Benguela-Belize-Lobito-Tomboco (BBLT): Uncertainty Resolution in Reservoir Performance Predictions*

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Search and Discovery Article #20071 (2009)
Posted May 8, 2009

*Adapted from oral presentation at AAPG International Conference and Exhibition, Cape Town, South Africa, October 26-29, 2008

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Abstract

BBLT was the first of Chevron's "Big 5" world class projects to come on line. The development consists of six main oil pools in about 1300 ft of water. It is composed of several deepwater turbidite channel complexes of middle-lower Miocene age, vertically stacked and grouped geographically around structural traps, with oil in place estimated at over 1 billion barrels. Oil quality in these prolific reservoirs ranges from intermediate to light (~24-37 API).

A total of thirteen exploration and appraisal wells were drilled in the four field BBLT discovery area. From the appraisal data, full scale subsurface geo-cellular models were built and experimental design used to evaluate the key uncertainties of the slope channel system reservoirs. Key static and dynamic uncertainties in these channel systems are clearly net rock volume (NRV), and reservoir connectivity. The highly variable and difficult to predict net-to- gross within the amalgamated channel system introduces significant NRV uncertainty. This complex internal architecture, in conjunction with faulting in the fields, also creates uncertainty in the degree of connectivity impacting drainage and sweep efficiency.

A pre-drill program, consisting of 11 development wells, was conducted in 2004 and early 2005 to ramp up oil production and address these key subsurface uncertainties. Log and core results from these wells were used to update reservoir models with new structure, sand, fluid contact, SCAL data, etc. From the new models, optimization of the remaining well location targets was conducted. Some of the key lessons learned from this pre-drill program will be demonstrated.

Reservoir Performance Characteristics

Production from dry tree (compliant piled tower) wells began in January 2006 and from subsea tie-backs in June 2006. Well and reservoir performance has been excellent with oil production averaging ~160,000 bopd since January 2007. This presentation will include observations from the first year of production regarding reservoir performance and connectivity, offer insights into appropriate reservoir modeling techniques and lessons learned in the development of deep water reservoirs.

During completion of the pre-drill wells for production, nearly uniform depletion was observed spanning several vertically distinct reservoir zones in the Belize Field. This depletion originated from a single zone producer, indicating a high degree of vertical and areal connectivity across the channel systems.

A similar behavior has been observed in the CN6 section of Tomboco Field as well. This degree of connectivity matched with the higher range connectivity models which had a higher net-to-gross and better connectivity introduced by using the GOCAD erode/dilate function. This function erodes the shale region creating more sand volume and higher net-to-gross. The dilate part of the function retains connectivity across thinner shale intervals. The new sand cells are populated with small values of porosity and permeability which do not create significant volume, but do enhance connectivity.

In Lobito Field the CN3 reservoir interval is the primary producing interval and is also an amalgamated slope channel system. This system differs from the Belize system in that it represents a more laterally confined channel complex. This system was originally modeled using Sequential Gaussian Statistics (SGS) based on seismic attributes PCA. This method created pressure choke points along the channel where the seismic signal dims. The impact of these choke points was to create greater pressure drops through the choke points than observed from production data.

Using multi-point statistics (MPS) as opposed to SGS methods had the impact of reducing the choke points and enhancing lateral connectivity along the channel. This resulted in a better match with the observed reservoir pressures during production. The overall impact on the development strategy or rate prediction was small at Lobito, but this method could prove more fruitful in lower net-to-gross systems.

More dramatic vertical and areal connectivity than seen is Belize Field are observed in the Tomboco Field CN6 reservoir. The TA6P2 well was completed in the T3 reservoir as a single completion in January 2007. The well produced at an initial rate of 24,000 bopd and began producing water within one month. The TA6P1 well was drilled in April 2007 and pressure measurements indicated pressure depletion across the entire 1,300 foot reservoir section. This was a quite unexpected result given the low net-to-gross of the reservoirs encountered, and the apparently thick (300 ft) continuous shale separating the T1 and T3 reservoirs. Lessons learned from these pre-drill wells have enhanced the development teams understanding of the reservoirs and enabled adjustment of the development strategy. The reservoir vertical and areal connectivity behavior represents a high-end outcome. The mechanism explaining this high level of connectivity is not fully understood but includes erosional amalgamation, injection or remobilization of sands, sandy shales, and faulting, fracturing, and sand juxtaposition.

Conclusions

Production data indicates that the reservoir models tend to under-predict sustained production rates on primary depletion. This will allow us to delay water injection for a few months to gather primary reservoir depletion data, and may reduce need for water injection in certain cases. The use of down-hole surveillance with pressure gauges is a key to gathering this critical data and managing subsurface uncertainties. Use of the erode/dilate and MPS GOCAD modeling tools provide a quick and effective method for increasing model connectivity to match dynamic pressure performance.

A key challenge still facing the BBLT Field development team is to understand the observed reservoir connectivity mechanisms and their impact on water-flood sweep efficiency. In addition, the drilling of long reach wells to develop thinly bedded and sometimes low net to gross reservoirs will continue to present a technical and economic challenge to the project.

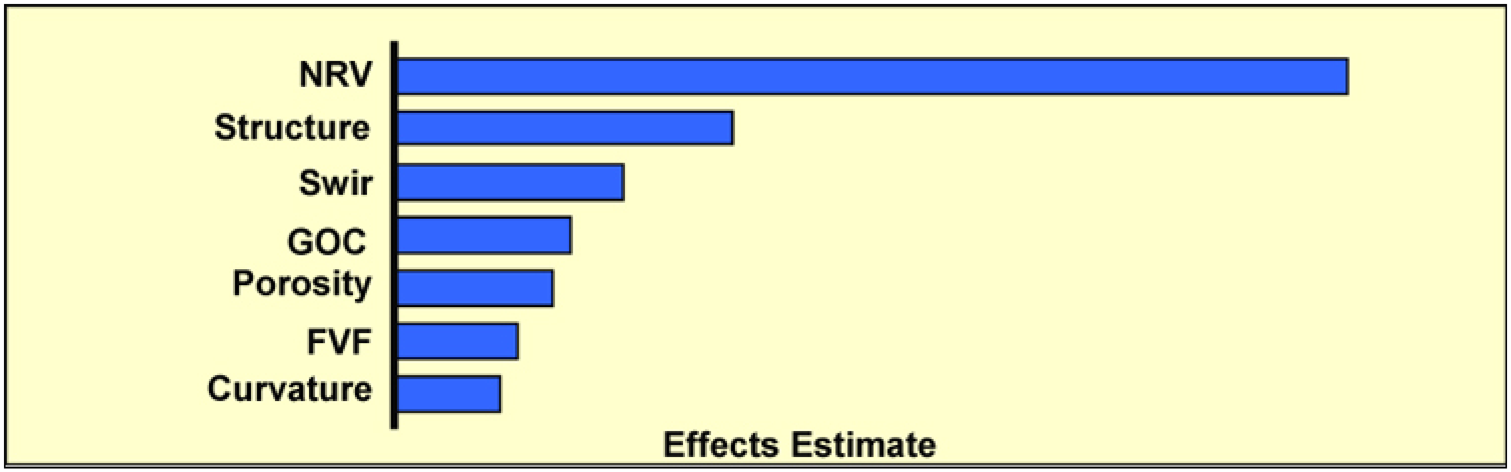

Figure 1. BBLT static uncertainties pareto chart – OOIP.

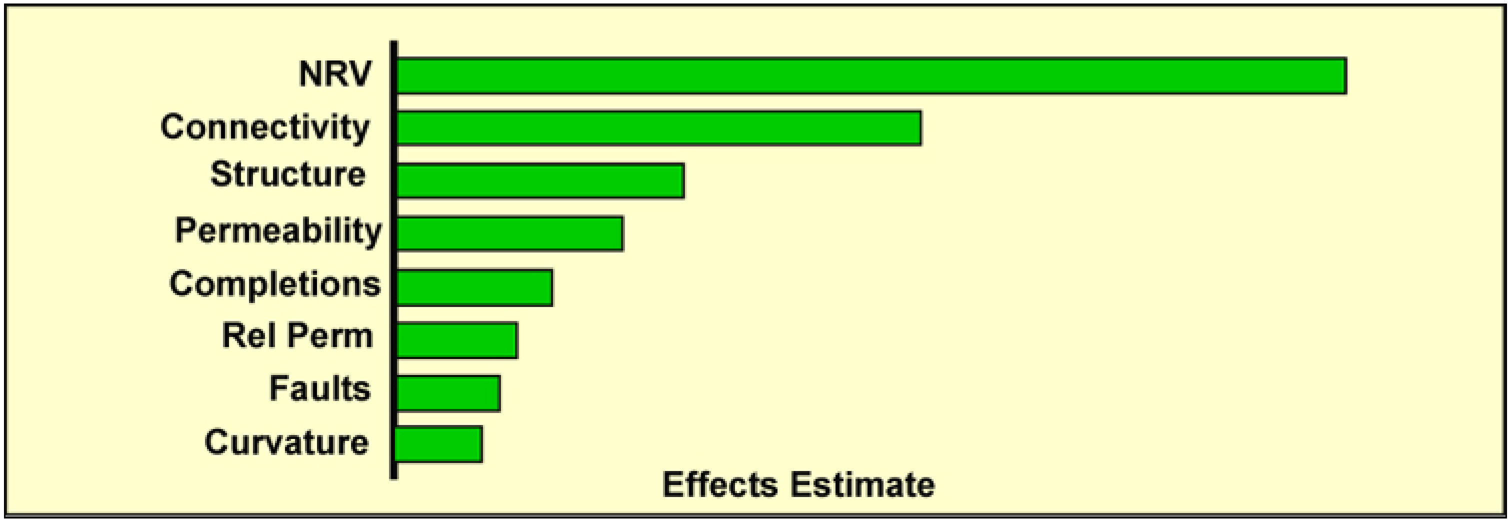

Figure 2. BBLT dynamic uncertainties pareto chart – Recovery.

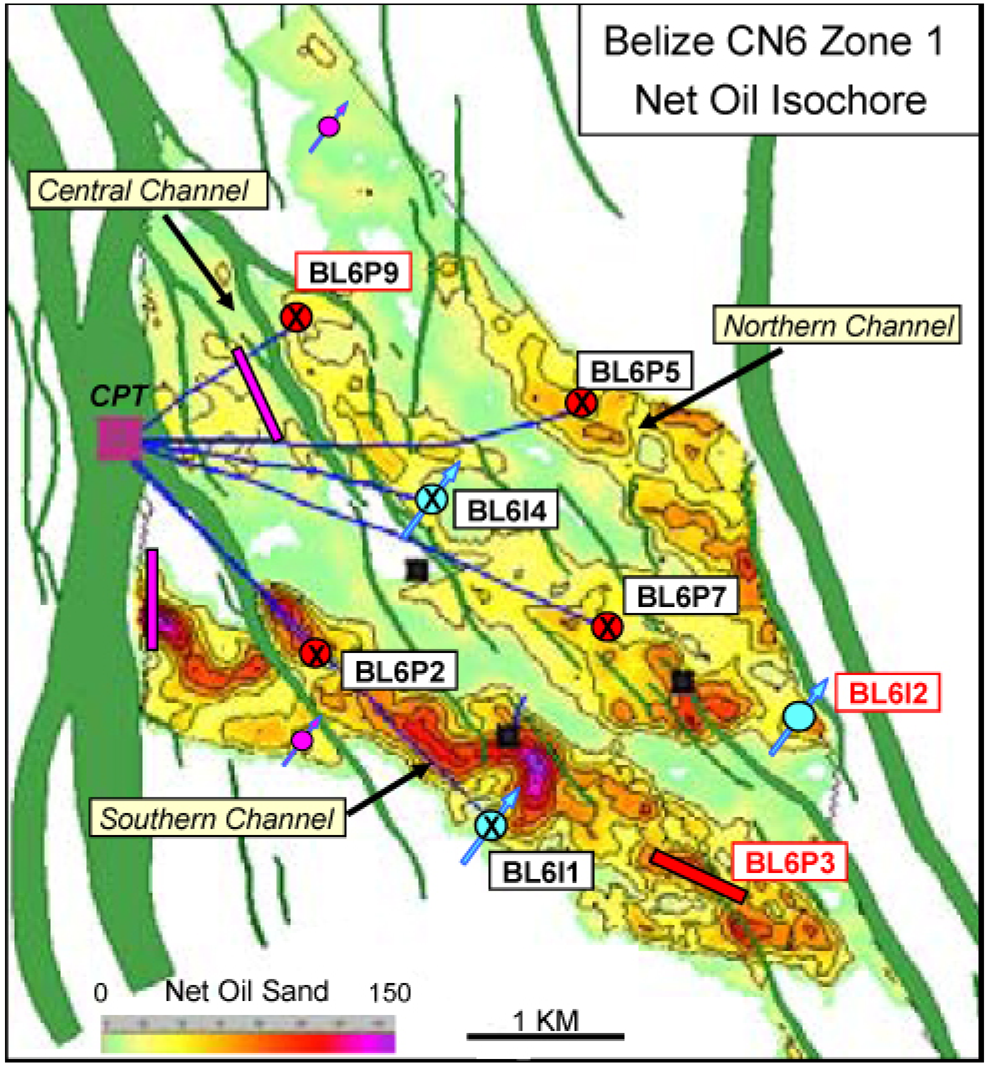

Figure 3. Belize CN6 Zone 1 net oil isochore.

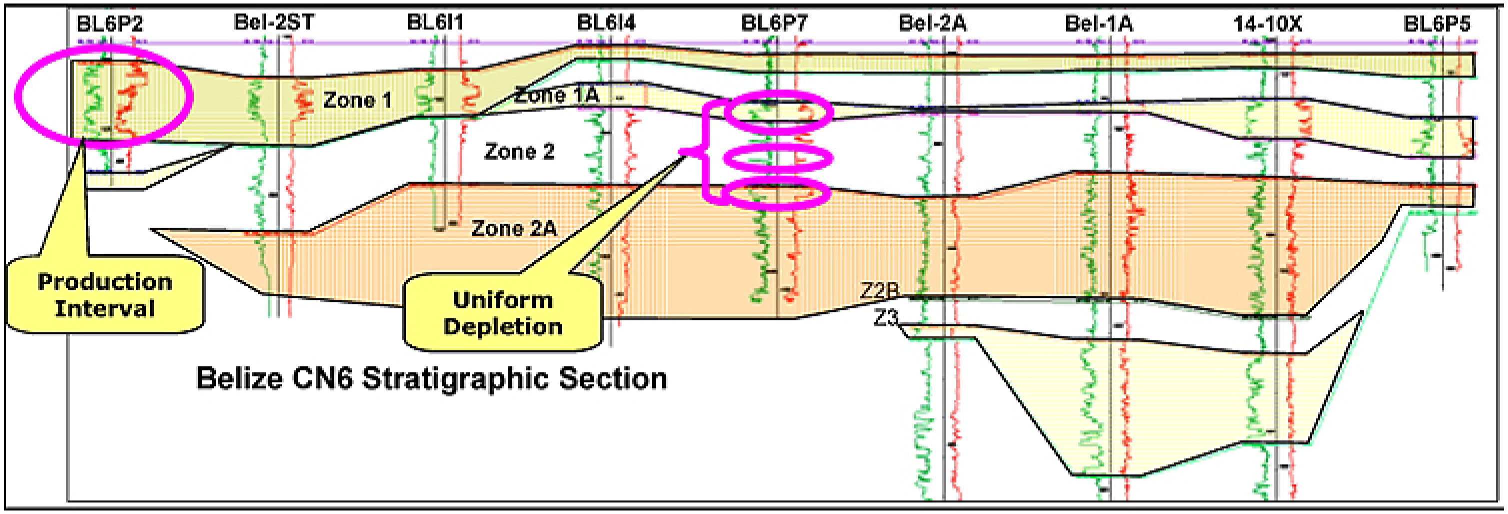

Figure 4. Belize CN6 stratigraphic section.

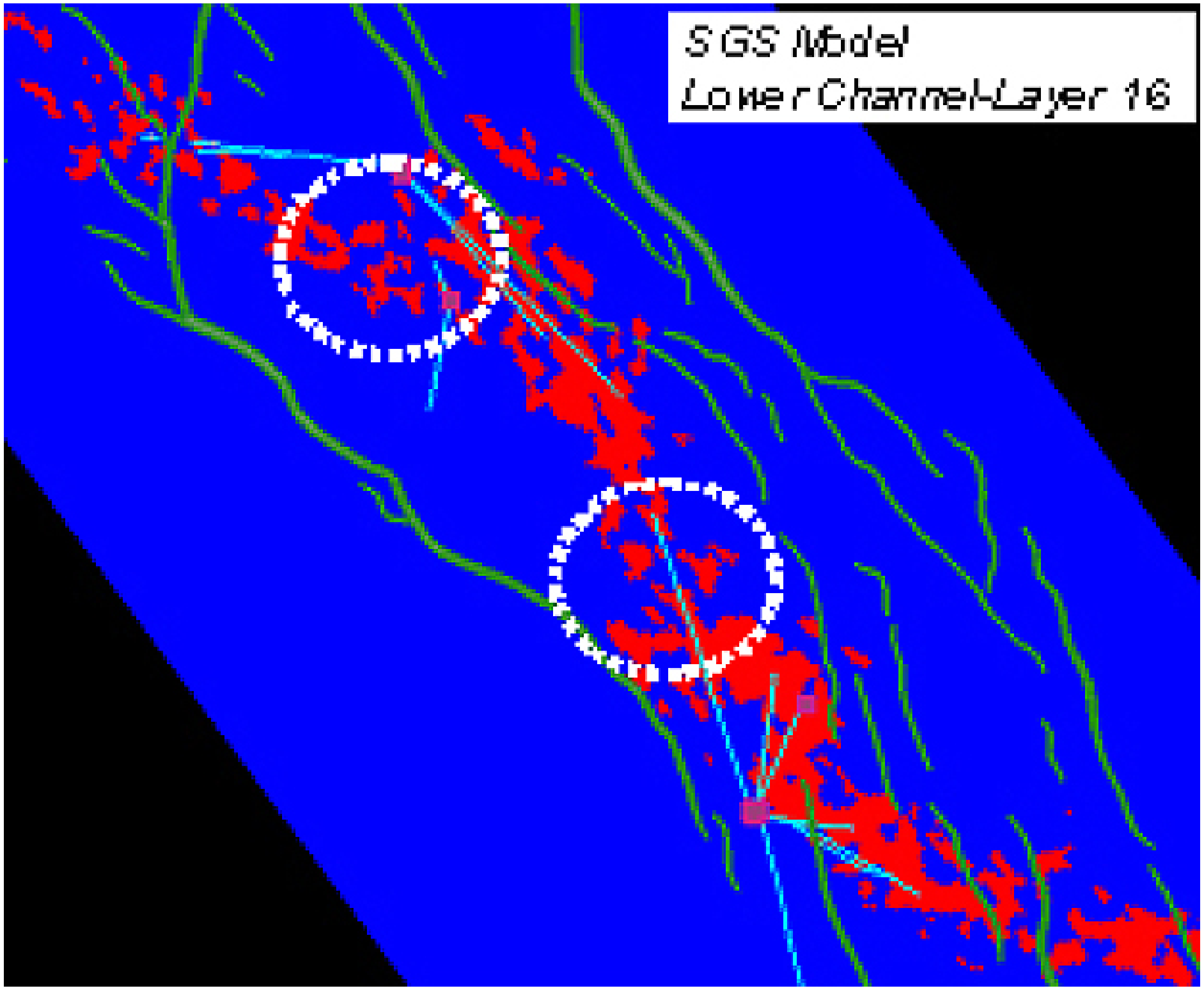

Figure 5. SGS model of Lower Channel – Layer 16.

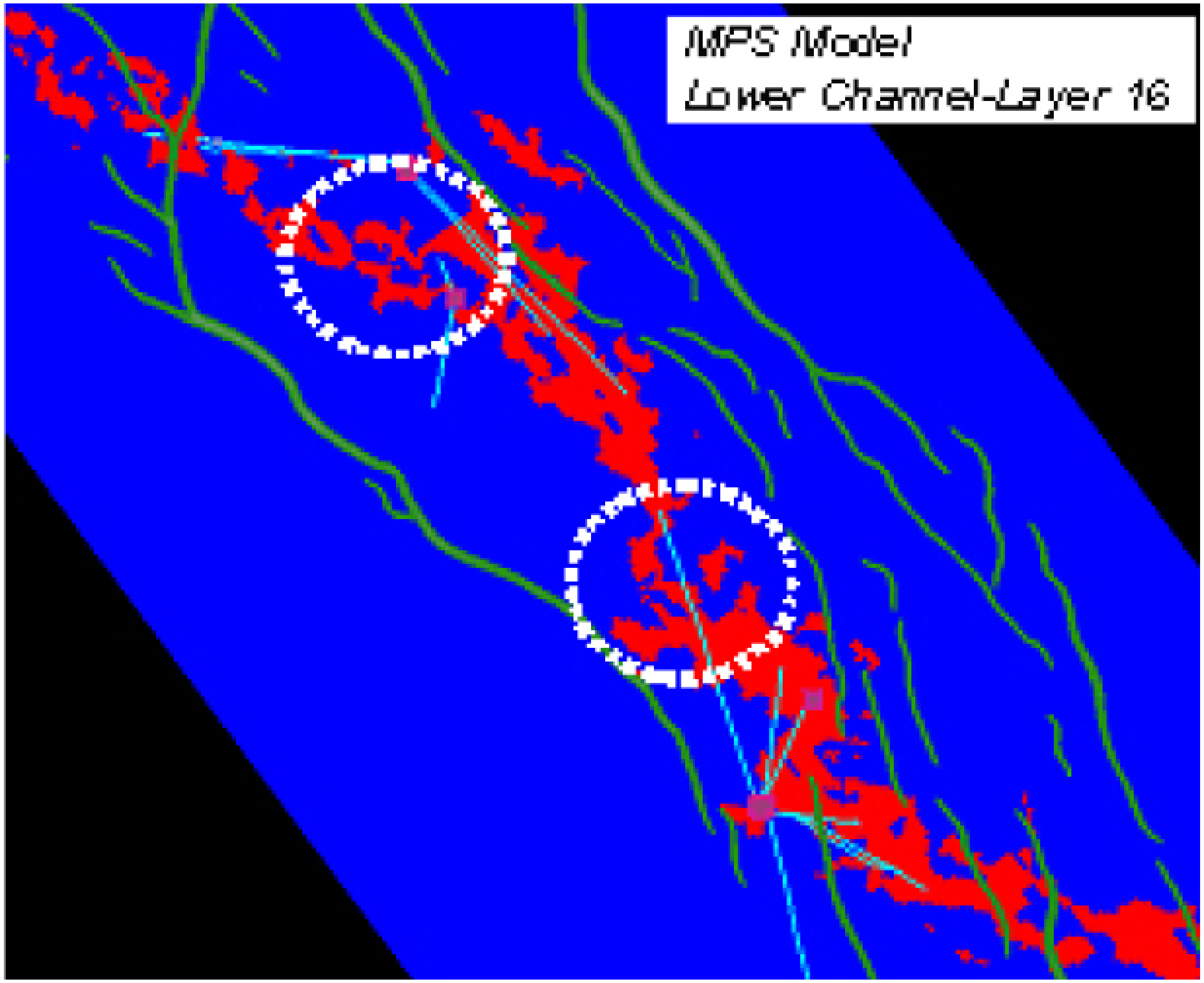

Figure 6. MPS model of Lower Channel – Layer 16.

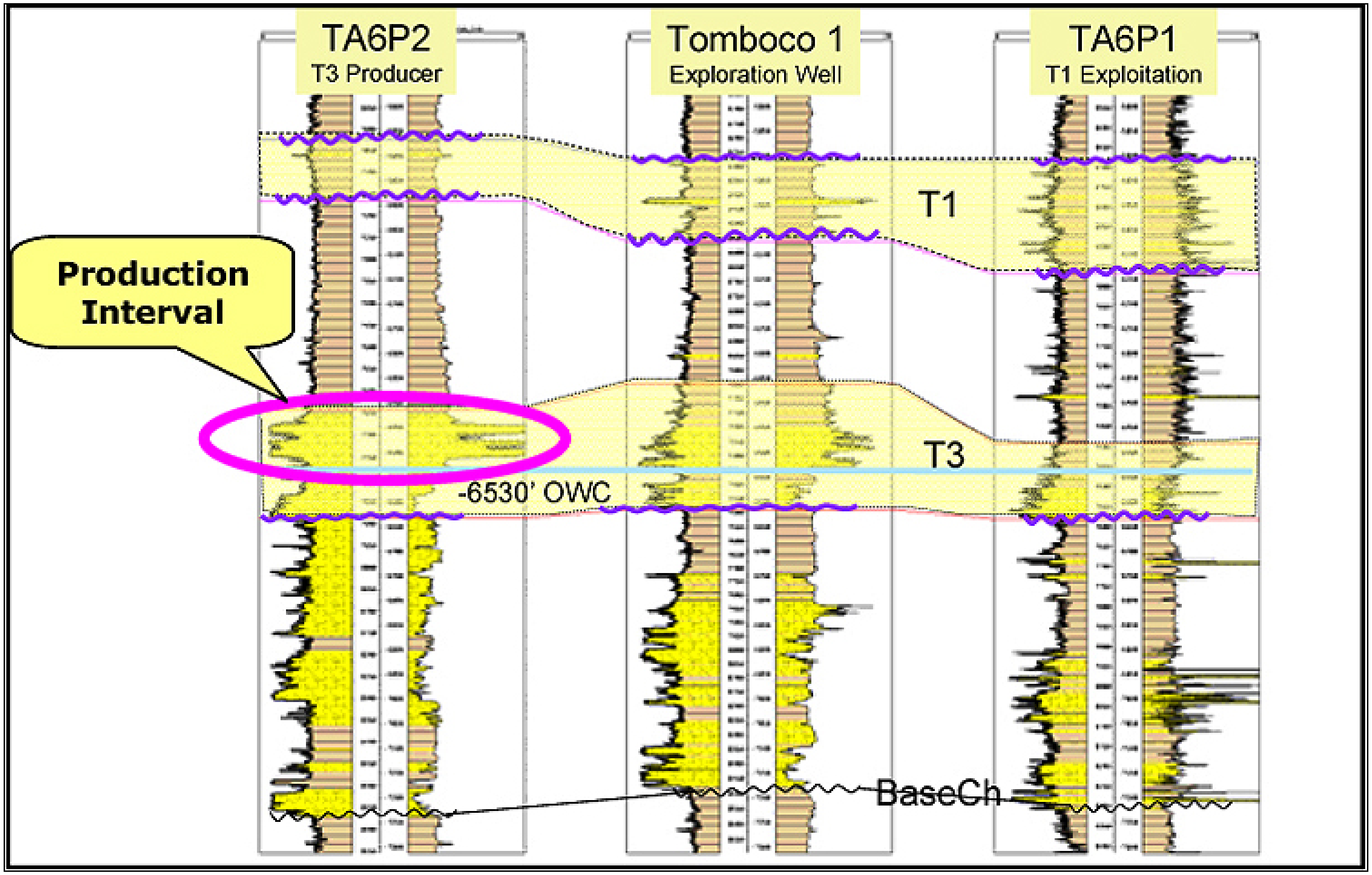

Figure 7. Cross section of T3 production interval.

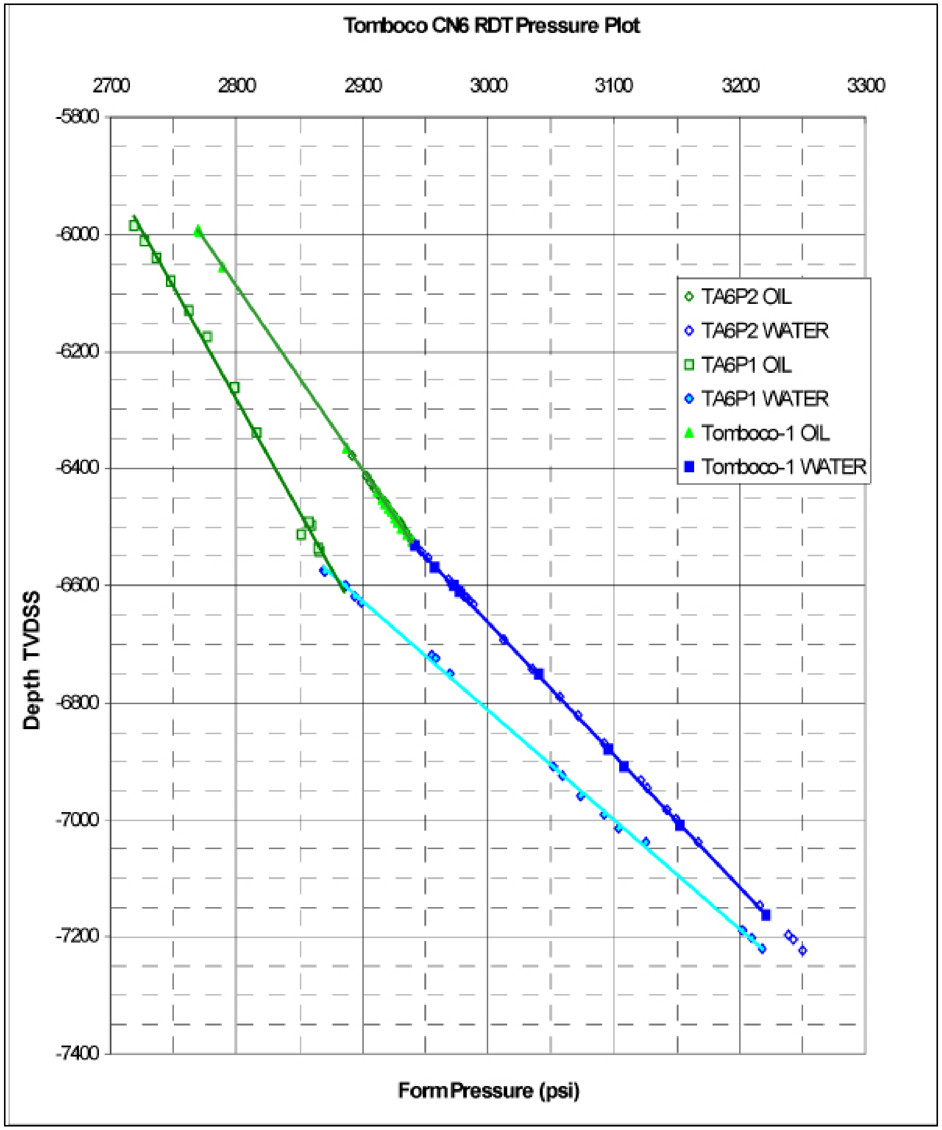

Figure 8. Tomboco CN6 RDT Pressure-Depth plot.