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Passive Seismic Monitoring of a Heavy Oil Field

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SUMMARY

A pilot project was designed to monitor induced seismic activity in a relatively shallow heavy oil reservoir located in a low permeability, high porosity, silicious shale. Several hundred microseismic events have been located over the past two years using data recorded at two borehole seismic arrays. Microseismic activity occurs predominantly in two separate depth zones: one within the reservoir and one in the shallow overburden. Larger events are located at the top of the reservoir close to the injection well; shallow clusters of smaller events could identify fluid migration pathways in the overburden.

Over the past few years the Passive Seismic Monitoring technical development team at Chevron supervised projects that span a wide range of applications and geological environments. Several pilot projects were designed to test the viability of the passive seismic monitoring method in different fields and to help improve the quality control analysis procedure. We present an example of permanent microseismic monitoring of enhanced heavy oil recovery.

The pilot project was designed to monitor induced seismic activity in a relatively shallow heavy oil reservoir located in a low permeability, high porosity, silicious shale. Steam is injected to fracture the reservoir and increase the mobility of the viscous oil. Well density is extremely high and the geology suggests the presence of possible fluid migration paths. Prior information indicates that injection fluid migration could occur above the main reservoir during and after stimulation, reducing reservoir pressure, creating surface uplift and threatening well integrity. The microseismic study was designed to complement traditional monitoring methods and help distinguish between possible fluid migration scenarios (out of zone fracturing; migration along weak pathways that might include adjacent wellbores).

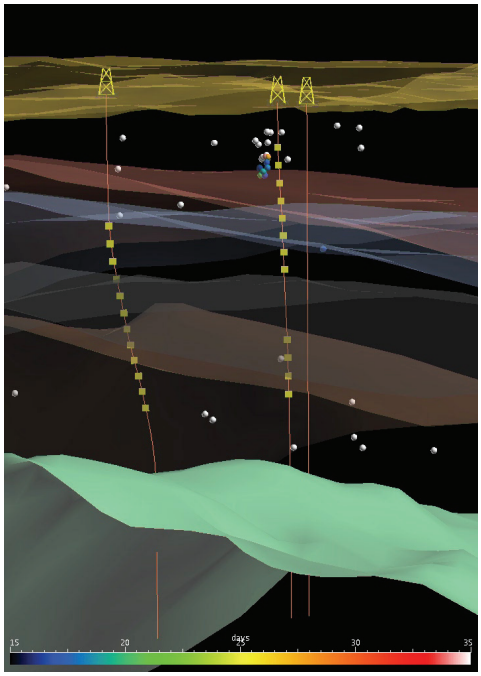

Figure 1. Sideview showing the distribution of a subset of microseismic events in a cronostratigraphic model. The locations of the geophone array elements are marked by the yellow cubes and the event locations are indicated by the spheres. Most events are located within two depth regions, one in the reservoir, where the injection takes place, and one in the overburden, showing possible fluid migration paths. A cluster of microseismic events with similar waveforms is highlighted with a color scale corresponding to elapsed time from reference event.

The two twelve level arrays of 3C geophones had been installed at shallow depth, above the reservoir; several hundred microseismic events have been located over the past two years. The two arrays are only a few hundred feet apart yet a significant number of microseismic events can be reliably picked on waveforms recorded by only a few receivers at one array requiring the use of particle motion information to constrain locations. The task is complicated by the fact that a few instruments are noisy or miss one or two channels and the particle motion is complex due to the velocity structure.

Event depths are well constrained and show that microseismic activity occurs predominantly in two separate depth zones: one at the level of the top of the reservoir and a shallower one in the overburden. In general, the larger events are located at the top of the reservoir and recorded by both arrays, while shallow events tend to be smaller and picked reliably on few seismic records. Clusters of small events were detected by waveform cross-correlation. Despite the azimuth uncertainty, cluster events are closely located and can be used to identify shallow fluid migration pathways.

The results of this study support the interpretation of fluid migration based on geology and can be integrated with other methods (tiltmeter arrays, satellite altimetry, well sensors) to help revise the injection procedures. The experience gained from the pilot will be applied to future experiments in the area.