NATIONAL RESEARCH COUNCIL OF ITALY
INSTITUTE OF MARINE SCIENCES
MARINE GEOLOGY SECTION (BOLOGNA)

ITALIAN NATIONAL ANTARCTIC PROJECT

JOINT RESEARCH PROJECT "BOUVET TRIPLE JUNCTION" CNR-GIN

GEOPHYSICAL AND GEOLOGICAL STUDIES IN THE BOUVET TRIPLE JUNCTION

REPORT ON THE MORPHOBATHYMETRIC, GEOPHYSICAL, GEOLOGICAL INVESTIGATIONS DURING CRUISE BVT94 (S18) ABOARD R/V A.N.STRAKHOV

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ISMAR Bologna TECHNICAL REPORT N. xx

Bologna, 1994

ISMAR-CNR Cataloging-In-Publication data: ISMAR Bologna TECHNICAL REPORT N. xx

Geophysical and Geological Studies in the Bouvet Triple Junction. Report on the morphobathymetric, geophysical, coring and dredging investigations during cruise BVT94 (S18) aboard *R/V A.N.Strakhov*.

by Zitellini N., Peyve. A, Ligi M., Gasperini L., Bortoluzzi G., Fabretti P., Lodolo E., Sciuto P.F., Turko N., Masarovich A., Sokolov S., Efimov V., Erofeev S., Yevgrafov L., Persev A., Kobolov V., Perfilev A., Rasnitzin Y., Rastorguyev V., Bulichev A., Gilod D., Gladun V., Averianov S. Simonov V.

Includes bibliographical reference and index.
1. tectonics 2. stratigraphy 3. paleoseismology 4. oceanography

Abstract - A summary of methodologies, technical details and ship-board results of the BVT94 (S18) cruise with *R/V A.N.Strakhov* in the Southern Atlantic Ocean is presented. The cruise studied the area of the Bouvet Triple Junction, by multibeam, magnetometric, gravimetric, reflection seismic and bottom dredging.

Sommario - Vengono presentati le metodologie e l'insieme dei risultati ottenuti durante la campagna BVT94 (S18) con la nave *R/V A.N.Strakhov* nell'Atlantico Meridionale. Durante la campagna di studio della giunzione tripla di Bouvet, sono stati fatti rilievi batimetrici, magnetometrici, gravimetrici, sismici a riflessione e di campionatura dei fondali.

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Hereafter a link to verbatim copy of this document (LATEX).

Production Notes - The document was edited with standard text editors, typeset with L.Lamport's LaTeX, translated to `PostScript` with `dvips` and printed with an A4 laser printer. The full production was done on a Linux box with `GNU-GPL` software. Converted to HTML by N.Drakos's LaTeX2HTML and to `PDF` by Alladin Ghostscripts's `ps2pdf`. Most of the maps included were produced by Wessel and Smith's `GMT` package. Some drawings were produced by `xfig` (www.xfig.org). Non `PostScript` images were converted by John Bradley's `xv` or other public-domain packages, among them `convert`.

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ACRONYM	DESCRIPTION	URL-email
CNR	Consiglio Nazionale Delle Ricerche	www.cnr.it
ISMAR	Istituto di Scienze Marine	www.bo.ismar.cnr.it
OGS	Oss. Geofisico Sperimentale, Trieste	www.ogs.it
GIN	Geological Inst. - Academy of Sc., Moscow	
UNIMOS	State University of Moscow	
SEG	Soc. of Exploration Geophysicists	www.seg.org
DTM	Digital Terrain Model	en.wikipedia.org
GEBCO	General Bathym.Chart Oceans	www.ngdc.noaa.gov/mgg/gebco
MBES	MULTIBEAM ECHOSOUNDER SYSTEM	
SBP	Sub Bottom Profiling	
MCS	Multichannel Seismic	
UTM	Universal Transverse Mercator	
UTC	Universal Time Coordinated	
WGS84	World Geodetic System 1984	
NMEA	National Marine Electronics Association	www.nmea.org
GMT	Generic Mapping Tool	gmt.soest.hawaii.edu/gmt
GNU,GPL	GNU is not Unix,General Pub. License	www.gnu.org

Table 1. Acronyms of Organizations, Manufacturers and Products

ACRONYMS

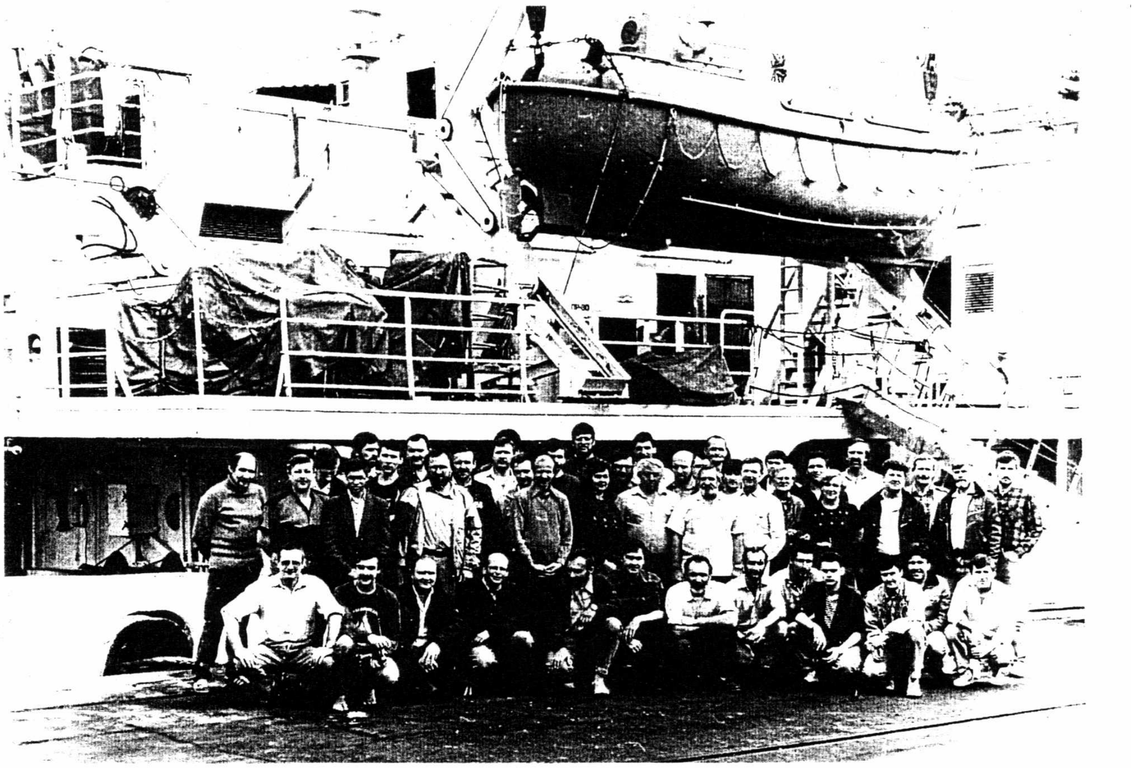

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Figure 1. At Capetown, end cruise.

HOW TO READ THIS REPORT

Section 1 gives the introductory and background information, including some technological and scientific issues of the organization and execution of tasks, whereas section 2 summarizes the cruise operations. Section 3 provides the technical aspects that were involved in the data acquisition and processing. Sections 4 and 5 discuss the initial results, the on-going data processing and usage, and give concluding remarks. See in the Technical Annexes information regarding Data Acquisition and Processing, Dredge Catalogs, and daily reports, including tables of iceberg detection and meteo information.

Some data processing procedures that were used in the production of this report along with additional technical details and data are presented in the Appendix.

ACKNOWLEDGMENTS

The project was funded by Italian National Antarctic Project. This work was done under heavy or very heavy weather conditions Ship's and scientific party's collaborative availability and instrument reliability were the key factors for the success of the expedition. We (the Italian Team) are particularly indebted to Captain Leonid Sazonov and bridge officers and crew of *R/V A.N.Strakhov* for the extra work required (See Fig.1). ENEA personnel is also thanked for their dedication on the organization of the cruise. Prof. Le Roex andDr. Rogers of University of Capetown gave also a valuable support during our stay in Capetown

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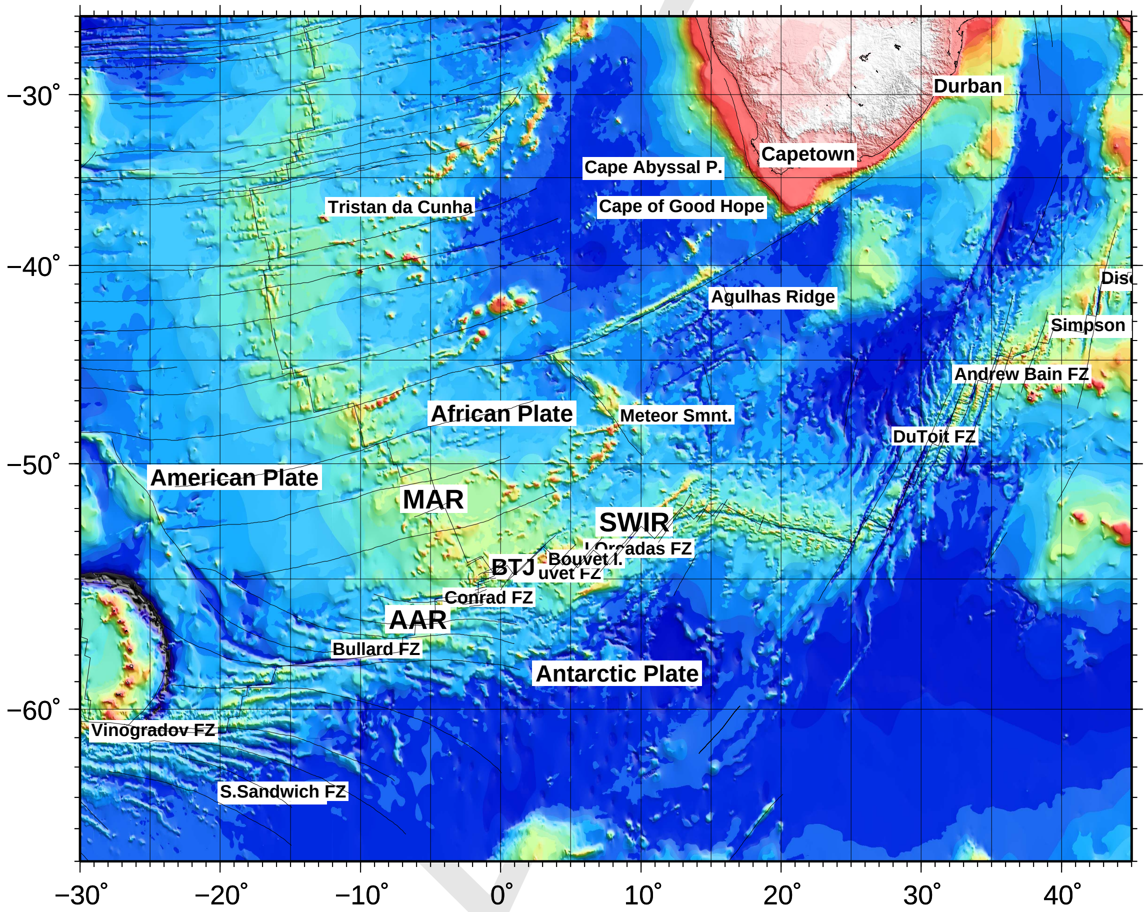

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Figure 2. Geographical setting of the study area. Topographic and bathymetric data by ?).

1 INTRODUCTION

In the South Atlantic (Fig.2) the Antarctica, South America and Africa meet at the Bouvet Triple Junction (BTJ, Fig.3) (54 50'S,00 40'W). Around 250nm eastward of the Bouvet Triple Junction the Bouvet Island arose a few millions years ago from sea bottom. This Island seats in the vicinity of a present day segment of a spreading axis and is thought that its emplacement is related to the presence of a feeding hot spot.

The general picture of the BTJ and surrounding areas were firts depicted in early-mid seventies by geophysical surveys Sclater et al. (1976) and by sampling of the sea bottom Le Roex & Dick (1981), Le Roex et al. (1983) and more recently by satellite-derived gravity anomaly mapping ?) (Haxby, personal communication). Nevertheless detailed morphologic maps as well as along-axis and across-axis transects of sampling were lacking to understand finer scale tectonic and compositional evolution of the area.

The main goal of this project is to delineate the structural composition and morphological differences between the "cold" ridge segment of the South America / Africa plates at the North branch of the Bouvet Triple Junction (BTJ) and the "hot" ridge segment eastward of the Bouvet Island. Additionally, the data of the ridge segment of SA/AF plates at BTJ will provide useful information on the evolution of the junction on the last 2Ma.

To accomplish this result we carried out multibeam, gravity, magnetic, multi- and single-channel seiemic reflection investigations, as well as sampling of the sea bottom in two selected areas (Fig.2): eastwrd of the Bouvet Island and nortward of the Bouvet Triple Junction. Thereafter in the text, the first area will be referred as Bouvet Area and the second as the Triple Point Area.

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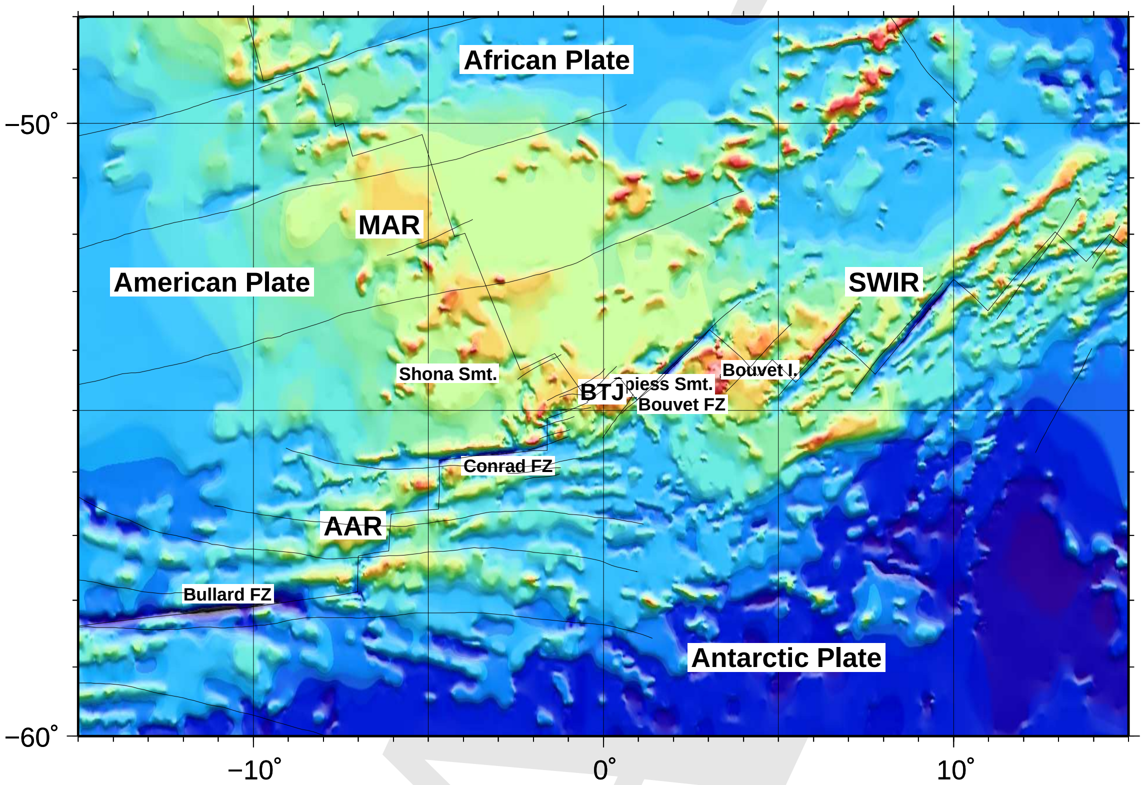

[H]

Figure 3. Geographical setting of the study area. Topographic and bathymetric data by **?**).

Hereafter, a description of the ship, equipment and their usage is given, along with details of the general settings, performances and some scientific and technical results.

2 CRUISE SUMMARY

SHIP: *R/V Gelendzhik*
START: 1994- PORT: Capetown
END: 1994- PORT: Capetown
SEA/OCEAN: Atlantic Ocean
LIMITS: NORTH -50:00.0 SOUTH -58.00 WEST: 25:30.0 EAST: 30:00
OBJECTIVE: GEOLOGICAL AND GEOPHYSICAL SETTING OF BOUVET TRIPL JUNCTION
COORDINATING BODIES: ISMAR-IGM CNR BOLOGNA (ITALY) PNRA (ITALY) GIN (MOSCOW)
CHIEF OF EXPEDITION: Nevio Zitellini (ISMAR-CNR) Alexander Peyve (GIN)
CONTACT: Nevio.Zitellini@ismar.cnr.it
DISCIPLINES: SWATH BATHYMETRY, MAGNETICS, GRAVIMETRY SEABED SAMPLING
WORK DONE: 5600 KM MULTIBEAM, MAGNETICS, GRAVITY, 67 DREDGES,

LOCALIZATION:

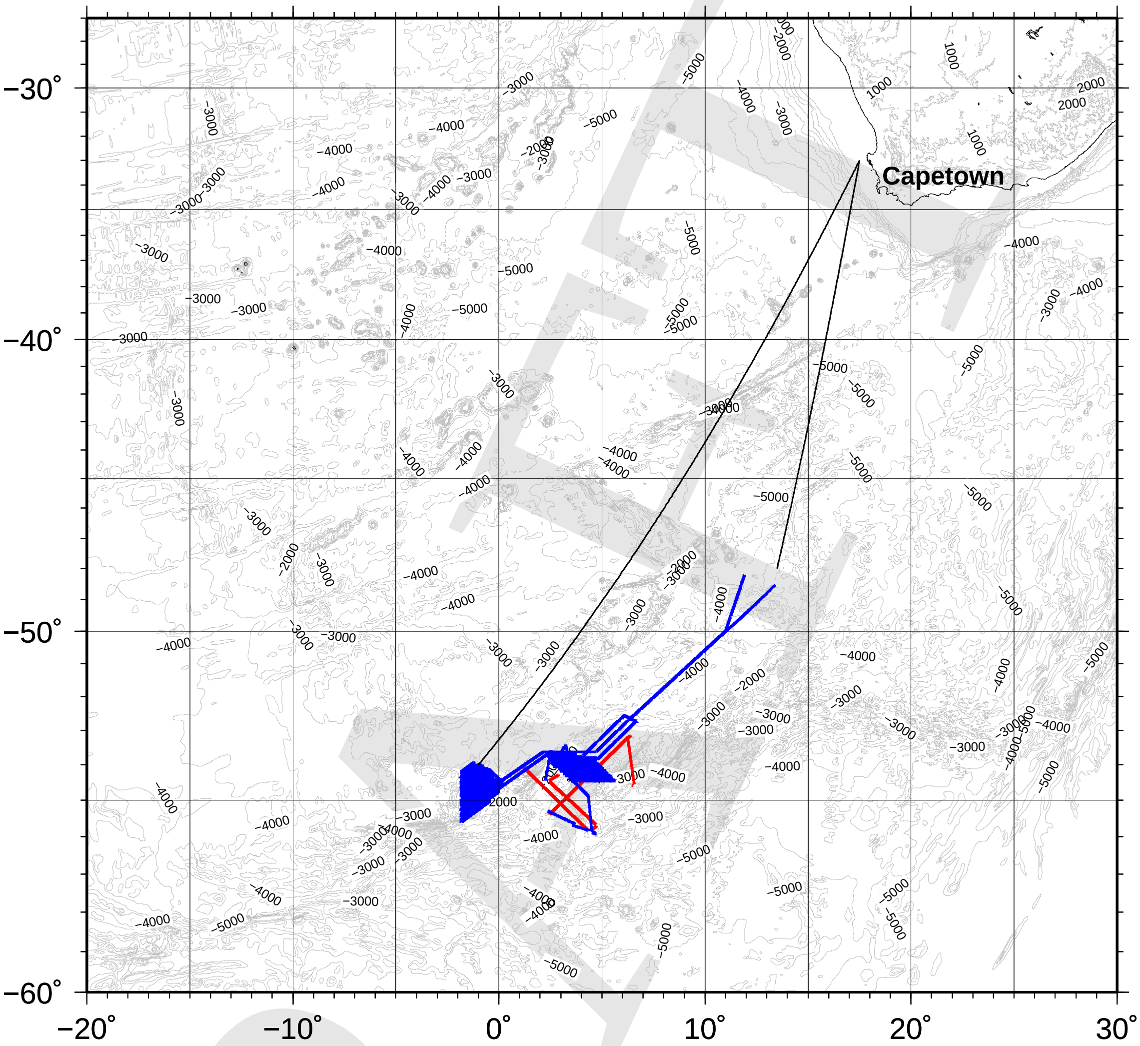

Figure 4: General ship track during Cruise BVT94, including transits.

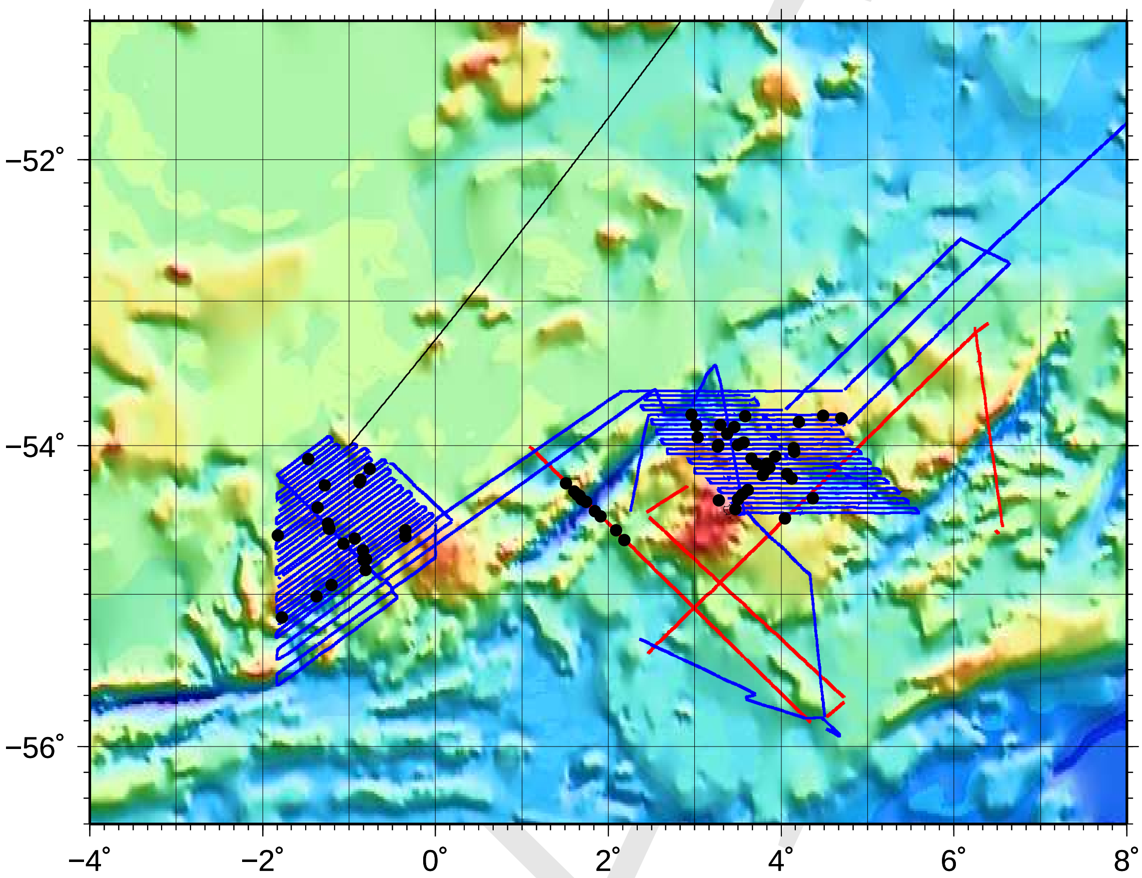

Figure 5: Ship tracks during Cruise BVT94. The black dots are sampling stations, red lines are multibeam and multi-channel seismic, blue lines are multibeam and single-channel seismic.

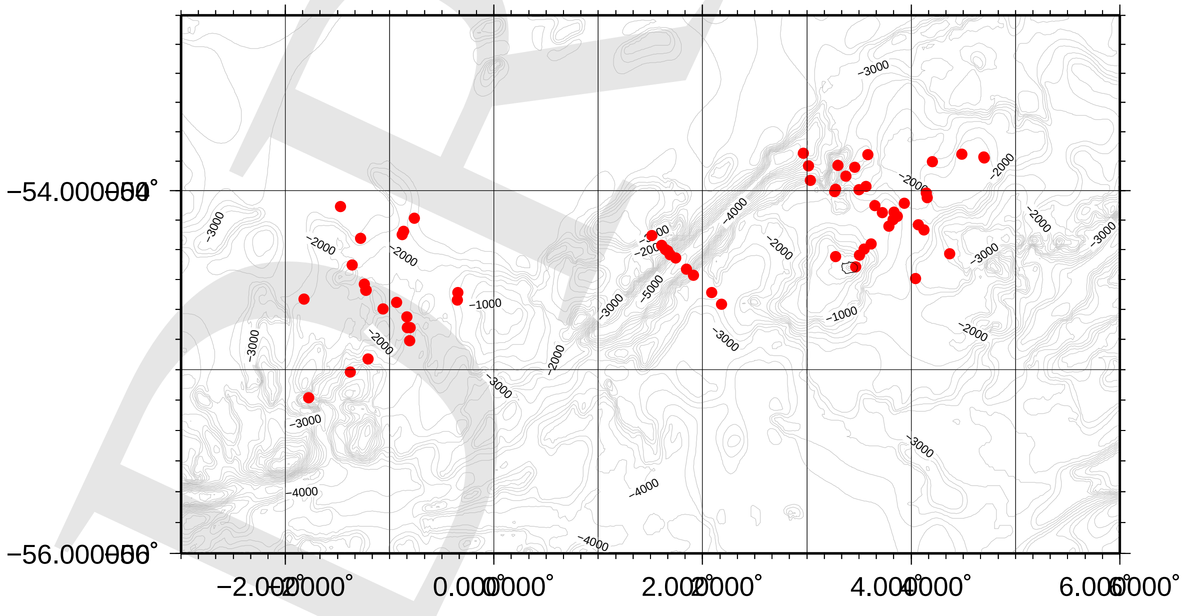

Figure 6: Bottom sampling stations.

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Sergey Erofeev	Geophysicist	GIN	
Dolore Gilod	Geophysicist	UNIMOS	
Victor Gladun	Geophysicist	UNIMOS	
Sergey Sokolov	Geophysicist	GIN	
Leonid Yevgrafov	Geophysicist	GIN	
Alexey Persev	Petrologist	GIN	
Vladimir Simonov	Petrologist	UIGGM	
Nataliya Turko	Geomorphologist	GIN	
Vasiliy Kobolov	Geologist	GIN	
Alexander Masarovich	Geologist	GIN	
Andrey Perfilev	Geologist	GIN	
Yuriy Rasnitzin	Geologist	GIN	
Vladimir Rastorguyev	Technician	GIN	

Table 2. Scientific and technical parties

SCIENTIFIC AND TECHNICAL PARTIES

SUMMARY OF OPERATIONS AND GENERAL REMARKS

Operations at sea during the cruise can be summarised as: (1) loading of fuel, supplies, victuals, and of equipment for the Italian team, (2) general ship's conduction and maintenance, (3) execution of planned field work. Point (1) was care of ENEA, under the Russian-ltalian Collaboration Agreement in the framework of the Italian Project for Antarctic Research (PNRA). Point (2) was care of officers, crew and technical staff of ship. Point (3) was care of the scientific teams.

In particular:

(i) ENEA organised all the port and chandelling operations directly or trough their correspondent agencies. This operations included ordering spares and consumable for ship. In addition, part of the new scientific equipment used in the cruise were delivered during the stay in Lisbon. This work was done with skilfulness and efficiency.
(ii) Ship conduction was excellent for navigation and sea attitude even in high seas. General maintenance was performed without limitations to scientific plans. Multibeam, navigation, data logging and distribution, winches and A-frame worked constantly within their standard performances.
(iii) IGM-CNR had the responsibility for Multichannel Seismic and magnetometry acquisition, geophysical data processing and automated mapping;
(iv) GIN of Moscow had the responsibility for Multibeam echo sounding and Single Channel Seismic acquisition and processing;
(v) GIN of Moscow and Novosibirsk had the responsibility for bottom sampling trough dredging and description of samples;
(vi) Dept. of Geophysics of Geology Faculty of Moscow State University had the responsibility for gravimetric data acquisition and processing.

The co-ordination was excellent, the work was performed efficiently also during heavy weather conditions and no major problem was evidenced. 100% of the proposed scientific objectives were reached mainly for the reasons above, and in part for the non-prohibitive weather conditions. For the sake of completeness, we would suggest some reorganisation of the scientific spaces available on board, especially at stern,

Figure 7: *R/V A.N.Strakhov*.

in order to give a better comfort for working people. This will be done on a separate document. During the transit Copenhagen-Lisbon the GIN team prepared the single channel equipment. During the transit Lisbon-Cape Town the Italian team tested the new geophysical equipment loaded in Lisbon., which allowed us to solve well in advance some technical problems encountered during testing (see later for more specific information). Weather Report From 12-march-1994 till the return to Capetown 1-may-1994, the automatic on-board weather station was running with sampling frequency every 1.5 minutes. Parameter acquired were: (1) air pressure, temperature, humidity, and (2) wind speed and direction, other than GMT time and positioning. These time series were plotted with the GMT package and are presented in the accompanying figures at the end of this report. Water salinity and temperature data were not recorded. However, data from magnetometer sensors towed astern at depth between 0 to 4 mt reported a water temperature ranging from 3 to 5 degrees in the two working areas.

3 MATERIALS AND METHODS

The research cruise was carried out with the 76m *R/V A.N.Strakhov*, owned and operated by *R/V A.N.Strakhov*http://http://ship.g (Fig.7)GIN and leased to PNRA for this expedition.

The boat is normally used for geological, geophysical and oceanographical work in the whole Ocean, including Arctic and Anantarctic (Ice CLASS).

Ship is equipped with GPS positioning system single-beam and multibeam bathymetry and integrated geophysical and oceanographical data acquisition systems, includingand other Sonar Equipment, other than water and seabed sampling. Additional equipment can be accommodated on the keel or towed.

The instrumental offsets are presented in Tab. 3

[H]

POSITION	ALONG	ACROSS	HEIGHT
REFERENCE	0.00	0.00	0.00
GPS	0.0	0.0	20.0
MBEAM	-3.08	0.70	-5.0
GYRO	-3.0	0.0	2.0
GRAV	-3.0	0.0	2.0
STERN	0.0	-43.0	
MAG	-5.0	-43.0	0.0
STERN-RIGHT	8.0	-43.0	0.0

Table 3.

Instrumental Offsets]Instrumental Offsets on *R/V A.N.Strakhov*. The GPS antenna (primary positioning system) is located on point GPS.

[H]

DATE	SITE	REFERENCE	SHIP
1994	Capetown	979348.66 +/- 0.02	979352.32
1994	Capetown		

Table 4. Gravimeter calibration.

3.1 MAGNETOMETRY

The GEM Mod. GSM-19D was used. The towfish was kept 200 m off the stern. The data was collected by the NAVMAP workstation along the multibeam lines, including some diagonal lines, as dictated by multibeam coverage.

The following data processing steps were applied:

- extraction of the navigation and total field ASCII data from the NAVMAP data files
- polar transport (240 m distance, angle (hdg-180)) to get the towfish position
- application of the IGRF to every point
- production of grids in geographical/metric coordinates for QC and analysis (step 0.75 nm/0.5 nm and 100 m)

3.2 GRAVIMETRY

At least two of a set of 4 quartz thermally stabilized MOD. GMN-K gravimeters assembled in Russia by Vniigeofisika were running during multibeam lines and medium range transits. The sensors were mounted on gyroscopic platforms very close to ship's center of gravity. Their height above sea level was measured to be 0.7 m. The instruments had a resolution of 0.04 mGal, and were equipped with a circuitry to reduce noise due to high waves. In the ports of Capetown (see Tab.4) the instruments were calibrated on known reference points with a portable gravimeter Lacoste and Romberg Mod.G-327.

3.3 SEABED SAMPLING

3.1 ROCK SAMPLING

The sea bottom samples were collected with dredges served by a 14mm diameter cable.

The sample locations are shown in Figg.6 and locations arepresented in Tab.**??**.

After dredge recovery, samples underwent several analytical steps, among them:

a description and measure(dimensions, raw composition and shape),
b basalt glass recovery,
c cutting,
d microscope description (phenocrystal composition, groundmass, texture analysis),
e sub-sampling and
f thin sections on selected subsamples.

3.4 Description Of Scientific Equipment

NAVIGATION AND DATA LOGGING

Ship's integrated navigation system was primary source for multibeam data. This because of the interface to gyrocompass, which is an essential piece of information, along with GMT time, latitude and longitude, for any further processing. Data were routed to main logging computer and to various laboratories trough a high speed network. For the sake of achieving data continuity and reliability, an additional GPS receiver (Mod. 1012R by Del Norte Int., Euless, USA) was located on the command bridge. This additional receiver was ready to be installed in place of ship's Trimble Navgraphic 4 channel receiver in case of faults. In addition, being it considered to be of intrinsic better quality, was used to check and integrate ship's system for multibeam data reduction. In the geophysical stern laboratory a PC-based logging system was installed. Program Navmap of IGM was re configured to accept data from new Del Norte 1012R GPS and from new

GEM magnetometer. From previous cruises, interface to ship's navigation data was already available. By so far latitude and longitude from two independent navigation sensors, GMT time (by continuously updating PC clock from GPS time), heading, speed, G-811 and GEM GSM-19 magnetic data were continuously recorded at a rate ranging from 5 to 20 seconds. Navigation files were constantly downloaded to IGM Computing Centre for data-bankin g and processing.

Other than data logging, the Navmap software was used to control the shot time during multichannel acquisition. This was achieved by constantly controlling ship's velocity from various sources and calculating the best figure for ship's speed, and by updating the shot time to the GI-GUN Synchroniser. The system had no problem during the survey, except for some software problems in the internal PC of the 1012R. This was solve by direct interfacing to it and changing the C-MOS parameters.

Multichannel Seismic

The streamer was a 24 channel, 25 mt group interval mod. 29500 (Teledyne Corporation, Houston, USA) towed at 12 meters depth. Each section was connected by plastic boots and program connector jumpers. Each active section was 100 mt long, plus 2 stretch sections 50 mt long. The tow-leader was 150 mt long. The system travelled with sections on wooden reels. In Lisbon they were rolled on Strakhov's winch. Three active sections and one tow-leader were available as spare. For use in cold water special PVC boots were used. The streamer had an average weight of lead cuts of 2-3 kg per section and his depth was controlled by 4 mod. RCL-4 cable levellers by SYNTRON, Houston, USA. Depth visualisation took place by Depth Monitor by Teledyne, Houston, USA.

The seismograph employed was the 48 channel mod. Strataview by Geometrics, Sunnyvale, USA. In addition to the seismograph, a QC and tape driving system by Lookout Geophysical of Denver, USA was used. Data were written in SEG-D format on high performance 3480 Fujitsu drives. An additional 24 channel seismograph mod. ES-2420 by Geometrics with two 1/2" tape drives was available as spare.

Seismic source was a two GI-GUN (Sodera/Seismic System of Houston, USA) array 3 mt long towed astern at a depth of 6 mt. The guns were set in Harmonic mode, 210 c.i. each, with medium-size port outlet. Air pressure ranged between 140 and 160 BARS. The array was driven by the 'GI-GUN Synchroniser? developed at IGM. This device performs a fully automatic delivery of delays to GI-GUNS so that optimum tuning of array is achieved. A third. GI-GUN was available as spare or for high speed towing. A high pressure pump by Sigma, USA was used to inject de-icant liquid in the compressed air. We used ship?s compressor that delivered 3000 NM3/hour without problems.

The system performed rather well, also in very heavy seas, except for:

1 a few noisy channels in the streamer (will be solved at Bologna)
2 some software interrupts in the QC PC (will be hopefully solved by Lookout, Denver). This caused the interruption and immediate restart of data acquisition
3 a broken hydrophone in one GI-GUN (changed)
4 a severe damage to the streamer's tow-leader during a storm (changed)
5 some software interrupts in the Strataview that hung-up acquisition (will be hopefully solved by Geometrics);this caused problems in Time-Break synchronisation

Magnetometry

The GSM-19MD by GEM, Ontario, Canada gradiometer was available. During test cruise before reaching Capetown. several problems were found in the thin kevlar cable connecting two fishes and in the junctions. This was thought to be caused by abrasions in the outer jacket during deployment on pulleys or on ship's deck. By so far, IGM decided to bring additional higher diameter kevlar cable in Capetown. During the transit to Bouvet, however, an accident occurred to the first fish. Probably a shock or a leaky connector provoked water intrusion in the sensor and the main PCB become inoperative. The decision was then taken to use the spare mod. G-8ll by Geometrics, in order to attain a gradiometer configuration. Distance between the fishes was 120 mt, the far sensor GEM being 320 mt astern. The GEM magnetometer performed very well and reliably, even in very high seas. Only a non significant percentage of acquisitions over a total of more than 100,000 presented some short spikes, which were corrected. These spikes were generally l0 to 50 nT. Some problems due to incorrect design, like connectors and cable routing inside sensors will be discussed with GEM. The G-811 magnetometer, in contrast, presented some problems during first part of the survey. These problems were due to sensor's cable termination at ship and to power supplies. The problem were solved, however the performances have to be evaluated after a full stage of editing, filtering and processing. We can presume, anyhow, that a full gradiometric data set will be achieved for a good percentage of the survey. Ship's magnetic deviation was tested in a low gradient area by passing over the same point at 45 degree step headings.

Computing Center

Since the target of the survey were seismic and mapping, some dedicated and general purpose workstations were installed on-board. A Micro VAX 3100/76, running the VMS Operating System acted as general purpose, plotting (with IGM package Plotrnap) and software development system. A DEC station 5000/240 running Ultrix (UNK) was dedicated to Spatial Analysis Processing. A Sun SPARC station 10 running Sun Os (UNIX) was dedicated to seismic processing and graphic visualisation. An Ethernet network connected the three computer, letting user connect to each computer and transfer data among them very easily by Tcp/Ip or Decnet connections,. Two terminal servers were used to provide access to the machines from stern laboratory. To do so ship's coaxial cable internal network was used. A 24" thermal printer/plotter mod. GS-624 was connected to the Sun Station. A rasterize software for GKS was developed for the VAX that allowed the use of 24" plotter from the network. Different tape drives were connected to various machines, including Storage Tek 9914 1/2" (for multibeam input), Fujitsu 3480, for SEG-D seismic input, Hexabyte and DAT for seismic processing and backup purposes. A PostScript laser printer was connected to the Sun. Some PC were also available for word-processing. The GMT package (Wessel and Smith, 1993) was installed on Dec and Sun. This computer network run constantly from the beginning to the end of the cruise without any software or hardware problem, and was found to be very productive.

Multibeam Echosounder

Morphobathymetric surveys were carried out with a Finnyards (formerly Hollming) mod. Echos 625 multibeam system. It operated 15 beams at a frequency of 12.5 KHz that roughly covered a swath of 2/3 of water depth alongside ship's tracks. Central beam data were acquired in analogic fomu on an ELAC mod. recorder, whereas digital data were recorded onto the ship's main computer trough the Echos high speed network. MB (navigation and beam data) and ES files were then made available for processing by writing them on 1/2" tapes in GF3 format. System run for 100% of survey time within its standard specifications. Only high seas with ship travelling bow to waves affected data quality due to reduced S/N ratios.

High Speed Single Channel

Seismic source consisted of two deeply modified Bolt Par air-guns that were redesigned and built at the GIN (Moscow). The guns had removable chambers of 0.3, 0.5, 0.6, 1.0 Lt.. The 0.5 Lt one was chosen for this survey. They were deployed in an array conhguration from both sides of the ship 3-4 mt from stern at a distance of 20 m each other and an average depth of 5 m. The working air pressure ranged from 40 to 60 Bars. This range produced optimum relationship between bubble frequency and water surface interference characteristics. Operation speed was 10 Kn except during periods of very bad weather when it was reduced to 8 Kn. Shot interval was set to 10 sec in order to allow recording of any deep reflections by Geometrics Strataview. Shot repeatability of the guns was within 1 msec. A constant delay of 12 msecs was applied by shot controller. Both Time-break generator than shot-controller were designed and built at GIN (Moscow). By having two independent towed guns it was possible to easily recover one in case of problems without interrupting data acquisition, at the cost of a slightly reduced system performance.

Seismic streamer was also designed and built by GIN (Moscow). Its 30 mt long active section was made up by 50 evenly spaced hydrophones. The sensitivity was supposed to be 10 μVolts/Bar. It was assembled in a vinyl jacket and filled with oil. A 10 mt long polyurethane section was at the head acting as shock-adsorbed. Within this air was completely taken out by vacuum pump. Tail section consisted of a 10 mt long tube filled with water and of a 30 mt long rope to help maintaining directionality. Tow-leader was made by a steel armoured cable. Total length of the cable was 250 m and shot-to-receiver distance was 180 m. Depth of streamer 1Il this configuration was supposed to be around 5 mt. The analog signal was pre-amplified 40-60 dB with and initial band-pass filters were set 10 Hz to 1 kHz. After this stage signal was further high-pass filtered 40-70 Hz depending on sea-state conditions, and delivered to: 1) mod.

Raytheon line scan recorder, which was set to a 4 sec window , 2) the STRATAVIEW seismograph, 3) IGM's Digital PC-based seismic processor (see above). In addition to this, data were also digitised by 12 bit fixed point A/D Converter in ship's CAMAC system. Data were then collected and written on 1/2" tapes by ship's PDP-11 like computer as a sequence of integer*2 numbers.

Gravimeters

Gravity measurements were done by 4 quartz thermally stabilised mod. GMN-K gravimeters assembled in Russia (Moscow). The sensors were mounted on gyroscopic platforms close to the centre of gravity of the ship in order to reduce acceleration effects. Their height above sea level was found to be 0.5 mt Before cruise, all the necessary tests were done in Moscow: evaluation of the scale parameter, accuracy of the system, dynamic parameters etc. According to the test results, gravimeters were combined into "working pairs" with sensor oriented to opposite directions to minimise cross-coupling effects. Data were input to analogic recorders and afterward digitised every 5 minutes for processing. Instrumental zero-drift was checked against absolute values in Lisbon, Las-Palmas, Cape Town. '

Rock Sampling

Dredges were carried out by ship's 10 Ton hydraulic winch and A-frame. The winch delivered at 1 mt/sec 5000 mt of steel rope 17 to 12 mm diameter. 4000 mt of 14 mm cable were available as spare. The dredges we used were ordinary 60 cm diameter tube dredge that had safety link for emergency recovery. Tensiometer gave constantly tension on the dredging wire and it was monitored and recorded on PC in the multibeam room. Speed of the ship while the dredge was on the bottom was 0.5-1.5 knots. When the dredge was anchored the ship made turn and moved in opposite direction. It was repeated until the dredge was free. While bites, we avoided increasing tension on the wire more than twice nom the general level before bites. One dredging operation took from 2 to 4 hours depending on the depth and type of structure that was sampled. Man work on deck and bridge and hardware reliability brought to a system that performed exceptionally well even in very bad weather conditions. One was lost and 5 empty dredges were recovered over 67 occupied stations.

Data Handling And Processing

Navigation

Navigation data recorded from main integrated acquisition system were merged with Del Norte GPS data to check and replace errors from Doppler sonar and from gyrocompass.

Multichannel Seismic

The receiving streamer employed 24 channels, spaced 25 meters apart. Seismic source and nearest channel were spaced 25 meters apart. Shot interval was 50 meters allowing 6 fold coverage. Digital acquisition was carried out with sampling rate of 1 msec, 12 secs record length and high pass filter set to 10 Hz to avoid low frequency noise of propeller. Standard processing were applied to the whole set of data until stack of traces. Kirchoff migration was done on a few selected lines due to the large amount of CPU time required.

Bathymetry

Multibeam data were logged and preliminary processed on VT-600 of ship's computing system Data were plotted and hand contoured between tracks. A fully automatic processing chain was established on IGM Computing Centre. First, tapes with MB files from ship's computer were read on the VAX. Then each beam was assigned latitude and longitude position according to navigation information and then all data suites were filtered. Basing upon the experience on the analysis of data sets collected in previous cruises, an attempt was done to editing time and increase error proofness. Multibeam swaths were filtered by a routine that performs a median-based linear fit trough the values of the characteristic data within a spatial window (namely 15 beams .by 15 swaths). These data are computed by 3-D trend-analysis and are accepted according to goodness-of- fit, correlation coefficient, F-test. The process is repeated within a continuously updating window of input data. During the survey on the Bouvet Area 50to bad weather conditions. ln contrast, during survey in the Bouvet Triple Junction area, 95% of data were considered acceptable. Edited data were then input to the PLOTMAP (Ligi and Bortoluzzi, 1989) and SURFACE H (Sampson, 1978) programs that produced contour maps in geographical coordinates at different node spacing. As an aid to interpretation colour shaded-re1ief and 3-D images were produced from the same gridded data (Fig. 8).

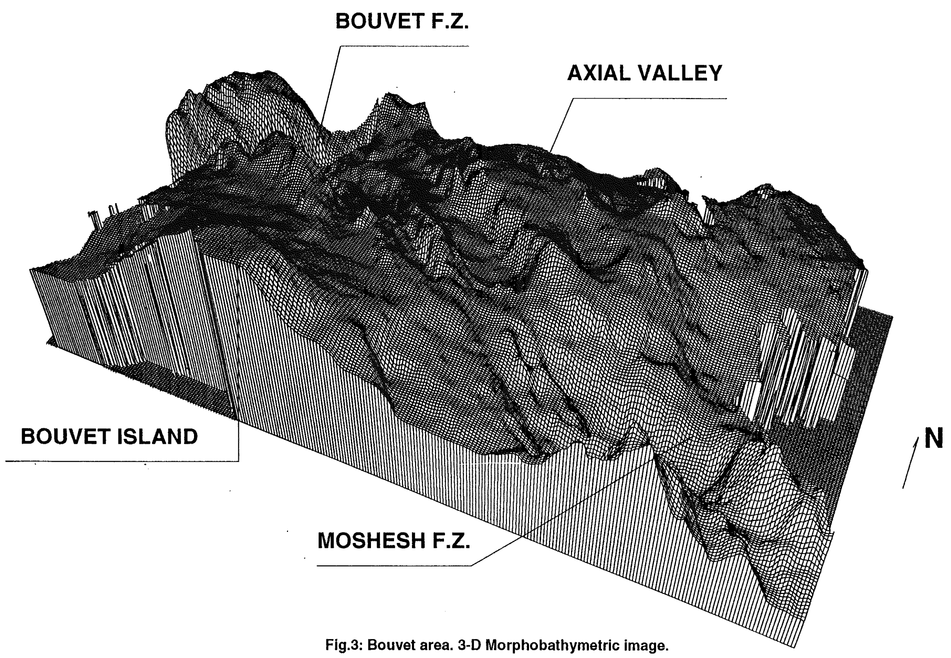

Fig.3: Bouvet area. 3-D Morphobathymetric image.

Figure 8: Example of processed bathymetric data.

Magnetometry

The magnetic data have been corrected for fish position and ship deviation. The anomaly field was computed by subtraction of regional fields using the IGRF coefficients. The data were then input to SURFACE II and GMT's "surface" programs for automatic contouring. Figure 9 show some results.

Gravimetry

Standard methods were applied to compute gravity anomaly from raw data:

(i) de-scaling and zero-drift corrections; for data collected in the Romanche area while transiting to Cape Town, zero-drift of gravimeters were evaluated according to the absolute measurements in Lisbon, Las-Palmas and Cape Town; the same zero-drift was used in preliminary processing of data from the Bouvet area;
(ii) relative dynamic corrections to reduce dynamic uncertainties;
(iii) averaging of values of 2 working pair gravimeters to minimise systematic uncertainties caused by cross-coupling
(iv) Eotvos correction for ship's speed and heading from navigation data set.

After this editing free-air gravity anomaly was computed basing upon absolute values in ports. No sea-level free air correction was applied, since it was non significant., It should be mentioned that during most of working period in the Bouvet area sea state was too rough for good gravirnetric measurements. This

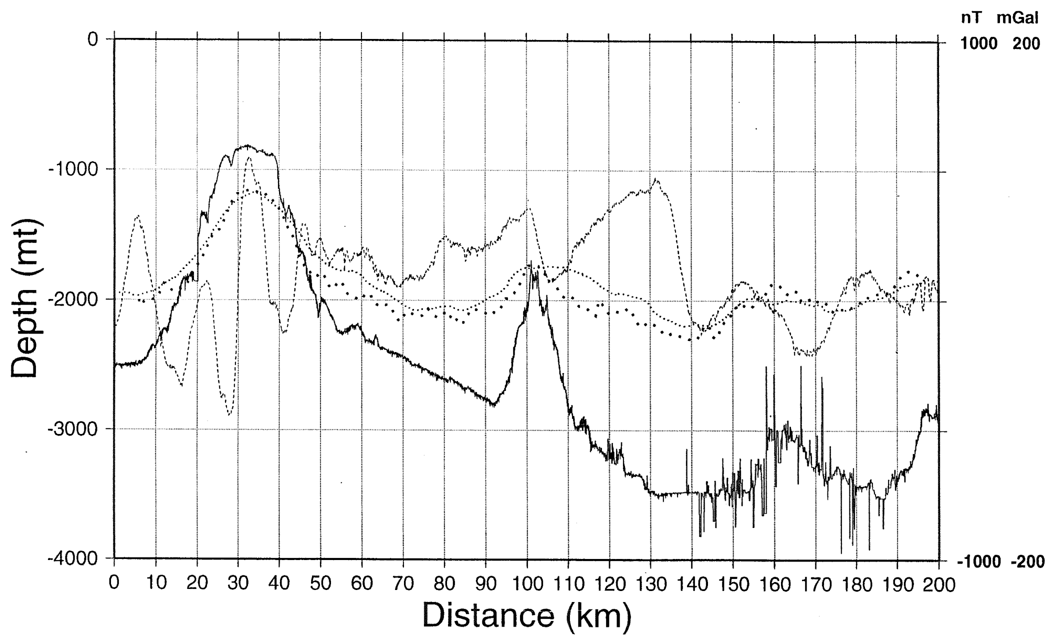

Fig.2b: Line BVT-11M: Bathymetry (solid)(Mbeam central beam), magnetic anomaly (dashed) (GEM GSM19-MD), Free-air gravity anomaly (heavy dotted) (GMN-K), and Satellite-derived Free Air Anomaly gridded data (light dotted) (Sandwell and Smith, 1992).
Note: 1) the good correlation between in-situ and satellite-derived gravity data, and 2) the decrease of performance of multibeam due to rough sea.

Figure 9: Example of magnetic data processing.

led to a loss of accuracy, especially during acquisition with bow to the waves. According to a preliminary evaluation accuracy ranged from 1 to 5 mGl depending on sea-state conditions. This figure resulted from the values of 2 pairs of gravimeters.

High Speed Single Channel Seismic

From the analog continuous seismic sections the thickness of sediments was measured. Data were then processed in PC DOS environment with. AUTO CAD package (Auto desk,) and SURFER to produce the sediment distribution map of study area.

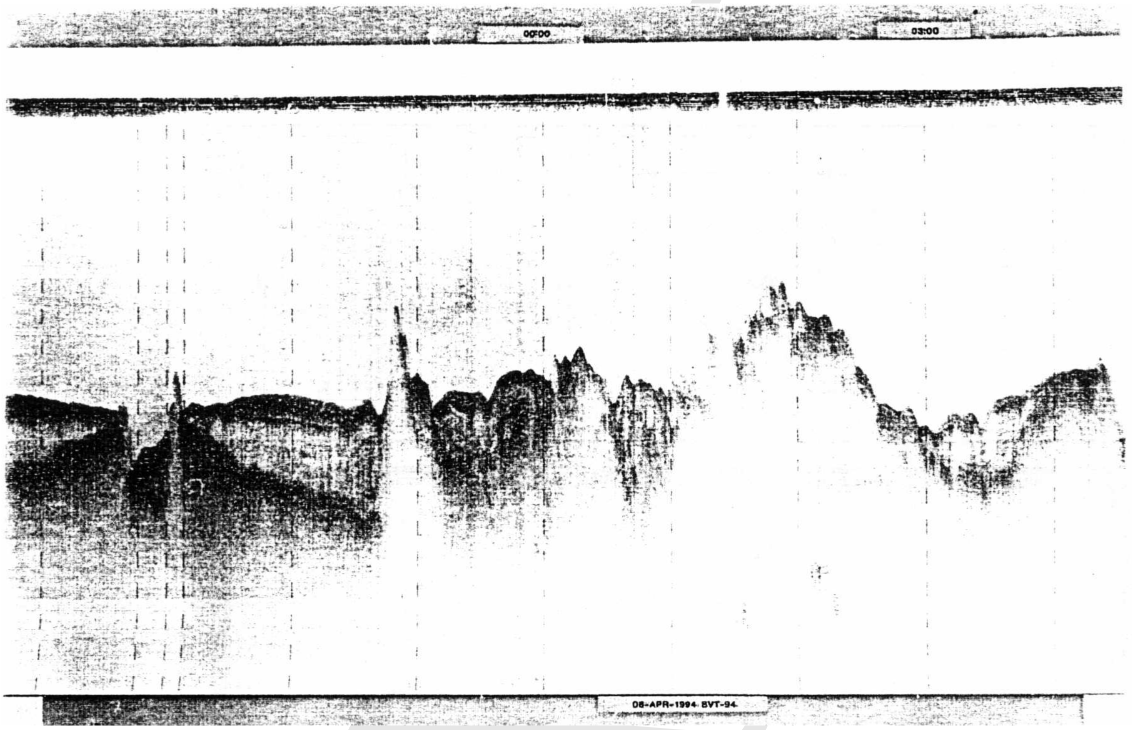

Figure 10: Example of single-channel seismic section.

Rock Sampling

Rocks and sedimentary samples collected were numbered, described and then divided in two identical parts: one delivered to I.G.M. of Bologna and the other one was sub-divided between Moscow Academy and GIN of Novosibirsk. Thin sections were made on board and partially analysed and described at the microscope. Some samples were kept for Italian and Russian museumsf Biological samples (fishes, plants, etc.) have been preserved in alcohol..

4 INITIAL RESULTS

4.1 Bouvet Area

This area encompasses the ridge segment located eastward of Bouvet Island until its termination against the two fracture zones that bound it northward and southward, the Bouvet and Moshesh Fracture Zone respectively. The area was first investigated by means of multibeam, magnetic, gravity, single and multichannel seismic investigations. The survey lines (fig.2,2b) were decided to run in the West/East direction because coincident with the prevalent seasonal wind and sea from West direction. The lines were spaced 2 nm because of the multibeam coverage (70% of the water depth) and were about 70 miles long to cross completely both sides of the ridge axis and the eastward edifice of the Bouvet volcanic Island. The multibeam data processing were carried out during survey acquisition to have bathymetric maps available at the start of sampling operations. Three long transect, about 200 nm long, of multichannel seismic, gravity, magnetic and multibeam were acquired before the begin of survey in Bouvet Area to figure out the presence of intraplate deformations (fig.l), ages of oceanic crust and to estimate long wave component of gravity anomaly. The Bouvet Fracture Zone was sampled along one of this transects. During most of the time the weather was rough and, as a consequence, only the multibeam data collected during the W-E runs were of good quality because of the reduced S/N ratio induced by the sea on the opposite direction. V After execution of 70% of the geophysical survey sampling of bottom was accomplished to optimise work of the different scientific teams on board. At the end of the survey of the Bouvet Area most of the Geophysical data had been processed and rocks classification well under the way. For details of processing sequence see addendum: "Daily operations".

MAIN RESULTS

The ridge axis East of the Bouvet Island has been fully investigated. The narrow axial valley typical of slow spreading rates was not found. Instead, it appears to be replaced by a shallower and broader depression centred, in the middle, by a topographic high corresponding to the actual zero age rocks as shown by magnetic anomalies and recovering of very fresh basalts (fig.3). The oldest magnetic anomaly identified in the Area_1 area is Chron 3n (around 4.5 Ma) (Cande and Kent, 1992). The magnetic anomalies are well developed in the northern half of the Area and become smoother in the southern one. The fracture zone that bounds southward the ridge axis strikes oriented W-E from the morphobathymetric map while the gravity and magnetic anomalies show a main NE-SW structure. During dredging operations in the Area a significant amount of sialic, ice-driven rocks from Antarctica were collected (fig.4). A more detailed description of rock sample will be found in the paragraph "Rock Sampling".

4.2 Triple Point Area

The area covered by the survey is the northern branch of the Bouvet Triple Junction, i.e. the termination of the Mid Atlantic Ridge (fig.l). The survey started from north with parallel lines, striking about SW-NE, 2 nm spaced, with increasing length moving south (fig.5). As in the first Area bathymetric, magnetic, gravity and single channel seismic were acquired. Due to the exceptionally good weather condition that lasted for 8 consecutive days we gained excellent data as far as 20/30 nm southward of the triple junction. Preliminary processing of the data were carried out during acquisition so that detailed bathymetric, magnetic and gravity maps were available for dredging operation which were performed at the end of the geophysical survey. Rocks were sampled along the axis and on two transect perpendicular to it. Fresh basalts with glass were collected on several sites. Main results The main target of imaging the ridge axis have been accomplished. Moreover the survey was extended some miles southward the Triple Junction so that we could get an image of all the three branches of the Junction having reached the Spiess Ridge and the ridge that connects the Triple Junction with the Conrad transform. The tectonic evolution of the area imaged appears not obvious. From morphobathymetric maps (fig.6) the 3 mayor trends of oceanic accretion show up very well, i.e. the N60E South America / Africa, N45E Antarctica / Africa and N85E South America Antarctica plate motions. Magnetic anomaly lineations and morphologic features fit very well with the exception of a strong magnetic lineation normal to the MAR which is not clearly related to morphology and might be the locus of transform movements between MAR and Spiess Ridge. The oldest anomaly identified is chron 2an (around 3.0Ma, fig.7), spreading rates derived from data confirms the estimate given by Sclater et al (1976). Beyond that the nature of the triple junction is not evident even if it appears to be of RPF type. The connection between the Mid Atlantic Ridge (MAR) and the Spiess Ridge should be of transform type even if the trace of the transform is not evident. The Spiess Ridge itself appears as a propagating rift which in the future will reach directly the Mid Atlantic Ridge cutting off the transform MAR/Spiess. The connection between the MAR and the Conrad Transform Zone is more complex. A short segment of a ridge axis is visible near the Conrad Transform which in turn is connected to the Mid Atlantic Ridge through a deep basin. This basin might indicate the presence of an oblique leaky transform. The Middle Atlantic Ridge moreover is here complicated by the presence of overlapping spreading centres, a feature not common in slow spreading centre. This picture is even more complicated by some evidence at the northern end of the polygon of structures that recall the presence of a northward propagating ridge. This last feature needs however a more extensive survey to be clarified

4.3 Rock Sampling

The sample descriptions can be found in Tab.4.3.

We occupied 67 dredge stations and rock samples were recovered from 54 of them. One dredge was lost.

Bouvet Area

We dredged (1) along the rift valley (8 dredge hauls), (2) along two transects normal the rift valley from 54S 3:16'E to 53:48'S 3:37'E (5 dredge hauls) (3) from Bouvet island to 53:45S 4:45'E (14 dredge hauls), (4) inside ridge-transform corner (with Bouvet F.Z.), (5)on the scarp 25 miles SE of Bouvet island (Fig. 4).

As expected, nearly all the dredges (except S1828 and S1835) recovered basaltic rocks. In S1828 only serpentinised peridotites. Peridotites were also sampled (9%) in S1835 site. Glacial erratics were recovered nearly in all sites. They are of continental origin (granites, quartzites, gneisses and blue scists), brought by icebergs from Antarctic continent ln some stations, especially near Bouvet island and to the East of it, it was recovered a lot of rounded basalts and basalt pebbles probably transported by ice on the Bouvet island. ln the rift valley such material was found only in front of the island. Along the rift valley the most common rocks are aphyric and microphyric (Pl-Ol) basalts (S1827, S1830, 81831). Pl-phyric varieties with big amount of large (up to 10 mm) Pl crystals were recovered in S1822, 81824 and partly in S1830 site. ln station S1825 were recovered - only Ol-phyric basalts. ln the rift segment, just north-east of Bouvet island, we collected vesicular hyalo-basalts, 51837 - aphyric, S1815 - Ol-phyric and S1816 - Ol-Pl- phyric. At station S1824 - we recovered a mixture of vesicular hyalo-basalts with aphyric and PL-phyric varieties. Fresh quench glasses were recovered in all sites except 81826 and S 1824. The most common rocks found along the NE transect: are aphyric and Pl-Ol- microphyric basalts even though Pl-phyric, O1-phyric and Ol-Pl-phyric were also collected in S1829, S1830, S1832 sites. Some altered dolerites, (with chlorite and sulphides) were dredged in site S 1832 while altered basalts in station S 1829. Fresh glasses were absent only in S 1832. A mixture of different basalts were found along the Bouvet island profile. Many samples were round-shaped and travelled probably from Bouvet island. At shallow depth near Bouvet island (S1813, S1820) only rounded rocks with huge amount of mud were recovered. In 81817 and S1843 there were no angular rocks as well. In most of the sites (81815, S1816, 51819, 81837, S1840 - S1842) predominate highly vesicular hyalo-basalts, some with Pl and O1 phenocrysts (S1815, S1816, 81819, S1841). Massive angular aphyric and O1-Pl-phyric basalts were recognised in S1814, S1841, S1844, S1845. Glasses were recovered from S1815 - S1817, S1819, S1841 and S1843.

Bouvet Fracture Zone

Dredging profle was done along the multichannel seismic line crossing Bouvet F.Z. approximately at 54:24'S 00:45'E. It included 10 dredge hauls, seven of which recovered solid rocks. Sites S1803 - S1805 recovered only loose basalt sand (Fig.4). ln individual dredges different continental glacial erratics made up 3 to 45% of the recovery. Few rounded vesicular hyalo-basalts were founded on the south part of the profile in S1810 and S1811. ln the middle-upper part of the north wall of Bouvet F.Z. we recovered basalts and dolerites (S1806, S1807). Basalts are aphyric and Pl-phyric, most are altered. Gabbro- dolerites along with basalts and dolerites were collected near the bottom of fracture zone valley (S1806). Sedimentary breccia and sarrdstones made up essentially of basaltic particles were recovered in S1806 and S1807 sites. On the south wall of Bouvet F.Z., from the middle part of the slope, (S1809) we recovered serpentinised peridotites (60From the upper part of the slope (S1810) peridotites (20%), aphyric and Pl-phyric basalts, dolerites with big phenocrysts of Pl (70%). Dredge S1811 localised in the south slope of the ridge, just south of Bouvet F.Z. (S1811) sampled basalts similar to S1810 and some peridotites (2%), the basalts were covered by a thin Fe-Mn crust. At S1813 site only consolidated clay with basalt (1-5 mm) particles was present

Triple Point Area

We dredged (1) along 3 segments of the MAR rift valley (10 sites), (2) along two transects normal to the southern part of MAR, from 55:09'S 1:49'W to the Spiess ridge (5 stations), and (3) to the northern part of MAR, from 54:37'S 1:49'W to 54:09'S 00:47'W (3 successful sites) (Fig. 8).

All dredges recovered basalts. In S1855 (west slope of the valley 40 miles west of the modern MAR rift valley) it was found gabbros which probably represent "roof facies" of magmatic chamber. A small amount of glacial erratics was found in dredges S1849, S1854, Sl857, Sl860, S1867. No rounded basalts were collected except some pumice of unknown origin. Basalt glass was recovered everywhere except in the outer stations: S1855, S 1856 and S1867. The rocks sampled along the southern rift segment appear are aphyric and micro P1- O1-phyric fresh basalts with a lot of glass (S1848, S1850 - S1852). It was recovered also a small number of vesicular hyalo-basalts in S1848 site and Pl-phyric - in S185l. Dredges from the central segment brought similar aphyric basalts (S1853); hyalo-basalts (S1861) and or1ly glass from S1860. In two dredges from the north segment (S1862, S1863) we collected P1- phyric basalts with numerous big (up to 1.5 cm) Pl crystals and some aphyric basalts. S1864 dredge brought only basalt glass. Among the stations along the southern transect dredges Sl855, S1856 (on the structures 30-40 miles away from MAR rift valley:) recovered mostly highly altered aphyric, Pl-phyric basalts and dolerites. In S1855 there were about 30% Gabbro and Gabbro-dolerites with highly variable grain size. Closer to the MAR, at site (S 1854) only fresh aphyric and Pl- phyric basalts were found. On the northern part of Spiess ridge we dredged (S1846, S1847) Pl-phyric basalts with abundant Pl crystals. Along the north transect at station (S1857) we recovered mostly altered Pl-phyric basalts and altered Pl-phyric dolerites. In two sites, on the eastem flank of MAR rift valley (81866 and 81867) we recovered aphyric basalts.

Table 5: Samples description.

DREDGE DATE LAT_S LON_S LAT_E LON_E DEPTH_S DEPTH_E	REC	ROCK_TYPE	NOTES
- - - ddmm.x ddmm.x ddmm.x ddmm.x m m	kg		
Romanche FZ			
S1801 20-feb-94 0047.6 -1309.4 0046.6 -1309.6 4400 4900	60	Basalts 50%; Fe-Mn concretions 48%; gabbro-dolerites 2%	
S1802 21-feb-94 0107.6 -1123.8 0107.6 -1123.8 4150 4150	0.35		Sand, mud
Bouvet FZ ,North transverse ridge, north slope			
S1803 23-mar-94 -5415.2 0130.7 -5416.6 0131.5 2200 3000	0.1		Sand
Bouvet FZ, North slope			
S1804 24-mar-94 -5419.9 0138.6 -5419.4 0138.5 2100 2200	0.1		Sand
S1805 24-mar-94 -5420.4 0140.1 -5420.4 0140.0 2900 3100	0.2	Sandstone pebble (0.5cm)	Sand
S1806 24-mar-94 -5422.8 0144.6 -5422.6 0144.0 4900 5200	12	Basalts 60%; dolerites, gabbro-dolerites 30%; sedimentary breccia 7%; glacial erratics 3%	
S1807 24-mar-94 -5421.7 0141.3 -5421.6 0141.3 4000 4200	15	Basalts, dolerites 50%; sandstones 40%; glacial erratics 10%	
S1808 24-mar-94 -5418.6 0136.5 -5419.0 0136.8 1500 1550	0.05	Basalt (1.5cm), dolerite (2cm)	
Bouvet FZ, South slope			
S1809 24-mar-94 -5426.6 0150.7 -5427.4 0150.9 4000 4300	9	Peridotites 60%; basalts 30%; glacial erratics 10%	
S1810 25-mar-94 -5428.6 0154.7 -5429.2 0154.2 2500 2600	400	Basalts, dolerites 70%; peridotite 20%; sandstones 1%; glacial erratics 9%	Mud
Antarctic plate near Bouvet FZ			
S1811 25-mar-94 -5434.3 0205.3 5434.6 0205.1 2300 2400	10	Basalts, dolerites 50%; sandstones 2%; sedimentary breccia 2%; Fe-Mn cores on peridotites 2%; glacial erratics 44%	
S1812 25-mar-94 -5438.2 0211.0 -5438.5 0211.3 2500 2200	5	Consolidated clay with basalt particles, sandstones	
North-East slope of Bouvet island			
S1813 30-mar-94 -5422.3 0316.6 -5422.4 0316.6 150 170	1	Rounded basalts 98%; sedimentary breccia (4 cm); glacial erratic (3 cm)	
S1814 30-mar-94 -5421.8 0330.2 -5422.2 0329.4 190 420	12	Basalts, some are rounded 95%; sedimentary conglomerate of basalt particles 5%	
West slope of neovolcanic rise in rift valley			
S1815 31-mar-94 -5408.7 0352.0 -5408.6 0352.1 1680 1780	25	Basalts, some are rounded 95%; volcanic breccia (3 cm); sandstone (3 cm); glacial erratics (10 cm)	
East slope of rift valley (bottom)			
S1816 31-mar-94 -5409.9 0349.5 -5409.9 0349.9 1640 1700	300	Basalts	
East slope of rift valley (top)			

S1817 31-mar-94 -5412.0 0347.2 -5412.5 0347.4 1450 1500	2.5	Rounded basalts 97%; sandstone (4 cm); glacial erratics 3%	
North-East slope of Bouvet island			
S1818 31-mar-94 -5418.1 0336.9 -5418.4 0336.2 1180 1270 S1819 31-mar-94 -5419.8 0333.0 -5420.3 0332.0 740 900 S1820 31-mar-94 -5425.8 0328.1 -5425.3 0327.4 35 140	0 25 2.5	 Basalts, some are rounded 70%;coarse grained sandstones 30% Rounded basalts 99%; sandstones 1%	Sand
Scarp 25 miles to the south-east from Bouvet island			
S1821 31-mar-94 -5429.6 04 02.6 -5429.6 0402.0 2600 2830	30	Basalts, some are rounded 80%; consolidated clay 18%; glacial erratics 2%	
West slope of rift valley			
S1822 1-apr-94 -5421.3 04 22.1 -5421.0 0423.5 3000 3200 S1823 1-apr-94 -5413.3 04 07.4 -5412.8 0403.9 2000 2200 S1824 1-apr-94 -5411.6 04 04.1 -5411.1 0401.8 1800 2050 S1825 1-apr-94 -5405.2 03 39.2 -5405.2 0338.0 1600 1800	12 Empty 11 40	Basalts Basalts, some are rounded 94%; consolidated clay (15 cm); glacial erratics 5% Basalts 75%; consolidated clay 25%	
Bottom of rift valley			
S1826 1-apr-94 -5358.7 03 34.0 -5358.8 0333.9 2300 2340	1.5	Dolerite (12 cm)	
East slope of neovolcanic rise in rift valley			
S1827 1-apr-94 -5351.5 03 17.8 -5351.9 0317.0 3480 3600	5	Basalts	
Inside ridge-transform corner, low part of the slope			
S1828 2-apr-94 -5347.3 02 57.9 -5348.8 0257.0 4170 4350	2	Peridotite (10 cm); siltstone (5 cm)	
Ridge 10 miles east from rift valley, west slope			
S1829 08-apr-94 -5347.9 03 35.2 -5348.2 0337.2 2400 2950	500	Basalts 95%; sedimentary breccia 3%; glacial erratics 2%	
East slope of rift valley			
S1830 8-apr-94 -5352.2 03 27.5 -5351.8 0328.1 2775 2900	120	Basalts 99%; glacial erratics 1%	
West slope of rift valley			
S1831 8-apr-94 -5355.1 03 22.5 -5355.5 0322.1 2800 3080	200	Basalts	
Ridge 10 miles west from the rift valley, east slope			
S1832 8-apr-94 -5359.6 0316.5 -5359.7 0316.6 2100 2200 S1833 9-apr-94 -5400.4 0315.9 -5400.5 0315.9 1450 1550	20 8	Basalts, dolerites 95%; sedimentary breccia 5% Sedimentary breccia, sandstones 100%	
Inside ridge-transform corner, middle-upper part of the slope			
S1834 9-apr-94 -5356.5 0302.0 -5356.7 0302.1 1900 2030 S1835 9-apr-94 -5351.6 0300.9 -5352.2 0300.1 3100 3380	Empty 200	 Dolerites 90%; peridotites 9%; gabbro (20 cm)	
West slope of rift valley			
S1836 09-apr-94 -5359.7 0329.9 -5400.9 0330.9 2000 2200	6	Rounded gabbro (15 cm); basalt (4 cm)	
East slope of rift valley			
S1837 09-apr-94 -5407.3 0350.2 -5406.9 0349.7 1380 1500	130	Basalts 98%; sedimentary breccia 2%	
West slope of rift valley			

S1838 09-apr-94 -5407.5 0343.4 -5407.7 0342.3 1700 1890	Empty		
Hill 32 miles east from rift valley, east slope			
S1839 10-apr-94 -5348.9 0442.1 -5348.9 0441.9 1450 1500	Lost		
Hill 32 miles east from rift valley, west slope			
S1840 10-apr-94 -5347.7 0429.1 -5348.3 0430.4 1300 1580	4	Basalts, most are rounded 98%; glacial erratics 2%	
Hill 32 miles east from rift valley, east slope			
S1841 10-apr-94 -5348.7 0441.7 -5348.9 0440.8 1350 1540	30	Basalts, some are rounded 80%; sedimentary breccia, tuff, rounded 8%; gabbro-dolerite (20 cm); glacial erratics 2%	
Hill 23 miles east from rift valley, west slope			
S1842 10-apr-94 -5350.2 0412.3 -5349.9 0412.5 1400 1600	80	Basalts	
Ridge 12 miles east from rift valley, west slope			
S1843 11-apr-94 -5402.4 0409.1 -5401.6 0409.0 1700 2000 S1844 11-apr-94 -5400.9 0408.6 -5359.9 0408.4 1380 1600	1 3	Rounded basalts 98%; sulfide ore breccia (5 cm); glacial erratics 1% Basalts, some are rounded 20%; sandstones 80%	
Ridge east side of rift valley, east slope			
S1845 11-apr-94 -5404.3 0356.0 -5404.9 0354.9 1900 2200	6	Basalts, some are rounded 95%; sedimentary breccia (5 cm); gabbro (4 cm); glacial erratics 2%	
Spiess ridge, east slope			
S1846 19-apr-94 -5436.8 -0021.0 -5436.3 -0020.0 1650 1800			
Spiess ridge. east top S1847 19-apr-94 -5434.4 -0020.9 -5434.7 -0021.3 1630 1680	0.1	Basalt glass	
West slope of rift valley			
S1848 20-apr-94 -5450.4 -0048.4 -5450.5 -0048.7 2600 2660 S1849 20-apr-94 -5446.0 -0048.1 -5445.8 -0049.1 2200 2300 S1850 20-apr-94 -5446.1 -0049.8 -5446.2 -0050.5 2000 2100 S1851 20-apr-94 -5442.5 -0050.2 -5442.7 -0050.6 2300 2400 S1852 20-apr-94 -5437.7 -0055.9 -5437.1 -0057.1 2450 2150 S1853 20-apr-94 -5439.8 -0103.8 -5440.0 -0104.9 2550 2700	300 40 500 150 40	Basalts Plagiogranite pebble Basalts Basalts Basalts Basalts	
Valley 30 miles west from rift valley, west slope			
S1854 20-apr-94 -5456.4 -0112.3 -5456.1 -0111.8 2750 3150	300	Basalts, dolerites 99%; sedimentary breccia 1%; glacial erratics 0.5%	
Valley 40 miles west from rift valley, west slope			
S1855 21-apr-94 -5500.8 -0122.7 -5500.8 -0123.2 3200 3500	110	Basalts, dolerites 70%; gabbros 30%	
Hill 35 miles east from rift valley, east slope			
S1856 21-apr-94 -5509.2 -0146.5 -5509.0 -0149.1 1700 2800	140	Basalts, dolerites	
Hill 30 miles east from rift valley, east slope			
S1857 21-apr-94 -5436.5 -0149.4 -5436.9 -0150.3 2000 2700	70	Basalts, dolerites 95%; glacial erratics 5%	
West slope of rift valley			
S1858 21-apr-94 -54 33.6 -0113.9 -5433.8 -0115.8 2100 2440 S1859 22-apr-94 -54 33.6 -0113.6 -5433.7 -0114.2 2400 2500 S1860 22-apr-94 -5425.1 -0121.7 -5425.3 -0121.7 2000 2100	Empty Empty 0.3	 Basalt glass (4 cm); granite pebble	

S1861 22-apr-94 -5431.6 -0114.7 -5431.9 -0117.8 1700 2500	0.1	Basalts, basalt glass	
S1862 22-apr-94 -5416.2 -0116.8 -5415.9 -0117.2 2560 2620	25	Basalts	
S1863 22-apr-94 -5410.3 -0123.4 -5410.2 -0124.4 2700 2750	120	Basalts	
S1864 22-apr-94 -5405.5 -0128.4 -5405.8 -0129.1 2800 2900	0.5	Basalt glass	
S1865 23-apr-94 -5413.8 -0052.0 -5413.2 -0054.9 2300 2500	Empty		
Ridge east side of rift valley, east slope			
S1866 23-apr-94 -5414.9 -0052.9 -5414.6 -0051.9 2400 2300	0.4	Basalts	
Ridge 25 miles east from rift valley, west slope			
S1867 23-apr-94 -5409.4 -0045.7 -5407.9 -0047.0 2050 2600	3	Basalts; glacial erratics	

%captionSamples description. %endcenter %endtable

5 CONCLUSIONS

During a 56 days (of more than 100 including transits) cruise in the Southern Atlantic Ocean we obtained:

- xx km gravimetric and magnetic
- xx km^2 multibeam
- 67 rock samples, including volcanic glasses (see Fig.11)
- xx km multichannel seismic

The data is under detailed processing and analysis, and we expect to have new insights into the geology of the investigated areas. Weather conditions in the study area were generally bad to very bad, except for very few days. No problems were encountered regarding neither the people nor environment during the cruise.

Figure 11: Beautiful curl of vitreous lava.

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6 APPENDIX

6.1 DIARY OF OPERATIONS

- 23-Jan-94 023 Ship left Kaliningrad at 11:50 GMT, destination Copenhagen.
- 25-Ian-94 025 Ship arrived in Copenhagen 14:30 GMT. Load of fuel, lubricants, foods. Remarks: two ENEA representatives assisted the operations.
- 27-Jan-94 027 Ship left Copenaghen 13:15 GMT, destination Lisbon.
- 28-Jan-94 028 Two containers 20' and l0' were taken at IGM, destination Lisbon.
- 03-Feb-94 034 Ship arrived in Lisbon 08:00 GMT. Part of abroad Italian equipment loaded. Gravimetric team started instrument calibration. Remarks : Italian team from IGM and ENEA arrived in Lisbon.
- 04-Feb-94 035 Two containers from Bologna arrived at the ship and the loading of scientific equipment begun. Late afternoon all the equipment ordered abroad were delivered and loaded onboard. At last, the two containers were put on board by port crane.
- 05-Feb-94 036 Installation of Italian equipment started: computing facilities, geophysical instruments. seismic streamer. Remarks :Two technicians from lookout Geophysical-Geometrics and Del Norte Int. started to install the new 48 channel seismograph and the 12 Channel GPS receiver. They were assisted by two IGM technicians.
- 06-Feb-94 037 The seismic streamer was rolled on ship's main winch. The installation of new seismograph and GPS receiver was completed. All the equipment were checked before departure.
- 07-Feb-94 038 Ship left Lisbon 14:00 GMT, destination Las Palmas.
- 08-Feb-94 039 All instruments were checked and prepared for tests. Gi-gun ombilicals were built for array and High Speed towing bars;
- 09-Feb-94 040 Test overboard were performed for: SODERA GI-gun array handling bar. SODERA high speed GI-gun towing bar, GEM gradiometer. The instruments were deployed and recovered in good conditions. Performance was considered good. Particular attention was given to deployment/recovery of GI-gun array and gradiometer.
- 10-Feb-94 041 Ship arrived in Las Palmas 08:00 GMT. All equipment installed ready for work. Remarks : The value of absolute gravimetric field in the harbour of Las Palmas was found trough a call to the University of Barcelona. The gravimetiy team on board calibrated the instruments.
- 11-Feb-94 042 Ship left Las Palmas, destination Central Atlantic, for test cruise.
- 17-Feb-94 048 Start of multichannel and geophysical equipment tests.
- 23-Feb-94 054 End of equipment test. Ship leave Central Atlantic, destination Cape Town
- 05-Mar-94 064 Italian Team left Italy for Cape Town, including ENEA representative.
- 06-Mar-94 065 Ship arrived in Capetown at 09:00 GMT. Italian team boards 15:00. Gravimetric team started instrument calibration.
- 07-Mar-94 066 In port at Capetown. Final check of equipment
- 08-Mar-94 067 After final deliveries ship left Capetown 14:50 GMT, destination the Bouvet Triple Junction survey area. Remarks Prof. Le Roex and Prof. Rogers of Capetown University visited the ship.
- 09-Mar-94 068 Transit to Bouvet. Remarks : Two seismic sections are checked and changed with spares, due to noise problems.
- 10-Mar-94 069 : Transit to Bouvet At 09:42 GMT single channel gun is deployed and the recording is started (line BVT-01S) along with multibeam and gravimetiy. Remarks: the GEM gradiometer is checked. First fish is not replying. After recovery the fish is opened and found filled with sea-water. Immediately the fish is flushed with fresh water and de-oxidants.
- 11-Mar-94 070 Transit to Bouvet. Line BVT-01S. Remarks: A repair is attempted to GEM fish, but damage to the main PCB is found to be not recoverable in the field. The decision is taken to use the G-811

GEOMETRICS as second fish. The instrument is rolled on the winch and deployed. The results were not encouraging, with lot of noise in the sensor and cable.

• 12-Mar-94 071 Transit to Bouvet. At 12:30 GMT line BVT-0lS ended. At 13:30 GMT start of single channel multibeam line BVT-02S. Remarks: The noise problems of G-811 magnetometers was recovered after having rebuilt the head section of the cable. ‘

• 13-Mar-94 072 Transit to Bouvet. Latitude -52.00. Very bad sea conditions. Continuous single channel profiling, Mbeam and gravimetry. At 09:10 line BVT-02S ended. At 14:30 GMT line BVT-03S started.

• 14-Mar-94 073 Reached the first operation area NE Island of Bouvet. At 07:05 GMT line BVT-03S is terminated and single channel guns and streamer are recovered. At 12:00 GMT seismic streamer and GI-gun array are deployed for multichannel line BVT-04M, that starts at 14:00 GMT. Remarks: During deployment of gun array one gun's hydrophone is found to be broken. However, the fault is estimated not to be critical. Sea state bad. Multibeam, magnetometers and gravimeters running normally.

• 15-Mar-94 074 At 03:20 GMT ends line BVT-04M. At 03:00 GMT start of line BVT-05M, which ends at 16:30 GMT. At 18:20 GMT start of line BVT-06M. Multichannel seismic continues along with multibeam, magnetometry and gravimetry. Data seems good Sea state and wind decreased, however. big swell persists.

• 16-Mar-94 075 At 12:00 GMT end of line BVT-06M. At 17:20 GMT start of line BVT-07M. Multichannel seismic continues along with multibeam, magnetometry and gravimetry. The Del Norte GPS receiver has a fault.

• 17-Mar-94 076 Line BVT-07M. Multichannel seismic continues along with multibeam, magnetometry and gravimetry. The gun-array is recovered and the broken gun's microphone is changed. Then the array is re deployed. Sea state very bad. At 22:00 the big tloatation buoy of gun-array is found to be submerged.

• 18-Mar-94 077 Multichannel seismic continues along with multibeam, magnetometry and gravimetry. At 12:00 GMT end of line BVT-07M. Sea state very bad. The gun array and streamer are recovered. The floatation buoy is found to be severely damaged. At 22:30 single channel gun and streamer are deployed. . At 22:35 start of line BVT-08S.

• 19-Mar-94 078 After having changed the buoys an attempt to re deploy the gun array fails due to very heavy seas and wind. Ship tries to move to another area more favourable to work. The seismic streamer is at last recovered to prevent heavy damages. During the recovery a stretched and exposed area is found in the tow leader close to the winch. At 19:50 GMT end of line BVT08S. At 20:30 start of line BVT-09S.

• 20-Mar-94 079 At 8:00 GMT end of line BVT-09S. During night ship sailed to anchor SE of the Bouvet Island. During morning and early afternoon the damaged tow-leader is taken off the winch and substituted with the spare one. Late afternoon the streamer is deployed NW of Bouvet Island and ship moves to multichannel line BVT-10M NW-SE west of Bouvet. At 24:00 start of line BVT-10M. Engineers repaired a water pump in the engine room. Remarks: During the operation of streamer deployment close to island, a South African Antarctic ship was contact via radio. Ship sailed from a South African Antarctic base and had just installed an automatic weather station in the Island. After a brief radio conversation, ship sailed for Capetown.

• 21-Mar-94 080 Multichannel seismic continues along with multibeam, magnetometry and gravimetiy. At 04:15 GMT end of line BVT-10M. At 04:55 start of line BVT-11M. Sea state decreased, but heavy rain and snow fall.

• 22-Mar-94 081 Multichannel seismic continues along with multibeam, magnetometry and gravimetry. At 03:10 GMT end of line BVT-11M. At 03:45 start of line BVT-12M. At 05:30 GMT end of line BVT-12M. At 07:10 GMT start of line BVT-13M. Sea state good with a snow fall.

• 23-Mar-94 082 Multichannel seismic continues along with multibeam, magnetometry and gravirnetry. At 16:05 GMT end of line BVT-13M. Gun array and streamer are recovered along with magnetometers. Early evening ship moves to Hrst dredging station in the Bouvet Fracture Zone area. Station S18-03 occupied.

• 24-Mar-94 083 Dredging in the Bouvet F.Z. continue. Stations S18-04,05,06,07,08,09 were occupied. Sea state good.

• 25-Mar-94 084 Dredging in the Bouvet FZ. Stations S18-10,11,12 were occupied. Early afternoon single channel gun and streamer and magnetometers are deployed. At 14:00 GMT start of line BVT-14S. Mbeam, single channel, magnetometry and gravimetiy on Area NE Bouvet. 2 nm spaced lines E to W are run with Multibeam and gravimeters. The computing centre started to process multichannel lines. Sea state bad. Remarks: Lines running Westward decrease the Mbeam performances. GEM magnetometer performs very well. In contrast GEOMETRICS magnetometer presents noises and spikes. The oil pump for seismic streamer LOWARA fails to work due to shore circuit in the winding. Ship?s engineer try to repair it, but the fault is considered to be not recoverable onboard. As a consequence, ship's engineers design and build a pneumatic pump to serve the purpose.

- 26-Mar-94 085 Line BVT-14S. Mbeam, single channel, magnetometry and gravimetry on Area NE Bouvet. Sea state bad increasing to gale.
- 27-Mar-94 086 Line BVT-14S. Mbeam, single channel, magnetometry and gravimetry on Area NE Bouvet. Sea state decreasing. G-811 magnetometers shows decreased performances.
- 28-Mar-94 087 Line BVT-14S. Mbeam, single channel, magnetometry and gravimetry on Area NE Bouvet. Sea state increasing. G-811 had a severe damage during a radio transmission. The low-voltage power supply had a transistor fully blown up.
- 29-Mar-94 088 Line BVT-14S. Mbeam, single channel, magnetometry and gravimetry on Area NE Bouvet. Sea state decreasing.
- 30-Mar-94 089 Line BVT-14S. Mbeam, single channel, magnetometry and gravimetiy on Area NE Bouvet. Line BVT- 14S ends at 17:30 GMT. Guns and magnetometers are recovered and ship steamed to occupy stations Sl8-13,14 in the Bouvet Ridge Area.
- 31-Mar-94 090 Dredging around the Island of Bouvet. Stations S18-15 ,16,l7,18,19,20,21 were occupied. In the afternoon a complete tum around the Island is performed at a water depth of 200 mt. This in order to attain data on the submerged structures of the Island. Sea state decreasing to good. Computer centre started to process bathymetric, magnetometric and gravimetric data of first part of Area 1. Concurrently, the multichannel processing continues. Remarks : The G-811 magnetometer is repaired by changing power supply units. Now performances appear to be acceptable.
- 01-Apr-94 091 Dredging in the Bouvet F.Z. Stations S18-22,23,24,25,26,27.
- 02-Apr-94 092 Dredging in the Bouvet F.Z. Station S18-28 occupied. Early moming ship sail to terminate the geophysical survey in the NE part of Area 1. Single channel guns and streamer and magnetometers are deployed. At 08:05 GMT start of line BVT-l5S. Sea state good. Late afternoon sea state increased to very bad.
- 03-Apr-94 093 Line BVT-15S. Mbeam, single channel, magnetometry and gravimetry on Area NE Bouvet. Sea state decreased. Geophysical lines approached the Island of Bouvet.
- 04-Apr-94 094 Line BVT-15S. Mbeam, single channel, magnetometry and gravimetryon Area NE Bouvet. Sea state increasing.
- 05-Apr-94 095 Line BVT-15S. Mbeam, single channel, magnetometry and gravimetry on Area NE Bouvet. Sea state very bad with snow fall.
- 06-Apr-94 096 Line BVT-15S ended at 11:45 GMT. Line BVT-16S started at 12:00. Mbeam, single channel, magnetometry and gravimetry on Area NE Bouvet. Sea state decreasing.
- 07-Apr-94 097 Line BVT-16S ended at 11:45 GMT. Line BVT-l7S started at 11:50 GMT. Mbeam, single channel, magnetometry and gravimetry on Area NE Bouvet. Sea state good.
- 08-Apr-94 098 Line BVT-17S ended at 05:15 GMT. Line BVT-18S started at 05:25 GMT, Line BVT-18S ended at 11:10 GMT. Mbeam, single channel. magnetometry and gravimetry on Area NE Bouvet. Sea state bad. Late morning the survey stops and the guns and magnetometers are recovered. Ship steamed to occupy stations S18-29,30.3l,32.
- 09-Apr-94 099 Dredging in the Bouvet Ridge Area continue. Ship occupied stations S18-33. 34, 35, 36, 37. 38. Sea state decreased. During night a heavy snow fall occurred. Computer centre received all the data of Area 1 and started final processing of bathymetry, magnetometiy, gravimetry. Late moming sea state increases to very bad. Air pressure falls to 946 mbars. Evening ship moved to anchor SE of Bouvet I.
- 10-Apr-94 100 Ship stays SE of Bouvet Island, not in anchor due to very high wind. Early moming wind and sea state decrease and ship moves to continue dredging . Stations S18-39,40,4l,42 were occupied.
- 11-Apr-94 101 Stations S18-43,44,45 were occupied. Early afternoon dredging of the Bouvet Ridge are completed. Ship sails to the NW comer of surveyed Area to perform the Magnetic Deviation turning lines. At 23:00 GMT bow is directed SW to the Bouvet Triple Junction study area. Sea state is very bad.
- 12-Apr-94 102 Transit to BTJ area, with single channel. magnetometers, multibeam, gravimeter running. Line BVT-19S started at 01:10 GMT. Sea state very bad with high seas. At 18:45 GMT ship arrived in the BTJ Area 2 survey area. Line BVT-19S ended. Line BVT-20S started at 18:55 GMT. Remarks : At 14:08 GMT at position 54 31.1' S 22.l' E an iceberg was targeted on the radar at a distance of 4.5 NM bearing 135 degrees. The approximate width was calculated to be round 100-150 mt with two hills round 50 mt each.
- 13-Apr-94103 Line BVT-20S. Mbeam, single channel, magnetometry and gravimetry on BTJ Area 2.

Sea state decreasing. Processing of Area 1 data almost complete, except final seismic and magnetometric processing. Rock sampling and sub-sampling on materials recovered in the BRA area continues.

- 14-Apr-94 104 Line BVT-20S ended at 00:10 GMT. Line BVT-21S started at?i00:45 GMT. Line BVT-21S ended at 21:05 GMT. Line BVT-225 started at 21:15 GMT. Mbeanm, single channel, magnetometry and gravimetry on BTJ Area 2. Sea state good.
- 15-Apr-94 105 Line BVT-22S ended at 20:45 GMT. Line BVT-23S started at 21:06 GMT. Mbeam, single channel, magnetometry and gravimetry on BTJ Area 2. Sea state good. yi
- 16-Apr-94106 Line BVT-23S ended at 21:45 GMT. Line BVT-24S started at 22:15 GMT. Mbeam, single channel, magnetometry and gravimetry on BTJ Area 2. Sea state good.
- 17-Apr-94107 -Line BVT-24S ended at 19:25 GMT. Line BVT-25S started at 19:36 GMT. Mbeam, single channel, magnetometry and gravimetry on BTJ Area 2. Sea state good.
- 18-Apr-94108 Line BVT-25S ended at 17:50 GMT. Line BVT-26S started at 18:00 GMT. Mbeam, single channel, magnetometry and gravimetry on BTJ Area 2. Sea state calm. IGM GI-guns are dismantled, cleaned and prepared for next expedition.
- 19-Apr-94 109 Line BVT-26S ended at 18:20 GMT. Mbeam, single channel, magnetometry and gravimeuy on BTJ Area 2. Sea state calm. Early evening single-channel guns and magnetometers are recovered. Ship steamed to occupy stations S18-46,47.
- 20-Apr-94 110 Dredging in the BTJ area. Stations S18-48,49,50,51,52,53,54 were occupied. Sea state calm.
- 21-Apr-94111 Dredging in the BTJ area continue. Stations S18-55,56,57,58 were occupied. Sea state increasing to very bad. Computer Centre starts to process Mbeam, magnetic and gravity data of BTJ Area 2.
- 22-Apr-94 112 Dredging in the BTJ area. Stations S18-59,60,61,62,63,64 were occupied. Sea state decreasing.
- 23-Apr-94113 Dredging in the BTJ area ended early aftemoon. Stations S18-65,66,67 were occupied. Guns and magnetometers are deployed and ship moves to complete survey of southern part of the Area. Sea state good. Line BVT-27S started at 13:55 GMT. Line BVT-27S ended 18:18 GMT, BVT-28S started at 18:20 GMT.
- 24-Apr-94 114 Line BVT-28S. Mbeam, single channel, magnetometry and gravimetry on BTJ Area 2. At 24:00 survey of Area 2 was terminated and ship's heading was directed to Capetown. Route was adjusted to cross magnetic lineations and structures NE of Bouvet Ridge. Sea state good.
- 25-Apr-94 115 Transit to Capetown. Sea state very bad. Line BVT-28S ended at 01:10 GMT. Line BVT-CT started at 01:15 GMT. Computer Centre started to process all data of Area 2.
- 26-Apr-94 116 Transit to Capetown. Very bad sea state during night. Line BVT-CT. Late moming sea state turned to better conditions. Processing of geophysical data in progress.
- 27-Apr-94 117 to 30-may-1994 Transit to Capetown. Sea state varyng from good to bad. Line BVT-CT.
- 01-May-94 121 Ship berthed in Capetown 08:00 ship time.
- 02-May-94 122 All heavy materials were allocated in the containers and the 20' container was put on-board. Remarks Italian Consulate offered a lunch party to the expedition members.
- 03-May-94 123 After refilling and food delivery 16:00 ship left destination Hamburg. Italian team flies to Italy.