An Innovative Approach to Monitor Depletion of Reserves Integrating 3D Static Models and Time-Lapse Saturation Logs*

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Search and Discovery Article #41471 (2014)
Posted October 27, 2014

*Adapted from extended abstract prepared in conjunction with poster presentation given at AAPG International Conference & Exhibition, Istanbul, Turkey, September 14-17, 2014, AAPG © 2014

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Abstract

Tracking depletion volume and pattern is of utmost importance for any mature field but a difficult task to accomplish. Thermal Decay Time (TDT) logs are very useful in assessing saturation around the bore-hole, provided the stipulated conditions for porosity and water salinity are met. A time lapse TDT campaign in a field over its production life can thus give us important clues on how the water front is advancing as a result of oil production/depletion.

This article attempts to integrate the information on the oil-water interface in wells using time lapse TDT logs with 3D static model properties (porosity and saturation volumes) to capture both the depletion pattern and volumetric. The study was conducted on a sector of a large Middle Cretaceous clastic reservoir in Kuwait having a commercial production history of several decades. The sector is part of a four-way dip closed anticline beneath the Middle Cretaceous Shales with a common oil-water contact of 4472 ft TVDss.

The sector is isolated by geological features like faults which ensure that there is no significant fluid movement in or out of the sector. It is rectangular in shape with a major north-northwest trending strike slip fault as its northeast boundary, whereas the western boundary is the flank of the anticline with minor north-northwest faults and the southern boundary grades into the crestal part of the anticline (Figure 1).

Method

The middle sandstone reservoir is composed of massive fluvial dominated stacked braided river channel sands of Albian age. The reservoir quality of sands is comprised mostly of fine- to coarse-grained, well sorted, poorly compacted quartz arenites with mainly primary inter-granular porosity in the range of 25-30% and high permeability in the range of 1-10 Darcy (average of 4 Darcy). The net-to-gross in the oil leg is typically greater than 0.90, occasionally reaching 1.00. The sands have an average thickness of 350 ft and productivity indices are 5-150 BOPD/psi.

Historically reported recovery factors are of 60-80%. The field is underlain by an extensive aquifer that provides strong drive energy for the middle sandstone reservoir (edge and bottom water).The high quality and continuity of the middle sands has allowed efficient sweep with a piston-like movement of the waterfront from the base and the sides. Water now underlies oil in the middle sand over almost the whole Field. High water salinities (~150,000 ppm) allow effective use of TDT logs as a reservoir monitoring tool.

Determination of hydrocarbon and water saturation behind casing plays a major role in reservoir management. Saturation measurements over time are useful for tracking reservoir depletion. The through tubing Thermal decay time logs are commonly used for evaluating reservoir performance, as it can see through casing. The TDT logs provide good saturation measurements when the formation water salinity is high, constant and known. They help in identifying presence of remaining hydrocarbons as a result of changes in water saturation during the production life of the well. A comprehensive study of TDT logs has been carried out to monitor fluid movement over the entire area.

The study attempted to reconstruct the oil-water interface at two different times, 2011 and 2012.There are 183 wells already drilled in this sector (Figure 2). Out of these 183 wells, TDT logs are recorded in about 60 wells every year. The TDT log gives us the exact location of the interface in the borehole. So we get about 60 such points on the oil-water contact surface each year. The 60 points were interpolated using geological judgments to generate the oil-water contact surfaces for 2011 and 2012 (Figure 3).

The process of volume calculation was simple. It used the reconstructed water contact surface as the bottom of the reservoir and then used the 3D porosity and saturation models to compute oil volume. As we generated two contact surfaces in 2011 and 2012 it computed the volume of oil remaining on those successive years (Figure 4). The result of this innovative method of volume calculation was compared with actual production recorded in all the sector wells. The produced oil must have come from the rock volume stacked in the between the two oil-water contact surfaces of 2011 and 2012.

The result was remarkable as it matched well with the actual production. Actual production from those wells was 69 MMBO. Three cases were run with 60%, 7% and 80% recovery factors for the volumetric calculations. The produced oil volume from the model was 65 MMBO with 70% recovery. This number matches with actual production, supporting the usefulness of the concept used.

The middle sand cumulative production is tabulated in Table 1. The annual production of 69 MMBO was found complementing with the results of the volumetric calculations performed using 0.7, suggesting that the middle sand has excellent sweep.

Conclusions

The study thus established an innovative way of tracking depletion in a Brown Field using time lapse TDT logs. This novel approach may be used to estimate the life of a field and to plan and propose infill locations in the sector to optimize and enhance oil recovery.

Acknowledgements

The authors are thankful to the KOC Management for giving this opportunity to share and publish this work.

Scenario (Recovery Factor)	STOIIP MM [STB] 2011	STOIIP MM [STB] 2012	Recoverable oil/MM[STB] 2011	Recoverable oil/MM[STB] 2012	Annual production from Volumetrics MM[STB]	Actual production 2011-2012
REC 0.6	597	504	358	302	56	69.9 MMBO
REC 0.7	597	504	418	353	65	
REC 0.8	597	504	478	403	75	

Table 1. Reserves in 2011 and 2012 against annual oil production.

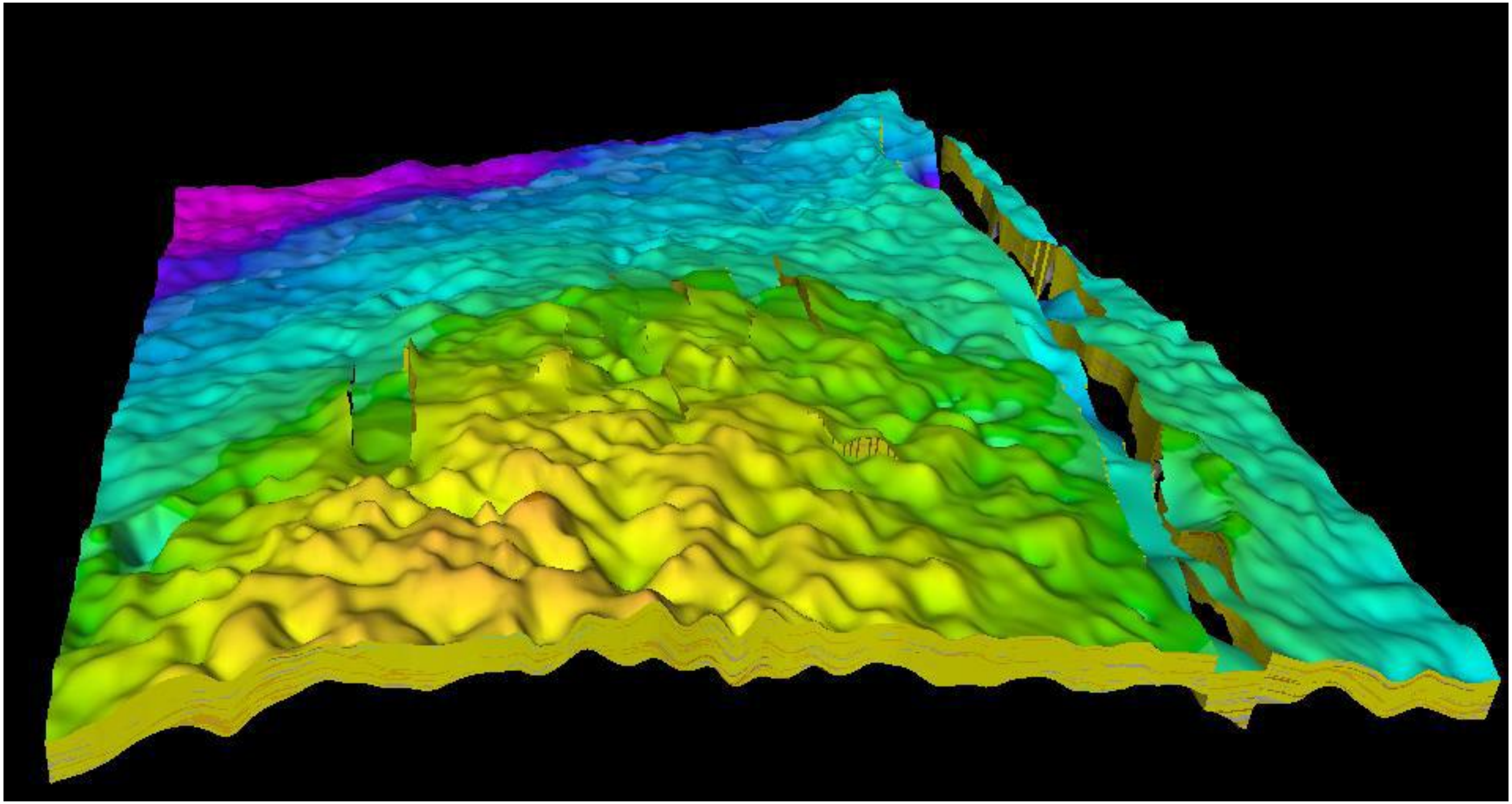

Figure 1. Part of the sector model under study.

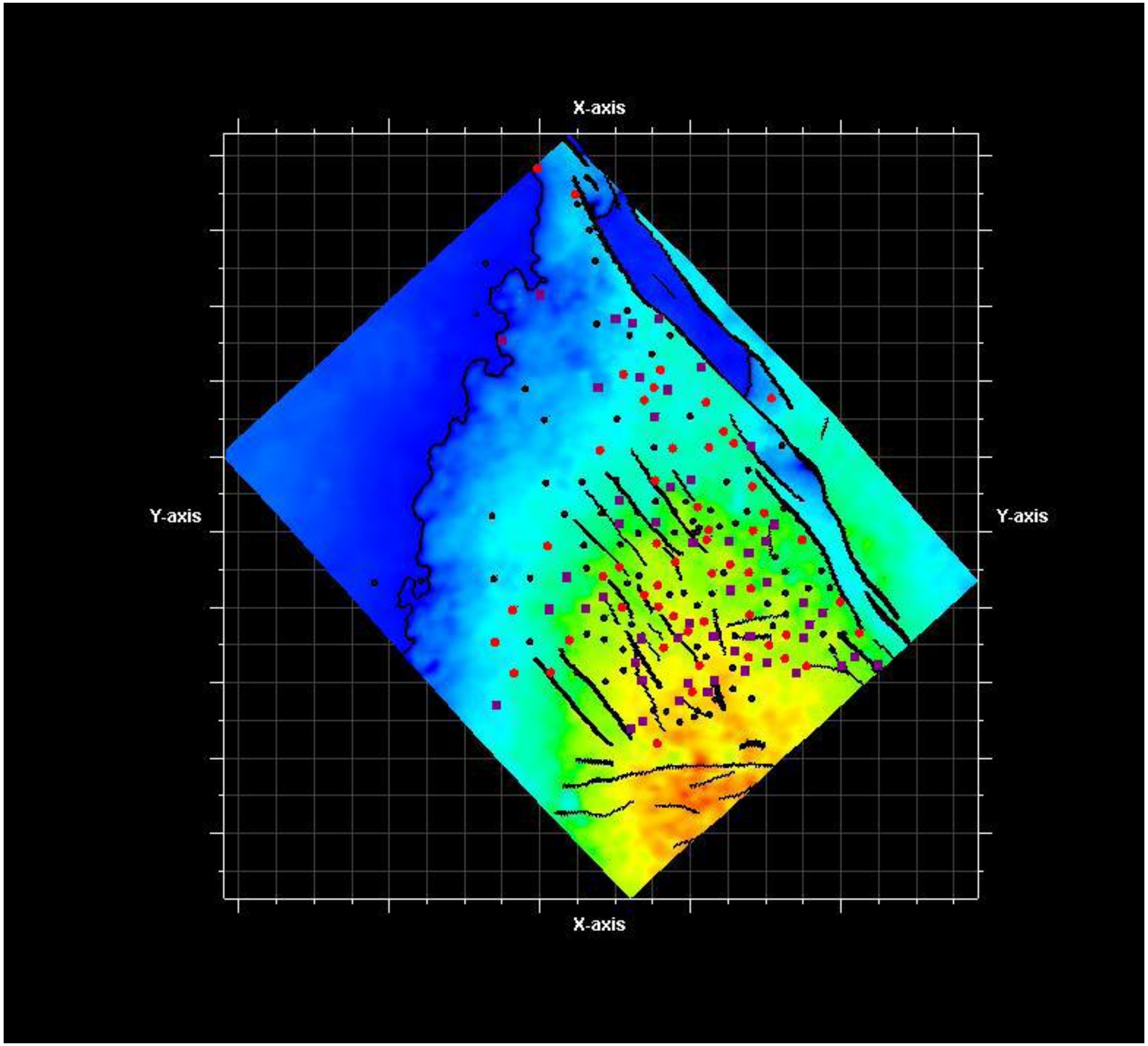

Figure 2. Distribution map of TDT logs in space and time.

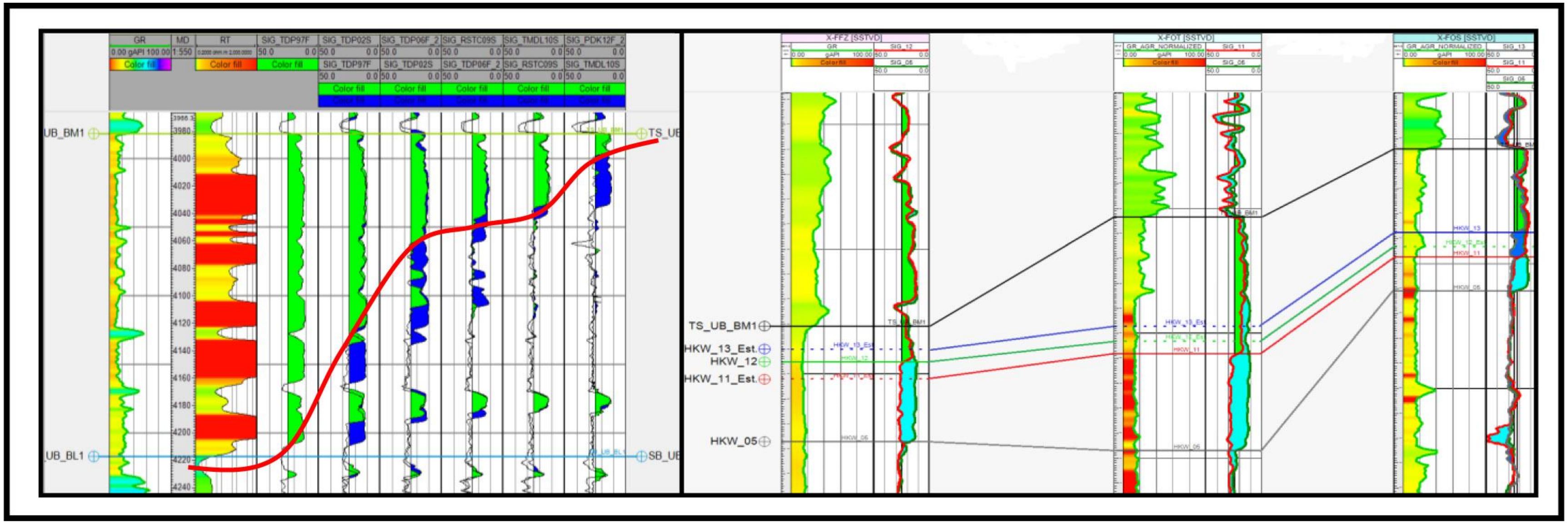

Figure 3. Single well rise in oil-water contact from TDT log and estimation of oil-water contact.

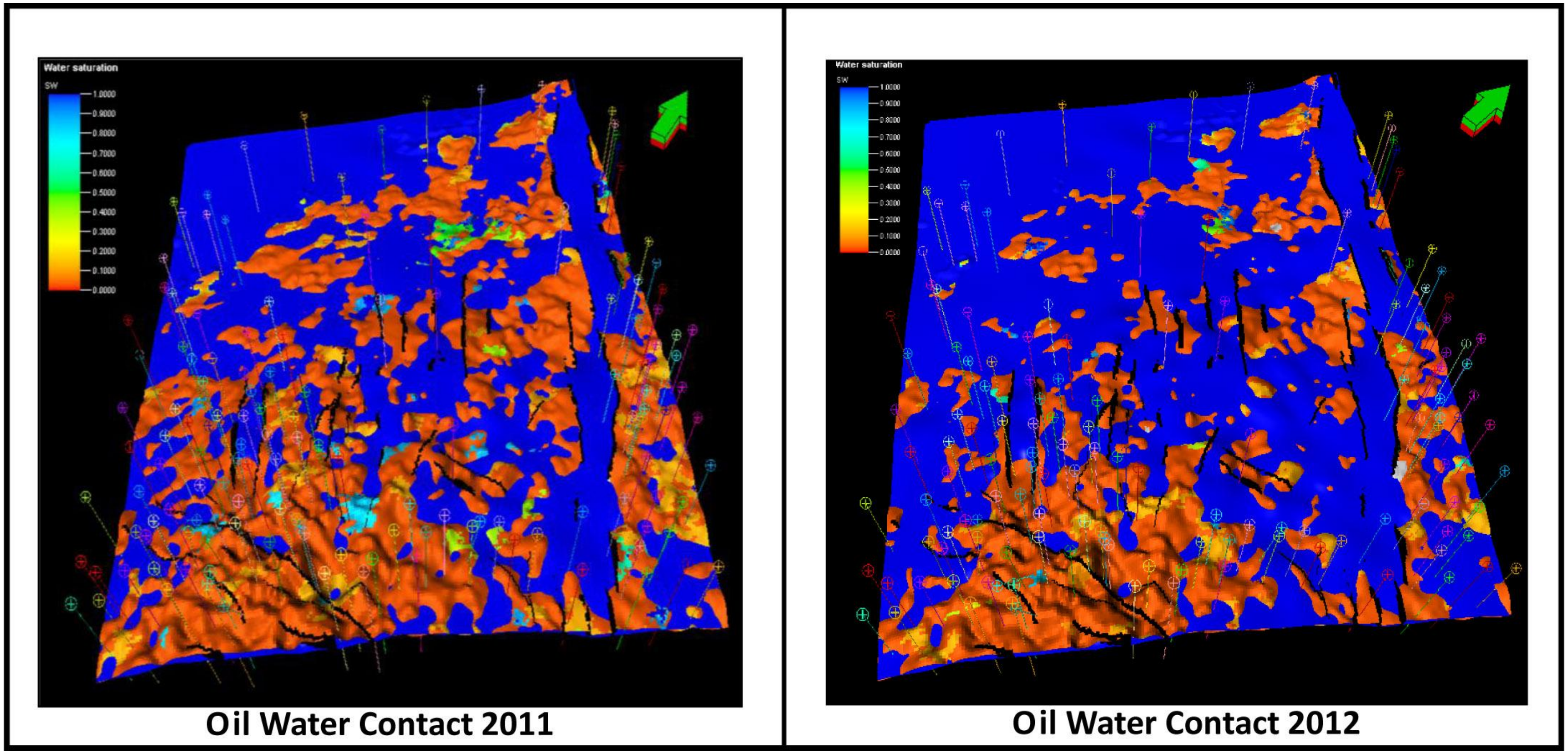

Figure 4. Shows 2011 and 2012 modeled oil-water contact superimposed on oil saturation.