Exploration Challenges and Opportunities in Deep Water Makassar Strait Basins, Indonesia : Review of Carbonate Play Based on Sequence Stratigraphy and Seismic Characterization

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Summary

This evaluation is made following the unsuccessful of six exploration wells drilling in the deepwater of Makassar Strait. The geological factor of this unsuccessful result is in interpreting the presence of reservoir and source rock, in particular: misinterpretation of age of the carbonate reservoirs in the seismic correlation and less attention on the detail of the seismic characters differences of the carbonate developed on the horst structures. Here we discussed the cause of the failure in our review study of the regional geology based on sequence stratigraphy concept, carbonate facies model, and re-identification of seismic character of the carbonate reservoir target based on drilled wells data. The goal of this evaluation study is to analyze in general and regional perspectives, to describe an overview of the petroleum system model which is different from the previous interpretation.

Unsuccessful of six expensive exploration wells in the deep water is a bit much influence to the activities of exploration in the South Makassar Basin. Each operator in the contract areas in this area need to evaluate the petroleum system more dtail based on those drilling results prior to drilling. This paper is to demonstrate the exploration opportunities and challenges in an effort to discover hydrocarbons in the deep water Makassar Strait Basins.

Introduction

The exploration of Oligo-Miocene carbonate play in the Makassar Strait has begun in 2007 and to date 11 exploration blocks have been working on this play. The Makassar Strait is a deepwater area developed by rifting in the continent, separated the eastern Kalimantan and western Sulawesi (figure 2). The target reservoirs, the Oligo-Miocene carbonates are well exposed in the eastern Kalimantan and western Sulawesi. The rifting phase separated Borneo and Sulawesi during Middle Eocene–Middle Miocene and slowly drowning the Makassar Strait area up to ± 2500 m of the present depth.

Horst and graben structures can be recognized along the Makassar Strait in the 2D seismic data (Figure 3). The carbonate deposition in the Makassar Strait which contemporaneously drowning due to rifting has been interpreted based on the Oligo-Miocene carbonates out crops in the eastern Kalimantan and western Sulawesi. This regional model has been referred by the oil and gas operators in their exploration activities and in locating the lead or prospect on the horst structures in their contract area.

However, the drilling of 6 wells by using that regional model was failed to show good results. The causes of the unsuccessful result are not the same for each case. The regional concept of the Oligo-Miocene carbonate has been proven in one exploration well, showing the occurrence of good reservoir rocks but with no evidence of charging of the hydrocarbon. The other well, extremely otherwise shows the horst structure was comprised of volcanic materials. Interestingly, there is one well that managed to show hydrocarbon in the Oligo-Miocene carbonates in only a small pinnacle geometry and the sealing of the hydrocarbon was leaked. Therefore, this discovery considered to be uneconomic well. The difference factors of the unsuccessful result of each exploration well showed all elements of the petroleum system were proven to be existed, but not integrated into the prospects that have been drilled.

Based on review of regional geology interpretation and the drilling results, we propose the cause of the misinterpretation in locating the occurrence of reservoir and source rocks is most likely in interpreting the age of the carbonates. Almost all of the operators working in the Makassar Strait have considered the carbonates as Oligo-Miocene in age, even though the Makassar Strait has been drowning since the Middle Eocene or Oligocene (van de Weerd and Armin, 1992; Hall, 2002). The growth and deposition of carbonates are sensitive to sea level. Therefore, the presence of carbonate out crops in the surface could not be directly correlated into the basin that has been drowning during the development of the carbonates. Nuraini et al., (2005) interpreted the carbonates were possibly developed during the initiation of rifting (Middle Eocene) to post-rifting (Late Eocene) (figure 3). Based on this study, the interpretation of carbonate reservoirs should be done by correlating in sequence stratigraphy the out crops of Middle-Late Eocene carbonates exposed in Sulawesi, to the east of Makassar Strait.

The drilling conducted by several operators using the consortium rig, has been operationally running back to

back until today. Therefore, a geologic re-modeling and seismic re-interpretation should be conducted soon in order to optimize the determination of the prospects to be drilled.

Theory and/or Method

We gathered information of exploration results from the operators work in the Makassar Strait, and combined them with the previous studies. For this evaluation, we used 6 drilled wells, 2Dseismic data set, surface geological data and results of previous research.

The method of this evaluation is by conducting a sequence stratigraphic correlation of surface and sub-surface data with more concern on detailed characters of the carbonate facies which are very sensitive to the sea level fluctuations. Based on limited well data we try to recognize seismic characters of the carbonates.

Sequence Stratigraphy and Seismic Character Review

One example of the evaluation with adequate data is the interpretation of a regional 2D seismic section trending west to east in the western Sulawesi. This section is crossing two drilled wells, so called A and B from west to east, drilled in 2010 and 2011, respectively. The geologic setting of the western part is in deeper water compare to the one in the eastern part, which is closer to Sulawesi. The previous interpretation of Nuraini et. al., (2005) interpreted that horst structure where Well-B is located, was covered by Middle-Late Eocene carbonate build-up. The carbonate build-up exhibits strong to low amplitude character, discontinuous and chaotic, and have mounded or conical shapes. On the contrary, on top of the horst structure where Well-A is located, there is no indication of carbonate deposition, because it was developed in the deeper area, and no indication of similar seismic characters of carbonate build-up. This interpretation (Nuraini et al. 2005) is different with the prognosis of drilling of Well A and B, where the two wells were expected to penetrate the target reservoir, the Oligo-Miocene carbonates.

Based on drilling result, Well-A has penetrated very thin (± 3 m) of carbonates on top of the horst structure. The carbonates are of Late Eocene age, not Oligo-Miocene as has been interpreted by the operator. Volcanic body remains beneath the carbonates. Meanwhile, Well-B, has successfully drilled through 2000 ft of porous carbonates. However, there was no indication of hydrocarbon charging (dry well). The age of the carbonates in Well B is the same within Well A (Late Eocene).

Those drilling results indicate the interpretation of the lithology developed on the horst structures (Nur'aini et al., 2005) has been proven to be valid. The changing of the interpretation of the carbonate reservoirs age would give significance implications in correlating the stratigraphic sequences. The equivalent sedimentary deposits exposed in Sulawesi are of fluvial, lacustrine and shallow marine sedimentary deposits (figure 2). Therefore, a profile from wells in the west to the outcrop in the east on land will shows correlated stratigraphic sequences. Started from Well-A with thin Late Eocene carbonates showing deeper depositional environment than the one in Well-B on the western side which penetrated 2000 ft of porous carbonates. Then to the west there are outcrops of terrestrial to shallow marine sedimentary deposits.

Seismic characters of the volcanic body constructed the horst structure where Well-A is located show different character with the one overlying the horst structure where Well-B is located. Seismic amplitudes in Well-A show discontinuous reflectors, whereas in Well-B shows high and continuous amplitudes such the one generally observed on top of carbonate bodies (figure 1). Such simple identification is expected to be used in recognizing other prospects with a reservoir rocks deposited on horst structure.

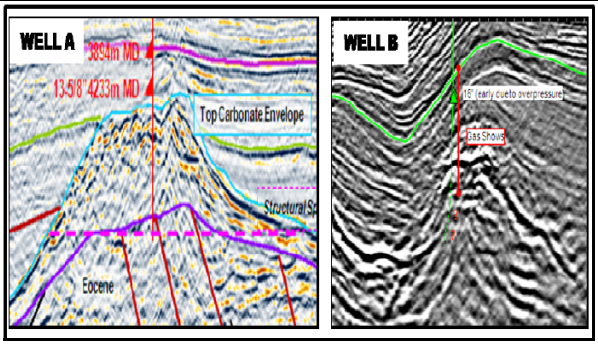

Figure 2: Seismic character diferentiation on top of horst structure. Well A penetrated only 3 m carbonate above the volcanic rocks and otherwise Well B penetrated 2000 ft porous carbonate.

This sequences model is not only has implication to the distribution of carbonate reservoir rocks but also to the distribution of source rocks deposited in terrestrial environments. On land, where the Eocene rocks exposed, oil and gas seeps occurred and were expected to be generated from the Eocene rocks. In the Well-A location, which were developed in deeper marine than the one in Well-B exhibit no hydrocarbon shows during the drilling. This indicates there was no deposition of fluvio-deltaic source rocks in the adjacent area, because the area was developed in deeper marine environment. Similar situation

in Well-B, which drilled porous carbonate reservoir rocks, there was no hydrocarbon shows. Carbonates in Well-B which located closer to the fluvio-deltaic outcrops and oil and gas seepages, were unable to get hydrocarbon charging. Therefore, detailed study on the distribution pattern of source rock and hydrocarbon migration in West Sulawesi is needed.

Another well drilling result in the South Makassar Strait Basin (SMSB) indicates gas discovery (uneconomic) in Well-C. The gas was discovered in Well-C, within a limited pinnacle carbonate body. Therefore the resources are found to be relatively small amount. In addition, leakage also identified on the cap rocks, recognized by the occurrence of faults in the upper part of the pinnacle, and made the gas to be poorly preserved. Location of Well-C is different from Well-A and Well-B, where it is located closer to western Kalimantan. Therefore, the sequence stratigraphic model for the area where Well-C is located should be the opposite of the model applied to the area where Well-A and B are located. SMSB is located on a structural deep to the east of a structural high so called the Paternoster platform. Paternoster is a stable platform where the Oligo-Miocene carbonates were developed. The target in Well-C which developed as carbonate pinnacle in the deeper part in front of the shelf edge has been expected if we refer to the carbonate facies model. Therefore, if the exploration in the SMSB is still targeting the Oligo-Miocene carbonates, than it is likely to find the similar pinnacle carbonates with high risk on the volume of the hydrocarbon to be economy, in the very high cost deepwater exploration. Not to mention the risk of leakage in the hydrocarbon trap such as the one in Well-C.

The kitchen zone that supplied the reservoirs in Well-C is estimated to be located in the south, where numerous of seepages indicated by Airborne Laser Fluorosensor (ALF) were found. Based on well data to the west of Well-C in the Paternoster High, the source rocks were interpreted of Middle - Late Eocene age, and deposited in fluvio-deltaic and lacustrine environments. By considering that the source rock were formed contemporaneously with the rifting process of the Makassar Strait, and based on the sequence stratigraphy model, the source rocks are most likely to be deposited in the kitchen zone, to the east of Well-C which is deeper than the Paternoster High and deposited in deltaic-shallow marine environments. If this interpretation is valid, then in the deep to the east of Well-C it is possible to have shallow marine-deltaic sandstones which have potential to become a reservoir rocks. However it will be more difficult to image this channeled deltaic sandstones geometry in 2D seismic or even with the 3D seismic data set.

Conclusions

This new stratigraphic sequence model can be be applied to the North Makassar Straits Basin (NMSB) and the South Makassar Strait South Basin (SMSB). We suggest exploration in the NMSB to get more close to Sulawesi and close to the location of hydrocarbon seepages on the surface. One can expect to discover well developed carbonate reservoir rocks similar to the one in Well-B and has been charged by hydrocarbon expelled from the fluvio-deltaic source rocks. Identification seismic characters is needed to distinguished carbonate bodies just like the case in Well-A and B. The target in Well-A has been proven to be comprised volcanics and the target in Well-B has been discovered as thick porous carbonates.

The exploration in SMSB is suggested to change the target of carbonate rock reservoir. It is likely to find carbonates in the other area of SMSB as small pinnacle reefs with relatively small geometry. Even if they were charged by hydrocarbon, it will be very hard to get economic value in this area of very high cost in oil and gas exploration and exploitation. Even though it was uneconomic, the charged pinnacle reef reservoirs in Well-C indicated the occurrence of source rocks and kitchen which are very close to the east and possibly deposited as deltaic-shallow marine sediments. The possibility of these Eocene deltaic-shallow marine sediments to the southeast of Well-C is expected to open the possibility of other reservoir rocks then the pinnacle reef.

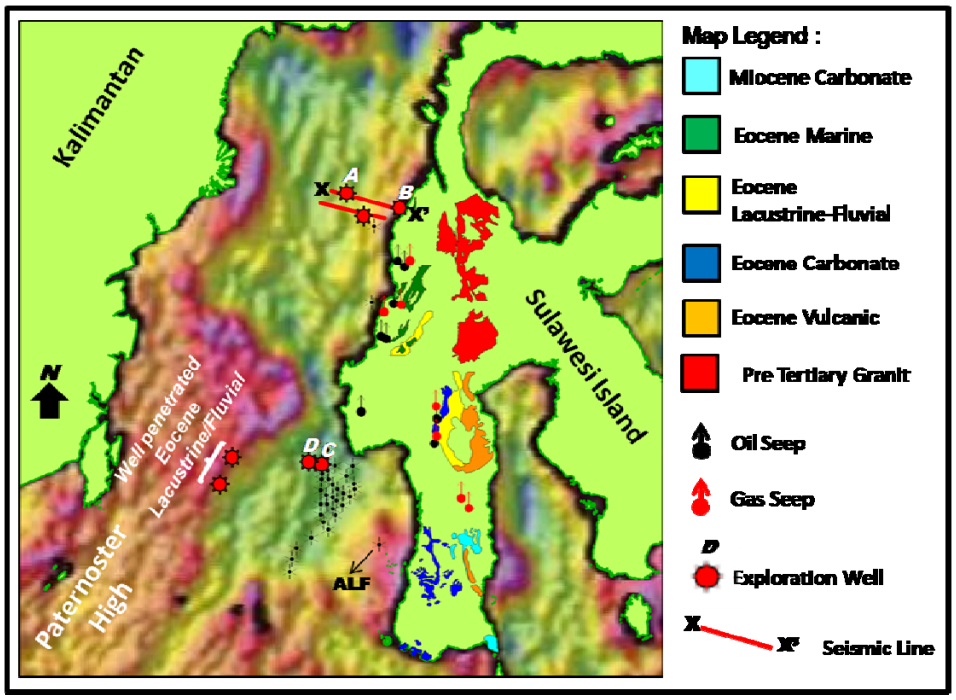

Figure 2: Simplified exploration map in deep water Makassar Strait

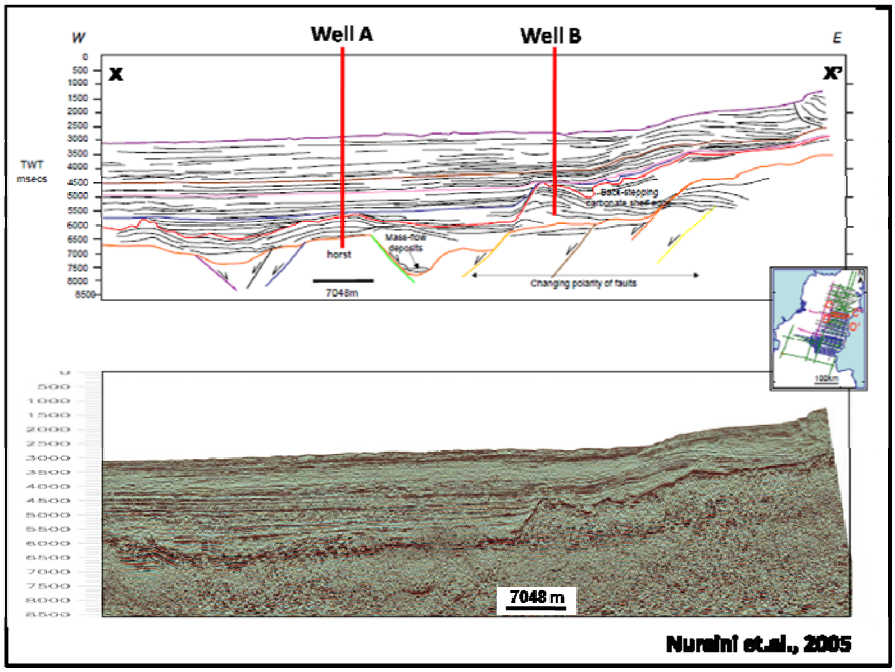

Figure 3: Regional geology model of North Makassar Strait Basin interpreted the build-up carbonate was developed in Middle-Late Eocene and showing the extrapolated position of Well A and B.

EDITED REFERENCES

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