Late Miocene Submarine Fan Seismic Geomorphology and Reservoir Architecture Revealed by 3-D Seismic and Visualization, Deepwater Toe-Thrusted Domain Exploration, NW Borneo

Rehill, Trent A.[1], Nordin Mohamad[2], Hans Schwing[3], Chan Yin-Hoe[3], Mark Beeson[4] (1) Murphy Sabah Oil, Kuala Lumpur, Malaysia (2) Petronas Carigali, Kuala Lumpur, Malaysia (3) Murphy Oil, Kuala Lumpur, Malaysia (4) DownUnder GeoSolutions, Subiaco, Australia

Exploration on the NW Borneo margin has been extremely active since Malaysia's awards of deepwater blocks in the late 1990's, with several important discoveries such as Kikeh and Kakap being made by Murphy and Petronas.

In this paper we outline what we believe to be the key aspects for petroleum exploration in an area which lies in water depths of between 1000-2000m. The area is currently dominated by basin-verging, thrust anticlines however; the turbidite reservoirs have depositional characteristics similar to systems deposited in passive margin settings.

The turbidite systems in this area comprise successions of reservoir and non-reservoir facies arranged in a variable array of stacking patterns. An upward succession of reservoir architecture styles suggests a gradual period of lower slope to basin floor profile evolution. The section evolves upward from laterally continuous, well developed sheet/lobe sands interpreted to have been deposited in a largely unconfined basin-floor setting; to more channelised fan lobes deposited in foreland basin setting; followed by amalgamated channels / lobes within a series of lower slope - basin plain channel-levee complexes influenced increasingly by the penecontemporaneous structuration.

The application of 3Dvolume interpretation techniques such as: optical stacking, multiple attribute rendering and horizon propagation to develop depositional models and generate prospects strongly contributed to the identification of a number of large-scale geometries and seismic facies within the basin-filling stratigraphy. Depositional geometries within these fan systems are illustrated with seismic geomorphology, well logs, and descriptions of analog outcrops

Late Miocene Submarine Fan Seismic Geomorphology and Reservoir Architecture Revealed by 3-D Seismic and Visualization, Deepwater Toe-Thrusted Domain Exploration, NW Borneo

Rehill, Trent A.[1], Nordin Mohamad[2], Hans Schwing[3], Chan Yin-Hoe[3], Mark Beeson[4] (1) Murphy Sabah Oil, Kuala Lumpur, Malaysia (2) Petronas Carigali, Kuala Lumpur, Malaysia (3) Murphy Oil, Kuala Lumpur, Malaysia (4) DownUnder GeoSolutions, Subiaco, Australia

Exploration on the NW Borneo margin has been extremely active since Malaysia's awards of deepwater blocks in the late 1990's, with several important discoveries such as Kikeh and Kakap being made by Murphy and Petronas.

In this paper we outline what we believe to be the key aspects for petroleum exploration in an area which lies in water depths of between 1000-2000m. The area is currently dominated by basin-verging, thrust anticlines however; the turbidite reservoirs have depositional characteristics similar to systems deposited in passive margin settings.

The turbidite systems in this area comprise successions of reservoir and non-reservoir facies arranged in a variable array of stacking patterns. An upward succession of reservoir architecture styles suggests a gradual period of lower slope to basin floor profile evolution. The section evolves upward from laterally continuous, well developed sheet/lobe sands interpreted to have been deposited in a largely unconfined basin-floor setting; to more channelised fan lobes deposited in foreland basin setting; followed by amalgamated channels / lobes within a series of lower slope - basin plain channel-levee complexes influenced increasingly by the penecontemporaneous structuration.

The application of 3Dvolume interpretation techniques such as: optical stacking, multiple attribute rendering and horizon propagation to develop depositional models and generate prospects strongly contributed to the identification of a number of large-scale geometries and seismic facies within the basin-filling stratigraphy. Depositional geometries within these fan systems are illustrated with seismic geomorphology, well logs, and descriptions of analog outcrops

The Geometric and Kinematic Evolution of the Deep Water Thrust Folds of Sabah, NW Borneo

Wilks, Bill[1] (1) Located at Sarawak Shell Berhad, Miri, Sarawak, Malaysia

The deep water thrustbelt of NW Borneo has proven to be an exploration heartland for Shell, partners and competitors over the last few years. Most proven traps are formed in hanging-wall folds above toe-thrusts, and tend to be confined to the four-way dip closure. As such, considerable volume potential in deep water NW Borneo resides in such traps. However, it is common to find that the geometries of thrusted folds are hard to interpret on seismic, due to wipeout effects associated with migrating gas and gas hydrates. This leads to the poor definition of fold/fault geometry and top seal retention capacity. All of these have a critical impact on the volumetric and economic assessment of the opportunity.

In addition to this, it is clear that the fore-limb geometries of such structures involve a degree of geological complexity that is beyond seismic resolution. This involves the inter-play between thrust propagation, on-lapping hanging-wall turbidites, pelagic drapes and the mass-wasting of the emergent fold by formation of slumps and related channelisation. These issues have a key bearing on column height predictions.

This contribution examines these issues by unravelling the evolution of several prospects within the NW Borneo toe-thrust belt. Detailed 3D seismic volume interpretation, seismic facies mapping, section reconstruction and forward modelling have been applied in the analysis. A significant improvement in risk and volumetric assessment is demonstrated, by rigorous structural evaluation in this environment.

Successful Exploration in a Deepwater Fold Belt: Examples from the Miocene Fan

Systems of the NW Borneo Active Margin

Chisholm, Timothy[1], Colin Grant[2], Gary Ingram[3], John Voon[4], Matthew Choo[4], George Kokkoros[5] (1) Shell Egypt NV, Cairo, Egypt (2) Shell International Exploration and Production, Houston, TX (3) Shell International Exploration and Production, Rijswijk, Netherlands (4) Shell Malaysia Exploration and Production, Deepwater Exploration, Lutong, Malaysia (5) ConocoPhillips, Lutong, Malaysia

Over the past three years, a string of material oil discoveries have been made within the NW Borneo deepwater fold-thrust belt. These successes followed an initial 5-year exploration campaign that had begun with a number of stranded gas discoveries, finished with several dry holes, and showed little evidence of the significant oil charge we now know to exist. This paper examines the factors that brought this reversal in fortunes about, the technology that had the greatest impact, and the lessons that can be learned and applied to help drive exploration success in other frontier basin settings in the future.

One of the key factors that contributed to this “revolution in good fortune” was the decision to focus on regional integration of sometimes-disparate geoscience disciplines: geophysical acquisition and interpretation, regional charge modeling, reservoir palaeogeography, pressure prediction and trap analysis. Altogether these provide a far-greater predictive capability than the sum of their individual parts. Today integration is commonly lauded as a prerequisite for effective petroleum systems analysis from frontier exploration to brown-field development. But integration alone doesn't always guarantee success, nor does an understanding of the petroleum system. In this situation, the paradigm shift that contributed most to this success story was the courage to use the drill bit to challenge old dogmas and prove up new trapping concepts that, if successful, would provide a sizeable prize. One such dogma, for example, was that high-relief “blown traps” are simply future exploration failures. Today we know from recent discoveries that leaky traps are active pressure release valves with varying retention capacity, both temporally and spatially.

Geochemical, Isotopic and Seismic Indicators of Fluid Flow in Pressurised Growth Anticlines and Mud Volcanoes in Modern Deepwater Slope and Rise Sediments of Offshore Brunei

Warren, John K.[1], Alwyn Chuang[2], Ian Cartwright[3] (1) Universiti Brunei Darussalam, Bandar Seri Begawan, Brunei (2) Petronas Malaysia, Kuala Lumpur, Malaysia (3) Monash University, Melbourne, Australia

Integration of 3D seismic with seafloor sedimentology (from 187 piston cores), organic geochemistry (gas analysis and chromatography) and stable isotopes of carbonate nodules in the cores, shows that seafloor sediment containing thermogenic gases and bitumens occur atop or adjacent to actively growing mud-cored compressional ridges, particularly where these pressurized fluids and muds periodically breakout onto the seafloor as mud volcanoes. Thermogenic signatures are not found where significant volumes of Holocene sediment are accumulating. There the sediment contains organic signatures and gases that are biogenic and related to the bacterial breakdown in the sulphate reduction zone. Seismic signature shows the volcanoes are regions of pressure build up and their incipient breakout is indicated by a combination of convex upward seismic reflectors and zones of discontinuity in the BSR (a seismic indicator of shallow levels of methane hydrates). This reflects the rise of warm fluids toward the surface and the consequent melting of the bottom parallel hydrate layer. Following pressure release at the seafloor and a period of inactivity, sediments layers within and adjacent to a mud volcano collapse, the reflectors bend downward into the neck of the volcano and a BSR re-establishes in the now inactive neck. Mud volcanoes in the continental slope and rise of Brunei occur in a downslope series of gravity-driven compressional ridges with seismic geometries similar to the salt-cored compressional ridges of the slope and rise setting of the circum-Atlantic salt basins. However, in the case of the shale-cored ridges and mud volcanoes it indicates fluids not lithology.

Hydrocarbon Potential of the Eastern Bengal Fan System in Offshore Northwest Myanmar

Yang, Su-Yeong[1], U. San Lwin[2], Heungbum Yi[3], Michelle Kim[3], Changwon Lee[3] (1) Daewoo International Corporation, Yangon, Myanmar/Burma (2) Myanma Oil and Gas Enterprise, Yangon, Myanmar/Burma (3) Daewoo International Corporation,

Exploration activities were concentrated in the structural highs in offshore northwest Myanmar in 1970's by international oil companies, resulting in only minor gas shows in poor reservoirs. Since then, the region had been barren during the past 20 years until Daewoo International Corporation started exploration in Block A-1 in 2000.

Seismic sequence stratigraphic analysis indicates that two different reservoir types were developed in deep-marine environment in this region: G-series sediments and overlaying D-series sediments. Both of them show seismic characteristics of high amplitude. However, isochore and seismic attributes define two different sedimentary patterns. The G-series sediments are deep-sea turbidites deposited in basin floor fans trending northwest to southeast as a part of the Bengal fan system while the D-series sediments are slope sediments transported from Indo-Burman ranges in the east.

The results of exploratory wells drilled at stratigraphic traps in Blocks A-1 and A-3 offshore northwest Myanmar proved the new play concept proposed by Daewoo International. Thick massive gas sands were discovered in the G-series sediments and the D-series sediments contain gas-bearing thinly-laminated sands. Biostratigraphic data support that the G-series and D-series sediments were deposited in the deep marine environment in Pliocene time. Amplitude maps of 3D seismic data confirm the existence of submarine channel systems which filled the G-series deep-sea turbidites from northwest to southeast to the basin floor fans. After deposition of the deep-marine sands, strike-slip faults and shale-fill channels were developed as flow barriers.

Australia's Southern Margin: A Significant Deepwater Exploration Frontier

Rigby, Stephen M.[1], Mark L. Taylor[1] (1) Woodside Energy Ltd, Perth, Australia

Australia's southern margin basins developed during the Jurassic and Cretaceous in response to rifting and break-up between Australia and Antarctica. Rift-induced depocentres include (from west to east) the Bremer, Eyre, Ceduna and Duntroon Sub-basins of the Bight Basin and the Otway and Sorell Basins further east. Sedimentary wedges composed mainly of Tertiary cold-water carbonates form the present-day continental shelf, while present-day deep water basins have thin Tertiary sedimentary cover.

The deepwater basins of Australia's southern margin remain sparsely explored, with only 3 wells drilled in water depths greater than 500m. Woodside-led joint ventures are actively exploring the vast deepwater frontier province of the Ceduna and Duntroon Sub-basins, where a Late Cretaceous delta system extends over more than 100,000 km^2. As part of a systematic exploration program an extensive regional 2D seismic grid has been acquired and one exploration well (Gnarlyknots-1A) has been drilled. Activity has continued with the recent acquisition of 3D seismic data.

The Otway Basin has been the focus of exploration activity for many years. During the past decade several significant gas discoveries have been made in the offshore shelfal part of the basin and developments such as the Woodside-operated Thylacine gas field are now supplying gas into the eastern Australian domestic market. Exploration is now moving into deep water, where a Woodside-led joint venture has acquired a substantial 3D seismic survey and intends to drill what will be only the second deep water Otway Basin exploration well during the coming year.

Australia's deep water southern margin is still largely unexplored and remains one of Australia's most significant exploration frontiers in an increasingly opportunity-constrained global E&P business.