

Cenozoic Carbonate Platforms Across the South China Sea: Controls on Their Initiation, Growth, and Termination and Implications for Petroleum Systems*

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Carbonate platforms of Paleogene to Recent age are widely distributed across the South China Sea (SCS) and provide important records of the tectonic, depositional, and climatic history of this extensive, geologically complex region. Isolated platforms are the dominant platform type and reflect the strong influence of tectonic deformation on platform growth. Land-attached ramps, transgressive shelf-edge reefs, and pinnacle buildups also developed locally, especially after siliciclastic facies filled or partially filled many depocenters. Most isolated platforms were initiated on fault-bounded highs that were either: (1) inherited from previous deformation phases (i.e., platforms do not have syn-deformational growth stratal patterns); or (2) actively deforming during platform growth (i.e., platforms have characteristic growth stratal patterns that reflect local kinematic histories of fault systems). Fault-bounded highs became submerged and areas where shallow-marine carbonate platforms could develop because of the combined effects of long-term sea-level rise and long-wavelength tectonic subsidence across the SCS. Fault-bounded highs served as substrates for carbonate platforms where adjacent depocenters were underfilled with sediment, so that siliciclastic sediment was trapped in the depocenters. Syn-tectonic platforms have internal growth stratal patterns and external morphologies that reflect local styles of extensional, transtensional, and transpressional deformation. Thus, syn-tectonic platforms also provide key records of regional deformation patterns throughout Cenozoic time, especially displacement histories on some important shear zones that transect the SCS region.

Other external factors that likely influenced development of SCS carbonate platforms include: (1) long-wavelength differential subsidence patterns that were either related to post-rift thermal subsidence (Pearl River Mouth Basin, Reed Bank and other parts of the Spratly and Paracel islands) or to flexural subsidence (Dangerous Grounds area, from South Palawan to offshore northwest Sarawak); (2) long- and short-term eustatic trends during Oligocene to Recent time; (3) climatic history, including evolution of the East Asian Monsoon; (4) siliciclastic influx from major river systems that drained southeast Asia, the Indonesian and Philippine volcanic archipelagos, and Borneo; (5) changes in oceanic circulation patterns; and (6) biotic evolution. In particular, regional trends in windward-leeward facies relationships and large-scale stratal patterns within carbonate platforms likely reflect changes in atmospheric and oceanographic circulation across the SCS during Cenozoic time and may provide some of the best proxy records for documenting the evolution of the East Asian Monsoon.

Inner-platform accumulation rates varied over time and reflect regional biotic, paleoclimatic, and eustatic changes. Icehouse platform successions appear to be thicker on average than greenhouse successions, which probably indicates that inner-platform settings were within optimal depths, for longer periods of time, during icehouse conditions. Platform termination histories across the SCS are also complex, with some apparent, but poorly understood, regional patterns. Most terminated platforms are buried beneath siliciclastic successions of the Sunda Shelf and other continental margins surrounding the SCS, which suggests that siliciclastic influx influenced platform termination. Regional seismic-stratigraphic relationships, however, commonly show that platforms were terminated, accumulated little to no sediment for several million years, and were submerged to several hundred meters water depth, before they were eventually downlapped by progradational siliciclastic facies. Many platforms across the entire SCS also were terminated during middle Miocene time, which probably reflects the major tectonic and climatic changes that occurred then. There appear to be few drowned Cenozoic platforms, however, in modern, deep-water parts of the SCS (except for the Miocene platforms in the deeply subsided flexural basins of offshore Palawan and northwest Borneo). This indicates that throughout Cenozoic time, many SCS platforms have been able to: (1) aggrade faster than long-term tectonic subsidence, including the highly thinned continental crust near the continent-ocean boundaries around the SCS, where post-rift subsidence rates should have been highest, and (2) recover from short-term eustatic fluctuations that either subaerially exposed the platforms or submerged them to sub-photoc depths. Thus, although the drowning histories of carbonate platforms around the SCS remain somewhat enigmatic, the specific reasons for drowning depend on the unique location of each platform and the exact time of their termination.

Petroleum reservoirs are extensively developed in Miocene isolated-platform successions, many of which were subjected to intense meteoric diagenesis and secondary porosity development. Petroleum charge is largely from older, syn-rift to early post-rift, lacustrine source rocks in adjacent rift depocenters. Several giant accumulations of natural gas have been discovered in isolated platforms of the southern SCS, but they are CO₂-rich. Top and lateral seals consist of basinal shale facies. Sand-rich clinoform and toeset beds that downlap directly onto platform carbonate reservoirs and later faults (typically related to differential compaction or inversion/reactivation events) represent top-seal risk elements.