Control Effect of Faults on Oil-Gas Contribution in a Block of Indonesia

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Abstract: Block A in Indonesia is a faulted anticline structure limited by reverse thrust faults on the east and west boundaries. The tectonic evolution mainly experienced rift period, rift-depression period, depression period and compression inversion period. Traps formed during the Pliocene-Pleistocene crustal inversion period, matching well with large-scale hydrocarbon generation and expulsion. The NNW strike faults, NNE strike faults and NEE strike faults mainly developed in the block. The NNW strike boundary faults are reverse thrust faults developed on the basis of the normal faults of the previous graben boundary and controlled the formation of structural trap of Block A. During the large-scale period of hydrocarbon generation and expulsion, the boundary inversion thrust faults acted as a channel for vertical migration of oil and gas. Hydrocarbons from the Lower Lahat Formation and the Talang Akar Formation were communicated to the upper reservoirs, and the oil and gas were blocked laterally. The NNE trending faults were controlled by NNW strike faults, and mainly developed in the rift-depression period and lateral sealing for oil and gas. The vertical and horizontal distribution of oil and gas in Block A makes the structure as the main controlling factor for oil and gas distribution in Block A.

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1 OVERVIEW

Block A is located at the junction of South Sumatra basin and Central Sumatra basin in Indonesia. The Betara Complex structure in the middle of Jabung block is the main gas field of Betara Complex structure, with abundant hydrocarbon resources (Xue et al., 2005). The tectonic evolution of Block A mainly experienced four stages, including the mid-Eocene to Oligocene rifting stage, the late Oligocene to the early Miocene rift-depression transition stage, the early Miocene to the end Miocene depression stage, the early Eocene to the present compression stage. The Lahat Formation deposited in the late Eocene rifting period, the Talang Akar Formation deposited in the Oligocene rift-depression transitional period, the Batu Raja Formation, the mid-Gumai Formation, the late Air Benakat Formation and the MuaraEnim Formation deposited in the Miocene period, and the Kasai Formation deposited during the Pliocene-Pleistocene compression inversion period (Rashid et al., 1998; Suseno et al., 1992). The sedimentary sequence of the Lahat Formation lacustrine mudstone and the lower Talang Aka transitional facies sedimentary sequence are the major hydrocarbon source strata. The reservoirs are clastic sandstone of Lower Talang Akar Formation, clastic sandstone of Upper Talang Akar Formation, sandstone of Gumai Formation and carbonate of Batu Raja Formation, and the Lower Talang Akar sandstone is the main pay formation of Block A.

2 STRUCTURAL FEATURES

2.1 Stratigraphic Features

The Lahat Formation and the Talang Akar formation was mainly filled sediments during the semi-graben rift, overlying the Pre-Tertiary basement. The lacustrine mudstone of Lahat was mainly filled in the semi-graben. The lower Talang Akar Formation mainly deposited alluvial-braided river-delta facies of the transitional facies, and was mainly composed

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of sandstone, siltstone and gray, lime-green mudstone, shale and thin coal seam. The Upper Talang Akar Formation transited into river-delta and marginal sea sediments and was mainly composed of interbedded shale, siltstone, a small amount of sandstone and several thin layers of limestone. Batu Raja deposited on broad carbonate platforms, the Gumai Formation was fine sandstone and siltstone, and the Air Benakat Formation was marine sandstone deposited in a regressive environment (Xue et al., 2005; Rashid et al., 1998; Suseno et al., 1992; Lu et al., 2004; Yuan et al., 2012).

Before the tectonic inversion of the Pliocene-Pleistocene, the tectonic formation in area A was the high-draped anticline structure draped the former Tertiary buried hill. During the Pliocene-Pleistocene period, the cross-sectional tendency of the half-graben boundary faults was reversed due to the extrusion effect, and the two boundary faults of semi-graben became reverse faults. At the same time, the strata flexural deformation occurred and formed saddle-shaped anticlines. Under the control of the boundary faults, the tectonic strike was consistent with the strike of the boundary faults. At the high structural site, the drape anticline was divided by the NNE faults and the NEE faults to formed several different types of small anticline traps and fault blocks. Figure 1 shows the structure of Talang Akar of Block A.

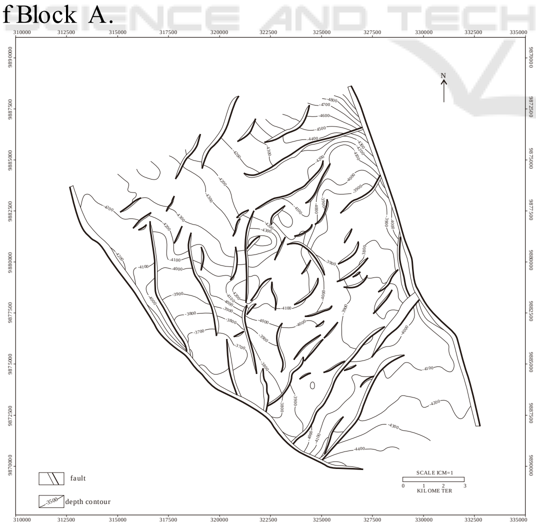

Figure 1: TVDSS map of Talang Akar of block A.

2.2 Fault Characteristics

Block A is faults developed, the faults were formed in different periods with different sizes and different types of fault system. According to the development of faults and the features of faults, three main fault systems were developed: NNW strike fault system, NNE strike fault system and NEE strike fault system.

The NNW strike fault system is boundary faults of Block A, mainly reversal thrust faults developed from the rifting stage to the depression stage and later on the normal faults of the graben boundary activated by the inversion period, and controlled the Block A structure. The NNE trending faults are controlled by NNW strike faults and are mainly syn-sedimentary normal faults developed from the depositional period of Talang Akar to Gumai sedimentary period. These faults did not activate during tectonic inversion. The NEE strike faults are mainly small faults, and mainly developed at the end of the sedimentary period of the Talang Akar and had no controlling effect on the sedimentation. They are non-sedimentary faults and mainly played stress-regulating roles.

On the plane, three sets of fault systems combine to form multiple small anticlines and fault blocks. In the profile, the faults are straight and the fault displacements are relatively small. The fault complexes are opposite or relative, and a few faults are Y-shaped.

3 FAULT CONTROL ON OIL AND GAS DISTRIBUTION

Faults in Block A have an important control over the distribution of oil and gas. Inversed faults of the east-west boundary not only control the formation and distribution of traps, but also channeled for transport and distribution during hydrocarbon migration.

3.1 The Faults Control the Trap Formation and the Trap Formed Period Had Good Matching with Large-Scale Hydrocarbon Expulsion Period

As mentioned above, the NNW strike and NNE strike faults controlled the formation of structural traps of block A, and formed different trap types. However, the formation of oil and gas reservoirs is a variety of geological elements within the petroliferous basin. The geological processes are matched in time and space of hydrocarbon expulsion period (Lu et al., 2004). Therefore, the traps formed

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earlier than or synchronized with the hydrocarbon expulsion period are the necessary conditions for the formation of oil and gas reservoirs in Block A.

In Block A, the rift-sag boundary faults developed from mid-Eocene continuously to the end of Miocene. In the basin of Early Pliocene, faults affected by the extrusion, the strata overlying the pre-Tertiary basement experienced tectonic deformation and formed basement intrusive extrusion anticlines during the Pliocene-Pleistocene. With the continued extrusion, the structural amplitude gradually increased. From the end of the Pleistocene to the present, it entered the relatively quiescent period of tectonic activity. With the increase of burial depth, the anticline remains intact.

The Lower Talang Akar and Lahat strata in the Tertiary are the main source rocks, and oil generation began in the late Miocene. The organic matter in the Pliocene source rocks entered the mature stage and began to enter hydrocarbon mass-generation and expulsion periods (Yuan et al., 2012). With the formation traps, oil and gas entered these traps and formed reservoirs. As traps formed time matcheed well with a large number of hydrocarbon expulsion stages and the post-tectonic structures were well preserved, it provided favorable conditions for the preservation of hydrocarbons .Figure 2 shows the cross section of Block A.

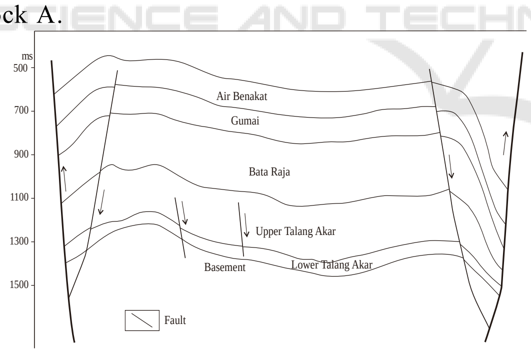

Figure 2: Cross section of block A.

3.2 Reversed Boundary Inversion Thrusts Were Important Vertical Transport Channel for Hydrocarbon Migration

The reverse rift thrust faults developed from the Eocene at the rift-semi-graben border run through the strata from the lower Tertiary Lahat and the lower Talang Akart source rock to the Upper Air Benakat, and the reverse thrust reverse faults became the most important vertical channel of hydrocarbon migration, especially during the Pliocene-Pleistocene period of hydrocarbon mass-generation and expulsion. During these period the reverse rift thrust faults were the reactivation of the boundary faults and the vertical transport of hydrocarbons to the Upper Talang Akar, Bata Raja and Gumai reservoir.

3.3 NNE Faults Controlled the Local Accumulation of Oil and Gas

The NNE fault developed mainly from the Talang Akar to Air Benakat depositional stages and formed different types of local traps with the boundary and NEE faults. On the one hand, part of the faults in the Lower Talang Akar source rock directly communicate with the source rocks and reservoirs. On the other hand, the oil and gas migrated from the lower part to the upper part through the boundary inversion thrust faults and further through the NNE strike faults in the horizontal direction, and finally formed different oil-gas contact and water-oil contact hydrocarbon reservoirs.

3.4 Control of Fault Lateral Sealing on Hydrocarbon Accumulation

The mechanism of fault docking is that the two layers of the two sides of the fault contact with each other due to the relative movement of hanging wall and footwall. At the same time, the mudstone undergoes plastic deformation when the formation slides; the fault is blocked by mudstone, so that the sandstone on both sides of the fault is in contact with the cross-section mud cake, and form a lateral seal (Fu et al., 1998; Yielding et al., 1997; Allan, 1989; Lv and Fu, 2002; Zou et al., 1992; ith, 1996). The boundary faults acted as a compressive reverse faults and the strata on both sides of the faults differ widely in their permeability, especially under the action of the Miocene extrusion tectonic movement. The fault surface was in a compressive stress state and the fault has obvious sealing in the lateral direction, so that oil and gas are mainly enriched in the upwelling trap of the faults. The vertical slide distance of the NNE strike is generally 10-50m. Both sandstones are basically juxtaposed with the mudstone facies of the plate. At the same time, because the sandstone and mudstone are interbedded thinly in this area, the mudstone was subjected to shear during the sliding and was squeeze into the fault plane to form a continuous fault mud that conducted to the lateral fault closure, and controlled local oil and gas accumulation. The NEE strike faults are relatively small and the vertical sliding distance is 2-10m. Both sides of sandstones are juxtaposed and the smaller sliding distance made it difficult to form a continuous cross-section mud cake on the fault planes, and played a lateral migration channel role of hydrocarbon. Figure 3 show the reservoir section of Lower Talang Akar of Block A.

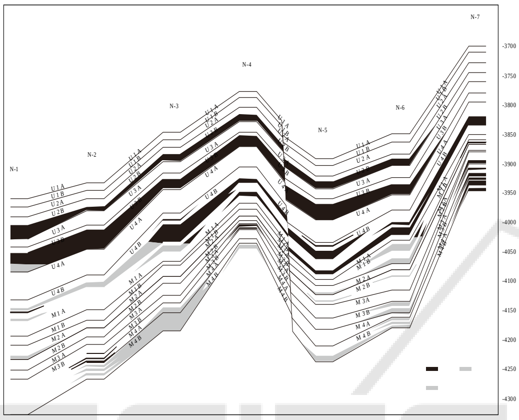

Figure 3: A reservoir section of lower Talang Akar of block A.

4 CONCLUSIONS

Based on the analysis of the controlling role of Block A on hydrocarbon accumulation, it shows that the faults played an important role in controlling the accumulation and distribution of oil and gas in Block A. The reverse thrusts controlled the formation of tectonic traps in Block A and were important channels for the vertical migration of oil and gas, and controlled the distribution of oil and gas throughout the Block A Formation. The NNE faults are secondary faults and controlled the formation of local traps. They were also the important channels for oil and gas redistribution. Faults sealed the oil and gas sideways and formed different types of oil and gas reservoirs with different oil-gas-water contacts.

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