Case Study

Microseismic monitoring of a thermal steam injection in a heavy oil reservoir in Northwestern Alberta

Microseismic monitoring throughout a heavy oil reservoir in Northwestern Alberta provided greater insight into heat transfer models and fracturing patterns following thermal steam injections, to optimize drilling and production operations.

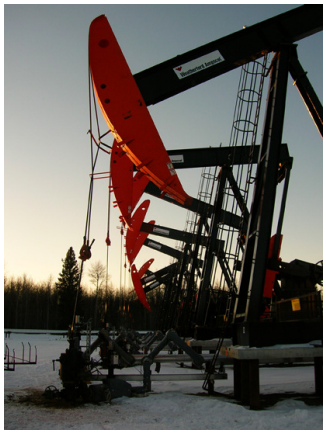

Fig. 1: Heavy oil wellhead

Cyclic Steam Stimulation (CSS) is a common oil extraction method used in the in the Peace River heavy oil sands in northwestern Alberta, Canada. Bitumen is located in a 30 meter thick sand layer at a reservoir depth of approximately 600 meters. CSS is a three stage thermal recovery method where steam is first injected into the well at temperatures in excess of 300°C and pressures of 10-12 MPa, heating the oil in the reservoir and reducing the viscosity so that it can flow. The steam is then left to 'soak' before production.

Challenge

In the Peace River fields, vertical wells are drilled to the reservoir level from the centre of the well pad, from which multi-lateral deviated wells branch out horizontally. The client had little knowledge of how heat propagated through the reservoir following the steam injection, making it difficult to optimize drilling and production operations to maximize recovery and improve well design. Heat distribution was assumed to occur in a uniform cylindrical manner, by dilation and thermal convection. Therefore, a pilot monitoring program was commissioned encompassing various geophysical techniques, including microseismic monitoring.

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ESG Solution

A feasibility study performed by ESG implemented a 50-level array of dual 3-component triaxial geophones. The array was secured into a 45 degree deviated observation well located near the centre of the well pad to provide optimal coverage and detectability of the microseismic events associated with steam dispersion through the reservoir.

Data acquisition was performed using ESG Paladin™ units and microseismic data was transferred via satellite to ESG for advanced processing. ESG reporting and visualization services provided the client with real-time images of the microseismicity within the reservoir, which could be used to define the steam front and infer steam behaviour. ESG instrumentation was also used in conjunction with time-lapse 3D-VSP and surface-to-surface seismic surveys.

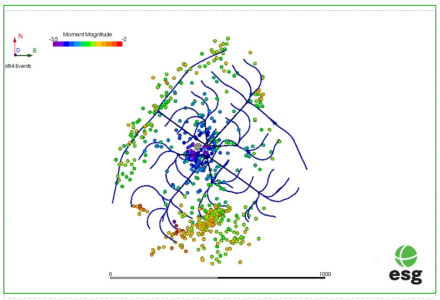

Fig. 2: Microseismicity associated with CSS

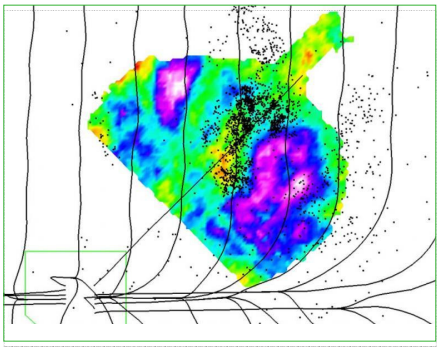

Fig. 3: RMS amplitude during CSS

Outcome

The information provided by microseismic monitoring proved that the original model of uniform steam development and heat transfer by thermal convection and dilation was incorrect. Steam distribution is greatly influenced by the geology of the reservoir, specifically pertaining to the permeability of the sand formation. Locations of microseismic events within the reservoir provided insight into fracture development. Fracturing was observed in a non-uniform distribution in the reservoir,

Integration of different monitoring techniques provided insight into the reservoir processes, for example, it became apparent that the heat from the steam was penetrating the porous reservoir sands rather than the less permeable areas. Correlation of event location with time- lapse surveys revealed that microseismic events associated with steam generated fractures were occurring at the edge of the heated zone. Therefore, the steam was fracturing the less permeable area of the reservoir as it came into contact this less permeable zone. Continued monitoring revealed that the heated area would eventually expand into these fractured areas.

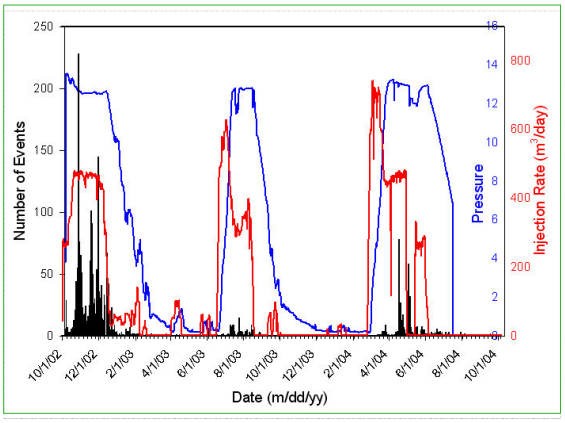

Fig. 4: Microseismic events and injection pressure

Finally, the monitoring system provided significant insight into steam controls. The original steam injection design had steam being pumped into three lateral kickoffs from the central vertical well. The distribution of heat and microseismic events indicated that only one of these wells was instrumental in putting significant amounts of steam into the reservoir, therefore operators were able to cease multi-lateral steam injections in ineffective wells.

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