Addressing Granitic Basement Reservoir Heterogeneity in Cauvery Basin: An Integrated Fracture Modelling Approach*

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Abstract

Commercial presence of hydrocarbon has recently been established in Archean basement of Madanam, Pandanallur, and Pundi fields of Cauvery Basin, a pericratonic basin within the domains of the Southern Granulite Terrane. The real challenge lies in understanding the uniqueness of fracture connectivity which is again directly related to distinct heterogeneity observed in basement lithology, prevailing stress fields, and the fracture anisotropy. The present study describes a workflow adopting an assimilative approach involving seismic and geological concepts, well data (petrophysical and geo-mechanical data), and geo-cellular stochastic modelling which helped derive conceptual 3D fracture model of Cauvery basement reservoir in aforementioned fields. The one model thus prepared calibrates reasonably well with hydrocarbon accumulation pattern in basement wells tested in the area and has been of immense help in planning and drilling exploratory and development wells in the area.

Cauvery basement reservoirs underlie a regional unconformity and almost all lie on an uplift or high. The uplifts or buried hills, that form the basement reservoir, are simple basement highs (or hills), upthrown sides of faulted blocks, horsts, or basement highs within a graben. Tectonically, the basin is divided into a number of sub-parallel horsts and grabens, trending in a general NE-SW direction. A number of E-W trending shear zones formed in Mid Neo-Proterozoic have affected the entire Cauvery basement. Post Pre-Cambrian tectonism viz., N-S faulting in Permian-Triassic, NE-SW main rifting phase in Upper Jurassic-Lower Cretaceous and NW-SE faulting in Lower Cretaceous have their inherent signatures on basement fault and fracture patterns. Geomatic studies indicate that areas of intersection of post Pre-Cambrian faults overlying older Pre-Cambrian shear zones are areas where maximum fracture intensity is observed.

Focal mechanism and fault plane solutions indicate regional maximum horizontal stress direction varying between NW-SE to ENE-WSW. After Early Cretaceous, since no major tectonic event is found to occur in the basin, the maximum horizontal stress direction (SHmax) is considered to be the same as the in-situ stress. In-situ stress directions as deduced from Drilling Induced Fractures and borehole breakouts in

wells drilled in different fields show frequent rotation of in-situ stresses which more or less follow the regional stress maxima. Morphotectonic analysis and kinematic studies have demonstrated that that the E-W shear trends are the most reactivated trends under the present-day stress regime and an overall strike slip stress regime prevails in Cauvery basement fields. It was also inferred that the fracture set oriented in NW-SE and E-W direction are more prone to being critically stressed and are likely to remain open. This trend is probably the most important trend instrumental in migration, remigration or non-migration of hydrocarbons and hence having significant bearing in heterogeneity observed in flow potential of basement reservoirs across different fields. Analyses of mafic and felsic content in basement as well as fracture anisotropy variations vertically and spatially, provide answers for prolific nature of basement reservoirs in Madanam and Pundi areas compared to Pandanallur and Mattur.

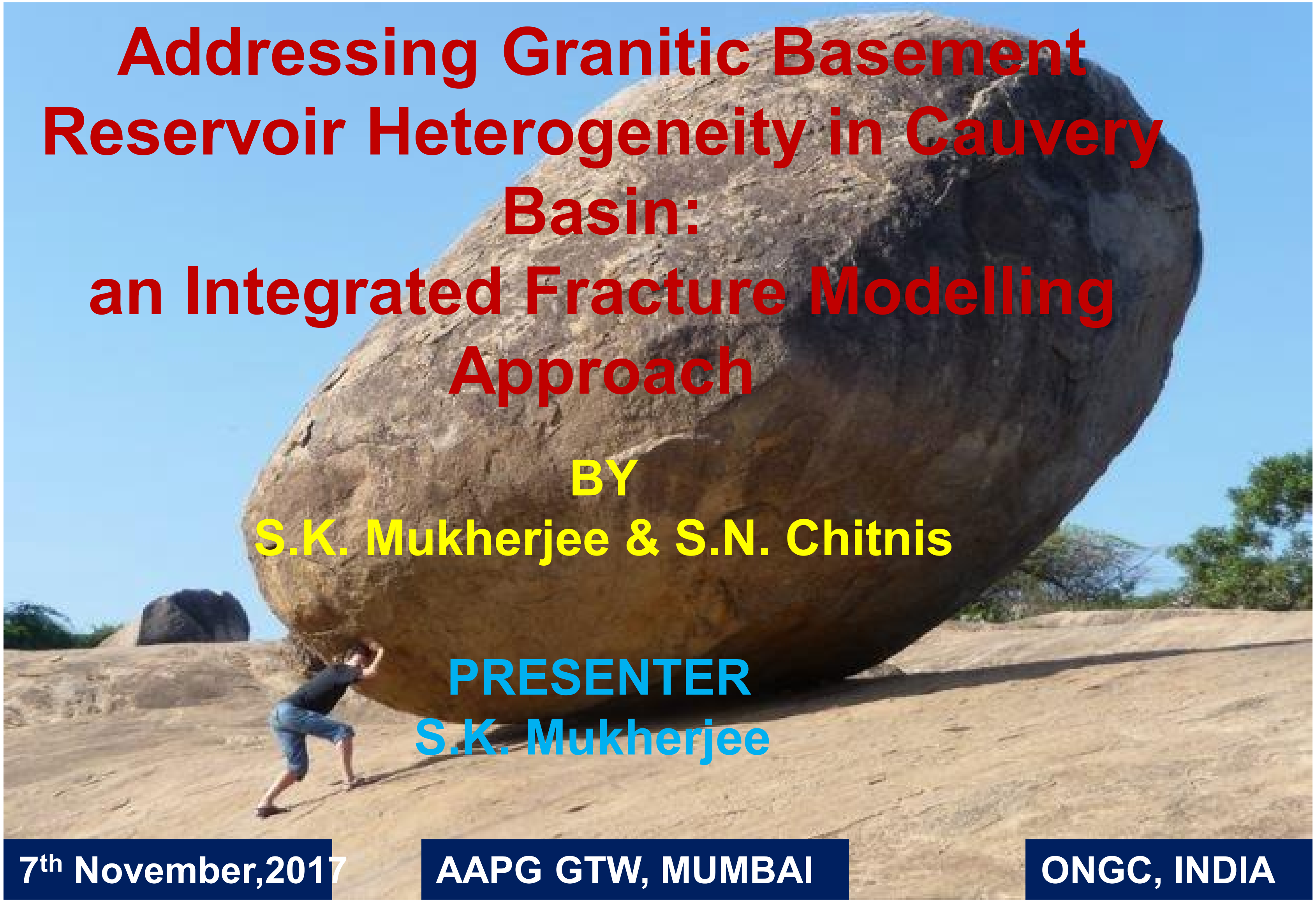
The need for addressing the heterogeneity in Cauvery basement reservoirs led to collation of separate workflows for creation of a robust fracture model combining seismic attributes with petrophysical, geo-mechanical, and geological inputs. Calibration of the 3D fracture model with well data in the form of masterlog data, cores, image and shear logs, and validated by PLT and reservoir tests have led to more accuracy in the static model, which in turn helped predict fracture networking and provided real time solution to guiding successful wells through basement and planning well stimulation jobs. This multi-pronged approach is the most realistic tool for basement exploration in complex basement reservoirs as in Cauvery.

References Cited

Chaudhuri, A., M.V. Rao, J.P. Dobriyal, G.C. Saha, L. Chidambaram, A.K. Mehta, L.V. Ramana, and K.S. Murthy, 2009, Prospectivity of Cauvery Basin in Deep Syn-Rift Sequences, SE India: AAPG Annual Convention and Exhibition, Denver, Colorado, USA, June 7-10, 2009, Search and Discovery Article #10232 (2010). Website accessed May 2018.

Chetty, T.R.K., 2006, Contrasting Deformational Systems and Associated Seismic Patterns in Precambrian Peninsular India: Current Science v. 90/7, p. 942-951.

Ramasamy, S.M., C.J. Kumanan, R. Selvakumar, and J. Saravanavel, 2011, Remote Sensing Revealed Drainage Anomalies and Related Tectonics of South India: Tectonophysics, v. 501, p. 41-51.



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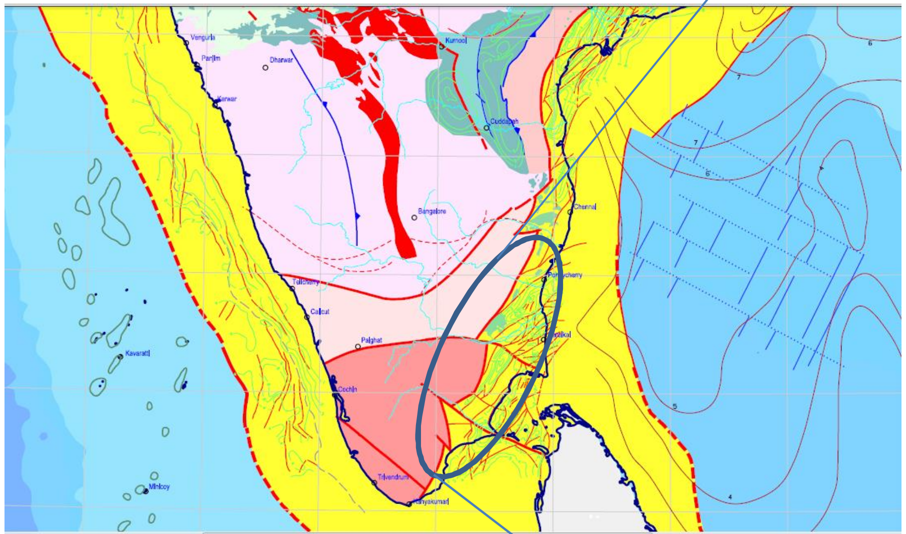
S.K. Mukherjee & S.N. Chitnis

PRESENTER
S.K. Mukherjee

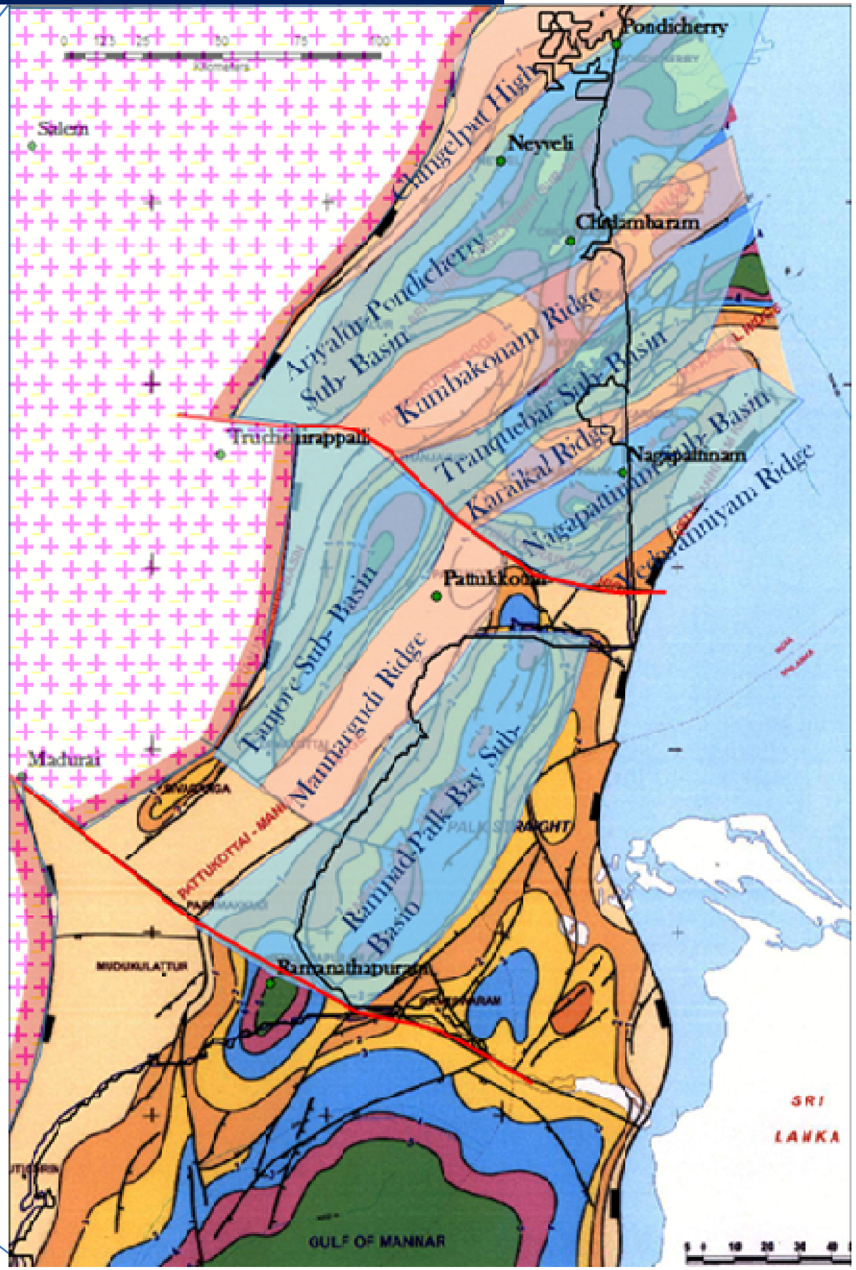
7th November,2017 | AAPG GTW, MUMBAI | ONGC, INDIA

POST PRE-CAMBRIAN BASIN ARCHITECTURE

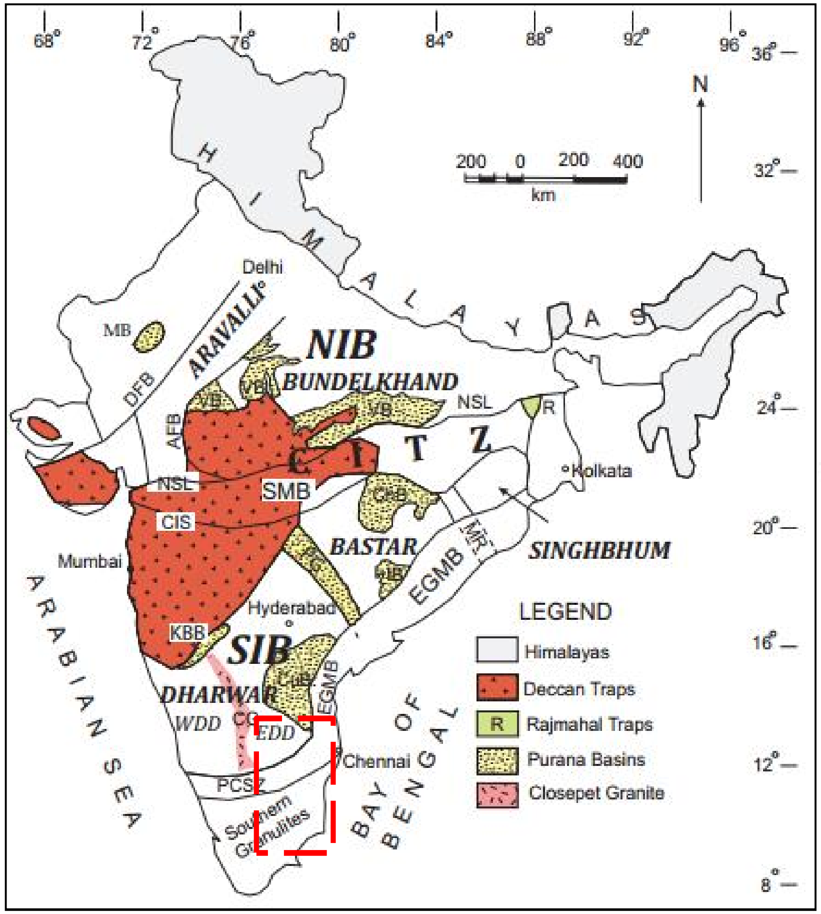
Pericratonic rift basin (Late Jurassic/ Early Cretaceous) in Southern Granulitic Terrane

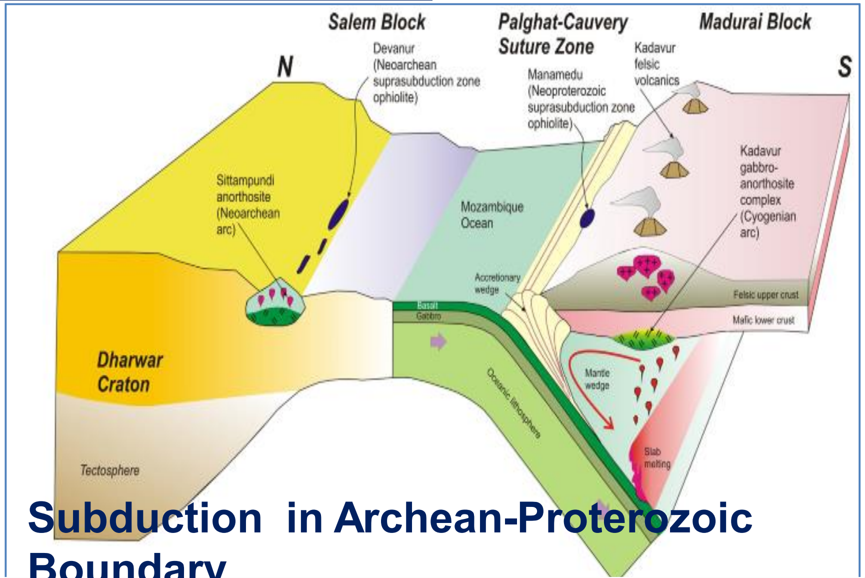


- N-S faults in Permo-Triassic
- NE-SW rifting in Lr. Cretaceous (horst-graben features)
- NW-SE cross faults (Subsequent drifting and rotation) in Lr. Cretaceous



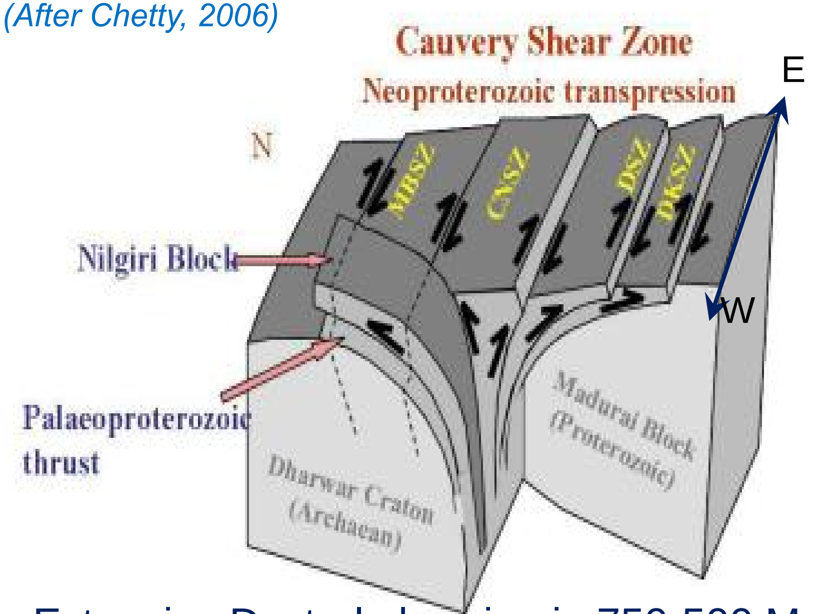
PRE-CAMBRIAN ARCHITECTURE





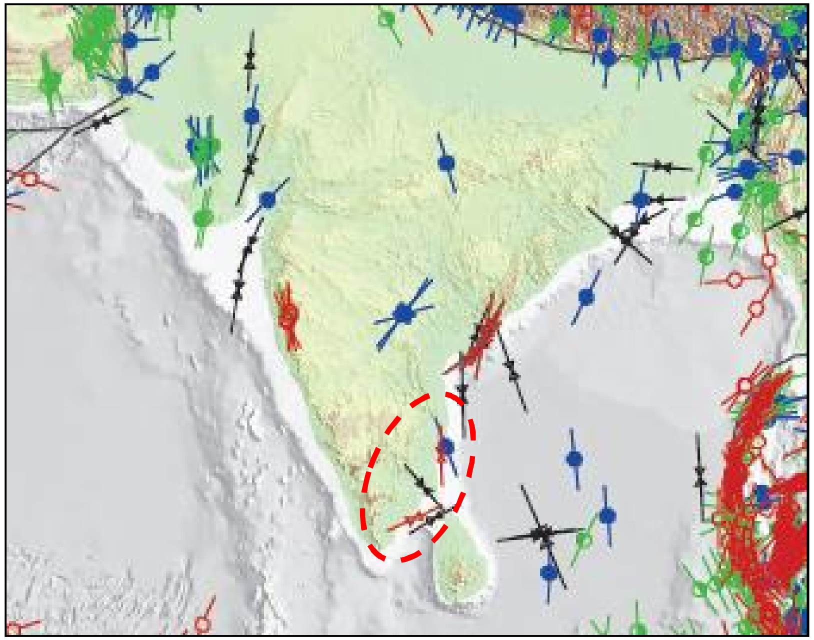
Subduction in Archean-Proterozoic Boundary

(After Chetty, 2006)

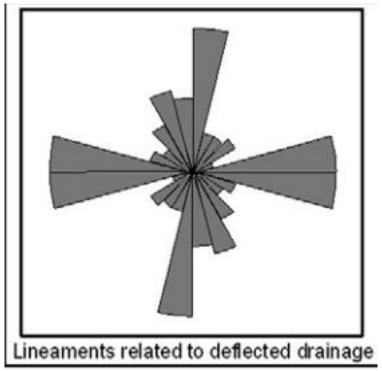


Extensive Dextral shearing in 750-500 Ma

REGIONAL STRESSES

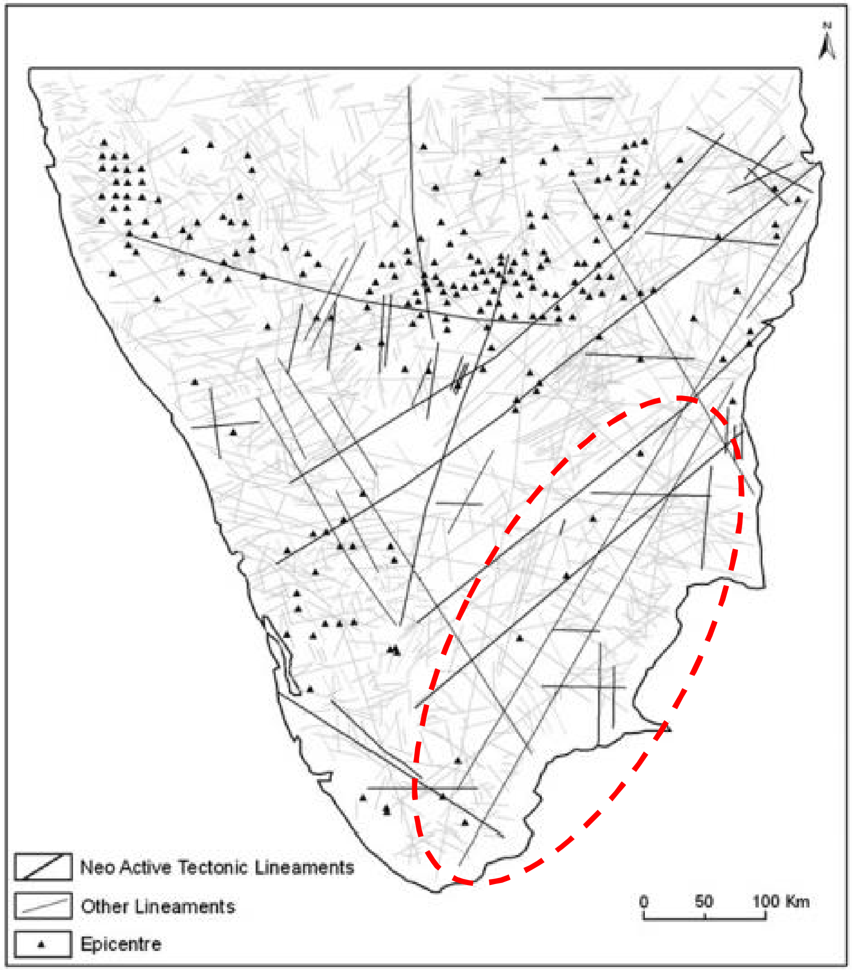


World stress map, 2016



Study based on mega drainage anomalies lead to the detection of a series of faults

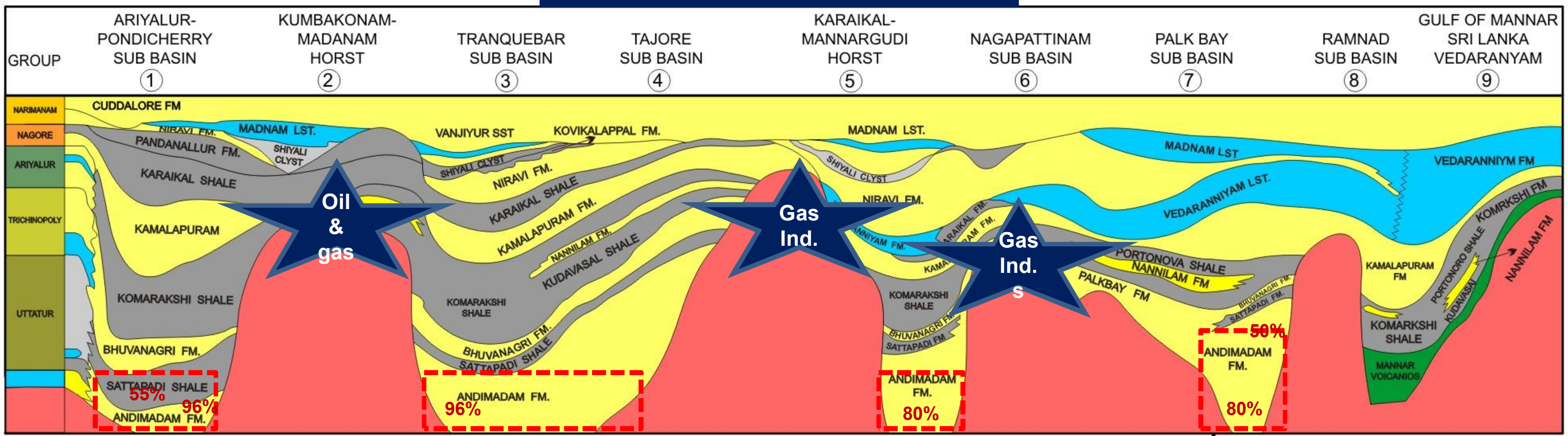
- Nï S extensional
- **NE–SW sinistral**
- **NW–SE dextral** ,and
- **E–W release failure.**



Seismicities and Neo-Active Tectonic Lineaments

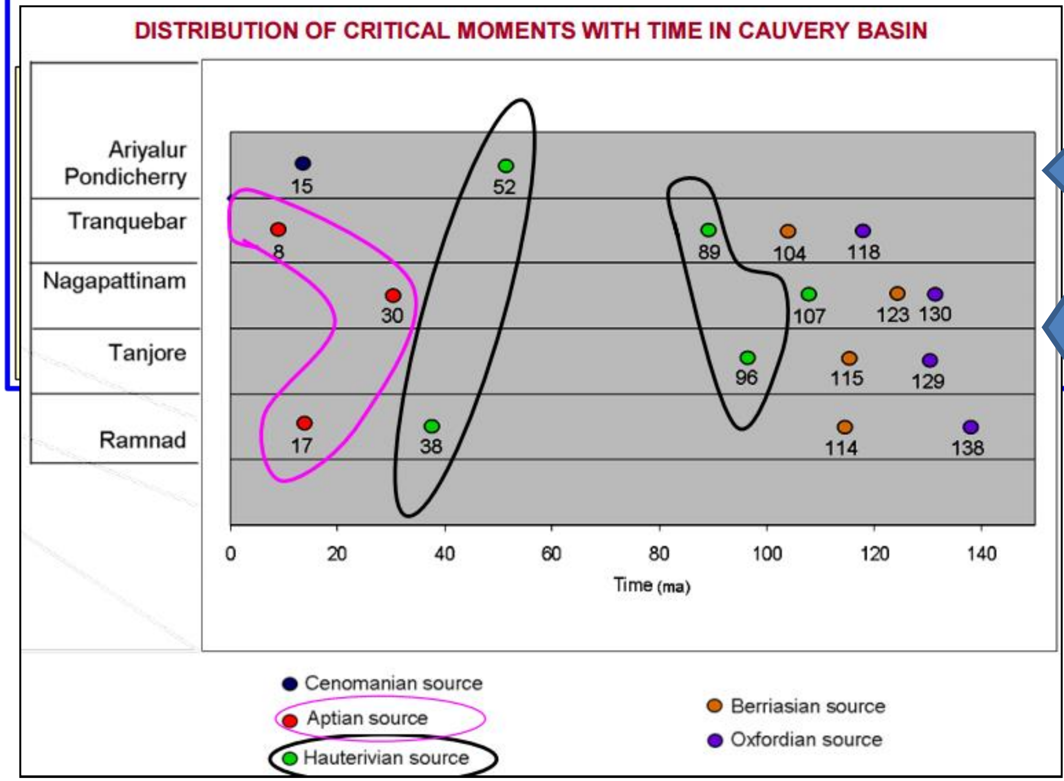
(*Ramasamy et al., 2011*)

PETROLEUM SYSTEM



(*National Data Repository*)

LIMESTONE
CLAYSTONE
SHALE
SANDSTONE
VOLCANICS
PRE-CAMBRIAN

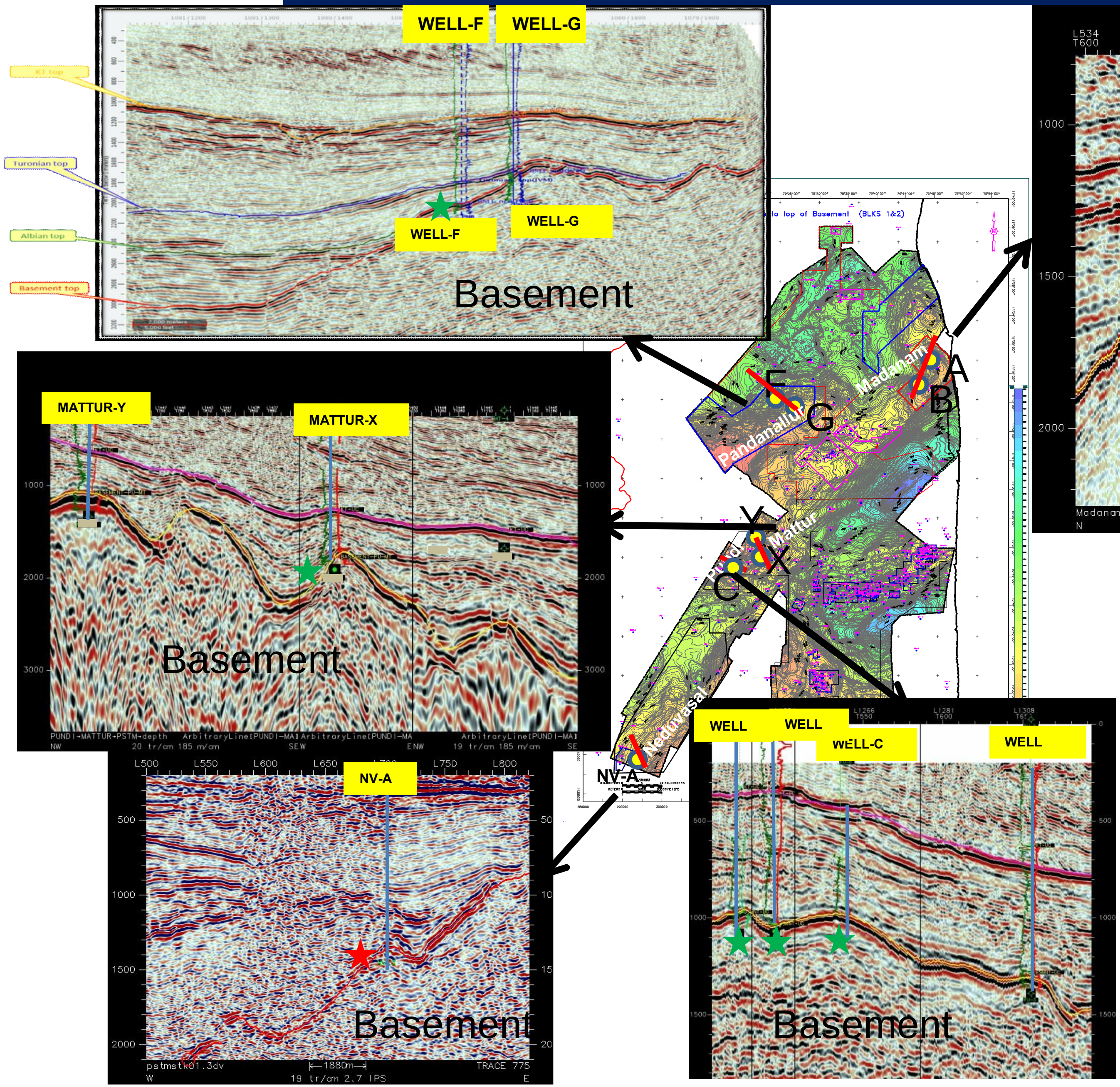


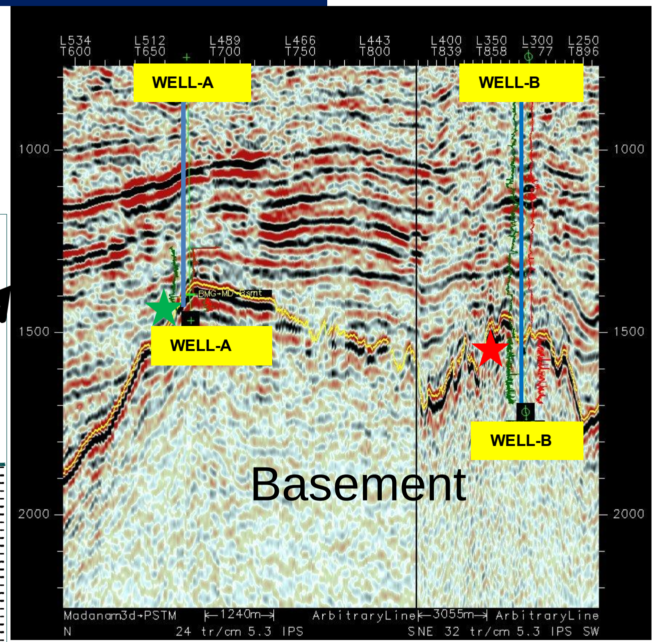
(*Chaudhuri et al., 2009*)

POST RIFT

SIGNIFICANT SYNRIFT

HETEROGENEITY IN STRUCTURAL ACCUMULATIONS





HETEROGENIETIES:

Crestal accumulations

Accumulation at flanks

Fluid anomalies

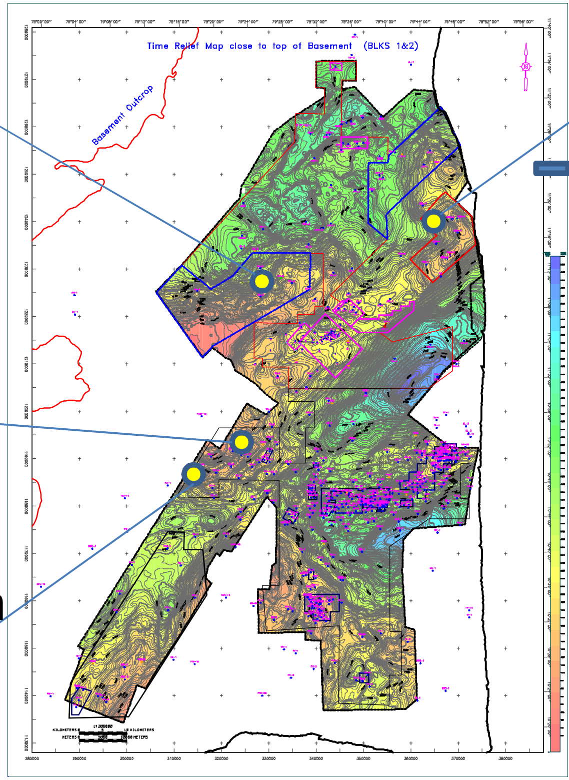
Key Elements:

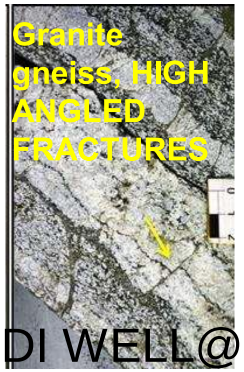
- **Role of faults**
- **Seal integrity**
- **Present day stresses**
- **Different sources**

LITHOLOGICAL HETEROGENEITY

Garnet biotite gneiss

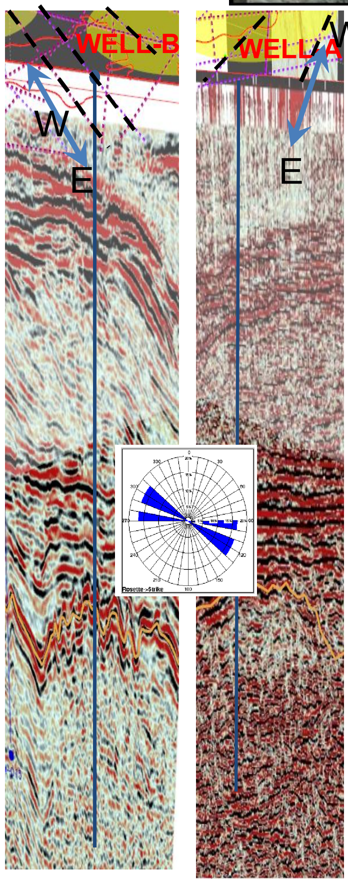
MATTUR WELL@ 1700m

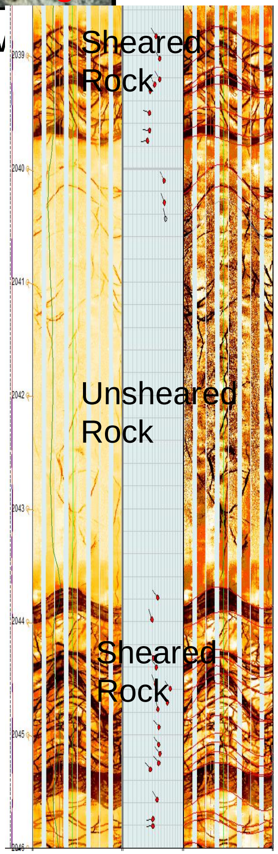




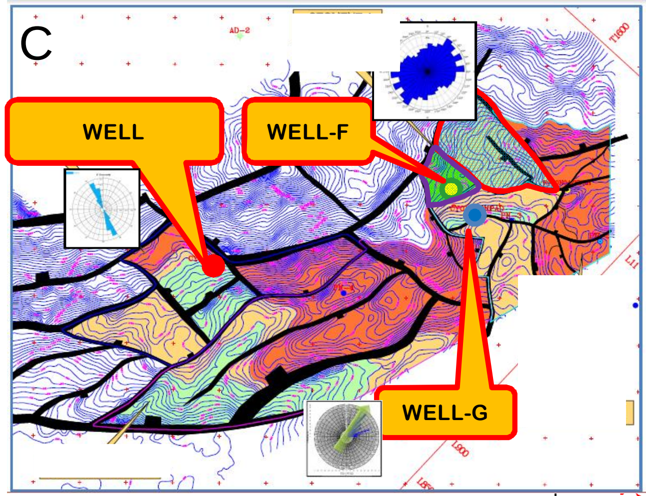
PUNDI WELL@ 1675m

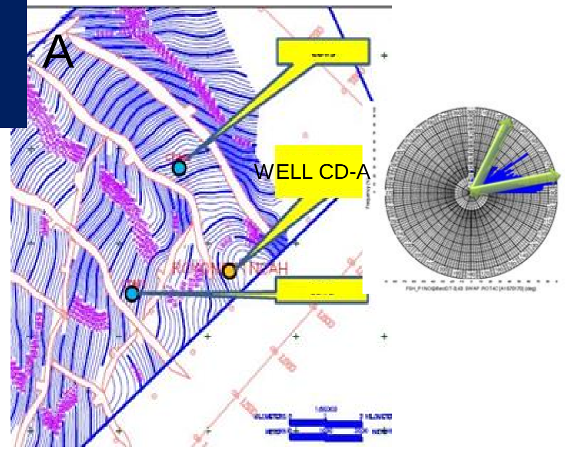
Granitoid gneiss

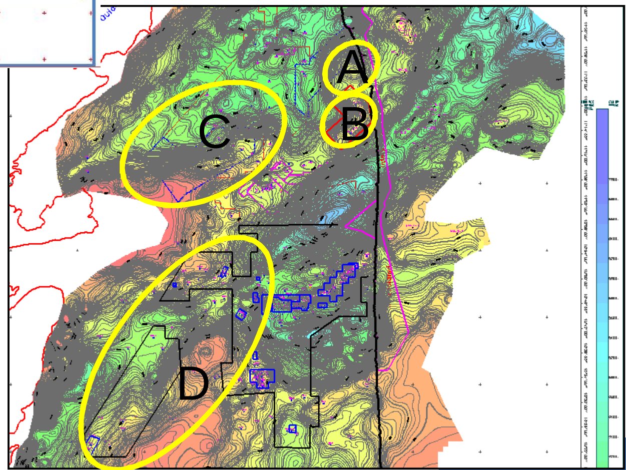


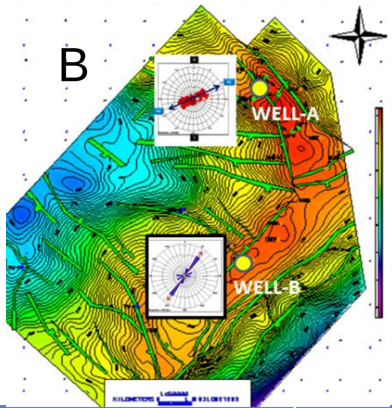


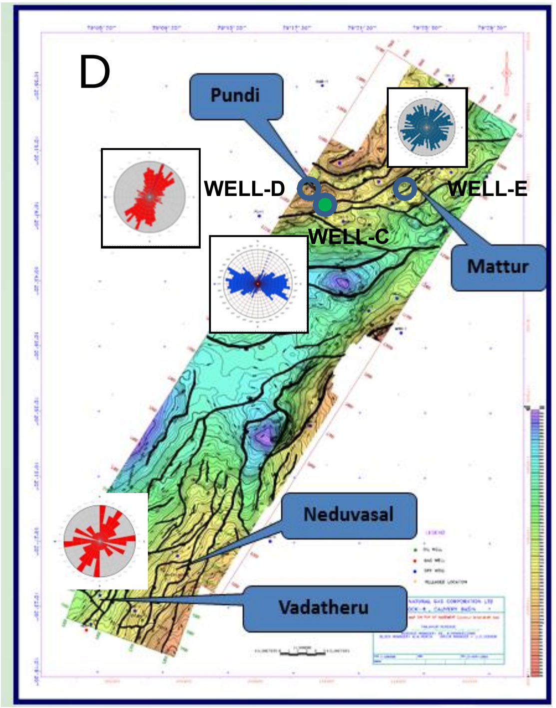
FRACTURE TRENDS FROM IMAGE LOGS











	WELL-B	WELL-A
Nature of basement	Highly fractured, brecciated basement	Weathered basement/ More foliated nature
	Felsic nature dominates	Mafics equally dominant
WBST	Lesser bulk porosity but better fracture support	More bulk porosity , moderate fracture support
SHmax	High variations	Follows regional orientation
Fracture dips	Mostly high angle	Average dips

INTEGRATED WORKFLOW

INTRODUCTION (KNOWN / UNKNOWN AREA; PEL/ML/NELP / JV)

↓

GEOLOGY OF THE AREA (WITH SPECIAL EMPHASIS ON BASEMENT LITHOLOGY)

↓

BASIN EVOLUTION AND DEPOSITIONAL HISTORY

↓

REGIONAL TECTONICS AND IMPLICATION ON BASEMENT (Role of Basin Margin faults)

↓

PALEO STRESSES vs. PRESENT DAY STRESSES

GOOD DATABASE → **WORLD ANALOGUES**

POOR DATABASE → **STRUCTURAL FRAMEWORK**

↓

ANALYSES OF DRILLED WELLS (H/C Shows, conventional cores, side wall cores, RFT/MDT; mud loss zones; analyses of conventional logs; integration of well with seismic)

↓

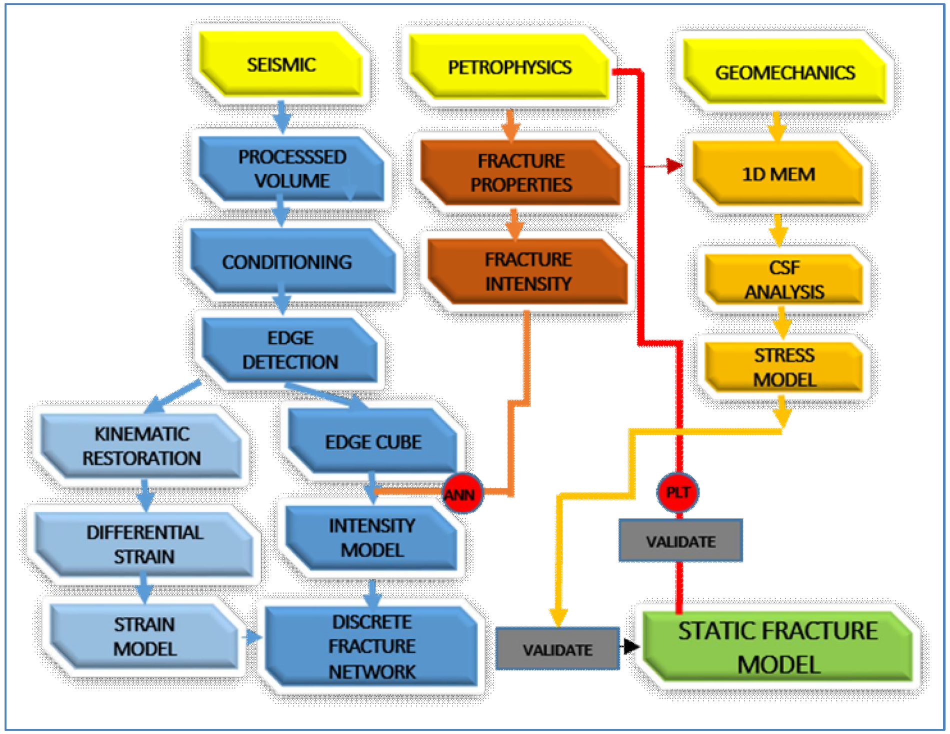
GEOLOGICAL / SEISMO-GEOLOGICAL MODEL

↓

PETROLEUM SYSTEM (Critical time of generation vis-à-vis evidence of reactivation of faults and tectonic history)

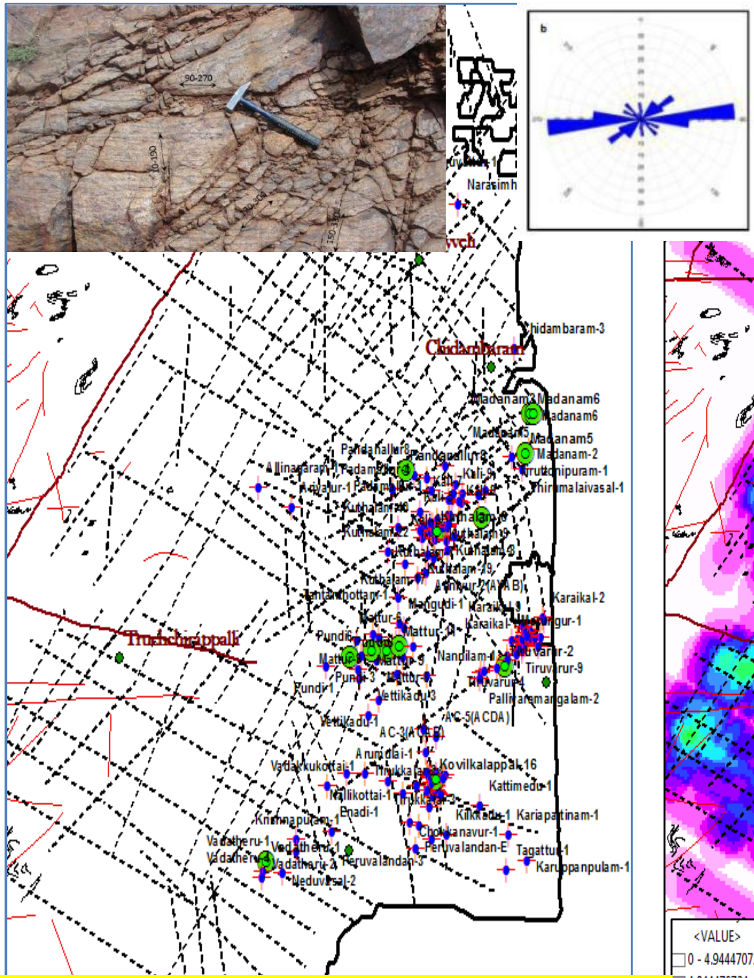
↓

GROSS PROSPECTIVITY (juxtaposition to source ; proximity to fault zone, flexure zone on a high)

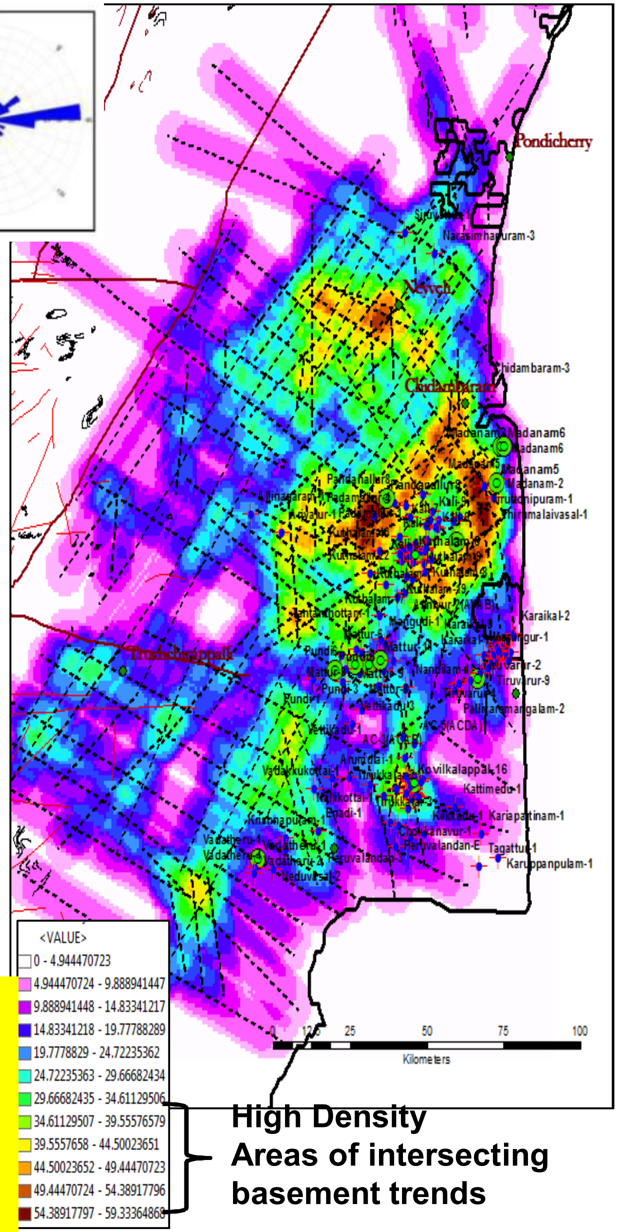


(CODBEXC, ON(

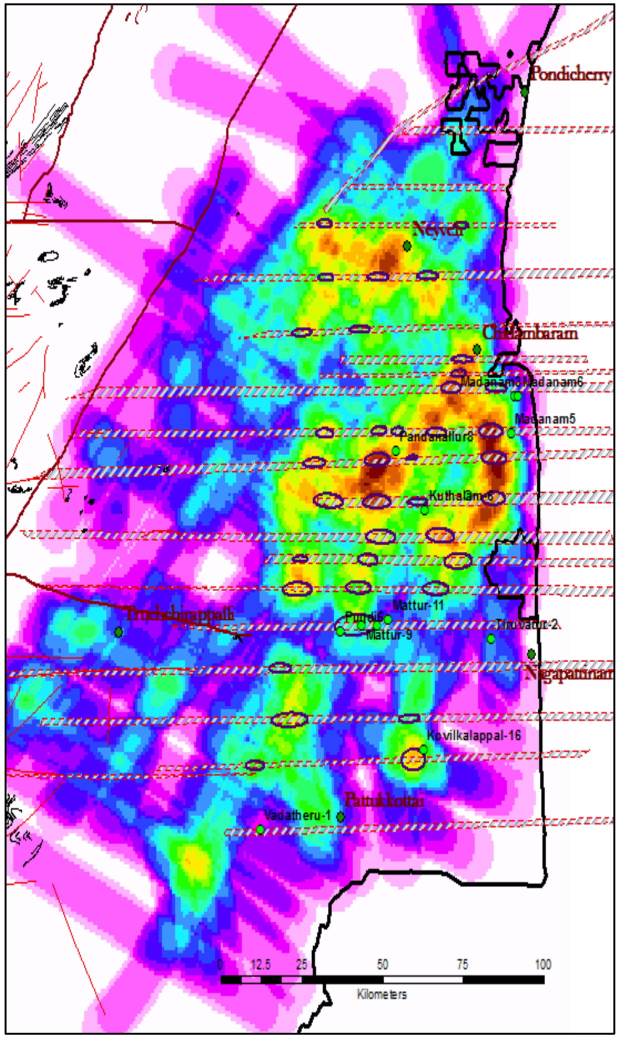
IDENTIFICATION OF DENSELY FRACTURED AREAS FROM MORPHOTECTONICS



- Lineament mapping from Landsat imagery
- Lineamant analysis from drainage anomalies
- Aspect/ slope variations
- Field evidences



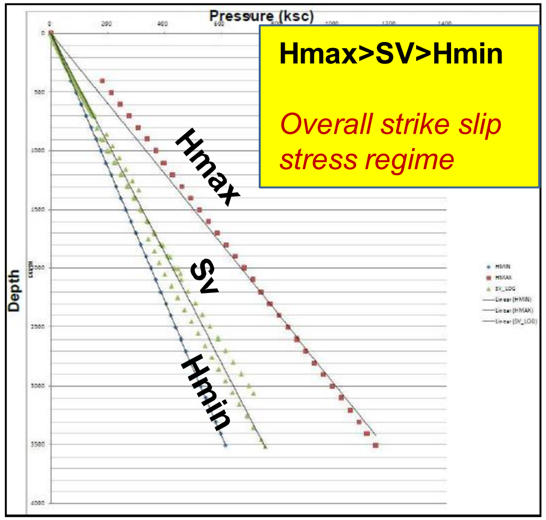
High Density
Areas of intersecting basement trends



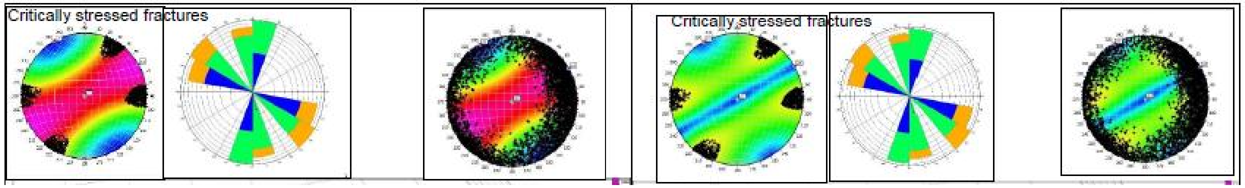
Areas of high Density Post pre Cambrian trends correlating with Shear Zones (marked in ellipses) will be areas which are supposedly most fractured

(KDMIPE, ONGC

PRESENT DAY STRESSES FROM KINEMATIC STUDIES (GEOMECHANICAL RESTORATION



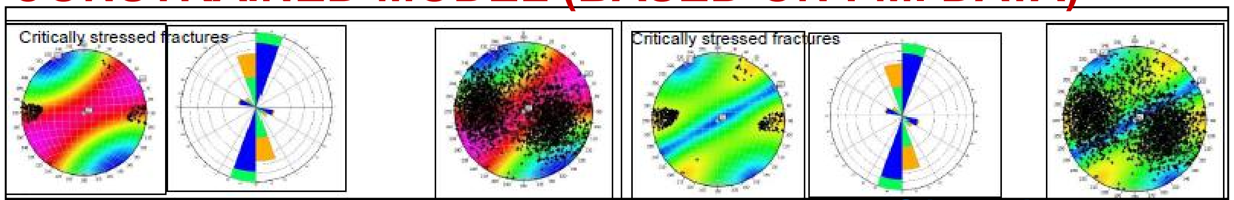
PREDICTIVE MODEL (BASED ON INCREMENTAL STR



Dilational tendency **Slip tendency**

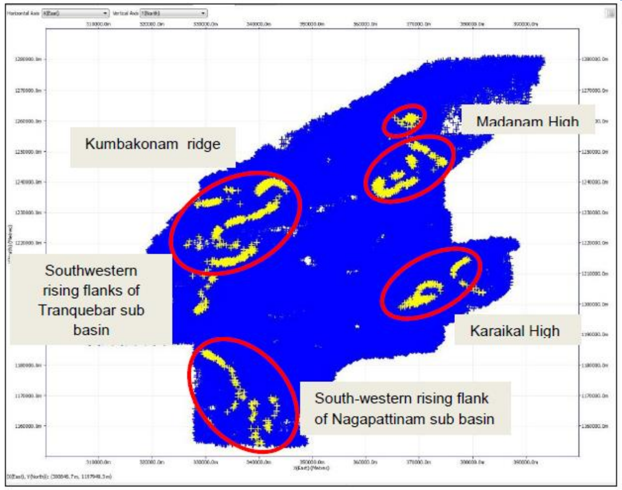
Modeled fractures have higher dilation tendency than slip tendency. Critically stressed fractures are oriented in NNW-SSE and N-S direction.

CONSTRAINED MODEL (BASED ON FMI DATA)



Dilational tendency **Slip tendency**

Modelled fractures have higher dilation tendency than slip tendency. Critically stressed fractures are oriented in NNW-SSE and E-W direction.



Fracture model

STOCHASTIC MODEL WORKFLOW

MAKE SIMPLE GRID USING BOUNDARY SURFACES

↓

3D GEOMETRY (*I *J *K)

↓

UPSCALE INTENSITY FROM WELL LOGS → STOCHASTIC PROPERTY FOR LOG FRACTURE INTENSITY

SEISMIC RESAMPLING PER FRACTURE SET OF ANT TRACK VOLUME → VARIOGRAM AND DATA ANALYSIS

↓

NEURAL NETWORK

↓

PROPERTY PROPAGATION

↓

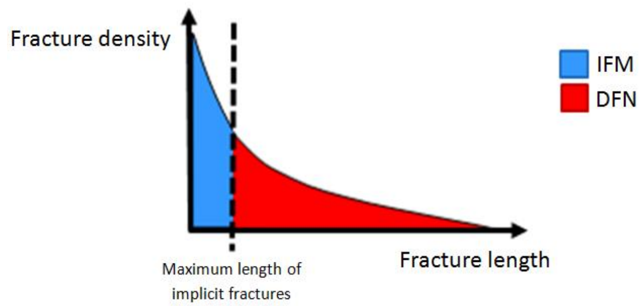
PETROPHYSICAL MODEL AND INTENSITY GENERATION

↓

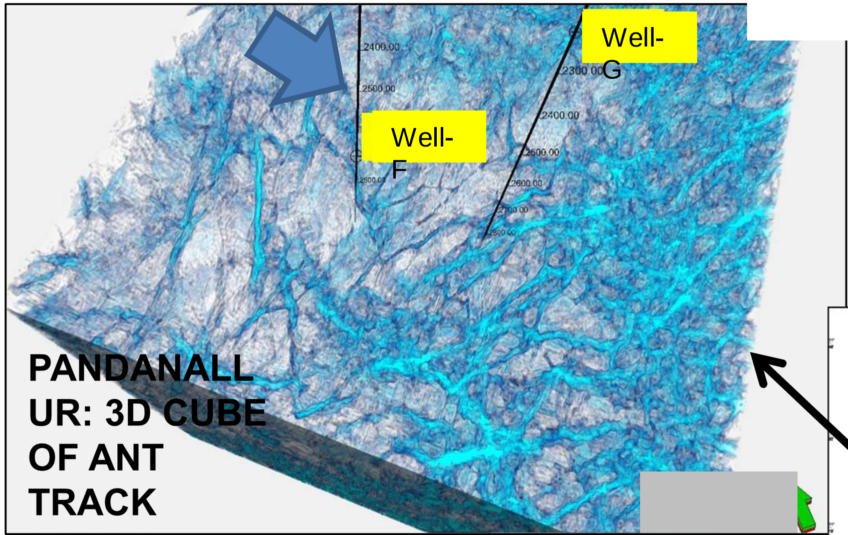
DISCRETE FRACTURE NETWORK

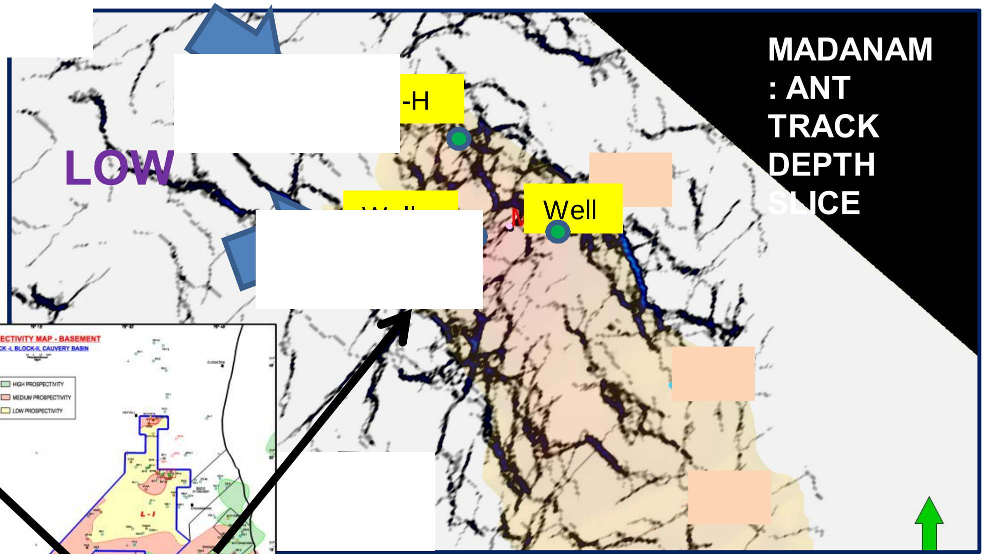
Discrete Fracture Network (DFN): The large/important fractures are modelled explicitly as discrete patches.

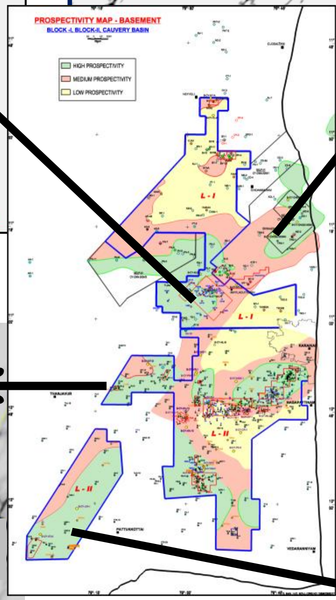
Implicit Fracture Model (IFM): The residual part of the distribution (smaller fractures) is statistically represented as grid properties.

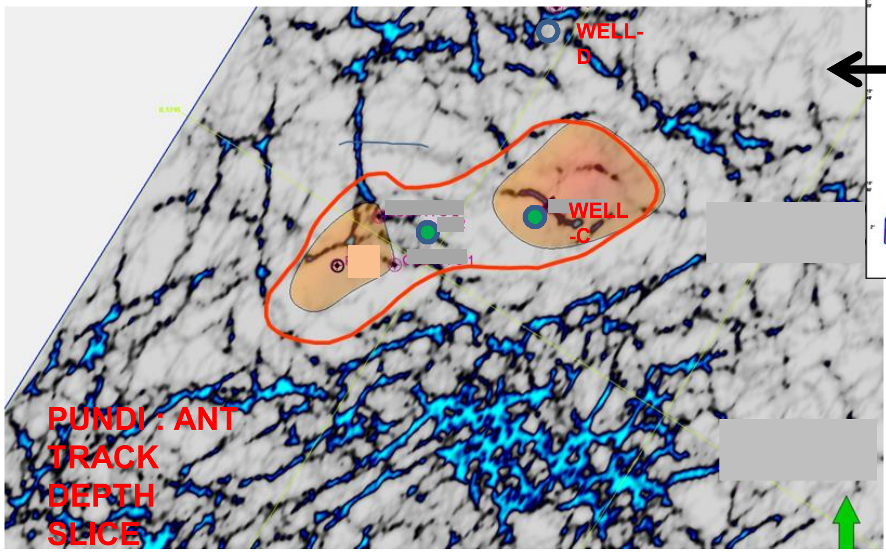


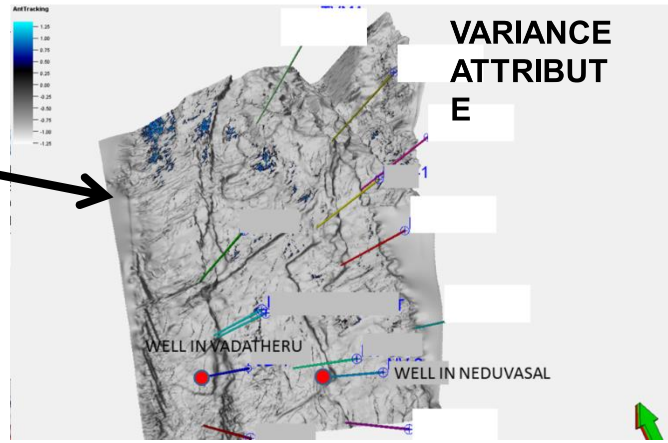
FRACTURE ATTRIBUTES (SEISMIC)



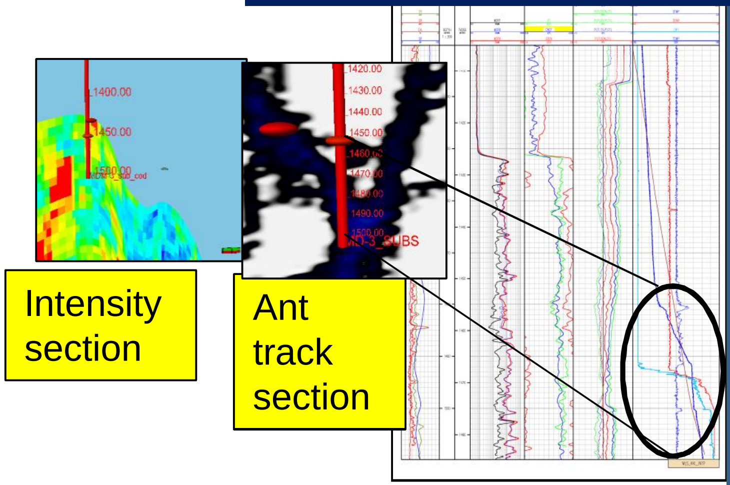




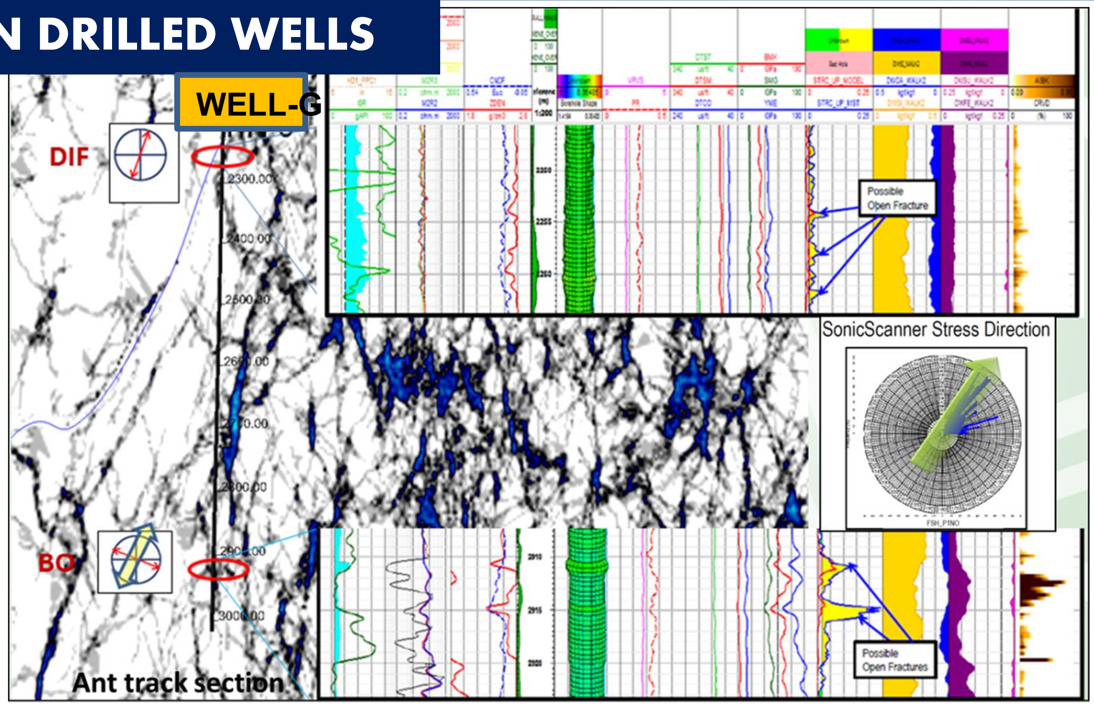


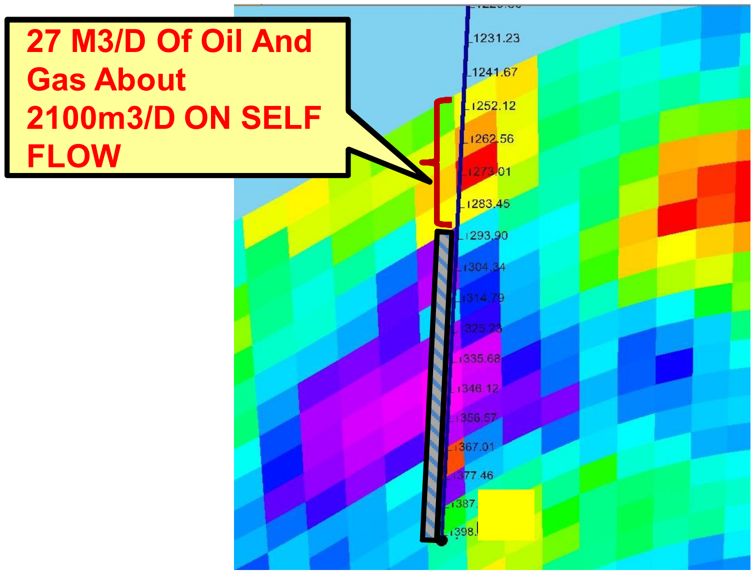


MODEL VALIDATION IN DRILLED WELLS

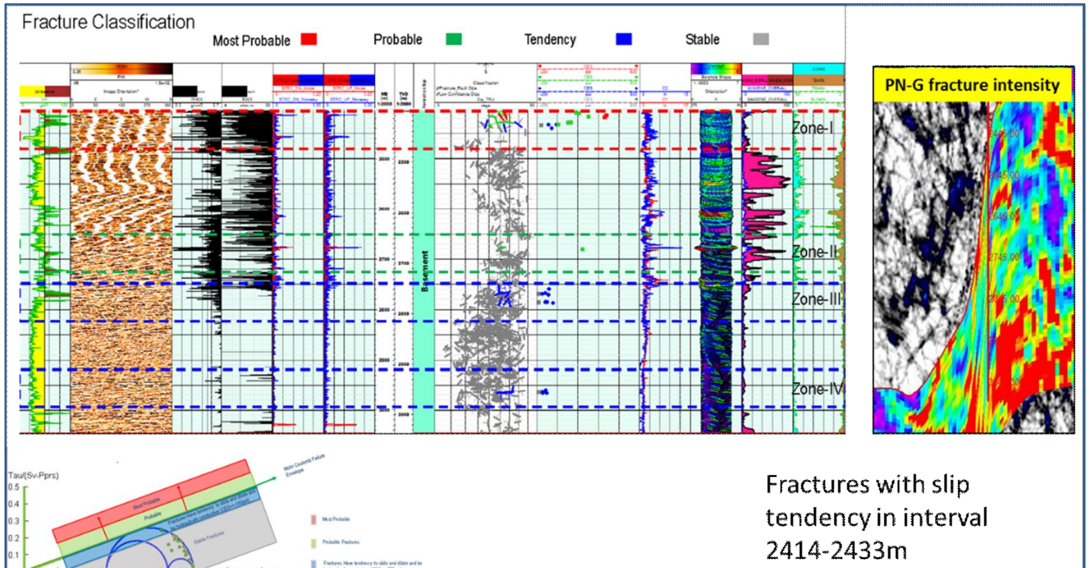


Development well in Madanam



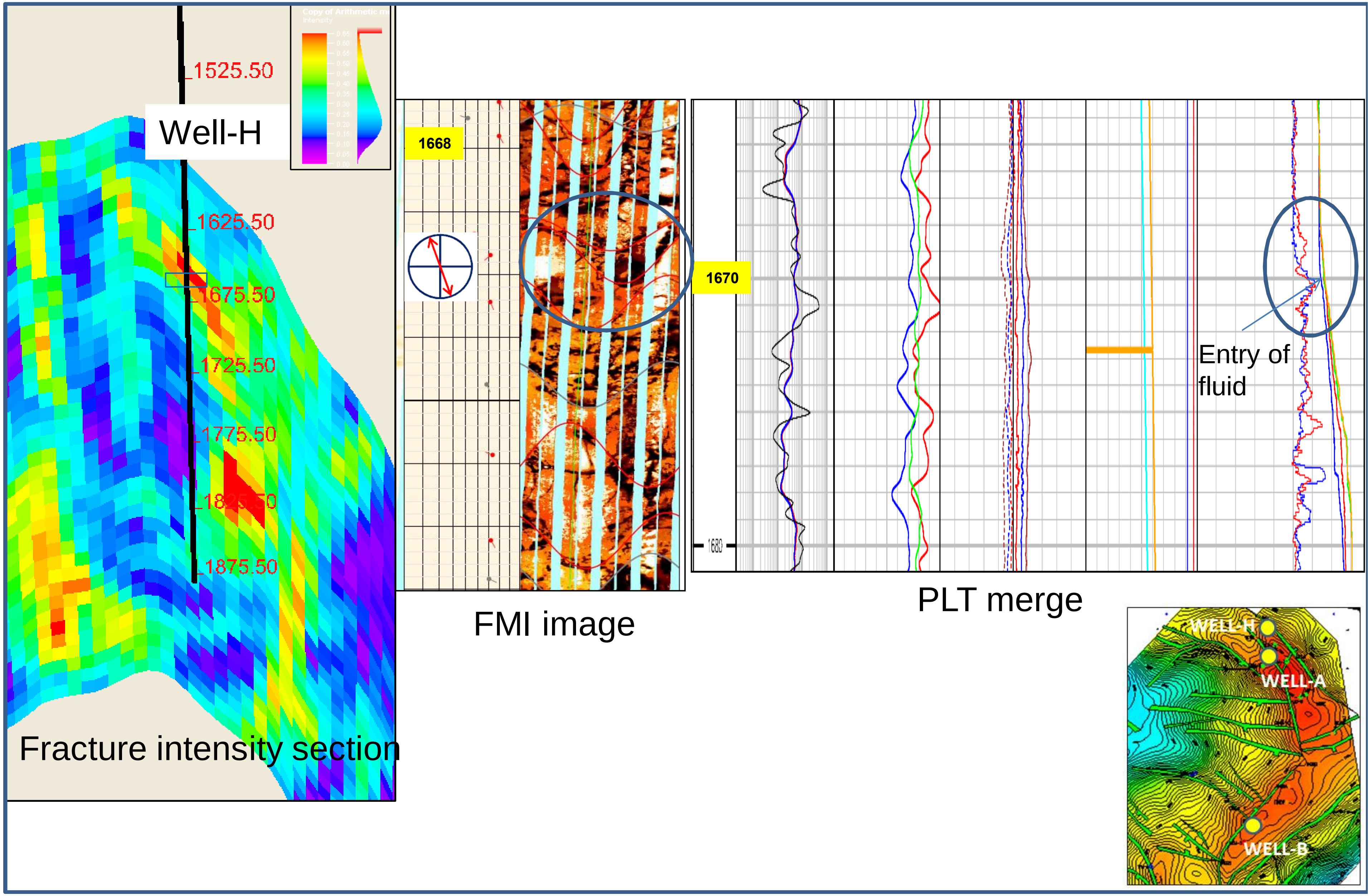


Development well in Pundi

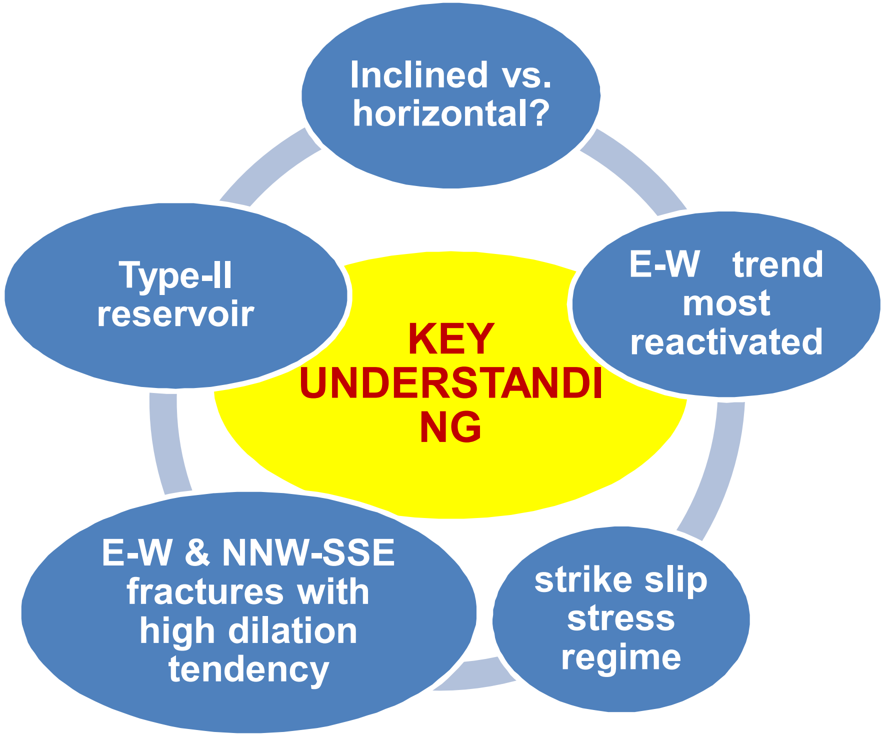


Exploratory well in Pandanallur

MODEL VALIDATION IN DRILLED WELL



KEY UNDERSTANDING AND WAY FORWARD



Advantages of integrated fracture model

- Effective visualisation of fault & fracture trends and network
- Anticipate fracture intensity and optimise well locations
- Design of suitable well stimulation and completion plan

Multi-pronged approach (integration of regional model, geomechanical model, stochastic fracture model) - the most realistic tool in HETEROGENEOUS granitic basement reservoirs of Cauvery Basin

Thanks for attention !