Lithofacies Identification and the Implications for SAGD Well Planning in the McMurray Formation, Christina Lake Area, Alberta

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Summary

This core display is focused on the identification of reservoir versus non-reservoir lithofacies within the McMurray Formation at Christina Lake. The vertical and lateral geometries of these lithofacies are often complex and as a result, detailed description is critical for well planning and for understanding ultimate production from this expansive bitumen reservoir. To exploit the reservoir, Cenovus Energy utilizes an in-situ Steam Assisted Gravity Drainage (SAGD) thermal technique to recover bitumen (Figure 1). SAGD requires two horizontal wells drilled along the same trajectory with approximately 5 meters of vertical separation. Steam is injected into the upper well creating a steam chamber in the reservoir which reduces the viscosity of the bitumen so that it can be produced from the lower well.

Important factors affecting SAGD well planning include potential steam barriers, SAGD reservoir thickness, SAGD interval structure, and lithofacies distribution. Geological and geophysical interpretations are geostatistically evaluated to create detailed reservoir models which are utilized for optimal SAGD well placement. The aim is to volumetrically maximize bitumen extraction, minimize the steam oil ratio (SOR), and maximize daily production.

Introduction

Christina Lake has been identified as a key production growth area for Cenovus Energy and its partner ConocoPhillips. The Christina Lake thermal project is located approximately 120 kilometers south of Fort McMurray in northeastern Alberta (Figure 2).The McMurray Formation at Christina Lake currently produces over 14,000 barrels per day (bbls/d) with regulatory approval for up to 98,800 bbls/d. Cenovus Energy is currently seeking regulatory approval for a proposed expansion that would take production capacity to approximately 218,800 bbls/d over the next decade. Cenovus has conducted comprehensive stratigraphic drilling and seismic programs within this area to fully understand the regional geology, reservoirs and the SAGD development potential (Figure 3).

Geological Setting

The McMurray Formation is the basal unit of the Lower Cretaceous Mannville Group, and is unconformably bounded by Paleozoic carbonates at the base and by Wabiskaw shale of the Clearwater Formation at the top. The bitumen is primarily hosted in the Lower Cretaceous fluvial, estuarine and marginal marine sands deposited in a major valley system draining east to northeast. This valley system which was formed on the Paleozoic erosional surface was gradually in-filled during lower McMurray time by non-marine fluvial deposits, followed by more brackish to marine sediments (estuarine and near-shore marine) during middle to upper McMurray time. The most exploitable bitumen is present within the middle unit of the McMurray Formation.

Lithofacies Identification

McMurray multi-stacked channels have inherently complex internal sand body geometries and therefore, abrupt lateral and vertical facies changes are expected. In general, the McMurray Formation in the Christina Lake area is informally subdivided into three units: upper, middle, and lower. The lower unit consists of massive, coarse to medium grained sands, which are often water saturated. The basal sand is overlain by the middle unit which consists of trough to tabular cross bedded, rippled cross laminated, fine grained sand with minor mud drapes and/or mudstone clasts. The cross bedded sand interval is gradually overlain by sand to mud dominated Inclined Heterolithic Stratification (IHS). IHS consists of rhythmically repeating cycles of sand and mud which are the result of the lateral growth of large scale bedforms such as point bars.

The McMurray Formation sediments in this study have been divided into six reservoir and non-reservoir lithofacies. The first defined facies is sand which is generally coarse to fine grained, quartz-dominated, subangular to subrounded, most often moderately sorted, and rarely contains trace fossils. Common sedimentary structures within this sand facies range from trough cross-bedding to massive. The sand facies is interpreted as being deposited along the bottom of river channels or through the formation of sand bars associated with both fluvial and estuarine environments. The cross-bedded and massive sands have high porosity (33%), high bitumen saturation (80%) and high permeability (7 Darcies) and thus are considered as having the highest reservoir potential for SAGD production. Other reservoir units include mudstone clasts and mud drape facies. Mudstone clasts which may or may not be sand supported, are light grey in colour, angular, and range in size from 0.5 to 25cm. Mud drape facies are generally limited in lateral continuity, consist of light grey, thinly bedded clay to silt sized grains, and have a unit thickness of less than 10cm.

IHS facies are common in the upper portions of the McMurray Formation with mud percentage controlling its reservoir or non-reservoir potential. Muddy IHS is defined as having greater than 30% laterally accreted mud beds whereas sandy IHS has less than 30%. The medium scale, low-angle interbedded muds within the IHS are light grey in colour with moderate to abundant bioturbation, while the sands are quartz-dominated, and fine to very fine grained. Reservoir quality within the sandy IHS lithofacies is inversely proportional to the thickness and frequency of the interbedded mudstones, therefore, some sandy IHS units may be considered reservoir. Mud drape and mudstone clast facies are generally not as laterally extensive or pervasive as the IHS facies and as a result are included in the SAGD reservoir criteria. The sixth lithofacies in the McMurray are mudstones, which are comprised of light to medium grey, laminated, variably silty muds which are interpreted as abandonment channels or deposits associated with flooding events.

Once lithofacies are identified through core and image logs, multiple geostatistical simulations are carried out and a final geological model is created. The three reservoir lithofacies that are utilized in the geological model include: Sand, Mud Drapes, and Mud Clasts. Non-reservoir facies include: Sandy IHS, Muddy IHS and Mudstones. These models are then combined with geological cross-sections and seismic data for the planning of horizontal well trajectories (Figure 4).

Two cores have been selected to demonstrate the differences in the lithofacies and their direct impacts on SAGD well planning; Phase A, Pad1, SAGD pair 3 observation well PCP PCR 5C2 LEISMER 5-16-76-6 (104/05-16-076-06W4/00) (Figure 5) and Phase B, Pad 2, SAGD pair 1 observation well ECA ECOG D5 LESIMER 5-15-76-6 (103/05-15-076-06W4/00) (Figure 6). The 104/5-16 well shows a poor to marginal SAGD reservoir with abundant IHS facies ranging from sand dominated (<30% Mud) to mud dominated (>30%). In contrast, the 103/05-15 well is more typical of the high reservoir quality which dominates the Christina Lake development area.

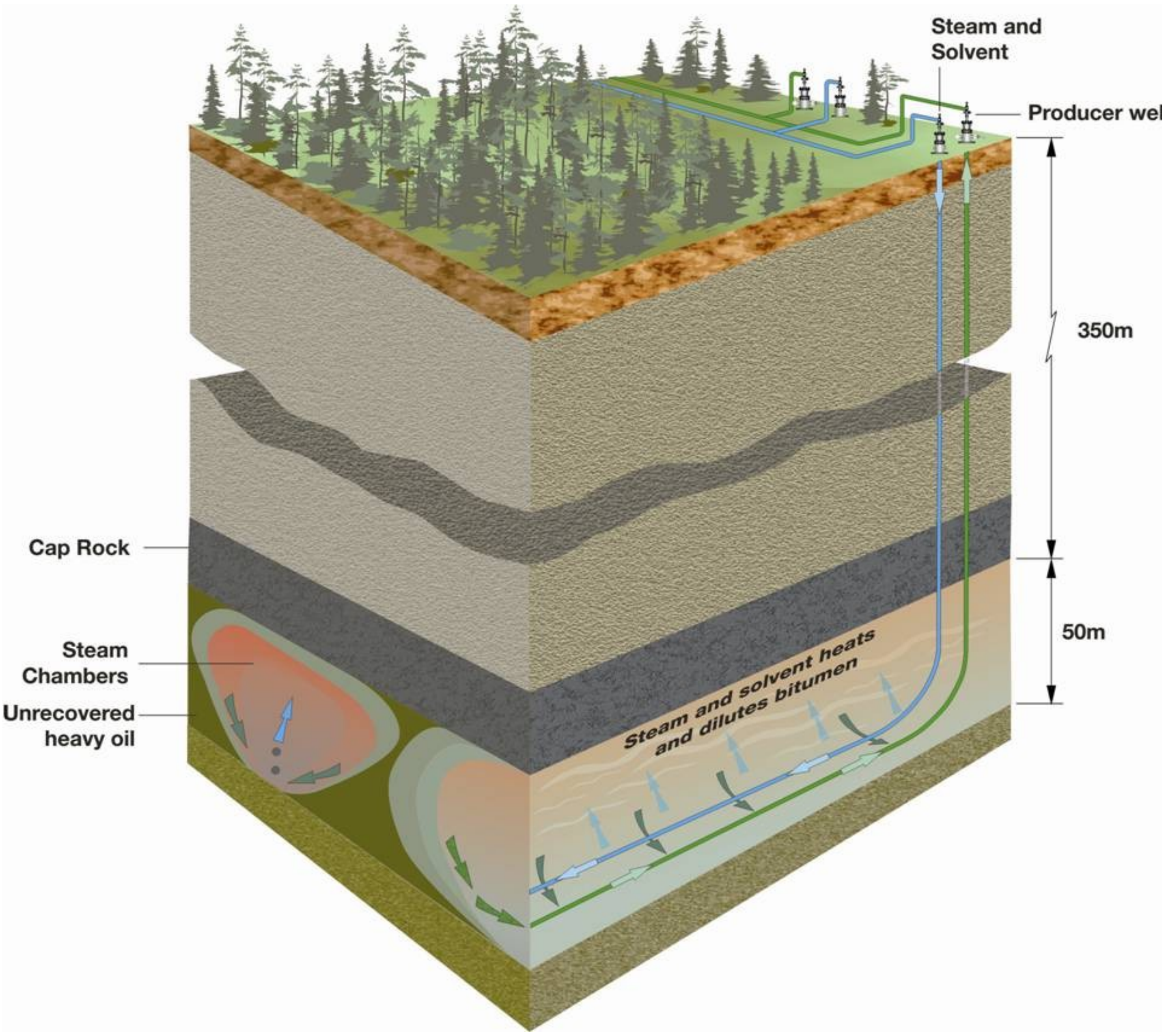

Figure 1: In-situ Steam Assisted Gravity Drainage (SAGD) thermal technique to recover bitumen.

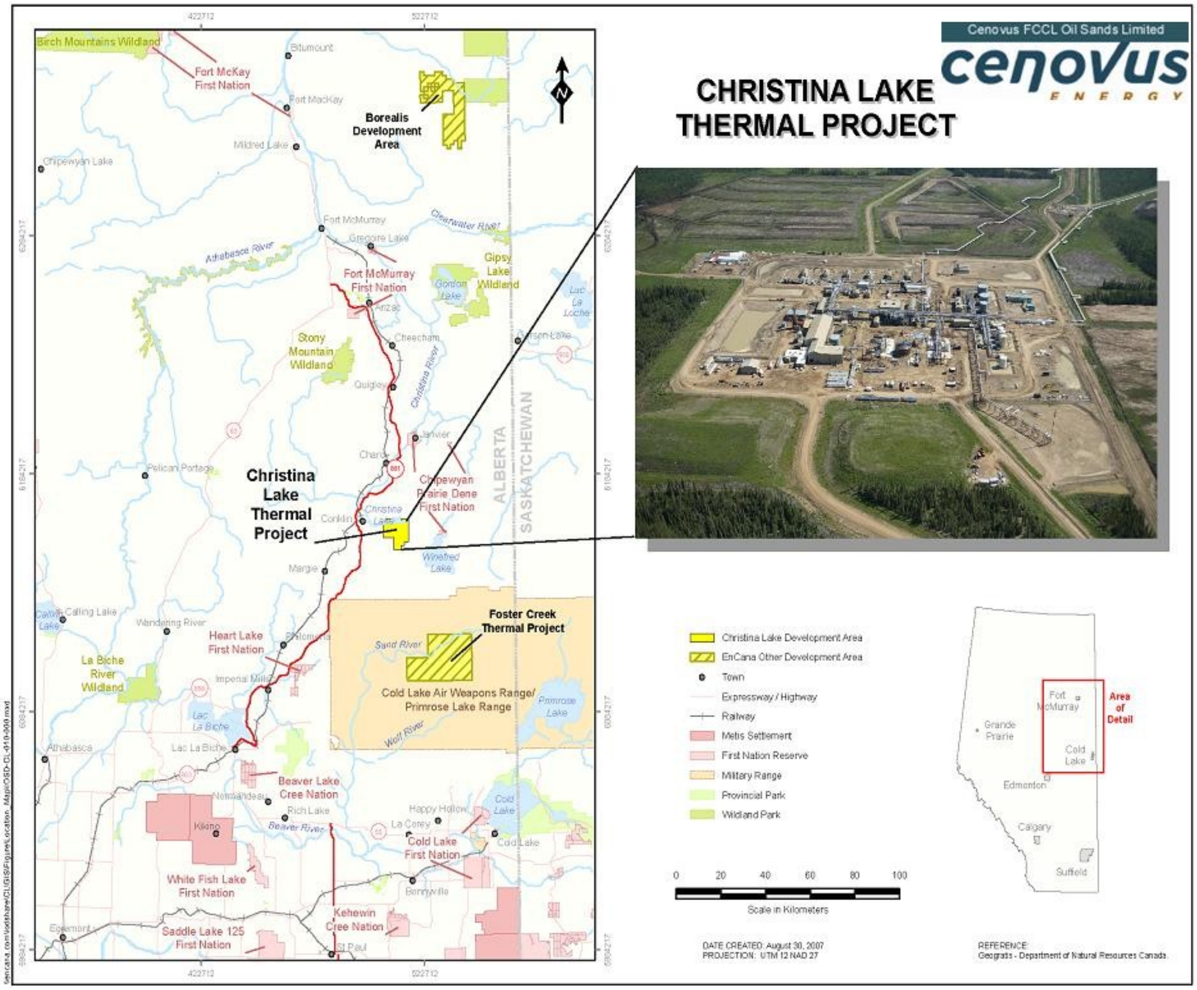

Figure 2: Location of the Christina Lake Project.

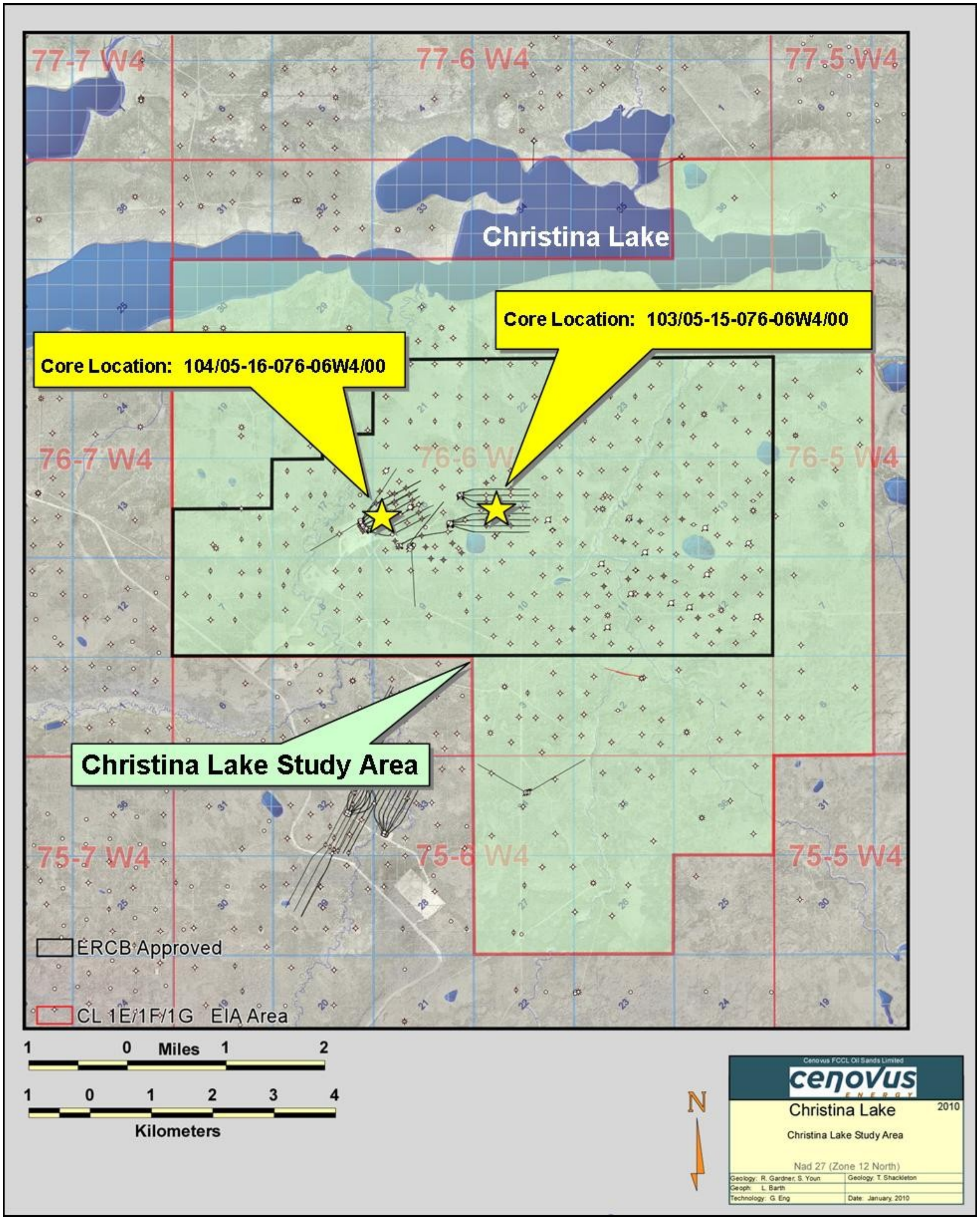

Figure 3: SAGD well locations and selected core display wells.

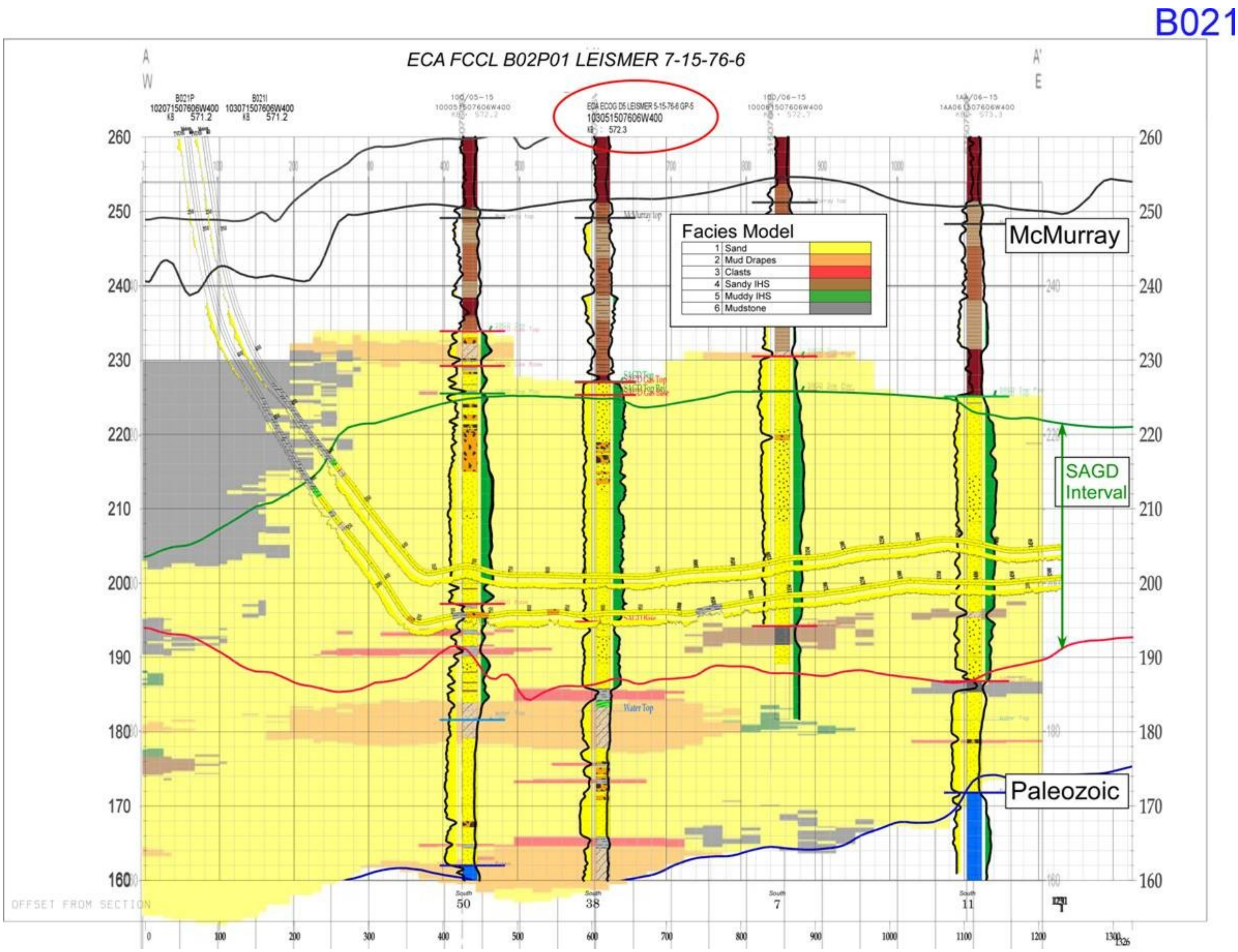

Figure 4: Reservoir model for the SAGD well pair B021 (Note: core well ECA ECOG D5 LEISMER 5-15-76-6).

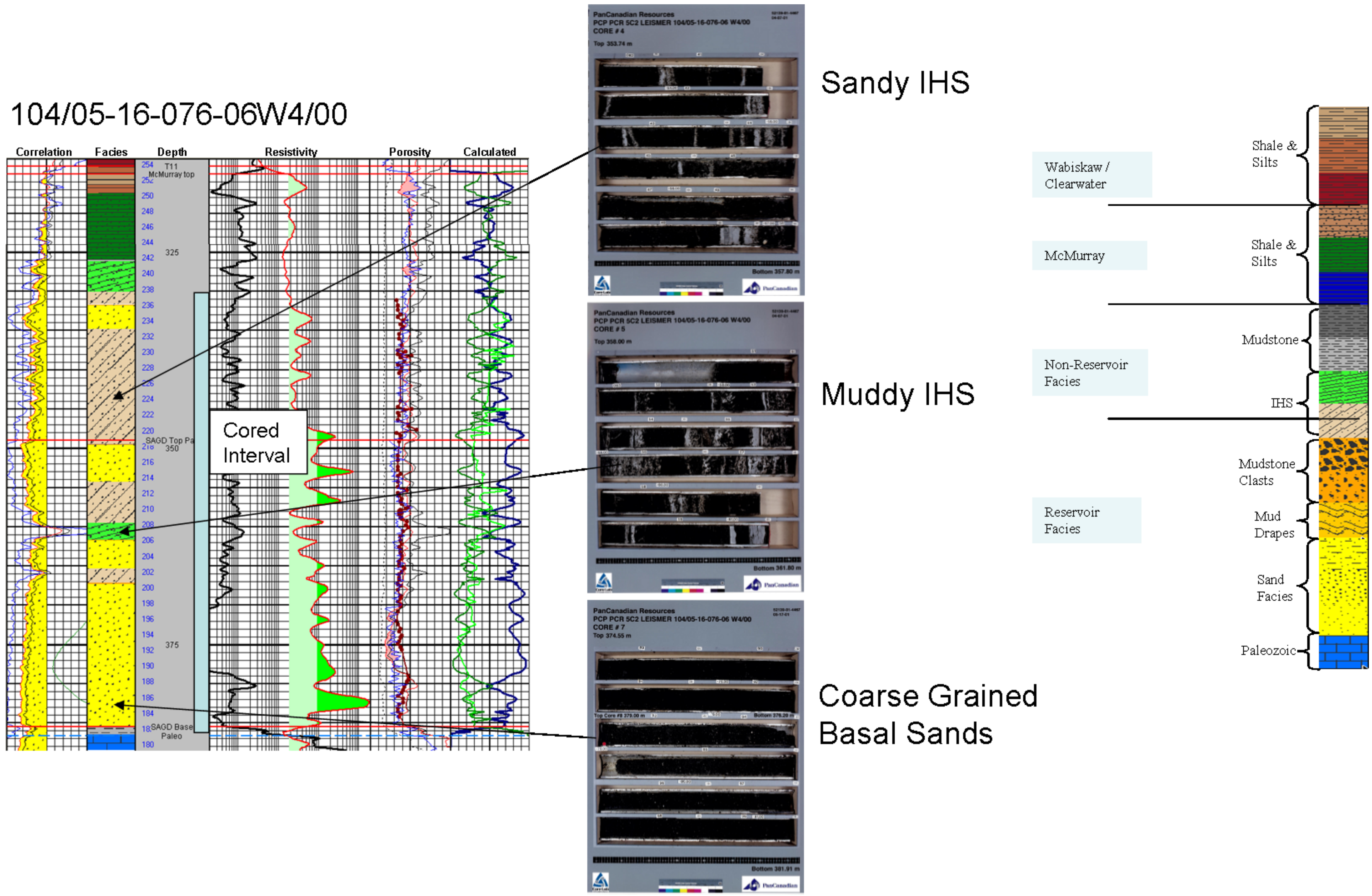

Figure 5: PCP PCR 5C2 LEISMER 5-16-76-6 (104/05-16-076-06W4/00).

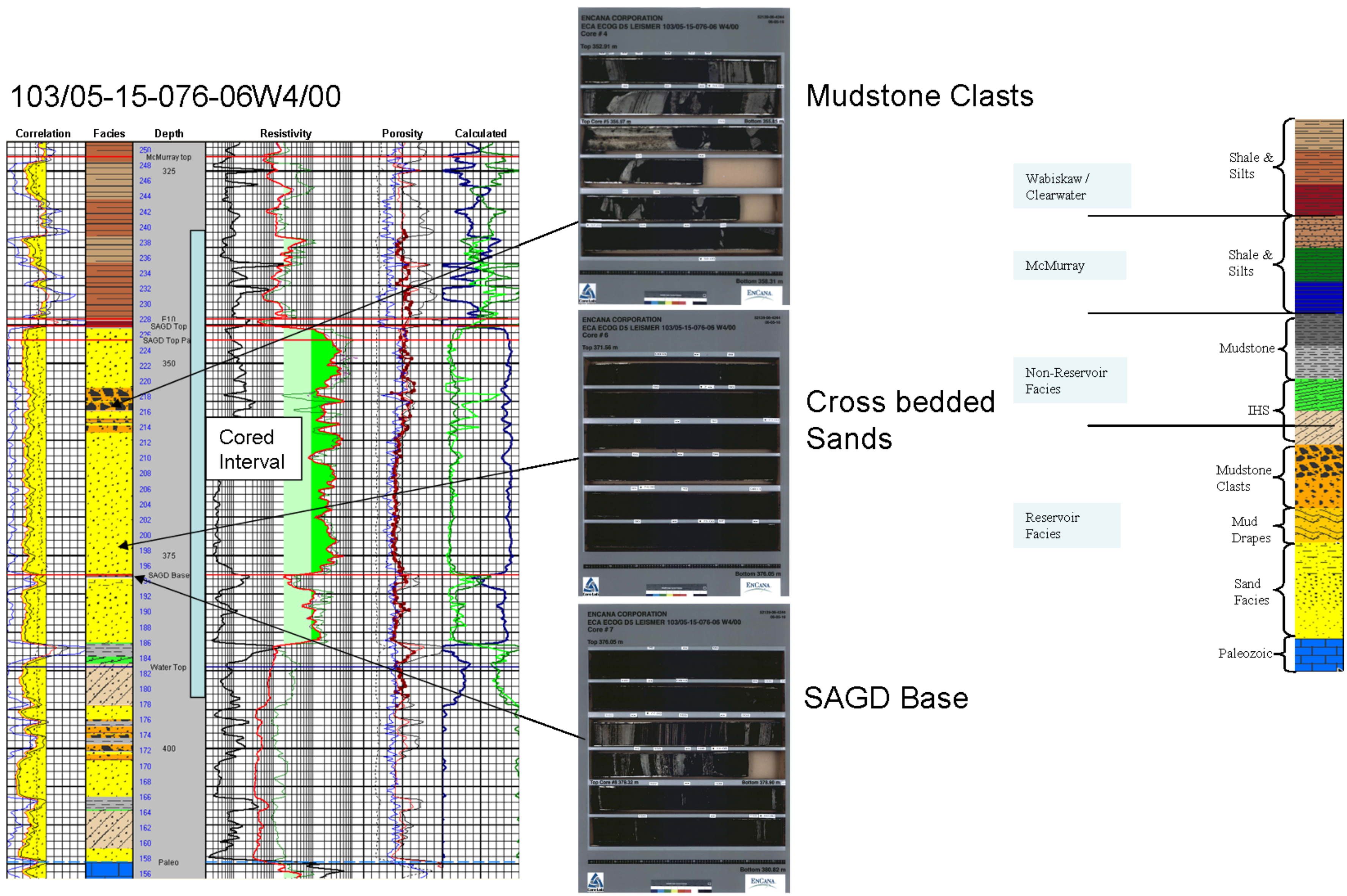

Figure 6: ECA ECOG D5 LESIMER 5-15-76-6 (103/05-15-076-06W4/00).