PRELIMINARY GEOLOGY MODEL OF MUARA LABOH: FACIES AND POROSITY ASSESSMENT

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ABSTRACT

In geothermal fields, the distribution of different lithologies in the reservoir is a major control over pore volume (porosity) variation, which is an important factor in making reserves calculations.

Porosity is also effected by open fracture width and density, and hydrothermal alteration; both which can also vary with lithology. Alteration control over porosity is complex as it can both increase or decrease porosity. Fractures increase porosity but less so than increases related to alteration (Rejeki *et al*., 2005).

During the exploration phase, well data is too limited to fully interpret rock type distribution, but can be supplemented by applying a facies model analog, in this case an andesite strato-volcano facies model.

A volcanic facies model was constructed at Muara laboh by using four strategically located wells. Rock types were identified from cuttings, cores, image logs, and drilling parameters from these wells. Lateral facies distribution was obtained from surface mapping and remote image interpretation.

After the volcanic facies model has been constructed, porosity values assigned according to the rock distribution. Porosity values are derived statistically from other strato-volcanic hosted fields in Indonesia and derived from core analysis (using both mercury and helium analysis technique). For this study, an average 2-4 % porosity is used for lava and 6-8% for pyroclastic rocks.

1. INTRODUCTION

Muara Laboh geothermal field is located in the South Solok Regency, about 150 km to the south east of Padang City (**Figure 1**). The prospect is situated along the Great Sumatra Fault (GSF) with 3 main volcanic eruptive centers surrounding the area.

Exploration drilling began in the third quarter of 2012 at the Muara Laboh Geothermal field. It finishes in 2013. Presently, four wells have been drilled and the fifth well is being prepared.

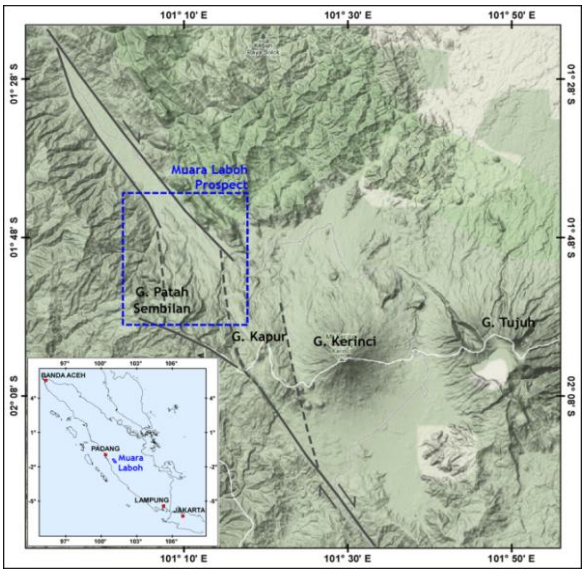


Figure 1. Location of Muara Laboh Geothermal Field.

A reserve estimation of the field is required to support the development program. A robust geological model has been constructed that

applies volcanic facies for an andesite strato-volcano.

2. GEOLOGY OVERVIEW

Muara Laboh field is located adjacent to the Great Sumatra Fault (GSF), an active right-lateral strike-slip fault that runs NW-SE throughout the length of Sumatra and northward into the Andaman Sea. Based on the Sumatra Fault segment map by Sieh and Natawidjaya (2000), this field is located at the end of the Suliti Segment.

The GSF runs on a NW-SE trend and appears to terminate at the NW flank of G. Kerinci. A splay of this fault runs southward (in N-S trends) toward G. Kapur and continues to the SE and merges with the main trace of the GSF where it is exposed south of G. Kerinci. This lateral strike slip fault creates a "releasing bend" or "pull-apart", where land between the two traces is put under tension in the direction of faulting. These bends typically create basins and are sites of volcanic activity (**Figure 2**), presumably due to deeply penetrating rifting faults that form between the two "master" strike slip faults.

Rocks in the prospect area are mapped as late Quaternary volcanic (Qyu and Qyl), early Quarternary volcanic (Qou and Qol), Cenozoic volcanic products and basement rocks that consist of metamorphosed Paleozoic Sediment and granitic rocks (Cretaceous) (**Figure 3**). Late Quartenary volcanic products apparently derived from G. Kapur and G. Patah Sembilan (Rosidi *et al.*, 1996) consist of lava and undifferentiated volcanic rocks. Early Quarternary volcanic products observed in western part of Muara Laboh are interpreted as products of Old G. Kerinci, G. Tujuh, G. Runcing and G. Panjang.

Cenozoic volcanic products are found farther to NW of the Muara Laboh area; on the west side of the GSF. They consist of lava, pyroclastics and minor amounts of sediment (they contain *Dicotylendenblad* fossils) of Oligo-Miocene age (Rosidi et al, 1996).

On the NE side, east of the GSF block, rocks are mapped as metamorphosed sedimentary rocks of probable Paleozoic age (>250 million years old), which have been intruded by Cretaceous age granites.

3. VOLCANIC FACIES

A volcanic facies model for andesite strato-volcanoes (Bogie and MacKenzie, 1998) is used in this paper. This model utilises four facies: Central, Proximal, Medial and Distal Facies (**Figure 4**).

The Central Facies are volcanic rocks emplaced closest to volcanic vents. Proximal Facies rocks are laid down at increasing distances on the slopes and outer flanks of a large volcanic complex. Medial Facies rock is laid down on the outer flanks of the volcano. Distal Facies Volcanic rocks are laid down well beyond the base of a large volcano tend to have a greater lateral continuity than those of inner zones and they conform more closely to conventional stratigraphic criteria, as epiclastics predominate.

4. MUARA LABOH FACIES MODEL

Based on surface mapping and remote image interpretation, there are two in-active volcanic centers around Muara Laboh Area; first are G. Patah Sembilan in the south and G. Kapur to the SE. Both of these two volcanic products are Late Quaternary in ages (**Figure 5**).

The Patah Sembilan Volcanic Centre appears to have been erupted up the Sumatran fault and has built up an andesitic stratovolcano (Bogie, 2013). A major set of lava flows to the NNE preceded formation of a summit caldera. Resurgent volcanism from the caldera occurred up the Sumatran fault to form a flow to the north that eventually overflowed the caldera to also flow to the south. Further volcanism associated with the Sumatran fault occurred to the SE of Patah Sembilan at G. Kapur and a long lava flow was formed to the north that abuts with the northern post-caldera Patah Sembilan lava flow. Effusive eruption products dominate over explosive products. The length of the flows suggests that they are basic in composition.

Sub-surface geological data has been gathered from strategically located wells. The data consists of cutting descriptions, drilling parameters, image logs and core samples. An example of rock type interpretation (B1 Well) from cuttings, drilling parameters and image log can be seen on **Figure 6**.

ML-A1 well is located about 4-5 km from Patah Sembilan Volcanic Centre. The lithology can be classified into three facies unit, proximal facies on top, medial facies in the middle and another proximal facies at the bottom.

ML-B1 well located 1 km to the west of A1 and about 5 km from Patah Sembilan Volcanic Centre. This well have similar facies unit with A1 well, just little bit different in lava layers composition.

C1 was the farthest well to the north, located about 8 km from Patah Sembilan Volcanic Centre. All lithology associations show a distal facies characteristic, mainly composed of tuff and coarse pyroclastic/epiclastic rocks, possibly lahars.

E1 well is located between A1 and C1 wells and located about 7 km from the Patah Sembilan Volcanic Centre. Lithology consists of medial facies on top, proximal facies in the middle and another medial facies at bottom.

Correlation between these wells suggests at least three deposition sequences of volcanic products (**Figure 7**). Sequence 1 is interpreted as the oldest unit from the Patah Sembilan volcanic centre. A1 and B1 have proximal facies from this sequence, E1 have medial facies at bottom and proximal facies above it, whereas C1 has the distal facies. The next sequence (Sequence 2) is composed of medial facies in A1, B1 and E1 wells and distal facies at C1 well. After both sequences formed, a caldera formed in the Patah Sembilan Volcanic Centre. After that a massive lava flowed from the center creating a thick lava flow on top of A1 and B1 wells.

Based on the drilling results, the top of reservoir at Muara Laboh is ranges from 600 – 1000 m depth. The facies distribution in the reservoir is dominated by proximal facies and change to medial(?) and or distal facies in the area between A1 and E1. Assuming that the heat source for Muara Laboh field is coming from Patah Sembilan, there is more than 70% proximal facies in the reservoir.

5. POROSITY

Porosity values are acquired from core samples from the bottom hole of A1 and B1. A1 core lithology was pyroclastic breccias with andesite fragments and porosity values range from 6-10%. B1 core litology was andesite lava with porosity 1.8-4 %.

Other strato-volcano geothermal fields in Java, such as Wayang Windu and Darajat, give similar porosity values. Wayang Windu lavas have 1% porosity and 6-12% porosity for pyroclastic rocks (Asrizal, 2006). Darajat has 2-4% porosity for lava and 6-12% porosity for pyroclastics (Rejeki et al, 2005).

Porosities used here are 2% for lava and 12% for pyroclastics. After assigning those values to volcanic facies, proximal facies have an average porosity of around 4-6%, medial facies about 10% and distal facies around 12% (**Table 1**). For reservoir in Muara Laboh, a qualitative estimation of average porosity is around 6%.

6. CONCLUSION

The results from facies study show that there are two in-active volcanic centers around Muara Laboh, G. Patah Sembilan and G. Kapur. The majority of volcanic rocks observed in the sub-surface come from the Patah Sembilan Volcanic Centre. Based on this model the Muara Laboh Field has at least three depositional sequences of volcanic products. The first of two sequences were developed before Patah Sembilan Caldera formation and the latest sequence is a resurgent lava flow from the southwest margin of the Patah Sembilan caldera.

Assuming that the heat source for Muara Laboh field is coming from Patah Sembilan and top of reservoir ranging from 600 – 1000 m depth, so

there is more than 70% proximal facies in the reservoir.

Assigning porosity values from rock type to the facies model, gives proximal facies average porosity of around 4-6%, medial facies of about 10% and distal facies around 12%. Average porosity in the reservoir for this field is around 6%.

7. PATH FORWARD

The relationship between rock types, especially lavas, can be validated with XRF analysis. So, the next step is to conduct XRF analysis in selected lava layers to validate the stratigraphic correlation.

The other work is to update the 3D geological model based on this new interpretation and distribute the porosity values using a statistical approach.

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Table 1. Porosity distribution on volcanic facies

Sequence		Facies	Lava Percentage	Pyroclastic Percentage	Average Porosity
Post Caldera		Proximal	80%	20%	4
Pre- Caldera	Sequence 1	Medial	20%	80%	10
		Distal	5%	95%	11.5
	Sequence 2	Proximal	60%	40%	6
		Medial	20%	80%	10
		Distal	-	100%	12

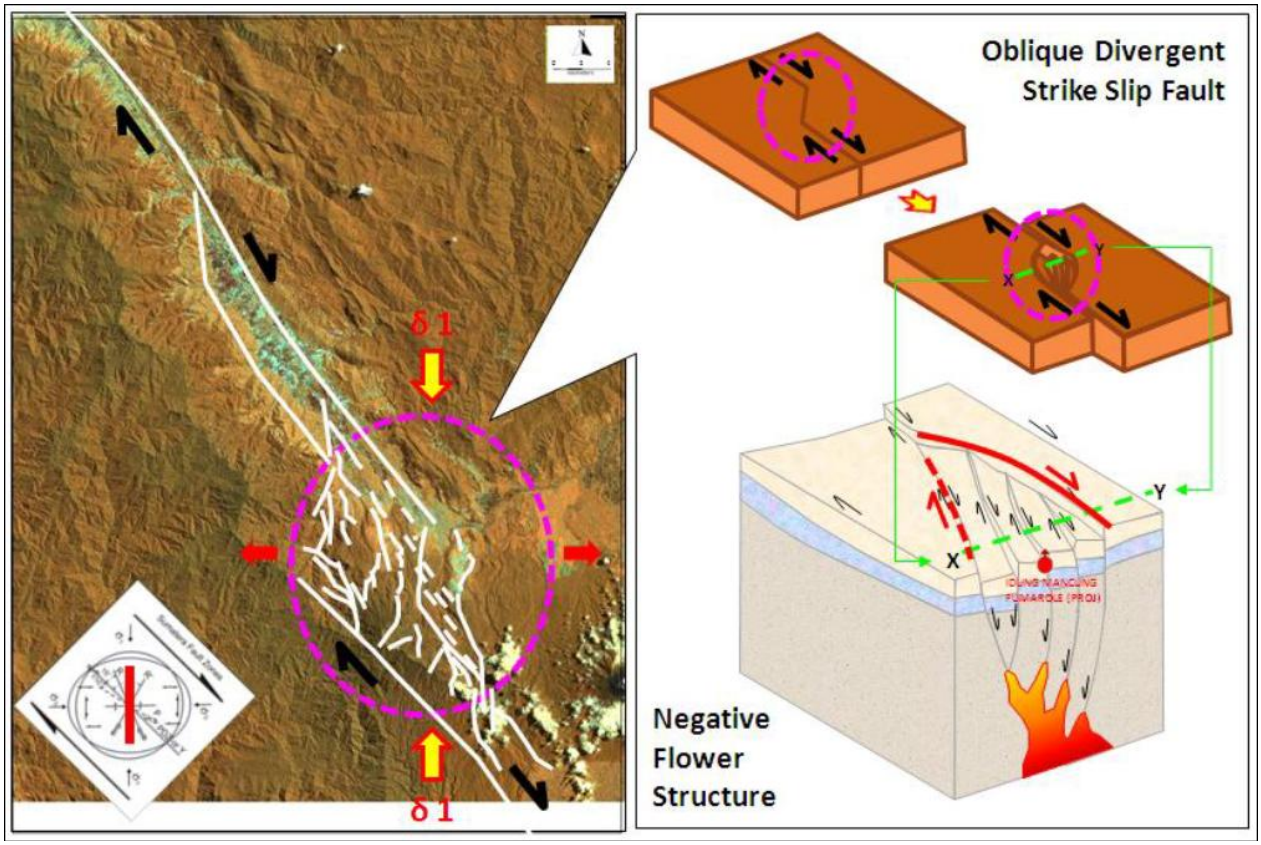


Figure 2. Regional tectonic setting of Muara Laboh (Azis et al, 2012). Right lateral fault that creating *pull-apart basin* system.

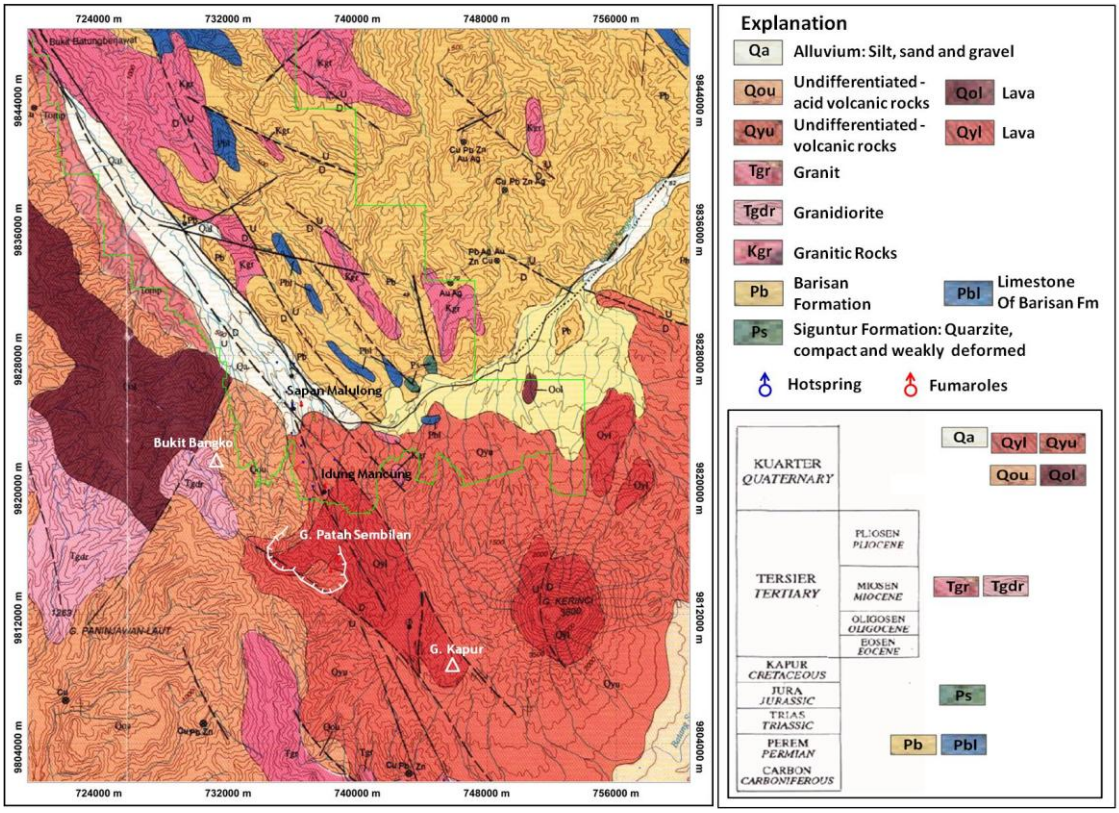


Figure 3. Regional Geology Map of Muara Laboh Area (Adopted from GRDC Geology Map, Rosidi et al., 1996)

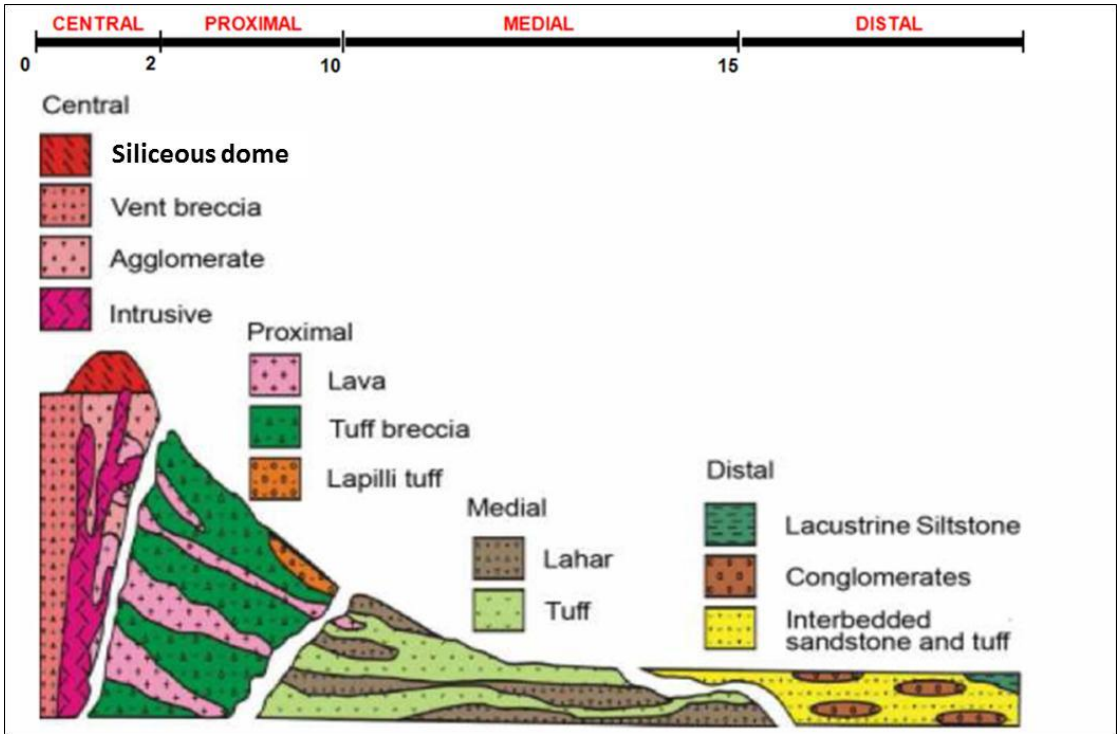


Figure 4. Andesite Stratovolcano Facies Model (Bogie & Mackenzie, 1998).

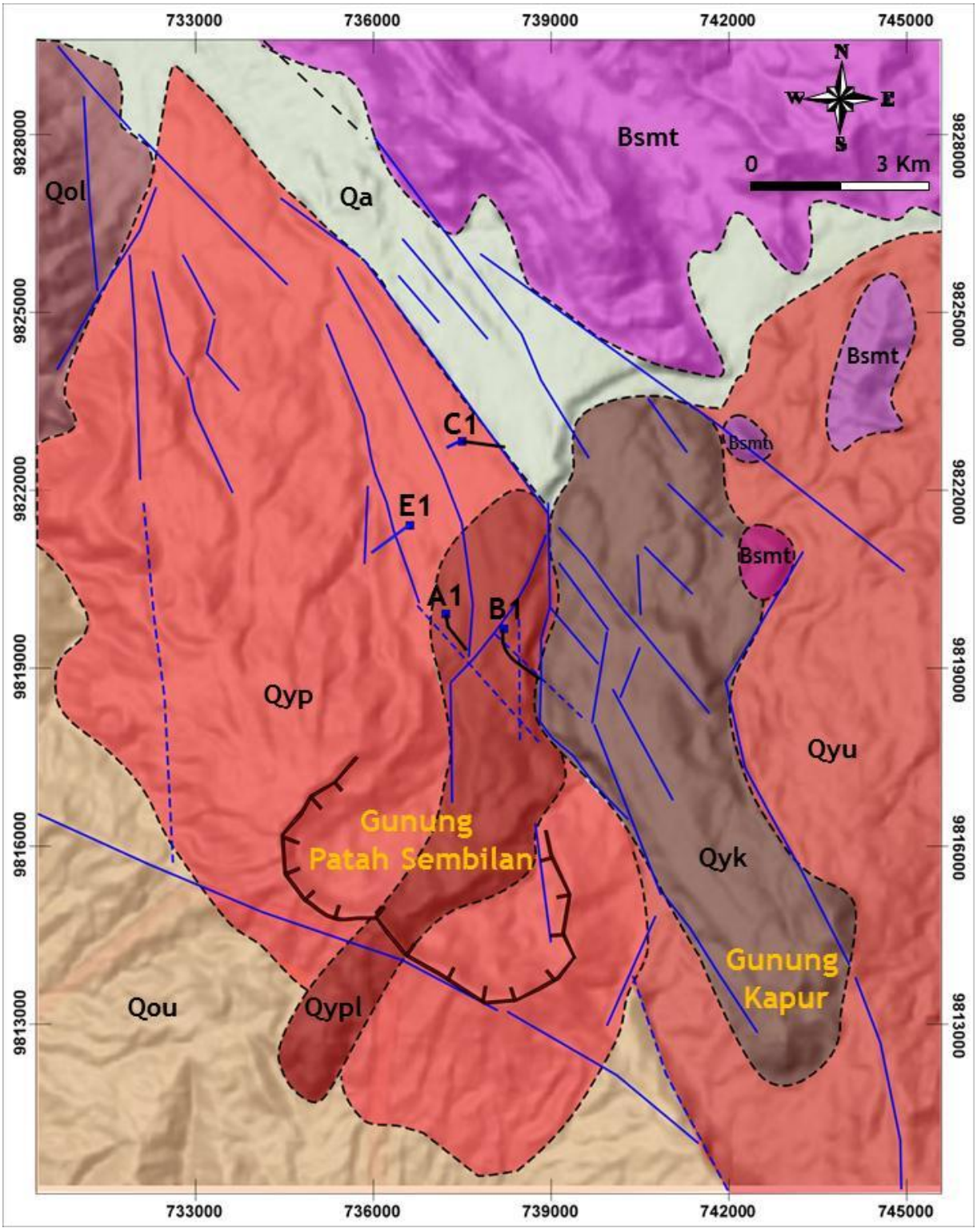


Figure 5. Simplified geology of Muara Laboh Field. Bsmt is basement rock unit consist of metamorphosed Paleozoic Sediment with granite intrusion (Cretaceous); Qou (undifferentiated volcanic rocks) and Qol (lava unit) are early qurternary rocks; Qyp is late Quarternary volcanic products from Patah Sembilan (before caldera deformation); Qypl is lava unit from Patah Sembilan (after/ante caldera deformation); Qyu is undifferentiated rock unit (possibly from Mt. Kerinci) with late Quarternary age; Qyk is lava unit (basaltic lava) derived from Mt. Kapur (Late Quarternary age).

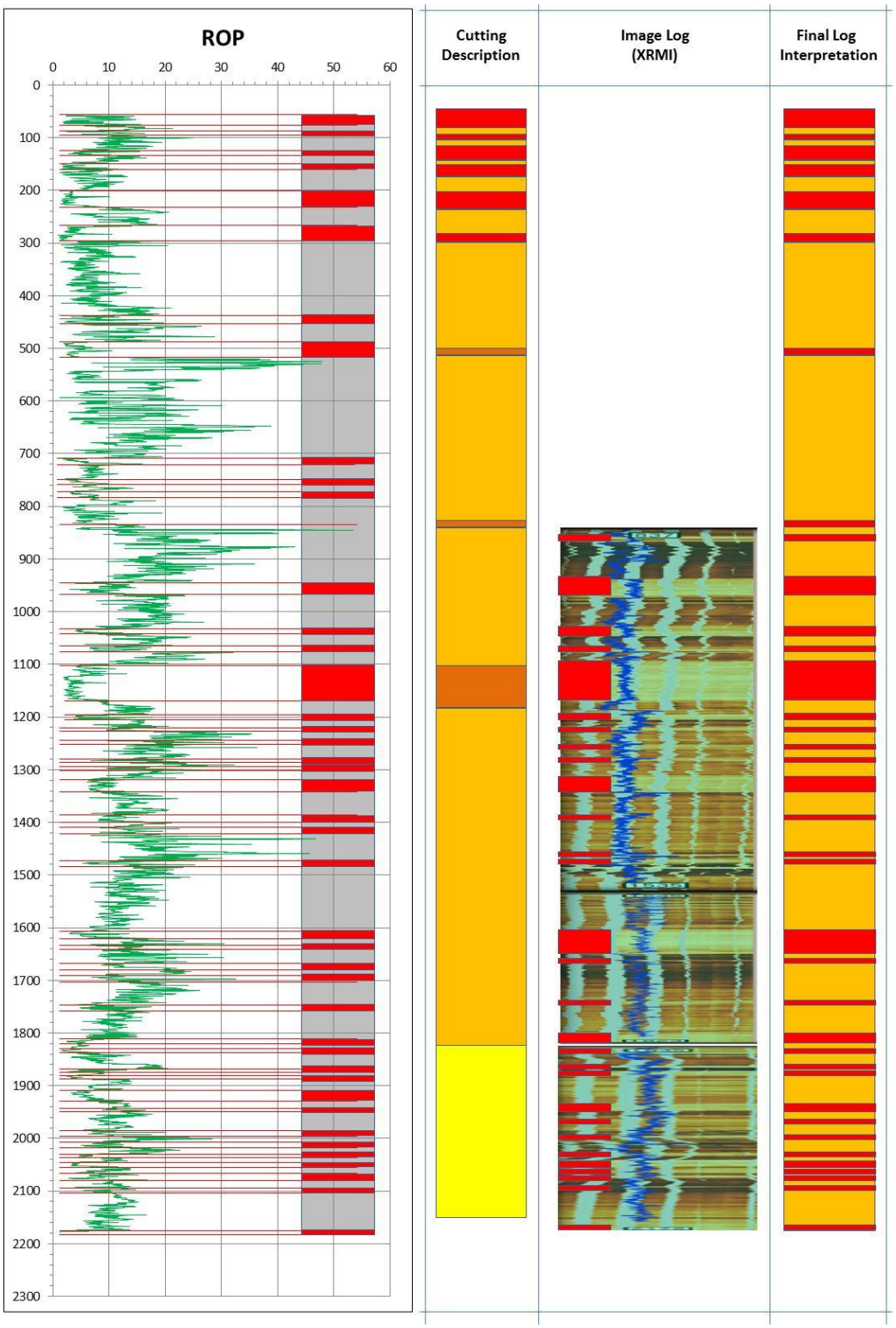


Figure 6. Example of rocks type interpretation using ROP, cutting samples and image logs. In ROP data, red block indicate hard formation and gray block indicate relatively soft. Cotting description show red block for lava, orange for pyroclastic and yellow for tuff. Final log interpretation only classified rock type into two, Lava (red) and pyroclastic (orange).

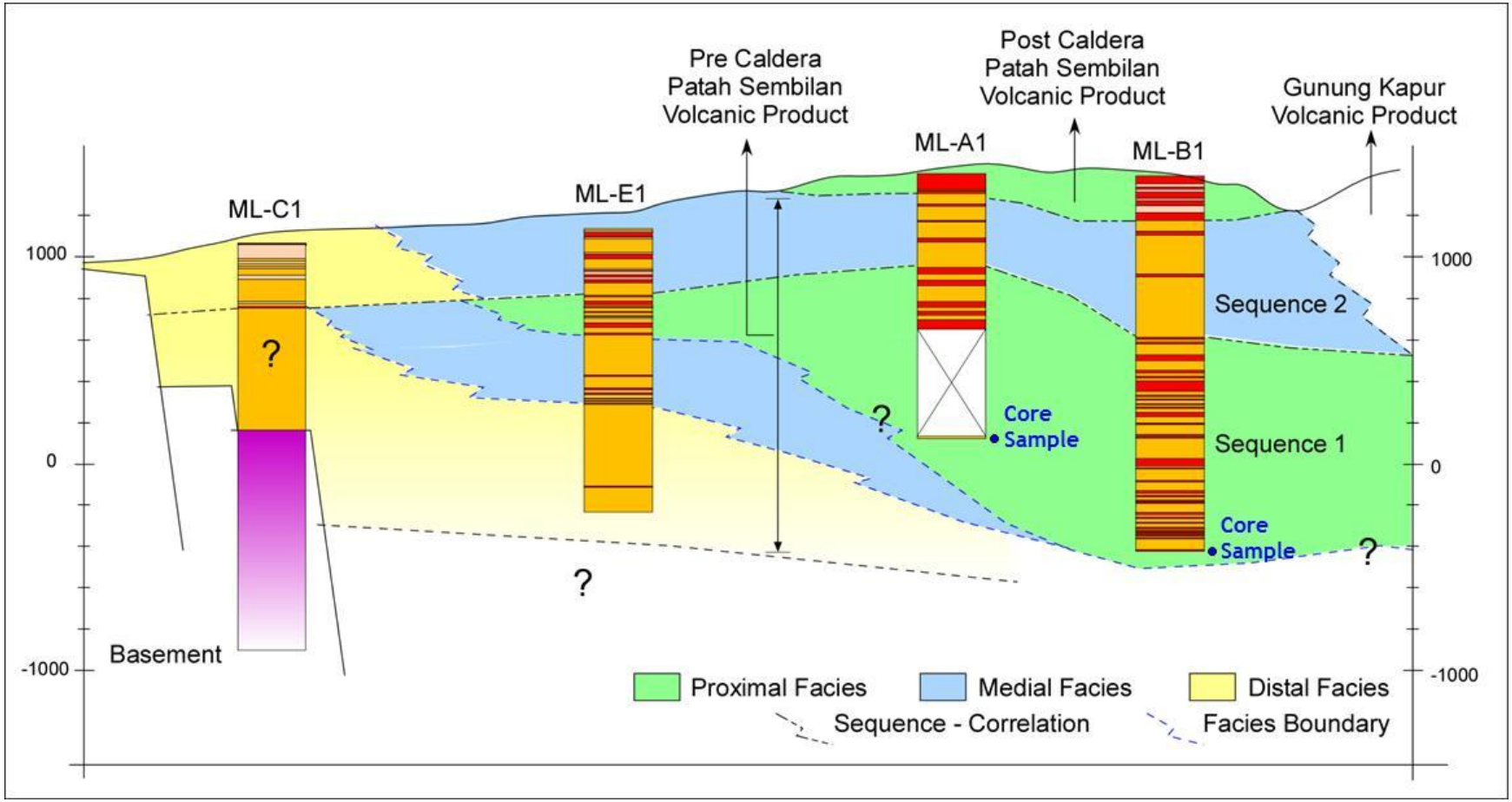


Figure 7. Muara Laboh Volcanic Facies Model (location of the wells can be seen on **Figure 5**).