Overview of multicomponent seismic field work at Spring Coulee, Alberta

Malcolm B. Bertram, Kevin W. Hall, Robert R. Stewart, Eric V. Gallant, Gary F. Margrave, Rolf Maier

ABSTRACT

In January 2008, the CREWES project, in association with ARAM Systems Ltd., conducted a multicomponent field program near Spring Coulee, Alberta. The purpose of this survey was to compare three-component geophone data to MEMS accelerometer data in a real world situation. A secondary purpose was to investigate the area for development potential on behalf of the University of Calgary, which holds subsurface rights on the land. A 2-D seismic line of 652 stations at 10 m spacing was acquired using 2 kg dynamite shots, two 48,000 lb vibrators and an 18,000 lb vibrator.

INTRODUCTION

Since the introduction of solid-state accelerometers as seismic sensors for field recording, there has been much debate about whether they provide data of quality equivalent to or better than geophones. There have been several comparisons already acquired and presented, but it was decided that for more compelling conclusions, CREWES should acquire their own, with full control over field design and parameters. This survey was conducted as a side-by-side comparison of three-component Sensor SM7 geophones with Sercel DSU3 solid-state sensors. Because the comparison involved different recording systems, an extra eighty three component Sensor SM24 geophones were laid out in pairs alongside the other sensors along a section of the line. Forty of these geophones were connected to the Aries recorder, and forty to the Sercel recorder. Using the data from these pairs of geophones, the difference in system responses of the two recorders can be determined and compensated for before comparing the geophones to the MEMS.

To get a true comparison of the two different sensors for parameters such as signal to noise and sensitivity, two different sources were used. The entire line was kept live for all shots to provide the most comprehensive data set for comparison studies. There was a limited third data set acquired on the Aries system alone, using the University of Calgary's EnviroVibe.

This paper describes the project, the recording parameters and presents some data. It is intended as an introduction to the data set for anyone interested in doing comparison studies. Some comparisons are being presented in this CREWES report e.g. Hons and Stewart, Suarez and Stewart, Lu and Hall, Ostridge and Stewart.

LOCATION

During discussions with the University of Calgary's lease manager in 2007, it was discovered that the University of Calgary had been endowed with the mineral rights to two sections of land in southern Alberta, Sections 14 and 23 T4 R23 W4M (Figure 1).

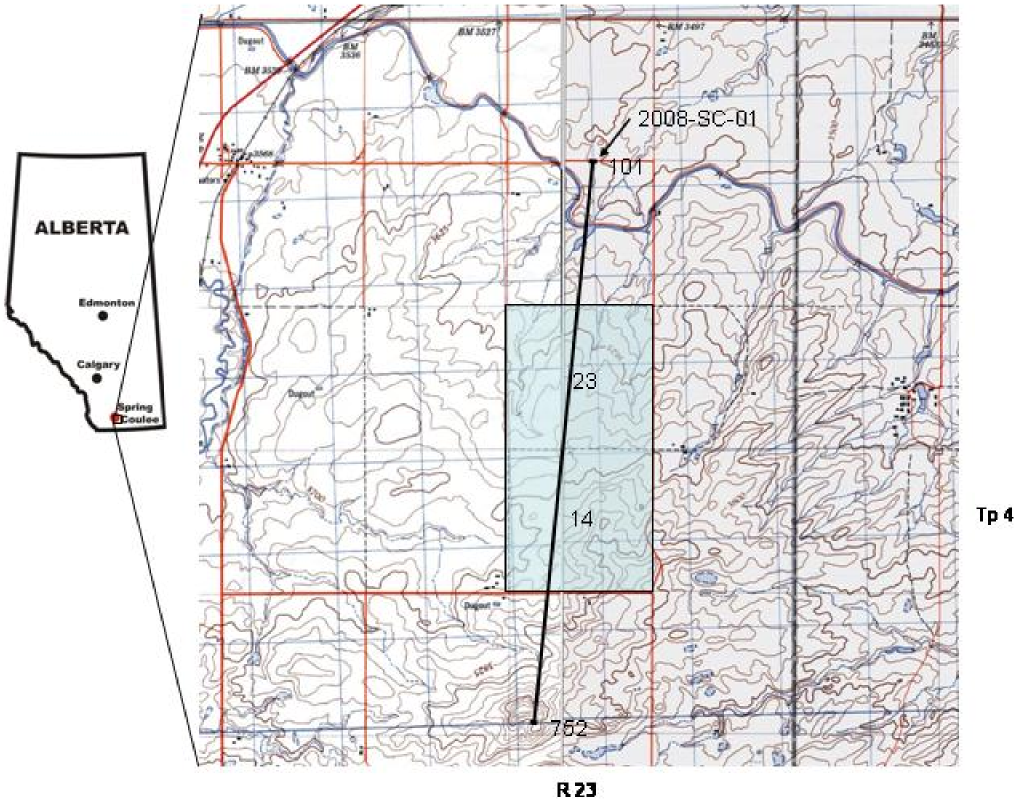

FIG. 1. Map of area showing the two sections of land for which the University of Calgary holds mineral rights. The position of seismic line 2008-SC-01 is shown.

The 2-D line 2008-SC-01 was placed to cover these two sections with a full section of surface coverage beyond them to the north and south. There were several constraints on positioning of the line, and restrictions on dynamite use along some of the line.

LAYOUT

The line started with flag 101 in the north, and ended with flag 752 in the south. Flags were spaced at 10 metres, and at each flag a three-component Sensor SM7 geophone and a Sercel DSU3 were planted about 0.5m apart. For both sensors, planting holes were drilled with a power auger. From flag 269 to flag 308 pairs of identical three-component Sensor SM24 geophones were planted alongside the other two sensors. The three-component SM7 geophones were provided by ARAM Systems Ltd, the DSU3 sensors were provided by CGG Veritas. The SM24 geophones belong to the University of Calgary. Figure 2 shows one of the flags with MEMS sensor and geophone.

FIG. 2. DSU3 MEMS sensor on left, SM7 geophone on right (Photo courtesy Glenn Hauer).

The acquisition system for the SM7 geophones and half of the SM24 geophones was the new 24-channel Aries II RAM provided by ARAM Systems Ltd. Data was recorded on the Aries SPMLite belonging to the University of Calgary. The acquisition software was upgraded to Version 3 to accommodate the 24 channel Aries II RAMs. This version is fully featured for three-component recording, with component separation and identification.

The recording system for the DSU3 sensors and the other half of the SM24 geophones was a Sercel 428XL system (software revision 3.4) provided by CGG Veritas.

Figure 3 shows the line layout with the patch of 40 pairs of SM24 geophones shown, and indicates the source lines.

All channels were recorded for all shots for the main comparison survey. Record length was 6 seconds to ensure capture of converted wave events. Sample rate was 2 ms.

Recording was controlled by the Sercel recorder, with the Aries recorder as a slave system. Source control was Pelton Advance II for the vibrators, and Pelton ShotPro for the dynamite.

Some data examples from the two systems are shown below.

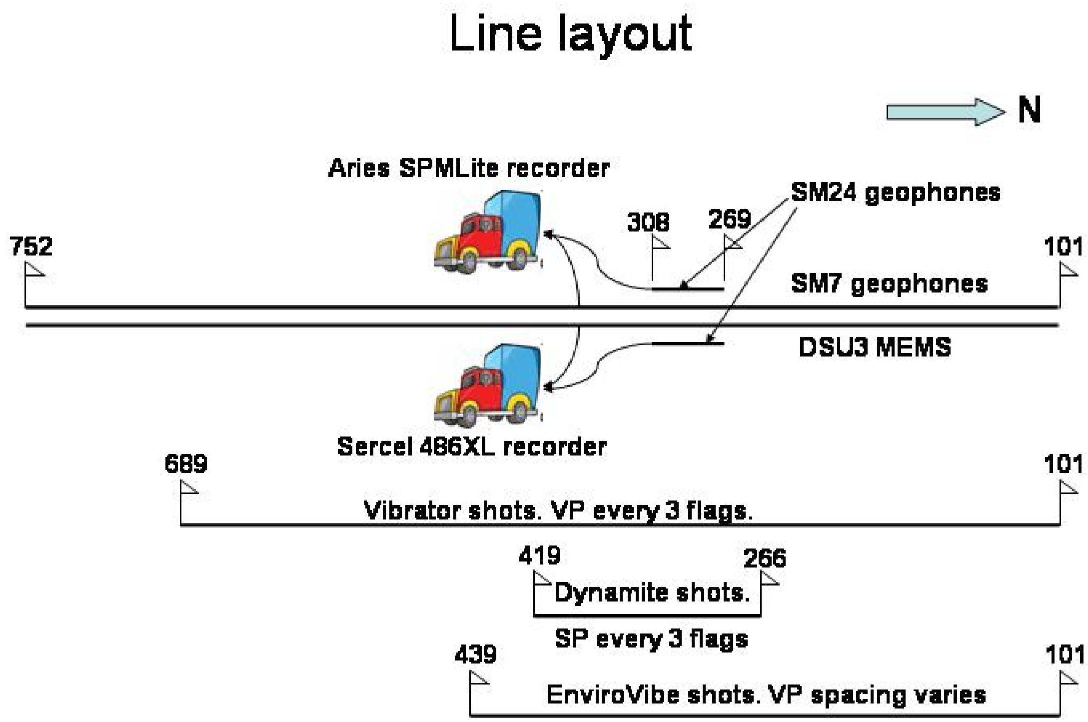

FIG. 3. Line layout.

THE SOURCES

The line was shot using two Mertz Hemi 48,000lb buggy mount vibrators from flag 101 to flag 689 at every third flag for a total of 196 VPs. The sweep was linear 4 Hz to 130 Hz over 12 seconds, 4 sweeps per VP. The Vibroseis units were provided by CGGVeritas.

The second energy source was a 2kg dynamite charge at 18m depth from flag 266 to flag 419 at every third flag. There were 54 dynamite shots.

There is a subsidiary data set acquired using the University of Calgary's EnviroVibe. Once the north half of the SM7 geophones had been laid out, the EnviroVibe started shooting at every flag from 101 to 224, then every third flag to 439, into the increasing spread as layout continued to the south. During this time, the CGG Veritas crew started laying out their DSU3 spread, so there is considerable noise on this data, but shooting continued until the entire spread had been laid out, by which time the EnviroVibe had shot up to flag 439. These shots were acquired only on the SM7 geophones attached to the Aries recorder, and were used as an early quality check on the surface conditions. The sweep was 10 Hz to 200 Hz over 12 seconds, 4 sweeps per VP. data is surprisingly good, showing acceptable energy out to 1500 m offset, and reflections to 1500 ms. There were 136 EnviroVibe shots into the Aries system.

The remarkable data quality obtained from the small EnviroVibe source in this program was a deciding factor in returning to the site in August 2008 for the Undergraduate Geophysics Field School, when two more lines were acquired on the road allowances on the east and west sides of the sections of interest. (see Addendum at the end of this paper).

SOME DATA EXAMPLES

A typical dynamite shot from the Aries recorder is shown in Figure 4. This is from SP 290 and shows the data quality, with good reflection energy at times up to 4 seconds. This deep event can be correlated to an event on the Lithoprobe transect which ran through southern Alberta close to this location.

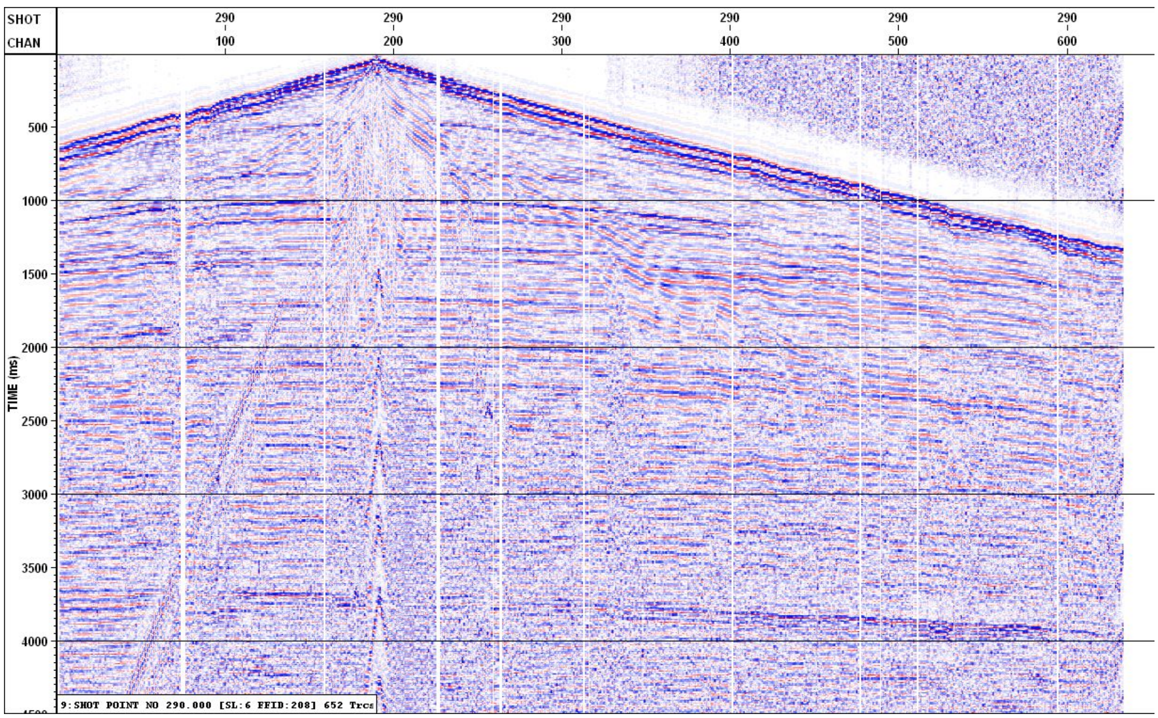

FIG. 4. Dynamite shot at SP290 from the SM7 geophones recorded on the Aries system. Filters of 10-15-55-60 Hz and 500 ms AGC applied.

For all the other examples following, the data has been truncated to 3 seconds.

An example of the EnviroVibe data from the survey is shown in Figure 5, and the same record filtered 10-15-55-60 Hz in Figure 6. Considering the small source size (one EnviroVibe) the data is exceptional.

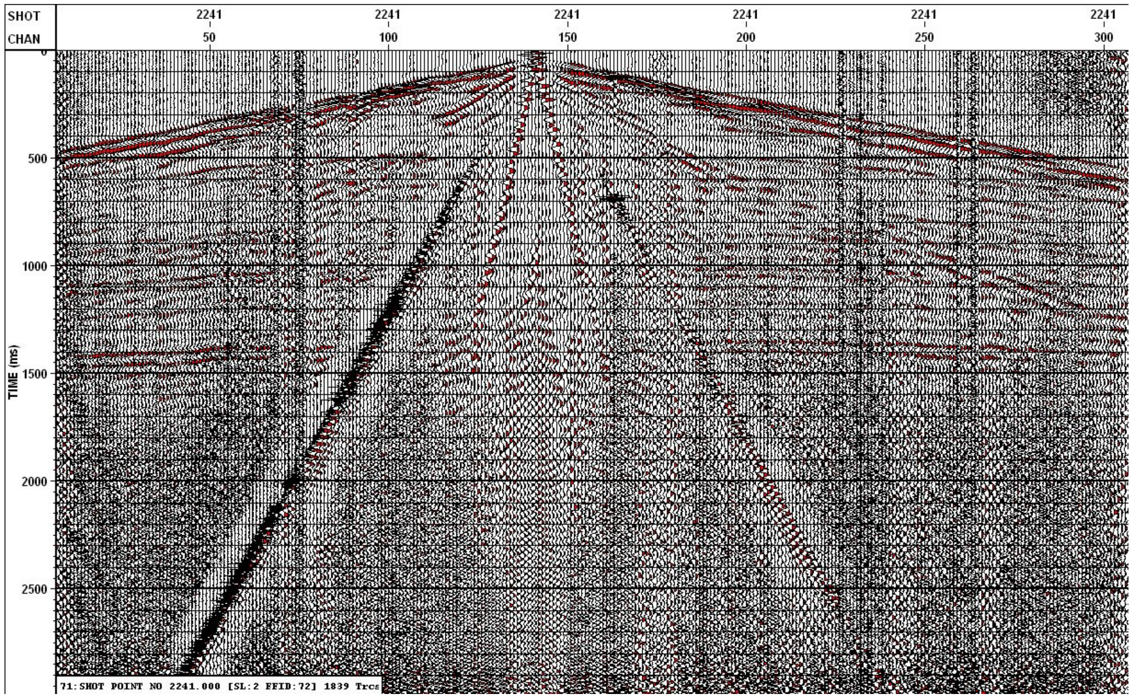

FIG. 5. Example of Envirovibe data. No filters, 300 traces displayed. Shot at flag 241. AGC applied.

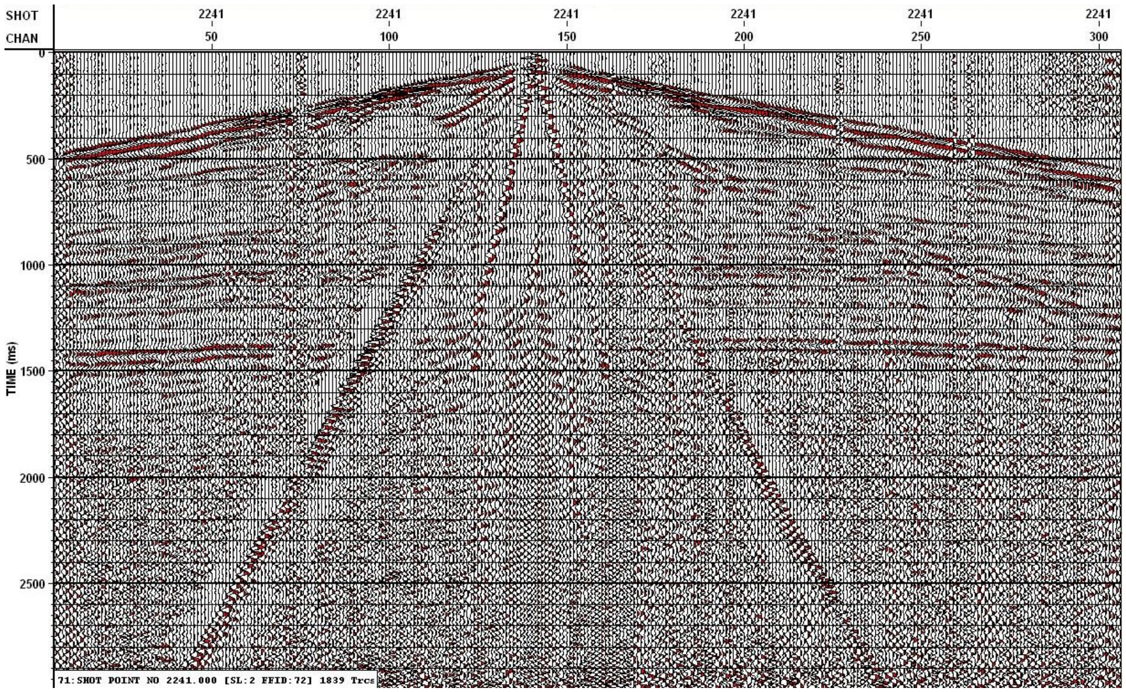

FIG. 6. The same record with 10-15-55-60 Hz filter and AGC applied.

An example of a dynamite shot from the SM7 geophones is shown in Figure7, and the same shot from the DSU3 sensors is shown in Figure 8. The same records filtered 10-15-55-60 Hz are shown in Figures 9 and 10. All displays are vertical component, with 500 ms AGC applied.

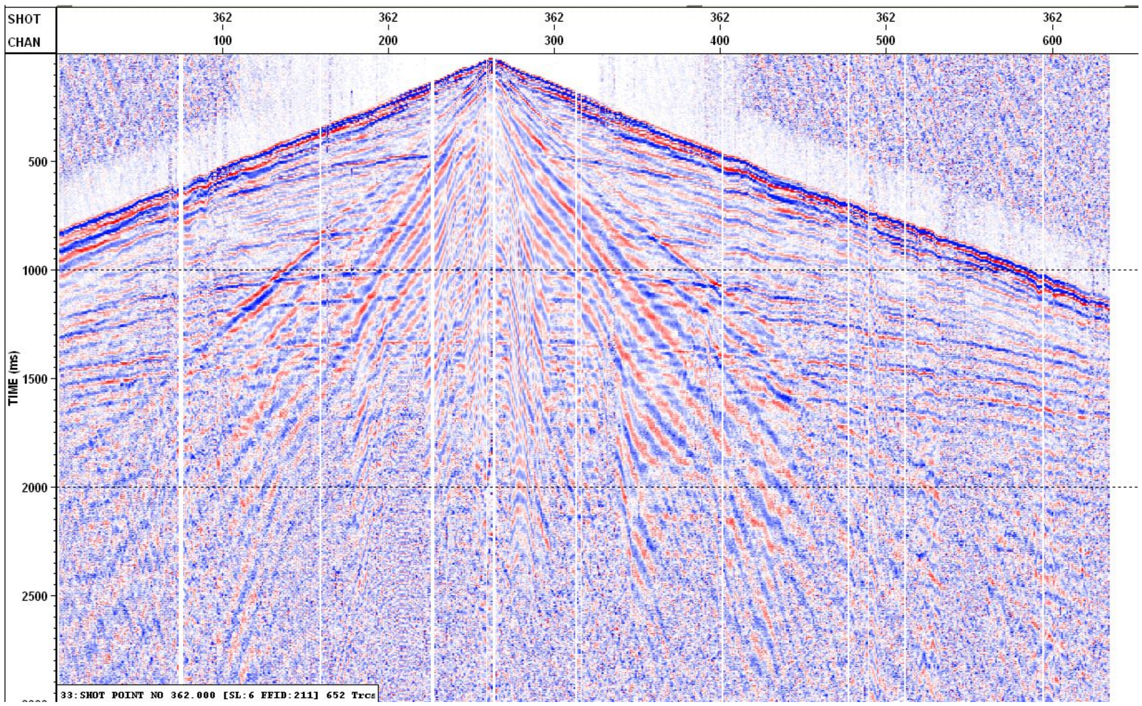

FIG. 7. Dynamite record from SM7 geophones (shot at flag 362). No filters, AGC applied.

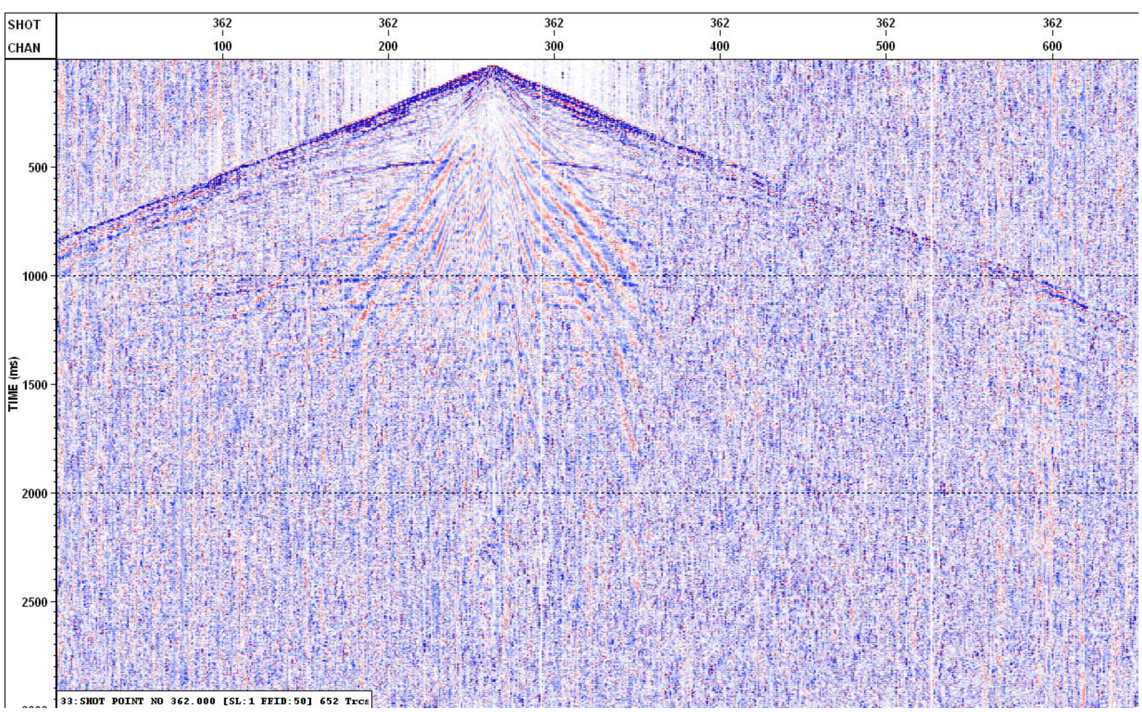

FIG. 8. Dynamite record from DSU3 sensors (shot at flag 362). No filters, AGC applied.

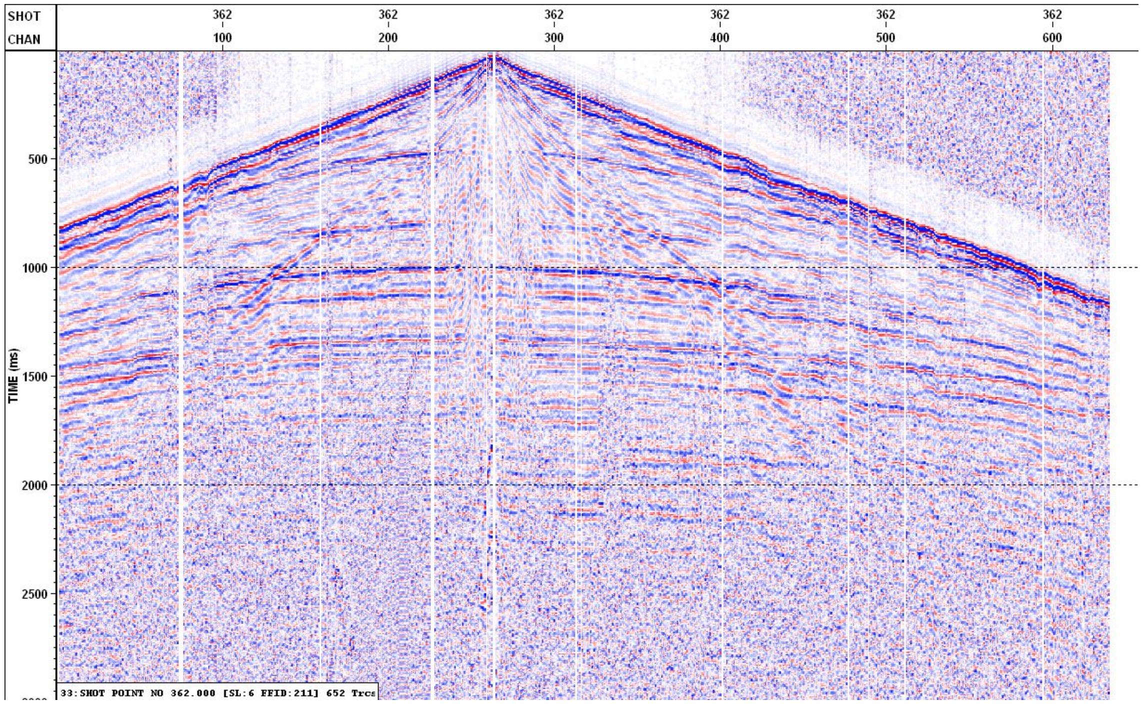

FIG. 9. Dynamite record from SM7 geophones (shot at flag 362). 10-15-55-60 Hz filter, AGC applied.

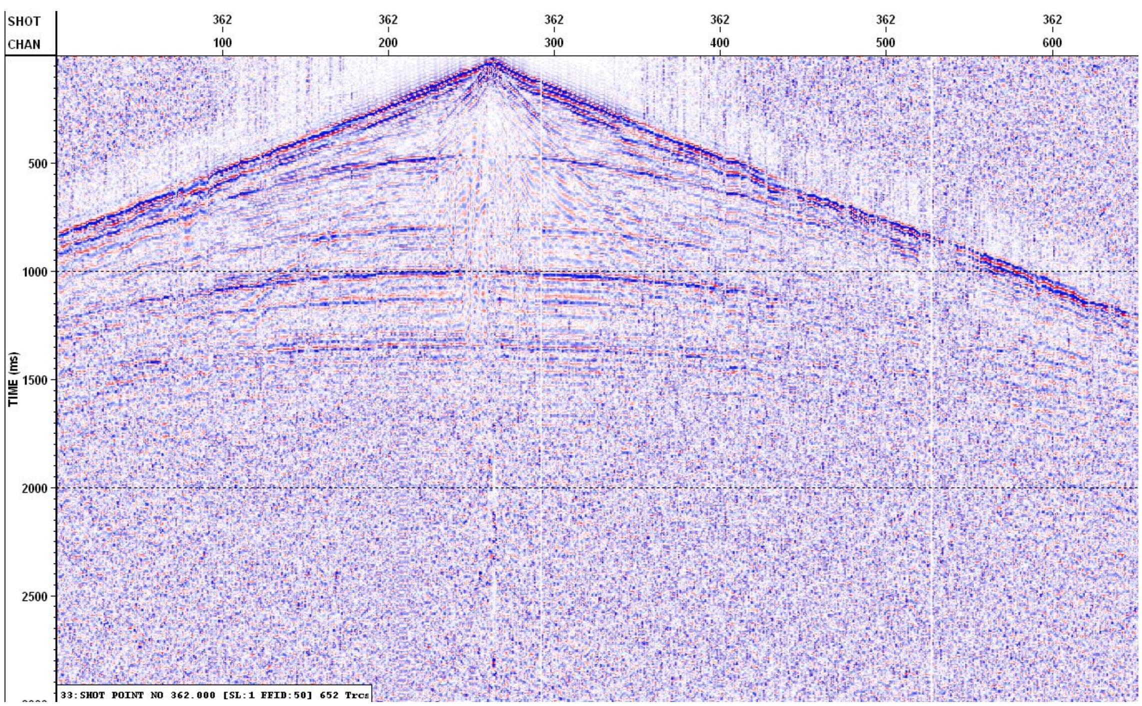

FIG. 10. Dynamite record from DSU3 sensors (shot at SP 362). 10-15-55-60 Hz filter, AGC applied.

For source comparison, the same two records are shown for the vibrators at the same shot location. The unfiltered records are shown in Figures 11 and 12, and the filtered records in Figures 13 and 14. Vertical component only is shown with 500 ms AGC applied.

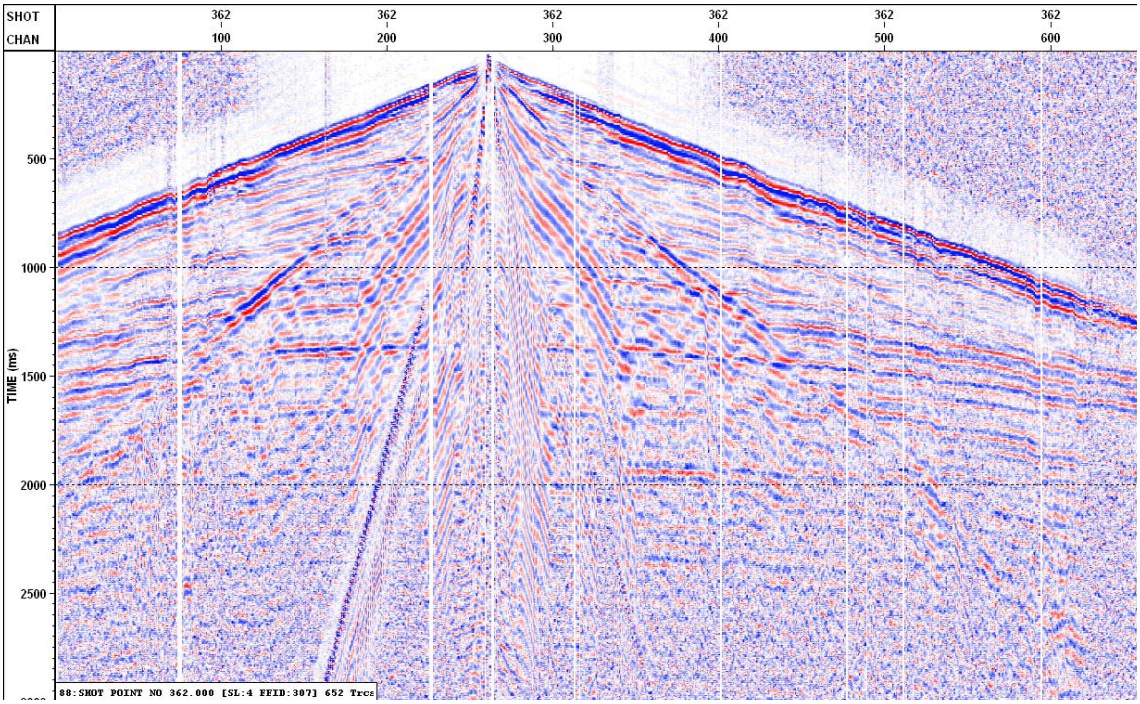

FIG. 11. Vibroseis record from SM7 geophones (shot at flag 362). No filters, AGC applied.

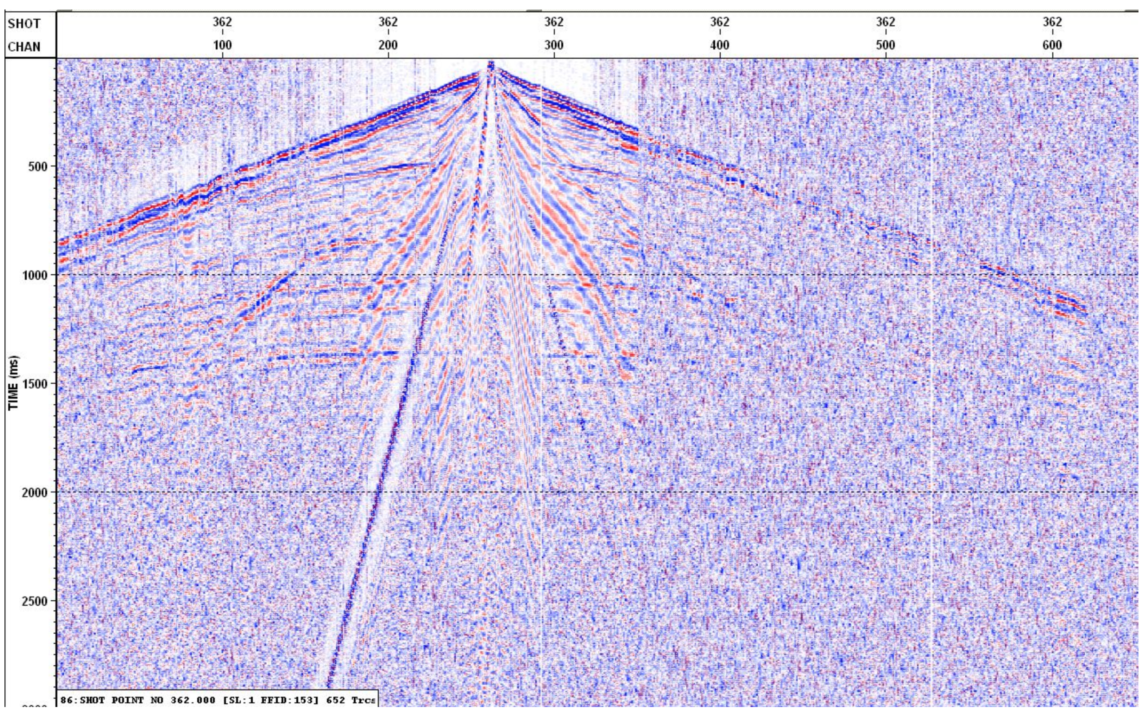

FIG. 12. Vibroseis record from DSU3 sensors (shot at flag 362). No filters, AGC applied.

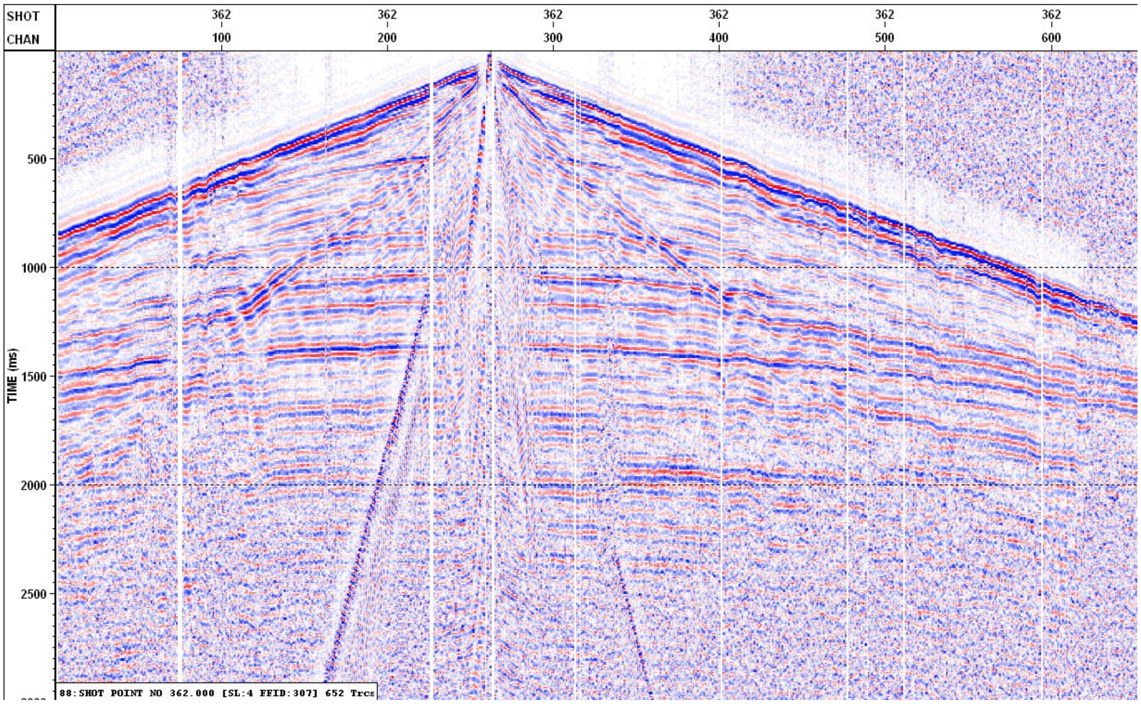

FIG. 13. Vibroseis record from SM7 geophones (shot at flag 362). 10-15-55-60 Hz filter, AGC applied.

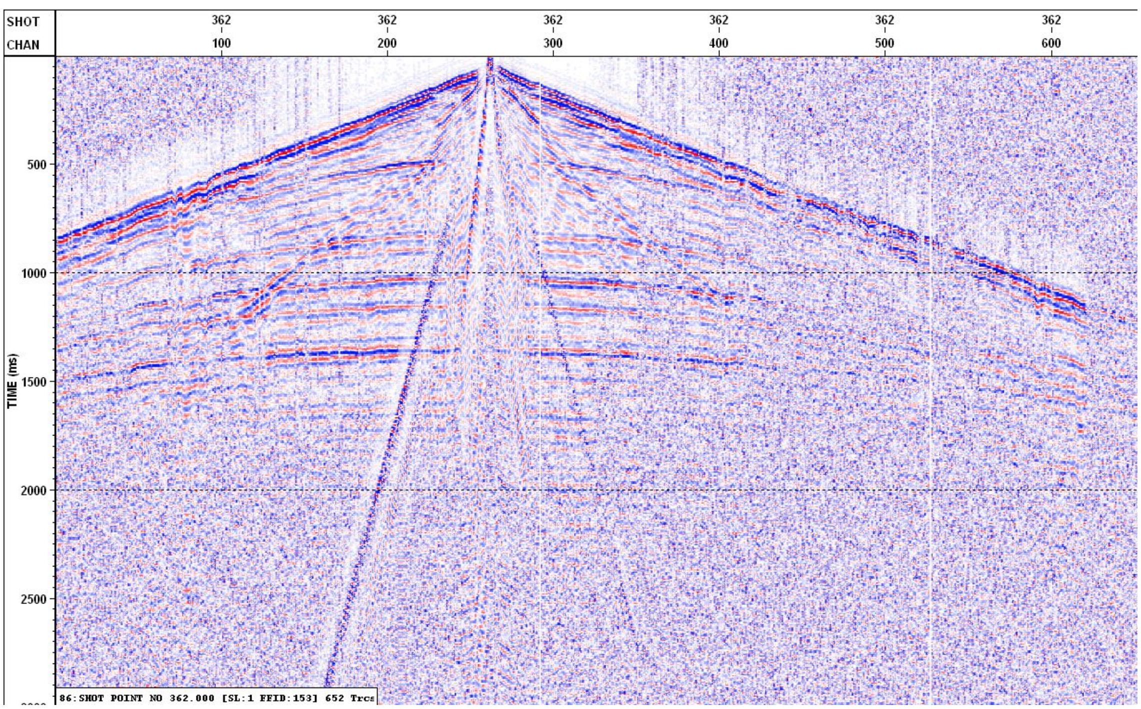

FIG. 14. Vibroseis record from DSU3 sensors (shot at flag 362). 10-15-55-60 Hz filter, AGC applied.

SYSTEM COMPARISONS

To compare the two recording systems, the 40 pairs of SM24 geophones provide almost exactly the same signal to the two recording systems. Figures 15 and 16 show the common receiver gather for the SM24 vertical element at flag 274 for all the vibrator shots. Figures 17 and 18 show detail from these records.

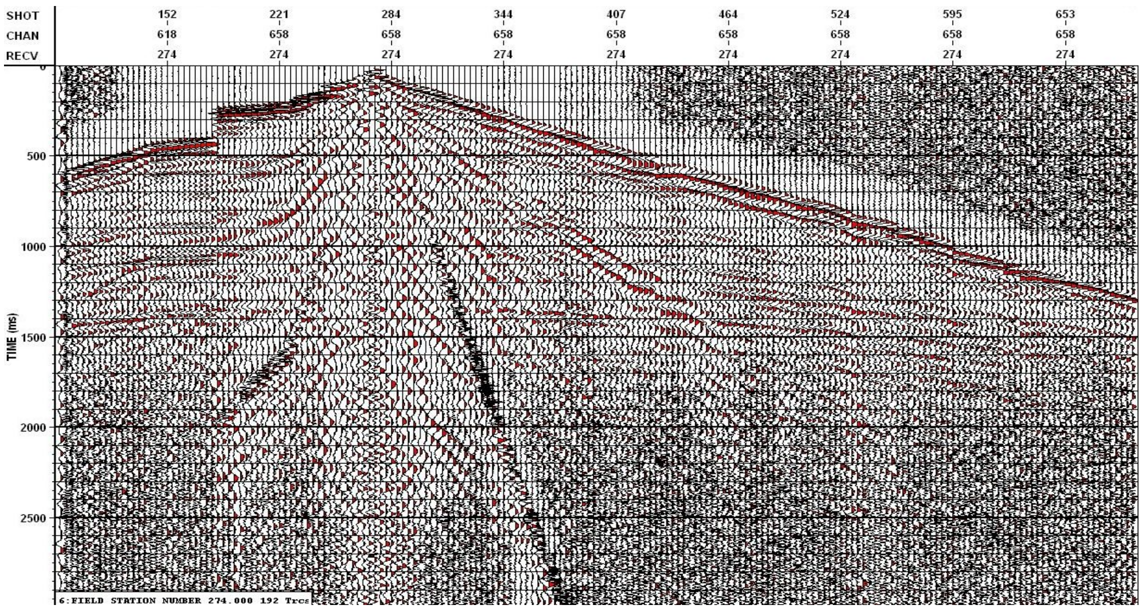

FIG. 15. Aries SM24 vertical receiver gather for flag 274 (vibrator shots). 500 ms AGC, No filter.

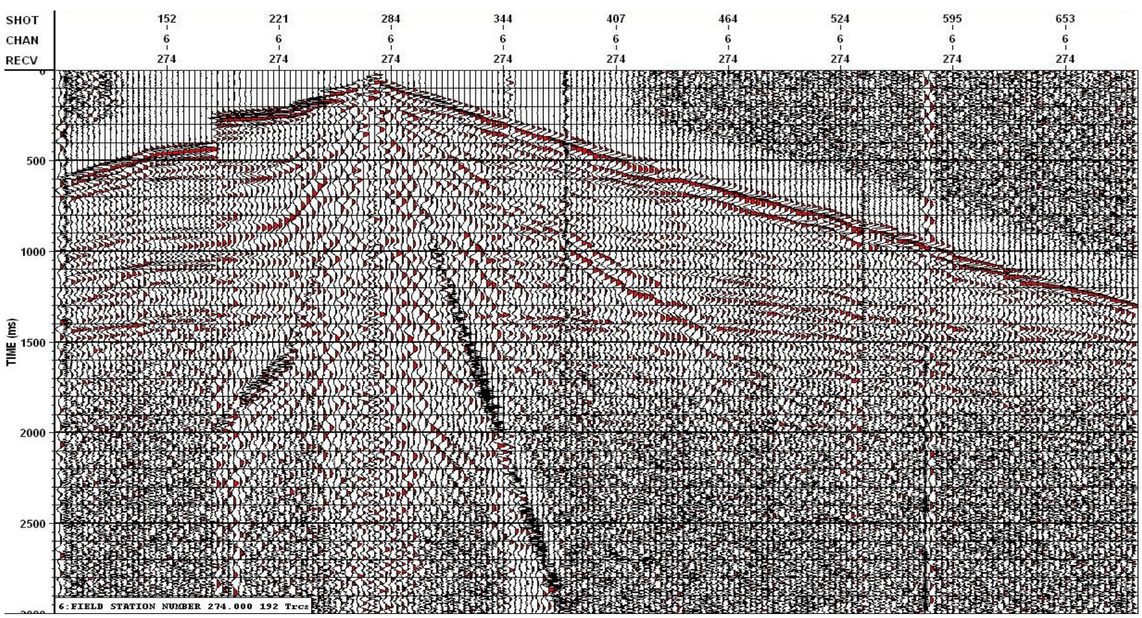

FIG. 16. Sercel SM24 vertical receiver gather for flag 274 (vibrator shots). 500 ms AGC, No filter.

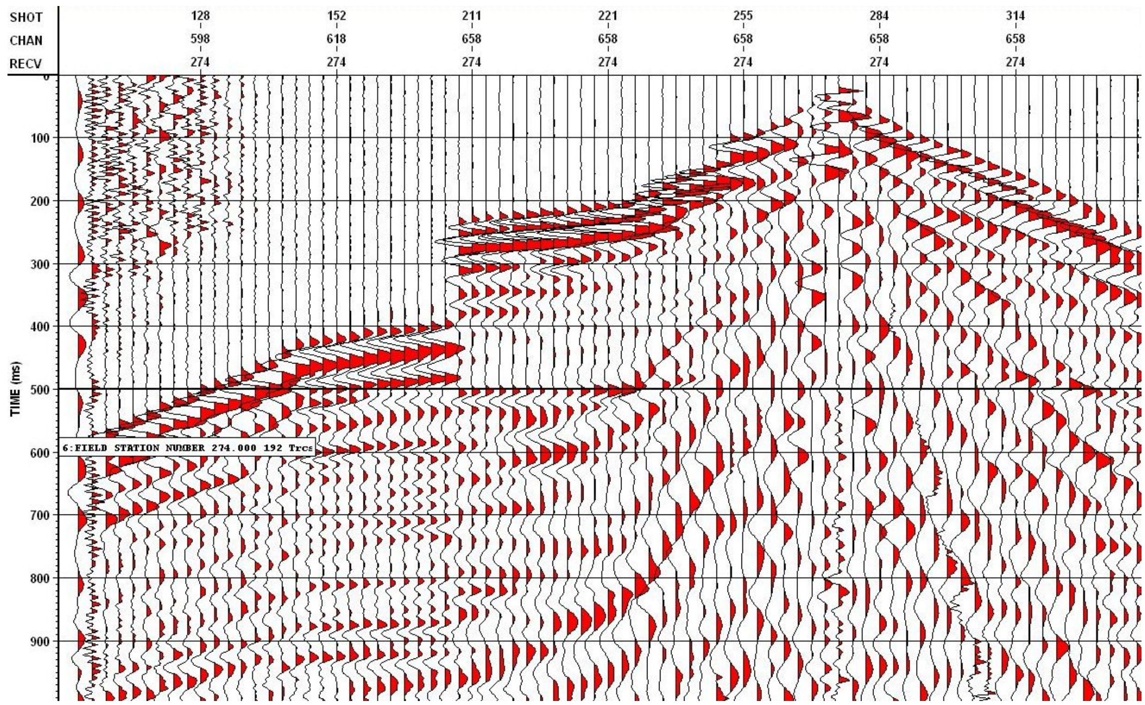

FIG. 17. Detail from an Aries SM24 geophone receiver gather.

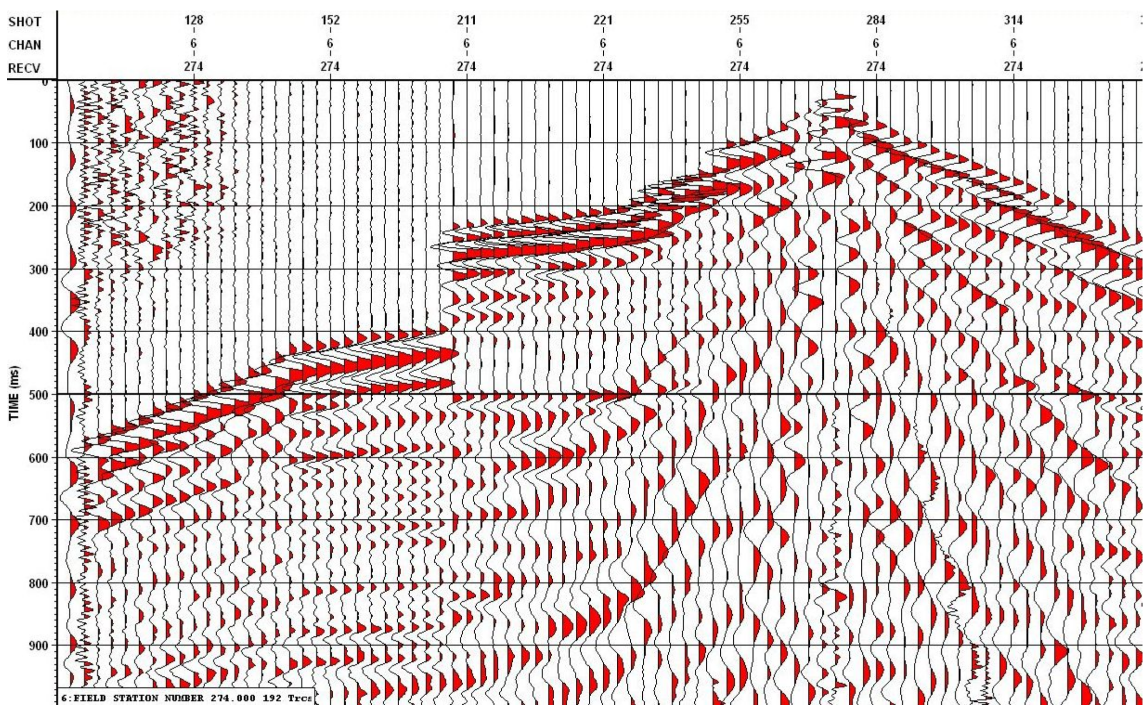

FIG. 18. Detail from a Sercel SM24 geophone receiver gather.

Visually these two receiver gathers are almost identical, including the noise appearing before the first breaks.

These receiver gathers are used to compare the two recording systems. The first pass is to subtract one data set from the other after normalizing to trace maximum amplitude. The normalized gathers are shown in Figure 19 and 20 with a fixed display gain of 0.3.

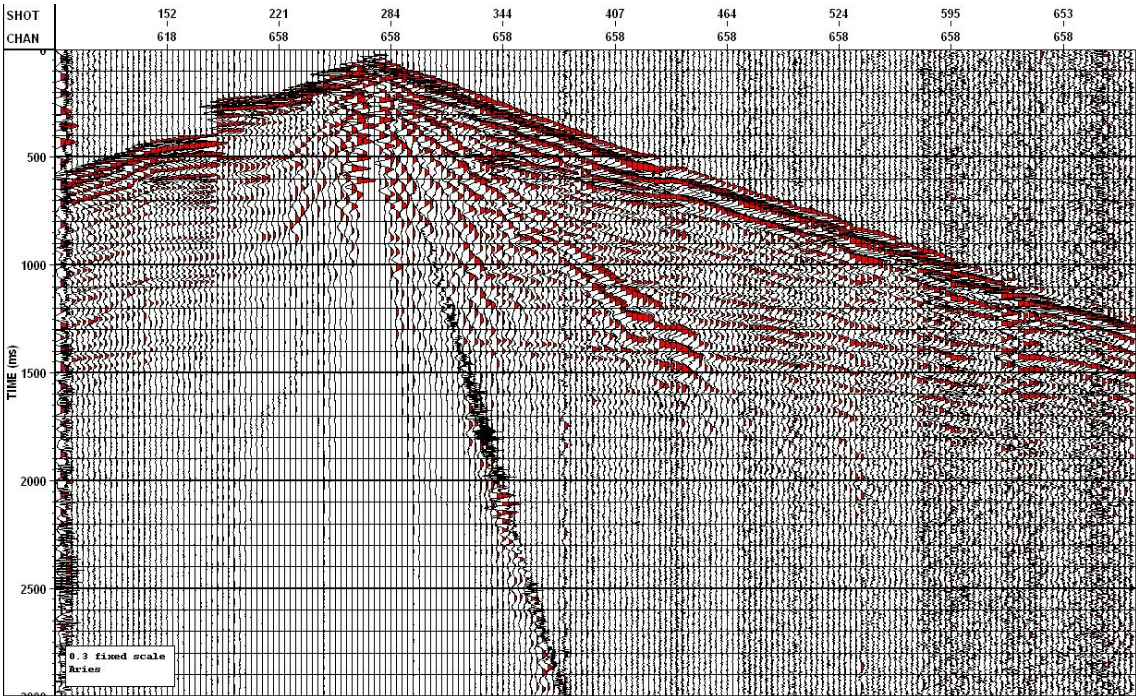

FIG. 19. The Aries gather after trace scaling. Fixed display gain of 0.3.

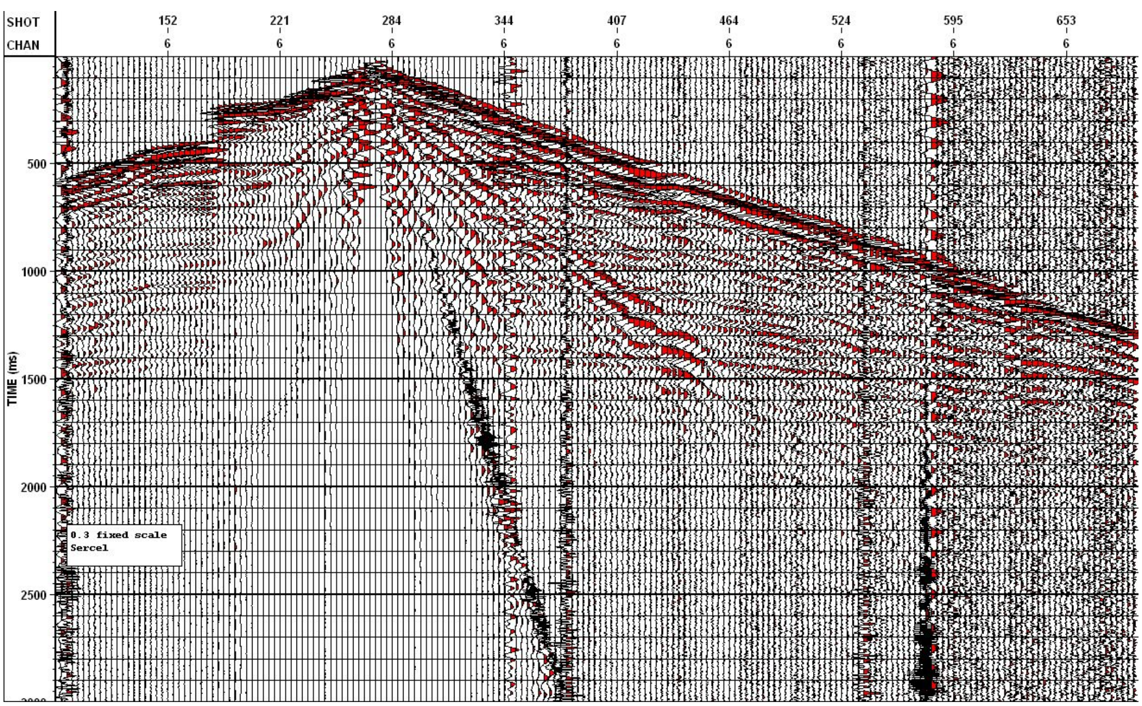

FIG. 20. The Sercel gather after trace scaling. Fixed display gain of 0.3.

Figure 21 shows the difference between these gathers.

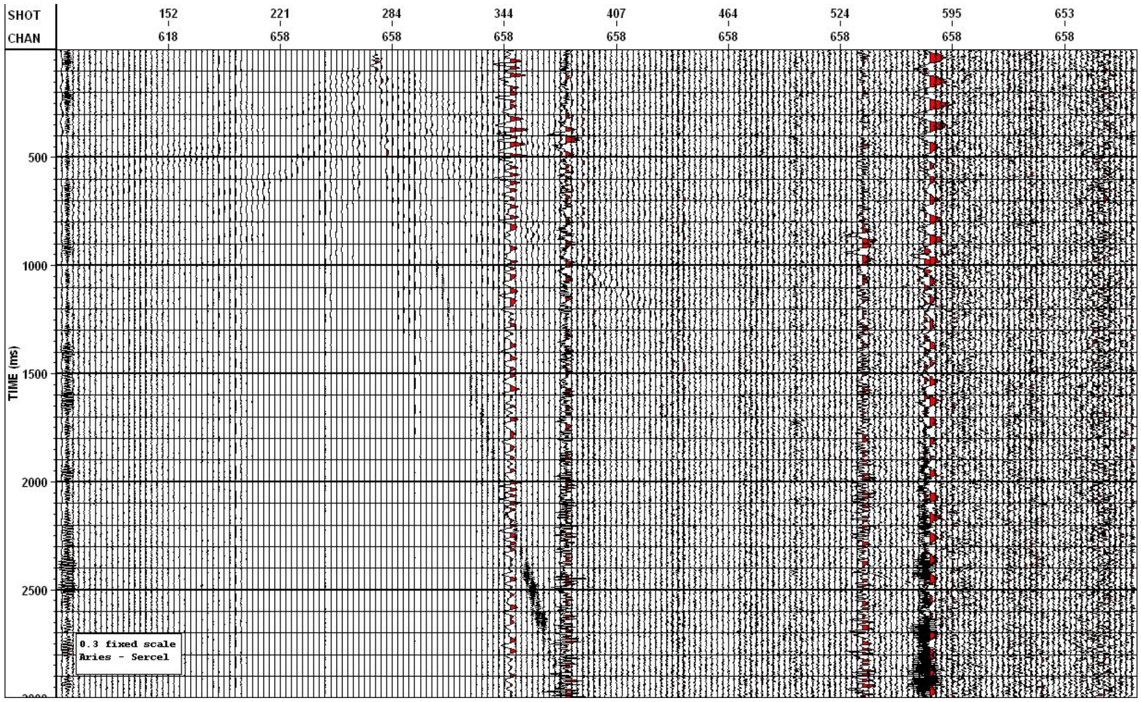

FIG. 21. The difference between the two gathers at a display gain of 0.3.

There is still some evidence of energy remaining, mostly in the air blast and ground roll. To better demonstrate this, the same record is displayed with AGC in Figure 22.

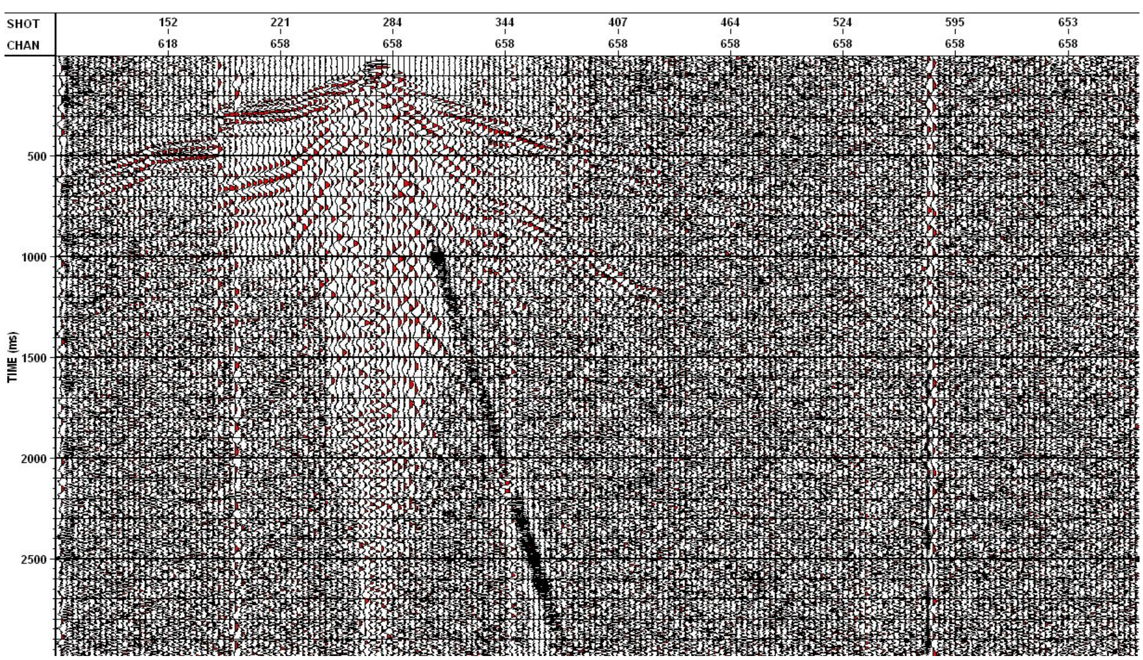

FIG. 22. The difference between the gathers with 500 ms AGC.

The lack of any coherent signal at the far offsets shows that the far field signal is almost identical. Also, the elimination of the reflection energy indicates that the timing between the two systems is good.

However, the amount of low frequency energy still apparent in Figure 20 suggests that there is a difference between the two systems. Both have a 3 Hz low cut filter applied, but the filter response is not known. To investigate this effect, the same difference is taken after a 30 Hz low cut filter has been applied. The result is shown in Figure 23. There is considerable improvement in the result, showing that there may be a need to establish a matching filter between the two systems before processing.

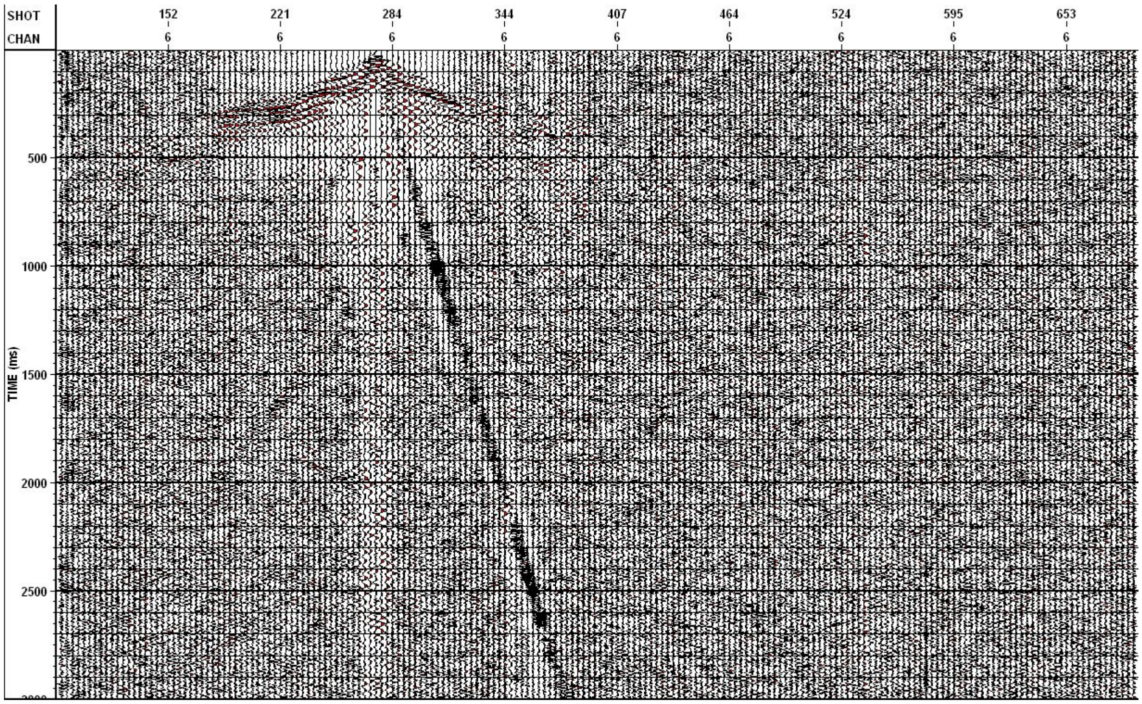

FIG.23. The same process applied with a low cut filter of 30 Hz applied before scaling.

The same process was tried with different scaling methods (mean, RMS). In all cases, the results were almost exactly the same.

The flag used for this comparison was a random choice, but the same method applied to other receivers produced very similar results.

CONCLUSIONS

The survey was a success, with excellent data being acquired from all systems and sources. The above examples have demonstrated only some of the vertical component data – the converted wave data shows some excellent results also.

Processing of the data has provided excellent quality sections, which show that for this type of survey with high fold coverage, there appears to be no definitive advantage of either the MEMS accelerometer or the geophone over the other.

There do seem to be some small differences in response of the Aries and Sercel recording systems at low frequencies which may be due to low cut filters.

ADDENDUM

Since the data acquired using the EnviroVibe on this project was of surprisingly good quality, it was decided to hold the University of Calgary undergraduate Field School in the same area in August 2008.

There were two lines shot for this project, along the road allowances on both the east and west sides of the two sections. For this survey, the sweep parameters selected were 10 Hz to 150 Hz, 12 second length, 4 sweeps per VP. Record length was 2 seconds, sample rate 1 ms. A 1500 m offset was decided on as optimal from an analysis of the January 2008 project.

A processed section from the line on the west side is shown in Figure 24.

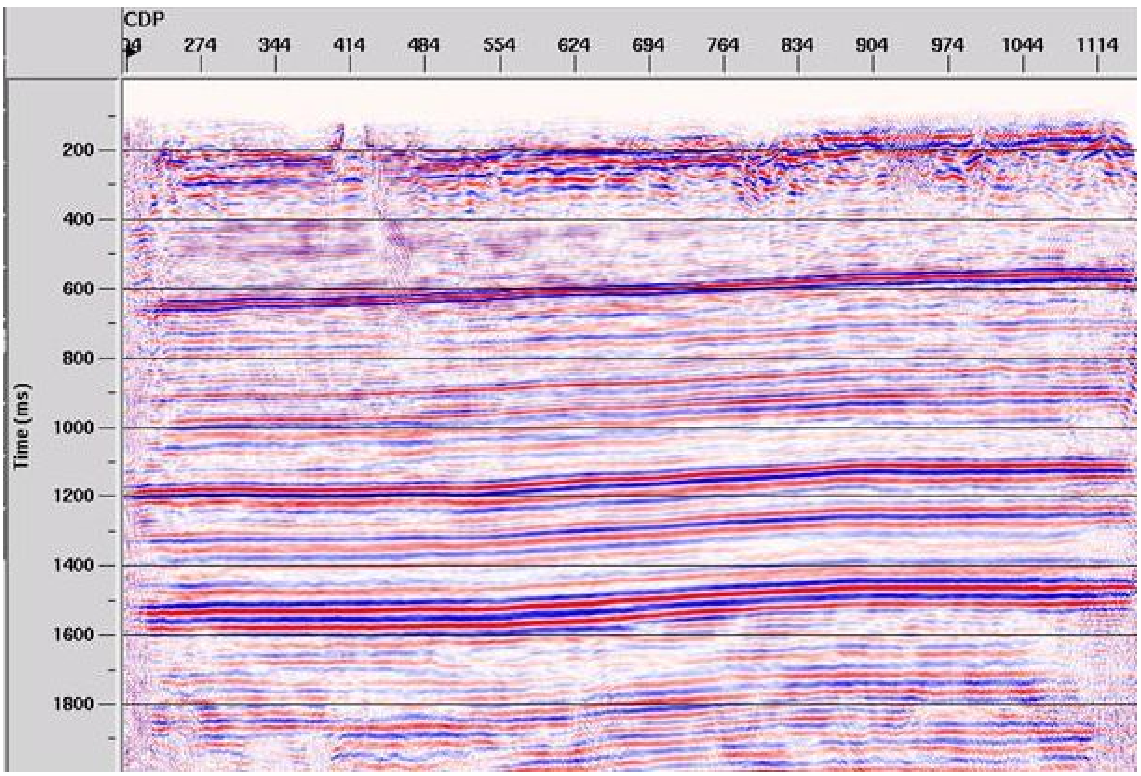

FIG. 24. Line 549A from the August 2008 geophysics Field School. North to the left.

ACKNOWLEDGEMENTS

We wish to acknowledge the CREWES sponsors for providing funding to undertake this work.

ARAM Systems Ltd. provided financial support, all the line equipment and some personnel for the project. Specifically Glenn Hauer, Frank Zurek, Shawn McCluskey and Gary Kuemper (CSRI) who provided invaluable help with the layout of the Aries spread, and made sure everything kept running.

CGG Veritas provided the Sercel system, and the Vibroseis units.

Our appreciation to Outsource Seismic for the permitting, surveying, drilling and general oversight of the project.

Thanks to GEDCO Ltd. for providing the Vista Seismic processing software.

Rob Ferguson assisted in the field for the project. Han-xing Lu processed the data from both the January survey and the August Field School.

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