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From Thrust to Strike-Slip: A Tentative Model for the Multi-Stage Evolution of the Sumatran Fault

Lin Guo[1,2], Yang Chu[1,2], Wei Lin[1,2], Iwan Setiawan[3], Maruf Mukti[3], Eko Puswanto[3], Xiaoran Zhang[1,2], Lingtong Meng[1,2], Qinghua Shang[4], Chen Ling[1,2], Ye Deng[1,2], and Shuiyue Xue[1,2]

1. State Key Laboratory of Lithospheric and Environmental Coevolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China
2. College of Earth and Planetary Sciences, University of Chinese Academy of Sciences, Beijing, China
3. Research Center for Geological Resources, The National Research and Innovation Agency, Bandung, Indonesia
4. Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China

Introduction

The Sumatra subduction zone, formed by the oblique subduction of the Indo-Australia Plate beneath the Eurasian Plate, is the most active one that has the strongest deformation and generates numerous destructive megathrust and intracontinental earthquakes. Instead of a widespread forearc basin often developed in orthogonal subduction, a 1900-km-long trench-parallel dextral strike-slip fault—the Sumatran Fault—has greatly modified the overriding Eurasian Plate to accommodate the highly oblique relative plate motion. The Sumatran Fault is a sinusoidal fault with 21 seismological segments which restrict most earthquake ruptures, while it can also be divided into 3 tectonic domains: the northern, central and southern domains. But it remains unclear ***how*** and ***when*** the fault initiated or interconnected.

Our low-temperature thermochronological study constrains the uplift–cooling history of the region near the central domain of the Sumatran Fault, and reveals the tectonic activity of the fault zone since the Late Mesozoic.

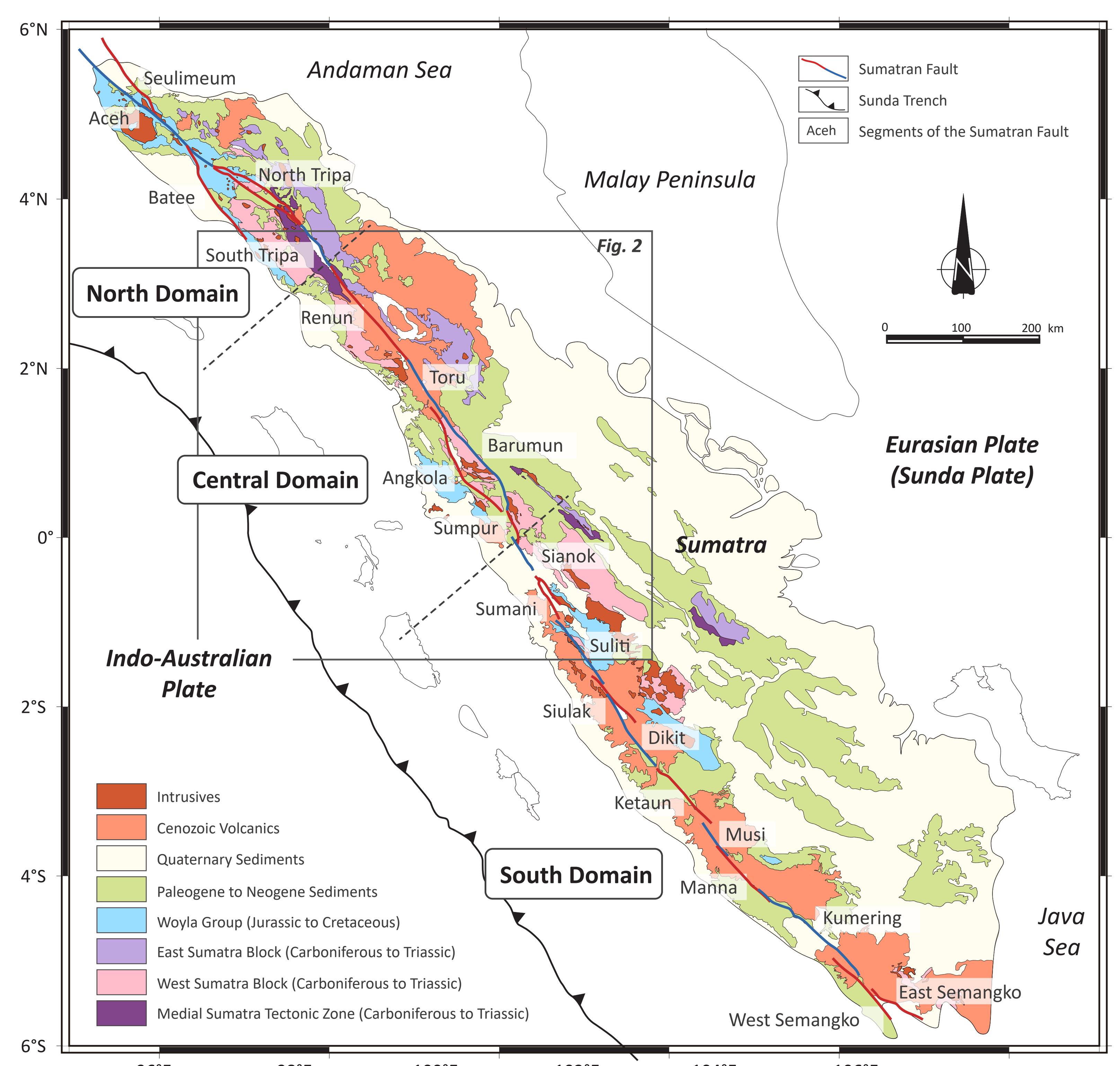

Fig. 1 Tectonic sketch map and segments of the Sumatran Fault.

Low-temperature Thermochronological Data

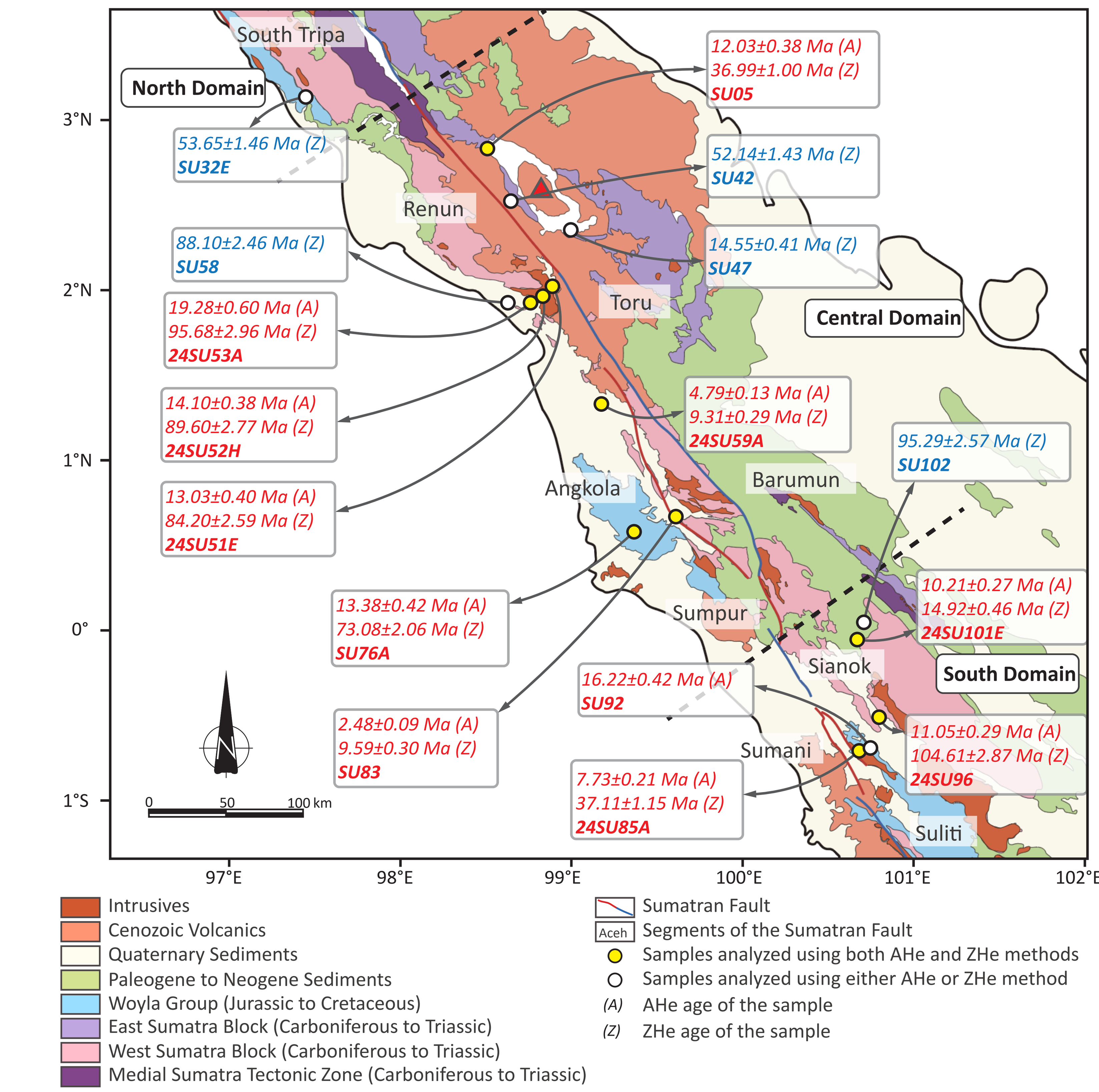

Fig. 2 Distribution of low-temperature thermochronological data

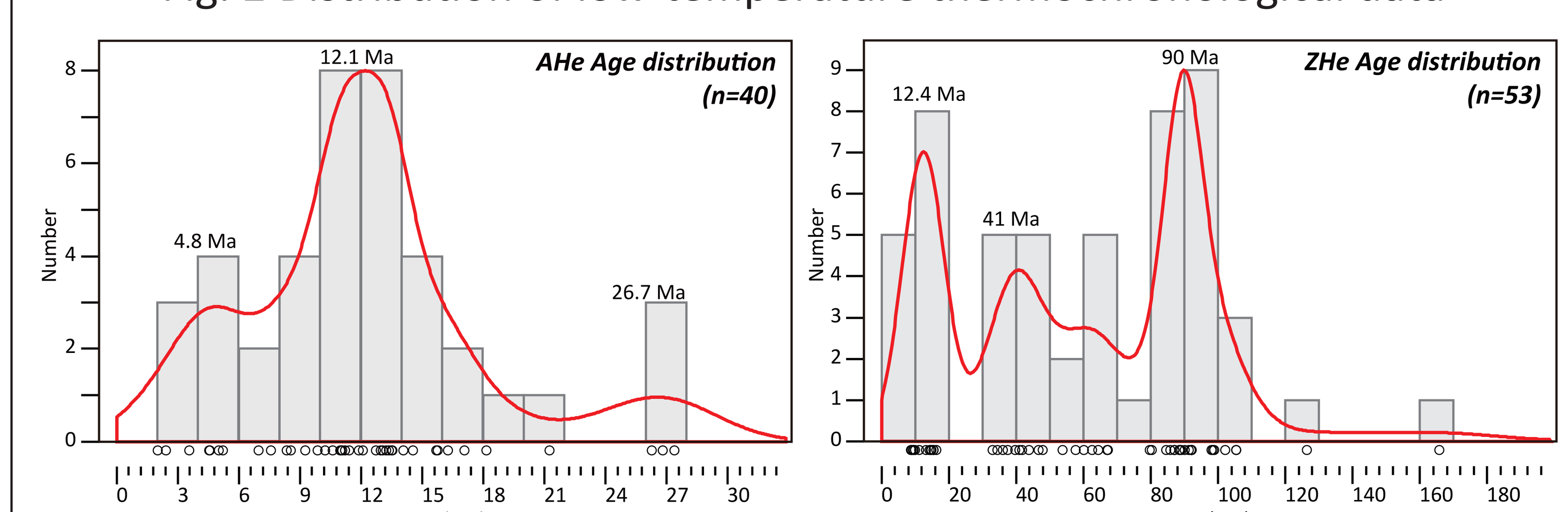

Fig. 3 Statistical distribution of single-grain (U-Th)/He ages

- Samples within 10 km of the fault yield AHe ages younger than 10 Ma, whereas samples located farther from the fault consistently yield AHe ages older than 10 Ma.
- ZHe ages are generally older overall, and grain-age distributions define three distinct age peaks at 12.4 Ma, 41 Ma, and 90 Ma.

Late Cretaceous Activity and Miocene Reactivation

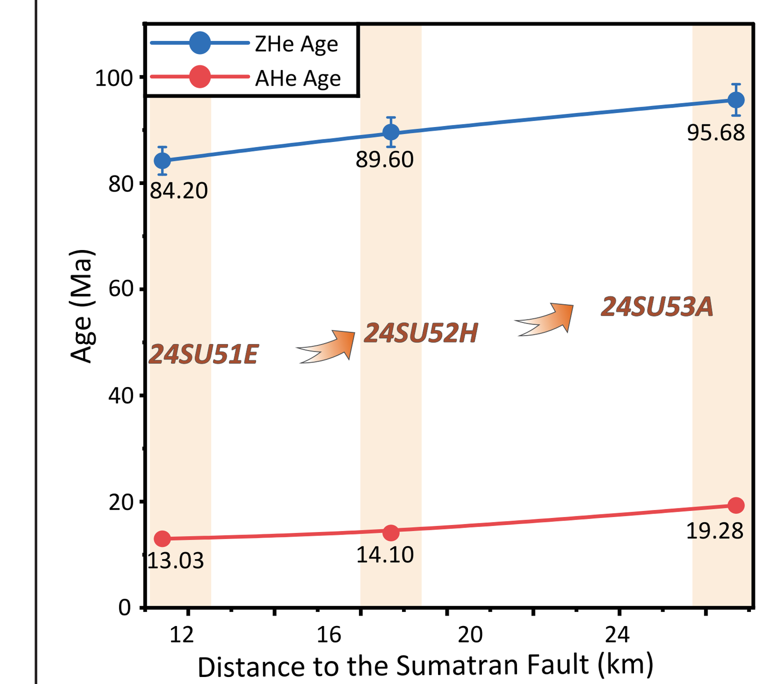

Fig. 4 Age–distance plot for samples along the same profile

For ***Late Triassic granite*** samples collected along the same profile perpendicular to the Sumatran Fault, plotting age against distance reveals that both ***Cenozoic AHe ages*** and ***Late Mesozoic ZHe ages*** become progressively older with increasing distance from the fault. This pattern indicates that fault-related activity was not restricted to the Cenozoic; tectonic activity had already occurred in the region of the present-day fault as early as the Late Cretaceous.

Interpretation

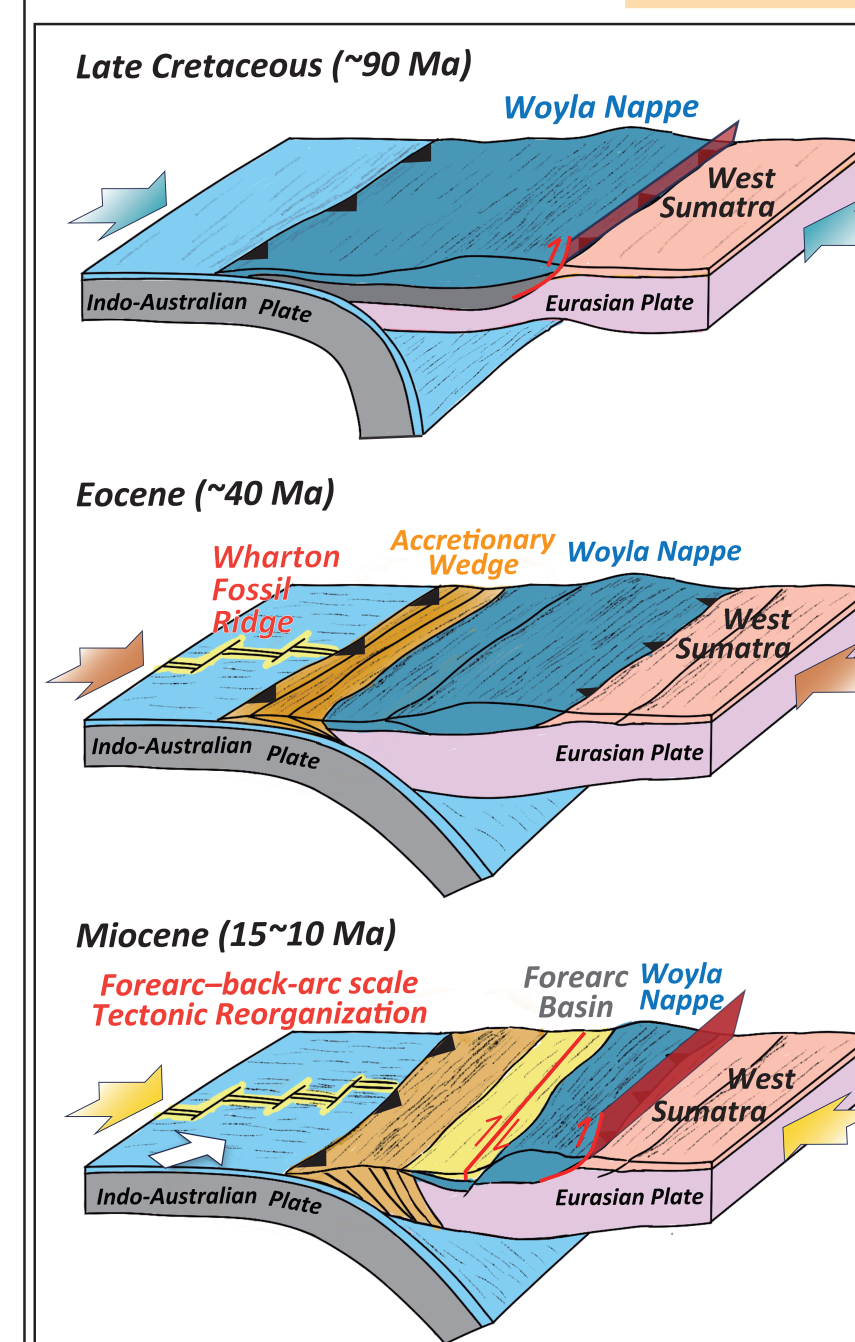

Fig. 5 Schematic diagram of three stages of compressional uplift events in the Sumatra region

- ***Late Cretaceous:*** emplacement of ***the Woyla Nappe***, forming an initial thrust faulting weakness zone
- ***Eocene: the Wharton Ridge*** extincted and subducted beneath Sumatra, leading to a change in the plate-boundary dynamics of the Indo–Australian Plate
- ***Miocene:*** the Sumatran Subduction system underwent ***forearc–back-arc scale tectonic reorganization***: *the forearc basin compressional shortening, forearc strike-slip faults (the Mentawai Fault) developing, and* ***the pre-existing thrust-related weak zones were reactivated.***

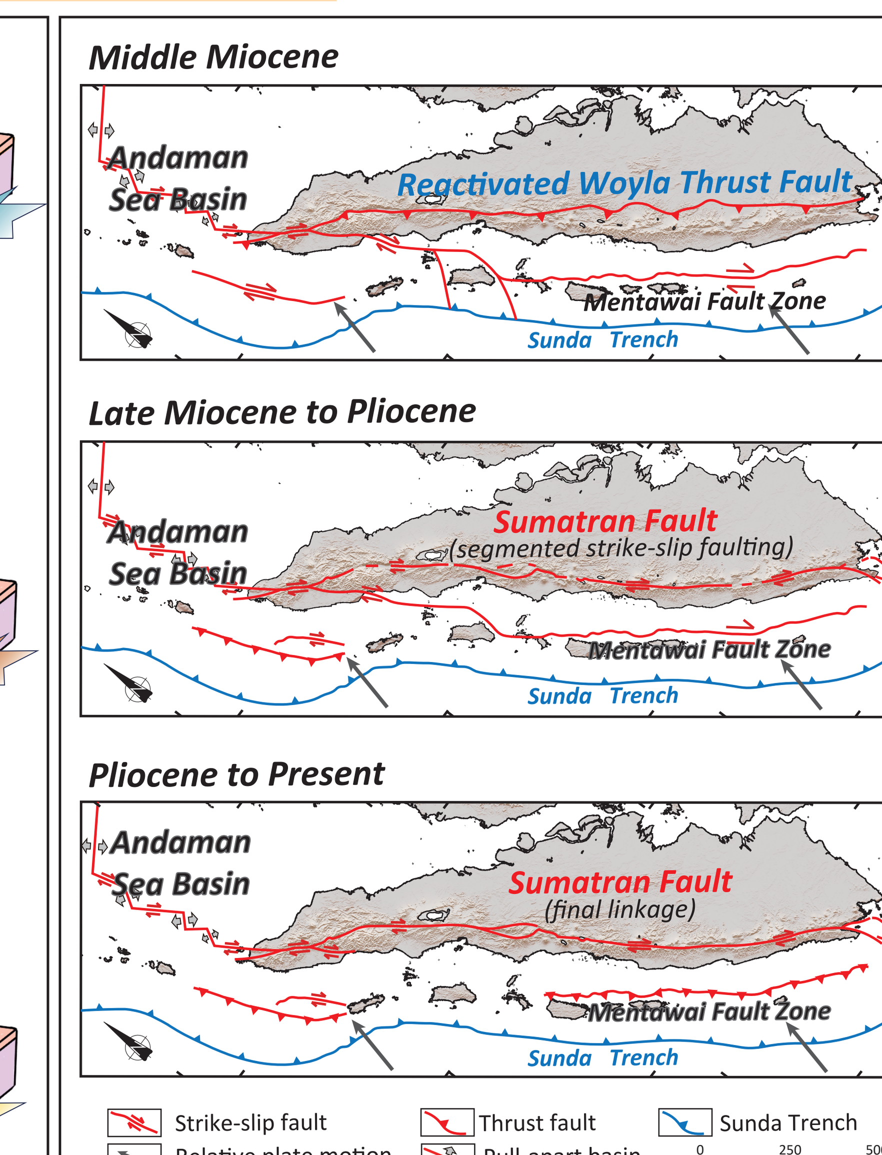

Fig. 6 Evolution of the Sumatran Fault during the Middle-Late Cenozoic *(fault locations modified after Sieh & Natawidjaja, 2000)*

- ***Middle Miocene:*** secondary faults linked with the Andaman Sea Basin and the Sunda Trench and other forearc faults (the Mentawai Fault Zone), accompanied by reactivation of thrust faults within the Woyla nappe in the main island.
- ***Late Miocene to Pliocene:*** strike-slip faulting began to develop across Sumatra, with the overall deformation progressively transitioning from dip-slip-dominated to strike-slip-dominated.
- ***Since Pliocene:*** the Sumatran Fault has become fully linked into a throughgoing structure, evolving into a major dextral strike-slip fault.