Multi-Scale Volcanic Facies Characterization of Deccan Volcanic Complex in the Barmer Basin of Rajasthan: Implication for Exploration in a Flood Basalt Province*

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Abstract

The Barmer Basin marks the northern limit of the Western Indian Rift system. It is a prolific hydrocarbon province with 38 discoveries and 6.4 BBOE in place. Cairn has discovered 3 fields in Deccan age volcanics, with over 700 MMBOIP. Raageshwari Deep Gas is the largest field, producing approximately 40 MMCFD of gas from a large rift block. The reservoirs are very similar to Deccan volcanic outcrops exposed in western and central India and form the northernmost limit. We map two seismic facies within the volcanic unit. The lowermost transparent unit is over 1000 m thick and unconformably overlies deeper reflections. It consists of very thin, compound braided and anastomosing lobes up to a few meters in thickness but covers broad areas. The upper reflective unit varies from 0-700 meters in thickness. It is dominated by much thicker (10-50 m) simple tabular basalt flows and pyroclastics. Porosity development and reservoir distribution are variable. The upper simple lava flows consist of a basal zone, a middle dense core with low vesicular porosity, and an upper highly porous (vesicular, brecciated/fractured) crust. The lower compound flows and ignimbrites have porosity controlled mainly by the amount of syn-depositional welding. Future volcanic hydrocarbon exploration requires an understanding of the emplacement processes, internal architectures, and controls on rock properties of the lava flows. We characterize the volcanic complex across the Barmer Basin integrating seismic, well logs, and core data. Learnings derived from this study can be applied widely to other basins and help delineate more resources within the Barmer Basin.

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Multi-scale volcanic facies characterization of Deccan volcanic complex in the Barmer Basin of Rajasthan: Implication for exploration in a flood basalt province

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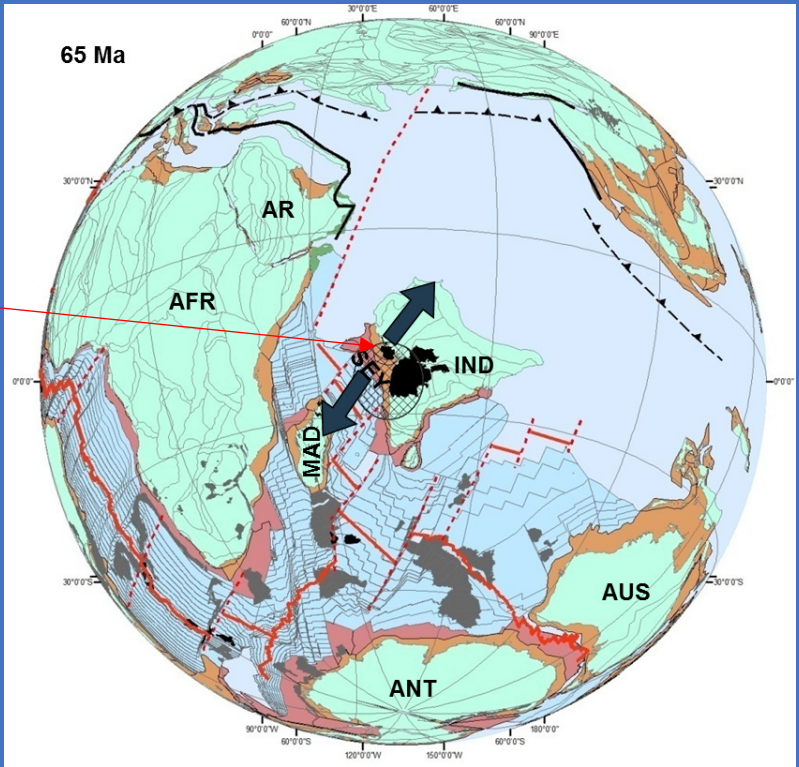
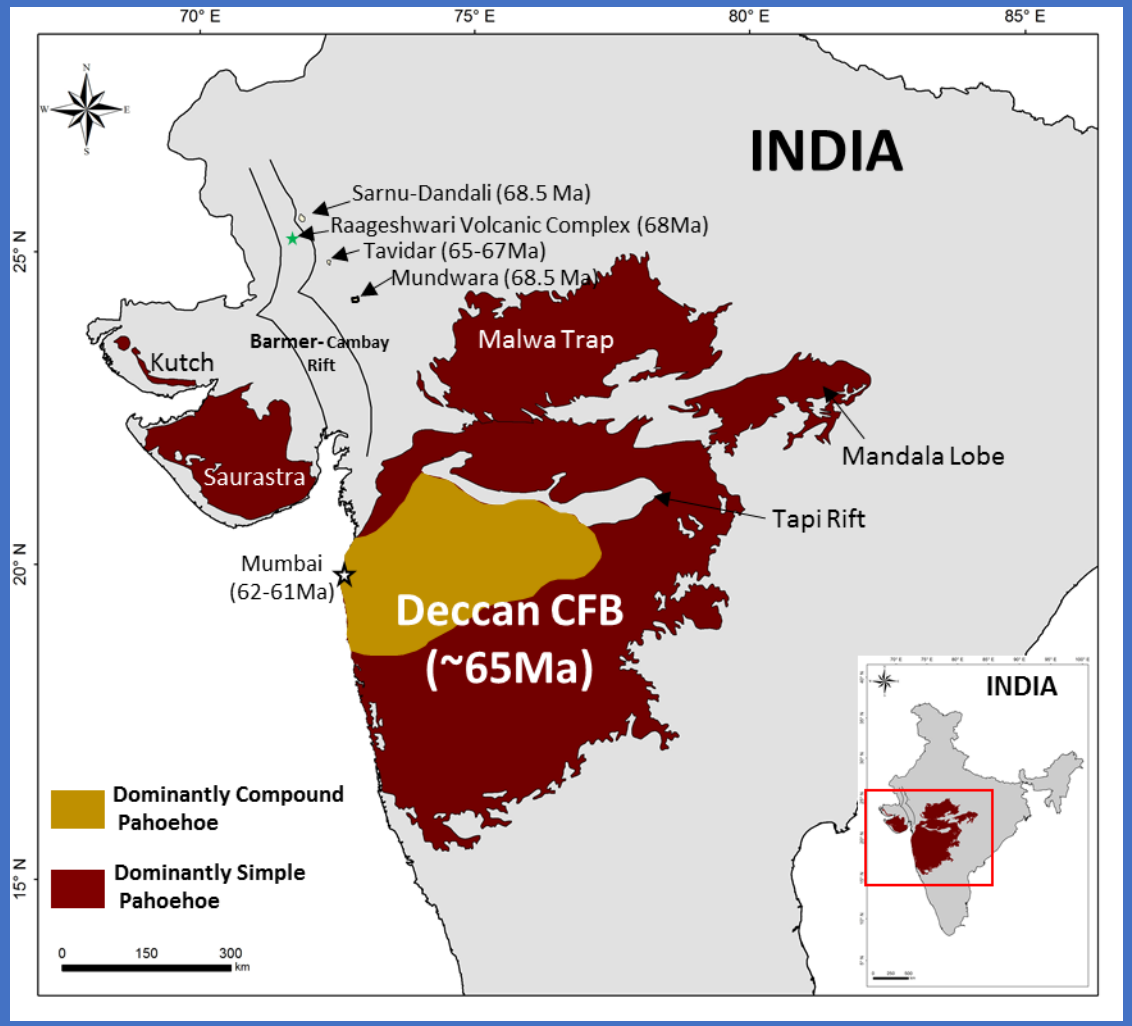
Seychelles Rifting and Deccan Volcanism in India

India- Seychelles Rifting

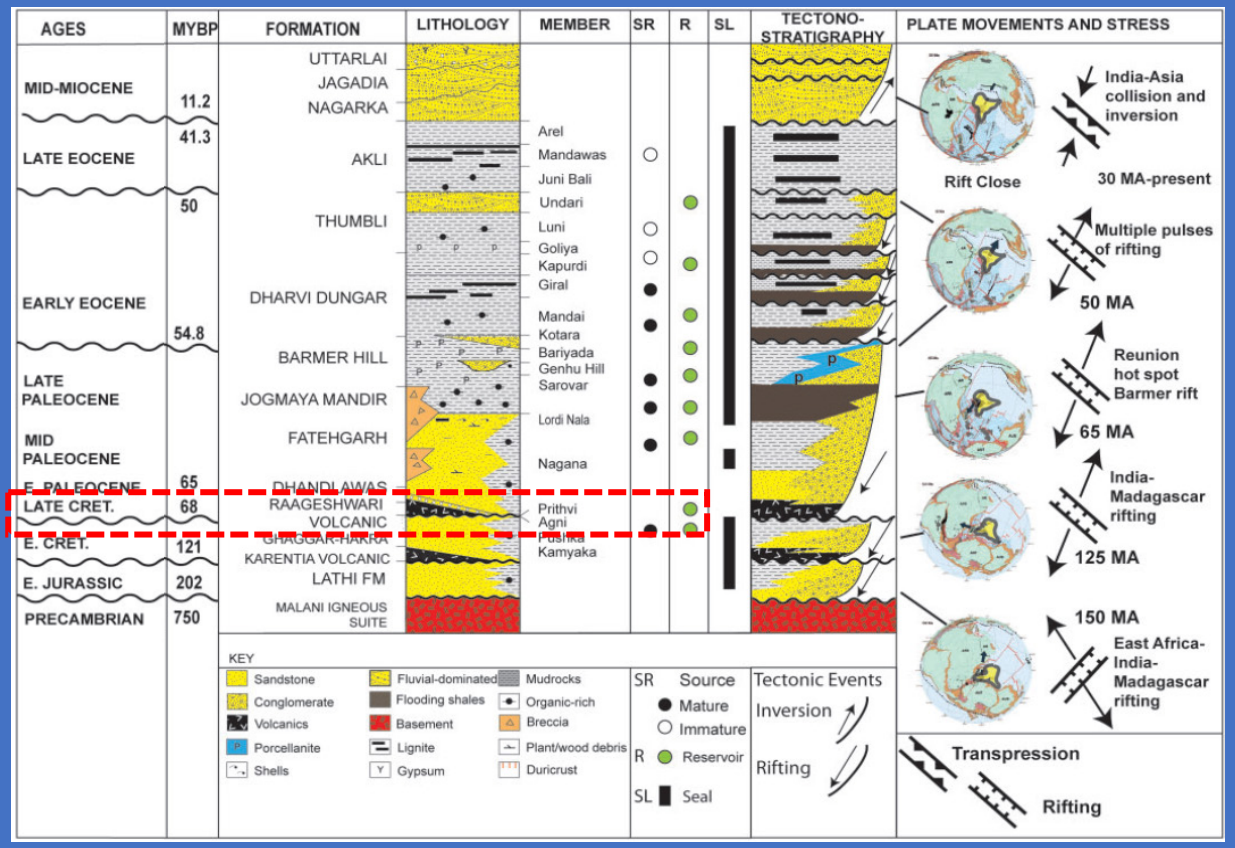


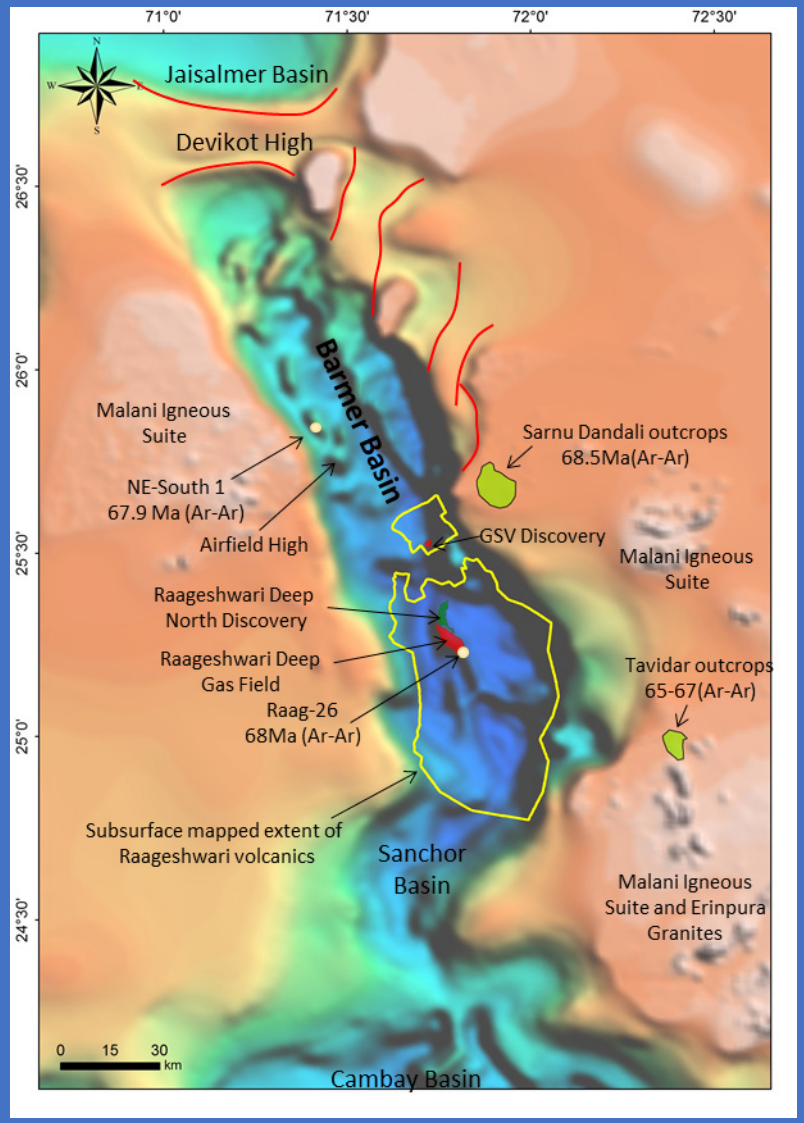
- Deccan volcanism: Continental flood basalt with area >**500000 sq. km.**
- Contemporaneous to Cretaceous- Paleocene (KT) global dinosaurs extension event
- Volcanic event result of reunion hotspot activity when Indian plate migrating northwards during Indian-Seychelles rifting



Surface Expression of Deccan Flood basalts in India

Barmer Basin Tectono-Stratigraphy and Deccan volcanism





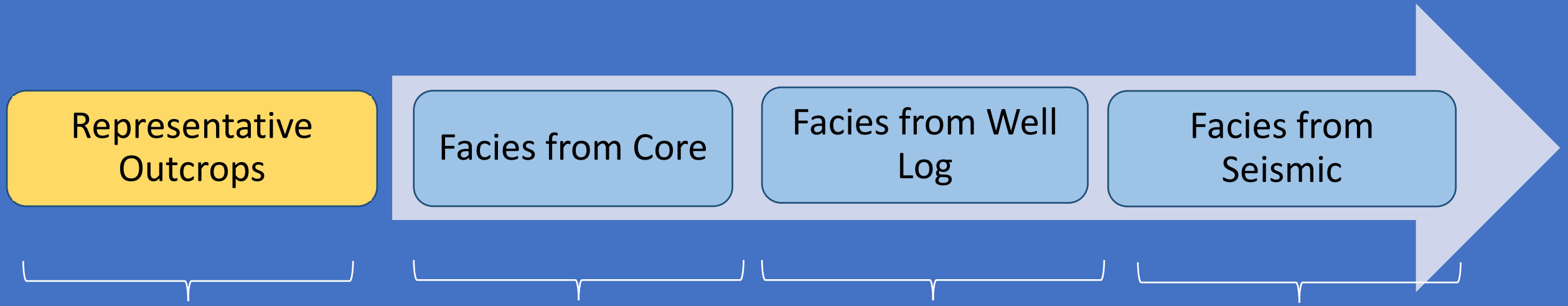
- Barmer Basin: NNE-SSW trending rift basin with ~6800 sq. km. area
- Deccan Volcanic Rocks known as Raageshwari Volcanic Complex in Barmer Basin with area **>2700 sq. Km**.
- 3 Oil and Gas fields in Volcanic rocks with over **700 MMBOIP**
- Raageshwari Deep Gas Field producing approximately **40MMCFD**

Why this Study?

- Prospects identification in Volcanic rocks
- Macro Scale volcanic Facies classification
- Core, well log, seismic data integration to constrain the 3D nature and structure of volcanic sequence in Barmer Basin
- Volcanic reservoir characterization for Reservoir derisking

Volcanic Facies Identification Approach

➢ 3 major scale Observations



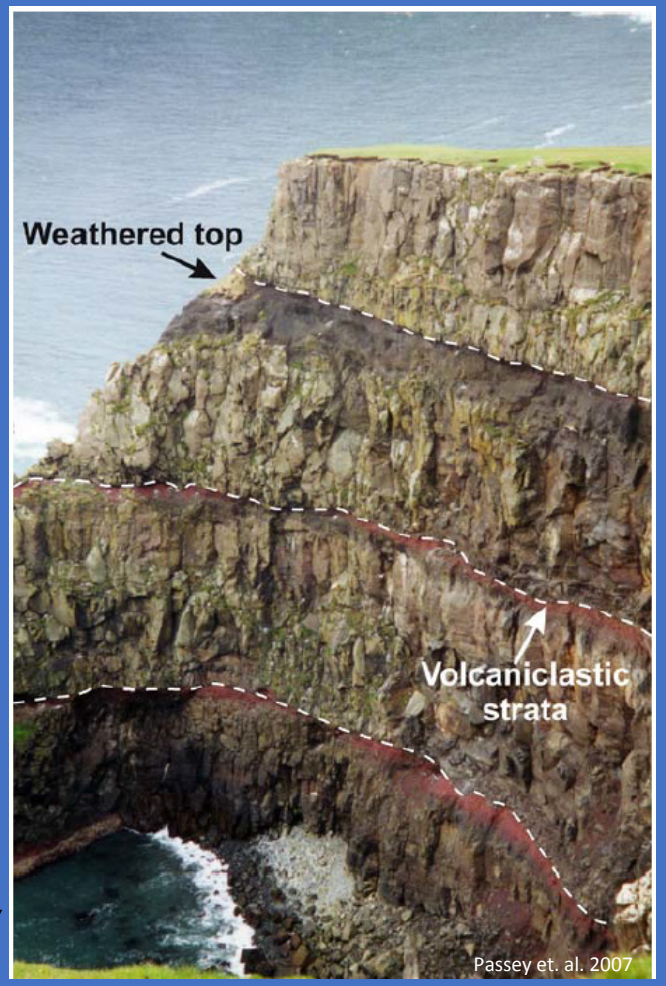
- Volcanic flow types
- Volcanic emplacement, architecture and process
- Multi-order features

- mms to meters
- Within lava flow scale
- 4th and 5th order features

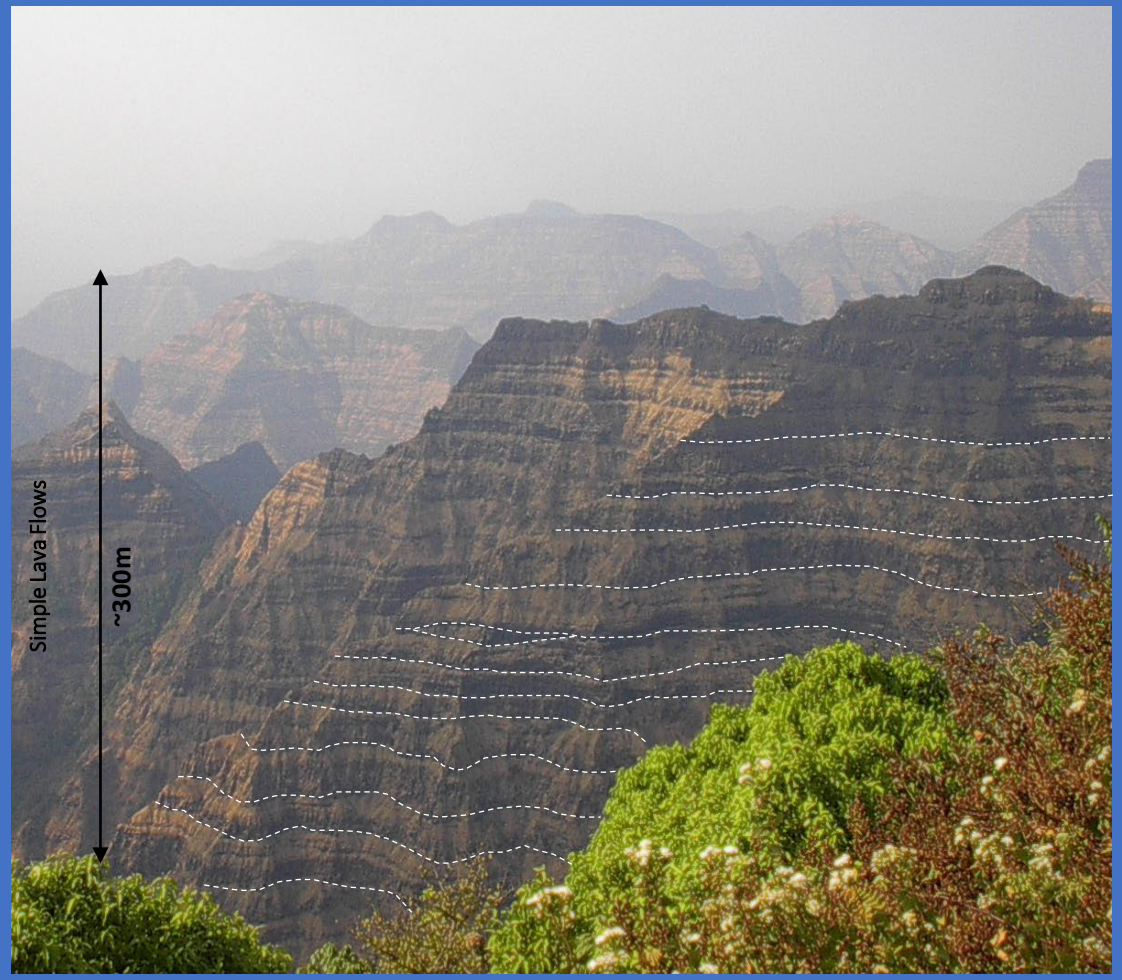
- mts to 100s of meters
- Lava flow to lava field scale
- 3rd order features

- Kms to tens of kms
- Province to seismic scale
- 1 and 2nd order features

Outcrops : Simple Pahoehoe Lava Flows

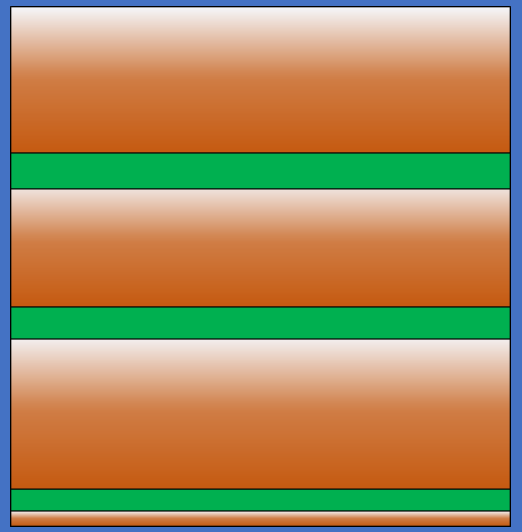


Simple flows, Beinisvord Formation, Faroe Island



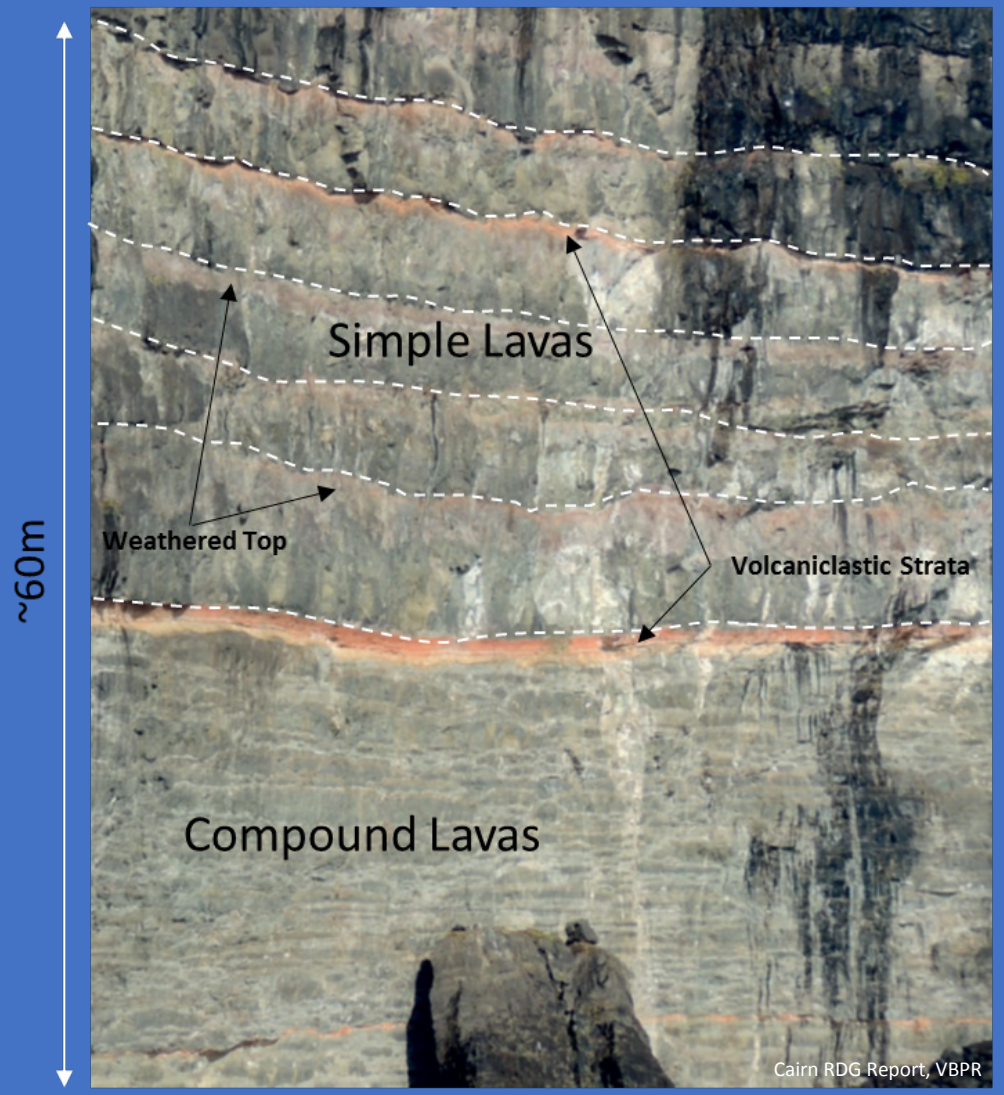
Deccan outcrops, Mahabaleshwar, India

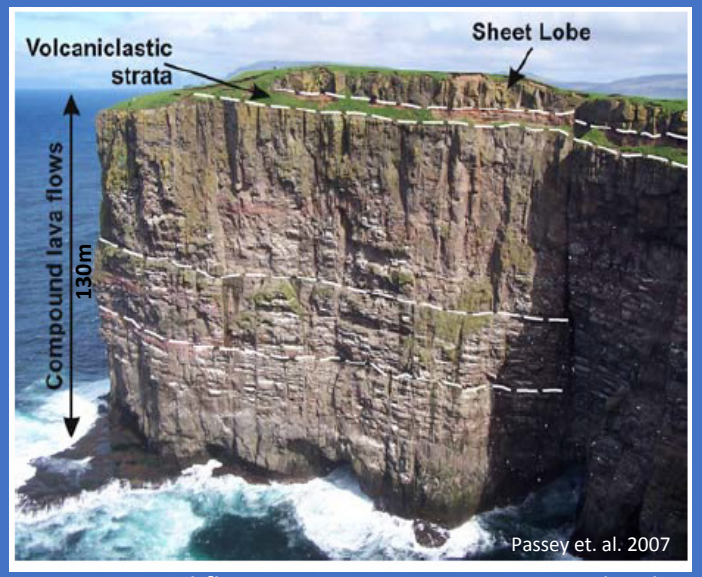
Architecture and connectivity



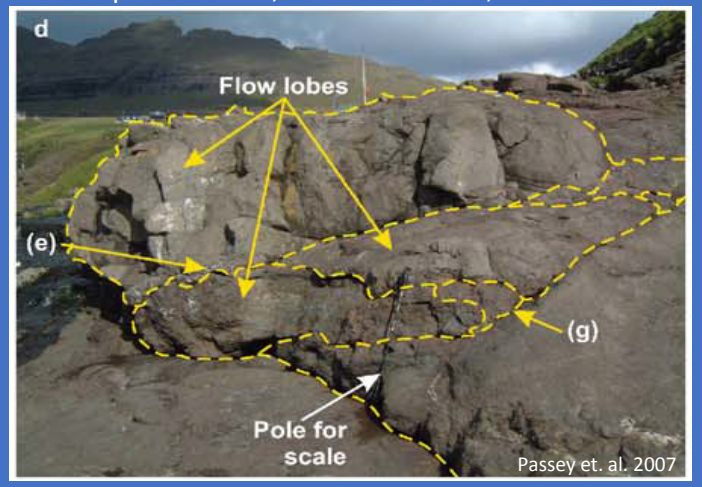
- High volume ,high effusion rate eruptions
- Laterally extensive in Deccan Volcanic Province (DVP)
- Dominant in upper Deccan Stratigraphy

Outcrops: Compound Pahoehoe Lava Flows



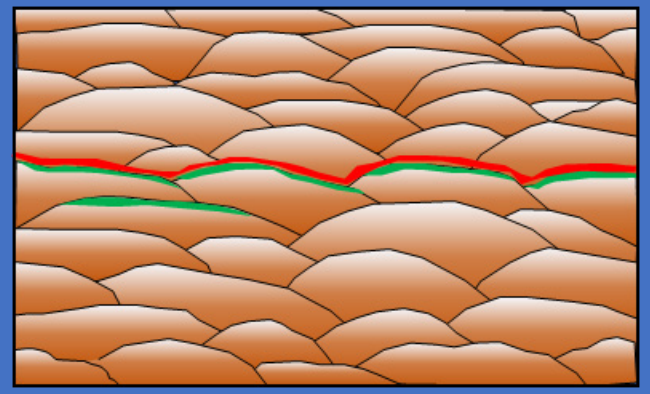


Compound flows, Enni Formation, Faroe Island



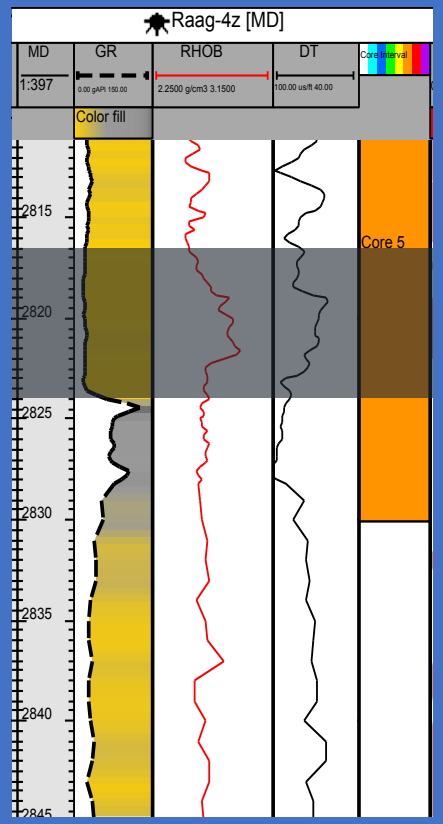
(e),(g): Compound flows lobes, Malinstindur Formation, Faroe Island

Architecture and connectivity



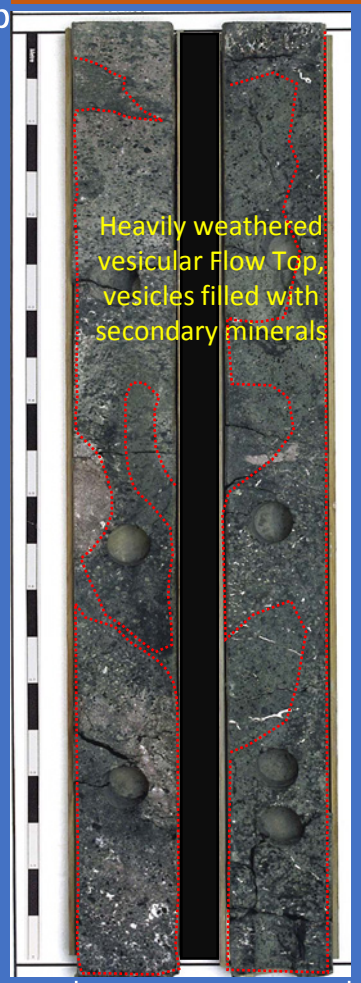
- Low volume, Low effusion rate eruptions
- Laterally constrained in DVP
- Dominantly in lower Deccan Stratigraphy

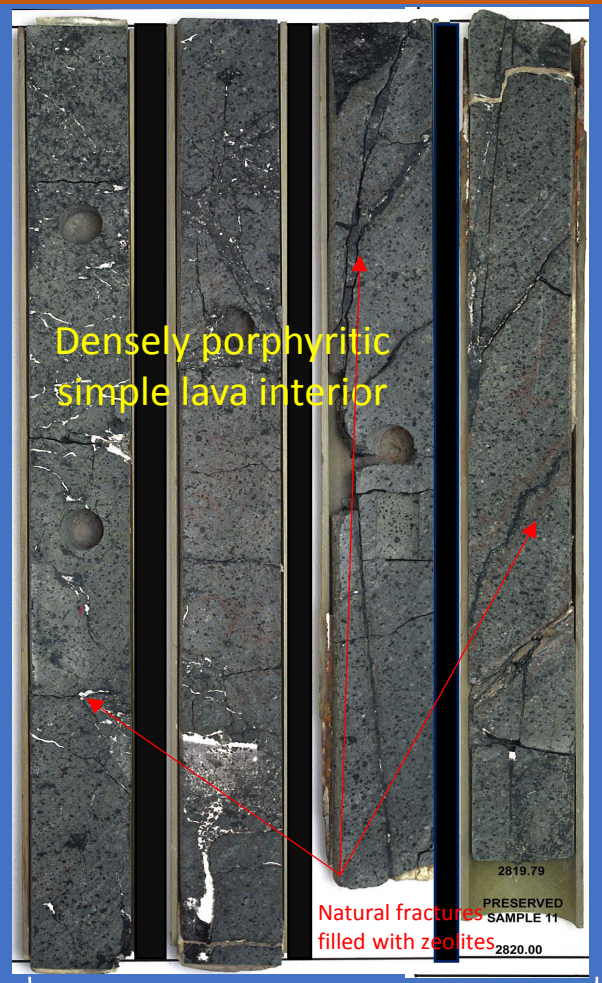
Volcanic Facies from Core



Simple Lava Flow unit

Top





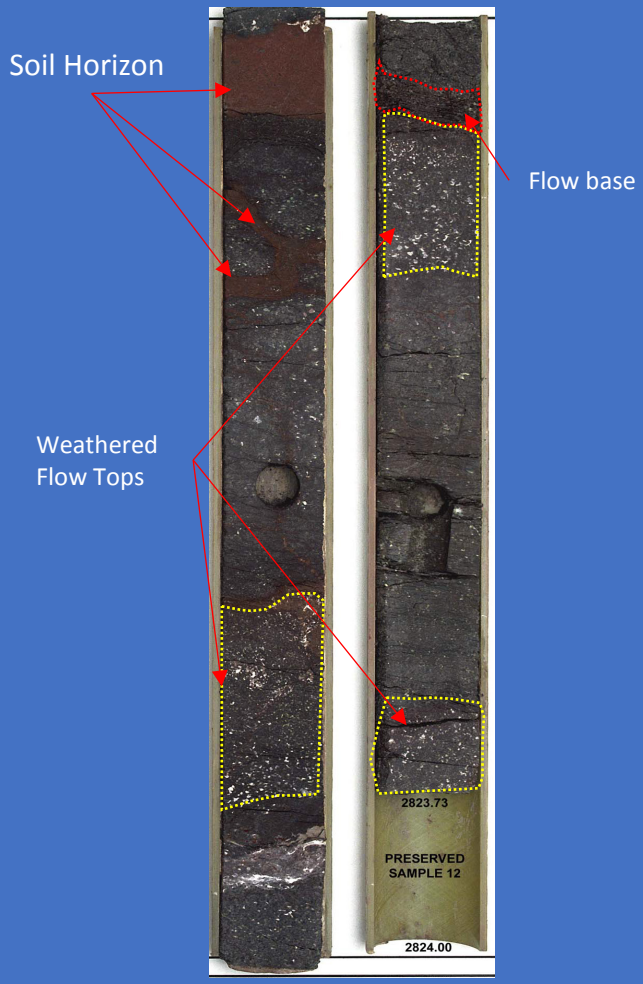
Bottom

Flow crust

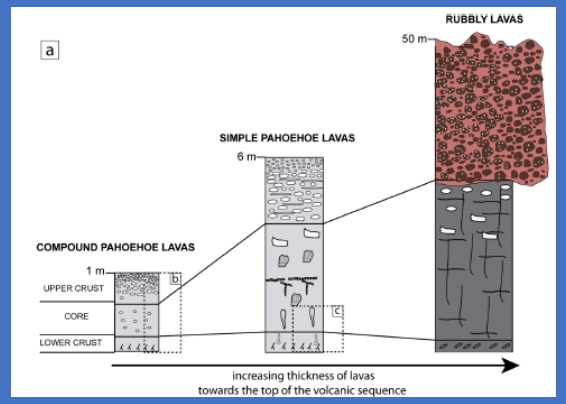
Flow core

Flow base

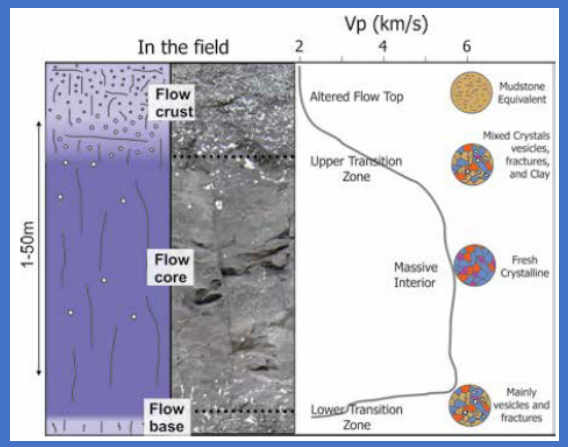
Compound flow lobes



Well Log Facies for Volcanic Sequence

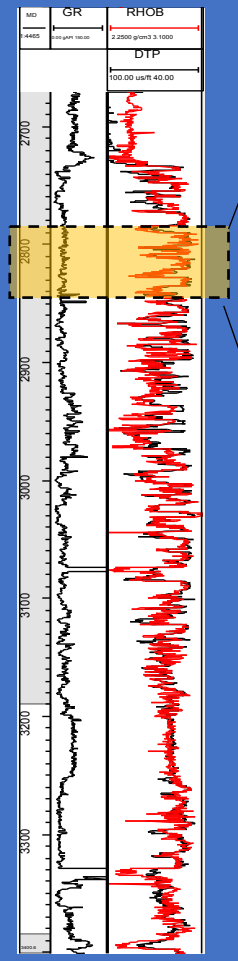


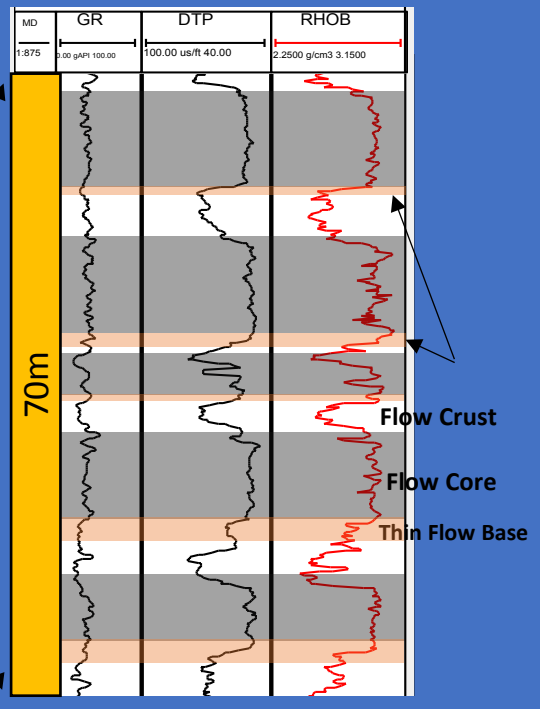
Barreto et. al. 2017

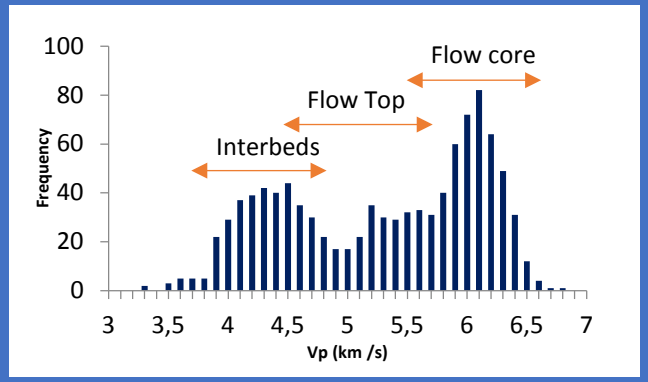


Nelson et. al. 2009

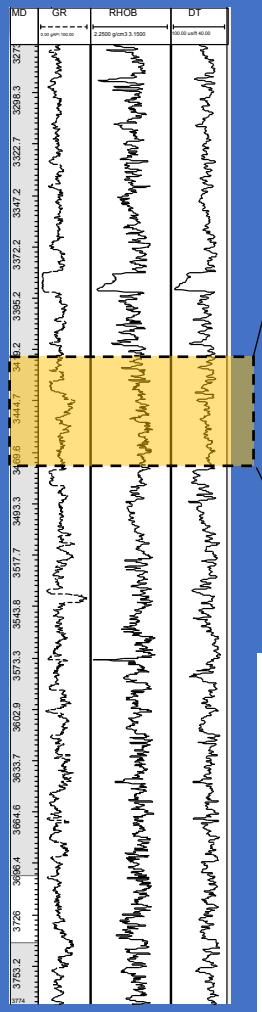
Simple Lava Flows

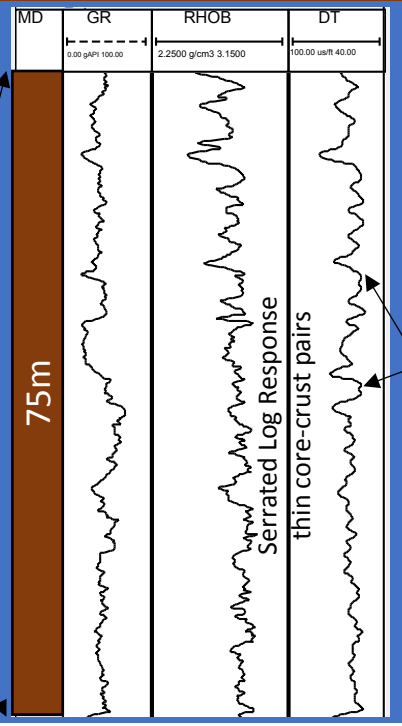


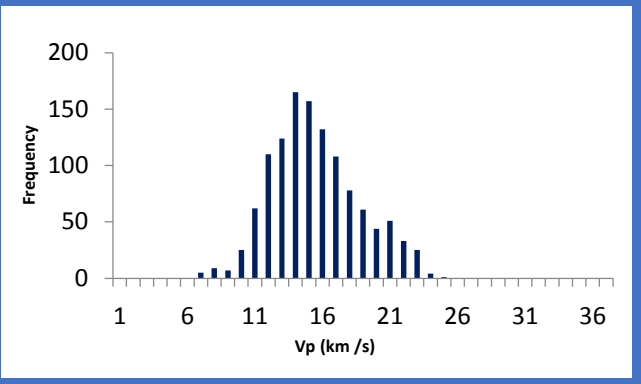




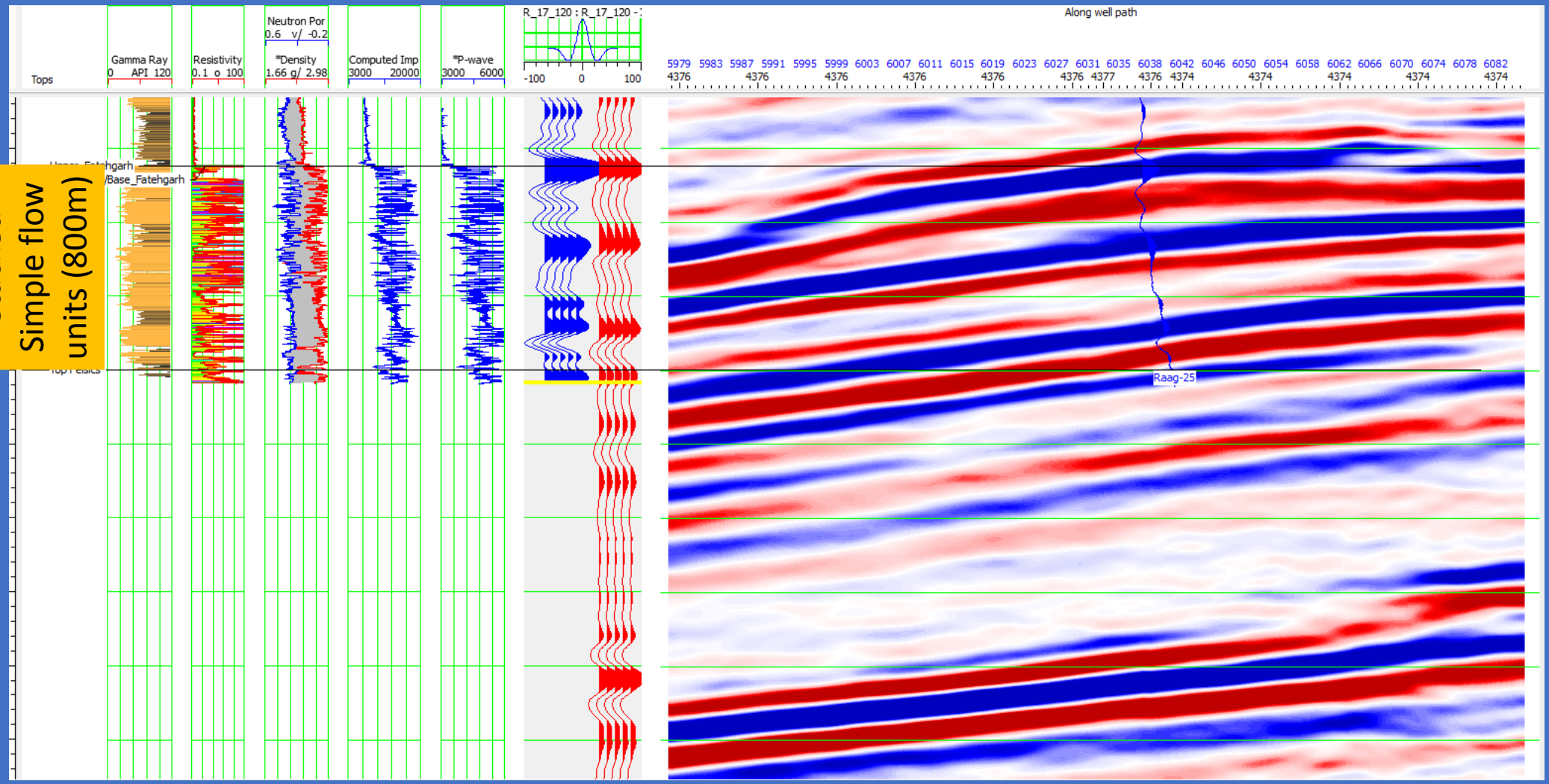
Compound Lava Flows



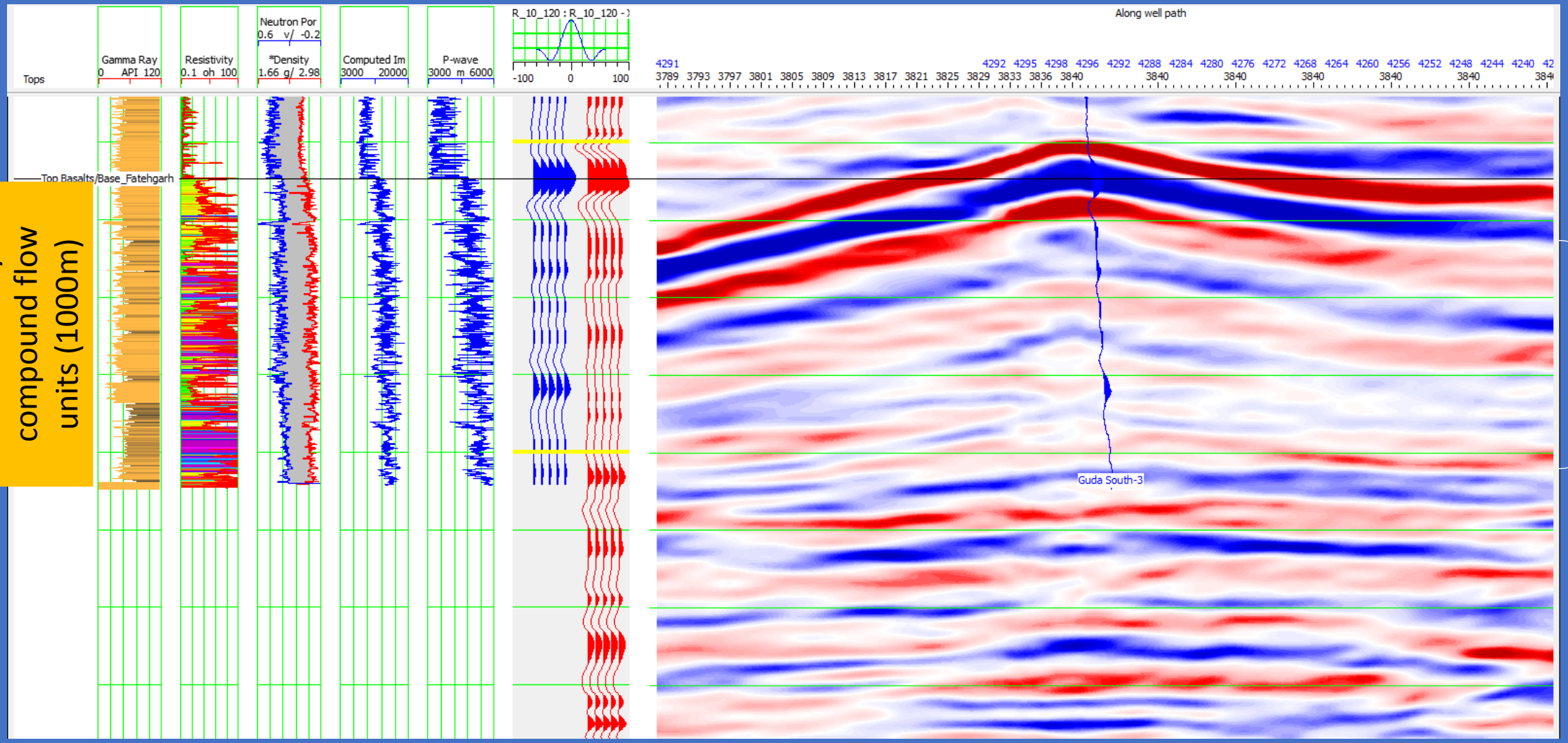




Simple Flow Well Tie



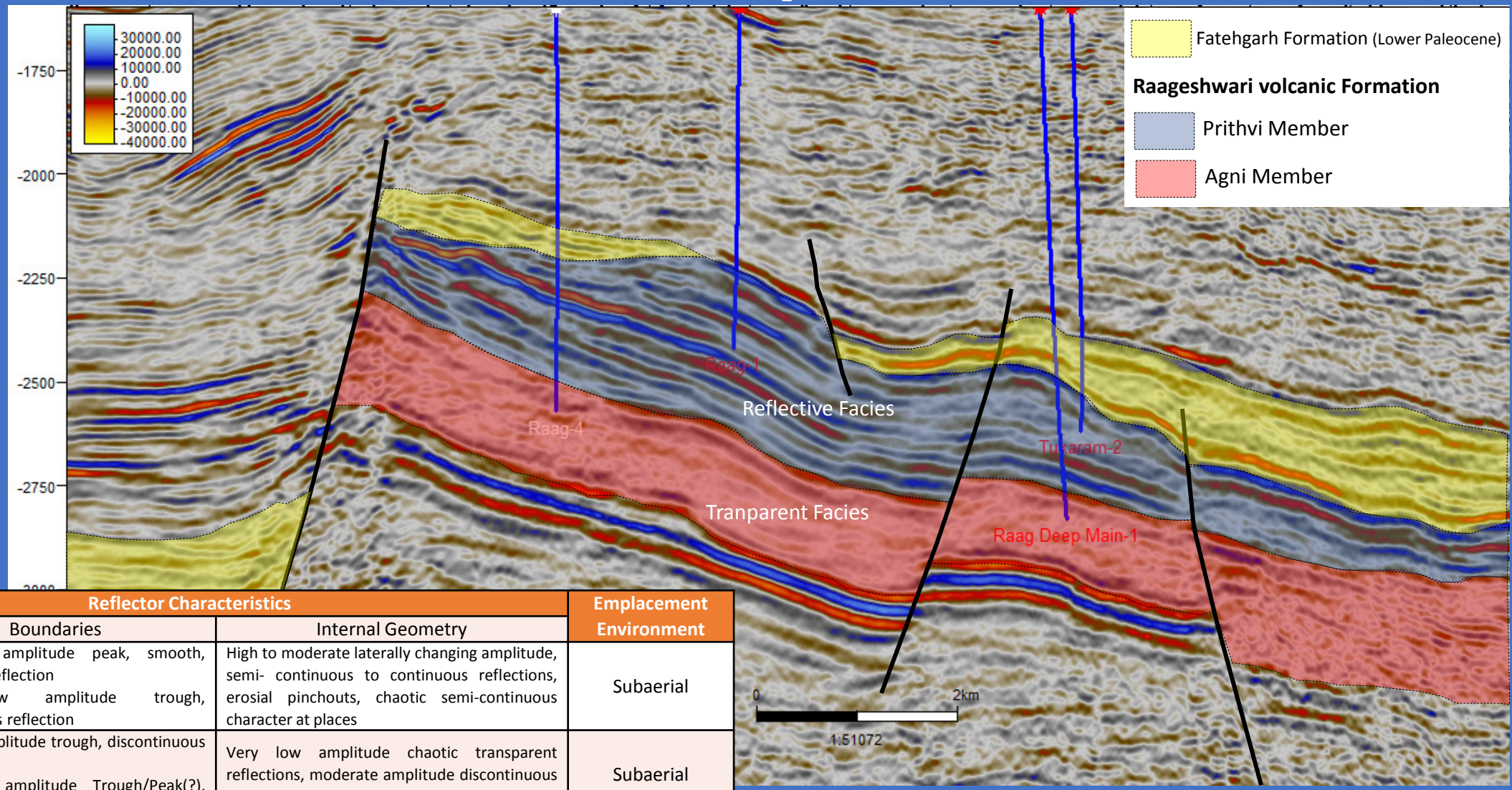
Compound Flow Well Tie



Dominantly compound flow units (1000m)

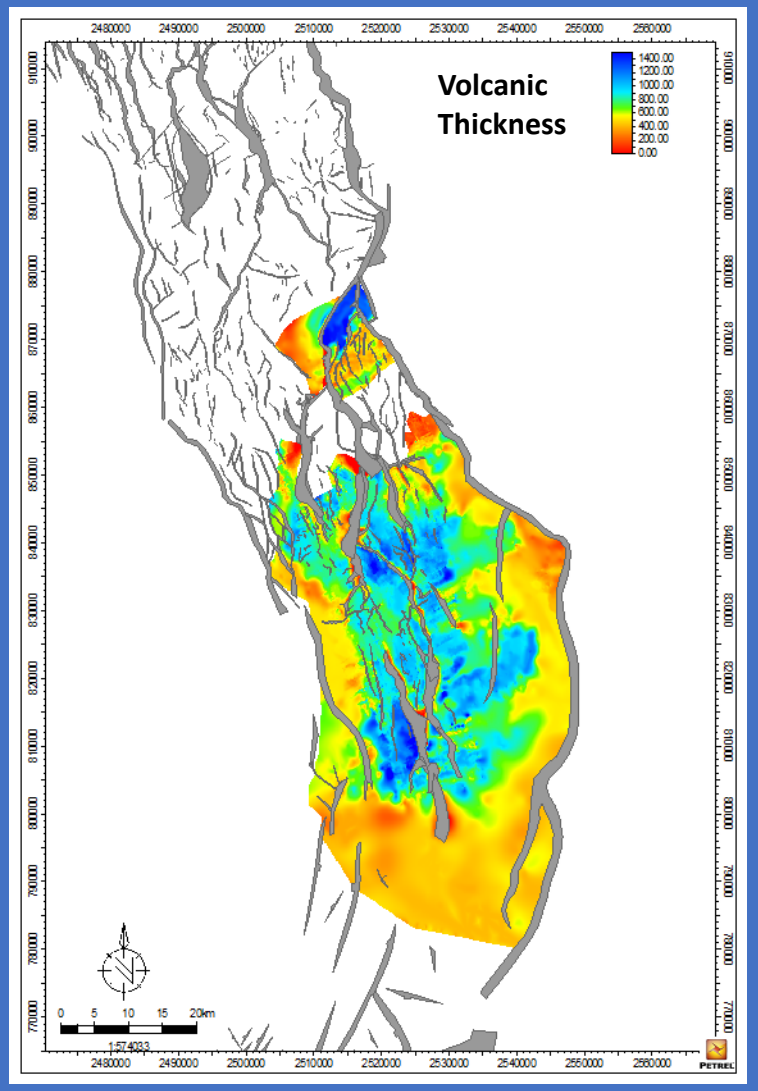
Transparent Seismic character

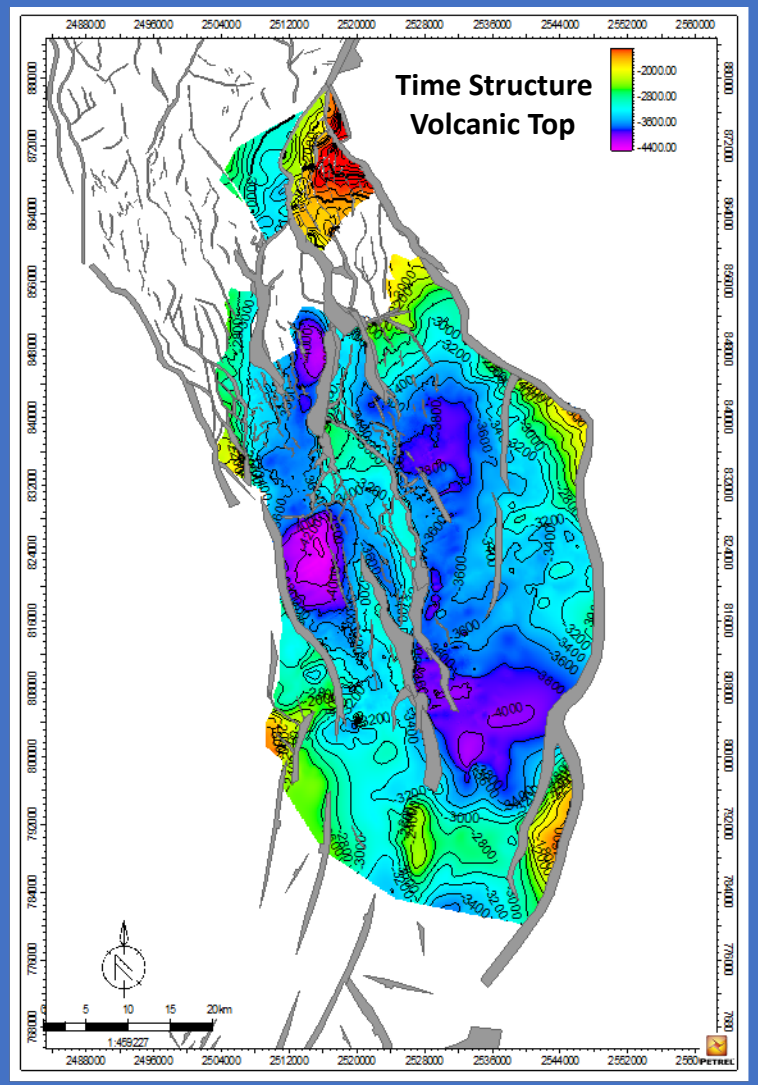
Seismic Facies for Volcanic sequence

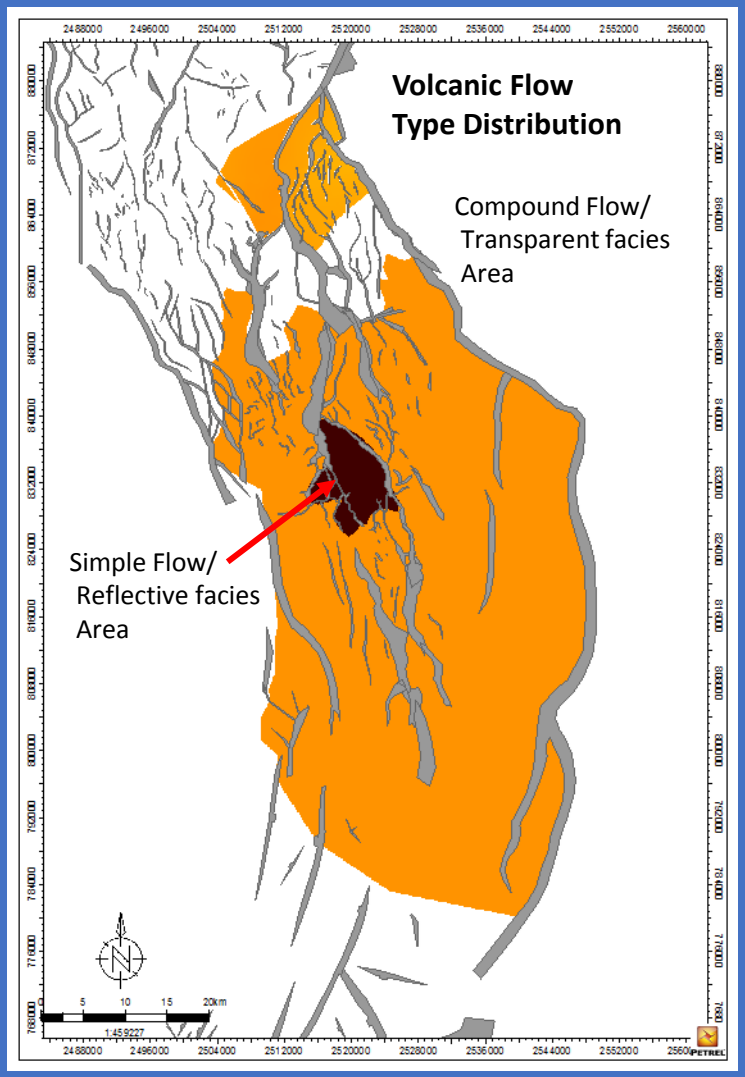


Seismic Facies	Reflector Characteristics			Emplacement Environment
	Shape	Boundaries	Internal Geometry	
Reflective	Wedge	Top: High amplitude peak, smooth, continuous reflection Base: Low amplitude trough, discontinuous reflection	High to moderate laterally changing amplitude, semi- continuous to continuous reflections, erosial pinchouts, chaotic semi-continuous character at places	Subaerial
Transparent	Sheet	Top: Low amplitude trough, discontinuous reflection Base: High amplitude Trough/Peak(?), smooth, continuous reflector	Very low amplitude chaotic transparent reflections, moderate amplitude discontinuous isolated reflections at places	Subaerial

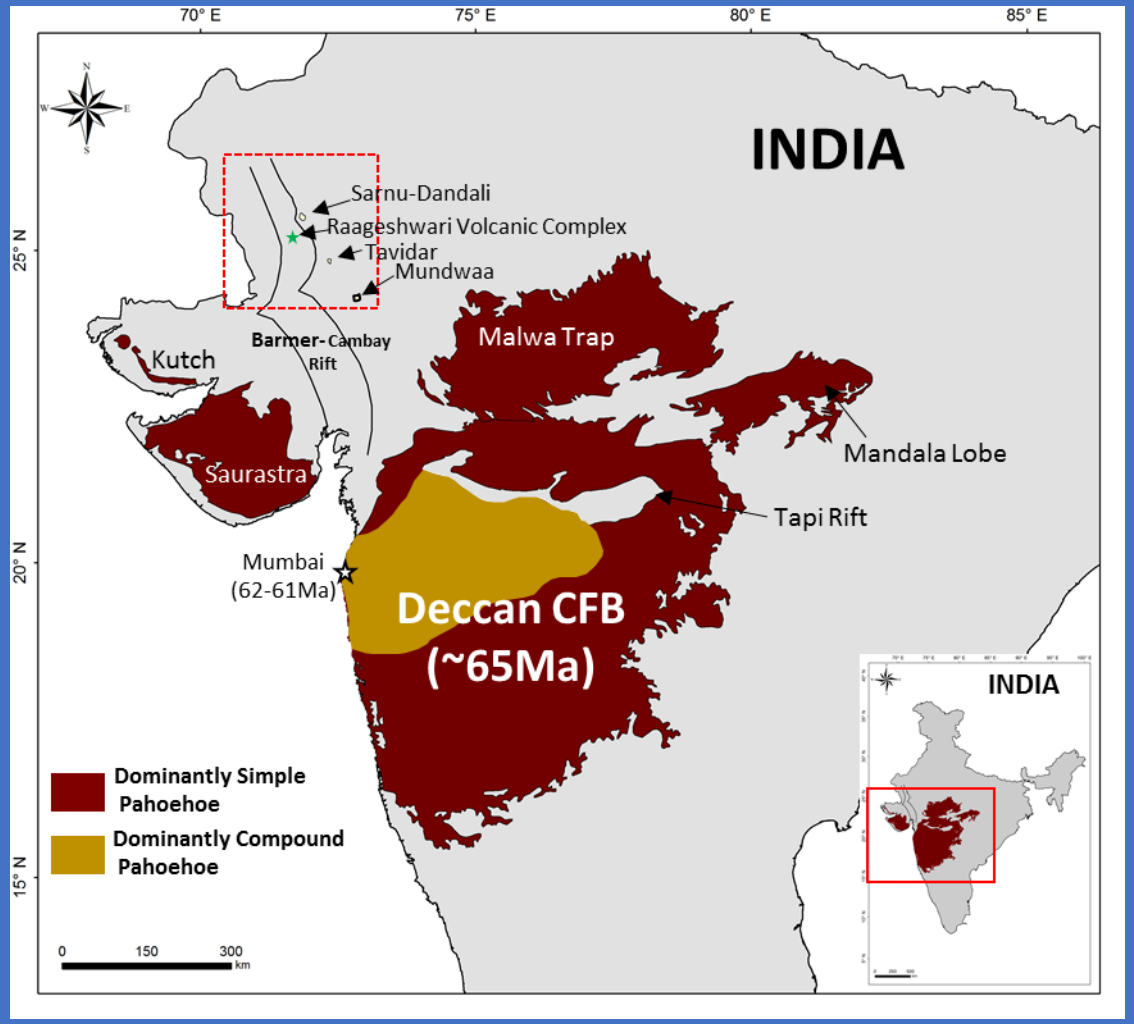
Volcanic Distribution in Barmer Basin



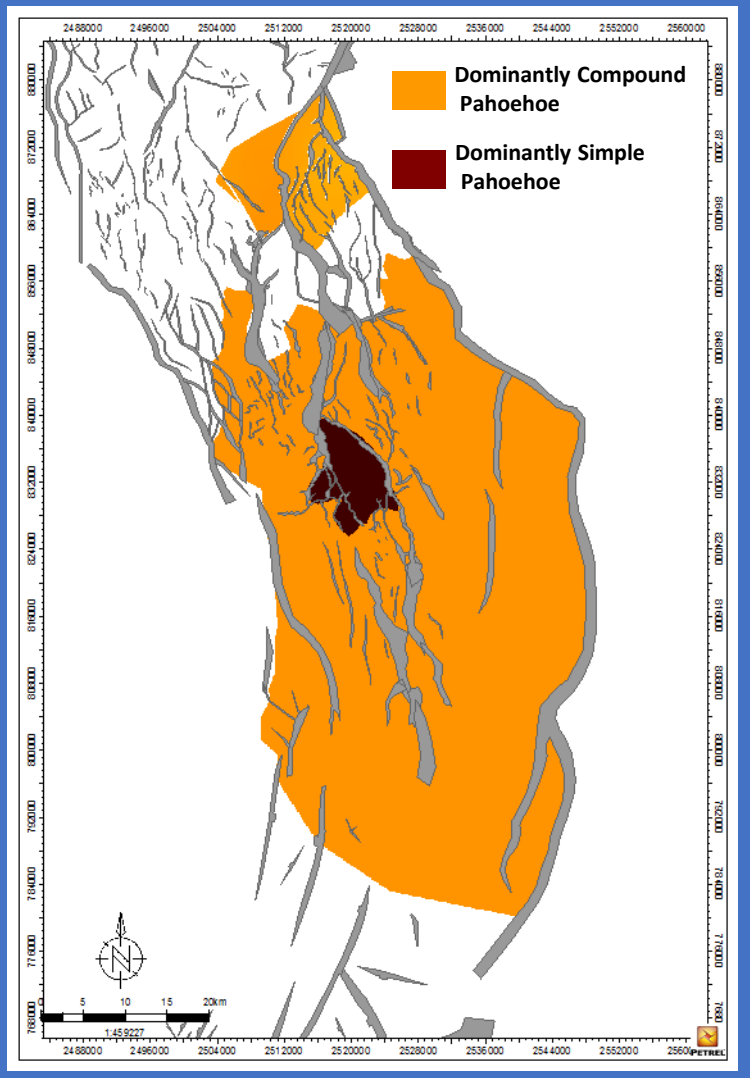




Regional Correlation

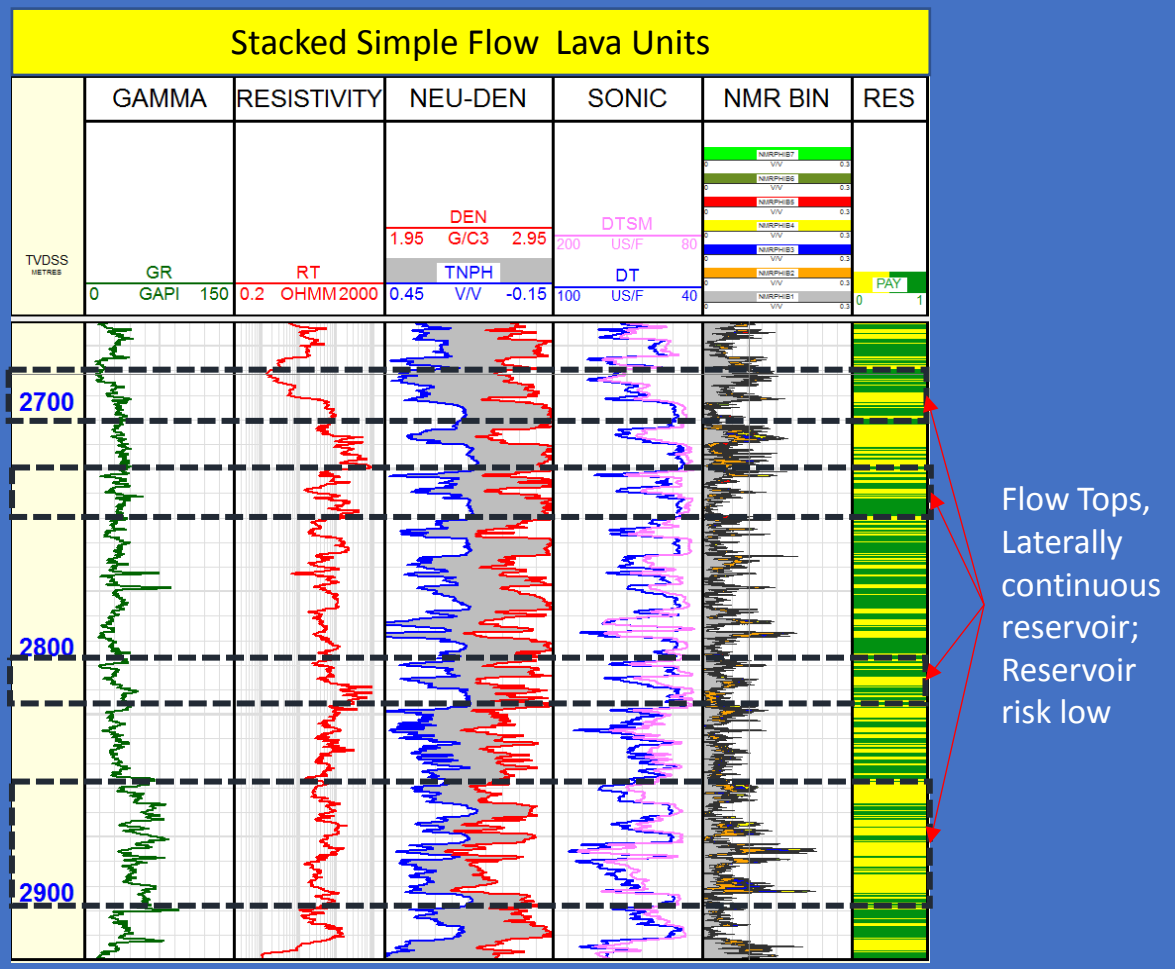


Surface Expression of Deccan Flood basalts

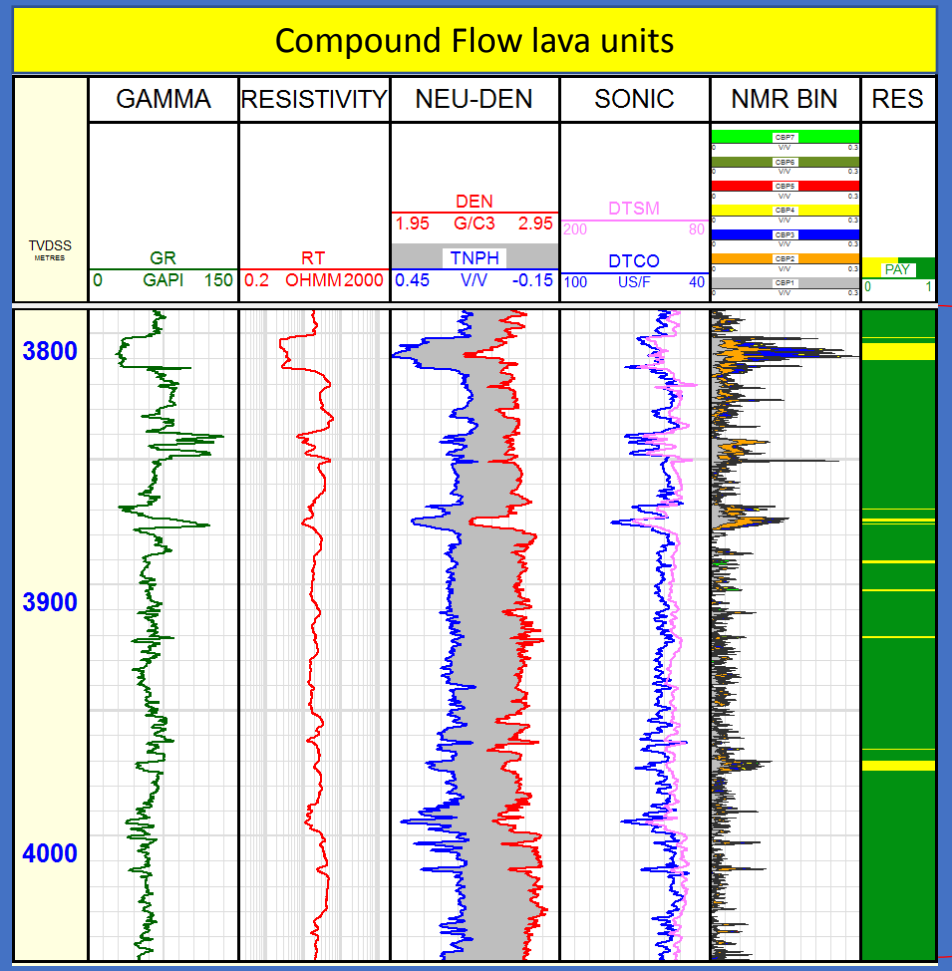


Subsurface Expression of Raageshwari Volcanic complex

Reservoir Distribution and Risk



Flow Tops, Laterally continuous reservoir; Reservoir risk low



Restricted Reservoirs Fractures and Joints Important; Reservoir Risk High

Conclusion

- Simple and Compound flood basalt eruptive lavas
- Effusion rate and volume controls emplacement architecture
- Integrated multi-scale volcanological characterization and correlation of volcanics in Barmer Basin
- Reflective and Transparent seismic volcanic facies in Barmer Basin
- Simple flow unit crust provide primary reservoir zones
- Reservoir in Compound flows is dependent on secondary mechanism i.e fractures etc

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