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# Provenance of Cenozoic sandstones from northern Borneo: record of a tropical climate and regional tectonics

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Cenozoic sandstones from Borneo were derived from local sources on Borneo and Peninsular Malaysia, not from mainland Asia. Conventional plots of detrital modes are misleading for tropical sandstones, but more reliable interpretations can be made from heavy mineral studies and detrital zircon SHRIMP U-Pb geochronology. These enable the sources to be identified.

Borneo is the third largest island in the world, and is located in equatorial SE Asia. There are large amounts of Cenozoic sediment in several basins on and around the island. Thicknesses of up to twelve kilometres of clastic sediments have been reported in places for the Neogene alone. In western and northern Borneo there are voluminous Paleogene deep marine sediments. Their source areas have been suggested to be either mainland SE Asia/Indochina or Borneo itself.

Tertiary sediments of northern Borneo consist of two major successions. During the Paleogene, deep marine turbidites were deposited as a fan at an active subduction margin. Continental collision in the Early Miocene uplifted and deformed these rocks. Subsidence resumed in the Neogene when fluvio-deltaic and shallow marine sediments were deposited.

Sandstone components in low-latitude tropical settings often experience extreme weathering during erosion at source and during transport. The characteristics of these sandstones reflect their climatic setting and their source rocks. Compositional and textural observations on both the light and heavy mineral fractions of the northern Borneo sandstones are in apparent conflict. Interpretations of modal compositions based on conventional QFL and QmFLt plots are misleading due to intense weathering and sometimes due to volcanic input, and first cycle sandstones appear to have a recycled origin.

The heavy minerals tend to be stable and ultrastable, and zircon and tourmaline are dominant. These suggest granitic source rocks. The unstable minerals are usually not preserved, or are very corroded. Some rocks contain unstable grains indicating a nearby ophiolitic source. The detrital zircons are mainly euhedral crystals, indicating a first-cycle igneous source, but there is also a proportion of rounded and coloured zircons.

Detrital zircon SHRIMP U-Pb age patterns are reported for the Eocene-Lower Miocene sandstones. There is a spread of ages from Archaean to Eocene, and the majority of ages are Mesozoic. The most important clusters of ages are Cretaceous, Permian-Triassic and Palaeoproterozoic. There is a strong correlation between the abundance of Permian-Triassic ages and Palaeoproterozoic ages. The most likely source areas were Cretaceous granites of the Schwaner Mountains in SW Borneo and Permian-Triassic granites and Proterozoic basement of the SE Asian Tin Belt.

The extensive Eocene-Lower Miocene Crocker Fan was derived from relatively nearby source areas, and not from mainland Asia. Paleogene sediment supply into the northern Borneo basins came from the Schwaner Mountains and Tin Belt in the west and southwest. An important Early Miocene orogenic event shifted the drainage divide, and drainage patterns in the Neogene became similar to those of the present day.