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HIGH RESOLUTION SEISMIC SURVEY, RAWLINS WYOMING

UNDERGROUND COAL GASIFICATION AREA

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**HIGH RESOLUTION SEISMIC SURVEY
RAWLING, WYOMING
UNDERGROUND COAL GASIFICATION AREA**

Final Report

**By
A. D. Youngberg, E. Berkman, and A. S. Orange**

January 1983

Work Performed Under Contract No. : DE-AC20-82LC10932

**For
U. S. Department of Energy
Laramie Project Office
Morgantown Energy Technology Center
Morgantown, WV**

**By
Emerald Exploration
Consultants, Inc.
Austin, TX**

**TECHNICAL INFORMATION CENTER
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HIGH RESOLUTION SEISMIC SURVEY OF THE RAWLINS,
WYOMING UNDERGROUND COAL GASIFICATION AREA

By

Alv Dan Youngberg¹, Ernest Berkman², Arnold S. Orange²

ABSTRACT

In October 1982 a high resolution seismic survey was conducted at the Gulf Research and Development Company's underground coal gasification test site near Rawlins, Wyoming. The objectives of the survey were to utilize high resolution seismic technology to locate and characterize two underground coal burn zones. Seismic data acquisition and processing parameters were specifically designed to emphasize reflections at the shallow depths of interest. A three-dimensional grid of data was obtained over the Rawlins burn zones. Processing included time varying filters, trace composition, and two-dimensional areal stacking of the data in order to identify burn zone anomalies. An anomaly was discernable resulting from the rubble-collapse cavity associated with the burn zone which was studied in detail at the Rawlins 1 and 2 test sites.

I. INTRODUCTION

In October 1982 a detailed three-dimensional (3-D) high resolution seismic survey was conducted at the Gulf Research and Development Company's underground coal gasification field site near Rawlins, Wyoming. The objective of the seismic survey was to utilize high resolution seismic technology to investigate, locate, and characterize two underground coal gasification burn zones (Rawlins 1 and 2) created in an underground coal gasification project.

It was recognized that the specific problems addressed by this survey presented a considerable challenge to the geophysicist. The coal seams of interest outcropped in the area and were steeply dipping (55-70 degrees). The shallow depth of investigation, extreme dip, plus the resolution required if the information was to be of practical use, dictated a carefully planned and executed project.

The approach proposed was to apply state-of-the-art exploration seismic technology to the problem. A three phase program was planned and executed: high resolution data acquisition; reference to seismic models and synthetic seismograms from a similar geologic and physical situation; and a data processing approach designed to provide

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maximum resolution at the depths of interest. An interpretation scheme was applied to these three phases where through iteration between preliminary interpretation, processing, and modeling, the goals of the project could be best met.

This report is concerned primarily with presenting and discussing the seismic data obtained. Prior to presenting the results, sections are included which summarize the geology of the area and describe field operations and data processing.

II. LOCATION AND REGIONAL GEOLOGY

The study site as shown on Figure 1 is located 8 miles (12.9 km) west of the town of Rawlins, Wyoming in the southeastern quarter of section 11, T21N, R89W. Topography at the site is gently rolling grassland with over 6 ft. (2 meters) of soil on the surface.

The site is located on the western flank of the Rawlins Uplift which separates the Hanna Basin from the Great Divide Basin. The extreme dip seen at the test site is the result of Laramide tectonic movement which caused the Rawlins Uplift. The data indicates that some relatively small scale folds or warps are present which tends to complicate the seismic interpretation. Formation dips decrease gradually with depth and are anticipated to be approximately 45 degrees at a depth of 1500 ft. (457 meters).

The Rawlins test site area contains surface outcropping beds of the Tertiary (Paleocene) Fort Union Formation, and the Cretaceous Medicine Bow, Lewis Shale, and Mesaverde Formations. The Fort Union Formation contains the coals of interest in its middle member which is approximately 1000 ft. (305 meters) thick. This member is composed of alternating sandstones, silty sandstones, and both gray and carboniferous shales. The three major coal seams of interest, from top to bottom are the Wally, G, and I, with thicknesses of approximately 7, 20, and 15 ft. (2.1, 6.1, and 4.6 meters) respectively. The gasification tests and main concern of the seismic survey involve the G seam. There are thin coal stringers (benches) above and below the G coal seam separated by shale partings. The lower member of the Fort Union Formation is approximately 1500 ft. (457 meters) thick and contains coarse grained sandstones and conglomerate with a highly calcareous coarse grained matrix. Although many beds are laterally consistent, others have significant lateral variations in thickness and lithology which tends to complicate the seismic interpretation.

The Medicine Bow Formation, which unconformably underlies the Fort Union Formation, consists of a thick section (approximately 4500 ft. (1372 meters)) of alternating beds of sandstone (medium to fine grained), silty sandstone, shale (occasionally carboniferous), and coals. Of most concern for the seismic study, the top 1600 ft. (488 meters) consists of mainly shale beds. This zone is recognizable in the seismic data as a zone containing virtually no reflections immediately below the zone of interest.

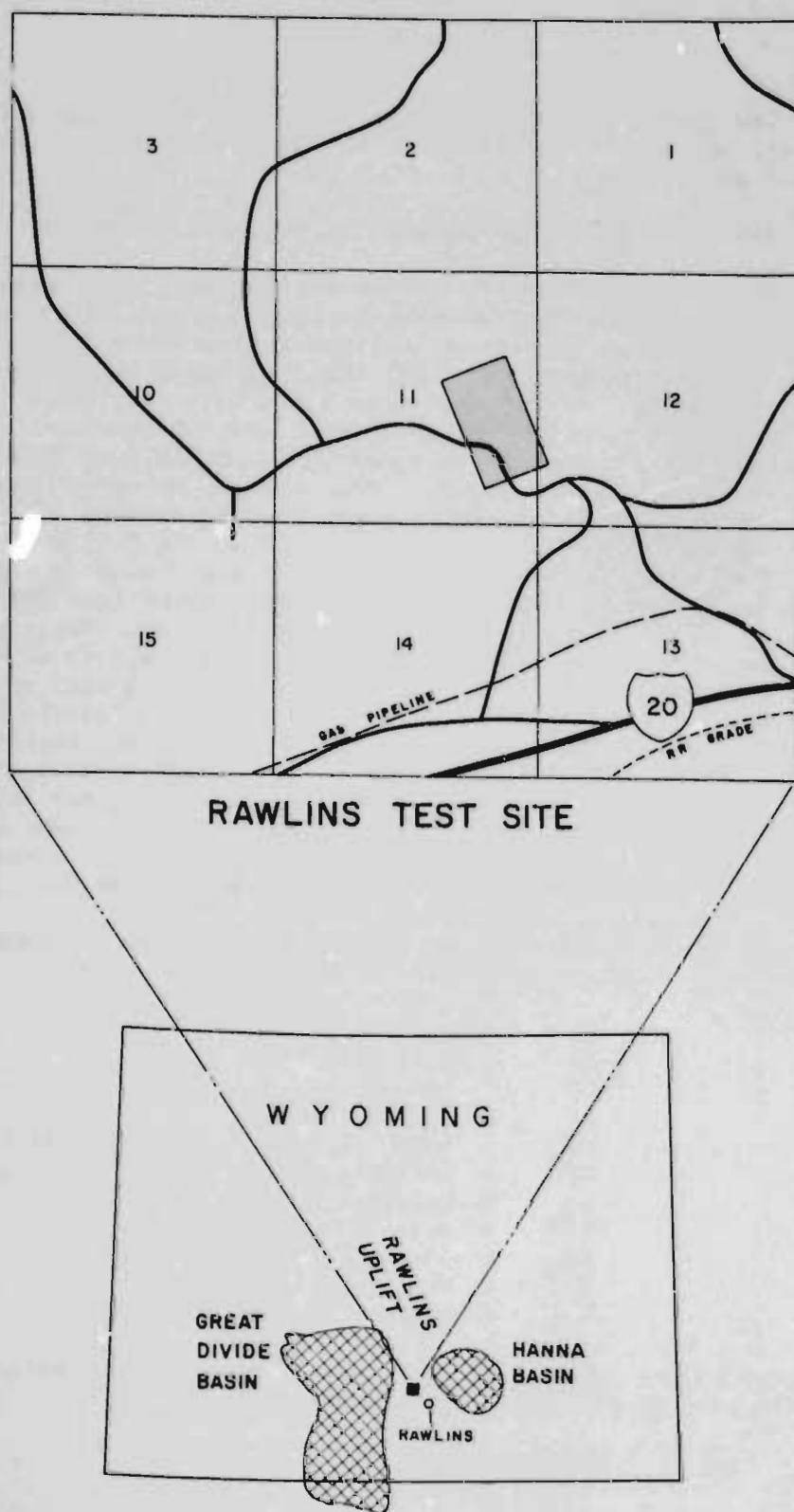


FIGURE 1. Location map of the Rawlins UCG site.

The Lewis Shale and Mesaverde Formations, although outcropping in the area, are sufficiently deep in the section to be of no concern to the seismic survey.

III. RAWLINS 1 AND 2 UNDERGROUND COAL GASIFICATION TESTS

The coal gasification method utilized at the Rawlins Test 1 and 2 sites consisted of the in-situ burning of the coal through use of air, oxygen and steam injection, and gas production wells. The burn initiated at the injection well, and the flame front progressed toward the production wells. As the coal burned, a cavity was formed which was enlarged as the overlying rocks fractured and collapsed. In steeply dipping beds, as the coal is consumed new coal falling from the top tends to fill in the void space. This concept is supported by drill hole data, and no subsidence has been noted on the surface.

The burn cavity at Rawlins Test 1 was thought to presently contain a small water-filled void at the top, rubble from the collapse of overlying rocks, "slag or clinker" at the base, and a zone of "char" at the edges of the burn zone. Figure 2 generally depicts this zone of interest. The burn cavity at Rawlins Test No. 2 was thought to presently contain a small air void at the top, and a similar configuration beneath. It should be noted that although corehole HFEM 2-9 at Rawlins Test 2 encountered 28 ft. (8.5 meters) of air void, most coreholes did not encounter any air void. From the standpoint of the seismic interpretation this presented a serious problem, because the presence of an air void generates a strong reflection which has been found in the past to be very useful in characterizing the post-burn configuration.

On the subsequent maps various drill holes of interest are shown; the identification code is as follows:

H	=	water monitoring
IW	=	instrument well
CH	=	core hole
E	=	exploration
HFEM	=	high frequency electromagnetic monitor
EXT	=	extensometer
T	=	thermocouple
VIW	=	vertical injection well
SIW	=	slant injection well
VLW	=	vertical link well
PGW	=	product gas well

The seismic survey correlated with drill holes listed below. Other drill holes have been added from various support material.

Rawlins Test No. 1

H-16
H-17
H-18
T-1

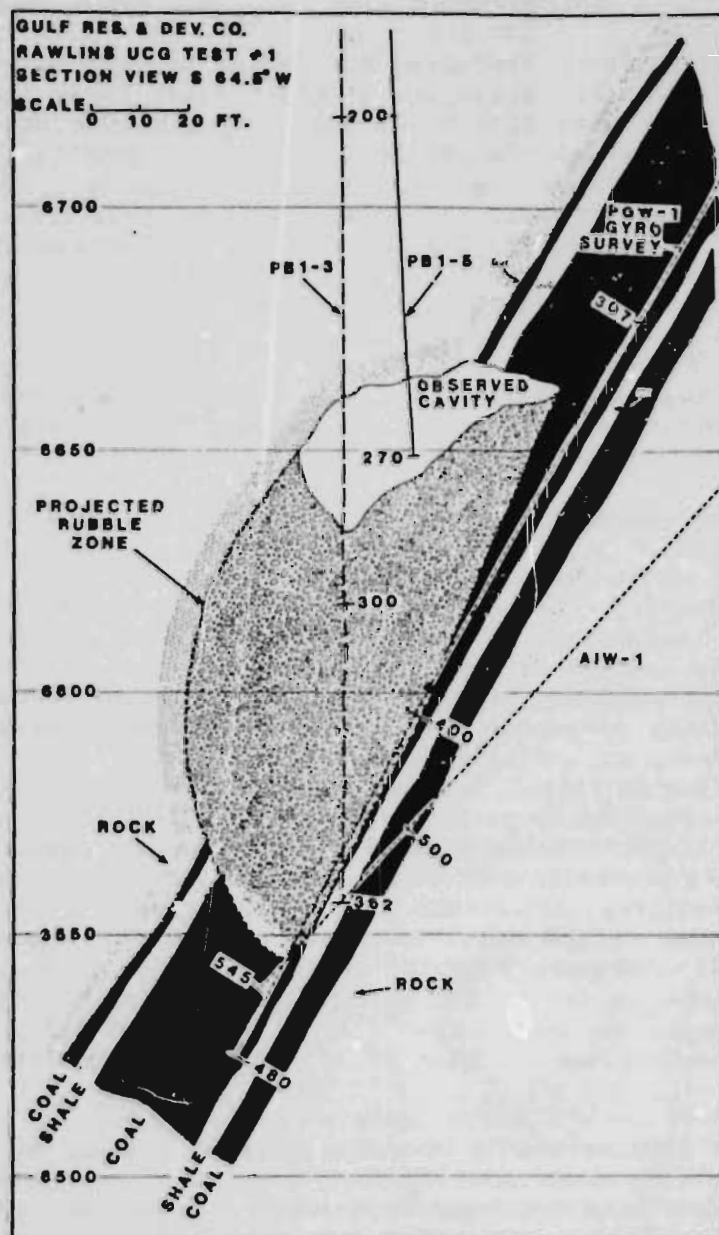


FIGURE 2. Burn zone configuration for Rawlins UCG Test No. 1.

Rawlins Test No. 2

H-21
EXT-2-3
HFEM-2-10
HFEM-2-8
EXT-2-1
HFEM-2-2
HFEM-2-1
HFEM-2-7
VLW-2-3
CH-232
VLW-2-2
EXT-2-2
H-20
H-22
H-19

It should be kept in mind that the various maps show the surface location of the drill holes, all of which have up-dip bottom hole locations due to the extreme dip.

IV. FIELD PROCEDURES

A. Introduction

The following is a very brief explanation of the seismic method as used in exploration. The fundamental principal of seismology is that when an acoustic (seismic) wave is propagating through the earth and the acoustic properties of the earth materials change, then the interface between the differing materials will act as a partial reflecting surface (Dobrin (1976), Telford (1976), Waters (1978)). The amplitude of the reflection is proportional to the change in acoustic properties. Since many of the interfaces between geologic formations involve changes in rock properties, if an acoustic wave can be launched into the earth, the resulting reflections from the interfaces can be utilized to locate and identify the units involved. Further, if a series of such reflections is observed along the surface, then changes in the travel time of the wave to the reflecting horizon and back can be used to map changes in depth to the horizon. Thus, an abrupt lateral change in physical properties can be detected as a change in the reflection waveform.

The application of the above simple concept to practice is complex, involving many sophisticated steps developed over the years. Instruments have been developed with large dynamic range that have the capability of recording signals (reflections) that are both extremely weak and extremely strong. The sensors themselves (geophones) are small, electrically stable, and capable of sensing the minute motions of the earth's surface caused by the arriving reflections while being rugged for field use. The use of geophone and source arrays (patterns) improve the signal-to-noise ratio, while a variety of sources are available to handle different surface and subsurface conditions.

Current practice is to record each shot (or, more precisely, the reflections from each shot) on several channels (termed "traces") simultaneously, with the sensors for these traces usually placed in a linear array on the ground. Each trace in turn may be made up of several geophones connected together and arranged on the ground so as to improve the signal-to-noise ratio. Each trace is digitized and recorded on tape separately for later computer processing.

The Rawlins survey was performed and the data processed using the Common Depth Point (CDP) method, which is summarized as follows: Figure 3 is a sketch of a unilateral 4 channel seismic survey. Shot number 1 is fired with the shot at SP1 and the geophones at positions 2 through 5 as shown. A through D are the subsurface reflection points from a reflective surface, using the ray path relationship that the angle of incidence equals the angle of reflection. For shot number 2 the whole array is moved one position, shooting at SP2 and receiving at positions 3 through 6. Subsurface reflection points are seen to be C through F. Shots 3 and 4 follow in the same fashion. It is seen that each subsurface point is sampled with two shots ("C" and "D" with shots 1 and 2, "E" and "F" with shots 2 and 3, etc.), hence this is called "Two Fold". In CDP processing, the data from shots that reflect off of "common depth points" are added together, or "stacked".

Consider the two shots that reflect off of common depth point "G", shot at 3, geophone at 6 and shot at 4, geophone at 5. The ray path 3-G-6 is much longer than ray path 4-G-5. This path-length difference forms the basis for seismic velocity determination which is the major strength of the CDP method.

The field procedures for the Rawlins project will be reviewed in detail in the following paragraphs.

B. Instruments*

The instruments used were Texas Instruments DFS-V. Sampling rate was 1 ms to allow data analysis to a frequency of 250 Hz. Filter settings were 27 Hz low cut and 256 Hz high cut, with an 18db/octave slope outside the filter bandpass. One second of data was recorded for each shot. Geophones used were Mark Products MP-L-28E with a nominal 40 Hz low frequency rolloff point.

C. Survey Parameters

It was mentioned in the introduction to this report that the Rawlins seismic project was unusual from the exploration geophysics standpoint in the shallow depth and extreme dip of the target, and the unknown nature of the seismic response of the burn zone. The survey field parameters were designed with these considerations in mind and departed somewhat from normal exploration seismic practice in the attempt to define the burn zone.

*Use of specific equipment does not constitute a recommendation by DOE.

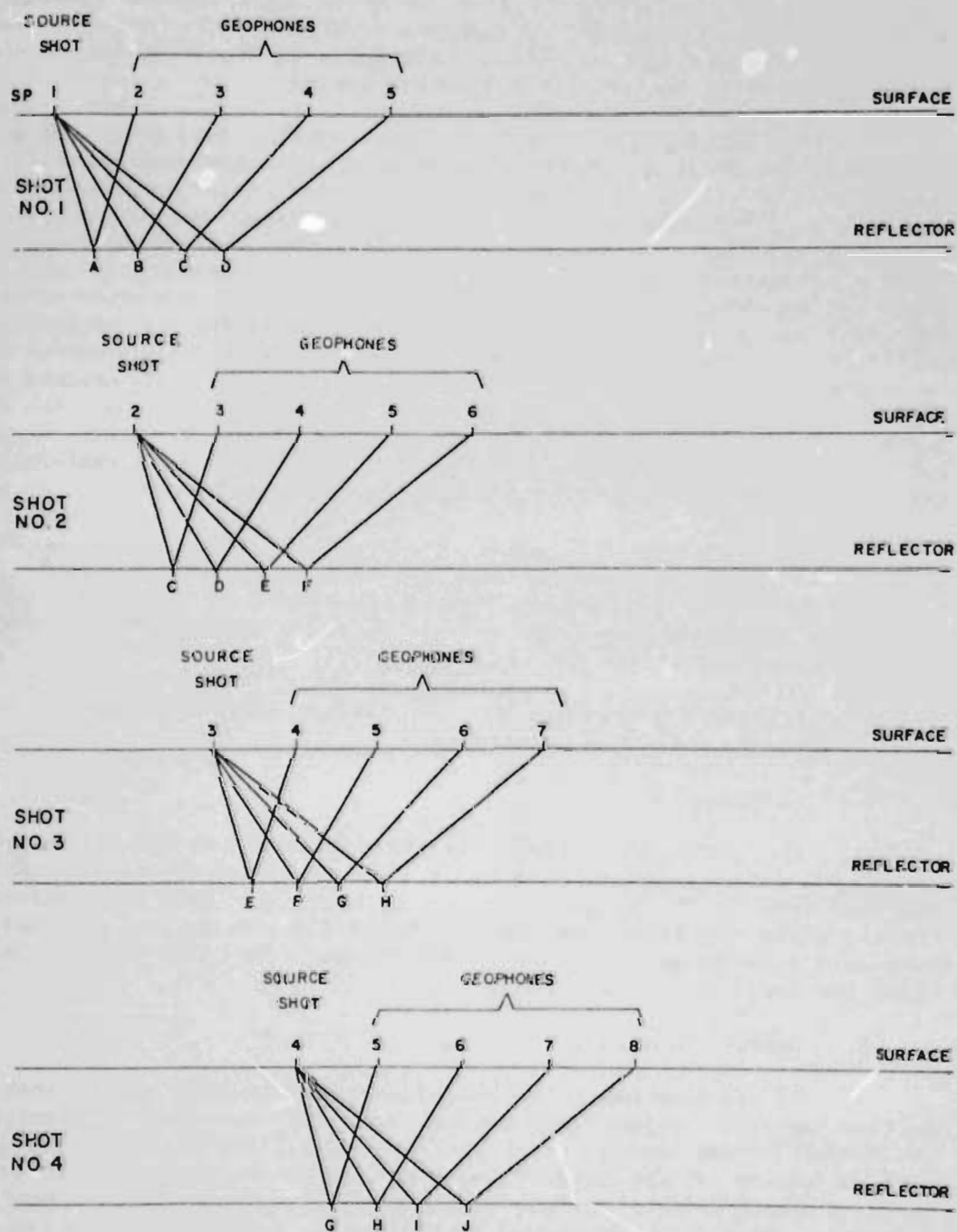


FIGURE 3. Simplified sketch of seismic geometry.

Figure 4 is a plan view of the geophone-shot hole geometry over the burn. For this three-dimensional (3-D) grid, the numbered lines each consist of 36 short, 12 ft (3.7 meter) geophone arrays spaced 20 ft (6.1 meters) apart. The lettered lines consist of 46 shot points, also spaced 20 ft (6.1 meters) apart. As the charges on each lettered line were shot in turn the reflections were recorded on the two geophone lines flanking the shot line. Thus, shots on line A were recorded on lines 1 and 2, shots on line B were recorded on lines 2 and 3, etc. Note that geophone lines 2 through 8 were used twice, once each for the shots on either side of the lines. The system utilized was to shoot at sequential shot points as required for 24 fold into a stationary 24 trace cable; then move the cable and repeat. This required some additional shots on each line but allowed for rapid completion of the field work by minimizing cable and geophone movement. Data for the appropriate recording sequences was utilized in processing each line, as will be discussed under Data Processing, section V, of this report. Note also that the reflection (CDP) points lay along subsurface lines midway between the shot and receiver lines (see Figure 5).

The burn area line geometry accomplished two things. First, it provided a high density of areal data in the burn zone, the zone with the most unknowns. Second, the array of data allowed great flexibility in the subsequent processing effort.

The 20 ft (6.2 meter) trace spacing was selected to give a close subsurface CDP reflection point spacing [10 ft (3.05 meter)] while still remaining cost-effective. The geophone array (6 phones) over 12 ft (3.7 meters) was selected as a compromise between the desire for a long array for noise reduction (by cancelling waves traveling along the surface) and the desire for a short array to provide maximum resolution.

The survey parameters used for the data acquisition are tabulated below:

Number of geophones per trace	6
Geophone array	12 ft (3.7m) centered on SP
Trace spacing	20 ft (6.1m)
First trace (offset)	20 ft (6.1m)
Shot spacing	20 ft (6.1m)
Fold	(Fold for this project will be discussed in detail below.)

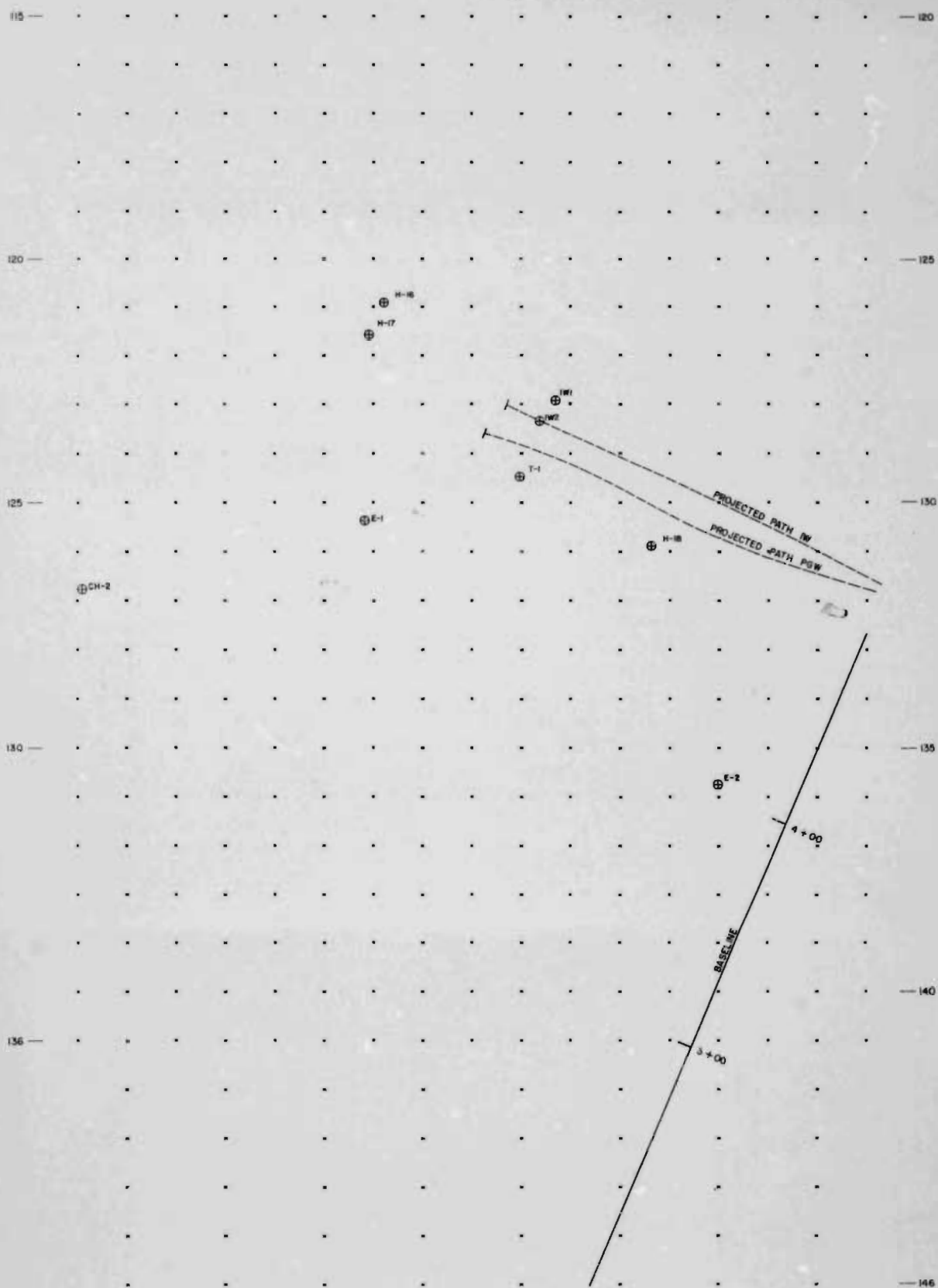
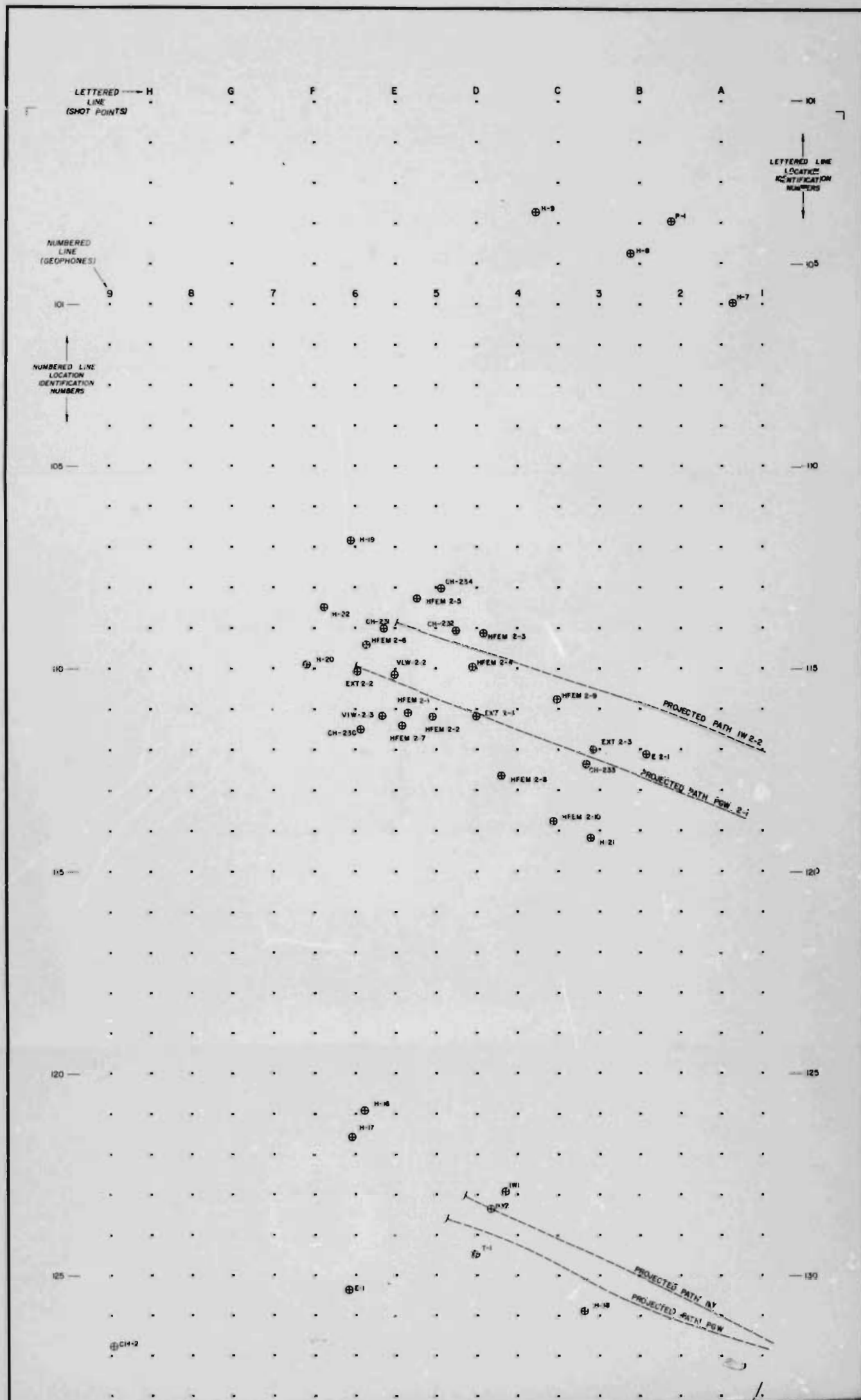


FIGURE 4
LARAMIE ENERGY
TECHNOLOGY CENTER
U.S. DEPT. OF ENERGY

GEOPHONE-SHOTHOLE
GEOMETRY

Intercepted by: E. BERMAN Date: 12/81
 Drawn by: J. WALKER Date: 12/81





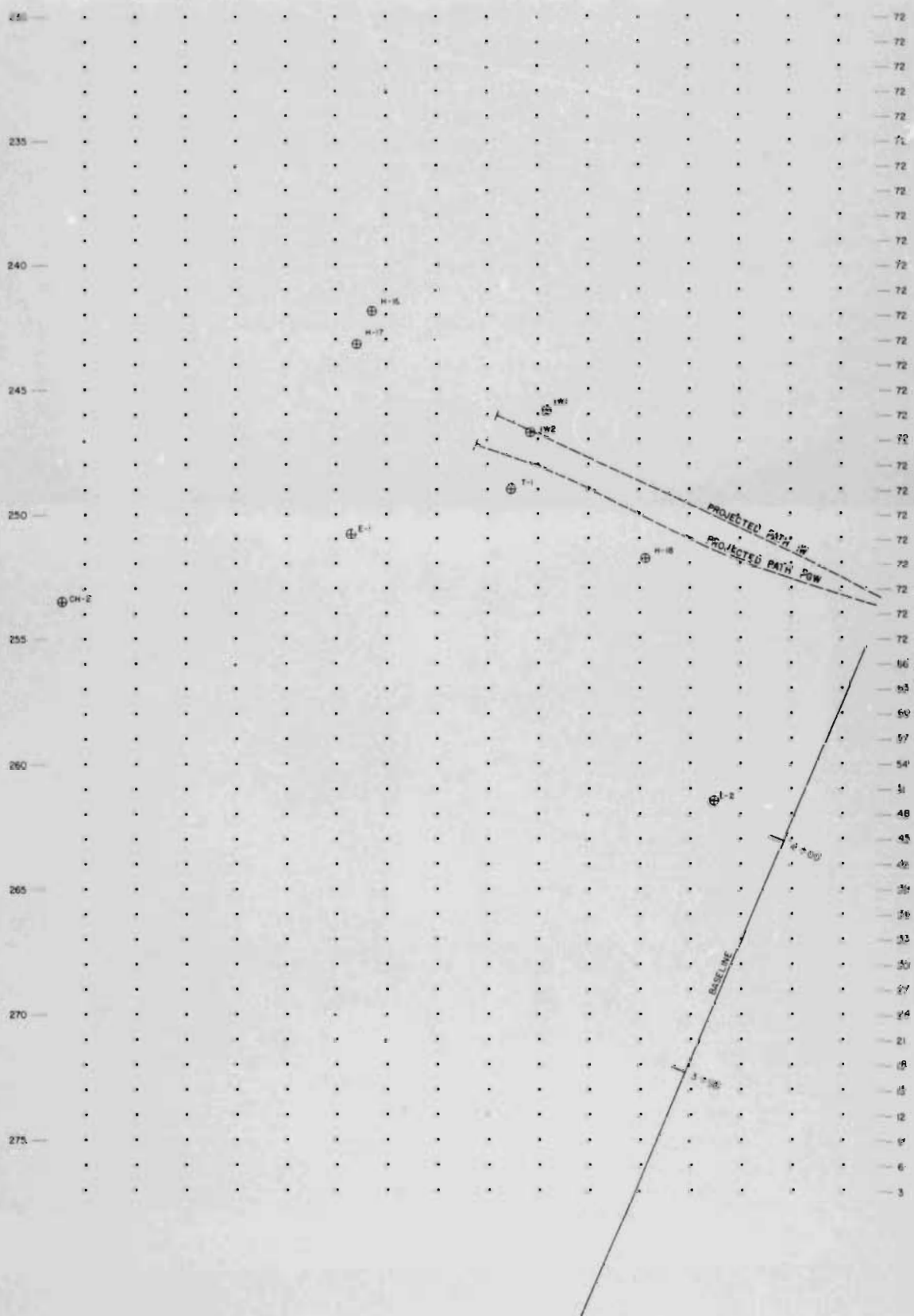


FIGURE 5
LAPORTE ENERGY
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LOCATION MAP
SUBSURFACE LINES

Interpreted by E. J. H. M. N. Date 12/82
 Drafted by J. M. N. E. S. Date 12/82

Shot size	6 to 18 units of Detaprime* (plastic explosive, unit weight .04 lbs (18 gms))
-----------	---

Shot depth	6 ft (1.8m)
------------	-------------

The fold, the sum of the number of shots at each subsurface reflection point, is the key parameter in CDP shooting, as described above. For these lines the fold was variable, reaching full fold over much of the line as indicated on Figure 5. Note that full fold was extended by placing shot points beyond the limits of the geophone grid (Figure 4). The fold was then further increased through use of computer manipulation and making use of the two-dimensional array of data obtained over the grid described earlier. The computer enhancement of the fold will be discussed fully in section V, Data Processing.

D. Source Parameters

Initial visual examination of the prospect site indicated that shallow 6-10 ft. (1.8-3.1 meter) Detaprime plastic explosive shots installed using a lightweight auger would be applicable to the surface conditions. Tests were performed in the field at the start of the data acquisition to determine optimum charge size. The charge needed to have sufficient energy to give adequate reflections, but not be so strong so as to result in shot-generated noise that would interfere with observations of the reflections. The shot size determined in the field was 9 units of Detaprime. The shot consisted of a standard cap with the plastic explosive wrapped around the cap. As the work progressed the charge size was modified as required.

Shot Line	Charge Size (units of Detaprime)
A	18
B	18
C	18
D	6
E	6
F	6
G	6
H	9

E. Field Operations

The Rawlins high resolution seismic survey was performed on October 10-12, 1982. No problems in the field were encountered, and field operations proceeded rapidly and uneventfully.

*Use of specific equipment does not constitute a recommendation by DOE.

V. DATA PROCESSING

This section of the report will discuss the processing of the seismic data and will include discussion explaining the reasoning behind the choices of processing parameters (Claerbout (1976), McQuillan (1979), Robinson and Treitel (1980)). It is important to note that the development of the processing sequence was an integral part of the interpretation. Each processing step was tested in sequence, and intermediate results were examined carefully with the goals of the processing in mind, in this case the maximum resolution of the geologic horizons at the depths of interest.

Each step of the processing sequence will be discussed in detail. The processing sequence listed below is found as part of the title block on the furnished data sections. The title block also contains the field parameters and certain bookkeeping and plotting notes.

Processing Sequence

Step (1) - "Demux". This is a bookkeeping" step. The data are recorded in the field in a complex format with all 48 channels mixed (or multiplexed) on the digital tape. The "Demux" step demultiplexes the data, arranging the data within the computer memory on a trace by trace basis, ready for further manipulation.

Step (2) - CDP Gather. The CDP technique has been described earlier and summarized in Figure 3. The "CDP Gather" step takes, or gathers, all of the source - geophone pairs that relate to a CDP point and stores them together in preparation for further processing. As noted in the field procedure section, the recording sequence necessitated great care at this stage to gather appropriate source - geophone pairs. The field format is trace sequential single fold and is a "gather" where all of the traces for an individual shot are displayed separately, arranged in the same sequence as they were arranged on the ground. Editing is included in this step to allow removal of noisy or defective traces from the "CDP Gather".

The concept of datum is illustrated on Figure 6. The data must be adjusted for surface elevation changes along the section so that the geometric configuration of reflecting horizons will be portrayed accurately and not influenced by surface elevation changes. The 3-D grid was corrected to a single stage flat datum (6900 ft, 2103 meters) since elevations in the local area were essentially flat. Each trace is corrected or adjusted by a time equal to the difference in shot and geophone elevation above or below the datum. The "time = distance/velocity" formula is used to determine the correction, with the velocity chosen from a knowledge of the velocity of the near surface rocks or through empirical testing. In this case a velocity of 5000 ft per sec (1524 meters per sec) was used based on information obtained using the seismic data itself. On the sections, 0 time is at 6900 ft (2103 meters).

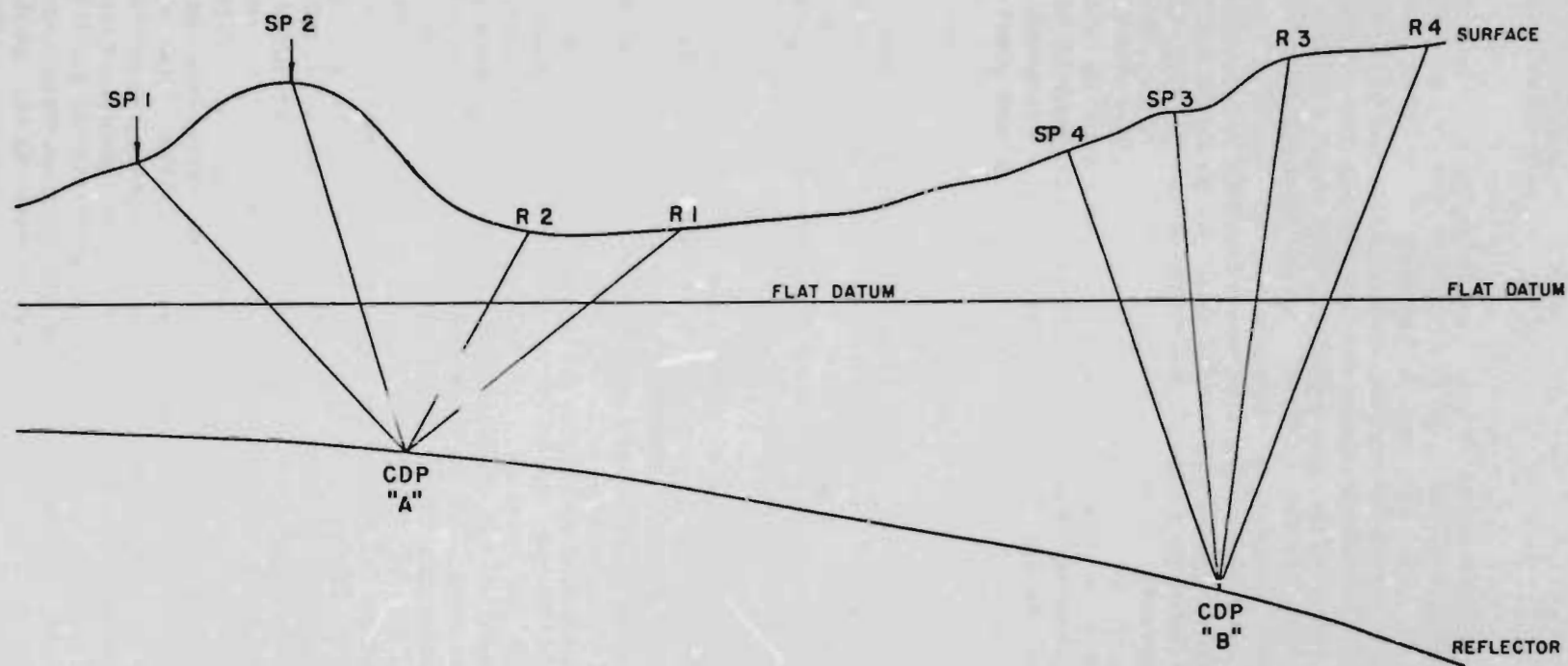


FIGURE 6. Datum correction

Step (3) - Gain Recovery. A " T^n gain" function was applied, which compensates for the energy loss as a function of distance (time) of the seismic wave as it propagates into the earth and back from the reflector. This energy loss is termed "spreading loss" since the energy in the spherical wave front is "spread" as the radius of the sphere increases. This loss is an exponential function; testing in this area indicated a value of 1.4 for n .

Step (4) - Filter. In this step a bandpass filter is applied to the data to enhance the reflections of interest by filtering out noise that is outside the frequency band that contains the majority of the reflection signal. The earth itself acts as a filter, with the lower frequencies penetrating further, for shallow reflections higher frequencies are present in the seismic data than for deeper reflections. Since high resolution at all depths was a requirement for this project, then it was desired to utilize the highest frequencies possible at each depth. The same record was subjected to a variety of bandpass filters, and the results analyzed. The results indicated that a "time variant" (TV) filter should be applied, as follows:

From .000 to .400 sec, bandpass = 80-160 Hz
.240 to .600 sec, bandpass = 50-100 Hz

The explosive detonation initially creates a sharp acoustic energy "spike" which propagates through the earth as described earlier. The filtering effect of the earth has the effect of broadening the short pulse into a lengthy, complex waveform. A processing step attempts to recreate the original sharp "spike" for each reflector by operating on the signal with the inverse of an assumed earth filter in a process called deconvolution. In practice the deconvolution operator, or inverse filter function, is chosen on the basis of experience and upon tests performed on the data and applied at this stage of the processing. Numerous tests were performed on this data. The testing involved the use of different operators and the sequence of applications, primarily whether before or after filter application. The deconvolution testing was performed on lines A-2 and H-9. Deconvolution testing was performed with second zero crossing, first zero crossing and spiking operators. No significant improvement could be detected with the application of deconvolution, therefore it was not applied.

Step (5) - Trace Composition (3 trace - common offset distance). It was recognized almost immediately that the reflections from the depth of interest were relatively weak, and that subtle variations in signal character would be difficult to discern. The concept utilized was that the reflections add linearly while the noise, being more random, partially cancels, thus increasing the signal-to-noise ratio. In order to improve the signal-to-noise ratio, three traces from three adjacent shots where the offset distance was equal were composited as shown diagrammatically in Figure 7. As seen on Figure 7, one result of the mixing is that instead of a CDP there is a "Common Depth Area" of 40 ft (12.2 meters) if the bed were flat. In the case of extreme dip the typical stacking sequence which assumes flat bedding encounters the same

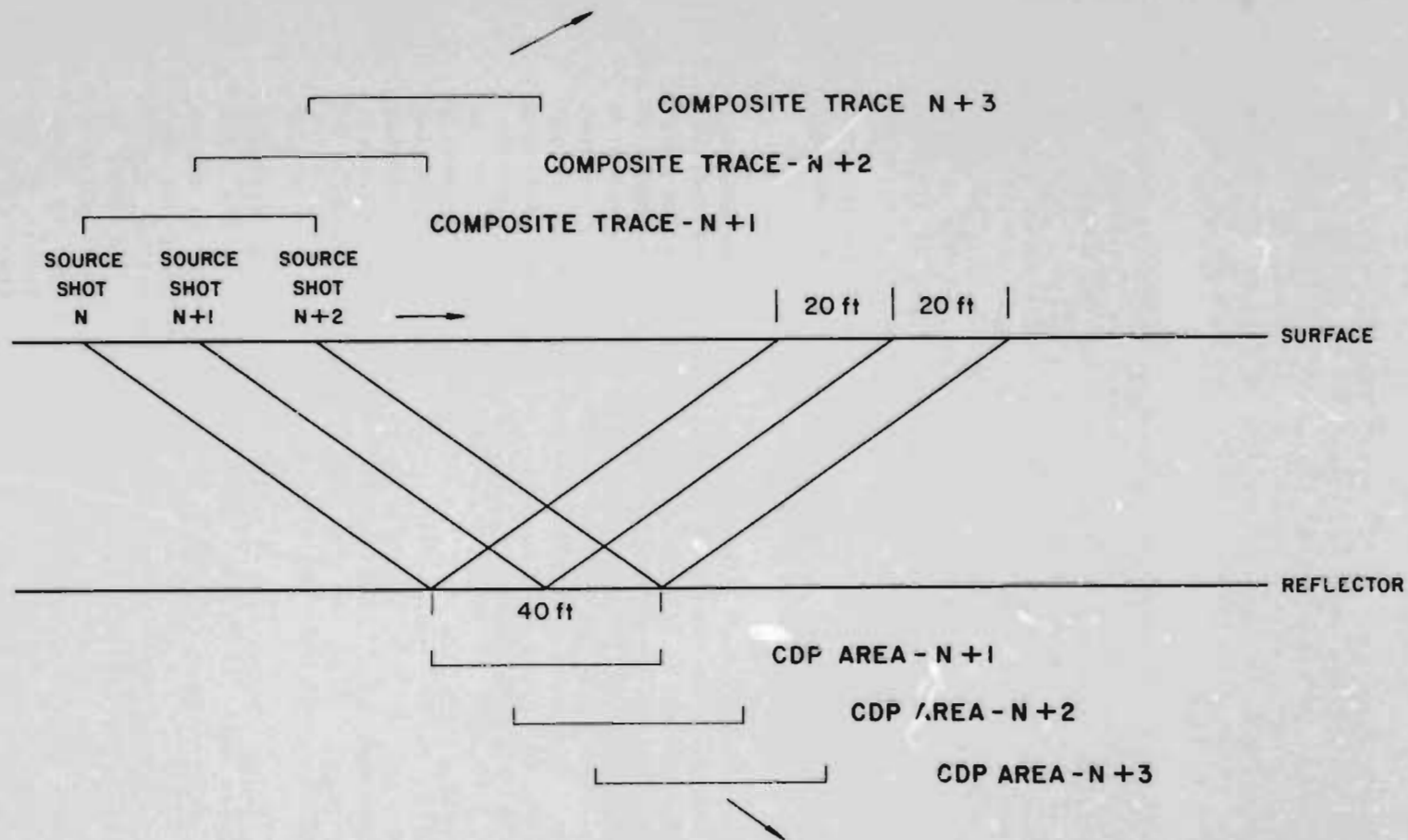


FIGURE 7. Three trace composition

problem of CDP areas instead of CDP points. Figure 8 demonstrates this effect which is caused by the fact that the angles of incidence and reflection must be equal. In the case of the Rawlins data where extreme dip is encountered, the CDP spreading effect of dip is countered by that of trace composition, which essentially corrects for the effect of dip in a qualitative sense. The trace composition essentially increased the fold from 24 fold to 72 fold in the center of the burn lines (Figure 5 shows the actual fold).

Step (6) - Velocity Analysis and Step (7) - "NMO". Consider the simple "CDP Gather" and resulting data display shown in Figure 9. Clearly, although both shots reflect off of the same point on the reflector, the ray path length from SP1 to R1 is considerably longer than the path length from SP2 to R2. This results in the time from shot to when the reflection is received t_1 from shot 1 being greater than the time t_2 from shot 2. If the reflections can be assumed as coming from the same point, then since the difference in time can be measured and the difference in path length determined geometrically, the average wave velocity of the rocks to the reflector can be estimated using the "velocity x time = distance" relationship. Since the seismic velocity varies as a function of depth (usually increasing) the average velocity varies as a function of time into the section. This variation is determined through a velocity analysis and the results are tabulated below:

Time (sec)	Velocity	
	(ft./sec.)	(m/sec.)
.000	5000	1524
.050	6200	1890
.100	7600	2318
.150	8300	2683
.200	9300	2987
.300	10500	3201
.400	11000	3353
.500	11500	3506
.600	12000	3658

The "NMO" or normal moveout, correction (Step 7) is applied as an adjustment to each component trace of the "CDP Gather", such that identical reflections occur at identical times on each trace (see Figure 9). This is required for a following step so that when the constituent traces of the "CDP Gather" are added, or "stacked", the reflections will add properly.

Step (8) - Mute. When a shot is fired, the first signals to reach each geophone are ground roll (waves propagated along the surface like ripples on a pond) and "first breaks", refracted energy from the most shallow high velocity interface. These "noise" signals mask reflections arriving at the same time. If the component traces of the "CDP Gather" are going to be added (stacked), then it is undesirable to add in this noise if present. Thus, the noisy, initial fraction of a second of each trace is removed, or muted. Since the farther traces receive the noise at a time later than the near traces, the mute applied to each

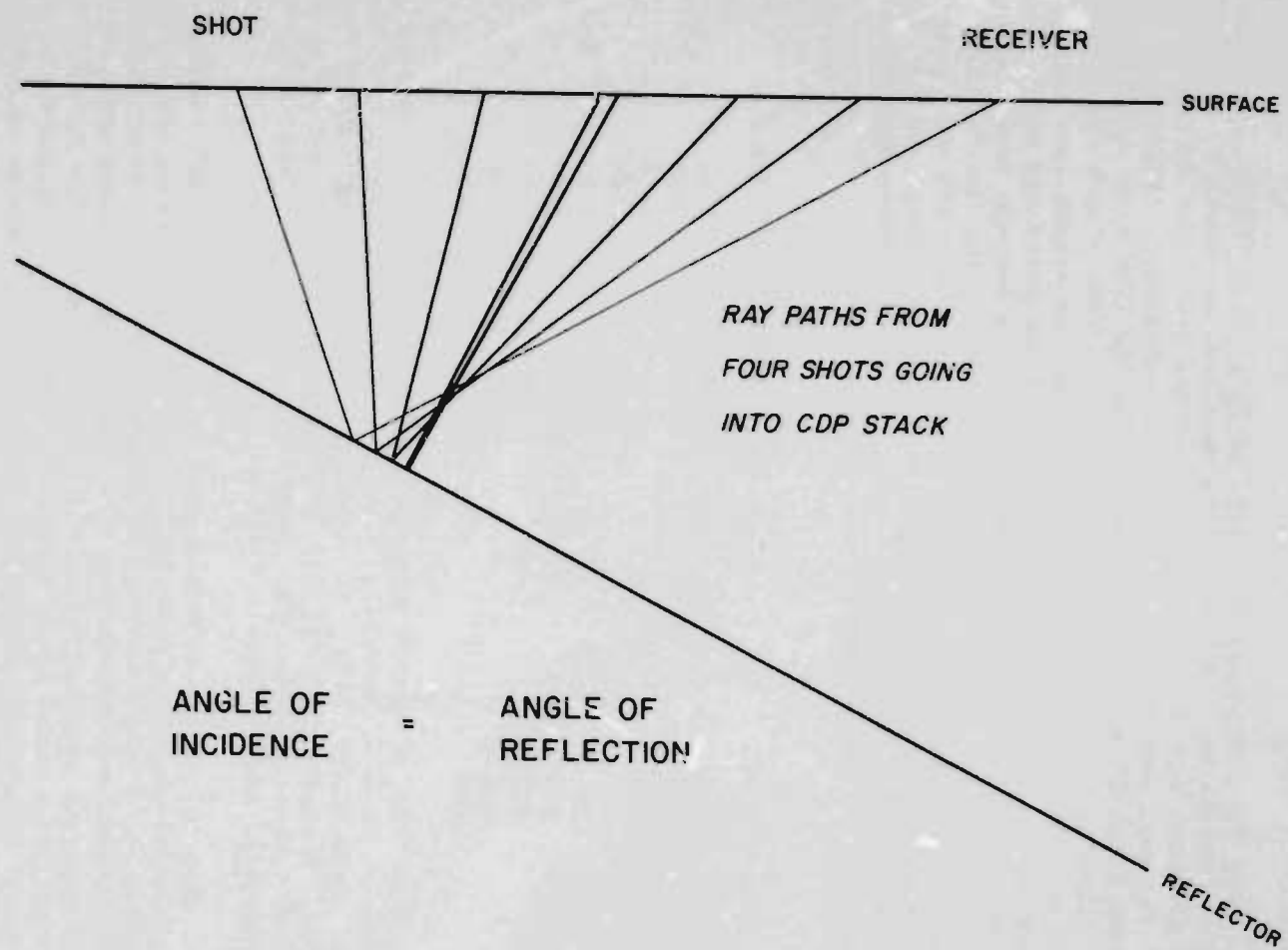


FIGURE 8. Effect of dip on CDP point

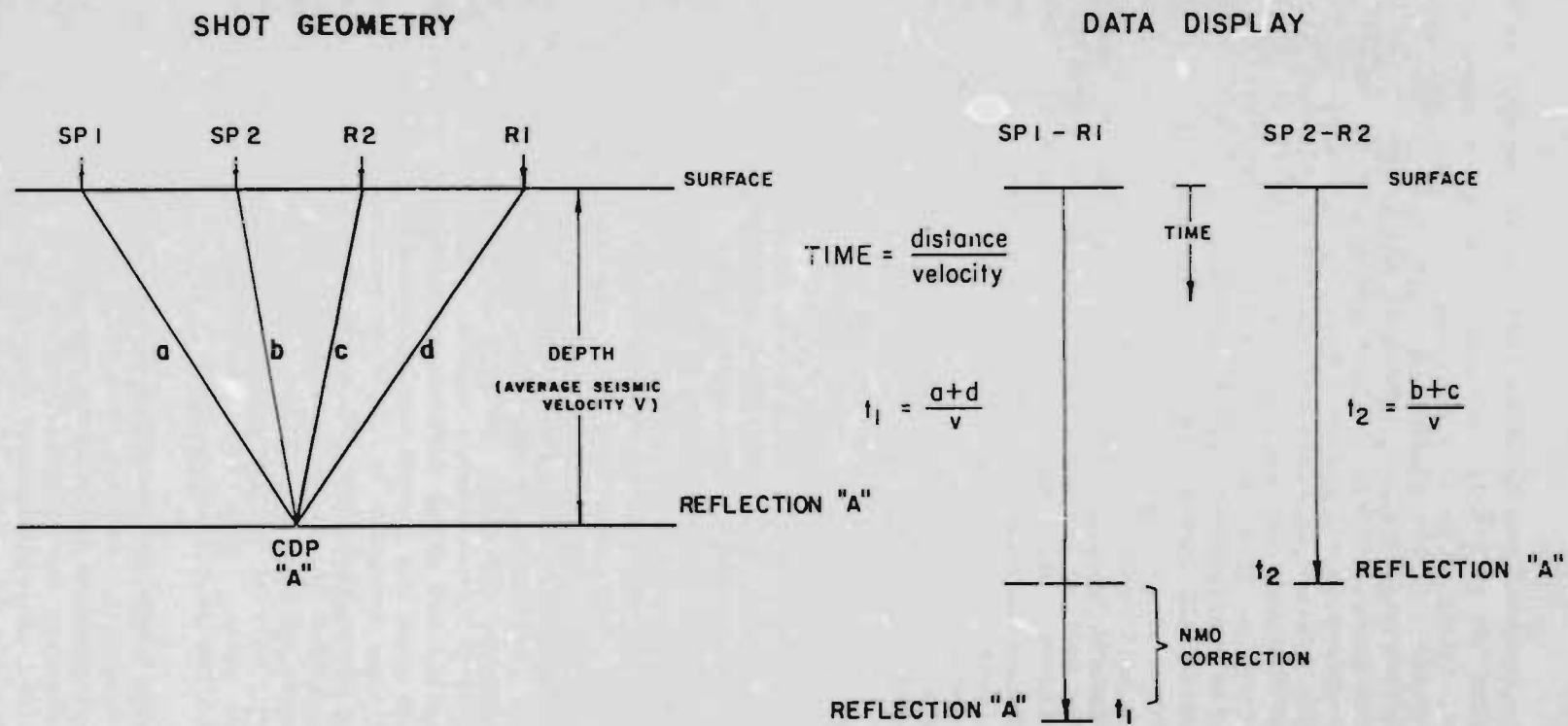


FIGURE 9. CDP Geometry and NMO correction

trace is a function of the location relative to the shot as well as the noise content of the signal.

Step (9) - Automatic Statics. In this step, which occurs immediately before stacking, or summing of the traces in the CDP Gather, a surface consistent residual statics correction is applied to ensure that the reflections on all traces are properly aligned and will sum for maximum benefit. Based on cross correlation of adjacent traces in the CDP Gather, reflections are corrected to line up so as to give maximum signal enhancement. This is called a statics correction since it is assumed that the misalignment (which is being corrected) is due to minor variations in the thickness and/or velocity of the near surface low velocity layer.

Step (10) - Stack. Stacking is the step of adding together the traces that make up the CDP Gather, to make one composite trace. If the static (datum) and dynamic (NMO) corrections have been applied correctly, the reflections will occur at the same time on each constituent and will be in phase and add numerically, while the noise will be of a random nature and will tend to cancel. The "fold" refers to the number of individual traces which have been added to yield the composite trace; 12 traces to make 12 fold, 6 traces to make 6 fold, etc.

Step (11) - Equalization. It was found that the " T^n gain" function (described in Step (3)) was inadequate to fully cope with the range of reflection strength over the short acoustic ray path distances involved. To further equalize trace amplitudes, amplitudes within a constant size "time window" were normalized. To some extent this compensates for the poor dynamic range of the plotting method and the human eye. A disadvantage is that some of the subtle natural variations in signal amplitude are reduced in the amplitude smoothing process.

Step (12) - Trace Composite for 3-D Areal Analysis. In addition to the trace composition, non-standard CDP Stacking was employed on the burn area. Referring to the plan view, Figure 5, the three-dimensional grid was divided into "boxes", 20 ft (6.1 meters), 40 ft (12.2 meters), and 80 ft (24.4 meters) square. Then, all of the CDP's within each box were stacked along reflection continuity. To accomplish this the reflection from the G seam was essentially flattened at 0.200 sec, stacked, and then returned to its true position. The resultant fold, including the three trace mix, is shown on Figures 11, 12, and 13. It should be noted that the fold shown on Figures 11, 12, and 13 represents the total number of traces utilized. The total number of traces utilized includes, because of the trace composition step, some duplicate shot-receiver paths. This had the effect of weighting the various "boxes" toward the center of the area.

A few words are in order at this point concerning the migration" of seismic data. Seismic data are presented as sections where the reflections or stacked reflections are shown beneath each trace as if the reflected energy was actually coming from a flat reflector directly below the point. In the case of dipping reflectors, as illustrated in Figure 8 and again in Figure 15, this will not be the case. Snell's law, which requires that the angles of incidence and reflection be equal, when applied to a dipping reflector has the effect of moving the

reflection point updip, away from the point directly below the midpoint between shot and receiver. This effect is particularly significant when the ray path is in the order of seconds, since a lengthening of the assumed vertical ray results in a lengthening of the offset due to dip. Thus when such reflections are plotted as if they did occur beneath the midpoint they will be in error. Computer processing approaches are available which "migrate", or move, the data to the correct position. Migration programs, however, have assumptions inherent in the mathematical approximations involved which limit their application to shallow dips, on the order of 30 degrees or less. Thus, the migration programs available are not applicable to the Rawlins data with dips well in excess of 45 degrees. The net effect is that, while the various reflectors at the Rawlins site may be detected and identified, placing them at their true depth through migration has not been attempted in the processing sequence.

The above is a brief summary of the processing procedure applied to the seismic data. In the course of the Rawlins high resolution seismic survey each processing step was analyzed, tested and checked to ensure that the resulting final section was the most accurate representation of the subsurface. The processing sequence, in particular the trace composition and areal CDP stacking, while non-standard, consisted of proven steps which when applied to the Rawlins data resulted in positive identification of the burn zone.

The data as displayed on the final record section was plotted so as to focus on the area of interest. The vertical scale is 20 in (50.8 cm) per sec, a considerable expansion over the conventional exploration section. The horizontal scale is 10 traces per in (15.25 cm), which is equivalent to 100 ft along the line per in (12.0 meters along the line per cm). For the displays where data within the various "boxes" were stacked, traces were repeated to yield to same horizontal scale as for the unsummed case. All seismic sections are presented in the Appendix. It should be noted that the numbering sequences for the processed lines is different than the numbering sequence for the field operations.

VI. RESULTS

The results are presented in two stages. First, the theoretical considerations which formed the basis for the interpretation are reviewed. Then, the interpretation of the burn area is presented with discussion referenced to the observed data.

A. Theoretical Considerations

The object here was, through the analysis of data obtained in related areas, to determine the range of anticipated results. These considerations aided in designing the field parameters, and supplied information with which the field results were compared in order to identify and characterize the reflections observed.

The problem facing the interpreter in the course of the Rawlins seismic survey was the absence of a complete sonic log from the

Rawlins gasification area. This meant that there was no way to establish a one-for-one correlation between the geologic stratigraphy and the observed reflections.

To alleviate this problem, models and synthetic seismograms constructed for a previous seismic survey concerning the Hanna, Wyoming UCG area (Youngberg 1982) were utilized. It is felt that the similarity of the geologic environment allows for the use of this data. Modifications relating to the Rawlins project will be discussed below. The velocity and density logs utilized are shown in Figure 10. The reflectivity series, or plot of reflection coefficient versus time, was computed from the velocity and density data. The principal is that at an interface between two materials of different velocity and density (acoustic impedance), the acoustic wave will be partially reflected and partially transmitted. The synthetic seismogram is created by convolving a pulse representing the source wave with the reflectivity coefficient series. This process has been found to yield an accurate representation of the actual seismic wave-real earth interaction phenomena. The pulse shape used was the Ricker wavelet, a standard acoustic pulse shape, which has been found to be typical of explosive sources of the type used here.

The pertinent seismic character changes will be discussed in the following sections. The calculated models are felt to be accurate enough to aid in the interpretation of the Rawlins data with the following qualifications kept in mind:

(1) The identification of the Rawlins G seam seismic reflection character was based upon the seismic data itself. It was anticipated that the data obtained for the 80 ft (24.4 meters) composite boxes would provide the most unambiguous signature for the coal reflection.

(2) The effect of burning and caving resulting in a rubble-filled cavity tends to reduce the seismic reflection amplitude. The loss of amplitude is a subtle effect and difficult to discern in the seismic data (Figure 10, case 12).

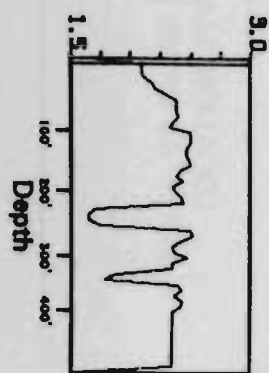
(3) The air filled void will produce a strong reflection if present, and sufficiently thick. The models of Figure 10, cases 14 and 21, show 6 and 12 ft voids detectable (for the case presented) by a strong reflection amplitude. The water filled void should also be detectable, on the same basis, but somewhat weaker. However, based upon corehole evidence the air or water filled voids associated with the Rawlins 1 and 2 burn are not extensive. Therefore, the strong reflection anomaly associated with a void as seen in Figure 10 would also not be anticipated to be extensive.

B. Interpretation

The processed seismic sections with interpretation added are presented in the Appendix and will be referred to in this discussion by line number. It should be recalled in viewing this data that the fold decreased toward the edges of each section as shown in Figures 11, 12 and 13.

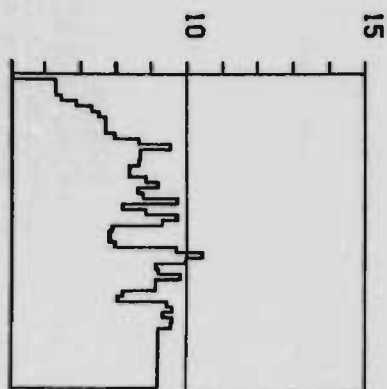
Density Log

gm/cc

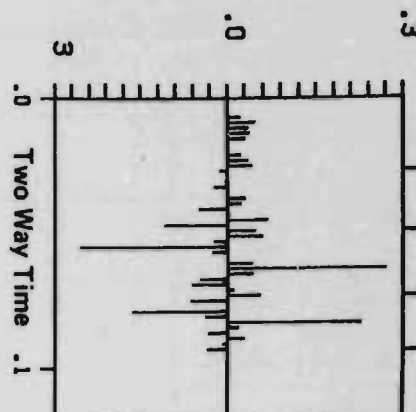


Velocity Log

ft/sec=1000



Reflection Coefficients



Models

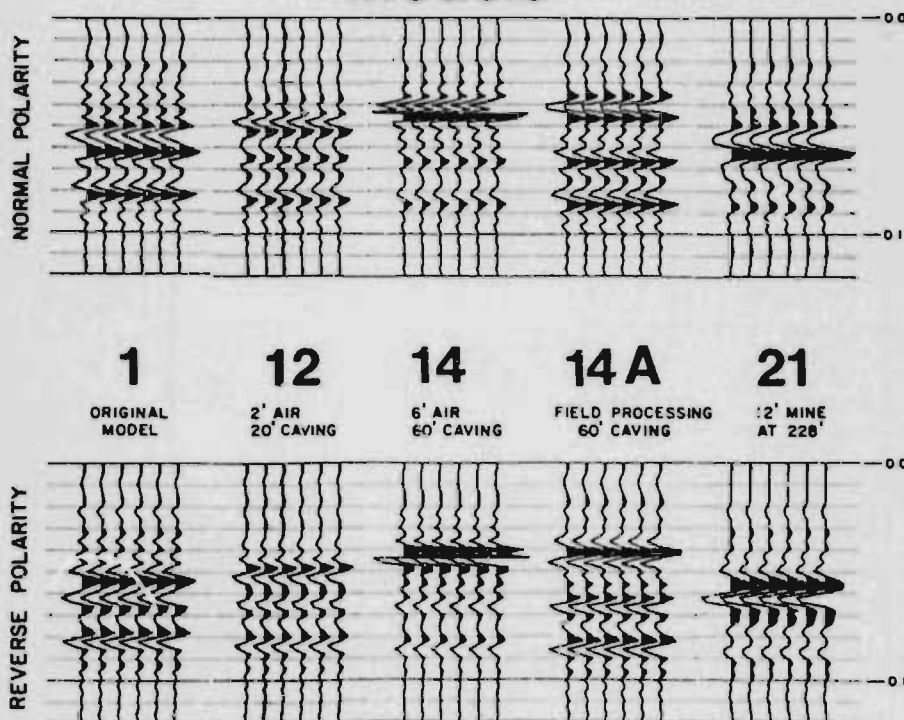
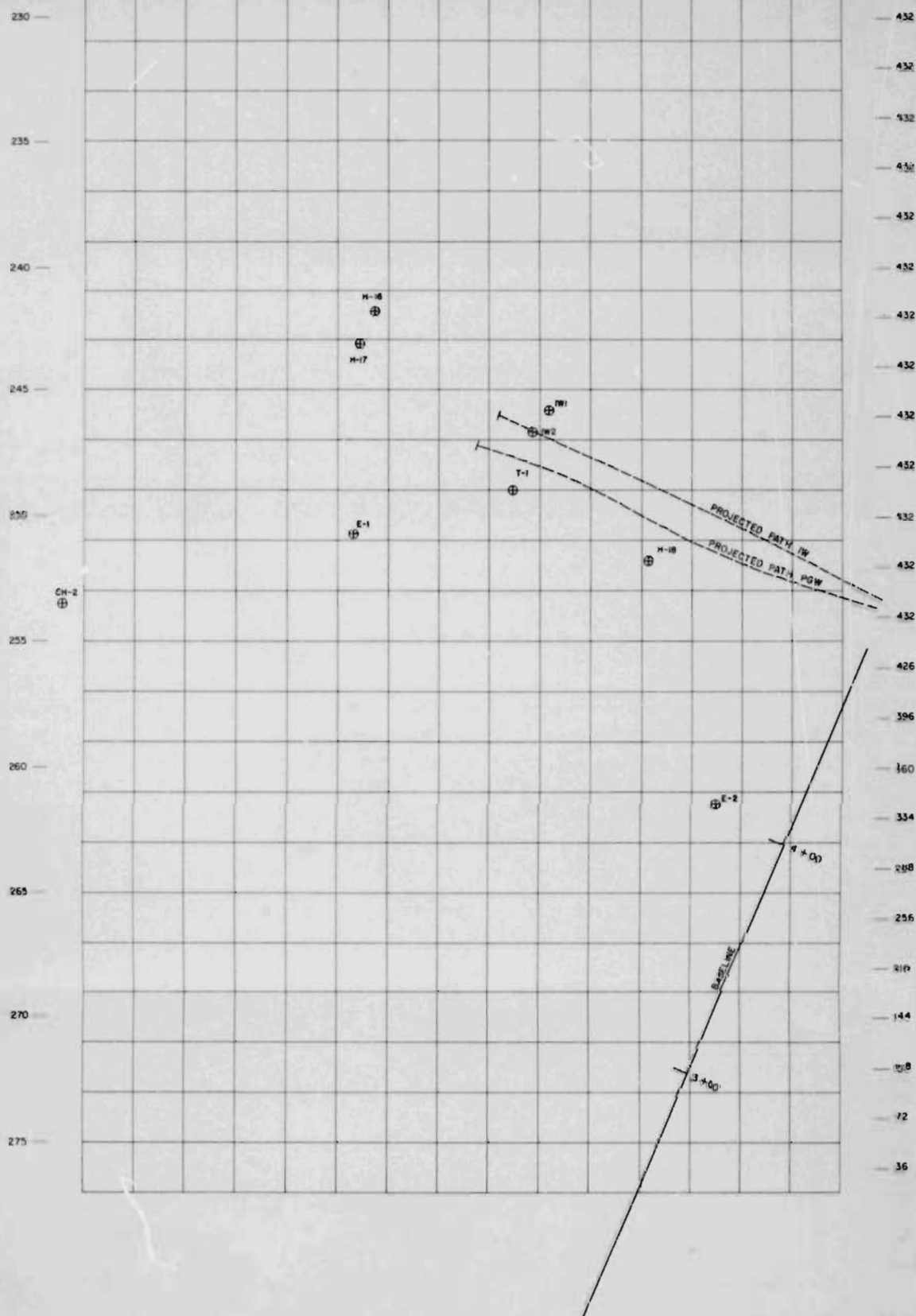


FIGURE 10. Seismic models



1/4" = 1 METER (20/45) BOXES.

⊕ DRILL HOLE



FIGURE 11

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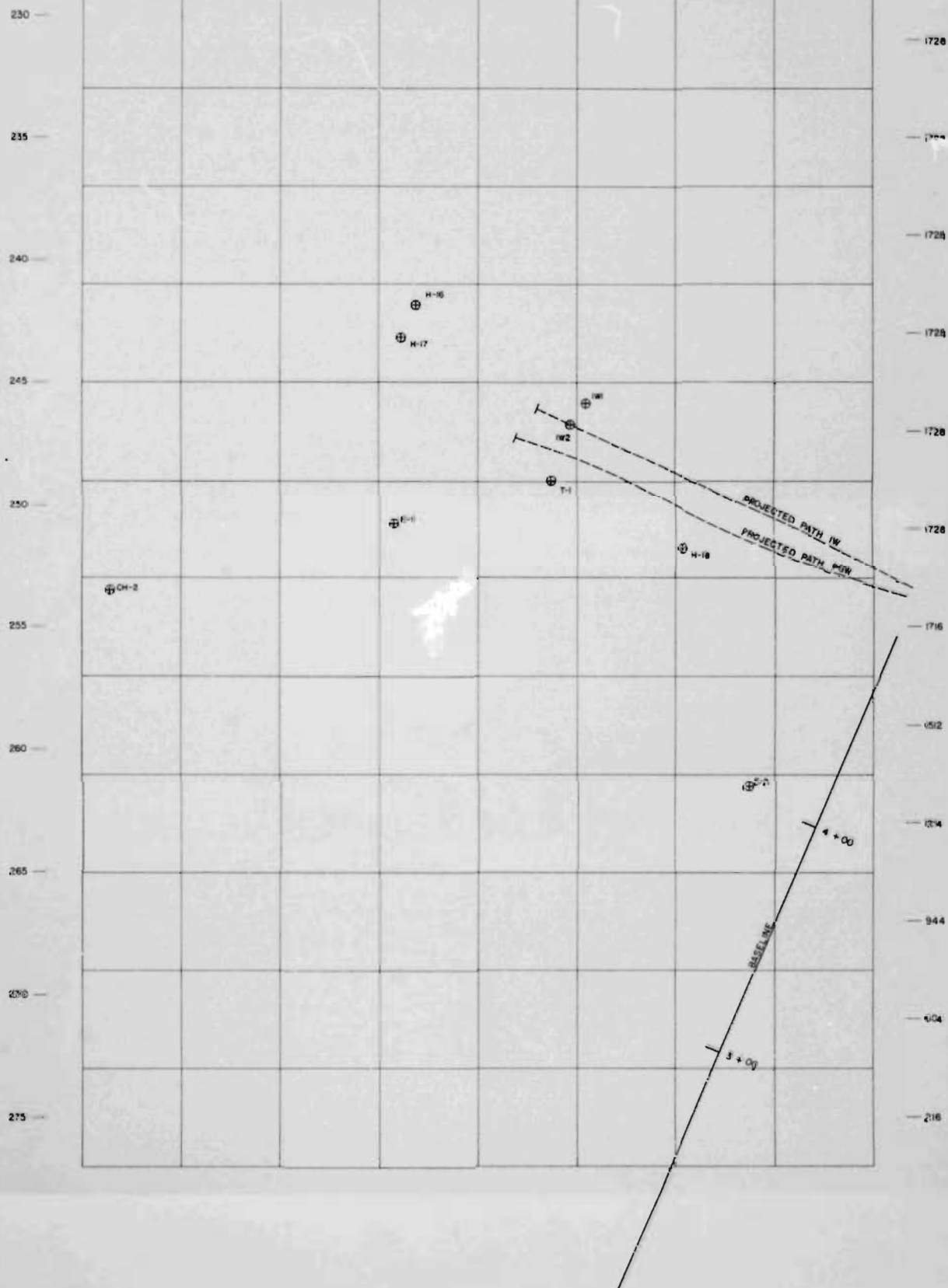
REVISIONS
REVISION NUMBER REVISION DATE

LOCATION MAP
20 FT - 6.1 METER BOXES

Prepared by: E. BERNARD Date: 12/82
Checked by: J. M. NELSON Date: 12/82

CDP FOLD
AFTER TRACE
COMPOSITION





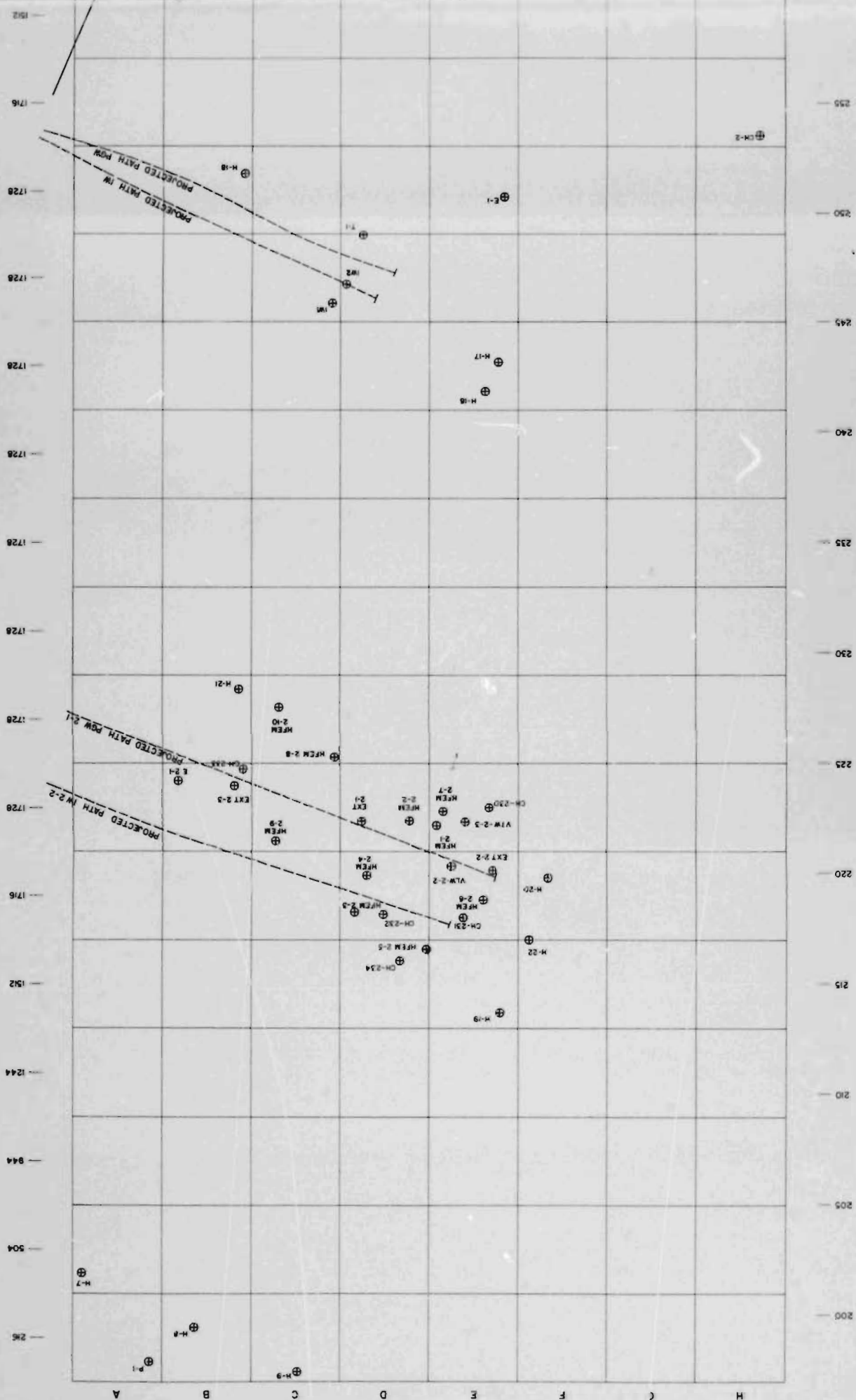
12.2 METER (40ft) BOXES

⊕ DRILL HOLE

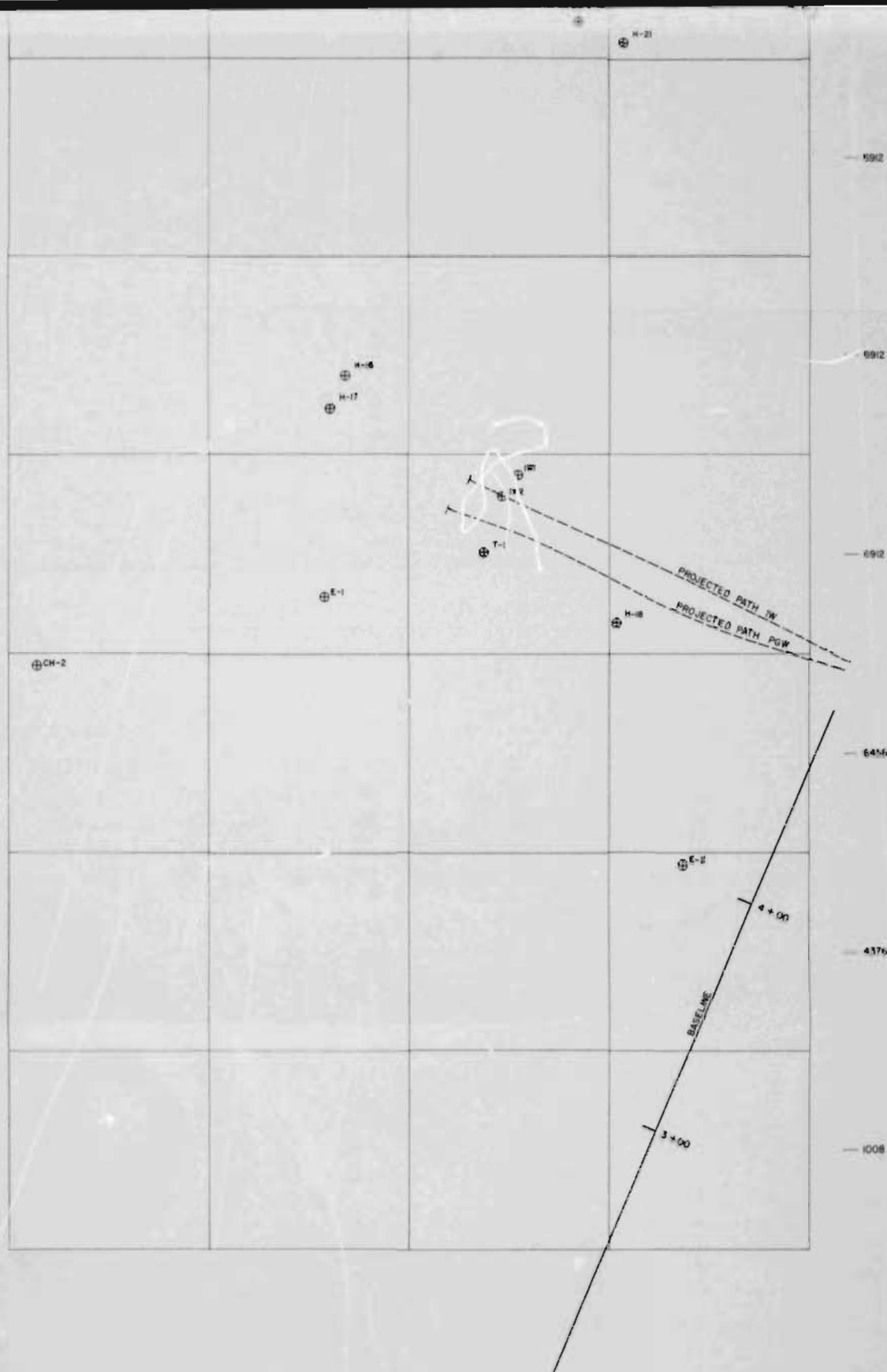


FIGURE 12

LARAMIE ENERGY TECHNOLOGY CENTER U.S. DEPT. OF ENERGY	
LOCATION MAP 40 FT-12.2 METER BOXES	
Prepared by: E. BECKMAN	Date: 12/80
Checked by: J. M. NELSON	Date: 12/80



230 —
235 —
240 —
245 —
250 —
255 —
260 —
265 —
270 —
275 —



183 METER (601) BOXES
⊕ DRILL HOLE



FIGURE 13

LARAMIE ENERGY
TECHNOLOGY CENTER
U.S. DEPT. OF ENERGY

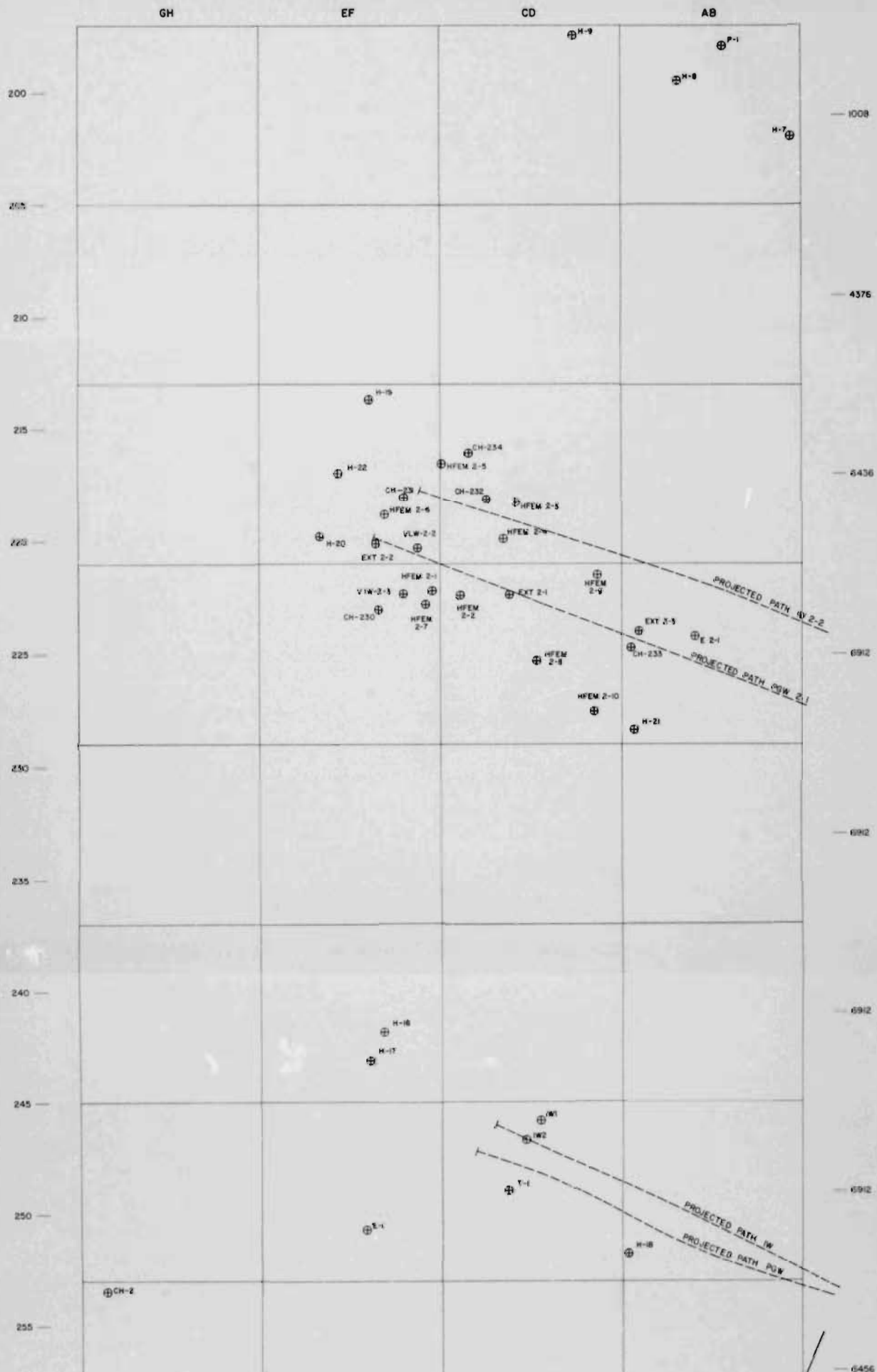
NOTES: 1. THIS MAP IS A SUMMARY OF THE DATA AVAILABLE AT THE TIME OF THE SURVEY. 2. THE MAP IS NOT A SCALE DRAWING. 3. THE MAP IS NOT A SCALE DRAWING.

LOCATION MAP
80 FT-24.4 METER BOXES

Interpreted by: E. P. H. M. N. Date: 12/83
Created by: J. H. N. E. L. Date: 12/83

LOCATION
IDENTIFICATION
NUMBERS

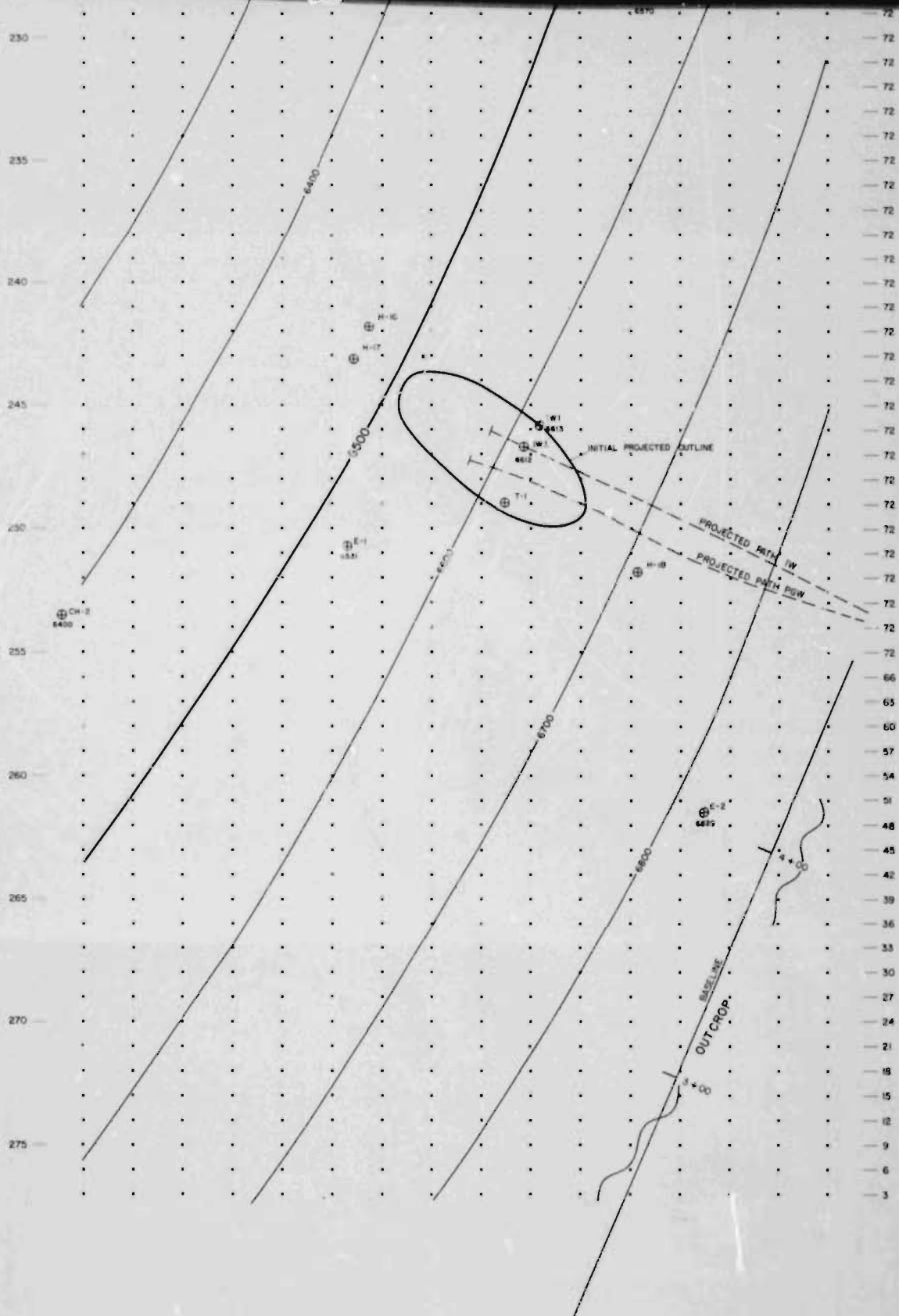
CDP FOLD
AFTER TRACE
COMPOSITION



As mentioned in the geologic section (section II), the steep dips and possible non-uniformity of dip is a severely complicating factor. A structure map on the top of the "G" seam (Figure 14) was prepared to help identify the G seam on the seismic sections. Well data as indicated controlled the structural contouring which was converted from the depth data to seismic wave travel time using the velocity function derived from the seismic data itself (see data processing). Once the G seam was identified on the individual CDP lines, trace composition along reflection continuity followed. The result of this trace composition was the observation of the G seam seismic reflection character as a double-peaked event with a pronounced low between the two peaks. The character is clearly seen at the north end of individual line GH, and on all of the 80 ft (24.4 meters) box lines away from the immediate vicinity of the burn zone. It must be noted that even at this high fold the reflection character is not consistent. It is felt that this inconsistency relates both to the data quality and to the complications discussed previously in the geologic setting and stressed above. All the individual CDP lines show a strong interference pattern generated by surface noise, with line F6 a typical example. This line also demonstrates the effects of migration (Figure 15), the phenomenon where the reflection from a dipping reflector comes from updip rather than from beneath the array. This phenomenon was to some extent corrected for in the processing, as far as correctly stacking the data, by using the three trace composition. Processing tests to further remove this effect were attempted on line F6 between the mapped top of G seam and the reflection from the G seam. It is felt that the disruption to the seismic character as well as the reflection from any air void should appear directly under the mapped location, since the top of the cavity is pictured as essentially flat (see Figure 2). Note should be made that the extreme dip causes the objective target size to be reduced due to the fact that observations are taken along the surface, rather than parallel to the bedding.

It should be emphasized that in interpreting the characteristics and location of the burn zone the changes in amplitude of the two signal peaks associated with the G seam, as well as those reflections which appear immediately above the coal, have been utilized. In most cases the effect is seen on both peaks but in many cases it is only discernable on one peak (see line B for examples of both). The individual CDP lines are clearly the most subjective as far as discernable waveform character is concerned. All lines in the appendix have been annotated to show the location of significant burn-related anomalies.

Once the reflection characteristics of the unburned coal were determined using the 80 ft (24.4 meter) boxes (and crosschecked with the lower fold data), and the range of characteristics of the burn zone determined through the model studies, the interpretation proceeded as follows: First the data for the coarsest grid, the 80 ft (24.4 meter) boxes (all data from a surface "box" 80 ft (24.4 meters) on a side stacked into one composite trace, as described in the section concerning data processing), were examined and an anomaly identified. This anomaly occurred at the location of the known burn and was well correlated with that expected from a rubble-filled burn cavity. The 80 ft (24.4 meters) boxes containing the anomaly are shown in Figure 16. Once the character



• SURFACE POINT
⊕ DRILL HOLE

DATUM SEA LEVEL



FIGURE 14

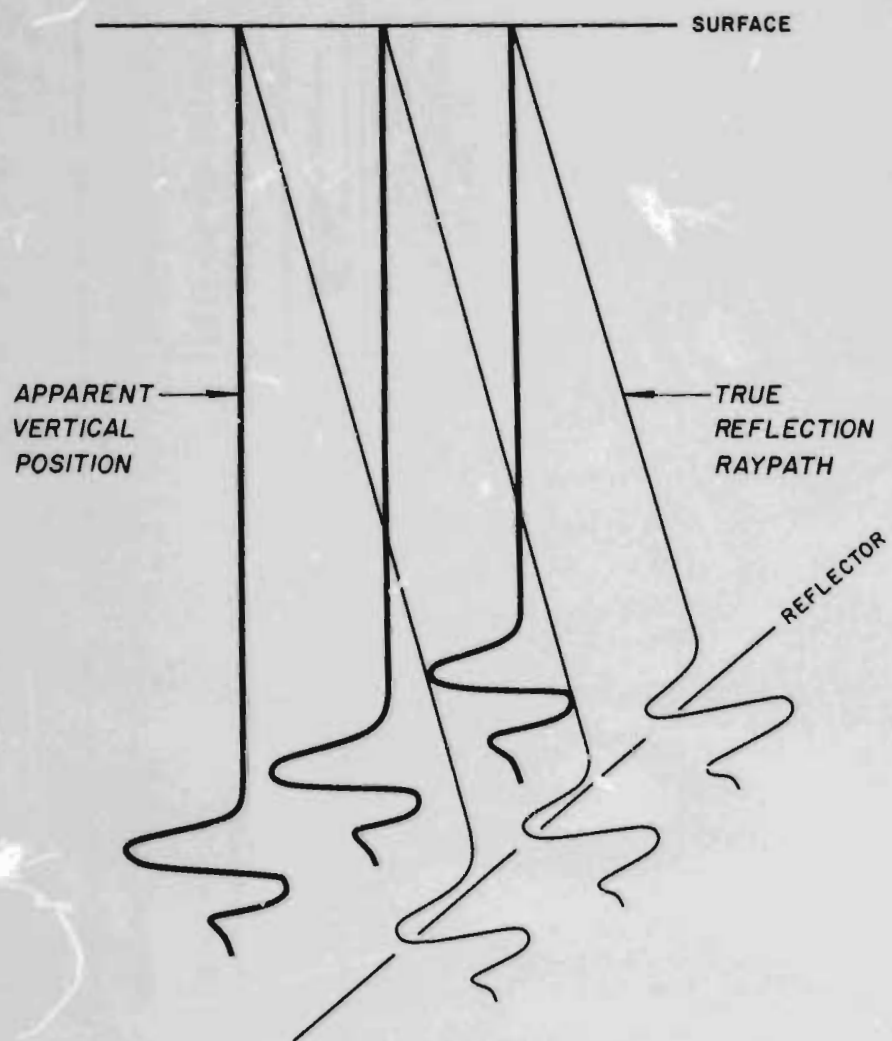
LARAMIE ENERGY
TECHNOLOGY CENTER
U.S. DEPT. OF ENERGY

STRUCTURE MAP
TOP OF "G" SEAM

Prepared by: J. M. NELSON Date: 12/80
Checked by: J. M. NELSON Date: 12/80

COPI FOLD
AFTER TRACE
COMPLETION





THEORETICALLY, MIGRATION MOVES DATA FROM
APPARENT VERTICAL POSITION TO TRUE SUBSURFACE
LOCATION.

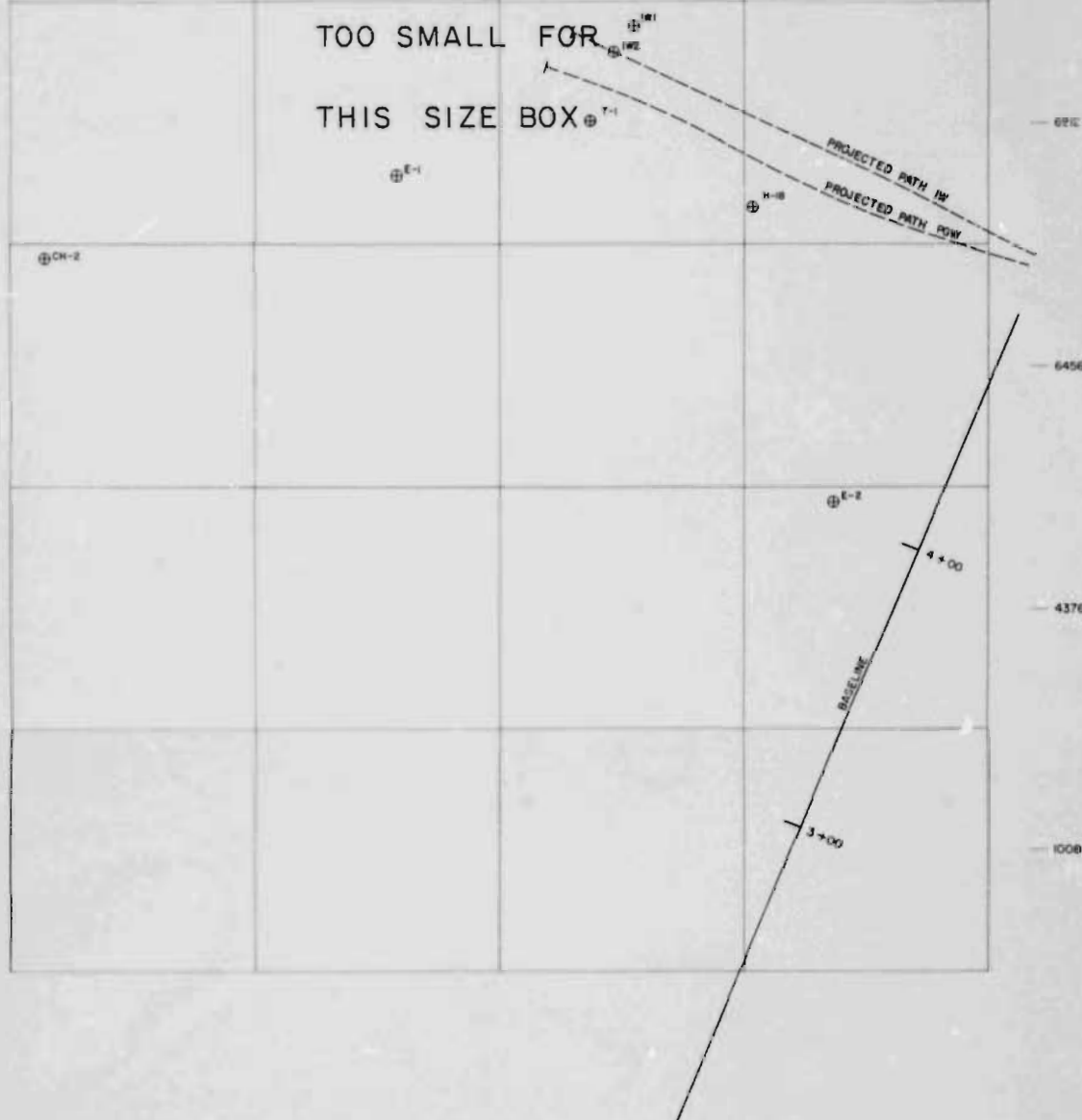
FIGURE 15. Migration

230 —
235 —
240 —
245 —
250 —
255 —
260 —
265 —
270 —
275 —

— 6912
— 6912
— 6912
— 6456
— 4376
— 1008

SOME QUESTIONABLE
TRACES — ANOMALY

TOO SMALL FOR
THIS SIZE BOX



18.3 METER (60 FT) BOXES

(H) DRILL HOLE



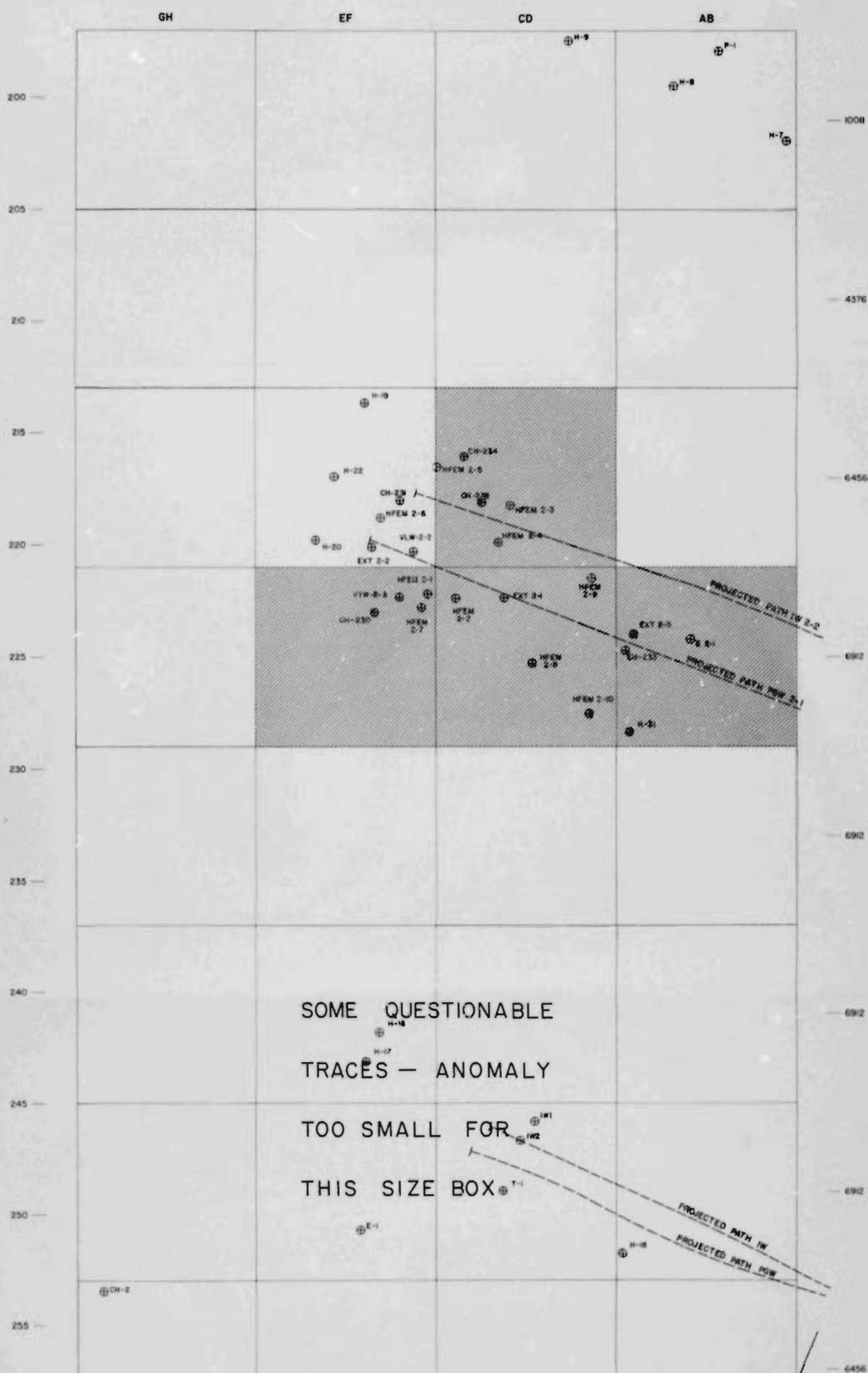
FIGURE 16

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REVISIONS

BURN OUTLINE
80 FT-24.4 METER BOXES

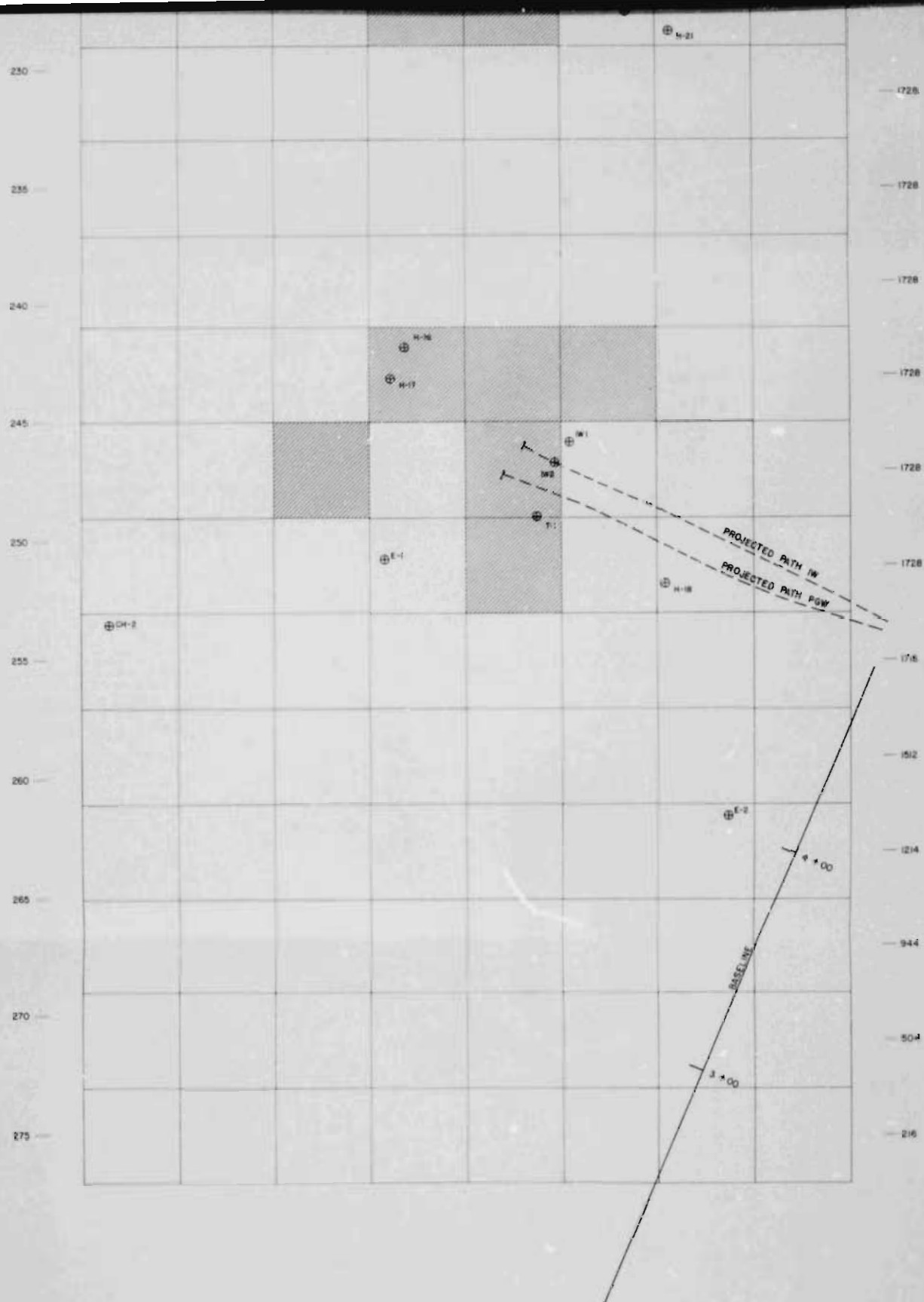
Reviewed By: E. BERRYMAN Date: 12/82
Created By: J. M. BELL Date: 12/82



of the anomaly was identified on the 80 ft (24.4 meters) box composite data, a similar anomaly was observed on the 40 ft (12.4 meters) box and 20 ft (6.1 meters) box data and, with difficulty, in the individual seismic lines. The burn outline for the 40 ft (12.2 meters) and 20 ft (6.1 meters) boxes as shown on Figures 17 and 18 should be viewed as a progressive refinement of that of the 80 ft (24.4 meters) boxes, with the outline of the burn as identified on the individual lines, Figure 19, the most detailed.

Note that the Burn 1 cavity was not observed in the 80 ft (24.4 meter) box composite data but could be identified on that for the smaller boxes. This is interpreted as an indication of the small volume of this burn, which when averaged with data outside the burn but within the 80 ft (24.4 meter) box, resulted in a composite reflection that was indistinguishable from that without the burn. One problem of the interpretation has been carried through to the final maps. That is the fact that minor changes in seismic waveform amplitude and character not related to the burn can be misconstrued. Note for the Rawlins Test 1 the area around H-16 and H-17 (Figure 20) were initially interpreted as burn related; however, it is not known why a seismic anomaly was observed at this location because from well and drill hole information it is known that the reactor cavity is not located within that area. It is suspected that gas leaked out of the test area and is trapped in a porous sand lense. In this regard it should be noted that seismic amplitude variations were just studied in detail to detect gas accumulations in porous rock.

As noted earlier, no strong amplitude reflections which could be related to an air or water filled void were found. This placed a strong reliance on identifying the subtle changes in the character of the data resulting from the rubble-filled void. The character changes, a loss in signal amplitude as discussed above, were difficult to see in the data, and required the trace composition and areal (box) summation for confirmation. A qualitative evaluation of the validity of the interpretation is difficult to make. It should be pointed out, however, that following the procedures set forth above, the interpretation is confirmed through the comparison in Figure 20, where the detailed seismic interpretation has been shown in conjunction with the initial projected outlines of the burn and an interpreted shape from other geophysical data which is in the public domain (Gulf Research and Development Company, 1982). The gross form of the burn outline is similar for all sources. Because of the areal data density and internal consistency of the seismic data, it is believed that the burn shape from this data is the most accurate.



12 METER (40 FT) BOXES

⊕ DRILL HOLE



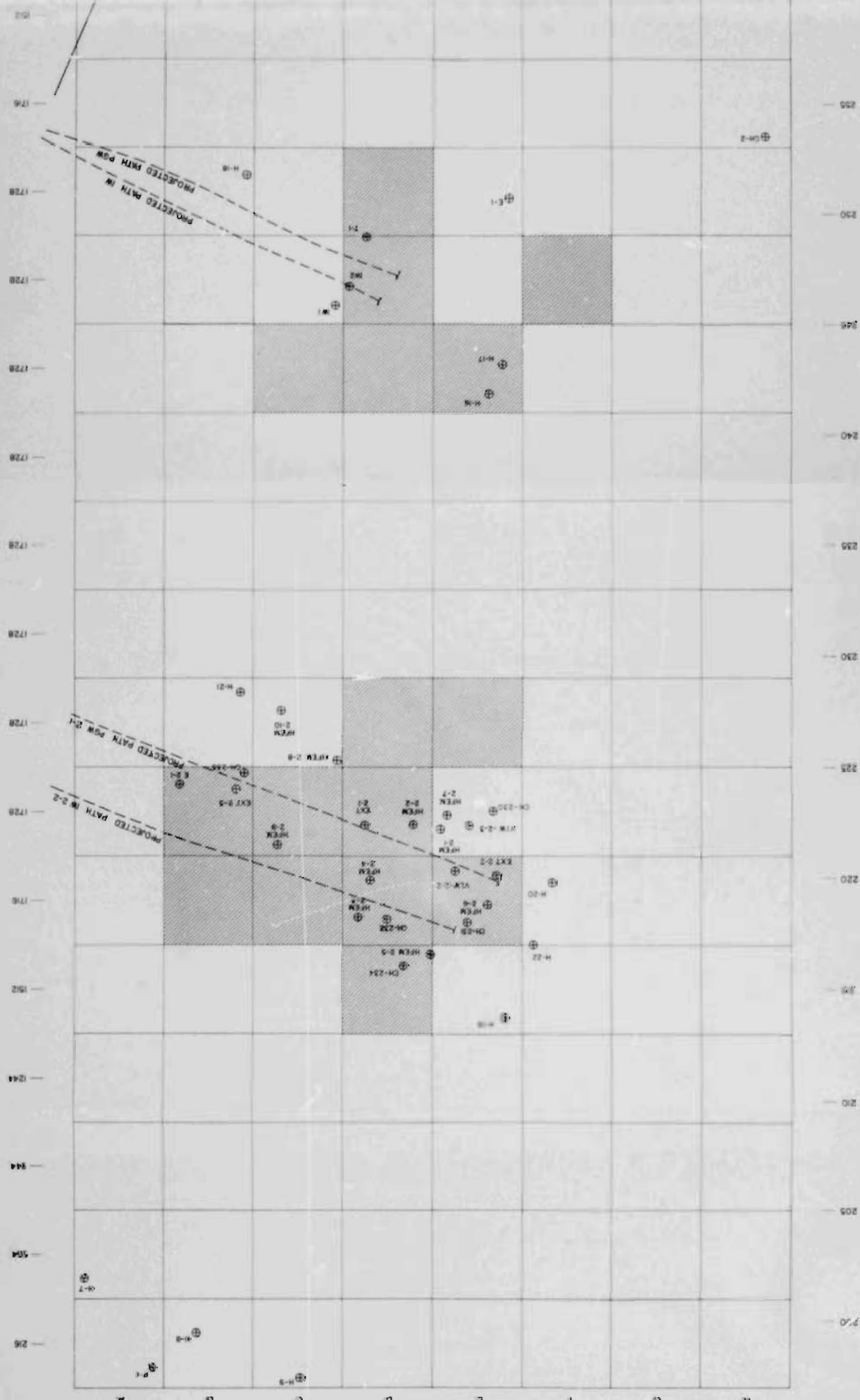
FIGURE 17

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ENVIRONMENTAL
STATE OF NEW MEXICO DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

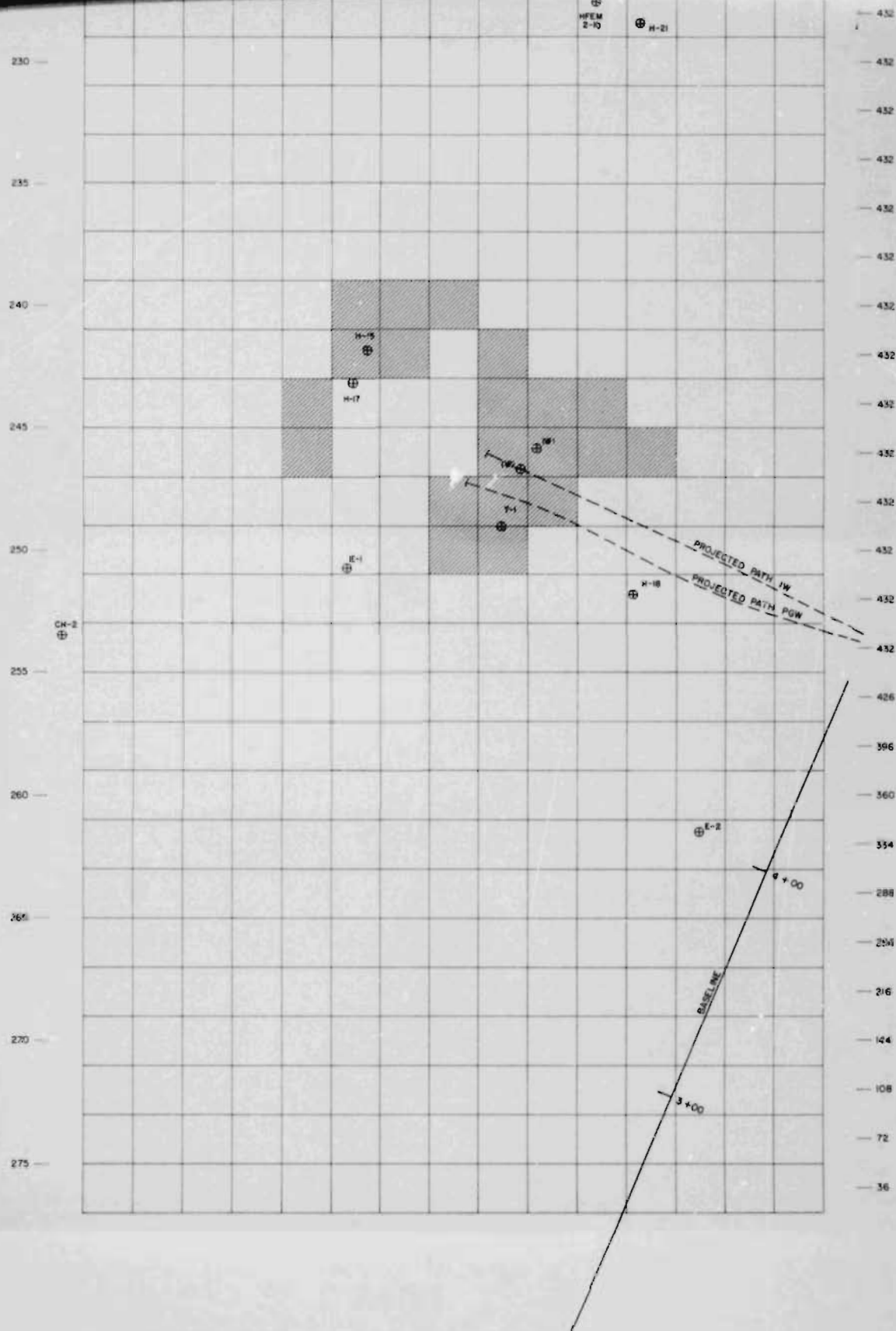
BURN OUTLINE
40 FT-12.2 METER BOXES

Investigated By: E. BERTMAN Date: 12/83
Drafted By: J. MURIEL Date: 12/83



CDP FOLD
AFTER TRACE
COMPOSITION

LOCATION
IDENTIFICATION
NUMBERS



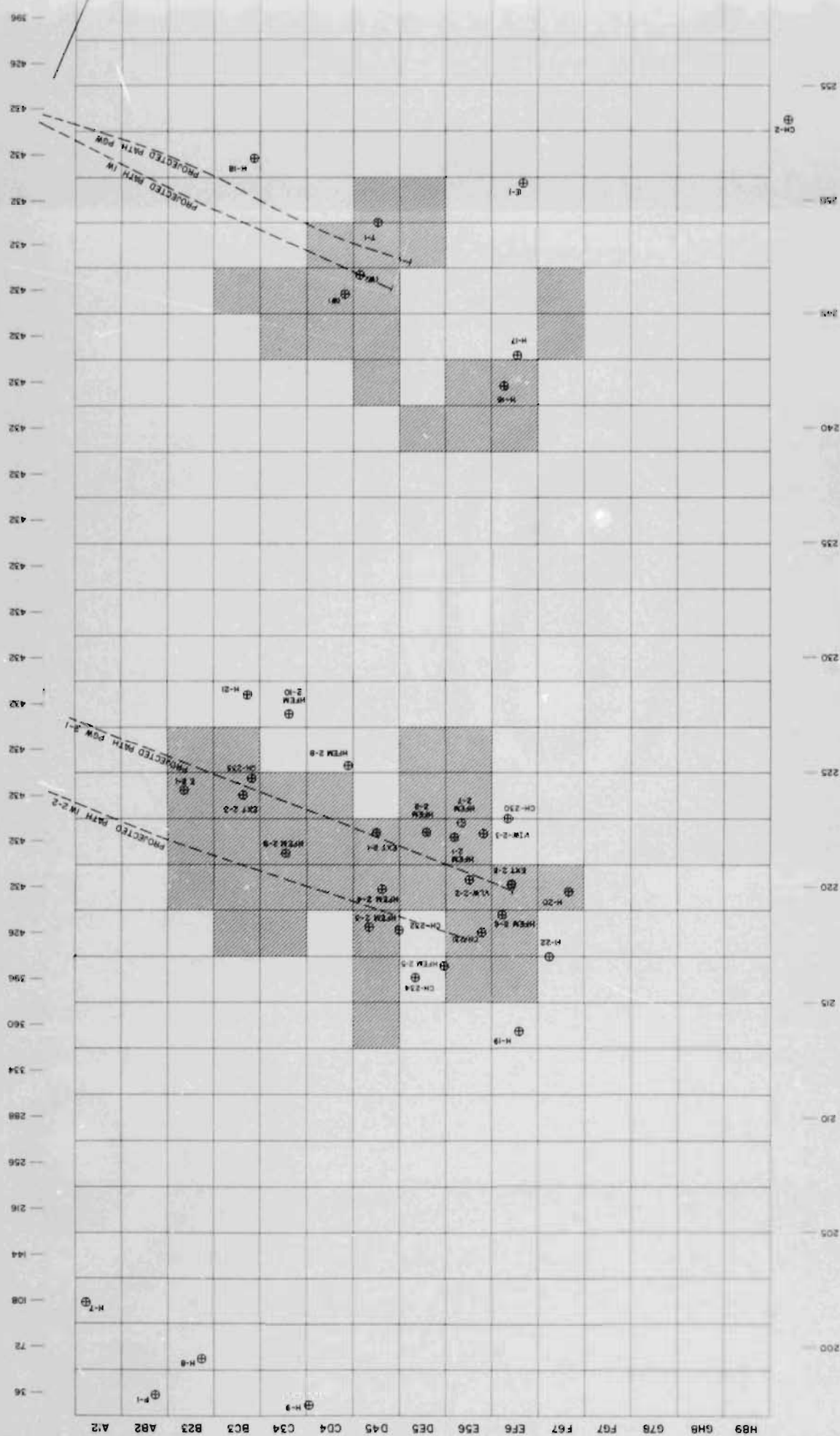
0.1 METER (20 FT) BOXES
 ⊕ DRILL HOLE



FIGURE 18
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U.S. DEPT. OF ENERGY

BURN OUTLINE
20 FT - 6.1 METER BOXES

Prepared by: E. BERKMAN Date: 12-88
 Drawn by: J. WICKS Date: 12-88



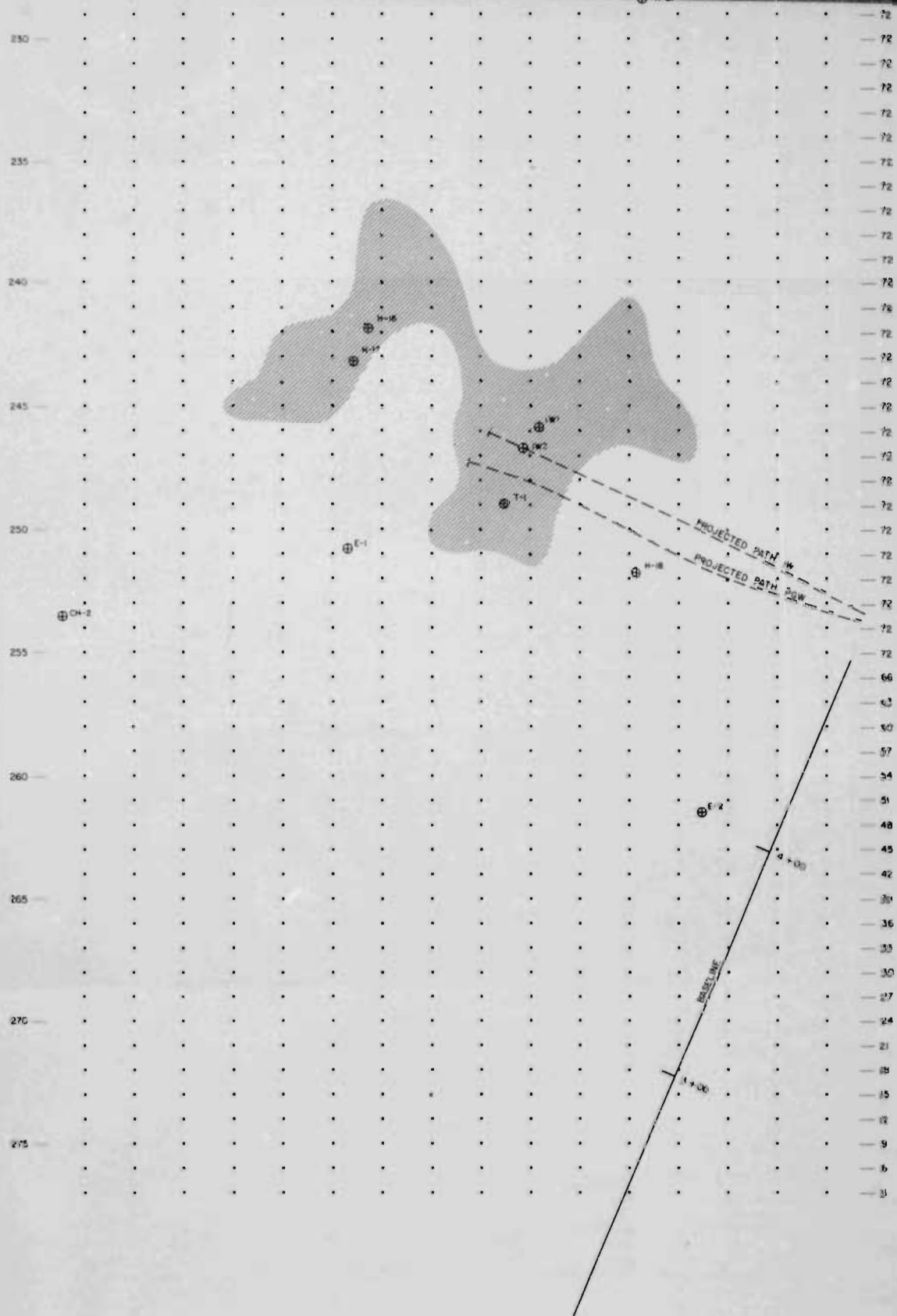


FIGURE 19

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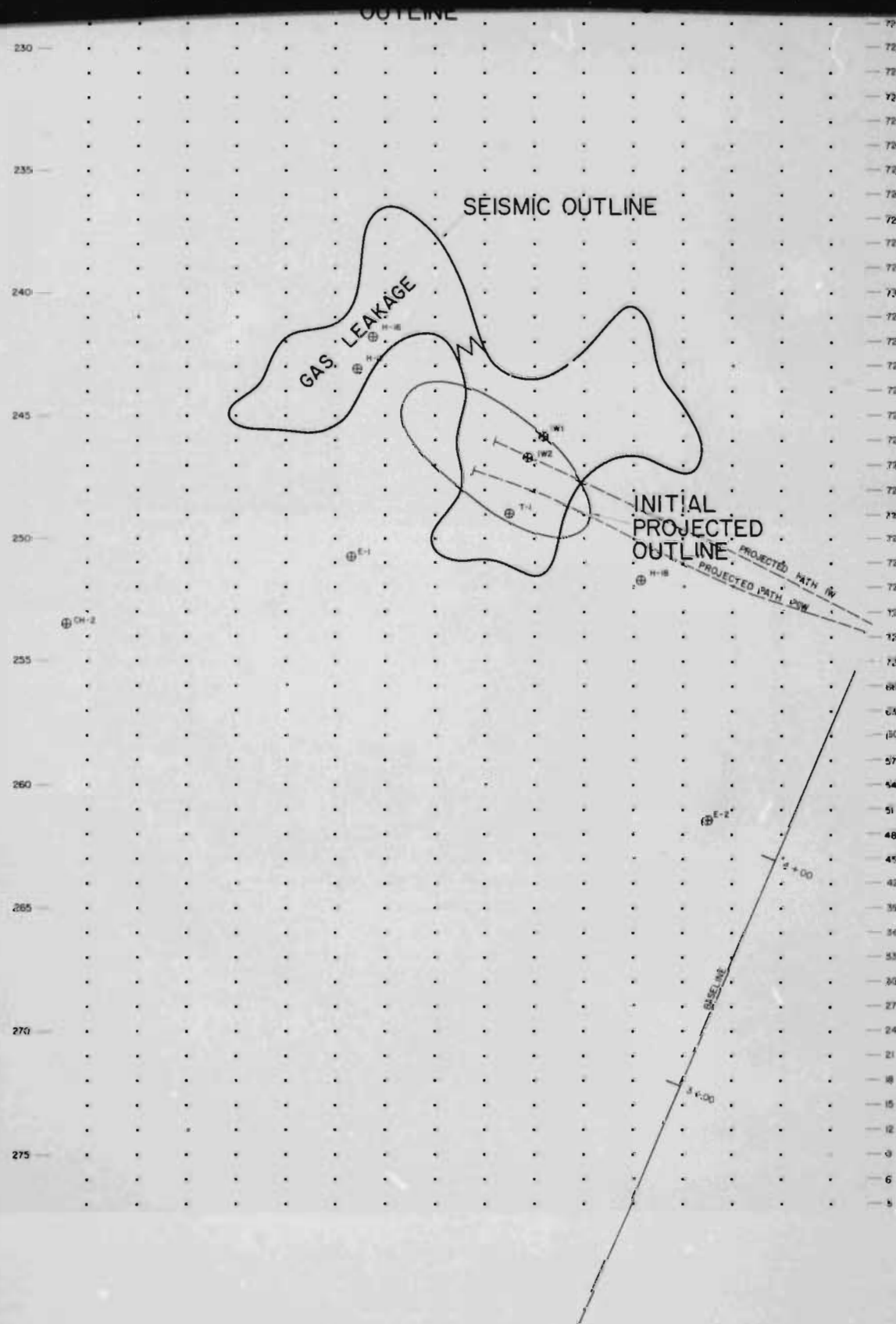
STUDY
Burn Outline Subsurface Lines

**BURN OUTLINE
SUBSURFACE LINES**

Interpreted by: E. BERKMAN Date: 12/72
Drawn by: J. McNEIL Date: 12/72

COP FOLD
AFTER TRACE
COMPOSITION





• SUBSURFACE POINT
⊕ DRILL HOLE



FIGURE 20

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REPRODUCED FROM THE LARAMIE ENERGY TECHNOLOGY CENTER

BURN OUTLINE
COMPARISON

Interpreted by E. SCHUMAN Date 12/82
Drawn by J. W. NELSON Date 12/82



VI. CONCLUSIONS

The interpretation of the seismic data obtained at the Rawlins test site has led to the following conclusions:

1. The seismic survey detected an anomaly in the vicinity of the rubble filled cavity at both Rawlins test sites 1 and 2. These anomalies did not correlate in all areas where the rubble filled cavity was located according to well and core hole information. The reason for this lack of correlation in some areas is not known and can only be conjectured.
2. The water filled void at the Rawlins 1 test site and the air filled void at the Rawlins 2 test site were not detected with any strong amplitude reflections. The reason for this can be any one or combination of the several complicating factors discussed.
3. Steep and possible non-uniformity of dip has a severe detrimental effect on the seismic data and its evaluation. Processing and interpretation procedures attempted may not have fully corrected for this problem. A computer processing approach needs to be developed that will adequately correct for dip in excess of 30 degrees.
4. Sonic logs should be run in future site characterization studies. These logs will establish a one-for-one correlation between the geologic stratigraphy and the observed reflections. Such correlations would make it easier to detect anomalies during the interpretation stage.

REFERENCES

- Ahner, P. F. et al, A Site Qualification Study of the UCG Site at North Knobs, Proceedings, 6th UCC Symposium, Afton, OK, 1980.
- Bartel, L. C., Potential Use of the CSAMT Geophysical Technique to Map UCG Processes, Proceedings 8th Underground Coal Conversion Symposium, Keystone, Colorado, August 1982.
- 1982, of Sandia National Laboratories, Personal Communication with J. M. Avasthi regarding the CSAMT Survey of Rawlins Test 2 Cavity, September 1982.
- Claerbout, J. F., Fundamentals of Geophysical Data Processing, New York, McGraw-Hill, 1976.
- Davis, B. E. et al, Test Plan and Status for the Gasification of Steeply Dipping Coal Beds, Proceedings, 5th UCC Symposium, Alexandria, VA, 1979.
- Rawlins T-1 Cavity Definition Study, 7th UCC Symposium, Fallen Leaf Lake, 1981.
- Status of the Rawlins UCG-SDB Program, Proceedings, 7th UCC Symposium, Fallen Leaf, CA. 1981.
- Dobrin, C. E., Bowen, C. D., and Hoots, H. W., Geology and Coal and Oil Resources of the Hanna and Carbon Basins, Carbon County, Wyoming, U. S. Geological Survey Bulletin 804, 1929.
- Introduction to Geophysical Prospecting, Third Edition, New York, McGraw-Hill, 1976.
- Duerring, N. T., and Davis, B. E., Evaluation of Coals from the Rawlins Postburn Cores, Proceedings, 7th UCC Symposium. Fallen Leaf, CA, September 7-11, 1981.
- Elliott, J. R., Steidtmann, J. R., A brief Summary of the Site Qualification of Steeply Dipping Bed at North Knobs, Wyoming, U. S. Department of Energy, unpublished.
- Glass, G. B., and Roberts, J. T., Coal and Coal Bearing Rocks of the Hanna Coal Field, Wyoming, Wyoming Geological Survey, Report No. 22, 1980, 43 pp.
- Gulf Research and Development Company, Underground Gasification For Steeply Dipping Coal Beds, Rawlins UCG Test 2 Cavity Definition Study, U. S. Department of Energy Report No. - LETC 13108-102, October 1982.
- Lindeman, R. A., Ahner, P. F., Davis, B. E., Mass Balances for Underground Coal Gasification in Steeply Dipping Beds, UCG Symposium, Afton, OK, 1980.

REFERENCES

(Page 2)

- McQuillan, R., Bacon, M., and Barclay, W., An Introduction to Seismic Interpretation, Houston, Gulf Publishing Co., 1979.
- Miranda, J. E., Rawlins 1 Product Gas Analytical Instrumentation, Proceedings of the 6th UCG Symposium, Afton, OK, 1980.
- Moore, J., Berry, K., Davis, B. E., An Industrial Hygiene Survey of the Rawlins UCG Site, 7th Annual UCC Symposium, Fallen Leaf Lake, CA.
- Robinson, E. A. and Treitel, S., Geophysical Signal Analysis, Englewood Cliffs, New Jersey, Prentice-Hall, 1980.
- Singleton, A. H., Noll, N. L., Allen, J. M., Summary Report of the Rawlins T-1 for Gasification of Steeply Dipping Coal Beds, Proceedings of the 6th UCG Symposium, Afton, OK, 1980.
- Telford, W. M., Geldart, L. P., Sheriff, R. E., and Keys, D. A., Applied Geophysics, New York, Cambridge University Press, 1976.
- Waters, K., N., Reflection Seismology, New York, Wiley, 1978.
- Youngberg, A. D., Berkman, E., Orange, A. S., High Resolution Seismic Survey of the Hanna, Wyoming Underground Coal Gasification Area, U. S. Department of Energy Report No. LCR1821, January 1982.

GLOSSARY OF TERMS

- Bandpass Filter:** A filter, either electronic or digital, that rejects signals with a frequency content outside chosen limits.
- Common Depth Point (CDP):** The subsurface point common to two or more source-geophone pairs, computed using the principals of ray optics (angle of incidence equals angle of reflection).
- Common Depth Point (CDP) Format:** A data display where traces with the same theoretical subsurface reflection point are displayed together. Each trace usually represents a different shot.
- Datum:** The elevation used as a reference in displaying the seismic data.
- Field Format:** A data display (usually Trace Sequential Signal Fold) where the trace and source location on the displayed record are identical to the locations on the ground.
- Fold:** In common depth point (CDP) seismology, the number of source-geophone traces stacked to yield the resultant CDP trace.
- Geophone:** A device which when placed on the surface of the ground yields a voltage in response to minute ground motions. Usually equipped with a spike which is inserted into the ground to ensure coupling of the geophone to the earth motion.
- High Resolution Seismic Survey:** A seismic survey where the field and processing parameters (source-geophone array geometry, source design, acoustic frequency band of interest, instrument and digital filtering, etc.) are chosen to allow resolution of the subsurface reflections from beds that are closer to the surface, and closer together, than normally considered in exploration seismology.
- Migration:** Migration transforms seismic sections, representing complex wave-fields, into sections which display subsurface reflectors and scattering features at their proper locations with the earth.
- Multiplex:** The mixing of two or more signals onto a single channel for transmission or storage purposes. For analysis the signals must be separated into their original form, or "demultiplexed".
- Noise:** Any signals other than those desired. For example, in exploration seismology, the shot induces acoustic waves that travel horizontally along the surface and interfere with the reflected waves from the subsurface, and are hence "noise". An example of natural noise is that caused by the motion of the geophones induced by wind.
- Operator:** In data processing, any mathematical function applied to the data to achieve the desired results.

Shot: Term used for the seismic source, usually explosive in nature.

Shot Hole: When explosive source is used, the hole in which the explosive is placed.

Sonic Log: Measurements made in a drilled well or corehole of the acoustic properties of the earth as a function of depth.

Stack (n): The summation of individual traces to yield a composite trace. The fundamental principal of stacking is that, if performed correctly, desired reflection signals will add linearly while "noise" signals will tend to cancel. If "n" traces are stacked, the signal-to-noise ratio improvement for random noise improves by a factor of n . For non-random noise the effect is more complex.

Stack (v): To add signals (traces) to improve the signal-to-noise ratio or, in the case of common depth point (CDP) processing.

Static Correction: A correction applied to seismic data which adjusts for source and geophone surface elevation changes relative to a datum and for velocity variations at the surface due to weathering, soil thickness, etc.

Synthetic Seismogram: A modeling technique where, utilizing a computer, a source waveform is assumed and subsurface reflection coefficients are calculated from sonic and density log information, the resultant reflections are displayed in the same format that actual seismic signals are displayed.

Trace: The received signal from a specific point on the surface. May be from one geophone or several geophones connected together. The term is sometimes used to refer to the geophone array itself.

Trace Sequential Single Fold: A seismic data display where 1) the traces are plotted in the same sequence that they occupied on the ground, and 2) only one source-geophone signal is included.

Uphole Survey: The successive detonation of a series of charges at varying depths in a shothole in order to determine the velocities of the near-surface formation, the weathering thickness, and (sometimes) the variations of record quality with shot depth.

APPENDIX

FIELD PARAMETERS

INST DFS V
REC LENGTH 1 sec.
SAMPLE RATE 1 ms
RECORDED BY ESI #1
SOURCE Delaprima
HOLE DEPTH 6 ft
DATE Oct, 1982

GROUP INT 20 ft
SP INT 20 ft
NO OF CHAN 24
GEOPH ARRAY 6 at 12 centered
SPREAD Shooting Thru Cable
NEAR OFFSET 0 ft
FAR OFFSET Varies

PROCESSING SEQUENCE



PROCESSED BY THE
SEISTRAC 32

APPLIED RESEARCH CONCEPTS

- (1) DEMUX/REFORMAT
- () RESAMPLE
- (2) CDP GATHER
DATUM: 6900 ft VELOCITY: 5000' / sec
- () FILTER
- () DECONVOLUTION

MS. OPERATOR

AUTO CORR. WINDOW:
WHITE NOISE: PERCENT

- (7) VELOCITY ANALYSIS
- (8) NMO
- (9) MUTE
- (10) AUTOMATIC STATICS WINDOW: 100-500
- () CDP X CORR. STATICS WINDOW:
- (11) STACK FOLD Varies - See Report
- (4) FILTER
60-80-160-180 Hz 0-400 msec
30-50-100-120 Hz 240-600 msec

- (5) EQUALIZATION
- (3) GAIN RECOVERY: T-1.4 FUNCTION
- (6) TRACE COMPOSITE: 3 Traces - Common Offset Distance
- () WAVE EQUATION MIGRATION
- () TRACE COMPOSITE FOR 3-D

DATE PROCESSED Nov, 1982 ANALYST Austin, Tx.

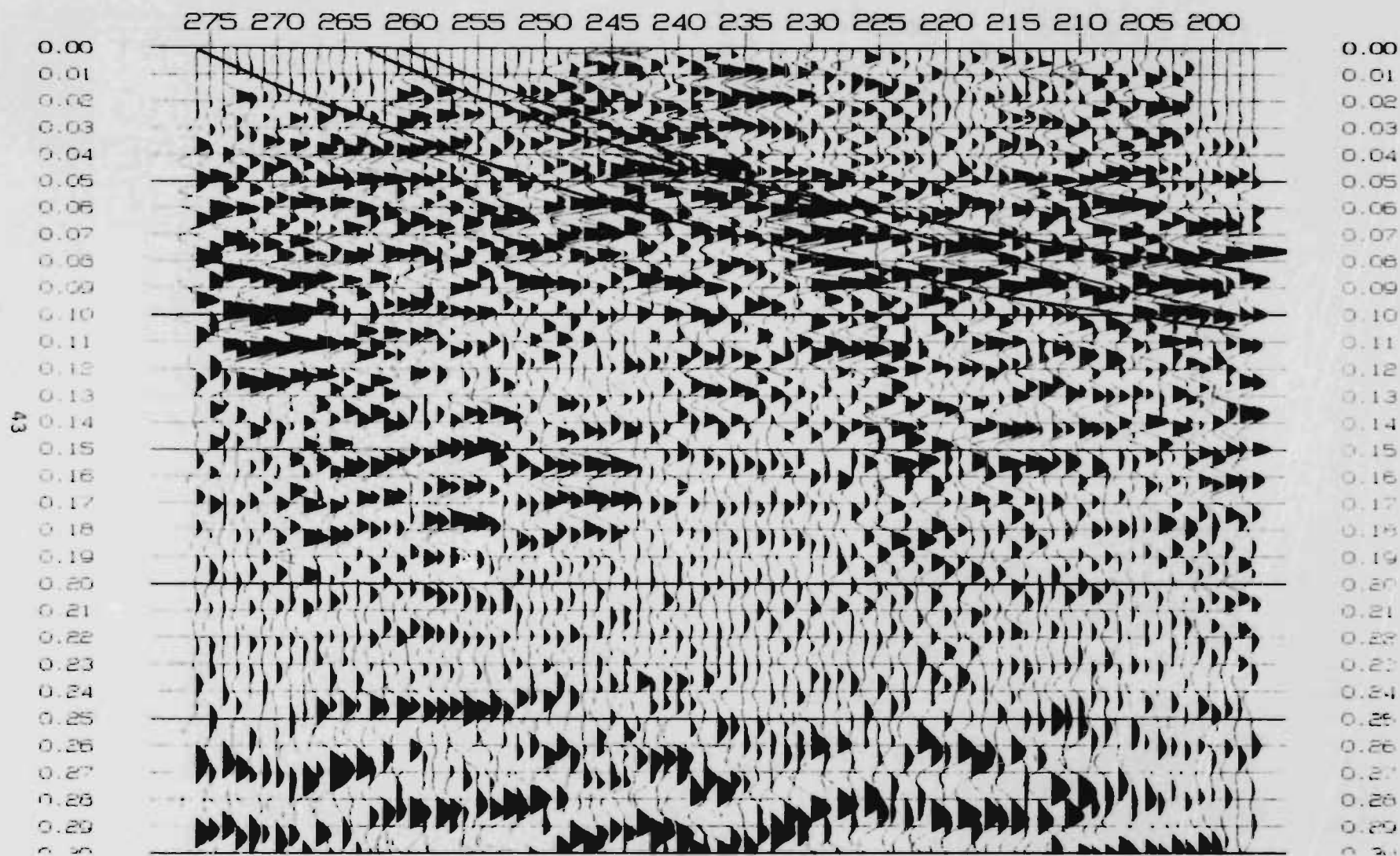
PLOTTER DISPLAY

VAWG 20 IN/SEC 10 TR/IN
POLARITY Black = Positive
DIRECTION OF PLOT R L
REEL NUMBER 42 JOB NO 441

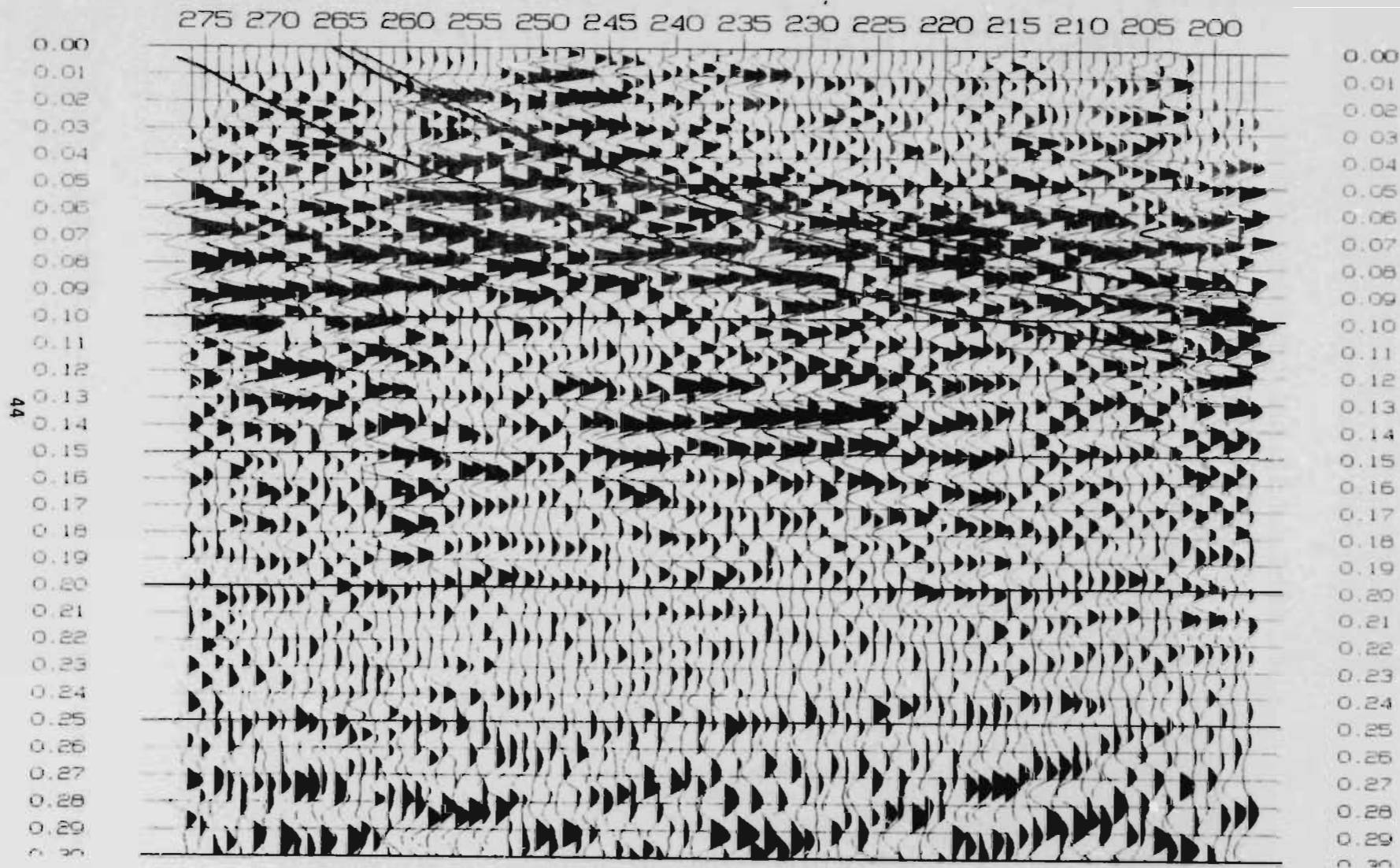
AREA: RAMLINS
LINE: A1A2 B2 B3 C3 C4 D4 D5 E5 F6 F7 G7 G8 H8 H9 SP 197-277
LOCATION: Carbon Co., Wyoming
FOR: Emerald Exploration
ORIG PRSPT:
PROCESS: CDP Stack

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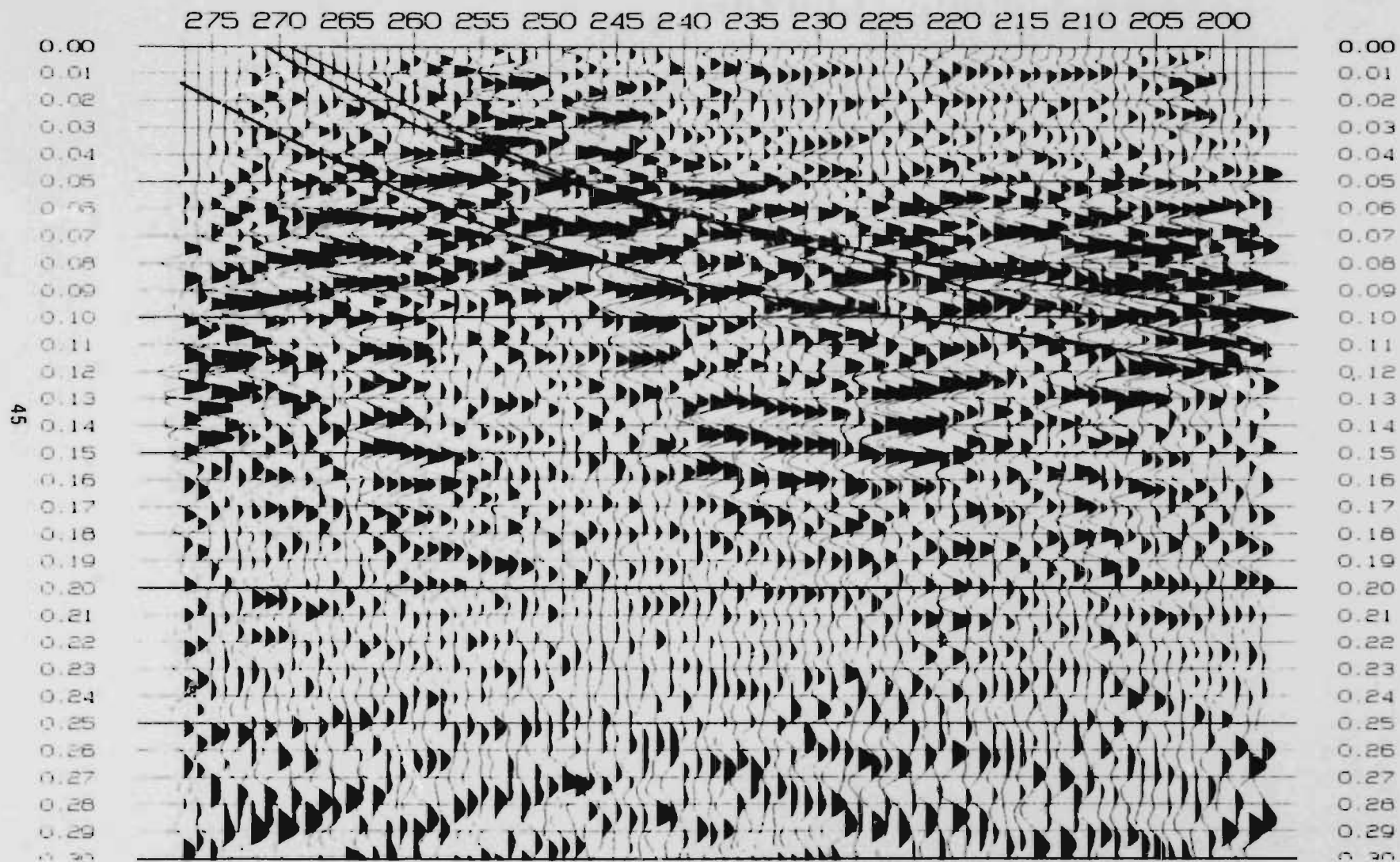
LINE AI CDP STACK



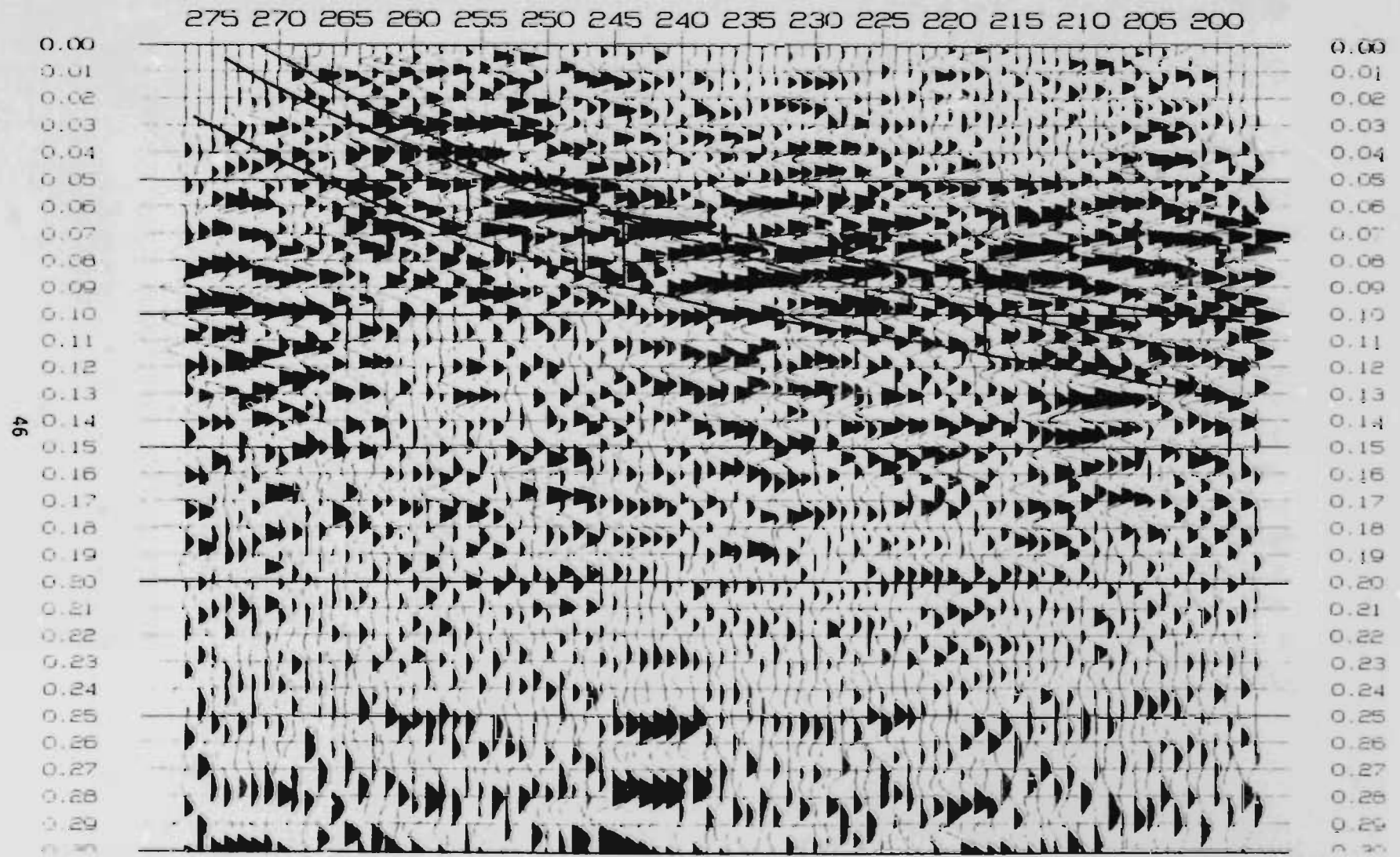
LINE A2 CDP STACK



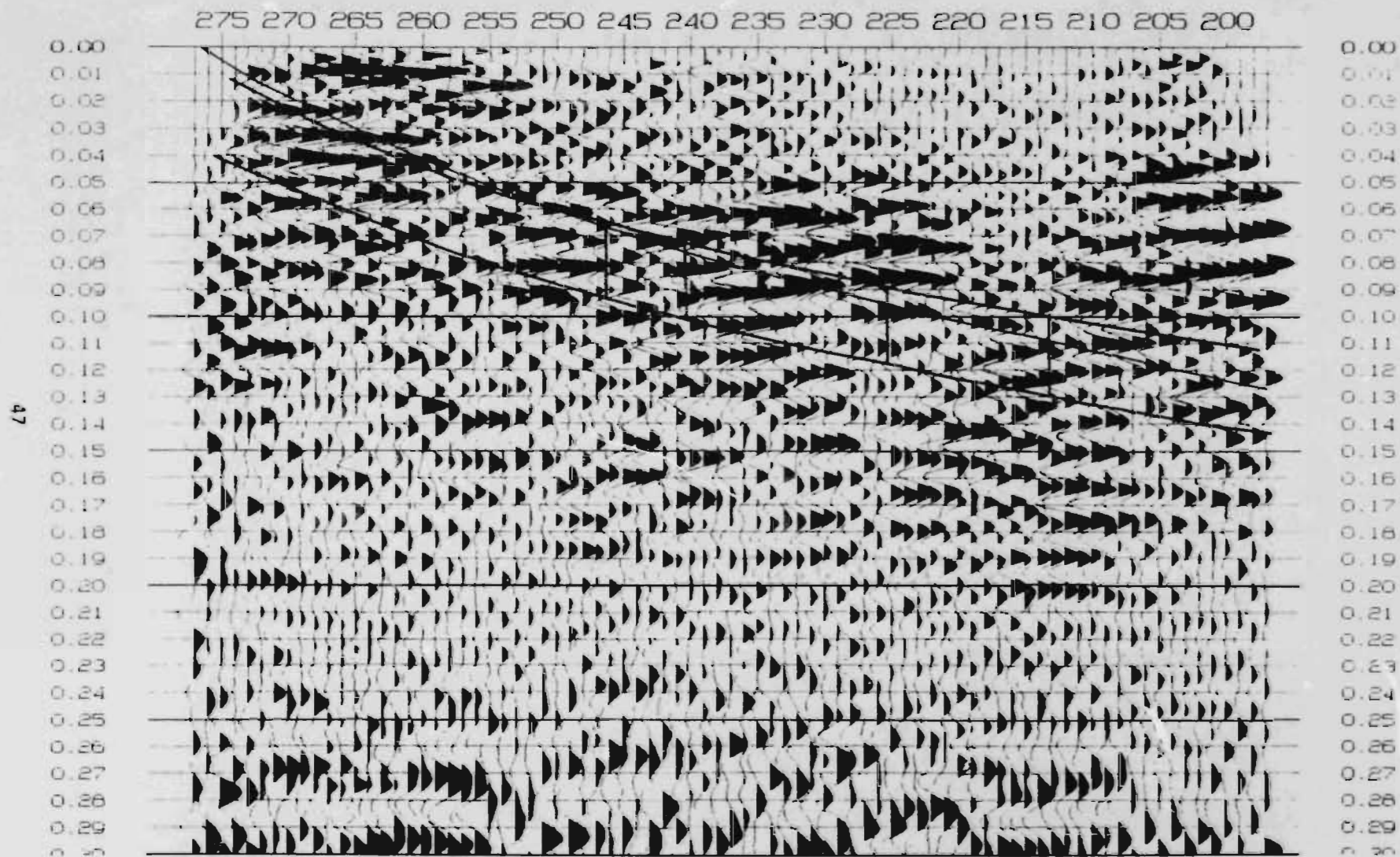
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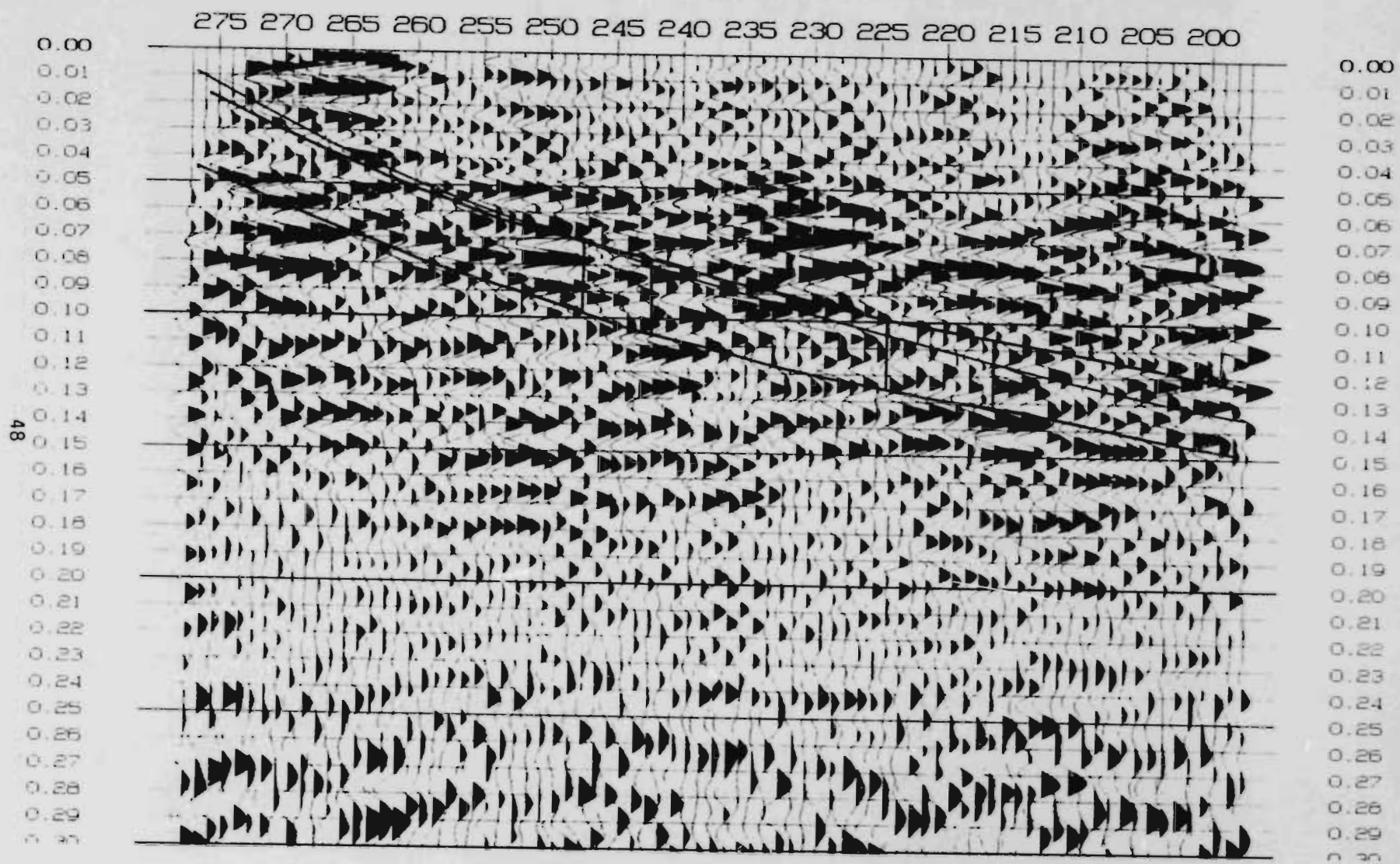
LINE B3 CDP STACK



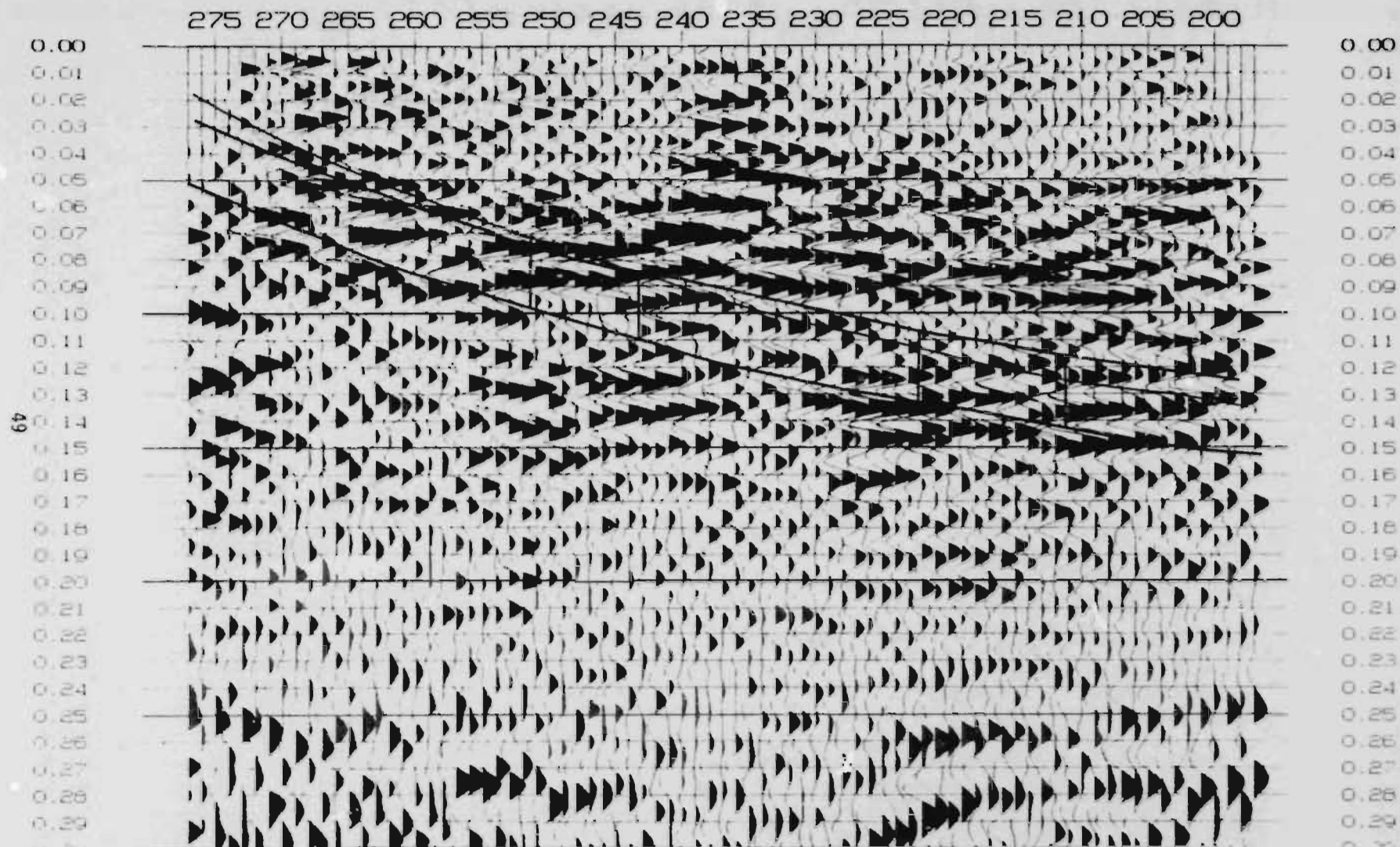
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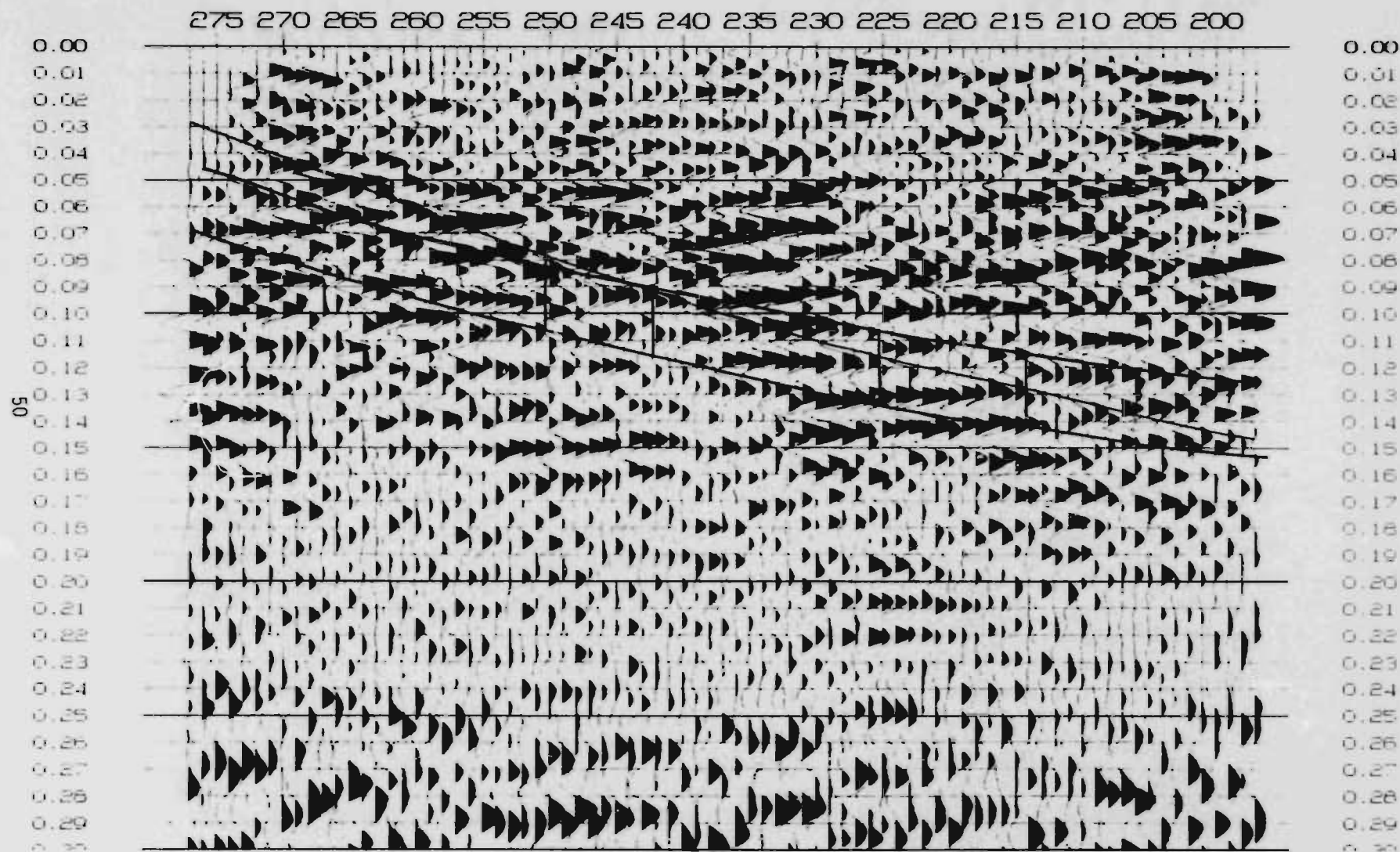
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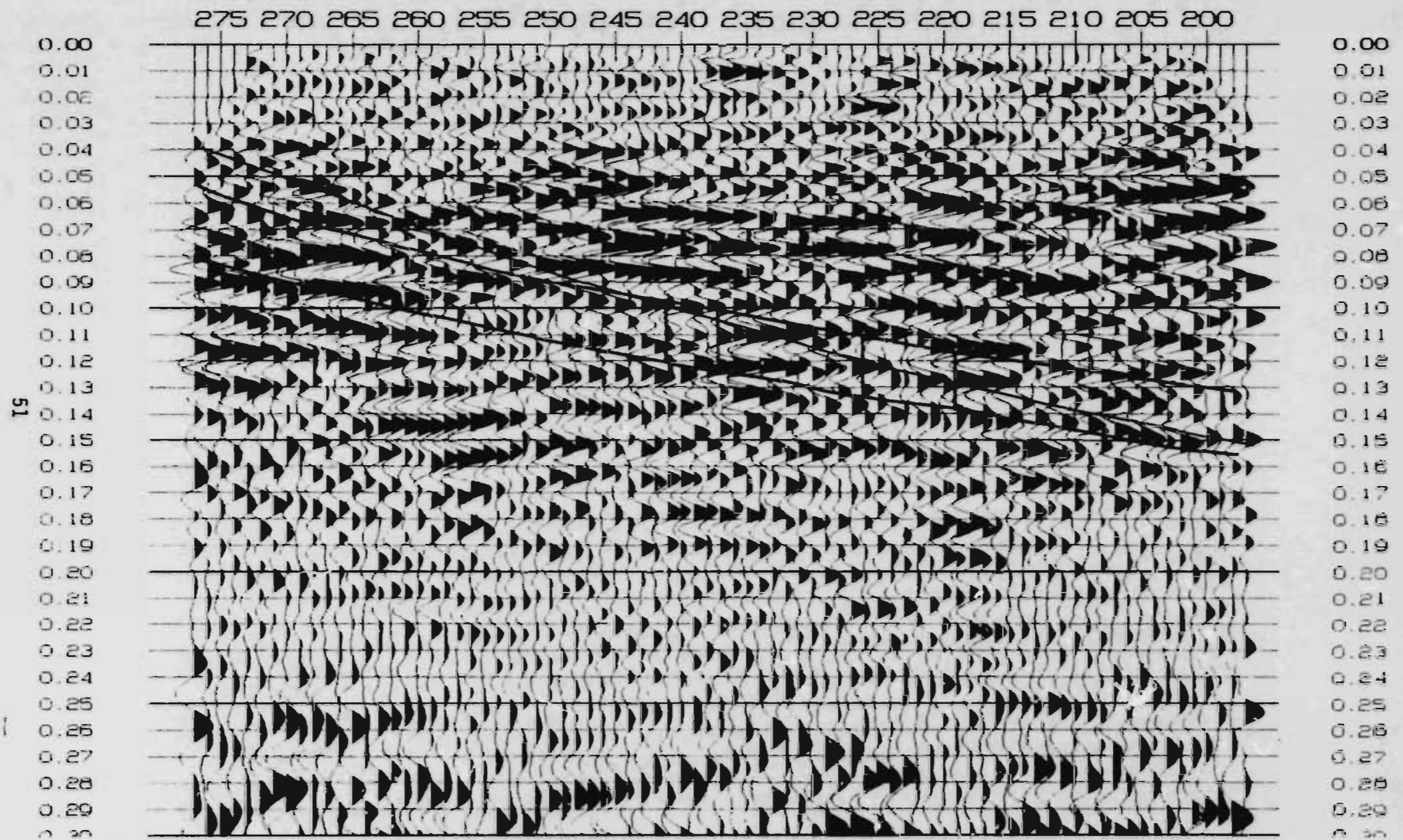
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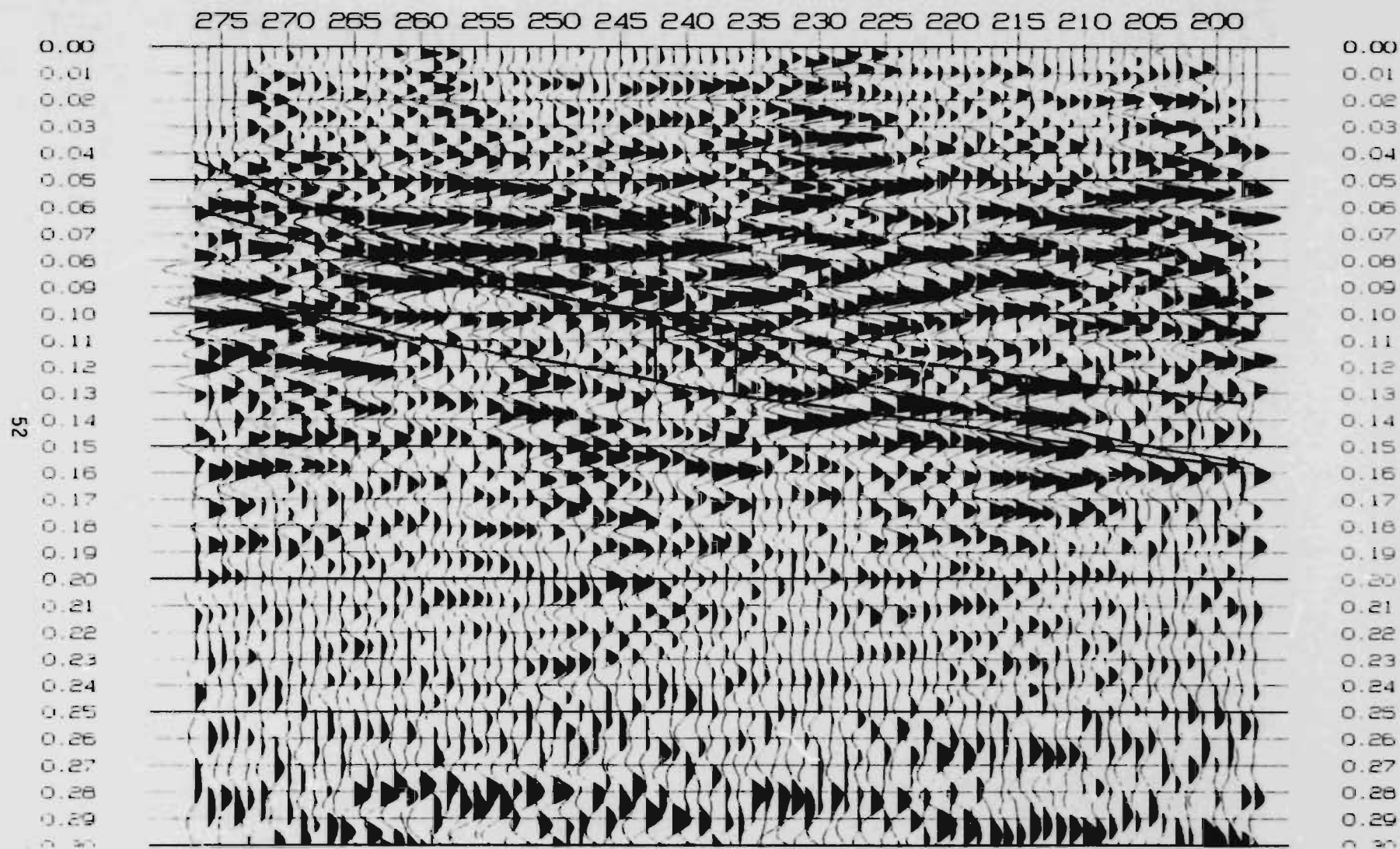
LINE D5 CDP STACK



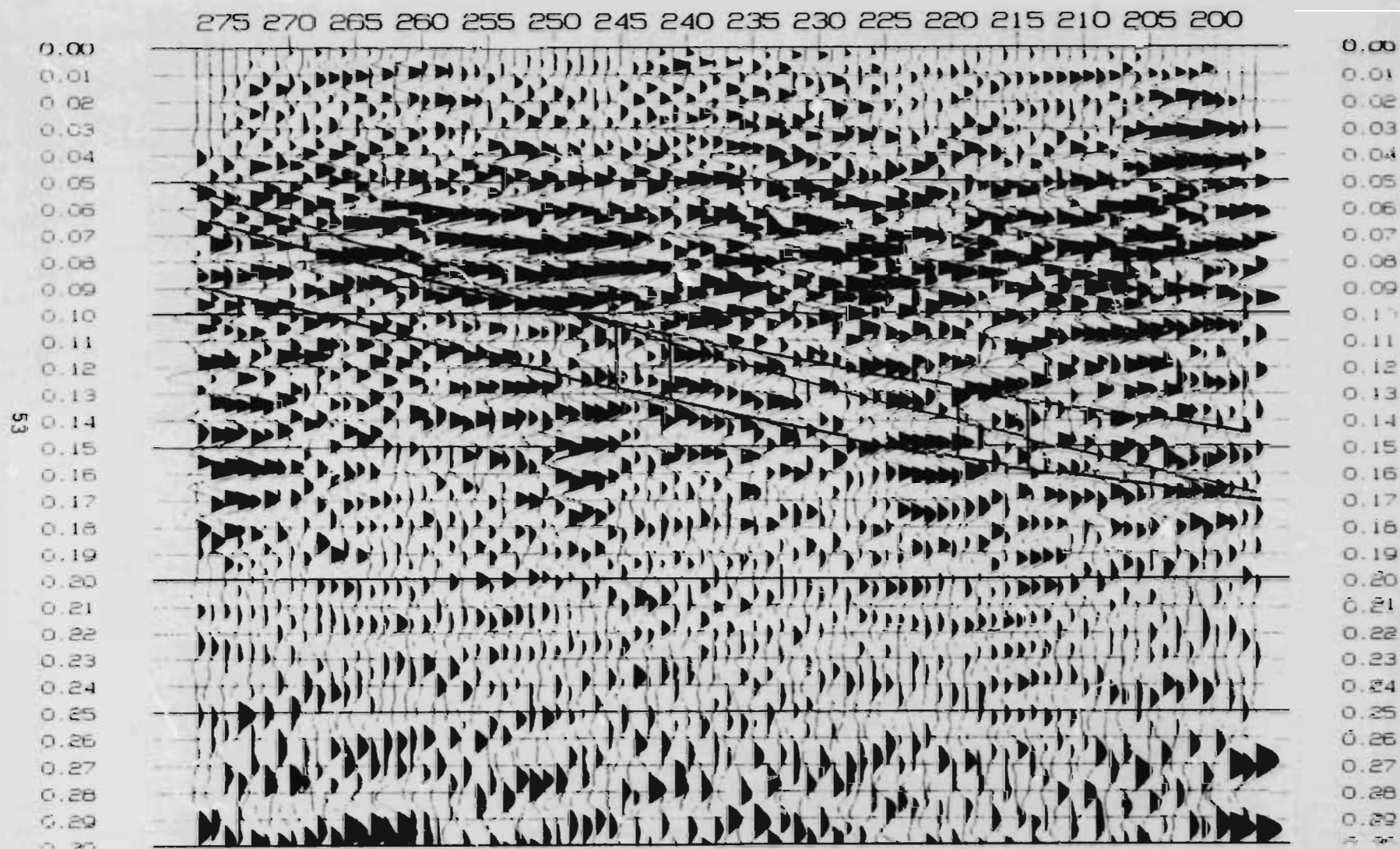
LINE E5 CDP STACK



LINE E6 CDP STACK



LINE F6 CDP STACK



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PAGE 2 OF 3

HIGH RESOLUTION SEISMIC

SURVEY

RAWLINS

WYOMING

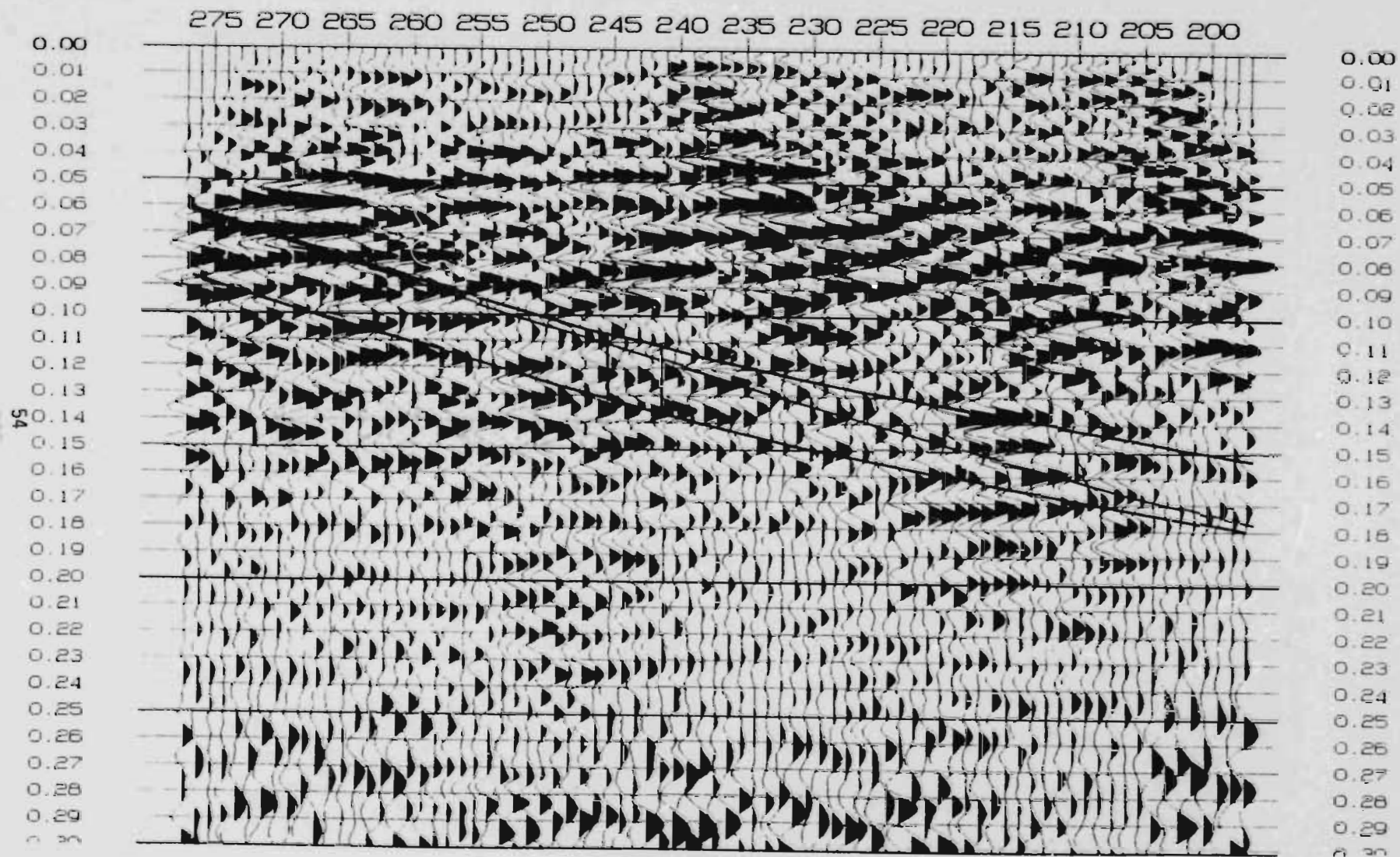
UNDERGROUND

COAL

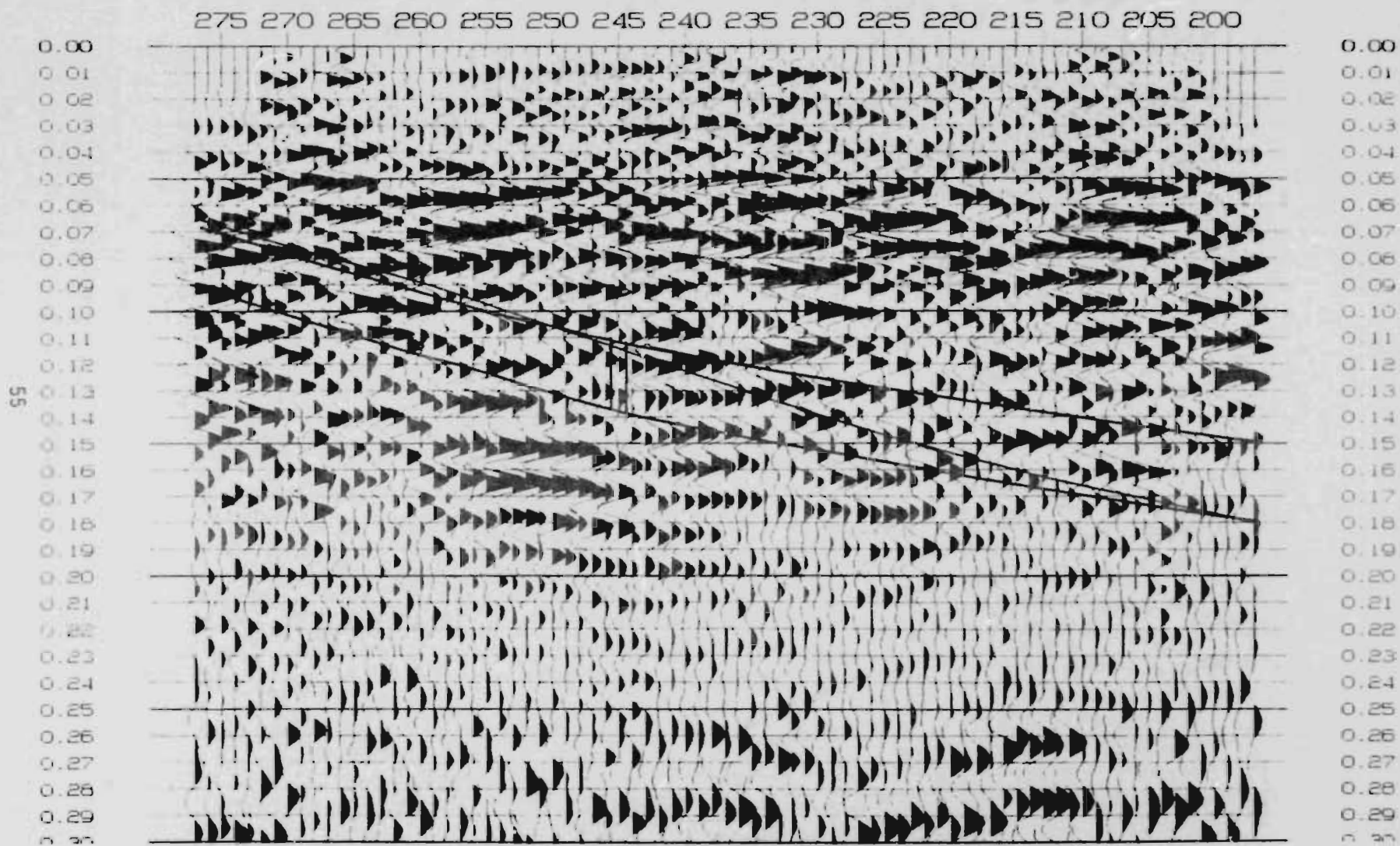
GASIFICATION

AREA

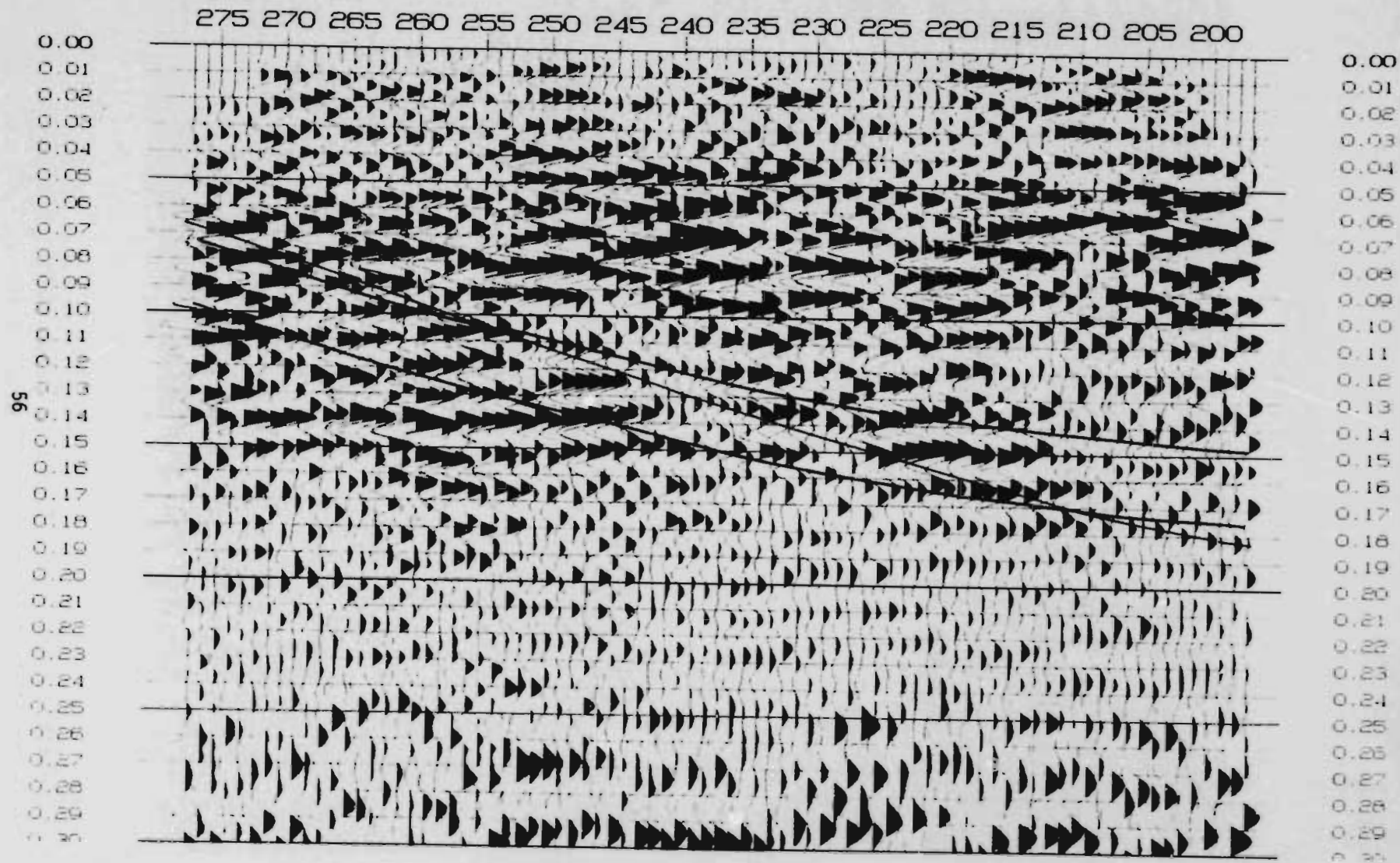
LINE F7 CDP STACK



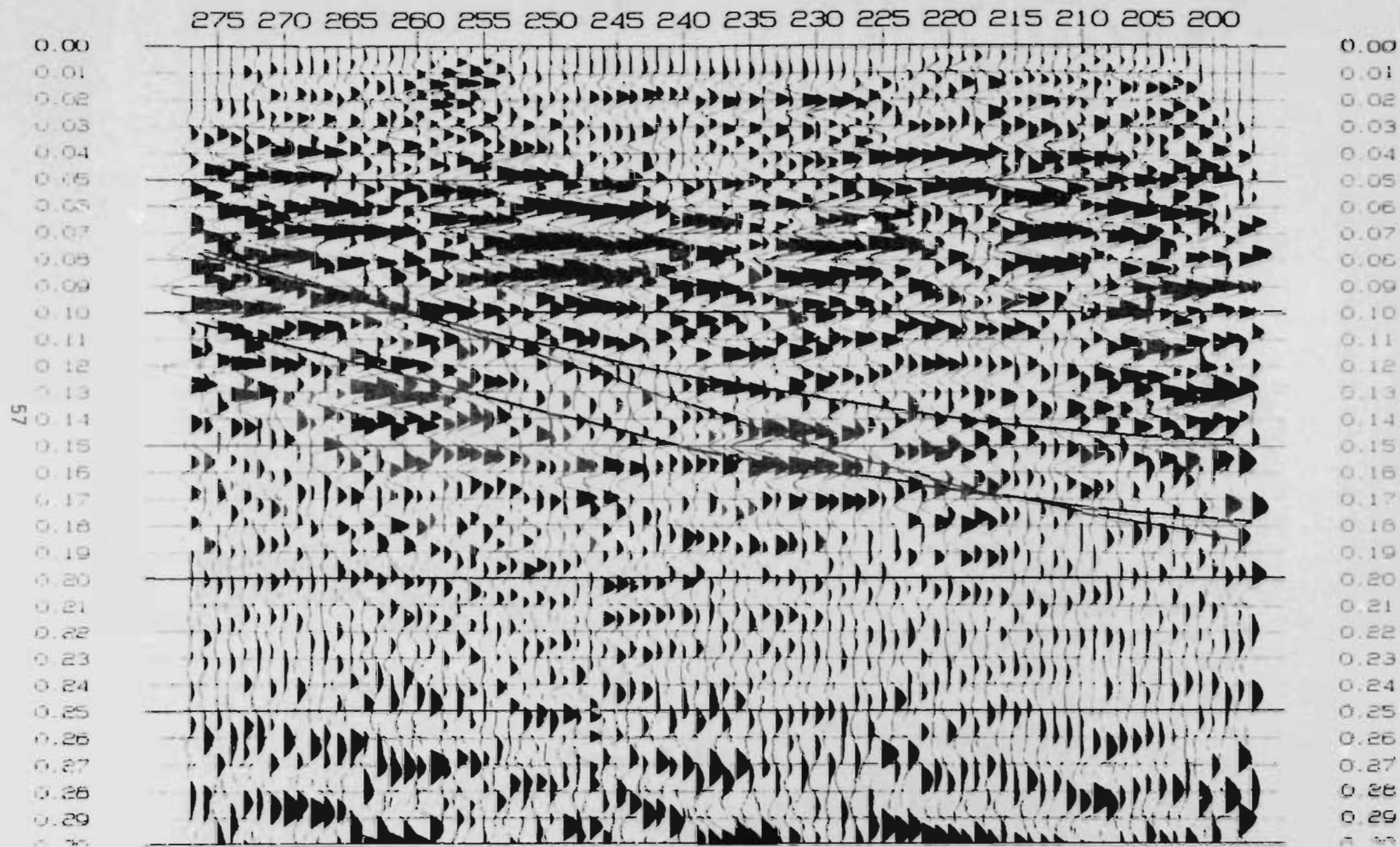
LINE G7 CDP STACK



LINE G8 CDP STACK



LINE H8 CDP STACK



LINE H9 CDP STACK

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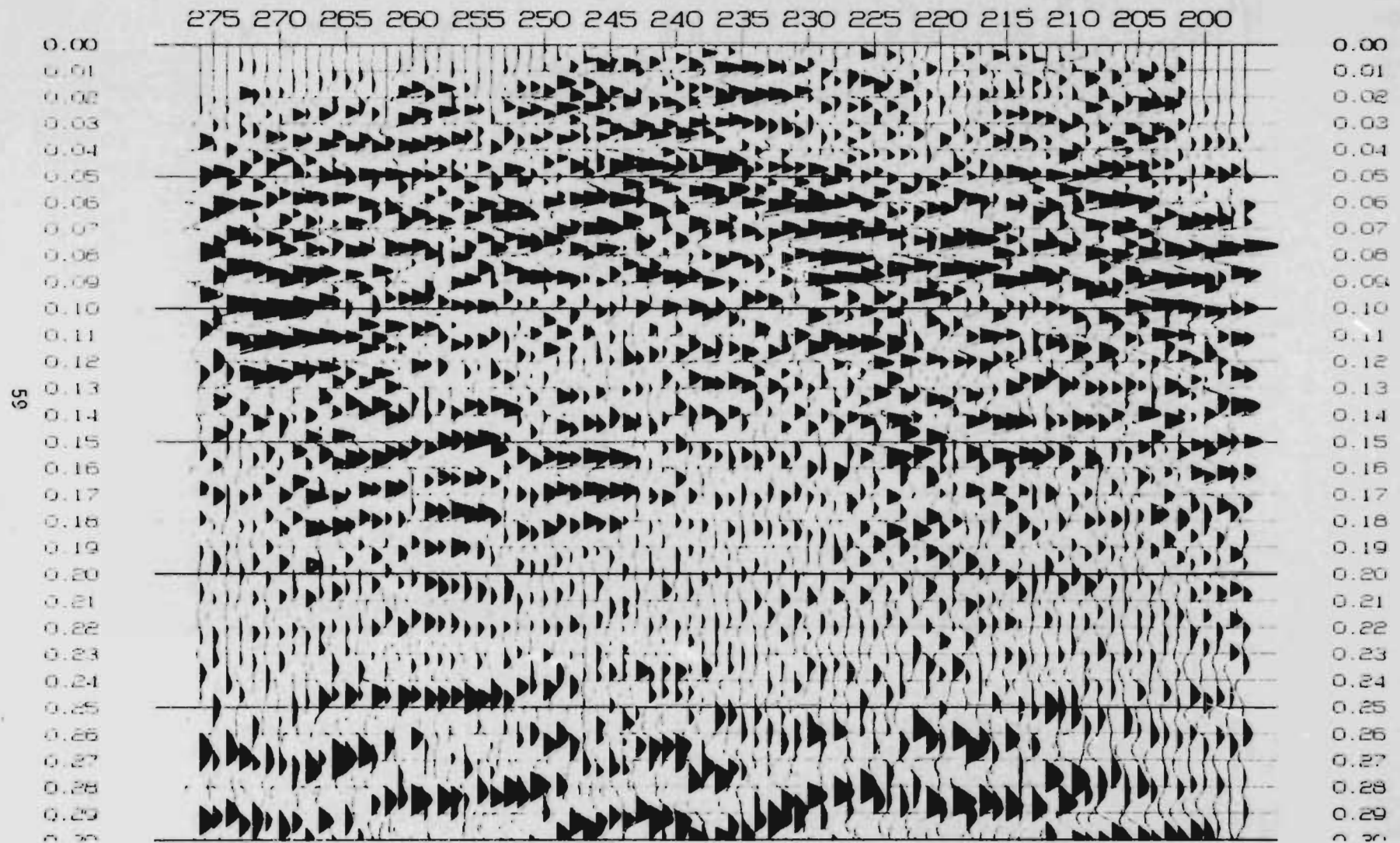
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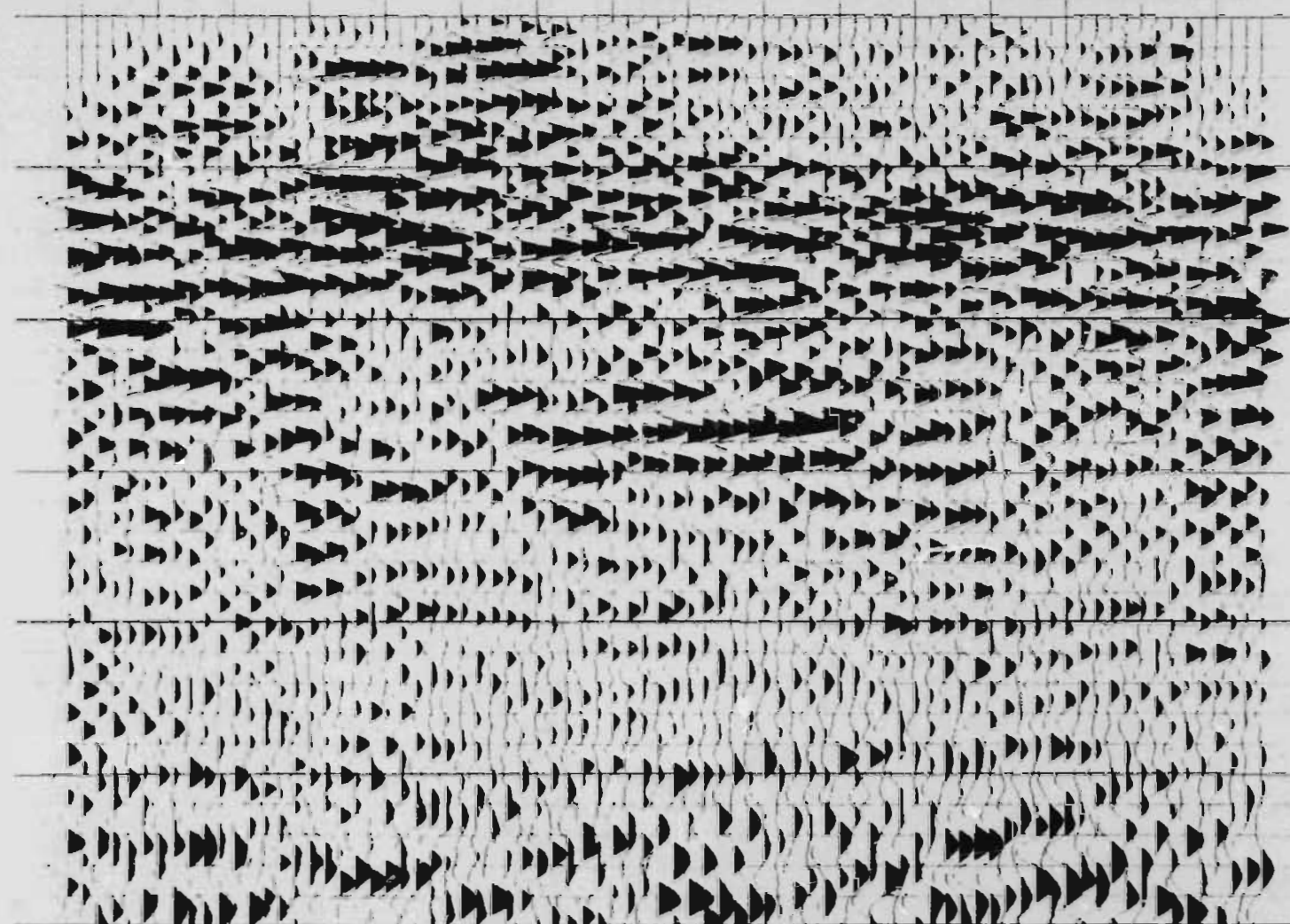


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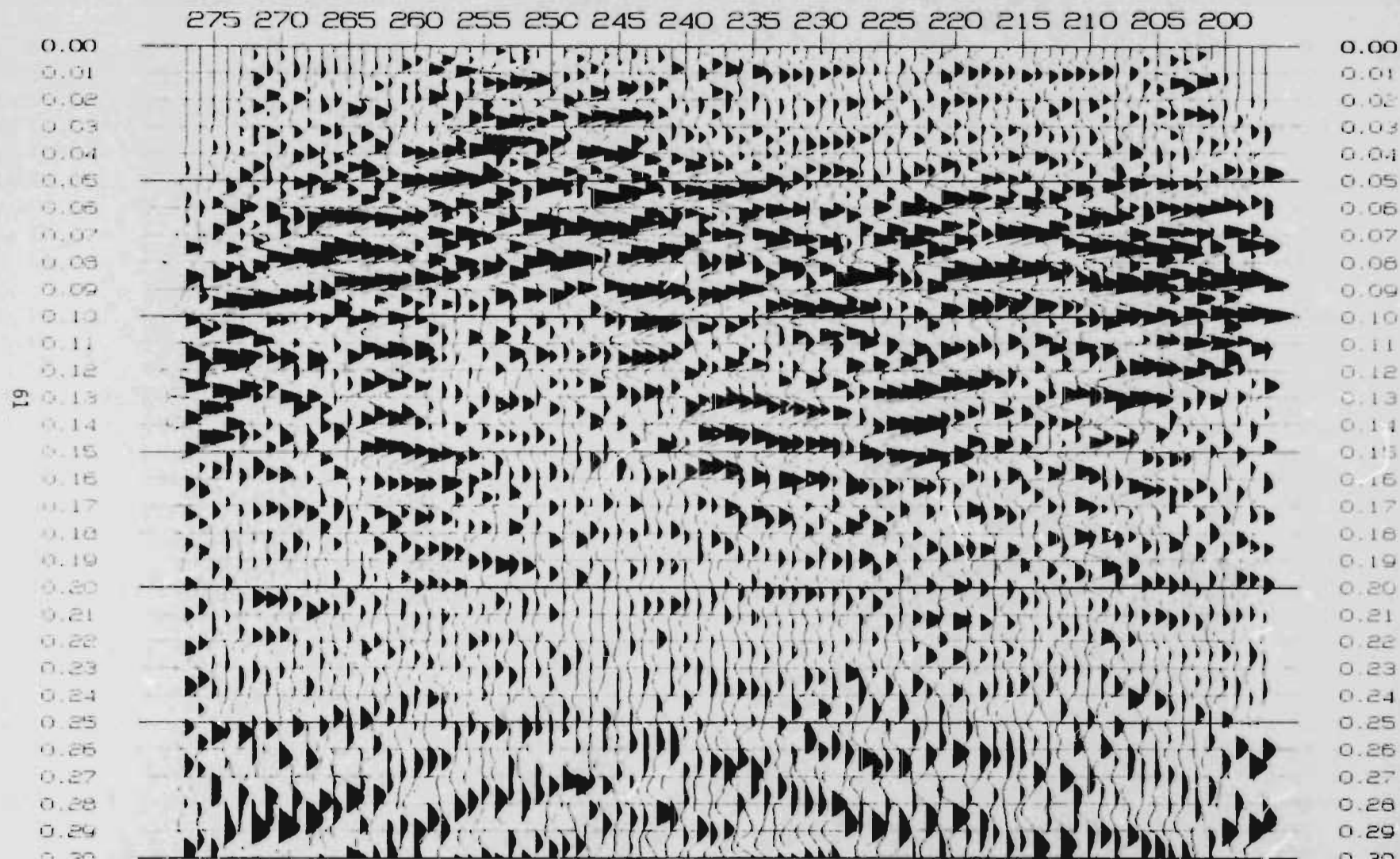
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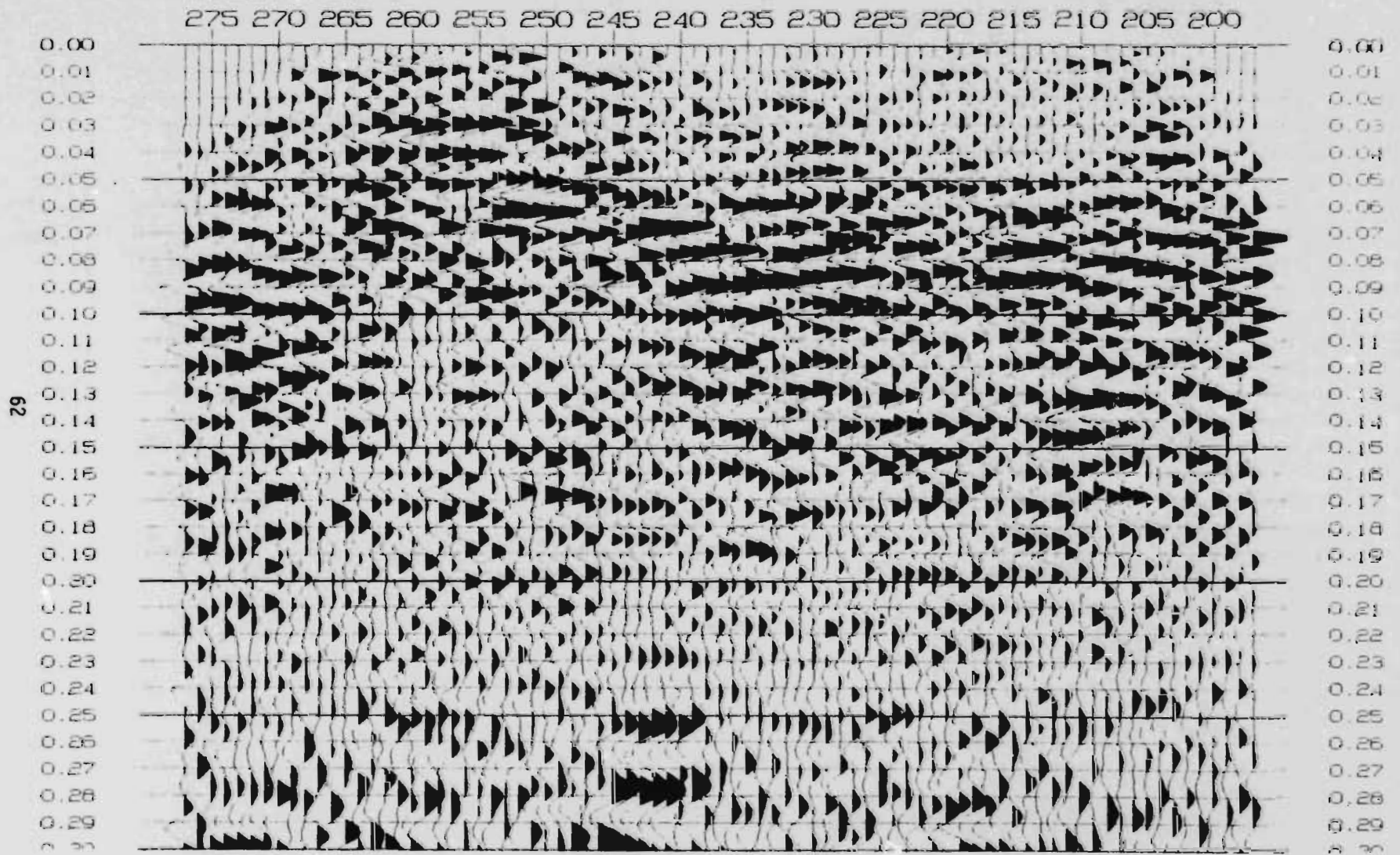


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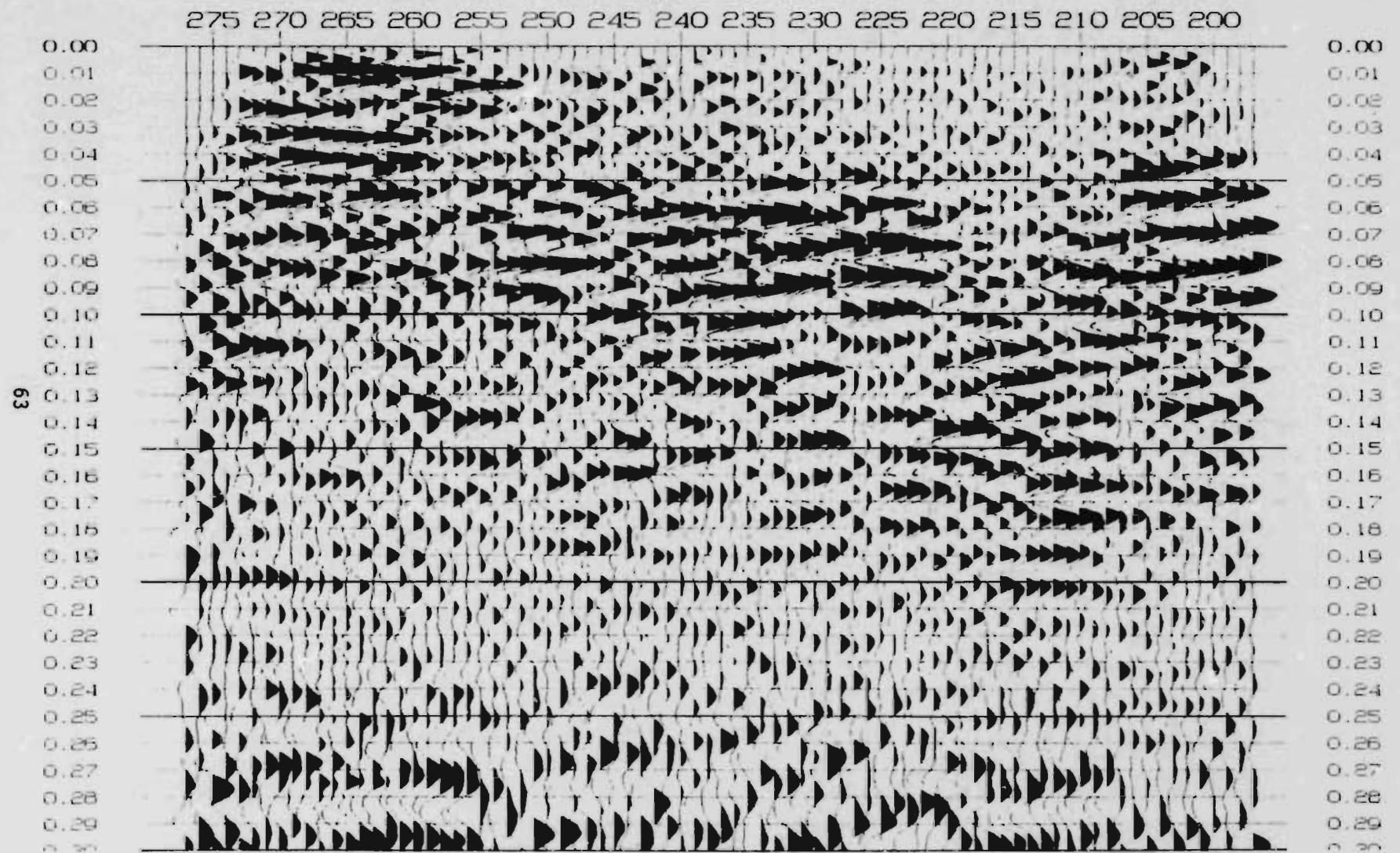
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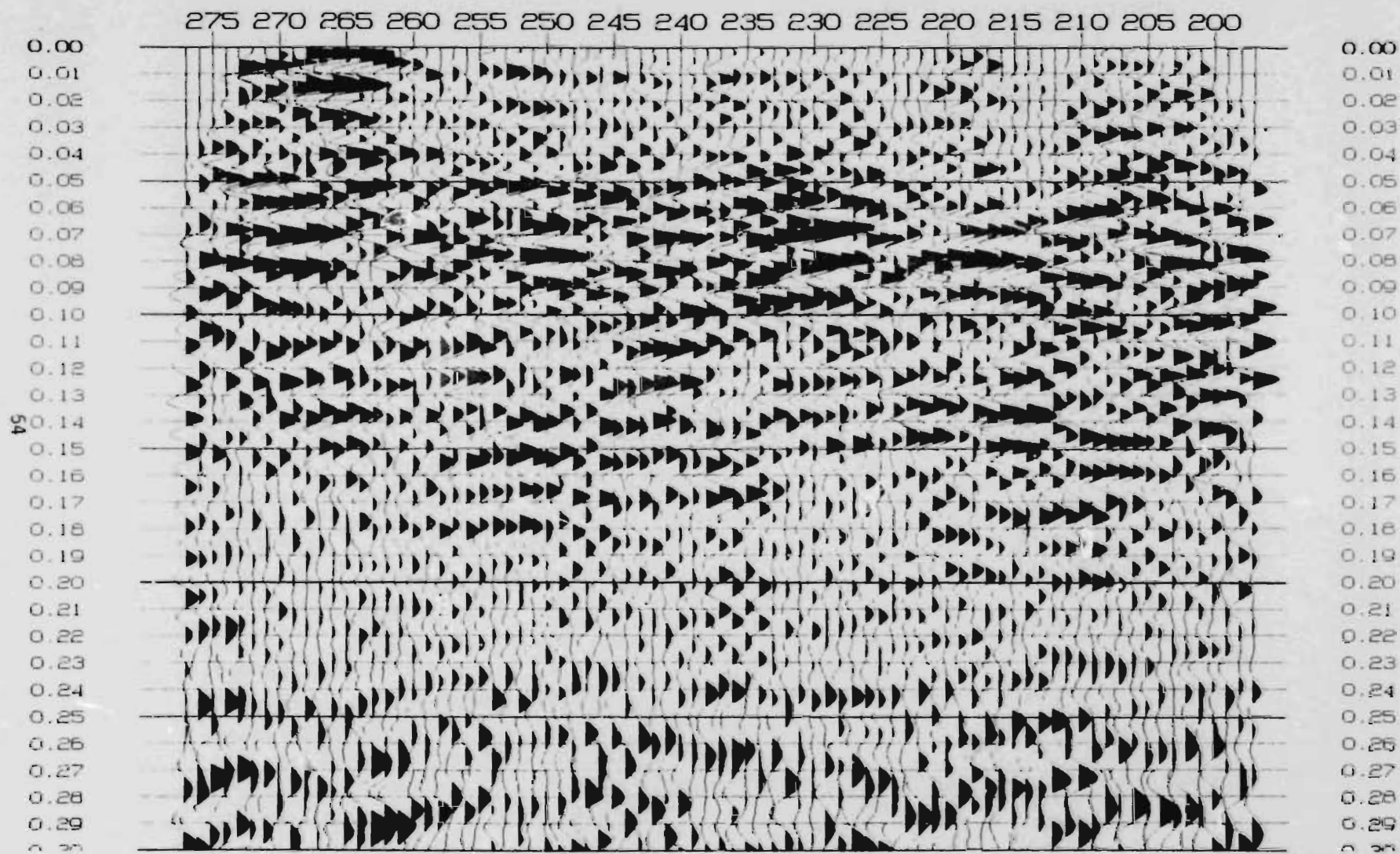
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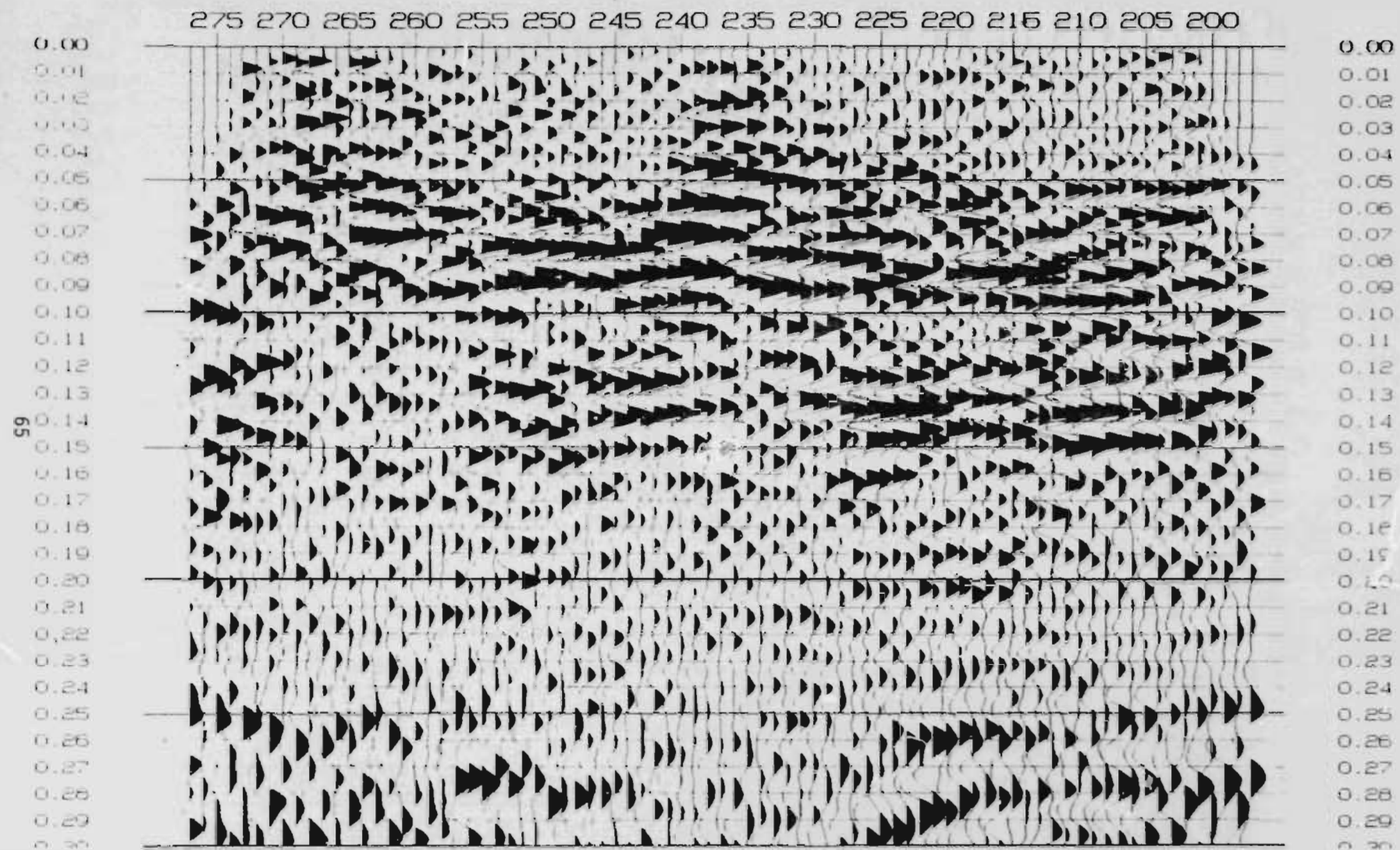
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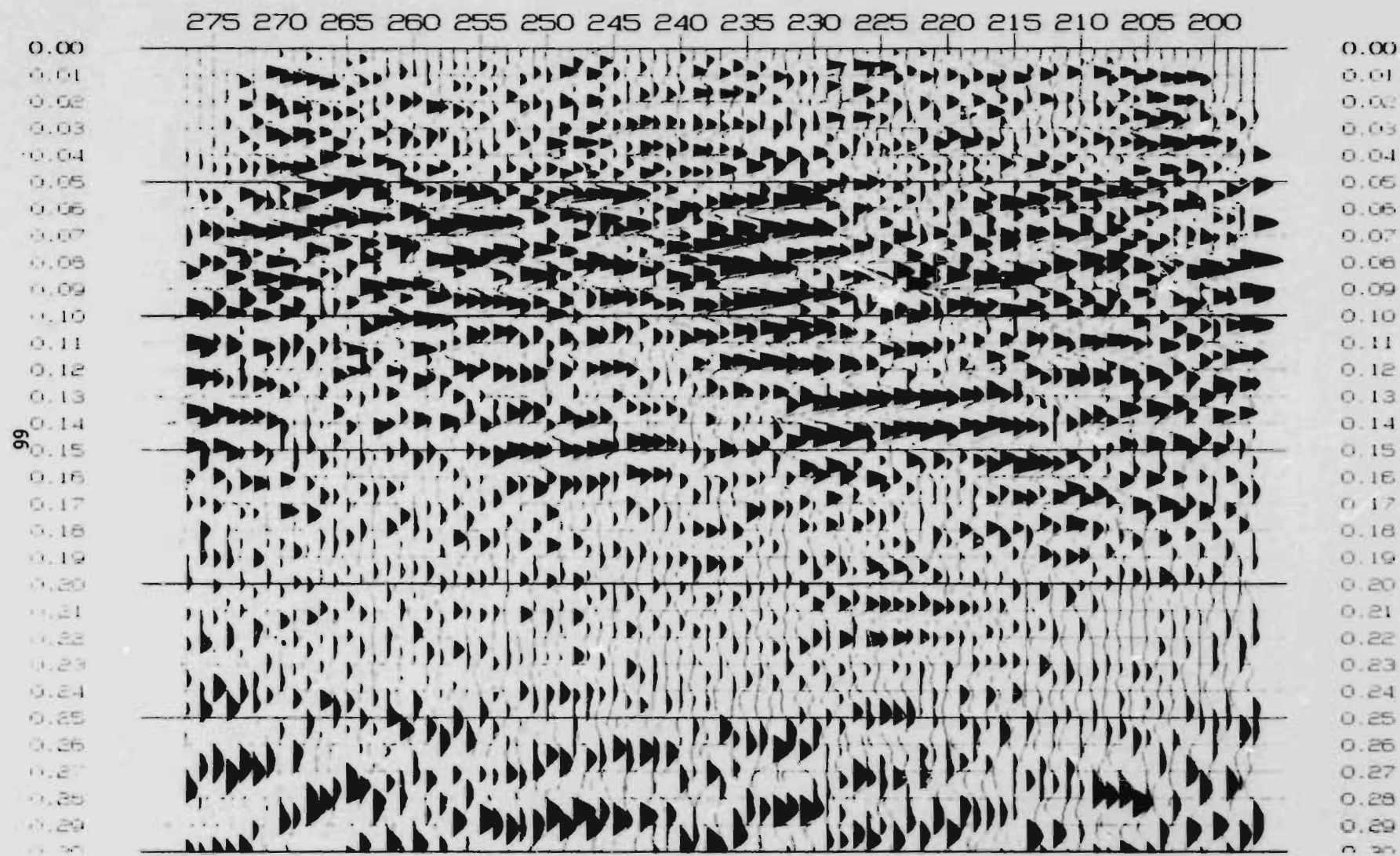
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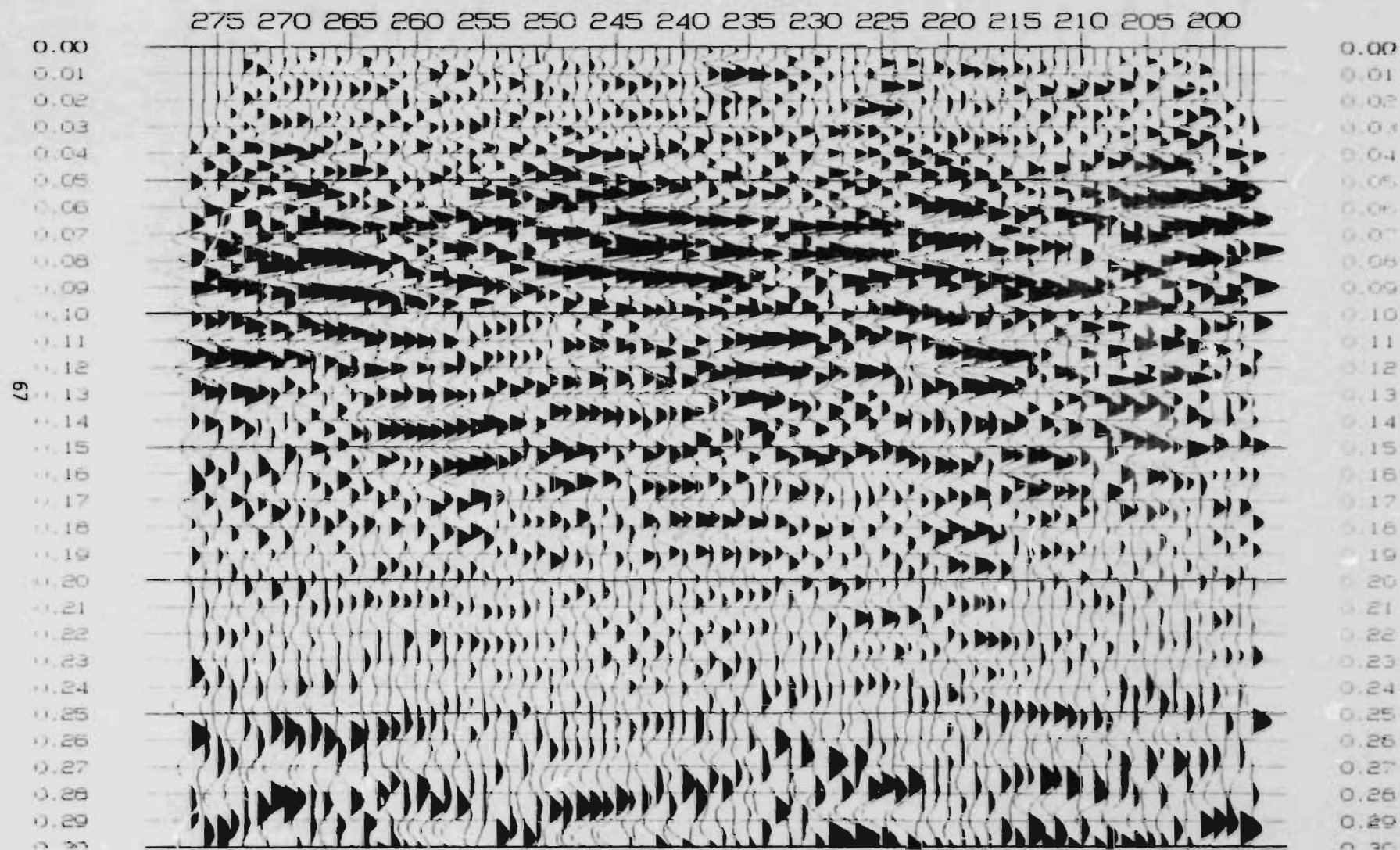
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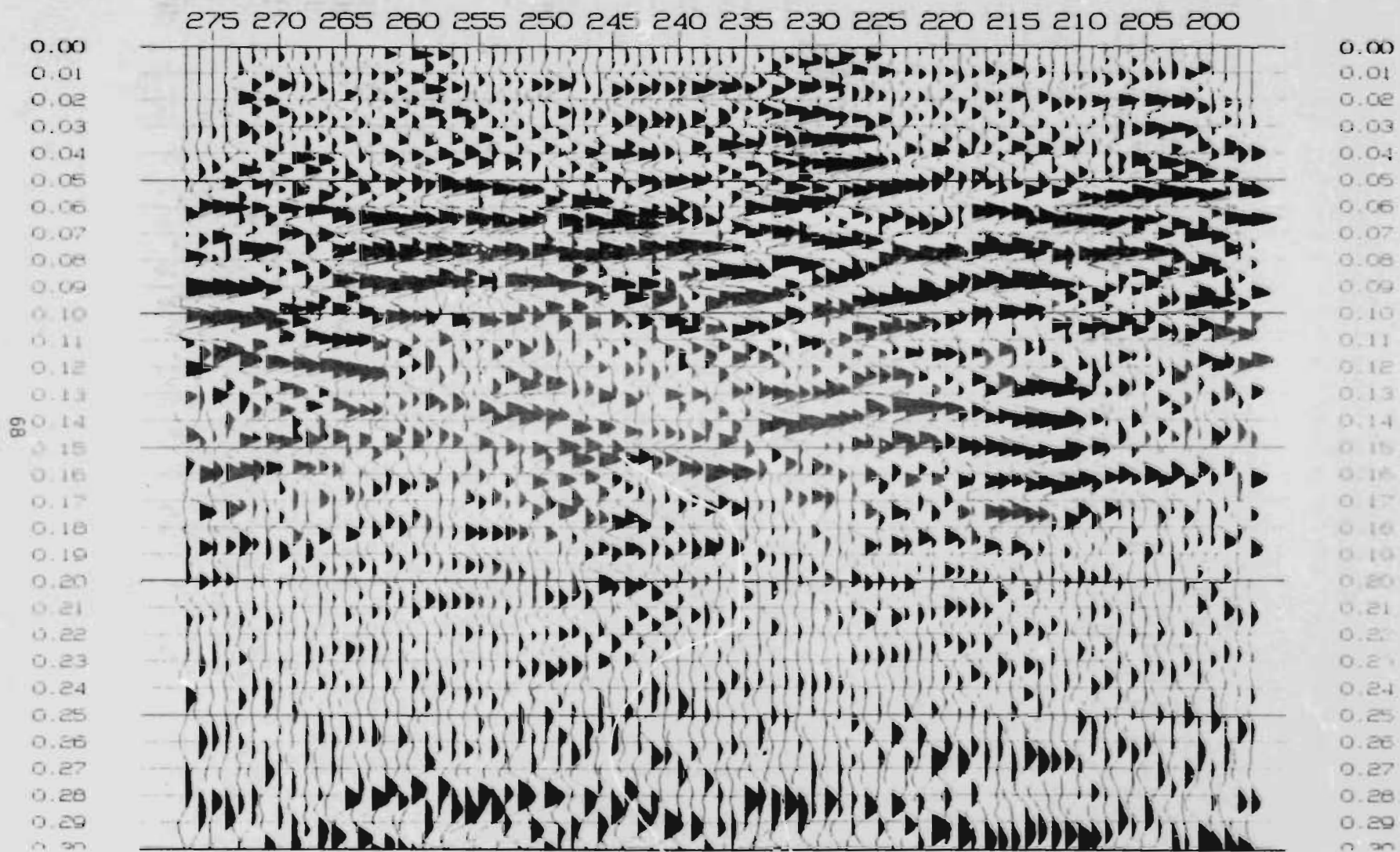
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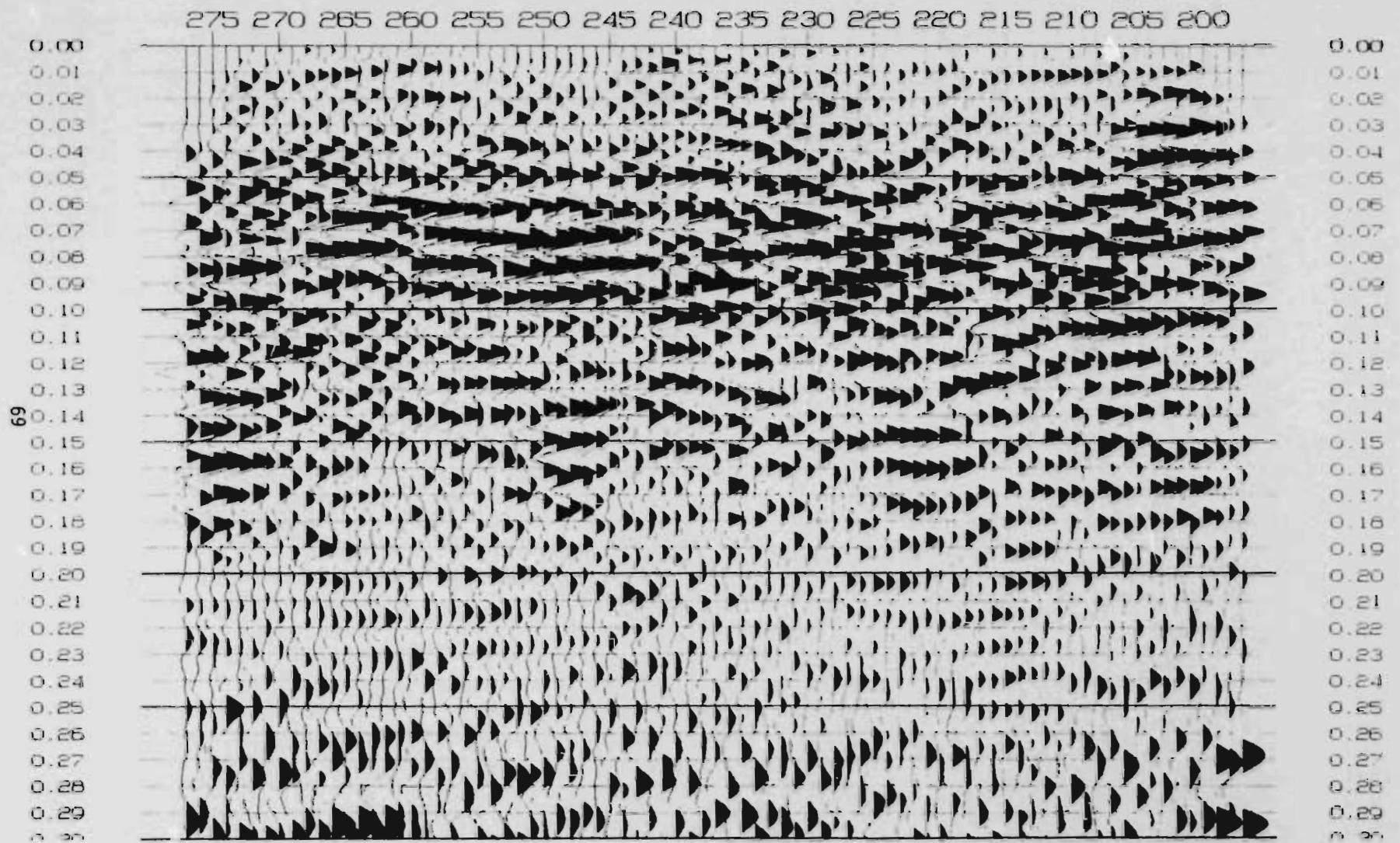
LINE E5 CDP STACK



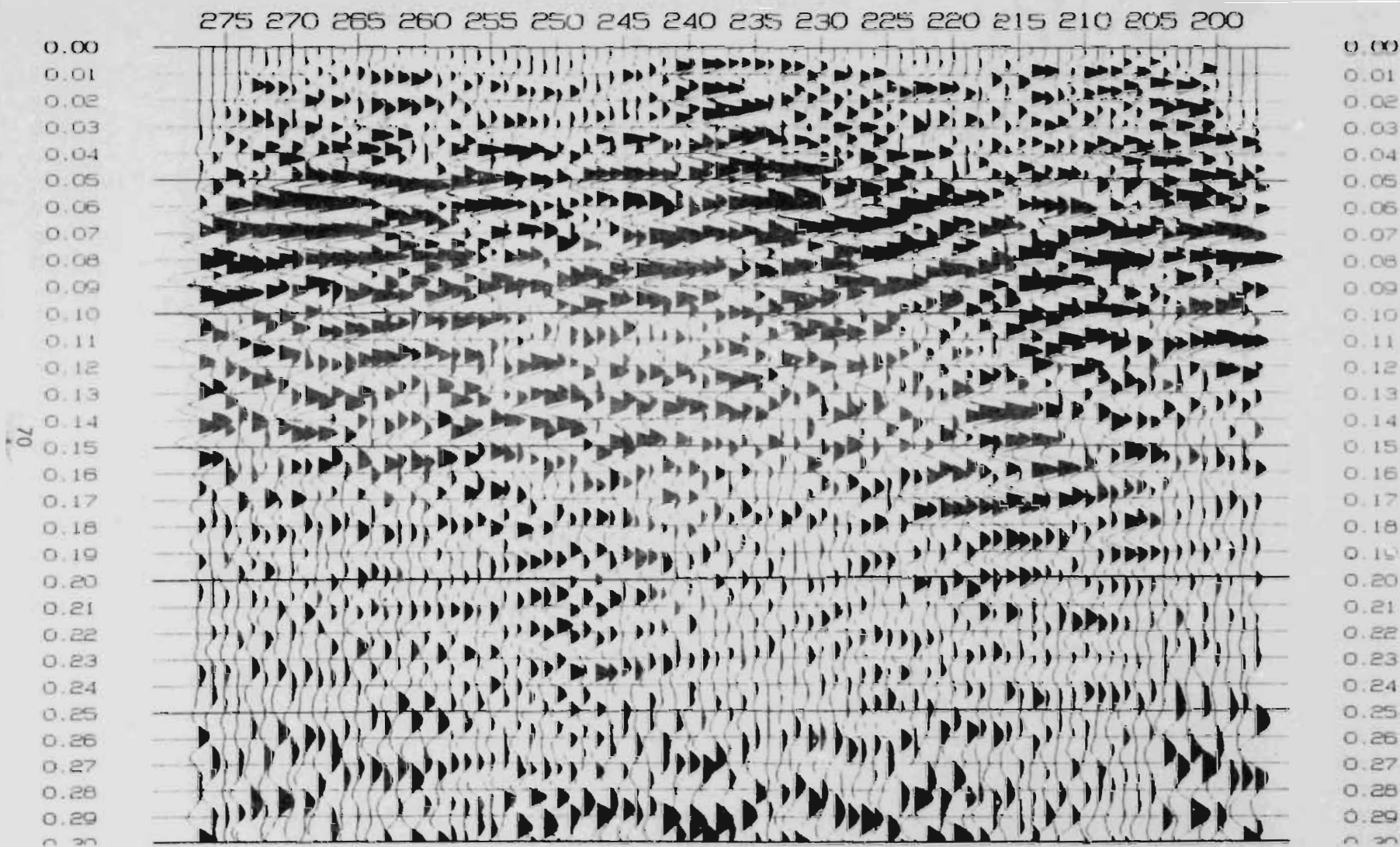
LINE E6 CDP STACK



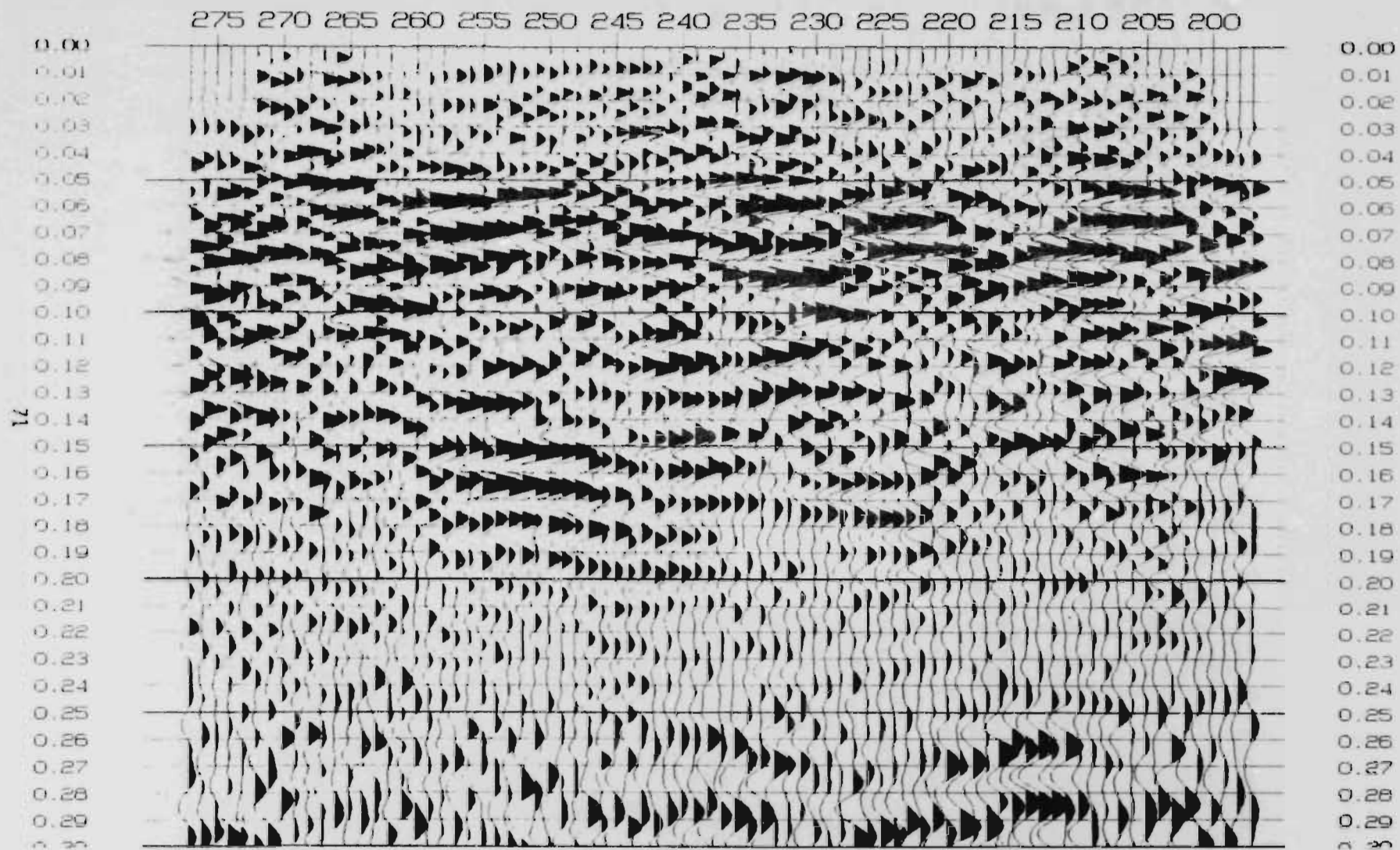
LINE F6 CDP STACK



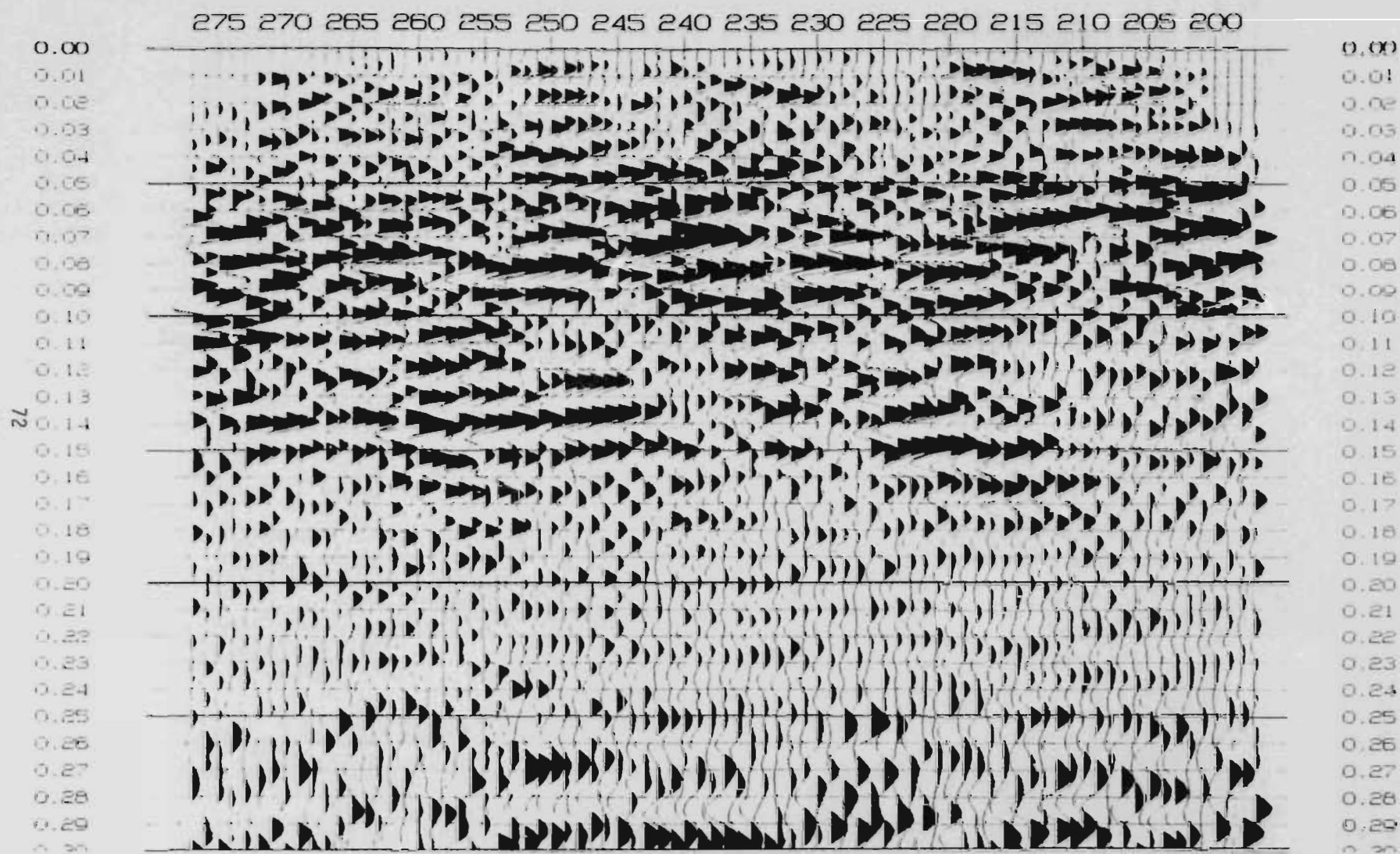
LINE F7 CDP STACK



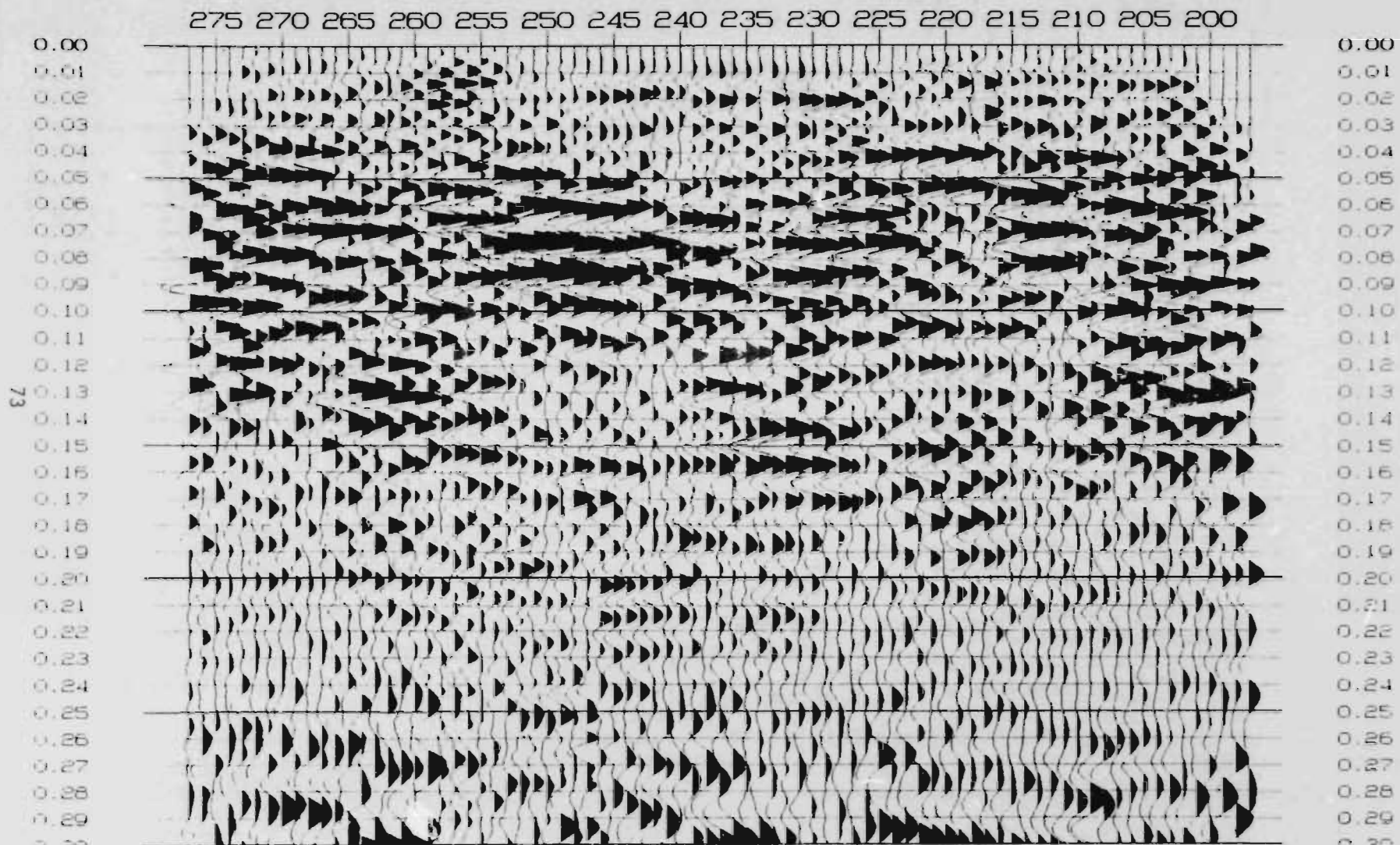
LINE G7 CDP STACK



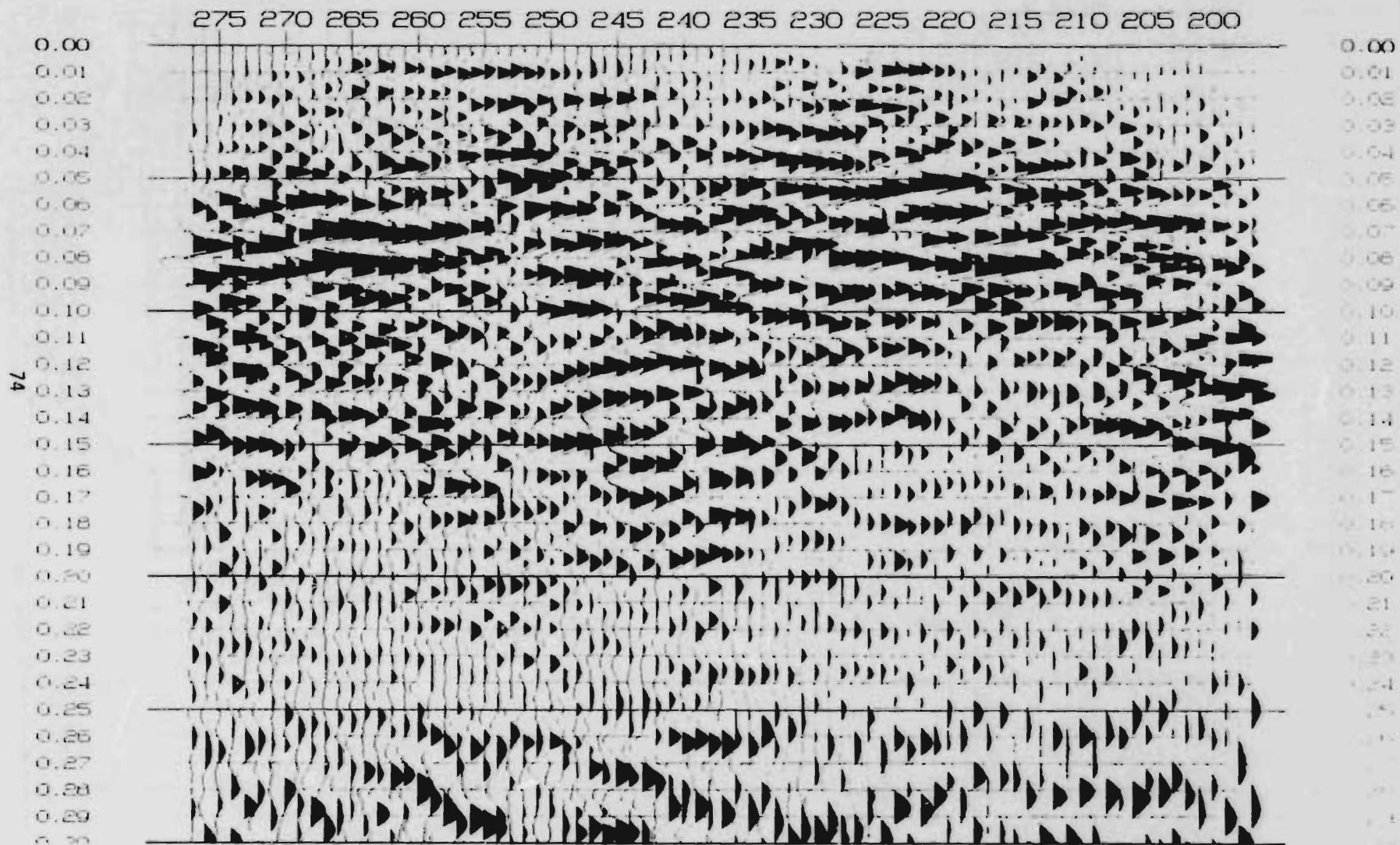
LINE G8 CDP STACK



LINE H8 CDP STACK



LINE H9 CDP STACK



FIELD PARAMETERS

INST: DFS II	GROUP INT 20 ft
REC. LENGTH: 1 sec	S P INT 20 ft
SAMPLE RATE: 1 ms	NO OF CHAN 24
RECORDED BY: ESI & I	GEOPH ARRAY: 6 all 12 centered
SOURCE: Detaprime	SPREAD: Shooting Thru Cable
HOLE DEPTH: 6 ft	NEAR OFFSET: 0 ft
DATE: Oct, 1982	FAH OFFSET: Varies

PROCESSING SEQUENCE



PROCESSED BY THE:
SEISTRAC 32

APPLIED RESEARCH CONCEPTS

- (1) DEMUX/REFORMAT
- () RESAMPLE
- (2) CDP GATHER
- DATUM: 6900 ft VELOCITY: 5000'/sec
- () FILTER
- () DECONVOLUTION

MS. OPERATOR

AUTO CORR. WINDOW:
WHITE NOISE. PERCENT

- (7) VELOCITY ANALYSIS
- (8) NMO
- (9) MUTE
- (10) AUTOMATIC STATICS WINDOW: 100-500
- () CDP x CORR STATICS WINDOW
- (11) STACK FOLD Varies - See Report
- (4) FILTER
- 60-80-160-180 Hz 0-400 msec
- 30-50-100-120 Hz 240-600 msec
- (5) EQUALIZATION
- (3) GAIN RECOVERY T-14 FUNCTION
- (6) TRACE COMPOSITE 3 Trace - Common Offset Distance
- () WAVE EQUATION MIGRATION
- (12) TRACE COMPOSITE FOR 3-D
- 20 FT BOX CONFIGURATION

DATE PROCESSED Nov, 1982 ANALYST Austin, Tx.

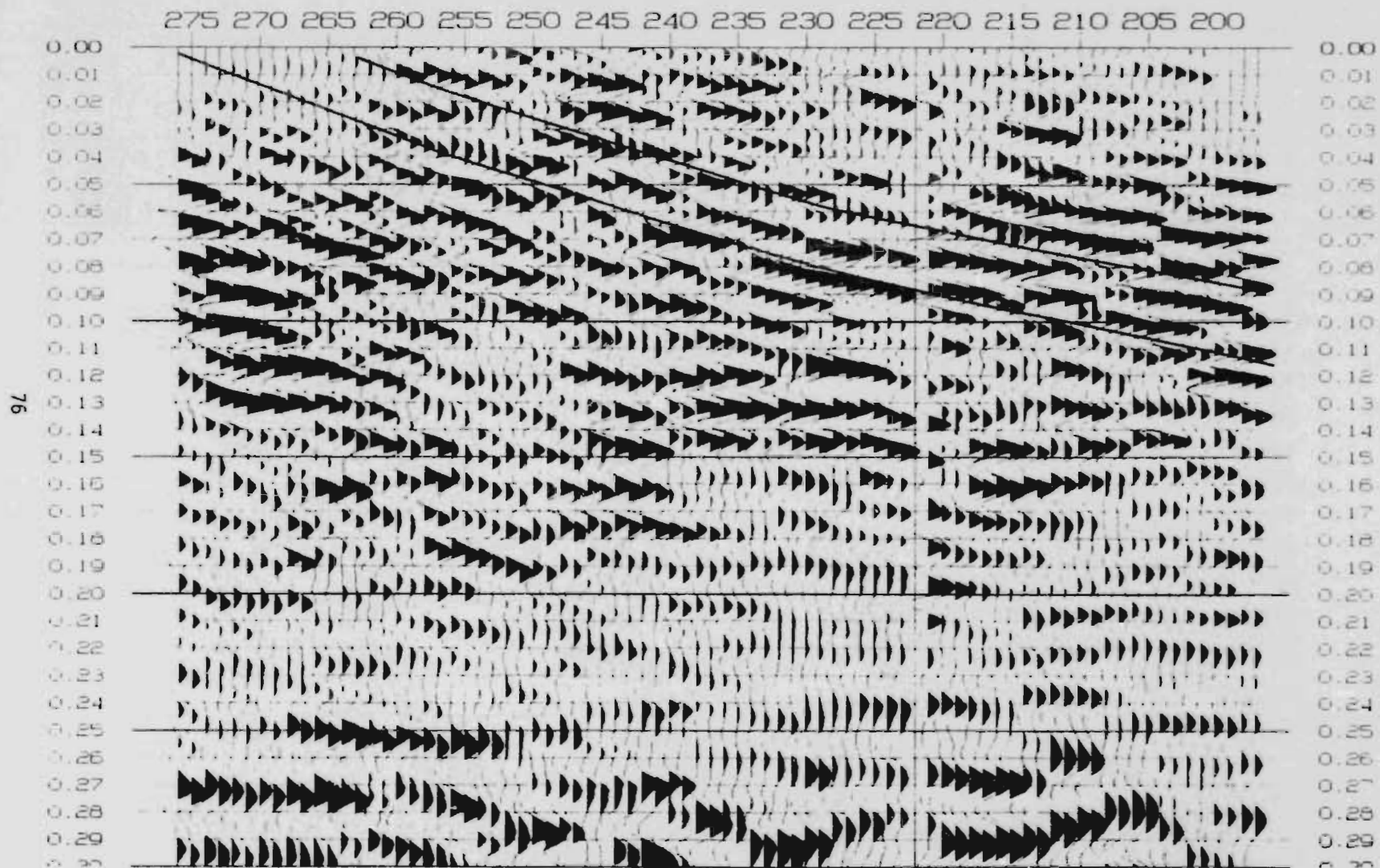
PLOTTER DISPLAY

VAVWG 20 IN/SEC 10 TR/IN
POLARITY Black = Positive
DIRECTION OF PLOT R-L
REEL NUMBER 75 JOB NO 441

AREA: RAWLINS
LINE: A12, AB2, B23, BC3, C34, CD4, D45, DE5, E56, EF6, FG7, G78, GH8, H89
LOCATION: Carbon Co., Wyoming
FOR: Emerald Exploration S.P. 197-277
ORIG PRSPT: _____
PROCESS: 20' Slack

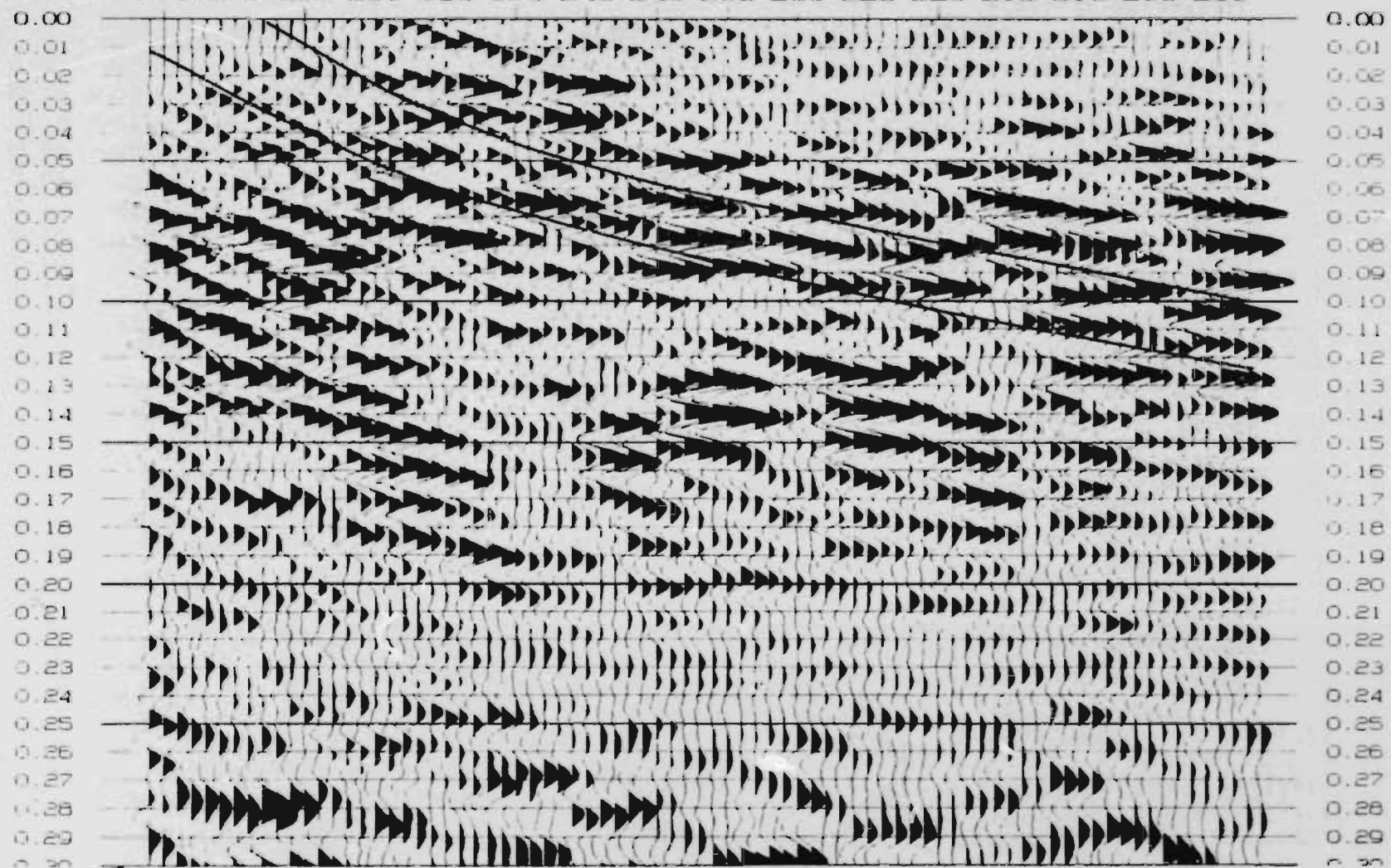
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LINE A12 20' STACK

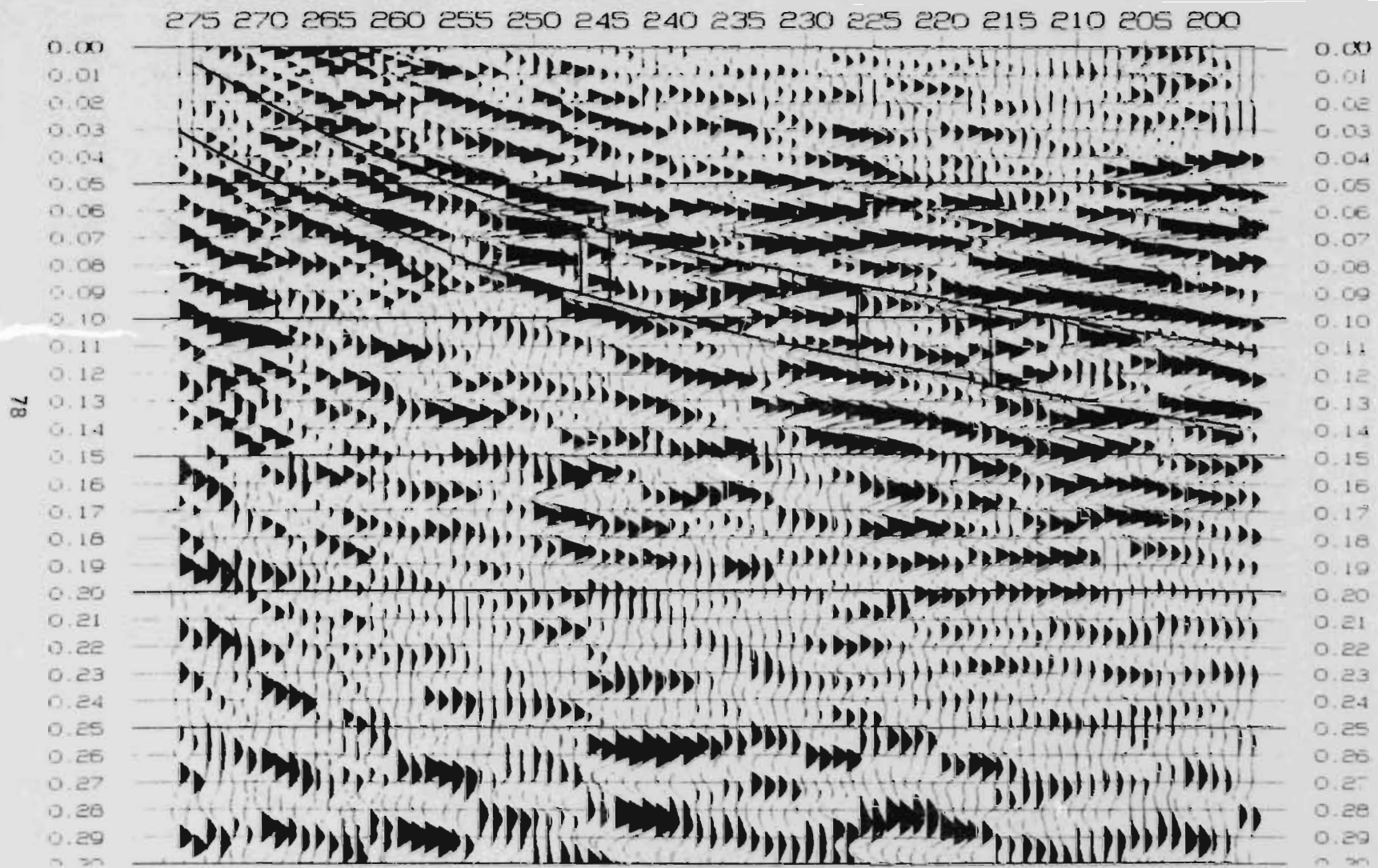


LINE AB2 20' STACK

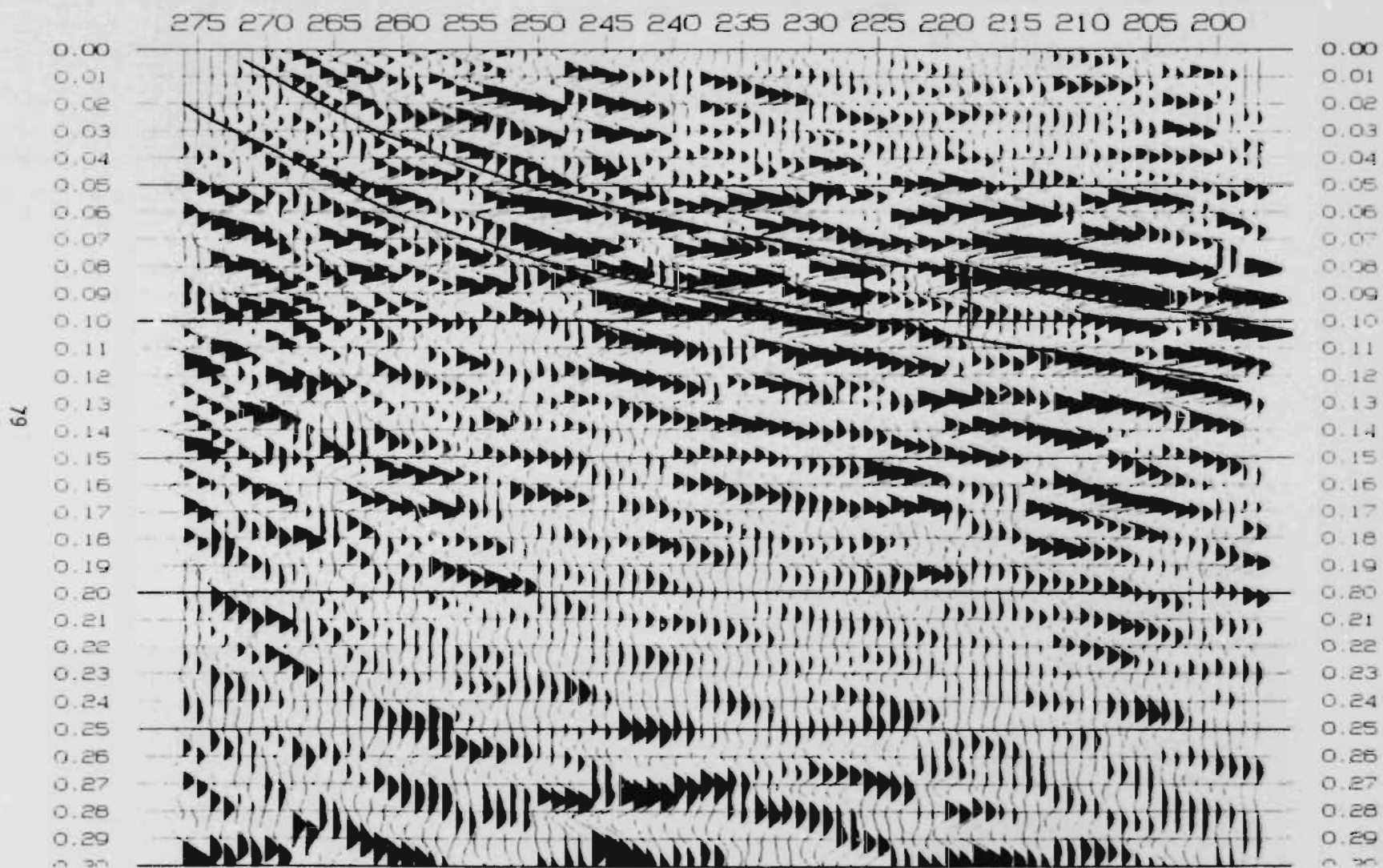
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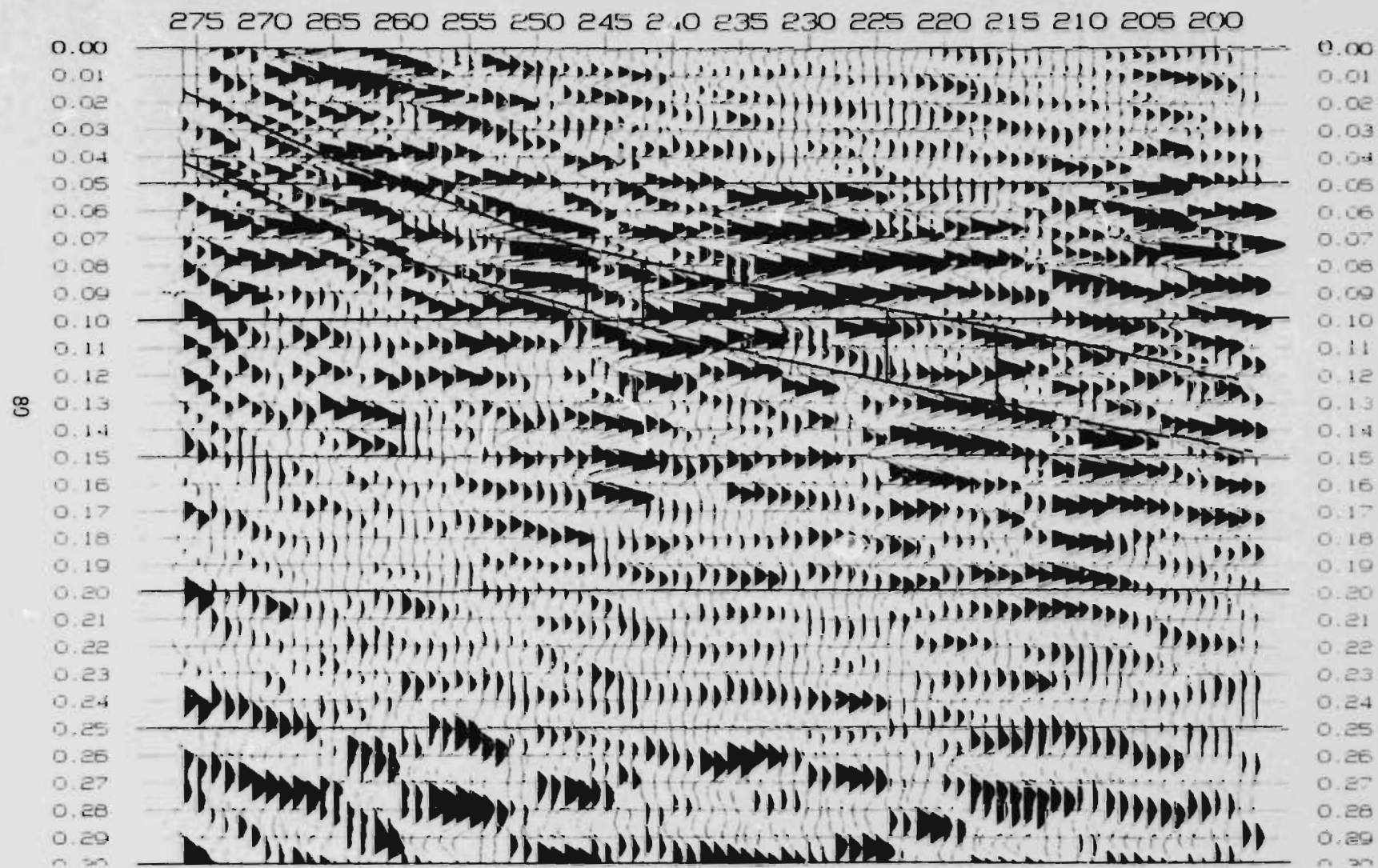
LINE BC3 20' STACK



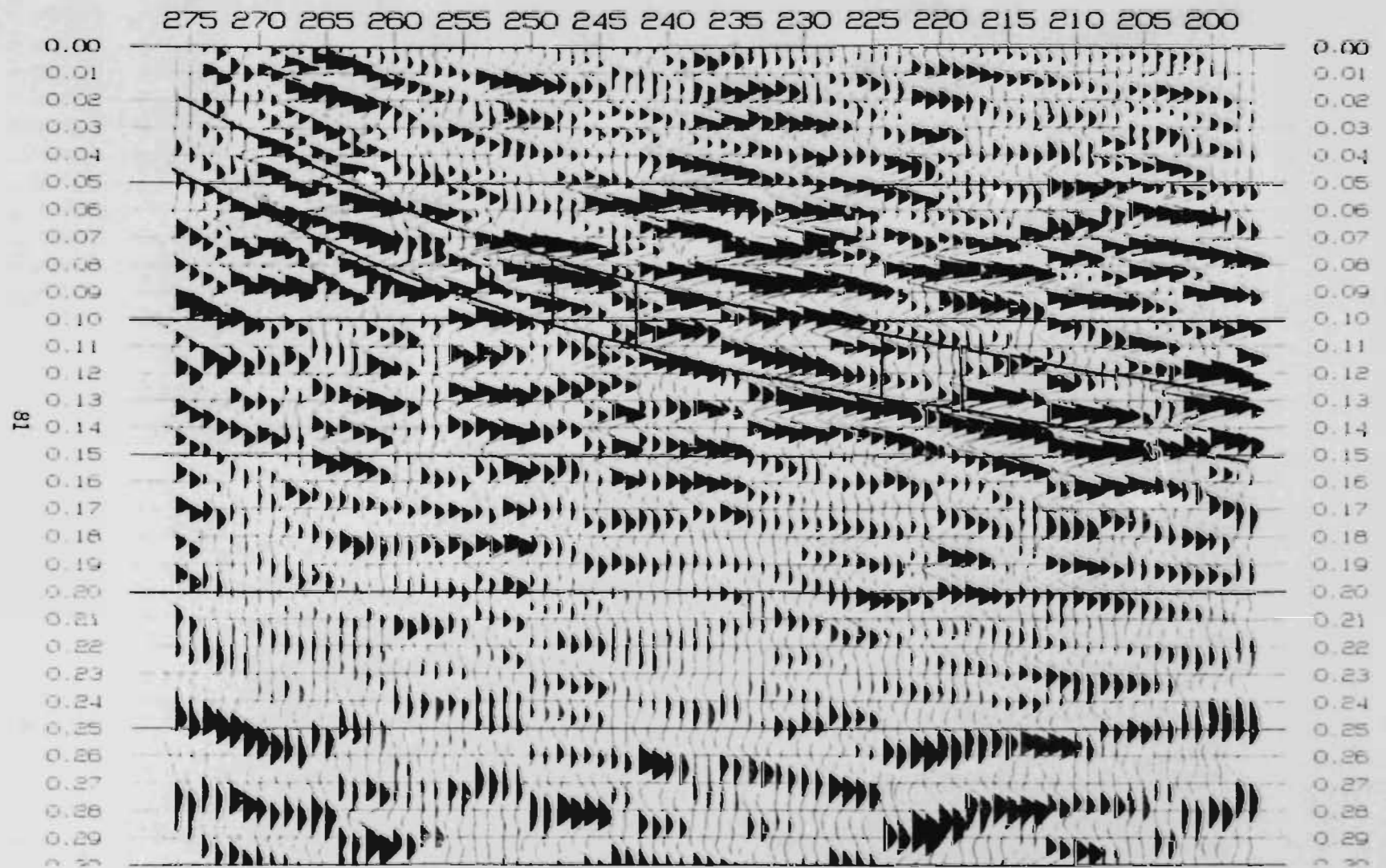
LINE B23 20' STACK



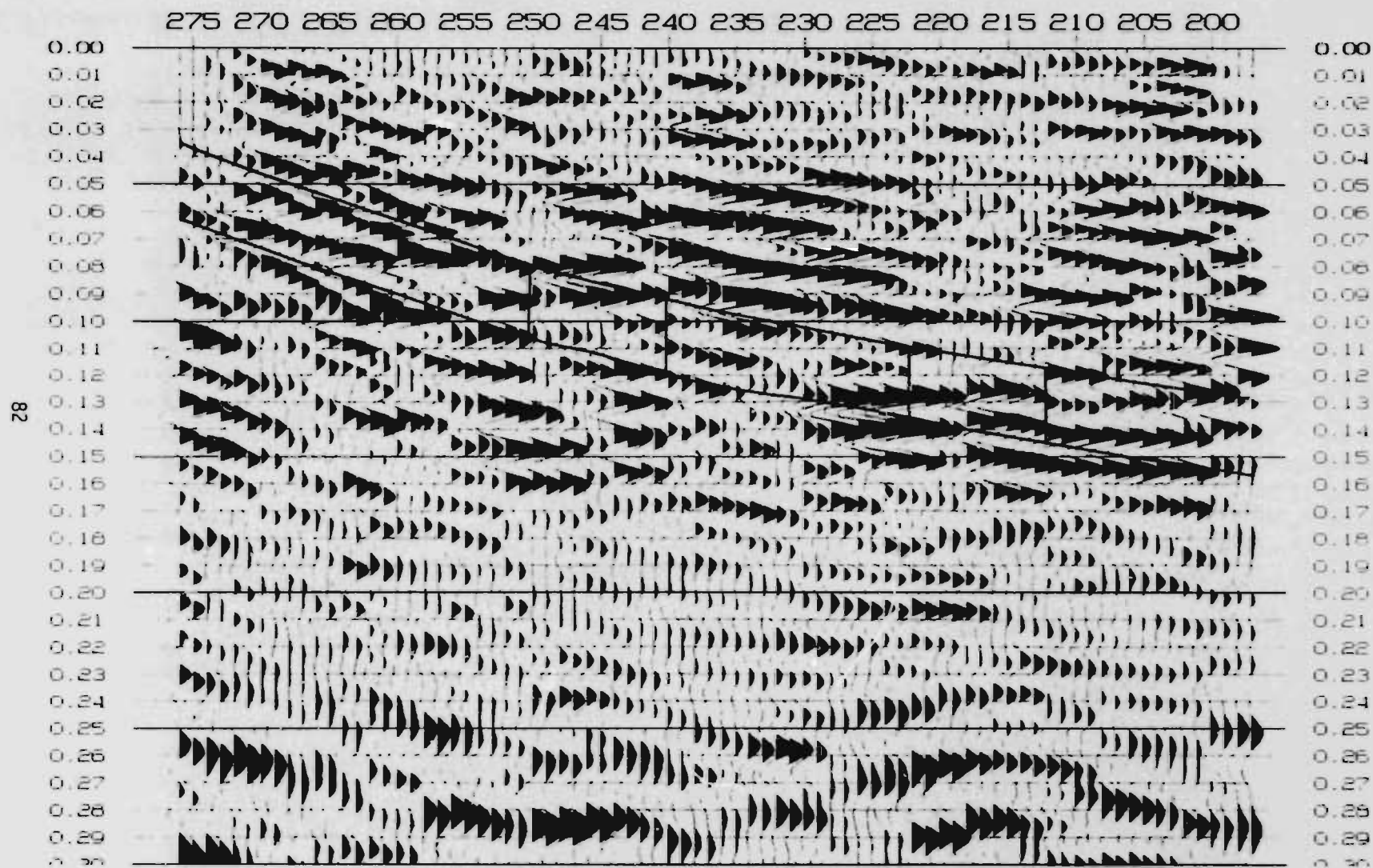
LINE C34 20' STACK



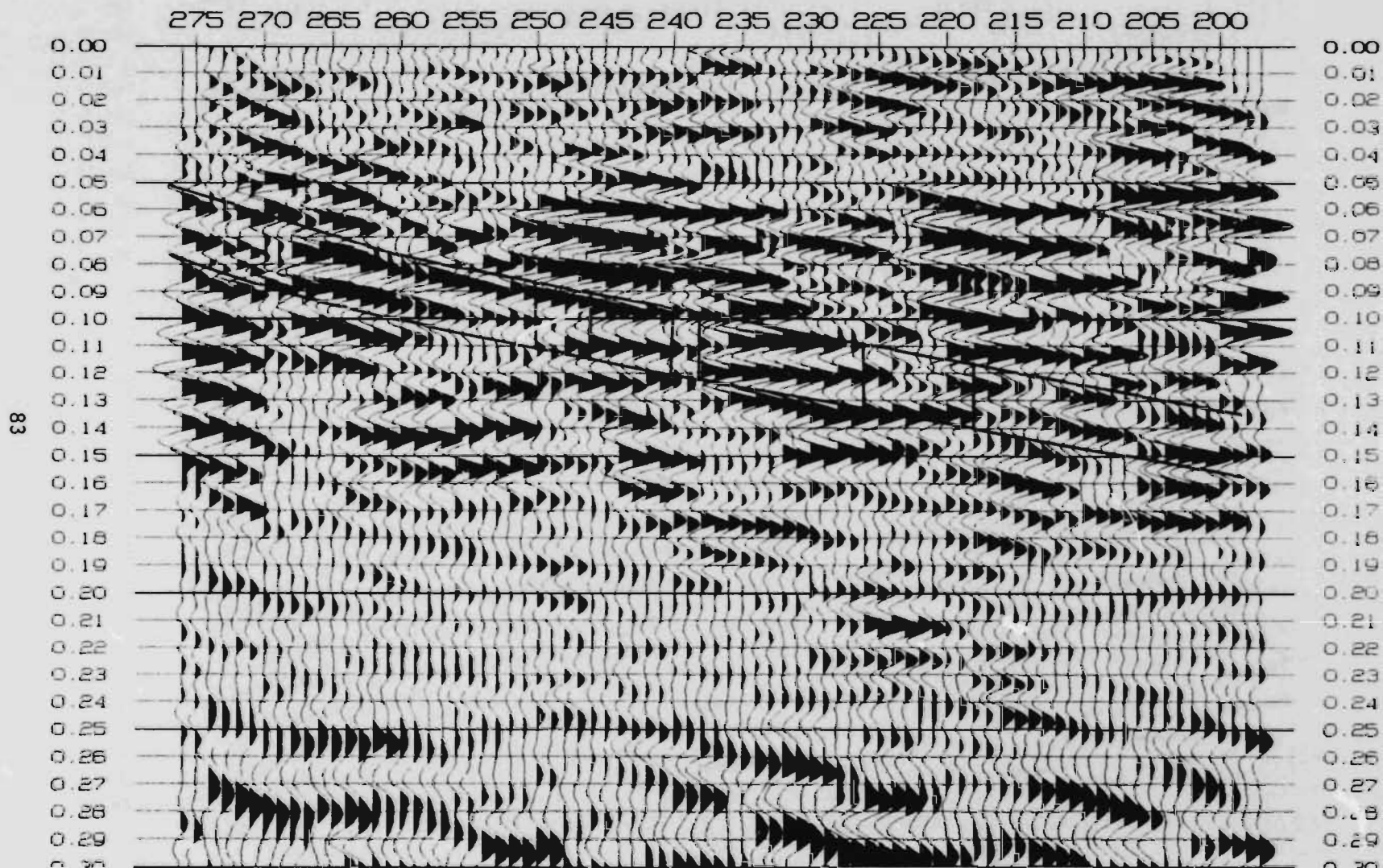
LINE CD4 20' STACK



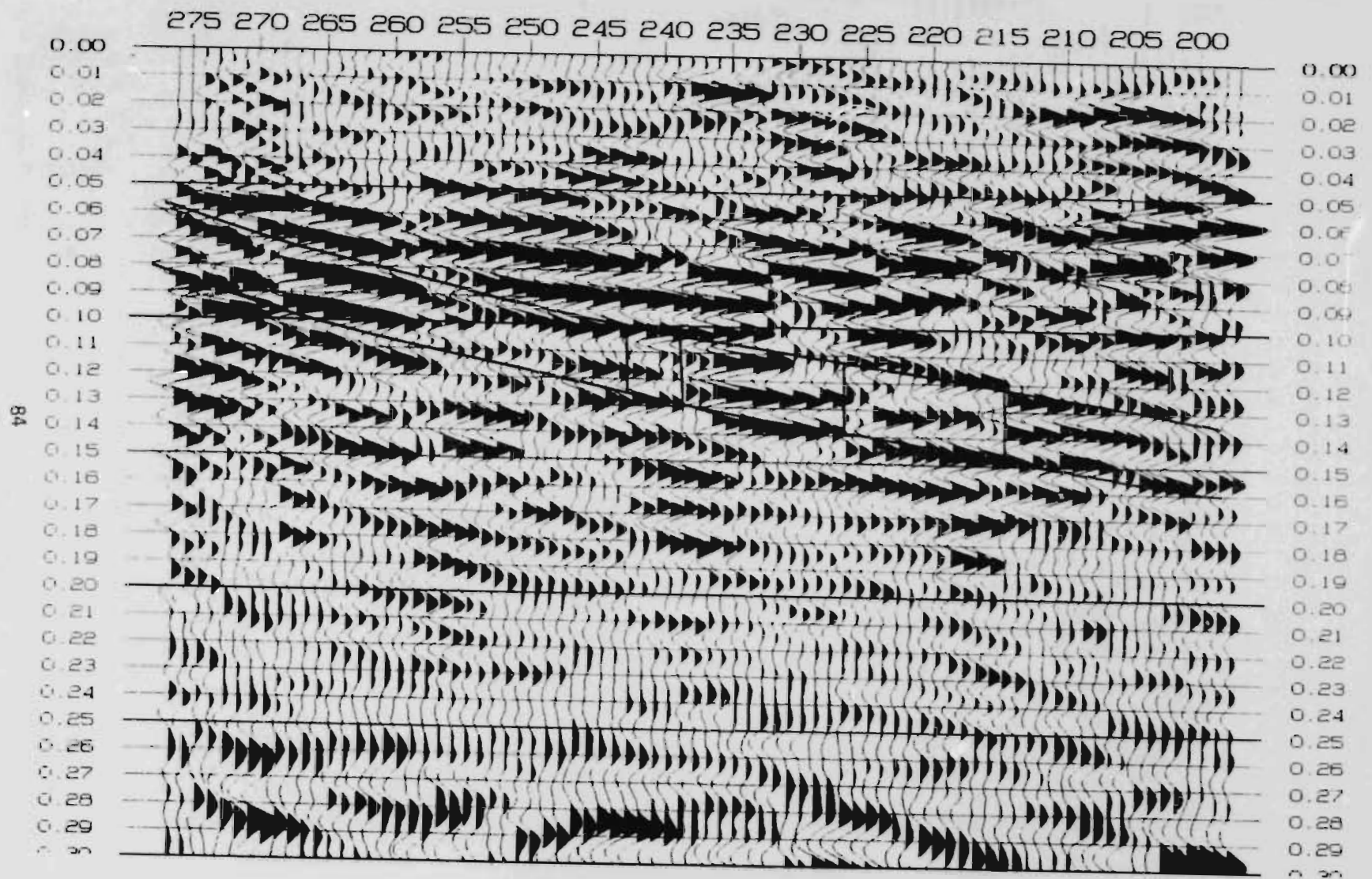
LINE D45 20' STACK



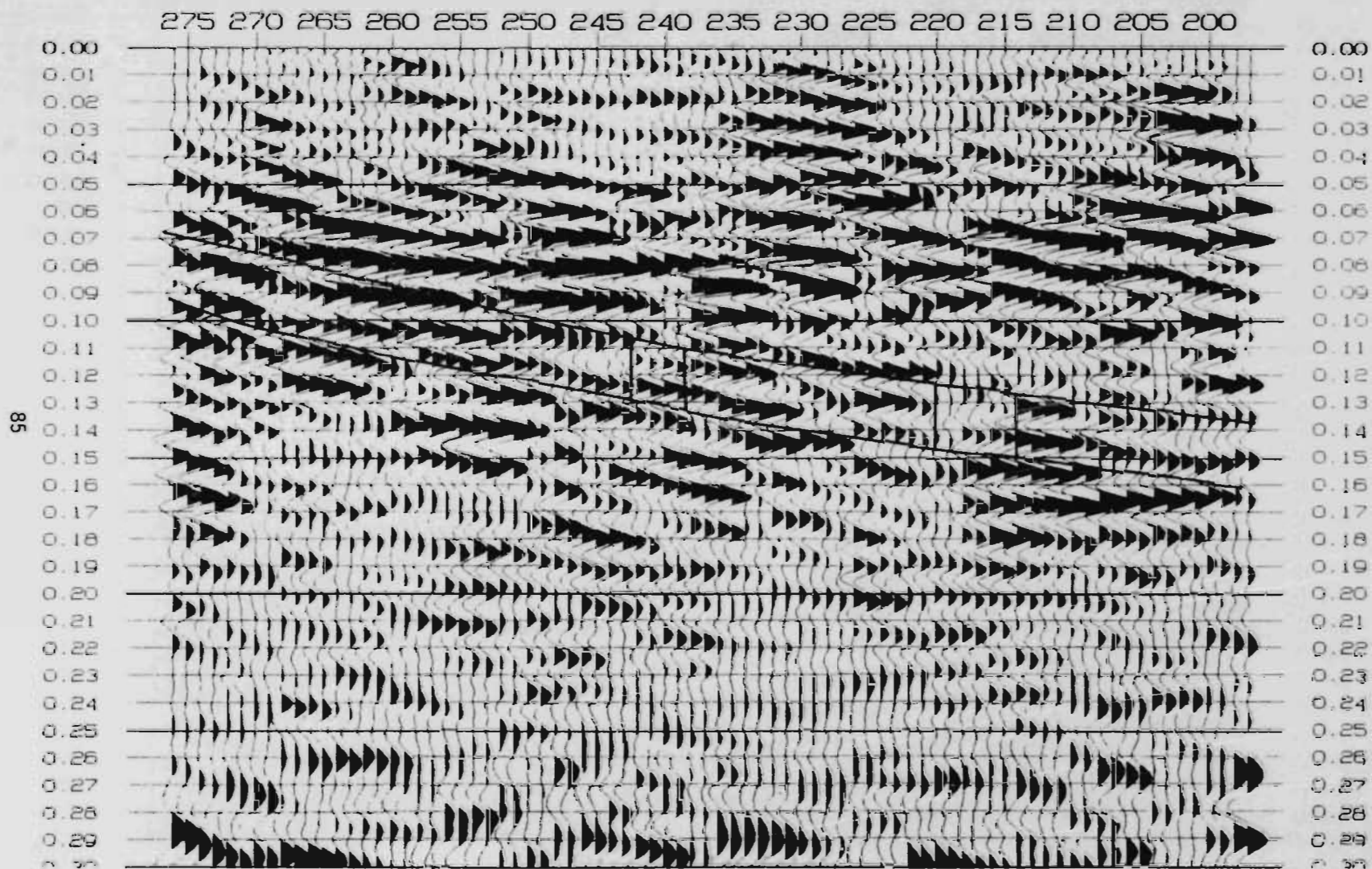
LINE DE5 20' STACK



LINE E56 20' STACK

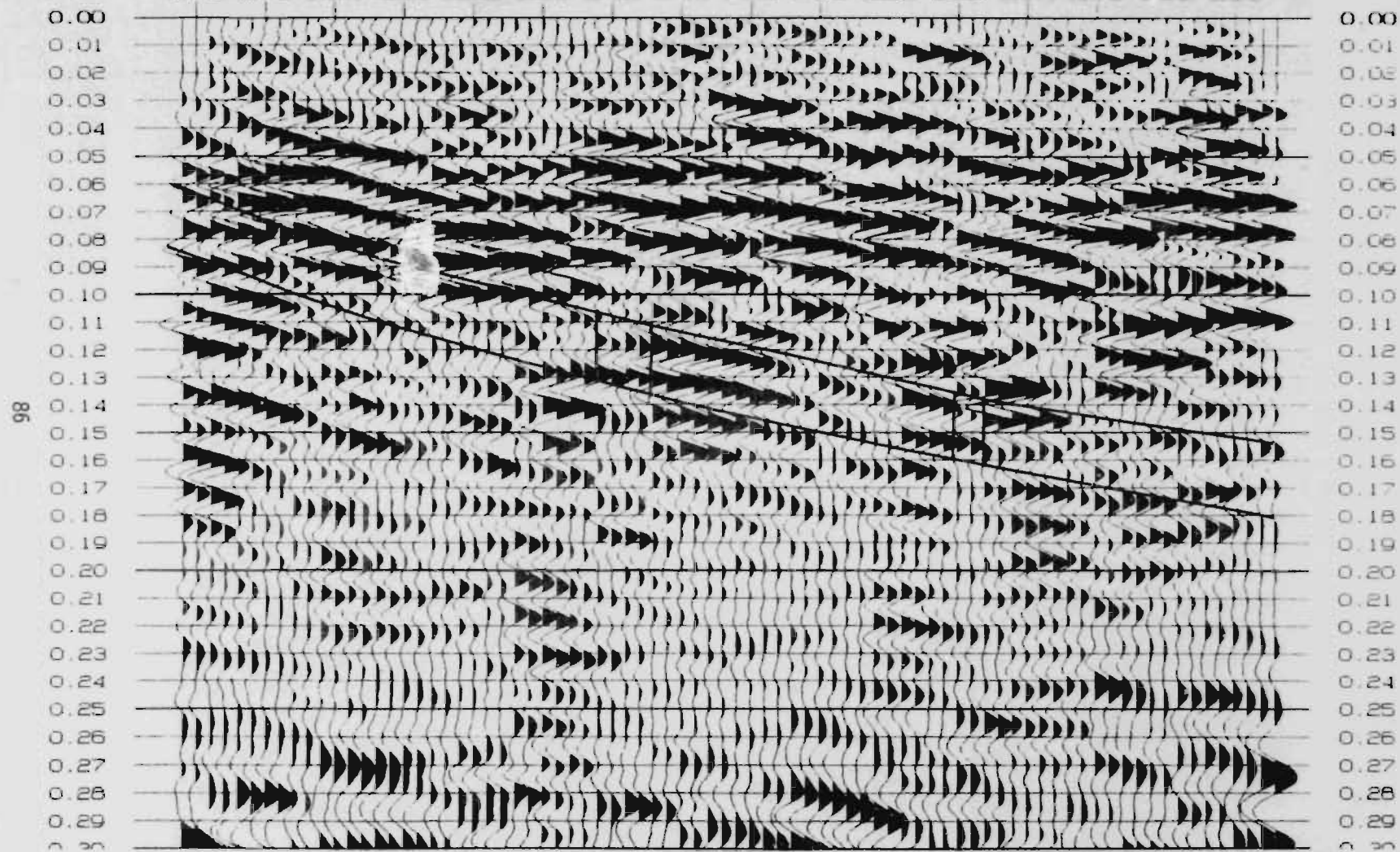


LINE EF6 20' STACK

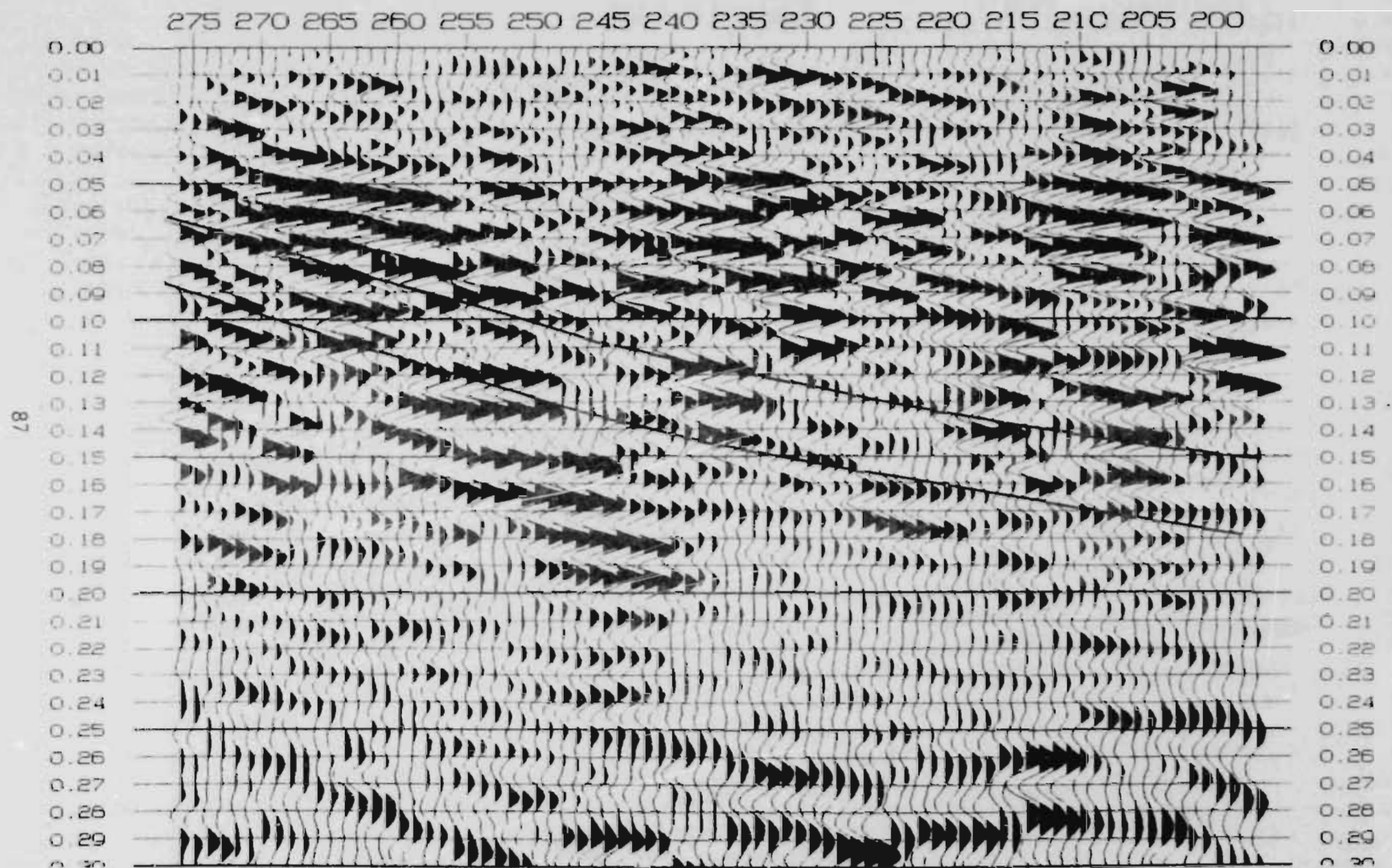


LINE F67 20' STACK

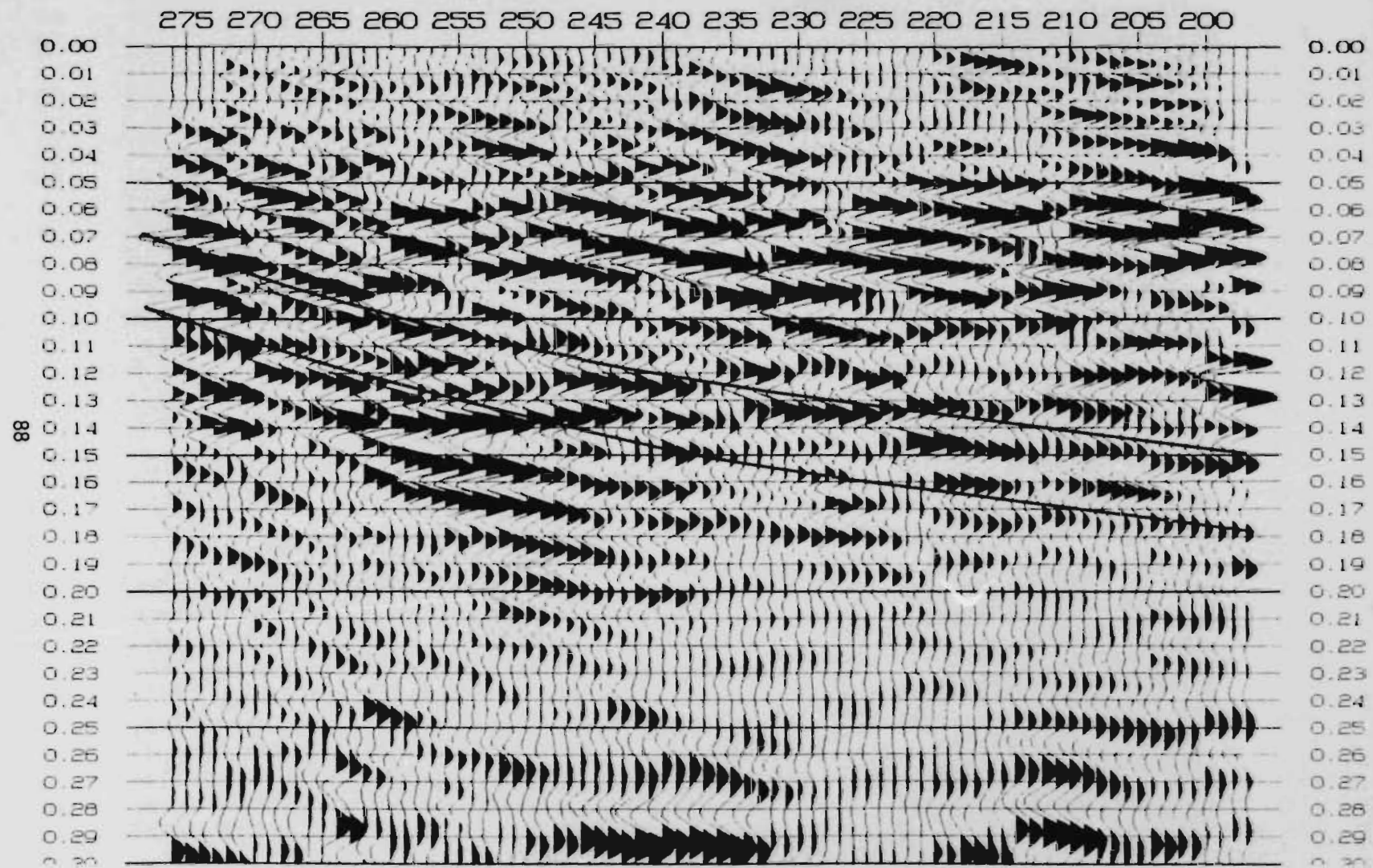
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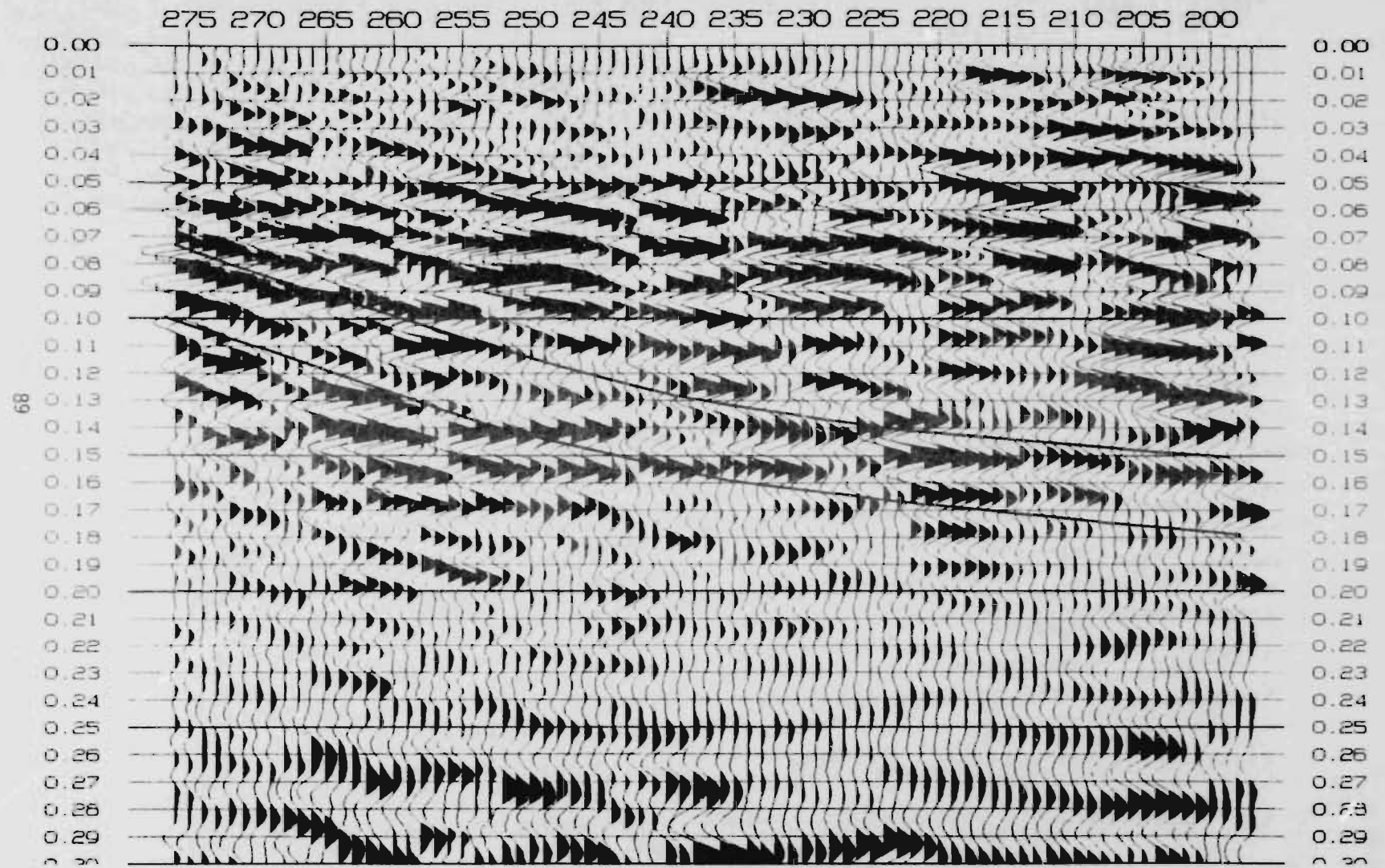
LINE FG7 20' STACK



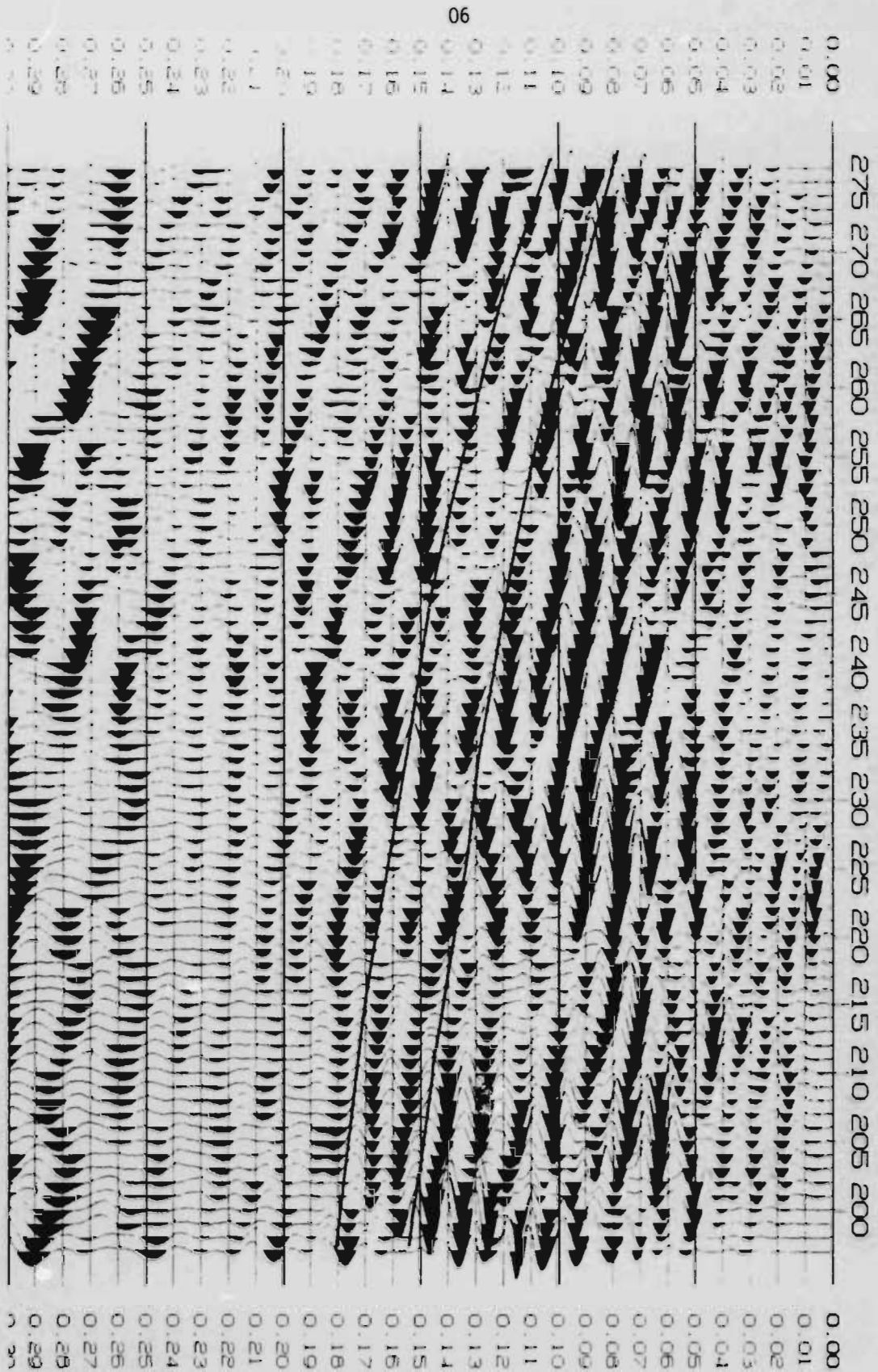
LINE G78 20' STACK



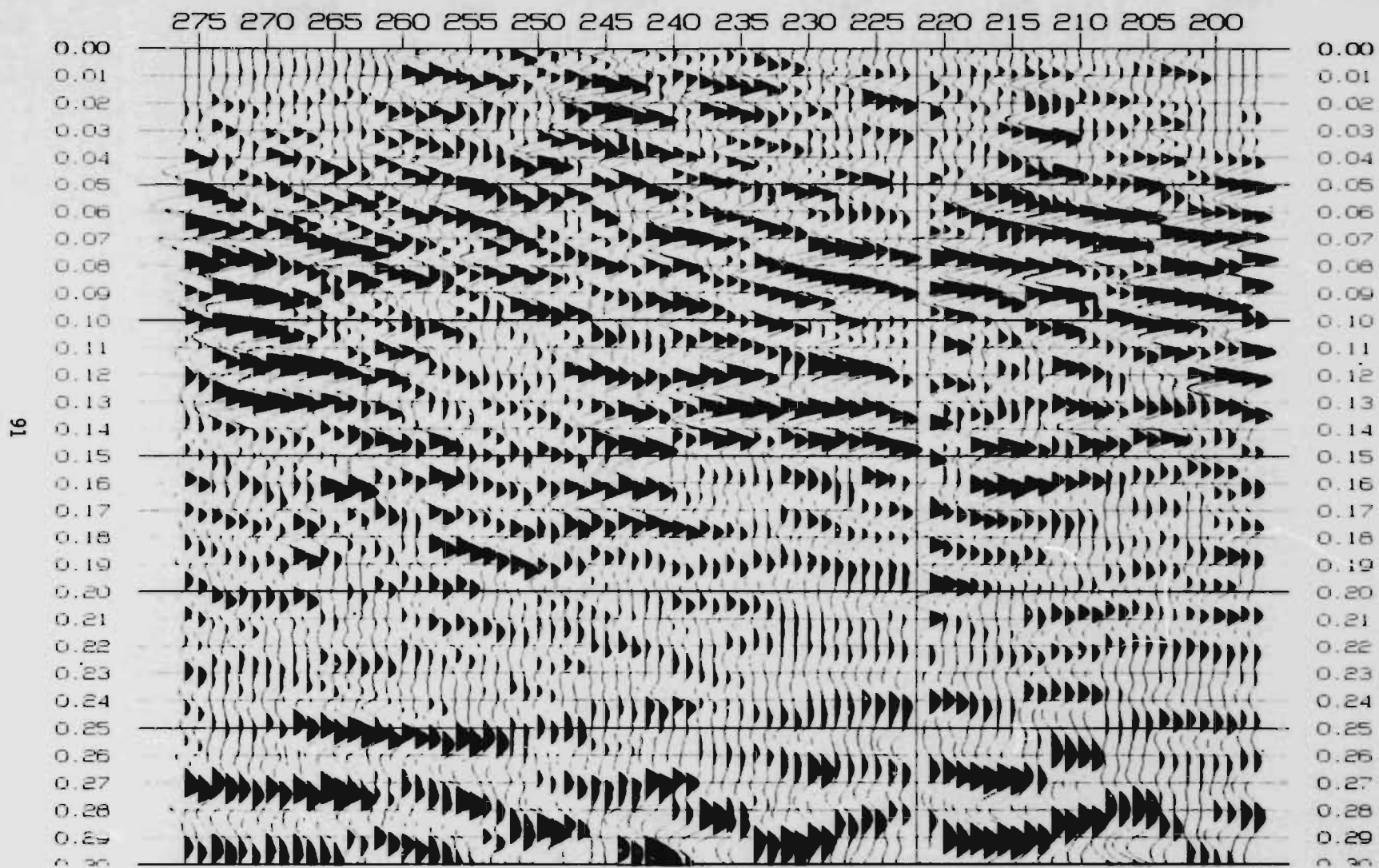
LINE GH8 20' STACK



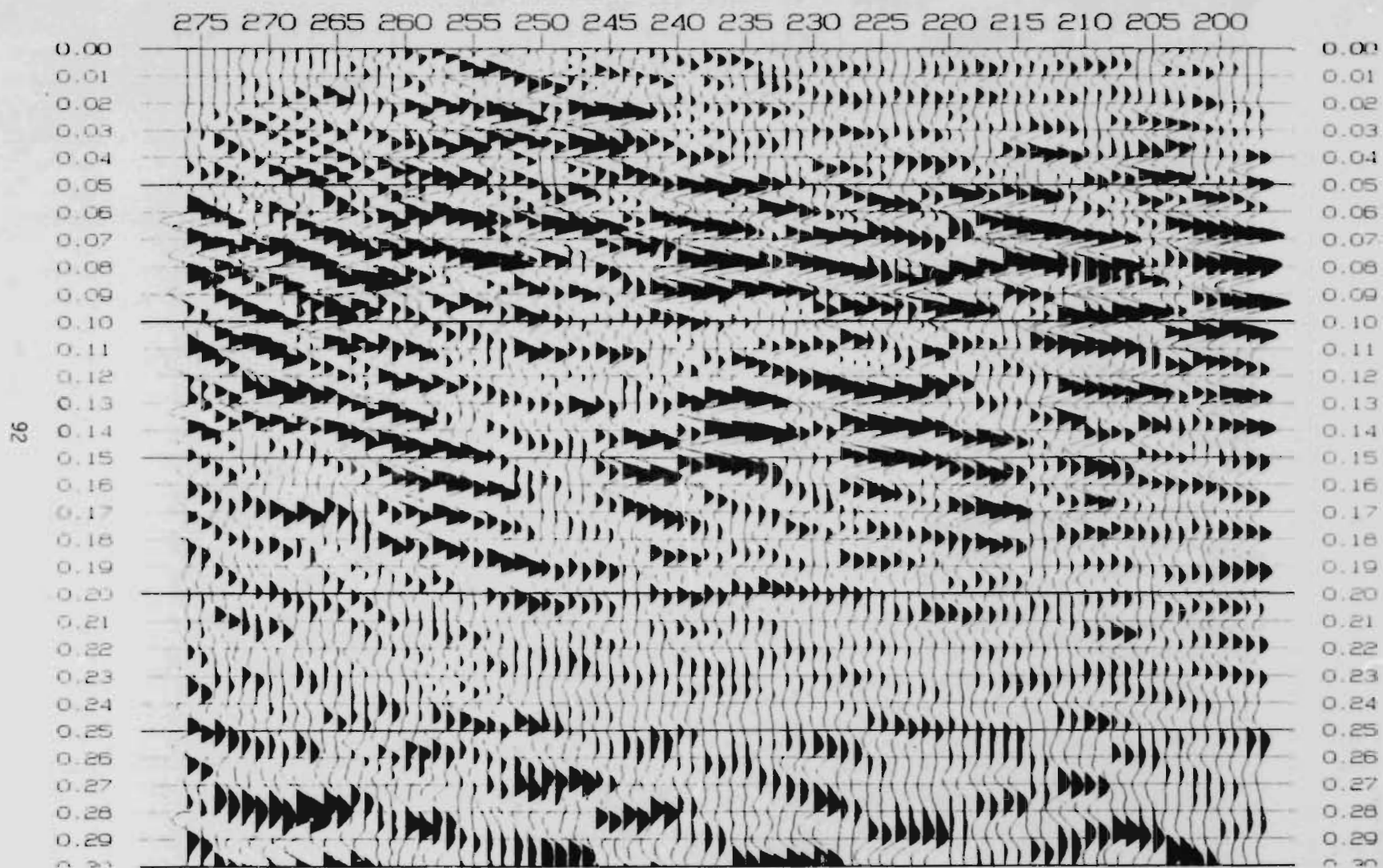
LINE H89 20' STACK



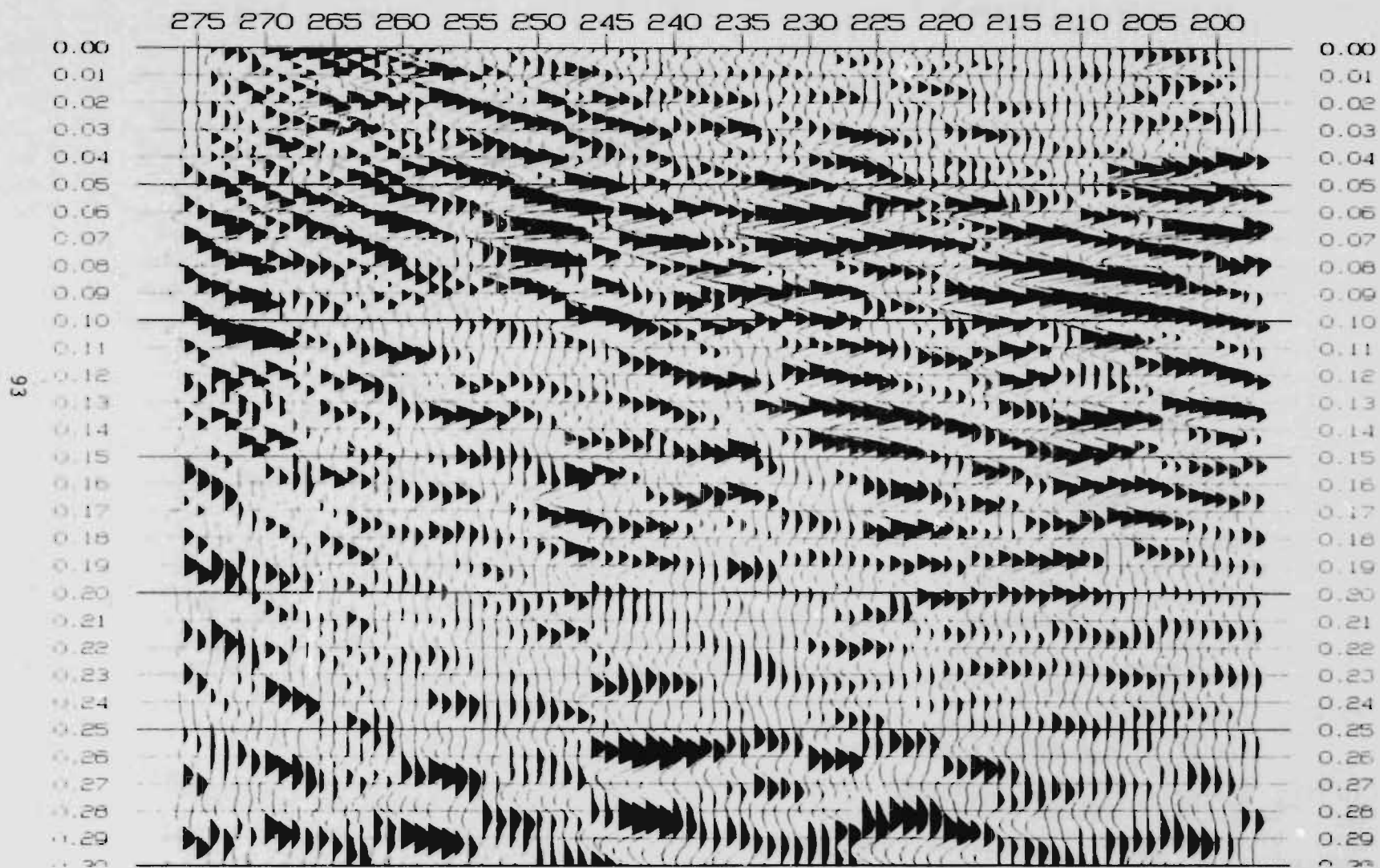
LINE A12 20' STACK



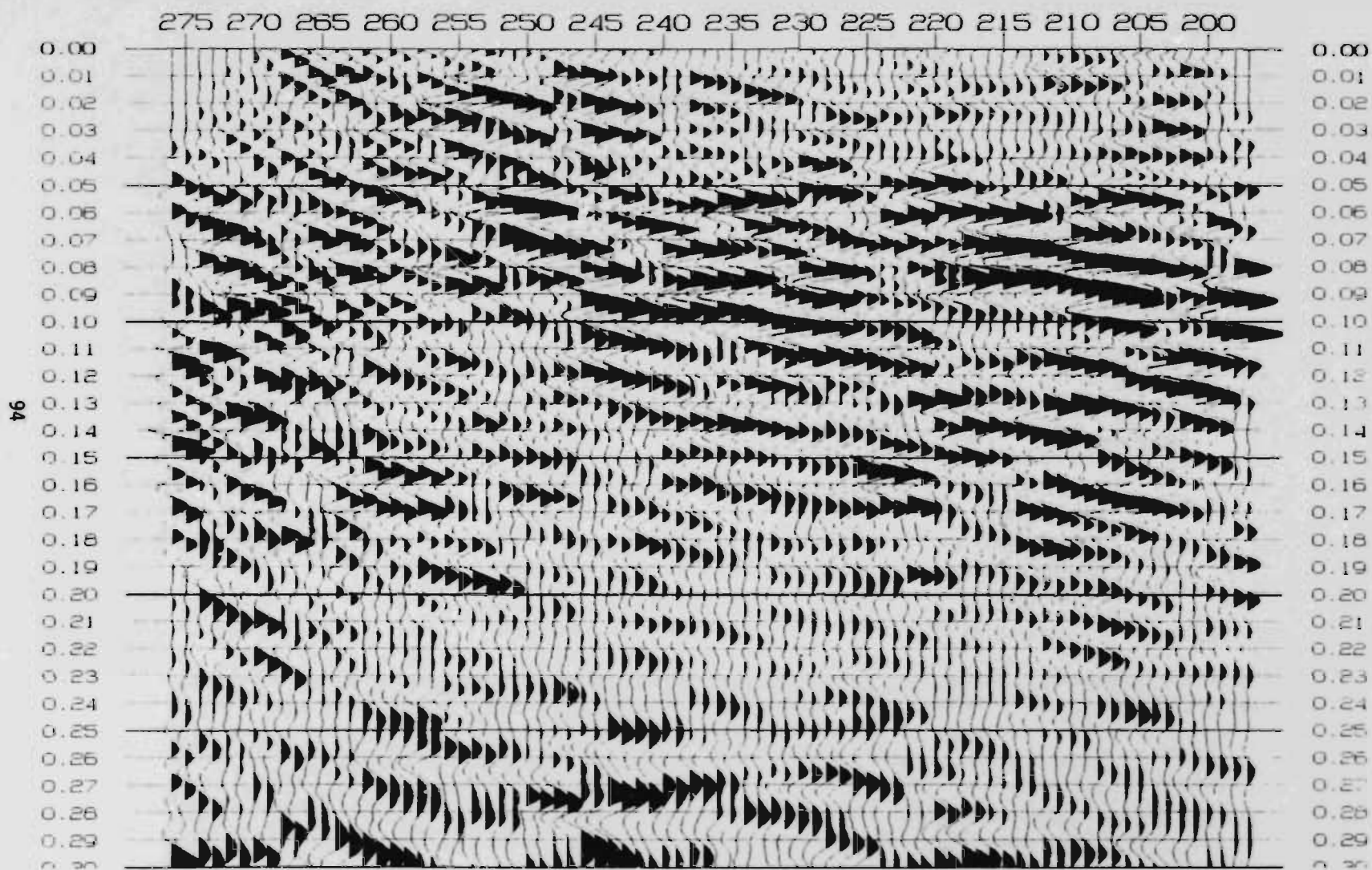
LINE AB2 20' STACK



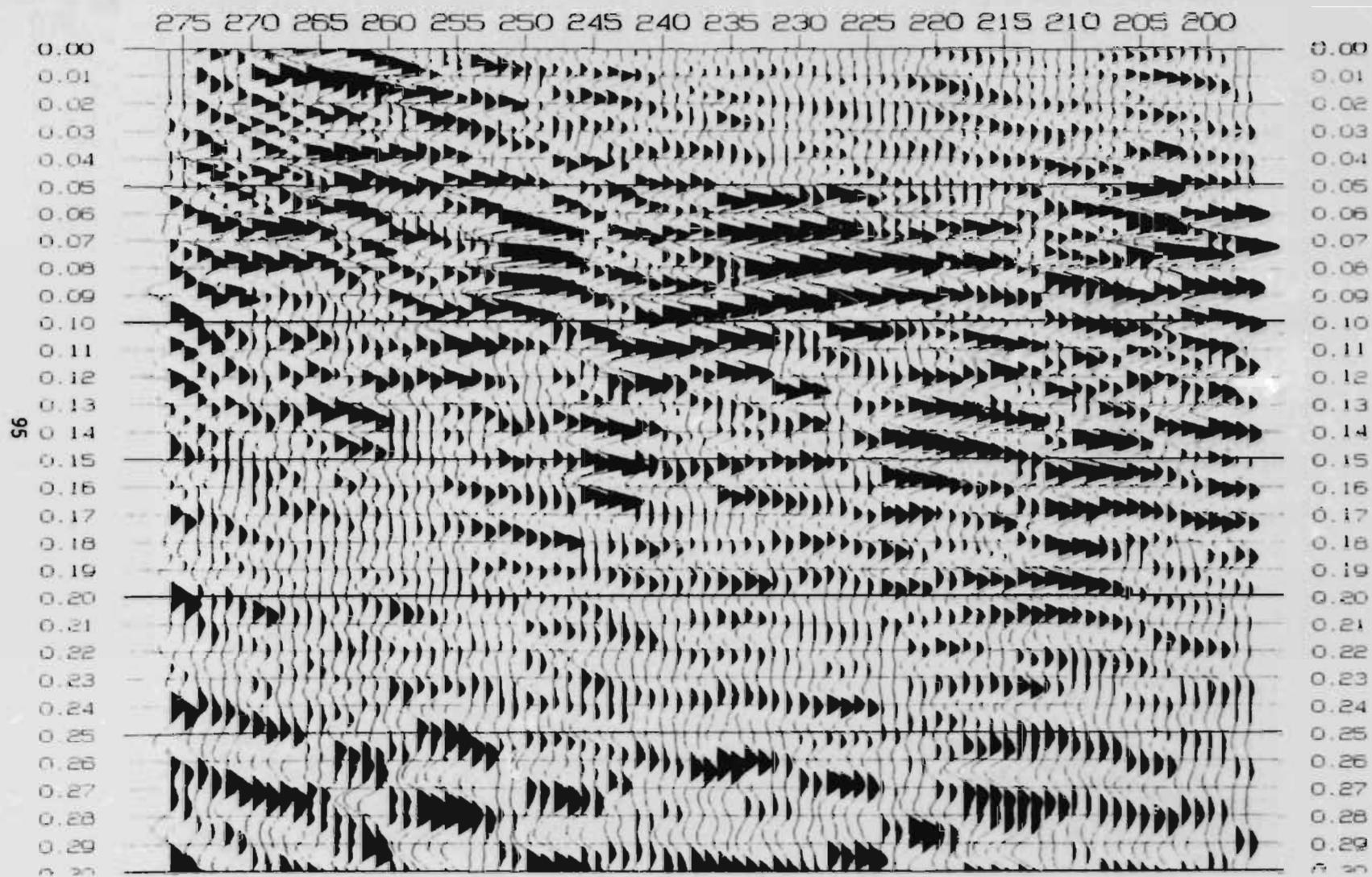
LINE BC3 20' STACK



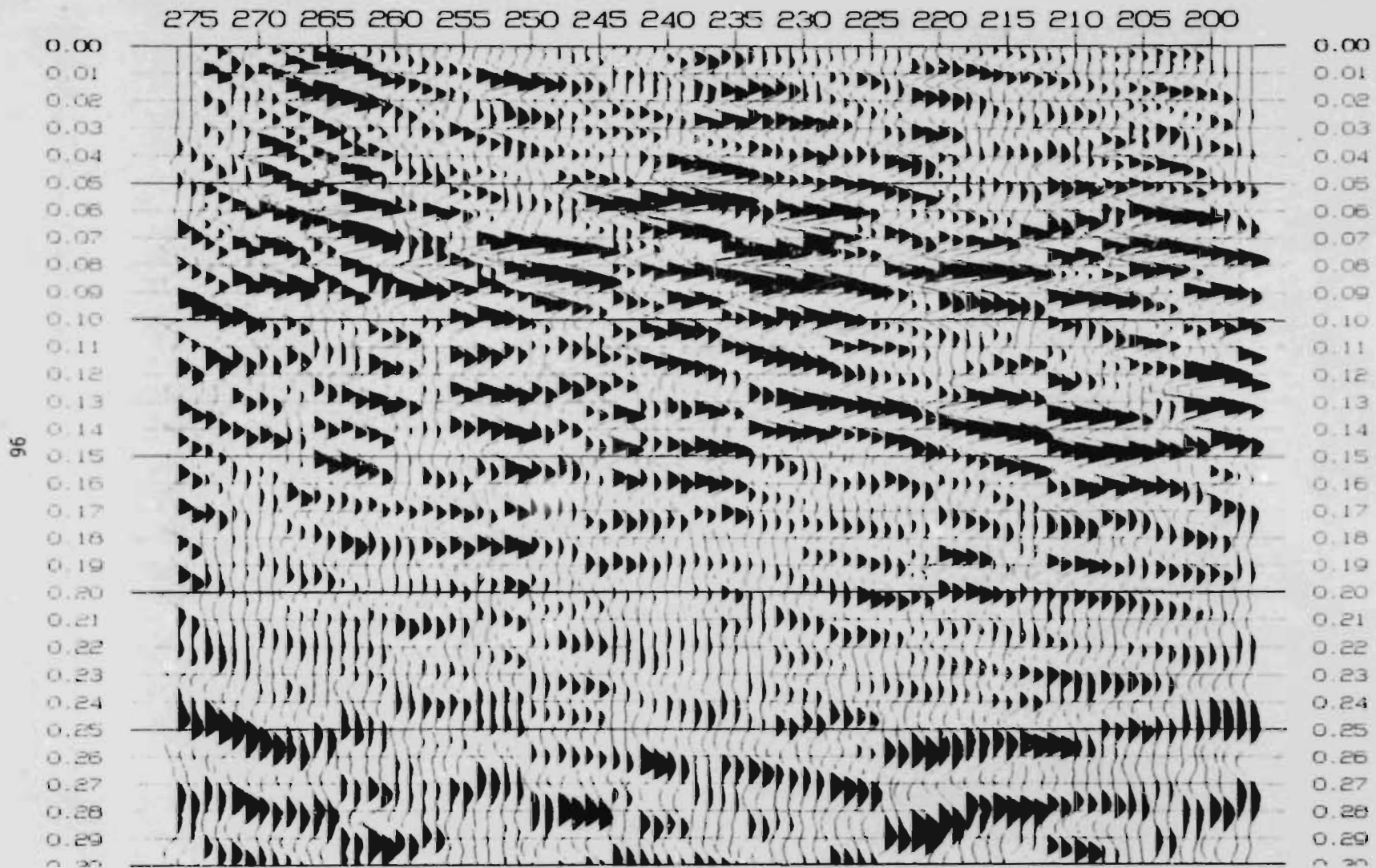
LINE B23 20' STACK



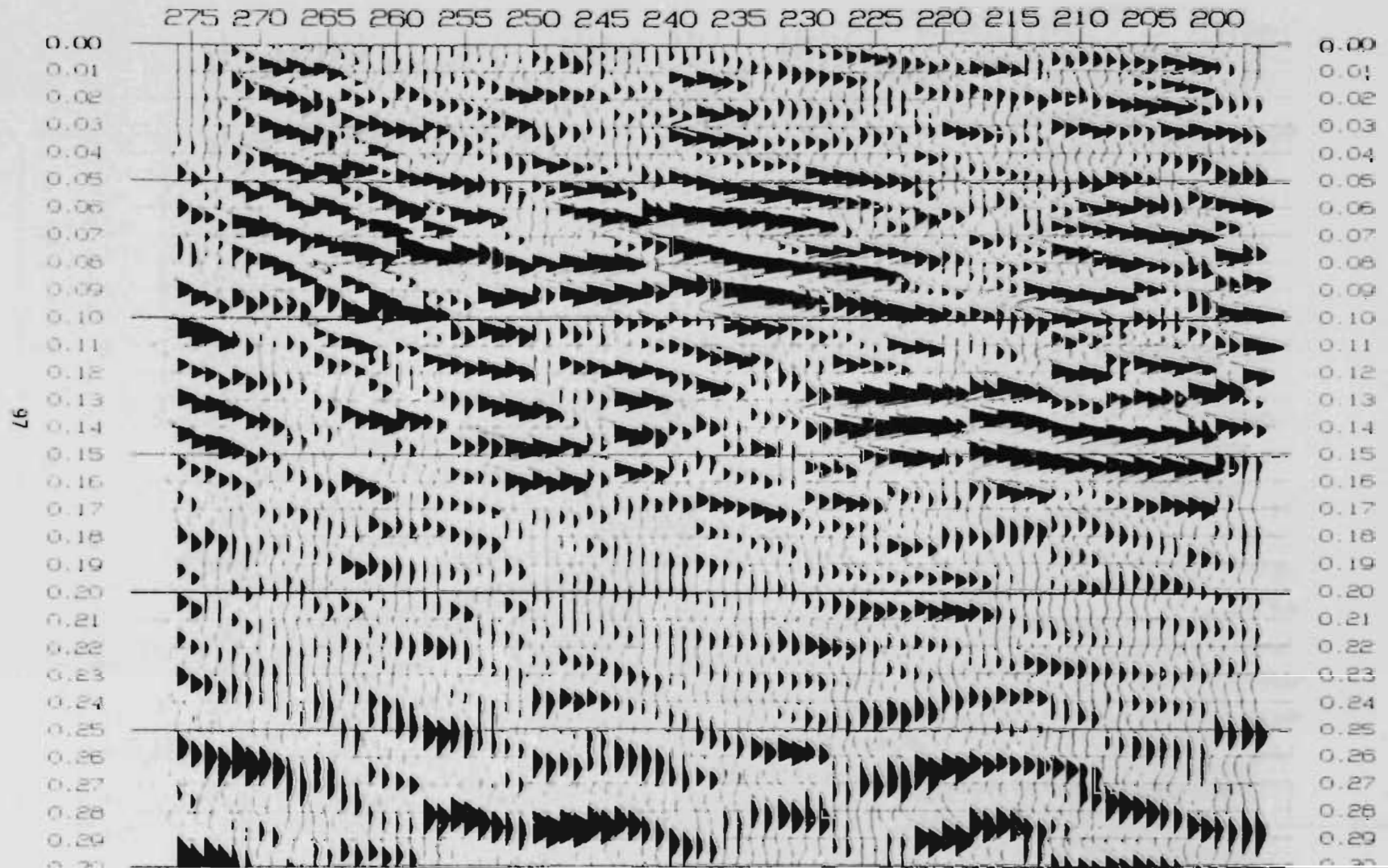
LINE C34 20' STACK



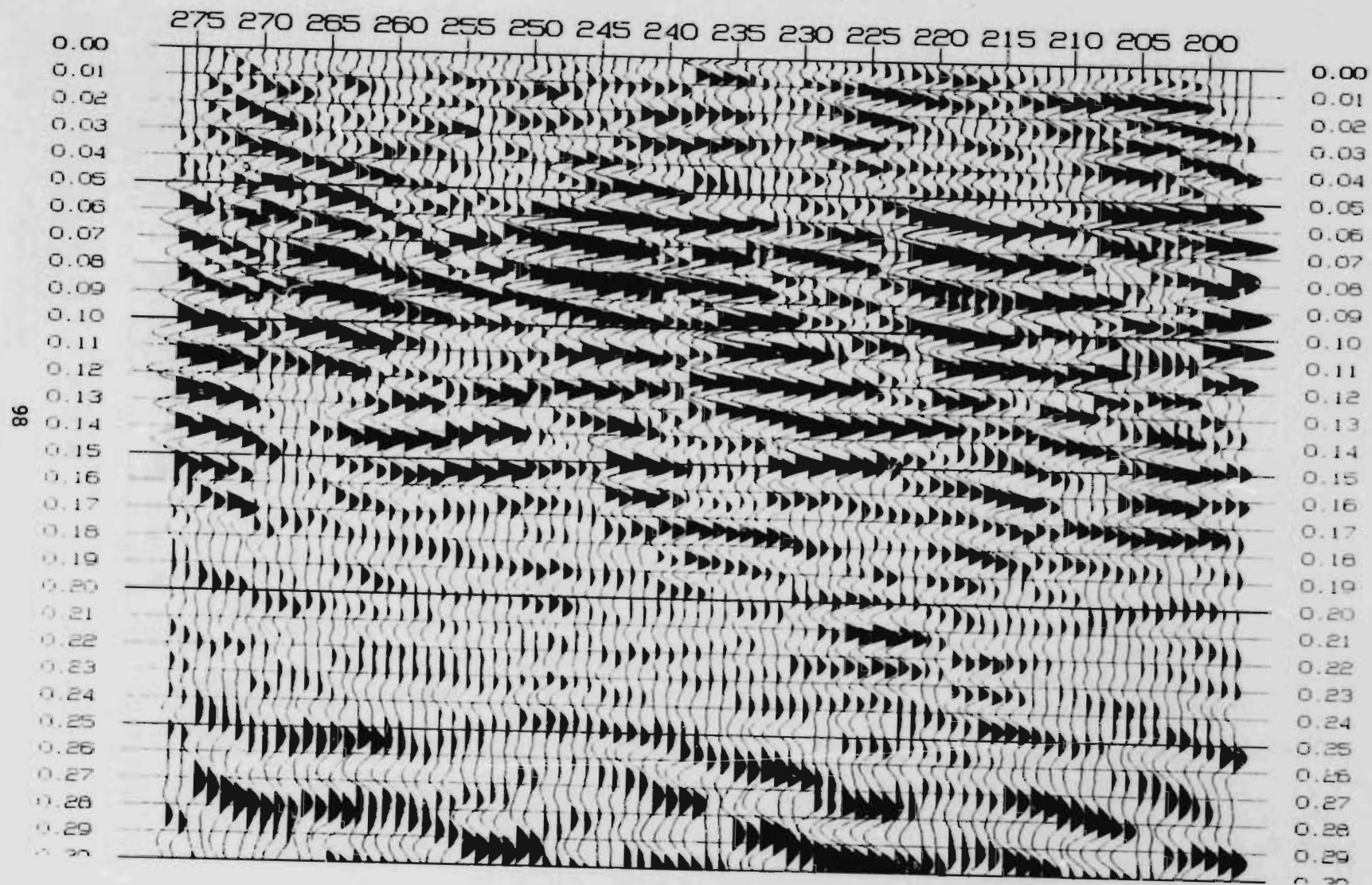
LINE CD4 20' STACK



LINE D45 20' STACK



LINE DE5 20' STACK



FIELD PARAMETERS

INST: DFS V
 REC LENGTH 1 sec
 SAMPLE RATE 1 ms
 RECORDED BY ESI #1
 SOURCE: Delaprine
 HOLE DEPTH: 6 ft
 DATE: Oct, 1982

GROUP INT: 20 ft
 SP INT: 20 ft
 NO OF CHAN: 24
 GEOPH ARRAY: 6 at 2 centered
 SPREAD: Shaping Thru Cable
 NEAR OFFSET: 0 ft
 FAR OFFSET: Varies

PROCESSING SEQUENCE



PROCESSED BY THE
 SEISTRAC 32

APPLIED RESEARCH CONCEPTS

- (1) DEMUX/REFORMAT
- () RESAMPLE
- (2) CDP GATHER
 DATUM: 6900 ft VELOCITY: 5000/sec
- () FILTER
- () DECONVOLUTION

MS OPERATOR

AUTO CORR WINDOW
 WHITE NOISE PERCENT

- (7) VELOCITY ANALYSIS
- (8) NMO
- (9) MUTE
- (10) AUTOMATIC STATICS WINDOW: 100-500
- () CDP X CORR STATICS WINDOW
- (11) STACK FOLD Varies - See Report
- (14) FILTER
 60-80-160-180 Hz 0-400 msec
 30-50-100-120 Hz 240-600 msec

- (5) EQUALIZATION
- (3) GAIN RECOVERY T-1.4 FUNCTION
- (6) TRACE COMPOSITE 3 Trace - Common Offset Distance
- () WAVE EQUATION MIGRATION
- (12) TRACE COMPOSITE FOR 3-D
 40 FT BOX CONFIGURATION

DATE PROCESSED Nov, 1982 ANALYST Austin, Tx

PLOTTER DISPLAY

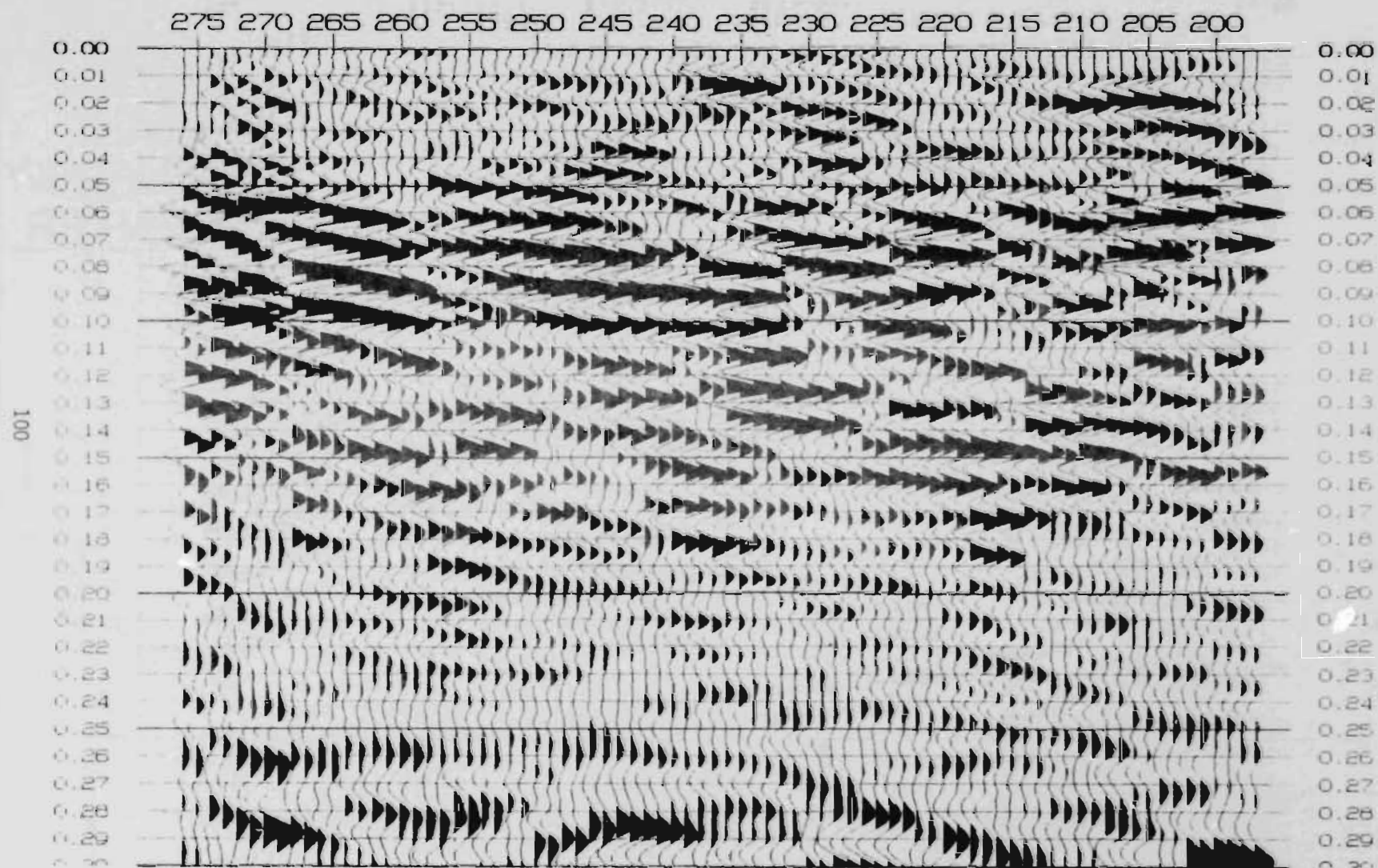
VAWG 20 IN/SEC 10 TRIN
 POLARITY: Black = Positive
 DIRECTION OF PLOT R-L
 REEL NUMBER 99 JOB NO: 1441

AREA: RAWLINS
 LINE: A,B,C,D,E,F,G,H
 LOCATION: Carbon Co, Wyoming
 FOR: Emerald Exploration
 ORIG PRSPT:
 PROCESS: 40' Stack

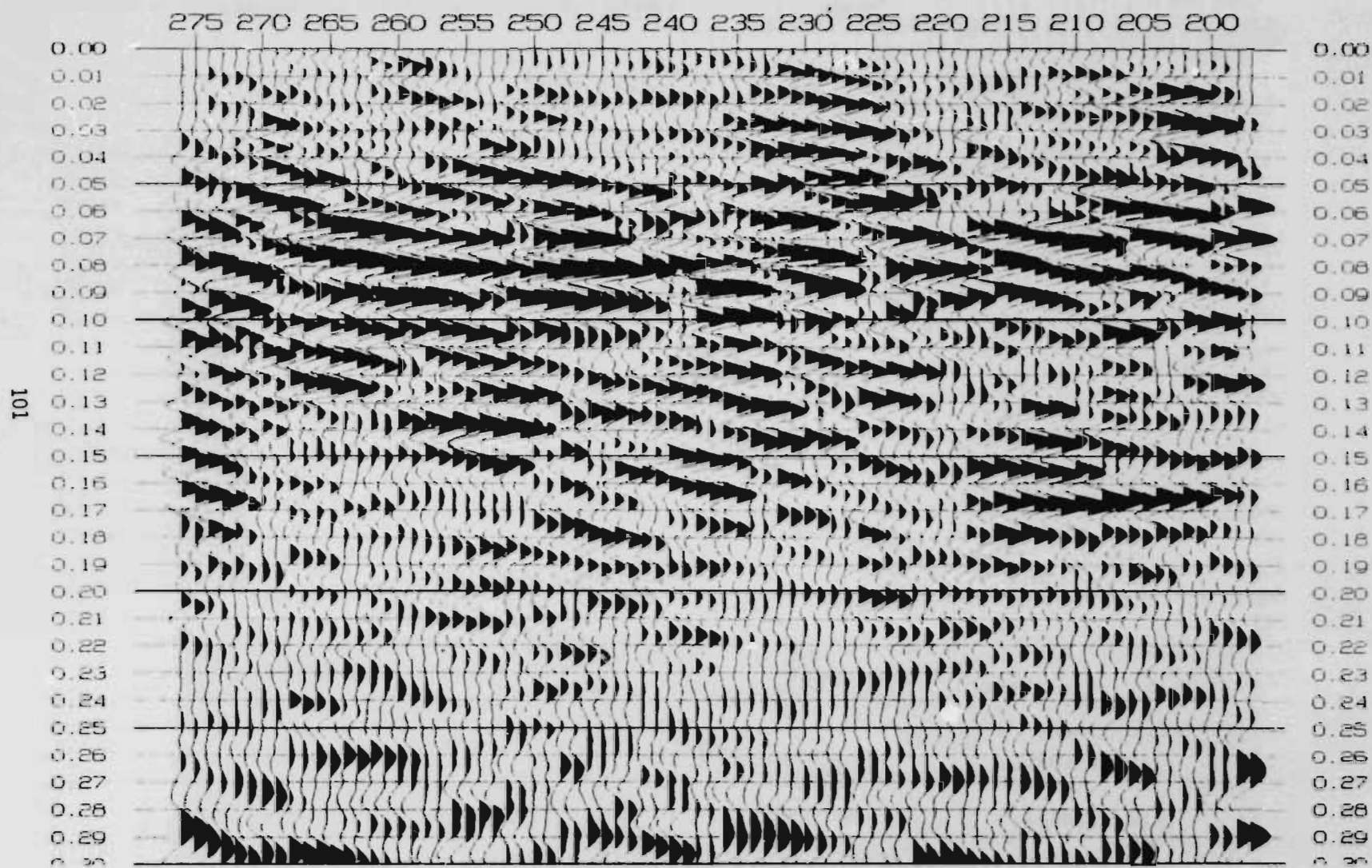
SP: 197-217

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 TECH. CENTER

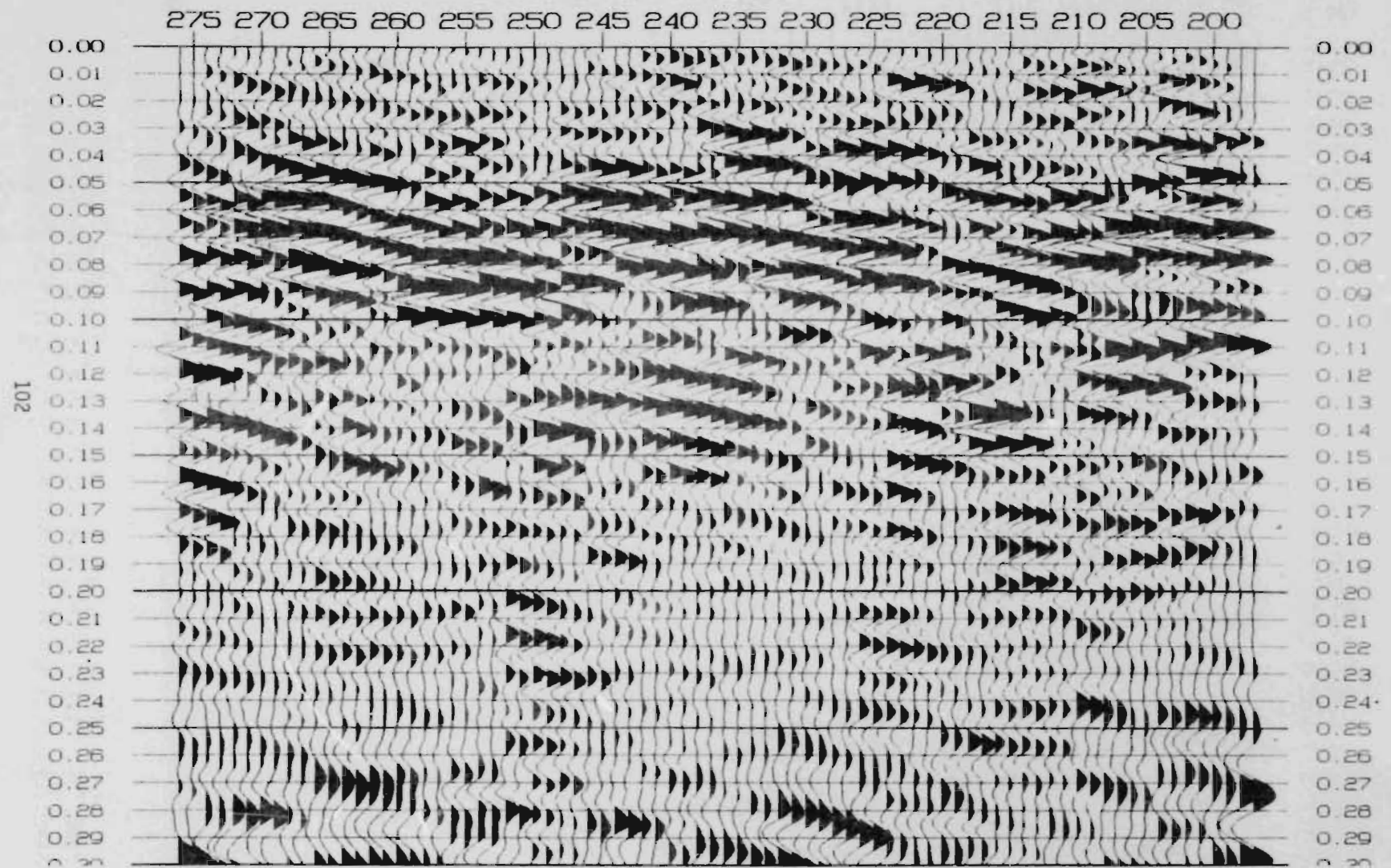
LINE E56 20' STACK



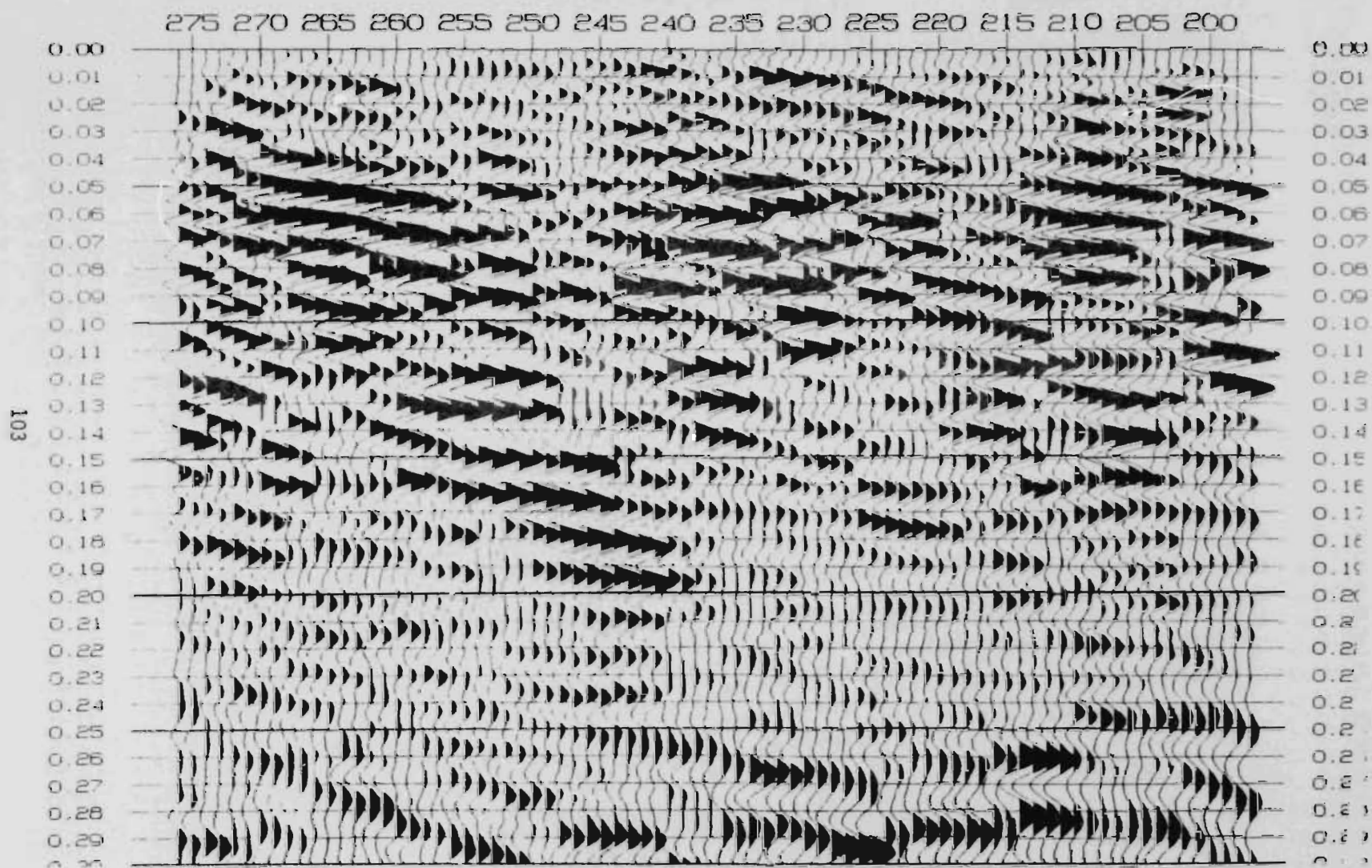
LINE EF6 20' STACK



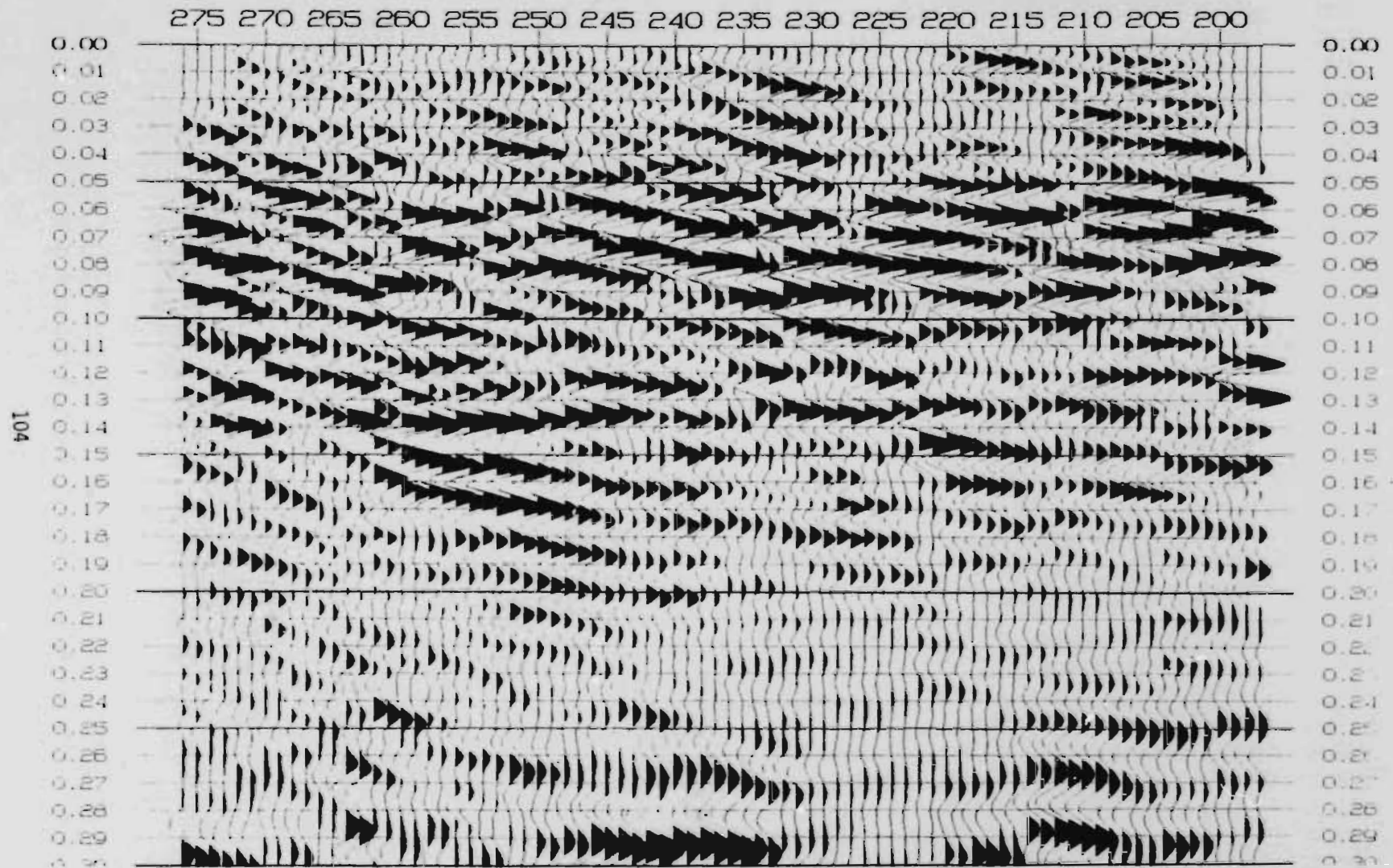
LINE F67 20' STACK



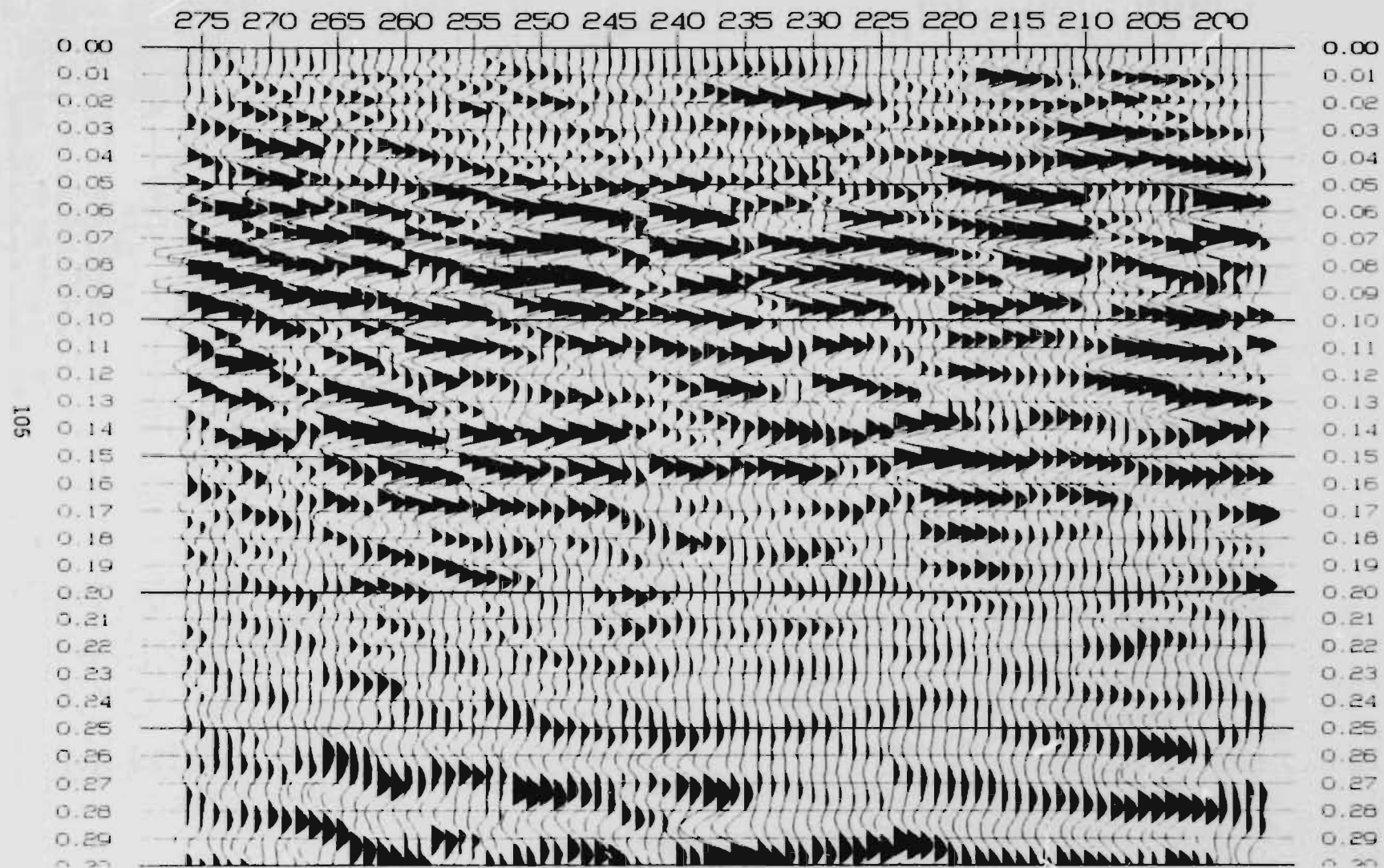
LINE FG7 20' STACK



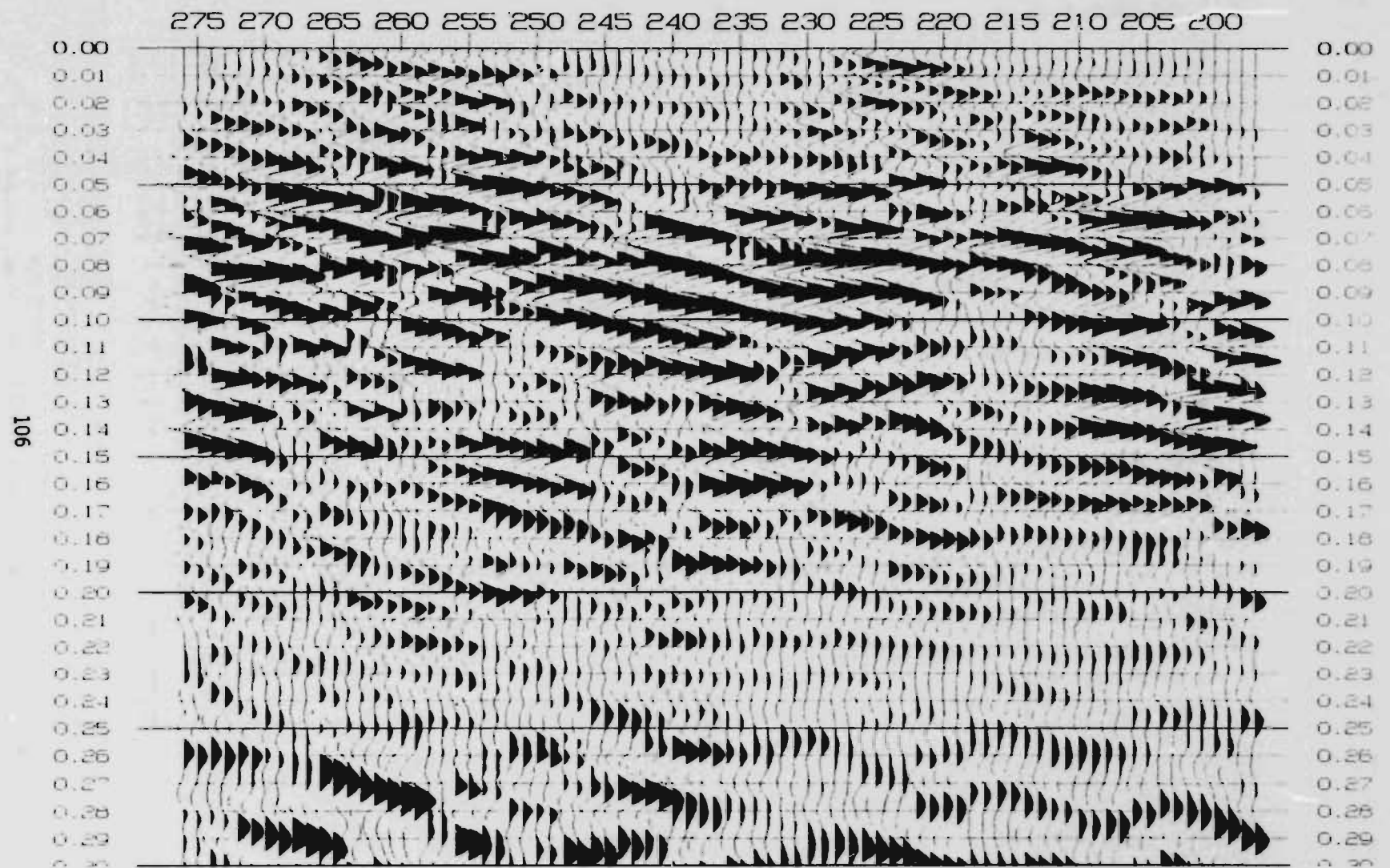
LINE G78 20' STACK



LINE GH8 20' STACK



LINE H89 20' STACK



FIELD PARAMETERS

INST DFS V GROUP INT 20 ft
 REC LENGTH 1 sec SP INT 20 ft
 SAMPLE RATE 1 ms NO OF CHAN 24
 RECORDED BY ESI #1 GEOPH ARRAY 6 at 12 centered
 SOURCE: Delaprima SPREAD Shooting Thru Cable
 HOLE DEPTH 6 ft NEAR OFFSET 0 ft
 DATE: Oct, 1982 FAR OFFSET Varies

AREA: RAWLINS
 LINE: A,B,C,D,E,F,G,H
 LOCATION: Carbon Co., Wyoming
 FOR: Emerald Exploration
 ORIG PRSPT: _____
 PROCESS: 40' Stack

SP: 197-277

PROCESSING SEQUENCE



PROCESSED BY THE
 SEISTRAC 32

APPLIED
 RESEARCH
 CONCEPTS

- (1) DEMUX/REFORMAT
- () RESAMPLE
- (2) COP GATHER
 DATUM: 6900 ft VELOCITY: 5000'/sec
- () FILTER
- () DECONVOLUTION

MS OPERATOR

AUTO CORR WINDOW
 WHITE NOISE: PERCENT

- (7) VELOCITY ANALYSIS
- (8) NMO
- (9) MUTE
- (10) AUTOMATIC STATICS WINDOW 100-500
- () CDP X-CORR STATICS WINDOW
- (11) STACK FOLD Varies - See Report
- (4) FILTER
 60-80-160-180 Hz 0-400 msec.
 30-50-100-120 Hz 240-600 msec

- (5) EQUALIZATION
- (3) GAIN RECOVERY T-14 FUNCTION
- (6) TRACE COMPOSITE 3 Trace - Common Offset Distance
- () WAVE EQUATION MIGRATION
- (12) TRACE COMPOSITE FOR 3-D
 40 FT BOX CONFIGURATION

DATE PROCESSED Nov, 1982 ANALYST Austin, Tx

PLOTTER DISPLAY

VAWG 20 IN/SEC 10 TR/IN
 POLARITY Black = Positive
 DIRECTION OF PLOT R-L
 REEL NUMBER 107 JOB NO 1441

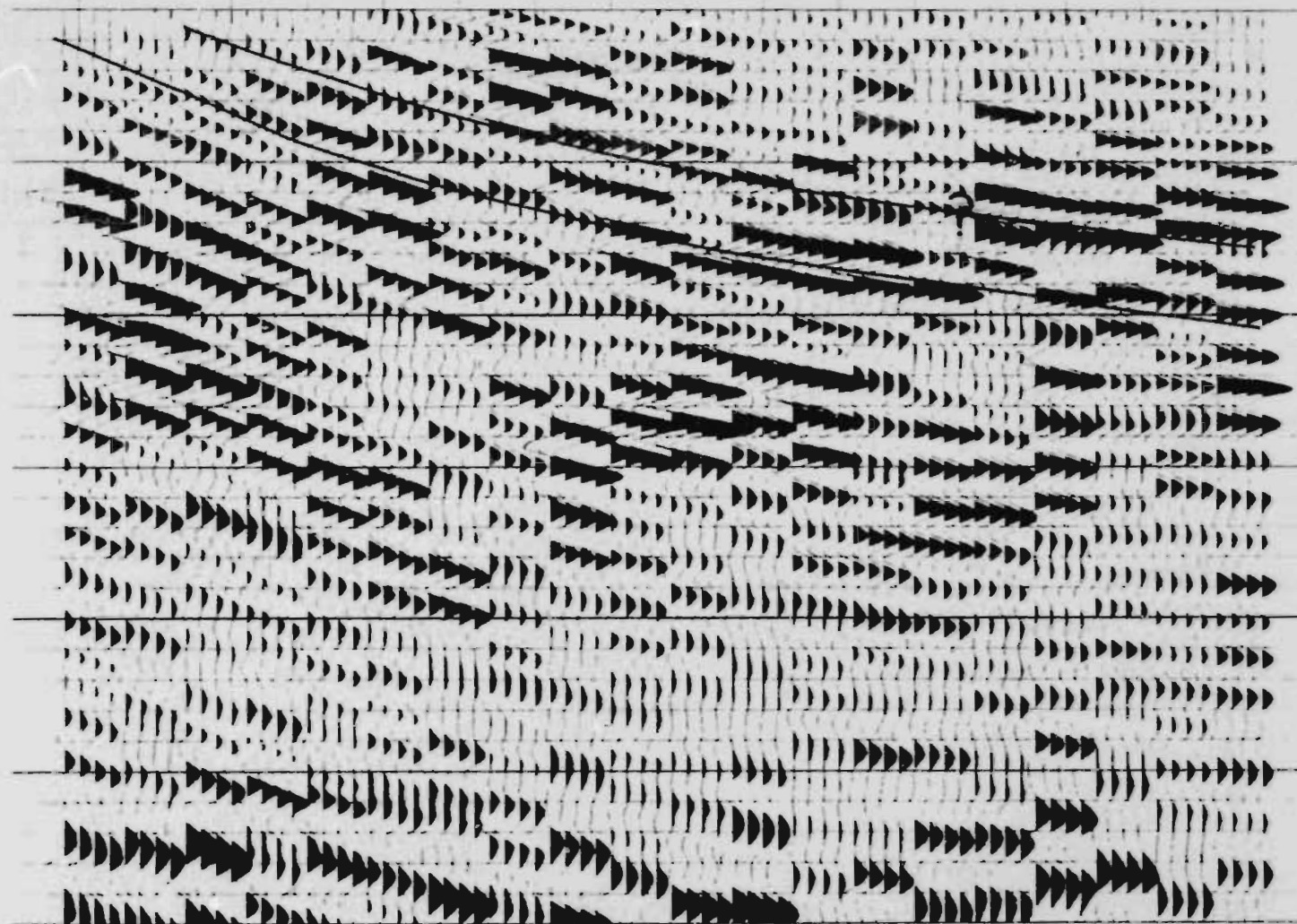
U.S. DEPT.
 OF ENERGY
 LARAMIE ENERGY
 TECH. CENTER

LINE A 40' STACK

275 270 265 260 255 250 245 240 235 230 225 220 215 210 205 200

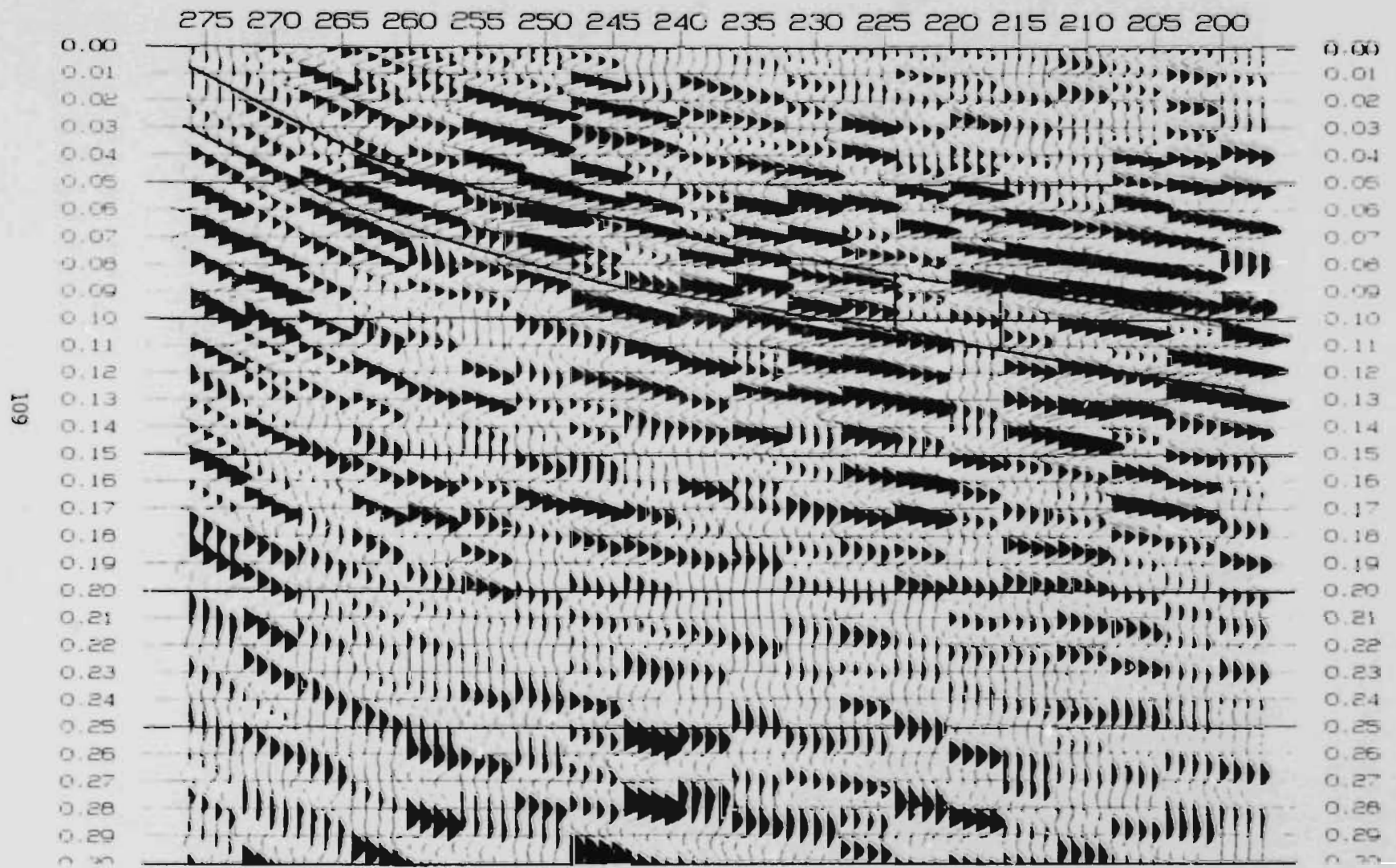
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0.30

108

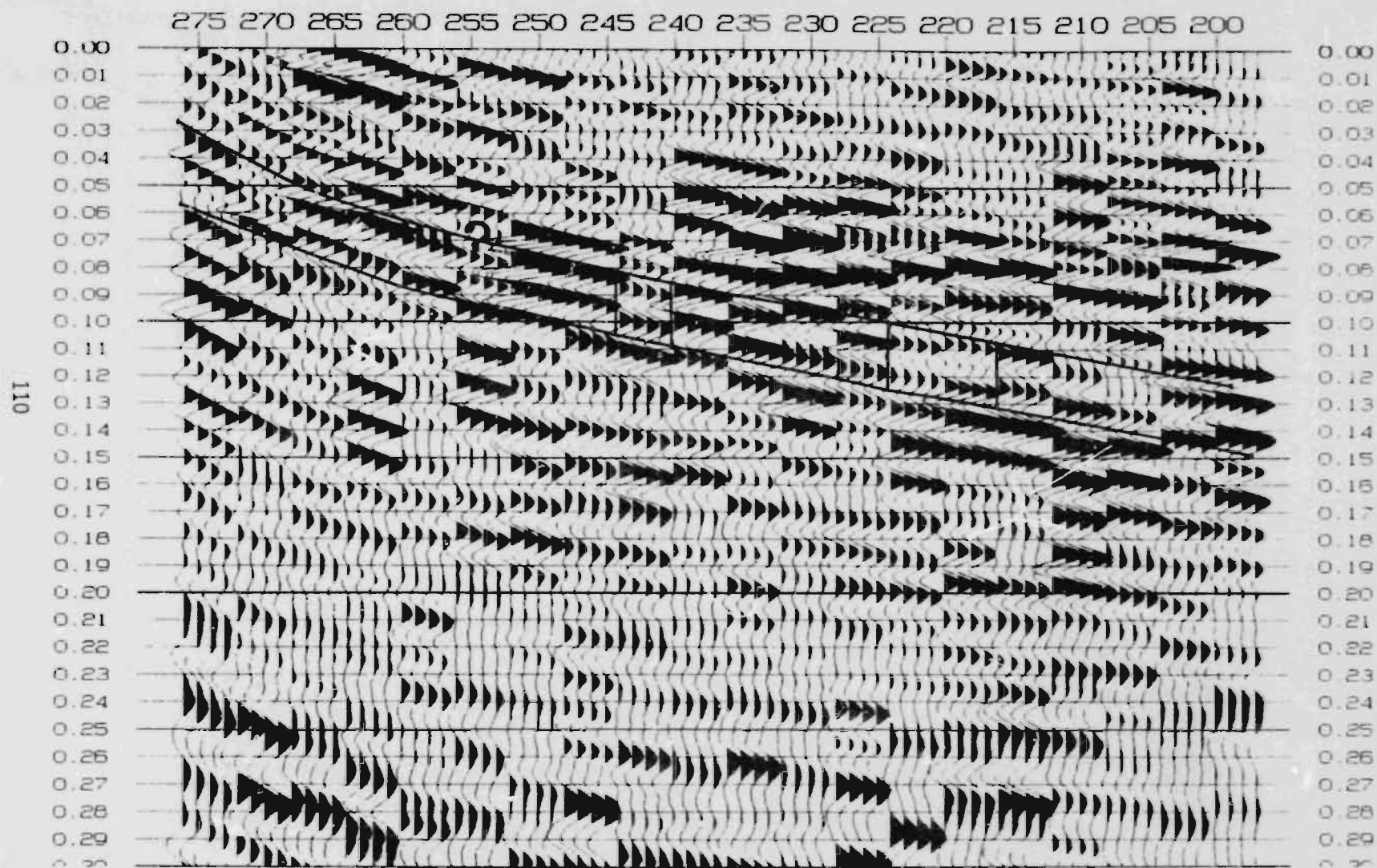


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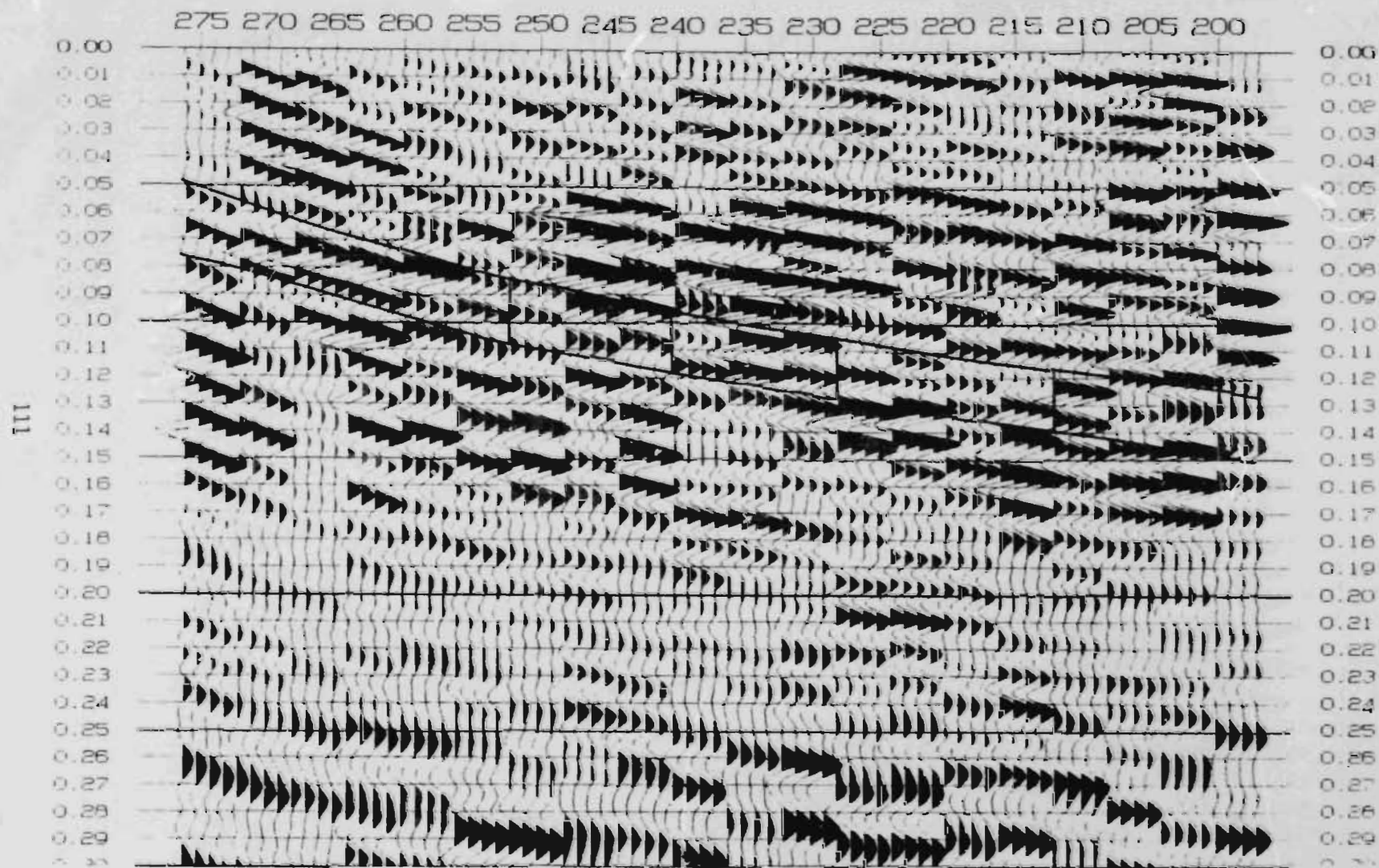
LINE B 40' STACK



LINE C 40' STACK

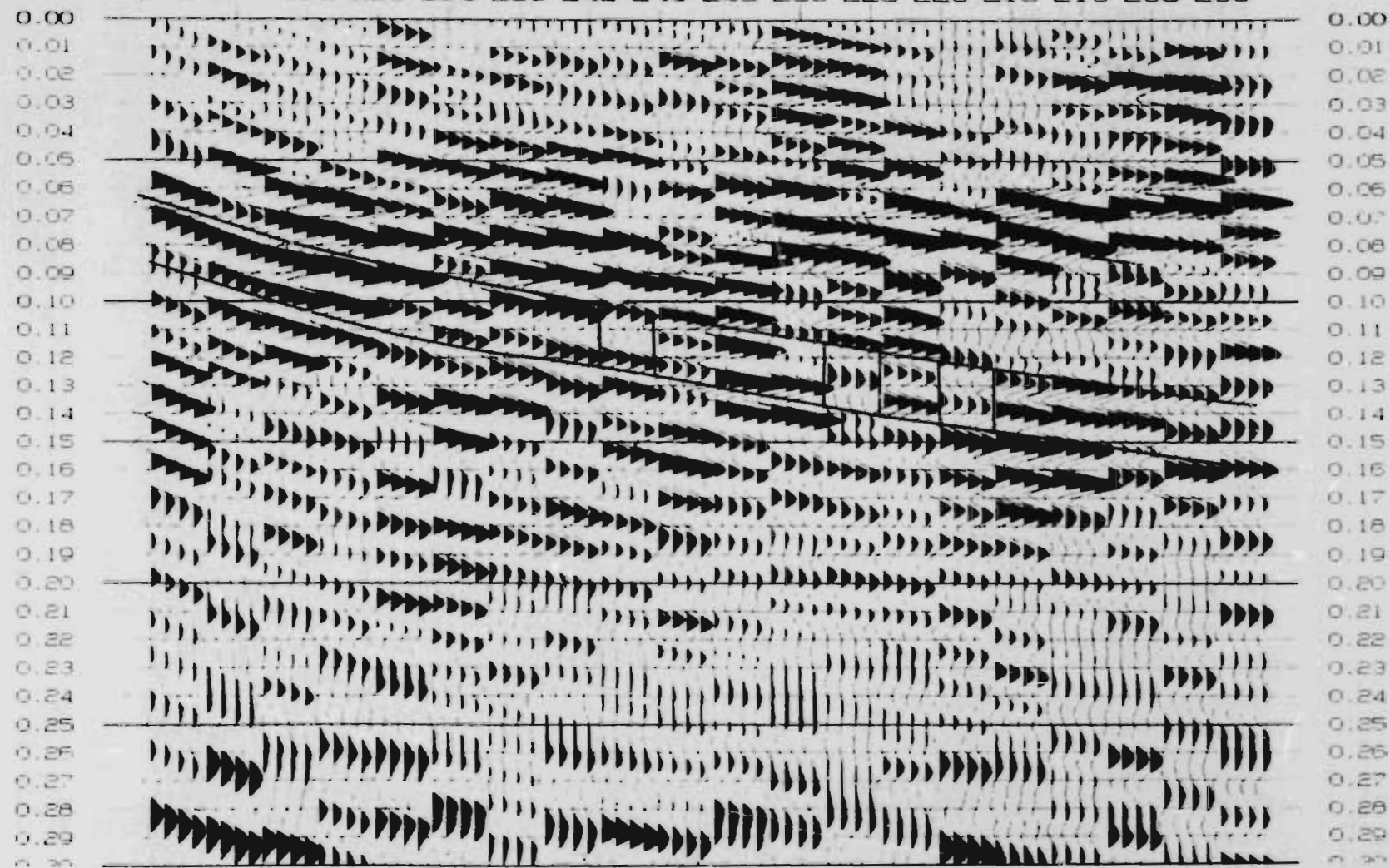


LINE D 40' STACK

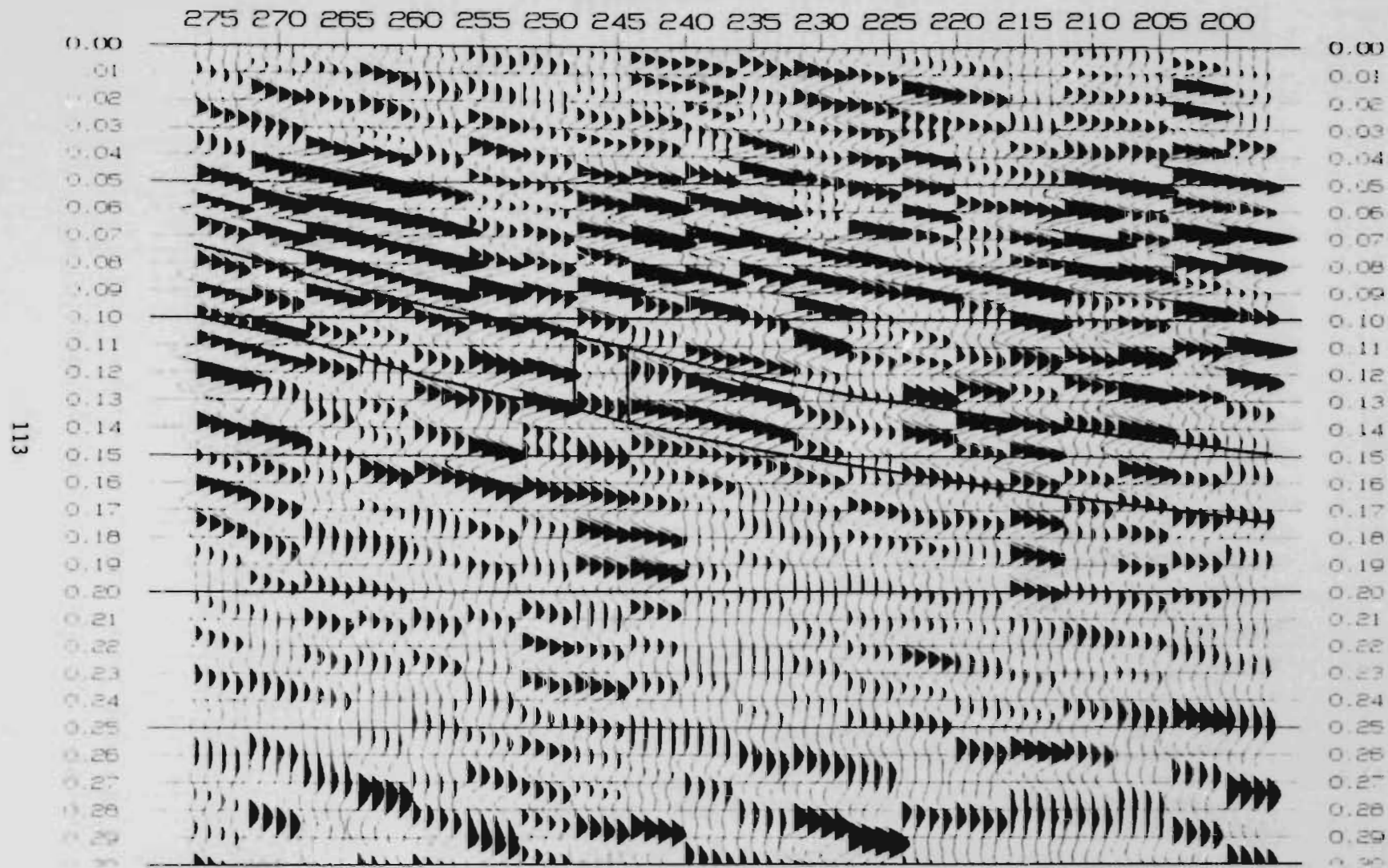


LINE E 40' STACK

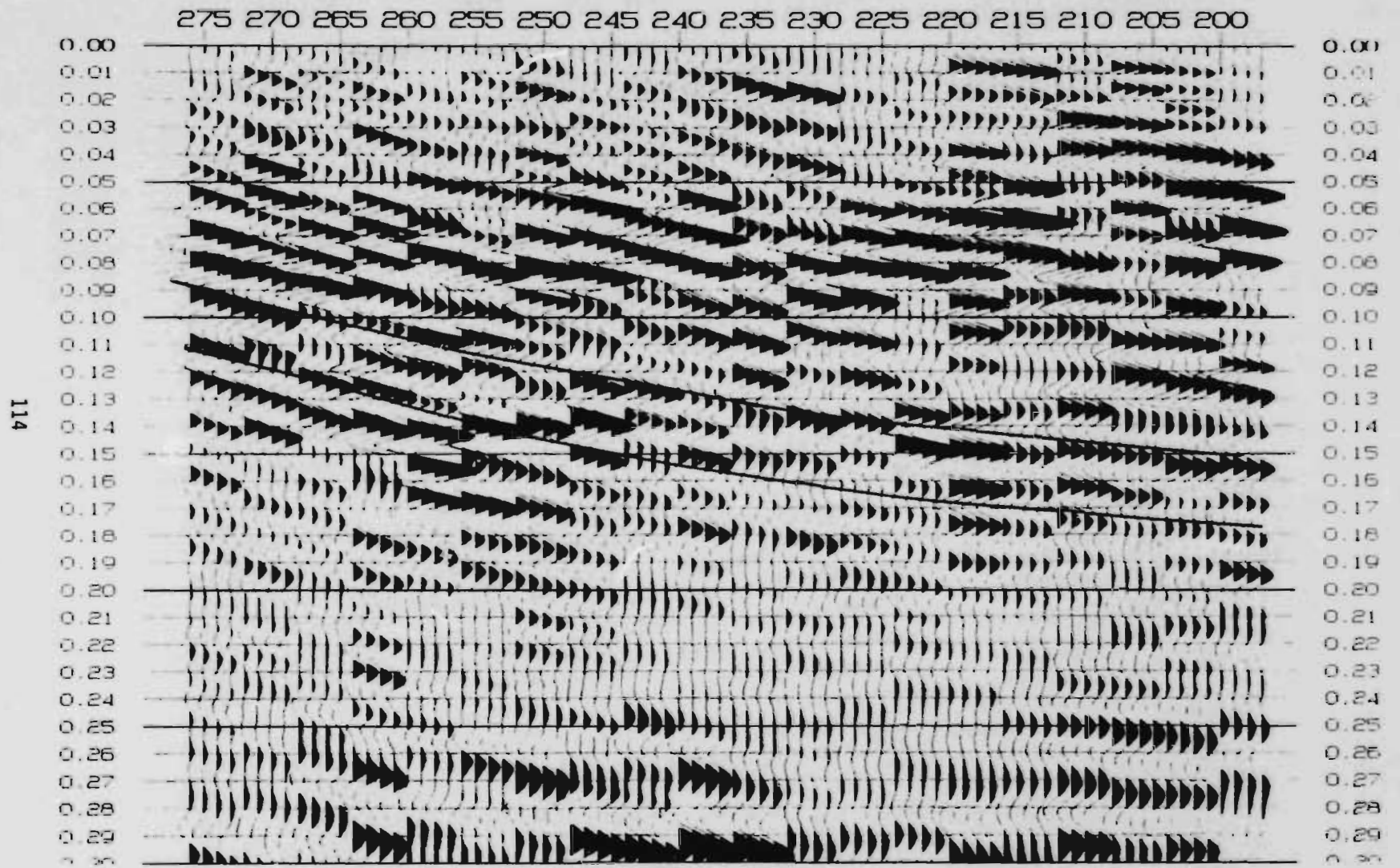
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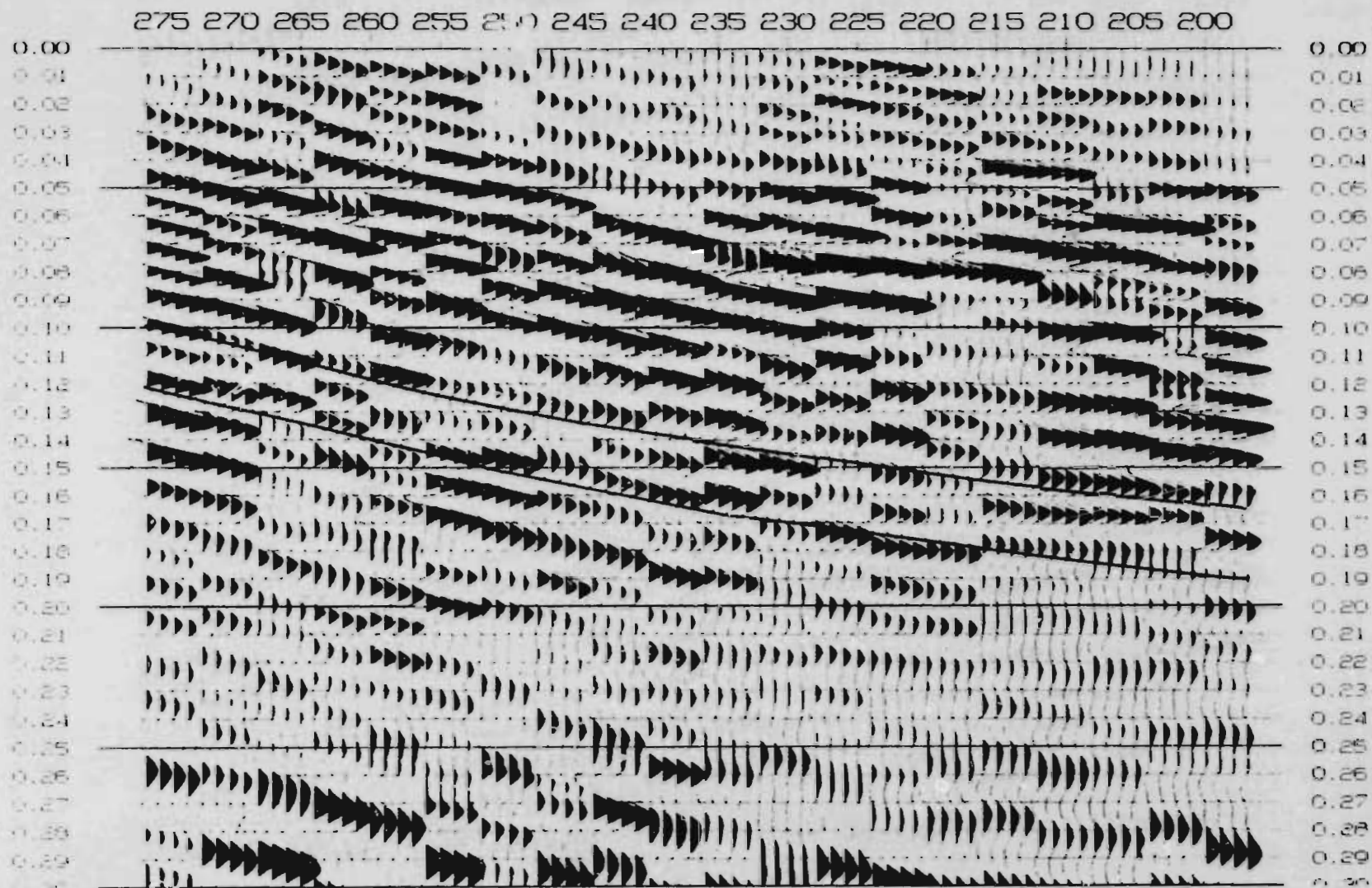
LINE F 40' STACK



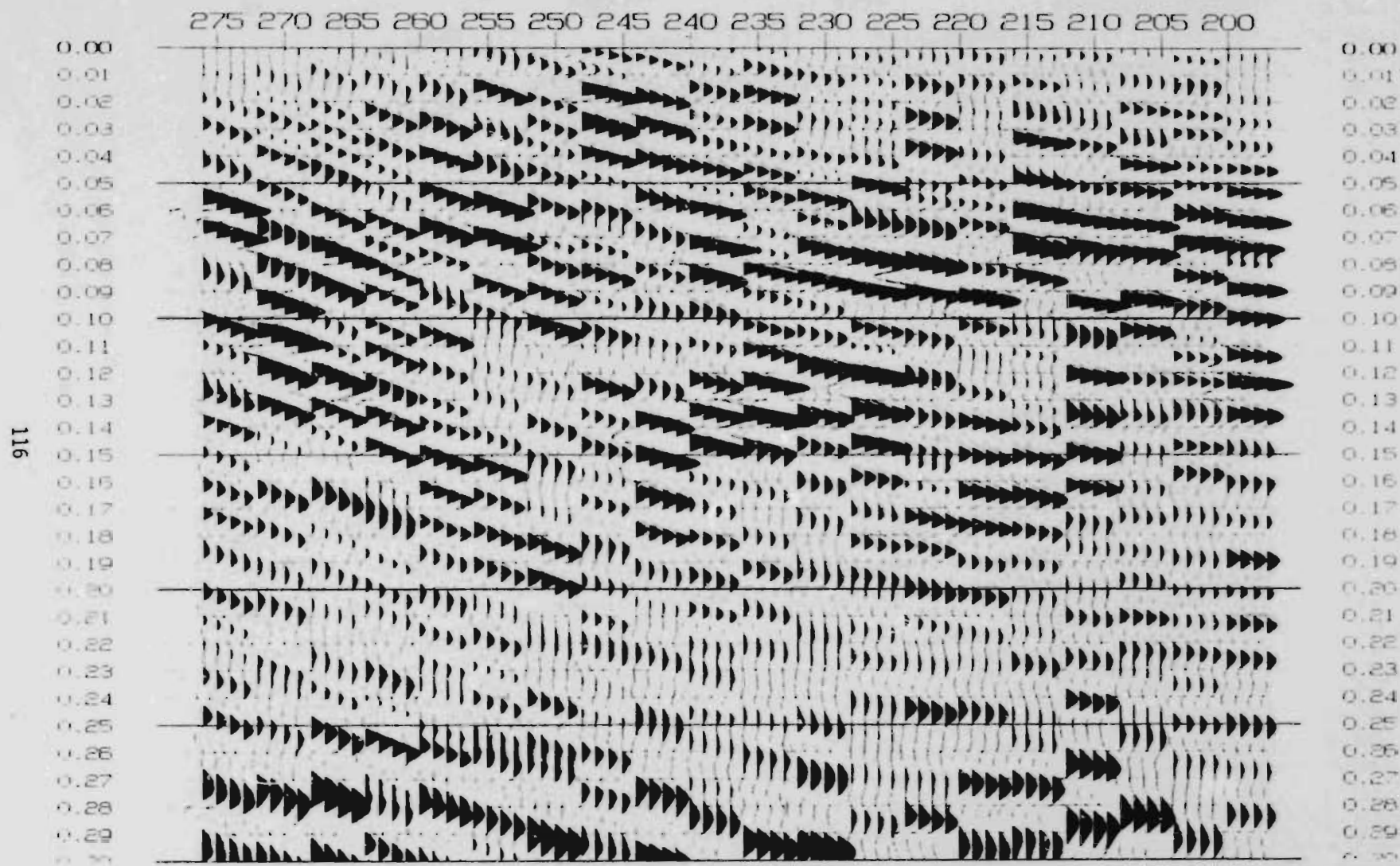
LINE G 40' STACK



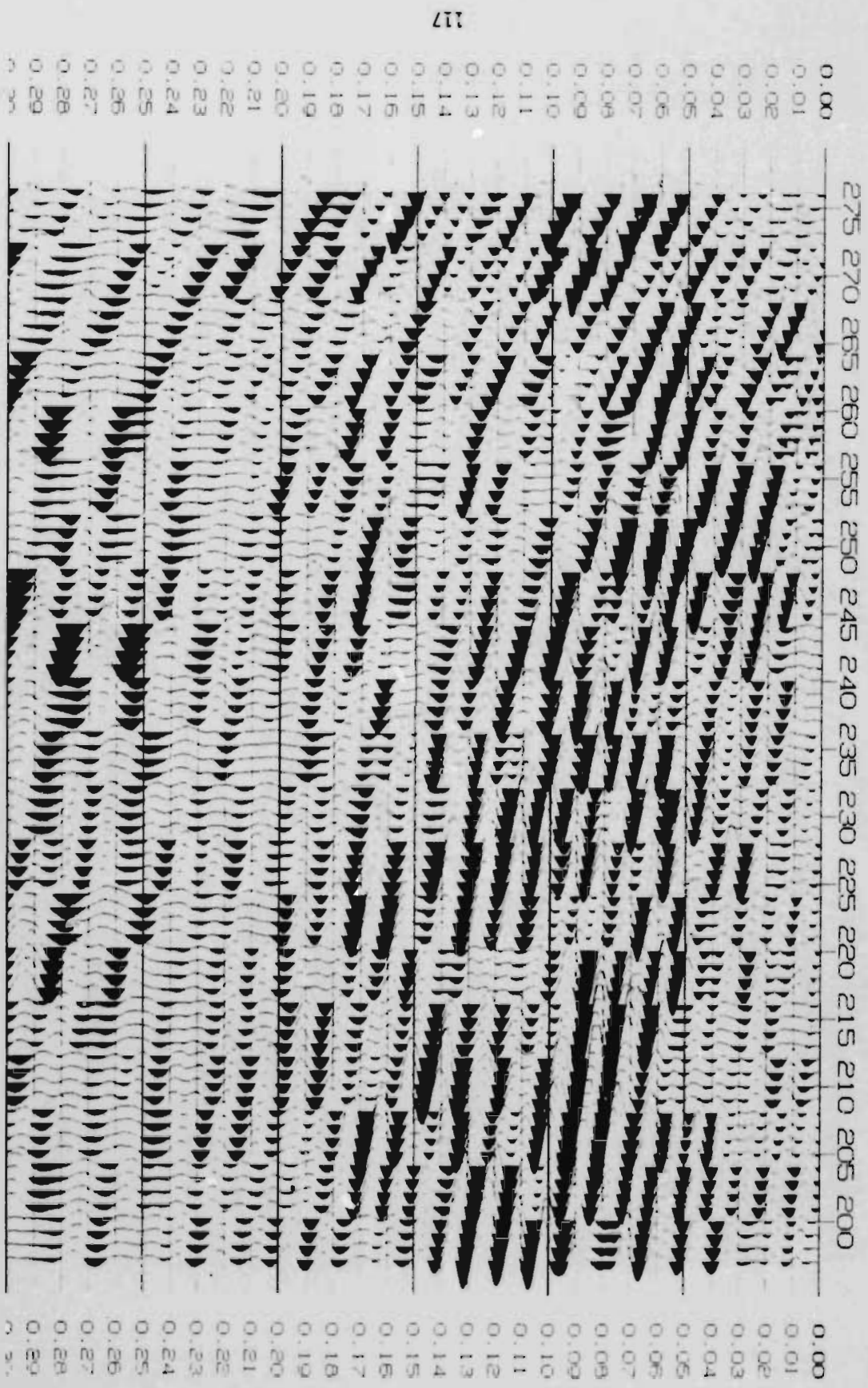
LINE H 40' STACK



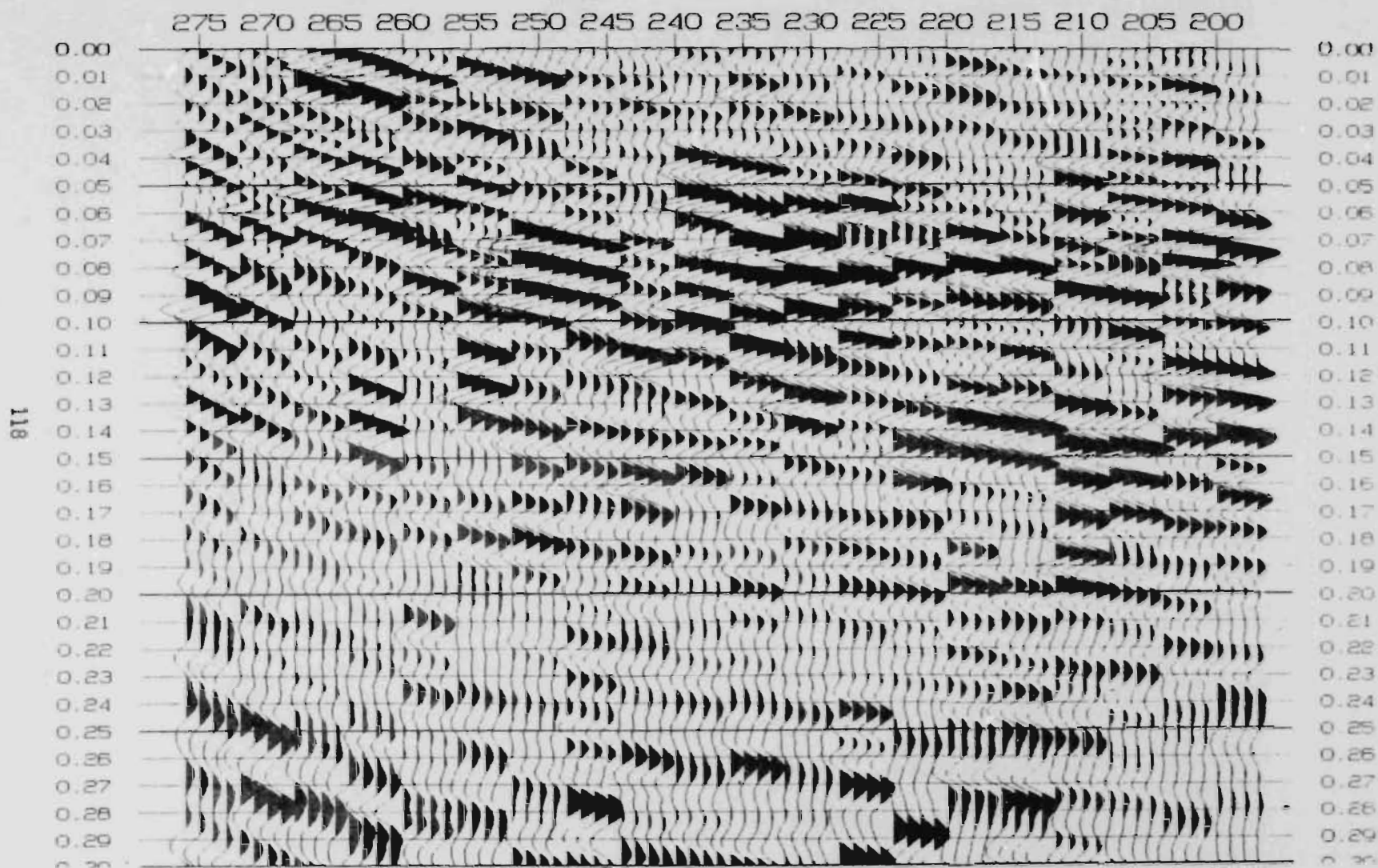
LINE A 40' STACK



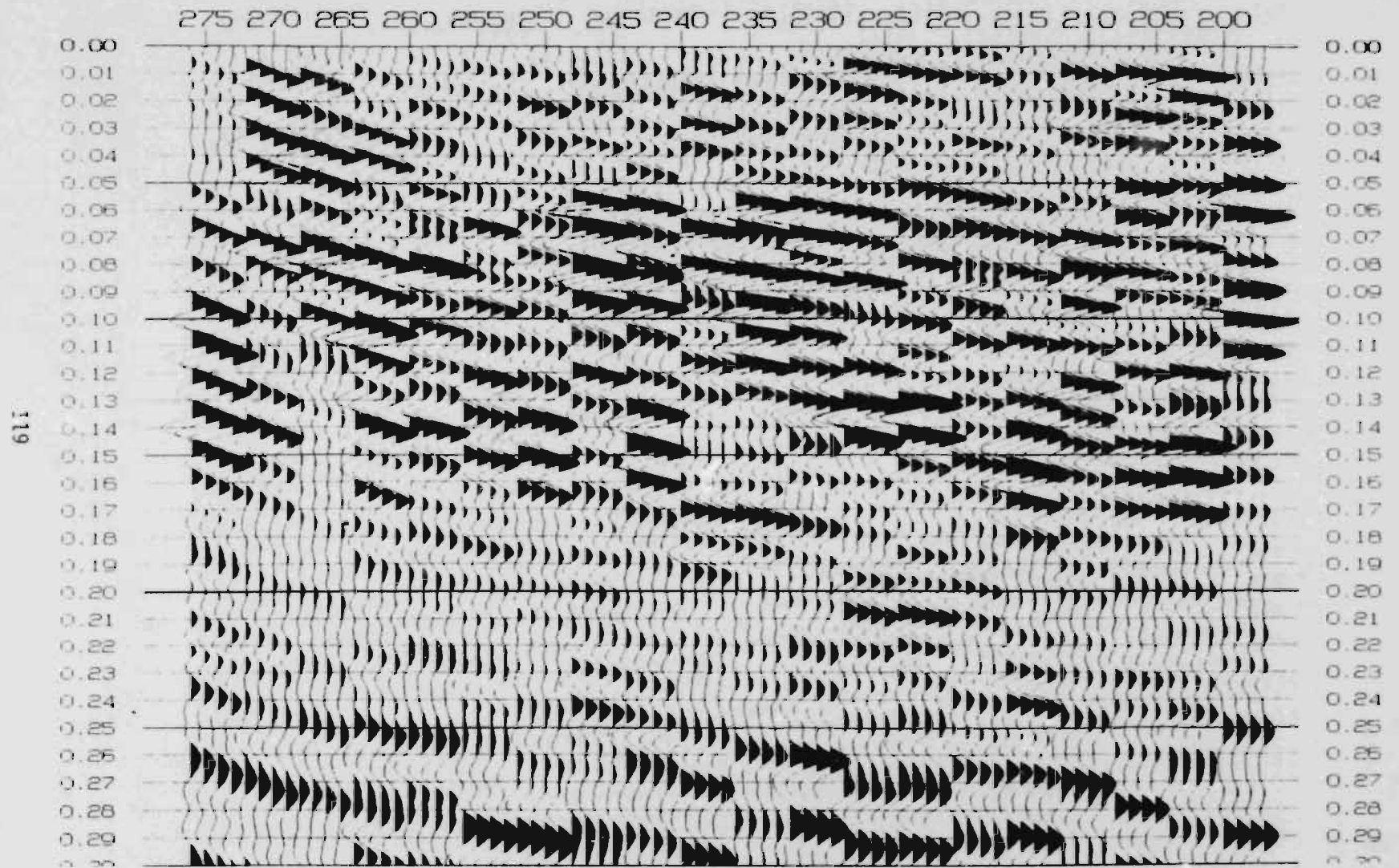
LINE B 40' STACK



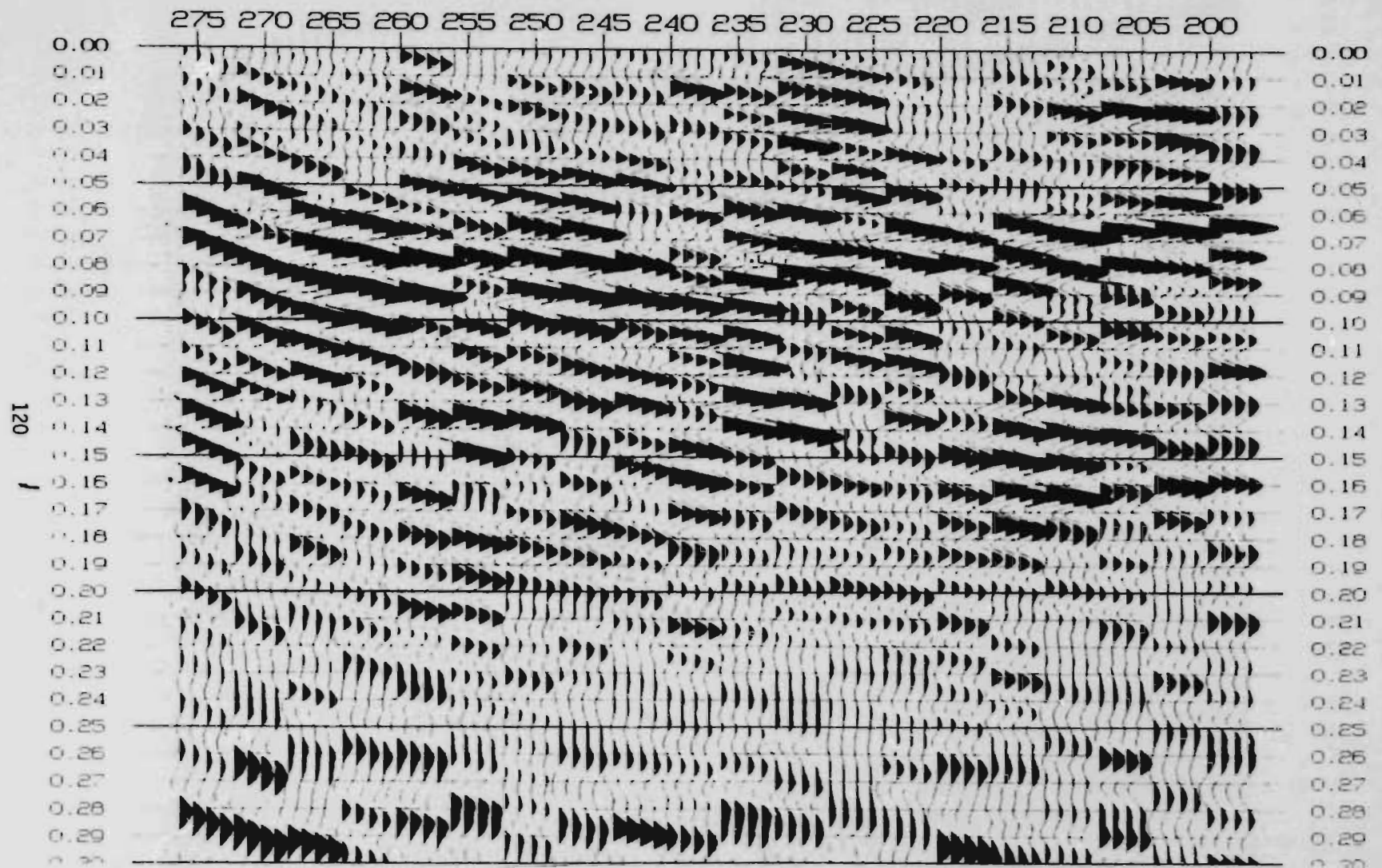
LINE C 40' STACK



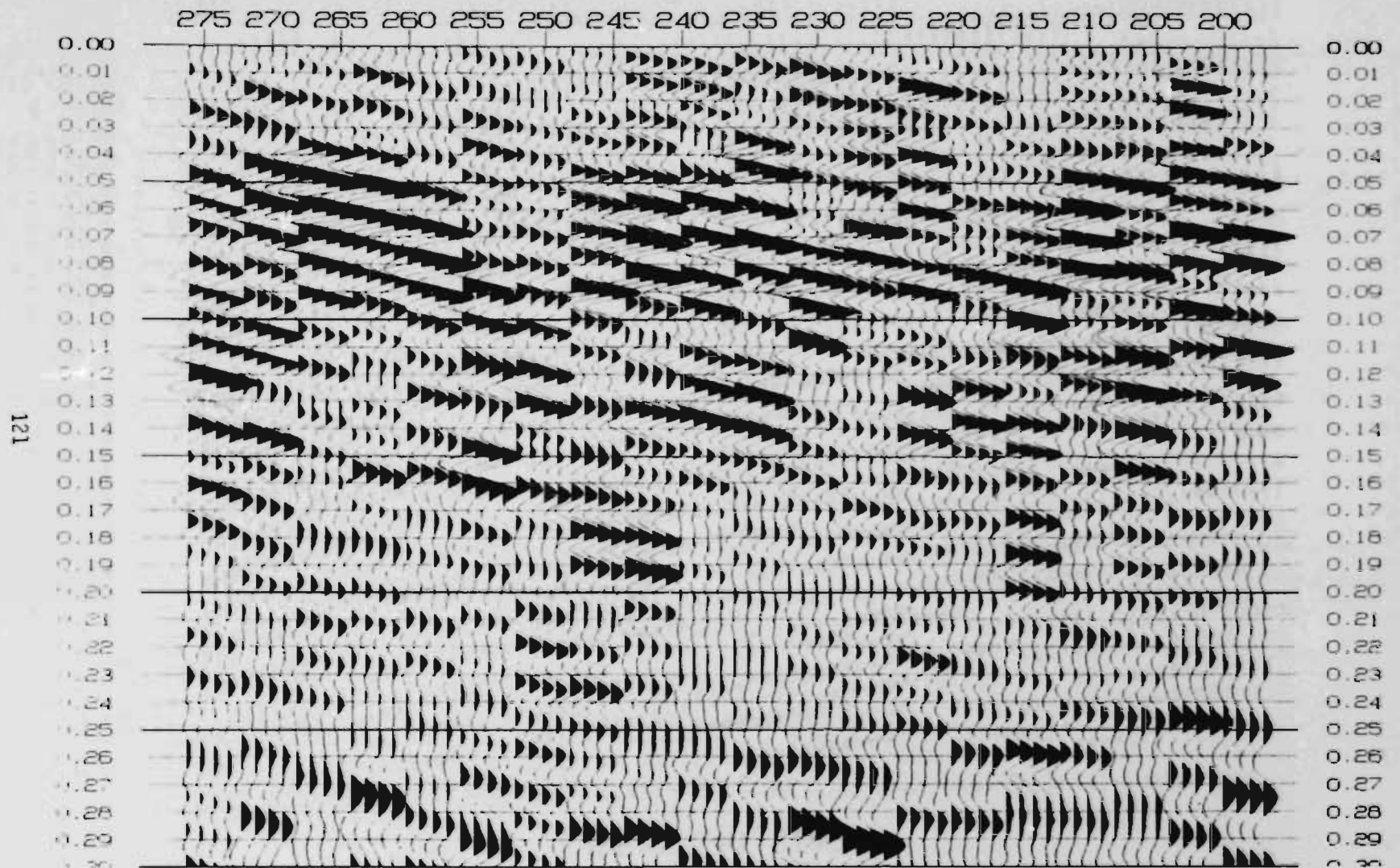
LINE D 40' STACK



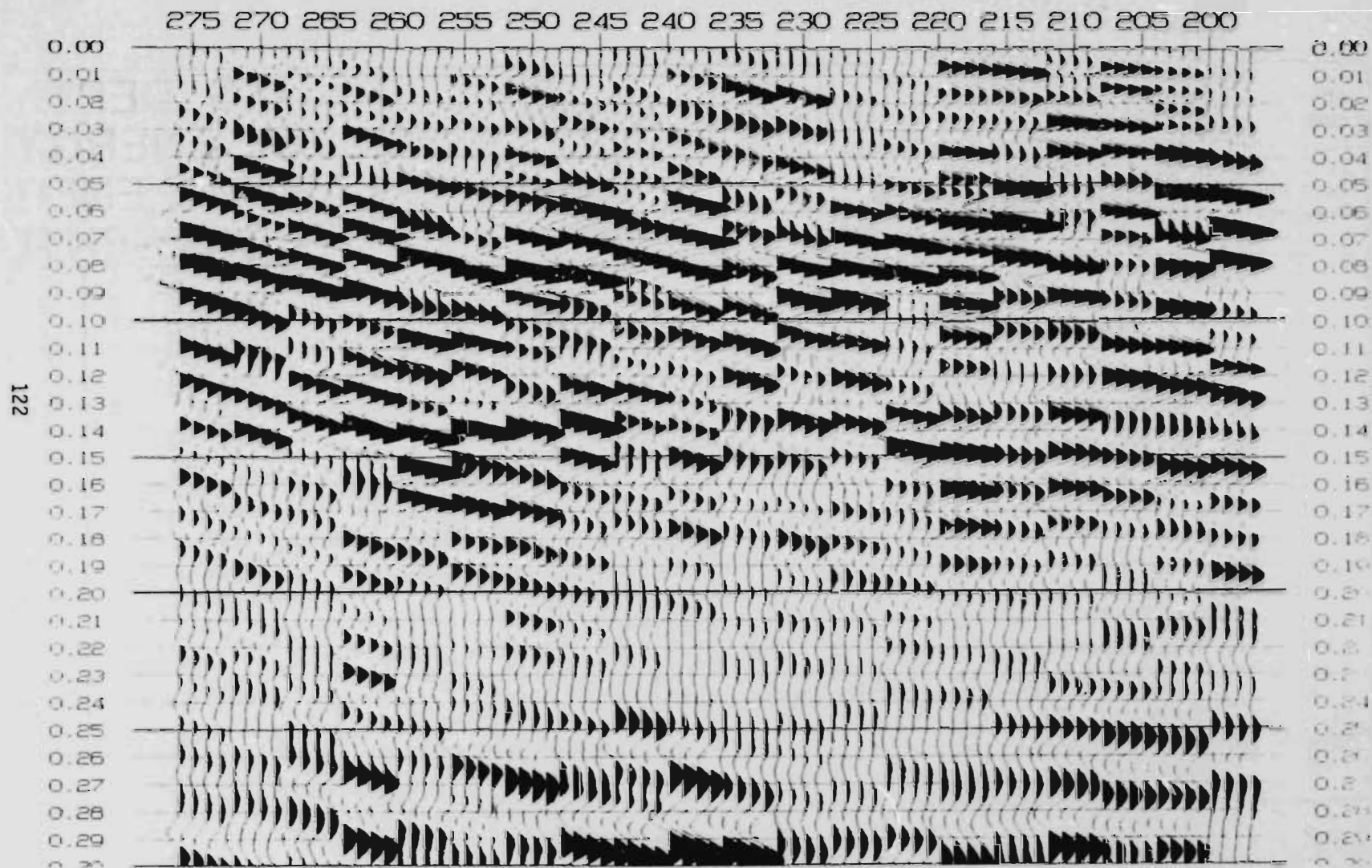
LINE E 40' STACK



LINE F 40' STACK



LINE G 40' STACK



FIELD PARAMETERS

INST DFS V
REC LENGTH 1 sec
SAMPLE RATE 1 ms
RECORDED BY ESI & I
SOURCE Dataprime
HOLE DEPTH 6 ft
DATE Oct, 1982

GROUP INT 20 ft
S P INT 20 ft
NO OF CHAN 24
GEOPH. ARRAY 6 at 12 centered
SPREAD Shooting Thru Cable
NEAR OFFSET 0 ft
FAR OFFSET Varies

PROCESSING SEQUENCE



APPLIED
RESEARCH
CONCEPTS

PROCESSED BY THE:
SEISTRAC 32

- (1) DEMUX/REFORMAT
- () RESAMPLE
- (2) CDP GATHER
- DATUM: 6900 ft VELOCITY: 5000'/sec
- () FILTER
- () DECONVOLUTION

MS. OPERATOR

AUTO CORR WINDOW
WHITE NOISE PERCENT

- (7) VELOCITY ANALYSIS
- (8) NMO
- (9) MUTE
- (10) AUTOMATIC STATICS WINDOW 100-500
- () CDP X CORR STATICS WINDOW
- (11) STACK FOLD Varies - See Report
- (4) FILTER
- 60-80-160-180 Hz 0-400 msec
- 30-50-100-120 Hz 240-600 msec

- (5) EQUALIZATION
- (3) GAIN RECOVERY T-14 FUNCTION
- (6) TRACE COMPOSITE 3 Trace - Common Offset Distance
- () WAVE EQUATION MIGRATION
- (12) TRACE COMPOSITE FOR 3-D
- 80 FT BOX CONFIGURATION

DATE PROCESSED Nov, 1982 ANALYST Austin, Tx

PLOTTER DISPLAY

VAWG 20 IN/SEC 10 TR/IN
POLARITY Block = Positive
DIRECTION OF PLOT R-L
REEL NUMBER 123 JOB NO 1441

AREA: RAM LINS
LINE: AB, CD, EE, GH
LOCATION: Carbon Co., Wyoming
FOR: Emerald Exploration
ORIG PRSPT:
PROCESS: 80' Stack

SP: 197-277

U.S. DEPT.
OF ENERGY
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TECH. CENTER

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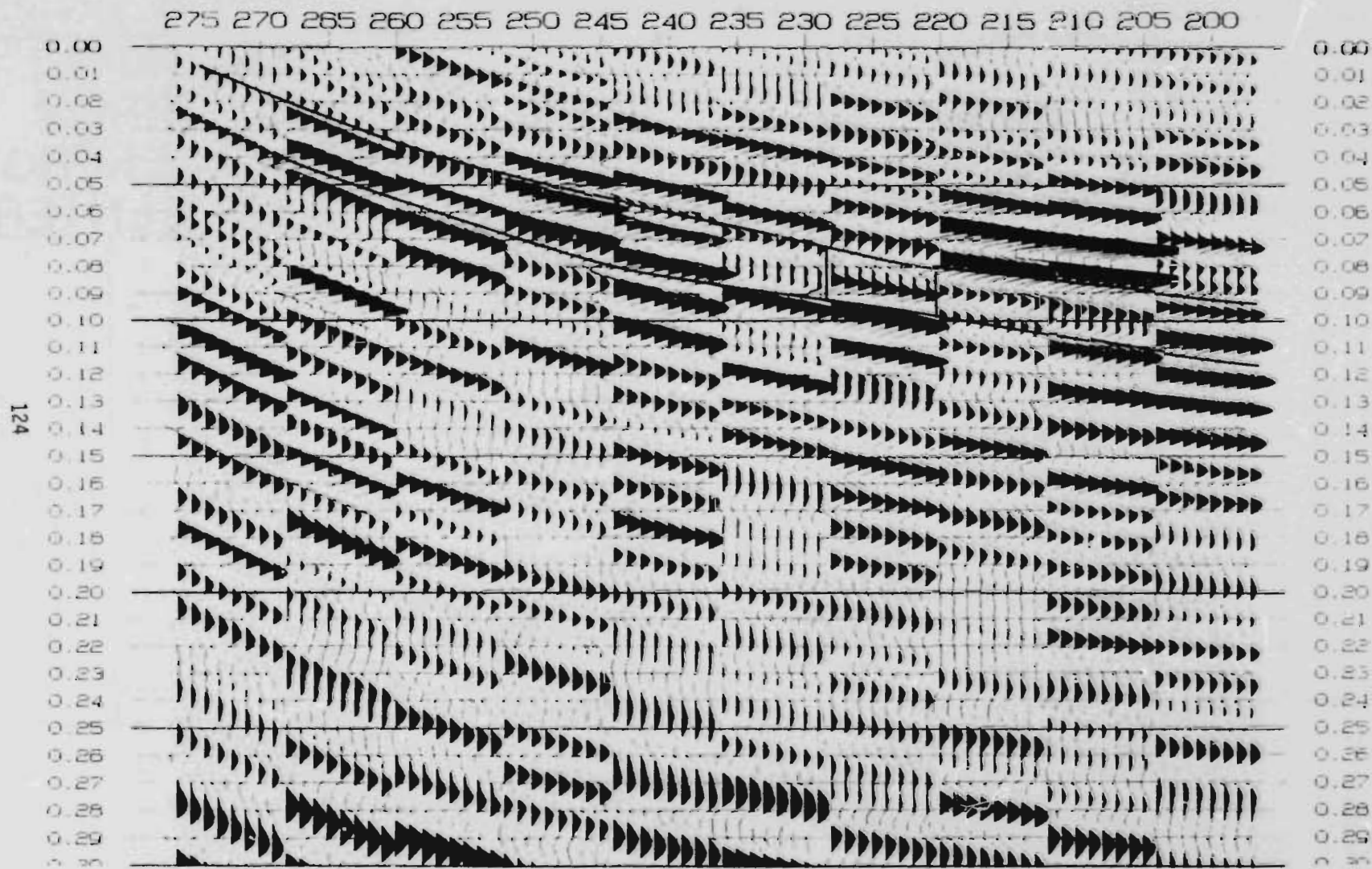
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PAGE 3 OF 3

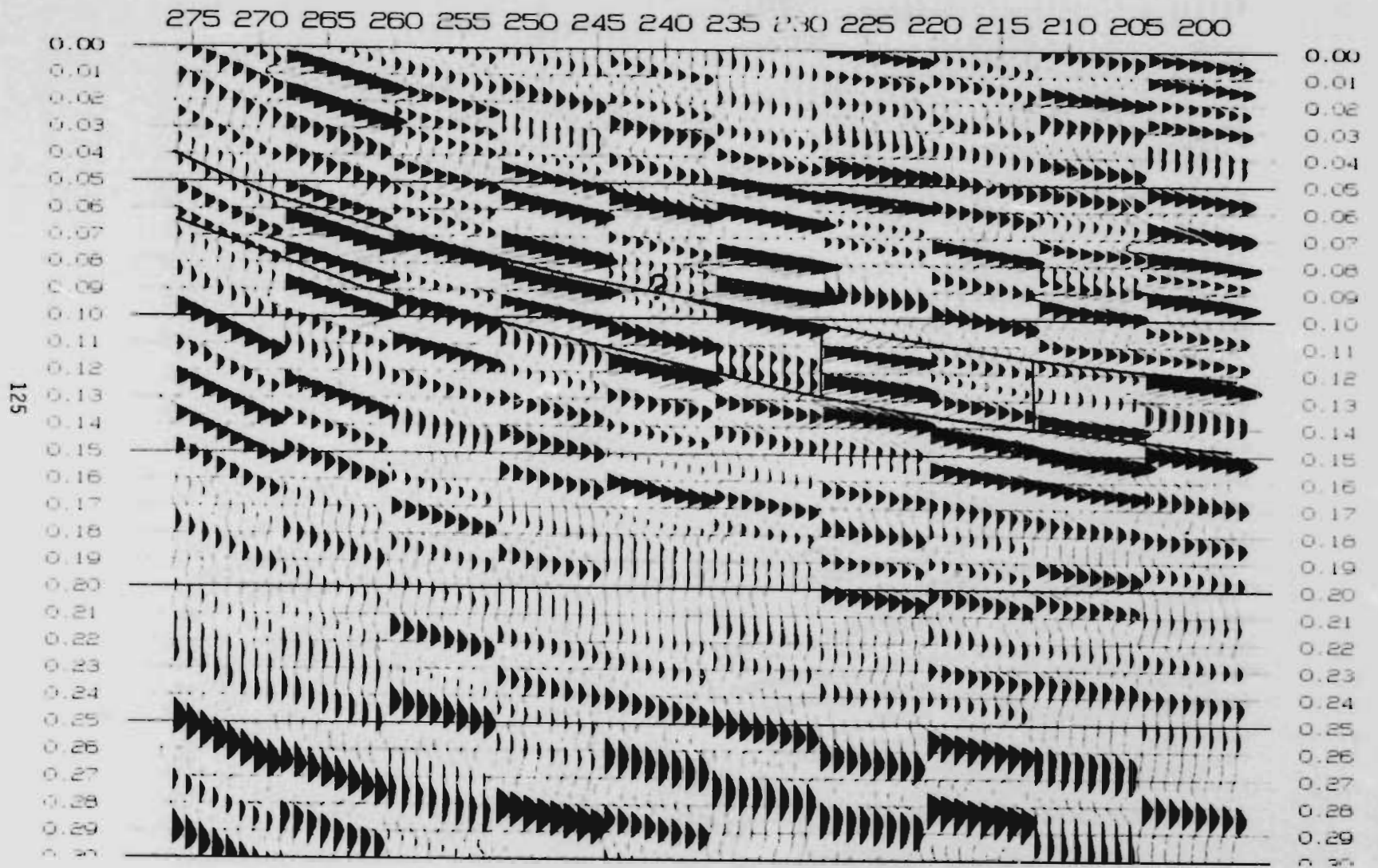
HIGH RESOLUTION SEISMIC SURVEY. RAWLINS, WYOMING.

UNDERGROUND COAL GASIFICATION AREA

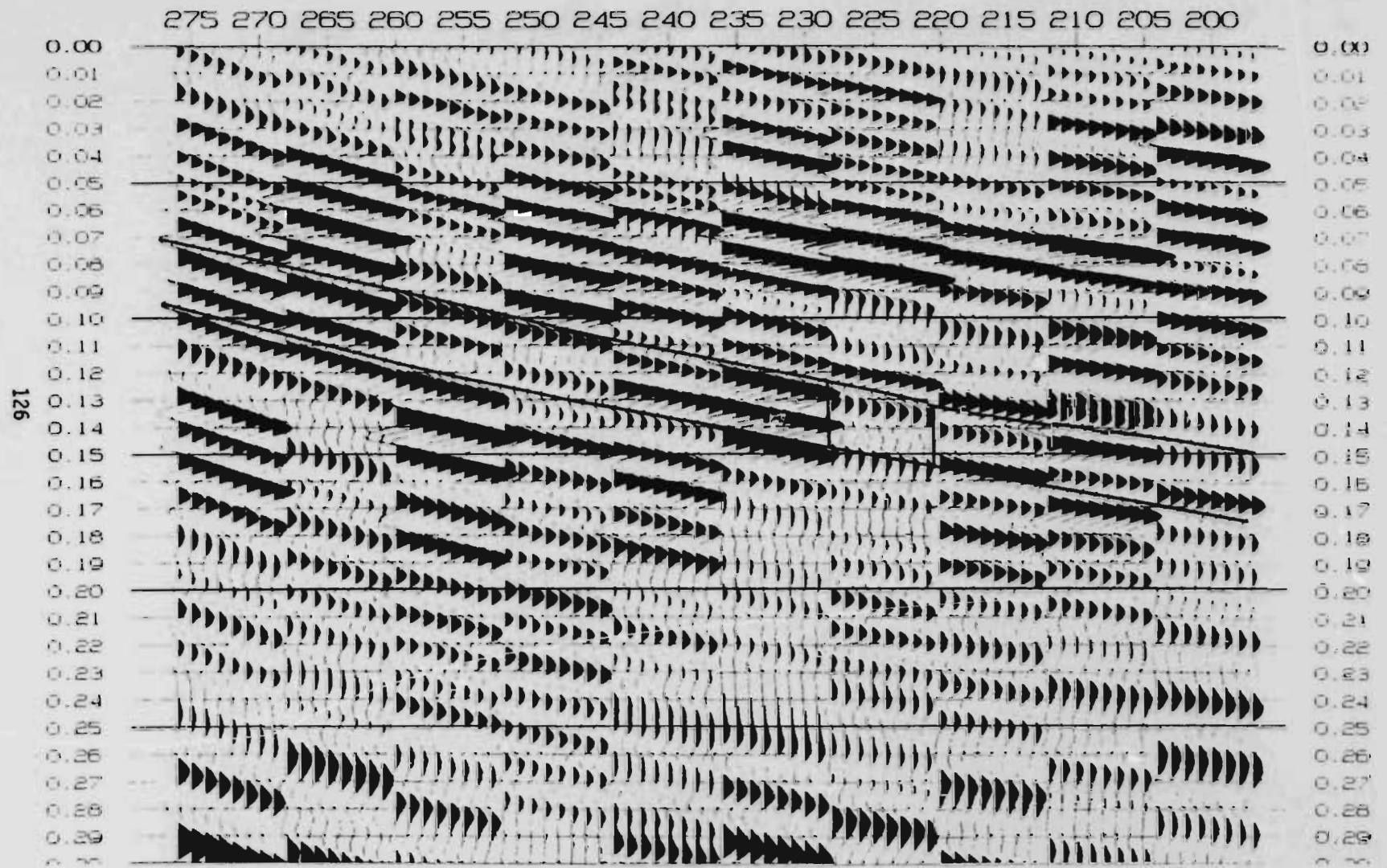
LINE AB 80' STACK



LINE CD 80' STACK

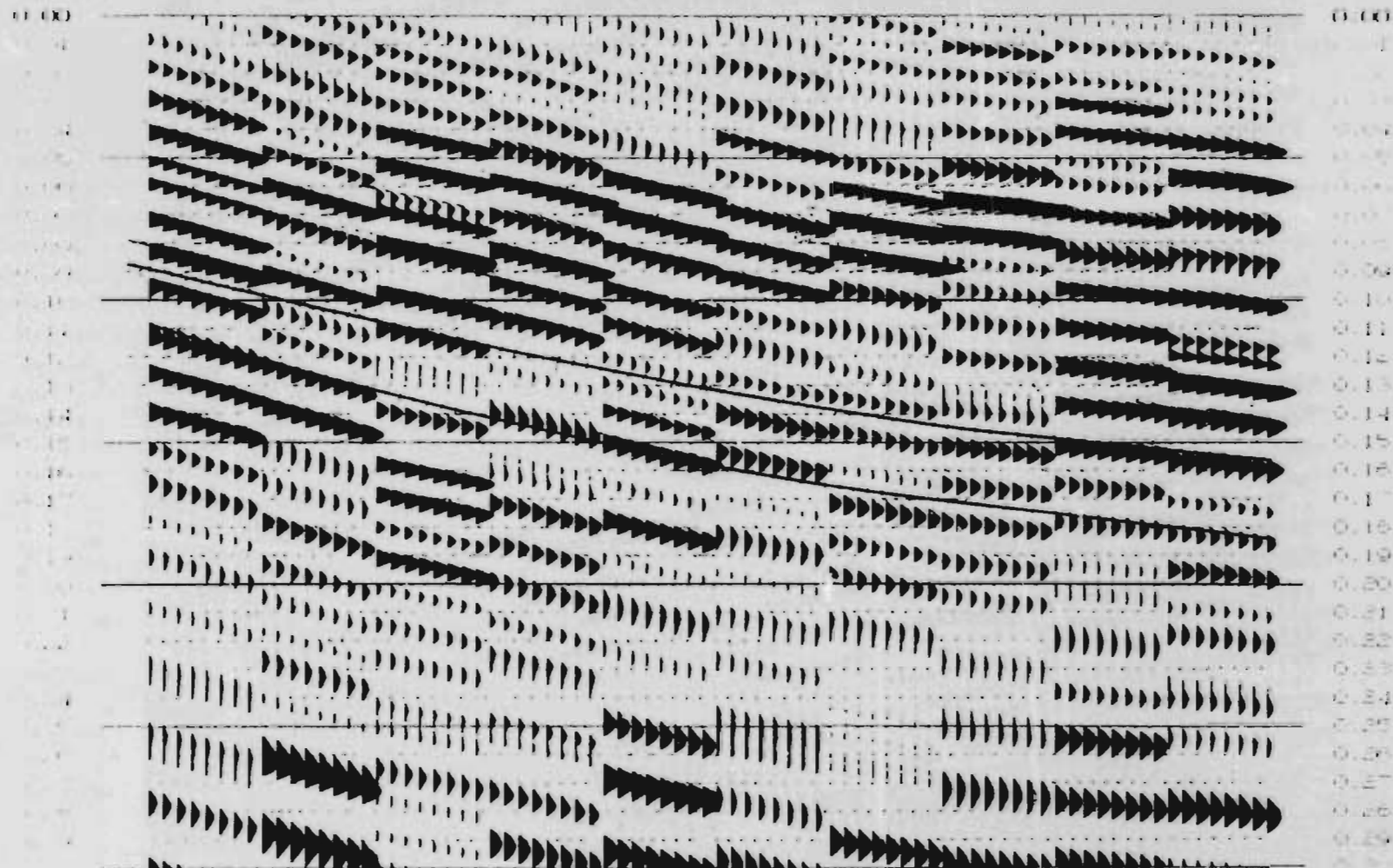


LINE EF 80' STACK

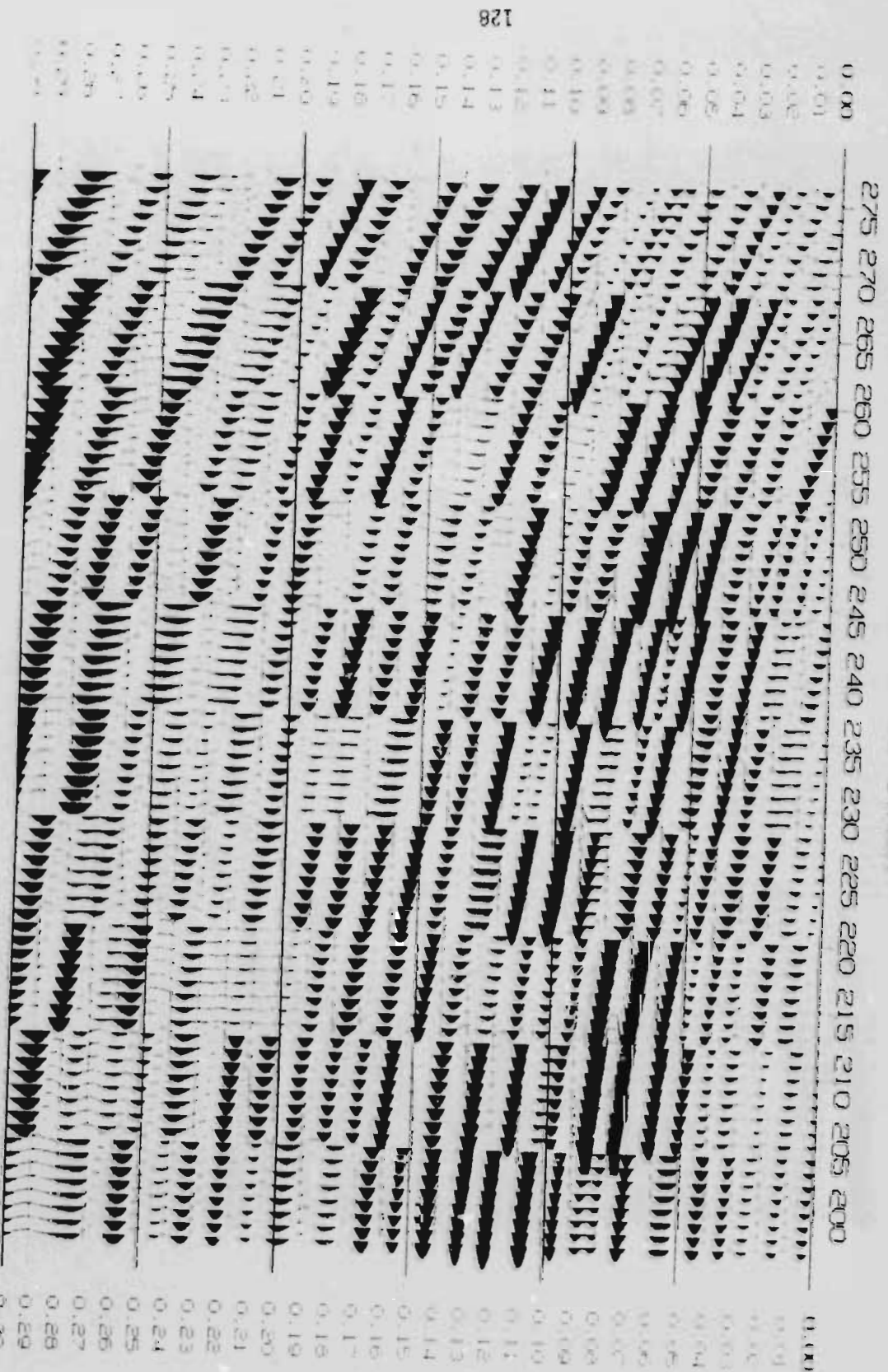


LINE GH 80' STACK

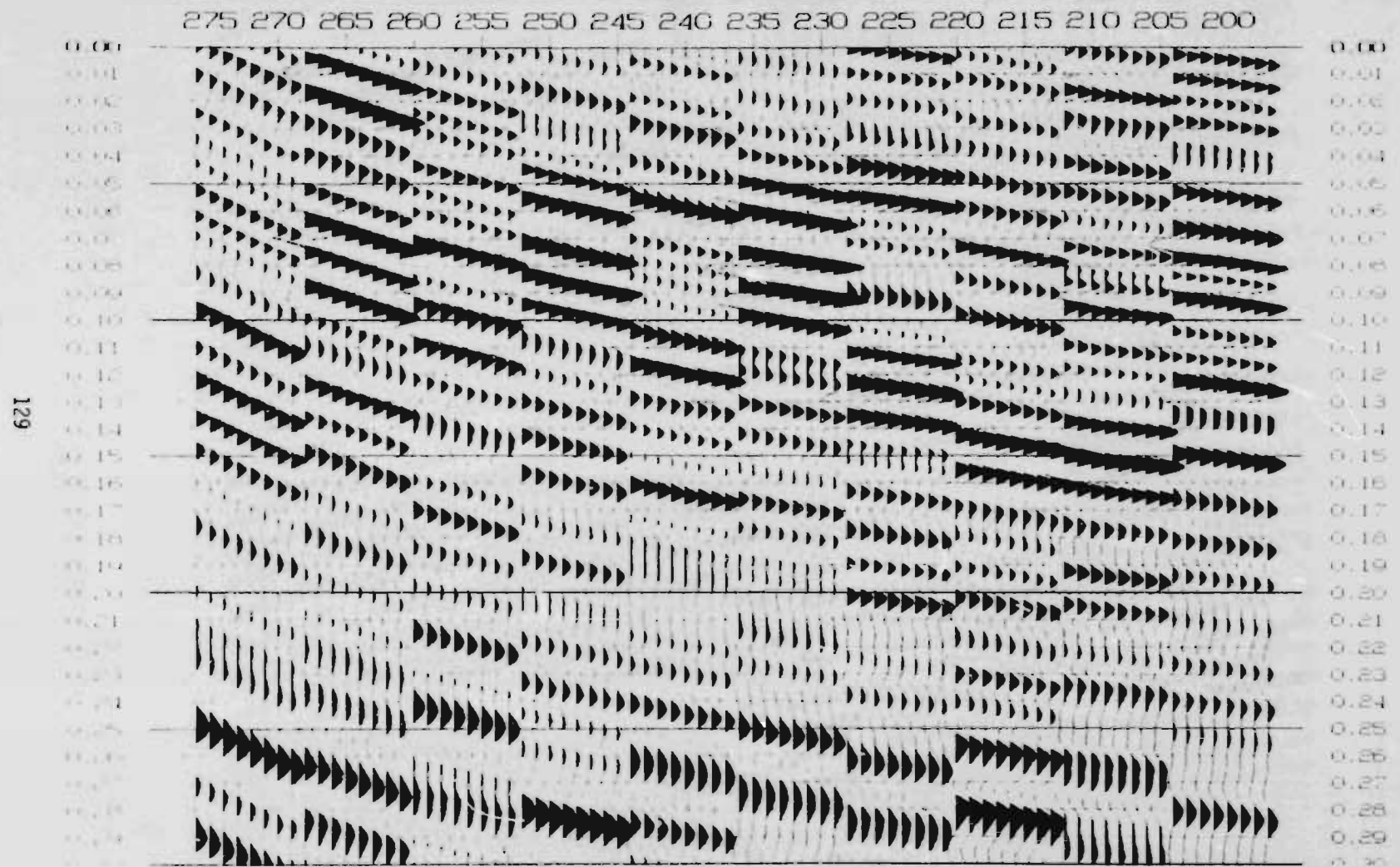
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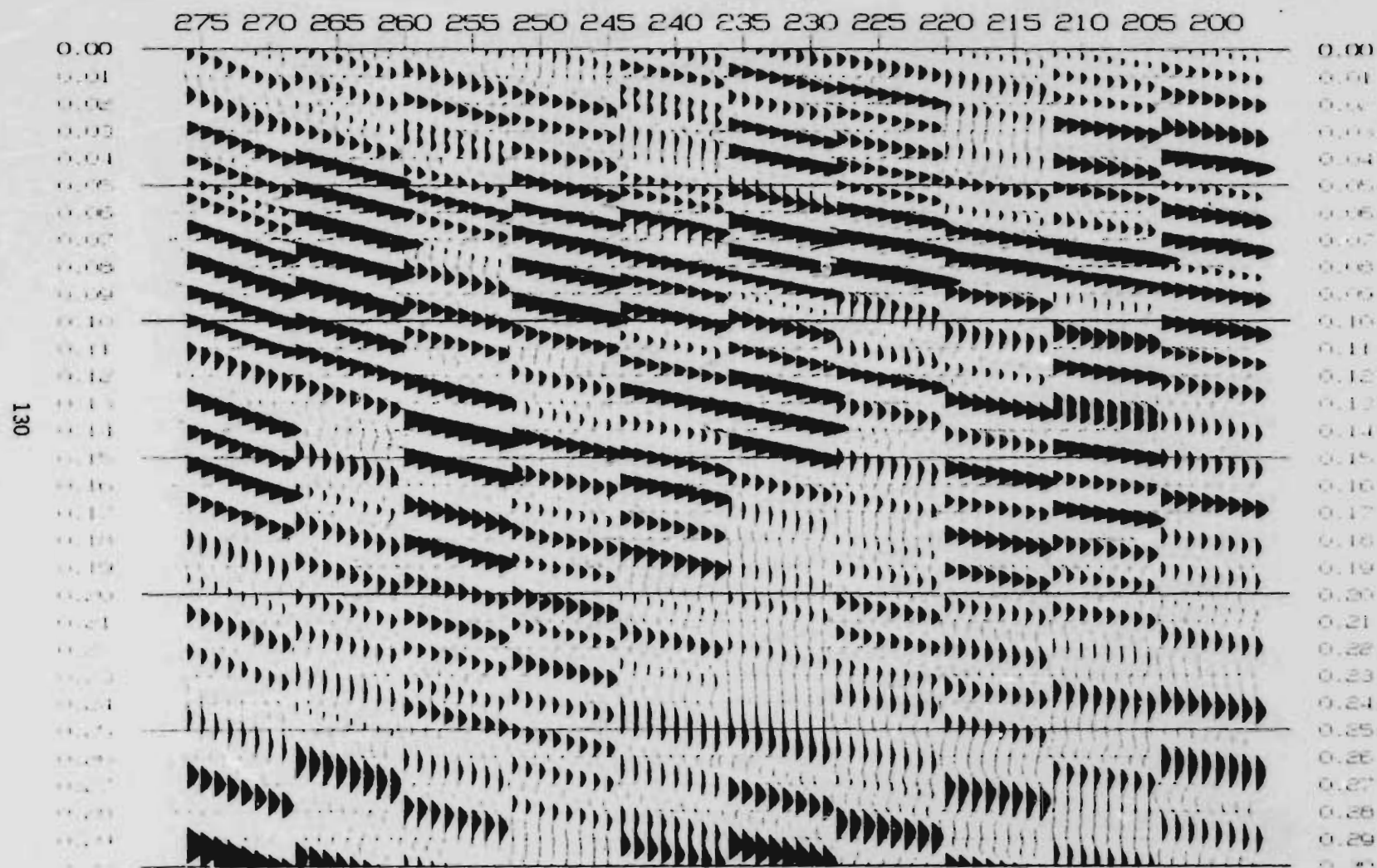
LINE AB 80' STACK



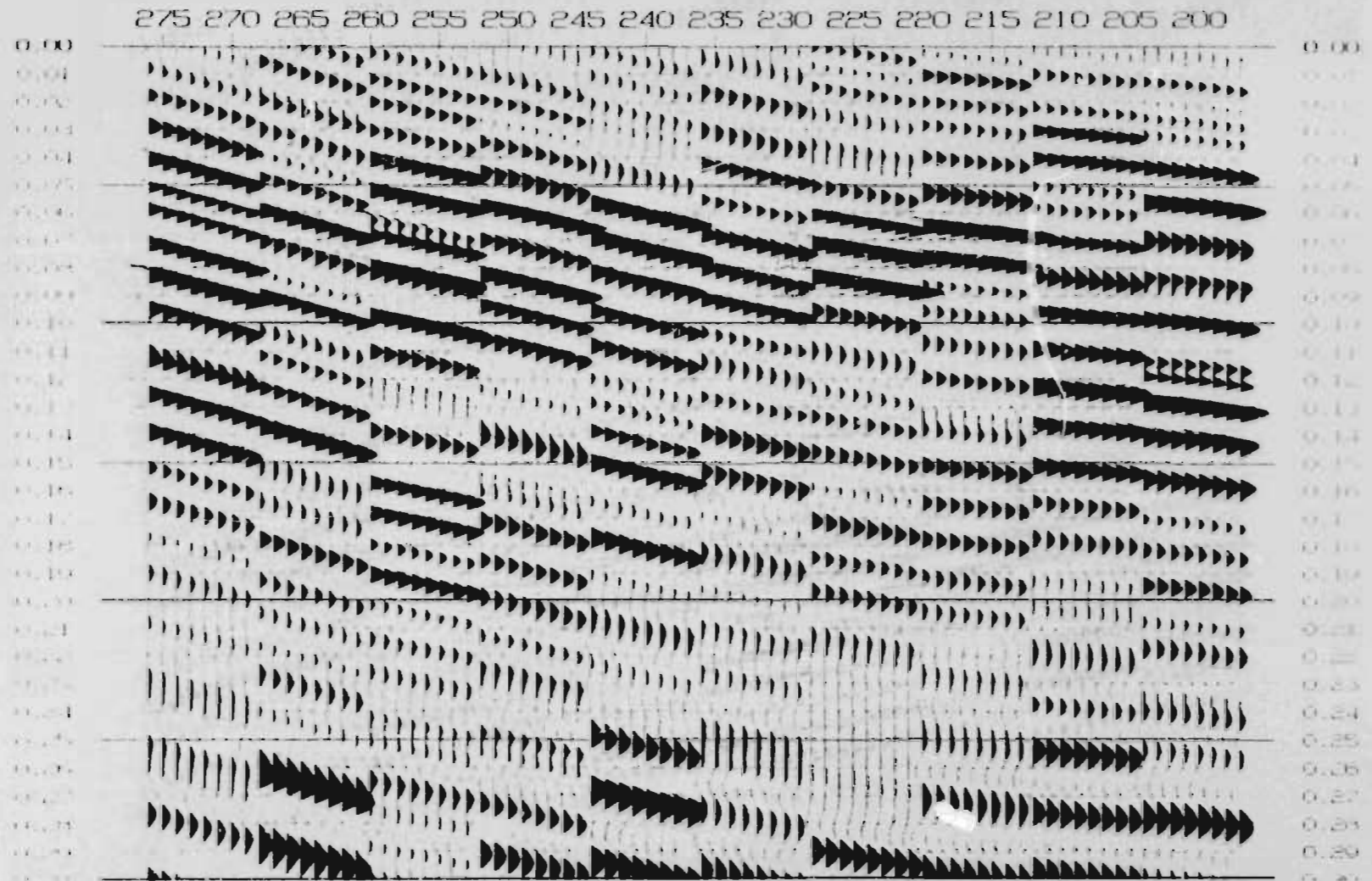
LINE CD 80' STACK



LINE EF 80' STACK



LINE GH 80' STACK



**END
of
PAPER**