The West Castle multicomponent seismic surveys: An overview

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SUMMARY

The West Castle River area of southern Alberta was host to a group of seismic surveys conducted in the early fall of 2006 by the University of Calgary, CREWES, and Kinetex Inc. The area, in the front range of the Rocky Mountains, is highly structural and prospective for hydrocarbons. The surveys included a 10 km multicomponent seismic line using the VectorSeis system and a simultaneously recorded ARAM line with vertical element geophones, both using an IVI vertical vibrator source. In addition, high-resolution 3C seismic surveys (with Geode and R60 systems), employing a hammer seismic source, were acquired. A set of shallow, borehole seismic surveys with a downhole 3C geophone and hydrophone cable were also undertaken. Preliminary analysis of all of these data sets is providing useful information from the very shallow (40 m) strata to several km depths.

INTRODUCTION

The West Castle seismic program was undertaken to gather data in a complicated structural zone (which hosts hydrocarbon potential) in the front ranges of the Rocky Mountains, southern Alberta. The seismic program was also designed as a CREWES research project and a University of Calgary educational exercise. The base camp for the work was at the Castle Mountain Resort located in an area of spectacular mountain topography and remarkable rock exposures. The southern region of our survey area is situated on the hanging wall of the Lewis Thrust, within the middle Proterozoic sediments of the Helikian Purcell Supergroup (Figure 1). Grey and green argillites of the Lower Siyeh and Grinnell formations outcrop on the valley floor, which is traversed by the West Castle River. The River and our surveys cross the Lewis Thrust (Figure 2) which is underlain by Jurassic and Cretaceous sediments of the Fernie, Kootenai, Crowsnest, Blackstone, Cardium, Wapiabi, and Belly River formations (Lawton, pers. comm., 2006.). There is considerable topography in the area (Figure 3) with the summit of the Castle Mountain ski resort some 800m above its base (Figure 4). The main seismic surveys were conducted along Highway 774, running north from the Castle Mtn. Resort.

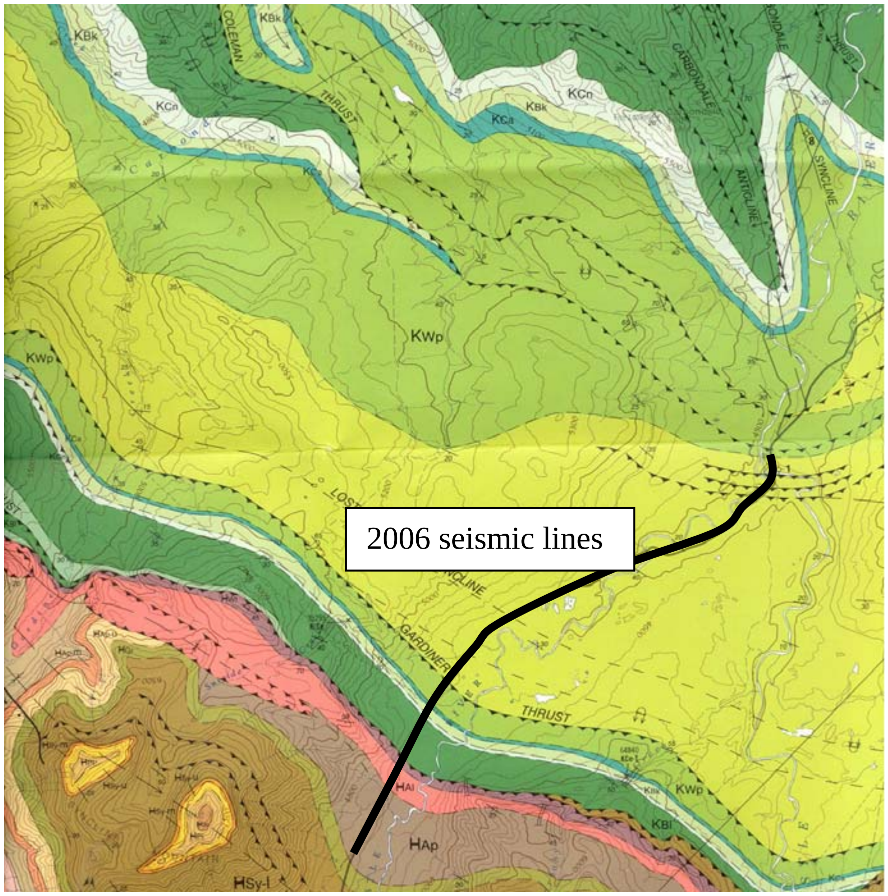

FIG. 1. Geologic map of the West Castle area. Note the transition from the Precambrian rocks in the southwest to Cretaceous sediments in the north, separated by the Lewis and Gardiner Thrusts (from Norris, 1993).

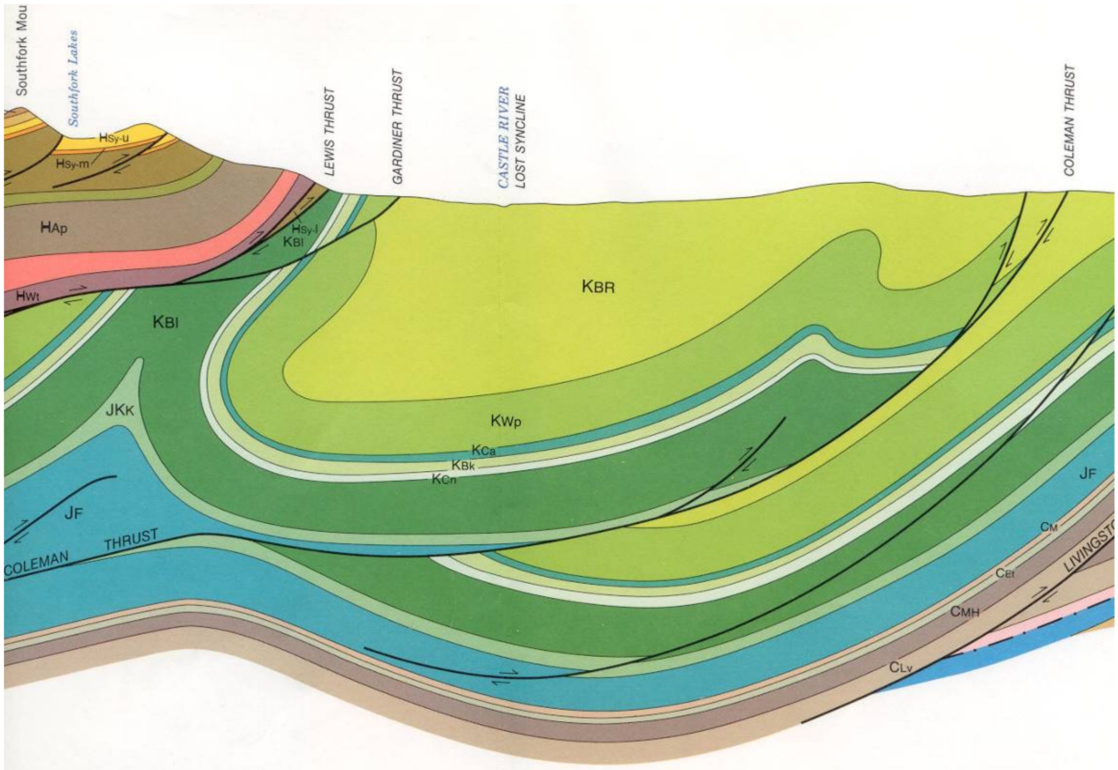

FIG. 2. Geologic cross-section from the south-west to north-east across the Lewis and Gardiner Thrusts in the West Castle area (from Norris, 1993).

FIG. 3. Eastward-looking view along the surface expression of the Lewis Thrust.

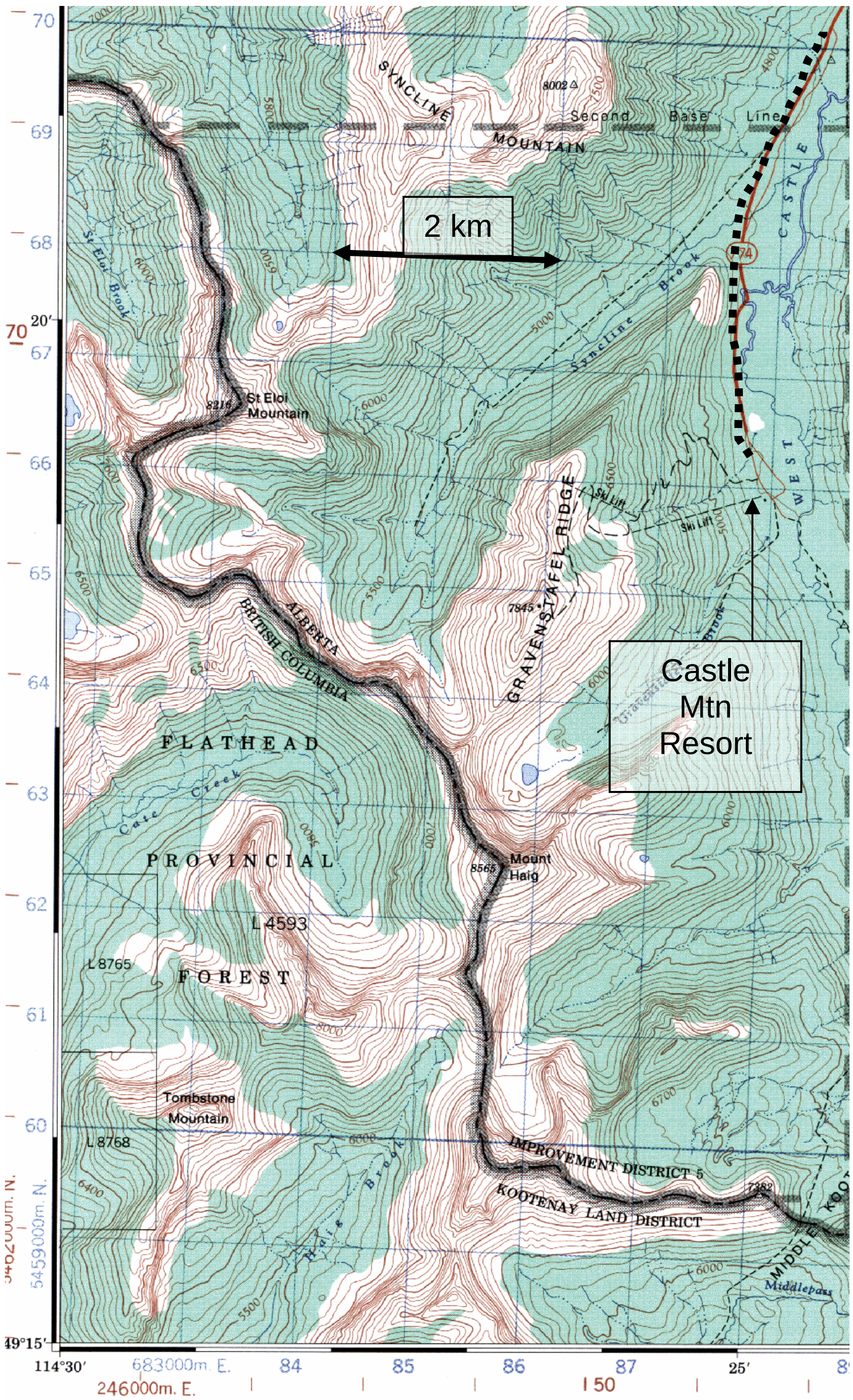

FIG. 4. Topographic map of the West Castle River area with the location of the southern part of the seismic lines annotated with a dotted line.

FIG. 5. Photograph, looking south, of the West Castle River area of southern Alberta. An outline of the seismic line, shot in August-September 2006, is annotated.

The acquisition used a number of sets of seismic equipment (Bertram et al., 2005; Lawton and Bertram, 2006; see also associated reports in this volume). The borehole seismic surveys were undertaken with a hydrophone string and a 3C wall-clamping downhole tool, in addition to a surface spread of 3C geophones recorded by a Geometric 60-channel recorder; our ARAM recording system employed vertical geophones listening to a vertical vibrator; the Kinetex VectorSeis 3C digital sensor system also recorded the vertical vibrator; and our 120-channel Geode equipment recorded a hammer seismic source into 3C geophones. These systems and their surveys are described in greater detail below.

The field program was conducted over two weeks from August 28th – September 8th, 2006. The CREWES component of the program was augmenting the University of Calgary's 2006 Geophysics Field School. There were 40 undergraduate and graduate student field participants along with six CREWES and University of Calgary personnel. Safety and logistical briefings were held every morning, prior to operations, for all personnel and de-briefings and discussions were held each evening. All operations including clean-up were conducted with personal protective gear (hard-hats, vests, eye protection, and work boots). There were severe fire-hazard conditions during part of the survey, so fires were not allowed. In addition, the area is home to numerous large animals – with grizzly bear sightings reported. Thus, all participants were required to stay in groups while outdoors and instructed in animal avoidance procedures. There is an ecological preserve close to the road where we were working. This area is said to be a breeding ground for certain salamanders and frogs. We measured the vibration level of our source (from the real-time bar graph on the seismic recording instruments) and attempted to compare it to the disturbances caused by the passing of forestry logging trucks (17,000lb vibrator versus 100,000lb trucks). We found that the vibration levels were very roughly similar.

As we were working on a fairly busy road (with logging and construction trucks and resident traffic), we posted seismic-work signs and reminded participants to be continually alert for traffic. The field program was completed without incidents or injuries.

ARAM SEISMIC SURVEY

The source that we used for the 10km seismic line was a 17,000lb IVI vertical vibrator. We employed a linear 16s sweep over 8 Hz to 120 Hz (early tests indicated a 25Hz dominant frequency at 1s reflection time). We recorded with 400 live geophones (14Hz verticals) captured by a 600-channel ARIES system using 1ms sampling and 4s record length (20s listen time). Vibrator points were taken every 10 m along the line with a single geophone every 5 m (Figures 6 and 7).

FIG. 6. ARAM and VectorSeis recording trucks simultaneously recording vertical vibrator source.

FIG. 7. The 17,000 lb. IVI vertical vibrator used as a seismic source in the ARAM and VectorSeis seismic lines.

VECTORSEIS® 3C SURVEY

Kinetex, Inc. of Calgary deployed a 500-station seismic crew to simultaneously record our vertical vibrator source along with our ARAM survey. They used the VectorSeis® 3C MEMS sensors, oriented to magnetic north (Figure 8) and spaced at 10 m. In detail, the Kinetex system (at 1ms sampling) first arms its cable-free boxes, then initiated our ARAM system, the vibrator, and its own recording.

FIG. 8. Kinetex crewman orienting the digital 3C accelerometer. A VectorSeis cable-free telemetry box is seen in the left centre of the photo.

HIGH-RESOLUTION 3-C SURVEYS

Four separate high-resolution surveys were conducted along portions of the large-scale seismic line. These surveys were conducted to obtain higher-resolution models of the near surface and to illustrate refraction survey techniques to students. A set of five networked Geometrics Geode acquisition boxes provided 120 channels of recording capability. A 7.2 kg (12 lb) sledgehammer was used as the source and a set of forty 3-C were used as receivers. Though near-surface refraction surveys are typically recorded with single-component geophones, we elected to use 3-component geophones to better familiarize the students with 3-C technology. In addition, we hoped that shear-wave refractions might be recorded to help improve our shear-wave models.

FIG. 9. High resolution spread. Geophones are located at orange flags. The Geode (yellow case) is connected to the other Geodes via a spool of yellow data cable.

A novel spread configuration was chosen (Figure 10). Three-component geophones were connected to the recorder using 24-takeout, single-component geophone cables. Eight geophones were connected to each Geode recorder with the cable arranged in a serpentine configuration. This configuration allowed us to hook-up the three geophone components on each pass of the cable. By wiring the geophones in groups of eight, we could roll the spread by deploying groups of eight geophones at a time (and leaving the rest of the spread untouched). Layout of the cable was tedious and labor intensive and highlighted the need for a set of purpose-built 3-C cables with six-pin connectors for simultaneous (and correct) wiring of all three geophone components in one plug.

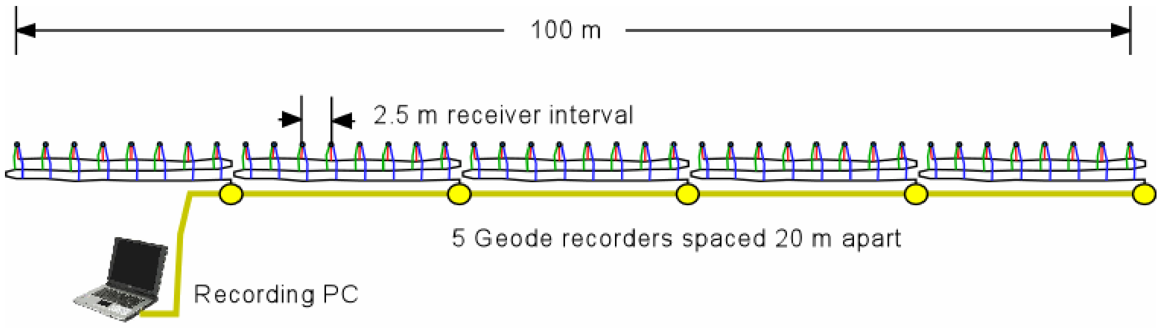

FIG. 10. High resolution geophone spread using 3-C geophones and 24-channel Geode recorders.

The survey was shot with spike-shaped 3-C geophones. These geophones, manufactured by I/O, contain SENSOR SM24 elements (horizontal and vertical) mounted in a PE-6S case. This case-style requires a 12 cm-deep planting hole. Holes were drilled with a gas powered auger fitted with a 6 cm diameter drill bit. Data were recorded using a 0.25 ms sample interval and a 0.5 s record length.

Hammer shots were taken at 20 m intervals within spread (at each Geode) and end-shots were taken at 20 m and 40 m offsets beyond the ends of the spread. The networked Geodes are each capable of supporting a hammer-switch input. This made it easy to use a short trigger cable as we progressed through the spread, typically connecting to the nearest Geode along the way.

The four high resolution datasets each contain 8-12 shots with 4 vertical stacks at each shot point. An initial review of the data shows that it will be acceptable for both P-wave and S-wave refraction processing.

FIG. 11. University of Calgary/CREWES cable crew picking up equipment from the high-resolution 3C survey.

BOREHOLE SEISMIC SURVEYS

We conducted a number of borehole seismic surveys using a GeoStuff 3C downhole clamping geophone as the receiver. In addition, we employed an 8-level hydrophone array provided by JODEX Applied Geoscience Limited. The energy source was a 16 lb sledge hammer swung manually, and the recording unit was a Geometrics R60 seismograph. A metal strike plate was wired to the seismograph as was the hammer. When the hammer contacted the plate, the circuit was closed and recording initiated. The surveys were conducted in two, cased water wells – one well near the day lodge (Lodge well shown in Figure 10) and the other at the north end of the condo development (the Duplex well displayed in Figure 11).

The Lodge well is 43 m deep, while the Duplex well is 32 m. At the time of the survey, the water level was about 5m below ground level in both the Lodge and Duplex wells. All our borehole survey depths were measured from the top of a sheave wheel used to guide and support downhole cables. This reference point, equivalent to a Kelly bushing elevation for us, was approximately 1.1 m above ground level. The sheave wheel is shown on top of the well casing on Figure 12.

FIG. 12. Dr. Joe Wong of CREWES and assistants conduct a shallow VSP measurement using a 3C wall-clamped geophone tool.

The downhole 3C geophone and 8-element hydrophone array required only a few of the 60 channels available on the R60 seismograph. The remaining channels were connected to surface 3C geophones so that, as we recorded VSP data in the Lodge well, we also recorded surface 3C data along a 40 m long line centered over the well. In addition, when we recorded VSP data in the Duplex well, we concurrently conducted a mini 3D/3C experiment covering a nearby area of about 20 m by 15 m. The mini 3D experiment was done mainly to demonstrate to students some of the basic ideas behind a full-scale 3D survey. However, it also should provide some information about the near-surface seismic velocity structure around the wells, information which may be useful in evaluating local groundwater conditions at the development site.

FIG. 13. Offset shallow VSP survey being conducted with a hammer-seismic source.

DISCUSSION

The seismic data and its analysis are discussed in associated reports in this 2006 (18th volume) CREWES Research Report

CONCLUSION

This set of surveys in southern Alberta acquired a variety of surface and downhole seismic data. The surveys have provided a number of excellent research data sets. Early analysis suggests that the data contain considerable usable information.

ACKNOWLEDGEMENTS

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