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# Trace of the Translated Subduction in Central Java and its Role on the Paleogene Basins and Petroleum System Development

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## ABSTRACT

Pamanukan Cilacap Fault Zone (PCFZ), which oriented in NW-SE (Sumatran Trend) has been interpreted to become barrier between Neogene deep water basins in western and central Java, Bogor Basin and North Serayu Basin, respectively. PCFZ also controlled the development of the intra-arc transtensional deep water basin, and the distribution of the volcanoclastic Halang Formation. The PCFZ has been interpreted to have translated the eastern extension of SW-NE pre-Tertiary subduction zone ±200 km to the southeast. These tectonics models suggest that the prolific hydrocarbon zone associated with Sundaland, originally developed to the east of the Northwest Java Basin (NWJB) has been translated to the southeast along the PCFZ. The PCFZ is interpreted as a regional fault which controlled the N-S transtensional pull-apart Paleogene basins in NWJB. The PCFZ is likely to be part of the dextral Malacca strike-slip fault which controlled the development of the Paleogene basins in Sumatra. This regional tectonic reconstruction can be a possible alternative model to explain the distribution of numerous hydrocarbon seep in the Neogene deep water North Serayu and Banyumas basins with enigmatic origin in petroleum system, differed with the adjacent Bogor Basin to the west which shows no hydrocarbon seeps.

## INTRODUCTION

Geological setting of central part of Java is unique due to the occurrence of numbers of undifferentiated geological phenomenon, differs with the adjacent western and eastern Java relatively. The unique features of Central Java include : (1) its position on the transition of basement rocks from continental to accreted crusts, (2) its position on the transition of structural trends from Sumatran to Meratus Trends, (3) the place where the exposure of the oldest basement rock complex of Java Island occurs in the Luk Ulo area, (4) the place where Java's Southern Mountains disappear in southern Central Java in direct contrast to those existing in southern West Java and southern East Java, (5) the place where the Quaternary volcanic arc lineament shifts northward compared with those in the western and eastern Java which are located more to the south, (6) the place where the coastlines of Java Island indent inward compared with those of West Java and East Java, and (7) distribution of numerous oil seeps with enigmatic origin in petroleum system. All of these unique features can be explained and related to the pair of major strike-slip faults – the Muria-Kebumen and Pamanukan-Cilacap Faults which flank central Java and deformed it during the Late Cretaceous-Paleogene (Satyana, 2002).

The reconstruction of the geology dynamics since the pre-Tertiary which explained the unique geologic setting of central Java is still matter of debate among geoscientists. Despite the abundant of surface geological data of this area, the subsurface geological data still remain less, lead to various different interpretations. The structural complexity has formed due to the changes of three main tectonic periods. Pre-Tertiary tectonic pattern so called the Meratus Trend (NE-SW orientation), translated by Paleogene-Neogene Sumatra Trend (NW-SE orientation), overprinted by Neogene tectonic pattern or Java Trend (E-W orientation), meanwhile reactivation of the Meratus and Sumatra fault trend experienced until the present time. Those complexities contribute to the difficulties in interpreting the geological history.

In addition to the tectonic complexity, volcanic covers on the mainland Java induced poor result of seismic image and lack of exploration drilled well in this area. This in turn, adds the difficulties in reconstructing the traces of the geology dynamics, especially prior to the Neogene. Therefore, this tectonic reconstruction is largely based on review of works on the trace of tectonic pattern of the Peleogene and the pre-Tertiary, and geological speculation. This reconstruction is expected to provide an alternative model to explain the basins formation and their implications for petroleum systems.

## REGIONAL SEDIMENTARY BASINS

Three basic Neogene sedimentary provinces can be outlined in West and Central Java, all trending east-west parallel with the long axis of the island: (1) The uplifted non marine to shallow marine sediments in the north, that is the prolific Northwest Java Basin, (2) The uplifted volcanic and carbonate sediments in the south (southern mountains), and (3) The subsided volcaniclastic sediments in the center (Bogor-North Serayu Basin) (Figure 1). Deepwater sedimentation is related with the last of these, a geologic province that has been significantly uplifted since the Plio-Pleistocene.

The Northwest Java Basin consists of sub-basins with their axis oriented in N-S direction (Sunda Trend), and formed at least since the Eocene. The Paleogene sedimentary basins developed along NE-SW zone (Meratus Trend) in west Java, coincide with the active Cimandiri Fault. This fault distributed along the boundary between the quartz-rich Eocene shallow marine-deltaic basins in the NNW (Bayah and Gunung Walat) and the quartz-rich Eocene-Early Oligocene deep marine basin in the SSE (Ciletuh/Ciemas, Cikalong and Cisambeng/Pada-larang) (Figure 2).

## THE TECTONICS OF SOUTHEAST ASIA

Java Island, located at the southern end of the Sundaland craton, was formed by rock assemblages associated with an active margin of plate convergence. The island has recorded plate convergence between the Indian oceanic crust and the Sundaland continental fragment since Late Cretaceous time. Therefore, the island is made up of a complex of plutonic-volcanic arcs, accretionary prisms, subduction zones, and related sedimentary rocks.

The development of the tectonic pattern in Java can not be excluded from the tectonic of SE Asia which experienced significant change since the Eocene (±50 ma). This significant change were coincide with the Indian-Asian continent collision event, characterized by the commencement of the Paleogene basins formation in Sumatra, Natuna and Java, changing of the pre-Tertiary subduction zone of NE-SW Meratus Trend into the E-W Java Trend. This tectonic change is still matter of debate among the geoscientist. This paper will discuss several theories that hypothesized the establishment of the Southeast (SE) Asia and its implications to the tectonics and the basin formation in Indonesia, especially in central and western part of Java.

Major tectonic changes in SE Asia occurred during the Indian-Asian continent collision (±50 ma) (Tapponnier et al., 1982). The collision followed by the extrusion of Indochina continental blocks to the southeast as far as ±800 km, and $\pm 25^{o}$ clockwise rotation. The extrusion accommodated by strike-slip faults, and one of them is the Red River Fault which is expected to have been translated approximately 550 km with left lateral motion between 32-15 Ma (Briais et al, 1993).

Daly et al., (1987) suggests it is sufficient to say that the block rotations predicted by the extrusion model of Tapponnier et al., (1982) appear to be acceptable in that they are supported by the limited paleomagnetic data. However, the very large displacements on strike-slip faults which Tapponnier et al., (1982) predicted are geologically unproven. Nevertheless, Daly et al., (1987) accepted some strike-slip displacements on the major fault structures and interpreted the initiation of much of the basins evolution in SE Asia corresponded temporally with the Eocene collision between India and Eurasia. The basin systems of Sumatra, Java, Malaysia, Thailand and Kalimantan were initiated during this Eocene period. The Malacca and Semangko Fault Zones (Sumatra Trend) respectively, they appear to have the geometry of large scale pull-apart basins generated by duplex right lateral displacements. Rift sediments in these basins are dated as Middle to Late Eocene. Along the strike of the Sumatra Trend fault system, similar basins developed in

Northwest Java but they appear to be slightly younger, with rift sedimentation dated as Oligocene (i.e. Sunda-Asri Basin) (Figure 3).

In respond to the extrusion theory (Tapponnier et al., 1982), Hall et al., (1998) suggested almost similar to the one of Daly et al., (1987), that despite the great attraction of this hypothesis and the spectacular evidence of displacements on the Red River fault (Tapponnier et al., 1990) the predictions of major rotations, southeastward extrusion of fragments, and the timing of events (Tapponnier et al., 1982), remain poorly supported by geological evidence in SE Asia. Hall, (1997) suggests that Sumatra, Java and Kalimantan were not rotated clockwise as has been interpreted by Tapponnier, et al., (1982) and Daly et al, (1987), but were actually rotated in counter clockwise in Tertiary. Furthermore, the formation of the Paleogene basins in Sumatra and Java was not initiated as transtensional process, but rifting that may represent the consequences of oblique convergence or extension due to relaxation in the over-riding plate in response to India-Asia collision, enhanced by slowing of subduction, further influenced by older structural fabrics.

Apart from the debate of geodynamic theories aforementioned above, based on the geological structures in the border of west and central Java, a NW-SE right lateral fault zone is suggested to have controlled the geologic setting. Whether this fault zone was caused by tectonic extrusion (Tapponnier, 1982) or the oblique subduction (Hall, 1998), can be further discussed. Based on review of regional pattern of the geodynamics of SE Asia, the following discussion will cover the regional tectonic pattern of Java and then focus on the interpretation of the unique tectonic setting of central Java.

## THE TECTONICS OF JAVA

There are some published studies on the structural patterns of Java Island based on surface geology, gravity, magnetic, aerial photos, satellite imagery, and seismic. Pulunggono and Martodjojo (1994) grouped the structural trends of Java Island into three groups, including: (1) Meratus Trend (southwest-northeast), (2) Sunda Trend (north-south), and (3) Java Trend (west-east). Based on gravity data interpretation (Untung, 1974; Untung and Hasegawa, 1975 ; Untung and Sato, 1978 ), there is another trend in addition to the previously three trends, namely (4) Sumatra Trend (northwest-southeast). The existence of the structures with Sumatra Trend is also supported by seismic data (Pramono et al., 1990; Gresko et al., 1995; Ryacudu and Bachtiar, 2000).

The structures with Sumatra Trend mainly exist in west Java area and disappear to the east of central Java area. In contrast, the structures of the Meratus Trend dominate the structural grains of northern east Java (Satyana and Darwis, 2001) and reduce or disappear to the west of central Java. It looks as though central Java again occupies a structural transition area between the Meratus and Sumatra Trends. The formation dates of these structures are: Late Cretaceous (Meratus Trend), Late Cretaceous-Paleocene (Sumatra Trend), Eocene-Late Oligocene (Sunda Trend), and since Early Miocene in the case of the Java Trend. The structural grains of Meratus, Sumatra, and Sunda Trends are generally comprised of normal and strike-slip faults, whereas folds and thrust-reverse faults constitute the Java Trend.

In general, the Sumatra and Meratus Trend fault system in Java Island expressed by two major strike-slip faults with opposing trends and slips are responsible for the indentation of northern coastline of Central Java. The Meratus trend faults are called the Muria-Kebumen Sinistral Fault (MKSF), trending southwest-northeast (eastern part of central Java) and the Sumatran Trend faults are called Pamanukan-Cilacap Fault Zone (PCFZ), trending northwest-southeast (western part of central Java). Those two faults crossed central Java, separated in the northern area but met in the southern area which made the triangle of compressive tectonic locked zone that uplifted the Karang Sambung area and subsided the outer area of triangle zone that caused the subsidence of Old Andesite (Oligo-Miocene) in southern part of central Java (Satyana, 2002) (Figure 4).

## TANSLATED SUBDUCTION BY PAMANUKAN-CILACAP FAULT ZONE (PCFZ)

The PCFZ which oriented in NW-SE (Sumatra Trend) is a large right lateral fault system that made the difference between the geology of west and central Java. The characteristics of the fault system movement are as follows:

1) PCFZ has been interpreted as a barrier and shifted the zone of Neogene deep marine basin in west Java (Bogor Basin) and in central Java (North Serayu Basin), and to have controlled the formation of an intra-arc transtensional deep water basin which characterized by the distribution volcanoclastic Halang Formation (Armandita et al., 2009) (Figure 5).

2) PCFZ is interpreted to have changed the structural pattern in the north of NWJB and Sunda-Asri from NE-SW Meratus Trend into the N-S Sunda Trend. This N-S is interpreted as transtensional faults of PCFZ duplex system (Figure 6) as has been suggested by Daly et al., (1987), proposed that the N-S trend Paleogene basins in Sumatra were developed due to transtensional duplex of right lateral Malaca and Semangko (Sumatra) faults The formation of the Paleogene NWJB and Sunda Asri basins is suggested to have been controlled by the PCFZ as the southeastern extension of the Malaca Fault (MF) (Figure 6, 7). During the time of its formation in the Paleogene, it is likely that the PCFZ and MF were developed as a unified system. However, in the present reconstruction, based on gravity anomaly map, both the fractures were not connected, even though these two fault system having the same orientation but PCFZ is oriented closer to E-W than Malaca Fault (Figure 6, 7). This is probably due to difference in degrees of the rotation between Sumatra and Java. Daly et al., (1987) suggested that Java and Sumatra were rotated clockwise during ±20 ma, whilst Hall, (1997) interpreted that these islands were unified in similar trend of NW-SE before ±10 ma and then Sumatra underwent $15^{o}$ counter-clockwise rotation while Java rotated $30^{o}$ counter-clockwised. The difference in degree of rotation of the two islands is suggested to have caused the break of the Malaca-PCFZ system and the opening of the tensional gap in Sunda Strait Sunda Strait and allowed the magmatism of Krakatau volcano.

3) USGS thematic map indicates differences in the zone of Peak Ground Acceleration (PGA) between west and central Java, and this boundary coincides with the PCFZ zone (Figure 8). West Java has higher PGA (2.4 - 3.2 m/s2) compared to central Java area (1.6 - 2.4m/s2). This value could be addressed to the basement rock resistancy to earthquake, where the basement rock in central Java is possibly stronger (continental crust?) than the one in west Java (oceanic crust?).

4) The PCFZ has translated the zone of the Paleogene shelf edge in west-central Java. The Paleogene shelf edge zone in west Java was indicated by the Cimandiri Fault which separates the quartz-rich Eocene shallow marine-deltaic sediments (Bayah and Gunung Walat area) in the NNE and the quartz-rich Eocene-Early Oligocene deep water sediments in the SSE (Ciletuh/Ciemas, Cikalong and Cisambeng/ Padalarang). Based on the structural interpretation of gravity data, the Cimandiri fault zone which oriented in E-W direction in Pelabuhan Ratu extended into NE-SW (Meratus Trend) in the eastern part (Figure 2). In Padalarang this fault zone has been broken and offset by the PCFZ.

Due to the great size of the PCFZ, it is possible that the eastern part of the Paleogene shelf edge has been shifted southeastward by this fault system. Unfortunately The Paleogene shelf edge zone in central Java was no longer obvious, which might have been overprinted by the E-W Java Trend structures. However, on the gravity data, traces of NE-SW Meratus Trend are still visible and might be reflection of the Paleogene shelf edge zone in central Java area (Figure 6).

The similarity of stratigraphy between the area of NW Worawari/Sigugur Terrane (Figure 6) and Padalarang could be one of the field evidence for the translation of the Paleogene shelf edge. An interesting analog stratigraphy outcrops shows by Early Oligocene of the Bagelen beds and nearby Sigugur limestone and the deep marine, Early Oligocene turbidites below the reef-complex, Late Oligocene Rajamandala limestone outside Bandung (Padalarang) (Lunt and Sugiatno).

Recent field observations in Padalarang area suggests that the Early Oligocene turbidites is quartz sandstone previously has been interpreted as shallow marine deposit due to the similarity of component with the one in the Batuasih Formation (Kurniawan W., 2008) is likely to be deposited as deep water turbidite channel based on the characteristic of the sedimentary structuresThe Early Oligocene.

The location of the Paleogene shelf edge has been interpreted to have developed paralel along E-W lineament (Lunt and Sugiatno) possibly due to assumption that the zone is developed along the Java Trend. However, by considering the Paleogene shelf edge is actually developed along SW-NE Meratus Trend, the Sigugur Terrane is likely to have translated to the southeast from its previous location by the PCFZ. Interestingly, the Sigugur Terrane is located near of the lineament interpretation of Paleogene shelf edge, or analog to the position of Padalarang which also located near to the the Paleogene shelf edge.

There is a possibility that Sigugur limestone might be an extremely large olistolith, therefore can not be compare with Rajamanda Limestone which is obviously not an olistolith (Lunt and Sugiatno). But, if we consider that limestone is olistolith, there is another possibility that olistolith would imply slumping of shallow marine carbonate from Paleogene shelf edge area (northwestern) into Palogene deep water (southeastern). Thus, the interpretation of translated Paleogene shelf edge in central Java still can be considered.

5) Two structural low areas so called the Western and Central Provinces have been interpreted to be separated by a deep seated pre-Miocene fault oriented in NW-SE (Bolliger and Ruiter, 1975). This interpretation was largely based on Shell N.V. exploration data during 1971-1974, including seismic data, magnetic and drilling well. This fault is interpreted to have right lateral movement, and based on the gravity map, its northwestern tip is relatively coincide with the southeastern tip of the PCFZ. Due to the similar orientation and nature of the movement, the NW-SE deep-seated fault in the offshore central Java is interpreted as the southeastern extension of the PCFZ (Figure 9). Furthermore, PCFZ is also interpreted to have translated the NE-SW structural lineaments (Meratus Trend) that separated structural highs and lows prior to Miocene. The translation Meratus Trends structures in the offshore central Java is interpreted to have extended to the onshore, which are no longer visible due to the overprinted of E-W Java Trend and thick volcanic covers. However, trace of the translation of the Meratus trend structures by the Sumatra Trend is still can be recognized in gravity anomaly map (Figure 6).

6) The PCFZ or also called Citanduy Fault has been interpreted as a dextral fault zone that translated the eastern part of the SW-NE pre-Tertiary subduction zone (Meratus Trend) to the southeast (Simanjuntak 1979; Koesoemadinata 2006) (Figure 10 and 11). The translation of this subduction zone has been interpreted by the occurrence of chert argillite, limestone and spilitic rocks in the lower part of Jampang Formation (Simandjuntak 1979). These rocks are thought to have been derived from the socalled Jampang High (West Java) and Menoreh High (Central Java) non-volcanic outer arc, which is developed as a submarine high during and subsequently after the Tertiary collision with Indian Oceanic plate. The separation of position of Jampang High in west Java (Citanduy) and Menoreh High in central Java (Sleman) is interpreted to have translated by the PCFZ. Because the rocks formed the lower part of Jampang Formation has been suggested as an outer arc of the subduction zone, the PCFZ is interpreted to have translated the pre-Tertiary subduction zone in Java. The translation of the northeastern extension of the Ciletuh pre-Tertiary subduction zone ±110 km to the southeast (Karangsambung subduction zone) along the PCFZ has been suggested by Koesoemadinata (2006).

The translation of the subduction zone is however, quite far, but based the on the six points discussed earlier, this translation is still plausible. Based on the extrusion tectonics of Tapponnier et al. (1982) the translation is not only occurred in Java. The Red River Fault has been suggested to have translated 550 km long(Briais et al, 1993). Even though not fully agree with the extrusion tectonics theory, Daly (1987) has suggested that several strike-slip faults developed due to the extrusion in SE Asia which have controlled the formation of the Paleogene pull-apart basins in Java and Sumatra. Hall (1997), although did not agree with the lateral movement developed as the compensation of the extrusion, has suggested the existence of strike-slip faults in the continent due to the Paleogene oblique subduction or analog to the development Sumatra Fault due to Neogene oblique subduction offshore western Sumatra.

## PETROLEUM IMPLICATIONS

Based on the facts mentioned above, the PCFZ is suggested to have largely controlled the geological conditions in central Java area. The amount of translation would have implications on the basin evolution and petroleum systems.

One of the unique geological aspects of central Java is the occurrence of hydrocarbon seeps in several locations in the Neogene deep water North Serayu and Banyumas basins. This is contrast with the western extension, the Bogor Basin, which shows no hydrocarbon seeps (Figure 12).

The interpretation of the translation of the pre-Tertiary subduction zone toward Central Java by the PCFZ has implication to the translation of the prolific NWJB or Sundaland Continent and the Paleogene shelf edge of west Java toward central Java. In other words, there is a possibility that part of the basement in central Java area was continental basement type that translated by PCFZ from its original position in the NW. The difference of PGA zone between the west and central Java along the PCFZ zone suggests differ basement type between the two area, and might indicates the development of this fault zone (see point 3 of the Translated subduction).

Based on the point mentioned above, there is a is possibility that the source rock responsible for the occurrence of hydrocarbon seeps in central Java is equivalent to the Oligocene continental-derived sediments of Talang Akar Formation in NWJB, or the fluvio-deltaic Bayah or Gunung Walat formations to the west of the Paleogene shelf edge .

The possibility of the Paleogene source rock sediments is rather difficult to trace due to the deepening of the deep water basins in Java, Bogor-North Serayu-Kendeng, as an isostacy compensation of the uplift of the Southern Mountain (Old Andesite) during Early Miocene. The development of deep water basin in Java marked the new tectonic period with E-W oriented structures and overprinted the pre-Tertiary and Paleogene structures. However, the Eocene sediments cropped out in some structural highs: Karangsambung and Bayat. The thick volcanic deposits buried the Paleogene to greater depth. The thick volcanics in central Java induced the poor image of seismic data that increased the difficulties in obtaining the subsurface data. The only way to identify the source rocks in central Java is through geochemical analysis of existing hydrocarbon seeps (oil to source analysis).

Based on geochemical analysis of oil seeps in the central Java, it has been interpreted that the source rocks for the oil seeps in Jati-1 well and Karang Kobar (sample LW05A) (Figure 12), were possibly the Eocene Karangsambung Formation and the Eocene fluvio-deltaic deposits equivalent to Wungkal Formation, respectively (Subroto et al., 2006; Soeboto et al., 2007). In the area where LW05A were sampled, the insitu Eocene rocks were not found, suggesting these rocks were still buried in Karang Kobar area.

Geochemical analysis of oil seeps in Cipluk area, Kendal, Central Java, has been taken by the excursion team of BPMIGAS 2009. The results show that oil in Cipluk is kerogen Type III or associated with fluvial/deltaic source rock. The source rock can be interpreted to be equivalent to Oligocene Talang Akar Formation in NWJB or maybe the Eocene fluvio-deltaic deposits in central Java prior the North Serayu subsided and became deep water basin.

Furthermore, the PCFZ zone in the border between west and central Java has been interpreted to have controlled the formation of the Paleogene basin before induced the development of volcaniclastic Halang Formation zone (Usman 2011, personal communication). The formation of the Paleogene basins by the PCFZ is analog to the formation of Paleogene basins in NWJB which also interpreted to have formed by PCFZ (see point 2 of Translated subduction). The Paleogene basins along the PCFZ between west and central Java is possibly to have formed as a zone where source rocks were deposited, incates by numerous oil seeps along this zone.

Based on analyses of the potential source rocks, it is possible to have the Paleogene lacustrine-fluvio-deltaic to shallow marine sediments as the source rocks in the central Java. The occurrence of the Paleogene terrestrial-shallow marine sediments in central Java can be explained by the translated subduction tectonic model.

Results of 8 drilled wells in the onshore-offshore north central Java revealed numbers of discoveries of non-economic oil and gas, and some of those exhibited hydrocarbon shows. These 8 wells were located in the North Central Java Basins (NJCB). It is likely, that the NJCB is not similar with the proven prolific oil and gas NWJB. It is interpreted that the eastern extension of the NWJB has translated toward the southeast NCJB along the PCFZ. The northern coast of central Java has been interpreted as a low area due to the isostacy of the uplift of Karang Sambung area (Satyana, 2002). Therefore the high area is interpreted to have developed to the south of NCJB and allow hydrocarbon migration from kitchen zone toward the high in the south (Armandita et al., 2010), indicated by numerous hydrocarbon seeps along the PCFZ..

Even though the southern part of central Java is rich in hydrocarbon seeps, but drilling results of some wells have not shown encouraging results. Numerous oil seeps in Banyumas area, south western part of central Java have been targeted and drilled by Dutch companies and the later operators (Pertamina and Coparex/Lundin). The wells so far failed to find commercial hydrocarbons. Most of the wells underwent mechanical troubles related to overpressuring generated by deepwater Halang and pre-Halang (called as Penosogan) volcaniclastics. The last well drilled in the area was Jati-1 well (Lundin, 2005). The well underwent many mechanical troubles, and did not get the objective, but the well reached the deepest horizon that has never been reached by previous wells. Jati-1 well found small amount of oil and gas from sandstone intercalations within the Middle-Miocene Penosogan volcaniclastics. There is no drilled well in Majenang area, even though numerous oil and gas seeps occur in this area.

The challenges of oil and gas exploration in the central Java region is due to the poor seismic image induced by to thick volcanic deposits and the dense population that will give significant effect to the complexity of the structure due to the overprinted structures since the pre-Tertiary to Recent and the license process, respectively. Despite the existence of hydrocarbons is highly convincing, but the poor seismic data add the difficulties on identifying the trap geometry and verifying the distribution of hydrocarbon trap. This will induce the uncertainty of the commercial of the prospect. Since seismic imaging is an important key in solving the petroleum system, it is a challenge for the the geophysicists to overcome such difficulties.

## DISCUSSIONS

The present reconstruction of the tectonic model is largely base on the secondary data or compilation of previous works. Furthermore, the lack of subsurface data in the study area, make the interpretation not solely based on the existing data, but also rather support by geological analog, logic and imagination (speculation). Nevertheless this model is expected to be an alternative concept of regional geology to explain the complexity of geology of of central Java, in particular for the presence of hydrocarbon seeps in central Java and can be used as a guide line to look for more detail analysis of petroleum system or further exploration strategy.

The translation of the strike-slip PCFZ is also hypothesized to govern the change the direction of the SW-NE pre-Tertiary subduction zone (Meratus) into the E-W Tertiary subduction as it is today. At the eastern margin of Sundaland, the accretion stopped at around 50 Ma (Middle Eocene) and the accreted crust started to disperse beginning with the opening of the Makassar Straits. The dispersion of terranes, by either rifting or sliding, results in the diminution of continents (Satyana, 2010). The cease of the accretion in the margin of Sundaland was initiated by the onset of India-Asia continents collision that restrained the Gondwanaland (India and Australia) to the north.

The first strike-slip fault system formed after the collision in Sumatra might also continued to Java, the Malaca-PCFZ zone, if refer to the extrusion of SE Asia block to the southeast (Tapponnier et al., 1982); then this extrusion block was clearly inhibited the movement of the Gondawanaland to the north. After the deceleration of the movement of India and Australia to the north, the PCFZ initiated to break Java which is a subduction zone located in the Sundaland margin. PCFZ is suggested to have developed approximately during the Late Eocene-Early Oligocene and form the transtensional/ pull-apart basin which later filled by syn-rift sediments in NWJB. Later on, the tectonic extrusion zone move further to the north or accommodated by the Red River Fault in 32 ma (Oligocene), which reduced the extrusion via Malaca-PCFZ fault. In addition, the emergence of the Early Miocene Old Andesite which became the large volcanic body in the south of Java is likely to affect the reduction of pressure of the extrusion, and enhanced the extrusion moved to the north. When the extrusion decreased, the movement of Gondwanaland to the North became faster, and commenced the reorganization of Meratus subduction zone that have been translated prior to the present Java subduction zone.

This present hypothesis refers to the extrusion model (Tapponnier, 1982) which not applied in the tectonic reconstruction model of Hall (1997). Therefore, this hypothesis is still open for further discussion. However, Hall (1997) accepted the deceleration of the India-Australia movement to the north during 42 ma (Middle Eocene) due to the collision of India and Asian continents. This deceleration if assumed to be followed by the translated subduction, then Australia may have moved to north faster and is expected to have changed the Meratus subduction zone into the present Java subduction zone.

## CONCLUSIONS

1. The Malaca-PCFZ fault is interpreted to be one of the strike-slip faults that have accommodated the extrusion of SE Asia blocks referred to the tectonic extrusion model (Tapponnier et al., 1982). In the other hands, the formation of the Paleogene basins has been interpreted due to the deceleration of Gondwanaland (India-Australia) to the north, and the formation of strike-slip faults in the western margin of the Sundaland (Sumatra-Java) is due to oblique subduction.

2. The PCDS is interpreted to have developed as right lateral fault and induced:
   a) the formation of the trantensional (pull-apart) Paleogene basins in NWJB and interpreted to have extended to the NW with the Malaca Fault system which have controlled the formation of the Paleogene basins in Sumatra (Daly et al, 1987and Sapiie B. et al, (2007),
   b) the separation of two Neogene deep water basins: Bogor and North Serayu basins,
   c) the separation of two differed Peak Ground Acceleration Zones in west and central Java. This indicates differed basement rock resistance to earthquakes, where the basement rock in central Java is stronger (continent basement?) than the one in west Java (oceanic crust?),
   d) the distribution of volcanoclastic Halang formation,
   e) translation of the Meratus Trend structures and became the boundary between the Western and Eastern Deeps offshore south central Java,
   f) Translation of the Paleogene shelf edge in west-central Java.
   g) Translation of the Meratus subduction zone as far for ±110 km to the southeast.

3. Indications of large translation of the PCFZ implies on the translation of the eastern extension of the prolific NWJB or Sundaland Continent and the Paleogene shelf edge in central Java. It is possible that some the basement in central Java might have been translated by PCFZ.

4. Based on geochemical analysis of the oil seeps, the hydrocarbon source rock in central Java is interpreted to have deposited as continental-derived Paleogene sediments equivalent to the Oligocene Talang Akar Formation in NWJB or to the fluvio-deltaic Bayah/Gunung Walat deposited to the west of the Paleogene shelf edge in west Java. This interpretation supports the hypothesis of the translated continental basement due to the PCFZ movement.

5. The non-commercial or no-oil discovery (hydrocarbons shows only) exhibit by drilled wells in the North Central Java basins (NCJB) shows that these basins can not be compared with the oil-rich NWJB. The eastern extension of the NWJB is interpreted to have translated to the southeast in central Java.

6. The regional pattern of hydrocarbon migration is interpreted toward the south of central Java, since the uplift of Karangsambung area has induced the northern coast of central Java to subside. The pattern of high and low areas explains the absence of hydrocarbon trap in the northern coastal area of central Java.

7. One of the biggest challenges in oil and gas exploration in central Java area is the poor seismic image due to thick volcanic covers. This implies on the necessity of geological model approach, and progressive improvement in geophysical method, especially in seismic reflection to obtain better image of the subsurface, in particular, for the area covered by thick volcanic products.

8. The translation of the subduction zone is suggested to have changed the direction of Pre-Tertiary Meratus subduction zone into the present Java subduction zone.

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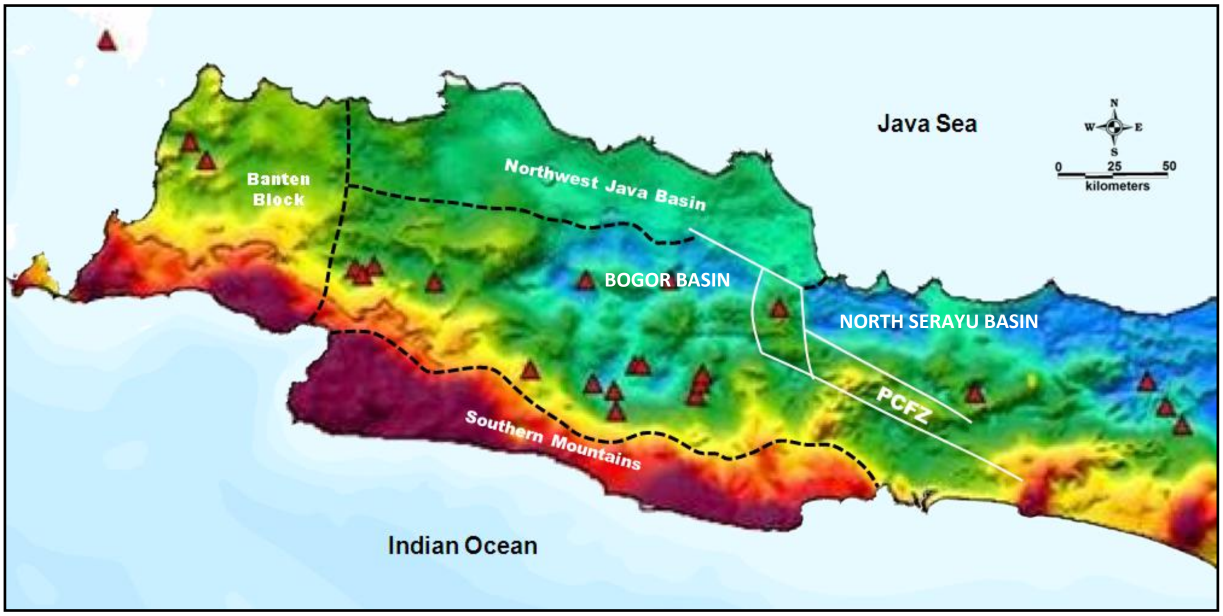


Figure 1. Sedimentary basins in west and central Java

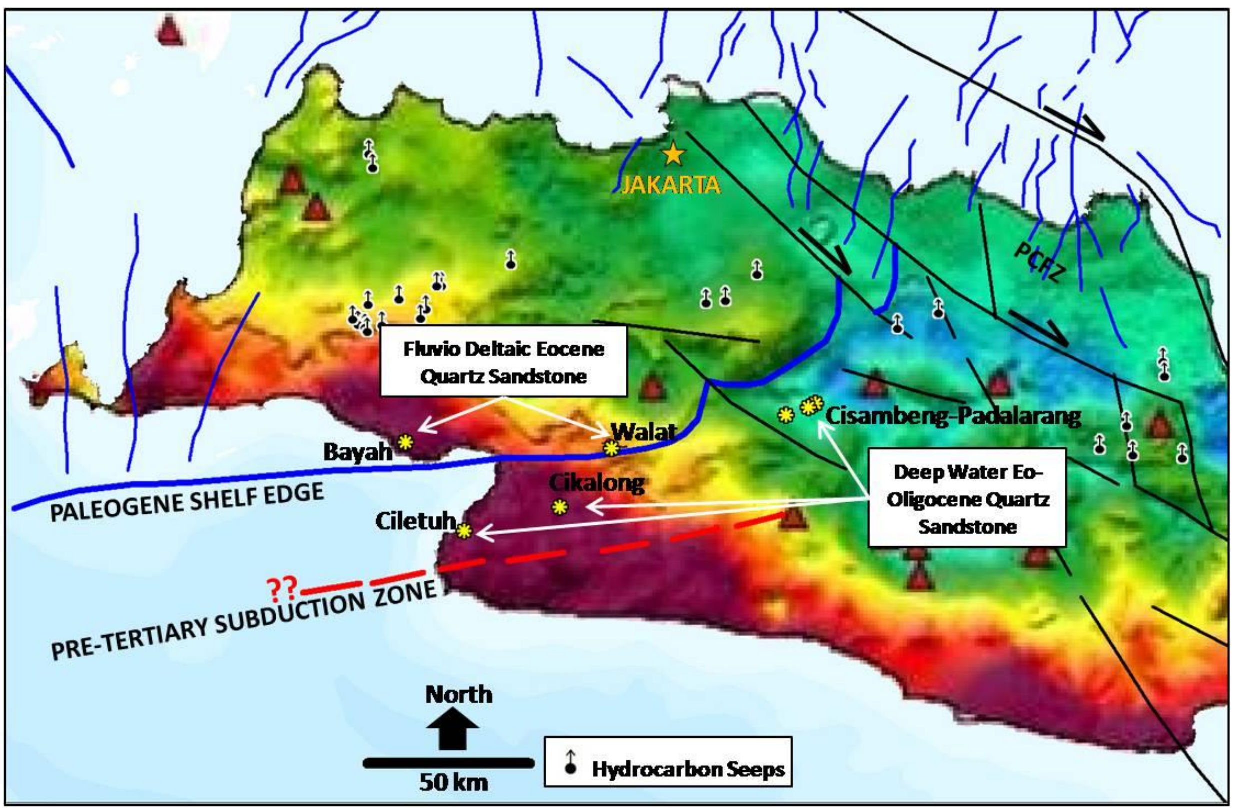


Figure 2. Distribution of the Quartzitic Paleogene outcrops, the Paleogene shelf edge and the pre-Tertiary Subduction Zone in West Java.

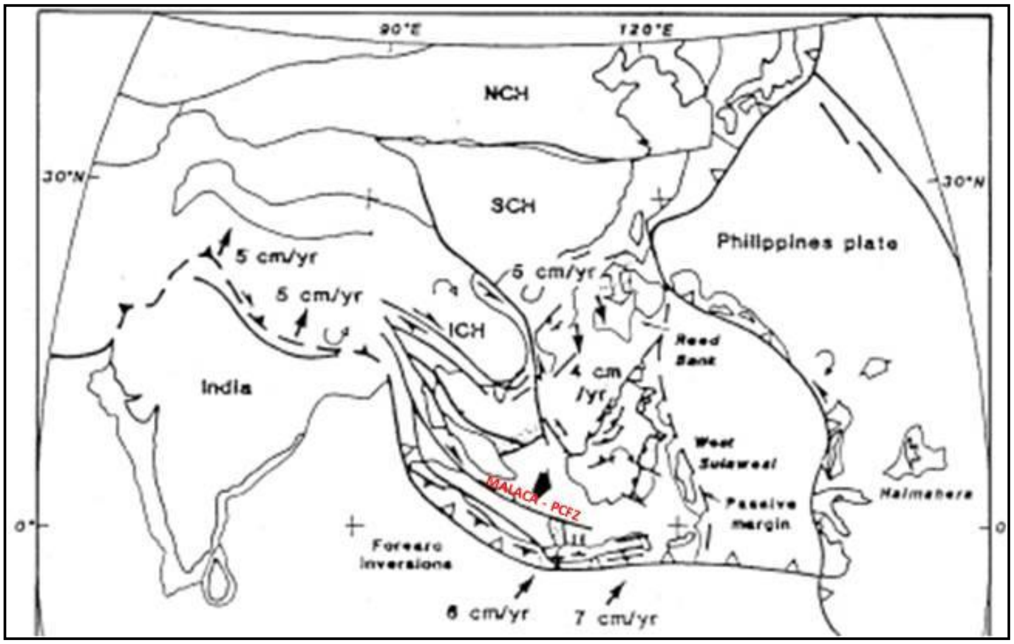


Figure 3. The Oligocene reconstruction. The India – Asia Collision induced the extrusion of SE Asia, accommodated by strike-slip faults, and the one developed along Sumatra-Java Island, the Malaca-PCFZ controlled the trantensional/pull-apart basins development in Sumatra during the Eocene and in North West Java/Sunda Asri Basins during the Oligocene (Daly et al., 1987).

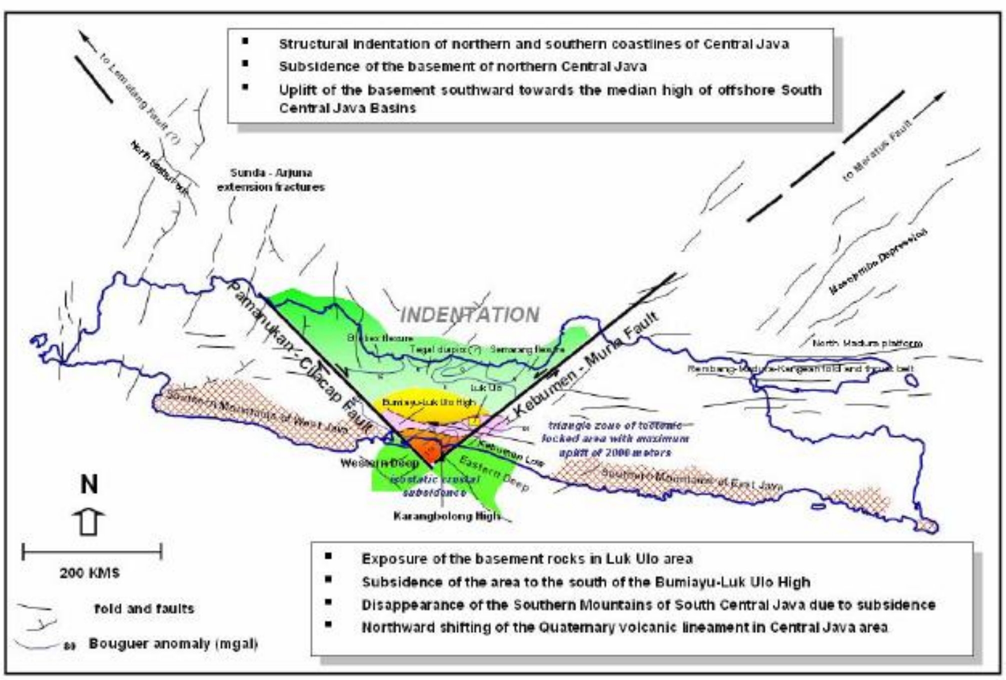


Figure 4. Two strike-slip faults crossed central Java, the sinistral Muria-Kebumen and dextral Pamanukan- Cilacap faults. These two faults linked in the southern area and formed the triangle compressive tectonic locked zone which uplifted the Karang Sambung area and subsided the outer area of triangle zone that induced the subsidence of Old Andesite (Oligo-Miocene) in the southern part of central Java (Satyana, 2002 & 2007).

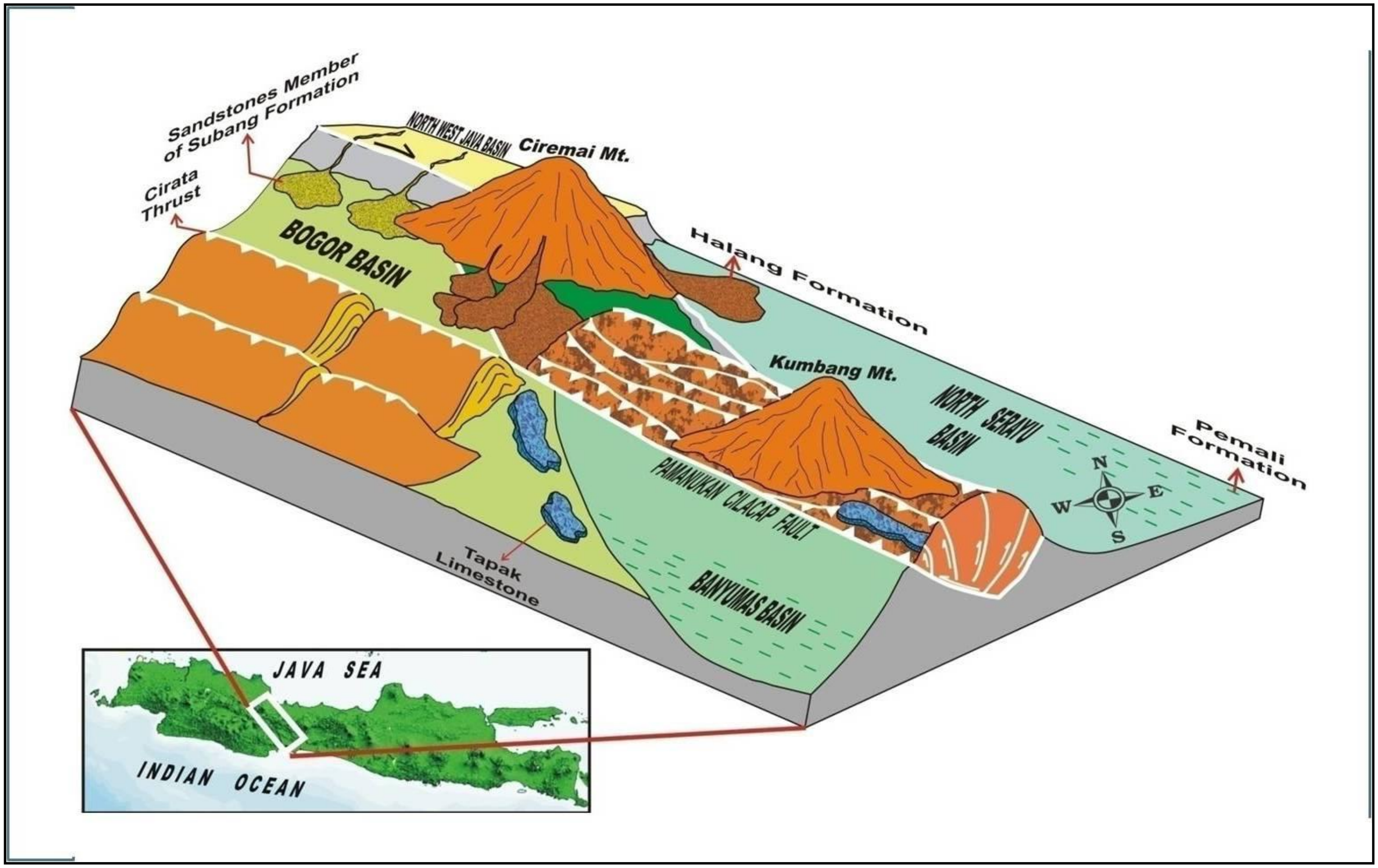


Figure 5. Paleogeographic sketch during the Pliocene, the PCFZ has been interpreted as a barrier and translated zone of the Neogene deep water basin in west Java (Bogor Basin) and in central Java (North Serayu Basin), and to have controlled the formation of an intra-arc transtensional deep water basin which characterized by the distribution volcanoclastic Halang Formation (Armandita et al., 2009).

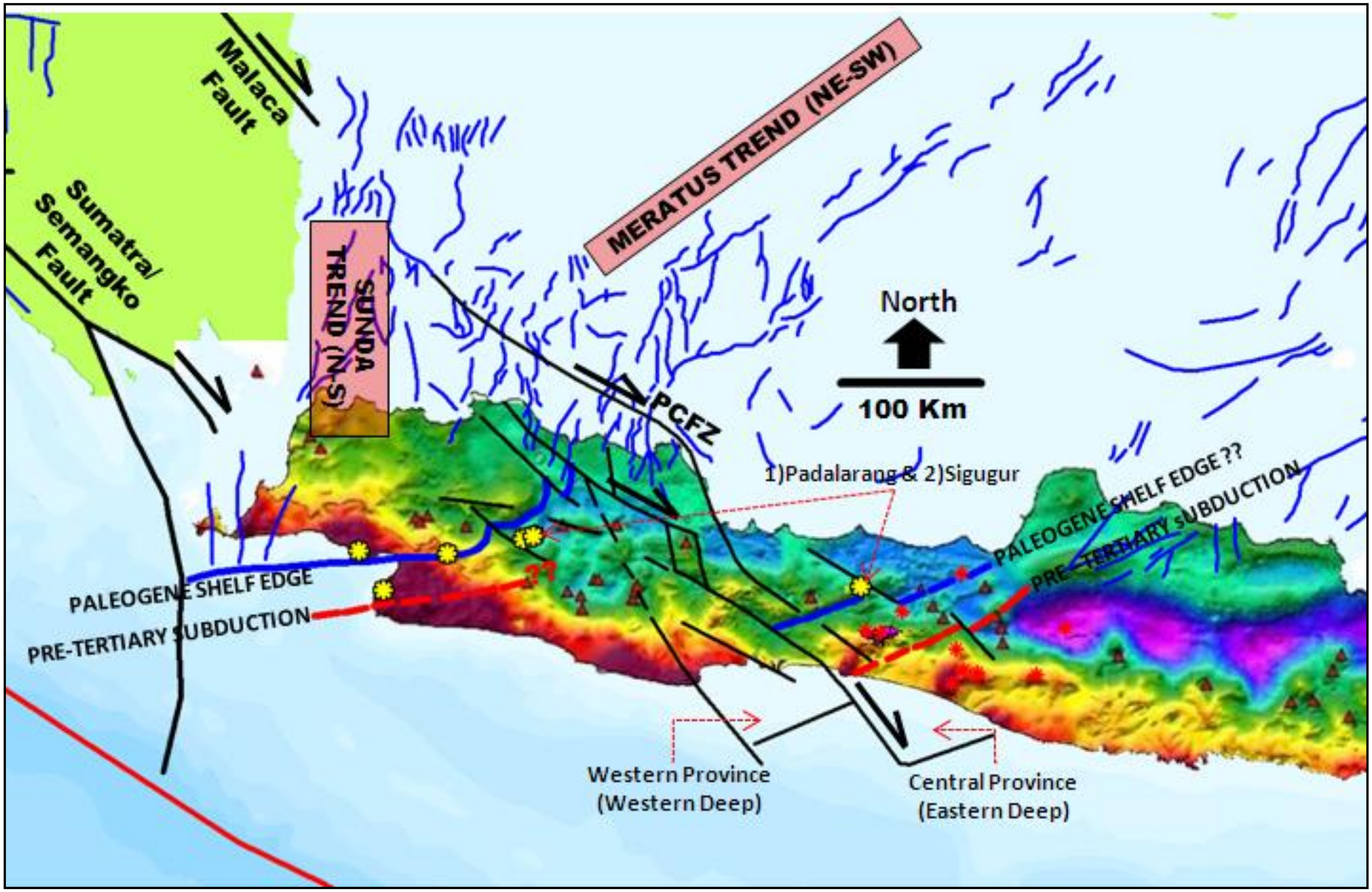


Figure 6. The PCFZ changed the Paleogene structural pattern (blue lines) in the north of NWJB and Sunda-Asri from NE-SW Meratus Trend into the N-S Sunda Trend. PCFZ is also interpreted to shifted the Paleogene shelf edge in West Java to the southeast (central Java). Paleogene shelf edge shifted indicated by two analog stratigraphy outcrops in Padalarang (Rajamandala) and Sigugur that shows Early Oligocene turbidites below the Late Oligocene limestone.

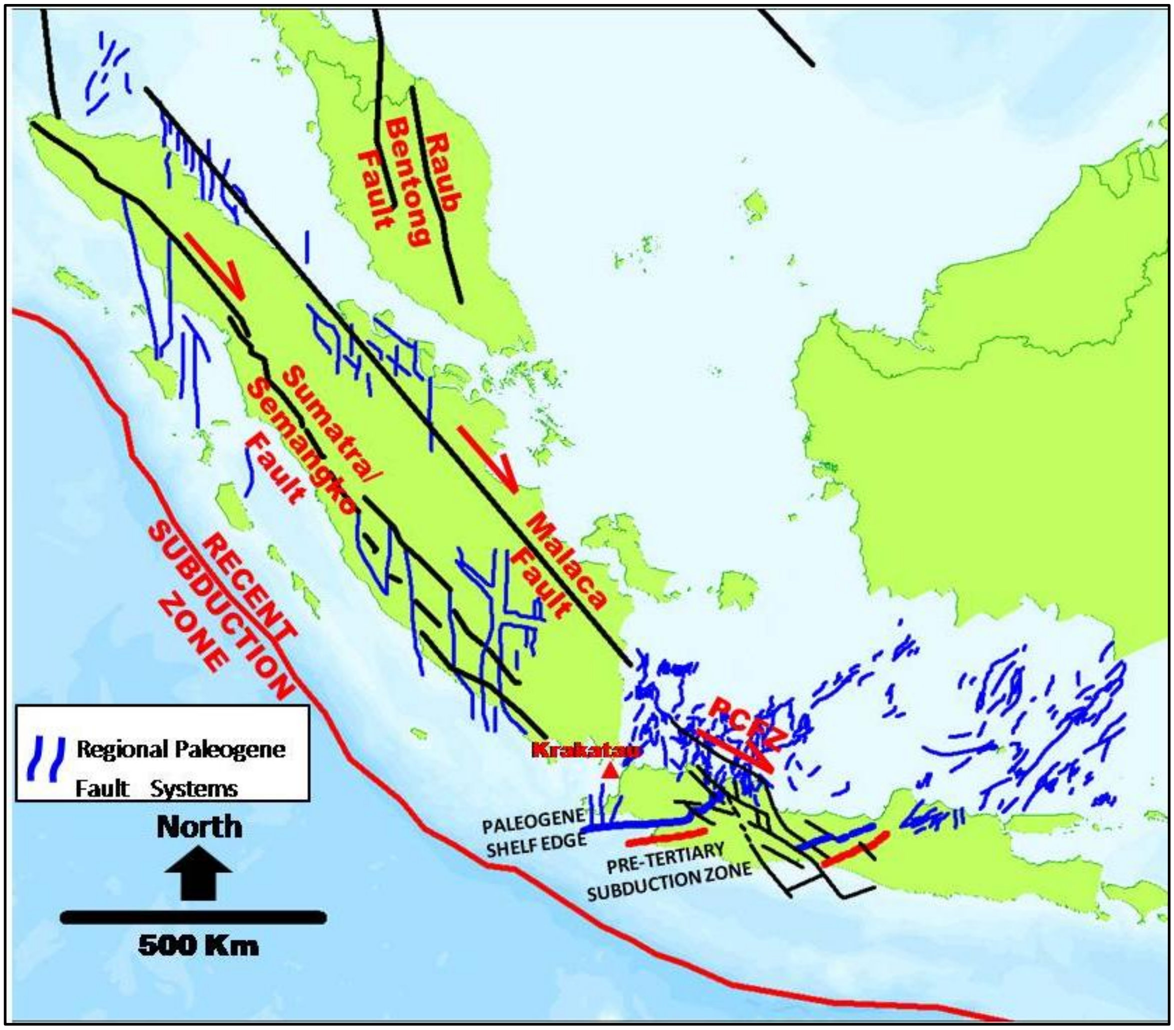


Figure 7. The PCFZ is oriented closer to E-W than the Malaca Fault, probably due to difference in degrees of the rotation between Sumatra and Java. The difference in degree of rotation of the two islands is suggested to have caused the break of the Malaca-PCFZ system, and the opening of the tensional gap in Sunda Strait Sunda Strait and allowed the magmatism of Krakatau volcano.

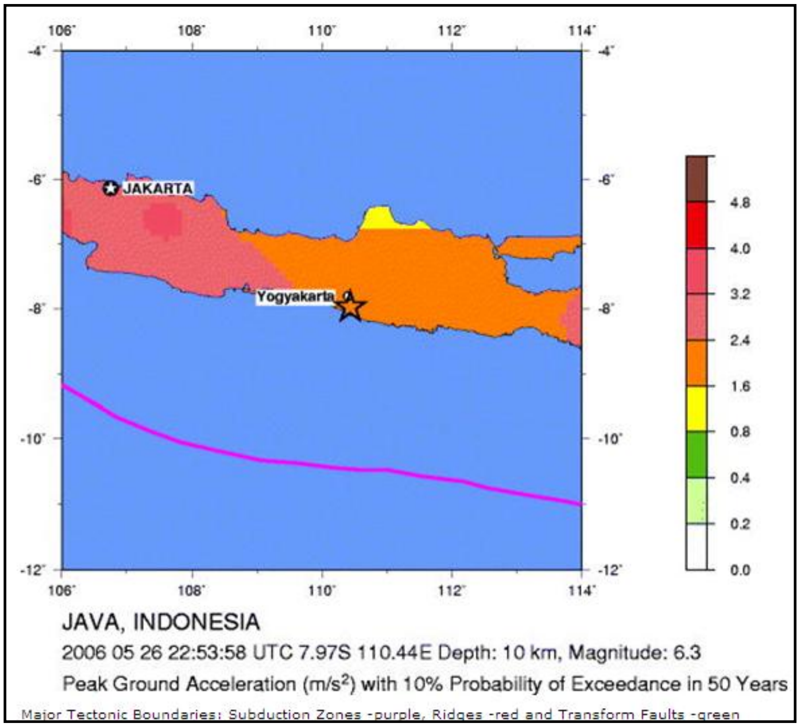


Figure 8. USGS thematic map indicates differences in the zone of Peak Ground Acceleration (PGA) between west and central Java and this boundary coincides with the PCFZ zone.

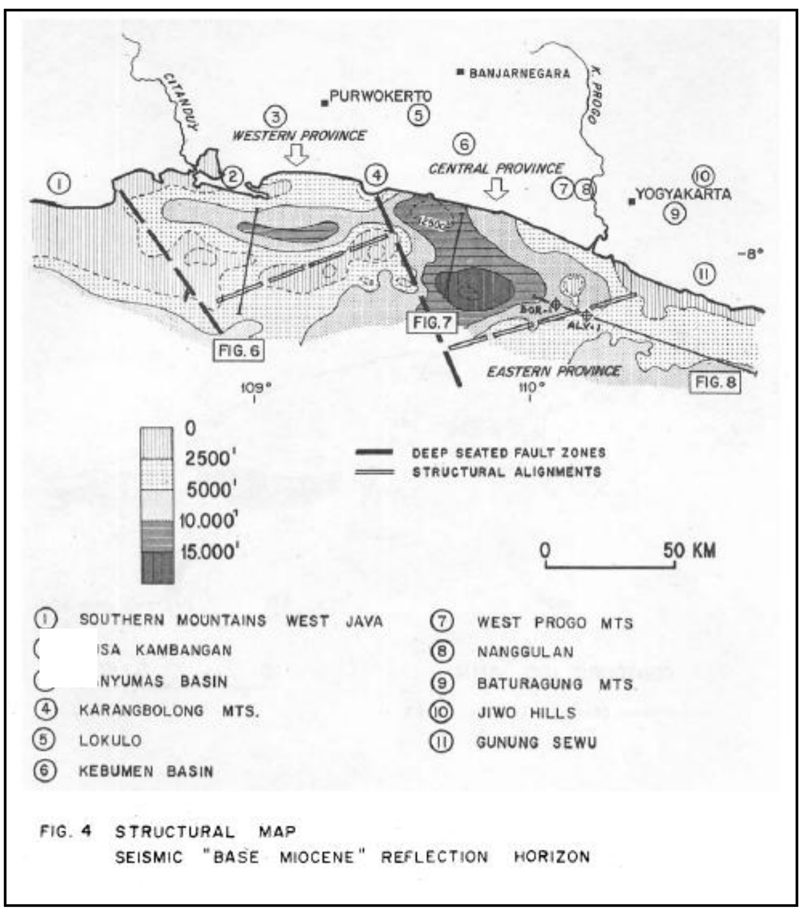


Figure 9. Two structural low areas so called the Western and Central Provinces have been interpreted to have separated by a deep seated pre-Miocene fault oriented in NW-SE (Bolliger and Ruiter, 1975). Due to the similar orientation and nature of the movement, the NW-SE deep-seated fault in the offshore central Java is interpreted as the southeastern extension of the PCFZ (see Figure 6).

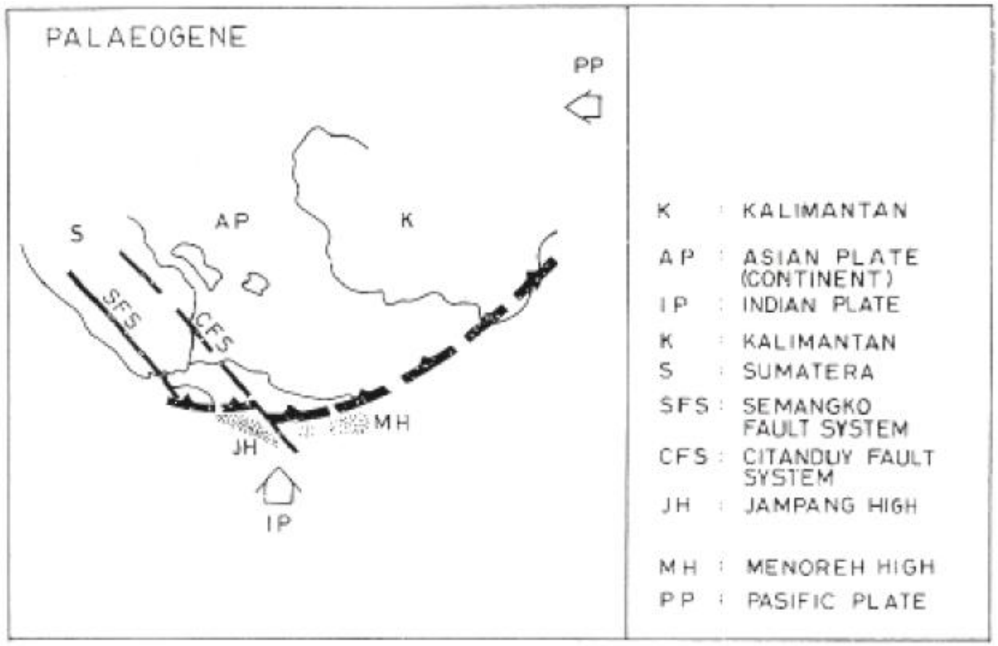


Figure 10. The separation of position of Jampang High in west Java (Citanduy) and Menoreh High in central Java (Sleman) is interpreted to have translated by the PCFZ. The translation of the pre-Tertiary subduction zone has been interpreted by the occurrence of chert argillite, limestone and spilitic rocks in the lower part of Jampang Formation (Simandjuntak 1979)

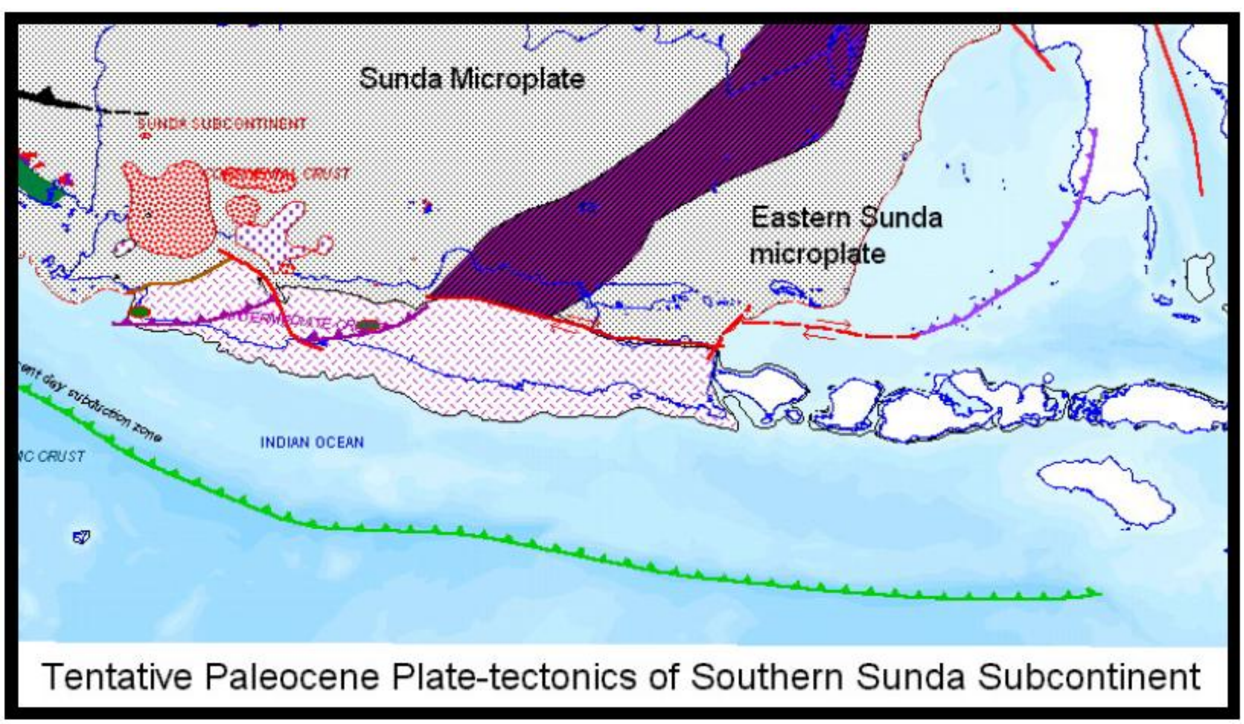


Figure 11. The translation of the northeastern extension of the Ciletuh pre-Tertiary subduction zone ±110 km to the southeast (Karangsambung subduction zone) along the PCFZ has been suggested by Koesoemadinata (2006).

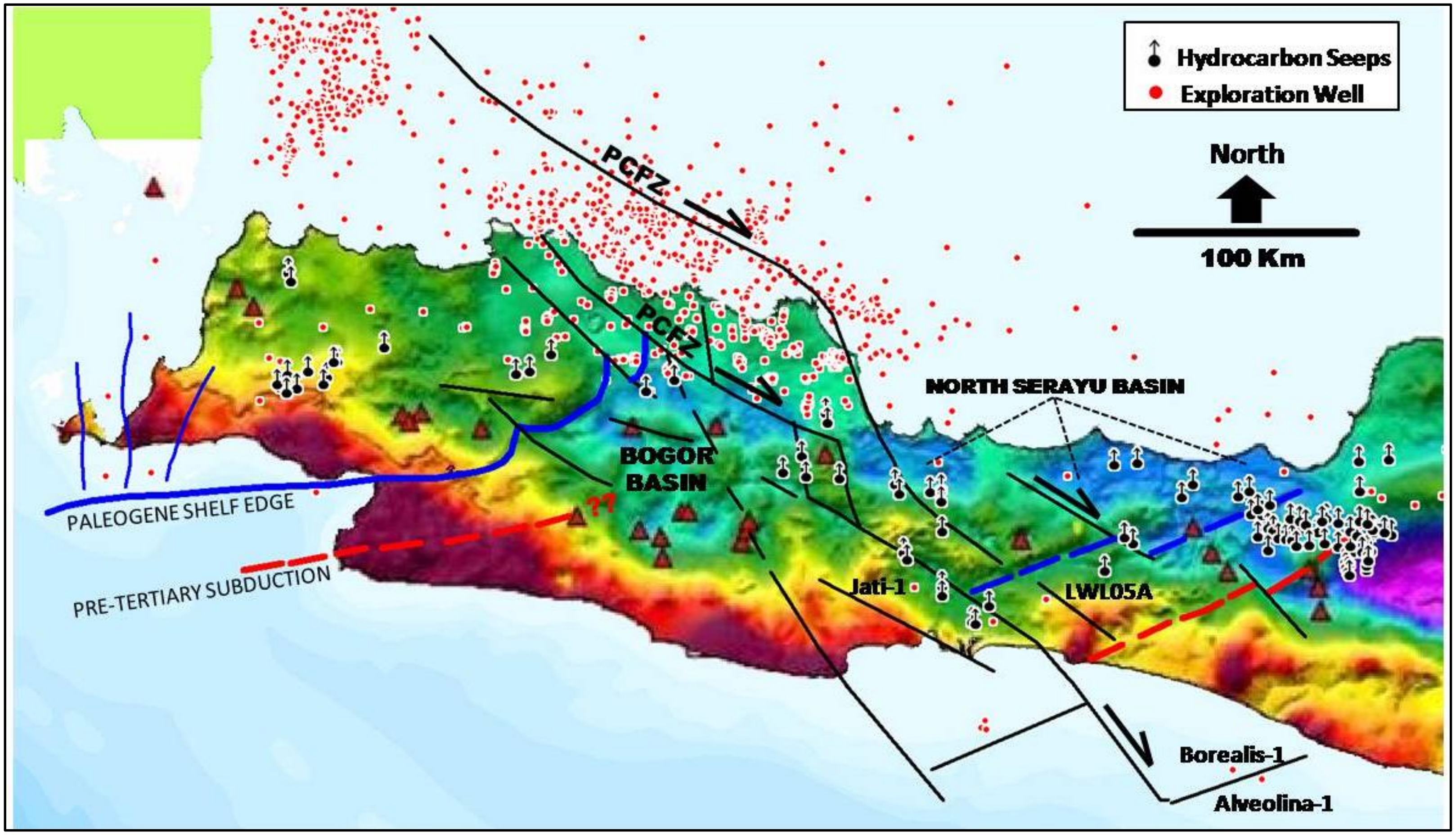


Figure 12. One of the unique geological aspect of central Java is the occurrence of hydrocarbon seeps in several locations in the Neogene deep water North Serayu and Banyumas basins. This is contrast with the western extension, the Bogor Basin, which shows no hydrocarbon seeps.