Multi-component Digital Receivers: Comparison of Subsurface and Conventional Surface Datasets

Tagir Galikeev*
Input/Output Inc., Denver, CO, United States
tagir.galikeev@i-o.com

Jason Criss
Input/Output Inc., Denver, CO, United States

and

Vince Rodych
Input/Output Inc., Calgary, AB, Canada

Datasets described in this abstract were acquired over an area planned for a heavy oil Steam Assisted Gravity Drainage (SAGD) project in Northeastern Alberta. Due to complex near-surface conditions in the area, surface seismic data, particularly C-waves, often deliver poor results, which can not be used reliably in the consequent process of lithology discrimination and, therefore, location planning for horizontal injector/producer well pairs. Optimal location of the wells ensures better oil sweep efficiency, and, thus, economics of a given SAGD project. As well, results of this data analysis also hold promise for 4D steam monitoring projects using subsurface multi-component digital receivers.

Introduction

An interest increase in oil sands, which according to the industry sources, hold up to 66% of total world oil reserves, is caused by several seemingly unrelated issues

- an increase in world hydrocarbon-generated energy demand,
- struggle by Western oil majors to replace reserves at a satisfactory rate
- calls for diversification of hydrocarbon sources in the developed countries
- historical higher cost of production from oil sands and lower rates of return (less than half when compared to deep water Gulf of Mexico) are offset by the current high pricing environment for crude oil.

Two countries, Canada and Venezuela, have most of heavy oil projects and reserves. Canada is more attractive because of political stability, investment climate and proximity to the United States, major hydrocarbon consumer. Canadian Athabasca Tar Sands hold about 1.7 trillion barrels out of 3.5 trillion barrels total for Canada and Venezuela.

Oil sands contain heavy oil characterized by high viscosity and density, which will not flow under natural conditions. Oil production from oil sands include open pit mining and in-situ production. In open pit mining the tar sands are delivered to a dedicated facility for a consequent separation process. In-situ process is a bit more complicated, which requires precision horizontal drilling, steam (solvent) infrastructure and reservoir stimulation in order to increase oil mobility and make it possible to pump it to the surface. Multiple techniques for in-situ production are available: cold flow, CSS (Cyclic Steam Stimulation), SAGD and some other more exotic methods. All of them are well described in related industry literature (Schmitt, 2004).

Project Description

Geometry of the undertaken project is shown in Figure 1. Two lines with a total of 17 surface and 17 subsurface locations were recorded with multi-component digital point receivers. A study area was selected where thick muskeg was present. The surface receivers were part of a larger 3D surface survey that had a typical layout: 30 m spacing between receivers and sources, 90 m between receiver lines and 150 m between source lines. The reservoir is shallow (no deeper than 500 ms of seismic two-way time). Resolution and frequency content of the seismic data plays an important role, since one of the objectives is to distinguish between the bitumen sands and thin shale layers, which act as barriers in the way of steam distribution and, therefore, degrading an ideal picture of steam chamber within the reservoir imaged by engineers.

Multi-component digital point receivers utilized in the survey are widely used in the seismic industry and have better and broader amplitude and phase characteristics than conventional geophones, which translates into higher frequency, higher resolution seismic image (Tessman and Maxwell, 2003 and Behr 2005). Some of the advantages of the digital multicomponent accelerometers over conventional geophone array are:

- Self-orienting to the vertical (ensures high degree of repeatability in 4D)
- Point-receiver (no intra-array statics, no averaging, no azimuthal directionality)
- Ground roll suppression using full-wave data (SVD-based or adaptive filtering by utilizing the multicomponent nature of the data)

The last point is especially valuable since we are dealing with the shallow data and preserving reflected data integrity within the range of near offsets is essential for maintaining fold and data quality.

17 subsurface receivers were planted in the middle of March 2006 at a depth of approximately 10 m (Figure 2). VectorSeis 3C sensors with a top axial entry option were utilized, allowing for easy subsurface deployment through open holes and holes cased with pvc pipe. After the test was accomplished, receivers were retrieved and tested for durability in October of 2006. Out of 51 MEMS elements (three per receiver) only one element was determined to be faulty.

Data Comparison

Data quality of all three components is illustrated in Figure 3. No processing was applied except an AGC of 100 ms for display purposes. Horizontal components are unrotated. Data represent common receiver gathers of the collocated surface and downhole receivers. Most dramatic improvement is evident on the horizontal components of the downhole receivers. Project area is characterized by a complex near surface, which renders horizontal components of the dataset unusable. Data analysis included well-to-seismic ties, frequency and amplitude analysis, synthetic modeling using wells with P- and S-wave sonic logs.

Conclusions and Future Work

Subsurface installation (both retrievable and permanent) of multicomponent digital sensors can be a viable option to avoid near-surface conditions caused by muskeg, and also as a means of locating receivers for repeatible time-lapse monitoring.

Subsurface receiver data demonstrated a better quality, with higher event coherency and continuity. However analysis was carried out on pre-stack data due to the lack of fold in downhole dataset.

References

Schmitt, D., 2004, Oil Sands and Geophysics: CSEG Recorder, November, 5-11.

Behr, J., 2005, Multicomponent Receivers for P-wave Seismic over Rough Topography: Motivation and Results: CSEG Convention 2005

Tessman, J., and Maxwell P., 2003, Full-Wave Digital Seismic Recording and the Impact of Vector Fidelity on Improced P-wave Data, October 2003, CSEG Recorder, 22-24.

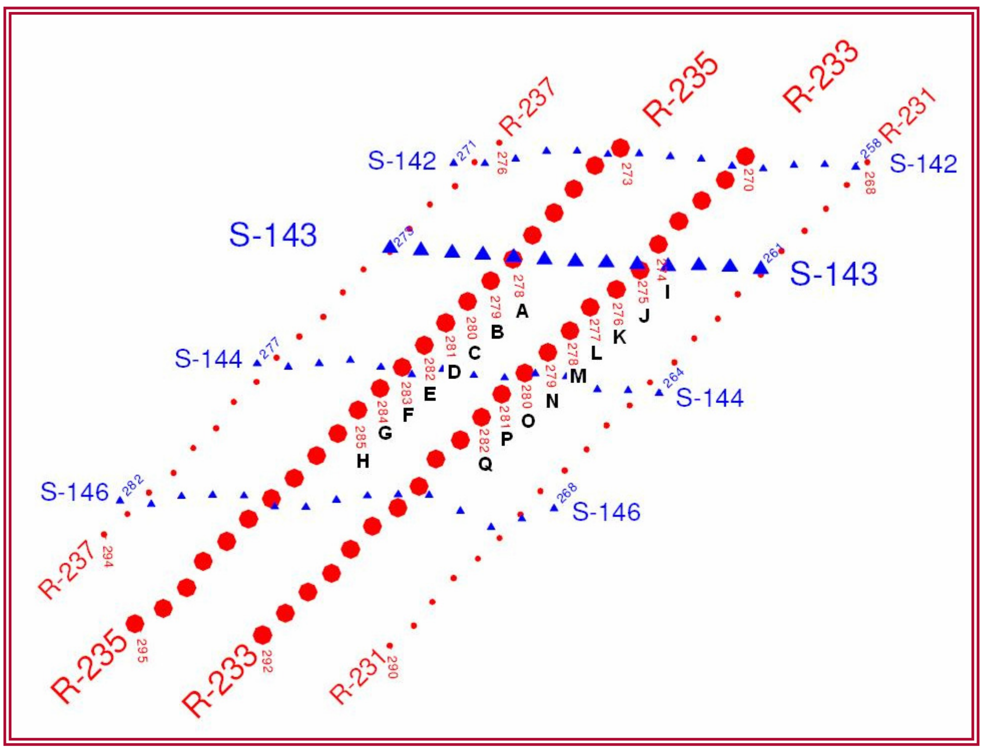

Figure 1. Survey layout. blue triangles and red dots correspond to receivers and sources. Red circles show placement of the downhole receivers.

Figure 2. Deployment borehole for a subsurface receiver (left). Retrieved receiver seven months later, showing deployment in clay-mud in subsurface below muskeg (right).

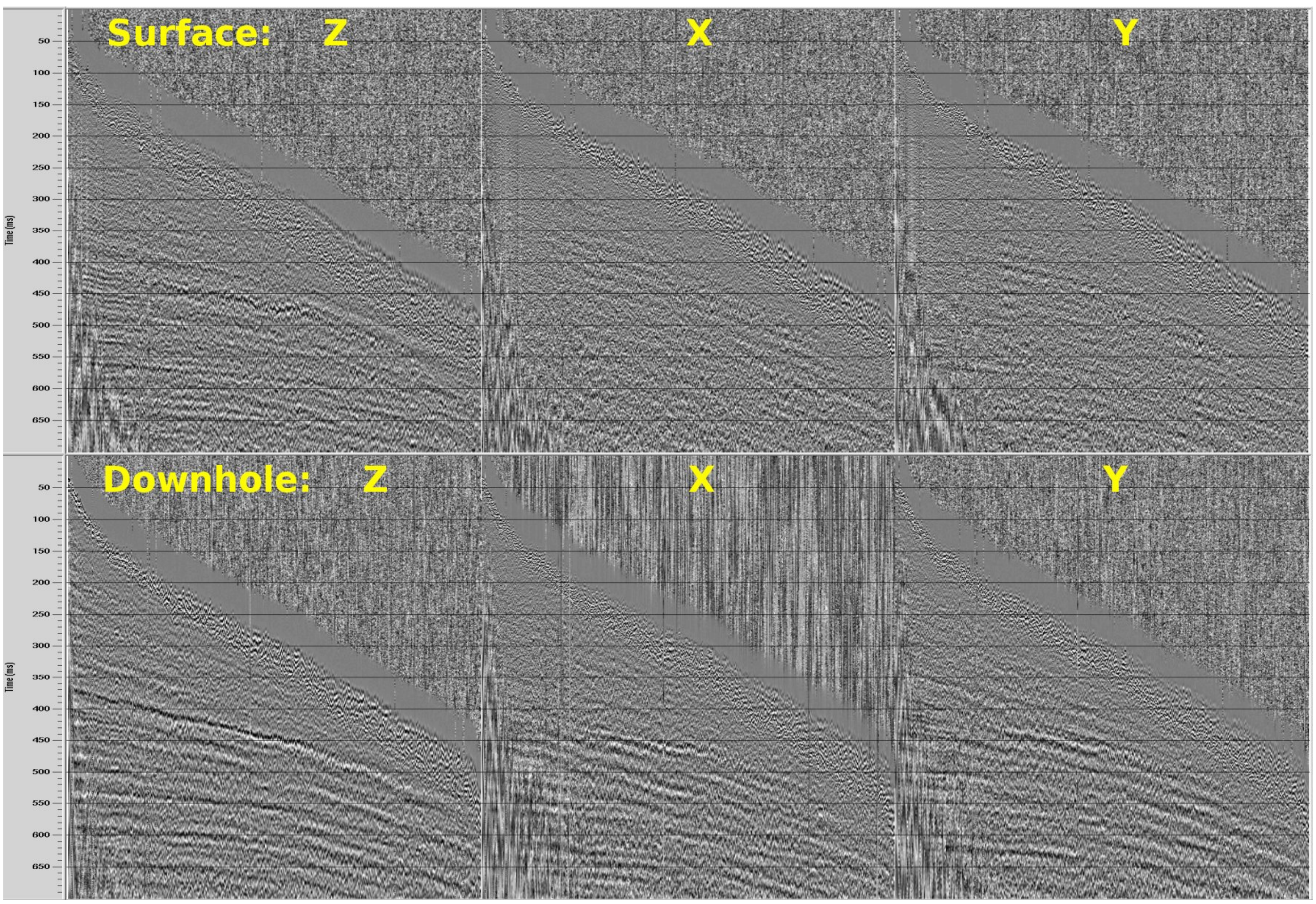

Figure 3. Common receiver gathers for all three components. Shown for collocated surface and downhole receivers. Horizontal components are unrotated.