Reservoir Analysis of the Vandji Formation of Berriasian-Valanginian Age in the Lower Congo Basin*

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Abstract

The Lower Congo and South Gabon basin have seen many hydrocarbon successes since the 1960's. Recently, forgotten plays in the lower rift section were revived with a huge discovery in Lower Congo basin. This paper aims to provide a comprehensive reservoir analysis on one of the lower rift plays, Vandji Formation of Berriasian-Valanginian age in Lower Congo and South Gabon basin. The Vandji Formation was deposited in the earliest stage of rift phase, primarily in the basin between eastern and Atlantic Hinge as thick high energy alluvial and fluvial clastic sediments in a lacustrine setting. This succession consists of conglomerate, fine- to coarse-grained sandstone. An analog of alluvial plain from Africa was used to better represent Vandji Gross Depositional Environment. Alluvial plain is generally 10-20km wide from basement highs and continents. The geometry of basement highs and shape of braided channel uses bouguer anomaly map as reference and consistent with wells that penetrated through braided channel facies. Rich well datasets of SEM, core data, mud logs, electrical logs, reports and bouguer anomaly map were used to constrain the boundaries of gross depositional environment map for Vandji formations. I established two models to capture the uncertainty between control points to investigate reservoir presence. Reservoir effectiveness was evaluated using porosity and permeability data to identify any correlation to the depositional environment. Vandji reservoir is perceived as poorly sorted and micropores are filled with interstitial clay such as illite filling the pore throat. Porosity depth trend for Vandji Formation shows high variability. Two trends were observed between alluvial plain and deltaic facies. I found that facies deposited in braided channel should belong to a different compaction curve. The wide range of porosity is also largely affected by diagenesis such as cementation, quartz overgrowth and clay filling. K-Phi trend shows that good permeability of more than 150 mD seems to be attributed by intragranular dissolution pores associated with feldspars and

deposited in high energy and constant movement creating void spaces. The porosity map is established underpinning isopach map between seabed-Top Vandji and most likely trend from porosity depth plot. Vandji reservoir quality is shown to have better porosity around basement highs with lower angle. Higher angle basement highs are more likely to erode and be deposited as alluvial plain.

References Cited

Brownfield, M.E., and R.R. Charpentier, 2006, Geology and Total Petroleum Systems of the West Central Coastal Province (7203), West Africa: USGS, Bulletin 2207-B, 52 p. Web Accessed January 13, 2019, https://pubs.usgs.gov/bul/2207/B/pdf/b2207b_508.pdf

Scotese, C.R., 2011, Paleogeographic and paleoclimatic Atlas: Search and Discovery Article #30192, Web Accessed January 13, 2019, http://www.searchanddiscovery.com/documents/2011/30192scotese/ndx_scotese.pdf

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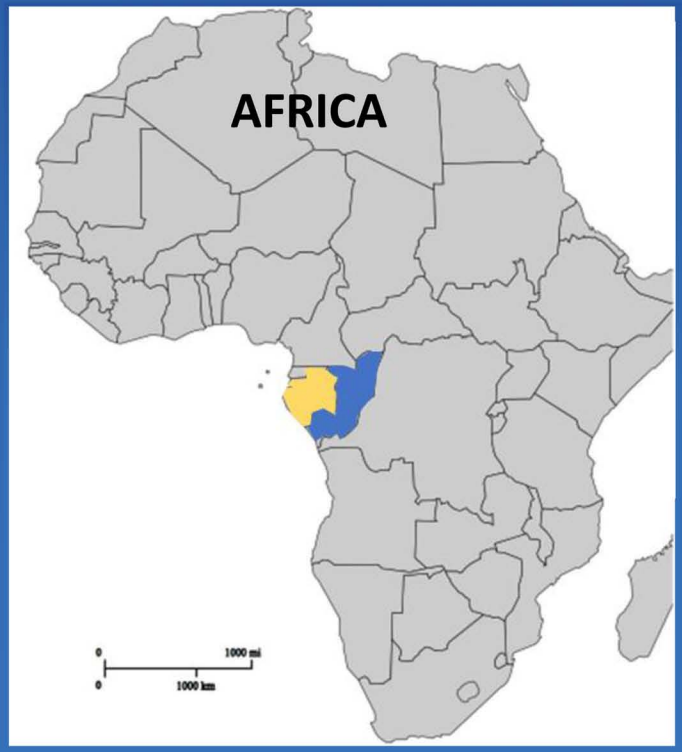
November 2018



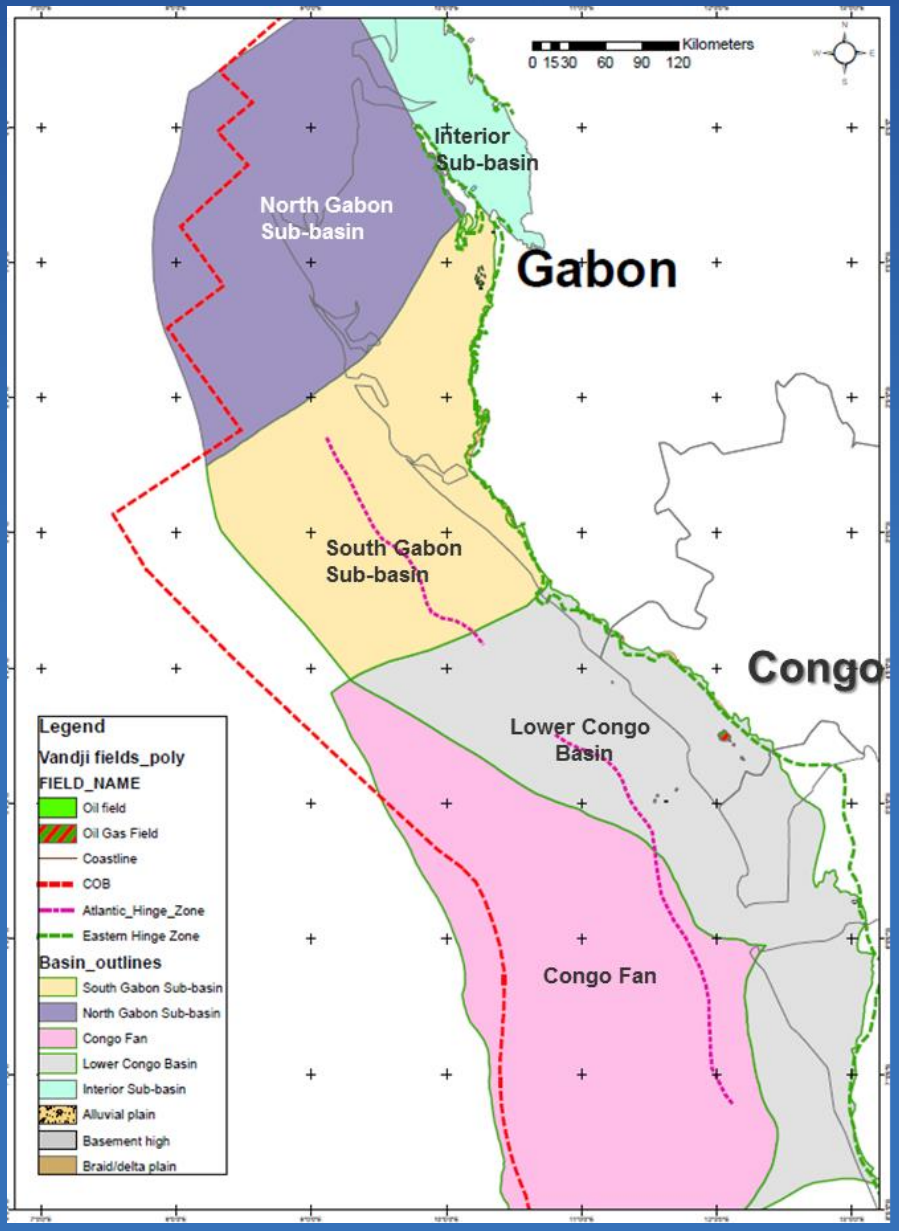
Outline

Intro: Valanginian-Berriasian Play
- Rifting History
- Play definition

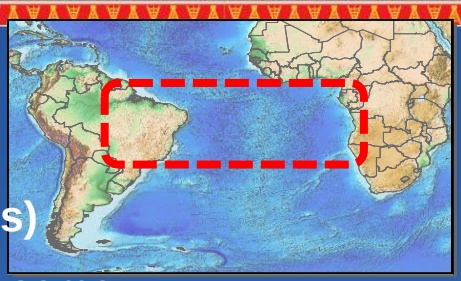
Vandji Reservoir Presence
- Workflow
- Well Correlation
- Vandji GDE map and evidences

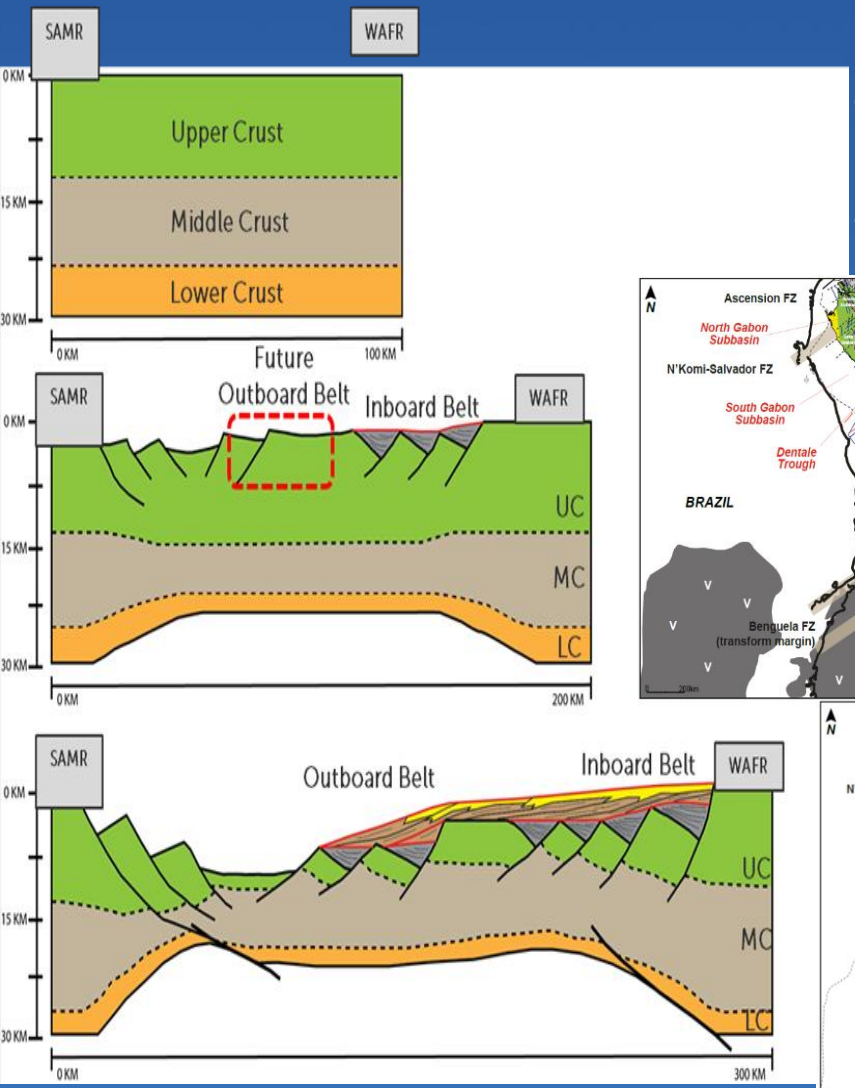
Vandji Reservoir Effectiveness
- Porosity Trend and Risks associated
- Porosity Permeability curve
- Porosity Map

Way Forward



Rifting History



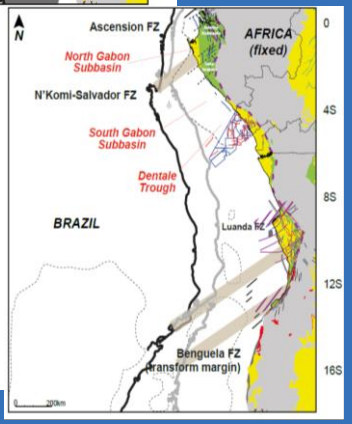


Pre Rift Phase (Pre-Cretaceous)

- Africa & Brazil still within the same position
- Non depositional phase

Early - Mid Rift Phase (Berriasian – Barremian)

- Crustal stretching within inboard basin
- Horsts and grabens created
- Deposition of early – mid rift sediments primarily within inboard area



Late Rift Phase (Pre-Cretaceous)

- Africa & Brazil still within the same position
- Non depositional phase

(Moulin et al., 2005)

Plays Identified in Gabon–Congo

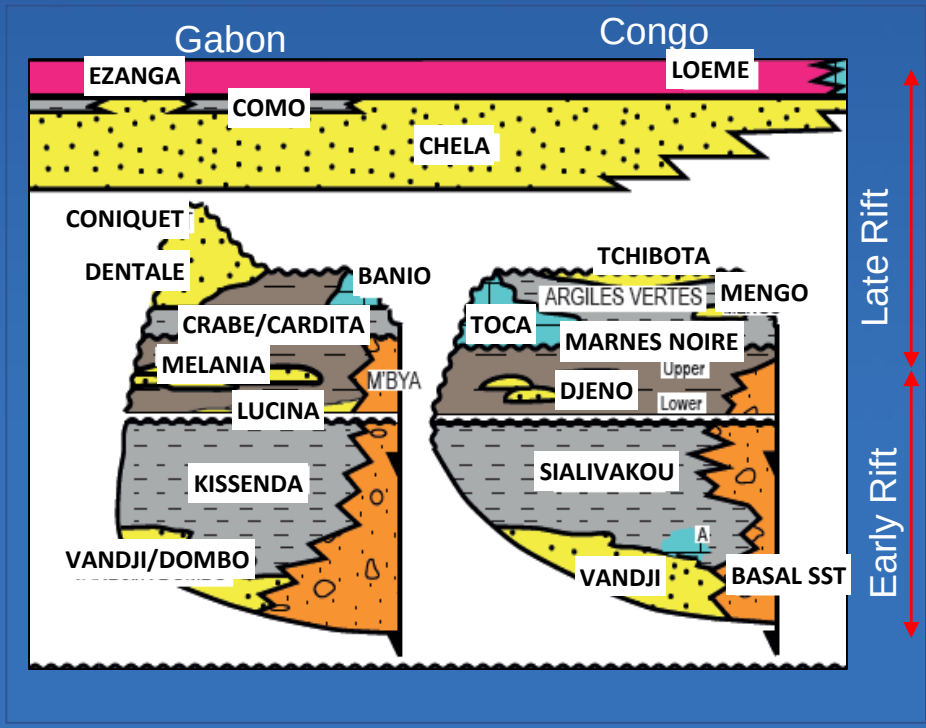
Multiple plays with proven petroleum systems in pre salt section

Current exploration focus in shallow water by major player is Djeno/Melania of Hauterivian Age

Vandji is mainly deposited in braided fluvial and alluvial plain setting.

Laterally charged and sealed by Sialivakou/Kissenda lacustrine Source Rock

Pre Salt Stratigraphic Chart



Workflow

Reservoir Presence

- Establish Formation Tops
- Well Log Correlation & Well to Seismic tie
- Depth maps through seismic interpretation
- Lithofacies using core data & cutting samples
- Integrate with fault trends, gravity data, seismic interp
- Develop GDE map and lithofacies map, display evidence

Reservoir Effectiveness

Porosity Depth Plot

Use Depth below Mudline as overburden thickness.

Normal Compaction Model

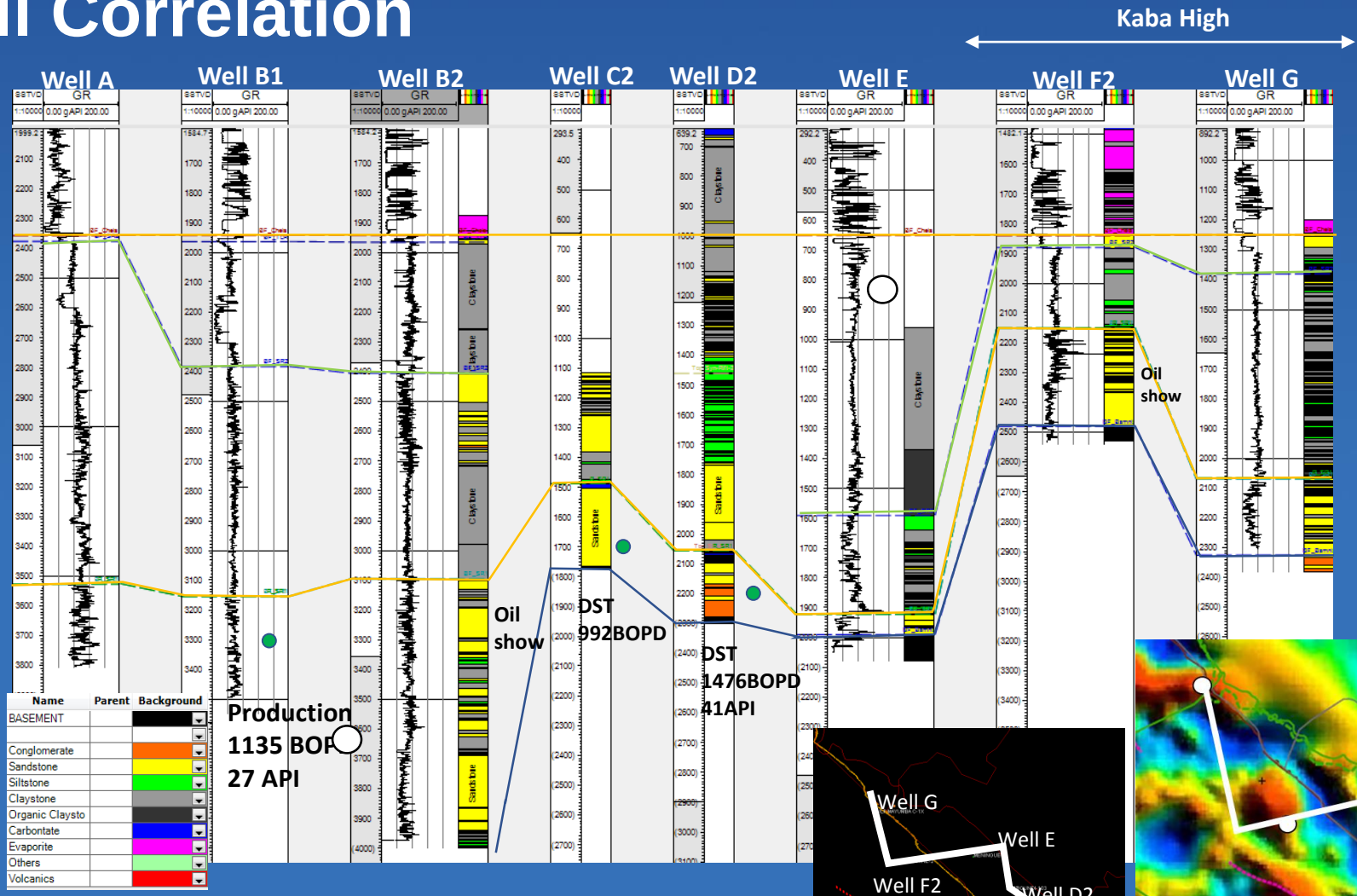
NTG, Porosity, Permeability, thin section, core data.

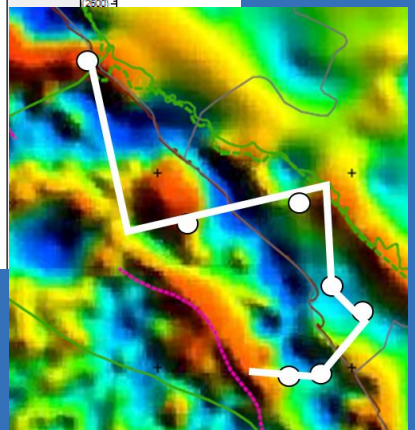
Identify other factors affecting the reservoir quality eg. cementation, diagenesis.

Porosity Map

Use overburden thickness as trend. Integrate with the equation obtained from porosity depth plot

Well Correlation

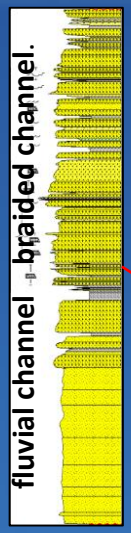


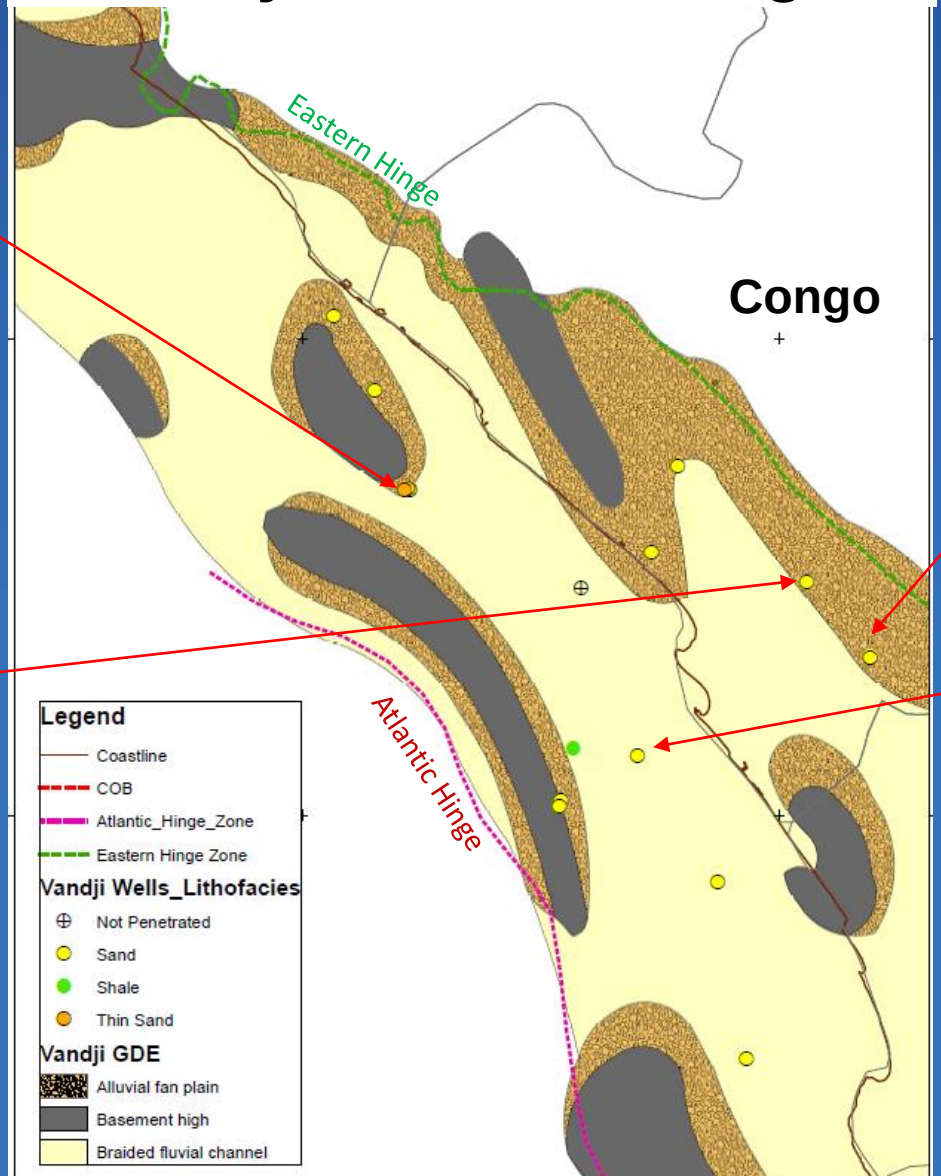


General increase in Gamma Ray within presalt, Vandji log is serrated – heterogeneous. Mostly encountered oil.
Wells located on the Kaba High encountered thin Vandji

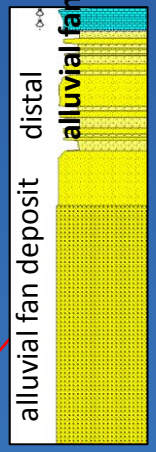
Vandji Sands in Congo

Well F2
Gross: 368m.
NTG: 80%.
Porosity: 16%.

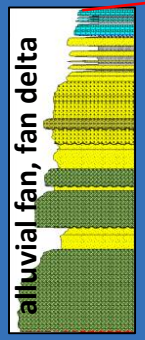




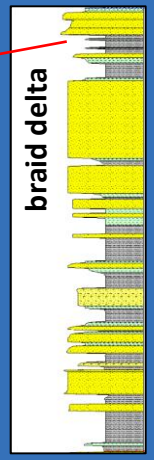
Well C2
Gross: 272m.
141m net OIL sand,
NTG: 65%.
Average Porosity 11%.



Well D2
Gross: 228m.
NTG: 70%.
Porosity: 4%.

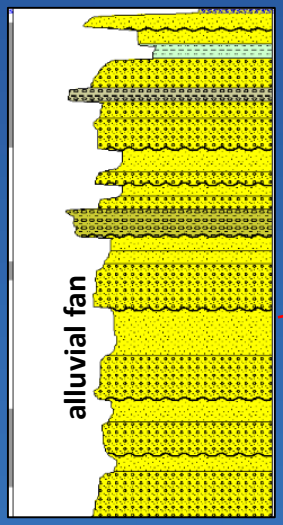


Well B2
Gross: 580m.
NTG 40%.
Porosity 16.3%.
Permeability 16.2mD.

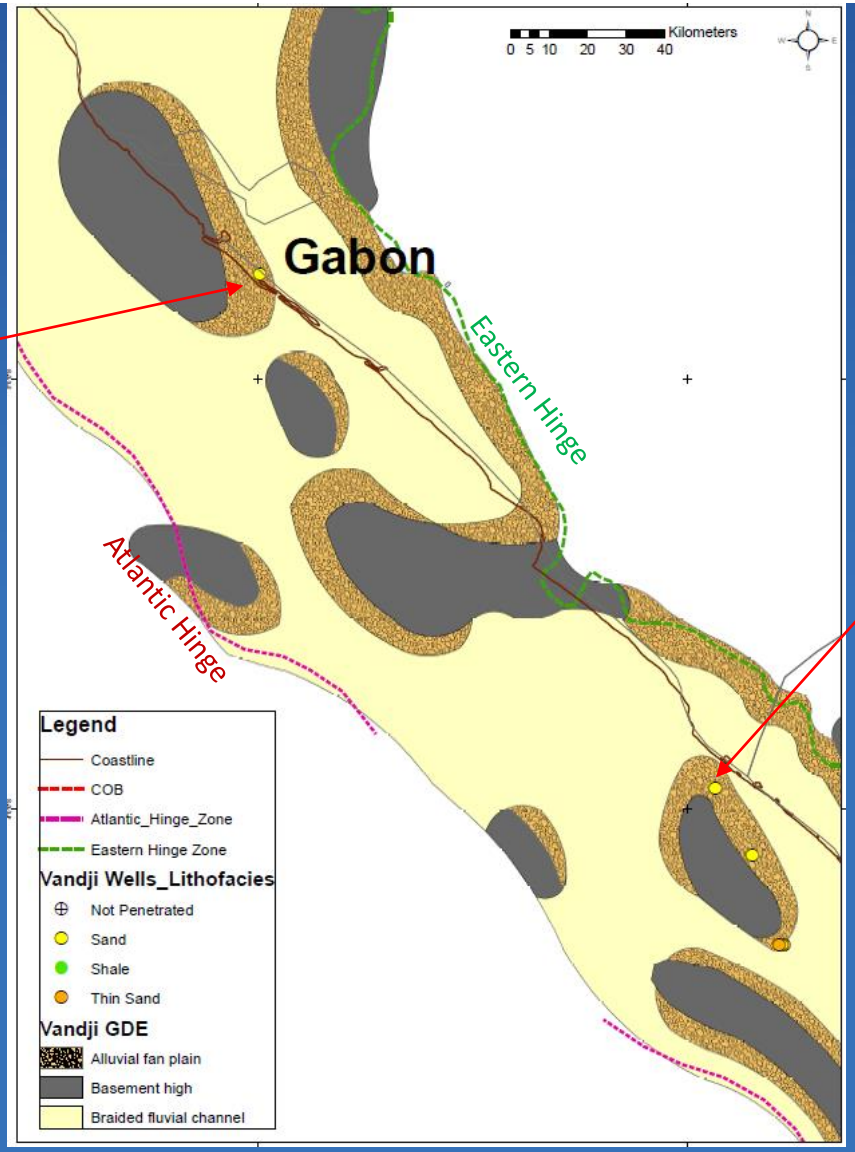


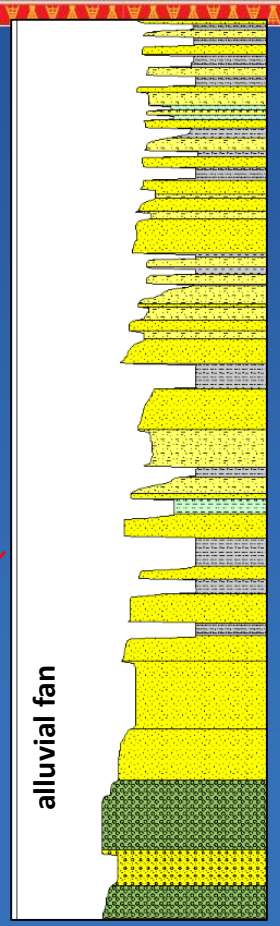
(Source of well data: Corelab)

Vandji Sands in Gabon



Lithology:
Fine to very coarse grained sandstone, pebbly sandstone. Cemented with ferroan calcite, ferroan dolomite.





Lithology:
Lower unit shows pebbly sandstone w fragments of schists siltstone and limestone. Likely to represent proximal conglomeratic rock fall deposits of lower Vandji with rework metamorphic and granite basement.

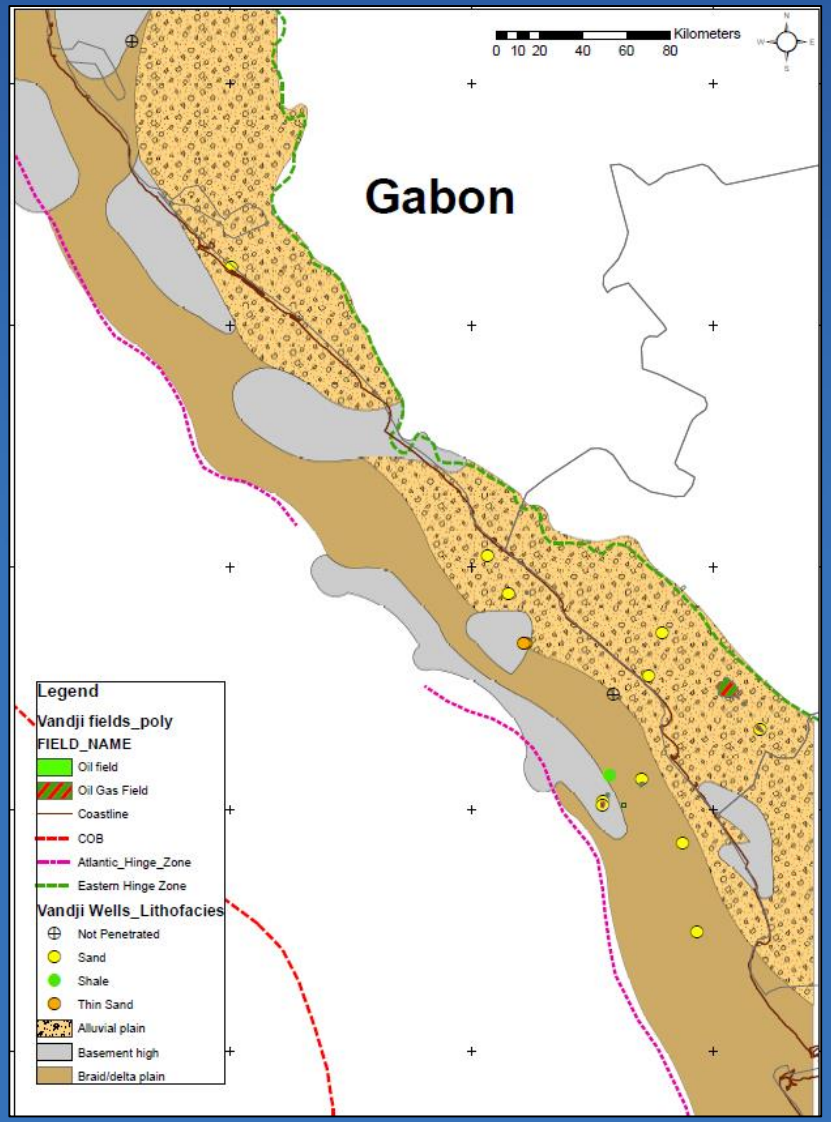
(Source of well data: Corelab)

In-house Gross Depositional Environment (GDE) at Vandji level

- Vandji GDE will be taken as the play element for Reservoir Presence
- Data used for this evaluation includes Pre-salt corelab report, well data retrieved from previous datarooms, Bouguer anomaly, basement depth map and isopach as reference.

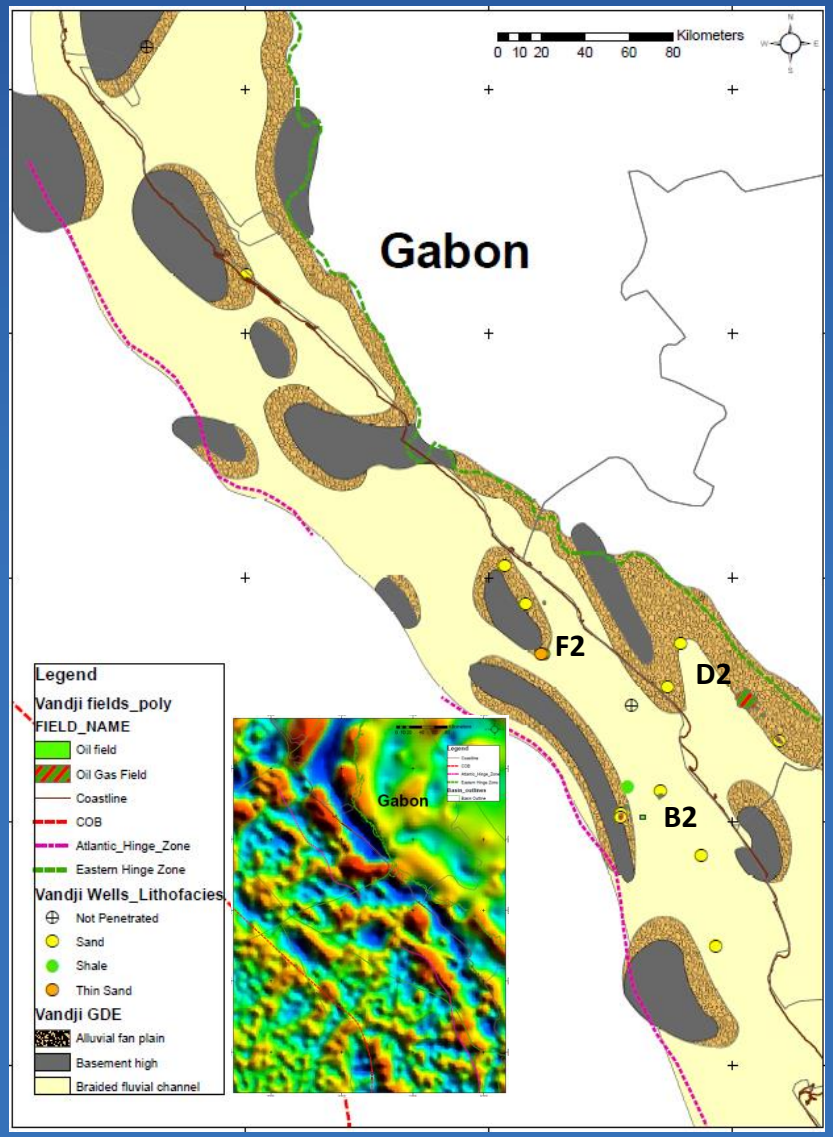
- Two models were established to capture the uncertainty in between the control points.
  - Model 1 is more general. Basement highs were included to show possible thin Vandji.
  - Model 2 considers alluvial plain analog from Africa whereby the width is generally 10-20km. Hence this model is a better representation of Vandji GDE.

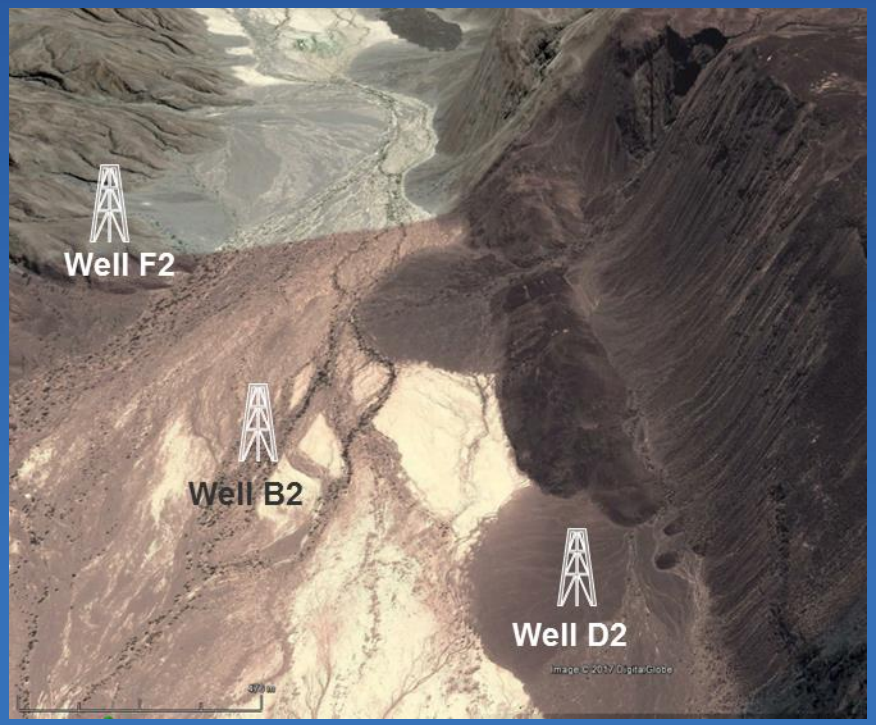
Vandji GDE map: model 1



- Corelab report and 18 well data are used as reference. Most wells are from Congo. Limited data control points, halve the inboard basin.
- Vandji is interpreted to be mainly deposited as alluvial plain starting from the eastern hinge rift shoulder. However, the width of alluvial plain shown in this model ~60km could be unrealistic.
- Going towards Atlantic hinge line, braided fluvial sands were encountered in Well F2 and B2.
- A sharp major boundary between the twos are also not realistic but rather fingering.

Vandji GDE map: model 2



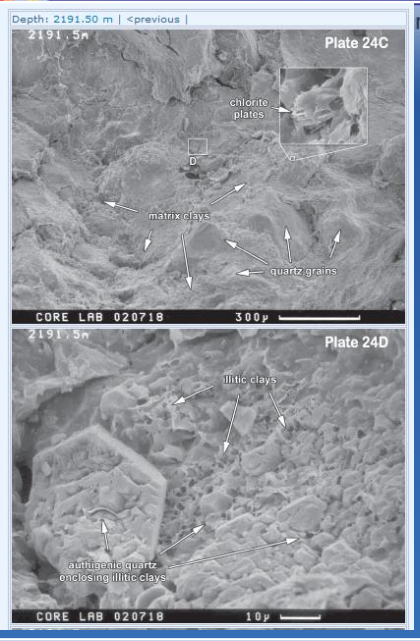


Realistic alluvial size ~10-15km from basement highs and continents.

The shape of braided channel is using gravity map low area and consistent with wells that penetrated braided channel facies.

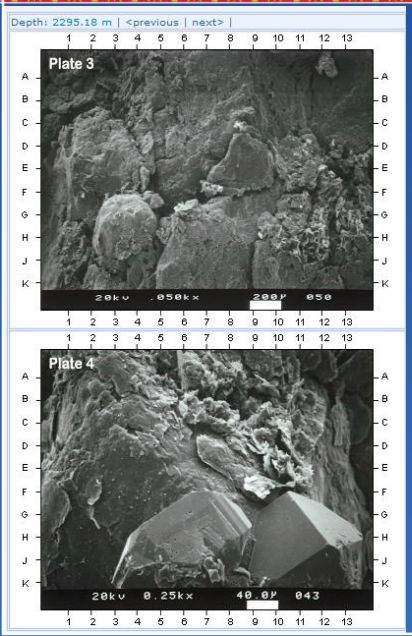
Reservoir at Vandji level is very likely to be present between Eastern hinge and Atlantic hinge as the West Africa margin started to rift apart from south America margin. Reservoir facies are predominantly alluvial fan and braided fluvial channel.

Reservoir Effectiveness



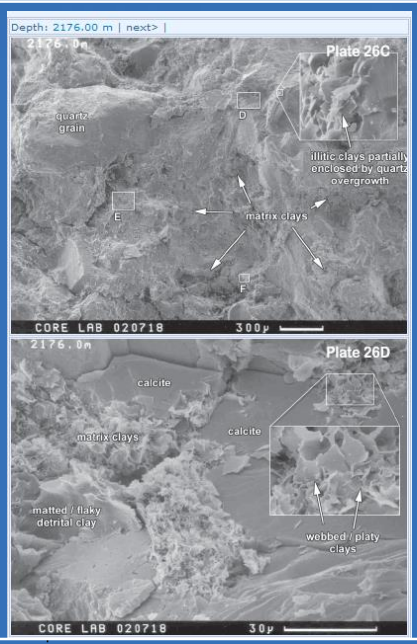
Well: D2
Porosity: 12%
Grain density: 2.61 g/cc
Depth 2191.5m

Porosity is moderately good but pores consist of microporosity with clay network.



Well: F2
Operator: Amoco
Depth: 2295.8m
Porosity: 14%
Permeability: 98mD

Abundant micropores associated w clay. Abundant intergranular pores and fractures resulting in floating grain.



Well: D2
Porosity: 5%
Permeability: 1.6mD
Grain Density: 2.61 g/cc
Depth: 2176m

Poor reservoir quality. Intergranular pore infilled by calcite cement or microporous clay

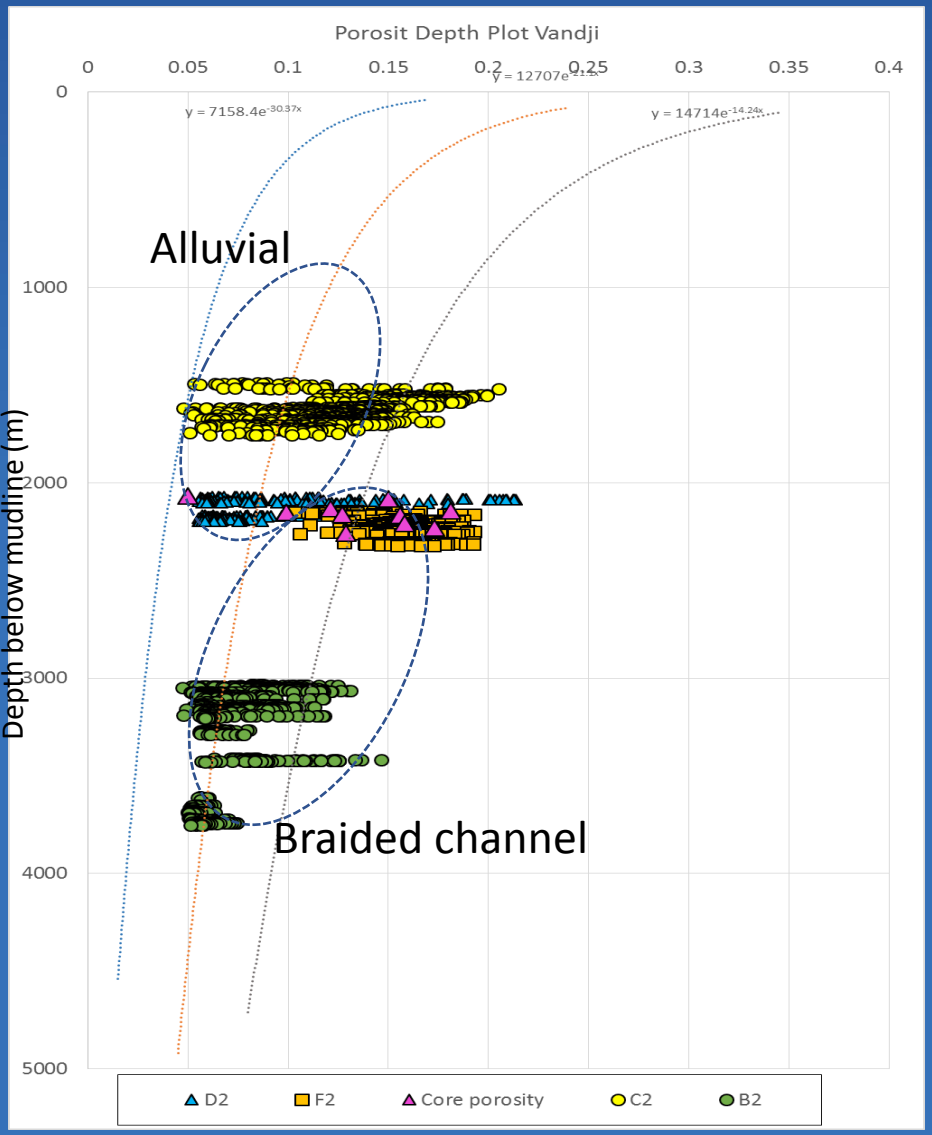
SEM Data

Wide range of porosity is observed within short interval

Eg. 2176m which is only 20m apart, due to diagenesis the porosity reduced to 5%.

(Source: Corelab)

Risk Associated with Vandji Reservoir Quality



Vandji reservoir is perceived as poorly sorted and micropores are filled with interstitial clay such as illite causing blocked pore throat.

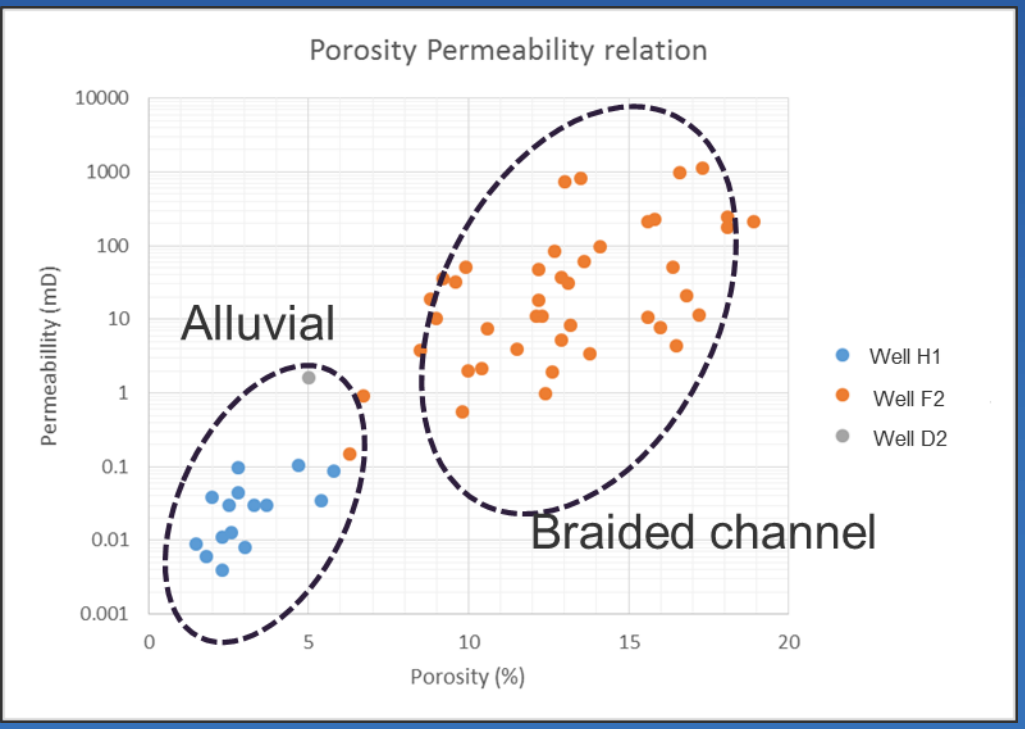
Two trends are observed in the Plot.

1. Porosity trend for alluvial plain and fan delta wells such as Well D2 and C2 is grouped in left compact quicker at average cut off depth of 1500m

2. Well F2 is deposited in braided channel setting and belongs to a different compaction curve.

This sweetspot to get good Vandji reservoir quality is targeting braided channel plain.

Porosity Permeability



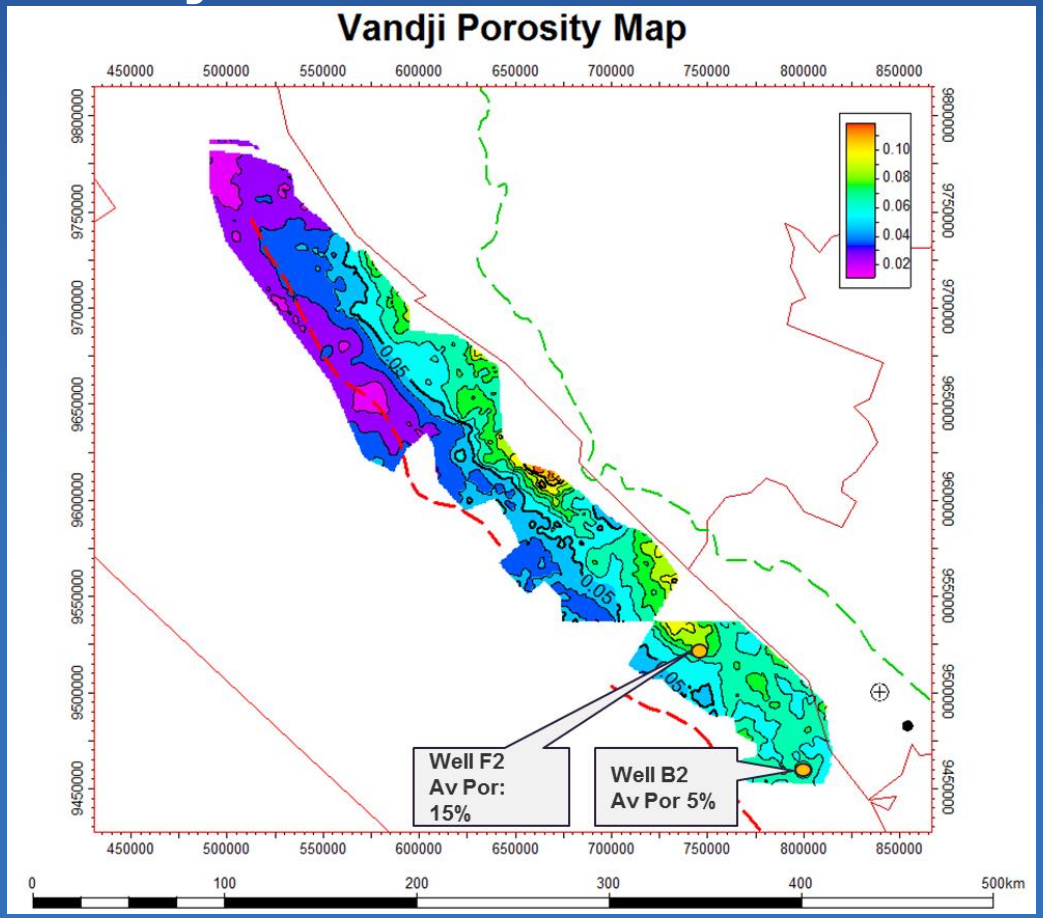
This poro-perm plot incorporates data from 3 wells.

Vandji at Well H1 and D2 are deposited in alluvial plain setting. Well F2 in braided channel setting. However, there is a wide range in permeability at Well F2 Vandji sands.

Good permeability of more than 150mD seems to be contributed by intragranular dissolution pores associated with feldspars – deposited in high energy, in constant movement creating void spaces.

At 10% porosity, Vandji sands can have 0.8-80mD of permeability.

Vandji Reservoir Effectiveness Map



Input: isopach map and Most Likely trend equation

Yellow to red area indicates optimum reservoir quality based on compaction trend.

NOTE: other factors like cementation, clay or calcite cementation and quartz overgrowth affects reservoir quality

Average Porosity of Well F2 is higher than porosity map as it falls on the maximum trend on porosity depth plot

Way Forward

- Strengthen our understanding, use more wells as control points.
- Porosity Model will be modified based on further detail petrophysicist evaluation
- Investigate the correlation between temperature with presence of qtz overgrowth
- To explore early rift play, Fraccing technology needs to be understood. Cannot explore Vandji play as single target.

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- Africa Basin Department: Mohd Redhani Abd Rahman, Azhar Yusof, Sumangal Dasgupta
- West Africa Team: Abdhes Kumar Upadhyay, Nur Qistina, Christine AK Babai

References

Brownfield, M.E., and Charpentier, R.R., Geology and Total Petroleum Systems of the West Central Coastal Province (7203), West Africa, *USGS, Bulletin 2207-B*

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