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Awang Harun Satyana[1], M. Djumlati[1] (1) Indonesia's Implementing Body for Upstream Oil and Gas Business, Jakarta, Indonesia

Oligo-Miocene Carbonates of the East Java Basin, Indonesia : Facies Definition Leading to Recent Significant Discoveries

Prospectivity of the Oligo-Miocene carbonates of the East Java Basin have been proven since early 1970s. However, the significance of the carbonates as oil producer have not obtained full attention until the late of 1990s when un-interrupted significant discoveries within the carbonates resulting in hydrocarbon reserves in excess of 900 MMB oil and 700 BCF gas take place. This number will be continually increasing since aggressive exploration ventures are being made by oil companies operating in this area. Eleven new working areas are offered in Indonesia in 2003, eight of them are located in the East Java Basin and the Oligo-Miocene carbonates are their main objectives. The geology and petroleum system of the Oligo-Miocene carbonates of the East Java Basin are increasingly well defined.

Geologic Setting

Located at the active southeastern margin of the Sundaland, Southeast Asia, the East Java Basin has recorded an active geodynamic history (Satyana and Darwis, 2001). The basin developed from an oceanic basin in front of the Late Cretaceous subduction zone to presently a backarc basin 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. Three main structural configurations can be established from north to south : the Northern Platform, the Central Deep, and the Southern Uplift.

Stratigraphic history of the basin is typified by the Paleogene synrift and postrift sediments deposited in segmented basement forming a series of SW-NE graben and horst areas. The sediments consist of synrift middle Eocene Lower Ngimbang, postrift Late Eocene to Early Oligocene Upper Ngimbang and "CD" shales. After a mid-Oligocene uplift, the transgression regionally flooded the basin during the late Oligocene to early Miocene and deposited Lower Kujung siliciclastic and carbonates. Transgressive carbonates peaked during the tectonic quiescence from the early Miocene to mid-Miocene and developed reefs of Upper Kujung - Tuban - Prupuh - Rancak. Tectonic inversion history started in mid-Miocene and peaked in Pleistocene time. Regressive and partly transgressive sediments of the Neogene Ngrayong, Wonocolo, Mundu, Paciran, and Lidah consisting of sands, shales, and carbonates were deposited during the periods. Volcanic materials intercalated the sediments.

Two principal structural trends of Tertiary origin can be distinguished : a northeast-southwest extensional fault trend and an east-west compressive - wrench fault trend. A tensional stress regime was active from the middle Eocene up to the early Miocene forming rifting in the Eocene and basin-wide subsidence in the Oligocene. Neogene tectonism formed widespread compressive and wrench-related structures from middle Miocene time to the Pleistocene.

Oligo-Miocene Carbonates and Reefs : Facies Definition

The Kujung-Prupuh-Tuban-Rancak carbonate formations represent a phase of continuous transgression during the Late Oligocene to Early Miocene. The Kujung Formation is divided into three units : Kujung III, II, and I. 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 (Prupuh Member) carbonates. High-energy clean limestones and common reefal build-ups developed. Early Miocene Tuban and Rancak carbonates ended a series of Oligo-Miocene

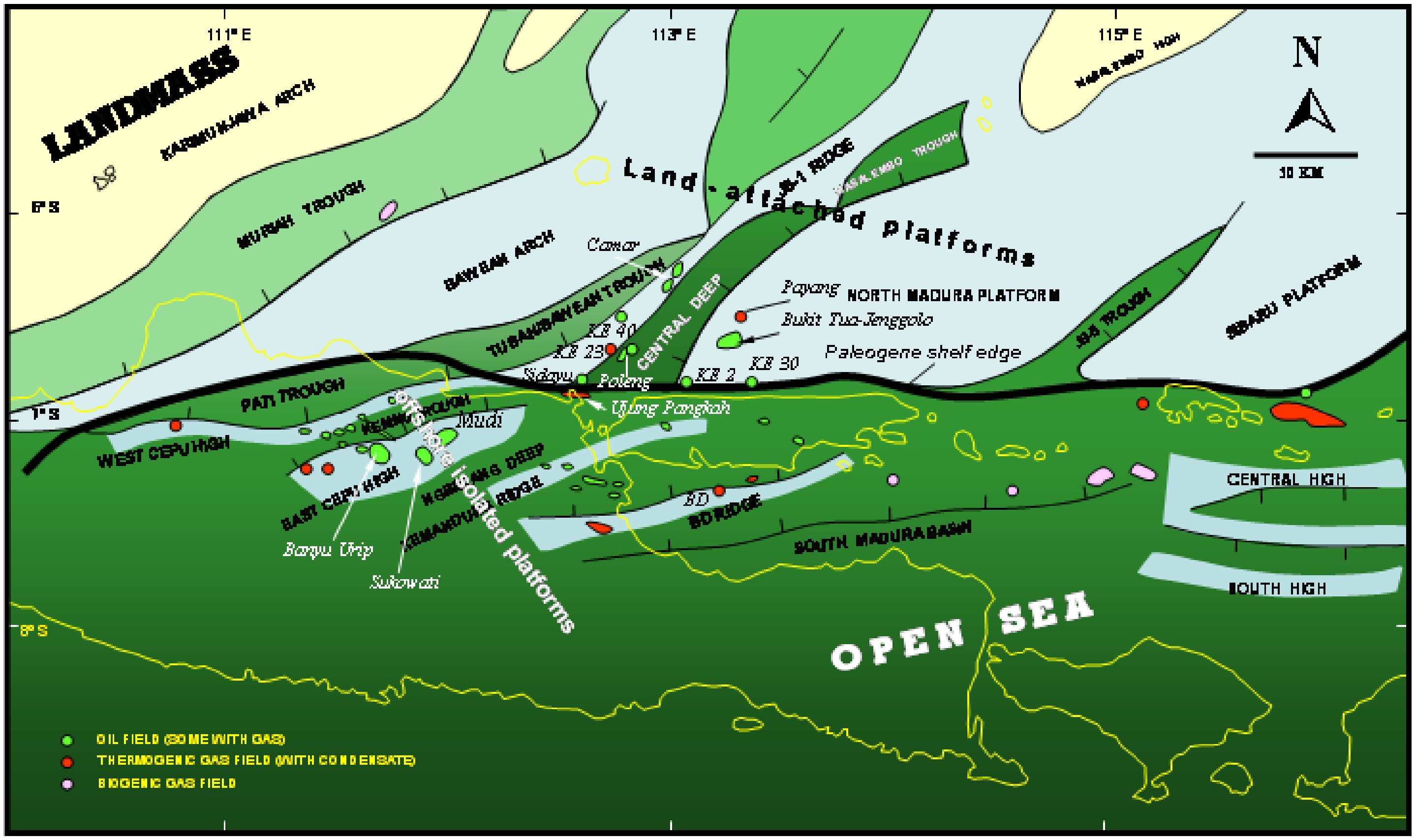

Figure 1 Paleogene paleo-geography of East Java Basin.

carbonate sedimentation.

Two modes of Oligo-Miocene carbonate deposition can be distinguished (Figure 1) : (1) deposition on a land-attached platform, and (2) deposition on offshore isolated platforms. A continuous southwest-northeast - bend - to west-east trending Oligo-Miocene shelf-edge separated these two domains of carbonate deposition. The bending of the shelf edge occurred to the south of Semarang and actually may represent two different principal tectonic trends during the Tertiary. The shelf-edge barrier had remained in its present position during the Tertiary and had accommodated the change of sediments from northern platform to central deep during the period of Kujung to Ngrayong sedimentation.

To the north of the shelf-edge barrier, the deposition of the Oligo-Miocene carbonates/reefs were controlled by the segmented basements of the land-attached platform. The segmented basement formed a number of horsts and grabens trending roughly southwest-northeast facilitating the deposition of the carbonates. From west to east, the main horsts and grabens are : the Karimunjawa Arch, the Muriah Trough, the Bawean Arch, the Tuban/Bawean-Florence Trough, the JS 1 Ridge, the Central Deep-Masalembo Trough, the North Madura Platform, the JS 5 Trough and the Sibaru Platform. Three carbonate reef facies are recognized within this area (Figures 1, 2) : (1) fringing reef at rim of basement, (2) basinal lime mud mound, and (3) patchreef over platform. Fringing reef at rim of basement is characterized by extensive shoal water carbonate deposition. Camar and KE 40 Fields is an example of this type. Basinal lime mud mound is a shallow basinal area of open marine characterized by fine clastic and low energy limestone deposits. KE-5 and Poleng Fields are examples of this type. Patchreef over platform is an extensive, east-west positive area of shallow water carbonate deposition characterized by a wave-washed, high energy bank edge carbonates. The Bukit Tua and Jenggolo Fields to the north of Madura are examples of this type. In this land-attached platform, reefal build-ups occurred mostly along the shelf margin and along the fault bounded basin margins of the structural units. They are less developed in the more northerly shelf areas where the rate of subsidence was

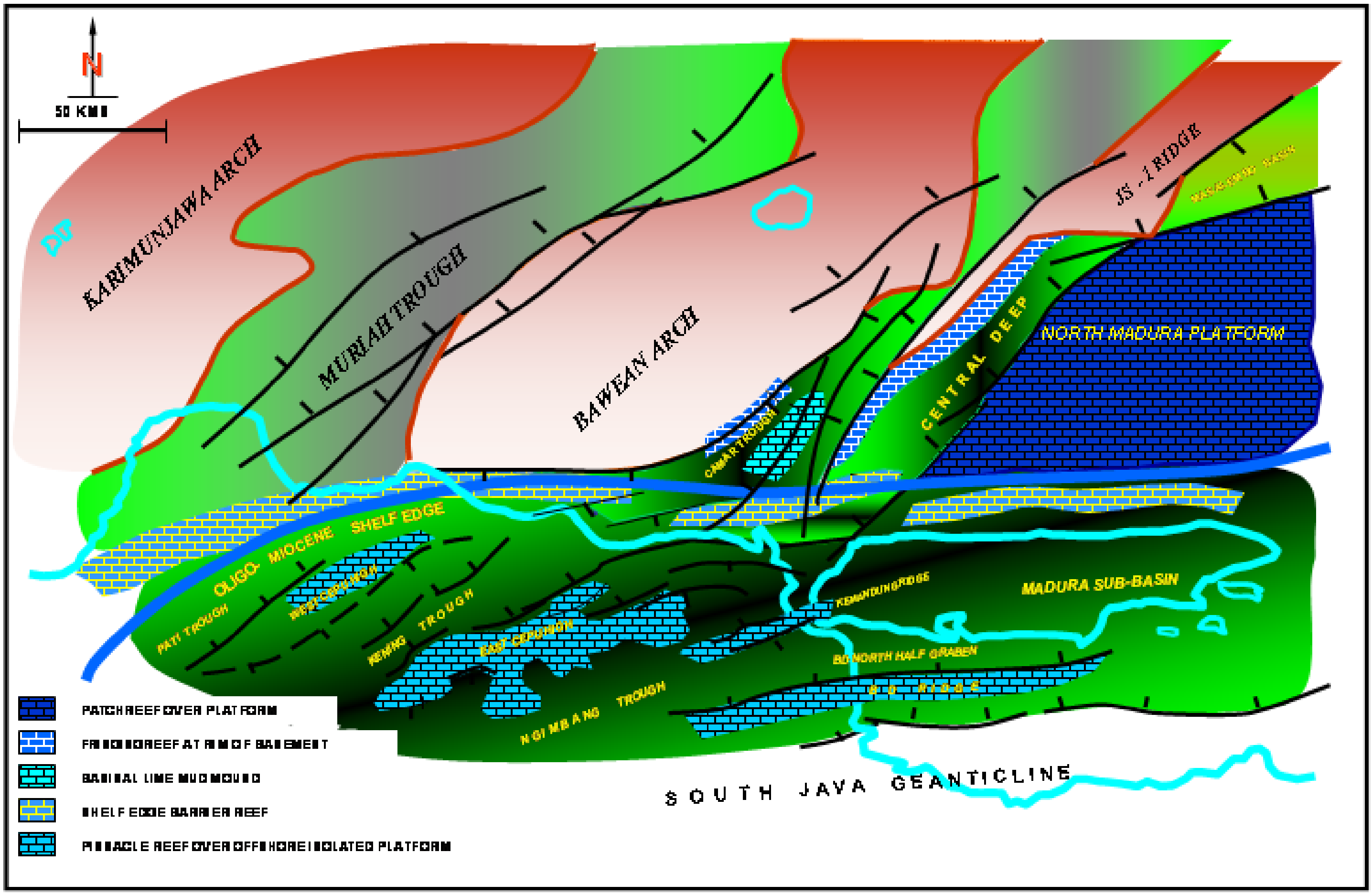

Figure 2 Depositional Facies of the Oligo-Miocene Carbonates of the East Java Basin

insufficient to allow substantial vertical growth in addition to much clastic poisoning.

Along the shelf-edge area, one type of carbonate facies is recognized namely the shelf edge barrier reef characterized by a wave-washed, high energy bank edge along the southern margin. The Ujung Pangkah, KE-2, and KE-30 Fields are examples of this type (Figures 1, 2).

To the south of the Paleogene shelf-edge barrier, the deposition of the Oligo-Miocene carbonates and reefs were controlled by the segmented basements forming the offshore isolated platforms (Figures 1, 2). The isolated platforms represent a number of horsts and grabens trending roughly WSW-ENE and laterally much narrower than their counterparts in the northern land-attached platform. These isolated highs are faulted basement highs.   From west to east, the horsts and grabens are : the Pati Trough, the West Cepu High, the Kening Trough, the East Cepu High, the Ngimbang Deep, the Kemandung Ridge, the North BD Half Graben, the BD Ridge, the South BD Half Graben, and the Central High-Southern Deep-South High to the south of the Kangean Island. Reefs grew above these highs forming pinnacle reefs over offshore isolated platforms. Pinnacle reefs on local paleo-highs were able to keep pace with transgression. The isolated platforms generally dip to the WSW drowning their western parts resulting in backstepping transgressive sequences to the east. Drowning history of the western East Cepu High and BD Ridge can be found in Purwaningsih *et al*. (2002) and Purwaningsih (2003). In this situation, reefs continually growing at the eastern parts of the isolated platforms and fine sediments were deposited at the western parts ending the reef growth. The Mudi, Banyu Urip, and BD Fields are examples of this type. Good to exellent porosities mainly in the upper parts of the reefs characterize these fields.

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). In some places like the Madura Platform porosity is expected from repeated exposure on the crest of the old Madura Platform.

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 related timing of generation-migration-trapping and good preservation of accumulation. Detailed petroleum system of the East Java Basin can be found in Satyana and Purwaningsih (2002, 2003).

The proven kitchen areas generating hydrocarbons for offshore discoveries of Camar, KE-13, KE-40, Ujung Pangkah, Sidayu, KE-23 B, Poleng, Bukit Tua, Payang, Jenggolo, and BD are the Bawean Trough, Central Deep and South Madura Sub-Basin. Source rocks are organically rich shales and some coals of the Eocene Ngimbang Formation. The source rocks are of marginal marine, deltaic, and lacustrine origin. Maturation started in 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, Banyu Urip and Mudi were sourced by Ngimbang and/or Early Miocene Tuban shales deposited in low areas flanking the West and East Cepu High. Onshore maturity is caused by compensational isostatic subsidence due to Middle to Late Miocene inversion along the Rembang-Madura zone. 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_2 polluted some discoveries and is considered may associate with thermal decomposition of carbonate sources/ reservoirs or volcanic activity in this area or with. A regional seal for reservoirs of the Kujung I is provided by widespread thick Tuban Formation claystones. Intraformational shales seal the carbonate reservoirs of the Kujung II and Kujung III.

Significant Recent Discoveries and Future Potential

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 East Java. The well tested 20,7 MMCFGPD, 703 BOPD, and 172 BCPD from the Lower Tuban and Upper Kujung carbonates. In the last five years, continuing significant oil and gas discoveries have been taking place within all carbonate facies. These recent discoveries have been reported by Satyana and Darwis (2001) and Satyana (2002). Average success ratio of the discoveries is around 70 %. The most significant discoveries were : Banyu Urip-1 (ExxonMobil Cepu, tested 3985 BOPD), Sukowati-1 (JOB Pertamina-Devon/now PetroChina Tuban, tested 7697 BOPD), Bukit Tua-1 (Gulf/now ConocoPhillips Ketapang, tested 7361 BOPD), and Jenggolo-1 (Gulf, tested 3602 BOPD).

These recent discoveries have contributed new hydrocarbon recoverable reserves in excess of 900 MMBO and 700 BCF gas. Total resources (in place) of prospects and leads of the PSC contractors working in the East Java Basin from the Oligo-Miocene reefs are around 15 BBO and 19 TCFG or 18 BBOE (billion barrels oil equivalent) from 45 prospects and 43 leads. Future prosperity of East Java Basin lies within these Oligo-Miocene reefs. Deliberate definition of the carbonate facies, integrated with the knowledge of the basin's stratigraphy, structure, geochemistry, and petroleum system, has enhanced the exploration success in this area.

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