SSC-SR-1137

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Project No. 87-888-0022
Report No. SSC GR-78
September 1990

TECHNICAL MEMORANDUM

SEISMIC REFLECTION INVESTIGATION C-1 TO F-1 SECTOR SUPERCONDUCTING SUPER COLLIDER

prepared for:

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August, 1990

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1.0 Introduction

The Earth Technology Corporation ("TETC") has contracted with LCT Houston ("LCT") and its subcontractor, Dobecki Earth Sciences ("DES") to perform a seismic reflection survey along a 16,600 ft ("as performed" line length was 16,850 ft on the ground surface) segment of the Superconducting Super Collider (SSC) ring west of Waxahachie, Texas (figure 1). The present survey is an extension of an earlier, feasibility survey performed some 1 mile to the south of the present survey (LCT, 1990). The earlier survey established the value of seismic reflection data in this area to define the nature of the Austin Chalk/Eagle Ford Shale contact as well as deeper beds. The continuity (faulting) of this key interface is of crucial importance to the construction planning for the ring tunnel construction - the Austin being a favorable tunneling medium and the Eagle Ford being more difficult.

In a request for proposal, TETC described the current 16,600 ft segment to be surveyed in similar fashion to the original (instrumentation, CDP fold, source/receiver type, acquisition geometries, and processing parameters). LCT Houston, in responding to this RFP, has put together a team consisting of LCT project management, DES data acquisition, processing QC, and interpretive expertise, plus the processing services of Entropic Geophysical, Inc. (EGI).

2.0 Site Characteristics

Depth to the Austin/Eagle Ford contact in the earlier survey was on the order of 200 ft; in the current study area the depth to this contact is some 2-50% shallower (depth range from 95-196 ft). The surface materials are, generally, grasses, some treed thickets, some cultivated (corn) fields, and water in cattle stock ponds. The thickness of soils over chalk was much thinner, on average, than at the prior survey site. The typical soil thickness was only about two inches which made shallow drilling for shotholes nearly impossible without a portable rockbit drill. Thicker soils and deeper Austin weathering were encountered in some deeper ravines along several creek runs. This thin soil, coupled with the very dry nature of the soils (also a significant difference from the prior survey), combined to cause our opting to use a surface sledgehammer source as opposed to the use of a "Buffalo Gun" source as on the prior survey (next section). The decision to make this adjustment was based upon the

results of our initial noise survey as well as periodic comparisons made during our production phase.

The seismic survey was initiated on 19 June, 1990 during an abnormal heat wave in north Texas. Temperatures were typically in excess of 100° F which prompted the seismic crew to start operations in early morning hours. Cultural interference included the cited stock ponds, an operating dairy with many hundreds of cows, but minimal road traffic interference. Other sources of site noise included significant airplane traffic and wind noise in the higher grasses and forested areas. The field data acquisition phase was completed on 29 June, 1990.

The northern third of the line was situated in heavy trees and undergrowth with steep sided ravines. In these areas, it was more practical to utilize the Buffalo gun seismic source which did not involve the swinging of a heavy sledgehammer in an area of very limited access,

A normal day of data acquisition accomplished, on average, 2000 ft of line shot with 600 % (6-fold) CDP coverage. This is in exact agreement with projected estimates cited for production rates in the final report from the initial survey.

3.0 Survey Parameters

Data were acquired in a "6-fold CDP" manner using a twenty-four channel seismograph, single 40 Hz geophones, and using nine stacked (repeated) sledgehammer blows on a steel plate as the seismic energy source. Figure 2 shows the ground setup of relative shotpoint/geophone positions. Every shotpoint (except a few in deep brush as cited previously) consisted of nine stacked hammer blows at a point 60 ft from geophone location #1. Each of the twenty four geophones was at a ten ft spacing, and consecutive shots were located at twenty ft intervals (figure 2). Figure 3 is a typical, raw seismic shot record. It is characterized by:

- clear first break arrivals representing refractions from the competent Austin chalk.
- a strong, high speed Rayleigh wave (ground roll)
- shallow reflections which are overidden by the ground roll
- deeper reflections which are typically lower in frequency content than the shallow reflections and the ground roll.

These were the same characteristics as data acquired in February except that the overall frequency content is less consistent across

the lines. That is, in some areas (southern part of the line or very thin soil cover), the high frequencies observed in the early survey are reproduced. In the more deeply weathered areas (near creeks), the overall record frequency content is dominated by the lower frequency end of the spectrum. The apparent controlling influence in determining the bandwidth observed on a given shot record is the thickness of the dry soil. For example, along one stretch of line where a artificial dike was constructed, seismic energy from hammer blows was severely diminished as is typical over deep fill. The thickness of the dike materials was only on the order of six feet, so its effectiveness as a moderator of frequency in the resulting section is rather significant. Similar statements can be made regarding the dry soil thickness; when we shot on outcrop or very thin soils, our bandwidth was maximized.

4.0 Processing Sequence

Processing of the shot files of seismic data were accomplished in the Houston offices of Entropic Geophysics, Inc. (EGI) under the direct QC supervision of Dr. Thomas L. Dobecki (DES). The sequence of processing is listed in the Title Block of the attached processed sections (figures 4 and 5) and is essentially the same sequence as followed during the processing of the original data set. In very broad terms, the processing accomplished a) removal of noise sources (e.g. the Rayleigh wave), b) increasing the resolution (sharpening the recorded wavelet), c) adjustment for time shifts due to topography and irregular weathering, d) a geometric combination of separate records to increase signal levels (CDP stack), and e) production of a final polished record section.

5.0 Results

5.1 General Observations and Interpretive Strategy

The processed section for line C1-F1 is presented in several formats. A larger horizontal scale (1" = 75') version of uninterpreted section is folded and included in a separate pocket. Smaller scale (1"=200') versions of both an uninterpreted as well as interpreted section of the line are folded and included within the report. The larger scale version is useful for removal and for working on at a large table. The smaller scale versions are useful for illustrating the interpreted structural results. In addition,

individual, distinct structural zones are presented on single sheet figures for ease of discussion within this report.

Overall, there are some obvious differences between the results of the initial feasibility survey and the present section. Key differences include:

- less clarity at the Austin/Eagle Ford (A/E) interface.
- less amplitude at the interpreted Base of Eagle Ford (BE).
- reduced amplitude on the very deepest reflections.

The same basic reflections are there, but they are not always as clear or as strong as before. The principal reasons for these differences lie in a) differences in sources used, b) differences in ground conditions, and c) differences in depth to the A/E. The first two reasons are inseparable - the source and how well it couples to the ground determines the attenuation and frequency character of the resulting sections. The very dry ground caused both the hammer and the Buffalo Gun to have less effective power at higher frequencies than we established during the prior survey; this reduced the energy seen at depth and therefore the reflection amplitudes. A key factor in determining the clarity of the A/E is its reduced depth. In areas where the depth to the A/E is similar to the prior survey, the comparable sections tie very well. In other areas where the A/E is at 50% (95') of its depth at the other site, the A/E event is very poor. This is an unavoidable feature of reflection surveying; the shallower a target becomes, the more it becomes immersed in noise generated at the shotpoint (refractions, Rayleigh wave, and air wave). So, for the very shallowest parts of the line, the A/E event is degraded by having fewer usable traces to combine for the stacked section. Although degraded in quality in specific segments, the seismic section (Figure 4 - processed section; Figure 5 - interpreted, annotated section) does reproduce the desired cross-sectional information: the A/E interface, intra- Eagle Ford reflections, base Eagle Ford, and the strong deeper reflections from below the Eagle Ford. The interpretation (Figure 5) is based upon the continuity of these individual reflections and tieing the reflections to the shallow boreholes and sonic logs located along the line.

For example, based on the sonic log from boring B-1677, the A/E contact is at 151 ft. The velocity of the Austin above is approximately 10,000 ft/sec; the velocity below (EF) is approximately 6,250 ft/sec. There is approximately 5 ft of soil and weathered chalk at the surface (assumed average velocity = 4,000

ft/sec). The predicted arrival time of the reflection from the A/E at this point on the reflection section (figure 5) would be:

$$Tr = 2 \times (5/4000 + 146/10000) \text{ seconds} = 0.032 \text{ seconds.}$$

This point is plotted on figure 5. If we further assume that the Eagle Ford is 355 ft thick in this area (Dale Hennon, personal communication based upon water well driller logs), then we can predict the approximate reflection time for the Base Eagle Ford as being

$$\Delta TBE = 2 \times (355/6250) \text{ seconds} = 0.114 \text{ seconds}$$

after the A/E or, at a total reflection time of 0.146 seconds. This point is also marked on figure 5. Doing a similar exercise at each point where a boring log and sonic values existed, we are able to tie the reflection times to depth. In addition to the various geologic contacts, DES has also placed the time-depth to the tunnel centerline on the interpreted seismic section.

By following the continuity of a specific reflection, we are able to detect dip changes or fault offset of that bed. To determine the throw or actual vertical offset of a feature, we first measure the time offset, ΔT.
The amount of offset, ΔZ is then

$$\Delta Z = \Delta T/2 \times VBAR$$

Where VBAR is the average velocity of the materials above the horizon which is offset. If the offset is the A/E, then VBAR = 10,000 ft/sec. If the horizon is the BE, then VBAR is some value between 6,250 and 10,000 ft/sec.

5.2 Structural Interpretation.

Firstly, we are impressed by the interpretation that there are few zones along the line which exhibit significant disruption - these tend to occur in distinctly separable groupings ('structure zones'). The beds, deep and shallow, show fairly consistent shallowing to the North becoming nearly horizontal near SP2100 (B1662). These dips are consistent with sections provided by TETC based upon boring logs.

We have, however, interpreted three zones of possible faulting or disruption which are described, as follows, progressing along section from South to North. Each faulted segment has been cut

from the entire section and is re-produced as a separate figure. The structural interpretations presented here are the result of an initial interpretation prepared by DES and reviewed and modified by TETC based on their understanding of geologic style in this area and upon the most up to date borehole results.

5.2.1 Zone 1 (SP 1130-1150; CP1567 & C1572). This disrupted segment (figure 6) exhibits displacement of the A/E and possibly the BE (Austin - Eagle Ford and Base Eagle Ford) reflection events. One fault (with question marks) is put on the section of figure 6 as an example structure. A/E displacements (individual) are on the order of 4 milliseconds or approximately 20 ft.

5.2.2 Zone 2 (SP SP 1670-1720; B1619, B1622). This zone (figure 7) shows numerous breakups of the A/E contact while the interpreted BE is rather continuous. Several small faults are seen; overall, the northern portion (e.g. B1637 area) appears to show a net deepening as compared with the southern (e.g. B1617) portion. This is also indicated from the borehole results. Individual faults show about 10-20 ft displacements while the net south-north displacement of 4 msec (20 ft) is somewhat greater than the 10 ft shown between borings 1617-1637. This feature is referred to as the "SE1 Graben" by TETC.

5.2.3 Zone 3 (SP 2540-2600; B1702, B1707). This final feature (Figure 8) is interpreted as a subtle graben with small displacement (est. < 20 ft). There is questionable offset of the BE event for this feature.

6.0 SUMMARY

Seismic data were recorded along a 3.5 mile segment of the Superconducting Super Collider ring in an area of critical structures and shallow (< 200 ft) Eagle Ford shale. The resulting seismic section, as interpreted, shows fairly distinct and separate faulting features (zones 1 through 3) which are generally grabens or normal faults with displacements on the order of 20 ft. While most faults appear to be contained within the Eagle Ford, some exhibit possible displacement at the interpreted base of the Eagle Ford as well. As with the initial survey done in early 1990, there are numerous deeper reflectors on the section. These show some faulting as well, but there is no clear link between a given fault at depth with the

shallower faults which cut the Austin. They appear to be distinctly separate structures.

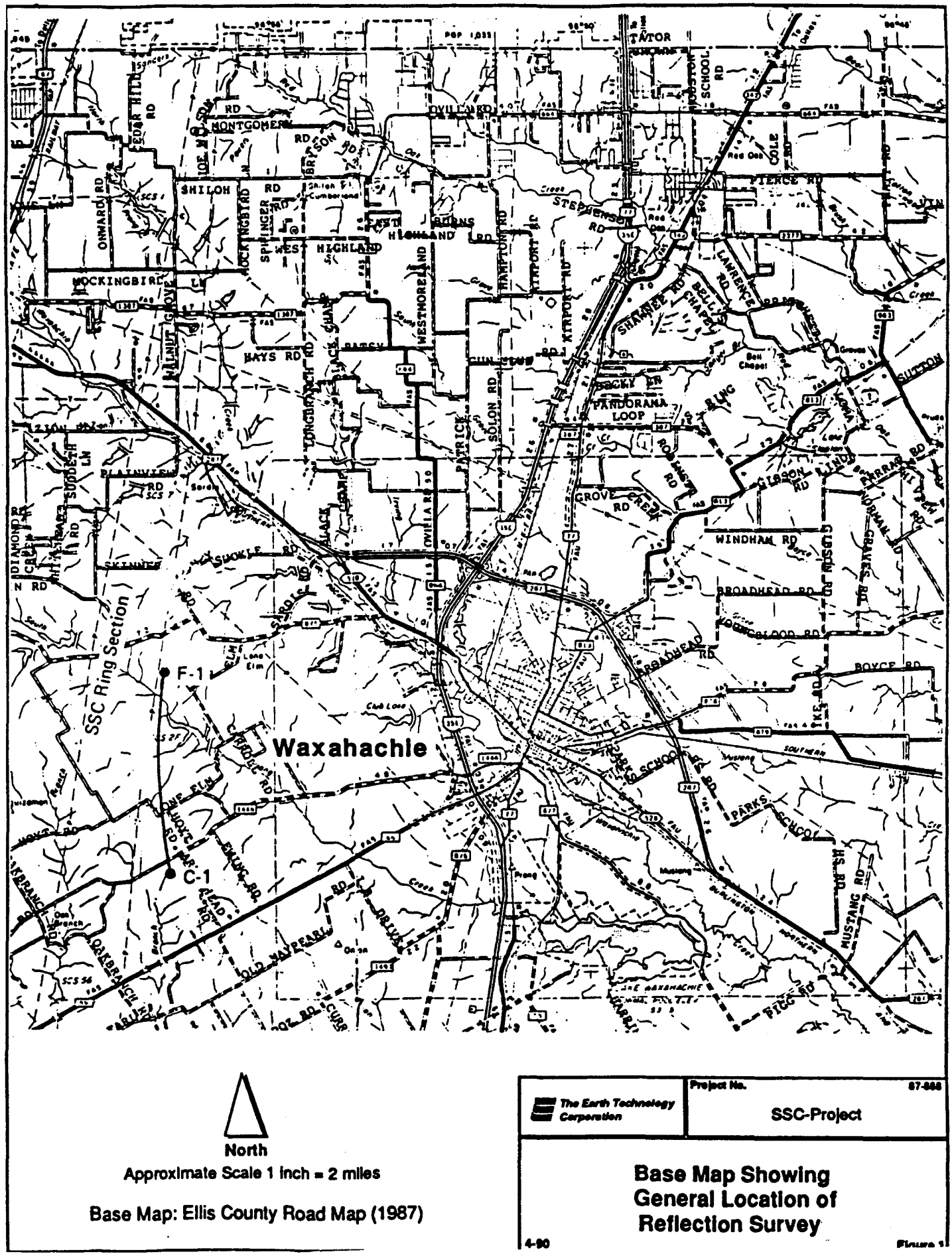

Figure 1 Location of seismic line segment C1-F1.

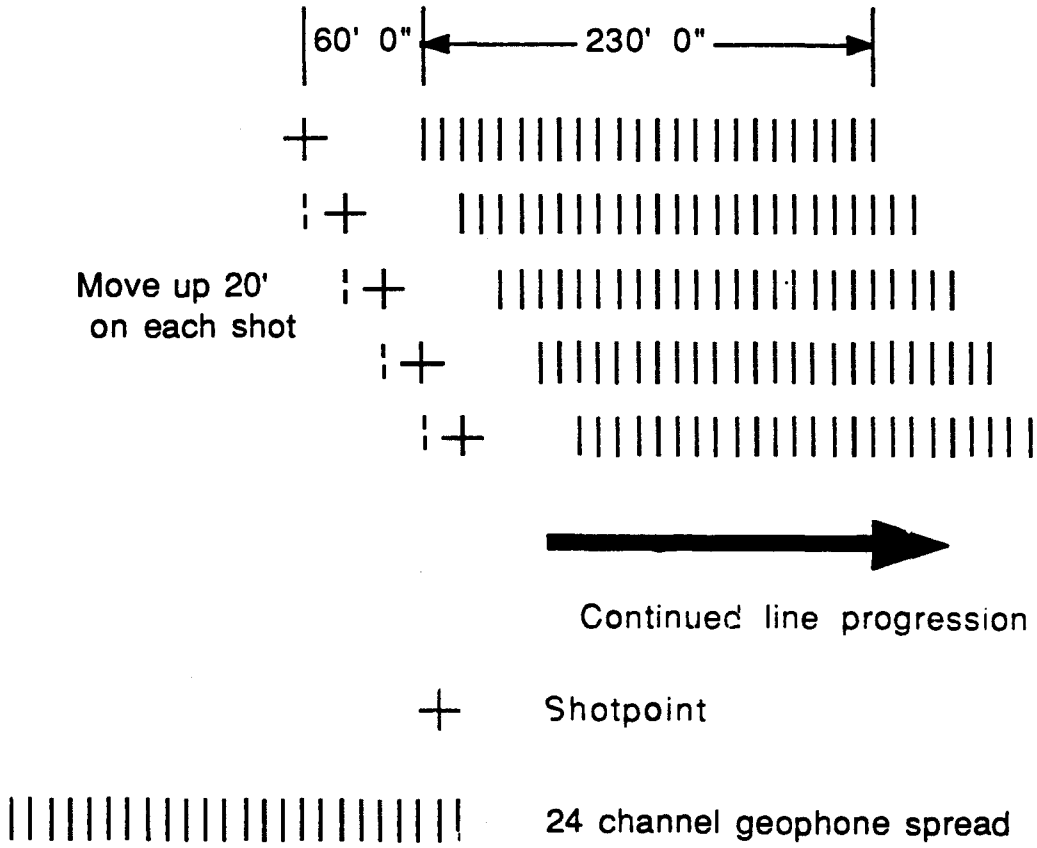

Figure 2 Layout of seismic data acquisition shooting parameters.

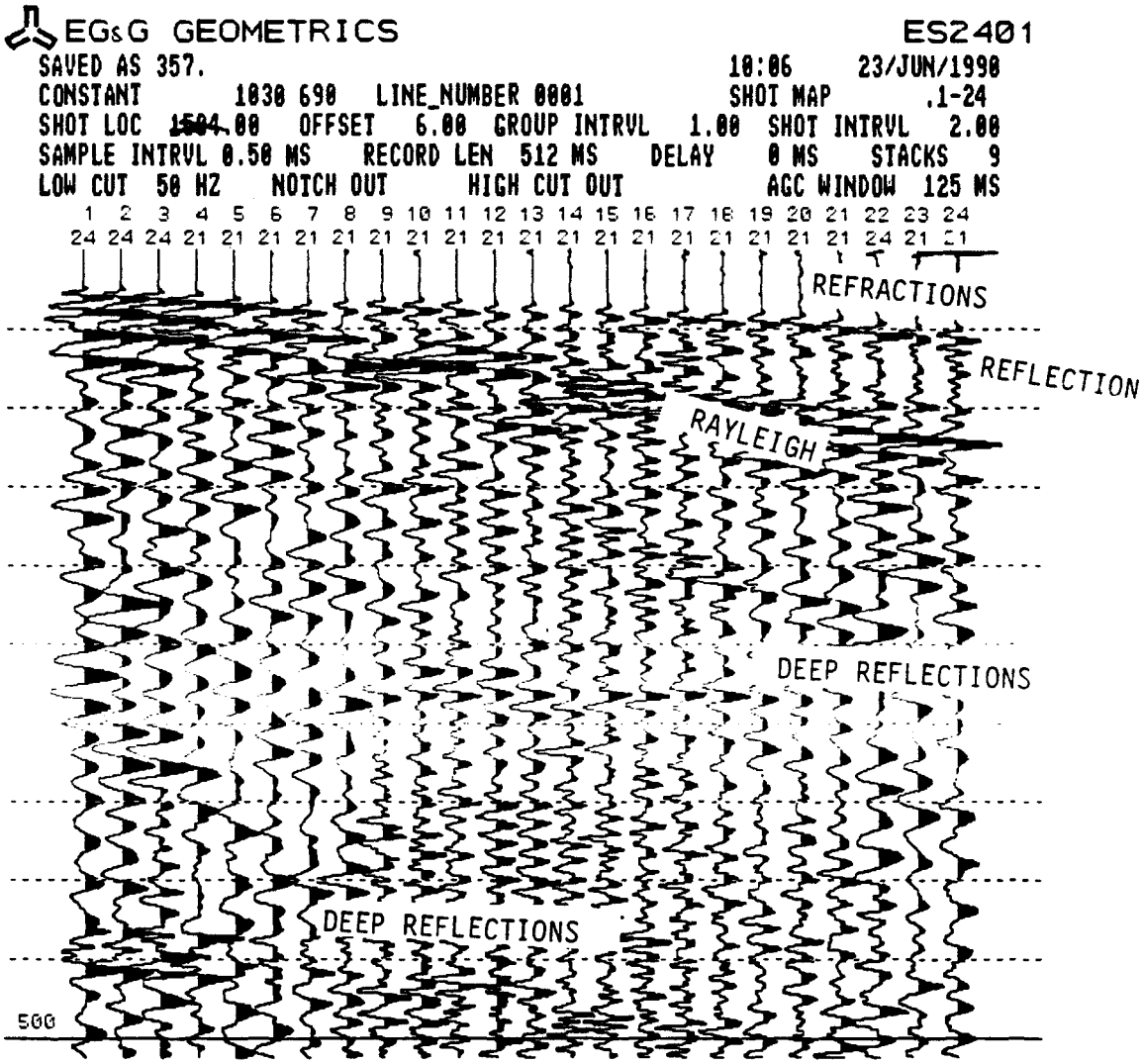

Figure 3 Raw (field) seismic shot recording.

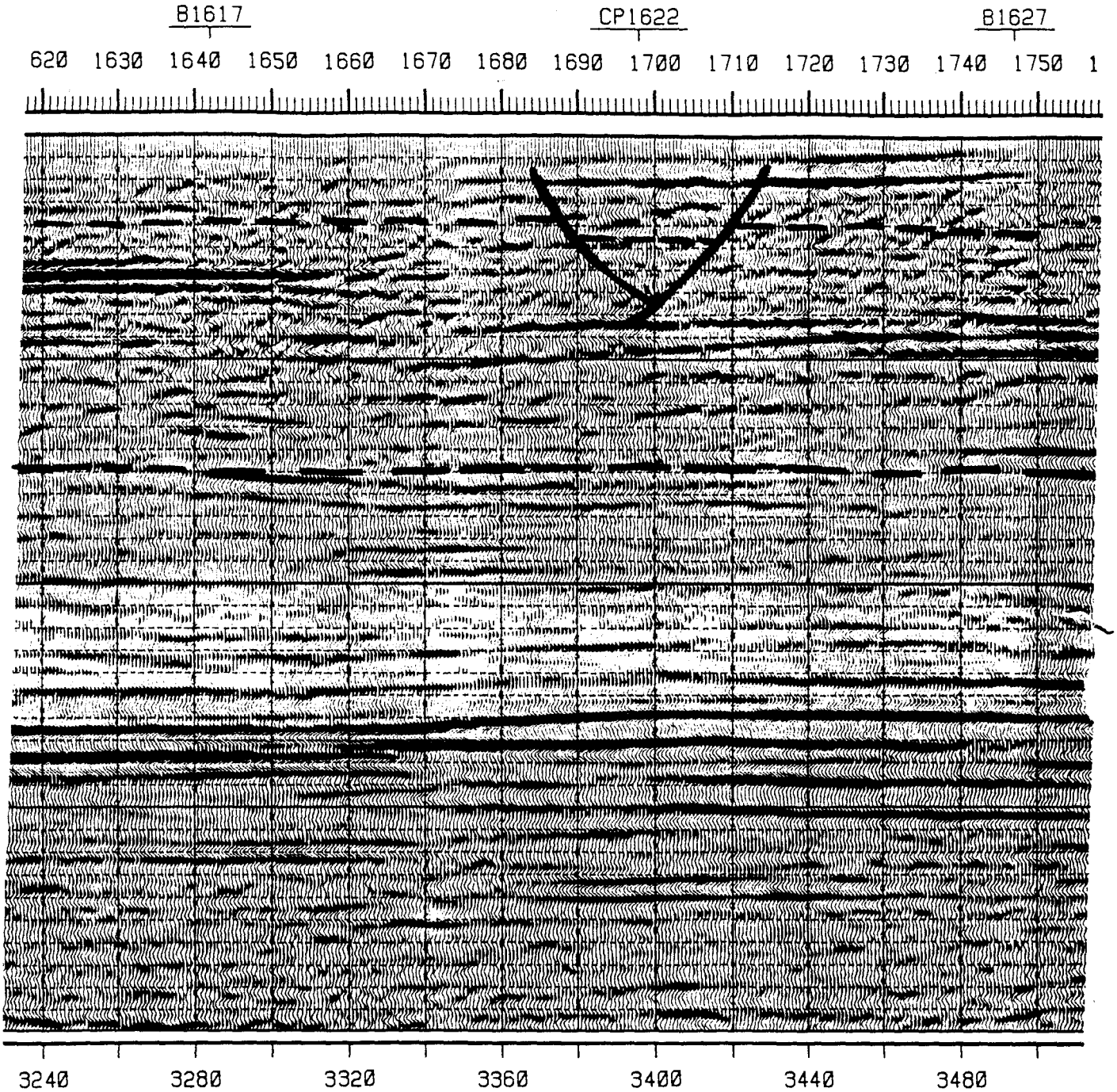

Figure 7 Seismic structural zone #2 ("SE1 Graben").

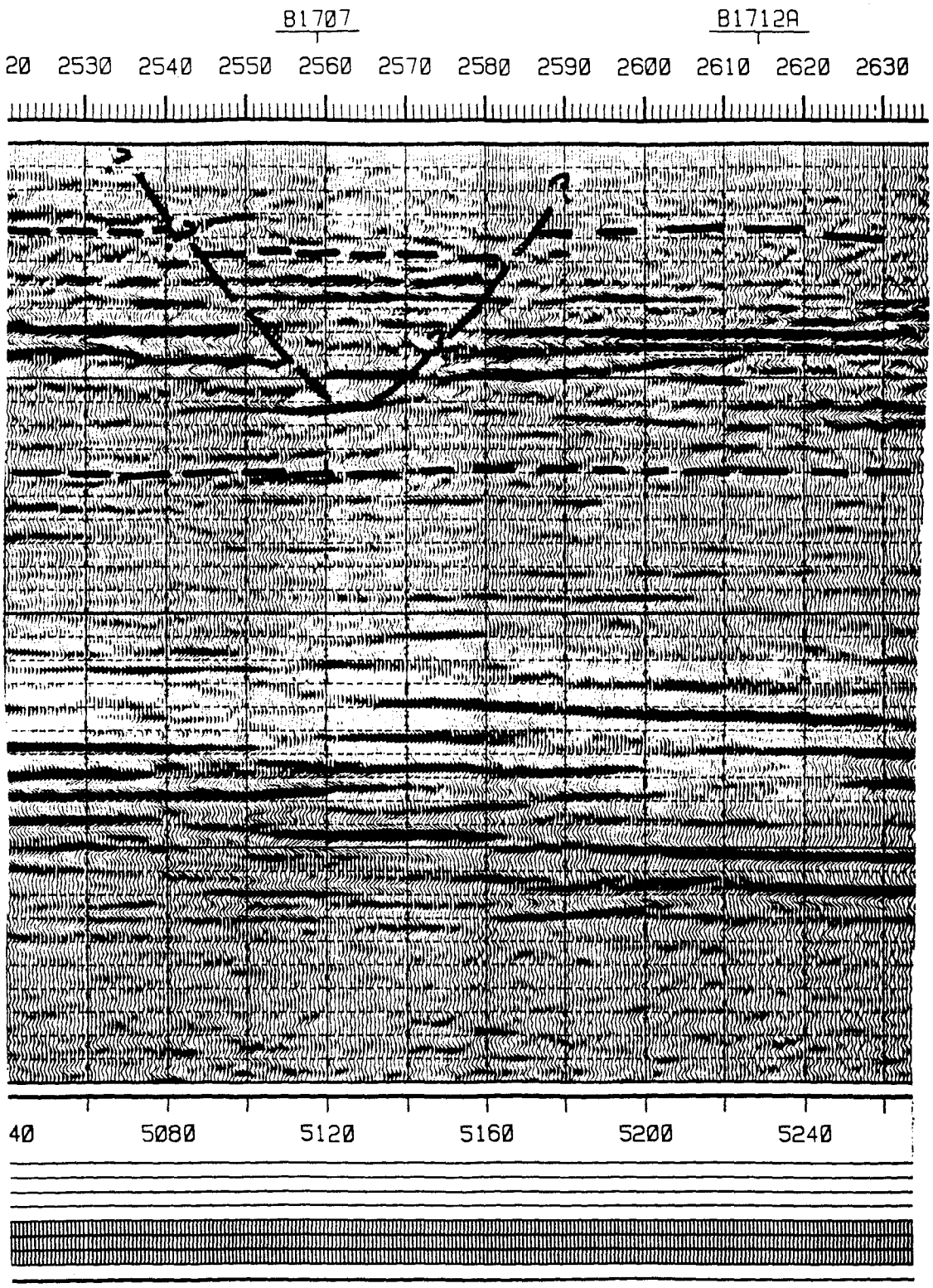

Figure 8 Seismic structural zone #3.