Bulletin of Earth Sciences of Thailand

Carbon Dioxide Distribution in Erawan, Platong and Pailin Fields, Gulf of Thailand

Weerawat Kongnonkok

Petroleum Geoscience Program, Department of Geology, Faculty of Science,
Chulalongkorn University, Bangkok 10330, Thailand

*Corresponding author email: sonic_plug@hotmail.com

Abstract

The Platong, Erawan and Pailin fields which have very good hydrocarbon potential are located in the Pattani Basin in the Gulf of Thailand. However, high carbon dioxide percentages within the producing reservoirs are the major problem for these fields production. This study aimed to identify possible sources of the carbon dioxide and to understand the distribution patterns of carbon dioxide in each field by using geochemistry for source identification and structural mapping to identify possible migration pathways. The geochemical analysis suggests that the main carbon dioxide source of the Platong, Erawan and Pailin fields comes from mineral decomposition of basement rocks. There is minor component from carboxylation of organic matter in Pailin field. Carbon dioxide migrated from source to primary reservoir by faulting. Basement penetrating faults are the major component that control vertical migration. Secondary faults provide minor lateral migration. These structures are formed above hinge zones of basement. The graben position above basement also controls the degree and continuity of gas charging. In general the carbon dioxide content increases with depth towards the source and is relatively high around the graben margins. However the charging history, stratigraphic complexity and structural styles are complex factors which affect the distribution pattern also, and produce variations from the simple model developed in this study.

Keywords: Carbon dioxide distribution, Gulf of Thailand

1. Introduction

The Platong, Erawan and Pailin fields are situated in the Pattani Basin in the Gulf of Thailand that has very good hydrocarbon potential. These fields have produced commercial gas to supply energy since 1981. However, not only commercial gas has been produced from the reservoirs. Non-commercial gases such as carbon dioxide and nitrogen are also produced associated with the commercial gas. Consequently, the gas monetary value is decreased because non-hydrocarbon gases decrease the gas BTU by dilution. High carbon dioxide reservoirs are still not well understood and are a major problem for Platong, Erawan and Pailin Fields production. Therefore, to lower the risk of high carbon dioxide production, the distribution of carbon dioxide and its related origin and migration should be well understood.

The Pattani Basin is unique in terms of its geological setting but has limited possible sources for carbon dioxide. Thus the Platong, Erawan and Pailin fields, which are located in the central and south of Pattani Basin, are thought to have identical origin of carbon dioxide. However the structural fabric varies from central to south in the basin and this variation affects the distribution pattern of carbon dioxide because carbon dioxide migration is structurally controlled, the same as hydrocarbon migration is.

This study aimed to identify possible sources of carbon dioxide in the area of interest and to understand the distribution patterns of carbon dioxide in each field. An integrated approach using geochemistry for source identification and structural mapping to identify possible migration pathways was used. As a result of this analysis this study will hopefully come up with a carbon dioxide distribution model that can be applied for hydrocarbon risk assessment in the fields studied and elsewhere in the basin.

2. Methods

The approach in this study has 3 parts that were used to analyze the provided data step by step. Carbon dioxide source, distribution pattern and migration pathways were considered respectively. Subsequently, all results were integrated to generate carbon dioxide distribution models for each area

Available data controlled the possibility of investigation. In this case the carbon isotope values are the only data that can help to define the source of the carbon dioxide. The carbon dioxide content was plotted against carbon isotope to consider the trend and distinguish possible sources by worldwide published comparisons.

In order to map the well test data, which include measured values of carbon dioxide percentage from several depths in the wells, it was necessary to calculate the number that represents carbon dioxide values for each well. Mean and maximums of carbon dioxide fractions were selected to post on base maps. These values were contoured based on their structural and stratigraphy relationship.

To present appropriate structural maps, key markers were selected. The regional stratigraphy and observations from well testing were used to reveal the relationship between the presence of carbon dioxide and depositional sequences. Selected mapping horizons were related to the occurrence of carbon dioxide and then used to generate time structural maps. These maps revealed structural relationship that controlled distribution patterns of carbon dioxide in each of the fields. In addition, seismic based cross-sections were over each of the fields under investigation. They focused on high carbon dioxide content areas. Low carbon dioxide content areas were also selected to compare the difference.

3. Results

3.1. Isotope Analysis

The carbon isotope plot is shown in Figure 1. All the fields show similar trends. High stable carbon isotope ratio has high carbon dioxide content. Based on the carbon isotope diagram, carbon isotopes from these three areas generally plot with values between -4 to -15 which according to Jeden (1989) indicates inorganic origin. The possible inorganic origin may come from mineral decomposition of basement rock or mantle. Whatever the case, both of them are related to deep origin. There are some values lower than -15 which indicates a possible origin from kerogen decarboxylation. This mechanism is a chemical reaction whereby organic matter releases carbon dioxide. It can occur during maturation processes.

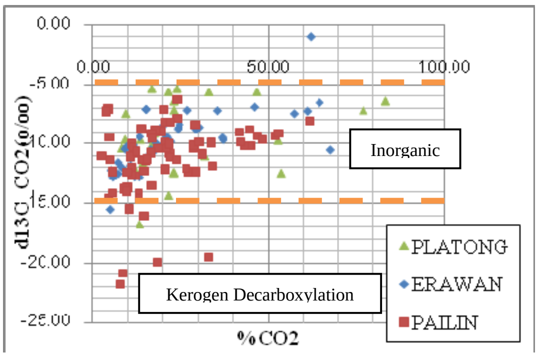

Figure 1. Stable carbon isotope ratio plotted against carbon dioxide content for three fields. Classification from Jeden, 1989.

3.2 Carbon Dioxide Distribution with Depth

The Platong field has an obvious trend which shows an increasing carbon dioxide content with depth (Figure 2). It is also clear that carbon dioxide content increases significantly around -5600' TVDSS. Below this depth the carbon dioxide content is variable but generally increasing with depth. The Erawan field data is similar to Platong field, the carbon dioxide content increasing with depth. It increases significantly around -7000' TVDSS. Carbon dioxide content varied in a narrower range compared to Platong field. In the Pailin field, carbon dioxide content also increases with depth. Clearly the carbon dioxide content increases significantly below -8000' TVDSS. Data from North Pailin area also shows a similar trend.

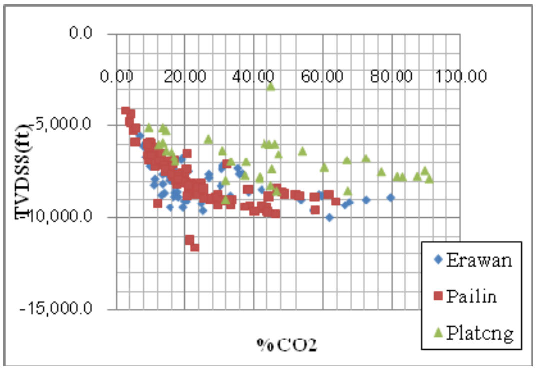

Figure 2. Carbon dioxide content of Platong, Erawan and Pailin fields plotted against depth.

3.3 Seismic Based Cross-Sections

In the Platong field, the normal faulted graben is the general structure at the reservoir level. However at depth this graben has major faults which penetrate to the basement section under the western graben margin. In the centre, minor conjugated faults are a common feature. The graben is commonly formed at the basement hinge zone where dip angle has changed. The carbon dioxide content is higher in the deeper section which corresponds to the depth plots. There is no significant difference of carbon dioxide content within each fault block. However carbon dioxide content is concentrated above the hinge zone.

The structural style in the Erawan field is similar to Platong field (Figure 3). A normal faulted graben is the general structure at reservoir level. The basement high is on the west and dips to the east. Basement penetrated faults occur where the basement changes slope at the hinge zone. Carbon dioxide content was high in the deeper part and close to basement above the hinge zone. East dipping faults have higher carbon dioxide content in general.

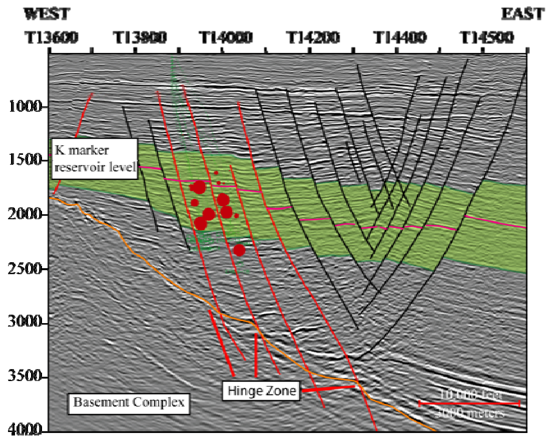

Figure 3. Cross-section A-A', Erawan field. Carbon dioxide content shown as red dot size. Basement penetrating faults are red. Location on Figure 5 and 6.

At the Pailin field, there are two structural styles. A graben that formed by east and west dipping faults is situated in the central to northern study area, similar to the structural style at Platong and Erawan. Major faults which define the graben margins cross-cut to the basement. At this position basement level is generally deeper than the area to the south. However, basement geometry still controls fault geometry as the graben occurs above basement where slope has changed. The southern part of the study area where the basement is shallower there are several faults that cut into basement. These faults dip in the same direction to the east. In terms of carbon dioxide distribution, this area shows an obvious carbon dioxide-depth relation with the carbon dioxide content increasing significantly with depth. This occurs in both structural styles. Also in the south, carbon dioxide is more widespread and uniformly distributed across the field.

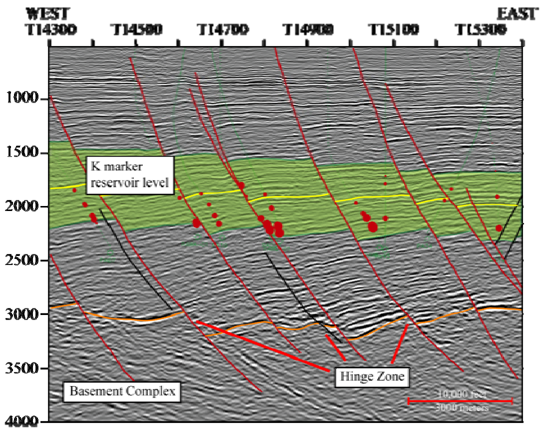

Figure 4. Cross-section across the southern Pailin field. Carbon dioxide content shown as red dot size. Basement penetrating faults are red.

3.4 Carbon Dioxide Distribution Mapping

For the Platong field, based on the D marker reservoir map, carbon dioxide is distributed in a north-south trend that conforms to the regional structure. The high carbon dioxide values tend to be on the graben margin. The carbon dioxide distribution on the basement map shows good relationship between carbon dioxide distribution and basement penetrating fault.

For the Erawan field, at the K marker reservoir level map (Figure 5), the general trend of carbon dioxide distribution was north-south trending. It is obvious that the high carbon dioxide content is associated with the graben margins. The graben margin commonly is associated with major faults that penetrate to basement. From the basement map, carbon dioxide content also shows a relationship to basement faults (Figure 6). The high carbon dioxide content zone is above basement faults.

Carbon dioxide is found mostly in the trough at the Pailin field. Based on distribution maps at the K marker reservoir level, the high carbon dioxide distribution is along the graben axis. In the northern area where basement is deep, carbon dioxide content is high above basement faults. In the south, basement is quite shallow and there are many faults penetrating to basement so carbon dioxide distribution is widespread.

4. Discussion

The sources of carbon dioxide in the fields studied are similar. Based on carbon isotope values and the classification of Jeden(1989), the source of carbon dioxide in these three fields is interpreted to be a predominantly inorganic source. The decomposition of low grade metamorphosed limestone within the basement complex most likely provides enough carbon dioxide for charging the reservoirs. However, in the Pailin field there is also a minor component from cracking of organic matter which have lighter carbon isotopes. The organic matter can generate carbon dioxide by decarboxylation during maturation.

The distribution with depth relationship of carbon dioxide also supports its sources. Without considering the migration history, the amount of gas should increase depending on distance from source to reservoir. The carbon dioxide content in these three fields is generally increasing with depth.

This indicates that carbon dioxide may come from the deep section and also that it does not migrate as easily as conventional hydrocarbon gases. However, the Pailin field has a narrower range of carbon dioxide content compared to the other fields. This difference may be caused by structural fabric that controls the migration pathway.

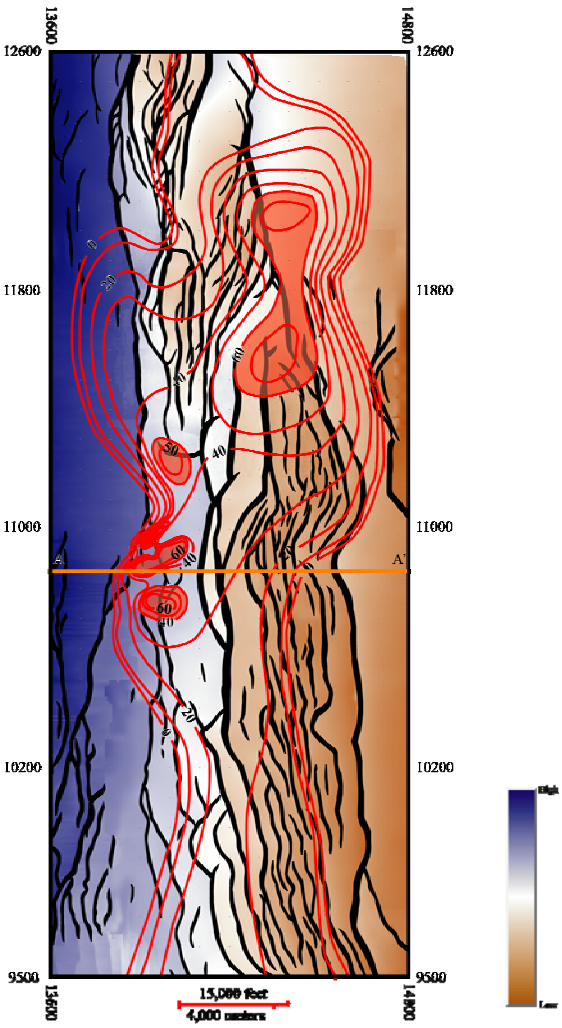

Figure 5. Maximum carbon dioxide content map superimposed on K marker and basement level structure map, Erawan field. Carbon dioxide contour values are mole percentage of the total gas.

Faults in this region provide the fluid conduits for migration. In the hydrocarbon system faults are suggested to be the major migration pathways. From the migration model, the carbon dioxide primarily came from the basement source to the reservoir along the major faults. There, fault intersection caused secondary migration. This

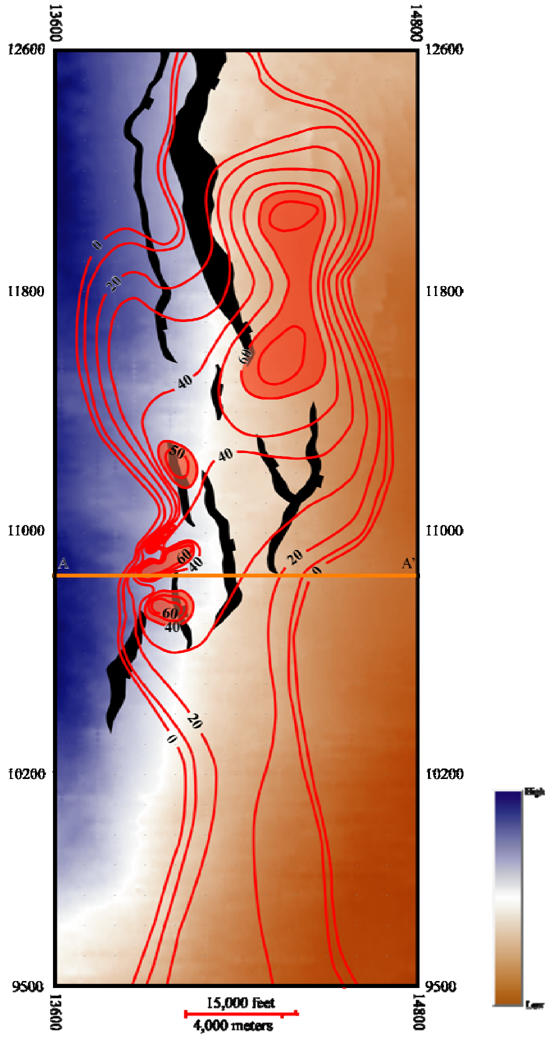

Figure 6. Maximum carbon dioxide content map superimposed on basement level structure map, Erawan field. Carbon dioxide contour values are mole percentage of the total gas.

mechanism improves migration across fault blocks when the geological stratigraphy cannot effectively provide lateral migration. Seismic based cross-sections also the show relationship between faults and basement structure. The grabens generally form above hinge zones in the basement. At this zone, basement surface changes to higher dip angles that caused failure of the section above. The southern Pailin field is a good example for fault related migration (Figure 7). The carbon dioxide in this field consistently increases with depth and also is widespread where there is high fault density penetrating to basement. The carbon dioxide distribution in Platong and Erawan fields are slightly different from that model (Figure 8). Migration history, complex stratigraphy and structural style are the main reasons. However, generally these fields have a similar trend of distribution.

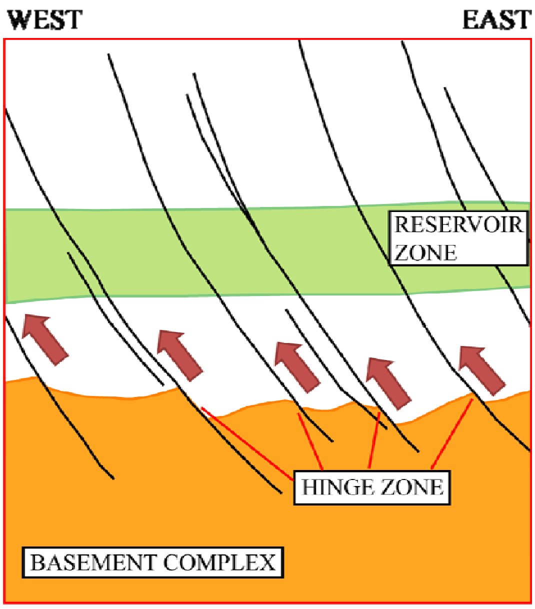

Figure 7. Migration model of carbon dioxide in the southern Pailin field. Red arrows represent migration direction.

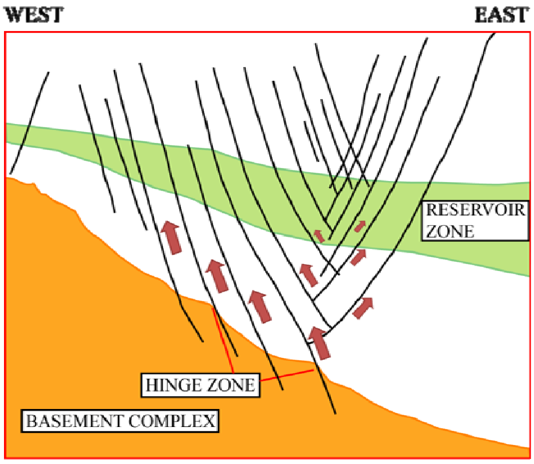

Figure 8. Migration model of carbon dioxide in Erawan field. Red arrows represent migration direction.

Carbon dioxide distribution in Platong, Erawan and northern Pailin field are relatively concentrated where the reservoir is close to the graben margin. Where basement dips to the east, east dipping faults have relatively high carbon dioxide content associated with them compared to west dipping faults. These faults conform to basement faults that penetrate up to the reservoir section. This also confirms that the carbon dioxide is basement sourced.

5. Conclusions

An investigation of carbon dioxide distribution in the Platong, Erawan and Pailin fields indicate that mineral decomposition of basement rocks is the main carbon dioxide source of the Platong, Erawan and Pailin fields. There is also a minor component from carboxylation of organic matter in Pailin field. Basement penetrating faults are the major component that control graben formation and vertical migration of carbon dioxide. Fault intersections cause secondary migration that also provides the minor lateral migration. These structures are formed above hinge zones at basement level. The graben position above basement also controls the degree and continuity of gas charging. The carbon dioxide content generally increases downward and relatively high around the shallow graben margins. However the charging history, stratigraphic complexity and structural style are the main causes of inconsistency.

6. Acknowledgements

I would like to express my sincere gratitude to Chevron Thailand Exploration and Production, Ltd (CTEP). I am very grateful and indebted to Prof. Philip Rowell and extend my grateful appreciation to Prof. John Keith Warren. I would like to thank Mr. Jim Logan Jr. and also thank my colleagues. Finally, I also would like to thank the Chulalongkorn University staff. The last thanks are for my family and all my friends.

7. References

Bustin, R. M. and Chonchawalit, A., 1997. Petroleum source rock potential and evolution of Tertiary strata, Pattani Basin, Gulf of Thailand, AAPG Bulletin, v. 81, no. 12, p. 2000-2023.

Jardine, E., 1997. Dual petroleum systems governing the prolific Pattani Basin, offshore Thailand, Petroleum systems of S.E. Asia and Australasia Conference, Jakarta, May 21-23, 1997, p. 351-363.

Jenden, P.D. and Kaplan I.R., 1989. Analysis of gases in the earth's crust, Collection of papers about the oil, gas and source rock geochemical investigations, AAPG Pacific Section, 2009.

Kornsawan, A. and Morley, C.K., 2000. The origin and evolution of complex transfer zones (graben shifts) in conjugate fault systems around the Funan Field, Pattani Basin, Gulf of Thailand. Journal of Structural Geology, v. 24, p. 435-449.

Lian, H.M. and Bradley, K., 1986. Exploration and Development of Natural Gas, Pattani Basin, Gulf of Thailand. Transactions of the Fourth Circum-Pacific Energy and Mineral Resources Conference, 1986.

Watcharanantakul, R. and Morley, C. K., 2001. Syn-rift and post-rift modeling of the Pattani Basin, Thailand: evidence for a ramp-flat detachment. Marine and Petroleum Geology, v.17, p. 937-958.