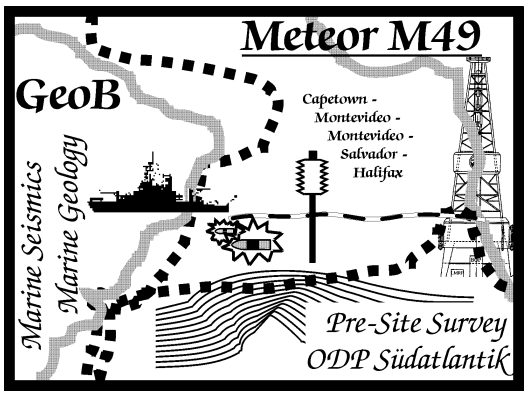

METEOR Cruise M49/3

ODP South Atlantic 2001

March 9 – April 1, 2001
Montevideo, Uruguay – Salvador, Brazil

Short Cruise Report

1 Participants

Name	Dicipline	Institution
Albrecht, Nicole, Student	Geophysics	GeoB
Bleil, Ulrich, Prof. Dr., Chief Scientist	Geophysics	GeoB
Breitzke, Monika, Dr.	Geophysics	GeoB
Brüning, Markus, Student	Geophysics	GeoB
Dehning, Klaus, Technician	Marine Geology	GeoB
Diekamp, Volker, Technician	Marine Geology	GeoB
Domingues, José Manoel	Observer	DHN
Donner, Barbara, Dr.	Marine Geology	GeoB
Franke, Philip, Student	Marine Geology	GeoB
Gerdes, Albert	Public Relations	MARUM
Klann, Marco, Technician	Marine Geology	GeoB
Krastel, Sebastian, Dr.	Geophysics	GeoB
Krüger, David, Student	Geophysics	GeoB
von Lom-Keil, Hanno, Dipl.-Geophys.	Geophysics	GeoB
Martins Lima, Luciana, Student	Marine Geology	UFF
Mulitza, Stefan, Dr.	Marine Geology	GeoB
Quental, Sandra, Student	Marine Geology	UFF
Rudolf, Thessa, Student	Geophysics	GeoB
Rühlemann, Carsten, Dr.	Marine Geology	GeoB
Santiago Grossmann, Guísela, Student	Marine Geology	UFF
Steinborn, Wiebke, Student	Geophysics	GeoB
Thiele, Julia, Student	Marine Geology	GeoB
Truscheit, Torsten, Technician	Meteorology	DWD

DHN	Diretoria de Hidrografia e Navegação Ponta da Armação S/N – Centro Niterói, R.J., Brazil
DWD	Deutscher Wetterdienst - Seewetteramt – Berhard-Nocht-Straße 76, 20359 Hamburg, Germany
GeoB	Fachbereich Geowissenschaften, Universität Bremen Klagenfurter Straße, 28334 Bremen, Germany
MARUM	Zentrum für marine Umweltwissenschaften Klagenfurter Straße, 28334 Bremen, Germany
UFF	Universidade Federal Fluminense Laboratório de Geologia Marinha Av. Bento Maria da Costa 115 “A” 24260 – Charitas, Niterói, R.J., Brazil

2 Research Program

Synopsis

R/V METEOR Cruise M49 combines four legs of the 'ODP South Atlantic 2001' expedition to the Walvis Ridge, to the eastern South American continental margin off central to northern Argentina, Uruguay and southern Brazil and to the equatorial Atlantic. All cruises are entirely or in major parts dedicated to pre-site surveys for active *Ocean Drilling Program* (ODP) proposals aiming at documenting and reconstructing the Paleogene and Neogene paleoceanographic history from sedimentary deposits in various key regions of the South Atlantic.

This third Leg M49/3 concentrates with multichannel reflection seismic, sediment echosounder and bathymetric swath sounder surveying as well as with geologic sampling on the South American continental margin bordering the northwestern parts of the Argentine Basin. It continues investigations of the preceding Leg M49/2 off Argentina and Uruguay. Both cruises are to support the ODP proposal *'Brazil – Falkland (Malvinas) Confluence: Paleoceanography of a Mixing Region'* (*Wefer et al.*, 1999) by identifying appropriate drill sites to recover continuous undisturbed Neogene sedimentary sequences allowing a detailed reconstruction of the past oceanographic and climatic evolution.

Scientific Background

The Neogene paleoceanography of the southwestern South Atlantic is of principal importance to understand the past global oceanic circulation system and its link to the geologic record. *Wefer et al.* (1999) have proposed for the first time an ODP scientific drilling campaign in this region comprising a number of transects on the Atlantic margin of South America at the boundary of the Argentine Basin (between Falkland Islands [Malvinas] and Rio Grande Rise). Main target is the late Neogene paleoceanography with special interest on the reconstruction of the mixing history of tropical and subantarctic water masses in this area representing the general locale of confluence of the Brazil Current and the Falkland (Malvinas) Current. The dynamics of this region are consequential in several contexts: for the heat budget of the South Atlantic, for the production of intermediate water, and for the efficacy of regional biologic productivity.

Due to the well known complexity of depositional regimes at the Atlantic South American continental margin, two R/V METEOR cruises employing geophysical methods of multichannel reflection seismics, *Parasound* sediment sounding and *Hydrosweep* swath bathymetry sounding combined with geologic sampling of the water column and the sedimentary deposits were assigned to the task of identifying a series of suitable ODP deep drilling sites.

During the foregoing R/V METEOR Cruise M49/2 pre-site surveys were carried out in two different sectors off Argentina (working areas 'A' and 'B') and off Uruguay (working area 'C'). Subsequently, Cruise M49/3 was to operate off southern Brazil (working areas 'D' and

‘E’). Relatively sparse information about the Cenozoic history of these regions is available from previous investigations, mainly because of the remarkable complexity of topography and sedimentary structures and the strong influence of bottom currents limiting the lateral continuity and extent of reflectors and sediment units. Knowledge of the near surface Quaternary sedimentation was improved during several R/V METEOR Cruises: M23/2 (*Bleil et al.*, 1993), M29/1 (*Segl et al.*, 1994), M29/2 (*Bleil et al.*, 1994), M46/2 (*Schulz et al.*, in press) and M46/3 (*Bleil et al.*, in press). Primary interest of the present R/V METEOR Cruise M49/3 is in the upper 200 to 600 m of the sediment cover that cannot be explored with sediment echosounding nor sampled by conventional coring techniques. Whereas the structural and stratigraphic resolution of standard seismic instrumentation is on the order of 10 m or less, the new Bremen equipment allows for much more detailed insight.

The continental margin bordering the northern Argentine Basin off southern Brazil is characterized by somewhat more regular depositional patterns than further south. This should provide improved conditions to locate potential drill sites for paleoceanographic research. Because of the greater distance to the Rio de la Plata river mouth, hemipelagic sequences with reduced terrigenous input and a higher proportion of biogenic components are expected here. However, the topography is regionally influenced by a complex structural tectonic framework, e.g., on the São Paulo Plateau, where an extensive salt tectonism has been recognized. Accordingly, more survey time was arranged in these areas to allow for more detailed investigations on closely spaced seismic grids.

Methods

Geophysical activities will particularly focus on seismic and echographic surveys using the Bremen high-resolution multichannel seismic equipment to depict small scale sedimentary structures and closely spaced layers which cannot be resolved with conventional seismic systems. The alternating operation of a small volume watergun (200 - 1600 Hz) and larger chamber GI airguns (100 - 500 Hz) yields simultaneously two seismic data sets, one of deeper penetration contributing extended insight into the structural and temporal context of near surface depositional processes, and a second revealing details of the upper about 200 m of the sediment cover.

Seismic records will be complemented by high frequency digital recordings of the shipboard *Parasound* sediment echosounder and the *Hydrosweep* swath sonar system. The broad signal frequency spectrum of seismoacoustic data sets acquired secures an optimum morphologic and structural resolution at all depth levels of the sedimentary formations. Both shipboard echographic systems will be permanently operated on a 24 hours watch during the cruise for the best possible selection and positioning of sediment sampling locations. Furthermore, multiple frequency recordings of the *Parasound* sediment echosounder are performed at geologic sampling sites for a direct comparison with sedimentological parameters and detailed shore based physical properties core log measurements which will be performed in the University of Bremen laboratories.

Working Plan

In the two projected working areas ‘D’ and ‘E’ seismic surveys will be accomplished with the primary objective to locate appropriate sites for deep drilling operations. The investigations concentrate on water depths between 1000 and 4000 m to cover the influences of different major water masses such as North Atlantic Deep Water (NADW) and Antarctic Bottom Water (AABW) on depositional regimes and sedimentation processes.

Already during the cruise, seismic data sets will be processed on board to support further planning and particularly to define crossing points on recorded lines, where promising structures were encountered that may be selected as potential drill sites. The analysis of sediment layering shall ensure that deposition was as continuous as possible and that major hiatuses can be avoided.

The main objective of geological work is the sampling of Quaternary sediments on the South American continental margin off southern Brazil. Wherever structural settings should provide an opportunity, also older deposits rising to near surface will be recovered to date deeper reflectors. The materials are analyzed for the stratigraphic and sedimentologic characterization of the top sequences at potential ODP coring sites. Moreover, they will be used to continue and extend paleoceanographic studies in the scope of a long-term program aimed at reconstructing the mass budget and current systems of the South Atlantic during late Quaternary established as a Special Research Project (SFB 261) at the University of Bremen since 1989. Along the proposed transects over the continental margin sediments are recovered from different water depths with multicorer and gravity corer devices. Their detailed investigation with sedimentological, geochemical and micropaleontological methods will yield information about the history of water mass fluctuations and sustain the understanding of past ocean circulation and the mechanisms of late Quaternary climatic changes.

3 Summarized Cruise Report

After two days in port, R/V METEOR sailed as scheduled in the morning of March 9, 2001 from Montevideo/Uruguay to Leg 3 of Cruise M49. Most of the scientific crew members had arrived from Bremen/Germany the day before, another six experts from the Earth Science Department at the University of Bremen already participated in the previous Cruise M49/2. Our scientific guests for this expedition were three young colleagues from the Laboratório de Geologia Marinha of the Universidade Federal Fluminense in Niterói/Brazil. Capitão-Tenente José Manoel Domingues from the Diretoria de Hidrografia e Navegação, Niterói, was appointed as the official Brazilian Observer for Cruise M49/3.

On transit to the first working area on the Brazilian continental margin at around 32 °S, during 6 hours in the early morning of March 10, R/V METEOR took part in a search operation off Uruguay for a helicopter which was lost a of couple days before. From the beginning expectations to be of substantial help with the ship’s various echosounding systems were

moderate due to the shallow water depth of around 20 m in sight of the coast. Nevertheless, on delivering the recordings to the R.O.U. frigate '*Montevideo*' it became evident that one of two more or less obvious peculiarities in our data sets strikingly coincided with observations of other ships that had been engaged in the region for several days. Subsequently, this position should have been investigated in more detail by divers. The time devoted to this goodwill action on request of the Uruguayan Navy was easily compensated during the remaining cruise schedule.

After several tests and some minor restorations of the streamer during the afternoon of March 10, scientific activities of the cruise were started at 22:00 UTC of the same day (at 33°44.4'S/052°19.4'W) with *Parasound*, *Hydrosweep* and *Thermosalinograph* recordings. Following launch of the streamer, watergun and two GI airguns, the first reflection seismic line in our study area 'D' (bound within 30°00.0'S/049°00.0'W - 32°00.0'S/045°30.0'W - 34°30.0'S/047°22.0'W - 33°00.0'S/051°14.0'W; see Figure 3) began on March 11, 09:48 UTC (see Table 1 for details of the seismic profiling). The multichannel reflection seismic survey was particularly to explore the deeper sedimentary formations from the shelf to water depths of around 4000 m in the Argentine Basin. Details of the sea floor topography and near surface sediment structures were recorded in parallel with the ship's echosounder systems *Hydrosweep* and *Parasound*.

The first series of seismoacoustic measurements comprised a total of about 475 nm along five lines and ended at 11:29 UTC on March 14. They provided a general framework of the sedimentary setting which, as expected, was found altogether quite complex so that three-dimensional configurations were occasionally difficult to conceive from line recordings of topography and reflection patterns. Marked changes in slope angle should primarily be controlled by basement (?) tectonics. They clearly separate erosional zones from areas with an apparently continuous sedimentation. Even there, frequently interlayered slump deposits have been observed. All potential ODP drill sites identified at this stage are hence compromised to some extent. A most interesting yet enigmatic feature encountered in the southern parts of working area 'D' is a BSR reminding phenomenon: distinctly enhanced amplitudes in around 0.5 s TWT sediment depth that were observable down to great water depth without a clearly developed reflector though.

Between March 14, 17:50 UTC and March 16, 03:44 UTC the first six geologic stations of this cruise (GeoB 6901 to 6906) were scheduled. In water depths from about 1700 to 3200 m 6 to 12 m long gravity corers have been successfully employed (see Table 2 for details of the geologic sampling program). Three of the coring locations were strategically positioned on steep intensely eroded slopes, where deeper reflectors presumably surface. Their sampling and later dating should allow an estimate of average sedimentation rates and periods of time comprised in depth intervals of ODP drill holes. At three locations also complete series of surface sediments were retrieved with the multicorer. As well, each time a CTD profile was registered. All these data were lost unfortunately, because of seawater intrusion into the electronics of the CTD device which, despite considerable efforts, could not be repaired and re-calibrated.

At 06:33 UTC of March 16, the seismoacoustic profiling activities were resumed. Until March 18, 10:00 UTC a total of ten lines along about 320 nm have been completed. The main objective of multiple parallel and crossing profiles around and over potential ODP drill sites was an improved understanding of the three-dimensional context of their structural and depositional settings. A final along-slope profile connected the different lines across the continental margin. Meanwhile the geologists successively opened the sediment cores recovered. After the standard procedures of sampling, describing and color scanning, the materials are stored at 4 °C in a cooling container which will be transported from Salvador back to Bremen.

Following an ultimate geologic station in working area ‘D’ (GeoB 6907) on March 18 at 30°53.6’S/048°30.8’W R/V METEOR set course to the second target region ‘E’ of Cruise M49/3 in the Santos Plateau realm. Underway, the ship’s 15 years commission was celebrated with a dinner on deck.

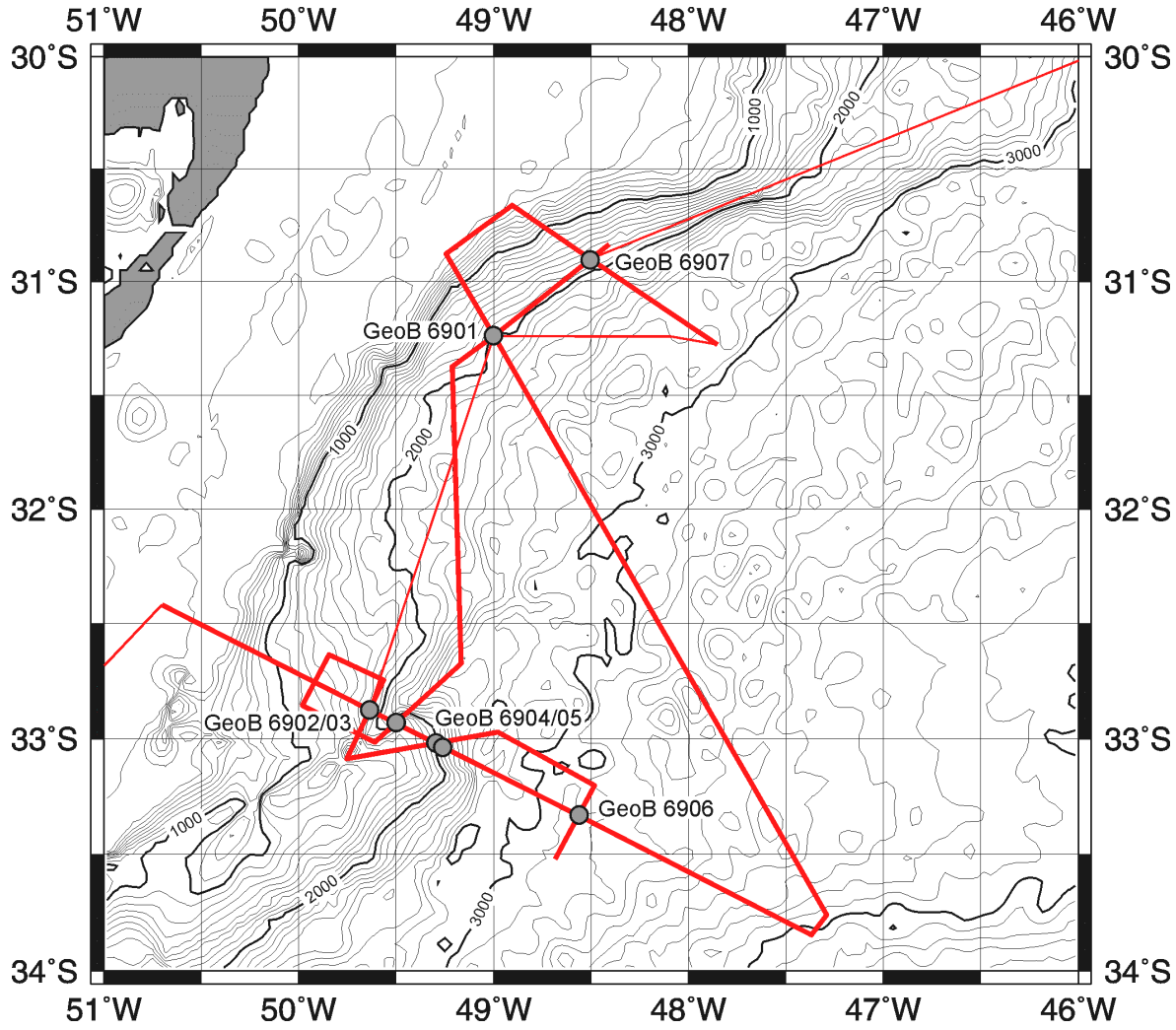

Figure 1 R/V METEOR Cruise M 49/3 track and station chart in the southern working area ‘D’. Thick lines denote seismic profiles, thin lines transit routes with *Parasound* and *Hydrosweep*. Bathymetry from Smith & Sandwell, 1997.

On March 20, at 5:30 UTC R/V METEOR reached the projected starting position in the northern working region ‘E’ of Cruise M49/3 at about 28,6°S/041,1°W. After deploying the streamer, the watergun and both GI airguns, seismic and echographic profiling operations began in this area (bound within 26°40.0’S/047°10.0’W - 24°20.0’S/044°25.0’W - 27°45.0’S/ 040°25.0’W - 29°25.0’S/ 041°10.0’W; see Figure 2). They ended on March 24, at 08:12 UTC completing 11 lines along around 600 nm. The initial crossing over the old *Deep Sea Drilling Project* (DSDP) Site 356, which has been probed in 1974, intended to couple the lithostratigraphic and chronostratigraphic concept developed for the sediment sequences recovered there with the recorded pattern of seismic reflectors and to further correlate it as far as possible into the seismic survey. As matters presently stand, this prospect can hardly be achieved as the drilling location was placed in a small scale isolated basin structure immediately at the São Paulo Ridge. The seismic attributes of its sedimentary filling can apparently not be traced from this southernmost marginal part further onto the São Paulo Plateau.

The first long transect up to the Brazilian shelf off Rio de Janeiro led across a broad belt of salt diapirs, similar structures as we have previously encountered at the conjugated African continental margin off Angola and, of course, producing identical complications to identify appropriate and safe potential ODP drill sites. Naturally, colleagues from industry were not too far in such an environment. At some distance to our courses several commercial seismic prospecting activities have simultaneously been active. On March at 17:00 UTC we passed by a most recent generation drill ship (‘*Deepwater Millenium*‘) which operated in more than 1600 m water depth (the world largest production platform was lost these days way to the north of our working area).

On approaching the continental slope, the upper portions of the sedimentary cover on the São Paulo Plateau above about 2300 m water depth appeared mostly undisturbed and more distinctly layered offering different suitable sites for ODP drilling. Within the penetration depth of our seismic instrumentation prominent salt diapiric structures were seemingly much less developed.

The geologic sampling program over the weekend of March 24/25 comprised four stations at the upper continental slope in water depths between 500 and 1600 m (GeoB 6908 to 6911), where after overcoming minor problems with gear, the multicorer and gravity corer successfully recovered Quaternary sediment sequences for the Special Research Project (SFB 261) at the University of Bremen, a long-term investigation aimed at reconstructing the mass budget and current systems of the South Atlantic during the late Quaternary. Unfortunately, no more CTD casts could be performed due to instrument failure. Subsequently, the multicorer and gravity corer have been employed once more at three potential ODP drilling locations (GeoB 6912 to 6914) on the upper São Paulo Plateau together with the rosette water sampler which was operated there for the last time on this cruise.

From March 25, 21:56 UTC on the scientific activities concentrated on final seismic and echographic surveys. First, the upper São Paulo Plateau region in the vicinity of the three coring sites GeoB 6912 to 6914 was explored to achieve comprehensive insight to their

structural and depositional environment. The preliminary results seem to imply that the influence of salt tectonism is generally more pronounced and the undisturbed sediment cover generally thinner in this area than observed on our initial profile which was of rather poor quality, however, due to substantial noise produced in the streamer. Presumably, these sites will be no prime choice for ODP drilling operations, therefore.

After once more crossing the salt diapir field on southeasterly courses, the final seismic survey was conducted on and around a location, where we had previously encountered a drift-like sediment body showing very regular internal structures. It ended on March 28, at 07:04 UTC, when the seismic gear was finally retrieved on deck. To conclude the scientific program in working area 'E', sediment series were successfully recovered at two stations (GeoB 6915 and 6916) on top of the drift with multicorer and gravity corer and at its lower flank, where deeper reflectors crop up, only with the gravity corer.

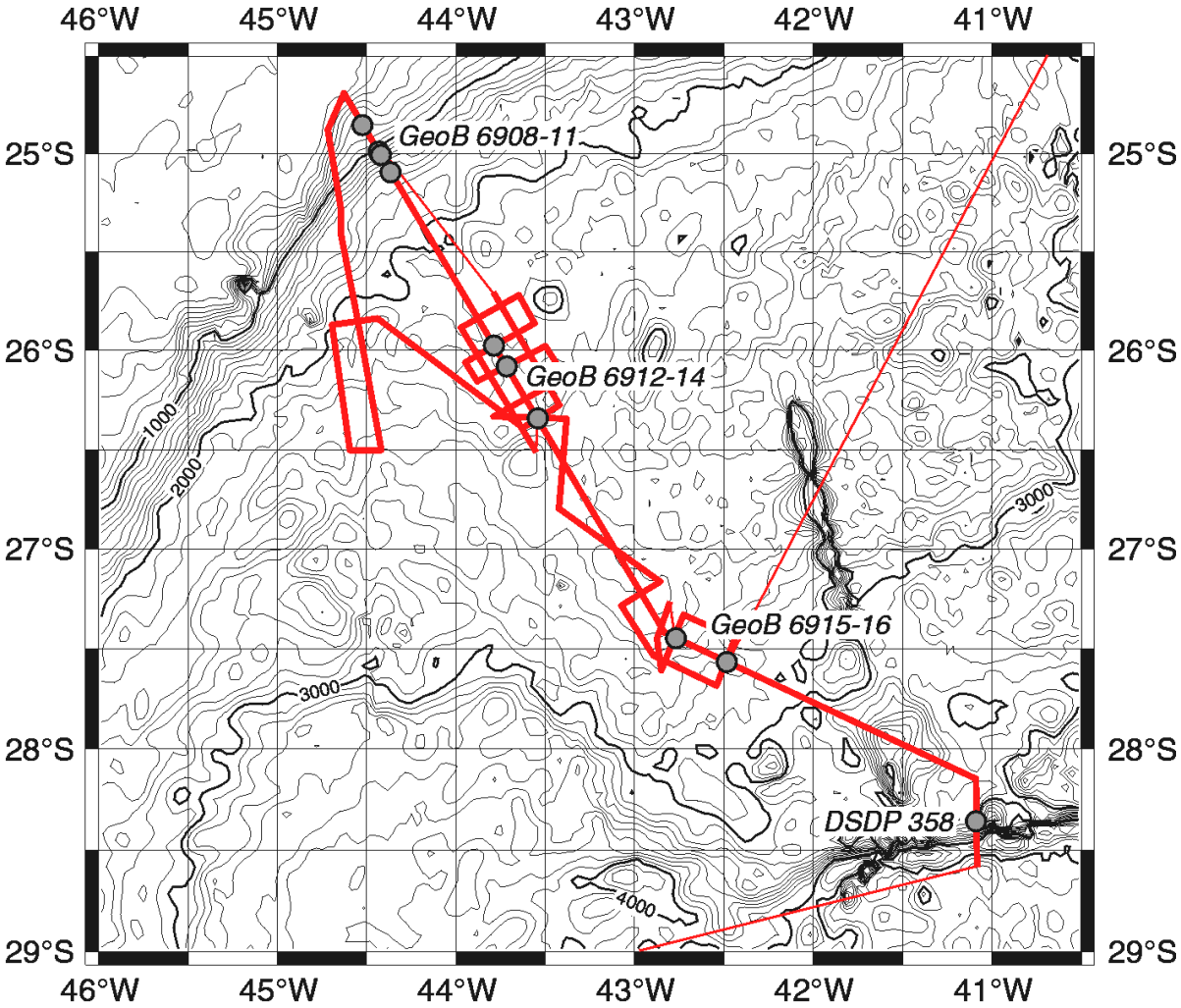

Figure 2 R/V METEOR Cruise M 49/3 track and station chart in the southern working area 'E'. Thick lines denote seismic profiles, thin lines transit routes with *Parasound* and *Hydrosweep*. Bathymetry from Smith & Sandwell, 1997.

On the transit to port the *Parasound*, *Hydrosweep* and *Thermosalinograph* instruments were operational until 10:00 UTC of March 31. As before, recordings of these systems underway to and in between working areas were approved by the official Brazilian observer on board. R/V METEOR safely arrived in Salvador da Bahia in the morning of Sunday April 1, 2001 completing Leg 3 of Cruise M49. Despite rather complicated geological settings encountered at the southern Brazilian continental margin, the overall summary of the expedition is definitely positive.

The scientific party aboard gratefully acknowledges the friendly and most effective cooperation with Captain Martin Kull, his officers and crew. Their as always perfect technical assistance substantially contributed to make this cruise a scientific success. We also appreciate the very valuable support by the Leitstelle METEOR at the University of Hamburg. The work was funded by the Deutsche Forschungsgemeinschaft.

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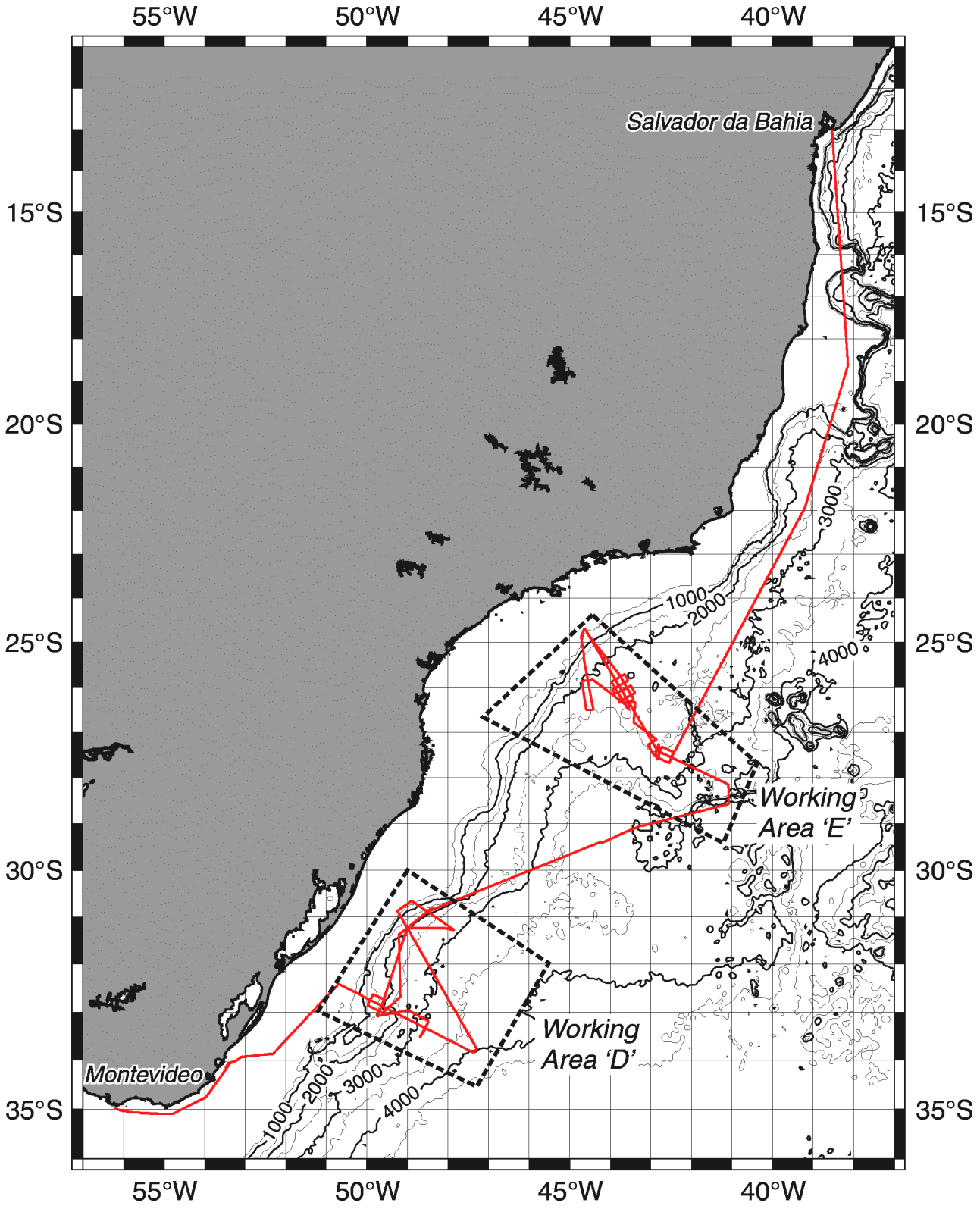

Figure 3 R/V METEOR Cruise M49/3 track chart and working areas. Bathymetry from Smith & Sandwell (1997).

Addendum

In addition to this Short Cruise Report, the following data sets are supplied:

(1) A complete set of DVS (ship's central data distribution system) data, comprising about 100 different measurements (navigation, weather, water attributes etc.) continuously collected en route and recorded every 10 seconds during the entire cruise. These data are stored on CD in ASCII format.

(2) A set of the underway digital bathymetric recordings of the shipboard *Hydrosweep* swath sonar system. These data are also stored on CD in ASCII format.

(3) A set of the underway digital recordings of the shipboard *Parasound* sediment echo-sounder system. This data are originally recorded and stored in special format. A converting program (public domain which can also handle the *Hydrosweep* 'surf' files) is provided together with the data and an explanatory 'read me' file.

(4) A full set of printouts of unprocessed seismic data (brute stack of 3 traces) of all lines recorded (see Table 2).

Results of shore based processing of seismic data as well as analyses of water and sediment samples collected during Cruise M49/3 are provided to the Diretoria de Hidrografia e Navegação, Niterói, as soon as they become available. Note that most of these studies will need several months to years to be completed.