# RV SONNE
# CRUISE REPORT SO 177

## SiGer 2004

## Sino-German Cooperative Project

## South China Sea Continental Margin: Geological Methane Budget and Environmental Effects of Methane Emissions and Gashydrates

**Cooperative Research between IFM-GEOMAR, Kiel, Germany and Guangzhou Marine Geological Survey, China Geological Survey, Guangzhou, Guangdong Province, P.R. China**

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| **Leg 1:** | **Hong Kong – Hong Kong** | **2 June – 23 June** |
| **Leg 2a:** | **Hong Kong – Shanghai** | **24 June – 15 July** |
| **Leg 2b:** | **Shanghai – Pusan** | **16 July – 19 July** |

**Edited by**
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**IFM-GEOMAR**
**Kiel**
**May 2005**

# Table of contents

# 1. Summary

The cooperative research project between Chinese and German leading marine research institutions, the Guangzhou Marine Geological Survey (GMGS) and Leibniz-Institut für Meereswissenschaften Kiel (IFM-GEOMAR) addressed the geological methane budget and environmental effects of methane emissions from gas hydrates along the passive margin of the northern South China Sea. Two areas were surveyed of which the NE area (A) was sampled in great detail, whereas area B, after an initial survey, yielded less promising results. Swath map bathymetry, ocean floor observation by continuous video survey (OFOS) and water column methane distribution pattern provided the basis for locating several sites of ongoing methane venting. Outstanding among these was a methane-derived carbonate structure in water depths of 600-900m. Vast accumulations of vent carbonate debris, pavements and edifices standing above the seafloor characterize this structure. A 30-m high edifice, named Jiu Long Methane Reef, proved to be an active cold vent site with chemosynthetic fauna and bacterial mats. At deep sites ( apprx. 3000m) in and adjacent to the Formosa Canyon methane anomalies in the bottom water and clam colonies also indicate active methane venting. Pore water and gas chemistry on gravity cores indicated rather shallow depths of the sulfate-methane-interface (SMI) and documented chloride anomalies. High methane concentrations (exceeding10.000 µM) in sediments, which when extrapolated, suggest that saturation might be reached at about 16-24 mbsf at which depths the shallowest gas hydrates might be encountered in the area. The project results contribute directly to several major science policy missions. (1) Documentation of vast amounts of methane emmited from the passive margin of the northern South China Sea is seen as evidence for long-term climate forcing by the greenhouse gas methane. (2) The functioning and significance of deep-sea biota as modulating the greenhouse gas budget is convincingly demonstrated by the vast amounts of methane carbon fixed as authigenic carbonates. (3) Further development of TV-guided deep-sea instrumentation, and above all the retrieval of undecompressed sediments, have again been deomonstrated as high a priority topic for the future of marine science. (4) The success of the project has demonstrated how international partnerships can efficiently been implemented.

## Zusammenfassung

Das gemeinsame deutsch-chinesische Forschungsprojekt SiGer 2004 zwischen führenden meereswissenschaftlichen Institutionen, dem Guangzhou Marine Geological Survey (GMGS) und dem Leibniz-Institut für Meereswissenschaften Kiel (IFM-GEOMAR), hatte zum Ziel, den Methanhaushalt aus submarinen geologischen Speichern abzuschätzen und die Bedeutung von Methanemissionen aus Gashydratzersetzung zu bewerten. Dazu fanden Untersuchungen in zwei Arealen am passiven Kontinentalhang des Südchinesischen Meeres statt. Das Areal A wurde detailliert vermessen und beprobt während das Areal B, nach einer Übersichtsvermessung, als wenig aussichtsreich eingestuft und nicht weiter untersucht wurde. Fächer-Echolotvermessung, Meeresbodenbeobachtung und Verteilungsmuster von Methan in der Wassersäule waren die Grundlage zum Auffinden mehrerer Lokationen mit aktiven Methanemissionen.

Unter diesen war eine Karbonatrücken zwischen 600-900 m Wassertiefe, aus Methan-C aufgebaut, die am eindrucksvollsten ausgebildete Struktur. Ausgedehnte Karbonat-Schotter, Krusten und Aufbauten kennzeichnen diese Struktur. Ein 30-m hoch aufragender Schlot, als Jiu Long Methane Reef neu benannt, war mit abgestorbenen und zementierten Kolonien chemosynthetischer Fauna belegt und mit Bakerienmatten ausgekleidet. Weiter südlich in einer Tiefwasser-Rinne (ca. 3000m) des Formosa Canyons wurden Methananomalien im Bodenwasser sowie Muschelkolonien festgestellt, die ebenfalls Anzeiger für aktive Methanaustritte sind.
Die chemische Zusammensetzung der Porenlösungen von Sedimenten aus dieser Rinne zeigte ein relativ flache Sulfat-Methan-Grenzfläche (SMI, im cm bis m-Bereich) sowie Cl-Anomalien;

beide Kriterien sind auf Fluid-Emissionen zurück zu führen. Hohe Methangehalte im Sediment (>10.000 µM), wenn zur Tiefe hin auf den Sättigungswert extrapoliert, machen das Vorkommen von Gashydrat in ca. 16-24 m Tiefe in der Rinne wahrscheinlich.

Die Ergebisse des Projektes tragen wesentliche Erkenntnisse zu mehreren Themenbereichen der GEOTECHNOLOGIEN-Initiative wie folgt bei: (1) *Klimawirksamkeit des geogenen Methans:* Die Entdeckung ausgedehnter Karbonatstrukturen aus Methan-C dokumentieren die langfristige Bedeutung von submarinen Emissionen für das Treibhaus-Budget. (2) *Stoffkreisläufe:* Die Funktionsweise des biologischen Filters bei der Festlegung von Methan-C durch AOM (= anoxic oxidation of methane) wurde für den oberen Kontinentalhang des Südchinesischen Meeres eindrucksvoll nachgewiesen. (3) *Innovative Technologien:* Der wesentliche Erfolg des Projektes SiGer 2004 beruht auf der TV-geführten Probennahme die über Jahre entwickelt wurde und auch weiterhin ein Thema hoher Priorität bleiben wird. (4) *Internationale Kooperation:* Das Vorhaben SiGer 2004 hat beispielhaft gezeigt wie Kooperation im WTZ-Bereich für beide Partner effizient umgesetzt werden kann.

## 2. Preface

The origin of the project can be traced back to the year 2001, when the former Vice Minister Mrs. SHOU Jiahua of the Ministry of Land and Resources visited Germany and saw first hand pieces of „burning ice“at IFM-GEOMAR, Kiel. She learned about the GEOTECHNOLOGY program of the German Ministry of Education and Research (BMBF) and one of the initiatives of that program: **Gashydrates in the Geosystem.** Mrs. SHOU put forward the suggestion of Sino-German gas hydrate cooperative research. Under the encouraging support and promotion by both Chinese and German government agencies, agreements on scientific cooperation between IFM-GEOMAR and GMGS and ship's charter between RF and CGS were signed in March of 2004 at the Marine Geological Survey in Guangzhou. This marked the official start of the cooperation project entitled: **South China Sea: Distribution, Formation and Effect of Methane & Gas Hydrate on the Environment.**

Following the agreement, from June 2 to July 15, 2004, the Sino-German research cruise SO-177 was carried out aboard the R/V SONNE jointly financed by the German Ministry of Education and Research (BMBF) and the Chinese Ministry of Land and Resources, through the China Geological Survey (CGS). Under the endeavor of scientists from both countries, the cruise has been a great success. Here we would like to express our appreciation and respect to the geoscientists of both countries to set an example of cooperation.

**One of the outstanding results of this cruise is the discovery of gas hydrate-associated limestone at the cold vent sites on the northern slope of South China Sea. The structure at the seafloor, henceforth know as the Jiu Long Methane Reef, is one of the largest of methane-derived limestones known from the world's marine environment and the first to be discovered in Chinese waters.**
**The success of the project was based on combining the expertise of both partners, the detailed knowledge of the regional setting of the South China Sea basin by the Chinese side and the advanced equipment of the German side which at the time was unique world-wide and only deployable from RV SONNE. The project developed into a milestone for the entire region bordering the South China Sea as well as other marginal seas and enhances our understanding of the role of methane as free gas or bound in gas hydrates as a factor affecting the global cycle of greenhouse gases and hence climate change.**
Under the endeavor of scientists from both countries, the cruise has been a great success. Herewith we would like to show our appreciation and respect to the geoscientists of both countries and also to the German government for the great support in this cooperation.

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# 3. Introduction

## 3.1 Objective

The general objective of project SiGer was an evaluation of methane emissions from continental margins, their contribution to the global green house gas budget, and their influence on the seafloor environment. This objective includes not only the potential of marine gas hydrates as an energy resource but more importantly the role of hydrate-bound methane ultimately on climate change and the functioning of a highly-adapted deep-sea benthic community in modulating methane emissions. In this context the significance of hitherto unappreciated “geological” methane sources to the atmosphere have repeatedly been emphasized.

Shallow gas accumulations in marginal basin sediments, gas emissions detectable as acoustic plumes in the water column, pock marks, cold seeps and mud volcanoes at the sea floor, populations of vent faunas, authigenic carbonate precipitates which may build up chemoherms, and near-surface gas hydrate layers are global phenomena which document an ongoing process of methane emissions from geological sources (Judd et al., 2002). Attempts to quantify the cumulative global budget of methane from these sources are highly unsatisfactory, yet have demonstrated that these fluxes may contribute between 14-38 Tg $CH_4$ per year and thus represent up to 4% of the total methane sources or up to 15% of the natural methane sources in the atmosphere (Judd et al., 2002; Milkov 2002; 2003).

Furthermore, it has been pointedly been stated that: “…international authorities responsible for advising and policy makers have failed to recognize the significance of geological processes in global climate change….”. This statement is amply supported by the “new” global carbon cycle proposed by Dickens (1999), by the lack of an appropriately identified “geological” methane reservoir in the predictive models promoted by the Inter-Governmental Panel on Climate Change (IPCC 2002; Houghton et al., 1996; Norris & Röhl, 1999). As a new development it was recognized that sea-floor biota may exert a dominating influence on the global methane input to the hydrosphere and atmosphere by oxidizing methane via sulfate reduction (AOM = anoxic oxidation of methane) in the absence of oxygen (Boetius et al., 2000). In this context, the occurrence of suspected vent biota and methane-derived carbonates documented on the northern slope of the South China Sea, an area underlain by recurring bottom-simulating reflectors, drew attention to possible “geological” methane sources. AOM at gas hydrate or cold vent sites is the controlling mechanism of methane emission from the seafloor to the water column (Boetius & Suess, 2003). This environmentally significant process has far reaching consequences for the global carbon cycle and budget and will be among the high priority objectives of any future research on methane and gas hydrates. Our previous work on authigenic carbonates at sites of methane emissison has shown that AOM controls authigenic carbonate formation, it is a crucial element for long-term methane-C sequestration and hence became an important objective of the SiGer-project.

### *Tasks*

The approach taken to address the overall objective during the field work is to locate, document, and sample cold vent manifestations, sites of methane emissions and near-surface gas hydrates and to clarify the geotectonic settings in which these occur along the northern margin of the South China Sea. For site selection 2 areas were chosen (Fig. 3.1.1), for which the GMGS provided a large set of seismic surveys with BSR patterns, knowledge of the regional marine geological setting, bathymetry, hydrographic data, sea floor observations, and preliminary geochemical evidence of pore water methane contents, Cl- and SO42-anomalies. For carrying out the field work, the German partners provide sea-going instruments developed explicitly for the discovery and sampling of sea floor vents and gas hydrates, quantification of methane emissions, and all ship-board laboratory facilities. The sea-going campaign is divided into several subtasks as follows:

(1) Locate and access cold seep sites and near-surface gas hydrates using multibeam bathymetric survey based on existing coverage and multi-channel seismics provided by GMGS;
(2) Seafloor video survey with real-time imaging using OFOS provided by IFM-GEOMAR; it is a proven and ideal tool for locating methane emission sites;
(3) Continuous sea surface monitoring of dissolved methane and carbon dioxide; this is accomplished by a sea-going analytical tool developed at IFM-GEOMAR for the detection of methane seeps in shallow water or at sites where the gas emissions reach the sea surface;
(4) Retrieval of sediment cores for detecting active methane emission sites at the seafloor by pore water chemistry; this task includes TV-guided coring and high-resolution pore water sampling on a cm-scale; it provides currently the best data to ascertain if active methane venting occurs as well as if gas hydrates are present based on negative Cl-anomalies. Sedimentological investigation of the core material provides the stratigraphic and chronological framework of the sampling sites.
(5) Methane release from the seafloor to the water column by CTD-based sampling and on-board analyses of dissolved methane; if free methane escapes as bubbles, high-frequency acoustic plume imaging is another method by which to detect methane release.
(6) Retrieval of authigenic carbonates formed by anoxic oxidation of methane. Focused fluid flow and methane emiasions produce chimneys, brecciated veins of fibrous aragonite, and/or micrite nodules and crusts. These lithologies precipitate along coarse-grained sediment layers, burrows and fluid channels and which are to be sampled by the available TV-guided ship-board tools. They are archives of fluid emission events, fluid source depths, and possibly hydrate occurrence and provide time-integrated information on methane emission.

### 3.1.1 Geologic setting and area of investigation

The South China Sea, one of marginal seas in the western Pacific, is located between a continental block and an off-shore block and developed when the SE-Asian continent rifted, drifted, and collided as the result of the progressive movement between the Pacific Plate and the India-Australia Plate during the Cenozoic. This process resulted in four different continental margin settings with different sedimentary basins (Fig. 3.1.2). The South China Sea basin is one of them; it is a passive margin formed during Middle Oligocene to Early Miocene times (32 Ma-17 Ma). Its northern continental shelf has subsided due to compression and received sediments continually since the Late Oligocene (Su & Wang 1994; Wang 1990, 1999; Wang et al 1995; Kudrass et al 1992). The OPD Leg 184 elucidated much on the sedimentation history of the South China Sea and particularly the development of the monsoonal climate in relation to the uplift of the Tibetan Plateau (Wang and Prell, 2000). Low sedimentation rates prevailed during the Early Miocene to the Early Pliocene and rapid rates during the Oligocene and the Late Pliocene. The sedimentary basin exhibits a lower section characterized by half-grabens formed during rifting and filled with non-marine sequences and an upper section characterized by a wide range of terrigenous and marine sediments deposited during the Neogene subsidence of the margin. During the Late Pliocene the sedimentation rates exceeded 100 cm $ky^{-1}$ with burial of large amounts of organic matter. This organic matter is the source of early diagnetic, microbially-generated methane pervasively found throughout the sediment sequences.

***Area A***

The major area of research (Area A) is located towards the east of the northern continental shelf of the South China Sea. Tectonically it is a passive margin setting grading into the South China Sea Basin and which abutts the accretionary wedge formed off-shore south-western Taiwan Island (Fig. 3.1.2). The northern extension of the Manila Trench (Penghu Canyon) and the branched off Formosa Canyon deliniate the borders of the area for which research clearance had been obtained. The Penghu Canyon is an extension of Manila Trench, the subducting zone where the South China Sea oceanic crust the Luzon Arc (Pilippine Sea Plate) and the Asian continental margin collide (Liu et al, 1998). According to Huang et al., 2000 from W to E there is the trench (Penghu Canyon), an accretionary complex consisting of syn-collision and pre-collision wedges (Kaoping slope and Hengchun Ridge), a forearc basin (North Luzon Trough) and volcanic islands (North Luzon Arc).

This area covers about 2.97 x $10^4$ $km^2$. Generally, the topography is very complicated and shows highly-changable vertical gradients (Fig. 3.1.3). The Formosa Canyon (Liu et al,1998) crosses the entire area from the NW to the SE and then turns into WE direction at around 21°17′N, 119°05′E. In the northern part of Area A the topography alternates between steep slopes and flat-topped ridges extending from the W to E and descend gradually from NW to SE into the deeper part of the South China Sea Basin. The average slope is about 7° and the water depth ranges from 150 m to over 3200 m. According to the topographic features, the slope can be divided into an upper and a lower portion. The upper portion slopes between 1-3°, the water depth is between 150-1500 m and it is about 30-70 km wide, whereas the lower portion slopes between 2-4° and is between 1500-3200 m deep. The morphology is especially complicated in the northern portion of Area A in which steep scarps and canyons have developed with erosional channels, valleys and ridges in between (Fig. 31.4 & 5). The transition zone between the upper and the lower slopes is usually marked by steps.

In the southern part of Area A the topography is relatively simple with water depths gradually increasing southward from 1500 to 3200 m. The southern boundary is marked by the WE-trending Formosa Canyon. The water depth here is from 3200 to 3400 m at the center of channel and 2900-3200 m on both flanks (Fig. 3.1.6). On the northern flank there are several vertical cliffs with displacements of up to 30 m. They appear to result from down-sloping moving sediment packages which break off as they are intersected by the channel.

The tectonics is complex in the norther part of Area A. Faults, folds and volcanic diapirs were well-developed at depth. Several active faults have developed both in deep and shallow sediment layers, some of which may reach the seafloor. According to GMGS previous surveys several marker horizons are recognozed in seismic profiles. There are extensive and well-developed bottom simulating reflectors (BSR) found in five regions (Fig. 3.1.7 & 8). Generally, the interpreted sections indicate strong BSRs (S-BSR) accompanied by strong amplitude blanking and weak BSRs (W-BSR) charaterized by weak amplitudes at wave crests-troughs. The amplitude blanking indicates the occurrence of gas hydrates. The BSRs generally occur about 170-400 mbsf. No evidence for near-surface gas hydrates nor active venting have been detected so far. The reasons are either too sparse sampling or the absence of tectonically-controlled upward migration of methane-saturated fluids. However, evidence for fluid and methane escape had been found in the SW-corner of the Area A (Haiyang IV Site). The evidence is in the form of articulated and disarticulated clams at about 3000 m, most likely taxa related to other known vent clams. The environment in which the clams live also shows bacterial mats and circular patches of discolored sediments. This location (Haiyan IV) was the prime site for investigation during SO 177 and the eqastward extenting Formosa Canyon. The underlying structure responsible for venting at this site is uncertain.

### *ODP Leg 184 geochemistry*

The geochemical results at Sites 1144 and 1146 are particularly relevant to the objectives of Cruise SO-177 indicating an enormous amount of methane in the pore space of up to $10^6$ ppmv. These concentrations are minimum values because of degassing of sediments and the loss of methane inherent in the void space analyses technique by which they were obtained (Wang & Prell, 2000). They are in the same order of magnitude as those encountered at Hydrate Ridge where gas hydrates were present (Suess et al 1999, 2001). Although no negative Cl-anomalies were found at Site 1144, however such deviations were documented at Site 1146. They may result from the dissociation of gas hydrates. Interstitial sulfate declined to below detection limits within 9 mbsf (= meters below sea floor) at Site 1144, indicating enormously active microbial sulfate-reduction, most probably caused by the anoxic oxidation of methane (AOM). High-resolution sampling of cores during SO 177 better defines this gradient and the depth of the sulfate-methane-interface (SMI). All criteria are in agreement with the wide-spread BSR-distribution and document the presence of gas hydrates in the subsurface.

### *Area B*

As an alternate area, in case weather conditions would require to abandon Area A, the central part of the Xisha Trough, 200 miles to the west (Area B) was also cleared for research activity (Fig. 3.1.9). This area is located SE of Hainan Island and to the N of Xisha Islands and covers an area of about 2.92 x $10^4$ $km^2$. Tectonically, Area B is located in the central part of Xisha Trough, a Cenozoic rifted basin which developed on the NW slope of the South China Sea. The Xisha Trough is a nearly EW-trending arched feature about 430 km long.Its eastern end is connected to the central sub-basin of the South China Sea. Generally, the trough dips gradually from W to E and becomes narrower with the water depth changing from 1650 m to over 3000 m. In the west, the gradients for both north and south flanks are relatively flat and the trough is U-shaped with a bottom width of over 14 km. In the central part, both flanks are relatively steep. The eastern part of the trough is V-shaped and 6 to 8 km wide. The northern flank is well developed with steep slopes and small terraced ridges whereas the southern flank shows an undulating topography. The thickness of Cenozoic sediment in the trough is between 2000 and 6000 meters, which provide favorable conditions for the generation of biogenic and thermogenic gas. Furthermore, many active faults both in deep and shallow layers are developed in the basin some of which may reach the seafloor. On the northern flank and the southern ridge of Xisha Trough, BSR and amplitude blanking zone have been observed in seismic profiles. The BSRs occurres widely at water depth between 350 and 3000 m and at 200 to 750 ms (about 180 to750 mbsf). Several seismic anomalies have been observed such as BSR polarity reversals and abnormal velocity distribution.

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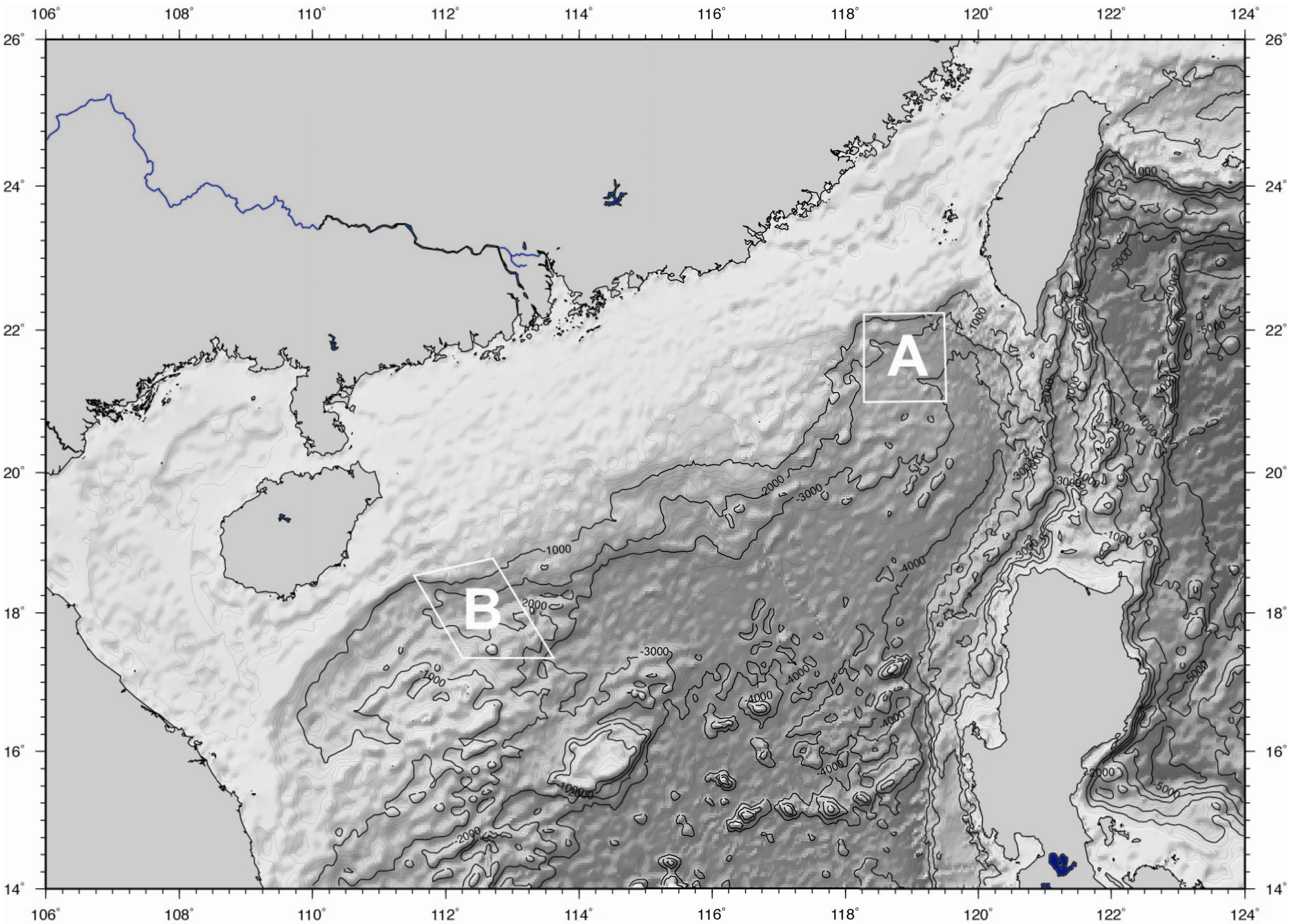



Figure 3.1.1 South China Sea and areas of investigation; Area A was the main target for which GMGS provided data on BSR patterns and swath bathymetry; Area B was of secondary importance.

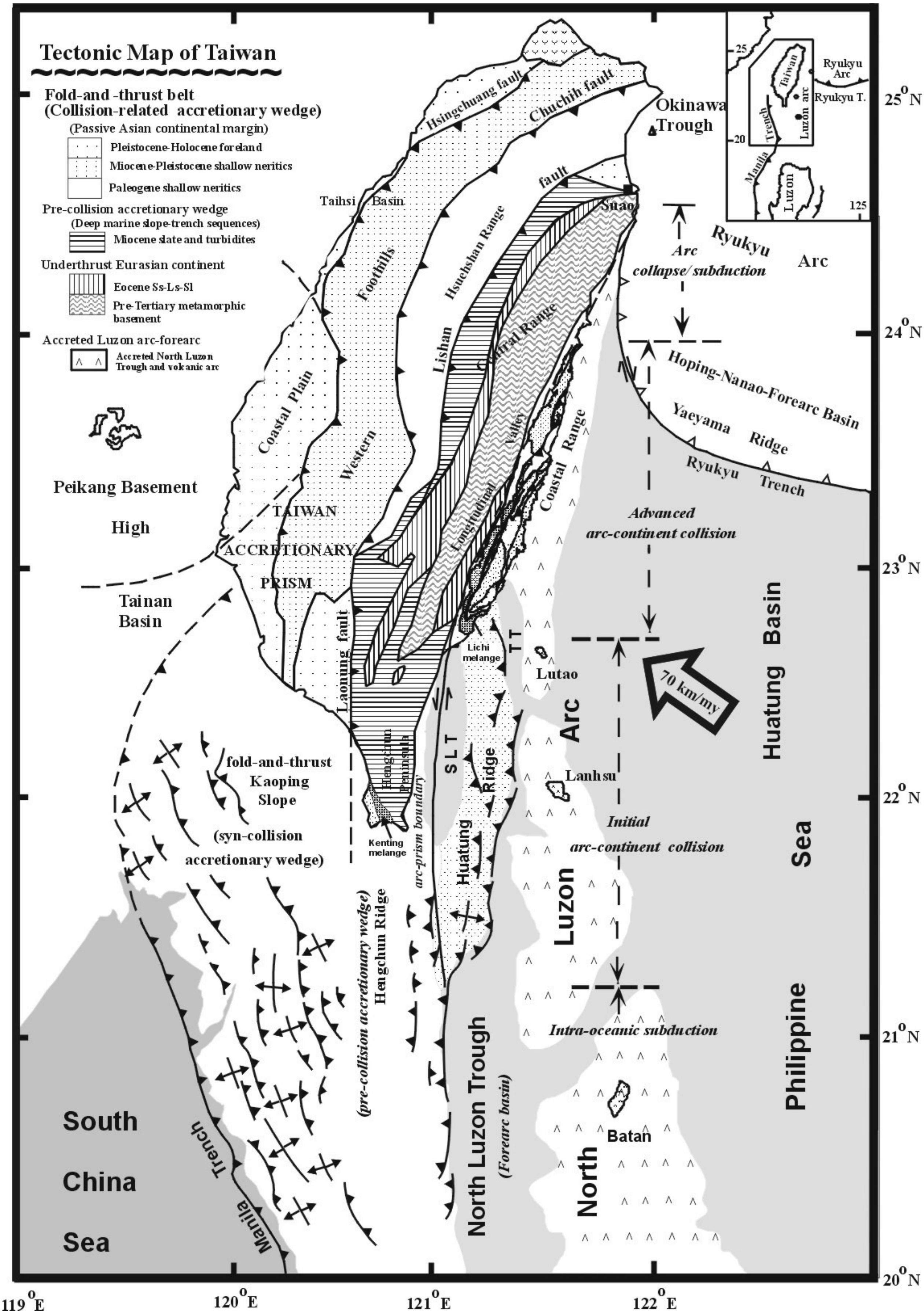



Figure 3.1.2 Tectonically the area of investigation of the South China Sea is a passive margin setting adjacent to the accretionary wedge formed off-shore SW-Taiwan Island; Manila Trench (Penghu Canyon) and Formosa Canyon deliniate he area for which research clearance had been obtained.

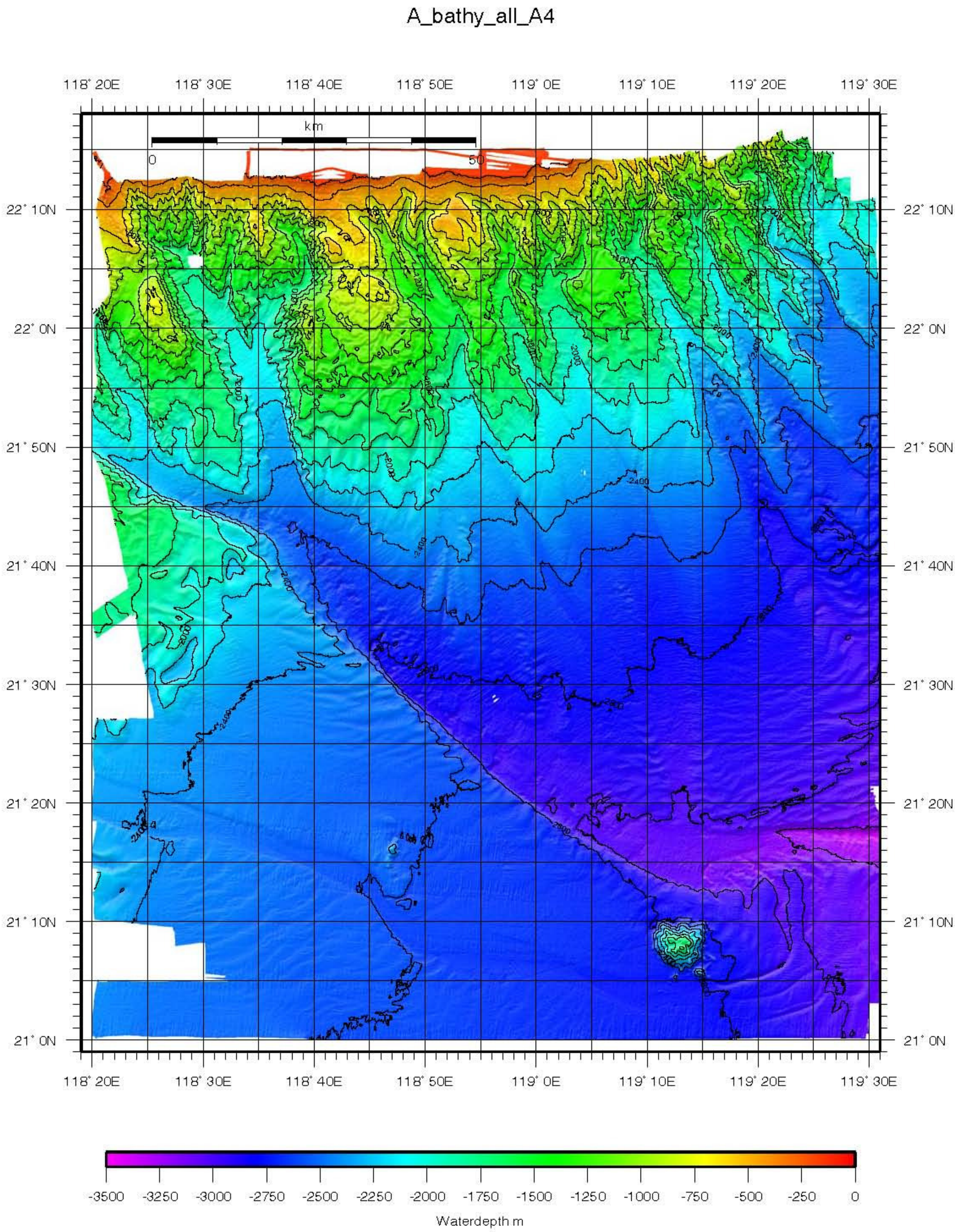
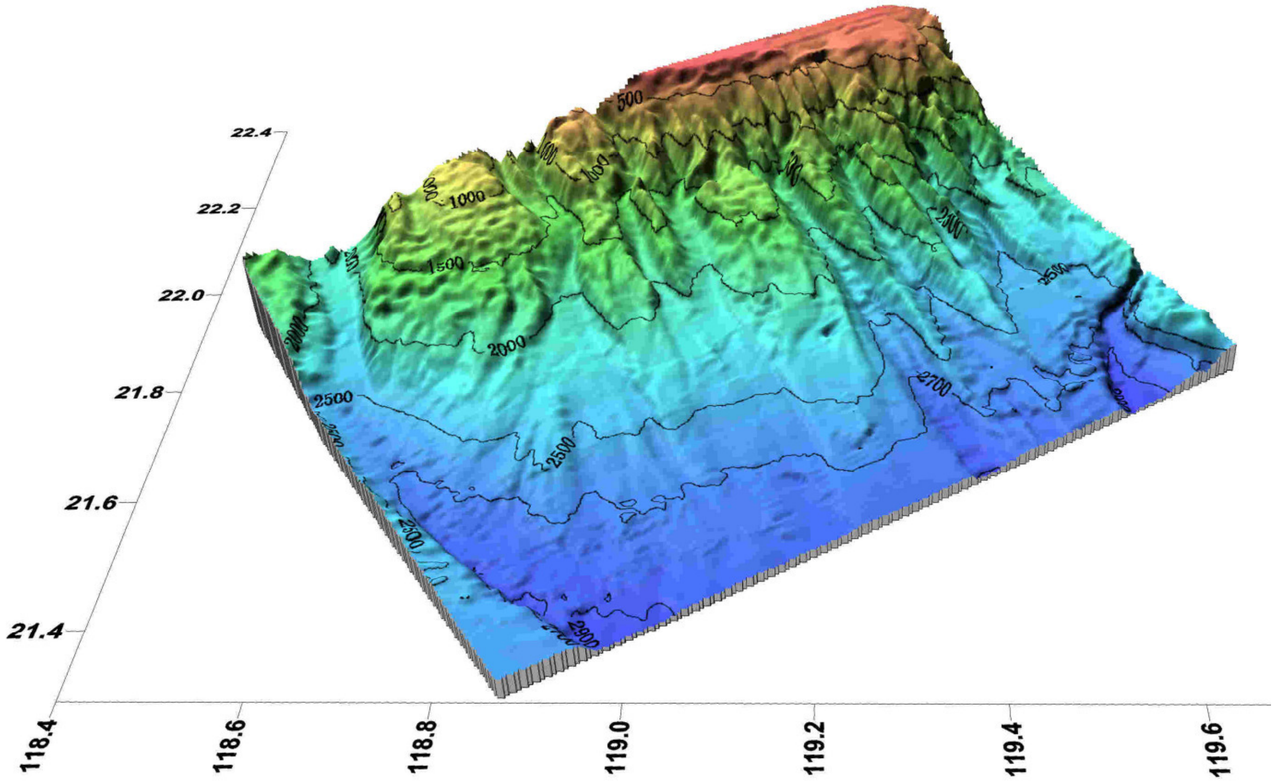



Figure 3.1.3 Newly completed bathymetric survey of Area A; note Formosa Canyon, complex and dissected slope morphology at northern margin and prominent seamount in SE .



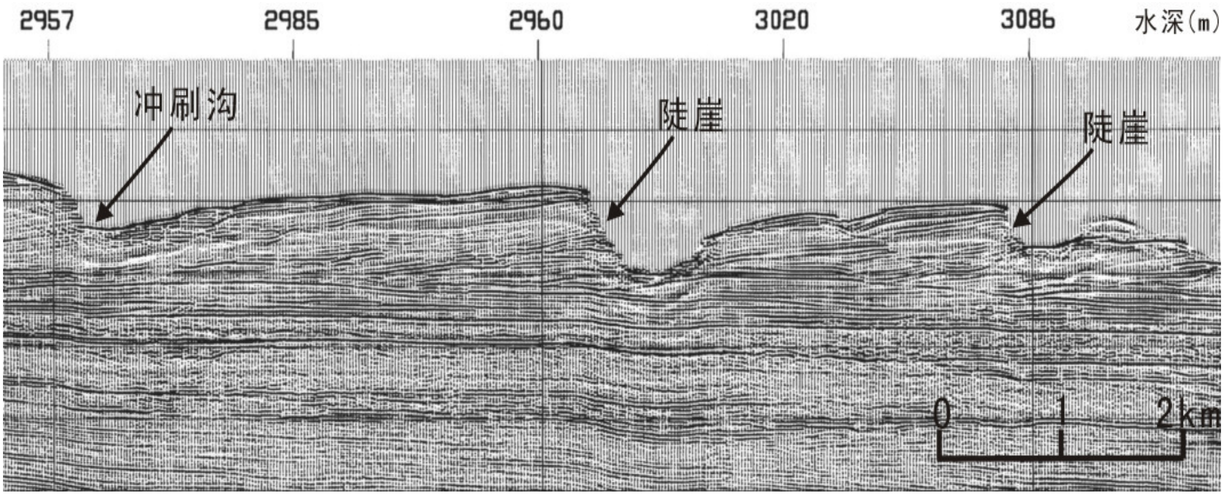




Figure 3.1.4 & 5 Detail of dissected slope with 2 carbonate complexes recognizable at the western edge (above); slope parallel seismic line with disecting canyons (below).

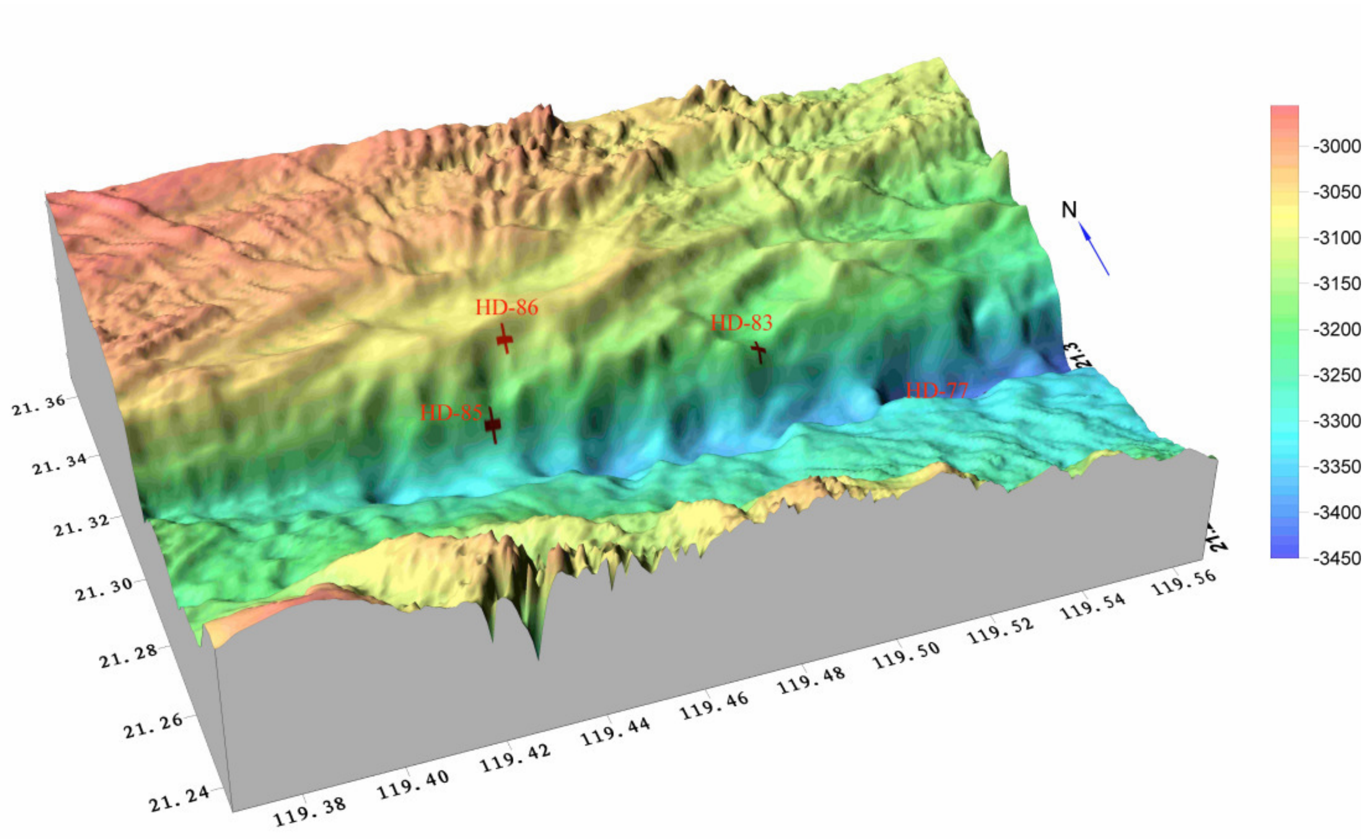
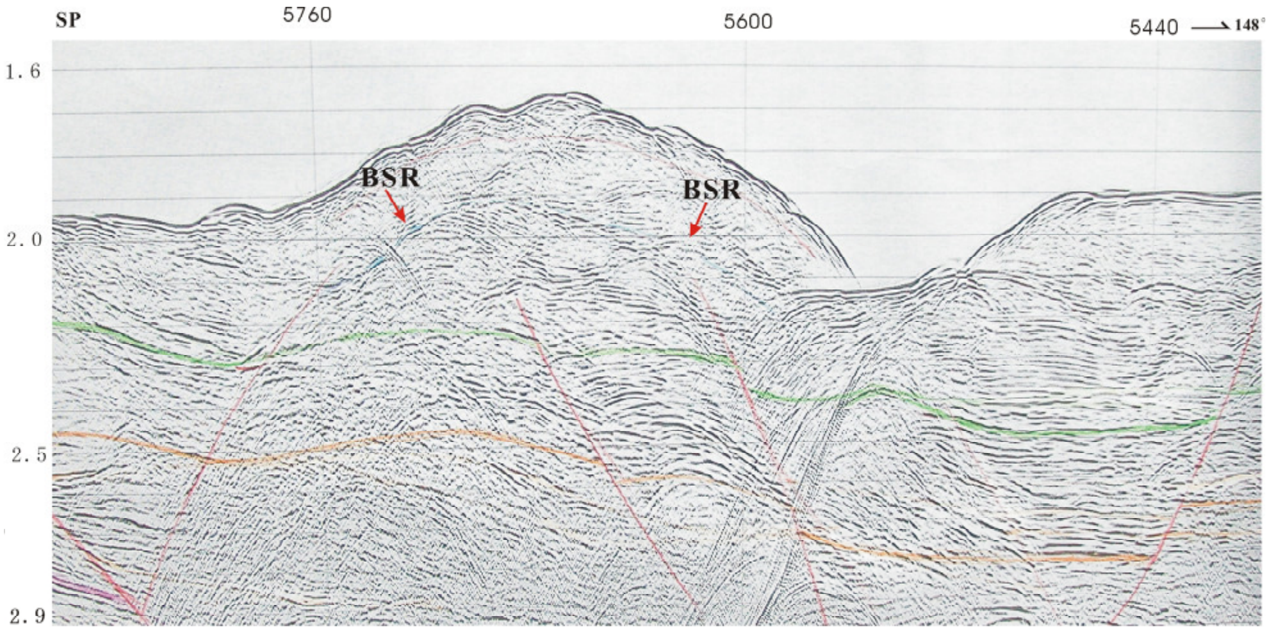



Figure 3.1.6 Detail of Formosa Canyon and coring sites of previous GMGS surveys with evidence of methane venting.



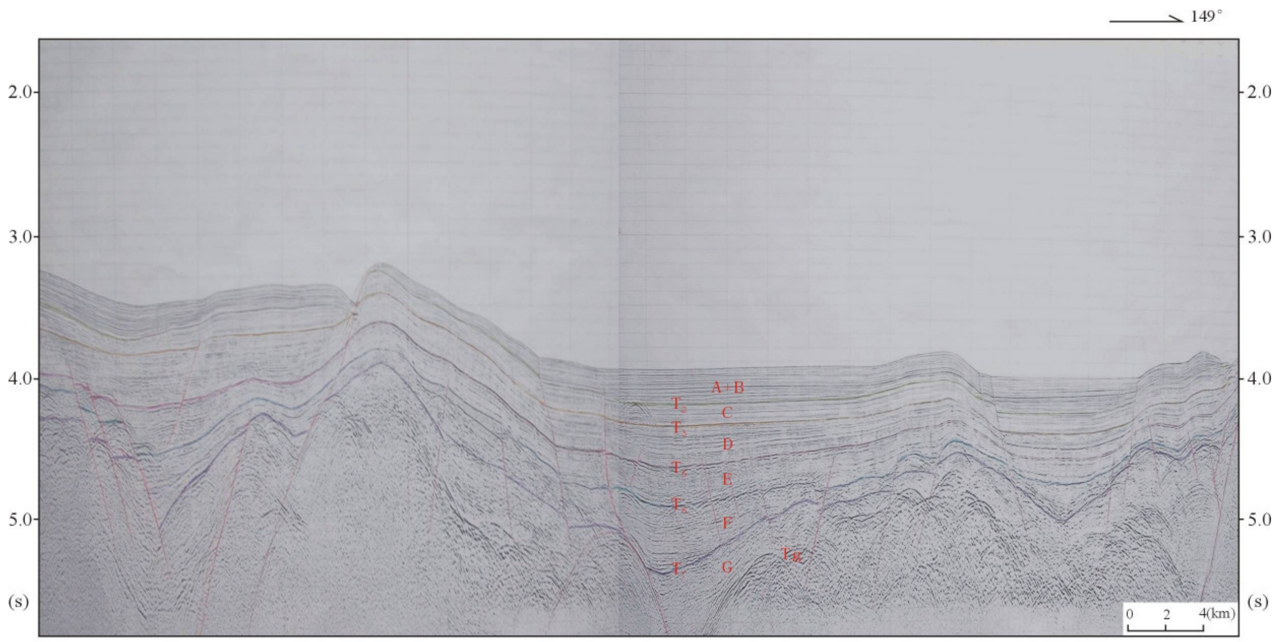




Figure 3.1.7 & 8 Multi- and single-channel seismic lines parallel to mid-slope region of Area A from previous GMGS surveys; note weak and discontinuous BSR-distribution cut by faults: in several places fault traces terminate at sea floor; such sites were investigated for methane seepage. (3.1.7); well-deloped seismic stratigrapic units above rough basement morphology with thick sediment packes; several are displaced by faults (3.1.8).

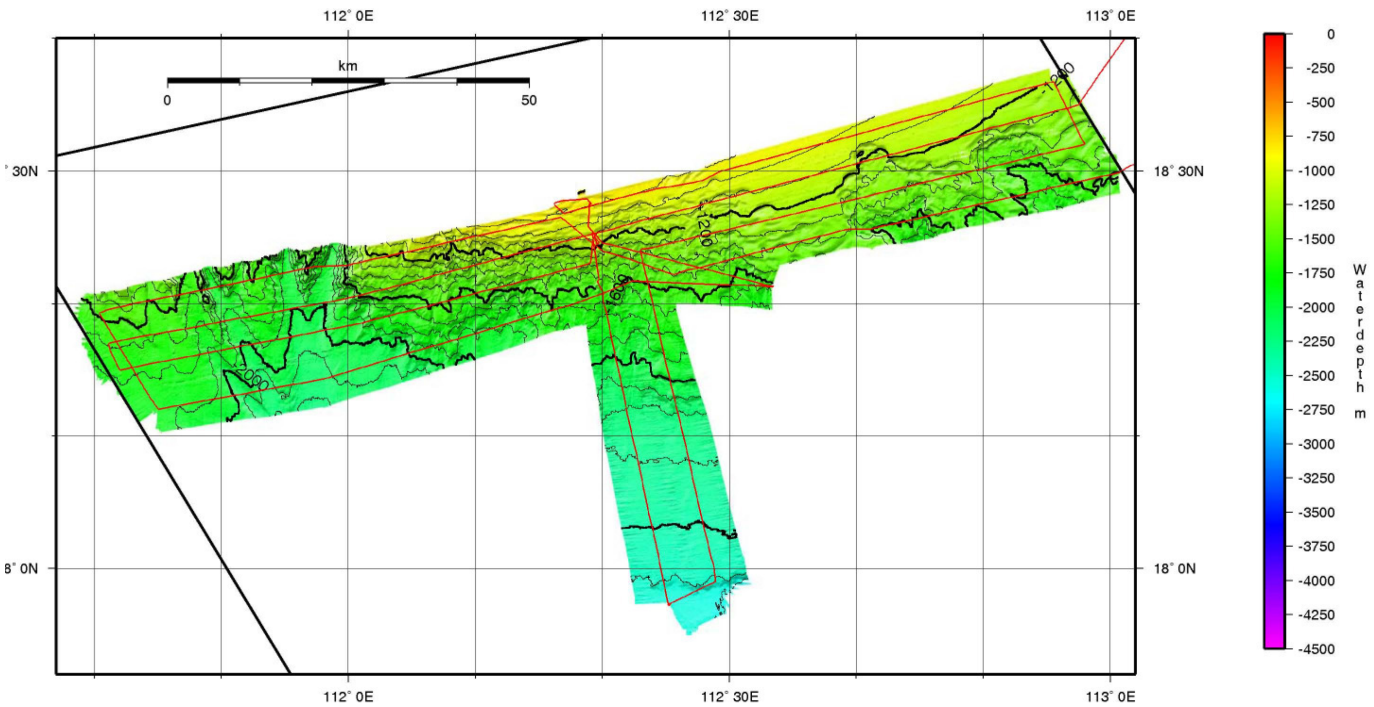



Figure 3.1.9 Area B; general bathymetry.

## 3.2 List of participants and institutions

### 3.2.1 Scientists - SO 177-Leg 1

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Figure 3.2.1: Participants Leg1

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Figure 3.2.2 Participants Leg 2

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# 4. Cruise narrative

## *4.1 Weekly Reports*

### *Introduction*

The weekly reports constitute an essential part of the cruise. They not only document progress on board during time at sea but detail the daily activities and define specific areas of high-resolution work where results are promising. Hence the sub-areas from which preliminary results are reported become part of the cruise narrative and supplement the overall cruise tracks (Figs. 4.1 and 4.2) and survey profiles. Accordingly, an overview map is provided here (Fig. 4.3) showing the locations of inset maps of several sub-areas and their ship-board nomenclature as follows:
Overall carbonate complex in Area A (Fig. 4.4.1);
Jui Long south ( Fig. 4.4.2) is the most active site which contains the pinnacle (Fig 4.4.4);
Jiu Long east (Fig. 4.4.3) is the shallowest part of the upper slope carbonate complex.
Haiyang4 asrea (Fig. 4.4.5) along the north bank of the Formosa Canyon and the location of the prominent seamount on the ancient oceanic crust.
OFOS surveys, coring sites and CTD stations are shoiwn on these inset maps; those stations which do not fall on any inset map are shown on the overview map.

### *4.1.1 Weekly Report; 2 –11 June 2004*

During 2 June, the first day of the vessel's charter by the Geological Survey of China, 22 ship board scientists arrived at Hongkong from Guangzhou and Gemany, respectively, settled on board and began equipping the laboratories. The next day was fully occupied with unloading containers, assembling heavy gear, stowing equipment and completing the laboratories. At 1000 in the morning of 4 June, RV SONNE left port and after a lengthy immigration procedure took course towards the area of investigation, designated area „A" located about 250 n.m. distant in the NE of the South China Sea. In the afternoon a science meeting was held primarily to get to know each other, to acquaint the groups with the shipboard procedures and to establish work teams. This was followed by a safety meeting, an introduction of the vessel's master, chief engineer, officers, system operator , technical services group and medical doctor and a tour through the vessel.

During mid morning of 5 June RV SONNE reached the area „A" to begin a multibeam survey preceeded by a CTD-station to obtain a sound velocity profile for calibration of the acoustic system. The survey ended in the morning of 6 June at the eastern edge of the prominent channel which runs E to W across the area. A CTD-station at 3060 m showed slight methane anomalies in the bottom water of the channel confirming that venting, albeit at low activity, must be present. This was confirmed by another CTD station with a more pronounced anomaly pattern , taken farther W along the S-facing channel wall. An OFOS track at an angle to the strike direction of the channel revealed a smooth and heavily sedimented featureless seafloor. The steepest section consisted of 7 distinct vertical cliffs, several meters each, caused by displacement of sediment blocks downslope. At the base of the 1st and 2nd of the cliff, several patches of clam communities were observed.

The survey was extented during the following night northward to cover the upper slope areas. Here on 6 June two OFOS lines were run between 600-1200m across a broadly elevated feature dissected and surounded by channels. The seafloor was covered by irregular patches of „doughnut"-shaped carbonates and rubble, typical of methane-derived carbonates at cold vents. No evidence for live benthic vent communities was observed, although one strong methane anomaly at about 400m could not be correlated to any morphological feature as the source. The multibeam survey was continued during the following night southward and ended again at the deep channel for an OFOS-survey along a track where previously the Chinese RV Haiyang4 had observed dense benthic communities as well as possible bubble escape. The

OFOS-run confirmed occurrence of rather dense clam communities and small circular patches of bacteria, although no significant methane anomaly was found in the waterr column at the site. The first attempt to sample by TV-guided multicorer was cut short by the advancing Taiphoon Coson, which approached the working area from the south. All research activities were halted at 1600 on 8 June when high winds, long swells and dense clouds appeared. RV SONNE steamed westward to stay out of reach and returned the next day in the later afternoon.

The excursion provided time for scientific meetings during 9 June with presentations dealing with the tectonics and seismic work of the South China Sea as well as with the use of cold vent carbonates as archives of fluid venting. During that time the taiphoon had past the area „A“ and turned east through Luzon Strait into the western Pacific. The closest approach of the core was 75 miles at 2100 on 8 June; reported winds were 75 miles/hour and waves between 6-14 m high. After return subsequent OFOS-runs perpendicular to the steep S-facing channel wall east of the reported „bubble“-site did not show new evidence for any venting activity such that it was decided to sample the „bubble site“ by TV-guided multicorer on 10 June. This turned out reseanably frustrating since none of the rather prolific clam communities could be relocated although the instrument functioned well and during each of 3 attempts 6 full core tubes were recovered. The cores showed variable thicknesses of the oxidized layer between 2-15 cmbsf followed by sand turbidites and sulfide-mottled dark gray sediments. The pore water data indicated that indeed the shallow oxidized layer indicates more vigorous upflow of methane-charged fluids than those with a thicker oxidized layer, although the total intensity of venting appeared greatly reduced from that at similar settings.

June 11 found RV SONNE again in the northern upper slope area to confirm and better resolve the depth of the previously observed strong methane anomaly, which was found to extent now from 150 to 450 m. An OFOS-run over the shallowest structure (550-900m) found carbonate patches, carbonate rubble fields, and one prominent 30m high carbonate edifice. Subsequent sampling by the TV-guided grab yielded every conceivable shape and form of authigenic carbonates such as crusts, concretions, odd-shaped fillings of burrows, chimneys with single and multiple open conduits as well as cemented conduits. Several of them appeared to be composed of dolomite, particularly the well-known „doughnut“- or ring-shaped concretions. The last TVG-deployment yielded very large block of carbonate (more than 100 kg) permeated by inumerable channels, burrows and flow structures as well as abundant benthic organisms either living on the surface or tiedly cemented into the carbonate matrix. The organisms seem not ot be related to the known chemosynthetic communities nor are the carbonates recently formed.

All evidence so far supports wide-spread and strong methane-venting activity on the upper slope of the northern South China Sea, certainly at times in the past, with reduced or ceased activity now. In the deep channel (3050 m) recent venting activity, however, is evident along the entire length of the S-facing flank over more than 25 n.m.. The sites investigated so far show comparatively weak activity with methane concentrations unliley to be associated with gas hydrates.

With the exception of taiphoon Coson, the weather has been excellent (water and air temperature around 28° and 26°C, respectively) and combined with the situation on the ship provide ideal working conditions, such that an optimistic outlook is maintained for the remainder of the cruise. All participants are well and send greetings to their respective home institutions.

On board RV SONNE 12 June 2004

### *4.1.2 Weekly Report; 12 –21 June 2004*

During the past 10 days our activity at sea was divided about equally between the two venting sites at the upper slope in the north and the lower slope in the south of the area of investigation. The transit times while traversing at night between them were almost exclusively used to complete a multibeam survey of the entire area. On the northern slope the survey clearly defined two broad almost circular, slightly elevated dome structures, one about 7 n.m. and the other about 12 n.m. across. Both structures show evidence of venting. The smaller one is located between 500-800 m of water depth with the summit at 480 m; the larger one lies at 800-1800 m and it's summit reaches to about 780 m. Additionally, the summit is topped (755m) by a steep edifice of blocky carbonates which was one of the major targets of our continued investigation.

OFOS-runs and CTD-stations conducted on 12/13 June gave evidence that the eastern slope is active while the western slope of the large dome structure appears devoid of any vent activity down to about 2200 m. The methane content at Station 34 of less than 1 micromol-L which is about one-half of the equilibrium value of methane in the atmosphere, thus provided a reliable background value against which positive methane anomalies, albeit small, can be evaluated.

The entire day of 13 June was devoted to run a grid of 8 OFOS-tracks, about 150m apart and each about 1 n.m. long, perpendicular to the south-facing deep channel wall, where previously several distinct vertical cliffs, caused by displacement of sediment blocks, and with patches of clam communities had been observed. Only 2 crossings in the vicinity of the earlier sightings showed clam fragments. Towards the east, where the broadening and deepening channel empties into the inactive Manila Trench outside our area of investigation, the individual cliffs became steeper, some with up to 30 m of sheer walls, and large and more chaotic blocks of sediments moving downslope. No evidence of venting was present.

June 14 brought RF SONNE back to the deep „bubble site“ at 3010 m at the western portion of the channel to sample life clam colonies. Two deployments yielded an impressive number of dead articulated and disarticulated vent clams, curiously almost all of the same size of between 3-4 cm. Most belonged to the genus Calyptogena but several specimens of dead Acharax were among them The uniform size distribution and lack of dissolution features suggest that the entire population might have died suddenly, either through termination of the vent activity or inundation by turbitity currents, as the entire channel is filled with numerous turbidites. These were evident in a 460cm long gravity core taken near the bubble site. The pore water composition as well as the methane content indicated that the core did not come from an active vent site but rather represented the channel environment of rapid sedimentation, intense early diagenesis, and that an advective flow was transporting methane upwards.

Early on 15 June a CTD-cast on the east slope of the large dome structure in the north showed a small but significant methane anomaly in the water column between 750-600 m. The large shallow methane maximum at 300 m, possibly derived from the nearby shelf was present as well, whereas the western slope showed background methane. Based on these data two OFOS-runs across the entire summit confirmed that the western edge was devoid of venting but contained bizarrly dissected pothole-type erosional features, whereas the eastern edge with the carbonate edifice was the most active on. In fact the extent, size and active appearance of this carbonate structure inspired to name it the „Jiu Long Chemoherm“ (= Nine Dragon Chemoherm).

Almost an entire day of sampling by TVG-deployments showed the blocky, erect carbonate edifice to be crossed by fractures at the bottom of which clam colonies thrieve and bacterial mats line the vertical walls. The erect structures are surrounded by a thick talus apron of carbonate rubble and an enormous number of dead vent clams of all sizes, the largest well over

10 cm long. Preliminary identification as provided by geologists, suggest that these clams belong to at least four taxa: Calyptogena sp., Acharax sp. Conchocele sp. and Bathymodiolus sp.; very likely other species and genera are present. Sampling on 16 June yielded several hundreds of whole, articulated as well as disarticulated specimens aside from several kilograms of shell fragments and huge carbonate blocks showing the well-known vent fabric.

June 17 was devoted to gravity coring the „bubble site“ at the southern channel arounf 3010m. Four cores were successfully taken each one longer than the previous one. A composite pore water profile showed almost exponentially increasing methane and hydrogen sulfide contents, which when extrapolated indicated that between 12-14 mbsf methane saturation and hence gashydrates might be reached.

For the following day and a half RV SONNE returned north to investigate the larger of the 2 dome structures. Here seismic surveys provided by GMGS suggested that several faults separating rotating slide blocks and originating from BSR-depths, come to the surface. OFOS-runs and CTD-casts along the east-facing slope however, revealed not the slightest evidence for methane venting. Venting activiy appears confined to the summit of the structure.

June 18 and 19 were largely spent coring the deep „bubble site“ in the hope of obtaining samples from the depth of methane saturation. Whereas the previous cores were taken using soft plastic tube liners for rapid access to the samples and hence could not exceed 9 m in length, the renewed attempt for greater depth (12m) had to make use of the rigid plastic core liners which greatly diminished penetration. Yet, after circumventing several technical obstacles, we managed to obtain an 830m long core. Preliminary analyses confirmed the continued rate of increase of methane with depth, yet the core did not reach the depth of methane saturation. In the morning of 19 June RV SONNE rendevouded with the GMGS-operated RV HAIYANG Nr. 4, which had been operating in the area to exchange some electronic equipment. The sea state was not ideal and the operation was quickly brought to a conclusion and station work continued.

On June 20 an OFOS-survey and CTD-cast were extended down the eastern flank of the northern dome to depths of over 2000 m; as previously, though, no evidence for venting was found. In the early morning of 21 June the Jiu Long chemoherm was sampled; hereby the TVG-sampler yielded an extraordinarily well developed chemoherm carbonate with thick aragonite linings. These grow into empty void spaces, conceivably left by dissociating gas hydrates. The carbonates did not contain iron-managese staining and appeared a lot fresher than the ones previously sampled, the same was the case for the clam shells. At about 0900 station work was completed and RV SONNE took course towards Hongkong, where she is expected to be at the pilot station on at 1200 in 22 June.

Weather continued to be excellent (water and air 28°C) with little or no wind thus providing ideal working conditions. Working together as a team, getting acquainted with each other on a personal level, and taking on new tasks by all participants was exemplary. Currently, a ping pong tournament on baord attended by almost all is underway; the winners will be determined shortly before arriving Honkong; therefore stay tuned...

On board RV SONNE 21 June 2004

#### *4.1.3 Weekly Report; 22 –30 June 2004*

With arrival in Hongkong in the early afternoon of 22 June, Leg 1 of the 177th voyage of RV SONNE came to an end; unfortunately without determining the champion ot the table tennis tournament (see 2. Report). The end of Leg 1 was celebrated in style at a Chinese restaurant at the invitation of the Guangzhou Marine Geological Survey. This was a really big affair and highly appreciated by all; we inspected the impressive tanks with life sea food before sitting down at round tables in an upstairs separate room of the restaurant. The numerous courses were splendid; abalony steak, glaced chicken, wanton soup, filled dumplings, spicy noodles, fresh water fish, and a rice-an-pork dish wrapped in bamboo leaves, to name a few. The latter is the traditional dish for the dragon boat festival which happened to be on that day. We learned the origin of that dish from ancient China, something to do with a poet who fell in disfavor with the administration .... it is a long story.

Early the next day, 7 membes of the scientific crew left the vessel and returned to Guangzhou and Germany, respectively before their replacements arrived during the afternoon. Further in the morning officials of the State Oceanic Administration (SOA), the agency responsible for granting the research clearance, arrived for an inspection of the scientific equipment and a ship's general tour. The German consul paid a visit around noontime and expressed considerable interest in the type of research being conducted. Much of the day on board was used to install a new transducer in the moonpool of the vessel, needed for the Super Short Base Line (SSBL) navigation of instruments while on the sea floor.

At 0900 the next morning RV SONNE departed Hongkong after an unexpected brief and efficient procedure with the immigration and customs authorities, unlike when departing 3 weeks earlier. After arrival at area „A" station work begun at 1400 on 25 June with 3 CTD-profiles at the eastern end of the deep channel. High methane values (4 µM/litre) were found here in a bottom water layer below 3150m. An OFOS-run across these sites however did not reveal any venting activity. Tentatively, we think that the continuous break-off of large blocks of sediment, which create the steep cliffs at the lower slope and are scattered over the channel floor, might actually release enough diagenetically-produced methane to enrich the bottom water layer; although this idea remains speculative.

On 26 June a successful operation at the Haiyang4-site yielded a 972 cm core in a 15-m barel, where the lower part showed clear degassing features. Yet another search for a live clam fields by TV-MUC s in that area was unsuccessful. June 27 brought us north again to the area of the carbonate mound for a CTD- cast and OFOS-survey of new targets between 550-600m of water depths, which had emerged while completing the multibeam map. They were northward extensions of the previously known carbonate mounds. Both areas proved to be large extinct features dominated by chimneys, open tubes, cemented burrows and doughnut-shaped crusts piled high to resemble bone-beds. At the northern JiuLong carbonate mound a flank collapse exposed a network of interconnected cemented channels enclosing indurated sediments. Several TV-grabs yielded abundant samples from the second of the new targets. Continued mapping in the northwestern corner of the area revealed at least one more likely carbonate mound feature. All seem aligned in SW-NE direction with their summits held up by a cap of carbonates, either as rubble, platforms or pinnacles.

June 27–28 was spent coring and surveying again at the Haiyang4-site; a 726 cm long gravity core and two TV-MUCs completed the sampling program. From the detailed pore water chemistry an interesting picture emerged showing broad, well-defined sulfate reduction and methane consumption zones located at roughly 750, 550, 400, 200 and 10 cmbsf (= cm below sea floor) which suggest doming of the interface and perhaps breaching of the seafloor at clam sites. Below the interface methane concentrations increase rapidly, which by extrapolation suggest methane saturation to be reached somewhere around 1400 cmbsf. Significant negative Cl-anomalies are also recorded below the interface suggesting either upward advection of deeply-sourced fluids or dissociation of minute amounts of gashydrates.

On 29 June at 1500 hrs local time RV SONNE departed area „A" and sailed towards area „B" just ahead of typhoon „Mindulle", which hand lingered between Luzon and Taiwan long enough for us to complete station work. Currently we are underway and expect to arrive in area „B" by midnight 30 June. The transit time was designated „Science Day" with presentations as follows:

- Xin Su: Variations in grain-size of sediments in correlation with gas hydrate distribution on Hydrate Ridge (Leg 204).
- Fritz Abegg: Investigation of the internal gas hydrate structure.
- Olaf Pfannkuche: Long-term deep-sea observatories based on lander technology.
- Xinghe (Bill) Yu: Seismic facies and dstribution of depostional systems in the Dongsha and Xisha areas of the South China Sea since Miocene times.

Weather continued to be good with little or no wind, although overcast skies and occasional thunder storms and nightly downpours prevail, yet ideal working conditions remain. The 11 new members of the scientific crew have become fully integrated into the working teams and provide much needed hands to work up the ever longer cores and larger samples retrieved from the seafloor.

On board RV SONNE 1 July 2004

### *4.1.4 Weekly Report; 1 – 10 July 2004*

On 1 July at 00:02 hrs local time RV SONNE entered area „B“ and started surveying roughly parallel to the 1000 m contour across the entire area. The profile ended on the following morning at a site previously selected for detailed studies based on video-camera deployment by the Chinese research vessel Haiyang4. Their survey had shown what appears to be an exposed crust parallel to the sea floor with several circular holes. We had interpreted this image to be an authigenic carbonate resulting from cold vent activity. A CTD-station placed downslope of this site, however did not show the slightest methane anomaly in the water column neither at the depth of the observed crust nor anywhere above. This was followed by an OFOS-run starting at a slump scar above the targeted site and crossing it, but no evidence for recent nor past venting was observed either. The following night the multibeam survey was continued, at first parallel to the slope and adjacent to the previously run profile but ending perpendicular to the slope at a deep location (2550m) in the south of area „B“. Here another CTD-station with high resolution spacing near the sea floor and bracketing the 1100 –700 m water depth in detail was completed the next day. It showed no trace of anomalous methane. Work continued by surveying upslope towards the vicinity of the suspected carbonate crust. Here another OFOS-run, ranging from 800 to 1200 and overlapping the first one, remained equally unsuccesful in locating any recent or fossil vent activity. A final attempt was made by placing a CTD-station at a location with elevated methane in sediments, but again no anomaly was found. In fact the concentrations measured at les than 0.3 nM/L were among the lowest values encountered anywhere and contributed to the decision to terminate work in area „B“ in the early morning of 3 July (05:30 hrs local time).

Terrmination of work in area „B“ does not imply that there is no recent cold vent activity but rather that the time needed to systematically search for such activity would not have been available. Moreover, the onboard interpretation of results were encouraging enough to warrent an early departure to make better use of ship time in area „A“.

The following transit was again used for science meetings and work on the cruise report. The presentations during 3 July were as follows:

- ZHANG Hangtao „Organisation and accomplishments of the Geological Survey of China (GCS)“ and
- Katja HEESCHEN and Jürgen HOHNBERG on „Concept and application of the pressure conserving coring system (DAPC = dynamic autoclave piston corer)“.

Although the GSC mission addresses largely land-based work, but three case studies presented by ZHANG on environmental issues (Hg-pollution), geohazard mitigation and agricultural geochemistry were very interesting and much appreciated by all. Equally strong interest was shown in the high-pressure technolgy developed jointly between TU-Berlin-GEOMAR-RCOM-Bremen primarily for gas hydrate research but also applicable to gaseous sediments as encountered at Haiyang4-site of the deep channel in area „A“, where we were headed.

Upon re-entering area „A“, while the southwest monsoon had started and moderate winds and overcast skies prevailed, RV SONNE conducted on July 4 and 5 four OFOS-runs, one TV-MUC and two gravity core deployments as well as one CTD-cast at specific target sites in the deep channel. The objective was to locate and sample active vent sites and penetrate deep (8-12 m) into the zone of predicted free gas. The newly installed SSBL-system (super short base line navigation) was expected to enable or at least facilitate this task by guiding the instruments towards the target site. Whereas the system worked very well at water depths down to 1000 to 1500 m, our deep targets at over 3000 m could not be re-located within the accuracy of a couple of 10s of meters deemed neccessary from the sea floor observations. The spread of fixes and hence the uncertainty increased dramatically below 2000 m such that it became impossible to sample the targeted sites. There is a clear depth limitation of the currently installed SSBL-system. The problem encountered was aggrevated a bit by the winds and shifting currents. In spite of these poorly suitable conditions, we deployed the DAPC. The system worked successfully as indicated by the pressure conservation of 95 bar, although no gas could be extracted because the site was not an active gas escape site.

During the night of July 5-6, while completing survey lines at the western margin of area „A“ RV SONNE headed northwest towards the newly mapped elevated feature in the hope that it would represent a similarly developed carbonate mound as the Jui Long methane reef. After completing 2 of 3 OFOS-runs it became obvious that this was not the case. The entire summit area had been searched as well as slope failures and slump scarpes on the western flank of the mound. The remaining time was used to complete an extented OFOS run at the northern extension of the Jui Long site, which previously had been surveyed for just 17 minutes. On the way there, by prior arrangement with the GMGS research vessel FENG DOU two scientists were üicked up at high seas who had been called on short notice to attend a proposal review panel meeting in Beijing.

The OFOS survey of the northern Jui Long extension revealed a vast accumulation of vent carbonate debris, pavements and edifices standing above the seafloor and covering the slopes. The peculiar circular pockmarks were observed again. They were concentrated along the southern and western flanks between 550-650m. In several cases a single upright columnar carbonate pipe was observed sticking up in the center of the pockmark. Although hard to imagine, it appeared that the pipe, initially embedded in a less indurated matrix, might have caused bottom currents to swirl around it and in the process eroded the circular depressions.

During the night the multibeam survey continued along the shelf edge, the northern limit of the area „A“ where the shallow water depths allowed only limited coverage. On 7 July TV-MUCs were taken at the small active center site of Jui Long and indeed showed 80 µM of methane just a few cm below seafloor. This is in agreement with the faint methane plume (1.8 nMol/l above a background of 0.8 nMol/l) detected in the water column at the same site. This concluded work in the northern part of area „A“ having fully documented hitherto unknown cold seep carbonate mounds. The size of these carbonate structures, now largely extinct or fading out fast, and the amount of methane carbon fixed are impressive and must be among to the largest cold seep carbonate accumlations known anywhere in the ocean. Laboratory analyses done on a piece of crust sampled during SO-177 Leg 1, speedily provided to us on board by Anton EISENHAUER of the Isotope Facility at IFM-GEOMAR, unambiguously show that the carbon is exclusively methane-derived ($\delta^{13}C$ = -56.5 to –57.5 per mil PDB) and that the calculated equilibrium isotopic composition of the precipitating fluid is between +0.98 and +1.11 per mil SMOW. Since precipitation occurred in contact with seawater, these values indicate glacial ocean water composition. This is further in excellent agreement with the $^{230}Th$-$^{234}U$-ages derived from that same crust placing it at 46.7 ky ago, the low sea level stand of O-isotope stage 4. Hence, the inferred enormous activity of gas venting at Jui Long, whether from dissociating gas hydrate or from a free gas reservoir, has occurred some time ago and might have been driven by pressure reduction due to lower sea level. This discovery ranks as the scientific high light of the entire cruise SO 177.

During the transit south during the remainder of 7 July two widely-spaced CTD-casts were run, 45 and 20 n.m. apart, resolving the water depths range between 2800 and 3000 m. They showed that bottom water methane anomalies were present only in the deep channel but much farther west than previously detected and also along the south-eastern bank of the channel, adjacend to the large seamount at the southern boundary of area „A“.

July 8 brought us back to the Haiyang4-site with further attempts to locate and sample active sites of gas escape. Two TV-MUCs appeared particularly well placed both with clam fragments and slimy-looking bacterial(?) matter. However, only one showed high methane concentrations (400 µM/L at 3 cmbsf) whereas the other showed only 5 µM/L at 20 cmbsf. The same difference was measured in the bottom water sampels above the MUC-cores; e.g. 480 nMol/L and 6.4 nMol/L, respectively . It remains a puzzle why such large differences occur on such a small scale, yet it illustrates the difficulty in hitting active sites by gravity- as well as DAPC-coring. The DAPC was deployed late on 8 July but unfortunately did not conserve the in situ pressure on account of a failed valve gasket. The gasket is supected to have been damaged during the previous deployment by coarse sediment grains causing grooves in the material. Another OFOS-run across a similar feature as Haiyang4 but located eastward across a tributary to the deep channel did reveal a few scattered clams but not anything spectacular to warrant a change in our planning.

Therefore, work during the remaining days concentrated on the south-side of the deep channel and the seamount because an OFOS-run mid-way from the seamount to the south bank of the channel had shown scattered clams at the base at 2800m water depth. This field could however not be relocated with the TV-MUC and we had to settle for an ordinary seafloor sample.

A final CTD-cast up-channel showed the well-developed steadily increasing methane concentration towards the sea floor (0.2 to 0.9 nMol/l) as with other channel stations. However, since it was placed at 2980m, significantly shallower than the others, we must conclude that the methane-rich bottom water layer is not bounded by a stratified water masse above but seems to be related to bottom water flow down the channel. During such a flow the bottom water would pick up and accumulate methane either from seafloor vents, such as the Haiyang4-site, or generate methane from suspended particles in the bottom nepheloid layer. This possibility must be entertained when interpreting all of the hydrographic hydrochemical data obtained during both legs of SO 177.

The ascertain a remote possibilty of hydrothermalism on or around the seamount, which the previous OFOS-run had shown to be largely free of sediment, we placed a final OFOS-transect from the summit if the seamount down its flanks towards the deep channel. The total vertical distance was over 1000m. All features of an extrusive seafloor volcano were observed. Most impressive of which were the pillow lavas; fewer occured on the summit but they were dominant at the flanks and at the base. Pillows and lava extrusions were exposed in ravines and along 50-100 m high cliffs alternating with sediment covered narrow ledges of seafloor. Bottom current featuers, such as ripples and winnowing were evident all around the volcano, particularly interesting was the difference in benthic fauna observed down the north-west-facing slope into the current with suspension feeders dominant and the south-east-facing slope located in the current shadow with deposit feeders dominant. Alas, no evidence for hydrothermal activity was found.

The route of departure from the southern boundary of area „A“ towards the north was placed to complete a 120 n.m. long gap in the multibeam coverage along the western boundary. This profile was completed at 12:40 on 10 July and the RV SONNE took course towards Shanghai. We eagerly anticipate the end of the Lge 2 and the visitors program in Shanghai. Tentatively, over 200 visitors from universities, government and research institutions are scheduled to tour the vessel on July 14 and 15. The 66 hrs. transit to the pilot boarding station at the mouth of the river will be used to hold meetings in preparation of the visitors program. This leaves little time to resume the table tennis tournament the enthusiasm for which had vanished through the arrival of several top class players, somewhat intimitading the regulars.

Weather continued to be good, although arrival of the southwest monsoon brought overcast skies and several windy days. Currently though the sun is out, the winds are down and the sea provides smooth sailing. On behalf of all cruise participants we send greetings to the respective home institutions, our families and friends from board RV SONNE; our last report will be from Shanghai and deal with logistics and visitors events.

On board RV SONNE 10 July 2004

### *4.1.5 Weekly Report; 11 – 20 July 2004*

In transit from the working area to Shanghai FS SONNE steamed first NW around the edge of Taiwan Banks and then NNE through the Taiwan Strait. On the evening of 11 July captain and chief scientist had invited all to a concluding party on the afterdeck. The weather was unusually favourable for this time of year and the festivities were enjoyed by all. On 12 July several meetings were held to organize the visitors program for the Shanghai port call. With moderate tail winds FS SONNE reached the pilot boarding station off the Huangpu River mounth easily in the early morning of 13 July. The pilot boarded at 0700 and the journey upriver through the southern channel lasted about 6 hrs. Initially the broad expanse of sediment-laden water and the inumerable vessels on the horizon indicated that we were nearing land. Then the low sand banks came into view and vessels streamed in and out of the water way. At about 10:00 the outer fringes of Shanghai were passed with Pudong Airport to be seen in the south and huge shipbuilding complexes, petroleum refineries and storage facilities following upriver. Traffic on the river became extremely heavy with barges, container ships, fishing vessels and others of non-definable function cruising passed on eiher side. After another bend in the river the skyline of the Huangpu district of Shanghai was reached offering plenty of photo opportunities before FS SONNE tied up at the international passenger terminal at about 1300.

Immediately thereafter the lay out of the visitors tour and the science stations were prepared as well as hand-outs printed. In all 22 stops throughout the ship were selected to be staffed by scientists starting with the welcome station upon entering the vessel up the gangway. Then the tour turned aft towards the work deck. Here deep-sea instrumtation were displayed and samplesshown and explained.Then the tour went foreward across the upper deck past the live rafts and up the outer stairs to the bridge. From here down past the library, the cabins, down another stairway to the main deck past the mess room to the conference room. Here a continuous slide show was installed entitled Life on board SONNE.

Form there the tour went aft on the starboard side past the hospital and down a last flight of stairs through the crews quarters and entering the Kegelbahn. Here in several laboratories stations were set up to explain and show the analytical facilities and work procedures onboard, e.g. pore water and gas analyses.The multibeam recording and processing rooms were next followed by the computer facility. From here the tour went up to the geology laboratory where further exhibits were displayed and a summary of the high lights of OFOS-,TVG- and TV-MUC-run were shown. This tour was thoroughly laid out and prepared and it was felt that it should be documented for future visitots tours.

At 09:00 visitors arrived hourly in groups of 30-40 persons. After checking in through security, a laborious process, smaller groups of about 15 persons were formed and each accomagnied by one German and one Chinese scientist were sent on their tour. In this way it we lead over 140 persons through the vessel between 09:00 and 16:00 hrs without delay or other complications and with an optimum of information conveyed. Although the guides were exhausted, everyone were pleased with the response shown by all. The visitors came from the following institutions with the approximate numbers indicated: Association of Mineral Resources (6), Zeijang University, Hangzhou (4 ), First Institute of Ocean Sciences, Qingtao (2), Sichuan Ocean Special Technology Institute (3), Guangzhou Marine Geological Survey (17), Shanghai Vessel Design Institute (21), Second Institute of Ocean Sciences, Hangzhou ( 53), Center for Marine Geochemistry, Nanjing University (13), China Geological Survey, Beijing (3) and Tongji Univesity, Shanghai (23).This listing shows the wide interest accorded the visit by RV SONNE to Shanghai but more importantly it demonstrates the interest in cooperation and future joint projects.

It should not go unnoticed that all visitors had to be processed through the immigration authorities including issuing prior invitations by name, providing original ID-documents and obtaining numbered boarding permits. This immense paperwork would not have been possible without the support provided on shore by the interrnational coordinator of GMGS. Nor should go unmentioned that the German watch standers on board RV SONNE had to cope with the permits issued in Chinese to check all against the visitors list. Miracuously in the end everything worked out well.

At the same time the visitors program went on, inspection teams from SOA, the State Oceanic Administration conducted an extremely throrough, sometime cumbersome inspection which occupied captain and chief scientist for most of the day with support by members of the GMGS. In the end though a joint inspection report was composed and signed and accepted by all parties.

Plans for the concluding dinner of cruiseSO 177 on 14 July were changed on short notice as Vice Minister Zou from the Ministry of Land & Resources arrived earlier because she would be unable to attend the reception scheduled for 15 July. Therefore, the ships scientific party and crew together with the German-Chinese goverment delegation currently in Shanghai were invited to the famous Seagull Restaurant, one of the oldest traditional eating places in Shanghai, for a brief ceremony and sumptous dinner attended by over 100 persons.

Following the dinner, Vice Minister Zou and a small delegation paid a visit to the vessel, where she followed the same tour as the visitors earlier in the day. She was an absolutely appreciative guest and showed considerable enthusiasm before departing around 23:00 hrs.

Most of 15 July was occupied with preparations for the late afternoon reception consuming considerable discussion time with the agent, the caterer, the officials from the Ministry of Land and Resources, the German Consulate General and the Bundesministerium für Bildung und Forschung. Not withstanding any unsettled issues, 15 minutes before the scheduled starting time, a banner was strung up on the side of the vessel, a red carpet rolled out on the pier, a band, in what appeared to us heavy duty uniforms, showed up, and flowers (pink) were unlaoded. At 16:05 sharp, the German consul general's car drove up, the band played one brief march then retreated into the rather narrow shadow of a nearby wall, and the speeches began. The scientists had lined up alongside the red carpet: all hoping the speeches would be over soon as the sun was beating down relentlessly and the thermometer was hovering near 40° (in the shadow). Indeed, the offical program was brief and all streamed aboard to take cover under the sunroof and disbursed into the various laboratories. The buffet had been set up in the geology laboratory and small groups of visitor embarked from here on individual tours. With the end of the reception around 19:00 hrs all scientists of SO 177, except four who sailed on to Pusan, were leaving the vessel to travel to their respective home towns.

On 16 July at 13:00 hrs RV SONNE set course for Pusan, where she tied up on 18 July at 14:00 hrs, thus officially ending the voyage SO 177. As the wealth of scientific data becomes viewed more closely, the experience gained in working together is fully appreciated and the offical speeches on cooperation become completely implemented, this voyage might truely stand as a mile stone in Chinese-German marine research. On behalf of all onboard scientists and technicians we wish to thank captain and crew for their continuous and unfailing highly professional support, which in no smallmeasure contributed to the success and always pleasant atmosphere during this voyage.

In port Shanghai 20 July 2004

## 4.2 Wochenberichte

### 4.2.1 Wochenbericht 2.-11. Juni 2004

Am 2. Juni, dem ersten Chartertag des Geologischen Dienstes der Volksrepublik China (GMGS, Guangzhou Marine Geological Survey) auf FS SONNE, traf eine 21-köpfige Gruppe von Wissenschaftlern aus Guangzhou und Deutschland in Hongkong ein. Der folgende Tag war ganz dem Entladen der Container, dem Aufbau schweren Geräts, dem Einrichten der Laboratorien sowie Stauarbeiten gewidmet.

Am Morgen des 4. Juni um 10:00 Uhr verließ FS SONNE den Hafen und nahm nach langwierigen Ausreiseformalien Kurs auf das ca. 250 Seemeilen entfernte Untersuchungsgebiet im Nordosten des Südchinesischen Meeres. Am Nachmittag fand sich die wissenschaftliche Besatzung zu einem Treffen zusammen, das vor allem dazu diente, sich gegenseitig kennenzulernen, die unterschiedlichen Gruppen mit den Gepflogenheiten an Bord vertraut zu machen und Arbeitsgruppen zusammenzustellen. Es folgten die Einführung zur Schiffssicherheit, die Vorstellung des Kapitäns, des Chefingenieurs, der Offiziere, des Systemoperators, der technischen Dienste und des Bordarztes sowie ein Rundgang durch das Schiff.

Am Morgen des 5. Juni erreichte FS SONNE das Untersuchungsgebiet. Nachdem mithilfe einer CTD-Station das Schallgeschwindigkeitsprofil für die Kalibrierung des akustischen Systems erstellt worden war, begann eine Fächerecholotvermessung, die am 6. Juni am östlichen Ende eines in Ost-West Richtung durch das Gebiet laufende Rinne endete. Messungen im Bodenwasser zeigten bei 3060 m leichte Methananomalie und bestätigten damit, daß eine, wenn auch nur leichte, cold vent Aktivität vorhanden ist. Durch weiteren CTD-Einsatz westlich entlang des Südhangs der Rinne, die jetzt ein deutlicheres Anomaliemuster lieferte, wurde dies bestätigt. Ein OFOS-Profil in einem Winkel zur Streichrichtung der Rinne zeigte einen glatten Meeresboden mit starker Sedimentbedeckung und ohne nennenswerte topographische Merkmale mit Ausnahme mehrer Steilstuen. Dieser Abschnitt besteht aus 7 deutlichen vertikalen Abrissstufen, jede mehrere Meter hoch, die durch Rutschung von Sedimentblöcken hangabwärts enstanden sind. Am Fuß der ersten und zweiten Stufe wurden mehrere Muschelkolonien beobachtet.

In der folgenden Nacht wurden die Beobachtungen in nördlicher Richtung ausgedehnt, um die oberen Hangebiete zu erfassen. Hier wurden am 6. Juni zwei OFOS-Profile von 600–1200 m über eine breite Erhebung gefahren, die von Kanälen umgeben und durchschnitten ist. Der Meeresboden war mit irregulären Feldern kringelförmiger ("Doughnut"-förmiger) Karbonate und Gerölls bedeckt, diese Lithologien sind typisch für Methan-Karbonate an Cold Vents. Es konnten keine Anhaltspunkte für lebende benthische Ventgemeinschaften gefunden werden, obwohl eine starke Methananomalie bei ca. 400 m gemessen wurde aber kein morphologisches Merkmal als Quelle identifiziert werden konnte. In der darauffolgenden Nacht wurden die Beobachtungen Richtung Süden ausgedehnt und endeten wiederum an der Rinne, um ein Profil nachzufahren, auf dem das chinesische Forschungsschiff HAIYANG 4 dichte benthische Gemeinschaften sowie mögliche Blasenaustritte beobachtet hatte. Die OFOS-Bilder bestätigen das Vorkommen relativ dichter benthischer Gemeinschaften und kleiner, kreisförmiger Bakterienfelder, es konnte in diesem Gebiet jedoch keine bedeutende Methananomalie in der Wassersäule festgestellt werden. Der erste Versuch, Proben mit dem TV-geführten Multicorer zu nehmen, wurde durch den herannahenden Taifun Coson unterbrochen, der sich aus südlicher Richtung dem Arbeitsgebiet näherte. Alle Forschungsaktivitäten wurden am 8. Juni um 16:00 bei starkem Wind, hohem Seegang und einer dichten Wolkendecke eingestellt. FS SONNE wich in westlicher Richtung aus und kehrte am späten Nachmittag des nächsten Tages zurück.

Dieser kurze Ausflug gab der wissenschaftlichen Besatzung am 9. Juni Zeit für ein Seminarprogramm, das Präsentationen zu Tektonik und seismischer Arbeit im südchinesischen Meer wie auch zur Rolle von authigenen Karbonaten als Archive der Ventingaktivität umfaßte. In der Zwischenzeit passierte der Taifun unser Untersuchungsgebiet und wandte sich westwärts durch die Luzon-Straße in den westlichen Pazifik mit nördlicher Richtung auf Okinawa zu. Am 8. Juni um 21:00 Uhr kam das Zentrum des Sturms dem Schiff mit 75 Meilen am nächsten; es wurde von Windgeschwindigkeiten um 75 Meilen in der Stunde und 6 – 14 m hohen Wellen berichtet. Nach der Rückkehr ins Untersuchungsgebiet wurde eine Reihe von OFOS-Profilen rechtwinklig zum steilen südwärtigen Abhang der Rinne östlich des beschriebenen Blasenaustrittes durchgeführt. Da keine neuen Hinweise auf Vent-Aktivität auftraten, wurde für den 10. Juni eine Beprobung dieses Blasenaustrittes mit dem TV-geführten Multicorer angesetzt. Dies sollte eine recht frustierende Aufgabe werden, da keine der vielversprechenden Muschelkolonien wiedergefunden werden konnten. Das Instrument selbst arbeitete gut, und bei drei Versuchen konnten jeweils sechs volle Kernrohre geborgen werden. Die Kerne zeigten eine oxidierte Schicht von unterschiedlicher Mächtigkeit (2–25 cm), gefolgt von Sand-Turbiditen und mit Sulfiden gefleckten dunkelgrauen Sedimenten. Die Porenwasserdaten weisen darauf in, daß diese dünne Oxidationsschicht in der Tat einen verstärkten Aufwärtsstrom methanhaltiger Fluide anzeigt als in den Gebieten mit einer mächtigeren Oxidationsschicht; im Vergleich zu ähnlichen Gebieten erscheint die Gesamtintensität des Austrittes jedoch stark reduziert.

Den 11. Juni verbrachte FS SONNE wiederum in der nördlichen Hangzone, um die Tiefe der vorher beobachteten starken Methananomalie zu bestätigen und besser aufzulösen. Die Anomalie zeigte sich jetzt zwichen 150 bis 450 m Wassertiefe. Ein OFOS-Profil über die flachste Struktur (550–900 m) zeigte Felder von Karbonaten und Karbonatgeröll sowie eine prominente 30 m hohe Karbonatstruktur. Eine darauffolgende Beprobung mit dem TV-Greifer erbrachte alle nur denkbaren Formen authigener Karbonate wie Krusten, plattige Präzipitate, bizarre, durch die Füllung von Zwischenräumen enstandene Formen, Schlote mit einzelnen und mehreren Öffnungen sowie zementierte Kanäle. Mehrere davon schienen aus Dolomit zu bestehen, besonders die bekannten kringel- oder ringförmigen Gebilde. Der letzte Einsatz des TV-Greifers lieferte einen großen Karbonatblock (mehr als 150 kg), durchzogen von unzähligen Kanälen, Gängen und Ausflußstrukturen sowie einer großen Zahl benthischer Organismen, die entweder auf der Oberfläche lebten oder fest in die Karbonatmatrix einzementiert waren. Weder scheinen diese Organismen mit den bekannten chemosynthetischen Lebensgemeinschaften in Verbindung zu stehen noch sind die Karbonate jüngeren Datums wie aus dem Überzug aus Mangan-Eisen-Oxid zu schliessen.

Alle bisher gefundenen Anhaltspunkte stützen die Vorstellung eines großflächigen und starken Methanaustrittes am oberen Hang des nördlichen Südchinesischen Meeres. In der Vergangenheit war dieser mit Sicherheit sehr ausgeprägt, heute ist die Aktivität der Vents reduziert oder erloschen. In der tiefen Rinne am Südende des Untersuchugsgebietes (3050 m) ist jedoch entlang der gesamten Südflanke über mehr als 25 n.m. eine rezente Vent-Aktivität nachweisbar. Alle bisher untersuchten Stationen zeigen eine vergleichsweise schwache Aktivität, die niedrigen Methankonzentrationen reichen wahrscheinlich nicht aus um auf obeflächennahe Gashydrate zu schliessen.

Mit Ausnahme des Taifuns Coson hatten wir hervorragendes Wetter (Wasser- und Lufttemperaturen bei 28 bzw.26°C). Zusammen mit der guten Stimmung und hervorragender Zusammenarbeit an Bord ergeben sich somit ideale Arbeitsbedingungen, so daß wir dem Fortgang der Arbeiten mit Optimismus entgegensehen. Allen Teilnehmern geht es gut, und sie grüßen ihre heimatlichen Institute.
Auf See FS SONNE 12. Juni 2004

### *4.2.2 Wochenbericht; 12.-21. Juni 2004*

In den vergangenen 10 Tagen waren unsere Aktivitäten auf See nahezu gleichmäßig zwischen den beiden Vent-Lokationen am oberen Hang im Norden und am unteren Hang im Süden des Untersuchungsgebietes aufgeteilt. Die beim Wechsel zwischen den beiden Lokationen entstehenden nächtlichen Transitzeiten wurden fast ausschließlich für die Fächerecholotkartierung des gesamten Areals genutzt. Am nördlichen Hang zeigt die Vermessung zwei breite, fast kreisförmige und leicht aufgewölbte Strukturen von 7 bzw. 12 n.m. im Durchmesser. Beide Strukturen zeigen Anzeichen von Venting, im einem Falle zwischen Wassertiefen von 500 und 800 m, wobei der Gipfel bei 480 m liegt. Im anderen Falle zwischen 800 und 1800 m mit der Gipfelregion bei 780 m. Zusätzlich findet sich auf dem Gipfel eine steile Struktur blockförmiger Karbonate (Wassertiefe hier: 755 m). Diese Struktur war eines der Hauptziele unserer laufenden Untersuchungen.

OFOS-Profile und CTD-Messungen vom 12. Juni an den Flanken der tiefer gelegenen Struktur lieferten Hinweise auf aktive Austritte am östlichen Hang während der westliche Hang bis etwa 2200 m keinerlei Aktivität erkennen läßt. Hier beträgt der Methangehalt weniger als ein Mikromol/Liter und damit etwa die Hälfte des durchschnittlichen Methangehalts im Gleichgewicht mit der Atmosphäre. Solche niedrigenWerte stellen damit einen verläßlichen Hintergrund dar, gegen den selbst kleinste positive Methananomalien bewertet werden können.

Nach Transit ins südliche Arbeitsgebiet wurde der gesamte 13. Juni zur Vermessung eines engen Rasters von 8 OFOS-Profilen genutzt. Diese wurden mit einer Länge von je 1 nm und in einem Abstand von etwa 150 m rechtwinklig zum Hang im östlichen Teil der tiefen Rinne angelegt. Hier waren zuvor mehrere deutlich erkennbare vertikale Abhänge, verursacht durch Rutschung von Sedimentblöcken, sowie Muschelkolonien beobachtet worden. Nur zwei Profile zeigten in Nähe der früherer Sichtungen Muschelfragmente. Richtung Osten, wo die Rinne sich verbreitert und vertieft und in den inaktiven Manila Tiefseegraben ausläuft, der außerhalb unseres Untersuchungsgebietes liegt, werden die einzelnen Abhänge steiler, teilweise mit bis zu 30 m hohen vertikalen Wänden. Größere Sedimentblöcke bewegen sich in chaotischer Form hangabwärts. Hier wurde keine Hinweise auf Venting gefunden.

Am 14. Juni dampfte FS SONNE zurück zu dem durch vermeintliche Blasenaustritte bei 3010 m gekennzeichneten westlichen Teil der Rinne, um hier lebende Muschelkolonien zu beproben. Zwei Probenahmen lieferten eine beachtliche Zahl toter Ventmuscheln, in den meisten Fällen mit noch zusammenhängenden Schalen; nur wenige Einzelschalen waren darunter. Bemerkenswert ist, daß fast alle die gleiche Größe von 3-4 cm aufweisen. Die meisten gehörten der Gattung Calyptogena an, aber auch einige tote Acharax Individuen fanden sich darunter. Die gleichförmige Größenverteilung und das Fehlen von Lösungserscheinungne lassen vermuten, daß die gesamte Population abrupt ausgelöscht wurde, entweder durch ein Versiegen der Methanzufuhr oder durch Turbidit-Ablagerungen, von denen die gesamte Rinne gefüllt ist. Turbiditlagen kommen hier in allen Schwerelotkernen vor. Die Zusammensetzung des Porenwassers sowie der Methangehalt wiesen darauf hin, daß die Kerne nicht direkt aus einem aktiven Vent stammten, sondern eher die Ablagerungsbedingungen mit schneller Sedimentation und intensiver Frühdiagenese widerspiegeln wobei Methan durch vertikalen Aufstieg zugeführt wird.

Am Morgen des 15. Juni ergab eine CTD-Beprobung der Wassersäule über der östliche Flanke der nördlich gelegenen Domstruktur eine kleine, aber signifikante Methananomalie. Auch das deutlich stärkere Methanmaximum bei 300 m, das schon früher gemessen wurde und möglicherweise vom nahen Schelf stammt, war hier festzustellen, während die westliche Flanke nur Hintergrundwerte aufwies. Auf der Basis dieses Befundes wurden zwei OFOS-Profile über den gesamten Gipfel gelegt. Hierdurch wurde bestätigt, daß nur an der östlichen Flanke, an der die Karbonatstruktur liegt, aktive Methan-Emissionen auftreten. Das Ausmaß, die Größe und die augenscheinlich starke Aktivität am Fusse dieser Karbonatstruktur rechtfertigt eine Namensgebung: "Jiu Long – Methane Reef" (= Neun-Drachen-Methanriff). Nach unserer Kenntnis ist diese Struktur die erste überhaupt die aus dem Südchinesischen Meer bisher bekannt ist; bemerkenswert ist, dass sie entlang eines passiven Kontinentalrandes auftritt.

An der westlichen Flanke der Struktur wurde keine Vent-Aktivität beobachtet jedoch bizarr zergliederte, schlaglochähnliche Erosionsstrukturen wie sie durch Malsteine bei starker Strömung entstehen. Zylindrische Vertiefungen von wenigen Dezimetern bis mehreren Metern im Durchmesser und ebenso tief zergliederten die gegenüberliegenden Wände eines steilen Einschnittes. Am Boden der Löcher waren ausnahmslos faustgrosse Karbonat-fragmente, wie sie in der aktiven Gipfelregion anstehen, zu erkennen.

Fast ein gesamter Tag wurde für Beprobungen des "Jiu Long – Methanriffs" mit dem TV-Greifer verwendet. Es zeigte sich, daß die blockartige, aufrechte Karbonatstruktur von Brüchen durchzogen ist, an deren Flanken Muschelkolonien im Karbonatschutt gedeihen. Bakterienmatten bekleiden jeweils gegenüberliegende vertikale Wände von Brüchen durchzogenen Karbonatblöcken. Die aufrechten Strukturen sind von einer dicken Schutthalde aus Karbonattrümmern und einer gewaltigen Zahl toter Ventmuscheln aller Größen umgeben. Die größten davon sind mehr als 10 cm lang und von massiver Schalenausbildung. Eine vorläufige Identifizierung, die von Geologen erstellt wurde, weist darauf hin, daß diese Muscheln mindestens vier Gattungen angehören: Galyptogena sp., Acharax sp., Conchocele sp., und Bathymodiolus sp.. Höchstwahrscheinlich sind auch noch andere Arten bzw. Gattungen dabei. Probenahmen am 16. Juni lieferten mehrere hundert vollständige erhalten Schalenpaare, Einzelklappen sowie mehrere Kilogramm Schalenfragmente und Karbonatblöcke, die die bekannte Struktur der Ventkarbonate aufweisen.

Am 17. Juni wurden an der Stelle des „Blasenaustrittes“ (der sich bei näherer Inspektion des Videobandes der chinesichen Expedition nicht bestätigen lassen konnte) bei 3010 m im südlichen Kanal Schwerelotkerne entnommen. Es konnten erfolgreich vier Kerne gezogen werden, von denen jeder länger als der vorhergehende war (630 –680 cm). Ein kombiniertes Porenwasserprofil zeigte fast exponentiell ansteigende Gehalte an Methan und Schwefelwasserstoff im untersten Teil. Eine Extrapolierung ergab, daß eine Methansättigung zwischen 12-14 mbsf und somit die Bildung von Gashydrat möglich ist.

In den folgenden eineinhalb Tagen orientierte FS SONNE sich wieder Richtung Norden, um die tiefer gelegenen Flanken der größeren der beiden Domstrukturen zu untersuchen. Seismische Daten, die durch den GMGS zur Verfügung gestellt worden waren, wiesen darauf hin, daß hier mehrere Störungen, an denen verstellte (leicht rotierte) Rutschungsblöcke voneinander getrennt sind, aus BSR-Tiefen bis zur Oberfläche reichen. OFOS-Profile und CTD-Proben den ostwärtigen Hang entlang lieferten minimalste Anzeichen für Methanaustritte die nicht weiterr verfolgt wurden. Die stärkere Aktivität scheint auf den Gipfel der Struktur beschränkt zu sein.

Der 18. und 19. Juni wurden wiederum für Kernentnahmen an der Stelle des tiefen „Blasenaustrittes“ verwendet, in der Hoffnung, Proben aus der Tiefe der Methansättigung zu erhalten. Während die früheren Proben mit Linern aus Plastikfolie genommen worden waren, um die Proben schnell zugänglich machen zu können, und daher nicht länger als 9 m sein konnten, machte dieser neue Versuch mit dem Ziel, in größere Tiefen (12 m) zu gelangen, die Verwendung fester Plastikliner notwendig. Hierdurch wurde die Eindringtiefe stark verringert. Nachdem jedoch einige technische Hindernisse umgangen worden waren, gelang es uns, einen 830 cm langen Kern zu ziehen. Vorläufige Analysen bestätigten die kontinuierliche Zunahme des Methangehalts mit der Tiefe (bis 10 mmol/L), der Kern reichte jedoch nicht bis in die Tiefe der Methansättigung (bei ca. 60 mmol-L). Am Morgen des 19. Juni hatte FS SONNE ein Rendezvous mit dem vom GMGS betriebenen FS Haiyang Nr. 4, das in der gleichen Gegend gearbeitet hatte, um elektronische Ausrüstung auszutauschen. Die Seebedingungen waren nicht ideal, daher wurde das Maneuver rasch beendet, um mit der Stationsarbeit fortzufahren.

Am 20. Juni wurden die OFOS- und CTD-Arbeiten die östliche Flanke des nördlichen Doms herunter bis in Tiefen von über 2000 m weitergeführt, wie zuvor waren jedoch keine Hinweise für Austrittsstellen zu finden. Am frühen Morgen des 21. Juni wurde das „Jiu Long – Merthanriff" erneut beprobt. Der TV-Greifer lieferte ein hervorragend entwickeltes Fragment an frischem Karbonat mit dicken Aragonitschichten. Diese wachsen in Hohlräume die denkbar von Gashydrat nach der Zersetzung hinterlassen wurden. Die Karbonate wiesen keine Eisen–Manganüberzüge auf und wirkten viel frischer als diejenigen, die zuvor beprobt worden waren. Dasselbe galt für die Muschelschalen. Gegen 09:00 Uhr wurde die Stationsarbeit beendet, und FS SONNE nahm Kurs auf Hongkong, wo wir am 22. Juni um 12:00 an der Lotsenstation erwartet werden.

Das Wetter war die ganze Zeit hervorragend (Wasser und Luft 28°C) mit wenig oder gar keinem Wind und bot somit ideale Arbeitsbedingungen. Alle Teilnehmer verhielten sich vorbildlich in Bezug auf die Teamarbeit, das gegenseitige persönliche Kennenlernen und die Übernahme neuer Aufgaben. Zur Zeit nehmen fast alle Teilnehmer an einem Tischtennis-Tunier teil, die Gewinner sollen kurz nach der Ankunft in Hongong bekanntgegeben werden, man darf also gespannt sein...
Auf See FS SONNE 21. Juni 2004

#### *4.2.3 Wochenbericht; 22.-30. Juni 2004*

Mit unserer Ankunft in Hongkong am frühen Nachmittag des 22. Juni endete der erste Fahrtabschnitt der 177. Reise des FS SONNE. Leider konnte bis zu diesem Zeitpunkt der Sieger des Tischtennisturniers (siehe 2. Wochenbericht) nicht ermittelt werden. Das Ende des ersten Fahrtabschnittes wurde auf Einladung des Guangzhou Marine Geological Survey stilvoll in einem chinesischen Restaurant gefeiert. Unsere Gastgeber hatten keinen Aufwand gescheut, und alle Teilnehmer wußten diese Mühe sehr zu schätzen. Zunächst nahmen wir große Becken mit lebenden Meerestieren in Augenschein, bevor wir in einem Séparée im oberen Stockwerk an runden Tischen Platz nehmen durften. Die zahlreichen Gänge waren hervorragend, darunter zum Beispiel Seeohr-Steak, kandiertes Huhn, Wantan-Suppe, gefüllte Klöße, pikant gewürzte Nudeln, Süßwasserfisch und ein Reisgericht mit Schweinefleisch in einer Hülle aus Bambusblättern. Bei letzterem handelt es sich um die traditionelle Speise zum Drachenbootfestival, das gerade an diesem Tag stattfand. Wir erfuhren, daß dieses Gericht seine Wurzeln im alten China hat, in der Geschichte eines Poeten, der sich bei der Verwaltung mißliebig machte – eine lange Geschichte.

Früh am nächsten Morgen verließen sieben Mitglieder der wissenschaftlichen Besatzung das Schiff und kehrten nach Guangzou und Deutschland zurück. Die Ablösung traf im Laufe des Nachmittages ein. Am Morgen fand außerdem eine Überprüfung der wissenschaftlichen Ausrüstung und eine Besichtigung des Schiffes durch offizielle Vertreter der State Oceanic Administration (SOA), die für die Vergabe der Forschungsgenehmigung verantwortlich ist, statt. Der deutsche Konsul stattete FS SONNE gegen die Mittagszeit einen Besuch ab und brachte ein großes Interesse an unseren Forschungsarbeiten zum Ausdruck. An Bord wurde der Tag vor allem dafür genutzt, im Moonpool des Schiffes einen neuen Transducer anzubringen, der für die "Super Short Base Line" (SSBL)-Navigation der Instrumente am Meeresboden benötigt wird.

Am nächsten Morgen verließ FS SONNE Hongkong um 09:00 Uhr, nachdem die Einreise- und Zollformalien, anders als bei der Abfahrt 3 Wochen zuvor, unerwartet rasch und effizient abgewickelt worden waren. Bei unserer Ankunft im Untersuchungsgebiet "A" begannen die Stationsarbeiten am 25. Juni um 14:00 mit drei CTD-Profilen an der Ostseite der tiefen Rinne.

Hier wurden in einer Bodenwasserschicht unterhalb von 3150 m hohe Methanwerte (4 nM/Liter) gemessen. Ein OFOS-Profil an dieser Stelle zeigte jedoch keine Venting-Aktivität. Am unteren Hang rutschen ständig große Sedimentblöcke ab, wie wir sie auf dem Boden der Rinne finden. Durch diesen Prozeß werden die Steilhänge des unteren Hanges gebildet, und nach unserer vorläufigen Vorstellung könnte dabei ausreichend Methan diagenetischer Herkunft frei gesetzt werden, um das Bodenwasser anzureichern. Diese Vorstellung ist jedoch spekulativ.

Am 26 Juni lieferte ein Schwerelot-Einsatz einen Kern von 972 cm Länge. Der untere Teil zeigte deutliche Anzeichen von Entgasung. Ein weiterer Versuch, in dieser Gegend lebende Muschelfelder zu finden, blieb jedoch erfolglos. Am 27. Juni wurden wiederum im Norden in der Gegend der Karbonatstruktur CTD-Proben genommen und OFOS-Erkundungen neuer Ziele in Wassertiefen von 550 – 600 m durchgeführt, die bei der Fertigstellung der Fächerecholot-Kartierung entdeckt worden waren. Es handelte sich um Verlängerungen der bekannten Karbonatstrukturen in Richtung Norden. In beiden Fällen handelt es sich um erloschene Strukturen, die durch Schlote, offene Röhren, zementierte Gänge und kringelförmige Krusten dominiert sind, jeweils hoch aufgetürmt, so daß sie Knochenhaufen ähneln. Am nördlichen Jiu Long – Methanriff hatte eine Rutschung an der Flanke ein Netzwerk von miteinander verbundenen zementierten Aufstiegs-Kanälen freigelegt, die verfestigte Sedimente durchsetzten. Mehrere Beprobungen mit dem TV-Greifer lieferten eine große Menge an Proben von diesem zweiten Untersuchungsobjekt. Die Weiterführung unserer Kartierungen in der nordwestlichen Ecke des Untersuchungsgebietes zeigte zuletzt eine weitere mögliche Karbonatstruktur welche bishe gänzlich ungekannt gewesen war. Die Strukturen scheinen in SW-NO-Richtung aufgereiht zu sein, ihre Gipfel sind jeweils von einer Karbonatkappe bedeckt, entweder in Form von Geröll, Plattformen oder freistehende Zinnen.

Den 27.-28. Juni verbrachten wir wiederum im Gebiet der Haiyang 4-Position, ein Schwerelotkern von 726 cm Länge und zwei TV-MUCs vervollständigten das Beprobungsprogramm. Die detaillierte Porenwasserchemie ließ ein interessantes Bild erkennen: Bei 750, 550, 400, 200 und 10 cmbsf (= cm below sea floor) fanden sich deutlich definierte Zonen von Sulfatreduktion und Methanverbrauch, die eine Aufwölbung der Grenzschicht und möglicherweise Durchbrüche zum Meeresboden dort vermuten lassen, wo Muschelfelder auftreten. Unterhalb dieser Grenzschicht steigen die Methankonzentrationen rasch an, und nach einer Extrapolation der Werte dürfte die Methansättigung ungefähr bei 1400 cmbsf erreicht werden. Unterhalb der Grenzschicht zeigen sich signifikante negative Chlorid-Anomalien, die entweder einen advektiven Aufstieg von Fluiden aus tiefen Quellregionen oder eine Zersetzung winziger Mengen von Gashydrat anzeigen.

Am 29. Juni verließ FS SONNE um 15:00 Ortszeit das Untersuchungsgebiet "A" und dampfte zum Untersuchungsgebiet "B", rechtzeitig, um dem Taifun "Mindulle" auszuweichen, der lange genug zwischen Luzon und Taiwan in seinen Fortgang gezögert hatte, um die Beendigung unserer Stationsarbeiten nicht zu gefährden. Zur Zeit sind wir auf dem Transit und erwarten, am 30. Juni gegen Mitternacht im Untersuchungsgebiet "B" einzutreffen. Die Transitzeit wurde zum "Tag der Wissenschaft" erklärt und es wurden die folgenden Vorträge gehalten:
Xin Su: Korngrössenverteilung und Auftreten von Gashydraten in Sedimenten des Hydrate Ridge (ODP Leg 204).
Fritz Abegg: Untersuchungen der inneren Struktur von Gashydraten.
Olaf Pfannkuche: Tiefsee-Langzeitobservatorien auf der Basis der Lander-Technologie.
Xinghe (Bill) Yu: Seismische Fazies und Verteilung von Ablagerungssystemen in den Regionen von Dongsha und Xisha im Südchinesischen Meer seit dem Miozän.

Das Wetter ist weiterhin gut mit wenig oder gar keinem Wind, obwohl ein bedeckter Himmel mit gelegentlichen Gewittern und nächtlichen Regengüssen vorherrscht. Die Arbeitsbedingungen sind dennoch ideal. Die elf neuen Mitglieder der wissenschaftichen Besatzung sind bereits vollständig in die Arbeitsgruppen integriert und sind eine große Hilfe bei der Bearbeitung der noch längeren Kerne und größeren Probenmengen , die wir vom Meeresboden bergen.

Im Namen aller Fahrtteilnehmer senden wir Grüße von Bord an die jeweiligen Heimatinstitute, unsere Familien und Freunde.
Auf See FS SONNE 1. Juli 2004

### *4.2.4 Wochenbericht; 1.-10. Juli 2004*

Am 1. Juli erreichte FS SONNE um 00:02 Ortszeit das Untersuchungsgebiet "B". Die Erkundung begann mit einem Profil, das in etwa parallel zur 1000-m-Kontur quer durch das gesamte Untersuchungsgebiet verlief. Dieses Profil endete am nächsten Morgen an einer Stelle, die zuvor auf der Basis von Videoaufnahmen, die das chinesische Forschungsschiff Haiyang 4 gemacht hatte, für eine detaillierte Untersuchung ausgewählt worden war. Die Videoaufnahmen zeigten etwas, das nach einer freigelegten Kruste parallel zum Meeresboden mit mehreren kreisförmigen Löchern aussah. Nach unserer Interpretation handelte es sich hier um authigene Karbonate, die auf "Cold Vent"-Aktivität zurückzuführen waren. Eine hangabwärts von dieser Stelle genommene CTD zeigte jedoch nicht die geringste Methananomalie in der Wassersäule: das galt sowohl für die Tiefe der beobachteten Kruste als auch für den gesamten Bereich darüber. Im Anschluß wurde ein OFOS-Profil gefahren. Es begann an einer Rutschungsspur oberhalb des Zielgebietes und führte dann quer über den fraglichen Bereich, jedoch waren keine Anzeichen für aktives oder früheres Venting zu erkennen. In der folgenden Nacht wurde die Fächerecholot-Vermessung fortgeführt. Der Kurs verlief zunächst hangparallel und direkt neben dem vorangehenden Profil, endete dann jedoch rechtwinklig zum Hang an einer tiefen Stelle (1550 m) im Süden des Untersuchungsgebietes "B". Hier wurde am nächsten Tag eine weitere CTD-Station mit hochauflösend gesetzten Abständen und einer besonderen Konzentration auf den Bereich zwischen 1100-700 m Wassertiefe gefahren. Es war keine Spur einer Methananomalie zu entdecken. Die Arbeiten wurden mit einer Vermessung hangaufwärts, auf die vermutete Karbonatkruste zu, fortgesetzt. Hier brachte auch ein weiterer OFOS-Einsatz, der von 800-1200 m überlappend mit dem ersten Profil durchgeführt wurde, keinen Erfolg im Sinne von Anzeichen einer neueren oder fossilen Vent-Aktivität. Als letzter Versuch wurde an einer Stelle mit erhöhten Methanwerten im Sediment eine CTD-Station durchgeführt, aber wiederum war keine Anomalie zu erkennen. Tatsächlich gehörten die Werte von weniger als 0,3 mM/l zu den geringsten, die an irgendeinem Ort gemessen werden konnten. Dies trug zu der Entscheidung bei, die Arbeiten im Gebiet "B" am frühen Morgen des 3. Juli (05:30 Ortszeit) zu beenden.

Die Einstellung der Arbeiten im Gebiet B bedeutet aber nicht, daß es hier keine jüngere Cold Vent–Aktivität gibt, sondern nur, daß die Zeit nicht für eine systematische Suche reichte. Außerdem ermutigten uns die Ergebnisse der Auswertungen an Bord zu einer frühen Rückkehr ins Untersuchungsgebiet "A", um dort mehr Schiffszeit zu investieren.

Die darauffolgende Transitzeit wurde wiederum für wissenschaftliche Seminare und zur Vorbereitung des Fahrtberichtes verwendet. Am 3. Juli wurden die folgenden Präsentationen gehalten:

- ZHANG Hangtao, "Organisation und Errungenschaften des Geologischen Dienstes der VR China (Geological Survey of China, GCS);
- Katja HEESCHEN und Jürgen Hohnberg, "Konzept und Anwendung des druckerhaltenden Kerngerätes (DAPC = Dynamic Autoclave Piston Corer)"

Obwohl der GCS sich vor allem landgestützten Untersuchungen widmet, waren die drei Fallstudien über Umweltfragen (Hg-Verschmutzung), Eindämmung geologischer Gefahrenpotentiale und Geochemie in der Landwirtschaft sehr aufschlußreich und stießen bei allen Teilnehmern auf großes Interesse. Ähnlich groß war das Interesse an der

Hochdrucktechnologie, die in einer Zusammenarbeit zwischen TU Berlin, IFM-GEOMAR und RCOM Bremen in erster Linie für die Gashydratforschung entwickelt worden war, sich aber auch für gashaltige Sedimente, wie wir sie in der tiefen Rinne im Untersuchungsgebiet "A" bei derHaiyang 4-Position vorfinden, bewährt.

Als wir wieder in das Untersuchungsgebiet "A" gelangt waren, hatte der Südwest-Monsun eingesetzt. Bei leichtem Wind und bedecktem Himmel fuhr FS SONNE am 4. und 5. Juli vier OFOS-Profile ab und führte jeweils an ausgewählten Positionen innerhalb der tiefen Rinne einen Einsatz des TV-MUC, zwei Schwerelot-Kernnahmen und eine CTD-Station durch. Das Ziel bestand darin, aktive Austrittsstellen zu beproben und tief (8-12 m) in die Zone einzudringen, in der wir freies Gas vermuten. Das neu installierte SSBL-System (Super Short Base Line Navigation) sollte dies ermöglichen oder zumindest erleichtern, indem es die Instrumente auf die Ziele zusteuerte. Während das System jedoch bis in Wassertiefen von 1000 bis 1500 m sehr gut funktionierte, konnten die tiefen Ziele bei über 3000 m Wassertiefe nicht mit einer Genauigkeit im zweistelligen Meterbereich, wie sie nach den Videobeobachtungen erforderlich schien, geortet werden. Die Streubreite der Peilungen und damit die Unsicherheit nahm unterhalb von 2000 m erheblich zu, so daß es nicht möglich war, Beprobungen an den Zielpositionen vorzunehmen. Das zur Zeit installierte SSBL-System weist damit eine deutliche Tiefenbeschränkung auf. Durch Wind und veränderliche Strömungen wurde das Problem noch etwas verschärft. Trotz dieser wenig günstigen Bedingungen wurde das DAPC eingesetzt. Das System funktionierte mit einer Druckerhaltung bei 95 bar einwandfrei, allerdings konnte kein Gas entnommen werden, da es nicht auf einem aktiven Gasaustritt abgesetzt worden war.

In der Nacht vom 5. auf den 6. Juli wurden die Vermessungsprofile am westlichen Rand des Untersuchungsgebietes "A" vervollständigt. Dabei bewegte sich FS SONNE Richtung Westen auf den neu kartierten Tiefseeberg zu, in der Hoffnung, es könnte sich um eine ähnlich ausgeprägte Karbonatstruktur handeln wie das Jiu Long – Methanriff. Nach 2 von drei geplanten OFOS-Profilen war klar, dass dies nicht der Fall war. Der gesamte Gipfelbereich war ebenso abgesucht worden wie Hangrutschungen und Rutschungsspuren an der westlichen Flanke des Tiefseeberges. Die restliche Zeit wurde dazu verwendet, ein ausgedehntes OFOS-Profil über die nördliche Verlängerung des Jui-Long-Methanriffs zu fahren. Dort war bisher nur eine 17-minütige Beobachtung durchgeführt worden. Auf dem Weg dorthin wechselten auf hoher See nach vorheriger Absprache zwei Wissenschaftler auf das Forschungsschiff FENG DOU des GMGS. Sie waren kurzfristig nach Peking abberufen worden, um dort an der Sitzung einer Gutachterkommission teilzunehmen.

Die OFOS-Bilder von der nördlichen Verlängerung des Jui-Long-Methanriffs zeigte eine große Ansammlung von Vent-Karbonat-Trümmern, Zementierungen und Strukturen, die über den Meeresboden hinausragten und die Hänge bedeckten. Wiederum wurden die charakteristischen kreisförmigen Eindellungen beobachtet. Sie waren auf den Bereich zwischen 550-650 m auf der südlichen und westlichen Flanke konzentriert. In mehreren Fällen war im Zentrum dieser Eindellungen eine einzige, aufrechte, säulenartige Karbonatröhre zu beobachten. Obwohl es schwer vorstellbar ist, sah es so aus, als hätten diese Röhren, die wohl zunächst in einer weniger verhärteten Matrix eingebettet waren, um sich herum kreisförmige Bodenströmungen verursacht, so daß durch Erosion die kreisförmigen Eindellungen entstanden.

In der Nacht wurden entlang des Schelfrandes die Fächerecholotvermessungen fortgesetzt. Im flachen Bereich war, da wir an die nördliche Grenze des Untersuchungsbereiches "A" kamen, nur eine unvollständige Abdeckung möglich. Am 7. Juli wurden in dem kleinräumigen aktiven Zentrum des Jui Long – Methanriffs TV-MUC-Proben genommen. In der Tat fanden sich nur einige Zentimeter unter dem Meeresboden 80µM Methan. Dies entspricht dem schwachen Methanplume (1.8 nMol/l bei einem Hintergrund von 0.8 nmol/l), der an dieser Stelle in der Wassersäule gemessen worden war. Diese Messungen bildeten den Abschluß der Arbeiten im nördlichen Teil des Arbeitsgebietes "A". Damit waren zuvor unbekannte Cold-Seep-

Karbonatstrukturen vollständig dokumentiert worden. Die Ausmaße dieser Karbonatstrukturen, die jetzt einem schon weit fortgeschrittenen Zerstörungsprozeß ausgesetzt sind, und die Mengen des gebundenen Methankohlenstoffs sind beeindruckend.

Dies dürfte eines der größten Vorkommen von Cold-Seep-Karbonaten im gesamten Ozean sein. Laboranalysen an einem der auf dem ersten Fahrtabschnitt geborgenen Krustenstücke, deren Ergebnisse uns von Anton EISENHAUER vom Isotopenlabor des IFM-GEOMAR innerhalb kürzester Zeit an Bord übermittelt werden konnten, zeigen eindeutig, daß es sich ausschließlich um Methan-Karbonat handelt ($\delta^{13}C$ = -56.5 bis –57.5 Promille PDB) und daß das errechnete isotopische Gleichgewicht bei Ausfällung der Fluide zwischen +0.98 and +1.11 Promille SMOW liegt. Da die Ausfällung in Kontakt mit Meerwasser stattfand, deuten diese Werte auf eine glaziale Zusammensetzung des Meerwassers hin. Dies stimmt auch hervorragend mit den $^{230}$Th-$^{234}$U-Datierungen der gleichen Kruste überein, nach denen das Alter bei 46,7 Ma liegt und damit in einer Zeit niedrigen Meeresspiegels mit Sauerstoffisotopen der Stufe 4. Der am Jui-Long vermutete enorme Gasaustritt, sei er durch die Zersetzung von Gashydrat oder durch ein Reservoir freien Gases gespeist worden, hat also schon vor längerer Zeit stattgefunden und könnte durch eine Druckverminderung aufgrund des niedrigeren Meeresspiegels verursacht worden sein. Diese Entdeckung kann als das wissenschaftliche Highlight der Fahrt SO 177 angesehen werden.

Während wir für den Rest des 7. Juli nach Süden dampften, wurden in Entfernungen von 45 und 20 nm noch zwei CTD-Stationen mit großen Abständen gefahren. Hier wurden die Wassertiefen zwischen 2800 und 3000 m aufgelöst. Es zeigte sich, daß nur in der tiefen Rinne Methananomalien auftraten, jedoch wesentlich weiter westlich als zuvor beobachtet und ebenfalls entlang des südöstlichen Walls in der Nähe des großen Tiefseeberges am südlichen Rand des Untersuchungsgebietes "A".

Am 8. Juli wurden wiederum im Bereich der Haiyang-4-Position Versuche unternommen, aktive Gasaustrittstellen zu orten und zu beproben. Zwei TV-MUCs schienen besonders günstig abgesetzt worden zu sein: Sie enthielten Muschelfragmente und schleimig aussehende (bakterielle?) Substanz. Jedoch wies nur einer davon hohe Methankonzentrationen (400µM/l bei 3 cmbsf) auf, während der andere nur 5 µM/l bei 20 cmbsf enthielt. Der gleiche Unterschied wurde auch in den Bodenwasserproben oberhalb der MUC-Kerne festgestellt: 480 nMol/l bzw. 6.4 nMol/l. Es bleibt rätselhaft, wie auf so engem Raum derartig große Unterschiede auftreten können. Um so anschaulicher wird dadurch jedoch die Schwierigkeit, aktive Stellen mit Schwereloten bzw. dem DAPC zu treffen. Das DAPC wurde spät am 8. Juli eingesetzt, leider jedoch versagte aufgrund einer defekten Ventildichtung die Druckerhaltung. Es wird vermutet, daß die Dichtung bei dem vorhergehenden Einsatz beschädigt worden war: das grobkörnige Sediment könnte in dem Material Schrammen verursacht haben. Ein weiteres OFOS-Profil von einer Struktur, die der Haiyang-4-Position ähnelt, aber weiter östlich jenseits eines Nebenarmes der tiefen Rinne gelegen ist, zeigte einige verstreute Muscheln, aber nichts, das spektakulär genug wäre, um unsere Planungen zu ändern.

Daher wurden die Arbeiten an den verbleibenden Tagen auf die Südseite der tiefen Rinne und auf den Tiefseeberg konzentriert: Ein Einsatz des OFOS, der auf halbem Wege vom Tiefseeberg bis zum südlichen Wall der Rinne gefahren wurde, zeigte am Fuße des Walls bei 2800 m Wassertiefe verstreute Muscheln. Dieses Feld konnte jedoch beim Einsatz des TV-MUC nicht wiedergefunden werden, daher mußten wir uns mit einer gewöhnlichen Probe des Meeresbodens zufrieden geben.

Eine letzte CTD-Station rinnenaufwärts zeigte wie andere Stationen innerhalb der Rinne zum Meeresboden hin stetig zunehmende Methankonzentrationen (0.2 bis 0.9 nMol/l). Da sie jedoch mit 2980 m deutlich flacher durchgeführt worden war als die anderen, müssen wir darauf schließen, daß die methanreiche Bodenwasserschicht nicht durch eine darüberliegende stratifizierte Wassermasse begrenzt ist, sondern mit dem Bodenwasserfluß entlang der Rinne zusammenzuhängen scheint. In diesem Fall würde das Bodenwasser entweder Methan aus Austrittsstellen am Meeresboden wie der Haiyang-4-Position aufnehmen und sich damit anreichern oder in der nepheloiden Bodenschicht würde aus suspendierten Partikeln Methan freiwerden. Auch diese Möglichkeit muß also bei der Interpretation aller hydrographischen hydrochemischen Daten, die auf beiden Abschnitten der Fahrt SO 177 gesammelt wurden, in Betracht gezogen werden.

Um die entfernte Möglichkeit eines Hydrothermalismus auf dem Tiefseeberg, der nach den vorhergehenden OFOS-Aufnahmen weitgehend frei von Sedimenten war, oder in seinem Umkreis zu verfolgen, wurde ein letztes OFOS-Profil von seinem Gipfel die Flanke hinunter in Richtung der tiefen Rinne gelegt. Insgesamt wurden in vertikaler Richtung über 1000 m zurückgelegt. Es konnten am Meeresboden alle Kennzeichen eines extrusiven Vulkans beobachtet werden. Am eindrucksvollsten waren dabei die Kissenlaven. Auf dem Gipfel waren weniger davon anzufinden, aber auf den Flanken und am Fuße waren sie dominant. Lavakissen und –extrusionen lagen in Klüften und entlang 50 – 100 m hoher Abhänge offen da, sie wechselten sich mit schmalen, sedimentbedeckten Simsen ab. Überall im Bereich des Vulkans waren von Bodenströmungen erzeugte Strukturen wie Riffelungen oder Auswaschungen zu erkennen. Besonders interessant war der Unterschied der benthischen Fauna auf dem nordwestlich in die Strömung gewandten Hang, auf dem Organismen vorherrschten, die sich von Schwebeteilchen ernähren, zu jener auf dem südöstlich im Strömungsschatten liegenden Hang, wo sich vor allem Organismen angesiedelt hatten, die sich von Ablagerungen ernähren. Hinweise auf Hydrothermalismus ergaben sich jedoch leider nicht.

Unser Kurs vom südlichen Rand des Untersuchungsgebietes "A" Richtung Norden wurde so gesetzt, daß eine 120 nm lange Lücke in den Fächerecholotdaten entlang des westlichen Randes geschlossen werden konnte. Dieses Profil wurde am 10. Juli um 12:40 fertiggestellt, und FS SONNE nahm Kurs auf Shanghai. Wir freuen uns schon auf das Ende des 2. Fahrtabschnittes und das Besuchsprogramm in Shanghai. Mehr als 200 Besucher von Universitäten, Regierung und Forschungseinrichtungen werden zur Besichtigung des Schiffes am 14. und 15. Juli erwartet. Der 66stündige Transit bis zur Lotsenstation in der Flußmündung wird für Besprechungen zur Vorbereitung des Besuchsprogramms genutzt werden. Damit bleibt wenig Zeit zur Wiederaufnahme des Tischtennisturniers: Der Enthusiasmus war zuletzt geschwunden, da die Ankunft mehrerer Spitzenspieler die Stammspieler eingeschüchtert hatte.

Das Wetter war weiterhin gut, obwohl das Einsetzen des Südwestmonsuns einen bedeckten Himmel und einige windige Tage mit sich brachte. Momentan schient jedoch die Sonne, der Wind ist gering und die See erlaubt uns eine ruhige Fahrt. Im Namen aller Fahrtteilnehmer schicken wir von FS SONNE Grüße an die jeweiligen Heimatinstitute, an unsere Familien und Freunde. Unser letzter Wochenbericht wird aus Shanghai kommen und von den Ladearbeiten und dem Besuchsprogramm berichten.
Auf See FS SONNE 10. Juli 2004

### *4.2.5 Wochenbericht; 11.-20. Juli 2004*

Die Transitstrecke vom Arbeitsgebiet nach Shanghai führte FS SONNE zunächst nordwestlich in Richtung der taiwanesischen Küste und dann nordnordöstlich durch die Straße von Taiwan. Für den Abend des 11. Juli hatten der Kapitän und der Fahrtleiter alle Fahrtteilnehmer zur Abschlussparty auf dem Achterdeck eingeladen. Das Wetter war für die Jahreszeit ungewöhnlich freundlich, und Alle hatten viel Spaß an der Feier. Am 12. Juli wurden noch mehrere Treffen zur Organisation des Besuchsprogrammes im Hafen von Shanghai abgehalten. Mit mäßigem Rückenwind erreichte FS SONNE die Lotsenstation nahe der Mündung des Huangpu-Flusses problemlos am frühen Morgen des 13. Juli. Der Lotse ging um 07:00 Uhr an Bord, und die Reise flussaufwärts *durch den südlichen Kanal/ entlang der* *südlichen Fahrrinne(?)* dauerte etwa 6 Stunden. Zunächst deuteten ein breiter Strom sedimentführenden Wassers und unzählige Schiffe am Horizont an, daß wir uns dem Land näherten. Dann kamen die niedrigen Sandbänke in Sicht, sowie Schiffe, die in die Wasserstraße hinein bzw. hinaus strömten. Um etwa 10:00 hatten wir die Außenbezirke von Shanghai passiert, im Süden waren der Flughafen von Pudong sowie große Werftanlagen zu sehen. Flussaufwärts folgten dann Ölraffinerien und Speichergelände. Auf dem Fluss herrschte inzwischen ein äußerst reger Verkehr. Binnenschiffe, Containerschiffe, Fischereifahrzeuge sowie weitere Schiffe undefinierbarer Funktion passierten uns auf beiden Seiten. Nach einer weiteren Flussbiegung kam die Skyline des Huangpu-Distrikts von Shanghai in Sicht und bot zahlreiche Fotomotive, bevor FS SONNE um 13:00 am internationalen Passagierterminal anlegte.

Unverzüglich wurden der Besichtigungsrundgang und die wissenschaftlichen Schaustationen vorbereitet und Handzettel gedruckt. Beginnend mit der Begrüßungsstation beim Betreten des Schiffes über die Gangway wurden 22 Punkte auf dem Schiff ausgewählt, die von Wissenschaftlern betreut werden sollten. Nach dem Betreten des Schiffes wandte der Rundgang sich nach achtern auf das Arbeitsdeck. Hier war das Tiefsee-Instrumentarium ausgestellt, außerdem wurden Proben gezeigt und erklärt. Danach ging es nach vorn über das Oberdeck an den Rettungsflößen vorbei und die Außentreppe hinauf zur Brücke. Es folgten die Bibliothek und die Kabinen. Eine weiteren Aufgang hinunter ging es zum Hauptdeck und an der Messe vorbei zum Konferenzraum. Hier lief eine ständige Diashow mit dem Titel "Leben an Bord der SONNE".

Von hier aus wandte sich der Rundgang auf der Steuerbordseite am Hospital vorbei und einen letzten Aufgang hinunter nach achtern. Nach dem Passieren der Mannschaftsquartiere gelangte man auf die Kegelbahn. Hier waren in mehreren Laboren Schaustationen eingerichtet worden, anhand derer die analytischen Gerätschaften und die Laborarbeiten an Bord, wie z. B. Porenwasser- und Gasanalyse, erläutert und dargestellt werden sollten. Als nächstes kamen die Fächerecholot-Station und die Datenverarbeitungsräume, gefolgt vom Rechnerraum. Nun ging es wieder aufwärts zum Geolabor, wo weitere Schaustücke standen und die Highlights der OFOS-, TV-Greifer- und TV-MUC-Einsätze gezeigt worden. Der Rundgang war sehr sorgfältig geplant und vorbereitet, und es wurde angeregt, diesen für spätere Besuchsprogramme zu dokumentieren.

Ab 9:00 trafen stündlich 30-40köpfige Personengruppen ein. Nachdem sie sich einer Sicherheitsüberprüfung unterzogen hatten – ein aufwändiger Prozess – wurden kleinere Gruppen von etwa 15 Personen gebildet und je von einem deutschen und einem chinesischen Wissenschaftler auf ihrem Rundgang begleitet. Auf diese Weise konnten wir zwischen 09:00 und 16:00 mehr als 140 Personen durch das Schiff führen, ohne daß es Verzögerungen oder andere Schwierigkeiten gegeben hätten, und dabei ein Höchstmaß an Information vermitteln. Obwohl die Führer hinterher sehr erschöpft waren, freuten sich alle Beteiligten über die gute Resonanz. Die Besucher kamen von den folgenden Institutionen (ungefähre Teilnehmerzahl in Klammern): Gesellschaft für minerale Ressourcen (6), Zeijang-Universität, Hangzhou (4 ), Erstes Institut für Meereswissenschaften, Qingtao (2), Institut für spezialisierte Meerestechnologie von Szechuan (3), Meeresgeologischer Dienst Guangzhou (GMGS) (17), Institut für Schiffbau Shanghai (21), Zweites Institut für Meereswissenschaften, Hangzhou ( 53), Zentrum für Marine Geochemie, Nanjing-Universität (13), Geologischer Dienst der VR China, Peking (3), Tongji-Universität, Shanghai (23). Diese Liste zeigt das breite Interesse, das der Besuch des FS SONNE in Shanghai ausgelöst hat, wichtiger noch, es zeigt das Interesse an Kooperation und zukünftigen gemeinsamen Projekten.

Wir sollten nicht unerwähnt lassen, daß alle Besucher von den Einreisebehörden abfertigt werden mußten. Dies schloß die vorherige Ausstellung namentlicher Einladungen, die Vorlage originaler Passdokumente und die Erteilung nummerierter Genehmigungen zum Betreten des

Schiffes ein. Diese immense Verwaltungsarbeit wäre nicht möglich gewesen, wenn wir nicht an Land durch den internationalen Koordinator des GMGS unterstützt worden wären. Auch die deutschen Wachgänger an Bord der FS SONNE, die die auf chinesisch ausgestellten Dokumente mit der Besucherliste abgleichen mußten, sollen nicht unerwähnt bleiben. Wie durch ein Wunder klappte am Ende Alles hervorragend.

Noch während das Besuchsprogramm lief, führten Inspektionsteams der staatlichen Schiffahrtsbehörde (State Oceanic Administration, SOA) eine extrem genaue, mitunter sehr beschwerliche Inspektion durch, die den Kapitän und den Fahrtleiter mit Unterstützung durch Mitglieder des GMGS für den größten Teil des Tages beschäftigte. Schließlich konnte jedoch ein gemeinsamer Inspektionsbericht erstellt und von allen beteiligten Parteien genehmigt und unterzeichnet werden.

Die Pläne für das Abschlußessen wurden kurzfristig geändert, als Vizeministerin Zhou vom Ministerium für Land und Rohstoffe früher eintraf als erwartet, da sie zum Empfang am 15. Juli verhindert sein würde. Die wissenschaftliche Besatzung und die Schiffsbesatzung wurden daher zusammen mit der zu diesem Zeitpunkt in Shanghai weilenden deutsch-chinesischen Regierungsdelegation in das berühmte Seagull-Restaurant eingeladen. Hierbei handelt es sich um eines der ältesten traditionellen Speiselokale von Shanghai. Hier fanden eine kurze Zeremonie und ein üppiges Abendessen für über 100 Personen statt.

Nach dem Abendessen statteten Vizeministerin Zhou und eine kleine Delegation dem Schiff einen Besuch ab. Hierbei folgten sie dem gleichen Rundgang wie zuvor die Besuchergruppen. Sie war ein sehr dankbarer Gast und drückte sehr viel Enthusiasmus auf, bevor sie gegen 23:00 Uhr das Schiff verließ.

Der größte Teil des 15 Juli war den Vorbereitungen für den Empfang am späten Nachmittag gewidmet. Die Besprechungen mit dem Agenten, dem Catering-Service, den offizielen Vertretern des Ministeriums für Land und Rohstoffe, dem deutschen Generalkonsulat und dem Bundesministerium für Bildung und Forschung nahmen viel Zeit in Anspruch. Ungeachtet der ungeklärten Punkte wurden jedoch 15 Minuten vor dem festgelegten Termin ein Banner an der Seite des Schiffes aufgehängt und ein roter Teppich auf der Pier ausgerollt. Es stellte sich eine Kapelle ein, deren Uniformen für uns nach *Kampfanzügen/ Schwerlastausrüstung(?)* aussahen, und rosafarbene Blumen wurden entladen. Genau um 16:05 fuhr der Wagen des deutschen Generalkonsuls vor. Die Kapelle spielte einen kurzen Marsch und zog sich dann in den schmalen Schatten einer nahen Mauer zurück, womit die Reden begannen. Die Wissenschaftler hatten sich entlang des roten Teppichs aufgestellt, in der Hoffnung, daß die Reden bald vorbei sein würden, denn die Sonne brannte erbarmungslos und die Temperaturen lagen bei 40° im Schatten. Tatsächlich war das offizielle Programm kurz, und Alle strömten an Bord, um unter dem Sonnensegel Schutz zu suchen und sich in die verschiedenen Labore zu verteilen. Das Buffet war im Geolabor aufgebaut worden, und kleine Besuchergruppen brachen von hier aus zu individuellen Rundgängen auf. Der Empfang endete um 19:00 Uhr und alle Mitglieder der wissenschaftlichen Besatzung der Fahrt SO 177 mit der Ausnahme vierer, die nach Pusan mitfuhren, verließen das Schiff, um in Richtung ihrer jeweiligen Heimatstädte zu reisen.

Am 16. Juli setzte FS SONNE um 13:00 Uhr Kurs auf Pusan, wo sie am 18. Juli um 14:00 einlief. Damit war die Fahrt SO 77 offiziell beendet. Während die wissenschaftlichen Ergebnisse jetzt genauer unter die Lupe genommen werden, ist die gemeinsam bei der Zusammenarbeit gesammelte Erfahrung unschätzbar, und wenn die offiziellen Reden zur chinesisch-deutschen Kooperation voll umgesetzt werden, könnte diese Fahrt tatsächlich einen Meilenstein in der internationalen Meeresforschung darstellen.
In port Shanghai 20. Juli 2004

china_tracks_A

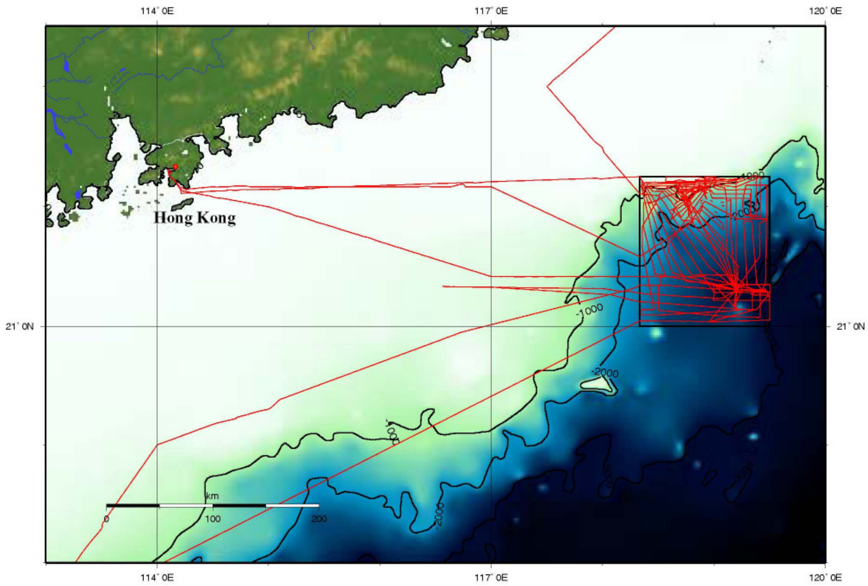



Figure 4.1 Cruise track Area A

china_tracks_B

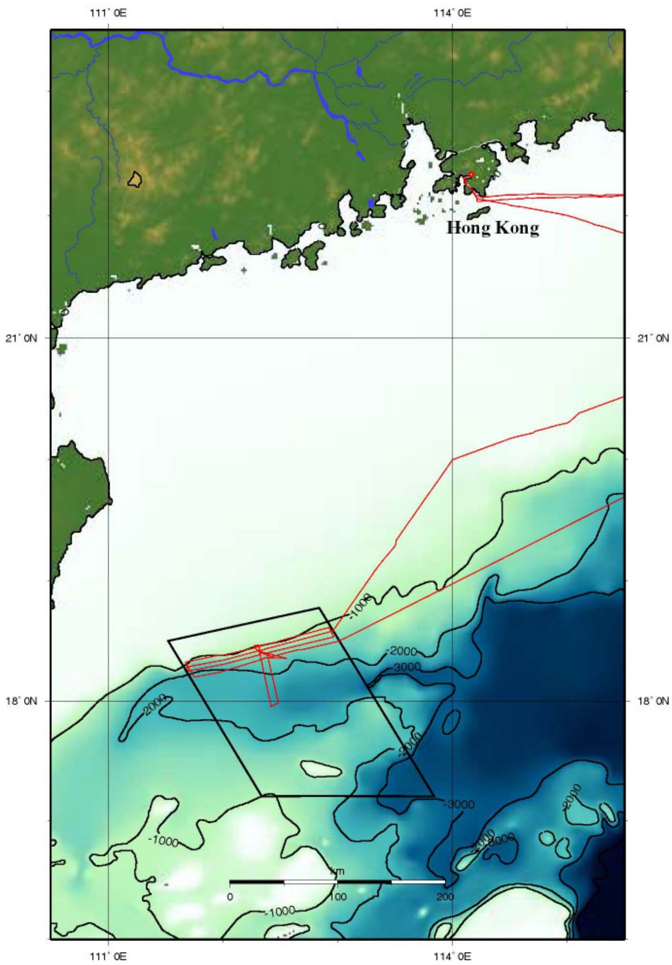



Figure 4.2 Cruise track Area B

A_bathy_all_inserts_text_A4

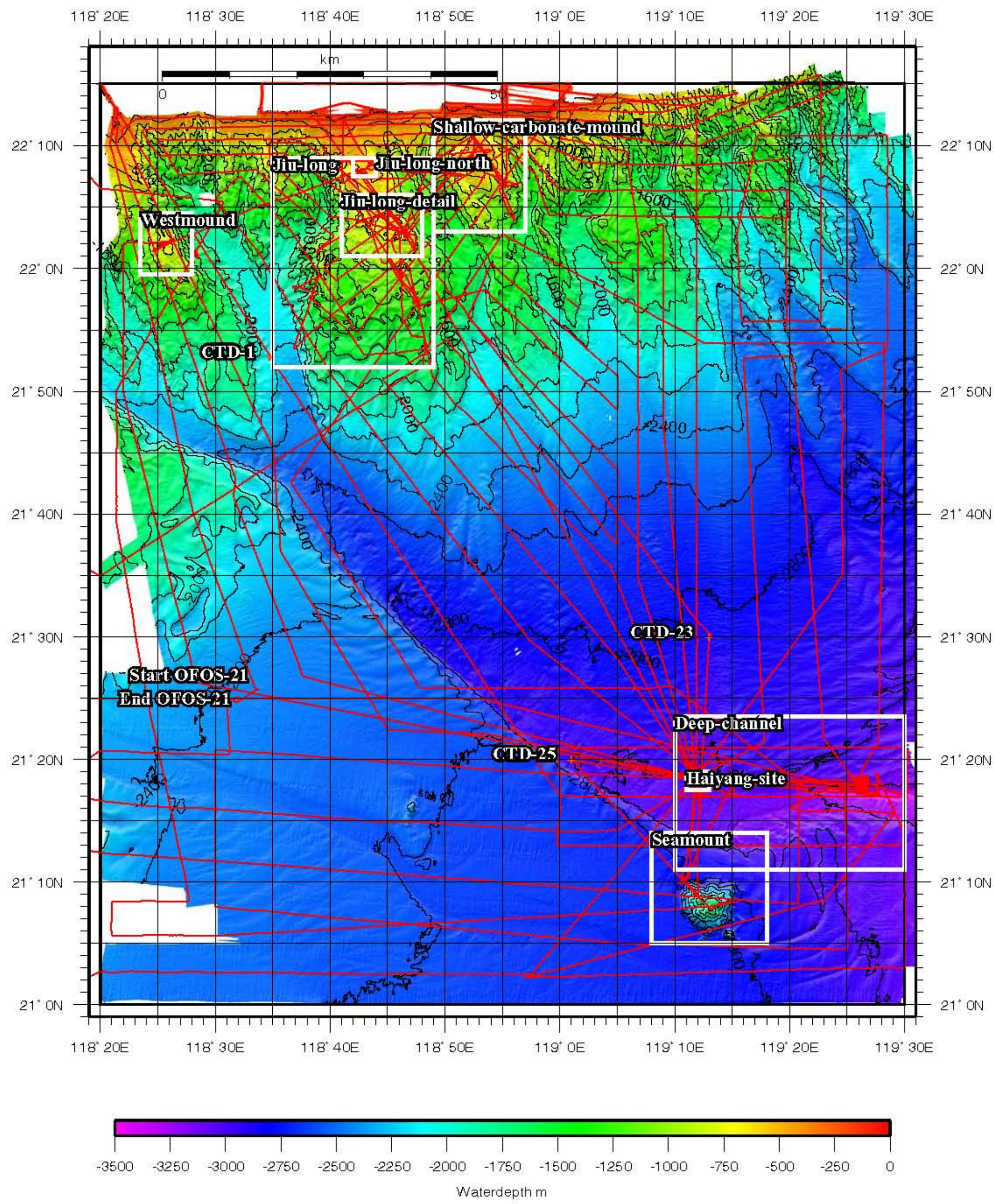
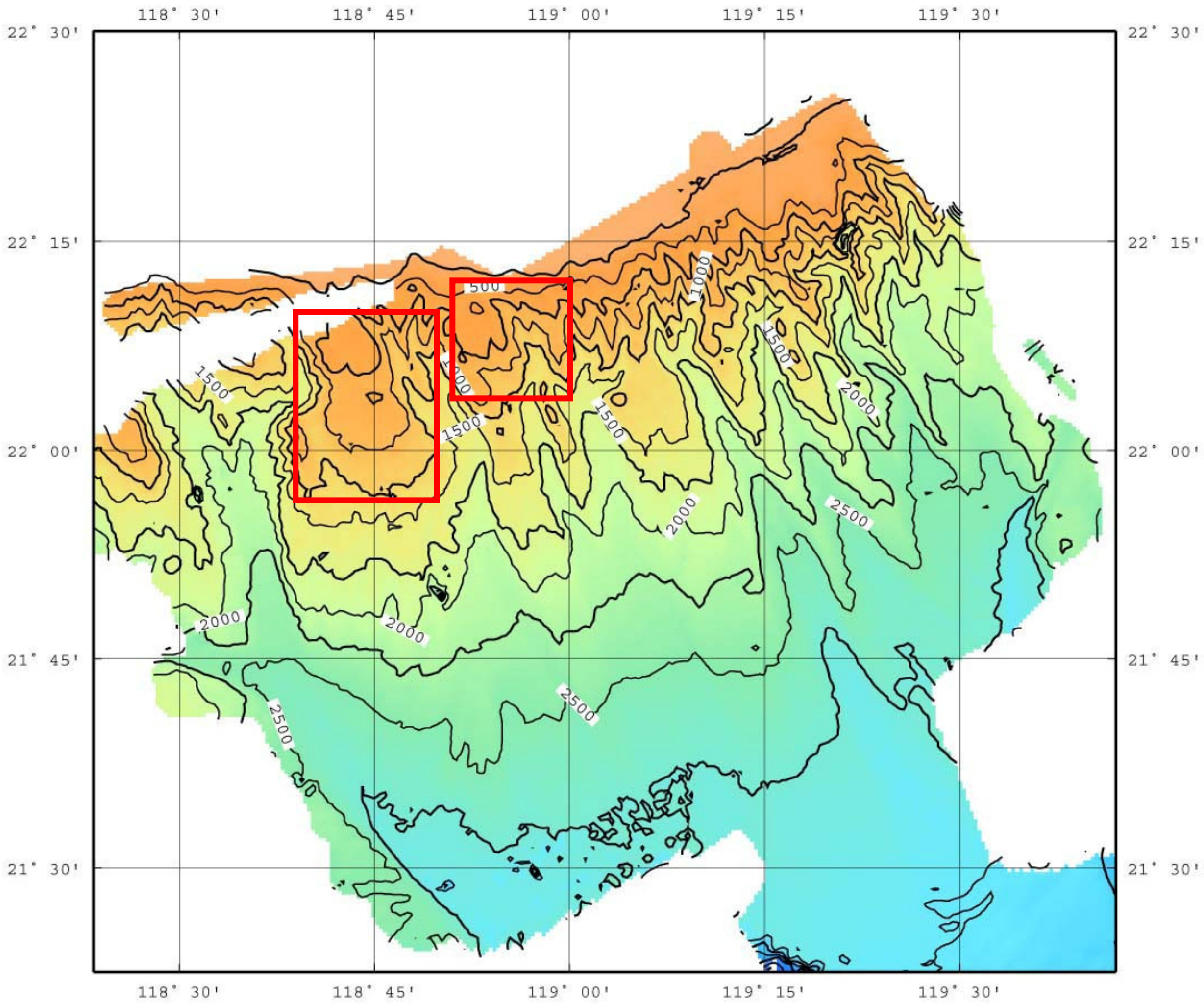



Figure 4.3 Overview map with locations of inset maps and their ship-board nomenclature.




*/
Figure 4.4.1 Overall carbonate complex in Area A

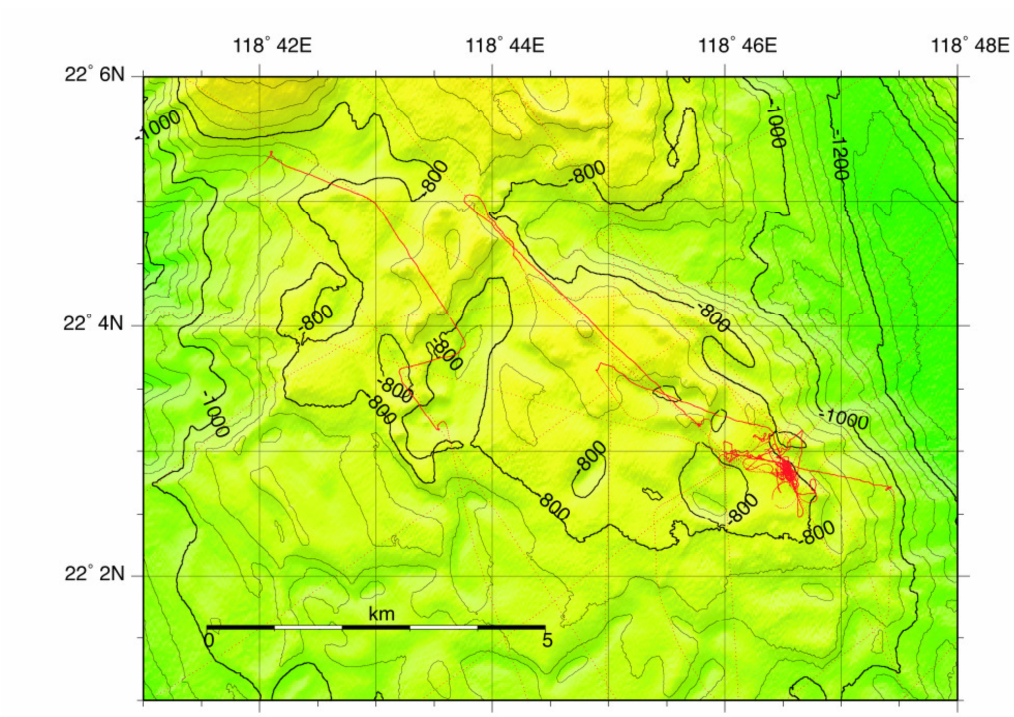



Figure 4.4.2 Jui Long methane reef; southern extention

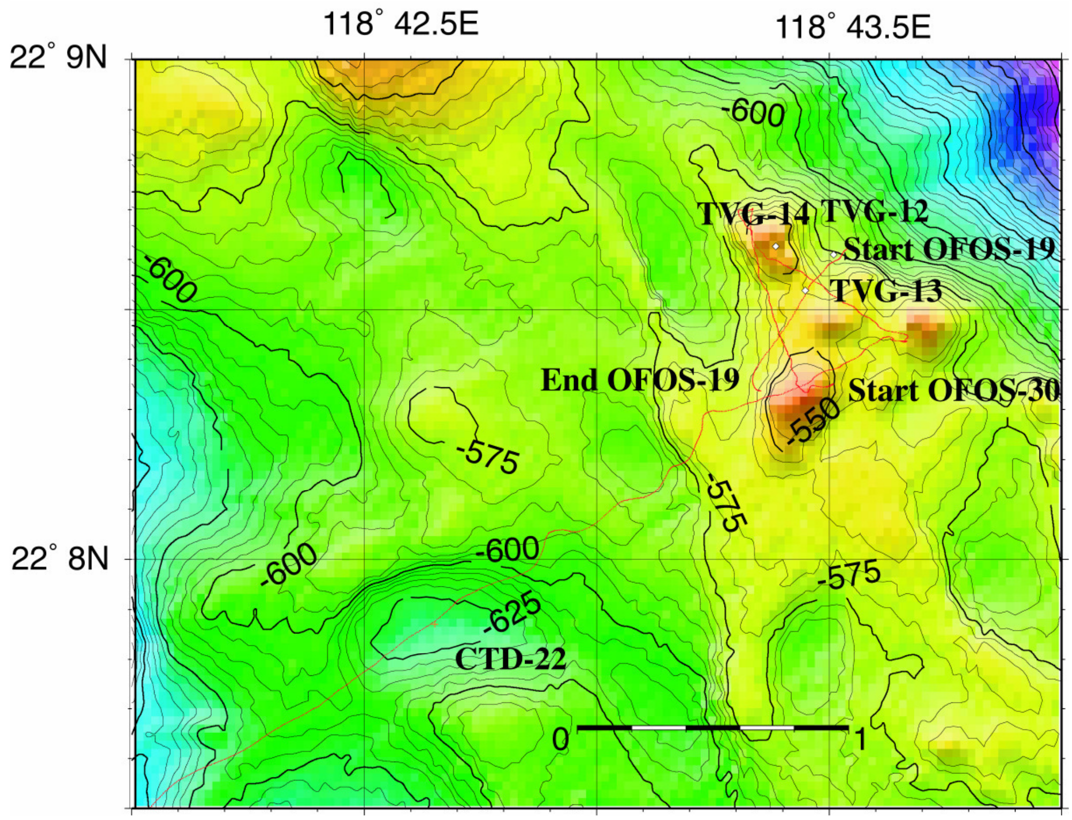



Figure 4.4.3 Shallowest part of the upper slope complex; carbonate rubble

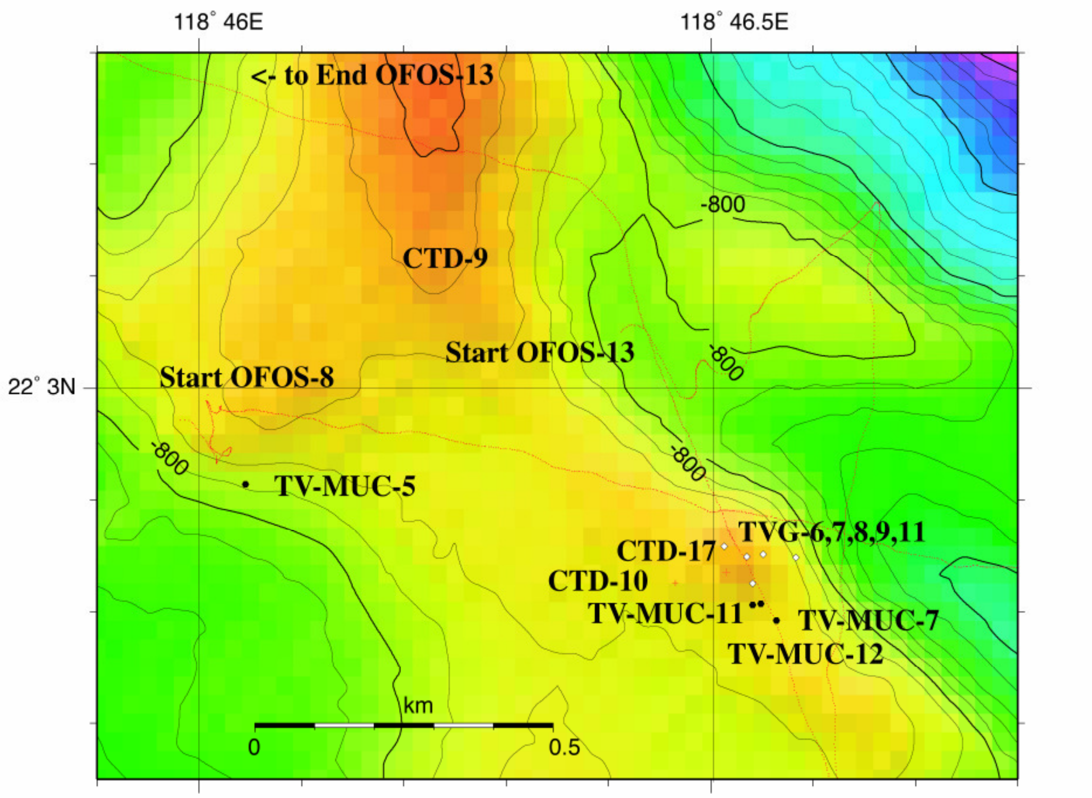



Figure 4.4.4 Pinnacle at Jiu Long southern extention; most active site

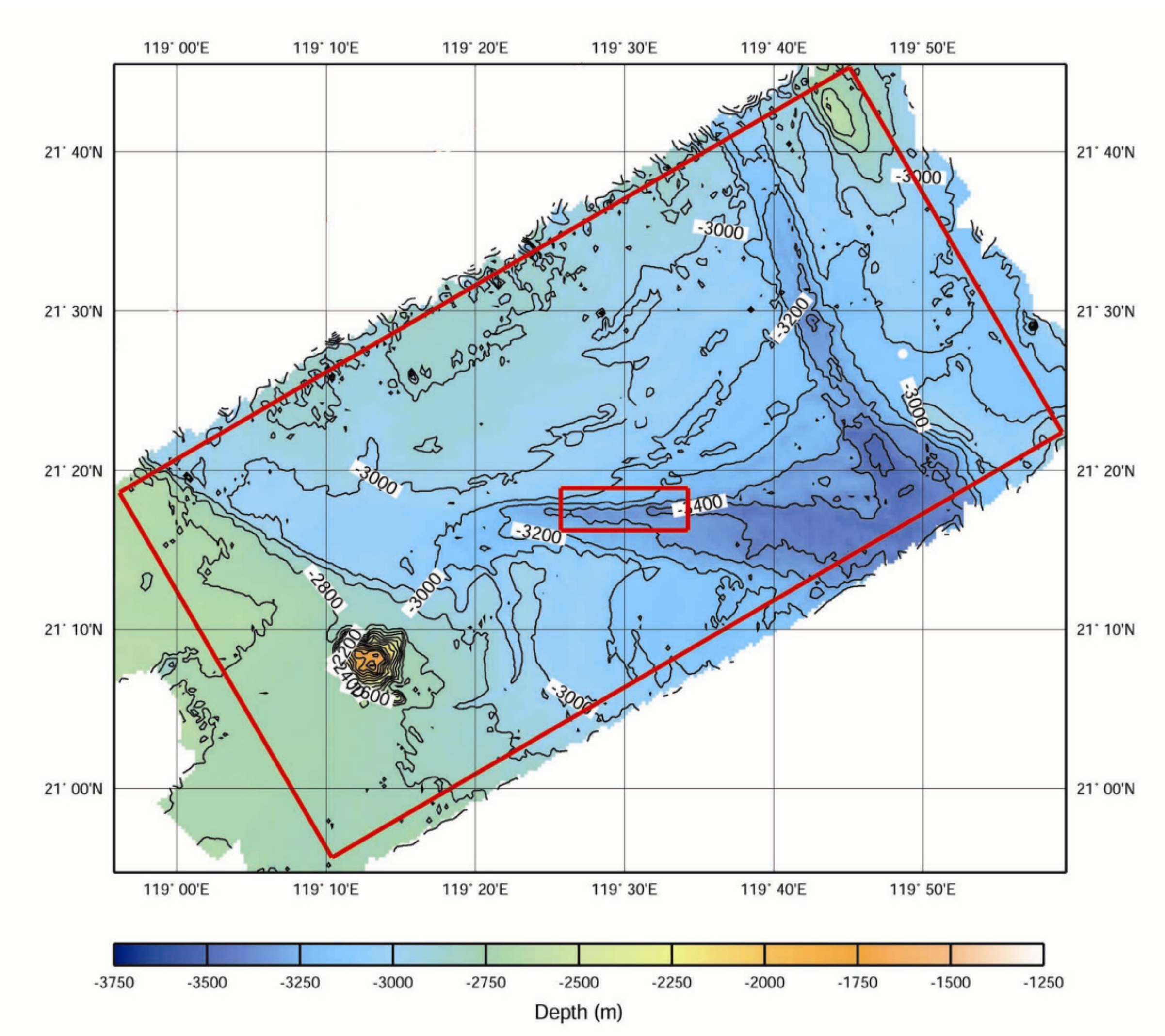



Figure 4.4.5 Haiyang 4 area along the north bank of Formosa Canyon

# 5. Instruments, methods and preliminary Results

## 5.1 Bathymetry

### *5.1.1 Navigation*

A crucial prerequisite for all kinds of marine surveys is the precise knowledge of position information (latitude, longitude, altitude above/below a reference level). Since 1993 the global positioning system (GPS) is commercially available and widely used for marine surveys. It operates 24 satellites in synchronous orbits, thus at least 3 satellites are visible anywhere at any moment (Seeber, 1996). The full precision of this originally military service yields positioning accuracies of a few meters. In the past this was restricted to military forces and inaccessible to commercial users (Blondel and Murton, 1997). Since about two years the full resolution is generally available.

The resolution of GPS can be enhanced with the Differential GPS (D-GPS) scheme (Blondel and Murton, 1997, Knickmeyer, 1996). Using several reference stations the determination of the ship's position can be corrected in real time and enhanced to a 1 m to 5 m accuracy. Since the cruise SO-109 (1996) D-GPS service is available onboard R/V SONNE. The ships ASHTEC system provides a validated accuracy better than 5 - 10 m in the area.

D-GPS-values as well as most other cruise parameters are continuously stored in the navigation database, and are distributed via the DVS- ("data distribution system") on the ship's network.

Unfortunately, the precision of the position information does not correspond to the accuracy of the time base in the navigation database, as the navigation processing unit Atlas ANP 2000 does not copy the precise GPS-time values, but adds time stamps of its internal unsynchronized clock.

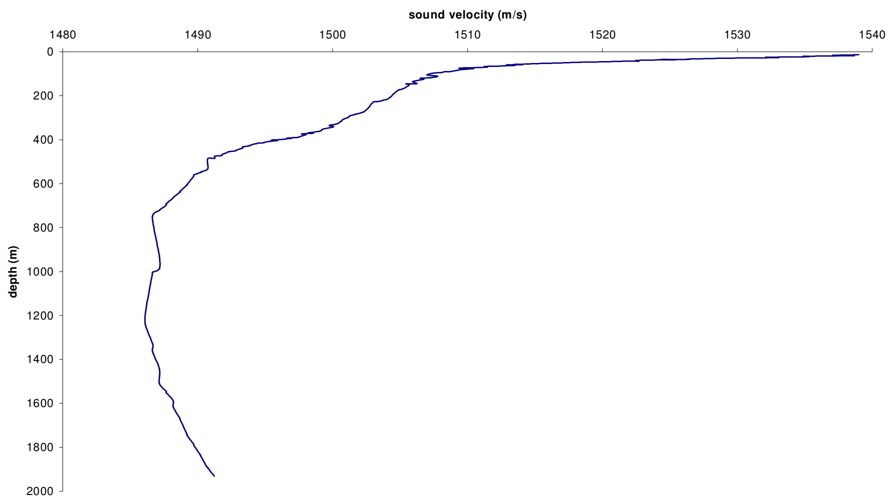



Figure 5.1.1 Sound velocity from CTD cast at 21°52.80 N 118°34.78E (2200m); using the Seabird-Software this sound velocity profile was calculated and used to calibrate all SIMARD survey data.

### *5.1.2 SIMRAD EM120*

The EM120 System is a multibeam echosounder (with 191 beams) providing accurate bathymetric mapping up to depths greater than 11000 m. This system is composed of two transducer arrays fixed on the hull of the ship, which send successive frequency coded acoustic signals (11.25 to 12.6 kHz). Data acquisition is based on successive emission-reception cycles of this signal. The emission beam is 150° wide across track, and 2° along track direction (Fig.

1). The reception is obtained from 191 overlapping beams, with widths of 2° across track and 20° along it (Fig. 1). The beam spacing can be defined as equidistant or equiangular, and the maximum seafloor coverage fixed or not. The echoes from the intersection area (2° by 2°) between transmission and reception patterns (Fig. 1), produce a signal from which depth and reflectivity are extracted.

For depth measurements, 191 isolated depth values are obtained perpendicular to the track for each signal. Using the 2-way-travel-time and the beam angle known for each beam, and taking into account the ray bending due to refraction in the water column by sound speed variations, depth is estimated for each beam. A combination of phase (for the central beams) and amplitude (lateral beams) is used to provide a measurement accuracy practically independent of the beam pointing angle. The raw depth data need then to be processed to obtain depth-contour maps. In the first step, the data are merged with navigation files to compute their geographic position, and the depth values are plotted on a regular grid to obtain a digital terrain model (*DTM)*. In the last stage, the grid is interpolated, and finally smoothed to obtain a better graphic representation.

Together with depth measurements, the acoustic signal is sampled each 3.2ms and processed to obtain a cartographic representation, commonly named mosaic, where grey levels are representative of backscatter amplitudes. These data provide thus informations on the sea-floor nature and texture; it can be simply said that a smooth and soft seabed will backscatter little energy, whereas a rough and hard relief will return a stronger echo.

During the SO 177 cruise, the Simrad EM 120 Multibeam echosoundeur, available on R/V SONNE since June 2001, was used continuously. During DeepTow profiling dense line offset was used to reduce the opening angles of the beams in order to receive higher resolution images while still covering the complete area. Bathymetric data were processed routinely onboard during the survey, using the NEPTUNE software from Simrad, available on board and the academic software MB-System from Lamont-Doherty Earth Observatory. At the beginning of the cruise a water velocity profile was measured to a depth of 2000 m, at the entrance to the beginning of the Formosa Canyon; these results were used throughout the cruise to produce maps; the velocity profile is shown in Figure 5.1.2.1

### *5.1.3 Parasound*

There is a Krupp Atlas Parasound system installed on RV Sonne which operates in concert with the SIMRAD EM120. The Parasound system is a sub-bottom profiler or sediment echo sounder. The transducer and receiver units are permanently installed in the ships hull. It utilizes the parametric effect appearing in the generation of two acoustic waves with similar frequencies. A new acoustic wave of the difference-frequency is generated. The Parasound emits a sound frequency of 18 kHz, and a second variable frequency of 20.5 to 23.5 kHz (0.5 kHz steps). On Sonne cruise 177 a difference frequency of 4 kHz was used. The parametric wave is restricted into the cones of the high-frequencies and narrower than those, it has no side-lobes. The footprint is then 7 % of the water-depth. Resolution and accuracy increase significantly using the parametric effect.
The applied pilot mode improves the along-track resolution in deep water greater than 450m by sending a narrow beam sounding (18 kHz), which measures the depth only, followed by several parametric soundings. The result is a higher trace-density, on cost of the equal separation of soundings.
For digitization and storage of data, the ParaDigMa software, developed at the University of Bremen, was run on a pentium DOS-PC. The sampling frequency was 40 kHz.

To reduce the amount of disk-space necessary, only a 200 m depth / 266 ms time-window was recorded. To adjust the delay and keeping the seafloor in the upper half of the recording

window, different operators watched the system on a 24 hour watch schedule. The ParaDigMa software also delivers online filtered (1.5 – 6.5 kHz bandpass) screen display and online prints of navigation and profiles.
Again, as the multibeam echo sounder, the Parasound was run during surveys and along OFOS-tracks, and transits in the research areas, collecting nearly 9 GB of data. The data format is in standard SEG-Y (Society of Exploration Geophysicists) – format.
The penetration depends on the seafloor properties. For soft sediments penetrations of 150m were observed on SO 177. Hard sediments reduce the penetration to few 10s of metres. For example, the Jiu-long carbonates are clearly visible on the Parasound-profile.

Another windows based version of ParaDigMa was installed on another computer to record bubble flares in the water column. It uses the same data emitted from the Parasound, but records a 400 m window with the seafloor in the lower part of the recording window. It was run several times during station work on test-purpose. As there were no indications for bubble-sites, no special flare-imaging profiles were deployed.

### *5.1.4 Compilation of Maps*

During Sonne cruise 177 many different maps were generated from the Simrad multibeam data with Generic Mapping Tool (GMT), Windows version 3.4.3. For instance each OFOS deployment required a detailed map of the track. The system operators delivered one large A0 format map after each processing of data sets, which was used for further route-planning.

This report contains overview maps of the region, of the surveyed working areas, and details therein. Each box in a larger map indicates the insets of a smaller, more detailed map. The database is a 30 m grid file.

The list of maps is provided below and the maps are in Appendix 8.7.

Table 5.1.4: List of maps

| Name | Area | Purpose | Grid | Comment |
|---|---|---|---|---|
| China_arb_geb | northern SouthchinaSea | overview | Gebco | |
| China_tracks_A | HK-area A | overview | Gebco | tracks |
| China_tracks_B | HK-area B | overview | Gebco | tracks |
| | | | | |
| A_bathy_all_A4 | all A | | EM120-30m | only bathymetry |
| A_bathy_all_inserts_text_A4 | all A | | EM120-30m | boxes indicating smaller maps, stations not included in detail maps |
| Westmound | NW-mound | detail | EM120-30m | stations |
| Jiu-long-carbonate-mound | jiu long | detail | EM120-30m | |
| Jiu-long-carbonate-mound_text | jiu long | detail | EM120-30m | stations |
| Jiu-long-north | jiu-long | detail | EM120-30m | stations |
| Jiu-long-carbonate-mound_detail | detail in jiu long | detail in Jiu-long carbonate-mound | EM120-30m | |
| Jiu-long-carbonate-mound_detail_text | detail in jiu long | detail in Jiu-long carbonate-mound | EM120-30m | stations |
| Jiu-long-carbonate-mound_detail2_text | detail in jiu long | detail in Jiu-long carbonate-mound_detail | EM120-30m | stations |
| Shallow-carbonate-mound | shallow-mound | detail | EM120-30m | |
| Shallow-carbonate-mound_text | shallow-mound | detail | EM120-30m | stations |
| Deep-channel | SE-3000m | detail | EM120-30m | |
| Deep-channel_text | SE-3000m | detail | EM120-30m | stations |
| Deep-channel_text | SE-3000m | detail in Deep-channel | EM120-30m | stations |
| Haiyang-site | SE-3000m | detail in Deep-channel | EM120-30m | |
| Haiyang-site_text | SE-3000m | detail in Deep-channel | EM120-30m | stations |
| Detail 1 | SE-3000m | detail in Haiyang-site | EM120-30m | stations |
| Detail 2 | SE-3000m | detail in Haiyang-site | EM120-30m | stations |
| Seamount | | | EM120-30m | |
| Seamount_text | | | EM120-30m | stations |
| B_bathy | all B | overview | EM120-30m | |
| B_bathy_text | all B | | EM120-30m | stations |
| B_bathy_detail_text | all B | | EM120-30m | stations |

### *5.1.5 Sub-positioning*

Fritz Abegg

R/V SONNE is equipped with an underwater Hydro-Acoustic Position Reference (HPR) system. The system is manufactured by SIMRAD Subsea A/S, Norway and has the type number 'HPR 1507'. It is working on the super short baseline (SSBL) principal where the acoustic transmitting and receiving elements are housed in a single hull mounted transducer unit. The position of the transponder is calculated from its distance and direction relatively to the transducer.

The system in general consists of the transducer, a so called transceiver unit (type HPR 300) which contains the electronics, a control and display unit with an additional display in the GeoLab of SONNE, a vertical reference unit, fixed transponders on OFOS and TVG and a mobile transponder used for TV-MUC, GC and DAPC.
To measure the angle and distance of the transponder, the transducer sends a trigger pulse. The transponder answers with a reply pulse from which direction and distance is calculated. The trigger pulse is either transmitted acoustically from the transducer or send through the data connection cable depending on which tool is used.
The accuracy of the system is stated by the manufacturer to be 3% of the slant range to the transponder when using a wide beam transponder (120°) as mounted on SONNE. At a water depth of 3000m this amounts to an accuracy of 90m. Additional drawbacks as noise in the water, generated by propeller and thrusters, and reflections of sound by sea surface, seafloor and other reflections from different layers in the water body and on the seafloor may lower the accuracy. Additionally the signal is physically attenuated with increasing depth. The manual does not quote a maximum operation depth but ships crew mentioned it is limited to 3000m.

During Leg 1 of SO 177 cruise the transducer had a total breakdown. No SSBL data could be acquired and so all positions in the station list are ship's positions.
During the port call in Hong Kong a new transducer was mounted in the moon-pool and taken in operation immediately. It was noted that the scatter of the transponder fixes dramatically increased at a rope length of approx. 1500m. Subsequent smoothing of the SSBL-fixes at leased showed the track of OFOS at the Haiyang4 area. Another line in the deep channel at a water depth of 3100m clearly showed no correlation between ships track and OFOS track.

Sampling at the Haiyang 4 area needed either video-guided tools as has been done with the TV-MUC and TV-Grab or very preceise navigation of the coring tools as GC or DAPC with an accuracy below 10m. During the deployment of TV-MUC 14 the SSBL signal was recorded graphically. Figure XX shows a detail of the chart with the ships position represented by the black circle. The short black line starting from the circle indicats the ships heading and the long orange line the ships course. The orange line beginning at the ships indicator represents the ships track during the deployment. The blue and white dots indicate the scatter-cloud of the SSBL fixes. The figure contains four plots starting with the upper left panel taken at a rope length of 780m, upper right panel at a rope length of 1500m, the lower left panel taken at 2000m and the lower right panel taken at 2750m.

It is obvious that the SSBL scatter is small up to a depth of approx. 1500m. From this depth on the scatter increases, at 2750m is exceeds a size of 75 m x 130 m and at the working depth of 3000m at the Haiyang4 area the scatter is worse.
Additionally we found that changes of the ships heading resulted in a fast movement of the SSBL fixes which could not be confirmed by the video observation (see lower right panel of Fig. 5.1.2). Due to the great water depth, the accuracy of the SSBL system of RV SONNE was not sufficiently good to gain samples at the necessary resolution.

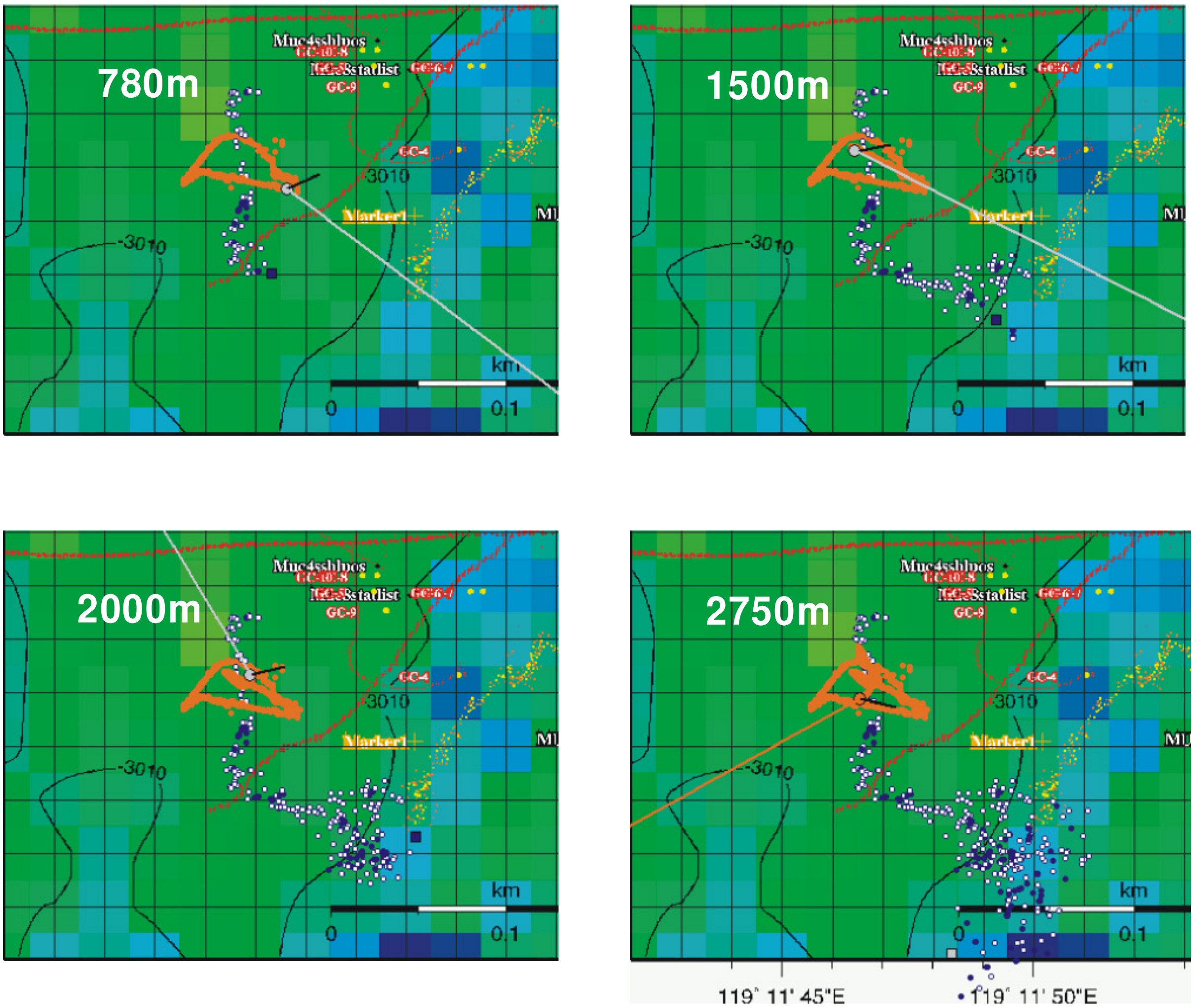



Fig. 5.1.5: Plot of the SSBL fixes during TV-MUC 14 deployment at increasing cable length; note increasing scatter deep tha 1500 m.

## *5.2 WATER COLUMN*

Gregor Rehder, Katja Heeschen, Karen Stange, Jinghong Yang, and Xiqiu Han

The main goal of the hydrographic program on cruise SO177 was the investigation of the methane distribution in the water column, with the aim to narrow the field of methane emitting bottom sources (vents) and monitor the methane pattern over areas of potential methane release sites suggested by video and seismic observations (OFOS, EM120). For this purpose we carried out CTD hydrocasts including a water-sampling rosette and sampled the bottom water from the TV guides Multi-Corer (TV-MUC, see 5.4). Samples were regularly taken for oxygen, methane and nutrient analysis. In case of hydrocasts nutrients were analyzed on a few stations to complete the picture of the water column properties in this region of the South China Sea. In addition, an seawater-air equilibrator was set up for a nearly continuous survey on the methane distribution of the surface water and the air above. This allows us to determine methane fluxes at the water-air interface.

### *5.2.1 Methane and $pCO_2$ monitoring in surface waters*

The methane concentration and $pCO_2$ in surface waters and the overlying marine air was continuously surveyed during the entire cruise using a fully automated, semi-continuous seawater-air equilibrator. A full description of the system is given in [REHDER AND SUESS., 2001]. Temperature within the equilibrator, as well as essential data of the the DVS-system of RV SONNE (such as time, position, meteorological, nautical and thermo-salinograph data were continuously recorded and merged in one file using a software recently developed by J.

Greinert. The system was shut down during larger parts of the cruise to use the gas-chromatographic system for the measurement of methane from hydrocast or sediment sampling. Nevertheless, the transits as well as the multibeam mapping was used to cover a large area of the survey areas as well as long sections along and across the shelf.
The determination of $CH_4$ and $pCO_2$in surface seawater is based on the equilibration of a re-circulating gas phase with a counter-current flow of continuously renewed seawater. The gas enters the equilibration vessel (about 2 l) from the bottom at a flow rate of about 1.5 l/min and is dispersed into small gas bubbles through a coarse glass frit. A 45-cm glass column is mounted on top of the equilibration vessel. The seawater inlet is installed on the top of the column, providing a laminar flow along the inner walls of the column (about 2,5l/min). The air leaves the equilibration chamber at the top of the column and is re-circulated via a backpressure regulator and a flow meter. A vent to the atmosphere assures equilibration at ambient pressure. The entire glass apparatus follows a design described by KÖRTZINGER et al. [1996] and is a combination of a 'bubble type' and 'laminar flow' equilibrator. However, the volume of both water and air phase in the system is larger by about a factor of 2, as the detection by gas chromatography requires the consumption and replacement of a part of the gas phase. When a sample of equilibrated air is taken from the system, an electronic valve closes the vent to avoid immediate replacement of the sampled air. This results in a slight under-pressure in the system, which can be seen as an increase of the water level in the chamber, which however is less than 0.4 mm (i.e. the pressure drop is less than 0.4 ‰ of the total). In addition, the equilibration time is long compared to the flushing time of the sample loops. Hence, the effect has a negligible influence on the quantity measured. The valve opens after the sample is taken, and the time between two measurements of the equilibrated air (20 min) is sufficient to allow replacement of the removed air via the vent and re-equilibration of the gas phase.

The sequence used for the analysis of the gas is in general CG1-E-A-E-CG2-E-A-E, where CG1 and CG2 are the calibration gases, E is the air equilibrated with surface seawater, and A is the atmospheric air sample. The time for a single measurement is 10 min, which yields atmospheric values every 40 min and values for the equilibrated air every 20 min. On a few transects 2o ml samples were taken in evacuated headspace vials while the system was running. These gas samples will be analyzed for stable carbon isotopes in the onshore laboratory. of A total of 90 gas samples was taken.

The surface water concentration in the working area varies very little and is commonly in equilibrium with the overlaying air. This agrees with measurement of surface water samples from CTD casts, which show methane supersaturations up to in the pycnocline but are in equilibrium with the atmosphere in 6 m depth. This depth is consistent with the depth of the equilibrators water pump.

### *5.2.2 Water column survey*

For sampling of the water column, the ship's own CTD system, equipped with a 24x 10 L rosette was used (SBE 911+ with Beckman oxygen sensor) for a total of 25 hydrocast stations. The location of all stations is shown in maps of the appendix, the purpose and samples taken are listed in Table 5.2.1.

Table 5.2.1 Water column program during Leg SO 177

| Station | Location | Depth | Tasks | $CH_4$ Samples |
|---|---|---|---|---|
| 002 CTD 01 | Westmound, southern slope | 2199 | Sound profile, water column sampling | $CH_4$, Oxygen |
| 007 CTD 02 | eastern channel, northern slope | 3360 | locating possible vent site | $CH_4$, Oxygen |
| 009 CTD 03 | central channel, northern slope | 3163 | locating possible vent site | $CH_4$, Oxygen |
| 013 CTD 04 | Shallow carbonate mound clam field (OFOS-2) | 911 | locating possible vent site | $CH_4$, Oxygen |
| 016 CTD 05 | Haiyang site | 3011 | locating possible vent site | $CH_4$, Oxygen |
| 026 CTD 06 | Shallow carbonate mound clam field (OFOS-2) | 919 | locating possible vent site | $CH_4$, Oxygen |
| 032 CTD 07 | upper slope | 402 | high resolution of methane in upper water column | $CH_4$, Oxygen |
| 034 CTD 08 | Jiu Long, western slope | 2205 | locating possible vent site | $CH_4$, Oxygen |
| 044 CTD 09 | Jiu Long carbonate mound | 768 | locating possible vent site | $CH_4$, Oxygen |
| 047 CTD 10 | Jiu Long carbonate mound | 769 | locating possible vent site | $CH_4$, Oxygen |
| 061 CTD 11 | Jiu Long, southern slope | 1357 | locating possible vent site | $CH_4$, Oxygen |
| **Station** | **Location** | **Depth** | **Tasks** | **$CH_4$ Samples** |
| 068 CTD 12 | central channel, northern slope | 3283 | locating possible vent site | $CH_4$, Oxygen |
| 075 CTD 13 | Jui Long, southern slope | 1747 | locating possible vent site | $CH_4$, Oxygen |
| 078 CTD 14 | eastern channel, northern slope | 3329 | locating possible vent site | $CH_4$, Oxygen |
| 079 CTD 15 | central channel, northern slope | 3252 | locating possible vent site | $CH_4$, Oxygen |
| 080 CTD 16 | eastern channel central depth | 3247 | locating possible vent site | $CH_4$, Oxygen, Nutrients |
| 086 CTD 17 | Jui Long carbonate mound | 762 | locating possible vent site | $CH_4$, Oxygen, Nutrients |
| 102 CTD 18 | Area B | 1183 | locating possible vent site | $CH_4$, Oxygen |
| 105 CTD 19 | Area B | 2555 | locating possible vent site | $CH_4$, Oxygen |
| 108 CTD 20 | Area B | 1651 | locating possible vent site | $CH_4$, Oxygen |
| 117 CTD 21 | Haiyang site | 3013 | locating possible vent site | $CH_4$, Oxygen |
| 127 CTD 22 | Jiu Long, northern depression | 630 | locating possible vent site | $CH_4$, Oxygen, extra samples |
| 128 CTD 23 | eastern channel, northern slope | 2850 | locating possible vent site | $CH_4$, Oxygen, Nutrients, extra samples |
| 129 CTD 24 | eastern channel, southern slope | 3019 | locating possible vent site | $CH_4$, Oxygen, Nutrients |
| 139 CTD 25 | eastern channel, southern slope | 2983 | locating possible vent site | $CH_4$, Oxygen, |

For CH4 analysis aboard, a modification of the vacuum degassing method described by *Lammers and Suess* [1994] was used [*Rehder et al.*, 1999]. 1600 ml of water were injected into pre-evacuated 2200ml glass bottles, which leads to almost quantitative degassing. The gas phase was subsequently recompressed to atmospheric pressure and the $CH_4$ concentration of the extracted gas was determined by gas chromatography. A Shimadzu GC14A gas chromatograph equipped with a flame ionization detector was used in connection with a Shimadzu CR6A Integrator. Nitrogen was used as carrier gas, and separation was performed using a 4m 1/8' SS column packed with Porapack Q (50/80 mesh) run isothermally at 50℃. For the FID calibration, a bottled mixture of 9.78 ppmV methane in synthetic air was used.

The total gas content of the sample will be calculated from the measured dissolved oxygen concentration (see below) under the assumption that $N_2$ and Ar were 100% saturated relative to their atmospheric partial pressures [*Weiss*, 1970]. The dissolved methane concentration was calculated as the product of the mole fraction in the extracted gas phase and the amount of total gas (STP) in the sample.

Sub-samples were taken from each gas sample for further measurements of the stable carbon isotopic signature of $CH_4$. These sub-samples were sampled into pre-evacuated crimped cap glass vials sealed with a butyl rubber septum. 7mL of 1/100 saturated $HgCl_2$ solution was added into each vial and the sample stored upside down to protect it for contamination from atmospheric gases during storage. The stable carbon isotopic ratio of methane ($\delta^{13}CCH_4$) will be determined on selected samples onshore.

Oxygen was analyzed using by the standard method developed by Winckler. The reading of the continuously operating oxygen sensor can thus be calibrated against the chemical analysis.

*Hydrography*

The water column shows a strong stratification in the upper water column, mainly driven by the strong gradient of seawater temperature (Fig. 5.2.1). The upper 35 m are almost homogenous. In fact, it was observed that the upper 40 m were completely mixed after typhoon Coson had passed near the research area, and a slight recoverage of the stratification in the upper meters has been observed since this event. Below this wind driven mixed layer, temperature decreases uniformly, while an inversion of salinity can be observed roughly between 80 and 150 m. This relates to the strong evaporation of surface waters which results in the subsidence of dense, salty surface water to intermediate depth. The variations in the T-S properties of the upper water column show up in the Temperature-Salinity-plot of Figure XXX. Oxygen is slightly supersaturated in the subsurface waters within the photic zone due to productivity-driven oxygen generation. Various temporal mixed layers and thus changes in water mass properties such, temperature and salinity, are found in the between 400 - 700 m as can be seen in the Temperature-Salinity plot in Figure 5.2.1. The oxygen minimum zone is between 700 m and 900 m, but the oxygen content stays above 2 ml/L.

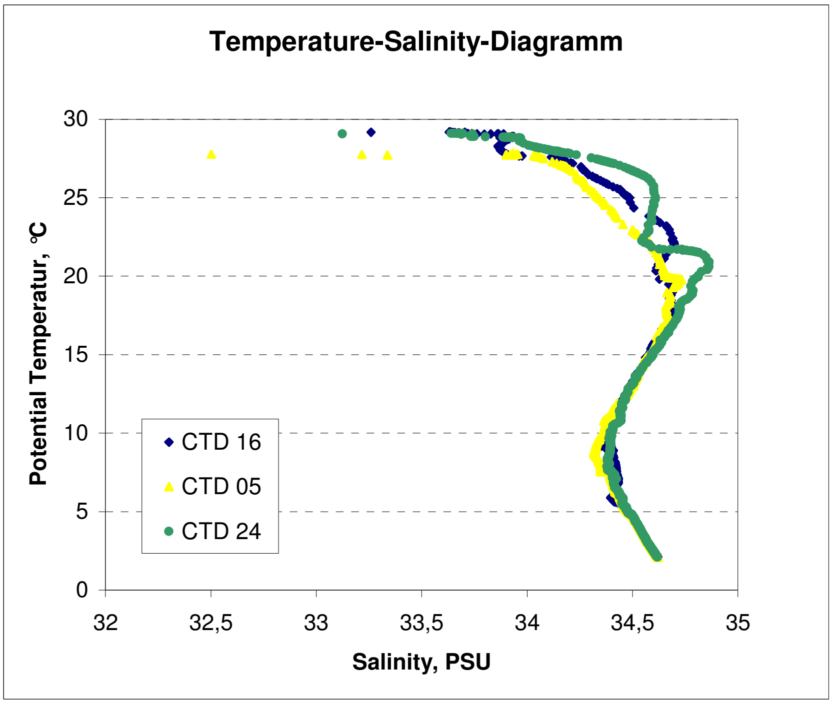



Figure 5.2.1 Temperature-Salinity diagram for selected hydrocasts of the deep channel

Changes in temperature and salinity below 1000 m are small but consistent at about 1400 m and 2500 m depth. The latter coincides with the deepest sill depths between the open Pacific Ocean and the South China Sea (Tomczak and Godfrey, 1994) and is shown in Figure XX. Below 2500 m the density gradient is very small, i.e., the stratification is very weak (Fig. 5.2.1). It can be assumed that this deepest part of the water column below the sill depth has a higher residence time and is well mixed. More detailed investigation of the water column properties will follow on land.

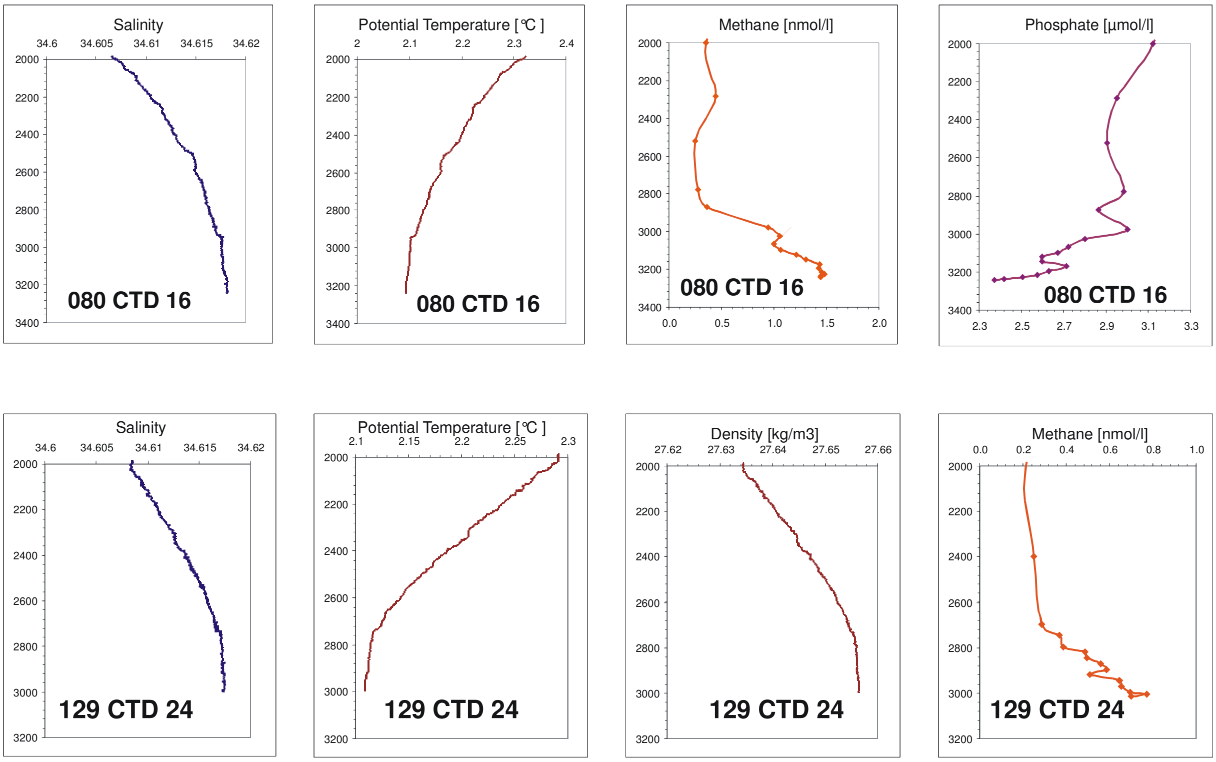



Figure 5.2.2 Depth profiles of various hydrographic parameters, methane and phosphate of CTD casts 16 and 24.

*Methane distribution*

Methane concentrations in the deep water column of the channel (CTD 1, 2, 5, 12, 14, 15, 16, 21, 23, 24, 25) did not exceed 3 nmol/l, with the highest concentrations found in CTD 14 which was deployed on the northern slope in the eastern channel (Figure Appendix Haiyang site). In the western part the concentrations did not exceed 2 nmol/l. The increase in concentration starts from about 0.5 nmol/l at about 2600 m towards the ocean floor. It coincides with a change in the depth profiles of temperature, salinity, and density which are described above (Figure 5.2.2; CTD 24). As methane increases with depth in the lower 600 m of the water column, the phosphate gradients decrease within the same depth range reflecting a different environment within this deepest water parcel (CTD 17, CTD 24 – Figure 5.2.2). Temperature and salinity profiles indicate a thick bottom mixed layer in the deepest part of the channel. The elevated methane concentrations might relate to this layer which is likely to have a high particle fright and residence time. Particle enriched layer often show higher methane concentrations (e.g. Pak et al, 1980). Methane concentrations in CTD 19 which was deployed in Area B were below 0.5 nmol/L throughout the deep water column.

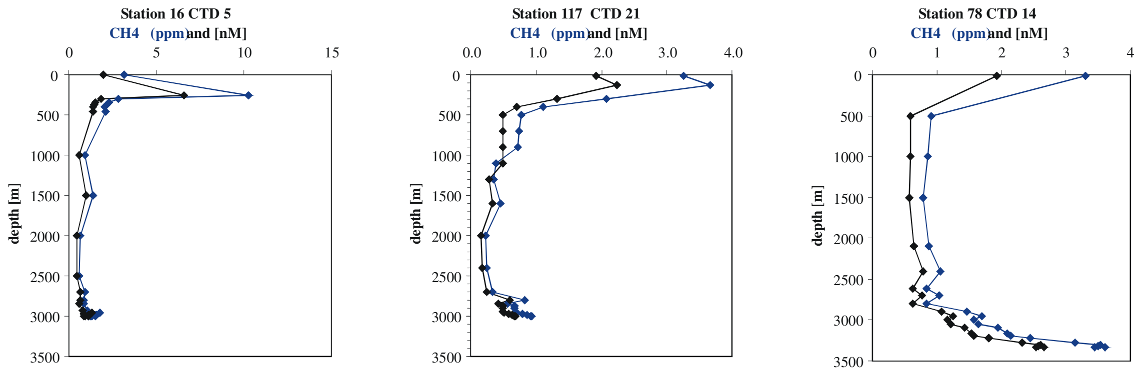



Figure 5.2.3 Methane concentrations of hydrocasts in the deep channel of area A.

CTD stations of intermediate water depth at various locations on the slopes (1200 - 2500 m, CTD 8, 11, 13, 18, 20) had very small changes in methane concentrations towards the ocean floor and showed varying behaviors. In CTD 11 and 13 methane concentrations increased by 0.3 nmol/l to 1.2 nmol/l, whereas hydrocasts from area B showed a decrease in methane below 1000 (CTD 18) or hardly any changes (CTD 20). In contrast to the concentration changes in the deep channel those on the slope did not increase towards the ocean floor but are consistent throughout the mixed layer.

The shallower CTD stations above the various shallow chemoherm structures in area A (CTD 4, 6, 9, 10, 17, 22) had a slight decrease in methane towards the ocean floor rather than an increase. The bottom depth is within the range of various changing mixed layers which often correlate with changes in methane concentrations (CTD 17). In case of CTD 17 phosphate is higher in the lowest depth range than it is above.

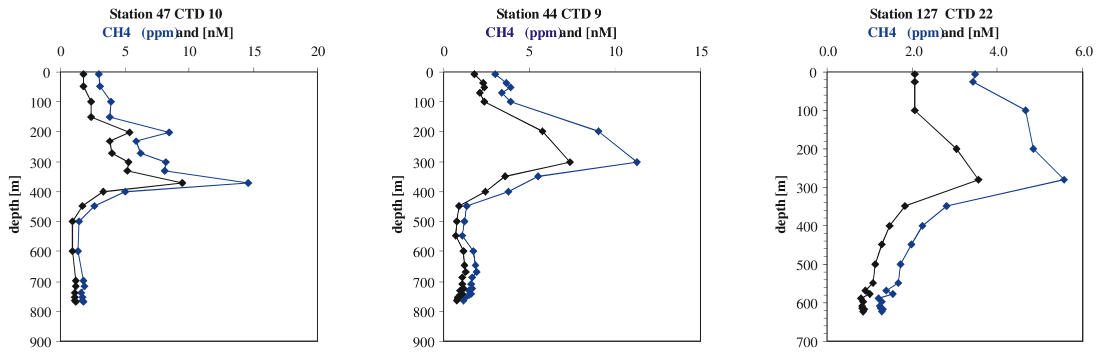



Figure 5.2.4 Methane concentrations above carbonate mounds on the northern slope in area A.

The highest methane concentrations up to 10 nmol/l were found in various hydrocasts of leg 1 at depth between 200 - 400 m. During leg 2 these maxima were much smaller or had vanished completely. Likely these methane maxima relate to Intermediate Nepheloid Layers (INL; Pak et al., 1980) which are particle enriched bottom boundary layers from the upper slope. They detach due to turbulence in slope currents e.g. due to eddy formation or internal waves and are carried offshore. They are time limited but are often found over a wide area. A smaller methane increase above the INLs was seen at the pycnocline which is typical for the methane distribution in the ocean and relates to the increase in particles and plankton towards the surface while the exchange with the atmosphere is still limited.. The surface water on the other hand is in close equilibrium with the atmosphere.

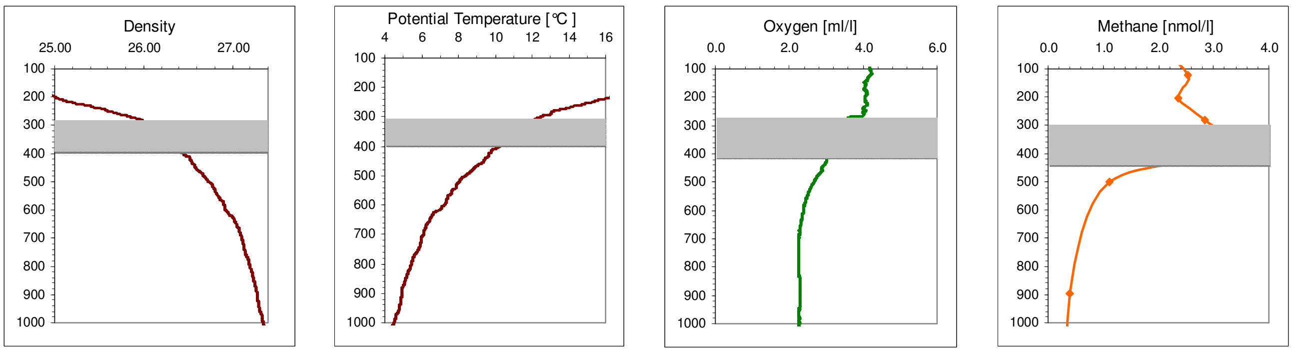



Figure 5.2.5 Mixed layer characteristics of the upper water column in CTD 24

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### *5.3 Seafloor Imaging (OFOS)*

F. Abegg, A. Eisenhauer, O. Pfannkuche, Xin Su, E. Suess, Jun Tao, Nengyou Wu

The main task of the visual seafloor observation was to locate active vent sites in the South China Sea. The application of an ocean floor observation system (OFOS) allows the precise detection of possible sampling sites for the TV-MUC and TV-Grab sampling. Furthermore, OFOS is also useful for the interpretation of sediment echo sounder investigations or side scan sonar mapping by providing visual images of the seafloor character.

#### *5.3.1 Equipment and Observation Procedure*

The Ocean Floor Observation System is a TV-guided sled of 165x125x145 cm equipped with a black/white and a colour video camera, two Xenon lamps (Fa. Oktopus), an underwater still camera with flash bulbs (Fa. Benthos), three laser pointers (Fa. Oktopus) and a FSI memory CTD.

For the seafloor observation procedure, OFOS is towed by the ship about 1m to 2m above the sea floor at less than about 1 kn along a pre-defined track. The distance between the sled and the seafloor is controlled manually by the winch-operator. Still photos are taken during a deployment either manually or at pre-set time intervals along the tracks (maximum 800 frames). The video signal of a black & white and a colour camera is permanently recorded onboard on video tapes and in digital form and on a DVD storage unit (only b/w).

The ship based recording of OFOS data during SO177/1 the OFOS observations were also stored into a protocol software (OFOP) which automatically recorded UTC time, ship positions, depth of the OFOS and other data from a NMEA-link/DVS online string. The OFOP program is particularly useful because it allows the exact determination of the OFOS position independent from the ship's position. This serves for better site identification and exact positioning of other sampling devices like MUC, GC and TVG.

#### *5.3.2 OFOS Observations in Area A during SO177-1*

During the 16 OFOS tracks and the approx. 82 hours of seafloor observation the morphology, geology, sediment texture and the benthic biology of the operation area was visualized. In general the sediments appeared to be well oxygenated with a clear dominance of dark to light grey in colour. The highly structured and complicated morphology of Area A is characterized by submarine hills having steep slopes where sediments are being transported downhill. In this regard a major feature is the occurrence of sediment "walls" characterized by sharp edges on the steep flanks of the slopes of the submarine hills. Mostly 3 to 7 "walls" occurred down slope at some of these hills. The walls showed heights in between 1 and up to 30 m. Related to that the presence of steep ledges and sharp canyons interrupting the morphology provide pathways for material transport from the continental slopes to the deep.

Mostly the flanks of the submarine hills with moderately steep flanks showed the presence of rocky outcrops of scattered carbonate boulders grouped in fields of several square meters in diameter. The presence of doughnuts and chimney like structures indicate active or fossil fluid venting areas. Clam shells were occasionally associated with some of the carbonate fields. However, none of these fields appeared to be active indicating recent or even past fluid and gas flow activity. In this regard we also did detect only very few small bacterial mats and no living clam fields associated to the carbonates usually indicating active fluid of gas vent sites.

The most prominent carbonate structure with huge carbonate blocks (boulder massif) and upright chimney like structures show an extension of several tens of meters and a height of up to ten meters and was named "Jiu Long" (found during the course of OFOS 8). In particular, this

structure closely resembles chemoherms as seen in the Hydrate Ridge area off Oregon (Figures 5.3.2 and 5.3.3)
The rare biological activity is evidenced by the presence of burrows and sea cucumbers. In general, the fauna is dominated by shrimp, sponges, sea pens, starfish and a few fish (e.g. rattails).

Table 5.3.1 Summary of OFOS deployments during Leg 1; Station Protocols OFOS 1 to 16

**Station (UTC):** SO177/1, STATION 08 OFOS 01

**Date**: 06.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 02:36 | 5 :49 | 21° 18.87´ | 119° 25.17´ | 3049 |
| On Deck/end | 08:25 | | 21° 17.08´ | 119° 26.81´ | 3282 |

Important observation during OFOS 1: An OFOS track at an angle to the strike direction of the channel revealed a smooth and heavily sedimented featureless seafloor. The steepest section consisted of 7 distinct vertical cliffs ("walls"), several meters each, caused by displacement of sediment blocks down slope. At the base of the 1st and 2nd of the cliff, several patches of clam communities were observed.

**Station (UTC):** SO177/1, STATION 11 OFOS 02

**Date**: 06.06.2004/07.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 23:00 | 6:58 | 22° 08.14 ´ | 118° 54.23 | 625 |
| On Deck/end | 05:58 | | 22° 04.00´ | 118° 56.06´ | 1260 |

**Station (UTC):** SO177/1, STATION 12 OFOS 03

**Date**: 07.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 06:27 | 3:12 | 22° 06.39´ | 118° 54.73´ | 899 |
| On Deck/end | 09:39 | | 22°06.99´ | 118° 56.49´ | 900 |

Important observation during OFOS 2 and 3: Two OFOS lines were run between 600-1200m across a broadly elevated feature dissected and surrounded by channels. The seafloor was covered by irregular patches of „doughnut"-shaped carbonates and rubble, typical of methane-derived carbonates at cold vents. No evidence for live benthic vent communities was observed,

**Station (UTC):** SO177/1, STATION 12 OFOS 04

**Date**: 07.06.2004/08.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 23:00 | 3 :24 | 21° 18.79´ | 119° 11.98´ | 2987 |
| On Deck/end | 02:24 | | 21° 17.54´ | 119° 11.69´ | 3039 |

| **Station (UTC):** SO177/1, STATION 20 OFOS 05 | | | | | |
|---|---|---|---|---|---|
| **Date**: | 09.06.2004 | | | | |
| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
| In the Water/start | 13:55 | 3:27 | 21° 18.16´ | 119° 20.84´ | 3037 |
| On Deck/end | 17:22 | | 21° 17.54´ | 119° 21.25´ | 3165 |

| **Station (UTC):** SO177/1, STATION 21 OFOS 06 | | | | | |
|---|---|---|---|---|---|
| **Date**: | 09.06.2004 | | | | |
| | Time (UTC) | | Latitude (N) | Longitude (E) | Water Depth |
| In the Water/start | 18:21 | 3:54 | 21° 18.19´ | 119° 14.90´ | 2994 |
| On Deck/end | 22:15 | | 21° 16.96´ | 119° 15.32´ | 3070 |

| **Station (UTC):** SO177/1, STATION 27 OFOS 07 | | | | | |
|---|---|---|---|---|---|
| **Date**: | 11.06.2004/12.06.2004 | | | | |
| | Time (UTC) | | Latitude (N) | Longitude (E) | Water Depth |
| In the Water/start | 00:16 | 3:58 | 22° 10.54´ | 118° 52.56´ | 484 |
| On Deck/end | 04:14 | | 22° 08.16´ | 118° 52.30´ | 529 |

| **Station (UTC):** SO177/1, STATION 33 OFOS 08 | | | | | |
|---|---|---|---|---|---|
| **Date**: | 12.06.2004 | | | | |
| | Time (UTC) | | Latitude (N) | Longitude (E) | Water Depth |
| In the Water/start | 03:27 | 2:56 | 22° 02.98´ | 118° 46.01´ | 955 |
| On Deck/end | 06:23 | | 22° 02.72´ | 118° 47.41´ | 932 |

Important observation: OFOS-run over the shallowest structure (550-900m) documented carbonate patches, carbonate rubble fields, and one prominent 30m high carbonate edifice (named “Jiu Long”). OFOS revealed all shapes and sizes of authigenic carbonates such as crusts, concretions and chimneys.

| **Station (UTC):** SO177/1, STATION 35 OFOS 09 | | | | | |
|---|---|---|---|---|---|
| **Date**: | 12.06.2004 | | | | |
| | Time (UTC) | | Latitude (N) | Longitude (E) | Water Depth |
| In the Water/start | 10:27 | 3:30 | 21° 59,35´ | 118° 39.00´ | 1160 |
| On Deck/end | 13:57 | | 21° 58.42´ | 118° 37.04´ | 1833 |

**Station (UTC):** SO177/1, STATION 37 OFOS 10

**Date:** 12.06.2004/13.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Water Depth |
|---|---|---|---|---|---|
| In the Water/start | 23:27 | 12:26 | 21° 18.51´ | 119° 25.90´ | 3056 |
| On Deck/end | 12:27 | | 21° 17.39´ | 119° 26.79´ | 3319 |

**Station (UTC):** SO177/1, STATION 38 OFOS 11

**Date:** 13.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Water Depth |
|---|---|---|---|---|---|
| In the Water/start | 12:51 | 15:44 | 21° 18.13´ | 119° 25.76´ | 3119 |
| On Deck/end | 15:44 | | 21° 17.39´ | 119° 25.75´ | 3296 |

**Station (UTC):** SO177/1, STATION 46 OFOS 12

**Date:** 14.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Water Depth |
|---|---|---|---|---|---|
| In the Water/start | 23:26 | 5:25 | 22° 03.20´ | 118° 45.78´ | 744 |
| On Deck/end | 04:51 | | 22° 04.68´ | 118° 44.17´ | 777 |

**Station (UTC):** SO177/1, STATION 48 OFOS 13

**Date:** 15.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Water Depth |
|---|---|---|---|---|---|
| In the Water/start | 07:08 | 4:44 | 22° 03.03 ´ | 118° 46.49´ | 803 |
| On Deck/end | 11:52 | | 22° 03.70´ | 118° 44.96´ | 733 |

**Station (UTC):** SO177/1, STATION 62 OFOS 14

**Date:** 17.06.2004/18.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Water Depth |
|---|---|---|---|---|---|
| In the Water/start | 00:49 | 6:41 | 22° 00.79´ | 118° 45.21´ | 913 |
| On Deck/end | 07:30 | | 21° 56.93´ | 118° 47.74´ | 1290 |

**Station (UTC):** SO177/1, STATION 63 OFOS 15

**Date:** 18.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Water Depth |
|---|---|---|---|---|---|
| In the Water/start | 08:32 | 4:59 | 22° 05.35´ | 118° 42.10´ | 826 |
| On Deck/end | 13:31 | | 22° 03.17´ | 118° 43.55´ | 845 |

| **Station (UTC):** SO177/1, STATION 74 OFOS 16 | | | | | |
|---|---|---|---|---|---|
| **Date**: | 20.06.2004 | | | | |
| | Time (UTC) | | Latitude (N) | Longitude (E) | Water Depth |
| In the Water/start | 16:25 | 6:25 | 21° 55.89´ | 118° 46.31´ | 1355 |
| On Deck/end | 22:50 | | 21° 53.11´ | 118° 48.33´ | 1616 |

### *5.3.3 Deployments in Area A and B during SO 177-2a*

Seventeen OFOS deployments were carried out during SO177/2, 15 of which were in area A and 2 deployments in area B.

Area B was surveyed with two down slope transects on the upper and middle slope between 880 -1400m water depth. Both surveys revealed a similar sediment structure of well oxygenated soft sediments mainly of light grey in colour. No indications for fluid seepage or methane venting were found. The benthic communities showed a clear zonation with a dominance of sea pens in the upper parts of the transect indicating enhanced bottom currents. In the lower parts of the transects brittle stars were the dominant megafauna organisms indicating a shift in the community structure from s filter feeding community to a deposit feeding community. Endobenthic organisms indicated by various types of borrows, holes and spoke traces also became more dominant on the lower part of the transects.

Returning to area A the deployments again concentrated on the sites already selected during leg 1 focussing on the upper slope chemoherms (Jui Long, Fig. 4.4.2) and the abyssal Haiyang 4 area (Fig. 4.4.5). The surveys in the Jui Lung site exhibited large carbonate structures with pronounced flanks and rocky outcrops of scattered carbonate boulders (Figures 5.3.4 and 5.3.5). More areas with “doughnuts” and chimney like structures indicating fossil fluid venting areas could be mapped. Few clam shells were occasionally associated with some sediment patches in the carbonate fields. However, none of these fields appeared to be active.

OFOS profiles in the Haiyang 4 site were designed to get a better understanding of the spatial coverage of the clam clusters to provide a better basis for TV-MUC , DAPC and gravity corer sampling. Although no indications for active venting were found.

A prominent submarine volcano in the south eastern corner of area A was surveyed with two OFOS transects (Fig. 5.3.7). The volcano rises from the abyssal plain (ca. 3000m) to about 1500m above the sea floor. The transect on the western flank from the mountain crest to the abyssal plain showed a dramatic scenario of volcanic rocks, steep flanks and piled up pillow lava (Figures 5.3.8 and 5.3.9). Scattered sediment patches showed pronounced ripple marks indicating strong bottom currents. The fauna consisted of several taxa of corals, sponges and sea lilies. On the abyssal plain directly adjacent to the volcano base a large cluster of clam shells was found. The transect on the eastern flank was obviously placed in lee side of the volcano, since many parts of the slope were covered with sediment, which were mainly inhabited by crustaceans indicated by abundant borrows. Rocky outcrops, flanks and boulders were again inhabited by corals and sponges with sponges dominating.

Table 5.3.2 Station Protocols OFOS 17 to 33

**Station (UTC):**SO177/2, STATION 82, OFOS 17

**Date :** 25-26.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 23:50 | 5 : 19 | 21° 18.68´ | 119° 27.60´ | 3058 |
| On Deck/end | 05:09 | | 21° 17.73´ | 119° 27.68´ | 3186 |

**Station (UTC):**SO177/2, STATION 88, OFOS 18

**Date :** 27.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 03:07 | 4 : 05 | 22° 10.748´ | 118° 52.5318´ | 512 |
| On Deck/end | 07:12 | | 22° 09.583 | 118° 54.067´ | 557 |

**Station (UTC):**SO177/2, STATION 89, OFOS 19

**Date :** 27.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 08:23 | 0 : 44 | 22° 08.587´ | 118° 43.478´ | 569 |
| On Deck/end | 09:07 | | 22° 08.441 | 118° 43.363´ | 562 |

**Station (UTC):**SO177/2, STATION 95, OFOS 20

**Date :** 28.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 01:14 | 0 4: 44 | 21° 18.926´ | 119° 12.288´ | 3016 |
| On Deck/end | 05:58 | | 22° 18.523´ | 119° 11.325´ | 2929 |

**Station (UTC):**SO177/2, STATION 99, OFOS 21

**Date :** 29.06.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 02:35 | 0 3: 36 | 21° 24.939´ | 118° 31.669´ | 2429 |
| On Deck/end | 06:11 | | 22° 24.935´ | 118° 31.325´ | 2431 |

**Station (UTC):**SO177/2, STATION 103, OFOS 22

**Date :** 01.07.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 03:36 | 0 5: 00 | 18° 25.311´ | 112° 19.193´ | 1073 |
| On Deck/end | 08:36 | | 18° 21.650´ | 112° 19.610´ | 1401 |

**Station (UTC):**SO177/2, STATION 107, OFOS 23

**Date :** 02.07.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 00:16 | 0 4: 49 | 18° 27.526´ | 112° 18.959´ | 884 |
| On Deck/end | 05:05 | | 18° 24.588´ | 112° 20.012´ | 1200 |

**Station (UTC):**SO177/2, STATION 111, OFOS 24

**Date :** 04.07.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 08:21 | 0 2 :44 | 21° 18.553´ | 119° 11.978´ | 3007 |
| On Deck/end | 11:05 | | 21° 18.355´ | 119° 11.817´ | 3006 |

**Station (UTC):**SO177/2, STATION 112, OFOS 25

**Date** : 04.07.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 11:08 | 0 2 :51 | 21° 18.570´ | 119° 11.963´ | 2999 |
| On Deck/end | 13:59 | | 21° 18.307´ | 119° 11.492´ | 3006 |

**Station (UTC):**SO177/2, STATION 113, OFOS 26

**Date** : 04.07.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 15:59 | 0 2 :31 | 21° 18.520´ | 119° 26.050´ | 3072 |
| On Deck/end | 18:30 | | 21° 18.170´ | 119° 26.060´ | 3101 |

**Station (UTC):**SO177/2, STATION 114, OFOS 27

**Date** : 04.07.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 18:47 | 03 :30 | 21° 18.450´ | 119° 26.140´ | 3094 |
| On Deck/end | 21:17 | | 21° 18.030´ | 119° 26.200´ | 3107 |

**Station (UTC):**SO177/2, STATION 121, OFOS 28

**Date** : 05 – 06.07.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 22:59 | 02 :34 | 22° 02.083´ | 118° 25.972´ | 744 |
| On Deck/end | 01:33 | | 22° 02.065´ | 118° 24.289´ | 973 |

**Station (UTC):**SO177/2, STATION 122, OFOS 29

**Date** : 06.07.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 02:02 | 02 :4 1 | 22° 02.426´ | 118° 26.210´ | 815 |
| On Deck/end | 04:43 | | 22° 01.534´ | 118° 24.640´ | 835 |

**Station (UTC):**SO177/2, STATION 123, OFOS 30

**Date** : 06.07.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 08:36 | 06 :02 | 22° 08.362´ | 118° 43.414´ | 528 |
| On Deck/end | 14:38 | | 22° 06.945´ | 118° 41.118´ | 621 |

**Station (UTC):**SO177/2, STATION 130, OFOS 31

**Date** : 07.07.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 15:17 | 04 :39 | 21° 08.948´ | 119° 11.912´ | 1896 |
| On Deck/end | 19:56 | | 21° 10.396´ | 119° 10.531´ | 2750 |

**Station (UTC):**SO177/2, STATION 136, OFOS 32

**Date** : 08.07.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 14:14 | 03 :46 | 21° 19.538´ | 119° 14.924´ | 2924 |
| On Deck/end | 18:00 | | 21° 18.263´ | 119° 14.973 | 2951 |

**Station (UTC):**SO177/2, STATION 140, OFOS 33
**Date** : 09.07.2004

| | Time (UTC) | | Latitude (N) | Longitude (E) | Depth (m) |
|---|---|---|---|---|---|
| In the Water/start | 11:40 | 04 :33 | 21° 07.697´ | 119° 13.081´ | 1504 |
| On Deck/end | 16:13 | | 21° 08.281´ | 119° 15.067´ | 2778 |

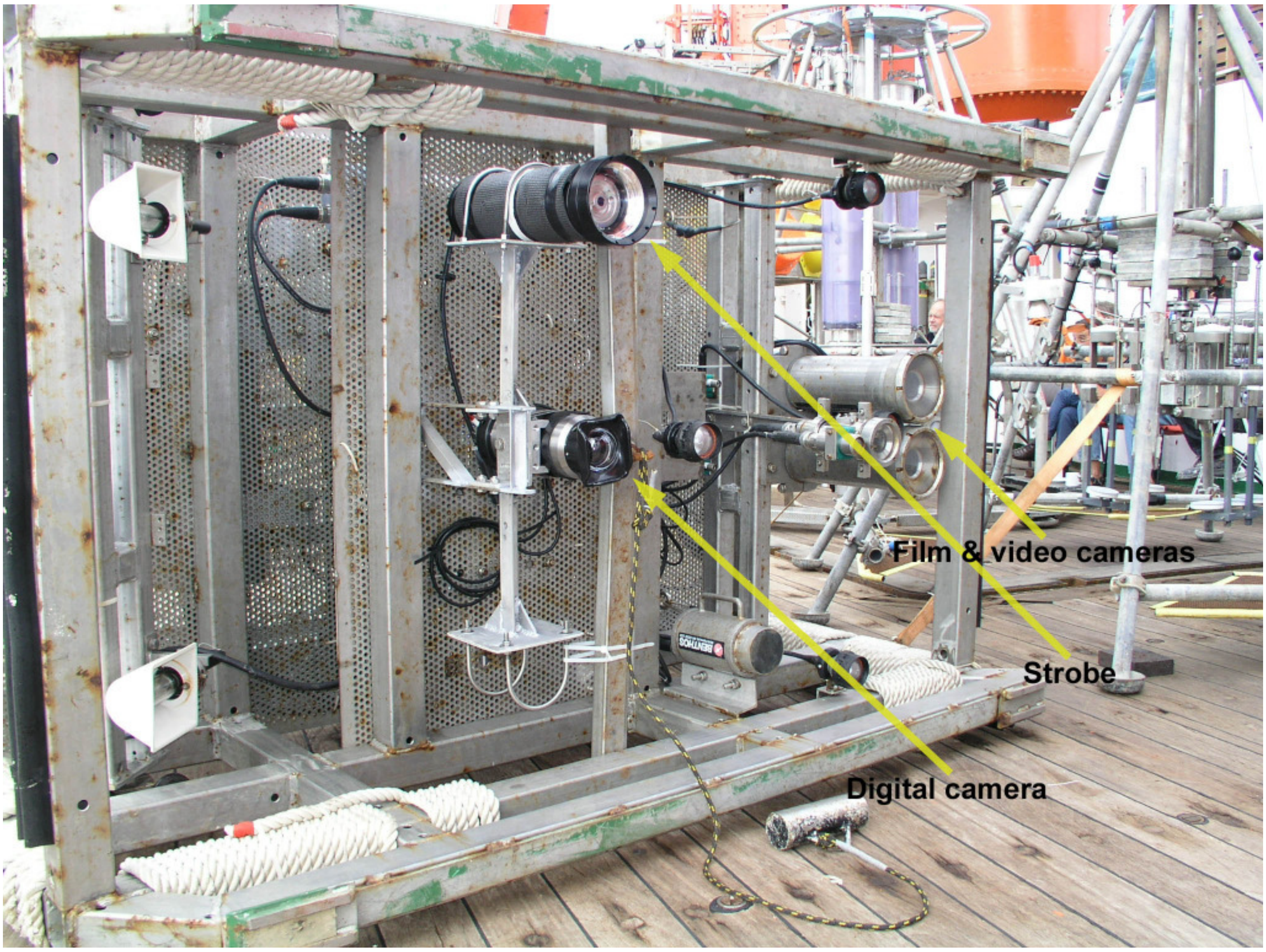
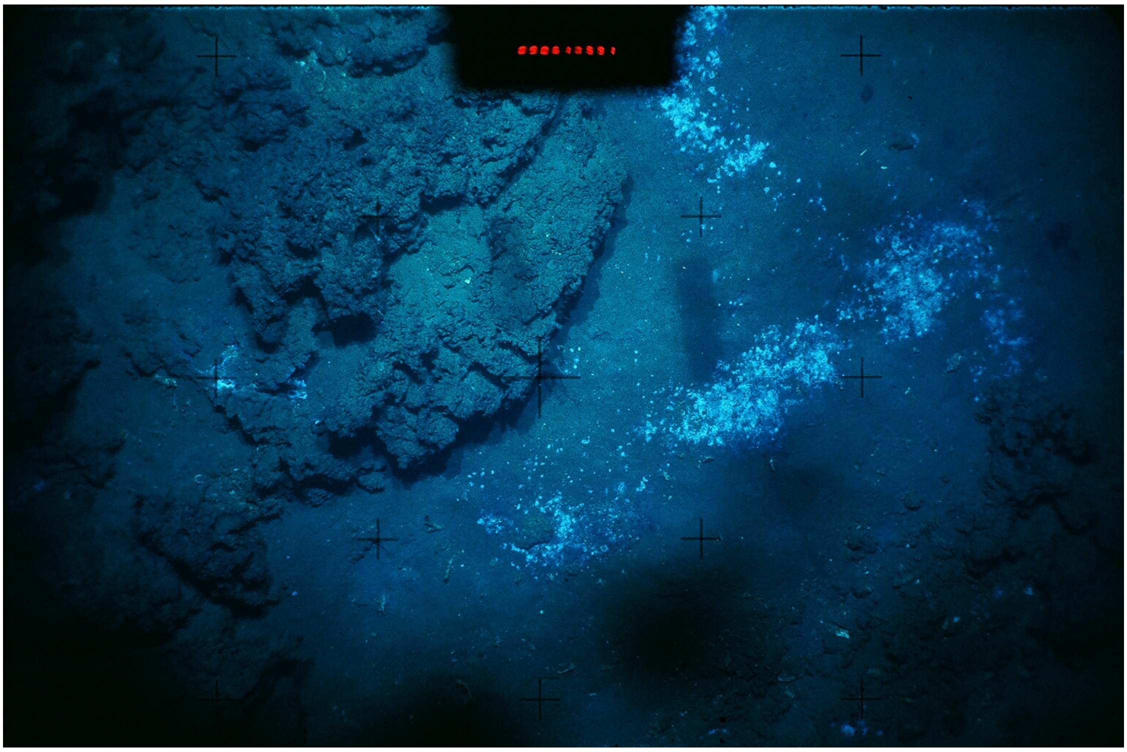



Figure 5.3.1 Ocean Floor Observation System (OFOS) with camera placement; note that digital as well as the strobe were not mounted to the system during SO 1777/1

**OFOS images**



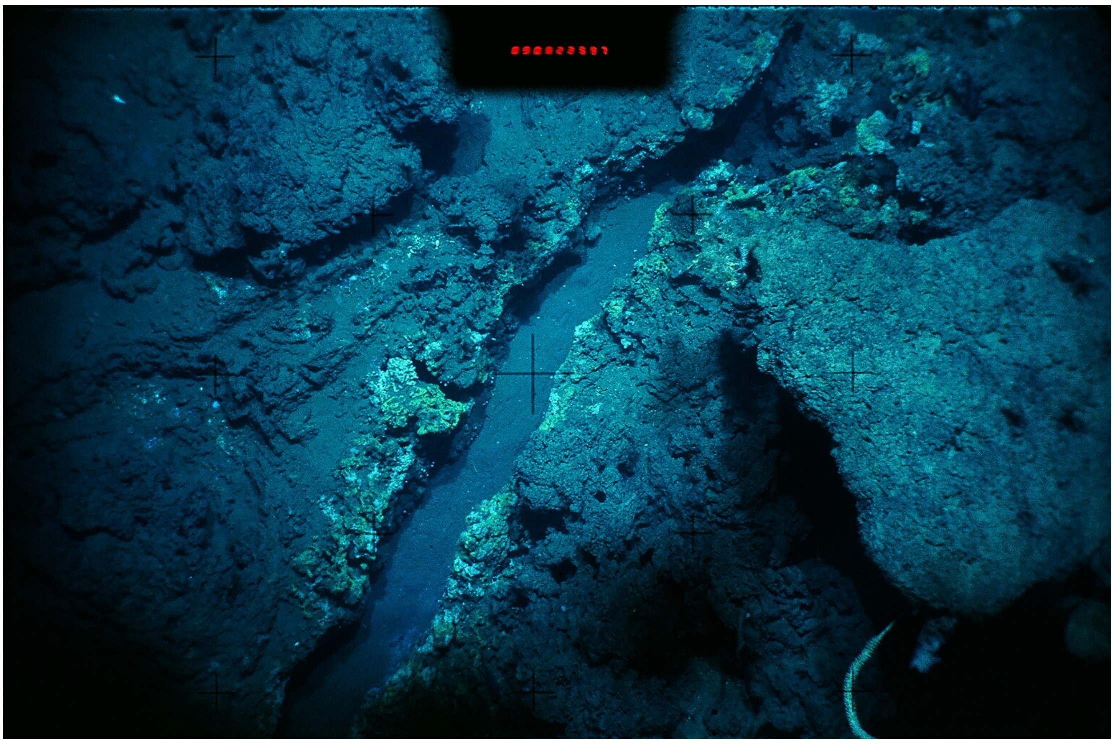


Figure 5.3.2 and 3: Jiu Long methane reef, pinnacle site; white bacterial mat on sediment pacth between carbonate boulders (2); yellow bacterial lining along fractured carbonate blocks (3)

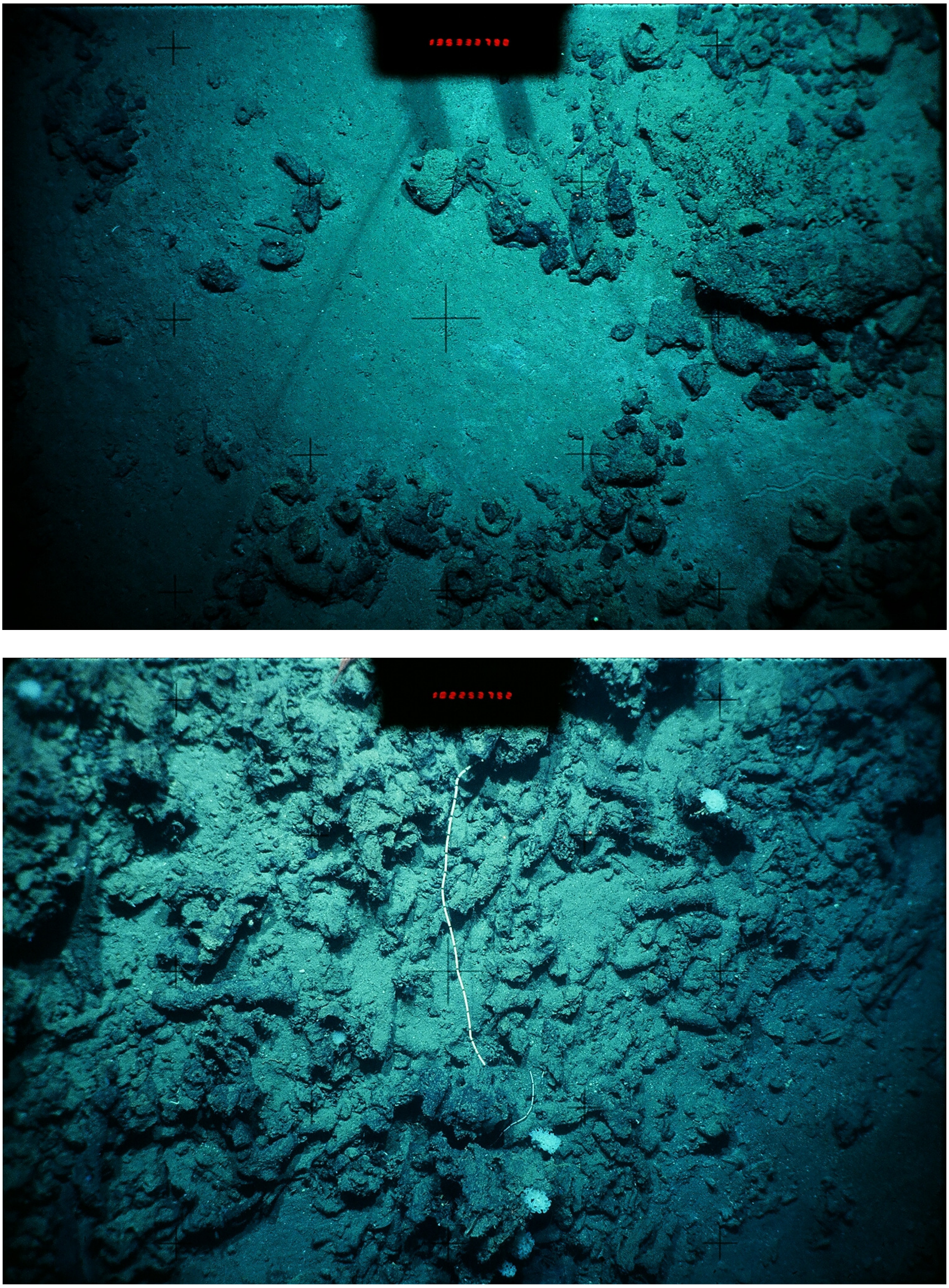


Figure 5.3.4 and 5: Jiu Long carbonate complex, shallow eastern extension, carbonare rubble (4) and fallen chimneys (5)

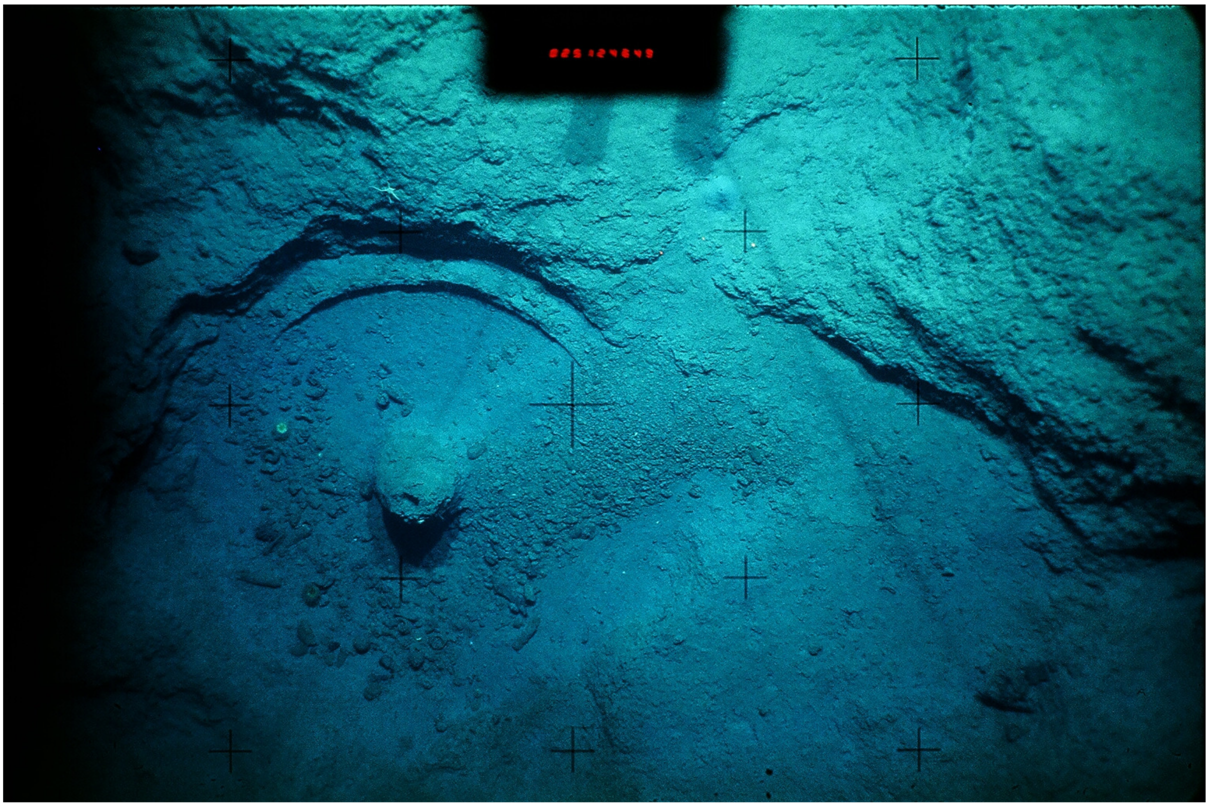


Figure 5.3.6: Jiu Long carbonate complex, shallow eastern extension, upright carbonate chimney inside circular pit

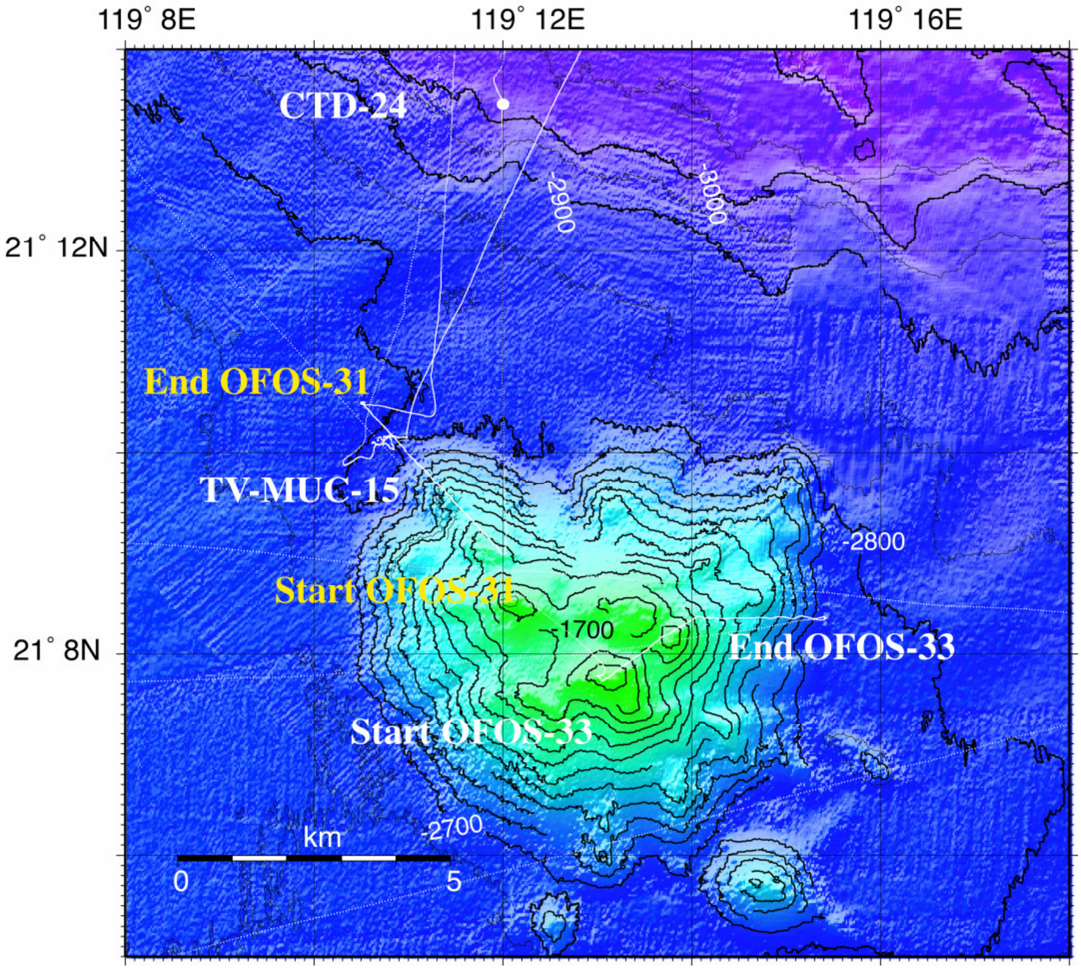



Figure 5.3.7: Volcanic seamount on ancient oceanic crust, souther Area A

Figure 5.3.8 and 9: Pillow lavas on slope of seamount; near summit (8); on flank with sediment patches (9)

## 5.4 Recovery of sea floor samples

### *5.4.1 Sampling Equipment including DACP-Autoclave tool*

Fritz Abegg, Hans-Jürgen Honberg, Asmus Petersen

Sampling for geological and geochemical investigations was conducted with four different tools, the television-guided grab sampler (TVG), the gravity corer (GC), the television guided multi corer (TV-MUC) and the dynamic autoclave piston corer (DAPC).

*Television-guided grab sampler (TVG)*

The TV-guided grab (TVG) is a heavy tool to collect sediment, rock or biological samples from the seafloor. After lowering it into the bottom the jaws can be closed hydraulically. It is powered by deep-sea batteries allowing closing and opening about 4 - 6 times. The area between the jaws while open is about 1.8 m2. Depending on the material sampled, the maximum volume to be recovered is approx. 0.8 $m^3$. The grab is equipped with a black-and-white camera and a colour camera. Accurate position can be acquired by a SSBL responder.

This tool is permanently located onboard RV SONNE and operated jointly between the deck's crew and the scientific crew. It is a television guided grab-sampler, weighing approx. 3 tons in air, towed closely to the seafloor and thereby providing either colour and black and white video images prior to sampling. This deployment procedure allows to select well-defined positions for sampling. The video signal is conducted through a LWL-cable and is displayed online onboard the ship and is also been recorded on video tape. The grab function is controlled through a deck unit, located in the geological laboratory but the power for the hydraulics and the underwater lights is provided by two deep-sea batteries which limits the operation time of the TV-Grab.

When the desired sampling spot has been found through video imaging, the tool is quickly lowered to the seafloor by the winch and the jaws closed by manually pressing the signal button. Due to the relatively rough operation the samples are not very well oriented and may become disturbed. The TV-Grab can also be used with great success to sample carbonate rocks. Sampling operation is sometimes difficult because the construction of the grab requires most of its weight in the topmost part which may lead to tilting of the tool and loss of the sample. The advantage is that the battery power allows several grabbing operations before they have to be replaced. In total there were 14 deployments of the TVG during SO 177.

*Gravity Corer (GC)*

The gravity corer is equipped with a 2-ton weight stand and can be deployed with several different core lengths of barrels, usually 6 m, 12 m, 18 m, or 24 m. Operations started with a core barrel of 6m using plastic tubing instead of PVC-liner. The advantage of this combination is that the GC is deployed and recovered without the core deployment cradle and the sediment can be accessed very rapidly which is important for gas content measurements.
Extrapolations of the methane content recovered at the Haiyang 4 site demonstrated the need for longer cores to possibly access gas hydrates during SO 177. The GC core barrel was lengthened to 12m using PVC-liner instead of tubing. Core recovery did not significantly increase but the time used to cut and open the PVC liner did. For this reason, after recovery of a double banana, a test with plastic tubing in the long version showed that the tubing was stable enough to be used as well. This resulted in a maximum core recovery of 9.7m. This remarkable considering the relatively light weight stand. Subsequent use of a 15m core barrel did not show an improvement of core recovery. The newly attempted use of flexible plastic tubing in gravity cores with a core barrel length of up to 15m was successful but required that the core barrel be divided in segments of approx. 4m before extracting the tube. In this procedure the barrel segments are taken apart, then the tubing is cut and extracted from the barrel. During the cruise

core recovery varied between 3.4 and 9.7m. The gravity corer deployments have all been done at the Haiyang 4 site. In total the gravity corer has been deployed 16 times and over 80 m of sediment recovered.

*Television guided multi corer (TV-MUC)*

This tool allows to gain soft access to the seafloor and hence recover undisturbed surface sediments of up to 50 cm in length. It provides high quality cores. Its advantage compared to the gravity corer is that the sediment surface is well preserved. This is very important because the topmost part of cores obtained with the gravity corer are usually disturbed and often the TV-MUC cores and the GC-cores overlap and can be matched for more accurate depth determination. For the deployments during this cruise the multi corer has been equipped with underwater TV. The video control is a pre requisite for choosing the desired sampling location, here mostly at sites characterized by clusters of clam shells. Additionally it allows to observe the proper functioning of the tool during deployment. It can been set up with either 6 and 4 liners and the recovery rate was very good.
For this cruise the TV-MUC had been equipped with a new data-telemetry. Several initial problems were solved by the ship's electronic support personnel and eventually a black-and-white camera, owned by the ship, had to installed to improve the video quality. In total there were 15 TV-MUC deployments, one deployment was terminated due to a Taifun.

*Dynamic autoclave piston corer or DAPC-Autoclave tool.*

The Dynamic Autoclave Piston Corer (DAPC) was developed with the aim of recovering, preserving and analyzing sediment gases under in-situ conditions. The DAPC is a sampling device for sediment cores. Its total length is 7.2 m, its total weight 500 kg. It was designed to cut sediment cores from the seafloor surface to a maximum length of 2.3 m and preserve them at in situ pressure corresponding to water depths of up to 1500 m. The DAPC is equipped with a pressure control valve allowing deployment of up to 6000 m water depth. The cutting pipe, which is relatively short (2.7 m), hits the seafloor with a very strong impact. Therefore, it is especially suitable for sampling layered, gas-hydrate-bearing sediment. The device allows various analytical approaches. Due to the novel construction of the pressure barrel, this is the first system that allows CT-scanning of such cores (80 mm in diameter) in their pressurized state.
The pressure barrel consists of special reinforced plastic (GRP), aluminum alloys, seawater resistant steel and aluminum bronze. The pressure chamber is 2.6 m long and weighs about 180 kg. All parts of the pressure chamber exposed to seawater are suitable for long-term storage of cores under pressure for several weeks. The DAPC is to be deployed from a research vessel on the deepsea cable. It can be released from variable heights (1-5 m) and enters the seafloor in free fall mode.

*Materials used*
The DAPC pressure chamber is made of stainless steel (1.4571), aluminum bronze (CuAl10Ni) and a GRP pipe. The balls of both ball-valves are made of 1.4404. The cutting system, consisting of a cutting-shoe and outer cutting-pipe, is made of St52. Further materials used are ball bearing steel 1.4301 and PVC. All materials used for the pressure chambers have been approved by the Technical Safety Standard Bureau (TÜV) and classified through so-caleld 3.1b or 3.1a certificates.

*DAPC testing procedure*
The deployment from RV SONNE was similar to that of normal piston corers, pushed by a weight and released by a release mechanism. The video telemetry was not used for the sampling tests with the DAPC, which was released at water depths of 3000m.

*DAPC tests*
Two DAPC deployments were made during SO 177 (Table 5.4.1).

Table 5.4.1: DAPC deployments So 177/2.

| Deployment No. | Station | Area | Position at seafloor (N°;E°) | Water depth (m) |
|---|---|---|---|---|
| DAPC 01 | 119 | | 21°18.443;119°11.914 | 3011 |
| DAPC 02 | 135 | | 21°18.391,119°11.820 | 3007 |

*Stations sampled by DAPC*
Station 119 (DAPC 1) was sampled in 5 July. The first deployment of the DAPC was a success with a pressure retained at 95 bar and a core recovery of 1,85m in length. The accumulator pressure had been adjusted to 100 bar, the water depth was 3011 m. The degassing yielded 00 liter of gas.
Station 135 (DAPC 2) was sampled on 8 July. The second deployment of the DAPC was of limited success because the pressure chamber did not retain any excess pressure but a core of 1,65 m length was retrieved. The accumulator pressure had been adjusted to 110 bar, the water depth was 3007 m. The seat of the ball in the ball-valve was damaged and had to be repaired. After improving the seat of the ball valve the DAPC is fully functional, yet the liner cutting system has to be re-designed improved in order to allow CT scanning and subsampling.

### 5.4.2 Sediment facies

Thirteen sediment cores between 4 - 10 m in length (total length of recovered sediment 0 64 m) were taken by gravity coring (GC) during SO177/1+2. The gravity corer device was equipped with a 2 ton weight attached to the top of a 6 to 12 m steel tube surrounding an inner PVC-tube. As soon as cores arrived on deck, they were cut into approximately 1 m long segments and the segments were sampled at both ends for gas-geochemical investigations. The core segments were then split into archive and working halves. The working halves were immediately sampled for pore water analyses and physical property determinations. The archive halves were described using standard sedimentological characteristics, largely based on the ODP lithology classification and using Color Chart. Photographs of 1 m sediment segments and close-up photographs of particular features were taken with a Nikon Coolpix 995.
Since a major cruise objective was the detection of gas hydrates, it was decided early during the cruise to use flexible tubing instead of plastic liners for more rapid access to the sediment. This was assumed necessary because of the possibility of dissociation of gas hydrate during the lengthy process of core segmentation and splitting. The time needed to process cores taken with flexible tubing was only about 1/3 to 1/4 of the time needed using plastic liners and hence constituted a great improvement.
Gravity cores were taken only in the Haiyang 4 area at over 3000 m depth where hemipelagic sediments allowed good penetration. An overall summary of core descriptions is provided here, whereas the complete core description sheets are provided in the Appendix 8.2. Generally, 3 lithological intervals or units were recognized in sediments recovered from Haiyang 4 area: silty clay interval at the top of each core, turbidite sequences in the middle part, and silty clay interbedded with thin silt layers at the base. The lengths of these intervals vary greatly with cores. The outstanding feature of the sediments in this area is the numerous well-developed carbonate-rich turbidites. These deposits are carried down slope through the Formosa Canyon and probably spilt over the bank of the canyon at about where it changes course from a NNW-SSE to a W-E direction. Preliminary carbonate analyses show that the turbidite layers are well-correlated, which suggests the possibility of establishing an accurate time- and litho-stratigraphic framework for the area of the Formosa Canyon (Fig. ).

***Summary of core descriptions***

SO177/1 station 42 GC-1 (21° 18.543 N, 119° 11.926 E, 3002 mbs) The total core length is 440 cm. The sediment mainly consists of silt at its top (0-165 cm), turbidite sequences in the middle section (165-350 cm), and silty clay at the base.

SO177/1 station 55 GC-2 (21° 18.534 N, 119° 11.926 E, 3006 mbs) A total core length of 440 cm was brought to deck, however no core description was made because the lithology was very similar to that recovered by GC1 and the core was returned to sea after photography.

SO177/1 station 56 GC-3 (21° 18.534 N, 119° 11.919 E, 3005 mbs) 513 cm sediments were recovered. No core description was made due to the same reason given by GC 2.

SO177/1 station 57 GC-4 (21° 18.422 N, 119° 11.851 E, 3010 mbs) The total core length is 430 cm. No core description was made due to the same reason given by GC 2.

SO177/1 station 58 GC-5 (21° 18.448 N, 119° 11.823 E, 3011 mbs) The total core length is 600 cm. The sediment mainly consists of silt at its top (0-102 cm ), turbidite sequences in the middle section (102-394 cm), and silty clay interbedded with thin silt layers at the base.

SO177/1 station 65 GC-6 (21° 18.448 N, 119° 11.855 E, 3010 mbs) The core length is 440 cm. The sediment mainly consists of clay and silt at its top (0-165 cm), turbidite sequences in the middle section (165-350 cm), and silty clay at the base.

SO177/1 station 66 GC-7 (21° 18.448 N, 119° 11.859 E, 3010 mbs) 660 cm of sediments were recovered. The upper 175 cm consists mainly of silty clay. Turbidite sequences dominate the middle part (175-563 cm). The lower part consists mainly of silty clay interbedded with thin silt layers.

SO177/1 station 67 GC-8 (21° 18.453 N, 119° 11.824 E, 3007 mbs) The corer was curved and then no sediments were obtained.

SO177/1 station 70 GC-9 (21° 18.442 N, 119° 11.827 E, 3009 mbs) The total core recovery was 850 cm.The upper 126 cm consist of clay and silt. The middle part of the sediment (126-372 cm) is dominated by interbedded turbidite sequences with silty clay layers. The lower part consists of clay. The lowest part below 666 cm was washed out.

SO177/2 station 83 GC-10 (21° 18.453 N, 119° 11.819 E, 3008 mbs) The core recovery was 937 cm. The upper 166 cm consist mainly of silty clay. The middle part (166-478 cm) is dominated by turbidite sequences containing shell debris sized to 2 cm. The lower part consists of silty clay interbedded with thin silt layers. Sediments at the interval of 771-937 cm are remarkably very dry and fulfilled with cracks and voids textures caused by gas expansion.

SO177/2 station 94 GC-11 (21° 18.481 N, 119° 11.967 E, 3008 mbs) 726 cm of sediments were recovered. The upper 175 cm consist of clay and silt. Turbidite sequences dominate the middle part (176-398 cm). The lower part consists mainly of silty clay interbedded with thin silt layers. Mousse-like texture occur at 522-547 cm, while soupy texture were observed at depths of 672-678 cm and 680-689 cm. These textures are caused probably by melting of gas hydrates during recovery. Sediment between 609 cm and 710 cm are very dry and fulfilled with cracks and voids textures caused by gas expansion. At the base of the core occurs a turbidite layer (710-726 cm) consisting of fine shell gravel in sizes of 0.2 –0.5 cm.

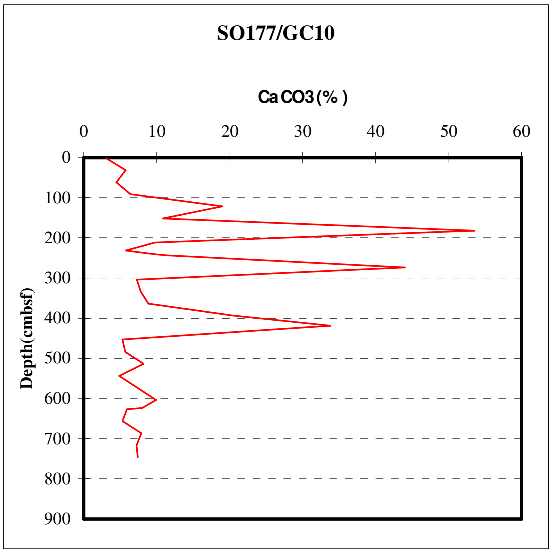
SO177/2 station 116 GC-12 (21° 18.409 N, 119° 11.869 E, 3010 mbs) The core recovery was 668 cm. The upper 125 cm consist mainly of silty clay. The middle part (125-229 cm) is dominated by turbidite sequences. The lower part consists of silty clay interbedded with thin silt layers.

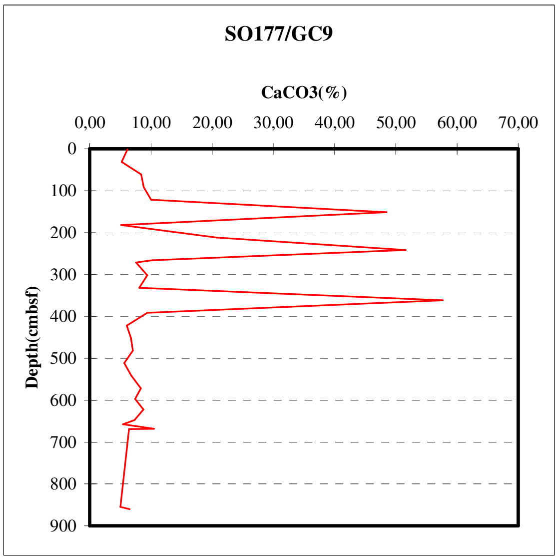
SO177/2 station 118 GC-13 (21° 18.469 N, 119° 11.950 E, 3012 mbs) 668 cm of sediments were recovered. The upper 125 cm consist of clay and silt.Turbidite sequences dominate the middle part (125-451 cm). The lower part consists of silty clay interbedded with thin silt layers. At the base of the core (650-668 cm) there is a turbidite layer of shell gravel in sizes of 0.2 –0.5 cm.

SO177/2 station 133 GC-14 (21° 18.407 N, 119° 11.829 E, 3004 mbs) The total core length is 340 cm. The sediment mainly consists of silty clay at its top (0-127 cm), turbidite sequences in the lower part.

SO177/2 station 134 GC-15 (21° 18.380 N, 119° 11.835 E, 3007 mbs) The core recovery was 529 cm. The upper 129 cm consist mainly of silty clay. The middle part (129-382 cm) is dominated by turbidite sequences. The lower part consists of silty clay interbedded with thin silt layers.

SO177/2 station 138 GC-16 (21° 18.351 N, 119° 11.803 E, 3007 mbs) 529 cm sediments were recovered. The upper 129 cm consist mainly of silty clay. Turbidite sequences dominate the middle part (129-382 cm). The lower part consists of silty clay interbedded with thin silt layers.



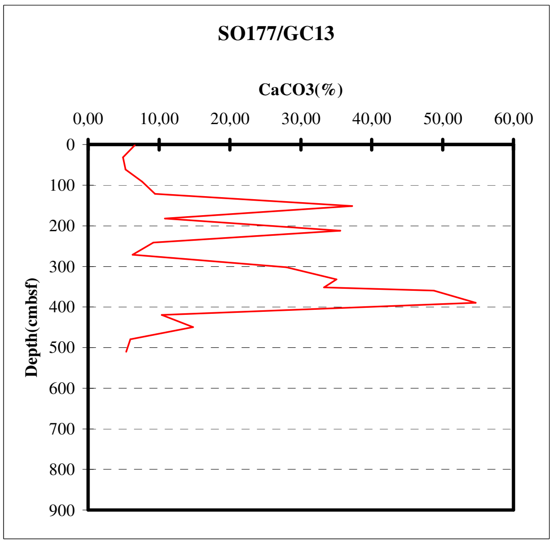




Figure 5.4.2.1
Carbonate content of cores GC-9. –10, 13 from Haiyang 4 site (water depth 3000 m); maxima are calcareous silt and sand derived from shallow water turbidites

### 5.4.3 Lithologies and biological samples

#### *5.4.3.1 Authigenic Carbonates*

Xiqiu Han, Erwin Suess, Anton Eisenhauer, Nengyou Wu, Xin Su, Gerhard Bohrmann,Yongyang Huang

The formation of authigenic carbonates at cold vent sites of continental margin has been associated with methane-rich fluid and the activity of chemosynthetic biological communities(Suess et al., 1985, Boetius et al., 2000, 2004). In Jiulong methane reef area, where the water depth is in the range of 500-800 m, observation from TV-guided instruments revealed that several huge chemoherm edifices standing above the seafloor, and abundant authigenic carbonate chimneys, slabs, blocks together with shell debris of chemo-authotrophic bivalves lying or protruding from sediments. However, in Haiyang 4 site, where the water depth is around 3000 m, it was observed that abundant shell debris from vent clam scattered in patches on the sea floor but very few carbonate concretions occurd. Altogether 14 TV-guided grabs were deployed and hundreds of carbonate samples were collected mainly from the area of Jiulong methane reef. Samples were mechanically cleaned, washed with seawater, cut, photographed and described.

The carbonates recovered are comparable with the cold seep carbonates discovered in continental margin in the world ocean, e.g. Costa Rica margin( Han et al., 2004), Orgegon margin (Kulm et al., 1986; Bohrmann et al, 1998), Gulf of Mexico (Aharon et al., 1992), the Black Sea (Thiel et al., 2001), etc.. According to the morphology and texture, the carbonate samples in South China Sea were preliminary classified into 4 types, they are chemoherm carbonates (Fig. 5.4.3.1-2), seepage associated carbonates (Fig. 5.4.2.3), gas hydrate-associated carbonates(Fig. 5.4.3.4), and carbonate concretions which can be subgrouped as carbonate chimney (Fig. 5.4.3.5-6), tubular carbonate (Fig. 5.4.3.7-9), tabular carbonate (Fig. 5.4.3.10) and massive carbonate (Fig. 5.4.3.11). About the criteria of the classification please see Han et al. 2004 and references cited. Table 5.4.3.1 provides a comprehensive summary of the recovered authigenic carbonates.

It has been shown that the formation of authigenic carbonates in cold venting sites is driven by the anaerobic oxidation of methane (AOM) (ref. ), these carbonates provide an archive of fluid venting and information on the fate of gas hydrates in the South China Sea. Shore-based research will include the study of petrology, mineralogy, stable isotope geochemistry, and dating which will help to constrain the geochemistry and temporal variations of fluid flow and methane release events related to the dissociation of gas hydrate in the South China Sea.

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## Table 5.4.3.1 Summary of authigenic carbonates in South China Sea

| Type | | Characteristics | Sampling location |
|---|---|---|---|
| Chemoherm Carbonates (Type 1) | | Chermoherm carbonate block, contain abundant shells or shell debris, aragonite lining the voids or precipitates in contact with shells, some samples is greenish gray looks like freshly cemented, some samples has brownish Fe-Mn coating on the surface | TVG 9, 7 |
| Seepage associated concretions (Type 2) | | Massive carbonate concretion, dark brown surface with Fe-Mn oxide coating, inside is gray, micritic, abundant in holes with chitinous wall left by tube worms (2-5mm dia.). | TVG 1, 2 |
| Gas hydrate carbonates (Type 3) | | Irregular dark gray aragonite cemented highly breciated carbonates, aragonite layer lining the elongated voids or chimney like vents (3-7mm thick), the surface of the aragonite layer usually has several nodular protuberance (1-2.5cm dia.). The voids were perhaps left by the dissociation of gas hydrate, and the nodular protuberance might be the imprints of gas hydrate bubbles. | 22°02.858 N, 118°46.513 W, water depth 769 m, TVG 11 |
| Carbonate concretions (Type 4) | Chimney-shape (Type 4-1) | Carbonaceous chimneys in various shapes, some shaped like doughnuts, some have furcated and linked pipes, some shaped like funnels, with the bottom (3.5-18cm dia) bigger than the top. The chimneys are usually 4-10 cm high, with the orifice 2-4 cm in dia..Some of the channels have have been filled with porous clay (TVG 8), some have white carbonate mineral precipitates (TVG 14). Some look old and have brownish surface, some are gray and look like newly weak cemented. | TVG 1, 2, 3, 11, 13, 14, 8 |
| | Tubular (Type 4-2) | Tubular, molds of bioturbation tube or fluid channels, some are spiral-like. 1-3cm dia., 5-16cm long, no open channel inside, but some have tube worm holes | TVG 1, 2, 6, 8, 13, 14 |
| | Tabular (Type 4-3) | Tabular carbonate concretions, micritic,0.5-2 cm thick, some have central holes | TVG 13 |
| | Massive (Type 4-4) | Irregular massive carbonate concretions, micritic, some are porous, the pores usually 1cm size and pinholes 1-3mm | TVG 6, 7, 8, 11, 13, 14 |
| | | Huge irregular carbonate blocks, dark brown surface, porous with many protuberance in the size of 1-2.5cm dia., and many organisms living (corals, sponge, etc. shrimps) on the surface. Gray inside, micritic, aragonite precipitated inside some of the elongated voids, but no venting clams included. | 22° 08.983 N, 118° 52.337 W, water depth 473 m, TVG2, 3 |

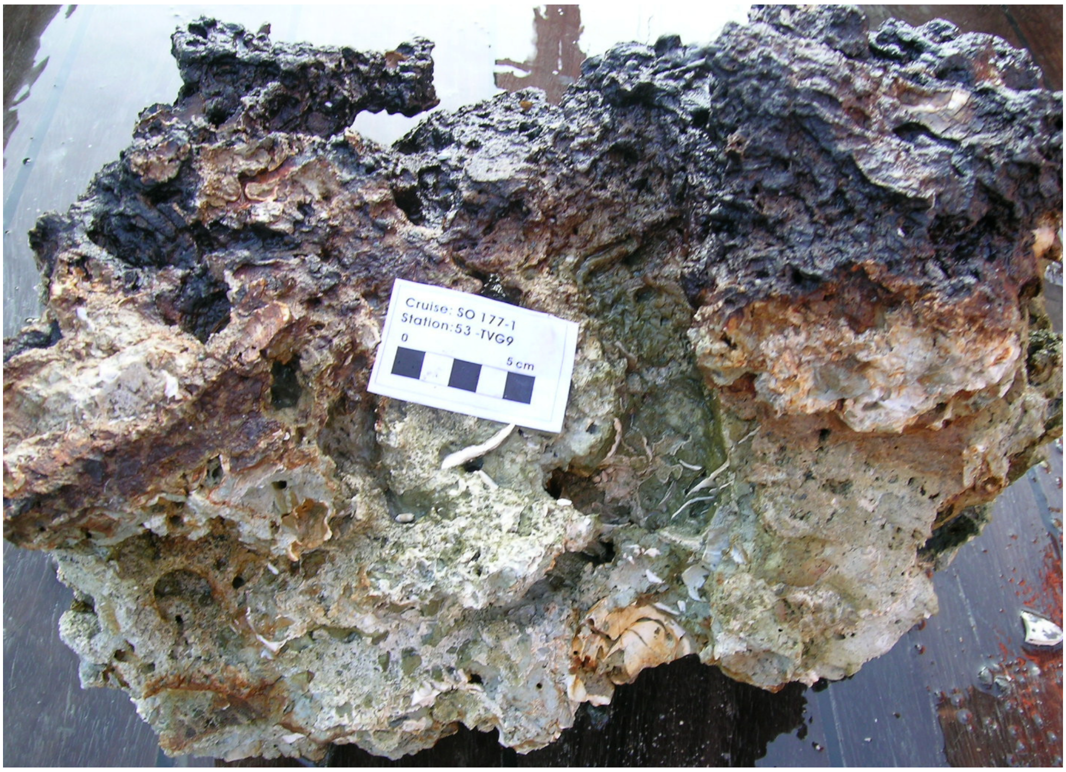



Fig. 5.4.3.1 Type 1: Chemoherm block, irregular, brownish Fe-Mn coating (about 1mm thick) with many protuberances (0.5cm in dia. porous), gray inside, abundant in shell or shell debris and carbonate breccia. 55x42x24cm, TVG 9


Fig. 5.4.3.2 Type 1: Cross section of a chemoherm block, contains shells (Mytilus),one big clam is 9cm long and the thickest part is 1cm, aragonite lining the voids and the inside of clams, fresh sediments fill in open voids. 32x17x14cm. TVG 9


Fig. 5.4.3.3 Type 2: Seepage-associated concretion, massive, dark brown surface with Fe-Mn oxide coating and protuberances. Cross cutting shows that the inside is gray, micritic, abundant in holes with chitinous wall left by tube worms (2-5mm in dia. ), 12x8x4cm,TVG1

Fig. 5.4.3.4 Type 3: Gas hydrate associated concretion, cross section shows that it contains elongated layering voids (1~6x1~2cm), the matrix was highly brecciated and cemented by aragonite which looks like surrounded by white network, TVG11.

Fig. 5.4.3.5 Type 4-1: Carbonate chimneys in various shapes, with brownish surface, some shaped like doughnuts, some have furcated and linked pipes, some shaped like funnels, with the bottom (3.5-18cm dia) bigger than the top. The chimneys are usually 4-10 cm high, and up to 13 cm in diameter, with the orifice 2-3cm in dia., TVG 13

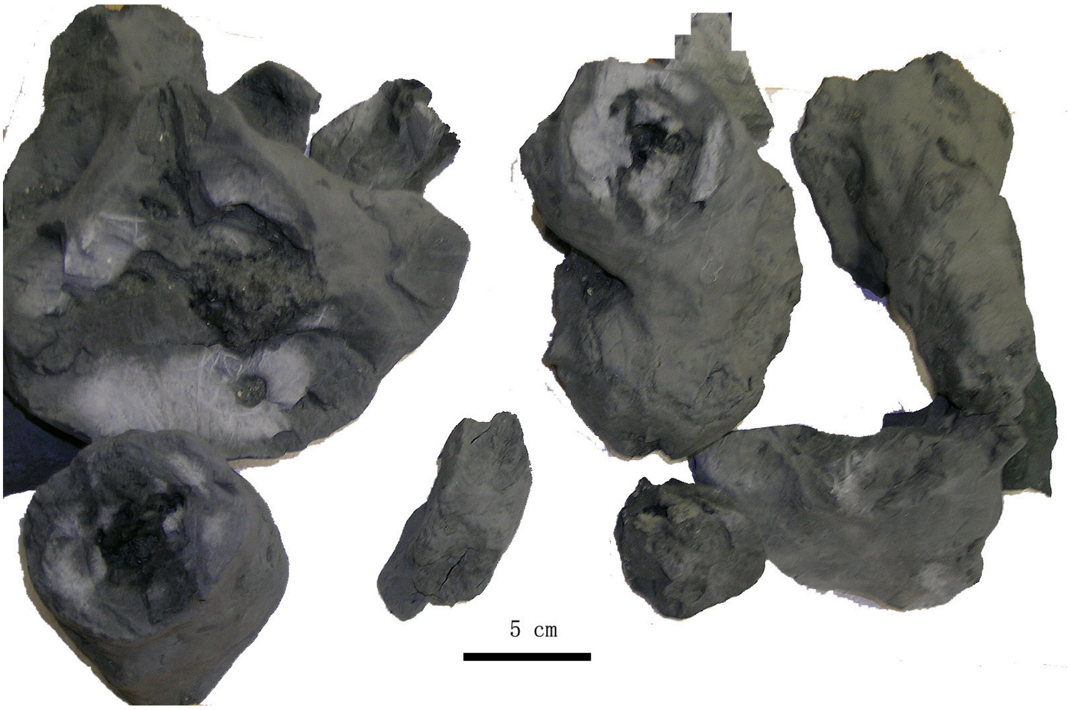



Fig. 5.4.3.6 Type 4-1: Carbonaceous chimneys, max. 16x12x6cm, with porous clay filling. The central orifice is about 3x4cm in dia.,in bottom side is bigger than that in the top side, micritic, blackish gray, look like newly weak cemented. TVG 8


Fig. 5.4.3.7 Type 4-2: Tubular carbonate concretions, molds of bioturbation tube or fluid channels, some are spiral-like. 1-3cm dia., 5-16cm long, no channel inside. TVG 1


Fig. 5.4.3.8 Type 4-2: Tubular carbonaceous concretions, bullet like, 2.5cm in dia.,cross section shows some samples have tube worm holes inside with chitinous walls. One sample has abundant pinholes. No apparent channel inside. TVG 6


Fig. 5.4.3.9 Type 4-2: Tubular carbonaceous concretions, molds of bioturbation tube or fluid channels, 6-20cm long, 2-4cm in dia.gray or dark green in colour. TVG 8


Fig. 5.4.3.10 Type 4-3: Tabular carbonate concretions, micritic,0.5-2 cm thick, some have central holes. TVG 13


Fig. 5.4.3.11 Type 4-4: Huge irregular carbonate block, dark brown surface, porous with many protuberance in the size of 1-2.5cm dia., and many organisms living (corals, sponge, etc. shrimps) on the surface. Gray inside, micritic, aragonite precipitated inside some of the elongated voids, but no venting clams included. TVG 3

### 5.4.3.2 Biological sample summary

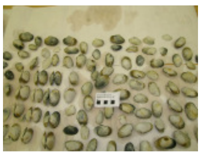
*Recovery by TVG*

The TV-guided grab (TVG) is a heavy tool to collect sediment, rock or biological samples from the seafloor. Its jaws can be closed hydraulically. It is powered by deep-sea batteries allowing closing and opening several times. The area of the grab when open is about 1.8 $m^2$. The instrument is equipped with a black-and-white camera and a colour camera.

An overall summary of biological samples is provided here (Table XX ), whereas the complete description sheets are provided in the Appendix XX. Biological samples recovered are benthic assemblages dominated by clams, with common gastropods, worm tubes, sponges and corals, and occasionally worm and brachiopods.

Types of biological groups obtained from the **Jiu Long Methane Reef** area are clearly different from those from Haiyang 4 area, for example, clam shells in the former area are larger and thicker, while they are smaller and thinner in the later area. The diversity of the assemblages from the "Nine Dragon Methane Reef" area is also larger than that from the deeper **Haiyang 4** area.

Table 5.4.3.2 Summary of biological samples recovered during SO177 cruise

| | Biological groups recognized | Selected photographs of main groups | Sites of TVG |
|---|---|---|---|
| Nine Dragon Methane Reef area | Bivalves |   | TVG 6<br>TVG 7<br>TVG 8<br>TVG 11 |
| | Corals |   | |
| | Worm tubes (left)<br><br>Gastropods (right) |   | |
| Haiyang 4 area | Bivalves |   | TVG 4<br>TVG 5<br>TVG 10<br>TV-MUC 10<br>TV-MUC 14 |
| | Worm |   | |

### *5.4.4 Pore-water geochemistry of surface sediments*

B. Domeyer, K. Nass, Shaoying FU, Youhai ZHU, Jianming GONG

The geochemical composition of pore-waters provides information on early diagenetic reactions and impacts redox- and mineralization processes within the upper sediment column. During cruise SO 177 the pore water composition of surface sediments was investigated at more than 28 locations to characterize and quantify sediment diagenetic processes and fluid geochemistry in the South China Sea. Concentration vs. depth profiles of pore-waters were determined for major nutrients, total alkalinity, chloride, hydrogen sulfide, sulfate, bromide and methane to identify locations influenced by seepage and to assess the effect of methane formation and particularly anoxic oxidation of methane (AOM). Below is an overview on the procedures of sediment retrieval, pore water processing, and geochemical laboratory methods followed by some preliminary results.

*5.4.4.1 Sampling, processing, and analyses*

Sediments were generally retrieved by using a TV-guided multi corer, a gravity corer and rarely by a TV-grab. To prevent a warming of the sediments after retrieval, the cores of the multi corer were immediately placed in a cooling room and maintained at a temperature of about 4°C. Supernatant bottom water of the multicorer-cores was sampled and filtered for subsequent analyses. The multicorer-core was processed immediately after recovery. Each core of the multicorer was cut into slices for pressure filtration with a minimum depth resolution of 0.5 cm. Instead of plastic liner we used plastic tubing in most cases for gravity coring to provide very fast access to the sediment samples. Cores were placed in the geological laboratory and sampled quickly after retrieving.

In addition to the pore water sampling each core was sampled for methane at the same depth intervals. Therefore 3ml sediment was taken with a syringe and injected into a 2o ml septum vial. Seven ml of 1M NaOH solution was added and the vial was closed with a hand crimping tool. Before measurements the sample were shaken for one hour. Each sample depth for pore water was sampled for the calculation of sediment density as well. Porosity sub-samples were filled into pre-weighed plastic vials.

Pore water was extracted by pressure filtration using a PE-squeezer. The squeezer was operated with argon at a pressure gradually increasing up to 5 bar. Depending on the porosity and compressibility of the sediments, up to 30 ml of pore water were received from each sample. The pore water was put through 0.2 µm cellulose acetate membrane filters.

Pore water analyses of the following parameters were carried out during the cruise: ammonia, phosphate, alkalinity, hydrogen sulfide, chloride, methane, silicate, sulfate, and bromide. Listed in Table 5.4.4.1 are the analytical techniques used on board to determine the various dissolved constituents. Modifications of some methods were necessary for samples with high sulfide concentrations. Detailed descriptions of the methods are available on http://www.geomar.de/zd/labs/labore_umwelt/Analytik.html.

Table 5.4.4.1: Techniques used for pore water analyses.

| Constituent | Method | Reference |
|---|---|---|
| Alkalinity | Titration | Ivanenkov and Lyakhin (1978) |
| Silicate | Spectrophotometry | Grasshoff et al. (1997) |
| Phosphate | Spectrophotometry | Grasshoff et al. (1997) |
| Ammonium | Spectrophotometry | Grasshoff et al. (1997) |
| Chloride | Titration | Gieskes et al. (1991) |
| Hydrogen sulphide | Spectrophotometry | Grasshoff et al. (1997) |
| Methane | Gas chromatography | Niewöhner et al. 1998 |
| Sulfat,Chloride, Bromide | Ion Chromatographie | METHROM Applications http://www-odp.tamu.edu/publications/notes/tn15/f_chem3.html |

Silicate, ammonium and phosphate were measured photometrically using standard methods described by Grasshoff et al. (1997). The total alkalinity of the pore water was measured by titration of 0.5-1 ml pore water according to Ivanenkov and Lyakhin (1978). Titration was completed until a stable pink color occurred. During titration the sample was degassed by continuously bubbling nitrogen to remove the generated $CO_2$ or $H_2S$. The acid was standardized using a IAPSO seawater solution. The method for sulfide determination according to Grasshoff et al. (1997) has been adapted for pore water concentrations of $S^{2-}$ in the range of millimolar amounts. For reliable and reproducible results, an aliquot of pore water was diluted with appropriate amounts of oxygen-free artificial seawater; the sulfide was fixed by immediate addition of zinc acetate gelatin solution immediately after pore-water recovery. After dilution, the sulfide concentration in the sample should be less than 50 µmol/l. Chloride was determined by titration with $AgNO_3$ standardized against IAPSO seawater. Acidified sub-samples (30µl suprapure HCl + 3 ml sample) were prepared for ICP analyses of major ions (K, Li, B, Mg, Ca, Sr, Mn, Br, and I) and trace elements. Sulfate, DIC, $\delta^{18}O$ and $\delta^{13}C$ of $CO_2$ will be determined on selected sub-samples in the shore-based laboratories. Table 5.4.4.2 summaries the total number of samples analyzed per core during the SO 177 cruise, amounting 513 samples with an astonishing 5500 individual measurements. All analytical results are listed in the Appendix 8.5

### *5.4.1.1 Preliminary results*

The results pertain to three issues: Degradation of sedimentary organic matter, characterization of the sulfate-methane-interface (SMI), and documentation of chloride anomalies. Negative Cl-anomalies and SMI are related to and indicative of methane gas hydrates in the sedimentary strata, whereas organic matter degradation is the general early diagenetic process active in young sediments which are unaffected by cold seepage.

*Sulfate-methane-interface at Haiyang 4 area*

Two sets of TV-guided multi-cores exemplify the near-surface processes and show the very high variability in pore water chemistry on very small spatial scales. All cores are unusually high in methane; sediments from TV-MUC-13-A and -13-G (Station 131; Figs 5.4.4.8 & 9) have near-surface methane concentrations between 100 – 400 µM within 5-10 cm below sea floor (cmbsf) which drop off down core. Similarly TV-MUC 4 (Station 24; Fig. 5.4.4.10) has methane contents of between 10-50 µM within 5-25 cmbsf. Simultaneously all 3 cores show a strong sulfate decrease (28 to less than 25 mM) and strong hydrogen sulfide increase within the zone of high methane. This relationship indicates anoxic methane oxidation (AOM) near the sediment water interface; in fact from the hydrogen sulfide profiles it can be inferred that the sulfate-methane-interface lies at 2 cmbsf, 5 cmbsf and 10 cmbsf, respectively in these MUCs (Figs. 5.4.4.8 & 9 & 10). This is highly unusual for normal hemipelagic sediments and clearly indicates methane supply into the sulfate reduction zone. What is unusual however, is the fact that there is no evidence for methane supply directly from below, since the concentrations decrease downcore, instead methane could be provided horizontally along highly stratified turbidite layers which are ubiquitous throughout the Haiyang4 Site.

The other interstitial nutrient and chloride concentrations show no unusual features and are in agreement with increased reactivity within and near the methane-oxidation sulfate-reduction zone. Remarkable is the high variability in pore water composition over small distances. This is exemplified by cores -A and -G which come from the same location (station 131; Figs. 5.4.4.8 & 9) and are not more than 50 cm horizontally apart from each other. This situation might also point to horizontal fluid transport within the sediment surface.

Of the more than 100 m of sediment taken by gravity coring at 13 sites in the Haiyang4 area. Four cores will be discussed here in detail: GC-3 (station 56; Fig. 5.4.4.3), GC-9 (station 70; Fig.5.4.4.5 ), GC-10 (station 83; Fig. 5.4.4.1), and GC-13 (station 118; Fig. 5.4.4.2) because each contains remarkable features in the pore water composition. GC-13 shows one of the highest hydrogen sulfide concentrations (8000 µM) yet the methane concentration is only 200 µM. On the other hand core GC-9 has a 40-times higher methane content at depth (8000 µM) but the sulfide content is only one-half that (5000 µM) measured in core GC-13. The lowest methane concentration was measured in core GC-3 (maximum 30 µM) yet the hydrogen sulfide content exceeded 3000 µM; core GC-10 reaches at depth 3000 µM methane and 9000 µM hydrogen sulfide. In each core the sulfate concentration is completely exhausted within the depth interval cored.

The high resolution sampling of these cores and the large concentration changes of the reactants involved in AOM (methane, sulfate and hydrogen sulfide) allow for a very precise determination of the sulfate-methane-interface, which in reality is not an a 2-dimensional interface but rather a zone of finite thickness. This is illustrated by the data from GC-13 and GC-9 (Figs. 5.4.4.2 & 5). In each core the beginning of sulfate reduction coincides with the increase of hydrogen sulfide; e.g. at 400 cmbsf in GC-9 and 320 cmbsf in GC-13. The end of sulfate reduction coincides with the increase in methane; e.g. 640 cmbsf in GC-9 and 420 cmbsf in GC-13. This delineates distinct sulfate-reduction and methane-consumption zones; e.g. 240 cm thick in GC-9 and 100 cm thick in GC-13.

The difference in thickness of the reaction zone is remarkable and perhaps has to do with the rates of supply and dispersal of the reactants. A more detailed explanation needs to be worked out. If the middle depth of the reactions zone is taken as the SMI then for all cores, including the near-surface MUCs, a regional pattern of the SIM can be constructed at the Haiyang4 area (Fig. 5.4.4.11). This figure shows the high variability of excess methane in the sediment. The interpretation is that up-doming of the SMI indicates upward advection of methane-saturated fluids, perhaps originating from gas hydrates in the subsurface.

Extrapolation of the highest methane concentration measured at GC-9 to depths suggests that saturation might be reached at this site at about 16-24 mbsf. Such depths estimates are the shallowest range at which gas hydrates might be encountered at Haiyang4 area.

*Cl-anomalies*

In contrast to strong and spiky negative Cl-anomalies, usually caused by dissociating gas hydrates, all GC-cores showed modest, smooth but discontinuous Cl-decreases. The high sample resolution and the comparison of results from shipboard titration and shore-based ion-chromatography confirm beyond doubt that modest Cl-anomalies are present but also illustrate the importance of doing careful and reliable shipboard analyses. The latter being much more consistent and showing less scatter (Figs. 5.4.4.12). Core GC-10 shows the strongest Cl-decrease to 540 mM amounting to about 3.5 % of the seawater value. For this decrease to be significant a precision of < 1%; e.g. +/- 2.5 mM as attained by the titration analyses is required.

Interestingly all cores show the onset of any Cl-anomaly to be at about the same depth interval as the sulfate-methane-reaction zone (GC-9, GC-10, GC-11). Since Cl does not participate in this reaction it is be assumed that the methane-rich fluids advecting upwards must be depleted in Cl. This confirms the conclusion that the observed Cl-anomalies are atypical for gas hydrate dissociation within the cored sediment package.

The cause for Cl-depletion is currently not clear, either it could be derived from deep fluids subjected to clay dehydration or indeed from dissociation of gas hydrates at depth.

*Sulfate-methane-interface at Jiu Long area*
Coring was difficult on the Jiu Long carbonate complex and hence pore water data are few. However, two cores were obtained by TV-guided multi-coring from a sediment patch between the chemohem carbonates (TV-MUC 11 station 125 and TV-MUC 12 station 126) one of which is illustrated here (Figs. 5.4.4.6 & 7). The outstanding feature of this core is the high methane concentration of 60 µM at 5 cmbsf and simultaneous sulfate decrease and hydrogen sulfide increase. Similar as with the MUC-cores from the Haiyang 4 area this relationship indicates anoxic methane oxidation (AOM) very near the sediment water interface. Also as at Haiyang4 there is no evidence for methane supply directly from below, because methane decreases downcore. Howeve, the depth resolution of samples is too poor to invoke a horizontal transport of methane-rich fluids, what is however beyond doubt is the fact the AOM is active here at the sediment surface.

Table 5.4.2.2a: Total number of samples analyzed per core

| Station | 22 TV-MUC-2 Core G | 23 TV-MUC-3 Core F | 24 TV-MUC-4 Core B | 40 TVG-4 | 41 TVG 5 Core A | 41 TVG 5 Core B | 42 GC-1 | 52 TVG-8 | 56 GC-3 | 58 GC-5 | 59 TVG-10 | 65 GC-6 | 70 GC-9 | 83 GC-10 | 84 TV-MUC-6 | 87 TV-MUC-7 Core A | 87 TV-MUC-7 Core G |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shipboard analyses | | | | | | | | | | | | | | | | | |
| Hydrogen sulfide | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Chloride titration | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Alkalinity | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Phosphat | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Silica | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Ammonia | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Ion chromatography | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Chloride, bromide, sulfate | | | | | | | | | | | | | | | | | |
| Subsamples for shore based work | | | | | | | | | | | | | | | | | |
| del 13C | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| del 18O | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| I C P analyses | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Ion chromatophy | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| (iodide) | | | | | | | | | | | | | | | | | |
| Number of samples | 20 | 20 | 18 | 17 | 12 | 9 | 16 | 9 | 20 | 9 | 13 | 22 | 32 | 38 | 19 | 12 | 9 |

## Table 5.4.4.2b

| Station | 94<br>GC-11 | 97<br>TV-MUC-9<br>Core A | 115<br>TV-MUC-10<br>Core A / E | 116<br>GC-12 | 118<br>GC-13 | 125<br>TV-MUC-11<br>Core E / A | 126<br>TV-MUC-12<br>Core G / E | 131<br>TV-MUC-13<br>Core A / G | 132<br>TV-MUC-14<br>Core G | 137<br>TV-MUC-15<br>Core A | 138<br>GC-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Shipboard analyses | | | | | | | | | | | |
| Hydrogen sulfide | x | x | x | x | x | x | x | x | x | x | x |
| Chloride titration | x | x | x | x | x | x | x | x | x | x | x |
| Alkalinity | x | x | x | x | x | x | x | x | x | x | x |
| Phosphat | x | x | x | x | x | x | x | x | x | x | x |
| Silica | x | x | x | x | x | x | x | x | x | x | x |
| Ammonia | x | x | x | x | x | x | x | x | x | x | x |
| Ion chromatography | x | x | x | x | x | x | x | x | x | x | x |
| Chloride, bromide, sulfate | | | | | | | | | | | |
| Subsamples for shore based work | | | | | | | | | | | |
| del 13C | x | x | x | | | x | x | x | x | x | x |
| del 18O | x | x | x | x | x | x | x | x | x | x | x |
| I C P analyses | x | x | x | x | x | x | x | x | x | x | x |
| Ion chromatophy (iodide) | x | x | x | x | x | x | x | x | x | x | x |
| Number of samples | 24 | 24 | 41 | 19 | 25 | 14 | 21 | 41 | 20 | 19 | 20 |

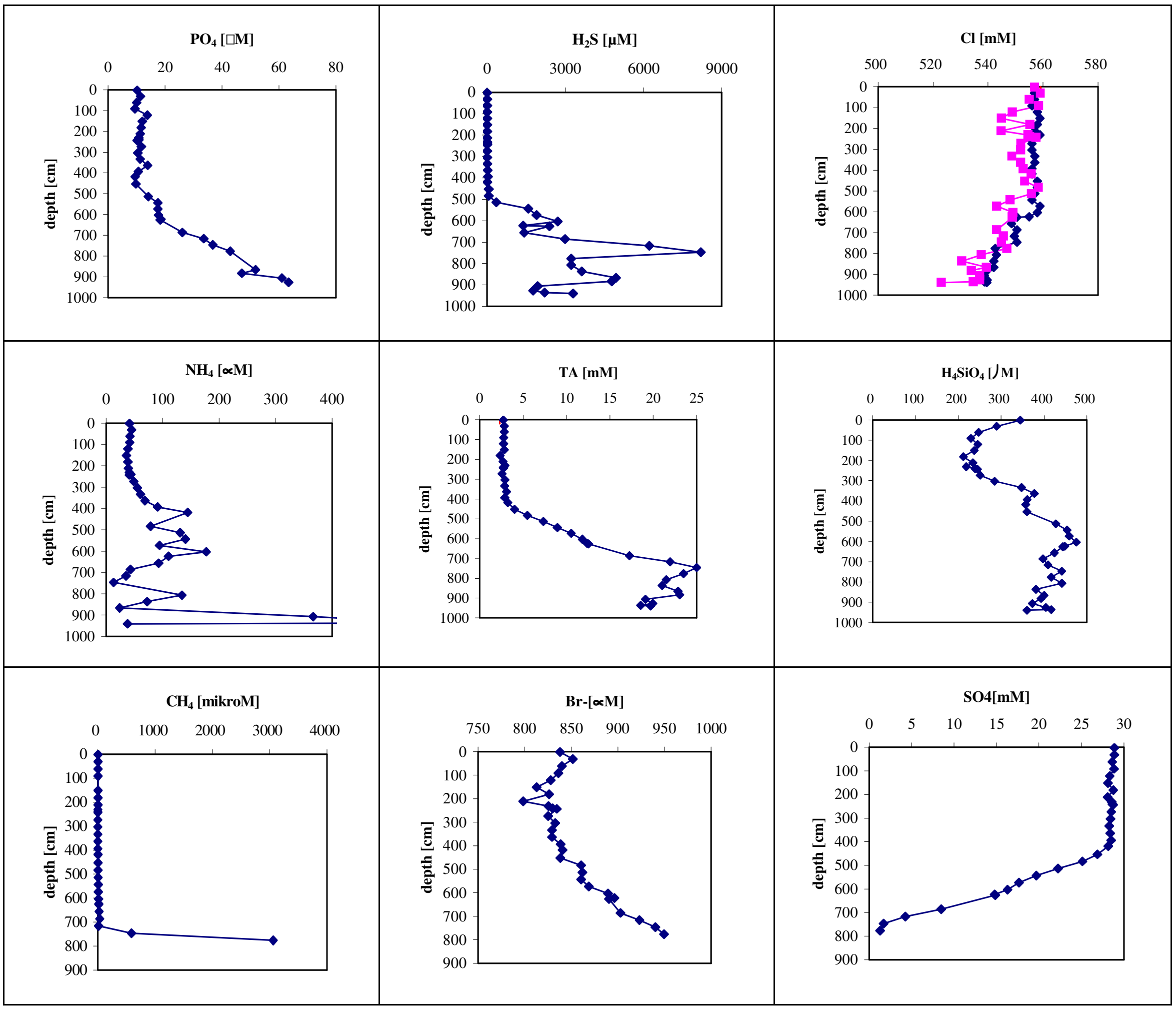



Figure 5.4.4.1 Pore water composition gravity core GC-10

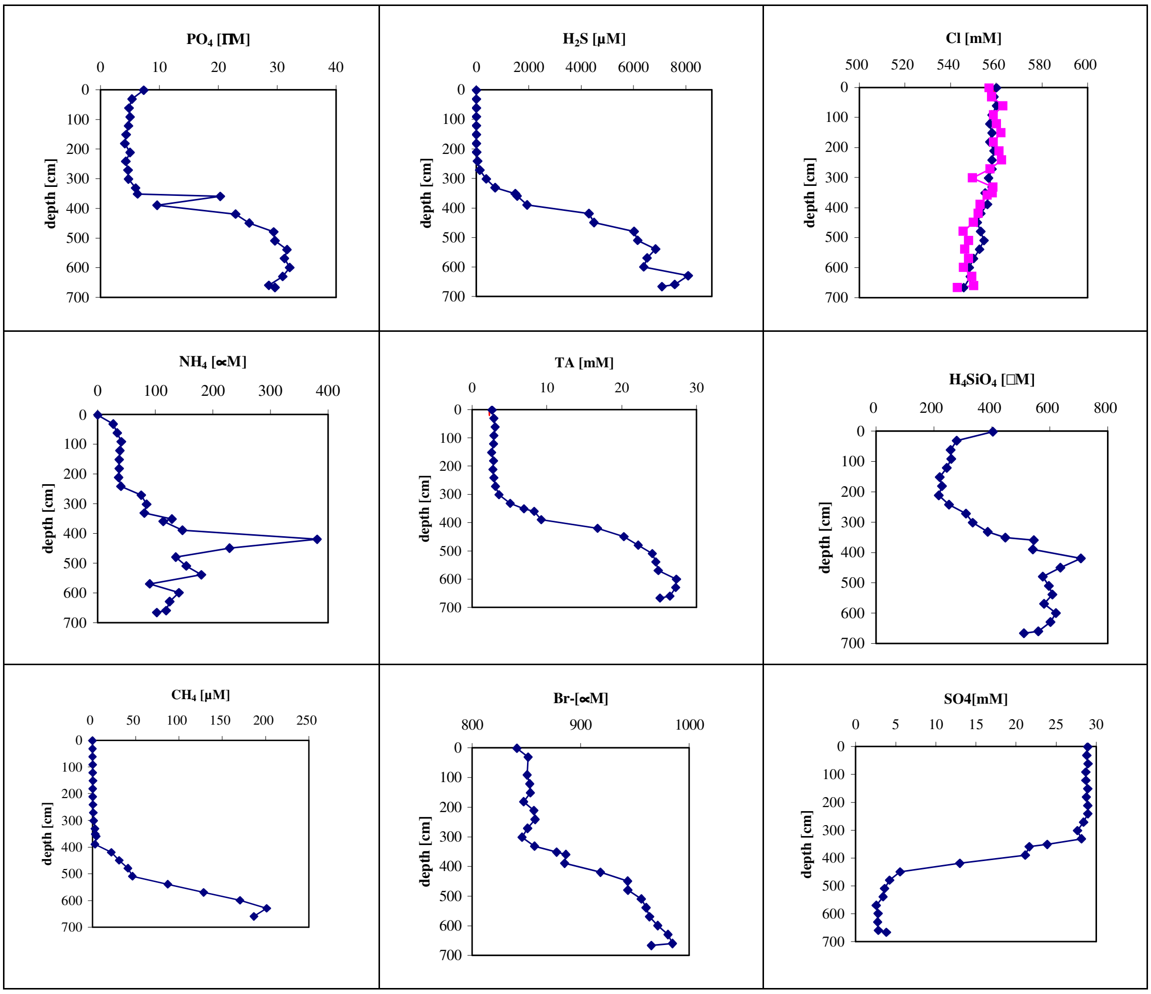



Figure 5.4.4.2 Pore water composition gravity core GC-13

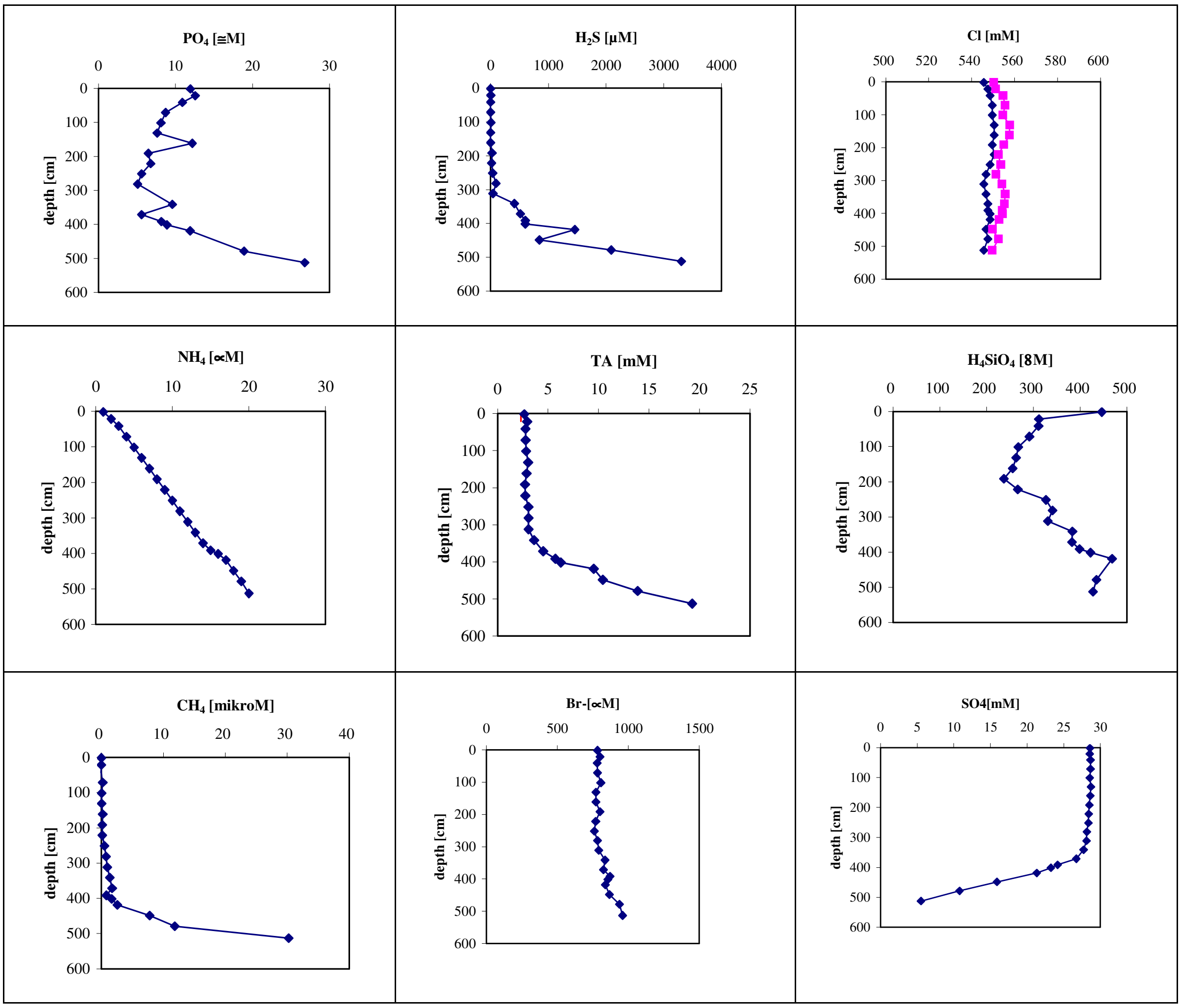



Figure 5.4.4.3 Pore water composition of gravity core GC-3

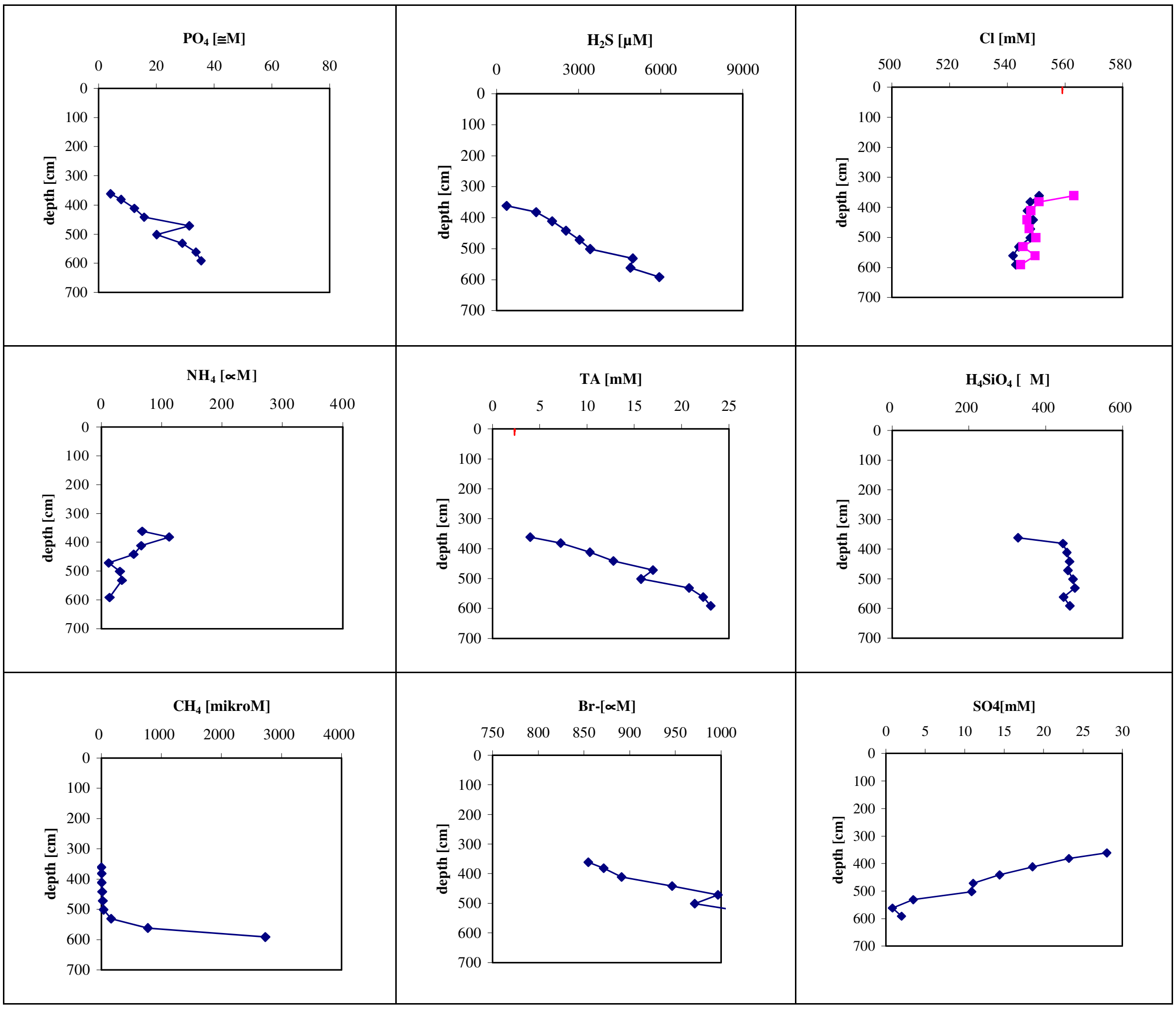



Figure 5.4.4.4 Pore water composition gravity core GC-5

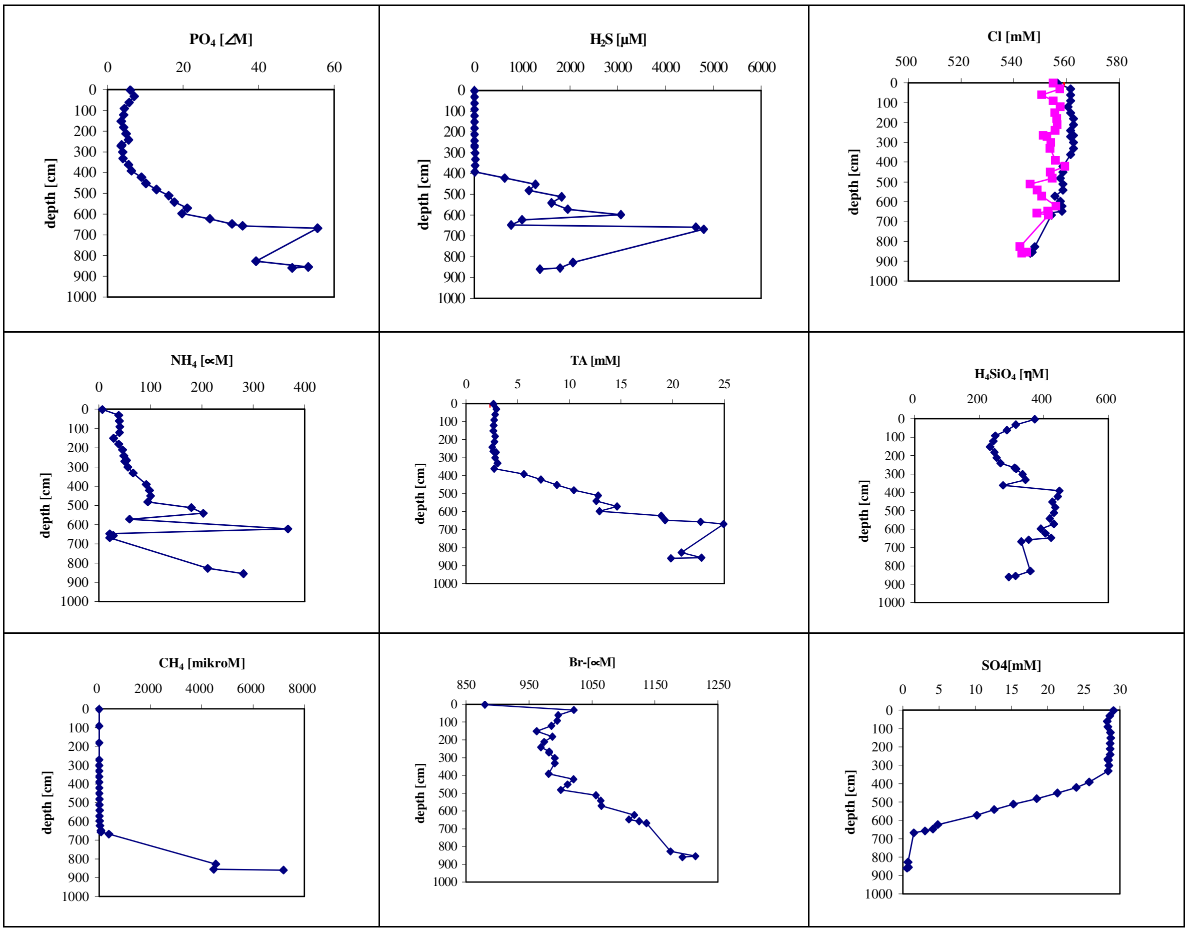



Figure 5.4.4.5 Pore water composition of gravity core GC-9

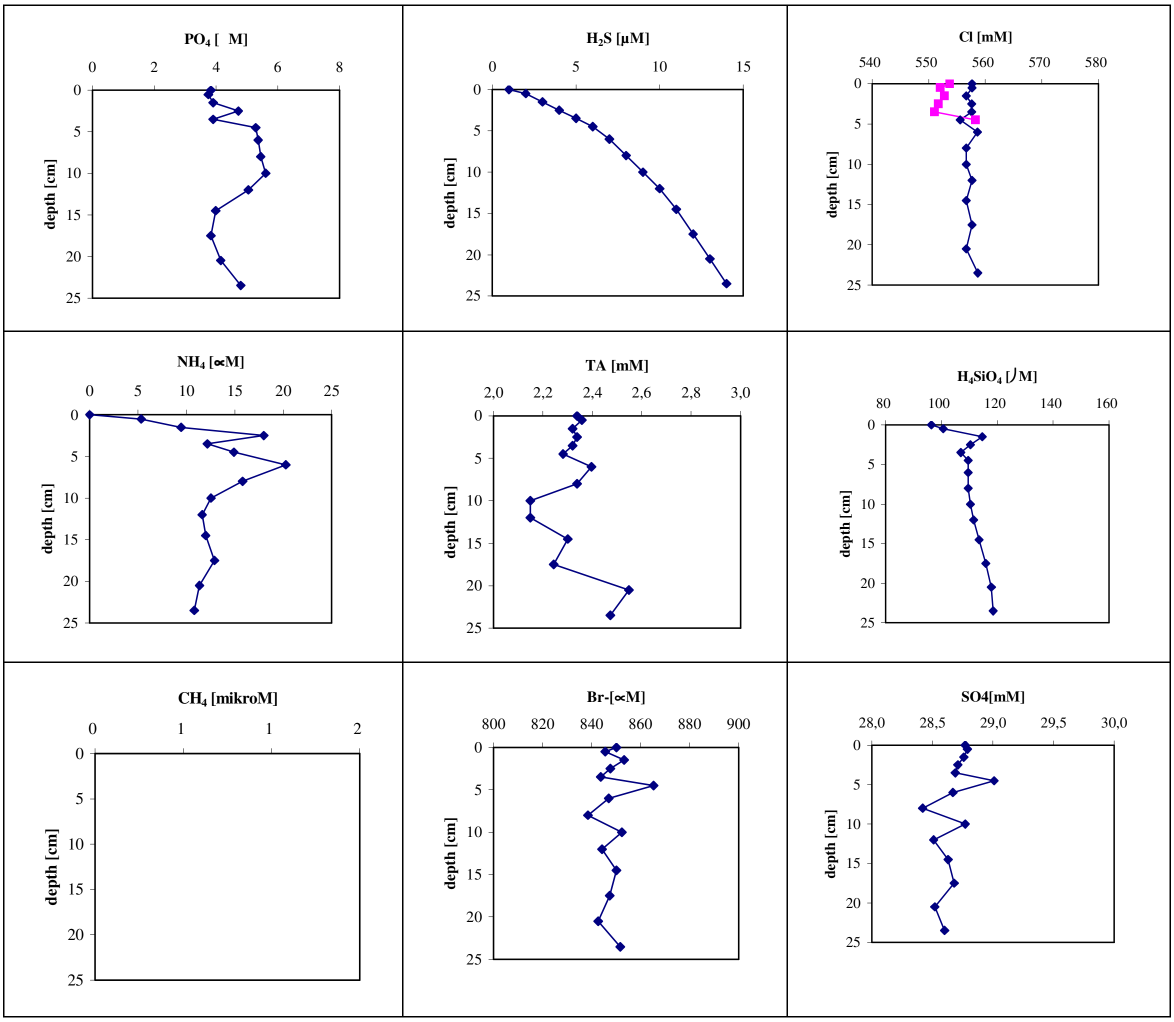



Figure 5.4.4.6 Pore water composition of core TV-MUC–12-E

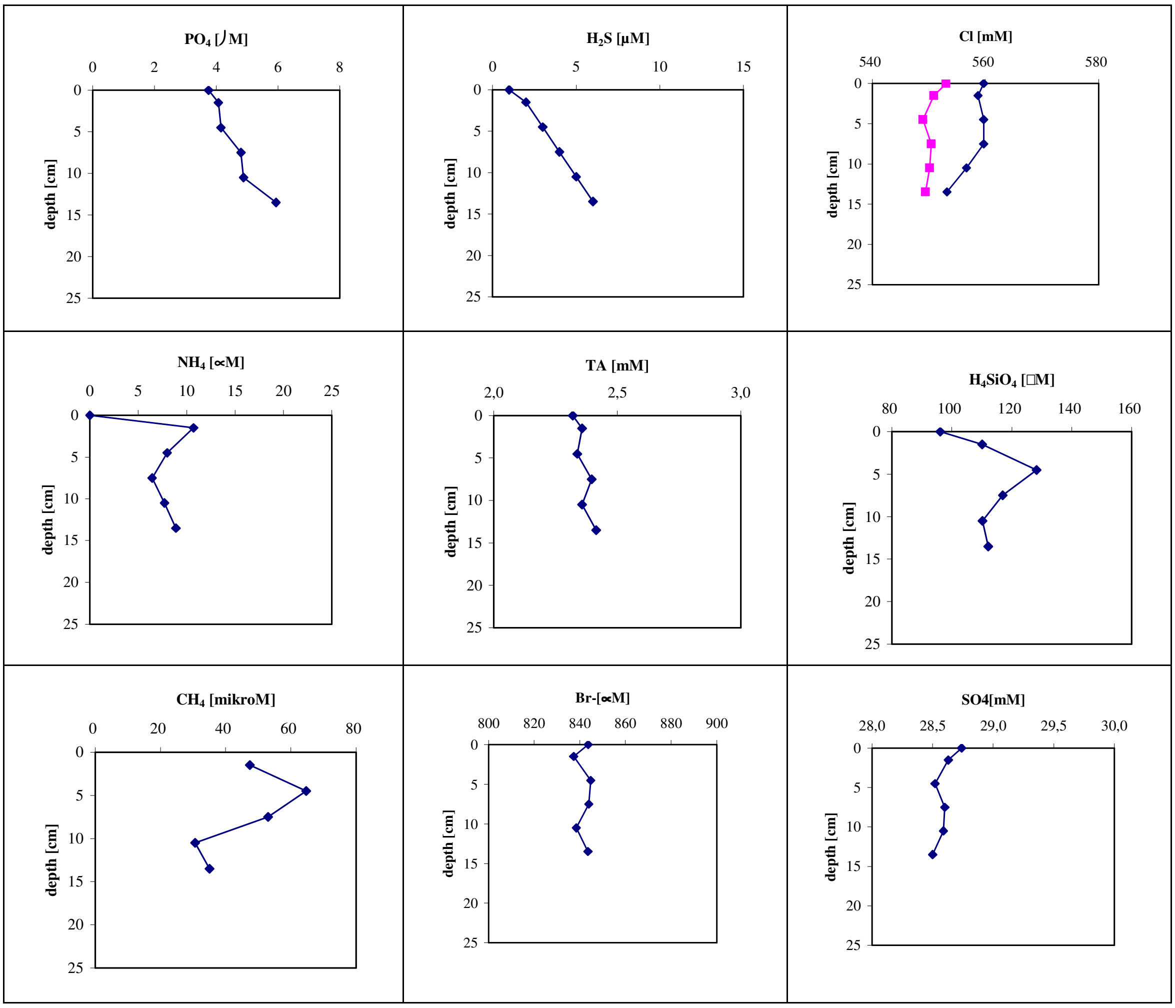



Figure 5.4.4.7 Pore water composition of core TV-MUC-12-G

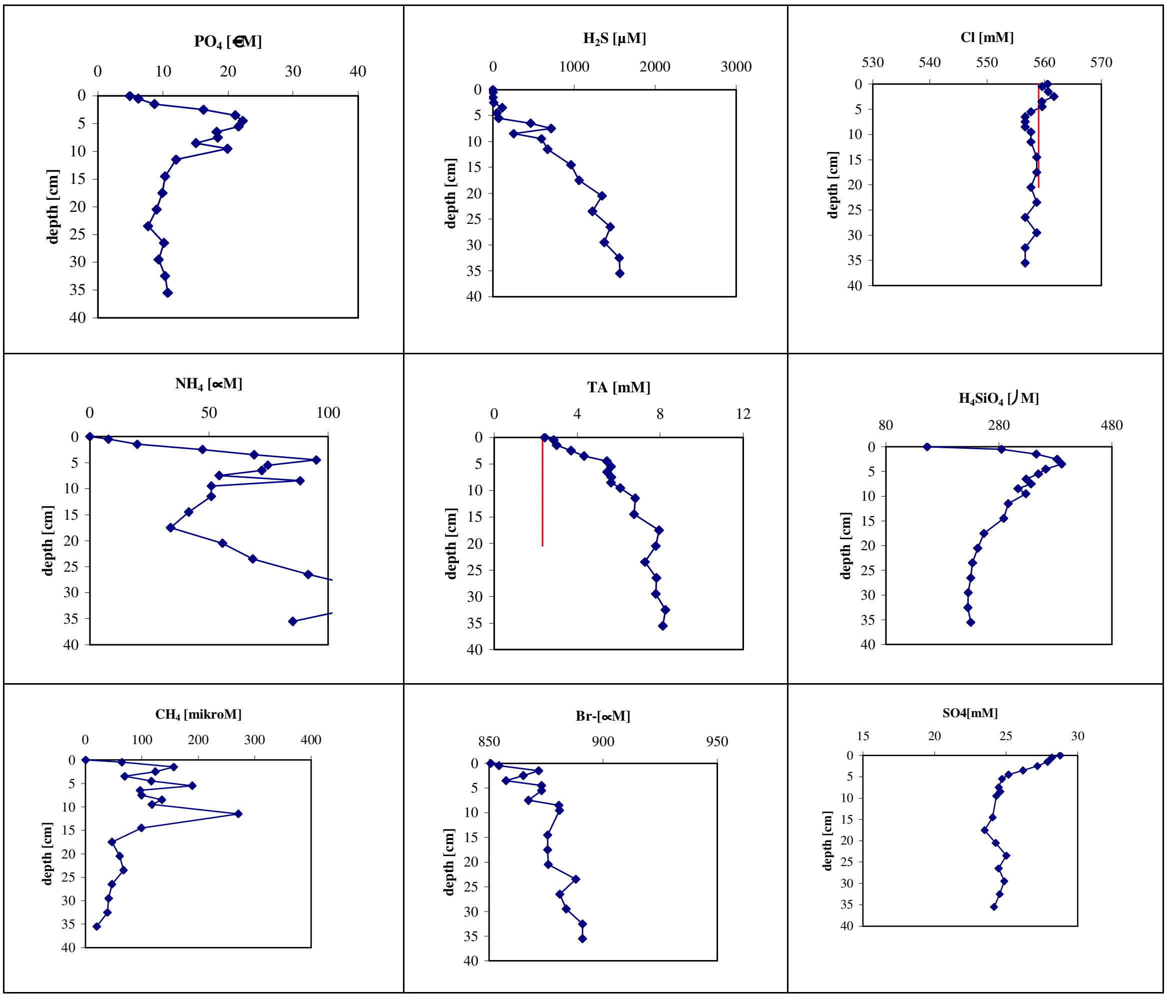



Figure 5.4.4.8 Pore water composition of core TV-MUC-13-A

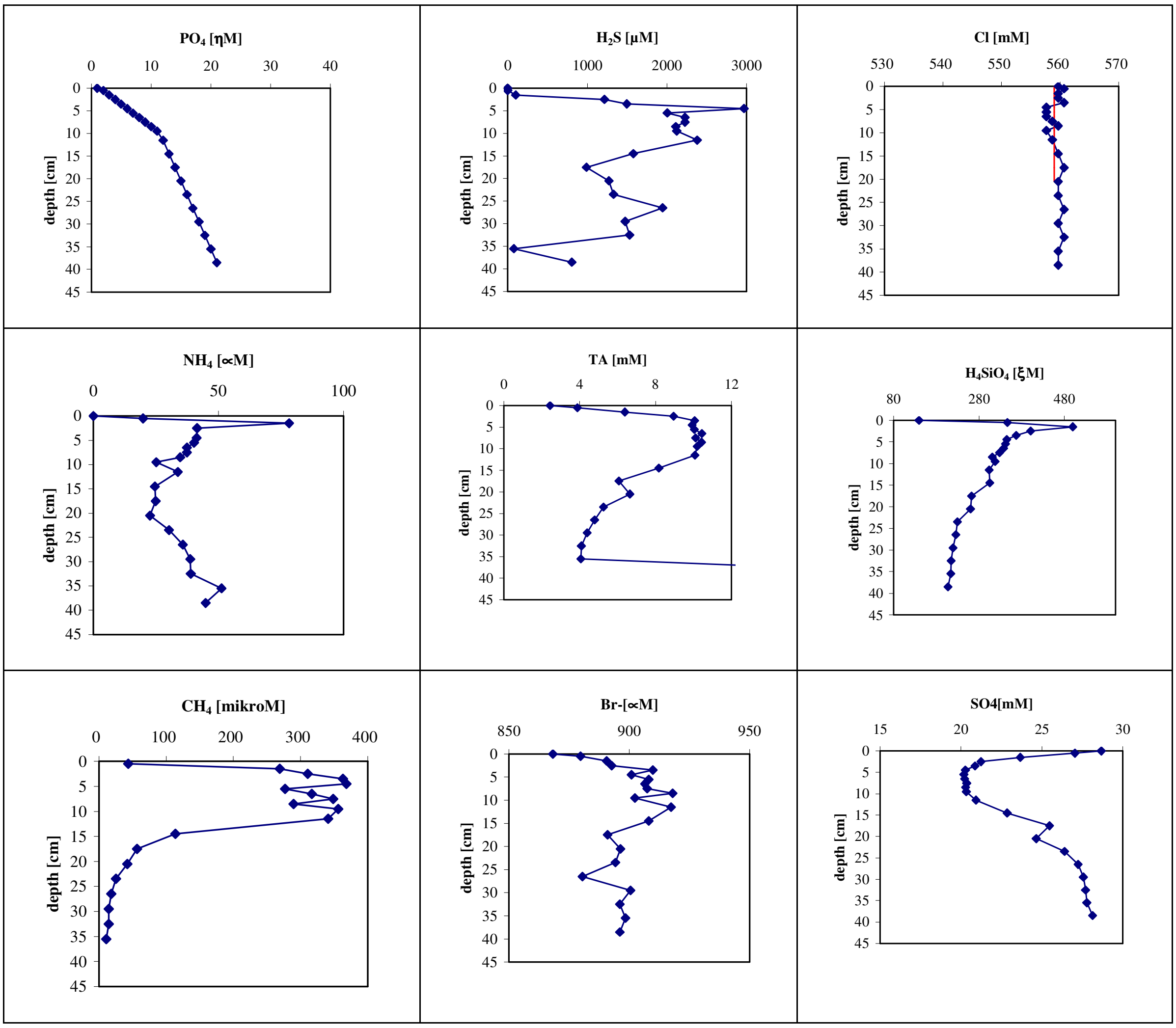



Figure 5.4.4.9 Pore water composition of core TV-MUC-13-G

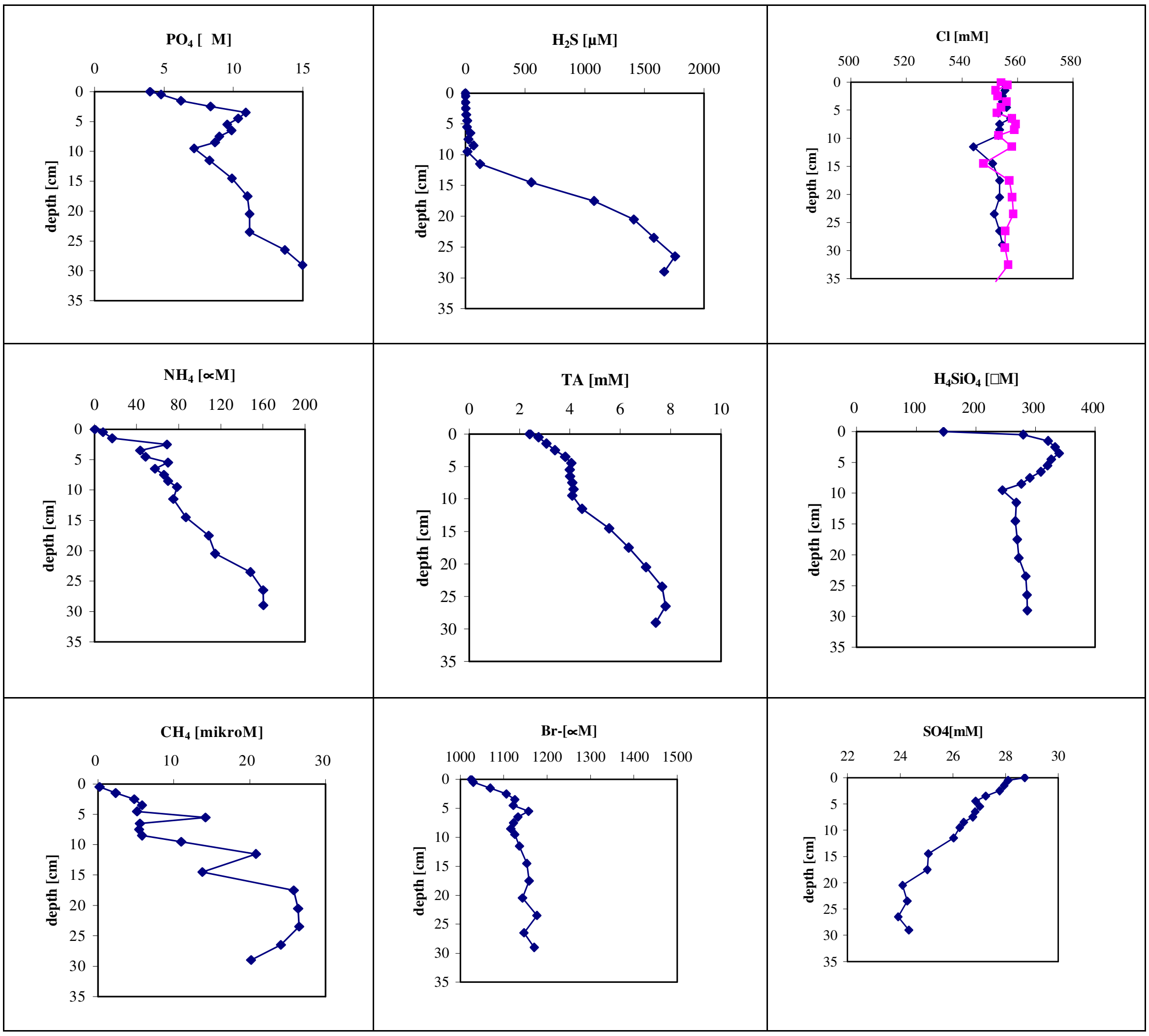



Figure 5.4.4.10 Pore water composition of core TV-MUC-4

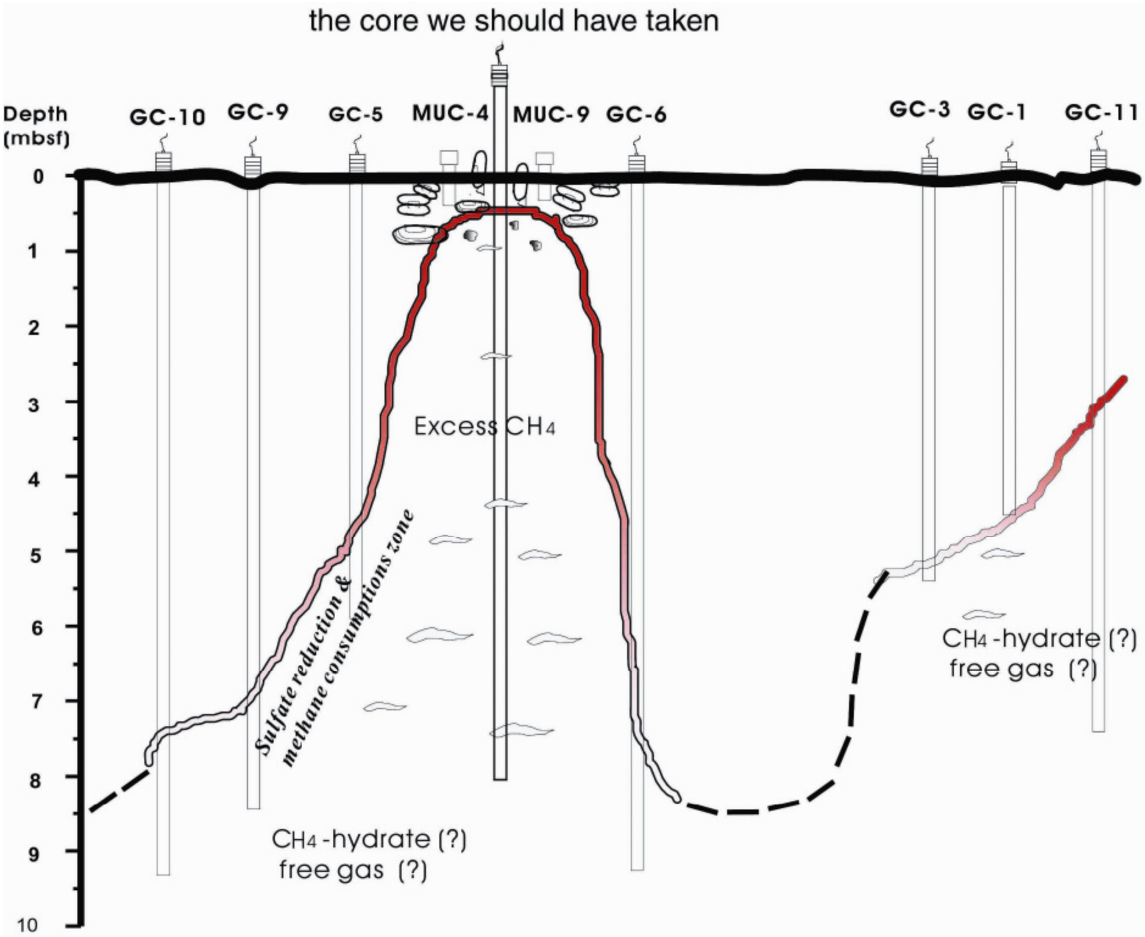



Figure 5.4.4.11: Schematic summary of depth distribution of sulphate-methane-interface at Haiyang 4 area; the "core we should have taken" would perhaps have recovered gashydrates because of expected methane supersaturation.

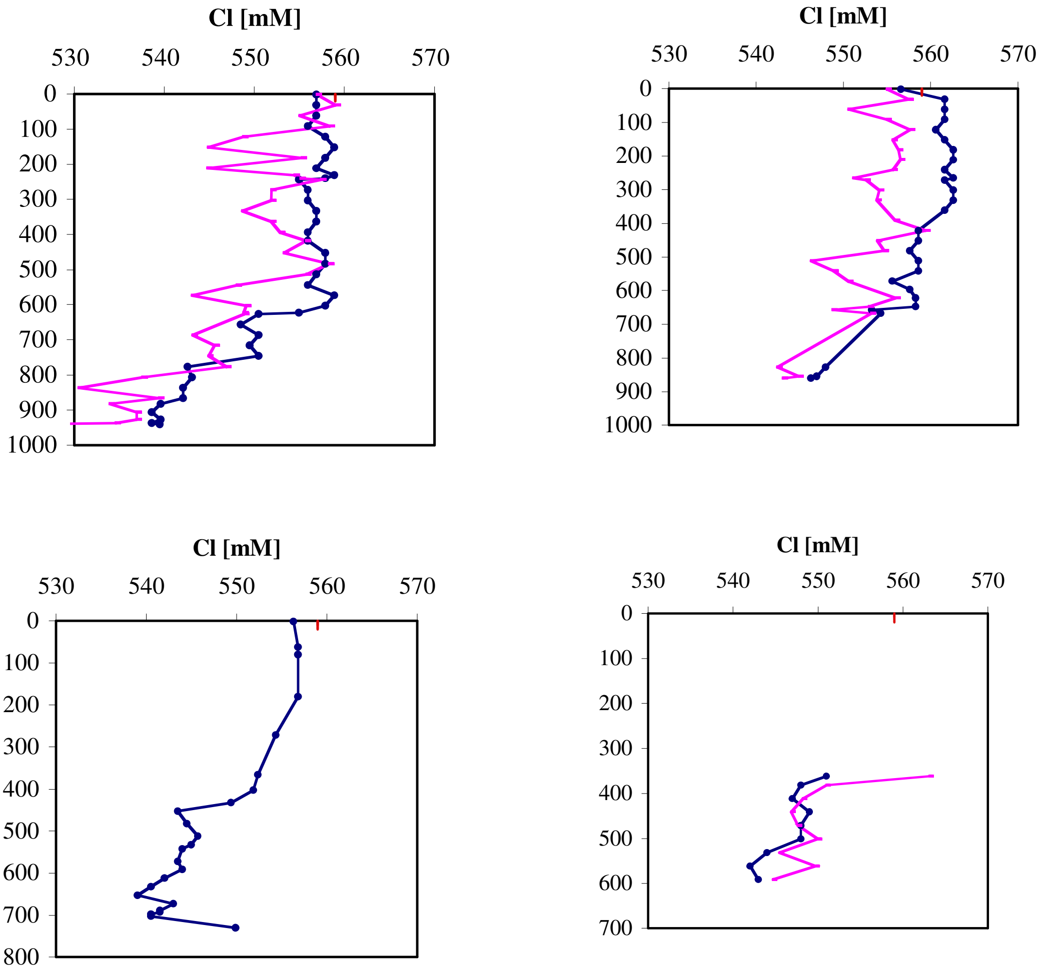



Figure 5.4.4.12: Cl-anomalies in pore water of selected GC-cores;
bars = shore-based ion chromatography; dots = shipbaord titration

## 6. Acknowledgements

Many thanks go to politicians, adminstrators and fellow scientist from both countries for their unwaverig suppport and confidence in the success of the SiGer 2000 project. Among these special mention goes to former Vice Minister Mrs. SHOU Jiahua of the Ministry of Land and Resources, Beijing when she visited GEOMAR. It took several delegation visits afterwards and a memorable test cruise for some Chinese colleagues aboard the RV SONNE until finally in March 2004 a charter agreement and a scientific cooperation agreement were signed. During these negotiations the support by Dr C. von Spee of the RF-company, Bremen is highly appreciated as is the help by the German diplomatic staff in Beijing and Hongkong, notably by Dr. Keune. During time at sea from 2 June to 15 July the vessel's master and crew did their best to make all participants feel at home; this helped a great deal in cementing Sino-German cooperative research. Here we would like to express our appreciation to all from both countries who made this a successful project and helped to set an example of good international cooperation.

# 7. Public relations

## 7.1 Open ship 14/15 July 2004

### 7.1.1 RV SONNE Leaflet

**RV SONNE**
A German research vessel for multi purpose oceanographic research

Since many years RV SONNE is an integral part of the larger sized vessels of the German research fleet. Built as a commercial stern trawler in the mid 1970ies, the ship was converted into a research vessel in 1978. In the next 13 years it was mainly used for geological and geophysical research in the Indian and Pacific Ocean. New tasks for a broader scale of oceanographic objectives required substantial improvements. In 1991 the ship was enlarged by a 10m section and underwent other structural changes which made RV SONNE compatible for all modern oceanographic reseach objectives.
RV SONNE is owned by a the private research shipping company RF in Bermen (Germany) and is operated on a longterm contract with the German Ministry of Education and Research as rearch platform for German marine research. The vessel is also available for other charterers for several weeks each year.

**Main ship´s particulars:** Length 87,90m, width 14,20m, draught 6,80m, 3557 BRT, deplacement 4734t
**Travel speed:** 12.5kn
**Maximum sea time:** 50days
**Crew:** 30 (nautical/technical), 27 (scientists)
**Propulsion:** Diesel-electric , 2x 1150kW DC-motors
**Dynamic positioning**
**Scientific area:** 260m$^2$ working deck, 21 rooms with 425m$^2$
Permanent technical scientific installations:
Multi beam echosounder Simrad EM 120 (full ocean depth)
Paremetric echosounder (Parasound)
CTD/Rosette
TV-grab
Ocean floor observation system (OFOS)
**Scientific winches:**
Deeep sea winch with 2 storage drums for 8000m
18mm glas fibre optical cable
18mm geological heavy duty wire
wave compensator
hydrographic winch with 2 storage drums for 8000m
11mm conductive wire
**Lifting gear:**
24m core catcher
2 A-frames
5 cranes
**Container space: 5 on working deck; 1 in hold**

### 7.1.2 RV SONNE Leaflet (Chinese version)

# “太阳号”船
# 德国多功能海洋科学调查船

**“太阳号”科学调查船是德国科学调查平台中较大的调查船。20世纪70年代，“太阳号”原为商业拖捞船，1978年被改装为科学调查船。在随后的13年中，“太阳号”船主要用于印度洋和太平洋地质、地球物理调查。随着海洋调查科学目标和需求的拓展，“太阳号”船于1991年进行了实质性的改造，中部截断加长了10米，并对船体结构进行了较大的改进，以满足所有现代海洋科学调查研究的需要。**

“太阳号”船属于德国RF公司(一家从事调查、运输的船舶私有公司，位于不莱梅)，作为德国海洋调查研究的主要平台，与德国教育研究部具有长期的调查研究合同。该调查船也可以租用给其他机构进行海洋科学调查研究。

**主要参数:** 长87,90m, 宽14,20m, 吃水深度6,80m, 3557 BRT, 吨位 4734t

**巡航速度:** 12.5节

**最大持续力:** 50天

**定员:** 30 (船员和技术员), 27 (科学家)

**推进力:** 柴油机, 2x1150kW DC-发电机

**动力定位系统**

**科学工作区域:** 260m$^2$工作甲板, 21个房间, 面积425m$^2$

固定调查仪器设备：

Simrad EM 120 多波束测深仪

Parasound浅剖仪

CTD/Rosette

TV-grab电视监视抓斗

OFOS海底电视观测系统

**科学绞车:**

深海绞车，具备8000m 长18mm光缆和18mm地质缆

涌浪补偿器

水文绞车，具备8000m长11mm传输缆

**起重装置：**

24m 岩心支撑支架

2 A-架

5 起重机

**集装箱空间:**

工作甲板上具备5个集装箱空间

1 个货舱集装箱

### 7.1.3 Tour guide for RV SONNE Open ship

**Tour Guide to RV SONNE**

**“太阳号”科学调查船参观线路指南**

**Station 1**: Welcome 欢迎入口

Distribute the SO-177 cruise logos 分发SO-177航次徽标

**Station 2**: Meeting Point甲板集合点

General introduction to RV SONNE and its capacity on the deck “太阳号”船及其调查能力总体介绍

**Station 3**: TV-G(TV-guided grab sampler) & Samples 电视监视抓斗取样器及其抓取的样品

**Station 4**: OFOS(Ocean floor observation system)海底电视观测系统

**Station.5**: TV-MUC(TV-guided multi corer) & Air-gun Room Station
电视监视多管取样器和地震气枪室

**Station 6**: CTD(Salinity-temperature-density 24-bottle rosette sampler) 温盐深测量24桶采水器

**Station.7**: Heave Compensator and Winch Control
Room涌浪补偿器和钢缆清洁压缩气瓶及绞车控制室

**Station.8**: CTD Winch CTD绞车

**Station.9**: Bridge 驾驶台

**Station.10**: Scientific Bridge and Poster 科学工作区和图展

Down stairs and walk through the library, small meeting room, cabins, laundry,
etc下楼穿越图书馆、小会议室和船长、首席科学家房间、洗衣间等

**Station.11**: Mess Room 餐厅

**Station.12**: Conference Room 会议室

Slide show: operation at sea during SO-177 幻灯片展示海上工作场景

Walk through the cabins穿越科学家住房

**Station.13**: Hospital 医院

**Station.14**: Geochemistry Lab. 地球化学实验室

**Station.15**: Electronics Lab. 电子仪器室

**Station.16**: Computer Lab. 计算机室

**Station.17**: Chemistry Lab. Wet 湿化学实验室

**Station.18**: Chemistry Lab. Dry (X-Ray) 干化学实验室

**Station.19**: Hydro Acoustic Lab.( Simrad EM120 Multibeam survey & Parasound survey instruments)
多波束水深测量和浅剖调查工作室

**Station.20**: Cold Lab. 冷冻岩心样品库和冷冻工作间

**Station.21**: Geology Lab & OFOS 地质实验室和海底电视观测工作室

Summary movie show from OFOS, TV-G and TV-
MUC海底电视观测、电视抓斗和多管取样录像放映

**Station.22**: Water Column Chemistry Room 水体地球化学分析实验室

**End, Bye and Thanks** 参观结束

## 7.2 Media reactions

### *7.2.1 Print media*

*7.2.1.1 The Geological Exploration Herald, September 23, 2004:*

Gas Hydrate: How Far from Us ?
Interview with the Co-chiefs of SO-177, the Chinese-German Cooperative Project, Prof. Yongyang HUANG and Prof. Erwin SUESS


□陈惠玲

# 可燃冰：离我们还有多远？

——访"太阳号"合作项目中德首席科学家黄永祥、埃文·休斯

2004 年 7 月 13 日，"太阳号"科考船完成了航次任务返回上海，遗憾的是，"太阳号"并没有如人们所愿带回可燃冰样品。那么中国海域存在可燃冰的结论是否可信？可燃冰距离我们有多远？本报记者采访了中、德首席科学家黄永祥和埃文·休斯(Erwin Suess)教授。

**可燃冰在海底以下 15 米左右**

**记者：**休斯教授，您好，非常高兴您能接受《地质勘查导报》的采访。中国南海确实存在可燃冰吗？如果有，它在距离我们多远的地方呢？

**休斯：**我们这次的研究区域不到南海的 1/100。此前，中国科学家已经做了一些工作，获得了似海底反射界面等，表明在南海海域从海底到以下较深处分布有可燃冰。

我的专长和兴趣点在出露于海底浅表层的可燃冰，目前在南海还没有发现。但是，我们发现了在这个区域的海底表面的确有可燃冰存在的证据。它大约在海底以下 15 米左右的地方，但目前我们的设备还达不到这个深度。

**记者：**这些证据包括什么？

**休斯：**我们拍摄到的海底照片就是证据。在我们工作的东沙"九龙甲烷礁"的地方，发现了与海底浅表层可燃冰相关的碳酸岩结壳。它实际上起源于可燃冰，通过一些化学反应形成的。它的存在就说明了可燃冰的存在。

另外，在工作区域的东南角，对重力柱状取样取到的海底以下 8~9 米深度的孔隙水样品，通过无机化学分析，这些数据与甲烷分布有关，其中最主要的有甲烷、硼、硫酸根。在正常的没有可燃冰存在的沉积物中，甲烷的含量约为 100ppm，但现在可以看到它达到了 5000 ~ 15000ppm。根据三者之间的关系来推测，表明可燃冰存在于海底 15~20 米的深度。

**记者：**但是，这里会不会仅仅是海底天然气，而并非已形成可燃冰？

**休斯：**这里的地质环境为 3200 米水深下的海底气水合物的稳定带，不管其中的天然气从哪里来，一定是以水合物的形式存在。我们当时确定了两个突破点，但是由于水深，底流太复杂，水下定位很困难，同时，沉积物分布很复杂，尽管我们布置了 15 米的柱状样，但是由于沙层的存在，只达到七八米的深度，没有达到预想的 12 米的计划。

**记者：**休斯教授，通过中国南海的这次科学考察，您对可燃冰是否形成一些新的认识？对中国下一步在这方面的调查与研究，您有些什么建议？

**休斯：**这次通过我们的工作，包括海底照相、摄像、化学分析等，我们有了一些新的认识。南海作为被动大陆边缘，对我们来说，是一个新的例子，但是我们这次研究的区域比较困难，我建议，将来可以通过水下钻探穿过这一深度。

**记者：**请您谈一谈对这次合作的印象？

**休斯：**这次合作最深的感受就是得到了中国科学家的大力支持。为了促成这次合作，中国地质大学的苏新、杭州二所的韩喜球等做了长期的准备。这次合作并不局限于德国基尔大学海洋科学研究所和广州海洋地质调查局，还包括德国不来梅大学海洋边缘研究所、中国地质调查局、中国地质大学等等。我们的工作得到了中、德政府的大力支持，在双方科学家的努力下，取得了大量成果。

**可燃冰钻探的位置可以确定**

黄永祥是广州海洋地质调查局总工程师，他担任了我国海洋可燃冰勘查航次首席科学家。记者听他讲述了"太阳号"上的工作经历和感受。

**记者：**在"太阳号"，你们是怎样去发现可燃冰这一目标的？

**黄永祥：**南海北部是一个特殊的可燃冰形成构造环境。这次国际合作的一个目的就是寻找更多的关于可燃冰存在的证据。"太阳号"的海底观测系统通过电缆来控制水下系统进行工作，最长可以在水下连续工作 16 个小时，观测海底的各种地质现象，包括可燃冰存在的各类样，发现异常后再进行海底摄像观测，发现地表证据后，再进一步进行现场海底沉积物取样。取到的样品在"太阳号"上现场分别做甲烷、孔隙水、硫酸根、氯离子等化学测试、分析，并及时指导船上的后续考察研究。确定目标后，再进行保温保压取心。保温保压取心装置是"太阳号"特有的设备。它一旦取到样品，马上自动封闭，可以保持样品的原始状态。

**记者：**有哪些发现？

**黄永祥：**从 1999 年广州海洋地质调查局开展可燃冰资源调查以来，我们已经取得了关于可燃冰存在的包括地球物理、地质、地球化学等一系列的重要证据，可以证明在我国的南海北部海域存在可燃冰。但是，由于我们现有技术装备的局限，一直没有获得可燃冰的样品，也就是说，我们并没有取得直接证据。

海底深部的可燃冰由于温压等复杂条件的变化，产生分解，并沿一些断裂构造溢出海底后形成海底冷泉。因此，要获得可燃冰的样品，首先必须找到还在喷溢的冷泉喷出口。通过"太阳号"的海底电视观测和海底电视监视抓斗取样，我们发现了南海可燃冰"冷泉"喷溢形成的巨型碳酸盐岩，经过同位素测试，证明这是由海底的可燃冰分解形成的碳酸盐岩。而且这片碳酸盐岩面碳酸盐结壳裂隙中发现了可燃冰甲烷气体喷溢形成的菌席和双壳类生物。通过分析，这片碳酸盐岩结壳最早形成于 4.67 万年前，可能是因为压力的降低，曾经有过强烈的甲烷气体喷溢，至今仍在活动。

同时，我们还通过综合采样和现场分析，证实了我们工作海域的海底浅表层存在可燃冰。在调查区南部陆坡，利用海底电视，观测并获得了与可燃冰密切相关的大批双壳类生物及与之伴生的管状蠕虫；对沉积物甲烷气体和沉积物孔隙水进行现场测试分析，发现了与陆坡浅表层可燃冰存在密切相关的显著地球化学异常。说明该区域的浅表层存在可燃冰。但是，要真正取到可燃冰的样品，条件非常苛刻。尽管我们已经找到了碳酸岩结壳和冷泉、菌席及双壳类生物，但是，碳酸岩结壳太多，很硬，目前的浅表层取样器还无法穿透获得样品。

通过这次科学考察，我们原来确定的地球物理异常重点区与"太阳号"发现的大片的碳酸盐岩结壳的区域是吻合的。下一步要打钻，这里就应该是我们布孔的位置。

*7.2.1.2 China Land and Resources News, June 16, 2004:*

Gas Hydrate Research in the Scientific Thinking: Interview with the Scientists of Chinese-German Cooperation Project, Profs. Yongyang & Nengyou WU

# 以科学态度开展可燃冰研究

## ——访中德合作项目中方专家黄永样、吴能友

本报记者 陈惠玲

我国海域天然气水合物资源的调查与研究工作开展近5年来，在我国南海北部取得了可证实天然气水合物存在的多种证据，但至今没有获得实物样品。今年6月2日，中德合作项目《南海北部陆坡甲烷和天然气水合物分布、形成及其对环境的影响研究》，在南海北部陆坡联合实施“太阳号”船SO177航次，本航次将获取天然气水合物存在的更多直接证据、争取在海底浅表层取得天然气水合物的样品列为首要目标，遂成为媒体和公众关注的焦点。针对媒体、公众对直接获取天然气水合物的关切，考察船出发之前，本报记者采访了项目中方专家黄永样、吴能友。

**黄永样**：我国海洋天然气水合物勘查航次首席科学家，中德合作项目《南海北部陆坡甲烷和天然气水合物分布、形成及其对环境的影响研究》中方首席科学家，广州海洋地质调查局总工程师

**吴能友**：国家高技术研究发展计划(863计划)《天然气水合物探测技术》课题负责人，中德合作项目《南海北部陆坡甲烷和天然气水合物分布、形成及其对环境的影响研究》中方协调员，广州海洋地质调查局副总工程师

### 南海海域可燃冰资源前景可观

**记者**：我国海域天然气水合物调查和研究工作已取得哪些进展？

**黄永样**：从1999年起，广州海洋地质调查局在我国南海北部海域进行了以天然气水合物资源调查为目的的地质、地球物理勘查和相应的研究工作，并取得了一系列重要地质勘查成果：在珠江口外的深海区发现了天然气水合物存在的地质、地球物理标志，初步证实我国南海北部海域具有丰富的天然气水合物资源；在南海北部海域发现了天然气水合物存在的地质、地球物理、地球化学、生物等多种重要的间接标志；对天然气水合物成矿远景区进行了预测，初步认为我国南海存在多个天然气水合物成矿远景区；推测珠江口外深水海域天然气水合物的分布面积有几万平方公里，南海北部天然气水合物的总资源量可能大于100亿吨油当量。

天然气水合物是20世纪才发现的一种新型后备能源，调查研究有其复杂性。受我国现有技术方法和技术设备等因素的限制，我国海域天然气水合物调查和研究仍有很多技术性问题未能解决，基础理论研究也未开展，有关天然气水合物的环境效应研究刚刚起步。尽管已经在我国南海北部取得了可证实天然气水合物存在的多种证据，但至今还没有获得实物样品。

**记者**：中德合作开展南海天然气水合物研究主要解决哪些问题？

**吴能友**：今年3月，广州海洋地质调查局与德国基尔大学Leibniz海洋科学研究所签署了中德合作开展《南海北部陆坡甲烷和天然气水合物分布、形成及其对环境的影响研究》协议，项目截止时间为2004年~2006年。合作双方要通过对南海北部陆坡甲烷和天然气水合物分布及其形成研究，了解甲烷循环过程，研究释放甲烷的冷泉特点，评估南海北部陆坡甲烷和天然气水合物在全球环境变化中的潜在作用。根据合作项目要求，今年6~7月间联合执行“太阳号”SO177航次，并明确了6项任务：(1)通过多波束测量和各种电视监视取样设备，确定有利于天然气水合物赋存的构造体和冷泉的位置，力争获取浅表层天然气水合物；(2)运用海底电视观测系统进行海底摄像实时调查；(3) 对表层海水游离甲烷和二氧化碳进行连续监测；(4)通过对各种电视监视多管取样、电视抓斗和重力取样等设备采集的沉积物孔隙水进行化学、同位素分析测试，追踪甲烷的释放和通量；(5)通过水柱图像分析，研究海底到水体的甲烷释放和通量；(6)通过自生碳酸盐岩地球化学和同位素分析，研究甲烷碳的长周期沉积。

### 采集可燃冰无需科学家“下海”

**记者**：把获取海底浅表层天然气水合物作为这一合作项目的首要目标，由此可见其重要性。目前，新闻媒体和社会公众都非常关注这一航次工作，请介绍将通过什么方法采集天然气水合物？

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(上接第五版)

**吴能友**：在广州海洋地质调查局2002年、2003年调查基础上，我们确定了东沙海域和西沙海槽作为合作项目的两个研究区，其中东沙海域为优先研究区。“太阳号”将通过海底多波束测量系统、浅层剖面仪等先探测研究区海底，同时对海水中甲烷和二氧化碳的浓度进行测试，经过综合分析确定其中的有利目标区后，再投放海底电视进行实时观测，以寻找目标区中是否存在海底冷泉、甲烷菌席、瓣腮类生物、海底的陡坎等，这些都是可以证实天然气水合物存在的有利证据，据此再确定有利的构造体和冷泉的位置作为取样点。然后根据实际情况，选用带海底电视的抓斗、带海底电视的多管取样装置、大型重力活塞取样或保温保压装置等进行现场取样。

**记者**：采集上来的天然气水合物怎么验证？如何保存这些样品？

**黄永样**：天然气水合物外貌似冰雪，可以像固体酒精一样被点燃，因此，它又被人们称作可燃冰。取到的样品通过直接的观察、点火等就完全可以验证。紧接着，我们将进一步对样品进行化学和物理性质测试。由于天然气水合物在常温常态下非常容易融化挥发，所以，要直接把样品保存在能保持零下10度左右的液氮罐中。

### 建议：通过钻探采集可燃冰

**记者**：看来，采集可燃冰并不像一些媒体报道的那样，需要载人深潜器下到海底取样，而是通过海底电视进行观测，操作海底取样设备进行工作。那么通过调查，在我国南海北部获取位于海底浅表层的天然气水合物可能性有多少？难度有多大？

**黄永样**：科学地来说，在我国南海北部海底表面有可能存在天然气水合物，但没有必然性。天然气水合物在海底形成需要很多重要的条件，如温度、压力条件、甲烷气的浓度等，这些条件缺一不可。对天然气水合物的取样需要保温保压的技术装备等，因此，在海底浅表层直接获取天然气水合物的难度很大。2002年，广州海洋地质调查局“海洋四号”船在东沙群岛海域地震资料圈定的范围内作业时，发现海底断层，并得到取样站位甲烷含量自浅表层向深层增高、最高含量高出正常值几千倍的测试结果。同时，在另一站位柱状取样的岩心管中，出现了两段稀化的沉积物及泥浆，岩心管出现负压变形的现象。这些都极有可能是海底浅表层天然气水合物分解导致的结果！

**记者**：假如在南海北部采集海底浅表层可燃冰不成功，那是不是说明我国南海海域没有可燃冰的存在，或者说，在这一海域可燃冰资源的前景并不乐观？

**吴能友**：我个人认为，南海北部海域海底浅表层存在天然气水合物的条件先天不足。比如，我国南海海域地热值较高，在南海北部陆坡海底的海水温度达到4摄氏度，而目前在世界其他已经取得海底浅表层天然气水合物的海域，海底温度一般为1摄氏度。海底温度偏高，不利于浅部天然气水合物的储存。而通过我们现有的取样设备，最深也只能采集到海底以下0~12米的样品，要在这一深度范围内采集到天然气水合物样品，难度非常大。天然气水合物可以存在于海底以下0~1100米的未固结沉积层中，因此即便取样不成功，也并不能否定我国南海北部海域天然气水合物资源的前景。比如，在美国的布莱克海台，尽管科学家们在海底表层实施天然气水合物取样没有成功，但是通过大洋深钻，取得了位于海底以下几十米至几百米处丰富的天然气水合物，证实了这一资源的存在。在全球已取得天然气水合物的31处海域，仅有10处是在海底浅表层取到样品的，其他都是通过钻探予以验证。这说明，即便海底浅表层不存在天然气水合物，也不能就此说明这一海域没有天然气水合物资源。

**黄永样**：在南海北部陆坡，我们获得的天然气水合物存在的证据包括：天然气水合物矿藏底界的地震标志——似海底地震反射界面(BSR)；天然气水合物矿体分解形成的甲烷异常和其他地球化学标志，利用海底摄像技术发现了沉积物中的甲烷菌席，证实了有天然气水合物存在的冷泉标志以及发现了天然气水合物存在的矿物标志——碳酸盐结壳等。可以肯定，在我国南海北部存在天然气水合物矿藏的证据是非常有说服力的。因此，下一步最重要也是最必要的工作，是必须依靠钻探获取天然气水合物来证实我们调查的结果，丰富我们对南海海域天然气水合物形成、分布规律等多方面的认识。尽快在我国南海北部实施海底钻探，是验证海底天然气水合物存在的最可靠、有效的手段。

### 评估南海可燃冰的环境意义

**记者**：这一合作项目还有其他实质上的意义吗？

**吴能友**：天然气水合物具有巨大的能源意义和环境效应，被喻为石油的替代资源，是地球上尚未开发的最大未知能源库。天然气水合物往往同自然环境处于十分敏感的平衡之中，环境变化往往会导致各种环境效应，导致海底失稳，引起海底滑坡等，其分解产生的甲烷可能诱发温室效益，对全球环境变化具有重要影响。通过这一合作项目，我们希望借鉴德国的成功经验，利用其先进的技术装备进行调查和地质取样研究，提高我国在天然气水合物研究方面的水平，缩小与世界先进国家间的差距，填补我国在天然气水合物相关环境研究方面的空白，获得关于研究区的更为丰富和准确的资料。

**黄永样**：这一工作具有重要的现实意义和长远的战略意义。目前，在天然气水合物的调查研究领域，我们较美国、日本等落后了近20年，对此，我国的态度是：在学习引进国外先进技术的同时，积极开展国内调查、开发及技术方法研究，不断提高我国在天然气水合物研究方面的水平。

**相关链接**

**德国基尔大学Leibniz海洋科学研究所**成立于1987年，主要从事海洋科学基础研究，在海洋天然气水合物调查与研究方面处于国际领先水平，尤其在海底天然气水合物高清晰摄像调查与采样、地球化学探测和地震资料特殊处理，以及天然气水合物识别技术方面具有特长和优势。

**担任航次德方首席科学家的Erwin Suess教授**是目前国际上天然气水合物研究的领军人物，曾任多个水合物方面国际合作项目和调查航次的首席科学家。

**德国“太阳号”科学考察船**，是一艘具有国际先进水平的科学考察船，它拥有动力定位、深水水下定位、海底电视观测系统等设备，曾经在1999年7~9月，首次在美国俄勒岗外海某处利用采集、合成、取样等三种不同的方法获得了海底浅表层天然气水合物的实物样品，并在全球至少5处海域采集到天然气水合物的样品。

*7.2.1.3 China Land and Resources News, July 19, 2004:*

RV SONNE Return to Port, the Chinese-German Joint Research Vessel Carrying with the Fruitful Results

满载丰硕调查成果

# 中德联合科考船顺利返航

王世元参加欢迎仪式并讲话

**本报讯** （记者 赵凡 陈惠玲）7月13日，历时42天的中德联合科考船“太阳号”驶入上海港，与中德26名科学家同时进港的是丰硕的调查成果。7月15日，中德两国政府官员在上海港为科学家们举行了欢迎仪式。部党组成员、办公厅主任王世元代表国土资源部在欢迎仪式上讲话。

据介绍，这次科考获得了一批重大发现：

——经过海底电视观测和海底电视监测抓斗取样，首次发现了南海天然气水合物气体“冷泉”喷溢形成的巨型碳酸盐岩，面积达430万平方公里，被认为是世界上迄今发现的最大的自生碳酸盐岩区。科学家已经将该区域中最典型的一个构造体命名为“九龙甲烷礁”。在“九龙甲烷礁”区碳酸盐岩结壳裂隙中，科学家发现了天然气水合物甲烷气体喷溢形成的菌席和双壳类生物。这证实了“冷泉”仍在活动。通过同位素测年分析，“九龙甲烷礁”区碳酸盐岩结壳最早形成于大约4.67万年前，至今仍在释放甲烷气体。

——全面进行综合采样和现场分析，证实了南海北部陆坡东沙东南海域浅表层沉积物中存在天然气水合物。海底电视观测到与天然气水合物密切相关的双壳类生物，取样获得大批双壳类生物及与之伴生的管状蠕虫；对沉积物甲烷气体和沉积物孔隙水甲烷、硫化氢、硫酸根、氯离子、总碱度、氮等进行现场测试分析，发现了与陆坡浅表层天然气水合物存在密切相关的显著地球化学异常。

——首次运用水体地球化学站点调查，在工作海域不同水层中发现了甲烷异常，说明在调查区存在甲烷气体喷溢。

——成功获得了一批沉积物地质、地球化学资料，为我国海域天然气水合物形成机理、分布规律和环境效应研究提供了丰富的资料。

王世元代表国土资源部向参加这次考察活动的全体科学家和工作人员表示衷心的感谢和诚挚的慰问。他说，根据中德双方政府的决定，德国“太阳号”科学考察船今天向社会公众开放，这对于普及海洋科学、提高大众的资源环境意识具有十分重要的意义。我们借此机会呼吁全社会都来关心海洋地质事业，树立科学利用海洋资源、保护海洋环境的意识。

据了解，德国“太阳号”是一艘具有动力定位、水下定位、海底电视观测系统、电视监测取样等先进设备的调查船，在浅表层天然气水合物调查研究方面具有丰富的经验。

*7.2.1.4 China Ocean News, July 20, 2004:*

Open Day of RV SONNE, A German Research Vessel in Shanghai after the Investigation on Gas Hydrate in the South China Sea

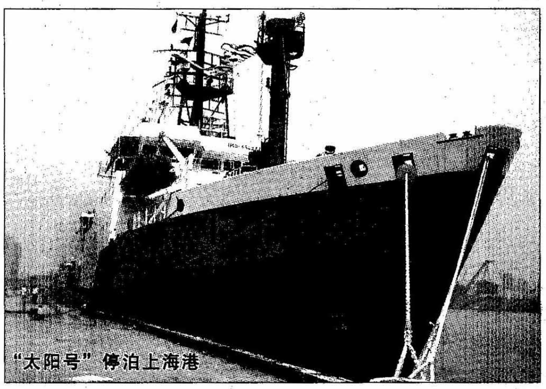
## 完成我国南海“可燃冰”调查
## 德“太阳”号在沪举行开放日

**本报讯** 记者**陈荣发**报道 德国“太阳”号在完成在南海的调查任务后，日前到达上海港，并举行了对中国公众的开放日。

今年3月，中国地质调查局所属的广州海洋地质调查局与德国基尔大学在广州签署合作协议，在中国南海进行“可燃冰”(天然气水合物)调查，由德国“太阳”号科学考察船执行合作项目的海上调查航次。“太阳”号是今年6月2日从香港出航，这是“太阳”号的第177航次。中德科学家在此次联合考察中发现，中国南海确实存在天然气水合物。

据参加这一航次调查的国家海洋局第二海洋研究所的韩喜球和方银霞两位女科学家说，这次虽然没有找到“可燃冰”的实物样品，但找到了“可燃冰”存在的充分证据。记者在“太阳”号上看到甲烷气体喷口的蛤觅食的轨迹和蛤的洞穴、海底双壳类死亡的沉积体以及甲烷礁的图片和实物。

“太阳”号是一艘可以满足所有现代海洋科学调查研究需要的船，从上世纪80年代起曾多次被我国的海洋科研机构租用。该船长97.90米，宽14.20米，吨位4734吨。德国“太阳号”科考船已经离开上海返回德国，中德合作项目将进入实验室阶段。


“太阳号”停泊上海港

*7.2.1.5 China Ocean News, July 27, 2004:*

The Largest Authigenic Carbonate Area Discovered in the South China Sea

## 南海发现世界最大
## 可燃冰喷溢岩区

**本报讯** 中德科学家首次联合对南海北部可燃冰的海上调查航次近日结束，并传来令人振奋的消息：首次发现了南海北部可燃冰“冷泉”喷溢形成的巨型碳酸盐岩，被认为是世界上最大的自生碳酸盐岩区。

可燃冰是天然气水合物的俗称，是近20年来在海洋和冻土带发现的新型洁净资源，是天然气和水在一定的温度、压力条件下相互作用所形成的貌似冰状可以燃烧的固体，可以作为传统石化原料如石油、碳的代替品。而且，可燃冰储量巨大。世界上许多国家如美国、日本、俄罗斯、加拿大、德国等都先后制定了可燃冰的研究和发展计划以及成立了相应的研究机构，并已至少在全球116个地区发现了可燃冰存在的证据。我国从1999年起才开始对可燃冰开展实质性的调查和研究，近5年来已在南海北部陆坡、南沙海槽和东海陆坡等3处发现可燃冰存在的证据。

今年3月，国土资源部广州海洋地质调查局与德国基尔大学合作。6月初，我国与德国科学家利用德国“太阳号”科学考察船首次执行合作项目——《南海北部陆坡甲烷和可燃冰分布、形成及其对环境的影响研究》的海上调查航次，进一步深入对该海域内有可能蕴藏的可燃冰进行勘察和取样。

历时42天的中德联合科考船“太阳号”近日结束海上航行，并取得了丰硕的调查成果。据介绍，这次科考获得了一大批重大发现。其中，科学家们通过海底电视观测和海底电视监测抓斗取样，首次发现了南海天然气水合物气体“冷泉”喷溢形成的巨型碳酸盐岩。科学家已经将该区域中最典型的一个构造体命名为“九龙甲烷礁”。在“九龙甲烷礁”区碳酸盐岩结壳裂隙中，科学家发现了天然气水合物甲烷气体喷溢形成的菌席和双壳类生物。这证实了“冷泉”仍在活动。 **(陈惠玲)**

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## *7.2.1.6 China Land and Resources News, July 26,2004:*

The Voyage of RV SONNE in the South China Sea

■科技纵横

# "太阳号"南海之旅

本报记者 赵 凡

7月13日，在大海工作42天的"太阳号"在上海停泊。 本报记者 赵 凡 摄

7月13日，中德联合科考船"太阳号"驶入上海，中德26名科学家结束了令他们流连忘返的42天的海上风浪生活，与他们同时从甲板上卸下的是丰硕的科学调查和研究成果。

2004年6月2日，根据广州海洋地质调查局和德国基尔大学海洋科学研究所在广州签订的中德合作协议，中德科学家登上德国著名的科考船"太阳号"，从香港起航，联合实施南海天然气水合物的调查与分析评价项目。

42天，经历了台风和晕船，同时经历了浪漫和充实，中国和德国两国的科学家在"太阳号"上相互切磋，携手并肩，共完成多波束探测量约5000公里、沉积地层浅层剖面调查约5000公里、海底电视观测200小时、水体地球化学剖面调查约2000公里、水体地球化学站位25个站点、电视监测抓斗取样14个站点、电视监测多管取样15个站点、重力取样16个站点、沉积物保压取样2个站位等。

狭小的船舱，装满了科学家的科学激情和严谨的科学作风。

这是一艘具有动力定位、水下定位、海底电视观测系统、电视监测取样等设备的先进调查船，被德国政府称为"高贵的船"。科学家说，在科学文献中关于海洋科研的文章中，它出现的频率最高。

天然气水合物是科学家期待得到的未来的接替能源之一。它在海底里的赋存，一般是在400米到3000米的海底沉积物中。据说，此次科考的最重要成果就是，首次发现了南海天然气水合物气体"冷泉"喷溢形成的巨型碳酸盐岩。由于温度和压力的变化，海底天然气水合物分解产生"冷泉"，并形成碳酸盐岩，所以，碳酸盐岩一直被认为是天然气水合物的重要指示物。而此次发现的碳酸盐岩，面积达430万平方公里，被认为是世界上迄今发现的最大的自生碳酸盐岩区。由于该工作区距离中国香港九龙最近，科学家将该区域中最典型的一个构造体命名为"九龙甲烷礁"。"龙"代表中国，"九"代表了研究团体的合作。

科学家们在"九龙甲烷礁"区碳酸盐岩结壳裂隙中发现了天然气水合物甲烷气体喷溢形成的菌席和双壳类生物。海底底水和沉积物中含有异常丰富的甲烷气体，证实了"冷泉"仍在活动。通过同位素测年分析，"九龙甲烷礁"区碳酸盐岩结壳最早形成于大约4.67万年前，至今仍在释放甲烷气体。

参加科考的中德团队，来自五湖四海，他们是：中方的中国地质调查局及其所属的广州海洋地质调查局、青岛海洋地质研究所、中国地质科学院矿产资源研究所，中国地质大学，南京大学，国家海洋局第二海洋研究所等；德方的基尔研究所、不来梅大学、柏林工业大学等。船上工作期间，两国科学家混合编为多波束水深测量和沉积地层浅层剖面调查、水体剖面和站位地球化学调查、海底电视观测、沉积物取样、沉积学、空隙水地球化学测试分析等6个工作小组。

"太阳号"于6月2日从香港起航，来自中国的18名科学家先后登上考察船。

7月15日，两天前靠岸的"太阳号"静静地停泊在上海高阳码头，来自中德双方的政府官员为出行了42天的中德联合科考科学家们举行了简单然而喜气洋洋的接风仪式。国土资源部党组成员、办公厅主任王世元代表国土资源部在仪式上作了热情洋溢的讲话。

中方首席科学家、国土资源部广州海洋地质调查局总工程师黄永样在接受记者采访时说，此次中德合作，不仅取得了丰硕的调查研究成果，也见识了一流的仪器设备，学到了先进的管理和技术。德方首席科学家、基尔大学海洋科学研究所海洋地质教授欧文·休斯称在他用德国著名的科考船"太阳号"20年的对外合作经历中，"这是我感觉合作气氛最良好的一次"。

**(本版图片除署名外均由柯雷提供)**

## *7.2.1.7 China Land and Resources News, July 26, 2004:*

Comments: International Cooperation is the Foreshadowing of Developments

■评论

# 合作是发展的伏笔

安 安

中国和德国科学家联合考察南海天然气水合物，并且取得了一定的成果，这在中德地学合作史上是一件标志性的大事，在中外地学合作史上，也是一个成功的范例。

科学的发展，从来都不是封闭的结果。而广泛的国际合作与交流，更是地学发展的重要环节。因为地球科学本身涉及的领域就是非国界的，就领域而言，地质科学家在研究方法和信息处理上更需要对比和交流。

新中国建立以来，我国的地学研究基本坚持了对外合作姿态，上世纪70年代前，主要是学习借鉴苏联的模式。随着中国改革开放步伐向前迈进，中国的地学研究也越来越多地融入世界的大圈子里。据国土资源部国际合作与科技司副司长李志坚介绍，国土资源部自成立以来，已经与约30个国家进行了地学研究的合作，取得了丰硕的成果。其中中德地学合作，已经在大陆科学钻探、航空遥感、天然气水合物等研究领域取得明显成绩。

能源是人类社会赖以发展的重要基础。我国目前经济建设正处在快速发展阶段。与此同时，我国对能源的需求与日俱增。一项数据显示，我国石油的年消费量已经突破2亿吨，但自给率仅为一半左右，能源形势相当严峻。

上世纪末，世界科学家对天然气水合物开始进行商业性勘查、开发的探索。我国也不失时机开展了前期研究。但是，由于课题本身的前沿性和起步较晚等原因，我们与几个走在前列的国家，比如美国、德国、日本，差距还很大。尽管我们的研究和调查已经有了成果，但获取直接证据仍是当前最大的科技难题。

中德地学界的此次合作，正是在这样的背景下进行的。"太阳号"是闻名世界的德国科学考察船，它不仅在天然气水合物的检测采集上有世界上最先进的仪器设备，而且在天然气水合物样品采集、分析方面有丰富经验。中国科学家以合作的身份走进"太阳号"，这一合作的收获，不仅仅是取得的样品实物，更有价值的也许是认识上的提高。

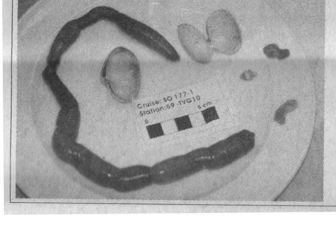
中国的地学，已经在世界上占有重要的一席之地，起点较高，目标远大。正如有人所说，我们的地学今后要成为世界前沿的一分子，参与所有国际重大的计划，并且要成为走在前列的国家。笔者以为，这个目标的实现，前提是我们必须更好地进行国际合作交流。因为只有不断地看到前列者的位置，不断学习更新更先进更成功更出色的东西，才能给自己跻身前列埋下伏笔。

中德政府官员接见顺利归来的"太阳号"上的科学家。 本报记者 赵 凡 摄

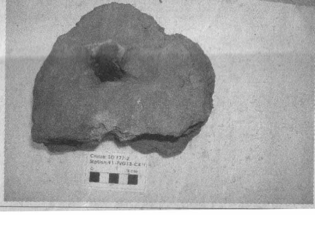
先进的仪器和技术——『太阳号』上电视监测抓斗取样。

船上技术培训正在进行中。

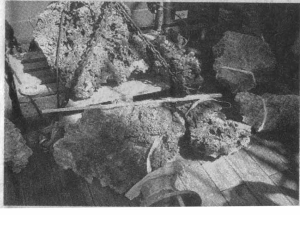
科学家正在检查海底电视观测系统。



食用甲烷气的双壳类和蠕虫。



具有甲烷气体喷溢标志的碳酸盐岩。



国内首次发现的碳酸盐岩结壳样品浮出海面。

*7.2.2 Interview with Dr. Nengyou Wu by China Radio International*

China Radio International

CRI Online Deutsch

(GMT+08:00) 2005-01-21 15:38:31

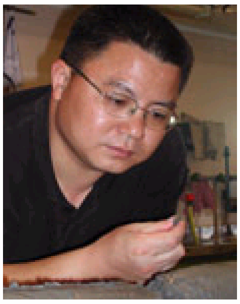
# Gemeinsame Suche nach brennbarem Eis im Südchinesischen Meer

Bislang sind bereits in über 10 Prozent aller Meeresgebiete Methanhydrate nachgewiesen worden. Gibt es in den ausgedehnten chinesischen Meeresregionen auch Vorräte dieser Zukunftsenergie? Auf einer gemeinsamen Expeditionsreise vom Juni bis Juli letzten Jahres haben chinesische und deutsche Meeresgeologen dazu eine zufriedenstellende Antwort gefunden.

"Brennbares Eis" - diese als Energiereserve der Zukunft geltenden Methanhydrate, haben seit Ende des letzten Jahrhunderts Wissenschaftler in aller Welt beschäftigt. Bei geschätzten zwölf Milliarden Tonnen Methaneis ist mehr als doppelt so viel Kohlenstoff gebunden wie in allen Erdöl-, Erdgas- und Kohlevorräten der Welt. Bislang sind bereits in über 10 Prozent aller Meeresgebiete diese Methanhydrate nachgewiesen worden. Gibt es in den ausgedehnten chinesischen Meeresregionen auch Vorräte dieser Zukunftsenergie? Auf einer gemeinsamen Expeditionsreise vom Juni bis Juli letzten Jahres haben chinesische und deutsche Meeresgeologen dazu eine zufriedenstellende Antwort gefunden.

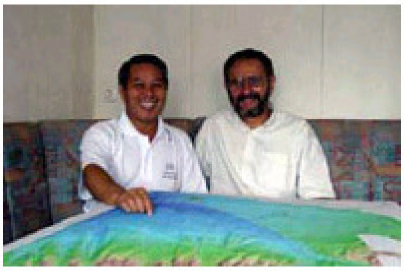
Am 15. Juli 2004 ist das weltweit bekannte deutsche Forschungsschiff "Die Sonne" mit 32 deutschen und chinesischen Meeresgeologen an Bord in der ostchinesischen Hafenstadt Shanghai angekommen - mit großer Ausbeute in der Tasche, die wichtige Beweise für das Vorhandensein von Methanhydraten im Südchinesischen Meer lieferten, darunter mehrere Tonnen Sedimente und weitere zahlreiche mit Methanhydraten verbundene Materialien und Bivalven. Im Hafen von Shanghai wurde das Team von Regierungsvertretern beider Länder und der chinesischen Öffentlichkeit feierlich begrüßt.

Am 2. Juni stach von Hongkong aus das Forschungsschiff "Sonne" ins Meer. 18 chinesiche Wissenschaftler mit ihren 14 Kollegen aus Deutschland arbeiteteten 42 Tage erfolgreich auf dem Schiff, die lange Reise hatte sich gelohnt. Dank kabelgebundener Fernsehenüberwachung des Meeresbodens und Sammlung diverser Bodenproben mit modernen Baggern sowie weiteren verschiedenen Mitteln haben die Meeresgeologen ihr Forschungsziel erreicht. Dazu sagt uns der chinesische Projektkoordinator, Dr. Wu Nengyou vom Guangzhouer Erkundungsamt für Meeresgeologie beim chinesischen Ministerium für Land und Ressourcen:



"Wir haben wichtige direkte Beweise für das Vorhandensein von brennbarem Eis gefunden. Zum einem haben wir am nördlichen Festlandsockel des Südchinesischen Meeres ein großes Gebiet von Karbonatfelsen entdeckt. Entstanden waren sie vor etwa 46.700 Jahren durch Eruptionen der sogenannten kalten Quellen aus Methangashydraten. Das Gebiet ist rund 430 qkm groß und stellt damit die bislang weltweit größte Zone von Karbonatfelsen dar. Zudem haben wir dort auch Thallophyten und Bivalven, die in Symbiose mit Methangas leben, entdeckt."

Mit einem Methangehalt von 80 bis 99.9 Prozent verfügt dieses Gashydrat über eine Kristalstruktur, die bei tiefen Temperaturen unter hohem Druck entsteht. Diese feste farblose Verbindung von Methangas und Wasser sieht genau wie Eis aus. Und sein von Wassermolekülen vollständig umschlossenes Methan kann angezündet werden. Deshalb nennt man diese Substanz brennbares Eis oder Methaneis. Normalerweise existiert Methaneis in Permafrostböden der polaren Regionen oder im Tieftemperaturbereich der Meere in 400 bis 3.000 Meter Wassertiefe. In Methaneis steckt doppelt so viel Kohlenstoff wie in allen Erdöl-, Erdgas- und Kohlelagerstätten zusammen. Ein Kubikmeter brennendes Methaneis ist in der Lage, 164 Kubikmeter Methangas abzugeben.



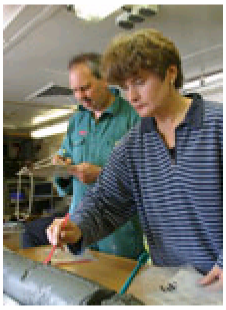
Der deutsche Chefwissenschaftler des Projekts, Professor Dr. Erwin Suess vom dem Leibniz-Institut für Meereswissenschaften an der Universität Kiel (IFM-GEOMAR), ist international bekannt für seine Forschungen in Biogeochemie in Meeren. Als erster in der Welt hat er Methangashydrate im Mexikanischen Golf entdeckt. Die Entdeckung im Südchinesischen Meer ist für ihn von besonderer Bedeutung. Denn sowohl der Mexikanische Golf als auch der

Norwegische Golf oder andere Gebiete, wo zuvor Gashydratereserven entdeckt wurden, gehören alle zu aktiven Kontinentalrändern. Das Südchinesische Meer aber befindet sich an einem passiven Kontinenalrand.

Das sei gerade der Grund, warum Meeresbiologen beider Länder auf der deutschen "Sonne" zusammenkamen, wie uns Dr. Wu Nengyou erklärt. Wenn man über Methaneisforschung spreche, dann seien deutsche Wissenschaftler die erste Adresse. Die deutsche Seite wolle damit einen Durchbruch in ihrer Forschung erzielen und die entsprechenden Theroriegrundlagen bereichern. Deshalb fand Dr. Wu sofort starkes Interesse an der deutschen Forschung, und seine erste E-Mail landete im Jahre 2000 bei Professor Dr. Erwin Suess. So kam es im August 2000 zur ersten China-Reise des bekannten deutschen Meeresgeologen, der damals das Kieler Institut leitete. Dabei wurde bereits die erste Bereitschaft von beiden Seiten zur Kooperation geäußert.

Seitdem schlugen einschlägige Partnerinstitutionen und Behörden beider Länder energisch die Werbetrommel für das große Vorhaben. Ohne großartige Leistungen von Prof. Suess und ohne großzügige finanzielle Unterstützung des deutschen Bundesministeriums für Bildung und Forschung (BMBF) und des chinesischen Ministeriums für Land und Ressourcen wäre das Projekt wohl kaum zustande gekommen, so der chinesische Projektkoordinator Dr. Wu Nengyou. Auch das chinesische Wissenschaftsministerium habe Mittel für das Projekt bereitgestellt.

Die starke Besatzung des Forschungsschiffes mit dem deutschen Chefwissenschaftler Professor Suess und dem chinesischem Chefwissenschaftler Professor Huang Yongyang an der Spitze war also eine wichtige Garantie für die erfolgreiche Reise. Die 14 deutschen Wissenschaftler kamen vom Kieler Institut, der Universität Bremen und der Technischen Universität Berlin. Die 18 chinesischen Wissenschaftler entsandten das Chinesische Geologische Erkundungsamt, das Guangzhouer Erkundungsamt für Meeresgeologie, die chinesische Universität für Geologie, die Nanjing-Universität sowie das staatliche Meteorologieamt und mehrere andere Institute. Dr. Wu Nengyou sagt:



"Es ging dabei um eine substanzielle Zusammenarbeit, nicht aber um reines Lernen von deutschen Experten an Bord. In einer äußerst guten Atmosphäre zeigten unsere deutschen und chinesischen Kollegen Arbeitseifer und Tüchtigkeit. Rund um die Uhr arbeiteten wir im Turnus gemischt in 6 Gruppen. Da die deutschen Teammitglieder im Durchschnitt älter waren, arbeiteten die jüngeren chinesischen Wissenschaftler in der Schicht von 2 bis 4 Uhr morgens früh."

Doch die deutsche Rücksichtnahme hat die Chinesen auch beeindruckt. Dr. Wu sagt:

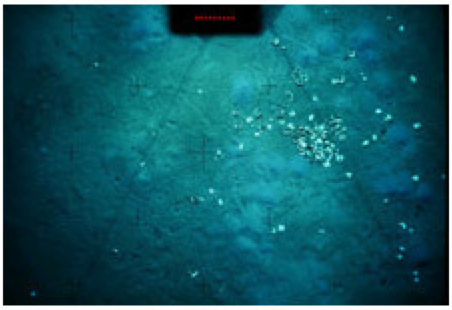
"Alles, was man an Bord zu essen bekam, war rein europäisch, woran wir Chinesen gar nicht gewohnt waren. Doch der Schiffseigner, die Bremer Reedergemeinschaft für Forschungsschifffahrt, nahm große Rücksicht auf uns. Sie engagierten für uns extra einen Koch und Dienstpersonal, die zwar in Deutschland aufgewachsen aber doch chinesischstämmig waren. Sie konnten zwar kaum chinesisch kochen, aber wir konnten mit ihnen Chinesisch reden und unsere kulinarischen Wünsche erläutern, die dann auch erfüllt wurden. So war das Leben auf der Sonne für uns leichter."

Wegen der schlechten Seewetterlage - zwei große Taifune erlebten die Wissenschaftler - musste das Forschungsteam zeitweise seine primäre Arbeit einstellen. Sie wollten aber die Zeit nicht vergeuden und veranstalteten auf der "Sonne" zwei Forschungseminare. Zehn Wissenschaftler hielten dabei wissenschafttliche Vorträge, was zum akademischen Austausch und zur Wissenserweiterung beider Seiten beitrug.

Gegenüber unserem Sender sagt Dr. Wu ferner, er und seine chinesischen Kollegen schwärmten alle von den Arbeitsbedingungen auf der "Sonne", die heute als eines der modernsten und erfolgreichsten Forschungsschiffe der Welt bekannt ist.

Moderne Winden und Bagger bringen Proben des Meeresbodens mittels der Fernsehüberwachung aus 1000 Meter Wassertiefe ans Deck, das sehr großen Platz bietet. Ausgestattet ist das Schiff zudem mit Systemen zur Antriebsposition und Unterwasserposition. Sie kann drei Kilometer lange Stränge mit Schallquellen hinter sich herziehen. Die Schallwellen werden im Meeresboden reflektiert, und aus dem Wellenmuster errechnet der Computer ein dreidimensionales Bild des Untergrundes. Darauf können Methaneisvorkommen identifiziert werden.

Von der "Sonne" wurde bereits im August 1996 das erste größere Vorkommen des begehrten Methaneises im Nordostpazifik entdeckt. Und im Indischen und im Atlantischen Ozean entdeckten "Sonne"-Expeditionen auch große Vorkommen von Methaneis. Dass man heute mit Hilfe der "Sonne" doch auch im Südchinesischen Meer Methaneisvorkommen entdecken konnte, sei ein gemeinsamer Erfolg chinesischer und deutscher Wissenschaftler und damit auch ein kräftiger Ausdruck einer Zusammenarbeit des gegenseitigen Nutzens, betont Dr. Wu Nengyou:



"In unserer Kooperationsvereinbarung ist festgehalten, dass alle Forschungsmaterialien beiden Seiten gehören. Alle Sedimente, Steine und Erde sind je zur Hälfte an beide Seiten verteilt worden. Nur die jeweiligen Forschungsschwerpunkte sind ein bisschen anders. Die geborgenen Bodenproben und andere Materialien werden derzeit noch in den Labors unserer beiden Länder analysiert."

Die Fachkreise erwarten schon jetzt die Veröffentlichung des Cruise Reports jeweils in Englisch und Chinesisch noch vor Ende März dieses Jahres. Wie geplant soll im Oktober 2005 in Kiel ein Symposium über das Projekt stattfinden. Und für den Dezember ist die Einberufung einer Arbeitssitzung in China vorgesehen. Dabei werden beide Seiten über die nächsten Schritte der Zusammenarbeit diskutieren.

*7.2.2.2 Interview with Prof. Dr. Suess by China radio International*

(April 17, 2005; to be broadcast June 2005)



**CRI-Interview mit Prof. Dr. Erwin Suess**

1. Prof. Suess, in Deutschland und in der Welt sind Sie ja aber schon längst bekannt durch die Auffindung und Erforschung von Gashydraten. Aber dass Sie seit einigigen Jahren eng mit chinesischen Wissenschaftlern zusammenarbeiten, ist vielen vielleicht doch noch nicht bekannt. Was machen Sie derzeit in China?
2. Was für eine Bedeutung haben Ihre Entdeckungen im südchinesischen Meer? Worin liegt das deutsche Interesse dabei?
3. Nun sind Sie sicher, dass Sie eine Schlussfolgerung machen können, dass es doch im südchinesischen Meer wirklich große Reserven dieser Zukunftsenergie vorhanden sind?
4. Sie haben im vergangenen Oktober die Gustav-Steinmann-Medaille der Geologischen Vereinigung erhalten. Was sagen Sie Als weltbekannte Methaneisforscher zu möglichen umweltlichen Folgen der Förderung und Nutzung von Methaneis? Was sind die jüngsten Fortschritte bei der Forschung auf diesem Gebiet?
5. Gab es vor dieser Entdeckungsreise schon Kontakte zwischen Ihnen und anderen chinesischen Institutionen oder Universitäten? Wann war das und wie war das ganze verlaufen?
6. Kommen Sie gern nach China? Was ist Ihr Eindruck zu dem Land und zu seiner Forschungskapazität?
7. Was wollen Sie und Ihr Institut noch weiter mit Ihren chinesischen Kollegen tun? Können Sie uns einige Ihrer Pläne verraten?

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### 7.3 Ceremony at Beijing Geological Museum

*7.3.1 Sample donation ceremeony*

On 14 April 2005, a ceremony of donating a piece of methane-derived authigenic carbonate retrieved by SONNE 177 cruise to China Geological Museum was held. Mr. Xuelong Wang, (Vice Director China Geological Survey, Beijing), Mr. Liwei CHENG (Director of Geological Museum, Beijing), Prof. Dr. Erwin Suess (Co-chief scientist of SO177, Leibniz Institute of Marine Sciences, Germany) made speeches. Prof. Yongyang Huang (Co-chief scientist of SO177, Guangzhou Marine Geological Survey, China) received an interview with media afterwards. SO 177 participants: Nengyou Wu, Xiqiu Han, Xin Su, Youhai Zhu, Haiqi Zhang attended the ceremony.


Fig. 7.3.1 Ceremony of sample donation to China Geological Museum, Beijing, 14 April 2005


Fig. 7.3.2 Vice director Xuelong Wang was giving a speech


Fig. 7.3.3 CHENG Liwei, Director of China Geological Muesum was giving a speech

Fig. 7.3.4 Chief Scientist Prof. Dr. Erwin Suess replied


Fig. 7.3.5 Prof. Dr. Suess received azurite mineral speciman

### *7.3.2 Speeches at the donation ceremony*

14 April, 2005, China Geological Museum, Beijing

**Speech by Xuelong Wang**

***Vice Director of China Geological Survey, Beijing***

Good afternoon!
Honorable Professor / Mrs. Suess, Ladies and Gentlemen,

Today we gathered here for a short but significant ceremony. The German research center IFM-GEOMAR and the CGS will present a unique gas hydrate-associated carbonate sample, discovered at cold vent sites in the South China Sea, to the Geological Museum of China.
Here, please allow me, on behalf of the Director of CGS Meng Xianlai and the CGS to extend congratulations. Also I would like to welcome warmly every guest here for the ceremony and to thank IFM-GEOMAR, Prof. Suess for your support and assistance to our China Geological Survey and contributions to the cooperative project.

The sample represents one significant result of the Sino-German cooperation project SO-177 under the endeavor of geoscientists from the both countries. The outstanding significance of this specimen to the museum lies in its recording pf the biogeochemical and geological processes related to methane seepage from subsurface gas hydrates.

Thereby presents significant evidences of the existence of the gas hydrate in the subsurface of the northern South China Sea, the region investigated by the SO 177 project. It also signifies important progress of Chinese marine gas hydrate research. To keep this special and significant specimen in Geological Museum of China on display can help to popularize geo-science and enhance the public understanding and the resource consciousness in China.
In 2001, the former Vice Minister of Ministry of Land and Resources, Mrs. Shou Jiahua visited Germany, paid a special delegation visit to GEOMAR at Kiel and put forward the suggestion of Sino-German gas hydrate cooperative research. Under the positive support and promotion by both Chinese and German government agencies, an agreement of cooperation was signed in March 2004, which was the official start of the cooperation project entitled: **South China Sea: Distribution, Formation and Effect of Methane & Gas Hydrate on the Environment.**

Following this agreement, from June 2 to July 15, 2004, the Sino-German joint research cruise SO-177 was carried out aboard the R/V SONNE jointly financed by the German Ministry of Education and Research (BMBF) and the Chinese Ministry of Land and Resources, represented by the China Geological Survey (CGS). Under the endeavor of scientists from both countries, the cruise has been successful. Herewith I would like to show my honor and respect to the geoscientists of both countries and also to the German government for the great support in this cooperation.

One of the outstanding results of this cruise is the discovery of the gas hydrate-associated carbonate at the cold vent on the north slope of South China Sea; henceforth know as the **Jiu Long Methane Reef.** This structure is one of the largest of this type of methane-derived carbonates known from the world's marine environment. The geological, geochemical and biological information shows that the specimen records the rich methane-saturated fluid activity and attests to direct evidence for the existence of gas hydrate in the deeper subsurface of this region. The carbonate sample both institutions present here is a typical specimen recovered during the Sino-German joint cruise and is representative of the much larger methane-derived carbonate complex between 550 – 750 m of water depth.

There is an Chinese ancient saying that **a good beginning means half of the success.** The SO-177 cruise was such a success. I believe that throughout the endeavor of both countries, this cooperative project was a milestone and provided a strong back-up to gas hydrate research in the South China Sea. Geoscientists of China and Germany will continue to devote their expertise to understanding the Earth, to resources utilization as well as towards environmental protection.

Thank you all.

**Speech by CHENG Liwei**

***Director, China Geological Museum***

Good afternoon! Honorable Professor / Mrs. Suess, Vice Director Wang Xuelong, Ladies and Gentlemen,

Firstly, on behalf of the Geological Museum of China, I am very pleased to welcome everyone here for the ceremony of presenting the methane hydrate-associated carbonate specimen to our Museum by GEOMAR and CGS.

Gas hydrate is a kind of new resource discovered in recent years, widely distributed, and appears to have great energy resource potential. There is optimism that methane hydrates may provide us with one step towards easing the energy shortage in the world. The cold vent carbonate sample recovered in the South China Sea during the Sino-German joint cruise provides the strong evidence of the existence of gas hydrate in the subsurface of the South China Sea.

The Geological Museum of China is the earliest public museum of a scientific nature in China. The museum is mainly engaged in the collection, study and exhibition of material related to earth history, fossils, minerals, rocks, gemstones and Chinese land and resource potential. After having been establish 90 years ago, there are now more than 20,000 specimens from all over the world of great value to research and public display awareness, which cover the fields of rocks, minerals, paleo-biology and many other topics

Today, the methane-derived carbonate sample which we received is taken from the first discovery of cold vent sites Chinese seas and the first one of its kind preserved and exhibited the Geological Museum of China. The specimen will take an active role in enriching our collection and promoting the Sino-German geo-scientific exchange and cooperation.

Thank you all.

**Reply by Erwin SUESS**

***Professor of IFM-GEOMAR and Director of German Marine Research Consortium***

Dear Vice Director WANG Xuelong
Dear Director CHENG Liwei
Dear colleagues and friends

Thank you for your gracious remarks, I am most pleased to be here today for a very special occasion, an occasion that normally does not belong in a daily schedule of active scientists:**To unveil a limestone rock specimen from the Jiu Long Methane Reef for public exhibition.**

What is so special about that?
Special is that it was discovered as a result of Chinese-German cooperation.

Special is that it gave one strong focus to the joint effort of German and Chinese scientists during last year's expedition aboard RV SONNE, several expedition members are present here today and to whom I extent warm greetings.

Special is also that it comes from an undersea feature -known as Cold Seeps- which result from methane escaping from gas hydrates below the seafloor; Cold seeps occur world-wide but had never before been known to exist in the South China Sea.

Special is that we can explain the exact process of formation of this type of unusual limestone - as shown in these posters alongside to my left over here which we prepared in both English and Chinese. The formation of methane-derived carbonates ultimately relates to the world's greenhouse gas budgets and hence to the environment, a concern that is of primary importance to all of us today.

And last but not least, special is that the China Geological Museum is -to my knowledge- the first museum to exhibit such an unusual type of limestone including its expert description and explanation.

So these are the many good reasons for all of us to be here at this ceremony today.

There are also many good reasons to be thankful to and acknowledge persons and organizations that made this occasion possible:

Guangzhou Marine Geological Survey of the China Geological Survey;
German Ministry of Education and Research; both institutions financed the expedition;

International Office of the China Geological Survey;

Colleagues from GMGS Guangzhou, SIO/SOA Hangzhou, CUB Beijing,
IFM-GEOMAR Kiel and University of Bremen who worked hard for the cruise during preparation, at sea and after the cruise.

Especially Prof. HUANG Yongyang, Prof. BOHRMANN Gerhard, Dr. WU Nengyou, Profs. SU Xin, HAN Xiqiu, and also Ms. BAI Qin; and of course thanks go to the representative of the Geological Museum of China for responding enthusiastically in preparing for this ceremony.

I hope this exhibit will stimulate much research activity among Chinese geoscientists and that many people will come to see it and find it as interesting as we scientists do.

Thank you very much

| | **SIGER: R/V SONNE Cruise 177/1** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date 2004 (UTC) | Station No. | Instrument | Begin (UTC) | at seafloor max. depth | off seafloor | End (UTC) | Duration hh:mm | Latitude N° begin: at sf. / end: off sf. | Longitude E° begin: at sf. / end: off sf. | SSBL | Water depth (m) | Recovery and Remarks |
| 5-Jun | 177/1-1 | PS-1 | 3:10 | | | 5:45 | 2:35 | 22° 14.89 / 21° 52.70 | 118° 20.11 / 118° 34.71 | | 178-2180 | start NW corner Area A |
| 5-Jun | 2 | CTD-1 | 6:00 | 6:40 | | 7:35 | 1:35 | 21° 52.80 | 118° 34.78 | | 2199 | 2000m; sound velocity profile |
| 5-Jun | 3 | PS-2 | 7:42 | | | 12:09 | 4:27 | 21° 52.74 / 21° 17.01 | 118° 34.72 / 119° 01.94 | | 2182-2709 | continue PS-1 |
| 5-Jun | 4 | PS-3 | 12:10 | | | 14:50 | 2:40 | 21° 17.01 / 21° 16.63 | 119° 29.95 / 119° 29.95 | | 2709-3277 | channel |
| 5-Jun | 5 | PS-4 | 15:31 | | | 18:01 | 2:30 | 21° 13.07 / 21° 12.99 | 119° 29.77 / 118° 59.82 | | 3094-2669 | channel |
| 5-Jun | 6 | PS-5 | 18:49 | | | 21:32 | 2:43 | 21° 21.01 / 21° 20.99 | 119° 00.01 / 119° 30.09 | | 2945-3071 | channel |
| 5-Jun | 7 | CTD-2 | 22:25 | 23:42 | | 1:34 | 3:09 | 21° 17.17 | 119° 30.00 | | 3360 | CTD central channel, E |
| 6-Jun | 8 | OFOS-1 | 2:36 | 3:30 | 7:24 | 8:25 | 5:49 | 21° 18.87 / 21° 17.08 | 119° 25.17 / 119° 26.81 | | 3049-3282 | 7 slump scars, start at 05:35; 1. with clams |
| 6-Jun | 9 | CTD-3 | 9:19 | 10:19 | | 12:06 | 2:47 | 21° 17.62 | 119° 21.48 | | 3163 | CTD central channel, N-slope |
| 6-Jun | 10 | PS-6 | 12:13 | | | 22:37 | 10:24 | 21° 17.66 / 22° 06.98 | 119° 21.43 / 118° 54.98 | | 3156-637 | profile to shallow doughnut site |
| 6-Jun | 11 | OFOS-2 | 23:00 | 23:17 | 5:32 | 5:58 | 6:58 | 22° 08.14 / 22° 04.00 | 118° 54.23 / 118° 56.06 | | 625-1260 | doughnut drift 1 |
| 7-Jun | 12 | OFOS-3 | 6:27 | 6:51 | 9:14 | 9:39 | 3:12 | 22° 06.39 / 22°06.99 | 118° 54.73 / 118° 56.49 | | 899-900 | doughnut drift 2 |
| 7-Jun | 13 | CTD-4 | 10:10 | 10:36 | | 11:21 | 1:11 | 22° 06.811 | 118° 55.943 | | 911 | CTD, clam field from OFOS-2 |
| 7-Jun | 14 | PS-7 | 11:31 | | | 22:32 | 11:01 | 22° 06.83 / 21° 18.64 | 118° 55.98 / 119° 12.22 | | 913-3003 | back to channel |
| 7-Jun | 15 | OFOS-4 | 23:00 | 23:53 | 1:30 | 2:24 | 3:24 | 21° 18.79 / 21° 17.54 | 119° 11.98 / 119° 11.69 | | 2987-3039 | Haiyang 4 |
| 8-Jun | 16 | CTD-5 | 4:40 | 5:38 | | 7:04 | 2:24 | 21° 18.15 | 119° 11.86 | | 3011 | CTD bubble site |
| 8-Jun | 17 | PS-8 | 7:16 | | | 7:37 | 0:21 | 21° 18.03 / 21° 16.01 | 119° 11.97 / 119° 12.23 | | 3017-3044 | profile terminated |
| 8-Jun | 18 | TV-MUC-1 | 7:57 | | | 8:15 | 0:18 | 21° 18.19 | 119° 11.80 | | 3017 | station terminated, taiphoon Coson |
| 9-Jun | 19 | PS-9 | 7:34 | | | 13:50 | 6:16 | 21° 12.43 / 21° 18.24 | 118° 20.05 / 119° 20.76 | | 2213-3042 | |
| 9-Jun | 20 | OFOS-5 | 13:55 | 14:53 | 16:22 | 17:22 | 3:27 | 21° 18.16 / 21° 17.54 | 119° 20.84 / 119° 21.25 | | 3037-3165 | channel |
| 9-Jun | 21 | OFOS-6 | 18:21 | 19:14 | 21:18 | 22:15 | 3:54 | 21° 18.19 / 21° 16.96 | 119° 14.90 / 119° 15.32 | | 2994-3070 | channel |
| 9-Jun | 22 | TV-MUC-2 | 22:56 | 1:06 | | 2:16 | 3:20 | 21° 18.402 | 119° 11.903 | | 3017 | Haiyang 4 |
| 10-Jun | 23 | TV-MUC-3 | 2:50 | 8:54 | | 10:04 | 7:14 | 21° 18.378 | 119° 11.956 | | 3018 | Haiyang 4 |
| 10-Jun | 24 | TV-MUC-4 | 10:24 | 12:27 | | 13:35 | 3:11 | 21° 18.449 | 119° 11.843 | | 3012 | Haiyang 4 |
| 10-Jun | 25 | PS-10 | 13:58 | | | 21:52 | 7:54 | 21° 18.40 / 22° 06.68 | 119° 11.88 / 118° 55.10 | | 3008-905 | |
| 10-Jun | 26 | CTD-6 | 22:15 | 22:30 | | 23:30 | 1:15 | 22° 06.81 | 118° 55.33 | | 919 | clam field from OFOS-2, high res. |
| 11-Jun | 27 | OFOS-7 | 0:16 | 0:21 | 4:01 | 4:14 | 3:58 | 22° 10.543 / 22° 08.16 | 118° 52.56 / 118° 52.30 | | 484-529 | doughnut drift 3, chemoherm like struct. |
| 11-Jun | 28 | TVG-1 | 5:00 | 5:46 | | 6:02 | 1:02 | 22° 09.060 | 118° 52.344 | | 498 | carbonate, chemoherm like struct. |
| 11-Jun | 29 | TVG-2 | 6:43 | 8:05 | | 8:22 | 1:39 | 22° 08.940 | 118° 52.366 | | 484 | carbonate, chemoherm like struct. |
| 11-Jun | 30 | TVG-3 | 8:51 | 9:02 | | 9:17 | 0:26 | 22° 08.983 | 118° 52.337 | | 473 | carbonate, chemoherm like struct. |
| 11-Jun | 31 | PS-11 | 9:45 | | | 0:47 | 13:02 | 22° 08.82 / 22° 11.95 | 118° 51.95 / 118° 54.95 | | 494-379 | |
| 12-Jun | 32 | CTD-7 | 1:20 | 1:41 | | 2:08 | 0:48 | 22° 11.88 | 118° 55.07 | | 402 | up slope /shelf |
| 12-Jun | 33 | OFOS-8 | 3:27 | 3:45 | 5:59 | 6:23 | 2:56 | 22° 02.98 / 22° 02.72 | 118° 46.01 / 118° 47.41 | | 955 | Jiu Long Chemoherm |
| 12-Jun | 34 | CTD-8 | 7:42 | 8:29 | | 9:43 | 2:01 | 21° 53.74 | 118° 36.90 | | 2205 | |
| 12-Jun | 35 | OFOS-9 | 10:27 | 10:52 | 13:25 | 13:57 | 3:30 | 21° 59,35 / 21° 58.42 | 118° 39.00 / 118° 37.04 | | 1160-1833 | |
| 12-Jun | 36 | PS-12 | 14:05 | | | 22:33 | 8:28 | 21° 58.45 / 21° 21.43 | 118° 36.75 / 119° 27.73 | | 1855-3007 | |
| 12-Jun | 37 | OFOS-10 | 23:00 | 23:59 | 11:35 | 12:26 | 13:26 | 21° 18.51 / 21° 17.39 | 119° 25.90 / 119° 26.79 | | 3056-3319 | channel |
| 13-Jun | 38 | OFOS-11 | 12:51 | 13:44 | 14:44 | 15:44 | 2:53 | 21° 18.13 / 21° 17.39 | 119° 25.76 / 119° 25.75 | | 3119-3296 | channel |
| 13-Jun | 39 | PS-13 | 15:56 | | | 22:45 | 6:49 | 21° 17.45 / 21° 18.43 | 119° 25.80 / 119° 11.84 | | 3293-3011 | |
| 13-Jun | 40 | TVG-4 | 23:21 | 0:38 | | 1:34 | 2:13 | 21° 18.416 | 119° 11.876 | | 3006 | Haiyang 4 |
| 14-Jun | 41 | TVG-5 | 2:02 | 4:16 | | 5:21 | 3:19 | 21° 18.533 | 119° 11.915 | | 3010 | Haiyang 4 |
| 14-Jun | 42 | GC-1 | 6:07 | 7:18 | | 7:59 | 1:52 | 21° 18.543 | 119° 11.926 | | 3002 | Haiyang 4, 4.4 m |
| 14-Jun | 43 | PS-14 | 8:24 | | | 12:58 | 4:34 | 21° 18.94 / 22° 03.07 | 119° 11.61 / 118° 46.38 | | 2963-803 | |
| 14-Jun | 44 | CTD-9 | 13:03 | 13:24 | | 14:10 | 1:07 | 22° 03.11 | 118° 46.25 | | 768 | |

**SIGER: R/V SONNE Cruise 177/1**

| Date 2004 (UTC) | Station No. | Instrument | Begin (UTC) | at seafloor max. depth | off seafloor | End (UTC) | Duration hh:mm | Latitude N° begin: at sf. / end: off sf. | Longitude E° begin: at sf. / end: off sf. | SSBL | Water depth (m) | Recovery and Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14-Jun | 45 | PS-15 | 14:21 | | | 23:30 | 9:09 | 22° 03.10 / 22° 03.23 | 118° 46.31 / 118° 45.20 | | 772-744 | |
| 14-Jun | 46 | OFOS-12 | 23:26 | 0:24 | 4:31 | 4:51 | 5:25 | 22° 03.20 / 22° 04.68 | 118° 45.78 / 118° 44.17 | | 744-777 | Jiu Long Chemoherm |
| 15-Jun | 47 | CTD-10 | 5:22 | 5:45 | | 6:25 | 1:03 | 22° 02.827 | 118° 46.463 | | 769 | |
| 15-Jun | 48 | OFOS-13 | 7:08 | 7:24 | 11:38 | 11:52 | 4:44 | 22° 03.03 / 22° 03.70 | 118° 46.49 / 118° 44.96 | | 803-733 | Jiu Long Chemoherm |
| 15-Jun | 49 | PS-16 | 12:09 | | | 22:13 | 10:04 | 22° 03.54 / 22° 02.63 | 118° 45.27 / 118° 46.61 | | 747-779 | |
| 15-Jun | 50 | TVG-6 | 22:25 | 23:59 | | 0:18 | 1:53 | 22° 02.848 | 118° 46.583 | | 769 | Jiu Long Chemoherm |
| 16-Jun | 51 | TVG-7 | 0:36 | 2:23 | | 2:38 | 2:02 | 22° 02.825 | 118° 46.541 | | 768 | Jiu Long Chemoherm |
| 16-Jun | 52 | TVG-8 | 2:53 | 4:06 | | 4:24 | 1:31 | 22° 02.851 | 118° 46.551 | | 769 | Jiu Long Chemoherm |
| 16-Jun | 53 | TVG-9 | 5:30 | 8:53 | | 9:15 | 3:45 | 22° 02.849 | 118° 46.535 | | 771 | Jiu Long Chemoherm |
| 16-Jun | 54 | PS-17 | 10:52 | | | 23:45 | 12:53 | 22° 03.36 / 21° 18.61 | 118° 46.62 / 119° 11.79 | | 898-3008 | |
| 17-Jun | 55 | GC-2 | 0:00 | 0:54 | | 1:54 | 1:54 | 21° 18.534 | 119° 11.926 | | 3006 | Haiyang 4, 4.4 m |
| 17-Jun | 56 | GC-3 | 1:57 | 2:45 | | 3:20 | 1:23 | 21° 18.534 | 119° 11.919 | | 3005 | Haiyang 4, 5.1 m |
| 17-Jun | 57 | GC-4 | 3:35 | 4:36 | | 5:17 | 1:42 | 21° 18.422 | 119° 11.851 | | 3010 | Haiyang 4, 4.3 m |
| 17-Jun | 58 | GC-5 | 5:50 | 6:43 | | 7:26 | 1:36 | 21° 18.448 | 119° 11.823 | | 3011 | Haiyang 4, 6.0 m |
| 17-Jun | 59 | TVG-10 | 8:12 | 9:38 | | 10:50 | 2:38 | 21° 18.431 | 119° 11.865 | | 3009 | Haiyang 4 |
| 17-Jun | 60 | PS-18 | 11:07 | | | 22:20 | 11:13 | 21° 18.40 / 21° 57.01 | 119° 11.82 / 118° 47.51 | | 3007-1337 | |
| 17-Jun | 61 | CTD-11 | 22:24 | 22:56 | | 0:11 | 1:47 | 21° 56.95 | 118° 47.73 | | 1357 | |
| 18-Jun | 62 | OFOS-14 | 0:49 | 1:09 | 7:03 | 7:30 | 6:41 | 22° 00.79 / 21° 56.93 | 118° 45.21 / 118° 47.74 | | 913-1290 | |
| 18-Jun | 63 | OFOS-15 | 8:32 | 8:59 | 13:16 | 13:31 | 4:59 | 22° 05.35 / 22° 03.17 | 118° 42.10 / 118° 43.55 | | 826-845 | |
| 18-Jun | 64 | PS-19 | 13:40 | | | 23:30 | 9:50 | 22°02.62 / 21° 18.40 | 118° 43.75 / 119° 11.86 | | 909-3014 | |
| 19-Jun | 65 | GC-6 | 1:57 | 2:53 | | 3:51 | 1:54 | 21° 18.448 | 119° 11.855 | | 3010 | Haiyang 4, 6.7 m |
| 19-Jun | 66 | GC-7 | 4:58 | 5:57 | | 6:45 | 1:47 | 21° 18.448 | 119° 11.859 | | 3010 | Haiyang 4, 6.6 m |
| 19-Jun | 67 | GC-8 | 7:40 | 8:37 | | 9:30 | 1:50 | 21° 18.453 | 119° 11.824 | | 3007 | Haiyang 4, double banana |
| 19-Jun | 68 | CTD-12 | 11:26 | 12:34 | | 14:15 | 2:49 | 21° 17.65 | 119° 24.82 | | 3283 | |
| 19-Jun | 69 | PS-20 | 14:21 | | | 0:49 | 10:28 | 21° 17.60 / 21° 18.40 | 119° 24.77 / 119° 11.82 | | 3287-3011 | |
| 20-Jun | 70 | GC-9 | 0:59 | 1:56 | | 2:37 | 1:38 | 21° 18.442 | 119° 11.827 | | 3009 | Haiyang 4, 8.5 m |
| 20-Jun | 71 | PS-21 | 3:37 | | | 8:00 | 4:23 | 21° 17.57 / 22° 02.60 | 119° 11.89 / 118° 46.63 | | 3036-780 | |
| 20-Jun | 72 | TVG-11 | 8:03 | 11:16 | | 11:35 | 3:32 | 22° 02.858 | 118° 46.513 | | 769 | Jiu Long Chemoherm |
| 20-Jun | 73 | TV-MUC 5 | 12:13 | 14:57 | | 15:16 | 3:03 | 22° 02.914 | 118° 46.045 | | 779 | Jiu Long Chemoherm |
| 20-Jun | 74 | OFOS-16 | 16:25 | 16:56 | 22:17 | 22:50 | 6:25 | 21° 55.89 / 21°53.11 | 118° 46.31 / 118° 48.33 | | 1355-1616 | |
| 20-Jun | 75 | CTD-13 | 23:13 | 23:51 | | 0:51 | 1:38 | 21° 52.00 | 118° 47.86 | | 1747 | |
| 21-Jun | 76 | PS-22 | 1:00 | | | 4:08 | 3:08 | 21° 51.71 / 21° 35.01 | 118° 47.83 / 118° 20.00 | | 1664-1754 | |
| **END SO 177/1** | | | | | | | | | | | | |

Abbreviations:

CTD (Conductivity temperature depth sensor + hydrocasts)
GC (Gravity corer)
OFOS (Ocean floor observation system)
EM120 (Multibeam echosounder)
MUC (Multicorer)
TV–MUC (TV–Multicorer)
PS (Parasound)
TV-G (TV–Grab sampler)
EQL (Gas equilibrator methane)
DAPC (Dynamic autoclave piston corer)

**SIGER: R/V SONNE Cruise 177/2**

| Date 2004 (UTC) | Station No. | Instrument | Begin (UTC) | at seafloor max. depth | off seafloor | End (UTC) | Duration hh:mm | Latitude N° begin: at sf. / end: off sf. | Longitude E° begin: at sf. / end: off sf. | SSBL | Water depth (m) | Recovery and Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25-Jun | 177/2-77 | PS-23 | 21:49 | | | 0:00 | 5:09 | 21° 25.00 / 21° 17.31 | 118° 20.00 / 119° 27.20 | | 2232-3324 | |
| 25-Jun | 78 | CTD -14 | 3:13 | 4:18 | | 6:07 | 2:54 | 21° 17.110 | 119° 27.904 | | 3329 | channel |
| 25-Jun | 79 | CTD -15 | 7:25 | 8:31 | | 10:08 | 2:43 | 21° 17.603 | 119° 23.301 | | 3252 | channel |
| 25-Jun | 80 | CTD -16 | 12:05 | 13:10 | | 14:58 | 2:53 | 21° 21°15.502 | 119° 29.005 | | 3247 | channel |
| 25-Jun | 81 | PS-24 | 15:08 | | | 22:43 | 7:35 | 21° 15.51 / 21° 18.73 | 119° 28.98 / 119° 27.61 | | 3249-3056 | |
| 25-Jun | 82 | OFOS-17 | 22:53 | 23:50 | 4:10 | 5:09 | 6:06 | 21° 18.68 / 21° 17.73 | 119° 27.60 / 119° 27.68 | x | 3058-3186 | channel |
| 26-Jun | 83 | GC-10 | 6:52 | 7:48 | | 8:36 | 1:44 | 21° 18.453 | 119° 11.819 | | 3008 | Haiyang 4, 9.7m |
| 26-Jun | 84 | TV-MUC-6 | 9:16 | 12:44 | | 13:41 | 4:25 | 21° 18.572 | 119° 11.687 | | 3000 | Haiyang 4 |
| 26-Jun | 85 | PS-25 | 13:42 | | | 22:55 | 9:13 | 21° 18.80 / 22° 02.82 | 119° 11.63 / 118° 46.61 | | 2984-787 | |
| 26-Jun | 86 | CTD-17 | 23:39 | 0:03 | | 0:46 | 1:07 | 22° 02.835 | 118° 46.515 | | 762 | Jui Long Chemoherm |
| 27-Jun | 87 | TV-MUC-7 | 1:08 | 1:41 | | 2:00 | 0:52 | 22° 02.792 | 118° 46.564 | | 773 | Jui Long Chemoherm |
| 27-Jun | 88 | OFOS-18 | 3:07 | 3:20 | 6:55 | 7:12 | 4:05 | 22° 10.748 / 22° 09.583 | 118° 52.531 / 118° 54.067 | x | 513-557 | |
| 27-Jun | 89 | OFOS-19 | 8:23 | 8:36 | 8:53 | 9:07 | 0:44 | 22° 08.587 / 22° 08.441 | 118° 43.478 / 118° 43.363 | x | 569-562 | |
| 27-Jun | 90 | TVG-12 | 9:44 | | | 9:57 | 0:13 | 22° 08.61 | 118° 43.51 | | 579 | station terminated, no video signal |
| 27-Jun | 91 | TVG-13 | 10:08 | 10:36 | | 10:50 | 0:42 | 22° 08.538 | 118° 43.449 | x | 555 | |
| 27-Jun | 92 | TVG-14 | 11:12 | 11:39 | | 11:53 | 0:41 | 22° 08.626 | 118° 43.385 | x | 533 | |
| 27-Jun | 93 | PS-26 | 12:08 | | | 22:32 | 10:24 | 22° 08.51 / 21° 18.51 | 118° 43.42 / 119° 12.02 | | 551-3011 | |
| 27-Jun | 94 | GC-11 | 22:57 | 23:58 | | 0:45 | 1:48 | 21° 18.481 | 119° 11.967 | | 3008 | Haiyang 4, 7.3m |
| 28-Jun | 95 | OFOS-20 | 1:14 | 2:06 | 5:03 | 5:58 | 4:44 | 21° 18.926 / 21° 18.523 | 119° 12.288 / 119° 11.325 | x | 3016-2929 | Haiyang 4 |
| 28-Jun | 96 | TV-MUC-8 | 6:34 | 10:03 | | 11:03 | 4:29 | 21° 18.447 | 119° 11.835 | x | 3006 | Haiyang 4 |
| 28-Jun | 97 | TV-MUC-9 | 11:28 | 13:39 | | 14:30 | 3:02 | 21° 18.472 | 119° 11.876 | | 3012 | Haiyang 4 |
| 28-Jun | 98 | PS-27 | 14:45 | | | 2:01 | 11:16 | 21° 18.66 / 21° 25.96 | 119° 11.65 / 118° 33.42 | | 2998-2433 | |
| 29-Jun | 99 | OFOS-21 | 2:35 | 3:18 | 5:23 | 6:11 | 3:36 | 21° 24.939 / 21° 24.935 | 118° 31.669 / 118° 31.325 | x | 2429-2431 | |
| 29-Jun | 100 | PS-28 | 6:54 | | | 7:50 | 0:56 | 21° 20.96 / 21° 20.73 | 118° 30.91 / 118° 20.00 | | 2427-2348 | |
| **Leave AREA A** | | | | | | | | | | | | |
| 30-Jun | 101 | PS-29 | 16:02 | | | 1:44 | 9:46 | 18° 34.89 / 18° 24.86 | 112° 57.21 / 112° 19.27 | | 1335-1096 | |
| 1-Jul | 102 | CTD-18 | 2:00 | 2:29 | | 3:17 | 1:17 | 18° 24.491 | 112° 19.601 | | 1183 | |
| 1-Jul | 103 | OFOS-22 | 3:36 | 4:03 | 8:05 | 8:36 | 5:00 | 18° 25.311 / 18° 21.650 | 112° 19.193 / 112° 19.610 | x | 1073-1401 | |
| 1-Jul | 104 | PS-30 | 8:46 | | | 10:54 | 2:08 | 18° 21.52 / 18° 57.39 | 112° 19.70 / 112° 25.20 | | 1511-2555 | |
| 1-Jul | 105 | CTD-19 | 11:07 | 11:59 | | 13:20 | 2:13 | 17° 57.300 | 112° 25.201 | | 2555 | |
| 1-Jul | 106 | PS-31 | 13:28 | | | 23:46 | 10:18 | 17° 57.24 / 18° 27.47 | 112° 25.29 / 112° 16.24 | | 2554-823 | |
| 2-Jul | 107 | OFOS-23 | 0:16 | 0:35 | 4:35 | 5:05 | 4:49 | 18° 27.526 / 18° 24.588 | 112° 18.959 / 112° 20.012 | | 884-1200 | |
| 2-Jul | 108 | CTD-20 | 6:26 | 7:03 | | 8:07 | 1:41 | 18° 21.291 | 112° 33.407 | | 1651 | |
| 2-Jul | 109 | PS-32 | 8:12 | | | 21:30 | 13:18 | 18° 21.25 / 18° 29.44 | 112° 33.34 / 113° 00.58 | | 1664-1600 | |
| **Leave AREA B** | | | | | | | | | | | | |
| 4-Jul | 110 | PS-33 | 0:57 | | | 6:37 | 5:40 | 21° 02.70 / 21° 18.61 | 118° 20.23 / 119° 11.97 | | 2434-3009 | |
| 4-Jul | 111 | OFOS-24 | 8:21 | 9:15 | 10:10 | 11:05 | 2:44 | 21° 18.553 / 21° 18.355 | 119° 11.978 / 119° 11.817 | x | 3007-3006 | Haiyang 4 |
| 4-Jul | 112 | OFOS-25 | 11:08 | 11:59 | 13:08 | 13:59 | 2:51 | 21° 18.570 / 21° 18.307 | 119° 11.963 / 119° 11.492 | x | 2999-3006 | Haiyang 4 |
| 4-Jul | 113 | OFOS-26 | 15:59 | 16:55 | 17:33 | 18:30 | 2:31 | 21° 18.52 / 21° 18.17 | 119° 26.05 / 119° 26.06 | | 3072-3101 | |
| 4-Jul | 114 | OFOS-27 | 18:47 | 19:40 | 20:17 | 21:17 | 2:30 | 21° 18.45 / 21° 18.03 | 119° 26.14 / 119° 26.20 | | 3094-3107 | |
| 4-Jul | 115 | TV-MUC-10 | 22:58 | 1:21 | | 2:16 | 3:18 | 21° 18.497 | 119° 11.921 | | 3020 (?) | Haiyang 4 |
| 5-Jul | 116 | GC-12 | 2:46 | 3:52 | | 4:44 | 1:58 | 21° 18.409 | 119° 11.869 | | 3010 | Haiyang 4, 4.3m |
| 5-Jul | 117 | CTD-21 | 5:21 | 6:20 | | 7:47 | 2:26 | 21° 18.465 | 119° 11.915 | | 3013 | Haiyang 4 |
| 5-Jul | 118 | GC-13 | 7:57 | 8:57 | | 9:55 | 1:58 | 21° 18.469 | 119° 11.950 | | 3012 | Haiyang 4, 6.7m |

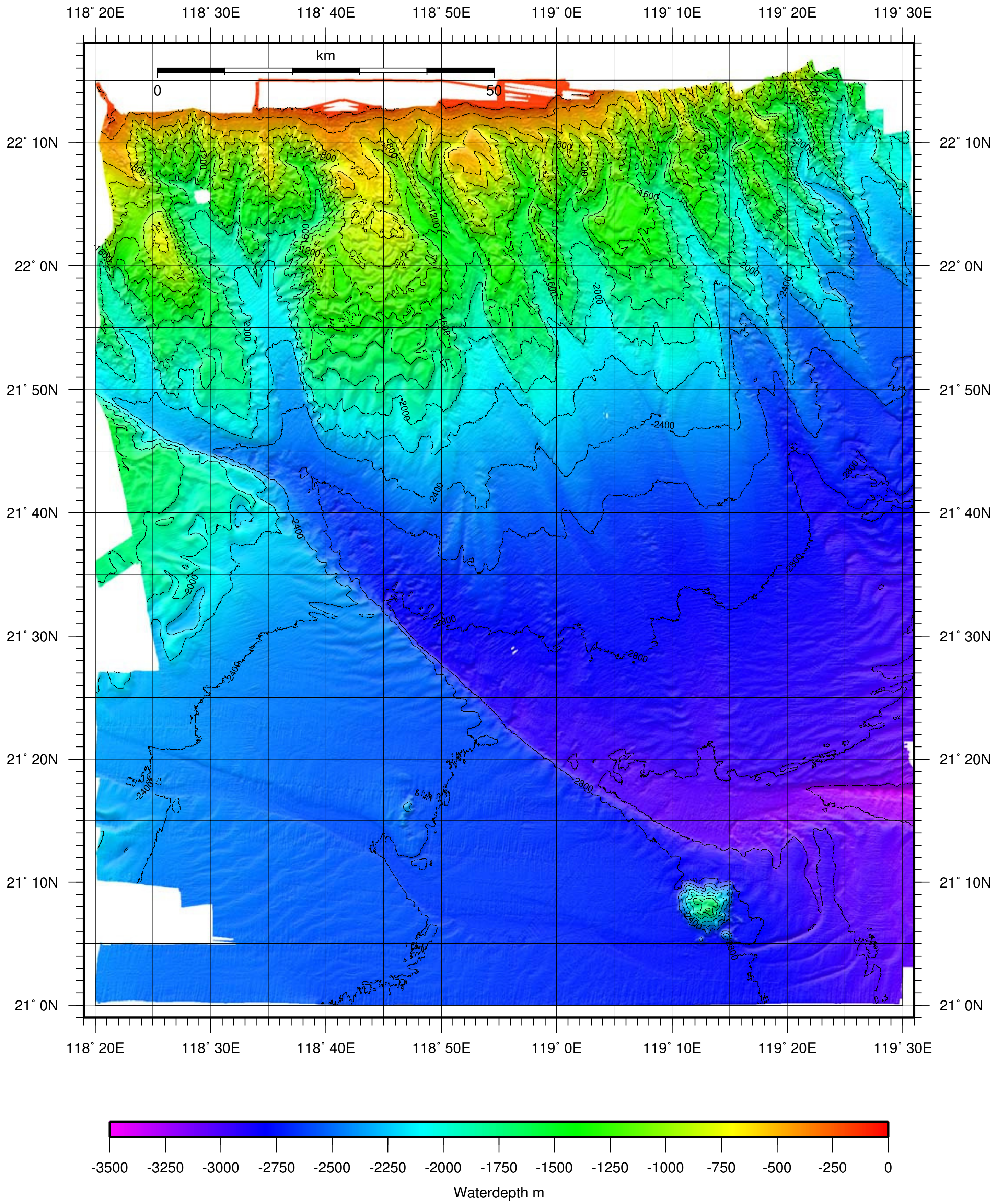
| | SIGER: R/V SONNE Cruise 177/2 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date 2004 (UTC) | Station No. | Instrument | Begin (UTC) | at seafloor max. depth | off seafloor | End (UTC) | Duration hh:mm | Latitude N° begin: at sf. / end: off sf. | Longitude E° begin: at sf. / end: off sf. | SSBL | Water depth (m) | Recovery and Remarks |
| 5-Jul | 119 | DAPC-1 | 10:42 | 11:45 | | 12:35 | 1:53 | 21° 18.443 | 119° 11.914 | | 3011 | Haiyang 4, 95bar; 1.85m |
| 5-Jul | 120 | PS-34 | 13:16 | | | 22:40 | 9:24 | 21° 18.41 / 22° 02.07 | 119° 11.88 / 118° 25.94 | | 3014-741 | |
| 5-Jul | 121 | OFOS-28 | 22:59 | 4:04 | 1:15 | 1:33 | 2:34 | 22° 02.083 / 22° 02.065 | 118° 25.972 / 118° 24.289 | | 744-973 | |
| 6-Jul | 122 | OFOS-29 | 2:02 | 2:19 | 4:25 | 4:43 | 2:41 | 22° 02.426 / 22° 01.534 | 118° 26.210 / 118° 24.640 | x | 815-835 | |
| 6-Jul | 123 | OFOS-30 | 8:36 | 8:50 | 14:26 | 14:38 | 6:02 | 22° 08.362 / 22° 06.945 | 118° 43.414 / 118° 41.118 | x | 528-621 | |
| 6-Jul | 124 | PS-35 | 14:50 | | | 21:58 | 7:08 | 22° 71.33 / 22° 12.41 | 118° 40.99 / 118° 38.46 | | 673-240 | |
| 6-Jul | 125 | TV-MUC-11 | 23:06 | 0:12 | | 0:32 | 1:24 | 22° 02.806 | 118° 46.541 | x | 768 | Jui Long Chemoherm |
| 7-Jul | 126 | TV-MUC-12 | 0:45 | 1:23 | | 1:40 | 0:55 | 22° 02.807 | 118° 46.549 | x | 773 | Jui Long Chemoherm |
| 7-Jul | 127 | CTD-22 | 2:43 | 3:02 | | 3:35 | 0:52 | 22°07.871 | 118° 42.652 | | 630 | |
| 7-Jul | 128 | CTD-23 | 7:37 | 8:35 | | 10:09 | 2:32 | 21° 29.989 | 119° 12.991 | | 2850 | |
| 7-Jul | 129 | CTD-24 | 12:04 | 13:01 | | 14:31 | 2:27 | 21° 13.498 | 119° 12.001 | | 3019 | |
| 7-Jul | 130 | OFOS-31 | 15:17 | 15:54 | 19:05 | 19:56 | 4:39 | 21° 08.948 / 21 10.396 | 119° 11.912 / 119° 10.531 | x | 1896-2750 | |
| 7-Jul | 131 | TV-MUC-13 | 22:49 | 0:26 | | 1:19 | 2:30 | 21° 18.435 | 119° 11.805 | x | 3015 | Haiyang 4 |
| 8-Jul | 132 | TV-MUC-14 | 1:41 | | 3:38 | 4:37 | 2:56 | 21° 18.378 | 119° 11.830 | x | 3007 | Haiyang 4 |
| 8-Jul | 133 | GC-14 | 5:04 | 7:09 | | 7:58 | 2:54 | 21° 18.407 | 119° 11.829 | x | 3004 | Haiyang 4, 3.4m |
| 8-Jul | 134 | GC-15 | 8:35 | 9:39 | | 10:30 | 1:55 | 21° 18.380 | 119° 11.835 | x | 3007 | Haiyang 4, 5.3m |
| 8-Jul | 135 | DAPC-2 | 11:16 | 12:24 | | 13:18 | 2:02 | 21° 18.391 | 119° 11.820 | x | 3007 | Haiyang 4, no pressure |
| 8-Jul | 136 | OFOS-32 | 14:14 | 15:05 | 17:05 | 18:00 | 3:46 | 21° 19.538 / 21° 18.263 | 119° 14.924 / 119° 14.973 | x | 2924-2951 | |
| 8-Jul | 137 | TV-MUC-15 | 22:50 | 1:59 | | 2:47 | 3:57 | 21° 10.145 | 119° 10.813 | x | 2803 | |
| 9-Jul | 138 | GC-16 | 3:57 | 5:21 | | 6:11 | 4:57 | 21° 18.351 | 119° 11.803 | x | 3007 | Haiyang 4, 6.1m |
| 9-Jul | 139 | CTD-25 | 7:25 | 8:23 | | 9:58 | 5:57 | 21° 20.005 | 119° 00.995 | | 2983 | channel, west |
| 9-Jul | 140 | OFOS-33 | 11:40 | 12:11 | 15:30 | 16:13 | 6:57 | 21° 07.697 / 21° 08.281 | 119° 13.081 / 119° 15.067 | x | 1504 | |
| 9-Jul | 141 | PS-36 | 16:31 | | | 4:39 | | 21° 08.01 / 22° 06.53 | 119° 12.83 / 118° 20.08 | | 1742-506 | |
| **END SO 177/2** | | | | | | | | | | | | |

Abbreviations:

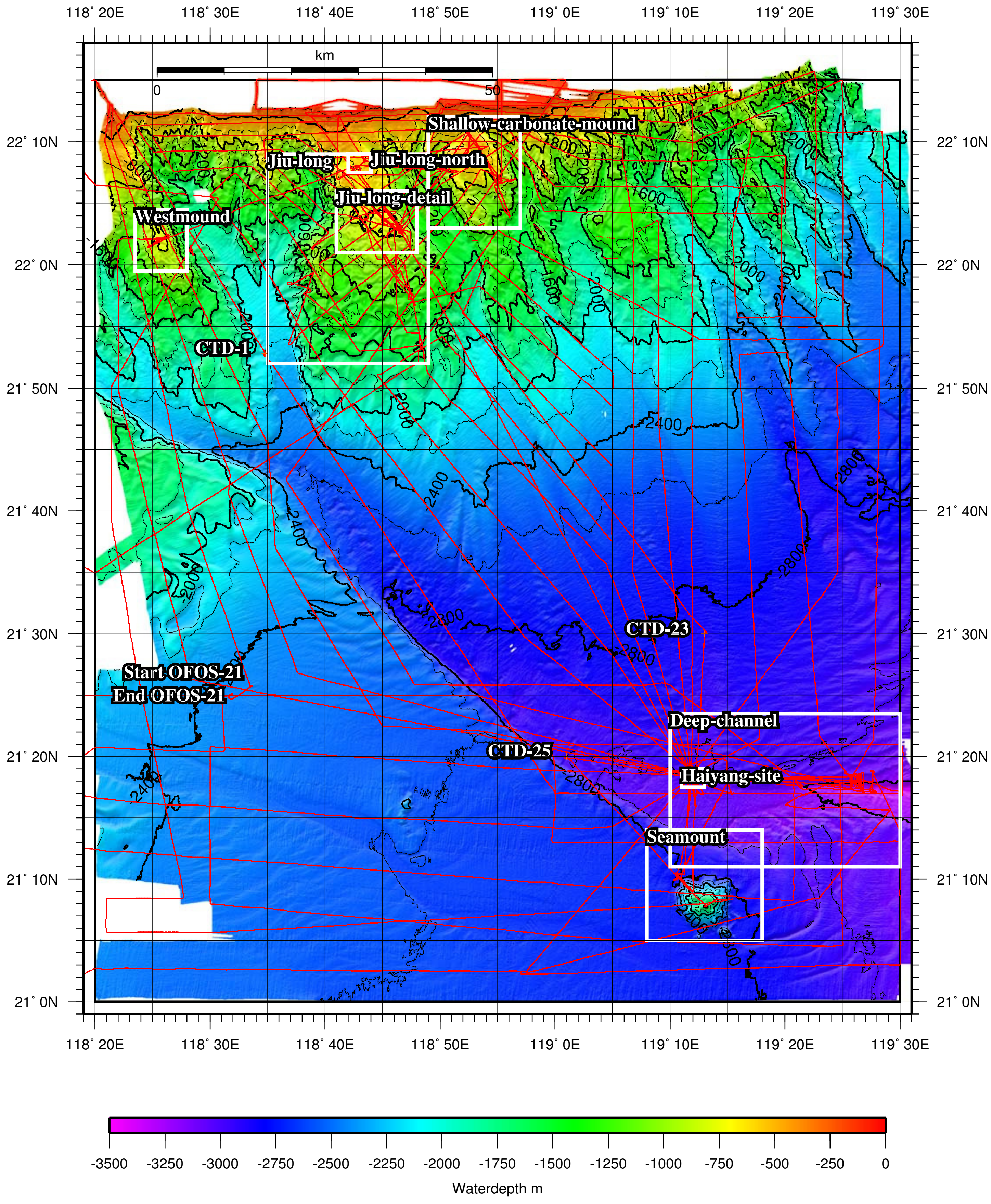
CTD (Conductivity temperature depth sensor + hydrocasts)
GC (Gravity corer)
OFOS (Ocean floor observation system)
EM120 (Multibeam echosounder)
MUC (Multicorer)
TV–MUC (TV–Multicorer)
PS (Parasound)
TV-G (TV–Grab sampler)
EQL (Gas equilibrator methane)
DAPC (Dynamic autoclave piston corer)

| Name | Area | Purpose | Grid | Comment |
|---|---|---|---|---|
| 8.7.1 China_arb_geb | northern SouthchinaSea | overview | Gebco | |
| 8.7.2 China_tracks_A | HK-area A | overview | Gebco | tracks |
| 8.7.3 China_tracks_B | HK-area B | overview | Gebco | tracks |
| | | | | |
| 8.7.4 A_bathy_all_A4 | all A | | EM120-30m | only bathymetry |
| 8.7.5 A_bathy_all_inserts_text_A4 | all A | | EM120-30m | boxes indicating smaller maps, stations not included in detail maps |
| 8.7.6 Westmound | NW-mound | detail | EM120-30m | stations |
| 8.7.7. Jiu-long-carbonate-mound | jiu long | detail | EM120-30m | |
| 8.7.8 Jiu-long-carbonate-mound_text | jiu long | detail | EM120-30m | stations |
| 8.7.9 Jiu-long-north | jiu-long | detail | EM120-30m | stations |
| 8.7.10 Jiu-long-carbonate-mound_detail | detail in jiu long | detail in Jiu-long carbonate-mound | EM120-30m | |
| 8.7.11 Jiu-long-carbonate-mound_detail_ | detail in jiu long | detail in Jiu-long carbonate-mound | EM120-30m | stations |
| 8.7.12 Jiu-long-carbonate-mound_detail2 | detail in jiu long | detail in Jiu-long carbonate-mound_detail | EM120-30m | stations |
| 8.7.13 Shallow-carbonate-mound | shallow-mound | detail | EM120-30m | |
| 8.7.14 Shallow-carbonate-mound_text | shallow-mound | detail | EM120-30m | stations |
| 8.7.15 Deep-channel | SE-3000m | detail | EM120-30m | |
| 8.7.16 Deep-channel_text | SE-3000m | detail | EM120-30m | stations |
| 8.7.17 Deep-channel_text | SE-3000m | detail in Deep-channel | EM120-30m | stations |
| 8.7.18 Haiyang-site | SE-3000m | detail in Deep-channel | EM120-30m | |
| 8.7.19 Haiyang-site_text | SE-3000m | detail in Deep-channel | EM120-30m | stations |
| 8.7.20 Detail 1 | SE-3000m | detail in Haiyang-site | EM120-30m | stations |
| 8.7.21 Detail 2 | SE-3000m | detail in Haiyang-site | EM120-30m | stations |
| 8.7.22 Seamount | | | EM120-30m | |
| 8.7.23 Seamount_text | | | EM120-30m | stations |
| 8.7.24 B_bathy | all B | overview | EM120-30m | |
| 8.7.25 B_bathy_text | all B | | EM120-30m | stations |
| 8.7.26 B_bathy_detail_text | all B | | EM120-30m | stations |

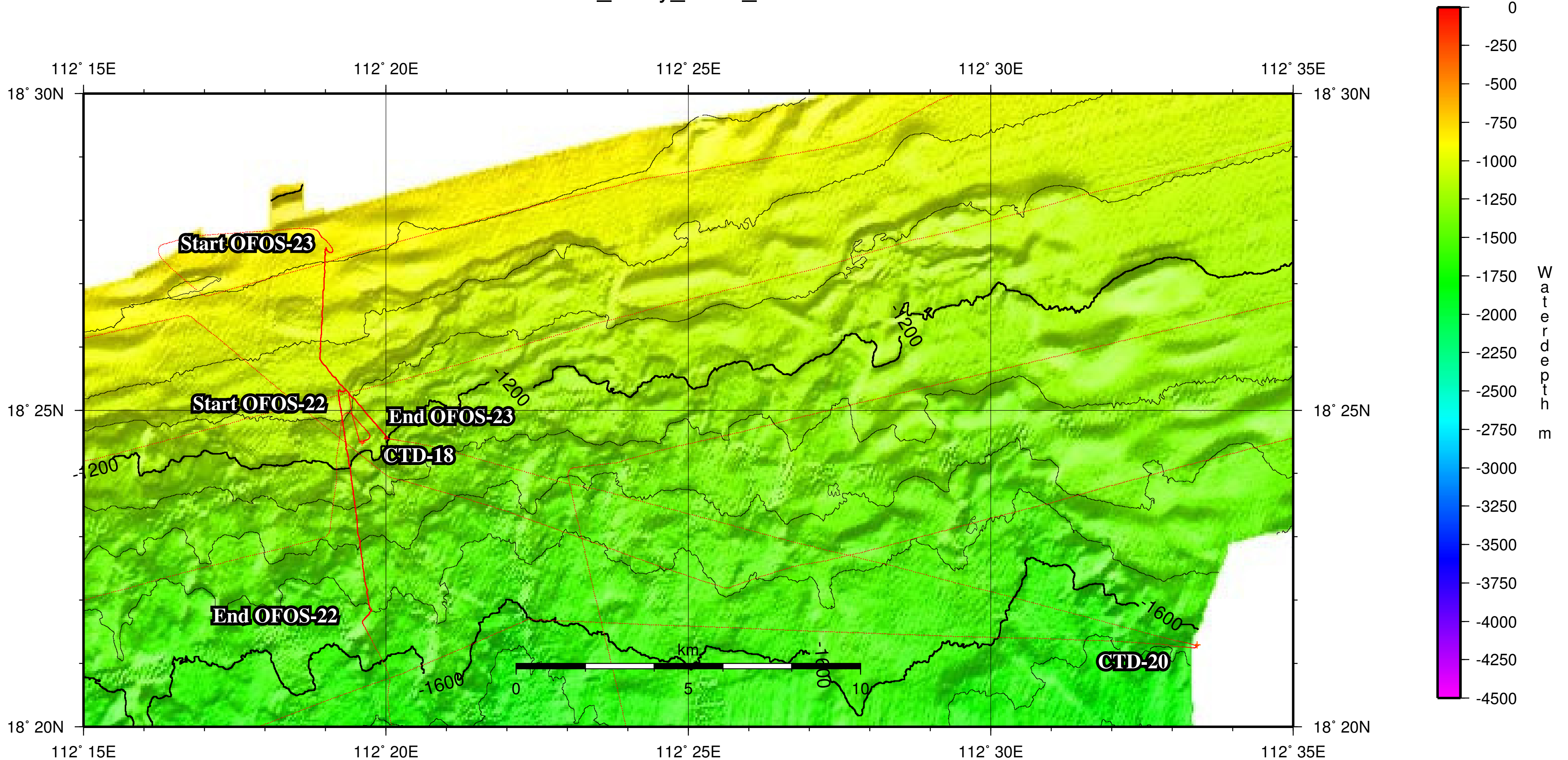
A_bathy_all_A4



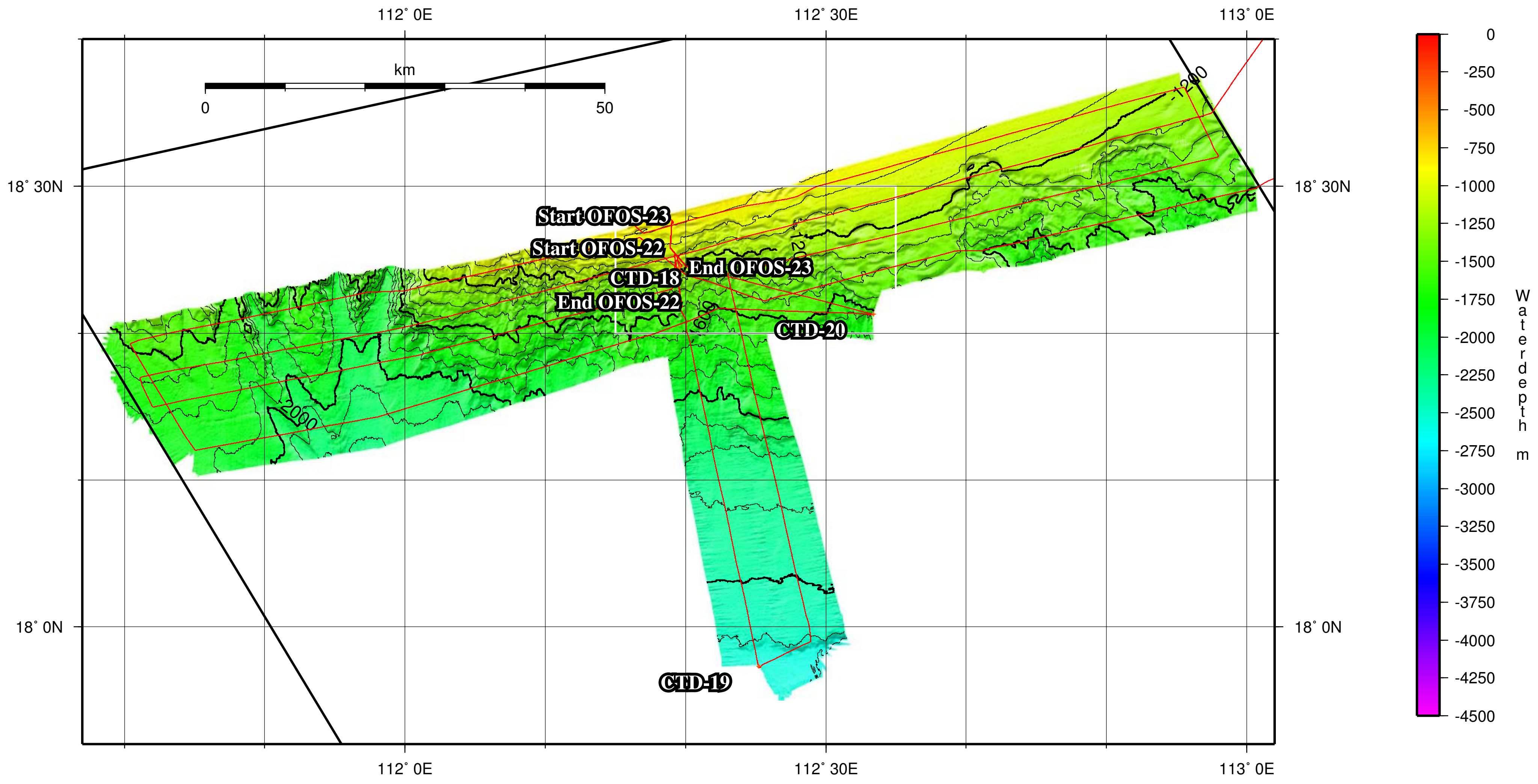
A_bathy_all_inserts_text_A4



B_bathy_detail_text

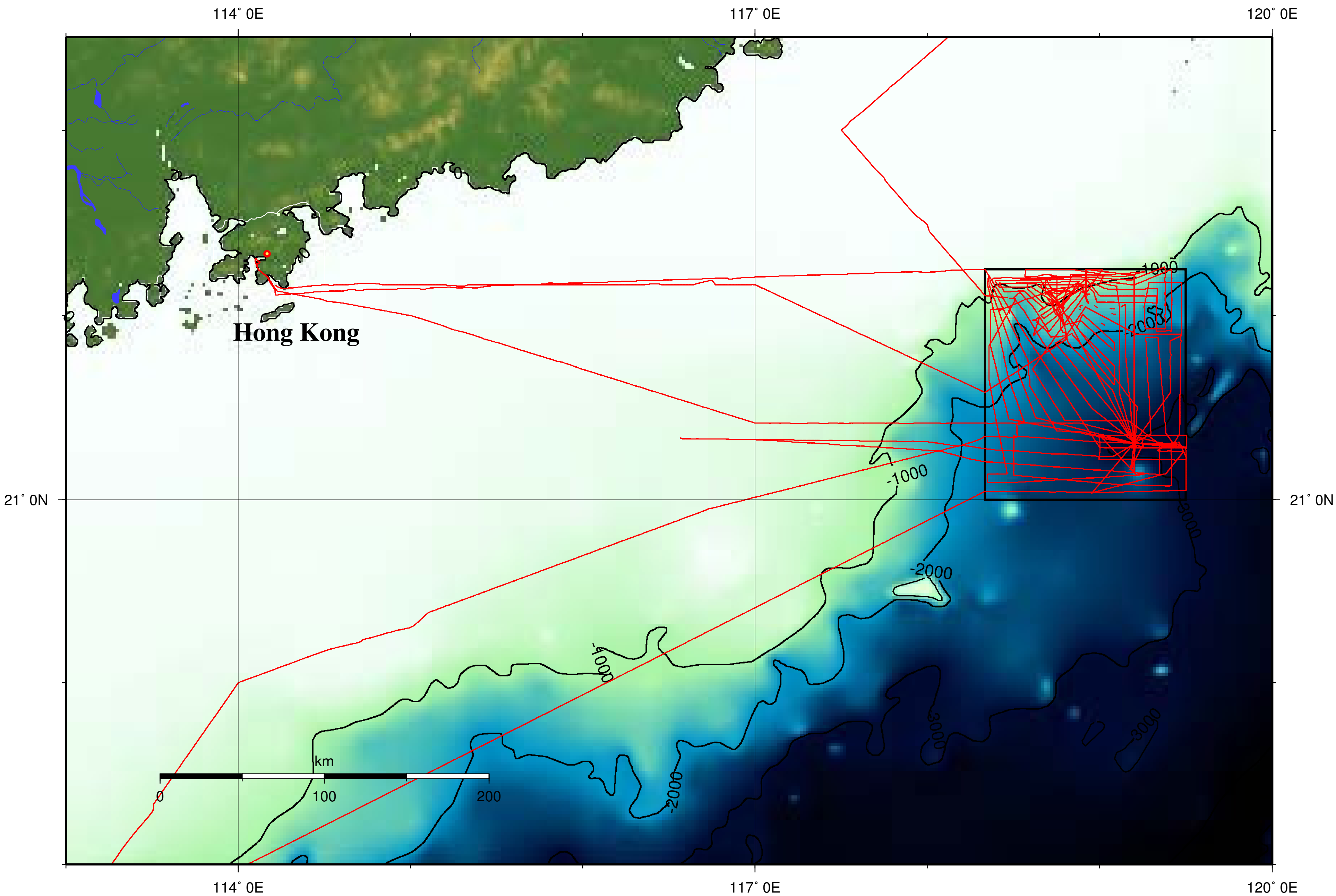


B_bathy_text

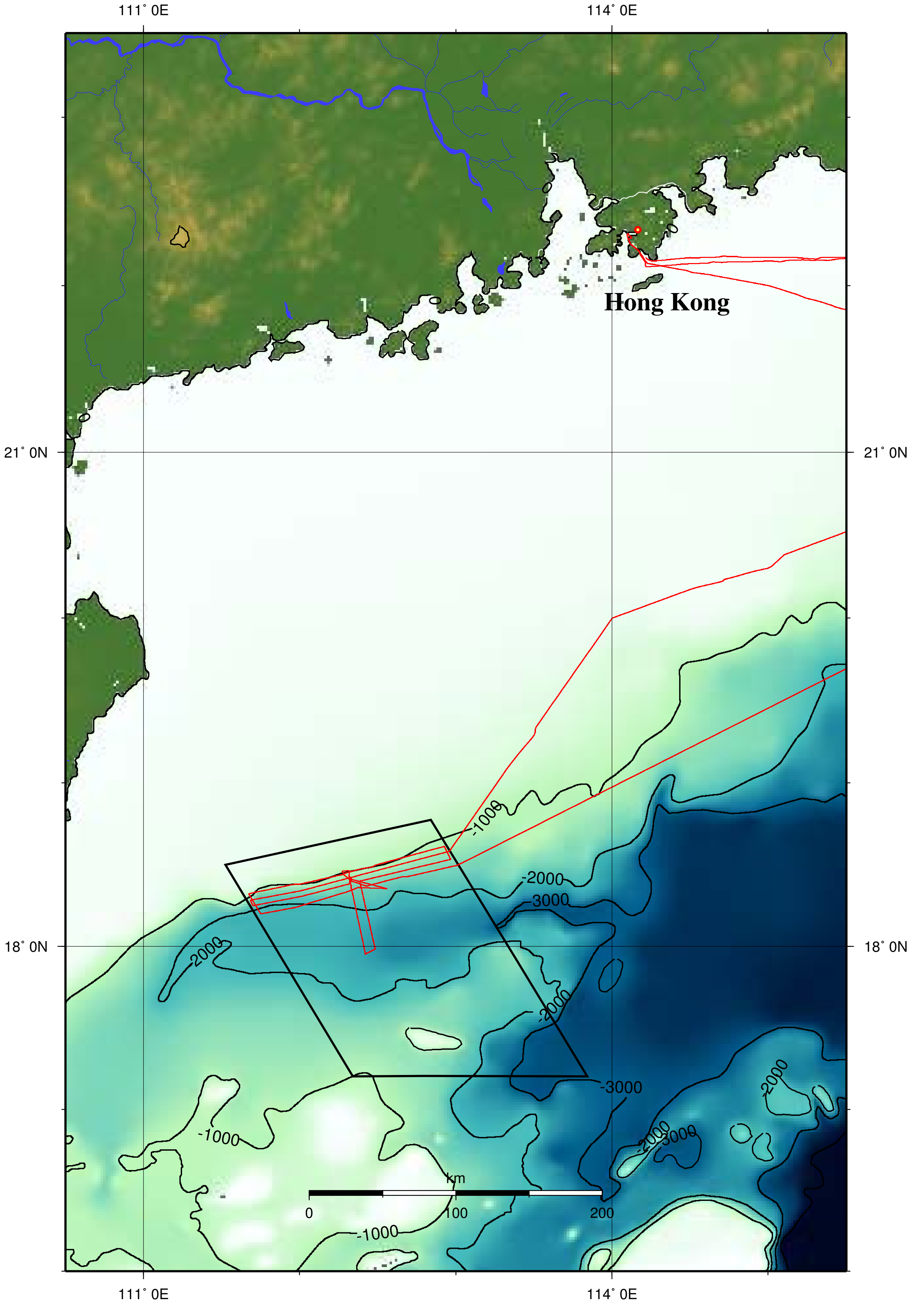


112˚ 0E
112˚ 30E
113˚ 0E
18˚ 30N
18˚ 0N
km
0
50
Start OFOS-23
Start OFOS-22
End OFOS-23
CTD-18
End OFOS-22
CTD-20
CTD-19
-1200
2000
0
-250
-500
-750
-1000
-1250
-1500
-1750
-2000
-2250
-2500
-2750
-3000
-3250
-3500
-3750
-4000
-4250
-4500
Waterdepth m

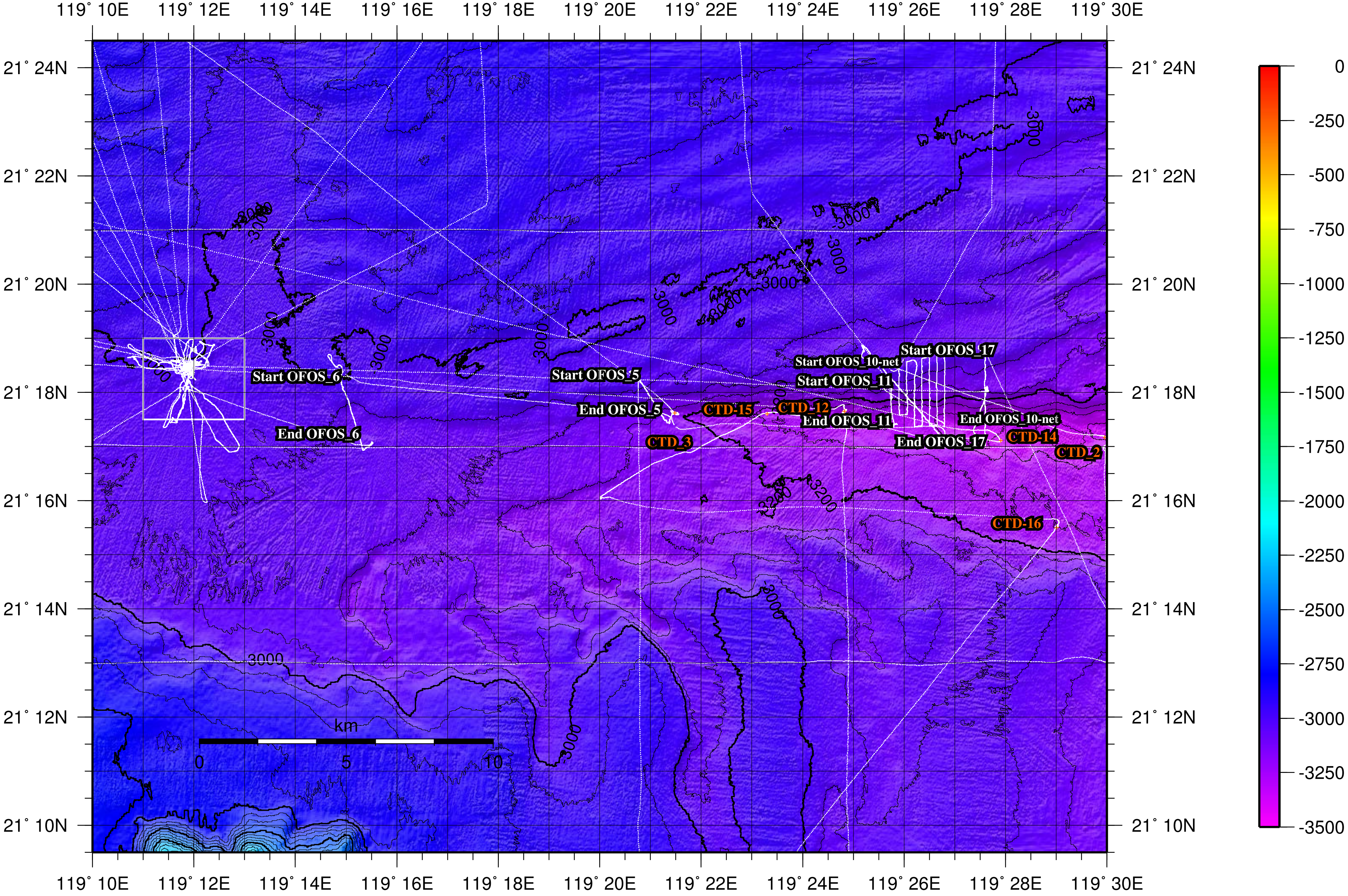
china_tracks_A



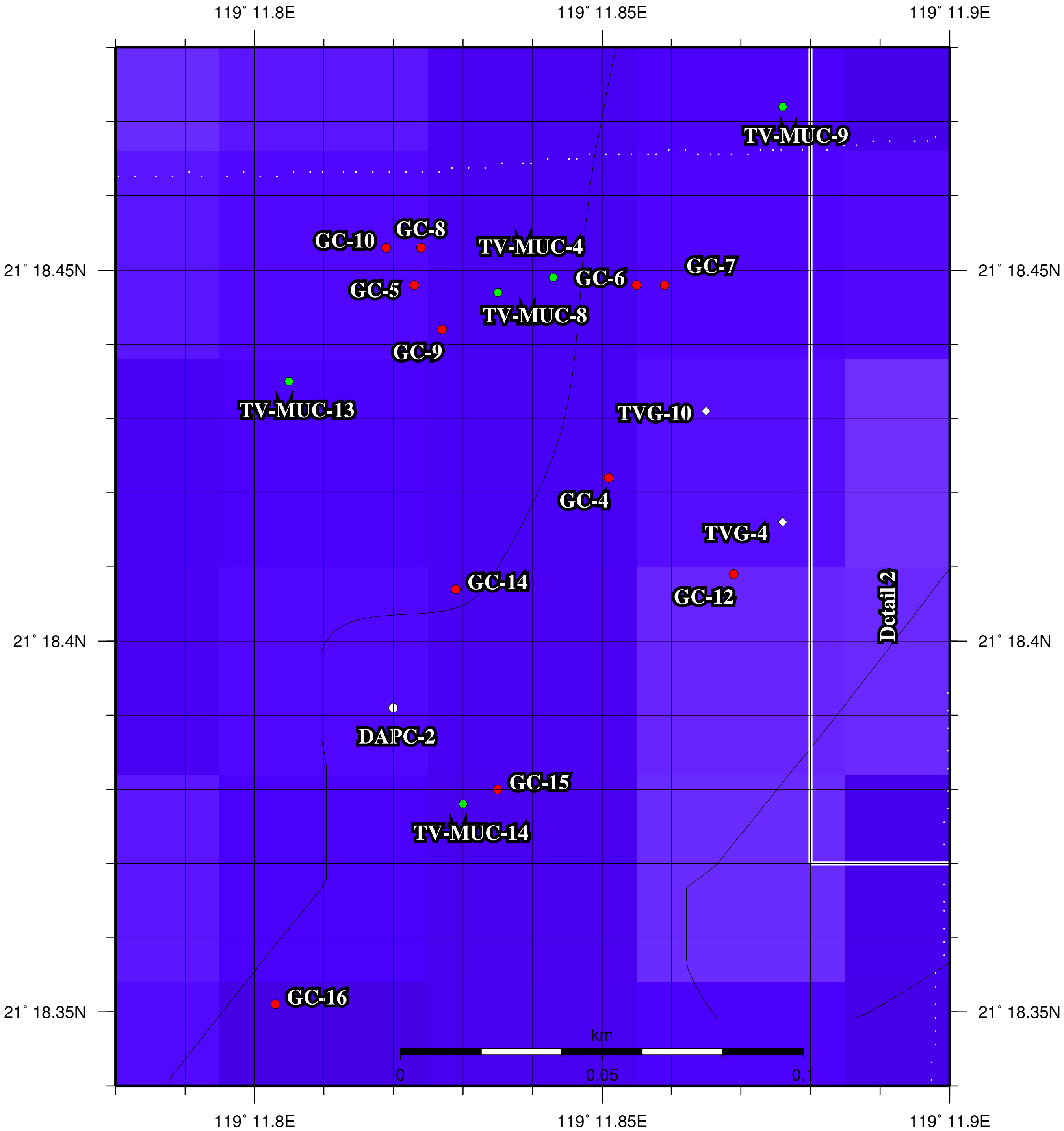
china_tracks_B



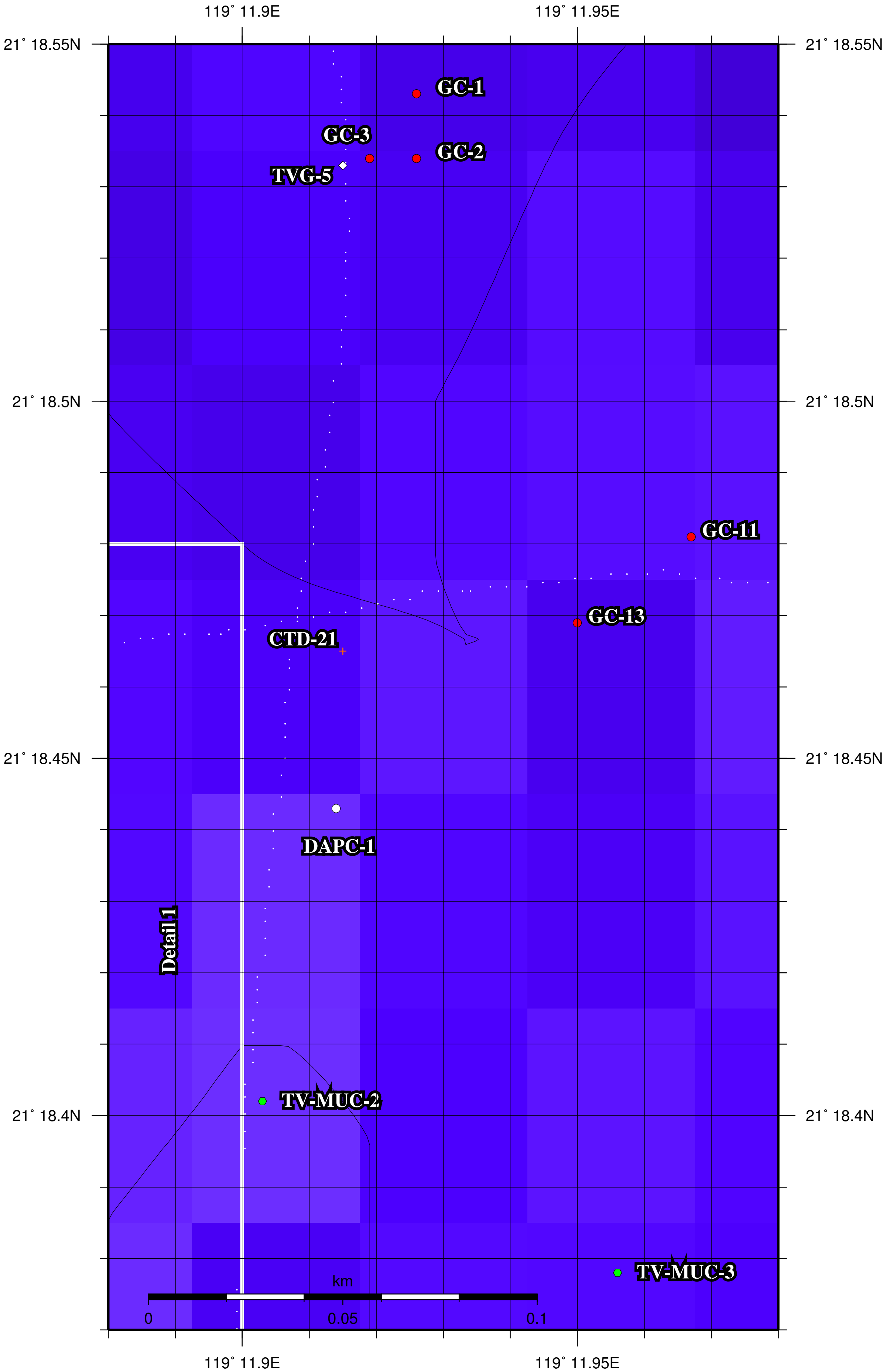
deep-channel_text



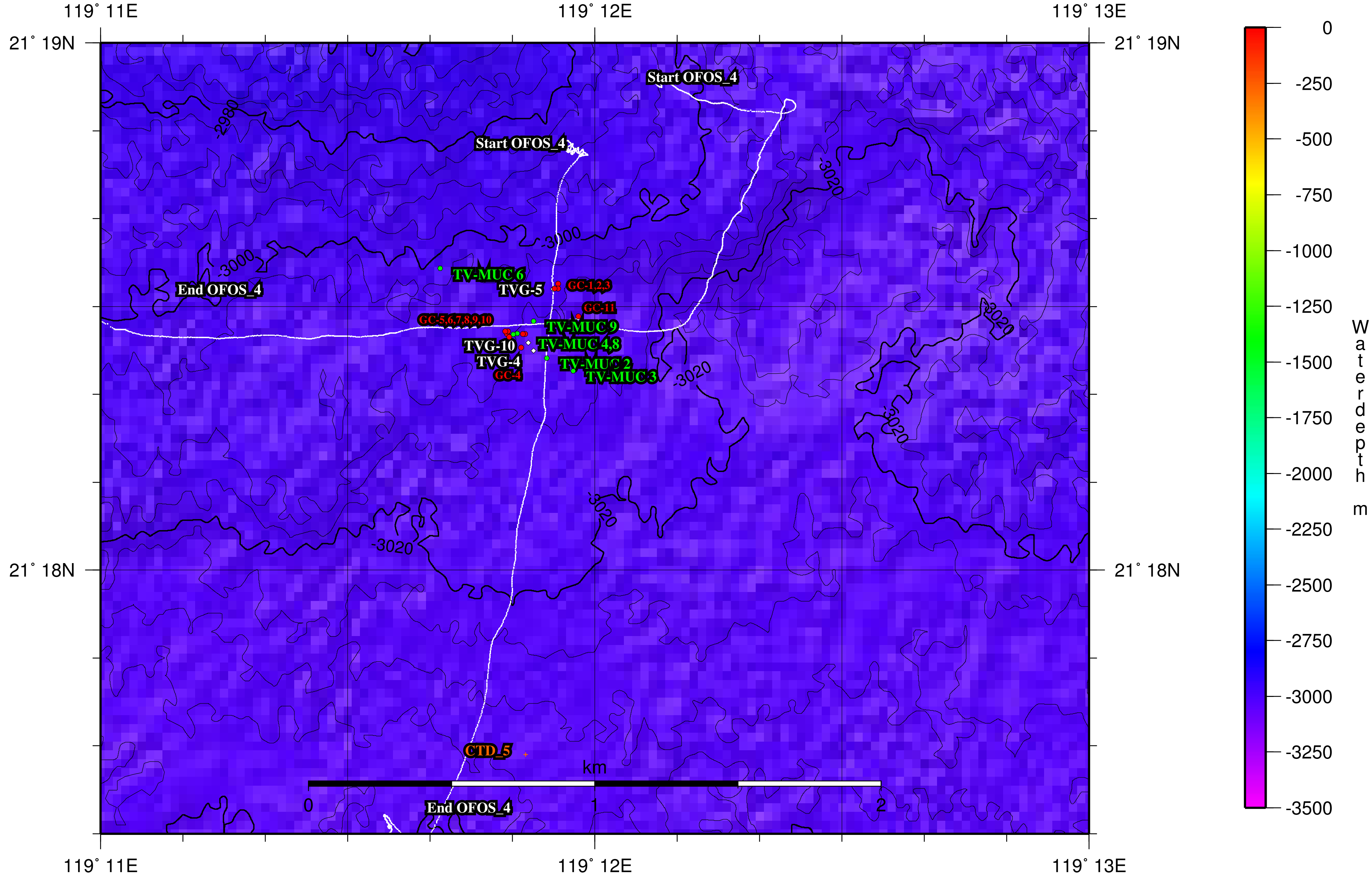
haiyang-site_detail1_text

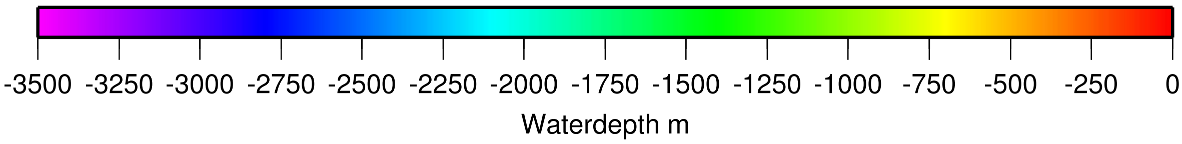


haiyang-site_detail2_text

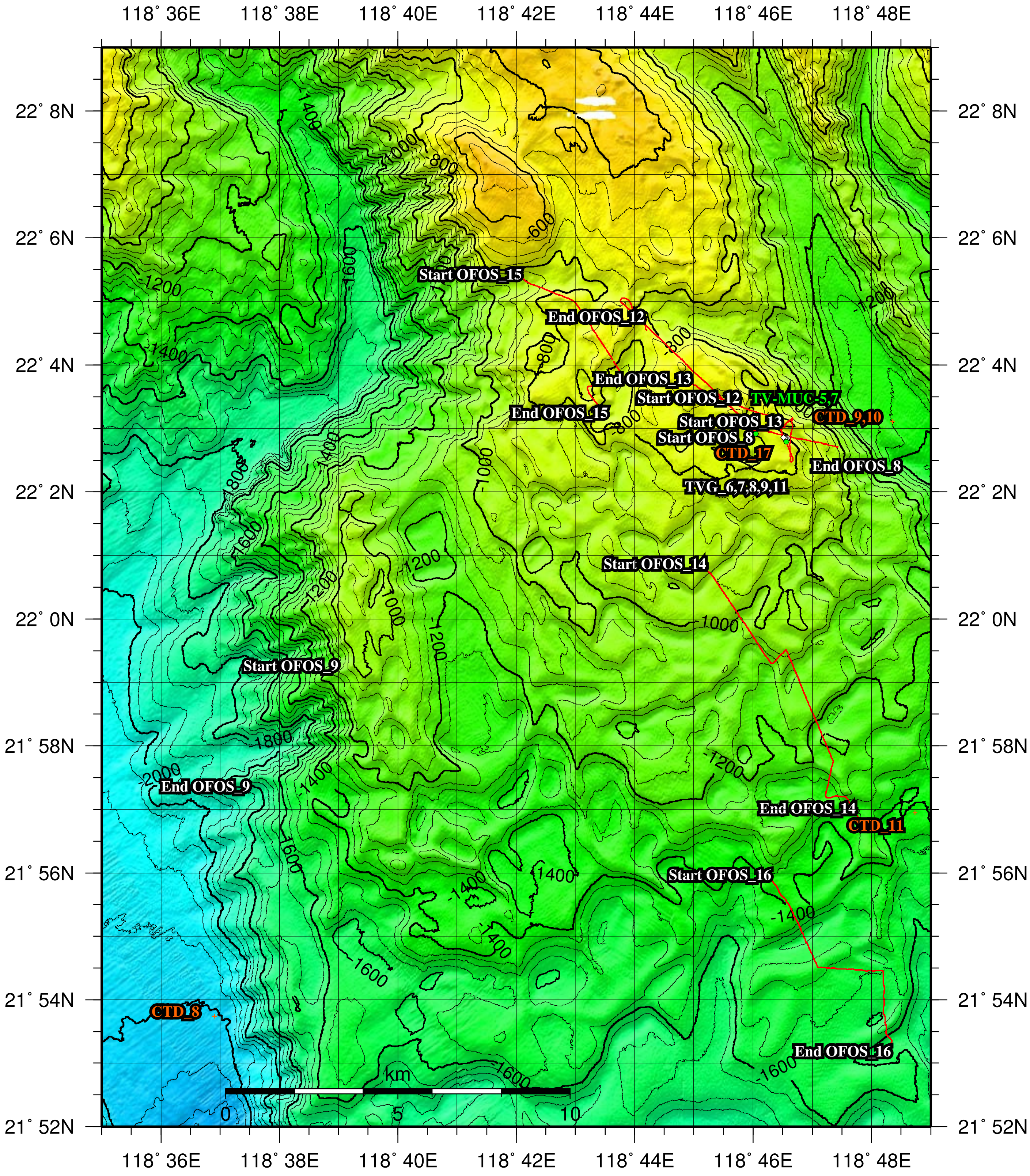


haiyang-site_text

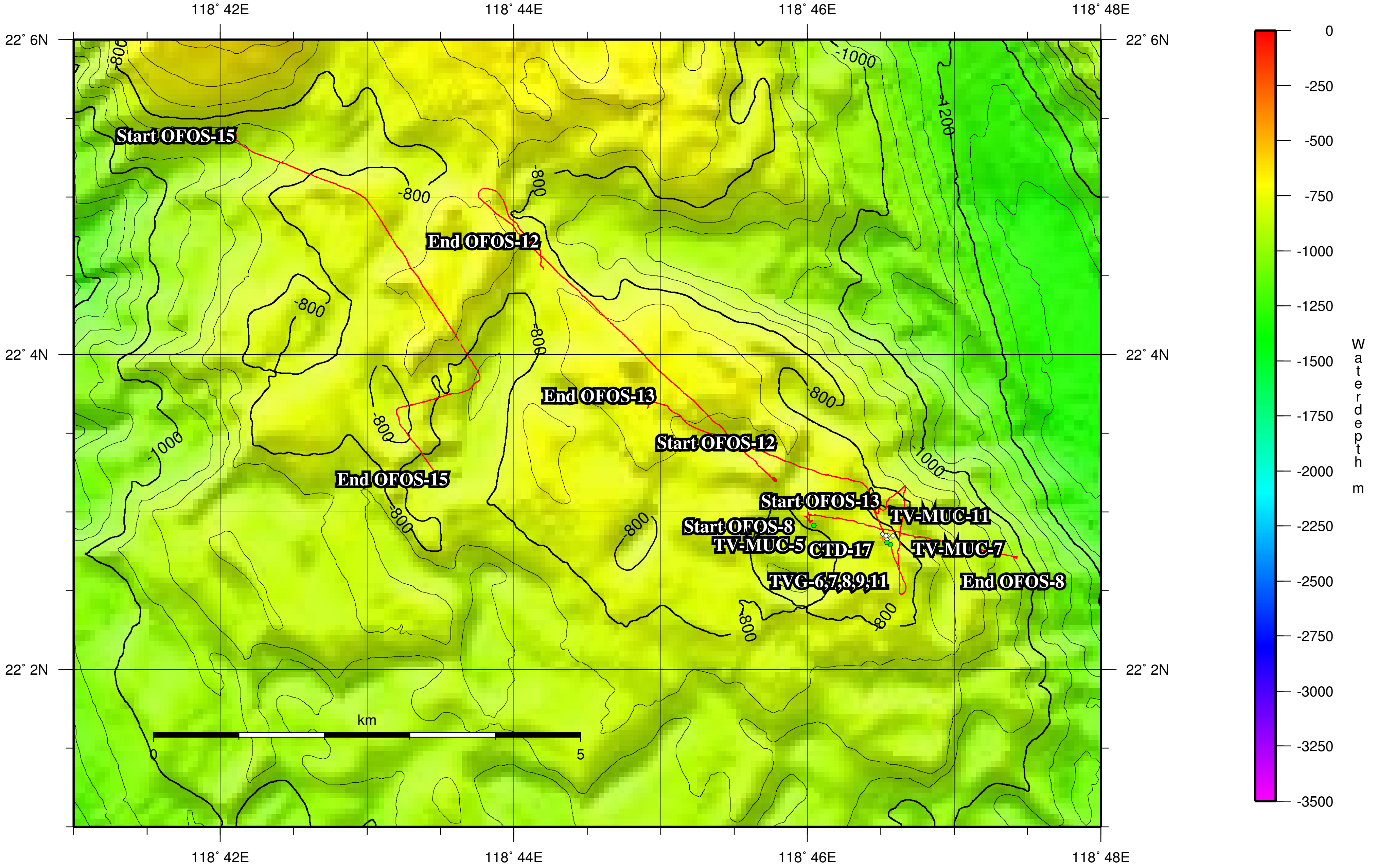




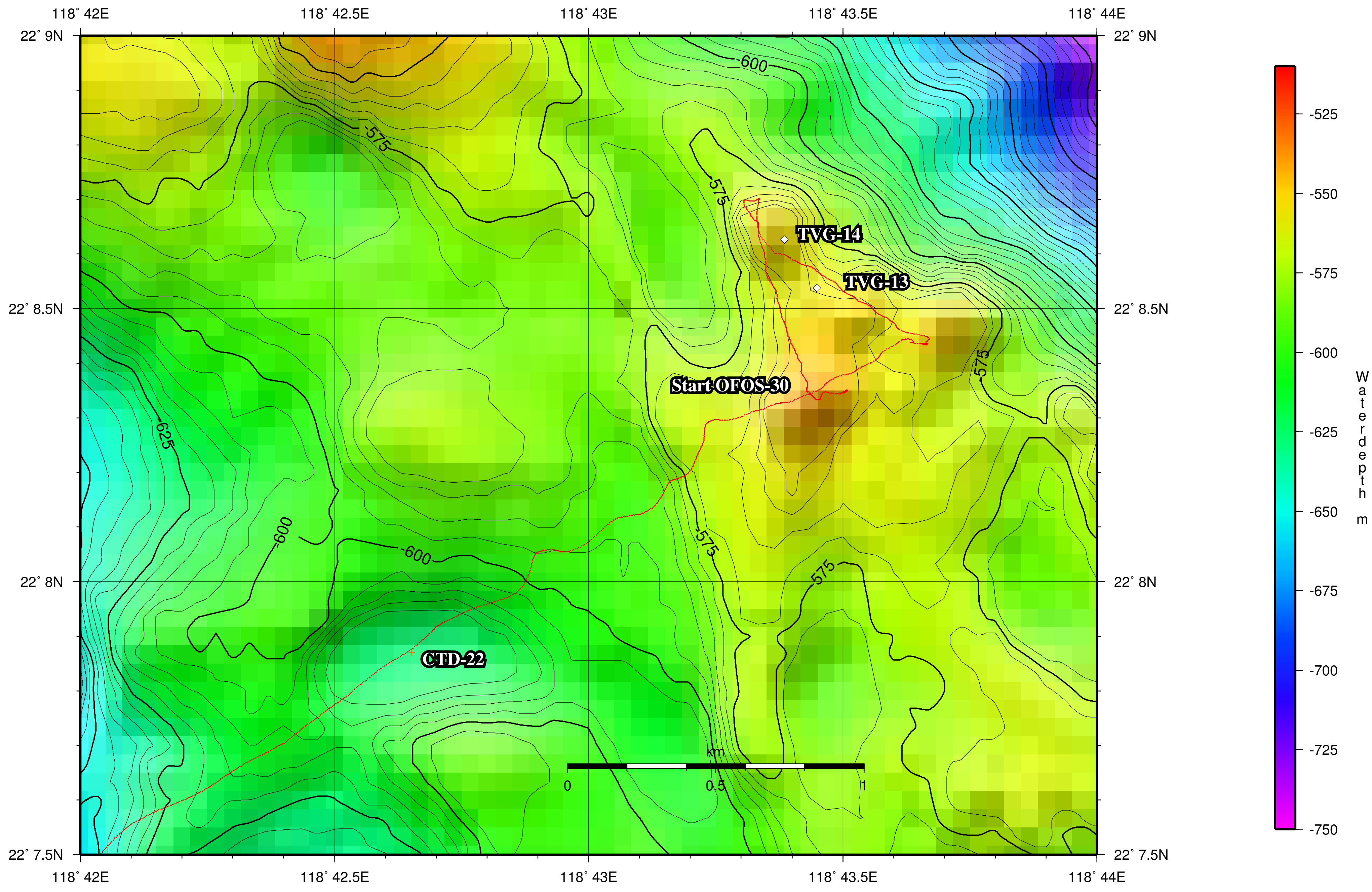

jiu-long-carbonate-mound_text



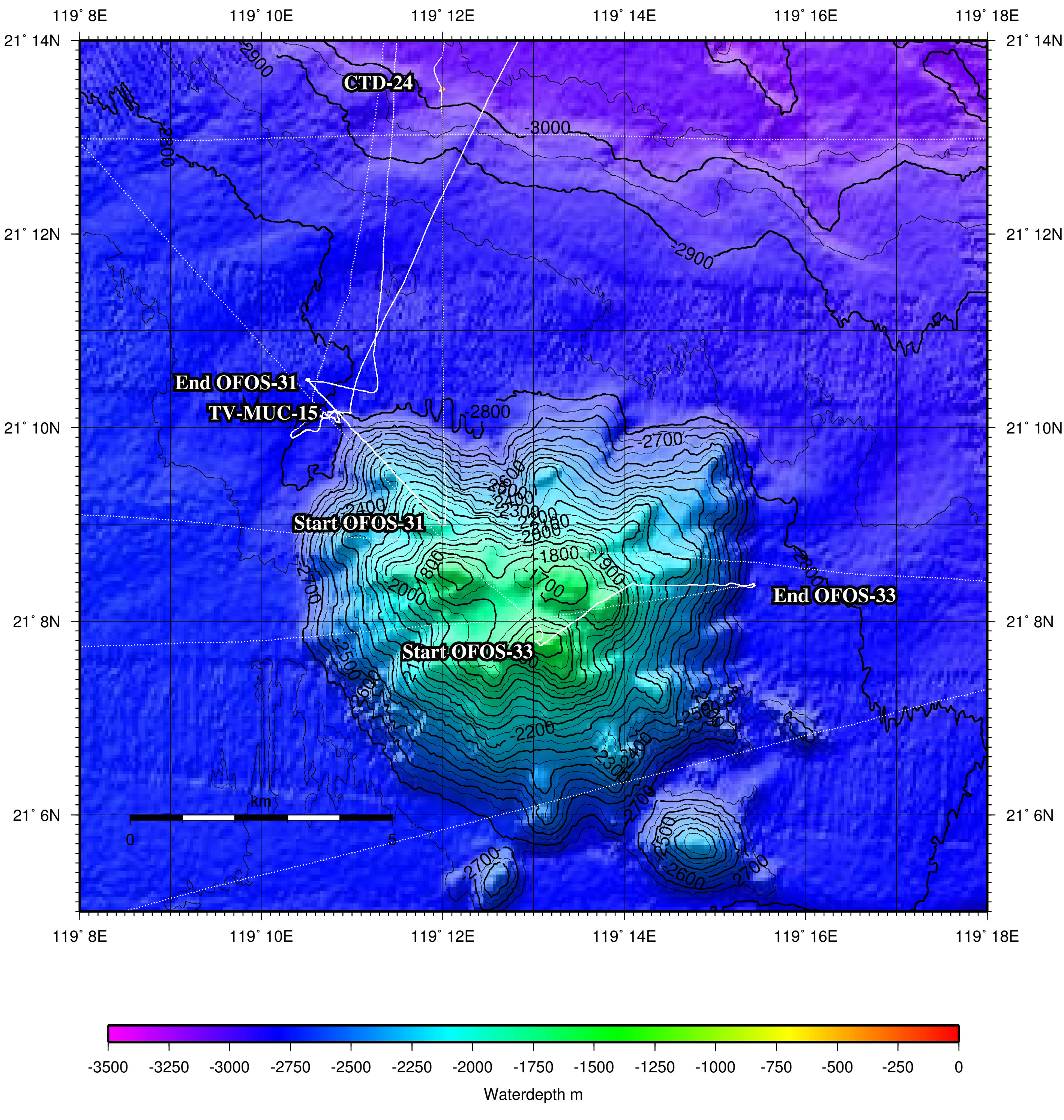
jiu-long-carbonate-mound_detail_text

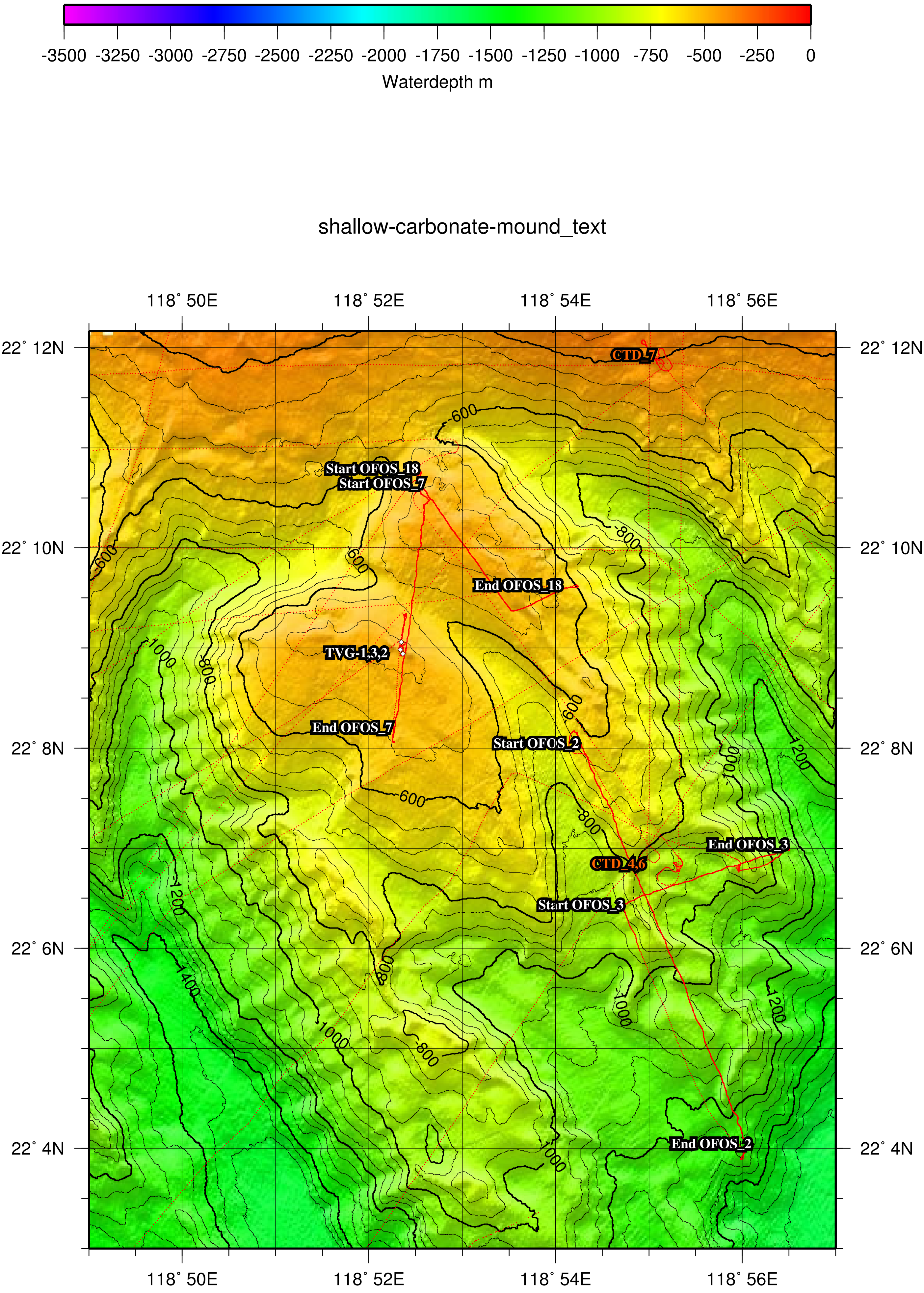


jiu-long-north

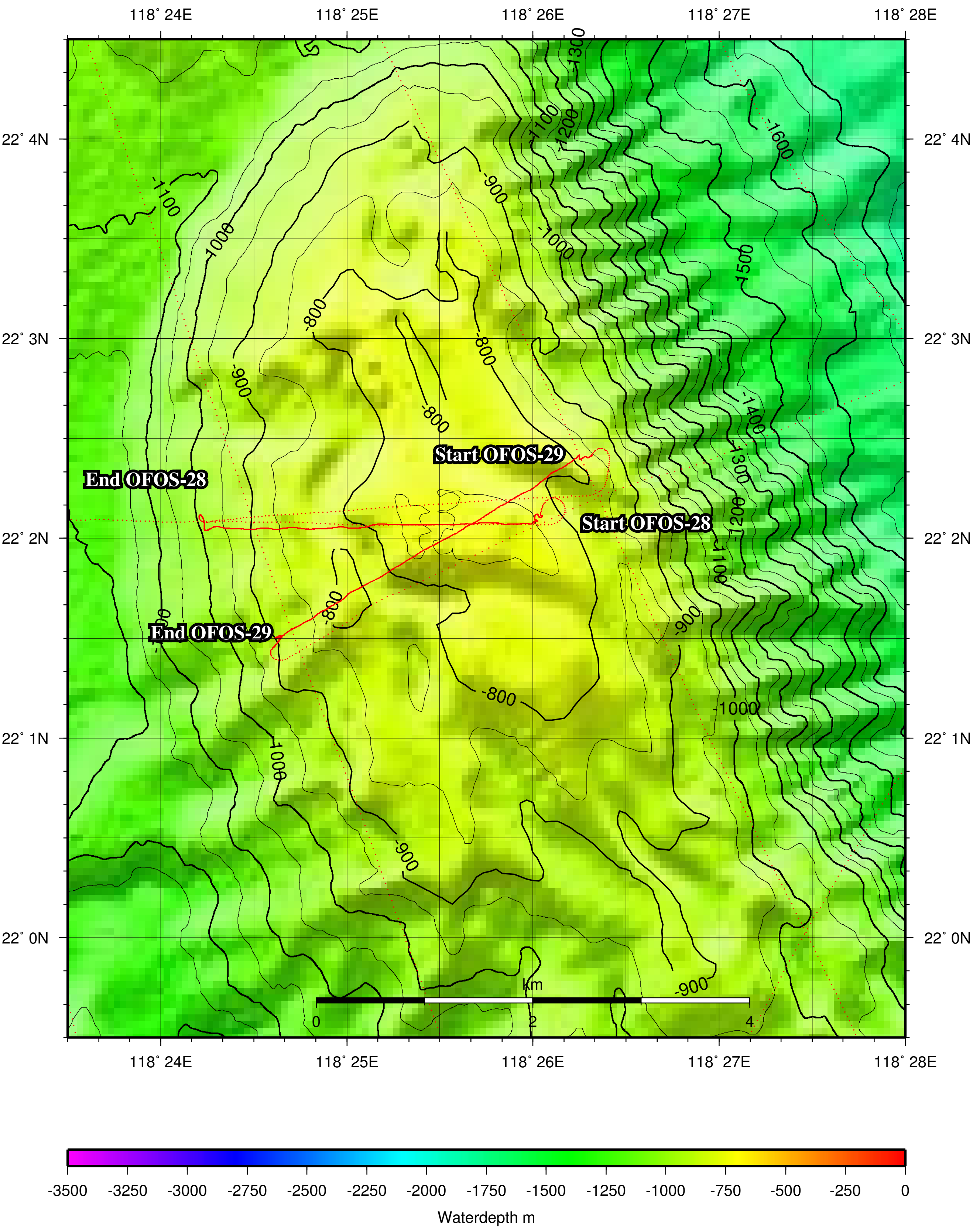


seamount_text




-3500 -3250 -3000 -2750 -2500 -2250 -2000 -1750 -1500 -1250 -1000 -750 -500 -250 0
Waterdepth m
shallow-carbonate-mound_text
118˚ 50E
118˚ 52E
118˚ 54E
118˚ 56E
22˚ 12N
22˚ 10N
22˚ 8N
22˚ 6N
22˚ 4N
CTD_7
Start OFOS_18
Start OFOS_7
End OFOS_18
TVG-1,3,2
End OFOS_7
Start OFOS_2
End OFOS_3
CTD_4,6
Start OFOS_3
End OFOS_2

westmound



118° 24E
118° 25E
118° 26E
118° 27E
118° 28E
22° 4N
22° 3N
22° 2N
22° 1N
22° 0N
Start OFOS-29
End OFOS-28
Start OFOS-28
End OFOS-29
-800
-900
-1000
-1100
-1200
-1300
-1400
-1500
-1600
km
0
2
4
-3500
-3250
-3000
-2750
-2500
-2250
-2000
-1750
-1500
-1250
-1000
-750
-500
-250
0
Waterdepth m