Abstract

The Gulf of Thailand lies on the southern margin of the Eurasian Plate and contains a number of north-south trending Tertiary aged rift basins. These basins form a series of en echelon grabens and half graben systems. Significant graben shifts because of transfer zones between the early rift structures are expected in the area, but on conventional seismic no such discontinuities can be observed. The main reservoirs of the area are Lower to Middle Miocene sands associated with fluvial depositional systems. The facies distribution pattern of these reservoirs are of limited scale showing rapid lateral and vertical changes, which is not easy to resolve on conventional seismic data. The objective of the present study is to develop geophysical workflows to better image the faults and reservoir sand distribution in the area. We applied spectral decomposition (Discrete Fourier Transform) techniques, semblance and sweetness on a seismic data set from the Pattani Basin and on selected frequency slices observed NW-SE discontinuities, which were additional to the N-S faults interpreted using conventional full spectrum seismic data. Iso-frequency volumes for phase and amplitude were also calculated. Key horizon slices of different phase volumes were examined and it was found that the 30 Hz phase volume best resolved both sets of faults (N-S and NW-SE). We also observed the same set of faults on horizon slices of semblance. Channels were identified on 25~30 Hz amplitude volumes within less tectonically disturbed zones. The good match between sweetness and gamma ray at well locations indicates that we can use sweetness for sand prediction. Combining the results of amplitude volumes and sweetness, two types of channels can be identified: 1) those having high sweetness and high amplitudes at selected frequencies (25~30); and 2) those with low sweetness and low amplitude at selected frequencies which were associated with point bars of high sweetness and high amplitudes. We interpreted these types of channels as sand filled and mud filled associated with sandy point bars respectively. Both sets of faults also affect the anomalies associated with sand bodies. The present study reveals that spectral decomposition
techniques combined with semblance and sweetness can successfully delineate sand geometries within the complex tectonics and depositional environments in the Gulf of Thailand.

References


Application of Spectral Decomposition and Seismic Attributes to Understand the Structure and Distribution of Sand Reservoirs within Tertiary Rift Basins of the Gulf of Thailand

By

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Acknowledgements
• The Gulf of Thailand is composed of a series of north–south trending linear ridges, separated by major fault-bounded sedimentary basins.

• The Pattani basin is a major hydrocarbon area in Gulf of Thailand. It is approximately 270 km long and 100 km wide.
Tertiary rifting in the Pattani basin

• Developed by E-W extension which produced N-S regional faults.

• Secondary faults are NW-SE and NE-SW and trending oblique (or at high angles) to N-S regional faults.

• Inherited pre-existing fabric.

Inferred trend of oblique pre-rift fabric

Morley, et al., 2004
Major tectonic phases

- Active early syn-rift (Upper Eocene to the end of Oligocene).
- Late syn-rift (Lower Miocene to Late Middle Miocene).
- Post-rift (Late Mid Miocene to Recent).
Stratigraphy—Fluvial sands are primary objective

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Study Interval

Legend

- Marine Clays
- Fluvial Sandstone
- Claystones & mudstones
- Alluvial Claystones
- Lacustrine mudstones
- Conglomerates & Breccias

(Sequence/Age: Oligocene Early, Late; Miocene Middle, Late; Pliocene; Eocene Late)

(after Morley & Racey, 2011)
Main issues to resolve

**Imaging faults associated with graben shifts**
- Significant graben shifts because of transfer zones are in the area.
- These faults are not easy to map on full spectrum seismic data.

**Mapping of reservoir sands**
- Reservoir sands show rapid horizontal and vertical change in thickness and size because of fluvial depositional environment.

Kornsawan & Morley, 2002
Methodology for resolving issues

Spectral Decomposition Workflow

Reconnaissance Tuning Cube for zone of interest

Analysis of Ampl. & Phase slices

Iso-frequency Volumes of Ampl. & Phase

Fault Detection on Phase Volumes

Channel detection on ampl. volumes

Attribute Calculation Workflow

Seismic Data

Sweetness calculation

Sand mapping

Fault mapping

Semblance calculation
Investigation zone defined from 1400-2100 msec (~1500 to 2700 m depth)
Reconnaissance tuning cube of zone of interest

No meaningful signal beyond 80 Hz

Frequency cross section of phase

Frequency cross section of amplitude
Fault Analysis
Fault analysis on full spectrum Semblance horizon slice of H2 Horizon

- N-S Regional Faults
- NW-SE Discontinuities
Discrete frequency volume analysis of 30 Hz phase horizon slice of H2

North-South discontinuities match the interpreted faults.

NW-SE discontinuities are better resolved on 30 Hz phase horizon slice as compared to Semblance.
30 Hz phase horizon slice of H2 along with interpreted polygons of regional N-S faults

NW-SE discontinuities may represent localized graben shifts/transfer zones as

1. Opposite dipping faults are Juxtaposed.
2. Bends in the N-S faults along the NW-SE discontinuities.
Fault Analysis on Filtered Section (20-25-35-40)

1 km

H2 Horizon

1.5 2.0 2.5

+i ve  

NW-SE Discontinuity

Horizon H2

Main North-South Fault
Analysis of Amplitude Anomalies For Sand Prediction
Horizon H2 amplitude map at 30 Hz frequency overlain by 30 Hz phase slice to highlight anomalies along fault zones.

- Amplitude anomalies along N-S regional faults.
- Amplitude anomalies cut by NW-SE secondary faults.
Comparison of Sweetness and GR at Wells
Sweetness is calculated for sand prediction

- High Sweetness matches with sands of thickness greater or equal to 13~15m down to the depth of 1700 m.
- Sands below 1700 ~1800 m do not show good correlation with sweetness.

![Diagram showing depth, wells, and sweetness/GR correlation](image)
Distribution of sand from sweetness section

Sand bodies are not continuous vertically and laterally

30 Hz Amplitude Anomaly Map of H2 Horizon
Look at amplitude anomalies in the shallow section (124 ms) to obtain analogues for deeper section reservoirs.

Point Bars

Channel associated with high amplitude sand
Same feature on 30 Hz amplitude spectra and on Sweetness attribute at 124 ms

Sands deposited in broad point bars associated with high sinuous channels
Amplitude anomalies of narrow meander belts at shallow section (148ms)

Amplitude anomalies associated with narrow meander belt
Same feature on 30Hz amplitude spectra and Sweetness time slice (148ms)

30 Hz amplitude spectra

Narrow channel

Sweetness slice
Broad point bar related anomaly along H2 horizon

High amplitude at broad point bar on H2 horizon slice

30 Hz amplitude spectra
Sweetness and 30 Hz amplitude spectra slice along H2 in NE part of the area

High amplitude/High Sweetness anomalies of point bars

Possible Channel

Point Bar

2 Km

1 Km
Amplitude spectra of narrow meander belt on 30 Hz time slice of 1624 ms

Amplitude spectra of 30 Hz at 1624 ms

Vertical section of full spectra showing 1624 ms time slice position

High amplitude associated with channel cut by NW-SE fault

NW-SE Fault

Area Focus in next slide

0.4 Km

1 Km

1 Km

High Amplitude Anomaly Associated with Channel

+ive

-ive

Vertical section of full spectra showing 1624 ms time slice position
Same feature of narrow meander belt at 1624 ms time slice of Sweetness

• High Sweetness represents Sand associated with narrow meander belt.
• Shows compartmentalization by cross fault.
Key Observations

- 30 Hz phase volume shows regional N-S faults as well as NW-SE secondary faults. 30 Hz phase spectra better image the both set of faults as compared to semblance of full spectrum data.

- Filtered seismic section (25~35 Hz) more effectively resolve NW-SE faults as compared to full spectrum seismic.

- Amplitude anomalies are aligned along both set of faults.

- Spectral decomposition output of 30 Hz amplitude volume highlights sand associated with meander belts.

- There is reasonable match between GR and sweetness up to 1700~1800 m depth.
Conclusions

- Spectral Decomposition technique can be used to detect subtle faults, especially related with graben shifts or transfer zones, in the Gulf of Thailand.
- NW-SE faults may help compartmentalized the reservoir.
- 30 Hz Amplitude spectra can be used to detect the nature of channels and predict the sand distribution associated with fluvial system in the area.
- Sweetness volume may help to predict the sand distribution down to certain depth.
- Two types of channels are detected; 1) high sinuous with broad point bars and low sinuous narrow meander belts.
- Amplitude spectra of 30 Hz and Sweetness can help to differentiate zones of broad point bars and sands associated with narrow meander belts within the interval of reservoir.
Thanks