

Acquisition of the Blackfoot broad-band seismic survey

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ABSTRACT

A broad-band seismic survey undertaken by the CREWES Project was conducted in July 1995 at the Blackfoot Field, southeast of Stratmore, Alberta. This paper discusses the geometry and the equipment used during the survey. The objective of the survey was to test 2 Hz, 4.5 Hz and 10 Hz 3-component geophone use in recording broad-band exploration seismic data. With this significantly broader bandwidth, the signal may considerably improve the resultant seismic sections, especially the low frequency component in velocity inversion.

INTRODUCTION

The survey was conducted over the Blackfoot Field, which is owned and operated by PanCanadian Petroleum Ltd. This field is located 15 km east south east of Stratmore, Alberta (Figure 1). There has been extensive seismic work done in this area by PanCanadian, including both 2-D and 3-D surveys. The area has 16 wells that have both sonic and density logs. Eight of these wells have been cored, 3 have dipole shear logs and 2 have VSP's. The seismic line in this survey intersected one of these wells, the 14-09-23-23-W4M well, at station #156 (Figure 2). The line was 4km long with receiver stations at every 20m and shot points of 6 kg @ 18m, at every half station. The spread was fixed, and all 200 receivers were live for each shot.

The Blackfoot Field is also the location of a large CREWES designed 3-D 3-C survey starting in November 1995.

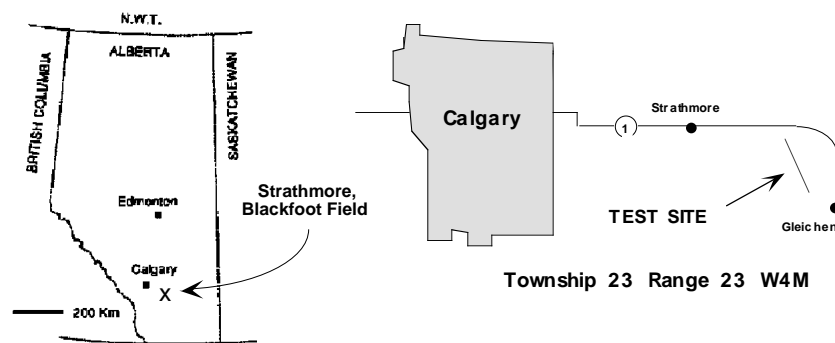


Fig 1. Map showing the location the of Blackfoot Field .

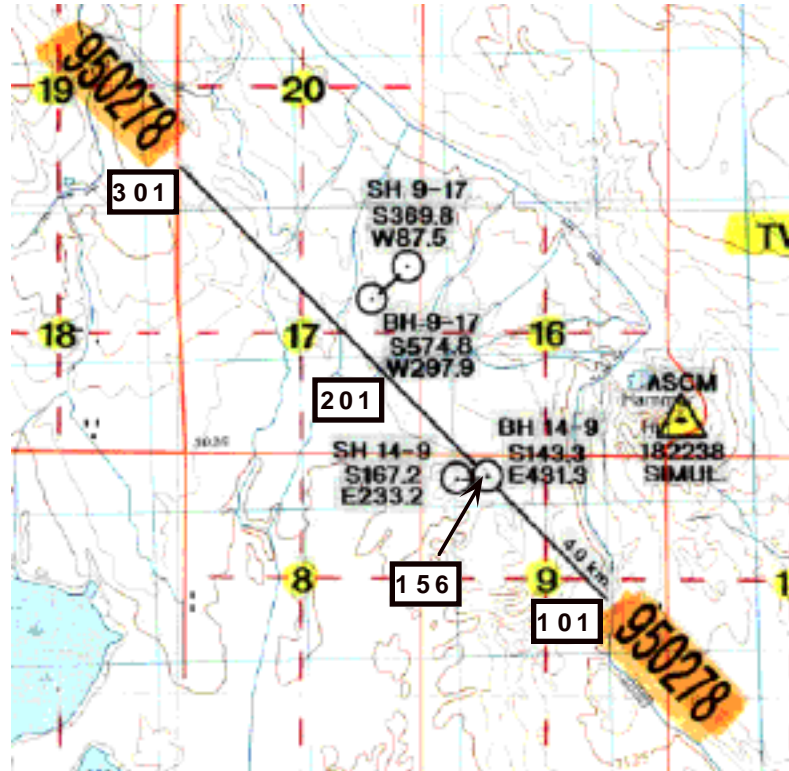


Fig. 2 Topographic map showing the shot line intersecting the 14-09 well at shot point #156.

INSTRUMENTS

To provide a maximum recording range, 24 bit instruments were used in this survey. Because we expected significant ground roll, we were using no arrays for the 3-C geophones, and wanted to be able to extract signal, we need this large dynamic range. In addition, with the 2 Hz geophones being used, it was necessary to have a low end frequency response of better than two octaves below geophone resonance to ensure that the limiting factor for the low frequency was the geophone itself. This therefore required a low end cut off of at most 0.5 Hz.

From the instruments with sufficient channel capability available to us, we decided on the ARAM-24 manufactured by Geo-X Systems Ltd., with Enertec Geophysical Services Ltd. as the contractor. The ARAM-24 instruments have no low cut filter applied before the analog to digital converter in the acquisition boxes, and the "field" low cut filter is applied digitally post-acquisition in the recorder. Discussions with Geo-X provided a switch to entirely remove any low cut filters from the acquisition software. The resultant data written to tape is a direct representation of the digital output of the analog to digital converters. Frequency spectra from the data show very good low frequency content in the records.

Two recorders were used to record the survey in a master / slave configuration. The master recorded data from the 10 Hz vertical strings, half of the 10 Hz 3-component and half of the 4.5 Hz 3-component geophones. The slave recorded data from the other half of the 10 Hz 3-component geophones and the other half of the 4.5 Hz geophones.

The slave recorder also recorded the 2 Hz vertical and horizontal geophones. Both recorders were located at the center of the spread, between station #208 and #209. A total of 1660 channels were recorded in this survey.

Instrument Type:	ARAM-24	Shooting System:	Macha
Serial Number:	24b-12	No. of Channels:	816
Pre-amp Gain:	18 dB	Record Length:	6 Seconds
Tape Density:	3480 bpi	Sample Rate:	1 mS
No. Traces:	816	Notch Filter:	OUT
Low Cut Filter:	OUT	High Cut Filter:	240 Hz
Low Cut Slope:	OUT	High Cut Slope:	70 dB/Octave

Fig 3. The recording instrument settings for the slave recorder.

GEOPHONES

There were three geophone manufacturers represented in this survey; Oyo Geospace Ltd., Litton Resource Systems and Mark Products Ltd. At each receiver station there were 9 recording channels and individual cables for each channel. The 9 cables were flagged with different colors to identify each channel (Figure 4). On the first line, 200 strings of Oyo Geospace GS-30CT 10 Hz vertical geophones were deployed. These geophones were in strings of 6, in a 3 series x 2 parallel configuration. These phones were spread out equally over the 20m receiver spacing. Because the phones had a marsh case, a planting pole was used to ensure good coupling.

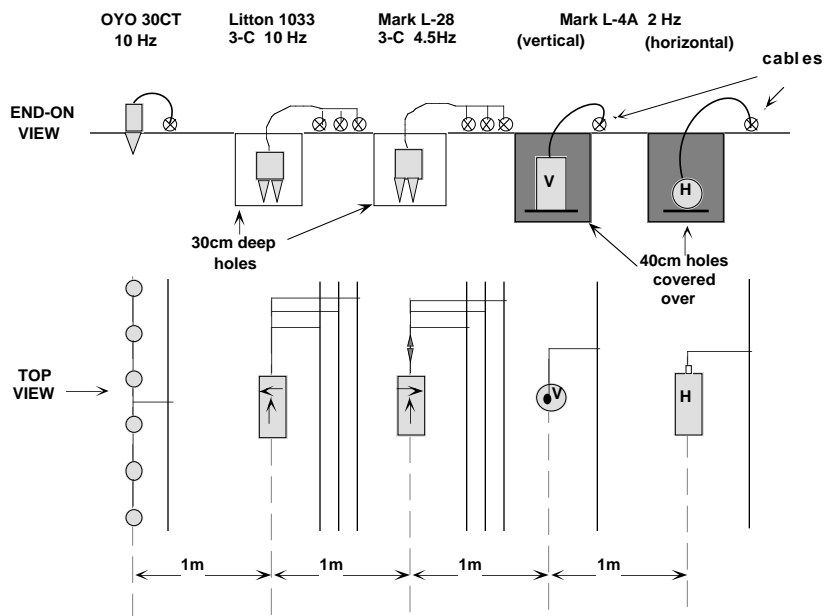


Fig 4. Diagram showing the geophone and cable layout at each receiver station.



Fig. 5. A string of Oyo Geo-Space Ltd., GS-30CT geophones with marsh cases.

One meter from the first line, a second line of 200 Litton Resource Systems LRS-1033 10 Hz 3-component geophones were deployed in holes 30 cm deep. Individual cables were laid out for each of the three components, for a total of 600 live channels (Figure 6).



Fig. 6. The LRS-1033 3-Component 10 Hz geophone (on the left) planted in a 30 cm deep hole. The L-28 3-Component 4.5 Hz geophone (on the right) which is also in a 30 cm deep hole. The cable between the phones which at the time of deployment was laid straight, has been rearranged by the cattle who share the pasture with our seismic line.



Fig 7. This photo shows the L-4A 2 Hz geophones, set up in a 3-component configuration. The phones are beside a Scintrex 3 channel recorder.

At one meter from the second line, a third line consisted of 200 Mark Products L-28 4.5 Hz 3-component geophones were installed into holes 30 cm deep. These geophones also had individual cables for each component, for a total of 600 live channels (Figure 6).

The fourth line consisted of 200 Mark Products L-4A 2 Hz vertical geophones. These geophones were put into garbage bags and set on a base plate which was planted in holes 40 cm deep. The bagged geophones were then covered over with dirt. At a meter from the fourth line, a shorter line of 60 L-4A 2 Hz horizontal geophones were also bagged, set on a base plate, buried in 40 cm deep holes and covered over. These geophones were installed in the center of the spread from station 153 to station 213. It would have been better to have a complete 3-component 2 Hz line, but availability of geophones was limited .

Both of the L-4A 2 Hz vertical and horizontal elements are cylindrical in shape, 7 cm in diameter and 13.5 cm long (Figure 7). These elements had leveling bases on which the geophones were set on in the holes. They were also put into in plastic garbage bags to prevent dirt and water from entering the geophones through the connector. Due to the large magnetic field generated from the 500g magnet in the elements, they had to be installed at 1 meter apart.

The 2 Hz geophones were provided completely undamped. Because of the high coil resistance (5600 ohms) the required damping resistors for 0.7 critical damping was 9100 ohms. To complicate matters, the input resistance of the instrument amplifiers is 20,000 ohms, meaning that a shunt resistor of about 17,000 ohms was required. The value actually used was a 20,000 ohm, metal film 1% low noise resistor. These were the only resistors available in sufficient quantity at short notice to provide a consistent response for all 260 geophones. As a result, these geophones are not optimally damped, but frequency spectra of recorded data suggest that the response is adequate.

Both 4.5 Hz and the 10 Hz 3-component geophones had leveling bubbles and orientation arrows to aid in installation. The 2 Hz L-4A geophones had a leveling bubble on the base plate. To avoid confusion in phone planting it was decided to plant all of the geophones with the geophone lead pointing in a north-westerly direction even though the coil orientation was different between the phones.

SOURCE AND GEOMETRY

Most seismic shooting in this area uses dynamite, generally 2-4 kg at a depth of 18m. We were interested in recording the most broad-band possible, especially low frequencies, so we used a slightly larger charge. Other experiments and some numerical modeling suggest that a larger charge could lower the dominant frequency of the seismic data, but increase the magnitude of energy at all frequencies. Thus we chose 6 kg of explosive as a compromise between cost and total frequency enrichment (Figure 8).

The geometry of the line is as follows:

Line length	4km (46 km of cable)
Shot spacing	20m on the half station 6 kg @ 18m
Receiver spacing	20m
Line azimuth	Northwesterly 313°

Fig. 8. Table showing the geometry of the broad-band seismic line.

LOGISTICS

The Oyo 30-CT and Litton 3-C LRS-1033 were supplied to us by Veritas Geophysical Ltd. of Calgary. Being standard industry geophones, they had KC2L-4 connectors for plugging into the seismic cables.

The 4.5 Hz and the 2 Hz geophones did not have standard seismic cable connectors. The 3-C L-28 geophones were supplied to us by Iris/Passcal Instrument Center, Stanford, California. These geophones had a water tight, wiper-type connector (U77/U) that couples all three elements into a Ref-Tek or Scintrex 3 channel seismic recorders. Adapters were manufactured for us by Mark Products Ltd. (Calgary). These adapters consisted of a mate for the wiper type connector (U78/U) and a pig-tail going to three KC2-L connectors to connect the three geophone elements to individual seismic cables.

The L4A geophones, which were supplied to us from Department of Energy, Mines and Resources, Ottawa, Ontario, also had nonstandard connectors, these being of a pin and socket type connector. For the 200 vertical 2 Hz geophones, single pigtailed with KC2-4 connectors were used to connect the geophones to the line and pins were soldered to the other end of the pigtail which were inserted into the plug on the geophones. A 20,000 ohm resistor in parallel with the geophone coil to provide 0.7 damping, was also installed, when the pins were soldered to the end of the pigtailed. For the 60 horizontal elements, a six pin connector was used. This connector also had a damping resistor in parallel to the geophone coil. These geophone connections did not provide a water-tight seal so there is some noise evident on some traces due to water leakage.

SURVEY CONDITIONS

The survey was conducted in a typical rolling prairie area. The line crossed three different types of crops and two cattle pastures. Holes were dug for the 3-component and the 2 Hz geophones to reduce trace noise from the wind. Digging the 670 holes in cultivated farm land was easily accomplished. The survey line crossed 2 secondary roads, with minimal traffic, so there was not too much noise from this source. It was fairly windy and rainy for most of the survey, with numerous thunder storms passing through. This caused most of the noise on the spread. Other sources of noise were cattle walking across the spread, flowing shot holes (about 7 holes were flowing before they were shot), pump jacks on either side of the line, and 6 high pressure gas lines crossed the spread between station #202 and #204. There were also 2 irrigation canals

on the line which were flowing with large water fluxes. One, a large canal (5m x 4m deep) that ran in a north/south direction was 100m from the beginning of the line. The second canal ran east/west and intersected the spread at station #165. This canal was 2-3m wide and 0.5-1m deep.

THE CREW

Deployment of the geophones on the line was done by the members of the CREWES Project, staff, students and hangers on. The geophones were deployed in about 3 days and the cable was laid out in about 5 days. Most of the cable work was handled by the Enertec crew who had two observers and four field men on site, but some of the more lucky staff members of the CREWES Project have first hand knowledge of how to horse-collar seismic cable (Figure 9). Tim Cartwright of the GSC helped in the deployment of the 260 2 Hz geophones and helped trouble shoot the line. Due to weather conditions it took about 3 days to shoot.



Fig. 9. Intrepid members of the CREWES crew.

CONCLUSION

Apart from the weather being wet and windy most of the time, the survey went very well. The deployment of separate flagged cables for each of the live receiver channels worked well especially in the cattle pastures where the cattle crossed our line on several occasions and twice cut our cable. The cattle would also drag the cables around disconnecting the geophones, having color coded cables aided greatly in reattaching the cables to the right geophones. Spacing the geophones at a meter apart worked well with adequate space for three cables. Digging holes to bury the 3-C geophones worked well

and no doubt helped reduce the wind noise especially for the 2 Hz geophones which were also covered with dirt.

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