Reservoir Navigation in Njaba Field: Challenges, Procedure and Results.

By


Abstract

Due to the low oil price, Exploration and Production (E&P) companies are driven to reduce the cost per barrel of oil equivalent (BOE). The application of reservoir navigation services, in the placement of high angle and horizontal (HAHZ) wells in the sweet spot of reservoirs, has aided in meeting this economic need of the E&P, while also improving hydrocarbon recovery. Reservoir navigation services (RNS) can be regarded as another tool for improving the odds of success while drilling of HAHZ wells. This service involves the integration of real-time data (deep-reading azimuthal resistivity, gamma-ray, density image, resistivity image logs, near bit inclination and a fit for purpose rotary steerable system) to accurately position the well-bore relative to specific subsurface targets, while remaining within the constraints of the drilling and completion program. RNS also require a software package capable of pre-well modeling, displaying the acquired real-time data and interactively adapting the model to the real-time data.

Geosteering in Njaba field involved a comprehensive pre-well planning, discussions, documentation and management approved decision-tree. Using four wells for this study, this paper describes the challenges, procedures and results of geosteering in Njaba Field located on-shore Niger-Delta. From different entry points, wells NJX1, NJX2, and NJX3 were planned to drain the same reservoir and optimize hydrocarbon recovery within the reservoir. Some of the challenges encountered includes geosteering the wellbore above a pre-determined production TVD hardline while simultaneously avoiding drilling into an overlying undulating shale cap rock, vertical seismic uncertainty and undulating formation boundaries.

Keywords: Geosteering, Njaba, Depth Uncertainty, High-angled, Reservoir Navigation, Borehole Image

Introduction

The Njaba structure is located onshore, some 15 km north-east of the Izombe Field, in the eastern part of OML-124. It is located in the hanging wall of the Awomama fault and is controlled by a combination of rollover fault, crestal fault and fault closure. OML-124 is situated in the northern part of the Niger Delta in the transition zone between the main Tertiary Niger Delta to the south and the Cretaceous Anambra Basin to the north. The stratigraphic column shows a prospective sequence that consists of Early/Middle/Late Eocene overpressured shales of the Akata Formation that is overlain by Late Eocene pro-delta deposits, shallow marine shelf and coastal sands and shales of the Agbada Formation. The sequence is followed by the Benin Formation (Oligocene to Pleistocene) continental fresh water bearing sands.

*Addax Petroleum Development Nigeria Ltd.
**Baker Hughes, a GE company.
1 Fig 1.
To geosteer the wells, Reservoir Navigation Services (RNS) was employed. RNS provided a fit-for-purpose, multidisciplinary approach to the geosteering. It focuses on optimizing wellbore placement in real time. RNS utilized real-time measurement-while-drilling (MWD) and logging-while-drilling (LWD) data to optimally position each well-bore relative to the reservoir geometry. Recent innovations in rotary steerable drilling technology, azimuthal resistivity services, LWD, drilling data and 3D visualization were integrated to address wellbore placement uncertainties. RNS Supervisors and image specialists were available 24-7 to provide expertise for the real-time interpretation of resistivity and borehole image data. The supervisors had knowledge of the tools, software and know-how to generate/update interactive predictive response models in real-time allowing effective geosteering decisions to be made. They were involved from the initial feasibility study stage to post well reviews. During the execution phase, they were the focal point for RNS operation, liaising with the client representative and were responsible for all aspects of geosteering advisory. Reservoir Navigation Software with JewelSuite™ Real-Time Reservoir 3D visualization software was used during the job. The geosteering tools/services used for project execution include:

1. Azimuthal propagation resistivity, multiple propagation resistivity, gamma ray, bulk density, and neutron porosity for integrated formation evaluation, lithology/fluid typing, well-to-well correlation and remote conductive boundary detection.
2. Borehole imaging and dip picking for structural interpretation.
3. Rotary steerable assembly for drilling performance and directional control.
Pre-drill Challenges
The well objective of placing a horizontal drain in the eastern part of the reservoir structure, delivering a minimum of 1000ft lateral section, was met with a couple of challenges. The Njaba structure is separated from the main reference well by a fault and seismic character changes occur laterally, adding uncertainties in the seismic correlation between the two structures. The other envisaged challenges are:

1. Few offset wells (one penetrating hydrocarbon, the other penetrating water leg).
2. Presence of heteroliths.
3. High resistivity water leg (leading to reduced resistivity contrast between fluid boundaries).
4. Seismic vertical depth uncertainty.
5. Possibility of early water breakthrough.

Fig 2: Visual description of the stages and work cycle for a RNS supervisor

Fig 3: Top structure map of target reservoir showing fault lines and position of wells
**Result Description**

**NJX1**

The target was encountered 12ft deeper than prognosis and the landing section drilled to 4890ft MD at 85.4 degrees inclination. The top region of target reservoir is heterogeneous and not considered as sweet spot. At target penetration, dip direction from seismic agreed with direction from LWD borehole image but differed in absolute dip value. Borehole images interpreted a steeper surface.\(^5\)

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\(^5\) Fig 5
A summary of decisions and observations are listed below:

1. Tool detected the approaching lower boundary of the heterogeneous zone.
2. Decision was taken to increase TVD from 3791ft TVD to 3793ft TVD (TVD hardline).
3. Again, tool detected the approaching lower boundary of the heterogeneous zone. Drilled into the heterogeneous zone since trajectory was already at the TVD hardline. No further decision was taken until TD was called at 6390.94ft MD after achieving about 1500ft gross drain length.

NJX2

The top structure at this flank of the reservoir is undulating, with some steep boundaries. Borehole image interpreted the steep boundaries as high-angled features. The resistivity contrast between the target reservoir and the overlying shale is good and azimuthal propagation resistivity tool can detect the proximity of the overlying shale when the trajectory is within the DOD range.

A summary of decisions and observations are listed below:

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\(^6\) Fig 6

\(^7\) Fig 7
1. Top structure at this flank of the reservoir is undulating, with some steep boundaries. Steep boundaries were supported by LWD borehole image dip values. Tool detects a conductive boundary from the high side.
2. Drill further at 90deg, as per decision tree.
3. Decision to drop inclination from 90deg to 88deg, and then back to 90deg at 7118ft MD.
4. Drilled through another abrupt high-angled boundary.
5. Decision to drop inclination from 90deg to 88deg, and then back to 90deg at the TVD hard-line of 3770ft TVD, but TD was called before drilling to the hard-line. 1500ft gross and 1100ft net sand was achieved in this well.

![Diagram showing RNS curtain section juxtaposed with borehole image to see the high-angled boundaries drilled through.](image)

**NJJX3**

Part of the well objective was to geosteer the 6in hole drain section, deliver a minimum of 1000ft lateral section to drain the reservoir, complete well with gas lift and sand control equipment. The geosteering plan was to stick to the pre-drill drain section strategy – maintain 90 degrees inclination, drill to TD position, and any conductive bed drilled through will be cut off with a blank during completions. The TD for 8.5in landing section was at 4840ft MD.
The reservoir top structure is down-dip and the horizontal trajectory got close to the top structure and drilled into some heterogeneous beds at the distal part of the drain hole section. A gross drain length of 1100ft was achieved, with about 900ft being in good reservoir quality rock.

**Fig 8:** RNS curtain section showing the wellbore drilling close to the top structure due to the down-dip nature of the structure.

**Conclusion**
Given the uncertainties surrounding the depth of target reservoir in this field and the dip variations, geosteering should be included in the planning for both landing and drain sections. The geosteering of 3 wells in Njaba field has substantiated some assumptions and thrown up some new realizations. Some of the realizations are:

1. Due to the vertical uncertainty in seismic depths, consideration should be given when landing the well to ensure the trajectory is placed at the optimum horizon and with the planned hole inclination. Soft-landing approach is recommended to cover for formations coming shallower or deeper than expected.
2. The stratigraphic attributes seen in the wells drilled in same block exhibited lateral continuity. A 1D layer-cake RNS model was used in all five wells (2 offset and 3 actual) for both pre-well modelling and real-time geosteering.
3. The top of the reservoir is heterogeneous with some high gamma ray values and planning for drain sections should expect to see this feature in the first 10-12ft true stratigraphic thickness into the reservoir.
4. Before the end of every landing section, some factors (GOC, OWC, expected thickness of heterogeneous layer in top of target reservoir, upper and lower TVD hardlines from fluid contacts and expected structural attitude of target reservoir) should be clearly defined to determine the geosteering window for the drain section.
5. The top structure map has some undulations and high-angled features are not unexpected. This becomes more important near the fault line.

*Fig 8*
Acknowledgement
For the permission to write this paper, the authors will like to thank Baker Hughes, a GE company and Addax Petroleum Development Nigeria Ltd. Profound thanks to all other reviewers that contributed in various way to improve the quality of the paper.

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