Paper 24

Stress fields of Sundaland during the Tertiary

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Sundaland contains the geologically stable Sunda Platform and Cenozoic crustal material that accreted onto it and now forms Sumatra, Java, and Kalimantan/Borneo. Throughout the Cenozoic, changing plate dynamics exerted varying degrees of control onto the stress regime of the region. Partitioning of stress conditions in space and time is most apparent in the Sarawak-Brunei-western Sabah segment, but in other sectors of Sundaland the stress fields appear only to reflect the large-scale plate reorganisations that began in late Early Miocene and in some areas continued until the present. Generally, these changing plate movements resulted in mid-Miocene angular unconformities. In spite of the strong mid-Miocene tectonic disturbances, there are areas where the maximum principal stress (P) orientation persisted across the tectonic event. In the Strait of Melaka, P has remained orientated NE-SW since pre-Oligocene time. The P-orientation is shown by outcropping folds, reverse faults, distribution patterns of depocentres and graben-halfgrabens, en echelon fault zones, and wellbore breakouts. The existing structural database occasionally also provides reliable evidence of significant lateral fault displacements. Current stress fields are indicated by first-motion orientations of shallow earthquakes and are derived from repeated, detailed GPS measurements at about 40 stations distributed throughout the Indonesian and Philippine islands.

During the Cenozoic, Sundaland was subject to the following processes.

(1) From the Eocene onward, sub-plate India has collided with Eurasia. Its far-field effects in Southeast Asia manifested as SE-ward crustal slab extrusion of Indosinia and part of Sundaland along major NW-trending strike-slip faults such as the Three Pagodas and the Red River zones. Initially this so called model of extrusion tectonics was facilitated by sinistral wrenching on the regional NW faults, but later field work has provided evidence for slip reversals. For instance, the Three Pagodas fault that is believed to extend as the Axial Malay fault zone in the basement of the NW-striking Malay Basin shows such evidence. In pre-Oligocene time, the Axial Malay fault zone moved sinistrally and in the process produced east-west halfgrabens in the basement. Sedimentary fill of these depocentres were later compressed into large E-W anticlines, whose orientations and positions where predestined by those of the halfgrabens. Earlier regional sinistral wrenching was transtensional while subsequent dextral fault slip occurred in a transpressional regime. Proponents of extrusion tectonics believe that as consequence Sundaland rotated clockwise.

(2) The Indian Ocean-Australian Plate converges onto Sundaland throughout the Cenozoic. Subduction occurs at the Sunda Trench. Along the Sumatra-Java segment the convergence angle has grown more acute by as much as 50 degrees according to some workers, who also proposed that Sundaland achieved this situation by counterclockwise (CCW) rotation. The Sunda backarc basins are thought to be CCW-associated rifts, of which the North Sumatra Basin developed as a pullapart depression. The arcuate distribution of the Sunda backarc basins and their uniform tectonic divisions in sections are difficult to reconcile with the hypothesis. Instead their origin is better explained by crustal thinning when thermal convection patterns of the asthenosphere became disturbed by subduction.

(3) During the Cenozoic changing plate dynamics of the Pacific, the smaller Philippine, Caroline and South China Sea also significantly influenced the tectonic history of the basins of Sundaland. Until the Middle Eocene, the Pacific Plate proceeded NNW-ward and left the Emperor seamounts in its track. Thereafter, the plate moved WNW which is documented by the Hawaiian chain of seamounts and volcanic islands. The volcanic centres of the island chains all originated above of long-lived mantle plume that currently is under Hawaii Island. The WNW-ward thrust of the Pacific Plate only became effective for Southeast Asia after seafloor spreading ceased in the South China Sea Basin and in the other smaller named basins. Most of the Tertiary stratigraphy of Sundaland is characterised by mid-Miocene unconformities.

(4) The South China Sea Basin consists partly of oceanic lithosphere and partly of attenuated continental crust. In its northeastern part are East-West magnetic stripes symmetrically arranged about the Scarborough Ridge which is considered the spreading axis. The E-W magnetic lineations indicate spreading activity between 32 Ma and 17 Ma). Magnetic stripes in the SW sector trend SW-NE and probably represent earlier spreading. At the southern margin of the basin, the spreading had been accommodated by subduction beneath Borneo. However, associated volcanism is yet to be reported and the NW Borneo "Trench" is but a downwarp caused by sediment loading according some researchers. On the other hand, structural style that includes imbrication verging NW is consistent with tectonic convergence of Borneo and the South China Sea Basin.

(5) The central part of the Andaman Sea Basin consists of oceanic crust whose magnetic lineations represent spreading since 13 Ma. The basin is bordered by the active Andaman-Nicobar island arc in the west and by the Mergui Ridge in the east. The latter is the separation with the greater North Sumatra Basin. The rift axis is segmented and forms the connection between the dextral transform Sagaing and Sumatra fault zones.

(6) The eastern Kalimantan older stress field is associated with opening of the Makassar Strait that probably occurred between early Palaeogene and Early Miocene (44 Ma–34 Ma). The separation is suggested by geological similarities of both sides of the Strait. Upon this tensional regime has become superimposed strong compression that manifests as mid-Miocene and younger fold-thrusts verging towards the axis of Makassar Strait.