

Fractured Granite Reservoir Characteristics in Eastern Edge of Cuu Long Basin, Offshore Vietnam*

Tran Nhu Huy¹, Nguyen Dinh Chuc^{2,3}, Vu Viet Hung^{2,3}, Nguyen Van Thang^{2,4}, Nguyen Xuan Kha³, Truong Tuan Anh², Tran Van Lam², Nguyen Manh Tuan², Nguyen Xuan Vinh², and Hoang Viet Bach²

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¹Petrovietnam Exploration Production Corporation (PVEP), Ho Chi Minh City, Viet Nam (huytn@pvep.com.vn)

²Petrovietnam Exploration Production Corporation (PVEP), Ho Chi Minh City, Viet Nam

³Ho Chi Minh City University of Technology (HCMUT), Ho Chi Minh City, Viet Nam

⁴Ha Noi University of Mining and Geology (HUMG), Ha Noi, Viet Nam

Abstract

Following the first oil discovery (1987) in fractured granite reservoir (FGR) in Cuu Long Basin (CLB), offshore Vietnam, more and more oil was discovered and produced from fractured granite reservoir in Cuu Long Basin, which contribute around 65-75% production of Vietnam. However, most of these are distributed in the central areas of the basin. Recent exploration and production results in the eastern flank of Cuu Long Basin demonstrated hydrocarbon potential not only in the clastic reservoirs but also from the fractured granite reservoir. Beside the general characteristics of fractured granite reservoir such as: very low porosity compared to clastic and oil contained and flowed from fractures zones. There are several typical characteristics of the fractured granite basement reservoir in the faulted margin area of a rift basin. Throughout the case study in the eastern edge area of Cuu Long Basin, this paper discusses these characteristics: low relief, regular porous, early water breakthrough and the indications to detect fractured zones to determine subsurface targets and well total depth (TD) criteria for fractured granite reservoir in the margin area of the rift basin.

Geological Setting

CLB covers approximately 36,000 km² off the southeast coast of Vietnam. It is a Cenozoic continental rift basin, formed and developed on Pre-Cenozoic crystalline basement. The CLB geological evolution undergo as followings: (i) Pre-rift: late Jurassic – Paleocene; (ii) Syn-rift: late Eocene - early Miocene, which can be divided into 2 stages: early stage (ESR) from Eocene till early Oligocene and late stage from late Oligocene to early Miocene; and (iii) Post-rift: end of early Miocene till present day ([Figure 1](#)). The structural elements with main fault systems (NE-SW, E-W, NW-SE, N-S directions) and deformation phases in CLB are shown in [Figure 2](#). The potential and discovered reservoirs are Pre-Tertiary fractured granite, early Miocene, and Oligocene sandstones.

Discussion on Characteristics of FGR in the Eastern Edge of CLB

Petroleum System

The Eocene-early Oligocene lacustrine organic rich shale units contain average values of TOC from 3.1% to 18.12%, S₂ >10 mg/g and HI > 500 mg/g. Kerogen type I and II indicate that the black shales not only are high potential source rock (Figure 3) but also are capable of acting as top seals for the underlying fractured granite basement reservoirs overlapped by Oligocene basal sandstones. The hydrocarbon generation timing of those shale layers started in early Miocene; however, the strong generation and expulsion occurred in middle-late Miocene up to present days.

Migration took place during Miocene following multiple paths from clastic sections into the fractured granite basement as shown in Figure 4. The traps were formed during early syn-rift stage (Eocene – early Oligocene) as 2-3 way faulted structures parallel with the Con Son swell. The fractured granite basement reservoir is described as dual-porosity and single-permeability model in which oil is stored in both macro and micro fracture systems and the main flow is coming from macro fractures with micro fracturing as supporting role for the long-term production. (Figure 5)

Reservoir Characteristics

The general characteristics of FGR in CLB include seismic, petrography, petrophysics, and dynamic behaviors are illustrated in Figure 6, Figure 7, Figure 8, and Figure 9. The distinctions between the FGR in the eastern edge of CLB are compared and discussed with respect to the FGR in central area of the basin.

Impacts on Optimum Well Design

The existence of Oligocene basal sandstone units with similar physical characteristics such as velocity, density, lithology, etc. to the underlying FGR at some structures in the eastern edge of the basin led to the incorrect picking of Basement tops in seismic interpretation prior to drilling (Figure 6) as well as during drilling and logging. Consequently, the casing point has not been optimized for separate well testing and later production isolation between clastic and basement sections. Correspondingly, the eventual well cost is high with inconclusive comingle data. These problems can be strongly mitigated with the integration of side wall core and image log analyses to get the correct top basement picking (Figure 10).

One of the key elements for a successful exploration wells with FGR target is to intercept as many fractured zones as possible. Therefore, it is crucial that the well trajectory be designed to serve such purpose. However, for FGR in the edge of rift basin having medium vertical thickness below 500 m, early water coning is inevitable if the well TD is too close to the water zone. Experiences and lesson learnt from drilling in the eastern edge of CLB have demonstrated that the well trajectories should be designed to intercept many fractured zones in FGR while having shallower well TD of at least 50 to 100 m above structural spill or free water level (Figure 11).

Conclusions

Recent exploration and production results in the eastern flank of CLB have revealed hydrocarbon potential not only in the clastic reservoirs but also from the FGR.

Beside the general characters of FGR such as: very low porosity compared to clastic, oil contained and flowed from fractures zones, there are typical characteristics of the fractures granite basement reservoir in the faulted margin area of a rift basin as following:

- 2-3 way faulted structures formed during early syn-rift stage and parallel with Con Son swell.
- Low relief compared to the reservoir in central areas (200-500 m vs. 1000 m).
- The reservoir formed under tectonic activities: faults and accompanied shear and tension fractures.
- Usually underlying a basal sandstone unit with similar physical characteristic → Incorrect top of basement picking prior and while drilling.
- Earlier water conning than the FGR in the central area of CLB.

Lessons learnt for optimum well design in FGR in the eastern flank of CLB:

- Applying Seismic Attributes (EPS, An-tracking...) to define multi sub-surfaces targets in fractured granite reservoir → optimum well trajectory for fractures interception.
- TD concept: at least 50-100 m shallower than spill to avoid early water conning.
- Image logs and sidewall core are useful data to correctly identify top of basement for isolation with above clastic formation → support accurate casing shoe depth for proper testing and production.

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Selected References

Dong, L.T., and H.D. Phung, 2007, Cuu Long Sedimentary Basin and Petroleum Resources: The Petroleum Geology and Resource of Vietnam, Vietnam Science and Technics Publishing House, Chapter 9, p. 277-324.

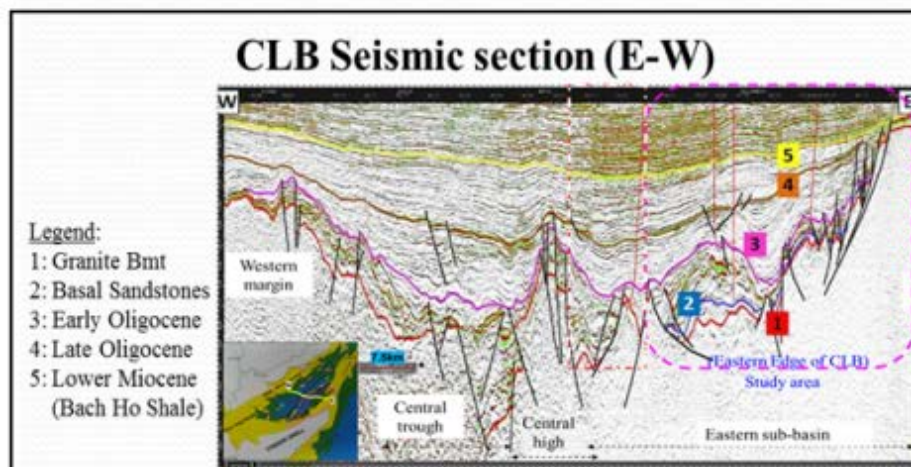
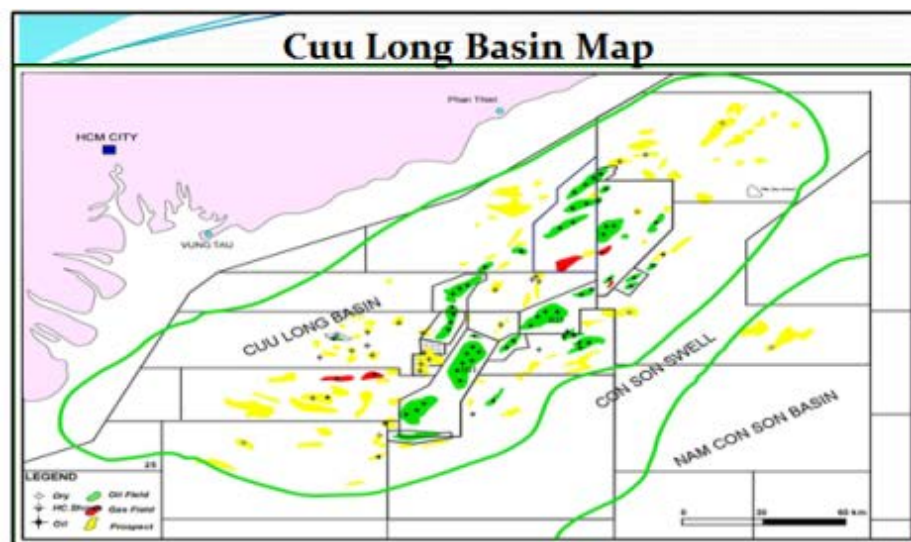
Lambiase, J.J., and C.K. Morley, 1999, Hydrocarbons in Rift Basins: The Role of Stratigraphy: Philosophical Transactions of the Royal Society of London, v. 357/1753, p. 877-900.

Ngoc, H.N, Q.N. Quan, N.H. Dong, H.P. Long, and N.T. Huy, 2009, Application of “From Seismic Interpretation to Tectonic Reconstruction” Methodology to Study Pre-Tertiary Fractured Granite Basement Reservoir in Cuu Long Basin, Southeast Vietnam Offshore: AAPG International Conference and Exhibition, Rio de Janeiro, Brazil, November 15-18, 2009, [Search and Discovery Article #40507 \(2010\)](#). Website accessed January 2018.

Hung, D.N., and V.L. Hung, 2003, Hydrocarbon Geology of Cuu Long Basin – Offshore Vietnam: AAPG International Conference, Barcelona, Spain, September 21-24, 2003, [Search and Discovery Article #10062 \(2004\)](#). Website accessed January 2018.

Huy, T.N., H.N. Dang, and V.T. Xuan, 2015, Hydrocarbon Potential of Early Syn-Rift Plays in the Flank of Continental Rift Basin: A Case Study in the Eastern Edge of Cuu Long Basin, Offshore Vietnam: SPE-177815-MS, Abu Dhabi International Petroleum Exhibition and Conference, 9-12 November, Abu Dhabi, UAE, 10 p.

Huy, T.N., N.Q. Thap, H.N. Dang, T.M. Cuong, V.T. Xuan, N.D. Chuc, N.X. Vinh, and T.V. Lam, 2016, Factors Controlling Sedimentary and Petroleum System of Early Syn-Rift Plays in Faulted Margin of Continental Rift Basin: An Example in the Eastern Edge Cuu Long Basin, Offshore Vietnam: AAPG/SEG International Conference & Exhibition, Cancun, Mexico, September 6-9, 2016, [Search and Discovery Article #10878 \(2016\)](#). Website accessed January 2018.



CLB Stratigraphy Column

ERA	PERIOD	EPOCH	SUB-EPOCH	FORMATION	LITHOLOGY	Stratigraphic sequence	TOC	DESCRIPTION	Environment	Tectonic events
CENOZOIC	NEOGENE	PLIOCENE		BEN DONG		CL.10 CL.11 CL.12		Coarse grained sand, clay, interbedded with carbonate, coal, fossil: <i>Dacrydium</i>	Marine	POST - RIFT
				DONG NAI		CL.20 CL.21 CL.22		Fine - coarse sand, clay, carbonate, coal, fossil: <i>Stenoceras</i>	Planktonic	
		MIOCENE	Upper	CON SON		CL.30 CL.31 CL.32		Sand, clay, carbonate and coal, fossil: <i>F. Moridona</i>	Shallow marine	
			Lower	BACH HO		CL.40 CL.41 CL.42		Sandstone, siltstone, clay and claystone interbedded, fossil: <i>F. Levipol</i> , <i>Magnesianites</i>	Lagoon, lacustrine	
				TRA TAN		CL.50 CL.51 CL.52		Claystone, siltstone and sandstone interbedded, and fossil: <i>F. Tridacna</i> , <i>Vermeticolporites</i> , <i>Cicatricolporites</i>	Lacustrine, alluvial	
	PALEOGENE	OLIGOCENE	Upper	TRA CU		CL.60 CL.61 CL.62		Sandstone, claystone and siltstone interbedded, Palyno: <i>Oculopollis</i> , <i>Magnesianites</i>	Lacustrine, alluvial	SYN - RIFT
			Lower	CA COI		CL.70 CL.71 CL.72		Gravelstone interbedded with thin clay layer, Palyno: <i>Oculopollis</i> , <i>Magnesianites</i>	Deltaic, alluvial	
		Eocene				CL.80		Granite, granodiorite basement, fracture metamorphic rock		
	PRE CENOZOIC					CL.90				PRE - RIFT

Figure 1. CLB location map, Seismic (E-W) section and Stratigraphy column.

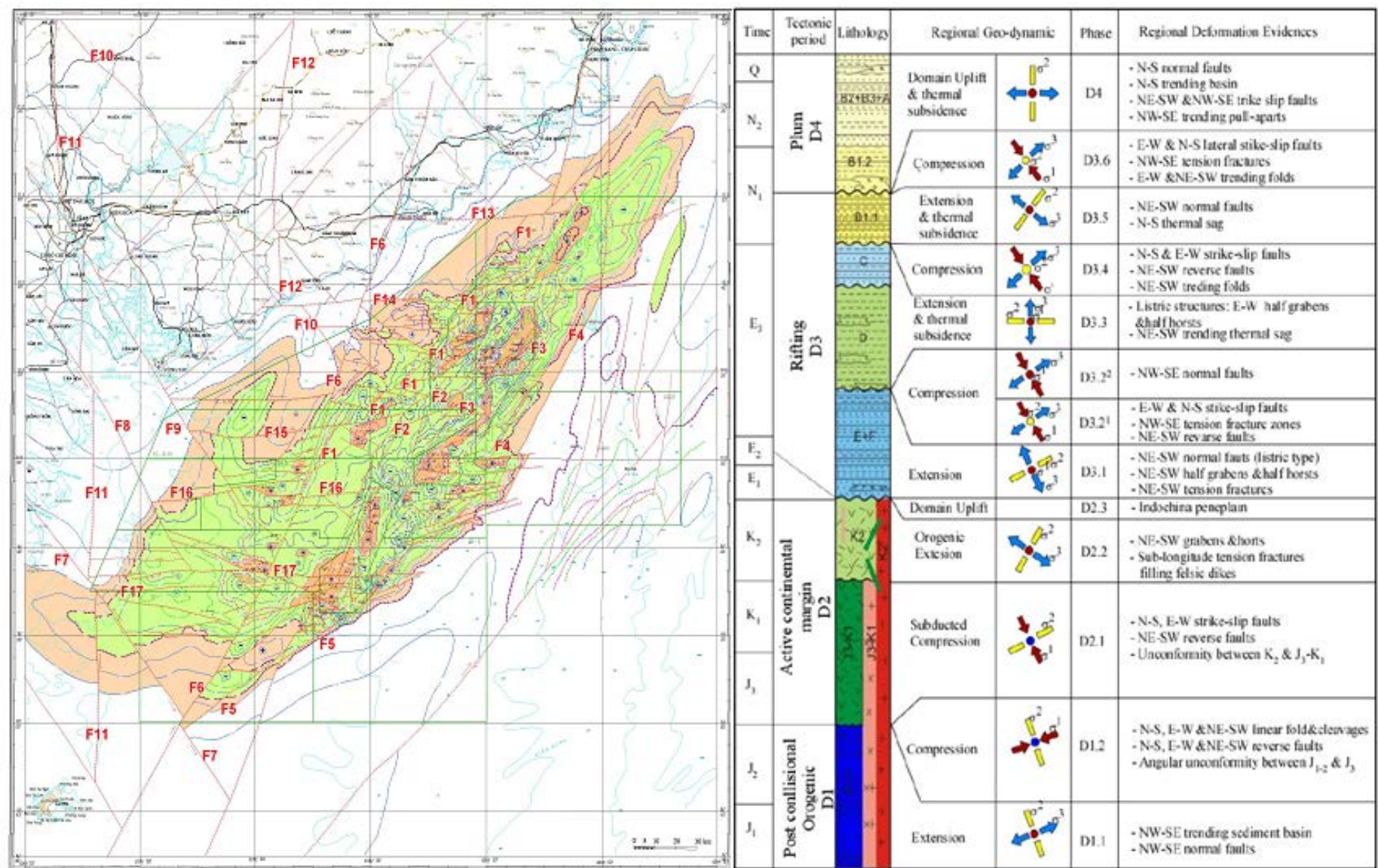


Figure 2. CLB Fault systems and Deformation phases (after P. H. Long et al.).

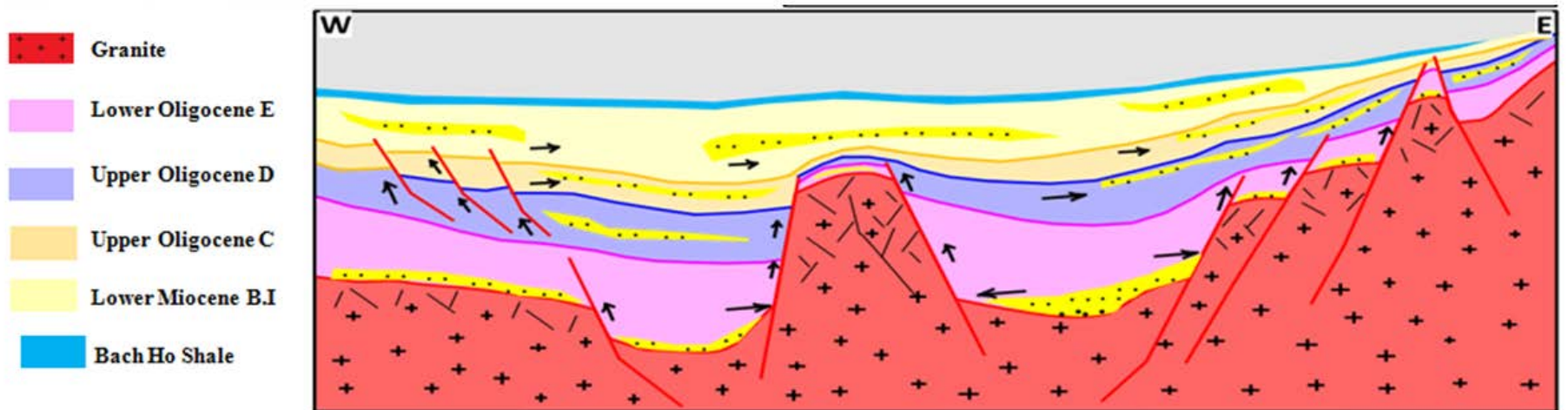
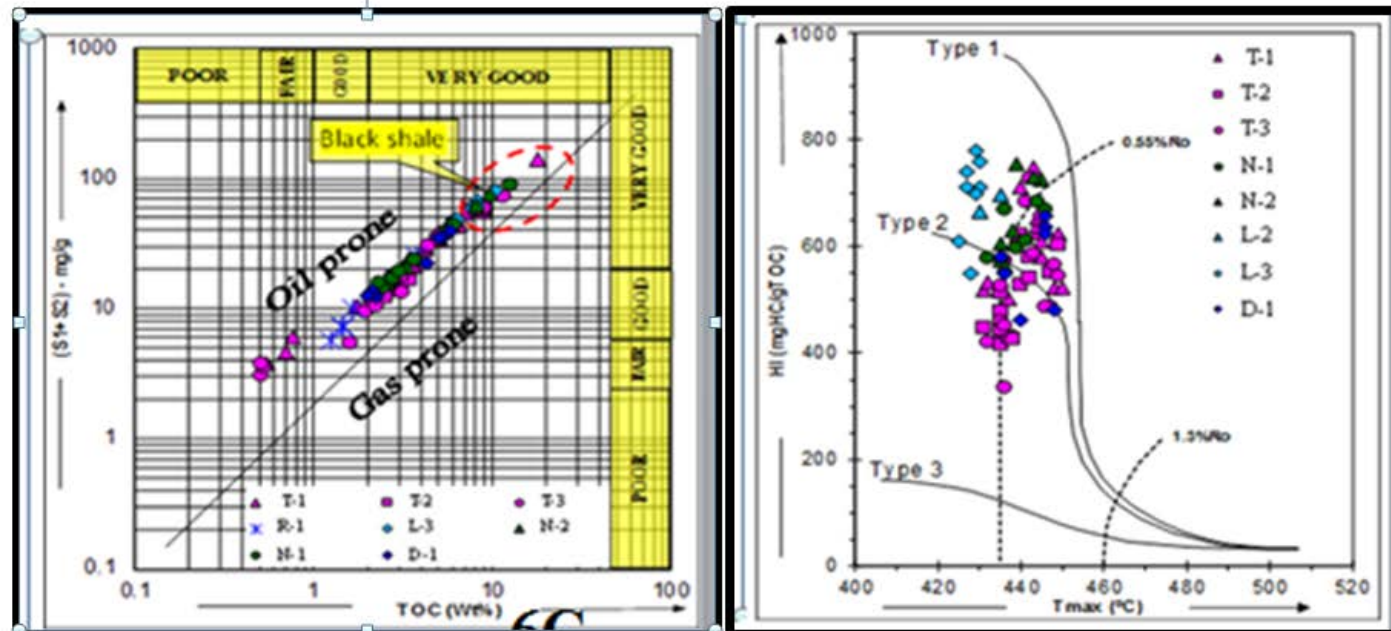


Figure 3. Geochemical analysis charts of Eocene-Early Oligocene lacustrine shale and migration pathway schematic in the Eastern Margin of CLB.

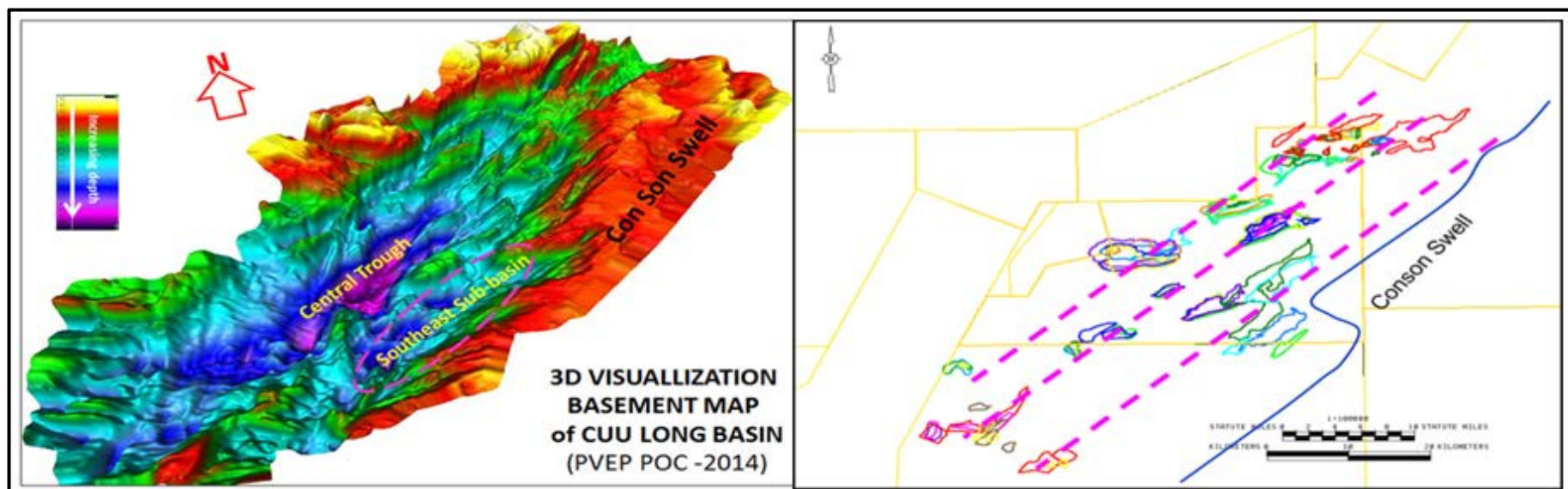


Figure 4. CLB basement map and distribution trend of fractured granite structures in study area.

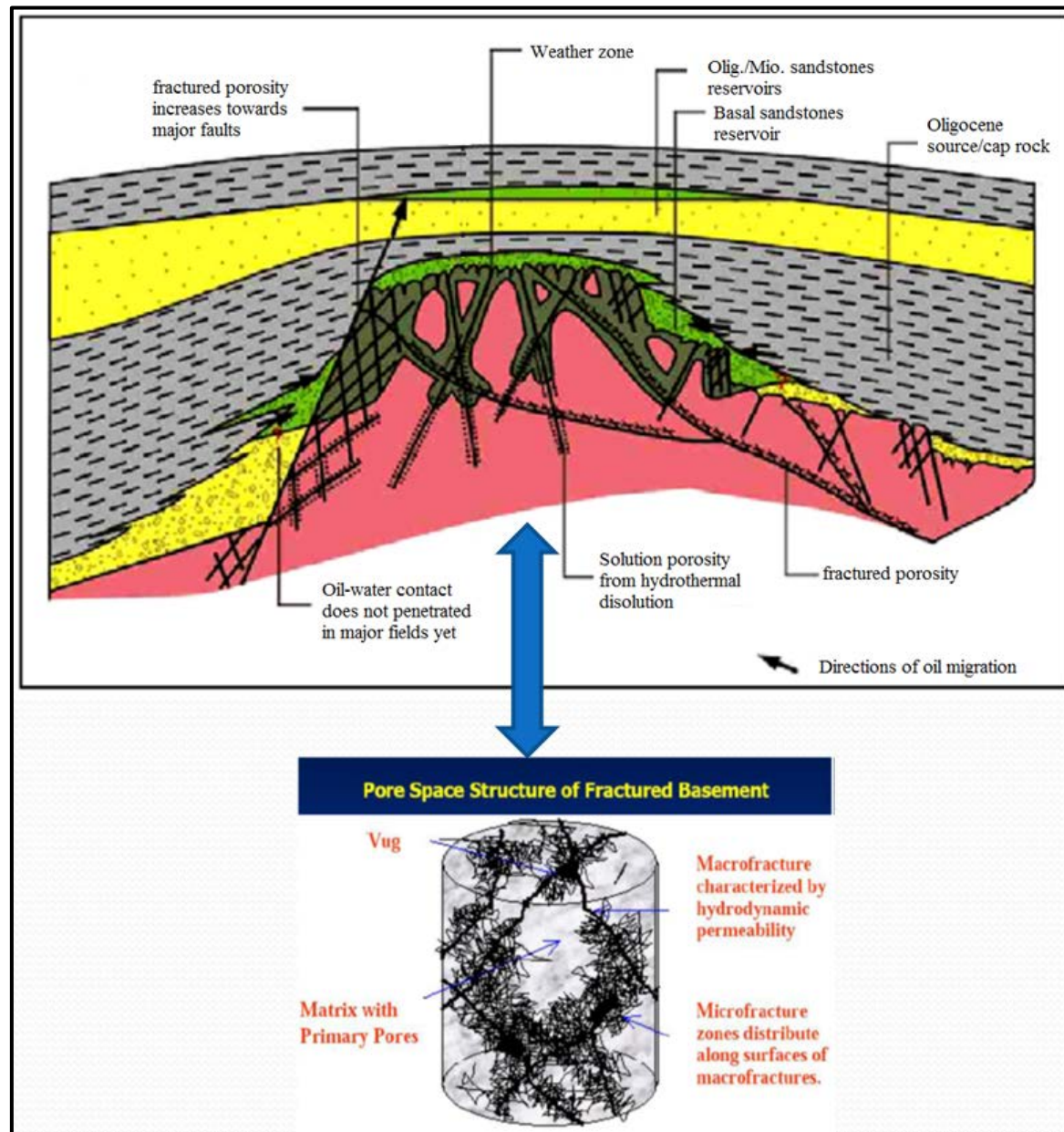


Figure 5. Dual-porosity model of CLB's FGR in which oil is stored in both micro and macro fractures but main production from macro fractures only with supporting flow from micro fracture systems in the long term (after Hung and Hung, 2003).

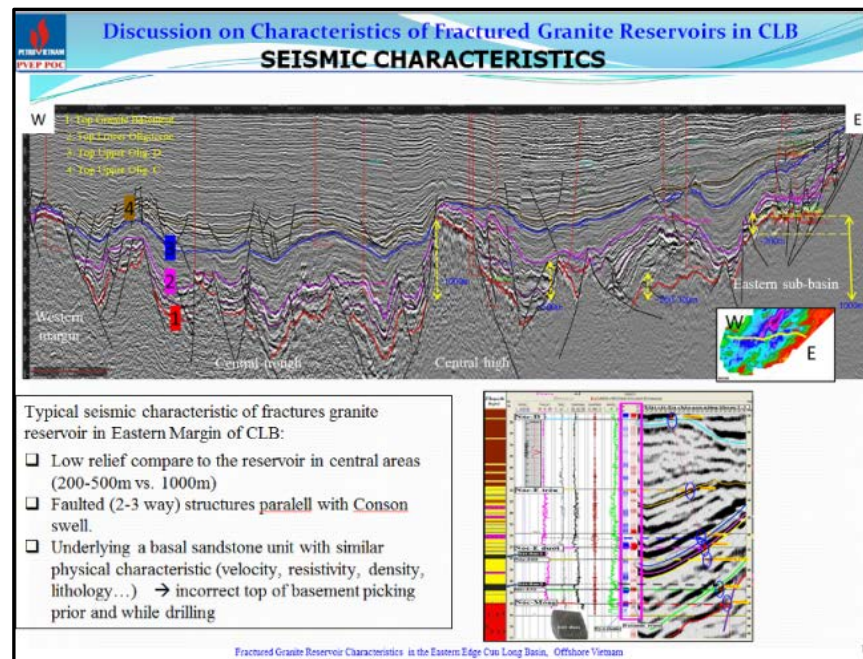
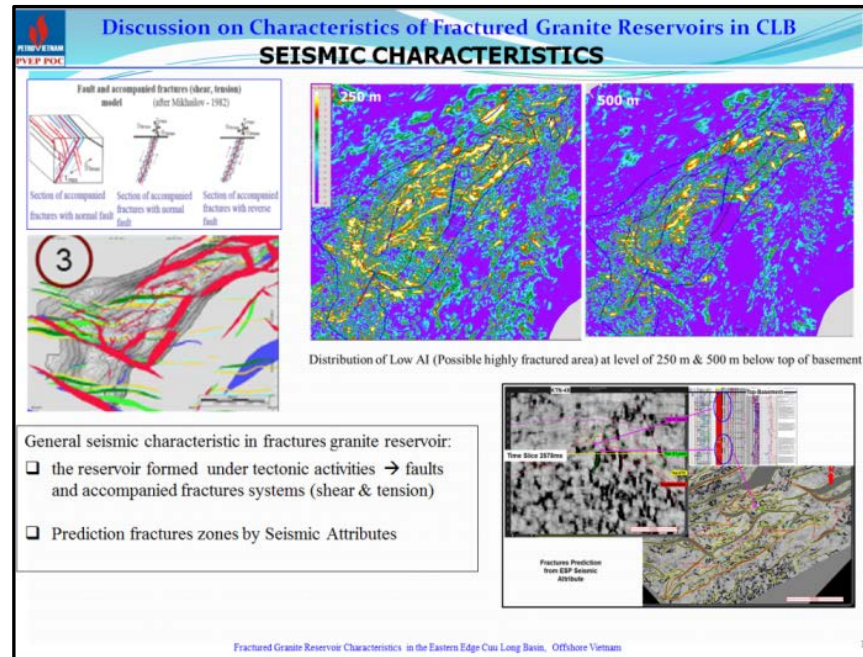


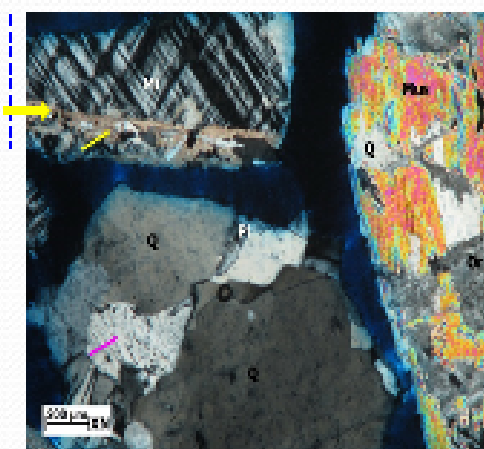
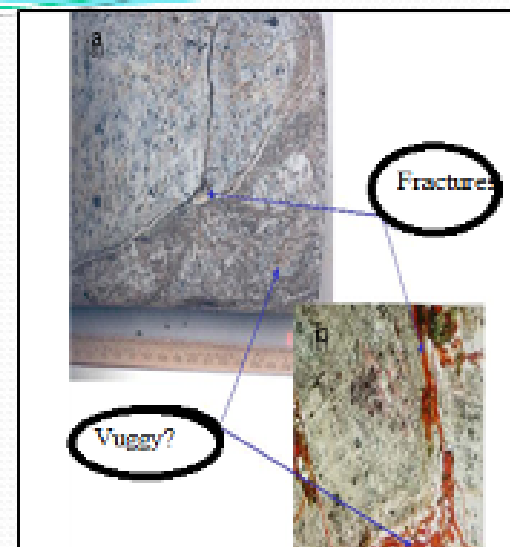
Figure 6. Seismic characteristics of FGR in eastern edge of CLB.

Discussion on Characteristics of Fractured Granite Reservoirs in CLB

Petrography Characteristics

System Period	Formation	Lithology	Main rock types	Intrusive series
Cenozoic			Fluvial, fluvial-marine sediment and fossil bank	
Cretaceous	Mai Trang (K ₁ M)		Dioritic and dioritic	
	Long Phien (K ₁ L)		Trachyte and grey conglomerate, sandstone and micaceous silty claystone	
	Ng Lon (K ₁ N)			
	Đuối Tông (K ₁ Đ)		Comglomerate, sandstone, siltstone, siliceous shale	
	Châu Sơn (K ₁ C)		Heavy grey bedded sandstone grain - sized sandstone, interbedded with yellowish sandstone and white grey siltstone	
	Lư Mã (K ₁ L)		Sandstone, siltstone and black shale bedded	
	Đuối Lũn (K ₁ Đ)		Conglomerate, gneiss, coarse grained sandstone, fine grained siliceous sandstone, calcareous siltstone and mud interbedded	
Triassic	Đuối Ngai (T ₁ Đ)		Shale interbedded with sandstone, siltstone	
	Mai Sơn (T ₁ M)		Grey limestone	
	Châu Sơn (T ₁ C)		Conglomerate, sandstone, limestone, siltstone, siltite, grey siltstone, siliceous shale	
	Núi Ngai (T ₁ N)		Calcareous sandstone, calcareous siltstone, mud interbedded and sandstone	
Permian	Ta Thán (P ₁ T)		Conglomerate, sandstone, siltstone, grey limestone, black calcareous clay	
	Hu Thán (P ₁ H)			
Carboniferous	Hu Phung (C ₁ P, M)		Siltstone shale with thin layers, sandstone, siltstone, and sandstone with sandstone, claystone and black limestone interbedded	
	Hu Chong (C ₁ C, M)		Siltstone, calcareous silty sandstone, sandstone, quartzite	

The fracture (yellow arrow) have been filled with clays, calcite. No visible porosity



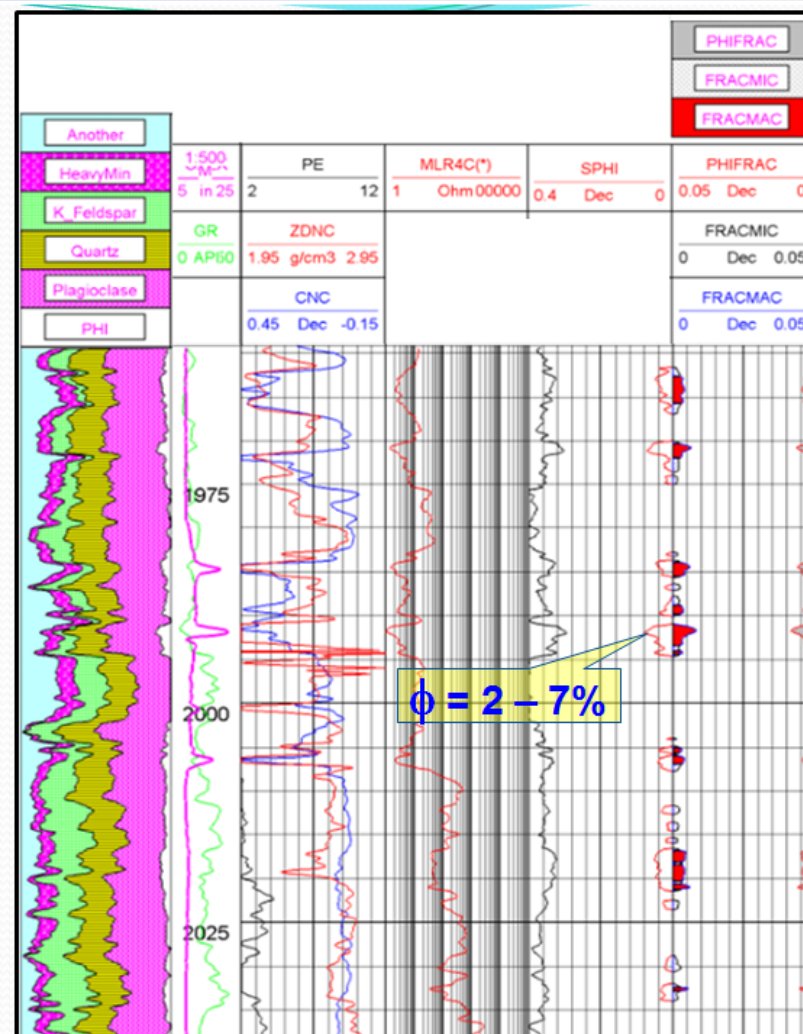
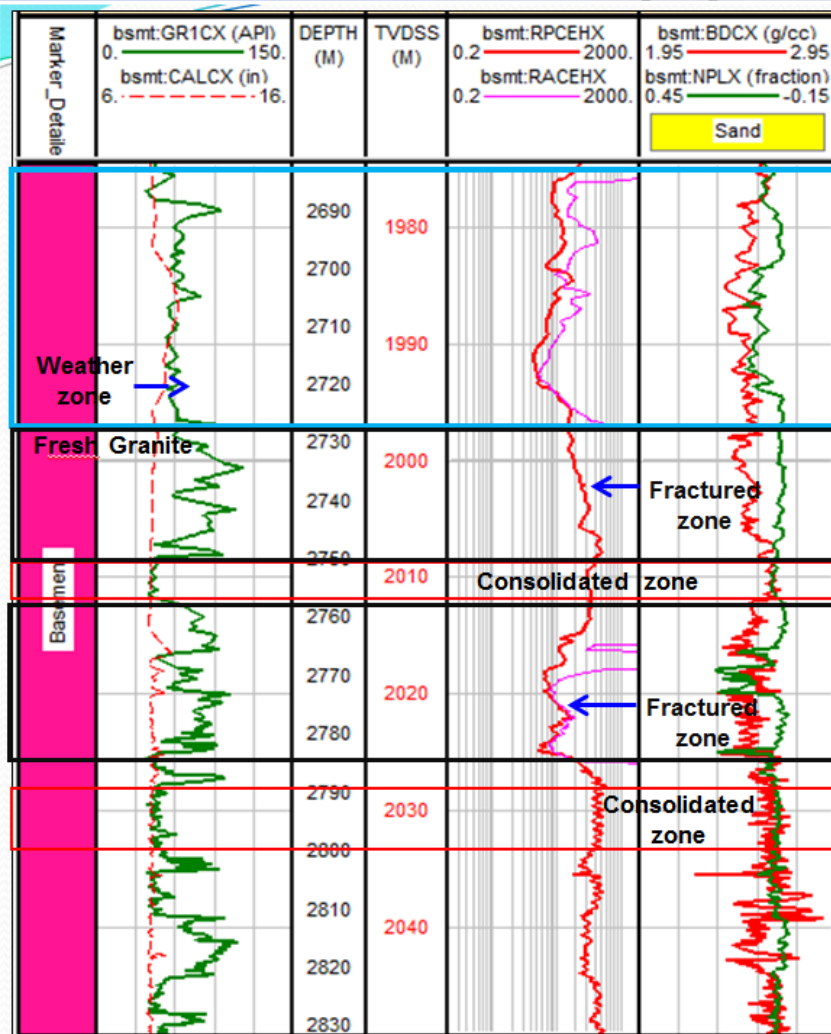
General Lithology characteristics in fractures granite reservoir in CLB:

- ❑ The reservoir formed under tectonic activities → faults and accompanied fractures systems (shear & tension)
- ❑ Based on the lithology and absolute age, the granitic basement in CLB is equivalent to the Hon Khoai, Dinh Quan and Ca Na Complexes in the onshore intrusive magmatic.
- ❑ Granite: Quartz (Q), K-feldspar, plagioclase (Pl) and colour minerals as mica (biotite and muscovite), hornblende (Hr); some biotite has been slightly altered by chlorite and epidote; trace of apatite and zircon..

Figure 7. Petrography characteristics of FGR in eastern edge of CLB.

Discussion on Characteristics of Fractured Granite Reservoirs in CLB

Petrophysic Characteristics



Petrophysical characteristics in FGR:

- ☐ Weather & Fresh (Fractured vs. Consolidated) Zones
- ☐ Very low porosity compare to clastic reservoir (2-7% vs. > 10%)

Figure 8. Petrophysic characteristics of FGR in eastern edge of CLB.

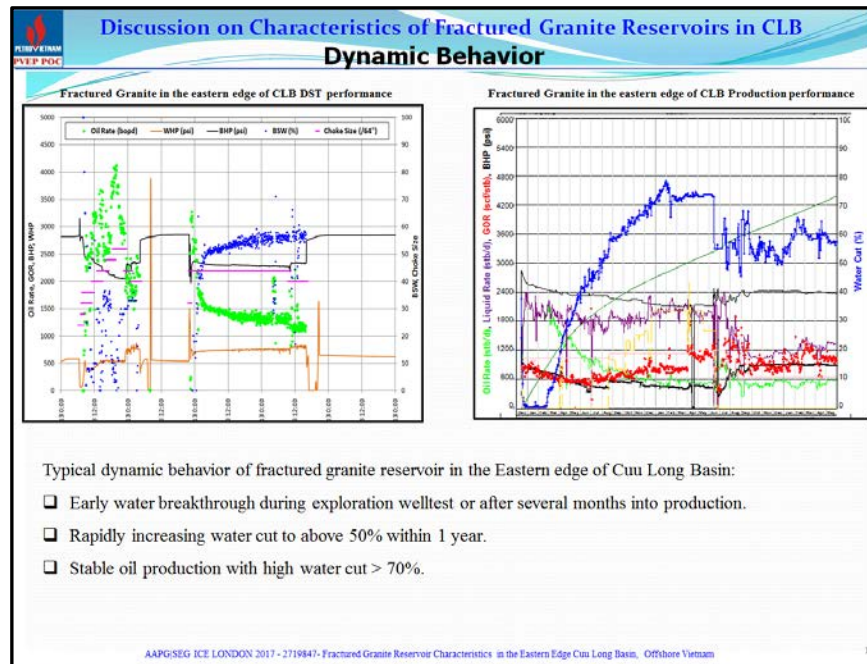
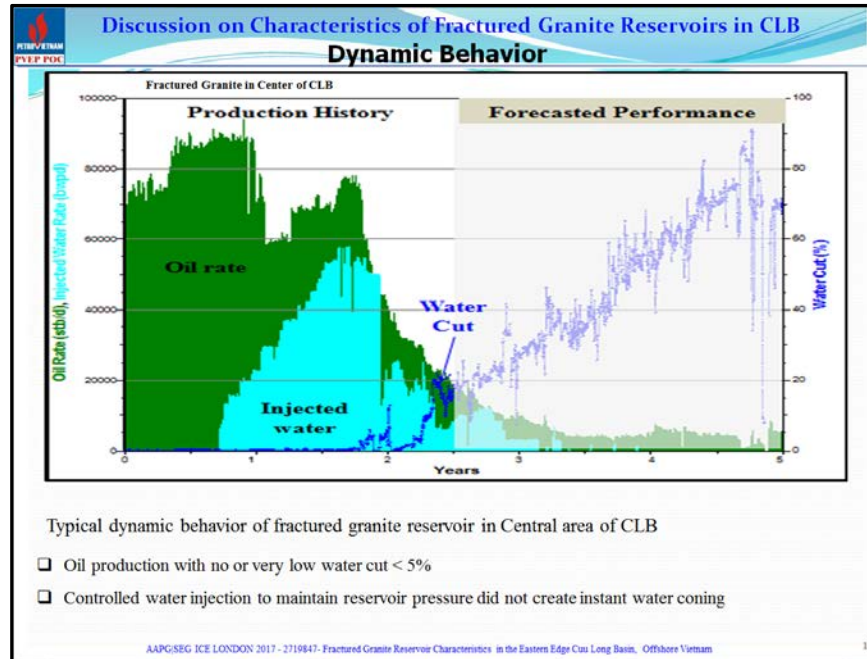


Figure 9. Dynamic behaviors of FGR in central basin versus eastern edge of CLB.

Discussion on Characteristics of Fractured Granite Reservoirs in CLB

Impacts on optimum well design

- Basal sandstone: Arkoses & Feldspathic Greywacke Sandstones, predominant Quartz, Feldspar Kali, *Granitic fragments*.
- Incorrect top of basement picking while drilling
- Costly (casing, testing...)

While drilling

Top of basemen picked :

- Granite fragment in cutting
- LWD: GR (low) & Resistivity (high) similar to granite

After logging:

Basement top was corrected

- Image logs
- Sidewall core

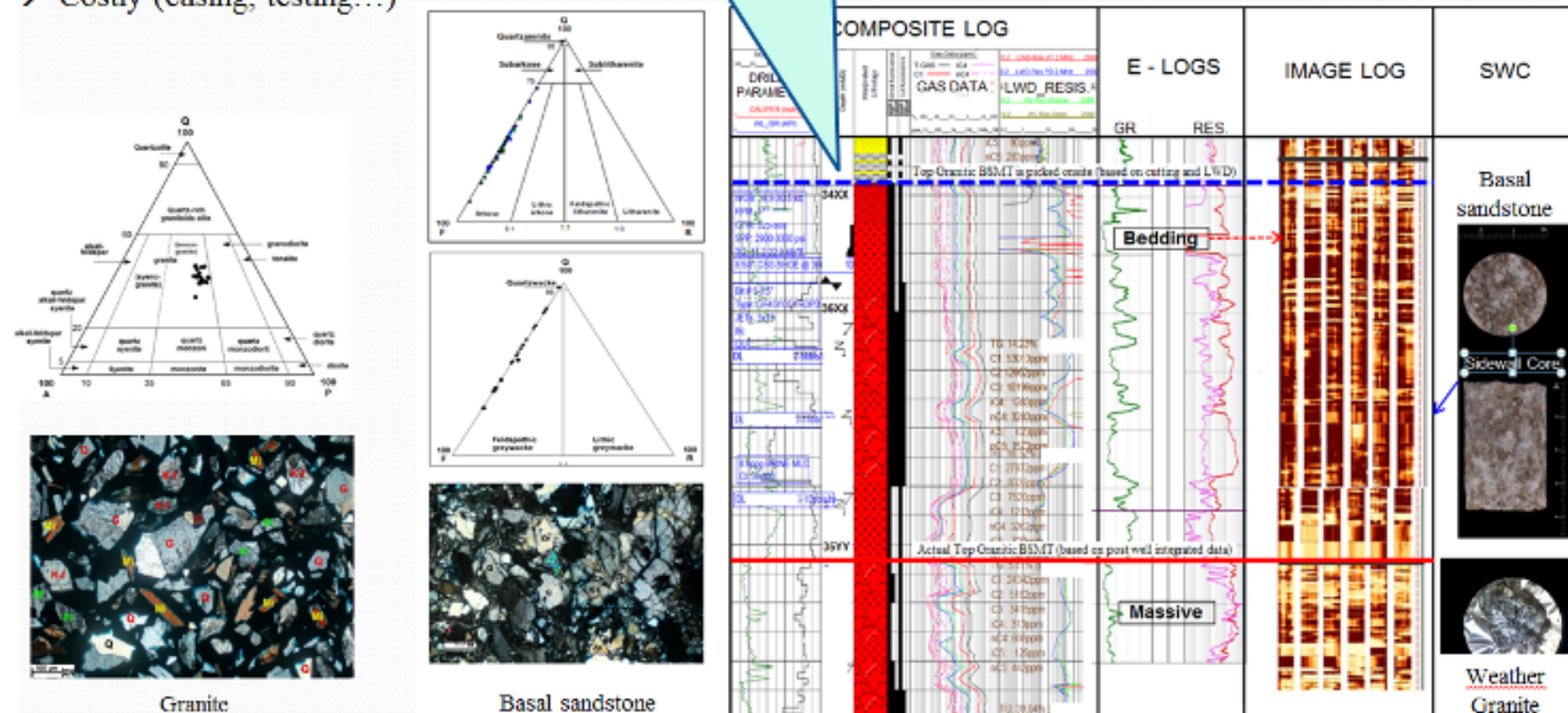
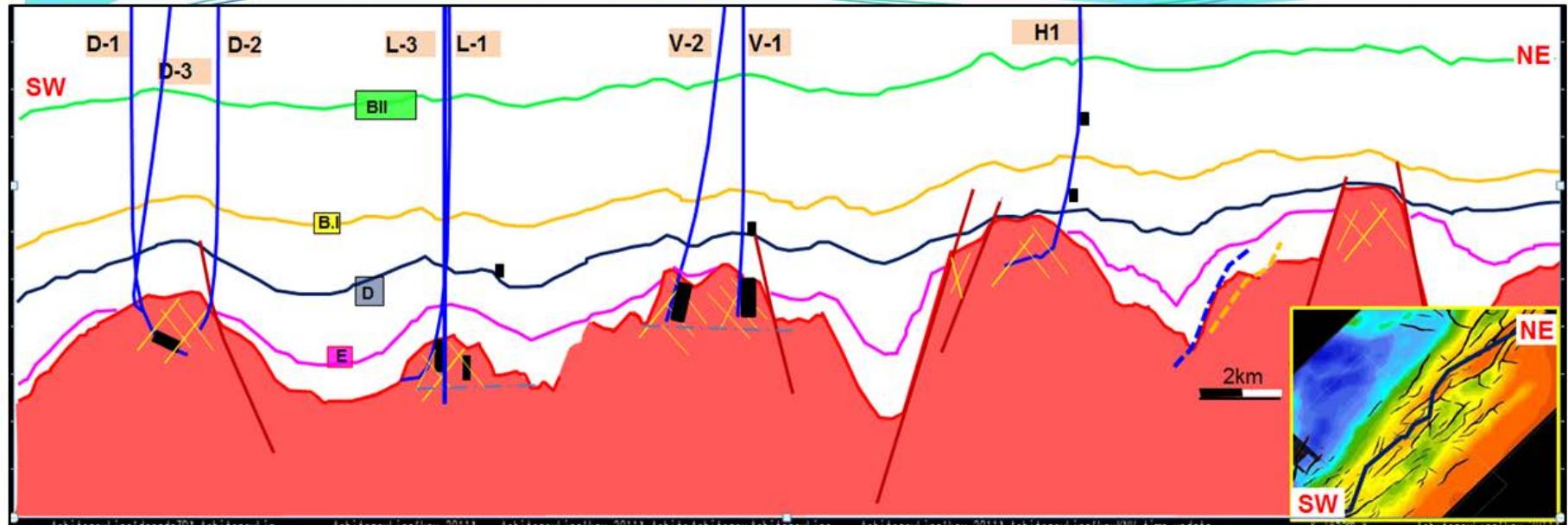


Figure 10. Impacts of incorrect top of basement picking on casing point and lesson learnt.

Discussion on Characteristics of Fractured Granite Reservoirs in CLB Impacts on optimum well design



- ☐ Applying Seismic Attributes (EPS, An-tracking,...) to define multi subsurfaces targets in fractured granite reservoir → optimum well trajectory for fractures interception.
- ☐ TD concept: at least 50-100m shallower than spill to avoid early water conning.

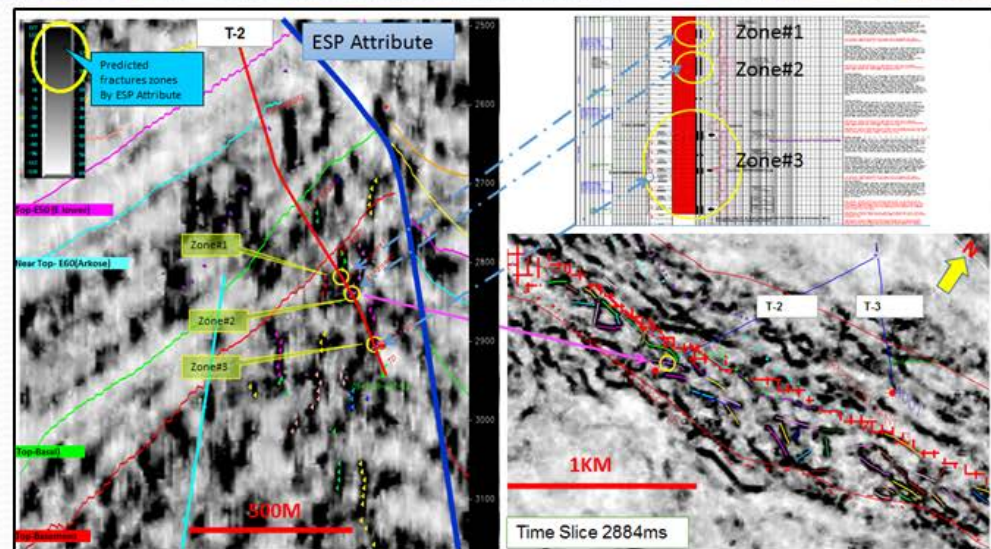


Figure 11. Impacts of FGR characteristic on well trajectory and TD concept.