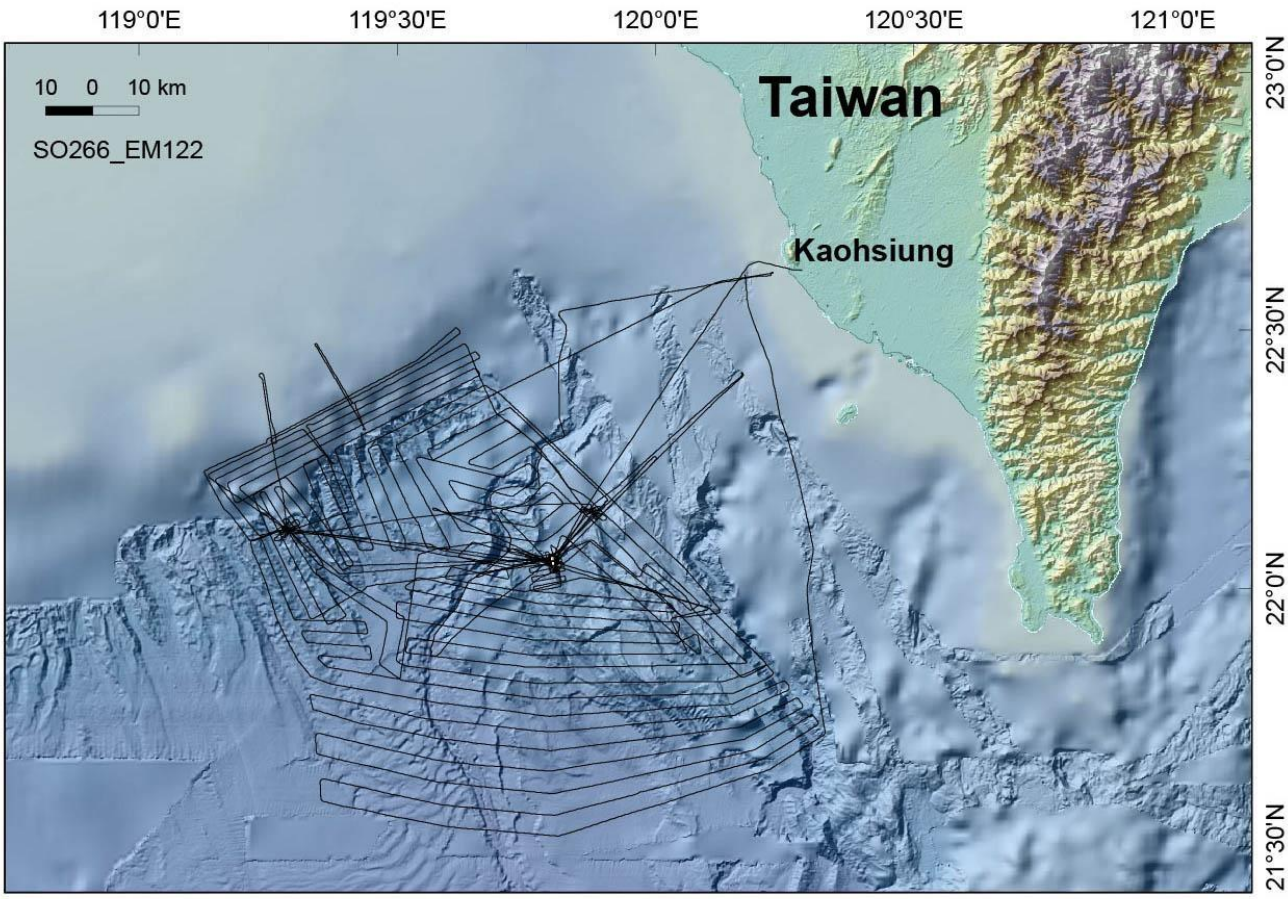
Prof. Dr. Gerhard Bohrmann
MARUM – Center for Marine Environmental Sciences
and Department of Geosciences
Klagenfurter Str.
28359 Bremen – GERMANY
Tel. +49 421-218-65050
Email: gbohrmann@marum.de

Short Cruise Report
R/V SONNE–SO266
Kaohsiung – Kaohsiung
October 15 - November 18, 2018
Chief Scientist: Gerhard Bohrmann
Captain: Lutz Mallon



Track lines of R/V SONNE Cruise SO266 from Kaohsiung to the northern South China Sea and back to Kaohsiung .

Objectives

The main objective of the MeBo drilling campaign on SO266 was to obtain information on the physical properties of the subsurface in relation to gas hydrate deposits. A second goal was to obtain information on the gas composition and abundance in the subsurface to assess the source for the gas that forms gas hydrates off SW Taiwan. A third goal was to obtain information on the lithology and stratigraphy of the study area.

Cruise Narrative

On **Monday 15 October** 2018 at 05:12 p.m. local time, RV SONNE left her berth at Pier 7 in Kaohsiung seaport to investigate the distribution of methane hydrates at the Taiwanese continental margin by using the mobile seafloor drill rig MeBo200. Before we had five days of intense work on board, mobilizing the equipment for the expedition. We arrived at the ship on **Wednesday 10 October**. First two containers from the cruise before had to be unloaded. When the eleven containers for our cruise SO266 arrived we had to install nine containers onboard and one 20‘ and one 40‘ container had to be discharged. The extended stay in the port was necessary for the setting up MeBo. During the mobilization, the 12 people-strong installation crew from Germany had the opportunity to take in the bustle of urban life of Kaohsiung a 2.7 million city and its seaport which is the biggest of Taiwan and the 13th biggest in the world. Most of the Taiwanese oil import is passing through this port onto the industry around.

On **Friday 12 October** SONNE moved to the so-called Banana Pier whose name refers to the former main export good bananas that was handled on this pier. Nowadays this berth with its former warehouses has been developed into a very attractive maritime leisure and culture area, that is enjoyed by Taiwanese families and tourists alike. By assistance of the Honorary Director of the German Institute in Kaohsiung and using the mayor’s press distributor list, journalists had been invited to attend a press event onboard RV SONNE. Numerous journalists used the opportunity to see the ship and its research facilities, and to get information on the Taiwanese-German Research project on marine methane hydrates. More than 30 visitors were invited to the following reception in the vessel’s hangar. Along with representatives of the seaport, the German Institute in Taipei, also the Director General of the Taiwanese Ministry of Science and Technology, Mrs. Hsinya Huang had arrived. Consequently, the port visit of the German research vessel and the joint Taiwanese-German research program on methane hydrates in the ocean lead to a considerable echo in local and nationwide press.

At the weekend further scientists from Germany and Taiwan arrived and set up their own labs on the ship. After having discharged another container with ship equipment from Germany, we finally heard the command „cast off” on **Monday 15 October**, and SONNE left the natural port of Kaohsiung in a beautiful sunset. The elongated port basin is separated by the narrow but 8.5 km-long Qijin Island that consists of a former raised coral reef, and an offshore sandbank in the South towards Taiwan Strait.

After a 24-sea-mile transit, we crossed the 24 nm border of Taiwan and carried out a CTD cast for measuring the water sound velocity. These data were used to calibrate the ship’s own multi-beam system. The subsequently acquired seafloor maps of the so-called „Four-Way-Closure–Ridge“, once more documented the superior quality of SONNE’s multi-beam system which is the biggest that was ever installed on any research vessel. **Tuesday 16 October** was used to install the newly acquired OFOS (ocean floor observation system) on board and to take two gravity cores while the MeBo-team finished the last preparations for the first drilling. After collecting more multi-beam data during the night, on **Wednesday 17 October**, the MARUM MeBo200 was deployed to the seafloor. The drill site was chosen based on a comprehensive geophysical experiment that was carried out during SO227 in 2013. In particular the seismic 3D seismic data proved to be an invaluable tool for deciding on the final drilling location because it allows to image the subsurface with a resolution of 3.5 m. By means of a micro-bathymetry map which had been acquired by an autonomous underwater vehicle (AUV) by our Taiwanese colleagues, we could find an acceptable slope gradient for MeBo. After MeBo had landed on the seafloor successfully it drilled to 21 m below seafloor. Unfortunately, there was a small leak in the hydraulic system and we had to retrieve the drill rig. When redeploying after the repairs on the next day the winch malfunctioned and only on **Sunday 21 October** we could start drilling again. In the meantime, the sediments we had recovered with MeBo and the gravity corer had been processed.

Two heat-flow transects, one CTD transect and three OFOS dives and further hydro-acoustic mapping completed the program. Especially impressing were the OFOS-derived seafloor imagery. It was easy to maneuver the instrument on the seafloor based on the AUV micro-bathymetry and the backscatter intensity maps and we could identify several active fluid- and gas emissions based on the benthic ecosystems on the „Four-Way-Closure-Ridge“ in 1340 m water depth. Due to a military exercise in that area we had to leave and continued drilling successfully on Formosa Ridge.

The second week at sea turned out to be very exciting as we started on **Sunday evening 21 October** with a MeBo drilling on the Formosa Ridge in our western working area on the Chinese continental margin, which is part of the Eurasian Plate. To the east of it lies the Taiwanese continental margin, which has a completely different geological structure as it is a convergence zone of the lithospheric plates. In this area southwest of Taiwan, we had the opportunity to conduct comparative investigations of the methane hydrate distribution at these different continental margins. We would like to understand by way of example the different tectonic influences on the gas hydrate distribution and dynamics. Geophysical surveys have been carried out in this area for many years, but up until now drilling for methane hydrates in the sediments has been lacking. Although drilling data are very important to calibrate the geophysical measurements.

The MeBo200 drill hole on Formosa Ridge was the first one we have drilled. Formosa Ridge is an elongated, submarine ridge about 40 km long and 7 km wide. It runs perpendicular to the continental slope and is bounded on both sides by deep canyons. With slope angles of more than 10 and up to over 30 degrees, it was difficult to find a stable landing site for MeBo that was interesting in terms of the geological structures that we had selected from the GEOMAR 3D seismic data. For MeBo we need a seabed dip of less than 5 degrees slope. In order to find such a place in 1,300 m water depth, we used an AUV-based micro-bathymetric survey from which we have converted the depth to a fairly accurate slope map. This allowed us to identify a flat plateau of 100 m in diameter on the narrow crest of Formosa Ridge. This turned out to be very suitable and after a safe landing on the seabed, MeBo could start drilling.

With 33 core barrels, the sediment sequence was drilled down to a sediment depth of 109.91 m below the seafloor. The recovered sediments consist mainly of very fine-grained hemipelagic muds with low methane hydrate saturations in about 20-30 m sediment depths and higher methane hydrate concentrations at 98 m depth and below. The methane hydrates, which were very likely disseminated in the sediment, had decomposed on the way through the water column and onto the deck of the research vessel. But some data, such as the chloride content in the pore water, proved that we had penetrated methane hydrates. Based on the chloride anomalies, we can also quantify the saturations of methane hydrate very well. At a sediment depth of 86 m, we penetrated a very prominent seismic reflector, which is caused by a carbonate cementation zone. In addition to abundant limestone shells numerous diagenetically-formed calcareous nodules were found. We suspect that this cementation zone constitutes a seal for ascending methane, which solidified below with the pore water to methane hydrate. Two borehole logging probes produced particularly valuable extra data during the removal of the drill string. Both the measured acoustic velocities and

the values of the natural gamma radiation in the borehole are perfectly correlating with the drilled lithologies, so that a correlation of the drilling data to the 3D seismic data is possible.
The seabed drill was able to complete a second deep hole on "Four Way Closure Ridge" after just 14 hours on **Thursday 25 October**. In contrast to the Formosa Ridge, the Four-Way-Closure-Ridge is an accretionary ridge, which was lifted up on the upper plate due to subduction. The compressional stress at this active margin generates different pathways for vertical methane ascent, which should also be expressed in the methane hydrate distribution. During mapping we found significantly more sea floor gas emissions in the form of acoustic water column anomalies than on and around Formosa Ridge. Drilling on Four-Way-Closure-Ridge sampled a sediment sequence of 126.35 m. After recovery of MeBo on board the ship the scientists had to deal with 32 core barrels of 3.50 m in length. A detailed work plan for the scientists ensured a systematic and fast processing of the core liners. After gas sampling of the core catcher, the liners filled with sediment were scanned for temperature anomalies with an IR-camera and were then divided into individual sections and labeled. Since this Sunday morning, the sections were split into 2 halves lengthwise, described for details in sedimentology, photographed and sampled.

The more than 100 m deep borehole on Four Way Closure Ridge resulted in more than 90.6% core recovery and kept us busy in the laboratories last weekend. Based on pore water chloride data, the geochemists were able to show that from 70 m below the seafloor, negative anomalies occur at several depth intervals, which can be explained by small but significant methane hydrate accumulations at those depth. The temperature of each core was measured with an infrared camera immediately after the core had been retrieved from its core barrel. This fast measurement of the still unopened liner indicates discrete gas hydrate accumulations by a temperature that differs significantly from the overall core. As gas hydrates are not stable at the pressure/temperature conditions aboard the ship, they decompose into their components, i.e. water and methane. This fairly rapid decomposition is an endothermic reaction that consumes heat from the immediate environment. As a result, we saw pronounced cold sections of the core. Since we scanned all cores from the seabed drilling rig with this fast method, methane hydrate accumulations above a certain gas hydrate concentration were detected very well and the intervals coincided with those for which the geochemists found the chloride anomalies. Then, all sediment cores were logged with the multi-sensor core logger before they were split into archive and work halves. Our Taiwanese colleagues from TORI (Taiwan Ocean Research Institute), a national institute in Taiwan similar to our Helmholtz institutions in Germany, provided the logger in a laboratory container for this cruise. On a calibrated bench (Fig. 2) physical properties of the cores, such as density, magnetic susceptibility, conductivity and P-wave velocity are measured. These data are in turn compared with the other data from the core description, the geochemical data and the high-resolution 3D seismic data.
Very helpful for the localization of previously existing gas hydrates were also the measurements of the ratios of light hydrocarbons of gas samples, which are obtained with a special syringe from gas bubbles in the sediment liners. In sediment sections with methane hydrate, the ethane/propane ratio is significantly higher, since ethane is incorporated into the gas hydrate structure and is released again during hydrate decomposition. In contrast, propane is not incorporated in the gas hydrate structure and accumulates in gas hydrate-free sediment sections.
As of **Monday 29October**, we were impacted by the approaching super-typhoon YUTU, which had wind speeds of up to 195km/h and caused a strong to stormy north-easterlies in our working area. In our northwestern working area on Formosa Ridge station work was no longer possible. In the lee of Taiwan in our eastern working area, we were still able to perform station work with OFOS, CTD and gravity corer. Unfortunately, on Tuesday we were expelled also from this area by a short-term military drill, so we had to move closer towards the Taiwanese coast to remain in a relative quiet area, 13 nautical miles off the coast. On **Thursday, 1 November**, the typhoon reached the South China Sea on its westward course, sweeping across the Philippines with wind speeds still up to 140 km/h and sadly doing a great deal of damage. We stayed in the lee of Taiwan at the safe distance, but registered significantly increased wind speeds and wave movements. On **Friday, 2 November**, after

the cyclone abated, we conducted further station work on Four-Way-Clousure Ridge with OFOS, CTD, and gravity corer. However, it was too early for a new MeBo mission, as there was still a strong swell from various directions, as a remainder of the typhoon, that prevented the deployment of the drilling system.

On **Saturday 3 November**, all signs of the typhoon had disappeared and we were able to launch the MeBo in bright sunshine. The positioning of the drilling system on the seabed was very difficult due to the geological conditions. The seafloor was very hummocky due to numerous limestone blocks. The ship's photo and video sled (OFOS) had revealed only a few flat areas of about 10 m in diameter, in which a landing was possible. A new sonar called Echoscope helped us to find such a place. The Echoscope, which can see through a hatch in the bottom plate of the MeBo, is a sonar that provides in real time a very good 3D representation of the seabed. Using this technology from 40 m above the seafloor allowed us to find a suitable location on which the MeBo could land safely. The subsequent rotary drilling had to be stopped after 5.06 m due to gas bubbling from the well. A very well-preserved sequence of typical seep limestones with more than 85% core recovery, could be obtained.

During the weekend MeBo took rotary cores from the carbonate formation on Four-Way-Closure Ridge . Unlike other sediment cores, we did not split them lengthwise, but they remained in their liners to enable a CT analysis of the entire rock sequence when we get home. As the liners are transparent, it was possible to do a first macroscopic analysis. Different bright aragonite-rich horizons could be identified between darker, micrit-rich layers. The age of the sequence will be analyzed with U/Th dating in order to correlate the temporal evolution of methane emissions with the geological development of the Four-Way Closure Ridge.

On **Sunday 4 November**, we left our eastern working area and moved back to the passive continental margin of the South China Sea in the area of Formosa Ridge. A gravity corer at the MeBo station yielded astonishing results. In the 8,11 m-long sediment core of fine-grained, very homogenous mud, two to three fluid channels could be traced over large parts of the gravity corer length. These channels appear to be caused by gas bubble ascent in the sediment. Since the channels were significantly more water-rich, we believe that the channel walls were covered with gas hydrates, which have decomposed during the recovery of the core. As these observations were also made in the previously acquired MeBo core on Formosa Ridge, this suggests wide-spread gas bubble ascent in the sediments.

The next MeBo drilling began on **Monday 5 November**, on the small plateau southeast of the Formosa Seeps. A first drilling at this location two weeks ago cored a sediment sequence of 108 m, where gas hydrates could be detected in two layers. In the upper layer between 15-42 m sediment depth, gas hydrates showed a saturation of the pore space of 10%, while the layer below 100 m reached a gas hydrate saturation of approximately 33%. The second hole at this location was not drilled to recover sediment cores, but it was only drilled to perform logging. In addition to natural gamma radiation, electrical resistivity was logged, which clearly imaged the two horizons of hydrate in the borehole. This measurement was able to show the presence of gas hydrate down to a depth of 120 m, which had not been sampled previously. The maximum of natural gamma radiation was between about 80 and 90 m and represents a layer with numerous carbonate nodules, which seem to change the fluid circulation pathways. Two horizons with volcanic ash at 39 and 72 m depth represent the explosive volcanic eruptions on the Philippine island of Luzon that happened 39,000 and 61,000 years ago according to dated sediment cores. Together with the micro-paleontological examinations of our Taiwanese colleagues, these age determinations already give us on board a rather good age model for the sediment sequence.

During MeBo drilling on the small plateau, we have repeatedly observed gas emissions with the ship's hydro-acoustic systems on the summit area only 50-100 m to the north. The summit of this ridge segment is at 1120 m water depth and rises dome-like 15 m over the crest of the ridge. As recent publications by our Asian colleagues describe, the summit hosts one of the most interesting seeps of the South China Sea. On Wednesday, 7 November, we conducted observation profiles with the new OFOS over this seep area which is about 140 m wide. OFOS is a newly built video and photo imaging tool that was requested by the scientific community. It is operated by the ship's science officers. It showed its outstanding qualities as a new working tool. The HD camera, the high-speed camera with a resolution of 30 megapixels, very good seabed illumination, and a modern deck unit that is linked by a fiber optic cable make OFOS a very valuable scientific instrument. The video footage of the seafloor was transmitted to all possible monitors on the ship. The flash unit on the OFOS allowed us to generate a digital image every 3 seconds so that entire photo transects can be assembled via photo mosaicking. This helps tremendously when interpreting the high-resolution maps that are based on the ship's hydro-acoustic data. In addition to blocky, rugged carbonate formations seep organisms are especially of interest. Mussels are ubiquitous. Apart from living mussels there is shell detritus, that is also found in the carbonate crusts. As chemosynthetic animals they depend on the dissolved methane and represent the main inhabitants of the seeps. A curiosity are the almost monospecific deep-sea lobsters, which in some places cover the entire seabed. *Shinkaia crosnieri* is mainly known from the hydrothermal vents of the Okinawa Trough, but they also live at cold seeps.

Last week, with the 10th and 11th MeBo drilling of this cruise, two important holes were drilled in the eastern working area in the accretionary wedge. On **Monday and Tuesday, 12 and 13 November**, we drilled 77.4 m deep on South Yungan East Ridge, recovering older sediments of the accretionary ridge below a geological unconformity. Unfortunately, the hope of drilling gas hydrates in the fracture zones that are visible in the seismic data was not fulfilled. While indications of large gas volumes were ubiquitous, there were no indicators of gas hydrates, such as chemical anomalies, or soupy layers in the sedimentary sequence. The well-trained work force in all laboratories ensured that we were able to present all data from this drilling as early as **Wednesday, November 14**, as part of the daily science meeting at 15:30. The MeBo team started on this day with our last hole on Four Way Closure Ridge, which was aimed at drilling a deep sediment sequence between 115 and 140 meters, which is represented by high amplitudes in seismic data. An earlier hole that we drilled at the same site previously only reached depths of 126 meters, but showed signs of sand deposits, which have a high potential for gas hydrate presence. A second earlier hole at the location that used a different drilling technique, i.e. it did not core sediments but merely logged physical data of the rock formations at depths of up to 144 m. Based on the results we proposed numerous layers of sand at depth. In the new core drilling, which unfortunately did not quite reach the depth of 144 m, numerous sand layers were actually present, whose gas hydrate saturation could be determined with a high degree of confidence on the basis of the chloride and IR temperature anomalies. Thus, a very important goal to prove gas hydrate occurrences in coarse-grained accretionary wedge sediments was reached in the last week of the expedition.

On **Thursday and Friday, 15 and 16 November**, we sampled the water column above the Formosa Seep with the ship's CTD at many sampling points around the seep area which has a diameter of approx. 140 m. Significantly higher methane concentrations up to 2000 nM were measured in the sampled water, whose distribution pattern also clearly indicated the source at Formosa Seep. On **Thursday morning, 15 November**, we were visited by the new Taiwanese research vessel LEGEND, which TORI is currently commissioning.

After nearly 5 weeks of intensive research on FS SONNE, we look back on eleven MeBo boreholes that we have successfully completed at 6 different locations. No other exploration could previously drill 8,300 feet with the MARUM seabed drill, with over 420 meters of drilling and over 350 sediment cores collected. This corresponds to a core recovery of more than 83% in predominantly difficult-to-recover gas-rich deposits, which expand during retrieval from their rock formation, so that it often comes to loss of sediments. Two pressure cores successfully recovered sediments with gas hydrates. Never before has MeBo completed over 480 meters of borehole logging. In addition, 15 CTD stations were carried out during the cruise, 9 gravity cores were taken and 26 heat flow measurements in surface sediments and 6 observation profiles on the seabed were carried out with the new OFOS. Between station work, the swath bathymetry and sediment echosounders measured over a distance of 4,180 km along the seabed, so that a bathymetric map of about 8,000 km^2 with the highest resolution ever in Taiwanese waters could be created.

R/V SONNE is ideally suited for research cruises with MeBo200 due to its ample deck space, cranes, laboratories and accomodation capacity (40 science berths). One of the highlights is the large space on the working deck, the large hangar and the cold rooms at working deck level, which greatly facilitate the handling long sediment cores. The joint cruise of GEOMAR in Kiel and MARUM Bremen is a scientific cooperation with Taiwanese institutes, whereby the National Taiwan University (NTU) in Taipei with Prof. Saulwood Lin is the coordinator on the Taiwanese side. The scientific post-processing of the valuable data collected during the SO266 expedition will be jointly performed during the upcoming months and presented at a first meeting in Taipei in October 2019 during the 9th TaiGer meeting. On **Sunday, 18 November**, we reached the port of Kaohsiung and immediately began to clear the expedition equipment and the containers. While our Taiwanese scientists are already at home, most of us will return home by plane tomorrow.

Acknowledgements

R/V SONNE cruise SO266 to the passive and active margins southeast of Taiwan was planned, coordinated and carried out by MARUM "Center for Marine Environmental Sciences" at the University of Bremen, by GEOMAR Helmholtz Centre for Ocean Research in Kiel, and by the Institute of Oceanography, National Taiwan University in Taipei. The cruise was financed in Germany by the Ministry of Education and Science, project Taidrill – SO266 (Ref. #03G0288A). The project is funded in Taiwan by the Ministry of Science and Technology (MOST) Project TaiGer drill MOST107-3113-M-002-004. The shipping operator Reederei Briese Schiffahrts GmbH & Co KG provided technical support on the vessel. We would like to specially acknowledge the master of the vessel, Lutz Mallon and his crew for their continued contribution to a pleasant and professional atmosphere aboard R/V SONNE. Many thanks to the staff of the German Research Fleet Coordination Centre and to the Logistic Department of MARUM as well to the German Institute in Taipei. For organizing the reception and the press event in Kaohsiung in advance of the research cruise we thank Prof. Tse-Fong Tseng (Honorary Director German institute).

Cruise participants

Name	Discipline	Affiliation
AHRLICH, Frauke	MeBo	MARUM
BERNDT, Christian	Co-chief scientist	GEOMAR/GeoB
BERGENTHAL, Markus	MeBo	MARUM
BOHRMANN, Gerhard	Chief scientist	MARUM/GeoB
CHEN, Jhen-Niem (Janette)	Microbiology	NTU-DOG
CHEN, Sheng-Chung	Microbiology	NCHU
CHEN, Tzu-Ting (Pingping)	Sedimentology	NTU-IO
CHEN, Wei-Rong	Pore water	NTU-IO
CHI, Wu-Cheng	Hydro-acoustics	Academia Scinica
DEUSNER, Christian	Pore water	GEOMAR
ELGER, Judith	Geophysics	GEOMAR
FRÖHLICH, Siefke	MeBo	MARUM
KLEIN, Thorsten	MeBo	MARUM
FREUDENTHAL, Tim	MeBo	MARUM
KRAMER, Laura	Hydro-acoustics	MARUM/GeoB
KUHNERT, Markus	MeBo	BAUER
FAN, Lan-Feng	Pore water	NTU-IO
HSU, Ho-Han	MSCL logging	NTU-IO
LAI, Mei-Chin	Microbiology	NCHU

LIN, Saulwood	Co-chief scientist	NTU-IO
LIN, Tien-Shun (Andrew)	Sedimentology	NCU
MAI, Hoang Anh	MeBo	MARUM
MAU, Susan	CTD, water column work	MARUM/GeoB
MALNATI, Janice	Gas analyses	MARUM/GeoB
MEYER-SCHACK, Birgit	Core curation	MARUM
NIEDERBOCKSTRUCK, Bryan	Infrared imaging	MARUM/GeoB
PAPE, Thomas	Gas analyses	MARUM/GeoB
ROSIAK, Uwe	MeBo	MARUM
STACHOWSKI, Adrian	MeBo	MARUM
STAMP, Andreas	MeBo	BAUER
TSENG, Yi-Ting	Pore water	NTU-IO/MARUM
TU, Tzu-Hsuan	Microbiology	NTU-DOG
WALLMANN, Klaus	Pore water	GEOMAR
Wang, Yun-Ju	Pore water	NTU-IO
WETZEL, Gero	Heat flow lance	GEOMAR
WEI, Kuo-Yen	Micropaleontology	NTU-DOG
WINTERSTELLER, Paul	Hydro-acoustics	MARUM/GeoB
WU, Yi-Min	Military observer	NMOO
WUNSCH, David	Autoclave technology	CORSYDE
YU, Pais-Sen (Epson)	MSCL logging	TORI

Academia Sinica Institute of Earth Sciences, 128 Academia Road, Section 2, Nankang, Taipei 11529, **Taiwan**, https://www.sinica.edu.tw/en

BAUER BAUER Maschinen GmbH, BAUER-Straße 1, 86529 Schrobenhausen, **Germany**, http://www.bauer.de/bma/

CORSYDE Corsysde International GmbH & Co. KG, Reuchlinstr. 10-11, D-10553 Berlin, **Germany**, http://corsyde-international.com/

GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel, Wischhofstr. 1-3, 24148 Kiel, **Germany**, http://www.geomar.de

GeoB Fachbereich Geowissenschaften der Universität Bremen, Klagenfurter Straße, D-28359 Bremen, **Germany**, https://www.geo.uni-bremen.de/

MARUM Zentrum für Marine Umweltwissenschaften, Universität Bremen, Leobener Str. 8, D-28359 Bremen, **Germany**, http://www.marum.de

NCHU Department of Life Sciences, National Chung Hsing University, No. 250, Kuo Kuang Rd, Taichung 402, Taipei 20627, **Taiwan**,

NCU Department of Earth Sciences, National Central University, No. 300, Zhongda Rd., Zhongli District, Taoyuan City 32001, **Taiwan** (R.O.C.), https://www.ncu.edu.tw/

NTU-IO Institute of Oceanography, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd.,Taipei 10617, **Taiwan**, https://www.ntu.edu.tw/

NTU-DOG Department of Geosciences, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd.,Taipei 10617, **Taiwan**, https://www.ntu.edu.tw/

NMOO Naval Meteorological and oceanographic office, P.O. BOX 90186 Zuo-Ying Kaohsiung City 81300 **Taiwan**, https://cnmoo.mnd.gov.tw/

TORI Taiwan Ocean Research Institute**,** National Applied Research Laboratories**,** No. 196, Henan 2nd Road, Qianjin District, Kaohsiung City, 801, **Taiwan,** http://www.tori.narl.org.tw/

List of Stations

			Time (UTC)		**on seafloor**		
Date	**St.**	**Instrument**	**on**	**off**	**Latitude**	**Longitude**	**Water**
2018	No.	abbreviat.	seafloor	seafloor	N	E	depth (m)
2018/15/10	01-1	CTD	14:35	14:37	22°03.117	119°47.467	1446
2018/16/10	02-1	OFOS	01:12	07:19	22°03.373	119°47.895	1351
2018/16/10	03-1	GC	09:09		22°03.518	119°48.007	1358
2018/16/10	03-2	GC	10:32		22°03.521	119°48.014	1359
2018/17/10	04-1	MeBo	05:17	17:25	22°02.916	119°48.091	1322
2018/18/10	05-1	GC	08:38		22°02.891	119°48.098	1322
2018/19/10	06-1	OFOS	07:56	11:02	22°03.440	119°47.950	1350
2018/19/10	07-2	HF	15:56	16:12	22°02.755	119°48.169	1276
2018/19/10	07-3	HF	16:47	17:05	22°02.884	119°48.137	1304
2018/19/10	07-4	HF	17:40	17:57	22°02.972	119°48.337	1363
2018/19/10	07-5	HF	18:54	19:10	22°02.760	119°48.611	1510
2018/19/10	07-6	HF	19:47	20:03	22°03.023	119°48.614	1488
2018/19/10	07-7	HF	20:34	20:51	22°03.013	119°48.800	1538
2018/19/10	07-8	HF	21:22	21:39	22°03.200	119°48.763	1552
2018/19/10	07-9	HF	22:04	22:22	22°03.353	119°48.729	1554
2018/19/10	07-10	HF	23:02	23:21	22°03.569	119°49.044	1591
2018/20/10	08-1	CTD	01:22		22°03.428	119°47.963	1349
2018/20/10	08-2	CTD	01:49		22°03.461	119°48.000	1347
2018/20/10	08-3	CTD	02:10		22°03.471	119°48.039	1355
2018/20/10	08-4	CTD	02:35		22°03.479	119°48.064	1357
2018/20/10	09-1	OFOS	12:43	16:38	22°03.502	119°47.452	1425
2018/20/10	10-1	HF	18:41	18:58	22°03.530	119°48.728	1570
2018/20/10	10-2	HF	19:34	19:51	22°03.456	119°48.448	1477
2018/20/10	10-3	HF	20:36	20:53	22°03.254	119°47.983	1343
2018/20/10	10-4	HF	21:20	21:37	22°03.348	119°48.004	1346
2018/20/10	10-5	HF	23:24	23:41	22°03.021	119°45.367	1962
2018/21/10	10-6	HF	00:16	00:33	22°03.099	119°45.636	1918
2018/21/10	10-7	HF	01:10	01:26	22°03.346	119°45.346	1950
2018/21/10	10-8	HF	02:00	02:17	22°03.712	119°45.443	1905
2018/21/10	10-9	HF	03:06	03:25	22°03.694	119°44.930	1991
2018/21/10	11-1	GC	05:29		22°03.465	119°48.036	1354
2018/21/10	11-2	CTD	07:21		22°03.467	119°48.033	1353
2018/21/10	12-1	MeBo	14:32	19:00	22°06.888	119°17.130	1142
2018/22/10	13-1	MeBo	15:00		22°06.886	119°17.136	1142
2018/24/10	13-1	MeBo		10:13	22°06.886	119°17.136	1142
2018/24/10	14-1	XCTD	12:02		22°07.013	119°17.168	1189
2018/25/10	15-1	XCTD	00:45		21°09.552	119°25.663	2377
2018/25/10	16-1	MeBo	06:23		22°02.919	119°48.089	1322
2018/27/10	16-1	MeBo		09:06	22°02.919	119°48.089	1322

2018/28/10	17-1	CTD	09:48		22°02.111	119°48.001	1370
2018/28/10	17-2	CTD	10:34		22°02.155	119°48.224	1272
2018/28/10	17-3	CTD	11:22		22°02.194	119°48.441	1338
2018/28/10	18-1	OFOS	14:30	19:21	22°09.110	119°52.016	1307
2018/29/10	19-1	CTD	09:29		22°03.262	119°47.491	1408
2018/29/10	19-2	CTD	09:51		22°03.254	119°47.521	1398
2018/29/10	19-3	CTD	10:08		22°03.257	119°47.539	1397
2018/29/10	20-1	XCTD			21°52.625	119°33.982	2899
2018/31/10	21-1	CTD	06:51		22°09.202	119°52.368	1227
2018/31/10	21-2	GC	08:36		22°09.207	119°52.377	1228
2018/31/10	22-1	GC	10:35		22°09.213	119°52.651	1261
2018/02/11	23-1	OFOS	04:33	08:18	22°08.276	119°52.889	1287
2018/02/11	24-1	CTD	10:52		22°02.512	119°47.759	1409
2018/03/11	25-1	MeBo	04:09	11:45	22°03.487	119°47.979	1352
2018/03/11	25-2	CTD	14:54		22°03.496	119°47.984	1353
2018/04/11	26-2	MeBo					
2018/04/11	26-3	GC	07:02		22°06.887	119°17.134	1142
2018/05/11	27-1	MeBo	04:14		22°06.886	119°17.137	1142
2018/06/11	27-1	MeBo		20:36	22°06.886	119°17.137	1142
2018/06/11	28-1	OFOS	23:11		22°06.855	119°17.149	1147
2018/07/11	28-1	OFOS		05:30			1133
2018/07/11	29-1	CTD	06:44		22°06.891	119°17.117	1146
2018/07/11	29-2	CTD	07:06		22°06.912	119°17.121	1129
2018/07/11	29-3	CTD	07:31		22°06.9444	119°17.127	1136
2018/07/11	29-4	CTD	07:54		22°06.971	119°17.122	1154
2018/07/11	30-1	MeBo	14:56	21:48	22°06.887	119°17.147	1141
2018/08/11	31-1	MeBo	11:39		22°02.919	119°48.083	1324
2018/09/11	31-1	MeBo		18:33	22°02.919	119°48.083	1324
2018/09/11	32-1	CTD	22:47		22°04.354	119°42.952	2243
2018/10/11	32-1	CTD			22°04.354	119°42.952	2243
2018/10/11	33-1	GC	01:52		22°03.478	119°48.039	1356
2018/10/11	34-1	MeBo	10:40		22°03.461	119°48.049	1355
2018/11/11	34-1	MeBo		06:17	22°03.461	119°48.049	1355
2018/11/11	35-1	GC	12:33		22°06.886	119°17.131	1142
2018/11/11	36-1	CTD	13:57		22°06.896	119°17.125	1140
2018/12/11	37-1	MeBo	06:39		22°09.139	119°52.493	1231
2018/13/11	37-1	MeBo		05:21	22°09.139	119°52.493	1231
2018/13/11	38-1	CTD	11:53		22°06.958	119°17.131	1145
2018/13/11	38-2	CTD	12:09		22°06.942	119°17.139	1136
2018/13/11	38-3	CTD	12:22		22°06.932	119°17.147	1136
2018/13/11	38-4	CTD	12:38		22°06.918	119°17.158	1138
2018/13/11	38-5	CTD	13:01		22°06.945	119°17.107	1144
2018/13/11	38-6	CTD	13:22		22°06.934	119°17.129	1129
2018/13/11	38-7	CTD	13:35		22°06.923	119°17.141	1130
2018/13/11	38-8	CTD	13:48		22°06.915	119°17.146	1134
2018/13/11	38-9	CTD	14:09		22°06.915	119°17.146	1134
2018/13/11	38-10	CTD	14:24		22°06.923	119°17.116	1129
2018/13/11	38-11	CTD	14:34		22°06.915	119°17.146	1134
2018/13/11	38-12	CTD	14:44		22°06.915	119°17.146	1134
2018/13/11	39-1	HF	16:39	16:55	22°05.868	119°15.827	1971
2018/13/11	39-2	HF	18:26	18:41	22°06.861	119°17.145	1144
2018/13/11	39-3	HF	18:54	19:11	22°06.880	119°17.168	1142
2018/13/11	39-4	HF	19:22	19:39	22°06.896	119°17.184	1143
2018/13/11	39-5	HF	20:07	20:24	22°07.030	119°17.333	1265
2018/14/11	40-1	MeBo	03:44	21:00	22°02.926	119°48.075	1324
2018/15/11	41-1	CTD	04:07		22°06.926	119°17.114	1129

2018/15/11	41-2	CTD	04:25		22°06.914	119°17.131	1129
2018/15/11	41-3	CTD	04:44		22°06.899	119°17.136	1134
2018/15/11	41-4	CTD	05:01		22°06.891	119°17.149	1140
2018/15/11	41-5	CTD	05:21		22°06.880	119°17.132	1144
2018/15/11	41-6	CTD	05:38		22°06.898	119°17.119	1140
2018/15/11	41-7	CTD	07:28		22°06.916	119°17.114	1128
2018/15/11	41-8	CTD	07:46		22°06.924	119°17.105	1135
2018/15/11	41-9	CTD	08:12		22°06.917	119°17.090	1149
2018/15/11	41-10	CTD	08:27		22°06.901	119°17.101	1148
2018/15/11	41-11	CTD	08:43		22°06.886	119°17.108	1154
2018/15/11	41-12	CTD	08:55		22°06.874	119°17.117	1153
2018/15/11	41-13	CTD	09:24		22°06.928	119°17.121	1126
2018/15/11	42-1	CTD	21:47		22°06.896	119°17.123	1140
2018/15/11	42-2	CTD	22:02		22°06.911	119°17.117	1131
2018/15/11	42-3	CTD	22:15		22°06.923	119°17.107	1134
2018/15/11	42-4	CTD	22:30		22°06.936	119°17.096	1146
2018/15/11	42-5	CTD	22:43		22°06.945	119°17.107	1144
2018/15/11	42-6	CTD	22:59		22°06.933	119°17.116	1133
2018/15/11	42-7	CTD	23:14		22°06.919	119°17.128	1126
2018/15/11	42-8	CTD	23:30		22°06.905	119°17.136	1134
2018/15/11	42-9	CTD	23:43		22°06.909	119°17.143	1132
2018/15/11	42-10	CTD	23:58		22°06.909	119°17.143	1132
2018/16/11	42-11	CTD	00:10		22°06.939	119°17.131	1134
2018/16/11	42-12	CTD	00:24		22°06.957	119°17.119	1150
2018/17/11	43-1	XCTD	04:30		21°38.690	119°59.899	2819

MeBo: 11 stations with MeBo200
GC: 9 stations gravity corer
CTD: 15 stations CTD with hydro-casts
XCTD 4 expendable CTDs
OFOS: 6 stations with the Ocean Floor Observation System
HF 3 stations for heat flow measurements