Paper 16

Exhumation of Sabah based on fission-track thermochronology: relevance to the Baram Delta

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A fission-track dating study of Sabah was undertaken to date and quantify the uplift history and indicate the provenance of the Tertiary strata (Hutchison *et al.*, 2000). The results have an important bearing on the sedimentary history of the Baram Delta and basins on the margins of the Sulu and Celebes seas.

MOUNT KINABALU GRANITOIDS

All fission track ages of the Middle Miocene (10 –13.7 Ma) igneous rocks of Mount Kinabalu are related to cooling as a result of crustal uplift and unroofing. Apatite fission track ages represent cooling < 80°C (Late Miocene) and zircon < 225°C (Late Miocene). The values are independent of outcrop elevation, indicating very rapid cooling, related to uplift and erosion (exhumation) during the spectacular Late Miocene inversion of the Western Cordillera of Sabah, as recorded in the offshore oilfields as a series of unconformities, dated by detailed oil-field stratigraphy (Hutchison, 1996). They are the Deep Regional (15 Ma), Lower Intermediate (13 Ma), Upper Intermediate (12 Ma) and Shallow Regional (9 Ma). The unconformities are spectacular onland; become less pronounced and die out into conformity towards the outer part of the Inboard Belt. The Late Miocene mountain building event has been named the Sabah Orogeny (Hutchison, 1996).

WESTERN CORDILLERA-LABUK HIGHLANDS UPLIFT

The apatite fission track ages (Middle to Upper Miocene) have been totally reset, suggesting the rocks have been buried by 4 to 8 km of overburden causing heating to > 120°C after deposition (a conclusion supported by vitrinite reflectance) then exhumed and cooled in the Late Miocene. The mean fission track

Warta Geologi (Newsletter of the Geological Society of Malaysia), Vol. 26, No. 6, November-December 2000

lengths of 13 to 15μm characterize rocks which have cooled rapidly, at > 10°C.Ma^{-1} through a temperature range from 120° to 60°C. The fission track data suggest extremely rapid exhumation rates for the Western Cordillera of ~600 ± 100 m.Ma^{-1} (0.5 to 0.7 mm.a^{-1}), comparable to Irian Jaya, New Zealand and the Himalaya.

The zircon fission track ages all pre-date the depositional age of the strata and represent the Cretaceous provenance from which the zircon grains have been eroded and transported, interpreted ultimately as the Mesozoic *Indosinias* terrain of eastern Indochina (Hutchison, 1989), brought to Borneo by the great Mekong River, but the grains have gone through at least one intermediate sedimentary and erosion cycle (The Rajang Group of Sarawak).

The Kulapis and Kuamut Formation blocks in mélange have re-set apatite fission track ages, that may have resulted from incorporation in the marine mud matrix of the mélange, which was < 100°C. However apatite is partially annealed at 60°C and completely annealed at 110°C.

There is strong petrological evidence for uplift. The Chert-Spilite Formation rocks, 5 km N.W. of Telupid, contain porphyroblasts of glaucophane and piedmontite (7–8 kbar at a low geothermal gradient), requiring the Labuk Highlands to have been dramatically inverted and exhumed from a depth of ~ 20 km.

ISOSTATICALLY STABLE EASTERN LOWLANDS

The fission track data, by contrast, indicate isostatic stability. An Oligocene age for the andesite tuff beneath the Sandakan mosque is likely, making it an onshore extension of the NE-SW trending Sulu Sea volcanic Cagayan Ridge.

All the zircon fission track ages are Cretaceous, indicating the provenance of the detrital grains. The apatite fission track ages are all older than the strata and range from Cretaceous to Eocene. They have been only partially or in some cases not reset, showing that the host rocks have remained at a temperature < 60–80°C since deposition. Diagenesis and organic maturity data also support this observation. The apatite fission track data indicate the strata have been buried by less than ~2 to 3 km.

It has been concluded that the Late Miocene and younger strata of this terrain have been cannibalized from the exhumed Western Cordillera-Labuk Highlands, which were dramatically uplifted in the Middle to Late Miocene. The zircon fission track ages, consistently Cretaceous, offer support for this.

TECTONIC MODEL

Subduction followed by underthrusting of continental lithosphere, driven by Oligocene-Early Miocene spreading in the South China Sea marginal basin, account for the tectonic features of Sabah. Isostatic rebound then caused Late Miocene uplift of the Western Cordillera. Rapid erosion of the Western Cordillera and Labuk Highlands supplied abundant clastic sediments to the Miocene-Pliocene Baram Delta oil-bearing basin and to the Eastern Lowlands and Sulu and Celebes Seas. The Eastern Lowlands were affected by Miocene rifting of the Sulu Sea marginal basin. The terrain has been isostatically stable; there is no isostatic rebound and hence no underthrust continental crust.