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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

An Evaluation of Seismic Reflection
Studies in the Yucca Mountain Area, Nevada Test Site

by

Thomas F. McGovern²

with an introduction by

L. W. Pankratz¹ and H. D. Ackermann¹

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Introduction to the Report

by

L. W. Pankratz¹ and H. D. Ackermann¹

The U.S. Geological Survey (USGS) working under an Interagency agreement, DE-AI08-78 ET 44802, with the Department of Energy is engaged in a broad program to assess and identify potential repositories for high level nuclear waste on the Nevada Test Site (NTS). The USGS program consists of integrated geologic, hydrologic and geophysical studies which range in nature from regional to site specific. This report is an evaluation of seismic reflection studies made at the Yucca Mountain potential repository site in the southwestern part of NTS.

As part of this study the U.S.G.S. contracted with three different organizations in the years 1980, 1981, and 1982 to conduct progressively more complex seismic reflection surveys focusing in the Yucca Mountain area, Southwest quadrant of the Nevada Test Site: 1.) A study was conducted by The Colorado School of Mines in 1980, which resulted in a Master of Engineering Thesis (ER-2429) by Charles Barry (1981). The results presented in this thesis emphasized the negative results of a high resolution seismic survey conducted in the presence of the high background noise environment which exists at Yucca Mountain. 2.) The second survey by Birdwell/SSC was designed with the insight gained by a noise study using elaborate receiver arrays. Extensive computer processing of these reflection data showed, either the possibility of a reflected event or a computer generated false reflection. (Later computer analysis of the noise profiles showed that the recording parameters used for the survey were still insufficient to cancel the predominant noise trains). 3.) On the basis of this possible reflected

¹U.S. Geological Survey

event, an even more extensive study was undertaken. Following thorough review, a request for bids was issued in January 1982, and a contractor selected in March, 1982. In the meantime at the request of the reviewers the services of a data acquisition processing specialist, Mr. Stanley Brasel, Seismic International Research Corporation, were used to advise the USGS on implementation of the reflection survey. The data acquisition contractor, Seisdata Services, Inc., began operations in March, 1982. Due to the untimely death of Mr. Brasel in February, 1983, SIRC hired a sub-contractor, Subsurface, Inc., to complete the final report which is presented herein.

The seismic reflection technique was predicted to provide information on the geological homogeneity of the host rock in the repository. Unfortunately, the nature of the rock structure, over 6000 feet of interbedded highly fractured densely welded and nonwelded volcanic tuffs, coupled with the highly absorptive and ringing nature of the near surface rocks (Pankratz, 1982; Barry, 1980), was not conducive to the reception of reflected events at the surface with sufficient power to be recorded above the noise level. Norman Burkhard (1983) essentially presents this same argument when he concludes that "I believe that the transmissivity of the alluvial and volcanic sections is the single most important factor". The conclusion is reached by the studies presented in the following report, that even with powerful source and receiver arrays the seismic reflection technique cannot discern a signal which can be seen above the noise level received from the tuffs that underlie Yucca Mountain. This problem coupled with the difficult terrain and the prohibitive expense of utilizing the increased power of arrays results in our recommendation that the seismic reflection method should not be employed at Yucca Mountain except as experimental surveys to evaluate new sources or techniques.

The following report by Thomas McGovern of Subsurface, Inc., presents a comprehensive analysis of the seismic reflection work performed at Yucca Mountain.

References of the Introduction

Barry, C. T., 1980, A study of the Verticle Vibrator Source for Seismic Profiling in the Yucca Mountain Area of the Nevada Test Site, Master of Engineering Thesis, ER 2429, Colorado School of Mines, 58 p.

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A Geophysical Evaluation of Seismic
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by

Thomas F. McGovern¹

ABSTRACT

As part of a total geophysical evaluation of Yucca Mountain for use as a Nuclear Waste Repository the seismic reflection technique has been applied. This study has been conducted to analyze the historical and technical efforts which have been used by three geophysical contractors employing a wide variety of techniques ranging from the most simple to very elaborate 3-D surveys. In each case elaborate noise studies were conducted, and based upon their evaluation parameters were chosen for multifold CDP recording. In every case, the signal-to-noise ratio was such that no reflections were discernable. Since the reflections cannot be separated from the noise even using very elaborate noise suppression techniques and up to 384 fold multiplicity it is apparent that in this volcanic terrain reflection surveys can not work.

¹Subsurface, Inc., Parker, Co.

INTRODUCTION

Yucca mountain (Nevada Test Site) has been the site of some recent important seismic reflection studies (Figures 1 and 1A), conducted by the following geophysical contractors: the Colorado School of Mines (1980), Birdwell/Seismograph Service Corporation (1981), Seismic International Research and Seisdata Services Inc. (1982). Each reflection survey was accompanied by an elaborate noise study. In the most recent study, Seismic International Research Corp. was responsible for the design of the field technique and data processing while Seisdata Services Inc. was responsible for data acquisition. Western Geophysical Inc. was also contracted to process one seismic reflection line as a quality control check on the Seismic International Research data processing. It is the purpose of this investigation by Subsurface Inc. to evaluate the applicability of the seismic reflection technique in the Yucca Mountain (Nevada Test Site) area.

HISTORICAL REVIEW OF SEISMIC REFLECTION SURVEYS DONE AT THE NEVADA TEST SITE

Table 1 displays the field acquisition parameters used in gathering seismic reflection surveys from the years 1972-1982 in the Nevada Test Site. It also shows the survey location areas, geologic setting and estimate of the reflection data quality. Table 1 indicates that most seismic reflection surveys at the Nevada Test Site were acquired as two dimensional profiles employing numerous input sources (Vibroseis¹, Primacord², Dynamite) and source array patterns. Many different receiver arrays were also utilized. These arrays were both short and long (up to 440 ft) and employed from 1 to 144 geophones. Our visual examination of the processed data revealed that the profiles from areas usually characterized by complex faulting, volcanics and paleozoic outcroppings (Yucca Mountain, Wahmonie, Calico Hills, and Syncline Ridge) (Christiansen and Lipman, 1965, Lipman and McKay, 1965, Hoover, 1982, Synder and Carr, 1982, and Pankratz, 1982) did not produce any accurate reflection information. However, reflection data acquired in the flat lying alluvial plain (Yucca Flat) which is not quite as complex geologically appeared of much better quality.

In 1982, a three dimensional seismic reflection survey was conducted at Yucca Mountain utilizing a field technique that produced stack fold ranging between 192 and 384. This report will illustrate that this very powerful field technique also did not produce any interpretable reflection events.

¹ Registered trademark, Continental Oil Co.

² Registered trademark, Ensign Bickford, Co.

TABLE I

Yr. & Contractor	Instrument	Channels	Amplifier	Geophone Frequency (Hz)	Geophones Trace	Geophone Pattern	Geophone Spacing (ft)	Profile Type	Source	Source Array	Source Spacing (ft)	Stack Fold	Group Interval (ft)	Source Interval (ft)
1972 SSC	T1 10000	24	Fixed - Gain	7.5	36	In Line	12.5 ft. Over 440 ft.	2-D	Vibroseis	4 Vibrators In Line	75 Apart	12	220	220
1978 Western	Litton Cobra	48	Floating Point	10	36	In Line Over 440 ft.	12.5	2-D	"	"	75 Total Pattern 440	24	220	220
1978 Western	Litton Cobra	48	"	10	24	In Line	19	2-D	"	"	75	24	220	220
1979 Geosource	GUS-HDDR	24	"	10	20	"	2.8	2-D	Dynamite	n/a	n/a	12	55	55
1980 CSM	DFS-5	48	"	18	1	"	55	2-D	Vibroseis	Vibrator In Line	220	24	55	55
1980 Seisdata	DFS III	48	"	10	12	"	10	2-D	Primacord	n/a	n/a	24	55	55
1980 Seisdata	DFS III	48	"	10	12	"	17	2-D	"	n/a	n/a	24	55	55
1981 Birdwell	DFS-5	48	"	10	120	In Line Weighted Array	8.5	2-D	Vibroseis	30 In Line	5	24	50	50
1982 Seisdata	MDS-10	96	"	10	96	Weighted Array	15	3-D	Dynamite	1 Deep Hole	200	192	100	200
1982 Seisdata	MDS-10	96	"	10	96	Weighted Array	15	3-D	Vibroseis	3 Vibrators 18 Sweeps	12.5	384	105 - 210	105 - 210
1982 Seisdata	MDS-10	96	"	10	12	In Line	9	3-D	Vector Pulse (Primacord)	7 Elements In Line	16	288	50	50

TABLE I [cont'd.]

Yr. & Contractor	Near Offset (ft)	Far Offset (ft)	Sweep (Hz)	No. of Sweeps	Sweep Duration (sec)	Listening Time (sec)	Sampling Interval (ms)	Field Filter (Hz)	Area	Data Quality	Geological Setting
1972 SSC	880	3300	17-56	16	7	10	4	14-70	Syncline Ridge	poor	VR over PH
1978 Western	660	5720	14-56	16	16	5	4	out-62	Syncline Ridge	poor	"
1978 Western	880	11220	8-32	up 32	12	3	4	out-62	Syncline Ridge	very poor-poor	"
1979 Geosource	n/a	n/a	n/a	n/a	n/a	n/a	25	23-180	Yucca Flats	poor-fair	Alluvium over VR
1980 CSM	55	1320	30-120	9	6	3	2	12-180	Wahmonie Yucca Mt. Calico Hills	very poor	AFT over IC & VR
1980 Seisdata	192	1457	n/a	n/a	n/a	n/a	2	18-124	Yucca Flats	poor-fair	Alluvium over VR
1980 Seisdata	220	1465	n/a	n/a	n/a	n/a	2	18-124	Yucca Flats	poor-fair	"
1981 Birdwell	500	1650	48-6	30	16	6	4	out-128	Yucca Mt.	very poor	AFT in MT
1982 Seisdata	800	3100	n/a	n/a	n/a	n/a	2	12-125	Yucca Mt.	very poor	"
1982 Seisdata	840	1940	10-56 22-84 16-62	18	14	4	2	out-125	Yucca Mt.	very poor	"
1982 Seisdata	840	2415	n/a	n/a	n/a	n/a	2	12-125	Yucca Mt.	poor	"

LEGEND

n/a - Not Available
 IC - Intrusive Complex
 PH - Paleozoic High
 VR - Volcanic Rock
 AFT - Ash Flow Tuff
 MT - Mountainous Terrain

COLORADO SCHOOL OF MINES REFLECTION SURVEY

In 1980, The Colorado School of Mines (CSM) (Barry, 1980) conducted seismic reflection surveys in three areas of the southwest Nevada Test Site. These areas were: Yucca Mountain, Wahmonie, and Calico Hills (Figures 1 and 1A). Their objective was to obtain detailed shallow subsurface geologic information. With this objective in mind, their field technique was directed toward high resolution acquisition utilizing short geophone arrays and high source frequencies. Initially, a detailed noise analysis was conducted in each of the three areas. Each noise profile consisted of a small common depth point reflection line, various geophone arrays and a broad range of input sweep frequencies (8 to 120 hz.). Detailed computer analysis of the noise data indicated that noise patterns, in all three areas, were not effectively cancelled by the suite of receiver arrays tested. Table 2 is a summary of the CSM measured velocities of noise patterns in all the three areas.

In accordance with their high resolution objective, the CSM selected as final production acquisition parameters a receiver array consisting of one buried geophone and a sweep frequency of 30 to 120 hz. Additional acquisition parameters included: 18 hz. geophones, 55 ft. station intervals, 6 second up sweep at nine vibrator positions, 6 ft. vibrator move up, 48 channel recording, 24 fold stack, 2 millisecond sampling interval, and near and far offsets of 55/1320 ft. This survey produced no interpretable subsurface reflection information. It also demonstrated that simple high resolution data acquisition techniques are not applicable in the Yucca Mountain vicinity (Barry, 1980, pp. 36-40).

TABLE 2

<u>NOISE TYPE</u>	<u>VELOCITY ft./sec.</u>
Refraction	11500
Direct Wave	4000-4200
Groundroll	1600-2000
Airwave	1100

BIRDWELL REFLECTION SURVEY

In 1981, Birdwell conducted a seismic reflection survey at Yucca Mountain near Drill Hole Wash from drill holes USW-G1 to USW-H1 (Figure 1A). The objective of this study was to further test the feasibility of the reflection method at Yucca Mountain and establish a tie between the two drill holes. The noise study and a reflection survey were recorded within a few days of each other. The noise study used elaborate receiver arrays (Figure 2) which allowed the testing of various configurations of geophone receiver arrays using different channels in a simultaneous recording. This method utilized the VibroseisTM source walkaway technique (Sheriff, 1974) where receiver arrays remain stationary as the source moves away in a linear pattern. This profile differed from a standard walkaway procedure in that it utilized closely spaced source points that were received by various array patterns configured on each recording channel. This procedure can provide many types of walkaway profiles by computer plotting of each recording channel for each source point. Analysis of the noise profiles revealed that all receiver arrays tested exhibited similar noise attenuation properties.

Figure 3 is a typical noise profile with automatic gain control. Table 3 is a summary of the measured velocities of the noise patterns as recorded by the Birdwell survey.

TABLE 3

<u>NOISE TYPE</u>	<u>VELOCITY ft/sec.</u>
Refraction	6000, 8000, 10000
Direct Wave	4000-4200
Groundroll	1600-2000
Airwave	1100

Recording parameters for the reflection survey were chosen on the basis of field examination of the noise profiles. They consisted of a rectangular 100 x 200 ft. receiver array containing 10 rows of 12 geophones each separated 8.5 ft. and a 48 to 6 hz. downsweep. Additional parameters included: 24 channels, 24 stack fold, 16 second downsweep, 3 vibrators 50 ft. apart inline with a 5 ft. move up, 50 ft. station intervals, 4 millisecond sampling interval and near and far offsets of 500/2850 ft.

The raw unstacked records were dominated by several types of noise the character of which appears to change with shot-receiver offset distance (fig. 4). For the near receiver offsets, the seismic records are dominated by high frequency random noise, probably produced by instrument electronics, wind and seismic crew related activities. For far offsets the records are dominated by low frequency source generated coherent noise which propagates horizontally through the near surface. No reflections could be observed on the raw reflection records. Processing was done by Seismograph Service Corporation (SSC). The data were initially demultiplexed, summed, cross-correlated,

edited and CDP sorted using standard procedures (Anstey, 1977). Various tests were then employed (e.g. autocorrelation, power spectrum analysis , filtering, deconvolution, and scaling) to help determine further processing procedures. The data set was filtered with a 14 to 48 hz. bandpass and constant velocity stacks run to determine normal moveout.

At this point, a source and receiver simulation test was performed to determine if a larger array interval would effectively cancel dominant noise patterns. (This procedure mathematically transforms one recorded source and receiver array configuration to another by means of a running sum mix of adjacent traces). Selective stacking was performed using varying offset distances to determine whether lateral continuity of reflection events could possibly be enhanced by using only the near, or the intermediate, or the far offset traces. These specific stacks led to the conclusion that both the near and medium to far offsets were dominated by noise. Figure 4 displays a typical field recording which exhibits very coherent noise patterns in most areas of the seismic reflection record.

During the normal data processing routine, several CDP stacks were generated for quality control and these, curiously, led to some interesting conclusions. First, a CDP stack was produced that had only a normal moveout correction applied (Figure 5). This type of stack is normally produced as a quality control check before application of automatic residual statics. This CDP stack yielded no interpretable continuous reflection events. Then automatic residual statics were applied to the data (Figure 6) which produced an apparent reflection at 1.2 seconds. In reference to Figure 4, we note that the shallow part of the seismic reflection record above 2.0 sec is dominated by coherent noise which may be the source of this apparent reflection. To test this concept (Taner et al, 1974), a CDP stack was produced without the

presence of this coherent noise (Figure 7) using velocity filtering (Sheriff, 1974) and selective muting to eliminate these coherent noise patterns. Automatic statics were also applied and the CDP stack (Saghy and Zelei, 1975) yielded no apparent continuous reflection information, therefore, we conclude that the automatic statics routine aligned noise trains to produce an inferred reflected event. A discussion of this routine necessarily follows. The automatic statics routine used by SSC employed a seven CDP correlation model and a 0.5 - 1.2 second correlation window. Seven common depth points and their respective traces were stacked to produce this model which was then cross-correlated with each trace within the central common depth point. The time shifts observed between the model and the CDP traces are assumed to be residual static errors and these time shifts are then applied to the traces. This cross-correlation technique is amplitude dependent. If high amplitude events existed within the correlation window, they were shifted to align with corresponding high amplitude events contained in the model. If these high amplitude events represented coherent noise, the resulting stack would have aligned coherent noise. Therefore, the reflection at 1.2 seconds observed in figure 6 is no more than alignment produced by the automatic statics routine. Despite this maximum processing effort no interpretable reflections were observed.

In 1982, Seismic International Research Corp. (SIRC) and Seisdata Services Inc. (SSI) conducted a three dimensional seismic reflection survey in the Yucca Mountain vicinity. (Figure 1A). A historical analysis of previous reflection surveys proved that standard simple acquisition techniques could not be applied in this area. This reflection survey had to maximize all field efforts if reflection information was to be obtained. A three dimensional effort was proposed and accepted because it favored an extremely high stack fold (192 to 384) for common depth points and provided a very effective method of attenuating noise patterns thereby improving the signal to noise ratio.

The VibroseisTM method was chosen for use as long as the terrain was flat and accessible, however, where the terrain was rugged and inaccessible, surface source explosives (PrimacordTM) were employed. Previous acquisition efforts utilized simple receiver and source arrays. Serious consideration had to be given to the concept of employing complicated source and receiver arrays which with their combined effort offered a very powerful technique for coherent noise attenuation.

Several conclusions can be reached from the two previous reflection surveys conducted in the Yucca Mountain vicinity. First, the CSM survey was designed with high resolution acquisition in mind. Therefore, they utilized short geophone arrays and high source frequencies. This technique employed a simple 9 element single vibrator source array and a single geophone array. However, this method was much too simple for an area where the dominant recorded energy is noise. Figure 8 is an array response curve for the total combined technique (Halzman, 1963) used in the CSM reflection survey. This technique resulted in a maximum effort of 12 db. attenuation for noise

wavelengths of 10 to 70 ft. The Birdwell reflection survey differed from the CSM survey in that it did not employ high resolution acquisition techniques, only a complicated receiver array and a simple source array. The input source frequencies were fairly low (6 to 48 hz.) Figure 9 is an array response pattern for the combined field technique used in the Birdwell reflection survey. The maximum effort is a 29 db. attenuation for noise wavelengths of 12 to 160 ft. Because no reflection information was obtained, this still proved too low of an attenuation factor for this noise dominated area.

SIRC/SSI designed a much stronger method using receiver arrays consisting of 120 geophones, and either 3-4 vibrator trucks or Vector PulseTM for source arrays. Figure 10 is a response curve for a total combined source and receiver array using 3 vibrator trucks (Geyer, 1970), 54 sweeps with 12 foot spacing and a 96 geophone array at 15 foot spacing. This combined technique produced an attenuation power of 68 db. for noise wavelengths of 18 to 122 feet. Figure 11 shows the response curve employing the same receiver array but a Vector PulseTM source array consisting of 12 equally spaced elements. This combined effort is also very powerful because it provides a 53 db. attenuation for noise wavelengths of 18 to 122 feet.

- 1.) Vector Pulse is a Registered Trademark, Seisdata Services Inc. It employs elements consisting of 0.5 in steel rods approximately 4 ft long loaded with PrimacordTM emplaced in the earth.

Noise studies conducted by SIRC/SSI consisted of both inline (walkway) and circular (tornado) profiles. These noise profiles were recorded in the alluvial valley directly east of Yucca Mountain which afforded accessibility and mild terrain and also allowed the use of both VibroseisTM and Vector PulseTM source methods. The objectives of these noise studies at Yucca Mountain were:

- a) to measure the range in velocity of all source generated noise,
- b) to test for reflected or broadside noise,
- c) to determine the dominant noise patterns,
- d) to test several input frequency ranges for penetrating and resolving power,
- e) to compare VibroseisTM and Vector PulseTM energy sources,
- f) to generate a physical model of noise distribution, and
- g) to seek a window between noise patterns for observing reflection information.

INLINE NOISE PROFILE

The inline noise spread was designed to measure velocity, frequency and wavelength of source generated noise in the line of profile. It consisted of 96 recording stations each with 12 bunched geophones 10 feet apart. Four shotpoints were used, each 950 feet apart as illustrated in Figure 12. Both Vector PulseTM and VibroseisTM energy sources were tested. The VibroseisTM sweep frequencies used were 10 to 56, 16 to 72, 22 to 84, 32 to 96 and 38 to

104 hz. This profile simulated a standard walkway procedure (Sheriff, 1974) with the source moving away at selected increments from a stationary recording cable. Table 4 is a summary of the measured velocities, frequencies and wavelengths of the dominant noise patterns.

TABLE 4

NOISE RELATED PROPERTIES FOR THE INLINE SPREAD

<u>Noise Type</u>	<u>Velocity (ft/sec)</u>	<u>Frequency(hz.)</u>	<u>Wavelength(ft.)</u>
Groundroll	1640-2000	12-20	82-166
Direct	3170	20-35	91-159
Reflected	none observed	N/A	N/A
Refracted	none observed	N/A	N/A

CIRCULAR NOISE PROFILE

In addition to identifying the functions of noise in the line of profile a circular noise spread was used to identify noise patterns originating as reflected-refractions or broadside noise from hills, mountain ranges or man-made objects. It is ideal, therefore, in the Yucca Mountain area. This profile used concentric circular spreads (Brasel, 1979) with 32 stations at 10 foot spacing on the inner circle of 52 ft. radius and 64 stations at 10 foot spacing on the outer circle of 102 ft. radius (fig. 13). Each station consisted of 12 bunched geophones. The radii were chosen to effectively measure the smallest noise wavelength which may exist in this area. Source points (VP-1) began at the center of the circles and progressed outward in a straight line at 200 foot intervals. Several input sources were tested in

this study. Shotpoints 1-19 were recorded using VibroseisTM with 32-96 hz. sweeps. Shotpoints 1, 3, 6, 9, 12, 15, and 18 were recorded with both Vector PulseTM and VibroseisTM using sweep frequencies of 10 to 56, 16 to 72, 22 to 84, 38 to 104, 44 to 108 hz.

Table 5 displays the measured velocities, frequencies, and wavelengths of dominant noise patterns interpreted from offset distances of 400 to 2850 feet from the circular noise spreads.

TABLE 5

NOISE RELATED PROPERTIES FOR THE CIRCULAR SPREAD

<u>NOISE Type</u>	<u>Velocity(ft/sec)</u>	<u>Frequency(hz.)</u>	<u>Wavelength(ft.)</u>
Groundroll	1800	15-25	72-144
Direct	2100	20-50	65-156
Reflected	none observed	N/A	N/A
Refracted	none observed	N/A	N/A

ANALYSIS OF NOISE PROFILES

The final acquisition parameters for the three dimensional reflection survey were selected based upon the analysis of the properties observed in the noise profile data. The dominant noise recorded on both inline and circular noise spreads is groundroll and direct. The noise wavelength range observed for groundroll and direct noise is 65 to 166 feet. These wavelengths are well within the attenuation power of the combined source and receiver arrays discussed in a previous section (Figures 10 and 11).

Source frequency tests showed that of the five sweep frequencies tested (Figures 14 to 25), 16 to 72 and 22 to 84 hz. provided the least noise generation and best resolving power. The Vector PulseTM method generated sufficient resolving power but a large amount of coherent source noise.

In order to understand the relationship between noise distribution and reflection information, a signal and noise schematic was made (Figure 26) which graphically displays all noise distribution common to the Yucca Mountain vicinity. From this graph an offset dependent recording window for observing reflection information can be defined. Analysis of this schematic suggested that a window of 750-2000 feet be utilized if reflection information, for example from the base of the Topopah Spring Tuff, is to be observed. Any defined offset lying outside the perimeters of this window would be overwhelmed by shot generated noise.

THREE DIMENSIONAL PRODUCTION ACQUISITION PHASE

Initial production acquisition parameters were based on results of the noise studies and existing terrain limitations. Three dimensional grids (Figure 27) were designed which employed 96 recording channels and an optimum offset recording window.

Line W-4 (Figure 1) was recorded initially with an 8 x 12 three dimensional receiver array grid consisting of 105 foot station intervals and 800 to 1900 foot receiver offsets. A weighted receiver array of 96 geophones spaced at 15 feet over pattern length of 210 feet, was used. A source array of 3 vibrators sweeping 18 times at a spacing of 12.5 feet and a pattern length of 156 feet was utilized. The initial sweep was 10 to 56 hz. which due to mechanical difficulties caused decoupling effects. The sweep was later

changed to 16 to 62 hz. which eliminated these effects. Due to excessive mechanical failures, VibroseisTM activity was temporarily halted and a Vector PulseTM source array of 11 elements spaced at 9 feet was employed. VibroseisTM was once again employed until mechanical failures forced the use of Vector PulseTM until termination of the project. Because of operational equipment problems and the decision to attempt to record reflections from the beds lying less than 500 feet deep, lines S-2, and S-4 were recorded using different source and receiver arrays. The source array consisted of 7 Vector PulseTM elements spaced at 16 feet while the receiver array was shifted to a linear pattern of 12 geophones spaced at 9 feet. The three dimensional grid was also changed to a 6 x 16 grid (Figure 27) employing 50 foot station intervals.

Line G-2 which is located along one of the ridges was recorded with a different source and receiver array. The source consisted of 10 pounds of dynamite detonated in 200 foot deep holes and was recorded by receiver arrays of 96 geophones spaced at 15 feet with a total pattern length of 210 feet. The three dimensional grid was changed to a 4 x 24 grid (Figure 27) employing 100 foot station intervals.

THREE DIMENSIONAL DATA PROCESSING METHODS

All of the three-dimensional data were processed by SIRC. Western Geophysical was also contracted to process line S-4 as a quality control check.

SIRC's data processing began with a standard demultiplex and VibroseisTM cross-correlation. Raw records were plotted for editing and shooting pattern review. Geometry is coded and placed in the trace headers assigning each

record trace to it's respective common depth point within the 3-D grid. Several tests were performed on the data at this stage which included: filter tests, autocorrelations, power spectra, deconvolution tests and scaling tests. These test results were analyzed for optimum processing parameters. The data were then filtered with a 10 to 30 hz. operator. Constant velocity stacks were run on the data to provide accurate normal moveout corrections. SIRC elected not to apply automatic residual statics because tests concluded that no apparent reflection information was present for the automatic static picking technique to function properly. The data were stacked in many different configurations (figures 28 to 30) to seek any relevant reflection information. SIRC chose for their final presentation, a stacking configuration that would produce the highest stack fold for each common depth point (figures 31 to 34). The data were filtered with a 10 to 36 hz. operator and scaled with automatic gain control. Western Geophysical, however, elected to apply automatic residual statics and for their final presentation chose to break up line S-4 into 11 CDP lines each consisting of 48 stack fold. Each company produced final CDP stacks that contained no interpretable reflection information. Horizontal time slices were produced by both companies during their data processing efforts, which are discussed in the following section.

SIRC 3-D TIME SLICE DISPLAYS

Seismic reflection surveys are usually displayed as vertical two dimensional profiles that exhibit subsurface strike and dip information. In order to acquire an accurate description of this subsurface information, numerous 2-D reflection profiles must be interpreted. Because 2-D profiles usually offer a coarse sampling of the subsurface, there is a great potential

for error. In contrast, a 3-D reflection survey consists of a dense concentration of common depth points distributed over a 3-dimensional grid which provides time planes (Horizontal time slices) common to all depth points (Brown et al, 1982). Subsurface reflection information can be accurately interpreted by observing dip and strike changes with respect to time. Thus, the 3-D grid offers a very fine sampling of the subsurface while a two dimensional grid offers a very coarse sampling of the subsurface. By decomposing the subsurface into small time increments, the interpreter can accurately judge the size and shape of a subsurface geologic structure. However, the poor reflection data in the Yucca Mountain area, produced no interpretable results from the horizontal time slices. Figure 35 represents time slices produced by SIRC. These time slices range from .370 to .480 seconds and are color coded for amplitude strength. In hypothetical terms, a time slice cut through a very strong reflection would be color coded black, and as the reflection strength (amplitude) changes the shade would change. If a reflection event dips from northeast to southwest, corresponding time slices would be color coded black as they intersect the dipping event; therefore, if a black color exists for time slice at .370 seconds at the northeast end of a line, the same color would appear at a time at .480 seconds at the southwest end of a line. This would infer the dip of the strong reflecting event. As figure 35 shows this survey produced no interpretable time slice data.

RECOMMENDATIONS

Subsurface Inc. has reviewed in depth all seismic reflection surveys recorded in the Yucca Mountain region. It is conclusive that useful seismic reflection data cannot be acquired in this area even using the elaborate techniques outlined in this report. The seismic reflection method was developed and has been employed primarily in sedimentary rock environments. Rugged volcanic areas such as Yucca Mountain are not well suited to the seismic reflection technique. Many powerful noise suppression techniques were tested in this survey with none of these techniques producing useful reflection information. Additional seismic reflection studies will undoubtedly produce negative results and Subsurface Inc. discourages any additional seismic reflection surveys in the Yucca Mountain complex.

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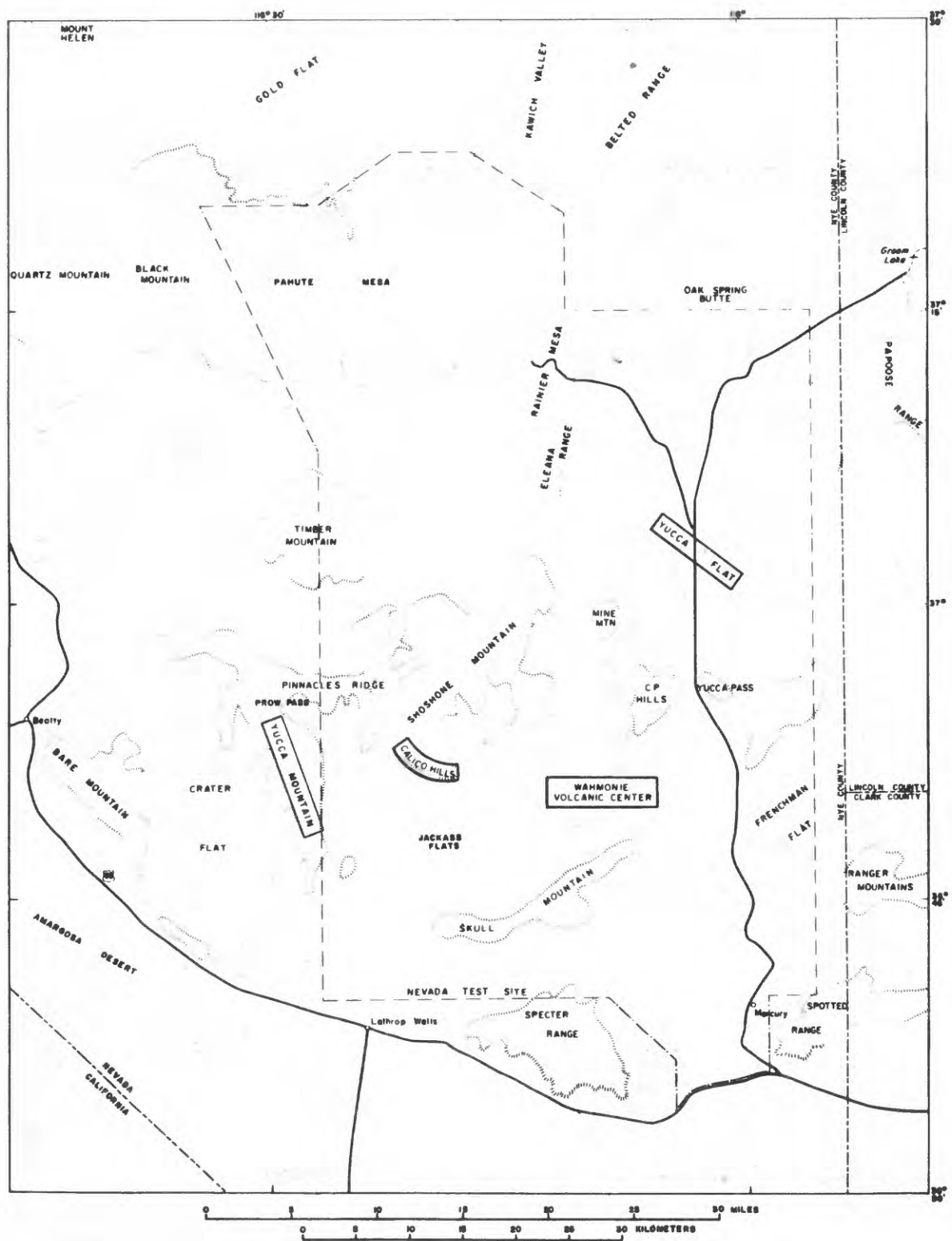
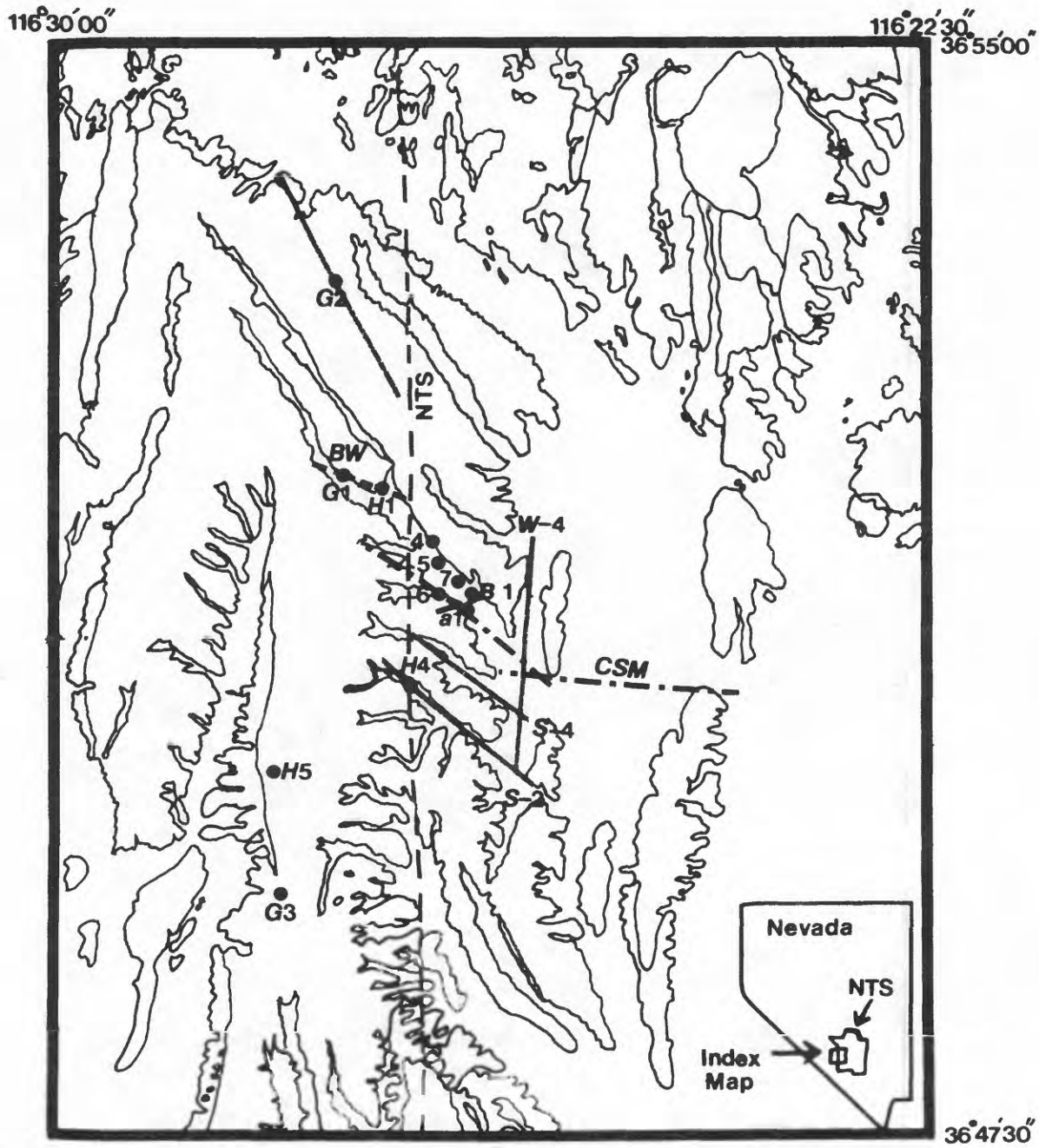


Figure 1.-- Index map of the Nevada Test Site and vicinity showing the areas of investigation

Figure 1A



Yucca Mountain Index Map

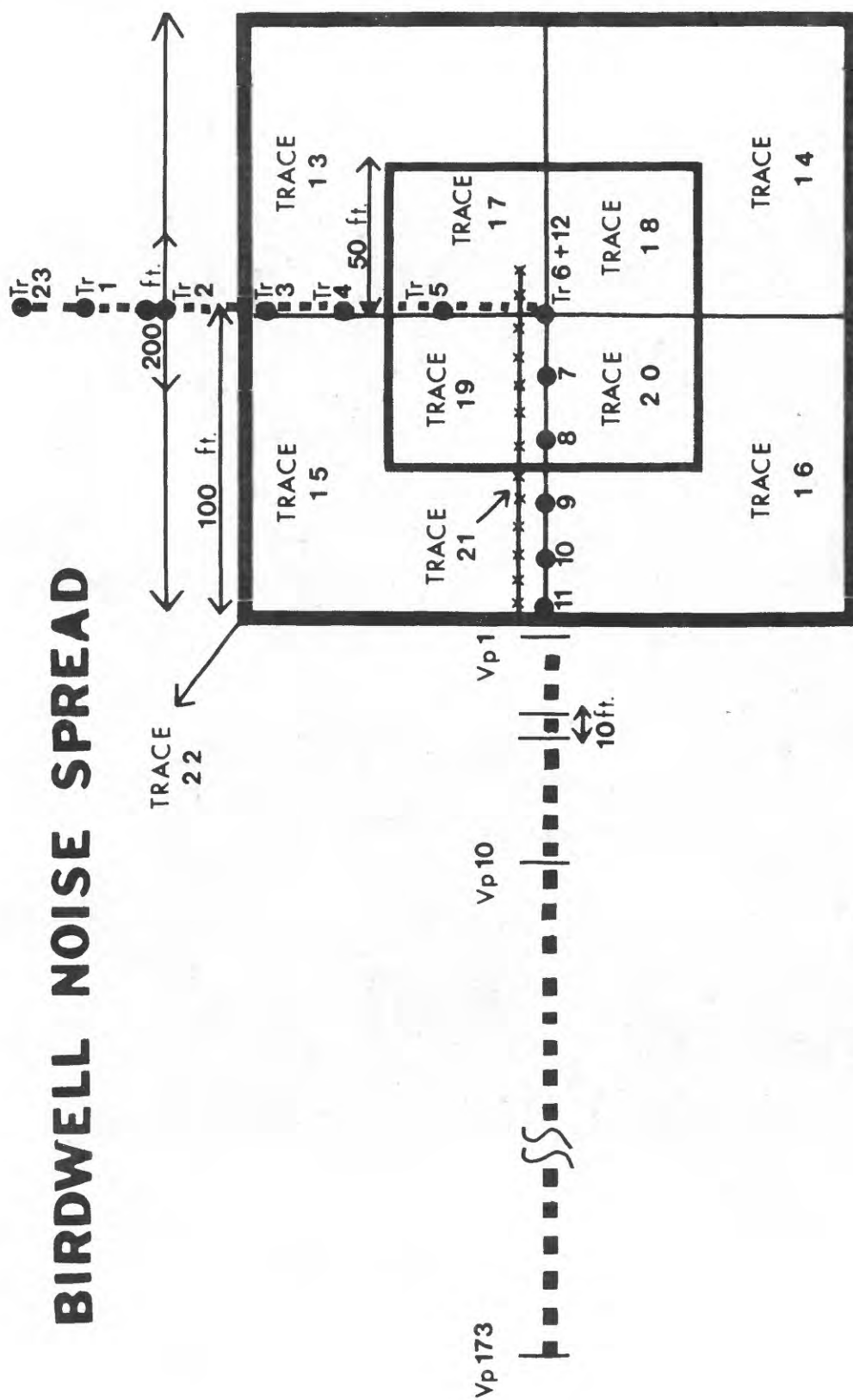
LEGEND

— - SSI / SIRC

- . - CSM

— - BIRDWELL

BIRDWELL NOISE SPREAD



- Trace 22 (200 x 200 ft. grid 144 geophones)
 Traces 23, 1-6 (Form perpendicular part of L spread bunched group of 6 geophones 30 ft. apart)
 Traces 6-11 (In line part of L spread bunched group of 6 geophones 20 ft. apart)
 Trace 12 (Bunched group of 6 geophones)
 Traces 13-16 (Consist of a 100 x 100 ft. grid 144 geophones each)
 Traces 17-20 (Consist of a 50 x 50 ft. grid 144 geophones each)
 Trace 21 (Array of 12 clustered geophones covering 105 ft)

figure 2

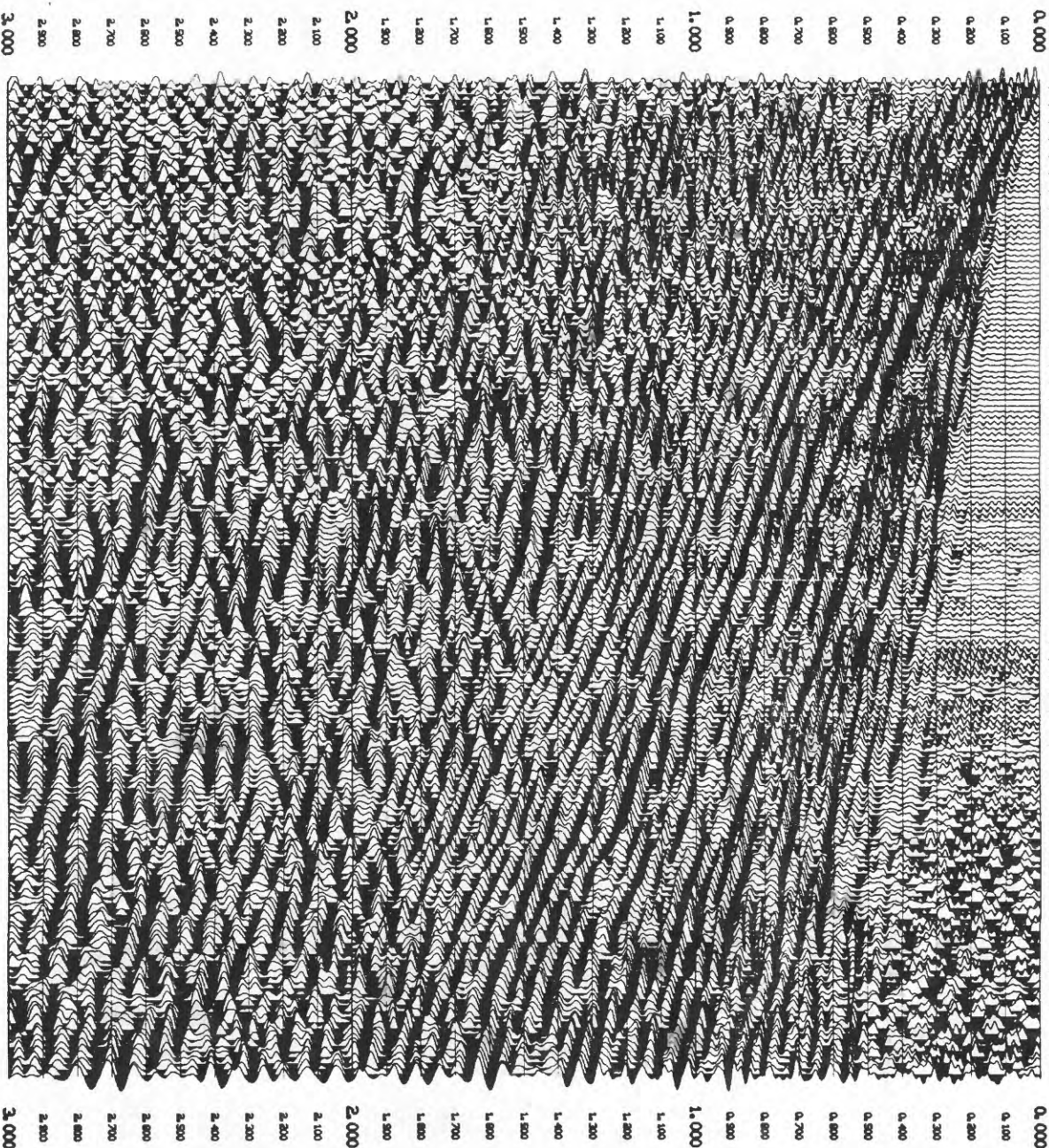
TRACE 22, SECT. 5

200 BY 200 ARRAY NOISE SPREAD

FIGURE 3

STATIONS

2 5 8 11 14 17 20 23 26 29 32 35 38 41 44 47 50 53 56 59 62 65 68 71 74 77 80 83 86 89 92 95 98 101 104 107 110 113 116 119 122 125 128 131 134 137 140 143 146 149 152 155 158 161 164 167 170 173



BIRDWELL FIELD RECORD

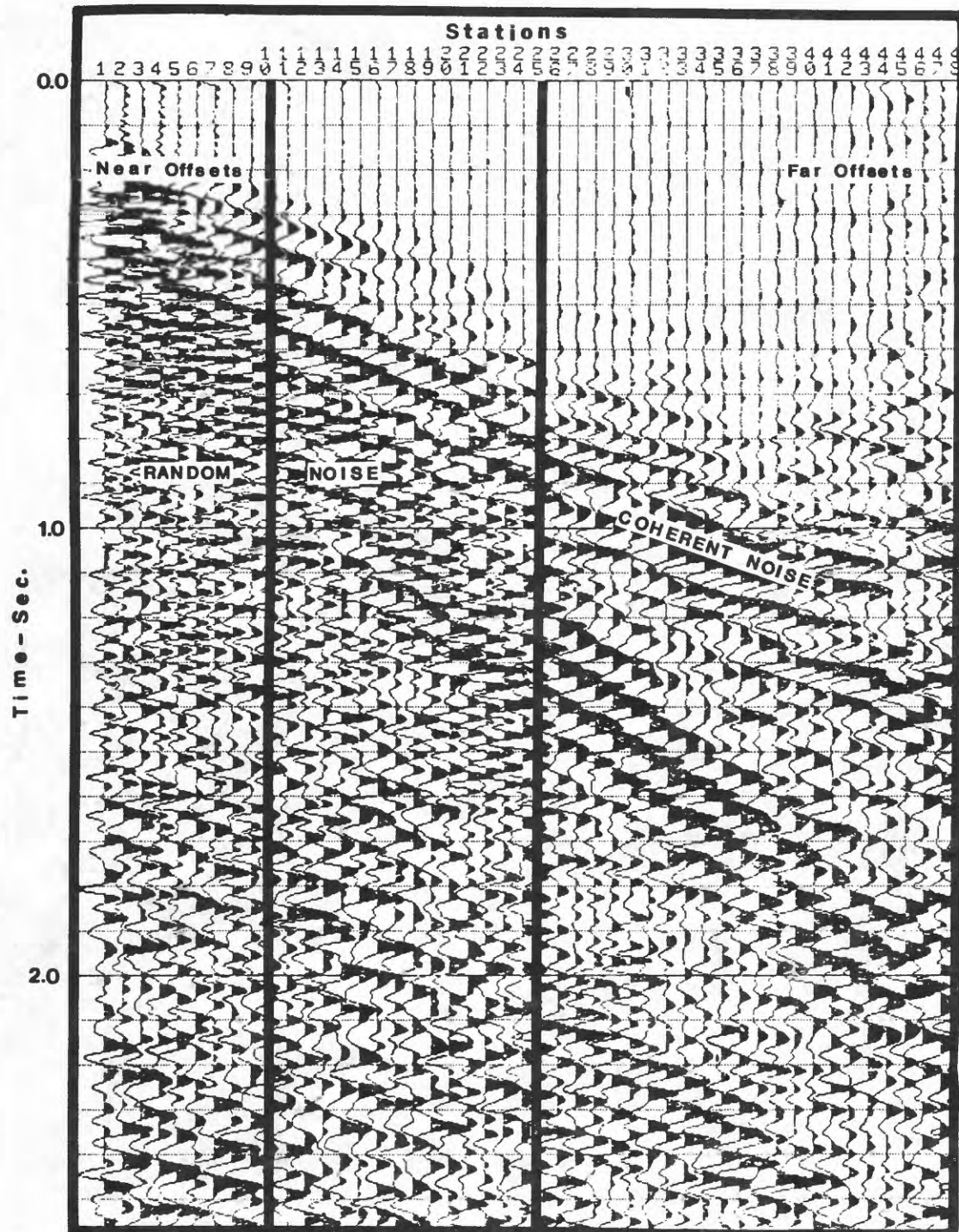


figure 4

Normal Moveout Stack

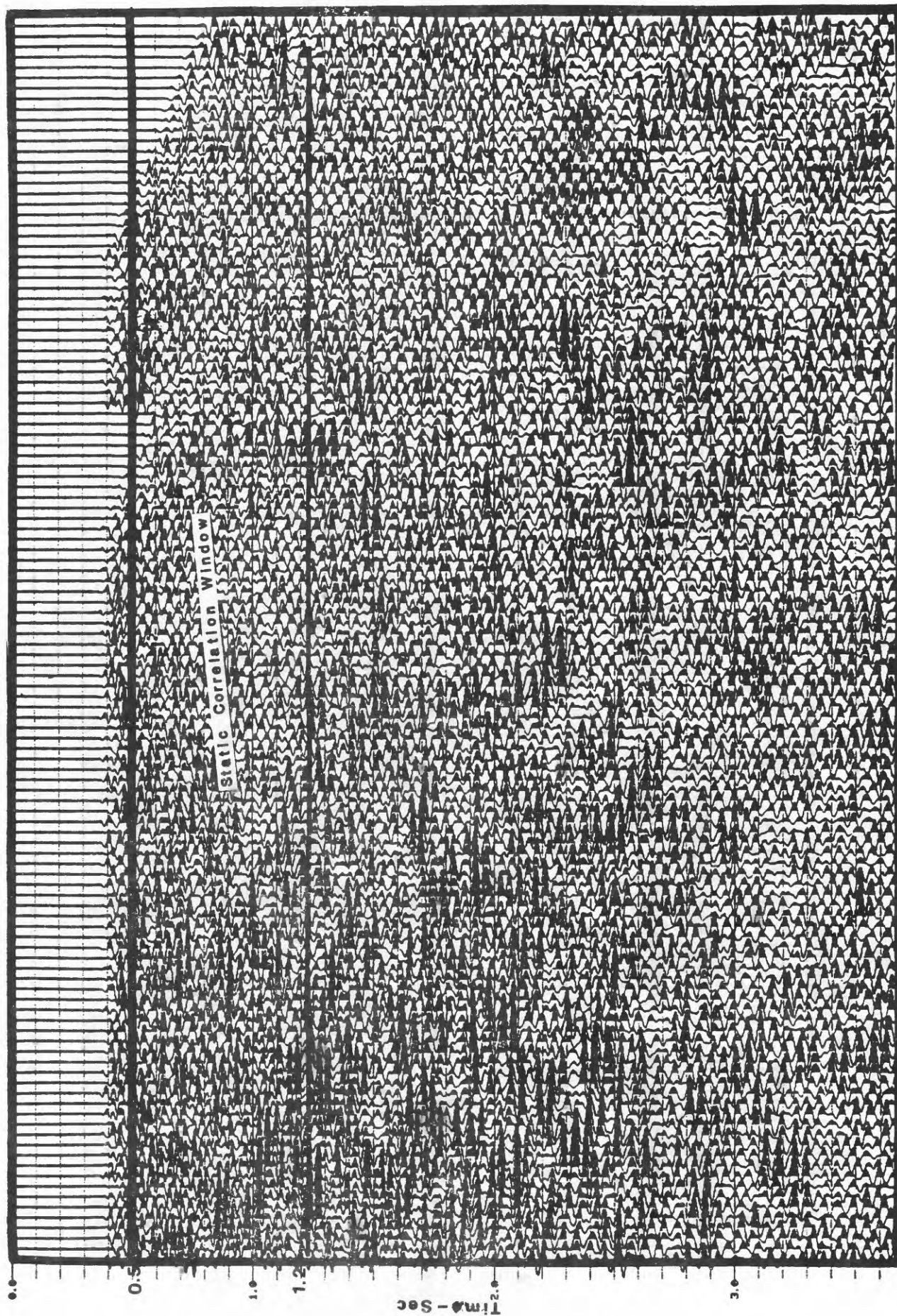


figure 5

BIRDWELL SSC

Automatic Statics Stack

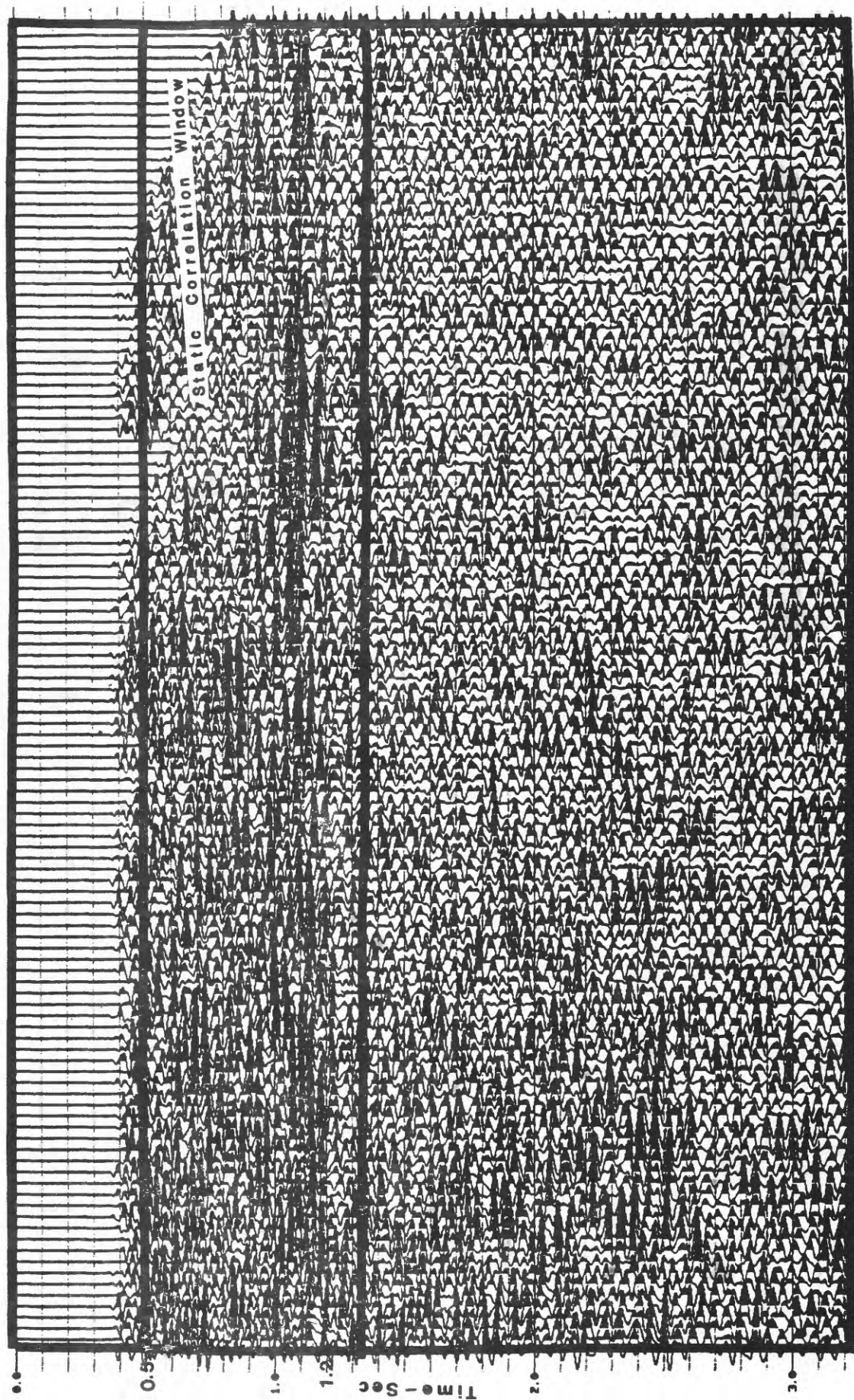


figure 6

BIRDWELL SSC
Velocity Filter Mute Stack

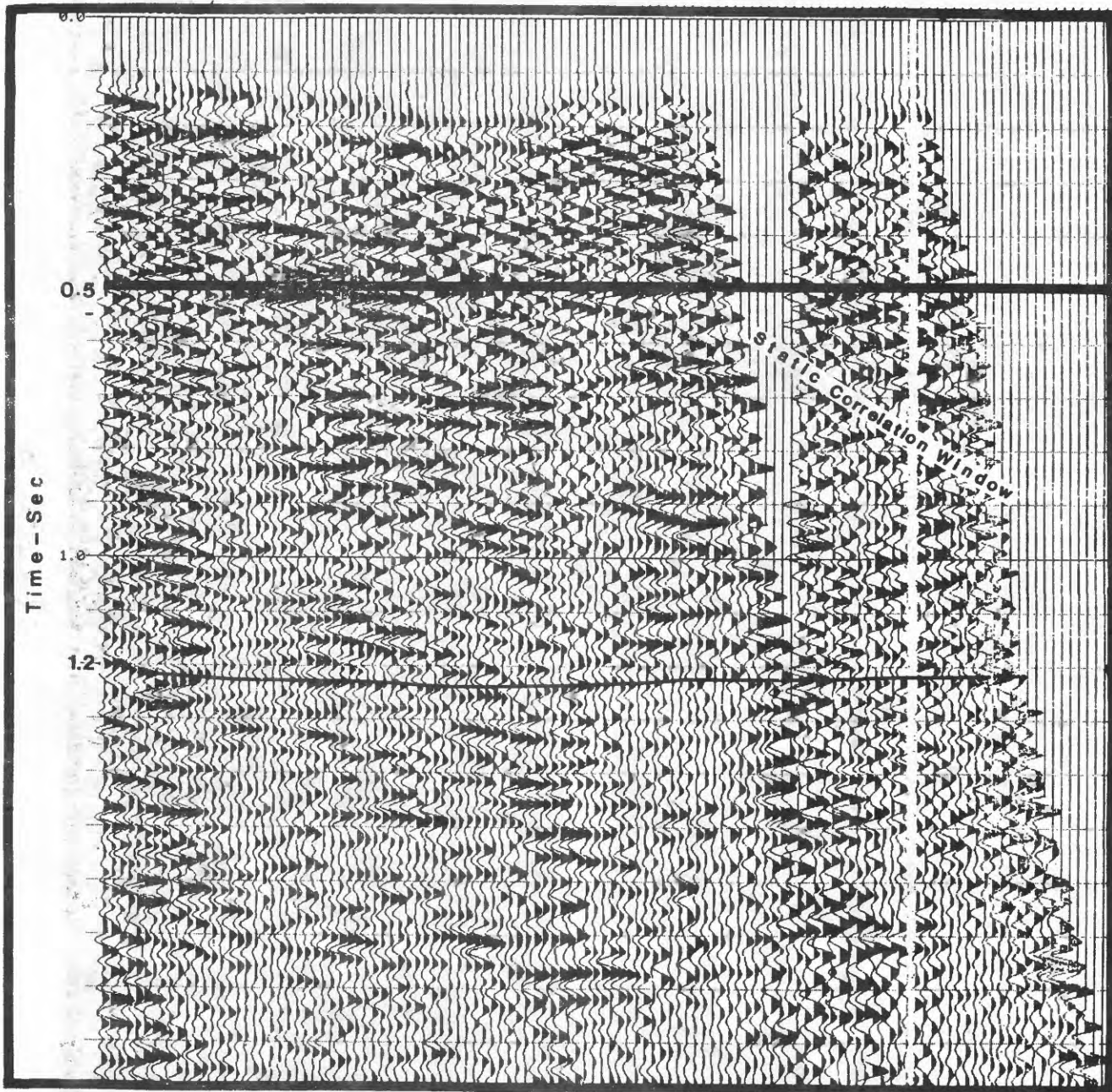


figure 7

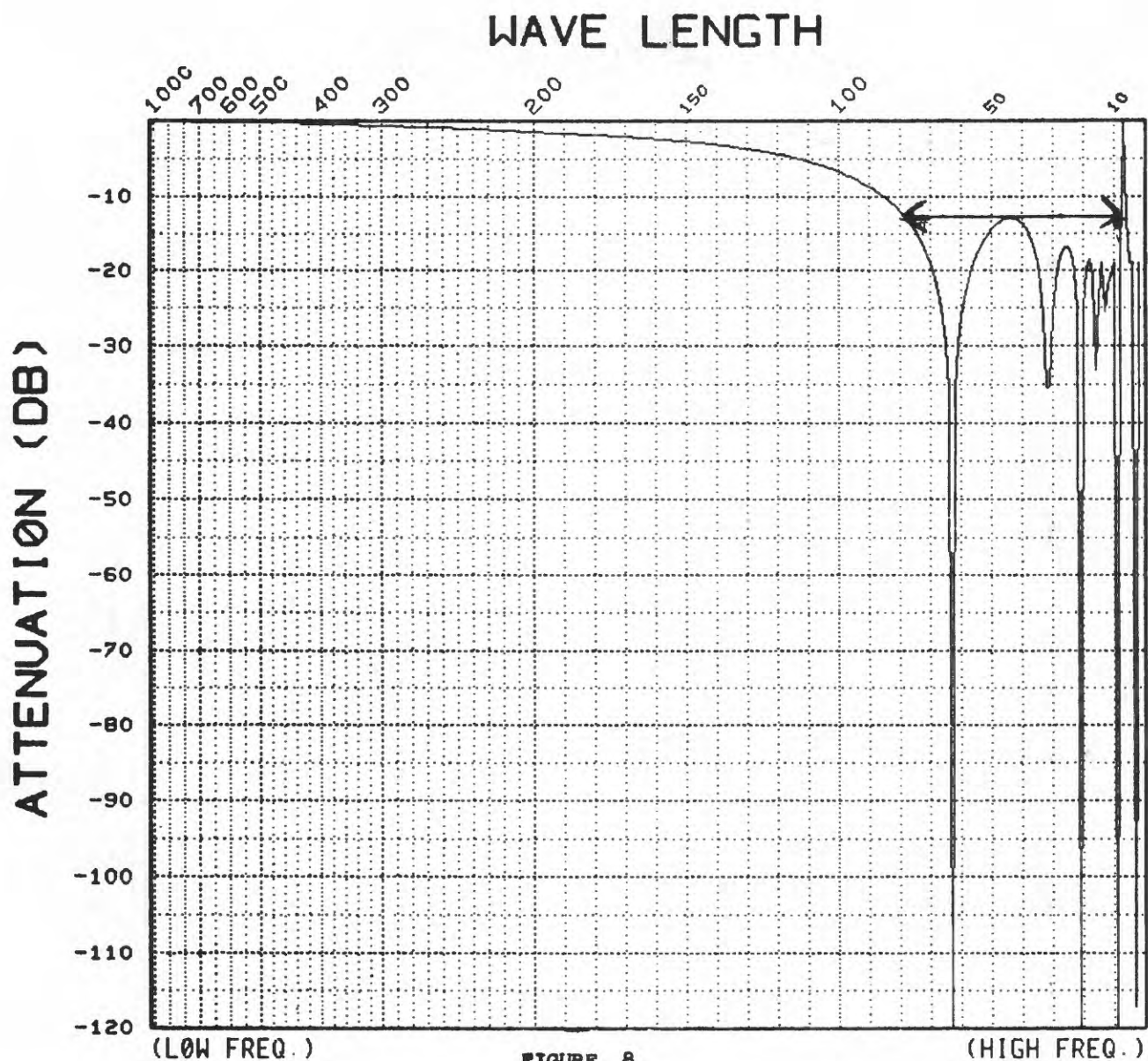


FIGURE 8

SPACING 7
LENGTH 56
WEIGHTS 1 1 1 1 1 1 1 1 1

POINTS 9
ELEMENTS 9

SPACING 55
LENGTH 0
WEIGHTS 1

POINTS 1
ELEMENTS 1

S/N IMPROVEMENT (AMBIENT NOISE ATTENUATION POWER) 23 03 DB

The COLORADO SCHOOL of MINES COMBINED FIELD TECHNIQUE

TOTAL FIELD EFFORT 12 DB FOR BAND 10 TO 70

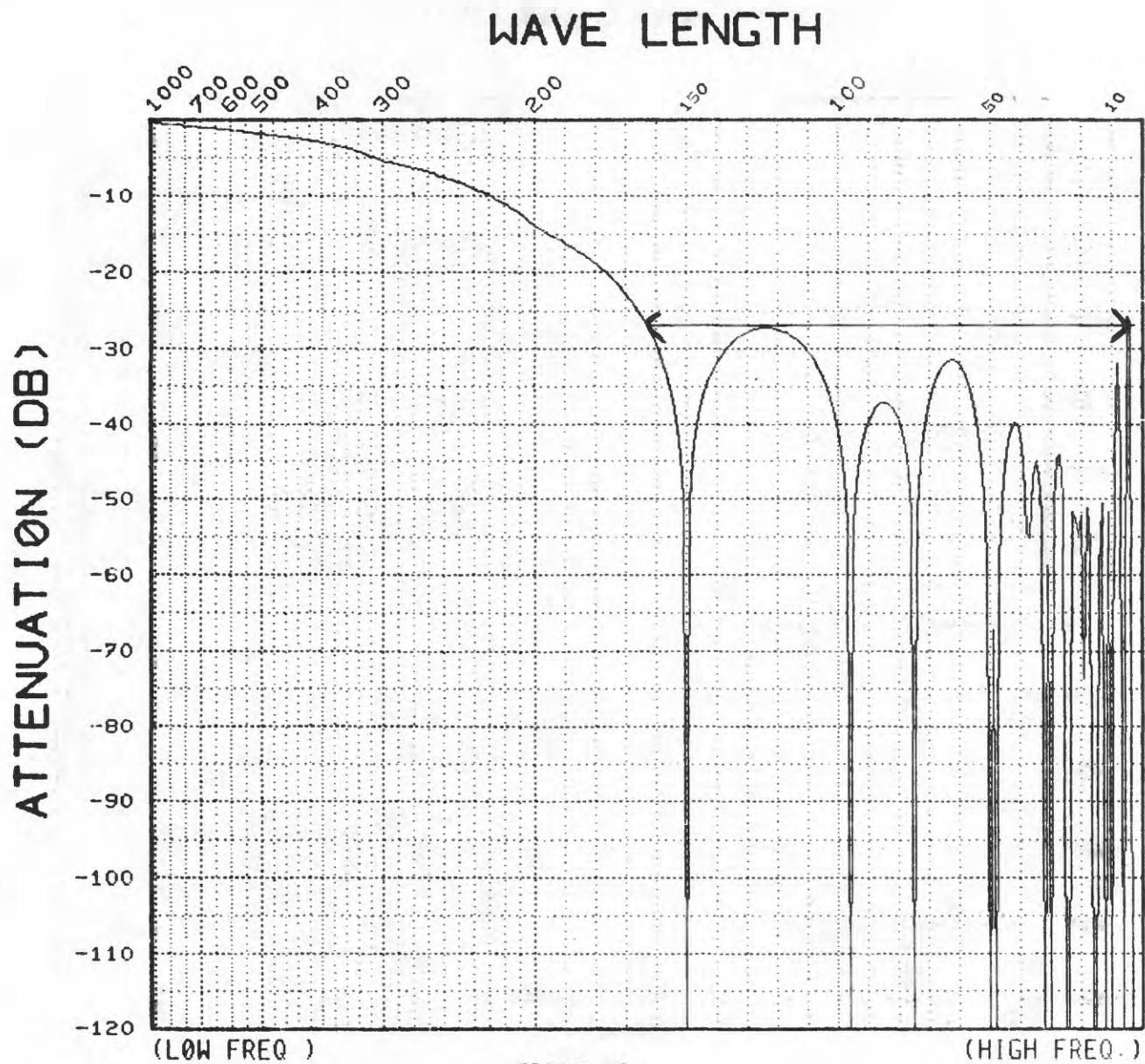


FIGURE 9

SPACING	5	POINTS	30
LENGTH	145	ELEMENTS	30
WEIGHTS	1 1		
SPACING	8	POINTS	12
LENGTH	88	ELEMENTS	12
WEIGHTS	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		

S/N IMPROVEMENT
(AMBIENT NOISE ATTENUATION POWER) 37 38 DB

BIRDWELL COMBINED FIELD TECHNIQUE

TOTAL FIELD EFFORT 29 DB FOR BAND 12 TO 160.

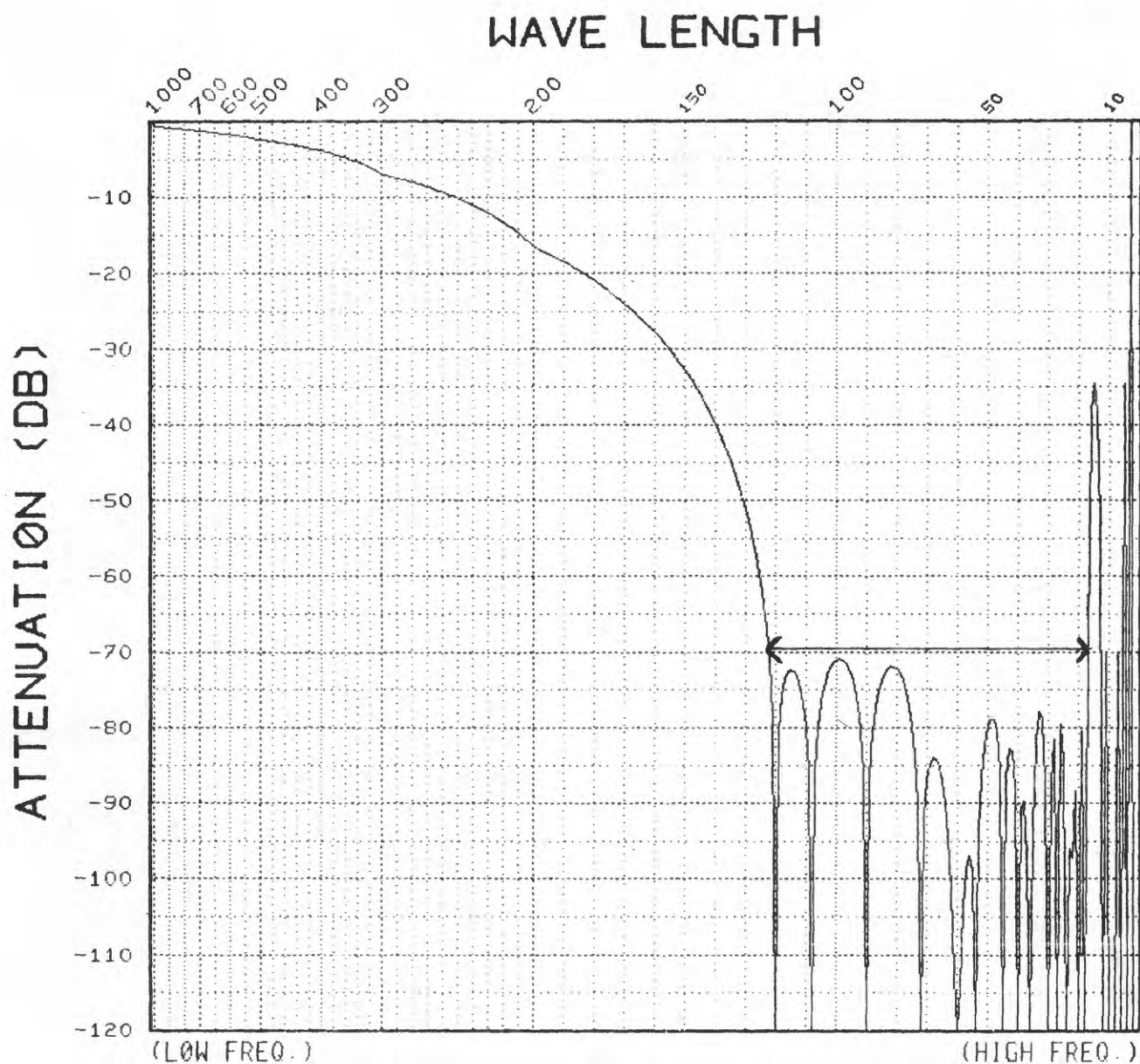


FIGURE 10

SPACING	12	POINTS	14
LENGTH	156	ELEMENTS	54
WEIGHTS	1 2 3 4 5 6 6 6 6 5 4 3 2 1		

SPACING	15	POINTS	15
LENGTH	210	ELEMENTS	96
WEIGHTS	1 2 4 6 8 10 11 12 11 10 8 6 4 2 1		

S/N IMPROVEMENT (AMBIENT NOISE ATTENUATION POWER) 30 35 DB

SEISMIC INTERNATIONAL RESEARCH/SEISDATA SERVICES COMBINED FIELD TECHNIQUE

(VIBRATOR SOURCE)
TOTAL FIELD EFFORT 68 DB FOR BAND 18 T0122

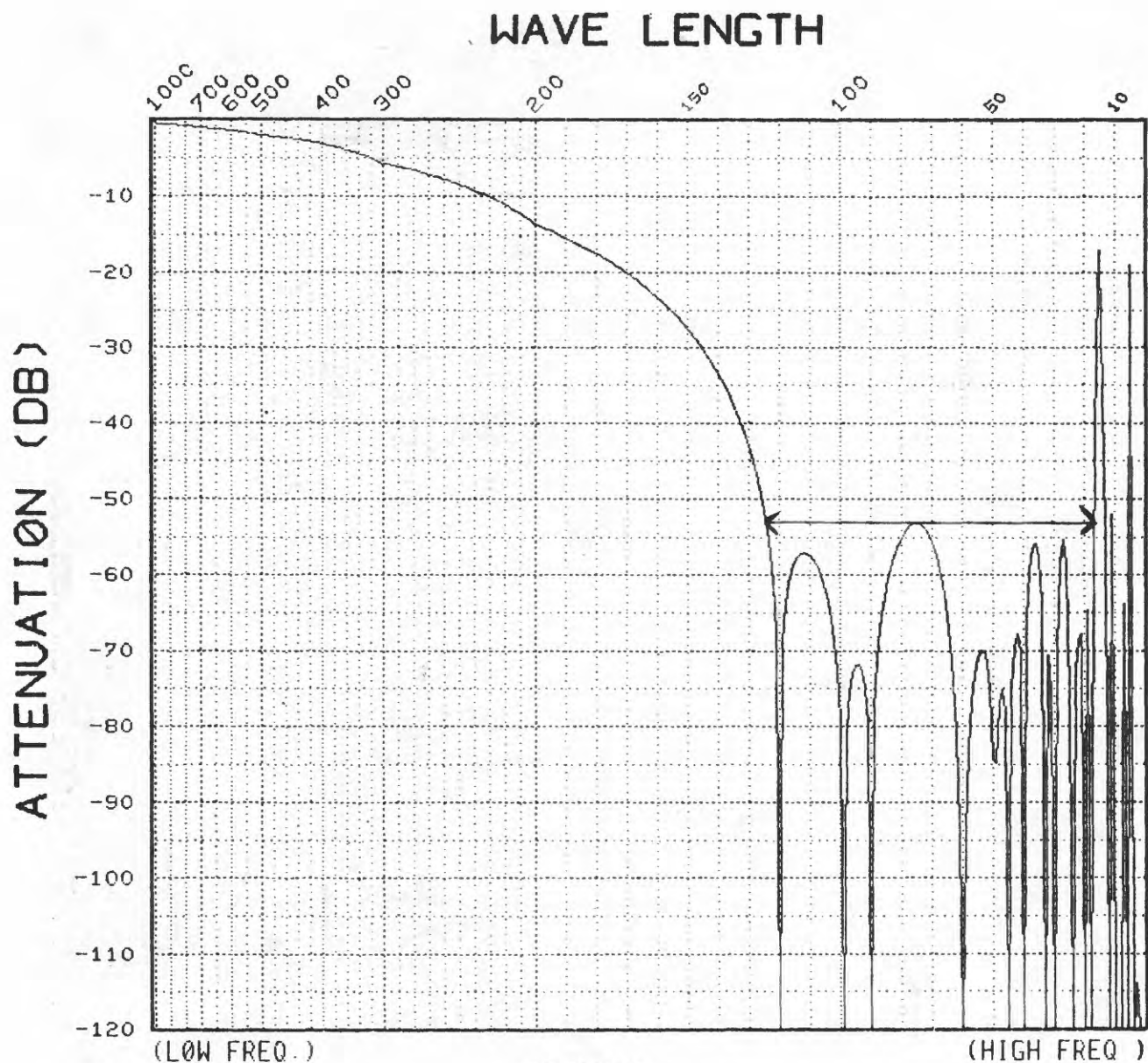


FIGURE 11

SPACING	9	POINTS	11
LENGTH	88	ELEMENTS	11
WEIGHTS	1 1 1 1 1 1 1 1 1 1		

SPACING	15	POINTS	15
LENGTH	210	ELEMENTS	96
WEIGHTS	1 2 4 6 8 10 11 12 11 10 8 6 4 2 1		

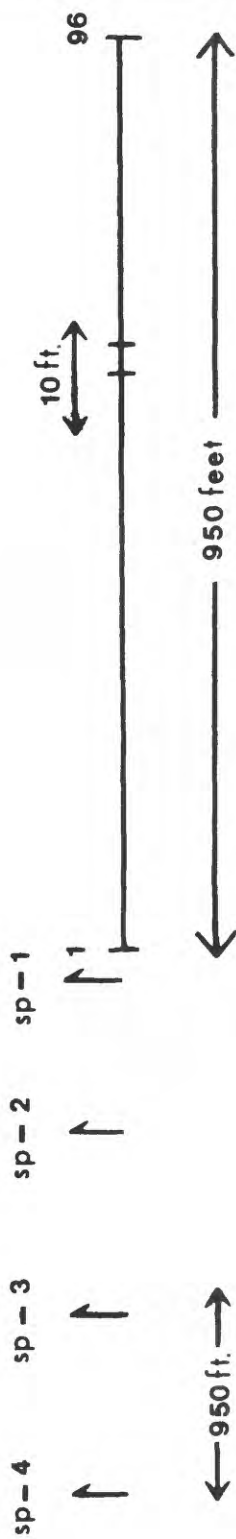
S/N IMPROVEMENT
(AMBIENT NOISE ATTENUATION POWER) 25 78 DB

SEISMIC INTERNATIONAL RESEARCH/SEISDATA SERVICES COMBINED FIELD TECHNIQUE

(PRIMACORD SOURCE)

TOTAL FIELD EFFORT 53 DB FOR BAND 18 TO 122

In Line Noise Spread Configuration



96 Recording stations @ 10 feet

12 Bunched geophones per station

Shot points separated by 950 feet

figure 12

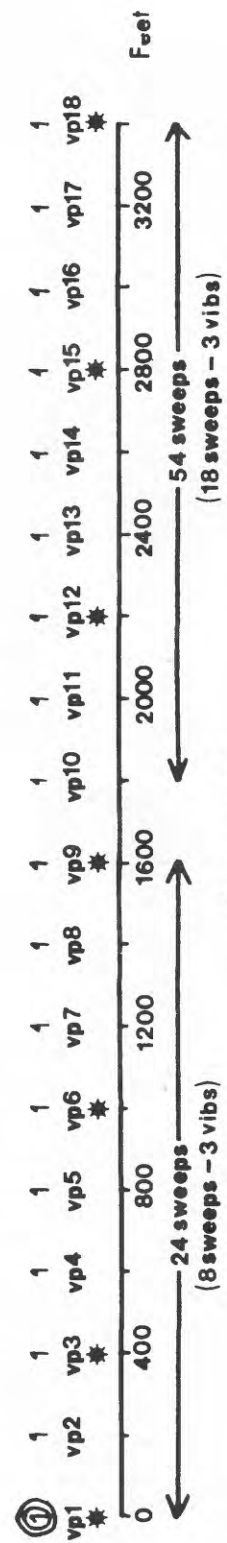
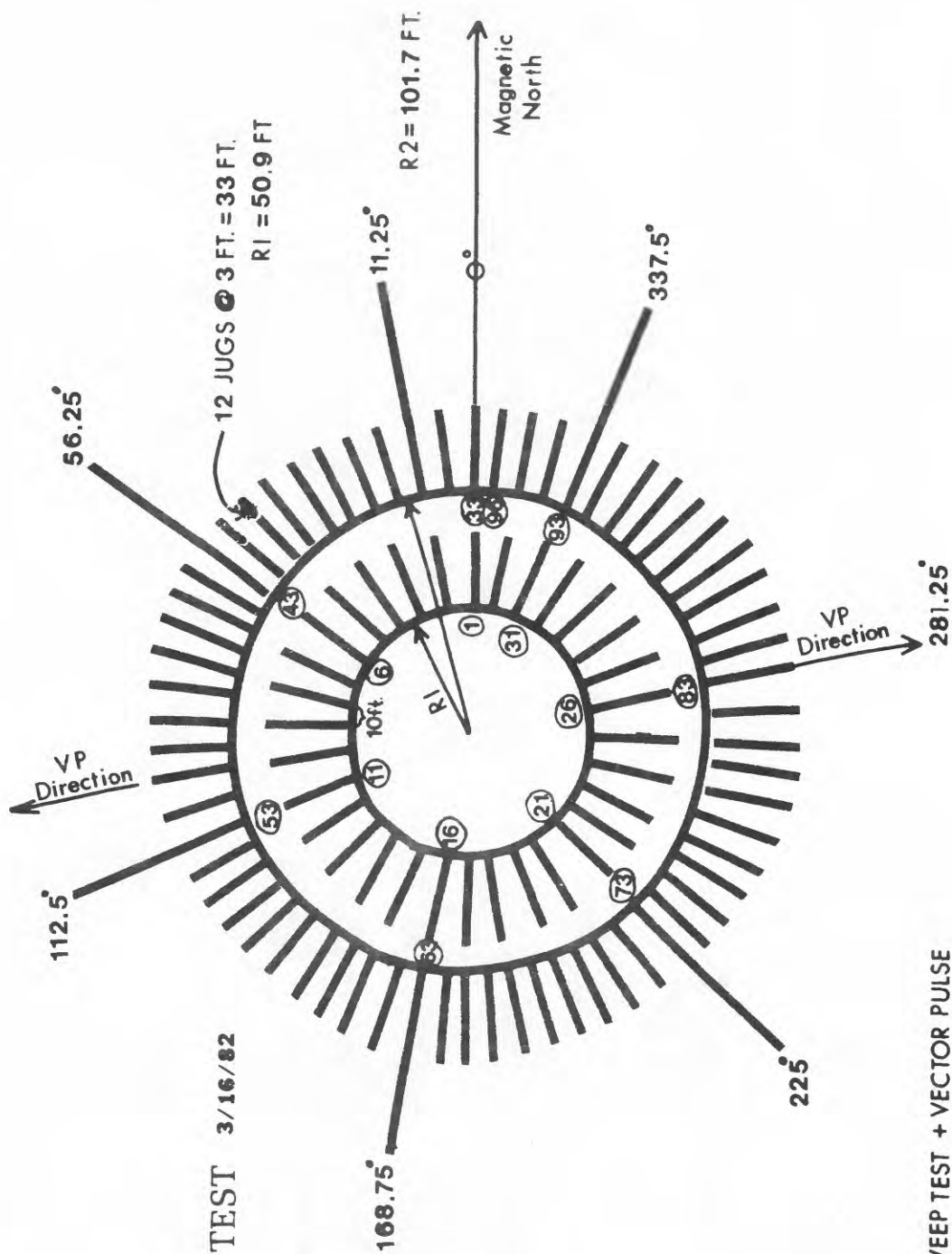
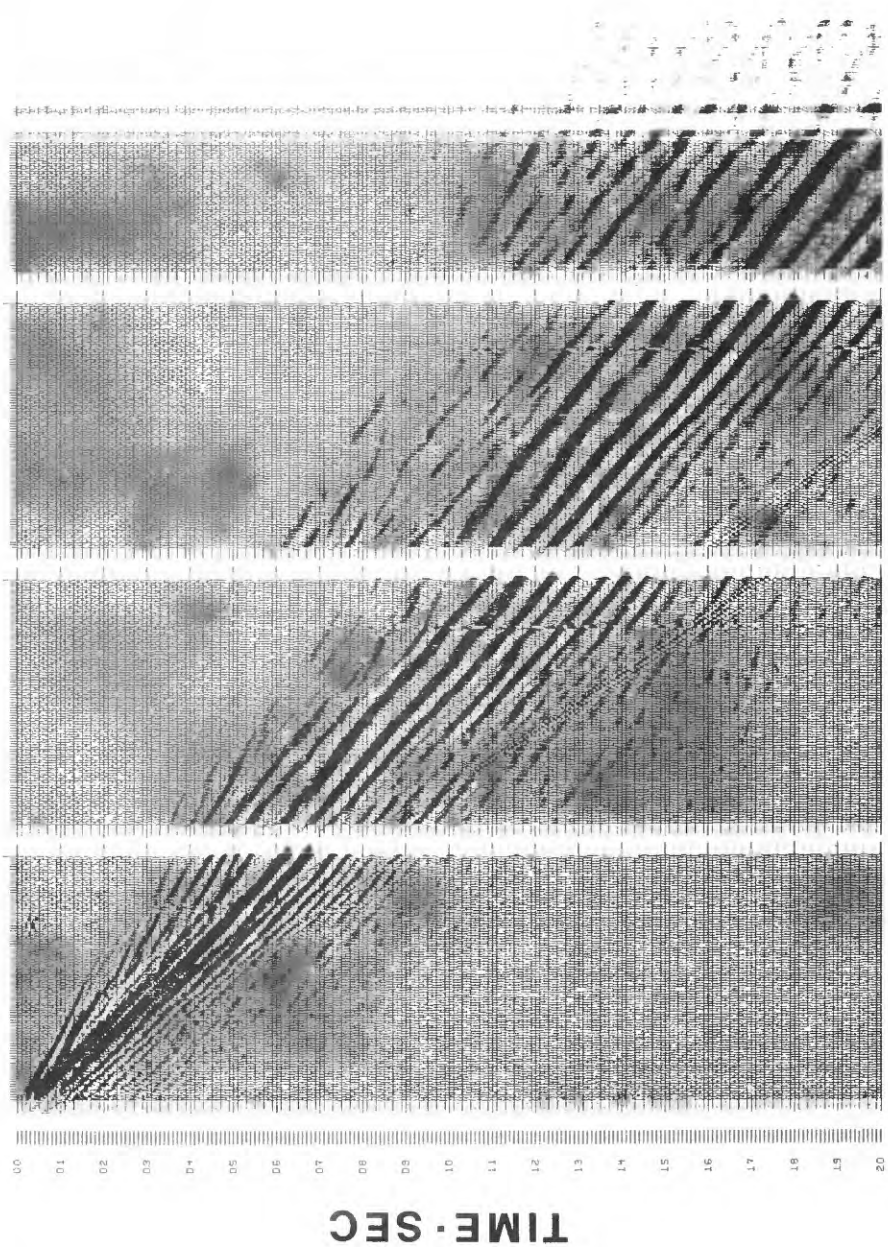


Figure 13



DEPT OF ENERGY FENIX & SCISSON

U S G S

YUCCA MOUNTAIN AREA
NEVADA TEST SITE NYE COUNTY, NEVADA

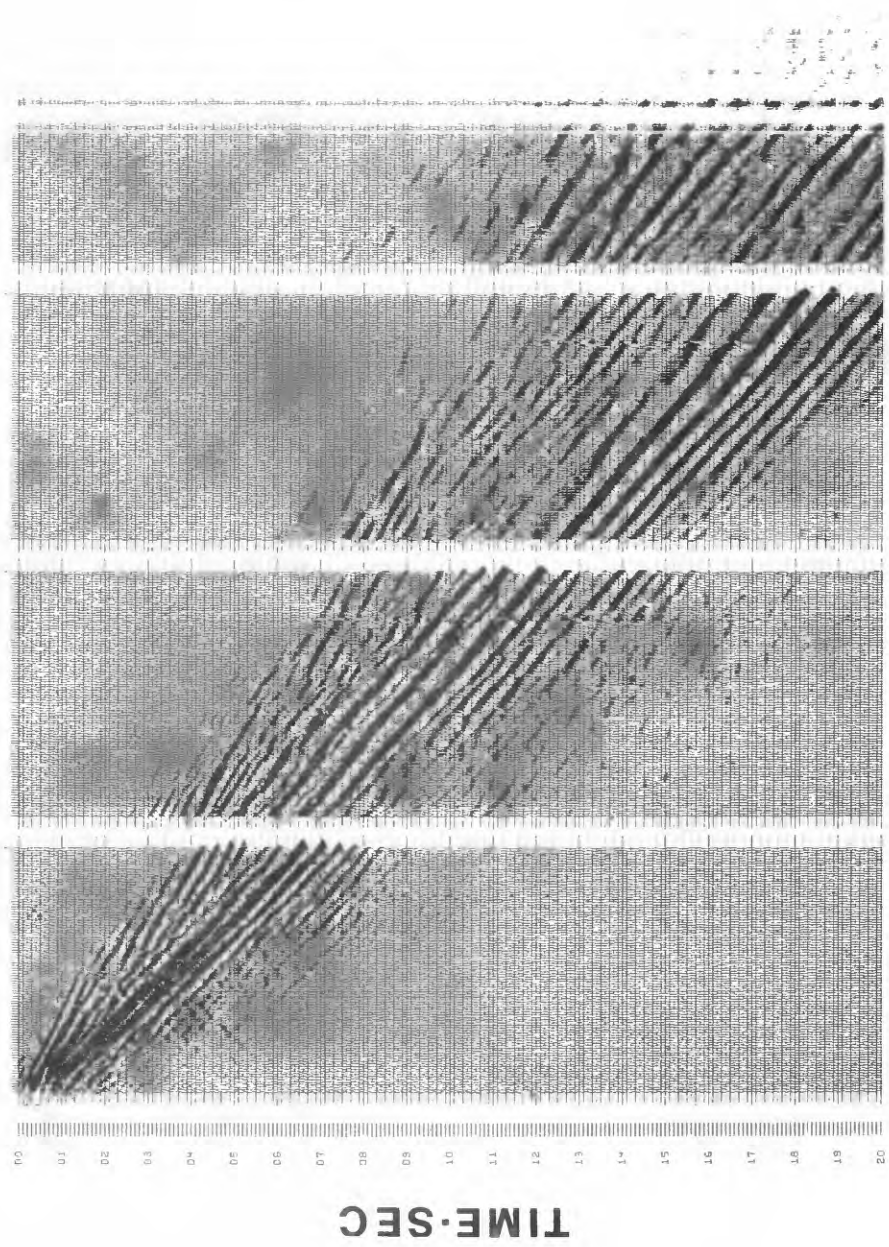
(IN LINE SPREAD PRIMACORD)

FIELD ACQUISITION
BY SEISDATA SERVICES INC. (CPEN 003 APRIL 1982
36 CHANNEL RDS-10 INSTRUMENTS 4 SECONDS 2 MS
12 STATIONS AT 10 FT INTERVAL (IN-LINE NOISE SPREAD)
12 LOGS 1000 1000Z GRAPHONES 13FT INTERVAL PER STA

SP-101 SP-102 3FT PRIMACORD AT 4FT DEPTH 6 HOLES
SP-103 SP-104 3FT PRIMACORD AT 4FT DEPTH 11 HOLES

RECORD 1 4 SP-101 10 FEET TO 960 FEET OFFSET
RECORD 2 4 SP-102 10 FEET TO 1920 FEET OFFSET
RECORD 3 4 SP-103 10 FEET TO 2880 FEET OFFSET
RECORD 4 4 SP-104 10 FEET TO 3840 FEET OFFSET

FIGURE 14



DEPT OF ENERGY FENIX & SCLISSON
 U S G S
 YUCCA MOUNTAIN AREA
 NEVADA TEST SITE NYE COUNTY, NEVADA
 (IN-LINE SPREAD 10-56 HZ SWEEP)

FIELD ACQUISITION
 BY SEISDATA SERVICES INC (CPM 003 APRIL 1982
 56 CHANNEL MCS-10 INSTRUMENTS 4 SECONDS 2 MS
 SAMPLE RATE 1000 HZ FILTER 10-56 HZ
 STATIONS 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 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1478 1479 1480 1481 1482 1483 1484 1485 1486 1487 1488 1489 1490 1491 1492 1493 1494 1495 1496 1497 1498 1499 1500 1501 1502 1503 1504 1505 1506 1507 1508 1509 1510 1511 1512 1513 1514 1515 1516 1517 1518 1519 1520 1521 1522 1523 1524 1525 1526 1527 1528 1529 1530 1531 1532 1533 1534 1535 1536 1537 1538 1539 1540 1541 1542 1543 1544 1545 1546 1547 1548 1549 1550 1551 1552 1553 1554 1555 1556 1557 1558 1559 1560 1561 1562 1563 1564 1565 1566 1567 1568 1569 1570 1571 1572 1573 1574 1575 1576 1577 1578 1579 1580 1581 1582 1583 1584 1585 1586 1587 1588 1589 1590 1591 1592 1593 1594 1595 1596 1597 1598 1599 1600 1601 1602 1603 1604 1605 1606 1607 1608 1609 1610 1611 1612 1613 1614 1615 1616 1617 1618 1619 1620 1621 1622 1623 1624 1625 1626 1627 1628 1629 1630 1631 1632 1633 1634 1635 1636 1637 1638 1639 1640 1641 1642 1643 1644 1645 1646 1647 1648 1649 1650 1651 1652 1653 1654 1655 1656 1657 1658 1659 1660 1661 1662 1663 1664 1665 1666 1667 1668 1669 1670 1671 1672 1673 1674 1675 1676 1677 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2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213 2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226 2227 2228 2229 2230 2231 2232 2233 2234 2235 2236 2237 2238 2239 2240 2241 2242 2243 2244 2245 2246 2247 2248 2249 2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 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2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659 2660 2661 2662 2663 2664 2665 2666 2667 2668 2669 2670 2671 2672 2673 2674 2675 2676 2677 2678 2679 2680 2681 2682 2683 2684 2685 2686 2687 2688 2689 2690 2691 2692 2693 2694 2695 2696 2697 2698 2699 27

DEPT OF ENERGY FENIX & SCISSON

U S G S

YUCCA MOUNTAIN AREA
NEVADA TEST SITE Nye County, Nevada

[IN-LINE SPPRAD 16.72 HZ SWEPT]

FIELD ACQUISITION
BY SEISMATA SERVICES INC CRM 003 APRIL 1982
96 CHANNEL MDS-10 INSTRUMENTS 4 SECONDS 2 NS
LOW CUT FILTER 0.07 HIGHER CUT FILTER 12.5 HZ
16 STATIONS 700 FT INTERVAL (IN-LINE NOISE SPPRAD)
12 LOG1000 100Z DEEP-HOMES (3PT INTERVAL) PER STA

VP-101 VP-102 3 VIBRATORS 8 SHEEPS/VIBRATOR
VP-103 VP-104 3 VIBRATORS 18 SHEEPS/VIBRATOR
16 SECOND RECORD 14 SECOND SWEPT 16.72 HZ

RECORD 1 VP-101 10 FEET TO 960 FEET OFFSET
RECORD 2 VP-102 920 FEET TO 1920 FEET OFFSET
RECORD 3 VP-103 1920 FEET TO 2880 FEET OFFSET
RECORD 4 VP-104 2880 FEET TO 3840 FEET OFFSET

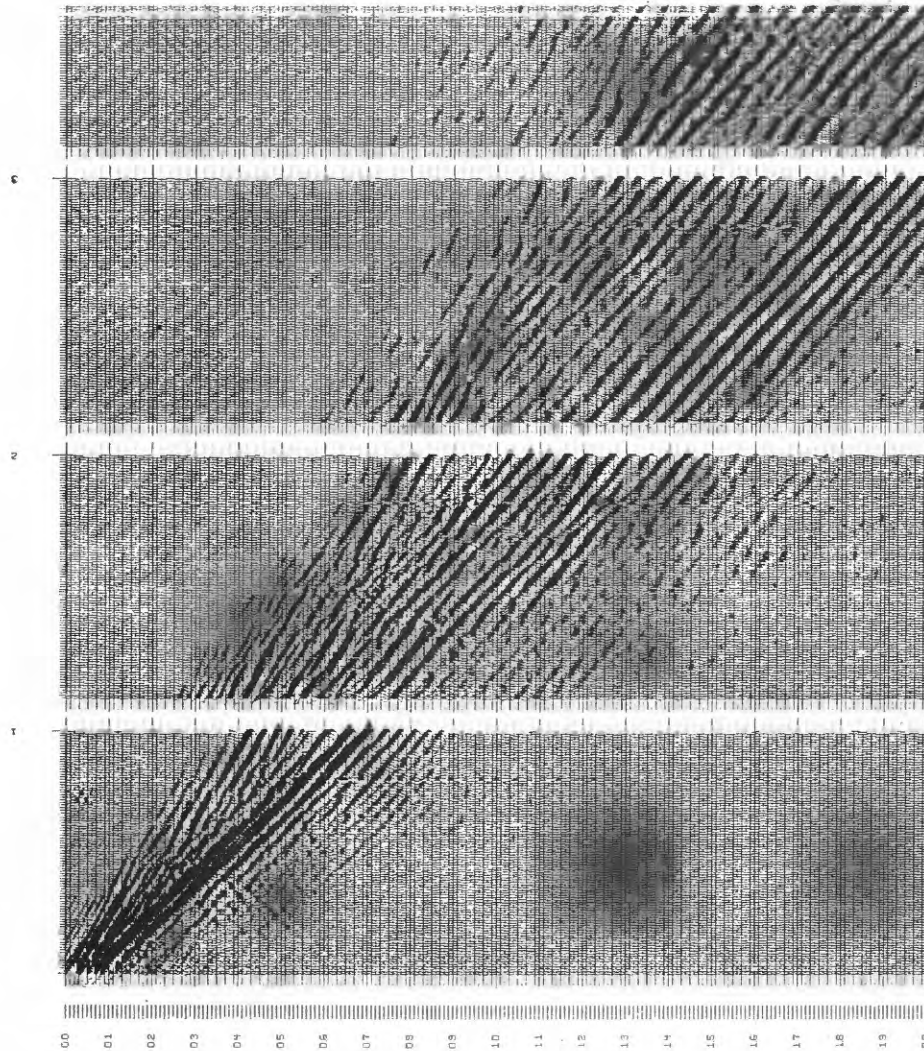


FIGURE 16

DEPT OF ENERGY FENIX & SCIENSON

5555

YUCCA MOUNTAIN AREA
NEVADA TEST SITE Nye County, Nevada

141115 ZH VB-22 UV KKH5 IN17-NI

BY REASONATE SERVICES INC FROM 003 APRIL 1982
96 CHANNEL NO-10 INQUIRIES 4 SPONSORS 2 MS
LOWEST FUEL COST HIGHEST FUEL COST
96 STATIONS AT 100 INTERVAL (IN-LINE NOISE SPREAD)

VP-101 VP-102 3 VIBRATORS 8 SHEETS VIBRATOR
VP-103 VP-104 3 VIBRATORS 10 SHEETS VIBRATOR
10 SECOND RECORD 14 SECOND SHEET 22-04 HZ

RECORD 1	VP-101	10 FEET TO 960	FEET OFFSET
RECORD 2	VP-102	920 FEET TO 1920	FEET OFFSET
RECORD 3	VP-103	1920 FEET TO 2920	FEET OFFSET
RECORD 4	VP-104	2890 FEET TO 3840	FEET OFFSET

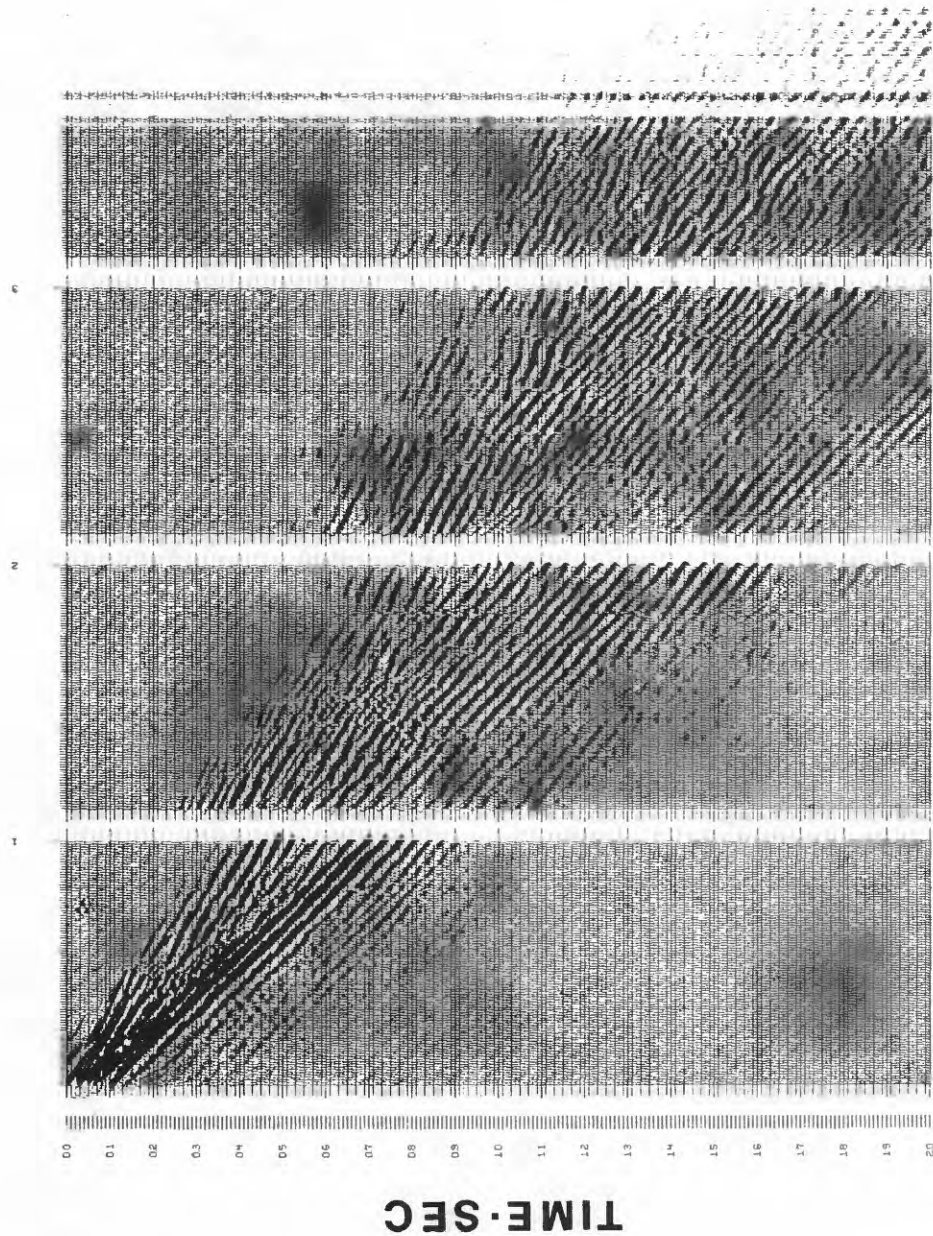
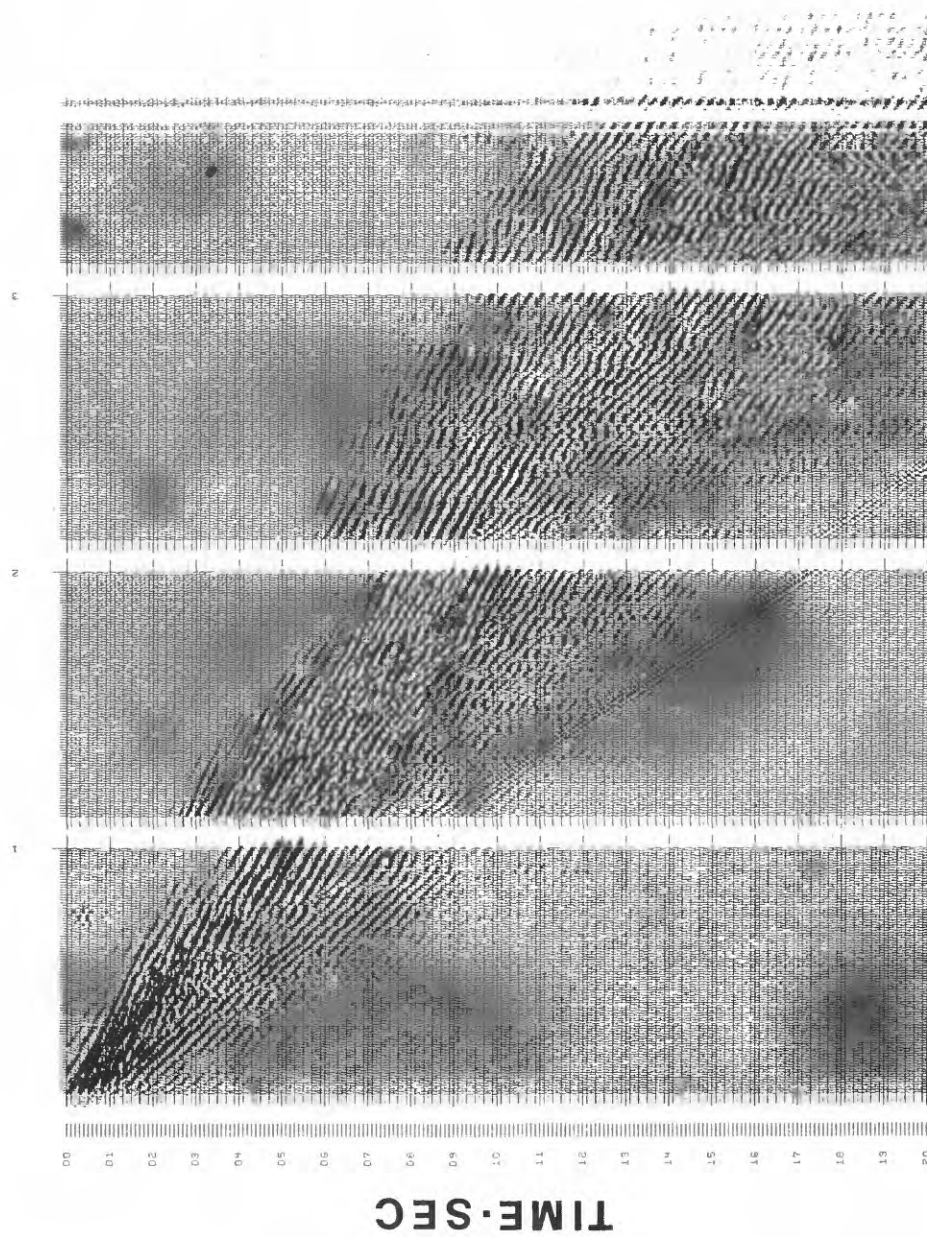


FIGURE 17

RECORD	1	0	VP	101	10	1127	10	560	3127	06387
RECORD	2	0	VP	102	970	1127	10	1920	1121	01361
RECORD	3	0	VP	103	1970	1127	10	0037	0037	01361
RECORD	4	0	VP	104	2000	1127	10	0040	0127	01351

FIGURE 18



DEPT OF ENERGY FENIX & SCISSON

U S G S

YUCCA MOUNTAIN AREA
NEVADA TEST SITE NTE COUNTY, NEVADA

(LINE SPREAD) 88 10447 SHEEP

FIELD ACQUISITION
BY GEISDA'S SERVICES, INC. CPM 103 APRIL 1992
96 CHANNEL HD5-10 INSTRUMENTS 4 SECONDS 2 MS
LGR COT FILE 8/11 HX-A-03 FILE 113-02
88 STATIONS AT 10 FT INTERVALS (NOISE SPREAD)
12 LOGS/00 1042 060-0005 0.01 IN. SCALE PER STA

VP-101 VP-102 3 VIBRATORS 8 SHEETS/VIBRATOR
15-103 VP-104 1 VIBRATOR 19 SHEETS/VIBRATOR
18 SECOND RECORD 14 SE-000 SHEET 38-104 M2

RECORD 1 0 VP-101 10 FEET TO 560 FEET 04-SET
RECORD 2 0 VP-102 560 FEET TO 1320 FEET 04-SET
RECORD 3 0 VP-101 1320 FEET TO 2640 FEET 04-SET
RECORD 4 0 VP-104 2640 FEET TO 3840 FEET 04-SET

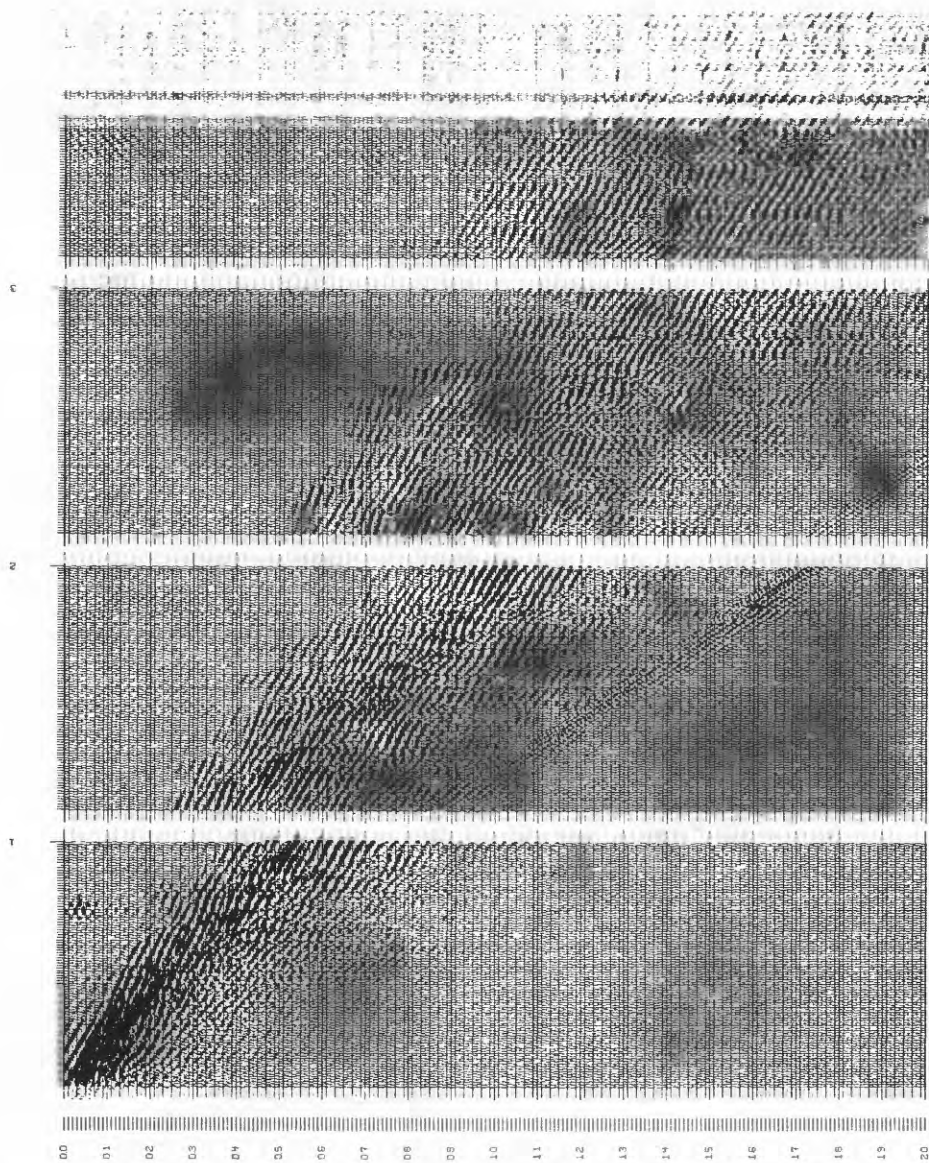
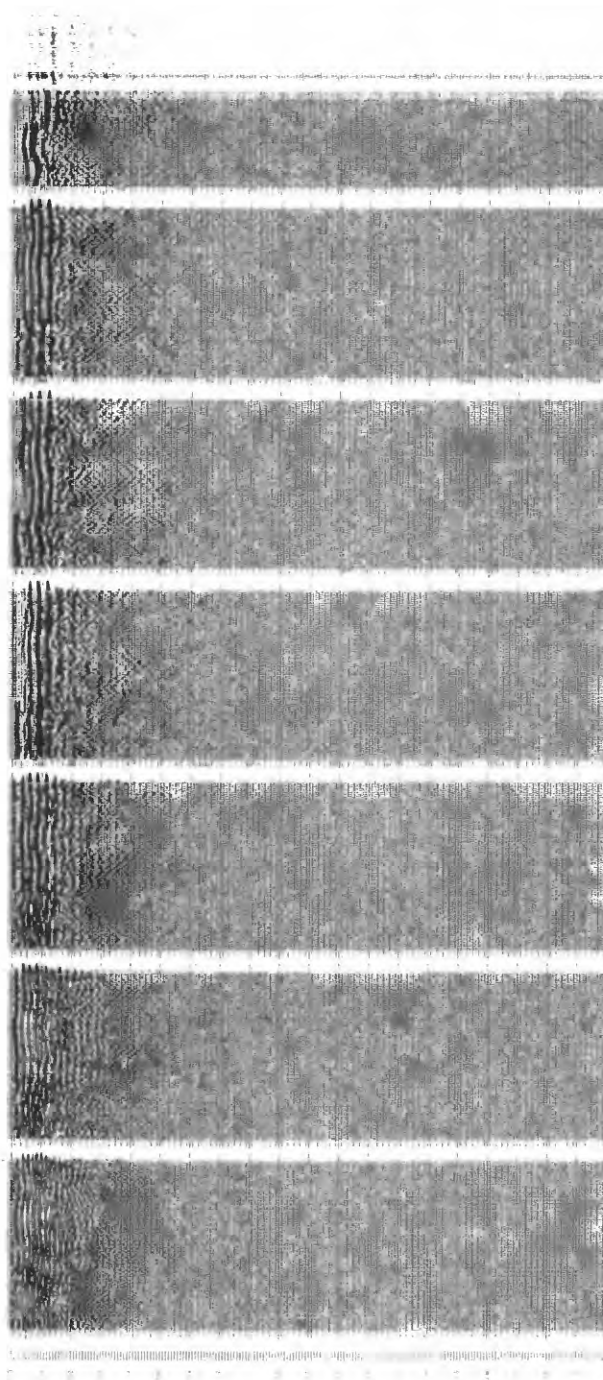


FIGURE 19

Time-sec





TEST OF THE TEST

65
66
67
68

YUCCA MOUNTAIN AREA
NEVADA 115 mi. E. of LOHAT, CHIVILA

1511. 1512. 1513. 1514. 1515. 1516. 1517. 1518. 1519. 1520. 1521. 1522. 1523. 1524. 1525. 1526. 1527. 1528. 1529. 1530. 1531. 1532. 1533. 1534. 1535. 1536. 1537. 1538. 1539. 1540. 1541. 1542. 1543. 1544. 1545. 1546. 1547. 1548. 1549. 1550. 1551. 1552. 1553. 1554. 1555. 1556. 1557. 1558. 1559. 1560. 1561. 1562. 1563. 1564. 1565. 1566. 1567. 1568. 1569. 1570. 1571. 1572. 1573. 1574. 1575. 1576. 1577. 1578. 1579. 1580. 1581. 1582. 1583. 1584. 1585. 1586. 1587. 1588. 1589. 1590. 1591. 1592. 1593. 1594. 1595. 1596. 1597. 1598. 1599. 1600. 1601. 1602. 1603. 1604. 1605. 1606. 1607. 1608. 1609. 1610. 1611. 1612. 1613. 1614. 1615. 1616. 1617. 1618. 1619. 1620. 1621. 1622. 1623. 1624. 1625. 1626. 1627. 1628. 1629. 1630. 1631. 1632. 1633. 1634. 1635. 1636. 1637. 1638. 1639. 1640. 1641. 1642. 1643. 1644. 1645. 1646. 1647. 1648. 1649. 1650. 1651. 1652. 1653. 1654. 1655. 1656. 1657. 1658. 1659. 1660. 1661. 1662. 1663. 1664. 1665. 1666. 1667. 1668. 1669. 1670. 1671. 1672. 1673. 1674. 1675. 1676. 1677. 1678. 1679. 1680. 1681. 1682. 1683. 1684. 1685. 1686. 1687. 1688. 1689. 1690. 1691. 1692. 1693. 1694. 1695. 1696. 1697. 1698. 1699. 1700. 1701. 1702. 1703. 1704. 1705. 1706. 1707. 1708. 1709. 1710. 1711. 1712. 1713. 1714. 1715. 1716. 1717. 1718. 1719. 1720. 1721. 1722. 1723. 1724. 1725. 1726. 1727. 1728. 1729. 1730. 1731. 1732. 1733. 1734. 1735. 1736. 1737. 1738. 1739. 1740. 1741. 1742. 1743. 1744. 1745. 1746. 1747. 1748. 1749. 1750. 1751. 1752. 1753. 1754. 1755. 1756. 1757. 1758. 1759. 1760. 1761. 1762. 1763. 1764. 1765. 1766. 1767. 1768. 1769. 1770. 1771. 1772. 1773. 1774. 1775. 1776. 1777. 1778. 1779. 1780. 1781. 1782. 1783. 1784. 1785. 1786. 1787. 1788. 1789. 1790. 1791. 1792. 1793. 1794. 1795. 1796. 1797. 1798. 1799. 1800. 1801. 1802. 1803. 1804. 1805. 1806. 1807. 1808. 1809. 1810. 1811. 1812. 1813. 1814. 1815. 1816. 1817. 1818. 1819. 1820. 1821. 1822. 1823. 1824. 1825. 1826. 1827. 1828. 1829. 1830. 1831. 1832. 1833. 1834. 1835. 1836. 1837. 1838. 1839. 1840. 1841. 1842. 1843. 1844. 1845. 1846. 1847. 1848. 1849. 1850. 1851. 1852. 1853. 1854. 1855. 1856. 1857. 1858. 1859. 1860. 1861. 1862. 1863. 1864. 1865. 1866. 1867. 1868. 1869. 1870. 1871. 1872. 1873. 1874. 1875. 1876. 1877. 1878. 1879. 1880. 1881. 1882. 1883. 1884. 1885. 1886. 1887. 1888. 1889. 1890. 1891. 1892. 1893. 1894. 1895. 1896. 1897. 1898. 1899. 1900. 1901. 1902. 1903. 1904. 1905. 1906. 1907. 1908. 1909. 1910. 1911. 1912. 1913. 1914. 1915. 1916. 1917. 1918. 1919. 1920. 1921. 1922. 1923. 1924. 1925. 1926. 1927. 1928. 1929. 1930. 1931. 1932. 1933. 1934. 1935. 1936. 1937. 1938. 1939. 1940. 1941. 1942. 1943. 1944. 1945. 1946. 1947. 1948. 1949. 1950. 1951. 1952. 1953. 1954. 1955. 1956. 1957. 1958. 1959. 1960. 1961. 1962. 1963. 1964. 1965. 1966. 1967. 1968. 1969. 1970. 1971. 1972. 1973. 1974. 1975. 1976. 1977. 1978. 1979. 1980. 1981. 1982. 1983. 1984. 1985. 1986. 1987. 1988. 1989. 1990. 1991. 1992. 1993. 1994. 1995. 1996. 1997. 1998. 1999. 2000. 2001. 2002. 2003. 2004. 2005. 2006. 2007. 2008. 2009. 2010. 2011. 2012. 2013. 2014. 2015. 2016. 2017. 2018. 2019. 2020. 2021. 2022. 2023. 2024. 2025. 2026. 2027. 2028. 2029. 2030. 2031. 2032. 2033. 2034. 2035. 2036. 2037. 2038. 2039. 2040. 2041. 2042. 2043. 2044. 2045. 2046. 2047. 2048. 2049. 2050. 2051. 2052. 2053. 2054. 2055. 2056. 2057. 2058. 2059. 2060. 2061. 2062. 2063. 2064. 2065. 2066. 2067. 2068. 2069. 2070. 2071. 2072. 2073. 2074. 2075. 2076. 2077. 2078. 2079. 2080. 2081. 2082. 2083. 2084. 2085. 2086. 2087. 2088. 2089. 2090. 2091. 2092. 2093. 2094. 2095. 2096. 2097. 2098. 2099. 2100. 2101. 2102. 2103. 2104. 2105. 2106. 2107. 2108. 2109. 2110. 2111. 2112. 2113. 2114. 2115. 2116. 2117. 2118. 2119. 2120. 2121. 2122. 2123. 2124. 2125. 2126. 2127. 2128. 2129. 2130. 2131. 2132. 2133. 2134. 2135. 2136. 2137. 2138. 2139. 2140. 2141. 2142. 2143. 2144. 2145. 2146. 2147. 2148. 2149. 2150. 2151. 2152. 2153. 2154. 2155. 2156. 2157. 2158. 2159. 2160. 2161. 2162. 2163. 2164. 2165. 2166. 2167. 2168. 2169. 2170. 2171. 2172. 2173. 2174. 2175. 2176. 2177. 2178. 2179. 2180. 2181. 2182. 2183. 2184. 2185. 2186. 2187. 2188. 2189. 2190. 2191. 2192. 21

FILED APR 15 1967
BY TELETYPE UNIT
96 CHARLES STREET
NEW YORK 10003

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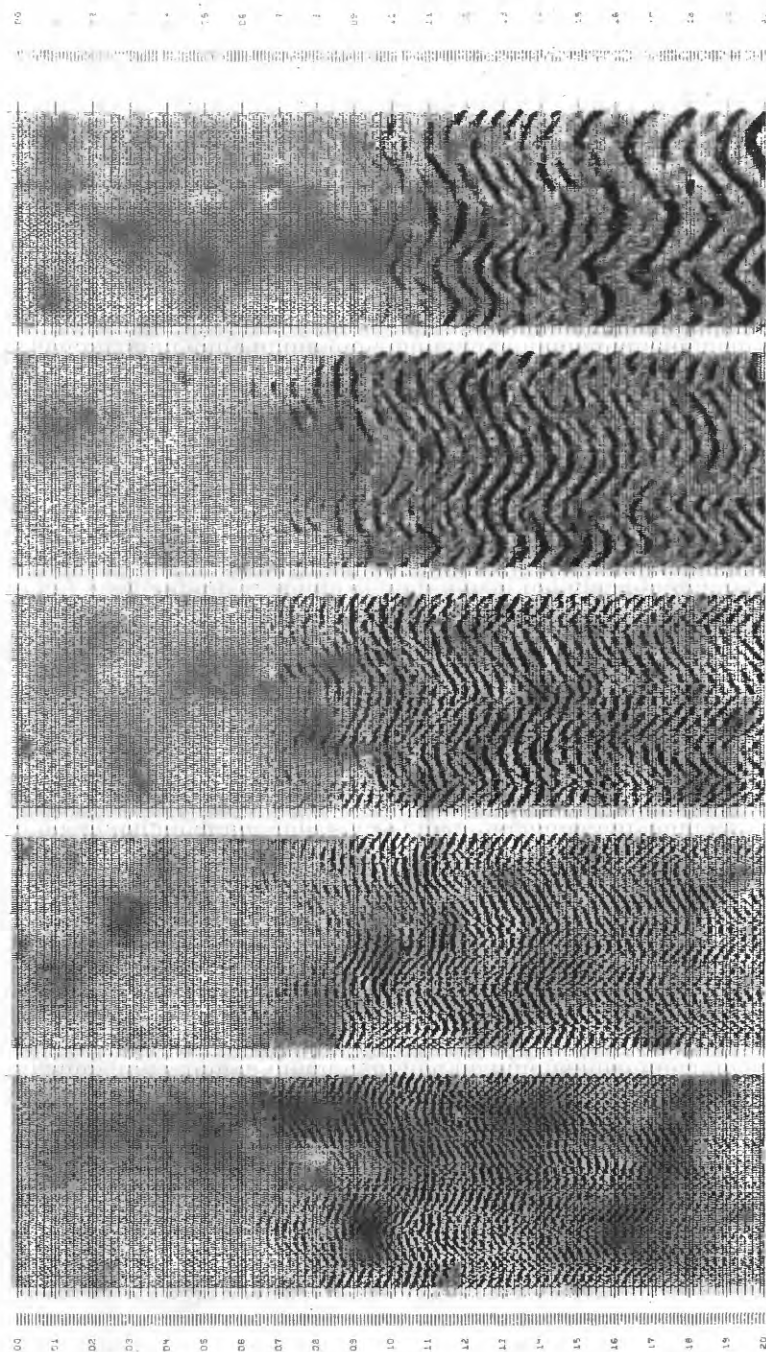
6TH RECEIVED
JESUIT UNIVERSITY AT DAYTON, OHIO
JAN 11 1965
STATION 11 HOLLS[illegible]

EIC 34

FIG 47

Time-sec

FIG 24



TIME-SEC

DEPT OF ENRG. FENIX & SCLISSON

U S G S

YUCCA MOUNTAIN AREA
NEVADA TEST SITE NTE COUNTY, NEVADA

TORNADO SEISMOID 2900' OFFSET

BY SEISMOGRAPHIC RECORDING ABOUT 1992
96 CHANNELS 1000 Hz 4.5 INCHES 2 INCHES
LOW-CUT FILTER CUT HIGH-CUT FILTER 155 HZ

TORNADO CIRCUIT 16 MSEC OR FAN 1000 Hz CIRCULAR
INNER LITTLE RADIUS 40 INCHES 25 STATIONS 10 FT
OUTER LITTLE RADIUS 100 INCHES 25 STATIONS 10 FT
12 LBS/1000 10 HZ CIRCULARS (300 INTERVAL) PER STA
3 VIBRATORS 18 CIRCLES 1000 50 1000 1000
18 SECOND DELAY 150 INCHES 14 SECOND VIBRATOR SPEED
40-15 ABOUT 0.1 SEC HIGH CENTER OF 100000 W/HEAD

151 HZ/100 50-100 HZ 50-100 HZ
2ND RECORD 30-50 HZ 30-50 HZ
4TH RECORD 10-20 HZ 10-20 HZ
5TH RECORD 5-10 HZ 5-10 HZ

151 HZ/100 50-100 HZ 50-100 HZ
2ND RECORD 30-50 HZ 30-50 HZ
4TH RECORD 10-20 HZ 10-20 HZ
5TH RECORD 5-10 HZ 5-10 HZ

FIG 25

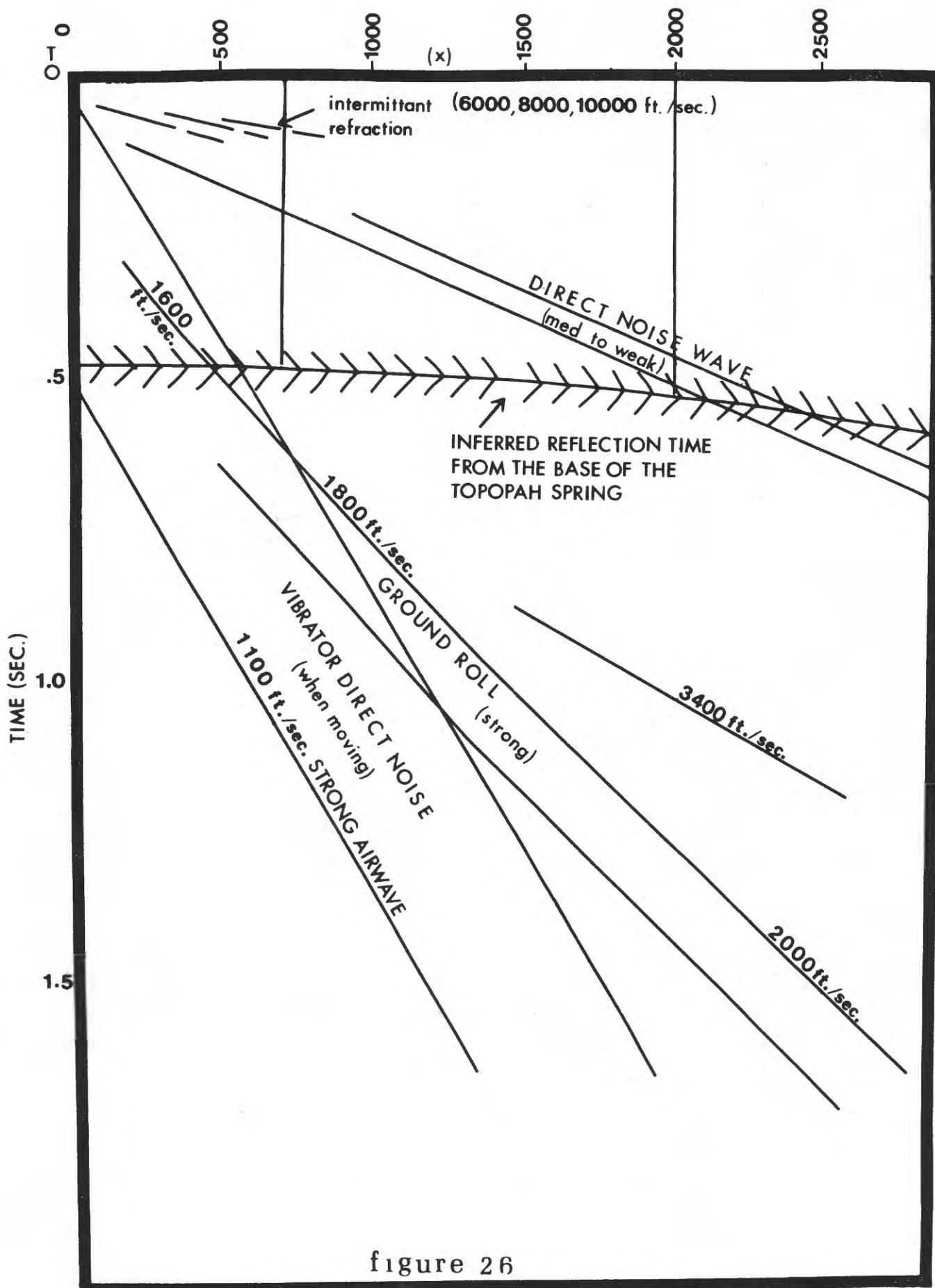


figure 26
SCHEMATIC — SIGNAL AND NOISE

THREE DIMENSIONAL TRAVERSES

| SOURCE | RECEIVER |
|-------------|---|
| x | o |
| x | o |
| x | o |
| x | o |
| 4 X 1 | 4 X 24 |

TOTAL CDP FOLD 192

| | |
|-------------|---|
| x | o |
| x | o |
| x | o |
| x | o |
| x | o |
| x | o |
| 6 X 1 | 6 X 16 |

TOTAL CDP FOLD 288

| | |
|-------------|-----------------------------------|
| x | o o o o o o o o o o o o o o o o o |
| x | o o o o o o o o o o o o o o o o o |
| x | o o o o o o o o o o o o o o o o o |
| x | o o o o o o o o o o o o o o o o o |
| x | o o o o o o o o o o o o o o o o o |
| x | o o o o o o o o o o o o o o o o o |
| x | o o o o o o o o o o o o o o o o o |
| 8 X 1 | 8 X 12 |

TOTAL CDP FOLD 384

- 1). 4 x 24 at 100 ft. = 800-2800 ft.
- 2). 6 x 16 at 100 ft. = 800-2300 ft.
- 3). 8 x 12 at 100 ft. = 800-1900 ft.
- 4). 4 x 24 at 50 ft. = 400-1550 ft.
- 5). 6 x 16 at 50 ft. = 400-1200 ft.
- 6). 8 x 12 at 50 ft. = 400-1000 ft.

FIGURE 27

DEPT OF ENERGY FENIX & SCISSON

U S G S

YUCCA MOUNTAIN AREA
NEVADA TEST SITE NYE COUNTY, NEVADA

LINE W-4 STACK CENTER CDPs

FIELD ACQUISITION
BY SEISDATA SERVICES INC. CREW 003 APR-JUN 1982
96 CHANNEL RDS-10 4 SEC 2 MS FILTER 100-125000
3000 HZ BANDPASS NORTH-SOUTH IN 52 SFT INTERVALS THRU
RIDGEPOINT OF RDS 365-372/380-373, THEN 105 FT INT
RECEIVER STATION MATRIX 8-8Y-12 SOURCE 8-8Y-1
SOURCE MATRIX OFFEND 840FT TO NEAR RECEIVER RDS
NARS1000 10 HZ GAIN-1000 STATION (SET UP N-T0-S)
TIME 1 2 4 6 8 10 11 12 11 10 8 4 2 1 INT 18FT
TWO REINFORCED CONCRETE CHARGES AND VIBES
3FT PC AT 4FT 11 22 HOLE ARRAY 9FT 2 18FT INT
2 VIBES 637 SFT (8 PGS 912 SFT) 10 SLEEPS-VIB = 54
2000 1 2 3 4 5 6 6 6 4 3 2 1 NORTH-SOUTH
LENGTH 182 SFT (DOUBLED FOR 210FT RDS) 16-62 HZ
12SEC RECORD 12SEC SILEP TOTAL TECHNIQUE = 6008
STATION 101 TO 652 PROGRESS NORTH TO SOUTH

PROCESSING INFORMATION

SEPTEMBER 10, 1982
REFERENCE DATUM 8000 FT VCORR 9000 FT/SEC
DEMUTIPLEX SEC-8 TO SEC-Y RECORD & TRACE EDITING
CDPS GATHERED NORTH-SOUTH IN 52 SFT INTERVALS THRU
RIDGEPOINT OF RDS 365-372/380-373, THEN 105 FT INT
GATHER CENTER FIVE COLUMNS OF CDPs (6 TO 10)
RESAMPLE TO 4 MS BANDPASS FILTER 10 TO 30 HZ
DIGITAL AUTOMATIC GAIN CONTROL (AGC) 500MS OPERATOR
NORMAL MOVEOUT (2-HAY TIME IN MS - RMS VELOCITY)
100-8000 480-8000 600-9000 1200-10000 2000-13000
CDP STACKING (FIELD 190)
BANDPASS FILTER 10-36 HZ DIGITAL AGC 1000 MS LEN

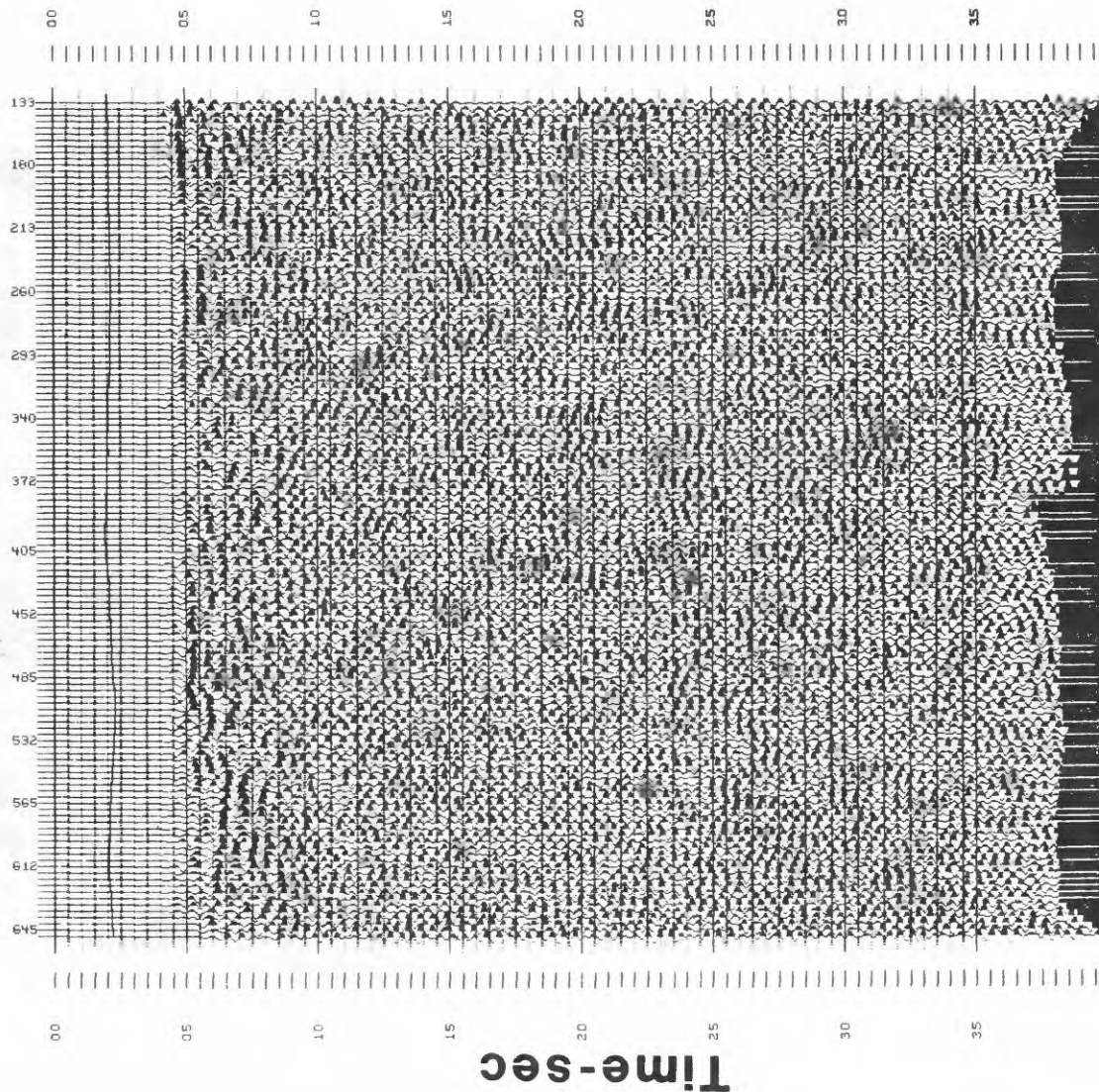


FIGURE 29

DEPT OF ENERGY FENIX & SCISSON

USGS

YUCCA MOUNTAIN AREA
NEVADA TEST SITE NYE COUNTY, NEVADA

LINE W-4 STACK WESTERN CDP 14

FIELD ACQUISITION
BY SEISDATA SERVICES INC. CREW 003 APR-JUN 1982
96 CHANNEL NOS-10 4 SEC 2 MS FILT OUT-T0-125HZ
30 AREA 8 STATIONS BY 74 RMS (STA INT 100 FT E/H)
ROW INTERVAL (N/S) 105FT TO STA 364, THEN 210 FEET
RECIEVER STATION MATRIX 8-BY-12 SOURCE 8-BY-1
SOURCE MATRIX OFFEND 840FT TO NEAR RECIEVER ROW
96 LRS1000 10 MZ GEOPHONES/STATION (SET UP N-T0-S)
ARRAY 1 2 4 6 8 10 12 11 10 8 6 4 2 1 INT 15FT
TWO SEISMIC SOURCES PRIMACORD CHARGES AND VIBS
3FT PC AT 4FT 11 & 22 HOLE ARRAY 3FT & 18FT INT
3 VIBS 937.5FT (8 POS 912.5FT) 18 SHEEPS/VIB = 54
ARRAY 1 2 3 4 5 6 6 6 4 3 2 1 NORTH/SOUTH
LENGTH 162.5FT (DOUBLED FOR 210FT RMS) 16-62 HZ
16SEC RECORD 12SEC SHEEP TOTAL TECHNIQUE = 6008
STATION 101 TO 692 PROGRESSIVE NORTH TO SOUTH

PROCESSING INFORMATION
SEPTEMBER 10, 1982
REFERENCE DATUM +5000 FT VCCORR 8000 FT/SEC
DEMULPLEX SEG-B TO SEG-Y RECORD & TRACE EDITING
CDPS GATHERED NORTH-SOUTH IN 105 FT INTERVALS
GATHER ONE WESTERN CDP COLUMN (14)
RESAMPLE TO 4 MS BANDPASS FILTER 10 TO 30 HZ
DIGITAL AUTOMATIC GAIN CONTROL (AGC) 500MS OPERATOR
NORMAL MOVEMENT (2-MAY TIME IN NS - RMS VELOCITY)
100-6000 480-8000 600-9000 1200-10800 2000-13000
CDP STACKING (FOLD 28)
BANDPASS FILTER 10-36 HZ DIGITAL AGC 1000 MS LEN

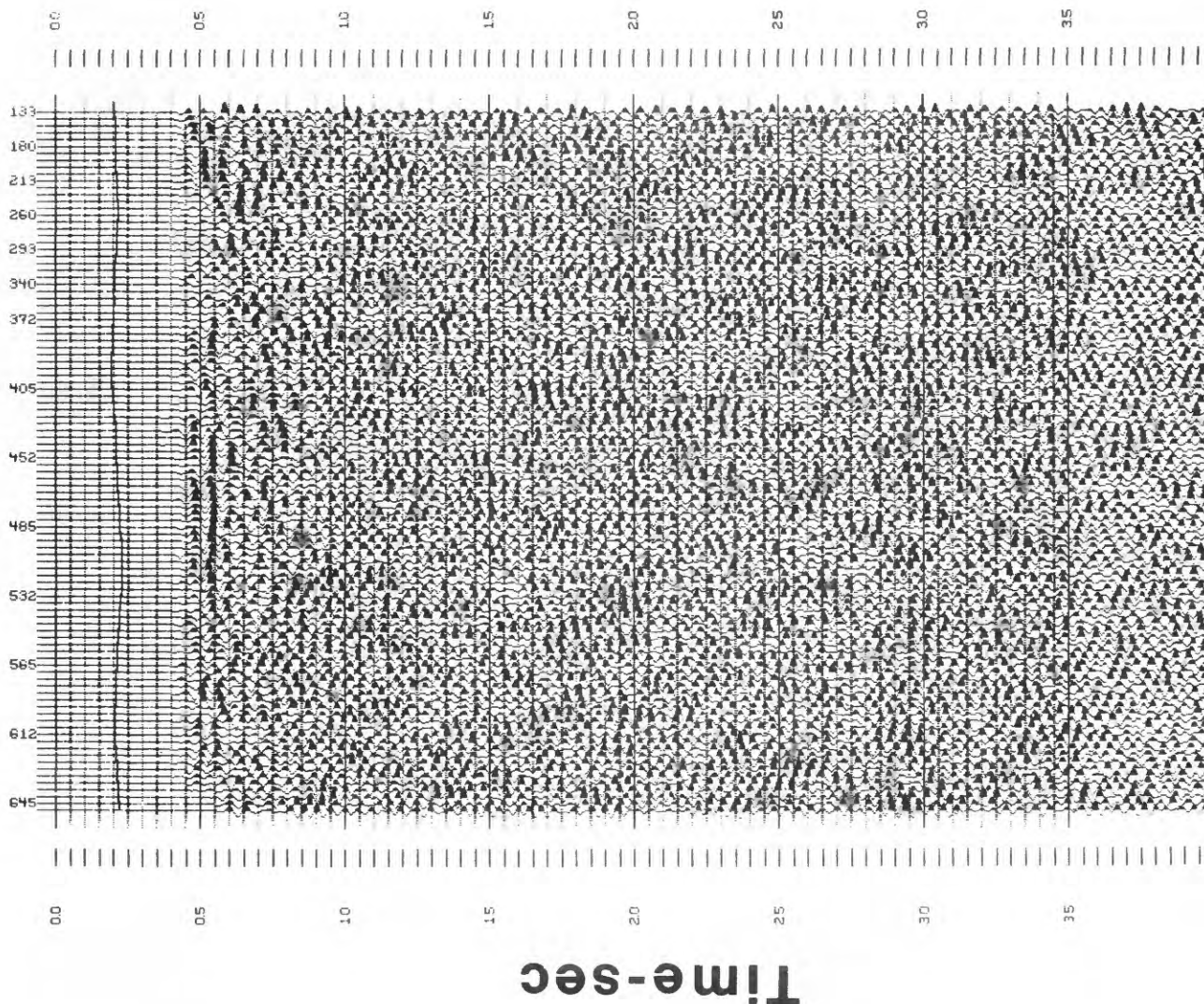


FIGURE 30

DEPT OF ENERGY FENIX & SCISSON

U S G S

YUCCA MOUNTAIN AREA
NEVADA TEST SITE NYE COUNTY, NEVADA

W-4 OPTIMUM PROFILE (105'CDP)

FIELD ACQUISITION
BY SEISDATA SERVICES INC. CREW 003 APR-JUN 1982
96 CHANNEL MDS-10 4 SEC 2 MS FLT OUT-TO-125HZ
30 AREA 8 STATIONS BY 74 ROWS (STA INT 100 FT E/W)
ROW INTERVAL (N/S) 105FT TO STA 364, THEN 210 FEET
RECEIVER STATION MATRIX 8-BY-12 SOURCE 8-BY-1
SOURCE MATRIX OFFEND 840FT TO NEAR RECEIVER ROW
96 LRS1000 10 HZ GEOPHONES/STATION (SET UP N-T0-S)
ARRAY 1 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
THE SEISMIC SOURCES PRIMACORD CHARGES AND VIBS
3FT PC AT 4FT 11 12 22 HOLE ARRAY SFT 1 18FT INT
3 VIBS 037 5FT (8 PGS 912 5FT) 18 SUEEPS-VIB = 54
ARRAY 1 2 3 4 5 6 6 6 4 3 2 1 NORTH/SOUTH
LENGTH 162 5FT (DOUBLED FOR 210FT ROWS) 16-62 HZ
16SEC RECORD 12SEC SUEEP TOTAL TECHNIQUE = 6808
STATION 101 TO 692 PROGRESSES NORTH TO SOUTH

PROCESSING INFORMATION
SEPTEMBER 10, 1982
REFERENCE DATUM +5000 FT VCCORR 8000 FT/SEC
DEMULIPLX SEG-B TO SEG-Y RECORD 1 TRACE EDITING
CDPS GATHERED NORTH-SOUTH IN 105 FT INTERVALS
RESAMPLE TO 4 MS BANDPASS FILTER 10 TO 30 HZ
DIGITAL AUTOMATIC GAIN CONTROL (AGC) 500MS OPERATOR
NORMAL MOVEOUT (2-HAZ TIME IN MS - RMS VELOCITY)
100-6000 480-8000 600-9000 1200-10800 2000-13000
CDP STACKING (OPTIMUM PROFILE FOLD 384)
BANDPASS FILTER 10-36 HZ DIGITAL AGC 1000 MS LEN

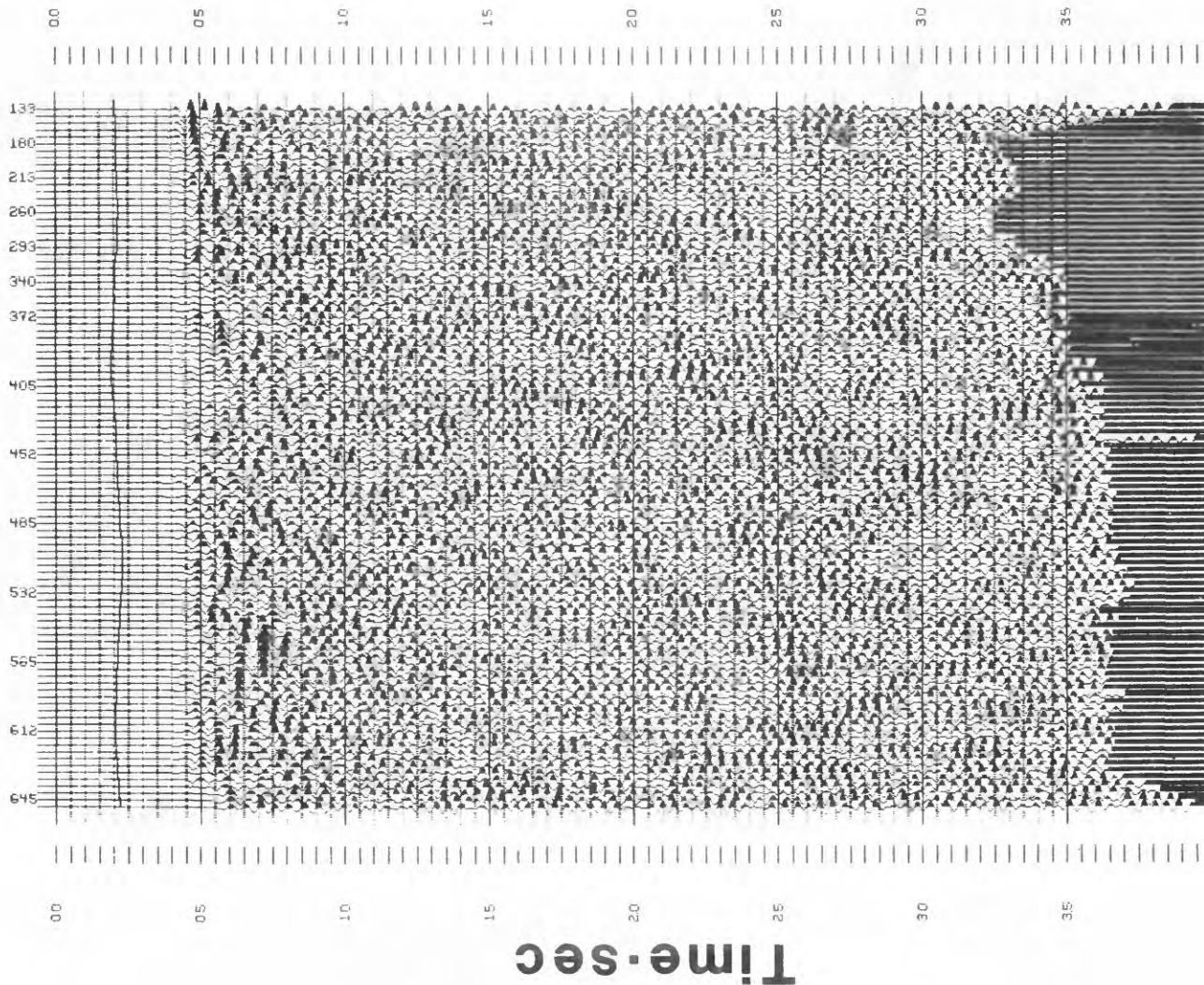


FIGURE 31

DEPT OF ENERGY FENIX & SCISSON

U S G S

YUCCA MOUNTAIN AREA
NEVADA TEST SITE NYE COUNTY, NEVADA

THREE-D LINE G-2 STACK

FIELD ACQUISITION

BY SEISDATA SERVICES INC. CREW 003 JUNE 1982
96 CHANNEL MOS-10 INSTRUMENTS 4 SECONDS 2 MS
FIELD FILTER 12 TO 125 HZ REC MADE WAS GP IFF
96 LRS1000 10WZ GEOPHONES PER GROUND STATION
RECEIVER MATRIX 4-BY-24 100 FT STATION INTERVAL
SINGLE HOLE DYNAMITE SHOT 10-25LB 195/200FT DEPTH
SOURCE OFFSET 400FT TO NEAR RECEIVER, 2700FT FAR
STATION 101-240 SE/NE SHOTPOINTS 1-19 SE/NE

PROCESSING INFORMATION

SEPTEMBER 10, 1982

REFERENCE DATUM +5000 FT VCORR 8000 FT/SEC
DEMULIPLX SEG-B TO SEG-Y RECORD & TRACE EDITING
ARRANGE TRACES TO THREE-D COMMON DEPTH POINTS(CDP)
RESAMPLE TO 4 MS BANDPASS FILTER 10 TO 30 HZ
DIGITAL AUTOMATIC GAIN CONTROL(AGC) 500MS OPERATOR
NORMAL MOVEOUT (2-WAY TIME IN MS - RMS VELOCITY)
100-6000 480-8000 600-9000 1200-10800 2000-13000

CDP STACKING (MAXIMUM FOLD 92)

1ST DISPLAY FILTER 10-36HZ DIGITAL AGC 1000MS
2ND DISPLAY TIME SERIES INTEGRATION

Time - sec

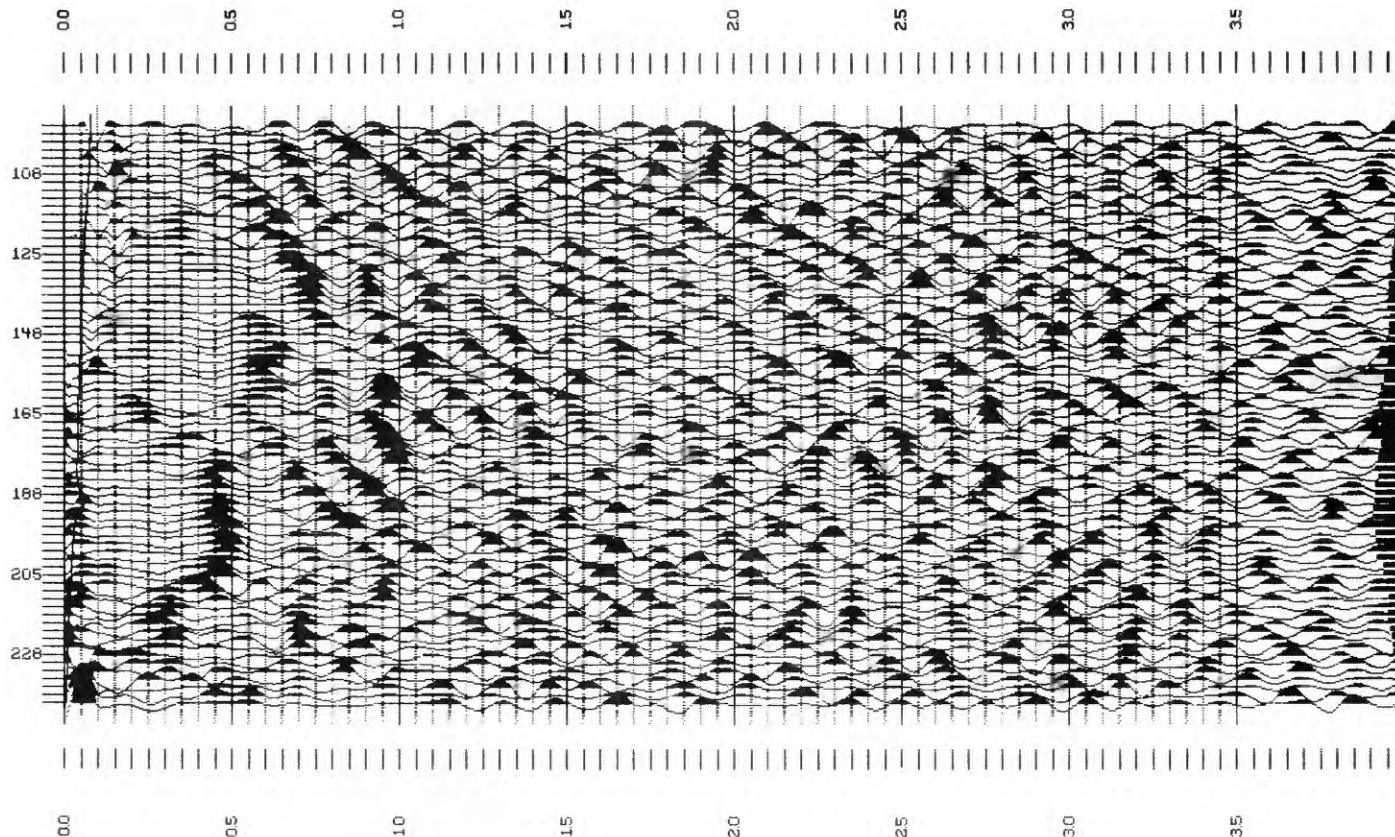


FIGURE 32

DEPT OF ENERGY
FENIX & SCISSION

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YUCCA MOUNTAIN AREA
NEVADA TEST SITE NVE COUNTY, NEVADA
THREE-D LINE S-2 STACK

FIELD ACQUISITION
BY SEISDATA SERVICES INC. CDEM 003 JUN-JUL 1982
300 AREA 5 (V) 1000 1000 1000 1000 1000 1000
RECEIVER STATION MATRIX 8-21-15 (80 TOTAL STA)
VECTING PULSE SOURCE MATRIX 8-21-1 (80000 450 FT)
STATION 001 TO 811N 1000000 1000000 1000000
PACKAGING INFORMATION
REFERENCE DATUM 45000 FT. RECORD 80000 FT. REC
ARRANGE TRACES TO THREE-D COMMON DEPTH POINTS (CDP)
DIGITAL AUTOMATIC GAIN CONTROL (AGC) SOME OPERATOR
NORMAL INVENT 2-HAY TIME IN MS - 4000-15000
200-5000 50-8115 1500-9530 4000-15000
PST-TWENTY NINE 150000-1000000 DATUM STATION
CDP STACKING (MAXIMUM FREQ 297)
BANDPASS FILTER 10-30 HZ DIGITAL AGC 1000 MS LEN

FIGURE 33

56

DEPT OF ENERGY
FENIX & SCISSON

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YUCCA MOUNTAIN AREA
NEVADA TEST SITE NYE COUNTY, NEVADA
THREE-D LINE 5-4 STACK

FIELD ACQUISITION
BY SEISDATA SERVICES INC. CDEU 003 JULY 1982
96 CHANNEL RDS-10 4 SEC 2 MS FILTER 12 - 62 HZ
30 AREA 6 STATIONS BY 126 RMS 50 FT STATION INT
12 LPS/1000 10 HZ GEOPHONES STATION 9 FT INTERVAL
12 LPS/1000 10 HZ GEOPHONES STATION 9 FT INTERVAL
VECTER PULSE SOURCE MATRIX 6-B-1 (88FT/1000 FT)
56 IN DC BURIED 0.18 IN 7 HOLE ARRAY 16 FT SPACING
STATION 101 TO 855 NORTHWEST-TO-SOUTHEAST

PROCESSING INFORMATION
SEPTEMBER 10, 1982
REFERENCE DATUM +5000 FT VCOFF 8000 FT/SEC
DEMULIPEX SEC-8 TO SEC-9 RECORD & TRACE EDITING
ARRANGE TRACES TO THREE-0 COMMON DEPTH POINTS (CDP)
DIGITAL AUTOMATIC GAIN CONTROL (LCC) RMS OPERATOR
EARLY MUTING AND AIRMAVE SUPPRESSION MUTING
NORMAL MOVEOUT (2-MAY TIME IN MS - RMS VELOCITY)
500-5000 320-8125 1320-9530 4000-15000
POST-MOVEOUT RATE (500MS/100MS) DATUM STATION
CDP STACKING (MAXIMUM FOLD 288)
BANDPASS FILTER 10-36 HZ DIGITAL AGC 1000 MS LEN

FIGURE 34

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TIME

YUCCA MOUNTAIN

3-D

TIME SLICES

LINE S-2

NORTH

FIG 35

SCALE 1" = 1000

