

Significant Erosion during Development of the Middle Miocene Unconformity and Its Effect on Hydrocarbon Generation in the Gulf of Thailand*

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Abstract

More than 20 oil and gas fields are located in the Pattani Trough in the Gulf of Thailand. The Pattani Trough is rift type sedimentary basin of Tertiary age and is approximately 200 kilometers in length and 50 kilometers in width. Maximum thickness is more than 7500 meters divided into five sedimentary units from Unit 1 to Unit 5. Main reservoirs are deltaic to fluvial sandstones (Units 3 and 4) and the source rocks are lacustrine shales of Oligocene age and coaly shales of middle Miocene age (Units 1 and 3, respectively). Structural style is graben-anticline or collapsed anticline.

Although the presence of the middle Miocene Unconformity (MMU) of 10.5 Ma is well understood in the Gulf of Thailand and is commonly observed in other areas of offshore Southeast Asia, eroded thickness is not well documented because the erosional surface is located in Unit 4, in which key marker beds are poorly developed due to the predominant continental sedimentation. There has been little attention paid to the eroded thickness of sediments as an input to basin modeling. The eroded thickness in the Erawan gas field is estimated to be approximately 4500 feet based on the shale compaction trend analysis using sonic log data. Interval velocities at the Erawan-1 well changes from 8400 feet/sec in Unit 5 to 10,800 feet/sec in Unit 4 below the MMU with an increase of more than 20% but only within a couple hundred feet apart in actual separation. Another supporting evidence for erosion at the MMU is the “Paleo-Anticlinal structure” that was present at a time of the MMU.

There is no report on reverse faults in the Gulf of Thailand although more than 2000 wells have been drilled so far. This observation contradicts the above hypothesis. However, there are many large anticlines of Mesozoic and Paleozoic sediments onshore Thailand (Khorat) formed by the Himalayan orogeny during Tertiary age. Therefore, it is most reasonable to assume that this kind of deformation may have also occurred in the Gulf of Thailand.

This hypothesis suggests that this significant erosion at the MMU may have an impact on the pattern of hydrocarbon generation and accumulation in the Gulf of Thailand.

Introduction

More than 20 oil and gas fields in the Gulf of Thailand have been discovered since the first discovery was made at the Erawan structure in 1970 (Figure 1). Most discoveries are located in the Pattani Trough and are of Tertiary age. The Pattani Trough is a rift type sedimentary basin and is approximately 200 kilometers in length and 50 kilometers in width. Maximum thickness is more than 7500 meters and is divided into five sedimentary units from Unit 1 to Unit 5 (Figure 2). The Erawan gas field is located in the western margin of the Pattani Trough, which is a highly faulted graben anticline 30 km long and 8 km wide (Figure 3). Main reservoirs are deltaic to fluvial sandstones (Units 3 and 4), and the source rocks are lacustrine shales of Oligocene age and coaly shales of middle Miocene age (Units 1 and 3, respectively). The dual petroleum systems are active in the basin. The dominant petroleum system is made up of Miocene gas-generating terrestrial coals and shales currently mature in the deeper central portion of the basin (Jardin, 1997). Migration pathways are relatively short to charge interbedded sandstone reservoirs. Leaky fault traps require active charge to sustain gas accumulations. The second system consists of Oligocene oil-prone lacustrine shales mature in basin flank areas but over-mature in the central trough. Oil is found on basin slopes where it has migrated into overlying Miocene reservoirs via basement onlap and fault conduits. Additionally, early oil generated in basin axis regions may be trapped in older, stable structural highs. In general, gas and condensate fields are predominant in the southern Pattani Trough and oil and gas fields are located in the northern part of the Pattani Trough.

Estimation of Erosion Thickness -- Middle Miocene Unconformity (MMU)

Although it is well understood in the Gulf of Thailand that the middle Miocene Unconformity (MMU) of 10.5 Ma is commonly observed in the offshore Southeast Asia, its erosion thickness and tectonic implications are not well documented because its erosional surface is located in Unit 4 in which key marker beds are poorly developed due to the predominant continental sedimentation. For this reason there has been almost no attention paid to the erosional thickness in basin modeling. There are some common methods to estimate erosional thickness such as: a) well and seismic correlation, b) stratigraphic correlation, c) vitrinite reflection correlation, d) velocity correlation, and e) shale compaction trend (Magara, 1978) as shown in Figure 4. In the Gulf of Thailand, it is almost impossible to correlate wells in Unit 4 in which the MMU overlies Unit 4. Therefore, shale-compaction trend methods were applied into the Erawan field area because there is enough well data from almost the seabed to total depth. Its erosional thickness in the Erawan gas field was estimated to be approximately 1372 meters, based on the shale-compaction trend analysis using sonic log data in which there are more than 10 wells (Figure 5). Interval velocity at the Erawan-1 exploratory well changes from 2560 meters/sec in Unit 5 to 3292 meters/sec in Unit 4 below the MMU (Figure 6). Interval velocity at the Erawan-1 well increases by more than 20% from Unit 5 to Unit 4 only within a couple hundred meters. Other supporting evidence for erosion at the MMU is the “Paleo-Anticlinal structure” at the time of the MMU, as shown in Figure 7. In turn, an anticlinal structure at the Erawan field was already formed by the time of formation of the MMU, although some normal faults cut the MMU, which had been active until recently. As such, this evidence suggests significant erosion during formation of the MMU at the Erawan field. In

addition, the same amount of erosional thickness (1981 m) by the shale-compaction trend analysis at the nearest field, Baanpot, was also obtained.

Discussion

There is no report on reverse faults in the Gulf of Thailand although more than 2000 wells have been drilled so far. Yet the erosion thickness tends to suggest they may be present. Also, there are several large gentle anticlines in onshore Thailand (Khorat), such as Kuchinarai and Phu Phan anticlines in which Mesozoic and Paleozoic sediments were uplifted by the Himalayan orogeny during Tertiary age due to the collision of the Indian Plate with the Asian Plate. This kind of deformation may have occurred in the Gulf of Thailand. Therefore, it is reasonable to suggest that because the initial sedimentary basin was formed in the Oligocene, synrift sediments were accumulated under a tension regime until time of formation of the MMU. Then, lateral compression uplifted Gulf of Thailand, after which compression waned, and the Gulf of Thailand returned to a tension regime.

Conclusions and Recommendations

A considerable amount of the thickness is estimated to have been eroded during development of the MMU at Erawan field, but a certain degree of error is possible due to the compaction trend. This hypothesis suggests that the substantial erosion represented by the MMU may significantly impact the pattern of hydrocarbon generation and accumulation in the Gulf of Thailand.

To confirm this hypothesis the following studies are recommended:

- Further work to determine thickness of strata that were eroded in other fields in the Gulf of Thailand.
- Other data, such as vitrinite reflectance and interval velocity data, should be collected and analyzed.
- Correction of published papers in Asia regarding the MMU.

References

Jardin, E.,1997: Dual petroleum system governing the prolific Pattani Basin, offshore Thailand: Indonesian Petroleum Association Proceedings of the Petroleum System of SE Asia and Australasia Conference, p.351-363.

Magara K., 1978: Compaction and Fluid Migration: Developments in Petroleum Science, no. 9, Elsevier, Amsterdam, 319p.

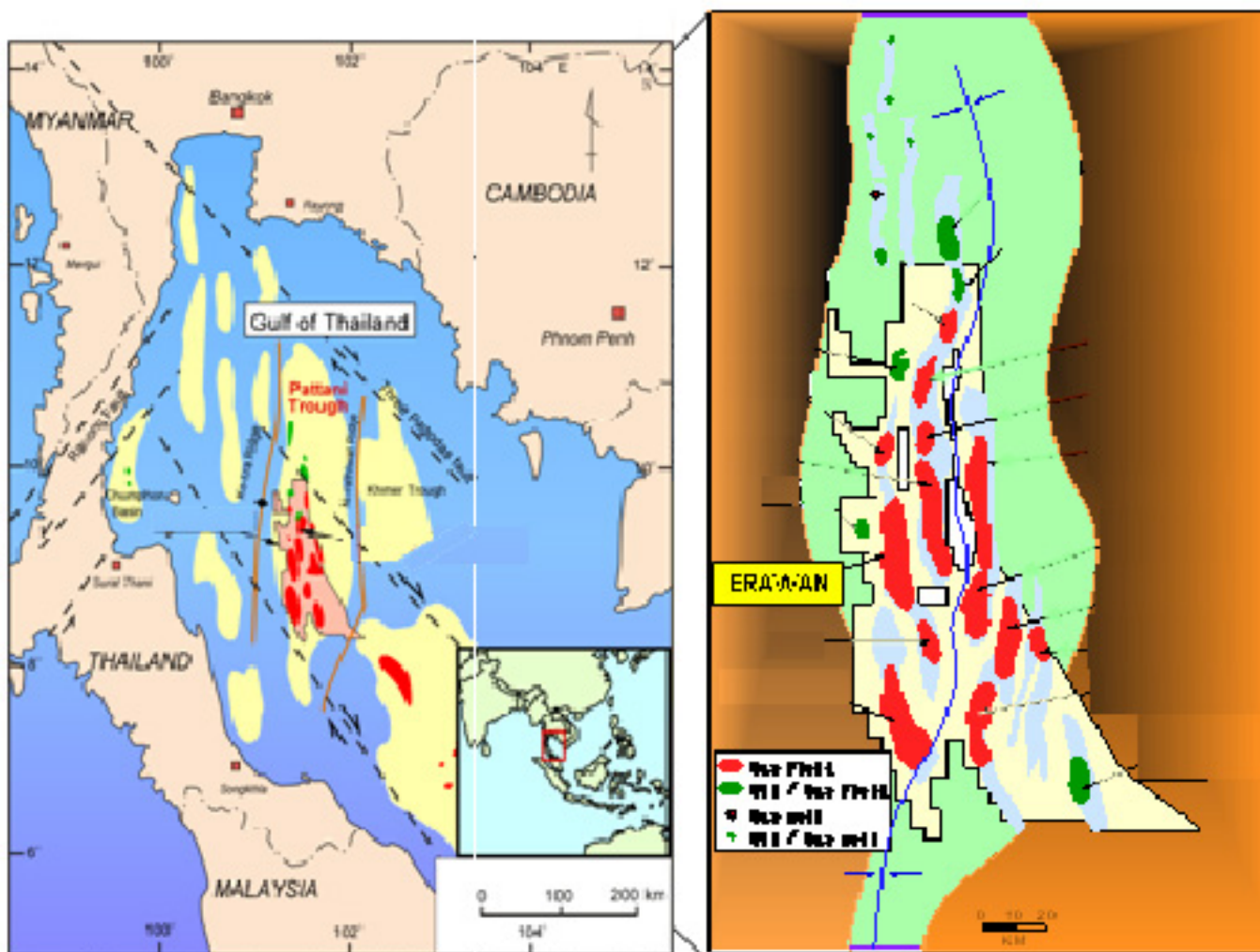


Figure 1. Location map of the Erawan gas field in the Gulf of Thailand.

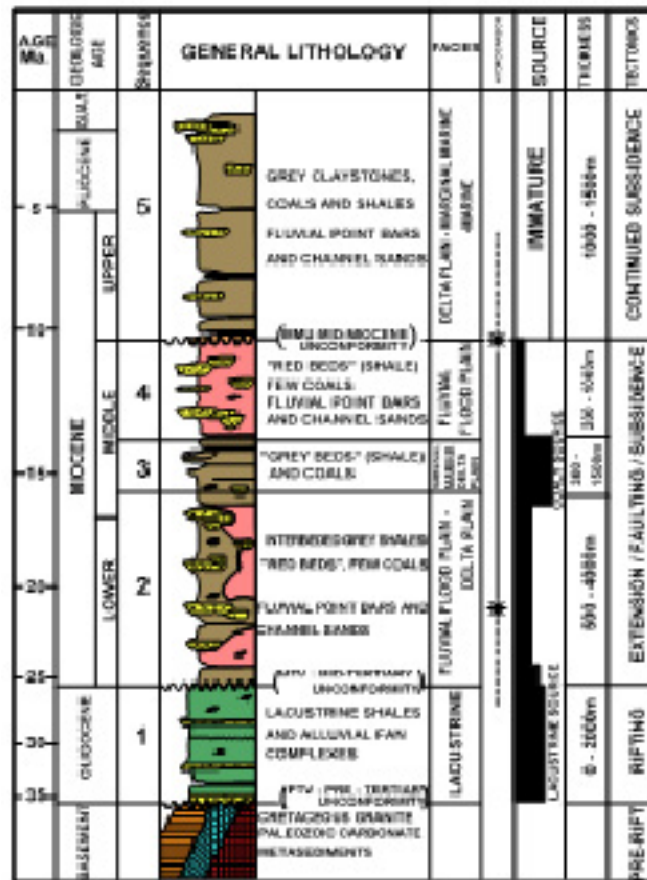


Figure 2. Generalized stratigraphy of the Pattani Trough (Jardin, 1997).

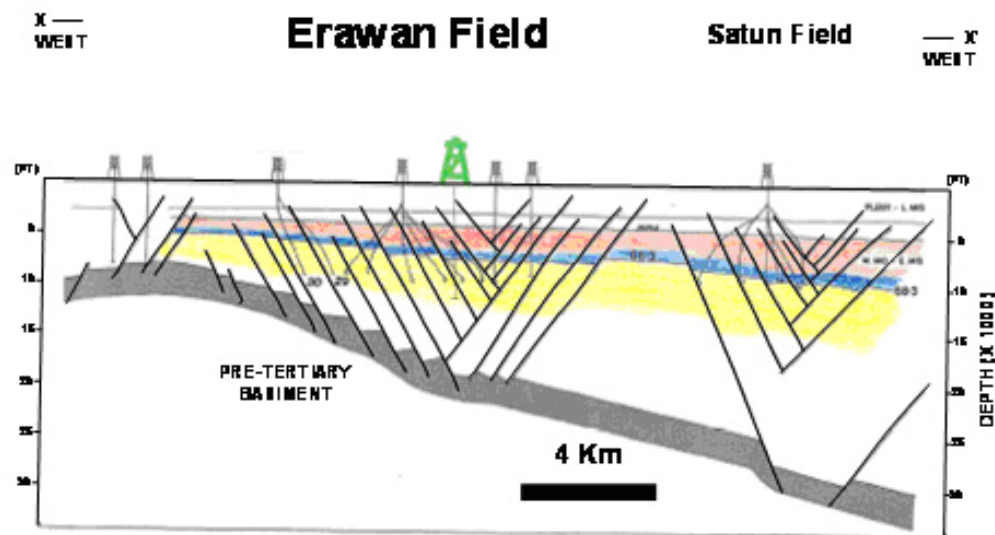


Figure 3. Geologic cross section through the Erawan gas field.

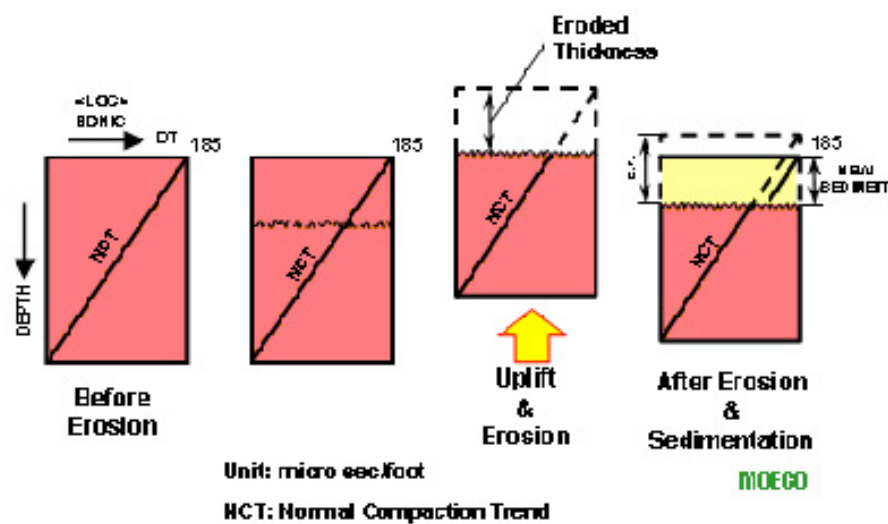


Figure 4. Estimation of eroded thickness from sonic log (Magara, 1978).

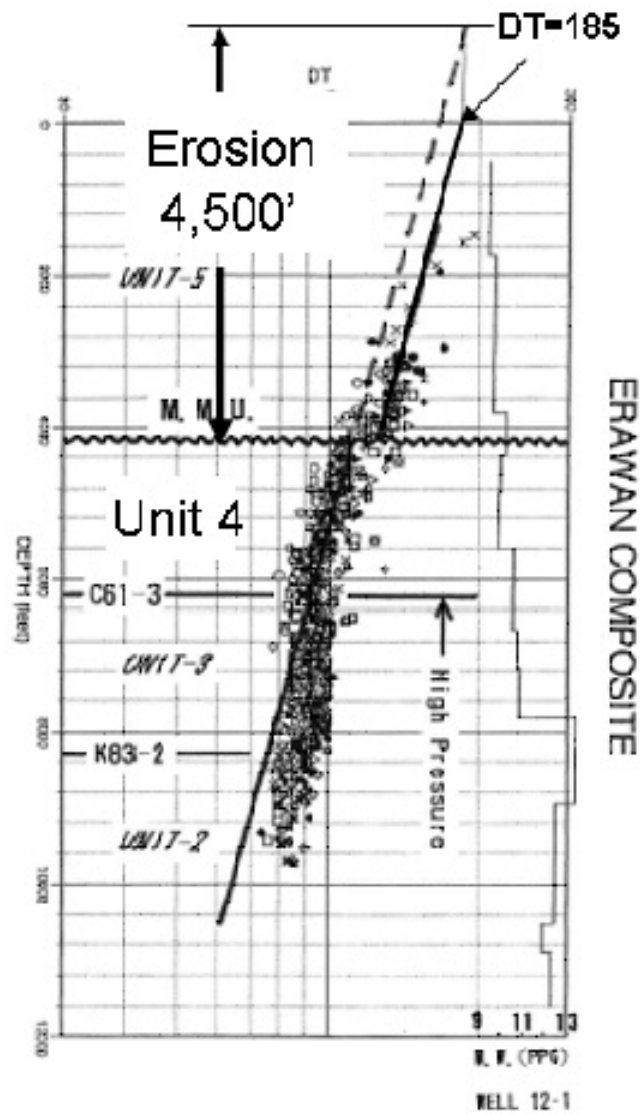


Figure 5. Shale compaction trend of Erawan field.

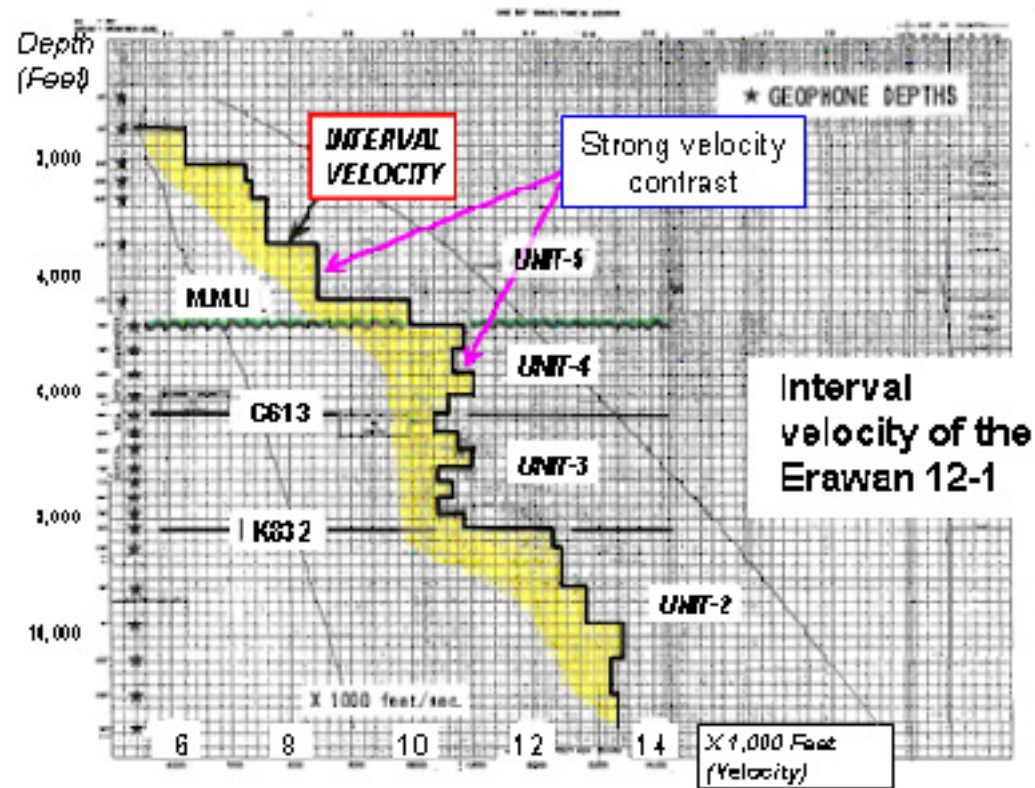


Figure 6. Interval velocity of the Erawan 12-1 well.

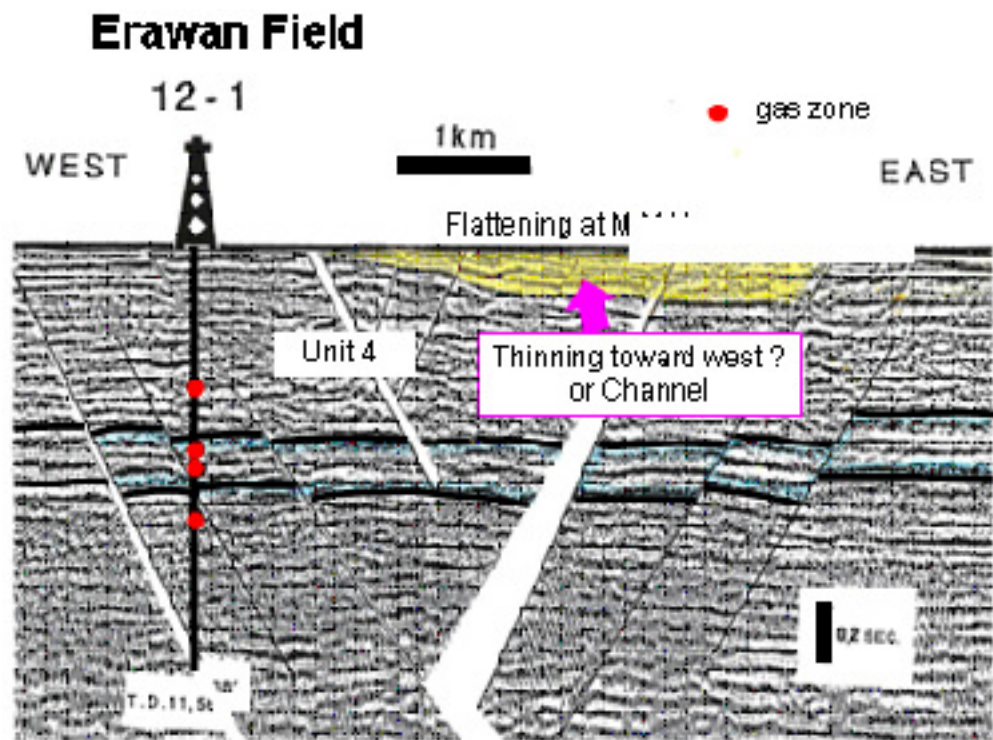


Figure 7. Flattening at the MMU at the Erawan gas field, showing gentle anticline.