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STRUCTURAL CONTROL ON SEDIMENT DISTRIBUTION IN OFFSHORE BRUNEI DARUSSALAM, SOUTH CHINA SEA

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ABSTRACT

The Neogene clastic intervals, deposited in a shelf to deepwater setting, dominate the Brunei offshore area, South China Sea. Systematic mapping results based on 3D seismic and well data have been used to establish the basin framework. The Brunei offshore area is compartmentalized by faults controlled by gravitational gliding mechanism and tectonics. In general, these processes generated two types of fault systems, northwest dipping, down-to-the-basin faults and southeast dipping, counter-regional faults.

The southeast dipping, counter-regional faults are developed in the eastern offshore of Brunei where they confine a significant amount of sediment. The stratigraphy is dominated by Upper Miocene to Pleistocene, shelf to tidal deposits, known as the Champion system.

Deep faults in the offshore west dip to the southeast and younger and shallower structures dip in the opposite direction. Although the younger structures in the west are more complex compared to the eastern offshore, they are dipping down-to-the-basin and therefore do not significantly block the sediment supply to the slope area and the basin floor. The sedimentary system in the west is similar to that deposited in the east but with a thicker Pliocene interval.

The Ampa-Magpie anticline, with a significant shale injection zone as its core, occurs in the middle of offshore Brunei separating the Baram system from the Champion system. This large structure is likely related to deep NW-SE oriented basement faults.

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INTRODUCTION

The sediment in the offshore part of Brunei Darussalam consist of Neogene clastics, deposited in shelf to deepwater settings. The regional geological framework has previously been established primarily based on lithostratigraphy (e.g. James, 1994 & Sandal, 1996). In this study, however, a consistent sequence stratigraphic evaluation using wells and 3D seismic data was applied. The result gives a significant improvement in regional geological understanding and enables consistent mapping for the entire offshore Brunei region. This paper documents part of the results of the regional mapping exercise and shows how the structures influenced the sediment accumulation.

METHODS

This study uses a 10,000 km^2, merged 3D seismic data set, that covers almost the entire Brunei shelf. Consistent regional seismic horizons are tied to more than 50 key wells with systematic sequence boundaries picked using the Haq et al. (1988) nomenclature.

The study focussed first on understanding the regional depositional systems active during the Upper Miocene to Pleistocene, and then characterizing the depocenters of each system. Since knowledge of the interplay between regional basin tectonics, sea level fluctuations, sedimentation rate, sediment type and source of sediment supply is key to this study, seismic sequence stratigraphy, volume interpretation, and horizons slices were employed to give the best combination of observations that enable identification of the depositional elements.

Regional basin setting

The study area is part of the Northwest Borneo Basin, which lies between the South China Sea in the northwest, the Sundaland Shield in the south and the Sulu Sea and Celebes Sea regions in the east (Figure 1). The basin developed in response to rifting, sea floor spreading, and subsequent strike-slip faulting during the Tertiary (Hall, 1996). Tectonics and gravitational gliding processes control the structures developed in the study area (Morley et al., 2003).

Most of the sediments in the study area are deposited in paralic to deep-water settings. Stratigraphically, the sediments developed by overall progradational system (Scheurs, 1997; Figure 2), which can be divided into:

- Champion system, sourced from the north of Brunei. Major development of this system occurred from the Late Middle Miocene to Early Pliocene, in the present-day onshore and eastern offshore areas.

- Baram system sourced from the south of Brunei, with major development during the Early Pliocene to the present day.

Structural Framework

In the east, the structure is dominated by the SE-hading, Frigate counter-regional fault and the NW-hading, Champion growth fault (Figures 2 & 3A). Hodgetts et al. (2001) reported a maximum displacement of 4-6 km on the Frigate counter-regional fault which has a minimum vertical extent of 6 seconds two way travel time. Fanning of seismic reflections due to rollover in the hanging-wall of the Frigate fault occurs over almost the entire imaged sequence. The hanging-wall rollover extends eastwards from the fault for approximately 40 km and terminates abruptly along the Champion growth or Sliver fault. The Champion growth fault is a northwest-hading, down-to-the-basin, growth fault system, with a series of syn-depositional collapse grabens developed over its crestal area. Approximately flat-lying beds occur on the up-thrown side of this fault. Tight ridges in the deepwater area developed as toe-thrusts with significant tectonic compression.

The structures in the western offshore Brunei area are relatively more complex compared to the eastern offshore area. There are two large, faulted anticlines close to the coastline, the Seria and Ampa structures (Figures 2 & 3B). These structures are possibly inversion features of older, counter-regional faults. Between the Fairley and Merpati wells, listric growth faults occur above an older, delta-toe zone of thrusts and diapiric shale bodies (McClay et al., 1998). The largest fault developed in this area is the E-W oriented, Outer Shelf Growth Fault with a throw of more than 2.5 km. These structures created a depocentre for the Baram system in the west. Most of the regional faults dip towards the northwest. In the western deepwater area, an active delta-toe zone developed with relatively gentler structure compared to the eastern deepwater area.

The structural style in the west is more extensional in nature than in the east. In the east, the Champion area developed first within an extensional regime during the Miocene to Pliocene. Compressional tectonics developed later during the Pliocene, limiting the structural development towards the northwest (Figure 4).

A large anticline extending to the northeast from Ampa and swinging to the north in the Magpie-Petrel area separates the west and east structural systems (Figure 2). Parts of this large structural high are cored by shale diapirs. Gravity and magnetic data show that the NW-SE orientation of this anticline is probably related to the deep sinistral wrench structure in the basement. Although this deep structure is relatively long, the lateral offset is not significant (Figure 4; Morley, 2002)

Sediment Accumulation and Distribution

Significant thickening of the Upper Miocene to Pleistocene interval occurs in the downthrown block of the Frigate fault in the east (Figure 3A). The largest portion of the Champion system is accumulated in this depocentre (Figure 2) and thins further towards the southeast (Figures 3A & 4). During the Pliocene, the sediment supply exceeded subsidence and sediments spilled over towards the slope. Some Pliocene and younger sediments are trapped on the slope by tight toe of thrust or slope structures in the eastern deepwater area.

In the western offshore area, there are local thickenings within the Lower Upper Miocene, which occur on the down-dip side of the older counter-regional faults below the Ampa and Seria anticlines shown by seismic reflector fanning (Figure 3B). These wedges developed prior to the compressional tectonics during the Upper Miocene.

The Neogene Baram depocentre in the west mainly accumulated in the Fairley-Gannet area where intensive, NW-dipping growth faults developed (Figures 2 & 3B). In contrast to the Champion system, which is controlled by counter-regional faults, the Baram system is controlled by growth faults and thickens in the opposite direction (Figure 4). The thickest intervals developed on the footwall side of the fault and thin towards the northwest. These faults control the lateral distribution of the Pliocene-Pleistocene, Baram sediment system. However, significant amounts of sediments were still transported to the slope and basin areas.

CONCLUSION

Regional sequence stratigraphic mapping of the Brunei offshore region provides a solid understanding of the geological framework of the basin. The results of this study give a better understanding of the differences in the structural settings of the eastern and western areas.

Counter-regional faults dip to the southeast, have confined the sediments and have acted as barriers to sediment supply. Such faults also occur in the west below the Ampa and Seria anticlines.

Regional, normal and growth faults dipping to the northwest are well developed in the Fairley – Gannet area and at Champion in the east. Relatively small amounts of sediments were trapped by the regional growth faults.

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Figure 1 - Crust map of Southeast Asia, showing the Northwest Borneo Basin outline and the location map of the study area (modified after Doust and Lijnbach, 1997).

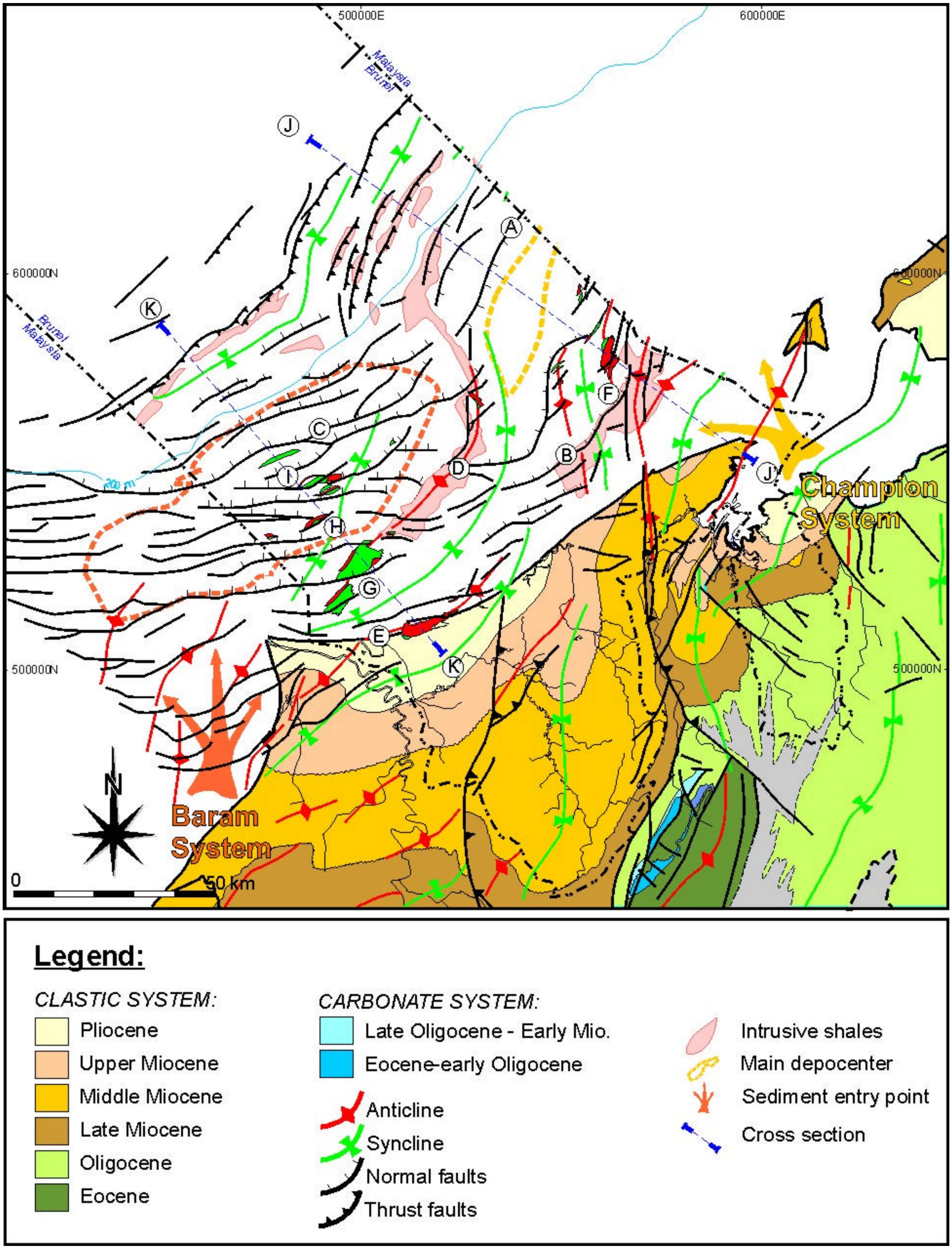

Figure 2 - Structural map of Brunei Darussalam and the adjacent area, with Baram and Champion system estimate entry point and main depocentres. Note: A) Frigate Counter Regional Fault, B) Champion Growth Fault, C) Outer Shelf Growth Fault, D) Ampa-Magpie Anticline, E) Seria Anticline, F) Champion Field, G) SW Ampa Field, H) Fairley Field, I) Gannet Field, J-J') Location of section A in Figure 3, K-K') Location of section B in Figure 3.

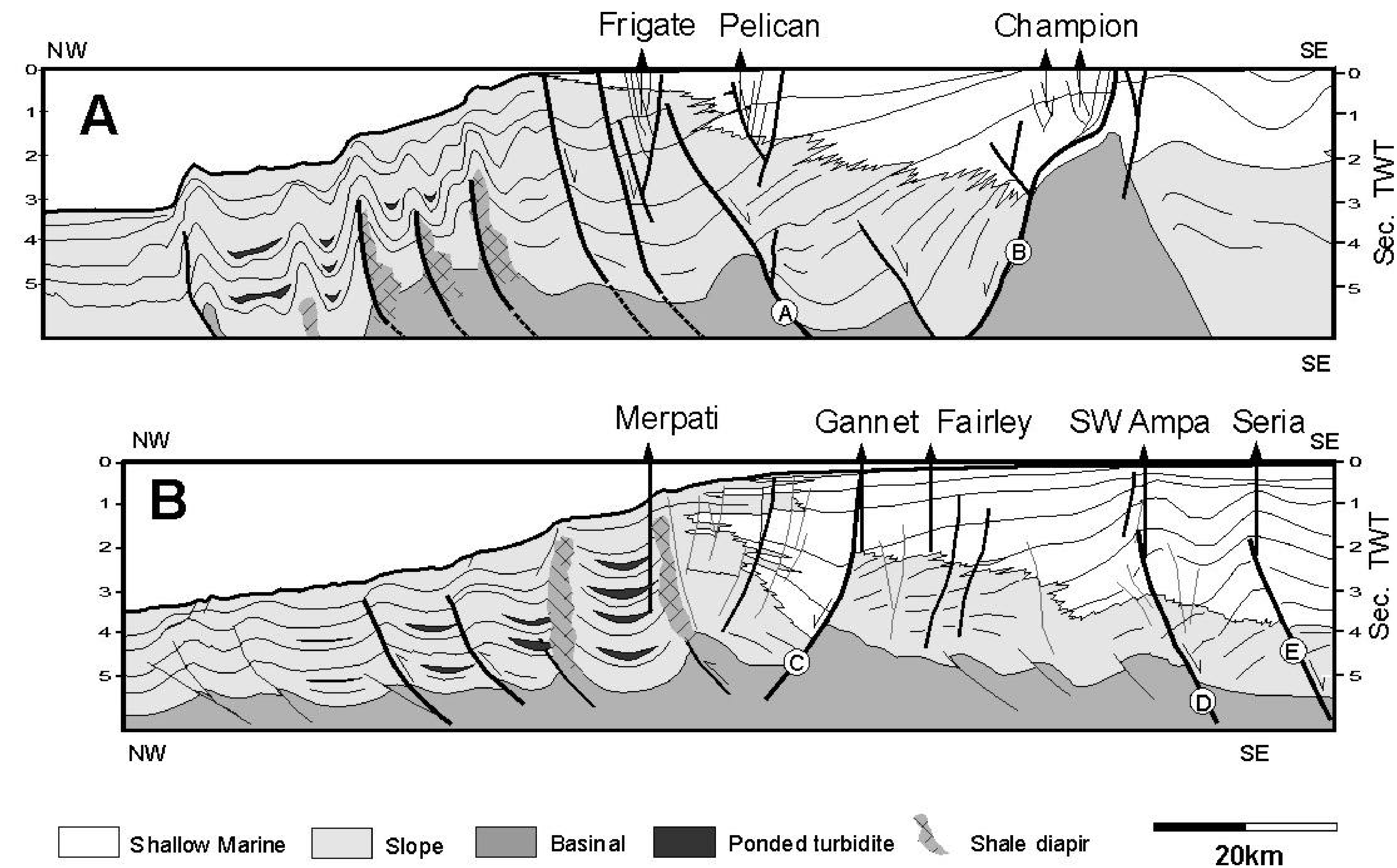

Figure 3 - A) Geoseismic section of the Brunei eastern offshore. Champion growth fault developed in the SE. A series of SE-dipping, counter-regional faults occur in the Frigate-Pelican area. Tight toe-thrust ridges dominate the deep-water part. B) Geoseismic section of the western Brunei offshore. Older, counter-regional faults developed below the Ampa and Seria structures. NW-dipping, growth faults developed around the Gannet-Fairley area. Gentle toe-thrust ridges occur in the deep-water area (Modified after McClay et al., 1998). Note: A) Frigate Counter Regional Fault, B) Champion Growth Fault, C) Outer Shelf Growth Fault, D) Ampa-Magpie Anticline, E) Seria Anticline.

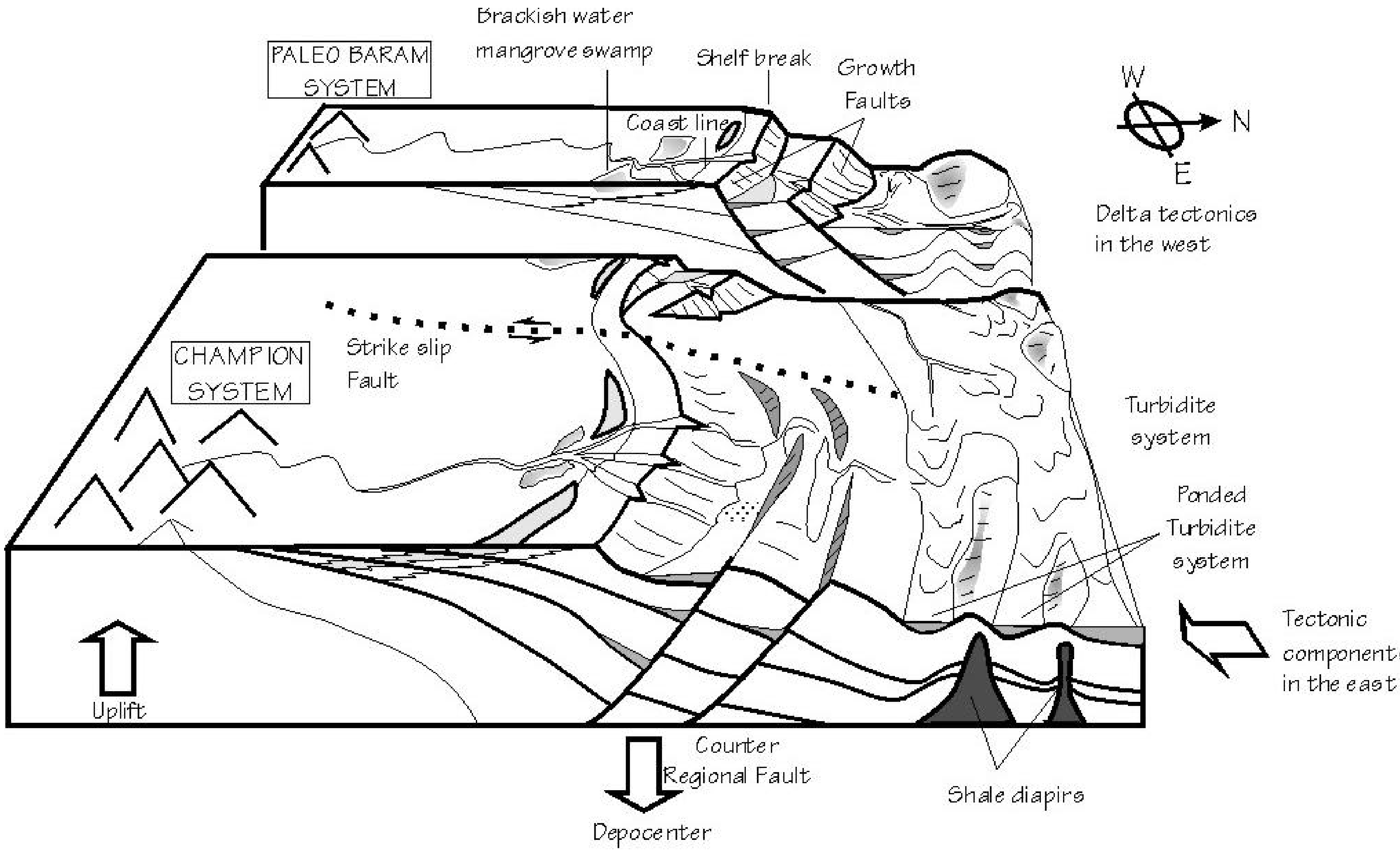

Figure 4 - Three-dimensional sketch of the relationship of the structures and sedimentary systems developed offshore Brunei. The Champion system developed in the east and trapped by the SE- dipping, counter-regional faults. The sediments thin towards the SE. In the west the Baram system was deposited on the down thrown side of the fault but the majority of the sediments by- passed into the slope and the basin.