THE MOST SHALLOW OIL TRAP IN THE WORLD OF WONOCOLO ANTICLINE AS A BEAUTIFUL EDUCATION OBJECT

by Dedy Kristanto

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THE MOST SHALLOW OIL TRAP IN THE WORLD OF WONOCOLO ANTICLINE AS A BEAUTIFUL EDUCATION OBJECT

Jatmiko Setiawan*, Dedy Kristanto, Hariyadi
Universitas Pembangunan Nasional Veteran Yogyakarta
**Corresponding author* e-mail : jatmikosetiawan@upnyk.ac.id

ABSTRACT

Kawengan is one area in Bojonegoro, East Java , which is the area between Pertamina EP Joint Operation Asset 4 with GCI (Geology Cepu Indonesia). This area is one point Geosite of 20 points geosite of Petroleum Geoheritage Bojonegoro. This area was selected to become an applied research UPN "Veteran" Yogyakarta, cause in the region exposed rock layers that are petroleum system in Kawengan. As well as still found anticline are exposed at the surface and at its peak there were wells modern means of extracting the oil. So it can be used as educational areas for geoscience students mainly Petroleum Geology and Geophysics department.
Keywords : *geosite, geoheritage, petroleum, anticline*

INTRODUCTION

Anticline kawengan structure was discovered by the Dutch in 1894 and was developed in 1926 by BPM. The anticline structure of Kawengan is one of the oil and gas producing structures in the North East Java Basin. The structure is included in the old field groups that continue to produce until now, it is evidenced by the presence of wells that are still active to produce up to now both operated by the company and managed by the community.

Research Purposes

The purpose of this research is to know the process of development of petroleum system that occurs in anticline structure kawengan, by conducting an integrated geophysical, geological and reservoir study. Where the results of these studies can be a teaching material in learning the process of development of petroleum system, especially in anticline structure kawengan.

Formulation of the problem

The formulation of the problem proposed in this research is to study the process of development of petroleum system in anticline structure kawengan.

Research area

Geographically the Kawengan Anticline Structure is located about 20 km northeast of Cepu City, including the area of Bojonegoro East Java (Figure 1.)

Figure 1. Research Area (*PT Pertamina EP*)

METHODOLOGY

The research was conducted by using the analysis of field data (primary data) and secondary data. Where will be conducted an integrated analysis between the evaluation of geology, geophysics, and reservoir, so that will produce a pattern / concept of a development of petroleum system in Kawengan Anticline Structure.

GEOLOGY AND REGIONAL STRATIGRAPHY

The Kawengan Anticline Structure is located in the North East Java Basin that extends west-east direction from the Rembang Zone (Suyanto and Yanto, 1977). This basin is formed since the Tertiary Beginning associated with the subduction of the Indo-Australian Plate under the Eurasian Plate. Since then it has also formed as a foreland basin or back-arc basin (Hamilton, 1979) to the present day. Physiographically, the Rembang Basin is an anticlinorium produced by inversion and reactivation of old faults. This results in the formation of folding and faulting, shown in (Figure 2.)

Figure 2. Fisiography North West Java (*Van Bemmelen, 1949*)

Regional Geological Structure

The active structure since the early Miocene until now is the sinistral strike slip zone RMKS (Rembang-Madura-Kangean-Sakala) limits the Kendang Zone and Randublatung Zone (Bransden and Matthews, 1992) (Figure 3). This basin has occurred 2 (two) tectonic regimes in the back-arc basin. Strain or tension regimes occur in Paleocene to Central Miocene and compression regimes occur in Central Miocene to Quaternary. In the regime strain occurs subsidence and sedimentation, while the compression regime occurs lifting, folding, and faulting. Pattern structure of Java that direct west-east and same direction with Java Island.

The evidence of the compression regime is that of the seismic cross-section it is seen that the normal fault basement of the Paleogenic Period is active again and again to the younger sediment undergoing a reverse fault or thrusting fault, while the basement undergoes inversion of the transtentional basin system (Bransden and Matthew, 1992). Sediment distribution and structural patterns in East Java are controlled by basement architecture.

According to Bransden and Matthew (1992), the North East Java Basin is structurally occurring 2 (two) major periods of fault reactivation resulting in new structures, following the Indo-Australian Plate accretion in Late Cretaceous. The first phase, of reactivation involves the paleogenic strain phase above the Pre-Tertiary filth fault which produces a low-angle local electrical strain geometry. The second phase, reactivation during the inversion of Neogen when the main foci of

Palaeogen move again produces the maximum removal of the paleogen depositor. Paleogen rifting in East Java is evaluated regionally as part of the back-arc extensional system influenced by the Southeast Eurasian Plate. Rapture on Neogen as a result of orthogonal compression of Indo-Australian plate subduction under the Eurasian Plate.

Figure 3. Structure Regional Geology West Java
(*Bransden and Matthews, 1992*)

Regional Stratigraphy

Samuel and Genevraye (1972) and Pringgoprawiro (1983) divide the stratigraphy of the North East Java Basin of two Mandala, Mandala Kendeng and Mandala Rembang. Mandala Rembang covers areas within the Randublatung Tektono-physiography zone, while Mandala Kendeng includes Tektono-physiographic zone of Kendeng. Stratigraphy Mandala Rembang called Stratigraphy Rembang. Generally, the sedimentation of Mandala Rembang is a deposition of exposure, rich in carbonate deposits (claystone, napal, limestone) and hardly any pyroclastic deposits, the sediment slopes to the south, thickness of 1500 m. Pringgoprawiro (1983) has divided Mandala Rembang into fourteen rock units. The regional stratigraphy of the Rembang Zone (Pringgoprawiro, 1983) and sea-level changes from (Exxon, 1996) show a picture of tectonic effects and sea-surface changes that make the Rembang Zone have structural complexity and sedimentation (Figure 4). The explanation of Mandala Rembang stratigraphy from old to young is briefly as follows

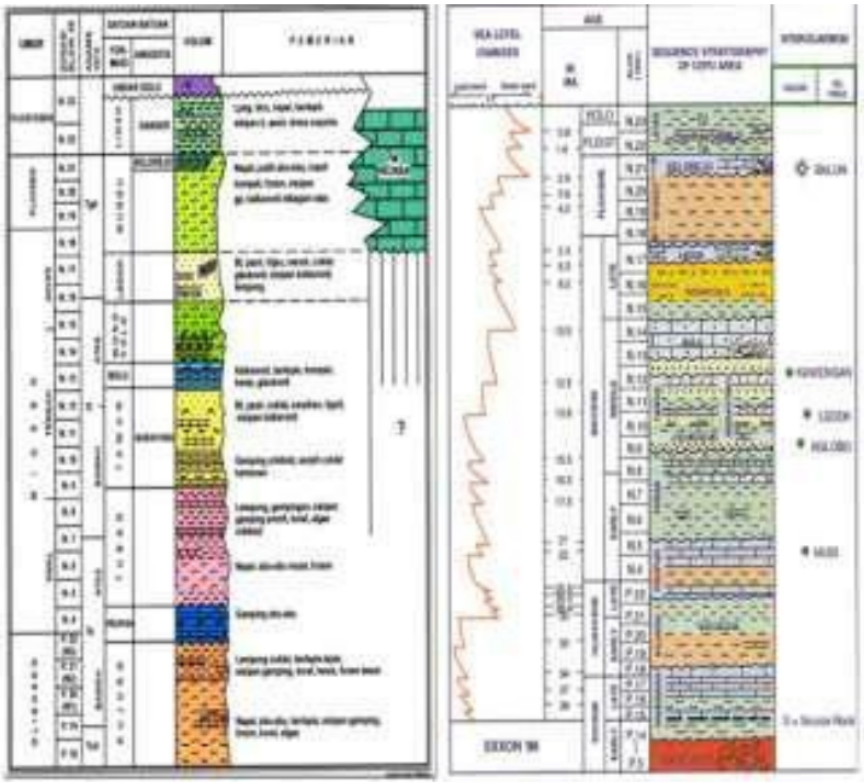

Figure 4. Regional Stratigraphy Mandala Rembang
(*Pringgoprawiro, 1983, left and Exxon, 1996 right*)

Pre-Tertiary bedrock

This unit is not exposed on the surface and can be observed from oil well drilling data. This unit is the bedrock of the Mandala Rembang basin. Composed by batakabak, filit, sekis and granite that is 100 million years old or commensurate with zones of age range N.4 - N.5 or Early Miocene (Zoning Blow, 1969). Its thickness reaches ± 76 m, deposited in shallow marine environments. The relationship with the Tuban Formation on it is confirmity.

Ngimbang Formation

This unit is also not exposed on the surface, and is observed from oil drilling well data (such as: Ngimbang-1, as a stratotype). The Ngimbang Formation is the oldest Tertiary rock unit in this area. The arrangement, the lower part is the iteration of quartz sandstone, shale and silt with thin insert of coal, upward of bioclastic limestone intercession with thin insert of gampingan and napal flakes. Ngimbang Formation has a thickness of 600 - 700 m. Based on the large and small foram

fossils this unit's age is the Early Oligocene (Tc-d), deposited on the edge-transition nerve environments. The limit of this formation with the formation above is difficult to determine due to gradual changes. The presence of thick limestone, can be used as a mark of the Ngimbang Formation with the units on it.

Kujung Formation

Types of locations are located in Kali Secang, Kujung Village, Tuban (Trooster, 1937), arrangement of napal, claystone with bioclastic limestone insertion (thickness 20 - 25 cm). This unit is widespread throughout the Anticline Kujung on the Tuban Heights, the thickness of this formation is unknown, but based on measurements in Kali Tepon ± 500 m. Based on large and small foraminifera fossils, the age of the Kujung Formation is the Upper Oligocene (P.19 - N.1) (Pringgoprawiro, 1983). Depositioned on open ocean environment. The relationship with the Prupuh Formation on it is confirmity.

Prepuh Formation

In Prupuh Village, Panceng, Paciran Gresik, trajectory length (stratotype) ± 300 m. The formation is composed of chalk limestone, bioclastic limestone (rich in Orbitoid fossils, and contains *Spiroclypeus orbitodes, Lepidocyclina sumatrensis, Spiroclypeus tidoengensis*, indicating early Miocene age.) Limestone limestone is found on the lower fossil *Globigerina ciperoensis, Globigerina primodius, and Globigerina disimilis*, upper part Globigerinoides immaturus, which shows the age of N.4 or early Miocene (Zoning Blow, 1969).

Tuban Formation

In the village of Drajat, Paciran Tuban, composed by claystone insert limestone. Good outcrop available in Kali Sirwula, Drajat Village with customs 144 - 166 meters. The clay fossil is rich in foraminifera fossil (*Globigerina primodius, Globorotalia opimanana, Globigerina tripartita dissimilis, and Globigerinoides alttiaperture*), where it shows zones of age range N.5 - N.6 or Miocene Early - Middle (Zonation Blow, 1969), on bioclastic limestone inserts Rich in *Orbitoid* fossils and contains *Cycloclypeus Miogypsina, Lepidocyclina*, including early Miocene age). Also found bentos fossils such as *Cibicides concentricus, Epinoides antilarum, Epinbides umbonatus and Ammonia beccarii*, shows the central neritik environment. This unit can not be confirmity by the Paciran Formation. The formation is to fend each other with Pelang Formation from Mandala Kendeng.

Tawun Formation

The name is first by Brouwer (1957) to refer to the unit that watched BPM Tawun-5. The Stratotype is arranged at the bottom: shale flakes, shellings, relatively fine

grained quartz sandstones, upward there are relatively coarse grained quartz sandstone (Ngrayong members) with a quartz sandstone thickness of up to 90 m, there is an *Orbitoid* limestone insertion, paste lignite. In the hypostratotypic sectional area, the granules contain *Gastropods*, upwards of the bioclastic bouquet are rich in orbitoids (ex *Lepidocyclina atuberculata, Lepidocyclina ephippioides, Lepidocyclina sumatrensis, Lepidocyclina niponica, Miogypsina bantamensis and Cycloclipeus* spp., Indicating middle Miocene age) (Pringgoprawiro, 1983) . In some places found by *Globorotalia praemenardii, Globorotalia siakensis, Globorotalia obesa, Globorotalia subquadratus, Globigerinoides alttiaperture* (N.8 - N.12) early Miocene-Middle (Zoning Blow, 1969). It is deposited on an exposure environment not far from the closed beach (lagoon). This unit works for the Tuban Formation, and is confirmity with the Ngrayong Formation on it.

Ngrayong Formation

Changes from the Tuban group with Tawun Formation and Ngrayong Members. Ngrayong Formation Naming by Pringgoprawiro and Sukido (1985), whose previous name is the Ngrayong Formation of Tawun (Pringgoprawiro, 1983). Tawun Formation, in several places different from Tawun Formation with Middle Miocene age (N.13). Its constituent lithology is composed of quartz sandstone adjacent to clay and sandstone limestone inserts.

Bulu Formation

The location of its type in the village of Bulu, Rembang, consists of limestones, limestone sandstone, rich foram large and small, coral, algae. Spread wide ranging from Ngrejeg - Klumpit - Rengel to Purwodadi, and disappear in the area Pati closed alluvial sediment. The thickness of this unit is 54 - 248 m. Based on the small fossil of the Bulu Formation is the lower end Miocene or N.14 - N.15 (Zoning Blow, 1969). It is deposited on the outer-batial upper neritik environment. Relationship with Wonocolo Formation sorted is confirmity.

Wonocolo Formation

Confirmity above the Bulu Formation, with locations around Wonocolo, Cepu. This unit is composed by the claynapal-sandnapal , rich in plankton foram, there is a calcarenite insert with a long layer of 5-20 cm. The spread is relatively west-east, ranging from Sukolilo (in the west) - Sedan - Wonosari - Kedungwaru - Metes - Banyuasin - Mantengan - Bulu, Anticline Ledok, Anticline Kawengan, continue towards Manjung - Tawun, Jojogan - Klumpit - thinning towards Tuban in east. The thickness of this unit is 89 - 600 m, the lower end Miocene ends to the middle end Miocene or N.15 - N.16 (Zoning Blow, 1969). Deposited on the open ocean

environment (outer neritik) - upper batur. The relationship with the Ledok Formation behind is confirmity.

Ledok Formation

Locations in Ledok, Cepu, consist of an iteration of sandstone and calcarenite, with napal and sandstone. The upper part of this unit is characterized by sandstones with glauconite concentration. Calcaarenite often tells the crossbedding layers. Spread from the Pati Depression (in the west) to the east until Tuban, where the unit is thinned (with the Highness of Tuban). Based on planktonic foram fossils (*Globorotalia pleistumida*) the age of Ledok formation is the upper end Miocene or N.17 - N.18 (Zoning Blow, 1969). It is deposited on the outside neritik environment (± 200 m) in the lower Ledok Formation, continuing upwards showing shallower (60 -100 m).

Mundu Formation

Type location is in Kalen River, Mundu Village, Cepu Made from Napal that rich planktonic foram, not layered. The uppermost part of this unit is occupied by limestone that rich of plankton foram. The upper portion of this unit is called Selorejo Member, which consists of intercession limestone sandstone and a napal sandstone. The spread is quite wide, with a thickness of 75 - 342 m. Bardasarkan small foram fossils, age Selorejo members are Pliocene or N.18 - N.20 (Zoning Blow, 1969), deposited on shallow exposure. The bottom of the Mundu Formation is an open sea sediments (middle Batur).

Paciran Formation

The location of the type is on the Paciran Piramid Hill, a ef limestone unit, composed of algae, coral, large foram. The spread starts from Jojogan - Montong - Tuban - Palang - Paciran - Paceng - Gresik - continue to Madura Island. Its thickness is 105-150 m. Based on large foram fossils, this formation is done Pliocene - Plistocene. It is deposited in a shallow marine environment, near the coast, warm, clear climates, ie at the litoral area - the sub-lithoral edge.

Lidah Formation

Lidah Formation is a dark blue, monoton, not layered unit. This unit can be configured to be the top, middle, bottom. At the bottom of the Lidah Formation is a blue claystone unit (called Tambakromo Member). The back consists of a claystone with Marl (Napal) inserts and quartz sandstones containing glauconite (Called Turi Member). In the Kawengan Antiklin area, this two-part room serves with *coquina* limestone units there are mollusk shells (Malo Members) (Pringgoprawiro & Baharudin, 1979). Based on its fossil content, the age of this formation: Upper

Pliocene - Lower Plistocene, deposited in a closed environment, and gradually becoming more shallow. The relationship with the Mundu Formation is confirmity, and in the Lidah Formation there is un confirmity with alluvial sediment and river porch sediments.

Undak Solo

The unit naming was given to several steps "undak-undak" along the Bengawan Solo river (Pringgoprawiro, 1983). Divided into six sub-steps, each naming is entirely based on the classification made by Sartono (1976). Its lithologic features generally consist of polymic conglomerates with napal, andesite fragments, sandstone containing Vertebrate fossils. Stratigraphic relationship: Located in a different place with an older place.

The North East Java Petroleum System

Bransden & Matthews (1992) and Phillipi et al. (1991) stated that potential parent rocks in the North-East Java Basin, which are rich in organic matter are the Eocene-Dower Formations found in drilling wells are shallow sea sediments, transitions, delta and lakes, with TOC of about 1.1%, at depth of about 2500 meters to produce hydrocarbons. This type of kerogen is algal sapropel lake mixed with highland plant material as potential producer of oil and gas.

Specific gravity hydrocarbons in the North East Java Basin range from 10^o - 60^o API, but the largest production is around 30^o - 40^o API. The Kujung Formation on it is a potential Source rock as well. The lithology of Orbitoid Kalk is rich in organic end-fertilized Miocene especially as a Source rock in the onshore of this basin.

The migration / history of its maturation takes place in the Middle Miocene to the End when tectonic inversion fault inversion on Paleogen and Neogen sediments from the Source rock to the reservoir. This is caused by heat flow factors, rapid inversion on the RMK (Rembang-Madura-Kangean) zone and reactivation and subsidens on the basins north of the RMK zone after burial.

Manur and Barraclough (1994), concluded that the types of pebbles are generally structural reserves that are limited by the tilting fault block, the Oligocene to Pliocene reef complex and the late Miocene compression / inversion structure. The type of deposit bounded by the tilted fault block is related to the formation of rifting and graben in the hollows formed by the anticlines in the Rembang Anticlinorium.

Generally the formation of hydrocarbons starts at the beginning of the Eocene Middle-Oligocene dilution associated with heat flow during the inversion period. Reactivation during Middle Miocene deformation forms the flower

structure and folds to the early deformation of Plistocene (Suparyono and Lennox, 1989).

The reservoir rocks on this mandala: Clastic Limestone Ngimbang Formation, Limestone Coral Reef Formation or Kujung Units, Quartz Sandstone Ngrayong Formation, Orbitoid Limestone Inserts in Ngrayong Formation, and Selantinejo Selamination Foraminifera Sandstone. The traps are structural types (anticline and fault) and stratigraphy (reef limestones). Rock cover, regionally the Wonocolo Formation and Mundu Formation, while intraformasional are clay and shale from Ngrayong Formation.

Reservoir Rock

In the East Java Basin the major accumulation of oil and gas is found in the reservoir:

(1) Eocene Sandstone at Lower Bottom
(2) Eocene Limestone on Upper Ngimbang
(3) Miocene limestone on Prupuh Member (Kujung Unit I)

Secondary Reservoir targets are:

(1) Miocene Sandstone on Ngrayong Formation
(2) Sandstone Formation Wonocolo and,
(3) Sandstone Formation Ledok

RESULTS AND DISCUSSION

Kawengan Field Survey

Survey of field conditions needs to be done to increase the results of the analysis, where the survey conducted in Kawengan Field. The location of observation (LP) observed to 22 (twenty two) Observation Locations (LP).

The location survey starts from the southern wing of the Kawengan anticline to the southeast of the anticline structure kawengan. The observation includes rock outcrop and indication of fault section, and active oil wells are produced by PT GCI or managed by the residents.

Reconstruction of Kawengan Anticline

The formation of anticline structure kawengan regionally interpreted influenced by big fault forming East Java that is fault RMKS (Rembang-Madura-Kangean-Sakala), and height which is on east side and west at Cepu, can be seen in Figure 5 and development of structure anticline kawengan shown in Figure 6. And the condition of anticline structure kawengan now shown in Figure 7.

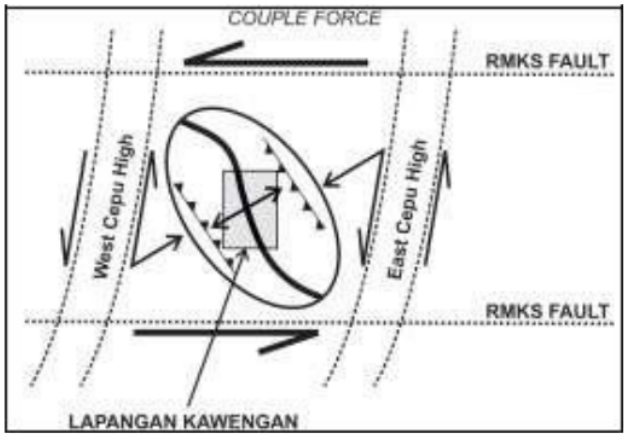

Figure 5. Geological Structure Model Structure of Kawengan Anticline

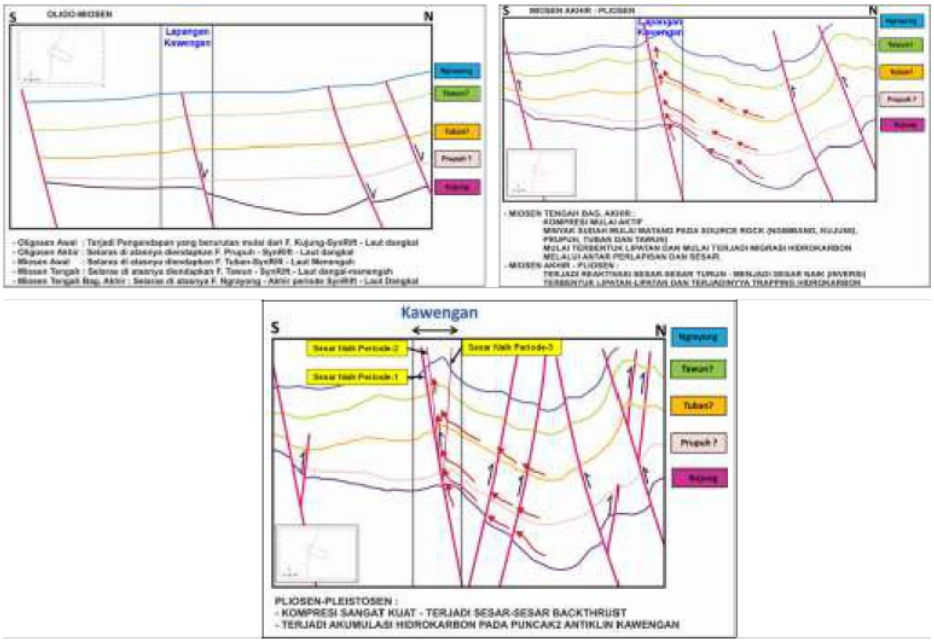

Figure 6. Development of Structure Anticline Kawengan Period

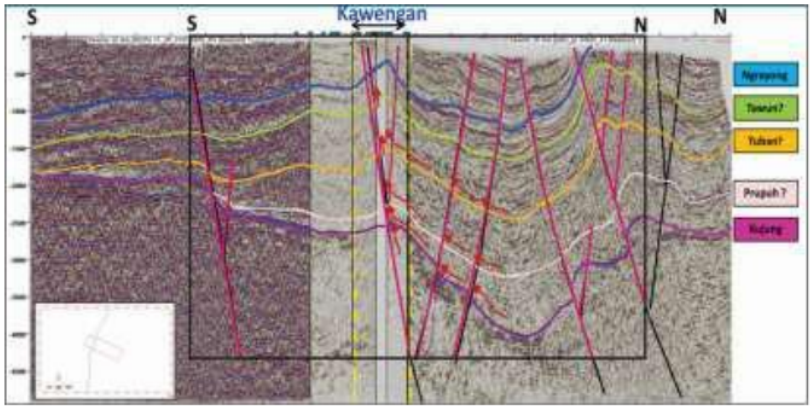

Figure 7. Condition of Structure Anticline Kawengan

Oligocene Period - Miocene

The history of geology is a blend of the structurally controlled precipitation basins and used for the deposition of rock layers or formations. In Kawengan Square the deposition of the oldest layer begins from the Early Oligesen. Early Oligocene (Syn-rift Period), the occurrence of normal fault that direct almost Northwest-Southeast that forms a basin in Kawengan, along with the occurrence of normal fault, occurs the precipitation of Ngimbang Formation form of brownshale and then covered in confirmity by Kujung Formation in shallow marine environment. Ngimbang Formation in the form of brown shale that can be the deepest Sourcerock in the Kawengan Basin, while the Kujung Formation in the form of layered limestone can be the deepest reservoir in the Kawengan Basin.

End Oligocene (Syn-rift Period)

Still in the syn-rift period, confirmity above the Kujung Formation precipitated Prupuh Formation in shallow marine environments. Prupuh formation in the form of Marl (Napal) contain thin limestone this can be a Souce rock in the Kawengan Basin.

Early Miocene (Syn-rift Period)

In this continuous syn-rift period, Confirmity above Prupuh Formation precipitated Tuban Formation in intermediate environments. This Tuban Formation consists of a blackish gray clay that has the potential as a Source rock in the Kawengan Basin.

Middle Miocene (Syn-rift Period)
In Central Miocene, the syn-rift process is still ongoing and confirmity above the Tuban Formation precipitated Tawun Formation. These formations are deposited in shallow and intermediate marine environments. This formation consists of gray sandstone inserted limestone and thin sandstone. This formation serves as a Source rock in the Kawengan Basin.

End Miocene (End of Syn-rift Period)
At the end of the syn-rift period it is precipitated Ngrayong Formation confirmity above Tawun Formation in shallow marine environments. This formation is composed by quartz sandstone so as well as a reservoir on the Kawengan Basin.

The Late Miocene Period - Pliocene
In the late Middle Miocene period until the final Miocene (period of compression), in this period of tectonics began to activate the collision between Indoaustralia with mikrosunda (Java). In this period the oil began to mature on the Source rock Ngimbang Formation, Kujung Formation, Prupuh Formation, Tuban Formation and Tawun Formation. The fold that direct Northwest-Southeast begin to form and inversion begins with the normal fault that direct almost Northwest-Southeast. It starts the hydrocarbon migration from the Souce rocks passes between layers and faults towards the upper Ngimbang Formation reservoir, upper Kujung Formation, Prupuh Formation, Ngrayong Formation Formation, Fur Formation and Wonocolo Formation.

Period of Late Miocene-Pliocene (Compression Period)
In this period, the reactivation of the down faults changes into upward fault (Inversions), forming folds that are directed almost Northwest-Southeast. And in this period has been formed hydrocarbon trapping in the trap formed

Pliocene - Pleistocene
In this period, the collision between Indo-Australia and Java (mikro Sunda) has occurred very strong, causing the inversion (Fault increased period 1) next happened the reverse fault (period 2). The compression continues so that backthrust faults. Further, hydrocarbons accumulate on the tops of the Kawengan anticlines.

Petroleum Kawengan Field System
The growing Petroleum System in Kawengan Field consists of the main rocks, rock reservoirs, traps, rock cover and migration of petroleum. It can be described as follows

Soucerock

Rocks that can be a Souce rock in Kawangan Field include Ngimbang Formation, Kujung Formation, Prupuh Formation, Tuban Formation and Tawun Formation. These formations are shales and claystone that contain plankton fossils.

Rock Reservoir

The Rock Reservoir found in Kawengan Field is actually comprised of the upper Ngimbang Formation, the Upper Kujung Formation, the Prupuh Formation, the Ngrayong Formation, the Wonocolo Formation and the Mundu Formation. But the contract for Geo-Cepu Indonesia is only in the Ngrayong Formation reservoir consisting of fine-to-medium grained quartz sandstone with a mixture of clay and gampingan. This will reduce the large porosity function of the quartz sandstone as a reservoir in Kawengan Field.

Trap

The traps that are found in Kawengan Field consist of traps of anticline structures (anticlinorium) of Northwest-Southeast direction and stratigraphy trap in the form of onlapping and cross bedding. Maturation of Oil and Migration in Kawengan Field especially petroleum starts maturing early Miocene to Central Miocene and begins to migrate in the final Miocene between layers and reverse faults towards structure and stratigraphy.

Cover Rocks

The cover rock at Kawengan Field consists of claystone interlayer in each formation. The ngrayong formation is the Marl (Napal) of Wonocolo Formation, Marl (Napal) of Ledok Formation and Clay of Lidah Formation.

CONCLUSION

1. The formation of anticline structure kawengan regionally interpreted influenced by a large fault that forms East Java namely fault RMKS (Rembang-Madura-Kangean-Sakala), as well as the height located on the east and West on Cepu
2. The formation of anticline structure kawengan begins at some period of the Oligocene – Miocene period where the precipitation is controlled by the structure and the deposition of the oldest layer starting from the Early Oligocene (Syn-rift Period) deposition Ngimbang Formation in the form of brownshale then covered in confirmity by Kujung Formation on the shallow marine environtment, End Oligocene (Syn-rift Period), Early Miocene (Syn-rift Period), Middle Miocene (Syn-rift Period), Late Miocene (End of Syn-rift

Period), Period of Miocene End-Pliocene (Compression Period) and Pliocene - Pleistocene.

3. Petroleum of Kawengan Field system, The Souce rock namely Ngimbang Formation, Kujung Formation, Prupuh Formation, Tuban Formation and Tawun Formation. Rock Reservoir Formation Ngrayong and Wonocolo Formation, trap in the form of anticline traps (anticlinorium) directed northwest-southeast and stratigraphic traps in the form of onlapping and cross bedding; the maturation of the earth's oil from the Early Miocene to the Central Miocene and begin to migrate to the Late Miocene, the cover rock at Kawengan Field consists of a clay interlayer in each Formation, but the main cover for the reservoir of the Ngrayong Formation is the Marl (Napal) of Wonocolo Formation, Marl (Napal) of Ledok Formation and Clay of Lidah Formation.

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