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Steam Injection Seismic Monitoring Experiment

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Abstract

A buried receiver network has been installed in 1998 on a heavy oil SAGD (Steam Assisted Gravity Drainage) pilot project in northern Alberta in order to record one conventional 3D time-lapse seismic survey every year. This network has been used to evaluate the ability of a new seismic technique using permanent sources and receivers to provide a fast indicator of the steam motion. The high repeatability of this technique enabled observation of the steam progression over a month.

Introduction

ConocoPhillips set up a SAGD pilot project in 1998 at SURMONT (operated by ConocoPhillips, partner Total). The reservoir consists in high porosity unconsolidated sand at 400 m depth. The injection of steam in the reservoir was expected to lead to significant changes in seismic impedances; it was therefore decided to install a buried permanent receiver network of 1,300 geophones buried at a depth of 9 m in order to record 3D time-lapse surveys every year.

A New Seismic Monitoring Technique

Since 1998, CGG, GDF (Gaz de France) and IFP (Institut Francais du Petrole) have developed a comprehensive seismic monitoring system based on low-energy stationary seismic sources operating continuously and simultaneously in conjunction with permanent receiver antennae. The antennae can be vertical when very high sensibility is needed or horizontal when spatial information is necessary (figure 1). Sources and receiver being stationary, one of the major causes of nonrepeatability (positioning differences) disappears.

Further, over the course of the system development, it was found that unlike their surface counterpart, buried sources and buried receivers could be almost insensitive to weather perturbations and provide a far better repeatability. The seismic source selected is a 1-kW piezoelectric source, which presents excellent reliability.

This system, called SeisMovie™, is fully automated and remotely controlled (Meunier, et al., 2001). This high-resolution seismic monitoring has the potential to optimize exploitation scenarios: tiny changes in the seismic response (a few microseconds and a few percents) can be measured and calibrated to direct reservoir measurements (Bianchi et al., 2004).

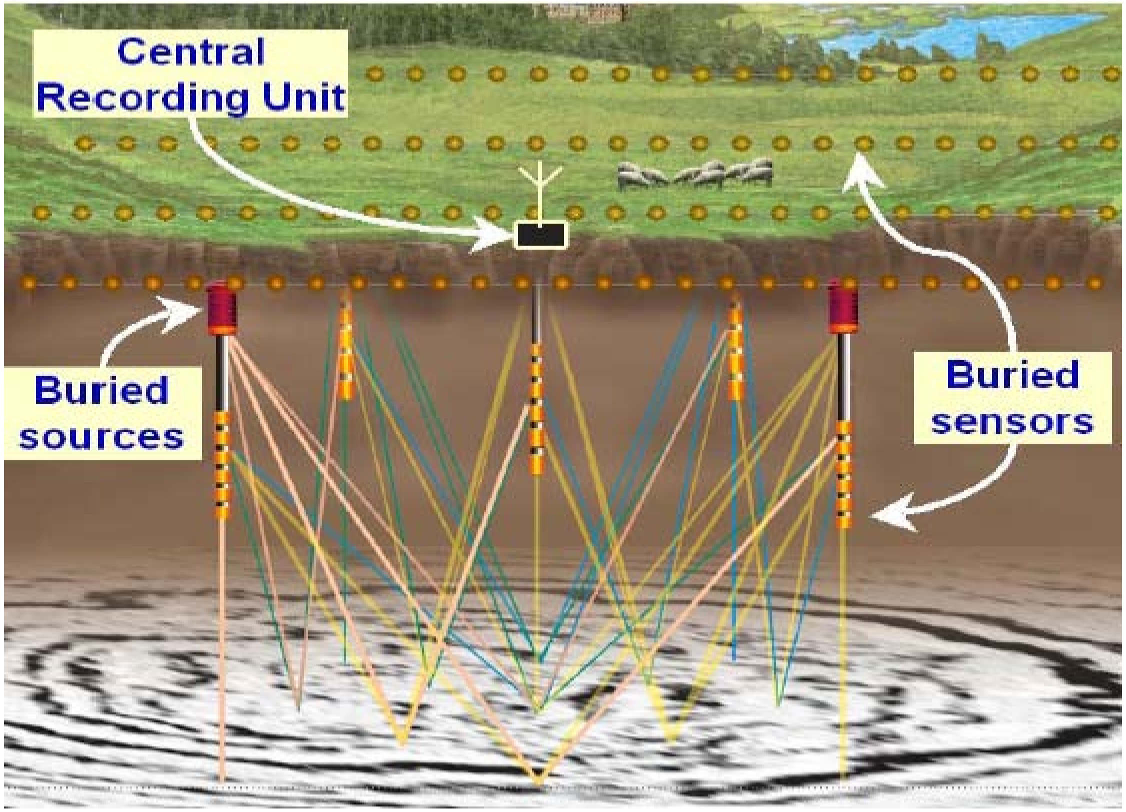

Figure 1: Seismic monitoring system with five sources, five vertical and four horizontal antennae of receivers.

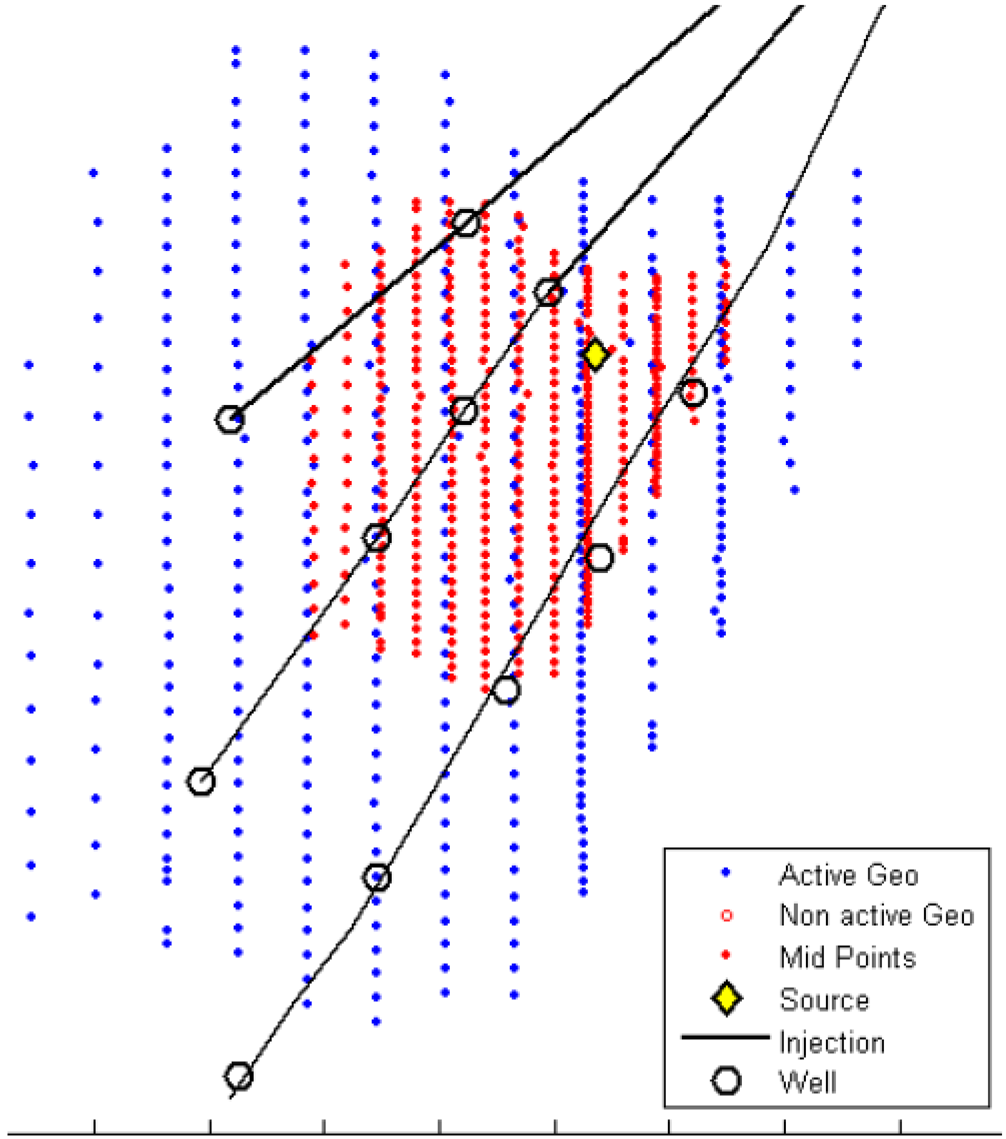

Figure 2: Location map of buried geophones (blue), the buried source (yellow), illuminated area (red), horizontal wells (black).

Survey Planning

Preliminary tests on the IZAUTE gas storage reservoir (in the south of France) have qualified the system repeatability. In parallel, a modeling exercise conducted by Total showed that at the Surmont Pilot a steam injection rate corresponding to a 10-m yearly rise in the steam chamber would result, for a one-month period, into a 0.4-ms rise of the steam top and a 0.1-ms pull down of the Devonian reflector below the reservoir. This order of magnitude was compatible with the system expected sensitivity. Consequently, it was decided to record a one-month experiment using a piezoelectric source and a selection of the available buried receiver network shown on figure 2.

Data Recording

The Piezoelectric source was buried at a depth of 46 m on September 23rd, 2005. The actual recording started on October 5th with a night of field tests for parameter selection. Two hundred forty records corresponding to one hour of recording were averaged in the field and were transferred to France via Internet every two days. The parameters were the following:

Sweep Frequencies	15 to 300 Hz
Sweep Length	30 s
Record length	1.5 s
Sample rate	1 ms
Number of Seismic Channels	397
Number of auxiliary traces	10
Number of records	82,071
Number of recording days	30

Results

The corresponding data quality can be seen on figure 3.

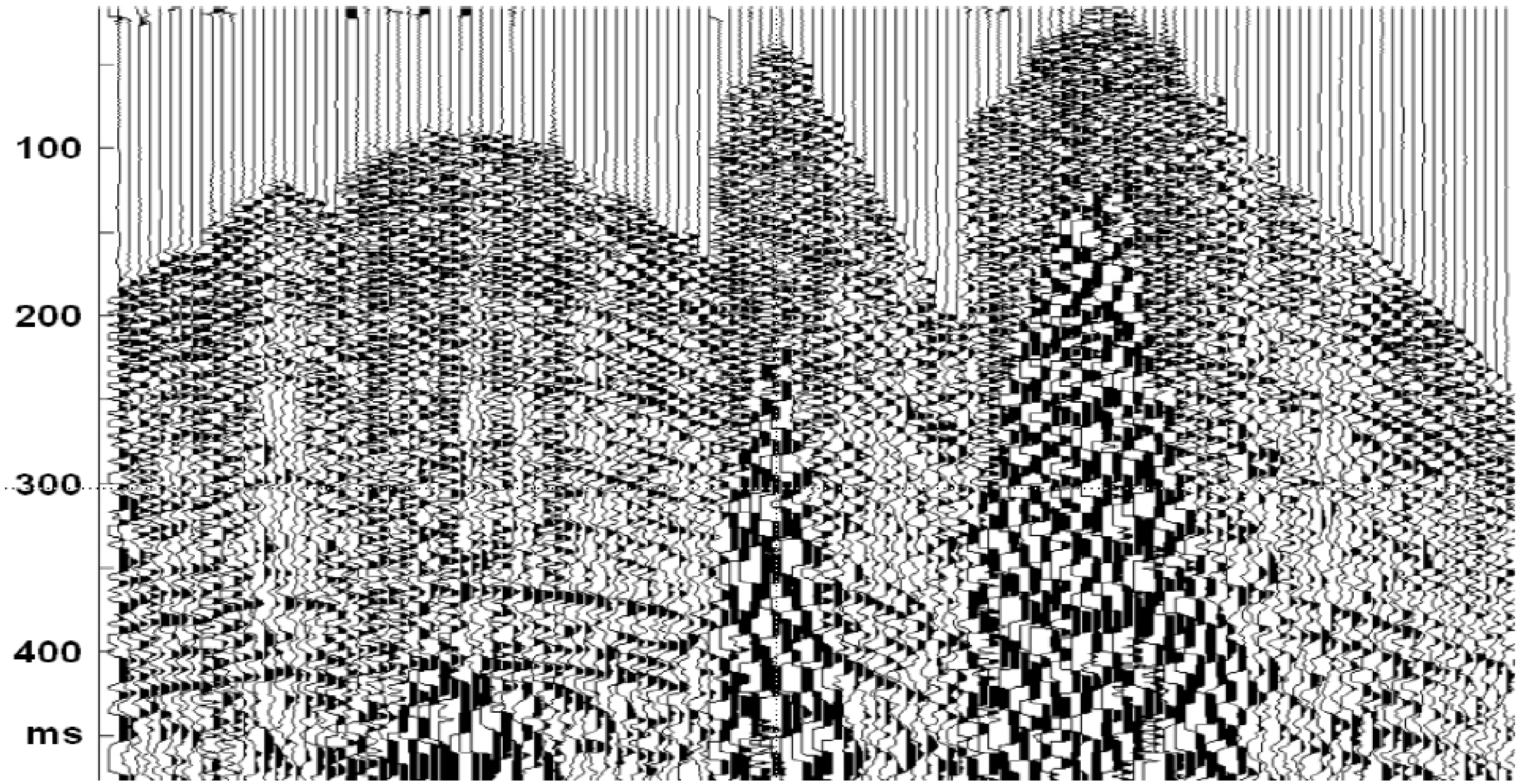

Figure 3: Data close-up on one- hour recording average (240 records).

The frequency content at the base of the reservoir at 360 ms reaches 240 Hz. This is considerably higher that what could be achieved conventionally using shot holes. Further noise reduction is obtained by averaging records over 1-day periods. The corresponding data repeatability can be appreciated on figure 4. It enables the detection of travel time variations smaller than 1/10th of a millisecond.

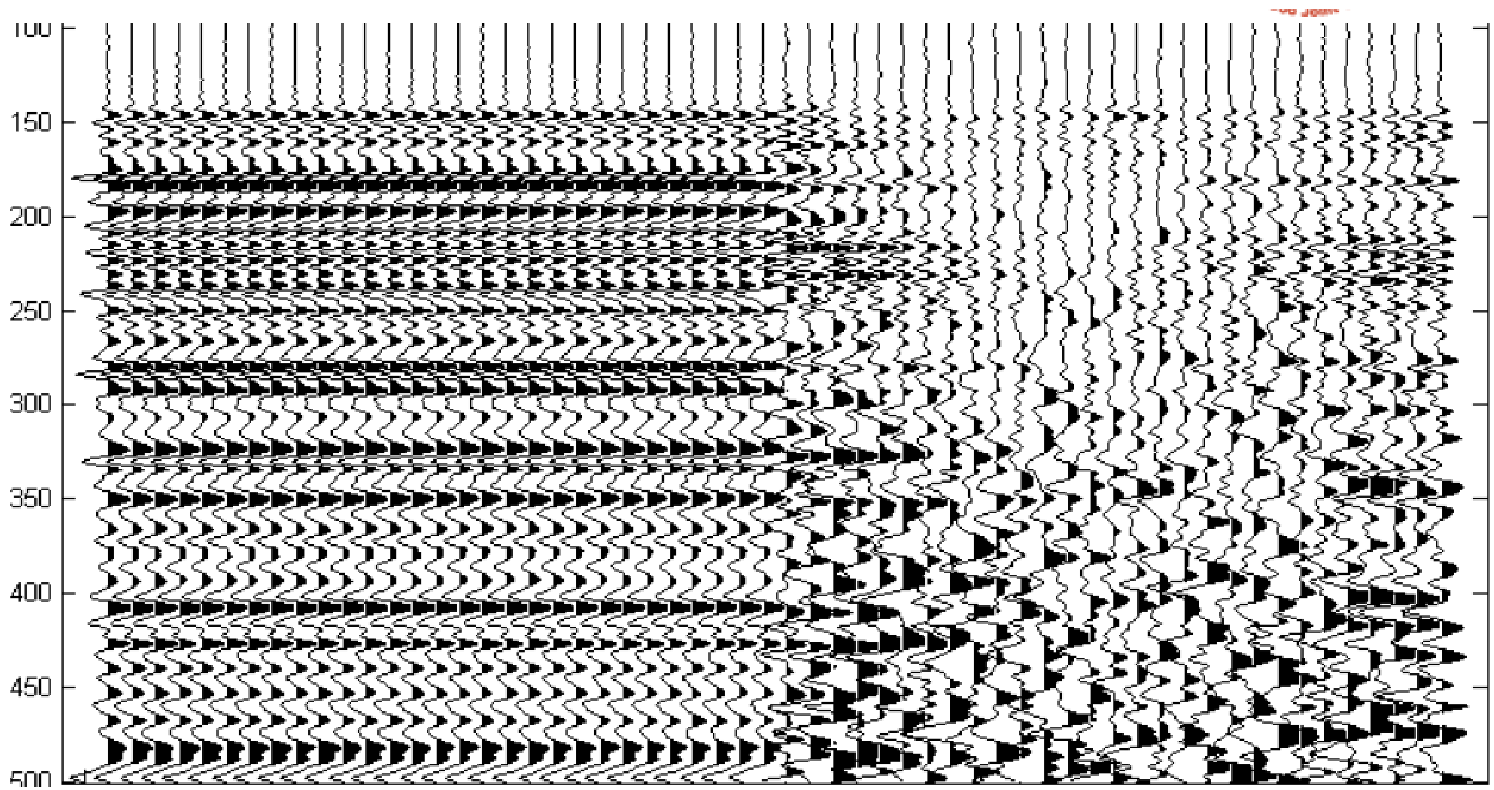

Figure 4: Daily repetition of a seismogram over one month. Left: Raw seismogram, Right: difference with average * 10.

Conclusion

Transit time variation through the reservoir could be measured every day. It showed a steady increase in the region of the eastern well pair. After one month, at the end of the experiment, this variation reached 0.15 ms (figure 5). This experiment on the SAGD pilot shows a high level of repeatability in an industrial context. The steam plant adjacent to the recording area and drilling operations nearby during this period did not prevent the system from being able to detect significant 4D seismic signals. Transit time variation through the reservoir could be measured every day. It showed a steady increase in the region of the eastern well pair. After one month, at the end of the experiment, this variation reached 0.15 ms (figure 5). Therefore, SeisMovieTM is a promising monitoring tool for SAGD developments and might be considered as a possible alternative to 3D time-lapse seismic.

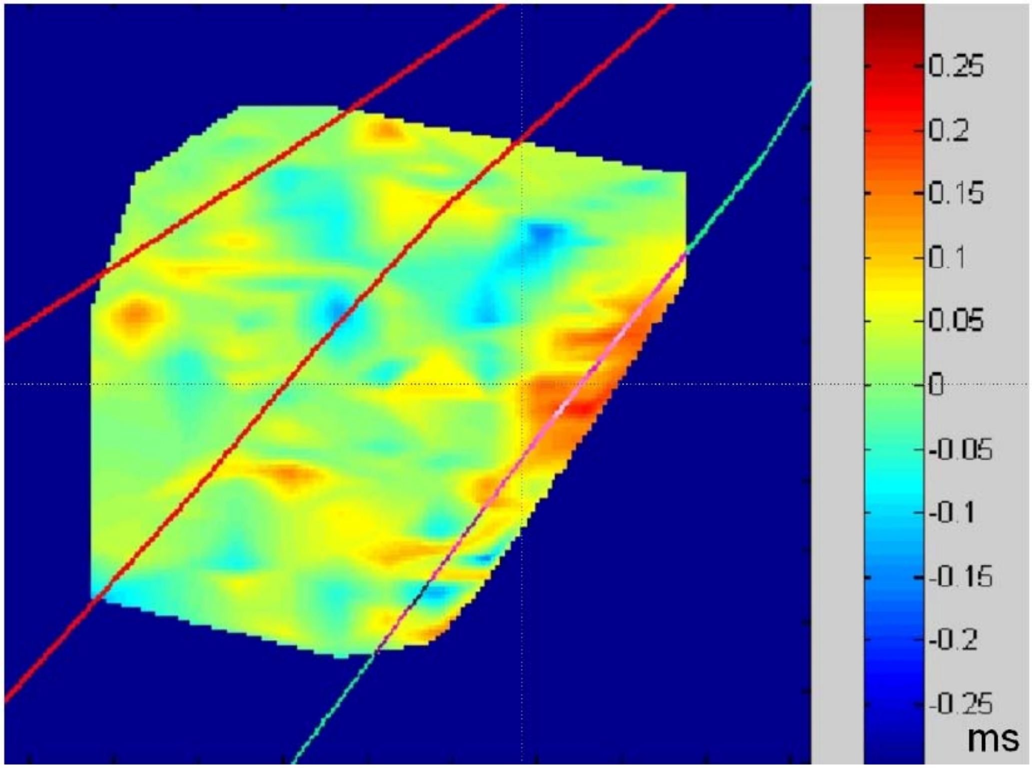

Figure 5: Transit time variation through the reservoir measured over a period of 1 month (ms). Red lines are injection wells.

Acknowledgement

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