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Late Paleogene rifting along the Malay Peninsula thickened crust

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ABSTRACT

Sedimentary basins often develop above internal zones of former orogenic belts. We hereafter consider the Malay Peninsula (Western Sunda) as a crustal high separating two regions of stretched continental crust; the Andaman/Malacca basins in the western side and the Thai/Malay basins in the east. Several stages of rifting have been documented thanks to extensive geophysical exploration. However, little is known on the correlation between offshore rifted basins and the onshore continental core. In this paper, we explore through mapping and seismic data, how these structures reactivate pre-existing Mesozoic basement heterogeneities.

The continental core appears to be relatively undeformed after the Triassic Indosinian orogeny. The thick crustal mega-horst is bounded by complex shear zones (Ranong, Klong Marui and Main Range Batholith Fault Zones) initiated during the Late Cretaceous/Early Paleogene during a thick-skin transpressional deformation and later reactivated in the Late Paleogene. The extension is localized on the sides of this crustal backbone along a strip where earlier Late Cretaceous deformation is well expressed. To the west, the continental shelf is underlain by three major crustal steps which correspond to wide crustal-scale tilted blocks bounded by deep rooted counter regional normal faults (Mergui Basin). To the east, some pronounced rift systems are also present, with large tilted blocks (Western Thai, Songkhla and Chumphon basins) which may reflect large crustal boudins. In the central domain, the extension is limited to isolated narrow N-S half grabens developed on a thick continental crust, controlled by shallow rooted normal faults, which develop often at the contact between granitoids and the host-rocks. The outer limits of the areas affected by the crustal boudinage mark the boundary towards the large and deeper Andaman basin in the west and the Malay and Pattani basins in the east.

At a regional scale, the rifted basins resemble N-S en-echelon structures along large NW-SE shear bands. The rifting is accommodated by large low angle normal faults (LANF) running along crustal morphostructures such as broad folds and Mesozoic batholiths. The deep Andaman, Malay and Pattani basins seem to sit on weaker crust inherited from Gondwana-derived continental blocks (Burma, Sibumasu, and Indochina). The set of narrow elongated basins in the core of the Region (Khien Sa, Krabi, and Malacca basins) suffered from a relatively lesser extension.

1. Introduction

The western side of the continental core of Sundaland consists of an elongated N-S peninsula (Fig. 1a) bordered by wide Cenozoic Basins (Fig. 1b). If the thick basins and hyper-stretched crust are located in the region of Andaman Sea and Pattani-Malay-Penyu basins, the basins located within the Peninsula are smaller and appear separated by magmatic bodies and broad folds. On both sides of the Peninsula, wide areas consist of a series of half-grabens separated by horsts (Fig. 2). The original basement highs referred hereafter as "pre-rifting setting" are the result of a long history of early and late Mesozoic collisions leading to crustal thickening associated with both island arc and post-collision magmatism (Gardiner et al., 2015; Hutchison, 2013; Metcalfe, 2013; Morley, 2012). The migration of the Indian Plate and its possible interactions with the western margin of Sunda plate during the Late Cretaceous to Paleogene might have played an important role in the observed deformations. The rifting style varies throughout the region and is conditioned by pre-existing basement fabrics reactivated as crustal discontinuities during the Cenozoic.

We hereafter present fieldwork and mapping data across the Malay Peninsula, together with a review of the state of the art of the pre-rifting

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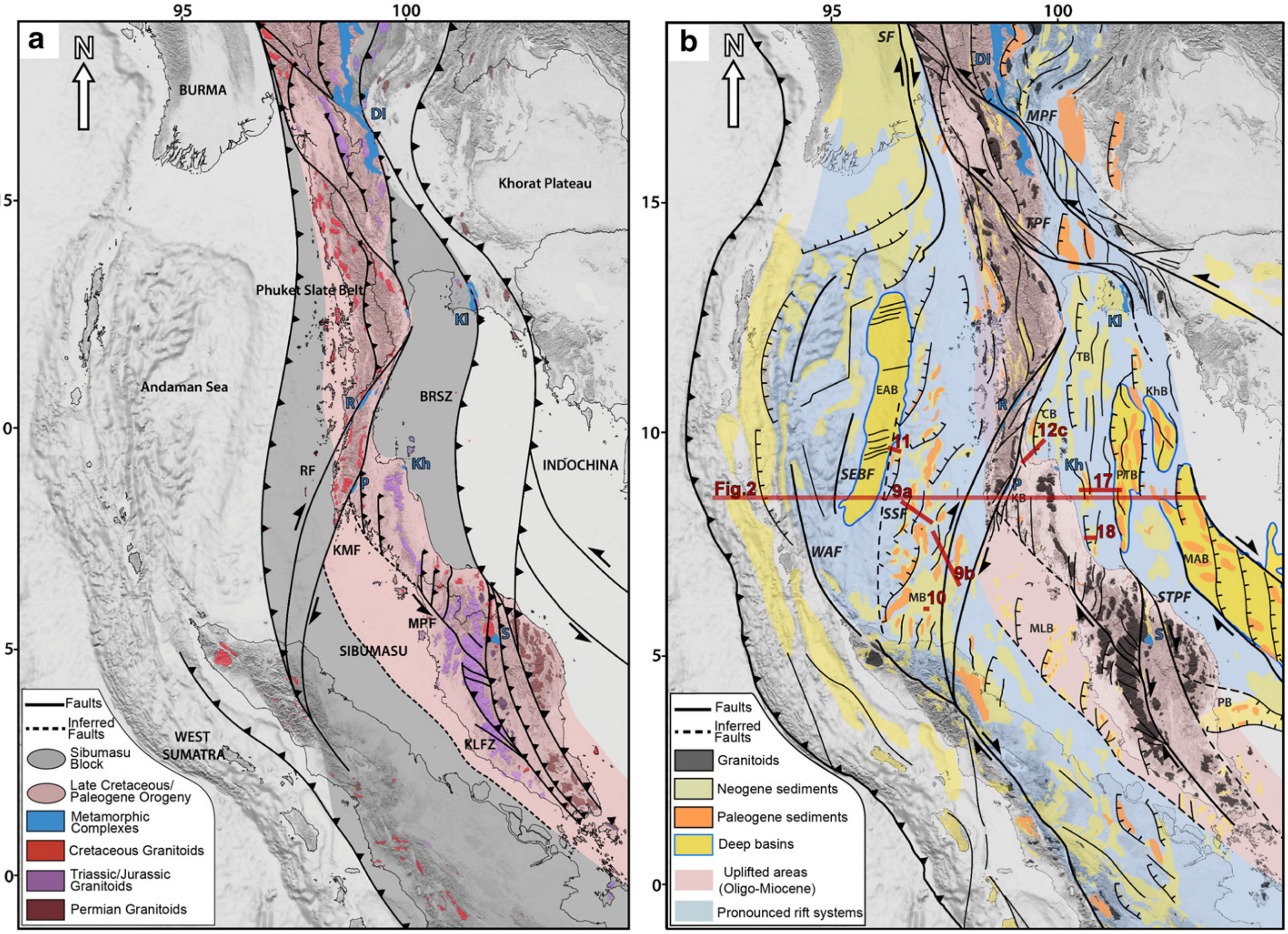

Fig. 1. Structural maps of the western Margin of Sunda Plate in the present day Geography. a) By the end of the Late Cretaceous/Paleogene Orogeny. The pink area represents the uplifted core of the orogeny, corresponding approximately to the Malay Peninsula. From North to South: DI. Doi Inthanon; Kl. Klaeng Ductile core; BRSZ. Bentong Raub Suture Zone; R. Ranong ductile core; Kh. Khanom Metamorphic Core Complexe; P. Phanom ductile core; RF. Ranong Fault; KMF. Klong Marui Fault; S. Stong Complexe; KLFZ Kuala Lumpur Fault Zone b) rifting setting in the Cenozoic. The faults pattern is represented at Paleogene period. From North to South: SF. Sagaing Fault; MPF. Mae Ping Fault; TPF. Three Pagodas Fault TB. Thai Basins; EAB. East Andaman Basin; CB. Chumphon Basin; SEBF. Seawell Rise East Bounding Fault; PTB. Pattani Basins; KB. Krabi Basin; SSF. South Sagaing Fault; WAF. West Andaman Fault; MAB. Malay Basin; MB. Mergui Basin; STPF. South Three Pagodas Fault; MLB. Malacca Basins; PB. Penyu Basin.

setting, with a synthesis of published geochronological data including fission tracks to constrain the timing of the deformation at a regional scale. Unpublished 2D seismic data from the Mergui and Andaman Shelf and the western gulf of Thailand tied to well data allow us to constrain the rifting mechanism and timing. In this paper, we aim at demonstrating the role of the transition from the late stage of an orogeny with the development of subsequent continental rifting. The extension as a consequence of crustal thickening is debated. We propose a model in which the evolution of the rifting with time and the localisation of the main depocentres is conditioned by two main causes: 1) the presence and migration of a free edge (e.g. path of India), 2) the presence of a strong backbone (core of the orogeny) which act as a barrier separating two kinds of basin geometries; to the west, narrow elongated basins conditioned by the obliquity of the convergence (subduction) and to the east, basins isolated from the subduction effects with deformation controlled by internal forces of Sunda's core.

2. Pre-rifting setting: Mesozoic to Paleogene deformation of the western margin of Sundaland

The post-Indosinian morphology of the Thai/Malay Peninsula was deformed during the Mesozoic and Early Paleogene by two major events. The closure of the Paleo-Tethys led to the emplacement of epizonal I-Type subduction related Late Permian granitoids running from Singapore to the East Himalayan Syntaxis (Hutchison, 1977) (Fig. 1a). Subduction ended during the Indosinian Orogeny when the Sibumasu Block docked against Indochina. In Malaysia this event led to 1) high Greenschist and locally low Amphibolite metamorphism confined to the areas covered by the suture, and 2) Late Triassic/Early Jurassic mesozonal anatexic granitoids (Hutchison, 1977; Metcalfe, 2000, 2013). Elsewhere, the metamorphism is mild and only represented by cleavage fractures. These granitoids constitute the Main Range province and run parallel to both the Permian volcanic arc and the Middle Triassic Bentong-Raub suture zone. Basement sedimentary rocks are metamorphosed to Greenshist facies and deformed by kilometric-scale folds (Tjia and Almashoor, 1996). The host rocks are schistose and exhibit folds with N-S trending hinges. Geomorphological and field evidences suggest E-W contraction at the time of deformation (Md Ali et al., 2016; Metcalfe, 2006, 2013). The fault spacing and the folds width (km scale) suggest thin skin tectonics along an east-dipping shallow decollement (Ridd, 2013). East of the Indosinian Bentong-Raub suture zone, a major shear zone hosting the Malay, Penyu, and Khmer basins marks the boundary of the stable continental core of Sundaland (Khorat/Khao Kong basin/Natuna) where thick continental to locally marine Khorat sediments were deposited during the Mesozoic (Fyhn et al., 2010).