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Organic-rich tropical rivers and their role in CO2 and methane generation

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Introduction

Reservoirs with high CO2 contents are common throughout the Asia Pacific region, notably the Gulf of Thailand, Malaysia, Indonesia and Vietnam. Typically, the source of the CO2 is considered to be from deep thermogenically altered basement or carbonates, and indeed in some regions, this is the origin of the CO2. However, in many cases, the high CO2 reservoirs are found shallow in the section or are isolated from deep-generated CO2. In these reservoirs, diagenetic breakdown of organic material can generate significant amounts of CO2.

CO2 Distribution, North Malay Basin

The amount of CO2 encountered in wells in the North Malay Basin (Figure 1) varies from a few percentage points to as high as 90%. In that the percent CO2 has a significant impact on the economic value of the sales gas, it is important to understand the source and the distribution of the CO2 so as to avoid those reservoirs where the percent CO2 exceeds the economic threshold.

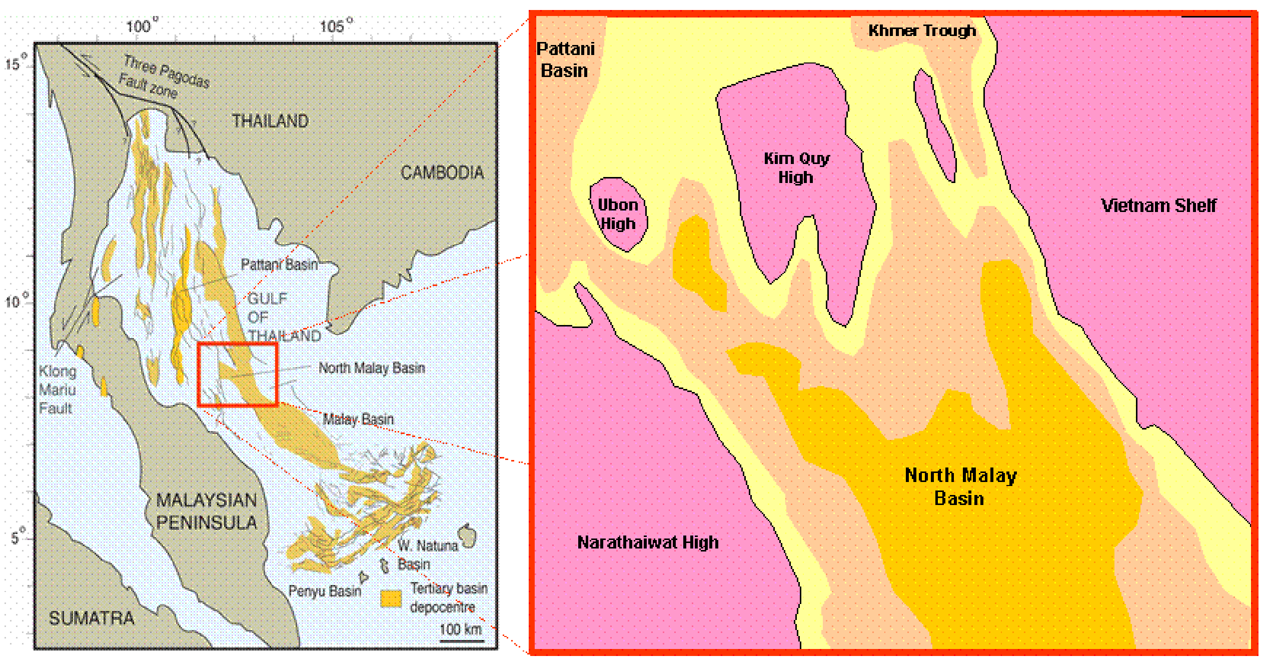
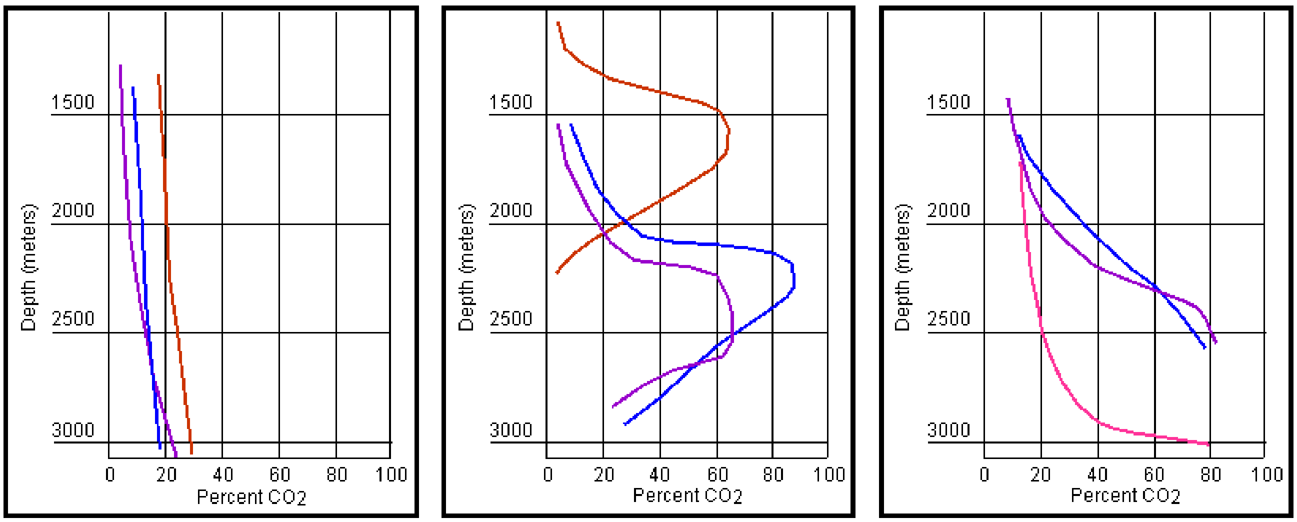


Figure 1: North Malay basin

North Malay Basin wells exhibit three trends in regards to the percentage of CO2 with depth (Figure 2). In the first trend the percent CO2 can be seen to increase gradually with depth from 0% to approximately 30% or less. In the second trend, the percentage of CO2 can be seen to increase with depth from 0% to approximately 80% or higher, before decreasing back to 10 to 30%. The depth and the Formation in which the maximum percentage of CO2 is observed to vary from well to well. The third depth versus CO2 percentage trend observed in the North Malay Basin is characterized by a relatively rapid increase in the percentage of CO2 from 0% to approximately 80% or higher. No break back to lower CO2 percentages are observed in this CO2 trend, however, the maximum CO2 values are encountered near the well TD. It is conceivable that had these wells drilled deeper, a reduction of CO2 percent may have occurred.



Trend 1 **Trend 2** **Trend 3**

Figure 2: North Malay Basin CO_2 Trends

The most prevalent theory for the origin of the inorganic CO2 in the North Malay Basin, is that it is generated by the thermal breakdown of carbonates, presumably in the basement. Although Eocene-aged carbonates occur in the regions offshore Borneo and in portions of the Gulf of Thailand, they are not known to occur in the North Malay Basin. It is possible that the basement underlying the basin consists of metamorphosed Permo-Triassic Ratburi carbonates such as those encountered in the Chumphon rift basin to the north and west of the North Malay Basin. However, cuttings from wells that encountered basement indicate that the North Malay Basin is underlain by granitic basement. Therefore, it seems unlikely that carbonates are the source.

The second possible explanation for the inorganic CO2 encountered in the North Malay Basin is that it is sourced from the mantle. It is possible that mantle-generated CO2 migrates into the shallow section along deep-seated faults. If mantle-derived CO2 is the source of CO2 in the North Malay basin, it would be expected that the percent of CO2 would increase with depth as observed in trend 3. However, the decrease of CO2 percent with depth as seen in trend 2 is not readily explained by migration of mantle-derived CO2, or any deep-sourced CO2.

Diagenetically sourced CO2

The most-likely source for CO2 in the North Malay Basin is from in-situ generation during diagenesis. It has been shown that the interaction between organic and inorganic constituents in a sedimentary sequence undergoing diagenesis during progressive burial can play a major role in generating CO2 (Surdam et al, 1989).

In the first stage of this diagenetic process, bacterial decomposition of interbedded organic material will result in the generation of carboxylic acid anions. At reservoir temperatures between 80^{o} and 120^{o} C the concentrations of carboxylic acid anions will increase exponentially (Figure 3).

As formation temperatures increase with increased burial, the carboxylic acid anions are destroyed by thermal decarboxylation. Although destruction of carboxylic anions will initiate at approximately 100^{o} C, the maximum rate of carboxylic anion destruction occurs between 120^{o} and 200^{o} C (Figure 3). During the process of thermal decarboxylation, both methane and CO2 are generated (Equation 1).

Equation 1: $CH_3COOH \rightarrow CH_4 + CO_2$

The process of CO2 generation by diagenesis seems to provide the best explanation for the distribution of CO2 observed in the North Malay Basin. The highest concentration of CO2 in the North Malay Basin occurs in the northernmost portion of the basin in the region of the Kim Quy High. The present-day reservoir temperatures across the Kim Quy High range from 100^{o} C and 140^{o} C which are ideal for the generation of CO2 through thermal decarboxylation.

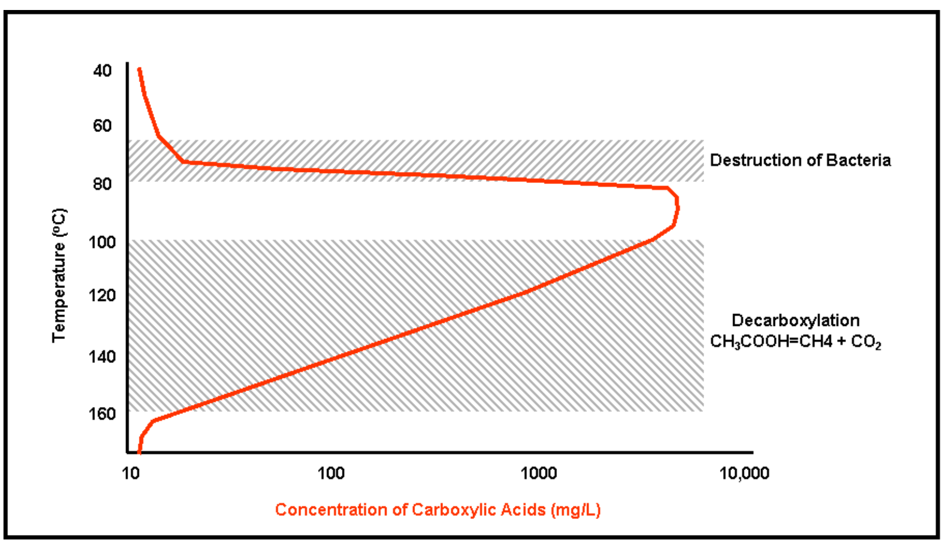


Figure 3: Organic-Inorganic Interactions and Sandstone Diagenesis, Surdam et al, 1989

Organic-rich Tropical Anastomosing Rivers

Depositional settings in which large amounts of organic-rich material are deposited are common in tropical settings, notably mangrove and peat-forest swamps. In addition to the deposition of coals and thick layers of organic-rich shales, outcrops of clastic reservoirs deposited in tropical estuarine settings typically contain abundant laminations of organic matter. However, deposition throughout much of the North Malay Basin was dominated by fluvial systems, not estuarine systems. Did these river systems deposit enough organic material for diagenesis to be the source of the CO2 observed in the North Malay Basin?

A satellite study of modern tropical rivers in northern Thailand indicates that when rivers in tropical climates enter wide valleys, they tend to change from a meandering river into a multi-branching anastomosing river. Seasonal monsoons ensure that for most of the year, the river valley is flooded, forming an ephemeral lake or wetland. As the rivers flow through these flooded wetlands, they deposit extensive levee and crevasse splay sediments along the length of the valley. Tributaries flowing into the valley develop fluvial-fan deltas along the margins of the valley. As a result, the alluvial fill of these wide valleys consists of mixed coarsening upward deltaic and crevasse splay deposits interbedded with fining upward channel deposits as well as organic-rich muds and peats. These inter-channel wetlands comprise between 30 and 60% of the valley area. Individual wetlands can range in area from a few square meters to many square kilometers. (Figure 4).

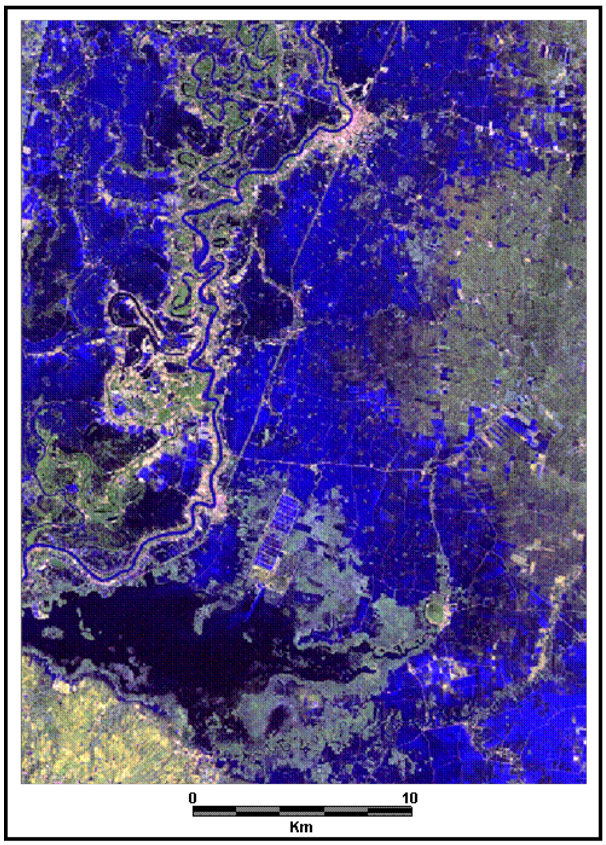
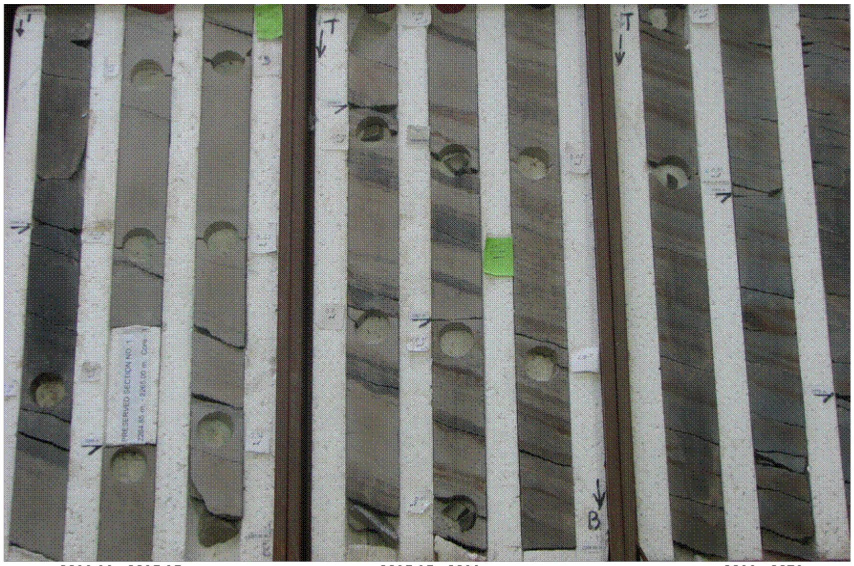


Figure 4: Wet season Inter-channel wetland, northern Thailand

Several cores acquired in the North Malay Basin confirm the presence of interbedded laminations or organic-rich mudstone in fluvial – crevasse splay deposits (Figure 5). Additional cores, acquired more distal to the channels encountered several meters of peat in addition to the laminated organic material observed in the crevasse splay deposits. Therefore, it is possible to conclude that the amount of organic material deposited in tropical river systems can be the source for much of the CO2 encountered in the North Malay Basin.



2263.68 - 2265.85 | 2265.85 - 2268 | 2268 - 2270

Clean SS | **Lam SS** | **Shaley Lam SS**

Figure 5: North Malay Basin Core, channel to crevasse splay facies