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JOINT RESEARCH PROJECT "BOUVET TRIPLE JUNCTION"
Coordinated by E.Bonatti

GEOPHYSICAL AND GEOLOGICAL STUDIES IN THE BOUVET TRIPLE JUNCTION

REPORT ON THE MORPHOBATHYMETRIC, GEOPHYSICAL, DREDGING AND OCEANOGRAPHICAL INVESTIGATIONS DURING CRUISE BVT96 ABOARD R/V GELENDZHIK

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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 BVT96 with *R/V Gelendzhik*is presented. **Sommario** - Vengono presentati le metodologie e l'insieme dei risultati ottenuti durante la campagna BVT96 di rilievi batimetrici, geologici e geoficisi nella zona di giunzione tripla di Bouvet, Atlantico Meridionale. E' stata utilizzata la nave da ricerca *R/V Gelendzhik*del CGGA.

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ACRONYMS

ACRONYM	DESCRIPTION	URL-email
CNR	Consiglio Nazionale Delle Ricerche	www.cnr.it
ISMAR	Istituto di Scienze Marine	www.bo.ismar.cnr.it
LDEO	Lamont-Doherty Earth Observatory	www.ldeo.columbia.edu
SEG	Soc. of Exploration Geophysicists	www.seg.org
XTF	Extended Triton Format	www.tritonelics.com
UNESCO	United Nations Scient. and cultural org.	www.unesco.org
IOC	Intergov. Oceanogr. Comm. of UNESCO	ioc.unesco.org
IHO	Int. Hydrographic Organization	www.iho.org
GPS-DGPS-RTK	Global Positioning System	samadhi.jpl.nasa.gov
DTM	Digital Terrain Model	en.wikipedia.org
GEBCO	General Bathym.Chart Oceans	www.ngdc.noaa.gov/mgg/gebco
SRTM	Shuttle Radar Topogr.Mission	www2.jpl.nasa.gov/srtm/
MBES	MULTIBEAM ECHOSOUNDER SYSTEM	
SBP	Sub Bottom Profiling	
MCS	Multichannel Seismic	
PSU	Practical Salinity Scale	ioc.unesco.org
TS	Temperature-Salinity Diagram	
XBT	Expendable BathyTermograph	www.sippican.com
UTM	Universal Transverse Mercator	
UTC	Universal Time Coordinated	
WGS84	World Geodetic System 1984	
NMEA	National Marine Electronics Association	www.nmea.org
DHCP	Dynamic Host Configuration Protocol	en.wikipedia.org
NAT	Network Address Translation	en.wikipedia.org/wiki/NAT
SO.PRO.MAR.	Societa' Promozione lavori Marittimi	Fiumicino (Italy)
SBE	Sea Bird Electronics	www.seabird.com/
RESON	Reson	www.reson.it
COMM-TECH	Communication Technology	www.comm-tec.com
NEPTUNE	Simrad MBES Software	www.kongsberg-simrad.com
CARAIBES	Traiment Cartographique Batimetrie	www.ifremer.fr/dnis_esi
MB-SYSTEM	MB-SYSTEM	www.ldgo.columbia.edu/MB-System
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

HOW TO READ THIS REPORT

After a brief and schematic presentation of the cruise in section 2, Section 1gives the introductory and background information, includingsome technological and scientific issues of the organization and execution of tasks Section 3 provides the technical aspects thatwere 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. Section 6 in the Appendix summarizes the cruise operations.

ACKNOWLEDGMENTS

The project was funded by Italian National Antarctic Project within a Joint Research Program between CNR and GIN of Moscow.

This work was done under heavy or very heavy weather conditions, with a particularly difficult and dangerous navigation within icebergs. 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 Yuriy Shikera and bridge officers and crew of *R/V Gelendzhik*for the extra work required.

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1 INTRODUCTION

In the South Atlantic (Fig.1) the Antarctica, South America and Africa Plates meet at the Bouvet Triple Junction (Fig.2), a key place for the understanding of structure and composition of ocean ridges. In the framework of Italian and Russian cooperative project with the main goal of depicting the structural, morphological and compositional elements of accretionary plate boundaries in the region, a first PNRA expedition in the area with R/V Strakhov in 1994 [?] was performed. The areas West of the Bouvet I. and around the Triple Junction were investigated, including the terminal portion of the axial valley of Mid Atlantic Ridge (MAR) south of 54 15'S. Other than multibeam, multichannel and single channel reflection seismic, gravimetric and magnetometric investigations, several stations were occupied and sampled in the two areas. Our survey time was over when we were just in the proximity of the Bouvet Triple junction, leaving open several questions regarding its structural expression, that is broadly depicted by the intersection of MAR with the Conrad and Bouvet fracture zones.

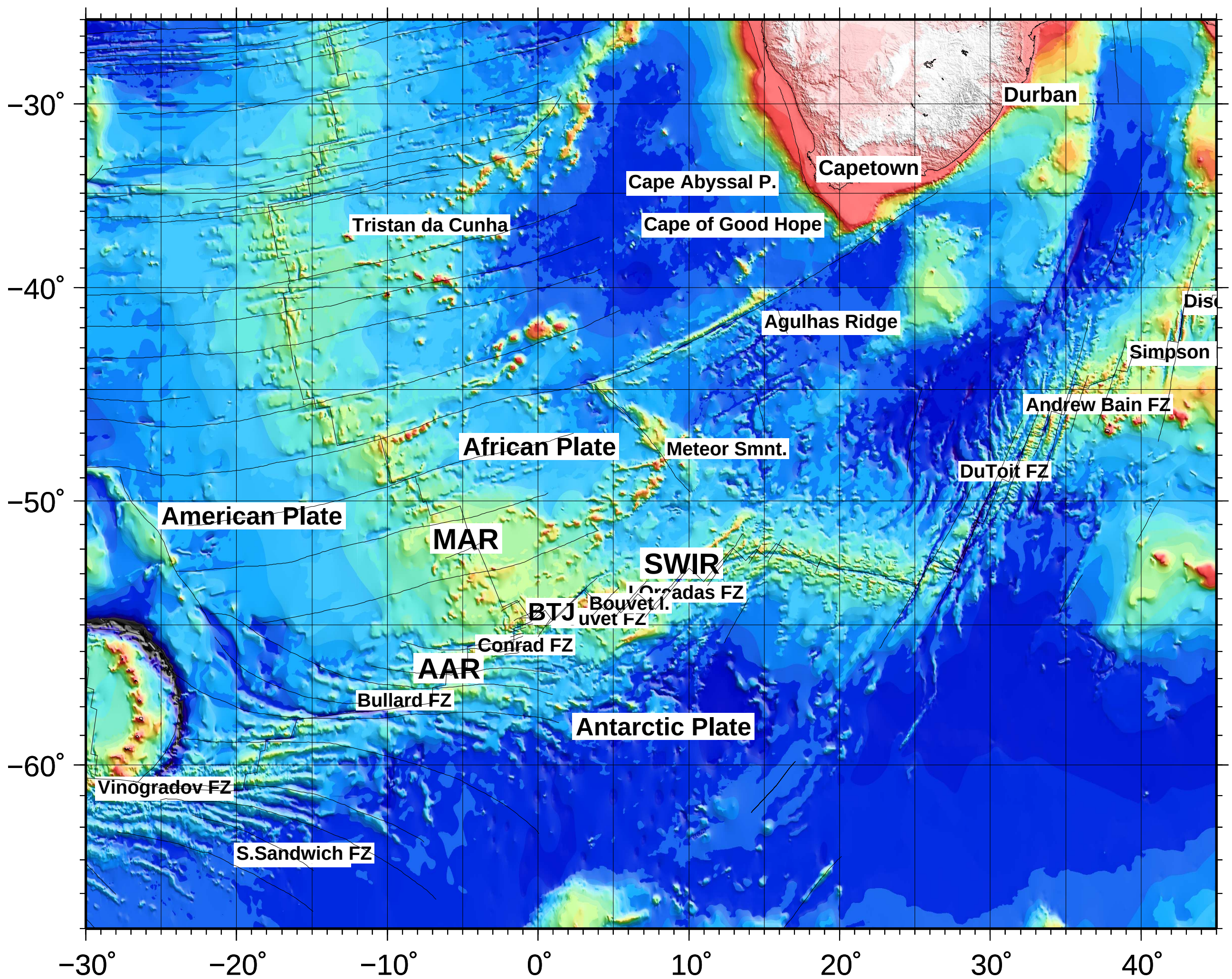

Figure 1: Geographical setting of the study area. Topographic and bathymetric data by Sandwell and Smith [Sandwell and Smith(2001)].

A second cruise was proposed to PNRA by IGM and planned in the area, focusing on swath-bathymetry investigations, magnetometry, gravimetry and sampling. We took the opportunity of the availability of *R/V Gelendzhik*of Central Geological Geophysical Expedition (CGGE, Russia), that was going to install a state-of-the-art multibeam system (EM-12-120S, SIMRAD, 3.3 times coverage of sea bottom). After some months of negotiations, at the end of 1995 PNRA and CGGE signed the contract. This second expedition started in Ravenna 9-feb-1996. Test and calibration of the multibeam system was done in two areas of Southern Adriatic Sea and of Ionian Sea (Taranto Canyon). After transit to Durban (South Africa), where ship embarked Italian and some russian scientists and technicians, we left 7-Mar-1996, and reached Abidjian (Ivory Coast) 8-may-1996, after 39 days of scientific operations in the Bouvet Area.

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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.

GEOLOGICAL SETTING

The Antarctic Plate is almost completely surrounded by divergent margins and meets the south American and African Plates in the South Atlantic at the Bouvet Triple Junction (BTJ) located at 54 50'S, 00 40'W according to [Johnson et al.(1973), Forsith (1975)], [Sclater et al.(1976), Apotria and Gray (1985)] studied the evolution in space and time of the BTJ for last 20m.y., suggesting a Ridge-Transform-Transform(RFF) occasionally shifted to a Ridge-Ridge-Ridge configuration. The three ridge system that bound the plates and converge in the BTJ (MAR, AAR and SWIR)are among the slowest ridges on the planet (1.6, 0.9 and 0.83 cm/yr, respectively, [Sclater et al.(1976)]). The volcanic island of Bouvet, emerging 780 m from the sea level, located 140nM E of the BTJ, has been considered to be espression of a mantle plume [Morgan (1972)], capable of influencing topography and geochemistry of westernmost SWIR and easternmost AAR [LeRoex (1987)]. The southernmost MAR portion may also have influenced by the (hypothetical) Shona and Discovery plumes [LeRoex (1987), Douglass et al.(1995), Small (1995)].

PLANNING AND STRATEGY

We planned to:

- better define the morphotectonic and geophysical images of Bouvet Triple Junction area. We espected to obtain some key information for the geological history of triple junction in the past 8-10 m.y. along with detailed investigations of the Conrad and Bouvet Fracture Zones, including the area south of the Triple Junction;

- Delineate the main features of MAR South of 53 00'S, which is not well depicted by free-air gravity maps [Sandwell et al.(1995)], and by available bathymetric maps. Morphology and geochemistry of spreading axial valley in this zone should reveal theinfluence of Shona 'hotspot', as proposed by [Small (1995), Douglass et al.(1995)],

- investigate the Shona Smt. area (54 32'S, 5 50'W).

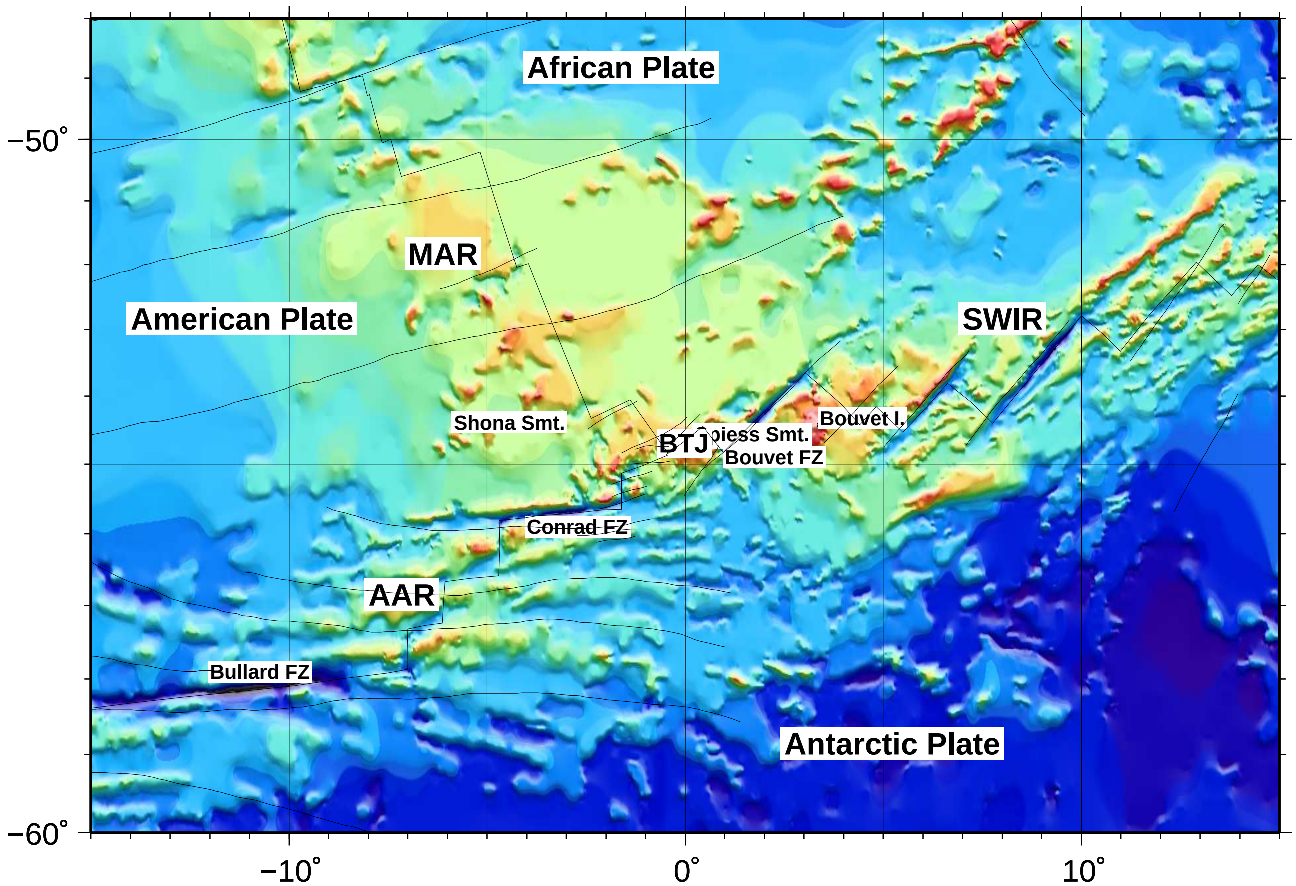

Figure 2: Geographical setting of the study area. Topographic and bathymetric data by Sandwell and Smith [Sandwell and Smith(2001)].

2 CRUISE SUMMARY

SHIP: *R/V Gelendzhik*
START: 1996-03-05 PORT: Durban
END: 1996-05-10 PORT: Abidjian
SEA/OCEAN: Atlantic Ocean
LIMITS: NORTH -50:00.0 SOUTH -58.00 WEST: 25:30.0 EAST: 30:00
OBJECTIVE: Geology and evolution of the Bouvet Triple Junction.
COORDINATING BODIES: ISMAR-Bologna BOLOGNA (ITALY)
CHIEF OF EXPEDITION: Giovanni Bortoluzzi (ISMAR-CNR)
CONTACT: Giovanni.Bortoluzzi@ismar.cnr.it
DISCIPLINES: SWATH BATHYMETRY, MAGNETICS, SEABED SAMPLING
WORK DONE: 5600NM MULTIBEAM, MAGNETICS, GRAVITY
26 DREDGES, 5 HEAT FLOW, 5 SVP

LOCALIZATION:

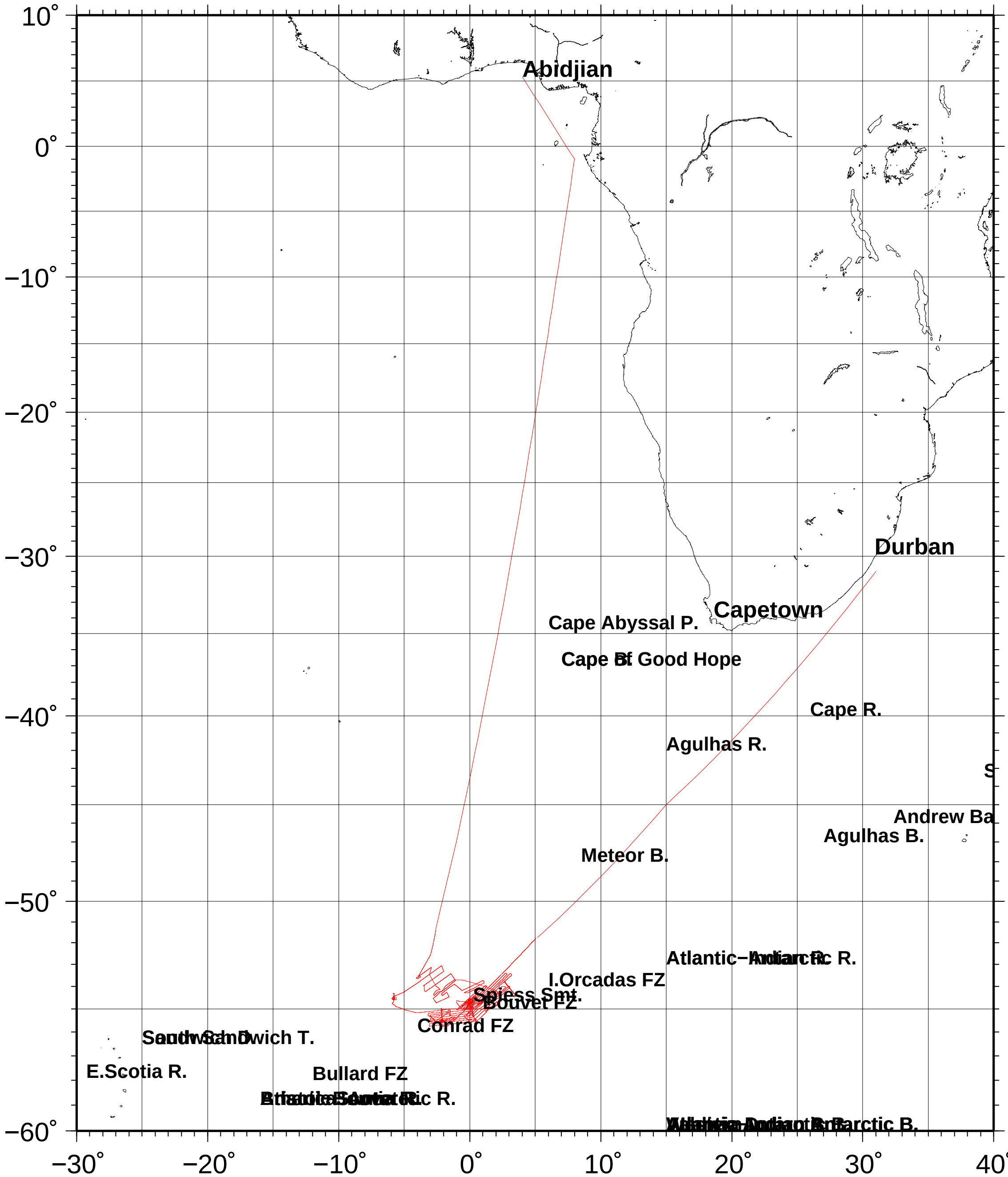

Figure 3: General ship track during Cruise BVT96, including transits from Durban and to Abidjian.

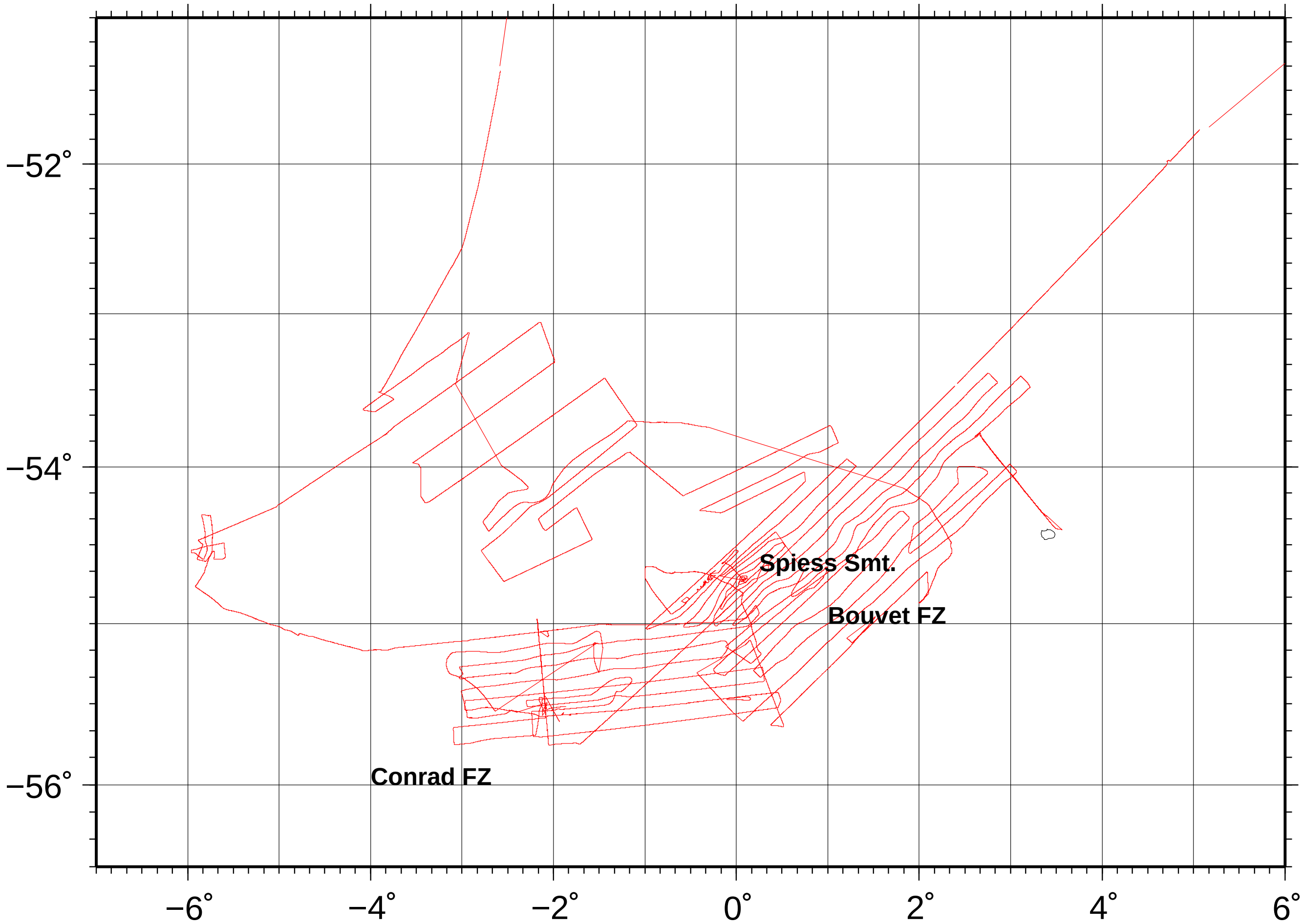

Figure 4: Ship tracks during Cruise BVT96. The blue squares are SVP stations.

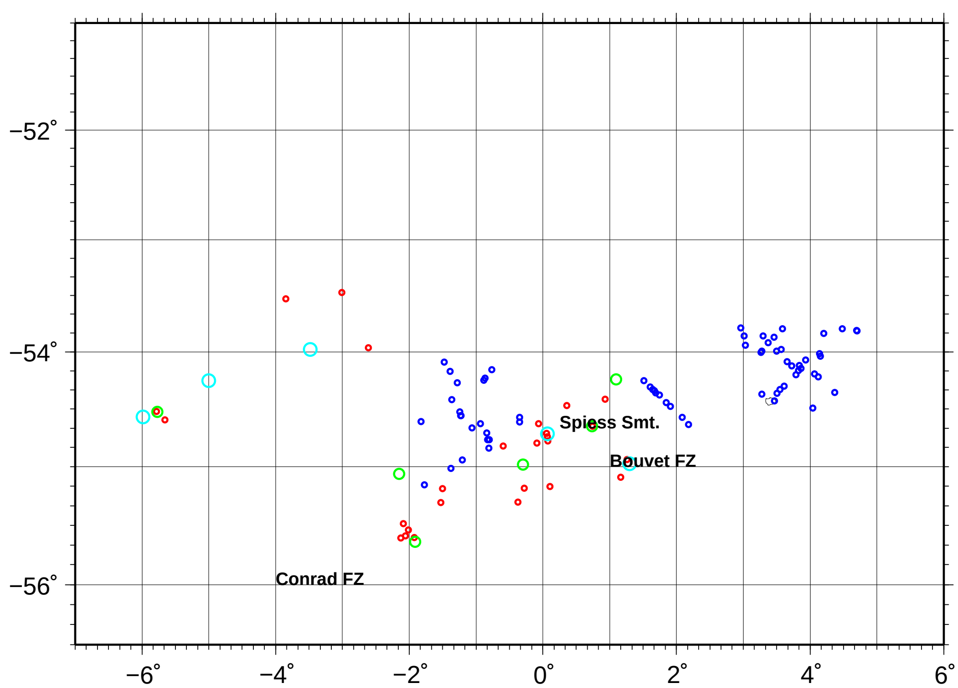

Figure 5: Bottom sampling stations (red).Cyan and green circles are heat flow and SVP stations.

SCIENTIFIC AND TECHNICAL PARTIES

PARTICIPANTS	EXPERTISE	ORGANIZATION	tel & email & www
Giovanni Bortoluzzi	Chief of Expedition	IGM	G.Bortoluzzi@ismar.cnr.it
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Terenzoni Michele	Student	IGM	
Bertozzi Fabio		ENEA	
Peyve Aleksandr	Scientist	GIN	
Skolotnev Sergey	Scientist	GIN	
Turko Nataliya	Scientist	GIN	
Gilod Dolores	Scientist	MSU	
Shirokozhukhov Boris	Party Chief	CGGEA	
Ovcharov Aleksandr	Scientist	CGGEA	
Lygin Petr	Scientist	CGGEA	
Koshman Aleksey	Scientist	CGGEA	
Pavlov Andrey	Scientist	CGGEA	
Zuev Oleg	Scientist	CGGEA	
Gubenkov Vladimir	Scientist	CGGEA	
Khrenov Sergey	Scientist	CGGEA	
Tsyganenkov Vitaliy	Scientist	CGGEA	
Yubko Valeriy	Scientist	CGGEA	
Shanin Andrey	Technician	CGGEA	
Kishko Petr	Technician	CGGEA	
Isachenko Sergey	Technician	CGGEA	
Nikanorenkov Boris	Scientist	NIPIO	
Zlotnikov Leonid	Scientist	NIPIO	
Skorkin Vasiliy	Scientist	NIPIO	
Vragov Vladislav	Scientist	NIPIO	
Artemenko Vitaliy	Scientist	NIPIO	
Rudnev Aleksandr	Scientist	NIPIO	
Zinin Robert	Scientist	NIPIO	
Maraev Sergey	Scientist	NIPIO	
Amelin Vladimir	Scientist	NIPIO	
Guselnikov Andrey	Scientist	NIPIO	
Sushchevskaya Nadezhda	Scientist	VIG	

Table 2: Scientific and technical parties

3 MATERIALS AND METHODS

The research cruise was carried out with the 105 meter *R/V Gelendzhik*, owned and operated by *R/V Gelendzhik*http://www.cggeinternational.com (Fig.6)CGGE and leased to PNRA for this expedition. The *R/V Gelendzhik*is normally used for geological, geophysical and oceanographical work in the whole Ocean, including Arctic and Antarctic. Ship is equipped with DGPS positioning system single-beam and multibeam bathymetry and integrated geophysical and oceanographical data acquisition systems, including more Sonar Equipment, other than water and seabed sampling. Additional equipment can be accommodated on the keel or towed.

Figure 6: *R/V Gelendzhik*.

3.1 NAVIGATION AND DATA ACQUISITION

The vessel was set-up for multibeam data acquisition and navigation with Trimble's HYDROPro and IGM's NAVMAPsoftwares.

Three workstations were used for the acquisition of

- (Navigation) GPS, gyro;
- (magnetics) GPS, magnetometer.
- (gravity)

The MBES was the 12kHz, 81 1.5°, 120°aperture EM-12S (11000 m range) by SIMRAD . The sonar head is positioned flush on the ship's keel. A sound velocity probe at the Sonar Head is interfaced directly to the MBES processor, thus providing the necessary real-time data for the beam-forming. The data were acquired by a SIMRAD's MERMAID workstation, who collected also the gyrocompass and TSS MRU data for the real time corrections. A Simrad's NEPTUNE workstation served as quick data quality check and post-processing. The datum WGS84 and the UTM, zone 30 and 31, were chosen for navigation and display purposes. Timing was set to UTC for data acquisition.

The instrumental offsets are presented in Fig. 7 and in Tab. 3

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 on *R/V Gelendzhik*. The GPS antenna (primary positioning system) is located on point DGPS.

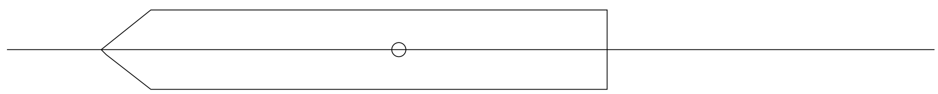

Figure 7: Cruise BVT96. Instrumental Offsets on *R/V Gelendzhik*.

3.2 CTD AND SOUND VELOCITY DATA

The SV profiles were obtained by an AML SOUND VELOCITY PROFILER, and were used for real-time MBESacquisition and post-processing. The position of the SV stations are reported in Table **??** and can be viewed in Fig. 8.

LAT	LONG	DATE	STATION
54:14.50S	01:05.78E	16-mar-96	1
54:58.88S	00:17.65W	16-mar-96	2
55:38.43S	01:54.60W	17-mar-96	3
55:03.70S	02:08.90W	28-mar-96	4
54:31.50S	05:46.40W	30-mar-96	5
54:38.90S	00:44.20E	14-apr-96	6

Table 4: SVP Station position.

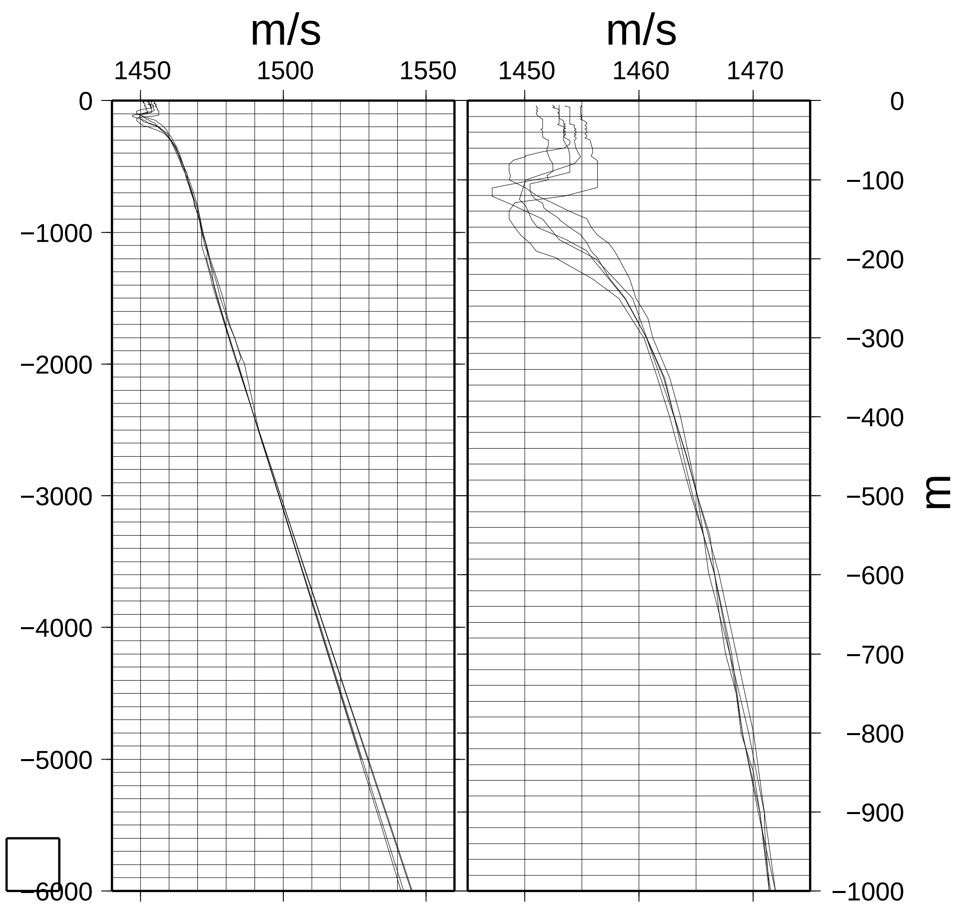

Figure 8: SV profiles.

3.3 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

3.4 GRAVIMETRY

At least two of a set of 4 quartz thermally stabilized model 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 Durban and Abidjian (see Tab.5) the instruments were calibrated on known reference points with a portable gravimeter Lacoste and Romberg Mod.G-327.

DATE	SITE	REFERENCE	SHIP
1996-03-07	Durban	979348.66 +/- 0.02	979352.32
1996-05-09	Abidjian		

Table 5: Gravimeter calibration.

Since the pattern of planned profiles was predominantly E-W, some N-S connecting lines were run for control. In addition, ship went to the Island of Bouvet crossing 1994 line pattern and repeating a 1994 station in anchor.

3.5 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.5 and locations are presented 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.

3.2 HEAT FLOW

The core sampling and geothermal research were carried out with system GRUNT, designed and assembled at the Thermal Exploration Laboratory (NIPIOkeangeofisika), Gelendzhik, Russia. The sea-going part (KADR-1M) incorporates: a) a corer that ensures the recovery of undisturbed sediments, b) a self-recording thermogradiometer (ACTM-1), b) deepwater camera and bathometer for nearbottom water sampling. The shipboard module consists of a programmable control and recording unit ensuring: programming of self recording instruments, readout, visualization, processing, and storage of measurements results. An Automated geotechnical module (NGM-1) was also available for engineer-physical parameter measurements on the cores. Heat flow data were obtained by the separate measurement of the geothermal gradient (γ, K/m) in sediments,and bottom sediment conductivity (λ, (W/m^{2}K). After penetrating the sediments, system was held in position for a minimum time of 15 minutes to reach equilibrium. As a result of the self-recording geothermal gradient measurements (γ) and value of the thermal conductivity (λ), the heat flow density is calculated as $q = -\gamma\lambda \ \ (mW/m^2)$.

The Station positions are shown in Tab.6 and in Fig.5.

LAT	LONG	DEPTH	STATION	DATE
-54:34.1	-05:59.0	1860	HF-01	1996-03-30
-54:15.1	-05:00.1	2640	HF-02	1996-03-31
-53:58.7	-03:28.8	2157	HF-03	1996-04-01
-54:43.0	00:04.0	811	HF-04	1996-04-12
-54:58.5	01:18.0	3270	HF-05	1996-04-17

Table 6: Heat flow Station position.

3.6 MISCELLANEOUS

The datum was set to WGS84 and the UTM, zone 31 was chosen for navigation and display, and data acquisition. The time zone was set to the UTC for the instrumental data acquisition.

The positioning maps and bathymetric images were produced with GMT [Wessel and Smith (1995)].

4 INITIAL RESULTS

We arrived in the operation area 15-mar-1996, and realized soon that our workplan should have been reorganized. 17-Mar we met the first of a long series of icebergs. This was a very bad surprise, since during previous expedition we had only one detection, at the end of survey. Some of the icebergs had so small relief to be undetectable by radar, expecially during rough seas (almost 70-80% of cruise). The decision was taken to reduce speed during night to a maximum of 5 Kn.

After having investigated part of the Conrad F.Z. and SW part of BTJ, we decided to go to the Shona Smt., since we were contrasting a very strong storm from NW and were forced to drift straight there. After having obtained bathymetric maps, rock samples and one Heat Flow on the top, we moved toward MAR with the aim to trace the axial valley and have some detailed bathymetric maps for dredging. We crossed MAR on 3 transects with good magnetic, bathymetric and gravimetric data. Between Shona Smt. and MAR we had a second Heat Flow Station, with the recovery of a very interesting core.

When we reached our 1994 survey area we did two additional lines west of it. Finally, we went to northern area of Bouvet F.Z. where we started a NE-SW survey. On Spiess Smt. we interrupted the long offset lines, starting a more detailed survey on the shallower part of the seamount. During this period we occupied several dredging stations, partly originally planned while other were decided upon the results of swath-bathymetry data processing.

Toward the end of the cruise, on the southern area of Bouvet F.Z. we had very rough weather, with a severe storm that stopped all the operations for 3 days. During this stand by the ship drifted North for more than 120 miles and we decided to go to survey on MAR. We performed additional multibeam and magnetics lines, and occupied three dredging stations on the rift valley. On 23-apr-1996 ship left the operation area, with heading to Abidjian. Additional magnetometric and multibeam data were collected during transit.

A total of 5600 Nm of Multibeam and Magnetic lines were run. A total of 26 dredging stations were occupied, 22 of them recovered samples, one was lost. Glasses were collected in 18 dredges. In all dredges but ones in the areas of neo-volcanic activity glacial erratics were present, reaching up to 30-50% of materials.

From geophysical lines we obtained detailed morphobathymetric and magnetic images of the area. Gravity data +have to be reduced after calibration, and we believe to be able to make good analysis of high frequency anomalies.

Three types of basalt associations were recovered :

1 fresh, highly vesicular aphyric and Cpx-Ol-Pl-phyric basalts,

2 sligthly altered Cpx-Ol-Pl phyric and aphyric basalts, covered by Fe-Mn crust (3 to 20 mm),

3 hydrothermally altered (with chlorite, calcite, quartz, sulphides, etc.) sometimes tectonized aphyric basalts.

Heat flow data (4 stations) ranged from 50 to 300 mW/m^2.

Initial results are presented for the different study areas, in order to address the importance of the preliminary findings and processing sequence of the data acquired.

The sample descriptions can be found in Tab.7.

ID	MONITORING SITE	DESCRIPTION	COMMENTS
G9623	NE slope of high S of W end of Bouvet F.Z.	Fe-Mn crust 2 cm; little glassy basalt	NULL
G9622	S slope of high S of W end of Bouvet F.Z.	basalt with 0;5 cm Fe-Mn crust	NULL
G9621	S wall of the E-W basin; 30 miles S of Spiess ridge	fresh and different alteration rate basalts; thick Fe-Mn crust	NULL
G9620	N wall of the E-W basin; 30 miles S of Spiess ridge	pillow fragments with thick Fe-Mn crust; fresh vesicular basalts; interesting big vitrobasalt sample; sandstone in situ; erratics	NULL
G9619	little high SW of Spiess ridge	basaltic breccia; including glass; with thick Fe-Mn crust; up to 2 cm; small basaltic samples	NULL
G9618	S slope little high; E of Spiess ridge	basalts and fresh glasses with thin Fe-Mn coating	NULL
G9617	E-W deep slope NE of Spiess ridge	pillow fragments with fresh glass; tectonized basalts; different degrees of hydrotermal alteration; Fe-Mn patina; sulphides	NULL
G9616	S slope of high NE of Spiess ridge	pillow fragments basalts with thick Fe-Mn crust; high vesicular fresh basalts with thin Fe-Mn patina	NULL
G9615	top of little high; N of Spiess; place of highest magnetic anomaly	fresh pillow fragments; high fluidal cord lavas with thin glassy crust; fresh glasses; thin Fe-Mn coating	we decide to pass trough caldera during dredge; so the ending depth is bigger then the starting depth
G9613	S slope of caldera	pillow fragments and flow lavas with glassy crust; fresh glass; 1 mm max Fe-Mn coating	NULL
G9614	N slope of high SW of Spiess ridge	big pillow fragments; basaltic breccia; lavas with thin glassy crust; lightly altered	NULL
G9612	S slope of caldera	fresh high vesicular basalt; flow lavas with Pahoe-hoe structures; big amount of fresh glass	NULL
G9611	NW wall inside caldera of Spiess ridge	pillow basalt with thin Fe-Mn crust; vesicular basalts; glassy crusts; Fe-hydroxide alteration	NULL
G9610	N slope of high SW of Spiess ridge	olivine basalt 85%	vesicular lavas 10%; one big sample (50 kg) of olivine tholeite
G9609	N slope of high; SE of Shona seamount	basalts 60%	30
G9608	NE slope; top of Shona seamount	basalts 60%	glacial erratics 10%
G9607	SW wall of the oblique basin; (Axial valley)	lost	lost
G9606	NW wall of the oblique basin; (Axial valley)	empty	empty
G9605	high inside corner; S slope	one sample of basaltic breccia	NULL
G9603	high inside corner; W top	empty	empty
G9604	high inside corner; N slope of W top	peridotites 30%	calcarenites 30%
G9601	high inside corner; S slope near nodal basin	empty	empty
G9602	high inside corner; S slope	basalts 80%	gabbro 5%
G9624	M.A.R.	fresh pillow basalt sectors; with glassy crust; no erratics; no Fe-Mn crust; abundant fresh glasses	NULL
G9625	M.A.R.	1 pillow fragment; little basalts with glass; thin Fe-Mn patina	NULL
G9626	M.A.R.	One big very fresh lava burr;	NULL

4.1 CONRAD FZ

We begun the survey from the E intersection of South America-Antarctic Ridge (SAAR) with Conrad F.Z. to 3W. Other than the planned E-W lines, additional survey time was necessary in order to obtain the full coverage of the high inside corner (minimum depth 600 m). Morpho-bathymetry and geophysics (magnetometry) revealed the presence of a ridge segment of SAAR changing its direction from N-S to SW-NE (Fig. 3), in good agreement with recent Sandwell's free-air gravity maps. The S portion of ridge axis has a deep axial valley (mean depth 4000 m, 1.5 km width) that becomes wider and deeper at transform fault - ridge axis intersection. The central magnetic anomaly of ridge axis (Chron 1n, 0.78 m.y, [Cande and Kent (1992)] time scale) is 15 km wide, and the resulting half spreading rate is 0.95 cm/yr. The SW-NE segment is 4000 m deep and 5 km wide; its morphotectonic features suggests the presence of shear stresses. Dredging was performed on high inside corner. We occupied 3 stations (2, 5, 4) recovering peridotites, gabbros, gabbro-dolerites, Cpx-Ol-Pl phyric and aphyric basalts covered by Fe-Mn crust, and glacial erratics.

4.2 SPIESS COMPLEX

The Spiess complex has an elliptical shape elongated in NW-SE direction. It is articulated in a central volcanic apparatus rising from 1200 m to 340 m and two main lateral reliefs. We did a detailed multibeam survey on the top, and morphological data revealed the existence of an elliptic caldera 2.8 x 2 Nm, 450 mt deep; the bottom is rough and some smaller cones appear. Magnetic data evidence an intense positive magnetic anomaly with a NW-SE trend. NW of the top we found the highest positive anomaly of the area (> 2500 nT).

We occupied 6 stations (11,12,13,14,15,16): (a) around the main top and to the NW we recovered fresh vesicular aphyric and Cpx-Ol-Pl phyric basalts, with traces of post-eruptive oxidation, and (b) on the lateral reliefs we recovered Cpx-Ol-Pl phyric and aphyric basalts covered by Fe-Mn crusts fragments. We tried an heat-flow station (HF04) in the caldera, and recovered fresh glassy basalts from the corer. Figure 9 shows the investigated area.

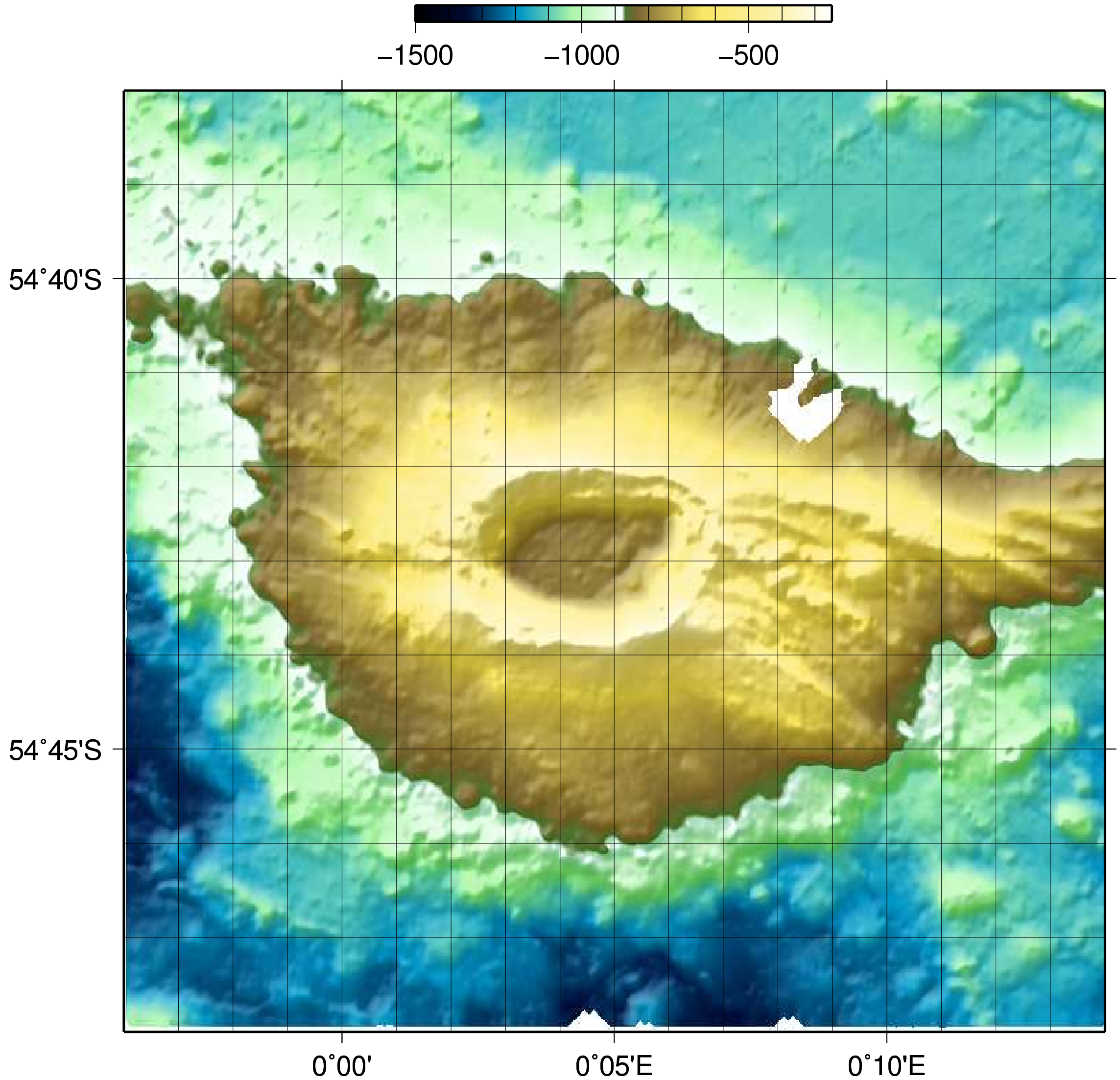

Figure 9: The Spiess Seamount bathymetry.

4.3 AREA SW SPIESS

Morphobathymetric data showed interesting structure. South of 54 45'S average depth deepens to 2500-3000 m to form a depression with rough morphology. Highest relief (1400 m) is located WSW of Spiess. From its northern flanks (10) we recovered olivine basalts, Cpx-Ol-Pl phyric and vesicular aphyric basalts.

The southern part of this area is characterized by troughs that surround a triangular relief 2200 m high. The northern flank of this relief was sampled (20,21), alongwith the walls of the eastern trough. We found slightly altered Cpx-Ol-Pl phyric and aphyric basalts covered by Fe-Mn crust. Magnetic anomalies are negative for both the reliefs.

4.4 AREA NORTH OF BOUVET FZ

A very rough morphology with main features oriented E-W was evidenced. We dredged two reliefs E of Spiess. In the Northern one (17) we sampled hydrothermally altered basalts with chlorite, calcite, quartz, sulphides, some of them tectonized. The station on southernmost relief (18) revealed the presence of slightly altered Cpx-Ol-Pl phyric and aphyric basalts covered by Fe-Mn crusts. A complex magnetic anomaly pattern is probably due to strong tectonics.

4.5 AREA SOUTH OF BOUVET FZ

A broad depression area is located S of the western tip of Bouvet F.Z., whose northern slope is formed by an EW topographic high, with a negative magnetic anomaly centered on the top. The western slope of the depression is characterized by an arcuated relief. Sampling of the two structures (22, 23) recovered slightly altered Cpx-Ol-Pl phyric and aphyric basalts covered by Fe-Mn crust. We also did an Heat Flow station (HF05) at a depth of 3270 m and the associated core recovered sandy clay intercaled with diatomitic sediments.

4.6 SHONA SEAMOUNT

We did a high resolution bathymetric survey of the seamount, that rise from 3100 m to 950 m at the top. The complex is formed by a central cone and by two smaller edifices to the south. The westernmost edifice has the shape of a collapsed caldera. On the eastern flank of the volcano a small cone 200 m high was found.

Two dredges (8, 9) were collected on the southern slope of main cone and on the northern scarp of southern cone. We recovered altered mostly aphyric basalts and dolerites with chlorite, and rather fresh vesicular Ol-Cpx-Pl phyric basalts. An Heat Flow (HF01) station was performed in a flat area south of the main cone. From Shona seamount we moved NE toward MAR. Another Heat Flow station (HF02) was done at a depth of 2640 m, slightly NE of Shona. The gravity core recovered diatomitic layers interbedded with levels of volcanoclastic sediments. Gravity and magnetic data in the transect to the MAR revealed a very interesting pattern of high frequency anomalies.

Figure 10 shows the investigated area.

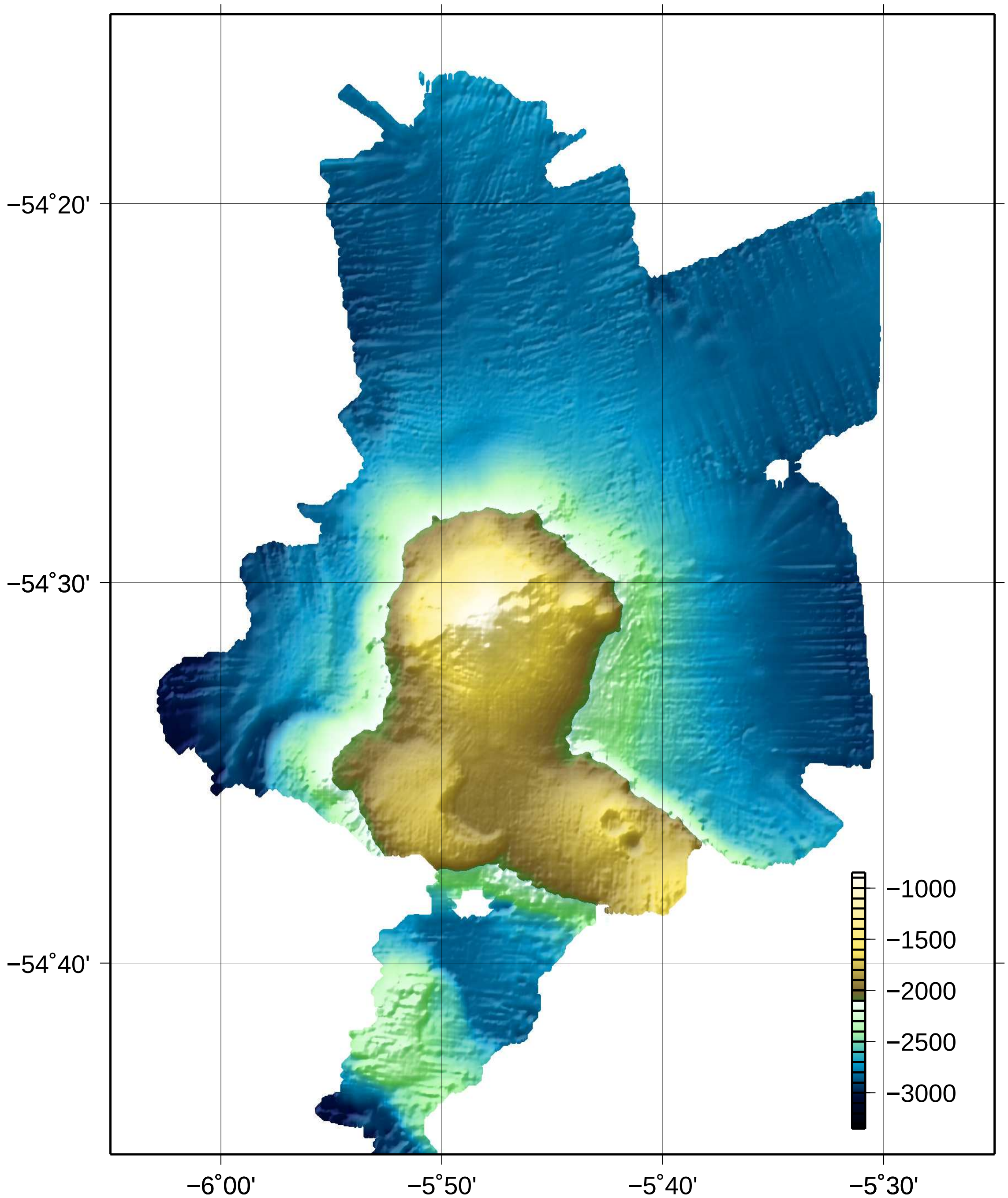

Figure 10: The Shona Seamount bathymetry.

4.7 MID ATLANTIC RIDGE BETWEEN 53 20'S AND 54 15'S

Magnetic and multibeam surveys provided the location of ridge axis, that appears to be offset to the W at latitude 54 00'S and 53 30'S. The resulting full spreading rate (Cande and Kent, 1992 time scale) ranges from 2.4 cm/yr to 3.3 cm/yr.

Three stations (24, 25, 26) were sampled in the neovolcanic zone. The southern one recovered fresh Cpx-Ol-Pl phyric basalts. In the mid one we obtained (Pl)-Ol phyric basalts. In the northern one we collected glomero (Cpx)-Ol-Pl porphyric basalts from a beautiful big fresh lava burr.

4.8 HEAT FLOW

Table 8 shows the data obtained on the HF stations.

STATION	q (mv/m^2)
HF-01	116
HF-02	49
HF-03	89.1
HF-04	>430
HF-05	293

Table 8: Heat flow data results.Station HF-04 (Spiess Caldera) had no penetration. Heat flow values calculated using near bottom water temperature gradient (λ_{wb}) and effective thermal conductivity ($\lambda_{eff\ w}$.

5 CONCLUSIONS

During a 39 days (of total 63 including transits) cruise in the Southern Atlantic Ocean we obtained:

- medium to high resolution swath bathymetry data of the Bouvet and Conrad FZ and of the Southern tips of MAR; figure 11 shows the compilation of bathymetric data from the two cruises of 1994 and 1996,
- magnetometric and gravity data,
- rock samples of the Bouvet and Conrad FZ and MAR.

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.

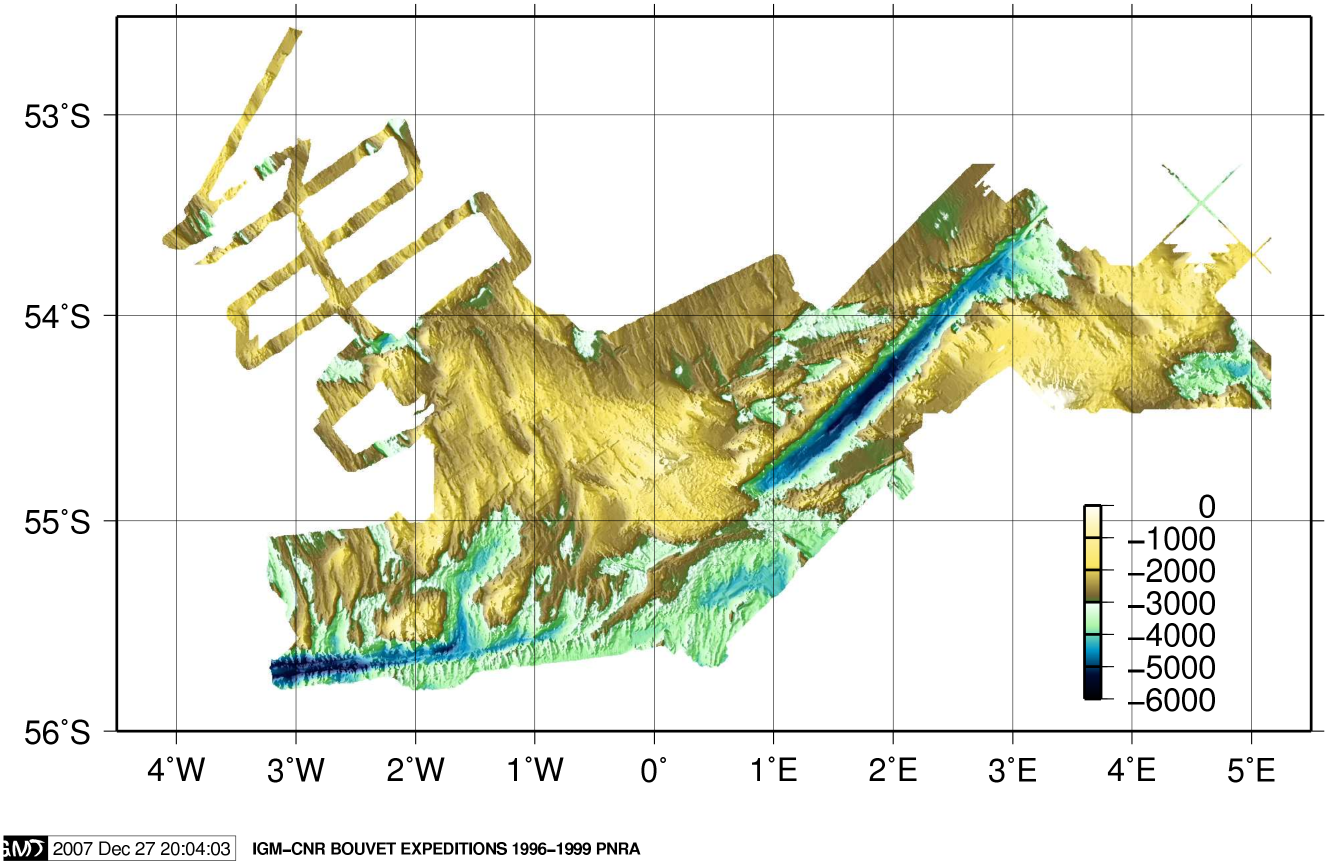

Figure 11: Compilation of bathymetric data from Cruises S18 (*R/V A.N.Strakhov*) and G96 (*R/V Gelendzhik*).

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6 APPENDIX

DIARY OF OPERATIONS

- 04/03/1996 Departure of Italian Team with three members of R/V Gelendzhik surveyor team from Bologna (Italy).
- 05/03/1996 14.00 Arrive at Durban Airport, 15.00 on board of R/V Gelendzhik.
- 06/03/1996 Gravimeter calibration
- 07/03/1996 Bunkering, provisions and gravimeter calibration. 19.00 Departure from Durban for operation area.
- 08-14/03/96 Transit to operation area. Check and control of instrumentation. Hardware and software upgrade of computer center.
- 14/03/1996 17:20 Start of multibeam line 0001. Sound velocity profile calculated from Levitus database. Bad sea state. 19:40 Italian and russian magnetometers on. 22:40 Very bad sea state. Acquisition problems on Italian magnetometers. Probable cable disconnection.
- 15/03/1996 Reached planned point 1 (51 31.8'S, 5 25.18'E). Italian 1st magnetometer recovered. 2nd lost. Repair and start of sigle magnetometer survey (offset 330 m from GPS antenna). Magnetometer, gravimeter and multibeam profiling.
- 16/03/1996 Magnetometer, gravimeter and multibeam profiling. Sound velocity profiles SVP1, SVP2. 19:00 Icebergs (54 57'S 12 76'W).
- 17/03/1996 07:40 Magnetometer, gravimeter and multibeam profiling. Italian magnetometer offset 365 m from GPS Antenna 20:52 Sound velocity profile SVP3.
- 18/03/1996 Dredge G96-01 Magnetometer, gravimeter and multibeam profiling. Dredge G96-02.
- 19/03/1996 Dredge G96-03 09:11 Magnetometer, gravimeter and multibeam profiling.
- 20/03/1996 Magnetometer, gravimeter and multibeam profiling. Very disturbed acquisition.
- 21/03/1996 Magnetometer, gravimeter and multibeam profiling. Bad weather conditions.
- 22/03/1996 Magnetometer, gravimeter and multibeam profiling. Bad weather conditions. Dredge G96-04.
- 23/03/1996 Dredge G96-05. Magnetometer, gravimeter and multibeam profiling.
- 24/03/1996 Magnetometer, gravimeter and multibeam profiling. Bad weather conditions.
- 25/03/1996 From 3.00 to 22.52 stand by meteo. Magnetometer, gravimeter and multibeam profiling. Bad weather conditions.
- 26/03/1996 Magnetometer, gravimeter and multibeam profiling. Bad weather conditions. Dredge G96-06 Dredge G96-07. Dredge lost.

- 27/03/1996 Magnetometer, gravimeter and multibeam profiling. Bad weather conditions.
- 28/03/1996 Magnetometer, gravimeter and multibeam profiling. Sound velocity profile SVP4.
- 29/03/1996 Start of Shona SMT survey. Magnetometer, gravimeter and multibeam profiling. Bad weather conditions.
- 30/03/1996 Magnetometer, gravimeter and multibeam profiling. Strong wind. Dredge G96-08. Heat Flow 01. Dredge G96-09. Sound velocity SVP5.
- 31/03/1996 Start of MAR survey. Magnetometer, gravimeter and multibeam profiling. Bad weather conditions. Heat Flow 02.
- 01/04/1996 Start of Spiess survey. Magnetometer, gravimeter and multibeam profiling. Bad weather conditions. Heat Flow 03.
- 02-03/04/1996 Magnetometer, gravimeter and multibeam profiling. Bad weather conditions.
- 04-08/04/1996 Start of Bouvet F.Z. survey. Magnetometer, gravimeter and multibeam profiling.
- 09/04/1996 Magnetometer, gravimeter and multibeam profiling. Bad weather condition.
- 10/04/1996 Magnetometer, gravimeter and multibeam profiling. Bad weather condition 17:18 Multibeam Stand by Meteo, 55 11,57'S 0 16,06'W. Italian magnetometer OK.
- 11/04/1996 18:21 End of Stand by Meteo. Magnetometer, gravimeter and multibeam profiling. Bad weather condition.
- 12/04/1996 Magnetometer, gravimeter and multibeam profiling. Dredge G96-10. Heat Flow 04.
- 13/04/1996 Magnetometer, gravimeter and multibeam profiling. Dredges G96-11, 12, 13, 14, 15, 16.
- 14/04/1996 Magnetometer, gravimeter and multibeam profiling. Dredges G96-17,18. Sound Velocity station SVP6.
- 15 -16/04/1996 Magnetometer, gravimeter and multibeam profiling.
- 17/04/1996 Magnetometer, gravimeter and multibeam profiling. Heat Flow 05. Dredges G96-19, 20, 21.
- 18/04/1996 Magnetometer, gravimeter and multibeam profiling. Dredges G96-22, 23. 17:33 Multibeam Stand by Meteo.
- 19/04/1996 Stand by Meteo, sea state 12.
- 20/04/1996 18:34 End of Stand by Meteo. Magnetometer, gravimeter and multibeam profiling. Bad weather condition.
- 21/04/1996 Magnetometer, gravimeter and multibeam profiling. Dredge G96-24.
- 22/04/1996 Magnetometer, gravimeter and multibeam profiling. Dredge G96-25, 26.
- 23/04/1996 Magnetometer, gravimeter and multibeam profiling. Big iceberg detected on radar. 05:47 End of survey (52 33,90'S 3 00'W). 08.30 Transit to Abidjan
- 24/04- 01/05/1996 Transit to Abidjan. Magnetometer and multibeam profiling.
- 04/05/1996 Bunker Port Gentil.
- 08/05/1996 Arrive in Abidjan.
- 09/05/1996 Gravimeter calibration.
- 10/05/1996 End Cruise.