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SE Asian–West Pacific Tectonics and Mantle Structure

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It is probably impossible to interpret mantle structure without having a tectonic model first – which immediately raises some difficult questions. Particularly problematic is a reference frame. For Eurasia it is common, and probably reasonable, to assume little Cenozoic movement of the lithosphere relative to the underlying mantle, but can this assumption be justified for the Mesozoic? Even for the Cenozoic a small drift could mean significant misinterpretation of cause and consequence.

Bearing this caveat in mind, for SE Asia and the adjacent West Pacific the upper mantle contains a record of little more than the last 15 Ma, with a few exceptions. The obvious features of subduction are recorded, with some interesting details, but some convincing subduction zones are not seen. The upper mantle structure shows us that we cannot yet see such details, such as multiple nearby subduction systems, tearing slabs, or rollback, deeper in the mantle or in parts of the region where resolution of tomographic models is poor. The lower mantle therefore displays only a crude record of tectonic history and probably nothing older than Mesozoic.

On the other hand, the tectonic history we find recorded at the surface at the boundaries of SE Asia with the Indian–Australian and Pacific plates is also incomplete and problematical. In many areas the major plates have no clear-cut boundaries, the structure of the upper crust is much more complex than the deeper lithosphere, and for the continental regions it seems that the upper parts of the deforming lithosphere may be completely decoupled, within the crust, from what is beneath. SE Asia is not a plate in any meaningful sense, but is a heterogeneous region of weak and strong parts.

There has been a long history of subduction beneath SE Asia. The deep high velocity anomaly in the lower mantle beneath the region appears to be a composite entity that formed by subduction in the Mesozoic and then influenced the position of later subduction zones. This long term, but not continuous, subduction resulted in a weak and thin lithosphere, which is very responsive to changing forces at plate boundaries and contributed to a hot and weak lower crust that can flow due to tectonic and sedimentary loading. During the Cenozoic there were unusually rapid vertical motions (both subsidence and uplift), with gravity-driven movements of the upper crust, accompanied by exceptionally high rates of erosion, and by massive movements of sediment. The magnitude of these motions is probably far greater than dynamic topographic effects within SE Asia although mantle-driven vertical movements may be detectable in stronger continental parts of the region and in some of the marginal oceanic basins.

Back-arc basins such as those of the Philippine and Banda Seas appear to have formed by rollback driven by the great age of the subducting lithosphere, mainly in intra-oceanic settings at plate margins. Other marginal basins within continental crust, such as the South China Sea, are more easily explained by slab-pull forces. Back-arc basins of Mesozoic age are not obvious, although ophiolite and arc remnants in Indonesia, the Philippines and New Guinea suggest that they formed at intra-oceanic margins of Pacific plates and perhaps not at the continental margins of SE Asia.