SANGATTA DELTA EVOLUTION WITH AN UPDATED MIOCENE PALEOGEOGRAPHY

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ABSTRACT

The Sangatta Delta is one of significant deltas which developed during Miocene in the northern part of Kutai Basin. Significant hydrocarbons and coals have been produced from Middle – Lower Miocene fluvio-deltaic sediments along the onshore – offshore parts of the Lower Kutai Basin since 1970 until present. The Sangatta Delta's architecture was already published since 1994 based on subsurface data around the Sangatta Field. However, information on stratigraphy and sedimentological model only covered the Middle – Lower Miocene sections and there were no publication of its complete stratigraphy succession for more than 15 years.

Recently, many road accesses have been developed, connecting villages and districts around Kutai Timur Regency. Most of the roads cut across perpendicularly to stratigraphy strikes measured from surface outcrops, including Miocene Section. Integrated surface geological study by using continuous measurement sections along the road accesses was used in generating composite, Miocene stratigraphic columns, which display information of stratigraphy, facies succession and paleogeography of Miocene deposits. Evolution of Sangatta Delta was interpreted by using chronostratigraphy built from outcrops observation.

The Sangatta Delta development was controlled by Rantau Pulung – Mangkupa paleohigh (Rantau Pulung Island), which is bound by NE-SW and N-S strike slip faults system called Bengalon – Batuampar Slip Faults (NE-SW) and Rantau Pulung – Himba Lestari Slip Faults (N-S). Those faults represent old basement faults that were reactivated several times during Neogene time and they controlled the accommodation space and structural development around the Sangatta Delta.

The delta development started in Early Miocene when at least two fluvial deltaic parasequence sets prograded toward east. During that time, the Rantau Pulung island was an exposed area, surrounded by marine environment. The delta continued to develop and became larger during Middle – Late Miocene as regional inversion and uplift took place at Kuching High to the west of the delta. More than ten stacking fluvial deltaic parasequence sets have been identified from stratigraphic composite columns and they all show progradation toward east. The stratigraphy deposited by the Early – Late Miocene progradation cycles could become new exploration targets around the Sangatta area, especially deep Neogene target or deepwater plays related to deltaic environment in distal facies area.

***Keywords**: Sangatta delta, Miocene paleogeography, Kutai Basin*

INTRODUCTION

The Miocene age Sangatta Delta includes Balikpapan and Kampung Baru Formations which are situated approximately 25km to the north of modern Mahakam Delta, Kabupaten Kutai Timur, East Kalimantan. Despite having similar outcrop formation names with those of the Mahakam Delta, the Sangatta Delta is completely different especially in its geometry, vertical succession units and structures.

The Sangatta Delta developed during Early Miocene, in the same time as several other deltas in the Lower Kutai Basin as the results of regional tectonic uplift in the Kutai Basin. Bachtiar (2004) proposed five major deltas which developed in the Lower Kutai Basin since Early Miocene – Present, including (from southernmost) Longikis Delta in the south of Gulf of Balikpapan, Wain Delta in Balikpapan area, the Mahakam Delta, Marangkayu Delta around the Bontang Area and Sangatta Delta in Sangatta area.

The Sangatta Delta's architecture was already published based on subsurface data (wells and seismic) within the Sangatta Field, which include eleven parasequence sets from Q to G within the Balikpapan Formation (Sadirsan et al., 1994). The deepest well within the field penetrated only the upper part of Middle Miocene (Fukasawa et al., 1987), which means the history of Sangatta Delta development during Miocene time is still incomplete. This paper focuses on Early – Late Miocene sedimentology – stratigraphy history of the Sangatta Delta based on comprehensive surface outcrop study around the Sangatta Area (Figure 1).

METHODS

The main data of this research was acquired from comprehensive surface geological mapping which could be subdivided into two general methods as follows:

Continuous Measurement Section / Data Acquisition (Chaining Geological Measurement)

Chaining geological measurements is a method of correlating and joining various measured stratigraphic sections into each other and tying them to the wells in the survey area. The objective of the chaining method is to determine the true thickness of rock formation thus understanding the sedimentology and stratigraphy. Data collected for this purpose are rock unit and sedimentology description, strike and dip measurement, (structural data), traverse slope, azimuth, distance, and rock samples for biostratigraphy analyses, petrography analyses, and petroleum system component analyses.

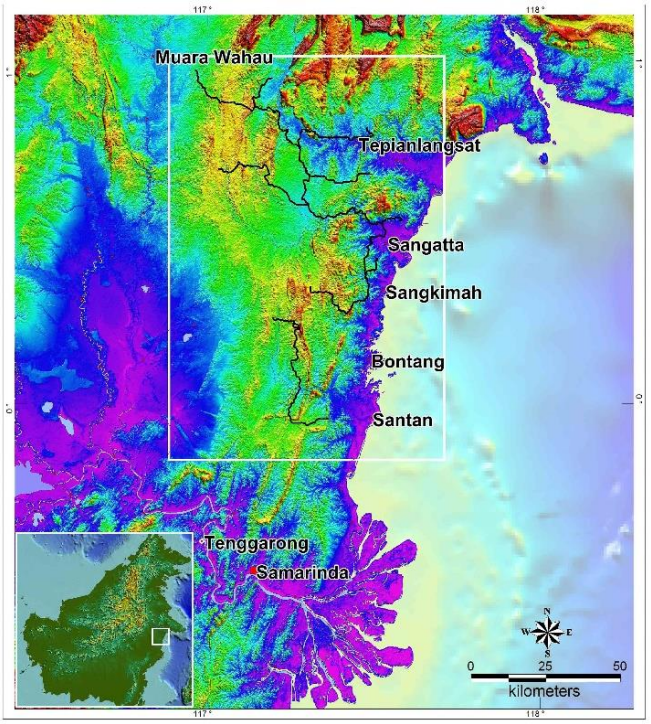


Figure 1: *Study area (white box) which is situated around the city of Sangatta, East Kalimantan*

STRATIGRAPHIC ANALYSIS

Measurement of stratigraphic cross-section

Measurement of stratigraphic cross-section is intended to determine the relationship of stratigraphy and sedimentology in the study area. Additional detailed measurements will be used to determine the depositional facies. Stratigraphic composite generally provides continued stratigraphic information along a certain surveyed line, and can be used to determine the stratigraphic relationship of the rocks along the line based on their positions, elevations, locations, lithology analysis and biostratigraphy. Each rock sample collected along this line was analyzed to determine the age and its depositional environment, petrography, and geochemistry.

REGIONAL TECTONIC, STRUCTURE AND STRATIGRAPHY

Regional Tectonic and Structure

Previous publications from the basin generally dealt with a small and restricted area, discussing exclusively the petroleum geology with very little reference of the regional tectonic or the sedimentation history of the area. Among the

regional geologists who worked on basin scale paleogeography are Samuel and Muchsin (1975), Pieters et al. (1987), Wilson and Moss (1999), Moss and Chambers (1999), and Bachtiar et al. (2013). The regional studies share a general perception on Kutai Basin's history during the Eocene to Oligocene of both Upper and Lower Kutai sub-basins. Both Upper and Lower Kutai show similar sedimentation styles during the Eocene to Oligocene, whereas during the Miocene, the Upper Kutai sub-basin was uplifted and became the provenance for the Lower Kutai sub-basin. Several attempts to reconstruct the Kutai Basin paleogeography in the sub-basin level were carried out by Wain and Berod (1989), Cloke (1999) in the Upper Kutai Sub-basin, Bachtiar (2004) in the Lower Kutai Sub-basin, and Sunaryo et al. (1988) in Bungalun Area, which is the northern part of the Lower Kutai Sub-basin.

The structural folds and faults in Kutai Basin generally trend NE-SE. In the western part, it consists of strongly folded anticlines that experienced reverse faulting, whereas to the east in the offshore area it becomes gently folded anticlines. The series of anticlines are known as the Samarinda Anticlinorium, which dominates the middle part of the Lower Kutai Basin. To the north and the south of the basin's edge, structural features trending WNW-ESE in the form of anticlines and normal faults affect existing regional structures (Biantoro et al., 1992; Pertamina BPPKA, 1997).

In the beginning, such structural pattern was interpreted as a result of gravity sliding due to the uplifting of the Kuching High in the northwestern part of the Kutai Basin (Ott, 1987). During the last decade, related studies infer that the formation of present structural features is also caused by inversion due to compression of thick deltaic Tertiary sediment package underlain abnormally pressured prodelta clay deposits (Jones, 1990; Van de Weerd and Armin, 1992; Biantoro et al., 1992; Chambers and Daley, 1995; Ferguson and Mc Clay, 1997; Ferguson, 1999; Moss and Chambers, 1999). Structural features associated with the above mentioned mechanism include the following: mud diapirism, clay dominated cores of anticlines (Pertamina BKKA, 1997), and thinning of sediment layers toward the anticline and thickening in synclines.

The structural configuration of Kutai Basin is also controlled by series of NW-SE strike slip faults (major shear zone) which are old Pre-Tertiary faults. The faults were subjected to several reactivations during the Tertiary to develop new younger structural pattern (Bachtiar et al., 2013). The major strike slip fault was part of a major shear zone which was developed due to "tectonic escape" of India docking to Asia during the late Cretaceous – Paleocene in South East Asia including Sundaland (Molnar and Tapponnier, 1975). Starting from the northern part, major strike slip faults in the Kutai Basin are the Sangkulirang Fault, Bengalon Fault, Batu Ampar – Santan Fault, Belayan Fault, Balikpapan Fault and Adang Fault (Figure 2; Bachtiar et al., 2013).

On top of the NW-SE trending strike slip faults, other old structural features which are also observed in the Upper Kutai Basin are the NE-SW/NNE-SSW trending lineaments which are associated with the Paleogene-pre- Tertiary. The Paleogene-pre-Tertiary outcropped with some evidence of volcanic material and act as the boundary of low gravity anomaly (Bachtiar et al., 2013).

Basin Architecture

Regional gravity data show several NE-SW isolated highs which are prominent in the Upper Kutai sub-basin and less prominent in the Lower Kutai sub-basin (Bachtiar, 2013). Several isolated highs were discussed in publications of the Upper Kutai sub-basin such as the Teweh, Muyup, Kutai Lake, Kahala, and the Kedang-Kepala Highs. Moreover, isolated highs located onshore of the Lower Kutai sub-basin such as (from north) Mangkupa – Rantau Pulung, Jonggon, Samarinda, and the Balikpapan Highs were also discussed in several publications (Figure 2; Bachtiar et al., 2013).

The isolated highs were interpreted from 'basement rift structure map' of Chambers et al. (2004). The structural highs may also be the cause of the early Middle Miocene fluvial sediment outcrops "provenance of chert pebbles" problem in Samarinda delineated by Bachtiar (2002).

This study also indicates that the isolated high became inverted blocks during inversion in Early Miocene and played a significant role in the development of Miocene deltas along the Lower Kutai Basin, including the Sangatta Delta.

Structural Configuration of the Sangatta Area

Topography lineament analyses around Sangatta area shows four trends; North/Northeast - South/Southwest, North – South, Northwest – Southeast and West – East trends. There are also boundaries of topographic lineaments trend which can be observed on topographic lineaments maps that are mostly related to faults in the study area.

Formline pattern integrates surface structural data (fold and fault), strike line outcrops, topography map and general facies information. Six different patterns could be determined around the study area. Every pattern zone is bounded by regional strike slip fault which is a part of an old reactivated fault and controlled the sedimentation. Those six formline patterns are: transpresional-related to Eocene sediment system, stable platform, transtensional-diapirism related to deltaic environment, transpresional related to deltaic environment, transpresional – transtensional related to deltaic environment, and transpresional – toe thrust related to marine environment (Figure 3). Sangatta Delta was developed along the transpressional – extensional related to deltaic environment zone. The delta was bounded to the west by Rantau Pulung - Mangkupa High and Rantau Pulung Fault, to the north by Bengalon Fault and to the south by Batu Ampar Fault.

STRATIGRAPHY AND SEDIMENTOLOGY

Stratigraphy analysis in the study area was carried out by integrating well data within the study area, correlating composite stratigraphy section, results of biostratigraphy, palynology analyses and other supporting data such as vitrinite reflectance and provenance analysis.

There are three stratigraphic composite columns which were developed from a total of 351 km traverse' length and intersect all formations in the Sangatta Area (Figure 1). The Miocene section is covered by 250 km of traverse length with more than 200 key outcrops, each being connected systematically.

Sangatta Delta development is a part of Miocene succession represented by the regional inversion event along the Kutai Basin. Miocene succession in the Sangatta area could be subdivided into three sequence set markers; Top of Early Miocene Marker, Top of Middle Miocene Marker and Top of Late Miocene Marker (Figure 4). Surface marker distribution is younger toward the east.

Early Miocene Succession

Regional nomenclature for the Early Miocene sediment units are Maau and Pamaluan Formations. Maau Formation refers to marine shale sediment while Pamaluan Formation refers to the fluvial – transition. Sedimentological character and depositional environment association of Early Miocene sediment consist of alluvial fan, fluvial, tidal flat, delta plain, delta front and outer shelf bathyal. The depositional environments could be grouped in to three sequences with total thickness of up to 2.2 km (calculated from chaining and geological cross section). The top of Early Miocene succession is marked by regional flooding surface related to reefal carbonate buildup of delta front – prodelta and outer shelf marine shale which is also evidenced by the presence of forams (Figure 4).

The paleogeography of Early Miocene in the Sangatta area was controlled by the presence of Rantau Pulung paleohigh (Figure 5). The paleohigh is bounded by Batuampar Fault to the south, Himba Lestari Fault to the west, Rantau Pulung Fault to the east and Bengalon Fault to the north. The faults were reactivated faults that formed the accommodation space and signify the depositional environment boundary in the Early Miocene. Geometry of Rantau Pulung High is approximately 18-30 km and it was overlain by the fluvial deposition thus forming an island during the Early Miocene. The presences of faults around the paleohighs significantly changed the depositional environment laterally to the north, east, south and west. The surrounding area became transitional - marine.

The Proto Sangatta Delta developed toward the east of the Early Miocene Rantau Pulung Island. The delta is characterized by two parasequences; fluvial – delta plain – delta front – prodelta and carbonate buildup around the delta front – prodelta.

Middle Miocene Succession

The Middle Miocene succession was marked by regional uplift of most of the Upper Kutai Basin. In the study area, this regional event is marked by the absence of the Middle Miocene or younger sediment to the west of Rantau Pulung Fault or previously Rantau Pulung Island. Another supporting evidence for the Early Middle Miocene sequence boundary is the presence of braided fluvial channel with abundant fossilized tree trunks and chert fragments as the base of Middle Miocene marker (Figure 4)

Middle Miocene succession in the study area could be generalized in three sequences; continuing previously prograding cycles of fluvial – delta plain – delta front and prodelta facies of the Sangatta Delta. Total thickness calculated from chaining and geological cross section is up to 800m.

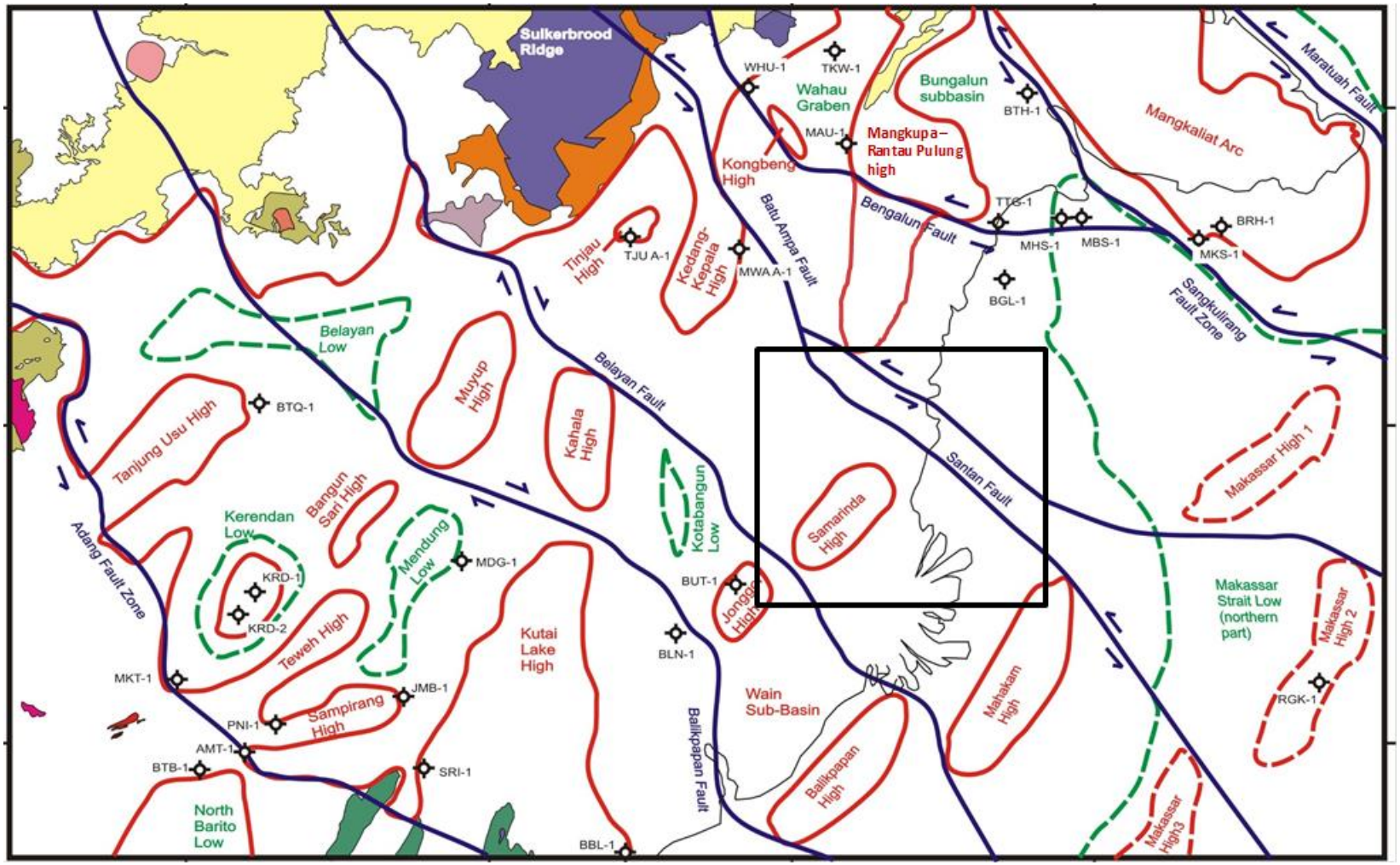


Figure 2: *Kutai Basin architecture shows isolated highs and lows, exploration wells, regional strike slip faults and the Pre-Tertiary – Earliest Tertiary rocks distribution (Bachtiar et al., 2013). Black box within the map is focus study location.*

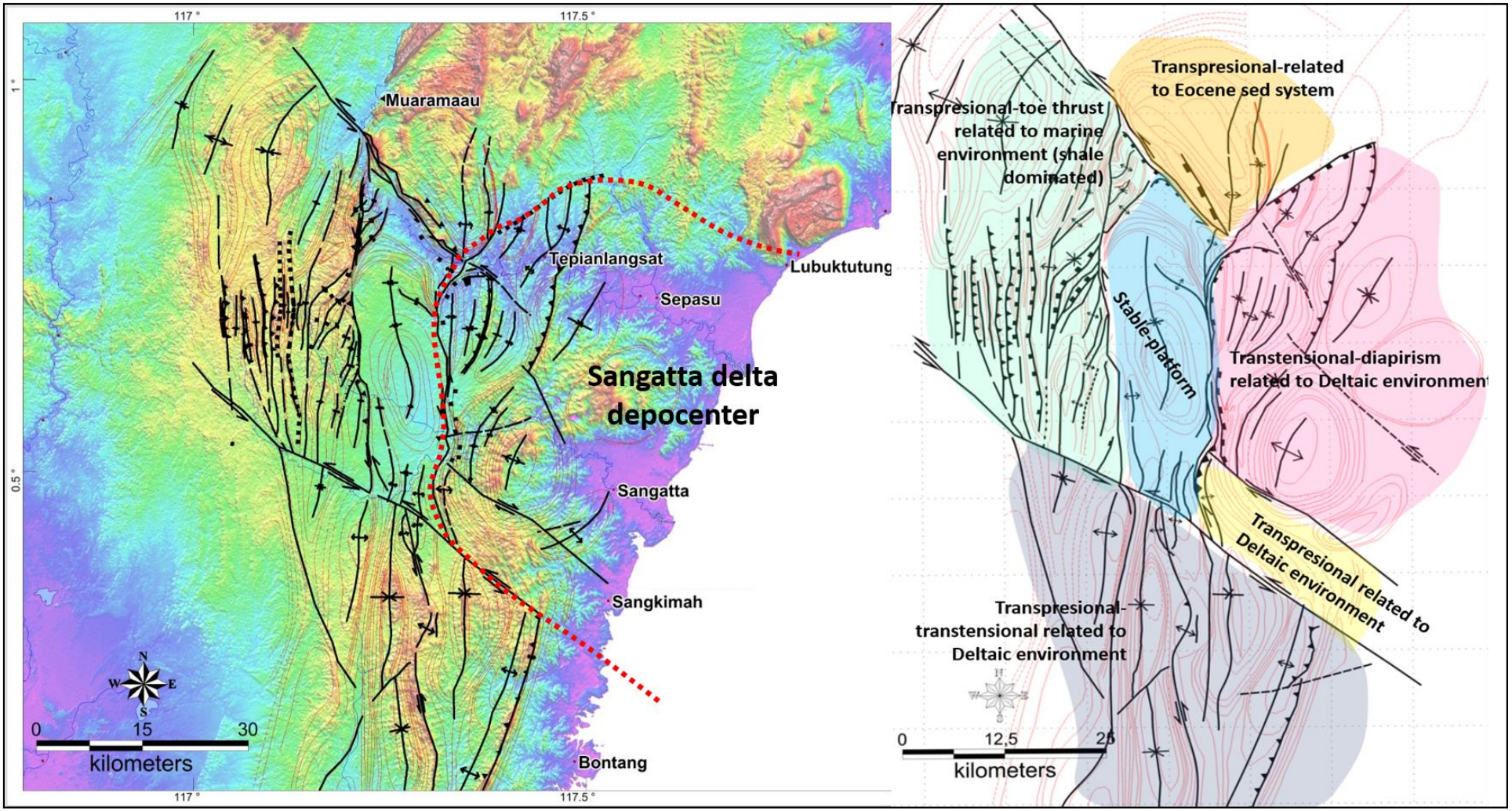
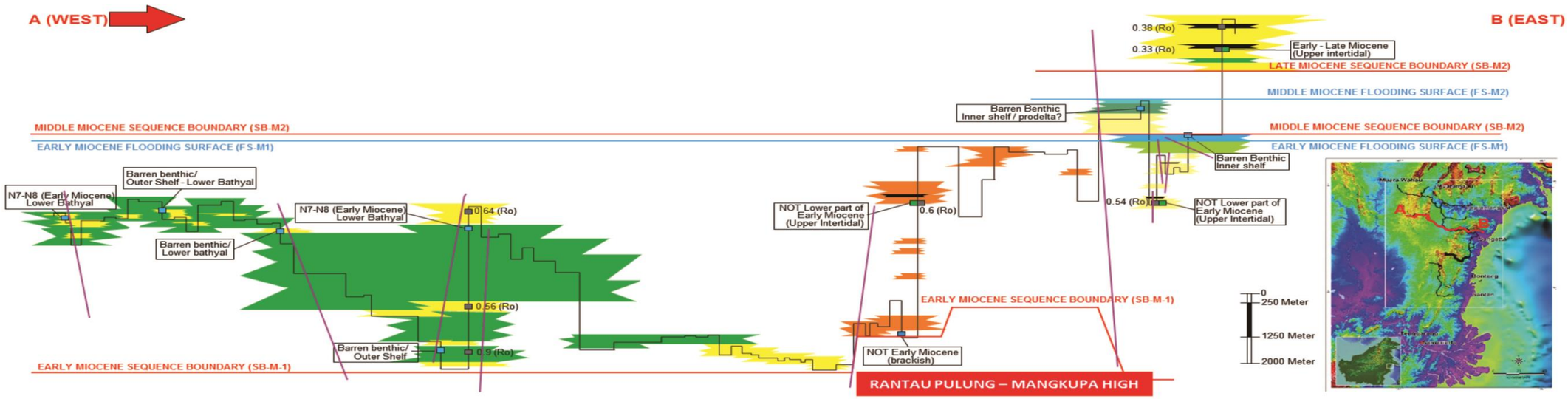
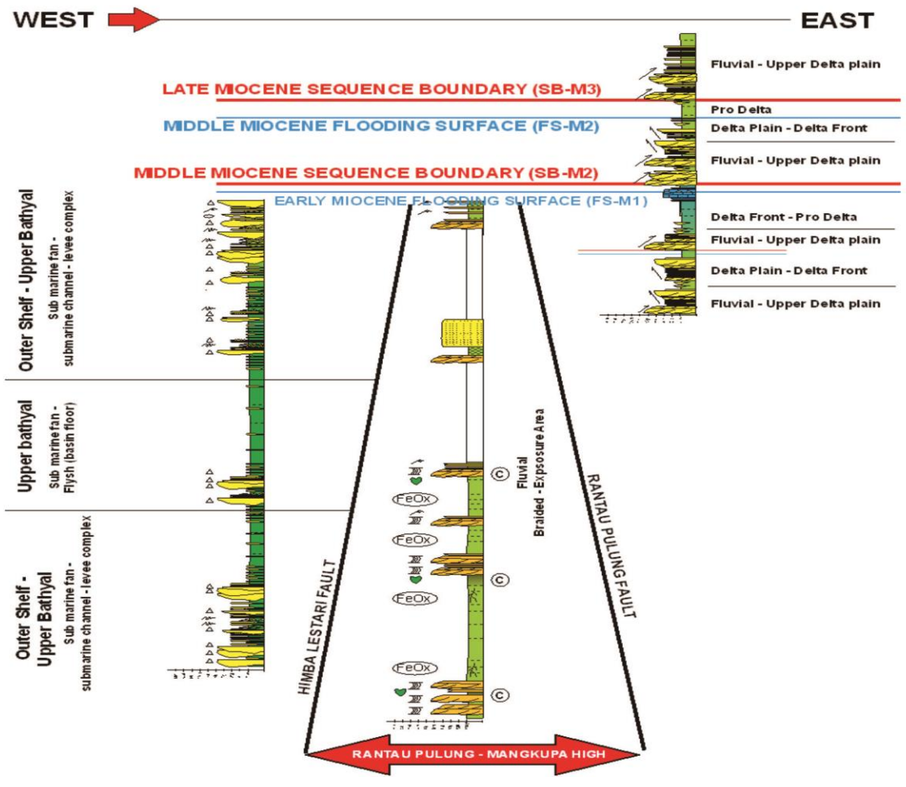


Figure 3: *Structural map of the surrounding Sangatta area showing structural distribution and tectonic style zonation constructed from surface structural mapping. The Sangatta Delta developed in transtensional – diapirism related to deltaic tectonic style zone which was controlled by a stable platform in the western part and NW-SE and N-S strike slip faults system*





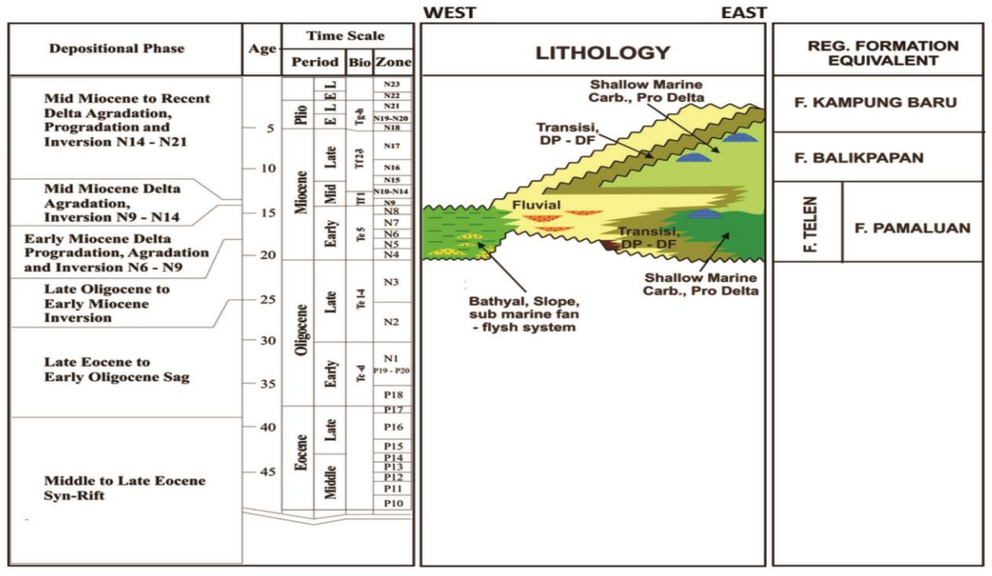


Figure 4: Stratigraphic column and correlation

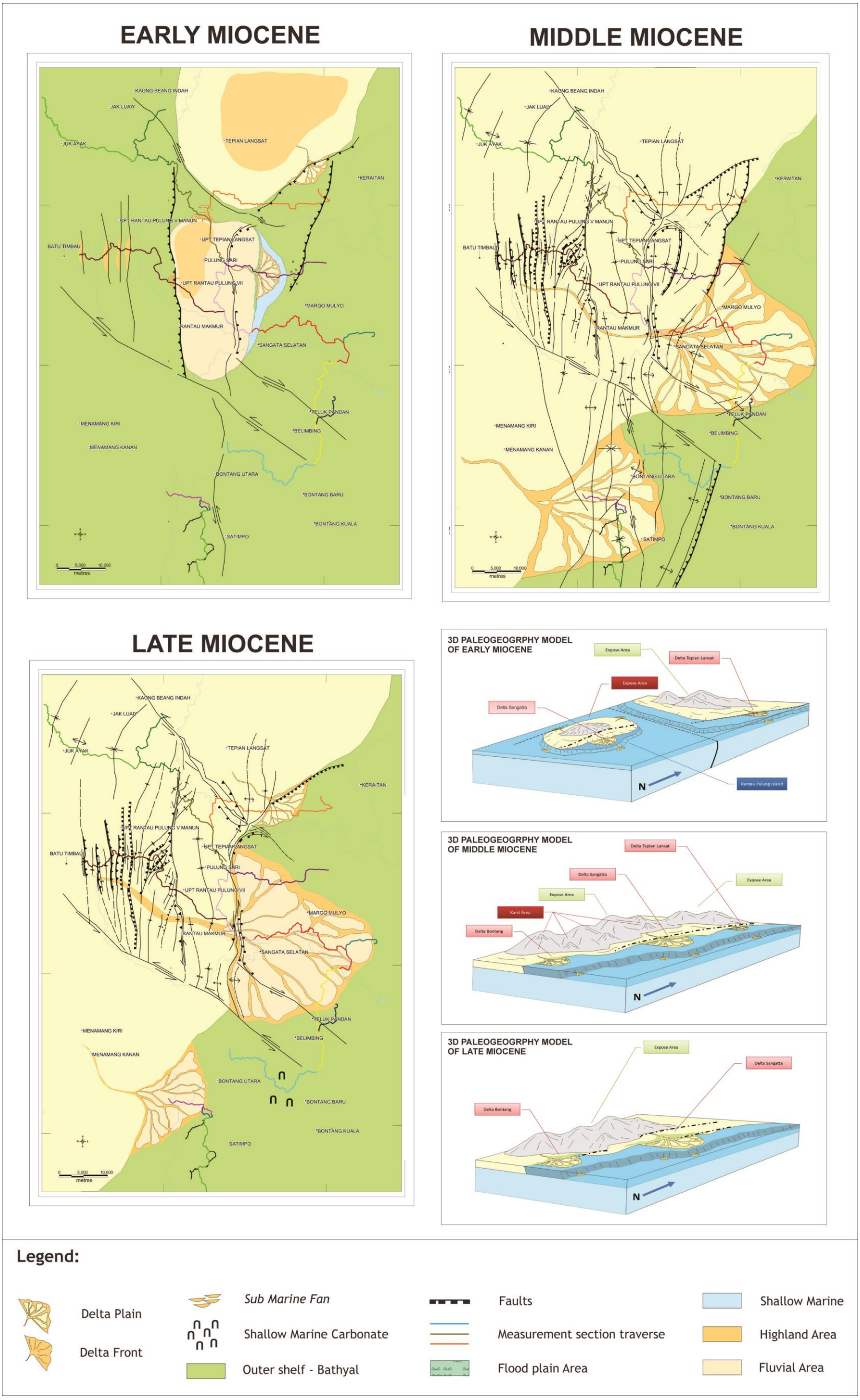


Figure 5: *Miocene paleogeography and the evolution of Sangatta Delta*

The delta during the Middle Miocene prograded toward the east of the previous Early Miocene delta (Figure 5). The depocenter during that time was situated around Rantau Pulung – Margomulyo – Sangatta area, characterized by stacked fluvial deltaic parasequences cycles. Especially in the northern part of study area, mud volcanoes are observed along the fault zone or sequence boundary (formation boundary). Biostratigraphy analyses of the mud revealed mixed of Early – Middle Miocene forams.

Late Miocene Succession

The Late Miocene succession outcrops are situated in the eastern most part of the study area, especially around the open pit of Kalimantan Prima Coal, the largest coal mining in Indonesia.

There are three sequences of deltaic cycles identified. The total thickness calculated from chaining and geological cross section is up to 1800m (Figure 4). The Late Miocene sequence set is also known as the coal units. The depositional environment identified from the stratigraphic composite column is stacking cycles of fluvial – delta plain – delta front which could be group in to 8 parasequences set (each parasequences set thickness is up to 150m). The vertical succession and lateral surface distribution of facies indicated that the Late Miocene succession was possibly the peak of the Sangatta Delta development (Figure 5).

CONCLUSION

1. The Sangatta Delta development was controlled by Mangkupa – Rantau Pulung paleo-high and Northwest – Southeast and North – South strike slip faults system.

2. The proto Sangatta Delta developed during the Early Miocene and consisted of two fluvial deltaic parasequences toward the east of the Rantau Pulung paleohigh. Middle Miocene succession was evidenced by the regional sequence boundary event along the Sangatta area; continued stacking cycles of fluvial deltaic toward the east. During the Middle Miocene, the geometry of the Sangatta Delta increased in size. The Late Miocene succession showed a continuation of stacking prograding cycles toward the east, which could be grouped in to three sequence cycles and up to eight parasequences (from surface chaining reconstruction). The vertical succession and lateral facies distribution indicated that the Late Miocene succession was the peak of the Sangatta Delta development.

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