IFM-GEOMAR REPORT

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Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

RV Chakratong Tongyai
Fahrtbericht / Cruise Report
MASS-III
Morphodynamics and Slope Stability of the Andaman Sea Shelf Break (Thailand)

Phuket - Phuket (Thailand)
11.01. - 24.01.2011

Berichte aus dem Leibniz-Institut
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RV Chakratong Tongyai

Cruise Report

MASS-III

Morphodynamics and Slope Stability of the Andaman Sea Shelf Break (Thailand)

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Contents

1. Summary

In the framework of the German-Thai cooperation on tsunami research, the aim of the MASS project is to assess the potential risk for tsunamis generated by submarine mass-wasting along the Andaman Sea shelf break off the west coast of Thailand. Numerous indications for mass-wasting, free gas in near surface sediments, and fluid venting have been found during the previous MASS cruises. Within the MASS-III survey multichannel reflection seismic data has been collected along the south-western corner of the Thai Exclusive Economic Zone for the first time in order to image older, buried mass wasting events. This is an essential information for determining the recurrence rate of slope failures. During the cruise several well defined submarine landslide deposits of varying size have been found along the slope. Seismic data also allowed to image geological structures on top of the acoustic basement including numerous fault systems displacing well stratified sediment packages, an assumed mud volcano, buried channel systems, as well as huge carbonate platforms in the northern part of the study area. Sediment cores were taken based on the acoustic data to determine the ages of young mass-wasting events as well as for sedimentological and geotechnical analyses. The synthesis of all available data shall characterize the current state of the slope and lead to a risk assessment of future slope failures.

Zusammenfassung

Ziel des MASS-Projekts, das im Rahmen der Deutsch-Thailändischen Kooperation zur Tsunami Forschung durchgeführt wurde, ist die Abschätzung des Risikos das von Tsunamis ausgeht, die als Folge von Hangrutschungen an der Schelfkante der Andaman See vor der Westküste Thailands ausgelöst werden. Anzeichen für Hangrutschungen, Gebiete mit freiem Gas in oberflächennahen Sedimenten und Fluidaustrittsstellen wurden bereits während der vorherigen MASS Ausfahrten gefunden. Im Rahmen der MASS-III-Fahrt wurden zum ersten Mal hoch-auflösende Mehrkanal-seismische Daten entlang der südwestlichen Ecke der ausschließlichen Wirtschaftszone Thailands aufgezeichnet. Ältere Rutschungsablagerungen unterschiedlicher Größe konnten somit identifiziert werden, was eine wichtige Grundlage darstellt um die Wiederholraten von Rutschungen in diesem Gebiet abzuschätzen. Mit den gewonnenen seismischen Daten lassen sich ebenfalls Strukturen oberhalb des akustischen Basements darstellen. Verwerfungszonen durchziehen gut stratifizierte Schelfsedimente. Zusätzlich wurden in den seismischen Daten einige geologisch interessante Strukturen abgebildet, wie z.B. ein Schlammvulkan, vergrabene Kanalsysteme, sowie große Karbonatplatformen im nördlichen Bereich des Messgebiets. Basierend auf den akustischen Daten wurden Sedimentkerne genommen, um sedimentologische sowie geotechnische Analysen durchzuführen. In einer Synthese soll mithilfe der gesammelten Daten die gegenwärtige Hangstabilität bestimmt und eine Risikoabschätzung für zukünftige Hangrutschungen durchgeführt werden.

2. Participants

Name	Discipline	Institution
Krastel, Sebastian, Prof. Dr.	Chief Scientist	IFM-GEOMAR
Arreesuriyasak, Vorapot	Student	BUC
Bhatrasataponkul, Tachanat	Marine Aerosol	BUC
Boonyuen, Paksamon	Student	KU
Brandt, Thomas	Technician	IFM-GEOMAR
Bunsomboonsakul, Suratta	Coring, Seismics	START
Gross, Felix	Seismics	IFM-GEOMAR
Grün, Matthias	Bathymetry, Seismics	IFM-GEOMAR
Jintasaeranee, Pachoenchoke	Bathymetry	BUU
Maliwan, Rataporn	Student	BUC
Nuangchamnong, Kamontip[1]	Student	KU
Pananont, Passakorn, Dr.	Seismics	KU
Payakleart, Punlop, Comander	Naval Observer	CU
Schwab, Julia[2]	Coring, Seismics	IFM-GEOMAR
Weinrebe, Wilhelm, Dr.[1]	Bathymetry	IFM-GEOMAR

BUC	Ocean-Atmosphere System Research Laboratory, Faculty of Marine Technology, Burapha University, Chanthaburi Campus, Chanthaburi, Thailand
BUU	Department of Aquatic Science, Faculty of Science, Burapha University, Bangsaen Campus, Chonburi, Thailand
CU	Survey Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand
IFM-GEOMAR	Leibniz Institute of Marine Sciences (IFM-GEOMAR), Kiel
KU	Department of Earth Sciences, Faculty of Science, Kasetsart University, Bangkok, Thailand
START	Southeast Asia START Regional Center, Chulalongkorn University, Bangkok, Thailand

[1]participated only at the first leg (11.01 – 14.01)
[2]participated only at the second leg (15.01 – 22.01)

Fig. 1: Participants of leg 2

3. Research Program

The proposed project aims in assessing the potential risk for tsunamis generated by submarine mass-wasting along the Andaman Sea shelf break off the west coast of Thailand. Since December 26, 2004 when a devastating tsunami generated by an earthquake off Sumatra hit the west coast of Thailand, claimed the lives of many people and destroyed large areas along the coast, the potential risk for future tsunami events in that area is of major concern to the Thai people and the scientific community. Aside the risk for tsunamis generated by large earthquakes along the Sunda Arc subduction zone, submarine slumping could be a potential cause for tsunamis in the Andaman Sea. Little is known about the sea-floor and the tectonic structure of the Thai part of the Andaman Sea.

During two previous cruises in 2006 and 2007, acoustic data were collected in order to characterize the sea-floor. Numerous interesting features were identified including escarpments, mud volcanoes, indications for fluid seepage, and a possible relationship between fluid seepage and slope stability. The initial phase of the project, however, demonstrated that additional data are needed to assess slope stability and possible consequences of major slides. The bathymetric data set needs to be extended but the main focus was on the collection of seismic data and seafloor sampling. Seismic data are needed to image older mass flow deposits, thereby determining the recurrence rate of major mass-wasting events, which is essential for a risk assessment. Seismic data will also help to identify free gas and gas hydrates in order to analyze their role for slope stability in the Andaman Sea. Cores are needed for sedimentological and geotechnical analysis as well as for dating of individual slide events.

The principal objectives of the MASS III-cruise are:

- **Acquisition and processing of new acoustic and core data:** Acoustic data (airgun seismic, sediment echo-sounder, bathymetric multibeam) shall be used to identify and map headwalls, escarpments, debris deposits and other evidence of slope failures and down-slope mass transport. Based on the acoustic data, cores were taken for sedimentological and geotechnical analyses.
- **Quantification of individual mass-wasting events.** Seismic and bathymetric data can be used to quantify individual mass-wasting events. The volume of mass-wasting events is an important factor for their tsunami potential.
- **Characterization of slope failures.** All slope failures shall be classified in order to distinguish between creeping, sliding and slumping as well as between single and multiple failure events. This classification will help to differentiate between sequential and catastrophic events.
- **Determination of sedimentary properties.** Cores were taken in order to determine sedimentary properties from normal (background) sedimentation, from creeping sediments, and from areas affected by catastrophic slope failures. Such investigations help to assess the current stability of the slope.
- **Age determination of mass-wasting events.** Sediments immediately above and below the failed sediments shall be dated to establish ages of slope failures.
- **Frequency of slope failures.** Seismic data allow to image older buried mass-wasting event. The seismic data set should be used to determine the recurrence rate of slope failures. The data shall also show if some parts of the slope experienced repeated slope failures.
- **Analysis of near-surface gas hydrates and fluid seepage.** Numerous seepage features were found in the available data set. Gas hydrate occurrence is not proven but very likely. A first analysis of the data might indicate a relationship between slope stability, gas hydrate occurrence and fluid seepage, which should be studied in detail in an area, where the gas hydrate stability zone reaches the sea floor.
- **Correlation of recent (small-scale) failure events with regional seismicity.** Earthquakes are the most likely trigger for slope failure in the Andaman Sea. We want to test whether individual mass-wasting events can be correlated with seismicity and local faults.
- **Determination of the current state of the slope.** A synthesis of all available data will characterize the current state of the slope and should lead to a risk assessment for future slope failures.

Data collection was originally planned on the Thai Research Vessel Chakratong Tongyai in December 2009. Due to problems with this vessel, it was decided to use the Thai Research Vessel RV Seafdec instead in late 2009 but this cruise had to be canceled on short notice. Hence data collection was delayed to January 2011 on RV Chakratong Tongyai. The cruise was split in two parts. The first leg was mainly planned for calibrating the Multibeam system and running one long seismic profile from the coast to the central working area. Unfortunately the frame for the multibeam-system broke shortly after calibration (see narrative of the cruise). The second leg was used for additional seismic surveying and sediment sampling.

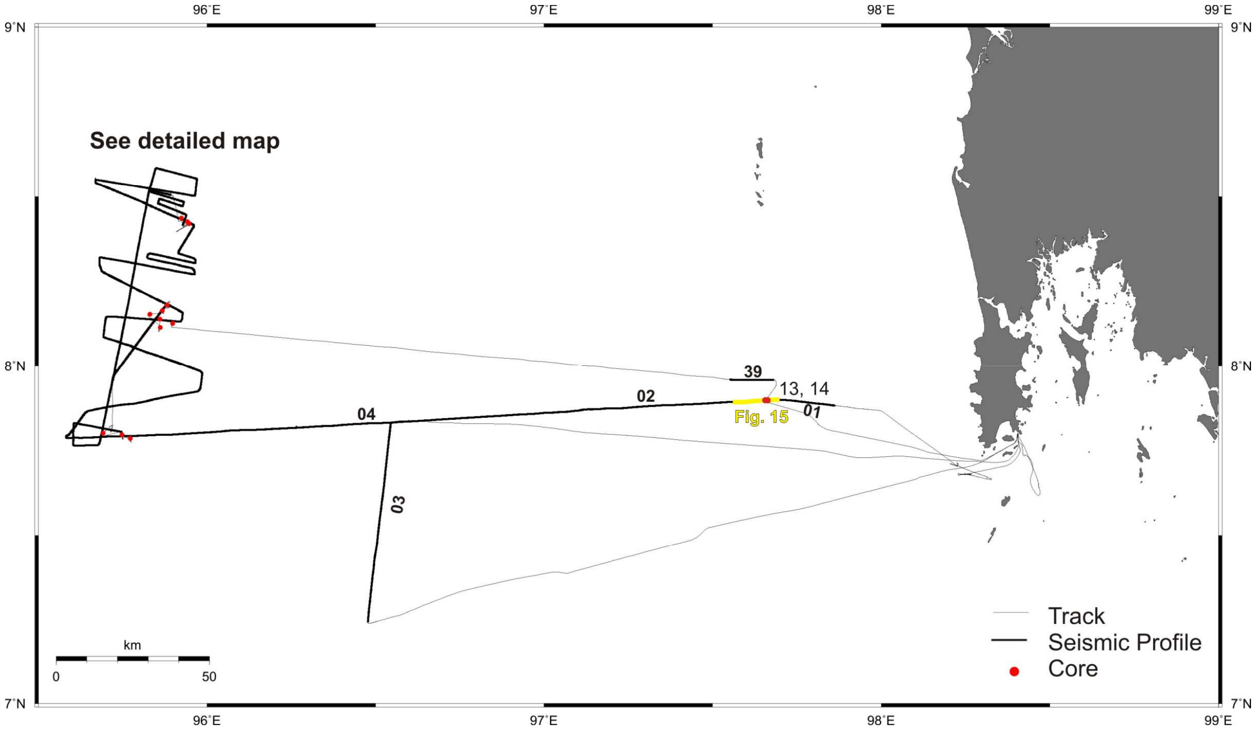

Fig. 2: Cruise track of the MASS III cruise. Thick black lines show location of seismic profiles. Red dots represent coring stations.

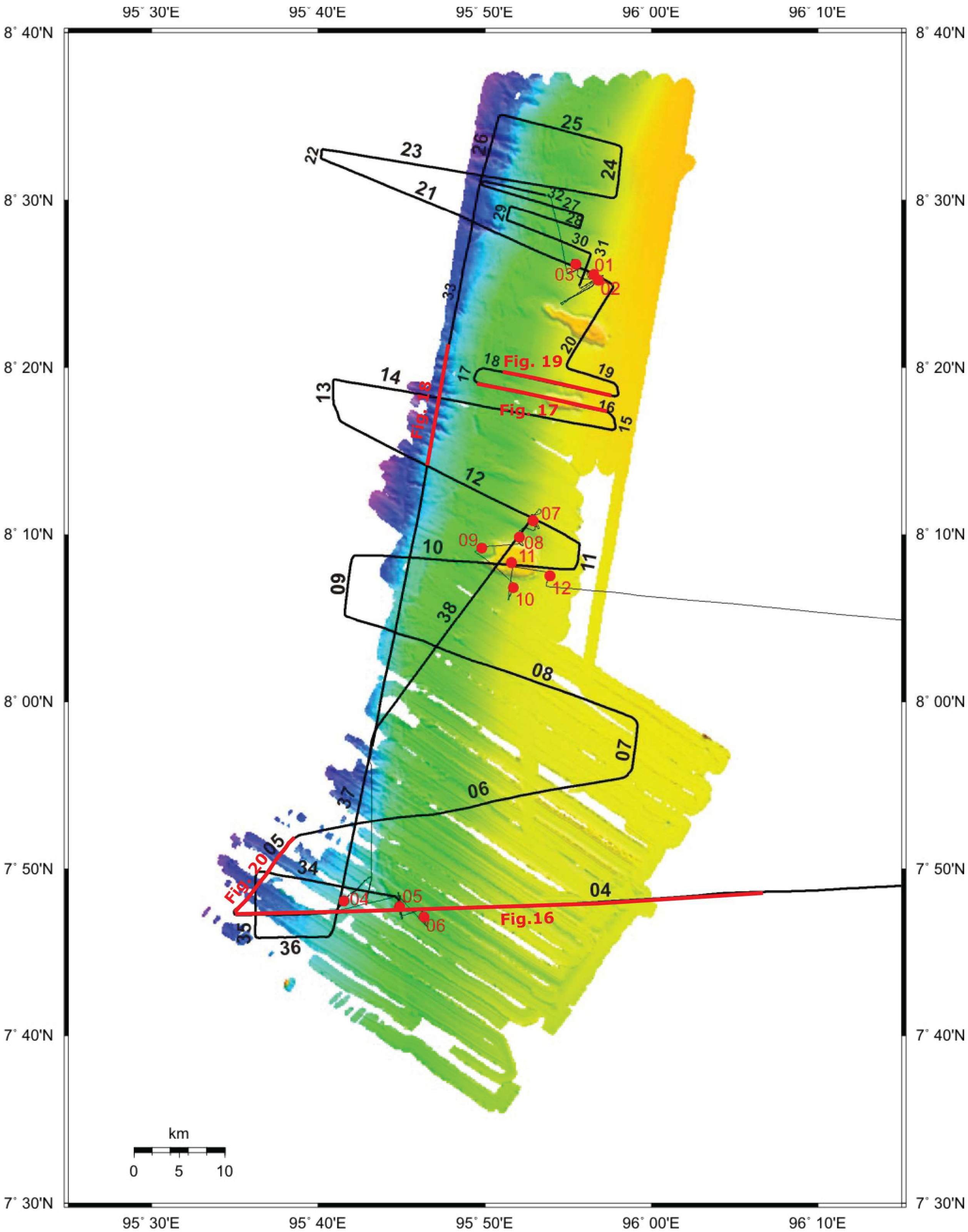

Fig. 3: Cruise track of central working area. Coring stations are marked by red dots; seismic profiles in red are shown in the preliminary results.

4. Narrative of the Cruise

The main group of the scientific party of the MASS-III cruise arrived at Phuket on January 4th and 5th for a cruise on the Thai Research Vessel Chakratong Tongyai. The scientific team consisted of 6 scientists from IFM-GEOMAR, and the Cluster of Excellence ‘The Future Ocean’ (Kiel, Germany), four scientists from Burapha University (3 from Chanthaburi Campus and 1 from Bangsaen Campus, Thailand), three scientists from Kasetsart University (Bangkok, Thailand), one scientist from the Southeast Asia START Regional Center (Chulalongkorn University, Bangkok, Thailand) and a naval observer currently at Chulalongkorn University (Bangkok, Thailand).

Originally it was planned to have two legs of 8 days each starting at January 7th with a two day mid-cruise port call from January 14th to 16th. This plan had to be changed at an early stage because the container with the equipment from Germany was delayed. In addition, some repairs of the ship were necessary before leaving for the cruise. The container arrived at Midnight on January 8th and was unloaded at the night. The installation of the multibeam arm was successfully finished on January 8th. However, we still had to wait for the repairs of the vessel, which were finished on January 10th. A sea trial of the repaired components was done in the morning of January 11th. All components were working fine. Hence we left the pier of the Phuket Marine Biological Center port for the cruise on January 11th around 19:00h after bunkering. As consequence of the delay, the first part of the cruise was only 3 days, because personnel had to be exchanged on January 14th.

Scientific work started by calibrating the Multibeam system in about 60 m water depth close to the port in the evening. After collection a sound velocity profile, the multibeam was corrected for roll. The pitch and yaw calibration was postponed to a later time due to intense fishing activities across the structure selected for the calibration. It was planned to start with seismic profiling immediately after the calibration but the captain suggested postponing the start for one to two hours due to intense fishing activities. The captain gave his OK for deploying the seismic system around 04:00h in the morning on January 12th. The streamer was deployed successfully but immediately after full deployment the captain requested to retrieve the streamer due to ship traffic. As there was no option to discuss this decision, the streamer was retrieved as quick as possible because the captain already stopped the vessel. When the streamer was in, the captain went full speed back along the track. This resulted in very high water pressure on the multibeam arm, which was constructed for velocities of 4 knots and finally the multibeam arm bent. Luckily we were able to retrieve the transducers without any obvious signs of damage. However, it was clear that the continuation of bathymetric profiling would only have been possible after a time consuming repair of the multibeam arm in port. As we already lost a lot of time, we decided to cancel the multibeam program and continue with seismic profiling. In order to avoid a similar situation as described above, the seismic system was not deployed before leaving the near shore area with heavy ship traffic and fishing activities. The deployment of the streamer started around 10:00h on January 12th. Deployment went smoothly but only the first section of the streamer could be detected. This problem could only be solved by taking out the first two sections of the streamer leaving us with eleven 12.5 m long sections and 88 channels. Seismic profiling started around noon local time with a first long profile to the area investigated at previous cruises. As time was short and we had to back in port on January 14th around noon, we did not continue this profile in the survey area but collected a profile into a basin close to the northern boundary of the

Thai EEZ. Data quality was very good and the first data show indications for numerous faults, buried channels, and submarine slides. The gear was successfully retrieved on January 13th around 19:00h. Afterwards we started our transit back to the pier of Phuket Marine Biological Center, where we arrived at noon on January 14th. The fuel was already waiting for us and the multibeam arm was dismounted. We were ready to leave the port again around 16:00h but in the meantime the air conditioning system of the ship stopped working. Repairs were not successful. A 21:00h the chief engineer suggested leaving without AC but this approach was refused by the captain. It took until the afternoon of January 15th to fix the AC. We left the pier at 17:00h and headed to the position, where we terminated the long profile to our main working area. This point was reached at 08:00h on January 16th. Streamer and gun were deployed successfully despite the slightly rougher sea state. Seismic data were collected for the next 72h without significant problems. We added one seismic section to the streamer, hence now acquiring 96 channels with 12 sections. During this survey we collected profiles across the entire area mapped during previous cruises. We detected numerous slides, faults, current induced sedimentary features, basement highs, and fluid migration pathways. The streamer was retrieved on January 19th in the morning. The schedule for the 19th was to collect a number of cores across a prominent slide feature in the northern working area. We selected this feature for our first coring attempt, because the target was relatively shallow (500 – 600 m). A mini-gravity corer of 2 m length and a total weight of 250 kg was used for this approach. Coring, however, was difficult due to numerous reasons. The cable length measuring device seems to be not very accurate and no tension on the wire can be measured on RV Chakratong Tongyai. Hence the bottom contact of the relatively light weighted corer is difficult to detect. The ship had major problems to keep the position and last but not least, regular failures of the coring winch caused a lot of delays. The first attempt probably did not reach the sea floor but the second attempt brought a full core. Afterwards coring operation had to be interrupted due to necessary repairs of the winch. Repairs were followed by one additional successful attempt but additional failures of the winch and sandy sediments did not allow recovering additional cores that day. Coring was stopped around 20:00h and the seismic equipment was deployed for the night. The aim was to collect one long along slope profile around 1000 m water depth. Seismic data acquisition was stopped in the morning for another day of coring. The main objective was to core potential slide deposits in the southern working area. The first station was in ~1.100 m of water depth but a new major winch failure caused and interruption of the coring program until noon. Additional attempts were not very successful. The ship was not able to keep position during coring operation but drifted with speeds of up to 1.5 knots corresponding to 0.8 m/s. We tried to lower to core with a winch speed of 1m/s meaning that the horizontal drift was in the same range as the vertical movement of the core. Therefore the core usually fell over, when it hits the ground. We increased the winch speed and managed to recover a ~30 cm long core at one position. The core contains almost pure sand, hence providing an additional explanation for no or poor core recovery. The last core for that day did not brought any major sediments but several shell fragments in the core catcher.

The night was used for additional seismic profiling and brought us to the last coring area around the southernmost guyot like feature. Finally the winch was working fine and we had a successful coring day bringing up lots of sandy sediments. Coring was finished at 17:00h on January 21st. Originally it was planned to run a long profile back to shore and take a core around the Similian Islands but we learned on very short notice that 6000 l of fuel had to stay in the tanks as reserve, hence cutting our program for another day. Therefore we started our transit without running a seismic line back to Phuket. On the transit we shot one last short profile crossing the Ranong fault; the scientific program was completed by two cores on both sides on the Ranong Fault but only a little bit of sand and gravel was recovered. RV Chakratong Tongyai arrived at the pier of PMBC on January 22nd at 16:30h local time.

Due to the numerous problems (repairs of the ship, fuel, water, logistics, etc) we had only 10 days at sea, which was about half the time as originally proposed. We were not able to collect any new bathymetric data and coring was significantly limited due to repeated winch failures. Seismic data were only collected in the area, where bathymetric data have been collected during previous cruises. Despite all the problems, sufficient data were collected to address most of the questions. A very valuable data- and sample set of short sediment cores in combination with seismic and hydroacoustic data will allow to asses the landslide risk in the Andaman Sea.

5. Preliminary Results

5.1. Bathymetric mapping

In addition to already existing bathymetric data of the continental slope it was planned to use a multibeam echo sounder system in order to achieve new bathymetric data from previously unsurveyed areas. Therefore a Seabeam Multibeam echo sounder system was deployed, which was already used during the previous MASS cruises in 2006 and 2007.

5.1.1.Technical description

Seabeam 1050 Multibeam Echosounder

The SEA BEAM 1050 System is a survey system of vast capability and is therefore highly suitable for hydrographic surveys. The operating frequency is 50 kHz. Maximum depth and coverage transverse to the ship is shown in Fig. 4.

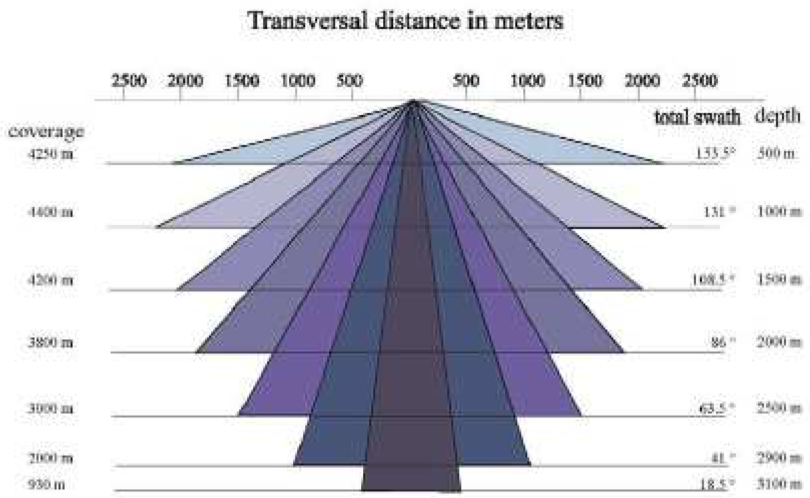

Fig. 4: Maximum depth and coverage of SEABEAM 1050

Two narrow beam width transducer arrays are pinging quasi-simultaneously into 14 directed sectors with a high acoustic transmission level. The receiving beamformer generates 3 narrow beams within each sector with a beam width of 1.5° (Phase calculator) and a spacing of 1.25°. This we call a subfan. A complete fan comprises three subfans, i.e. there are 14 sectors x 3 beams x 3 subfans = 126 beams in total. The relatively high operating frequency of 50 kHz in conjunction with special small size transducers offers two advantages: high coverage and narrow beam width. The application of preformed beams guarantees extremely good side lobe suppression and a very low error rate. This has a positive influence on measuring accuracy and gives the system a big advantage over one way procedures, i. e. non-directed transmission and reception.

5.1.2.System Configuration and holder construction onboard the vessel

For the multibeam transducers a holding construction was built that had been used also during the previous MASS cruises onboard of Chakratong Tongyai in 2006 and 2007. Construction of the poles was done at the pier of the PMBC. This time the multibeam was deployed on the starboard side of the vessel (Fig. 5). The holder construction consisted of:

- the holding arm pipe between multibeam transducer and the second arm pipe
- the second straight pipe arm
- the elbow holding arm pipe between the second arm pipe and the starboard pipe
- the starboard fixed pipe (Fig. 6)

By using flanges and screws the construction can be moved from the vertical position where transducers are in the water (during measurement) to a horizontal position with transducers fixed to the ships side (during transit), (see Fig. 6).

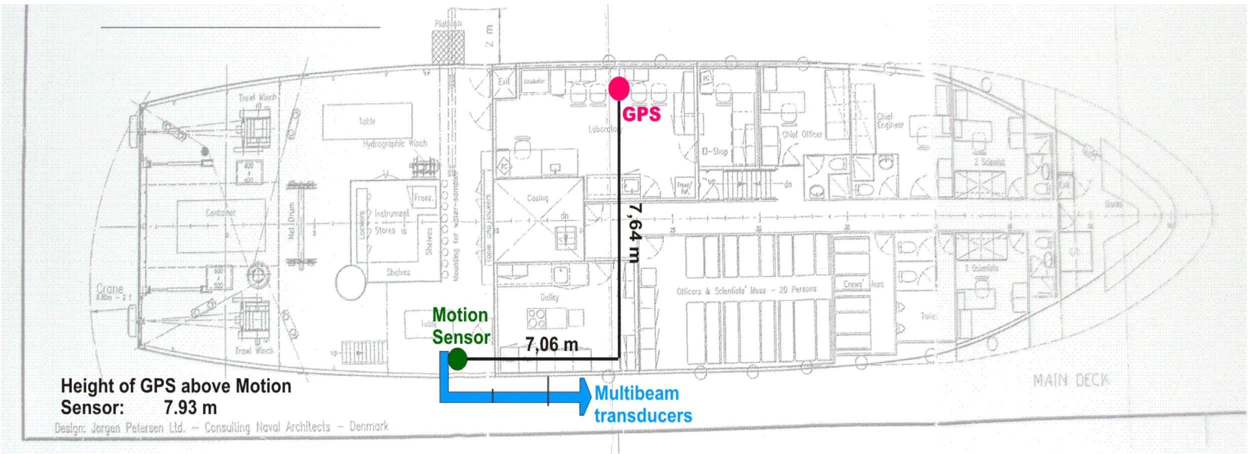

Fig. 5: Multibeam configuration onboard of Chakratong Tongyai

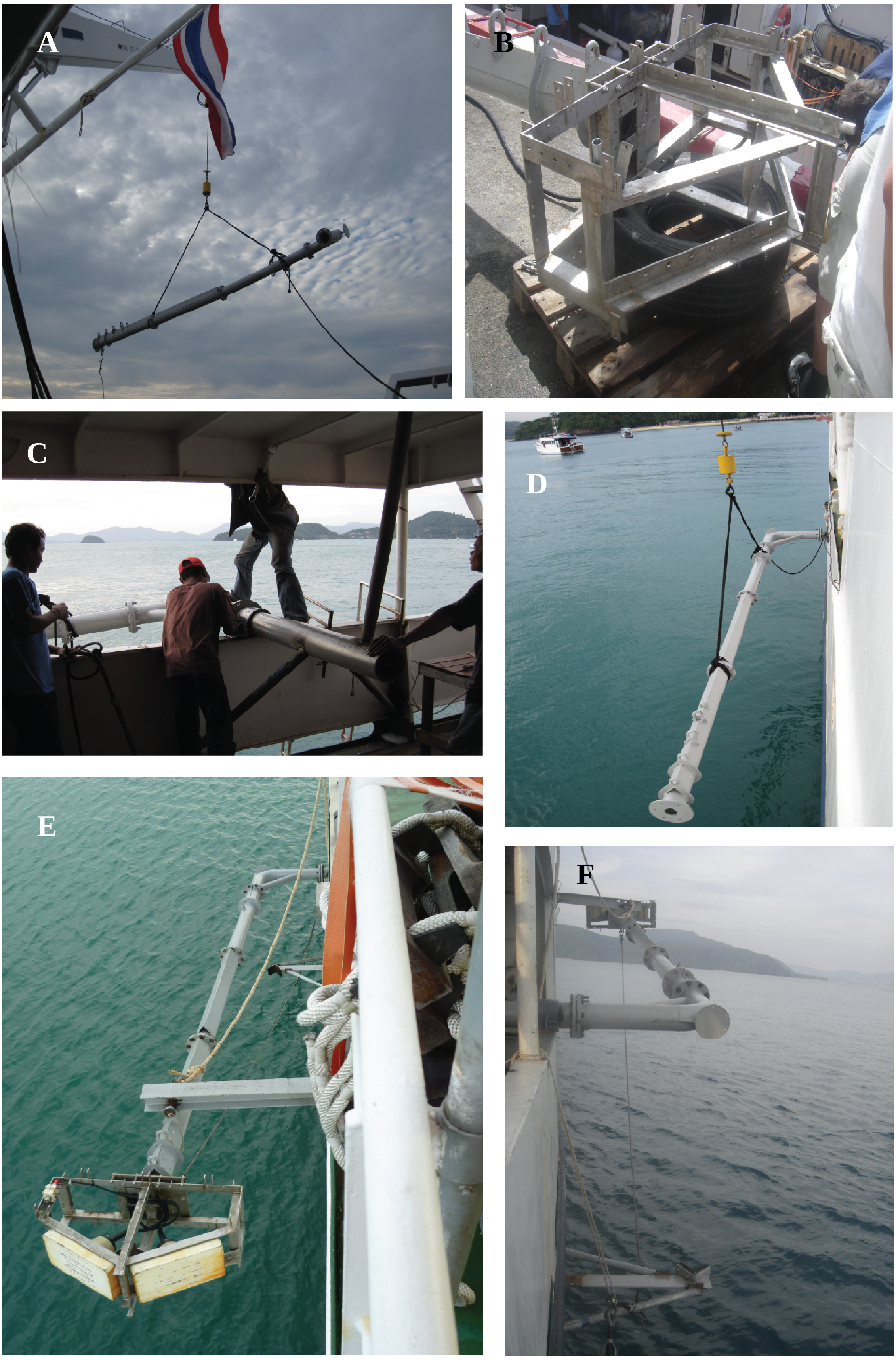

Fig. 6: Holder construction for multibeam transducers (A, B), installation on the starboard side of the vessel (C ,D), and the holder position during transit (E, F).

5.1.3.Description of the components

Transducer arrays LSE 237

The SEABEAM1050 system employs two transducer arrays of type LSE 237, port and starboard, both capable of transmitting and receiving. Their acoustic planes are tilted 30° to the horizontal. The arrays are normally installed fixed to the ship's hull. During the cruise with RV Chakratong Tongyai the transducers were mounted "over the side" using a construction with a mobile pole (Fig. 6). The ultrasonic transducer LSE 237 is used to transmit and receive ultrasonic impulses at a frequency of 50 kHz. It consists of 32 separate staves. By triggering the separate transducer staves with a phased transmit signal it is possible to point the direction of transmission to ± 50° with respect to the normal „untreated“ array transmission angle. In the transmit path both transducer arrays operate in parallel with a common power stage. All 32 staves of each transducer array are used for transmit beamforming. In the receive path port and starboard array signals are handled separately. 16 center staves of each transducer are used to form narrow beams. The number of beams and fan width is selectable.

Control Unit SEE 30

The Transmit/Receive Unit SEE 30 is accommodated within a transportable case (Fig. 7). It consists of a number of plug-in components contained in a rack.

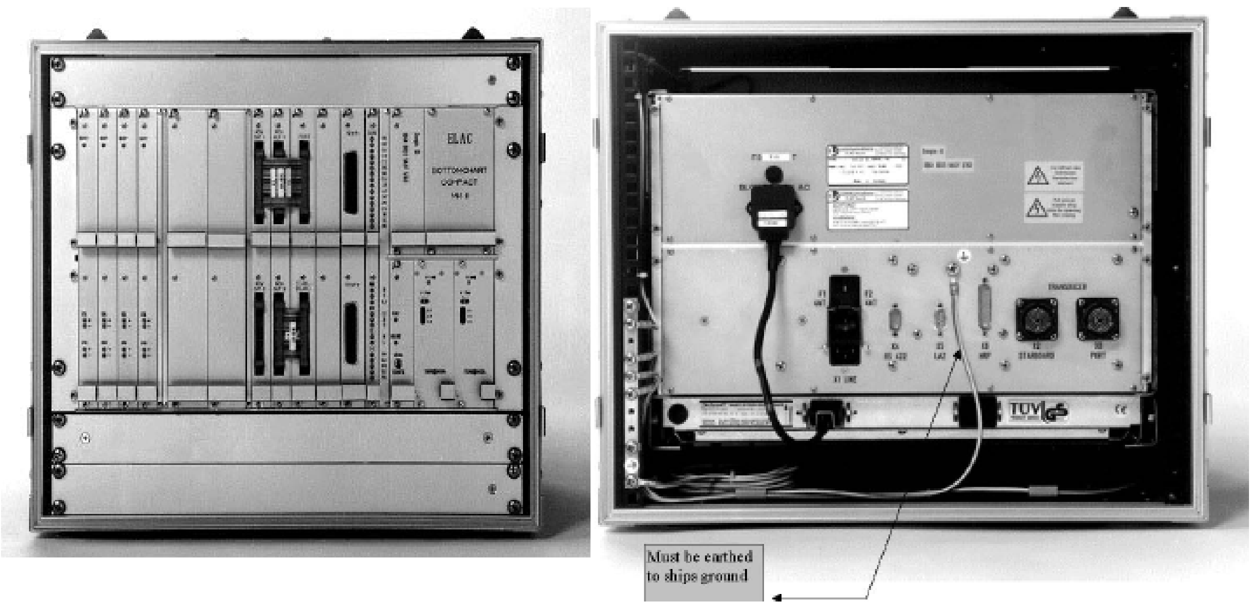

Fig. 7: Control Unit SEE 30, front and rear view

Motion Sensor IXSEA OCTANS 1000

The motion sensor OCTANS 1000 provides roll compensation signals to the system as well as pitch and heave correction signals to the processor. In addition, it also provides heading information to the data acquisition system. It was mounted at the starboard side of the vessel on deck, close to the multibeam construction (Fig. 5).

GPS-Receiver GARMIN 152

A GPS-receiver GARMIN 152 was used to get information on exact positions. The position data was provided to the data acquisition system in NMEA protocol via a serial interface.

Data acquisition

Data acquisition station was a standard industry size 19” PC, operating system was Windows XP professional. Operator interface includes a 19” graphic monitor, keyboard and mouse. To enable input of several sensor data via serial lines a special 8-port serial interface was installed. For data acquisition L3 communications ELAC Nautik online software Hydrostar 3.5.3 was used.

5.1.4.Results from bathymetric mapping

Roll correction for the multibeam was done in the night of January 11/12th . Unfortunately this was the only bathymetric data recorded during the cruise because the holder construction bent shortly after roll calibration was finished due to high ship speed (see narrative of the cruise). With the deformed pole it was not possible to collect bathymetry data anymore. Fig. 8 shows the bended pole of the multibeam construction.

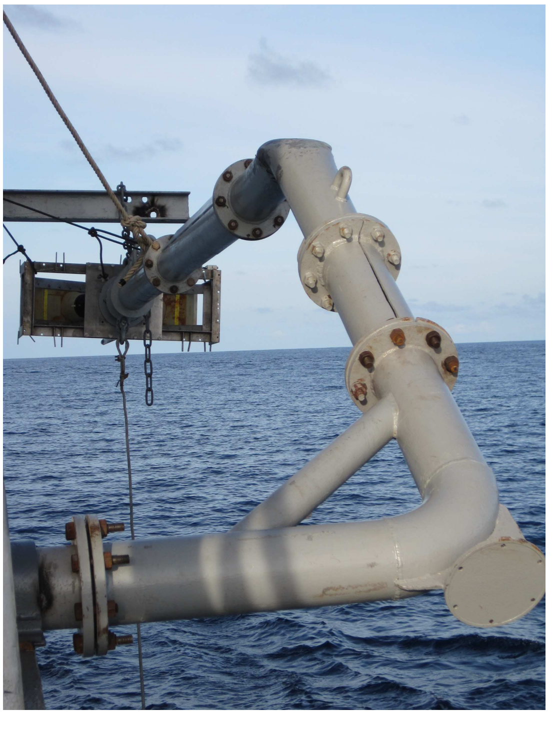

Fig. 8: Deformed holder construction for multibeam transducers shortly after roll calibration was finished.

Sea&Sun CTD48M-sound velocity probe

The CTD48M memory probe is a very small and handy microprocessor controlled multiparameter probe for precise online measurements as well as for self-contained operation in deep and shallow water. Due to its handiness and low weight of 1.2 kg it is particularly suited for portable operation without the use of winches. The probe is completely made of titanium (except screws). The housing is inert against nearly all chemical compounds (except hydrofluoric acid) and absolutely corrosion free. Due to the small housing diameter of 48 mm (including sensor protection tube) the probe can also be used for profiling in 2” boreholes. The standard CTD48M allows operation in different modes:

- Time mode
- Increment mode
- Continuous mode
- Online mode

Fig. 9: CTD48M sound velocity probe

Time mode is the most important mode for long term measurements, where the operator selects start and stop time and the measuring time interval. Increment mode is mainly used during profiling and enables the user to carry out a great number of profiles without reading out the stored data files in between. After configuration of start and stop depth and the measuring depth increment the probe will store one data set at each predestined depth. In online mode the CTD48M runs on multi-conductor cables supplied by a voltage of 7...16 VDC. The PC receives serial data directly from the probe as RS232C-signal. A specific interface is not required.

The CTD48M is equipped with a 4 channel data acquisition system with 16 bit resolution. A high long-term stability and automatic self-calibration of the analogue digital converter guarantees stable and precise CTD measurements for many years.

Mechanical characteristics

All parts of the probe which are exposed to seawater are made of corrosion-proof metals or plastic. Essentially the probe consists of the following mechanical structural components:

- Pressure housing
- Bottom cap with sensors
- Top end cap with battery box
- Sensor protection cage

Pressure housing

The pressure resistant housing is made of a solid-drawn seamless titanium tube with an external diameter of 48 mm and a wall thickness of 2.77 mm. There are 4 holes in 90° graduation on each tube-end. These holes are used for fixing both end caps of the housing to the pressure tube with 4 screws M3 * 5. Pressure pipe and end caps are sealed by O-rings 39 * 2.5 mm each.

Probe bottom end cap

The probe base is the bottom end cap, made of titanium, which is used for the fixation of all sensors. The base has room for maximum 3 sensors The pressure transducer has thread ¼” UNF 28THD as calibration connection to a pressure gauge. That allows the sensor to be calibrated when installed. A thread M44 * 1.5 is used for the mounting of the sensor protection tube which allows easy and comfortable removing of the protection in case of cleaning the sensors. On the inside of the bottom cap a bedplate mounting support is vertically fastened. It is made of 2 mm thick aluminum sheet and bears both of the probes printed circuit boards (digital board and analogue board).

Sound velocity measurements

A first sound velocity measurement was taken out on January 11th just before roll calibration of the multibeam started. Water depth of the area where CTD- measurements were taken was around 60 m. But loose contacts within the CTD probe did not allow to record continuous sound velocity profiles. Even after several trials it was not possible to store a complete CTD profile. Therefore it was decided to take existing sound velocity data from the previous MASS-I cruise for calibration of the multibeam echo sounder. After the holder construction of the multibeam was damaged shortly after calibration, further CTD measurements became obsolete.

5.2. High resolution multichannel seismic profiling

5.2.1. Introduction

High-resolution multichannel seismic survey was carried out during the MASS III-cruise on RV Chakratong Tongyai cruise with the object to resolve sedimentary structures along the continental margin west of Thailand. A micro-GI Gun was used to transmit a seismic signal and reflections from the seafloor and deeper geological structures have been recorded with a digital 150 m long streamer which was towed behind the ship. Configuration during the seismic survey is listed in Table 1.

Table 1: Source and receiver settings for individual profiles.

Profile	Source, mode, shooting rate (s)	Digital streamer
11-001	Micro GI Gun (0.1L), only Generator shooting, Source interval: 5 sec	11 sections (137.5 m)
11-002 - 11-003	Micro GI Gun (0.1L) in GI-mode, Source interval: 5 sec	11 sections (137.5 m)
11-004 - 11-027	Micro GI Gun (0.1L) in GI-mode, Source interval: 5 sec	12 sections (150 m)
11-027a - 11-031	Micro GI Gun (0.1L) in GI-mode, Source interval: 6 sec	12 sections (150 m)
11-032 - 11-039	Micro GI Gun (0.1L) in GI-mode, Source interval: 5 sec	12 sections (150 m)

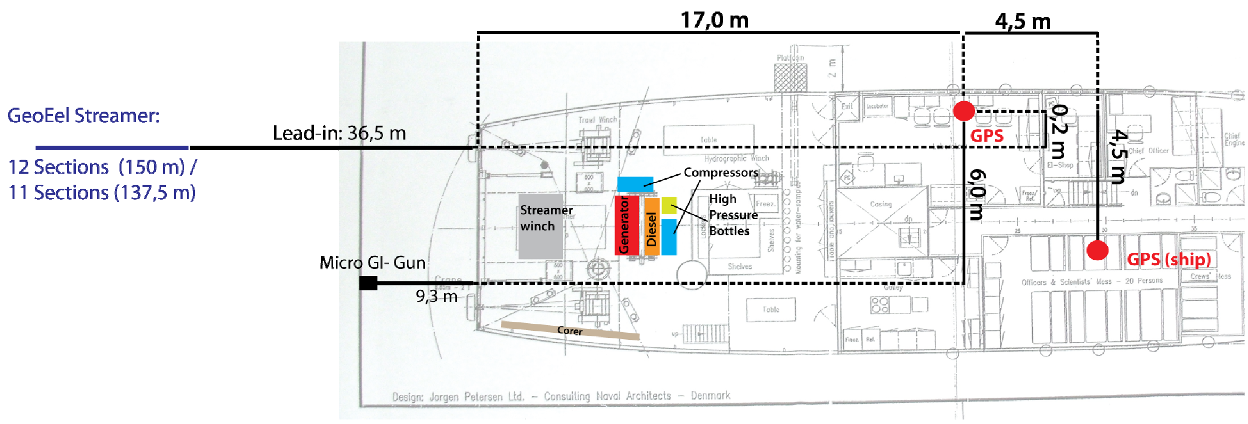

Fig. 10: Deck and seismic gun setting during MASS III-cruise on RV Chakratong Tongyai cruise.

5.2.2.System components

Seismic source

During seismic surveying a Micro-GI Gun (Fig. 11) was used shooting in GI-mode (Generator 0.1L, Injector 0.1L). During the first seismic profile only the Generator was shot due to problems with one of the two compressors. From the second profile on the GI-mode was applied and the Injector was triggered with a delay of 20 ms after the Generator signal for depressing the bubble signal. The Micro-GI Gun was towed about 0.5 m below the water surface. Shooting range was adjusted to the water depth, varying between 5 and 6 seconds. The gun was shot at an air pressure of around 120 bars and was working without problems during the whole seismic survey.

Fig. 11: Micro GI-Gun (0.1l) used during seismic surveying on Chakratong Tongyai.

Streamer-system

A digital streamer (Geometrics GeoEel) was used for measuring the seismic signals (Fig. 12). The first active streamer section was towed 36.5 m behind the stern of the ship (Fig. 10, Fig. 13). During the cruise 11 respectively 12 sections were used each with length of 12.5 m resulting in a total streamer length of 137.5 m / 150 m (Table 1). Each section contains 8 channels (channel distance is 1.56 m) and each channel consists of two hydrophones. One AD digitizer module belongs to each active section. These AD digitizer module are small Linux computers. Communication between the AD digitizer modules and the recording system in the lab is via TCP/IP. A repeater was located between the deck cable and the tow cable (Lead-In). The SPSU manages the power supply and communication between the recording system and the AD digitizer modules. The recording system is described below. Three birds were attached to the streamer (see below). Designated streamer depth was 3 m. A small buoy was attached to the tail swivel. Leakage problems at the beginning of the survey resulted in removing two sections of the streamer. After checking those sections onboard one sections was again attached to the streamer between seismic profile 11-003 and 11-004 (Table 1).

Fig. 12: Picture of the streamer system (on the winch) which was used on RV Chakratong Tongyai during the MASS III-cruise.

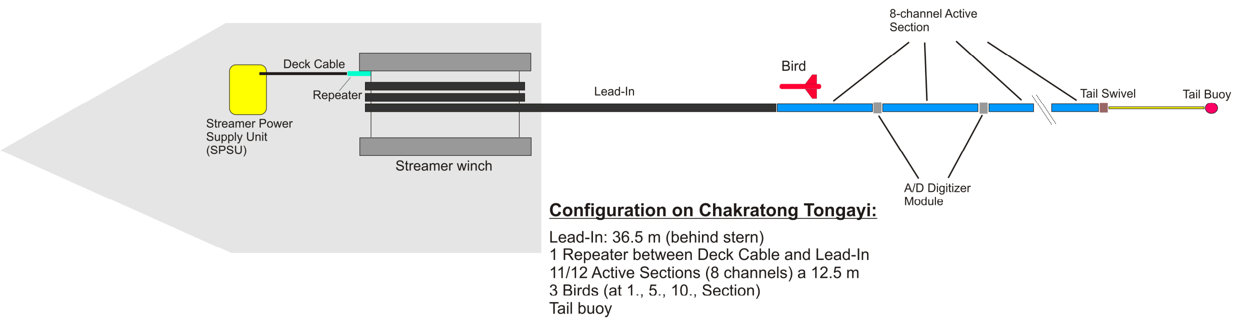

Fig. 13: Sketch of the streamer configuration

Bird Controller

Three Oyo Geospace Bird Remote Units (RUs, Fig. 14) were deployed at the streamer. The locations of the birds are listed in Table 2. All RUs have adjustable wings. The RUs are controlled by a bird controller in the lab. Controller and RUs communicate via communication coils nested within the streamer. A twisted pair wire within the deck cable connects controller and coils.

Operating depth of the birds was set to 3 m. Automatic depth position scanning during the survey was switched off because this might cause noise in the recorded data. The birds worked reliable during the whole cruise keeping the streamer in the designated depth and therefore allowed good quality of the recorded seismic data.

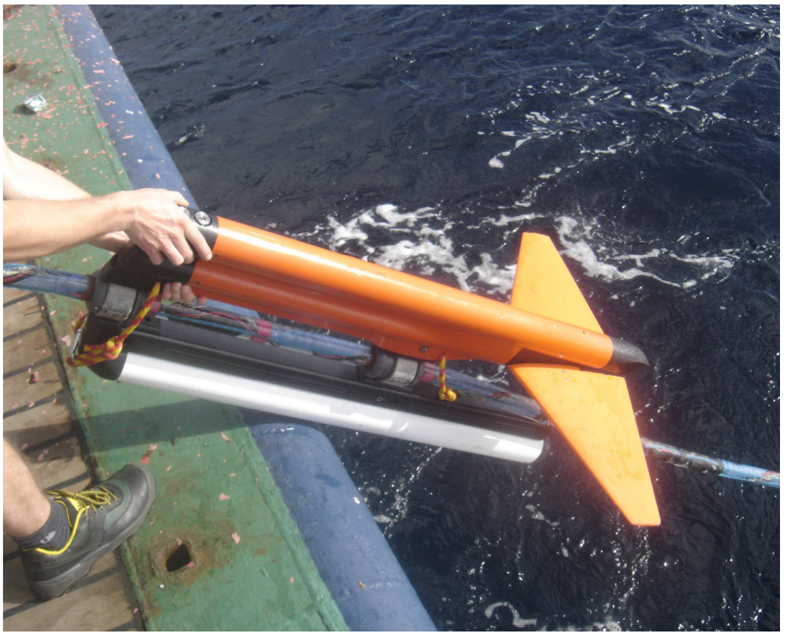

Fig. 14: Attaching the birds to the streamer

Table 2: Bird Positions during Chakratong Tongyai cruise

Distance behind stern		
Bird 20398	Bird 20399	Bird 40215
37.5 m	87.5 m	150 m

Data acquisition systems

Data of the streamer were recorded with acquisition software provided by Geometrics. The analogue signal was digitized with 4 kHz. The data were recorded as multiplexed SEG-D. One file was generated per shot. Data were recorded with delay but the delay is not written to the header. The delay was adjusted to the water depth. The acquisition laptop allowed online quality control by displaying shot gathers, a noise window, and the frequency spectrum of each shot. The cycle time of the shots is displayed as well. The software also allows online NMO-Correction and stacking of data for displaying stacked sections. Several log files list parameters such as shot time and shot position. Data were converted to SEG-Y file while being at sea.

For profile 01 to 03 problems with the recorded GPS data occurred and not for every shot GPS data could be stored because the Baud rate of the used GPS device was too low (4000). This was solved by using the system time of the computer from profile 04 on.

Trigger unit

A custom trigger unit, the so called SchwaBox was used during the cruise. The box generates triggers (TTL) at arbitrary combinations for controlling seismic sources, acquisitions systems, and bird controllers. The box was also connected to a gun amplifier unit. The trigger scheme was adjusted to the water depth during the survey. This trigger system worked very reliable during the entire cruise.

5.2.3.First results of seismic survey

Preliminary data processing was carried out for all profiles onboard. Several channels of each shot were filtered and stacked. These brute stacked were loaded to a seismic interpretation system (Kingdom Suite) and used for preliminary interpretation. In total we collected about 450 nautical miles of seismic profiles along the continental margin off Thailand (Fig. 3). Table 4 shows the list of all collected seismic profiles during MASS-III-cruise.

A long E-W profile was collected during the first leg and continued on the second leg. On relatively plain continental shelf several faults could be detected within the uppermost 0.5 sec TWT. Beneath these undisturbed sediments high amplitude reflections are imaged partly folded with irregular transition to the overlying sediments. Diffuse reflections do not allow to detect any further horizon beneath suggesting that these high amplitude reflections are lying on top of the seismic basement.

The prominent N-S elongated Ranong Fault was mapped on two profiles (02 and 39). Fig. 15 illustrates a steep vertical displacement of about 30 m height at the seafloor that offsets horizontal reflectors of the shelf region. We interpret this offset as submarine continuation of the Ranong Fault, which is well known from land. West of Ranong fault the seafloor is characterized by rough topography and the uppermost reflectors are deformed much more than east of the fault. Another fault can be seen beneath the deformed sediments west of Ranong fault; this fault can be traced for a depth about 0.2 sec TWT.

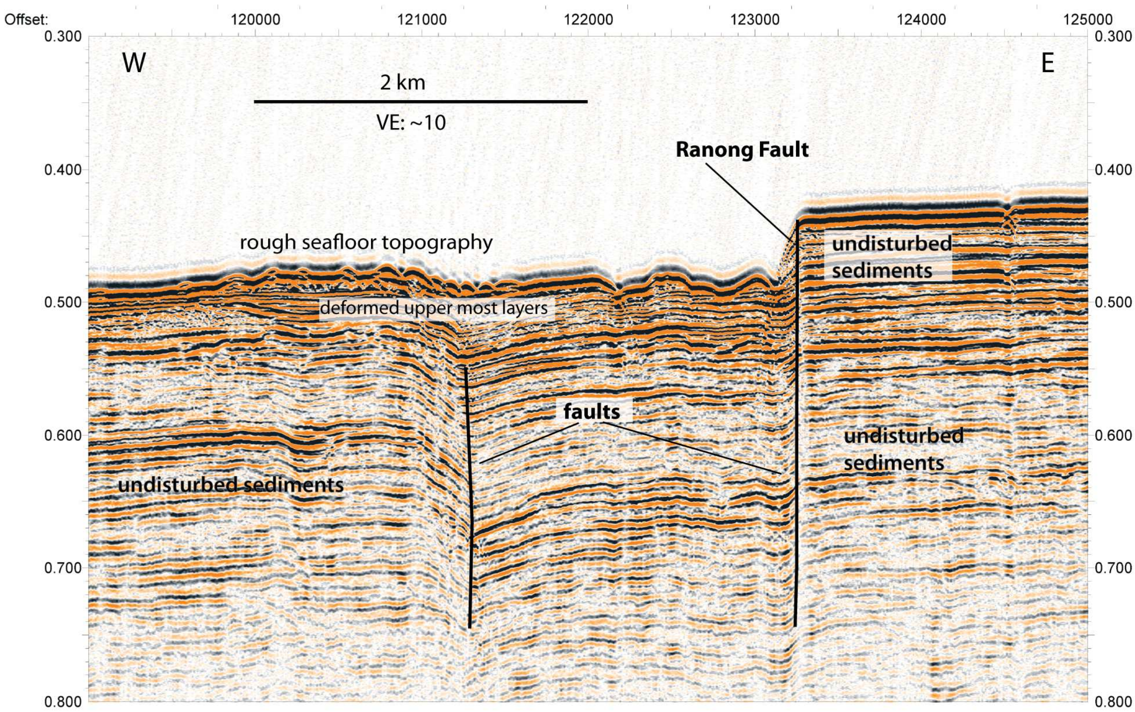

Fig. 15: Seismic image of Profile 02 showing the Ranong Fault. See Fig. 2 for location.

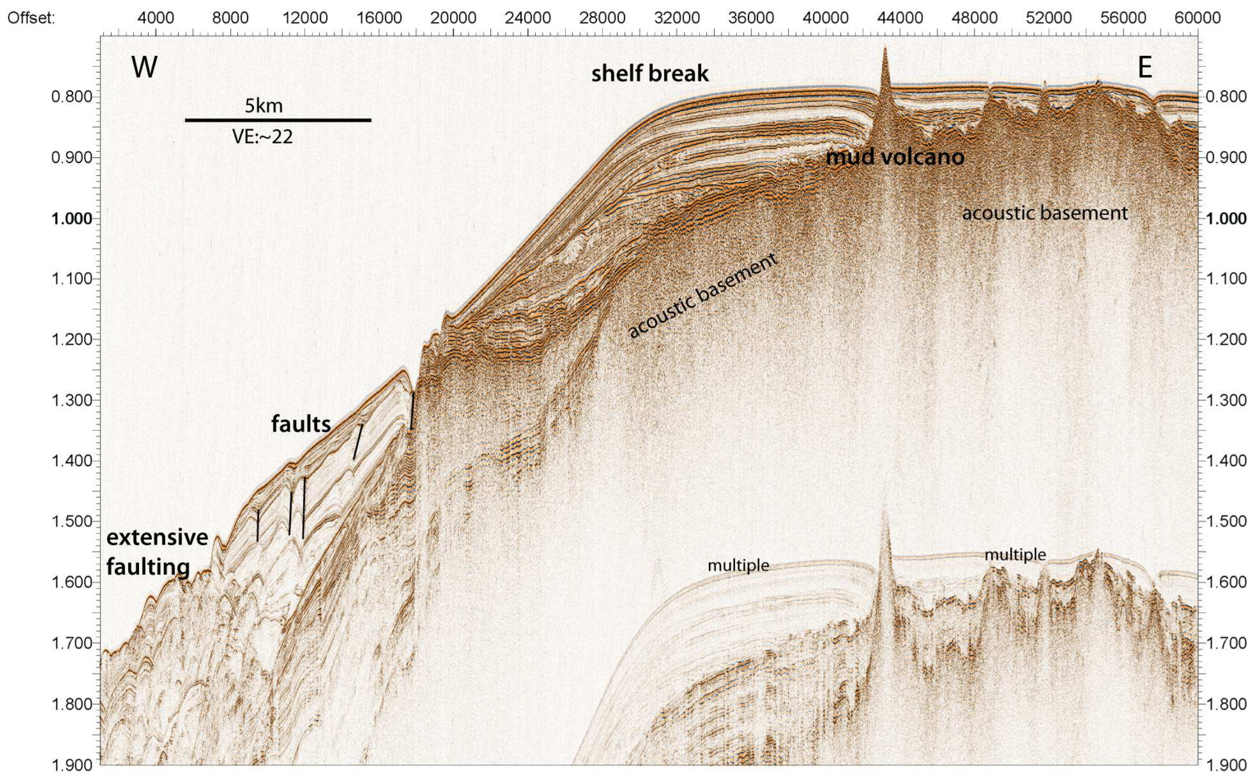

Fig. 16: Seismic line (Profile 04) along the continental slope. The suggested mud volcano is located east of the shelf break. See Fig. 3 for location.

The shelf up to a water depth of 600 m is characterized by rather plain morphology. A sharp break marks the boundary to the steep slope leading to more than 2000 m of water depth (Fig. 16). Slope parallel sediments are intensely deformed and several faults especially in the deeper part of the slope are associated with prominent incisions visible at the seafloor.

In the southern part of Profile 04 a prominent circular peak was imaged on the seismic data. This peak was interpreted as mud volcano based on bathymetric data. Seismic data show, that this peak is surrounded by well stratified sediments showing a small moat on its northern side. The peak itself (ca. 70 m in height) shows almost no penetration of the seismic signal but a few diffuse internal reflections might be visible. Similar features are visible east of the peak but they do not reach the sea floor. The shape and the seismic facies suggest that this feature is more likely a basement high and not a mud volcano but more detailed interpretation is needed.

Further north several prominent guyot-like features are clearly visible on the bathymetric map (Fig. 3). They were interpreted as large carbonate mounds based on the existing bathymetry map. During the MASS-III cruise, seismic profiles have been recorded over some of these features showing a few high amplitude reflectors at the top of these platforms (Fig. 17). Beneath these high amplitude reflections, no further seismic reflections are visible making it difficult to determine the root of these features. However seismic data clearly show that these features not only stand out as elevations from the seafloor but also have extremely different internal composition than the surrounding slope sediments.

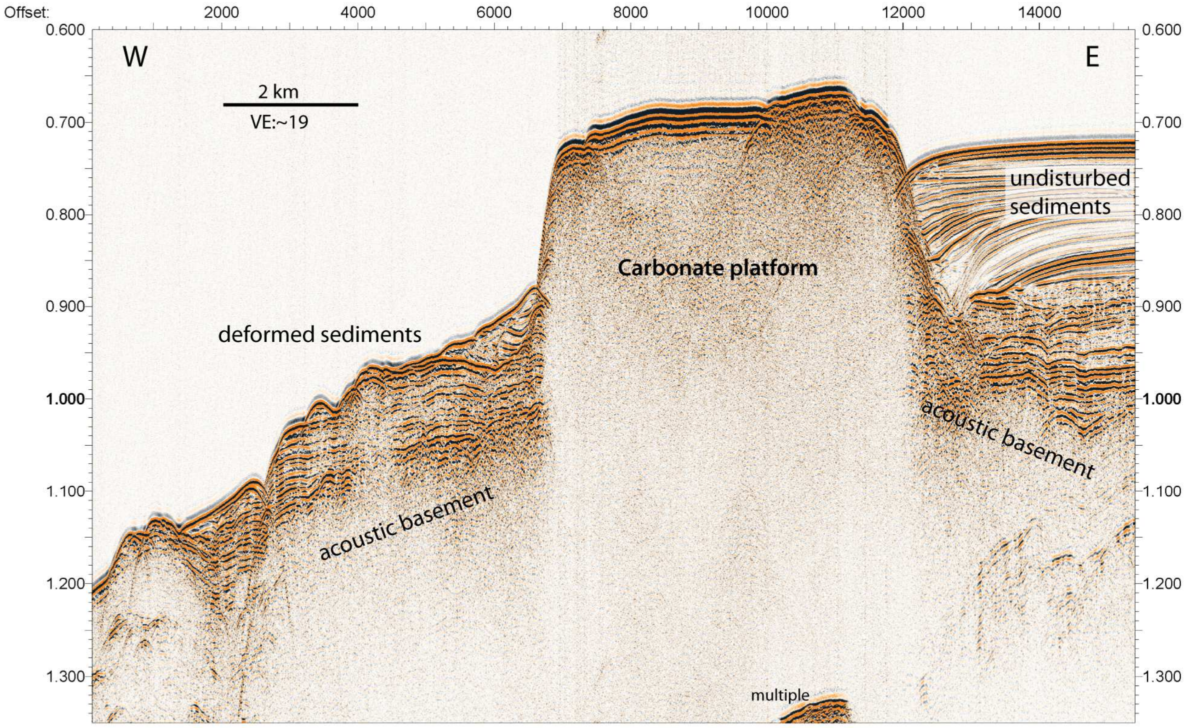

Fig. 17: Seismic line (Profile 16) along one of the assumed carbonate platforms. See Fig. 3 for location of profile.

Relatively undisturbed sediments are imaged upslope (east) of the platforms 8Fig. 17). The slightly diverging pattern and a moat-like feature in direct vicinity of the mound suggest intense bottom currents in this area, which are most likely focused by the mound. The sediments downslope (west) of the mound are more chaotic. A core was taken on top of the southernmost guyot-like features. No sediments were recovered; a few pieces of carbonate in the core catcher support the interpretation as carbonate mounds.

The base of the continental slope is characterized by numerous channel-like incisions especially in the northern part of the study area. Slope perpendicular running profile 33a (Fig. 18) highlights some of these features but this unmigrated data set makes it difficult to detect accurate depth or sediment infill within these incisions. Further processing of the data should therefore provide a better insight.

Several mass transport deposits were identified on the new data set. Profile 18 (Fig. 19) shows an area of rather disturbed reflections west of a morphological step which may present a headwall. The chaotic facies downslope of this morphological step is typical for slide deposits and can be traced for ~2 km in downslope direction. These deposits clearly contrast the undisturbed slope sediments. Relatively thin sedimentation on top of chaotic facies indicates a rather young event. Deeper sediments (0.1 – 0.2 sec TWT below seafloor) up slope the pronounced headwall show strong deformation on top of high amplitude reflections while the uppermost sediment layers are well stratified and rather undisturbed.

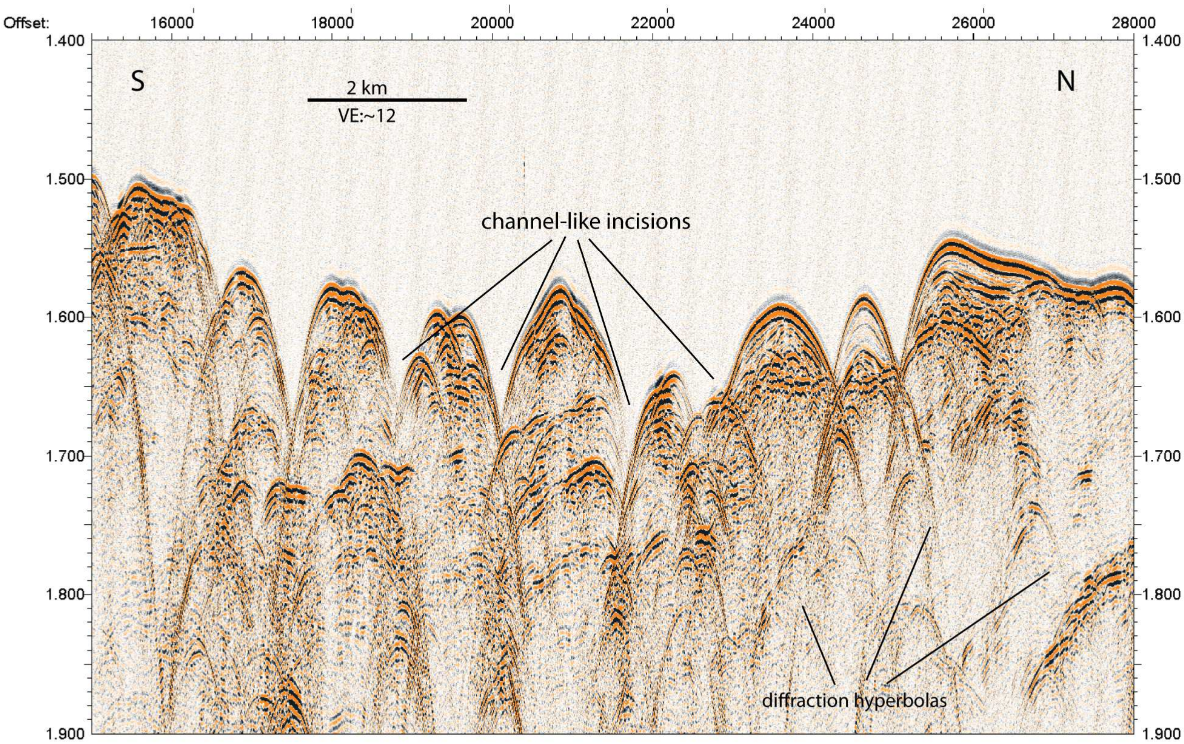

Fig. 18: South - North running seismic line (Profile 33a) at the base of the continental slope. See Fig. 3 for location of profile.

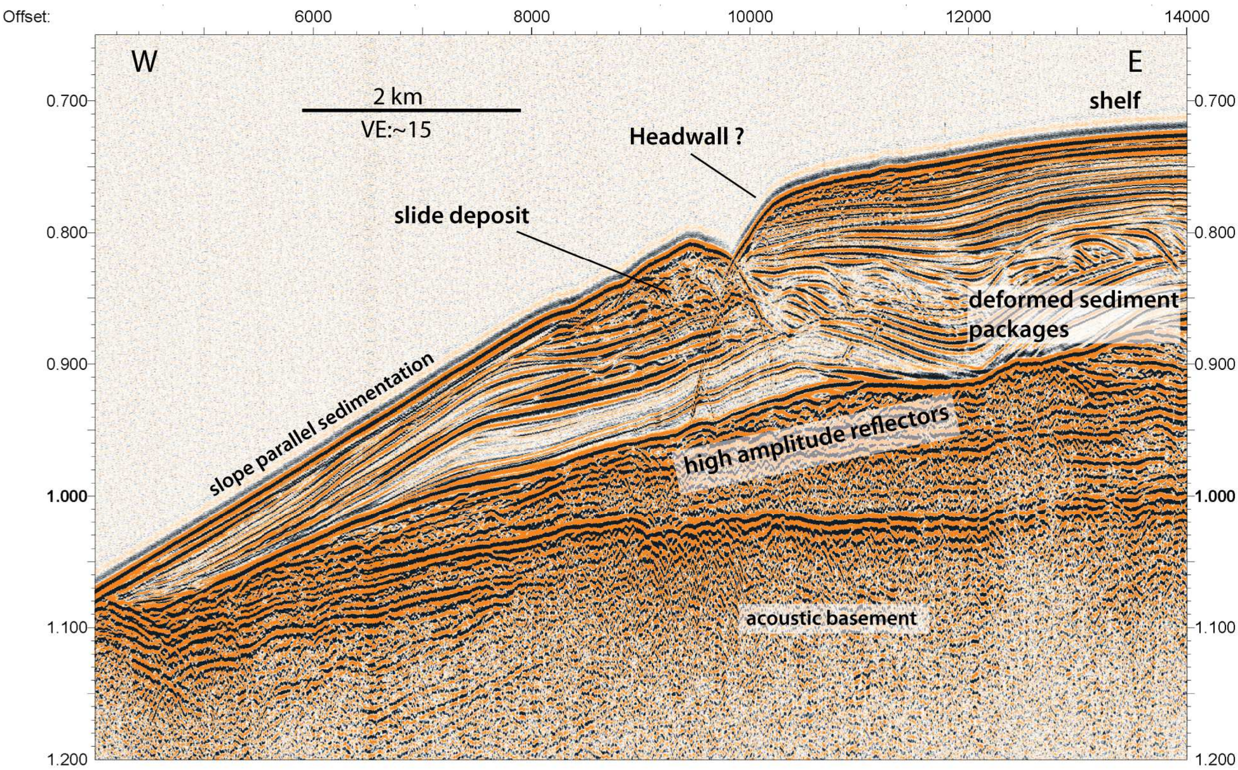

Fig. 19: Seismic line (Profile 18) showing slide deposits along the continental slope. See Fig. 3 for location of profile.

Fig. 20 shows another large mass wasting deposit at the base of the continental slope. Situated at the south-western margin of the study area this structure shows a well developed headwall of nearly 50 m height. A chaotic seismic unit is imaged immediately downslope of the failure scarp; the seafloor is characterized by a hummocky morphology. The base of this mass wasting deposit is marked by high amplitude reflector, which marks the top of a well stratified, nearly horizontal reflection package. The chaotic-to-transparent facies of the slide deposit shows a relatively constant thickness of about 0.03 sec TWT over most parts of the profile. Its downslope extensions cannot be detected because the seismic profile could not be continued further west. Within the same profile another, buried slide deposit can be found at a depth of ca. 0.1 sec TWT showing almost the same starting position as the large event close to the seafloor. Fig. 20 let assume a smaller dimension of this deeper event which is characterized by a more chaotic facies compared to the shallower event.

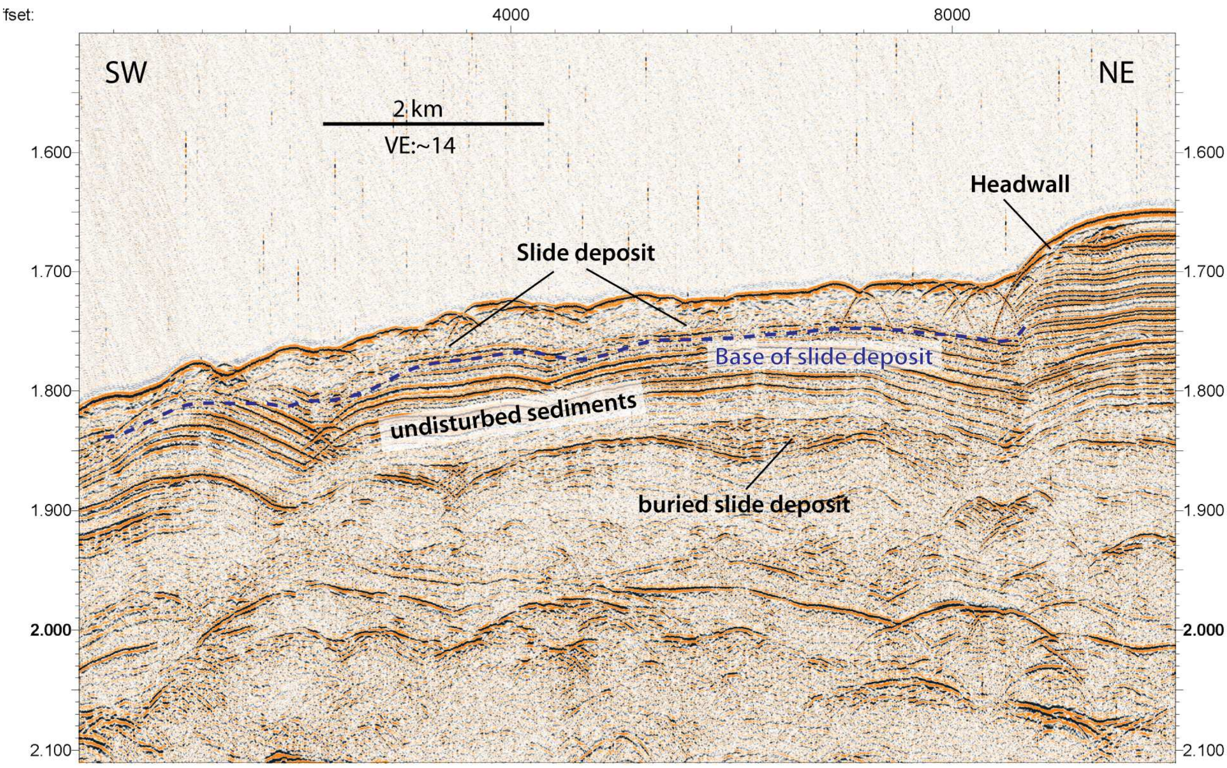

Fig. 20: NE- SW running profile 05. Headwall of a mass wasting deposit characterized by a transparent seismic facies just below the seafloor. Older buried slide deposits are imaged as well. See Fig. 3 for location of profile.

5.3. Sediment Sampling

5.3.1. Introduction

Different environmental settings have been targeted during the MASS-III cruise with a Mini-Gravity Corer in order to obtain sediment samples from the seafloor. Three main locations have been chosen for coring: within the northern study area (close to an assumed mass wasting deposit), around one of the large platforms and one location along the deeper part of the continental slope (see Fig. 3 for coring locations). It was not possible to collect more cores due to frequent failures of the winch and the significant reduction of the survey days.

5.3.2. Mini-Gravity Corer

In total 9 sediment cores from 14 stations were recovered using a Mini-Gravity Corer with a length of 2 m (Fig. 21) and a top weight of 250 kg. The gravity corer was launched over the stern of the ship. 2000 m of cable were available on the winch of the ship. Unfortunately major hydraulic problems with the winch in combination with a missing measurement device for the tension on the wire and problems in keeping the position made coring very difficult. Due to strong currents, the RV Chakratong Tongyai drifted with speeds of up to 1.5 knots (corresponding to 0.8 m/s). Hence the selected winch speed of 1 m/s was probably to slow, as horizontal and vertical movements were in the same range, which caused the gravity corer to fell over several times. Hence we decided to veer the winch with the maximal possible speed, which was also the speed which caused least technical problems with the winch. Coring was also difficult due to the dominance of sandy material at the sea floor.

After retrieval, the core liners were cut to the length of the recovered sediment, closed with caps and labeled. In core protocols GPS position of launching, bottom contact, and re-appearing at the water surface were documented as well as water depth of the station. The retrieved cores were not opened onboard but stored in vertical position on deck. Even for cores without recovery seafloor material could be found within the core catcher (as seen for example in Fig. 21) which was stored in zipper bags after photographing the samples (Fig. 21).

Coring locations have been chosen to achieve seafloor material from interesting geological structures. MASS III-007 to 012 were collected around one of the large plateaus along the continental slope. Material found within the core catcher showed significant differences in seafloor composition on top of the platform (carbonate fragments) and in its surrounding (fine grained sediments and muddy sand at the surface). Sediment cores derived from the deeper areas of the slope (850 - 980 m) at southern part of the study area showed sandy material with fragments of shells and also pieces of carbonate and/or wood.

Fig. 21: Mini-Gravity Corer launched at the stern of Chakratong Tongyai. Recovered sediment core and seafloor material received from the core catcher.

6. Station List

Table 3: List of Mini-Gravity Corer stations

Station Number	Core Number	Date	Time	Lat (at surface)	Long (at surface)	Depth	Recovery
MASS III-001[1)]	1	19.01.11	2:24	8°25.48	95°56.66	573.3	187 cm
MASS III-002[1)]	none	19.01.11	3:45	8°25.30	95°56.95	555.6	empty
MASS III-002[1)]	none	19.01.11	7:39	8°25.47	95°57.08	551.1	empty
MASS III-002[1)]	1	19.01.11	8:26	8°25.31	95°35.58	591.2	123 cm
MASS III-003[1)]	none	19.01.11	9:45	8°26.04	95°55.57	689.7	empty
MASS III-003[1)]	none	19.01.11	11:16	8°25.89	95°55.61	687.9	empty
MASS III-004[1)]	1	20.01.11	3:04	7°49.49	95°43.17	982.2	empty
MASS III-005[1)]	1	20.01.11	7:57	7°48.10	95°44.89	857.8	empty
MASS III-006[1)]	1	20.01.11	9:16	7°47.32	95°46.28	822.2	30 cm
MASS III-005[1)]	2	20.01.11	10:51	7°48.33	95°44.80	857.8	fragments
MASS III-007[1)]	1	21.01.11	1:48	8°11.97	95°52.96	597.8	142cm
MASS III-007[2)]	2	21.01.11	2:59	8°10.97	95°52.88	604.4	157cm
MASS III-008[2)]	1	21.01.11	3:56	8°09.95	95°52.06	686.7	empty
MASS III-008[2)]	1a	21.01.11	4:59	8°09.91	95°52.10	682.2	empty
MASS III-009[2)]	1	21.01.11	5:55	8°09.23	95°49.88	714.5	91cm
MASS III-010[2)]	1	21.01.11	6:55	8°06.92	95°51.74	632.2	150cm
MASS III-010[1)]	2	21.01.11	7:31	8°06.41	95°51.52	628.9	50cm
MASS III-011[2)]	1	21.01.11	8:22	8°08.40	95°51.64	512.2	empty
MASS III-012[2)]	1	21.01.11	9:15	8°07.61	95°53.91	557.9	empty
MASS III-012[2)]	2	21.01.11	9:43	8°07.27	95°53.76		125cm
MASS III-013[2)]	1	22.01.11	2:03	7°53.90	97°39.47	353.3	empty
MASS III -013[2)]	2	22.01.11	2:34	7°53.66	97°39.36	354.5	empty
MASS III -014[2)]	1	22.01.11	3:24	7°53.81	97°39.91	313.3	empty

[1)] Archived in core repository of IFM-GEOMAR in Kiel
[2)] Archived in core repository of Chulalongkorn University, Bangkok, Thailand

Table 4: List of seismic lines during MASS-III

Profil-Nr. GeoEEL	Date	Time Start UTC	Time End End UTC	Latitude Start xx°xx.x'	Longitude Start xx°xx.x'	Latitude End xx°xx.x'	Longitude End xx°xx.x'	Geometrics FFN Start FFN Start	Geometrics FFN End FFN End
11-001	12.01.2011	05:35	08:13	07°52.94	97°51.78	07°53,97	97°42.10	16	1954
11-002	12-13.01.2011	08:13	02:12	07°53,97	97°42.10	7°49.93	96°32.99	1955	14919
11-003	13.01.2011	02:18	11:57	07°49.76	96°32.70	7°14.45	96°28.62	14920	21756
11,004	16.01.2011	02:10	18:22	7°50.18	96°36.12	7°47.27	95°35.00	22000	33686
11_005	16.01.2011	18:29	20:01	7°47.53	95°34.98	7°51.75	95°38.44	33735	34826
11_006	16.01.2011	20:07	01:34	7°51.99	95°38.84	7°55.60	95°58.52	34885	38811
11_007	17.01.2011	01:38	02:30	7°55.77	95°58.56	7°58.76	95°59.11	38840	39464
11_008	17.01.2011	02:35	07:26	7°58.98	95°58.92	8°05.17	95°41.61	39507	43009
11_009	17.01.2011	07:26	08:26	8°05.17	95°41.61	8°08.58	95°42.04	43013	43709
11_010	17.01.2011	08:27	11:48	8°08.65	95°42.08	8°07.95	95°55.35	43710	46116
11_011	17.01.2011	11:48	12:14	8°07.95	95°55.35	8°09.48	95°55.62	46117	46411
11_012	17.01.2011	12:14	16:31	8°07.95	95°55.35	8°16.75	95°41.33	46412	49430
11_013	17.01.2011	16:31	17:14	8°16.75	95°41.33	8°19.22	95°40.90	49430	49880
11_014	17.01.2011	17:15	21:46	8°19.26	95°40.94	8°16.24	95°58.63	49881	53131
11_015	17.01.2011	21:46	22:05	8°16.24	95°58.63	8°17.03	95°57.64	53132	53352
11_016	17-18.01.2011	22:05	00:32	8°17.03	95°57.64	8°19.09	95°49.49	53354	55098
11_017	18.01.2011	00:32	00:47	8°19.09	95°49.49	8°19.78	95°49.59	55099	55283
11_018	18.01.2011	00:47	03:02	8°19.78	95°49.59	8°18.26	95°57.78	55284	56891
11_019	18.01.2011	03:02	04:04	8°18.26	95°57.78	8°19.88	95°55.12	56833	57625
11_020	18.01.2011	04:05	05:31	8°19.88	95°55.12	8°24.81	95°57.68	57626	58667
11_021	18.01.2011	05:32	10:39	8°24.89	95°57.66	8°32.48	95°40.67	58668	62338
11_022	18.01.2011	10:39	10:48	8°32.48	95°40.67	8°32.99	95°40.21	62338	62431
11_023	18.01.2011	10:49	15:28	8°33.00	95°40.22	8°33.12	95°58.18	62432	65828
11_024	18.01.2011	15:33	16:18	8°30.30	95°57.89	8°33.12	95°58.18	65829	66361
11_025	18.01.2011	16:18	18:16	8°33.17	95°58.15	8°35.07	95°50.96	66362	67777
11_026	18.01.2011	18:17	19:25	8°35.05	95°50.90	8°31.05	95°49.72	67778	68574
11_027	18.01.2011	19:27	20:24	8°30.93	95°49.78	8°29.98	95°52.84	68576	69230
11_27a	18.01.2011	20:26	20:53	8°29.98	95°52.84	8°29.54	95°54.30	69240	69460
11_27b	18.01.2011	20:53	21:20	8°29.54	95°54.30	8°29.05	95°55.83	69470	69746
11_28	18.01.2011	21:31	22:37	8°28.30	95°55.61	8°29.59	95°51.53	69752	70418
11_29	18.01.2011	22:37	22:49	8°29.59	95°51.53	8°28.88	95°51.29	70419	70526
11_30	18.01.2011	22:49	00:19	8°28.88	95°51.29	8°26.77	95°56.31	70527	71426
11_31	18.01.2011	00:20	00:51	8°26.55	95°56.27	8°24.81	95°55.65	71431	71702
11_32	19.01.2011	13:55	14:55	8°30.29	95°53.62	8°31.00	95°50.50	71800	72514
11_33	19.01.2011	14:59	15:30	8°31.00	95°50.50	8°29.21	95°49.34	72515	72879
11_33a	19.01.2011	15:35	21:20	8°29.21	95°49.34	8°07.05	95°45.16	72968	77051
11_33b	19-20.01.2011	21:25	00:00	8°06.82	95°45.11	7°57.35	95°43.24	77057	78918
11_34	20.01.2011	12:41	15:02	7°47.97	95°44.86	7°49.82	95°36.41	79015	80679
11_35	20.01.2011	15:02	16:02	7°49.82	95°36.41	7°46.02	95°36.22	80680	81388
11_36	20.01.2011	16:02	17:18	7°46.02	95°36.22	7°45.97	95°40.64	81389	82292
11_37	20.01.2011	17:19	20:41	7°45.99	95°40.67	7°58.16	95°43.36	82293	84717
11_38	20-21.01.2011	20:42	01:04	7°58.24	95°43.40	8°11.00	95°52.83	84718	87857
11_39	21.01.2011	22:51	00:53	7°57.54	97°32.91	7°57.49	97°41.02	87900	89388

7. Data and Sample Storage and Availability

The collected sediment cores are archived partly in the core repositories of IFM-GEOMAR in Kiel and Chulalongkorn University, Bangkok, Thailand. Distribution of particular cores between the two institutes can be seen in Table 3. Other data generated in laboratory work, e.g. from sedimentological and geotechnical analyses, will be stored in the IFM-GEOMAR data management system until publication. It is planned to publish these data in a World Data Center (WDC-MARE / PANGAEA) which will then provide long-term archival and access to the data.

The seismic and hydro-acoustic raw data as well as processed data will be archived on a dedicated server at IFM-GEOMAR, which is daily backed up and which holds all data since the founding days of IFM-GEOMAR.

8. Acknowledgements

The scientific party of the MASS III Cruise gratefully acknowledges the cooperation with the crew of RV Chakratong Tongyai. We would like to thank Prof. Somkiat Khokiattiwong and his colleagues from the Phuket Marine Biological Center for the opportunity to use RV Chakratong Tongyai and their support before and during the cruise. The expedition was jointly funded by the National Research Council of Thailand and the Deutsche Forschungsgemeinschaft (Project Morphodynamics and Slope Stability of the Andaman Sea Shelf Break) in the frame of the TRIAS co-operation (Tracing Tsunami Impacts onshore and offshore in the Andaman Sea Region).

IFM-GEOMAR
Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

IFM-GEOMAR Reports

No.	Title
1	RV Sonne Fahrtbericht / Cruise Report SO 176 & 179 MERAMEX I & II (Merapi Amphibious Experiment) 18.05.-01.06.04 & 16.09.-07.10.04. Ed. by Heidrun Kopp & Ernst R. Flueh, 2004, 206 pp. In English
2	RV Sonne Fahrtbericht / Cruise Report SO 181 TIPTEQ (from The Incoming Plate to mega Thrust EarthQuakes) 06.12.2004.-26.02.2005. Ed. by Ernst R. Flueh & Ingo Grevemeyer, 2005, 533 pp. In English
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