# Subduction zone processes in Central Java: Preliminary results of the MERAMEX amphibious project

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## 1. Introduction

Within the scope of the BMBF/DFG special initiative GEOTECHNOLOGIEN-Continental Margins, the joint interdisciplinary SUNDAARC project commenced in 2004. Within SUNDAARC, the subproject MERAMEX focuses on the high-risk volcanism and its tectonic implications on the active Sunda subduction zone. During the course of the project, RV SONNE cruises SO176&SO179 set out to collect geophysical data on the Java margin and the incoming oceanic plate to better understand the processes of fundamental importance related to the mechanics of plate convergence and the development of the Java forearc and volcanism. During the first cruise, SO176, in May 2004, 14 Ocean Bottom Seismic Stations (OBS) were deployed to monitor the natural seismic activity, augmenting a 120-element land array. The second cruise, SO179 in September/October 2004, was primarily dedicated to the acquisition of seismic profiles. The main aim was to shoot into the land array to allow for some 3-D control of the plate interface.

Three profiles, the two dip lines P16 and P18 reaching from close to the coast across the trench onto the oceanic plate as well as profile P19 located about 25 nm off the south coast of Java, were recorded onshore in a temporal seismological network which was installed in a dense grid of about 10-20 km station distance around Merapi volcano in Central Java. Due to the location of the eastern dip line across the Java margin and trench (profile P16), additional receivers (short periodic 95 MARK L4C-3D seismometers in combination with Earth Data Loggers) had to be installed in East Java in August 2004.

Altogether, 75 ocean bottom stations were deployed offshore, in addition to the acquisition of mini-streamer, bathymetric, gravimetric, and magnetic data. Here we report initial results of the refraction modelling (onshore and offshore) and bathymetric investigations, which shed some light on the subduction zone processes.

## 2. Objectives of the Project

One of the key elements within the study area is the so-called seismic »gap« around 110°E, where seismic activity is highly reduced while accumulations of earthquake hypocenters occur to the west and east of this 100 km wide corridor. The study focuses on the relation of subduction zone processes and the arc volcanism as it is manifested in the active Merapi strato volcano. In addition to the seismicity and seismotectonics, the three-dimensional subbottom structure of the forearc and the activity pattern of Merapi represent the main objectives of the project. It has generally been accepted that fluids released during subduction of the oceanic plate trigger partial melting in the mantle wedge. These melts are the source for the active volcanism along the arc. The knowledge of fluid pathways and the distribution of fluids and melts in the forearc is essential for the modeling of deformation processes and for a comprehensive understanding of the relation between subduction and volcanic activity.

In addition to the interrelation between the forearc processes at depth and the onshore volcanism, the study was also geared at unraveling the fundamental tectonic framework of this little investigated margin. Modes of mass transfer at subduction zones vary intensely, including accretionary and erosive styles. Most margins are non-uniform either in alternating phases of accretion and erosion or in supporting accretive and erosive regimes simultaneously. While accretionary systems are comparatively easy to identify due to the material accumulation in a compressive setting, the 'loss' of material in erosive systems makes them a more obscure target. One of the main objectives of the geophysical data acquisition during the SONNE cruises was the investigation of the tectonic regime of the central Java margin.

### 3. Re-evaluation of the tectonic regime of the central Java margin

The geological framework of a subduction zone, namely the thickness and the properties of the incoming sediments, the convergence rate, and the oceanic plate roughness, control whether accretion or subduction erosion will dominate, since these features guide the amount of material necessary for accretion and subsequent growth of a wedge or prism. Off central and eastern Java, these factors would currently clearly favour tectonic erosion over sediment accretion. While the minimal sediment supply (0< trench fill < 1km) and the high convergence rate (7.7 cm/a) would also be sufficient for intermediate type processes, i.e. non-accretive subduction, the subduction of severe oceanic basement relief causes active erosion of the forearc. Erosion may either occur along the front of the margin or along the base of the forearc wedge causing dismemberment of upper plate material along the shallow part of the plate interface and transfer of material to the downgoing oceanic plate. Frontal erosive processes along this margin segment are best documented by the broad retreat of the Java trench and deformation front in the projection of the oceanic Roo Rise (white dotted line in Figure 1). Between 109°E and 115°E, the

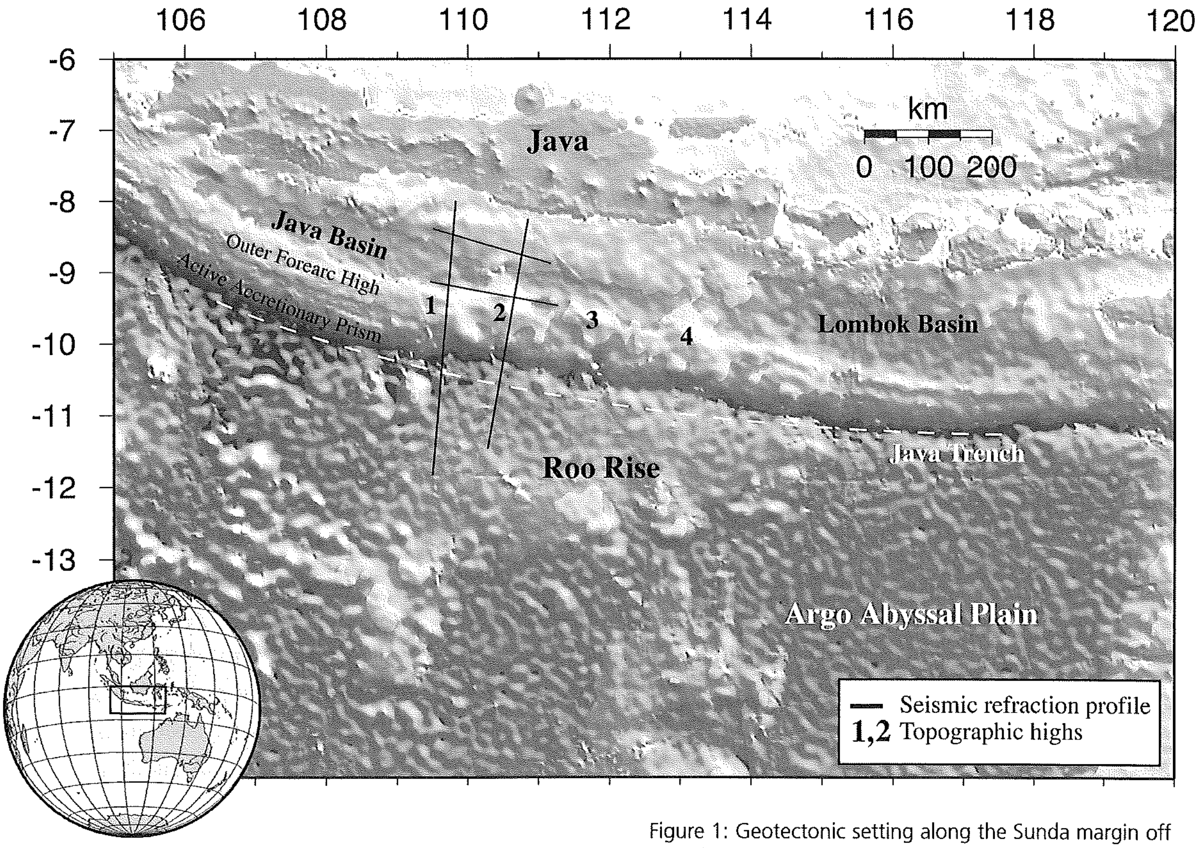

Figure 1: Geotectonic setting along the Sunda margin off Java displaying main bathymetric features and location of seismic profiles.

trench is deflected northward by approximately 50-60 km from its normal curvature trend. The collision of the Roo Rise with the forearc dominates the subduction processes off central and eastern Java. The Roo Rise represents a little investigated oceanic relief feature, which forms an irregularly shaped broad swell dotted with isolated morphological summits (Fig. 1). It continues into the trench and is interacting with the margin, where it causes broad-scale uplift of the entire forearc (Fig. 1).

Judging from the large-scale topographic features visible in the bathymetry map, seamount and oceanic basement relief subduction has largely destroyed the previous outer forearc high as its ridge-like framework gave way to isolated topographic units arising from subducted basement relief (1 through 4 in Figure 1). At this stage of the project, it remains unclear what volume of the eroded material has been displaced landward and to what extent the material has been transported beyond the forearc.

## 4. Current Status, Data Description and Methods

Three seismic profiles were shot with an array of four 32-l airguns at a shot interval of 60 s (black lines in Figure 1). One profile (SO179-19) was especially shot sub-parallel to the trench near the shoreline to allow for energy registration by the landstations and to attain additional 3D structural information to the other profiles. Data on the two profiles (SO179-16, SO179-18) perpendicular to the trench were recorded by a total of 43 ocean bottom stations (OBH and OBS). These profiles are 350 km long and start on the oceanic plate crossing the outer arc high and the forearc basin onto the continental shelf.

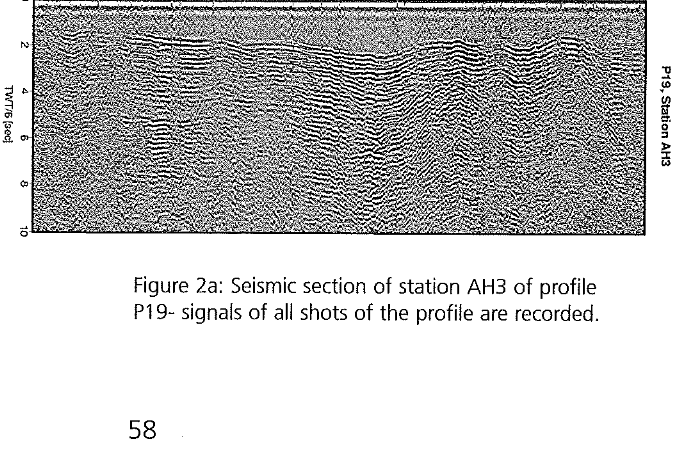

Figure 2a: Seismic section of station AH3 of profile P19- signals of all shots of the profile are recorded.

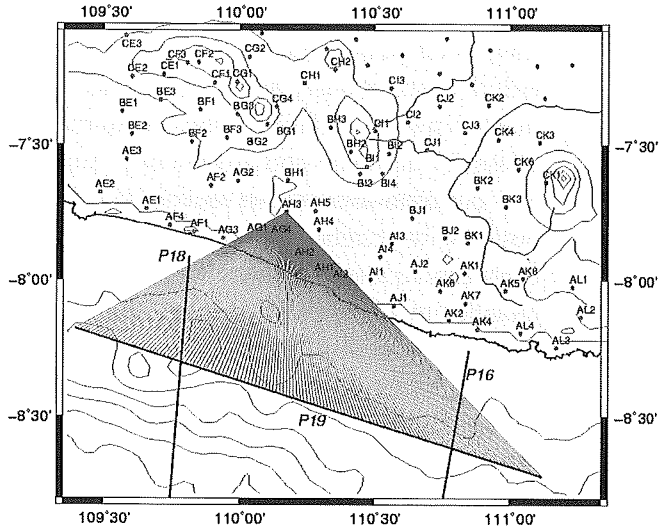

Figure 2b: Location map of the receiver stations and airgun profiles P16, 18, and 19. The ray coverage of profile P19 recorded on receiver AH3 is illustrated.

*Onshore registration of marine shots:*

The land receivers stored the raw data of profiles SO179-P16, P18 and P19 in MiniSEED data format, which subsequently was converted to SEGY and sorted to receiver gathers. Spectral analyses of each receiver gather helped to determine the ideal filter section. A bandpass-butterworth filter with filter edges of 3-12 Hz was applied in addition to a notch filter dependant on the individual receiver gather to eliminate spikes. All traces were individually normalized to the maximum amplitude.

Currently, data recorded by the landstations on P16, P18 and P19 and the relevant OBH for the tomography of the wide-angle data are processed and the first onsets are picked.

The quality of the data recorded onshore is generally good and the range of the air gun signals is high, as seen on Figure 2. For example, receivers as far as CI3 (130 km offset) and CK1 (115 km offset) recorded signals of P19 and P16. Figure 2a shows a seismic section of station AH3 of profile P19- signals of all shots comprising the profile were recorded.

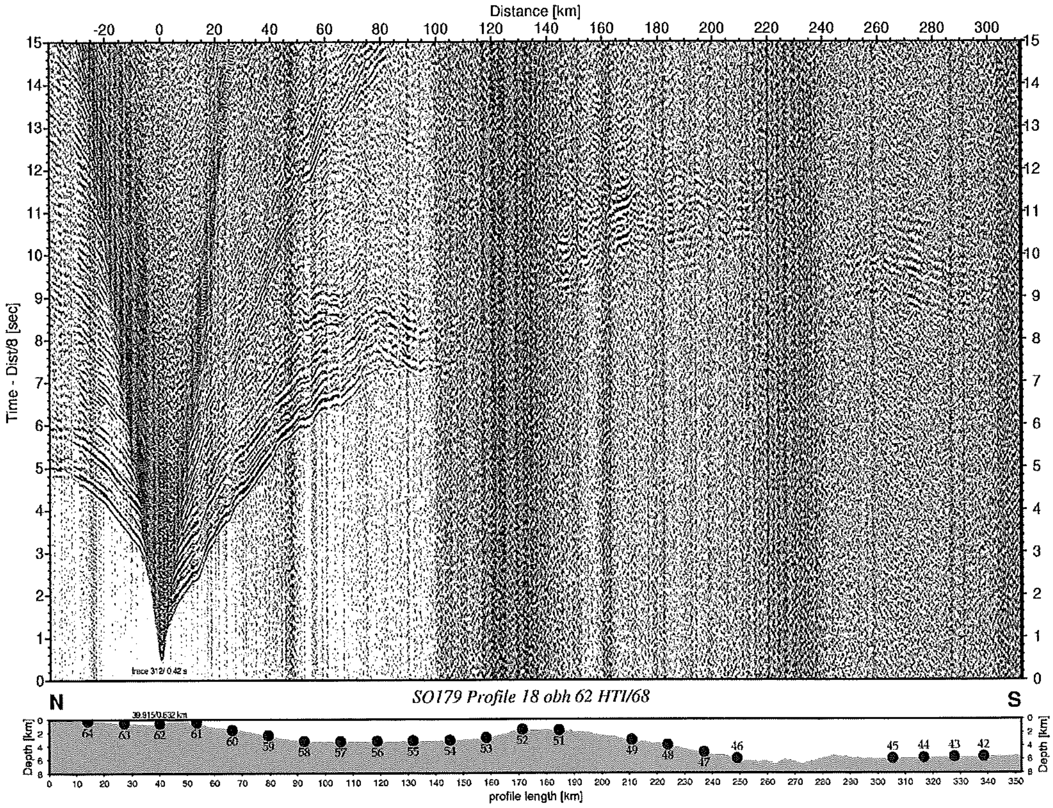

Figure 3: Wide-angle data section on the Java shelf, which registered energy from 300 km distance (SO179-18).

Figure 2b illustrates a location map of the onshore receiver stations, the airgun profiles P16, 18, and 19 and the ray coverage of Profile P19 recorded on receiver AH3.

Marine seismic wide-angle and reflection data: The marine refraction data were corrected for position and frequency filtering was applied to adjust for time- and offset-dependent variations. To further improve the temporal resolution of the data, a gated Wiener deconvolution was applied to compress the seismic wavelet. The data quality is generally very good, as seen on various stations, which received signals to a maximum distance of 300 km (Fig. 3).
Seismic reflection data were acquired simultaneously to the refraction profiles by a 50 m long four-channel streamer and are incorporated as a priori information into the refraction modelling. A forward modelling technique is performed on profiles SO179-16 and SO179-18 to gain a starting model for inversion and tomographic approaches. Future work will include tomographic inversion of the marine wide-angle data to unravel the structure of the forearc and possible fluid pathways. Incorporating the marine data and the land survey shall yield a composite model of the subduction zone and its linkage to the volcanic source of the Merapi volcano.

## Acknowledgements

The SUNDAARC and MERAMEX projects are supported by the BMBF/DFG special initiative GEOTECHNOLOGIEN-Continental Margins. The geophysical data were acquired using RV SONNE as platform. We are grateful to Cpts. Papenhagen and Mallon and their crews for the professional work and their support at sea.