AAPG Datapages/Search and Discovery Article #90236 © 2015 Asia Pacific Region, Geoscience Technology Workshop, Tectonic Evolution and Sedimentation of South China Sea Region, Kota Kinabalu, Sabah, Malaysia, May 26-27, 2015

Tectonic Development of Nam Con Son basin Based on New Seismic Data Interpretation

Nguyen Thanh Tung

Introduction

Nam Con Son basin (NCSB) is located in the south-eastern continental shelf margin of Vietnam with an area of circa 110,000 sq. km, bordered by Con Son swell in the North-West, the Khorat - Natuna highs in the Southwest and Tu Chinh high in the East.

Hydrocarbon was found in various stratigraphic sequences including fractured basement (Dai Hung, Gau Chua), Oligocene (Rong Doi, Ca Rong Do), Lower Miocene (Rong Vi Dai, Ca Rong Do), Middle Miocene (Chim Sao, Dua, Dai Nguyet, Thien Ung, Mang Cau), Upper Miocene (Hai Thach, Moc Tinh, Lan Tay, Lan Do).

The estimated resource potential of the basin is up to 4.2 bln boe but the probability of exploration success for a commercial discovery is rather low (~15%) probably because the complex tectonic settings of the basin has not been fully understood.

Over the last decade, despites a large amount of newly acquired seismic and well data there has not been any significant update on the tectonic development and history of basin development. This causes high uncertainties in evaluation of petroleum system traps integrity and HC generation & migration. A complete reinterpretation of the tectonic development in basin scale based on updated seismic and well data is therefore critical to improve the accuracy of the evaluation of petroleum system in Nam Con Son basin. This is the aim of the joint study between Viet Nam petroleum institute and TNK-BP that has been recently implemented.

Regional tectonic settings

In Paleocene, the southeast extrusion of the Indochina block, southward drift of the proto East Vietnam Sea (EVNS) associated with collision of the Luconia micro continent and Borneo, caused a series of right-lateral transforms in the East Vietnam Shelf extending to the East Luconia. This combination possibly derived North - South extension in the Sunda Shelf (Hall et al., 2002; Hutchison, 2004). Matthews (1997) and Fyhn et. al. (2009) proposed the onset of rifting in the proto-East Vietnam Sea as well as the NCSB initiated in Eocene and lasted to about 30 Ma (Early Oligocene). This rifting period is controlled by N - S extension, associated with E - W oriented faulting and deposition of rift-fill sediments in local W-E trending sub-basins.

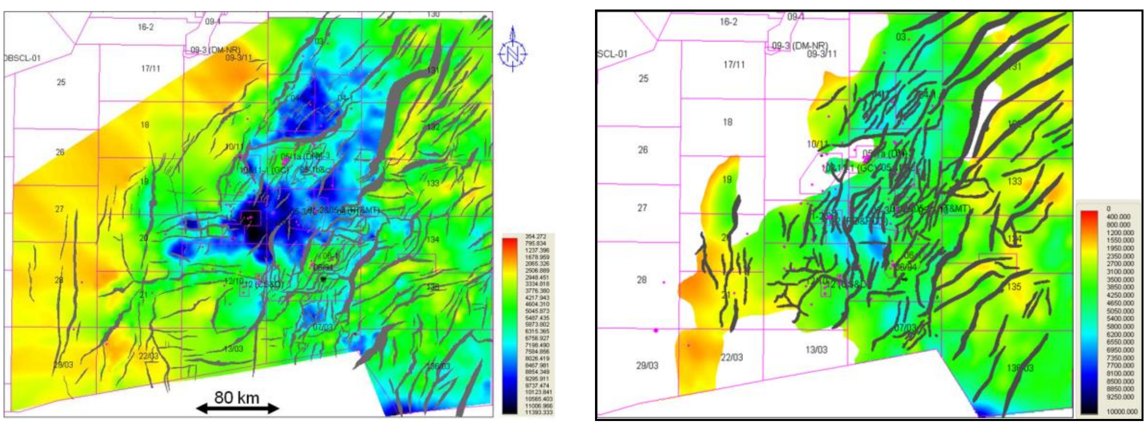
The rifting phase in Eocene - Early Oligocene then was followed by spreading of East Vietnam Seafloor propagated from East to West then WSW. At about 24.7 Ma, the axis of the seafloor spreading shifted from WSW trend to SW trend (Andrew, 2010; Morley, 2007).

At the end of Early Miocene, Southwestward propagation of seafloor spreading continued by continental breakup and caused the second rift phase at the SW of the rift tip including NCSB, associated with NE - SW normal faults and deposition of synchronous sediments in NE - SW grabens. The second rift phase is derived by NW - SE regional extension as slab-pull of SE drifting of Dangerous Ground and subduction of proto-EVNS beneath NW Borneo. As proto-EVNS were totally subducted at about 15 Ma and the arrival of buoyant attenuated continental crust caused regional tectonic uplift, marked by a pronounced unconformity at the end of Middle Miocene (MMU).

The second rifting phase is followed by thick post-rift sequence (Upper Miocene - Pliocene - Quaternary) due to increase in sediment supply with respect to onshore uplift and magmatism (Fyhn et al., 2009; Hall et al., 2009).

Data interpretation

The regional tectonic settings described above are the background guidelines for detailed data interpretation in this study. The comprehensive dataset consists of about 54 thousands km of 2D seismic lines covering the whole basin and information from 44 wells including bio-stratigraphic analysis and core samples taken for petrographic description. 17 wells with good log curves, biostratigraphic markers and check-shot data were selected to use for correlation with seismic data. Five main seismic horizons have been interactively interpreted, namely Top basement (T00), Top Oligocene (T20), Top Lower Miocene (T30), Top Middle Miocene (T65) and Top Upper Miocene (T85). These horizons have been defined with the help of synthetic seismograms generated from four wells with high quality log curve locating in different part of the basin. Several time depth conversion methods have been considered for generating depth structure maps of key sequences in the basin. After a careful test of accuracy, the depth structural maps of these key sequences have been generated from the time interpretation by layer cake method. Figure 1 shows depth-to-seabed maps of the top Basement, top Oligocene, top Lower Miocene and top Middle Miocene sequences.



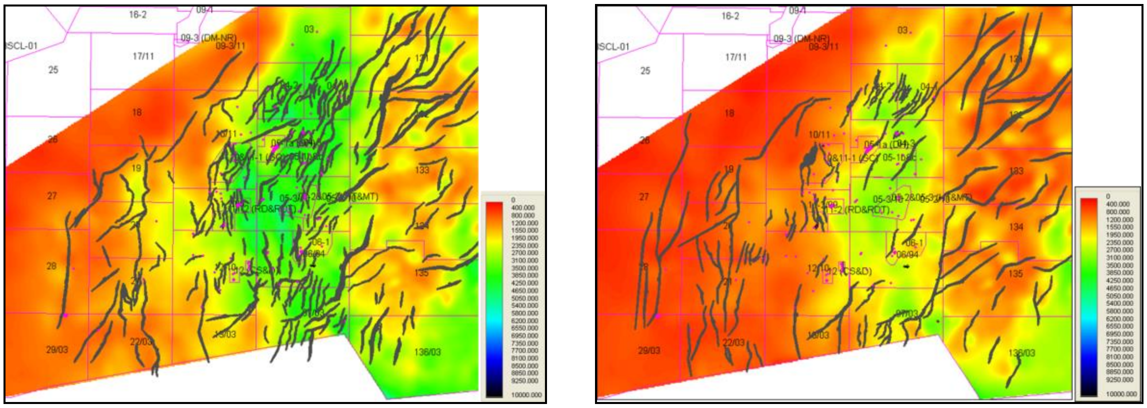


Figure 1. Total sediment thickness to seabed generated for top Basement (top left), top Oligocene (top right), top Lower Miocene(bottom left) and top Middle Miocene(bottom right)

To reconstruct the tectonic history of the basin, the fault systems have been interpreted with great attention. Fault heaves and fault timing were carefully picked to accurately reflect their development. As a results four major fault trends developing at different time intervals can be recognized: (1)East – West, (2)NE –SW, (3)NN East – SS West and (4)North – South trends.

(1)The East - West trended fault system dominated in the Southern part of the Nam Con Son basin especially from the area of block 11-2 in the West to blocks 05-3, 05-2, 133 and 134 to the East. The faults have extensional features that are clearly evidenced on the top crystallized basement but mostly buried by the Late Oligocene and Early Miocene sediments. The growth sequence of Early Oligocene to the top basement against the E-W trend faults suggests that the timing of E-W faulting activities is about Eocene - Early Oligocene during the regional first rift stage described in the previous section. This observation is also supported by the isopach map of the Oligocene sequence which shows clear E-W trend of sediment thickness controlled by E-W trending fault (Fig. 2). The E-W fault trend in Nam Con Son basin during the Eocene-Early Oligocene is consistent with the oldest magnetic lineation (~32 Ma) oriented ~E-W in the East Viet Nam Sea caused by slab-pull from southward movement of Dangerous Ground subducting the proto East Vietnam Sea beneath Borneo (Briais et al., 1993).

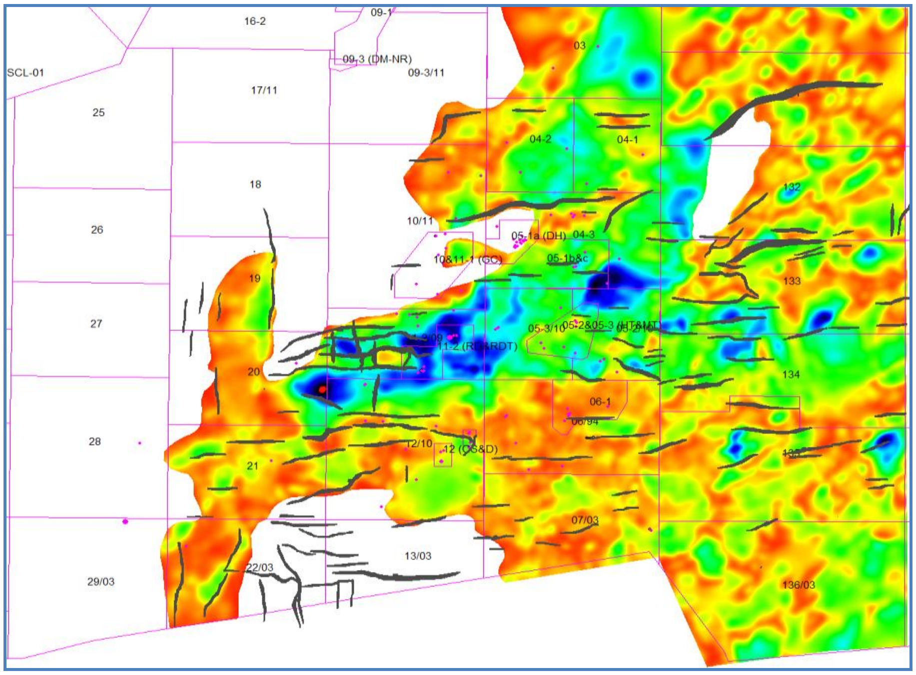


Figure 2. Isopach map of Oligocene sequence with overlap of faults activated during the first extentional phase in Eocene - Early Oligocene time. The basin was likely E-W orientation, which is consistent with E-W trending faults.

(2)The NE - SW trend faults developed strongly in the Northeastern part of the basin with listric feature during the Middle Miocene sequence. In the central part of the NCSB, the NE-SW faults gradually bend to (3)NNE-SSW trend suggesting that the faults was influenced by a N-S previously existed rock fabric that were possibly formed during the first rifting phase in conjunction with the N-S extension or even earlier in the Mesozoic/early Cenozoic time as exhibited in the model proposed by Morley 2004. Dipping to WNW, these faults created graben, half graben and rollover structures which are typical and easy to recognize on seismic sections as well as on structure maps.

The last major fault system is of (4)N-S trend which is superlatively recognized in the Western part of the basin. These faults mainly developed during the second extensional phase in Early-Middle Miocene but being further to the West their trend reflects the reactivation of pre-existing weak fabric and not affected by the main trend of EVN Sea floor spreading like the fault systems in the East of the basin. several of them still being active until today which make N-S faults distinctive from the rest.

Conclusion

From the systematic interpretation of seismic and well data in Nam Con Son basin the major geological history of Nam Con Son Basin it can be infered as follows:

The preceding morphology of the NCS area underwent a regional erosion until the first rift phase happened in Eocene – Mid. Oligocene. The N-S extentional force caused E-W fault system with local E-W grabens and halfgrabens to develope in the whole basin area. The tectonic activity could also create a N-S weakened fabric in conjunction with E-W faulting.

Intra Rift Phase (Late Oligocene – Lower Miocene): NCSB was relatively quiet because all extensional effects were accomodated by the NW – SE seafloor spreading of EVNS.

Second extensional phase (Middle Miocene) resulted from southwest propagation of seafloor spreading zone, NE – SW subducting proto East Sea beneath Borneo. This phase is believed to be the cause of the NE-SW, NNE-SSW and N-S fault systems in NCSB.

Post rift sequence (Upper Miocene – Recent) is represented by onshore uplift causing increase in sediment supply to the basin depocenter. NCSB has been tectonically quiet, only weak N-S fault system continues to be active in some area of the basin.

The significant Eocene - Early Oligocene rifting episode resulted in the deposition of ~ 5 km of sediments in E - W trending grabens in the southern part of the basin. In the northern part, the second regional extension phase of NE-SW trend had strong effect that dominates the current basin's structural characteristics and the E-W trend cannot be clearly observed on seismic data.

Reference

Andrew, C. (2010). Rifiting of the South China Sea: new perspectives. Petroleum Geosciene, 16, 273-282.

Briais, A., Patriat, P. and Tapponnier, P. (1993). Updated interpretation of magnetic anomalies and seafloor spreading stages in the South China Sea. Implications for the Tertiary tectonics of southeast Asia. Journal of Geophysical Research 98; issn: 0148-0227.

Fyhn, M.B.W, Boldreel, L.O. & Nielsen, L.H. (2009), Geological development of the central and south Vietnamese margin: implications for the establishment of the South China Sea, Indochinese escape tectonics and Cenozoic volcanism. Tectonophysics, vol 478, pp. 184-204.

Hall, R. (2002). Cenozoic geological and plate tectonic evolution of SE Asia and the SW Pacific: computer-based reconstructions, model and animations. Journal of Asia Earth Sciences, 20, 353-431.

Hutchison, C. S. (2004). Marginal basin evolution: the southern South China Sea. Marine and Petroleum Geology, 29, 1129-1148.

Matthews, S. J. (1997). Structure, stratigraphy and petroleum geology of the SE NCSB, offshore Vietnam. Geological Society Special Publication, 126, 89-106.

Morley, C. K. (2007). Variations in Late Cenozoic - Recent strike slip and oblique-extentional geometries, within Indochina: The Influence of pre-existing fabrics. Journal of Structural Geology, 29, 36-58.