

**Recent Significant Discoveries within Oligo-Miocene Carbonates  
of the East Java Basin : Integrating the Petroleum Geology**

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**ABSTRACT**

Prospectivity of the Oligo-Miocene carbonates of the East Java Basin have been proven since 1970s when the Cities Service discovered oil and gas within these carbonates at the East Java Sea. However, the significance of the carbonates as oil producer have not obtained full attention until recently when un-interrupted significant discoveries within the carbonates have been reported. This resulted in hydrocarbon reserves in excess of 880 MMB oil and 600 BCF gas. Aggressive exploration is being made by oil companies pursuing the prospectivity of these carbonates both at onshore and offshore parts of the East Java Basin. The carbonates will hold future prosperity of the East Java Basin. The discoveries have also shown that old-worked basin is always open for new exploration

Oligo-Miocene carbonates comprising the Kujung-Prupuh-Tuban-Rancak carbonates constitute the carbonate complex growing at the shelf edge areas to the southeast of the Sundaland. The carbonates trend ENE – WSW from the present onshore eastern part of the Central Java to the offshore areas north of East Java and Madura Island. The carbonates developed as platform carbonates, patchreefs, and shelf-edge reefs. Proven kitchens generating hydrocarbons trapped by these carbonates are located nearby within depression areas with mature sources range from the Eocene to the Early Miocene shales or carbonates.

The paper will summarize historical and recent exploration of the Oligo-Miocene carbonates of the East Java Basin and integrate aspects of petroleum geology including the regional geology, the carbonate sedimentology and the petroleum systems. *petroleum exploration of the East Java Basin*

**EXPLORING OLIGO-MIOCENE CARBONATES**

The Cities Service Indonesia pioneered exploration of the Oligo-Miocene carbonates in the East Java Basin in the East Java Sea area in 1967. The first well they drilled was JS 1-1 in 1970 and tested 2000 BOPD from the Kujung carbonate. Later exploration efforts were directed mainly towards prominent carbonate reefs. Poleng field was discovered in

1974 and developed in 1976. The field, however, was then shut in due to marginally commercial and rapid increase of gas oil ratio. The Cities Service relinquished the area in 1978. During 1980s, the Oligo-Miocene carbonates in the East Java Sea was explored by several companies and resulted in commercial discoveries including : Camar field (Kerr McGee, 1982), KE 5 field (Kodeco, 1983), and KE 2 field (Kodeco, 1984). There were no significant discoveries during early and mid-1990s until the end of 1998 when Premier Pangkah discovered the Ujung Pangkah field. Un-interrupted discoveries have been reported since then. Kodeco West Madura, Premier Pangkah, Gulf Ketapang, and Wirabuana Karapan explore the area nowadays.

In onshore part of the basin, the initiation of exploring the Oligo-Miocene carbonates was not as early as that in the offshore area. This because Middle Miocene to Early Pliocene sands have dominated the exploration target since the late of 1800s. Pertamina and its contractors started exploration into deeper objectives down to the Eocene clastics in early 1980s. There was no significant discoveries reported until 1994 when JOB (Joint Operating Body) Pertamina-Trend /Santa Fe tested 6000 BOPD from Early Miocene Tuban carbonates at the Mudi structure. Humpus Patragas/Mobil indicated significant upper Kujung (Prupuh) reef called as the Banyu Urip structure to the west of the Mudi field in mid 1990s. An exploration well was drilled on the top of the reef in 1998 and ExxonMobil later completed the well in early 2001 and became the significant discoveries ever made in the onshore Kujung carbonates. Nowadays, Pertamina, JOB Pertamina-Santa Fe, ExxonMobil and Coparex explore the area.

## **RECENT DISCOVERIES**

Recent success of exploring Oligo-Miocene carbonates of the East Java Basin was begun by the Premier Oil Pangkah in November 1998 when they drilled Ujung Pangkah-1 well at offshore area just to the northeast of the mouth of the Bengawan Solo River. The well tested 20,7 MMCFGPD, 703 BOPD, and 172 BCPD from the Lower Tuban and Upper Kujung carbonates. In May 1999, Coparex Blora B.V. at the onshore basin to the southeast of Semarang drilled Rembang-1 well and tested 19.1 MMSCFGPD from the Kujung carbonates. Premier Oil Pangkah repeated their success in November 2000 when they tested 1432 BOPD and small amount of gas from Sidayu-1 well located to the north of Ujung Pangkah discovery.

The end of 2000 marked the initiation of un-interrupted successes made in the Oligo-Miocene carbonates at both offshore and onshore parts of the East Java Basin. In December 2000, Kodeco West Madura offshore discovered 174 feet net gas pay and 300 feet net oil pay within Kujung I,III carbonates of KE-23 B structure. This was followed by the discovery of gas and condensate of 9.35 MMCFGPD and 91 BCPD within Kujung carbonates of KE 13 reef in January 2001. In February 2001, ExxonMobil Cepu onshore tested 3817 BOPD and 1.2 MMCFGPD within Kujung I-Prupuh carbonate of Banyu Urip-3 re-entry well. This discovery was confirmed with Banyu Urip-1 well drilled in March 2001 and tested 4692 BOPD. Also in March 2001, Kodeco West Madura offshore made a discovery within Kujung I carbonate of KE 24 reef testing 20.75 MMCFGPD. Gulf Indonesia Ketapang added the success of exploring Oligo-Miocene carbonates in

the East Java offshore when they discovered hydrocarbons in Bukit Tua structure offshore to the north of the Madura Island in April 2001. They tested as much as 7250 BOPD, 200 BCPD and 9.0 MMCFGPD from Kujung III, II carbonates of Bukit Tua-1 well. In April and June 2001, Gulf Ketapang repeated the success when they drilled Payang-1 and Jenggolo-1 wells. Payang-1 tested 16.5 MMCFGPD and 159 BCPD (Kujung I carbonate), Jenggolo-1 tested 3554 BOPD and 11.14 MMCFGPD (Kujung III-I carbonates). In the onshore basin, JOB Pertamina-Santa Fe Tuban drilled Sukowati reef and resulted in 4706 BOPD and 2.99 MMCFGPD from Tuban carbonate at open hole test.

Those recent discoveries have contributed new hydrocarbon reserves in excess of 880 MMB oil and 600 BCF gas. Significant contribution for future oil production of the East Java Basin will come from the Oligo-Miocene carbonates. ExxonMobil plans to commence production of the Banyu Urip field in 2003 at the rate of 25,000-30,000 BOPD and increase this to 100,000 BOPD in 2004 (Harris, 2001).

## **GEOLOGIC FRAMEWORK**

The East Java Basin presently occupies a position of back-arc basin situated behind the volcanic arc to the south. The basin is terminated to the west by the Karimunjawa Arch, passes eastwards into the deep water Lombok Basin, and shallows northwards onto the Paternoster High. The basin covers areas of the eastern Central Java, northern East Java, Madura Island, and the East Java Sea.

Two principal structural trends of Tertiary origin can be distinguished (Brandsen and Matthews, 1992; Manur and Barraclough, 1994) : a northeast-southwest extensional fault trend and an east-west wrench fault trend. Different stress regimes control the Paleogene rift-phase and the Neogene inversion phase. A tensional stress regime was active from the middle Eocene up to the early Miocene. The initial stage of extension was marked by rifting in the Eocene, directly followed by a second stage of basin-wide subsidence in the Oligocene. Neogene tectonism is marked by a fundamental change in stress regime leading to widespread inversion in the middle Miocene with active translational and rotational movement of major fault blocks coupled with widespread shale diapirism.

The stratigraphy of the East Java Basin was started by non-marine to marginal marine sediments of the Middle to Late Eocene Lower Ngimbang overlying the basement. Marine transgression took place during the Late Eocene to Early Oligocene and deposited the Ngimbang shales. The sediments shallow to the north and "CD" limestones (Ngimbang carbonates), partly reefal, developed. After a mid-Oligocene uplift and limited sands were deposited at shallow areas, the transgression regionally flooded the basin during the late Oligocene to early Miocene. Kujung carbonates were deposited during this period. After a local uplift in the northern area, the transgression resumed during mid-end of the Early Miocene and Tuban shales with local interbeds of carbonates (Tuban or "OK" carbonates), marls, and sandstones were deposited. Reefal carbonates (Rancak reefs) of upper Tuban Formation were deposited in the end of Early Miocene. The Ngrayong sands were deposited at the basal Middle Miocene. Middle Miocene to

Pleistocene clastic and carbonate sediments of Wonocolo, Kawengan (Karren, Ledok, Mundu), Paciran, and Lidah formations were deposited after that within depositional environments ranging from deep water to marginal marine-non marine upwards.

## **SEDIMENTATION OF OLIGO-MIOCENE CARBONATES**

Being located at the southeastern margin of the Sundaland, the East Java Basin was rich in carbonate sedimentation. The most extensive carbonate deposition took place in the Oligo-Miocene during which carbonate sediments of the Kujung Formation were deposited. Pre-Oligocene palaeogeographic configuration strongly controlled deposition of the Kujung carbonates. Extensive carbonate buildups grew on the highs and shales were deposited in the basinal lows. Reefal development occurred in places along the faulted margins of the basin and along the shelf edge.

The Kujung Formation from the oldest to the youngest is divided into several units : Kujung III, Kujung II, (both as Lower Kujung in onshore basin) and Kujung I (Upper Kujung). The basal Kujung III is a clastic-rich regressive sequence. Kujung II is a transgressive sequence of shallow water carbonates and calcareous shales with localized carbonate build-ups over high areas. By Early Miocene, most of the region was undergoing carbonate sedimentation depositing Kujung I carbonates. High-energy clean limestones and common reefal build-ups developed. Kenyon (1976) studied the palaeogeography of Kujung I carbonates and identified four settings : (1) a deep water, east-west trending open marine clastic basin in the south (the East Java-Madura Basin); (2) an extensive, east-west positive area of shallow water carbonate deposition to the north (the East Java-Madura Shelf) characterized by a wave-washed, high energy bank edge along the southern margin; (3) a shallow basinal area (the Central Deep) of open marine, fine clastic and low energy limestone deposition; and (4) a northeast-southwest trending ridge (the JS 1 Ridge) to the northwest of the Central Deep, characterized by extensive shoal water carbonate deposition.

Early Miocene Tuban and Rancak carbonates ended a series of Oligo-Miocene carbonate sedimentation. The Tuban platform and reefal carbonates were deposited overlying the mid Early Miocene deep-water Tuban shales. Extending offshore, the reefs are called as the Rancak reefs developed around the margins of the North Madura Platform off the north coast of the Madura Island.

## **PETROLEUM SYSTEM**

Recent hydrocarbon discoveries within the Oligo-Miocene carbonates of the East Java Basin reflect the effectiveness of the related petroleum system involving mature source rocks (kitchen area), migration pathways, good carbonate reservoirs, resilient seals, and good stratigraphic traps. This is supported with matched timing of generation-migration-trapping and good preserved accumulation.

The kitchen areas generating hydrocarbons for discoveries of Ujung Pangkah (Premier, 1998), Sidayu (Premier, 2000), KE-23 B (Kodeco, 2000), KE-13, KE-24 (Kodeco, 2001),

Bukit Tua, Payang, and Jenggolo (Gulf, 2001) are the Central Deep and South Madura Sub-Basin. Source rocks are organic rich shales (0.82 to 3.9 % TOC) and some coals of the Eocene Ngimbang Formation. The source rocks are of marginal marine, deltaic, and lacustrine origin. Maturation started at the Middle Miocene by reactivation and renewed subsidence of many depression areas causing further burial. Hydrocarbons migrated from kitchen areas into the Kujung carbonate traps through carrier beds laterally or through faults vertically. Onshore discoveries of Rembang (Coparex, 1999) was sourced by the Early Miocene Tuban shales deposited at the Pati Trough. Onshore discoveries of Banyu Urip (ExxonMobil, 2001) and Sukowati (JOB Pertamina-Santa Fe Tuban, 2001) were sourced by Early Miocene Tuban shales deposited in low areas flanking the East Cepu High. Organic content of the Tuban shales range from 1.0 – 2.45 % TOC. Onshore maturity is dominated by the Middle to Late Miocene inversion along the Rembang-Madura zone. Sources deposited at the flank of inverted structures became mature due to subsiding into the oil window by isostatic compensation of the uplift inversion. Late Eocene Ngimbang shales are also significant source rocks in this area. Charging of hydrocarbons took place through lateral migration by carrier beds or by interfaces between Upper Kujung reservoir and Tuban sources as well as through faults from Ngimbang shales. Moderate to significant content of CO<sub>2</sub> characterizes the onshore discoveries and is considered to associate with volcanic activity in this area or with thermal decomposition of carbonate sources/ reservoirs.

The Kujung III/II carbonates have moderate matrix porosity that has been enhanced locally by fracturing. The average porosity is 23 – 25 %. Average permeability is excellent (160 mD in Camar field). The Kujung I reefs exhibit good to excellent reservoir characteristics ( porosity 20 – 30 % and permeabilities up to 194 mD). Older structures and associated stratigraphic traps such as the reefs of the Kujung sequences often contain hydrocarbons. A regional seal for reservoirs of the Kujung I is provided by widespread and thick Tuban Formation claystones. Intraformational seals also locally developed for the carbonate reservoirs of the Kujung II and Kujung III. Many of the recent discoveries targeted Miocene carbonate buildups fringing shelf platforms. Bukit Tua of Gulf Resources, however, focused on platform limestones remote from the reefal buildups. Porosity was expected from repeated exposure on the crest of the old Madura Platform, and hydrocarbon migration could enter this area laterally through porous and permeable Kujung carbonates as well as via carrier beds in the clastic section overlying basement. Fringing reef areas remain prospective, but success at Bukit Tua confirms remaining potential in stable platform areas distant from the shelf edge buildups (Caughey, 2001).

## **CONCLUSIONS**

Recent intensified exploration on Oligo-Miocene Kujung-Prupuh-Tuban-Rancak carbonates of the East Java Basin has resulted in significant discoveries and adds hydrocarbon reserves in excess of 880 MMBO and 600 BCFG. Discoveries within Oligo-Miocene carbonates of the East Java Basin reflect the effectiveness of the petroleum system including available kitchen areas and migration pathways, good carbonate reservoirs, seals, and traps, as well as matched timing of generation-migration-trapping and good preservation on accumulation. New seismic technology and geological concepts

contribute most to the recent discoveries of the Oligo-Miocene carbonates of the East Java Basin, this also shows that old-worked basin is always open for new exploration.

## **ACKNOWLEDGMENTS**

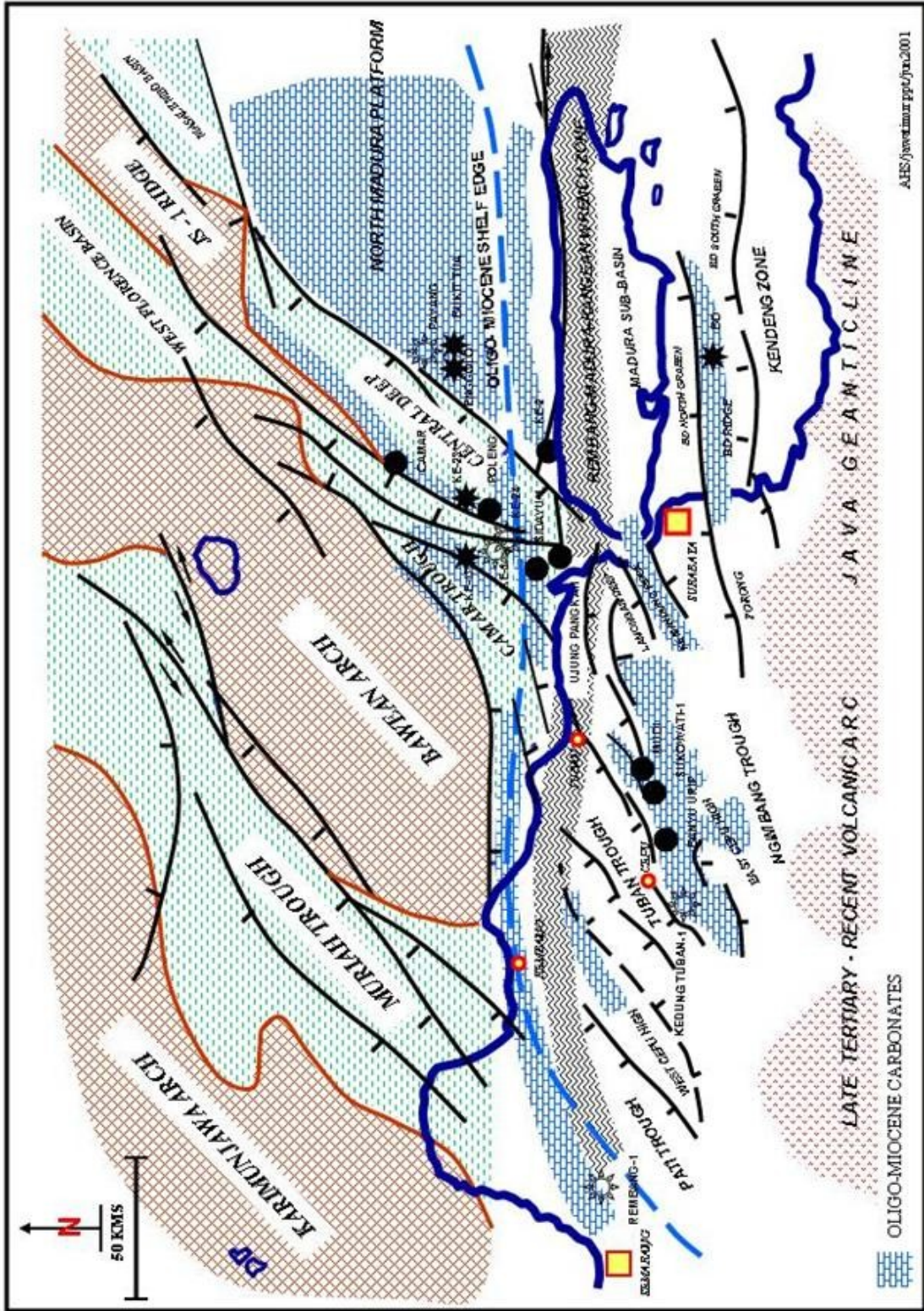
The paper is mainly benefited from materials provided by and discussions with explorationists working in the East Java Basin (Gulf Ketapang, Kodeco West Madura, Premier Ujung Pangkah, ExxonMobil Cepu, JOB Pertamina-Santa Fe Tuban, Coparex Blora, Pertamina Jawa Timur, and JOB Pertamina-Exspan Madura). The management of Exploration Pertamina MPS (Management of Production Sharing) is acknowledged for permission to publish the paper.

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## Geologic Setting of the Oligo-Miocene Carbonates of the East Java Basin



# Recent Significant Discoveries within Oligo-Miocene Carbonates of the East Java Basin: Integrating the Petroleum Geology

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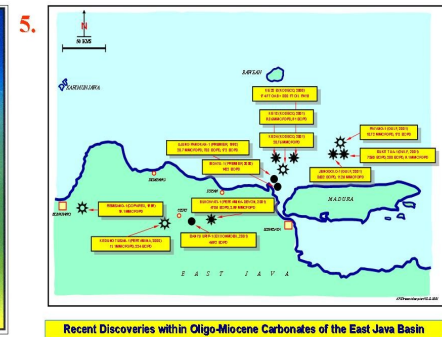
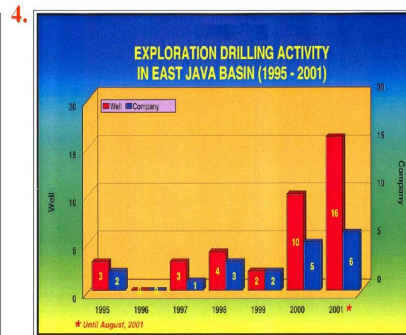
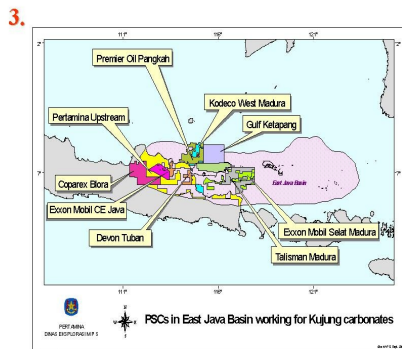
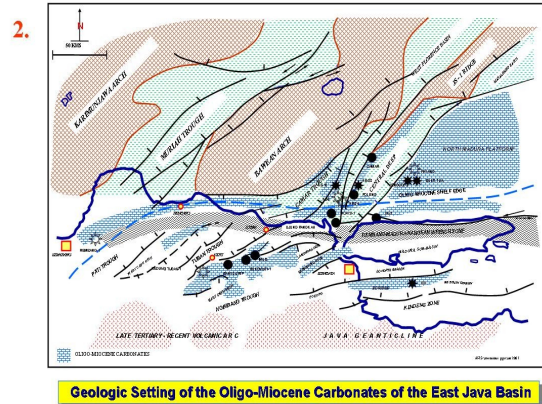
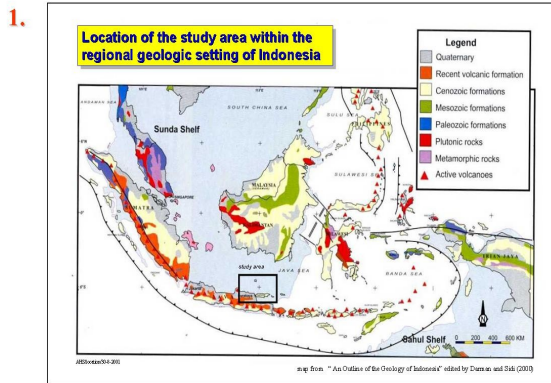
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## Abstract

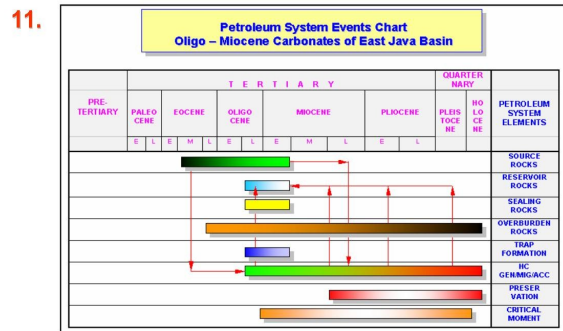
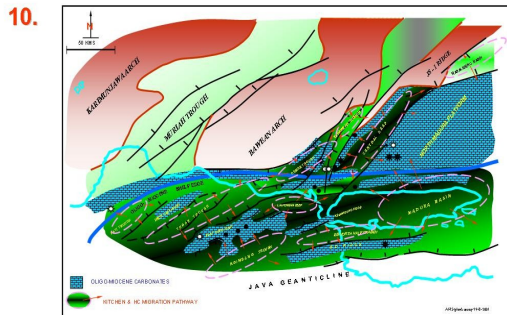
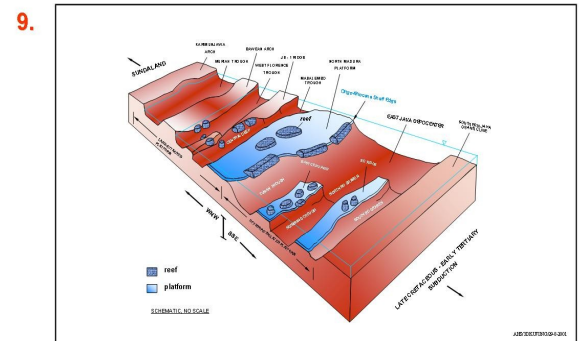
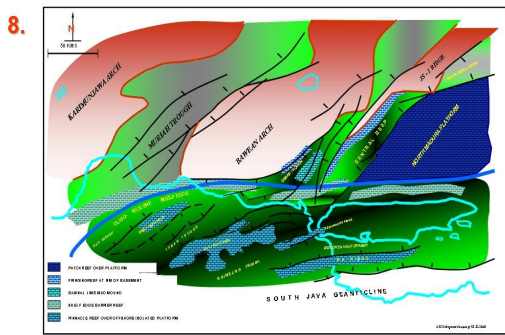
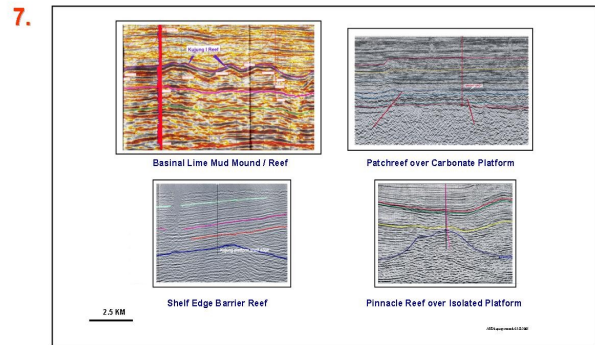
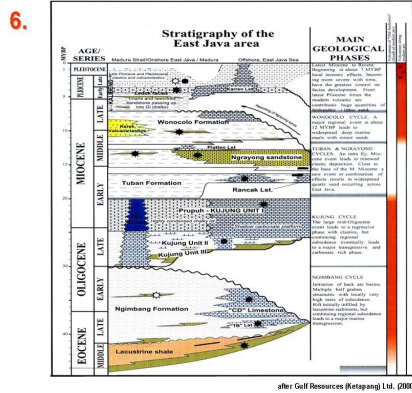
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Oligo-Miocene carbonates comprising the Kujung-Prupuh-Tuban-Rancak carbonates constitute the carbonate complex growing at the areas to the southeast of the Sundaland. The carbonates trend ENE -WSW from the present onshore eastern part of the Central Java to the offshore areas north of East Java and Madura Island. The carbonates developed in various environments from fringing reefs at rim of basement to pinnacle reefs over offshore isolated platform. Proven kitchens generating hydrocarbons trapped by these carbonates are located nearby within depression areas with mature sources range from the Eocene to the Early Miocene shales or carbonates.

This study summarizes historical and recent exploration of the Oligo-Miocene carbonates of the East Java Basin and integrate aspects of the petroleum geology including regional geology, carbonate sedimentology and petroleum systems. *petroleum exploration of the East Java Basin*







**Conclusions**

- East Java Basin's Oligo-Miocene carbonates developed in various environments, five facies, at least, have been identified.
- Recent discoveries within Oligo-Miocene carbonates of the East Java Basin reflect the effectiveness of the petroleum system.
- New geological concepts and seismic technology contribute most to the recent discoveries within the East Java Basin's Oligo-Miocene carbonates. This also attests that significant discoveries can still be made in old worked-basin.

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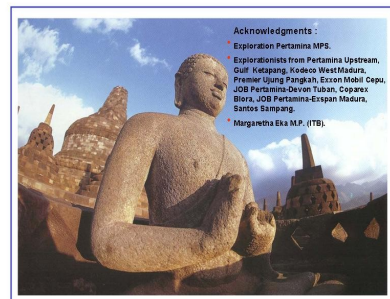
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The temple of Borobudur (AD 770-850), central Java, emerges from the dense mist. by Kiki Mulder (1994)