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Marine Geology 242 (2007) 141 – 153

MARINE GEOLOGY
INTERNATIONAL JOURNAL OF MARINE GEOLOGY, GEOCHEMISTRY AND GEOPHYSICS

www.elsevier.com/locate/margeo

Effects of landforms on tsunami flow in the plains of Banda Aceh, Indonesia, and Nam Khem, Thailand

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Accepted 7 October 2006

Abstract

Mapping on high-resolution satellite images and in the field shows differences in landforms and characteristics of tsunami flow on two contrasting coastal plains following the giant earthquake on December 26, 2004: the plain of Banda Aceh on the northern tip of the Sumatra island, Indonesia, and the Nam Khem plain in the Andaman Sea coast of Thailand. The landforms of the Banda Aceh coastal plain are characterized as deltaic lowland with tidal plains in the western and central parts, and strand plain with beach ridges in the eastern part. The run-up tsunami flow invaded areas about 3–4 km from the coast. Strong tsunami flow severely damaged the tidal plain and the landforms along the coast except coastal dunes in the east. Most of the landforms except sand dunes along the coast had almost no effect on the protection against the tsunami, but the higher micro-landforms such as beach ridges and natural levees prevented the flow of the tsunami from its invasion into the inland near the end of tsunami inundation.

The tsunami inundation spread out over the entire Nam Khem coastal plain with an average depth of 4–5 m. The direction of run-up flow was almost perpendicular to the coastline, whereas backwash flow directions were controlled by topography. Backwash flow was concentrated in the lower portions of the plain, for example in small stream channels. Wedge-shaped channels in the lower parts of the streams were formed due to the concentration of backwash flow. The existence of the swales between parallel beach ridges corresponds well with the distribution of thick tsunami deposits. Coastal erosion of the plain was caused by the direct attack of tsunami waves, and the lower reaches of small rivers were eroded by strong backwash flow.

Keywords: Sumatra–Andaman earthquake; tsunami flow; tsunami deposits; coastal plain; Banda Aceh; Nam Khem

1. Introduction

Large tsunamis produce significant geomorphological changes when they reach the coast, including extensive erosion and deposition of distinct sedimentary layers. Studies have been undertaken on the characteristics of deposits of former tsunamis (Atwater, 1992; Minoura et al., 1994; Dawson, 1994; Nishimura and Miyaji, 1995; Sato et al., 1995; Imamura and Takahashi, 1995; Dawson et al., 1995, 1996; Clague et al., 1999, etc.), and several reviews on paleo-tsunami deposits have been published by Dawson and Shi (2000), Goff et al. (2001), Scheffers and Kelletat (2003), Scheffers et al. (2005), but less research has focused on the change of coastal landforms by tsunami flow and on the spatial distribution of tsunami deposits in relation to coastal landforms.

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0025-3227/$ - see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.margeo.2006.10.030

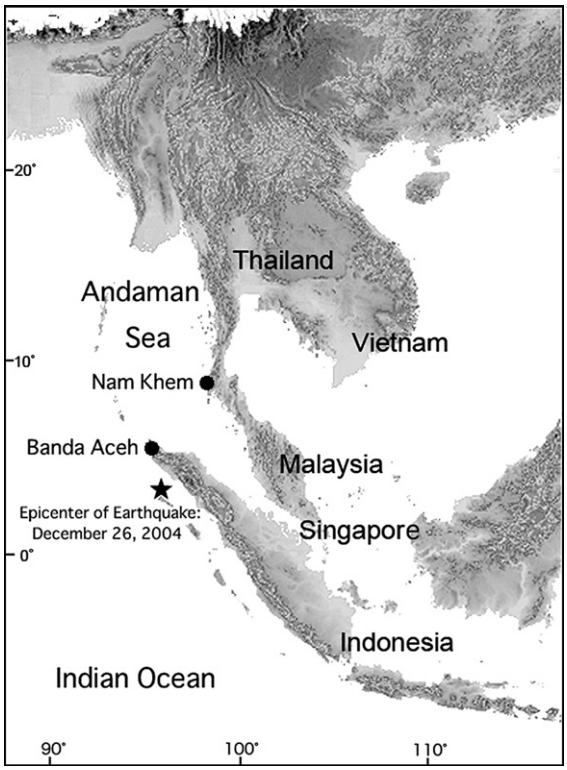

Fig. 1. Map showing the location of the Banda Aceh and the Nam Khem plains in Indonesia and Thailand.

Konno et al. (1961) studied tsunami deposits on the northeastern coast of Japan, which were deposited by the tsunami resulting from the 1960 Chile Earthquake. They discussed the relations among deposits and breached tsunami flow characteristics. Based on the morphology of a coastal embankment, they identified three types of tsunami flows: sheet flow, linear flow and eddies. Evidence for the three types of flow can also be seen on several coastal lowlands. Sato et al. (1995) clarified distribution of onshore tsunami deposits caused by the 1993 Southwest Hokkaido and 1983 Japan Sea earthquakes and found that the thick and widespread siliclastic tsunami deposits occurred where higher vertical run-up was observed. Gelfenbaum and Jaffe (2003) conducted detailed research on the 1998 Papua New Guinea tsunami deposits and clarified detailed characteristics of the tsunami deposits. They found that the incoming tsunami flowed nearly perpendicular to the shore, but a slower backwash or return flow was directed obliquely to the shore in local topographical lows.

These are limited case studies, and further detailed research on the distribution of tsunami deposits in relation to the flows on land and landforms of coastal lowlands is necessary.

The catastrophic tsunami accompanying the giant earthquake off Sumatra on December 26, 2004, inundated coastal lowlands in northern Sumatra, Indonesia,

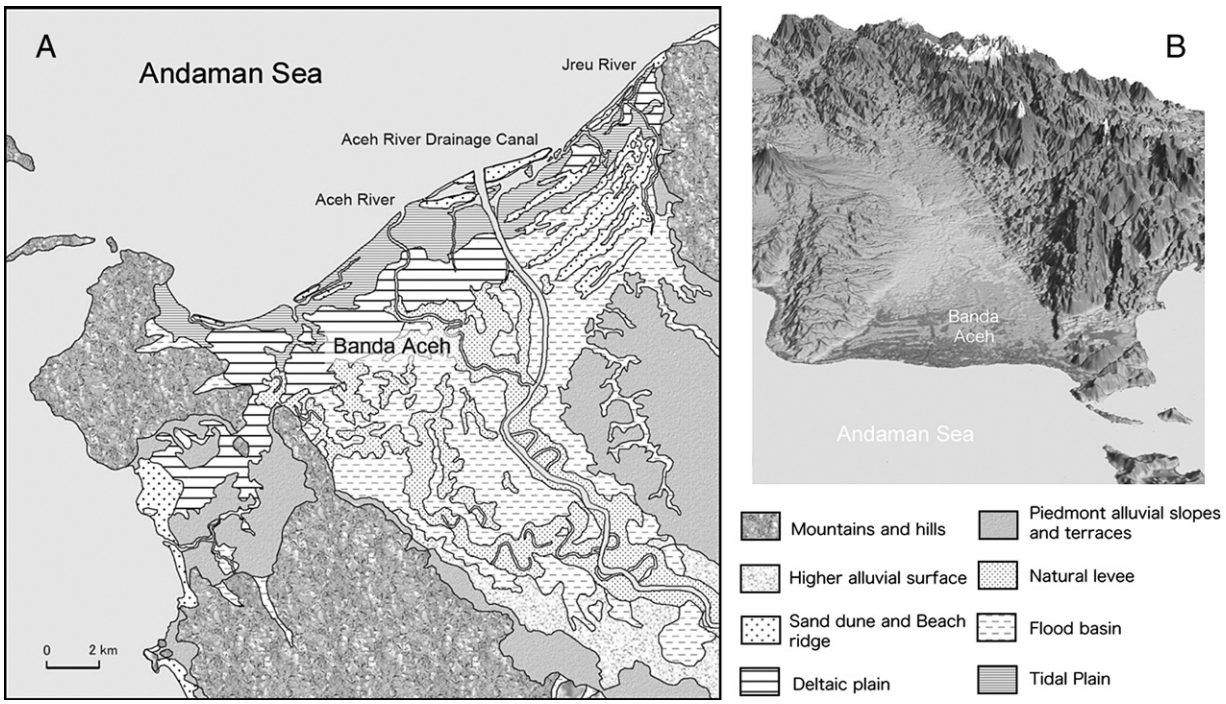

Fig. 2. Landform classification map of the Banda Aceh coastal plain.