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The Mentawai forearc sliver off Sumatra: A model for a strike-slip duplex at a regional scale

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ABSTRACT

At the Sumatran oblique convergent margin the Mentawai Fault and Sumatran Fault zones accommodate most of the trench parallel component of strain. These faults bound the Mentawai forearc sliver that extends from the Sunda Strait to the Nicobar Islands. Based on multi-channel reflection seismic data, swath bathymetry and high resolution sub-bottom profiling we identified a set of wrench faults obliquely connecting the two major fault zones. These wrench faults separate at least four horses of a regional strike-slip duplex forming the forearc sliver. Each horse comprises an individual basin of the forearc with differing subsidence and sedimentary history. Duplex formation started in Mid/Late Miocene southwest of the Sunda Strait. Initiation of new horses propagated northwards along the Sumatran margin over 2000 km until Early Pliocene. These results directly link strike-slip tectonics to forearc evolution and may serve as a model for basin evolution in other oblique subduction settings.

1. The Sumatran oblique convergent margin

In this paper we present a conceptual model of a regional scale strike-slip duplex that explains the evolution and structure of forearc sliver plates which are bounded by strike-slip faults at an oblique convergent margin. Oblique convergence is a common phenomenon along subduction zones. It is characterized by strain partitioning resulting in fold-and-thrust belts and strike-slip faults paralleling the active margin (Fitch, 1972) e.g. the Liquine-Ofqui fault zone (Cembrano et al., 1996) and Atacama Fault (Cembrano et al., 2005) in Chile or the Queen Charlotte/Fairweather fault system in Alaska (Doser and Lomas, 2000). Such strike-slip faults often occur at regional scales extending over several thousand kilometres.

The concept of strain partitioning was first applied regionally to the Sunda Trench by Moore et al. (1980). Along the Sumatran margin strain partitioning led to two arc-parallel, nearly 2000 km long strike-slip fault zones (Fig. 1): (1) the prominent onshore Sumatran Fault Zone running along the volcanic arc from the Sunda Strait in the south to the northern tip of Sumatra and (2) the offshore Mentawai- and West Andaman faults running along the western border of the forearc basins from the Sunda Strait in the south up to the Andaman Sea (Diament et al., 1992). In between these faults the Mentawai forearc sliver has developed in the overriding plate (Malod and Kemal, 1996). Splay faults connecting the Mentawai and the Sumatran Fault zones subdivide the forearc sliver into several tectonic blocks with distinct subsidence history and stratigraphy. Other Authors suggest, that the forearc is stretched and does not act as one or more rigid blocks (Bellier and Sébrier, 1995; McCaffrey, 1991) or propose that the Mentawai Fault is characterized by backthrusts, not strike-slip tectonics (Singh et al., 2010; Wiseman et al., 2011).

Based on bathymetric, multi-channel seismic and sub-bottom profiler data we have studied several of the forearc basins (Berglar et al., 2008; Susilohadi et al., 2005; Susilohadi et al., 2009) as well as the strike-slip tectonic features of the northern Mentawai and the West Andaman faults (Berglar et al., 2010). Here, we integrate these results and combine them with new observations from the central Mentawai Fault Zone. The focus lies on the concept of strain partitioning and strike-slip motion along specific fault zones to develop a conceptual model of regional strike-slip duplex evolution along the entire Sumatra margin.

Four forearc basins can be distinguished along the margin (Fig. 1): The Bengkulu Basin is the southernmost and largest, extending for 900 km from 7°S to 1°S. The Batu Islands separate it from the Nias Basin off central Sumatra. The Nias Basin is the narrowest one and is divided into two sub-basins of N-S and SE-NW elongation, respectively (Matson and Moore, 1992). The Banyak Islands separate the Nias Basin from the northerly located Simeulue Basin. The northernmost Aceh Basin is bordered from the Simeulue Basin by the submarine

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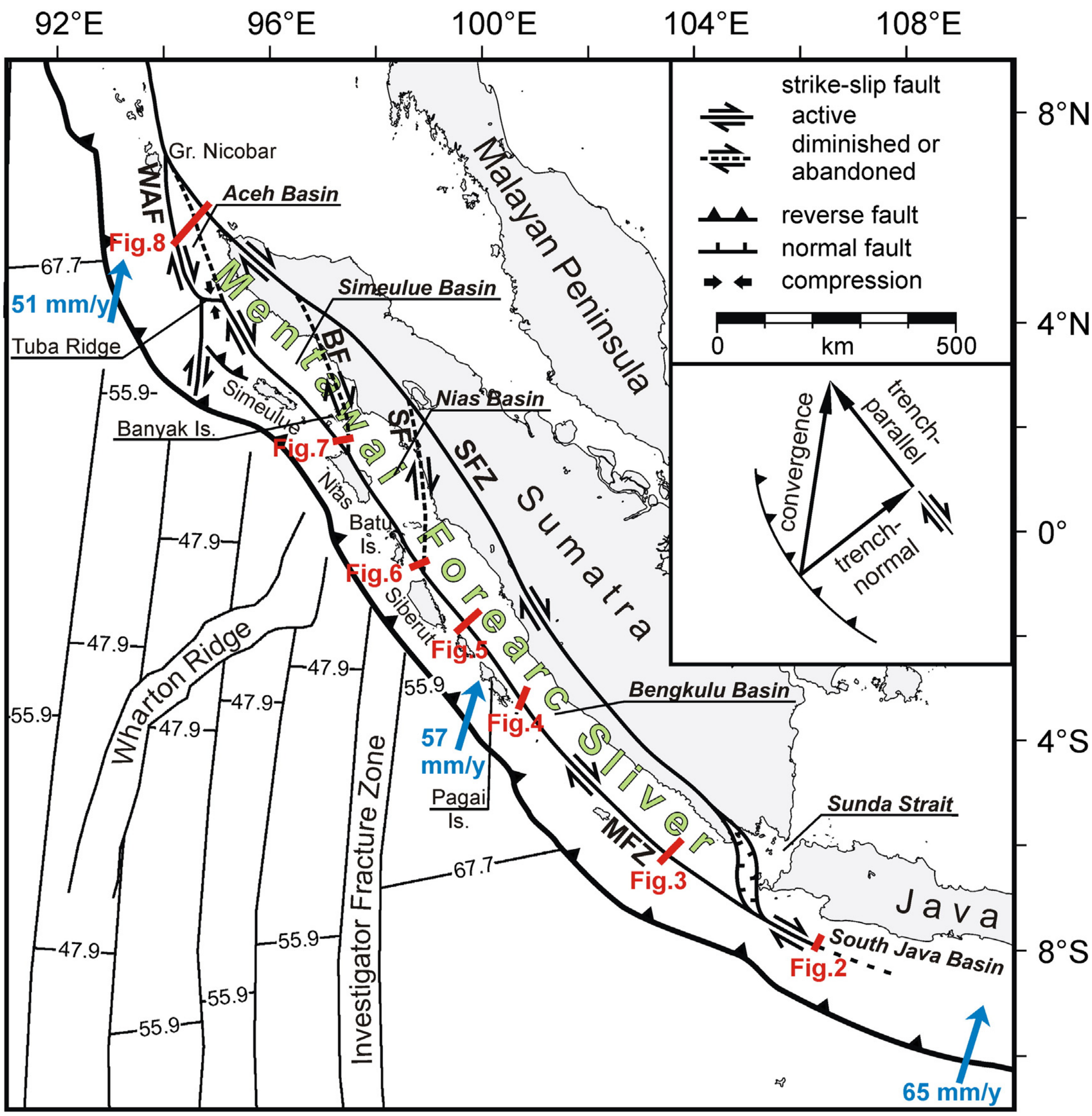

Fig. 1. Geological setting with major fault systems (modified from Berglar et al., 2010). WAF - West Andaman Fault, SFZ - Sumatran Fault Zone, MFZ - Mentawai Fault Zone, BF - Batee Fault, SF - Siberut Fault. Ages of the oceanic crust are after Müller et al. (1997) and Deplus et al. (1998). Arrows represent relative plate movements based on CGPS (Prawirodirdjo and Bock, 2004). Red lines indicate locations of seismic sections shown in Figs. 2 to 8. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Tuba Ridge (Berglar et al., 2010). Maximum water depth increases from the Nias (900 m) over the Simeulue (1300 m) to the Aceh Basin (2800 m).

A major tectonic event is documented in a Paleogene/lower Miocene unconformity from industry wells (e.g. Beaudry and Moore, 1985) drilled in all forearc basins off Sumatra. It is followed by forearc basin subsidence off Sumatra. This may be related to a major plate tectonic reorganization in SE Asia (Hall, 2002). Except for the Aceh Basin a second major unconformity between the Mid and Late Miocene documents the major phase of accretionary wedge growth and consolidation, and forearc basin subsidence (Moore et al., 1980).

The onshore Sumatran Fault Zone is traceable along the volcanic arc from the Sunda Strait in the south to the northern tip of Sumatra (Fig. 1). Horizontal offset is in the order of 100 km in the Sunda Strait (Barber et al., 2005). The Sumatran Fault Zone is segmented into three structural domains characterized by differences in structural style (Sieh and Natawidjaja, 2000). The boundaries of these domains can roughly be extended to the Banyak and Batu Island groups separating the forearc basins. Slip rates along the Sumatran Fault Zone increase from <10 mm/y in the Sunda Strait to 45–60 mm/y in the Andaman Sea (McCaffrey, 1991).

The second major system runs along the western border of the forearc basins from the Sunda Strait in the south to the Andaman Sea in the north. This fault system is composed of the Mentawai Fault Zone along the Bengkulu, Nias and Simeulue basins and the West Andaman Fault along the Aceh Basin. It is joined by the Sumatran Fault Zone east of Greater Nicobar in the Andaman Sea. Here, sea floor spreading in the Andaman Sea resulted in offset of 460 km (Curray et al., 1979) along major transform faults.

2. Methods

A geomorphological analysis of the seafloor based on compiled swath bathymetric datasets and 2-D multi- and single-channel seismic (MCS and SCS) data were used to determine type and time of activity of structures. Sub-bottom profiler data were used to verify if such structures affected the uppermost sedimentary layers. We had approximately 11,000 km of MCS data available along the continental margin of

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