Different Types of Organic-Rich Geological Markers in South Pailin Field, Pattani Basin, Gulf of Thailand

Jittikan Narapan

Petroleum Geoscience Program, Department of Geology, Faculty of Science,
Chulalongkorn University, Bangkok, 10330, Thailand.
Corresponding author e-mail: jn_jnn@hotmail.com

Abstract

Organic-rich sediments were recognized and differentiated by integrating conventional cores, wireline log characteristics, palynology, and petrographic data, in the South Pailin Field, southern part of Pattani Basin, Gulf of Thailand. The core study indicates three types of organic-rich sediments. Laminated burrowed muddy siltstone is interpreted as marginal marine shale, which has low-resistivity and moderate-high density log characteristics and is widely distributed. Coal with pyrite is interpreted as marginal marine coal, which has high gamma ray and spiky density and neutron curves and a wide distribution with a limited extent to the south. Mudstone with coal is interpreted as non-marine coaly mudstone; its wireline characteristics are indistinctive and cannot be correlated laterally with high certainty. The overall succession was deposited in fluvial/floodplain and marginal marine settings with two major marine transgressions that occurred during the late lower and middle Miocene. Marginal marine shale is the best geological marker in the South Pailin area and also potentially correlates regionally to other fields. This regional marker provides better understanding of stratigraphic correlation, depositional framework and marine influence, which is useful for developing and predicting reservoir character in the study area. In contrast, marginal marine and non-marine coals are not very useful for regional stratigraphic correlation due to their limited lateral extent.

Key Words: Organic-rich, Geological marker, Marginal marine sediment, South Pailin, Pattani basin

1. Introduction

Organic-rich sediments are currently used as geological markers for stratigraphic correlation in the South Pailin area, Pattani Basin by assuming that they are widely distributed (Figure 1). As regional depositional environments vary from fluvial to marginal marine, these organic-rich sediments need to be differentiated and defined for their depositional framework. However, they are generally defined and correlated based on wireline log characteristics only and these indirect interpretations often are inaccurate because of several factors. Thus it is essential to improve understanding of these organic-rich sediments by integrating all available data, especially conventional cores. The main objective of this study is to recognize and better understand the different types of organic-rich geological markers. Their distribution will be used to define their potential as good regional markers in the South Pailin area.

Conventional cores from five wells (PA-I, PA-II, PA-III, PA-IV, and PA-V), with spectral gamma logs, were used in this study as well as a palynology study in the low resistivity shales of PA-VI well and a petrographic study of PA-II and PA-VII. These were all integrated with wireline logs, which consist of gamma, resistivity, neutron, density, and transit time, from 80 development wells.

2. Facies Characterization

Stratigraphic units are divided into organic-rich facies, and their associated facies. The facies characterization is based on core description and interpretation, plus their wireline log characteristics.

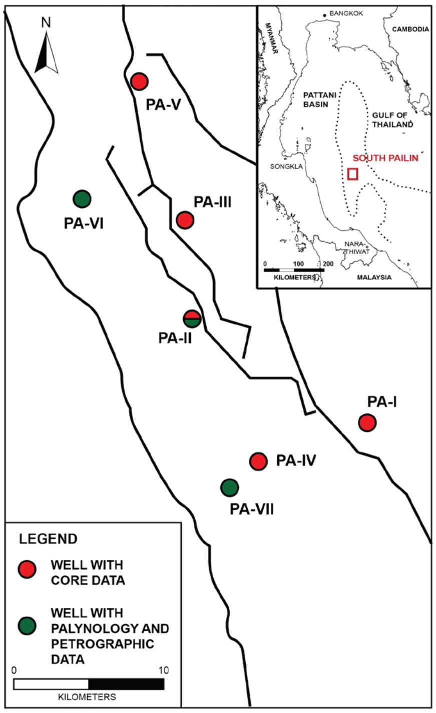

Figure 1. The South Pailin study area located in the southern part of Pattani Basin, with the location of the wells used in the study.

2.1 Organic-rich Facies

The organic-rich facies are laminated burrowed muddy siltstone, coal with pyrite, and mudstone with coal.

2.1.1 Laminated Burrowed Muddy Siltstone

Laminated, burrowed muddy siltstone comprises mainly dark grey, muddy siltstones and coaly mudstones (Figure 2A). Some alternating beds of siltstones are present locally. Sedimentary structures are mainly parallel lamination, 1 to 3 mm thick, and locally heavy bioturbation. Coals with pyrites are common, either as rubble or parallel laminated (1 to 2 mm thick).

Burrows and bioturbation are typically common (Figure 2B, 2C), as are siderite and calcite nodules. Basal contacts can be either gradational or sharp with adjacent units. Upper contacts are mostly gradational into upward-coarsening sandstone facies. Sharp contacts into overlying rock units also occur.

These laminated suspension sediment deposits indicate deposition under water in a low-energy setting. High bioturbation usually indicates marine influenced depositional settings. Based on these criteria, and that this facies is typically associated with estuarine sands; this facies is interpreted as an estuarine deposit. Thus, this laminated burrowed muddy siltstone is a marginal marine shale.

The wireline log characteristics of this laminated burrowed muddy siltstone are typically low resistivity (less than 2 ohm-m) and high density (2.55-2.64 g/cc).

2.1.2 Coal with Pyrite

This facies comprises black, partly vitreous coals and dark grey coaly mudstones that typically contain yellow-sulfur pyrite residues (Figure 3A). Most coals were recovered as rubble. There is some parallel lamination, 1 to 3 mm thick. Coal with pyrite is common within laminated burrowed muddy siltstone. Basal and upper contacts are gradational with either laminated burrowed muddy siltstone or greenish grey, rooted siltstone.

Sulfur is thought to be a direct indicator of a peat-forming environment. Coals with higher sulfur content or pyritization develop in reducing, sulfate-rich environments and in proximity to marine conditions (McCabe, 1984). Based on the criteria that this coal facies contains common yellow-sulfur pyrite residuals and is associated with laminated burrowed muddy siltstone, this facies is interpreted as a coal deposited in estuarine environments. Thin coals with pyrite associated with greenish siltstone, occurred at the top of fluvial successions suggest short-lived marginal marine transgressions.

The wireline log characteristics of this marginal marine coal are typically high gamma ray values (207-376 API) and spiky neutron-density curves. However, there is one coal with a low gamma ray value (64 API) corresponding to low uranium content (1.25 ppm) with very low density (1.3 g/cc) in PA-II.

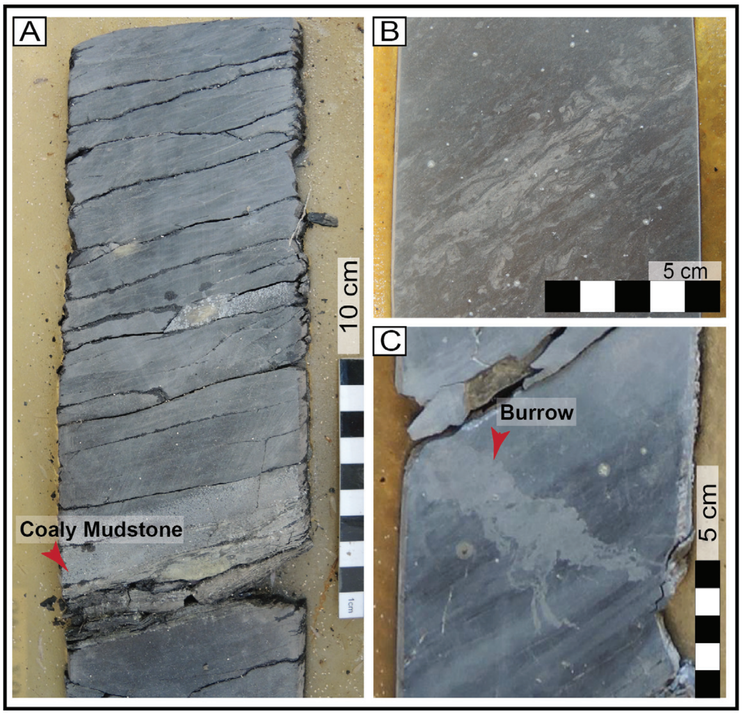

Figure 2. Core photographs of laminated, burrowed muddy siltstone
A) laminated muddy siltstones with coaly mudstone,
B) bioturbated muddy siltstone,
C) burrowed, interbedded muddy siltstone and siltstone

2.1.3 Mudstone with Coal

Mudstone and coal have similar characteristics to coal with pyrite, except that yellow-sulfur pyrite residues are rare (Figure 3B). This type of coal is 1.5 ft (0.5 m) thick in PA-III. Its basal contact is gradational with greenish grey siltstone, while the upper contact is gradational into laminated burrowed muddy siltstone.

As high-sulfur coals form proximal to marine environments while low-sulfur coals form in more landward, freshwater environments (Brady and Hatch, 1997), mudstone and coal with rare pyrite residuals is interpreted as swamp deposits on a floodplain. This is supported by its association with greenish grey floodplain sediments.

Non-marine coaly mudstone is poorly defined on wireline logs, as the wireline log characteristics are not distinctive.

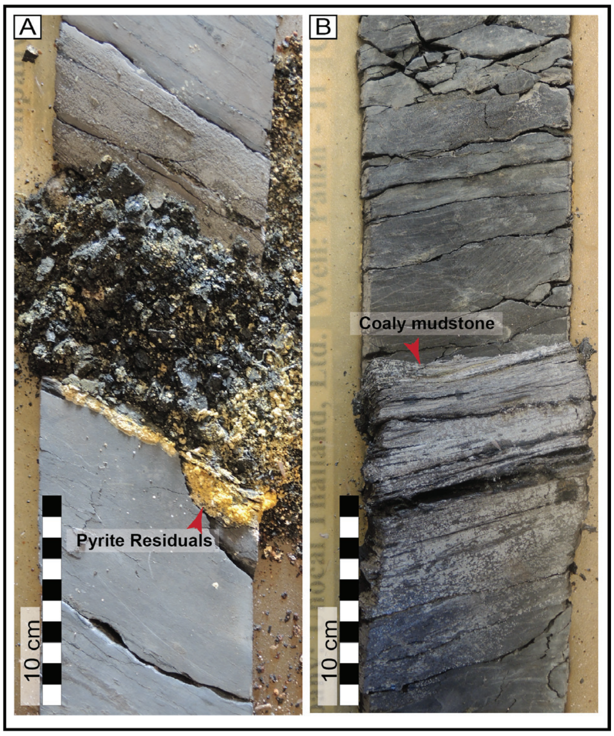

Figure 3. Core photographs of the coal and coaly mudstone A) marginal marine coal, containing yellow pyrite residuals, B) non-marine coaly mudstone

2.2 Associated Facies

Associated facies include non-marine and marginal marine strata. Non-marine depositional facies are fluvial channel and overbank deposits. And the marginal marine depositional facies is estuarine sands.

3. Wireline Log Correlations and Distribution Map

Three types of organic-rich sediments, 1) marginal marine shale, 2) marginal marine coal, and 3) non-marine coaly mudstone, have distinctive wireline log signatures that can be recognized in uncored well intervals. Isopach maps were generated based on the stratigraphic correlation and overlain on a middle Miocene structure map.

3.1 Marginal Marine Shale

Marginal marine shales can be recognized by their low-resistivity and moderate-high density log characteristics and can be correlated laterally to other wells. The correlations are consistent, which suggests a widespread distribution.

The isopach maps of marginal marine shales (Figure 4) indicate a wide distribution of marginal marine shale with thicker sections in the southeast, which implies a marine transgression to the northernmost part of the Pailin area in the lower to middle Miocene.

3.2 Marginal Marine Coal

Marginal marine coal can be recognized by its high gamma ray and spiky density and neutron curves, although some marginal marine coals have low to moderate gamma ray values. It can be correlated laterally to other wells with a limited lateral correlation in some wells. There also is a different change in lithology from coal to coaly mudstone in the same stratigraphic level, as the density and gamma ray values get higher.

The isopach maps of marginal marine coals indicate a wide distribution of marginal marine coal with a limited extent to the south (Figure 5). It is evident that the marginal marine coal markers are not continuous across the area, which may imply a specific reducing setting for coal formation or that it was eroded out later.

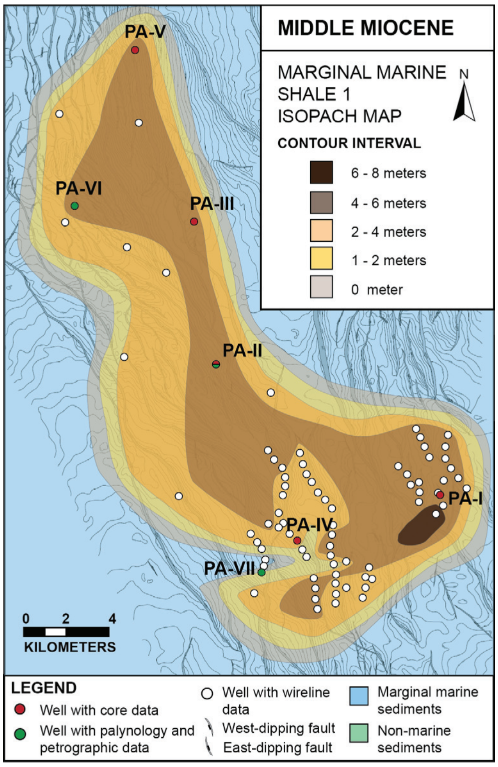

Figure 4. Isopach map of marginal marine shale 1 (middle Miocene)

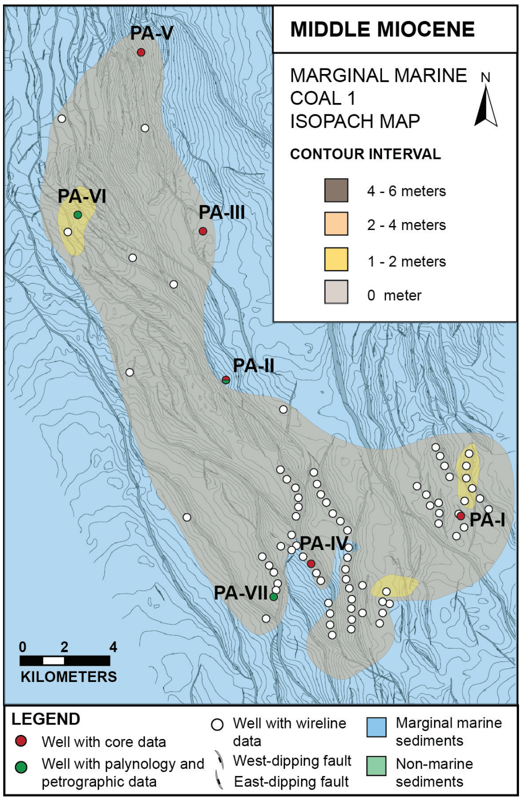

Figure 5. Isopach map of marginal marine coal 1 (middle Miocene)

3.3 Non-marine Coaly Mudstone

Wireline characteristics of non-marine coaly mudstone are indistinctive, as they have moderate gamma ray values and low-moderate density and neutron. However moderately spiky density and neutron curves can be used for well-to-well correlation. Non-marine coaly mudstone cannot be correlated laterally with high certainty, as the wireline log signatures are indistinctive.

The isopach map of non-marine coaly mudstone in the middle Miocene indicates widespread non-marine coaly mudstone in the north but a limited extent in the south (Figure 6). It is evident that the non-marine coaly mudstone marker is not continuous across the area. It may imply a specific environment, such as a peat swamp, for coal formation and it also suggests less marine influence in that stratigraphic interval.

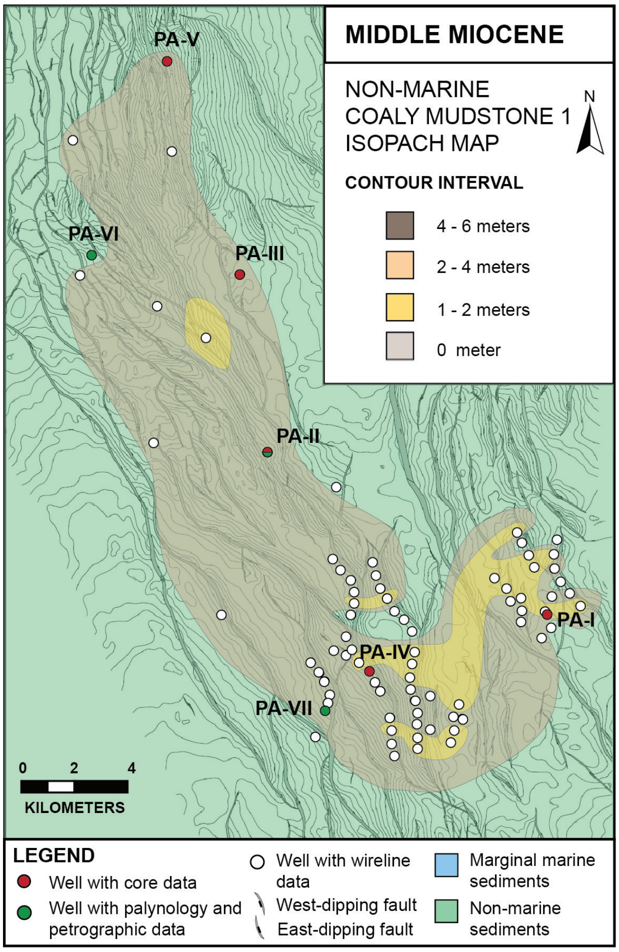

Figure 6. Isopach map of non-marine coaly mudstone 1 (middle Miocene)

4. Discussion

Palynology and petrographic data derived from either sidewall cores or cuttings are useful to support core interpretation, and can define marine transgressions, especially in the area where no conventional core data are available. However, they are not always applicable as a result of sample quality, which may not be good enough, especially when the palynology analysis is done long after the well was drilled.

The distinct wireline characteristics and consistent development of marginal marine shale at certain stratigraphic level suggests depositionally widespread units, which are considered as good regional markers for stratigraphic correlation. An ability to correlate the same stratigraphic level to other fields improves understanding of depositional framework and their lateral variation, especially marine influence in other parts of the basin, (e.g. marine incursion is expected in the Moragot area, which is located to the east of the South Pailin).

However, this regional marine shale correlation is more applicable to low-slope basins rather than high-slope basins, as transgressive events occur further landward generating consistent widespread depositional units. In contrast, in high-slope basins and high structure areas, (e.g. basin flanks) the transgressive deposits tend to be relatively thin, have a restricted area and limited lateral extent, which makes them not very useful for regional stratigraphic correlation.

Marginal marine coal and non-marine coal are also not helpful for regional stratigraphic correlation, as they tend to have a limited lateral extent. Also non-marine coal has indistinct wireline log characteristics. However, some marginal marine coal is used as a main stratigraphic marker in the South Pailin, as it is widespread and associated with an adjacent marginal marine shale unit. There is some correlation uncertainty as locally the lithology changes from coal to coaly mudstone in the same stratigraphic level.

In the study area, faults zones were active during late to middle Miocene deposition, when a thick section developed in the basin center and a thinner section developed toward the east where some wells used in this study are located.

This may be responsible for thin marginal marine sediments present in those wells. Thin transgressive sediments, which are mainly fine-grained, are difficult to detect in wireline log data, as the bed thickness is less than wireline resolution, so that a short-lived transgressive event may not be recognized when they are present within fluvial successions. This results in underestimating marine influence in the study area and it also may apply to other parts of the Gulf of Thailand.

As the late lower to middle Miocene is one of the major pay intervals in the Pailin Field, the widespread organic-rich sediments are a possible efficient seal. Understanding the depositional character of marginal marine sediments can improve the prediction and development of reservoirs with respect to transgressive-regressive depositional cycles and their reservoir characteristics as reservoir properties are different in the different phases. As widespread marine influence occurred during the late lower Miocene, especially in the middle Miocene, fluvial sandstone is expected to have more tidal influence, which may reduce reservoir porosity and permeability. Moreover, seismic amplitude mapping may be occasionally unreliable, as strong amplitude responses cannot discriminate gas filled reservoirs from coals.

5. Conclusion

Conventional cores, wireline log, palynology and petrography data in the South Pailin area were integrated to characterize different types of organic-rich sediments and their depositional environments. The study findings are:

1) There are three types of organic-rich sediments in the South Pailin area: marginal marine shale, marginal marine coal, and non-marine coaly mudstone.

2) The associated facies include marginal marine sand deposits and non-marine strata deposited in fluvial channels and overbank. Some fluvial successions are tide-influenced.

3) Two major marine transgressions occurred during the late lower Miocene and middle Miocene.

4) Wireline log data cannot distinguish marginal marine and non-marine sediments and cannot define marine transgressions.

5) Marginal marine shale has distinctive low-resistivity log characteristics and is widely distributed. It is the best geological marker in the South Pailin area and also potentially correlates to other fields.

6) Marginal marine coal has high gamma ray with low to moderate density log characteristics with limited lateral extent and is a fair geological marker in the South Pailin area.

7) Non-marine coaly mudstone has indistinct log characteristics and is not useful for stratigraphic correlation.

6. Acknowledgements

I would like to express my deeply sincere thanks to my supervisor, Professor Joseph Lambiase for his patient guidance, willing support and encouragement, and useful suggestions for this research. I am grateful to Chevron Thailand Exploration and Production, and Mr. Ken Werner, Geology Manager for the opportunity and Master Degree of Petroleum Geoscience program scholarship at Chulalongkorn University and also their data and budget support for this thesis. I would also like to extend my grateful thank to Mrs. Chalermporn Mangkang for her encouragement and support on core data.

7. References

Brady, L.L., and Hatch, J.R., 1997, Chemical analysis of Middle and Upper Pennsylvanian coals from southeastern Kansas, Kansas Geological Survey Bulletin 240, p. 43-62.

Choy, S. C. and W. E. Booth, 1994, Prolonged inundation and ecological changes in an Avicennia mangrove: implications for conservation and management, Hydrobiologia 285 (1-3), p. 237-247.

McCabe, P.J., 1984, Depositional models of coal and coal-bearing strata, in Rahmani, R.A., and Flores, R.M., eds., Sedimentology of coal and coal-bearing sequences: International Association of Sedimentologists, Special Publication 7, p. 13-42.