Facies Analysis and Reservoir Characterization of Eocene Carbonates in East of Daman, Mumbai Offshore Basin, India

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Gas indication in Paleocene- lower Eocene sediments has brought exploration impetus in the area east of Daman, Mumbai Offshore Basin Additionally a seismic feature was mapped and identified as a carbonate buildup within Eocene. The present paper deals with reservoir characteristics in terms of facies analysis, porosity distribution and understanding diagenetic processes which control the porosity in Eocene carbonates and to validate the existence of carbonate buildup. Based on core and petrographic studies, the microfacies identified are argillaceous-foram wackestone, foram-algal wackestone and rarely foram algal packstone within Bassein Formation equivalent. Upper part of this formation is mostly limestone with few shale layers in between and changes to argillaceous facies towards northeast part. Whereas middle and lower Bassein Formation is highly argillaceous with thin bands of limestone except in the area around well ED-B. The study indicates poor to moderate secondary porosity (8-10%) preserved within foram algal packstone/ wackestone facies, which normally decreases downward. The porosity is mainly of secondary origin and preserved in form of network of solution channels and interconnected vugs with some micritic porosity enhanced by solution activity. The secondary porosity lost at several places primarily due to cementation in freshwater phreatic zone, whereas the imprint of marine cementation is rare. The evidence of fresh water phreatic cement includes blocky calcite spar occupying the channels at many places. Based on the limited porosity data, it is apparent that porosity development is better in the central part around well ED-B as compared to the areas in northeast. The microfacies study suggests doubtful existence of carbonate buildup.

Reservoir Development of Cenozoic Carbonates in Southeast Asia

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Almost half of SE Asia's considerable hydrocarbon reserves are contained in carbonates. Although the majority of economic discoveries are in Miocene buildups, Paleogene reservoir intervals also occur. However, there is little data on how the spatial and temporal variability in depositional and diagenetic conditions influence the considerable heterogeneities in reservoir quality often encountered. Paleogene carbonates in SE Asia are commonly dominated by larger foraminifera. These carbonates developed on or around the margins of highs within subsiding basins, and typically form large-scale platforms or isolated shoals. Good poroperms can be preserved in shoal or redeposited carbonates lacking micrite. Secondary porosities develop due to fracturing, chemical dissolution during burial, or as karstic cavities. However, the lack of aragonite, paucity of eustatic fluctuations and deposition in generally subsiding environments reduces the potential for vadose or meteoric leaching. In comparison, Neogene carbonates often contain abundant aragonitic bioclasts, such as corals. Neogene carbonates typically develop as reefal buildups, shelfal deposits or as isolated platforms. Active Neogene compression in SE Asia resulted in increasing subaerial emergence, and many of the platforms were affected by tectonics or eustacy. Compared with Paleogene limestones, poroperms are generally higher in Neogene carbonates and interparticle, biomouldic, vuggy, cavernous and fracture porosities all occur. This evaluation of variability in SE Asian carbonate reservoirs provides much needed data as the hydrocarbon industry focuses on improving recovery from existing fields and exploring for new reserves.

Carbonate Sequence Stratigraphy of Central Luconia Build-Ups – New Thinking Needed

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Core and well log data from 28 Miocene carbonate fields were analysed in a sequence stratigraphic context. Paired with interpretation of regional seismic lines a new sequence stratigraphic scheme for the carbonate section of the Central Luconia province was developed. Analysis of data showed good agreement between the stratigraphic record and published global sea level curves, clearly indicating that eustasy was the main controlling mechanism in carbonate platform development. However, localised tectonics played a role at times and was responsible for considerable facies variations. The sequence stratigraphic scheme is supported by chronostratigraphic data (Sr-isotopes) and was used to aid reservoir correlations at a regional level.
Extensive periods of subaerial exposure marked by intense karstification are part of the carbonate record. Based on the new interpretation, the vast majority of Central Luconia build-ups were terminated at three different third-order sequence boundaries during periods of sea level lowstand, being thereafter progressively drowned by advancing pro-deltaic clastics. This is in contradiction to the current understanding, whereby the demise of build-ups was as a result of rapid transgression and terminal back-stepping.

Neogene Carbonate Platforms in the South China Sea and Indonesian Backarc Region as Recorders of the Evolving East Asian Monsoon

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Miocene to Recent carbonate platforms from southern parts of the South China Sea and Indonesian backarc region have variable internal growth patterns that likely reflect the gradual strengthening of the East Asian Monsoon, an annual seasonal cycle where precipitation and wind directions change dramatically across Southeast Asia. Extensive high-quality seismic-reflection data and published data were examined across the study area and showed that Neogene isolated carbonate platforms commonly have asymmetrical facies distributions and internal stratal patterns that reflect prevailing paleowind directions during growth. Early to middle Miocene platforms throughout the study area show consistent

windward-leeward asymmetry, which suggests that prevailing winds were fairly constant over long time scales. Starting at about 11 Ma, however, growth patterns became much more variable in many platforms, especially those from the East Natuna Basin and offshore Vietnam. These complex growth patterns continue until the present day. In the Indonesian backarc region, middle to late Miocene isolated platforms show strongly asymmetrical but consistent growth patterns that also reflect strengthening of the East Asian Monsoon at this time because prevailing winds during the winter monsoon are out of the west and stronger than the weaker, easterly winds of the summer monsoon. The gradual change to modern monsoonal wind patterns across the South China Sea and Indonesian backarc region began at about 11 Ma, which is consistent with other proxy records for the timing of major uplift in the Tibetan Plateau and associated strengthening of the East Asian Monsoon.

Architecture and growth history of a Miocene carbonate platform: Luconia Province., Malaysia

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Using 3-D seismic reflection data, wireline logs and core data we reconstruct the architecture and growth history of a Miocene Carbonate platform in the Luconia Province, offshore Sarawak, Malaysia. Platform growth started in the Late Oligocene to Early Miocene, by coalescence of isolated patch reefs. The growth history includes phases of progradation, backstepping and occasional collapsing of platform flanks, guided by syndepositional faulting. The most pronounced seismic reflections in the platform correspond to flooding events (thin transgressive system tracts). Subaerial exposure preceding the flooding could be demonstrated in only one case. Platform growth was terminated by gradual submergence (drowning) indicated by smooth, concentric seismic reflections forming a convex mound. Seismic response is strongly influence by variation in porosity. Three different processes have significantly contributed to porosity in the carbonate rocks: selective leaching during exposure, dolomitization and leaching during deep burial, probably related to warm fluids rising from depth. As most of the carbonate porosity formed by carbonate dissolution under deep burial, the slide masses and related turbidites may contain highly porous rocks in the basin between platforms. These porous bodies may onlap other platform slopes, terminate there and become enveloped in clay-rich hemipelagic sediment. On the other hand, the porous layers may establish fluid conduits between neighbouring platforms if slides and turbidites from different platforms touched one another on the basin floor.

Integrated Reservoir Characterization for Evaluating Development Opportunities in Mature Oil and Gas Reservoirs (Miocene Kais Carbonates), Salawati Island, Papua, Indonesia

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Miocene Kais Carbonates was one of mature hydrocarbon reservoir of Salawati Basin, which has been producing oil and gas since 1936 in Papua-Indonesia. A sufficient number of wells, cores, and cuttings are available for the study, resulting in a more rigorous stratigraphic framework for accurate mapping of porosity and permeability required for reservoir zonation. Enhanced petrographic analysis employed to 290 thin sections from 19 selected wells to resolve the relationship between reservoir quality and depositional facies, especially in massively dolomitized reservoirs. Petrophysical analysis and facies determination also conducted to well-log data from 32 selected wells. Careful examinations from previous studies combine with this study come to the idea that one geological model applied for the whole Salawati Island area is not sufficient. Reservoir compartmentalization, either structurally or stratigraphically is necessary.

Three distinct carbonate lithofacies subdivision identified within the reservoir unit: Open Marine Carbonate Shelf Facies, Shallow Marine Back Reef Lagoonal Bays Facies, and Shallow Marine Back Reef Carbonate Bays Facies. Each forms a separate flow unit, which characterized by different stratigraphic and organic skeletal characteristic based mainly on thin section analysis from cuttings and controlled by petrophysical analysis.

Within the reservoir unit, three distinct fluid flow pathways are defined. First, Most Conductive Flow Unit consists of wack-packstone to packstone lithologies, rich skeletal organic grains and dominated by intercrystalline, mouldic and vuggy porosities within matrix and grain, recrystallized to dolomitized cementation. Second, Less Conductive Flow Unit consists of wackestone to packstone lithologies, low skeletal organic grains and dominated by interparticle to intraparticle porosities within matrix and grain, low recrystallized or dolomitized cementation. Third, Non Conductive Flow Unit consists of mudstone, wackstone, and wack-packstone lithologies, very low skeletal organic grains and dominated by chalky porosities within matrix and grain, very low recrystallized or dolomitized cementation.

Input for Carbonate Reservoir Models: Trend Metrics of Modern Platforms and Reef Systems

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An accurate facies model is essential for reservoir development and realistic reservoir modeling, as depositional facies can be a main parameter controlling heterogeneity in porosity and permeability. Prediction of the quantitative attributes (size, shape, orientation, distribution) and variation of facies dimensions is also required for enhanced Multiple Point Statistics simulations for carbonate systems. To address these needs, we generated quantitative data on sizes and shapes of facies within and among different sized and shaped platforms. Landsat images from 19 modern carbonate platforms from the Caribbean and Indo-Pacific regions are used as analogs to offer insights into potential facies heterogeneity of carbonate reservoirs.

The workflow for identifying and quantifying attributes of facies tracts included integrating literature and satellite images in a GIS, followed by statistical analysis. Based on objective reproducible criteria, up to 9 different facies classes were mapped and hand-digitized on all platforms using ER Mapper. Reservoir facies included fully aggraded reef, partially aggraded reef, reef apron, shoals and shallow platform interior. A GIS provided a tool for quantitative characterization, measuring for every polygon of each facies attributes such as area, perimeter, width, length, orientation, and the variability within those metrics. Subsequent statistical analyses demonstrate the existence of certain predictive "rules" between the configuration and composition of facies tracts on and among carbonate platforms (e.g. size of platform versus number/abundance of facies or size of platform versus shape complexity.) These kinds of "rules" provide both general concepts and raw data that can be used as input for enhanced carbonate models.

Cat Cay Shoals Revisited: Contrasting Morphologies in A Bank Margin System, Bahamas

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The modern 1-3 km wide and 35 km long sand belt around Ocean Cay, western margin of Great Bahama Bank, includes considerable variability in sand body geometries and facies. The shoals north of Ocean Cay, commonly referred to as Cat Cay Shoals, and flood tidal deltas (south of Ocean Cay) are the only examples of shoal complexes on the leeward side of the Great Bahama Bank. Our observations indicate contrasting characteristics in shoal geometry and composition between the north and south areas.

We compared the two areas of Holocene deposits by examining about 220 bottom sediment samples, and bathymetry and tidal flow patterns from 60 acoustic Doppler current profiles. South of Ocean Cay, Pleistocene eolianite island ridges provide sufficient tidal flow restriction to promote stronger currents during flood tide. Elongate, narrow sand shoals consisting of moderately sorted, medium-sized skeletal grains abruptly pass laterally to bioturbated facies or to areas with rocky bottom and a thin sediment cover. Ebb flows, with lower velocities, shape morphology of sand bars creating small-scale bedforms. The size and type of sands of the Cat Cay shoal are less variable than southern areas.

These results illustrate that bedforms, constituents, grain size and sorting of the sand bodies are related to the tidal flow dynamics and are linked to the bathymetry and physiographic setting of each area. Heterogeneity within these deposits is similar to that expected in the ancient record. Sediment textures and information such as size, shape, orientation and lateral facies variation within these geobodies can be used in the construction of meaningful geologic models.

Architecture of Recent Reefs in the South China and Celebes Seas – the Perfect Analogue

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Submarine mapping of reefal architecture and carbonate facies carried out on several recent reefs in the South China and Celebes Seas, offshore Borneo has revealed new data that can be used to improve understanding of Miocene gas-bearing carbonate build-ups in the Central Luconia basin. In this respect, a wide range of recent coral reefs, ranging from proximal low relief mounds to distal isolated atolls and incipiently drowned reef complexes in water depths of up to 60 meters were investigated. The results are particularly interesting with regard to flank geometries and preferential progradational directions influenced by submarine currents. Mapping of flanks revealed the rate of reefal accretion since the last sea level lowstand. Furthermore, it was shown that the depth of submerged open caves in the flanks of recent reefs can be correlated with an uncertainty of ±2 meters from on side of Borneo to the other, over a distance of 650 km.

Stable Isotope Signatures in Carbonates as a Tool for Hydrocarbon Exploration

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Early marine aragonite cements are commonly precipitated from pore waters at the basal portions of coral skeletons. Inorganic Mg-calcite may also be added to the coral skeleton during early diagenesis in the marine environment. The progressive addition of early diagenetic inorganic aragonite and calcite toward the base of massive corals in Western Australia and Papua New Guinea produces an apparent increase in density and an increase in δ13C. Both diagenetic aragonite and Mg-calcite precipitated in the marine environment are enriched in 13C relative to coral aragonite. A comparison of the change in density and change in δ13C values in our corals leads to sound interpretations of the relation between the nature and degree of diagenesis and their effect on the δ13C values. Additional consideration of the relationship between δ13C and δ18O signatures confirmed the above interpretations. Calcite has almost the same density as aragonite (2.71 cf 2.93 g/cm3), and thus the addition of similar amounts of secondary calcite in the Papua New Guinea coral and secondary aragonite in the Ningaloo Reef coral would produce the same density increase. An apparent increase in density of about 25% due to infilling of pores in the coral skeleton would be accompanied by a ~1.6‰ decrease in δ13C in the coral affected by the precipitation of secondary inorganic aragonite as the latter is enriched in 13C, relative to coral aragonite. Inorganic Mg-calcite precipitated in equilibrium with seawater is also enriched in 13C relative to pristine coral aragonite (O'Neil et al. 1969), though not to the same extent as inorganic aragonite. Despite this, δ13C would still show a decrease of ~0.7‰ towards the present.