



BOOK REVIEWS

Tectonic Evolution of Southeast Asia

Edited by Hall, R. and Blundell, D. J. Special Publication Geological Society No. 106. List prices £79, \$132.

How many times have you heard a lecture on some older mountain belt which concluded that the palaeogeography of the area "may have looked something like the tectonics of SE Asia today"? If this sounds familiar, then the reason is that Southeast Asia is the home of some of the World's classical geological type localities: the marginal basins of the western Pacific, the great island arc systems such as the Izu-Bonin-Marianas arc and the highly evolved Sumatra-Java-Banda arc, accretionary thrust wedges such as Taiwan and Timor, obducting ophiolite belts such as Papua New Guinea, passive continental margins such as SE China and northern Australia. The area is immensely complex with practically every type of tectonic setting at the present day. The long-lasting northward subduction of the Indian plate has resulted in oblique convergence with the Sumatra-Java arc with a transtensional pull-apart basin developing in the Andaman Sea. The northward drift of Australia has resulted in the underthrusting of the Timor accretionary prism and deep subduction beneath the Inner Banda arc. The westward subduction of the Pacific plate beneath the Izu-Bonin arc has resulted in creation of the island arc systems that stretch from Japan southwards to New Guinea. The smaller marginal basins behind the Marianas arc such as the Philippine, Sulu, Celebes and Molucca Seas have a complex evolutionary history with contorted Benioff zones, rotations about vertical axes and development of back-arc spreading centres.

The book has two parts, the first seven papers dealing with the present-day tectonics and the second part, consisting of 27 papers, dealing with the tectonic development of SE Asia. Active tectonics is discussed based on GPS (Global Positioning System) satellite data and earthquakes to determine the motions and rates of plate movement. In the first paper, McCaffrey uses earthquake slip vectors, together with geological information and geodetic measurements, to infer the degree to which oblique convergence, which is ubiquitous in SE Asia, is partitioned. Regions where oblique convergence is strongly partitioned are the Marianas, New Hebrides, Philippines, Sumatra and New Zealand. Malod *et al.* show that the northward directed subduction is normal in front of Java but oblique in front of Sumatra with dextral strike-slip motion taking up much of the relative north-south convergence along the Andaman-Mentawai fault and Sumatra fault. Rangin *et al.* report on a swath mapping, gravity and single channel survey in the Molucca Sea. BIRPS deep seismic reflection profiles across the north Australian margin to the Banda arc combined with earthquake data are used by Richardson and Blundell to infer the deep structure of this convergent margin. It appears that, although in Timor the accretionary prism thrusts are all north-dipping and south vergent, to the north of Timor major reflectors all indicate structures dipping southward, antithetic to the subduction direction. Snyder *et al.* and Hughes *et al.* also use the BIRPS seismic reflection data combined with Bouger gravity anomalies to define some unusual features of the Banda arc, including anomalously thick crust east of Timor and a leaky fracture zone below an active volcano, Gunung Api. They postulate that a local indentor of Australian crust occurs beneath the Banda arc, east of Timor and that fractures propagate ahead of the indenting wedge. One of the most puzzling features of the entire SE Asian region is the 300 degree curvature at the eastern end of the Banda arc. Previous interpretations were that the subduction zone follows the deep Timor-Tanimbar trough and the Aru trough. Milsom *et al.* studied the Kai islands right at the maximum curvature of the arc, and postulate that the deformation front between Australia and the Banda arc extends between the Kai islands rather than following the trench to the east.

The second and longer part of the book is given over to the geological evolution and tectonic development of SE Asia. Plate reconstructions and palaeogeographic evolution of the area is the subject of several

contributions. In particular, the paper by Hall has a series of ten colour plates showing palaeogeographic reconstructions of the whole SE Asian region from 50 Ma to the present day. Two other papers discuss the pre-Cretaceous evolution (Metcalf) and the Cenozoic evolution (Packham). Linking the timing of deformation, metamorphism and accretion of terranes from Central Asia and the Himalaya into SE Asia proves problematic, and the palaeomagnetic data is, in places such as Borneo, at odds with rotations predicted by the indentation model. One major problem seems to be how the rotations of one block or terrane are accommodated in their neighboring terranes. Rotations may be easily picked up by palaeomagnetic data, but it is much harder to map out structures across these deforming zones to understand how strain is partitioned across the margins of these rotating blocks. The danger is that this approach might be taken to assume rigid block rotations in plate tectonic terms, whereas most recent work in Central Asia shows that the rigid block, plate tectonics *sensu stricto* cannot adequately explain the active tectonics of the continents. Earthquake data in the oceans shows that plates are commonly surrounded by narrow deforming zones; this is clearly not the case for continental areas such as Tibet or the Aegean, where earthquakes show very large areas of active deformation.

The remaining papers in the volume are arranged broadly in geographic order from the Burma (Myanmar)-Thailand-Laos area in the west to Papua New Guinea in the east. One of the most laudable aspects of this book is the collaboration of academic researchers with petroleum company geologists, and several papers in this volume show high quality seismic and well data that may otherwise have been buried forever in industrial drawers. This combination of industry and academic research has worked extremely well in past Special Publications (e.g. Oman region; Special Publication of the Geological Society no. 49) and it succeeds admirably again here. One paper by McCourt *et al.* deals with the Mesozoic and Cenozoic plutonic evolution of the Sumatra area where new K-Ar mineral dating indicates four main periods of plutonic activity from the Jurassic-early Cretaceous up to the Miocene-Pliocene. The granites are all calc-alkaline metaluminous ("I-type") subduction-related volcanic arc granites, continuous northwards with the western granite province of Thailand and Burma. It shows that the southern margin of Sundaland has been the site of active subduction-related magmatism since the early Mesozoic.

A large amount of new field, seismic, geochronological data is described from west Sulawesi and the Makassar Strait, east of Borneo in Indonesia, in a paper by Bergmann *et al.* Previously thought to be a rift-related tectonic feature, these studies now show that the Makassar Strait is a Neogene foreland basin, bounded in the west by the east-vergent Kutei fold belt, and to the east by the west-vergent Sulawesi thrust belt. The Lamasi ophiolite complex of eastern Sulawesi forms the uppermost thrust sheet and $^{40}\text{Ar}/^{39}\text{Ar}$ and fission track dating shows that, as expected, thrusts are sequentially younger from east to west across Sulawesi from the highest ophiolite to the youngest, lowest thrust tips in the Makassar Strait. Other papers describe the tectonics of the Halmahera (Baker and Malaihollo), Bacan (Malaihollo and Hall) and Obi islands at the western end of the Philippine Sea plate and the Seram ultramafic complex (Linthout *et al.*) at the northern extremity of the Banda arc.

This book arose from a conference on the Tectonic evolution of SE Asia held at the Geological Society in London in December 1994 to mark the retirement of Tony Barber, who has been a tireless researcher in SE Asia for many years and was instrumental in setting up the London University SE Asia Research group. The book is a splendid tribute to him and can be highly recommended to anyone with more than a passing interest, not only in the region for its own sake, but also in the tectonics of one of the most fascinating parts of the World. It brings together the latest research in active tectonics, geophysics and geology in SE Asia by academic and industrial researchers, and shows that only by combining all these elements will true advances, both in data acquisition and new ideas, in the Earth Sciences be made.

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