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REPORT AND PRELIMINARY RESULTS OF METEOR CRUISE M 49/3 MONTEVIDEO (URUGUAY) - SALVADOR (BRAZIL), 09.03. - 01.04.2001

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1 Participants

Name	Discipline	Institution
Bleil, Ulrich, Prof. Dr., Chief Scientist	Geophysics	GeoB
Albrecht, Nicole, Student	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/nº, Centro
Niterói, R.J., Brasil

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
Deptartemento de Geologia / Laboratório de Geologia Marinha
Av. Litorânea s/nº, Gragoatá
Niterói 24210-340, R.J., Brasil

2 Research Program

Synopsis

R/V METEOR Cruise M49 combined 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 were 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 concentrated 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 pursued 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 an ODP scientific drilling campaign in this region, for the first time 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 extraordinary heterogeneity 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.*, 1994), M29/1 (*Segl et al.*, 1994), M29/2 (*Bleil et al.*, 1994), M46/2 (*Schulz et al.*, 2001) and M46/3 (*Bleil et al.*, 2001). Of primary interest for the present R/V METEOR Cruise M49/3 are the upper 200 to 600 m of the sediment cover that cannot be explored with sediment echosounding nor sampled by conventional coring techniques. While 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 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 two larger chamber GI airguns (100 - 500 Hz) simultaneously, produces 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 measurements are complemented by high frequency digital recordings with the shipboard *Parasound* sediment echosounder and *Hydrosweep* swath sonar systems. The broad signal frequency spectrum of the seismoacoustic data sets acquired secures an optimum morphologic and structural resolution at all depth levels of the sedimentary formations. Both shipboard echographic systems are permanently operated on a 24 hours watch schedule 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 are later performed in the University of Bremen laboratories.

Working Plan

In the two projected working areas D and E seismic surveys were 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 are processed 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. 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. Wherever structural settings should provide an opportunity, also older deposits rising to near surface will be recovered to date deeper reflectors.

3 Narrative of the Cruise

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 had been lost a couple of 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 were engaged in the survey region for several days. This position was subsequently 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 the launch of the streamer, watergun and two GI airguns, the first reflection seismic line in 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; Fig. 1) began on March 11, 09:48 UTC. The multichannel reflection seismic survey was especially 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.*

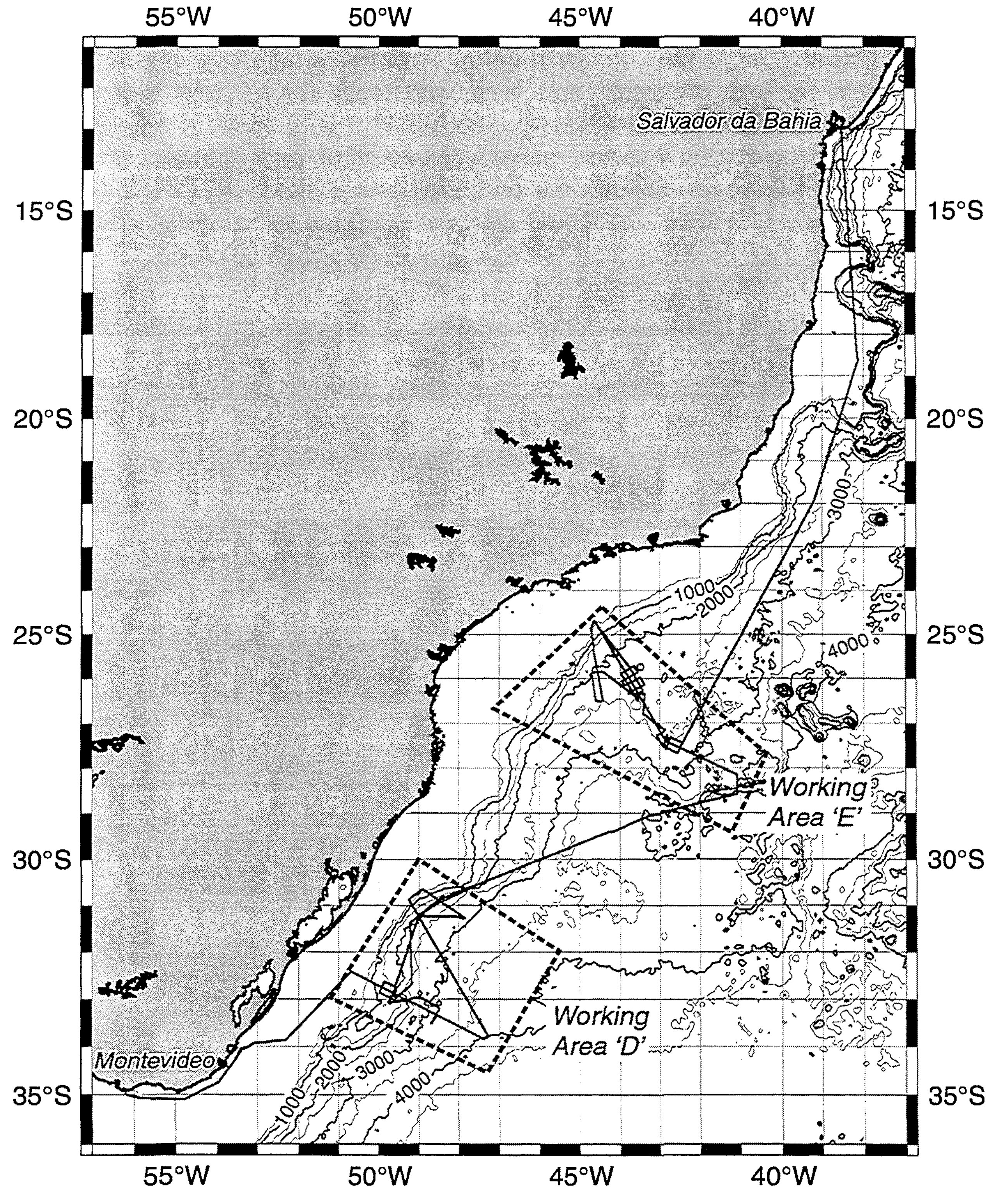


Figure 1 R/V METEOR Cruise M49/3 track chart and working areas. Bathymetry from *Smith & Sandwell* (1997).

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.

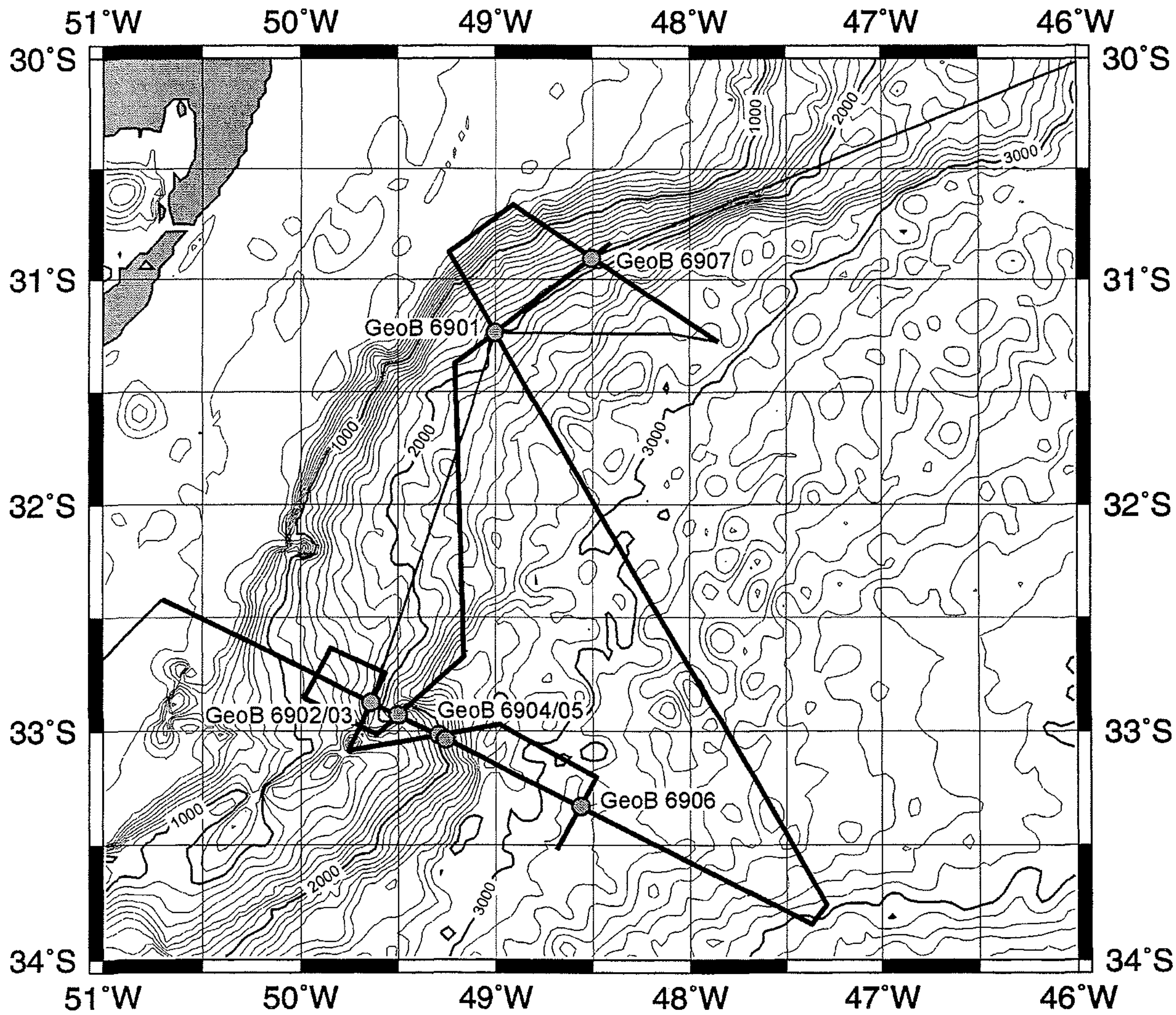


Figure 2 R/V METEOR Cruise M49/3 track and station chart in the southern working area D. Thick lines denote seismic profiles, thin lines transit routes with *Parasound* and *Hydrosweep*. Bathymetry from *Smith & Sandwell* (1997).

Between March 14, 17:50 UTC and March 16, 03:44 UTC the first six geologic stations of this cruise (GeoB 6901 to 6906; Fig. 2) were scheduled. In water depths from about 1700 to 3200 m 6 to 12 m long gravity corers have been successfully employed. 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 complete series of surface sediments were retrieved with the multicorer. Each time also 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 were stored at 4 °C in a cooling container which was 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.

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 were begun 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; Fig. 1). 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, was 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. In such an environment the colleagues from industry could not be too far. At some distance to our courses several commercial seismic prospecting activities were simultaneously in progress. 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 during 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. At least within the penetration depth of our seismic instrumentation, prominent salt diapiric structures seemed much less developed in this region.

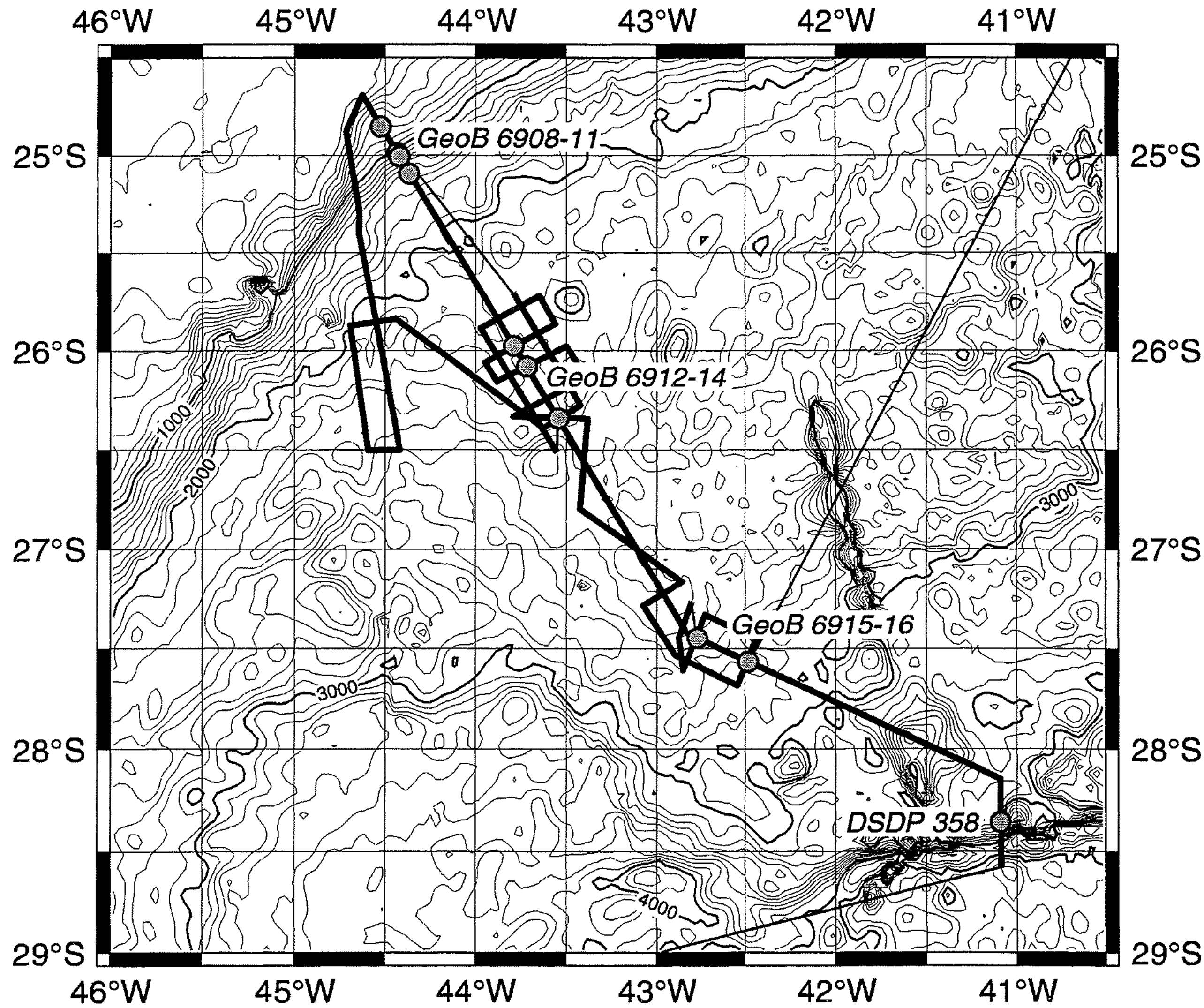


Figure 3 R/V METEOR Cruise M49/3 track and station chart in the northern working area E. Thick lines denote seismic profiles, thin lines transit routes with *Parasound* and *Hydrosweep*. Bathymetry from *Smith & Sandwell* (1997).

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 further CTD casts could be performed due to the 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 onward, 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 commonly 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 therefore, these sites will be no prime choice for ODP drilling operations.

After crossing the salt diapir field on southeasterly courses, the final seismic survey was conducted on and around a location, where we had earlier 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 the multicorer and gravity corer. At its lower flank, where deeper reflectors crop up, only the gravity corer was deployed.

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 in both working areas at the southern Brazilian continental margin, the overall summary of the expedition was definitely positive.

4 Preliminary Results

4.1 Underway Geophysics

(M. Breitzke, N. Albrecht, M. Brüning, S. Krastel, D. Krüger, H. v. Lom-Keil, T. Rudolf, W. Steinborn)

4.1.1 Study Areas

The Argentine, Uruguayan and Southern Brazilian continental margins between Falkland Plateau in the south and Rio Grande Rise in the north lie at the western boundary of the central subtropical gyre. The warm southward flowing water masses of the Brazil Current join the cold northward flowing water masses of the Falkland (Malvinas) Current at about 40°S, where the latter is retroflected and both water masses begin to mix on their way south (*Peterson & Stramma*, 1991). Knowledge about the paleoceanographic evolution of this region and about the sedimentation processes and sedimentary structures at the continental margins of the southwestern South Atlantic is sparse and not well resolved, particularly for the Neogene sedimentation history (e.g., *Hinz et al.*, 1999). Up to now, *Ocean Drilling Program* (ODP) drill holes applying modern APC coring techniques to recover high quality cores for paleoceanographic reconstructions are located in the eastern South Atlantic (Legs 108, 159, 175), in the Southern Ocean (Legs 113, 114, 177) and in the western equatorial Atlantic (Legs 154, 155), but are still lacking on the Argentine, Uruguayan and Brazilian continental margins in the southwestern South Atlantic. Only a few older *Deep Sea Drilling Project* (DSDP) sites exist here on the Falkland Plateau (Sites 328, 511, 512), in the Argentine and Brazil Basins (Sites 331, 358, 515), on the Rio Grande Rise (Sites 516, 517, 518) and on the São Paulo Ridge (Site 356) more less far away from the region, where western boundary currents dominate and affect composition and structures of the sediments.

R/V METEOR Cruise M49/3 together with the preceding Cruise M49/2 was dedicated to a pre-site survey for ODP Proposal 556 '*Brazil - Falkland (Malvinas) Confluence: Paleoceanography of a Mixing Region*' (*Wefer et al.*, 1999). Both cruises had the primary goal to collect high-resolution multichannel seismic, sediment echosounder and bathymetric swath sounder data from a total of five study areas A to E proposed as potential drilling targets for a reconstruction of the Neogene paleoceanographic history of the Brazil - Falkland (Malvinas) convergence.

The three southern areas A, B and C are located off southern, central and northern Argentina and Uruguay at about 44°S, 41°S and 39 - 34°S. They were surveyed during the preceding R/V METEOR Cruise M49/2 (*Spieß et al.*, in prep.). The two northern two areas D and E at 34 - 31°S and 29 - 25°S off southern and central Brazil were studied during R/V METEOR Cruise M49/3.

In contrast to the Argentine and Uruguayan continental slopes, which are steep, dissected by deeply incised channels and canyons and shaped by strong erosive currents (cf. R/V METEOR Cruises M29/1 (*Segl et al.*, 1994) and M49/2 (*Spieß et al.*, in prep.), the continental slopes of southern and central Brazil descend more gently and are not as furrowed and locally eroded as further south. Massive downslope transport processes occur less frequently and an interruption of stratigraphic sequences by slide, slump, debris flow and turbidite deposits or by erosional hiatuses is expected to be less important.

Area D is mainly located on the Rio Grande Cone, where a large amount of sediment has accumulated since Late Eocene times due to anomalous high sedimentation rates (*Bassetto et al.*, 2000) with important input of terrigenous material from the Rio de la Plata.

The northernmost area E is located off central Brazil on the São Paulo Plateau, a morphologic feature underlain by an extended salt diapir field. It developed during the early Aptian - Albian rift phase of the South Atlantic and forms the conjugate to the well-known Angola diapir field off Africa. Its southern boundary lies at about 28°S. Former seismic studies around DSDP Sites 515 - 518 on the adjacent Rio Grande Rise and in the Brazil Basin suggest that current control might also be expected for the depositional patterns on the São Paulo Plateau. Four major unconformities were identified in the vicinity of DSDP Site 515 in the Brazil Basin and associated with a change in global circulation pattern. Moreover, fine-scale wavy sedimentary structures and hyperbolae of different length in the sediment sequences indicate bottom current controlled sediment deposition (*Gamboa et al.*, 1983).

4.1.2 *Parasound, Hydrosweep* and Navigation

The *Parasound* system operates both as a low-frequency narrow-beam sediment echosounder and as high-frequency echosounder to determine the water depth. It makes use of the parametric effect which produces waves with secondary frequencies through nonlinear acoustic interaction of finite amplitude waves. If two sound waves of similar frequencies (here, 18 kHz and, e.g., 22 kHz) are emitted simultaneously, a signal of the difference frequency (in this case 4 kHz) is generated for sufficiently high primary amplitudes. The new component is traveling within the emission cone of the original high frequency waves which is limited to an angle of only 4° for the equipment used. Therefore, the footprint size of 7 % of the water depth is much smaller than for conventional 3.5 kHz systems and both vertical and lateral resolution are significantly improved.

The *Parasound* system is permanently installed on the ship. The hull-mounted transducer array has 128 elements over an area of approximately 1 m^2. It requires up to 70 kW of electric power due to the low degree of efficiency of the parametric effect. In 2 electronic cabinets, beam forming, signal generation and separation of primary and secondary frequencies is controlled. With the third electronic cabinet in the echosounder control room, the system is operated on a 24 hour watch schedule.

Since the two-way traveltime in the deep sea is long compared to the length of the reception window of up to 266 ms, the *Parasound* system sends out a burst of pulses at 400 ms intervals until the first echo returns. The coverage of this discontinuous mode depends on the water depth and produces unequal shot distances between bursts. On average, one seismogram is recorded per second providing a spatial resolution on the order of a few meters on seismic profiles at 6.0 - 6.5 knots.

The main tasks of the operators are system and quality control as well as adjustment of the reception window. Because of the limited penetration of the echosounder signal into the sediment, only a short window close to the sea floor is recorded.

The *Parasound* device is equipped with the digital data acquisition system *ParaDigma* which was developed at the University of Bremen (*Spieß,* 1993). The data are stored on two exchangeable disc drives of 4 GByte capacity allowing continuous recording between 5 and 10 days depending on water depth and shot rate. A *Pentium* processor based PC accomplishes buffering, transfer and storage of the digital seismograms at high repetition rates. From the emitted series of pulses usually every second pulse is digitized and stored, resulting in recording intervals of 800 ms within a pulse sequence. The seismograms were sampled at a frequency of 40 kHz with typical registration lengths of 266 ms for a depth window of about 200 m. The source signal was a band limited, 2 - 6 kHz sinusoidal wavelet of 4 kHz dominant frequency with 2 periods duration (~ 500 μs total length).

Already during data acquisition an online processing was carried out and *Parasound* sections were plotted with a vertical scale of several hundred meters for all profiles thereby limiting the number of changes in window depth. From these plots first insight to variations of sea floor morphology, sediment coverage and sedimentation patterns along the ship's track was achieved. To improve the signal-to-noise ratio, the echogram sections were filtered with a wide band pass filter. In addition, the data were normalized to a constant amplitude considerably below the average maximum amplitude to amplify especially deeper and weaker reflections. During the entire cruise, the combined *Parasound* / *ParaDigMa* systems were operated without major problems. Data storage with exchangeable hard discs worked reliably and avoided previous frequent alert situations due to errors of the magnetic tape recording.

Digital *Parasound* data displayed in Chapters 4.1.5 and 4.1.6 were bandpass filtered between 2 and 6 kHz and adapted to an 8 grade gray scale after application of a routine which suppresses the negative flanks of the envelopes of the wiggle traces. To achieve a maximum penetration of 20 - 60 m, the traces were normalized to a common constant amplitude. In all recordings the two-way traveltime is converted to a *Parasound* depth with a wave velocity of 1500 m/s.

The multibeam echosounder *Hydrosweep* on R/V METEOR was routinely employed during the cruise and serviced by the *Parasound* operators during a 24-hour watch. Sounding 59 preformed beams over an opening angle of 90 degrees, the hull-mounted system provides an image of the sea floor topography with a path width of twice the water depth perpendicular to the ship's track. It operates at a frequency of 15.5 kHz and uses a calibration mode to compress refraction effects on the outer beams by calculating a best fit mean sound velocity from central and outer beam depths intermittently measured in course direction. This procedure minimizes residual errors to less than 0.5 % of the water depth (*Grant & Schreiber,* 1990).

During the entire cruise GPS and DGPS were available and provided high quality navigational data.

4.1.3 High-Resolution Multichannel Reflection Seismics

4.1.3.1 Methods and Instruments

Reflection seismic surveys were carried out in both study areas D and E with the Bremen high-resolution multichannel equipment specifically designed to acquire high-resolution seismic data through optimizing all system components and procedural parameters. Figure 4 gives an outline of the setup used during R/V METEOR Cruise M49/3 allowing to image small-scale sedimentary structures and closely spaced layers on a meter to sub-meter scale which are usually not resolved with conventional seismic techniques.

The alternating operation of a small-chamber watergun (0.16 l; 200 - 1600 Hz), a GI-Gun with reduced chamber volume (2 x 0.41 l; 100 - 500 Hz) and a GI-Gun with normal chamber volume (2 x 1.7 l; 30 - 200 Hz) simultaneously yields three seismic data sets. Guns with larger chamber volume attain greater penetration into the sea floor delineating the larger scale structural framework, whereas guns with smaller volume are of higher resolution, revealing finer details of

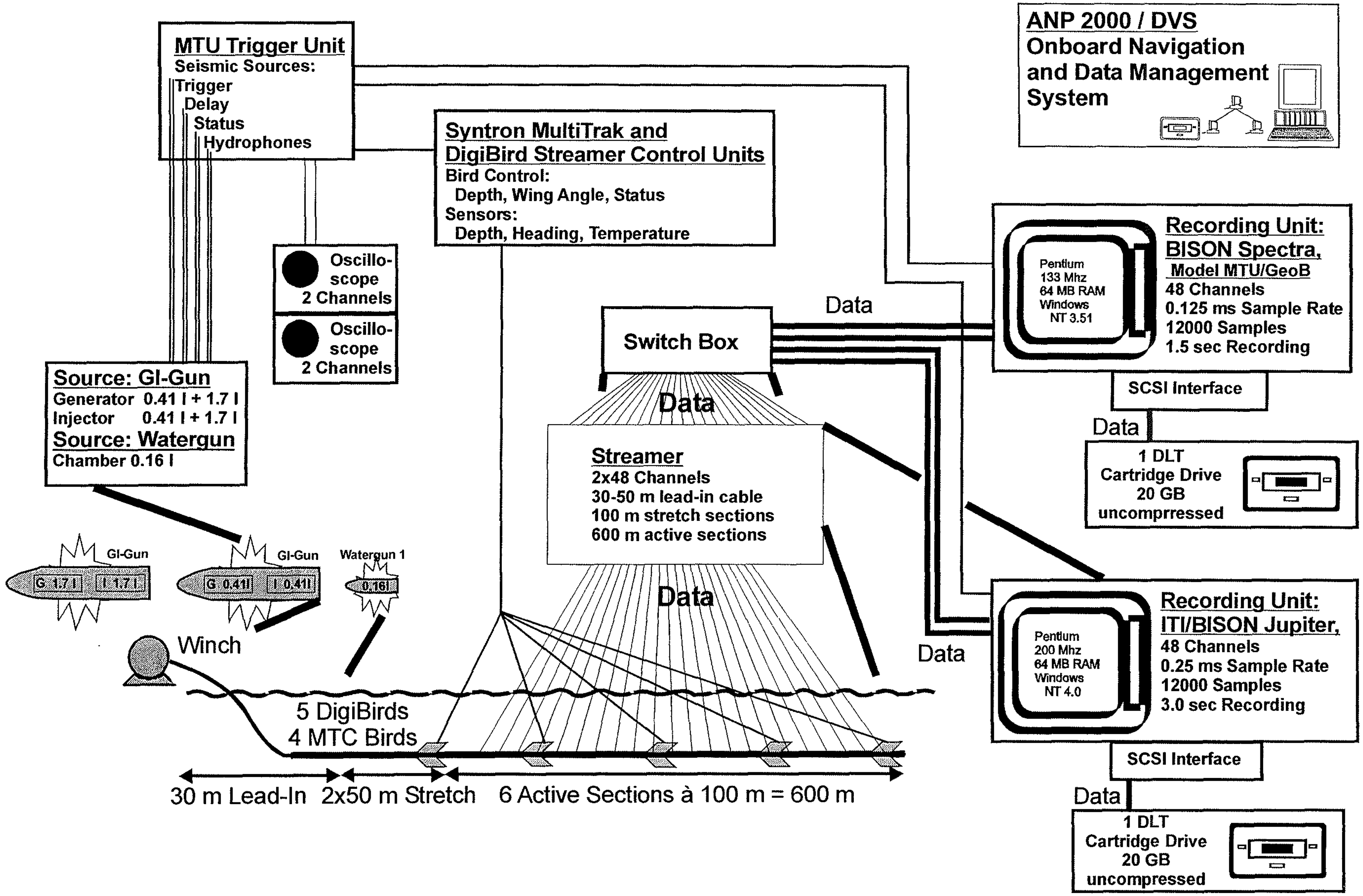


Figure 4 Multichannel seismic instrumentation used during R/V METEOR Cruise M49/3.

the upper 200 - 300 m of the sediment cover beyond the penetration of the *Parasound* sediment echosounder (10 - 60 m).

All multichannel seismic profiling activities are accompanied by a continuous operation of two hydroacoustic systems (*Parasound* sediment echosounder and *Hydrosweep* swath sounder) to determine the sea floor morphology, to characterize and analyze sediment depositional processes and structures in the uppermost 10 - 60 m and to provide detailed high-resolution information for site selection of gravity coring. Both hydroacoustic data sets were acquired digitally.

At selected locations the sediment column was sampled with a gravity corer (cf. Chapter 4.2) for two purposes: (1) In areas, where Cenozoic sediment sequences pinch out, the prime objective was to achieve stratigraphic and age information on such deeper layers. This strategy was followed in working area D. (2) At intersections of cross profiles the uppermost 5 - 10 m of the sediment column were sampled for detailed shore based analyses of the deposits. This strategy was followed in both areas D and E, where potential drilling targets could provisionally be defined on the basis of seismic online records and brute stacks of the multichannel seismic data produced by onboard processing.

4.1.3.2 Seismic Sources and Compressor

During seismic surveying three different seismic sources, two GI-Guns and one watergun, were triggered in an alternating mode at time intervals between 9 and 11.5 s (cf. Chapter 4.1.3.6). With an average ship speed of 6.0 - 6.5 kn, a shot distance of approximately 30 to 38 m was thus obtained for the alternating mode operation, corresponding to a shot point distance of 60 - 76 m for the individual GI-Gun and 30 - 38 m for the watergun. Each source type was shot more than 65'000 times at an air pressure of about 150 bar.

The geometry of source and receiver systems is shown in Figure 5. Ship velocity during deployment and retrieval was between 2.5 and 3.5 kn, respectively, depending on weather conditions and surface currents.

The standard GI-Gun (Generator-Injector Gun; *Sodera*) with normal chamber volume (2 x 1.7 l) was towed by a wire which was separate from the Meteor rope holding the umbilical of the gun about 17 m behind the ship's stern and 7 - 8 m portside of the streamer and the ship's axis. The towing wire was connected to a bow with the GI-Gun hanging on two chains 0.4 m beneath. An elongated buoy, which stabilized the gun in a horizontal position at a water depth of about 1.2 m, was connected to the bow by two rope loops. The injector was triggered with a delay of 50 ms with respect to the generator signal essentially eliminating a bubble signal.

The second GI-Gun with reduced chamber volumes (2 x 0.41 l) was towed by the wire of the starboard side crane, set off perpendicular to the ship's axis. Distance to the ship's stern was about 13 m, starboard distance to the streamer about 14 - 15 m. The towing wire was again connected to a bow with the GI-Gun hanging on two chains 0.4 m beneath. An elongated buoy, which stabilized the gun in a horizontal position at a water depth of about 1.2 m, was connected to the bow by two rope loops as well. The injector was triggered with a delay of 30 ms with respect to the generator signal which basically eliminated the bubble signal.

The third source was a S15 watergun (*Sodera*) with 0.16 l volume towed by a wire which ran over a roll at starboard side and was separated from the Meteor rope holding the umbilical of the gun about 15 m behind the ship's stern and about 4 - 5 m starboard side of the streamer and ship's

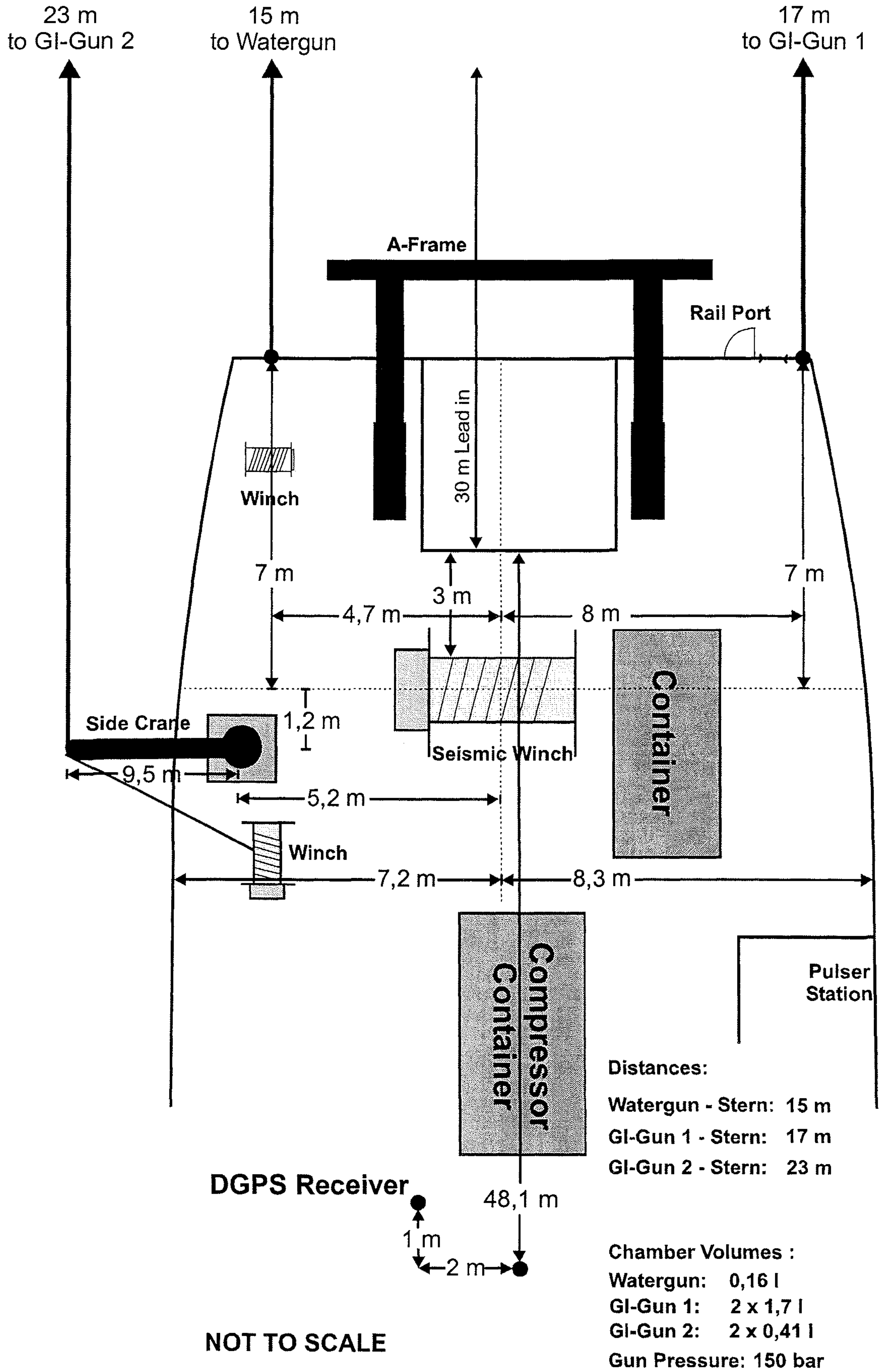


Figure 5 Seismic working deck setting during R/V METEOR Cruise M49/3.

axis. A steel frame held the watergun in a tight position parallel to the elongated buoy at a depth of approximately 0.6 m.

High-pressure air of 150 bar for gun operation was provided by a *LMF* compressor set up in an oversized container on the working deck and maintained by the ship's engineers. Only minor technical problems occurred. Thanks to the improved noise damping, which was mainly achieved by re-routing the surplus air (about 90 % of the total air production operating our small volume guns) into the water by a hose close to the pulser station at portside, the noise level could significantly be reduced compared to our first experience with this new compressor system during R/V METEOR Cruise M46/3 (*Bleil et al.*, 2001).

4.1.3.3 Streamer

The multichannel seismic streamer (*Syntron*) includes a tow-lead, two stretch sections of 50 m and six active sections of 100 m length each. A 100 m long Meteor rope with a buoy at the end was attached to the tail swivel. A 30 m long deck cable connected the streamer to the recording system. The winch position on the working deck is shown in Figure 5. During operations, the streamer was fixed with two Meteor ropes, the tow-lead laid out about 30 - 33 m.

Active sections are subdivided into 16 hydrophone groups of 6.25 m length (Fig. 6), each of them subdivided into 5 subgroups of different length. One subgroup is a high-resolution hydrophone with a preamplifier. A programming module distributes the subgroups of 4 hydrophone groups, i.e. a total of 20 groups, to 5 channels. As illustrated in Figure 6, every second 6.25 m hydrophone subgroup was completely used with all 13 hydrophones, whereas the two additional channels were reduced in length and number of hydrophones to 2.45 m (6 hydrophones) and 3.35 m (9 hydrophones), respectively. Midpoint locations of individual hydrophone groups are listed in Table 1.

Table 1 Channel assignments and midpoint distances of hydrophone groups in each active section.

Segments of 25 m Length	Hydrophone Group No.	Channel No. in Section	Midpoint Distance [m]
A (0-25 m)	1	1	3.1
A	2	3	11.3
A	3	2	15.6
A	4	4	23.3
B (25-50 m)	1	5	28.1
B	2	7	36.3
B	3	6	40.6
B	4	8	48.3
C (50-75 m)	1	9	53.1
C	2	11	61.3
C	3	10	65.6
C	4	12	73.3
D (75-100 m)	1	13	78.1
D	2	15	86.3
D	3	14	90.6
D	4	16	98.3

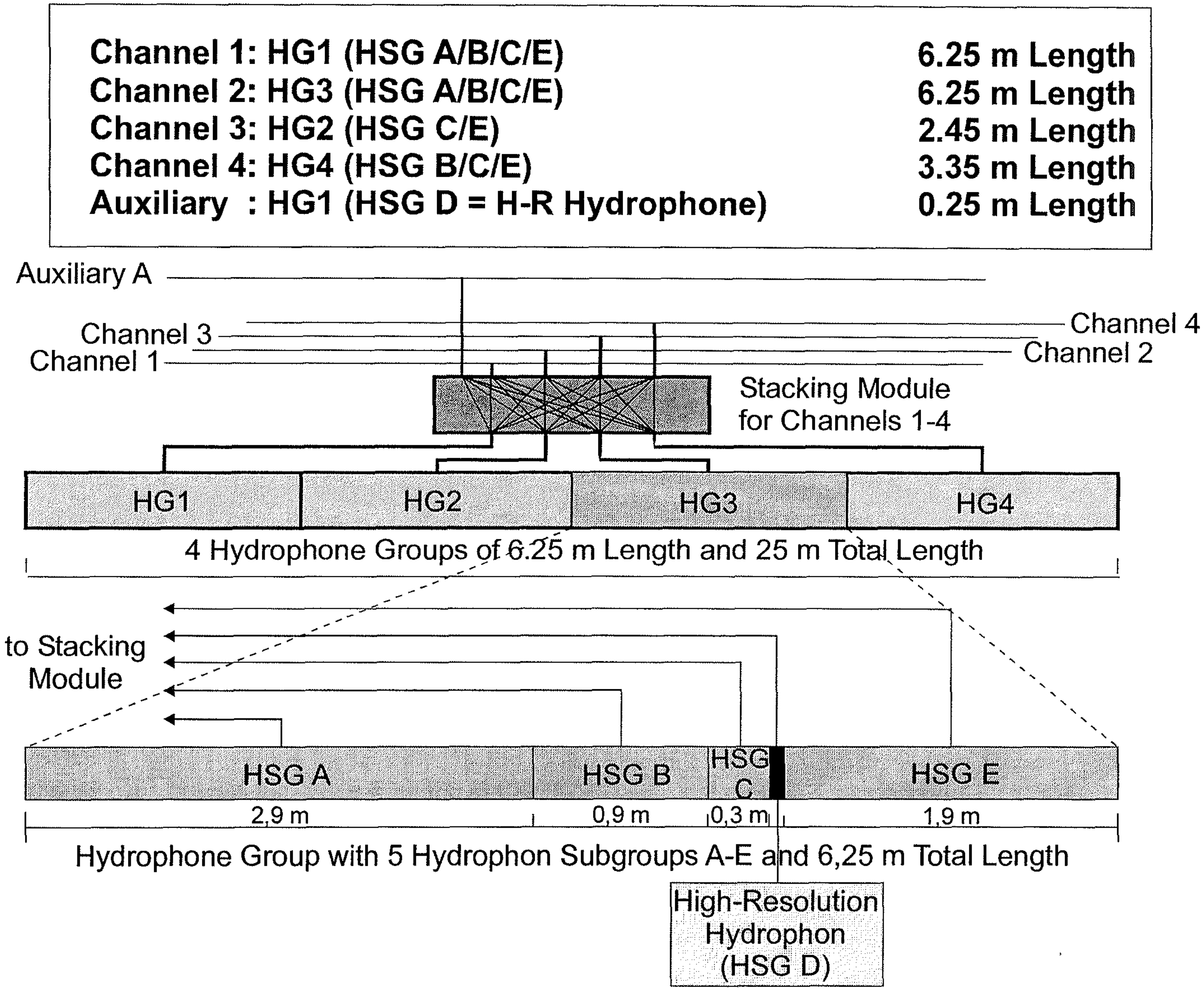


Figure 6 Multichannel streamer design used during R/V METEOR Cruise M49/3.

Table 2a Streamer channels 1 to 48 assignment to output channels for *Jupiter* recording system (GI-Gun).

Input Channel	Output Channel	Hydrophone Group	Number of Hydrophones per Group	Hydrophone Group Length [m]	Hydrophone Group Distance [m]
1	1	HG1	13	6.25	12.5
2	2	HG3	13	6.25	12.5
5	3	HG1	13	6.25	12.5
6	4	HG3	13	6.25	12.5
9	5	HG1	13	6.25	12.5
10	6	HG3	13	6.25	12.5
13	7	HG1	13	6.25	12.5
14	8	HG3	13	6.25	12.5
17	9	HG1	13	6.25	12.5
18	10	HG3	13	6.25	12.5
21	11	HG1	13	6.25	12.5
22	12	HG3	13	6.25	12.5
25	13	HG1	13	6.25	12.5
26	14	HG3	13	6.25	12.5
29	15	HG1	13	6.25	12.5
30	16	HG3	13	6.25	12.5
33	17	HG1	13	6.25	12.5
34	18	HG3	13	6.25	12.5
37	19	HG1	13	6.25	12.5
38	20	HG3	13	6.25	12.5
41	21	HG1	13	6.25	12.5
42	22	HG3	13	6.25	12.5
45	23	HG1	13	6.25	12.5
46	24	HG3	13	6.25	12.5
49	25	HG1	13	6.25	12.5
50	26	HG3	13	6.25	12.5
53	27	HG1	13	6.25	12.5
54	28	HG3	13	6.25	12.5
57	29	HG1	13	6.25	12.5
58	30	HG3	13	6.25	12.5
61	31	HG1	13	6.25	12.5
62	32	HG3	13	6.25	12.5
65	33	HG1	13	6.25	12.5
66	34	HG3	13	6.25	12.5
69	35	HG1	13	6.25	12.5
70	36	HG3	13	6.25	12.5
73	37	HG1	13	6.25	12.5
74	38	HG3	13	6.25	12.5
77	39	HG1	13	6.25	12.5
78	40	HG3	13	6.25	12.5
81	41	HG1	13	6.25	12.5
82	42	HG3	13	6.25	12.5
85	43	HG1	13	6.25	12.5
86	44	HG3	13	6.25	12.5
89	45	HG1	13	6.25	12.5
90	46	HG3	13	6.25	12.5
93	47	HG1	13	6.25	12.5
94	48	HG3	13	6.25	12.5

Table 2b Streamer channels 49 to 96 assignment to output channels for *Spectra* recording system (watergun).

Input Channel	Output Channel	Hydrophone Group	Number of Hydrophones per Group	Hydrophone Group Length [m]	Hydrophone Group Distance [m]
3	49	HG2	6	2.45	12
4	50	HG4	9	3.35	13
7	51	HG2	6	2.45	12
8	52	HG4	9	3.35	13
11	53	HG2	6	2.45	12
12	54	HG4	9	3.35	13
15	55	HG2	6	2.45	12
16	56	HG4	9	3.35	13
19	57	HG2	6	2.45	12
20	58	HG4	9	3.35	13
23	59	HG2	6	2.45	12
24	60	HG4	9	3.35	13
27	61	HG2	6	2.45	12
28	62	HG4	9	3.35	13
31	63	HG2	6	2.45	12
32	64	HG4	9	3.35	13
35	65	HG2	6	2.45	12
36	66	HG4	9	3.35	13
39	67	HG2	6	2.45	12
40	68	HG4	9	3.35	13
43	69	HG2	6	2.45	12
44	70	HG4	9	3.35	13
47	71	HG2	6	2.45	12
48	72	HG4	9	3.35	13
51	73	HG2	6	2.45	12
52	74	HG4	9	3.35	13
55	75	HG2	6	2.45	12
56	76	HG4	9	3.35	13
59	77	HG2	6	2.45	12
60	78	HG4	9	3.35	13
63	79	HG2	6	2.45	12
64	80	HG4	9	3.35	13
67	81	HG2	6	2.45	12
68	82	HG4	9	3.35	13
71	83	HG2	6	2.45	12
72	84	HG4	9	3.35	13
75	85	HG2	6	2.45	12
76	86	HG4	9	3.35	13
79	87	HG2	6	2.45	12
80	88	HG4	9	3.35	13
83	89	HG2	6	2.45	12
84	90	HG4	9	3.35	13
87	91	HG2	6	2.45	12
88	92	HG4	9	3.35	13
91	93	HG2	6	2.45	12
92	94	HG4	9	3.35	13
95	95	HG2	6	2.45	12
96	96	HG4	9	3.35	13

A switch box connects the streamer via the deck cable with the seismograph and allows the assignment and optional stacking of streamer hydrophone subgroups to individual recording channels. The incoming 120 channels (96 hydrophone groups and 24 single hydrophones) were distributed to the output channels of the recording systems with the same scheme during the entire cruise. Output channels 1 to 48 were connected to a *Jupiter* recording system (alternating mode of small volume and large volume GI-Guns; Table 2a), channels 49 to 96 to a *Spectra* recording system (watergun; Table 2b). Single hydrophones (streamer channels 97 to 120) were not recorded. Deployment and retrieval lasted about 45 minutes including installation of the ten Remote Bird Units (RUs, see below).

4.1.3.4 *MultiTrak* and *DigiBird* Controllers

Five *MultiTrak* and 5 *DigiBird* Remote Units (RUs) have been attached to the streamer. Each RU includes a depth and a heading sensor as well as adjustable wings. The RUs were controlled by two separate controllers in the seismic lab, the *MultiTrak* and the *DigiBird* controller. Controllers and RUs communicate via a series of coils nested within the streamer. A twisted wire pair within the deck cable connects controllers and coils.

Each shot trigger started a bird scan of depth in water, wing angle and heading data (delay 0.0 s, duration 1.0 s). The current location of the streamer can be displayed as depth or heading profile on a monitor. All parameters are digitally stored on the controller PC together with shot number, date and time. There are two ways of controlling the streamer depth. Most common is to send an operating depth range to the RUs (3 m during R/V METEOR Cruise M49/3). The RUs try to force the streamer to the predefined depth by adjusting the wing angles accordingly. Another option is to set a predefined wing angle or depth before deployment. This is useful if communication problems with the RUs arise and was partially applied during this cruise. Depth and wing angle statistics helped to set appropriate parameters.

Table 3a RU positions along the seismic streamer for lines GeoB 01-159 to GeoB 01-163.

RU No.	Type	Position	Distance to Tow-Lead [m]
-	-	End of Stretch Section No.1	48
3	*MultiTrak*	End of Stretch Section No. 2	98
11	*DigiBird*	Mid of Active Section No. 1	145
4	*MultiTrak*	End of Active Section No. 1	189
-	-	Mid of Active Section No. 2	245
13	*DigiBird*	End of Active Section No. 2	289
-	-	Mid of Active Section No. 3	345
6	*MultiTrak*	End of Active Section No. 3	389
-	-	Mid of Active Section No. 4	445
12	*DigiBird*	End of Active Section No. 4	489
5	*MultiTrak*	Mid of Active Section No. 5	545
14	*DigiBird*	End of Active Section No. 5	589
2	*MultiTrak*[1]	Mid of Active Section No. 6	645
15	*DigiBird*	End of Active Section No. 6	689

[1] RU No. 2 with defect compass

Table 3b RU positions along the seismic streamer for lines GeoB 01-164 to GeoB 01-173.

RU No.	Type	Position	Distance to Tow-Lead [m]
-	-	End of Stretch Section No.1	48
3	*MultiTrak*	End of Stretch Section No. 2	98
11	*DigiBird*	Mid of Active Section No. 1	145
4	*MultiTrak*	End of Active Section No. 1	189
-	-	Mid of Active Section No. 2	245
13	*DigiBird*	End of Active Section No. 2	289
-	-	Mid of Active Section No. 3	345
6	*MultiTrak*	End of Active Section No. 3	389
-	-	Mid of Active Section No. 4	445
12	*DigiBird*	End of Active Section No. 4	489
5	*MultiTrak*	Mid of Active Section No. 5	545
14	*DigiBird*	End of Active Section No. 5	589
-	-	Mid of Active Section No. 6	645
15	*DigiBird*	End of Active Section No. 6	689

Table 3c RU positions along the seismic streamer for lines GeoB 01-174 to GeoB 01-175, Part1.

RU No.	Type	Position	Distance to Tow-Lead [m]
-	-	End of Stretch Section No.1	48
11	*DigiBird*	End of Stretch Section No. 2	98
3	*MultiTrak*	Mid of Active Section No. 1	145
-	-	End of Active Section No. 1	189
13	*DigiBird*	Mid of Active Section No. 2	245
4	*MultiTrak*	End of Active Section No. 2	289
-	-	Mid of Active Section No. 3	345
12	*DigiBird*	End of Active Section No. 3	389
-	-	Mid of Active Section No. 4	445
6	*MultiTrak*	End of Active Section No. 4	489
14	*DigiBird*	Mid of Active Section No. 5	545
5	*MultiTrak*	End of Active Section No. 5	589
-	-	Mid of Active Section No. 6	645
15	*DigiBird*	End of Active Section No. 6	689

Table 3d RU positions along the seismic streamer for lines GeoB 01-175, Part2 to GeoB 01-184.

RU No.	Type	Position	Distance to Tow-Lead [m]
-	-	End of Stretch Section No.1	48
3	*MultiTrak*	End of Stretch Section No. 2	98
11	*DigiBird*	Mid of Active Section No. 1	145
-	-	End of Active Section No. 1	189
13	*DigiBird*	Mid of Active Section No. 2	245
4	*MultiTrak*	End of Active Section No. 2	289
-	-	Mid of Active Section No. 3	345
12	*DigiBird*	End of Active Section No. 3	389
-	-	Mid of Active Section No. 4	445
6	*MultiTrak*	End of Active Section No. 4	489
14	*DigiBird*	Mid of Active Section No. 5	545
5	*MultiTrak*	End of Active Section No. 5	589
-	-	Mid of Active Section No. 6	645
15	*DigiBird*	End of Active Section No. 6	689

Table 3e RU positions along the seismic streamer for lines GeoB 01-185 to GeoB 01-203.

RU No.	Type	Position	Distance to Tow-Lead [m]
3	*MultiTrak*	End of Stretch Section No.1	48
-	-	Stretch Section No. 2 removed	-
11	*DigiBird*	Mid of Active Section No. 1	95
-	-	End of Active Section No. 1	139
13	*DigiBird*	Mid of Active Section No. 2	195
4	*MultiTrak*	End of Active Section No. 2	239
-	-	Mid of Active Section No. 3	295
12	*DigiBird*	End of Active Section No. 3	339
-	-	Mid of Active Section No. 4	395
6	*MultiTrak*	End of Active Section No. 4	439
14	*DigiBird*	Mid of Active Section No. 5	495
5	*MultiTrak*	End of Active Section No. 5	539
-	-	Mid of Active Section No. 6	595
15	*DigiBird*	End of Active Section No. 6	639

Due to shark bites in the streamer during the preceding R/V METEOR Cruise M49/1 (*Spieß et al.*, in prep.) communication problems between the controllers in the seismic lab and the birds attached to the streamer occurred and increasingly more depth and heading data were lost. These problems could partially be solved by an appropriate re-positioning of the RUs along the streamer. Tables 3a to 3e summarize the distribution of RUs on the different seismic profiles of R/V METEOR Cruise M49/3. Possible depth variations of the streamer could be checked later during preliminary data processing and despite of the communication problems depth control appeared to be successful. In addition, the position of the tail buoy was frequently checked from the bridge to provide information about the heading of the streamer. In general, no sideward drift was observed. After finishing line GeoB 01-184 stretch section No. 2 was removed from the streamer, because we assumed broken or corroded cables inside which possibly impaired signal quality. Thereafter, the tow lead was paid out 45 - 48 m so that the distance of the remote units to the tow lead changed (Table 3e).

4.1.3.5 Data Acquisition System

Two systems were used to record the multichannel seismic data, one for the GI-Guns, a second for the watergun.

The first system is a 48 channel *Jupiter/ITI/Bison* seismograph, which allows for a maximum sample frequency of 4 kHz at 24 bit resolution. It is based on a *Pentium* PC (200 MHz; 64 MB RAM) operating under *Windows NT 4.0*. The seismograph performs online data display (shot gather), online demultiplexing and storage in *SEG-Y* format on a *DLT 4000* cartridge tape with 20 GByte uncompressed capacity. The GI-Gun data were recorded at a sample frequency of 4 kHz over an interval of 3 s resulting in 48 x 12000 samples of 4 bytes per shot. Preamplifiers were set to 48 dB, low cut filters to 4 Hz for each channel.

The second system, a 48 channel seismograph (*Bison Spectra*), was specially designed for the University of Bremen. It allows a continuous operation mode to acquire very high resolution seismic data with a sample rate of up to 20 kHz. The seismograph (*Pentium* PC; 133 MHz; 64 MB RAM) is a predecessor of the *Jupiter* system, runs under *Windows NT 3.51* and comprises basically the same features. It also provides online data display (shot gather), online demultiplexing and storage in *SEG-Y* format on *DLT 4000* cartridge tapes of 20 GByte uncompressed capacity. Sample frequency was 8 kHz for the watergun data and record length 1.5 s resulting again in 48 x 12'000 samples of 4 bytes per shot. Preamplifiers were set to 60 dB to ensure an optimum voltage range for digitzing the incoming signals. Analog low- and high-cut filters were set to 16 and 2000 Hz, respectively. On both systems the recording delay was controlled and adjusted to the actual water depth by the trigger unit.

4.1.3.6 Trigger Unit

The custom-built trigger unit controls seismic sources, seismographs, remote unit (bird) controllers, online plotter with separate filter and a digital scope (near-field hydrophones). The unit is set up on an *IBM* compatible PC operating under *Windows NT 4.0* and includes a real-time controller interface card (*Sorcus*) with 16 I/O channels synchronized by an internal clock. The system is connected to an amplifier unit and a gun amplifier unit. The PC runs under custom soft

Table 4 Trigger scheme for GI-Guns, watergun, GI-Guns and watergun recording systems, *MultiTrak* and *DigiBird* (RU) controllers and *EPC* online recorder used during R/V METEOR Cruise M49/3.

Water Depth [m]	TWT [ms]	Delay [ms]	Shot Time Watergun [ms]	Shot Time GI-Gun [ms]	Recording Time Watergun [ms]	Recording Time GI-Gun (*Spectra*) [ms]	*DigiBird* Controller [ms]	*MultiTrak* Controller [ms]	*EPC* Online Recorder [ms]	Total Trigger Period [ms]
0	0	0	0	1500	0 - 1500	1500 - 4500	5000	5500	0	9000
375	500	500	0	2000	500 - 2000	2500 - 5500	6000	6500	2500	9000
750	1000	1000	0	2500	1000 - 2500	3500 - 6500	7000	7500	3000	9000
1125	1500	1500	0	3000	1500 - 3000	4500 - 7500	3300	0	4500	9000
1500	2000	2000	0	3500	2000 - 3500	5500 - 8500	0	500	5000	9000
1875	2500	2500	0	4000	2500 - 4000	6500 - 9500	0	500	6500	9500
2250	3000	3000	0	1500	3000 - 4500	4500 - 7500	0	500	4000	9000
2625	3500	3500	0	1500	3500 - 5000	5000 - 8000	0	500	5000	9000
3000	4000	4000	0	1500	4000 - 5500	5500 - 8500	0	500	5000	9000
3375	4500	4500	0	1500	4500 - 6000	6000 - 9000	0	500	6000	9000
3750	5000	5000	0	1500	5000 - 6500	6500 - 9500	0	500	6000	9500
4125	5500	5500	0	1500	5500 - 7000	7000 - 10000	0	500	7000	10000
4500	6000	6000	0	1500	6000 - 7500	7500 - 10500	0	500	7000	10500
4875	6500	6500	0	1500	6500 - 8000	8000 - 11000	0	500	8000	11000
5250	7000	7000	0	1500	7000 - 8500	8500 - 11500	0	500	8000	11500

ware allowing to define arbitrary combinations of trigger signals to optimize the available recording time for three seismic sources and to minimize the shot distance.

Trigger settings can be changed at any time during the survey to adjust the recording delay to water depth without interruption of data acquisition. The amplifier unit converts the controller output to positive or negative TTL levels. The gun amplifier unit, which generates a 60V / 8 A trigger level, regulates the magnetic valves of the different seismic sources. It was placed in the pulser station near the gun pressure controls for immediate shutdown of gun operation if needed.

Table 4 summarizes the trigger schemes used for the two recording systems, the three different source types, the two RU controllers and the *EPC* online recorder during the surveys. Two trigger intervals were operated in an alternating mode, one controlling the watergun and the GI-Gun with the small chamber volume, the second controlling the same watergun and the GI-Gun with large chamber volume. Trigger intervals of generally of 9 s length had to be extended up to 11.5 s in greater water depth to avoid interference between the primary signal of one source with the first or second multiple of another source. Data of each source type were recorded on separate tapes in parallel and acquisition parameters adjusted according to the frequency content and signal penetration achieved for each source type prior to standard seismic data processing.

4.1.4 Onboard Seismic Data Processing

For an immediate evaluation of the data quality brute stacks of the GI-Gun data were produced for each multichannel seismic line. Processing was done with custom software and the public domain seismic package *Un*x* (*Stockwell*, 1997) on a *SUN Enterprise 250* workstation. For lines GeoB 01-159 to GeoB 01-173 the near-field traces 2 - 4 were chosen for the brute stacks in order to avoid time consuming NMO corrections. After application of a bandpass filter of 55/110 - 600/800 Hz, which suppresses a sometimes strong ringing of 50 Hz and concentrates the frequency content of both GI-Guns to about the same band, the three traces were simply added up for the brute stacks. An irregularly occurring up to now undefined short offset in the trigger time of both GI-Guns sometimes produced slightly smeared reflection horizons in the seismogram sections. For lines GeoB 01-174 to GeoB 01-203 the data quality of traces 2 - 4 was so poor that we preferred to use the far field traces 35 - 37 for the brute stacks. In this case, a NMO correction with a velocity of 1550 m/s was applied prior to bandpass filtering and stacking.

A list of the multichannel seismic lines acquired during R/V METEOR Cruise M49/3 is given in Table 5. Track charts displayed in Chapters 4.1.5 and 4.1.6 were produced with the public domain *GMT* software package (*Wessel & Smith,* 1998).

Based on the seismic GI-Gun brute stacks potential drilling sites were selected. In Chapters 4.1.5 and 4.1.6 the seismic line, the (nearest) crossing line and a *Parasound* record across each proposed drill site are presented together with a detailed track chart of each survey area. The proposed drill sites of the two survey areas D and E are summarized in Table 6 comprising shot date and time, longitude and latitude, the nearest crossing line, information about a gravity core available at or close to the site and a keyword characterizing the location. The proposed drill sites and their latitude and longitude are preliminary as they have to be adapted to CDP numbers after final processing of the seismic data. Where possible, also a (seismo-)stratigraphy was tentatively defined on the basis of sedimentation rate estimates from gravity cores for the uppermost 5 - 10 m of the sediment column and/or changes in seismic reflection patterns.

Table 5 Multichannel seismic lines collected during R/V METEOR Cruise M49/3.

	Start				End						
Profile	Latitude	Longitude	Date	Time [UTC]	Latitude	Longitude	Date	Time [UTC]	Course	Number of Shots	Length [nm]
GeoB 01-159	32°27.61‘S	50°35.92‘W	11.03.01	09:54	33°50.40‘S	47°22.60‘W	12.03.01	14:32	116	11164	180
GeoB 01-160	33°50.17’S	47°21.64’W	12.03.01	14:40	33°45.88’S	47°17.73’W	12.03.01	15:41	41	376	6
GeoB 01-161	33°45.10’S	47°17.77’W	12.03.01	15:49	30°53.30’S	49°14.20’W	13.03.01	22:25	330	12131	197
GeoB 01-162	30°52.25’S	49°14.13’W	13.03.01	22:34	30°39.98’S	48°54.64’W	14.03.01	01:49	53	1269	21
GeoB 01-163	30°40.11’S	48°53.67’W	14.03.01	01:57	31°14.97’S	47°54.01’W	14.03.01	11:30	124	3772	61
GeoB 01-164	33°27.45’S	48°39.02’W	16.03.01	06:36	33°12.45’S	48°29.07’W	16.03.01	09:13	30	1051	17
GeoB 01-165	33°11.39’S	48°29.47’W	16.03.01	09:24	32°58.12’S	48°58.49’W	16.03.01	14:00	298	1843	28
GeoB 01-166	32°58.08’S	48°59.32’W	16.03.01	14:07	33°05.20’S	49°44.20’W	16.03.01	20:03	258	2334	38
GeoB 01-167	33°04.44’S	49°45.34’W	16.03.01	20:20	32°45.29’S	49°33.81’W	16.03.01	23:40	24	1343	21
GeoB 01-168	32°44.54’S	49°34.08’W	16.03.01	23:49	32°38.21’S	49°50.22’W	17.03.01	02:09	295	938	15
GeoB 01-169	32°38.51’S	49°51.02’W	17.03.01	02:17	32°51.09’S	49°58.75’W	17.03.01	04:31	207	871	14
GeoB 01-170	32°52.00’S	49°58.20’W	17.03.01	04:42	33°00.94’S	49°37.54’W	17.03.01	07:43	117	1203	19
GeoB 01-171	33°00.90’S	49°36.30’W	17.03.01	07:53	32°40.93’S	49°10.59’W	17.03.01	12:27	46	1810	30
GeoB 01-172	32°40.44’S	49°10.28’W	17.03.01	12:32	31°22.82’S	49°12.63’W	18.03.01	01:00	359	4548	78
GeoB 01-173	31°22.17’S	49°12.07’W	18.03.01	01:08	30°49.80’S	48°25.20’W	18.03.01	09:15	52	3180	52
GeoB 01-174	28°29.60’S	41°05.52’W	20.03.01	07:00	28°09.20’S	41°05.30’W	20.03.01	10:15	360	1263	21
GeoB 01-175	28°08.75’S	41°05.85’W	20.03.01	10:24	27°25.00’S	42°49.90’W	21.03.01	02:33	295	6122	102
GeoB 01-176	27°24.61’S	42°50.28’W	21.03.01	02:38	24°41.94’S	44°37.36’W	22.03.01	09:50	329	11916	188
GeoB 01-177	24°42.37’S	44°38.55’W	22.03.01	10:03	24°52.80’S	44°42.95’W	22.03.01	11:53	200	725	12
GeoB 01-178	24°53.29’S	44°43.02’W	22.03.01	11:58	26°29.33’S	44°25.10’W	23.03.01	03:46	171	6138	97
GeoB 01-179	26°30.10’S	44°26.20’W	23.03.01	04:05	26°30.09’S	44°34.77’W	23.03.01	05:23	270	478	7
GeoB 01-180	26°29.33’S	44°35.74’W	23.03.01	05:38	25°52.93’S	44°41.78’W	23.03.01	11:54	351	2431	37
GeoB 01-181	25°51.96’S	44°40.98’W	23.03.01	12:07	25°50.25’S	44°26.50’W	23.03.01	14:21	82	831	13

Table 5 continued

	Start				End						
Profile	Latitude	Longitude	Date	Time [UTC]	Latitude	Longitude	Date	Time [UTC]	Course	Number of Shots	Length [nm]
GeoB 01-182	25°50.46'S	44°25.63'W	23.03.01	14:29	26°23.00'S	43°38.31'W	23.03.01	22:50	127	3110	54
GeoB 01-183	26°22.92'S	43°37.34'W	23.03.01	22:58	26°16.89'S	43°25.97'W	24.03.01	00:50	59	692	11
GeoB 01-184	26°15.97'S	43°25.72'W	24.03.01	01:00	25°43.76'S	43°46.29'W	24.03.01	06:44	330	2127	37
GeoB 01-185	26°25.70'S	43°36.40'W	25.03.01	21:56	25°53.78'S	43°58.04'W	26.03.01	03:50	328	2209	37
GeoB 01-186	25°57.77'S	43°57.70'W	26.03.01	04:02	25°43.55'S	43°39.65'W	26.03.01	07:00	62	1131	19
GeoB 01-187	25°43.76'S	43°38.86'W	26.03.01	07:12	25°50.83'S	43°34.11'W	26.03.01	08:27	151	469	8
GeoB 01-188	25°51.96'S	43°34.54'W	26.03.01	08:39	26°03.31'S	43°56.45'W	26.03.01	12:11	240	1345	22
GeoB 01-189	26°04.29'S	43°56.73'W	26.03.01	12:22	26°08.90'S	43°53.33'W	26.03.01	13:12	146	327	5
GeoB 01-190	26°09.00'S	43°51.83'W	26.03.01	13:26	25°58.88'S	43°30.65'W	26.03.01	16:46	61	1260	22
GeoB 01-191	25°59.15'S	43°29.26'W	26.03.01	17:00	25°07.46'S	43°23.99'W	26.03.01	18:28	150	559	10
GeoB 01-192	26°08.70'S	43°24.71'W	26.03.01	18:42	26°19.61'S	43°47.14'W	26.03.01	22:13	241	1300	24
GeoB 01-193	26°20.32'S	43°46.78'W	26.03.01	22:24	26°20.56'S	43°23.86'W	27.03.01	01:34	89	1207	20
GeoB 01-194	26°21.26'S	43°23.00'W	27.03.01	01:45	26°47.10'S	43°25.40'W	27.03.01	05:54	184	1629	26
GeoB 01-195	26°47.83'S	43°24.98'W	27.03.01	06:01	27°09.10'S	42°52.40'W	27.03.01	11:44	126	2254	36
GeoB 01-196	27°10.60'S	42°52.60'W	27.03.01	12:01	27°16.66'S	43°03.89'W	27.03.01	13:51	239	736	11
GeoB 01-197	27°17.51'S	43°04.33'W	27.03.01	14:02	27°31.65'S	43°54.01'W	27.03.01	16:36	147	1016	17
GeoB 01-198	27°31.83'S	42°53.72'W	27.03.01	16:41	27°40.69'S	42°33.17'W	27.03.01	19:51	115	1260	21
GeoB 01-199	27°40.24'S	42°32.46'W	27.03.01	20:00	27°26.90'S	42°26.60'W	27.03.01	22:14	20	958	15
GeoB 01-200	27°26.33'S	42°26.90'W	27.03.01	22:23	27°19.88'S	42°42.95'W	28.03.01	00:44	294	946	15
GeoB 01-201	27°20.29'S	42°43.81'W	28.03.01	00:55	27°35.25'S	42°50.22'W	28.03.01	03:26	200	1009	17
GeoB 01-202	27°34.81S	42°51.38'W	28.03.01	03:44	27°27.06'S	42°52.52'W	28.03.01	05:00	350	500	8
GeoB 01-203	27°26.73'S	42°52.47'W	28.03.01	05:03	27°18.90'S	42°49.50'W	28.03.01	06:22	17	527	9
									Total	208616	1698

4.1.5 Southern Brazilian Continental (Survey Area D)

4.1.5.1 Geologic Setting and Site Survey Strategy

Survey area D is located on the southern Brazilian continental margin between about 30°30' - 34°00'S and 47° - 51°W. The continental margin there is less steep than further south and furrows, channels or canyons are almost absent. Hence, the depositional patterns are expected to be more regular and less frequently disturbed by slides, slumps, debris flow or turbidite deposits. Apart from erosional terraces in very shallow water depth (*Bassetto et al.*, 2000), erosion of complete sedimentary units is unlikely, but depositional pattern may still be affected by contour currents. Due to the greater distance to the Rio de la Plata river mouth, the amount of suspended terrigenous material delivered to this region is less than in the more southern area C surveyed during R/V METEOR Cruise M49/2 (*Spieß et al.*, in prep.) and hemipelagic sequences with a higher proportion of biogenic components are expected. The southern part of survey area D between about 32° - 35°S comprises the Rio Grande Cone, a voluminous sedimentary wedge which has developed since Late Eocene times and to the north laps onto an erosional unconformity related to a basement structural high (*Bassetto et al.*, 2000).

The site survey strategy in this area was first to collect multichannel seismic data along two or three long profiles covering the complete continental slope and rise from the southern to the northern boundary of area D to achieve an general overview of the regional depositional pattern. Then, after selecting potential drilling locations on these lines a more or less dense grid of additional and crossing lines were to map the regional extent of sedimentary features and prominent reflectors.

4.1.5.2 Preliminary Results, Stratigraphy and Proposed Drill Sites

Figure 7 displays the track chart of R/V METEOR Cruise M49/3 in survey area D. The southern lines are located on the Rio Grande Cone, the northern lines on the northern foothills of this sedimentary wedge.

Figure 8 shows a brute stack of the GI-Gun data collected along line GeoB 01-159 on the Rio Grande Cone. The profile reveals an unusual topography and three different depositional regimes. Following the shelf break and upper continental slope, parallel undulating or wavy reflections are interrupted by pronounced sediment tectonics in 1.5 - 2.3 s TWT (about 1100 - 1700 m water depth) on a slightly descending plateau of 90 - 100 km length. At the adjacent slope, reflectors of an old sediment drift, which dips northwestward beneath the upper plateau, pinch out due to strong erosion. An about 1 s TWT (about 750 m) thick, parallel bedded hemipelagic sediment package laps onto this eroded slope and forms a second slightly descending plateau in 4.0 - 4.5 s TWT (about 3000 - 3400 m water depth). At the southeastern end of this plateau reflectors again pinch out indicating the influence of contour currents below 3400 m water depth. A band of unusually high reflection amplitudes, which follows the sea floor topography and crosses the reflection horizons, is observed in about 0.5 s TWT sediment depth beneath the upper plateau and the eroded slope. It disappears at the beginning of the lower plateau. Below the high reflection amplitude band, signals are strongly attenuated and disappear. Though this feature resembles a bottom simulating reflector (BSR), its origin here is not clear at present. The plateau with pronounced sediment tectonics might suggest gas hydrates, but other

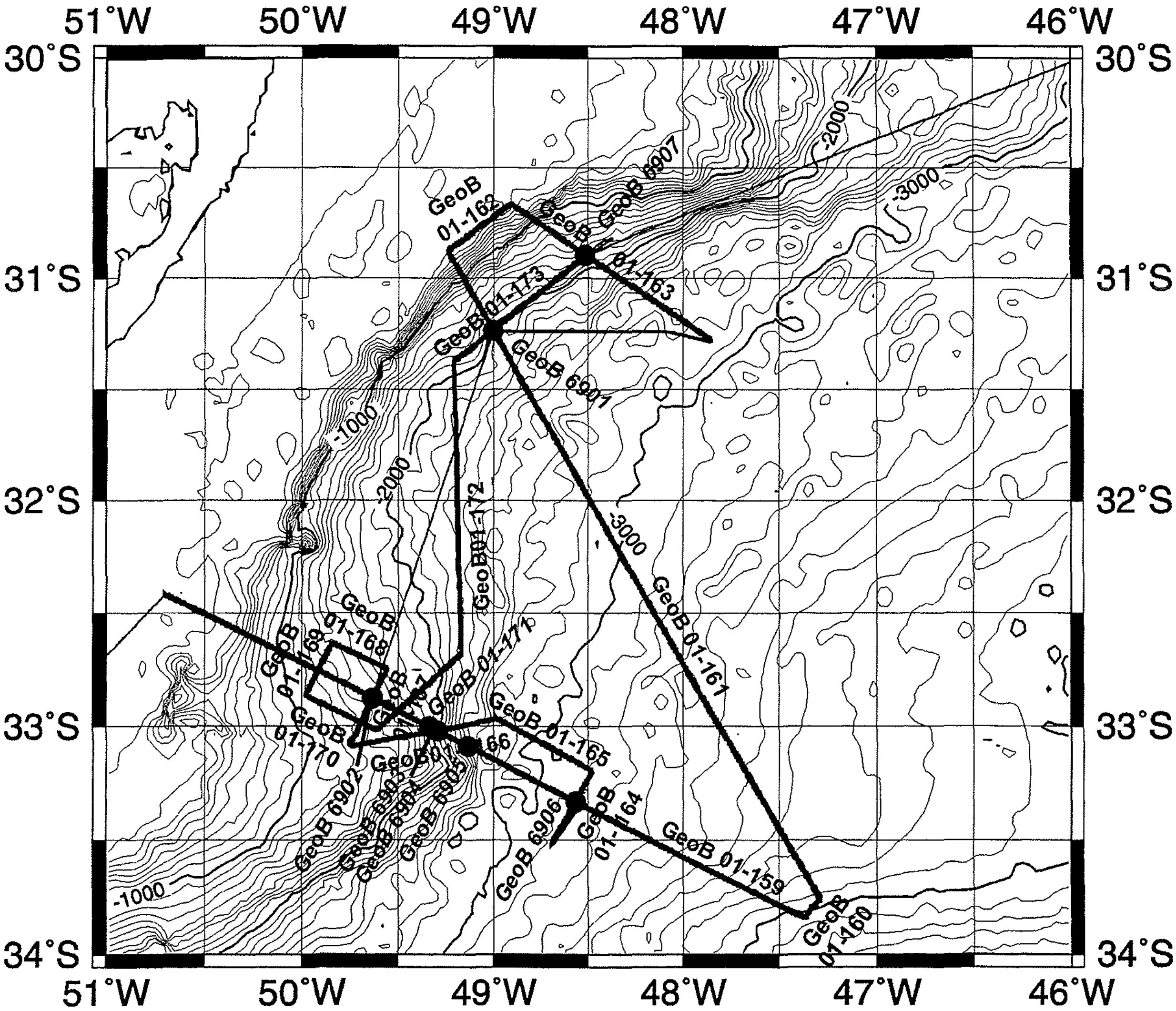


Figure 7 Track chart of R/V METEOR Cruise M49/3 on the southern Brazilian continental margin / Rio Grande Cone (Survey Area D) showing seismic profiles (thick lines with annotation) and gravity core positions (dots with italic annotation).

processes controlled by sediment depth, pressure and/or temperature could cause this unusual effect as well.

Suitable drilling locations were identified on both plateaus, four in about 1300 - 2100 m water depth and one on the lower plateau in about 3100 m water depth. These sites are intended to drill the uppermost 400 - 500 m of the sediment column of Holocene to Pliocene or Miocene age, depending on sedimentation rates.

Figure 9 shows a section of line GeoB 01-159 on the upper plateau with pronounced sediment tectonics and erosional truncations at the slope. Two drilling locations RGC-1 and RGC-2 were originally chosen at the intersections with lines GeoB 01-167 and GeoB 01-171 in about 1400 and 1600 m water depth. Closer inspection of crossing line GeoB 01-167 suggests, however, that RGC-1 should be moved 20 km upslope to the southwest in order to avoid a slump in about 0.4 s TWT (about 300 m below sea floor; Fig. 10). The corresponding *Parasound* record only shows weakly reflecting layers and an average signal penetration of 25 - 30 m (Fig. 11).

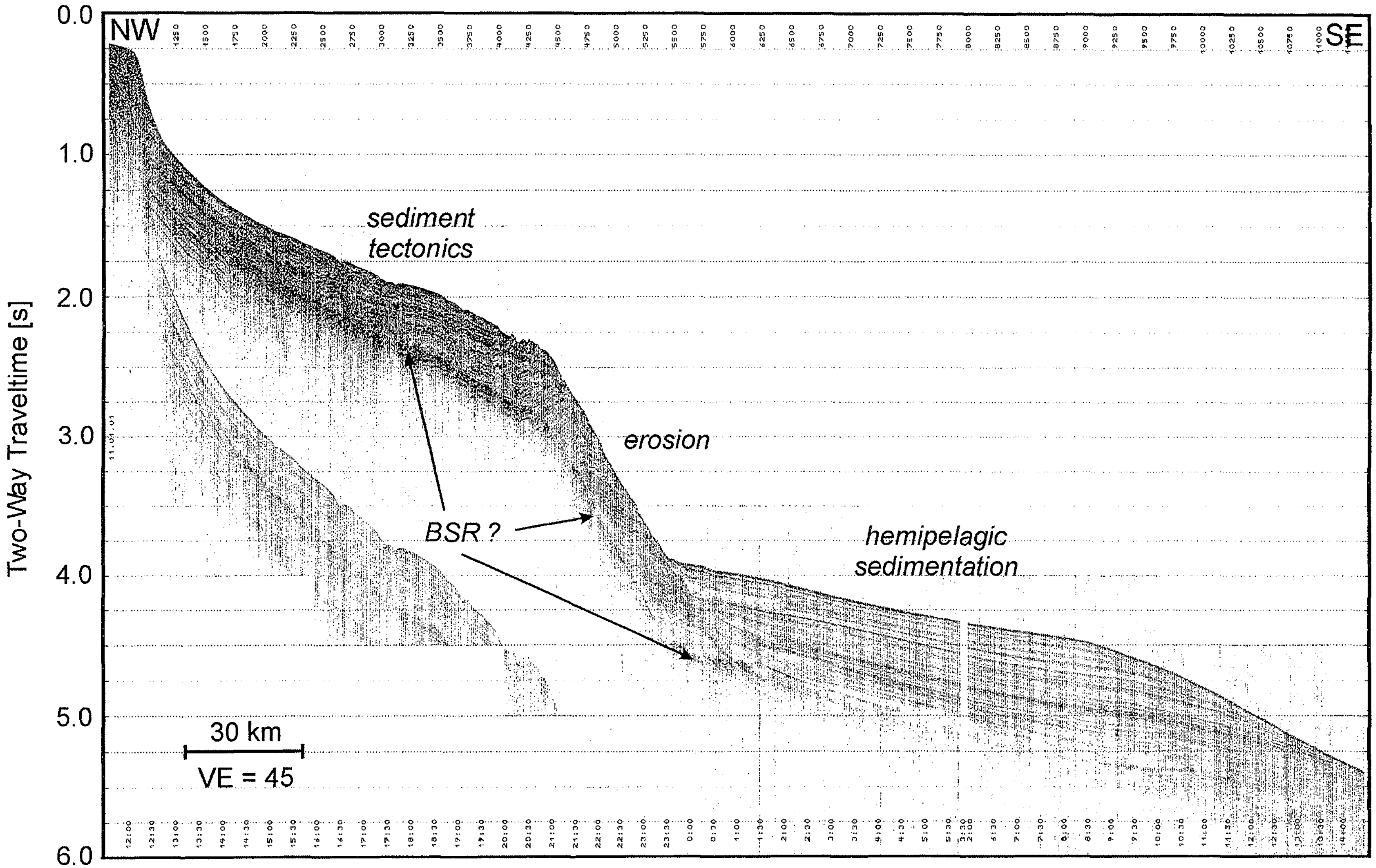


Figure 8 Multichannel seismic line GeoB 01-159 on the southern Brazilian continental margin across the Rio Grande Cone.

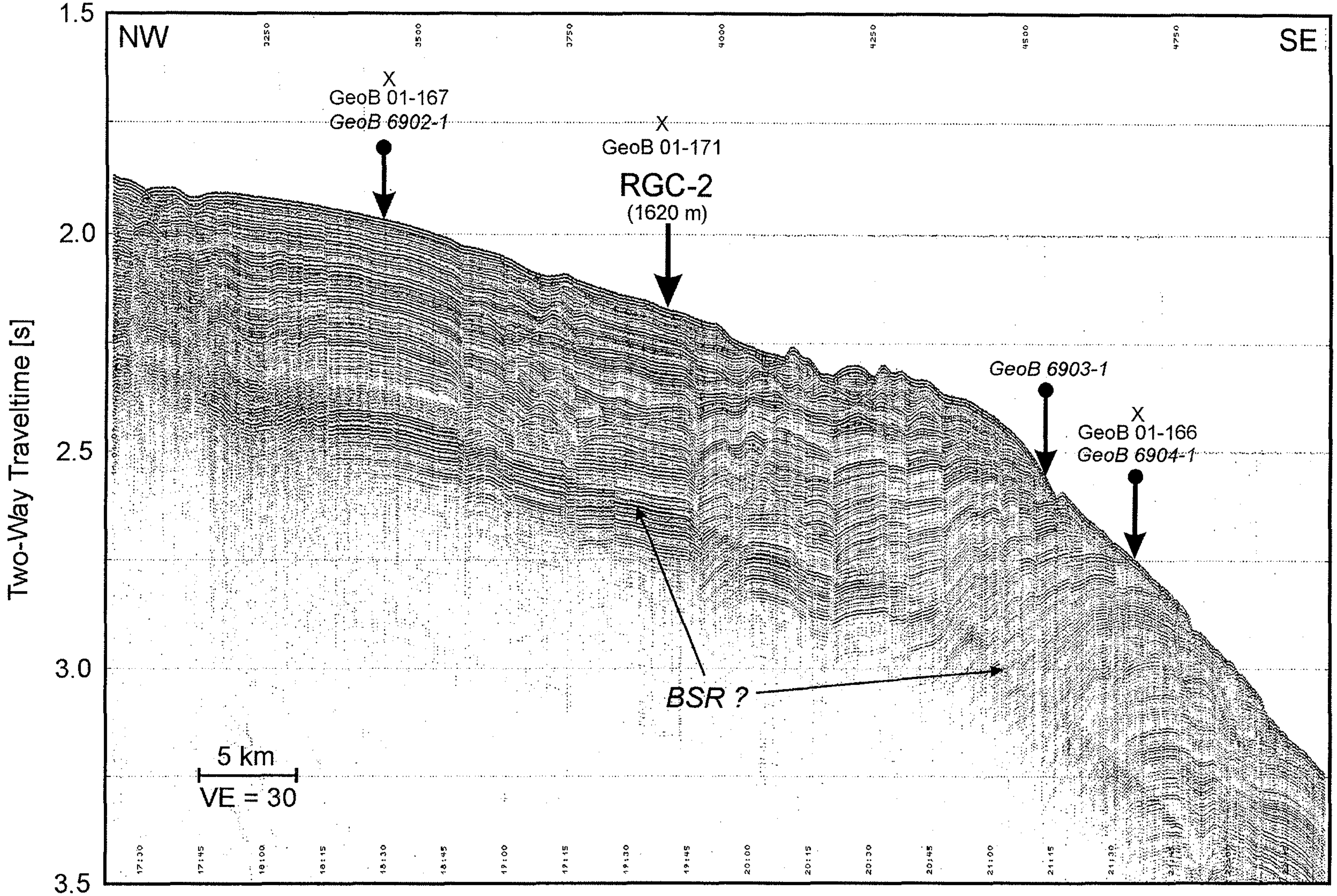


Figure 9 Section of multichannel seismic line GeoB 01-159 across Site RGC-2 and gravity core positions GeoB 6902-1 to GeoB 6904-1 showing pronounced sediment tectonics and erosional truncations at the slope of the Rio Grande Cone upper plateau. The intersections with lines GeoB 01-166, GeoB 01-167 and GeoB 01-171 are marked by crosses.

The crossing line GeoB 01-171 illustrates that the sub-bottom layers beneath Site RGC-2 might be more folded than was obvious from line GeoB 01-159 (Fig. 12). Therefore, two additional Sites RGC-3 and RGC-4 are proposed to the northeast further downslope in about 1800 and 2100 m water depth with less folded, almost parallel hemipelagic sub-bottom layering. The corresponding *Parasound* record is similar to Figure 11, signal penetration limited to 25 - 30 m and only weakly reflecting sub-bottom layers appear (Fig. 13). As can also be observed in the seismic section, erosional truncations probably caused by bottom currents occur particularly at the flanks of small-scale furrows.

For Site RGC-5 a location on the lower plateau in about 3100 m water depth is proposed as shallow as possible both in view of carbonate preservation and to avoid slumps or debris flow deposits (Fig.14). The respective crossing line GeoB 01-164 also reveals an obviously undisturbed sediment package (Fig. 15) and the *Parasound* record shows distinct subparallel reflections to a signal penetration depth of about 40 m (Fig.16).

Five gravity cores were taken along line GeoB 01-159, three to sample deeper layers outcropping at the eroded slope and one each on the upper and lower plateau at potential drilling locations. Unfortunately, the three cores (GeoB 6903-1 to GeoB6905-1) from the erosional slope recovered only Quaternary sequences thus not providing the anticipated stratigraphic age information. Gravity cores GeoB 6902-1 and Geo B6906-1 on the upper and lower plateau are mainly composed of a thin layer of foraminifer bearing nannofossil ooze at the top and terrigenous rich, almost carbonate free hemipelagic clays below. Core GeoB 6906-1 contained several thin turbidite horizons near the top of (cf. Chapter 4.2). Stratigraphic classification based on color reflectance data measured onboard led to a preliminary age estimate only for core GeoB 6902-1 indicating that it is younger than 70 ka at the base (6.45 m core length) which results in an average sedimentation rate of more than 90 m/Myr for the uppermost sediment column. Extrapolation to greater depth would suggest an age of 5 - 6 Ma in about 500 m depth (0.7 s TWT) below sea floor.

The area north of the Rio Grande Cone revealed a quite different depositional pattern. Line GeoB 01-163 shows a continuously descending slope with two zones of current controlled reduced sedimentation or erosion in around 1.25 to 3.25 s TWT (about 900 and 2400 m water depth; Fig. 17). In between a sediment drift with parallel sub-bottom layering is developed. The top of this drift body was initially chosen as drilling location RGC-6 (Fig. 18), but inspection of the crossing line GeoB 01-173 identified a slump deposit at this position. The proposed drilling site was therefore relocated about 8 km northeastward, where the slump has ended (Fig. 19). The corresponding *Parasound* record seems to indicate some erosional truncations to the southwest of Site RGC-6 so that a reduced sedimentation may be possible, at least for the uppermost 30 - 50 m (Fig. 20).

Two other drilling locations were tentatively defined on line GeoB 01-161 over a rather steep slope with thick slump deposits at its foot followed by a smoothly descending plateau with parallel sub-bottom layers erosionally truncated at the southeastern end of the line (Fig. 21). Site RGC-7 is located at the crossing with line GeoB 01-173 in about 2000 m water depth (Fig. 22). The sediment column there might be slightly disturbed by slumps or debris flows at around 0.25 s TWT (about 200 m) below sea floor, whereas the upper 50 m of the sediment column show undisturbed distinct parallel sub-bottom layering in the *Parasound* record (Fig. 20). RGC-8 is proposed as deepest site in about 3500 m water depth on top of a parallel bedded, about 1 s

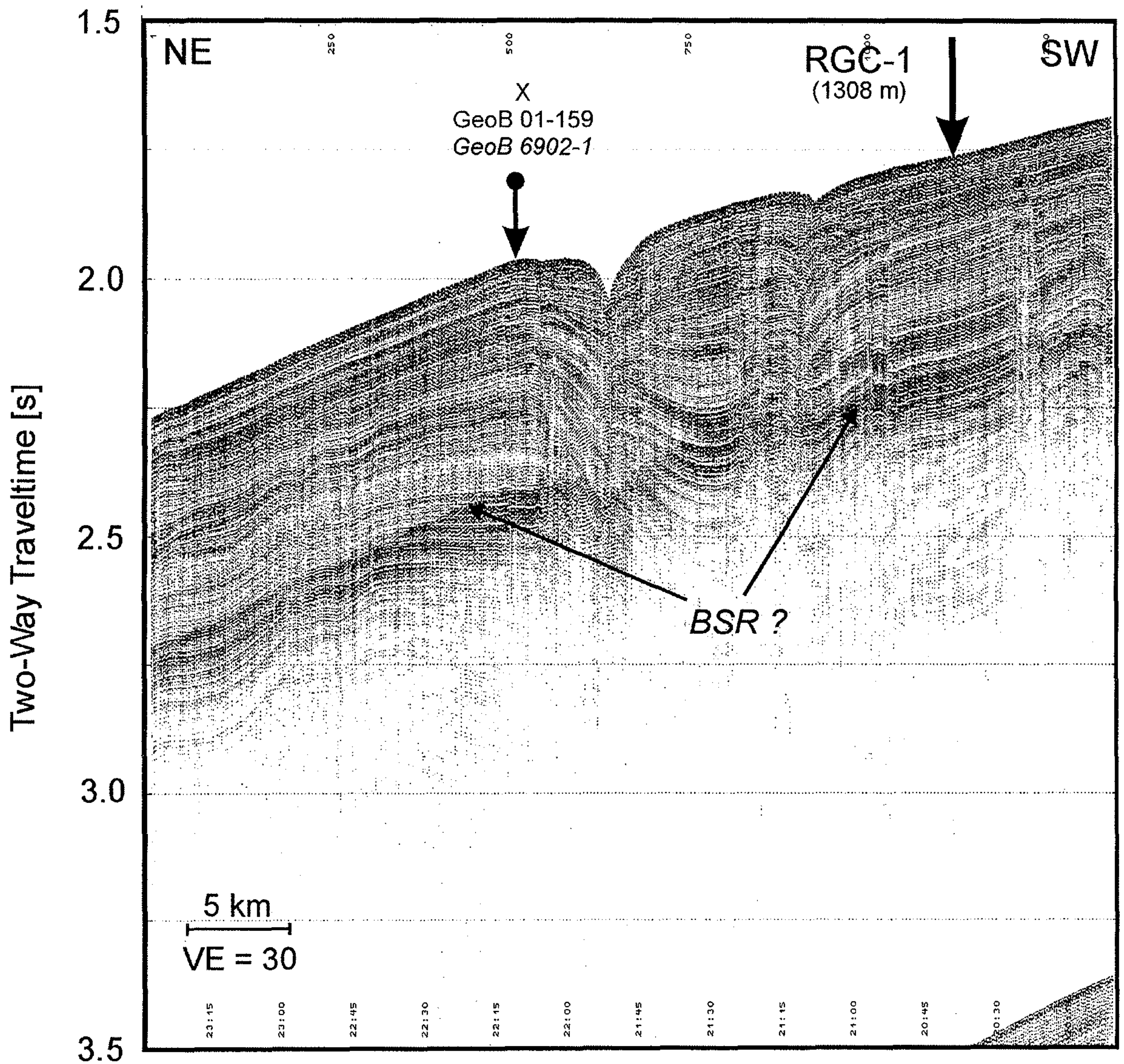


Figure 10 Multichannel seismic line GeoB 01-167 across Site RGC-1 with gravity core position GeoB 6902-1. Line GeoB01-167 is also crossing line GeoB 01-159 to Site RGC-2. The intersection is marked by a cross.

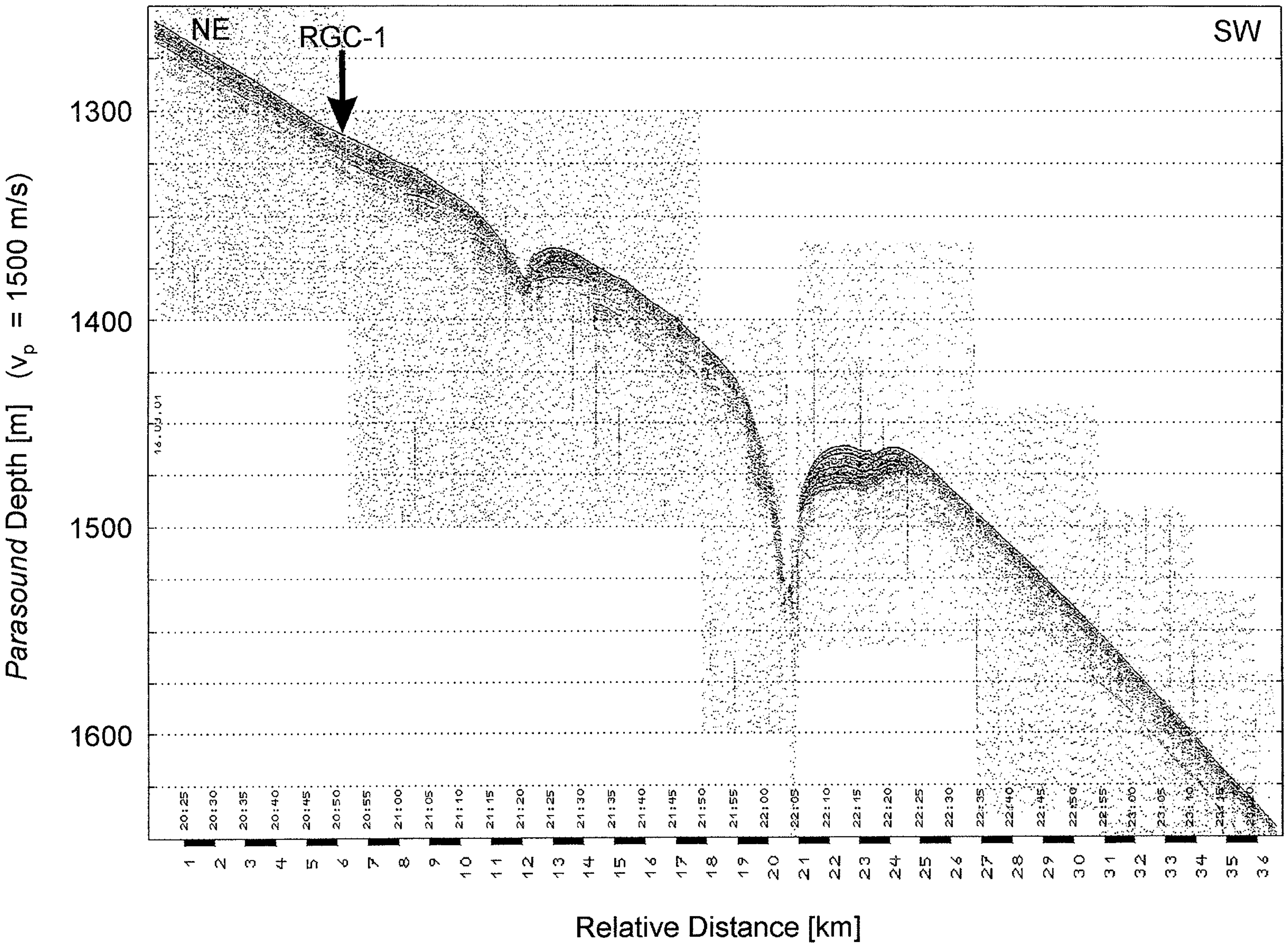


Figure 11 *Parasound* record along line GeoB 01-167 across Site RGC-1. Note that the orientation is opposite to the seismic line (Fig. 10).

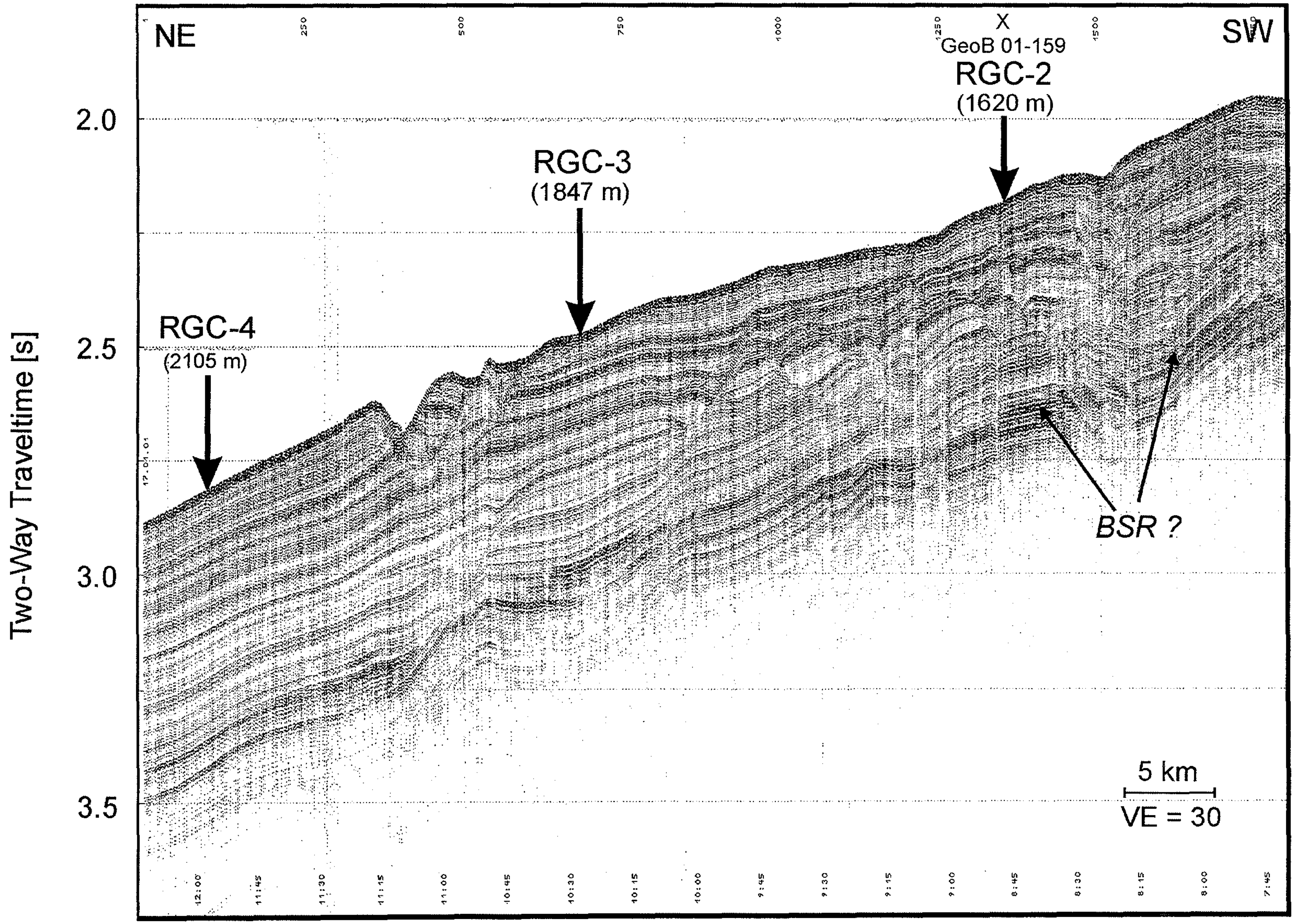


Figure 12 Multichannel seismic line GeoB 01-171 across Sites RGC-2, RGC-3 and RGC-4. Line GeoB 01-171 is also crossing line GeoB 01-159 to Site RGC-2. The intersection is marked by a cross.

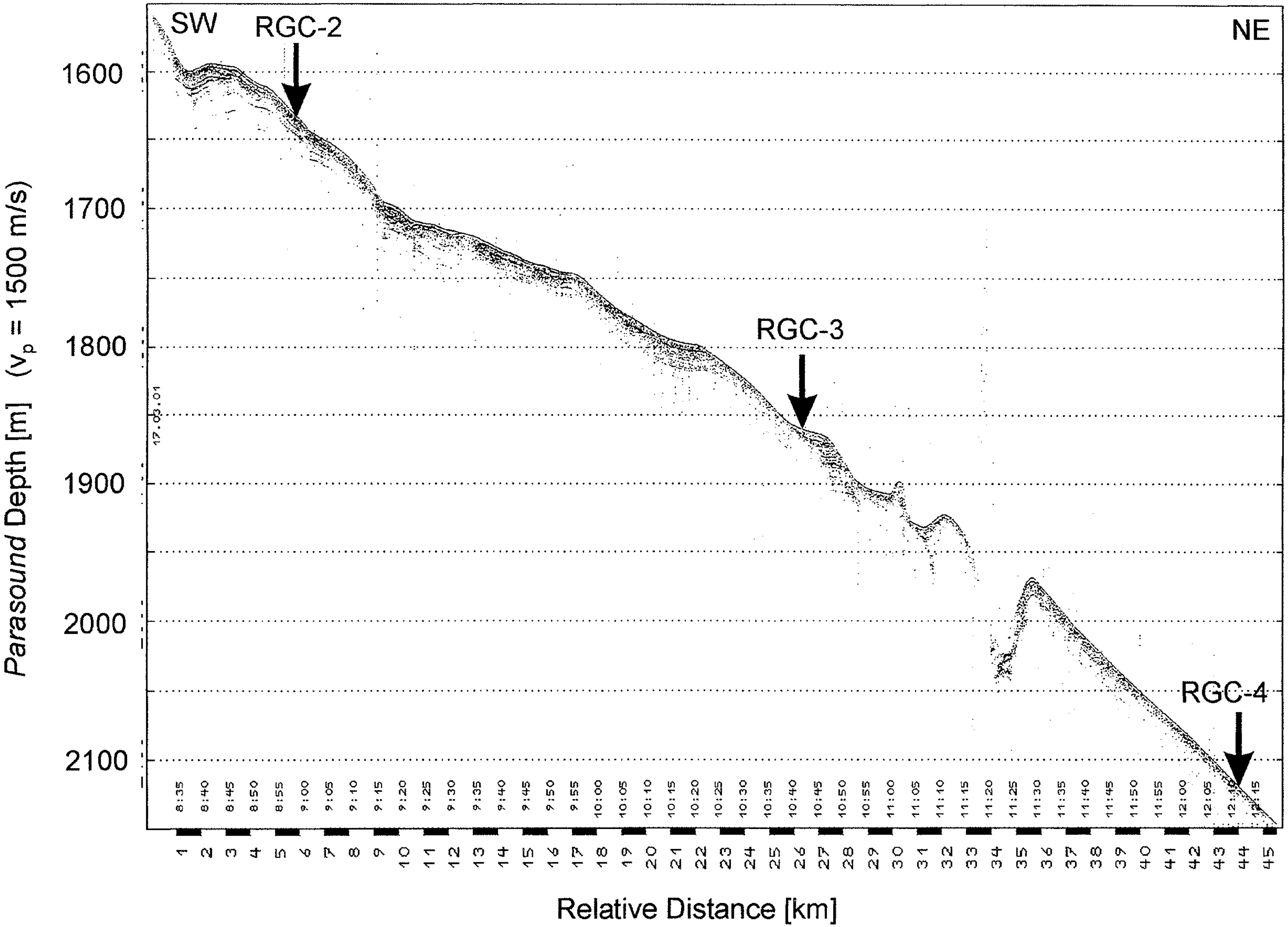


Figure 13 *Parasound* record along line GeoB 01-171 across Sites RGC-2 to RGC-4. Note that the orientation is opposite to the seismic line (Fig. 12).

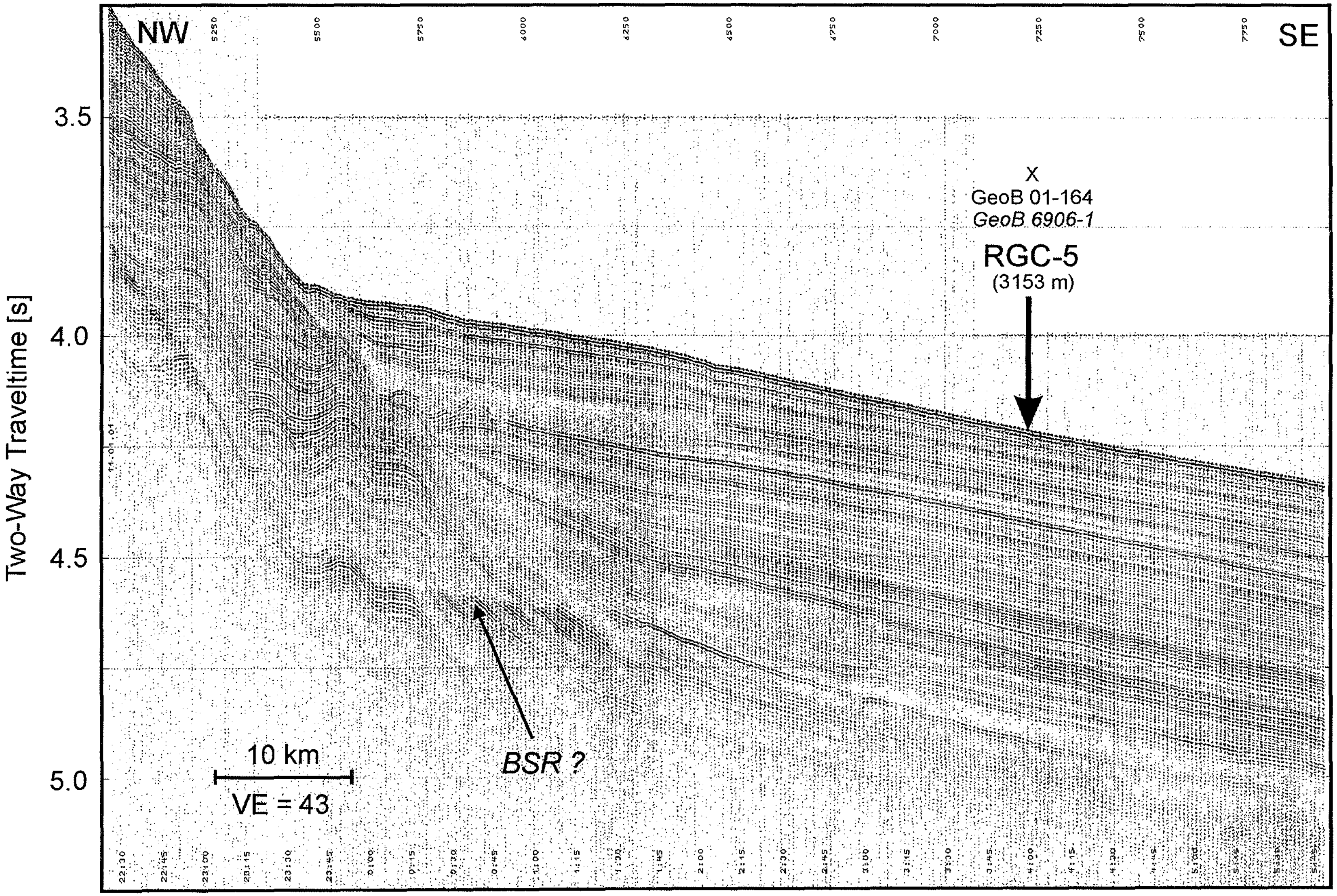


Figure 14 Section of multichannel seismic line GeoB 01-159 across Site RGC-5 and gravity core position GeoB 6906-1 recorded at the foot of the Rio Grande Cone. The intersection with line GeoB 01-164 is marked by a cross.

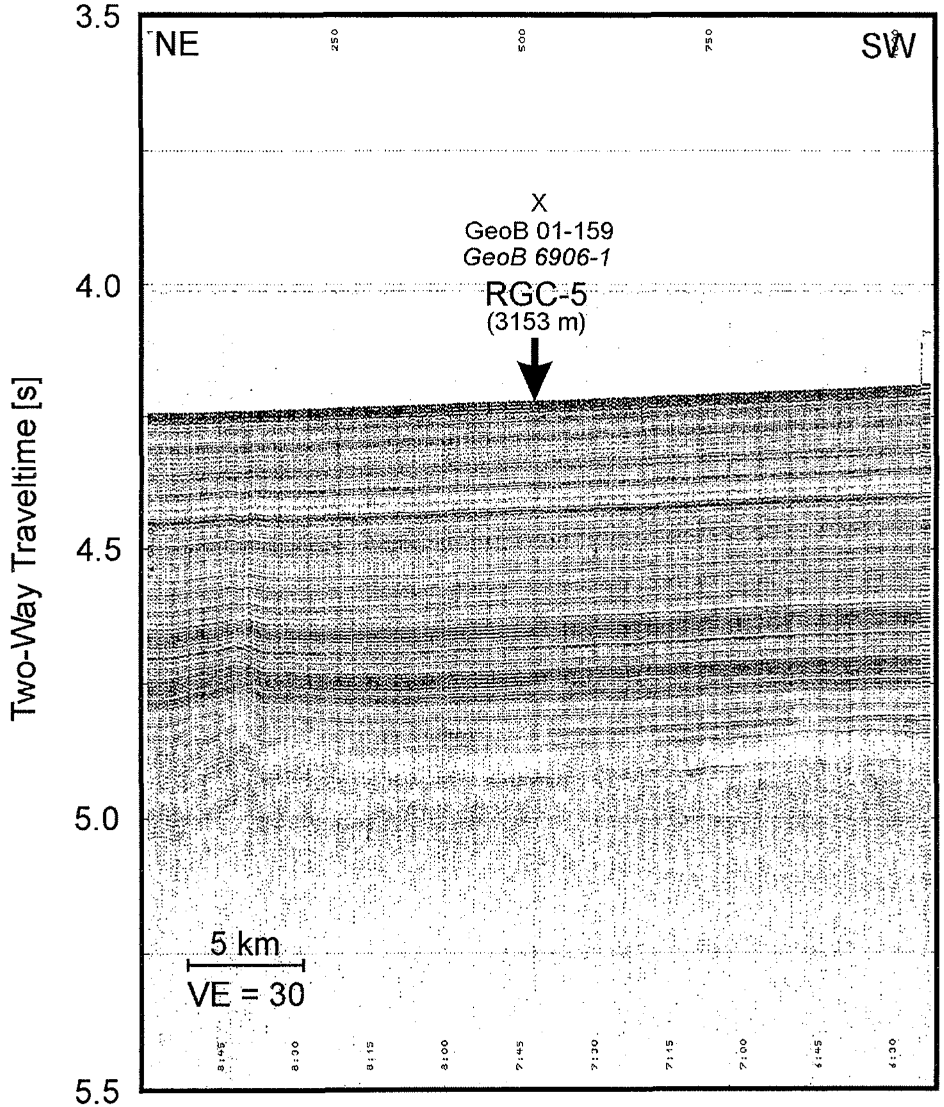


Figure 15 Multichannel seismic line GeoB 01-164 across Site RGC-5 and gravity core position GeoB 6906-1. Line GeoB01-164 is also crossing line GeoB 01-159 to Site RGC-5. The intersection is marked by a cross.

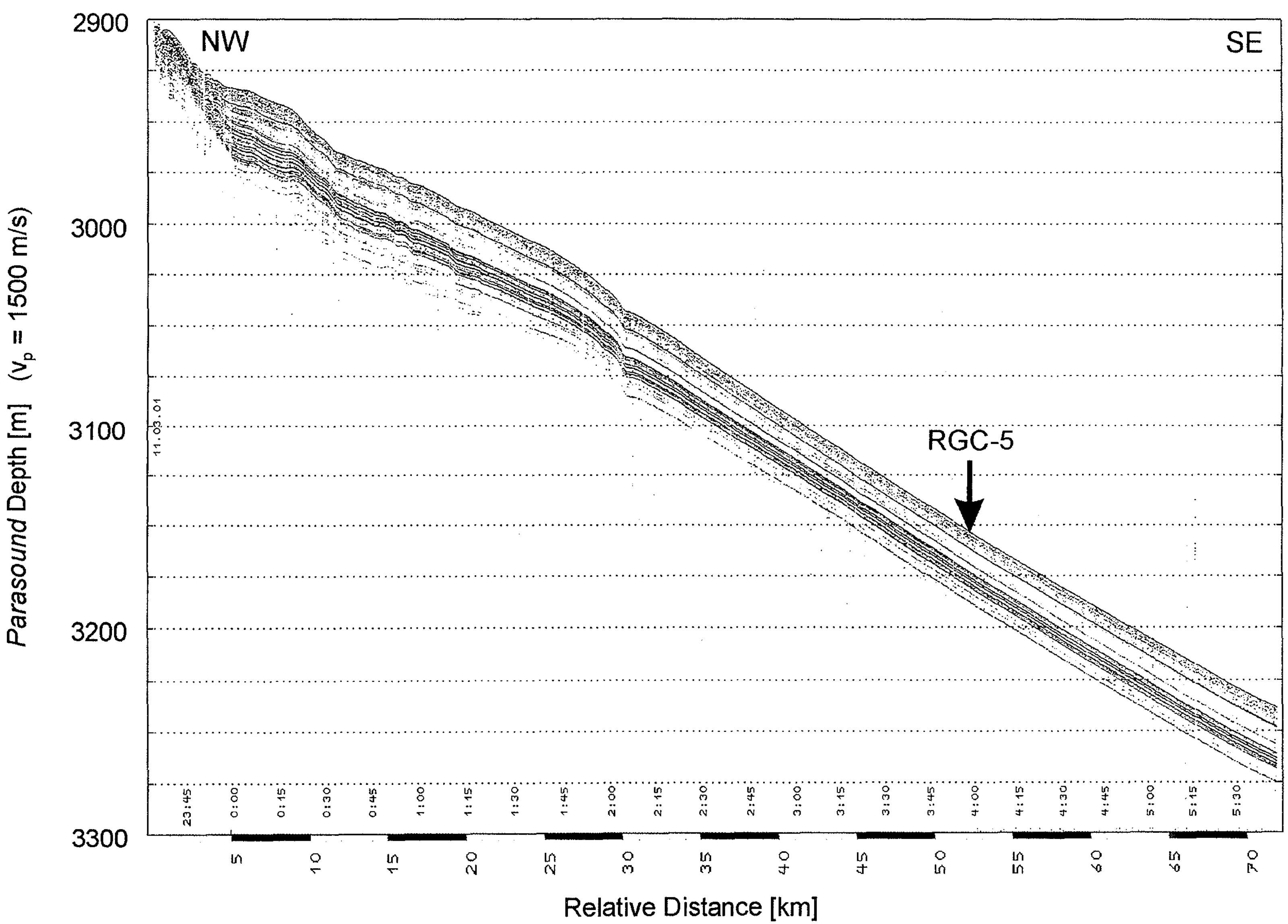


Figure 16 *Parasound* record along line GeoB 01-159 across Site RGC-5.

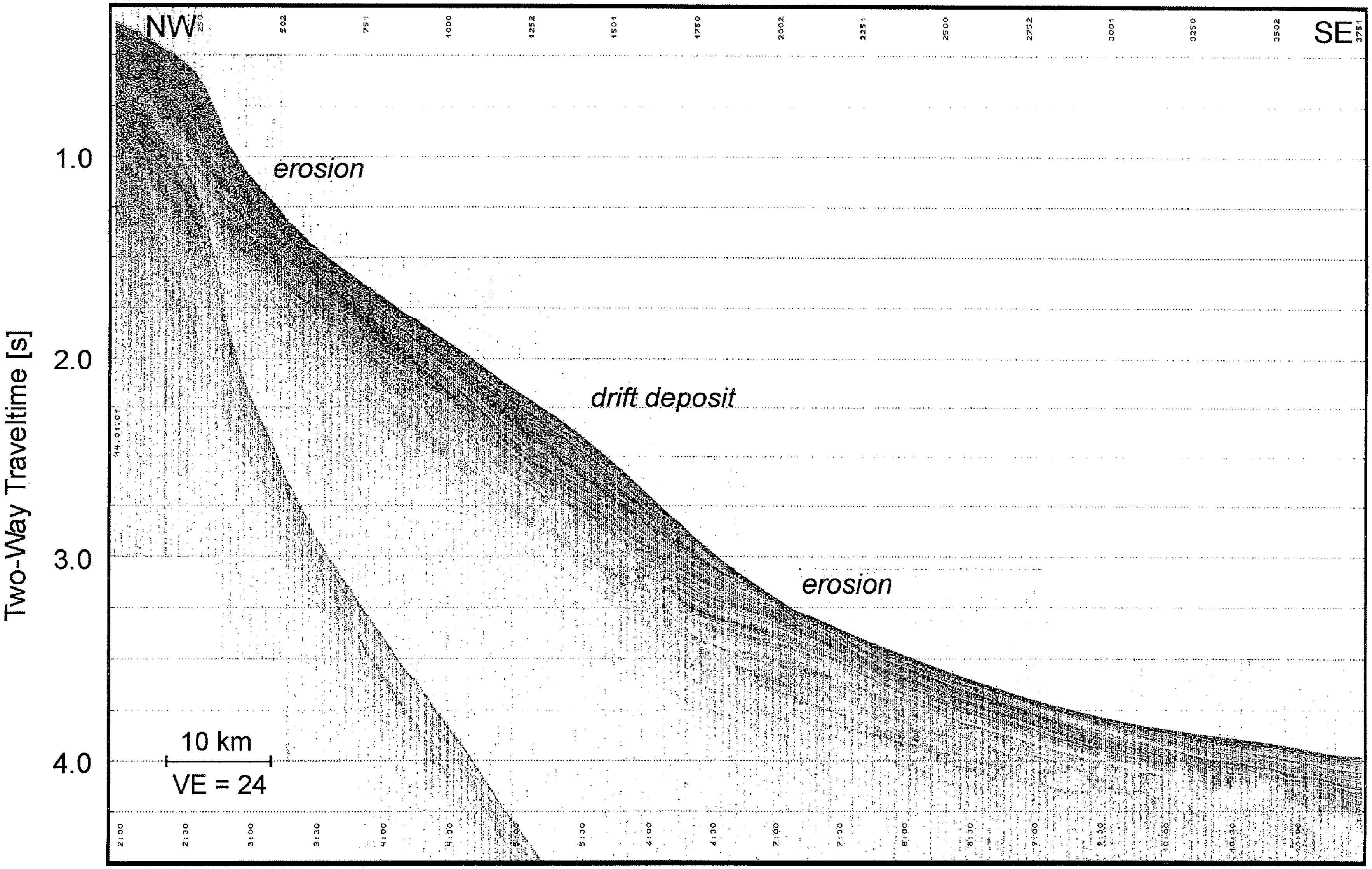


Figure 17 Multichannel seismic line GeoB 01-163 recorded at the Southern Brazilian continental margin north of the Rio Grande Cone.

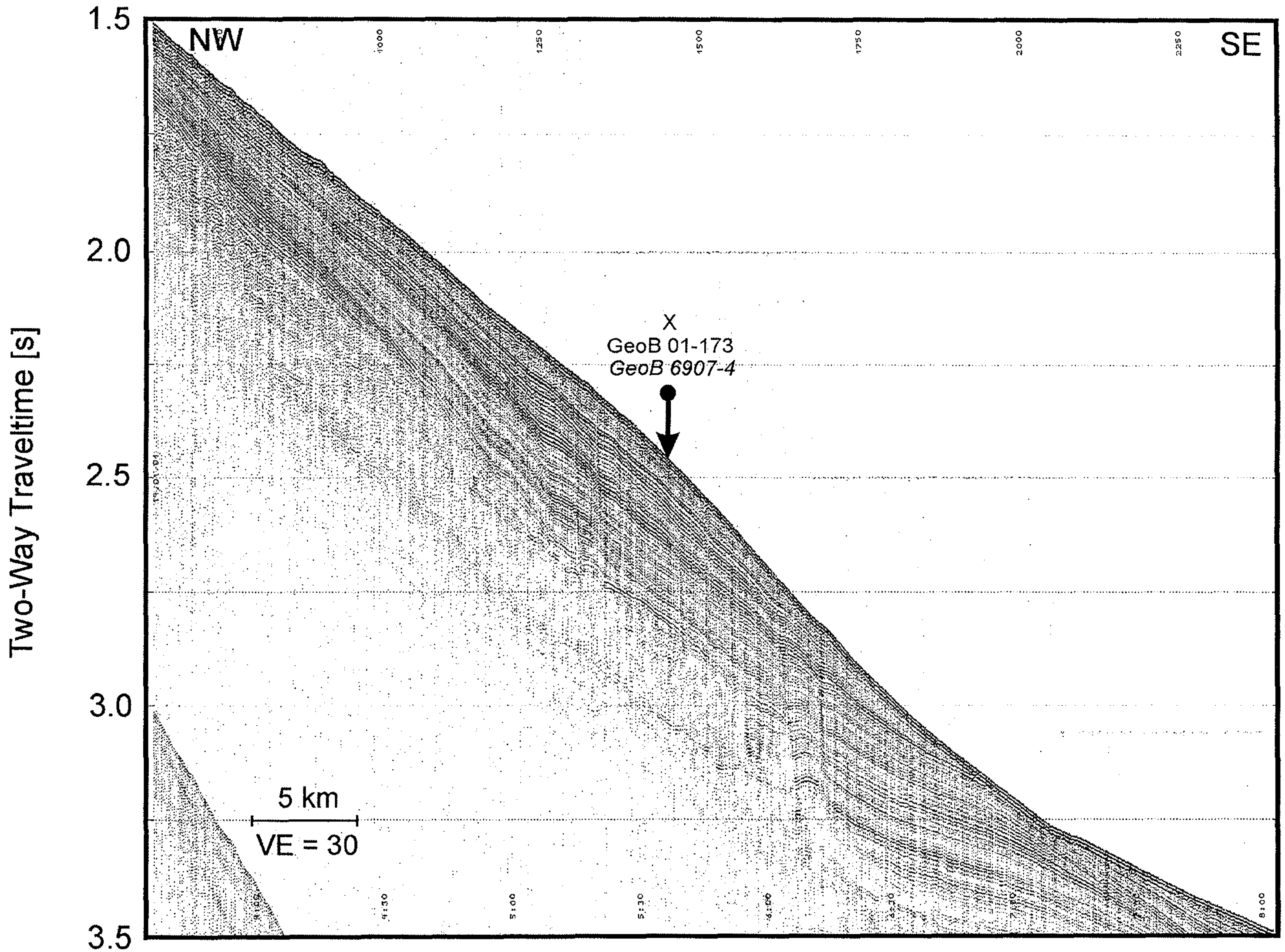


Figure 18 Section of multichannel seismic line GeoB 01-163 with gravity core position GeoB6907-4 showing a drift deposit between to erosional zones. The intersection with line GeoB 01-173 is marked by a cross.

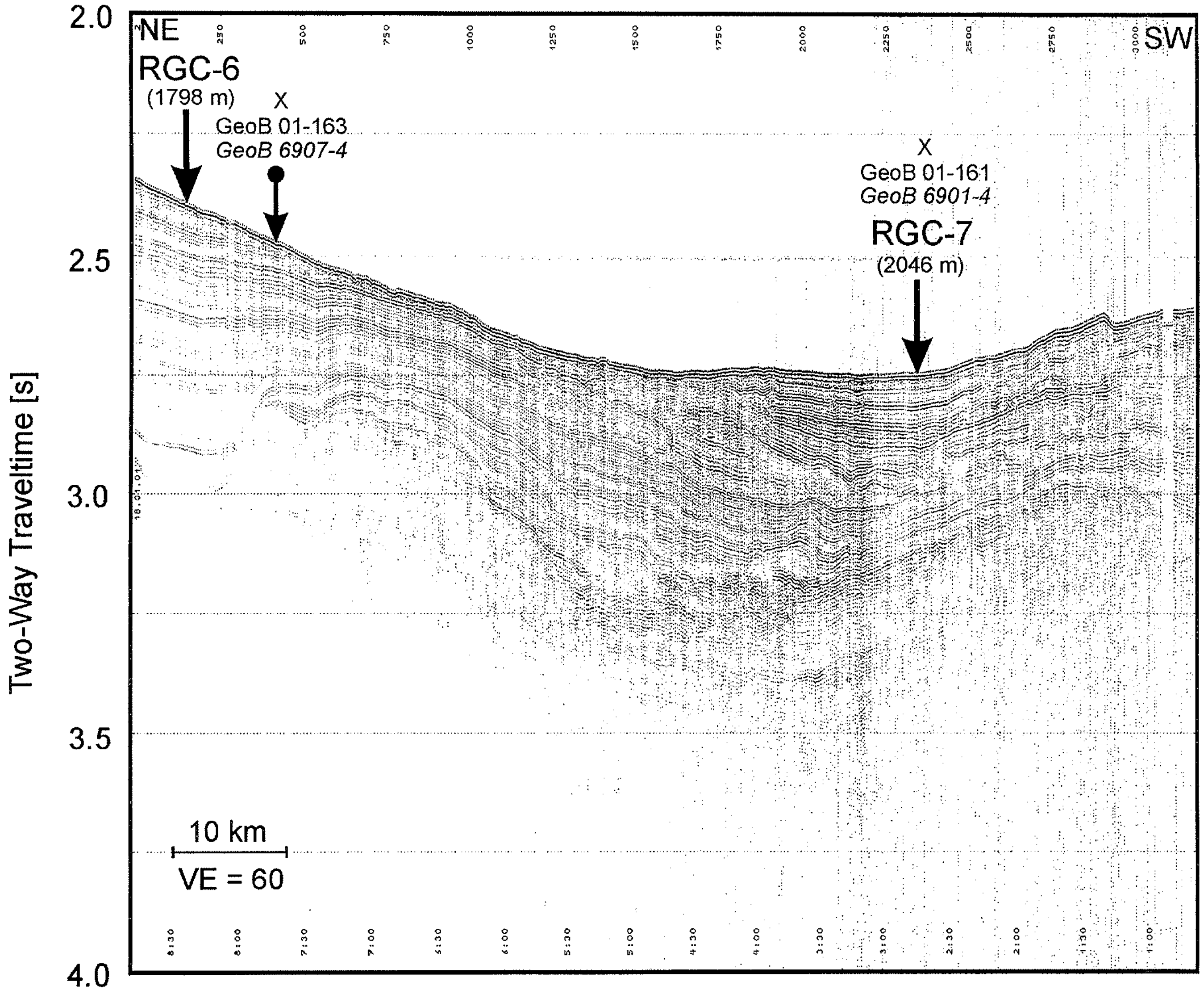


Figure 19 Multichannel seismic line GeoB 01-173 across Sites RGC-6 and RGC-7 with gravity core positions GeoB 6901-4 and GeoB 6907-4. Line GeoB 01-167 is also crossing line GeoB 01-161 to Site RGC-7 and line GeoB 01-163. Both intersections are marked by crosses.

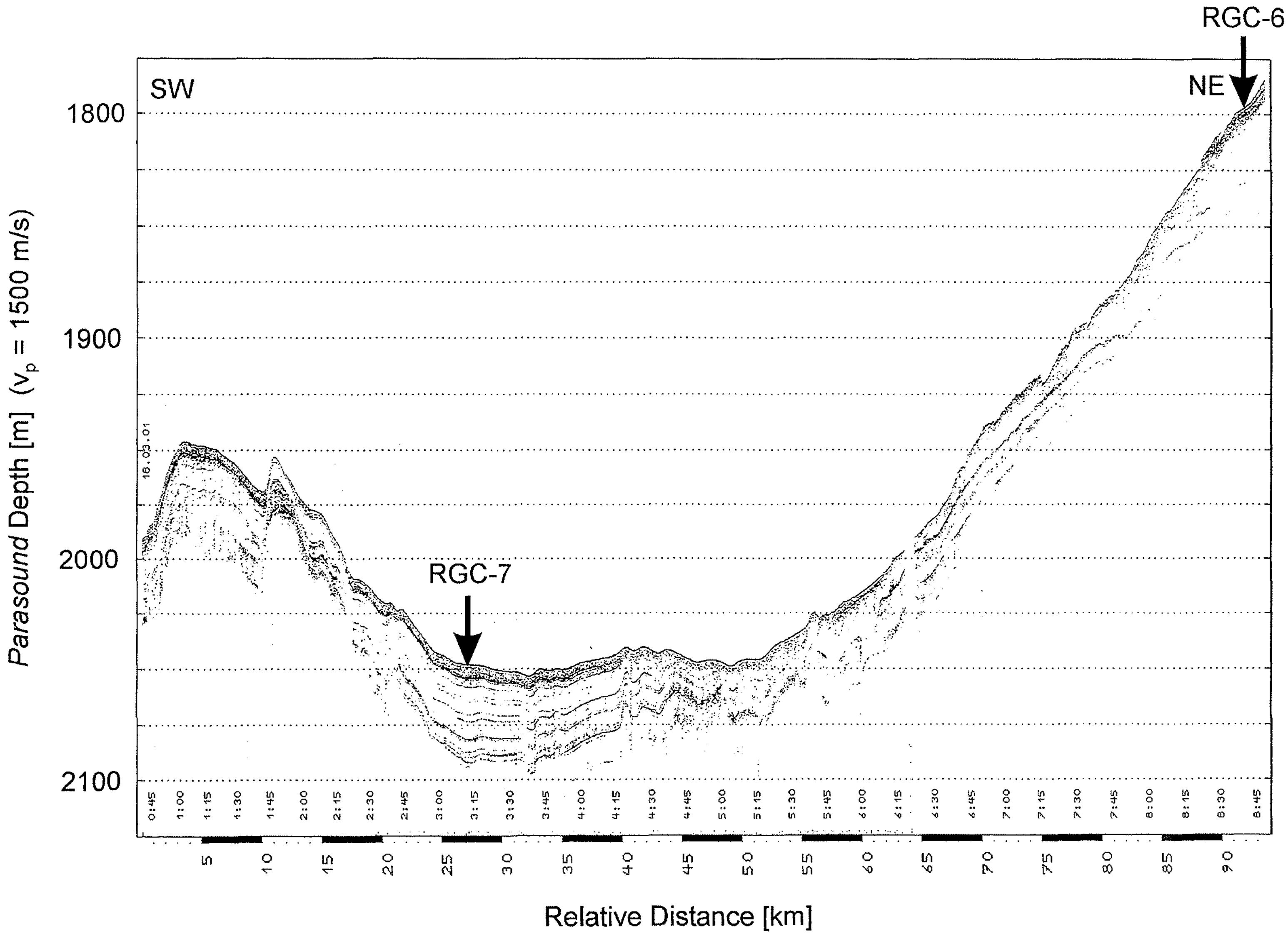


Figure 20 *Parasound* record along line GeoB 01-173 across Sites RGC-6 and RGC-7. Note that the orientation is opposite to the seismic line (Fig. 19).

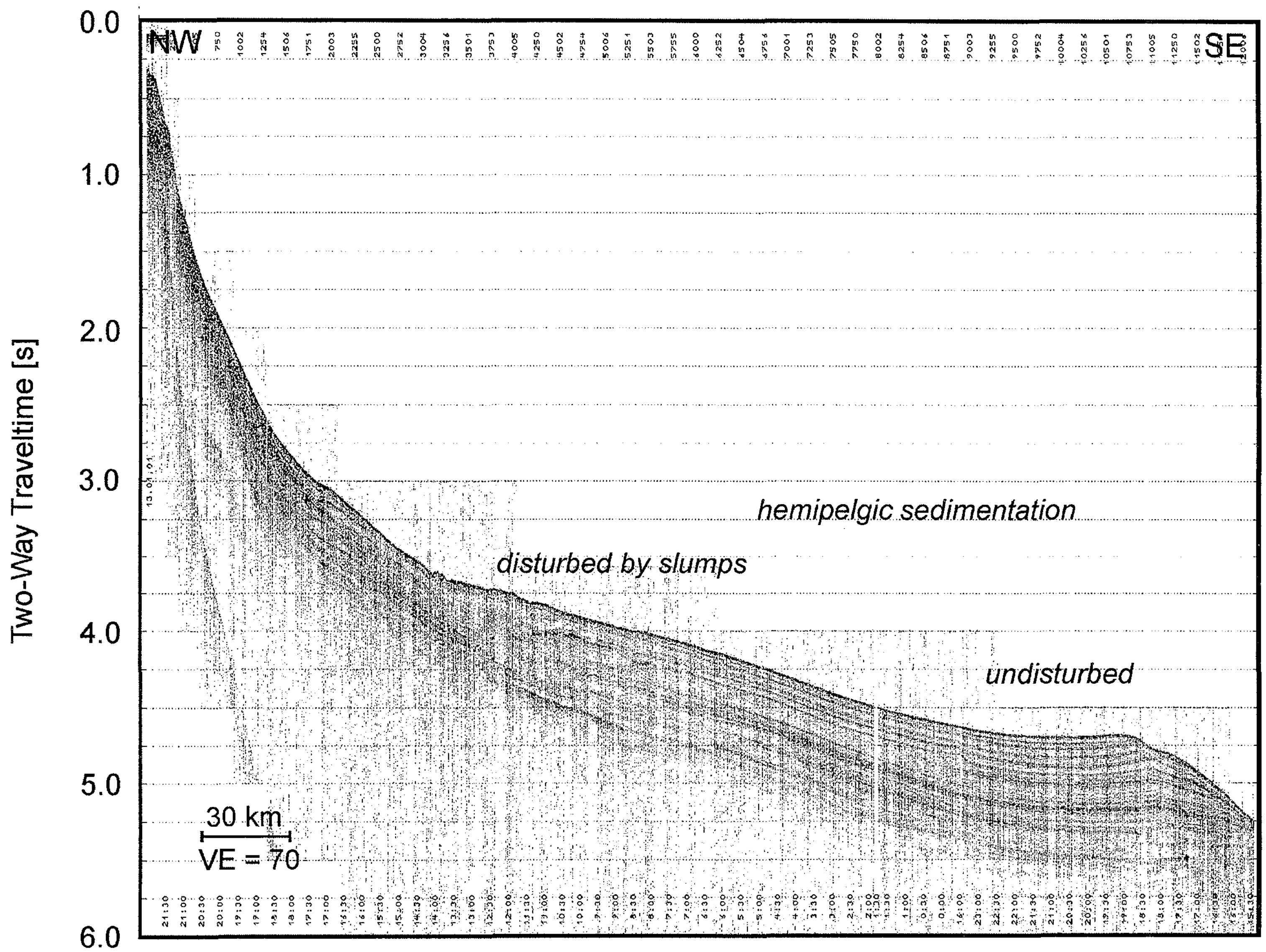


Figure 21 Multichannel seismic line GeoB 01-161 recorded on the northern foothills of the Rio Grande Cone.

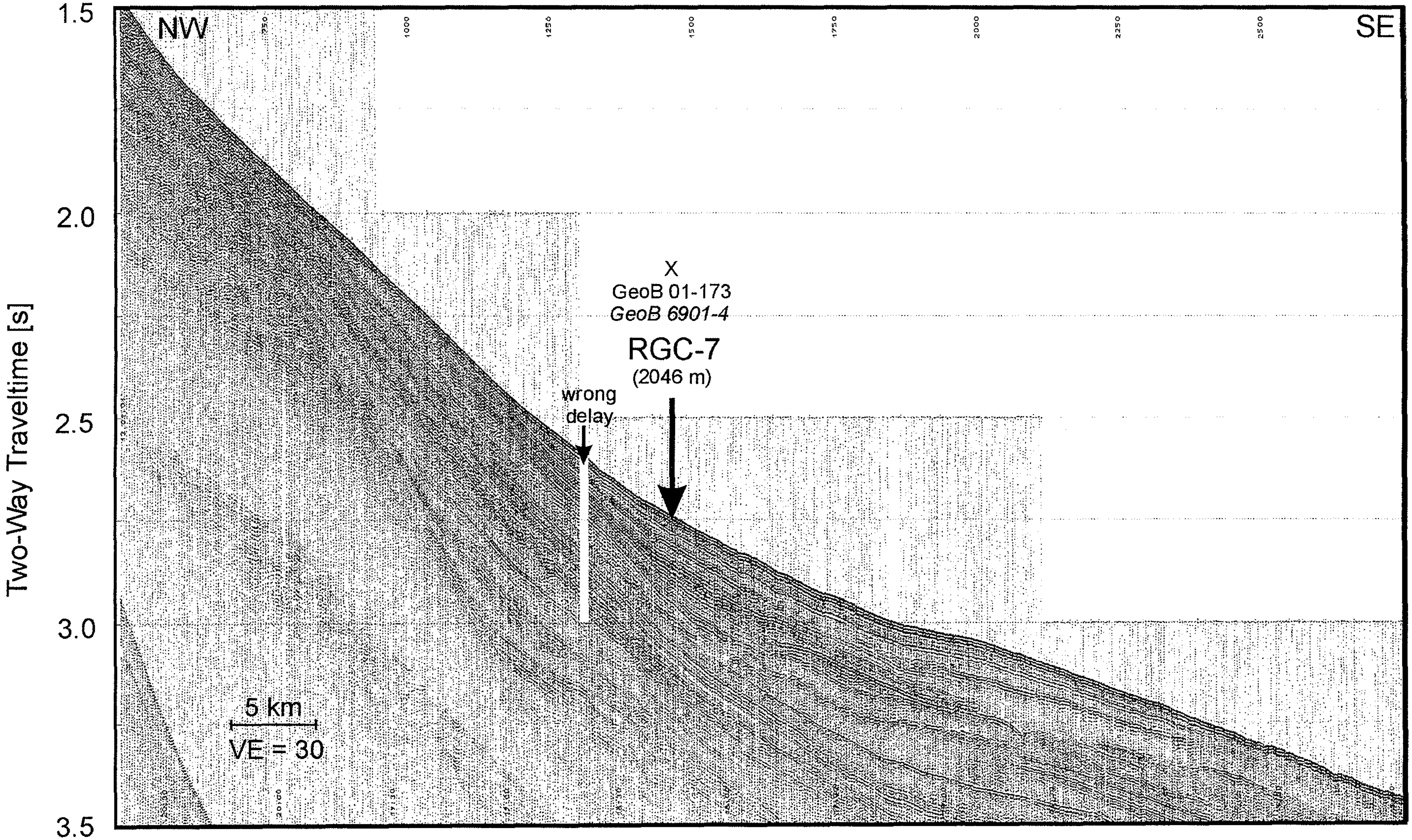


Figure 22 Section of multichannel seismic line GeoB 01-161 across Site RGC-7 with gravity core position GeoB 6901-4. The intersection with line GeoB 01-173 is marked by a cross.

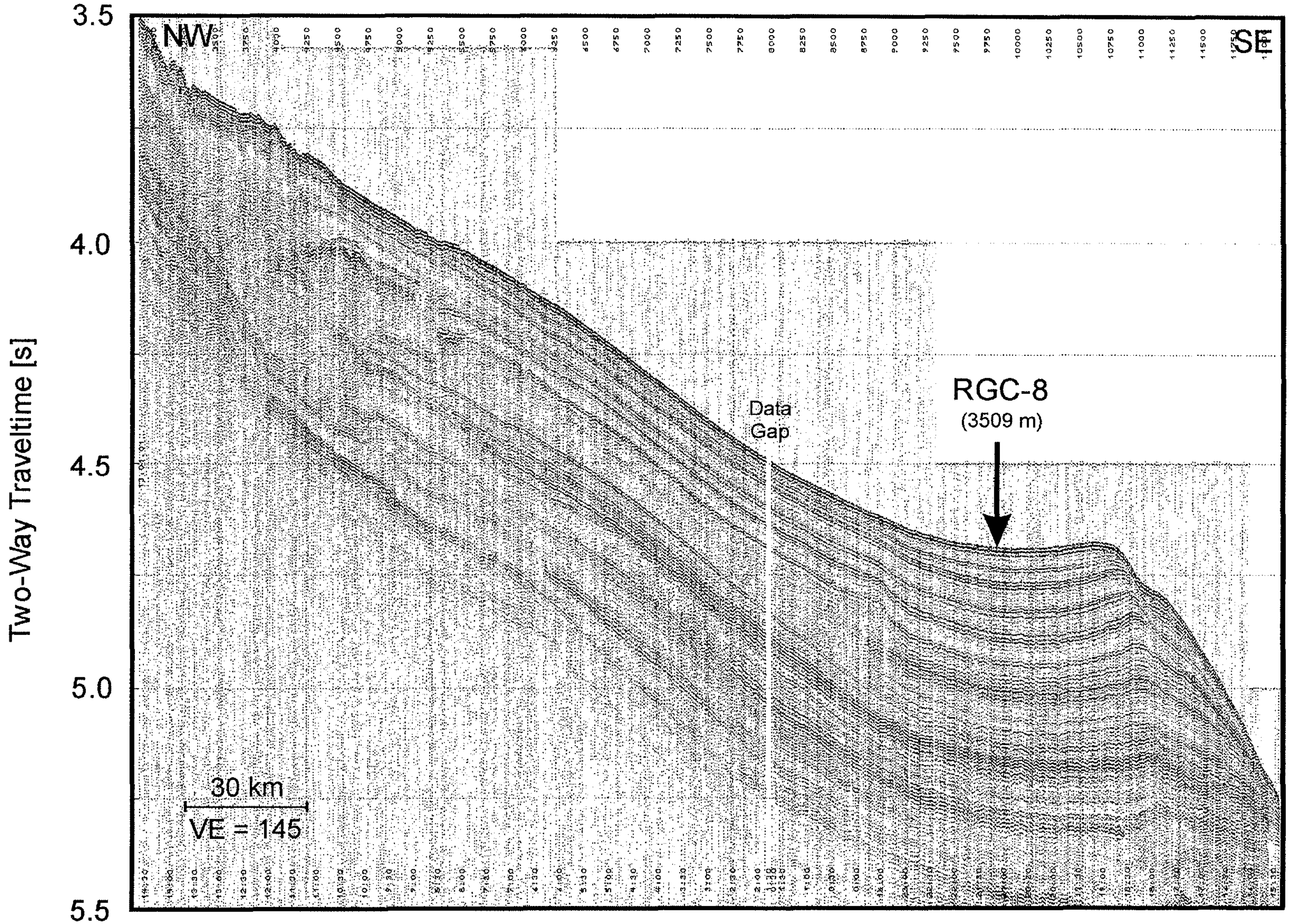


Figure 23 Section of multichannel seismic line GeoB 01-161 across Site RGC-8.

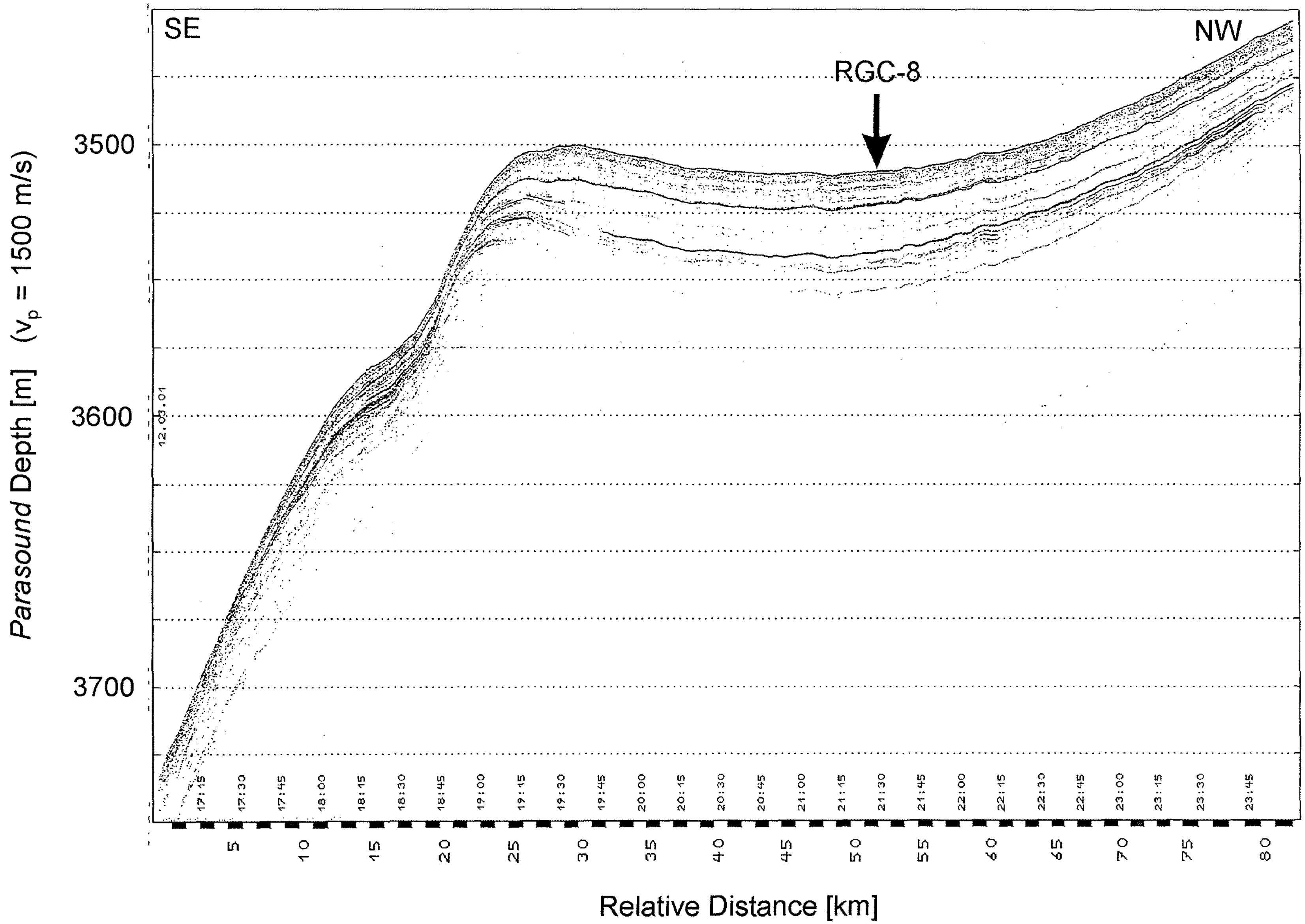


Figure 24 *Parasound* record along line GeoB 01-161 across Site RGC-8. Note that the orientation is opposite to the seismic line (Fig. 23).

TWT (about 750 m) thick hemipelagic sequence at the end of line GeoB 01-161 before sedimentation rates are significantly reduced and/or reflectors are erosionally truncated (Fig. 23). Here, it should be possible to extend the results of Site RGC-5 to greater depth. The corresponding *Parasound* record reveals undisturbed distinct parallel reflections as well and reaches a signal penetration of about 50 m (Fig. 24).

Gravity cores GeoB 6901-4 and GeoB 6907-4 recovered at or close to the proposed drilling Sites RGC-6 and RGC-7 have similar sediment compositions as cores GeoB 6902-1 and GeoB 6906-1 (cf. Chapter 4.2). Stratigraphic investigations based on shipboard measurements of color reflectance led to identical preliminary age estimates and average sedimentation rate for core GeoB 6901-4 as for core GeoB 6902-1, i.e. an age of more than 70 ka at the base of core GeoB 6901-4 (8 m core length) and a sedimentation rate exceeding 90 m/Myr for the uppermost sediment column.

4.1.6 Central Brazilian Continental Margin (Survey Area E)

4.1.6.1 Geologic Setting and Site Survey Strategy

Survey Area E is located on the São Paulo Plateau off central Brazil between 24°30' - 29°00'S and 41° - 45°W. The regional morphology is strongly influenced by an extensive salt tectonism. Salt diapirs are generally topped by a thin hemipelagic sediment cover, in places they reach the sea floor. This salt diapir field developed during the early Aptian - Albian rift phase of the South Atlantic from a rift basin filled with evaporites together with the conjugate Angola diapir field off Africa. Its southern boundary lies at about 28°S north of the São Paulo Ridge, in the east it ends between about 38 and 40°W. Due to the greater distance to the Rio de la Plata river mouth, the amount of suspended terrigenous material deposited on the São Paulo Plateau is further reduced compared to working area D and biogenic components predominate the sediment composition. Former seismic studies in the vicinity of DSDP Sites 515 - 518 in the adjacent Brazil Basin and on the Rio Grande Rise have revealed significant bottom current control on the depositional pattern, particularly in the Brazil Basin (*Gamboa et al.*, 1983). Four unconformities were identified in seismic records, among others a major hiatus at the Eocene/Oligocene boundary associated with the onset of Antarctic Bottom Water flow. Wavy reflections of different wavelength characterize the sedimentary units between these unconformities indicating a prolonged interaction between bottom currents and sediment deposition. A similar, probably reduced influence of bottom or contour currents was also expected for the São Paulo Plateau, although the focussing effect of the Vema Channel is absent here.

The site survey strategy in working area E orientated on the few low-frequency seismic profiles published with the results of DSDP Leg 39 (*Kumar et al.*, 1977). Using this sparse information, our first two long seismic transects over the São Paulo Plateau, acquired to provide a general overview of the depositional regime, have been arranged to encounter sediment deposits which seemed least disturbed by underlying salt diapirs. Potential drilling targets were selected on these two profiles and then further surveyed with a dense grid of crossing lines in order to map out the regional extent of prominent reflectors and diapir structures. At first, DSDP Site 356 on the São Paulo Ridge (*Kumar et al.*, 1977) was crossed, hoping that its seismostratigraphic division could be traced onto the São Paulo Plateau.

4.1.6.2 Preliminary Results, Stratigraphy and Proposed Drill Sites

Figure 25 shows the track chart of R/V METEOR Cruise M49/3 in survey area E, Figure 26 a blow-up of the detailed survey grid on the salt diapir field.

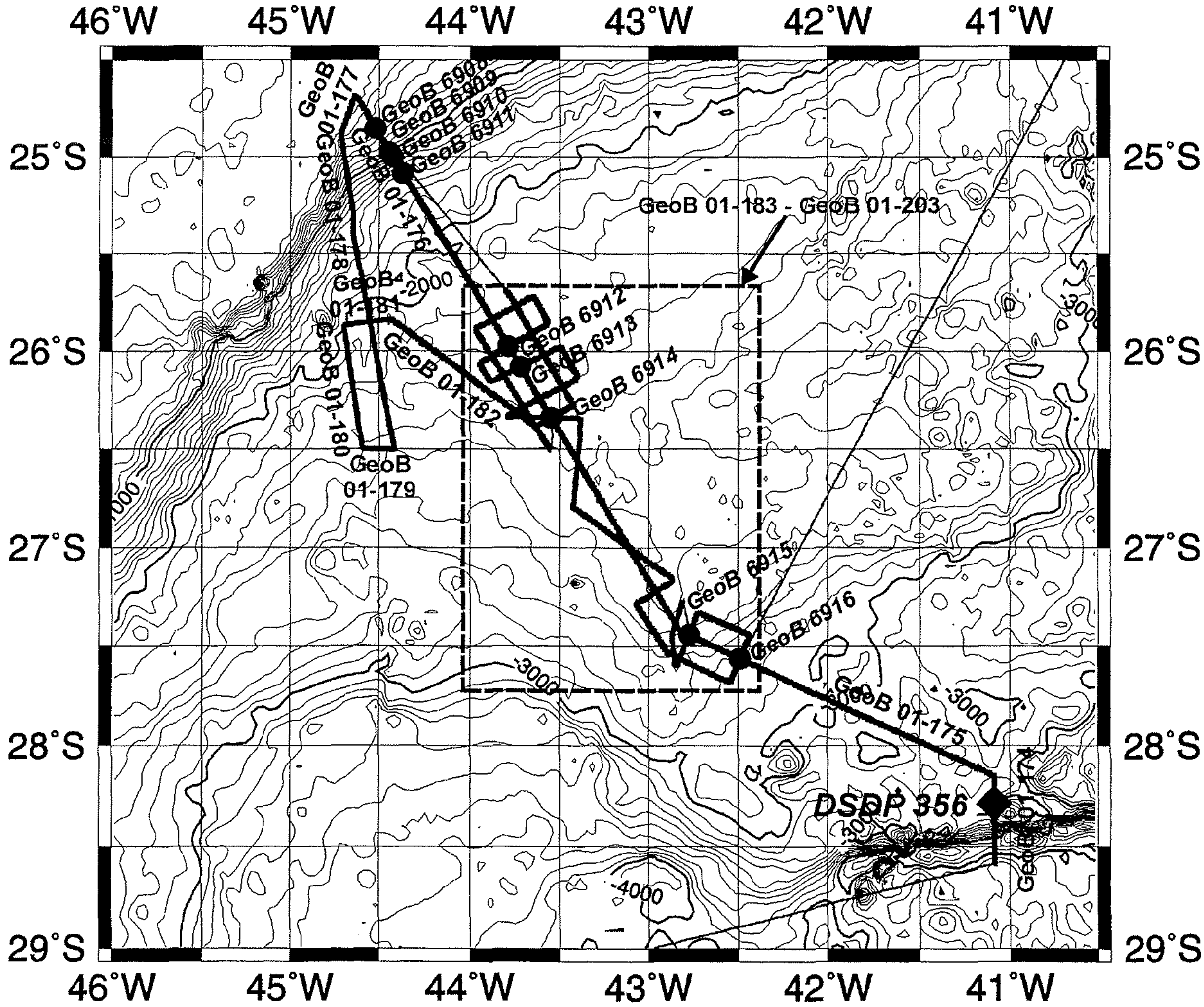


Figure 25 Track chart of R/V METEOR Cruise M49/3 on the central Brazilian continental margin / São Paulo Plateau (Survey Area E) showing seismic profiles (thick lines with annotation) and gravity core positions (dots with italic annotation).

The first seismic line GeoB 01-174 crossed DSDP Site 356 on São Paulo Ridge. Unfortunately, this site was actually located on the relatively steep flank of a basement structure, where the sedimentary cover showed no clearly traceable reflectors, so that stratigraphic information available from the drill core could be identified and transferred to the São Paulo Plateau.

Figure 27 displays the brute stack of GI-Gun data collected along line GeoB 01-176 as a first regional overview. The continental slope reveals dense, undulating, subparallel reflections. In about 0.8 - 0.9 s TWT (about 600 - 700 m water depth) an approximately 10 km long, 200 m high rough structure was encountered which we tentatively interpreted as subsided reef. The morphology of the continental rise is dominated by salt diapir structures. Namely in the southeastern parts and less pronounced also in the northwestern parts, they reach the sea floor and form topographic elevations with small basins in between. While the southeastern basins are

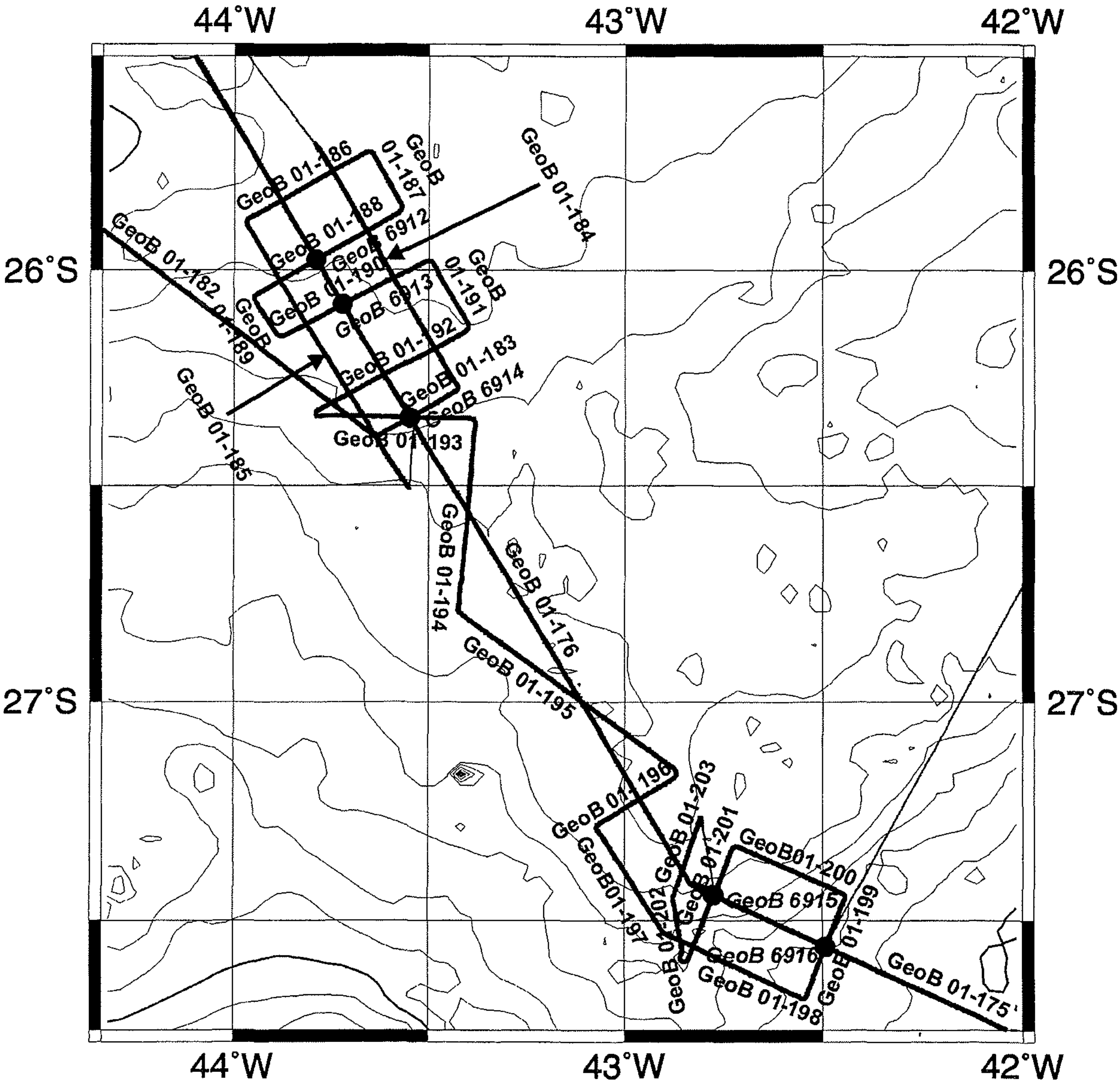


Figure 26 Detailed Track chart in the salt diapir area on the São Paulo Plateau showing seismic profiles (thick lines with annotation) and gravity core positions (dots with italic annotation).

filled with well stratified hemipelagic sediments, thick slump and turbidite deposits accumulated in the northeastern basins. In the central part of the profile the salt diapirs are covered by an about 0.5 s TWT (about 375 m) thick hemipelagic sequence with distinct, parallel, slightly undulating sub-bottom reflectors. This area appeared most promising for potential drilling targets and a close grid of crossing lines was acquired here.

The first three drilling locations SPP-1 to SPP-3, however, are proposed on the continental slope in 500 to 1600 m water depth upslope and downslope of the subsided reef in an about 0.5 - 0.6 s TWT (about 375 - 450 m) thick, parallel bedded sequence which might be slightly disturbed in 0.2 - 0.3 s TWT depth below Sites SPP-2 and SPP-3 (Fig. 28). From the sediments of these sites the shallow to intermediate water paleoceanographic history of this region shall be reconstructed. Also the *Parasound* record shows undisturbed, parallel bedded layers at these sites (Fig. 29). Gravity cores GeoB 6908-4 to GeoB 6911-1 recovered at or close to Sites SPP-1

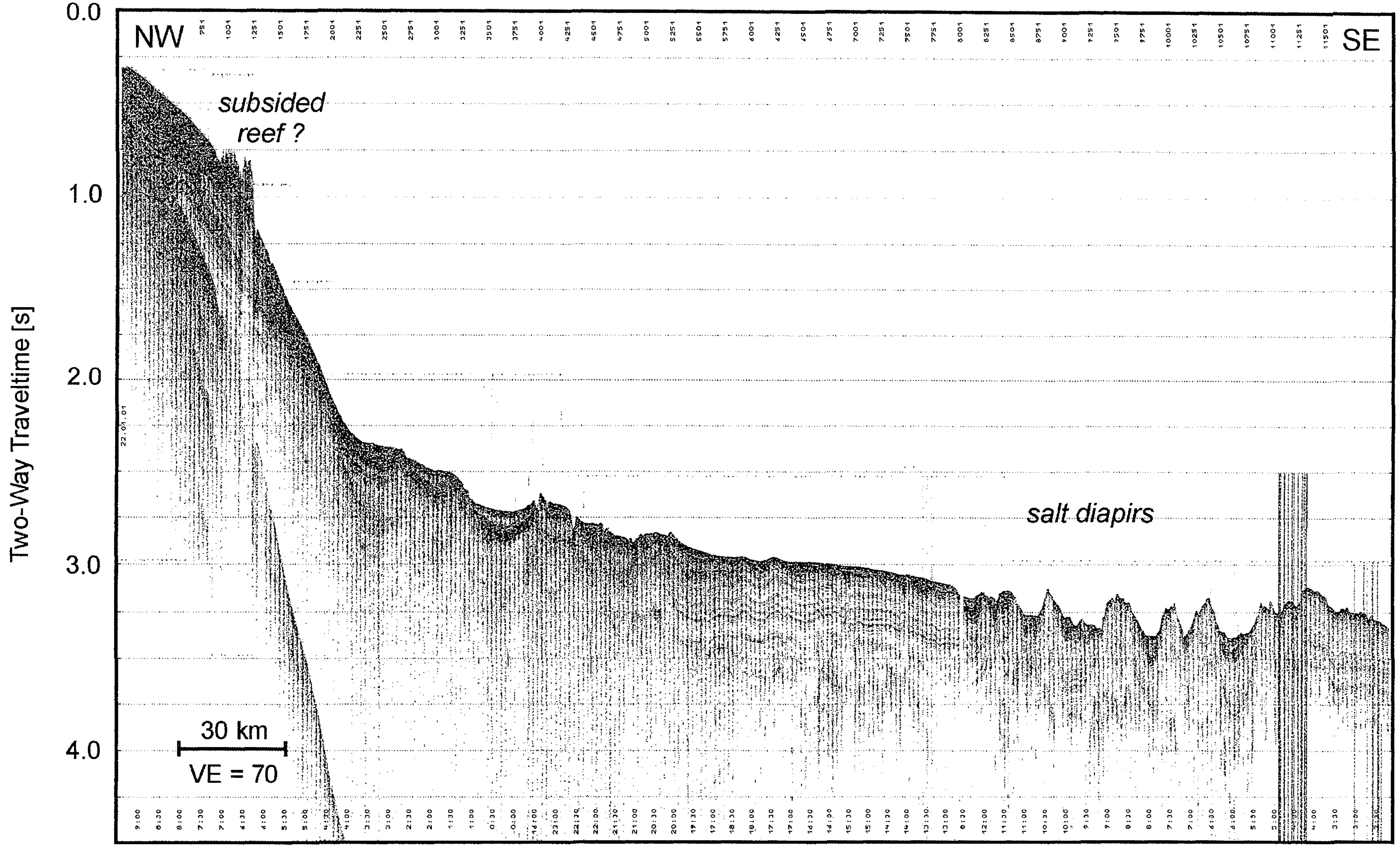


Figure 27 Multichannel seismic line GeoB0 1-176 across the salt diapir area on the São Paulo Plateau.

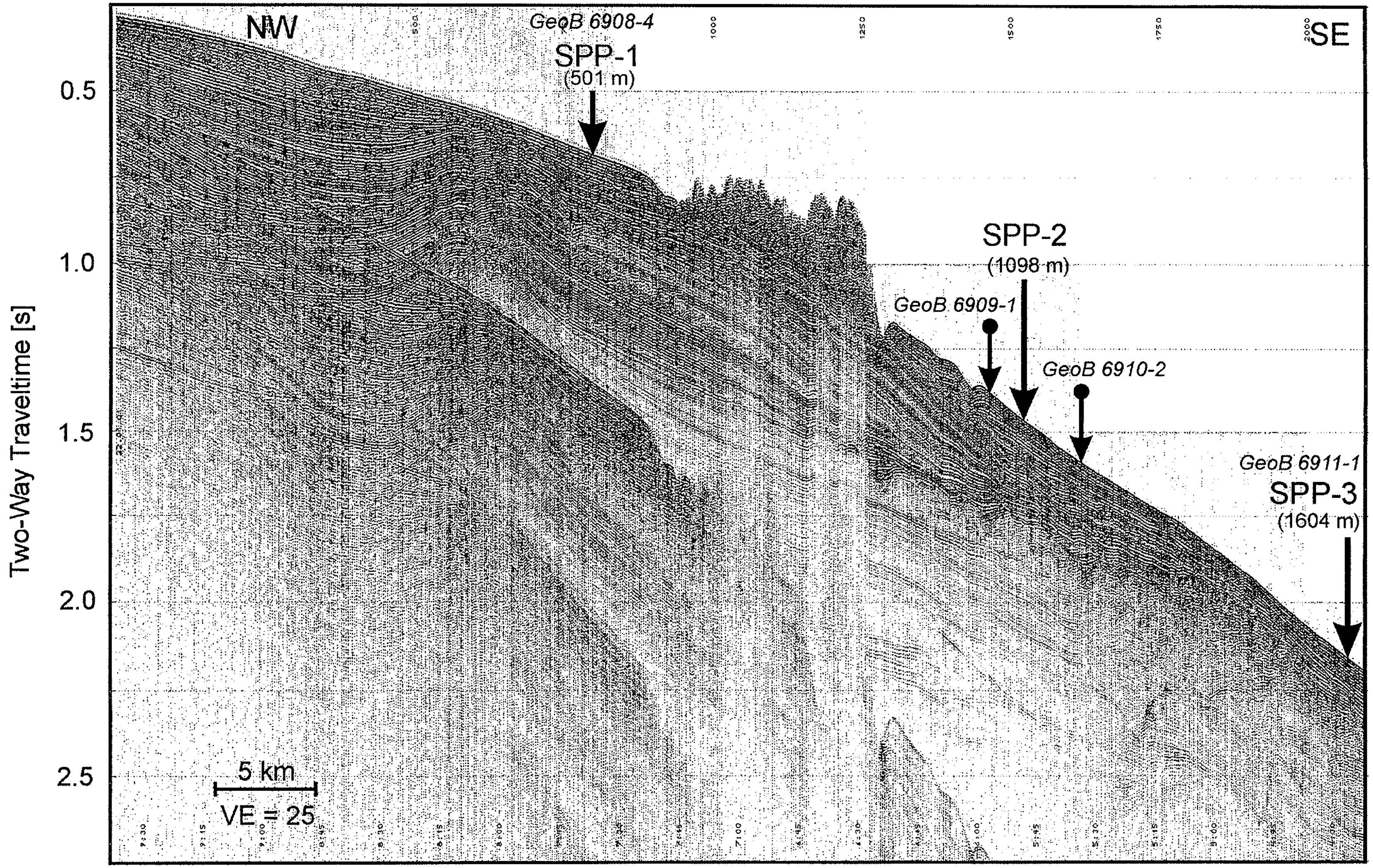


Figure 28 Section of multichannel seismic line GeoB 01-176 across Sites SPP-1, SPP-2 and SPP-3 with gravity core positions GeoB 6908-4 to GeoB 6911-1 on the upper continental slope of the São Paulo Plateau. The elevated rough structure between Sites SPP-1 and SPP-2 is interpreted as a subsided reef.

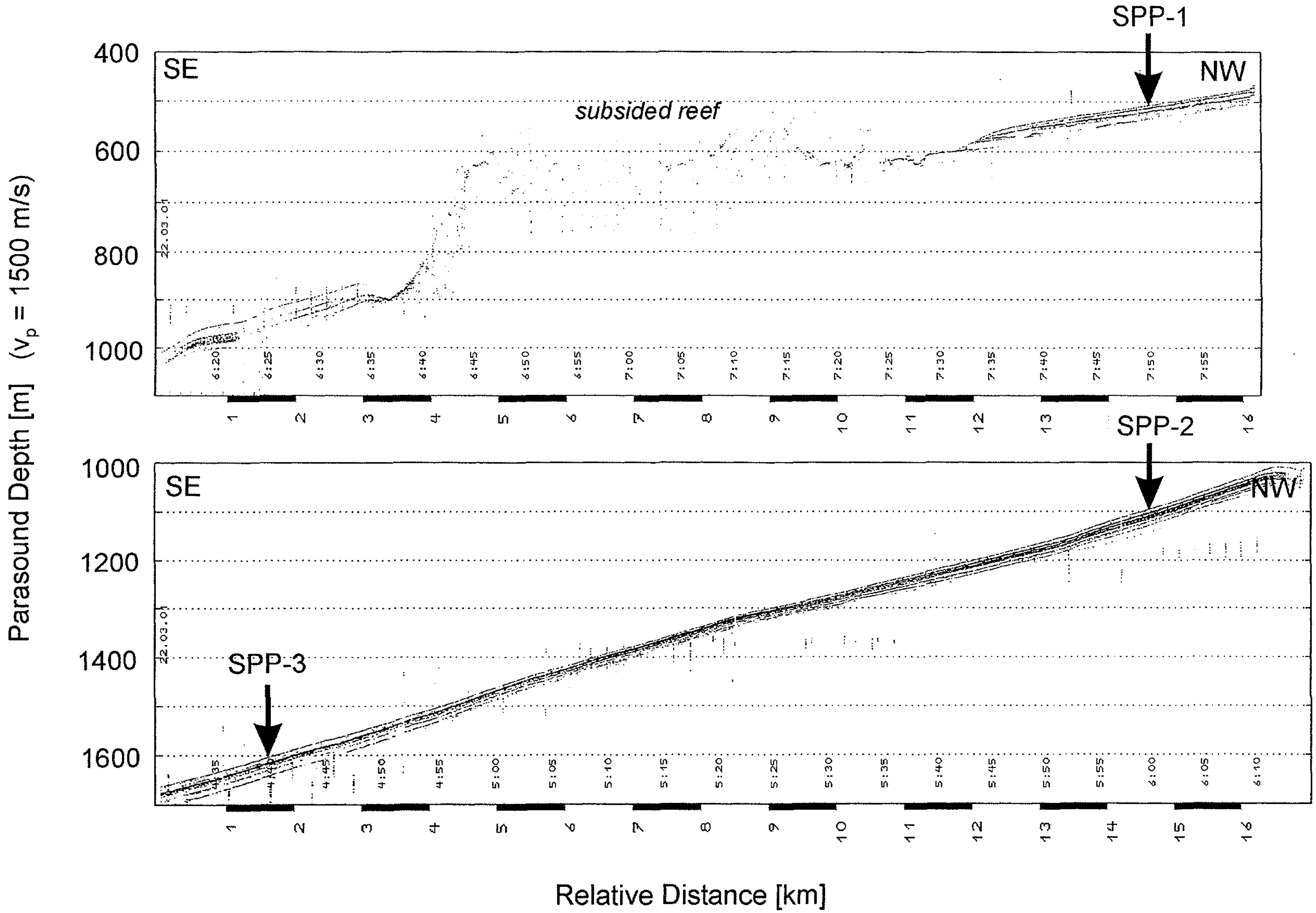


Figure 29 *Parasound* record along line GeoB 01-176 across Sites SPP-1, SPP-2 and SPP-3 with the subsided reef in the upper part. Note that the orientation is opposite to the seismic line (Fig. 28).

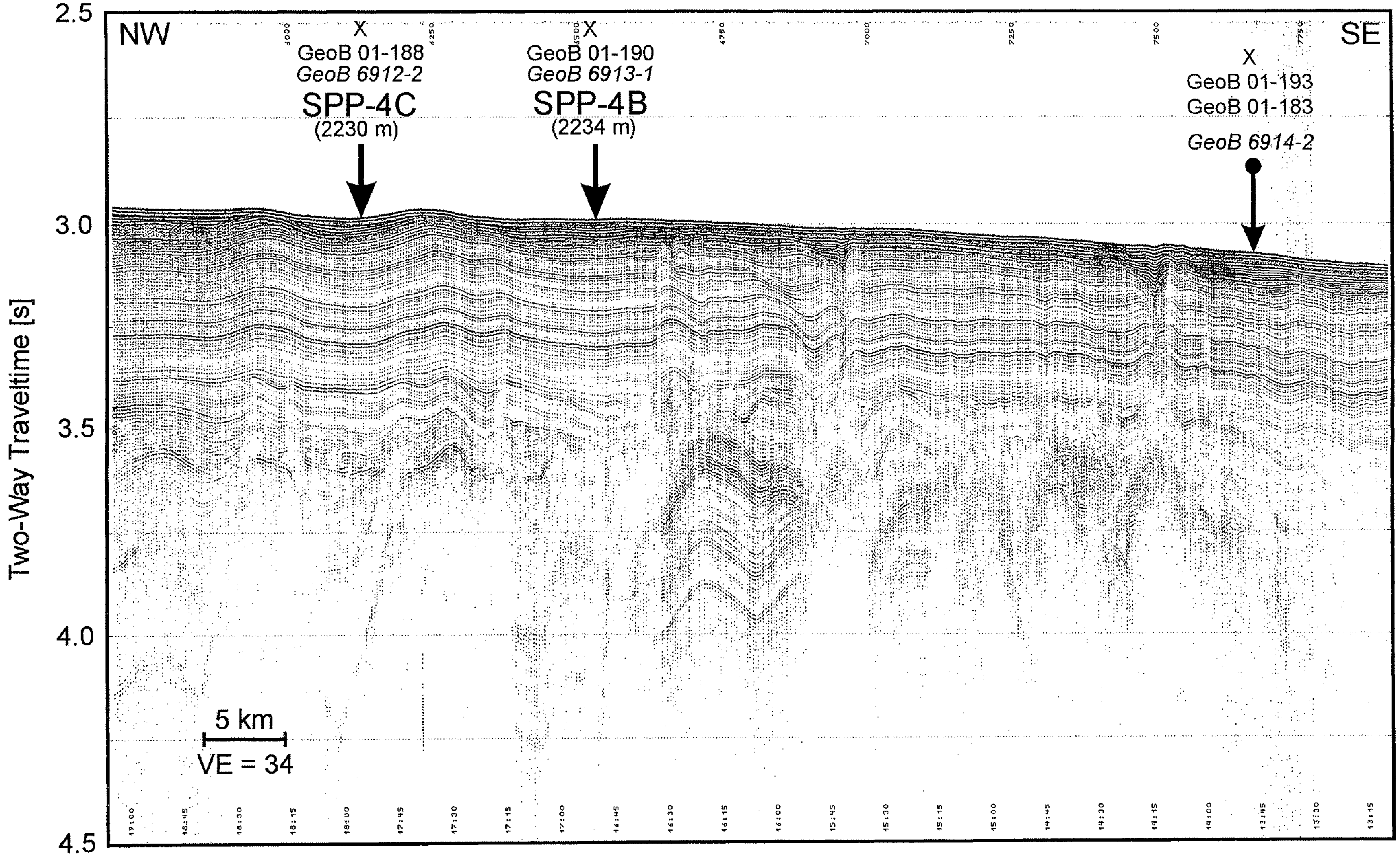


Figure 30 Section of multichannel seismic line GeoB 01-176 across Sites SPP-4B and SPP-4C with gravity core positions GeoB 6912-2 to GeoB 6914-2 in the salt diapir area of the São Paulo Plateau. The intersections with lines GeoB 01-188, GeoB 01-190 and GeoB 01-193 are marked by crosses.

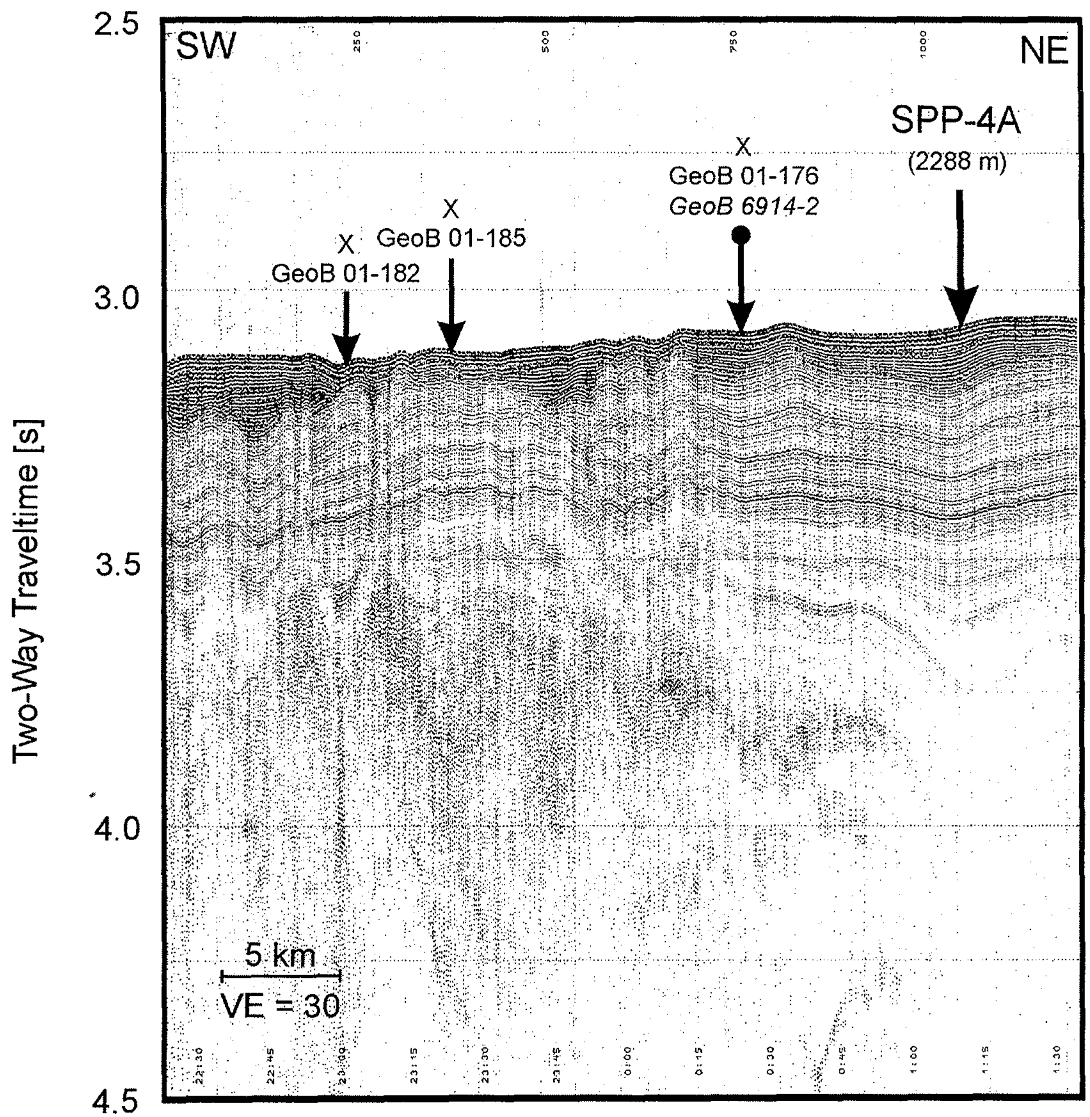


Figure 31 Multichannel seismic line GeoB 01-193 across Site SPP-4A with gravity core position GeoB 6914-2. The intersections with lines GeoB 01-176, GeoB 01-182 and GeoB 01-185 are marked by crosses.

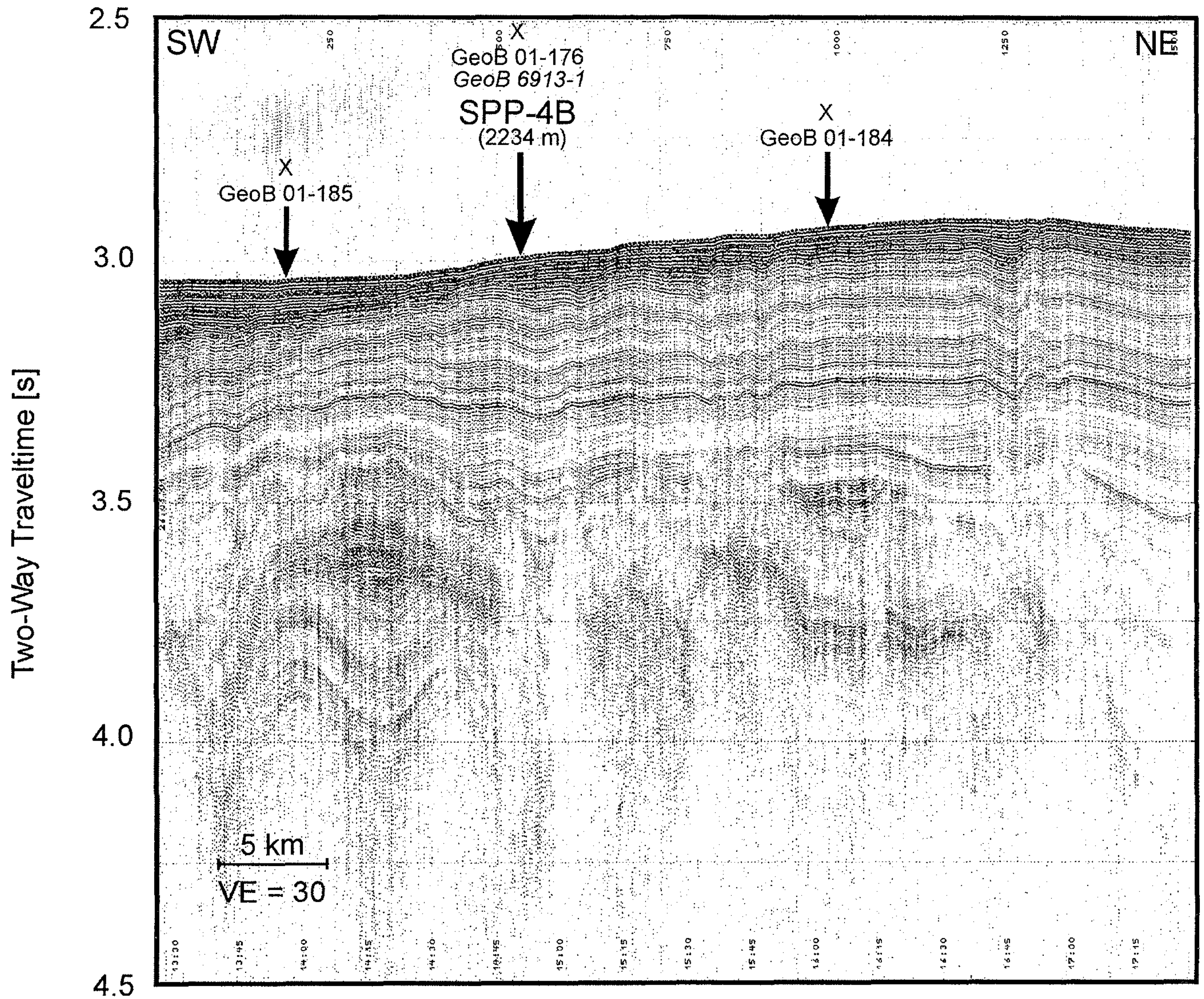


Figure 32 Multichannel seismic line GeoB 01-190 across Site SPP-4B with gravity core position GeoB 6913-1. Line GeoB 01-190 is crossing line GeoB 01-176 to Site SPP-4B. Intersections with lines GeoB 01-184 and GeoB 01-185 are also marked by a crosses.

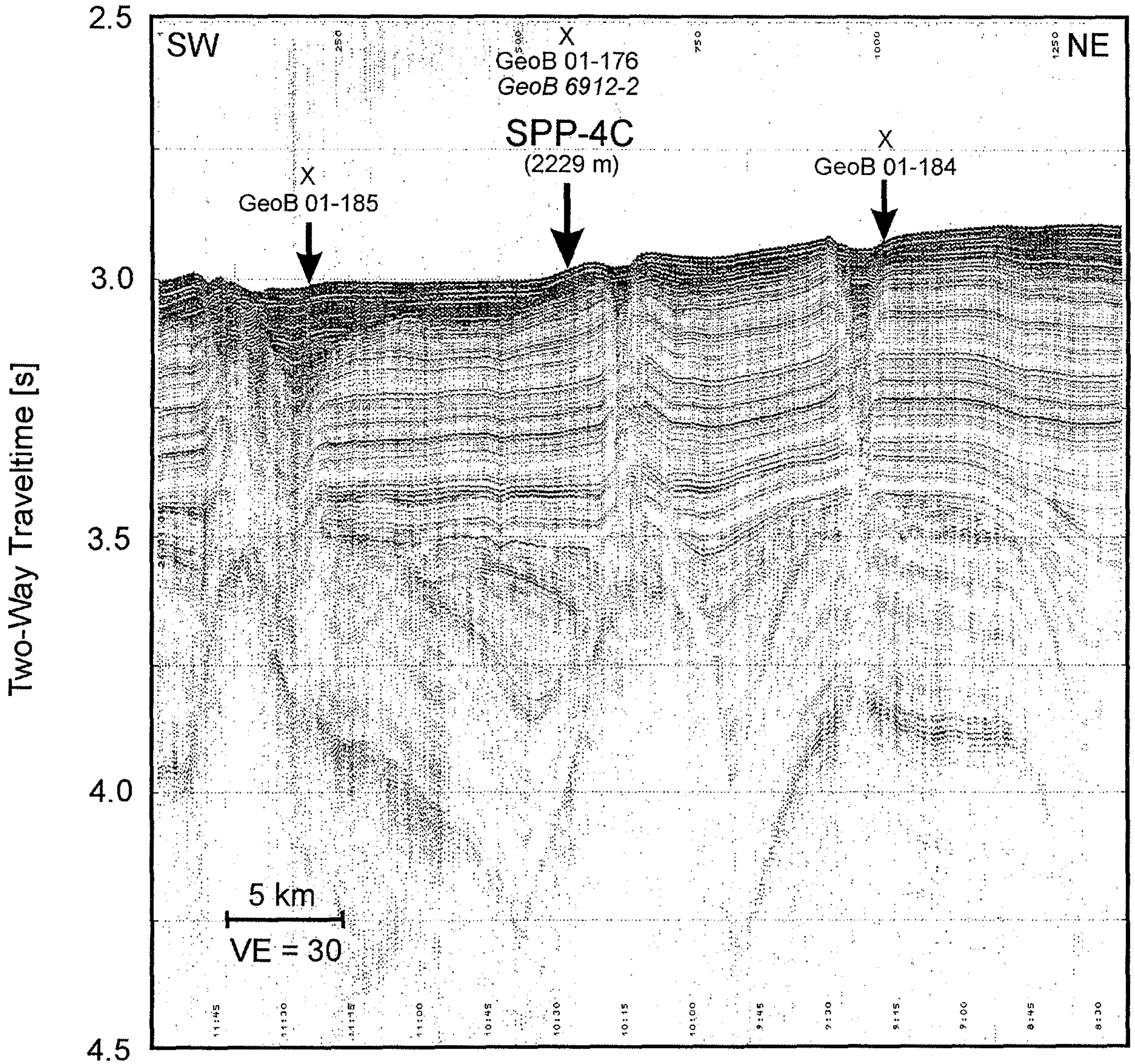


Figure 33 Multichannel seismic line GeoB 01-188 across Site SPP-4C with gravity core position GeoB 6912-2. Line GeoB01-188 is crossing line GeoB 01-176 to Site SPP-4C. Intersections with lines GeoB 01-184 and GeoB 01-185 are also marked by crosses.

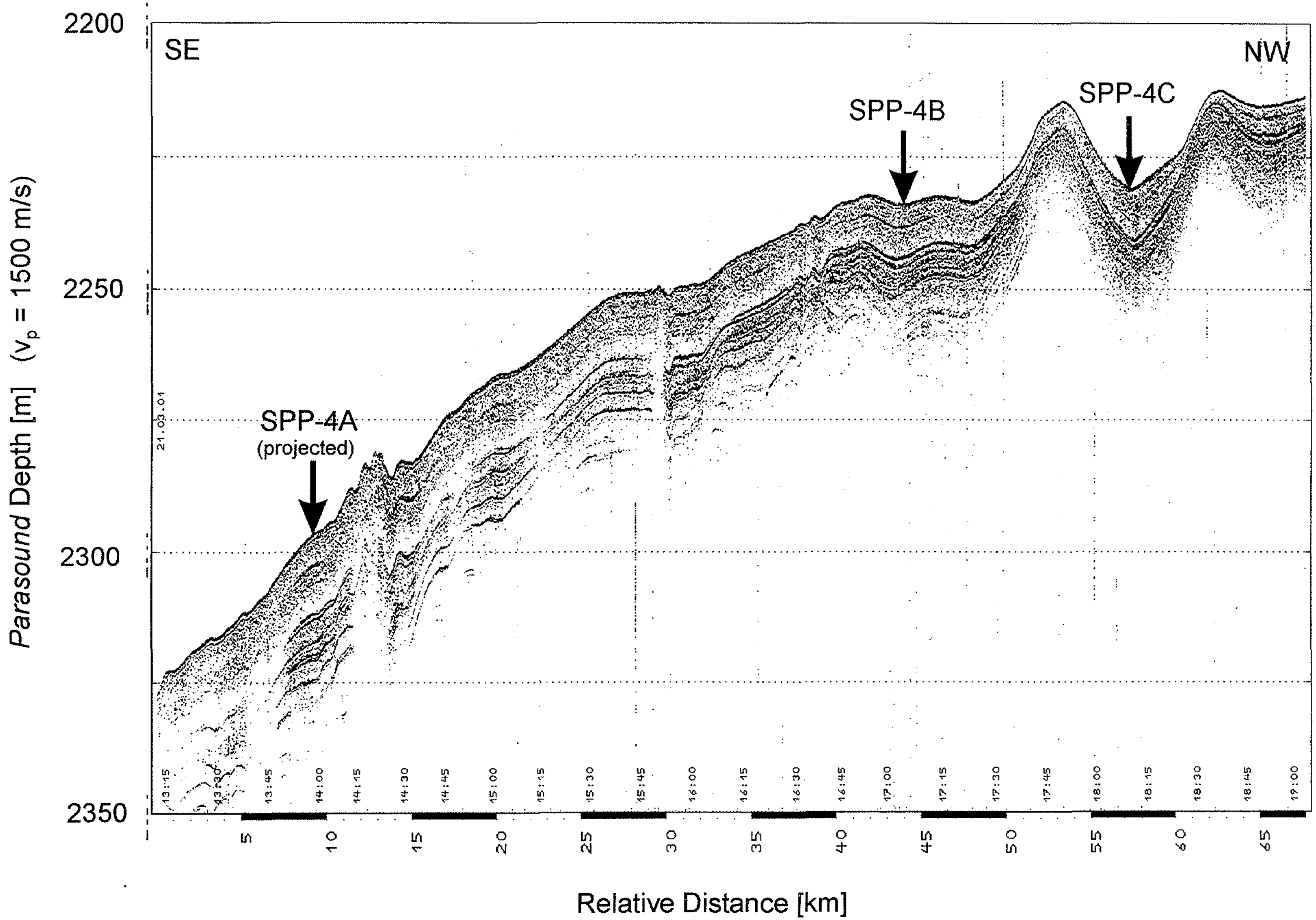


Figure 34 *Parasound* record along line GeoB 01-176 across Site SPP-4A (projected from line GeoB 01-193), Site SPP-4B and Site SPP-4C. Note that the orientation is opposite to the seismic line (Fig. 30).

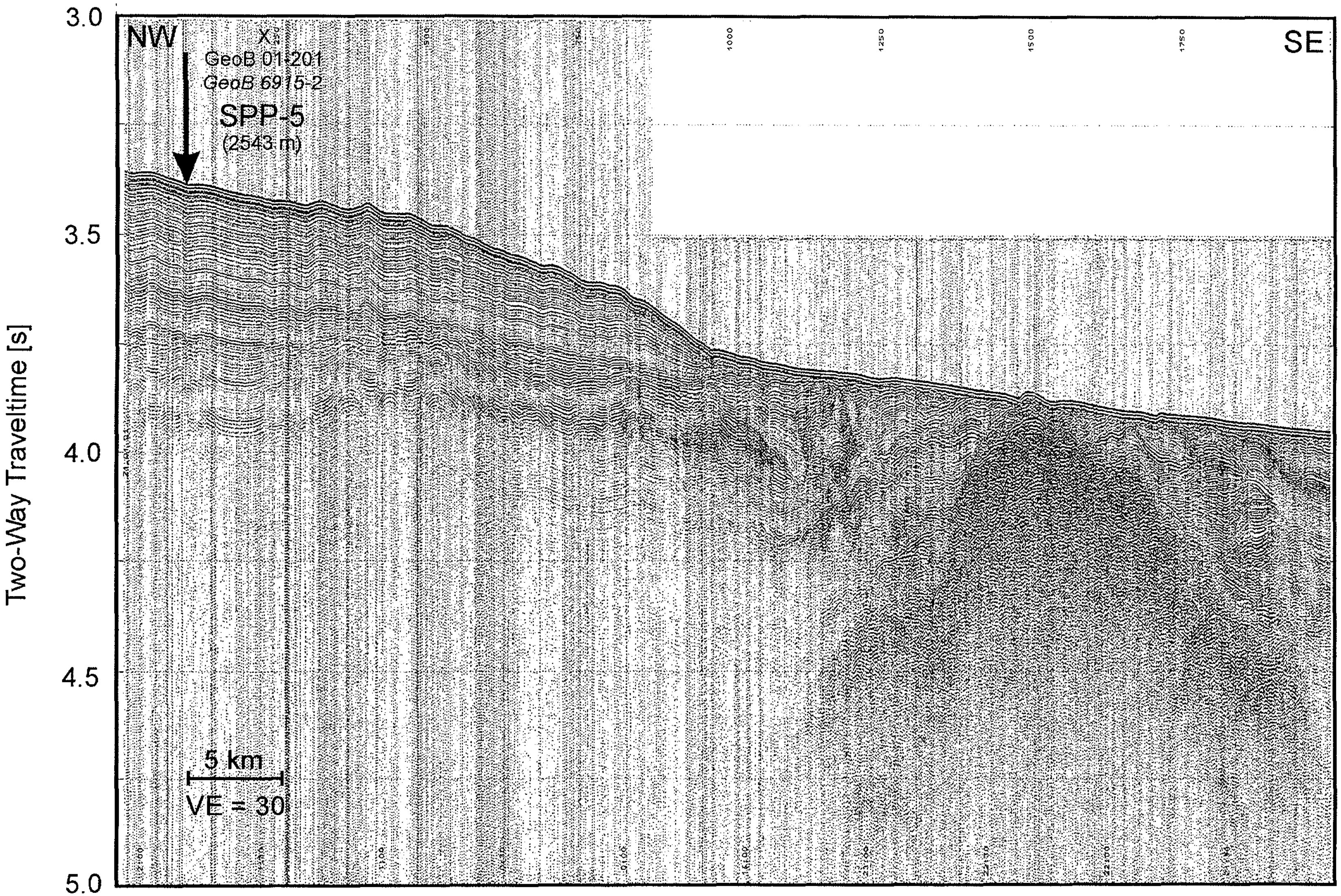


Figure 35 Multichannel seismic line GeoB 01-175 across Site SPP-5 with gravity core position GeoB 6915-2. The intersection with line GeoB 01-201 is marked by a cross.

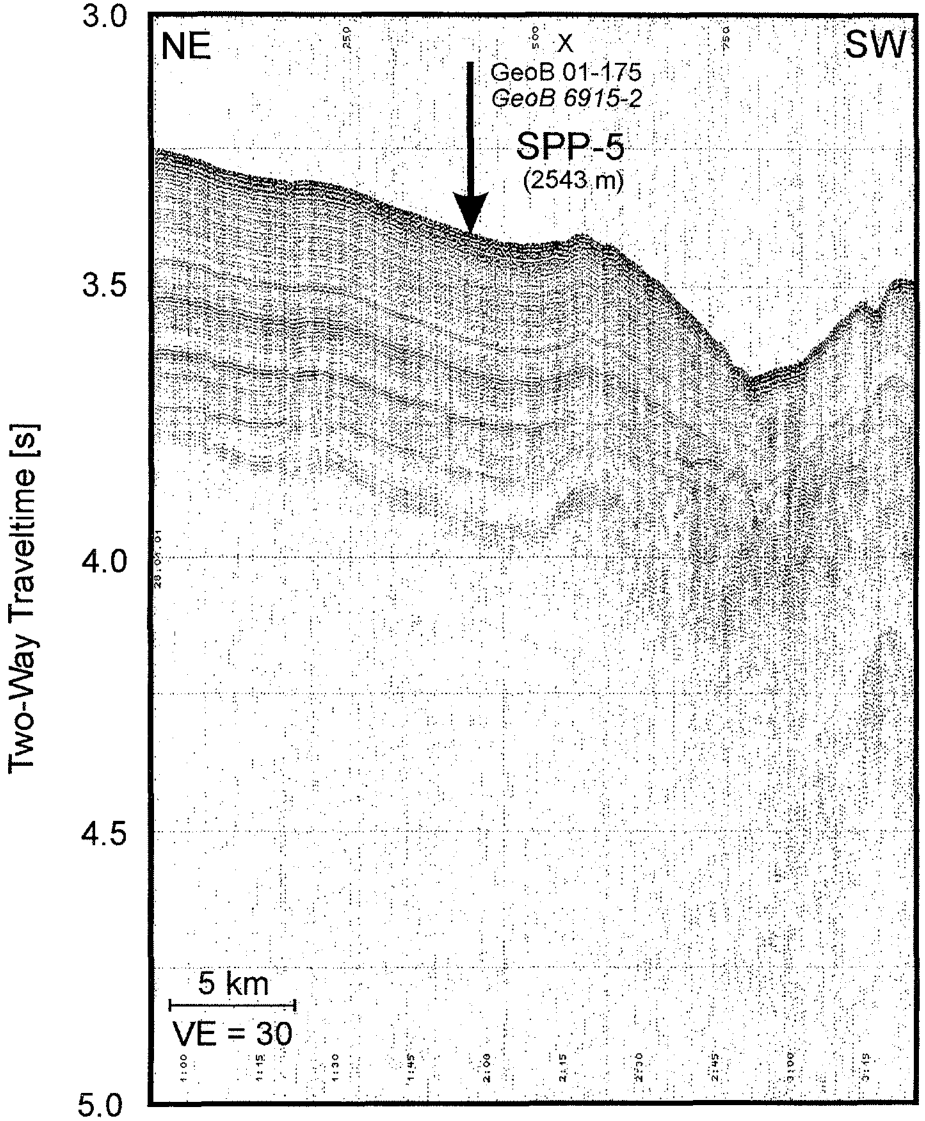


Figure 36 Multichannel seismic line GeoB 01-201 across Site SPP-5 with gravity core position GeoB 6915-2. Seismic line GeoB 01-201 is crossing line GeoB 01-175 to Site SPP-5. The intersection is marked by a cross.

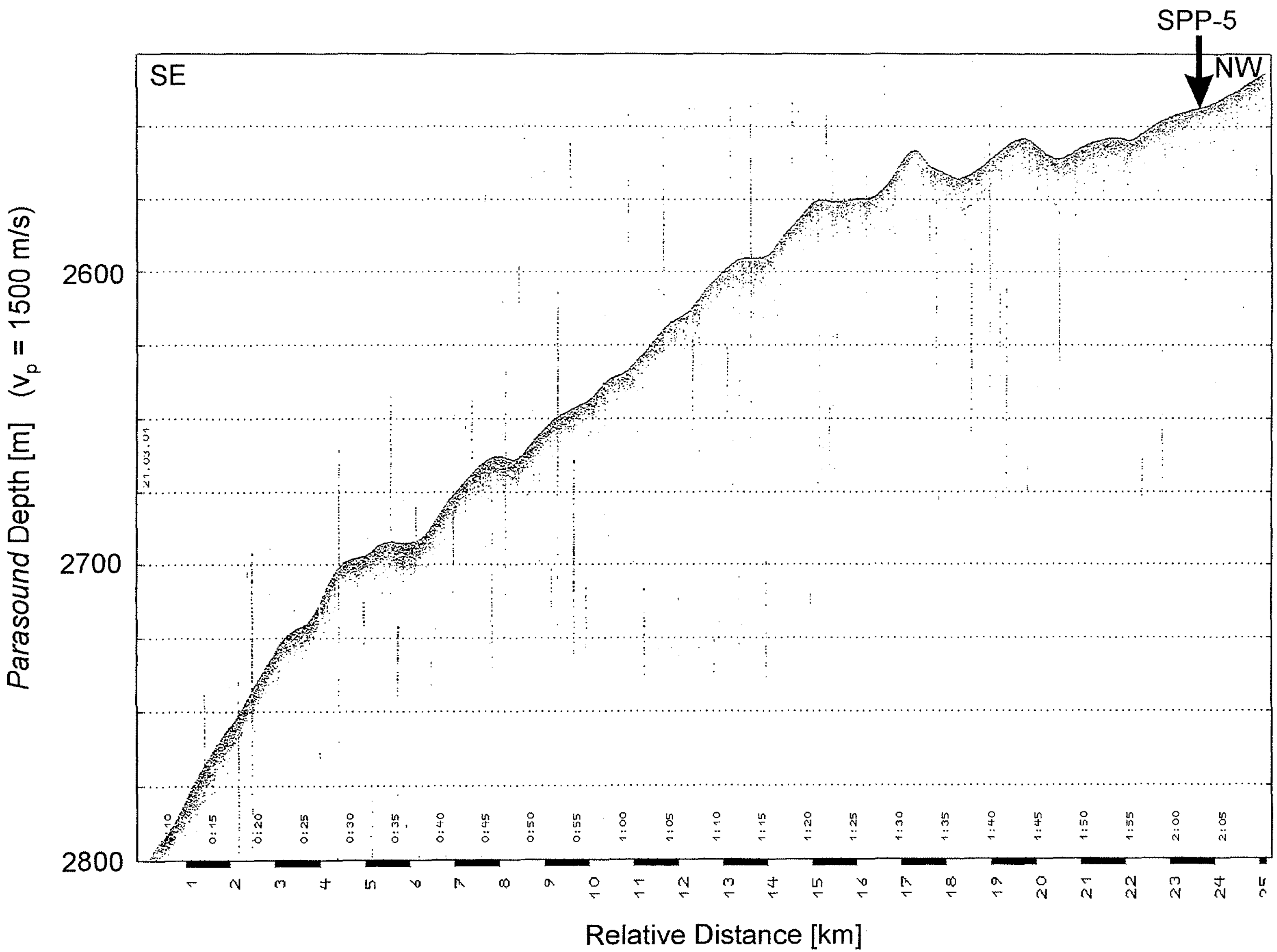


Figure 37 *Parasound* record along line GeoB 01-175 across Site SPP-5. Note that the orientation is opposite to the seismic line (Fig. 35).

to SPP-3 are mainly composed of nannofossil ooze (Chapter 4.2). Cores GeoB 6909-1 to 6911-1 appear to reach isotope stage 6 at their base (core lengths between 6.90 and 7.77 m). Inferred ages between 128 and 186 ka lead to preliminary average sedimentation rate estimates of 40 - 60 m/Myr for the uppermost sediment column.

Due to the complexity of the salt diapir structures two alternate Sites SPP-4B and SPP-4C are proposed in addition to Site SPP-4A on line GeoB 01-176 and on crossing lines GeoB 01-193, GeoB 01-190 and GeoB 01-188 in about 2200 m water depth (Figs. 30 to 33). Site SPP-4A was moved from line GeoB 01-176 about 8 km to the northeast along crossing line GeoB 01-193 to avoid problems with folded sediments close to the intersection (Fig. 31). Depending on sedimentation rates, one of these sites is intended to drill an undisturbed sequence of Holocene to Pliocene or Miocene sediments.

The parallel bedded about 375 m thick sediment sequence overlies a possibly erosional hiatus which separates the hemipelagic cover from the top of the salt diapir structures. This unconformity is best recognized in the seismogram section of line GeoB 01-188 (Fig. 33). Within the hemipelagic cover, at least two seismostratigraphic units can be identified. The upper strongly reflecting unit has an average thickness of about 0.1 s TWT (about 75 m) and shows some indications of current control, particularly in small depressions, e.g. close to Sites SPP-4B and SPP-4C (Fig. 30). The second unit beneath is about 0.4 s TWT (about 300 m) thick and characterized by less dense, weaker reflections.

The *Parasound* record along line GeoB 01-176 displays undisturbed sediment series with distinct, almost parallel sub-bottom reflectors. Signal penetration reaches about 60 m (Fig. 34).

The gravity cores GeoB 6912-2 to GeoB 6914-2 recovered at or close to Sites SPP-4A to SPP-4C are again mainly composed of nannofossil ooze. Cores GeoB 6912-2 and GeoB 6913-1 contain several thin turbidites at the top (Chapter 4.2). According to preliminary age estimates, core GeoB 6914-1 should reach isotope stage 7.3 at its base (6.75 m core length) resulting in a preliminary average sedimentation rate of about 30 m/Myr for the uppermost sediment column. Extrapolation to greater sediment depths leads to an age of about 2 - 2.5 Ma at the base of the upper sedimentary unit. Assuming the same or a slightly reduced sedimentation rate for Pliocene and late Miocene, sediments directly above the unconformity on top of the salt diapir would have an age of 12.5 - 15 Ma suggesting that the hiatus corresponds to a wide-spread Miocene unconformity found in the Brazil Basin and also in other parts of the South Atlantic (e.g., *Hinz et al.*, 1999).

Finally, a fifth Site SPP-5 is proposed in about 2500 m water depth on a extended sediment deposit located at the northeastern end of line GeoB 01-175 close to the beginning of line GeoB 01-176 (Fig 35). Inspection of the two short parallel lines GeoB 01-198 and GeoB 01-200 revealed that this sediment structure extends further to the northeast, whereas the deposits are affected by salt diapirs in southwestly direction. The crossing line GeoB 01-201 confirms this observation (Fig. 36). The *Parasound* section is characterized by rather diffuse sub-bottom reflections with a very limited signal penetration of 10 - 20 m (Fig. 37). Sediment of gravity core GeoB 6915-2 recovered at Site SPP-5 are mainly composed of nannofossil ooze (Chapter 4.2). A preliminary age estimate is not yet available, though.

Table 6 Preliminary summary of proposed ODP drill sites in survey areas D and E at the Brazilian continental margin.

Area D - Rio Grande Cone, southern Brazilian continental margin, 34 - 31°S

Site	Latitude [S]	Longitude [W]	Seismic Line	Date	Time	Water Depth [m]	Gravity Core	Location
RGC-1	33°01.624'	49°43.214'	GeoB 01-167	16.03.01	20:52	1308	GeoB 6902-1	Rio Grande Cone
Crossing	32°59.076'	49°41.834'	GeoB 01-170	17.03.01	07:06	1362		upper plateau
	32°52.549'	49°38.232'	GeoB 01-159	11.03.01	18:30	1467		
RGC-2	32°55.966'	49°30.105'	GeoB 01-159	11.03.01	19:40	1620	GeoB 6902-1	Rio Grande Cone
Crossing	32°55.986'	49°30.120'	GeoB 01-171	17.03.01	08:59	1619		upper plateau
RGC-3	32°48.567'	49°20.465'	GeoB 01-171	17.03.01	10:42	1847		Rio Grande Cone
Crossing	32°55.986'	49°30.120'	GeoB 01-159	17.03.01	08:59	1619		middle slope
RGC-4	32°42.061'	49°12.076'	GeoB 01-171	17.03.01	12:12	2105		Rio Grande Cone
Crossing	32°55.986'	49°30.120'	GeoB 01-159	17.03.01	08:59	1619		middle slope
RGC-5	33°19.926'	48°33.923'	GeoB 01-159	12.03.01	04:00	3153	GeoB 6906-1	Rio Grande Cone
Crossing	33°19.881'	48°33.904'	GeoB 01-164	16.03.01	07:56	3153		lower plateau
RGC-6	30°52.164'	48°28.640'	GeoB 01-173	18.03.01	08:41	1798	GeoB 6907-4	middle continental
Crossing	30°53.627'	48°30.814'	GeoB 01-163	14.03.01	05:36	1830		slope
RGC-7	31°14.188'	49°00.124'	GeoB 01-161	13.03.01	18:44	2046	GeoB 6901-4	middle continental
Crossing	31°14.248'	49°00.208'	GeoB 01-173	18.03.01	03:14	2045		slope
RGC-8	33°14.731'	47°38.512'	GeoB 01-161	12.03.01	21:30	3509		lower continental
Crossing	-	-	-	-	-			slope

Table 6 continued

Area E - Sao Paulo Plateau, central Brazilian continental margin, 29 - 25°S

Site	Latitude [S]	Longitude [W]	Seismic Line	Date	Time	Water Depth [m]	Gravity Core	Location
SPP-1	24°51.279'	44°31.292'	GeoB 01-176	22.03.01	07:50	501	GeoB 6908-4	upper continental slope
Crossing	-	-	-	-	-			
SPP-2	24°59.175'	44°26.236'	GeoB 01-176	22.03.01	06:00	1098	GeoB 6909-1 GeoB 6910-2	middle continental slope
Crossing	-	-	-	-	-			
SPP-3	25°05.211'	44°22.271'	GeoB 01-176	22.03.01	04:40	1604	GeoB 6911-1	middle continental slope
Crossing	-	-	-	-	-			
SPP-4A	26°20.560'	43°26.920'	GeoB 01-193	27.03.01	01:10	2288	GeoB 6914-2	salt diapir field
Crossing	26°20.520' 26°20.530'	43°32.749' 43°32.797'	GeoB 01-176 GeoB 01-183	21.03.01 23.03.01	14:00 23:44	2296 2296		
SPP-4B	26°04.677'	43°43.190'	Geo B01-176	21.03.01	17:03	2234	GeoB 6913-1	salt diapir field
Crossing	26°04.821'	43°43.210'	Geo B01-190	26:03.01	14:50	2233		
SPP-4C	25°58.498'	43°47.257'	GeoB 01-176	21.03.01	18:08	2230	GeoB 6912-2	salt diapir field
Crossing	25°58.473'	43°47.224'	GeoB 01-188	26.03.01	10:43	2225		
SPP-5	27°26.535'	42°46.386'	GeoB 01-175	21.03.01	02:03	2543	GeoB 6915-2	south of salt diapir field
Crossing	27°26.506'	42°46.378'	GeoB 01-201	28.03.01	01:58	2543		

4.2 Sedimentology

4.2.1 Sediment Sampling

(K. Dehning, V. Diekamp, B. Donner, P. Franke, M. Klann, S. Mulitza, C. Rühlemann, J. Thiele)

Sea floor sediments were sampled from about 500 to 3200 m water depth at 16 stations in the Rio Grande Cone and São Paulo Plateau working areas. For this purpose a multicorer (MUC) and gravity corers of 6, 9 and 12 m length (SL6, SL9 and SL12) have been used. A total of 12 multicorers and 18 gravity cores were retrieved. Detailed information about location, deployed equipment and recovery is summarized in the Station List (Chapter 8).

Multicorer

The multicorer is designed to recover undisturbed surface sediment sections together with the overlying bottom water. The device operated on this cruise was equipped with six large and four small plastic tubes, each of 60 cm length and 10 and 6 cm in diameter, respectively. Depending on the sediment composition, the recovery of the multicorer varied between 15 and 32 cm.

Wherever possible, the following standard scheme was applied to sample the multicorer:

- 2 large tubes were cut into 1 cm slices and stained with bengal rose to study foraminiferal assemblages,
- 1 large tube was cut into 1 cm slices and frozen for organic carbon geochemistry,
- 1 small tube was sampled for diatom and radiolarian analyses (only surface sediments),
- 1 small tube was preserved for sediment geophysical investigations,
- 3 large and 2 small tube were frozen as archive cores.

Table 8 Multicorer sampling (L = 10 cm diameter large tube, S = 6 cm diameter small tube).

Station GeoB	Position Latitude / Longitude	Organic Carbon	Foraminifera	Archive	Diatoms/ Radiolaria	Geophysics
6901-2	31°14.2'S / 49°00.1'W	1 L	2 L	3 L / 2 S	1 S	1 S
6902-2	32°52.6'S / 49°38.2'W	1 L	2 L	3 L / 2 S	1 S	1 S
6906-2	33°20.0'S / 48°33.9'W	1 L	2 L	3 L / 3 S	1 S	-
6907-3	30°53.6'S / 48°30.8'W	1 L	2 L	3 L / 3 S	1 S	-
6908-1	24°51.3'S / 44°31.4'W	1 L	2 L	1 L / 1 S	1 S	-
6909-2	24°58.6'S / 44°26.7'W	1 L	2 L	2 L / 1 S	1 S	-
6910-1	25°00.2'S / 44°25.6'W	1 L	2 L	2 L / 1 S	1 L	-
6911-2	25°05.2'S / 44°22.3'W	1 L	2 L	1 L / 2 S	1 S	-
6912-1	25°58.4'S / 43°47.2'W	1 L	2 L	3 L / 1 S	1 S	-
6913-2	26°04.8'S / 43°43.1'W	1 L	2 L	3 L / 2 S	1 S	-
6914-1	26°20.5'S / 43°32.8'W	1 L	2 L	2 L / 2 S	1 L	-
6915-1	27°26.5'S / 42°46.4'W	1 L	2 L	2 L / 3 S	1 S	-

At all stations two samples of the overlying bottom water were filled into 25 ml glass bottles for carbon and oxygen isotope analysis, respectively. The sample for $\delta^{13}C$ was poisoned with 1 ml saturated HgCl solution.

Table 9 Gravity core sampling.

Station GeoB	Position Latitude / Longitude	Water Depth [m]	Core Length [cm]	Organic Geochemistry 10 ml every 5 cm	Foraminifers 10 ml every 5 cm	Biostratigraphy 10 ml every 20 cm	Smear Slides
6901-3	31°14.2'S / 49°00.1'W	2047	-	-	-	-	-
6901-4	31°14.2'S / 49°00.1'W	2047	806	x	x	-	x
6902-1	32°52.6'S / 49°38.2'W	1464	661	x	x	-	x
6903-1	33°00.2'S / 49°20.2'W	1904	321	x	x	x	x
6904-1	33°01.3'S / 49°17.8'W	2046	-	-	-	-	-
6904-2	33°01.3'S / 49°17.8'W	2046	558	x	x	x	x
6905-1	33°05.3'S / 49°08.3'W	2660	192	x	x	x	x
6906-1	33°19.9'S / 48°33.9'W	3170	924	x	x	-	x
6907-4	30°53.6'S / 48°30.8'W	1826	174	x	x	x	x
6908-2	24°51.3'S / 44°31.3'W	501	607	x	x	-	x
6908-4	24°51.3'S / 44°31.3'W	501	163	x	x	-	x
6909-1	24°58.6'S / 44°26.7'W	1038	718	x	x	-	x
6910-2	25°00.2'S / 44°25.6'W	1187	787	x	x	-	x
6911-1	25°05.2'S / 44°22.3'W	1605	701	x	x	-	x
6912-2	25°58.5'S / 43°47.3'W	2229	575	x	x	-	x
6913-1	26°04.7'S / 43°43.1'W	2233	625	x	x	-	x
6914-2	26°20.5'S / 43°32.8'W	2298	689	x	x	-	x
6915-2	27°26.5'S / 42°46.4'W	2545	766	x	x	-	x
6916-1	27°33.6'S / 42°29.6'W	2858	483	x	x	-	x

Gravity Corer

To recover deeper and older sediment sequences, a gravity corer with pipe lengths of 6, 9 or 12 m and a weight of 2.5 tons was employed at 16 stations. In order to retain a common relative azimuthal orientation of the core, all liners have been marked lengthwise with a straight line. On board, the cores were cut into 1 meter sections, tightly closed with caps at both ends and labeled according to a standard scheme (Fig. 38). A total of seventeen cores were retrieved with recoveries between 1.63 and 9.24 m (Table 9). At two deployments the core tube returned empty.

The core segments were cut into 'archive' and 'work' halves. The archive half was used for core description, smear slide sampling, core photography and scanning of light reflectance. The work half was sampled with two series of 10 ml syringes for geochemical and foraminiferal analyses at 5 cm intervals. Additionally, whenever Tertiary sediments were expected, 10 ml syringe samples were taken for preliminary biostratigraphic investigations.

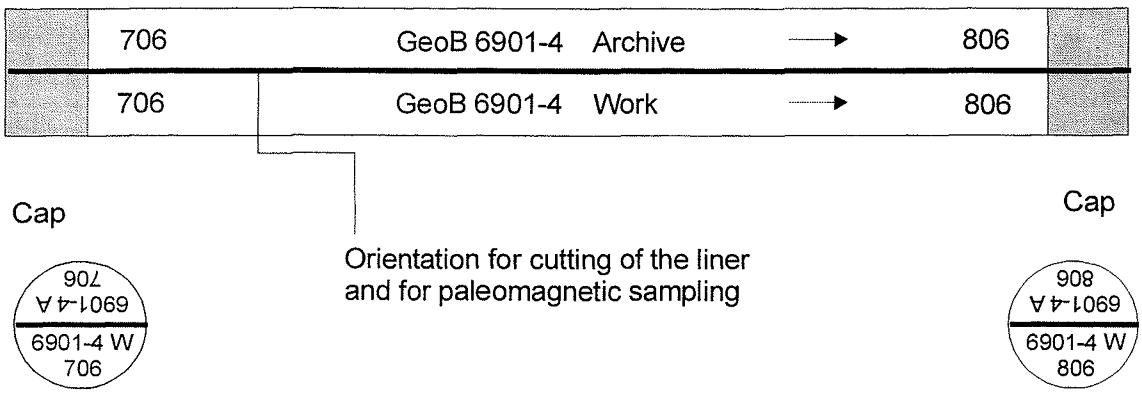


Figure 38 Inscription scheme of gravity core segments.

4.2.2 Core Description and Smear Slide Analysis

(B. Donner, S. Mulitza, C. Rühlemann)

Methods

The core descriptions accomplished on the archive halves of all gravity core segments summarize the most important lithological, structural and color characteristics of the sediments (Fig. 40 to 56) following ODP standards (*Sawyer et al.*, 1994). Primary objective of macroscopic core description is an identification of specific features such as slumps, turbidites, bioturbation, unconformities and discontinuities in the sedimentary record. The visual color classification, determined by comparison with the *Munsell* soil color chart and expressed as hue and chroma attributes, are supplemented by detailed measurements with a hand-held *Minolta* CM 2002 spectrophotometer. The lithologic examination is supported by smear slide analysis. In each core segment, smear slides were prepared from both representative and distinctive lithologies.

For smear slides 1 - 2 mm^3 of sediment was taken with a wooden toothpick, placed on a clean microscope slide, dispersed in a drop of distilled water and smeared out. After one hour, a few drops of '*Norland* Optical Adhesive' mounting media was poured on the sample and a glass cover slip applied, care being taken to expel any air bubbles from under the protecting glass. The slide was then placed under UV light for at least 45 minutes.

The samples were investigated using a *Olympus* light microscope at 125 – 200x magnification with cross polarized and transmitted light. Sediment composition was estimated using the ODP classification and nomenclature scheme.

A biostratigraphic analysis was performed only for those cores, where Tertiary sediments were expected (cores GeoB 6903-1, 6905-2, 6904-1 and 6907-4). Samples were taken from foraminifers bearing intervals. Depending on the sediment facies, 10 ml or the complete horizon of the core were washed using a 63 µm mesh sieve, dried at 50 °C and placed into glass tubes.

The biostratigraphic classification, mainly a test whether Tertiary sediments were recovered or not, was established using the following marker species:

- *Globorotalia truncatulinoides* which has a Quaternary first appearance datum,
- *Globorotalia menardii* a typical Quaternary species,
- *Globorotalia multicamerata* and *Globorotalia miocenica* two Tertiary markers,
- *Globigerinoides sacculifer* with the variety *fistulosa* as a Pliocene marker.

Results

Seventeen sediment cores were retrieved from water depths ranging from 501 to 3170 m, seven in the Rio Grande Cone region (working area D, Fig. 2), ten in the São Paulo Plateau region (working area E, Fig. 3). Core recoveries varied between 1.63 and 9.24 m. All sediment cores were opened and described on board.

Rio Grande Cone

The seven cores taken from water depths between 1464 and 3170 m in working area D varied in length between 174 and 910 cm. Most cores exhibit a relatively thin layer of brownish foraminifers bearing nannofossil ooze on top, presumably of Holocene age. The deeper sections of the cores mainly consist of gray terrigenous-rich hemipelagic clays, almost free of carbonate.

All cores from working area D show minor to moderate bioturbation. Cores GeoB 6901-4 to 6903-1 recovered virtually undisturbed sections. In contrast, cores GeoB 6904-2, 6905-1 and GeoB 6906-1 contain several turbidites or sharp and scoured contacts which may indicate reworked sediments or even hiatuses.

According to preliminary stratigraphic investigations all retrieved cores from the Rio Grande Cone region are of Quaternary age. A comparison of the reflectance data with the results of former cruises (*Bleil et al.*, 1993, *Schulz et al.*, 2001) suggests that cores GeoB 6901-4 and GeoB 6902-1 are younger than 70 ka at the base, which would indicate sedimentation rates of more than 9 cm/kyr.

São Paulo Plateau and Adjacent Continental Slope

The ten cores taken in working area E on the São Paulo Plateau and the adjacent continental slope between 500 and 2900 m water depth varied in length between 154 and 777 cm. The coring transect was arranged perpendicular to the continental slope to obtain depth stratified profiles of the Quaternary paleoceanographic evolution. Additionally, cores have been taken for dating purposes, where, according to the seismic data, older sediments crop out at the surface.

The sediments mostly consist of brownish or grayish nannofossile oozes. All cores show minor to moderate bioturbation. Cores GeoB 6912-2 and 6916-1 contain a series of turbidites.

Figure 39 Legend for stratigraphic columns of Figures 40 – 56.

GeoB 6901-4 Date: 14.03.01 Pos: 31°14,2´S 49°00,1´W
Water Depth: 2048 m Core Length: 800 cm

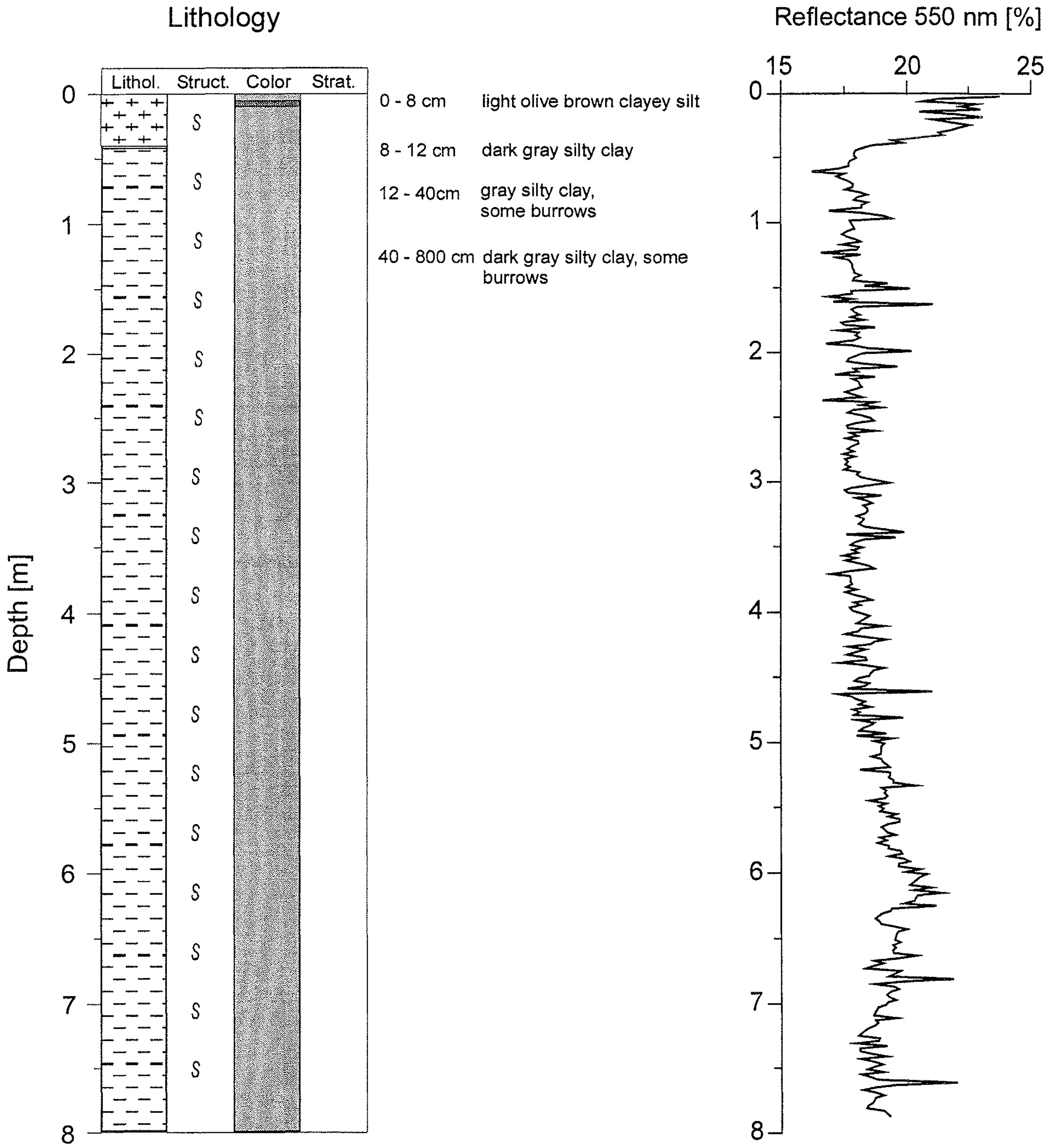


Figure 40 Core description of gravity core GeoB 6901-4.

GeoB 6902-1

Date: 15.03.01 Pos: 32°52,6'S 49°38,2'W
Water Depth: 1464 m Core Length: 645 cm

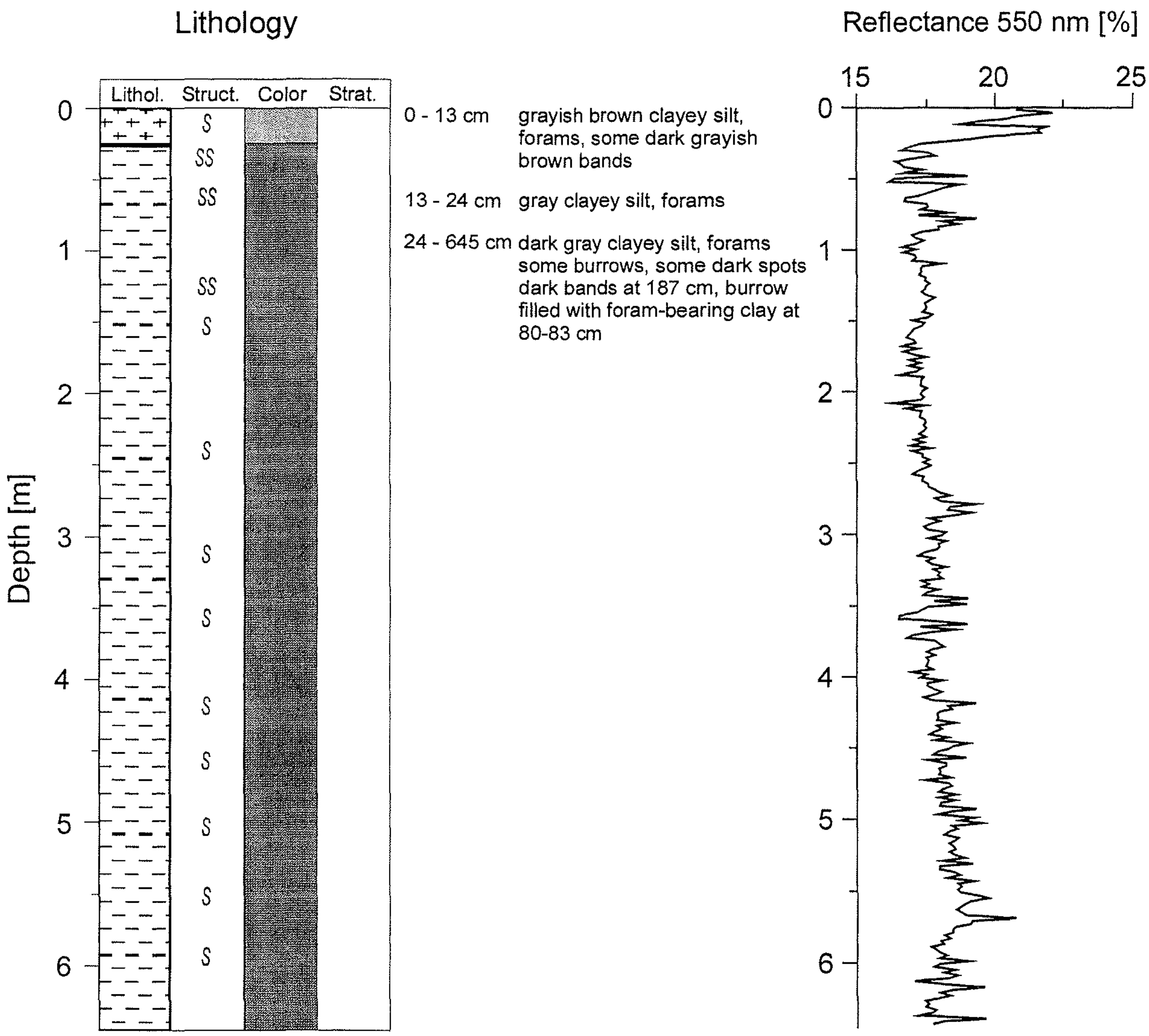


Figure 41 Core description of gravity core GeoB 6902-1.

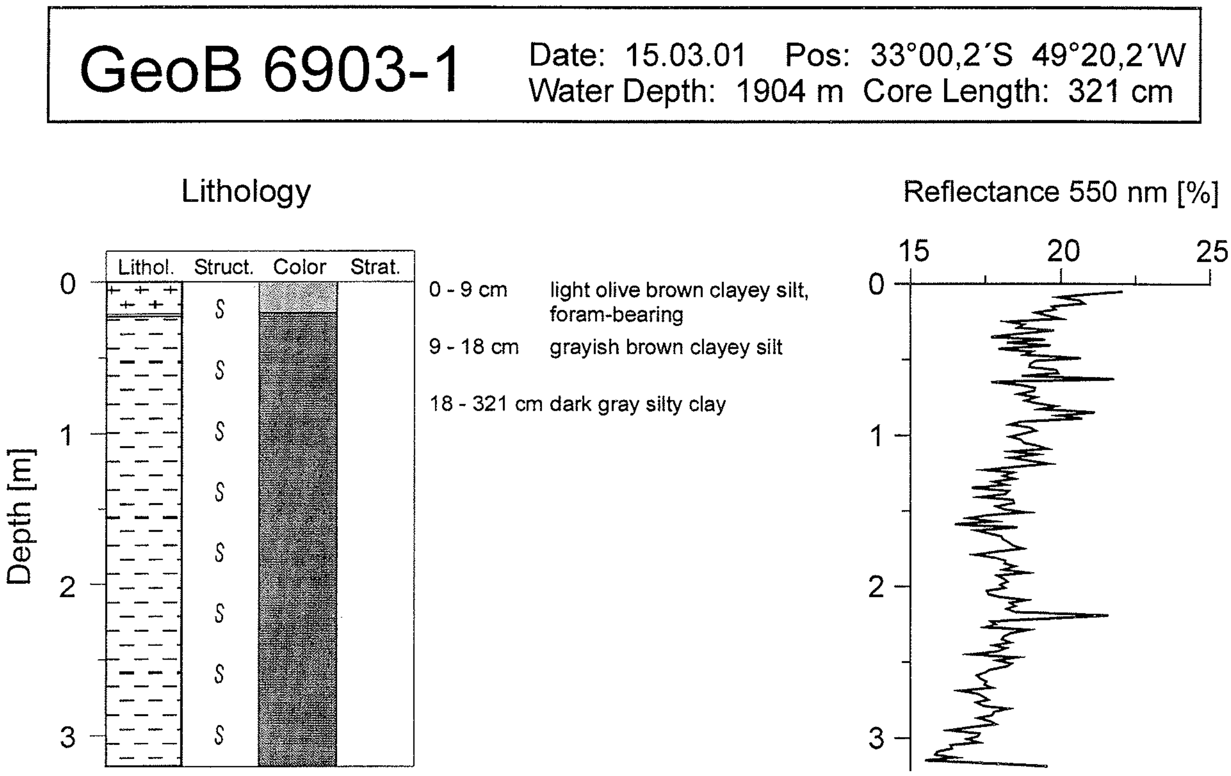


Figure 42 Core description of gravity core GeoB 6903-1.

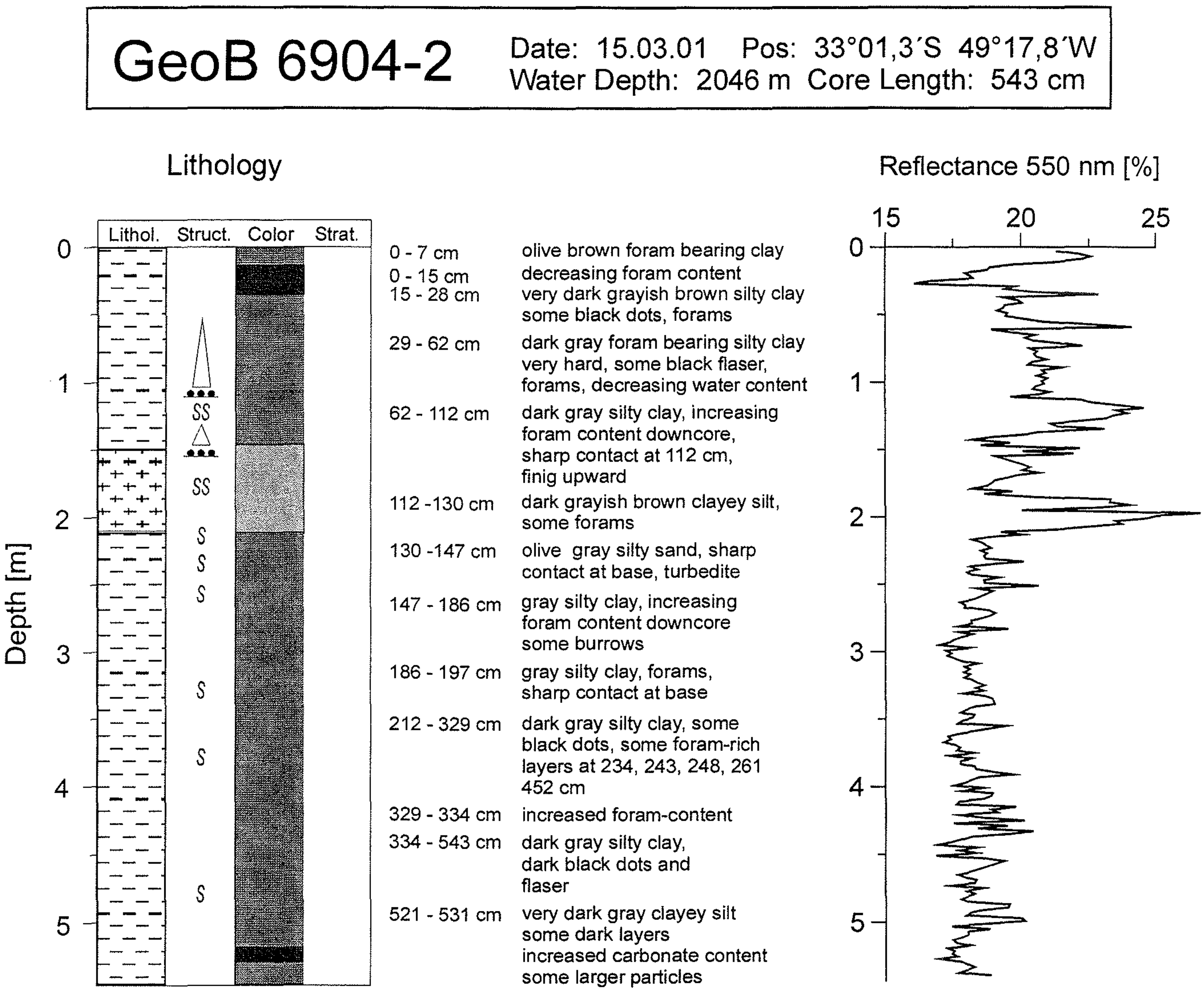


Figure 43 Core description of gravity core GeoB 6904-2.

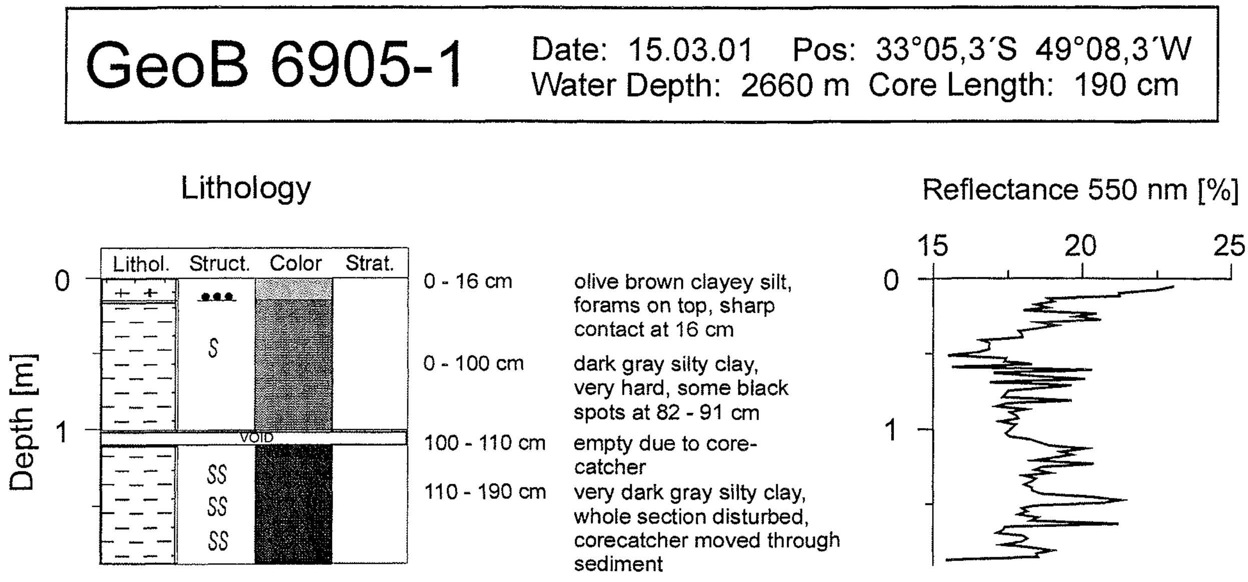


Figure 44 Core description of gravity core GeoB 6905-1.

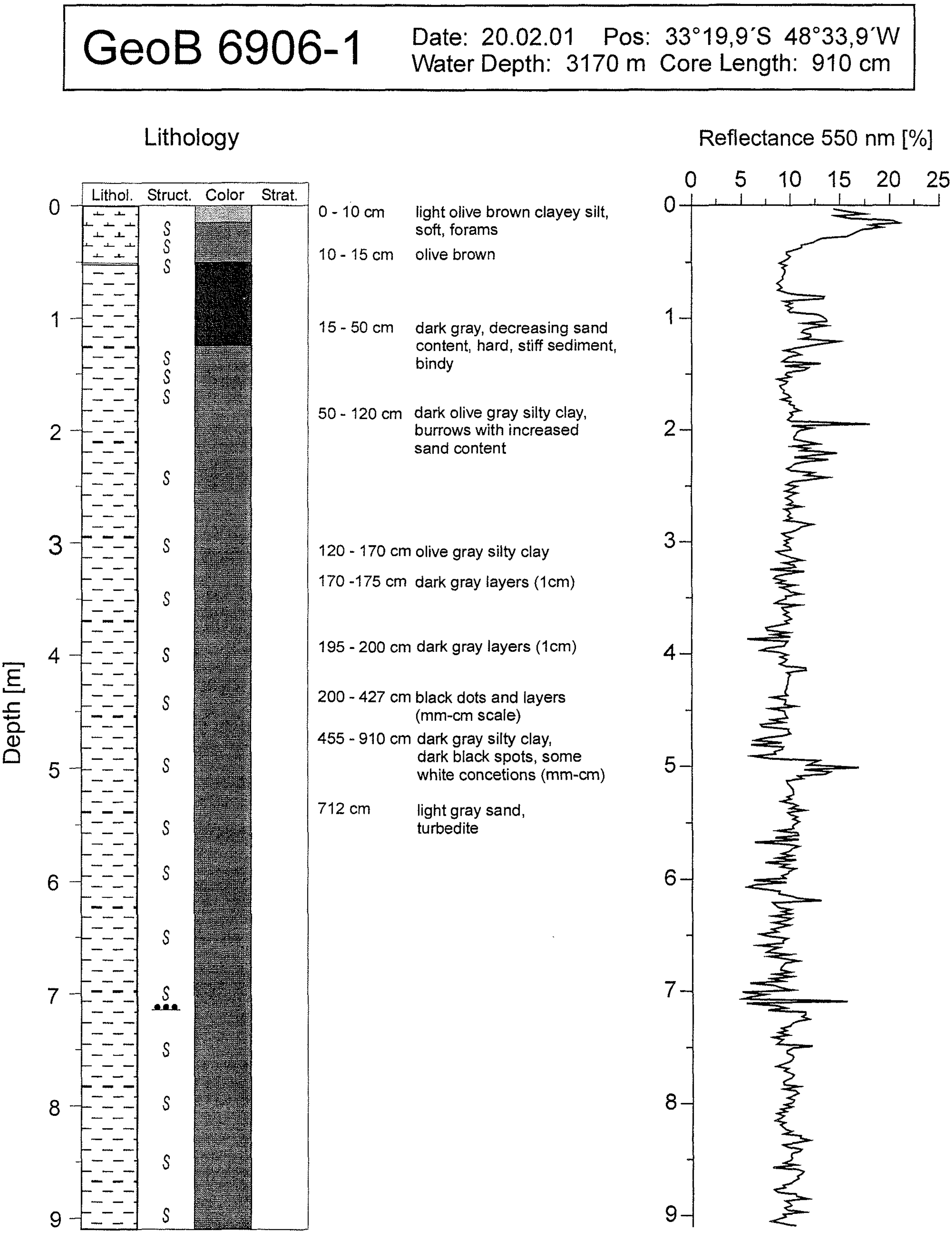


Figure 45 Core description of gravity core GeoB 6906-1.

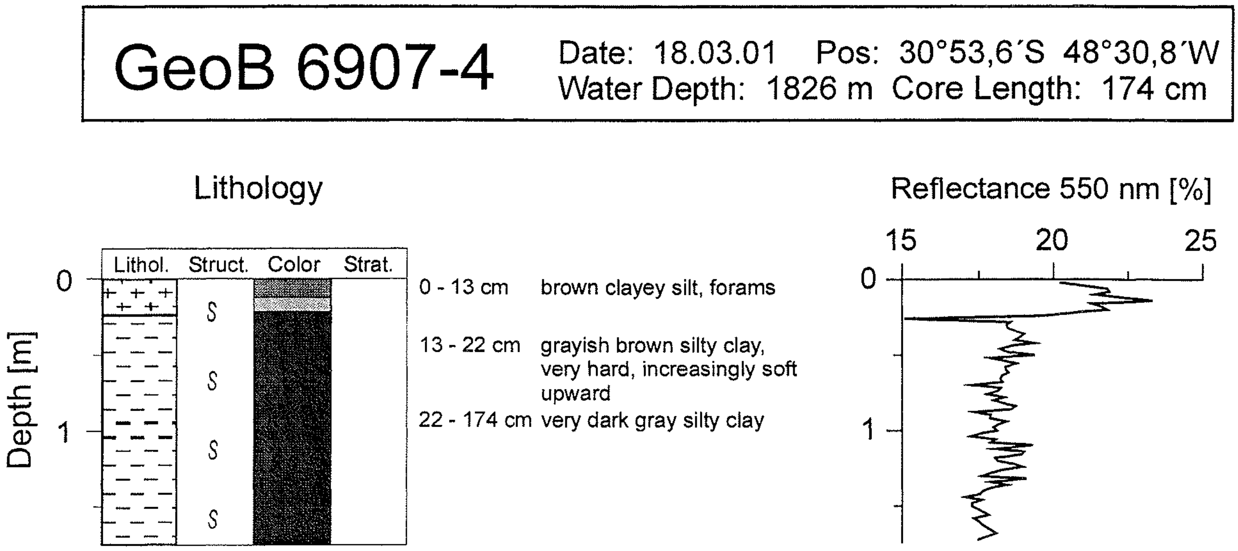


Figure 46 Core description of gravity core GeoB 6907-4.

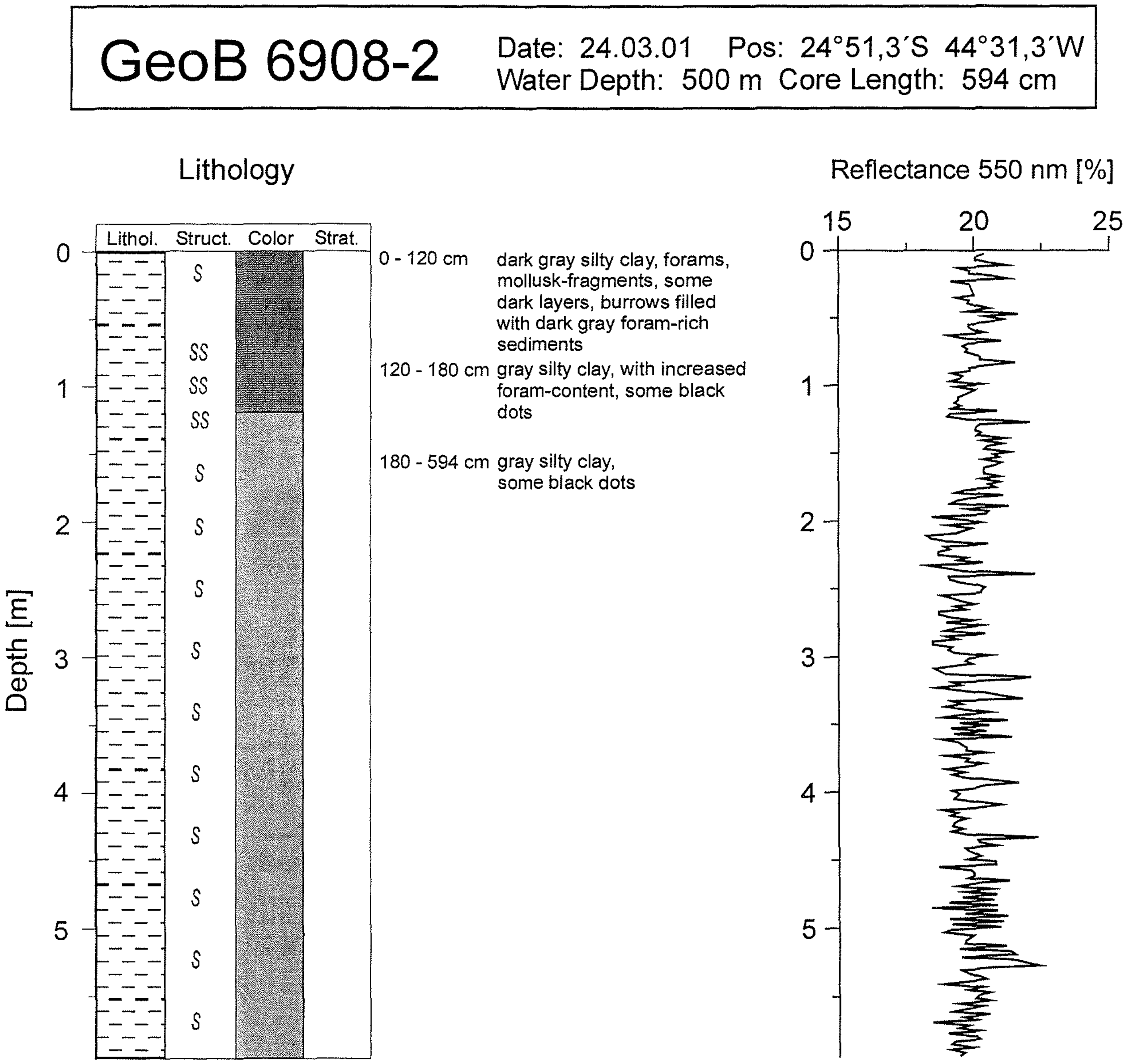


Figure 47 Core description of gravity core GeoB 6908-2.

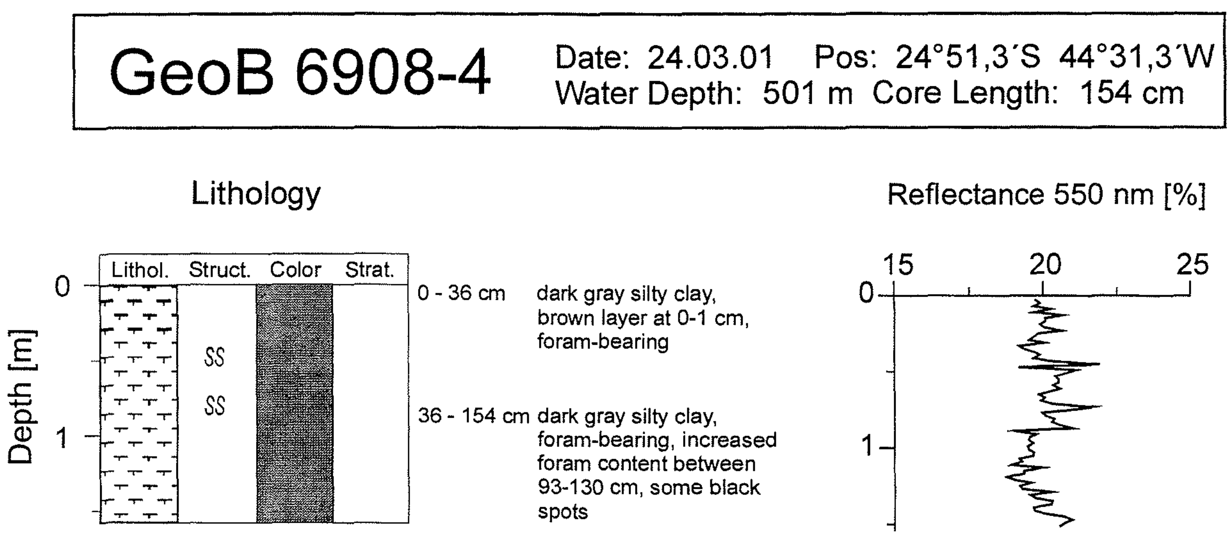


Figure 48 Core description of gravity core GeoB 6908-4.

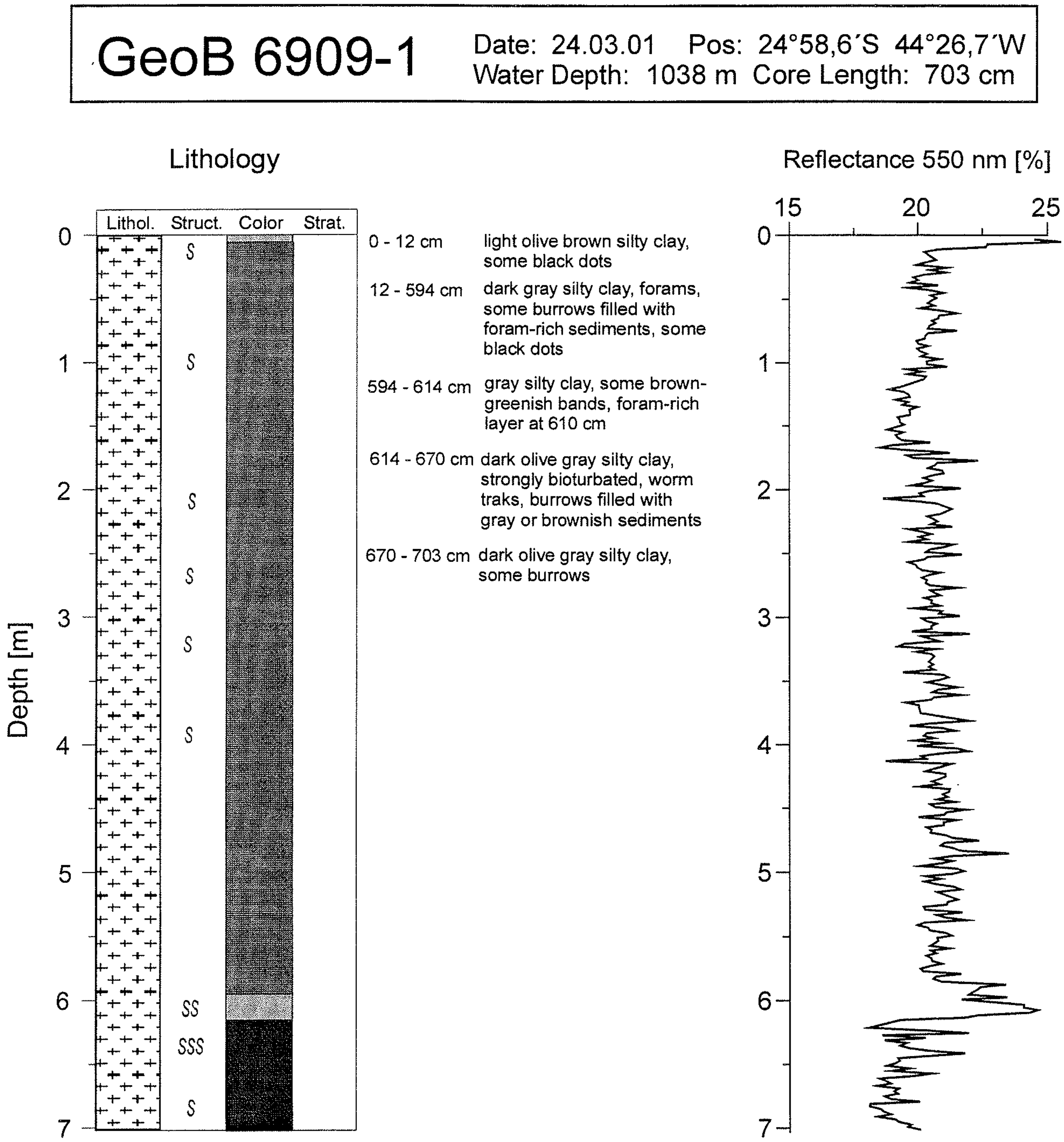


Figure 49 Core description of gravity core GeoB 6909-1.

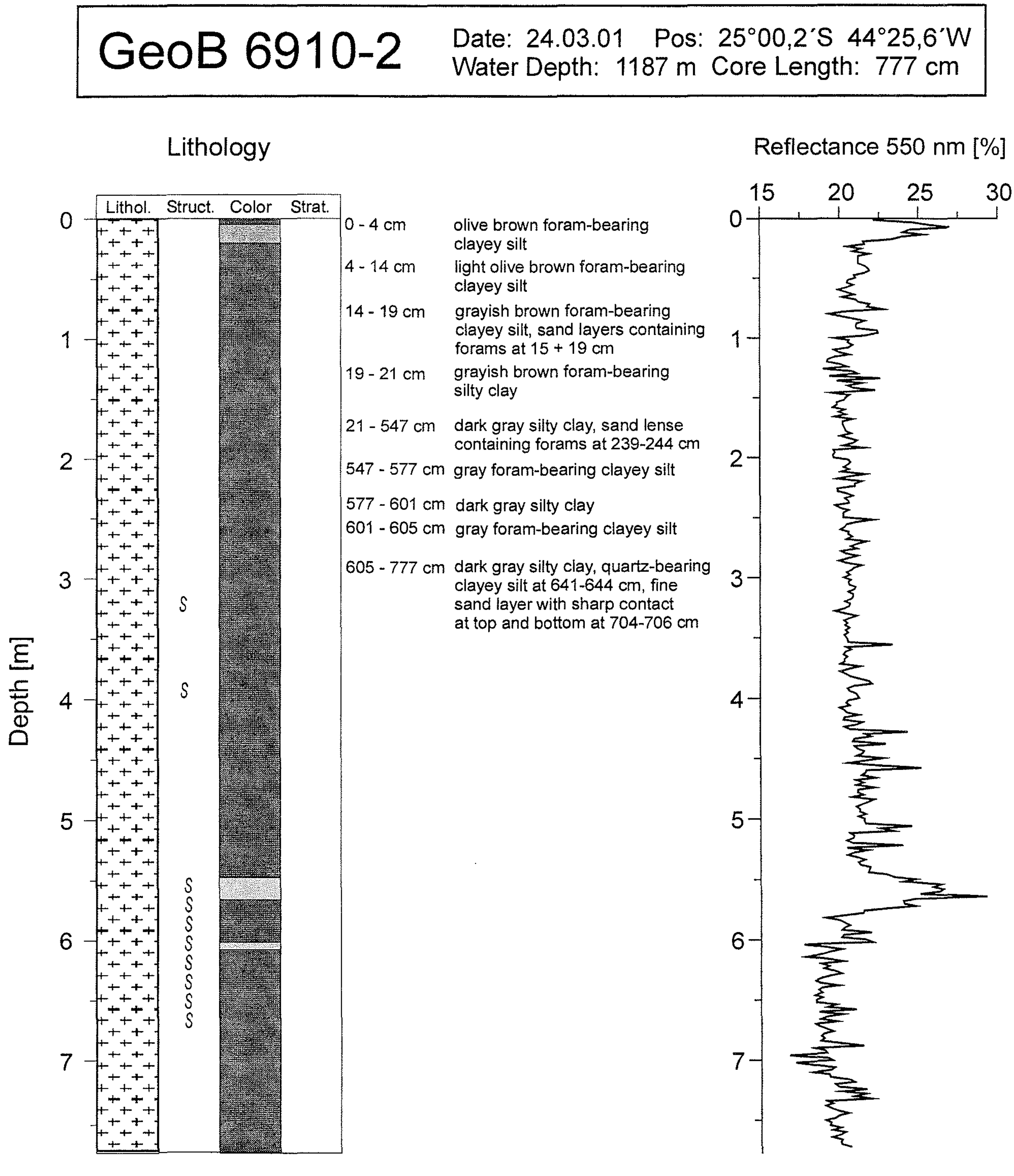
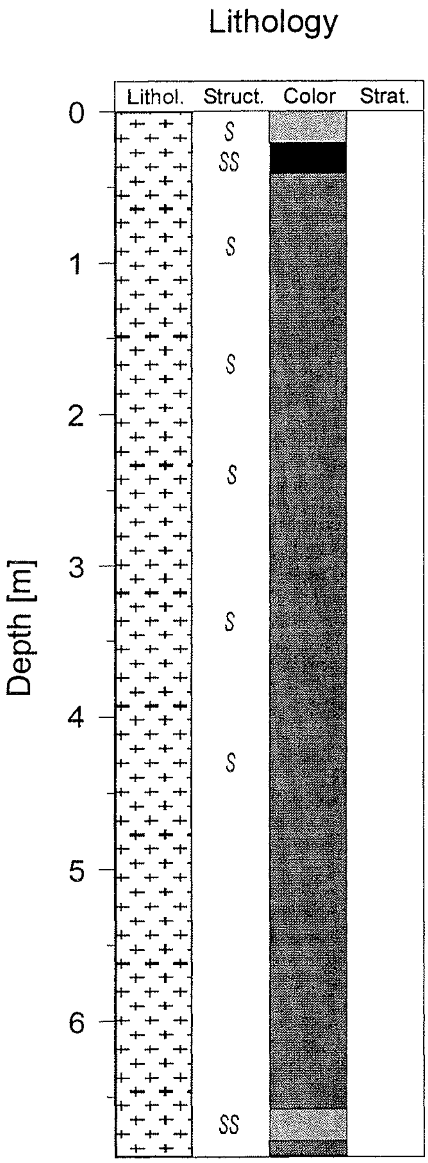


Figure 50 Core description of gravity core GeoB 6910-2.

GeoB 6911-1

Date: 24.03.01 Pos: 25°05,2´S 44°22,3´W
Water Depth: 1606 m Core Length: 690 cm



0 - 20 cm	grayish brown foram-bearing silty clay, soft
20 - 40 cm	gray silty clay, forams, some black dots, some yellowish bands at 35-40 cm
40 - 657 cm	dark gray silty clay, forams, black dots
657 - 680 cm	gray silty clay, some dark spots
680 - 690 cm	dark gray silty clay, some black spots

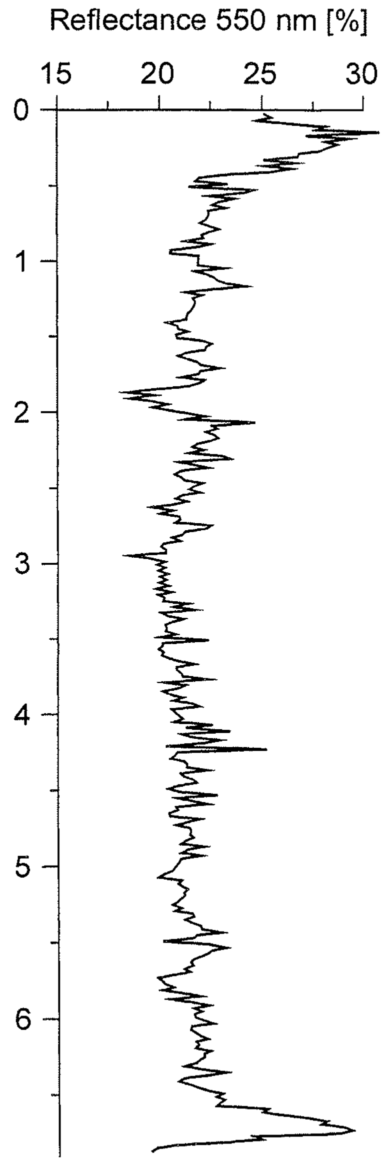


Figure 51 Core description of gravity core GeoB 6911-1.

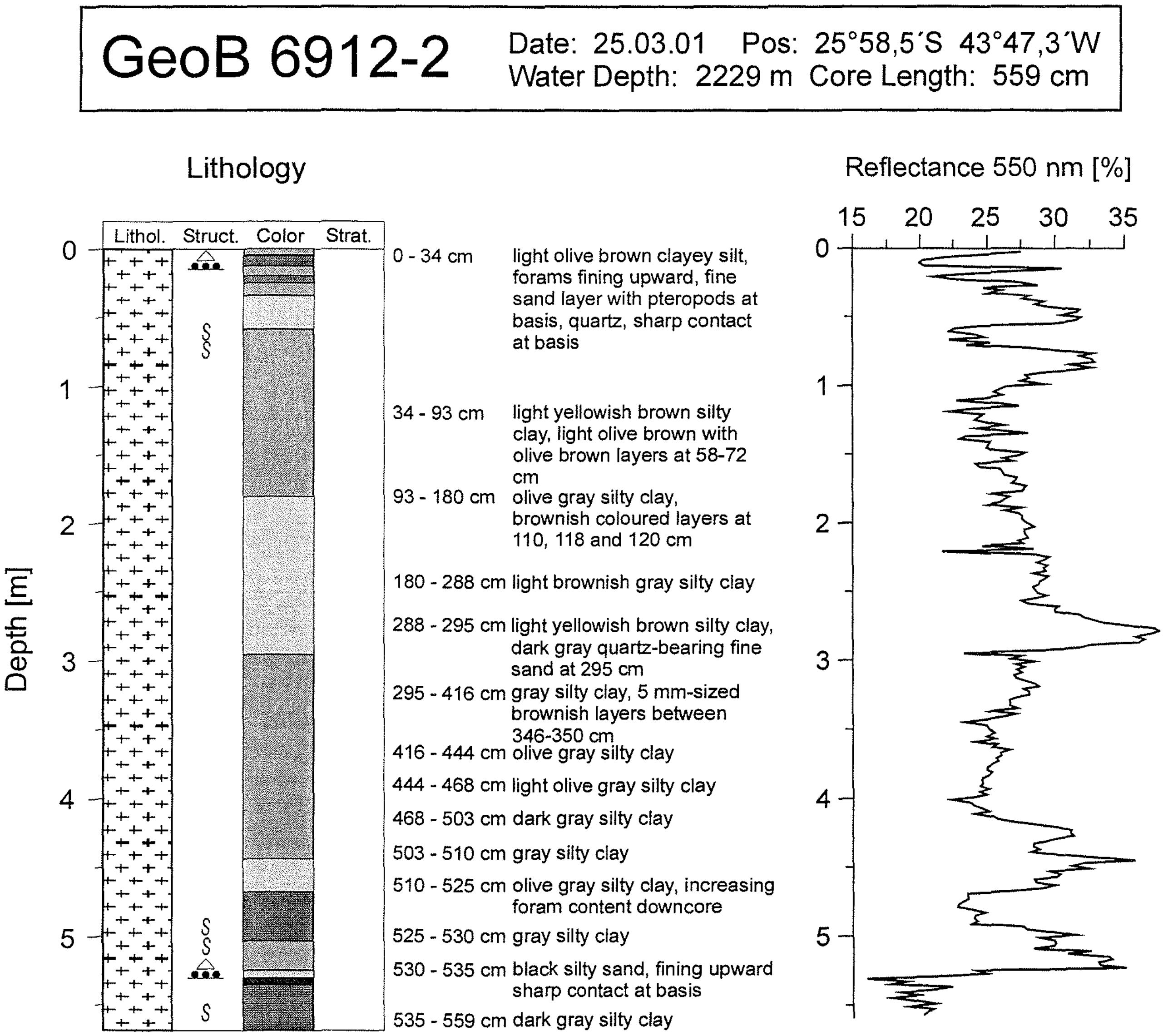


Figure 52 Core description of gravity core GeoB 6912-2.

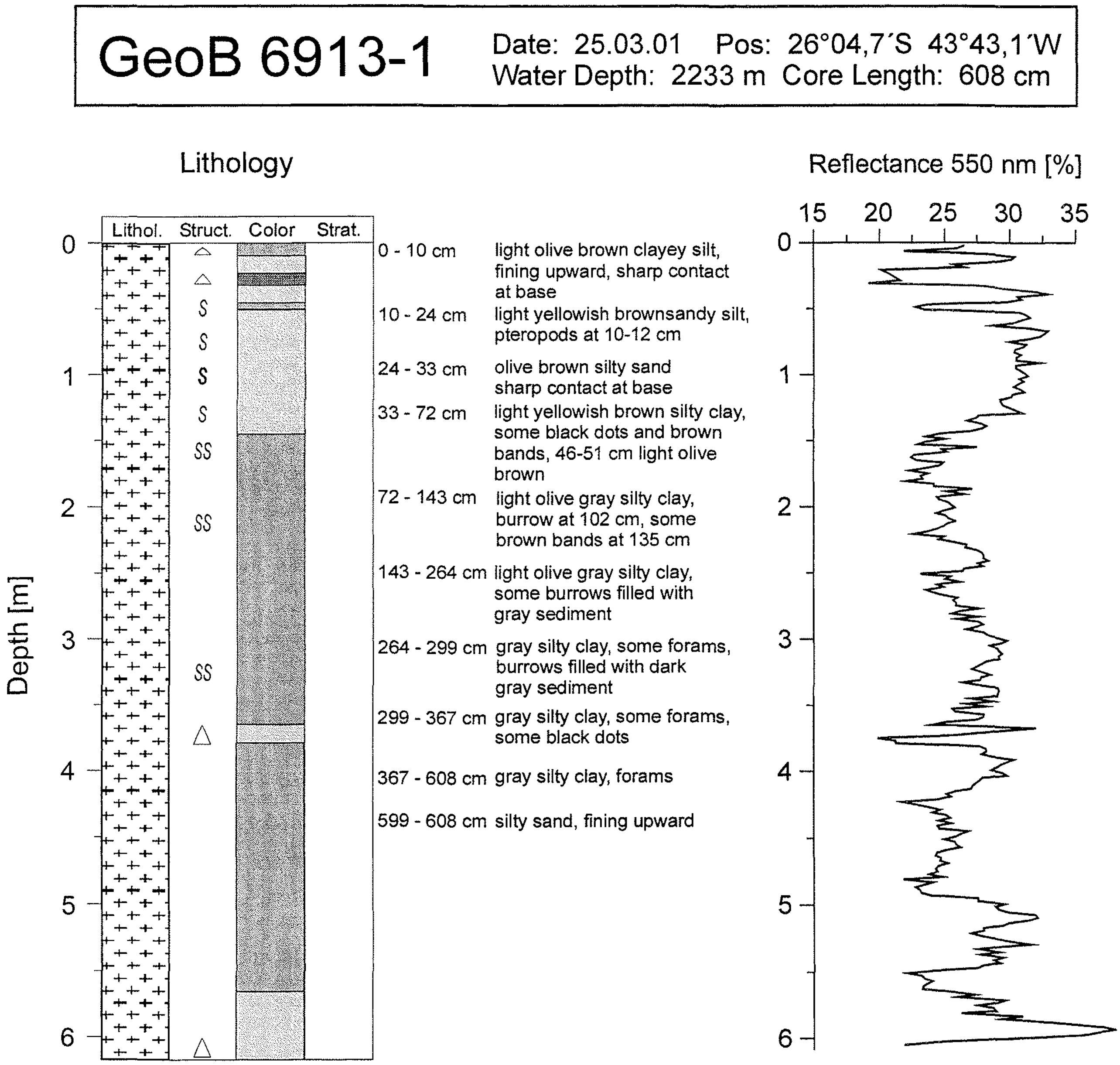
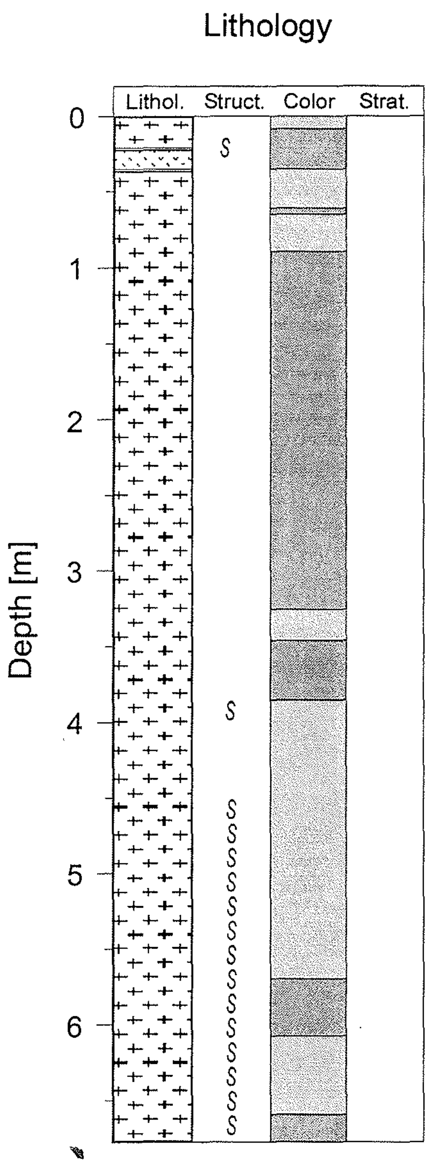


Figure 53 Core description of gravity core GeoB 6913-1.

GeoB 6914-2	Date: 25.03.01 Pos: 26°20,5'S 43°32,8'W Water Depth: 2298 m Core Length: 675 cm



0 - 22 cm	light yellowish brown clayey silt, forams, sharp contact and 2 mm-sized layer with increased sand content forams and carbonate particles at 9 cm
22 - 35 cm	light olive brown sand layer, sharp contact at base, mm-sized intercalation between dark brown and yellowish brown layers
35 - 62 cm	light yellowish brown clayey silt, pteropod-rich layer between 54 59 cm
62 - 89 cm	light olive gray clayey silt
89 - 200 cm	olive gray clayey silt
200 - 326 cm	olive gray silty clay
326 - 346 cm	light olive gray silty clay
346 - 376 cm	olive gray silty clay
376 - 570 cm	light olive gray silty clay, dark gray sand layers at 509 and 519-527 cm, sharp contact
570 - 615 cm	olive gray silty clay
615 - 669 cm	light olive gray silty clay, foram-bearing clayey silt between 644-650 cm
615 - 669 cm	olive gray silty clay

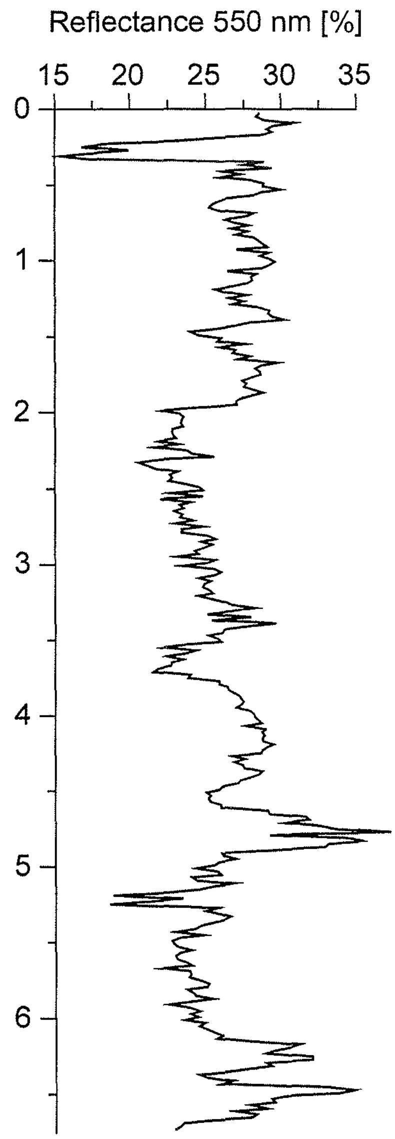


Figure 54 Core description of gravity core GeoB 6914-2.

GeoB 6915-2	Date: 28.03.01 Pos: 27°26,5´S 42°46,4´W Water Depth: 2543 m Core Length: 758 cm

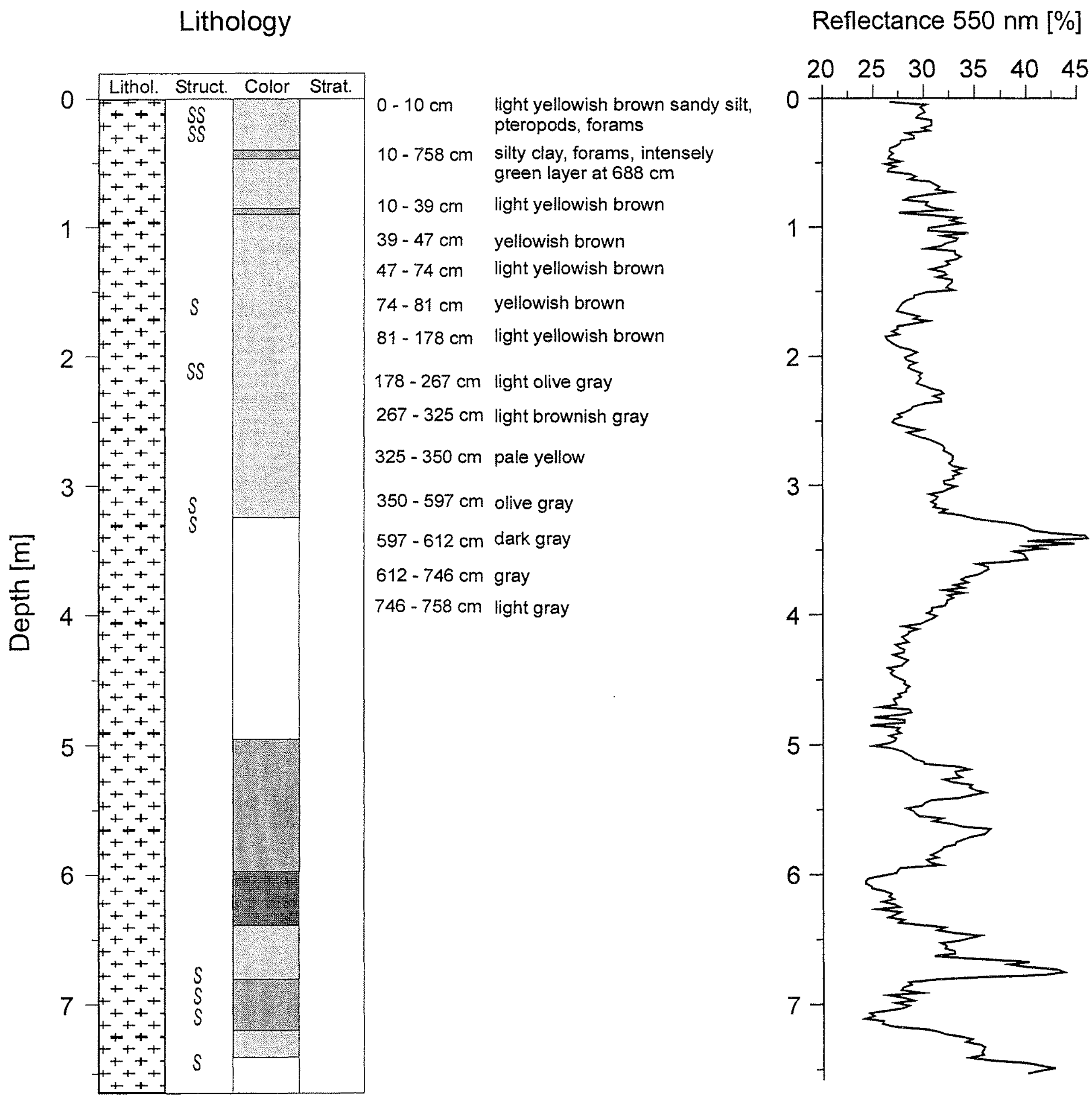


Figure 55 Core description of gravity core GeoB 6915-2.

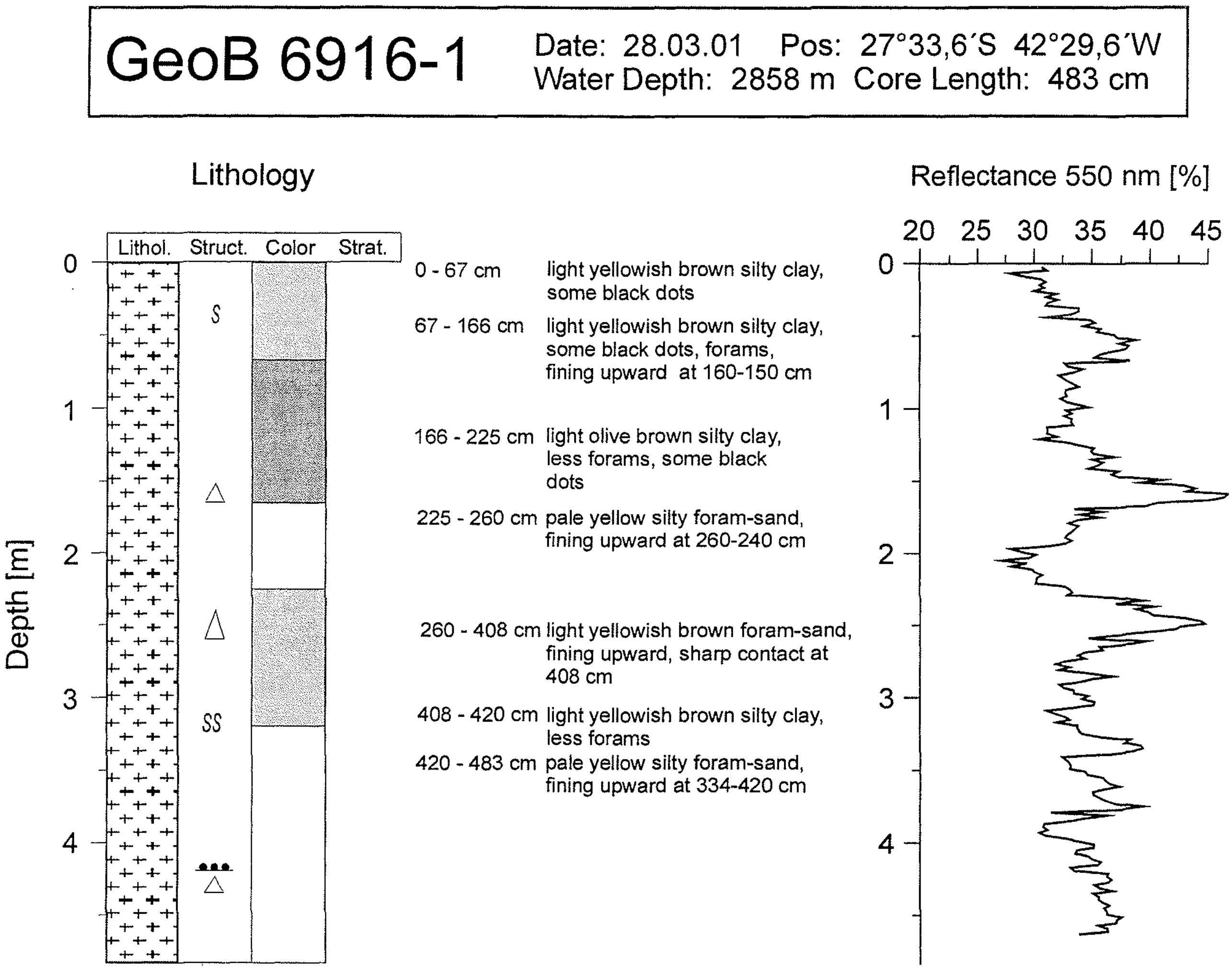


Figure 56 Core description of gravity core GeoB 6916-1.

The preliminary shipboard stratigraphic investigations indicate Quaternary ages for all sediments retrieved. In some cases a comparison of the reflectance data with those of former R/V METEOR cruises allows for a more precise stratigraphic classification. Cores GeoB 6909-1, 6910-2 and 6911-1 should reach isotope stage 6, equivalent to an age between 128 and 186 ka. Mean sedimentation rates in these cores are about 4 to 6 cm/kyr. Core GeoB 6914-1 from deeper waters presumably extends to isotope stage 7.3, indicating an average sedimentation rate of about 3 cm/kyr.

4.3 Water and Plankton Studies

4.3.1 CTD-Profiling

(B. Donner, M. Klann, S. Mulitza, C. Rühlemann)

A self-contained *Sea Bird* CTD 2069 profiler, equipped with conductivity, temperature and depth sensors, an oxygen probe and a *Chelsea* fluorometer was to monitor the variability of temperature, salinity, oxygen and Chlorophyll-a through the water column. Unfortunately, sea water penetrated into the profiler housing apparently during the first cast. All sensors stopped registration and when opening the instrument, the electronics showed conspicuous traces of corrosion. Despite considerable efforts a repair and re-calibration of the probe was not possible on board during the cruise. For this reason no further deployments of CTD profiler could be performed and no data were registered.

4.3.2 Rosette Water Sampling

(M. Klann, S. Mulitza, C. Rühlemann)

At four stations a rosette water sampler with 15 10 l Niskin bottles was deployed to collect sea water on vertical profiles in the water column. Depending on the regional hydrography, samples were taken between the surface and 3000 m water depth (see Station List, Chapter 8). Immediately after recovery, sea water samples were taken for the following purposes:

- 1 glass bottle (25 ml) for analyses of stable carbon isotopes of total dissolved CO_2,
- 1 glass bottle (25 ml) for analyses of stable oxygen isotopes of sea water,
- 1 glass bottle (250 ml) for shipboard analysis of alkalinity,
- 1 glass bottle (250 ml) to determine the concentration of total dissolved CO_2,
- 1 scintillation cup (5 ml) for nutrients.

To prevent any biological activity, the water samples for $\delta^{13}C$ and total CO_2 were poisoned with 1 ml saturated HgCl solution. The sample for alkalinity was analyzed immediately after recovery, the samples for nutrient determination were frozen and stored at –20 °C.

Alkalinity Measurements

Alkalinities were determined with a semi-automatic *Metrohm* titration device connected to a PC. The samples were first passed through a fiber glass filter. Aliquots of 100 ml were then given in a titration cell held at constant temperature of 25 °C. After adding an initial volume of 4 - 5 ml (depending on the pH of the sea water) of 0.05 molar hydrochloric acid with a *Dosimat*, further

40 volumes of 0.1 ml hydrochloric acid were added stepwise. After each step pH and temperature were measured automatically. The alkalinity of each water sample was determined twice or three times if the difference between the first two titrations was greater than 5 µmol kg^{-1}. The alkalinity determinations were corrected by comparison to a reference sea water for oceanic CO_2 measurements (available form A. Dickson, Scipps Institution of Oceanography, La Jolla).

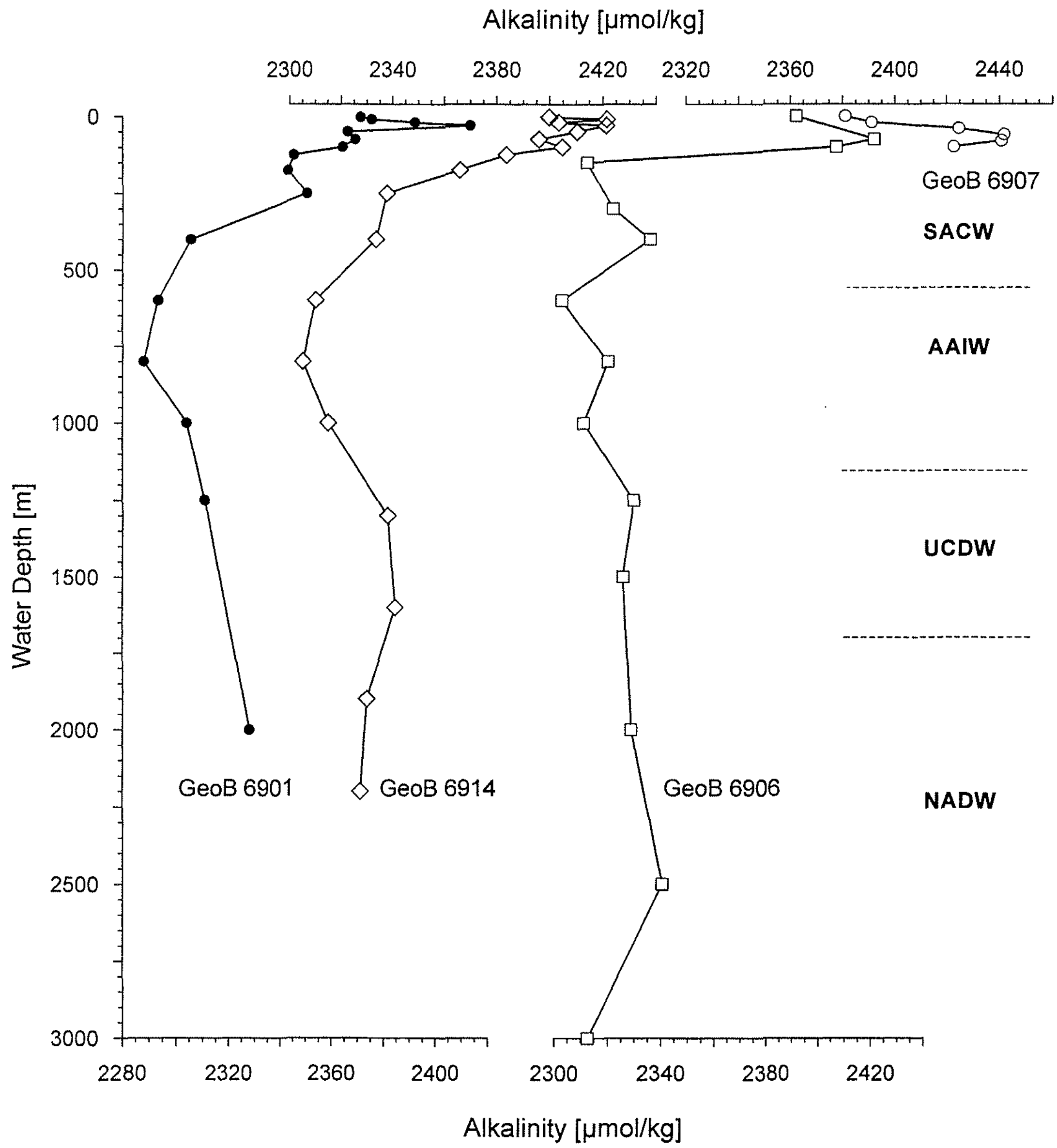


Figure 57 Distribution of alkalinity in the water column at stations GeoB 6901, 6906, 6907 and 6914.

Variations of alkalinity in the water column of working areas D (stations GeoB 6903 and 6906) and E (stations GeoB 6907 and 6914) are clearly related to the water mass distributions (Fig. 57). Highest values prevail between 50 and 100 m water depth. Antarctic Intermediate Water (AAIW) can clearly be distinguished from the overlying South Atlantic Central Water (SACW) and the underlying Upper Circumpolar Deep Water (UCDW) by lowest alkalinities at stations GeoB 6901 and 6914 and less pronounced at station GeoB 6906.

4.3.3 Sampling of Planktic Foraminifera

(B. Donner)

Planktic foraminifers were collected using a 75 µm mesh plankton net (*Hydro Bios*). Sea surface water (0 - 5 m water depth) was constantly pumped between 6 and 8 hours during day light with the vessel's fire extinguishing pump at a flow rate of more than 50 l per minute.

Each sample was rinsed several times with freshwater. Surface dwelling foraminifera were then separated from other particles, aggregates and organisms, dried and placed in storage cells for future isotope analysis. The oxygen isotope ratios will provide information on the isotopic composition of sea water in relation to sea surface temperatures. The data set accomplished with the results from this cruise is used to calibrate the $\delta^{18}O$ composition of shallow dwelling planktic foraminifers from surface waters and also from core tops against the present day regional surface water hydrography.

The number of foraminifera caught per sampling interval varied from day to day. Highest amounts were obtained during full and during new moon. Mean water temperature was 27 °C (ranging from 25.9 to 28.4 °C), mean salinity 36.5 ‰ (ranging from 36.1 to 37.2 ‰).

At this relatively high mean temperature the species assemblage along the cruise track (northern Argentine Basin to southern Brazil Basin) was always dominated by *Globigerinoides ruber* (pink). *Globigerinita glutinata* and *Globorotalia menardii* contributed with only minor amounts.

Table 10 Sampling of planktic foraminifera: location, surface water temperature and salinity and water depth at the start / end of each pumping transect.

No.	Date 2001	Start [UTC]	Latitude / Longitude	SST [°C]	SSS [‰]	Water Depth	Stop [UTC]	Latitude / Longitude	SST [°C]	SSS [‰]	Water Depth
1	11.3.	11:15	32°31.8'S / 50°26.3'W	27.0	35.9	126	21:13	33°00.2'S / 49°20.2'W	26.8	36.2	1917
2	12.3.	11:00	33°40.0'S / 47°47.1'W	24.6	35.9	-	19:17	33°26.8'S / 47°30.2'W	25.9	36.2	3524
3	13.3.	11:30	31°55.0'S / 48°32.7'W	26.5	36.7	2858	19:53	31°07.7'S / 49°04.6'W	27.0	36.1	1649
4	14.3.	11:15	31°14.3'S / 47°55.0'W	25.4	36.0	2988	18:15	31°14.1'S / 49°00.1'W	26.8	36.0	2057
5	15.3.	11:20	32°53.8'S / 49°35.2'W	27.0	36.2	1527	22:14	33°19.9'S / 48°33.9'W	27.0	36.7	3169
6	16.3.	11:25	33°05.3'S / 46°42.8'W	26.8	36.7	3052	20:14	33°05.0'S / 49°45.4'W	26.8	36.0	1260
7	17.3.	11:50	32°43.7'S / 49°15.1'W	26.3	36.5	2040	20:44	31°43.0'S / 49°12.0'W	26.6	36.6	2227
8	18.3.	14:15	30°51.5'S / 48°24.4'W	27.1	35.6	1889	18:40	30°35.6'S / 47°38.8W	27.3	36.6	-
9	19.3.	13:10	29°25.3'S / 44°17.8'W	27.4	36.6	3718	20:30	28°58.8'S / 42°53.4'W	27.4	36.6	4033
10	20.3.	12:00	28°04.1'S / 41°17.1'W	27.6	36.2	3222	20:22	27°42.4'S / 42°08.6'W	27.9	36.3	2989

Table 10 continued

No.	Date 2001	Start [UTC]	Latitude / Longitude	SST [°C]	SSS [‰]	Water Depth	Stop [UTC]	Latitude / Longitude	SST [°C]	SSS [‰]	Water Depth
11	21.3.	13:30	26°21.4'S / 43°23.2'W	28.2	36.7	2312	22:19	25°36.4'S / 44°01.8'W	28.4	36.8	2092
12	22.3.	11:45	24°55.6'S / 44°42.6'W	25.9	36.7	357	21:48	25°53.5'S / 44°32.6'W	28.3	37.2	2237
13	23.3.	15:00	25°27.2'S / 44°26.3'W	28.2	36.8	2065	22:14	26°20.7'S / 43°41.8'W	28.0	36.7	2353
14	sample discarded (contamination)										
15	sample discarded (contamination)										
16	28.3.	12:20	27°29.8'S / 42°38.6'W	28.0	36.7	2658	23:24	26°92.1'S / 41°35.1'W	28.2	36.9	2613
17	29.3.	13:00	24°22.0'S / 40°36.3'W	28.2	36.8	3123	20:30	23°27.3'S / 40°08.6'W	28.4	37.2	2860

4.3.4 Sampling of Suspended Organic Matter

(C. Rühlemann)

Periodically 300 - 1000 l of surface water were sampled with the vessel's membrane pump for shore based analyses of alkenones (Table 11) as well as stable nitrogen and carbon isotopes (Table 12). To retain the suspended particulate matter, the water was passed through glass fiber filters (GMF 5, *Sartorius*). After filtering, all samples were directly frozen and stored at –20 °C.

Table 11 Sampling of suspended organic matter for alkenone analyses: location, surface water temperature and salinity and water depth at the start / end of each pumping period.

No.	Date 2001		Time [UTC]	Position Latitude/ Longitude	Water Depth [m]	SST [°C]	SSS [‰]	Liters	Remarks
1	10.03	Start	13:20	34°04.86'S / 53°24.97'W	23	23.5	31.5		
		Stop	13:40	34°04.86'S / 53°24.97'W	23	23.5	31.5	39	filter stuffed
2	10.03.	Start	16:40	33°55.03'S / 52°53.44'W	30	25.3	31.4		
		Stop	17:30	33°54.74'S / 52°50.05'W	27	25.5	31.4	251	
3	10.03.	Start	21:21	33°48.94'S / 52°15.50'W	65	26.3	32.7		
		Stop	22:48	33°38.32'S / 52°03.60'W	50	26.4	33.3	332	
4	11.03.	Start	11:29	32°32.29'S / 50°25.06'W	133	27.0	35.9		
		Stop	12:20	32°34.77'S / 50°19.34'W	335	27.0	35.9	273	
5	11.03.	Start	19:45	32°56.36'S / 49°29.34'W	1649	26.8	36.1		
		Stop	20:27	32°58.06'S / 49°25.25'W	1726	26.8	36.2	248	
6	12.03.	Start	11:41	33°41.79'S / 47°42.82'W	3670	24.6	35.9		
		Stop	12:38	33°44.98'S / 47°35.36'W	3811	24.5	35.8	324	
7	12.03.	Start	17:08	33°38.10'S / 47°22.44'W	3737	25.7	36.2		
		Stop	18:28	33°31.09'S / 47°27.29'W	3602	26.1	36.2	391	

Table 11 continued

No.	Date 2001		Time [UTC]	Position Latitude/ Longitude	Water Depth [m]	SST [°C]	SSS [‰]	Liters	Remarks
8	13.03.	Start	11:37	31°55.02'S / 48°32.69'W	2861	26.5	36.7		
		Stop	13:30	31°44.23'S / 48°40.01'W	2766	26.6	36.7	594	
9	14.03.	Start	11:05	31°1347'S / 47°56.52'W	2964	25.4	36.0		
		Stop	12:07	31°16.40'S / 47°51.85'W	3008	25.4	36.0	382	
10	14.03.	Start	18:27	31°13.94'S / 49°00.33'W	2046	26.2	36.1		
		Stop	21:45	31°14.20'S / 49°00.11'W	2058	25.6	36.1	416	
11	15.03.	Start	11:30	32°54.85 S / 49°32.80'W	1565	26.9	36.1		
		Stop	11:58	32°57.30'S / 49°26.93'W	1698	26.9	36.1	192	
12	16.03.	Start	01:48	33°19.78'S / 48°33.27'W	3172	26.9	36.7		
		Stop	-	-	-	-	-	707	neglected
13	16.03.	Start	14:29	32°58.52'S / 49°01.99'W	3267	26.3	36.5		
		Stop	16:16	33°00.96'S / 49°15.82'W	2168	27.3	35.5	544	
14	18.03.	Start	11:00	30°53.62'S / 48°30.83'W	-	27.0	35.7		GeoB 6907
		Stop	11:56	30°53.62'S / 48°30.83'W	1833	27.0	35.8	365	
15	19.03.	Start	17:09	29°10.44'S / 43°35.54'W	3935	27.5	36.5		
		Stop	18:02	29°06.54'S / 43°24.39'W	4014	27.4	36.5	372	
16	20.03.	Start	13:32	28°01.05'S / 41°24.18'W	3228	27.6	36.2		
		Stop	17:22	27°50.53'S / 41°49.29'W	3066	28.3	36.6	1041	
17	20.03	Start	17:27	27°50.35'S / 41°49.77'W	3066	28.2	36.6		
		Stop	18:30	27°47.43'S / 41°56.68'W	3032	27.6	36.6	416	
18	21.03.	Start	14:00	26°20.54'S / 43°32.75'W	2309	28.3	36.8		
		Stop	14:40	26°17.26'S / 43°34.89'W	2287	28.3	36.8	299	
19	22.03.	Start	14:17	25°07.37'S / 44°40.52'W	886	27.6	37.1		
		Stop	15:04	25°12.04'S / 44°39.71'W	1243	27.6	36.9	263	
20	23.03.	Start	13:30	25°50.93'S / 44°32.24'W	2089	28.3	37.2		
		Stop	14:45	25°51.51'S / 44°24.10'W	2063	28.3	37.1	387	
21	24.03.	Start	11:43	25°09.73'S / 44°15.50'W	1764	28.4	37.2		
		Stop	12:24	25°03.74'S / 44°20.00'W	1568	28.5	37.2	259	
22	24.03.	Start	15:08	24°51.28'S / 44°31.28'W	504	27.9	37.0		GeoB 6908
		Stop	15:55	24°51.32'S / 44°31.26'W	505	28.0	37.1	292	
23	25.03.	Start	15:33	26°20.52'S / 43°32.77'W	2305	28.8	36.7		GeoB 6914
		Stop	16:58	26°20.51'S / 43°32.74'W	2306	28.7	36.7	494	
24	26.03.	Start	18:30	26°07.67'S / 43°23.93'W	2214	28.3	36.7		
		Stop	19:29	26°11.25'S / 43°29.70'W	2236	28.3	36.8	379	
25	28.03	Start	14:23	27°33.56'S / 42°29.60'W	2857	28.0	36.8		GeoB 6915
		Stop	16:37	27°19.60'S / 42°21.17'W	2761	28.2	36.8	655	
26	29.03	Start	11:45	24°32.67'S / 40°42.53'W	2919	28.1	36.7		
		Stop	13:04	24°22.49'S / 40°36.55'W	2942	28.2	36.8	442	
27	30.03	Start	17:07	20°12.50'S / 38°38.48'W	1835	28.9	37.3		
		Stop	18:28	19°59.27'S / 38°34.12'W	1154	28.9	37.3	475	
28	31.03	Start	11:25	17°03.92'S / 38°14.99'W	2129	29.1	37.2		
		Stop	13:52	16°27.35'S / 38°16.86'W	2016	28.6	37.0	744	

Table 12 Sampling of suspended organic matter for stable nitrogen and carbon isotope analyses: location, surface water temperature and salinity and water depth at the start / end of each pumping period.

No.	Date 2001		Time [UTC]	Position Latitude / Longitude	Water Depth [m]	SST [°C]	SSS [‰]	Liters	Remarks
1	11.03	Start	12:39	32°35.69'S /50°17.18'W	611	26.9	35.9	181	
		Stop	13:19	32°37.66'S / 50°12.59'W	867	26.7	36.2	181	filter stuffed
2	12.03.	Start	15:48	33°45.30'S / 47°34.63'W	3815	24.5	35.8		
		Stop	17:25	33°50.09'S / 47°23.35'W	4025	26.1	36.6	407	
3	13.03.	Start	13:37	31°43.81'S / 48°40.30'W	2764	26.6	36.7		
		Stop	14:32	31°38.58'S / 48°43.78'W	2709	26.5	36.6	330	
4	14.03.	Start	12:15	31°16.64'S / 47°51.45'W	3028	25.4	36.0		
		Stop	12:57	31°15.85'S / 47°58.13'W	2974	25.5	36.0	277	
5	15.03.	Start	00:00	31°15.07'S / 49°00.46'W	2071	26.0	36.1		
		Stop	01:12	31°26.25'S / 49°04.74'W	2156	25.9	36.1	388	
6	15.03.	Start	18:58	33°07.03'S / 49°04.07'W	2903	27.8	35.7		
		Stop	21:39	33°19.94S / 48°33.90'W	3169	27.1	36.7	614	
7	16.03.	Start	22:22	32°52.71'S / 49°38.31'W	1471	26.9	36.0		
	17.03.	Stop	00:12	32°43.47'S / 49°36.88'W	1661	27.1	36.2	575	
8	18.03.	Start	13:15	30°53.63'S / 48°30.82'W	1837	27.1	35.7		GeoB 6907
		Stop	14:00	30°53.20'S / 48°29.15'W	1853	27.1	35.7	315	
9	19.03.	Start	18:24	29°05.08'S / 43°20.31'W	4038	27.4	36.6		
		Stop	19:11	29°02.51'S / 43°10.12'W	4007	27.3	36.5	342	
10	22.03.	Start	23:17	26°02.38'S / 44°30.75'W	2166	27.6	36.0		
	23.03.	Stop	01:33	26°15.70'S / 44°28.01'W	2332	28.1	36.8	562	
11	24.03.	Start	15:58	24°51.32'S / 44°31.27'W	503	28.0	37.1		GeoB 6908
		Stop	16:52	24°53.91'S / 44°29.72'W	634	28.1	37.1	326	
12	25.03.	Start	17:00	26°20.51'S / 43°32.74'W	2308	29.0	36.7		GeoB 6914
		Stop	18.53	26°20.92'S / 43°32.27'W	2311	28.2	36.7	591	
13	28.03.	Start	16:41	27°19.02'S / 42°20.82'W	2757	28.2	36.8		
		Stop	22:05	26°32.07'S / 41°52.90'W	2393	28.4	37.2	812	
14	29.03.	Start	13:06	24°22.23'S / 40°36.45'W	2942	28.2	36.8		
		Stop	14:16	24°13.67'S / 40°31.42'W	2892	28.4	37.3	406	
15	30.03.	Start	18:35	19°58.06'S / 38°33.73'W	1106	29.1	37.4		
		Stop	20:32	19°38.32'S / 38°27.37'W	916	29.0	37.2	614	

4.3.5 Sampling of Surface Waters for Oxygen Isotope Analyses

(S. Mulitza)

Water samples for oxygen isotope analyses have been taken with the ship's membrane pump at 23 locations from about 3 m water depth (Table 13). 25 ml of sea water were siphoned into brown 25 ml glass bottles. Temperature and salinity have been taken from the ship's *thermosalinograph* record.

Table 13 Surface water samples for stable oxygen isotope analyses. Temperature and salinity data are from the ship's *thermosalinograph.*

No.	Date 2001	Time [UTC]	Position Latitude / Longitude	SST [°C]	SSS [‰]	Remarks
1	11.03.	23:28	32°58.10'S / 49°25.13'W	26.8	36.2	Strong rainfall
2	12.03.	15:43	33°44.93'S / 47°35.43'W	24.5	35.8	
3	12.03.	23:05	33°22.48'S / 47°33.22'W	25.9	36.1	
4	13.03.	14:30	31°55.75'S / 48°32.21'W	26.5	36.8	
5	13.03.	22:52	31°07.60'S / 49°04.58'W	27.0	36.1	
6	14.03.	15:11	31°16.52'S / 47°51.63'W	25.4	36.0	
7	14.03.	22:49	31°14.20'S / 49°00.14'W	25.3	36.1	
8	15.03.	19:36	33°02.90'S / 49°14.32'W	27.1	36.2	
9	16.03.	22:06	33°04.11'S / 49°37.05'W	27.0	36.2	
10	17.03.	23:59	31°47.76'S / 49°11.90'W	26.6	36.6	
11	18.03.	15:00	30°53.62'S / 48°30.83'W	27.0	35.8	
12	18.03.	22:34	30°32.11'S / 47°28.87'W	27.1	36.6	
13	19.03.	19:46	29°12.19'S / 43°40.09'W	27.4	36.6	
14	20.03.	21:40	27°47.07'S / 41°57.50'W	27.8	36.3	
15	21.03.	22:15	25°52.53'S / 43°51.24'W	28.3	36.8	
16	24.03.	15:32	25°02.73'S / 44°21.50'W	28.1	37.2	
17	25.03.	15:33	26°04.72'S / 43°43.00'W	28.1	36.8	
18	27.03.	19:50	27°32.20'S / 42°52.83'W	28.0	36.8	Strong rainfall
19	28.03.	15:23	27°30.02'S / 42°38.03'W	28.0	36.7	
20	29.03.	17:16	24°13.89'S / 40°31.55'W	28.5	37.3	
21	29.03.	22:05	23°38.41'S / 40°10.87'W	28.3	37.0	
22	30.03.	19:31	20°18.79'S / 38°40.51'W	28.8	37.3	
23	31.03.	16:53	16°37.06'S / 38°16.87'W	28.6	37.3	

5 Ship's Meteorological Station

(T. Truscheit)

On transit from Montevideo to the first working area D, R/V METEOR was under the influence of a subtropical high over the central South Atlantic branching into the Rio de la Plata river mouth realm. In between a high pressure zone over Patagonia moving eastward while intensifying and a low pressure system to the north of our track, the ship reached into a strong southeasterly current at the beginning of the third week of March. Both wind seas and swell increased to 3 m in east to southeast 7 Bft winds which reduced to 3 to 4 Bft around middle of the week and turned to E/ENE directions. In the following, a series of small scale lows passed the ship's positions and towards the end of the week another intensive southeasterly current prevailed, caused by an eastward moving low pressure zone just north of our actual position and a high to the southeast.

On March 18, on route to the northern working area E, the cloud field of a low pressure belt directed from Rio de Janeiro to the east, turning ESE and diminishing, occasionally produces short showers in the afternoon of this day and also during the following night. Air temperatures were closely linked to the water temperatures of the warm Brazil Current and reached on average 25 to 26 °C, sporadically up to 27 °C.

The beginning of the fourth week of March, when the ship operated in working area E, was characterized by an unstable layering of the troposphere. This repeatedly produced partially compact cumulonimbus overcast which resulted in only very short showers, but also in thunderstorms mostly at greater distance so that they could just be noticed as sheet lightning. Towards the end of this week, blue sky prevailed, at times interrupted by fields of light clouds.

Due to a low pressure cell at around 50°S/20°W, with an expanded frontal system way onto the South American continent, first an intense southwesterly swell reached the ship's position turning to a northeasterly direction at the end of the week.

A thunderstorm trough, which had built over NE Brazil, slowly crossed the working area from beginning to middle of the last week of March and produced heavy rainfall and thunderstorm during the night of March 26 to 27. Progressing eastward, it diminish to the end of the week. After leaving working area E, R/V METEOR got into a strong northerly current of 6 to 7 Bft causing wind seas of up to 3 m later decreasing to 4 Bft and turning to NE.

In the early afternoon of March 19, two water spouts could be observed quite close to the ship. Formerly water spouts were simply seen as 'tornados built over water'. Multiyear research mainly by US American meteorologists, as water spouts are regular weather phenomena at the Florida Keys, has resulted in a much more differentiated description. Because of their generating conditions, water spouts are mostly found at continental lee coasts in the tropics and subtropics. They ate most abundant at the Florida Keys.

6 Acknowledgements and Concluding Remarks

Despite a quite complicated geological setting to master at the Brazilian continental margin, almost all of the manifold research goals could be achieved during Leg 3 of R/V METEOR Cruise M49. A wealth of seismic and echographic data as well as large amounts of valuable sample material from the water column and the sea floor have been collected that will stimulate numerous shore based studies in the years to come.

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

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8 Station List M49/3

Station GeoB No.	Station Ship No.	Date 2001	Device	Time [UTC] Seafloor/Maximum Wire Length	Latitude [S]	Longitude [W]	Water Depth [m]	Samples / Core Recovery	Remarks
Working Area 'D' - Rio Grande Cone									
6901-1	18	14.3.	ROS+CTD	18:27	31°14.0'	49°00.3'	2036	18 x 10 l	2000, 1750, 1500, 1250, 1000, 800, 600, 400, 250, 175, 125, 100, 75, 50, 30, 20, 10, 3 m; all bottles closed; CTD at 10 m
6901-2		14.3.	MUC	20:12	31°14.2'	49°00.1'	2047	0.28 m	all tubes filled
6901-3		14.3.	SL9	21:48	31°14.2'	49°00.1'	2047	0.00 m	pipe empty
6901-4		14.3.	SL9	23:02	31°14.2'	49°00.1'	2048	8.06 m	geology
6902-1	19	15.3.	SL9	09:12	32°52.6'	49°38.2'	1464	6.61 m	geology
6902-2		15.3.	MUC+CTD	10:20	32°52.6'	49°38.2'	1463	0.24 m	all tubes filled; CTD at 50 m
6903-1	20	15.3.	SL6	13:12	33°00.2'	49°20.2'	1904	3.21 m	geology
6904-1	21	15.3.	SL6	14:36	33°01.3'	49°17.8'	2046	0.00 m	pipe empty
6904-2		15.3.	SL6	15:40	33°01.3'	49°17.8'	2046	5.58 m	geology
6905-1	22	15.3.	SL6	17:47	33°05,3'	49°08,3'	2660	1.92 m	geology
6906-1	23	15.3.	SL12	22:18	33°19.9'	48°33.9'	3170	9.24 m	geology
6906-2		16.3.	MUC+CTD	00:11	33°20.0'	48°33.9'	3153	0.27 m	all tubes filled, CTD at 50 m
6906-3		16.3.	ROS+CTD	02:36	33°19.9'	48°33.1'	3159	18 x 10 l	3000, 2500, 2000, 1500, 1250, 1000, 800, 600, 400, 300, 150, 100, 75, 50, 30, 20, 10, 3 m; all bottles but 50, 30, 20, 10, 3 m closed; CTD at 10 m
6906-4		16.3.	HWS	02:43	33°19.9'	48°33.1'	3179	10 l	surface water

Station List continued

Station GeoB No.	Station Ship No.	Date 2001	Device	Time [UTC] Seafloor / Maximum Wire Length	Latitude [S]	Longitude [W]	Water Depth [m]	Samples / Core Recovery	Remarks
6907-1	24	18.3.	ROS	11:05	30°53.6'	48°30.8'	1840	18 x 10 l	4 bottles from 100, 80, 60 m, 3 bottles from 40 and 20 m
6907-2		18.3.	HWS	11:34	30°53.6'	48°30.8'	1853	10 l	surface water
6907-3		18.3.	MUC+CTD	11:49	30°53.6'	48°30.8'	1827	0.26 m	all tubes filled; CTD at 50 m
6907-4		18.3.	SL9	13:15	30°53.6'	48°30.8'	1826	1.70 m	geology

Working Area 'E' - São Paulo Plateau

Station GeoB No.	Station Ship No.	Date 2001	Device	Time [UTC] Seafloor / Maximum Wire Length	Latitude [S]	Longitude [W]	Water Depth [m]	Samples / Core Recovery	Remarks
6908-1	25	24.3.	MUC	14:25	24°51.3'	44°31.3'	500	0.13 m	1 large / 2 small tubes washed out
6908-2		24.3.	SL6	15:14	24°51.3'	44°31.3'	501	6.07 m	pipe more than filled
6908-3		24.3.	HWS	15:13	24°51.3'	44°31.3'	501	10 l	surface water
6908-4		24.3.	SL9	16:15	24°51.3'	44°31.3'	501	1.63 m	geology
6909-1	26	24.3.	SL9	17:48	24°58.6'	44°26.7'	1038	7.18 m	geology
6909-2		24.3.	MUC	18:42	24°58.6'	44°26.7'	1032	0.31 m	1 large, 2 small tubes empty
6909-3		24.3.	HWS	18:50	24°58.6'	44°26.7'	1038	10 l	surface water
6910-1	27	24.3.	MUC	20:06	25°00.2'	44°25.6'	1188	0.34 m	3 small tubes empty
6910-2		24.3.	SL9	21:16	25°00.2'	44°25.6'	1187	7.87 m	geology
6911-1	28	24.3.	SL12	22:51	25°05.2'	44°22.3'	1605	7.01 m	geology
6911-2		24.3.	MUC	24:00	25°05.2'	44°22.3'	1604	0.43 m	1 small, 2 large tubes washed out
6912-1	29	25.3.	MUC	07:22	25°58.4'	43°47.2'	2227	0.31 m	all tubes filled
6912-2		25.3.	SL12	08:54	25°58.5'	43°47.3'	2229	5.75 m	geology

Station List continued

Station GeoB No.	Station Ship No.	Date 2001	Device	Time [UTC] Seafloor / Maximum Wire Length	Latitude [S]	Longitude [W]	Water Depth [m]	Samples / Core Recovery	Remarks
6913-1	30	25.3.	SL12	10:45	26°04.7’	43°43.1’	2233	6.25 m	geology
6913-2		25.3.	MUC	12:07	26°04.8’	43°43.1’	2233	0.31 m	all tubes filled
6914-1	31	25.3.	MUC	15:31	26°20.5’	43°32.8’	2296	0.32 m	2 small tubes washed out
6914-2		25.3.	SL12	17:05	26°20.5’	43°32.8’	2298	6.89 m	geology
6914-3		25.3.	ROS	18:30	26°20.9’	43°32.3’	2299	18 x 10 l	2200, 1900, 1600, 1300, 1000, 800, 600, 400, 250, 175, 125, 100, 75, 50, 30, 20, 10, 3 m; all bottles closed
6914-4		25.3.	HWS	18:35	26°20.9’	43°32.3’	2307	10 l	surface water
6915-1	32	28.3.	MUC	09:10	27°26.5’	42°46.4’	2545	0.28 m	1 large tube washed out
6915-2		28.3.	SL12	10:54	27°26.5’	42°46.4’	2543	7.66 m	geology
6916-1	33	28.3.	SL6	13:54	27°33.6’	42°29.6’	2858	4.83 m	geology

Equipment		
	CTD	CTD Profiler
	HWS	Surface Water Sampler
	MUC	MultiCorer
	ROS	Rosette Multiple Water Sampler
	SL6	Gravity Corer, 6 m
	SL9	Gravity Corer, 9 m
	SL12	Gravity Corer, 12 m