Implications of Integrated Sequence Stratigraphy, Geological Models and Formation Pressure Regime Understanding on De-Risking Shelf Edge to Slope Prospects in the Cenozoic Niger Delta

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ABSTRACT

Deeply buried deltaic to shelf edge/slope deposits in the Niger Delta have common exploration risks, principal amongst them being reservoir presence/quality and overpressure development. There is a strong observed relationship between these two factors (reservoir presence or interval net-to-gross and overpressure development/magnitude) that has been documented. It follows that there should be some level of inter-dependency in the de-risking techniques and concepts for such deeply buried shelf edge to slope deposits in the Cenozoic Niger Delta.
The combination of the seismic velocity data and geological model show consistent velocity reversals in shelf edge/slope systems particularly in a distinct relationship with the interval net- to-gross. Measured pressure kicks in studied wells occurred in outer shelf to shelf margin sediments with relatively low interval net-to-gross. Some deep leads are most likely very low net- to-gross sequences with substantial reservoir presence risk.

Keywords: Gross Depositional Environment, Coastal Swamp Depobelt, Overpressure.

INTRODUCTION

Proper understanding of regional relative sea level falls (at different geological ages/stages) is vital to sand re-distribution to the distal shelf edge/ slope systems. While these Rapid Relative Sea Level (RRSL) drops may provide sand input into the deeper sequences (for example in Kolo Creek and Gbaran areas), the equivalent erosive proximal events may not always be sand-prone as seen in the clay-filled ~10.6my relative sea level drop in the Southern block area of a field in the Coastal Swamp, Niger Delta (Adesida et al., 2022; Gradstein *et al.,* 2020).

An integrated effort of seismo-sequence stratigraphy, geological model concepts/framework and over pressure trend development analyses has proved very effective (in tested areas) and promising (in yet to be tested areas) for prospect evaluation. It reinforces the established framework for reservoir presence/quality prediction and reservoir chance factor assessment, strengthening the relationship between the gross depositional environments (GDEs) and formation pressure distribution in these areas.

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METHODOLOGY

Seismo-sequence stratigraphic analysis (using seismic facies, petrophysical well logs, core and biostratigraphic data) was carried out with data from 19 wells penetrating Tortonian 1,Serravalian 2 and Langhian 1 maximum flooding surfaces (MFS) coupled with reprocessed Pre-Stack Depth Migrated (PSDM) seismic data. A systematic integration of the seismo-sequence stratigraphic analysis, regional isopach maps, sand supply/distribution trend analysis, attribute extractions based on calibrated rock properties and acoustic responses were used to generate specific geo-feature highlighting volumes (Figures 1&2). This study went further to calibrate the seismic-based pressure regime with a forensic analysis of overpressured well data (with kicks) from the 1960s to 2000 providing the basis for extrapolation away from existing wells.

RESULTS AND DISCUSSION

In the Southern block, the dominant control on deposition in the basin is growth faulting where significant growth exists on the hanging wall of major faults in the field (Figure 1). The growth index on the interpreted major faults in the various fields point to a major control on sand deposition. Leads within the inner-mid shelf GDE are commonly sand-prone, while leads in outer shelf to shelf margin are moderately sand-prone. The equivalent stratigraphic objective sections of most leads have been tested/penetrated in adjacent blocks within the Southern

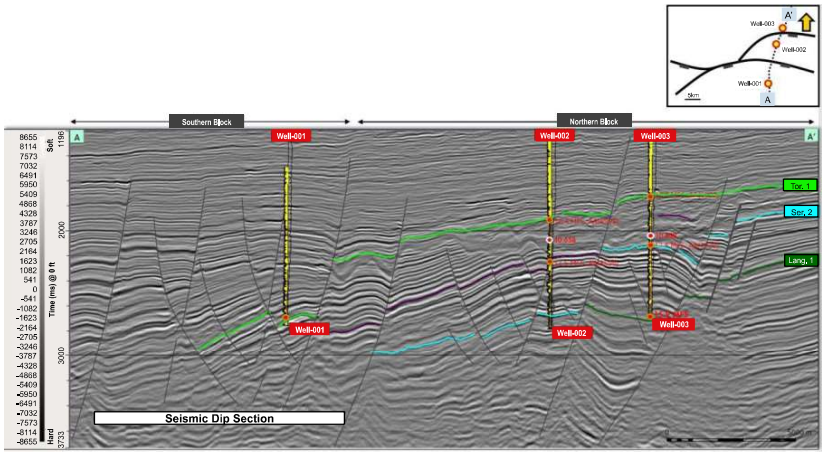

Figure 1: Seismic dip sections through wells with key stratigraphic markers (Langhian 1 to Tortonian 1 maximum flooding surfaces).

block area. Some seemingly prospective deep leads (~below 3s TWT) are most likely very low net-to-gross sequences with substantial reservoir presence risk (Figure 3).

The combination of the seismic velocity data and geological model show consistent velocity reversals in shelf edge/slope systems particularly in a distinct

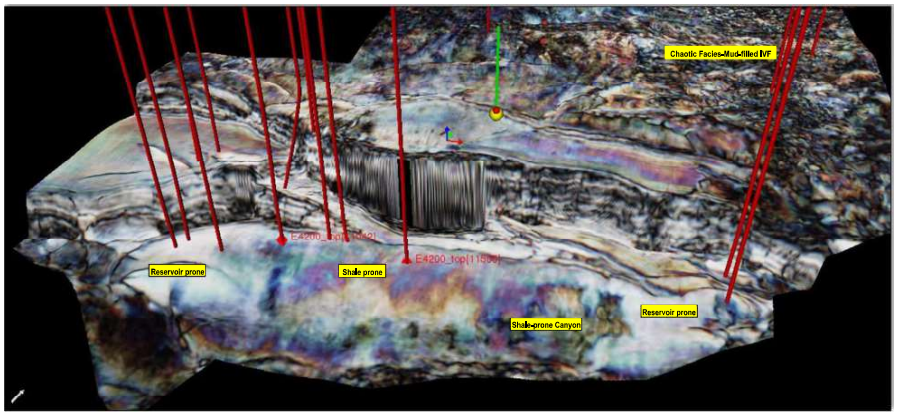

Figure 2: 3D View of the Stratigraphic Attribute Near Tortonian 1. Bright smooth colours signify probable reservoir/sand-prone facies. Dark colours signify probable reservoir-lean facies. Chaotic facies are within the incised valley fills/canyons.

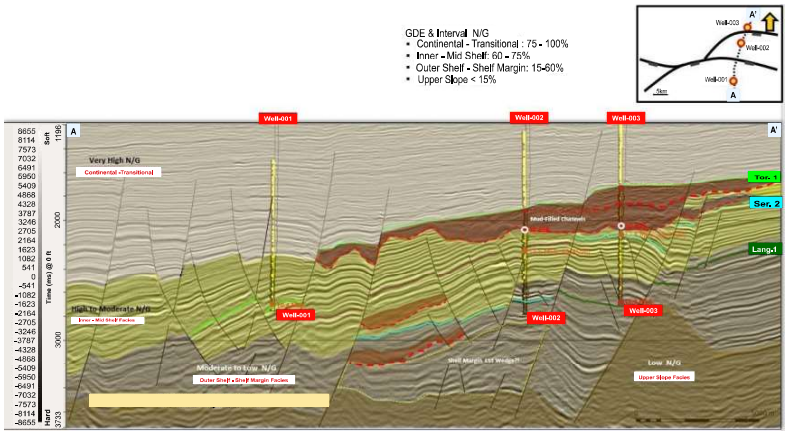

Figure 3: Seismic dip sections through wells with key stratigraphic markers (Langhian-1 to Tortonian-1 maximum flooding surfaces).

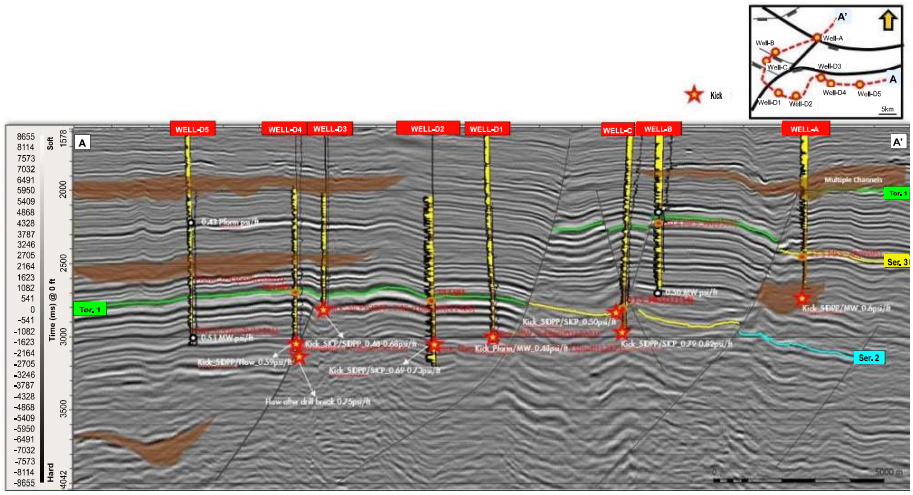

Figure 4: Seismic section through wells with key pressure data (Note: SIDPP is Shut-In Drill Pipe Pressure; SICP – Shut In Casing Pressure; MW – Mud Weight; Pform – Formation Pressure).

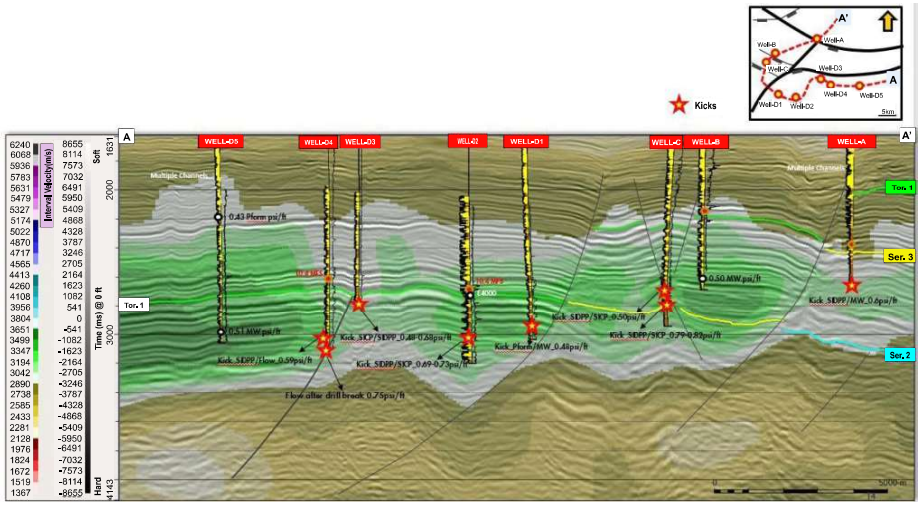

Figure 5: Seismic section through key wells. Seismic interval velocity, pressure and kicks data superimposed show that kicks occurred in stratigraphic sections having velocity reversals.

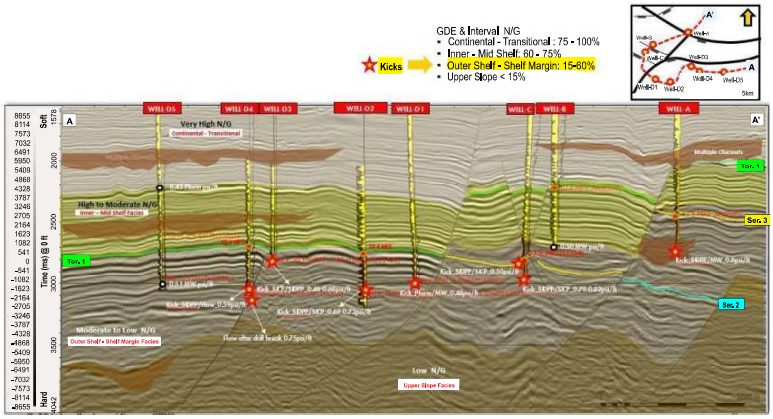

Figure 6: Seismic section through key wells. Superimposed pressure data, kicks data and GDE show that kicks occurred in outer shelf-shelf margin GDE characterized with velocity reversals highlighted in Figure 5.

relationship with the interval net- to-gross. Measured pressure kicks in studied wells occurred in outer shelf to shelf margin sediments with relatively low interval net-to-gross (Figures 3-6). While reservoir presence is indeed a risk in such deep intervals with relatively low net-to-gross, the notion that such intervals contain shales with high overpressure and, therefore, high fracture pressure, would still allow for significant hydrocarbon sealing capacity.

CONCLUSIONS / BUSINESS IMPACT

This work has significantly contributed to the understanding of the prospectivity and associated subsurface risks in deeply buried deltaic sequences to shelf edge/slope deposits in the onshore Niger Delta. It helped in the polarization of the exploration portfolio into low risk, medium-high NTG conventional opportunities and high risk, medium-low net-to-gross deep high-pressure opportunities. It also brought clarity on impact of depositional environments on formation pressure build-up and associated kicks (especially in reservoir-lean outer shelf to slope facies). It is the bedrock of the ongoing opportunity realization projects (prospect maturation through well delivery) to backfill vital gas resources needed to support domestic and export gas supply obligations.

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