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Mesozoic Arc Accretionary Tectonics and Dextral Strike-Slip Faulting in Singapore

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To address competing land-use requirements, and the needs of an ever-growing population, Singapore looks to the subsurface to meet many of its future development needs. The subsurface is now considered an attractive development space for, amongst other things, energy production and infrastructure, waste disposal and treatment, groundwater abstraction and water storage, transportation infrastructure, industrial manufacturing and logistics. Singapore aspires to become a 'smart' nation/city that integrates transportation, utilities and services infrastructure with information communications technology (ICT) in order to facilitate sustainable management of its societal assets. A comprehensive understanding of Singapore's geology is therefore critical to both future development and ongoing management of the subsurface.

The British Geological Survey (BGS) is working with Singapore Building and Construction Authority (BCA) to deliver that modern geological knowledge-base to benefit the widest possible stakeholder community, including the public and private sectors and academic institutions. BCA have implemented a new and comprehensive ground investigation programme, recovering drillcores from c. 100 deep boreholes (typically to 200 m depth) and acquiring conventional 2D seismic reflection data from across some 350 km2 of ground. All of this new data provides an unprecedented opportunity to unravel the complex geological relationships that exist, especially in southwest Singapore.

The geology of Singapore is dominated by the products of a period of late Permian to Triassic arc magmatism that was succeeded by collisional accretion tectonics in the latest Triassic to early Jurassic. Two distinct early Cretaceous (Berriasian and Barremian) sedimentary successions overstep the collisional tectonic structures. Faulting developed across Singapore in response to dextral strike slip tectonics in the mid-Cretaceous (?Cenomanian) further complicates the structural geological framework, and delineates the distribution of lithologies across Singapore. This paper reports on our new understanding of the structural geological evolution of Singapore; a new sedimentological environment analysis that supports a fully revised stratigraphical framework is described in a companion paper also presented at this conference (Dodd *et al.*).

In southwest Singapore, we assign the marine sedimentary succession that includes early Triassic volcanic rocks (ash, tuff and ignimbrite) to the Jurong Group, a correlative of the Raub Group in Malaysia. These strata have been deformed, along with an overlying succession of mainly coarse sandstones and conglomerate, into a northeast-vergent pattern of inclined asymmetrical folds. That shortening culminated in the development of a large scale northeast-vergent thrust system, most likely in the latest Triassic to earliest Jurassic Indosinian Orogeny. The fluvial succession that dominates the south-eastern part of the Jurong Group crop in Singapore may represent a piggyback succession in this fold and thrust collisional setting. The subduction-related magmatic complex represented by the Central Singapore Granite pluton probably acted as a backstop to thrusting at this time.

The fold and thrust deformation observed in Singapore is progressive with the earlier formed folds becoming transposed in the thrust transport direction; strata are typically very steeply dipping to the northeast, or even overturned, in the hanging wall of the thrust discontinuities. The long limbs of the hanging wall anticline/syncline structures are broadly flat-lying though undulating, and may locally display open to close upright folding at < 1 km wavelength. A locally penetrative S1 cleavage is developed in incompetent lithologies (mudstone to fine sandstone); in more competent sandstones a spaced fracture cleavage is locally seen, especially so in very steep to overturned strata. The Murai Thrust structure dominates the onshore geology of southwest Singapore, stretching from Murai Reservoir in the northwest through the Kent Ridge/Mount Faber area to the southeast where a thrust duplex is judged to explain the observed structural features and imbricated stratigraphy. Along with the thrusts, the S1 cleavage typically dips southwestwards, often as convergent or divergent fans in fold hinges according to the rheology of the folded rocks. This tectonostratigraphic framework is likely to continue into South Johor in Malaysia, and potentially also into Batam.

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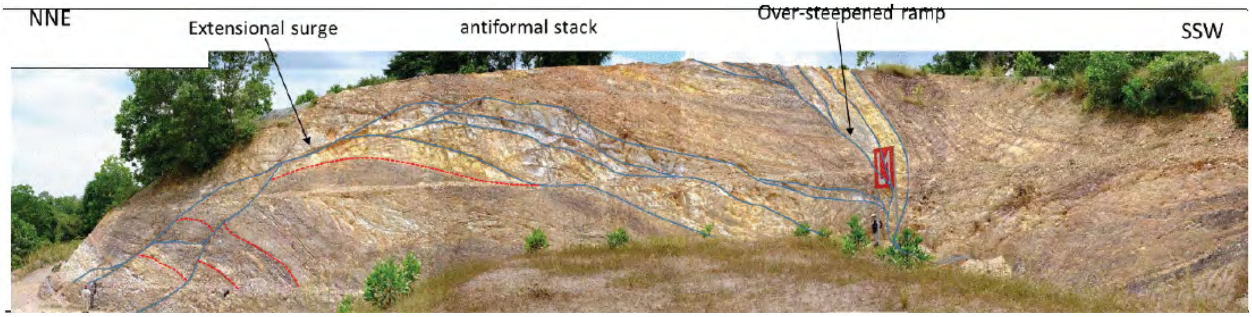
Age dating of detrital zircon population suggests that at least two distinct sedimentary successions overstep this orogenic deformation in the early Cretaceous before dextral strike-slip faulting affected the region, that deformation presumably co-eval with the period of dextral shear recorded across SE Asia at this time (c. 90-100 Ma). The Bukit Timah Fault that defines the southwest margin of the Central Singapore Granite pluton (and its continuation into adjacent Johor and Batam) was a principal displacement zone (PDZ) at this time; an associated and geometrically consistent array of steeply dipping R1, R2, P and X discontinuities are widely developed across Singapore and its offshore islands, and will essentially constrain the major features on the new geological map of Singapore.



Antiformal stacking of thrust imbricates in Jurong Group strata, top to NE tectonic transport. Murai Reservoir, NW Singapore.


Upright open anticline (Lokos Anticline) at the southeast end of St. John's Island, Singapore. View NNW. A fanning fracture cleavage is developed around the hinge of the anticline in these fluvial sandstones; a closely spaced fanning cleavage is seen in the NE-dipping fold limb.