A time lapse seismic experiment over a carbonate reservoir under-going miscible flood.

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Seismic monitoring has proven to be technically viable in steam flood applications and in some clastic reservoirs undergoing secondary and primary recovery since the early 1980's. Carbonate reservoirs have not been strong candidates for monitoring due to their stiffer frame modulus which tends to correlate with a lower sensitivity to pressure and saturation induced velocity changes. Western Geophysical and the Alberta Research Council undertook a joint research program in 1986 to study the feasibility of using time-lapse seismic data to monitor the movement of injected hydrocarbon solvent in carbonate reservoirs. This research program initially focused on measuring the acoustic velocity and density changes that occurred in Western Canadian carbonate reservoir rocks over the course of a miscible flood. We measured cores from the Rainbow B pool during the term of this project and we observed that a significant change in velocity and density occurred during flooding.

Canterra (now Husky) and Mobil became actively involved with this research program in early 1987. The Rainbow B Pool was initially discovered in April 1965 and it has been produced with primary production and secondary water flooding from the time of discovery up to March 1982. Husky and Mobil initiated a gravity stable vertical hydrocarbon miscible flood over the field in the early 1980's to displace residual oil that was bypassed by the waterflood. Laboratory measurements made on cores from the B pool reservoir indicated that miscible flooding could produce up to 25% of the original oil. One of the greatest uncertainties in enhanced oil recovery is related to the percentage of the reservoir rock that is contacted by the miscible flood. Since seismic monitoring data has the potential to provide information about the vertical and areal position of the injected solvents between wells it was decided during 1986 to study the feasibility of using time-lapse seismic techniques to monitor this reservoir.

A full-field reservoir simulation model had been developed on this field and predicted fluid contact information was available for various times in the model. We used velocity change information from the core testing to construct a variety of seismic models to determine the types of changes we could expect in the seismic data. A 2D field test was recorded across an active solvent injection well in April 1987 to determine the recording parameters that would provide optimum resolution for a monitoring experiment. Early results indicated that a 10 m solvent bank, present in the reservoir at the time of the test line recording, was visible in the data. However we could not confirm these results because there was no seismic information available prior to solvent injection. Solvent, followed by chase gas injection continued in the reservoir from 1987 to 1997 and the solvent/chase gas bank thickness grew from 10 to 30 m. We recorded a new testline over the solvent injection well in March 1997 to determine if the ~20 m change in solvent thickness was detectable in the seismic data. These results indicate that the seismic data is generally repeatable over the 10 year period and production related changes in the reservoir zone are clearly visible. These seismic differences correlate with the predictions made in earlier modelling study. These results indicate that the velocity changes observed in the seismic data are similar to the changes observed at the laboratory scale and seismic monitoring should be feasible in some carbonate fields.

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