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Generation and Migration of Hydrocarbons from Pre-Tertiary Source Rocks of the Kamundan Area, West Papua, Eastern Indonesia

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ABSTRACT

The Kamundan area, West Papua, Eastern Indonesia is located to the north of the giant gas field, the Wiriagar Deep, discovered by Arco Indonesia in 1994 within the Jurassic sandstones. This discovery is important for the Kamundan area since showing of how the possible pre-Jurassic source rocks generated and migrated hydrocarbons to the Wiriagar and the Kamundan areas.

To understand generation and migration of hydrocarbons for the Kamundan area, the expected source formation and the Jurassic reservoirs were mapped. The source and gas samples from available wells were geochemically analyzed. Heatflow history reflecting tectonic and source maturation history was generated using BasinMod – 1D and –2D softwares. The migration routes of the generated hydrocarbons then were modeled.

Thermal modeling carried out for Ayot-2, Tarof-2, and Wiriagar-1 wells show that the sources have been mature since 240-260 Ma (Permo-Triassic). The maturation of the source is considered to relate with rifting subsidence during the Triassic. In 210 Ma (Late Triassic), the hydrocarbons have migrated and charged the whole intervals of the Jurassic reservoirs. Migration kept taking place and charged the Cretaceous reservoir until tectonic activity of the mid-Cretaceous uplifted the area and changed the migration routes. Afterwards, the hydrocarbons re-migrated along the porous beds at the Cretaceous unconformity and charged the Late Cretaceous and the Paleocene reservoirs. This is considered to have caused the significant hydrocarbon accumulation in the Paleocene reservoirs.

The study concluded that the petroleum system of the Kamundan area is Permo-Triassic : Jurassic and Paleocene (.)

1. INTRODUCTION

The Kamundan Block covers areas of 1615 sq km and is situated at onshore Bintuni Basin in the Bird's Head area of West Papua, Eastern Indonesia. (Figure1)

The exploration activities by CONOCO in the 1970's have mainly been targeted for oil in the Miocene Kais limestone but with no success compared to that in the adjacent Salawati Basin. However, CONOCO discovered oil in the Kais limestone in the Wiriagar and the discovery encouraged them to look for deeper targets. However, their later wells, Tarof-2 and Ayot-2, were not success although Ayot-2 well encountered some minor oil and gas shows. CONOCO returned the area to Pertamina.

In 1994, ARCO made the first major gas discovery in the Berau Block by drilling the Wiriagar Deep-1 well which encountered gas in the Pre-Tertiary reservoirs. This success has enhanced the pre-Tertiary exploration of the Bintuni Basin. There are five operators currently working for exploration of the Bintuni Basin : Pertamina, Lasmo, IGO Japan, Coparex, and BP. Fields discovered to date are Wiriagar Deep, Roabiba, Vorwata., Mogoi Deep, Wos, and Ofaweri. Fields were discovered in the same clastics of the Permian and Jurassic sandstones.

The main source rocks are considered to be the coals and shales of the Permo-Triassic (Ainim) and Jurassic (Kembelangan) in a fluvio-deltaic environment. Laminated shales and coals have high TOC with hydrogen indices ranging from 240 to 260 suggesting signifant gas prone source rocks.

2. PROBLEMS

The main problem of this study is to examine the possibility of the Pre-Tertiary source rocks to generate and migrate hydrocarbons to the Kamundan area.

The migration routes of the hydrocarbons are evaluated considering the coeval tectonic activities undergone by the area.

3. TECTONICS AND STRATIGRAPHY

The Kamundan area is adjacent to the collision margin between the Australian, Sunda and Pacific plates resulting in a complex tectonics beginning in the Late Mesozoic. The northern margin of the Irian-Papua New Guinea Archipelago is composed of several different terranes which have fused as the intervening paleo-seas closed since the Late Mesozoic. In the early Tertiary, the Australian plate interacted with the Sunda plate where several major strike-slip faults were induced as the various different blocks adjusted to these new regimes. In the Late Tertiary, a compressive phase was introduced into the Bird's Head area. The Bintuni area, became a foreland basin as the Lengguru region was thrusted over the former Terrane. Subsequent westwards movement of the Lengguru thrust zones depressed the Bintuni area to now becomesa major and rapidly- filled depocentre with provenances from the highs flanking this topographic low.

The major east-west strike-slip faults, the Sorong fault (sinistral) and the Tarena-Aiduna fault (sinistral) which bound the Bird's Head area in the north and south respectively have realingned the thrust belt (the Lengguru foldbelt) to a more north-south orientation from the main northwest-southeast trend in the central part of the island of New Guinea-Irian Jaya. (Figure 2)

The stratigraphic column of the Bintuni area is shown on figure 3. The oldest sedimentary rock is the Devonian Kemum Formation. This deep marine sediment is believed to be the economic basement. The Kemum Formation is overlain unconformably by the sediments of the Aifam Group, which consists of the Aimau Formation, the Aifat Formation, and the Ainim Formation. The Aimau sediments were deposited in terrestrial and shallow marine environtments during the Carboniferous to the Permian. Afterwards, the shallow marine Aifat sediments and the fluvio-deltaic Ainim sediments were conformably deposited. The best potential of source rocks at the Bintuni Basin is the Ainim Formation and lower part of Kembelangan Formation. The shale of Ainim Formation contains up to 11 % TOC. Hydrogen indices range from 47 to 264 indicating the presence of mainly humic gas-prone kerogen with minor oil-prone sapropelic component, a composition confirmed by visual kerogen analysis. Pyrolysis potential yields are high indicating a very good generating potential (Perkins et al, 1993).

The Triassic Tipuma Formation was unconformably above the Aifam Group. The Tipuma Formation and the Aifam Group are the sediments deposited during the pre-Mesozoic Syn Rift Tectonic phase.
The Post-Rift Tectonic Phase which happened since the Mesozoic until the Early Tertiary produced various sediments. The contact berween each formation of this tectonic phase is generally unconformable. The Lower Kembelangan Formation, aged Jurassic, can be divided into three depositional sequences where the relationship between each sequences is uncorformable. The first sequence which was deposited during the Middle Jurassic was controlled by transitional and shallow marine environment, the second Middle-Upper Jurassic sequence was deposited in the shallow deep marine environment. The third, still in the marine environment, was deposited since the Upper Jurassic until Early Cretaceous. The

sandstones of the first sequence of the Lower Kembelangan Formation, called as the Roabiba sandstones, has been proven as the hydrocarbon reservoir.

After the deposition of the Lower Kembelangan , the sedimentary pattern changed to be transgressive. The thick marine shales of the Jass Formation covers unconformably the Lower Kembelangan Formation. Some authors named this formation as the Upper Kembelangan Formation.. The transgressive pattern continued until the Early Tertiary when the turbiditic Waripi sediments were deposited.

The transgressive deposition of the Waripi sediments was ended by the development of the Faumai carbonates during the Eocene to Oligocene. This period also ended the Post Rift Tectonic Phase and changed the depositional sequence to the Syn-Orogenic Tectonic Phase. Within the Oligicene time, the Australian Plate relatively moved to the west and collided with the available terrane. This collision controlled the uplifting processes in the Bintuni Basin. The materials which were eroded in the uplift area were transported and deposited at the lower part and composing the Sirga Formation.

The Oligocene uplifting process was continued by the stable tectonic activity in the region. This condition accommodated the development of a very broad lateral distribution of the carbonate deposits called Kais Fomation.

4. METHODS

Maturity history and migration of hydrocarbons is defined by BasinMod-1D dan 2D softwares. Well data (Ayot-2, Tarof-2 and Wiriagar-1) and a seismic line (line 98 KMD-06) from Kamundan area is used as input data for modeling. Paleo heatflow is one of the important data that must be entered.

Paleo heatflow history is obtained through thermal modeling by assuming various heatflow values throughout geologic time. This results in a present-day vitrinite reflection Ro-Depth curve, which is matched to the laboratory - determined Ro-Depth plot of the modeled well section. Using a constant present-day heatflow value, a Ro curve is derived which increases greatly towards the depth and completely is out of step with the corrected laboratory at the present-day heatflow value. The heatflow value for each geologic time interval is entered resulting in a paleotemperature value for each sedimentary layer interface. This temperature becomes input data for the vitrinite reflectance model by using the Easy % method (Sweeney & Burnham, 1990).

The resulting theoretical Ro vs depth curve is compared to the laboratory observed Ro vs depth plot. The paleo heatflow values is gradually increased backward until a gradual match is obtained between the theoretical Ro depth curve and the observed Ro-depth plot. The heatflow values for each interval is then plotted against time. Resulted curve reflects the paleo-heatflow history of the basin. This paleo heatflow is used as one of input data within the Basin Mod-2D.

5. RESULTS

5.1. Heatflow History

The heatflow history of the Ayot-2, Tarof-2 dan Wiriagar-1 located close to the *Ayot Low* can be seen on figure 4. It shows that at the Ayot-2 well, the *heatflow* increases very rapidly up to 3.1 HFU from 210 to 260 Ma. At the Tarof 2 well, *heatflow* increases sharply up to 3.2 HFU from 200 to 270 Ma. At the Wiriagar-1 well, the *heatflow* increases sharply to 4.9 HFU from 210 to 260 Ma. The definition of this *paleo heatflow* is supported by the *maching* results of Ro between laboratory-measured Ro and calculated Ro. The very rapid increase in *heatflow* from 210 to 260 Ma is considered due to the *Triassic Rifting*. The highest increase in heatflow at the Wiriagar-1 well is considered oweing to its position in the deeper part of the rifts than those of the Ayot-2 and Tarof-2 wells.

5.2 Maturity History

Maturity histories of the Ayot-2, Tarof-2 and Wiriagar-1 are shown on the figure 5. The figure shows that the source rocks have been mature since around 240 or 260 Ma (Permo-Triassic).

This timing of the maturation is supported by the analysis of *heatflow history.* Triassic Rifting is considered to be responsible for the source maturation.

5.3 Migrations and Trapping

The timing of migration is determined using expulsion diagram resulted from the *BasinMod-2D* modeling. Figure 6a shows that the hydrocarbons initially expelled at around 210 Ma (Late Triassic), this defines that the primary migration took place at 210 Ma .

Since their expulsion, hydrocarbons charged the both Jurassic and Cretaceous reservoirs. M*id-Cretaceous unconformity, however,* caused the hydrocarbons re-migration through *porous bed*s at the *unconformity* zone and charging the Late Cretaceous reservoirs. This also charged the Paleocene reservoirs. Present-day expulsion diagram shows that the hydrocarbons charged both the pre-Tertiary and the Paleocene reservoirs (figures 6b, 6c). An identified prospect located 10 kms to the southeast of the *Ayot Low* has an opportunity to be charged by hydrocarbons generated in the Ayot Low (figure 7).

The presence of Paleocene *marine claystones* (ARCO Indonesia, 1996) also put a possibility for oil generation from type II kerogen. The Paleocene reservoirs are also possibly charged by hydrocarbons generated from the Early tertiary source rocks in addition to the Permo-Triassic sources. This consideration should be further evaluated.

6. CONCLUSIONS

- The sources have been mature since 240-260 Ma (Permo-Triassic)
- The maturation of sources is considered to relate with the heatflow increase due to rifting subsidence during the Triassic
- In 210 Ma (Late Triassic), the hydrocarbons have migrated and charged the whole intervals of the Jurassic reservoir
- Migration kept taking place and charged the Cretaceous reservoir until tectonic activity of the mid-Cretaceous uplifted the area and changed the migration routes
- The hydrocarbons re-migrated along the porous beds at the Cretaceous unconformity and charged the Late Cretaceous and the Paleocene reservoirs
- This is considered to have caused the significant hydrocarbon accumulation in the Paleocene reservoirs

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