

Integrating Wells and 3D Seismic Data to Delineate the Sandstone Reservoir Distribution of the Talang Akar Formation, South Sumatra Basin, Indonesia*

Robet Widodo¹

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¹San Diego State University, San Diego, CA, USA (rbtwidodo@yahoo.com)

Abstract

This study describes the distribution and depositional environment of selected sandstone reservoirs in the Oligocene-Miocene fluvial-deltaic Talang Akar Formation (TAF), Delta (DLT) area, Jambi Sub-Basin, South Sumatra Basin. Three-Dimension (3D) seismic data covering an area of 170 km² and well logs from four wells are used.

The area lies in an early Tertiary rift basin that was subjected to Plio-Pleistocene compression. Growth strata along extensional faults demonstrate that the TAF was deposited during active rifting and basin growth. Well logs (gamma ray and mud logs) show interbedded sandstone, shale and coal typical of a fluvial-deltaic and shallow marine setting. Based on the well logs, the sandstone layers are interpreted as mainly distributary channel fill facies.

Two productive horizons defined by drill stem tests at two wells are mapped throughout the seismic volume, together with major faults and top basement. These two horizons are examined using amplitude maps. The amplitude maps are related to the character of the interface between the sandstone and the adjacent layers. They may also be affected by tuning effects.

Strong variations from amplitude maps from both horizons are visible appearing deltaic depositional features and are interpreted to be distributary channel and mouth bar clustering. Those clustering were controlled by northeast-southwest faults that were formed and

active at Oligocene-Miocene. New prospects can be recommended based on those intensive delineated facies sands with very careful thought about tuning effect.

Introduction

This study describes the distribution and depositional environment of selected sandstone reservoirs in the fluvio-deltaic Talang Akar Formation, Jambi Sub-Basin, South Sumatra Basin. The data are from the Delta (DLT) area, one of the blocks/fields owned by PT PERTAMINA EP. This area is at the northern flank of the Jambi Sub-basin ([Figure 1](#)) in the northwestern part of the South Sumatra Basin. The primary reservoirs in the DLT Area occur within sandstones in the Oligocene-Miocene fluvial-deltaic Talang Akar Formation (TAF). Initial prospects in the TAF were identified based on structural position but it is now clear that a better understanding of the stratigraphic variations and hence reservoir distribution is required, to reduce exploration risk and optimize production.

Regional Geology

The structural features ([Figure 2](#)) formed in the South Sumatra Basin were created in at least three distinct episodes during the mid-Mesozoic, Late Cretaceous-Early Tertiary and Plio-Pleistocene (de Coster, 1974; Ginger and Fielding, 2005).

During the mid-Mesozoic orogeny, Paleozoic and Mesozoic, strata were metamorphosed, faulted, and folded into large structural blocks or belts and intruded by granite batholiths. It is believed that west northwest-east southeast pattern of microplates was controlling the trend for this episode (Pulunggono and Cameron, 1984). In Late Cretaceous and Early Tertiary time, major tensional structures (grabens and fault blocks) were formed resulting in numerous half-grabens which have north-south orientation (Pulunggono, 1992) but in Jambi sub-basin, they tended to have a north-northeast to south-southwest trend. Then, South Sumatra rotated approximately 45° clockwise (Purwaningsih et al., 2006) since the Miocene resulting in a present day north-northeast to south-southwest graben orientation. Later, in the Plio-Pleistocene, the most prominent structural features in the basin were formed consisting of NW-SE trending folds and faults. The geometry of these structures is the result of early-accreted NW-SE belts as a result of the first episode (Pulunggono and Cameron, 1984) and has influenced the NW-SE Plio-Pleistocene trend (Ginger and Fielding, 2005).

The stratigraphy of the Jambi sub-basin as a part of South Sumatra Basin is summarized in [Figure 3](#) and has been discussed by de Coster (1974) and Ginger and Fielding (2005). As the objective of the study, the Talang Akar Formation (TAF) is late stage graben and early post-rift fill and overlies either the Lemat Formation or the pre-Tertiary basement. The TAF was deposited in late Oligocene

to early Miocene and consists of fluvial and deltaic sediments that grade basinward into marginal marine sediments. It is divided into two members: the Gritsand Member (GRM) in the lower part and the Transitional Member (TRM) in upper part. The GRM of the transgressive Talang Akar Formation consists of coarse to very coarse sandstone with shale and siltstone intercalations, deposited in a fluvial to deltaic environment with the thickness reaches 550 m. The TRM consists of shale intercalated with sandstones and coal, that infrequently are intercalated with calcareous sandstones and marine shale. This member was deposited in a littoral to shallow marine environment and the thickness reaches 300 m (de Coster, 1974; Ginger and Fielding, 2005).

For this study, test data from four wells are included to illustrate proven hydrocarbons in the area, which is predominantly gas ([Table 1](#)).

Data Interpretation

For the four wells in this study, facies identification has been conducted combining well log interpretation and mud log data showing fluvial-deltaic repetition cycles of sandstone, shale and coal in the lower part while shallow marine repetition cycles of calcareous and glauconitic sandstone-shale occur in the upper part ([Figure 4](#), [Figure 5](#), [Figure 6](#) and [Figure 7](#)).

1. **Distributary channel fill.** This facies is sandstone with a blocky and/or bell (fining upward) shape of gamma ray log and has mostly of quartz as its composition with some pyrite minerals and non-calcareous cement in the lower section. Conversely, in the upper section, pyrite is replaced by glauconite and calcareous cement. This facies has a thickness between 1 m to 9 m in all wells. Examples of this facies from DLT-1 well include 2320-2325 mMD (5 m thick), 2217-2221 mMD (4 m thick), and 2,079-2,078 mMD (9 m thick).
2. **Interdistributary channel.** This facies consists of mainly shale and coal intercalations. Shales have thickness around 1 m to 28 m and coals (in black color) vary from 1 m to 7 m in thickness in all wells. Examples of this facies from DLT-2 well include 2,026-2,032 mMD (6 m thick), 2,013-2,016 mMD (3 m thick), 2,004-2,011 mMD (7 m thick), and 1,998-2,001 mMD (3 m thick).
3. **Crevasse splay.** This facies has a coarsening upward (funnel shape) pattern and is a result of increasing upward-energy level. The crevasse splay facies has thickness from 2 to 12 m from all wells. Example of this facies from DLT-3 well includes 1,945-1,948 mMD (3 m thick).
4. **Distributary mouth bar.** This facies is in the upper part of the TAF with a coarsening upward sequence or funnel shape gamma ray log. It can be defined separately from crevasse splay facies as it lacks coals. The presence of glauconite (marine

origin) indicates the influence of a marine environment. The facies has a thickness ranging from 0.5 to 3 m. Examples of this facies from DLT-4 well include 1,680-1,683 mMD (3 m thick) and 1,659-1,662 mMD (3 m thick).

As the focus of the study is in the TAF, two productive horizons within the TAF were mapped. These horizons are DST 1 from DLT-1 well or Sandstone-1 horizon and DST-1 from DLT-2 well or Sandstone-2 horizon. Sandstone-1 is characterized by two facies from DLT-1 well log (Figure 4) i.e. distributary channel fill facies (2,217-2,222 mMD or 5 m thick) and crevasse splay facies (2,222-2,234 mMD or 12 m thick). Sandstone-2 is characterized by distributary channel fill facies from DLT-2 well log (Figure 5).

Results and Discussion

Reservoir and Facies Distribution from Stratigraphic and Seismic Cross-sections

An overview of the distribution of the TAF between wells can be obtained by creating a cross-section between the wells (Figure 11). Top Basement can be correlated from DLT-3 and DLT-4 wells where this top is characterized by high gamma ray, high resistivity and high-density logs at the lower part of the wells. Top Lahat Formation can be found at the bottom of DLT-1 well and correlating this top to another well is unclear. Another problem is the Sandstone-1 marker, where it cannot be found in DLT-2 well because the well is not deep enough. Considering this reason, seismic sections (Figure 8 and Figure 9) are chosen to help to correlate the markers. Mapping of this top in seismic data resulted in a time structure map (Figure 10) and shows the recognition of three major faults, labeled Berembang, Bajubang and F2 faults, sub-dividing the area into major structural elements.

From the cross-section, Sandstone-1 can be correlated with DLT-3 channel sand (1,935-1,939 mMD) and DLT-4 channel sand (1,761-1,763 mMD or DST-1). Sandstone-2 can be correlated with DLT-1 mouth bar sand (1,959-1,962 mMD), DLT-3 channel sand (1,868-1,892 mMD) and DLT-4 channel sand (1,663-1,665 mMD). The TAF thickens towards the northwest, a result that is consistent with the interpretation of its deposition in a half-graben. The interpretation is that a series of channels gradually filled the basin.

The evidence of depositional facies distribution can be seen on seismic sections from Figure 8 and Figure 9 that show discontinuity of strong reflectors. Well data prove that these correlate with the distributary channel fill and distributary mouth bar facies. That identification explains that the channels are isolated from each other forming compartmentalization of the reservoirs (Slatt, 2006).

Predicting Reservoir Distribution and Depositional Environment from Amplitude Mapping

Reservoir distribution prediction uses the horizon slice technique from reflection amplitude seismic. All the seismic amplitudes associated with a structurally interpreted horizon are gathered and extracted to produce an amplitude map. The amplitude map shows the strength of the interface (Brown, 2004). The purpose of this mapping method is to predict the sand reservoir distribution that infers depositional environment.

Sandstone-1 Horizon

Previous interpretation from the well log of DLT-1 well indicates that this gas bearing-sandstone may consist of two facies: distributary channel fill (2,217-2,222 mMD) and mouth bar facies (2,222-2,234 mMD or 12 m thick).

The amplitude map for this horizon ([Figure 12](#)) shows that there is high amplitude (yellow) at DLT-1 well and it is assumed that the high amplitudes correlate to the presence of thick sandstone and hence channels or deltaic lobes based on amplitude spectrum classification and their morphology on the map.

This classification consists of high amplitude in yellow that can be correlated with cleaner sand inferring channel-distributary channel sandstone facies. Medium amplitude in white to light brown can be correlated with muddy sand inferring distributary mouth bar-crevasse splay facies. Low amplitude in blue, red and green can be correlated with shale dominated inferring interdistributary channel facies.

From the map, it can be seen that the high amplitudes made clustering sands and these can be delineated into distributary mouth bar and alluvial fans for lobe shape morphology. Axial distributary channels and axial channels can be determined in that lobe shape based on yellow high amplitude lineation. Distributary channels can be defined from the branching of its channels. The clusters of channel and mouth bar sands were surrounded by shale dominated with coal intercalation. These clusters have trend northeast-southwest trend. The trend related with the direction of sediment sources from northeast area (Ginger and Fielding, 2005). Several big clusters can be found at DLT-1 and DLT-2 wells and southeast of DLT-4 well areas that have intensive distributary channels and mouth bars accumulation.

Alluvial fans can be found at downthrown of normal faults and close to the uplifted terrain of Berembang fault and a normal fault, east side from DLT-3 well location. Several channels and mouth bars cluster on the map were bordered by northeast-southwest normal

faults. This indicates that the faults controlled on sedimentation of the sands (Mack and Seager, 1990) in the Oligocene. The faults would restrict geometrically the lateral distribution of the sands.

Sandstone-2 Horizon

Well log interpretation of DLT-2 well suggests that the productive sandstone (6 meter-thick from 2,021-2,027 mMD) is a distributary channel fill facies.

Figure 13 shows an amplitude map of the horizons. It shows the sand in high red to green amplitude at the DLT-2 well location. Again, high amplitudes are assumed to correlate with thick sandstones. Several features can be seen on this map i.e. channels-distributary channels, mouth bars-crevasse splays and alluvial fans based on amplitude spectrum classification and their morphology on the map.

The classification consists of high amplitude in blue and red that can be correlated with cleaner sand inferring channel-distributary channel sandstone facies. Medium amplitude in light brown to white can be correlated with muddy sand inferring distributary mouth bar-crevasse splay facies. Low amplitude in yellow and green can be correlated with shale dominated inferring interdistributary channel facies.

As with the previous horizon, the clusters have northeast-southwest trends surrounded by shale dominated with coal intercalation. It can be seen that they shifted to the northeast area especially at DLT-1 well location when compared between amplitude maps from two horizons. This shift can be related with transgression stage that is started from southwest area (Ginger and Fielding, 2005). The other possibility is that these can be related with normally facies changes that occur at this horizon timing from clustering of distributary channels and mouth bars to shale dominated. Those changes, if both maps are compared, were able to produce appearances as if they were affected by transgression and result that shifting.

That event then replaced and moved the clustering sands when the area became a marginal and shallow to deep marine setting (Ginger and Fielding, 2005). The process also covered almost all the Muara Bulian high. This high structure could be related to the intensive distributary channel and mouth bar clusters found near Berembang flexural margin at the southwest and northeast area near DLT-4 well location. The high could be the local sediment source for the sands and only depositing the sediments near the site.

Several big sand clusters can be found at DLT-1 and DLT-2 wells and southeast of DLT-4 well area that have intensive distributary channels and mouth bars accumulation. Another area is at the east part of the Bajubang fault. Alluvial fans can be found close to the

uplifted terrain of the Berembang and Bajubang faults. Several alluvial fans made distributary channel inside their lobes, such as to the north of DLT-4 well.

As with the previous horizon, channels and mouth bars cluster on the map were bordered by northeast-southwest trending normal faults. This indicates that tectonics still controlled the sedimentation when the rate of denudation was slower than the rates of uplift and subsidence (Mack and Seager, 1990).

These two maps infer that the model built from windowed mapping technique and guided by electric logs from three (Sandstone-1) and four (Sandstone-2) wells show relatively good results. Although the facies from all well data did not positively match with clustering sand, both maps still can capture mouth bar and distributary channel morphology interpreted from DLT-1 and DLT-2.

Lateral distribution of depositional facies from both maps can be captured by this model and methodology using integration of well logs and 3D seismic data. Windowing interval that is used in this study should be considered because it can result in different maps and interpretations. Reservoir thickness should be important factor defining this windowed interval.

Conclusions

Several conclusions can be made from this study:

1. Several depositional facies can be determined i.e. distributary channel fill, interdistributary channel, crevasse splay and distributary mouth bar. The interpretations of these facies are consistent with regional fluvial-deltaic to shallow marine environments for the Talang Akar Formation.
2. Mapping of two horizons by horizon slice resulted in amplitude maps that are used to delineate and predict the distribution of the reservoir and depositional environment. The maps show several distributary channels, crevasse splays, deltas and alluvial fans that consistent with the depositional facies indicated by log data.
3. The clustering sands indicating fluvial-deltaic environments were shifted from Sandstone-1 to Sandstone-2 as seen on their maps. Such shifting is likely the result of a transgression event that was derived from southwest area.
4. New prospects can be proposed based on delineation of the clustering sands of the two amplitude maps but with consideration of tuning effects. It is recommended that new prospects should be evaluated using aspects of this study.

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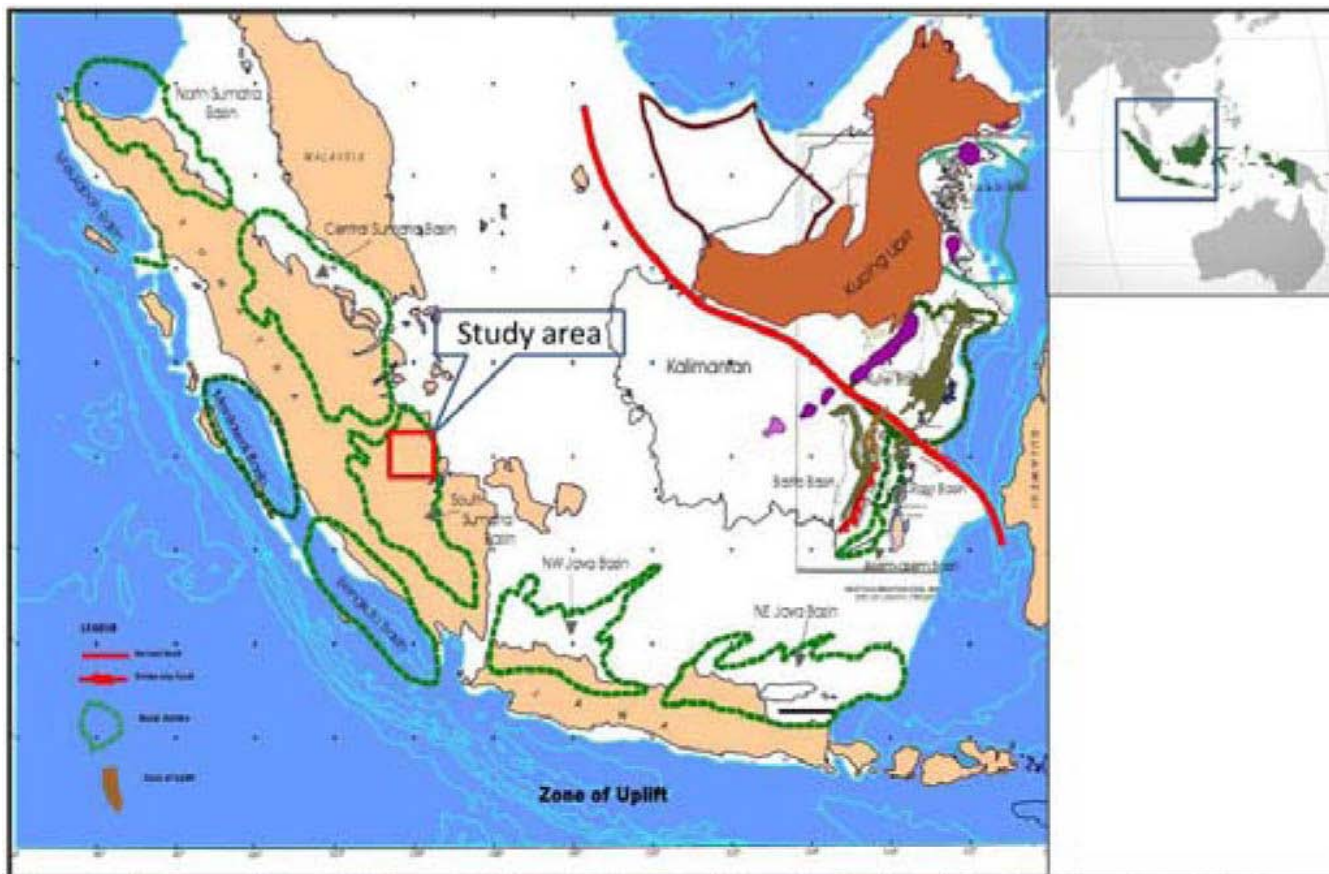


Figure 1. Location of the study within Jambi sub-basin, South Sumatra Basin, Indonesia (modified from Koesoemadinata, 2004 in Toha, 2011).

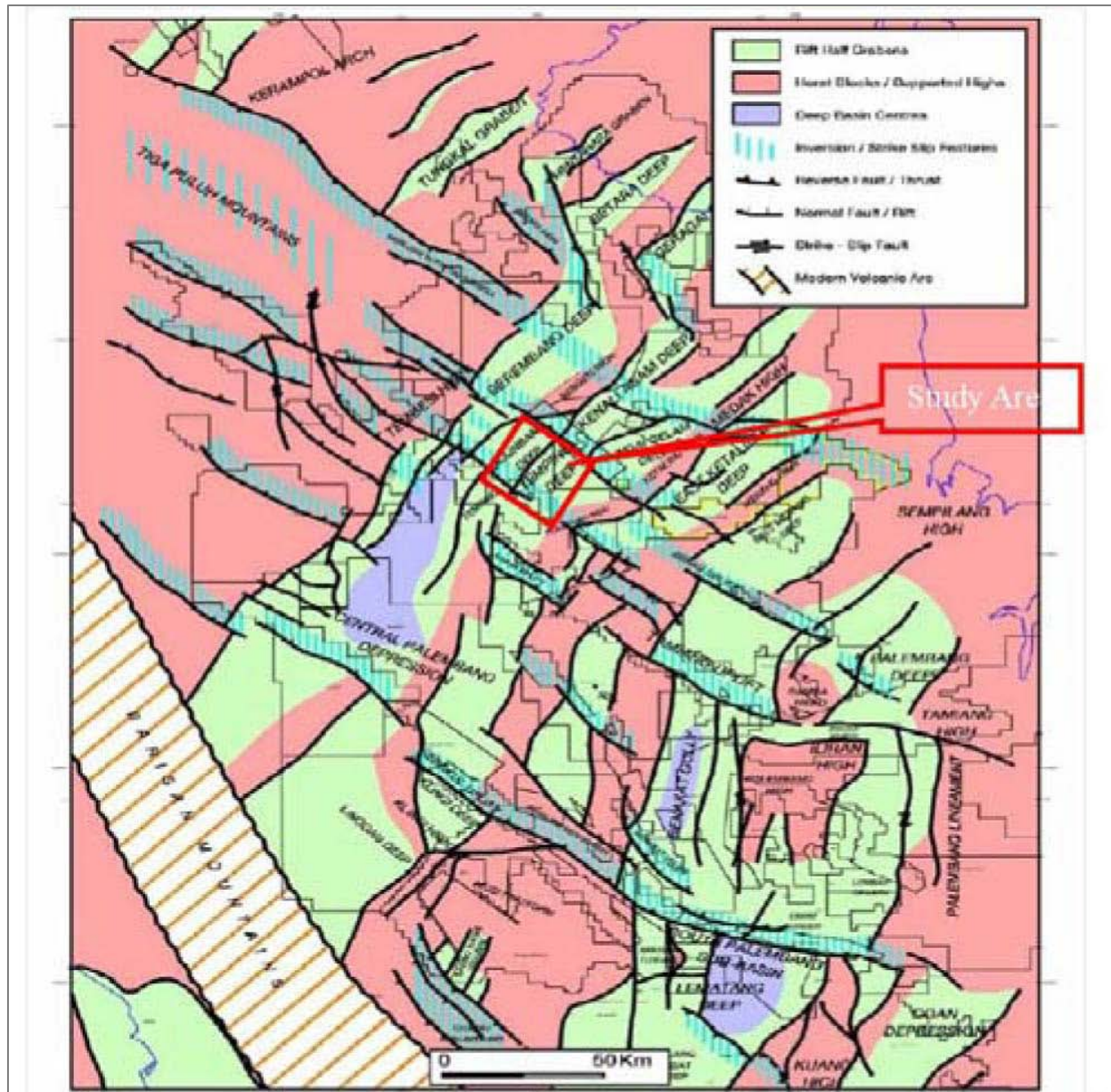


Figure 2. The map showing South Sumatra Basin subdivided into four sub-basins. The study area is on the north flank of Jambi sub-basin. This map also shows Late Cretaceous - early Tertiary age rifts (structures oriented northeast-southwest) cross cut by northwest-southeast Plio-Pleistocene inversion/transpression (Ginger and Fielding, 2005).

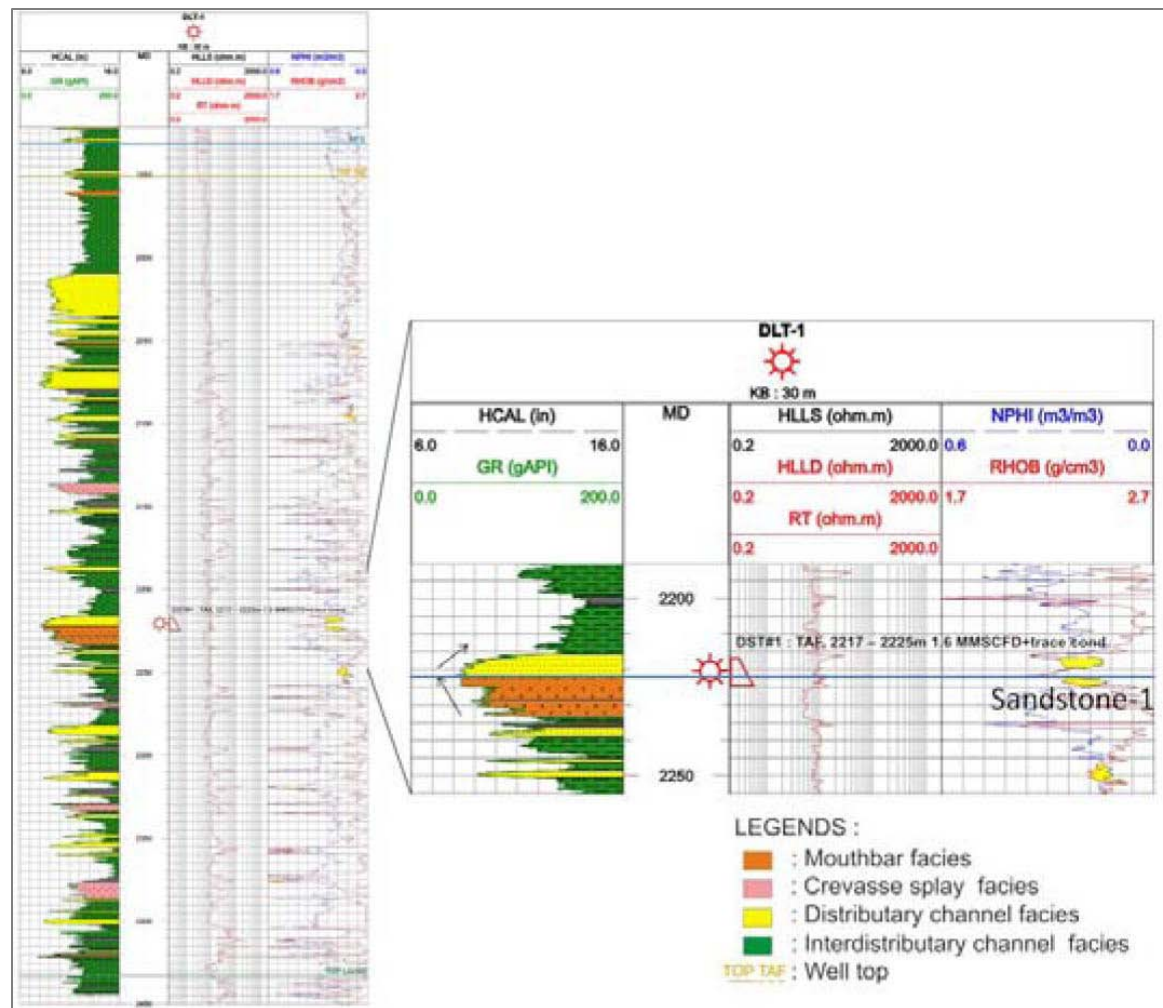


Figure 4. DLT-1 composite well log with facies interpretation showing distributary channel fill facies (yellow with black dots), interdistributary channel facies (green), crevasse splay facies (pink with black dots) and distributary mouth bar facies (orange with black dots). DST-1 interval has both distributary channel fill and mouth bar facies.

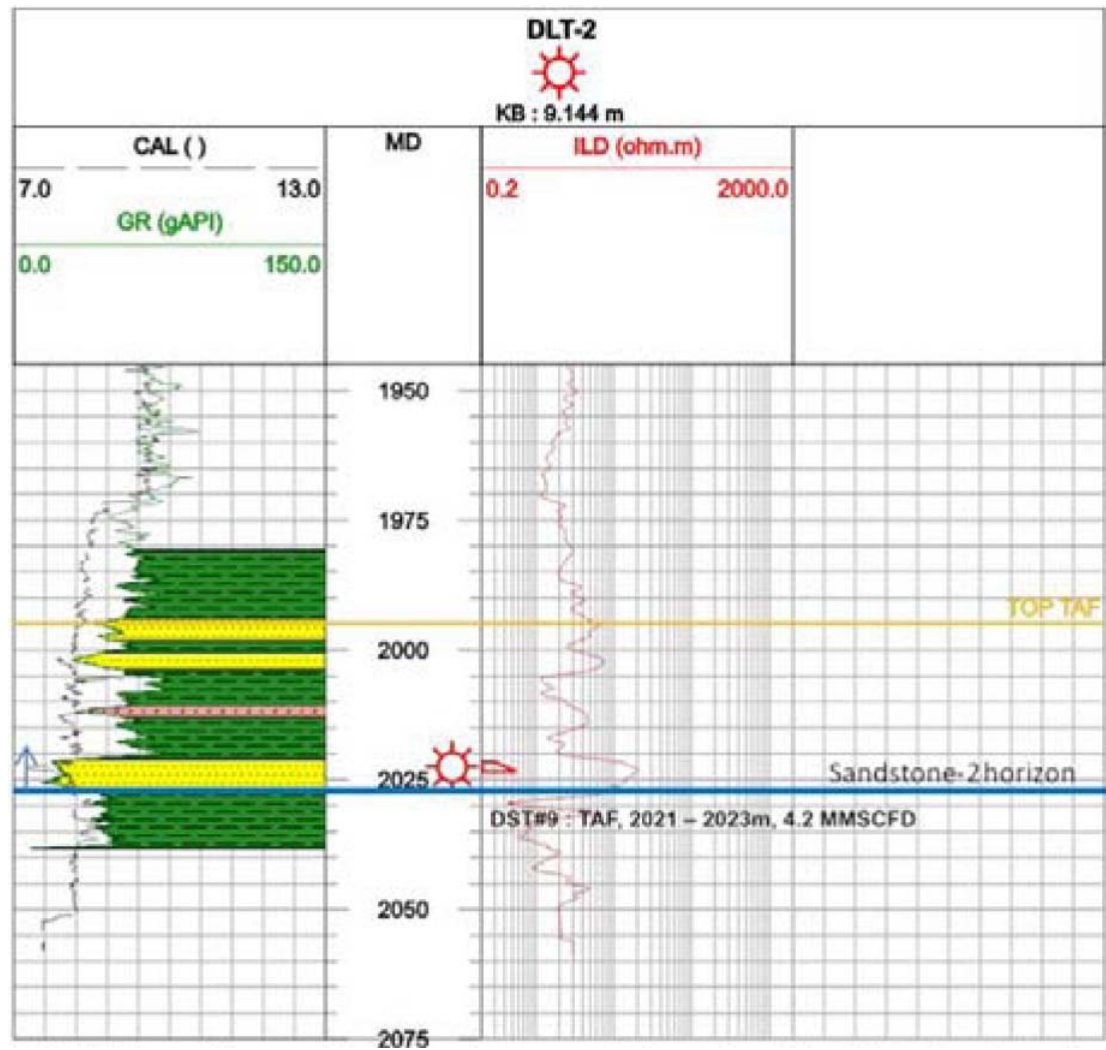


Figure 5. DLT-2 will log facies interpretation showing distributary channel fill facies (yellow with black dots), interdistributary channel facies (green) and crevasse splay facies (pink with black dots). DST-2 interval is characterized as distributary channel fill facies.

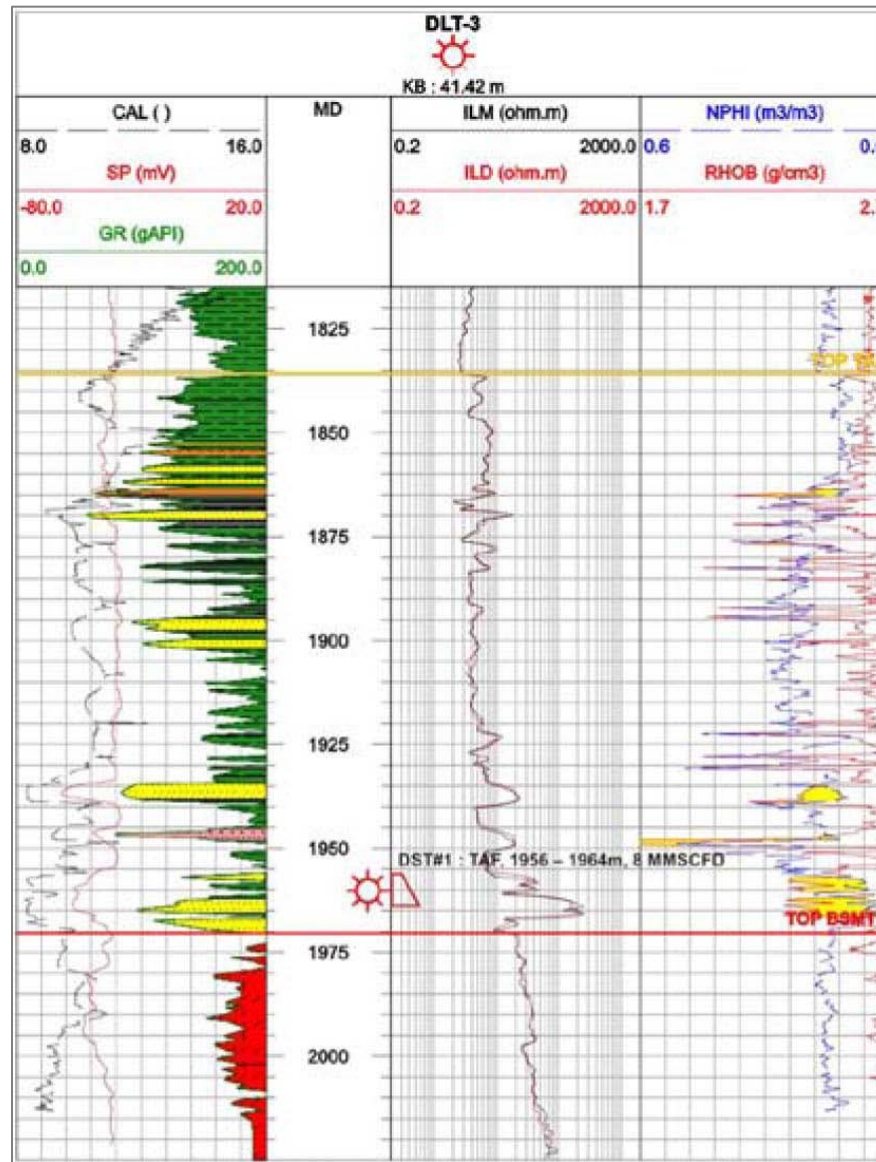


Figure 6. DLT-3 composite well log with facies interpretation and DST data showing distributary channel fill facies (yellow with black dots), interdistributary channel facies (green), crevasse splay facies (pink with black dots) and distributary mouth bar facies (orange with black dots).

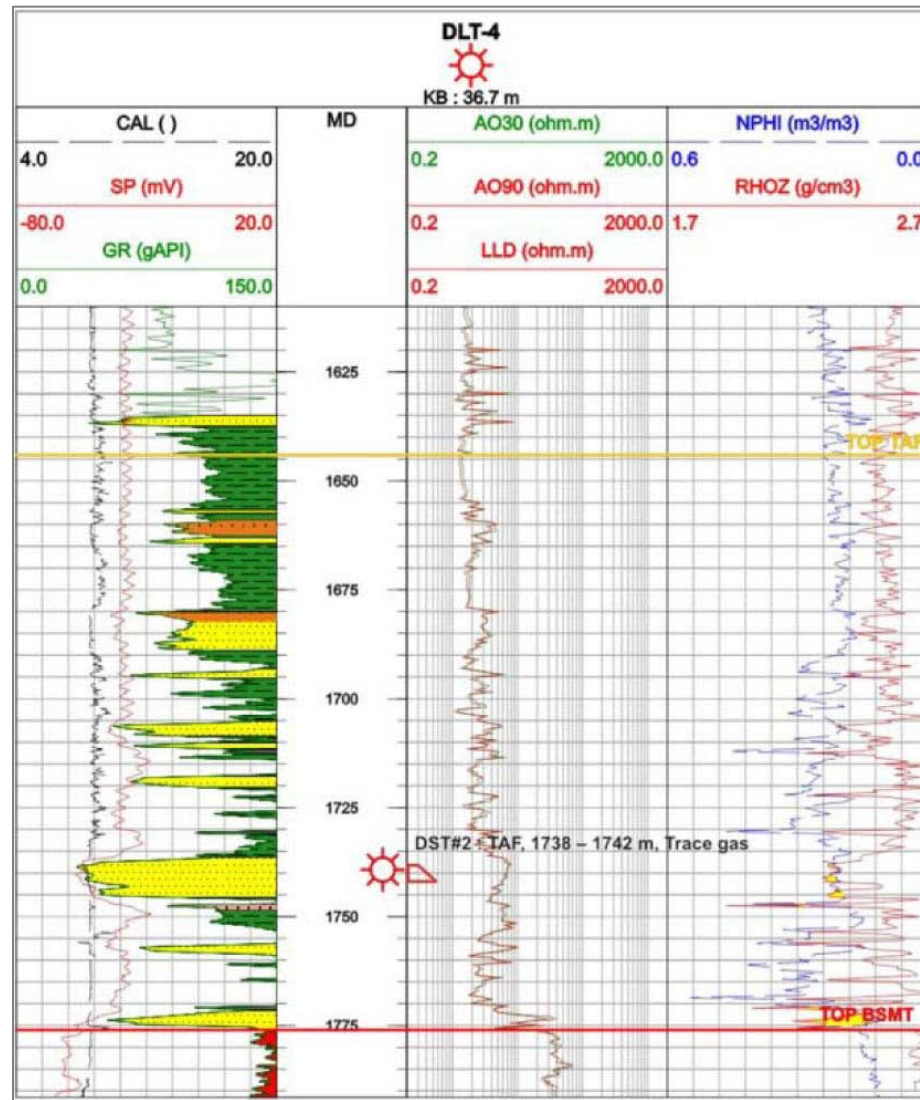


Figure 7. DLT-4 well log with facies interpretation and DST data showing distributary channel fill facies (yellow with black dots), interdistributary channel faces (green), crevasse splay facies (pink with black dots) and distributary mouth bar facies (orange with black dots).

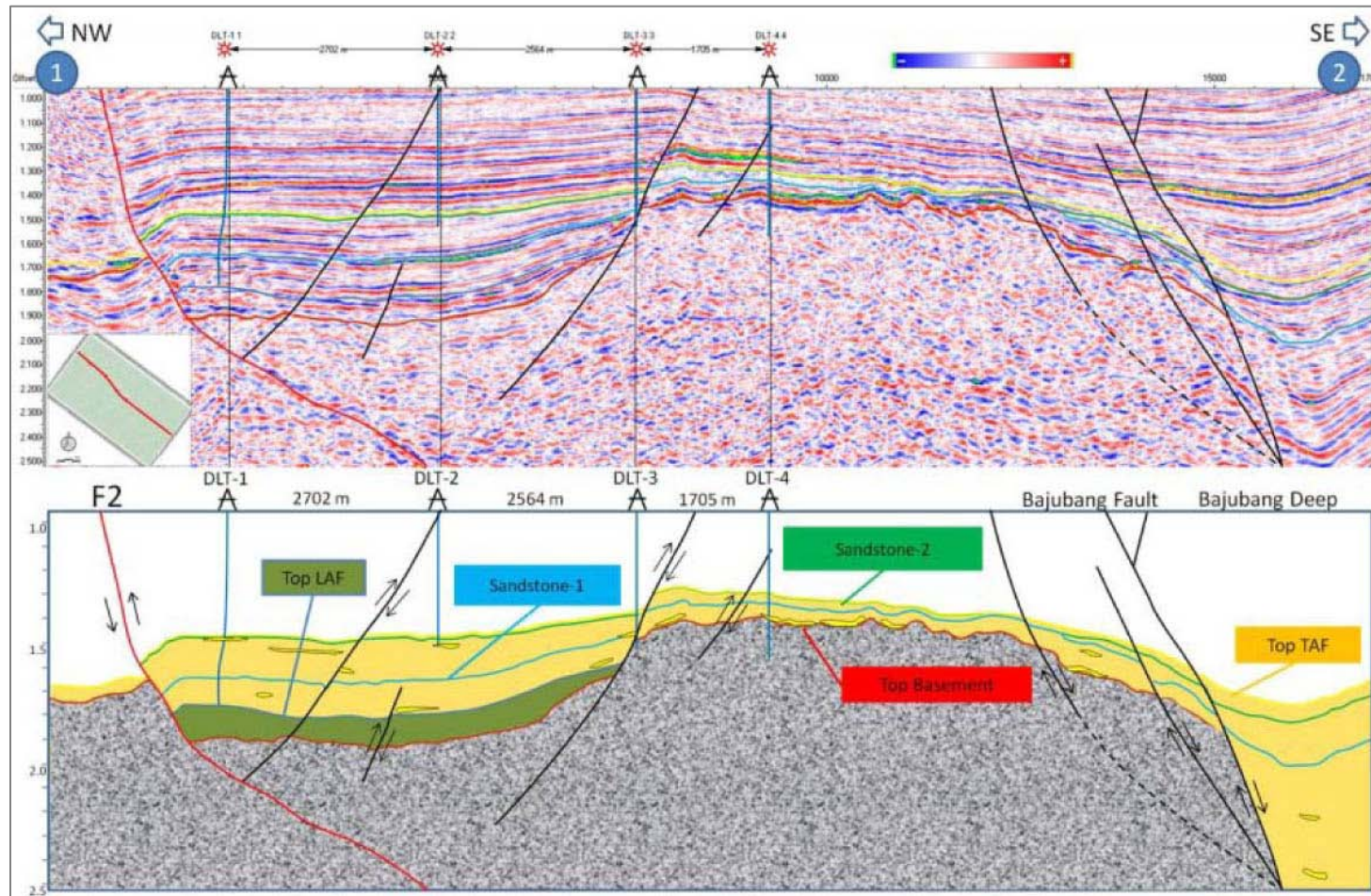


Figure 8. Arbitrary seismic line through DLT-1, DLT-2, DLT-3 and DLT-4 showing a reverse fault (red), a series of normal faults (black) and the Bajubang fault to the southeast. Lower figure shows simplified interpretation.

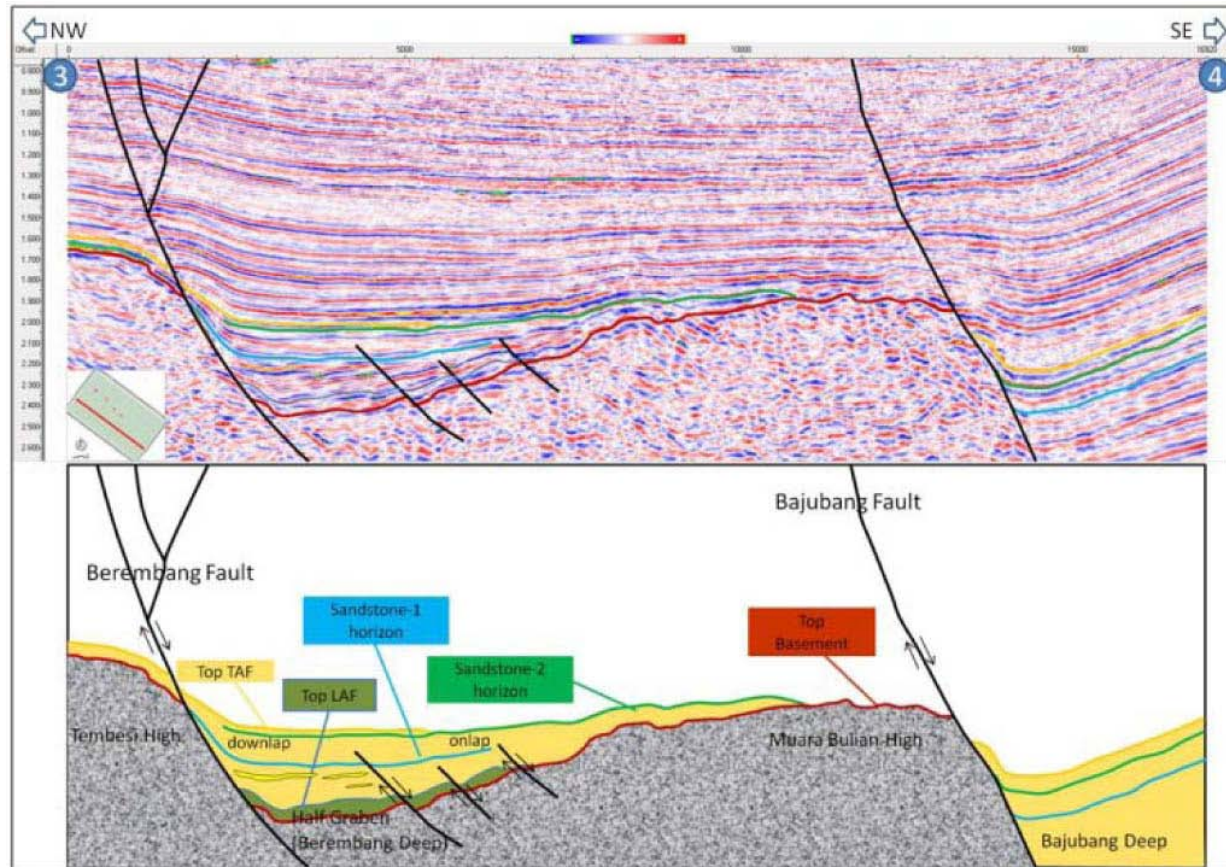


Figure 9. Crossline 111 (upper figure) showing Berembang fault dipping to SE as a half-graben border with a series of normal faults (black) and Bajubang fault. Lower figure shows simplified interpretation.

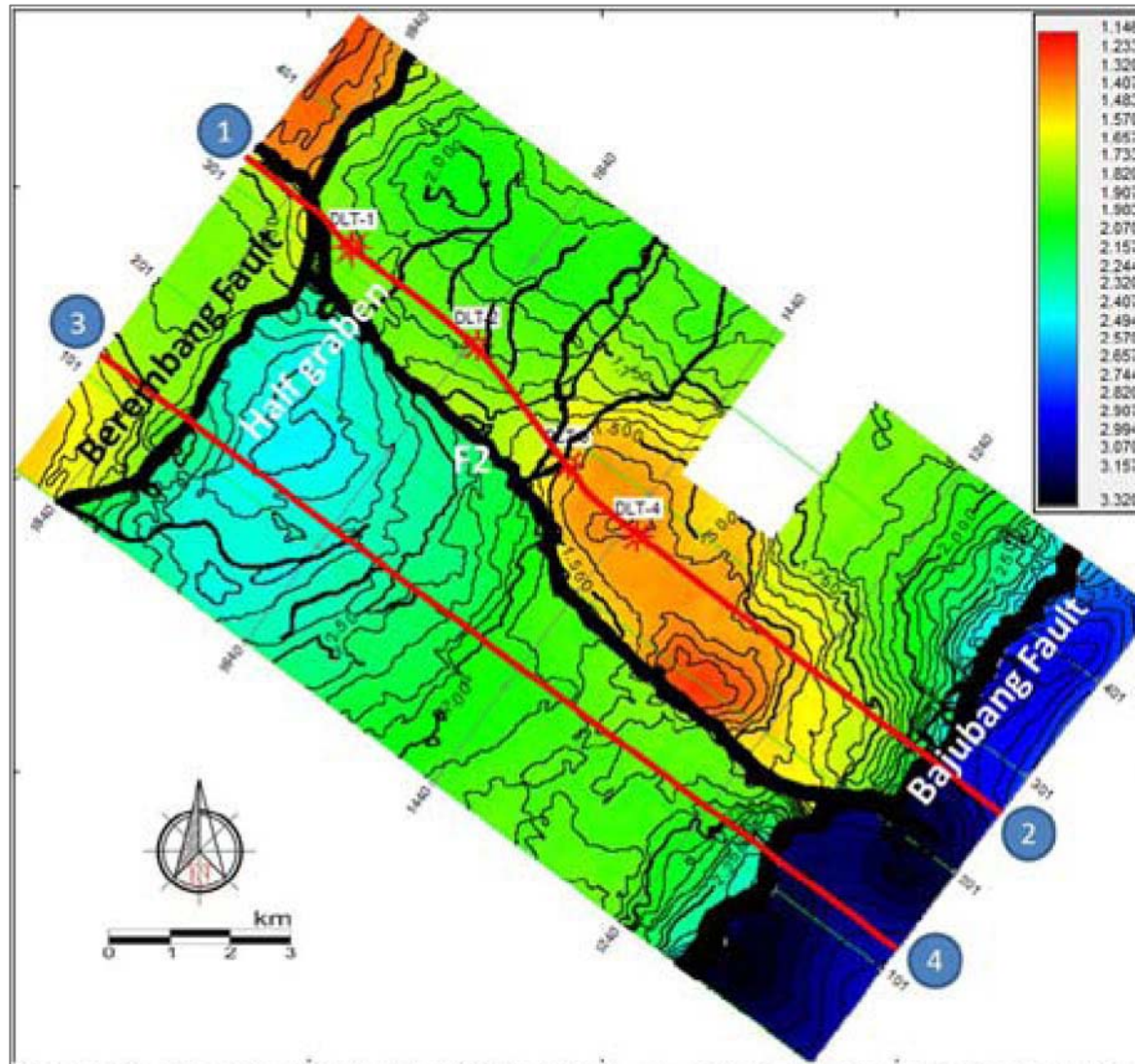


Figure 10. Time structure map of top basement showing structural elements of study area. Note that the red lines show the arbitrary crossline directions for [Figure 8](#) and [Figure 9](#).

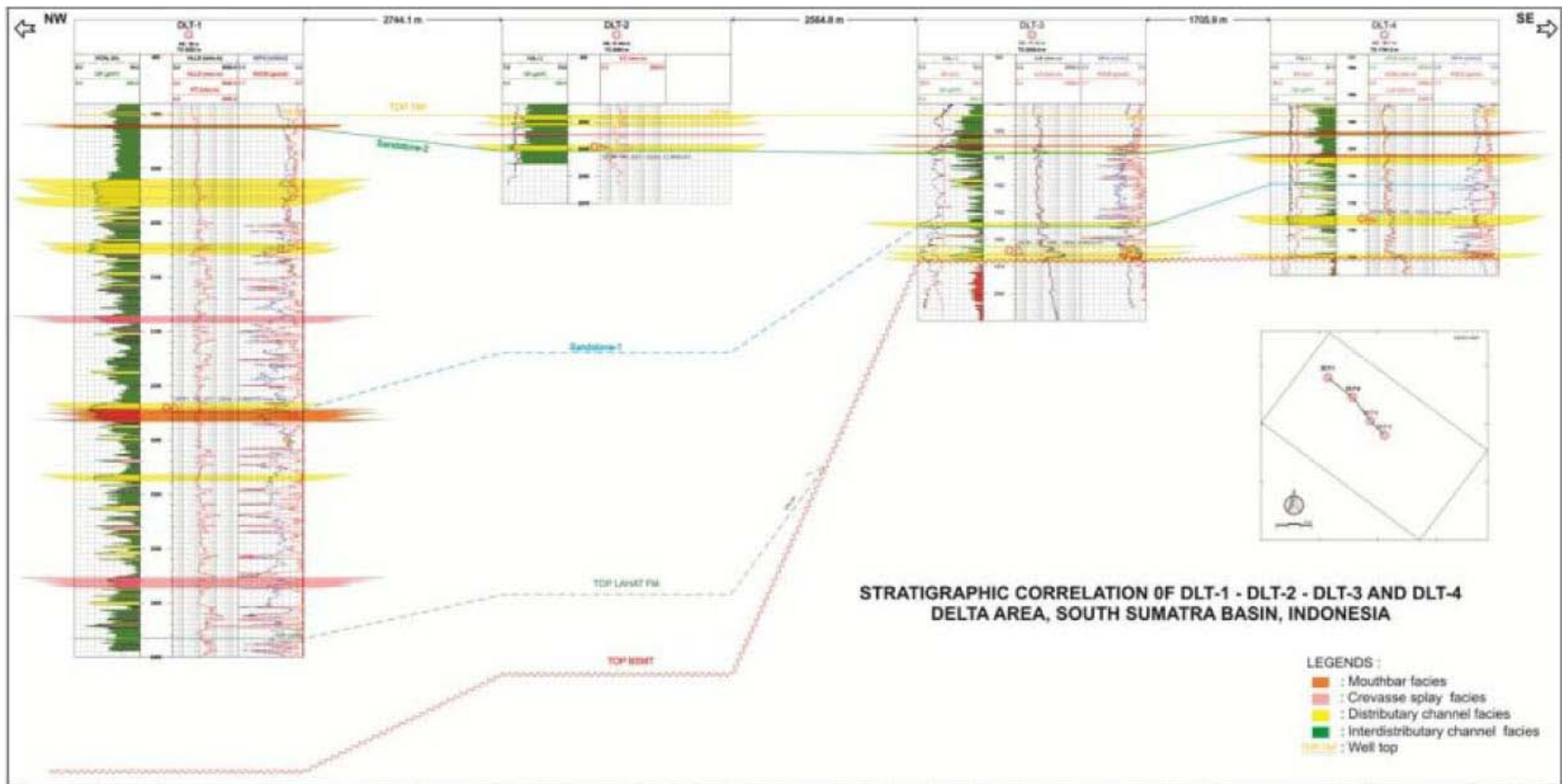


Figure 11. Stratigraphic correlation of DLT-1, DLT-2, DLT-3, and DLT-4 showing lateral distribution of TAF particularly unconnected distributary-channel facies in the study area.

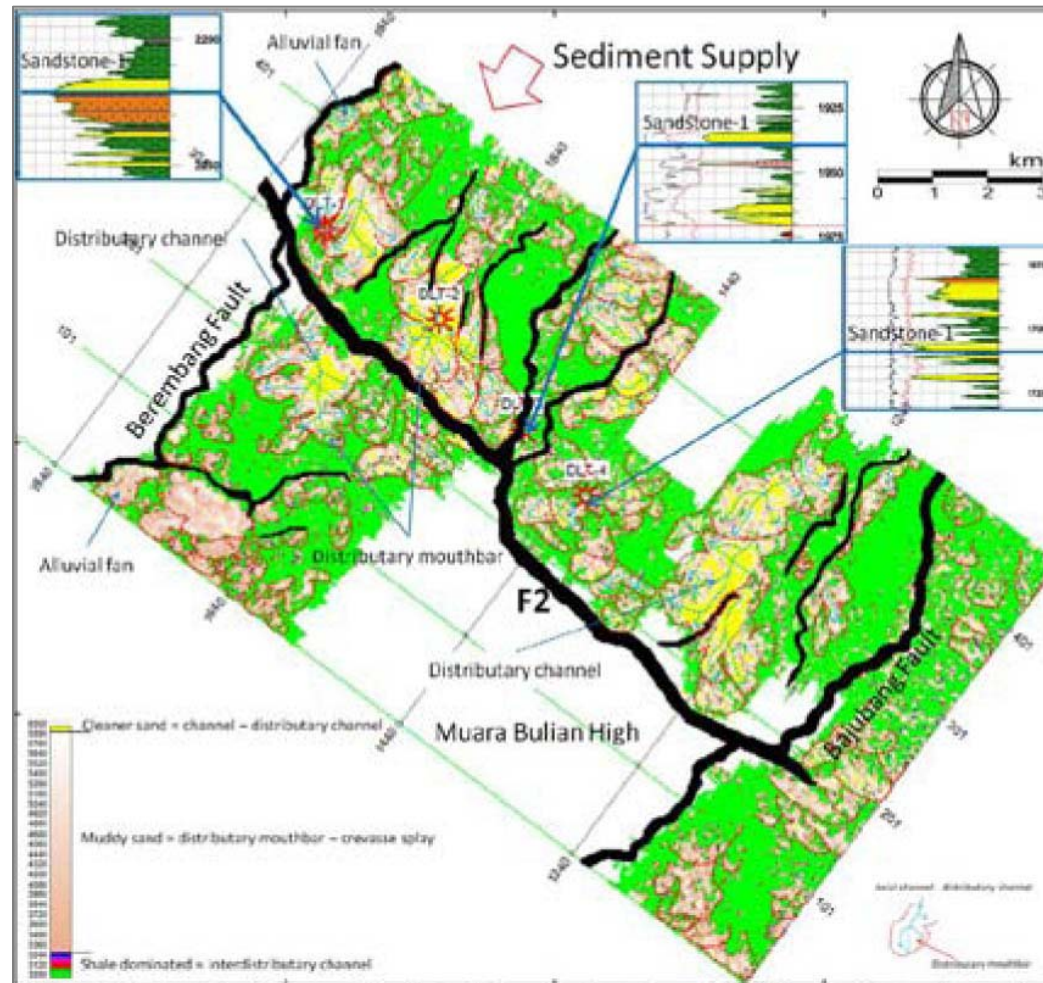


Figure 12. Amplitude map for Sandstone-1 showing distributary channels and mouth bars clusters surrounded by shale dominated with coal intercalation. These clusters trend northeast-southwest corresponding with the direction of sediment sources from the northeast area.

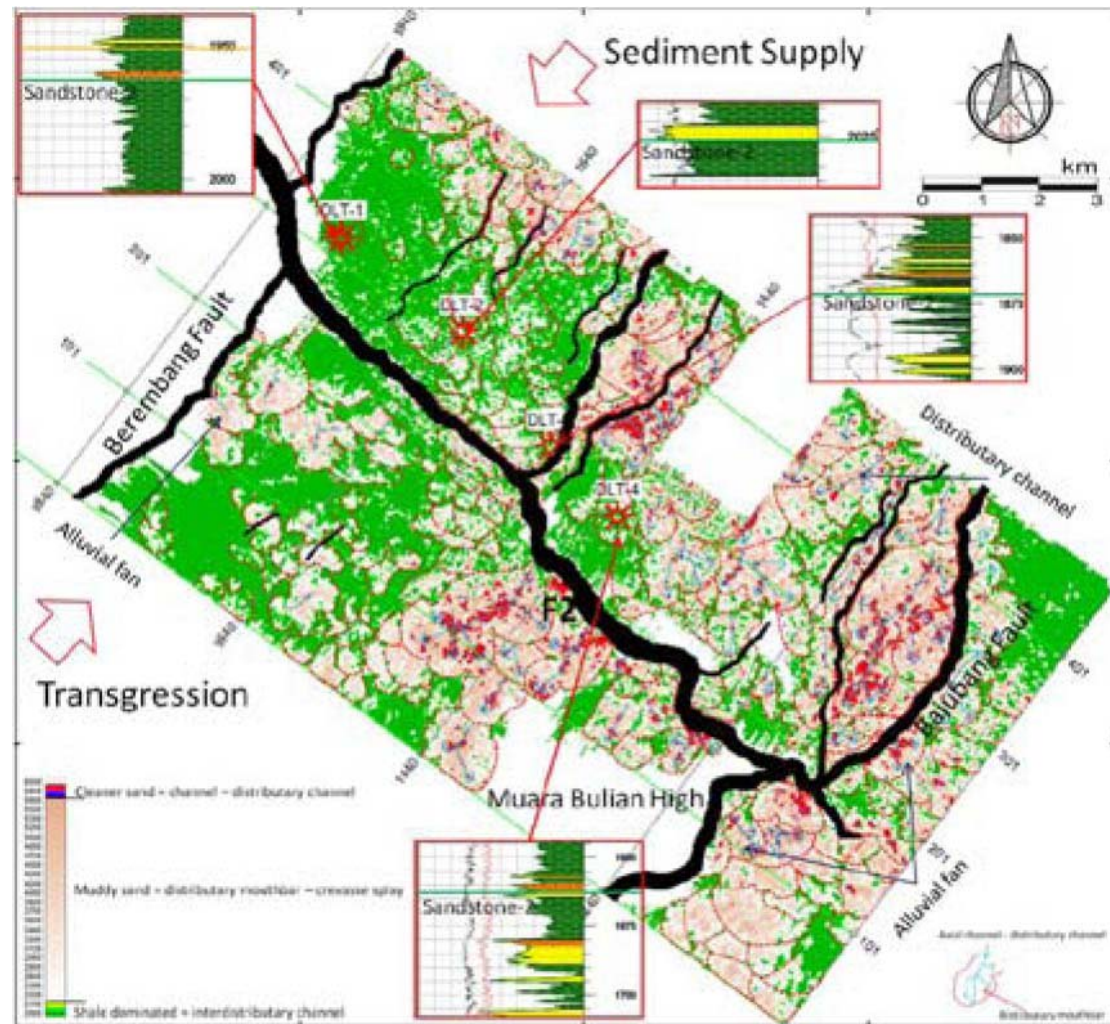


Figure 13. Amplitude map for Sandstone-2 showing distributary channels and mouth bars clusters that shifted to the northeast area especially at DLT-1 well location compared with amplitude map of Sandstone-1. This shift may be related to the transgression stage that started from the southwest area.

Well	Depth mMD		Interval (m)	Sandstone thickness (m)	Result
DLT-1	2217	2225	8	17	1.6 MMSCF gas + trace conde
DLT-2	2021	2023	2	6	4.2 MMSCF gas
DLT-3	1956	1964	8	7	8 MMSCF gas
DLT-4	1738	1747	9	9	trace gas

Table 1. DST data for each well shows mostly gas.