

## AN OVERVIEW OF THE PROVEN PRE-TERTIARY KARSTIFIED AND FRACTURED CARBONATE BASEMENT PLAY-TYPE IN THE OFFSHORE NORTHERN VIETNAM

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Over the past 6 years, PETRONAS Carigali Overseas Sdn Bhd (PETRONAS), through its exploration arm in Vietnam, has explored for the hydrocarbon potential of the Pre-Tertiary karstified and fractured carbonate Basement play-type in offshore northern Vietnam (Figure 1). The first encounter of this play type in the subsurface offshore northern Vietnam was in 2004 when severe mud losses were experienced when the A-1X exploration well penetrated ‘caves’ in the carbonate Basement. Since then, effort was intensified and further technical analysis was carried out until PETRONAS successfully made a commercial discovery in the “D” structure through the D-2X exploration/appraisal well drilled earlier this year. This milestone discovery has proven the prospectivity of the Pre-Tertiary karstified and fractured carbonate Basement play-type, the first of its kind in the offshore northern Vietnam.

The reservoir penetrated consists of limestone and dolomitic limestone, which can be closely analogue to the similar carbonate formation exposed as ‘islands’ at Ha Long Bay (Figure 2), located some 100km to the North-Northeast from the discovery. This Carboniferous-Middle Permian dolomitic limestone, interbedded with oolitic limestone and calcareo-cherty shale is referred to as the Bac Son Formation (C-P2), which is about 1000m thick, monoclinical and undulately folded, containing foraminifera beds from *Chernyshinella*, *Dainella*, etc. to *Cancellina*, *Neoschwagerina*, *Werbeekina* beds gathered with remains of crinoids, brachiopods, bivalves, bryozoa, etc. and corals, conodonts, radiolarians etc. (Tran Van Tri, et al., 2003).

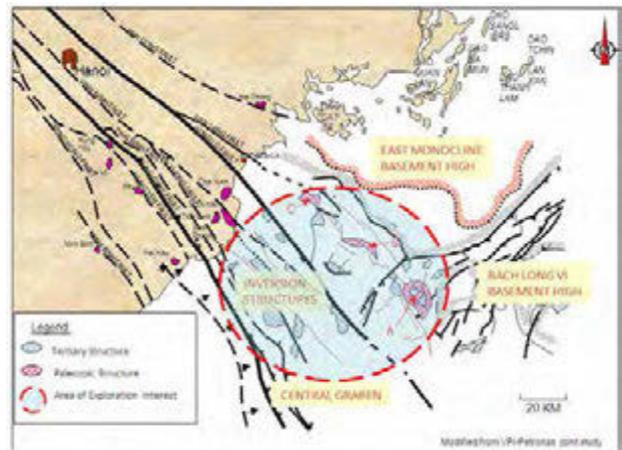


Figure 1: The offshore northern Vietnam area where PETRONAS had explored particularly for the Pre-Tertiary fractured and karstified carbonate Basement is circled in red. This map also shows the main structural element of the area which consists of; i) Central Graben and Miocene Inversion structures to the south of Song Lo fault, ii) A-B-C Ridge extending to B10-STB-1X well onshore, iii) Bach Long Vi Basement High in the east and iv) East Monocline Basement High in the north.

Apart from the cavern system evidence from the outcrop in Ha Long Bay (Figure 3), the carbonate karst-hill and tower karst structures are also fractured, similar to the results from the wells drilled into the Pre-Tertiary carbonate. These faults and fracture sets are believed to have contributed to the increased secondary porosities and permeabilities by acting as the reservoir conduits that connect to the cavern system and matrix (Nelson, 2001).

According to Jamin, et al, 2009, successful hydrocarbon exploration in such play-type offshore northern Vietnam is attributed to a working petroleum system defined by the interplay of the following factors: i) presence of porosities and voids in the carbonate reservoir; ii) increased permeability due to the presence of faults and fractures; iii) presence of a thick and mature lacustrine shaly section which acts both as a source rock and top and lateral seal; and iv) structural formation (Pre-Tertiary) predating oil expulsion and migration. Oil expulsion and migration from this lacustrine source rock began during early-mid Miocene.

The biggest uncertainties and challenges arise from the poor to marginal quality of the current seismic data at the reservoir level which puts a limitation on accurate fractures/lineament and cavern mapping and prediction and also on mapping the base of the carbonate. A much better data quality and more advanced techniques might help to reduce these associated uncertainties.

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Figure 2: The landscape of the Carboniferous-Middle Permian Limestone ‘islands’ in Ha long Bay, offshore Northern Vietnam showing karst geomorphology and fractures. Ha Long Bay belongs to Quang Ninh Province, adjoining to the Hai Phong City, with an area of 1553 km2 which includes 1,969 islets (Tran Van Tri, et al., 2003).



Figure 3: Modern cave as part of karst system, “Surprise” Cave, Ha Long Bay, offshore northern Vietnam. Clockwise from top left: i) cave opening with cave floor breakdown breccias; ii) pillars set forming a large limestone pillar; iii) cave chamber (over 30 meters high) and passage; iv) pillars and stalagmite with breakdown pile at the base.