The Value of Dipmeters and Borehole Images in Oil Sands Deposits - A Canadian Study

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Introduction:

Borehole image tools are making an increasingly important contribution to successful thermal operations in Canada's oil sands / heavy oil deposits. Recent advances in image logging and interpretation techniques using appropriate software have allowed consistent and reliable identification of critical reservoir facies, interpreted paleocurrent data, and sand body geometry, providing distinct advantages over conventional core data for reservoir characterization.. Prediction of the lateral extent and geometry of permeability barriers including mudstone beds is a distinct advantage of image logging, because of the addition of orientation and dip data provided. Image log data complements core hole data and can reduce the amount of coring required by 75% resulting in significant savings to drilling programs in terms of project cost and time.

Significant heterogeneity in these bitumen reservoirs is found on all dimensions and predicting reservoir continuity is challenging. The high resolution electrical imaging tool is a key component in understanding and interpreting reservoir geometry at the level of detail required. With a fundamental understanding of each reservoir, SAGD (steam assisted gravity drainage) well pairs can be placed at an optimal orientation and elevation to maximize production.

Interpretations based on image log data have been applied to many oil sands intervals. In this paper, practical applications of image logs are discussed for the McMurray Fm (Figures A, B and C) and the Wabiskaw D member (Figures D and E) of the Lower Cretaceous Mannville Group. Examples of previous studies on the application of borehole image and dipmeter data include Shang, Y (1999), Contreras et al.,(2003), Ray et al, (2003) , Strobl et al., (2004a, 2004b) and Shang and Tang (2005). In this study, an integrated approach, utilizing core and image log based data is presented for three distinct oil sands deposits, each with unique reservoir characteristics.

Methodology of Image Log / Dip Interpretation in Oil Sands:

It is common to have noise in the image and dip tadpole data. For the avid interpreter it is important to distinguish noise from actual signal at the initial data acquisition and processing stage. Operating challenges including stick and slip, poor pad contact, borehole breakouts and tool condition affect the quality of images and therefore it is advised that the interpreter understands and accounts for these though appropriate processing software. Image logs are displayed using bright colours for resistive units, and lower resistivity conductive units are displayed using dark colours (Figure A). Interpretation typically starts with hand picking dips (as opposed to auto-dips done by machine) using sinusoid techniques on oriented images presented at 1:20 or 1:10 scale (large scales) so that the geological features are easily visualized and the human error is minimized. Once dips have been picked they have to be classified into buckets such as bed boundaries, inclined heterolitic stratification (IHS), current beds, erosional unconformity surfaces, fractures and so forth (Figure B). Calibration with cores in key wells is essential in the initial project phase to get a confident image interpretation (Figure D). Electro-facies and Vshale calculations can also be obtained from electrical images.

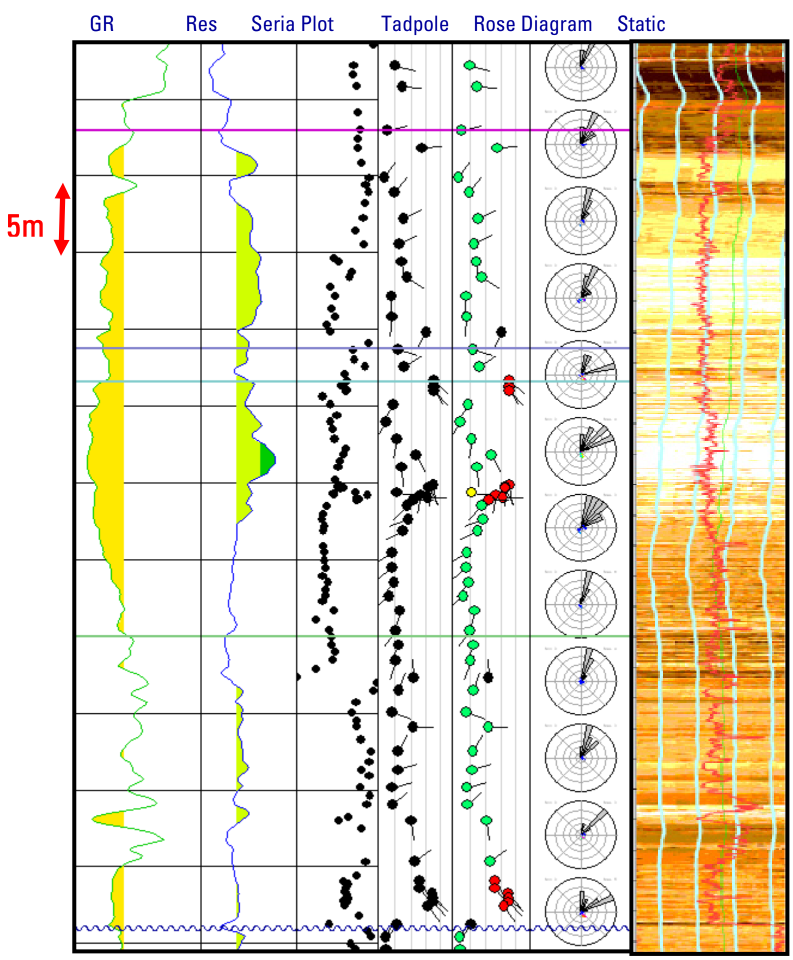


Figure A : Detailed 1:240 Scaled Plots of Image logs for stratigraphic interpretation in McMurray Formation.

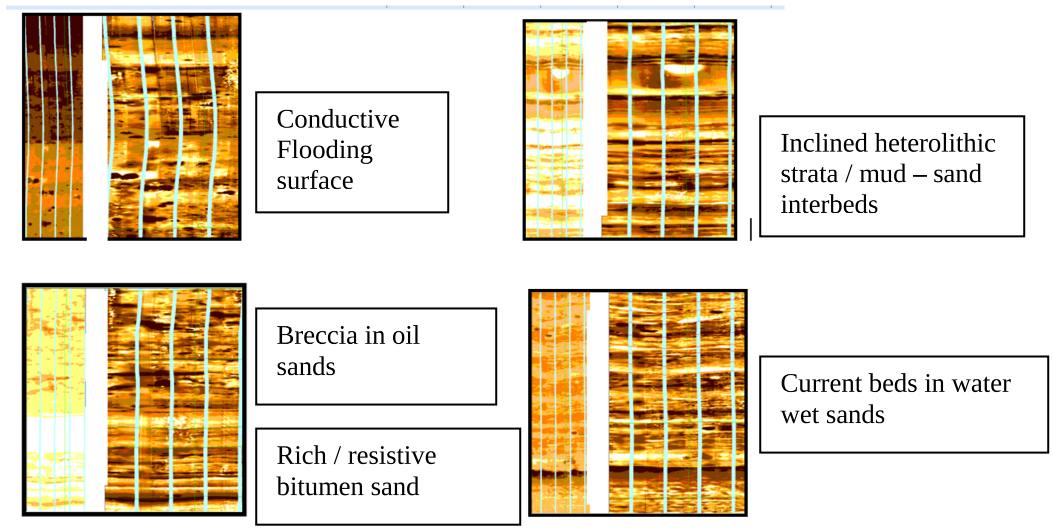


Figure B : Examples of static and dynamic image logs (Scale 1:20) for reservoir facies in the McMurray Formation.

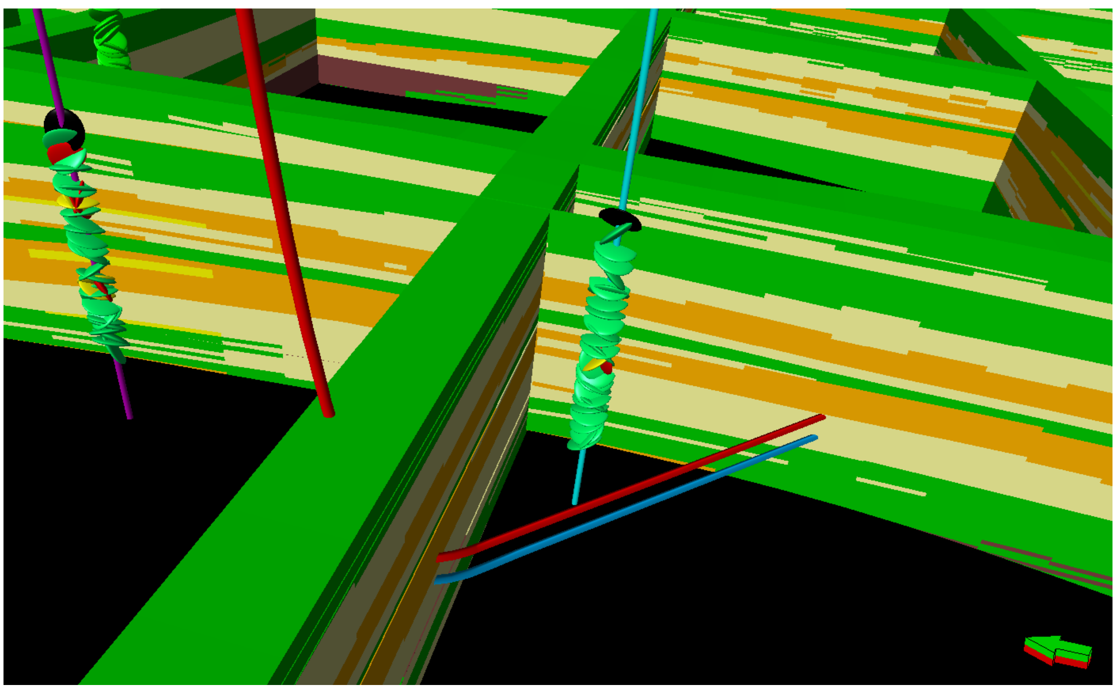
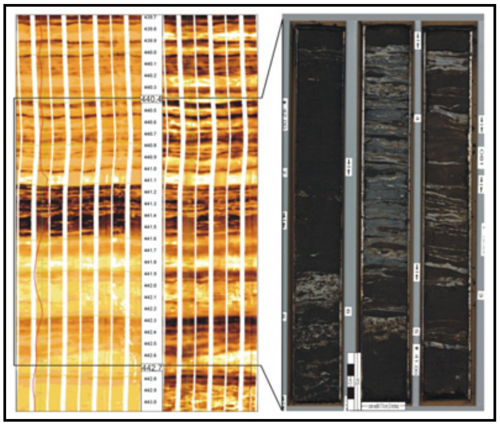
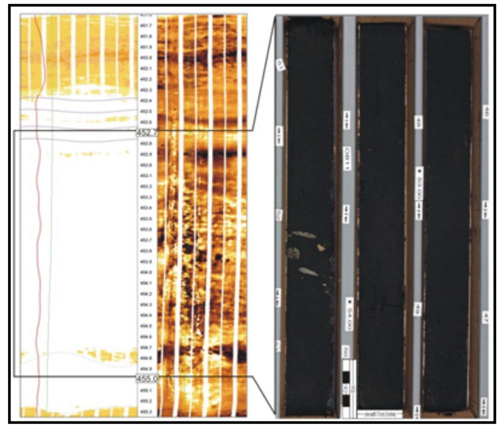


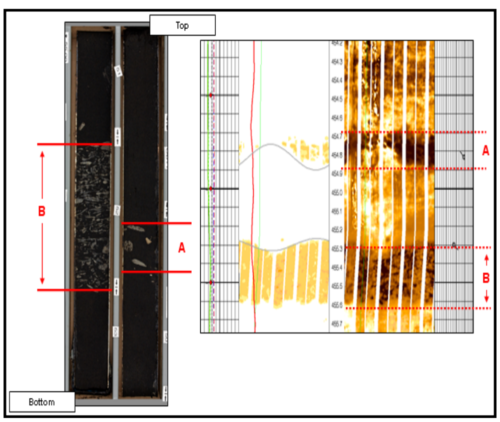
Figure C: Image log dips / core facies model in a possible SAGD well planning scenario in McMurray Formation.



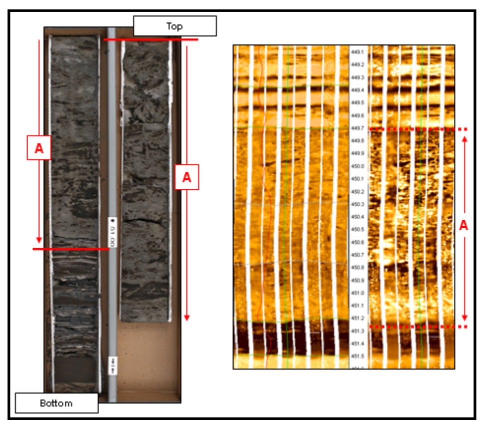
Lower Shoreface
Mudstone



Massive / Cross Bedded
Sand (Bitumen Saturated)

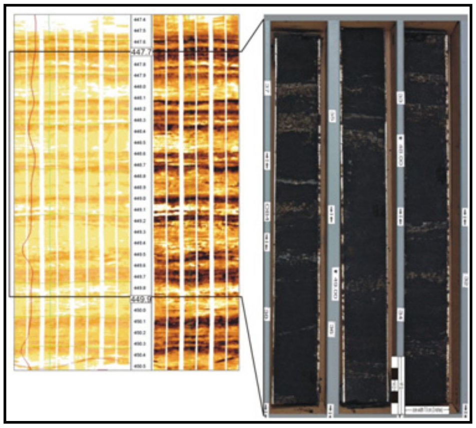


Mudclast Breccia

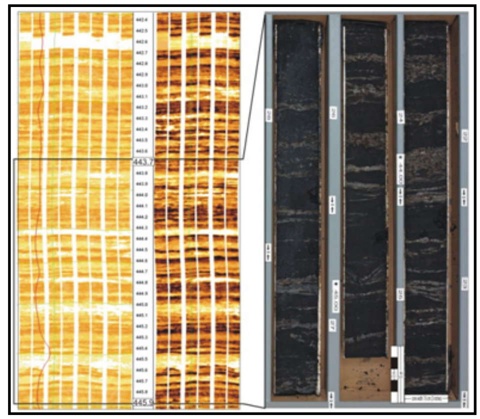


Heavily Bioturbated
(Churned) Interval

Figure D (Part 1): Examples of representative static and dynamic image logs with associated core intervals for reservoir facies in the Wabiskaw D Member.



Flaser Interbedded Sand and Mud (V_{shale} < 20%)



Flaser Interbedded Sand and Mud (V_{shale} 20 - 40%)

Figure D (Part 2): Examples of representative static and dynamic image logs with associated core intervals for reservoir facies in the Wabiskaw D Member.

Methodology of Image Log in reservoir characterization:

Image logs are very useful for reservoir characterization in all heavy oil and oil sand operations. These high resolution logs provide a detailed borehole image at a fraction of the cost of a cored well. By calibrating the image logs to core (in strategically placed cored holes) lithofacies can be reliably identified from the image log in non-cored wells. Discrete facies logs generated from the borehole images can then be incorporated into a 3D modeling software package to create a facies based geo-cellular reservoir model (Figures C, D, and E). This technique allows for a larger model dataset and as such a more complete reservoir characterization effort.

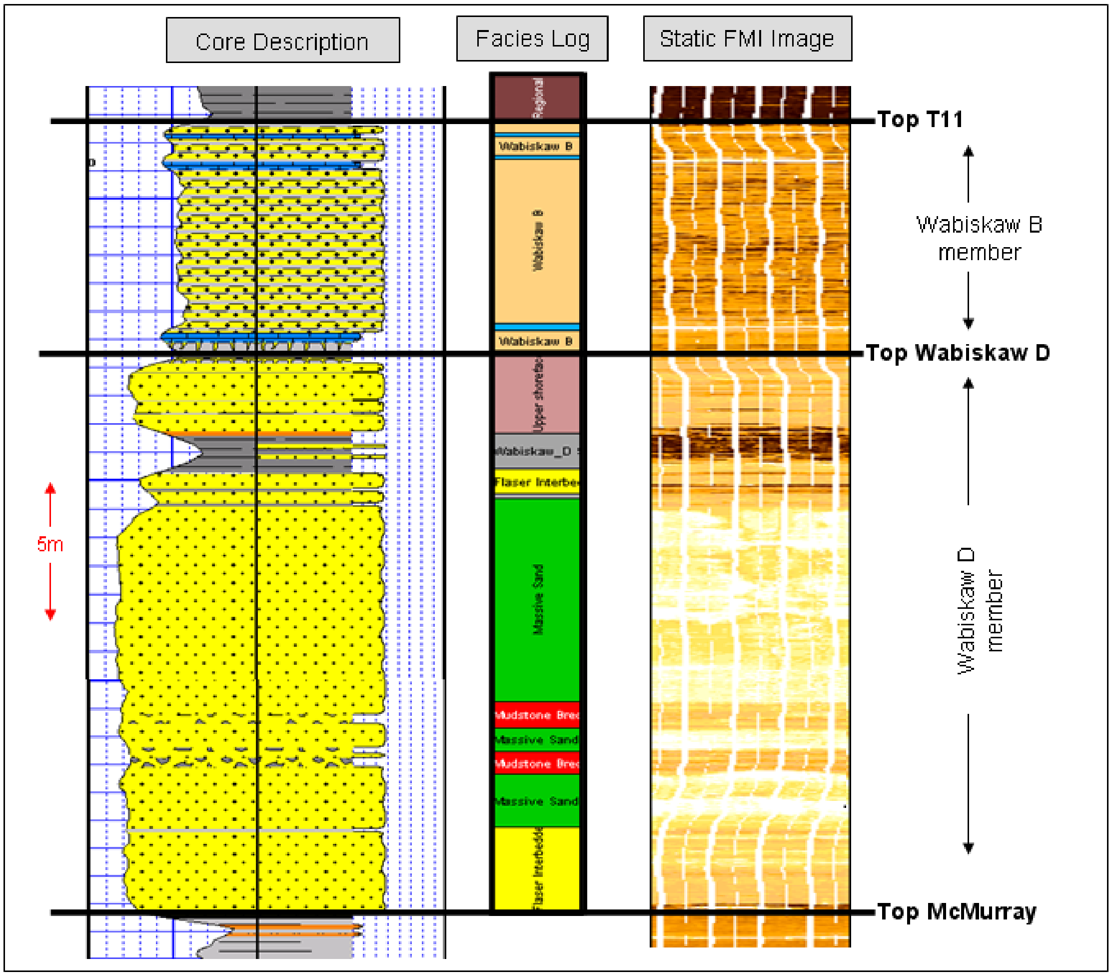


Figure E: Core description, facies model and static Formation Micro Image associated with the Wabiskaw D reservoir interval and associated cap rock.

Conclusions:

Hence it may be concluded that Borehole images (FMI* logs) and dipmeters have and continue to add value in oil sands geological interpretation. In conventional log correlation and modeling, a key unknown is the geometry and continuity of various reservoir units in the subsurface. The oriented Image data can be used for measuring paleocurrent direction, in addition to the true dip and dip directions of mudstones and related heterogeneous strata. In the absence of cores, properly processed image logs on their own provide a rapid facies interpretation, including cross bedded sands, breccia, nodules, key erosional contacts, sand dominated IHS, mud dominated IHS, fractures and unconformities. With a standard set of well logs (resistivity, gamma, neutron, density and sonic), differentiation and correlation these facies associations have to be educated "guesswork". Analysis based on image logs, calibrated with key core data, can help production teams in terms of geomodeling , horizontal well design and well planning in 3D reservoir space. Image logs also help in optimizing coring and saving project drilling costs and at the same time allowing more wells to be drilled in a limited weather window in Western Canada. Last but not the least, the high resolution component of image logs can resolve what seismic may have missed. This can be useful for predicting steam conformance and production on a sub seismic scale.

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