Tectonic Influence on Southeast Asian Carbonate Development during the Cenozoic

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Tectonically SE Asia is one of the most complex and active areas of the world. The warm, shallow waters of the region also host extensive and highly variable carbonate development with the highest global diversity of coral reef biota. Throughout the Cenozoic, tectonics has been a major control on the citing, development and demise of many of the carbonate platforms and may have influenced the development of the biodiversity foci.

The whole remit of tectonics settings, such as continental passive margins, rifted margins or microcontinental blocks, island arcs, backarc, forearc, foreland and strike slip basins, have all occurred in SE Asia during the Cenozoic. These settings may vary temporally and spatially, but in each a variety of carbonate depositional systems developed, often on structural highs. End-member carbonate systems in all settings are isolated platforms, land-attached shelves, and more localised or transient carbonates, including fringing reefs, buildups, patch reefs or mixed carbonate-clastic deposits.

Tectonics, through subsidence, uplift, active faulting, tilting or associated silici/volcaniclastic input strongly affected facies variability, stratal/platform geometries, sequence development and carbonate demise. In turn, evaluation of the carbonate successions can help determine the timing of tectonic events, rates of movement and the dynamic interplay of factors influencing marine sedimentation.

Structural Controls and Resulting Variations in Oligo-Miocene Carbonates of the East Java Basin, Indonesia: Examples from the Cepu and North Madura Areas

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Carbonates of the Oligo-Miocene in the East Java Basin exist in a variety of structural settings which influence buildup architecture and internal characteristics. Examples of these variations can be demonstrated at regional and local scales in the Cepu and North Madura areas. Regional and local influences were investigated through study of well and seismic data. At Cepu, many high-relief reefal carbonate buildups are imaged by 3D seismic on a structural high block. Absolute timing of deposition of the buildups and overlying sediments was established through integration of Strontium stable isotope and biostratigraphic data. These data indicate that carbonate deposition terminated from west to east due to more rapid subsidence in the western part of the Cepu area. North Madura, also imaged by 3D seismic, is a broad Oligo-Miocene carbonate platform that is bisected by a large interbuildup low that formed due to increased local subsidence. The interbuildup low hosts numerous buildups which are elongate and smaller than the adjacent platforms. Although they are of similar age and within the same basin, there is a marked difference between the styles of carbonate deposition in the two localities due to structural control. Cepu underwent higher subsidence rates that resulted in less areally extensive carbonate buildups that backstepped through time to keep-up with sea level. North Madura exhibited slower subsidence rates that enabled the carbonate system to build out and cover extensive areas. The differences have implications for variations in stacking patterns, facies distribution, and diagenesis which impact exploration assessments and reservoir performance.

Stratigraphic Evolution of Oligocene–Miocene Carbonates and Siliciclastics of East Java Basin, Indonesia

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The Oligocene–Miocene of East Java is characterized by multiple stages of isolated carbonate mound growth surrounded by deeper marine off-mound sediments or by shallow-marine mixed carbonate-siliciclastis or just clastics. Three stratigraphic intervals are recognized: Kujung (carbonate mound and off-mound), Tuban (mixed carbonate-siliciclastic), and Ngrayong (siliciclastic). Exposures of the Kujung unit are limited to a few isolated outcrops. At the base, the oldest Kujung exposed is represented by a high-energy, laterally extensive, shallow-marine carbonate facies that grades laterally into deep-marine off-mound sediments of calcareous mudstone and chalk (lower Kujung). The carbonates ramp was drowned around 28.0 Ma. The exposed Kujung shallow water carbonates where covered by chalks and deep water carbonate turbidites deposited around 23.44 and 24.31 Ma. These carbonate turbidites are time equivalent to tops of seismic reflectors capping the youngest Kujung mounds that often their location is fault controlled. The Tuban unit (22–15Ma) consists of widely exposed shallow-marine mixed carbonate and siliciclastic and poorly exposed open-marine shale and chalk facies. The Tuban consists of at least six stacked cycles that reflect deltaic deposition with episodes of shallow-marine carbonate mound growth. The Ngrayong unit (15–12 Ma) represents a period of regional siliciclastic influx and progradation of tidally influenced deltas and grades into turbidites, basinal shale, mudstone, and chalk. Ngrayong beds are truncated by Bulu carbonates (Serravallian–Tortonian). The timing of carbonate growth, mixed carbonate-silicilcastic, and clastic lithologies constrain the tectonic history of the area and controls on carbonate growth and demise.

Tectonic Controls on Carbonate Platform Evolution in Extensional Settings

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The tectonic history of extensional settings includes pre-rift, syn-rift, post-rift, and in some cases, inversion stages. Carbonate platforms are generally initiated during the late syn-rift to early post-rift stage but may continue to grow throughout the post-rift history of a basin, especially where siliciclastic influx is limited. Carbonate platforms are rare during pre-rift and inversion stages because there typically are no suitable flooded substrates for carbonate

sedimentation.
Subsidence patterns are strongly fault-controlled during syn-rift stages. Fault scaling laws and rules for fault growth, spacing, and linkage/interaction are important. Footwall highs are common nucleation sites for carbonate platforms. Active fault displacements and related surface deformations during platform growth may control platform-margin locations, facies distributions across fault-bounded highs, siliciclastic-carbonate interactions (especially in fault-bounded depocenters), and internal stratal patterns within syn-rift platforms. Growth stratal patterns of syn-rift platforms are well-documented in carbonate platforms exposed along the flanks of the Red Sea, but are also well-imaged on seismic profiles from other extensional settings such as the South China Sea.
During post-rift phases, remnant rift topography may continue to influence the location and morphology of carbonate platforms until it is largely filled in and smoothed by prograding depositional systems. Along passive margins, long-term stratigraphic development within post-rift carbonate platforms is controlled by long-wavelength thermal subsidence, patterns of flexural onlap, and regional stretching-gradients. Marginal plateaus and transform margins represent special passive-margin settings where stretching-gradients and complex partitioning of extensional strain during syn-rift stages may continue to influence carbonate-platform development into very late post-rift stages (i.e., >100 Myr after the beginning of post-rift stage).

Tectonic Control on Late Devonian Reef Complex Evolution, Lennard Shelf, Northern Canning Basin, Australia

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Mixed carbonate-siliciclastic deposition along the northern margin of the Fitzroy Trough (northern Canning Basin) was strongly controlled by extensional tectonism and half-graben development in the Late Devonian. Tilt block highs were favourable sites for reef complexes which are now preserved in exhumed limestone ranges on the inner Lennard Shelf as well as deeply buried reef complexes, some of which host oil, across the middle and outer Shelf. Half graben and large inter-reef basins were filled predominantly with siliciclastic sediments shed from the adjacent Kimberley landmass. Coarser (conglomeratic) equivalents deposited in deltaic systems are exposed within and adjacent to the limestone ranges.
Contemporaneous faulting during reef evolution is interpreted from pinnacle development and/or subaerial exposure surfaces on footwall blocks coeval with deeper water deposition on the hangingwalls. Outcrop studies form the basis for a platform evolution model for the northwestern Lennard Shelf in which third-order sequence boundaries define seven discrete (approx. 1-3 myr) phases of platform growth and demise. This model provides a framework for analysis of half-graben fills and, in particular, to assess the character of predicted lowstand deposits through integration of seismic, sedimentologic and biostratigraphic data. Various carbonate units as well as mounds and/or reef complexes are recognised in the half-graben fills. The similarity between these buildups and those which host oil, along with others interpreted on the outer Shelf, emphasize both a complex paleogeography and underexploration of the Lennard Shelf to date.