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4D Passive and Aggressive Monitoring of Air Injection at Telephone Lake, Alberta

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Summary

Simultaneous acquisition of borehole and surface seismic data is shown to be an effective way of monitoring air injection within a top water zone. The air was injected in an effort to dewater the zone just above the targeted bitumen zone and improve the oil recovery process. Mapping the air injection results is a key component to enhancing the production process. The seismic acquisition was done repeatedly over several days to map the extent of the dewatering effect and water movement in time.

Introduction

As a part of an air injection monitoring exercise in the Telephone Lake area of Northern Alberta, high resolution simultaneous surface 4D and downhole seismic was acquired to map the timing and extent of water displacement in a layer just above the Fort McMurray bitumen formation. The Telephone Lake, Fort McMurray project is expected to have an oil production capacity of 14,308 cubic meters per day (m3/d), or 90,000 barrels per day (bbl/d), in two phases with an estimated operational life of approximately 40 years.

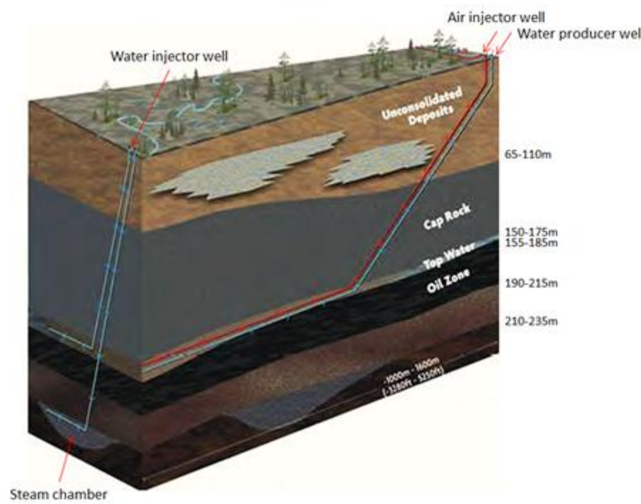

Figure 1) Telephone Lake geology showing the cap rock and top water overlying the bitumen zone.

The bitumen zone in the McMurray Formation is typically overlain by a layer of non-saline groundwater (top water). The first process to be used in the production is a dewatering technology (Cenovus patent pending). This will be done at the majority of the well pads to facilitate the replacement (with air) of a portion of this top water prior to SAGD operations. Figure 1 shows the Telephone Lake geology with the cap rock and top water overlying the bitumen zone. Knowing where and how the water is moving is important in the understanding of the dewatering and ensuring the containment of the oil and top water.

4D high resolution surface and downhole data was used to monitor the top water displacement during an air injection in the 02-27 well. 3C receivers were deployed in a well from bottom to top as well as surface receivers were placed in a tight space grid surrounding the well. Air was pumped into an injecting well that was 7 meters away from the observation well and 7 scheduled time lapse 3D's in a 4 day period were performed to monitor the air injection and water displacement.

Method

A series of 2D borehole walkaway lines were first acquired in a similar injection test just south of the 02-27 well location as a proof of concept in the winter of 2008. These walkaway lines were used to monitor Nitrogen injected into the top water and showed that the borehole seismic data was able to see the character change associated with reduced velocities from the injected Nitrogen. For the 2012 high resolution survey a 600 m x 600 m surface grid of source and receivers placed every 10 meters with 100 m line spacing as well as a downhole array deployed in the 02-27 monitor well with receivers placed from TD to surface every 4 meters was used. Figure 2 shows the air injection unit deployment in the 02-27 well. Some of the surface receivers used can be seen in the foreground.

Figure 2) Air injection set-up at the 02-27 location.

The source was a single MiniVibe with a; 10 – 180Hz, 1.5db/oct boost and 12 second sweep. The downhole tools used were the OYO Geospace DS150 with a bow spring clamping mechanism. In addition to the seismic acquisition downhole piezo equipment was deployed in the annulus between the production tubing and wellbore casing. The piezo equipment was deployed to measure downhole temperature and pressure.

A single source location was chosen to hourly monitor rapid changes in the water displacement. Once the air injection started comparisons of the raw shots showed the expected amplitude change in the water zone. Figure 3 shows the results of the single shot recording before injection and after just 3 hours of injection. Even after this short period of time we can see a very large amplitude event coming in at the point of the air injection. Every 6 hours a new 3D survey was recorded into both the downhole and surface arrays such that after 18 hours the air had extended past the imaging area of the borehole seismic. Surface 4D data was acquired every 24 hours for the next 3 days.

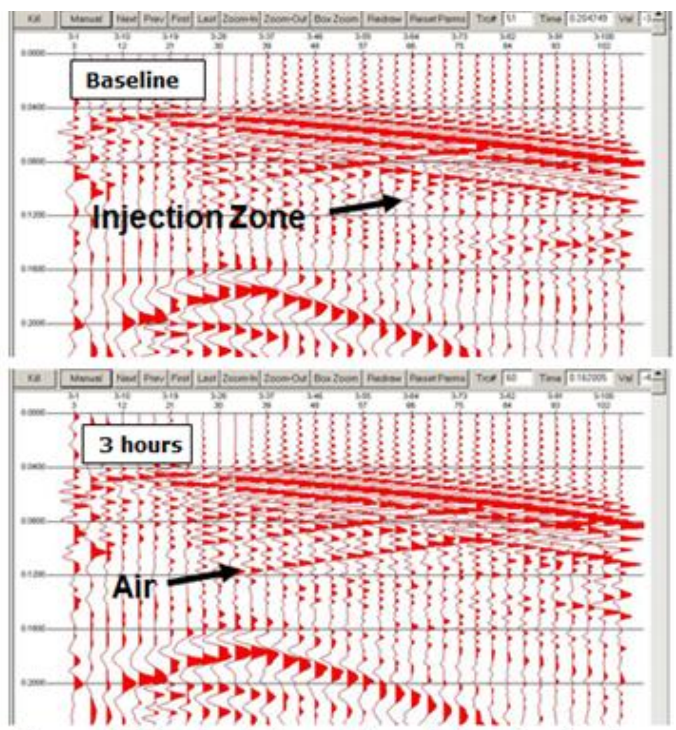

Figure 3) Single shot recordings before (top) and after three hours of air injection (bottom)

Passive observations of the air injection in real time was accomplished by monitoring the noise levels from the downhole tools. Figure 4 is a display of the noise in mVrms for each of the downhole levels – 3 components. The higher noise levels are shown in red. The receivers closest to the surface show the high level of noise generated by surface activity. At the bottom of the tool (right hand side) we can see an increase in noise associated with the air injection.

Processing of the borehole data was done in a standard way. The data was sorted and the source receiver geometry was assigned. Three component rotations were done to maximize the energy within each component. Wavefield separation was then done using a median filter then deterministic decon applied. Migration was used to map the data.

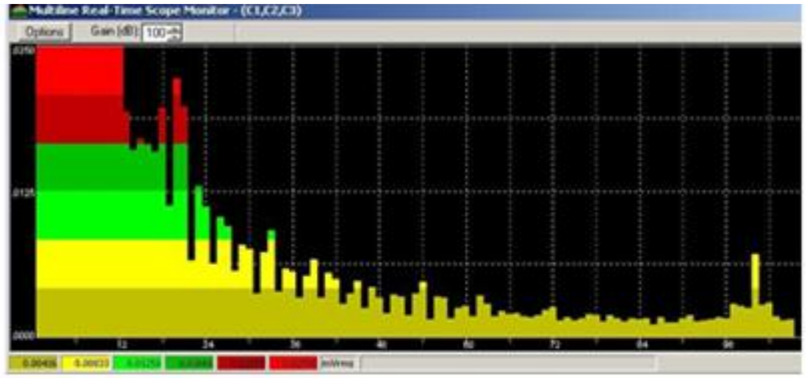

Figure 4) Screen capture of the tool noise levels during the air injection. The injection zone is on the right hand side of the image. The increase noise level from the air can be seen over the bottom tools.

The data showed an introduction of strong amplitude event within the injection zone. The direct arrival also showed a significant change in the velocity within the zone as the air was introduced. This velocity change resulted in a push-down effect in the data below the Fort McMurray sands. Figure 5 shows an extracted North/South line from the VSP data. You can see very strong amplitude event within the injection zone. Figure 6 shows the arrival times and interval velocities for the similar times as Figure 5 . Figure 7 shows the 4D surface seismic where it becomes apparent that the air bubble is elongated East to West not migrating to the North verifying the downhole data.

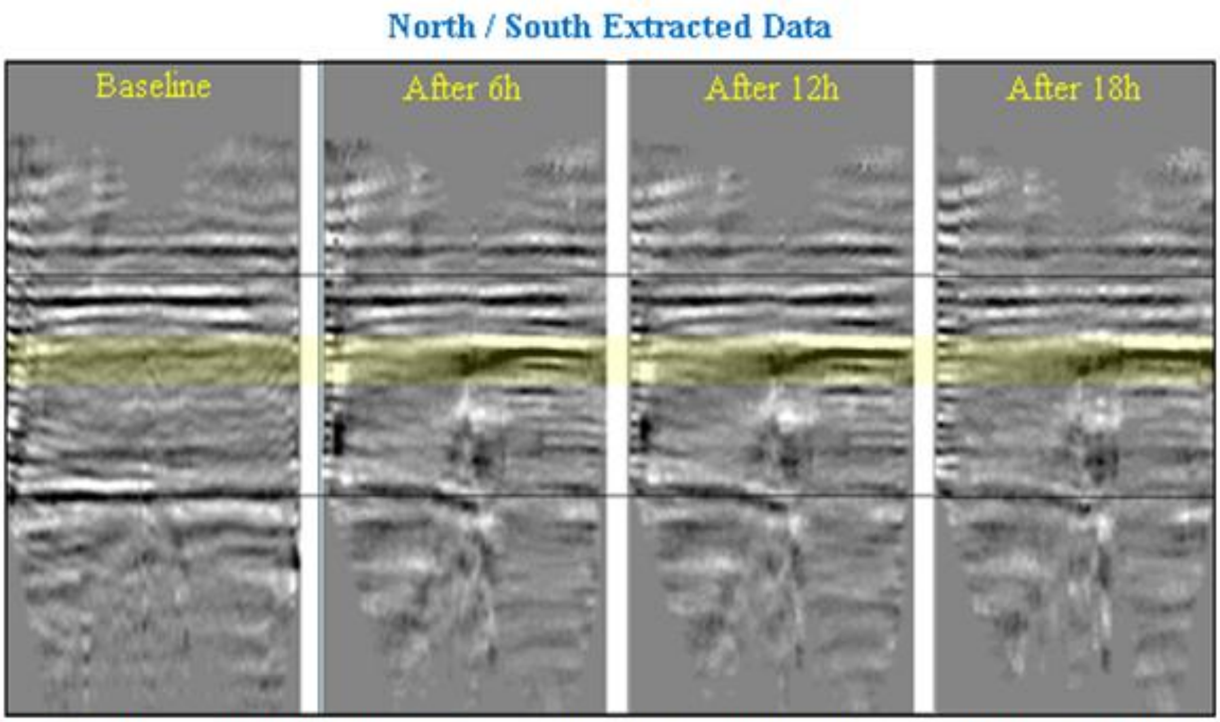

Figure 5) Extracted North/South line showing the amplitude changes with time as the air injection is preformed

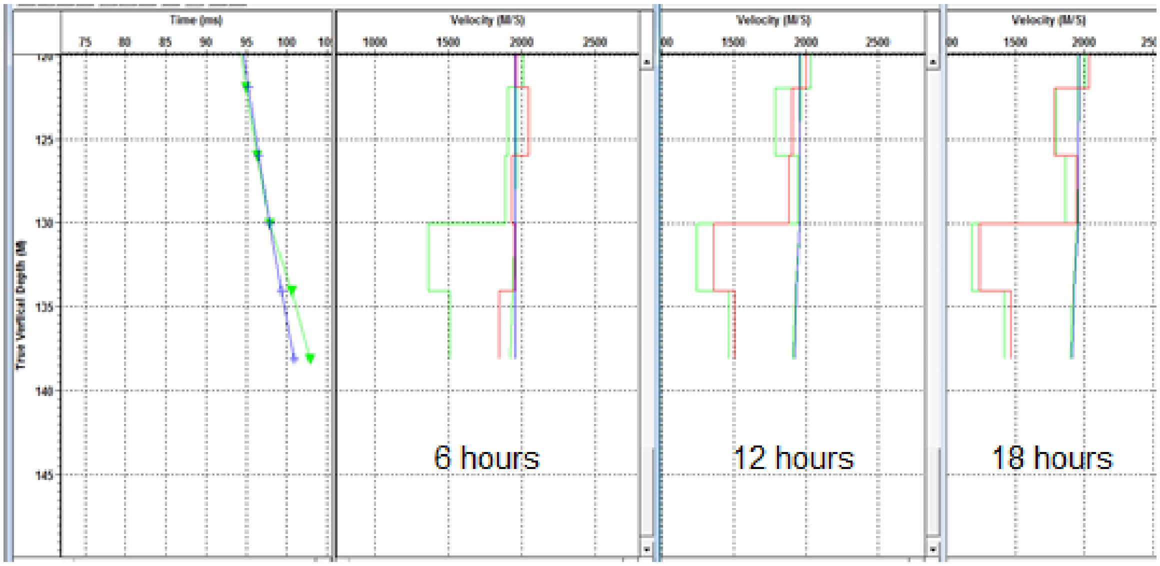

Figure 6) arrival times before injection (blue) and after 6h (green); 2) interval velocity before injection (red) and after 6h injection (green); 3) interval velocity after 6h injection (red) and after 12h injection (red); 4) interval velocity after 12h injection (red) and after 18h injection (red).

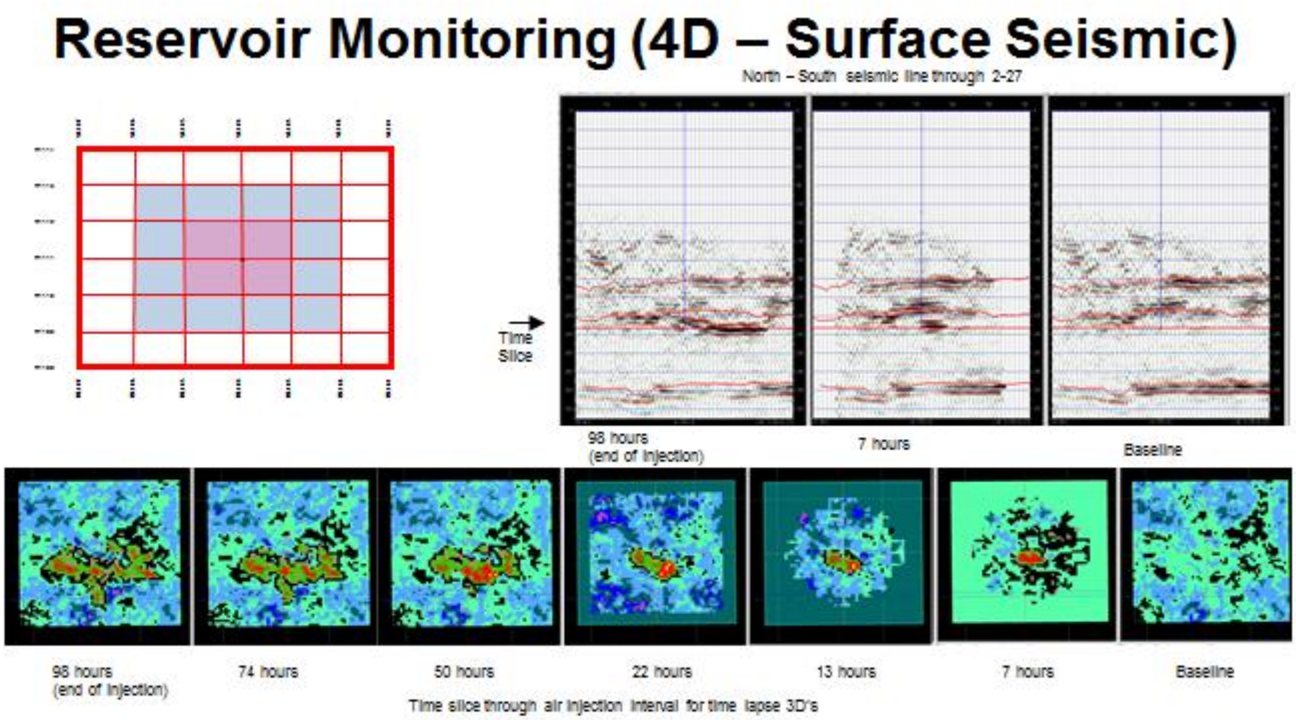

Figure 7) Surface seismic grid with North-South seismic and time slice through the air injection interval.

Conclusions

The use of the borehole seismic data to see the air injection in real time was successful. We were able to see the addition of the air within the McMurray formation within the first 3 hours of injection. Further processing of both the surface and downhole data showed the extent of the air injection and highlighted the lack of air in the north part of the survey resulting in a greater understanding of the water movement within the formation.

Acknowledgements

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