Exploration Challenges and Progress in South China Sea

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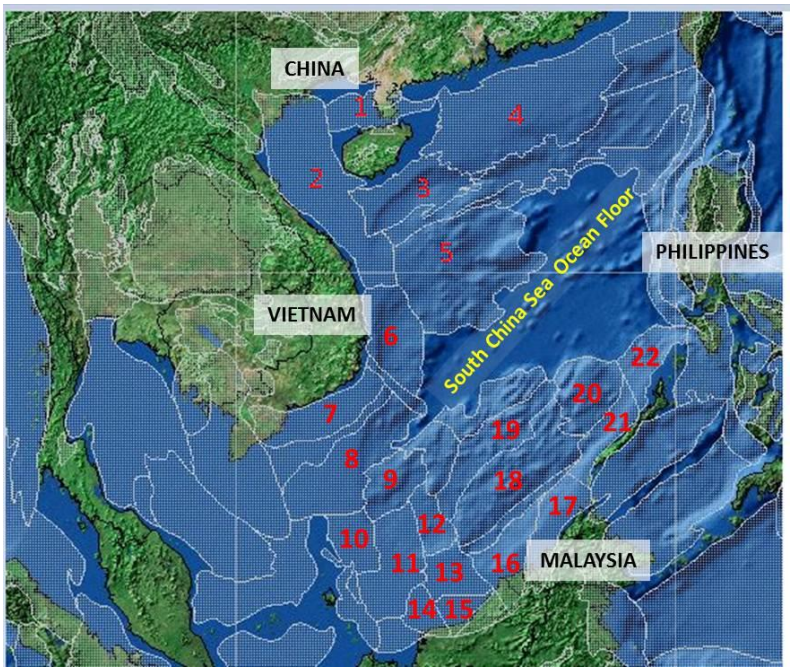
The South China Sea is a continental marginal rift basins, located in the most complex area caused by the converging of the three major plates namely the Eurasia plate, Indo-Australia plate and the Pacific plate, have undergone through poly-cycle tectonic movements since Early Tertiary times (He et al., 2014, Deng, 2009). These marginal basins are characterized by episodic tectonic evolution and creating numerous prospective sedimentary basin for hydrocarbon exploration.

The South China Sea is a vast region covering more than 22 sedimentary basins. Geographically, it runs approximately 1,200 km from east to west, and 2,000 km from north to south. Exploration drilling has been generally sustained over the past decade, with higher levels seen from 2010 to 2011. Most of these are in the proven basins and shallow water but key wells have likewise been drilled to test some of the frontier plays. Estimated total recoverable resources in the area are approximately 18 Bbl of oil and 220 Tcf of gas.

The long standing exploration history has led to a better data analysis which gives a good understanding of the sedimentation evolution, structural framework, as well as the petroleum system. This paper will discuss exploration successes and challenges in the South China Sea, identify key learnings and looks at finding analogue for some of the frontier basins such as the Reed Bank, Truong Sa, Hoang Sa and Vung May.

The area of study consists of 22 basins in the South China Sea summarized in map 1.



Map 1: Map of basins location

1. Beibu Gulf, 2. Song Hong/Yinggehai, 3. Qiongdongnan, 4. Pearl River Mouth (PRMB), 5. Hoang Sa, 6. Phu Khanh, 7. Cuu Long, 8. Nam Con Son 9. Vung May, 10. East Natuna, 11. West Luconia Province , 12. North Luconia Province , 13. Central Luconia Province , 14. Tatau Province, 15. Balingian Province 16. Baram Delta, 17. Northwest Sabah Province, 18. Northwest Sabah Platform, 19. Truong Sa, 20. Reed Bank, 21. Southwest Palawan, 22. Northwest Palawan.

Proven Plays

Exploration in the northern part of South China Sea has been focused in the Pearl River Mouth, Qiongdongnan and Yinggehai/Song Hong basins. The shallow water section of the Pearl River Mouth Basin has mainly oil-prone kitchens from the Eocene Wenchang and Oligocene Enping formations. Moving to the deepwater, in the Zhu-2 sub-basin, gas-prone kitchen exist in the Oligocene Enping formation. Most of the oil fields in the Pearl River Mouth basin were discovered in shallow water in 1980s when Chinese government opened its offshore oil and gas exploration to foreign firms. Main oil reservoirs are composed of shallow marine deltaic sands of Oligocene Zhuhai and Miocene Zhujiang formations. Miocene Zhujiang reefal carbonates form local reservoirs (Liuhua 11-1 field). In the deep water, the first major gas discovery was made by Husky in 2006. Since then, deep water exploration for gas has been pursued. Husky continued its success in the deep water and added Liuhua 34-2 and Liuhua 29-1 gas discoveries. CNOOC likewise discovered Liuhua 29-2 gas field in deep water. Effective source kitchen and short distance migration control the distribution of hydrocarbon accumulations.

Cuu Long Basin is predominantly located offshore southeast Vietnam and separated from the Nam Con Son Basin to the south by an area of uplifted basement, the "Con Son Swell". The basin is characterised by thick sedimentary of Upper Eocene to Recent sediments that overlie hydrocarbon bearing Pre-Cenozoic basement. Despite oil and gas discoveries found in the Miocene and Oligocene clastics, the main exploration target in the Cuu Long Basin is the fractured and weathered basement, composed of crystalline acid magmatic rocks such as biotite, granite, porphyry granite, granodiorite biotite and quartz leucodiorite (San & Dong, 1997). To date, basement play in the Cuu Long and Nam Con Son basin are the only successful granitic basement production in the region.

Similar to Miocene Zhujiang reefal carbonate in the Pearl River Mouth, Miocene Carbonate from Central Luconia is one of the main plays in the southern region. It holds up to 90% gas reserves in the Central Luconia and exploration success has increased in the recent years with new discoveries such as Bakong, Marjoram, B14, Kasawari, Pegaga, NC3 and NC8. The Miocene carbonate Stratigraphic play, as a whole, in South China Sea contributes ~ 37% of the total reserves.

Majority of hydrocarbon is in the Miocene stratigraphic-structural, which contribute to approximately 45% of total reserves in South China Sea in the Baram Delta, Balingian, Northwest Sabah Province, Pearl River Mouth, Cuu Long, Nam Con Son,

Qiongdongnan and Beibu Gulf. Most of the hydrocarbon in the Baram Delta and Northwest Sabah Province derived from the coaly and carbonaceous shale developed in the lower coastal plain and shelf environments. The local intraformational shales, mudstones and carbonaceous siltstones provide the top and flank seals for the hydrocarbon bearing reservoirs.

Yinggehai/Song Hong and Qiongdongnan basins are gas-prone basins and share similar over-pressured geological characteristics due to rapid sedimentation. Oligocene Yacheng and Lingshui formations are the main source rocks. Miocene Sanya and Meishan formations may also have source rock contributions in the Yinggehai/Song Hong Basin. Shallow marine Oligocene and Miocene sands comprise the main gas reservoirs. Several large gas fields in shallow water have been discovered in both basins.

Deepwater exploration flourished in the offshore Sabah has discovered good quality oil, as opposed to current understanding of gas-prone in deepwater exploration and research has suggested this could be contributed by sediment distribution. Petronas's oil discovery in the Pliocene sandstone with Hebat 1 in east Baram Delta offshore deepwater Sabah extends the oil play and proves a more distal sand distribution and source rock preservation. This lowers the reservoir and charge risks for other prospects nearby.

In the deepwater Qiongdongnan Basin in 2014, significant gas discovery from Lingshui 17-2 and Lingshui 25-1 by CNOOC revealed that Miocene-Pliocene central canyon sand-bodies can be an important target of deep water oil and gas exploration (Xie, 2014), with reservoir quality identified as the key risk for this play.

Two exploration wells were recently drilled in Hoang Sa Basin which could potentially opens up discussion on prospective play in that basin. Analogues from neighbouring Qiongdongnan and Phu Khanh basins, such as the Oligocene-Miocene sandstones and Miocene carbonate build-ups plays are being considered.