PROCEEDINGS
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Unlocking Undrained Oil through Integrated Reservoir Dynamic Model in Matured Waterflood Field, Offshore North West Java

Fitrah Arachman[1], Amrizal[1], Zona Nuansa Antariksa[1]
[1] Pertamina Hulu Energi ONWJ

Abstract

After 40 years of production, more than 40% of the E-22 reservoir hydrocarbon in place has been recovered through various mechanisms including natural depletion, gas lift implementation and waterflooding. Further development of the reservoir requires a reliable tool to identify the area of remaining oil saturation. Maximizing the recovery further has always been the stakeholder requirement. Identifying the remaining oil accumulation properly is one of the key for future development optimization -either through new infill wells, workover existing completion or rig less intervention- and yet it has many challenges to have such expensive information. Reservoir dynamic model may provide fluid movement and hydrocarbon saturation in the reservoir. However, the result is as best as the input data and production/injection history matching. The reservoir dynamic model was revisited with the integration of 3D seismic, sand ridge concept, petrophysical analyses and new rock type definition/distribution. The work has a positive impact on the reservoir model history matching which later on provide better insight on the oil and water movement in the reservoir. Three sidetrack development wells are executed to achieve production target set by stakeholders. The open hole logs from all sidetrack wells suggest undrained oil with pay thickness between 15-20 ft, as anticipated from the dynamic model. All wells were completed as single string completion with selected perforation. The workover job includes squeeze and perforation in order to maximize oil production from the undrained interval. The overall result is very positive, additional 1000 bopd is booked from these activities.

Introduction

Echo Main field is the biggest oil producing field in Offshore North West Java Area, which is located around 150 km north east of Jakarta. This field has been producing oil and gas since 1971 from Upper Cibulakan Sandstones (Main and Massive Formation, Figure 1). Reservoir E-22 is one of the major reservoirs hat have been undergo waterflood since early 2002. The reservoir has cumulative production of 130 mmboe (or 46% recovery factor).

This study focuses on the Early Main Sandstones (E-22), which consist of a middle-upper Miocene shallow marine siliciclastic succession (Reksalegora et al., 1996). These sandstones are thought to be formed as a product of erosion and subsequent reworking of previous sediments during transgression by shelf tidal currents (Posamentier et al., 2002). Moreover, shelf mudstone seal facies encases the zones since the reservoirs were deposited during transgression.

The geometry of these sandstones is one of important keys to generate proper static model combined with core, well log, and seismic 3D to understand its property distribution. The static model is an input data for the reservoir dynamic model, so that the model can simulate fluid movement and hydrocarbon saturation to match the production data. Finally, the history matched reservoir model may identify the potential area of the remaining hydrocarbon.

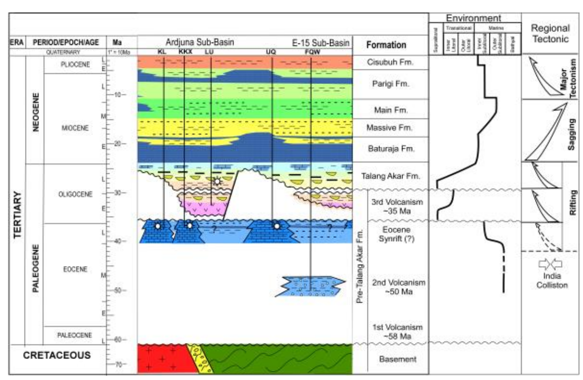

Figure 1: ONWJ stratigraphyc colom (modified after Aveliansyah, 2016)

Data and Method

This study uses data from 3D seismic, well log, core (routine and special analysis) and production/injection in E-Main Area. The 3D seismic data acquired in 1995 covers Echo-Main and Echo-East structures of approximately 24 km^2. Well data from 90 development wells and 10 exploration wells contain gamma ray, resistivity, sonic, density, and check-shot data are used in stratigraphic well correlation, seismic-to-well tie, and petrophysical analysis. The seismic attributes have been important in predicting the geometric of sandstone distribution. Core data is used to determine facies, rock typing, relative permeability and capillary pressure in the study interval. It is also complimented by lithostratigraphic correlation from the previous interpretation.

The static model is initialized based on initial reservoir pressure and fluid contacts prior to be used for dynamic production history matching. The reservoir properties and rock typing were iterated within the geological concept to provide the best fluid movement that matches the dynamic production/injection and pressure data.

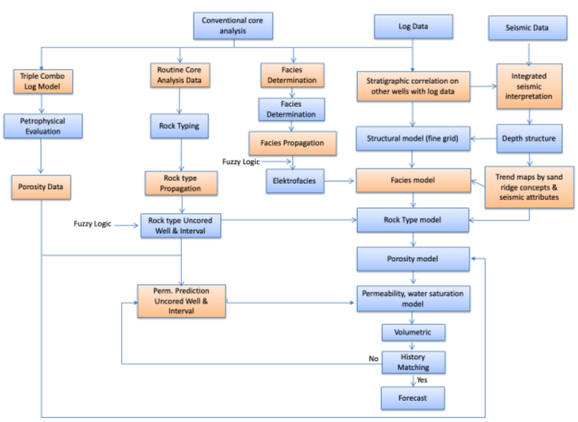

Figure 2: Study workflow integrates 3D seismic, well log, core (routine and special analysis) and production data

The integration has helped in developing an understanding vertical and horizontal distribution of the reservoir and seal pairs. Finally, once the dynamic model has been validated with the production data, it can be used to predict oil and water movement in the reservoirs and identify bypassed oil or undrain area. General workflow of this study can be seen in Figure 2.

Result and Discussion

Three zone reservoirs were identified in E-22 Series, comprises E-22C, E-22B, and E-22A. Seismic attribute (Figure 3) of E-22 series depicts that the trend of this series is NE-SW which was crossed by W-E channel trends. Stratigraphic correlation (Figure 4) shows that there are 4 flooding surfaces bounded the sandstone reservoirs. The lower sandstone of E-22 Series (E-22C, Figure 4) consists of two type's facies (tidal shelf ridge and channel sandstone facies). The channel sandstone facies crosses the previous tidal shelf ridge sandstone which is seen in the seismic line.

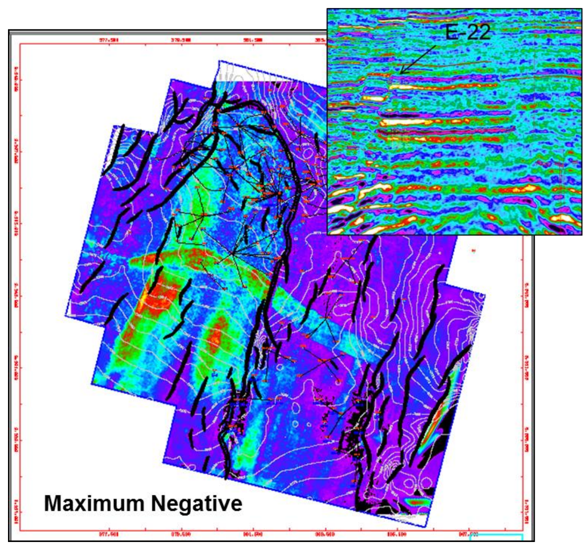

Figure 3: E-22C anomaly amplitude represents the trend of tidal shelf ridge (NE-SW) and channel sandstone (W-E)

The thickness of shelf ridge and channel sandstones facies at E-22C Zone is 10-19 ft and 43-62 ft, respectively). E-22B zone is located in the middle of E-22 series which is tidal shelf ridge sandstone. The trend of this reservoir is NE-SW with thickness around 8-33 ft. The last reservoir of E-22 Series is E-22A which has the similar trend with previous shelf ridge sandstone. The thickness of this zone is 19-33 ft.

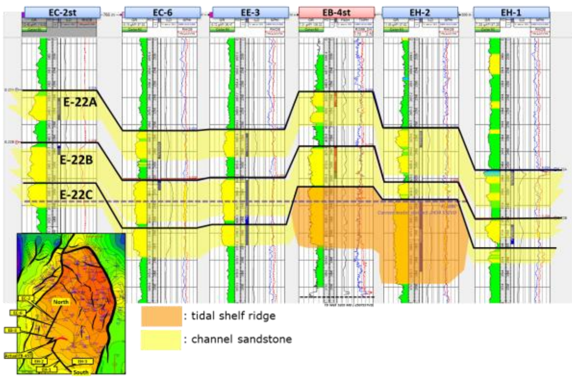

Figure 4: E-22 structural cross section depicts the distribution of tidal shelf ridge and channel sandstone facies in E-22 series.

Five rock types were identified in Echo Main based on Pore Geometry System (PGS) method (Permadi, 2009) from routine core data (Figure 5) and corresponding end point saturation and relative permeability from special core data are shown in Figure 6.

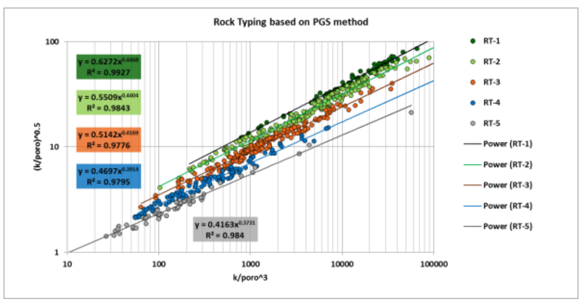

Figure 5: Reservoir rock typing definition based on PGS method. Rock Type 1 to Rock Type 4 are the reservoir rock, while Rock Type 5 (grey) is the non-reservoir

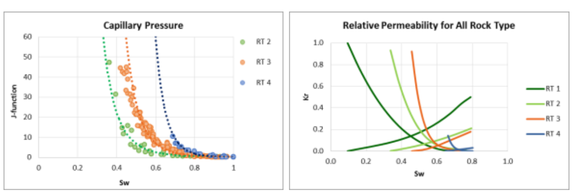

Figure 6: Capillary pressure and relative permeability curves for each rock types derived from core special analysis which were used in the reservoir dynamic model.

Porosity modelling is distributed based on facies map from E-22 anomaly amplitude and well data. Rock type modelling is generated based on the result of PGS method, and the distribution is constrained by facies distribution map. Permeability distribution is distributed as function of porosity and rock type model. Some adjustment trends were done, especially in the northern part of E-Main area as there is shallow gas issue in anomaly amplitude map (Figure 3). The workflow (Figure 2) is evaluated and compared to production data thus obtaining satisfactory result of production and injection history match data.

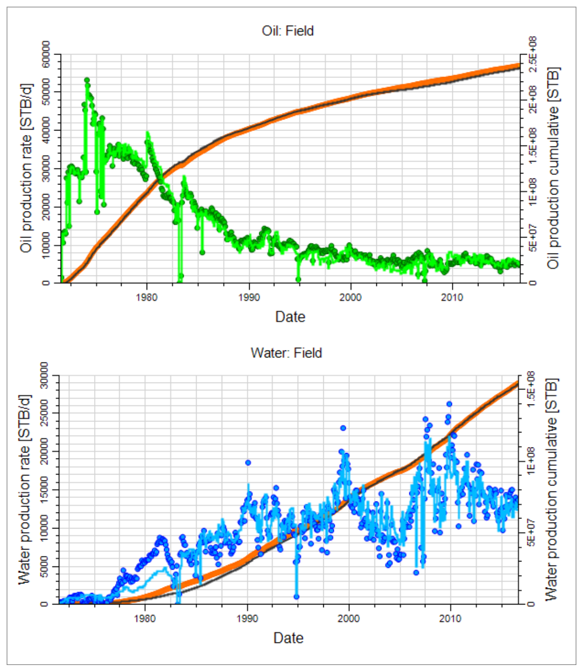

Figure 7: Reservoir dynamic model history matching with production data (oil and water)

Figure 7 shows the dynamic history matching with quite satisfactory result. Then, the reservoir model simulates the production profile until end of production sharing contract. It suggests that there are hydrocarbon undrained areas that cannot be drained from existing wells (Figure 8). Three development wells are proposed and executed to recover these hydrocarbon reserves. The result is quite as expected; there is still hydrocarbon in the top sand interval of each sub-reservoir.

Optimization was made on one of the well so that the well will penetrate the channel sandstone as its main production target. The result is extraordinary; the well is production at 160% of its original target. Total of 1000 bopd is booked from these development wells with average thickness pay per well is around 15-20 ft. Potential additional of 300 bopd is identified and to be recovered by a workover well.

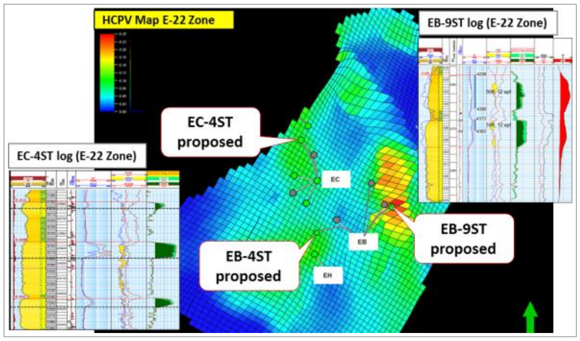

Figure 8: E-22 HCPV map shows the potential undrained hydrocarbon in E-Main Area

Conclusions

Three reservoirs were identified in E-22 Series, comprises E-22C, E-22B, and E-22A. The integrated 3D seismic, well data, core, and detail petrophysical analysis has helped to determine two dominant facies in E-22 series, which are tidal shelf ridge and channel sandstone facies. Tidal shelf ridge facies are found in all E-22 series, while channel sandstone facies was deposited only in E-22C zone crossing the existing tidal shelf ridge. The tidal shelf ridge has NE-SW trend while channel sandstone facies has W-E trend. These facies trends are important in generating porosity, rock type, and permeability model.

The reservoir dynamic model was revised by using an output data from the updated static model. So, the dynamic model for fluid movement and hydrocarbon saturation in the reservoir can be achieved properly. The HCPV map guides to determine the best location to recover undrained reserves from these reservoirs. Successful three sidetrack development wells that recover 1000 bopd from E-22 series proving the reliability of the final reservoir model obtained from the integration of all subsurface aspects. Additionally, workover well will book 300 bopd from potential additional reserves of this series later.

Thus, collaboration and synergy among all disciplines: geophysics, geology, petrophysics, and engineers, must be established in order to achieve good understanding of the reservoirs and mitigating risk in maximizing reservoir recovery.

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