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ORAL PRESENTATION

Animated, High Resolution Plate Tectonic Reconstructions of SE Asia Based on the Geognostics Earth Model (GEM) – a New Base for Paleogeographic Mapping

Jon Teasdale[1], Jan Bon[2]

[1]*Geognostics, UK*

[2]*GeoConsultants, Netherlands*

jon.teasdale@geognostics.com

INTRODUCTION

SE Asia is the most geologically complex region on Earth due to the three-way convergence of the Indo-Australian, Eurasian and Pacific plates. Many attempts have been made to unravel its tectonic history with varying levels of success, but most are limited by the lack of integration of offshore geological data, hence their utility as basin exploration tools is limited.

We have gone back to first-principals, by interpreting basement terranes and major structures across the region, both onshore and offshore, to provide a spatially consistent and continuous view of its geological fabric. We then worked back in time to undo deformation patterns on major shear zones, basins and subduction zones. A detailed understanding of the basins of the region helped us to unravel this history.

The resulting animated plate model provides a kinematically and geologically constrained view of the tectonic evolution of SE Asia. It is consistent with the evolution of basins and petroleum systems across the region and can be used as a predictive tool for hydrocarbon exploration.

MODEL BOUNDARY CONDITIONS

The starting point of our model is a spatially consistent interpretation of the present-day crustal framework of SE Asia, comprising basement terranes and major structures. Plate tectonic analysis is somewhat futile without a good definition of these building blocks, both onshore and offshore. We used published geological maps, digital elevation data, gravity, magnetics and seismic to map basement terranes and structures focussing on spatial continuity, especially offshore.

The complex collage of basement terranes in SE Asia comprises three broad terrane groupings:

1. Precambrian 'Cratons' including Greater India, Australia and South China-Indochina. At a first approximation these continents have behaved rigidly since the early Palaeozoic.
2. Proterozoic-Palaeozoic, Gondwana-derived continental terranes that crossed the Tethyan oceans and progressively amalgamated with Eurasia in the Mesozoic.
3. Mesozoic-Tertiary arc-related terranes that have amalgamated to SE Asia or formed in situ at its margins since the Cretaceous.

We have interpreted the regional structures that bound and deform these basement terranes, from subduction zones and orogenic thrusts, to strike-slip faults and basin-bounding normal faults. These structures have been attributed by age and plate code so that they appear and disappear appropriately when reconstructed.

In order to understand the temporal evolution of the geology of SE Asia, a detailed tectonostratigraphic event chart was constructed by analyzing more than 300 publications for relevant observations. These data were divided by basement terrane and basin, and then used to define a series of key events and corresponding basin phases. Stratigraphy and petroleum systems have been characterized in this 4D framework, and most SE Asian megasequences coincide with these time steps.

PLATE RECONSTRUCTION METHODOLOGY

Our plate modelling was undertaken using Rothwell's PaleoGIS software in ArcGIS. Starting in the present-day, we worked back in time to undo deformation patterns on major shear zones, basins and subduction zones, using the time steps outlined above. The resulting plate model was animated in Microsoft PowerPoint to enable controlled viewing both forwards and backwards in time. Animation is a key step in plate modelling as it highlights inconsistencies in plate rotation poles. Many published plate models do not animate well.

MODEL HIGHLIGHTS

Some significant outcomes of our plate model include:

- The recognition that SW Borneo and Peninsular Malaysia are part of the same rigid Sundaland basement terrane linked by mappable basement structures and compositional domains, discounting independent rotation of Borneo.
- 'Progressive rotational extrusion' of Sundaland, then Indochina was accommodated by a series of major strike-slip bounding shear zones that follow small circles, indicating block rotation. Firstly, the greater Wing Chao Shear Zones in Southern Thailand caused transpression in the Gulf of Thailand, opened the Malay Basin pull-apart, and 'horse-tailed' into the South China Sea opening the Penyu, Cuu Long and other rifts in the Late Eocene-Early Oligocene. As India moved northward, a second phase of extrusion occurred in the Mid-Late Oligocene, via sinistral strike-slip on the greater Red River Shear Zone in SW China and Northern Vietnam, opening a series of new syn-extrusion, strike-slip basins, most spectacularly in the Gulf of Thailand and the Nam Con Son Basin. These events caused clockwise rotation of Sundaland plus Borneo in two phases in the Late Eocene and Oligocene, consistent with observed basin evolution.
- The opening of the South China Sea is a logical consequence of our rotational extrusion model, which is consistent with the latest published data on the timing and kinematics of sea floor spreading, as well as rift ages for extension on its margins.
- A detailed analysis of the 'train wreck' of terranes in East Indonesia, consistent with the onshore geology, basin evolution, paleogeography and petroleum systems. This domain is dominated by westward movement of the Pacific Plate coupled with northward movement of Australia. We have analysed the complex counter-clockwise rotation of the Bird's Head in this context, explaining its surrounding basins and fold belts.
- A series of NW-trending sinistral strike slip shear zones linked the 'salami-slicer' tectonics of East Indonesia with NW Borneo, driving the Sabah Orogeny in the Mid Miocene. Unravelling these shear zones clarifies the geology of Northern Indonesia and the Philippines, and a series of linear island arcs and back-arc basins emerge that significantly simplify the geology of this highly complex region.