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Abstract

The aim of METEOR cruise M 24 was a detailed analysis of the facies variations of different types of volcaniclastic deposits on the submarine flanks of Gran Canaria, Canary Islands, their distribution at proximal, medial and distal distances from the island, the structure of the submarine island flanks and the density, gravimetric, magnetic and structural signature of the deeper basement beneath the island and the sedimentary basin north of Gran Canaria. Methods used included seismic, topographic, gravity, and magnetic measurements as well as near-surface sediment sampling (Fig. 1).

Emphasis on the first leg of the cruise was on high resolution seismics using an array of 4 sleeve guns (4 x 40 inch^3) fired at 5, 7.5, or 10 s intervals recorded by a 24-channel, 150 m long streamer. A total length of 2117 km was acquired along 50 profiles. At 9 stations sediment sampling in combination with measurements of heat flow density was attempted, resulting, however, only in 2 Kastencores (3 m) and 5 boxcorer samples (0.3 - 0.5 m).

Central operation of the second leg was a combined offshore-onshore refraction seismic survey using 8 ocean bottom seismographs (OBS) and 8 land stations on Gran Canaria. The seismic energy was generated by firing two 32 l airguns at 1- or 2-min. intervals. The seismic stations were distributed in an ~75 x 70 km array offshore and onshore with 7 landstations on the northern half of Gran Canaria and one in Fataga (~35 km south of the northern coast).

Gravity was measured continuously throughout the entire cruise at 10 s intervals and stored together with navigation data on hard disk and diskettes. Swath bathymetry using the onboard Hydrosweep system was recorded continuously as well, during bad weather (> 6 Bft), however, with significant unreliability. Magnetic measurements were taken along all seismic profiling as well as sedimentechographic recording with the onboard Parasound system.

The results of the cruise form the base to define the locations of drill sites along a traverse through the submarine apron of Gran Canaria (Volcanic Island Clastic Apron Project, VICAP).

Zusammenfassung

Das Ziel der METEOR Reise Nr. 24 war eine detaillierte Untersuchung der Faziesvariationen verschiedener Typen vulkanoklastischer Ablagerungen auf den submarinen Flanken Gran Canarias, ihrer Verteilung in proximalen, medialen und distalen Entfernungen zur Insel, der Struktur der submarinen Inselflanken und des Basements unter der Insel und dem Sedimentbecken nördlich Gran Canarias. Es wurden seismische, bathymetrische, gravimetrische und magnetische Messungen durchgeführt sowie Proben oberflächennaher Sedimente genommen (Abb. 1).

Das Schwergewicht lag im ersten Fahrtabschnitt auf hochauflösender Reflexionsseismik, die mit einem 4 x 40 inch^3 sleeve gun array und einem 24kanaligen 150 m langen Streamer durchgeführt wurde. Insgesamt wurden 50 Profile mit einer Gesamtlänge von 2117 km vermessen. An 9 Stationen wurden Versuche unternommen, Sedimentproben in Verbindung mit Wärmeflußmessungen zu gewinnen, die jedoch nur in zwei 3 m-Kernen (Schwerkastenlot) und 5 Kastengreiferproben (0,3 - 0,5 m) resultierten.

Zentrale Operation des zweiten Fahrtabschnittes war eine kombinierte refraktionsseismische Land-See Vermessung. Seismische Energie wurde durch 2 Airguns mit je 32 l Kammervolumen in 1 oder 2min. Intervallen angeregt und von 8 Ozeanbodenseismographen (OBS) und 8 Landstationen in einem ca. 100 x 70 km Stationsnetz aufgezeichnet.

Das Schwerefeld wurde kontinuierlich während der gesamten Fahrt in 10 s Intervallen gemessen und zusammen mit den Navigationsdaten auf Festplatte und Disketten gespeichert. Ebenso wurde mit dem an Bord befindlichen Hydrosweep Fächerlot kontinuierlich die Bathymetrie aufgezeichnet, allerdings mit signifikanten Ausfällen während Schlechtwetterphasen (> 6 Bft). Magnetische Messungen und sedimentechographische Aufzeichnungen mit dem bordeigenen Parasoundsystem wurden auf allen Profilen durchgeführt.

Die Resultate der Fahrt liefern die Grundlage zur Definition der Bohrpositionen entlang einer Traverse durch den submarinen Schuttfächer Gran Canarias (Volcanic Island Clastic Apron Project, VICAP).

1 Research Objectives

Background

Oceanic volcanoes are by far the largest volcanic structures on Earth (e.g. average volume Hawaii, Canary Islands ca. 20,000 km^3, compared with ca. 500 km^3 for an average stratovolcano); they form some of the highest mountains on the planet (Mauna Loa: 10,000 m from sea floor to summit). Oceanic volcanoes grow very rapidly (within ca. 0.5 Ma) during their main or shield stage (90 - 99% of their volume). They generally experience one or more later distinct volcanic phases of much lesser volume but different composition (Fig. 2), and are surrounded by volcaniclastic aprons whose volume may far exceed that of the source volcano (MENARD, 1956). Surprisingly, seismic stratigraphy, lithology, facies variations, structure and evolution of these aprons are very poorly known.

The Canary Islands evolved during migration of the African Plate over the vaguely defined Canary Hotspot (melting anomaly) (HOLIK et al., 1991). They represent one endmember type of volcanic islands. The stages of magmatic evolution of the Canary Islands in principle resemble those of the Hawaiian Islands, but there are major differences related to:

- Spreading rate;
- Mantle composition (continent-ocean transition area);
- Decompression rate of the mantle-source diapirs;
- Age, thickness, and rigidity of the lithosphere;
- Rates of erosion and sedimentation around the islands, and
- interfingering with sediments from the continental margin. Fundamental to the objective of the present project is the fact that (1) the lifetime of individual Canary Islands is much longer than those of Hawaiian Islands (ANCOCHEA et al., 1990; LEBAS et al., 1986) and (2) the very large volume of highly evolved magmas generating many ash falls and precisely datable layers in the clastic aprons of Gran Canaria.

Well developed seismic reflectors within the volcaniclastic apron SE of Gran Canaria, initially interpreted as representing the Cretaceous/Tertiary boundary, were found by drilling (DSDP Leg 47a, site 397) to be volcaniclastic massflow deposits and fallout ash layers. The lithology and stratigraphy of these deposits crudely reflect the submarine and subaerial temporal, volcanic, and compositional evolution of Gran Canaria, under- and overlain by volcaniclastic deposits from Fuerteventura and Tenerife (SCHMINCKE and v. RAD, 1979; SCHMINCKE, 1982).

Map of VICAP Drillsites

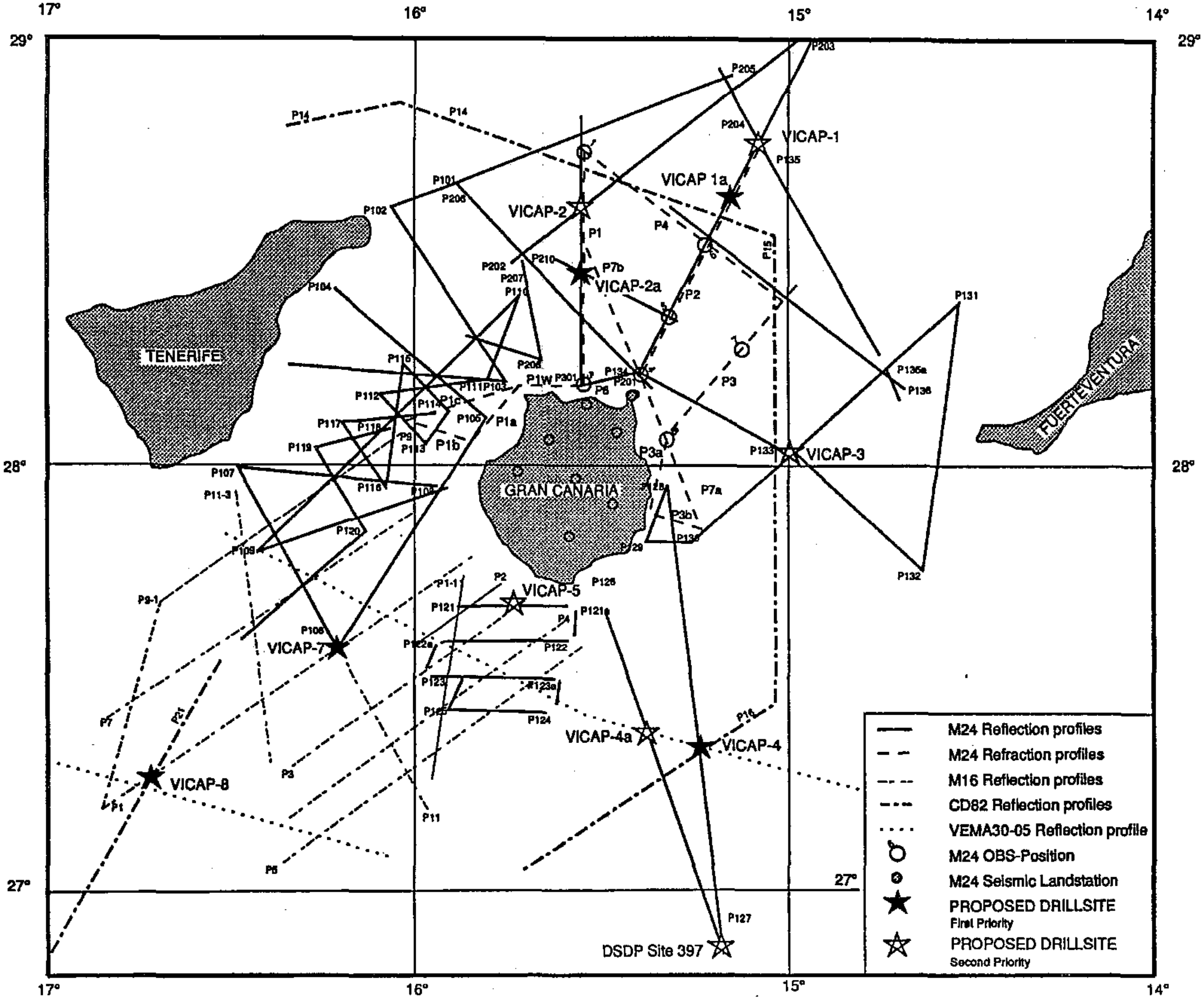


Fig. 1: Cruise track of METEOR cruise no. 24

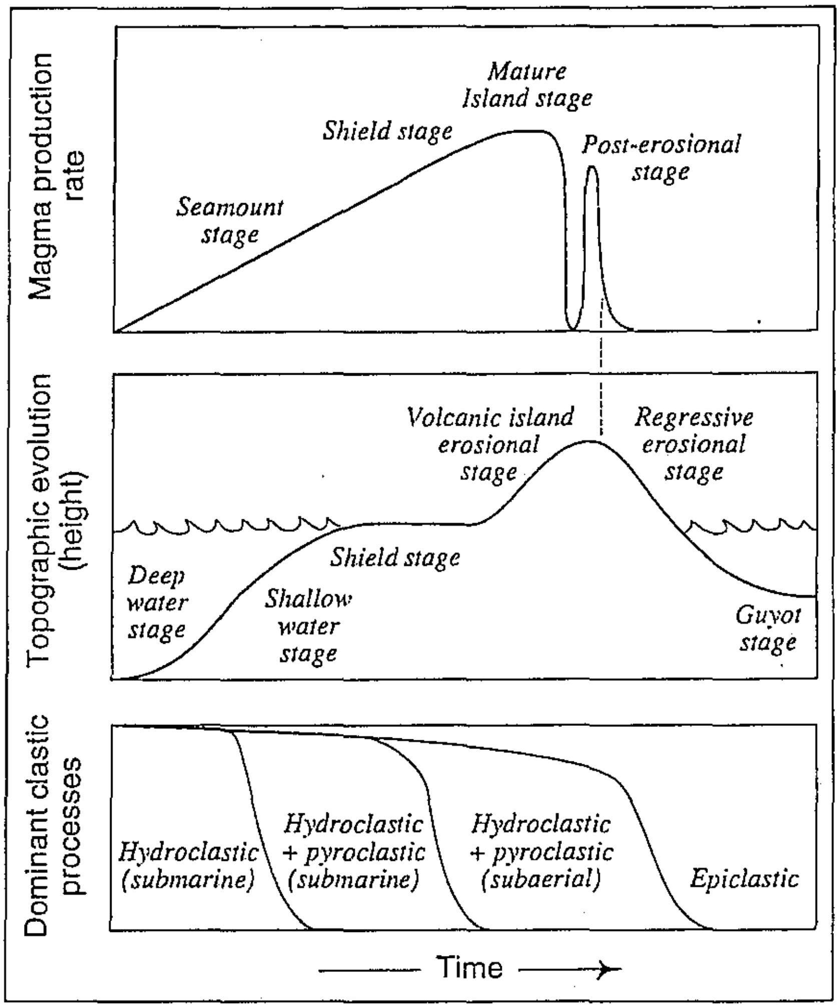


Fig. 2: General scheme of temporal volcanic island evolution showing variations in magma production, topography, and deposits formed.

Initial Cruise

METEOR cruise M 16/4 (Fig. 3), carried out in June 1991, SW of Gran Canaria, was the first pre-site survey for the VICAP drilling proposal and yielded Hydrosweep and Parasound, seismic reflection and refraction, magnetic and gravity data. An initial seismic stratigraphy of the volcaniclastic sediments was established on the southwestern flanks of the island using continuous seismic reflectors landward of a zone distinguished by a more chaotic facies, probably caused by slides, slumps and volcanic morphology on the steeper slopes of the island.

The reflection seismic data (75 m 6-channel ministreamer and 2.4 km 48-channel streamer) show a very high resolution of the upper sediments (ca. 700-1000 m), and allow to correlate seismic interfaces at up to 8 seconds TWT (two way traveltime), representing seismic waves that penetrated almost the entire crust. Refraction seismic data show clear first arrivals up to 50 km distance.

The total magnetic intensity map shows strong amplitudes in the vicinity of Gran Canaria, interpreted as igneous bodies on the sea floor. The free air gravity anomaly map illustrates the influence of the mass difference between the islands (positive anomalies) and the adjacent ocean basins (negative anomalies).

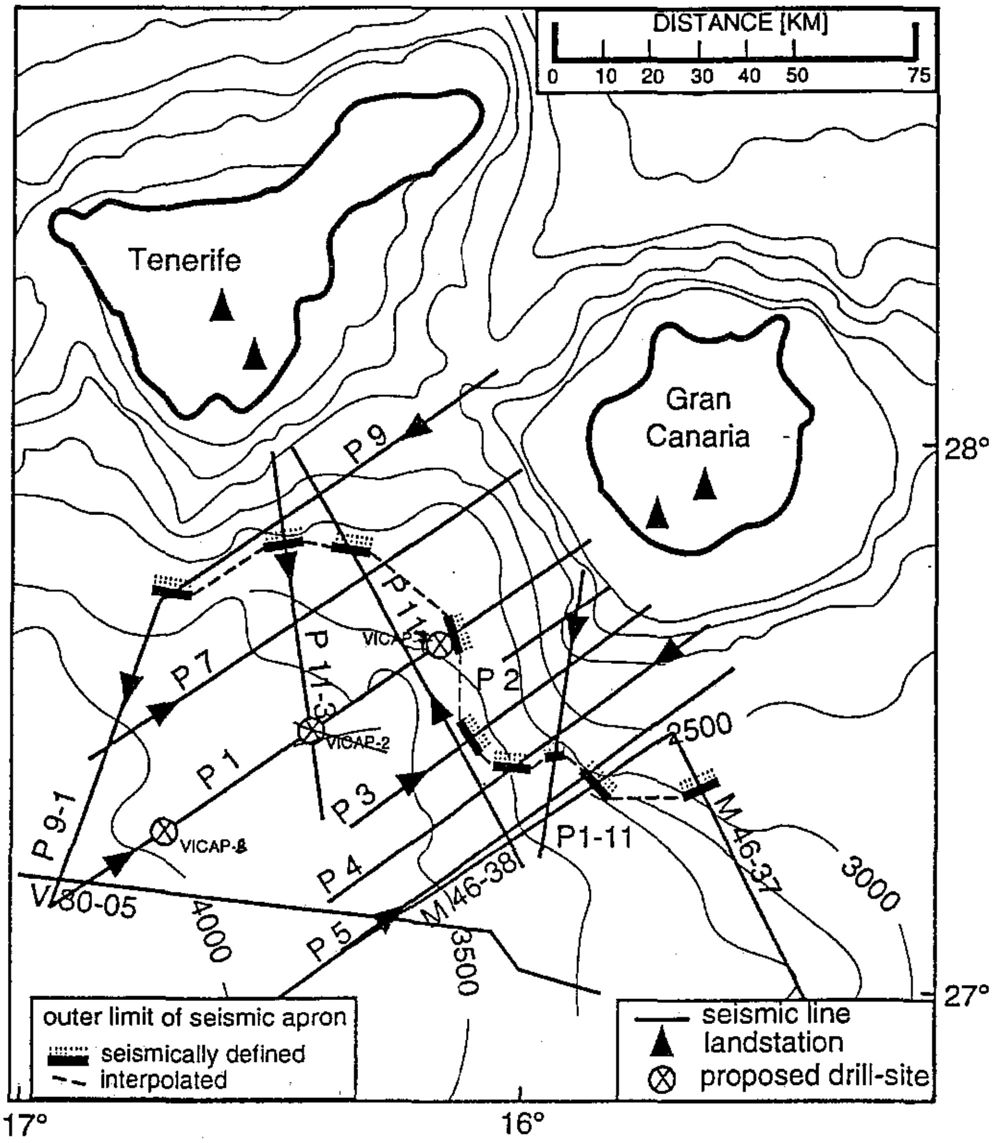


Fig. 3: Shiptracks of METEOR cruise M 16/4 and outer limit of seismically defined apron. Proposed drill locations VICAP-7 and VICAP-8 are indicated.

1.1 Introduction

The goal of METEOR cruise M 24 was to get a detailed survey of the northeastern, northern, and western volcaniclastic aprons around the prototype oceanic volcanic system of Gran Canaria continuing from METEOR cruise M 16/4. Figure 4 illustrates the relationship between the two cruises. The study focussed on the temporal and dynamic interdependence of the three main magmatic phases of Gran Canaria and the spatial and temporal relationship to the aprons and evolution of the older island of Fuerteventura to the east and the younger island of Tenerife to the west. In order to reconstruct the history of the island it is necessary to understand the entire island complex, petrologically and structurally, including both submarine and subaerial portions, as well as its peripheral sedimentary basins. To calculate the mass balances a 3-dimensional isostatic model of the island is needed, which is determined by the velocity distribution through the island to the upper mantle. Special emphasis is placed on geophysical data, particularly reflection seismic data and deep seismic studies with ocean bottom seismographs (OBS) in the area of Fuerteventura - Gran Canaria - Tenerife, in combination with land based studies on Gran Canaria.

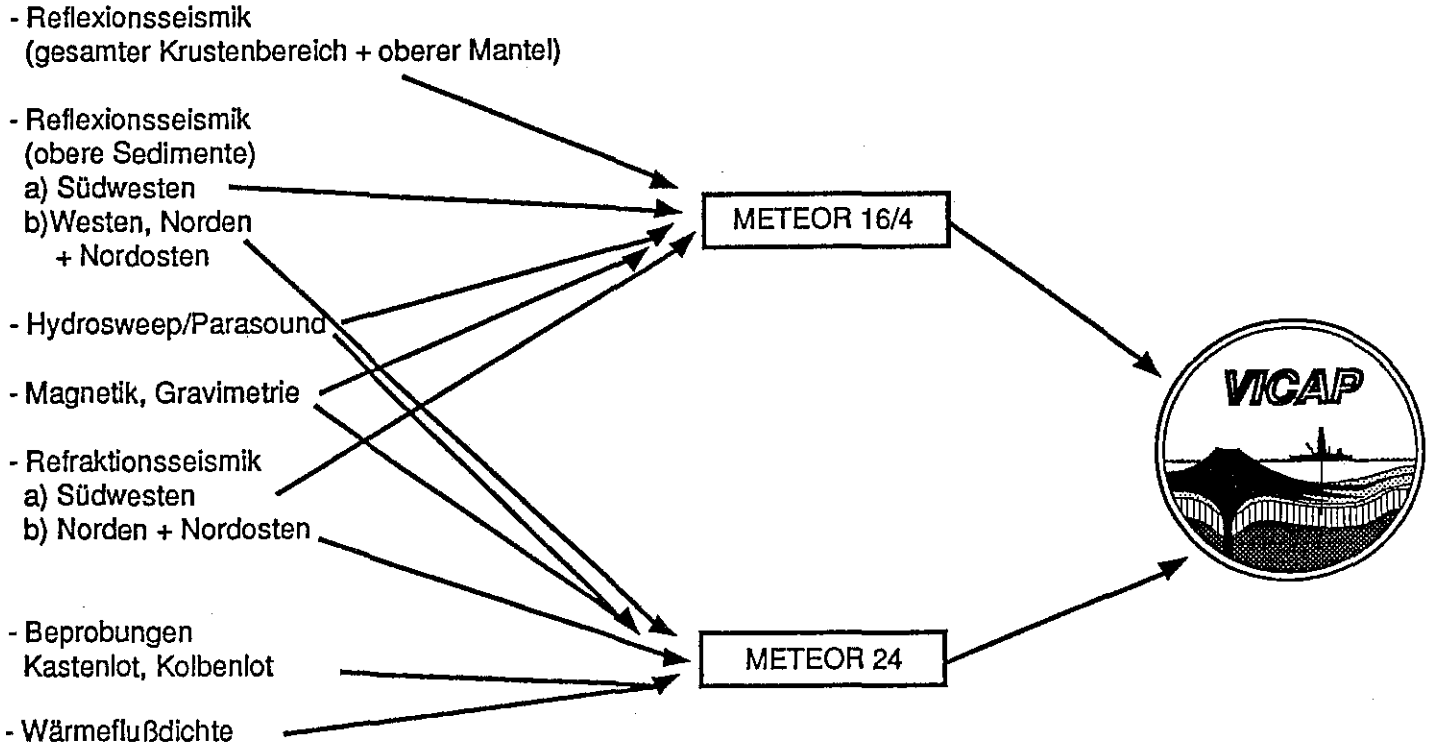


Fig 4: Relationship between cruises M 16/4 and M 24 as pre-site surveys for VICAP ODP drilling proposal.

Tab. 1: Legs and chief scientists of METEOR cruise no. 24

Leg 24/1
15 April - 27 April 1993
Las Palmas/Canary Islands - Las Palmas
Chief scientist: Prof. Dr. H.-U. Schmincke

Leg 24/2
27 April - 9 May 1993
Las Palmas - Malaga/Spain
Chief scientist: Prof. Dr. H.-U. Schmincke/Dr. R. Rihm

Coordination: Prof. Schmincke

Master (RV METEOR)
Captain M. Kull

1.2 Bathymetry and Surface Structure

The knowledge of the morphology of the proximal to medial submarine slopes of Gran Canaria and of the gently sloping sea floor is essential to evaluate erosional processes, the distribution, shape and size of primary volcanic features (submarine volcanic cones, lava flows etc.), faults, slump scars, slides, sediment fans etc. as well as the evolution of submarine deltas and canyons. These data are fundamental to understand the dynamic processes that characterize especially the shield stage but, also the major subsequent magmatic and erosional stages. Highly desirable GLORIA side scan data are not yet available for the area. The major magmatic phases, marked by rapid growth (high magma production and eruption rates), followed by regressive phases in which the complex morphology is buried by relatively slow sediment accumulation, should be reflected in the morphological data.

1.3 Reflection Seismology

High resolution reflection seismology is the best tool to portray and decipher the structures of the upper few hundred meters of the clastic apron in the proximal areas, a belt ca. 20-40 km wide around the island. Here, the reflection data should help to achieve a more rational subdivision and understanding of what is commonly called the "chaotic seismic facies" around volcanic islands, the volcanic apron sensu stricto as used in geophysics. In the medial and distal facies of the apron outside the rough topography of the proximal belt, thick, more regularly stratified sediment fillings can be subdivided by high resolution reflection seismology to depths exceeding 1 km using prominent single or, more commonly, grouped reflectors. The seismic stratigraphy so established is basically an eminent example of "event stratigraphy" that should reflect the major periods of high volcanic productivity of Gran Canaria.

1.4 Heat Flow

Heat flow density is the main parameter used for the description of the thermal state of the lithosphere, and is especially important in constraining reconstructions of young and recent magmatic processes. Heat flow values around the Canary Islands should help to constrain models for the origin of the islands, i.e. hot spot versus fracture origin. So far, there are no measured heat flow values known from the sea floor around the Canary Islands.

1.5 Near-Surface Sediments

Well-developed reflectors that are evident in Parasound records from M 16/4 are probably pre-dominantly tephra fallout and/or distal turbidites, probably the submarine equivalents of subaerial ash flow deposits. The upper 10 m of the sediments could contain some tephra layers from the 1 Ma year old active volcano Teide (Tenerife). Dating of such tephra layers can better constrain sedimentation rates and be most useful for calibrating the $\delta^{18}O$ stratigraphy.

Paleo-oceanological work around the Canary Islands aims at obtaining reference data for the marine sedimentary environment. The setting of the islands lacks the influence of local near-continental anomalies (e.g. coastal buoyancy belt).

The combination of tephra, seismic and isotope stratigraphy should enable precise resolution of the stratigraphy and of paleo-oceanographic events. A database of the sediment geophysical parameters is also important for calibration of seismic reflections. Thus, regional mapping of ash layers by high resolution Parasound echograms will be possible, and the assessment of mass balance involved in transport of volcanogenic material into ocean environments can be improved.

1.6 Volcanic Island Clastic Apron Project (VICAP)

A drilling program into the clastic apron around Gran Canaria (VICAP) within the Ocean Drilling Programme (ODP) is scheduled for August/September 1994 (Leg 157). In VICAP, the evolutionary history of a prototype volcanic island (Gran Canaria) will be reconstructed using a traverse through its clastic apron. M 24 has been the main pre-site survey for determining drilling locations for the VICAP project.
The objectives of the VICAP Drilling Proposal are:

- Mantle source evolution;
- High resolution compositional, temporal, structural and sedimentological analysis of a large volcaniclastic apron surrounding an intraplate volcanic island system and of the more distal Abyssal Plain sediments;
- 3D-basin modelling;
- Determination of the response of the lithosphere to loading and heating during magmatic activity and to enhanced levels of stress associated with temporal changes in plate dynamics.
- Calculation of sediment budgets for the growth evolution and unroofing of Gran Canaria;
- Assessment of chemical fluxes between components, especially volcanic glass and seawater, maturation of organic matter at elevated temperatures in the proximal facies near the hotter interior of the island as well as during low temperature diagenetic conditions away from the hot spot.

It will be possible to correlate the downhole measurements (planned within VICAP) and lithologic profiles to small-scale structures detected using the high resolution multi-channel reflection seismic of METEOR cruise no. 24.

1.7 Long Range Goals

METEOR cruise no. 24 and the VICAP drilling, together with ongoing land-based studies, are part of a long range comprehensive case study of an intraoceanic volcanic complex aimed at reconstructing the volcanic, structural, sedimentological, magmatic and temporal evolution of the intraplate volcanic system of Gran Canaria. The aim of this program is the modelling of the structural and morphological evolution of oceanic volcanic islands in relation to the mantle deformation, magma production and eruption rates. This includes the growth of the volcanic edifice from deep water, to shallow water/sea level, to subaerial stages of volcanic activity. The ultimate aim is to quantify mass and energy transfer from the mantle to the earth's surface and finally into the surrounding sediment basins.

2 Participants

Tab. 2: Participants of METEOR cruise no. 24

Leg M 24/1

Name	Specality	Institute
Schmincke, Hans-Ulrich, Prof. Dr. (Chief Scientist)	Vulcanology	GEOMAR
Baraza, Jesus, Dipl. Geol.	Sedimentology	CSIC
Bassek, Dieter, WFT	Meteorology	DWD
Blank, Dirk, Student	Geology	Uni Kiel
Buhlmann, Klaus, Dipl. Met.	Meteorology	DWD
Canales, Juan Pablo, Dipl. Geophys.	Geophysics	CSIC
Collier, Jenny, Dr.	Geophysics	UO
Dalwood, Rupert, Student	Geophysics	UO
Dekker, Muriel, Dipl. Geol.	Geochemistry	IOS
Dehghani, G. Ali, Dr.	Geophysics	IfGHH
Funck, Thomas, Dipl. Geophys.	Geophysics	GEOMAR
Götz, Lilian Gabi, Dipl. Geol.	Geology	IfGHH
Hoffmann, Julia, Student	Geology	Uni Kiel
Krastel, Sebastian, Student	Geophysics	Uni Kiel
Klügel, Andreas, Dipl. Ing.	Geology	GEOMAR
Krause, Stefan, Student	Geophysics	IfGHH
Lykke-Andersen, Holger, Prof.	Geophysics	UÅ
Neufeld, Sergej, Technician	Mechanic	GEOMAR
Pracht, Jens, Student	Geology	Uni Kiel
Radomski, Stefan, Dipl. Geophys.	Geophysics	GEOMAR
Rihm, Roland, Dr.	Geophysics	GEOMAR
Sabetian, Ali, Student	Geophysics	IfGHH
Schirnick, Carsten, Dipl. Geol.	Vulcanology	GEOMAR
Schwan, Lothar, Technician	Compressor	IfGHH
Sumita, Mari, Dr.	Vulcanology	GEOMAR
Trinhammer, Per, Technician	Reflectionseismic	UÅ
Weaver, Phil, Dr.	Sedimentology	IOS
Zahn-Knoll, Rainer, Dr.	Paleooceanography	GEOMAR
Zhang, Yong, Dr.	Geophysics	GEOMAR

Leg M 24/2

Name	Specality	Institute
Schmincke, Hans-Ulrich, Prof. Dr. (Chief Scientist)	Vulcanology	GEOMAR
Rihm, Roland, Dr. (Chief Scientist)	Geophysics	GEOMAR
Arlandi Rodriguez, Manuel› Student	Geology	ITGE
Bassek, Dieter, WFT	Meteorology	DWD
Bergmann, Peter, Dipl. Ing.	OBS	GEOMAR
Buhlmann, Klaus, Dipl. Met.	Meteorology	DWD
Canales, Juan Pablo, Dipl. Geophys.	Geophysics	CSIC
Collier, Jenny, Dr.	Geophysics	UO
Dalwood, Rupert, Student	Geophysics	UO
Dañobeitia, Juan J., Dr.	Geophysics	CSIC
Dehghani, G. Ali, Dr.	Geophysics	IfGHH
Funck, Thomas, Dipl. Geophys.	Geophysics	GEOMAR
Götz, Lilian Gabi, Dipl. Geol.	Geology	IfGHH
Krastel, Sebastian, Student	Geophysics	Uni Kiel
Klügel, Andreas, Dipl. Ing.	Geology	GEOMAR
Krause, Stefan, Student	Geophysics	IfGHH
Lykke-Andersen, Holger, Prof.	Geophysics	UÅ
Pracht, Jens, Student	Geology	Uni Kiel
Radomski, Stefan, Dipl. Geophys.	Geophysics	GEOMAR
Sabetian, Ali, Student	Geophysics	IfGHH
Schwan, Lothar, Technician	Compressor	IfGHH
Sumita, Mari, Dr.	Vulcanology	GEOMAR
Trinhammer, Per, Technician	Reflectionseismic	UÅ
Ye, Sanyu, Dr.	Geophysics	GEOMAR

Tab. 3: Participating Institutions

CSIC	Consejo Superior de Investigaciones Científicas Institute of Earth Sciences Martí i Francès s/n. 08028 Barcelona Spain
DWD	Deutscher Wetterdienst Seewetteramt Bernhard-Nocht-Str. 76 20349 Hamburg Germany
GEOMAR	Forschungszentrum für marine Geowissenschaften der Unversität Kiel Wischhofstr. 1-3 24148 Kiel Germany
IfGHH	Institut für Geophysik der Universität Hamburg Bundestr. 55 20146 Hamburg Germany
IOS	Institute of Oceanographic Sciences Deacon Laboratory Wormley / Godalming Surrey GU8 5UB United Kingdom
ITGE	Instituto Tecnológico GeoMinero de España c/ Cristobal Bordia 25 28003 Madrid Spain

Tab. 3: continued

UÅ	University of Århus Department of Earth Sciences Finlandsgade 6 8200 Århus Denmark
Uni Kiel	Geologisch-Paläontologisches Institut und Museum Olshausen Str. 40-60 24118 Kiel Germany
UO	University of Oxford Department of Earth Sciences Parks Road, Oxford OX1 3PR United Kingdom

3 Research Programme

3.1 Hydrosweep

The mapping of the steep slopes of Gran Canaria and the more distant ocean floor was carried out using the Hydrosweep system. The data have been evaluated and transformed to bathymetric maps on board, where possible, but the system onboard METEOR does not allow plotting of complete maps of an entire survey or 3-dimensional images of the ocean floor. We plan to have more complete bathymetric maps, also including other available data, and detailed 3-D images computed and plotted on land after the cruise.

3.2 Parasound

The Parasound sediment echoes were recorded continuously to magnetic tapes during profiling. In addition, continuous protocols with special emphasis on significant bathymetric, sedimentary and tectonic features were drawn manually and subsequently described. Processing of the Parasound data allows for correction of the time shifts applied to the monitor plot during data acquisition, and for appropriate scaling and presentation of the records. These records provide the basis for mapping the extent of different provinces of sediment types and - together with the high resolution reflection seismics - identification and mapping of structural and tectonic features.

3.3 Seismic Reflection

The high resolution multi-channel reflection seismicity permits detailed structural mapping of the volcaniclastic sediments in the apron. Areas to the west, north and northeast of the island where widely distributed slides and slumps had been suspected, were densely surveyed and will be studied in detail. The profiles were oriented in such a way as to provide as many radial sections as possible in order to document changes in thickness and structure of reflectors or groups of reflectors within the apron with distance from the island. Radial profiles are linked with tangential ones to form a seismic net. This net should allow together with other data sets (SEIBOLD and HINZ, 1976; UCHUPI et al., 1976; WISSMANN, 1979; DAÑOBEITIA and COLLETTE, 1989; ROEST et al., 1992; BANDA et al., 1992) accurate calculation of the volume of the apron, and aid in identification, correlation, and mapping of the mass wasting deposits.

3.4 Seismic Refraction

A wide angle reflection and refraction seismic net has been realized using 8 OBS and 8 land stations on Gran Canaria in order to determine the seismic velocities and structure of the middle and lower part of the crust and uppermost mantle beneath Gran Canaria and surrounding sediment basins. The length and arrangement of the profile is designed for measurements into the upper mantle, as well as lateral velocity variations and is supposed to produce a three dimensional velocity model of the structure of the crust and upper mantle. The effects of the plutonic core of the island on the dispersion of the seismic waves (velocity reduction, changes in the ratio of P- and S-wave velocities) will be studied. A 3-D tomography of the lithosphere will be produced by the inversion of the measured seismogram sections using ray-tracing methods.

Additional cruises into this area with similar objectives are planned in the near future: Oxford University (UK), Lamont-Doherty Earth Observatory (USA), and CSIC Barcelona (Spain).

3.5 Gravity / Magnetics

The gravimetric and geomagnetic measurements, an extension of the investigations done by the Geophysics Department at the University of Hamburg during the M 16/4 cruise, represent a significant expansion of the existing databases. A complete and detailed geomagnetic map will enable recognition of all significant geomagnetic anomalies that could be of volcanic origin, and, in combination with seismic and gravity, allows quantitative estimates of depth, total volume and mass. The expanded gravity data base will also be the basis for determining the isostatic state for each of the islands and for transforming the two-dimensional deep seismic models into a model of the crust and the upper mantle within the study area.

3.6 Heat Flow

The temperature gradients were measured simultaneously with the sampling, through an array of thermistors mounted on the sediment sampler. Thermal conductivity values were collected subsequently on deck.

3.7 Sampling

Samples were taken with a heavy box corer and Kastencore at suitable locations in between seismic reflection profiles. The profiling time between sampling sites was used for initial core descriptions (macroscopic description, photography, measurements of physical parameters of sedimentary cores). The mineralogy, chemical composition and age of the tephra beds will be an important contribution to the reconstruction of the most recent volcanism on Tenerife. For paleo-oceanological work, measurement of geophysical parameters (P-wave velocity, susceptibility, conductivity etc.) is planned. A data base comprising variability of stable isotopes, fauna and organic components will be compiled.

3.8 Navigation Data

All incoming information was organized by data base on a personal computer for preliminary evaluation. The computer was connected to the data transmission system ATLAS DVS 1300 which was installed on the ship and continuously recorded ship velocity, water depth, and the length of the winch cable.

4 Narrative of the Cruise (H.-U. Schmincke, R. Rihm)

The scientific crew boarded the ship in Las Palmas on April 13th and 14th 1993. Two groups of students from the University of Las Palmas visited the ship in the morning of the 14th. An informal reception aboard the ship on the evening of the 14th was attended by 15 guests. They included scientists from the University of Las Palmas, the Hydrological Survey (Servicio Hidraulico) and the Volcanological Observatory in Tenerife and some German journalists. The cruise thus began with an enjoyable evening, stimulating discussions and good wine.

The ship departed from Las Palmas on April 15th 1993, 10:00. Work began immediately by employing the five systems (Parasound, Hydrosweep, Magnetometer, Gravimeter, High Resolution Seismics (HRS)) running side by side for most of the cruise when profiles were shot, except during the wide angle reflection and refraction OBS seismic study (April 29th-May 5th). Some initial valve problems with the HRS along Profile 101 were soon overcome. For the rest of the cruise the sleeve gun array worked like a charm, generating an overwhelming amount of very high quality data.

For the first 6 days (April 15th-20th) profiles P101-120 were shot largely in the channel between Gran Canaria and Tenerife. We made a determined attempt to map the channel in some detail in order to

- delineate the boundary between the older flanks of the submarine part of Gran Canaria and the younger onlapping Tenerife flank deposits,
- find possible drill sites,

- check for the often postulated, but never really documented major fault between Gran Canaria and Tenerife, and
- survey the area of the 1989 earthquake.

Fault-hunting turned out to be a wild goose chase - major faults were simply not detected and our long-held suspicion appears to be confirmed that the fault does not exist - just as all postulated big faults on land (Gran Canaria) turned out to be fits of the imagination. The hot spot model for the origin of the Canary Islands appears to be the more robust.

The morphology of the channel area turned out to be most interesting and a more detailed bathymetric map prepared for the central area revealed young cones on the flanks of Tenerife at 2 to 2.5 km water depth. A "wall-like" feature could be a major slump scar on the western flank of Gran Canaria and allowed to define the two main submarine drainage (sediment flow) areas, the highest point (divide) of the channel lying to the southwest. In the evening of the 17th we had to approach Santa Cruz Harbor (Tenerife) to release a student with appendicitis. He was operated successfully the same day and returned to Germany a few days later.

The weather during the first week was variable, the wind force increasing to 8 and temporarily to 9 at the end of the first week, decreasing the quality of the HRS recording and forcing us to change the program by spending one day in the calmer lee of Gran Canaria (April 21st/22nd), where a succesful sample (station M24-7, 3 m core, Kastenlot) incl. heat flow measurement was taken in addition to the detailed profiling over the drainage delta. Some 6 hours were spent on April 22nd to rescue a 12 m yacht which had lost its orientation in the 4 m waves between Gran Canaria and Tenerife. Master Kull, officer Priebe and the crew handled the situation calmly and professionally.

On April 23rd and 24th we connected the M 24 profile net with two long lines (P126 and 127, >100 km each) to DSDP Drill Site 397 in order to correlate directly a 1300 m lithologic sequence drilled in 1976 by RV GLOMAR CHALLENGER with the stratigraphy of our survey. The remaining days until the stopover in Las Palmas on April 27th were spent profiling E and NE of Gran Canaria (P129-136). Some typical bottom-water controlled sedimentation patterns were found in the channel between Gran Canaria and Fuerteventura and in the basin N and NE of Gran Canaria well-layered regular sediments were found with major input from the island flanks indicated by sediment transport channels and slump or debris avalanche structures. Sediment sampling on the upper slope of Banco de Amanay, a prominent seamount off the southwest coast of Fuerteventura was unsuccessful. Figure 5 illustrates the major scientific methods applied and some events of the first leg of the cruise.

On April 27th the ship arrived in Las Palmas harbor at 08:00 for loading of OBS equipment and partial exchange of scientific personnel. The ship left port at 12:00.

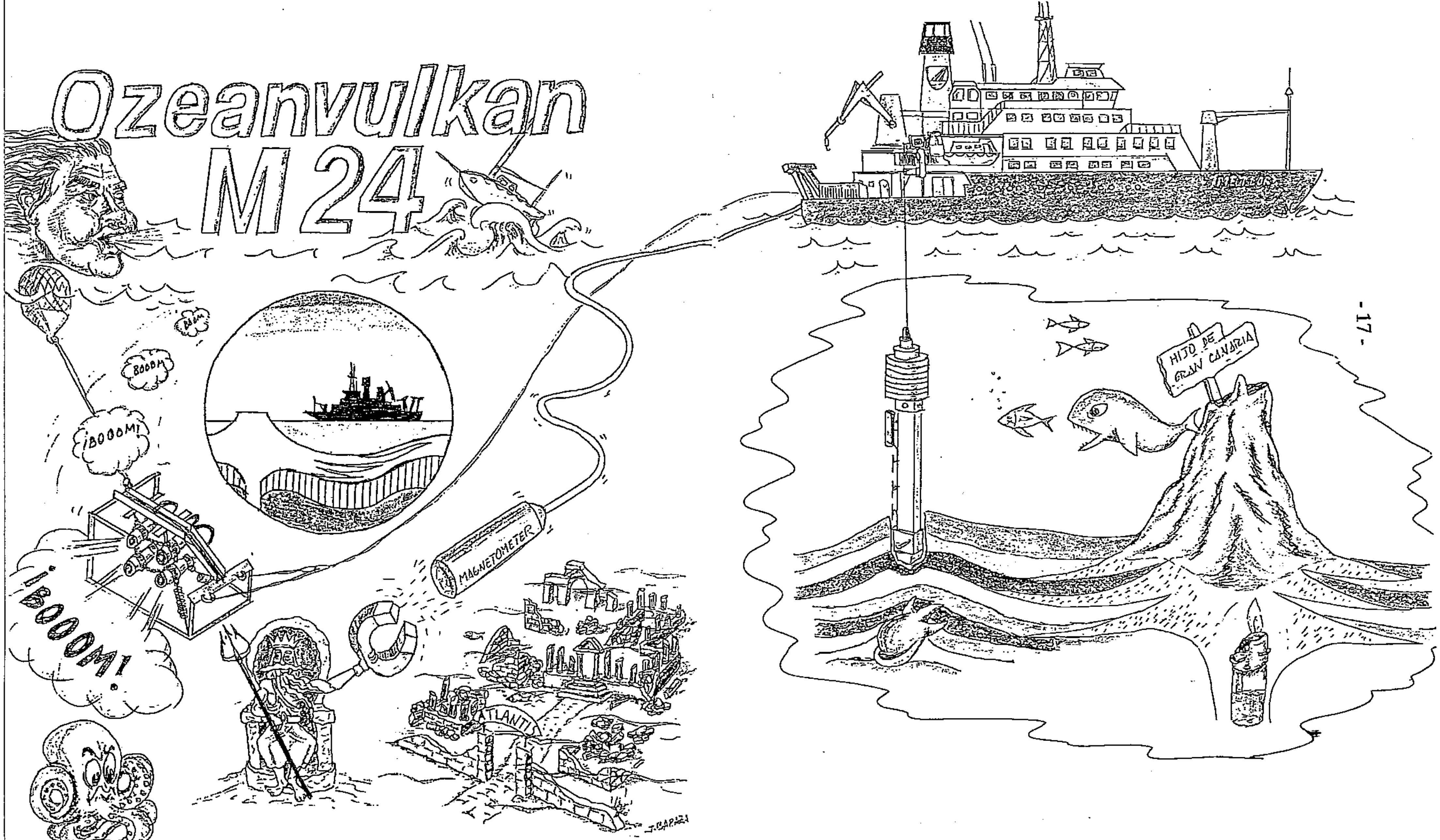


Fig. 5: Copy of METEOR guest book contribution (J. Baraza) illustrating the major components of METEOR cruise M 24

HRS profiling was continued N and NE of Gran Canaria (P201-208) during preparation of OBSs and large (2 x 32 l) airguns on April 27th - 29th, providing good data coverage in the region of the proposed highest priority ODP VICAP drill sites.
Pressure test of OBS transponders were performed later on April 29th and 8 OBS were deployed N/NE of Gran Canaria. Seismographs were installed at 8 landstations on Gran Canaria on April 29th. Continuous airgun shots on a profile net covering the OBS-sites were fired between April 30th and May 3rd. The shooting with the two large airguns was very successful. At 1-min intervals, however, only 110 bars of air pressure could be made available by the 4 Junkers compressors. We therefore shot the profiles in the vicinity of Gran Canaria at 1-min intervals with one airgun at 130 bar and the distant profiles at 2-min intervals with both airguns at 130 bar. Some 90% of the net were completed when strong winds forced us to abandon the last profile scheduled for May 4th at 02:00 in the morning. Alternative plans to shoot part of the remaining profile while some of the OBS were still on the ground were also aborted, because of bad weather. Recovery of OBS began on May 4th at 09:45 and ended on May 5th at 09:15. Seven of the 8 OBS were recovered. Preliminary inspection of the tapes indicated all had run and recorded successfully.
The next to last high resolution seismic reflection profile was shot between 11:30 and 15:30 north of Gran Canaria, before the vessel moved to Las Palmas on the evening of May 5th to drop off 7 scientists.

The lost OBS Pos. 4 was not recovered in the evening after departure from Las Palmas. The last HRS profile (301) was completed heading straight north off Gran Canaria. P301 was finished on May 5th, 03:17 and METEOR began her move to Malaga, where she arrived on the 9th of May 1993 at 08:00.

5 Operational Reports and Preliminary Results (H.-U. Schmincke, R. Rihm)

5.1 Introduction

The course of the cruise and the orientation of the profiles shot were frequently changed to optimize the scientific output and, during a period of 2 days, to adjust to local weather conditions. Work was carried out in 4 main areas.

The submarine morphology differs appreciably around Gran Canaria and can be subdivided for simplicity into several areas:

I The channel between Gran Canaria and Tenerife,
II the submarine slope and sedimentary basin south and southeast of Gran Canaria,
III the area between Gran Canaria and Fuerteventura,
IV the slope and sedimentary basin north of Gran Canaria.

Several main physiographic provinces are recognized around the submarine - and dominant - part of Gran Canaria (SCHMINCKE, 1993; see Figure 6):

- The main flank;
- The foot, and
- the northern and southern basins.

The main flank can be further subdivided into

- the very shallow shelf (ca. 100 m),
- a gently sloping flank section down to about 1000 m,
- the very steep flanks (ca. 1000-2000 m), and
- the lower flank (2000-2500 m).

The flank extends from ca. 2500-3500 m in the south and from 3000-3500 m in the north. Physiographic provinces are more difficult to delineate in the complex channels east and west of Gran Canaria.

The flank is roughly equivalent to the area of discontinuous reflectors, rough topography and is called chaotic seismic facies or volcanic apron in geophysics. The volcanic apron in a general volcanological and sedimentological sense includes the sedimentary basins adjacent to the volcanic edifice, extending roughly 100 km around the island. Actually, volcanic debris flows from the Canaries and distal volcanic turbidites can be traced to the area of the Madeira Abyssal Plain ca. 1000 km to the west.

The western channel between Gran Canaria and Tenerife is defined as the area enclosed approximately by the 3000 m contour line and the eastern channel between Gran Canaria and Fuerteventura by the 2000 m contour line. The submarine flanks of the island are quite variable in shape and gradients, steep gradients characterizing scalloped zones in the southwest, west, northwest and north-northeast. It is not clear whether these are true

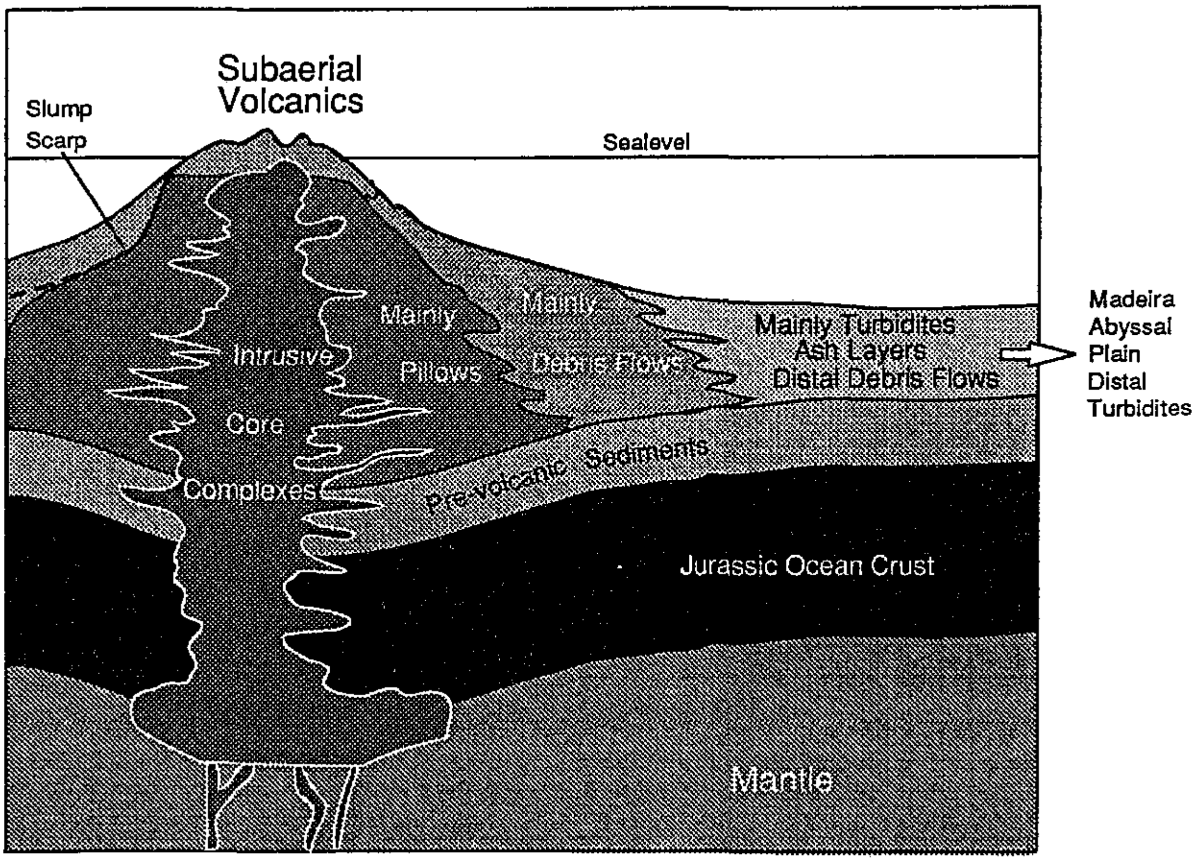


Fig. 6: Schematic drawing of an ocean island and its clastic apron. The volume of the clastic apron may by far exceed the volume of the island itself.

scallops, caused e.g. by large slumps or are due to sediment fans or lines of submarine volcanoes enclosing embayments, but the interpretation as slump scars seems most plausible at present.

Sediment aprons or deltas appear to have developed seaward off the large barranco systems of San Nicolas in the west, Arguineguin/Fataga in the south, Tirajana in the southeast and most prominently off the east coast, sediments and/or slumps filling the channel between Gran Canaria and Fuerteventura. This major eastern sediment depot may be the result of especially severe and prolonged erosion along the eastern slopes of Gran Canaria, possibly one or more slumps and slides coated by a more or less continuous cover of sediments.

The flanks of Gran Canaria extend about 40 km both to the north and south to the edge of sedimentary basins extremely gently sloping between ca. 3400 and 3650 m, the northern basin being slightly deeper than the southern one, possibly due to higher sediment influx from the continental slope into the latter. The basins started to develop separately in the east when Gran Canaria grew ontop of the western apron of Fuerteventura, but were joined in the west until the growth of Tenerife led to the formation of the western channel. Sediments shed from Gran Canaria and Tenerife into this channel are probably soon transferred into the northern and southern basins.

5.2 **Navigation** (G.A. Dehghani, J.P. Canales, J.J. Dañobeitia, S. Krause, A. Sabetian)

In order to determine the position of the ship the Integrated Navigation System 1300 (INS 1300) of Krupp-Atlas Company was installed. The system takes the data of individual navigation sensors and calculates an "optimal" ship position. The following navigation sensors were used during M 24:

- Global Positioning System (GPS) Trimble 4000 AX,
- Magnavox Satellite Receiver,
- Loran-C Receiver,
- Electro Magnetic Log (EM-log),
- Dolog,
- Gyro.

Using all this information the INS 1300 System calculated the position, course, speed etc. This calculation is done using a Kalmanfilter and giving the first priority to the GPS data. The Navigation Planing System NPL 1300 on METEOR is used to give the waypoints to the navigation computer. According to the information from INS 1300 and the waypoints the navigation computer calculated the course, time etc. for the coming profiles. All this information is sent to the data distribution system (DVS) and can be seen on monitor in the labs.

Since the GPS system was working well all the time during M 24, the final navigation data have a very good quality. The navigation data were collected separately on PC each 10 seconds. The coordinates of the profiles obtained during M 24 are listed in chapter 7.1.

5.3 **Parasound** (G. Götz)

5.3.1 Method

For the sedimentechographic work the Krupp ATLAS Parasound echo sounding system installed on the METEOR was used. The system consists of a Narrow Beam Sounder (NBS) deep-sea echo sounder for determination of the water depth combined with a sediment echo sounder with a maximum penetration of 100 m. The Parasound system uses high acoustic frequencies ranging from 18 to 23.5 kHz. These frequencies give a high resolution of the upper sedimentary layers, but are rapidly attenuated in the sediments. In addition to the 18 kHz pilot signal a variable signal of 20.5 to 23.5 kHz is transmitted creating a differential frequency with a main frequency ranging from 3.5 to 5.5 kHz. The opening angle of the transmitted beam is 4° resulting in optimum lateral resolution of the sea bottom and sediment structures (Fig. 7).

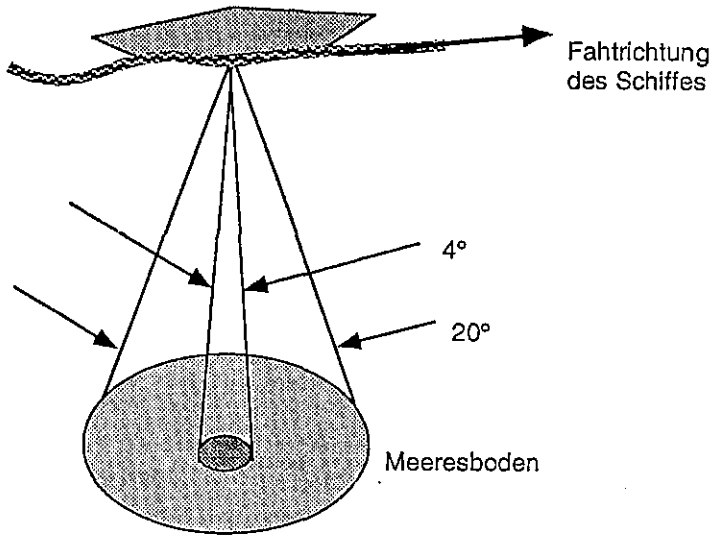
The Parasound record is plotted (black & white) on a DESO 25 echograph and displayed in color on the screen of the PARADIGMA recording unit (Fig. 8) developed at Bremen University (V. Spieß).

5.3.2 Preliminary Results

A total of 2500 km were profiled around Gran Canaria and east of Tenerife. First analysis of the Parasound data shows three different seismic facies domains distributed in the following regions around Gran Canaria:

i Steep slopes N and S off Gran Canaria;
ii Flat sedimentary basins N and S off Gran Canaria;
iii Channel between Tenerife and Gran Canaria.

i) North and south off Gran Canaria the submarine slope steeply drops from 100 m to 3100 m water depth. The Parasound records close to the island (P134, 301) show a rough relief of the sea bottom. A single strong black bottom echo indicates that the seafloor is hard and compact. No subbottom echos were recorded there. The profiles parallel to the slope (P133, 201 in the north; 121, 122 in the south) show numerous wide and narrow canyons deeply cut into the steep northern slope with depth increasing from 80 m on the flank to 1500 m in the canyon. In the south, the canyons are 500 to 1000 m wide and they are shallower (maximum depth 200 m). North of 28°27'N and south of 27°30'N the slope becomes more moderate and, at 3100 to 3400 m (north) and 2700 to



PARASOUND-MEßVERFAHREN

Fig. 7: Principle of Parasound measurements

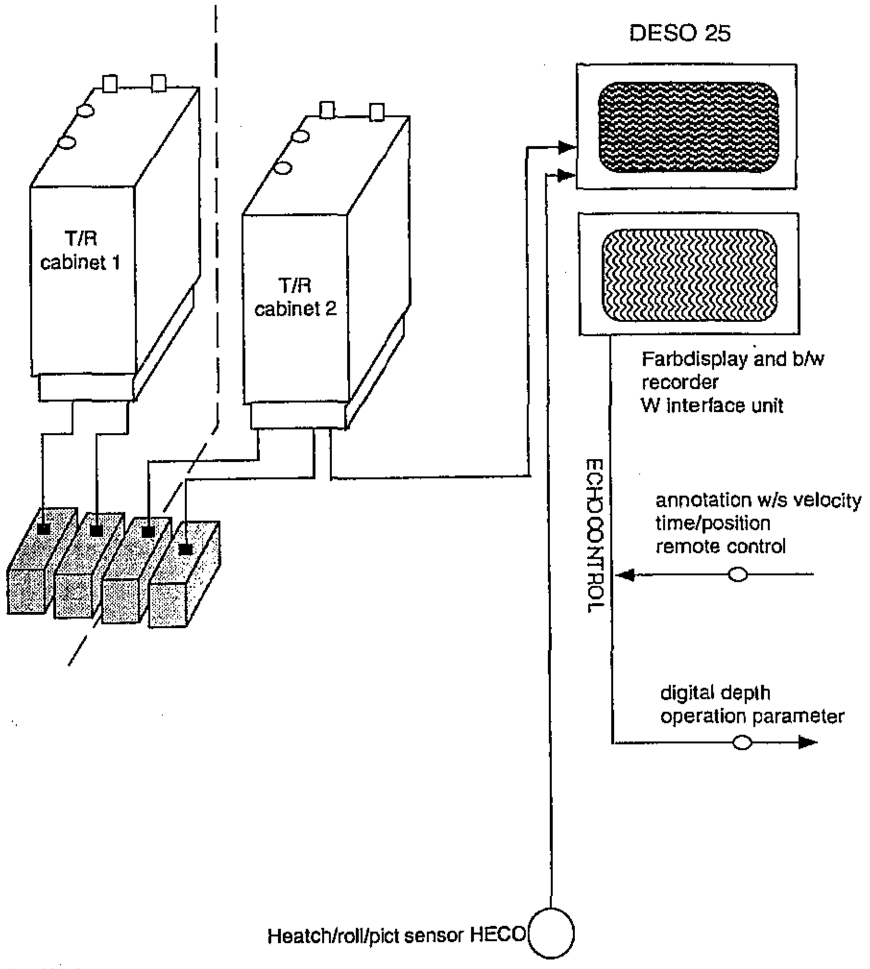


Fig. 8: Recording scheme of the Parasound system

3000 m (south) water depth, the canyons are wider and only cut 50 to 100 m into the surrounding. Seismic features (hyperbolae, variable number of subbottom echoes, overlapping reflectors, slump structures) indicate a high input of material transported down slope through the canyons. At greater depth the continuity of the strong (black) bottom echo increases, paralleled by at least five subbottom echoes.

ii) North of 28°28'N a wide submarine plain gently dips northward from 3400 to 3600 m water depth. The character of the echo recorded in this area differs from the slope region. The bottom echo is strong and continuous over several 10 km. At least 7 subbottom echoes run parallel to the seafloor, three of them strongly reflective and the others weaker and sometimes discontinuous (Fig. 9). The strong reflectors are interpreted to indicate volcanic material and probably correlate with high input of material due to redeposition or increased volcanic activity. In the southern plain the sediments appear less compact, allowing deeper penetration of the energy.

iii) The channel between Tenerife and Gran Canaria is bounded by steep flanks. Most of the records within the channel are characterized by overlapping wide amplitude hyperbolic echoes, occasionally with some weak subbottom echoes, or by diffuse, low frequency bottom echoes without subbottom echoes indicating an unstratified type of sedimentation. A few small basins were encountered with a strong bottom echo and at least two subbottom echos (e.g. at the crossing of P109 and P117, Fig. 10). In the regions of the steep flanks the Parasound record resembles that of the northern and southern slopes.

A detailed echofacies map will be prepared after processing of all profiles and of the corrected navigation data.

5.4 Seismic Reflection

5.4.1 Acquisition System and Data (P. Trinhammer, S. Radomski, T. Funck, S. Krastel, H. Lykke-Andersen)

Seismic equipment

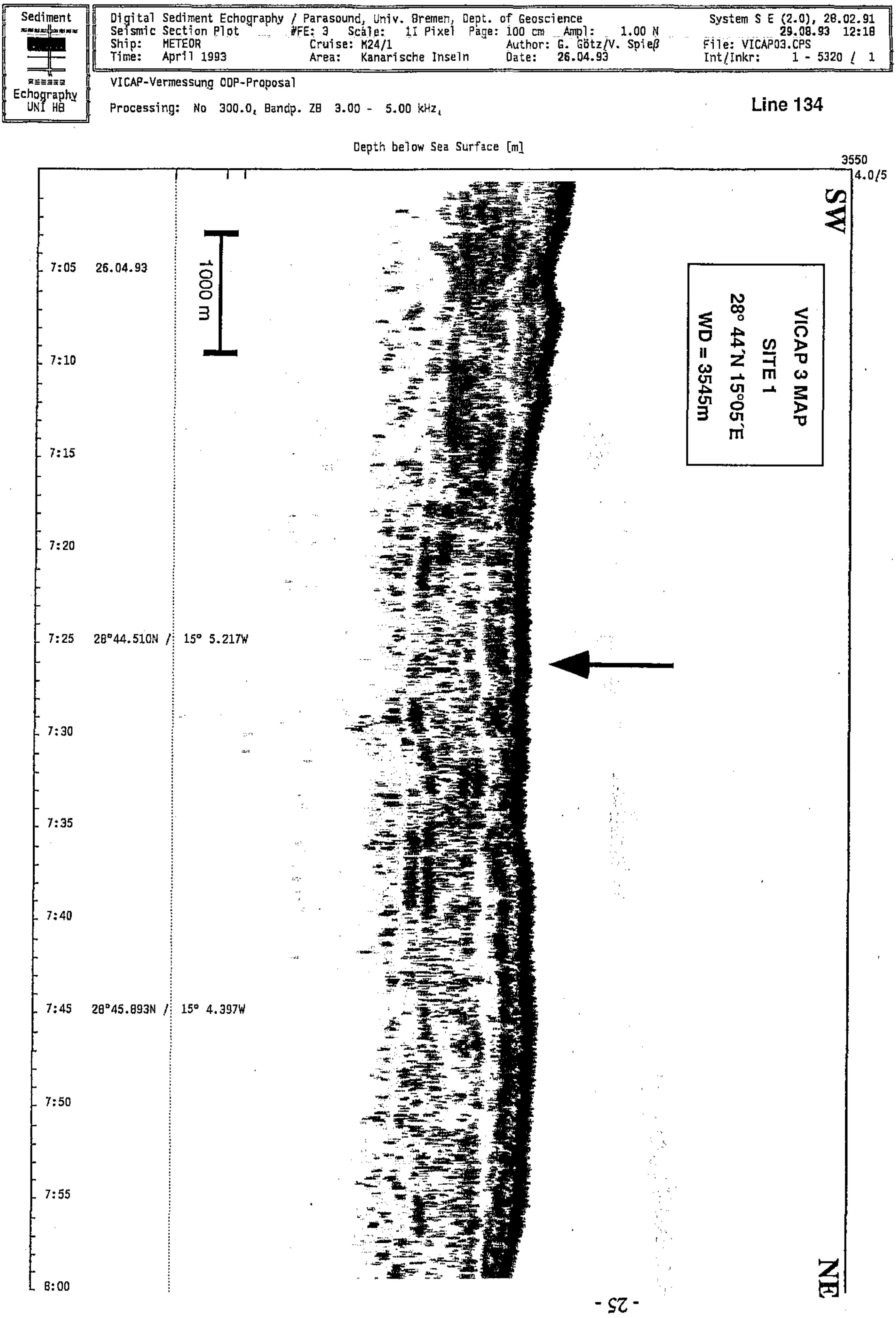
The equipment and field parameters applied on M 24 are listed up in Table 4.

Arrangement onboard METEOR

The instrumentation was arranged on METEOR in the following way:

- The recording equipment was installed in the measure room 768 on the main deck.
- The streamer winch was installed in the central part of the rear deck.

Fig. 9: Parasound record of P134 at proposed VICAP location 1) NE off Gran Canaria



Sediment Echography UNI HB

Digital Sediment Echography / Parasound, Univ. Bremen, Dept. of Geoscience
Seismic Section Plot #FE: 3 Scale: 1I Pixel Page: 100 cm Ampl: 1.00 N
Ship: METEOR Cruise: M24/1 Author: G. Götz/V. Spieß
Time: April 1993 Area: Kanarische Inseln Date: 26.04.93
System S E (2.0), 28.02.91
29.08.93 12:18
File: VICAP03.CPS
Int/Inkr: 1 - 5320 / 1

VICAP-Vermessung ODP-Proposal

Processing: No 300.0, Bandp. ZB 3.00 - 5.00 kHz,

Line 134

VICAP 3 MAP
SITE 1
28° 44'N 15°05'E
WD = 3545m

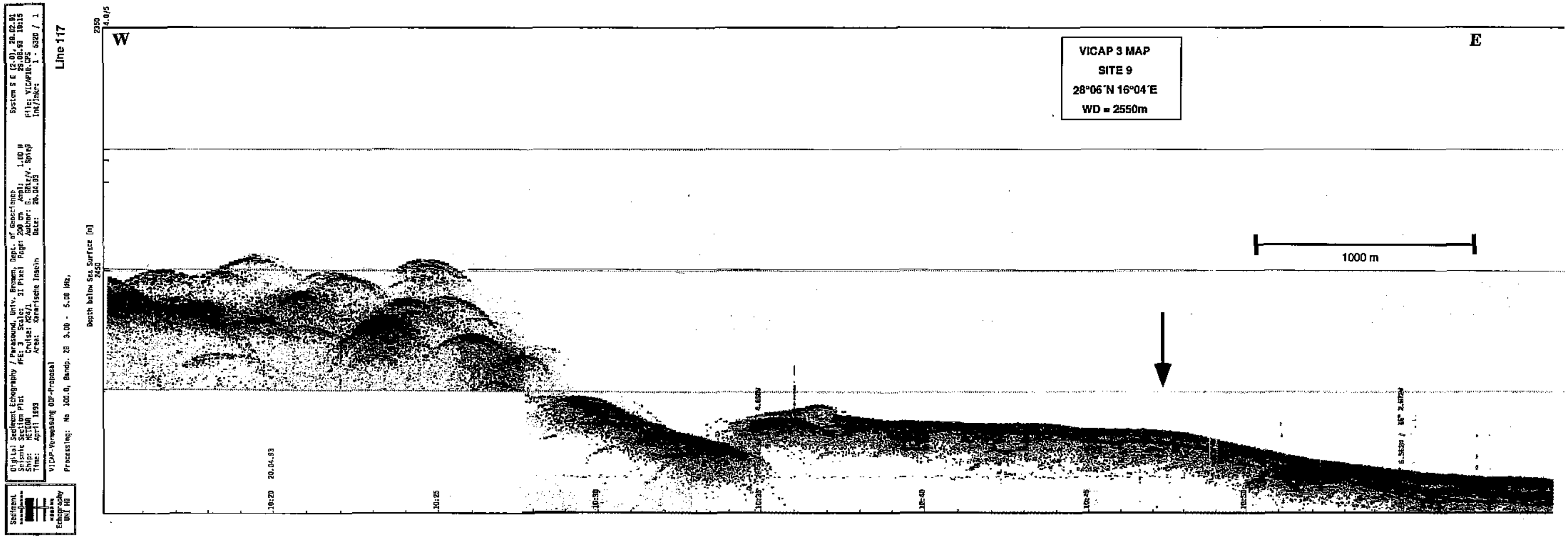


Fig. 10: Parasound record of P 117 at crossing with P 109 (proposed VICAP location 9) in the channel between Tenerife and Gran Canaria.

Tab. 4: Equipment and field parameters

Acquisition control unit:		EG&G Geometrics ES2420
	No. of channels:	24
	Sample interval:	1 ms
	Word size:	15+4 bits
	LC filter:	20 Hz
	HC filter:	360 Hz
	Data format:	SEG-D demultiplexed
Tape decks:		2 x STC model 2921
	Tape:	9 track 2400'
	Tape speed:	100 ips
	Data density:	6250 bpi
Data monitoring:		Signal from nearest hydrophone plotted for each shot
Acoustic source:		4 x HGS sleeve guns
	Configuration:	cluster 0.5 x 0.5 m
	Volume:	4 x 40 inch^2
	Pressure:	100 bar
	Firing rate:	5, 7.5 or 10 sec
	Firing delay:	12 msec
	Firing syncronization:	+/- 1 msec
	Tow wire length:	30 m
	Towing depth:	2 m
Streamer:		Teledyne
	Channels:	1-24 (Ch. 1 nearest guns)
	Hydrophones per group:	7
	Group length:	3.125 m
	Group spacing:	6.25 m
	Total length:	143.75 m
	Stretch section:	25 m
	Tow cable length:	90 m
	Depth transducers:	at Ch 1, 9, and 17
	Nominal towing depth:	4 m

- The 2 umbilical winches were located in the port side and behind the streamer winch on the rear deck.
- Unit containing reduction valves and air-cleaning filter was fixed on the wall next to the umbilicals.
- The triggering unit was fixed a few metres from the umbilicals on the same wall.
- The sleeve gun-cluster was located in port side close to the stern.

The sleeve gun-cluster was deployed by means of the A-frame with a wire through a block in the extreme port side of the A-frame. The gun-cluster was deployed before the streamer to avoid jamming. The streamer was deployed through the open stern gate and fixed in the starboard side of the gate. The towing cable was fixed to the stern by means of a ca. 2 m long elastic rubber string (two tractor bulbs). The perpendicular distance between the streamer and the sleeve gun-cluster was ca. 8 m.

The streamer was balanced by lead at five evenly spaced points along the streamer. The weight at the rear end of the active section was ca. 3 kg. At the other points ca. 4 kg. (On profile P210 and P301 the weight was increased, see below). The streamer depth was 4-6 m except on some profiles with high wind speeds where the depth was reduced sometimes to less than 2 m.

Compressed air was delivered from compressors (University of Hamburg) housed in a container fixed on the first deck above the main deck. Lothar Schwan was in charge of the compressors.

During the acquisition the data were monitored by continuous plotting of the near-trace. The plotting was normally done on an ink jet colour plotter, the amplitudes being colour coded. Shorter parts of some of the profiles were plotted in variable area mode by means of a 24-pin matrix printer. (The examples shown in this report are copies of the neartrace plots). The navigation data together with water depth were logged every 10 s from METEOR's GPS system and stored on diskettes with each profile stored as a file. The distance between the GPS antenna and the gun location was 82 m.

Acquisition of seismic profiles

In the period April 15 - May 6, 1993, 50 profiles were acquired as follows:

Area I (between Gran Canaria and Tenerife):	Profiles P101-P120	794 km
Area II (south of Gran Canaria):	Profiles P121-P127	368 km
Area III (E and NE of Gran Canaria):	Profiles P128-136, P203	534 km
Area IV (N of Gran Canaria):	Profiles P201-202, 204-208 P210, P301	421 km

The length of the individual profiles are listed in Chapter 7.1.2.

The shot distances were chosen according to the water depths along the profiles. With water depths exceeding 1125 m (1500 ms TWT) a recording delay was applied to avoid unnecessary recording of data in the water column. The relation between water depth, start delay record length and firing rate is shown below:

Water depth [m]	Start delay [ms]	Record length [ms]	Firing rate [s]
<1125	0	3000	5
1125-3000	1500	4000	7.5
>3000	3500	4000	10

With firing rates listed the nominal shotpoint distances are 12.5 m, 18.75 m, and 25 m, respectively. The real distance depends on the speed of the ship, which is kept as close as possible to 2.5 m/s (4.9 knots). With the three shotpoint distances a coverage of 6, 4, and 3 is obtained.

Data quality

The quality of the data is somewhat variable mainly due to varying weather conditions. During the acquisition of profiles P 101-P 105 the sea was calm. From profile P 106 the wind conditions were logged and were as listed in Chapter 7.1.3.

It seems that deterioration of the signal/noise was most pronounced on profiles where the heading of the ship was against the wind. In such cases the streamer was pulled to a relatively shallow position 1-2 m, resulting in increased wave-generated noise. During the acquisition of profiles P134, P135, P204, and P210 swells of considerable height and wavelength probably affected the data quality. At profile P210 and P301 the lead weights on the streamer were increased by 25% in order to increase the streamer depth. The bubble pulse was effectively damped by the gun-cluster applied (Fig. 11).

At many places diffractions are observed which very often seem to be generated by side swipes. On many of the lines this rather pronounced 3-D effect may cause troubles for the interpretation (Fig. 12).

On records with optimal signal/noise ratio the pulse length is estimated at 10-15 ms corresponding to a vertical resolution of 5-8 m (Figs. 11 and 13).

The depth of penetration seems to be strongly dependent on sediment/rock types. It seems that basalts cannot be penetrated by the seismic pulses. When basalts are shallow they therefore form the acoustic basement. In shallow water areas like the east coast of Gran Canaria (Profile P128) the depth of the first multiple reflection may determine the maximum depth to which the data can be interpreted (Fig. 14).

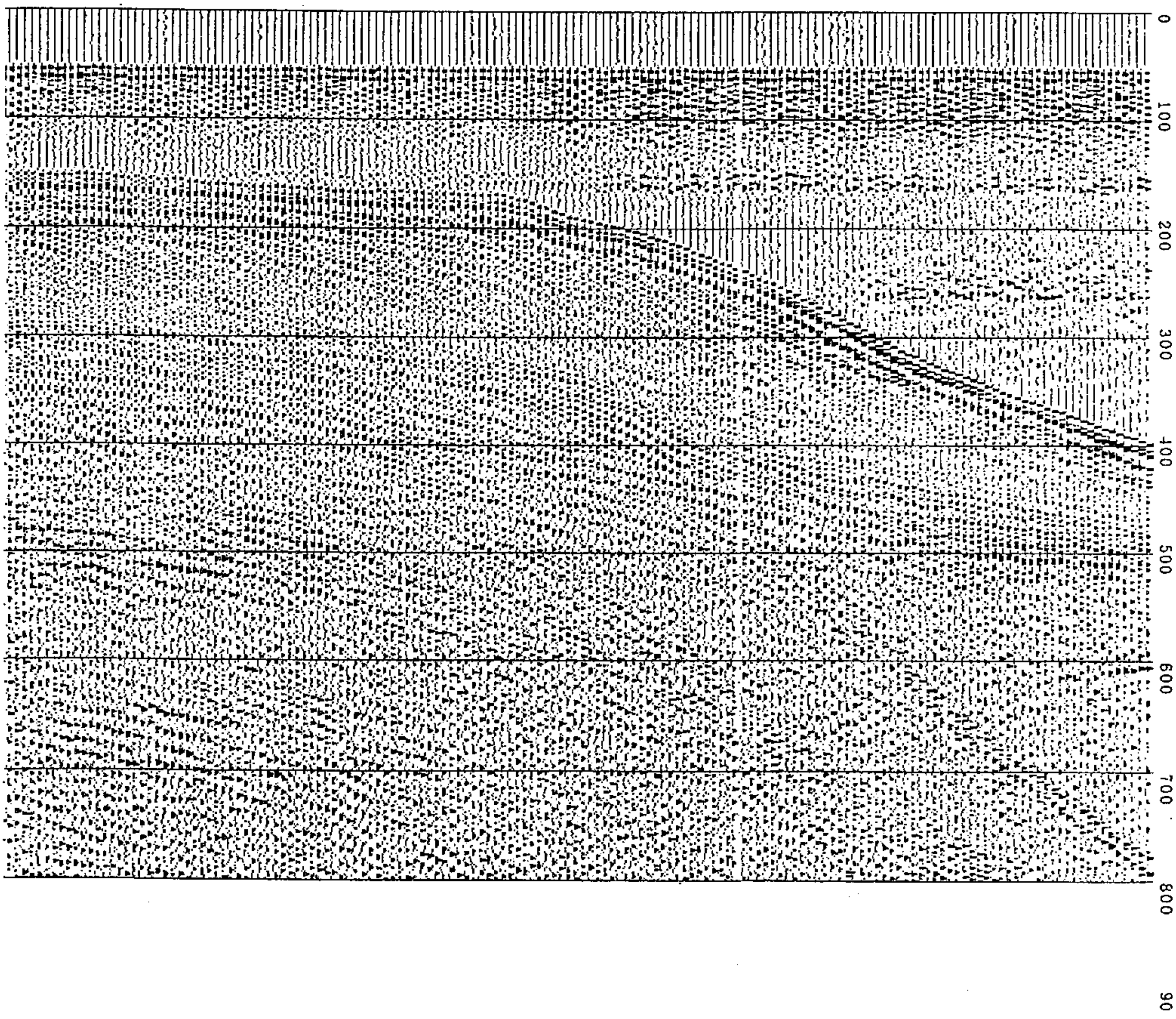


Fig. 11: Near-trace plot made on matrix printer (Profile P107)

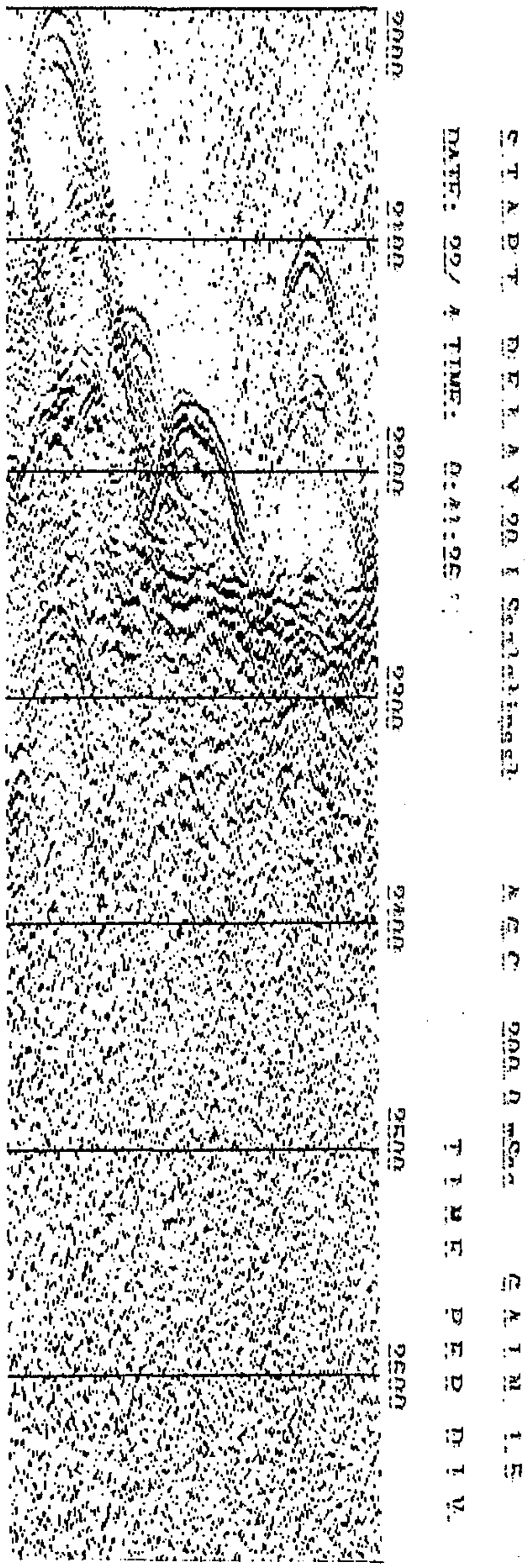


Fig. 12: Near-trace plot made on matrix printer (Profile P122)

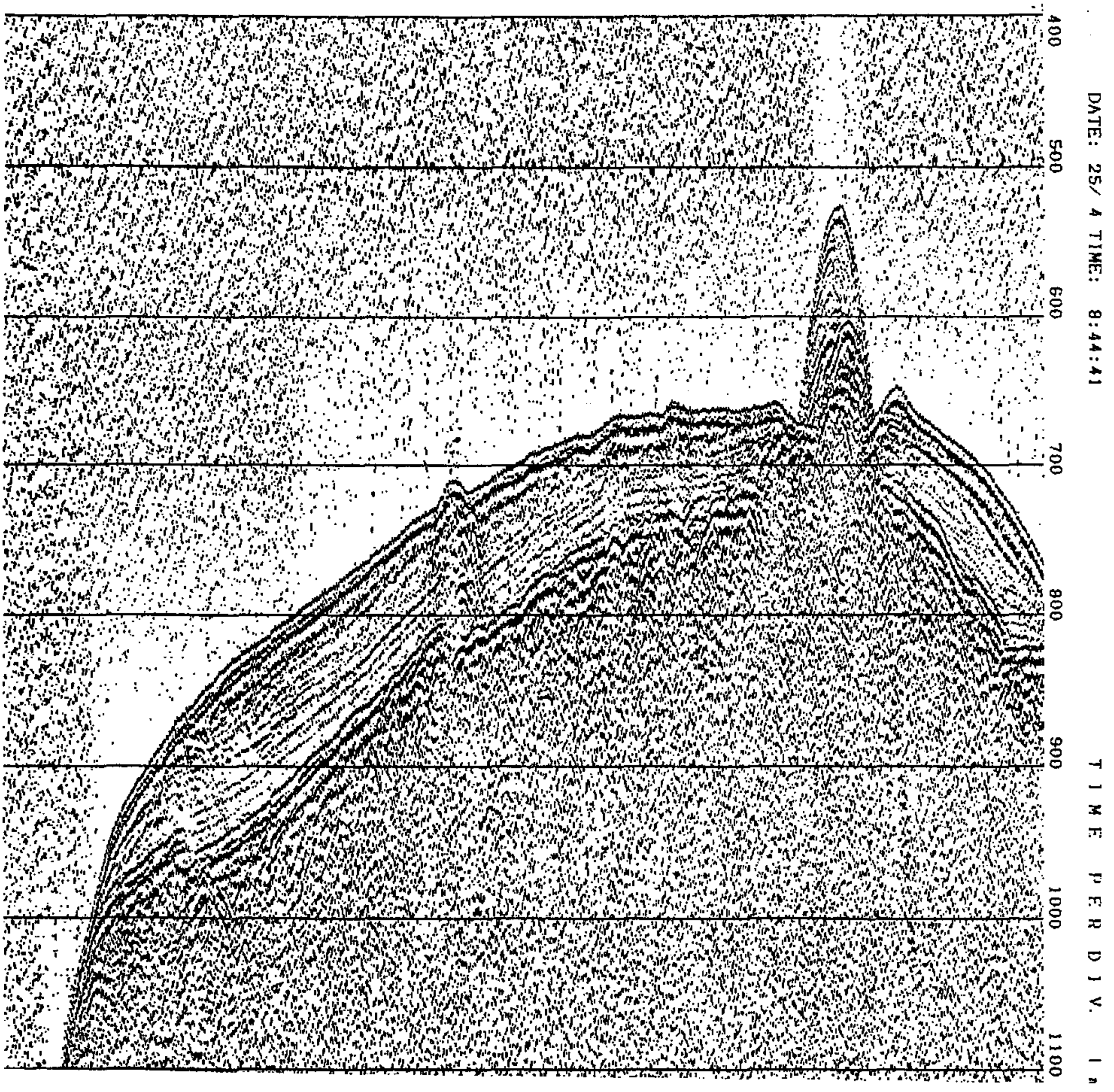


Fig. 13: Near-trace plot made on matrix printer (Profile P132)

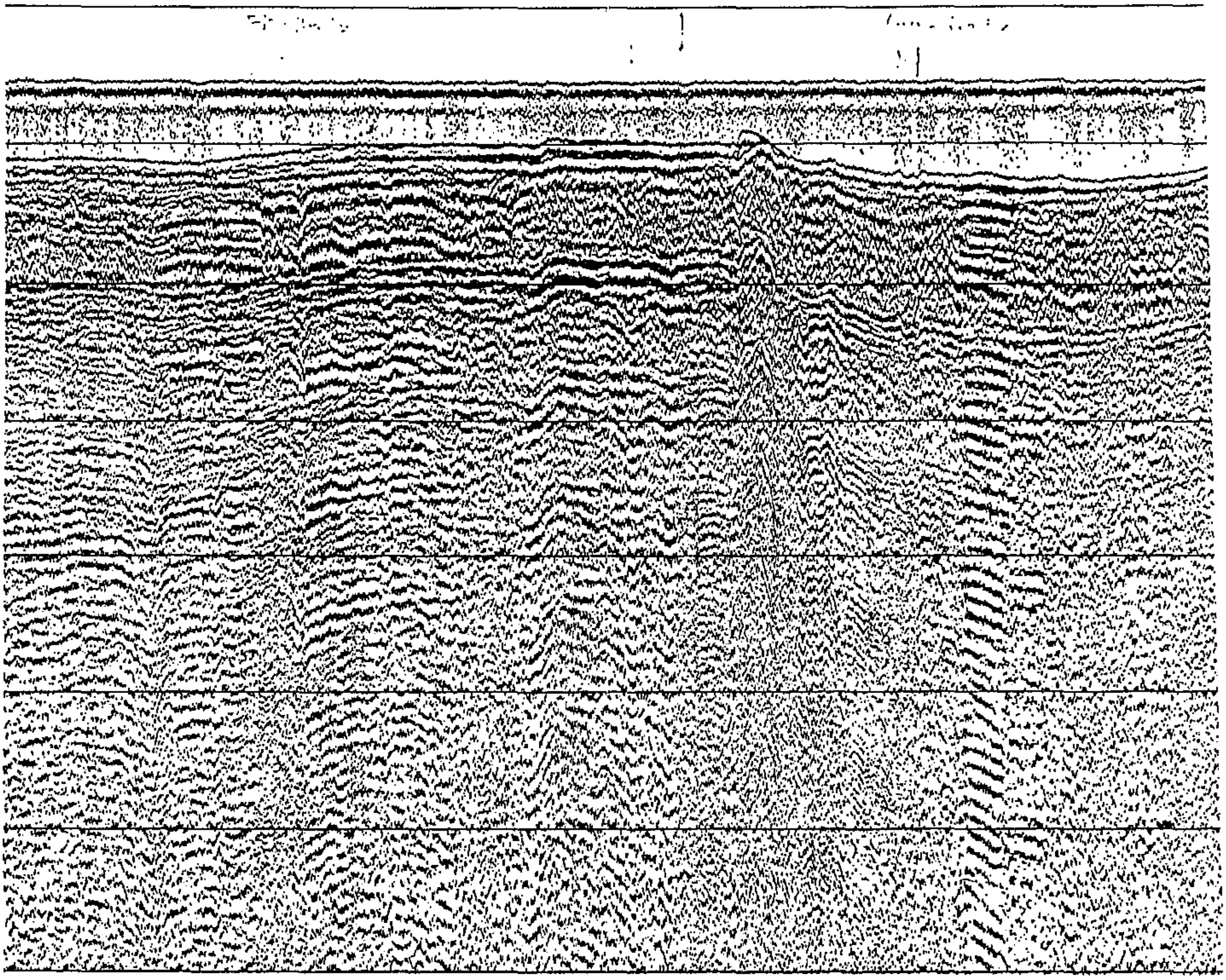


Fig. 14: Near-trace plot made on matrix printer (Profile P128)
(The distance between the lines is 100 ms)

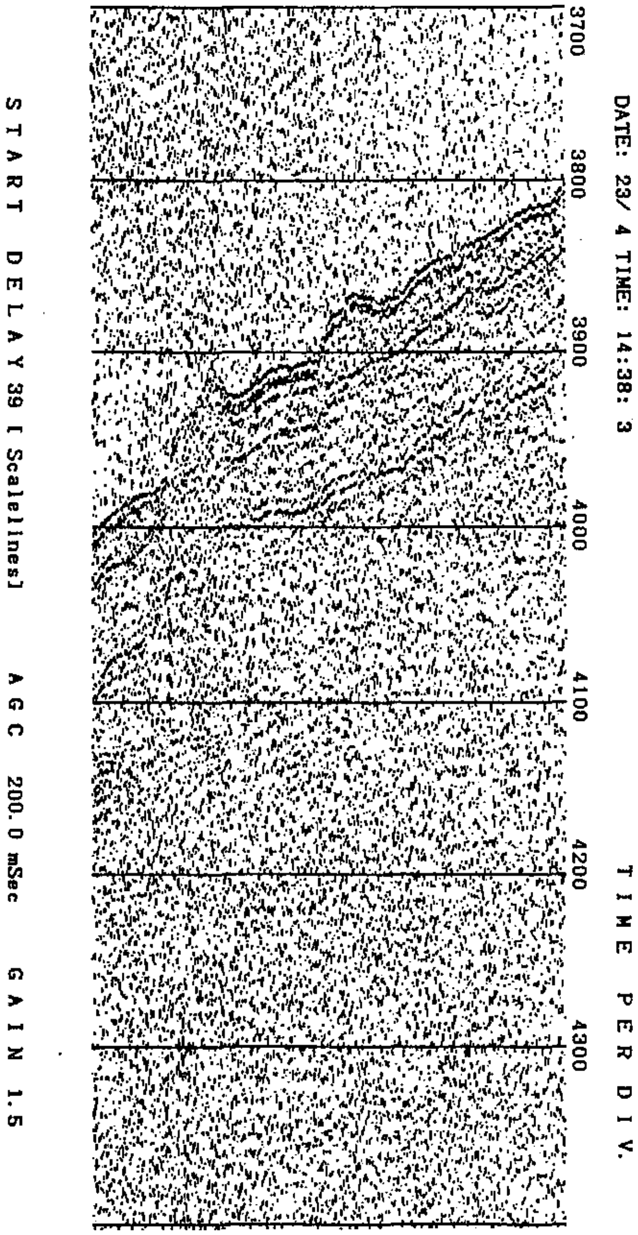


Fig. 15: Near-trace plot made on matrix printer (Profile P127)

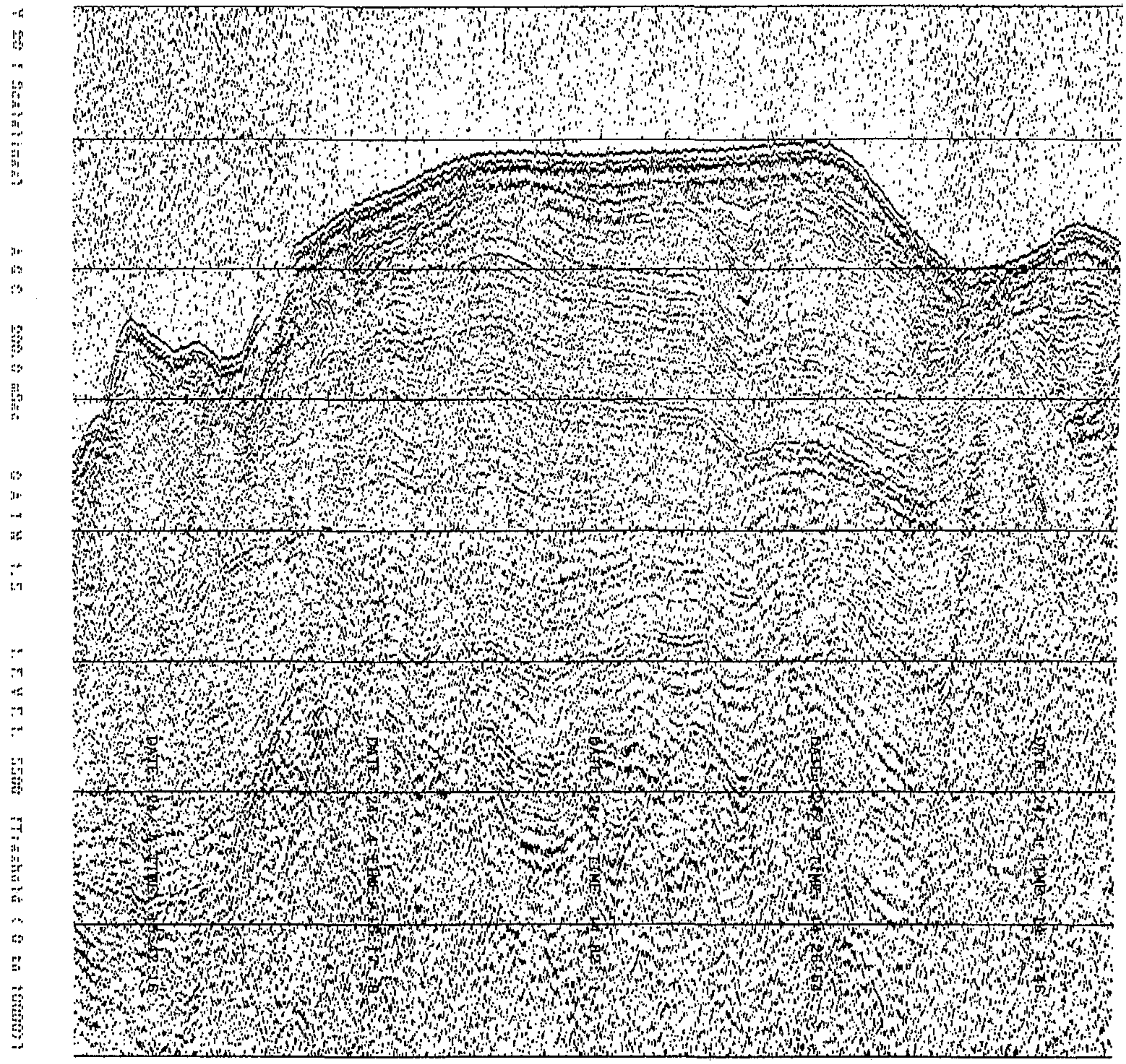


Fig. 16: Near-trace plot made on matrix printer (Profile P130)

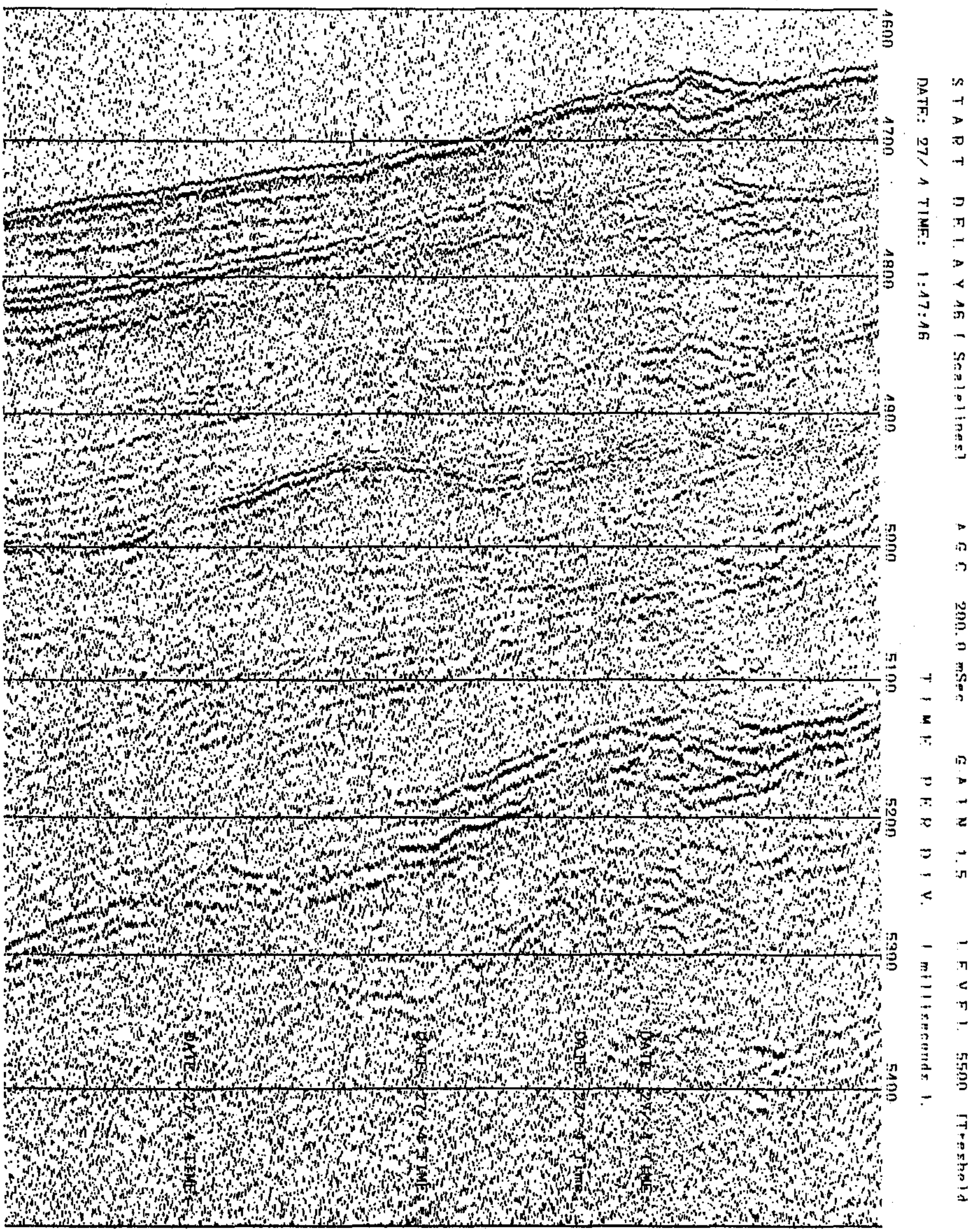


Fig. 17: Near-trace plot made on matrix printer (Profile P136)

At the site of the DSDP 397-well (Profile P126-P127) the deepest recorded reflection was at a depth in the sediments of ca. 750 m (ca. 800 ms TWT) below the seabed. The reflection seems to correspond to Middle Miocene tephra layers. (The weather conditions were rather poor during the acquisition of these profiles) (Fig. 15).
In area III and IV a penetration to at least 600 ms TWT below the sea bed was obtained as shown in Figures 16 and 17.

Supplementary reflection recording with big airguns
For the wide angle experiment with OBS-recording stations north of Gran Canaria and land stations on Gran Canaria the acoustic source was 2 x 32 l airguns. With the primary aim to record the firing time of the guns and for syncronization of the two guns an 8-channel streamer was towed between them, and the guns were located ca. 80 m behind the stern. (The streamer was a spare section for the streamer described above). The distance from the guns, towed at ca. 10 m, to the nearest hydrophone group was 15-20 m. The hydrophone group farthest from the guns were at a distance of 15-20 m behind the stern of the ship. The streamer depth was ca. 1 m. It was discovered that the gun delay was ca. 300 ms.
A spectral analysis of the direct pulse showed that the main energy is below ca. 10 Hz, but it also indicated that some energy is released at frequencies up to more than 100 Hz. On the OBS-profiles P1-P3, P3a-b and P7a-b the signals received on the streamer were recorded for all shots. The sampling rate was 4 ms and the record length 30 or 10 s. On the neartrace plotter indications of reflections were seen down to ca. 500 ms below the sea bed in the frequency band 50 Hz - Nyquist frequency (Fig. 18). By comparison with the high resolution profiles it was documented that the reflections observed were identical on the two data sets. No reflections were observed on the OBS-profiles at depths greater than the deepest reflections on the high resolution profiles.

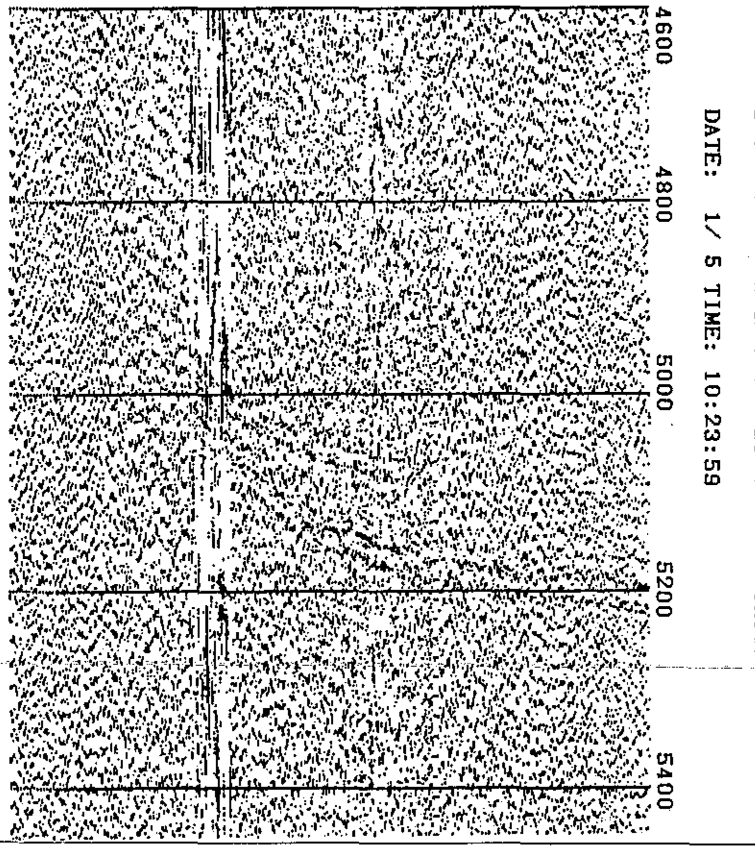


Fig. 18:

Near-trace plot made on matrix printer (Profile 1)

5.4.2 **On Board Processing** (J. Collier, R. Dalwood, S. Radomski)

Preliminary processing of the seismic data was made using hardware and software brought to the ship from Oxford University, GEOMAR and Århus University. The hardware consisted of 2 Sun computers (Sparc-10 and Sparc-SLC), 1 GByte hard disk, exabyte tape drive, half inch magnetic tape drive and postscript laser printer. Initial problems with the ethernet connection between the two suns were solved approximately half way through the cruise which significantly speeded up data processing. Up to that point all work was done on the much slower Sparc-SLC station. By the end of the cruise, processing data acquired during 1 hour took about 45 mins. The software used was developed at Scripps Institution of Oceanography and Oxford University and consisted of a series of conventional seismic processing algorithms.

The first step in the processing sequence was to perform quality control checks. Data quality was generally good and, with the exception of field trace 1 (which was contaminated with 50 Hz) all traces were consistently clean. It was noticed that traces 1-8 generally had been recorded with higher amplitudes than the other traces. In the centre of the survey (P114) pre-amp problems resulted in traces 1-8 being unusable and so they were omitted from the stacks. No bad shots (misfires) were detected. Frequency analyses showed there to be good signal content in the 80-120 Hz band, and also some energy above 200 Hz. Water column noise was generally less than 80 Hz. On the basis of frequency trials it was decided to leave the data unfiltered (other than the 0-300 Hz filter applied at acquisition time). Deconvolution of the data was unneccessary, because of the impulsive nature of the source and deep water. The final processing scheme therefore consisted of simple trace addition - with 12 and 24 fold stacking. On the rough flanks of the islands of Gran Canaria and Tenerife diffraction hyperbola was a problem and so fk migration (at a constant velocity of 1600 m/s) was used to obtain a more realistic image of the near surface structure. This procedure was generally successful except where the structure was obviously 3-dimensional and out-of-the-plain reflections were contained in the sections. The results of the processing were considered good - with well defined reflectors up to 1 s TWT below the seafloor (equivalent to 750-1000 m penetration). The processed sections enabled further interpretation of the data at sea than would have been possible from the single trace monitor plots produced at acquisition. Because of disk space and computer memory limitations the data were processed on a single field tape at a time (on average containing 1.2 hours of recording). In total 12 profiles were processed (101, 102, 103, 107, 109, 114, 126, 130, 134, 202, 203 and 205; see Fig. 1) - consisting of about 30% of the data collected.

5.4.3 Reflection Seismic Processing (S. B. Marstal)

The first stage of onshore processing was carried out at the Department of Earth Sciences, University of Aarhus, during the period June 1st - August 14th 1993, and comprises processing of a total profile length of 2117 km on 50 lines. In addition to this, navigation data were processed for calculation of line intersections and plotting of a shot point map. The work is a result of a cooperation agreement between the Department of Earth Sciences, University of Aarhus, Denmark, and GEOMAR, Germany.

The work was carried out on behalf of the Department of Earth Sciences by Stig Berendt Marstal. During the period June 3rd - July 7th 1993 Thomas Funck and Sebastian Krastel from GEOMAR, Kiel, were stationed in Århus to assist in the processing.

Sequence of processing
All the 50 stacked profiles have been processed with the same sequence. However, there will be minor differences as to the final bandpass filter (see Table 5).

Tab. 5:

Preparation:	Dumping of field tapes 001-252 Near trace and shot gather plots Editing (e.i. picking from mute parameters, velocity analyses, inserting of dummies etc.) Job setup (SEISCARD-files for stacking and plotting)
Stacking and plotting:	/airgun delay, -12 ms /compensation for start delay /reverse polarity (change to normal SEG polarity) /field geometry setup /static correction (source and receiver depth) /sorting to CMP gathers /velocity (regional and analysis) /NMO correction /time invariant offset-dependent equalization /stack (output STACK tape, SEGY format, start delay) /front mute (picked from neartrace plots) /tracemix of 5 traces, weights 1-1-1-1-1 /bandpass filter (30 or 40-240 Hz) /time variant scaling (AGC) /display of every 4th trace, horiz. scale 1:25000

Field tape dump
The first part of the preliminary routine is to dump all field tapes. Header information for all shots registered is read. In case of irregular gaps in time between the shot files this would be recognized. The output is a list of shot times for the first and last file on each field tape and the number of files. At the end of quite a lot of field tapes only every second shot has been registered, and by changing from one tape deck to the other at the end of a tape, one shot is skipped. Where a change of acquisition parameters has taken place, a larger gap in the data registration may occur (e.g. more than 2 minutes between field tapes 025 and 026 on profile P105). At the frequent stops in the data registration the missing number of shots on the profile has been calculated based on the shot time and the shot interval. For continuity the number has then been inserted in the shot sequence as empty shots, so-called dummies. The shot rates are calculated to 5.00 s, 7.50 s and 10.00 s, respectively.

Near-trace plots and editing
Data were recorded in demultiplex SEG-D format, so no demultiplexing was needed. Near traces from all shots along the line after data-dependent amplitude decay correction were displayed for quality control and also to give an early indication of the geological structure and water depth trend. To be exact, trace 2 was used as near-trace, because trace 1 was contaminated with relatively low frequency noise abount 50 Hz as a result of plotting the near-trace aboard the ship. Front mute parameters are picked manually from the near-trace plots. Two-way-traveltimes (TWT) are read about 5-10 ms above sea bottom at the shot points where the tangent for the sea bottom changes significantly. With the rapid change in sea bottom topography around the Canary Islands this has proven to be a rather elaborate and tedious affair. In the future, corresponding shotpoint (SP)-TWT pairs from the sea bottom will be digitized instead whenever working with data from such areas. Displays of all traces of regularly spaced shot gathered after data-independent amplitude decay correction were used for further quality control. No misfired shots were registered, and all hydrophone groups seem to have worked satisfactorily during most of the survey. There were, however, problems with noise spikes on channel 8 for a short period of time at the end of line P115 and all line P116. For this reason it was set to zero. All traces show evident signs of noise caused by the often rather poor weather conditions during the survey.

Setup of SEISCARD-files
One SEISCARD-file, a seismic job, is set up for every STACK output tape. Changes in acquisition parameters divide the profiles into different parts and therefore seismic jobs. The different processors used in the stack jobs are subsequently briefly described. Field tapes in SEG-D format are input, and STACK tape in SEG-Y format is output. For every stack job a plot is made to control whether the chosen parameters are satisfactory.

Polarity

The polarity is turned before stacking to make data at plotting agree with SEG standard for data representation with white trough for positive amplitude.

CMP sorting

Data are sorted to common mid point coordinates after specification of the geometric set-up. Throughout the entire survey offset was 60 m. The distance between midpoints of hydrophone groups is 6.25 m, so the distance between CMPs is 3.125 m. In connection with CMP, sorting corrections are made for depth of source and streamer, so in principle all channels refer to level 0 m.

Velocities

The short spread used for data acquisition and the big water depths in the area investigated do not make it possible to detract information about the velocity distribution in the formations by means of the acquired data. Instead the following probable regional stack velocities are used:

Valid at	Stack velocity
Water	1500 m/s
Upper 3-400 ms sediment	1600 m/s
Basalt -end of data (EOD)	3000 m/s

The uncertainty of stack velocities is, however, not expected to affect the stack quality, because data will stack under a broad fan of velocities. The only exception from this will be on the low water "shelf", where the water column is less than 2-300 ms. Here velocity analysis was carried out in a few places, but not as regularly as it would have been in the case with CMP gathers on output tape.

Offset-dependent scaling

In order to obtain the statistically optimum stack, offset-dependent scaling is made, which is a time invariant scaling after correction for normal move-out (NMO) with the purpose of giving the 24 traces the same amplitude level in the offset direction.

Stacking of data

Data are stacked with 3, 4, and 6 folds, respectively, after correction for normal move-out and offset-dependent scaling. The stacked trace is normalized with 1/(number of folds). The stacked data are stored on magnetic tapes in SEG-Y format with 6250 bpi. To save tapes, stacked data, as well as field tapes, are stored with start delay. Table 8 gives a list of record length, start delay, and shot rate.

Mute

Mute after stack has proved sufficient, as there are no problems with first breaks, stretching of data after NMO (normal move-out) corrections etc., because of the large water depths.

Tracemix

Tracemix has been made involving 5 traces with weigths 1-1-1-1-1, i.e. that each stacked trace is mixed with its two neighbour traces on both sides. Mean value is given to the middle one. Tracemix emphasizes the signal and damps both incoherent and coherent noise, and a bigger reflection continuity is thereby obtained.

In the remaining processing sequence only every 4th trace for plotting is being processed, but because of the mix used, all traces will be part of the final version.

Frequency filtering

The processed data are bandpass filtered. On most lines one space and time invariant bandpass filter of 30 or 40-240 Hz is used. Lower frequencies deteriorate the data, because of the rather poor weather conditions during the cruise. The cut-off slopes are 36 and 48 dB/octave, respectively.

Another filter was used for line P127, which was acquired during even poorer weather. Here a space and time variant filter of 80-240 Hz for the upper ca. 300 ms sediment and 40-240 Hz from 500 ms was used.

Scaling

To obtain short windows around the sea bottom and in the upper part of the sediment package where the decay of the amplitudes is highest, the upper ca. 500 ms have been scaled Automatic Gain Control (AGC) with a windowlength of 50 ms, rising to between 100 and 200 ms at the end of data.

Plot

The processed data are plotted in final versions as filtered stack sections. For simplicity only every 4th trace is plotted. This gives a desired horizontal scale of approximately 1:25,000. The plotter dependent scale is really 1:24,510. The plotter is a Versatec electrostatic plotter.

Plots are usually divided where acquisition parameters are changed. To keep the good resolution of data, the vertical scale should at least be 20 cm/s. The paper width of the plotter only offers a possibility of plotting max. 2.2 s, and 1.9 s where the line intersections are annotated on top of the sections. This means that the complete processed data length cannot be plotted at a time, and that profiles with highly variable topography has to be divided more often.

The plot interval is, however, for the most part, sufficient to include the whole sedimentary package.

On the deep ocean profiles, e.g. line P134, basement is probably not recognized, not because of the plotting width, but limitations of the equipment.

Navigation and shot point map

The navigation data used for constructing the shot point map was logged every 10 s from METEOR's GPS system and stored on diskettes with each profile stored as a file.
Shot points are found by interpolation between start and end times knowing the exact numbers of shotpoints (incl. dummies). On many lines, where the shotrate changes (see Table 8), these are split into two ore more files before interpolation. No filtering is made. It is assumed that the first and last shot file of each line are lying on the planned line. Only every 10th interpolated shotpoint together with the first, last and split shot points are used for the further processing.

Two shot point maps in Mercator projection with a scale of 1:650,000 have been made to date. One with all high resolution reflection seismic profiles of M 24, and one with the profiles from the VICAP-MAP Drilling Proposal 380 Rev 3 processed in Århus. On both maps the proposed drilling sites are plotted. Only every 100th shotpoint has been used for plotting along with the first and last shotpoint.
A program calculates the line intersections (see appendix). In addition to the uncertainty of the GPS system regarding the ship's position comes the fact that the distance between the GPS antenna and the gun location that was 82 m. In case of perpendicular line intersection the displacement is about 6 sp's with a shotrate of 5 s and 3 sp's with a shotrate of 10 s.

5.4.4 **Poststack Reflection Seismic Processing** (T. Dickmann)

The stacked high resolution data have been processed at the Department of Earth Sciences, University of Århus, as described before. After stacking the 24-channel data the data have been written on magnetic tapes in SEG-Y format.
Unfortunately the tape format is not standard SEG-Y and thus small modifications at the GEOMAR Processing System (GEOSYS by Geco-Prakla) had to be taken out for reading the data.
The last step in the usual basic data processing sequence is migration. With the present CMP stacked sections as an approximation to zero offset sections migration has to be applied to move dipping reflectors into their true subsurface positions and to collapse diffractions resulting in a better spatial resolution and interpretation. Such features are very often observed in the M 24 -Seismic Reflection Data, especially at the steep island flanks in the marine survey area.
Since the success of migration depends not only on the proper choice of parameter, but also on the effectiveness of the previous processing steps, some considerations have to be made before applying the migration technique.

Resampling

After calculating numerous amplitude spectra it was discovered that the seismic spectra lie in a bandwidth of 20 Hz to at most 240 Hz (Fig. 15). An uncritical resampling from 1 ms to 2 ms sampling interval was carried out resulting in a sufficient Nyquist frequency of 250 Hz with regard to economic processing, even for the migration.

Filtering

The main goal in processing reflection seismic data is the enhancement of the signal/noise ratio. Due to varying weather conditions M 24 data quality is variable as well as efforts for suppressing unwanted energy. Particularly on the noisy sections narrow band-pass filtered panels have to be computed to find out the bandwidth and the reference times for time-variant frequency filters. For some lines the bandwidth may be kept quite large (30-160 Hz) from top to bottom whereas other lines may be filtered up to only 70 Hz at the bottom according to waterdepth and depth of penetration (Fig. 15).

Beside frequency filtering, coherency-filters were applied in some cases where correlation of reflectors is difficult. Effective results were obtained, but the use has to be handled very carefully due to huge CPU time consumption.

Another point of consideration concerning the migration is spatial aliasing. Although the present CMP trace spacing is very dense (3125 m), spatial aliasing is observed in cases where the diffraction hyperbolas are very steep. Such aliased energy introduces dispersive noise on the migrated section. Calculated fk-spectra of such steep hyperbola flanks show in some cases that the aliased frequencies can be easily filtered out with a high-cut (Fig. 16), whereas other cases need a dip filter (fk-Filter) to remove unwanted seismic energy (Fig. 17, 18). Suitable fk-filter parameters for the present survey are below 3 ms/trace dip filtering.

Deconvolution

Looking at all the plotted lines there is no deeper penetration than 1.5 - 2.0 s under the water bottom. This means, that water-bottom multiples would disturb primary reflections down to 2 s waterdepth at most. Since only 10% of the total recorded profile length has a waterdepth under 1.5 s, predictive deconvolution to suppress the water-bottom multiples needs not to be a standard processing step in this survey. In addition the 10% profile length left to be considered lies mostly at the steep island flanks, where the CMP stacked data can not assume approximately vertical incidence and zero-offset recording. Some attempts of deconvolution showed that the performance of such an approach is not satisfactory. Finaly deconvolution will not be accomplished.

Stacked data composition

Keeping in mind the problem of spatial aliasing as for the migration, it is possible to generate stacked result traces from each four adjacent CMP stacked traces on the more or less horizontally layered sections far away from the steep volcanic flanks. This approach is a trace saving and therewith time saving routine for the subsequent processes and results in an enhancement of the signal/noise ratio with no lost of resolution having now a CMP trace spacing of 12.5 m in the corresponding areas.

Migration

The most time consuming procedure is migration. Firstly, human working time consuming, because the process of migration requires velocity information, which has not, been obtained by the process of CMP stacking. Secondarily, computer time consuming because of the huge amount of data, which comprises 576,539 CMPs and a two-way-traveltime of at most 7500 ms. Most lines have a recordlength only between 2000 and 3000 ms.

Due to the very short streamer of 150 m and the mostly deep water depth no intensive stacking velocity analysis was carried out in Århus and the only way to obtain any velocity information is a kind of migration velocity analysis. One has to migrate a portion of a section with various trial constant velocities values and evaluate the results. When the velocity in the migration equals the medium velocity, the diffraction hyperbola is expected to collapse to its apex. This means a trial and error method in finding the right velocity, which is certainly very time consuming. For this analysis a time migration in the frequency-wavenumber (fk) -domain is applied (STOLT, 1978) assuming a homogeneous subsurface. For the reason of CPU time saving this technique is very effective compared with other migration techniques. If some velocitiy values are obtained, a macro model will be built up according to prominent horizons. With the macro model a finite-difference migration in the time-space (tx) -domain or in the frequency-space (fx) -domain using a 63 degree or a 45 degree operator respectively can be applied. The finite-difference-method is very robust in tolerating large velocity errors and the fx-algorithm based on the 45-degree approximation to the scalar wave equation is very effective for steep dipping events without introducing much dispersive noise and so it was applied on such data sections, while the fd-migration in the tx-domain was applied on the remaining data (Figs. 19-23).

Another important advantage in the GEOSYS implementation of the finite-difference migrations is to let the migration start after the delay of recording time, hence very sensible time saving.

Nevertheless to illustrate the long execution times of migration, the following table gives an idea of used CPU seconds on a Convex 3220 Computer for 1000 traces and 1000 samples.

fk-migration with constant velocity	90 s
fd-migration in tx-domain	900 s *
fd-migration in fx-domain	1100 s *

* depends on the complexity of the velocity model.

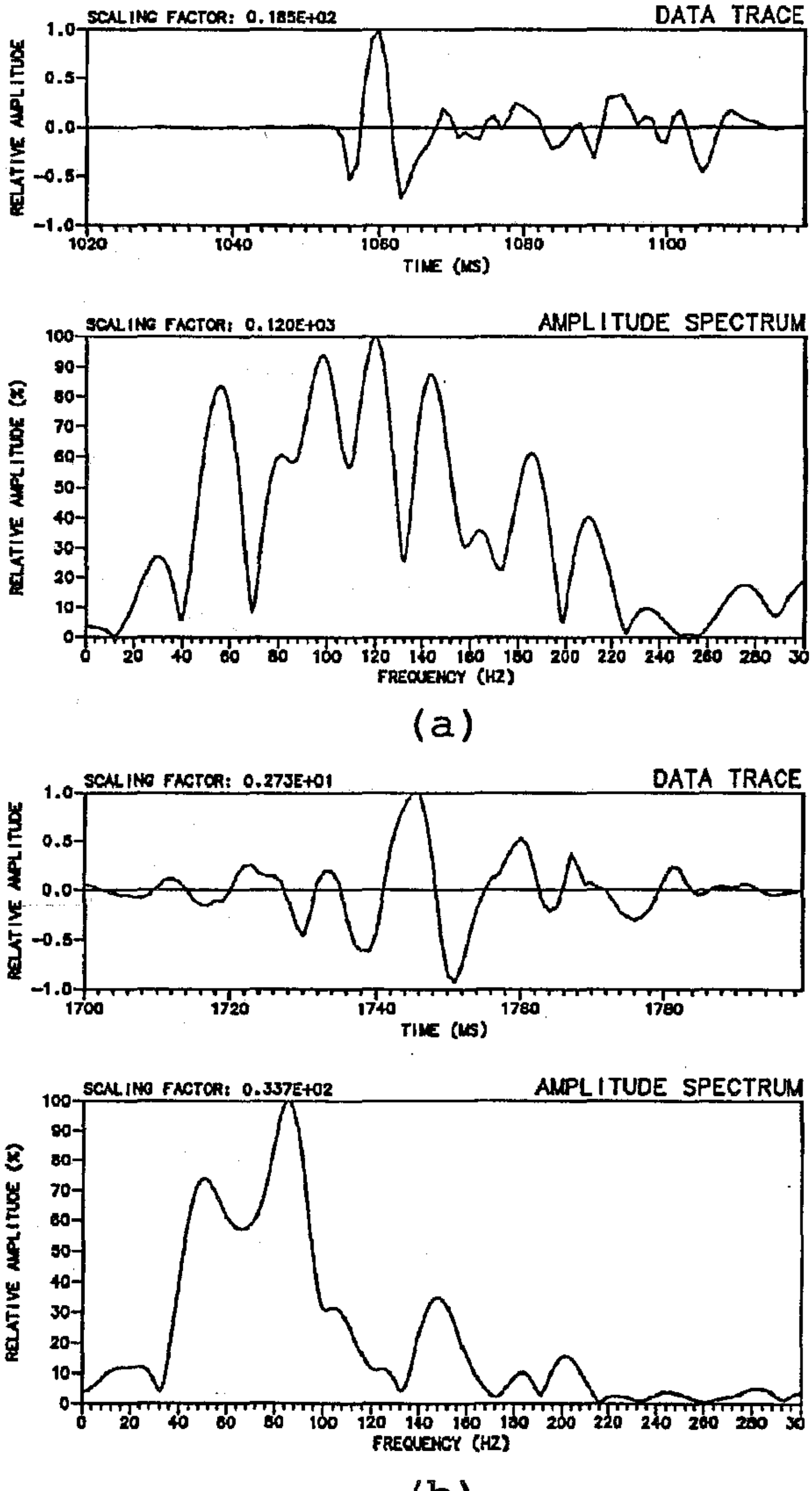


Fig. 19: Frequency spectra of an CMP-trace at (a) water bottom and (b) 700 ms under water bottom.

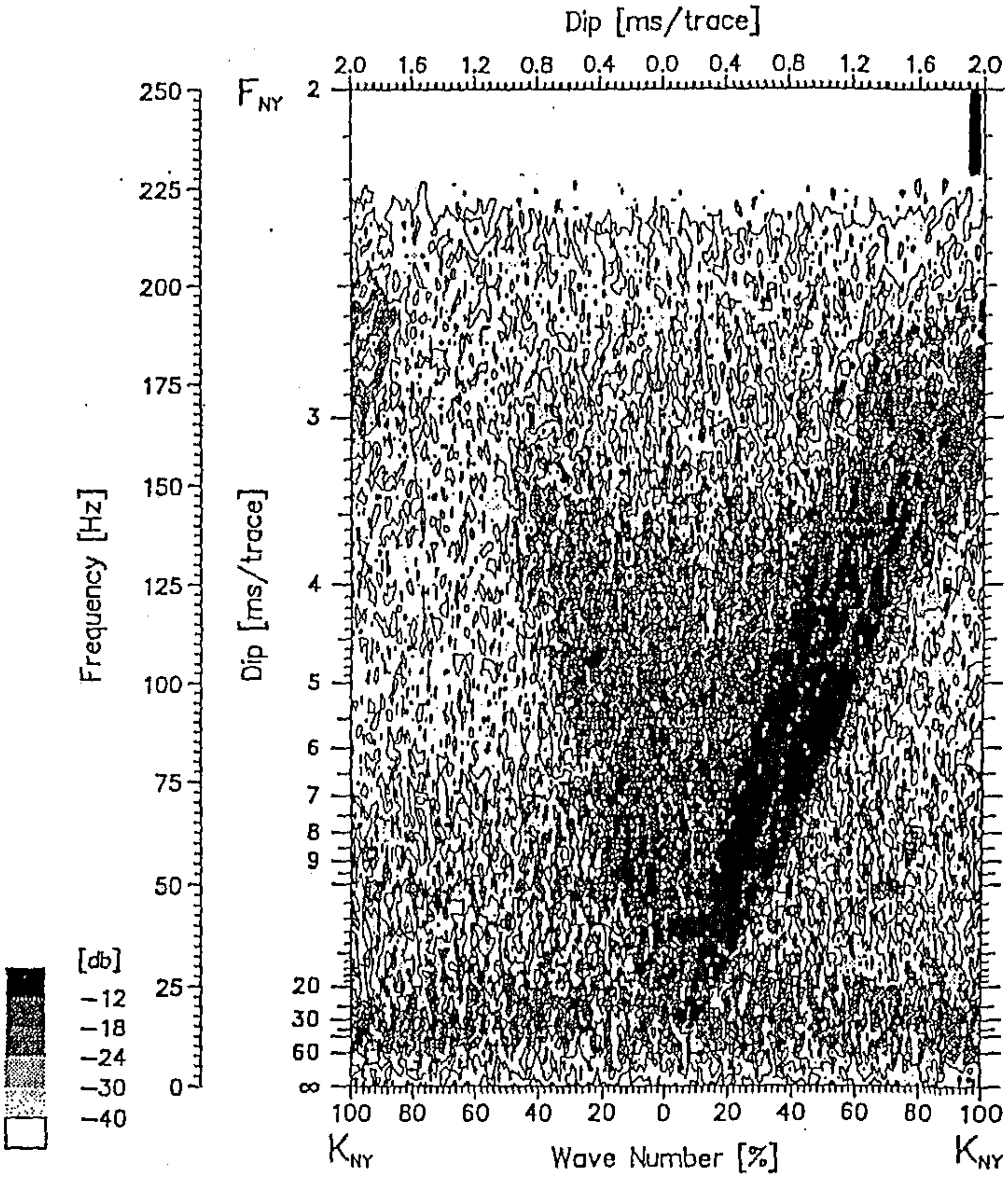


Fig. 20: FK-Spectrum of 235 CMPs and 500 ms, which shows aliased weak ene above 160 Hz. This non relevant energy can be filtered out with a high- filter of 160 Hz.

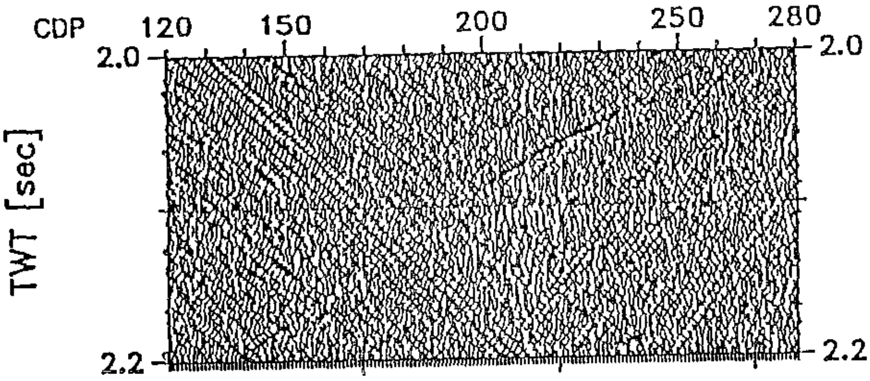


Fig. 21: Small seismic portion of profile 201.
Steep dipping hyperbola flanks showing aliased energy.

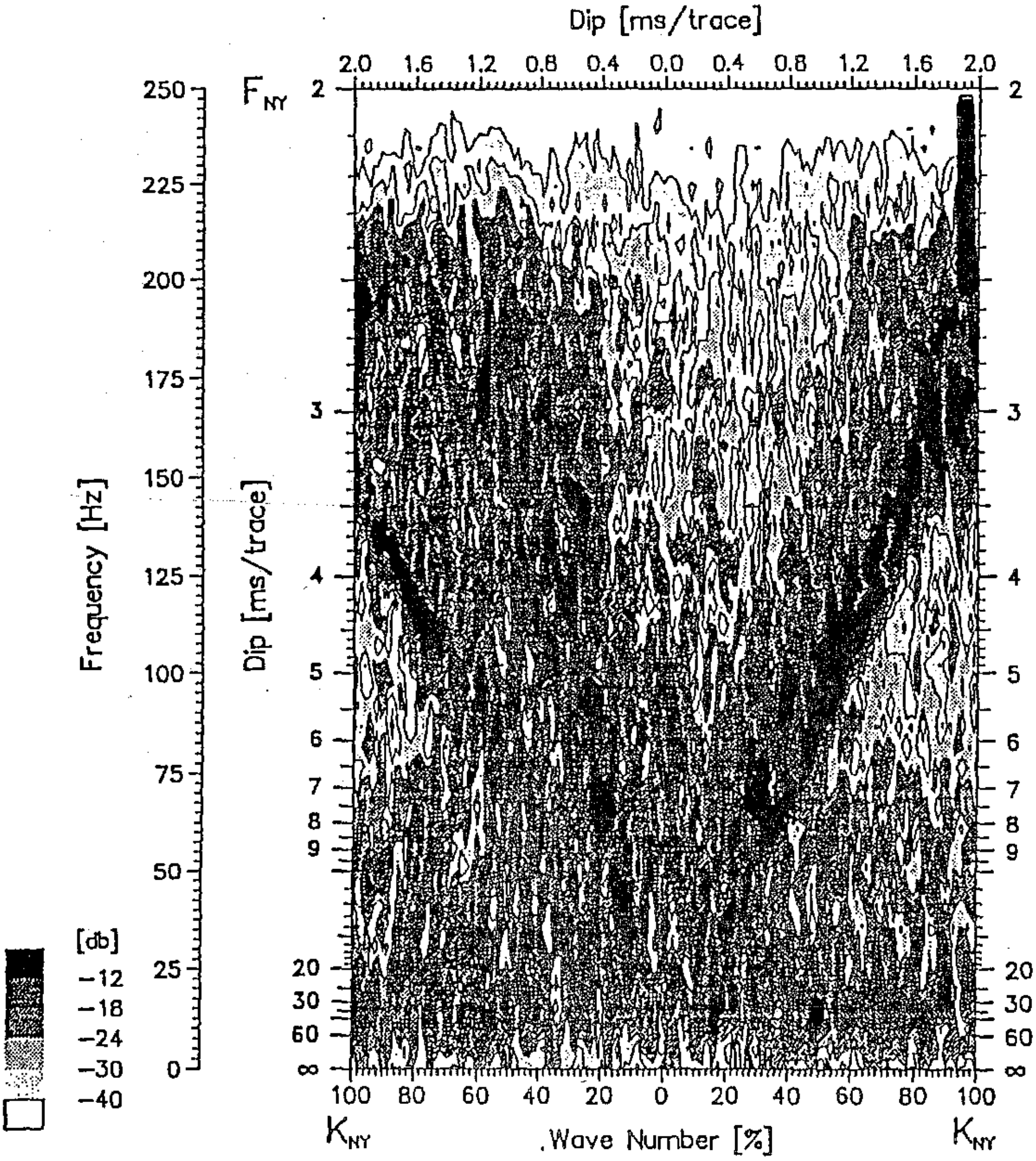


Fig. 22: FK-Spektrum of data shown in Fig. 8, which shows aliased energy and strong energy up to 200 Hz. A dip-filter has to be applied to remove the unwanted energy.

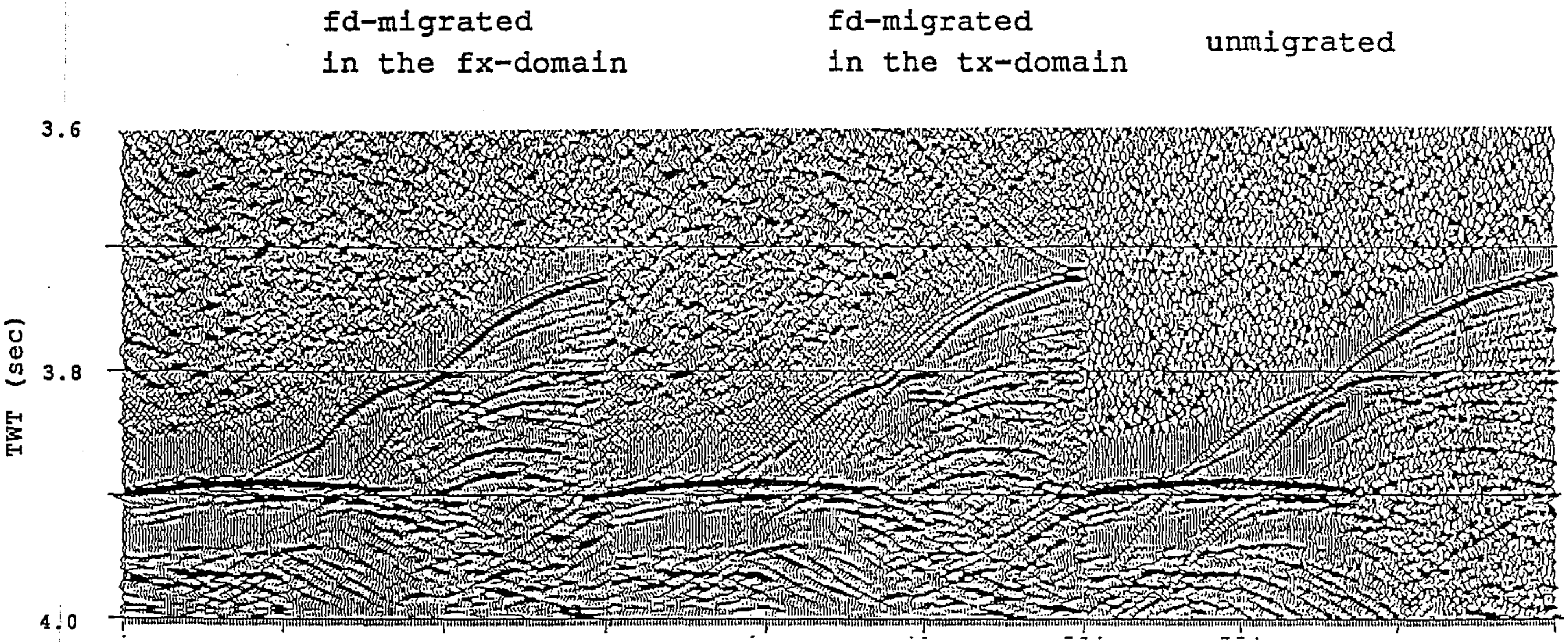
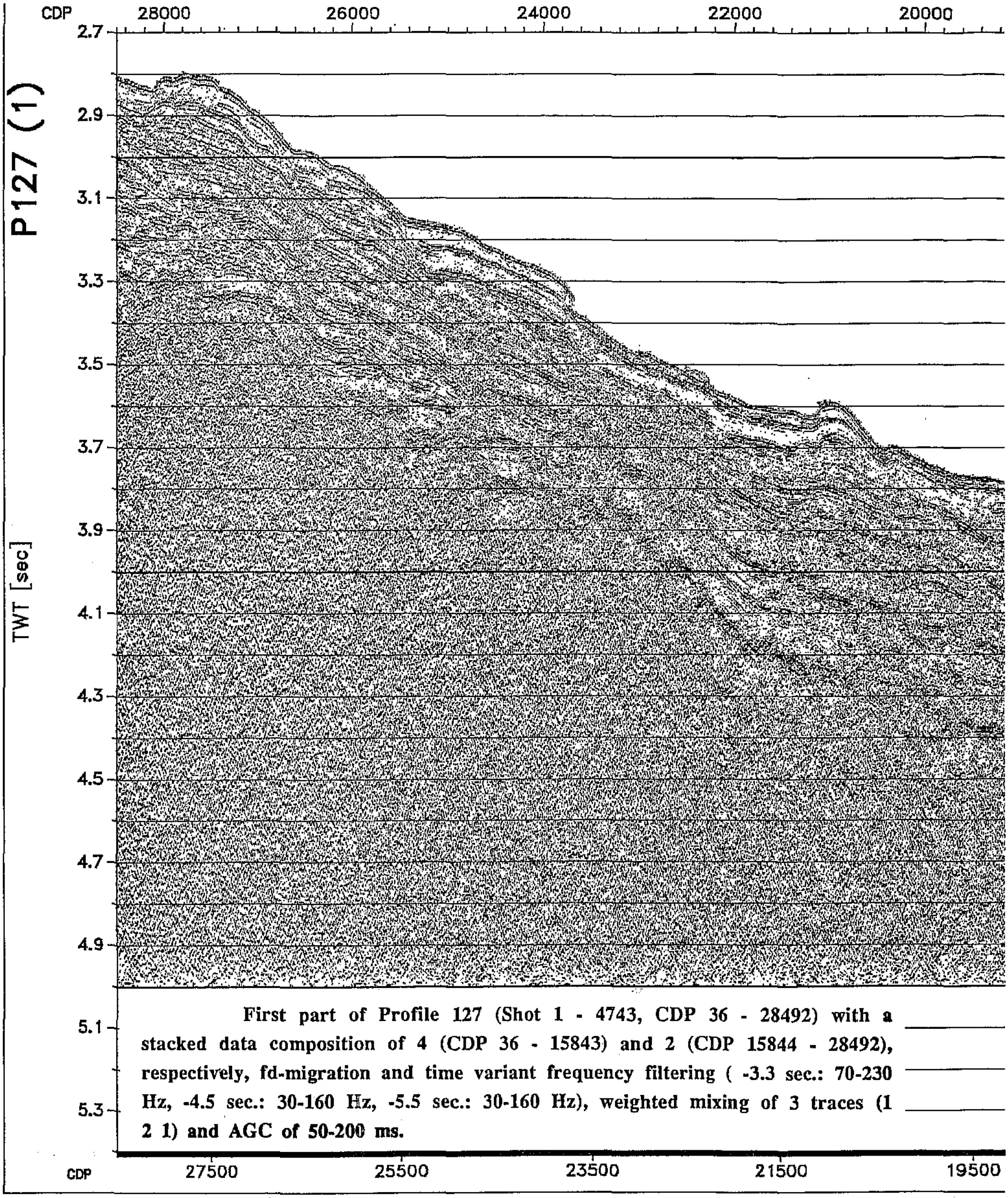
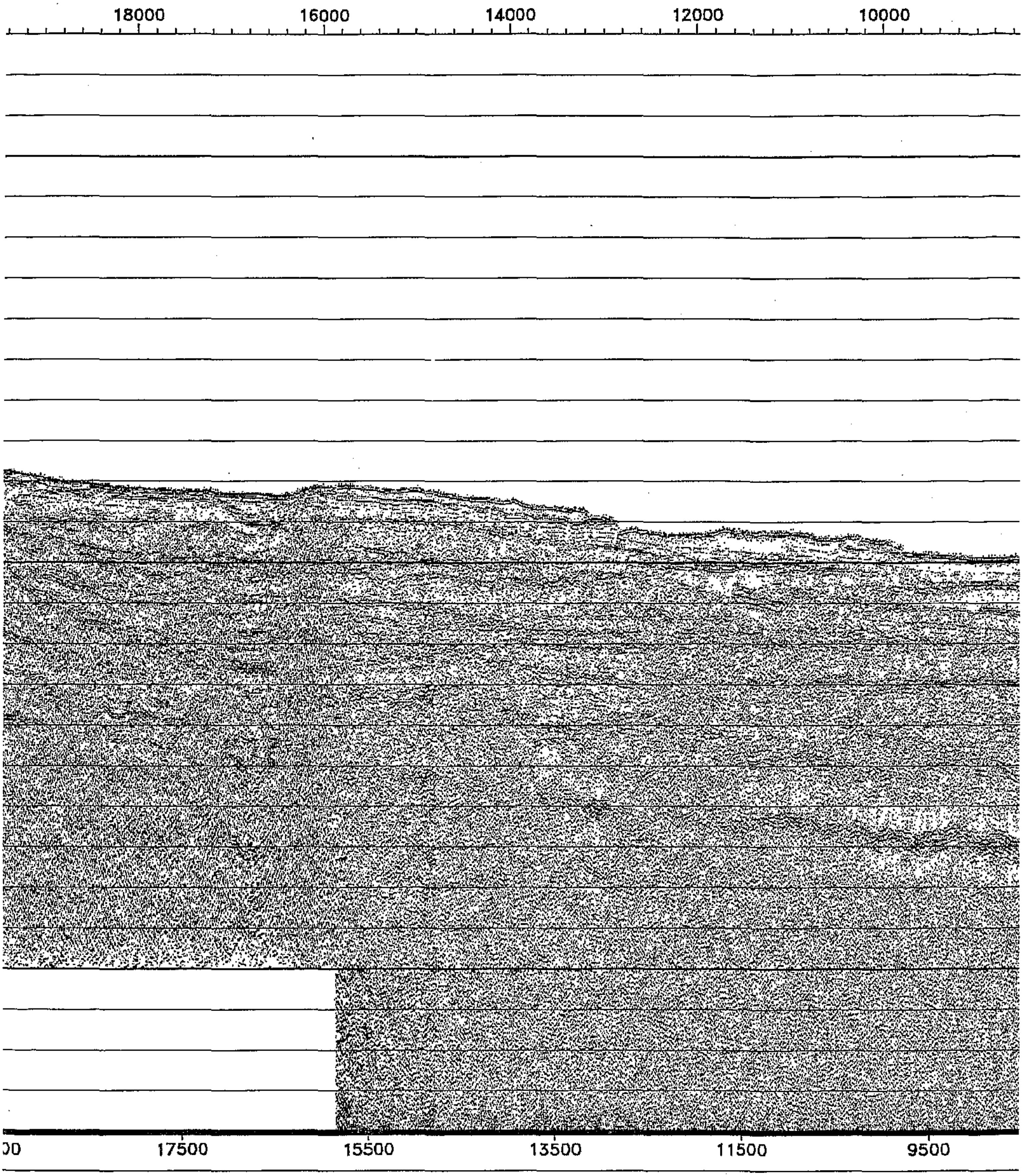


Fig. 23: Small seismic portion profile 109. Comparison of the results of two different fd-migration algorithms. Notice the introducing of much dispersive noise at steep dipping events, when applying the fd-migration in the time-space (tx) domain.



First part of Profile 127 (Shot 1 - 4743, CDP 36 - 28492) with a stacked data composition of 4 (CDP 36 - 15843) and 2 (CDP 15844 - 28492), respectively, fd-migration and time variant frequency filtering (-3.3 sec.: 70-230 Hz, -4.5 sec.: 30-160 Hz, -5.5 sec.: 30-160 Hz), weighted mixing of 3 traces (1 2 1) and AGC of 50-200 ms.


18000
16000
14000
12000
10000
00
17500
15500
13500
11500
9500

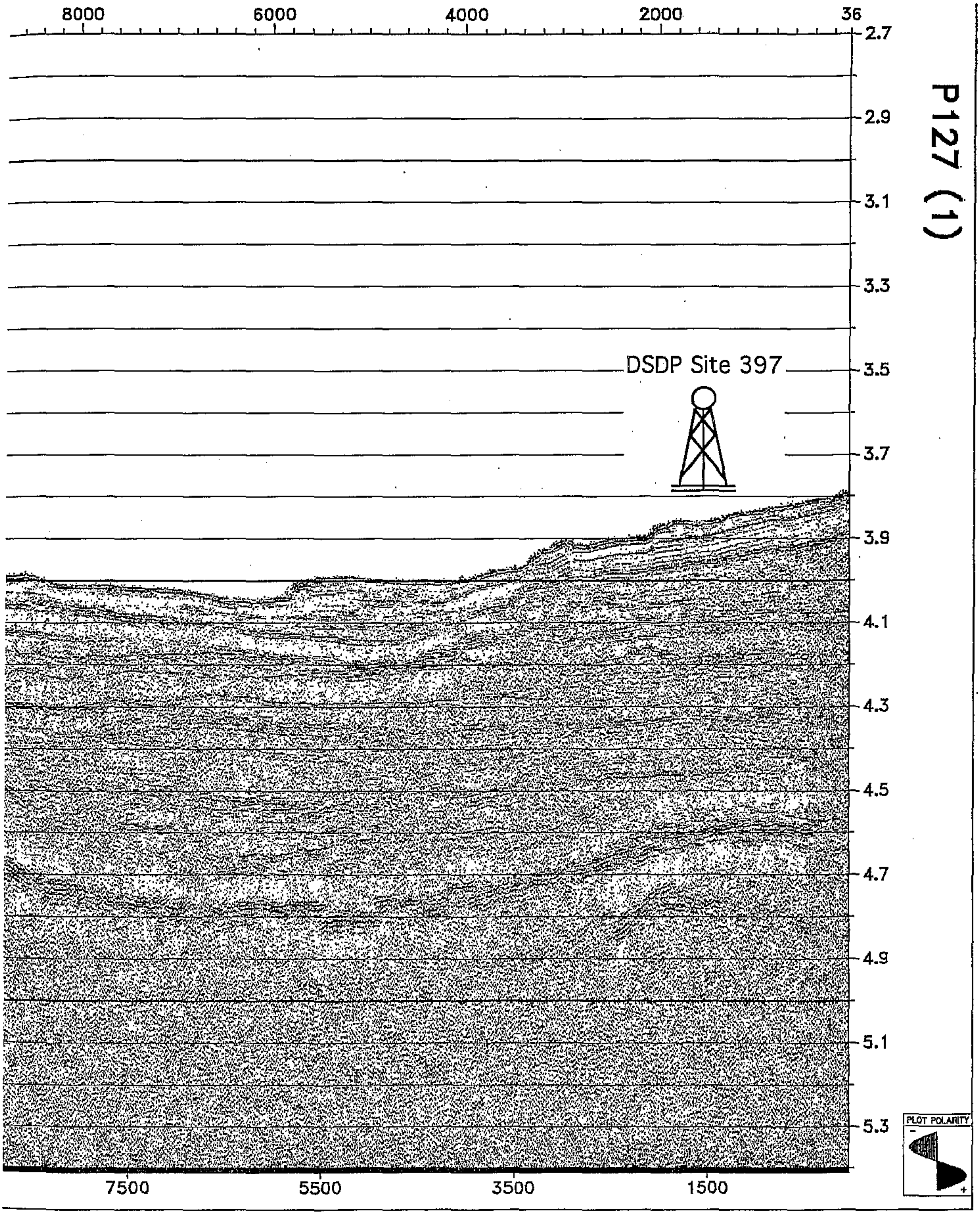
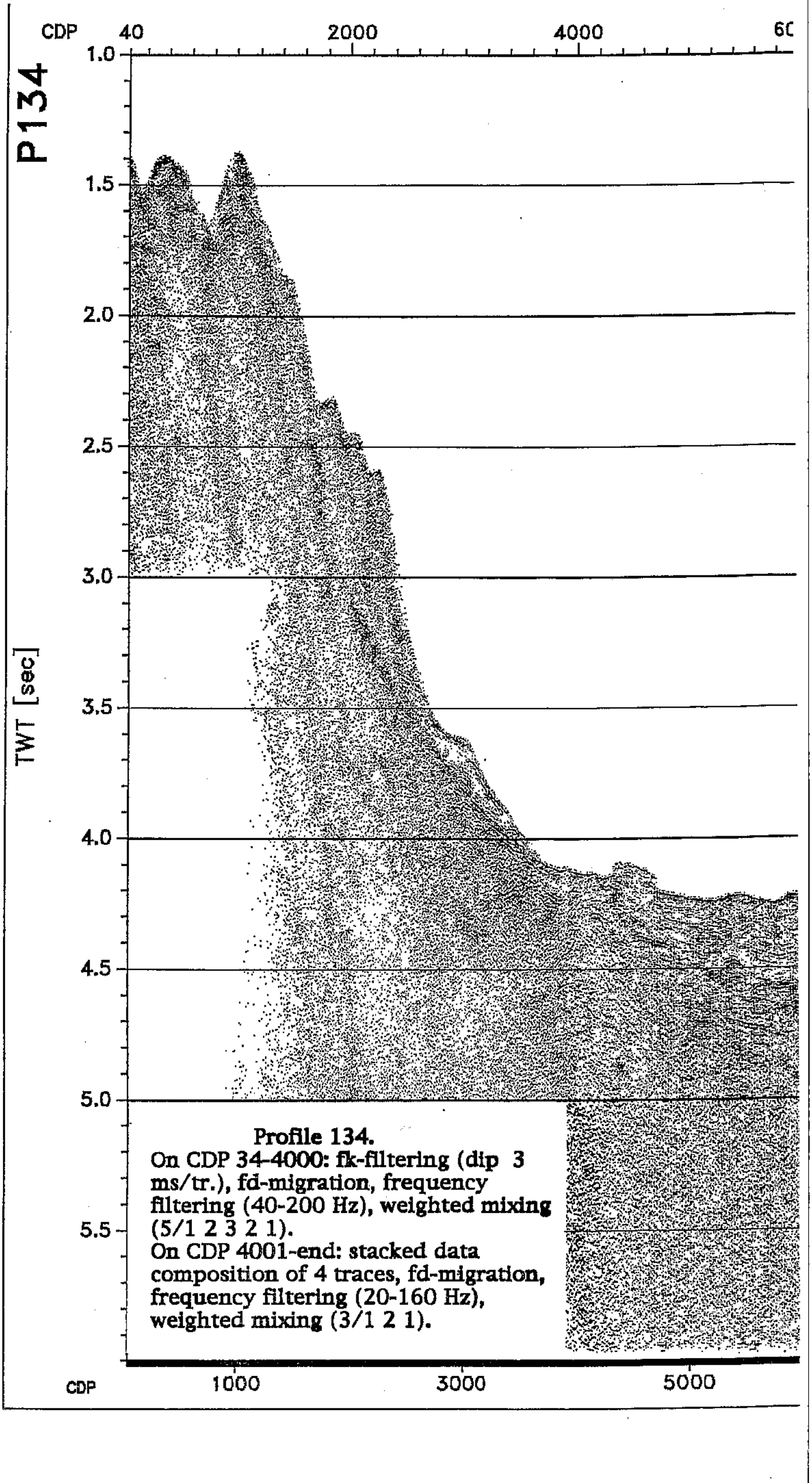
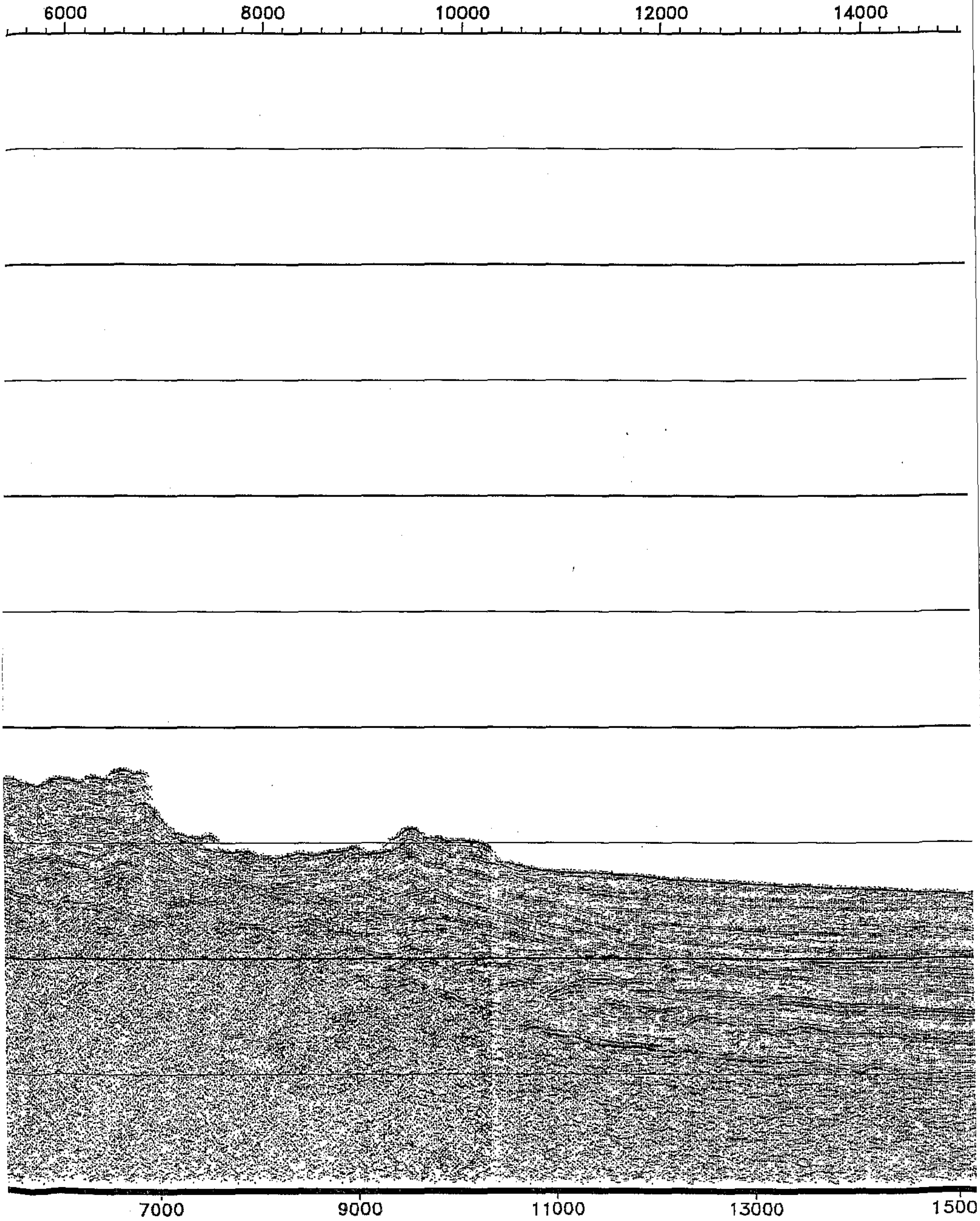


Fig. 24: Reflection seismic record of P127 crossing DSDP Site 397 near CDP 1000



Profile 134.
On CDP 34-4000: fk-filtering (dip 3 ms/tr.), fd-migration, frequency filtering (40-200 Hz), weighted mixing (5/1 2 3 2 1).
On CDP 4001-end: stacked data composition of 4 traces, fd-migration, frequency filtering (20-160 Hz), weighted mixing (3/1 2 1).


6000
8000
10000
12000
14000
7000
9000
11000
13000
1500

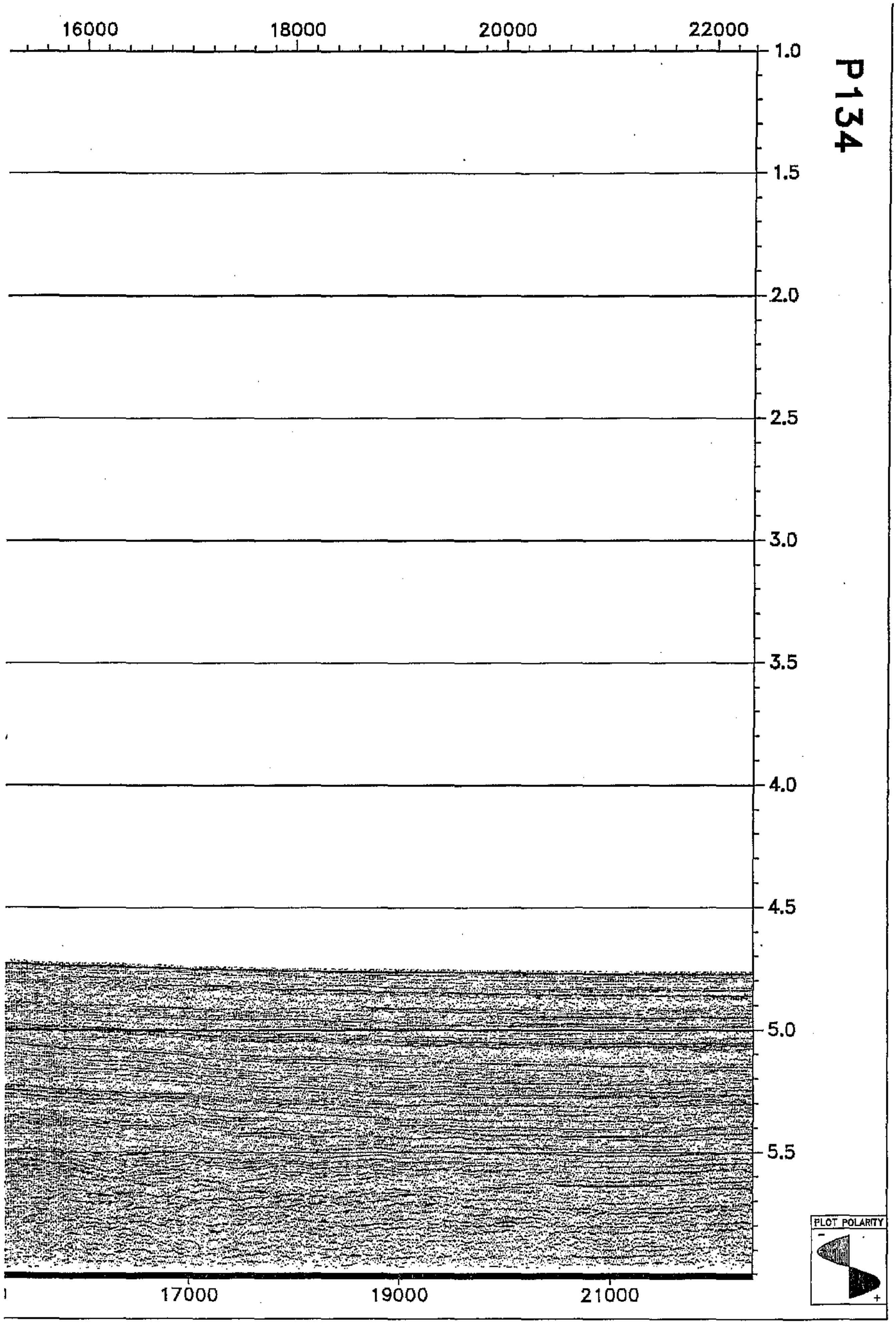


Fig. 25: Reflection seismic record of P134

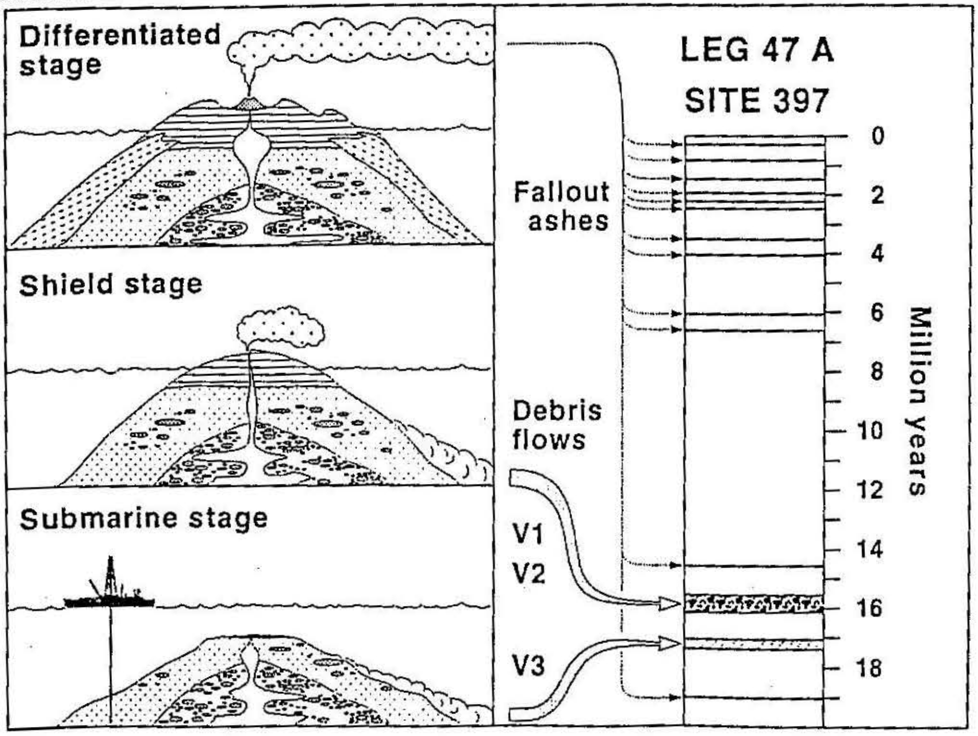


Fig. 26: Three schematic growth stages of a volcanic ocean island as reflected in three main types of submarine volcaniclastic rocks drilled in DSDP Site 397 south of the Canary Islands (SCHMINCKE and v. RAD, 1979).

5.7 Seismic Refraction

5.7.1 Airguns (P. Bergmann, T. Funck, S. Krastel, S. Radomski, P. Trinhammer)

Arrangement of the airguns

One of the two 32 liter-airguns used (see Tab. 6) during this cruise belongs to GEOMAR and the other is the property of the Alfred-Wegener-Institute (AWI) in Bremerhaven, Germany. Both guns were deployed by means of the A-frame. The GEOMAR-gun was deployed in the extreme starboard side of the A-frame and the AWI-gun in the same manner at the port side.

The air was delivered by 4 Junkers compressors of the Institute of Geophysics of the University of Hamburg. The air was distributed at the pulser-station on port side (ca. 20 meters away from the stern). The pressure was 130 bar, in case of a firing rate of 1 minute with both guns only 110 bar was reached.

To tow the airguns at a distance of 80 meters behind the ship a total length of 100 meters (port) respectively 130 meters (starboard) of the air-hoses was required. The depth of the guns was 10 meters. One end of a chain (7 meters) was connected to the gun, the other end to two ropes (3 meters) with the A6-buoys.

A 50 meter-streamer was deployed to synchronize the two guns. The streamer was a spare section for the streamer used during the high-resolution reflection-seismic. The streamer was deployed through the open stern gate and fixed in the middle, port or starboard side of

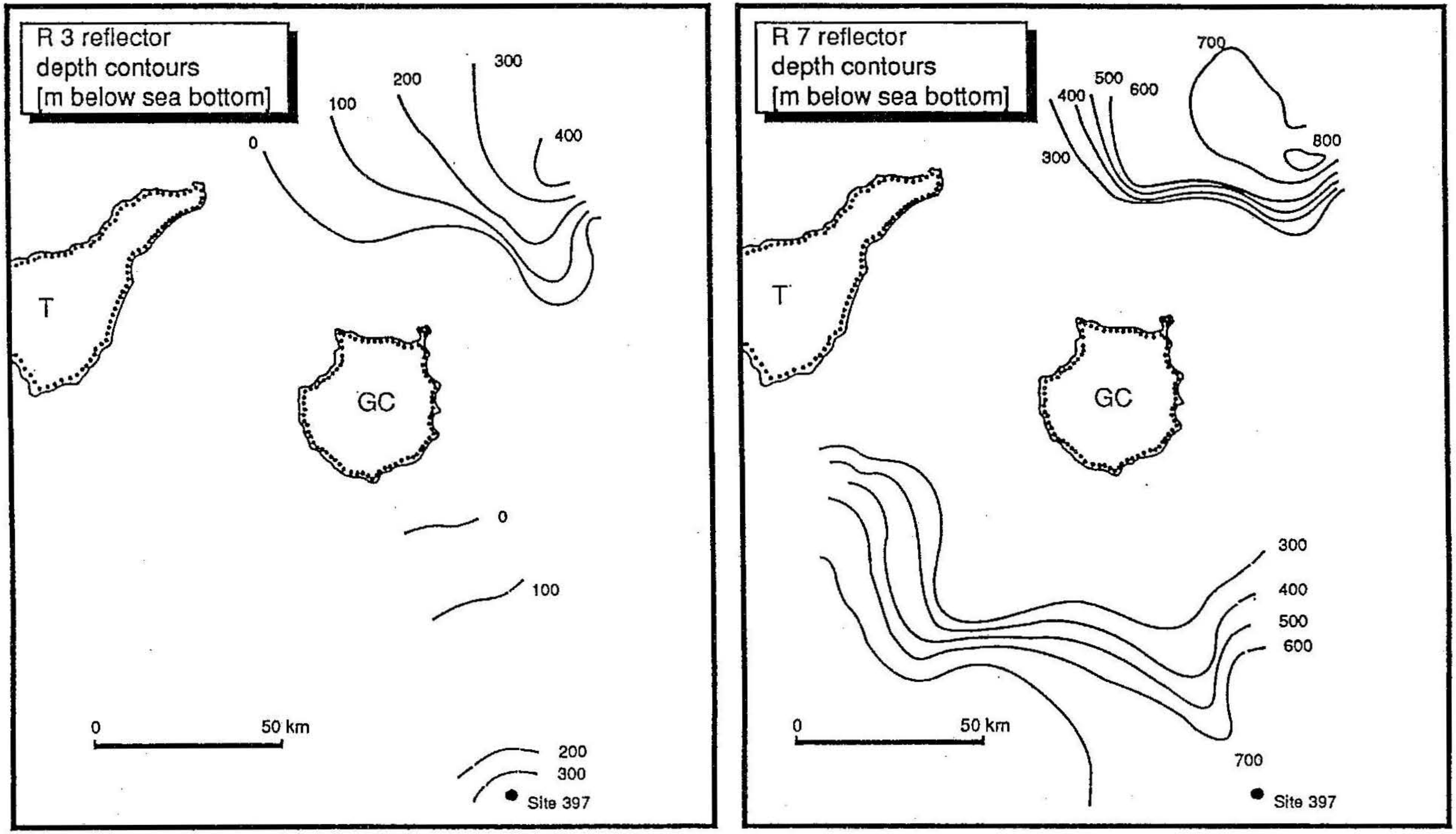


Fig 27: Depth contour maps of reflectors R3 and R7 derived from correlation of M 16 and M 24 seismic profiles with DSDP Site 397.

the gate, depending on the current and seastate. The signals of the guns were observed at the monitor of the danish control unit and thereafter the firing delay was regulated separately for each gun at the SEDASIS triggerunit.

To get a master time-signal a DCF77-receiver was used. Before each profile the oscillator of the danish triggerunit was started with the minute-pulse of the DCF-signal. Then the oscillator gave a signal to the SEDASIS triggerunit, which was located in the pulser-station, every one or two minutes.

Operation

During the first test of the airgun-array both guns failed. After a change of an O-ring in the GEOMAR-gun and a general overhaul of the AWI-gun the test was successful. Maybe because of the small diameters of the air-hoses in the pulser-station a higher initial pressure than indicated in the manual was necessary to close the airguns. The pressure used was more than 100 bar.

During the main operation the airguns worked very reliable, only two failures occured: An air-hose was chafed and leaking due to friction at the towing-wire (May 1st, 02:18) and the buoys of one gun were lost due to bad weather conditions (May 5th, 01:08).

Tab. 6: Airguns

	Type of airguns:	BOLT PAR AIR GUN MODEL 800 CT
	Volume of firing chamber:	32 liters
	Number of guns:	2
	Pressure:	110 - 130 bar
Towing-system		
	Tow wire length:	80 meters
	Towing depth:	10 meters
	Buoyancy:	2 A6-buoys per gun
Trigger-system		
	Synchronization:	with DCF77 before each profile
	Time-signal:	generated by the danish triggerunit (ES2420)
	Fire-pulse:	generated by a SEDASIS triggerunit
	Firing rate:	1 and 2 minutes
	Firing delay:	ca. 300 ms
Airgun-synchronization with streamer		
	Streamer-type:	Teledyne
	Channels:	1 - 8
	Hydrophones per group:	7
	Group length:	3.125 meters
	Group spacing:	6.250 meters
	Total length:	50 meters
	Streamer depth:	1 meter

The operating times of the guns are listed in Chapter 7.2.1.

5.7.2 **Ocean Bottom Seismograph** (OBS) (P. Bergmann, R. Rihm, S. Ye)

The second part of M 24 with emphasis on refraction and wide-angle reflection seismics began on April 27th and ended on May 4th. Eight ocean bottom seismographs (OBS) developed at GEOMAR were deployed N and NE off Gran Canaria (Fig. 1). The OBS positions were designed to form a seismic net with three radial and three transverse profiles. In addition, several short profiles were shot near the coast to obtain better coverage near Gran Canaria for 8 seismic landstations deployed and operated by scientists of CSIC Barcelona.
The GEOMAR OBS consists of three components: A floatation body made of polytactic foam, an acoustic release system and a recording unit with a modified DAT recorder, which can hold as much as 1 GByte of data (equal to 5 days of continuous recording, three data channels). Because the OBS was directly transported in from the North Sea to Las Palmas, where they were used under rough conditions only a few days ago, all systems had to be thoroughly checked. The control on April 27th proved 8 recording units to work without problems as well as 8 acoustic release units that were tested on April 29th. Each transponder has an identification code which can individually be activated by the "Telecommand" board unit. For the test four units at a time were attached to a central tube, lowered to a water depth of 3000 m and activated one by one.

Starting from site 8 at the coastal end of profile 3 (see Fig. 1) the deployment of the OBS began at 08:00 on April 30th. All OBS were programmed in continuous recording mode. Data were sampled at 200 Hz in two channels with different gain (2 and 8). The internal clock (channel 3) of each recording unit was synchronized using the DCF77 time signal output of a GPS receiver. To avoid difficulties with exact determination of the shot times, three types of signals were continuously recorded:

- The trigger pulse from the firing unit,
- the near field signal of the airguns received by one segment of the streamer, and
- the DCF time signal.

Shooting began shortly past midnight of May 1st after deployment of the last OBS at site 6 and was continued without major breaks until the morning of May 4th (see Chap. 7.2.1), when strong winds forced us to recover the airguns after completion of some 90% of the planned profiles. Seven OBS were recovered successfully, one instrument (site 4) did respond to the command unit signals but, however, failed to float up to the sea surface.

The on-board check showed that all recovered OBS had recorded successfully as programmed. Plotting of the data after the cruise at GEOMAR confirmed the high quality of the data (Fig. 28); seismic energy propagated along the whole length of the profiles was recorded well over distances up to 60 km from the OBS. Coordinates and dates of the OBS operation are listed in Chapter 7.2.2.

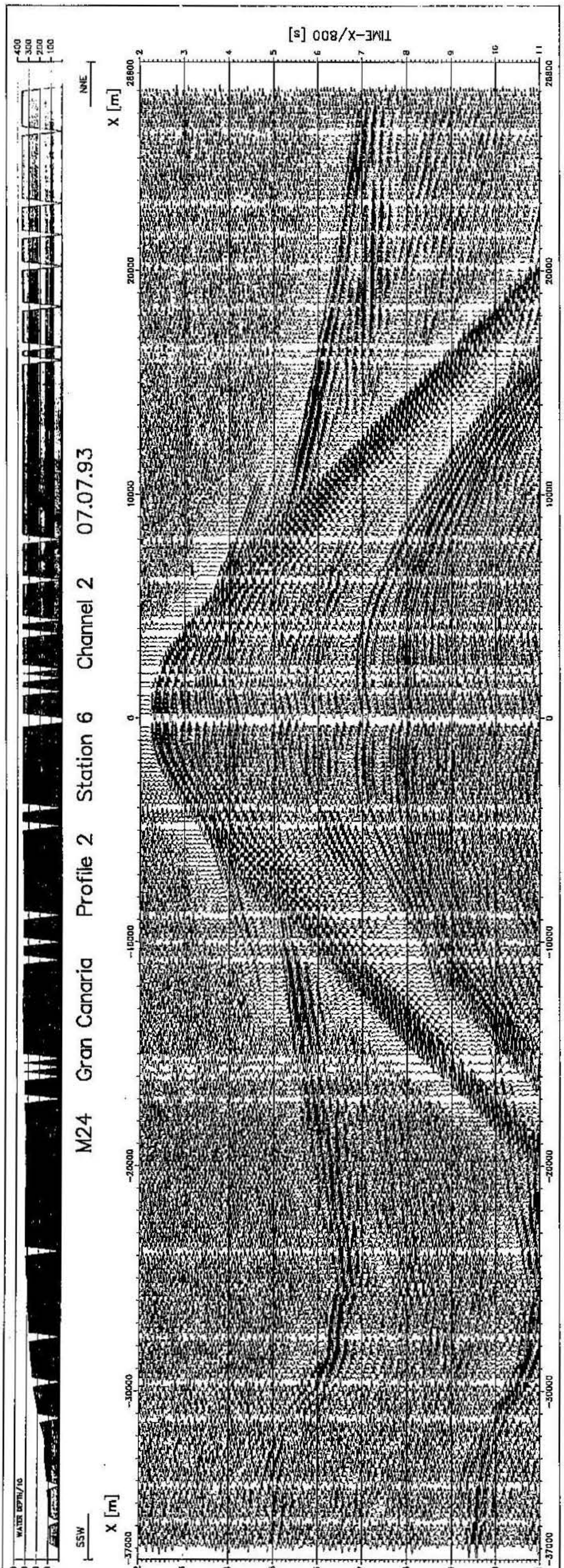


Fig. 28:
Wide-angle reflection and refraction seismic section of OBS Pos. 6 on METEOR 24 Profile 2

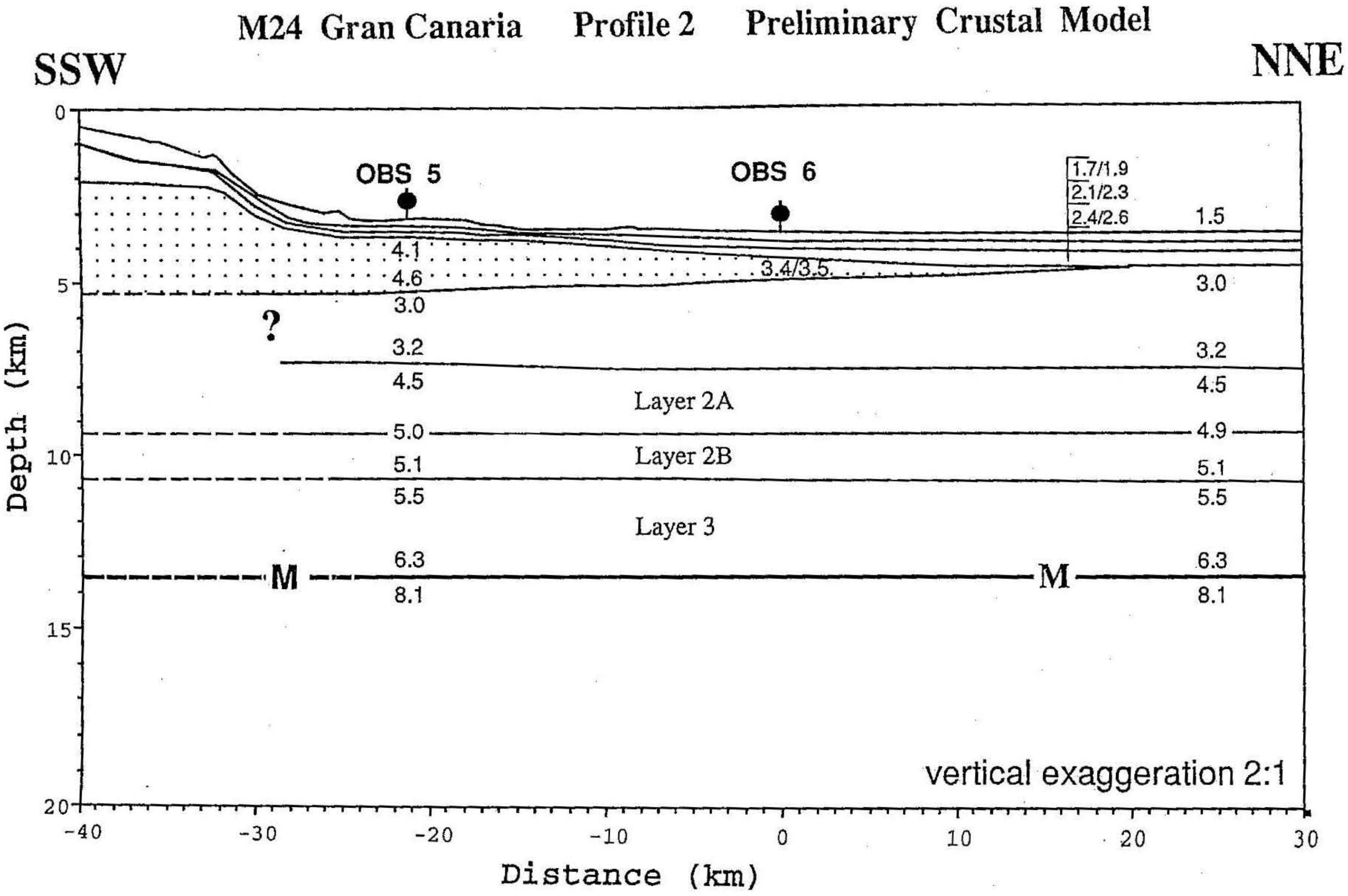

M24 Gran Canaria Profile 2 Preliminary Crustal Model

Fig. 29: Preliminary 2-D velocity-depth model for M 24 Profile 2 computed with the ray-tracing program MACRAY.

Preliminary results of modeling show that - using the reflection seismic interpretations as input information for the uppermost sedimentary sequence - the crustal structure can be resolved in more detail than before (DASH and BOSSHARD, 1968; BOSSHARD and MACFARLANE, 1970; BANDA et al., 1981) down to the upper mantle. In particular, the geometry of the island flank of the Miocene Gran Canaria shield stage and the presence of a low velocity layer of pre-volcanic sediments below it show up very clearly. The depth to the Moho is well constrained N and NE off Gran Canaria and was calculated to be 13 km, which is a little shallower than the 15-16 km found below the central Canarian Islands (BANDA et al., 1982). As in studies of geoid anomalies (FILMER and MCNUTT, 1988) no indication of a major flexure below the island as expected by theoretical considerations (WATTS and TENBRINK, 1989; WATTS, 1992) could be detected. Only integration of the landstation data, however, will - by extending the area of data coverage towards the island center and computing the landward parts of the models in more detail - allow for testing, wether a depth anomaly, as found below the Great Meteor Seamount (WATTS et al., 1975) and postulated for the Canary Islands to be in the order of 500-1000 m (DAÑOBEITIA, 1988) does exist or not. A preliminary model, yet without the input from the landstations, is presented in Figure 29.

5.8 Gravity

(G. A. Dehghani, J.P. Canales, J. J. Dañobeitia, S. Krause, A. Sabetian)

5.8.1 Introduction

The main objectives of M 24 in the potential field were to:

- Collect the gravity, magnetic and bathymetric data along the seismic profiles and also additional profiles to produce the gravity and magnetic maps of the area combining the data of this cruise with the marine data measured during M 16/4 (HIRSCHLEBER et al., 1992) and the marine data obtained from the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover (ROESER et al., 1971, ROESER and PLAUMANN, 1992, personal communication) with the gravity and magnetic data on land (BOSSHARD and MACFARLANE, 1970; VIEIRA, TORO and ARANA, 1986).
- Map the prominent tectonics features in the research area using all available gravity and magnetic data and to make a comparison between the surface geophysical data and the satellite data (SEASAT and GEOSAT).
- Calculate a realistic model of the present day tectonics of the research area using 2-D and 3-D modelling methods.

5.8.2 Instrument

The KSS 30 gyro-stabilised gravity measuring system no. 15 of the Institute of Geophysics, University of Hamburg, was used for the gravity measurements during M 24. The system is divided into two main assemblies:

- Gyro-stabilized platform with gravity sensor;
- Data handling and control system.

The gravity sensor includes the non-astatized spring-mass assembly as basic gravity detector and is able to measure the gravity with an accuracy of better than 1 mGal even at rough sea.

The Gyro-stabilized platform with the gravity sensor and the data handling and control system were installed in the gravity lab in the main deck. The data acquisition was done using personal computers (PC) installed in the gravity and magnetic lab (lab 7 and 8) in the second main deck of the vessel. The data logging part of the gravity system was interfaced with the navigation computer. The navigation was transmitted to the gravity system at 1 s intervals.

5.8.3 Gravity Base Connections

Since the gravity values at sea need to be tied to the World Gravity Net so that the measurements at sea become meaningful for global researches and since all gravity values at sea should be on the same common base so that the values measured by different instruments, different organisations or at different times can be combined, a dockside calibration of a shipborn gravimeter is required.

- Las Palmas: In order to determine the value of gravity at the dockside in Las Palmas (2 times within 11 days), we used the gravity base station in the Harbour which was installed during M 16/4 (HIRSCHLEBER et al., 1991). Using a land Gravimeter type LaCoste & Romberg Model G, No. 260, two new gravity base stations were established at the pier in the harbour (Figure 30). The absolute gravity values for the METEOR 1 and METEOR 2 are 979365.91 mGal and 979369.41 mGal respectively. The marine Gravimeter KSS30 shows a drift of 0.6 mGal for the time of 11 days which is much better than it was expected.
- Malaga: In Malaga the national gravity base station Malaga B was used with an absolute value of 979900.21 mGal. With the help of this station, a harbour station close to the position of METEOR in the Harbour was established. The absolute gravity value determined for the harbour station was 979892.91 mGal. For the whole period of the cruise (28 days) a drift of 1.5 mGal was determined.

5.8.4 Gravity Measurements in the Research Area

The gravity measurements during M 24 began on the 14th April 1993 in the harbour of Las Palmas. The end of the measurements was on the 8th May 1993 in the Malaga harbour. A total of approx. 3,500 km gravity profiles were recorded during this period of time along 63 different profiles (Fig. 31). Leaving the research area and on the way to Malaga, the gravity data were recorded along a profile parallel to the West African coast and through the Strait of Gibraltar. A total of aprox. 200,000 gravity stations were recorded during this cruise.

The gravity data were logged on the diskette every 10 seconds together with navigation data. A pre-processing of these data was done on the ship and the digitally recorded water depths were corrected for instrument drop-outs. On four profiles the whole water depth had to be re-digitised later on in Hamburg because of frequent and large data gaps due to Hydrosweep weather break-down.

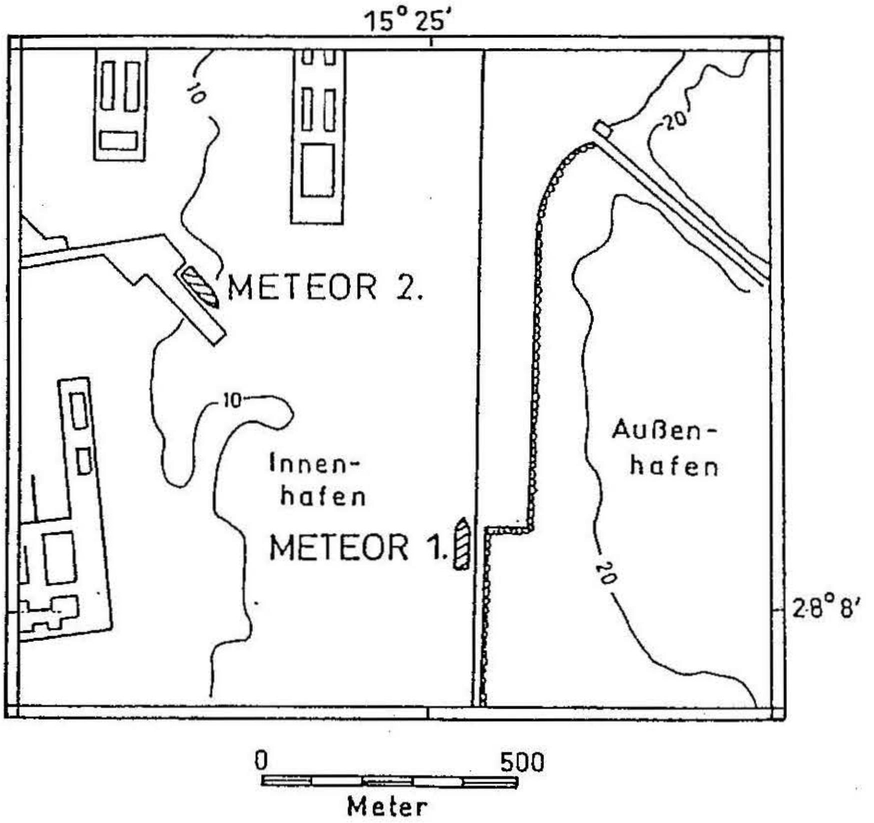


Fig. 30a: Positions of METEOR in the habour of Las Palmas (2 times)

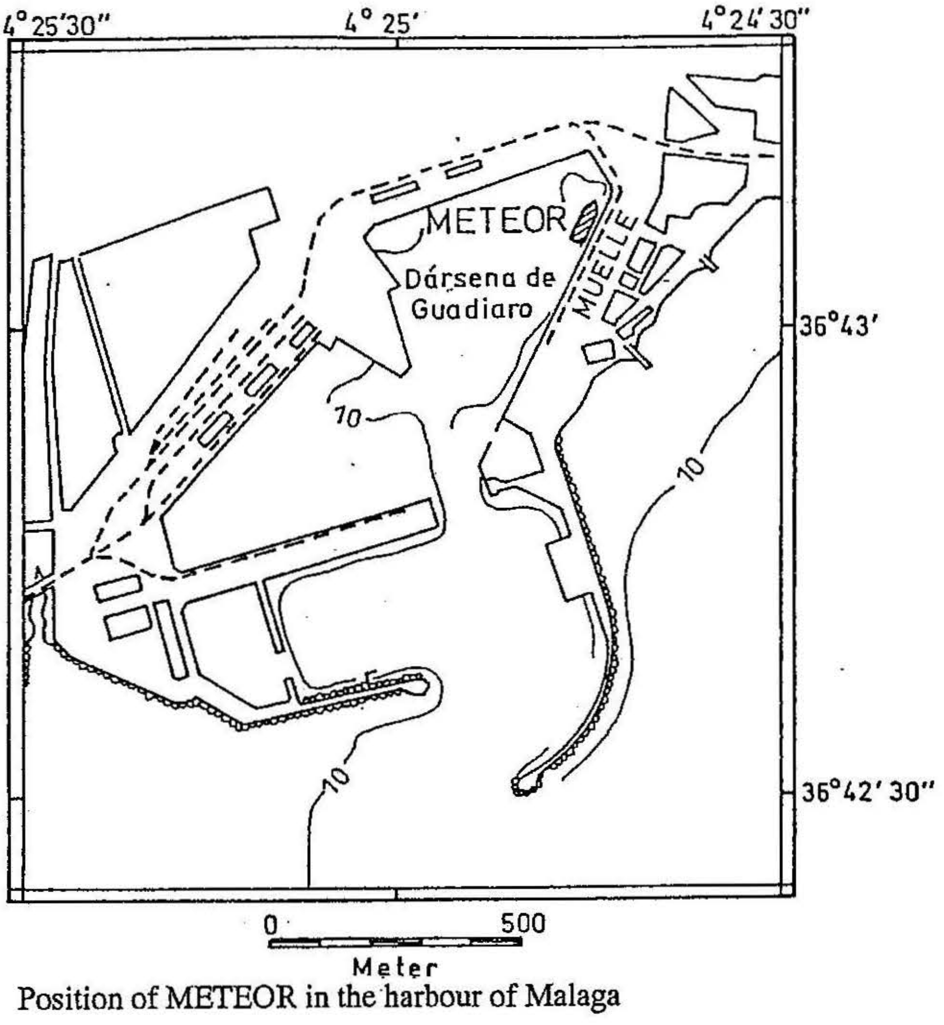


Fig. 30b: Position of METEOR in the harbour of Malaga

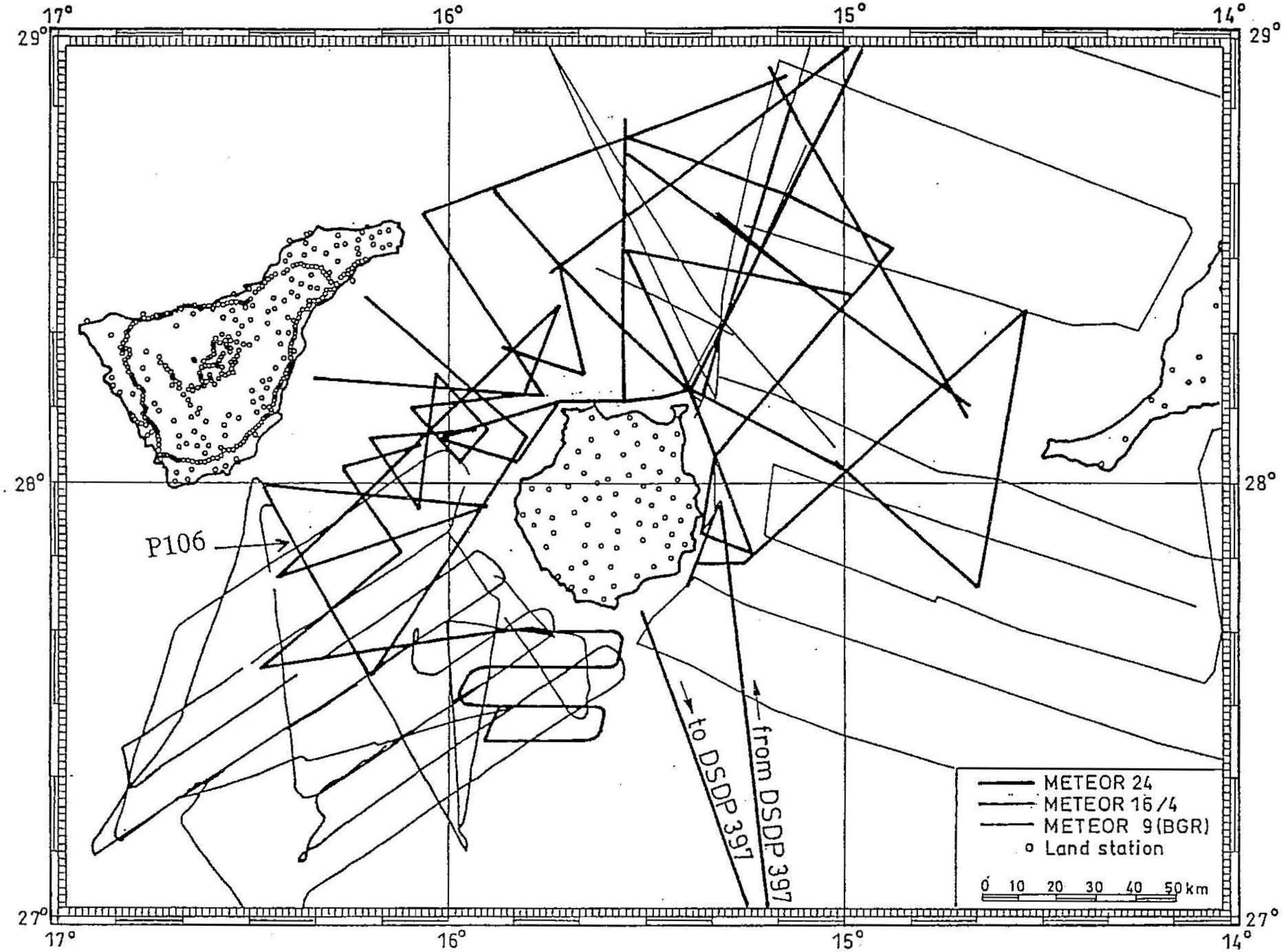


Fig. 31: Map of available gravity data collected onshore and during METEOR cruises no. 9 (BGR), no. 16/4 and no. 24.

The results of the pre-processed data show a very good quality of gravity data which can be even improved by post-processing. Using the gravity data along the profile 106 (which is exactly the northern part of profile 11 of M 16/4) a preliminary 2-D model was calculated. The crustal structure and sediment thickness for this 2-D model were constrained using the seismic information from M 16/4 (Steiner and Weigel, personal communications). The results of this calculation are shown in Figure 32.

5.9 Magnetics

(G.A. Dehghani, J.P. Canales, J.J. Dañobeitia, S. Krause, A. Sabetian)

5.9.1 Instrument

During M 24 the total intensity of the magnetic field of the earth was recorded along the seismic profiles as well as along some additional tracks.

The magnetic measurements were carried out using a proton precession magnetometer type ELSEC 7704. The omnidirectional sensor of the magnetometer was towed at a constant distance of 280 m behind the ship. This distance was a little too short, so that the magnetic influence of the vessel sometimes produced disturbance in the recorded magnetic field. This can be filtered by post-processing. According to the length of the ship (approx. 100 m), a minimum distance of 300 m would have been required, which was not possible during this cruise.

5.9.2 Magnetic Data

The magnetic data were recorded on profiles along the gravity lines. A total profile length of aprox. 2,400 km was measured during this cruise. Analogue data have been digitised continuously and were merged with navigational data.

It is planned to use the International Geomagnetic Reference Field (IGRF, 1990) for the epoch of 1993.3 as the regional field in order to calculate the residual magnetic field.

5.10 Heat flow (G. Götz, R. Rihm)

Due to initial instrument problems at the first successful sediment site (M24-5 MKC) and poor recovery of long sediment cores later on, only one heat flow value could be obtained at site M24-7 MKC, where 3 m of sediment were recovered and 4 thermal sensors had penetrated the seafloor to depths of 70 cm, 132 cm, 180 cm and 284 cm. The value for heat flow density computed for this site is 1.8 HFU (78 mW/m^2). The temperature gradients and conductivity values at M24-7 are listed in Chapter 7.3.

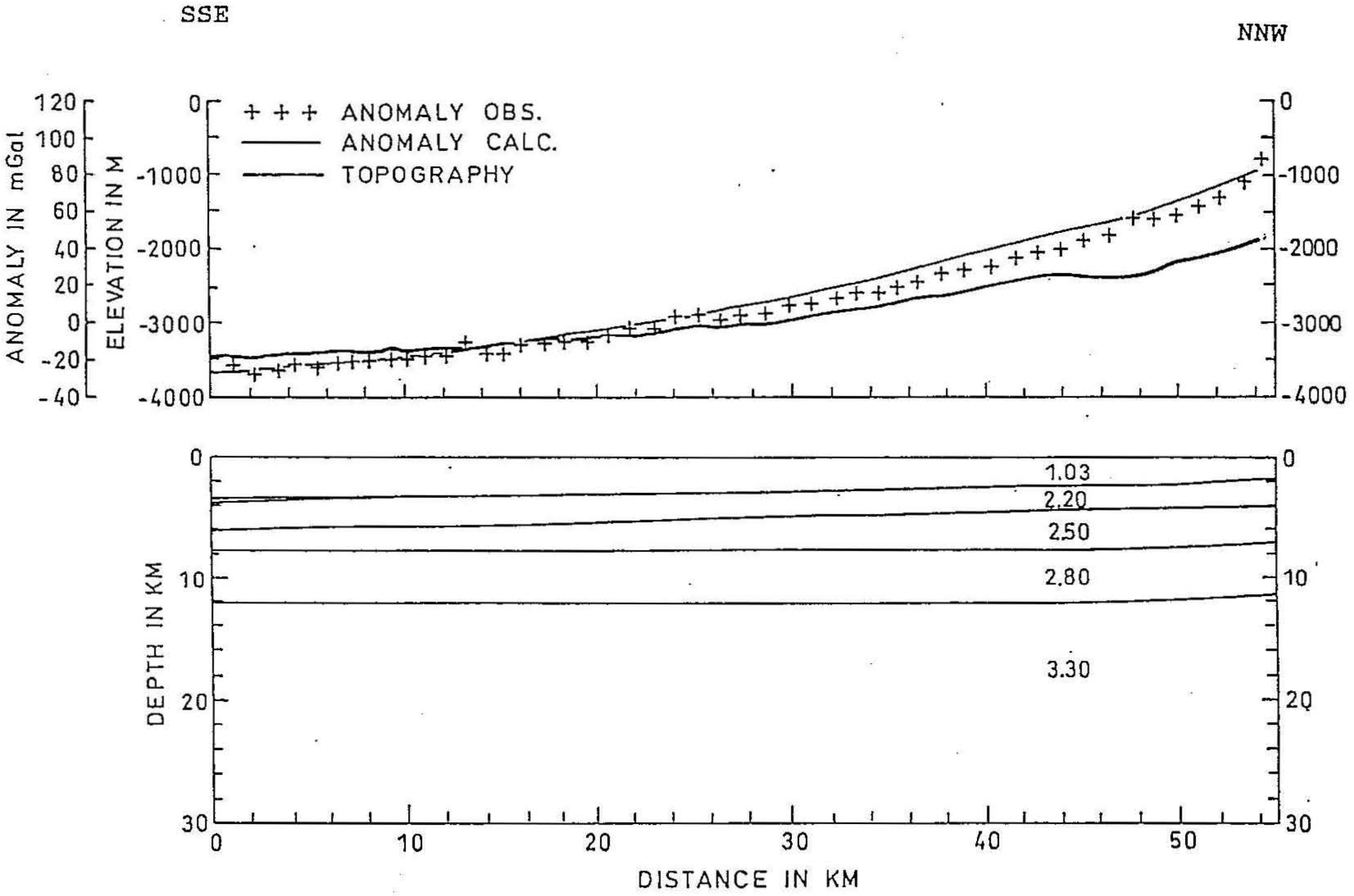


Fig. 32: 2-D gravity model along M 24 Profile 106 (identical with NW part of M 16/4 Profile 11.

5.11 Sediment Coring

The stations for sediment sampling were chosen on the basis of Parasound and airgun seismic records at appropriate positions for pre-site survey documentation of the upper sediment column for later ODP-drilling. Sites M24-1 and M24-2 were chosen as test sites to check handling of the equipment. Even though Parasound and MCS showed traces of sediment, both stations were unsuccessful in that the GKG (kastencore) did not retrieve any sediments so that the MKAL (Schwerkastenlot, on board called "Megakastenlot") was not deployed in either case.

Station M24-1 (28°14.5'N, 16°21.2'W, 701 m)

GKG-1, depth upon bottom contact: 702 m
recovery: none, not triggered

GKG-2, depth upon bottom contact: 702 m
recovery: none

GKG-3, depth upon bottom contact: 3443 m
recovery: none

Station M24-2 (28°13.6'N, 16°19.0'W, 1006 m)

GKG, depth upon bottom contact: 1002 m
recovery: none; box and frame damaged

Station M24-3 (27°33.4'N, 16°11.8'W, 3446 m)
This site is located just outside the volcanic flank on the southern flank of Gran Canaria in pelagic sediments. Parasound penetrates 20 m into sediments, multi-channel seismics (MCS) indicate a sediment blanket of at least 150 m thickness.

GKG, depth upon bottom contact: 3443 m
recovery: 38 cm

MKAL, depth upon bottom contact: 3443 m
recovery: 310 cm

GKG retrieved soft brownish and pale grey muds with numerous traces of bioturbation and one layer rich in tephra. Surface of GKG sample was covered with mud clasts. MKAL contained similar sediments with 3 turbidites (at 110, 141 and 158 cm) and 6 either silty or sandy volcanic layers (at 7, 26, 55, 119, 130, 150 cm) and 3 discontinuous layers at 216, 230, and 295 cm which possibly also consist of volcanic material. Otherwise the core consists of soft foraminiferal ooze with abundant condrites burrows.

Station M24-4 (28°10.8'N, 15°48.1'W, 550 m)

This station is located on the upper northwestern flank of Gran Canaria within its eroded submerged shield basalts. Parasound showed massive "hard" surface reflector with less than 10 m penetration into seabed. MCS indicated at least 80 m of sediment, again with a hard surface reflector.

GKG	length-wire (m)	400	450	500	550	bottom	pullout
	speed-wire (m/s)	1.0	1.0	1.0	0.5	0.0	-0.34
	tension-wire (kN)	5.86	6.35	6.84	7.37	1.46	10.5

depth upon bottom contact: 556 m
recovery: 31 cm

MKAL	length-wire (m)	400	450	500	550	bottom	pullout
(3 m)	speed-wire (m/s)	1.51	1.51	1.0	1.0	0.0	-0.34
	tension-wire (kN)	3.07	3.17	3.63	1.22	1.95	3.5

depth upon bottom contact: 540 m
recovery: none, fallen over

GKG recovered brown to grey sandy muds which had abundant living organisms at the surface, lots of planktonic and quite a few benthic foraminifera and pteropods, as well as a considerable proportion of volcanic components. The sediments were heavily bioturbated. MKAL was lowered to the seafloor at 1 m s^{-1}, the tensiometer indicated a sharp increase in weight on the wire immediately after the device hit the seafloor. Together with a rather low pull-out force these were the early indications that the corer had fallen over instead of penetrating into the sediments. Back on deck there were only about 5 cm of grey sandy muds in the core catcher which showed indications of hard rock encounter which was probably the reason why this coring attempt failed.

Station M24-5 (28°05.4'N, 16°03.0'W, 2539 m)

Site M24-5 is located in a sedimentary basin halfway between Gran Canaria and Tenerife at the crosspoint of seismic lines P109, P115, P117, and P118. Based on its thick sediment sequence (at least 200 m according to MCS) this site was considered a high-priority target for ODP-APC drilling. Parasound profile penetrated 20 m into the seabed.

1GKG	length-wire (m)	500	1000	1500	2000	2500	bottom	pullout
	speed-wire (m/s)	1.5	1.5	1.5	1.5	0.5	0.0	-0.32
	tension-wire (kN)	3.17	6.35	10.50	15.87	20.26	30.52	58.8

depth upon bottom contact: 2541 m
recovery: 37 cm

MKAL (12 m)	length-wire (m)	120	500	1000	1500	2000	bottom	pullout
	speed-wire (m/s)	1.5	1.5	1.5	1.5	1.5	0.5	-0.37
	tension-wire (kN)	28.81	31.49	38.65	41.26	46.67	52.0	57.0

depth upon bottom contact: 2529 m
recovery: 76 cm + 28 cm in core catcher

GKG recovered brown sandy muds with fragments of gastrapods, echinoids and a few rock fragments in the surface layer. The same sediments were found in the MKAL. After initial decrease of tension on the wire upon contact with the sea floor, the tensiograph showed a second sharp maximum of pull force indicating that core had fallen over into the wire.

Station M24-6 (27°32.9'N, 16°30.7'W, 3527 m)

This site was chosen within a pelagic section southwest of Gran Canaria at the southern end of seismic line P120. The site was located in seismically similar facies to site M24-3, i.e. just outside the volcanic apron. Parasound penetrated about 10 m into the seabed and showed two distinct subbottom reflectors. The MCS profile indicated a sediment thickness of about 150 m (200 ms TWT).

GKG	length-wire (m)	2500	3000	3470		bottom	pullout
	speed-wire (m/s)	1.3	1.3	0.5		0.0	-0.20
	tension-wire (kN)	25.63	31.98	39.70		28.36	67.24

depth upon bottom contact: 3258 m
recovery: 40 cm

MKAL (3 m)	length-wire (m)	350	2500	3000	3480	bottom	pullout
	speed-wire (m/s)	1.3	1.3	1.3	1.0	0.0	-0.25
	tension-wire (kN)	23.93	42.24	47.36	64.27	31.49	71.40

depth upon bottom contact: 3532 m
recovery: 90 cm + 44 cm in core catcher

GKG retrieved brownish ooze with some foraminifers and open burrows at the surface. A 1 cm thick sandy layer at the base was assumed to be a quite recent turbidite. The upper layers of the MKAL were similar to those found in the GKG. The Sediment further downcore showed occasional laminae and abundant dark mottles. The Sediments in core catcher showed bent structures as though they were part of a large fold.

Station M24-7 (27°31.0'N, 15°51.5'W, 2335 m)

The Station was located within the chaotic facies of the volcanic apron south of Gran Canaria at the crossover of seismic lines P123 and P125. Parasound penetrated about 5 m into seabed and showed 3 distinct subbottom reflectors. The multichannel profile showed about 70 m sediments above basement with numerous subbottom reflectors. Based on the rather hard surface and subsurface reflectors the short 3 m-MKAL was chosen for coring.

GKG	length-wire (m)	2000	2250	2290	bottom	pullout
	speed-wire (m/s)	1.3	1.3	0.5	0.0	-0.30
	tension-wire (kN)	19.29	24.66	29.54	18.07	62.3

depth upon bottom contact: 2323 m

recovery: 37 cm

MKAL	length-wire (m)	1000	2000	2300	bottom	pullout
(3 m)	speed-wire (m/s)	1.5	1.5	0.5	0.0	-0.3
	tension-wire (kN)		45.41	48.34	21.97	65.7

depth upon bottom contact: 2374 m

recovery: 313 cm + 24 cm in core catcher

Contrary to what was expected from the hard surface reflectors the GKG contained soft brownish soupy foraminiferal ooze with pteropod fragments. MKAL penetrated through 337 cm of foraminiferal ooze containing pteropod fragments. 3 turbidites were identified centered around 35 cm, 70 cm and 180 cm; the deepest one contained shell fragments indicating shallow-water sources.

Station M24-8 (28°02.4'N, 14°58.97'W, 1496 m)

This site is located in a shallow sedimentary basin between Gran Canaria and Fuerteventura. Parasound and MCS showed excellent penetration into the sediments and about 200 m of sediment thickness. This was considered to indicate pelagic sediments easy to core.

GKG	length-wire (m)	2000	2250	2290	bottom	pullout
	speed-wire (m/s)	1.3	1.3	0.5	0.0	-0.30
	tension-wire (kN)	19.29	24.66	29.54	18.07	62.3

depth upon bottom contact: 1496 m

recovery: 15 cm

MKAL	length-wire (m)	1000	2000	2300	bottom	pullout
(12 m)	speed-wire (m/s)	1.5	1.5	0.5	0.0	-0.3
	tension-wire (kN)		45.41	48.34	21.97	65.7

depth upon bottom contact: 1496 m
recovery: none

MKAL	length-wire (m)	1000	2000	2300	bottom	pullout
(12 m)	speed-wire (m/s)	1.5	1.5	0.5	0.0	-0.3
	tension-wire (kN)		45.41	48.34	21.97	65.7

depth upon bottom contact: 1513 m
recovery: none

GKG retrieved brownish sandy mud with lots of foraminifera and shallow water shells. Core was partly washed out and surface disturbed. Both MKAL coring attempts failed. In both cases the tensiograph showed sharp increase in tension shortly after bottom contact indicating that the core partly penetrated into the sediments and then fell over into the wire.

5.11.1 Operational Comments

5.11.1.1 Coring Equipment

When the coring equipment was prepared on deck after loading was finished it became apparent immediately that the diameter of the weight stand (50 cm) for the MegaKastenlot (MKAL) was too large to fit into the rig ("Absatzgestell"). The captain and master agreed that the MKAL would have to be deployed and retrieved by using the horizontal boom ("Schiebebalken") and the main crane. This procedure would allow deployment of the MKAL only under good weather conditions, i.e. winds of no more than 6-7 Bft. A first test deployment of the 3 m kastencore at station M24-3 showed that handling of this device is possible without major difficulties. Later on this proved to be true also for the 12 m MKAL which was handled by the master and his crew in an expeditious and professional manner with remarkable smoothness.

5.11.1.2 Preliminary Results (voice sampling)

A preliminary study of the cores retrieved during M 24 yields a surprising lack of tephra layers in the uppermost 3 m of the sedimentary record southwest of Gran Canaria. The sediments consist of biogenic detritus deposited as turbidites and pelagic muds (i.e. foraminiferal ooze) mixed with a minor (< 5 vol.%) volcaniclastic component. This component comprises a large variety of mineral fragments (e.g. alkali feldspar, amphibole,

biotite, clinopyroxene, olivine, FETi-oxide) equivalent to the common phases that occur in the mafic to evolved alkaline igneous rocks of the Canary Islands. Rather few clasts (< 1%) consist of dark brown glass shards or dark brown or colourless pumice shards.
Only a single, very thin (< 5 mm) distinct layer has been identified in a core M24-3 at a depth of 177 cm as a potential tephra layer of airfall origin. This layer consists of small (<< 2 mm), dark brown, highly vesiculated pumice shards and lacks the common detrital volcaniclastic component. Chemical analyses of several pumice clasts and few tephriphonolitic compositions. Although these compositions are similar to those of volcanic rocks erupted on Gran Canaria and Tenerife within the past 100,000 years, the results do not yet allow correlation with any particular volcanic event or a particular volcanic source on the Canary Islands.

5.11.1.3 Remarks

The MKAL coring device was thought to be especially well suited for coring in the area around Gran Canaria. It was believed that the heavy-weighted device should easily penetrate volcanic ash layers and even moderately thick turbidite sequences. Despite these forecasts coring with the MKAL was quite disappointing, none of the coring attempts with the 12 m kasten were succesful, in all cases the corer fell over. It is not obvious what ultimatley caused the failure of the long coring attempts. Four scenarios were discussed:

- The core was lowered into the seabed too fast; i.e. the cable was lowered faster than the core penetrated into the sediments so that the long kasten lost its vertical stability and fell over. However, even when the core was lowered at half the speed (0.5 instead of 1.0 m/s) coring was not successful and the tensiograph indicated only partial penetration into the sediments and subsequent fall-over.
- The weight on top of the core (2.5 t) was too high so that the core was too top heavy.
- In none of the coring sessions, either with the 3 m or with the 12 m kasten, did the core catcher doors close so that the little sediment which was in the 12 m kasten may have washed out on the way back up to the surface. There was however little evidence of sediment smearing inside the barrel.
- Hard layers were present in the sediment column below the depth of recovery of the GKG which prevented penetration leading to the corer becoming unstable and falling over. These layers could range from thick sands to large volcanic pebbles. In that case, the optimal lowering speed might even be higher than 1.0 m/s

So all in all it was felt that it is worth while to come back in a cruise entirely devoted to sediment coring. During this cruise one should have GKG, piston and gravity coring equipment available as well as the MKAL. There should be time reserved especially for the MKAL to run several test deployments in different settings so as to gain more experience and to obtain good quality long cores with this device. We wish to stress that handling of this device was carried out very professionally and smoothly by the ship's personnell and that this may be viewed as encouragement to further develop and use the MKAL technique.

6 Ship's Meteorological Station (K. Buhlmann)

From 15th until 26th April 1993 the scientific studies took place in the sea-area south and west of Gran Canaria. Later on from 27th April until 6th May the working region was situated north of Gran Canaria.

The region of the Canary Islands is mostly influenced by the northeasterly trade winds, which depend on the position and intensity of the subtropical high and the more or less marked thermal low over the northwestern Africa. During the first days until 20th April the tradewinds showed a normal intensity between Bft 4-6. On 21st a large high developed near the Azores and the wind increased to Bft 7-8, which continued for two days. In the strait between Gran Canaria and Tenerife the northeasterly gale reached Bft 9, caused by the high mountains on both islands in connection with the coastline. So the routine work ceased and METEOR set course for the leeside of Gran Canaria, where the wind became light and variable after a short time.

From 27th April until 2nd May the subtropical high disappeared slowly and the trade winds became very weak. One day later, very cold airmasses from northern latitudes began to move southwards towards the southwestern part of the Northatlantic and induced a deep cyclone north of Gran Canaria on 4th May. Due to this low, the wind increased quickly to galeforce Bft 8 from westnorthwest and continued for several hours. Such a cyclonic developement in this region is very seldom.

7 Lists

7.1 Reflection Seismic Profiling

7.1.1 Coordinates of M 24 Reflection Seismic Profiles

(first and last shotpoints)

Profile No.	Beginning Longitude W	Beginning Latitude N	End Longitude W	End Latitude N	Length [km]	Course Degree
P101	15.89182	28.65480	16.06783	28.59983	18.26	250
P102	16.06583	28.59850	15.81162	28.26500	44.57	146
P103	15.76300	28.19683	16.33633	28.23317	56.43	274
P104	16.20290	28.40930	15.79933	28.09933	52.43	133
P105	15.79983	28.09933	16.20150	27.55767	71.90	213
P106	16.19550	27.57285	16.46167	27.99500	53.64	332
P107	16.45933	27.99450	15.89983	27.95000	55.27	095
P108	15.90200	27.94917	16.43367	27.78367	55.48	251
P109	16.43233	27.78433	15.71183	28.40283	98.55	046
P110	15.71717	28.39950	15.80867	28.19917	23.95	202
P111	15.81050	28.19967	16.10117	28.17200	28.71	263
P112	16.10000	28.16633	15.96550	28.04233	19.07	135
P113	15.97883	28.03567	15.89850	28.12217	12.42	041
P114	15.89833	28.11533	16.03333	28.24167	19.28	317
P115	16.03200	28.24083	16.07367	27.94017	33.57	187
P116	16.07583	27.94267	16.20117	28.10050	21.40	325
P117	16.19817	28.10017	15.93300	28.11783	26.13	086
P118	16.06750	28.08400	16.25400	28.03700	19.06	254
P119	16.26783	28.03583	16.11667	27.84000	26.31	145
P120	16.11800	27.84283	16.46817	27.58300	44.96	230
P121	15.78383	27.07533	15.57800	27.66500	68.44	090
P122	15.59250	27.58667	15.90333	27.58317	30.69	270
P122a	15.93100	27.57767	15.96617	27.53850	5.56	245
P123	15.93950	27.50050	15.62917	27.49867	30.67	090
P123a	15.61033	27.47683	15.61967	27.43250	5.00	245
P124	15.64633	27.41583	15.92600	27.41617	27.66	270
P125	15.91167	27.41883	15.86383	27.49967	10.13	027
P126	15.51333	27.71250	15.16500	26.84500	102.13	160

7.1.1 continued

Profile No.	Beginning Longitude W	Beginning Latitude N	End Longitude W	End Latitude N	Length [km]	course degree
P127	15.16650	26.81867	15.31667	27.96667	128.08	353
P128	15.32317	27.95350	15.40133	27.76467	22.30	200
P129	15.36233	27.82067	15.25000	27.82300	11.07	090
P130	15.25250	27.82383	14.54133	28.39317	94.15	048
P131	14.54400	28.38917	14.66733	27.76617	70.10	190
P132	14.66800	27.76767	15.03000	28.05517	47.80	312
P133	15.01267	28.03733	15.40850	28.21850	43.77	298
P134	15.38483	28.22117	15.07300	28.76500	67.57	028
P135	15.09233	28.76183	14.78133	28.28550	60.94	150
P135a	14.73450	28.32917	14.69483	28.15300	19.91	150
P136	14.69367	28.17267	15.32483	28.59583	77.63	307
P201	15.19950	28.18017	15.74483	28.50750	64.62	315
P202	15.74550	28.46467	14.90150	29.02067	102.93	053
P203	14.91917	29.02617	15.10117	28.72033	38.27	208
P204	15.06567	28.27200	15.19467	28.29133	25.43	330
P205	15.14067	28.90333	15.87800	28.65933	76.91	249
P206	15.87750	28.64083	15.71733	28.48333	23.46	138
P207	15.71533	28.47767	15.62833	28.26767	24.79	168
P208	15.705	28.23950	15.85600	28.29667	16.10	294
P100	15.55845	28.73233	15.55900	28.19100	60.00	180
P200	15.36217	28.25400	15.09500	28.74717	60.59	025
P300	15.09400	28.28783	15.33333	28.04983	35.33	221
P3a	15.33283	27.99633	15.30683	27.86417	14.87	180
P3b	15.30695	27.86417	15.23600	27.84517	7.30	109
P7a	15.23817	27.84950	15.27133	27.93150	9.66	339
P7b	15.27133	27.93150	15.32667	28.05350	14.57	330
P210	15.62050	28.47450	15.30133	28.33450	34.91	117
P301	1.55883	28.19983	15.55817	28.77500	63.75	360

7.1.2 M 24 Reflection Seismic Profile Lengths

Profile	km	Profile	km	Profile	km
101	18	121	23	134	70
102	53	121A	4	135	50
103	56	122	28	135A	9
104	55	122A	6	136	79
105	73	123	32	201	50
106	59	123A	5	202	103
107	57	124	30	203	38
108	53	125	10	204	26
109	103	126	101	205	79
110	23	127	129	206	24
111	29	128	18	207	24
112	18	129	11	208	16
113	11	130	93	210	37
114	20	131	73	301	62
115	32	132	50		
116	20	133	43		
117	25				
118	21				
119	29				
120	39				

Total profile length: 2117 km

7.1.3 Wind Conditions during M 24 Reflection Profiling

Profile	Wind [m/s]	Wind dir. from	Profile dir.tow.	Profile	Wind [m/s]	Wind dir from	Profile dir. tow.
106	10-17	NE	NW	128	12-13	N	SSW
107	13-18	NE	ESE	129	14-16	N	ESE
108	9-11	N/NNE	SW	130	9-13	N	ENE
109	6-15	NE/N	NE	131	8-11	NNW	SSW
110	5-11	NE	S	132	9-10	NNE/N	NW
111	3-7	N/NNE	WSW	133	7-11	N	NW
112	8-10	NNE	SE	134	5-9	N/NW	NE
113	9-11	NNE	NE	135	5-6	NW	SSE
114	9-10	NE	NW	135A	9-11	NNW	SE
115	9-14	NNE	S	136	8-11	NW/NE	NW
116	11-14	NE	NW	201	6-11	NE	NW
117	8-12	N/NNE	E	202	3-8	NNE/NNW	NE
118	6-11	NE	SW	203	3-6	N	SW
119	11-13	NNE/ENE	SE	204	3-5	NNE	NW
120	14-19	NNE	SW	205	3-6	NNE/NNW	SW
121	3-14	SSW-E	E	206	4-6	NW	SE
121A	18	NE	S	207	5	NNW	SSE
122	7-18	SW-NE	W	208	3-7	N/NE	NW
122A	7-9	SW/WSW	SW	210	6-9	NW/NNW	ESE
123	3-15	SW-NE	E	301	3-6	N	N
123A	17	NNE/NE	S				
124	1-7	WNW-N	W				
125	8-13	NW/NNW	NE				
126	3-14	NNE	N				
127	11-17	NE/NNE	SE				

7.1.4 List of Record Length, Start Delay and Shot Rate for M 24 Reflection Seismic Profiles

Line	SP Interval	Shot Rate [s]	Start Delay [s]	Record Length [ms]
P104	1-2171	7.5	100	3500
	2172-3293	7.5	1500	2900
P105	1-2379	5.0	100	2900
	2389-2848	7.5	1500	4000
	2849-4230	10.0	3000	3500
P106	1-1563	10.0	3500	3000
	1564-2657	7.5	2300	2700
P107	1-2291	7.5	2400	2600
	2294-3287	7.5	800	2200
	2494-3287	5.0	100	2900
P108	1-1027	5.0	3000	3000
	1028-2085	7.5	2000	3500
	2086-2896	10.0	3000	3000
P109	1-1560	10.0	3000	2200
	1561-2596	7.5	2200	2800
	2597-4186	7.5	2800	2500
	4187-4771	10.0	4200	2000
P110	1-532	10.0	3800	2000
	533-950	7.5	1500	3500
	951-1074	5.0	1000	2000
P111	1-785	5.0	0	3000
	786-1831	7.5	1900	3100
P112	1-938	7.5	2500	2500
P113	1-518	7.5	1500	2500
	519-610	5.0	0	3000
P115	1-1681	7.5	2000	3000
P116	1-1089	7.5	2000	3000
P117	1-1348	7.5	2500	2500
P118	1-1139	7.5	2500	2000
P119	1-1466	7.5	2500	2500
P120	1-172	7.5	3100	2100
	173-1609	10.0	4000	2000
P121	1-1833	5.0	400	2100
P121A	1-296	5.0	2100	2000

7.1.4 continued

Line	SP Interval	Shot Rate [s]	Start Delay [s]	Record Length [ms]
P122	1-705	7.5	1500	2500
	706-894	5.0	1300	1700
	895-1665	7.5	1700	2300
P122A	1-294	7.5	3200	1800
P123	1-1709	7.5	2600	2000
P123A	1-265	7.5	2900	1600
P124	1-1591	7.5	3200	2000
P125	1-496	7.5	3000	2000
P127	1-2635	7.5	3700	1800
	2636-4743	7.5	2700	2300
	4744-5522	7.5	1500	3000
	5523-7535	5.0	0	3000
P128	1-1452	5.0	0	2000
P129	1-908	5.0	0	2000
P131	1-955	7.5	1500	2500
	956-2819	5.0	0	2500
	2820-4439	5.0	0	2500
	4440-5032	7.5	1900	2100
P132	1-933	7.5	1500	3500
	934-2311	5.0	5000	2500
	2312-3154	7.5	1700	2500
P133	1-2070	7.5	1500	2500
	2071-2394	5.0	900	2100
P134	1-174	5.0	0	3000
	175-211	7.5	0	3000
	212-307	5.0	0	3000
	308-739	7.5	1500	4000
	740-1549	10.0	4000	2000
	1550-3043	10.0	4500	2500
P135	1-1007	10.0	4500	2500
	1008-1812	10.0	3500	2500
	1813-2168	7.5	1500	3500
	2169-2632	5.0	0	3000
P136	1-1848	5.0	0	2500
	1849-2376	7.5	1800	3500
	2377-3294	10.0	3800	2200
	3295-4234	10.0	4500	2500

7.1.4 continued

Line	SP Interval	Shot Rate [s]	Start Delay [s]	Record Length [ms]
P201	1-752 753-1966 1967-2683	5.0 7.5 10.0	400 1800 4300	2600 3500 2000
P202	1-4124	10.0	4600	2900
P203	1-1542	10.0	4500	2500
P204	1-1038	10.0	4500	2500
P205	1-3174	10.0	4500	2000
P206	1-960	10.0	4500	2000
P207	1-768 769-1016	10.0 7.5	3500 2800	2500 2000
P208	1-526 527-784	7.5 10.0	1500 3900	3500 2000
P210	1-1495	10.0	3800	2500
P301	1-1050 1051-2724	7.5 10.0	1500 4300	4000 2200

7.2 Refraction Seismic (OBS) Operation

7.2.1 Operation Times and Firing Rates of Large Airguns during Deep Seismic (OBS) Profiling

Profile	Date	Time (UTC)	GEOMAR airgun	AWI airgun	Firing rate
P 4W	05/01/93	00:44-02:18	X	X	2 min
		02:18-05:33		X	2 min
P 1	05/01/93	08:39-12:45		X	1 min
		12:45-18:35	X	X	1 min
P 1W	05/01/93	18:55-20:45	X		1 min
P 1A	05/01/93	20:50-23:12	X		1 min
P 1B	05/01/93	23:17-01:50	X		1 min
P 1C	05/02/93	02:00-06:29	X		1 min
P 6W	05/02/93	08:30-10:00		X	1 min
		10:00-10:50	X	X	1 min
P 2	05/02/93	11:00-01:12	X	X	2 min
P 4E	05/03/93	01:18-04:24	X	X	2 min
P 3	05/03/93	05:21-12:55	X	X	2 min
P 3A	05/03/93	12:58-15:00	X		1 min
P 3B	05/03/93	15:12-17:00	X		1 min
P 7A	05/03/93	17:12-22:24			1 min
P 7B	05/03/93	22:30-01:08	X		1 min
	05/04/93	03:23-05:15		X	1 min

Thereafter stop of profiling due to bad weather conditions.

7.2.2 Locations and Times of the OBS Operation

OBS	Latitude (N)	Longitude (W)	Depth [m]	Deployment	Recovery	Drift [ms]
1	28°43'00.30"	15°33'21.54"	3588	04/30/93 19:45	05/05/93 03:45	-17
2	28°11'57.90"	15°22'29.22"	3517	17:45	06:15	-36
3	28°10'58.14"	15°33'31.80"	986	15:30	09:00	3
4	28°11'57.90"	15°23'44.40"	180	14:30	not recovered	
5	28°20'38.58"	15°18'50.84"	3150	13:00	05/04/93 21:10	-51
6	28°31'3.112"	15°13'12.30"	3541	23:00	23:30	*
7	28°15'31.74	15°8'31.15"	2905	11:50	15:30	-16
8	28°2'35.88"	15°19'57.48"	519	09:00	10:00	**

* unable to be checked   ** not checked

7.3 Heat Flow Measurements

7.3.1 Protocol of Heat Flow Measurements at M24-7

Station Nr.	M24--7-MKC	**Start:**	14:00 UTC	
Date:	22.4.1993	**End:**	17:33 UTC	
Range:	0° - 5°C	**Sample time :**	16:33 UTC	10 min
water depth:	3576 m	**Tape Nr.:**	M24-7	
		Recorder Nr	708	

Latitude	27° 33.344N	**Longitude**	16° 11.791W

Length of boxcorer (MKC):	300 cm	**Distance of probes**	
		bottom - sensor 1	70,5 cm
		sensor 1 - sensor 2	52,0 cm
		sensor 2 - sensor 3	48,0 cm
		sensor 3 - sensor 4	104,0 cm
		sensor 4 - sensor 5	-

Pressure reading	**478**
Penetration	300 cm

Gradient measurement	before Penetration	before pulling out	Δ N
Sensor 1		891	
Sensor 2		767	
Sensor 3		511	
Sensor 4		491	
Sensor 5		-	
BWT	455		

Comment: HFU= 1.8; 78 mW/m^2; preliminary result !

7.3.2. Conductivity Measurements at M24-7

depth (cm)	R_0	R_{20}	R_{40}	R_{50}	R_{100}	
50		2,64	2,62	2,62	2,6	
100	2,63	2,55	2,52	2,51	2,47	
150	2,66	2,56	2,54	2,53	2,47	Turbidite
200	2,64	2,55	2,51	2,5	2,47	
250	2,72	2,63	2,59	2,58	2,54	
300	2,72	2,62	2,59	2,58	2,55	

Heating voltage:	250 mA	Start:	2 V
		Mean:	2 V
		End:	2 V

8 Concluding Remarks

METEOR cruise M 24 was very international with participants from 8 countries and 9 institutions (Kiel, Hamburg, Århus, Wormley, Oxford, Barcelona, Madrid). It was also very interdisciplinary, emphasis being on geophysics, especially seismic reflection (array of 4 sleeve guns of 40 inch^3 each, 24-channel 150 m long streamer, total length of 2120 km acquired along 50 profiles) and refraction methods (seismic energy generated by firing two 32 l airguns at 1 or 2-mins intervals recorded by 8 OBS and 8 land stations distributed in an 110 x 70 km offshore - onshore array), but also gravity, magnetics and heat flow, bathymetry, paleoceanology, sedimentology, volcanology, and geochemistry.

Quantity and quality of the geophysical, especially the reflection seismic data acquired during the cruise exceeded our expectations. Our understanding of the structure and evolution of oceanic intra-plate volcanic systems and their peripheral sedimentary basins will be greatly advanced. Gran Canaria and its surrounding sedimentary basins can be regarded as a prototype oceanic intraplate island.

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The success of our work very much depended on the close cooperation with Captain Kull and his crew especially in view of our frequent change in the program, demanding a high degree of flexibility. Working under such professional conditions was a very good experience indeed.

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