



Delineation of thermally altered zones along second stage SAGD producer wells through resistivity characterization using an LWD azimuthal propagation tool

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Summary

In this paper, an attempt is made to study and characterize thermally altered zones within a bitumen reservoir in terms of varying resistivities reflecting the oil saturation variation due to active steam injection across the horizontal well bore. Resistivity profiles generated from real-time ADR (Azimuthal Deep Resistivity tool) data is compared with oil saturation models composed prior to drilling of two horizontal wells. Applicability of LWD (logging while drilling) azimuthal propagation tool's data is discussed with reference to real-time data from two geosteered second stage SAGD producer wells.

Introduction

In an era of ever increasing emphasis on maximizing oil recovery, an advanced geosteering approach is demonstrated to have definitive advantages. Most commonly, geosteering practices are used for optimal well placement to increase hydrocarbon recovery. Applications of geosteering tools and software in other areas, apart from placing the well, are still under-explored. Statoil Canada Ltd has only recently realized the potential for optimizing startup strategies by effectively delineating thermally altered zones in geosteered second stage SAGD wells.

LWD azimuthal resistivity offers the ability to investigate several meters beyond the well bore. Changes in the electromagnetic field from transmitter to receiver are due to the resistivity of the surrounding lithology. Resistivity is also a key component to Archie's equation for water saturation, providing a strong correlation between resistivity and oil saturation.

Combining resistivity readings from different depths of investigation, as well as a comparison of raw phase and attenuation values provides a means to indicate oil saturation variation due to steam infiltration across the horizontal SAGD well bore. Resistivity profile generated from real-time data is

compared with modified oil saturation log composed prior to drilling. Issues with such an approach are addressed and applicability of LWD azimuthal propagation tool's data is discussed with reference to real-time data from two geosteered second stage SAGD producer wells.

Theory and/or Method

In 2014 and 2015 a series of second stage SAGD producer wells were drilled in a mature heavy oil field for Statoil Canada Ltd in Western Canadian Sedimentary Basin using LWD azimuthal propagation tool and geosteering service (well placement). SAGD producer and injector well pairs were initially drilled within the area of interest between September 2008 and December 2009. After 4.5 years of production, the second stage producer wells are planned within the same area for the second phase of enhanced oil recovery. Objectives for drilling the horizontal second stage wells are (1) placing the well 4m above the base to increase the volume of recoverable bitumen and (2) demarcating the thermally affected areas.

Azimuthal deep resistivity sensor is used as a part of BHA (bottom hole assembly) in this study while drilling four wells. This azimuthal wave propagation tool is designed to detect resistivity changes within a few meters of the ADR tool (Bittar M., et al. 2007). Recorded changes in EM wave properties are modeled to reflect variation in the resistivity of the formations around the well bore (Pitcher J. and Bittar M., et al., 2011). Three spacings (between transmitter and receivers) viz. 112", 48" and 16" are used with tool's frequencies at 500kHz, 125kHz and 2MHz for readings at different depth of investigations.

Prior to drilling a conceptual model of the altered reservoir is created from the most recent saturation logs from nearby observation wells. Furthermore, pre-steam offset well logs are also available to establish a baseline for original reservoir properties. While drilling, a cross section profile for each well is created from real-time azimuthal resistivity data (Figure 1a) and is modelled with the help of geo-steering software. The resistivity variations are used to interpret the thermally altered zones in the reservoir along the well bore. Real-time temperature data from onboard the ADR tool sensor is also used to confirm the demarcated thermally affected areas.

IHS (Inclined Heterolithic Stratification) in McMurray formation may create barriers for steam movement and so affect the production from a single horizontal well at different zones. In this study, an attempt is made to correlate the shape of resistivity profile with heterogeneity of the rock structure within the reservoir. This plays critical role in understanding the extent of steam saturation / propagation.

To maintain minimum 4m TVD difference from the oil-water contact, a combined proactive geosteering approach is used. This is based on the combination of azimuthal resistivity, gamma ray, real time petrophysical information and a 3-D interactive correlation software. These data sets allows for the modeling of the geology in the area and the theoretical response of the tool based on offset wells' data.

Derivations from the deepest reading sensor, Geosignal (112" at 500kHz), is used to estimate the distance to bed boundary quantitatively. Theoretically a low resistivity response approaching from above may be indicative of a thermally altered zone. Conversely the same response approaching from below may indicate an approaching water boundary. Each response would dictate a unique geosteering corrective action.

Examples

The objective is to map and determine the effects of the thermal activity from the surrounding SAGD well pair and then delineate thermal unaffected zones (Figure 1b). The thermal unaffected zone should reflect the characteristics of the original in place bitumen. The thermal affected zone can represent (1) a zone of mobile bitumen, (2) a decrease in bitumen saturation, (3) an increase in temperature, and/or (4) an increase in steam saturation. The transition zone is reflective of the heat gradient between these two main zones.

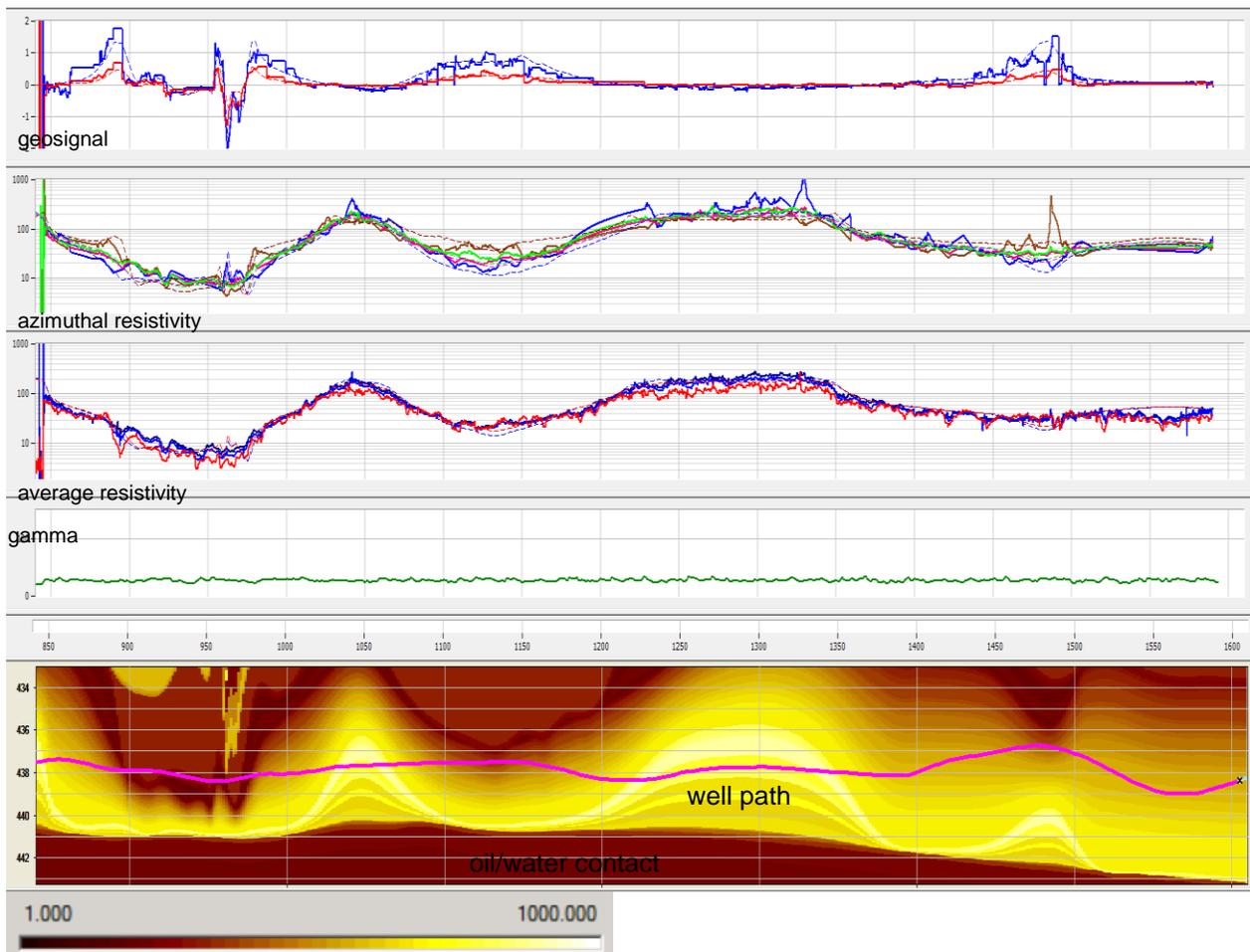


Figure 1a: Data used in modeling the resistivity within 5m of the well bore. Darker regions represent areas of low resistivity. The dark area several meters below the well path represents the oil/water contact while the darker regions around and over the well path reflect low resistivity are associated with thermally altered zones.

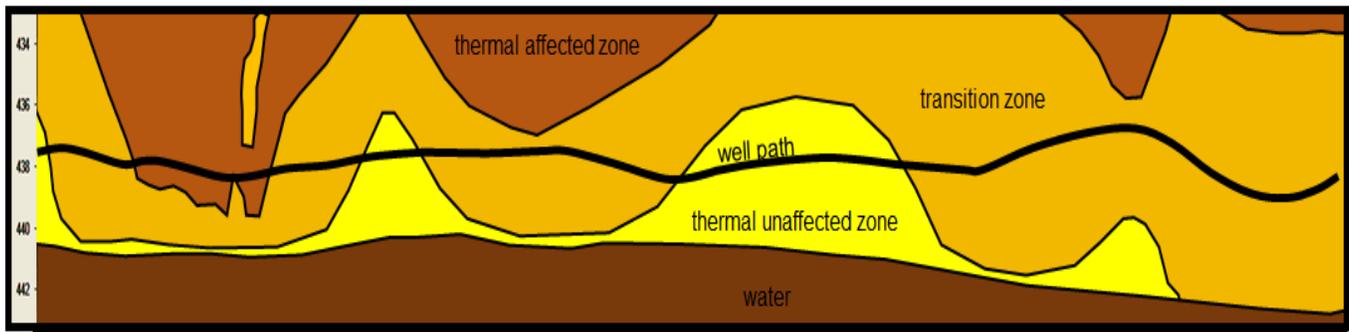


Figure 1b: Schematic diagram indicating the Azimuthal Deep Resistivity tool's and Stratasteer Geosteering Service's ability to map resistivity zones around the well bore, and correlate this to the thermal effects from the surrounding SAGD well pairs.

Conclusions

Azimuthal deep resistivity tool and its petrophysical interpretation greatly enhance the ability of well placement and improve the understanding of the reservoir. Thermally altered zones near a second stage SAGD horizontal producer well can be delineated along with an estimate of reservoir quality. Understanding the distribution of these different zones along the horizontal section of the wellbore can aid in optimizing the startup strategy and minimize time to bring a well into production phase. Furthermore, this information can be used to determine the feasibility of a second phase drilling campaign, design the liner configuration and/or help determine the best method of production.

Acknowledgements

The authors thank Statoil Canada for the support and permission to present this work.

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