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The Geology and Use of Geosteering in Deepwater Turbidites of Z-Field, Niger Delta.

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ABSTRACT

The Z-Field in the Niger Delta harbors a labyrinthine deepwater turbidite system brimming with untapped hydrocarbon potential. Complex stacking of reservoirs, shifting lithofacies, variable sand thickness, and pervasive fault networks all conspire to make well placement a formidable puzzle. This research sets out to unravel those challenges by marrying detailed geological analysis with cutting-edge geosteering. Through seismic interpretation, real-time LWD data, and three-dimensional stratigraphic modeling, we track the wellbore's path within target zones, ensuring optimal reservoir contact. Porosity, permeability, fluid saturation, and depositional architecture are examined to sharpen our understanding of the turbidite environment. Continuous monitoring of drilling parameters and formation evaluation informs dynamic updates to the geological model, honing drilling decisions on the fly. The insights gained promise to refine field-development strategies and bolster recovery rates, offering a roadmap for more efficient, profitable exploration and production in the Z-Field.

Keywords: Deepwater, Turbidities, Niger Delta, Geosteering, Logging-while-drilling, Z-field.

Introduction

Z-field is situated in eastern offshore Niger Delta (**Fig.1**). The Niger Delta basin is situated at the southern end of Nigeria bordering the Atlantic Ocean. From the Eocene to the present, the delta has prograded southwestward, forming depobelts that represent the most active portion of the delta at each stage of its development (Doust and Omatsola, 1990; Tuttle et al., 1999). It is also known that the Niger Delta Province contains only one identified petroleum system (Kulke, 1995; Ekweozor and Daukoru, 1994; Tuttle et al., 1999), that is also referred to as the Tertiary Niger Delta (Akata – Agbada) Petroleum System (Magoon and Dow, 1994). The tectonic framework of the continental margin along the West Coast of equatorial Africa is controlled by Cretaceous fracture zones expressed as trenches and ridges in the deep Atlantic. The fracture zone ridges subdivide the margin into individual basins, and, in Nigeria, form the boundary faults of the Cretaceous Benue-Abakaliki trough, which cuts far into the West African shield. The trough represents a failed arm of a rift triple junction associated with the opening of the South Atlantic. In this region, rifting started in the Late Jurassic and persisted into the Middle Cretaceous (Lehner and De Ruiter, 1977). In the Niger Delta region, rifting diminished altogether in the Late Cretaceous. After rifting ceased, gravity tectonics became the primary deformational process. Further evolution of the delta is controlled by pre- and synsedimentary tectonics (Omatsola, 1987). Continual progradation, tectonics, and the hydrodynamic conditions generated jointly by waves and tides actions in the Niger Delta develop complex stacked reservoirs. The numerous inland rivers running to the ocean created channel fairways. The channels created fluvio-deltaic or turbiditic reservoirs depending on the prevailing interplay between rates of accommodation and sediment supply. Deepwater turbidite systems in the Niger Delta have become increasingly important targets for hydrocarbon exploration and production.

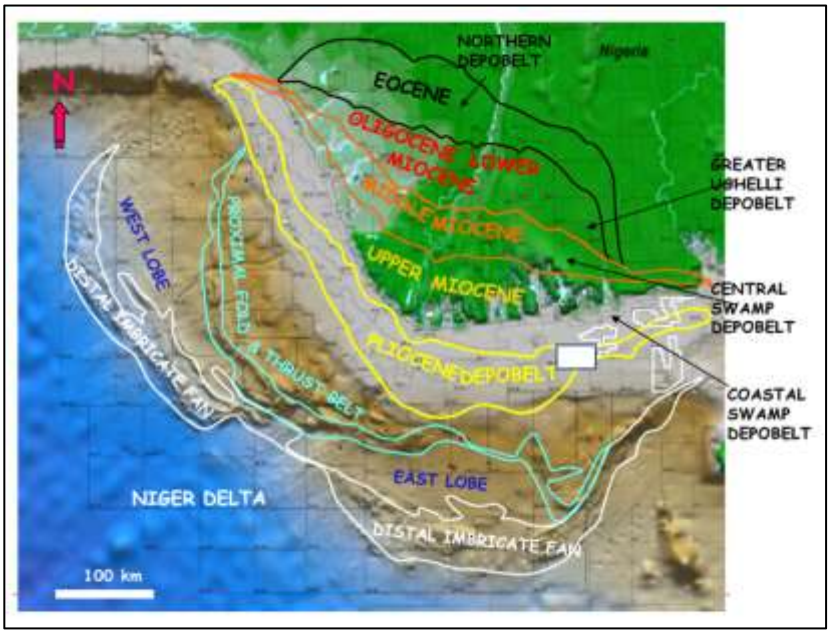

Fig.1: Location map of the study area (white inset is actual location of Z-Field)

Geological Setting

Interpreting the depositional environment of reservoir rocks help to answer a lot of questions on depositional processes, primary and secondary reservoir rock properties. The depositional environment largely controls the depositional process, while the process determines the texture, and by extension the porosity and permeability of the deposits. Understanding the depositional environment can also give insight to the distribution of poro-perm and the shapes of reservoir bodies. The Niger Delta Basin is characterized by a thick sequence of deltaic and deepwater sediments deposited since the Late Cretaceous. The Z-Field lies within the distal portion of the delta, where gravity-driven turbidite flows have deposited a series of channelized and lobate sand bodies (**Fig.2**). These deposits are interbedded with shales, resulting in a highly heterogeneous reservoir. Structural complexity is introduced by growth faulting and diapirism, which influence sediment distribution and reservoir continuity. Structurally, Z-Field lies in the compressional tectonic zone of the delta and comprises several distinct accumulations deposited during the Middle to Late Miocene. Specifically, it is in the translational zone of the deep offshore Niger Delta, where the reservoir comprises of series of channels, and turbidite lobes which are channelized in some areas.

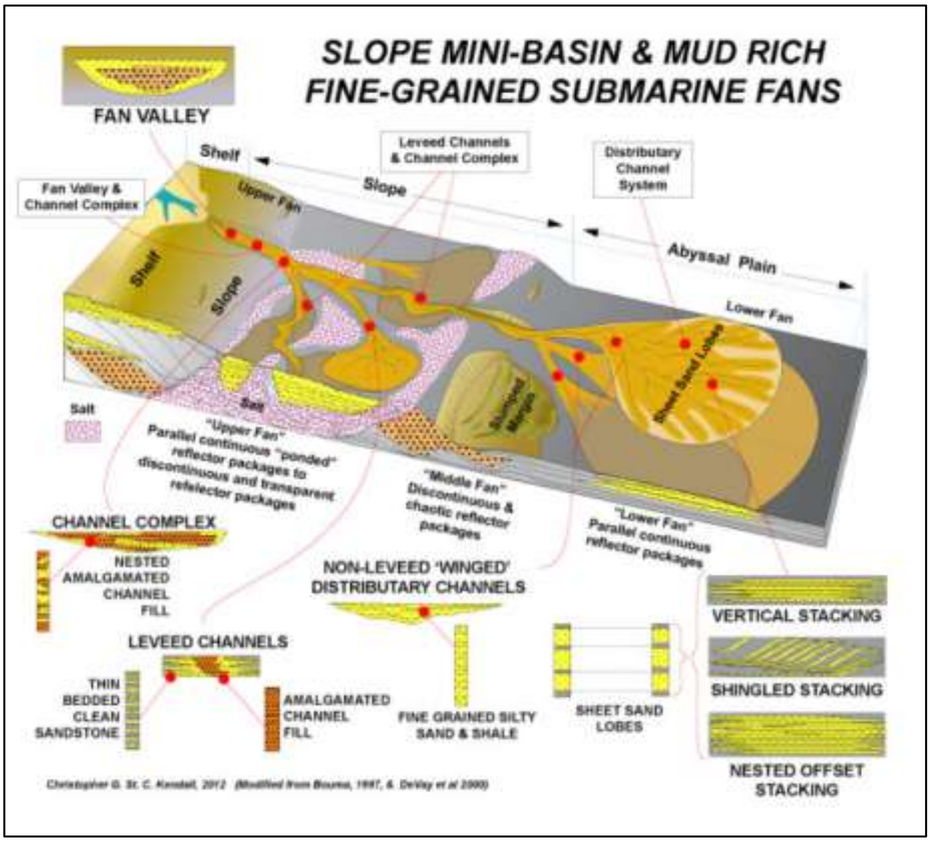

Fig.2:Turbidite geomorphology, architectural elements, and facies associations (Romans & Kendall, 2012)

Methodology

The Z-Field presents unique geological challenges due to its complex depositional architecture and structural setting. Geosteering, the process of adjusting well trajectory in real-time based on geological data, has emerged as a critical tool for navigating these reservoirs. Our approach integrates seismic interpretation, petrophysical analysis, and real-time drilling data (**Fig.3**). Seismic data interpretation and correlation of lithostratigraphic logs were used to delineate reservoir geometry and identify potential drilling hazards. LWD tools provided continuous measurements of gamma ray, resistivity, porosity, bulk density and formation dip, which were used for petrophysical analysis and interpreted in real-time to guide well trajectory. Stratigraphic models were updated dynamically to reflect new data, enabling proactive decision-making during drilling.

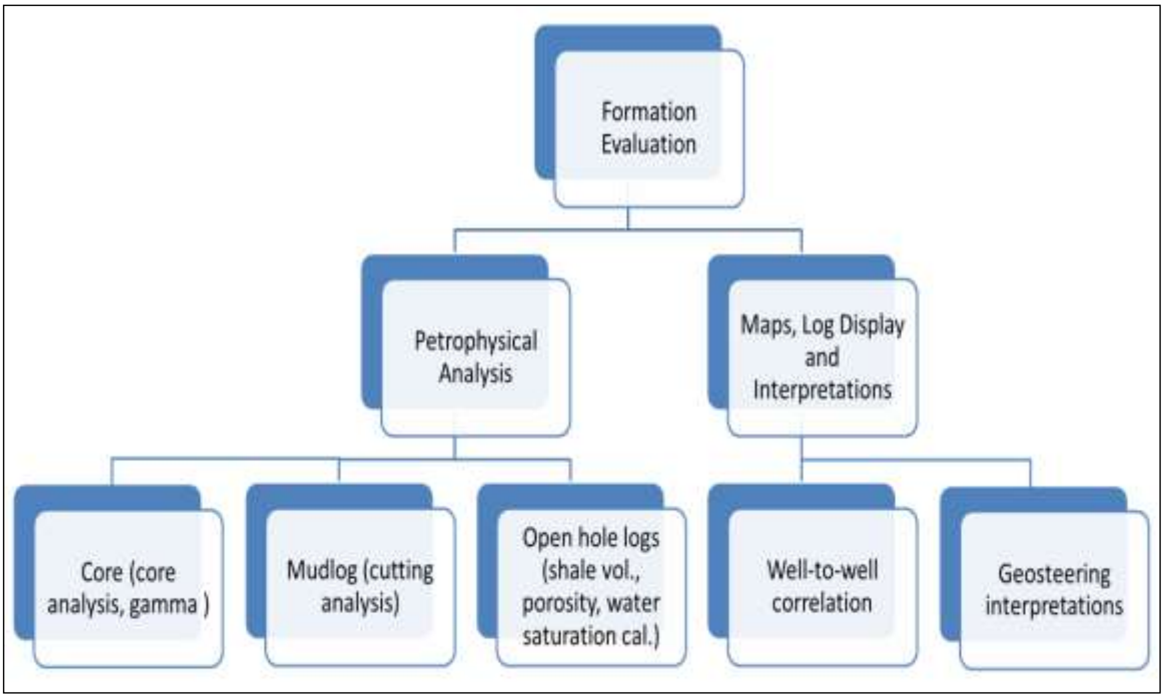

Fig.3: Schematic showing available data and method of the study

Results

Two horizontal wells drilled in the Z-Field are presented as case studies. In the first well (**Fig.4**), results from the inversion of azimuthal resistivity data showed that the wellbore initially crossed a sequence of small, isolated sand bodies with a markedly lenticular shape, bound by thick shale. This was interpreted as channel fills within a sedimentary environment dominated by shale deposition. As drilling progressed, the sand bodies increased in thickness and lateral continuity, whilst the shale intervals rapidly became thinner partitions within a massive sand-dominated body, consisting of amalgamated sand turbidites. The subsurface architecture deduced from an integration of seismic reservoir characterization, dynamic reservoir model simulation, and azimuthal resistivity modeling was consistent with a progradational turbidite system. At total depth, 390m along hole depth of net sand exposure, 213% of min case, 144% of base case, 96% of max case was achieved.

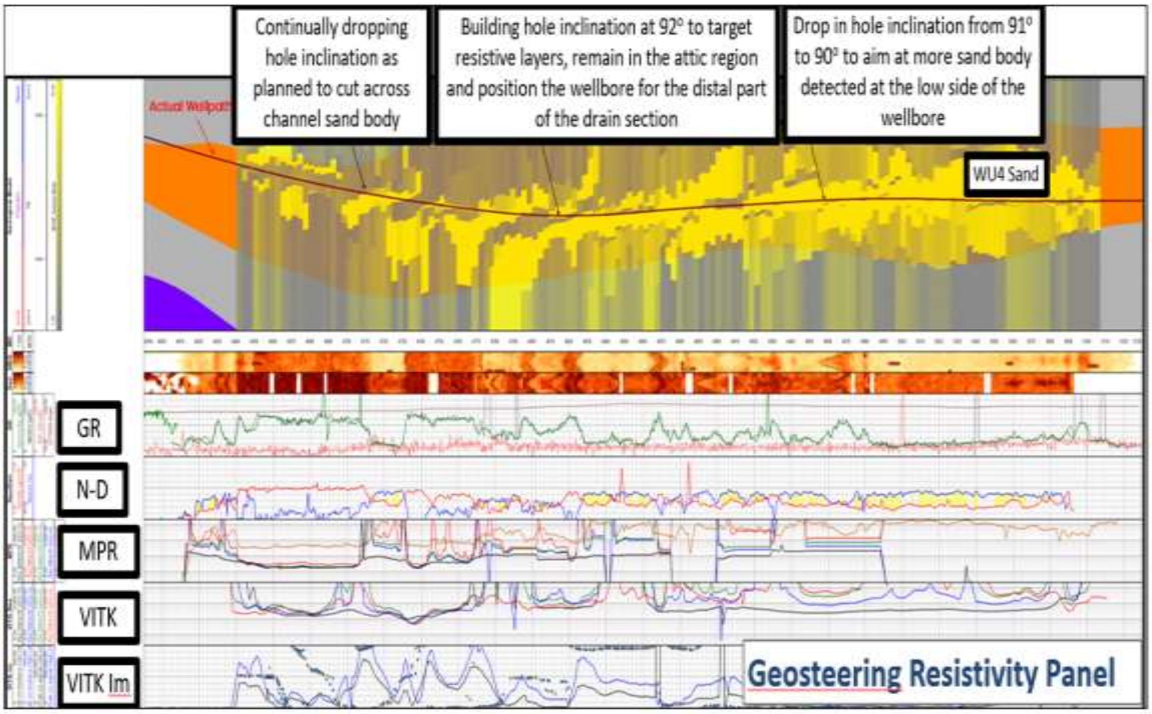

Fig.4: Navigation screen showing geosteering interpretation (Sudiro P. et. al., 2023)

In the second well, seismic events represented a complex heterogeneous architecture of turbidite channels, lobe sands and interbedded shale layers. Also interpreted are laterally offset seismic amplitude packages arising from the amalgamated channel systems. The stratigraphic and structural heterogeneities are manifested in the form of lateral discontinuity of sand bodies, lateral variations in sand thickness, multiple beds, and facies changes, and a dense fault network (**Fig.5**). 1717 m of lateral section was achieved in 55.7 hours, at an average ROP of 30.8m/hr, and drilled in one drilling run. The geosteering achievements included 850m, 221m, 115m of net sands in the different channels, and exceeded the base case expectation by 232%, 630% and 575% respectively.

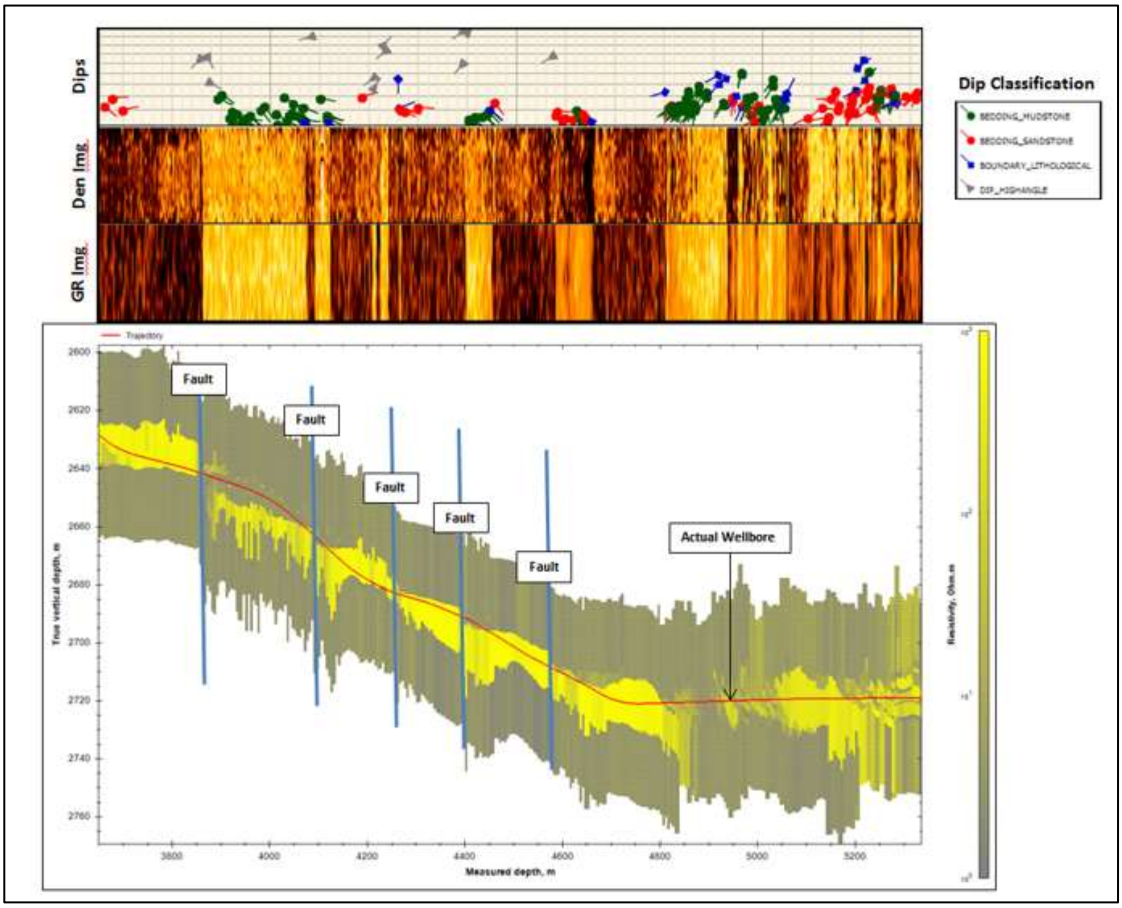

Fig.5: A diagram showing juxtaposed geosteering and borehole image interpretation (Olagundoye O. et. al., 2023)

Discussion

The application of geosteering in the Z-Field resulted in improved reservoir penetration and enhanced production performance. Key success factors included understanding the geology, the integration of multidisciplinary data, the use of predictive modeling tools, and effective communication among team members. Field studies revealed a fining-upward common turbidite sequence, complex internal heterogeneous architecture, with deformation and sub-seismic faults. Main sand intervals average 23% porosity and 26% clay. Relatively clean sand bodies reading about 40–60 gamma ray API exhibit 100–150mD permeability, whereas shaly intervals show less than 5mD permeability and read about 80 gamma ray API or more. Real-time LWD data recalibrated seismic facies models, pinpointing the exact locations of structural discontinuities, and the resistivity map helped to redefine the subsurface reservoir architectural interpretation. Challenges encountered included data quality issues and the need for rapid interpretation under time constraints. Lessons learned from these operations inform best practices for future geosteering projects in similar geological settings.

Conclusion

The Z-Field, located in the distal deepwater portion of the Niger Delta, presents a geologically complex environment characterized by turbidite channel-lobe systems, interbedded shales, and structural deformation due to growth faulting and diapirism. The integration of geosteering techniques, real-time LWD data, and seismic-petrophysical modeling has proven highly effective in navigating this complexity.

The key findings include:

1. Reservoir Architecture: The field comprises stacked, laterally variable turbidite sands with heterogeneous porosity and permeability distributions. Clean sands exhibit favorable reservoir qualities (23% porosity, 100–150 mD permeability), while shaly intervals are tight (<5 mD).
2. Reservoir Modeling: Real-time resistivity and gamma ray data enabled recalibration of seismic facies models, improving the understanding of subsurface architecture and guiding well trajectory decisions.
3. Geosteering Success: Horizontal wells achieved significant net sand exposure, exceeding base case expectations by up to 630%, demonstrating the value of real-time data integration and dynamic model updates.
4. Operational Efficiency: High rates of penetration (e.g., 30.8 m/hr) and long lateral sections (up to 1717 m) were achieved in single drilling runs, indicating optimized well placement and reduced non-productive time.

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