Deciphering an Unconventional African Reservoir: Geological Characterization of Granitic Basement from Bongor Basin, Chad*

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Abstract

Unconventional reservoirs of Precambrian basement in Africa are rare and poorly understood due to a number of reasons, including complex geological setting, limited technical knowledge and availability of data. Development of such reservoir requires a good understanding of fracture network and facies with secondary porosity. The study presents a workflow based on a case study from the Bongor Basin in Chad to effectively characterize granitic basement reservoirs with borehole images and open hole logs. Based on the integrated approach from geological and petrophysical analysis from the study wells, three main distinct facies and one sub-facies were interpreted; these are Unweathered, Leached, Fractured and Intensely Fractured granites, respectively.

Within the leached granite, there exist fault breccias and major faults with two dominant strike orientations: NE-SW and NW-SE. This resulted in the development of secondary porosity within these reservoir zones. The observed granite basement facies, particularly the fractured and leached granites, developed good secondary porosity due to differential leaching and fracturing. Two major classes of fractures striking in two different directions were identified across the study wells: WNW-ESE and WSW-ENE. Majority of these fractures are conductive, with high angles occurring within the reservoir zones. This probably indicates

that they are open (unless clay-filled). This is further investigated by the resistivity readings which were considerably reduced indicating a possible influx of drilling fluid thereby generating the low resistivity response on the borehole images. Fracture aperture and porosity were computed using the scaled borehole image logs. The maximum fracture porosity observed is 0.3% with a corresponding fracture aperture of 0.3 cm and this sets the stage for understanding the flow potential. Present day *in situ* stresses interpreted from the borehole breakout analysis suggest a slight rotation in stress-fields between the study wells. This can be attributed to the reactivation of the faults (due to the continuous migration of the Benue Trough) around the triple junction system that extends into southern Chad. This is an innovative work which offers an alternative method of fracture characterization, and potentially productive facies and fractures are identified based on their characteristics and *in situ* stresses in the absence of dynamic data.

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CNPCIC

Schlumberger

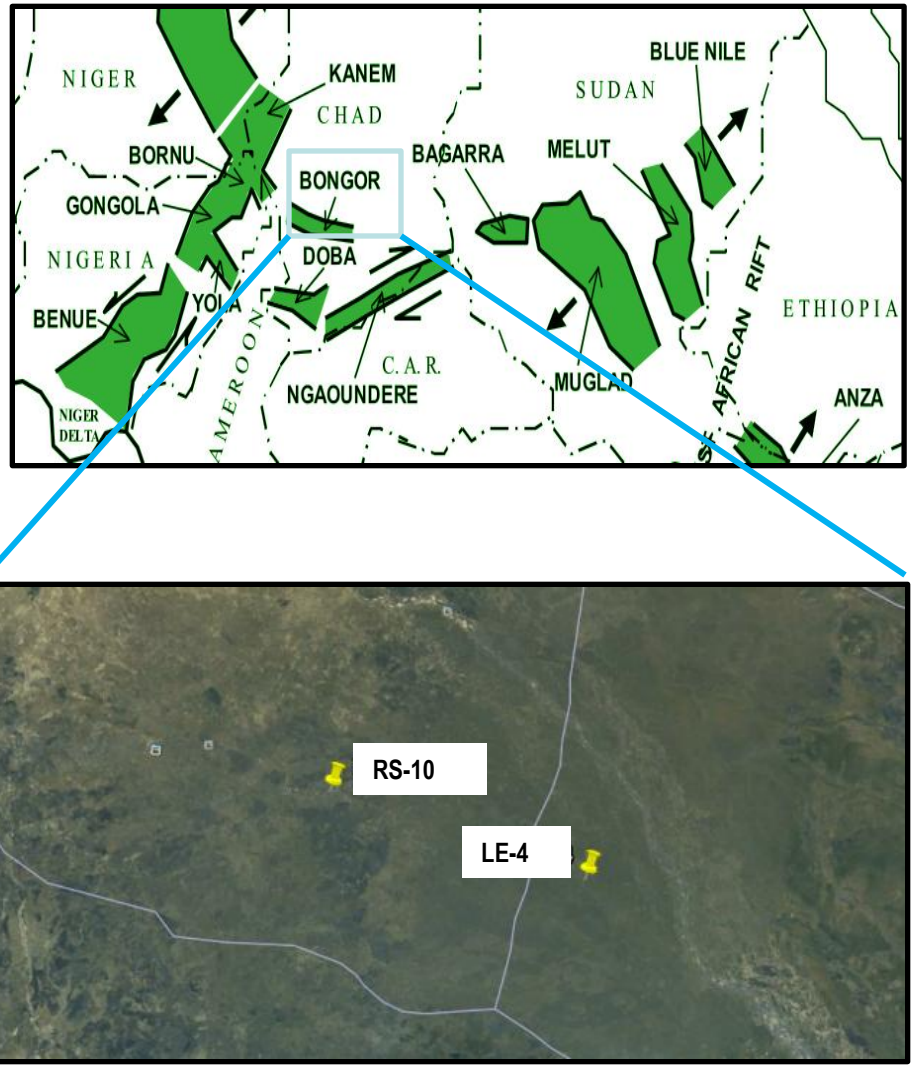
Outline

- Introduction to the Study Area
- Evaluation Challenges
- Workflow
- Analysis
  - Stress Regime
  - Structural Controls
  - Facies Controls
- Discussions
- Way Forward

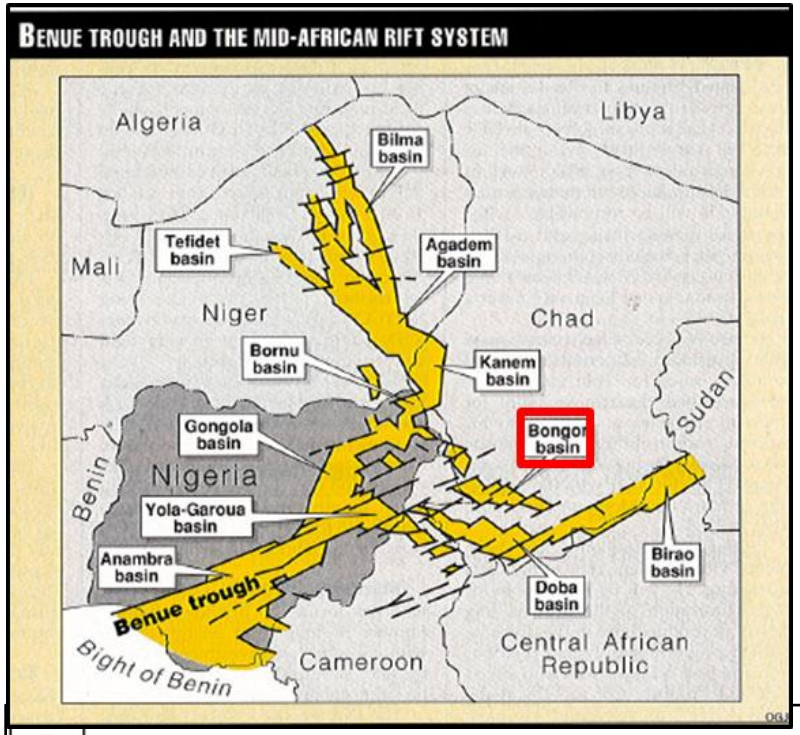
Ref: www.worldatlas.com

Study Area

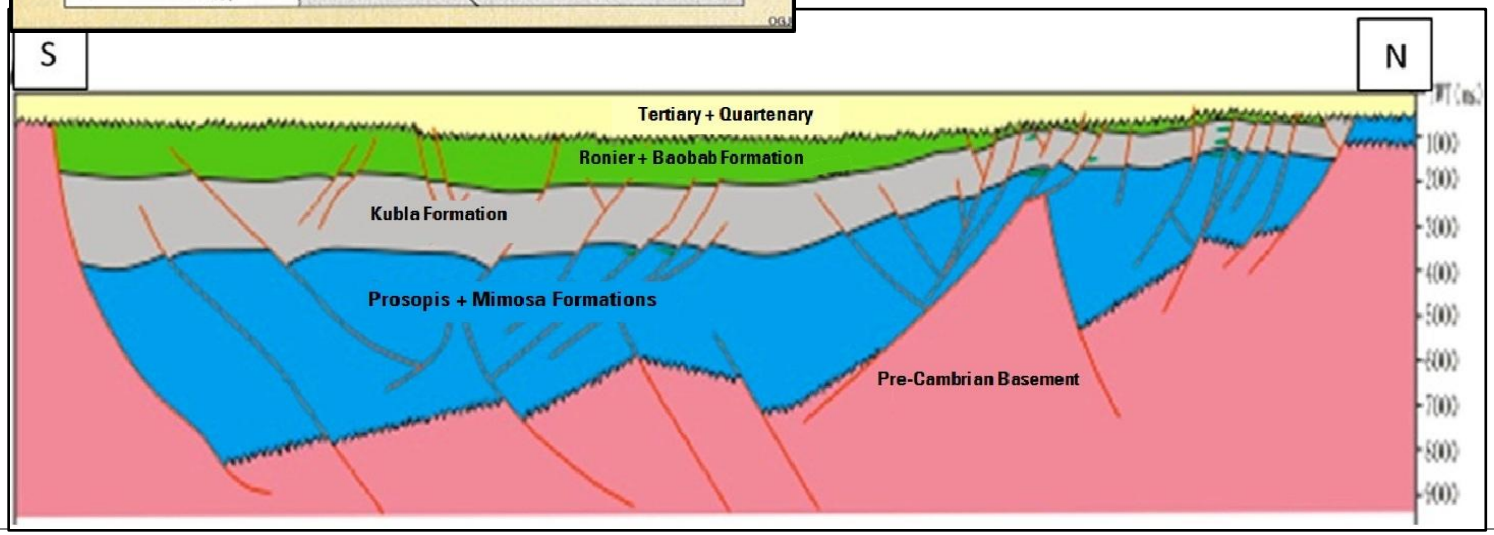
- Reservoir type: Fractured Granite (Basement)
- Wells: RS-10 and LE-4 located approximately 43km apart
- Field: Bongor Basin, Chad
- Data used: FMI* Images, Open Hole logs (GR, NPHI, RHOB, DT, URAN, MSFL, LLS, LLD)
- Over 80 wells have been drilled in the granitic basement and 5 oil discoveries have been made, with the first success in Jan 2013



Geology of the Sub-Surface

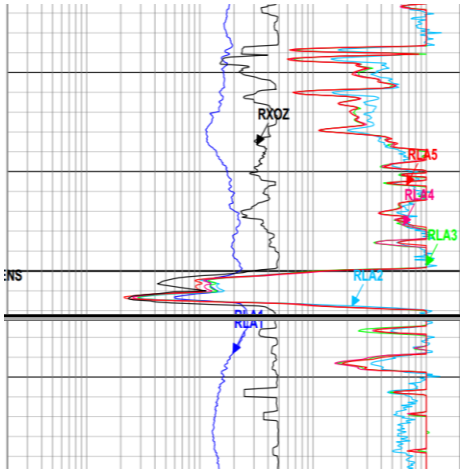


- Intra-continental Cretaceous-Tertiary rift basin with thick sediment pile
- Belongs to West African Rift System (WARS) Precambrian basement.
- Possible Source rock: Lower Cretaceous organic rich mudstone
- Prevailing structural style: **Half graben structure**

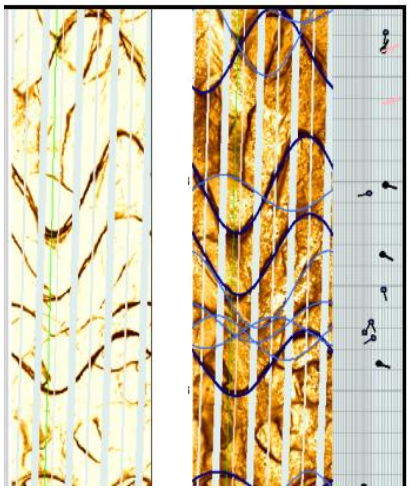


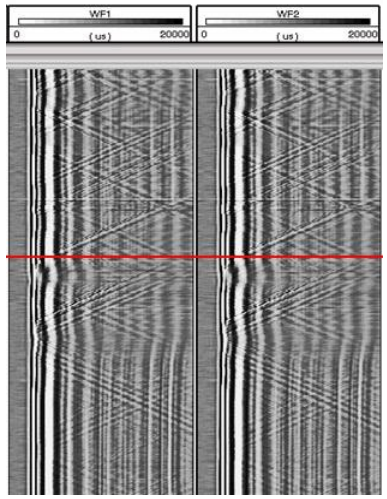
Evaluation Challenges

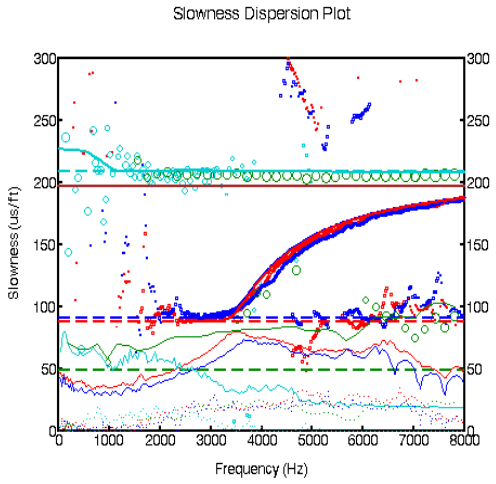
- Unconventional Reservoirs
- Well Log Measurement Limitations: Resistivity/ NMR/ N-D
- Static Modeling Issues
- Key Measurements for Subsurface Understanding
- Image Logs, Sonic Logs, Spectroscopy, Dielectric measurements, Cuttings/ Core Analysis

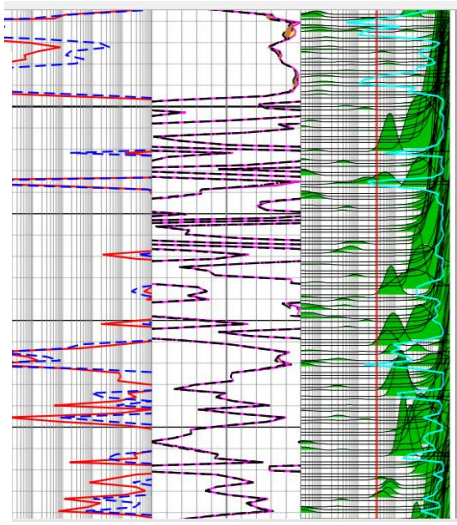


Identification of potentially productive facies and fractures using their relationship to InSitu and regional stresses in the absence of dynamic data.









Workflow

Image Interpretation

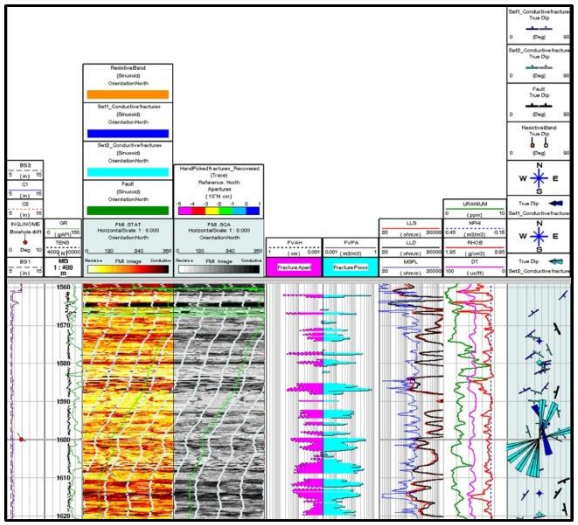
Fracture identification

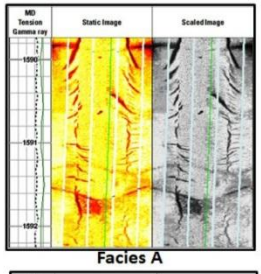
Computation of fracture properties

Facies characterization

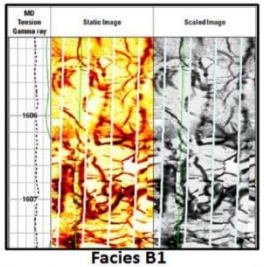
Using images, OH logs, core and cutting reports

Analysis of stress indicators, fractures and facies inter-relationship

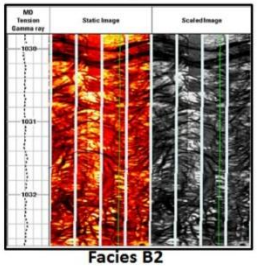




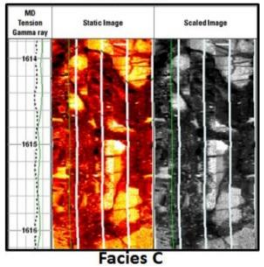
Facies A



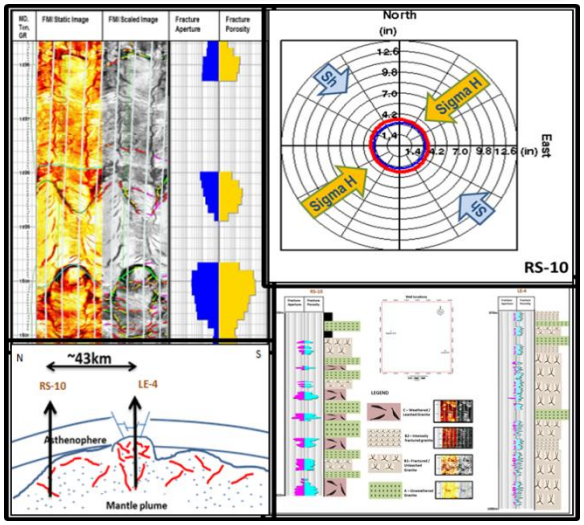
Facies B1



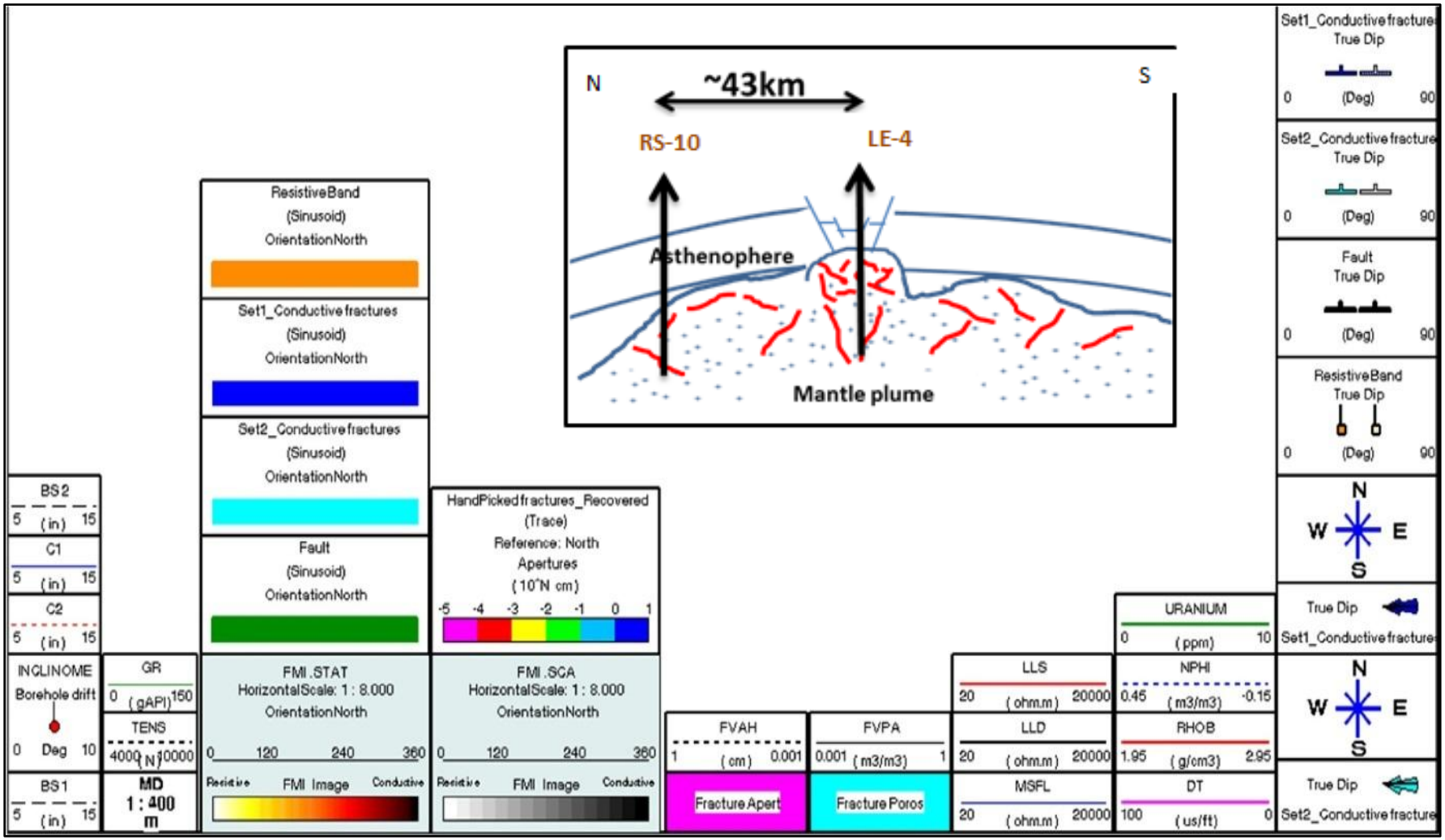
Facies B2



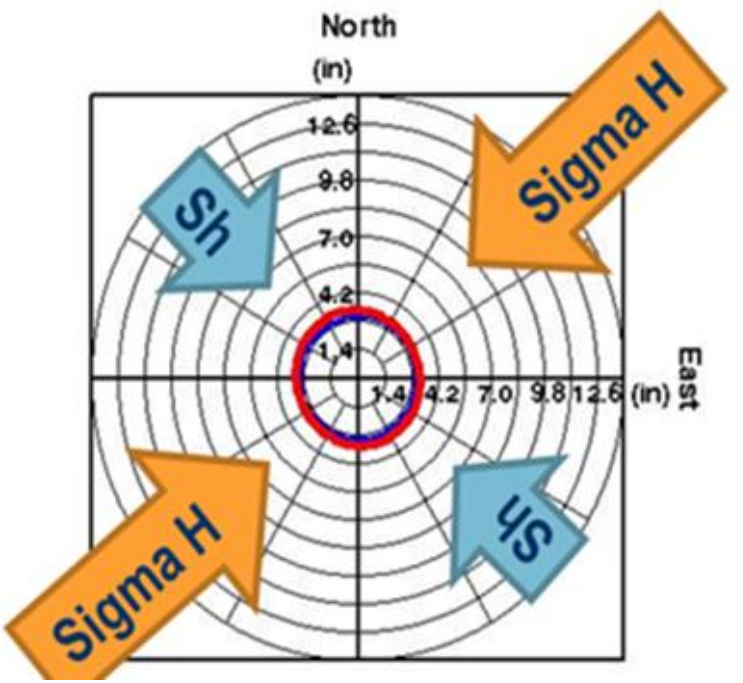
Facies C

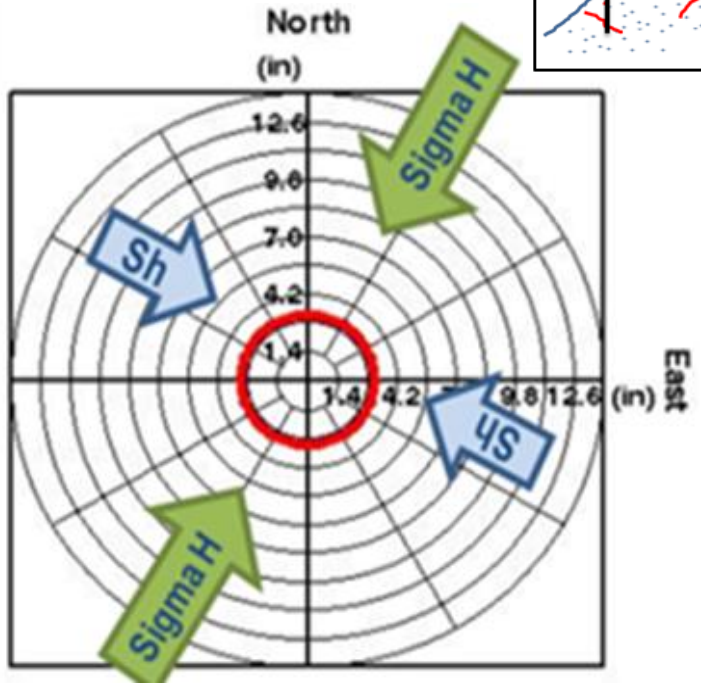


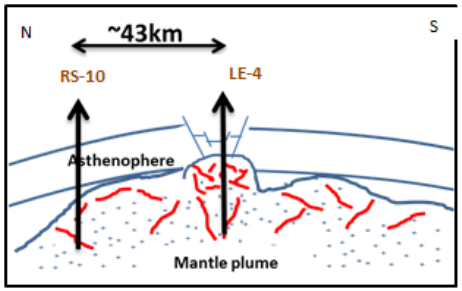
Analysis


N
~43km
S
RS-10
LE-4
Asthenophere
Mantle plume
ResistiveBand
(Sinusoid)
OrientationNorth
Set1_Conductive fractures
(Sinusoid)
OrientationNorth
Set2_Conductive fractures
(Sinusoid)
OrientationNorth
Fault
(Sinusoid)
OrientationNorth
HandPicked fractures_Recovered
(Trace)
Reference: North
Apertures
(10^N cm)
-5 -4 -3 -2 -1 0 1
Set1_Conductive fracture
True Dip
0 (Deg) 90
Set2_Conductive fracture
True Dip
0 (Deg) 90
Fault
True Dip
0 (Deg) 90
ResistiveBand
True Dip
0 (Deg) 90
BS2
5 (in) 15
C1
5 (in) 15
C2
5 (in) 15
BS1
5 (in) 15
INCLINOME
Borehole drift
0 Deg 10
GR
0 (gAPI) 150
TENS
4000 (N) 10000
MD
1 : 400
m
FMI .STAT
HorizontalScale: 1 : 8.000
OrientationNorth
0 120 240 360
Resistive FMI Image Conductive
FMI .SCA
HorizontalScale: 1 : 8.000
OrientationNorth
0 120 240 360
Resistive FMI Image Conductive
FVAH
1 (cm) 0.001
Fracture Apert
FVPA
0.001 (m3/m3) 1
Fracture Poros
LLS
20 (ohm.m) 20000
LLD
20 (ohm.m) 20000
MSFL
20 (ohm.m) 20000
URANIUM
0 (ppm) 10
NPHI
0.45 (m3/m3) -0.15
RHOB
1.95 (g/cm3) 2.95
DT
100 (us/ft) 0
N
W E
S
True Dip
Set1_Conductive fracture
N
W E
S
True Dip
Set2_Conductive fracture

Stress Rotation

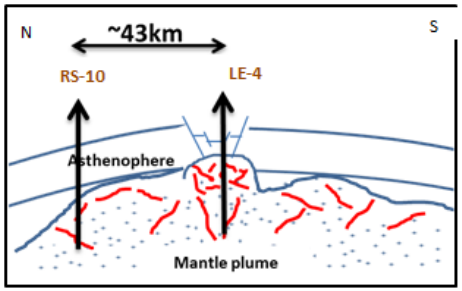


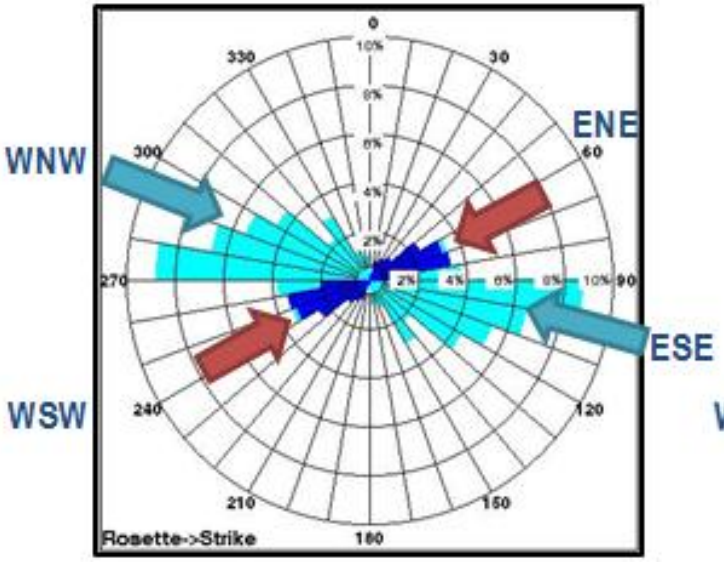


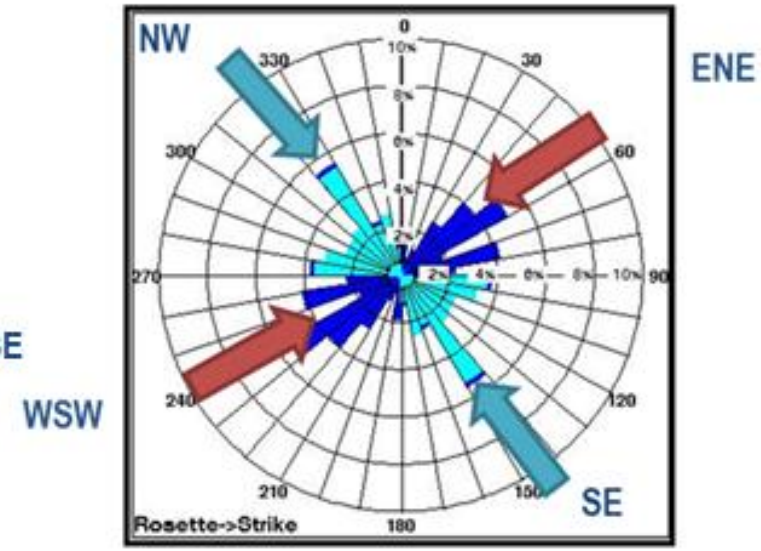


Borehole breakout analysis in both wells indicated a dominant minimum horizontal stress direction (Sh) trending NW-SE, although faulting and regional structural grain caused a slight rotation of the in-situ stresses. It is critical to understand the variation in stress for hydro-fracturing of the reservoirs, in designing the well-trajectory through the best productive facies.

Fracture Orientation





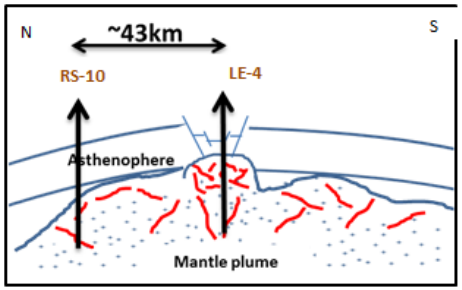


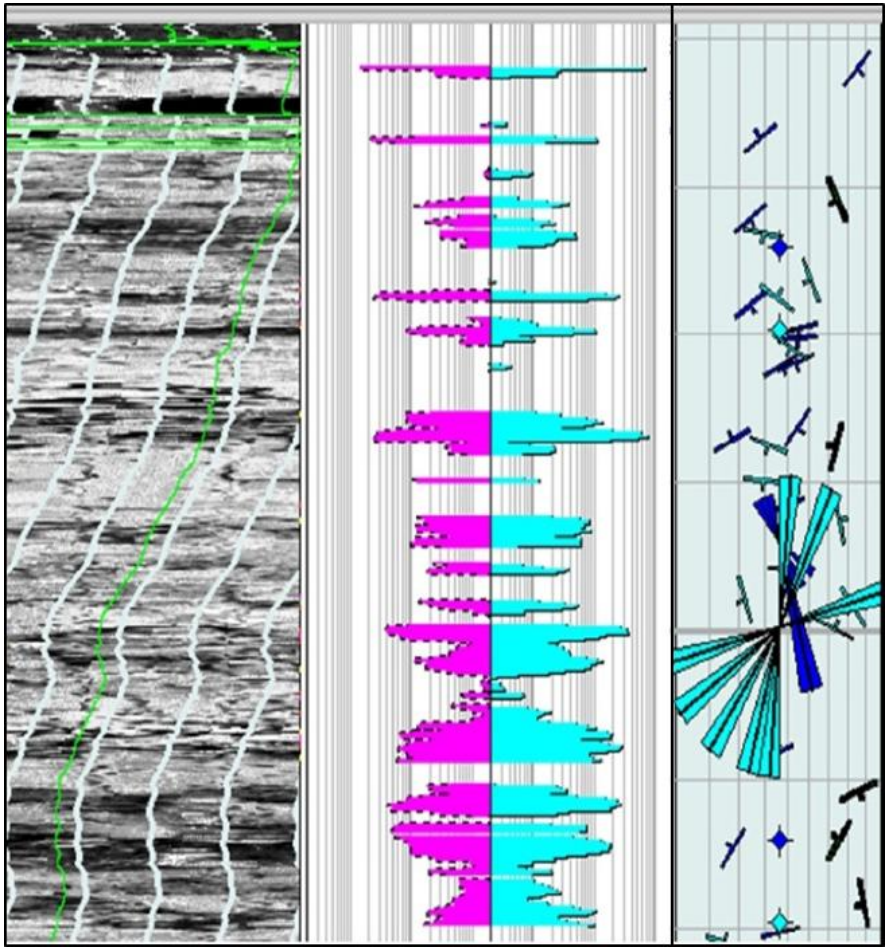
- Two sets of natural fractures identified in both wells
  - Set 1: Natural Conductive Fractures striking ENE-WSW
  - Set 2: Natural Conductive Fractures striking WNW-ESE

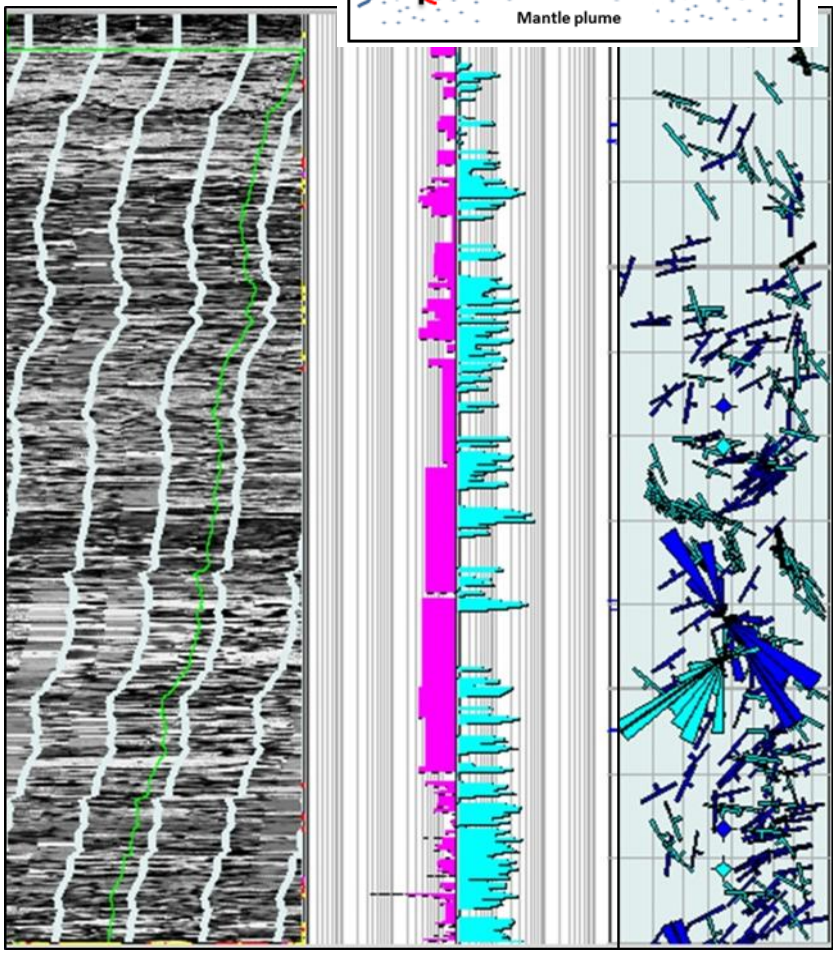
- 2 sets of high angled, natural fractures representing to two distinct tectonic regimes

Fracture Attributes

Though LE-4 is more intensely fractured; better reservoir properties are developed at RS-10.







Facies Analysis

3 major facies were identified

Facies A, Unweathered Granite (with mostly drill-induced and very few fractures)

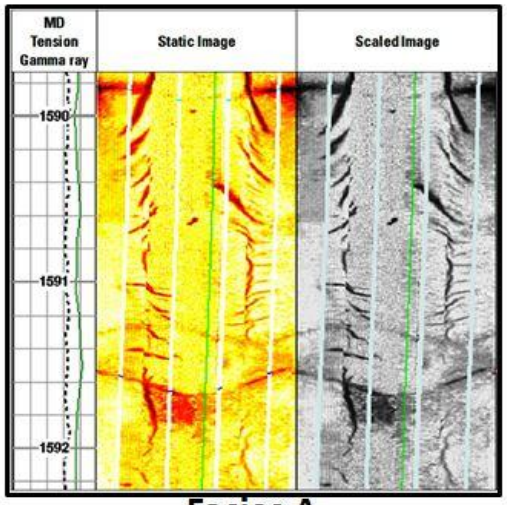
Facies B, Fractured Unleached Granite,

- Facies B1: regularly fractured
- Facies B2: intensely fractured

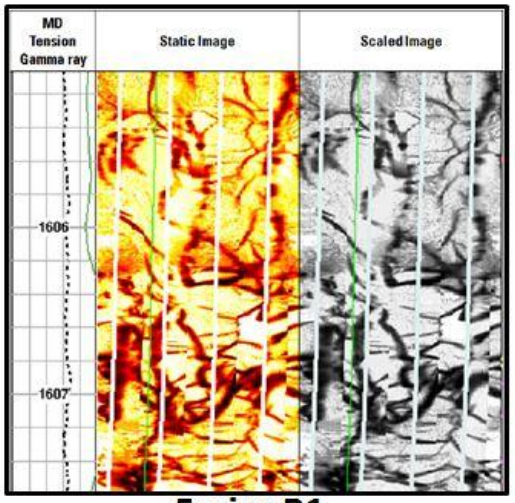
Facies C, Leached Granites, with fault breccia and altered fractures

Main reservoir units:

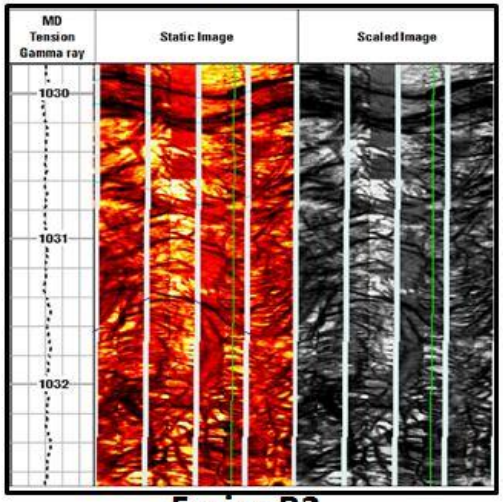
Facies **B** and **C**



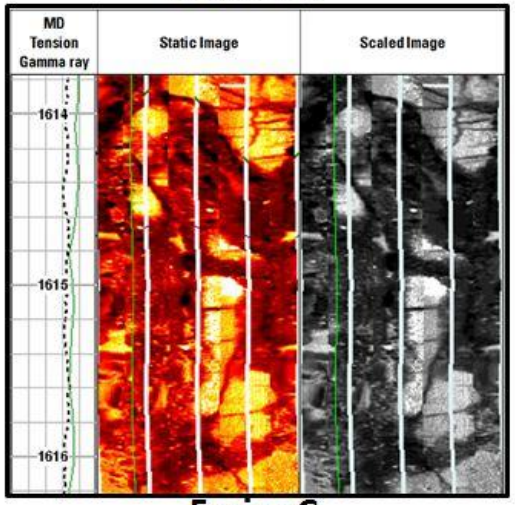
Facies A



Facies B1

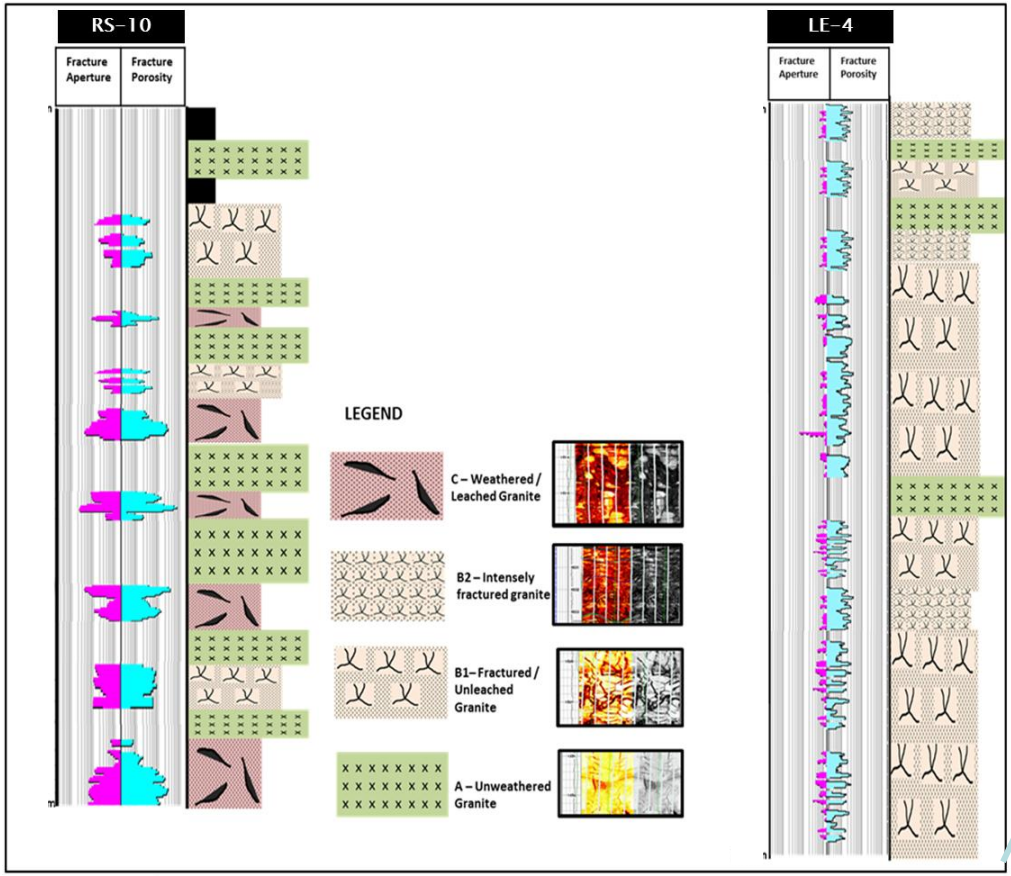


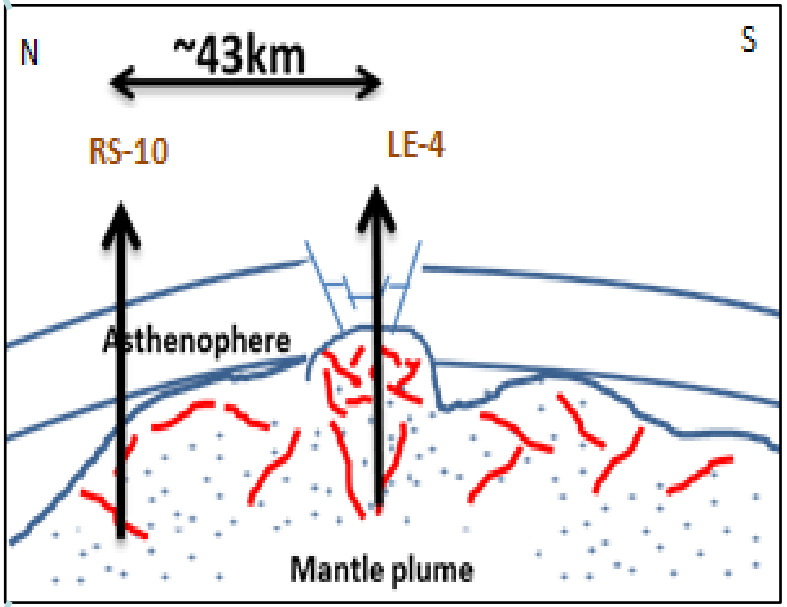
Facies B2



Facies C

Discussions: Comparative Study





- Intensity of fracturing increases southerly, from RS-10 to LE-4
- However, the best facies are developed in RS-10 due to weathering/ leaching.

Conclusions & Way Forward

- The Challenges are aplenty; though better understood now with a clear idea and defined roadmap … in these granitic reservoirs
- The interplay of stresses/ structure and facies is the key to evaluate and exploit the basement reservoirs of Chad
- Seismic interpretation to be refocused on productive facies
- The evaluation methodology needs further support with specific data acquisition (e.g. Production Logging/ Extended Well Tests)
- Based on the study, it can be concluded that placement of laterals and stimulation plans in the identified reservoir facies must be done taking into account the rotating stresses especially further down south.

Acknowledgements

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- Schlumberger