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Towards Modelling Three-Dimensional Oil Sands Permeability Distribution using Borehole Image Logs

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Summary

Calculating three-dimensional permeability distribution in Canadian Oil Sands reservoirs seems within reach. Bedding architecture, composition and morphology are reliably qualifiable from borehole images and the suggestion is to study the link between these parameters and reservoir permeability anisotropy and distribution. The most common depositional environments are presented and the ranges of permeability and their directional distribution are discussed, as is a proposal for how to present permeability in three-dimensions from borehole image data and a discussion on how to move forward with future empirical studies.

Introduction

With the significantly increasing demand for more effective exploitation of Oil Sands reservoirs, the need for understanding reservoir permeability distributions has become the holy grail of Oil Sands SAGD design. There are still significant gaps pertaining to SAGD design based on permeability, more specifically well pair and steam chamber designs as they relate to matters of internal reservoir architecture such as IHS lateral accretion, flow-cross bedding and sedimentary mud breccias of varying composition.

It is now wholly accepted that Oil Sands reservoirs are heterogeneous with respect to permeability in three directions (vertically and azimuthally in the horizontal plane), but this reservoir heterogeneity is rarely expressed in a manner useful for exploitation planning.

Numerous models and simulations have been presented over the last decade to account for reservoir heterogeneity, but most of the inputted permeability data remains uncertain as core disturbances are highly prevalent in the coring process and core analyses typically represent best sand intervals without reflecting the inclination and orientations of the permeability barriers. Although seismic is very useful, its resolution also has its limits and finer features are unaccounted for or are unresolvable in more complex reservoirs.

Borehole image logs are routinely recorded in both vertical and horizontal wells because they produce detailed lithofacies information comparable in quality to that obtained from core analysis while also providing the best measurement for borehole-scale sand, mud and breccia compositions and geometries. These results are expressed in terms of: Vsh, IHS bedding orientations, flow cross-bedding orientations, sand and mud bed thicknesses; but are seldom being used to compute the logical end-goal of a permeability distribution model in three directions.

Method

Modeling permeability from borehole image and petrophysical inputs is still in the early days. The goal of this paper is to outline what inputs we have, how they might relate to permeability in a variety of

lithofacies and bedform architectures, and to outline how we think the final presentation of three-dimensional permeability might be estimated from image data with calibration from other sources. We hope to express a picture of permeability changes in depth but also in terms of lateral direction around the wellbore to provide a tool to optimize steam chamber growth near the wellbore and beyond. Ultimately, we wish to launch a more detailed study including core data and production outcomes, should there be interested industry partners.

Public examples of borehole images will be examined and the discussion will be focused on the main Oil Sands reservoir components: clean sand flow cross-bedding, IHS lateral accretion bedding and sedimentary mud breccias, and permeability numbers and methods for accounting for bedding heterogeneity will be presented in terms of ranges and methods derived from published papers.

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