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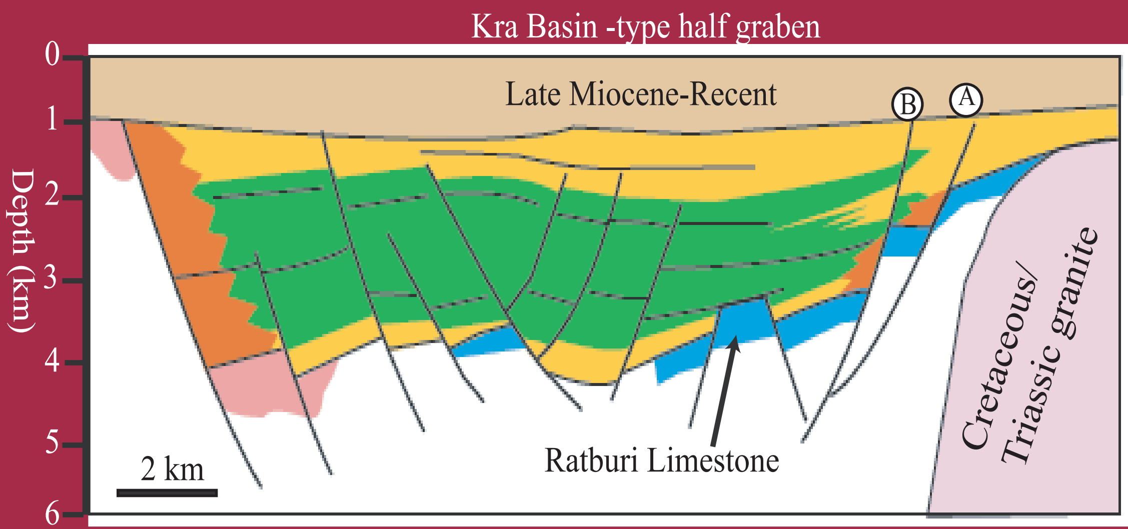

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Cover: A schematic model of the Kra Basin (page 3)

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Preface

The Bulletin of Earth Sciences of Thailand (BEST) has established itself as an international academic journal of the Geology Department, Chulalongkorn University (CU) since the year 2008. This Number 2 issue of Volume 3 is devoted specifically to the publications contributed by the International Petroleum Geoscience M.Sc. Program of the Geology Department, Faculty of Science, CU for the academic year 2009/2010. Certainly this Bulletin has attained more and more international recognition, not to mention the citation of publications in previous volumes, as can be seen from the contributions of 17 research papers by international students of the M.Sc. program. This program is an intensive one year curriculum that has been taught in the Geology Department of CU in the academic year 2009/2010 for the first year. These scientific papers were extracted from the students' independent studies which are compulsory for each individual student in the program. Because of the confidentiality reason of a number of contributions, the requirement of the Chulalongkorn Graduate School as well as time constraints of the program, only short scientific articles were able to release publicly and publish in this Bulletin.

Lastly, on behalf of the Department of Geology, CU, I would like to acknowledge the Department of Mineral Fuels, Ministry of Energy, Chevron Thailand Exploration and Production, Ltd, and the PTT Exploration and Production Public Co., Ltd., for providing full support for the Petroleum Geoscience Program and the publication cost of this issue. Sincere appreciation also goes to guest editors; Professors Joseph J. Lambiase, Ph.D., John K. Warren, Ph.D., and Philip Rowell, Ph.D., the full-time expat staff, for their contributions in editing all those papers. Deeply thanks also go to Associate Professor Montri Choowong, Ph.D., the current editor-in-chief, and the editorial board members of the BEST who complete this issue in a very short time. The administrative works contributed by Ms. Suphannee Vachirathienchai, Ms. Anamika Junsom and Mr. Thossaphol Ditsomboon are also acknowledged.

Associate Professor Visut Pisutha-Arnond, Ph.D.
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August 2010

Diagenetic and Isotopic Evolution Recorded in Calcite Cements in a Large Indosinian Fault Zone in Permian Platform-interior Carbonates, North Central Thailand

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Abstract

Diagenetic evolution and fracture style is recorded in calcite cements in fault-damage zones in outcrops of a strike-slip fault and a nearby thrust fault in the Permian Saraburi (Ratburi) Limestone, western Khorat Plateau, Northeast Thailand. Two fractures patterns were identified with respect to the strike slip and thrust fault zones. Releasing bends of the strike-slip fault facilitated higher fluid mobility than the damage zone in the nearby thrust fault. Such releasing bends show a higher degree of calcite infilling and preserve multiples stage of cementation. Petrography and isotopic data indicate a sequential diagenetic evolution, which started with marine diagenesis (eogenesis), followed by early mesogenetic (early burial) dolomitization and chert nodule development in the matrix, then mesogenetic calcite cementation (non-ferroan and ferroan calcite) and later mesogenetic calcite cementation as high temperature hydrothermal non ferroan cement focused in the fault related fractures. Radiogenic concentrations in the later stages of the cementation history give an elevated peak to the gamma ray signature which in similar uncored intervals in the subsurface could be misinterpreted as a shale zone or a flooding surface in the carbonate platform.

Keywords: Isotopic, diagenetic evolution, Permian carbonate, Indosinian fault zone

1. Introduction

Permian platform carbonates in the study area have been experienced several diagenetic stages preserved in the multiple stages of burial cements and associated fracturing events. Understanding the evolution of the porosity occlusion and creation associated with these events gives a model for understanding porosity in subsurface counterparts.

2. Data and Methods

All the data sets utilized in this research are derived from outcrop observation. Several representative samples from a limestone quarry and road-cut in Highway 12 were selected for thin section, XRD, stable isotope determination, and spectral gamma ray measurements across limestone outcrops in the Chumphae areas (Figure 1). Half of each thin section was stained with Alizarin Red S - potassium ferricyanide in order to define the distribution of carbonate mineralogies at the micro-scale. Four spectral gamma ray sections were measured, across the fault zones under study in order to distinguish several possible sources of radioactivity in the Permian Ratburi Limestone and so relate the gamma signature to timing of cement emplacement versus depositional enrichment.

3. Results

3.1 Carbonate facies

Permian Ratburi limestone bedding planes trend 45^{o}NE/40^{o} in the studied quarry. Lithologies are shallow marine platform-interior carbonates which range from wackstone in the road cut outcrop on

Highway 12, to packstone, and crinoidal fusulinid rudstones in the limestone quarry.

3.2 Fracture pattern in fault zones

A large SE-NW trending Indosinian strike-slip fault zone crosses the limestone quarry and is expressed by intensive fracturing with non-ferroan and ferroan calcite cements fills in veins a few centimeters wide and large cavern up to a metre wide (Figure 3). A NE-SW trending Indosinian thrust fault zone crops out in limestones in a road cut on Highway 12, and is expressed by fractures and calcite fills in zones parallel to the main fault plane in a 0.5 – 1.0 m wide fractured damage zone. Compared to the fault zone in the quarry, this outcrop is characterized by lower degree of calcite cementation and narrower open fracture apertures (less than 3 cm).

3.3 Oxygen and Carbon isotopes

Isotope values were determined from 15 samples in and around the fault zone in the quarry in order to better define the origin and timing of both the current matrix and the fault-associated cements. The data are reported in δ-notation relative to the PDB standard matrix ($\delta^{13}C$ and $\delta^{18}O$ in % PDB). Isotope values in the limestones and chert nodule exhibit $\delta^{13}C$ values clustered around 1 to 1.8 and $\delta^{18}O$ around -8.3 to -11.5. And isotope of non-ferroan and ferroan calcite cements in veins and caverns exhibit $\delta^{13}C$ values clustered around -4 to 3 and $\delta^{18}O$ around -6.5 to – 15%.

3.4 Spectral gamma ray

Spectral gamma ray measurements were collected in four traverses across the fractured zone of the strike slip fault in the quarry and the fracture zone in thrust fault zone. The fractured zone of both faults is expressed by high total gamma ray values with high Uranium, Thorium, but very low Potassium element. An exception to typically low gamma values in the unfaulted areas was noted some hundred meters from the fault in the road-cut fault zone where it shows high values in uranium with low value in Thorium, and Potassium (Figure 7).

4. Discussions

The Permian Ratburi limestone in the studied area preserves evidence of several stages of diagenetic evolution. First is early marine diagenesis, characterized by prismatic calcite cements typical of Permian sea water (Baird and Bosence, 1993) and preserved in some bivalve skeletal grains, this was followed by early mesogenetic (early burial) dolomitization and chert nodule development. (Figure 4). Isotopic data defines this early burial group as possessing typical marine (mesogenetic) burial values, with moderately negative oxygen values indicative of normal subsurface recrystallisation under increasing burial depth and temperature (Figure 5).

Then the Indosinian Orogeny took place (latest Permian-early Triassic) and resulted in fault-related fracturing and calcite cementation in the study area. During this event, two stages of fracture-related fluids are defined, based on two different groups of isotopic trends that depart from the typical values identified in Baird and Bosence (1993). These fracture fills are interpreted as mesogenetic calcite cements (ferroan and non ferroan calcite), with carbon isotope values that start off more negative than typical carbon burial values and become positive (from -4 to 1). The corresponding oxygen isotope values become more depleted, passing from -7 to – 11.5 (Figure 6). These calcite cements are followed by later mesogenetic non ferroan calcite cement defined as hottest fluid solution by their more depleted oxygen isotope values.

The increasingly positive values of carbon, mentioned above, possibly relate to an overall fluid evolution passing from a situation with some bicarbonate coming from CO_2 dissolved in the pore fluid being supplied from organic maturation catagenesis (thermal degradation) to metagenesis. Development of an even earlier shallow burial dolomite and subsequent fracturing has the potential to produce porosity in zones away from the most intense faulting. Vuggy porosity resulted from fracturing but was occluded by later multiple stages of calcite cementation that typifies the fault damage zones in study area

The high degree of fracturing facilitated increased fluid flow volumes in the deep subsurface, giving the active fault zones the capability to mobilize and so concentrate radiogenic minerals (K,U and Th) in the resulting calcite precipitates (Ruffel *et al*, 2004). This mechanism is well defined by the high Uranium, Thorium, and Low potassium values observed in the spectral gamma ray traverses across the faults (Figure 7). In the subsurface in uncored intervals, this fault-related high gamma signature could easily be confused with that of shale or a flooding surface in its platform carbonate host. This observation is of direct relevance to subsurface interpretations of fractured Permian Carbonate reservoirs in Thailand, and similar faulted platform carbonate elsewhere in the world. It strongly suggests that such subsurface interpretations of the depositional significance of a gamma peak should be supported by additional log evidence that ideally include image logs (e.g. acoustic or FMI)

5. Conclusion

a. Fractured Permian carbonates preserve fault-related petrographic and isotopic signatures that depart from the typical carbonate burial curve developed for the subsurface of the region.

b. The isotope and petrographic signatures relate to fluids flowing in the fault damage zone and derived, at least in the early stages of deformation and fracturing, from external bicarbonate sources that have seen the higher temperatures of oil window. Later fluids were hotter and precipitated calcites with carbon isotope signatures showing a bicarbonate source that was more indicative of fluids derived by thermal alteration of deeply buried limestone.

c. Cements precipitated from later hotter fluids passing through remnant porosity in these cavities were more Fe-rich and carried elevated levels of U and Th. Gamma traverses across this zone show elevated values of Uranium and Thorium elements.

d. Subsurface interpretation of spectral gamma ray logs in highly fractured Permian carbonate in Thailand or other similar places need a reliable suite of supporting data such as acoustic logs or FMI.

6. Acknowledgements

The author would like to thank Petroleum Geoscience Department of Geology. Chula-longkorn University for funding the project, and is also very grateful to Prof. John Warren for his supervision and valuable ideas.

7. References

Baird, A. and Bosence, D., 1993. The sedimento-logical and diagenetic evolution of the Ratburi Limestone, Peninsular Thailand: *Journal of Southeast Asian Sciences*, 8, 173 -180.

Ruffel A., McKinley J.M, and Evans R., 2004. Distinguishing faults from flooding surfaces on spectral gamma-ray logs: *The American Association of Petroleum Geologists*, 88, 9, 1239 – 1254.

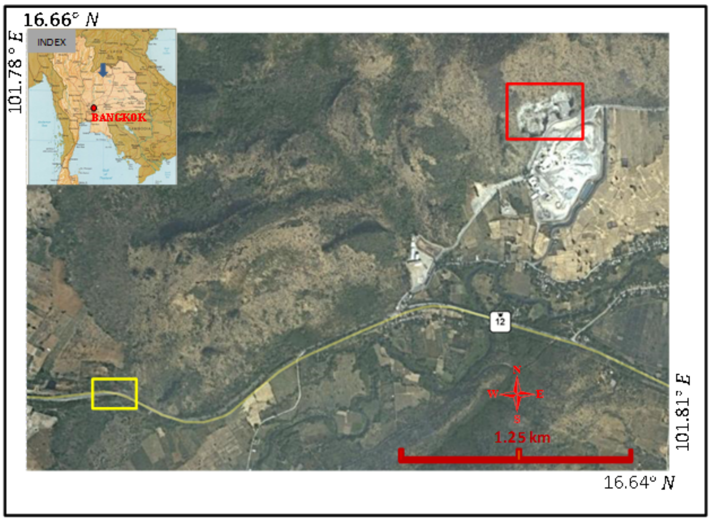

Figure 1. Location map of study area (quarry marked by red box and road-cut HW 12 by yellow box).

Figure 2. Fractured zone in strike slip fault with high degree of calcite cementation.

Figure 3. Fracture pattern in thrust fault zone parallel to the fault plane (road-cut HW 12).

Figure 4. Prismatic calcite cement in bivalve skeletal grain (yellow arrow) and dolomite mineral (blue arrow).

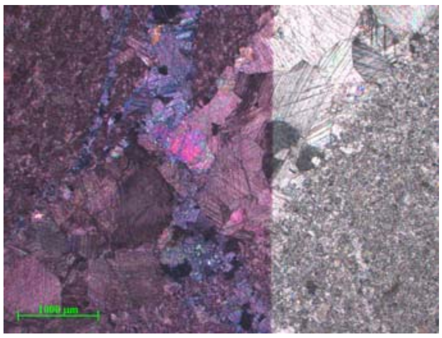

Figure 5. Multiple stages of calcite cement with early calcite vein cross-cut by later ferroan calcite cemented vein (blue stain).

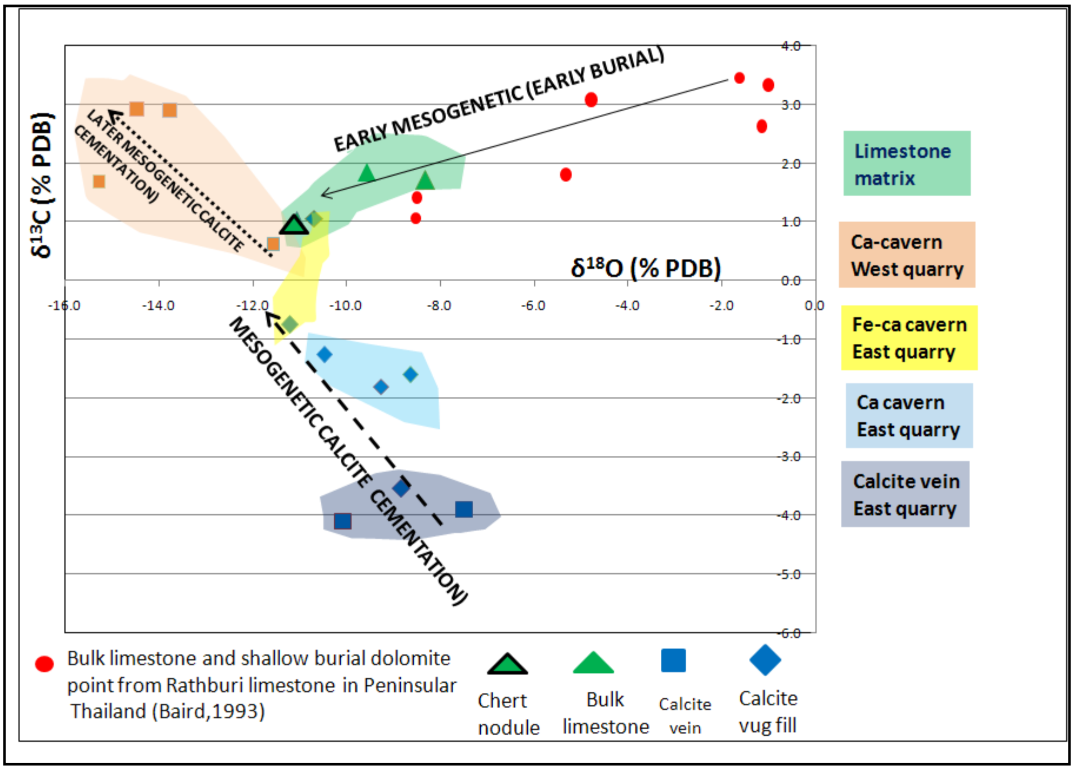

Figure 6. Carbon and oxygen isotopic plot.

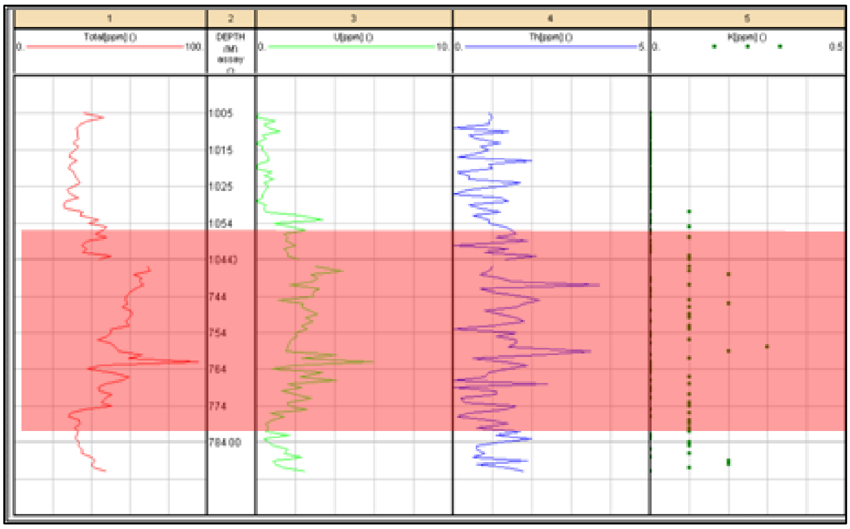

Figure 7. Spectral gamma ray with elevated total gamma ray values in the fault damage zone (shaded zone).