Expedition SO251

Weekly Report No.1

By September 30, all 29 scientists (11 from Germany, 7 x Japan, 2 x Switzerland, 2 x USA, and each 1x from Belgium, Brazil, UK, China, Netherland, Poland and Austria) from 10 different universities or research institutions safely arrived in Yokohama, Japan, and embarked research vessel *Sonne* on Oct 1st. Unfortunately, our scientific equipment, which was shipped from Bremen by a carrier that declared insolvency while the containers were on their way to Yokohama, did not arrive. Nevertheless, and thanks to the great support by our Japanese colleagues from JAMSTEC (Japan Agency for Marine Earth Science and Technology), the Geological Surveys of Japan, and the University of Tokyo, that kindly provided coring and laboratory equipment for our research cruise on very short notice, we could start our voyage with nearly complete infrastructure and a delay of 2 ½ days to leave the harbor on Tuesday Oct. 4 at 15:00. The additional time in port, we used for science meetings and discussions to optimize work flows on deck and in the laboratory using the various „new“ equipment and to prepare for our „EAGER-Japan“ expedition.

„EAGER-Japan“ stands for „Extreme events Archived in the GElogical Record of Japan’s Subduction margins”. The focus of R/V Sonne voyage SO251 thus is the investigation of the geological archive off the coasts of Japan. Here, at the southeastern edge of the Eurasian Plate, Japan hosts two of the most interesting subduction systems, both prone to devastating megathrust earthquakes: The Japan Trench east of Honshu with subduction erosion/subsidence in the north, and the Nankai Trough with a huge accretionary prism in the southwest. In 2011 the Japan Trench area was struck by a Magnitude 9 earthquake that caused unusually large slip all the way to the trench, and a series of landslides which are believed to be partly responsible for amplification of the catastrophic tsunami following the event. At Nankai, frequent Magnitude 8+ earthquakes are also documented, and landslides and other sediment remobilization processes related to seismicity are attested.

The overarching goal of R/V Sonne cruise SO251 and subsequent post-cruise research is to investigate fluid- and sediment mobilization processes by mud volcanism, earthquake-triggered seafloor displacement, submarine landslide and related “paleoseismologic event deposits” and to compare inferred earthquake processes and rates along accretionary vs. erosive subduction margins of Japan (Nankai Trough and Japan Trench, respectively).

The working area of the first part of the SO251 expedition, the Japan Trench, was reached after a transit of 17h. After first short multibeam bathymetry and Parasound mapping survey, but still within the first day in the working area, we successfully retrieved a piston core from the deepest part of the Japan Trench in more than 8000m water depth and started our laboratory work flow (porewater-geochemistry, geotechnical and physical properties, core photography, visual core description and smear-slide microscopy). Since Wednesday Oct 5 we then conducted detailed mapping and coring along the trench axis from S-N to have arrived in

the norther part of the study area by today. So far we have retrieved three nearly 10m long cores from the very deep trench basins in the >7000km deep Japan Trench. Furthermore, we have sampled two sections from the lower slope of the upper plate that in the central part oft of the study area moved co-seismically more than 50m eastward during the large earthquake 5 ½ years ago. Shipboard core analyses are well underway and today first results by the various research groups were presented in our regular science meeting. We are discussing how the geological fingerprint of the Tohoku-oki earthquake is represented in the various datasets and are fascinated about the emerging potential of the acquired data and samples to be further analyses in post-cruise research to advance our fundamental understanding about cause and consequence of earthquakes in deep marine environments.

Further impressions and reports about our scientific mission can be accessed and followed in the following „ships logs“ and blogs.

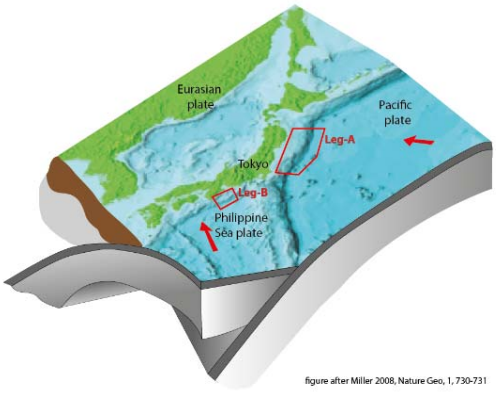
http://www.marum.de/Logbuch_SONNE_251.html

http://www.planeterde.de/logbuecher/fs-sonne-japan/logbuch-japan/

https://www.uibk.ac.at/newsroom/live-vom-forschungsschiff-sonne.html.de

Michael Strasser (chiefscientist SO 251-A) representing onboard science party

Yokohama Bay Bridge on 4.Oktober when leaving for good tot he Japan Trench working ara (Foto Jess Hillmann)



Japan’s subduction zones are the focus oft he two legs of R/V Sonne voyage SO251 (A: Japan Graben, B: Nankai Trog).

The piston coring system kindly provided by JAMSTEC for our cruise is being prepared for coring in the deepest part of the Japan Trench at >8000m water depth. Photo by Kazuko Usami

Expedition SO251

Weekly Report No. 2

Research Vessel *Sonne* now is back at the Terminal of Yokohama harbor, where our first leg ended on Saturday October 15 around 8 o'clock in the morning. Our first scientific experiment at the beginning of the second and already last week of our short research voyage to the Japan Trench, was to acquire a 175km long East-West bathymetric profile perpendicular to the margin at 39.3°N. The track from the incoming oceanic plate across the trench and slope to the shelf followed the exactly same track of a bathymetric survey conducted by JAMSTEC in 2007 (i.e. 4 years before the Tohoku-oki earthquake). By analyzing the differences between the 2007 data set (pre-earthquake) and our newly acquired dataset (post-earthquake) we can test if the seafloor at the location around the northern extend of the Tohoku-oki rupture zone experienced co-seismic displacement during the earthquake. In the recently published literature some rupture and/or tsunami inversion models suggest seafloor displacement in this area, while other models predict no significant movement. With our dataset we will be able to test these models to better constrain the along-strike variation or earthquake rupture along the Japan Trench megathrust.

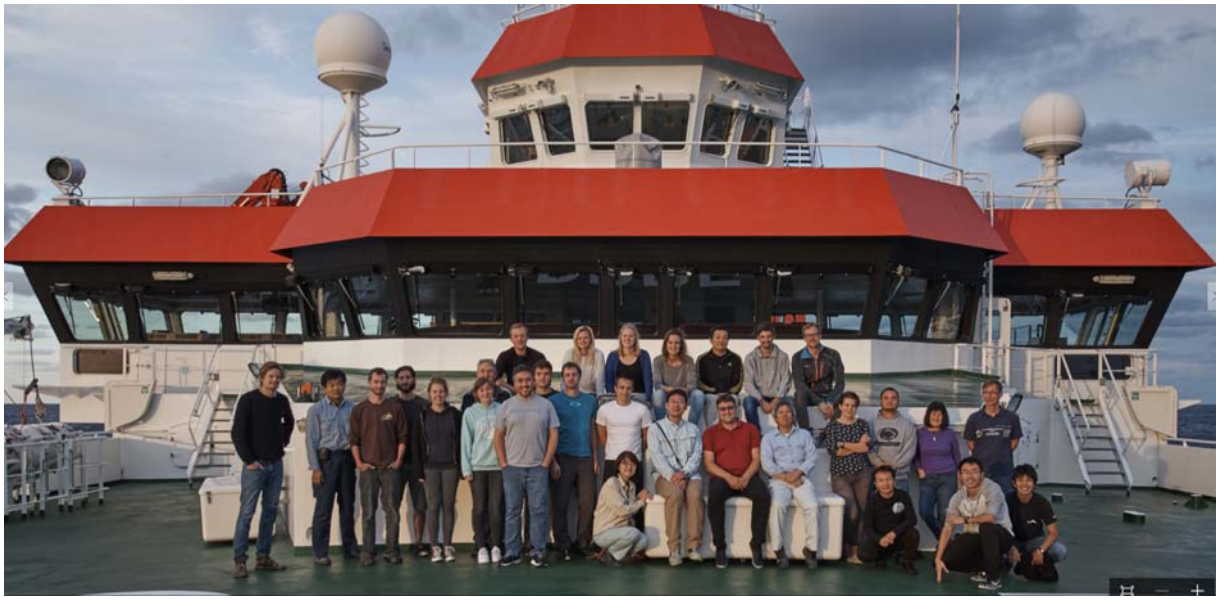
Followed by detailed multibeam and Parasound mapping along the trench axis to the North, we arrived at the northernmost station of our expedition on Tuesday October 11 to take a 10m long core from the trench basin infill, which allows to document sedimentary processes and extreme-event deposits along the northern part of the Japan Trench Subduction zone (Sanriku segment). At the same day, we also managed to obtain a double coring of the slope sediment in the northern part. For each of the three slope sites of representative location of the landward slope of the subduction system, we retrieved two cores, one of which is kept closed and will be analyses by the Marine Geotechnics research group at MARUM to study strength and deformation behavior upon dynamic stresses simulating different earthquake shaking scenarios. With such experiments, we aim at assessing critical earthquake intensities needed to trigger sediment remobilization, towards quantitatively calibrating the geological record of extreme event deposits for past earthquakes.

On Wednesday Oct 12, R/V Sonne navigated back southwards, there while filling small gaps in mapping to eventually succeed in acquiring a complete high-resolution bathymetric map of the trench axis and nearly 2000 km of subbottom Parasound profiles, covering the entire along-strike extent of the Japan Trench from 36° to 40.3° N. On our voyage back south there remained enough time to take two additional cores in the deep trench, including the successful recovery of a core from the very same location, where we cored the deep sea trench sediment during previous Sonne cruise SO219-A in 2012. At that time, the geochemists documented striking anomalies in porewater-geochemistry data, which are interpreted to be transient signals induced by remolding and resedimentation triggered by the Tohoku-earthquake. Now, 5 ½ year after the earthquake, we repeat the porewater and solid phase geochemistry analyses at this location to study the transient signal and assess

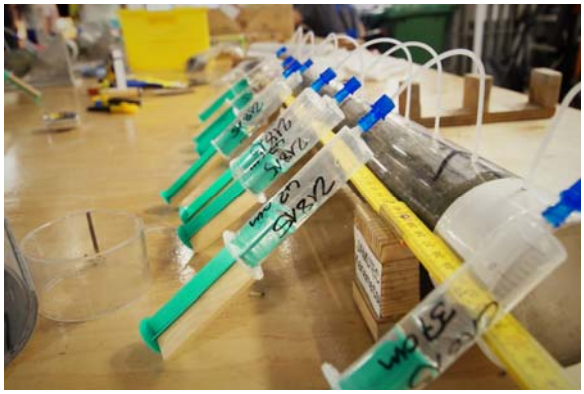
post-depositional processes and rates to learn how the event-deposit becomes archived in the geological record and what distinct chemical signals remain.

In summary, we can look back to a very successful leg, during which we achieved all priority objectives of the EAGER-Japan project in the Japan Trench working area. We are thankful to Captain Meyer and his crew for excellent hospitality and collaboration and acknowledge the BMWF for support of this fascinating research expedition.

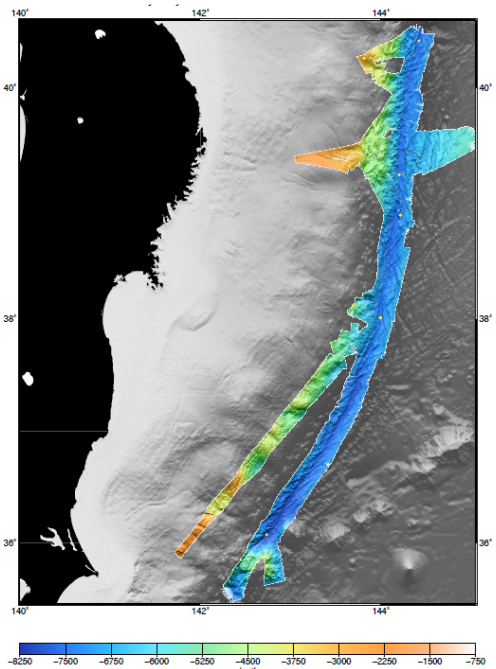
Michael Strasser (chief scientist SO 251-A) representing onboard science party



SO251-A Science Party (from left to right: Gauvain Wiemer, Yukihiko Nakano, Dominik Jaeger, Timo Fleischmann, Katarina Bachmann, Marie Rex, Martin Kölling, Christian dos Santos Ferreira, Sebastian Trütner, Karl Lange, Jasper Moernaut, Neeske Lübben, Kazuko Usam, Alex Rösner, Mareike Höhne, Asuka Yamaguchi, Jana Molenaar, Toshyia Kanamatsu, Michael Strasser, Paul Töchterle, Ken Ikehara, Tobias Schwestermann, Jess Hillmann, Toshyia Fujiwara, Matt Ikari, Cecilia McHugh, Tian Sun, Witold Szczucinski, Arata Kioka)



Sampling pore water fluids for geochemical analyses



Complete bathymetric map along the entire Japan Trench trench axis acquired during SO251-A. Yellow dots locate coring sites (9 sites, nearly 90m core recovery)

Expedition SO251

3. Weekly report

RV Sonne was in Yokohama port from 15.-18. October in order to load and mobilise the Heat flow probe as well as the remotely operated vehicle PHOCA of our colleagues from GEMAR Kiel. Despite the delivery of ROV PHOCA on very short notice because oft he stranded expedition equipment on HANJIN vessels, the harbour test was successful. In Yokohama we also had visits from several groups from JAMSTEC and CDEX to see RV Sonne and discuss scientific strategies. We also had a visit from GOOGLE Culture videographers, footage of which will soon be available as a virtual ship's tour on RV Sonne via the internet.

The SO251 science party was partly exchanged to meet the requirements in the second study area and expedition leadership went to Achim Kopf, Professor of Marine Geotechnics at MARUM Bremen. The international scientific team now consists of 34 persons from 10 countries (20 Germans, 4 Japanese, 2 Taiwanese, 1 Italian, 1 Brazilian, 1 American, 1 Dutch, 1 Austrian, 1 Belgian and 2 Swiss). The team had partly worked together on leg SO251-1 already and harmonises extremely well.

On 18.10. at 8 o'clock, RV Sonne left Yokohama and reached the research area of leg SO251-2, the Nankai Trough, in perfect weather conditions. In contrast to the Japan Trench margin with subduction erosion in the North, the Nankai Trough region is characterised by a huge accretionary complex. In Nankai we have fairly regular earthquake activity with magnitudes exceeding M8, which are often accompanied by mass wasting and tsunamis. Regardless of the earlier campaigns by IODP (expeditions 332/333/338/348) there is still a severe lack of understanding which factors control the onset and recurrence of large earthquakes. During the recent MARUM expedition SO222 we completed several MeBo seafloor drill holes in Nankai, some of which host observatory instruments since 2012. One major objective of the second leg of the *EAGER-Japan* project is thus the recovery of these instruments using ROV PHOCA. Additional piston and push cores in both the Kumano Basin and the slope of the accretionary prism are aimed to shed light on both fault slip activity and fluid seepage as a result of seismicity. Heat flow measurements and hydro-acoustic surveys will further allow us to identify fluid originating from depth and reaching the seafloor.

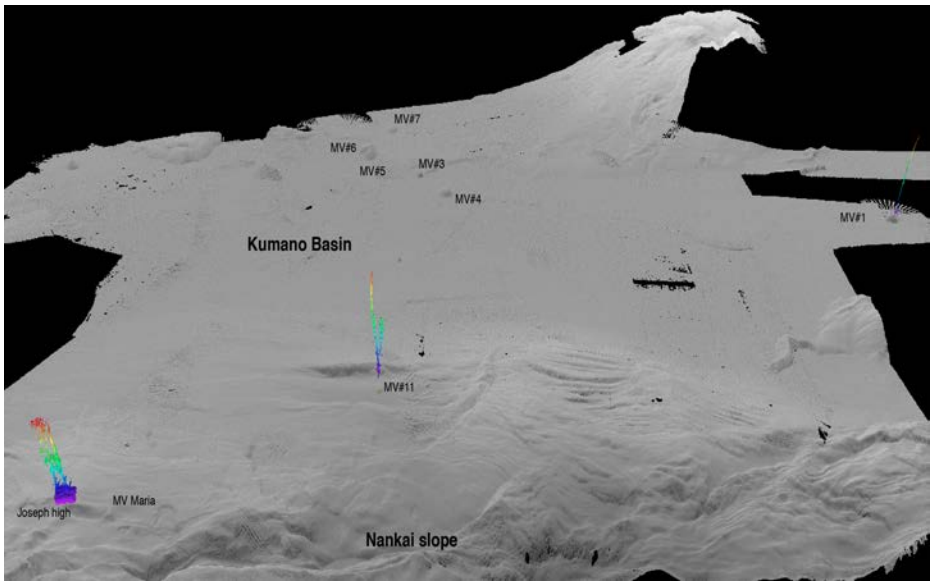
The scientific work on leg SO251-2 started with heat flow measurements across a mud volcano and along a N-S profile across the Kumano Basin, which complements data from cruise SO222 in 2012. Elevated heat flow values on mud volcano MV13 indicate fluid mobilisation from depth. Equally, the first dive of ROV PHOCA on mud volcano MV2 found several younger mud extrusions. Measurements by the ROV with a short temperature lance (T stick) attested that the most active zone is the crater area in the southwestern summit. At the crest we also observed living clams, bacterial mats, and occasional large clasts of several decimeters in diameter.
Indications for fluid seepage were also found on mud volcano MV1, MV11 as well as on a topographic high termed „Joseph" given its vicinity to „Maria" mud volcano. In a piston core

from that area we suspect elevated methane concentrations (which will be measured at University Bremen later), but primarily hemipelagic background sediments. Mud breccia was probably absent, however, some intervals may be interpreted as mud flow deposits. Detailed interpretations will be gained from post-cruise research in the laboratory.
Piston cores at the flank of mud volcanoes „Maria“ and MV1 show homogeneous mud breccia with light grey matrix and occasional small clasts. Pore waters show subtle freshening (i.e. 80-90% SW salinity), indicating deep-seated fluid origin.
Dives 2 und 3 with ROV PHOCA served to localise and recover the MeBo-borehole observatories. In the summit area of MV3 we had problems with the positioning system but still discovered one of the two instruments. On mud volcano MV4 we found one observatory quickly and worked on it. Given that the hotstab connection was too tight to be loosened, the skillful approach by the ROV pilots allowed us to unscrew the entire upper MeBo drill rod. As a consequence of the longer item, the so-called MeBoCORK-A currently resides on the seafloor and an attempt for recovery is planned in an upcoming dive.

We are currently in transit to the pilot station where we drop the JAMSTEC coring technician, who is needed on another mission. We want to thank our Japanese colleagues again for their willingness to collaborate and help out with equipment without which this cruise would have been impossible to run.

Achim Kopf (Chief Scientist SO251-2) on behalf of the entire SO251-Team

Right: Flares in the water column indicate seepage activity of mud volcanoes MV1, MV11 and „Joseph“ topographic high.



Below: Photos of ROV PHOCA operated by GEOMAR Kiel with observatory recovery device (left) and underwater pictures of the MeBoCORK-A (middle) and –B (right) instruments.

Expedition SO251

4. Weekly Report

After having dropped off the Japanese piston coring technician, RV SONNE headed back to the Kumano Basin for its final week of operations. For most of this period, we had fair weather so that we could dive using ROV PHOCA, run numerous hydroacoustic surveys to identify flares, acquire seismic lines for the geodynamic reconstruction of the Kumano Basin evolution, measure heat flow across several mud domes, and also take cores using an improvised system attached to the heat flow probe. The results can be summarised as follows:

Despite the extremely variable weather conditions with changing wind speeds and directions, we were able to dive four more times with ROV PHOCA. The very demanding work at the seafloor aimed at the recovery of the remaining MeBo-observatories, which was carried out successfully. The detailed analysis of the time series data, where pressure and temperature in the borehole inform us about mud volcanic activity as a function of seismicity in the Japan area, has to wait until the cruise has ended.

The less nice weather windows we used to do hydroacoustic surveys such as Parasound profiling and Multibeam mapping, during which we discovered two new mud volcanoes. Careful analysis of the water column data further attested that there are currently more than 40 flares seen in the study area. Interestingly, fluid seepage is not restricted to the mud volcanoes alone, but is also seen at the seafloor outcrops of prominent structures such as the so called Megasplay Fault of the Nankai accretionary complex.

During our station work we also acquired seismic profiles along strategic transectts and took additional sediment cores to unravel the sequence / seismic stratigraphy and geodynamicand sedimentological evolution oft he Kuamno Basin. A particular focus was on deposits from event layers such as earthquake induced turbidites and mass wasting deposits. Given that the Japanese piston coring technician had left, we were forced to improvise and developed a coring device mounted to the heat flow probe. With this instrument we successfully took another 5 sediment cores for description, analysis, and post-cruise geotechnical testing.

Work on the various mud volcanoes attested elevated heat flow, thermal conductivity and low strength, e.g. in a fresh mud flow from MV2. These mud extrusions must have been emplaced during the past 4 years they were not there during the earlier expedition SO222. Differential bathymetric charts support this finding by showing a rim of added material at the base opf the mud dome. We now try to use chemical pore water gradients to narrow down the exact time of emplacement of the mud flow and how it could have been triggered.

In a parallel approach, we measure shear strength at the slope of the Nankai-accretionary complex and compare it to values of Japan Trench (Leg SO251-1). In both regions, the skope deposits undergo so called seismic strengthening, an increase in undrained shear

strength as a function of dynamic loading and pore water drainage. Our preliminary data suggest that the Japan Trench deposits are stronger than their Nankai counterparts.

On 01.11.2016 we left the research area at about 14h and are now on transit to Yokohama where expedition SO251 will end tomorrow. All station work was very successful and the main goals of the cruise were reached. We hence want to conclude with our sincere gratitude for the additional support we received to overcome the problems with the missing equipment containers, most importantly PtJ/BMBF and also our Japanese colleagues.

Achim Kopf (chief scientist SO251-2) on behalf of the entire SO251 team

Links und Mitte: Der „MeBoPlug“, ein kleines Bohrlochobservatorium, kam mit ROV PHOCA sicher an Deck. Auf der Platine befinden sich 720 Mbyte an Daten des Schlammvulkans, die auf dem Laptop gesichert werden. Rechts: Der MeBoCORK-A an Decke, nachdem er aus dem Bohrgestänge gelöst wurde.

Links: Typischer Schlammvulkankern vom Gipfel des MV1, zum Teil mit mächtigen authigenen Karbonatkrusten. Rechts: Das improvisierte Kerngerät an der Wärmestromlanze.