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Structural evolution and strike-slip tectonics off north-western Sumatra

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ABSTRACT

Based on new multi-channel seismic data, swath bathymetry, and sediment echosounder data we present a model for the interaction between strike-slip faulting and forearc basin evolution off north-western Sumatra between 2°N and 7°N. We examined seismic sequences and sea floor morphology of the Simeulue- and Aceh forearc basins and the adjacent outer arc high. We found that strike-slip faulting has controlled the forearc basin evolution since the Late Miocene. The Mentawai Fault Zone extends up to the north of Simeulue Island and was most probably connected farther northwards to the Sumatran Fault Zone until the end of the Miocene. Since then, this northern branch jumped westwards, initiating the West Andaman Fault in the Aceh area. The connection to the Mentawai Fault Zone is a left-hand step-over. In this transpressional setting the Tuba Ridge developed. We found a right-lateral strike-slip fault running from the conjunction of the West Andaman Fault and the Tuba Ridge in SSW-direction crossing the outer arc high. As a result, extrusion formed a marginal basin north of Simeulue Island which is tilted eastwards by uplift along a thrust fault in the west. The shift of strike-slip movement in the Aceh segment is accompanied by a relocation of the depocenter of the Aceh Basin to the northwest, forming one major Neogene unconformity. The Simeulue Basin bears two major Neogene unconformities, documenting that differences in subsidence evolution along the northern Sumatran margin are linked to both forearc-evolution related to subduction processes and to deformation along major strike-slip faults.

1. Introduction

Oblique convergence of colliding plates is a common feature at convergent margins. Partitioning of strain results in two major structural components: one that is perpendicular to the trench, represented by folds and thrusts in the accretionary prism, and a second component, accommodating the oblique convergence in strike-slip faults parallel to the trench (Beck et al., 1993; Beck, 1983; Fitch, 1972; Malod and Mustafa Kemal, 1996; McCaffrey, 1991). Examples of such strike-slip motions are the Liquine–Ofqui Fault (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). Studying such major strike-slip systems is crucial to understand the evolution of oblique margins and their behavior in terms of forearc basin evolution.

The study area is located off north-western Sumatra between 2°N and 7°N, covering the offshore region between the Mentawai Fault Zone and West Andaman Fault and the Sumatran Fault Zone (Fig. 1). Strong tectonic forces influence this area where the 2004 M_w 9.0 Sumatra–Andaman and 2005 M_w 8.6 Nias Island earthquakes nucleated (Engdahl et al., 2007). The right-lateral offshore fault systems and the onshore Sumatran Fault Zone accommodate the trench-parallel component of the oblique convergence between the Indo-Australian and the Eurasian Plates (Diament et al., 1992; Malod and Mustafa Kemal, 1996; Samuel and Harbury, 1996; Sieh and Natawidjaja, 2000). The study area includes the Simeulue- and Aceh forearc basins and parts of the outer arc high. The studied basins show a change in water depth from about 1300 m in the Simeulue Basin to about 2800 m in the Aceh Basin and are clearly separated by an anticlinal structure that is elevated above the seafloor and referred to as Tuba Ridge by Malod et al. (1993).

The main purpose of this work is the assessment of the structural evolution of the strike-slip fault system and its relation to the forearc basin evolution off northern Sumatra based on the combined analysis of reflection seismic data, swath bathymetry and high resolution parametric echosounder data. The availability of a nearly complete swath bathymetric map in combination with a dense grid of seismic datasets of different resolutions allows us to address the questions of when strike-slip movements started and if these movements have had a notable influence on the evolution of the forearc basins. Our data make it possible to distinguish the interaction of the Mentawai

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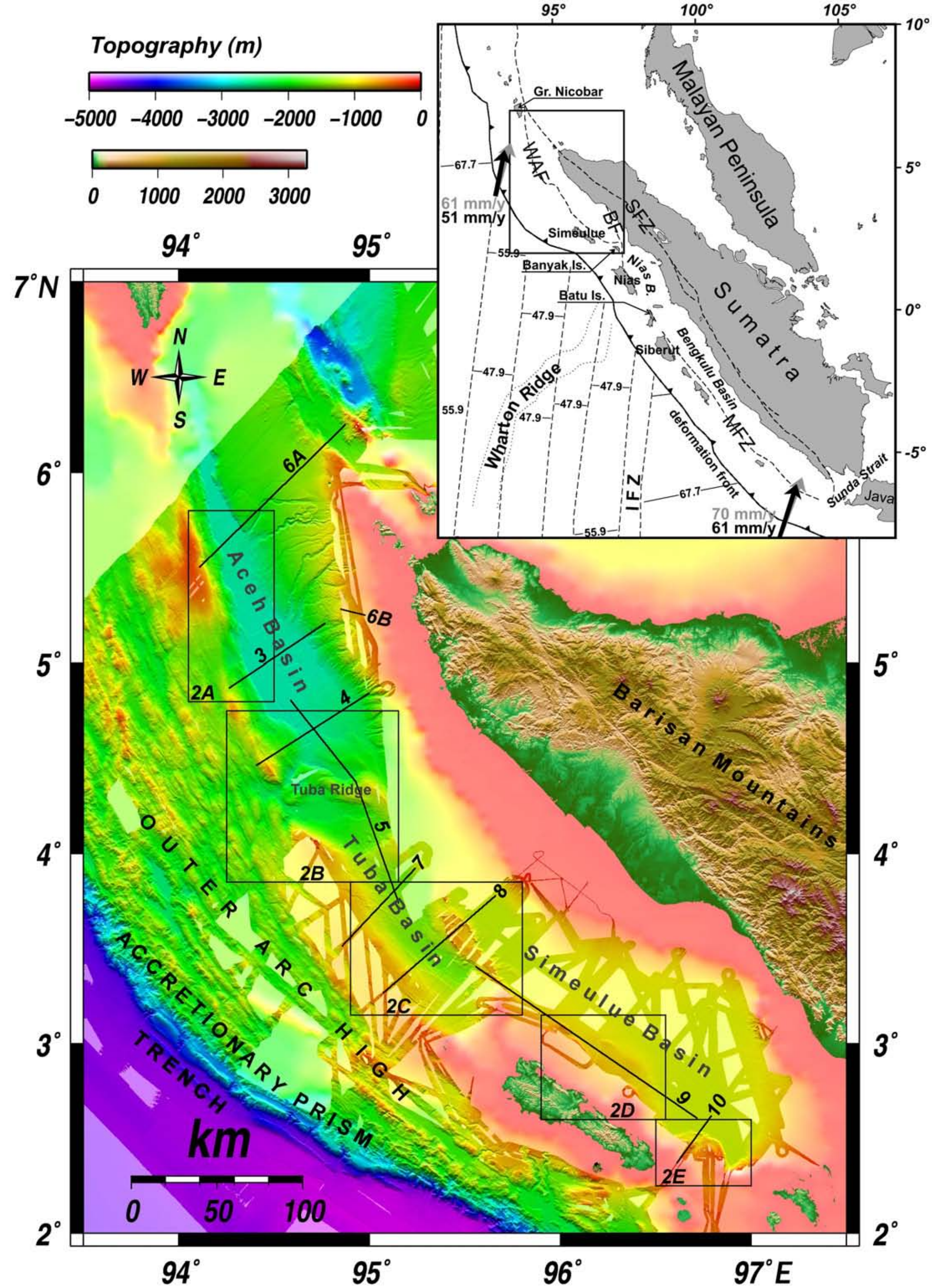

Fig. 1. Bathymetric map off northern Sumatra. Lines indicate positions of seismic sections (Figs. 3–10), boxes of detailed bathymetry (Fig. 2). Land image is derived from SRTMv2 data, light bathymetric background from the GEBCO One Minute Grid. The inset shows the regional tectonic setting of the Sumatran subduction zone. IFZ = Investigator Fracture Zone. Sumatran Fault Zone (SFZ), Mentawai Fault Zone (MFZ), Batee Fault (BF), West Andaman Fault (WAF) and deformation front are based on Sieh and Natawidjaja (2000). Ages of the oceanic crust are after Müller et al. (1997) and Deplus et al. (1998) in million years. Gray arrows indicate relative plate movements based on NUVEL-1A (DeMets et al., 1994), black arrows based on CGPS (Prawirodirdjo and Bock, 2004).

Fault Zone and the West Andaman Fault in the Simeulue area which is not yet fully understood.

2. Tectonic evolution of the western Sunda Arc

Along the Sunda arc the oceanic Indo-Australian Plate subducts beneath the continental Eurasian Plate. The rate and direction of convergence of the Indo-Australian Plate with respect to the Eurasian Plate show a decreasing and slightly anticlockwise trend from southeast to northwest (Fig. 1). Based upon GPS measurements Prawirodirdjo and Bock (2004) proposed convergence rates of 61 mm/y (N17°E) off the Sunda Strait and 51 mm/y (N11°E) off northern Sumatra. The plate motion model NUVEL-1A (DeMets et al., 1994) gives values of 70 mm/y (N20°E) and 61 mm/y (N15°E)