DOE/MC/31224 -- 5075
(DE96000606)

Naturally Fractured Tight Gas Reservoir Detection Optimization

Quarterly Report
April -June 1995

August 1995

Work Performed Under Contract No.: DE-AC21-94MC31224

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
Coleman Research Corporation
Blackhawk Geosciences Division
Golden, Colorado
and
Lynn Incorporated
Houston, Texas

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301 Commercial Road, Suite B
Golden, Colorado 80401
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1642 Fall Valley Drive
Houston, Texas

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1.0 3D-3C

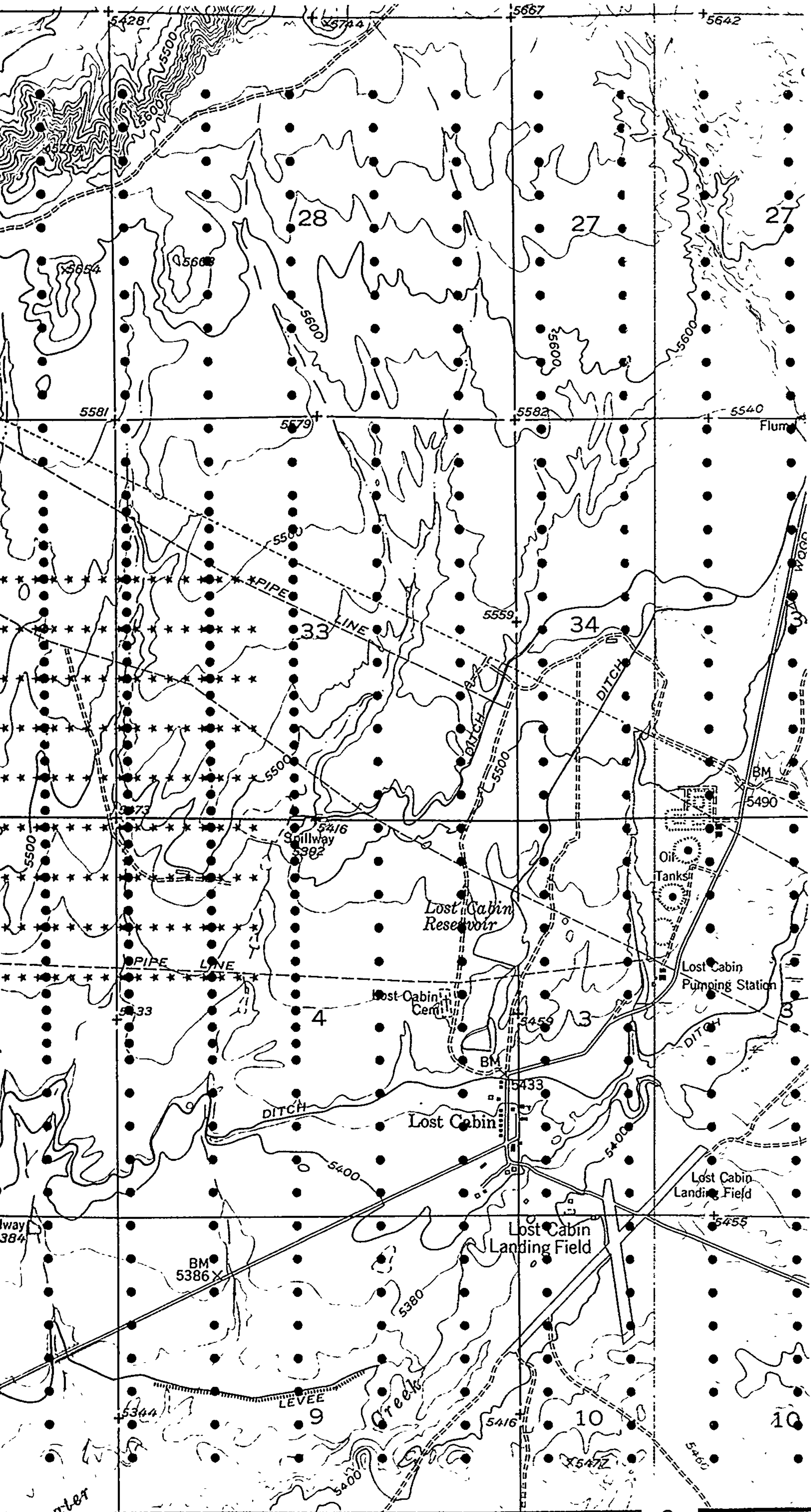
During the second quarter the request for bids for the seismic contractor were sent out. Four companies responded namely, Capilano, Veritas, Geco-Prakla and Northern. A recommendation to use Northern Geophysical was made to and subsequently approved by the DOE. The 3D-3C survey design is described in further detail below. Modeling of the shot/receiver layout was accomplished by Dr. D. Lawton of the University of Calgary and his final shot receiver layout is given in fig 1-1. The offset limits for this survey were planned by Charles Jenkins (Jenkins and Associates) and D. Phillips (Blackhawk).

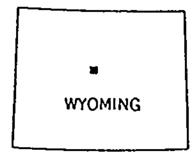
2.0 SURVEY DESCRIPTION

In order to ensure proper offset and azimuth distribution in the P-S converted wave data set, a static patch will be laid and all 3-C receivers will remain live during shooting. Further detail of survey geometry follows:

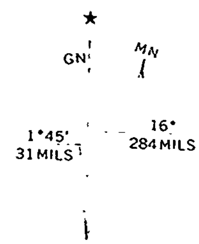
2.1 Receiver Information

Receiver Station Interval:	220 Feet
Receiver Line Spacing:	660 feet
Receiver Array:	Circular, 20 to 30 foot diameter centered on flag
Receiver Stations per Line:	51
Number of Receiver Lines:	9
Number Live Receiver Stations per Line:	51
Number Live Receiver Lines:	9
Receiver Line Orientation:	E-W
Required:	12 3-Component per Receiver Station, Buried
Source Line Orientation:	N-S
Source Line Increment:	1100 feet
Shot Spacing E-W:	440 Outside Receiver Patch, 220 Inside Receiver Patch (see Fig. 3)
Number of Source Lines:	24
Maximum Source Line Length:	18,480 feet
Maximum Number of Shots per Line:	59
Estimated Number of Shots for Survey:	1212

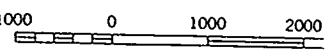




QUADRANGLE LOCATION



UTM GRID AND 1952 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET



SCALE IN FEET

EXPLANATION

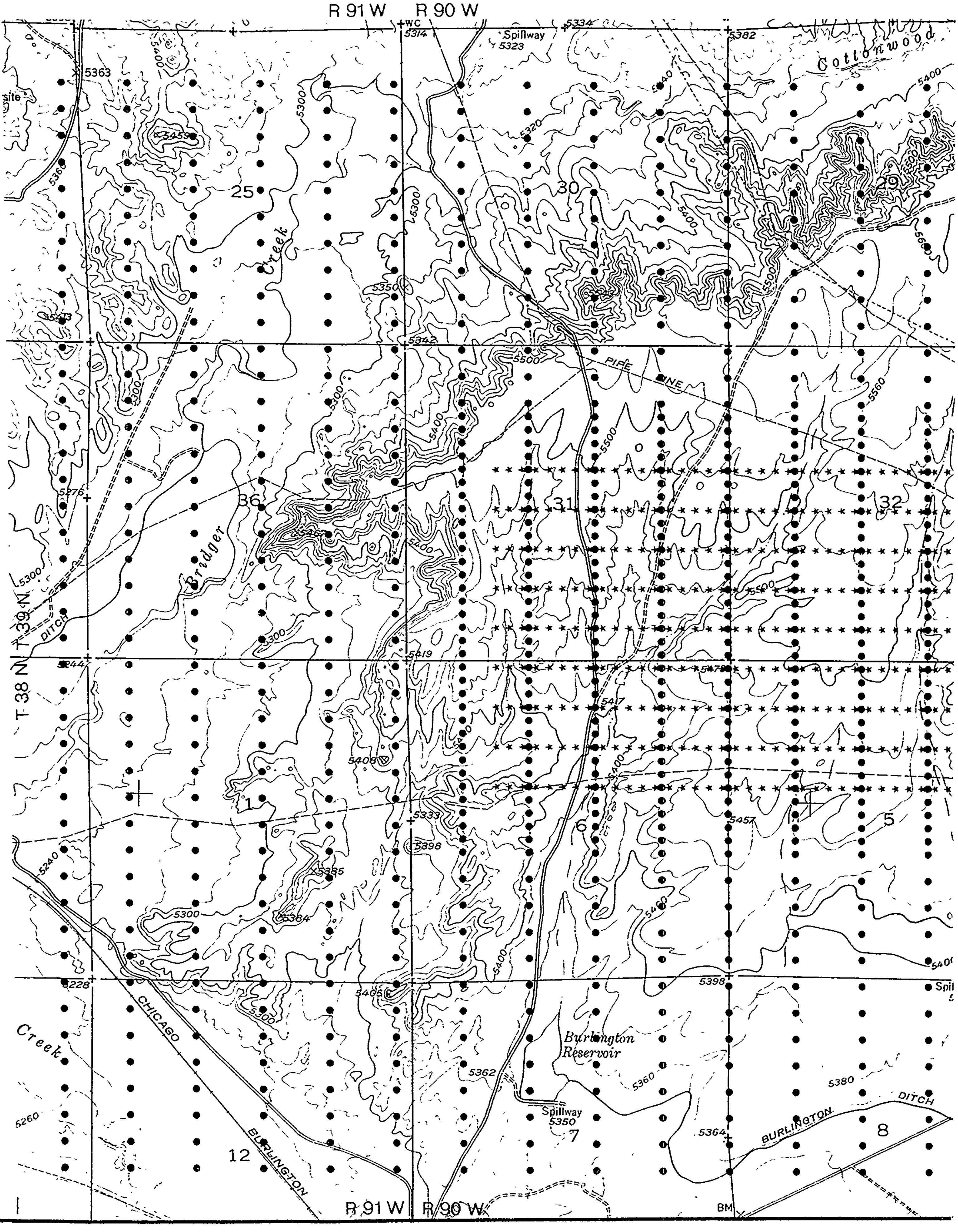
BLUE STARS = RECEIVERS

RED DOTS = SHOTS

SEISMIC SURVEY LOCATION MAP

FREMONT COUNTY, WYOMING

Figure 1–1


R 91 W
R 90 W
Spillway
5323
5314
5334
5382
Cottonwood
5363
5459
5300
5400
25
30
29
Creek
5350
5342
5500
PIPE LINE
5560
5276
36
31
32
Bridger
5467
5300
T 39 N
DITCH
5419
5244
T 38 N
5478
5417
5408
1
6
5
5333
5457
5398
5240
5385
5384
5228
5405
5398
CHICAGO
Creek
Burlington Reservoir
5362
5360
5380
Spillway
5350
7
5364
BURLINGTON DITCH
8
5260
12
BURLINGTON
BM

2.3 Recording Information

Recording System:	24-bit distributed system
Bin Size:	110 by 110 feet
Nominal Fold:	45-Fold P-P; 55-Fold P-S
Recording Channels:	1377 (1473 preferred, See Section 5.1)
Sampling Rate:	2 ms
Record Length:	Dynamite- 8 sec required, 10 sec requested

3.0 SOURCE EFFORT

3.1 Introduction

In 1994, the Owner/Operator conducted a source test to select the source parameters for their 37 square mile, compressional wave 3-D seismic survey. The recorded data from these tests were made available to Blackhawk so that source selection could be made for the unique objectives of the 3-D, 3-C survey to be conducted for the DOE. The primary differences between the owner/operator survey and the DOE survey are given below in Table 1-1.

TABLE 1-1

OWNER/OPERATOR OBJECTIVE	DOE OBJECTIVE
Target depth of 20,000 feet	Target depth of 5,000 to 10,000 feet
Record compressional waves only	Record shear and compressional waves

3.2 Description of Source Test

3.2.1 Setup

The geometry, methodology and source parameters were chosen such that the source parameters yielding the highest data quality at the target depth could be selected. The parameters which were varied for this test were:

1. Depth of shot hole
2. Amount of explosive (charge size) used per shot hole
3. Ground location of test hole patch

The different hole depths and charge sizes tested are given in Table 2-1.

TABLE 2-1

HOLE DEPTH	CHARGE SIZE
10 feet	1 pound 2 pounds
20 feet	1 pound 2 pounds
60 feet	5 pounds 10 pounds 20 pounds
85 feet	5 pounds 10 pounds 20 pounds
110 feet	5 pounds 10 pounds 20 pounds

All of the different shot types were drilled and loaded in a group (called a shot patch) at discreet positions. By placing all shot types in a shot patch, seismic waves are generated at the same position, and different shot types can be compared more easily. The shot patches were located along a line of receivers in the southern portion of the proposed location of the DOE survey.

3.3 General Considerations in Source Tests

A brief description of factors influencing the final choice of source parameters is given below. The advantages/disadvantages associated with each different source parameter are described. These and results are site specific and do not necessarily hold true at every site. A thorough discussion of source testing can be found in the literature.

Charge Size:

In general, a larger the charge will produce more energy, thus yielding useable data at greater depths. Larger charges, however, also tend to produce energy of lower frequency, and reduction of charge size can often deliver a more desirable, higher frequency seismic signal.

Hole Depth:

Deeper shot holes can often reduce the amount of ground roll (ground roll is an undesirable seismic wavetrain evident on most seismic records) produced by a shot. Also, if increasing the depth of a shot hole puts the explosive beneath the water table, higher quality data is often obtained. The benefits associated with shallower holes aré mostly economic, as costs associated with drilling and loading constitute approximately 80 % of the total coat of the source effort.

Use of Different Locations for Shot Patches:

Several different locations are used as shot patches because of the heterogeneity in ground conditions. For instance, at some locations propagation of seismic energy is extremely difficult due to loose, dry conditions in the subsurface. By using multiple locations, an evaluation of the heterogeneity or variations in shot conditions can be made.

Data Display:

By varying display parameters, mutes and gain functions, different aspects of the recorded data become clearer. The test results were delivered to Blackhawk as plots of the recorded seismic records displayed with several different gain functions and muting schemes. The data discussed in this section was taken from un-muted data with a geometrical spreading gain function applied.

3.4 Results

3.4.1 Initial Considerations

The data from the 1 and 2 pound shots at 10 and 20 foot depths was not of sufficient quality to be considered for the 3-D, 3-C survey.

A comparison of all shots using 5 pound charges showed a significant reduction in energy levels from the shots using 10 and 20 pound charges. From this, it was decided that the energy from the 5 pound charges would be too low for the 3-D, 3-C survey. Additionally, several of the 10 pound charges would not detonate in the field, which made comparison of these 10 pound charges to other shots in each patch impossible.

One of the principal unknowns concerning this source test is that only vertical geophones (the geophone recording compressional seismic waves) were used. The DOE survey will employ both vertical and horizontal (the geophone recording shear waves) geophones to record the 3-C wavefield. However, during the Owner/Operator 3-D acquisition of 1994, the shear wave field was recorded with 3-C geophones. The Owner/Operator used 20 pound charges for their acquisition.

Through consideration of the following factors:

- shear energy was recorded during the 3D survey with 20 pound charges
- poor performance with 5 pound charges
- missing data with 10 pound charges
- no apparent frequency loss with increased charge size

It was decided that to ensure sufficient seismic energy a 20 pound charge size would be used for the DOE survey.

3.4.2 Selection of Shot Hole Depth

To select the optimum shot hole depth, the shots recorded with 20 pounds and drilled to depths of 60, 85 and 110 feet were compared at shot patches A, B, and C. The shot records and results of the comparisons are given below. On all shot records (Figures 3-1, 3-2 and 3-3) the horizontal axis represents distance and the vertical axis represents time.

3.4.2.1 Shot Patch A

This location showed the poorest data quality of the three shot patches. The data from the 60, 85 and 110 foot shot holes are shown on Figure 4-1. The area where the most obvious reflectors are present is highlighted in yellow on the figure. There are also deeper reflectors (light blue) evident on the 60 foot shothole record, but less so on the 85 and 110 foot record. As expected, the ground roll (orange) is more pronounced on the records from the 85 and 60 foot holes.

3.4.2.2 Shot Patch B

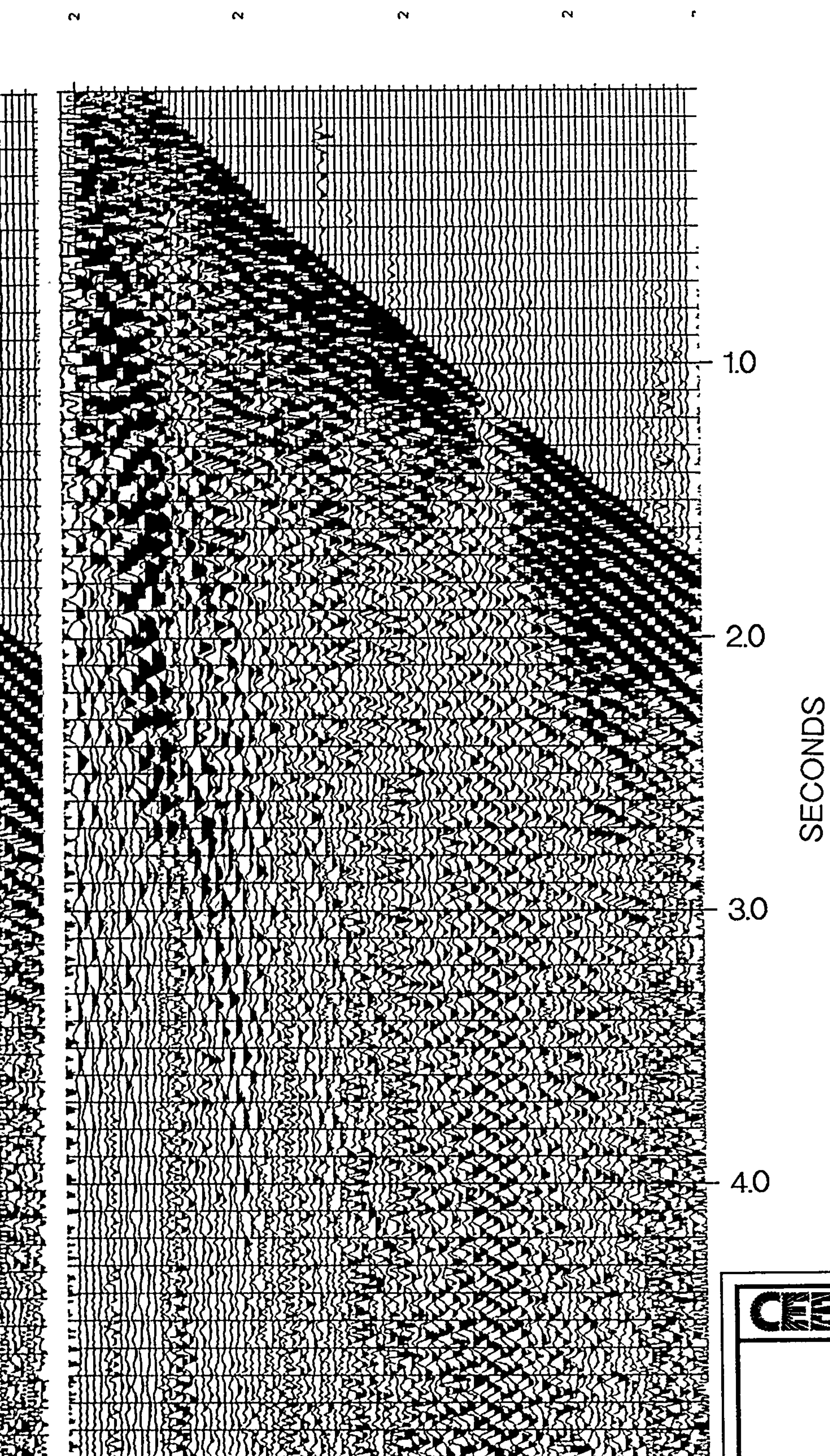
At shot patch B (Figure 3-2) the data quality of the shallow reflectors through the DOE target formations of the Lower Fort Union (yellow) is better than at shot patch A. The reflectors appear to be the clearest in the 85 foot record, but are of good quality on the 60 and 110 foot records as well. The 85 foot record also appears to have the least amount of ground roll (orange).

3.4.2.3 Shot Patch C

Shot patch C is the location which showed the highest reflector quality in both the shallow and middle areas (yellow and pink). Deep reflectors are also seen on the 60 foot record (light blue). The best reflector quality seen on any shot in the source test are shown on the 60 foot shot hole record in Figure 3-3. As with the data at shot patch A, the ground roll (orange) is slightly stronger on the shallower shot holes.

3.5.0 Conclusions

From comparisons of the data, the data quality from the 60 foot shotholes appears to be better or as good as the data from the deeper shotholes. The slightly increased amount of ground roll is not expected to significantly impact the data, and can be compensated for during processing. A shothole depth of 60 feet was selected for the 3-D, 3-C survey. In order to ensure sufficient energy for both the compressional wave and shear wave data sets, a charge size of 20 pounds was selected.



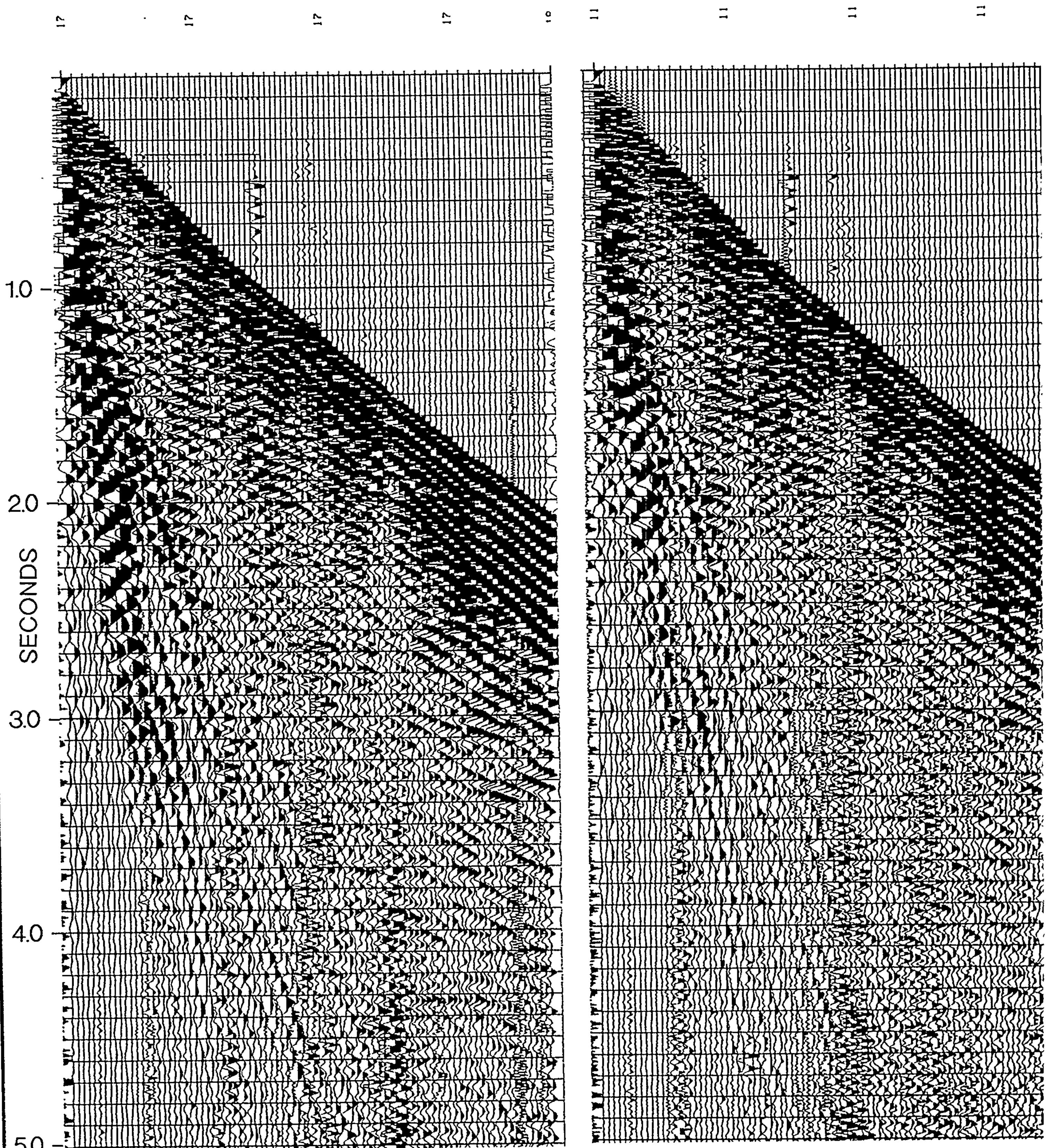
110 ft. SHOT HOLE

CEES BLACKHAWK GEOSCIENCES DIVISION

SHOT PATCH A

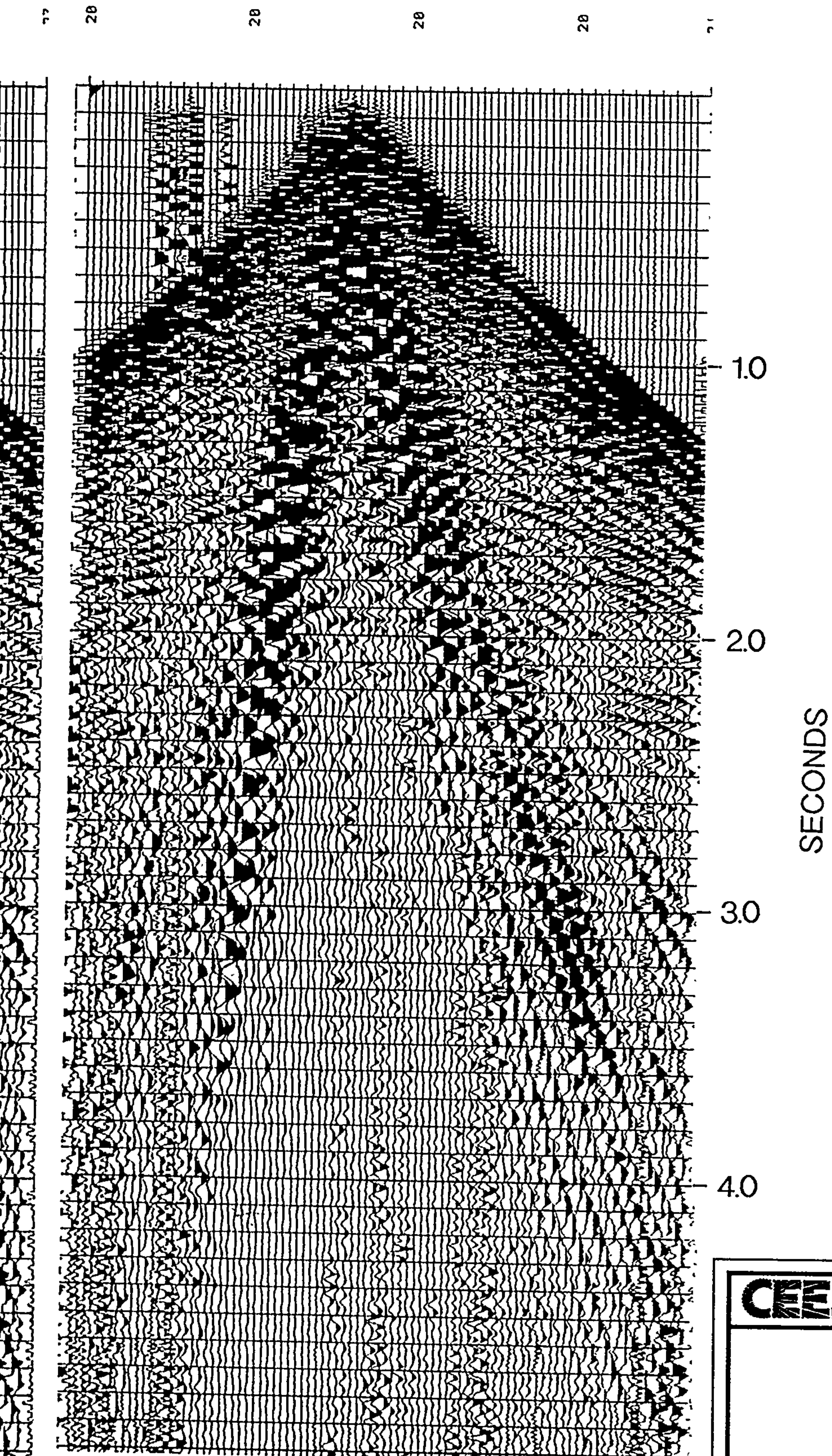
Project 6805

Figure 3-1



60 ft. SHOT HOLE

85 ft. SHOT HOLE



110 ft. SHOT HOLE

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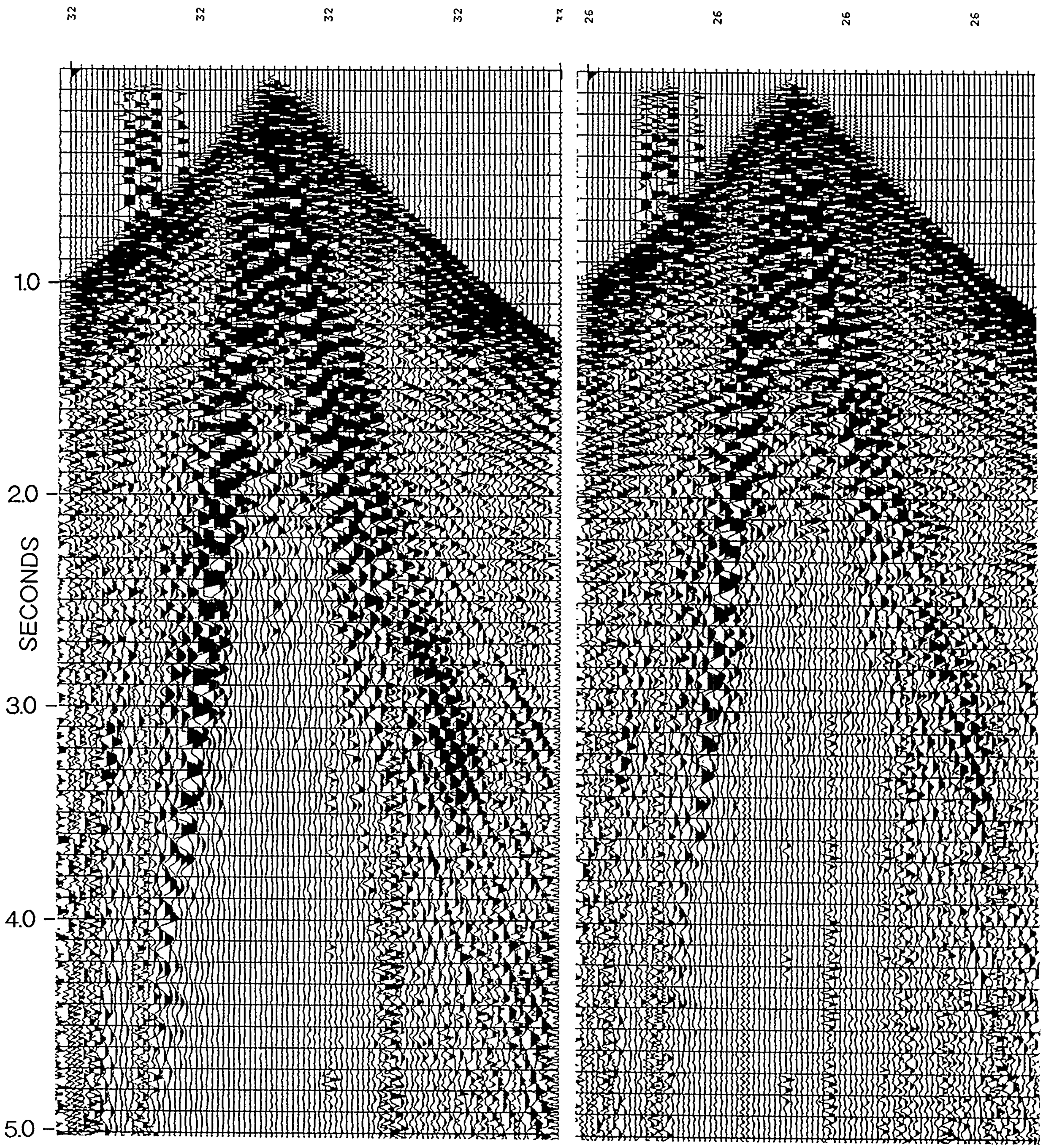
SHOT PATCH B

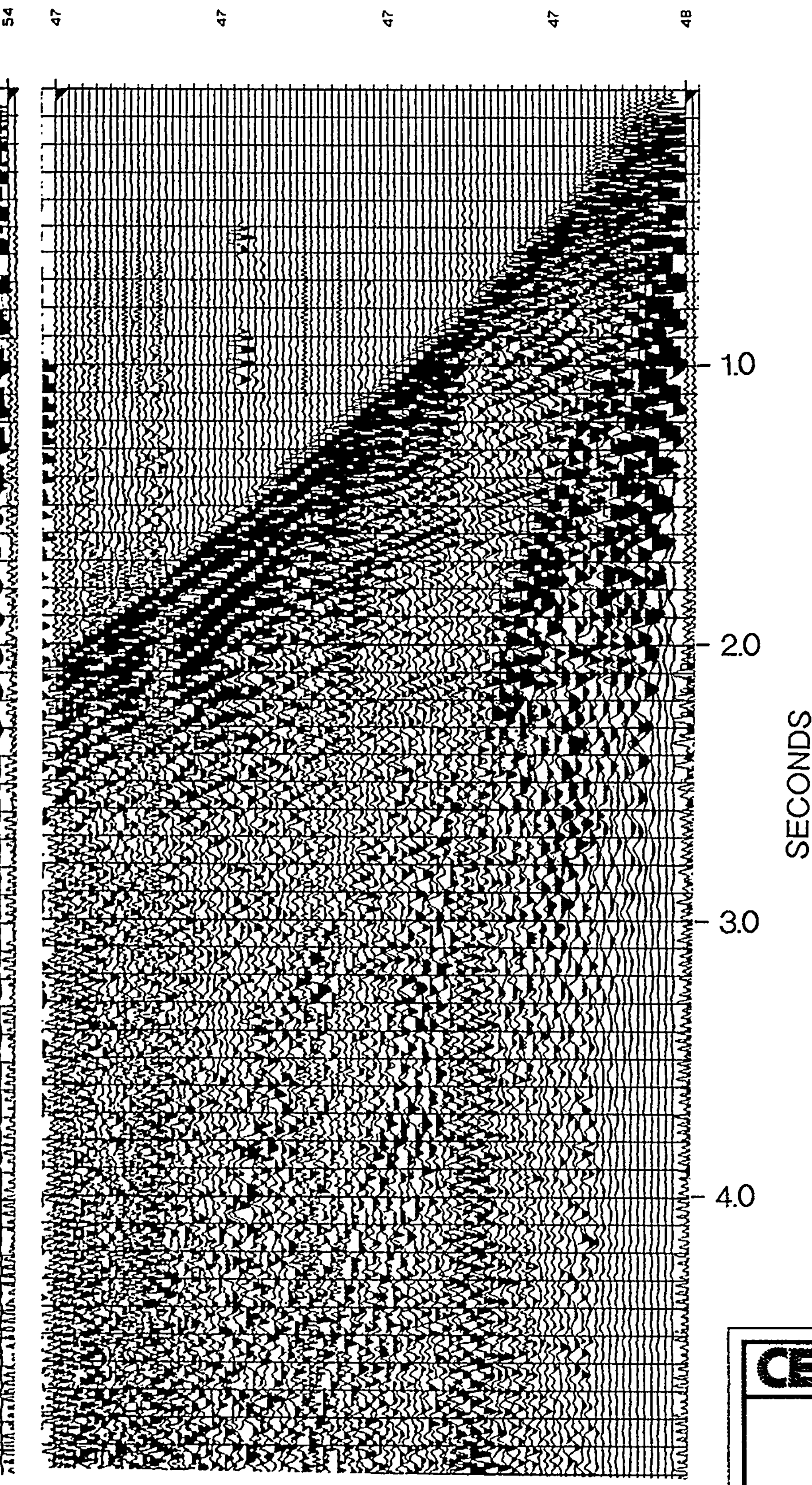
Project 6805

Figure 3-2



60 ft. SHOT HOLE

85 ft. SHOT HOLE



110 ft. SHOT HOLE

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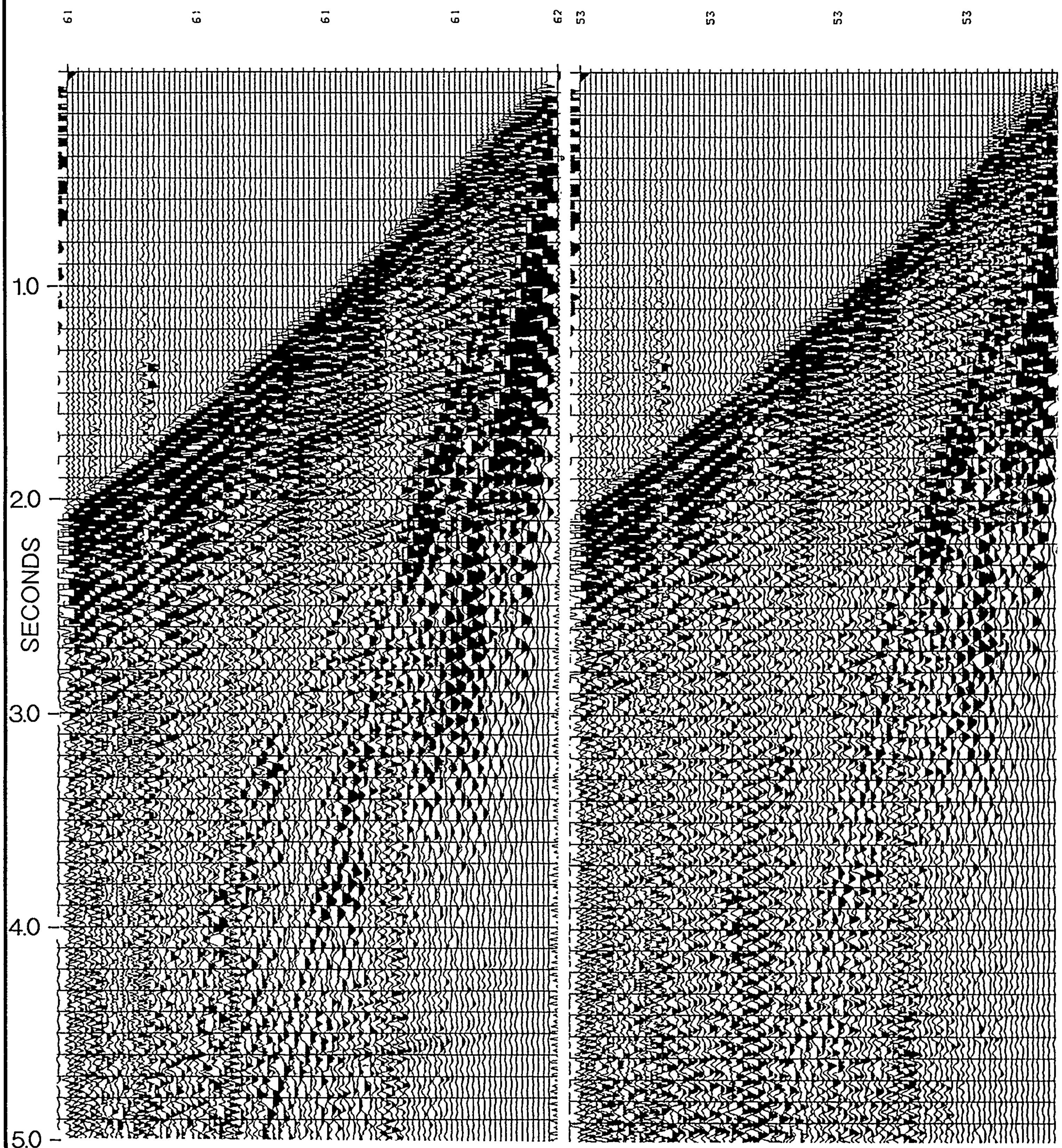
SHOT PATCH C

Project 6805

Figure 3-3



60 ft. SHOT HOLE

85 ft. SHOT HOLE

4.0 ARCHAEOLOGICAL INVESTIGATION

Under Federal law, all land administered by the Bureau of Land Management (BLM) must have an archaeological study performed prior to seismic data acquisition.

Archaeological studies are required by the government to ensure that historical sites on BLM lands are not disturbed or obliterated during activities which can create disturbance of the ground surface. These activities include pipeline burial, building and construction, seismic surveys, etc. Many historical sites have already been discovered in the area of the proposed 3-D, 3-C seismic survey, including a section of the Bridger Trail. During the Archaeological survey, sites of historical significance are clearly flagged so that all vehicular traffic can avoid the area. The only access allowed on an archaeological site is by foot. The sites are also fully described and recorded on maps. These documents are then submitted to the BLM for cataloging.

Scope of Archaeological Work

The study area is shown on the map in Figure 1-1. Private lands are shown in yellow, and state lands are shown in blue. Archaeological studies are not required on private and state lands. During the summer of 1994 a 37 square mile P-wave 3D survey was acquired over some of the same area as the proposed 3-D, 3-C seismic acquisition program. Blanket archaeological studies were performed for this survey, and because of this, previously discovered archaeological sites over much of the area will need only to be re-flagged.

The remaining area (approximately 3640 acres) required a blanket archaeological survey. Mr. Charles Bramley of the BLM supplied a list of contractors licensed to conduct archaeological studies in Wyoming. Using this list, and with the help of Mr. Charles Jenkins of Jenkins and associates (who ran the archaeological study contracting for the 37 square mile 3-D), three contractors were selected to bid on the archaeological study work, namely: Archaeological Energy Consulting, located in Casper, WY, Larson - Tibesar associates, Inc., located in Laramie, WY, and Pronghorn Archaeological Services, located in Mills, WY. Pronghorn Archaeological Services were selected, and a recommendation to use them was made to and accepted by DOE. The archaeological work was completed by the beginning of June.

5.0 PERMITS

Permits for land damage were filed with the local land owners, pipe line operators, overhead power lines, rail road, State and County officials. No difficulties were experienced in this process.

6.0 9C-VSP (SCHLUMBERGER)

Processing of the 9C VSP continued at Schlumberger, Canada. Tool spin corrections were successfully calculated after accounting for a source position move up during acquisition. Following this an inspection of the data revealed that a few traces needed to be reversed. This was accomplished and hodograms re-plotted over the down going shear wave energy. Preliminary analysis of this data showed that from surface to a depth to approximately 7,000ft S1 azimuth is N110E. At 7,000ft the azimuth of S1 changes to N70E. This result demonstrates a need to layer strip the data before S1-S1 and S2-S2 corridor stacks can be produced. This will be the focus of work in the third quarter.

7.0 3D ALTERNATE PROCESSING (WESTERN)

During the second quarter the following analysis and processing was accomplished on the 3D p-wave data:

1. Processing continued on the split azimuth volume (N-S and E-W). DMO velocity volumes and DMO'd split azimuth bin gathers were generated and are currently undergoing analysis. The split volumes have been migrated and resorted into bin gathers for further residual velocity analysis. Velocity scans have been generated by Western and these data are awaiting further analysis by Western and Palantir. If these data analyses prove nominal then the data will be submitted for AVO analysis, if however there are anomalies then the data will be re-submitted for residual migration.
2. Review and adjustment of the owner/operator horizons is ongoing, however Western has provided access to their workstation for initial analysis of the velocity volumes. This has resulted in a number of time and vertical slices being generated through the velocity volumes. These were presented to the owner/operator along with DMO'd slices through the split volumes. Anomalies in the data are interpreted as resulting from heterogeneity in the geology and in particular open, gas filled fractures.
3. Processing of the log data from the owner/operators data base continues by the creation of synthetic seismograms together with significant production and gas show data posting on the logs.
4. Two independent bodies have approached Blackhawk and the owner/operator with the possibility of using the p-wave data set to conduct independent analysis of the AVO. It is the opinion of Blackhawk that in this new area of research, namely the AVO with azimuth, it is critical that a QA/QC analysis is done on the data and methodology for processing the data. With respect to this, the Colorado School of Mines has been solicited to review the data under a small separate sub-contract (negotiations on this are continuing) and Western Research, Houston are conducting the same process internally within Western.