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# Chasing a New Carbonate Fracture Play Type at South Sumatra Basin

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## Abstract

The newly discovered giant basement fracture gas reservoir in Sakakemang block located in the central part of North Palembang Sub-Basin has been an interesting subject and brings a new perspective in exploration on that basin. However, due to the lack of recent exploration activity, the southern part of this basin, the hydrocarbon potentiality is less known although the remaining potential remains high. This paper will discuss the hydrocarbon potential of the basement fractured in an area located in the southern part of the North Palembang sub-basin, 100 km to the southeast of Sakakemang block.

The geological delineation from Kaliberau discovery trend can be continued, about 100 km to the southeast, called the “X” Structure. The evidence from the well, seismic, and gravity data are integrated to construct the geological model. The previous operator has made a gas discovery from the shallow gas reservoir of Telisa. However, the current operator sees there is a new potential basement fracture at the deeper level.

The “X-1” well drilled 75 m of recrystallized carbonate. While drilling the carbonate, the previous operator experienced a partial loss and the petrophysical analysis reveals the development of secondary porosity. The total gas reading also increased, even higher than the current pay zone at Telisa sand. The seismic facies are showing a widespread carbonate platform, with “X-1” well at the crest of the structure. The thickness of the carbonate can reach >250 m.

The seismic evidence is showing a large (5x10 km), inverted structure from the seismic. This is also supported by the geochemistry and basin modeling evidence. The basin modeling records that there were at least 2 inversion timing, which are Middle Miocene and Plio-Pleistocene. The erosion calculation from basin modeling is showing more than 1000 m sediment has been eroded at the “X” structure. The petrography analysis is showing a feature of type III/IV twinning-calcite, indicating a hot paleotemperature, with intensive microfracture. This inversion history is very important to facilitate the fracture porosity in the basement.

The “X” carbonate reservoir represents a buried carbonate which inverted massively. Without the fracture, there is no chance for this reservoir to develop a matrix porosity. Adjacent to 2 km, the kitchen is able to produce gas. Within the fracture and permeable sand, the gas should be able to reach carbonate. In South Sumatra Basin, there is no current analog that has been discovered in this play type. The discovery of carbonate play type will bring a new play concept into South Sumatra Basin.

**Keywords:** Basement Fracture, Carbonate, South Sumatra Basin

## Introduction

This paper will focus on the topic of basement fracture potential at “X” Structure, at South Sumatra Basin. The “X” Structure is the geological delineation of Kaliberau recent discovery to the southeast.

The “X” Structure represents a large ~50 km$^2$ structure with a faulted four-way dip type closure. This structure is a result of geological inversion during Middle Miocene and Plio-Pleistocene. Two wells have been drilled on this structure and resulted a discovery in Telisa sand. However, the new operator sees the new play potential from basement.

We did the basin, play, prospect analysis to understand the nature of petroleum system in this area. The “X” Structure is located on the southern edge of the North Palembang Sub-Basin. The sediment is thinning to the northern of the present-day coastal area and Bangka area. The “X” Structure is surrounded by two deeps. These deeps are separated by “X” Structure by a NW-SE reverse fault, dipping to the NE. The question is whether these deeps are mature to reach hydrocarbon generation window.

Among the reservoirs we identified, Telisa, TAF, and Basement, the thickness and areal extend of reservoir is greatest on the basement layer. However, this basement is never been focused.

This paper aimed to analyze the new carbonate play from seismic, gravity, well, and petrography data.

## Data and Method

The data and method used is from seismic, well, gravity, petrography, and XRD data. The interpretation of seismic horizon is carried from biostratigraphy data that used in regional seismic mapping. The geochemistry data is used to build a 1D to 3D basin modeling to understand the nature of the petroleum system.

## Result and Discussion

The previous operator targeted TAF as a main objective reservoir. The well resulted in a good reservoir quality of TAF, however the hydrocarbon containment in the TAF layer is insignificant. In contrary, the Telisa sand which above the TAF layer has a significant hydrocarbon containment. The gas in Telisa sand has a 93% of $C_1$ but also mixture content amount to $C_{11}$, indicating the gas is not biogenic. Therefore, the source rock identification is very important.

The" X" Structure is an inverted syn-rift structure, as indicating by thickening of Lemat and TAF sand. The geohistory in this area begun from the deposition of carbonate. The carbonate age is unknown, because no fossil recovered from this carbonate. The carbonate is a pre-Tertiary (below the Lemat Fm), and has a widespread distribution, probably in a passive margin in a pre-rift tectonic.

The first Tertiary sediment deposited in this area is Lemat Fm, deposited in a lacustrine environment. This Lemat shale is a very prolific source rock that can generate oil and gas.

The TAF sand has a good reservoir quality because this structure is nearby to the paleohigh as the provenance, probably a metamorphic high. Based on the biostrat data, the TAF is deposited in the shallow marine during a highstand system, so the reservoir has a widespread thick blanket sand as also indicated in the seismic facies.

The Telisa sand is indicating a post inversion deposit during a transgressive succession. The Telisa sand is deposited in a tidal environment. The sand is not widespread as TAF, but more isolated and channelized.

At the top of Telisa sand is Telisa shale, which deposited in a shallow marine during the peak of transgressive sequence, some of these layers are eroded due to a great inversion during Plio-Pleistocene. Based on the 1D modeling and rough calculation from seismic section, there is approximately 1000 m sediment is eroded.

The basin inversion plays a very important role as the tectonic force created a massive fracture from basement to Telisa. There were two episodes of major inversion, which is Middle Miocene and Plio-Pleistocene.

The occurrence of this inversion follows the pre-Tertiary structural suture zone, which is the boundary of plate to plate collision. This collision can be tied to the Sakakemang on the NW area. The suture zone is becoming reactivated in the younger geology time becoming a strike-slip tectonic. This strike slip tectonic is NW-SE oriented and becoming the major hydrocarbon field trend. This is very similar to Sumpal, Dayung, Rayun, Grissik, and Illiran trend which is oriented NW-SE hydrocarbon belt.

This inversion also creates a major deep as the compensation of the uplifted structure. As the result of uplift, the "X" Structure is surrounded by two deeps. To understand the maturity, generation, and expulsion history of the basin we create the petroleum system modeling.

The structural correlation shows that show the context of carbonate basement fracture play can be seen at Figure 1. Interestingly, at "X" Structure, the geochemistry depth plot showing there was a great inversion and erosion at "X" Structure. As we can see at Figure-2, the plot of porosity and vitrinite to depth (y-axis), showing there is a geological event or break consistently from porosity and vitrinite plot at X-1 well.

Normally, increasing to the depth, the porosity will be reduced exponentially with a continuous trend. However, in the X-1 there are two trends of porosity. These 2 trends indicating there is a sedimentation break, which means there is an erosion or uplift. This also applied to vitrinite, normally the vitrinite will be increasing linearly to the depth. However, in X-1 well there is a break of VR trend at top of the TAF (Upper Talang Akar Fm). This section breaks also coincide with the last thickening event. It means this break is indicating the inversion after the deposition of TAF (Figure-2).

To confirm the maturity window at the kitchen, the 3D basin model must be conducted. To conduct the 3D basin model, the surface depth must be created, and the facies map has to be assigned. The basement depth structure is showing that the ”X” Structure is surrounded by two deeps on the west and eastern part, if these deeps reach the maturity window then hydrocarbon can be expelled from the kitchen. From the currently available seismic data, the X- 1 is penetrated the highest elevation of basement surface and the surface geology shows there is an outcrop of older formation, represents the X-1 is the crest of the anticline.

The result of the basin modeling is showing there is a hydrocarbon generation in 20.8 Ma from Lemat as a source rock. The first fluid expelled from Lemat is oil, and later due to increasing thermal and beginning thermal cracking on 19 Ma, gas is expelled from source rock. If there is a reservoir, seal, and trap preserved during the time of migration, the accumulation will occur. To summarize the sequence of basin evolution and timing of generation, migration, and accumulation:

- 20.8 Ma is the start of oil expulsion from Lemat source rock
- 19 Ma is the start of the gas expulsion from Lemat source rock
- 15.5 Ma is the start of the peak of Lemat hydrocarbon generation
- 11.8 Ma is the beginning of accumulation
- Until present day, the Lemat is modelled still in gas maturity window, the hydrocarbon charging is still continuing.

The 2-D basin modeling section at 11.8 Ma when accumulation occurs can be seen at Figure-2.

The cutting study is very important to confirm the presence of basement fracture in X-1 carbonate. The low-density carbonate is obvious from seismic, and the porous carbonate can be seen from AI anomaly, showing a low AI. The low AI is showing a porous carbonate. In order to know how the lithology reflects the geophysical data, we collect petrography analysis from cutting. If it is a porous lithology, we want to know if the porous matrix coming from the matrix, fracture, or combination.

Sample from X-1 cutting was delivered to analyze biostratigraphy, petrography, and XRD. The result of this lab analysis is very important to understand the lithology, type of reservoir, and diagenesis history of carbonate.

The result of petrography is showing a very interesting result. The lithology of the X-1 carbonate is showing a recrystallized limestone or marble. This recrystallized limestone is composed by mostly a deformed twinning calcite (Figure-4). This limestone is heavily fractured, and some fractures are filled by secondary mineral, such as muscovite, indicating an alteration by hot temperature was occurred.

If we compared to the reference from Ferrill et al., (2004), the type of twinning calcite in the X-1 carbonate is categorized as type III. According to the reference, the paleotemperature can reach >200°C, meaning the carbonate was buried deeply and later uplifted.

Normally, this type of rock will give a high density reading in the velocity and gravity. However, the gravity gives a low anomaly density and there is also velocity reversal in the seismic. This is very contrary to the nature of carbonate lithology. However, this will make sense if there is fracture filled with fluid presents in the carbonate.

The XRD is showing an interesting result as the illite mineralogy presents as a dominant portion in clay mineralogy, and smectite is not present at all. The illite mineralogy commonly represents a higher temperature since smectite to illite transformation requires an increasing temperature. This correlate to the burial history of the “X” Structure.

The hydrocarbon indication also shown in the carbonate from CWT and AVO analysis as the class III. This means the chance of success to discovery become higher. This study needs to be tested for the future exploration program.

## Conclusions

We have identified a new carbonate fracture play in South Sumatra. Comprehensive study from regional, seismic, gravity, geochemistry, petrography, and XRD show there is anomaly in carbonate basement fracture that may be correlate to the presence of hydrocarbon. This analysis should be tested for the next exploration program.

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## Reference

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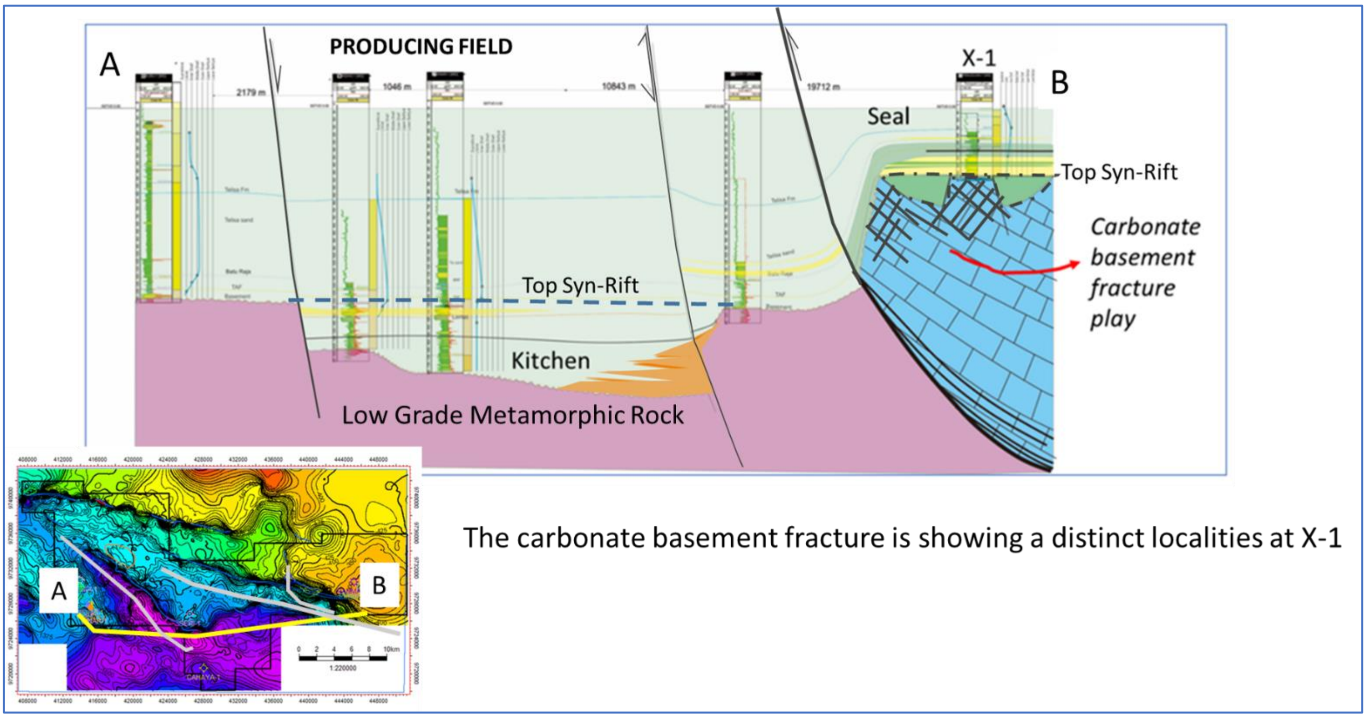


Figure 1: The regional cross section emphasizes the carbonate basement fracture play

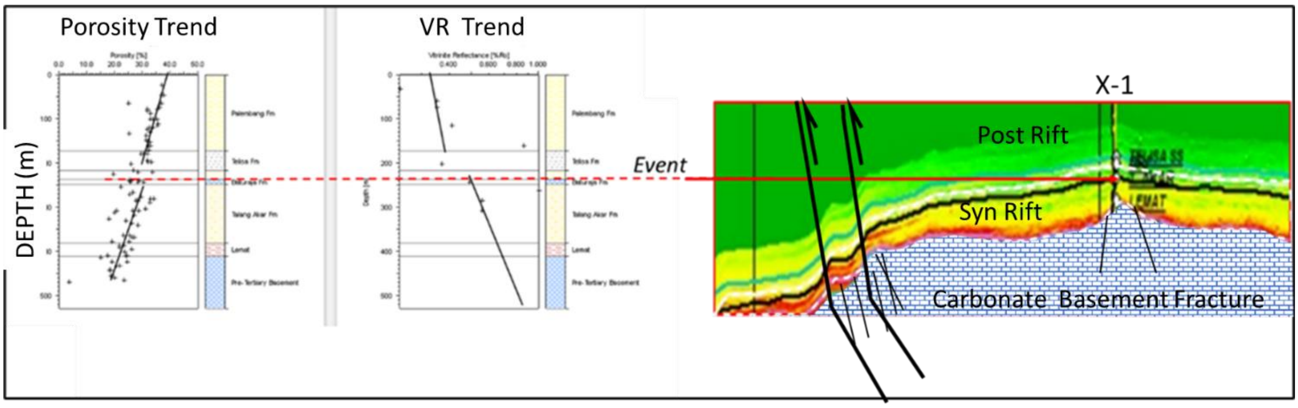


Figure 2: The porosity and vitrinite break that coincides with the last thickening event of syn-rift . This breaks means there is inversion occurs (at Middle Miocene) as we can see as the reactivation of reverse fault from section

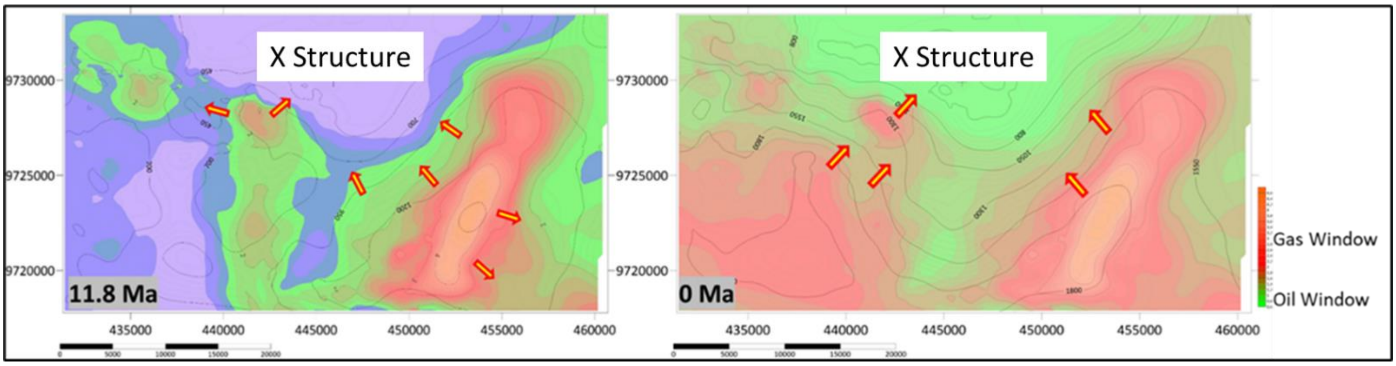


Figure 3: The “X” Structure at 11.8 Ma when the accumulation occurs

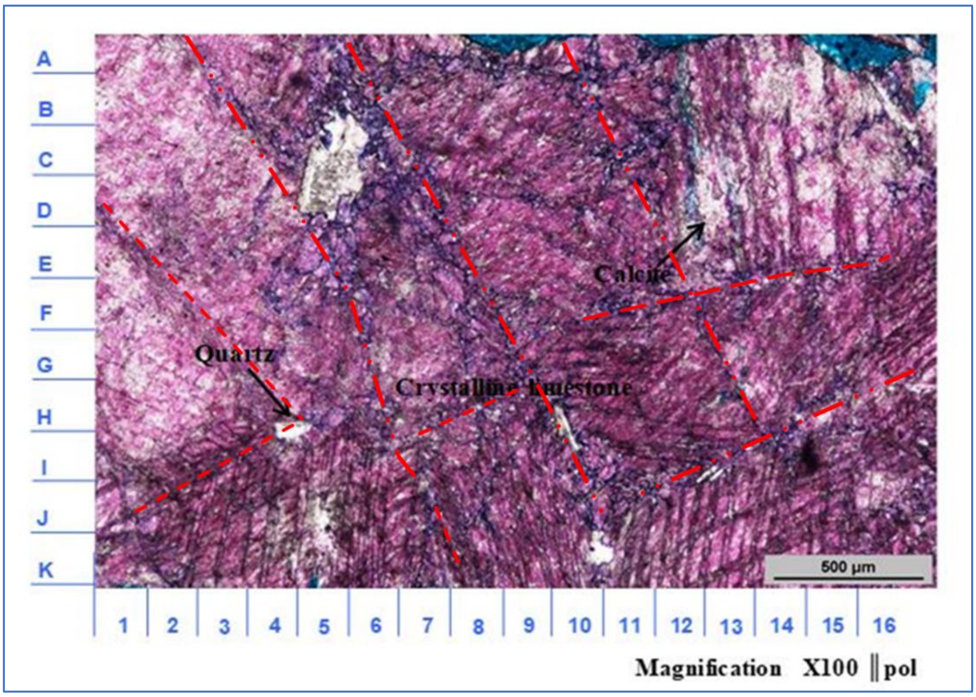


Figure 4: Fractured twinning calcite showing a deformed and highly tectonized carbonate basement