Reservoir Characterisation of the Bluesky Formation at Shell Canada's Carmon Creek Thermal Project, Northwestern Alberta, Peace River Oil Sands Area: An Example of Interdisciplinary Data Integration

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Asset Summary

The Peace River Oil Sands Area of northwestern Alberta contains over 155 billion barrels of bitumen in-place. These oil sands deposits are host to Shell Canada's largest thermal *in-situ* project, referred to as Carmon Creek. The Carmon Creek Project covers an area of over 285 km^2, contains over seven billion barrels of bitumen in-place and is located across townships 84 to 86, and ranges 16 to 19 west of the 5th Meridian. Bitumen has been produced from Township 85 Range 18 west 5th Meridian for almost 40 years. During that time, various methods were tried and tested to extract bitumen from the reservoir, including pressure steam drive, steam assisted gravity drainage (SAGD) and various forms of cyclic steam stimulation (CSS). After much persistence and perseverance, it was decided that the main process for bitumen extraction would be by cyclic steam stimulation. In this process, steam will be injected for a certain period of time into the formation by horizontal wells placed low in the reservoir. Once the steam injection cycle is complete, the wells become shut-in for several months after which they are opened during a production cycle. The process is repeated several times until bitumen production volumes per cycle fall below a certain critical threshold.

The Bluesky Formation is the main bitumen-bearing reservoir in the Peace River Oil Sands Area. It is a clastic deposit that was formed in a marginal marine depositional environment during lower Cretaceous times. Geological models of the Bluesky Formation for the area have evolved over several decades. They have changed from marine shoreface deposits to wave-dominated estuaries to the current ideas of tide-dominated estuaries and tide-dominated deltaic deposits. Incorporation of a wide variety of interdisciplinary information has resulted in the construction of a detailed geological and reservoir model.

Detailed core description of delineation wells in the area provided an improved understanding of the reservoir facies. Physical sedimentological, ichnological and palynological information was used to arrive at an interpretation of the depositional environment. The integration of geological, petrophysical and geophysical data has provided a clearer picture of the reservoir distribution, its extent and the variability of reservoir quality. Not only has the construction of a reservoir model provided us with a clearer understanding of the reservoir geometry and internal quality, but it has also helped in resolving the geographical location of thermal CSS pads and the vertical placement of these wells within the reservoir.

Reservoir Description

Bitumen within the Bluesky reservoir was originally trapped as oil and contained by the existence of top, basal and lateral seals. The Wilrich Member, a widespread marine shale that was deposited during a significant marine transgression, overlies the Bluesky Formation. This shale acts as an effective top seal to the reservoir. The Bluesky Formation unconformably overlies the Lower Cretaceous Gething Formation that comprises a series of interbedded sandstones, siltstones and mudstones deposited in a delta plain environment. The Gething Formation displays variable thickness (0 to 30 metres) as it infills palaeotopography of the underlying Mississippian Debolt carbonates. The Debolt Formation is a tight carbonate that acts as both a basal and a lateral seal to the bitumen-bearing Bluesky reservoir sands wherever the Gething does not occur.

The Bluesky Formation comprises a 20 to 30 metre thick sand, which is divided into two intervals. The lowest interval is referred to as the Deltaic Interval and the upper one as the Estuarine Interval. These names reflect the depositional interpretations assigned to them. The lower sand interval was deposited as part of a tide-dominated delta plain, consisting of feeder channels to the east and sandy tidal bars at the mouth of the delta to the west. Laminated, thin clays drape ripple bedforms and foresets of cross-beds throughout the entire deltaic region. In contrast; the estuarine interval is interpreted as a tide-dominated estuary based on process sedimentological evidence and the distribution of facies associations. The head of the estuary, to the east, exhibits evidence of stacked tidal channels. Each is characterised by a sharp base, cross-bedded sands that pass up into an abandonment facies characterised by wavy- to flaser-bedded sands containing rare *Planolites* traces. The feeder channels pass westward into upper flow regime tidal flats characterised by parallel-laminated to ripple laminated fine-grained sand beds. Further to the west, the tidal flats pass into cross-bedded sands deposited as tidal sand bars towards the mouth of the estuary. Trace fossils in both intervals are rare.

Each reservoir interval demonstrates contrasting reservoir quality. It has been demonstrated through petrographical and petrophysical means, that the Deltaic sand ranges from fine- to course-grained, exhibits a low clay content and has a horizontal permeability in the range of several Darcies. In comparison, the Estuarine Interval is fine-grained, exhibits a higher clay content and displays permeabilities in the 100’s of millidarcies This contrast in reservoir quality can influence the behaviour of steam injection and bitumen production. Optimal placement of thermal wells will be crucial in maximising bitumen recovery from both intervals.

Construction of Reservoir Model

The reservoir model was constructed from the understanding of the geological model. The geological model was built from sedimentological interpretations that were contained within a stratigraphic framework for the reservoir. The first step in construction of the reservoir model was generation of a structural model of the reservoir. This was conducted by integration of 1600 km of 2-D and 7.5 km^2 of 3-D seismic data from which the top and base of the Bluesky and top Debolt carbonates were interpreted. The seismically-defined reservoir structure was tied to well control and the resulting structure maps were imported into the modelling package. The structural surfaces were QC’ed against well picks in the reservoir model, and the reservoir model was made to honour the stratigraphic architecture. The second step was to honour the facies information of the reservoir by creating electrofacies from the well-logs. The electrofacies were identified manually, and this information was then modelled between well control points using the Sequential Indicator Simulation algorithm (SIS). The next step was to model the reservoir parameters (porosity, oil saturation and permeability) within the electrofacies model. These parameters were calculated at the wells and then subsequently modelled between the well control points. All modelled cubes were QC'ed to make sure that they honoured the average value and spread of input data. Top gas and basal water surfaces were also constructed in the reservoir model. The resultant reservoir property cubes and structural information were used to help plan future pad locations and trajectory placement of thermal wells in the reservoir.