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Priddis 2014 broadband surface and walkaway VSP seismic experiment

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Summary

CREWES and INOVA conducted a high-resolution broadband multi-component seismic surface and borehole test survey at the Priddis Geophysical Observatory (PGO) in late October and early November of 2014. The PGO consists of buried targets and three geophysical test holes numbered 1, 2 and 4, all of which are less than 150 m in depth (Hall et al, 2014). Before beginning the 2014 seismic survey, natural gamma-ray logs and full waveform sonic logs were acquired in Testhole 2 using equipment described by Wong et al., 2009. Four dynamite source lines (E-W, NE-SW, N-S, NW-SE, 0.125 kg, 5 m deep, 6 m spacing) arranged in a star pattern centered on Testhole 1, and one Vibe source line (E-W, 6 m spacing) were recorded by permanent three-component 28 Hz geophones (3 m vertical spacing) in Testhole 1, clamping three-component optical sensors (20 m vertical spacing) in Testhole 2, as well as single-component accelerometers (6 m spacing), single-component high-sensitivity 10 Hz geophones (6 m spacing), three-component 10 Hz geophones within ground-screws (6m spacing) and three-component 10 Hz geophones (3 m spacing) on the surface. The data are of generally good quality, but are contaminated with acoustic and electrical noise from generators powering various recording systems, as well as from regional power lines.

Introduction

The 2014 field program at the Priddis Geophysical Observatory (PGO) had many objectives:

- Obtain many closely spaced dynamite shots from many azimuths into the permanent geophones in Testhole1
- Acquire hi-resolution three-component 2D surface seismic lines at a variety of azimuths
- Deploy USSI fiber optic system in Testhole2. This is the first time we have deployed this system.
- Source tests (Dynamite vs. Vibe)
- Receiver tests (Geophone vs. Accelerometer)
- Receiver test (planting methods)

Layout

Various line locations at the PGO have been permitted until 2020 with the Alberta government. Four of the permitted lines (TH6, TH1-02, TH11-01 and TH1-04) were used for this program. These lines will be referred to as E-W, NE-SW, N-S and NW-SE for the remainder of this report. All four lines intersect at Testhole1 (Figure 1). Testhole 2 is located between the NE and E arms of the E-W and NE-SW lines 50 m away from Testhole1

Recording systems

Five separate recording systems were used for this survey. Four cabled systems (two Aries SMP Lites, one G3i and one USSI) were triggered by Pelton VibePro's, and one nodal system (Hawk) recorded continuously. All systems sampled at 1 ms with the exception of the USSI recorder, which sampled at 0.25 ms.

Three recording trucks were used. Two of the trucks were seismic recorders with generators on board. These trucks were parked about 270 m away from the closest geophone, and were connected to the spread with long baseline cables. A rental cube van was used as a recorder for the USSI system and was connected to the tool in Testhole2 with a short fibre optic cable. The length of this cable meant the truck had to be parked beside Testhole2, about 15 m away from the closest geophone. This system was powered by a small gas generator placed on the ground as far away from any surface sensors as possible.

Sources

Two source types were used, dynamite and Vibroseis. Dynamite shotholes were drilled and loaded at every second station from 101-181 of the E-W, NE-SW, N-S and NW-SE lines. There were a total of one hundred and fifty 0.125 kg dynamite shots spaced 6 m apart, with the charges placed 5 m below ground level. An Inova Univib operated by Geokinetics acquired the E-W line with a vibe point every 6 m. A linear 1.5-180 Hz sweep was used.

Receivers

Testhole 1 has 45 permanent GS-14-L9 28 Hz three-component geophones strapped to the outside of the casing and cemented into the ground at a 3.06 m spacing (Hall et al., 2014). Geophone cables come up to the surface and were plugged into an Aries recording system using adapter boards.

A six level three-component fibre-optic system from USSI that has nodes spaced 20 m apart was deployed in Testhole 2. A nitrogen powered clamping system provided by USSI was used to hold the nodes against the inside the casing from 15 to 115 m depth, with a node every 20 m. This is the first time we have deployed this system in a borehole.

Three kinds of receivers were deployed on the surface (Figure 2). These included SM-7 three-component 10 Hz geophones in nail-type cases and within ground-screws, SM-24HS single-component high-sensitivity geophones and AccuSeis single-component SL11 accelerometers on the surface. The SM-7 nail-type cases were planted in augered holes and were oriented to magnetic north with the pigtail pointing to the south. These geophones were planted on all four lines at every station from 101 to 180 at a 3 m geophone spacing. The SM-7 groundscrews were screwed into augered pilot holes from stations 143-165 at a 6 m spacing on the E-W line only. The SL11 and SM-24HS vertical component sensors were planted at stations 83 to 271 at a 6 m spacing on the E-W line only. These sensors were planted with just the sensor spike in the ground or with the entire case in the ground in an alternating pattern, so that a particular planting method had a 12 m spacing down the line.

While this survey was intended to be processed as four 2D lines, almost every shot was recorded by almost every receiver, which means that it may be possible to process the downhole and surface data as a 3D, although the resulting azimuthal coverage in each bin may not be of the best (Figure 1).

Initial results

Figures 3 and 4 show the vertical and radial component data from the SM-7 geophones in nail-type cases for SP 2101 and VP 2101 on the E-W line. Figures 14 and 15 show the same results for VP 2102 on the same line. The component rotation was a purely geometric one, assuming that all of the geophones were planted perfectly with H1 oriented towards magnetic north. The transverse component is not shown. A correction for the 10 Hz geophone response from 0-10 Hz has been applied. This brought up a lot of very low frequency noise (less than 1 Hz), which has been removed by applying a 1-2-180-200 Hz Ormsby bandpass filter. It is visually apparent that the geophone correction has enhanced data below 10 Hz.

Note that most of the energy is in the 0-40 Hz band, which is disappointing. This story may improve after ground-roll removal and stacking. Narrow horizontal bands indicate the presence of electrical noise, likely due to the presence nearby powerlines, as well as to acoustic and electrical noise from the variety of gas and diesel generatore powering recording systems near and within the survey. The repetitive nature of the bands indicates the data also contains harmonics of the generator/powerline noise.

Future work

The horizontal data need to be more carefully rotated to radial and transverse components. Some of the dynamite shots will be used in order to determine the actual orientation of the permanent geophones in Testhole1 for future surveys. Electrical noise issues need to be dealt with, possibly by modelling and subtraction, especially on the SM-7 data. Ground-roll needs to be carefully removed in order to preserve shallow reflections. All data volumes, including the ones we don't have copies of at time of writing, need to be stacked, migrated, inverted and interpreted.

Discussion

The well-logging and seismic programs were successfully carried out, meeting all of the initial objectives. However, there are some issues with electrical noise in the data that still need to be addressed.

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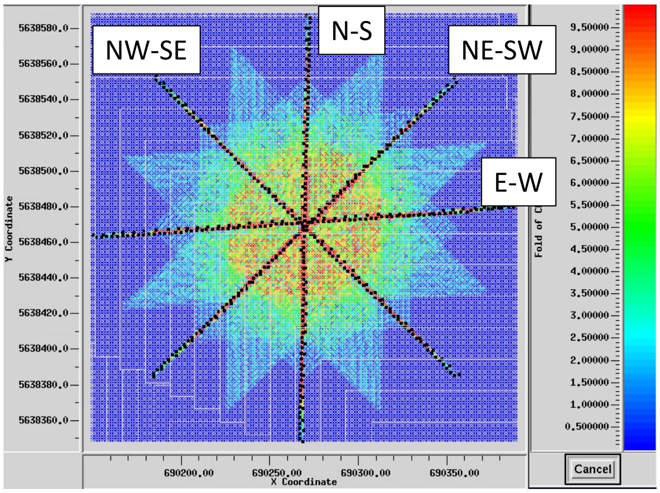

Figure 1. Dynamite CMP fold for SM-7 geophones binned with 1.5x1.5 m bins. Colour bar extent has limited to a maximum of 10 fold.

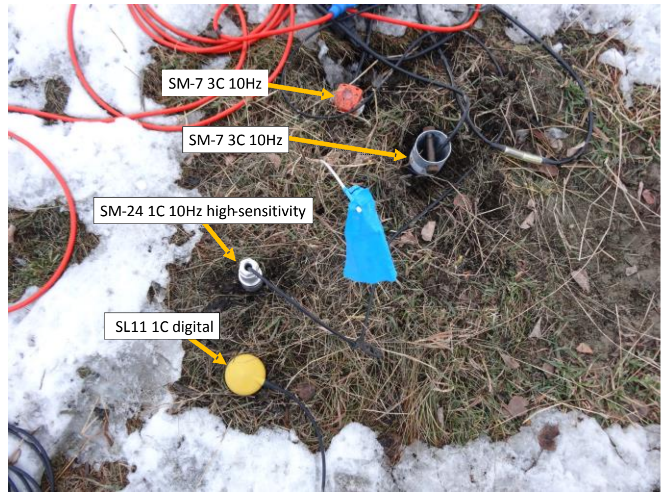

Figure 2. Surface sensors; SM-7 in nail-type case (top), SM-7 in ground-screw, SM-24HS and SL11 (bottom).

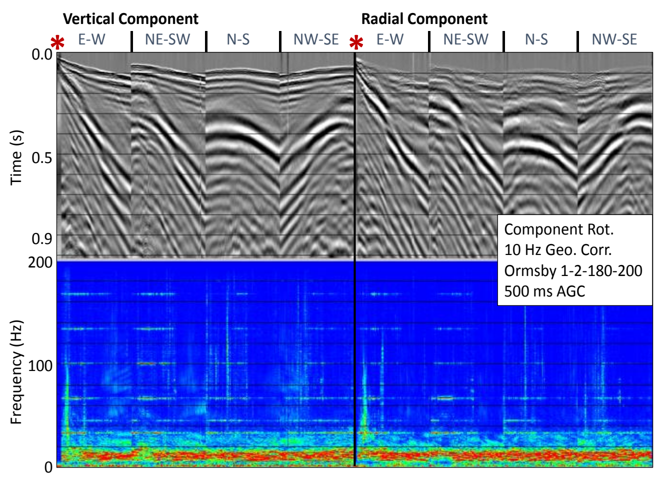

Figure 3. SP 2101, 0.125 kg Dynamite @ 5m, SM-7 in nail-type case.

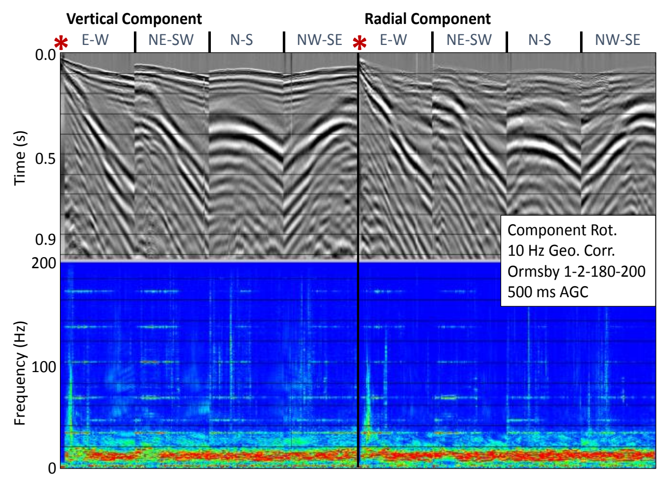

Figure 4. VP 2101, Linear 1.5-180 Hz sweep, SM-7 in nail type case.