Steam Injection Seismic Monitoring Experiment in Northern Alberta*

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Abstract

A buried receiver network was installed in 1998 on heavy oil SAGD pilot project in Northern Alberta in order to record one conventional 4D 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 daily steam progression.

Introduction

The Gravity Drainage project started in 1998 over the Surmont area. The reservoir is a high porosity sand at 400 m depth. One of the challenges of this project is to evaluate the profitability and the difficulties to produce heavy oil using Steam Assisted Gravity Drainage (SAGD). The presence of steam in the reservoir was expected to lead to significant changes in seismic impedances; it was therefore decided to take profit of this pilot survey to install a buried permanent receiver network of 1,300 geophones buried at a depth of 9 m in order to record 4D surveys every year.

A New Seismic Monitoring Technique

Since 1998, CGG, GDF and IFP 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 areal information is necessary (Figure 1). With sources and receivers being stationary, one of the major causes of non-repeatability (positioning differences) disappears.

Further, over the course of the system development, it was found that contrary to 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 percent) can be measured and calibrated to direct reservoir measurements (Bianchi et al., 2004).

Survey Planning

Preliminary tests done in the south of the France for a GDF gas storage reservoir have qualified the system repeatability. In parallel, a modeling exercise conducted by ConocoPhillips and TOTAL showed that the current steam injection rate corresponding to a 10-m yearly rise in the steam chamber would result, for a one-month period, in a 0.4-ms rise of the steam top and a 0.1-ms pull down of the Devonian reflector below the reservoir. This figure 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. Figure 2 shows receivers (blue dots) and source (yellow diamond) locations over the three horizontal steam injection wells.

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. The parameters are shown in Table 1. 240 records corresponding to one hour of recording were averaged in the field and were transferred to France via Internet every two days.

Results

The corresponding data quality can be seen in Figure 3. The frequency content at the base of the reservoir at 360 ms reaches 240 Hz. This is considerably higher than 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 in Figure 4. It enables the detection of travel time variations smaller than 1/10th of a millisecond.

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 in Northern Alberta, on the SAGD pilot, shows a high level of repeatability in an industrial context. The steam plant adjacent to the recording area and the drilling of a well during this period did not prevent the system from being able to detect significant 4D seismic signal. Therefore, we can expect to be able to build a “seismic movie” during the several years of steam injection and oil production.

Acknowledgement

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References Cited

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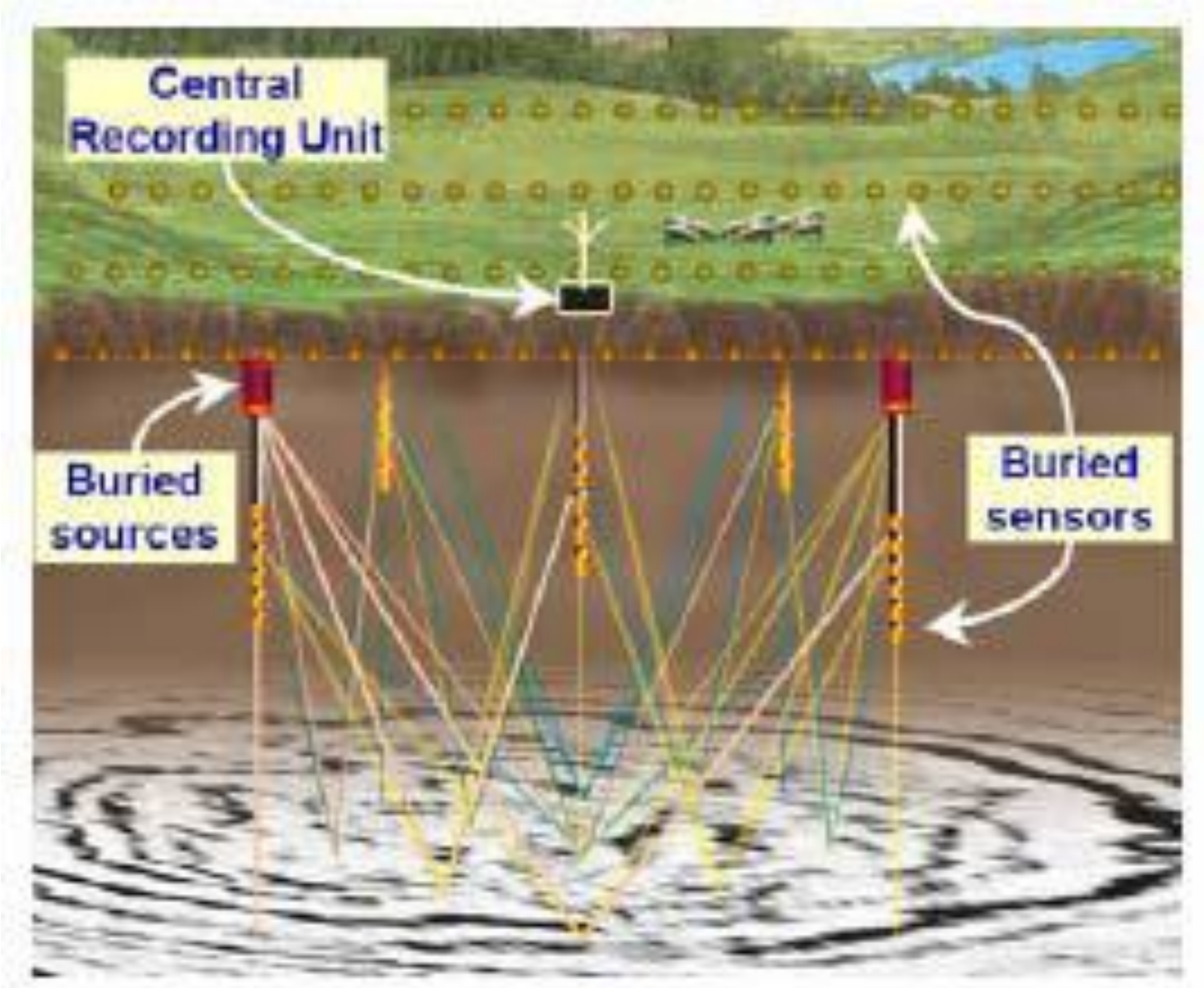

Figure 1. Seismic monitoring system with 5 simultaneous sources, 5 vertical and 4 horizontal antennae of receivers.

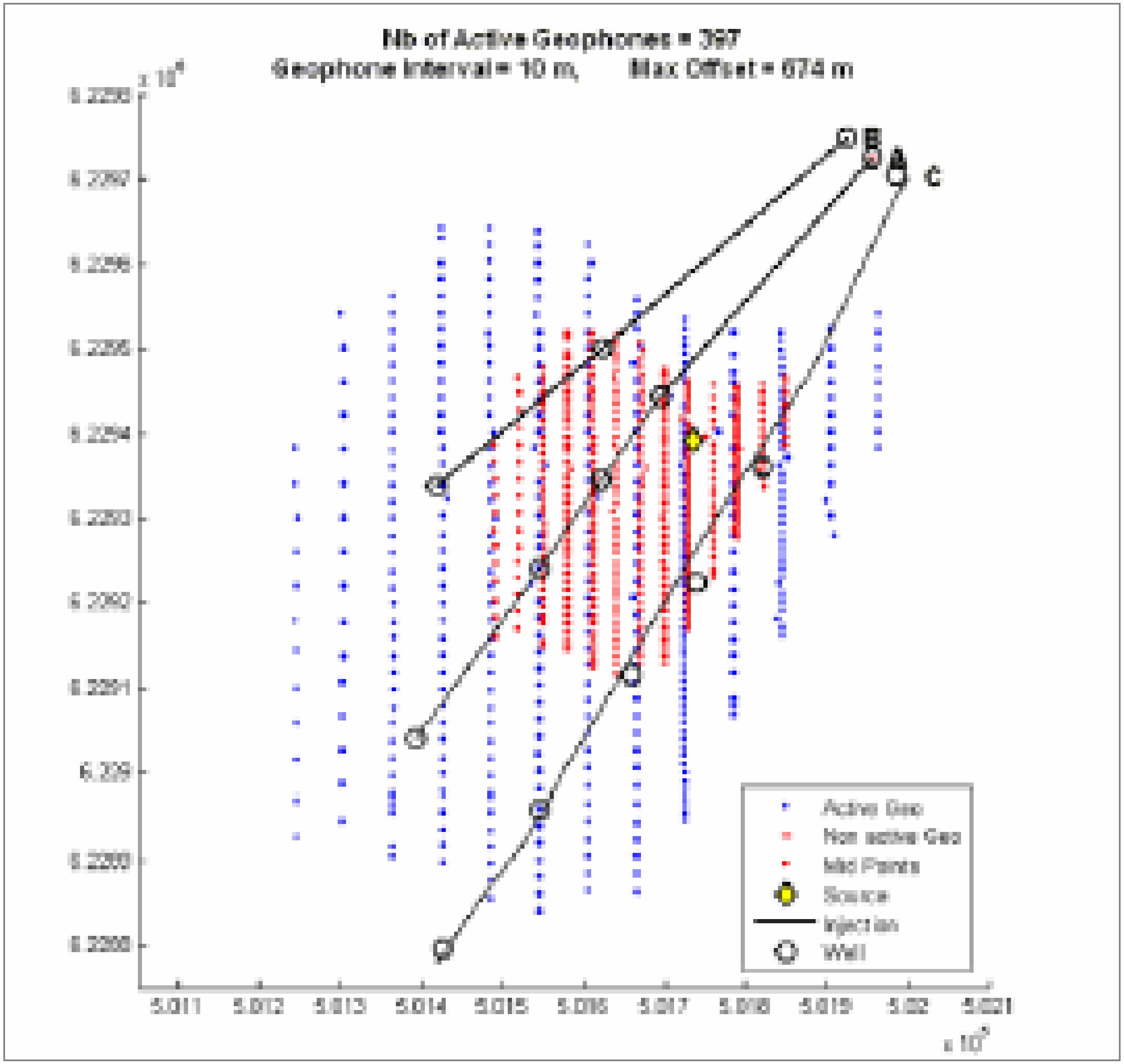

Figure 2. Location map of buried geophones (blue), the buried source (yellow), illuminated points (red), horizontal wells (black).

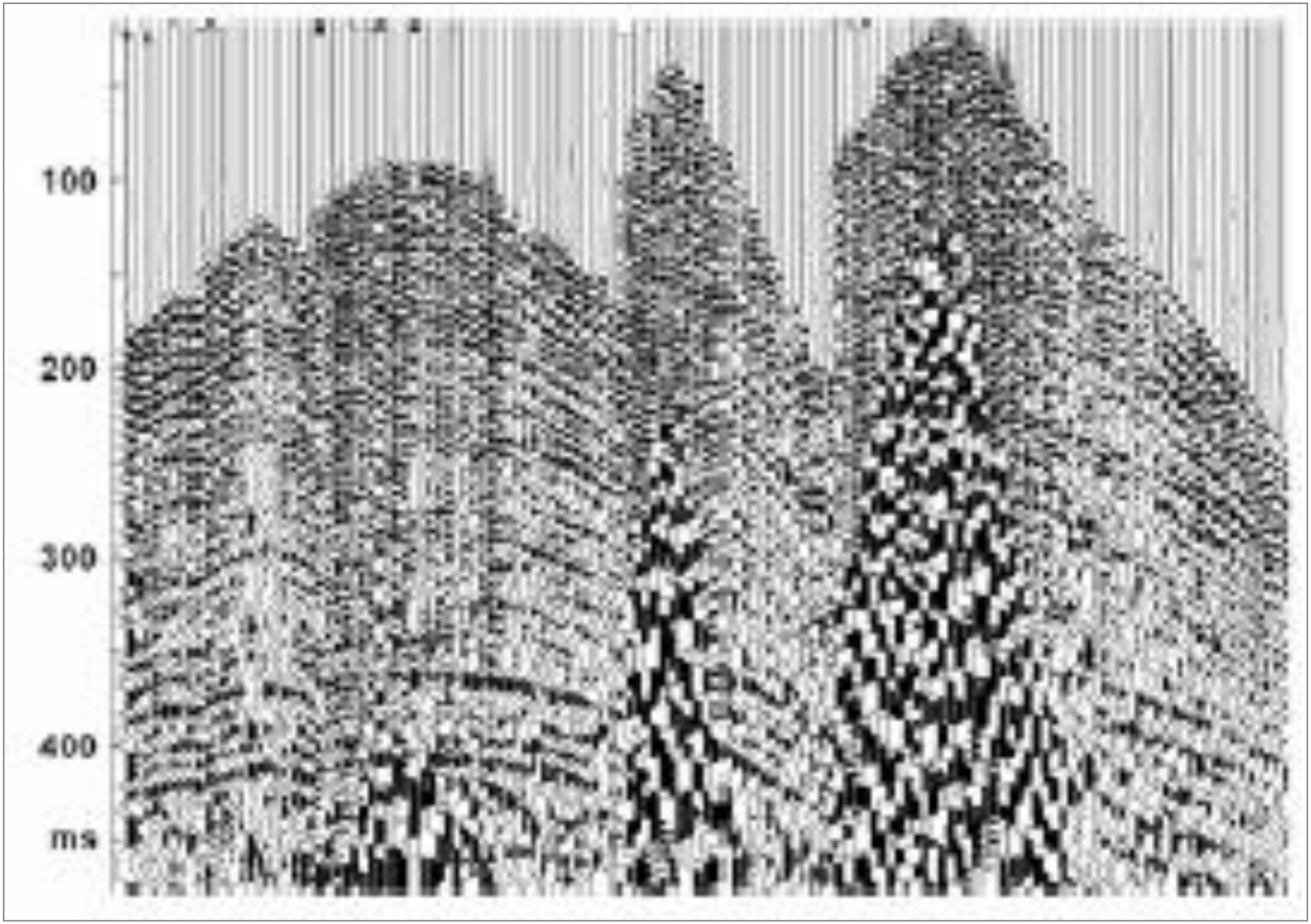

Figure 3. Data close-up on one-hour recording average.

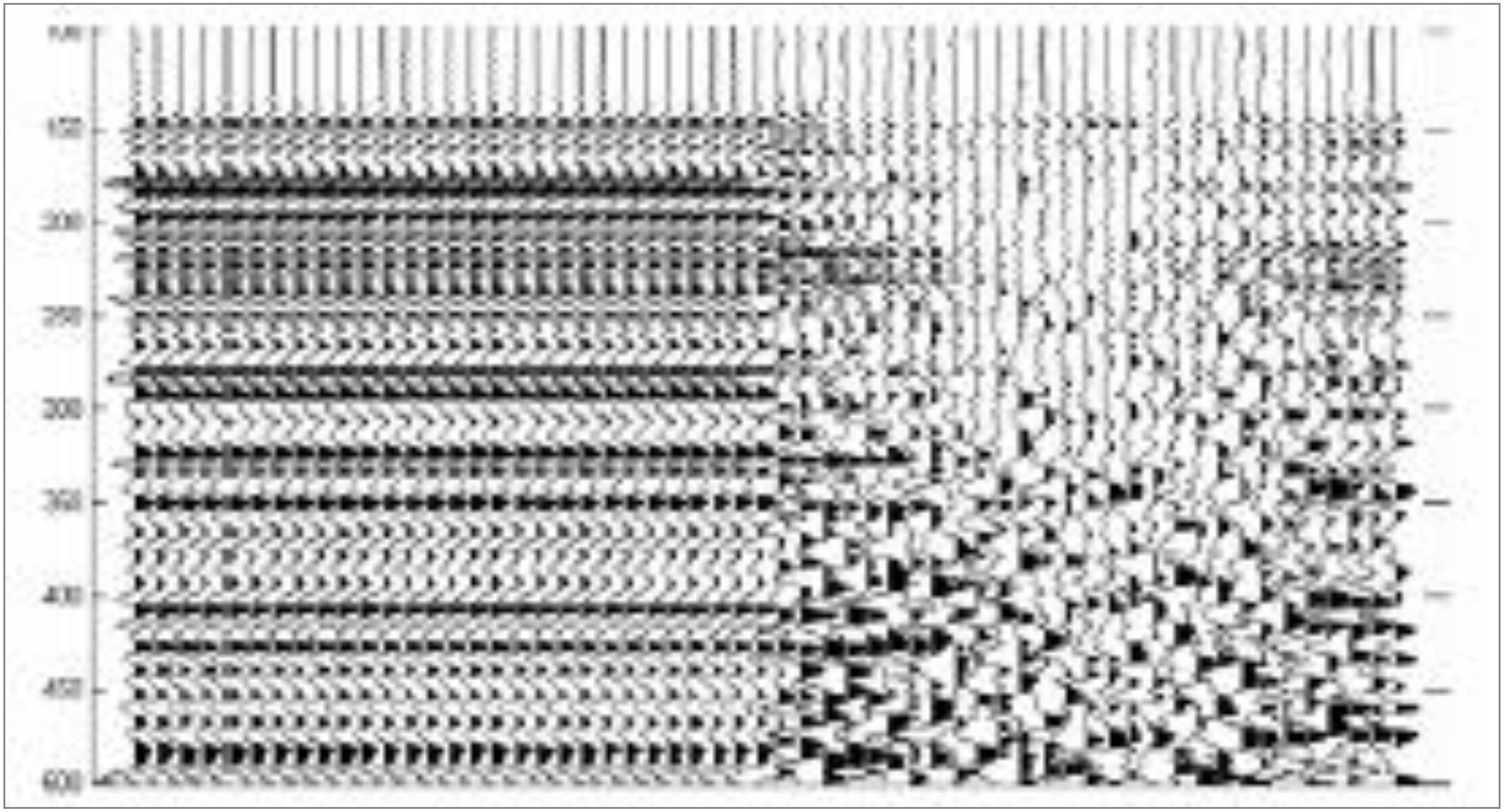

Figure 4. Daily repetition of a seismogram over one month.
Left: Raw seismogram
Right: Difference with average * 10

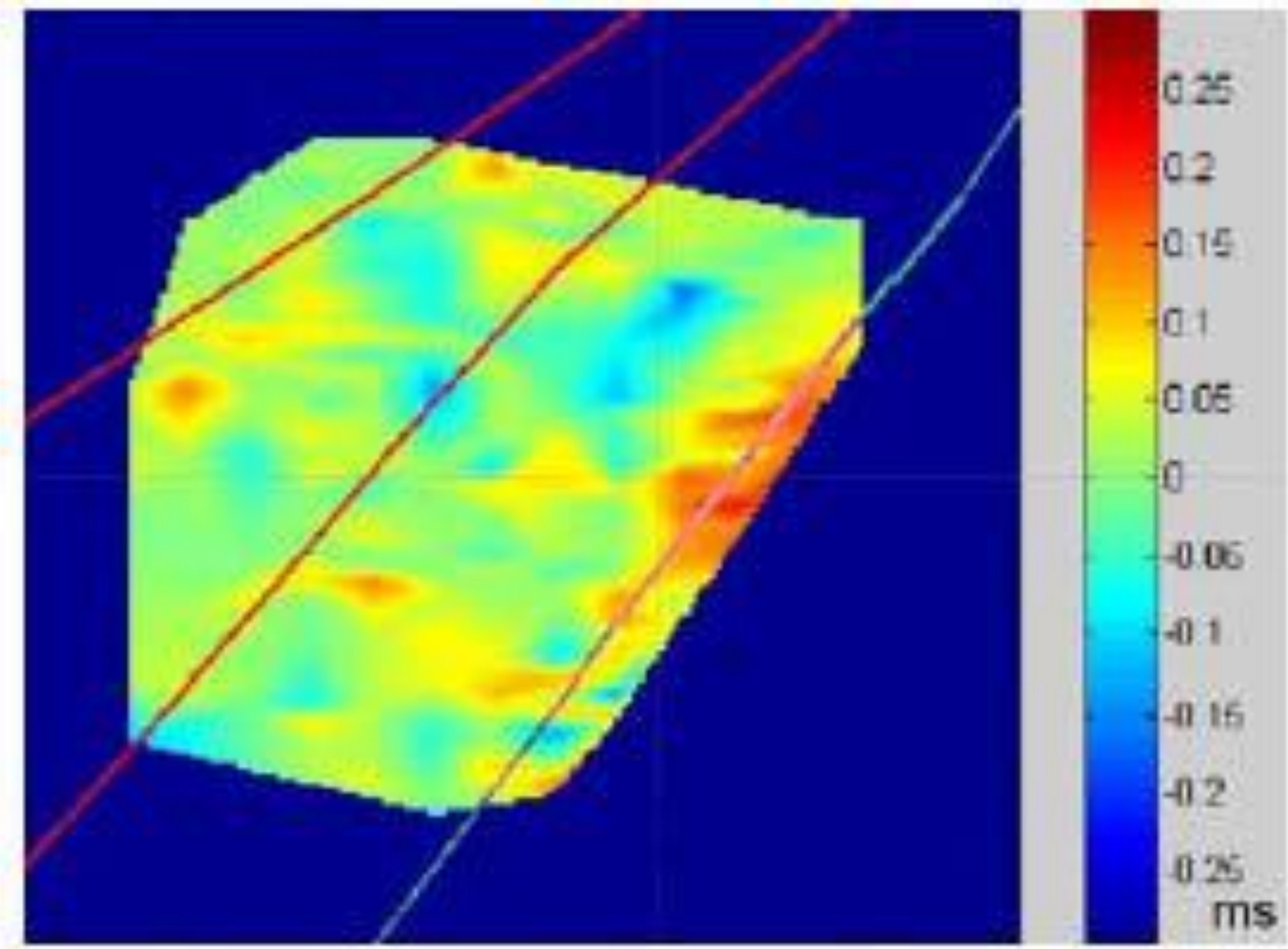

Figure 5. Transit time variation through the reservoir measured over a period of one month (ms). Red lines are injection wells.

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 Channels	10
Number of Records	82071
Number of Recording Days	30

Table 1. Data recording parameters.