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

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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 km^2 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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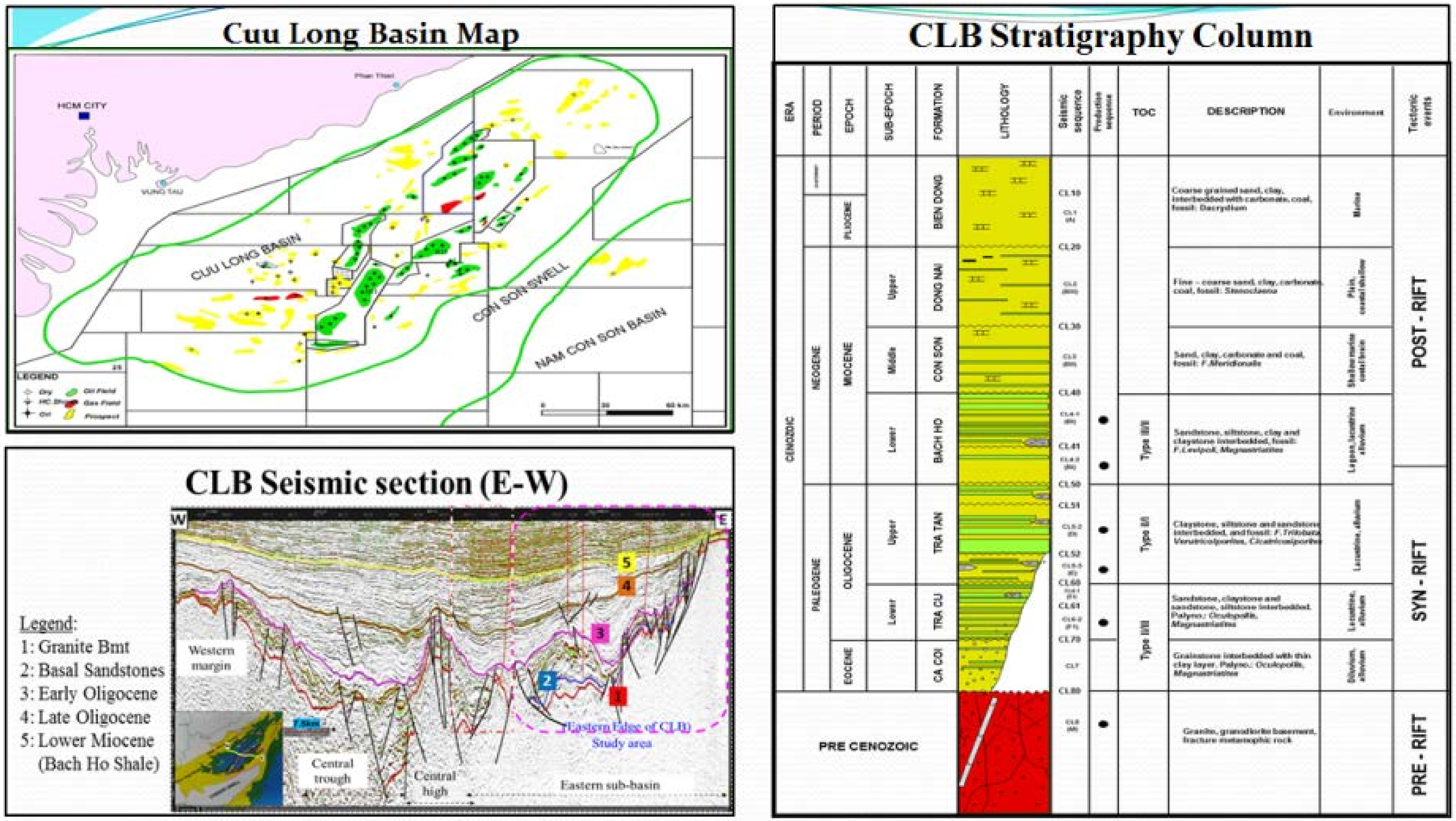


Figure 1. CLB location map, Seismic (E-W) section and Stratigraphy column.

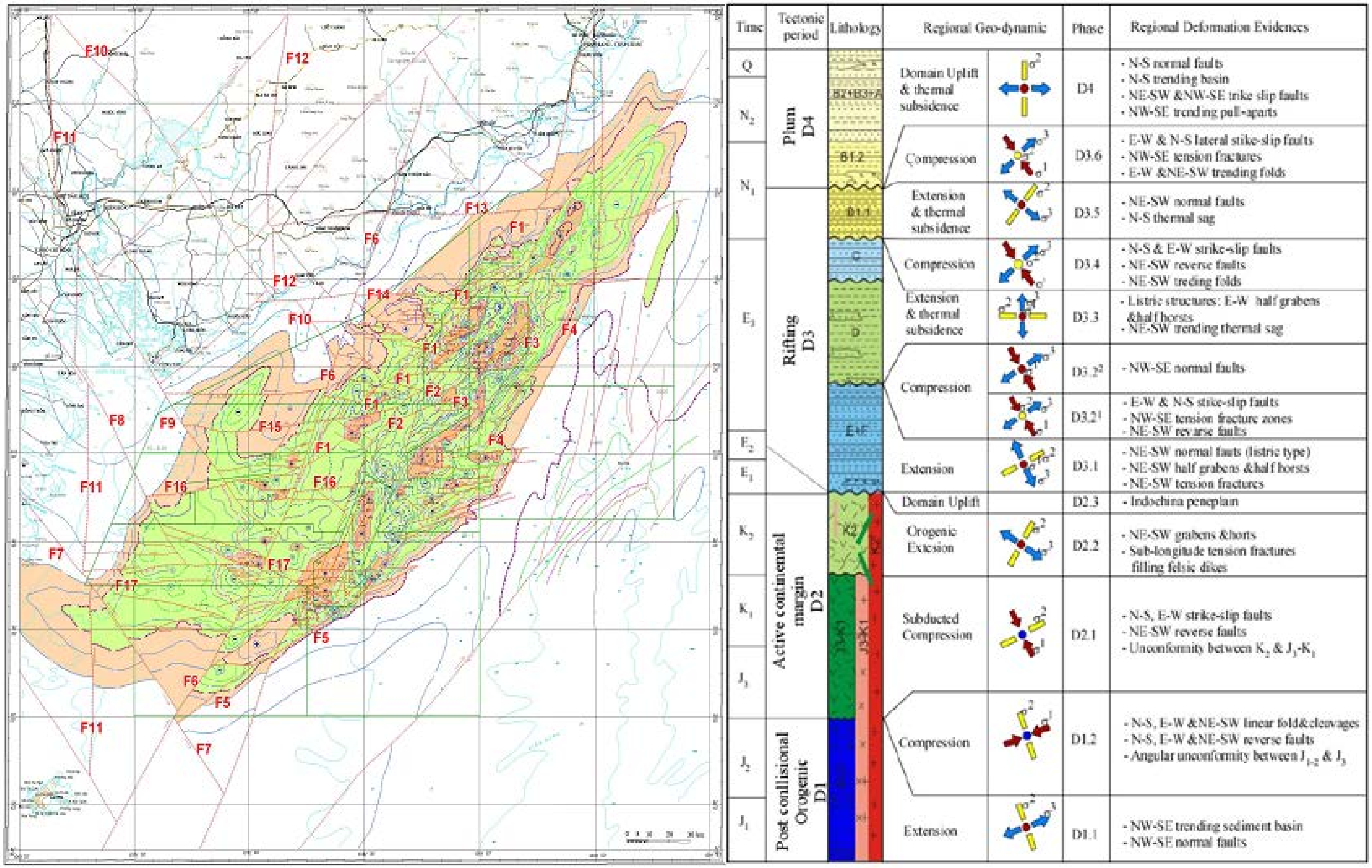


Figure 2. CLB Fault systems and Deformation phases (after P. H. Long et al.).

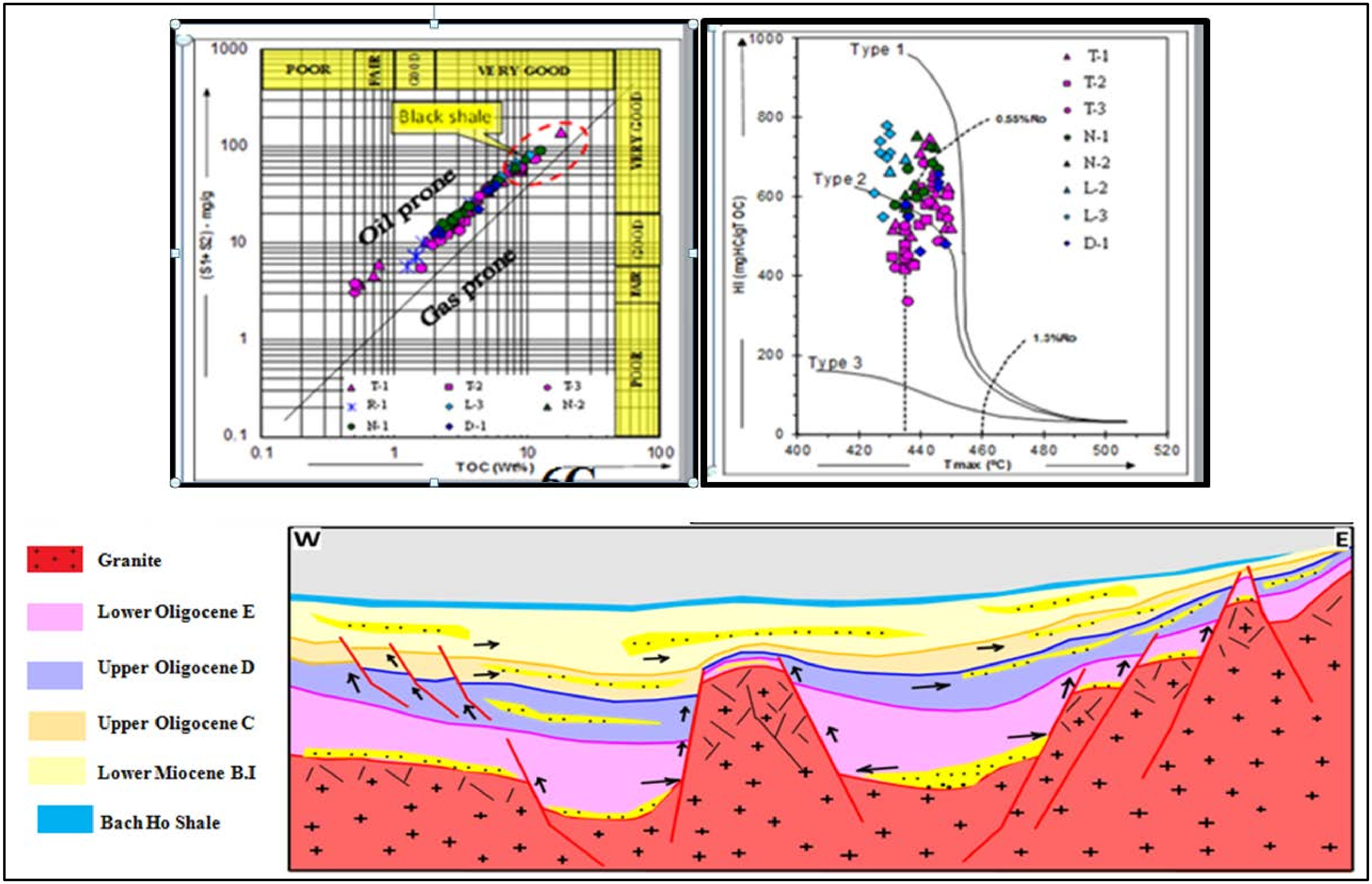


Figure 3. Geochemical analysis charts of Eocene-Early Oligocene lacustrine shale and migration pathway schematic in the Eastern Margin of CLB.

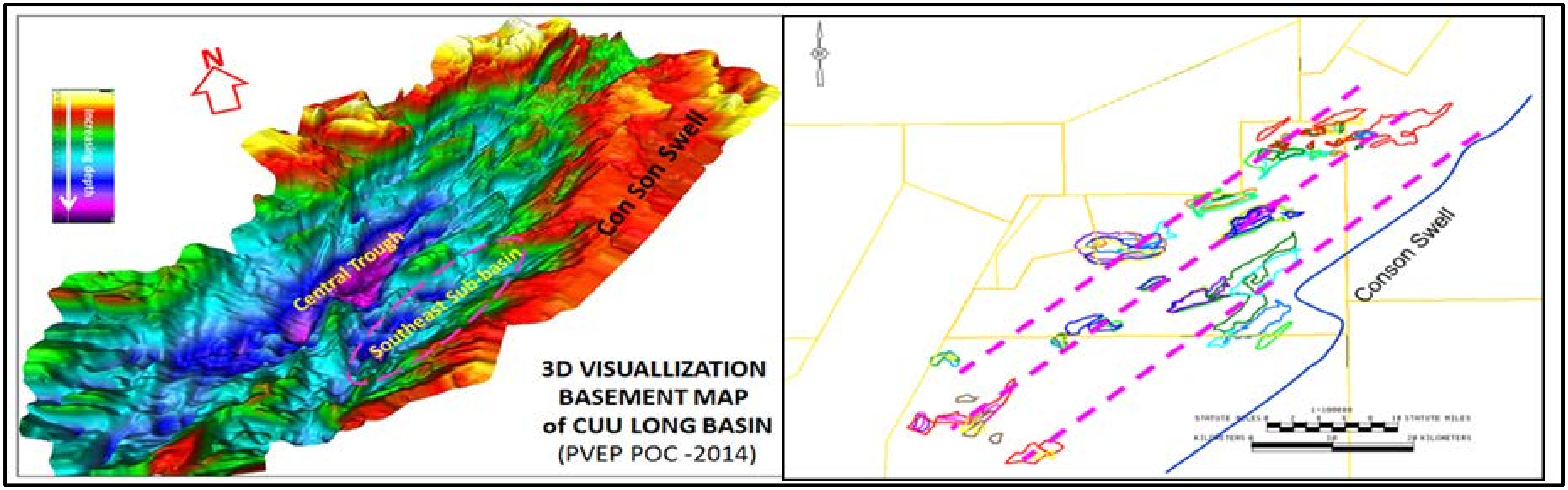


Figure 4. CLB basement map and distribution trend of fractured granite structures in study area.

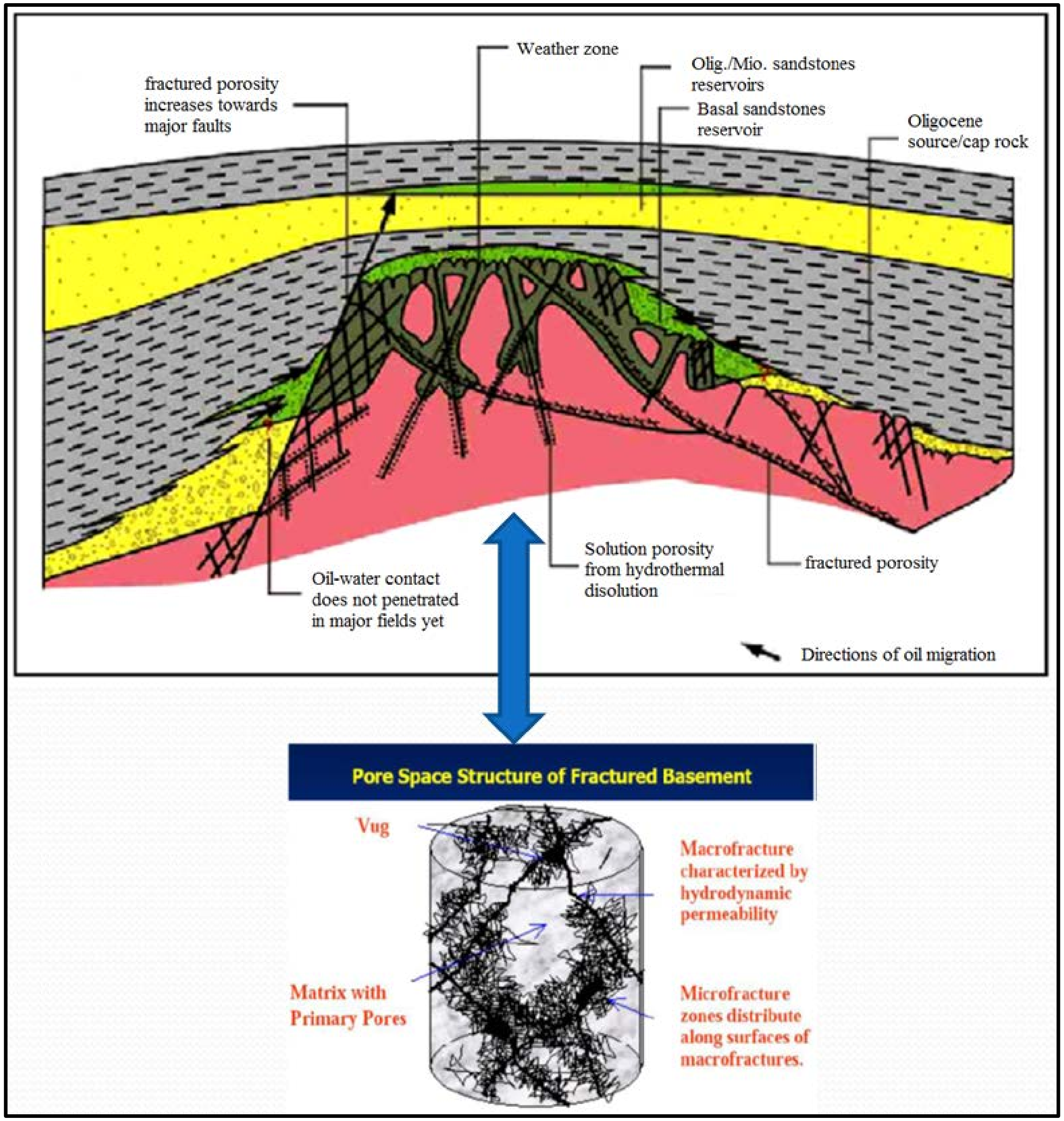
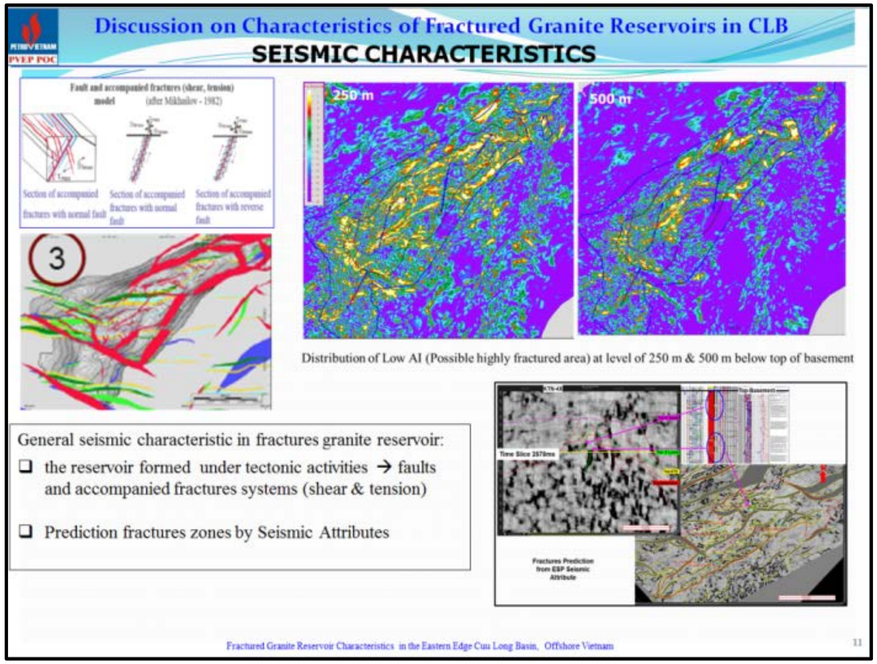


Figure 5. Dual-porosity model of CLB's FGR in which oil is stored in both micro and macro fractures but main production from macro fractures only with supporting flow from micro fracture systems in the long term (after Hung and Hung, 2003).



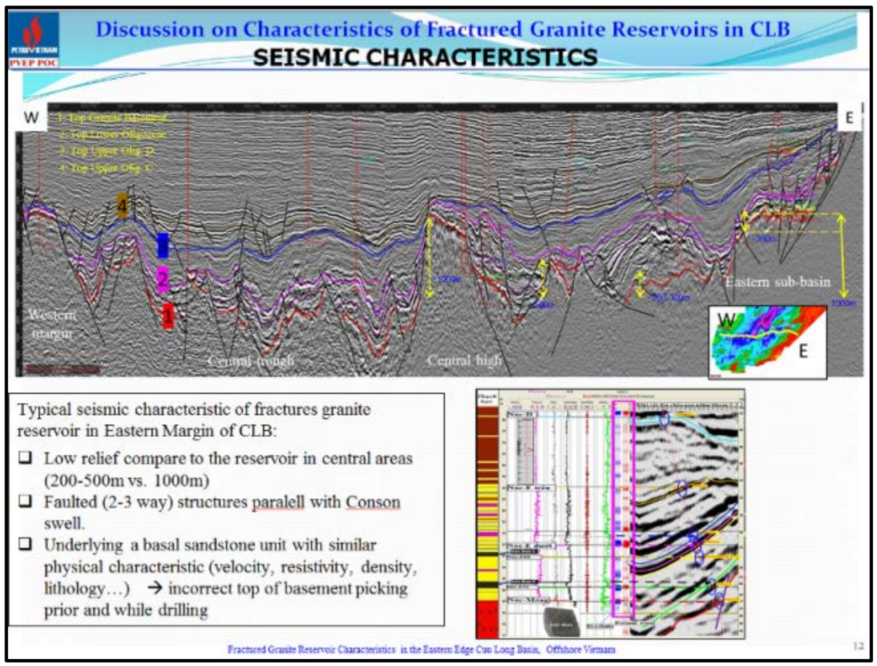


Figure 6. Seismic characteristics of FGR in eastern edge of CLB.

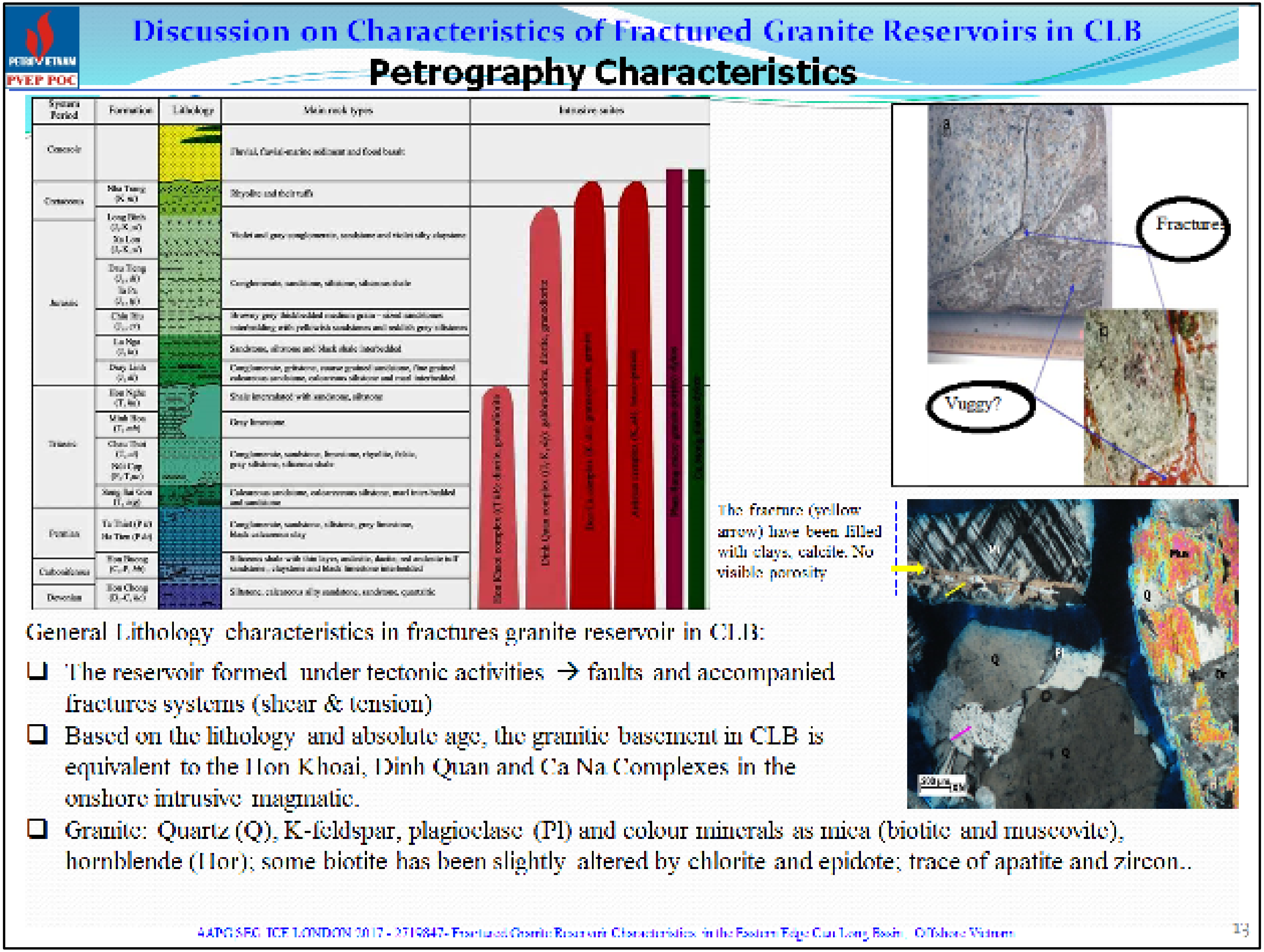


Figure 7. Petrography characteristics of FGR in eastern edge of CLB.

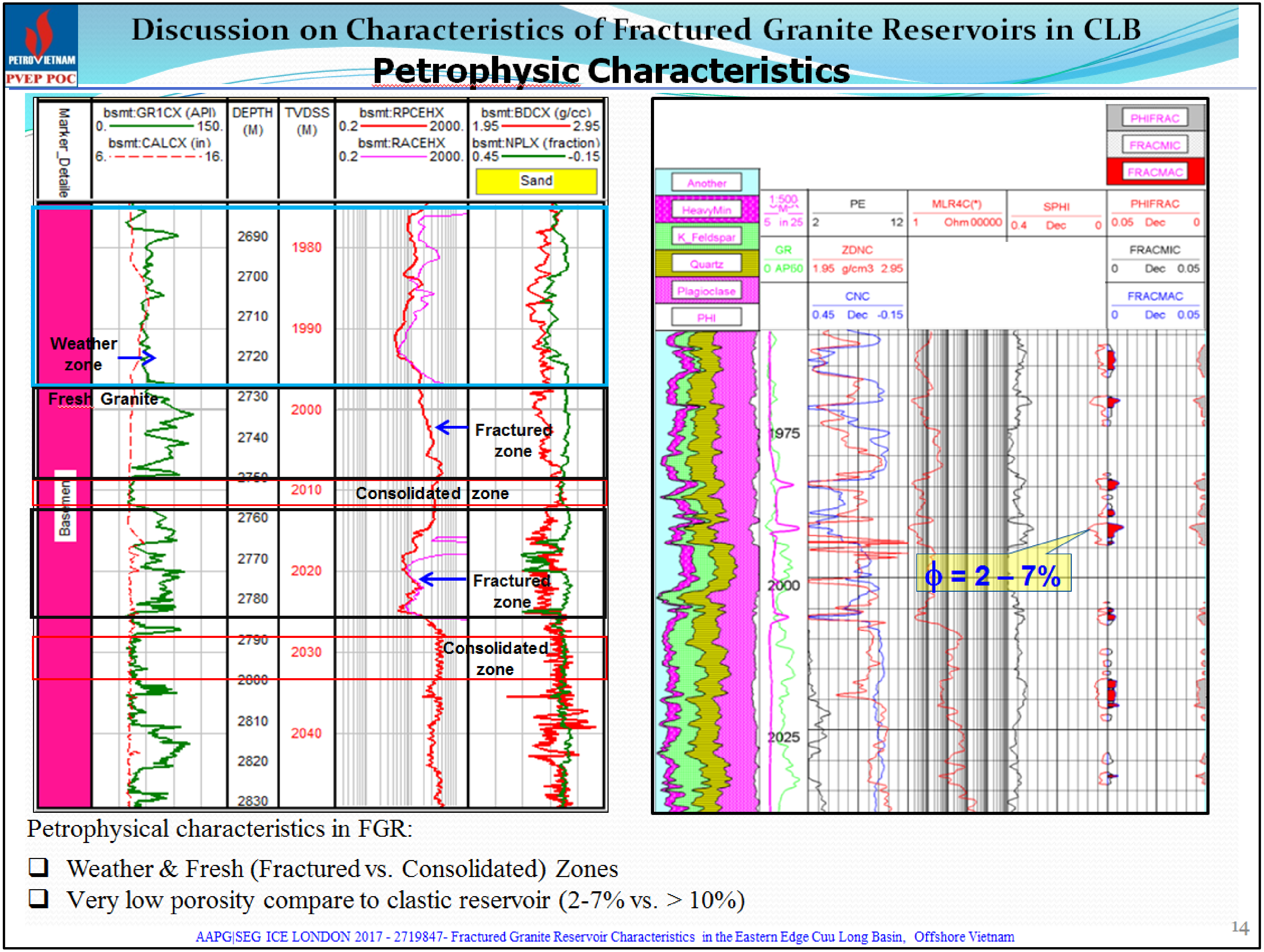
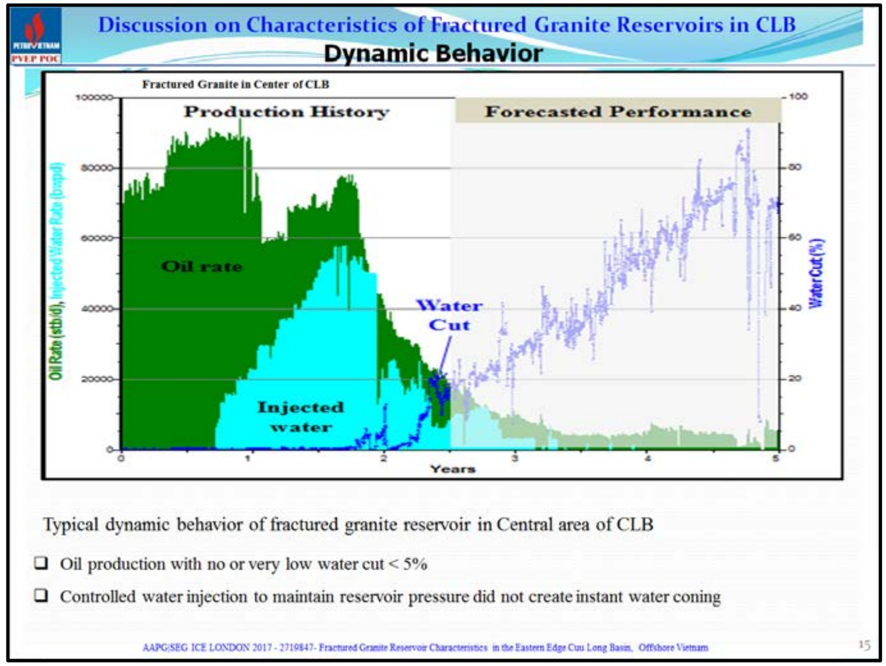


Figure 8. Petrophysic characteristics of FGR in eastern edge of CLB.



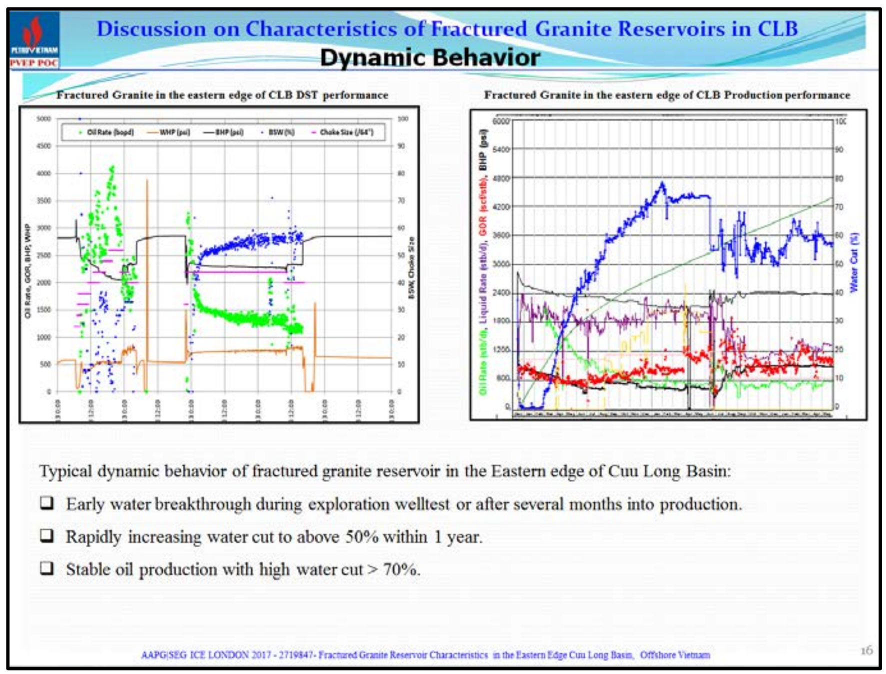


Figure 9. Dynamic behaviors of FGR in central basin versus eastern edge of CLB.

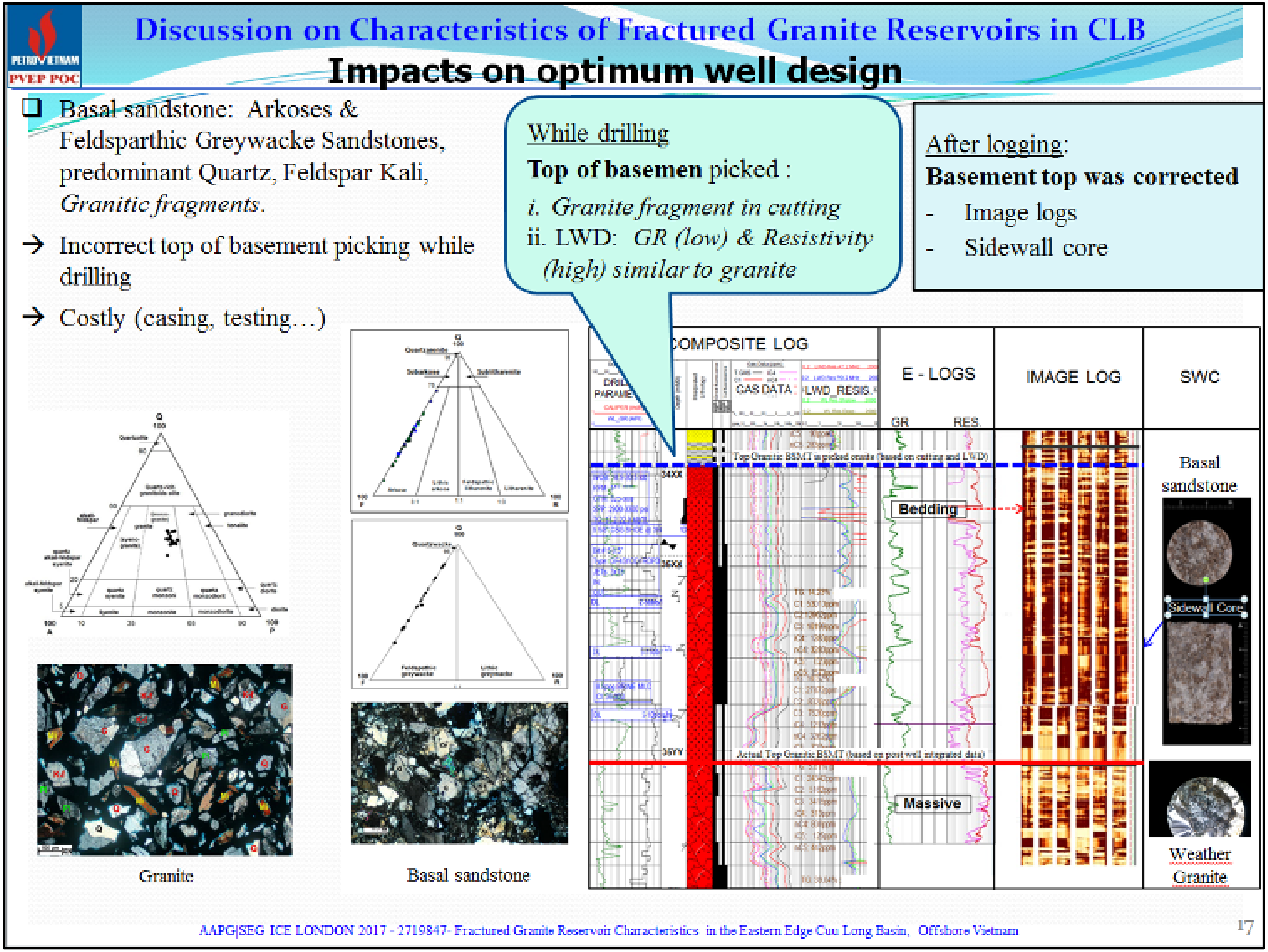


Figure 10. Impacts of incorrect top of basement picking on casing point and lesson learnt.

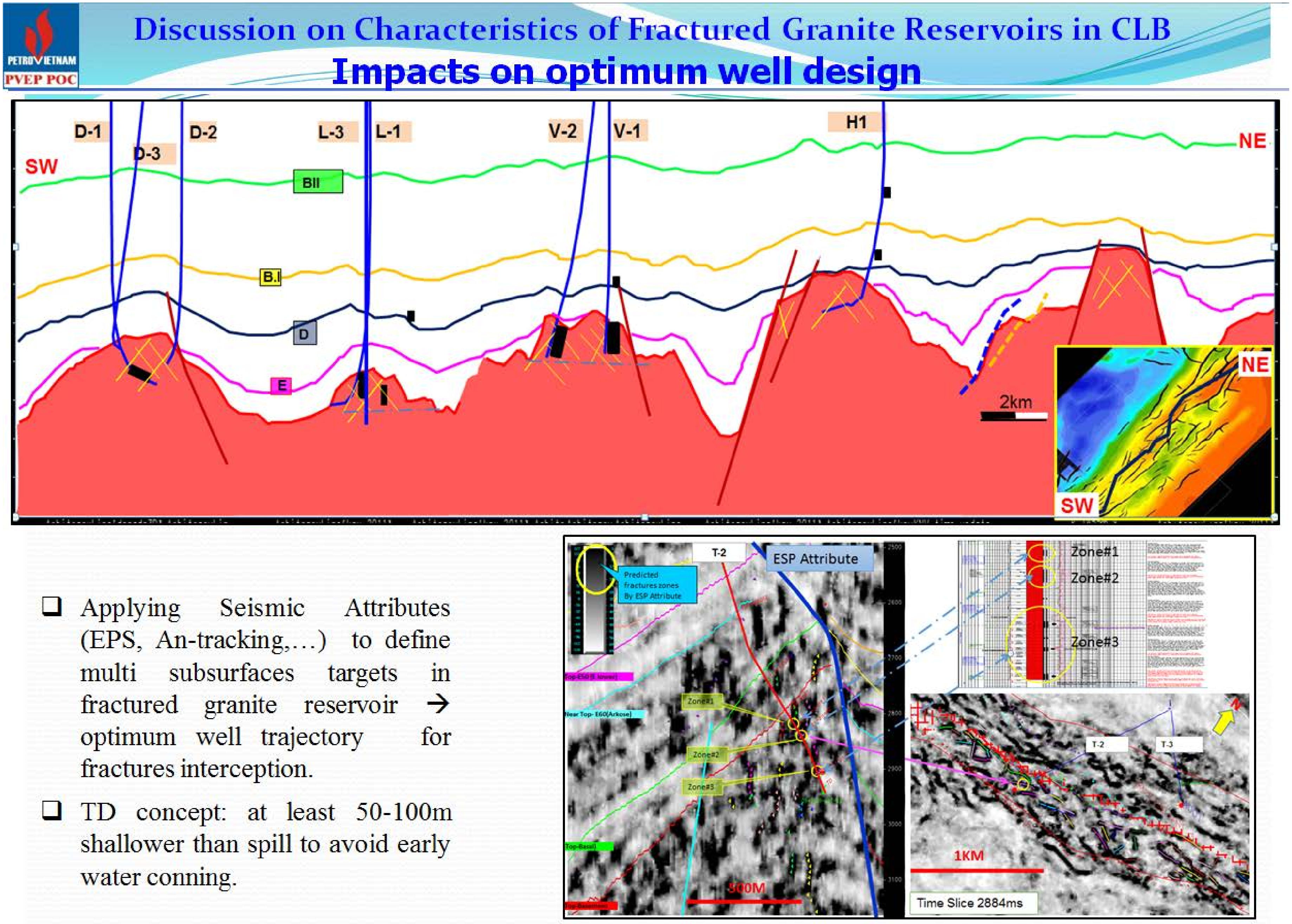


Figure 11. Impacts of FGR characteristic on well trajectory and TD concept.