Introduction

Land Permanent Reservoir Monitoring has not so far received the same attention (and the same funding) as Marine Permanent Reservoir Monitoring. It has been used in three main areas.

Artificial gas storage reservoir management

One of the first buried permanent receiver arrays (as per my knowledge) was deployed by a research consortium including Compagnie Générale de Géophysique, Gaz de France, and Institut Français du Pétrole in 1980 over the Gournay-sur-Aronde gas storage reservoir about 100 km north of Paris. The reservoir is a sandstone anticline at a depth of 730 m with an average thickness of 45 m. It consists of two intersecting 2D lines of about 3 km with a group interval of 10 m. Three surveys were shot in December 1980, May 1981, and October 1981 with a weight drop and a P-wave vibrator. A time shift of about 1 ms could be measured between May 1981 (low gas level) and October 1981 (high gas level). However, the results were not judged significant enough to be published. Now thirty years later, looking at this good data quality, it seems probable that this project suffered from a lack of adequate processing techniques. A sister project recorded at about the same time over another zone of the same reservoir and using surface receivers was more successful: its results were published by Blondin and Mari in 1986.

Thirteen years later, Gaz de France launched a new project in Céré-la-Ronde (200 km south of Paris), over another similar reservoir at a similar depth. The recorded data were used to develop time-lapse processing techniques including surface-consistent cross-equalization (Meunier and Huguet, 1998). Seismic reflection was perfectly able to see initial gas injection in 1994 (see figure 1). It could hardly detect gas motion in the subsequent years. This disappointing result led to the conclusion that conventional seismic techniques were not sensitive enough to monitor the gas plume. It also led to the launch by Compagnie Générale de Géophysique, Gaz de France, and Institut Français du Pétrole of a research project around permanent receivers and permanent sources. This project resulted in the SeisMovie reservoir monitoring technique, which proposes buried horizontal or vertical receiver cables and buried piezolectric sources emitting continuously and simultaneously. This technique provides excellent repeatability.

Steam flood monitoring

A pilot steam flood seismic monitoring project was recorded between 1992 and 1995 on the Duri Field in Sumatra by Caltex. (Jenkins, 1997). The Duri field is a heavy oil Miocene sandstone reservoir between 350 and 750 ft. with excellent porosity and permeability. 3-D seismic surveys were repeated eight times (two bases and six monitors) using a grid of 480 receivers and 301 shotpoints. Hydrophones were flushed below the weathered zone before recording and flushed out after recording. The source consisted of 50 g. of dynamite in 45 ft. holes. The first monitor survey was recorded two months after the base and showed a very clear pull-down in the region of the injector. This pull-down grew to about 20 ms in 31 months. This pilot survey proved successful and many more 4D grids were recorded over the field. Similar projects (albeit, not using hydrophones) were recorded over heavy oil reservoirs in particular in Northern Alberta over the last fifteen to twenty years.

CO2 sequestration monitoring

Although permanent receivers are not used, the Weyburn project is emblematic of CO2 flooding seismic monitoring and multi-component time-lapse seismic imaging. The Weyburn field is a 30 m. thick fractured carbonate reservoir at 1400 m. depth operated by Encana. A 9 km² 4-D, 9-C seismic survey was recorded by the Reservoir Characterization Project of the Colorado School of Mines first in 2000 prior to CO2 injection, then in 2001 and 2002. This project showed that time-lapse multi-component seismology enabled monitoring fracture permeability. (Davis and Benson, 2005)
Conclusion

Although not a very new technique, Land PRM cannot be said to have reached maturity yet. It was successful in projects associated with very large acoustic impedance variations, whereas many onshore reservoirs are expected to produce only small changes. Perhaps one of the most difficult challenges it must overcome is to increase its sensitivity by one order of magnitude or even more. It would not be the first time in seismic history that a technique takes a very long time to take off.

References

Blondin, E. And J.L. Mari, 1986, Detection of Gas Bubble Boundary Movement: Geophysical Prospecting, 34, 73-93

