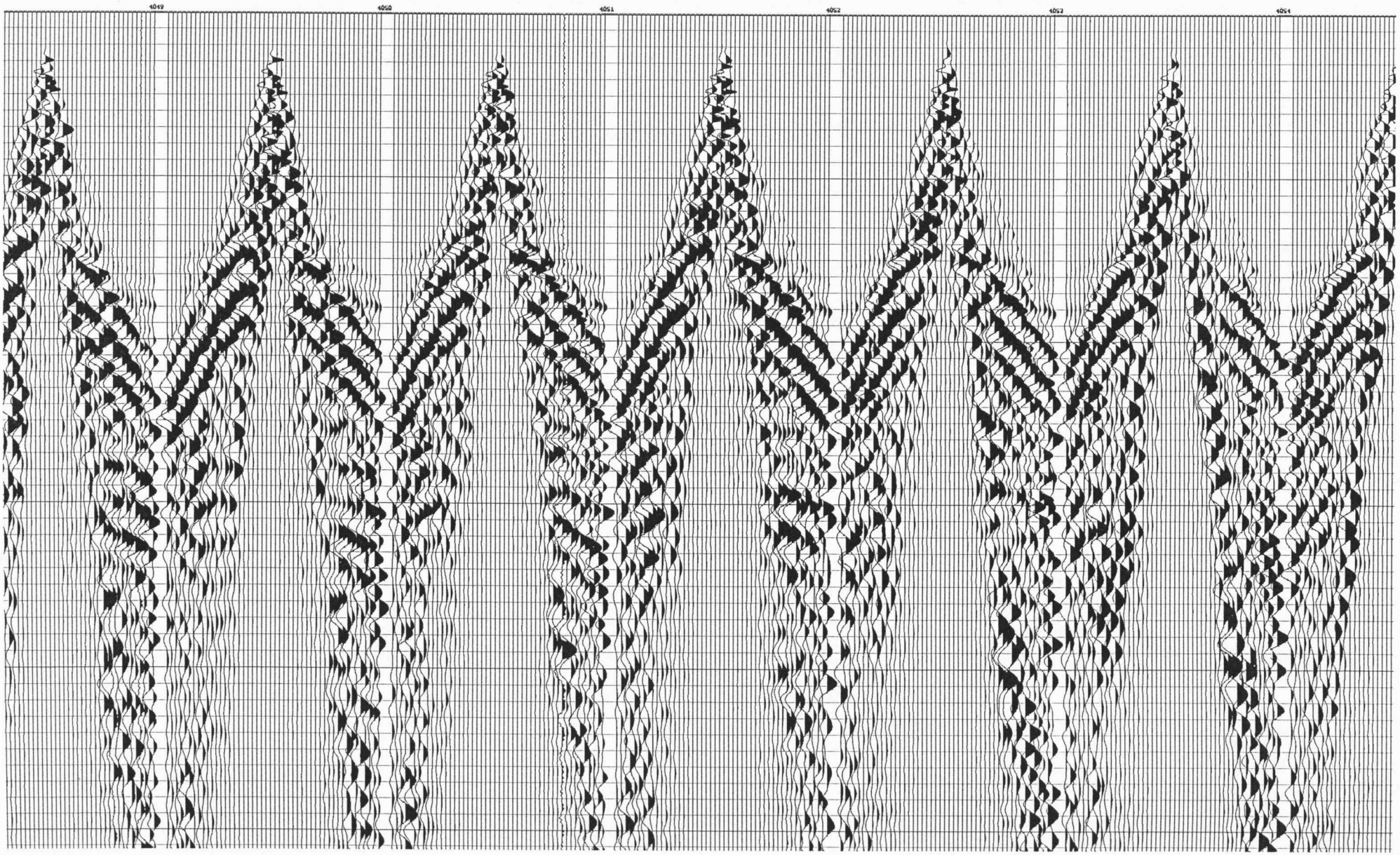
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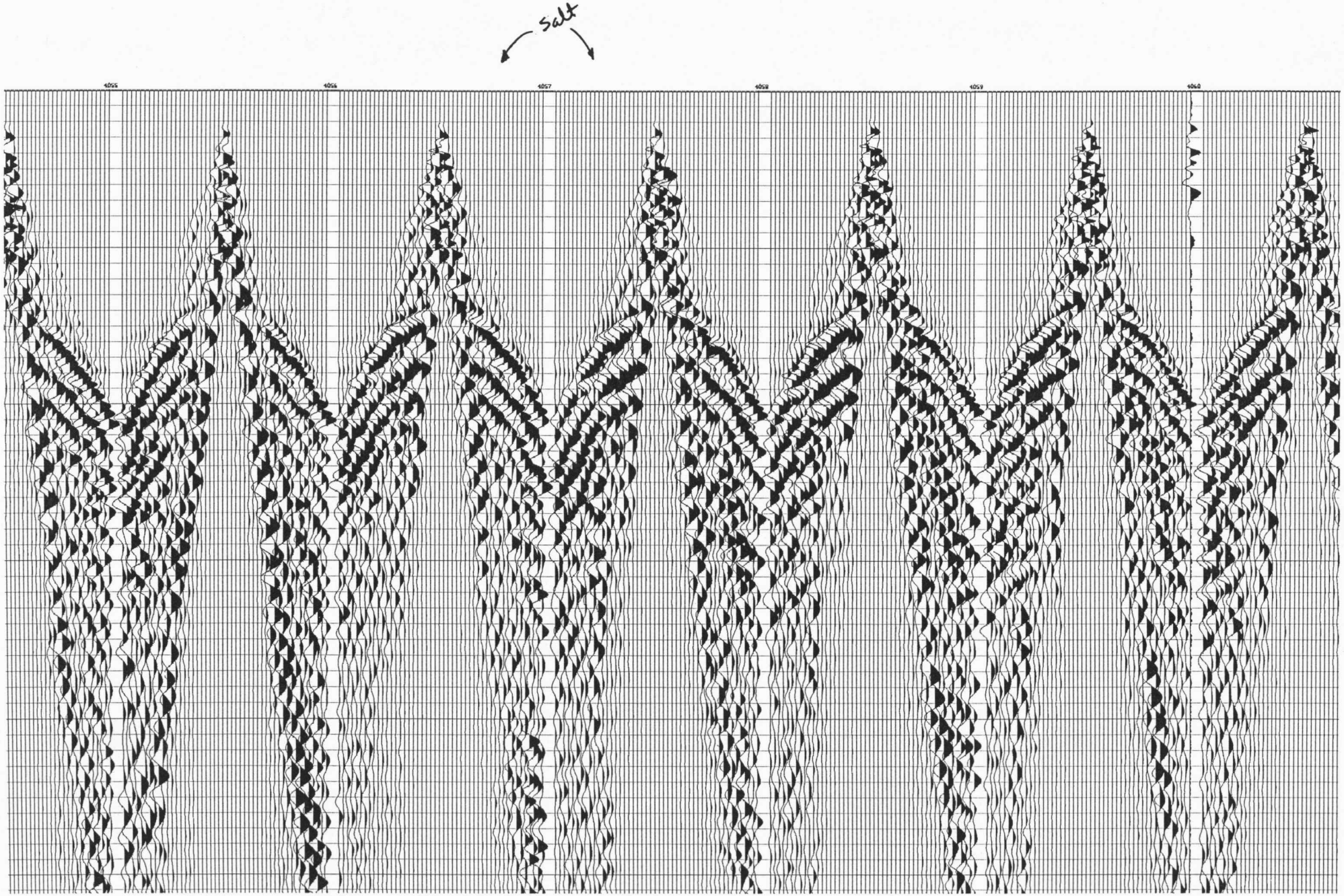
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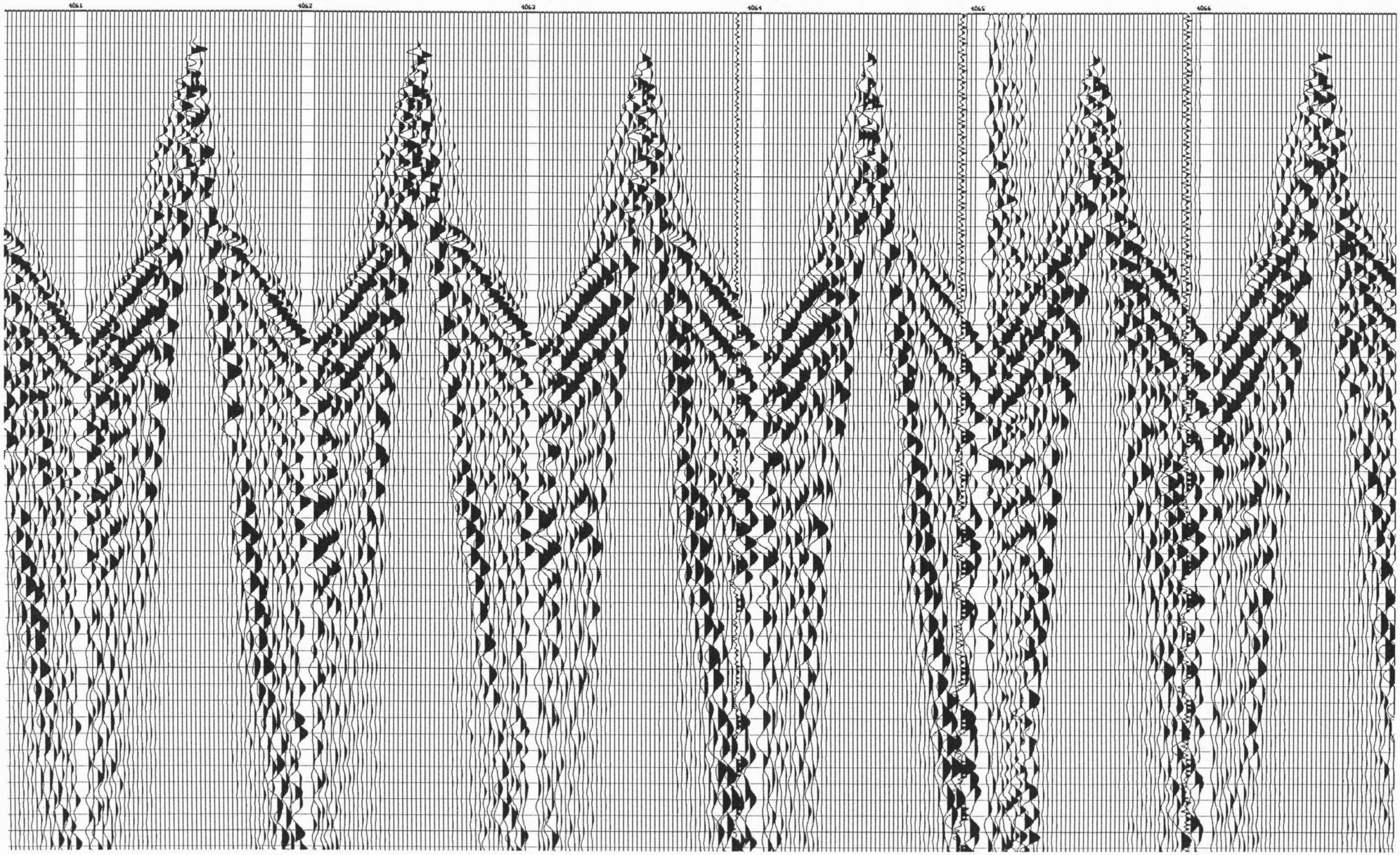
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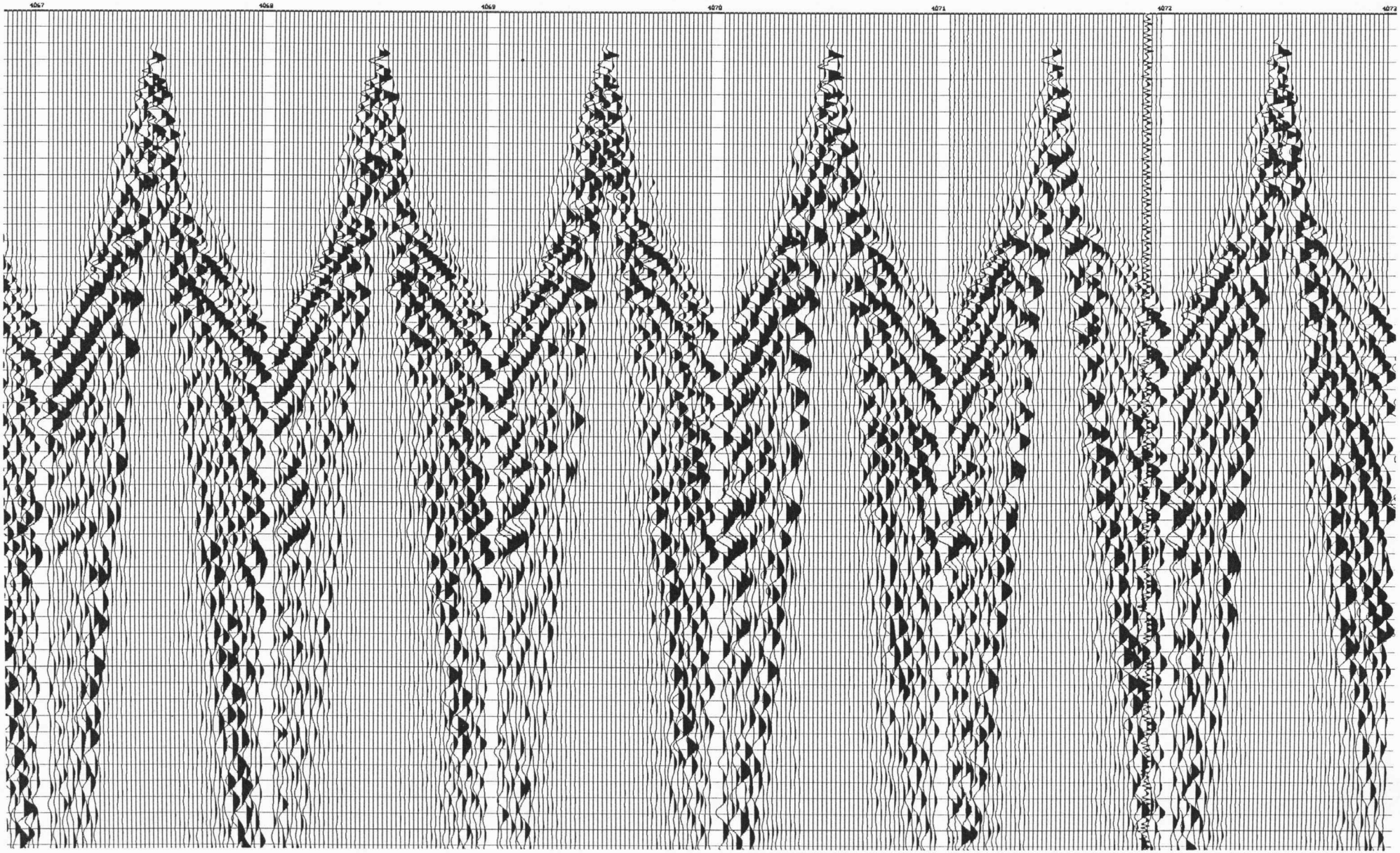
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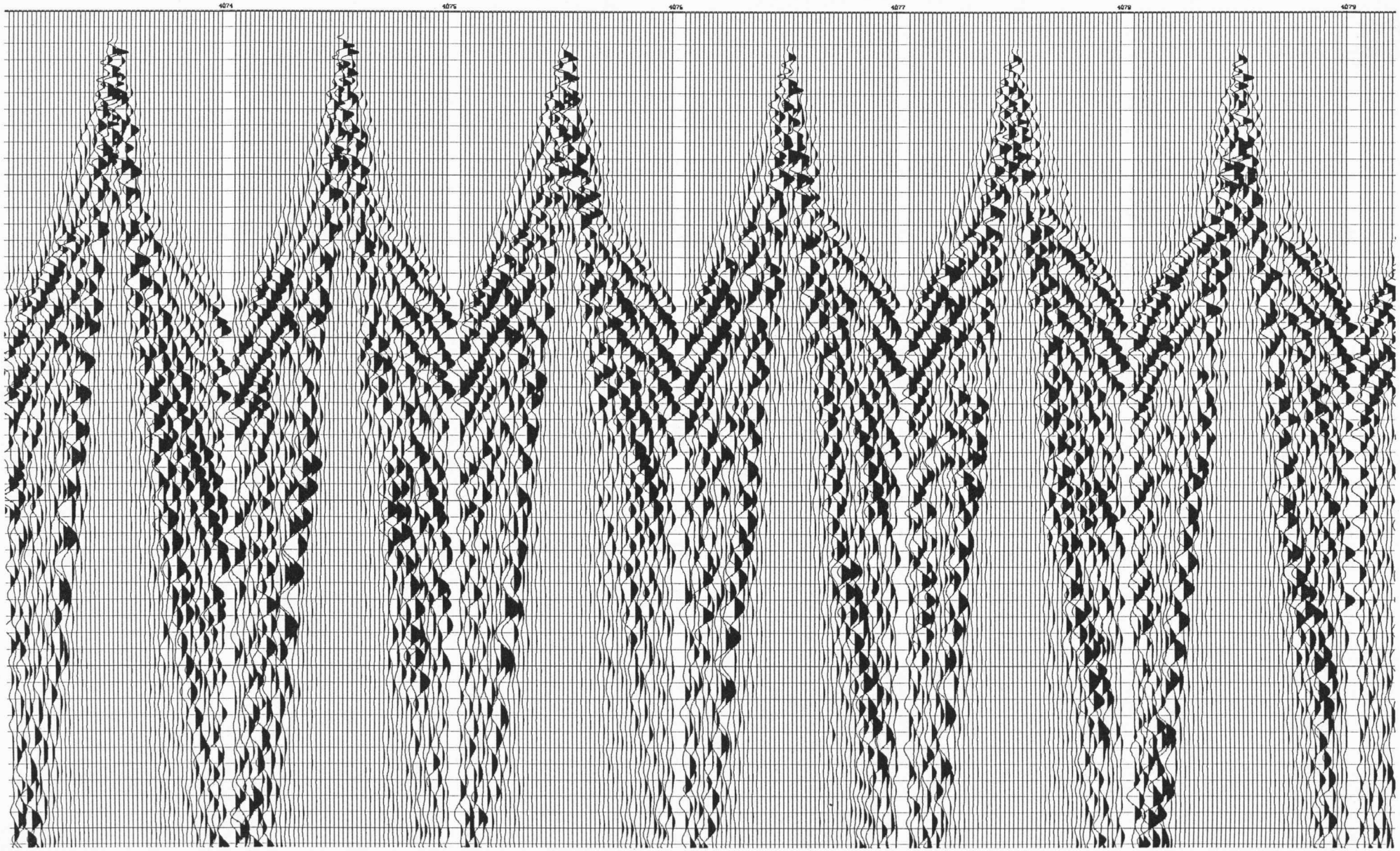
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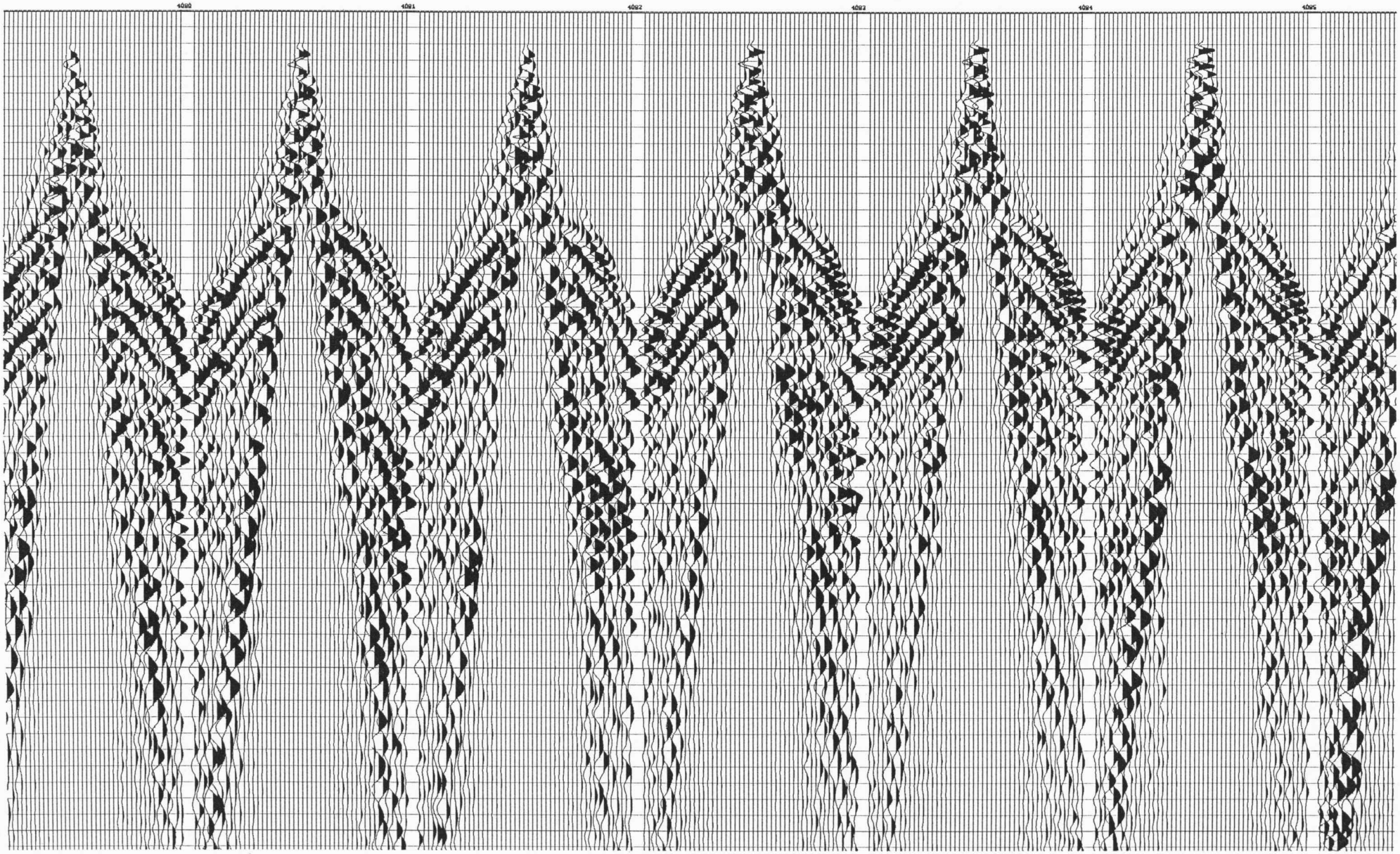
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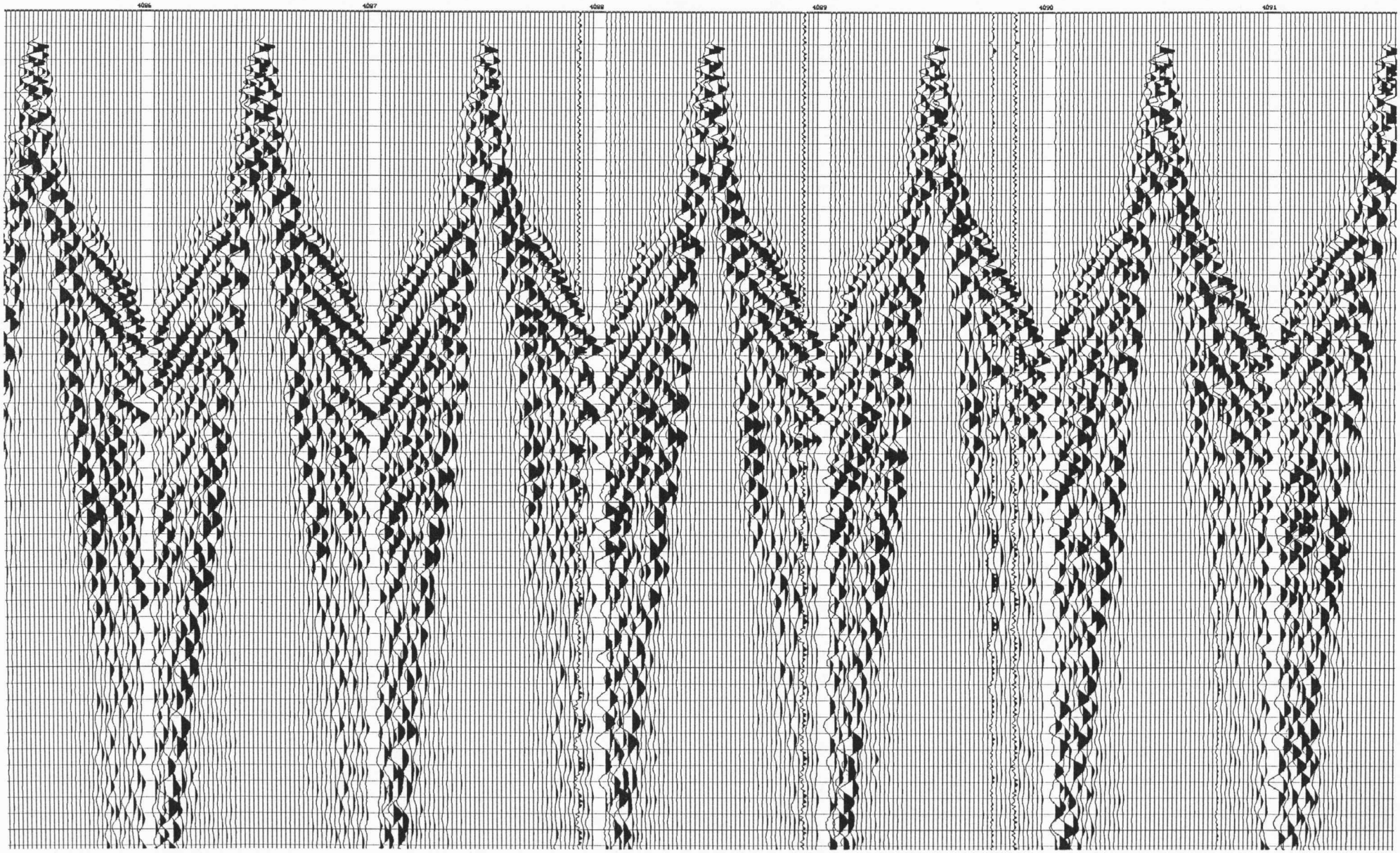
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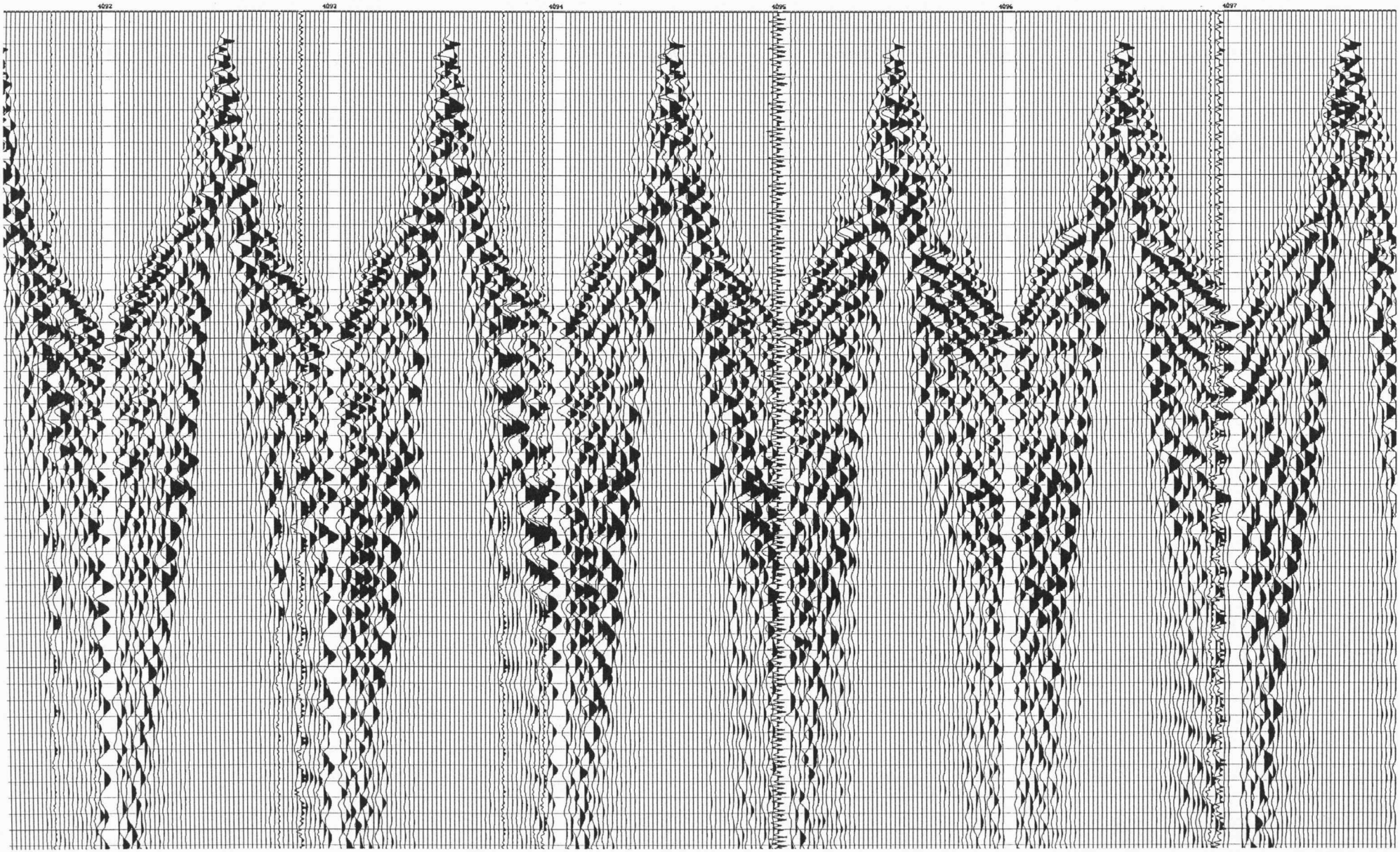
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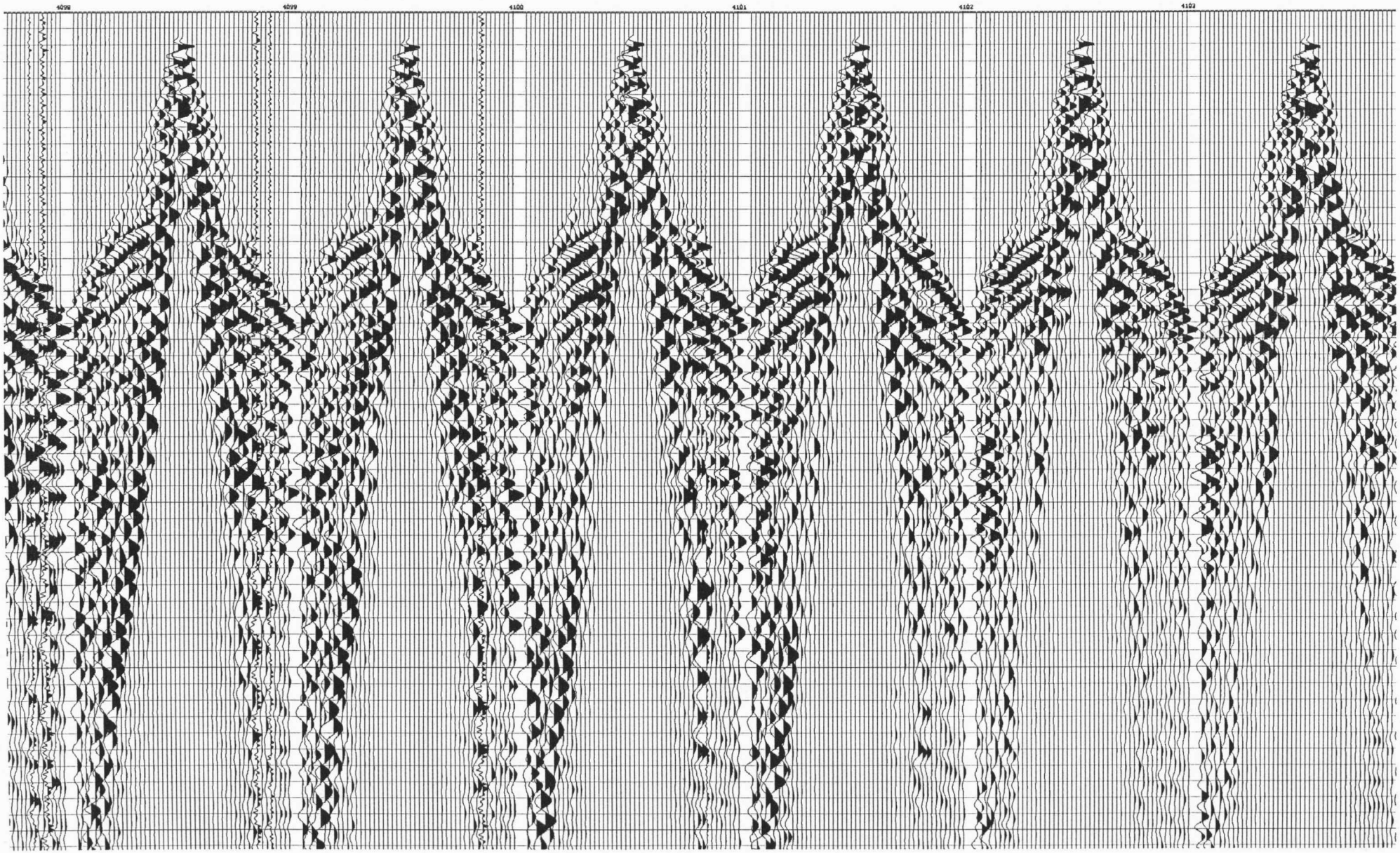
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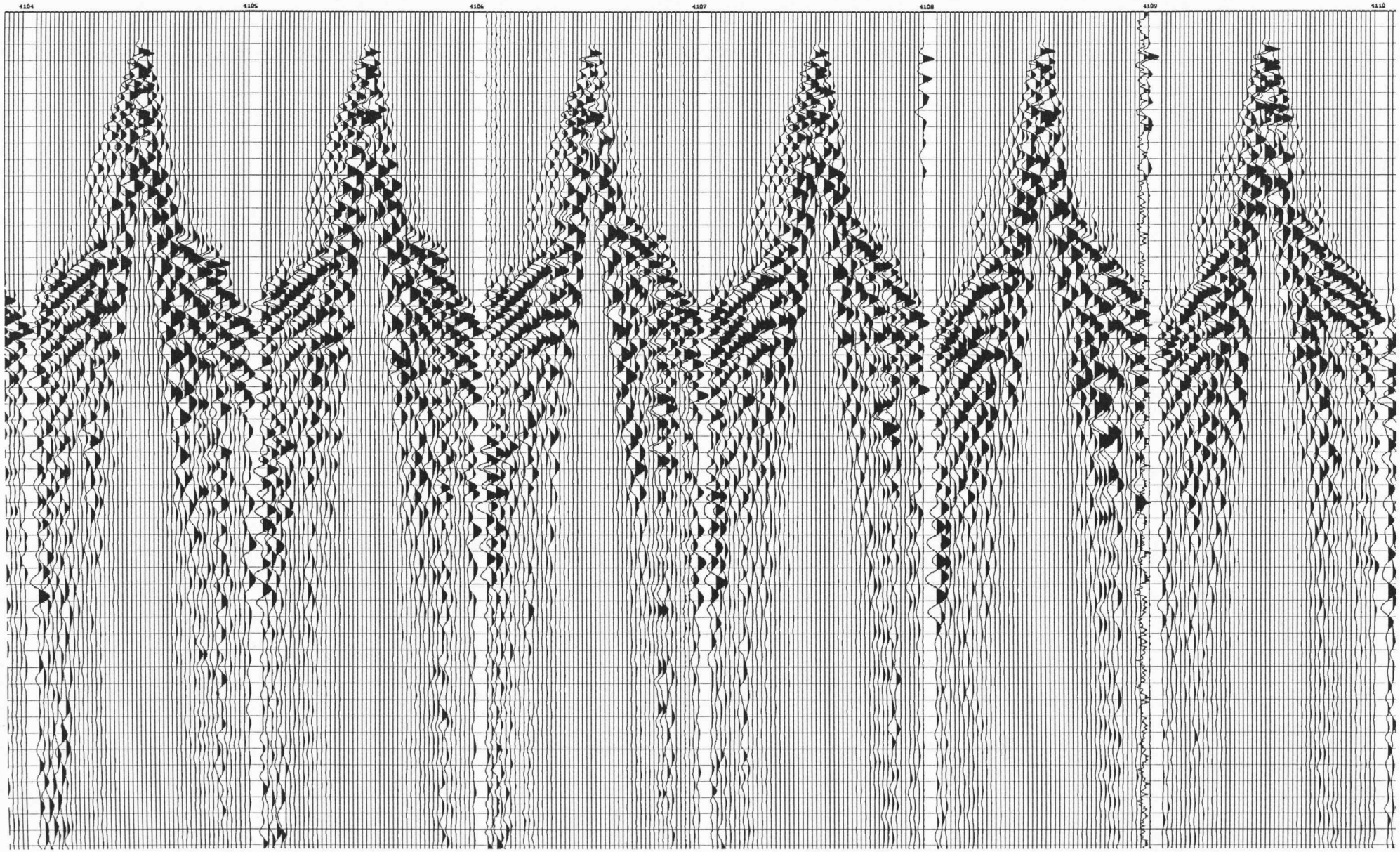
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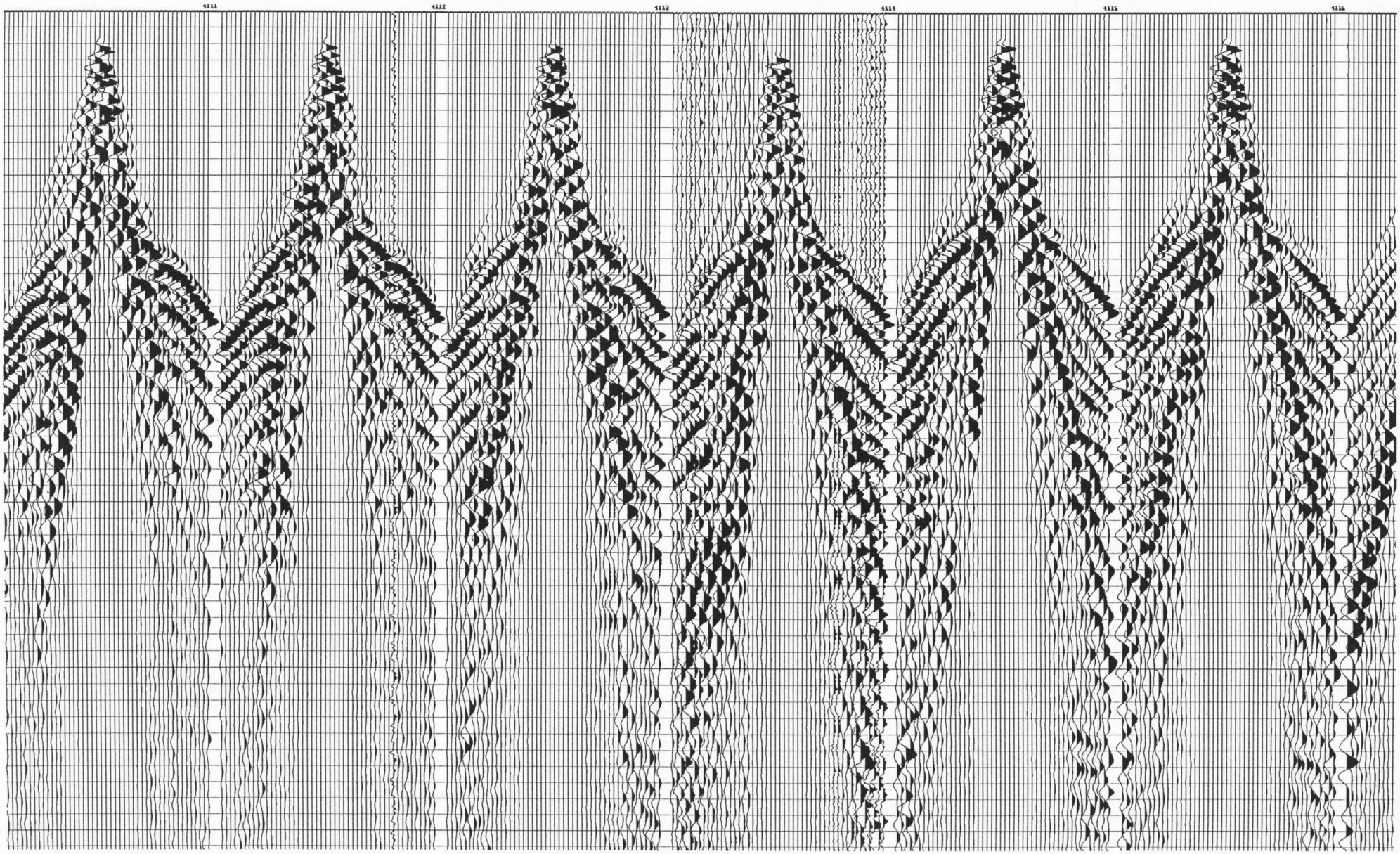
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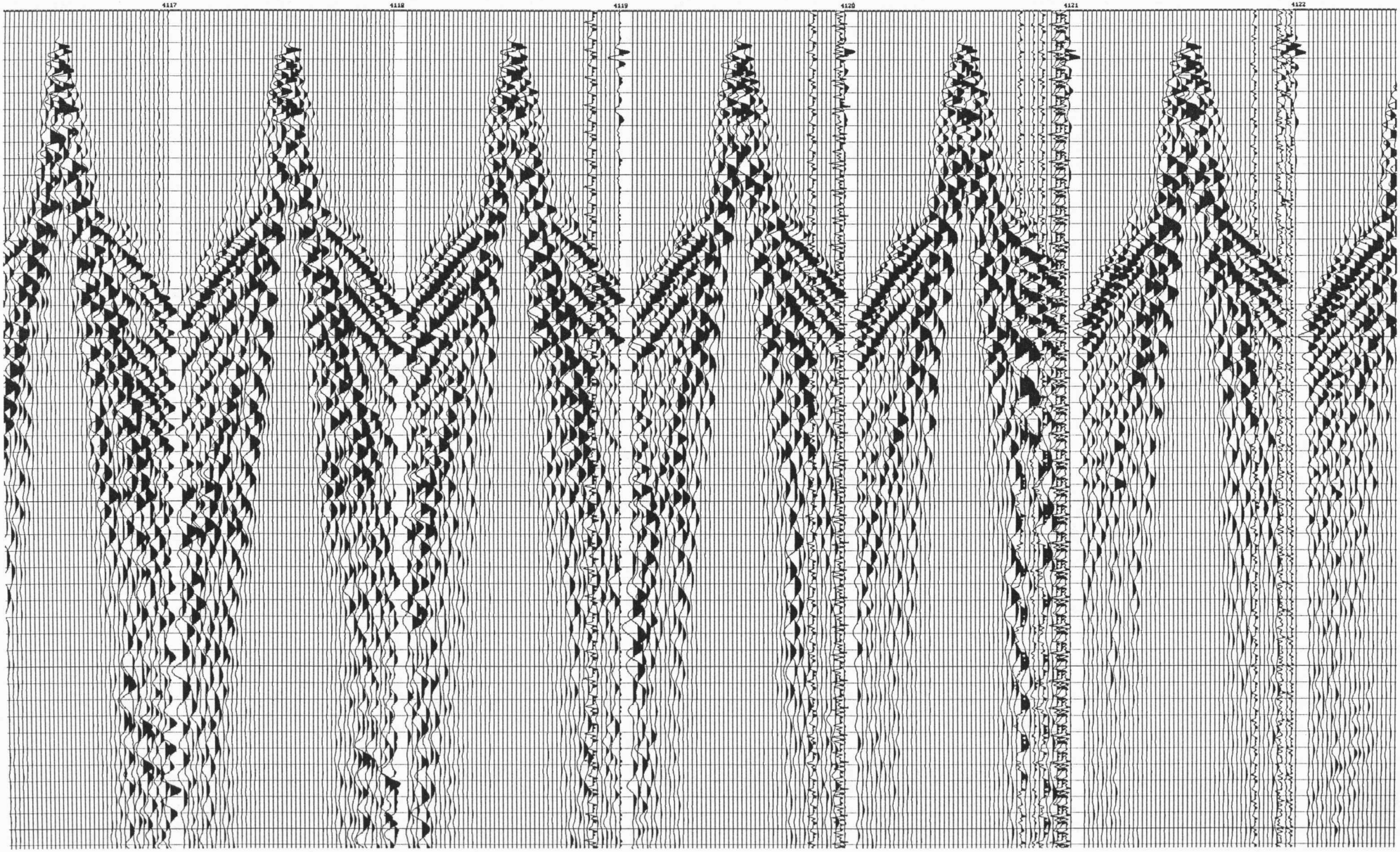
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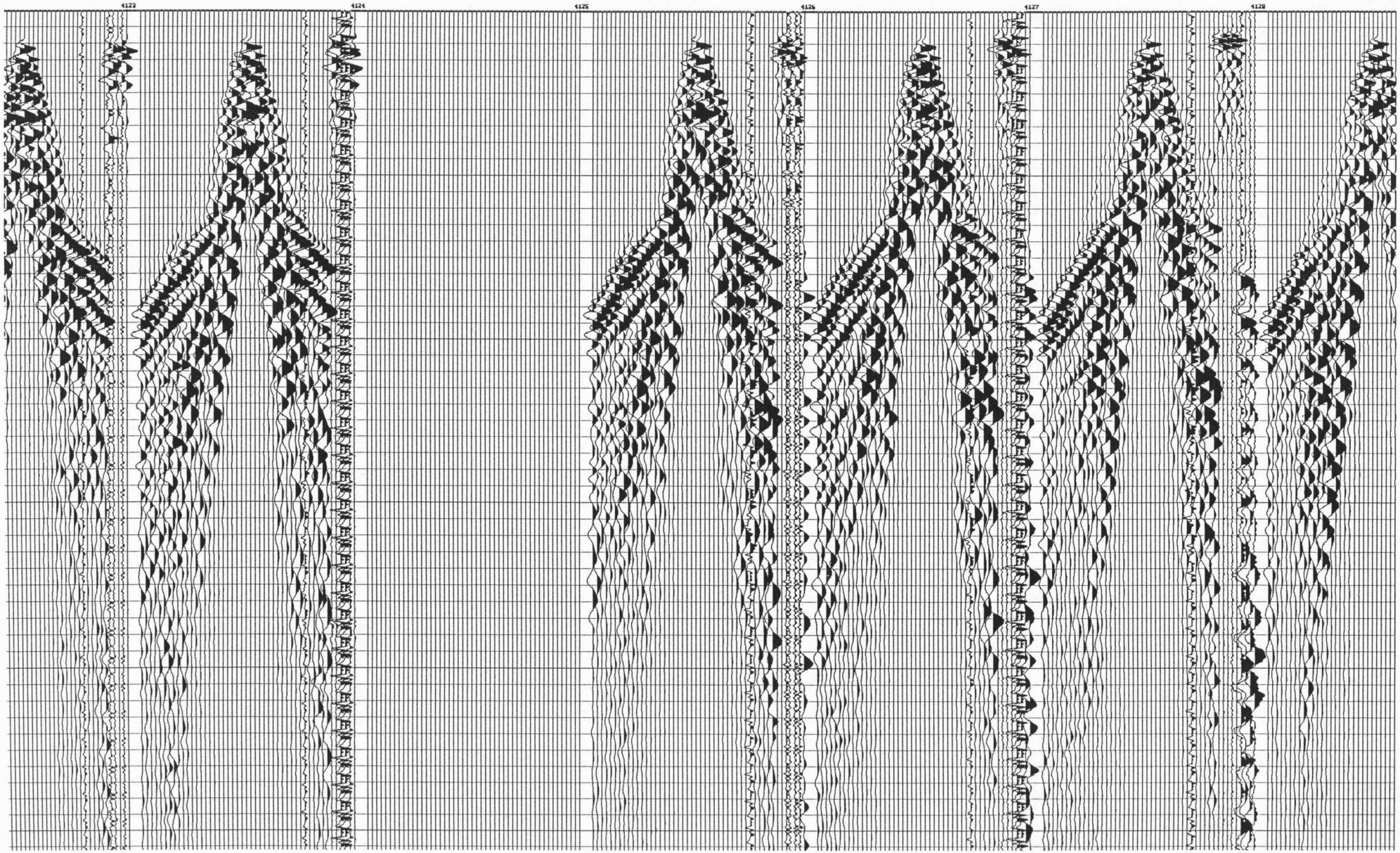
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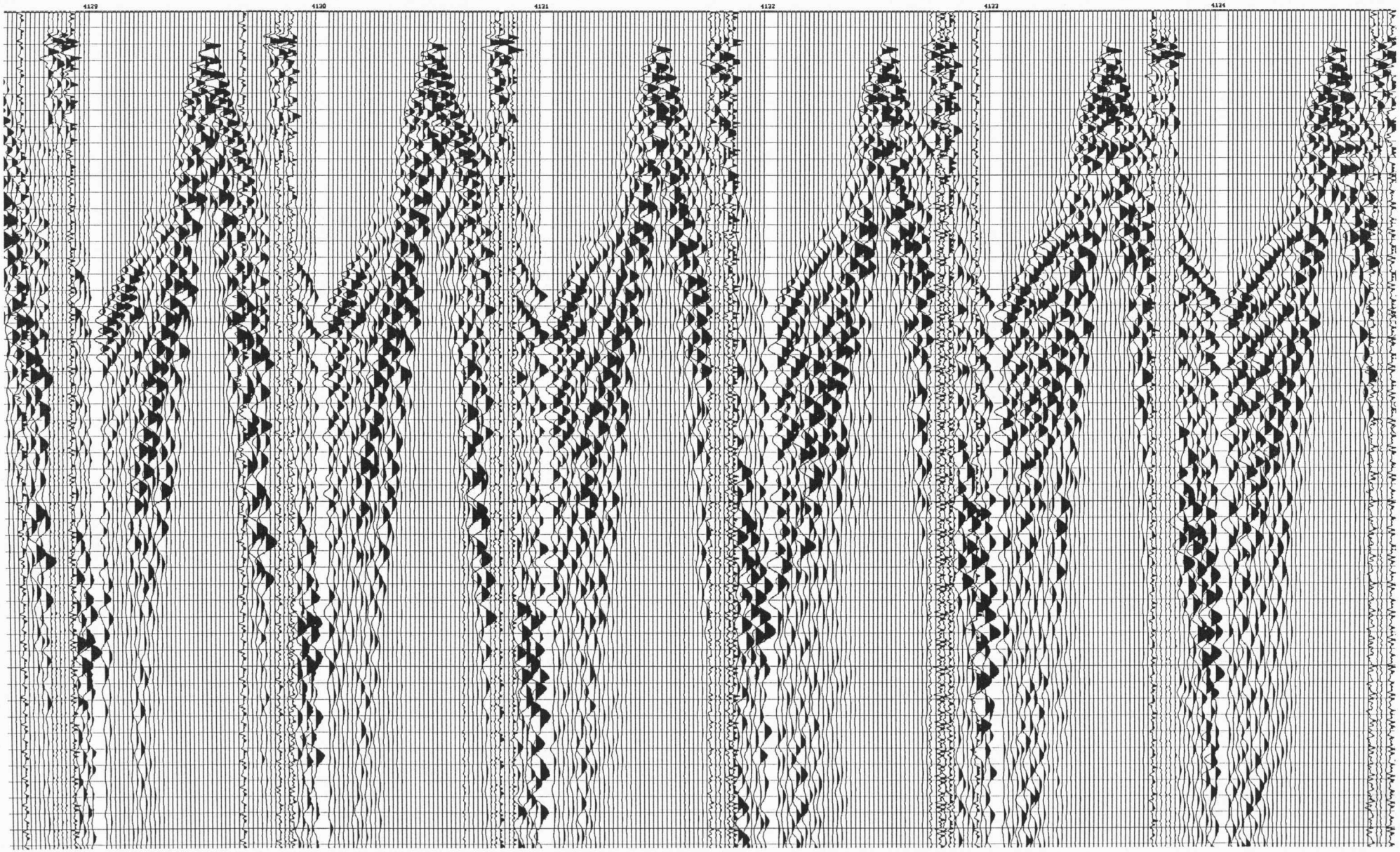
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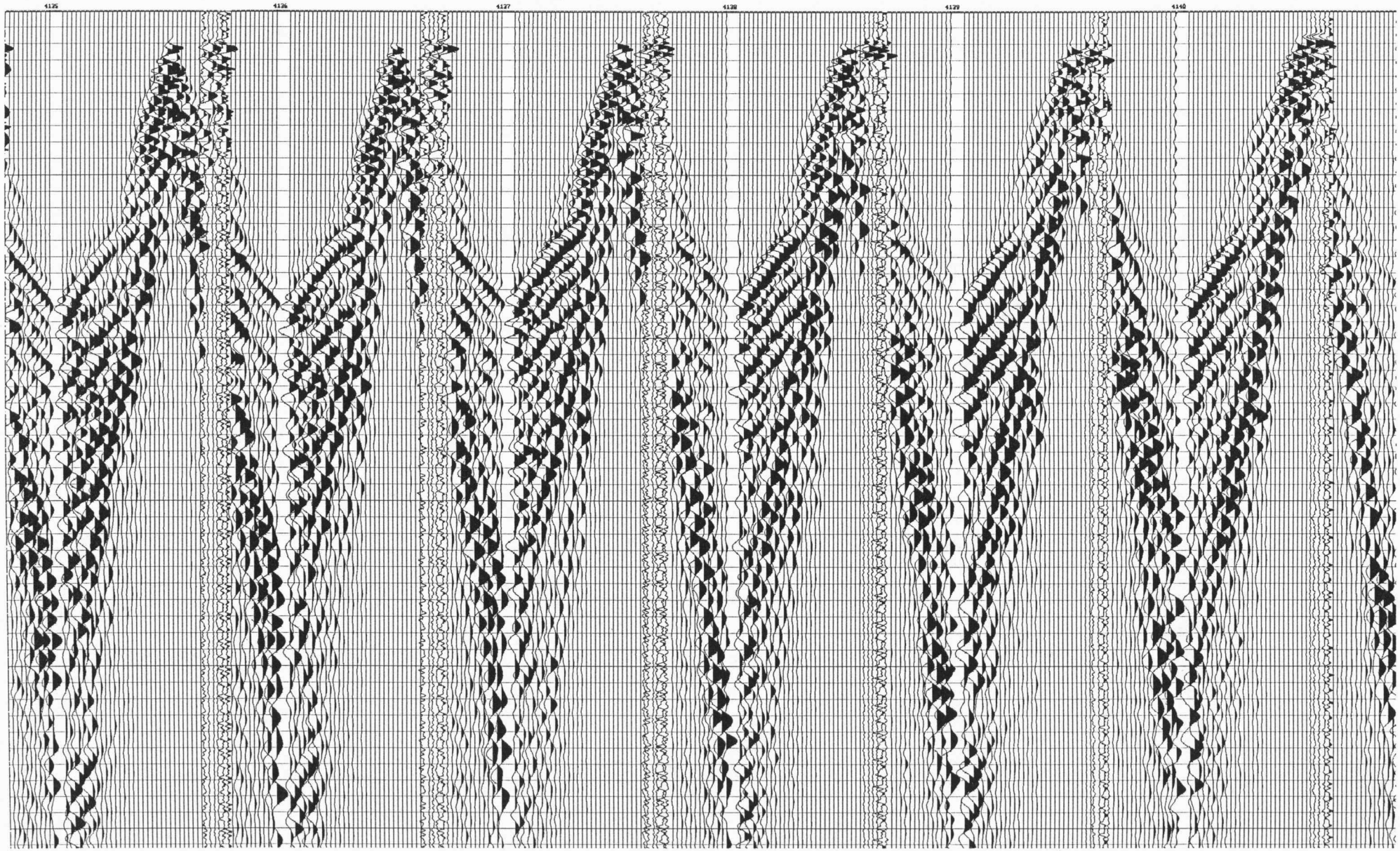
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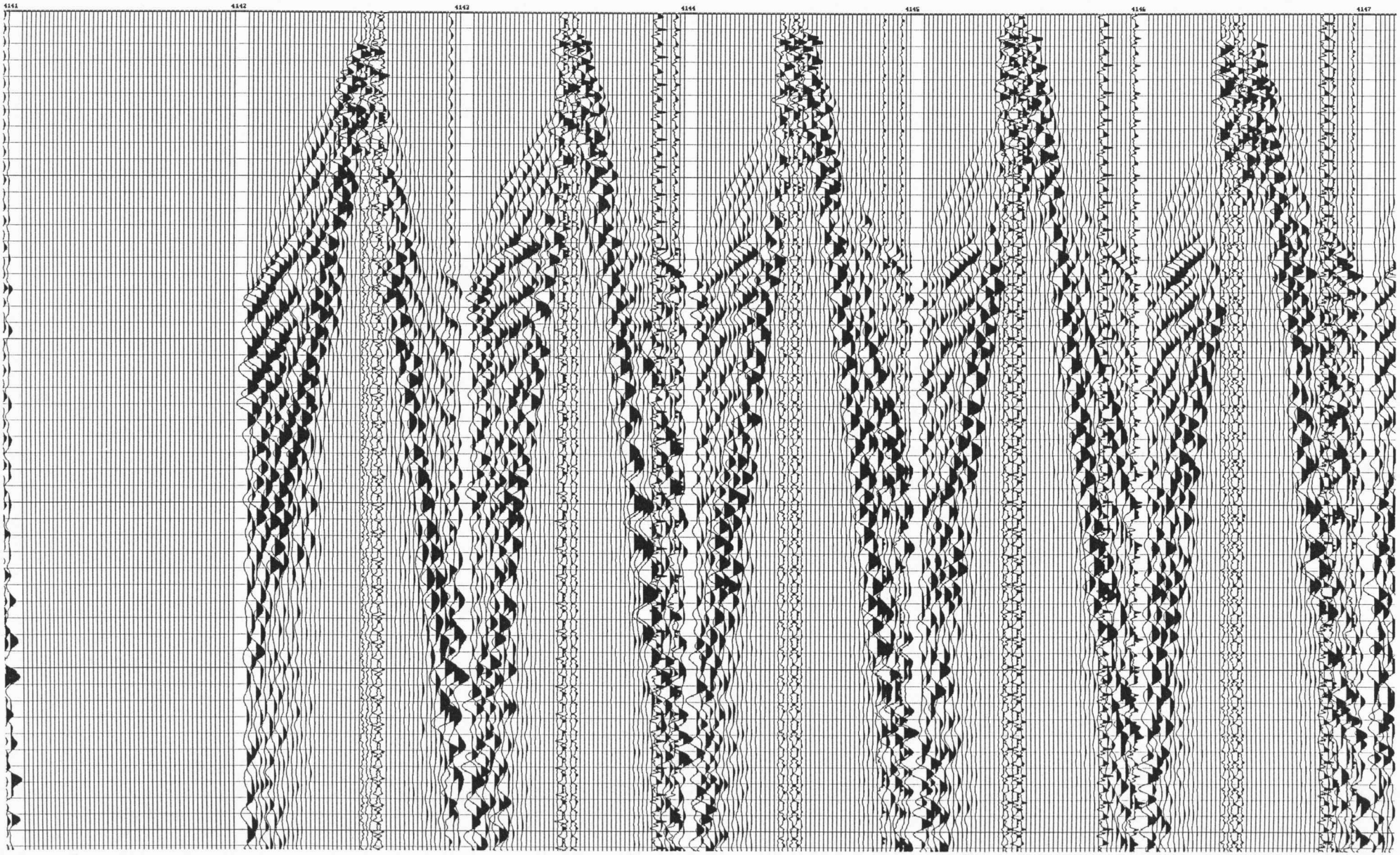
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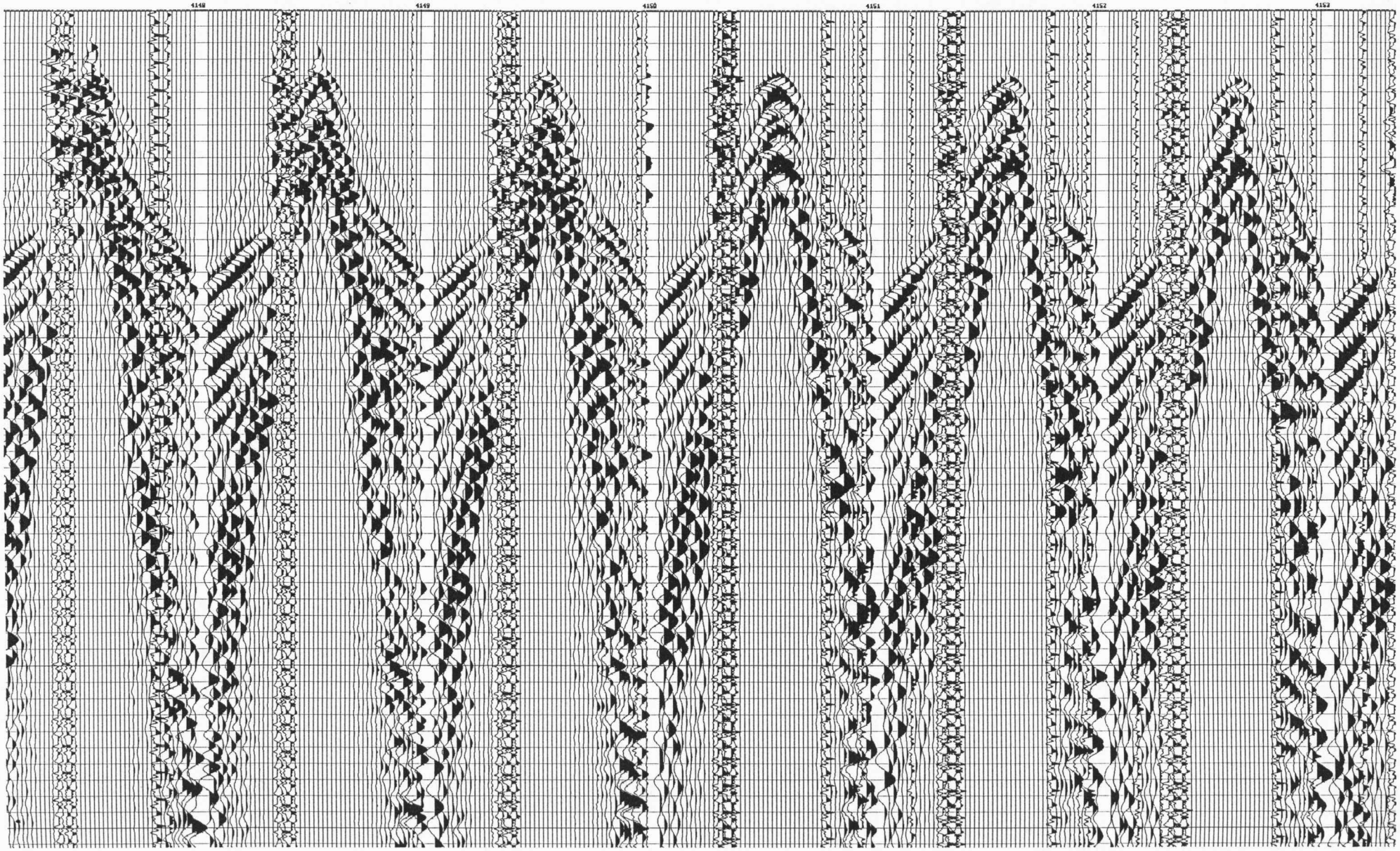
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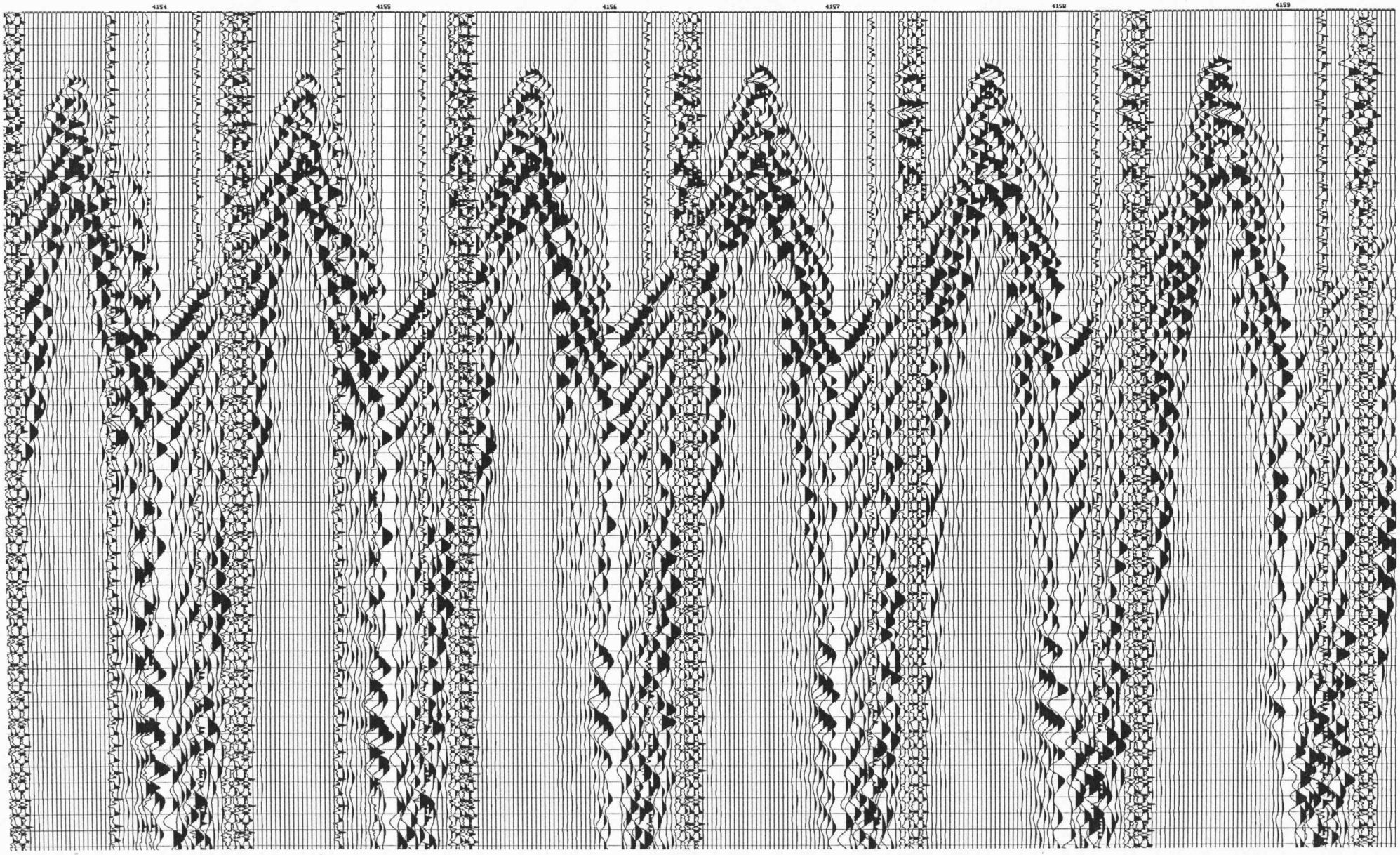
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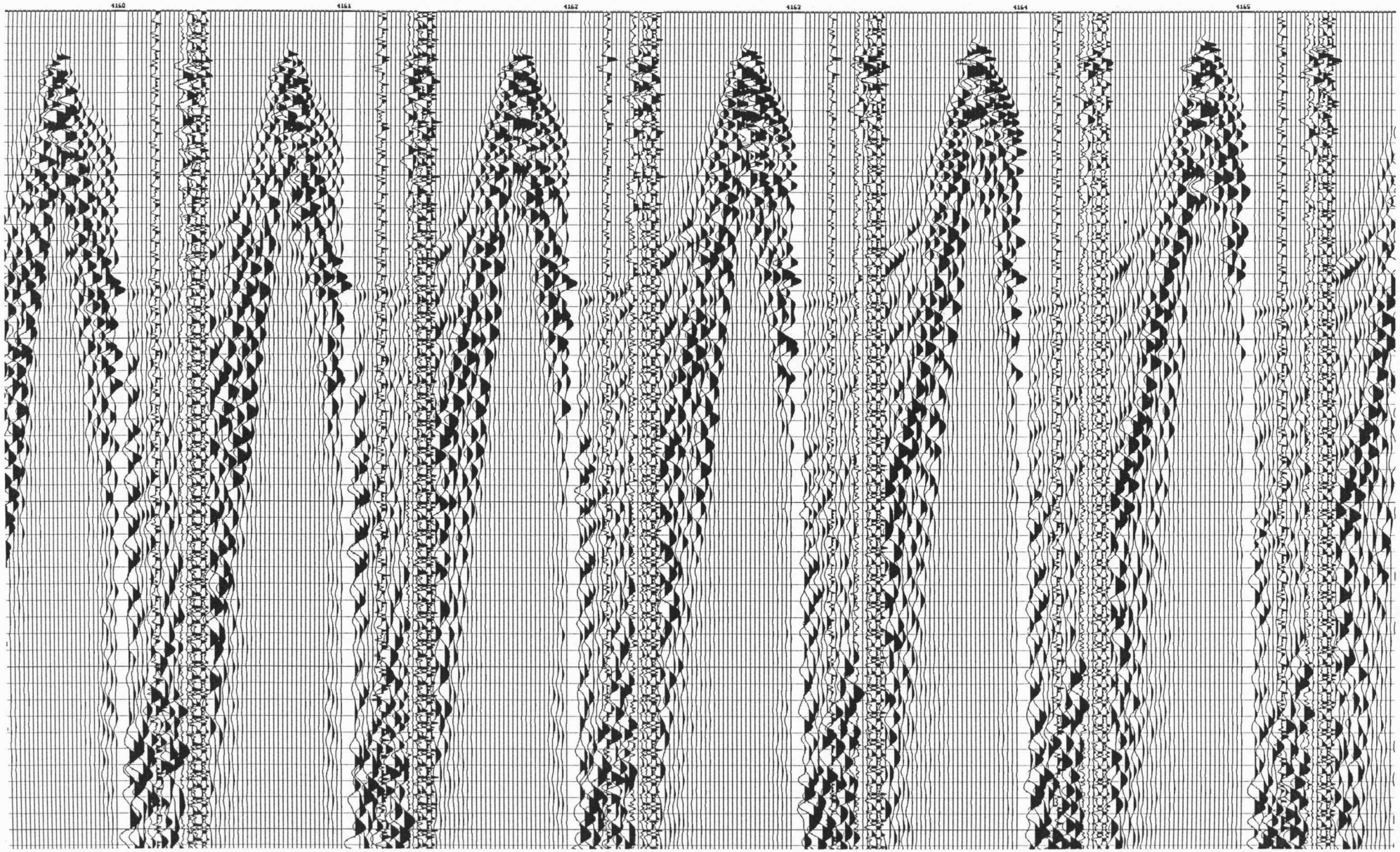
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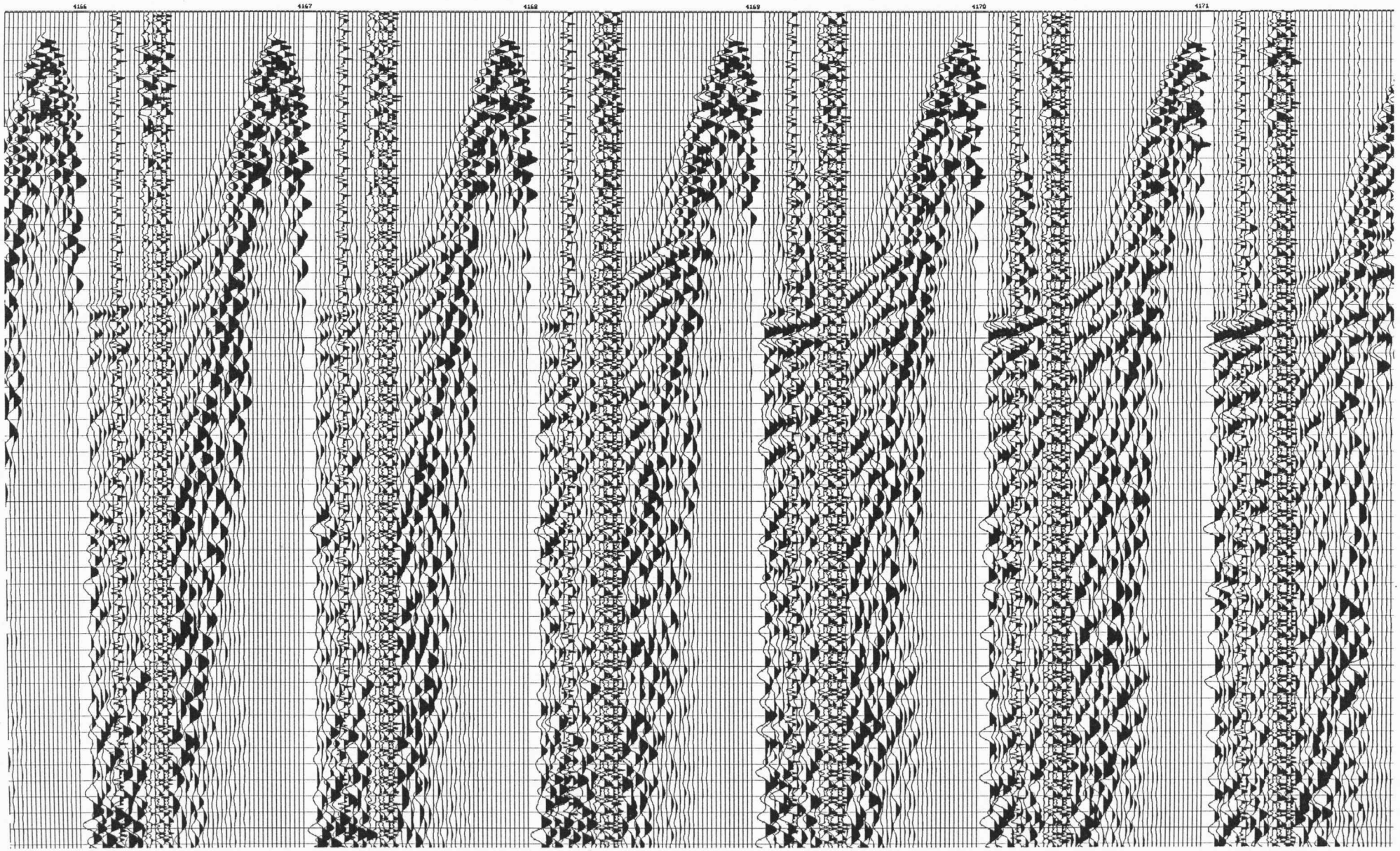
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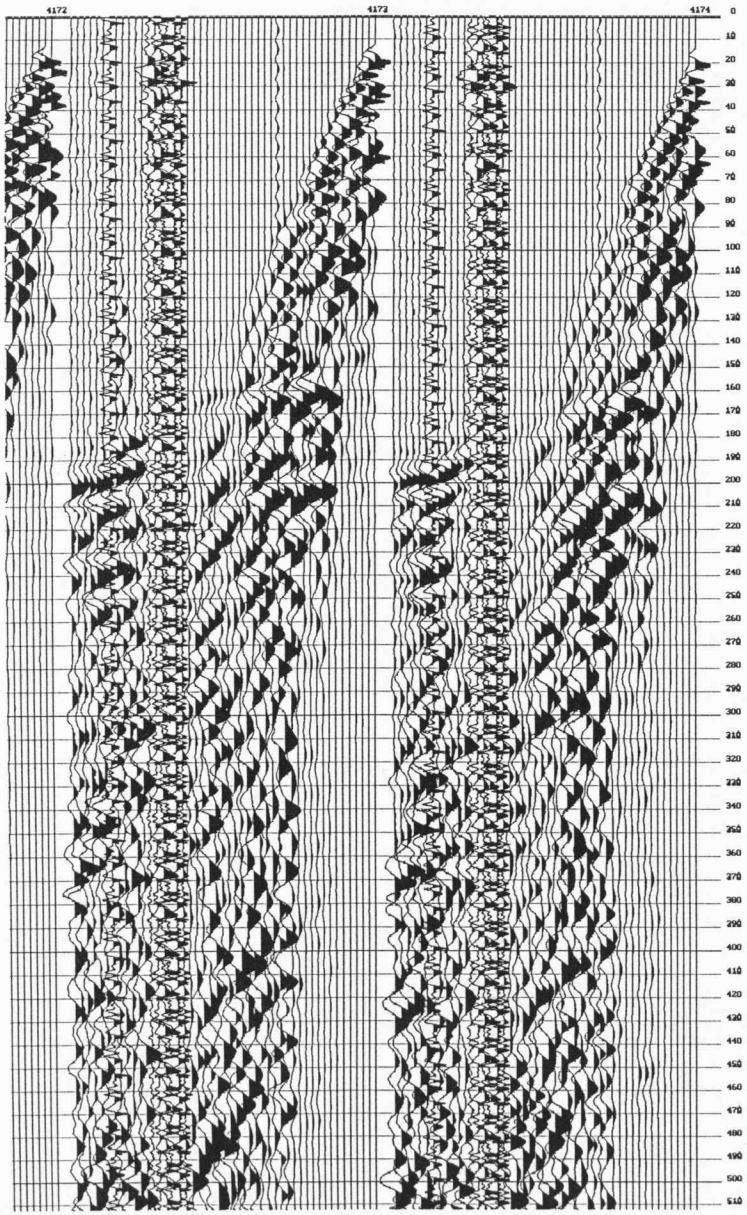
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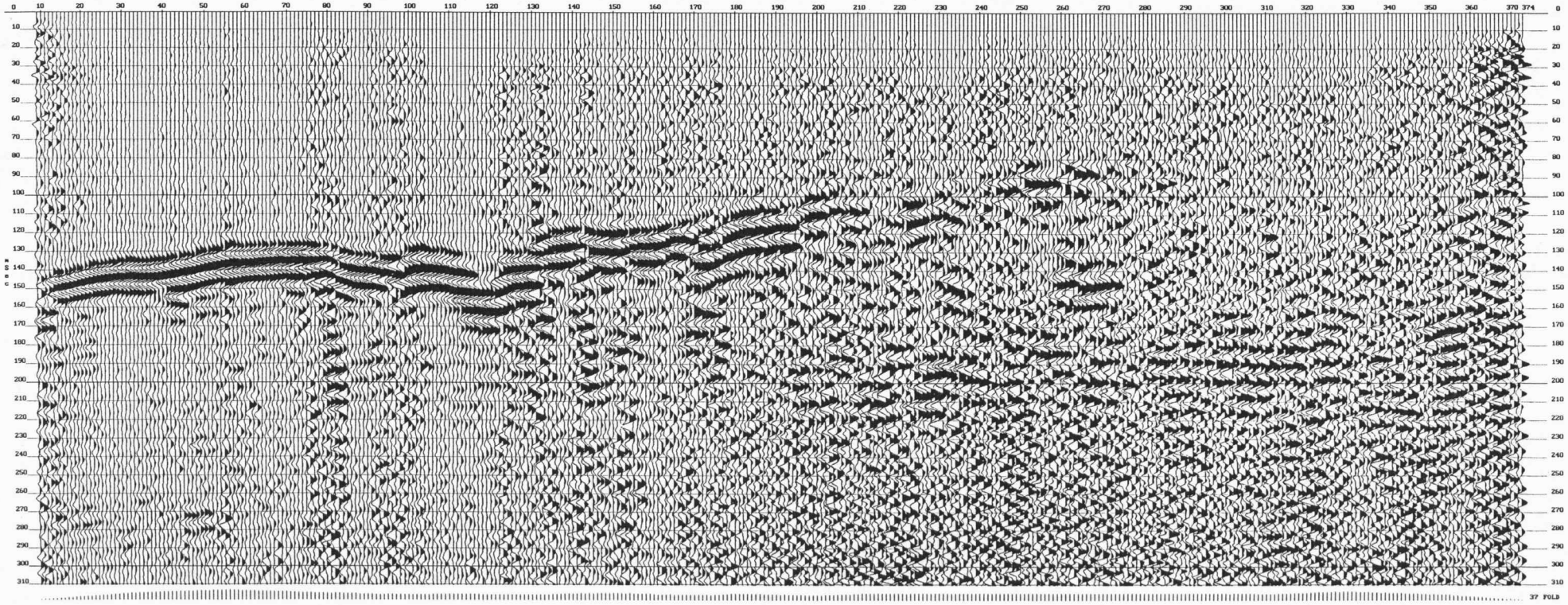
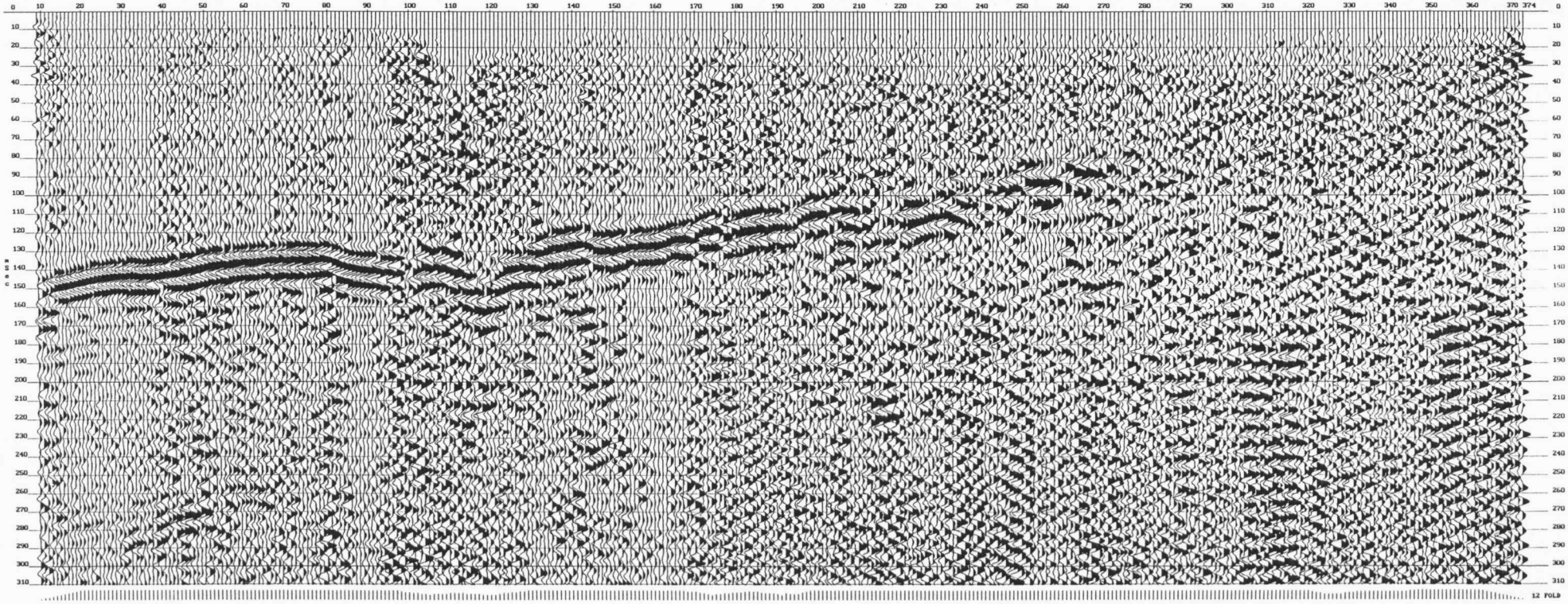
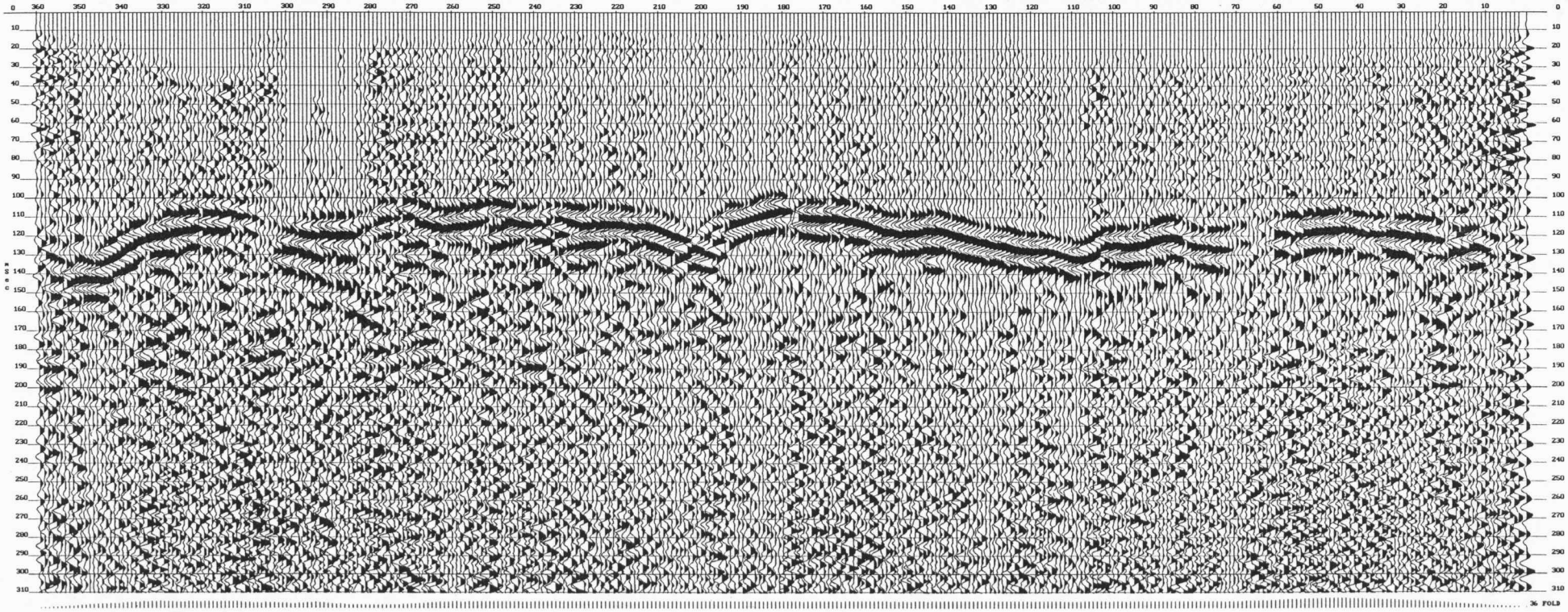
Appendix B. Line 1a



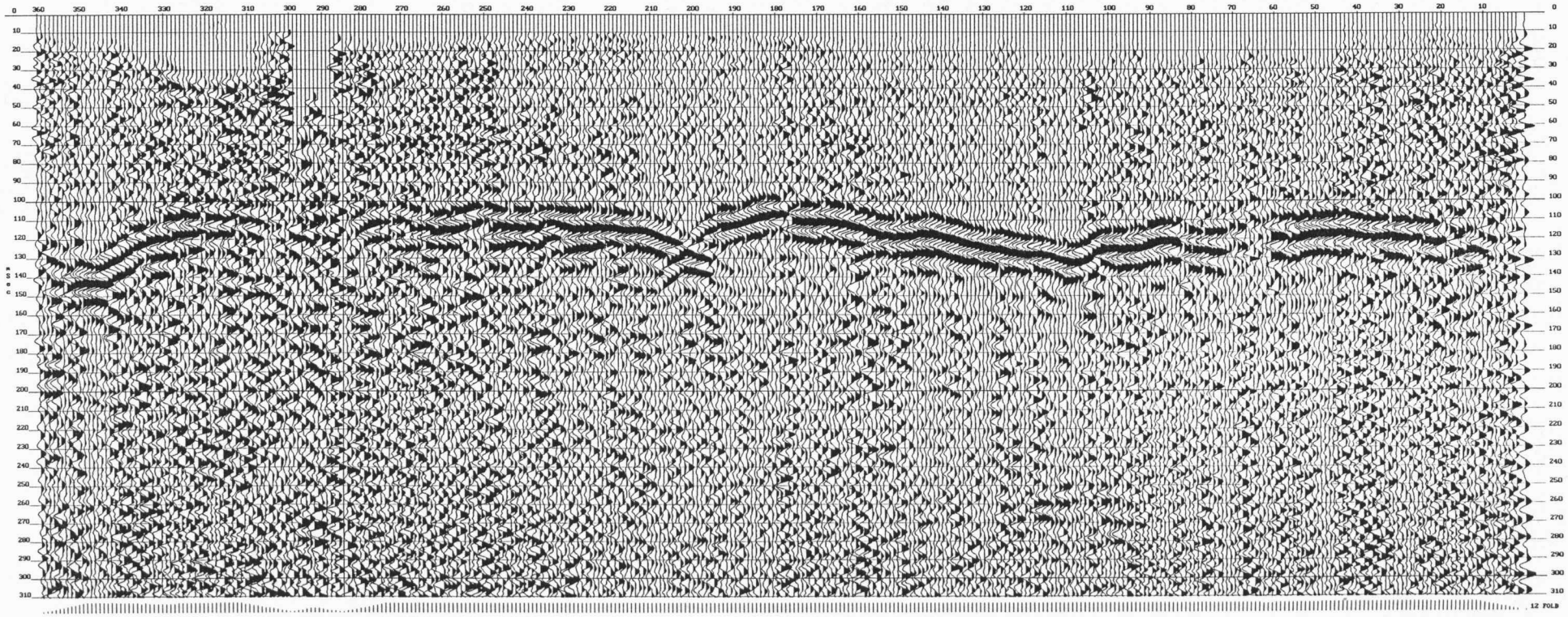
Appendix B, Line 1b



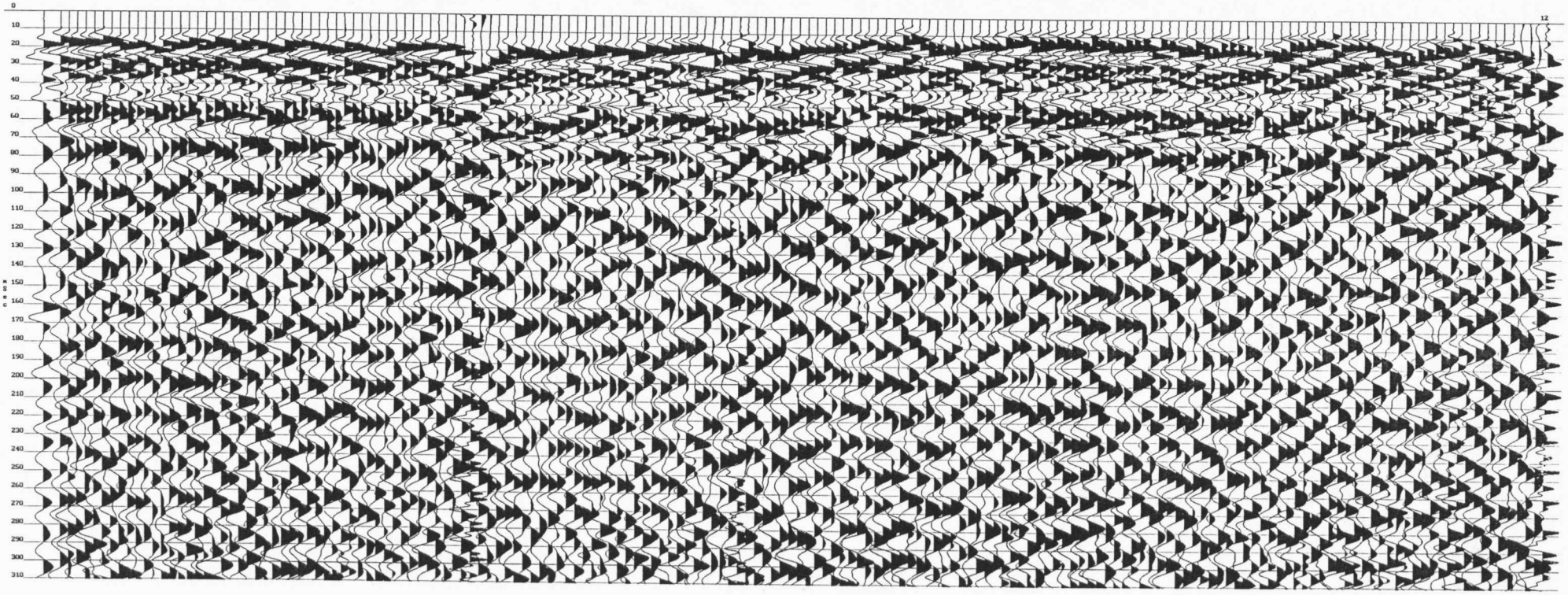
Appendix B, Line 4a



Appendix B, Line 4b



Appendix C, Line 1
Common offset gather
12 ft.



Appendix C, Line 1
Common offset gather
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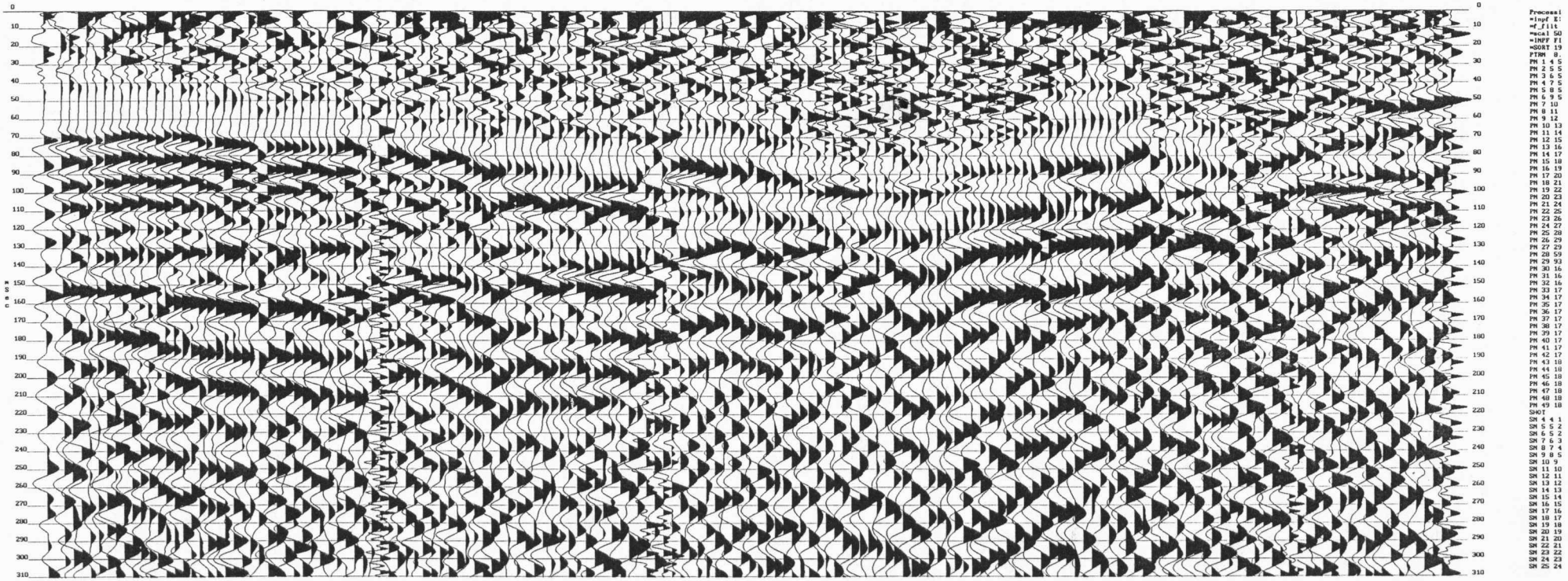

Appendix C, Line 4
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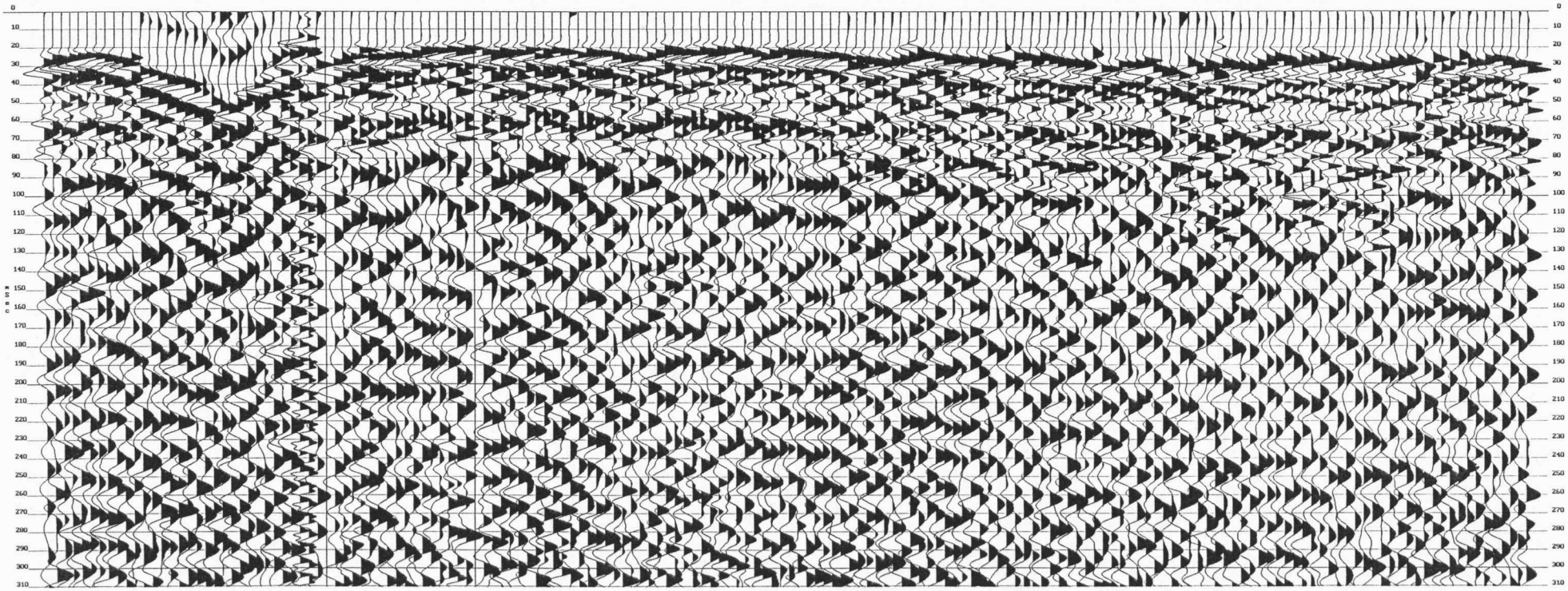

Appendix C, Line 4
Common offset gather
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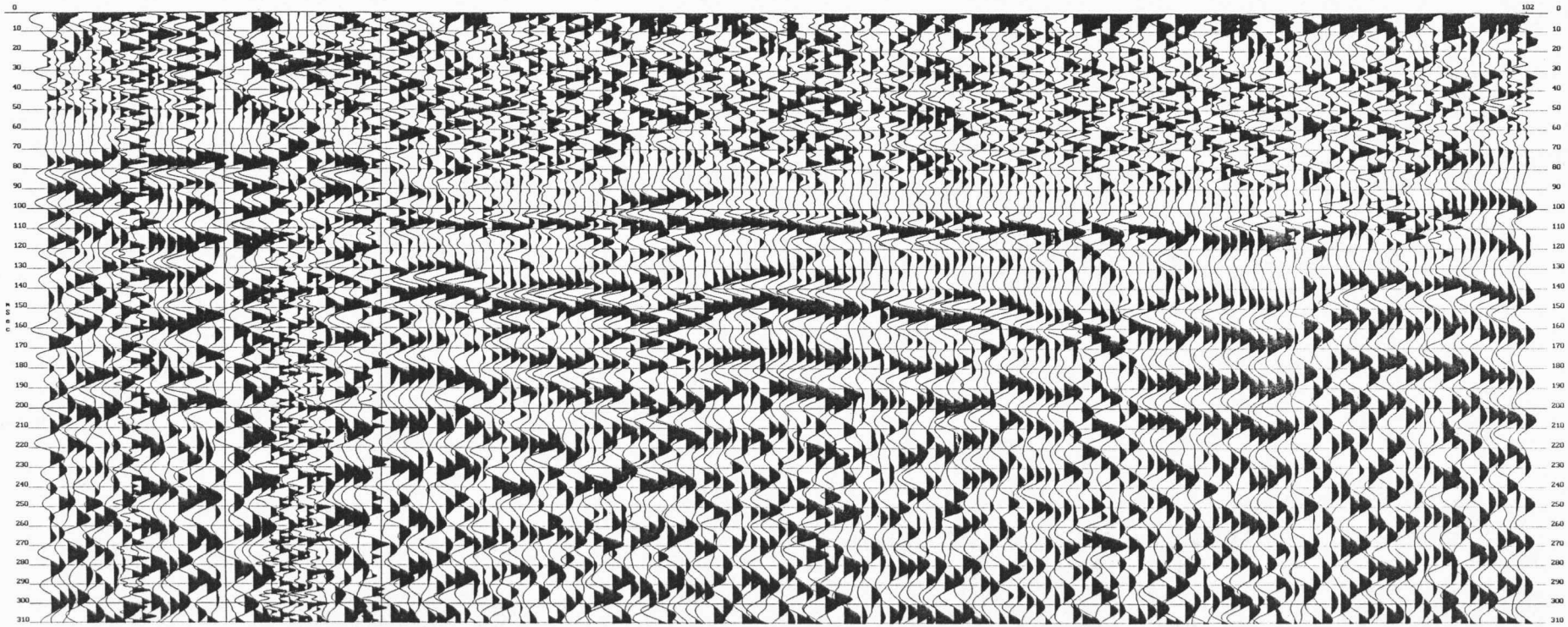


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