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Overcoming Pressure Limitations in Niger Delta Basin: "Digging Deep into New Frontier on Block-X"

Michael Chukwuma[1]* Christine Brunel[2], Tristan Cornu[2] and Guillaume Carre[2]

[1]*Geopressure Responsible, Total Upstream Companies of Nigeria, Port-harcourt, Nigeria*
[2]*Total S.A, France*

Abstract

Deeper plays of mature acreage is part of the new frontiers for petroleum upstream companies in the Nigeria Niger Delta basin, and have helped revive the exploration interest on mature and declining block-X. The mature oil producing block-X which is located in the eastern Niger delta (65 km NW of Port-Harcourt) is currently undergoing facilities upgrade to increase gas production capacity by 50%, end flaring and achieve target level domestic market obligation.

The investment on block-X facilities not only leverages on gas caps of depleted oil fields, but will be gearing on undeveloped deep gas reserves and identified prospects in the acreage. Hence, understanding the spatial pressure distribution, pressure generation mechanism and geo-stresses acting in the deeper zone of the basin is paramount for prospecting and unlocking potential economic gas reserves in the block.

A pore-pressure study focusing on the southern part of the block (Ubeta/Ihugbogo compartment) was launched by operator with aim of constructing a deep 3D pressure cubes model using 8 existing wells and seismic velocities. Post-mortem analysis performed on the 2 deepest wells in the area (Erema West-2 and Ihugbogo East-1) with depth greater than 3800 m show deviation from the classical Eaton method of pore-pressure prediction in under-compacted shale. The observed departure from the porosity related over-pressure was found to be mainly related to burial and has varying magnitude and spatial distribution (suspected to be fault conduction and proximity degree dependent).

Pore-pressure prediction uncertainty due to this observed "unloading" phenomenon in deeper deposits (>3800 mMSL), understanding the structural plumbing network/nature, establishing a workable Normal Compaction Profile (NCP), short hard overpressure transition ramp and narrow drilling mud window are challenging the maturing and drill-ability of the deeper plays in the block-X.

Keywords: Deeper plays; Block-X; Deep gas reserves; Pressure generation mechanism; Geo-stresses; 3d pressure cubes; Erema West-2; Ihugbogo East-1; Eaton method; Pore pressure prediction; Under-compacted shale; Unloading; Normal compaction profile

Introduction

Although Nigeria is ranked the 8th global petroleum production it has not been able to make the list of 10 largest oil and gas discovery in almost a decade. According to Wood Mackenzie's recently published information on global oil and gas discoveries in 2011 only about 75% of 2011 world oil/gas consumption was replaced, leaving a 25% deficit on the world petroleum reserves.

This recurrent reserve deficit situation has challenged key industry players to keep pushing the boundaries to unlock more of this precious resource. With the high commitment and strong strategic alliance the block-X operator has with Nigeria, the company is poised to pursue new frontiers in the country to leverage on her existing assets/investments and consolidate its position as a bold partner. While the operator is currently bringing on-stream discoveries in the deep-water plays (last decade's frontier), it is also thinking ahead for the next new frontier.

Like in most fields in the conventional Niger-Delta context, the block-X production is currently on the decline and with already existing facilities and some redundant production capacity exploring deeper buried plays is the first consideration for the "next frontier".

Block-X located in the eastern Niger Delta 65 kilometers northwest of Port Harcourt is the only remaining onshore block in the operator's Joint Venture portfolio. Since 2005, significant investments have been made to upgrade the block-X facilities in order to exploit its gas reserves. This includes a major new gas pipeline which will allow LNG gas supply to increase by 50% in the near term. There are also longer-term plans to supply gas to a 440 MW power plant at nearby location.

New frontier exploration and geo-pressure study

The Niger-Delta basin is a known petroleum province with sound petroleum system, but prospecting in deeper buried plays requires more understanding of hydrocarbon trapping and spatial pressure/temperature behavior. This led to a detailed pressure study on the southern part of the block-X where majority of the deep prospects were identified [1].

The pressure study used direct measured data sourced from 8 analogue wells of which 3 were deep wells (>3800 m MSL) and seismic velocity cubes (indirect) data to understand deep pressure distribution and determine prospects potential and drill-ability.

The available data were used directly or indirectly as inputs to the classical Eaton approach to estimate pressure in shale, while the reservoir/sand pressure were deduced from WFT measurements or

***Corresponding author:** Michael Chukwuma, Geopressure Responsible, Total Upstream Companies of Nigeria, Port-harcourt, Nigeria, Tel: 2348034024119; E-mail: michaelchukwuma@hotmail.com

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estimated by relationship assumption with surrounding or nearby shale unit(s).

$$P_{sh} = OBG - \left(OBG - P_{hydro}\right) * \left(\frac{NCP}{DT}\right)^3$$ Eaton

Geo-pressure study challenges and findings

Establishing a workable Normal Compaction Profile (NCP) for shale starting from the sand prone Benin formation (high pressure drainage effect) and transferred overpressure prone deep buried units (unloading effect) retains some considerable level of uncertainty on the estimated pressures [2].

The study was able to confirm the presence of unloading effect due to transfer of deeper generated pore-pressure through vertical re-opening of faults and that leads to a short/sharp pressure transition zone and very narrow drilling mud window [3].

Unloading mechanisms covers the mechanisms that generate a decrease in the effective stress. The decrease is caused by a rise in the pore pressure, and not by a diminution of the weight of the sediment. The mechanism of the pressure rise is not only based on under-compaction.

The most classical way to identify "unloading" is the plot effective stress versus velocity:

- When the trend remains monotonic, there is only normal compaction and conventional compaction disequilibrium
- When the trend change, and that effective stress decrease with depth, it implies that an additional mechanism is at play,

To identify unloading the Plot of effective pressure versus sonic which is representative of the regional behavior of the wells, can be used (The effective pressure is defined as; OBG-MW) [4]. NB: It is mainly the trend of the relation which is important, more than the absolute value (Figure 1a and 1b).

Drill-ability of the new frontier

With the sharp pressure ramp transition zone and narrow drilling mud window characteristic the deep play prospect drill-ability will require special planning and introduction of advanced drilling services such as Managed Pressure Drilling (MPD) system combined with the classical PWD tool and proactive real-time pressure monitoring approach like the Long Connection Test (LCT). This will help optimizing casing shoe placement and efficient responds to well control incidents [5-7].

Robust well planning and team-work is needed to unlock this new frontier potential and change the game from conventional to HPHT in the Niger-Delta Basin (Figure 2).

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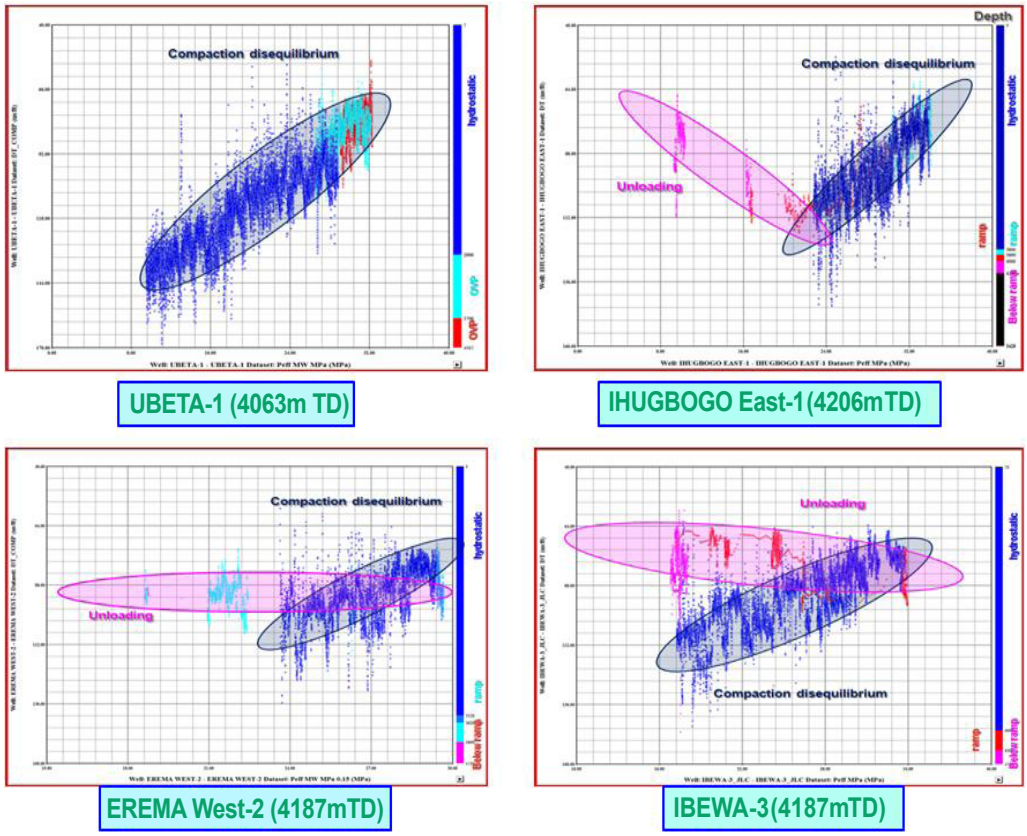

Figure 1a: Sonic (DT) versus Pseudo-Effective Stress (OBG-MW) cross-plots.

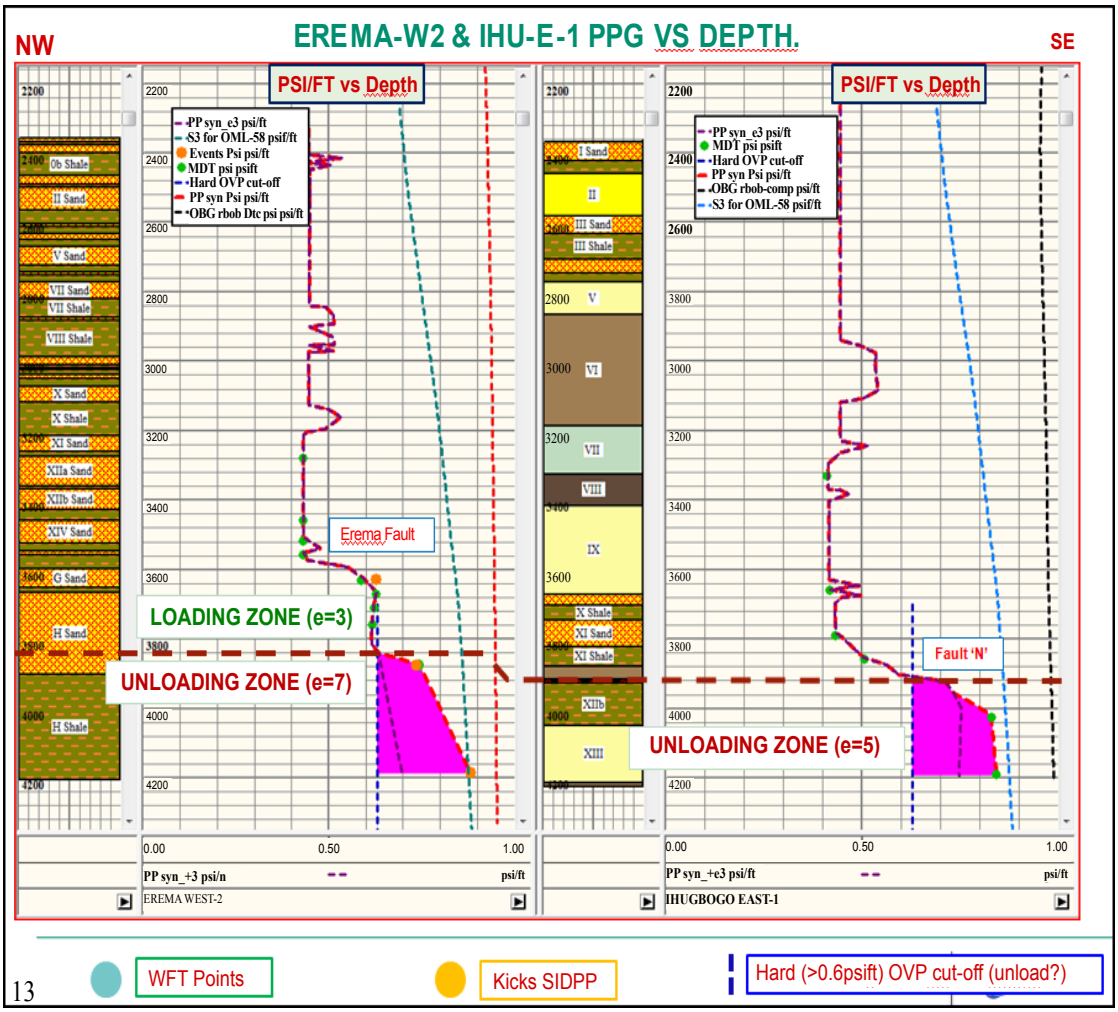

Figure 1b: Pressure versus depth plots of deep objective targeting wells in Block "X". Note the need change the Eaton's co-efficient in the hard overpressure zone.

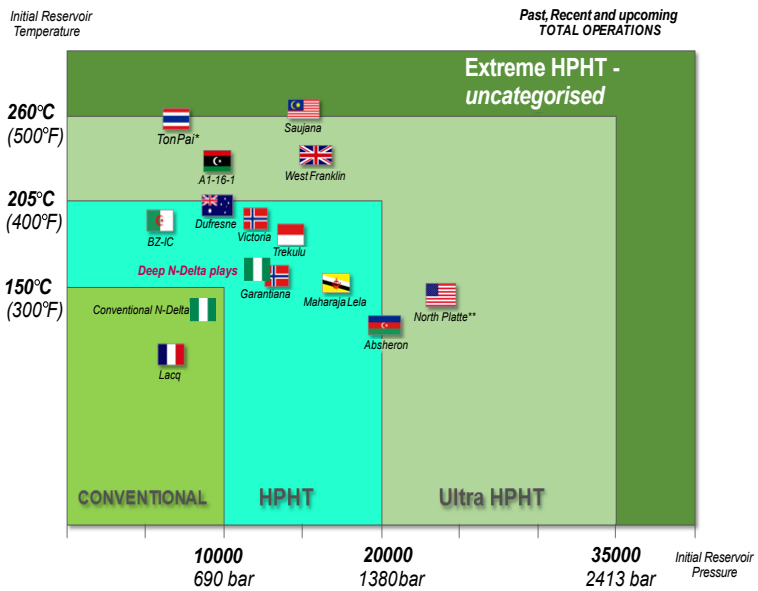

Figure 2: Classifying Pressure and Temperature regime of the new frontier.

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