Fractured Basement in Mature Basin Exploration: New Play Analog in Central Sumatra Basin*

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Abstract

Basement rocks are any metamorphic or igneous rocks, regardless of age, which are unconformably overlain by a sedimentary sequence. Basement rocks led by faults to creation of fracture network underlying a sedimentary basin are fractured basements. Most mature basins in Indonesia are assumed to have little to no potential since they have reached their peak and start to decline in production. To mention, several basins in Indonesia categorized as mature are Kutai, West Natuna, South Sumatra, and Central Sumatra. As the result, a number of abandoned mature basins are increasing along with the depletion of national fossil fuel production. Fractured basements, however, are possibly to bear significant amount of hydrocarbon under the right conditions. Though hydrocarbon is not in the rocks, it will be accumulated in the cracks between the rocks. Thus, exploration and exploitation of hydrocarbon in fractured basements of Indonesia mature basins are compulsory.

Basement rock considered as a non-productive reservoir because of its limited data. Reservoirs in the basement is one type of reservoir that begins to be seen and is of particular concern in oil and gas exploration because it has proven success. Central Sumatra Basin is one of the mature basins that has oil production. One example of a producing field in the Central Sumatra Basin is the Beruk Northeast Field. The Beruk Northeast oil field in the Central Sumatra Basin was discovered in 1976 by the drilling the Beruk Northeast No. 1 which tested 1680 BOPD from Pre-Tertiary basement. Beruk Northeast shows that Pre-Tertiary basement is a feasible exploration objective especially in mature basin exploration in Indonesia.

Central Sumatra basement rocks are Uppermost Devonian unmetamorphosed greywackes (“pebbly mudstones”) containing abundant angular to subrounded clasts of granite (Uppermost Devonian), volcanic, and metamorphic composition; and Late Carboniferous granite containing muscovite, albite, and microline (Eubank and Makki, 1981). Several scientific publications and literature were collected to gain the information about fractured basement characteristics, chiefly Central Sumatra’s. This paper centers on the Central Sumatra Basin as an analogue to other mature basins in Indonesia.

Central Sumatra Basin is believed to be an ideal analogue due to its age that indicates good maturity level and the occurrence of hydrocarbon in its fractured basement. Central Sumatra Basin as the subject of an analogue will provide important information about basement configuration. Basement configuration data that are used as analogues include age of rocks, lithology, and fault. The use of basement configuration as analogue data is intended as an alternative way for exploration and exploitation considerations due to the lack of basement rock data. The use of these data is discussed with reference to selected previous papers. Decision of abandoning mature basins in Indonesia is needed to be re-examined since under the right condition, mature basins will most likely to have hidden potential of hydrocarbon in their basement rocks. Hydrocarbon bearing basements are always incidental, however, by analoging fractured basements of mature basins with proven hydrocarbon reserves to target mature basins, the level of certainty to keep exploring, developing, and exploiting particular mature basins will guarantee the decision-making.

Introduction

Fractured basements have begun to be widely studied in the world of oil and gas exploration lately. Basement rocks are any metamorphic or igneous rocks, regardless of age, which are unconformably overlain by a sedimentary sequence. It led by faults to creation of fracture network underlying a sedimentary basin are fractured basements. The oil is being stored in fractures which formed in basement rocks caused by tectonics processes.

Several basins in Indonesia categorized as mature are Kutai, West Natuna, South Sumatra, and Central Sumatra. One of several basement rocks in Indonesia is located in the Central Sumatra Basin. Basement in the Central Sumatra Basin was formed during Cretaceous or older which is continental alluvial. Central Sumatra Basin was formed during an extensional process during Early Oligocene until Early Miocene. Furthermore, it has a compressional process during Middle Miocene until Pliocene.

Central Sumatra Basin is producing oil from its basement through the Beruk Northeast Oil Field. It was discovered in 1976 and drilled to a total depth of 1634 ft into the basement.

Basement Configuration

Basement configuration has a purpose to simplify an understanding about the properties of the basement rock. Basement rock is a rock which unconformably is overlain by a sedimentary sequence. Basement rock which has an accumulation of hydrocarbon is called basement reservoirs. There are three possible states for oil to be in basement reservoirs. The first possibility is an overlying organic rock from which oil was expelled downward during compaction. The second is laterally off the basement but topographically lower organic rock from which oil was squeezed into an underlying carrier bed through which it migrated up dip into the basement rock. The third is lateral reservoirs from which earlier trapped oil was spilled due to tilting or overfilling. The basement configuration is required since the comprehension of basement property on basement rock is still lacking.

Basement configuration is a parameter to do an analogue method in basement rock as a reservoir. It is important because basement reservoir data are still deficient and there is still not enough guarantee for the decision-making in the exploitation process. The use of basement

configuration as analogue data is intended as an alternative way for exploration and exploitation considerations due to the lack of basement rock data. There are three basement configurations, which are age, lithology, and fault. Age is an important aspect to determine the basin in relation to hydrocarbon maturity. Lithology of basement rocks are narrowed down into igneous rock and metamorphic rock. Lithology of basement is essential to be discerned due to its different hardness associated with the drilling process. Oil stored in cracks which formed in basement rock. These cracks are formed because it is caused by the fault.

Basement Configuration of Central Sumatra Basin, Indonesia

Central Sumatra Basin is a back-arc basin extending North West – Southeast. The creation was influenced by subduction of Hindia-Australia Plate towards the Asia Plate.

The basement of the Central Sumatra Basin is constituted by Uppermost Devonian unmetamorphosed greywackes ("pebbly mudstones") containing abundant angular to subrounded clasts of granitic (Uppermost Devonian), volcanic, and metamorphic composition; and Late Carboniferous granite containing muscovite, albite, and microline. The Pre-Tertiary basement rocks in the Central Sumatra Basin consist of inhomogeneous lithology and ages. However, it is prevailed by granite.

Granite of plutonic activity intruded those minor various lithologies locally. The heat produced by granite and from compression activity have been deduced to intensify fractures then develop potential reservoirs. The significant heat rate has been increasing during this time and might have generated hydrocarbon. Natural fractured basements as a result of the compression phase have an opportunity to be a reservoir because the fault rejuvenation may have enriched porosity and permeability. The migration pathway also may have been created by fault rejuvenation. It may also affect rock properties, particularly by developing secondary porosity.

The fault which mainly controls geological structures in the Central Sumatra Basin is the Cretaceous Sumatra Fault. Reverse faults which form flower structures are developed in the basement.

Basement Configuration of Cuu Long Basin, Vietnam

The structural evolution of Cuu Long Basin (see Figure 1) can be expounded in terms of: (i) the propagation of the South China (East Vietnam) Sea rift around 17-32 Ma and (ii) the collision of India and Eurasia beginning in the Palaeogene, which drove the extrusion of Indochina along the Mae Ping and Red River Faults.

The basement of Cuu Long Basin is composed of granitic rocks. The basement blocks are separated into upthrown and downthrown, creating a horst and graben pattern with significant vertical relief. The upthrown blocks constituting the granite basement have been tested by exploratory drilling and proved to be important commercial hydrocarbon discoveries. All the exploration and production wells drilled in the oil fields have shown that oil can be produced not only from the uppermost weathered part of basement, but also from fresh fractured basement at very great depths.

Weathered basement of the Cuu Long Basin consists of granite biotite, granite, and granodiorite of Late Jurassic to Cretaceous age. It is believed that they were formed during two main phases: Early phase – granodiorite and Late phase – granite. Weathered granite basement was also affected by changes such as feldspar transformation to kaolinite.

Fresh granite basement is characterized by untransformed biotite and feldspar, low penetration rates, and high resistivity.

Basement rocks were later transformed by tectonic and hydrothermal activity and thermal plastic bending of magmatic batholith blocks. Hydrothermal processes occurred at various stages, and filled up fractures with secondary crystals such as zeolite and calcite, creating small caverns and vugs of various sizes. Sample analysis of fractured formations shows great variation, with much cericite and kaolinite in the matrix. Fractures are filled with cancite and zeolite, the caverns with quartz crystals. Sulfur minerals are also common in the fracture systems.

A major NE-SW late Oligocene reverse fault system cross-cuts are developed in the basement. However, it dies out along strike and passes into a linked normal fault to both NE and SW.

Analogue: Cuu Long Basin to Central Sumatra Basin – Table 1

Cuu Long Basin and Central Sumatra Basin are both hydrocarbon producing basement reservoirs that have been proven to be commercially successful. Therefore, analogue trial is applied to these basins (Cuu Long Basin to Central Sumatra Basin) to ensure that the principal configurations (age, lithology, and fault) are certain. Breaking down the configurations of both basins, knowing that the basements of both basins having granite domination as lithology, fractures that are controlled by reverse fault then causing chaotic fractures, and Pre-Tertiary age of rocks. It is possible to conclude that the key configurations are ideal.

Analogue: Central Sumatra Basin to Kutai Basin – Table 2

By analoging Central Sumatra Basin to Kutai Basin, it can be inferred a status of Kutai Basin basement to be a fractured reservoir. Despite both basins do not have a similar fault, only age and lithology of both basins match. This leads to a condition where Kutai Basin will not be a commercial fractured reservoir. However, chaotic fractures found in the basement as a response to fault re-activation will be likely to act to fine secondary porosity. There is a possibility that Kutai Basin will be a potential fractured reservoir.

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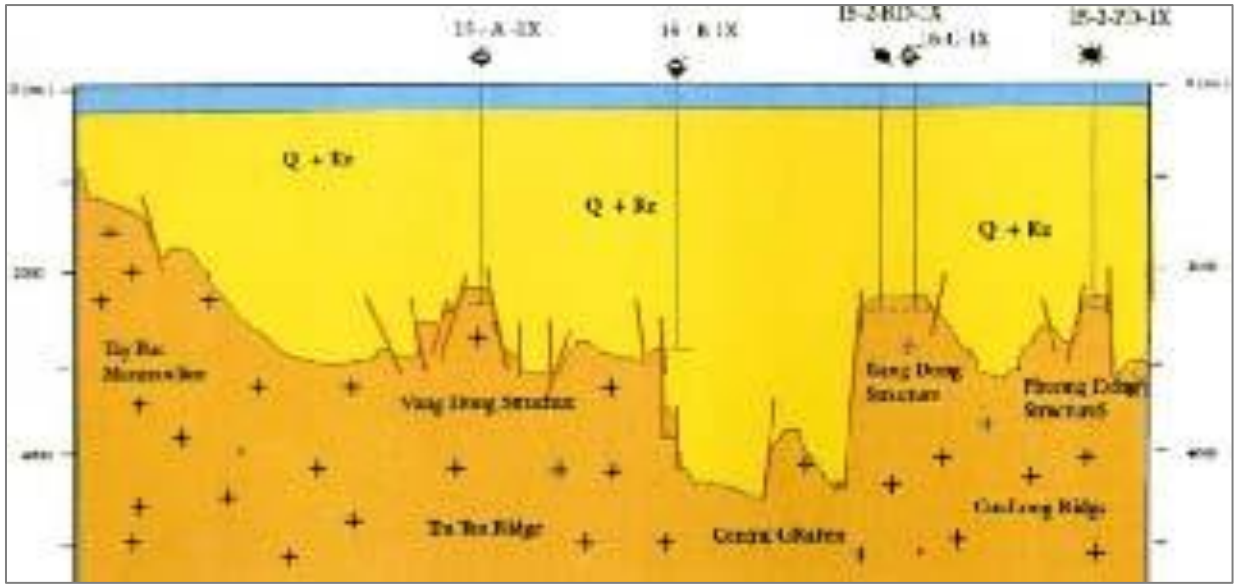

Figure 1. Schematic Cross Section of Cuu Long Basin.

No	Basement	Age	Lithology	Fault
1	Cuu Long Basin	Jurassic to Cretaceous	Granite, Granodiorite	Reverse Fault, Fractures
2	Central Sumatra Basin	Pre-Tertiary	Granite	Reverse Fault (Flower structures)

Table 1. Analoging Cuu Long Basin to Central Sumatra Basin based on Age, Lithology, and Fault.

No	Basement	Age	Lithology	Fault
1	Central Sumatra Basin	Pre-Tertiary	Granite	Reverse Fault (Flower structures)
2	Kutai Basin (Continental)	Pre-Tertiary (Permocarboniferous - Cretaceous)	Granite, Gabroic	Strike-slip (En Echelon)

Table 2. Analoging Central Sumatra Basin to Kutai Basin based on Age, Lithology, and Fault.