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PREUSSAG
Meerestechnik/Marine Technology

SO 32

GARIMAS 1

GALAPAGOS RIFT MASSIVE SULFIDES

CRUISE REPORT

1.3.1985

PREUSSAG MEERESTECHNIK

GARIMAS 1

GALAPAGOS RIFT MASSIVE SULPHIDES

CRUISE 32 OF MS SONNE

09.05. - 09.07.1984

CRUISE REPORT

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HANNOVER, 15.1.1985

CONTENTS

PAGE

SUMMARY

GARIMAS 1 (Galapagos Rift Massive Sulphides) is the name of the 32nd research cruise of R/V Sonne. The operation started in San Cristobal, Panama, on May 9th and ended in Balboa, Panama on July 9th, 1984. The purpose of GARIMAS 1 was the collection of data and material concerning metallogenesis along the Galapagos Rift spreading centre between 85 and 95°W.

Using Seabeam, narrow-beam echo sounder and subbottom profiler the position of the rift axis was determined in order to examine this zone by visual sea floor observations. Some more important sections were charted entirely. 96 TV profiles and 64 photo stations totalling 22,000 photographs allowed the explanation of the morphological structures, the estimate of the relative age, the recognition of the benthos coverage and the discovery of hydrothermally active places. 16 multisonde measurements including water sampling and 16 sediment sampling stations using the Reineck corer served for the development of geochemical exploration methods.

During 53 dredge stations and 29 stations using the newly developed electro-hydraulic TV-grab, about 5 tons of rock could be recovered including one ton of massive sulphides from two different location.

ZUSAMMENFASSUNG

GARIMAS 1 (Galapagos-Rift, Massivsulfide) war die 32. Forschungsfahrt der "Sonne". Sie begann am 09.05.1984 in San Cristobal, Panama und endete am 09.07.1984 in Balboa, Panama.

Zweck von GARIMAS 1 war die Sammlung von Daten und Material zur Metallogese entlang der Krustenakkretionszone des Galapagos-Rifts zwischen 85 und 95°W.

Mittels Seabeam-, Schelfrandlot- und Sedimentechograph-Profilen wurde die Lage der Achse soweit eingegrenzt, daß gezielte visuelle Bodenbeobachtungen in diesem Bereich durchgeführt werden konnten. Besonders wichtige Teilgebiete wurden flächendeckend kartiert. 96 Fernsehprofile und 64 Fotoserien mit zusammen 22 000 Aufnahmen ermöglichten die Deutung der morphologischen Strukturen, die Abschätzung des relativen Alters, die Erkennung der Benthos-Besiedelung und die Auffindung von hydrothermal aktiven Bereichen. 16 Multisondenmessungen mit Wasserprobenahmen und 16 Sedimentprobenahmen mit dem Kastengreifer dienten der Entwicklung geochemischer Prospektionsmethoden.

Mittels 53 Dredschstationen und 29 Stationen mit dem neuen elektrohydraulischen TV-Greifer wurden etwa 5 t Gestein gefördert, darunter eine Tonne Massivsulfide von zwei Lokationen um 86°W.

1. INTRODUCTION

Cruise SO 32 named GARIMAS 1 (Galapagos Rift Massive Sulphides) is part of a major effort aimed at the understanding of metallogenetic processes active along the Galapagos Rift spreading centre and at the finding of economically interesting resources of the metals zinc, copper and silver.
Based upon previous work done within the scope of the geographically more extended project GEOMETEP (Geothermal Metallogenesis East Pacific) and on findings made by the American submarine "Alvin", GARIMAS 1 covers the axial portion of the total length of the Cocos/Nazca plate boundary between the Inca Fracture Zone and the De Steiguer Deep.
The work was carried out under authorizations issued by the Ecuadorian Ministerio de Recursos Naturales y Energeticos and by the Dirección General de Intereses Marítimos, Armada del Ecuador.
This report describes the cruise performance, the methods and equipment used, the places of investigation and first results.

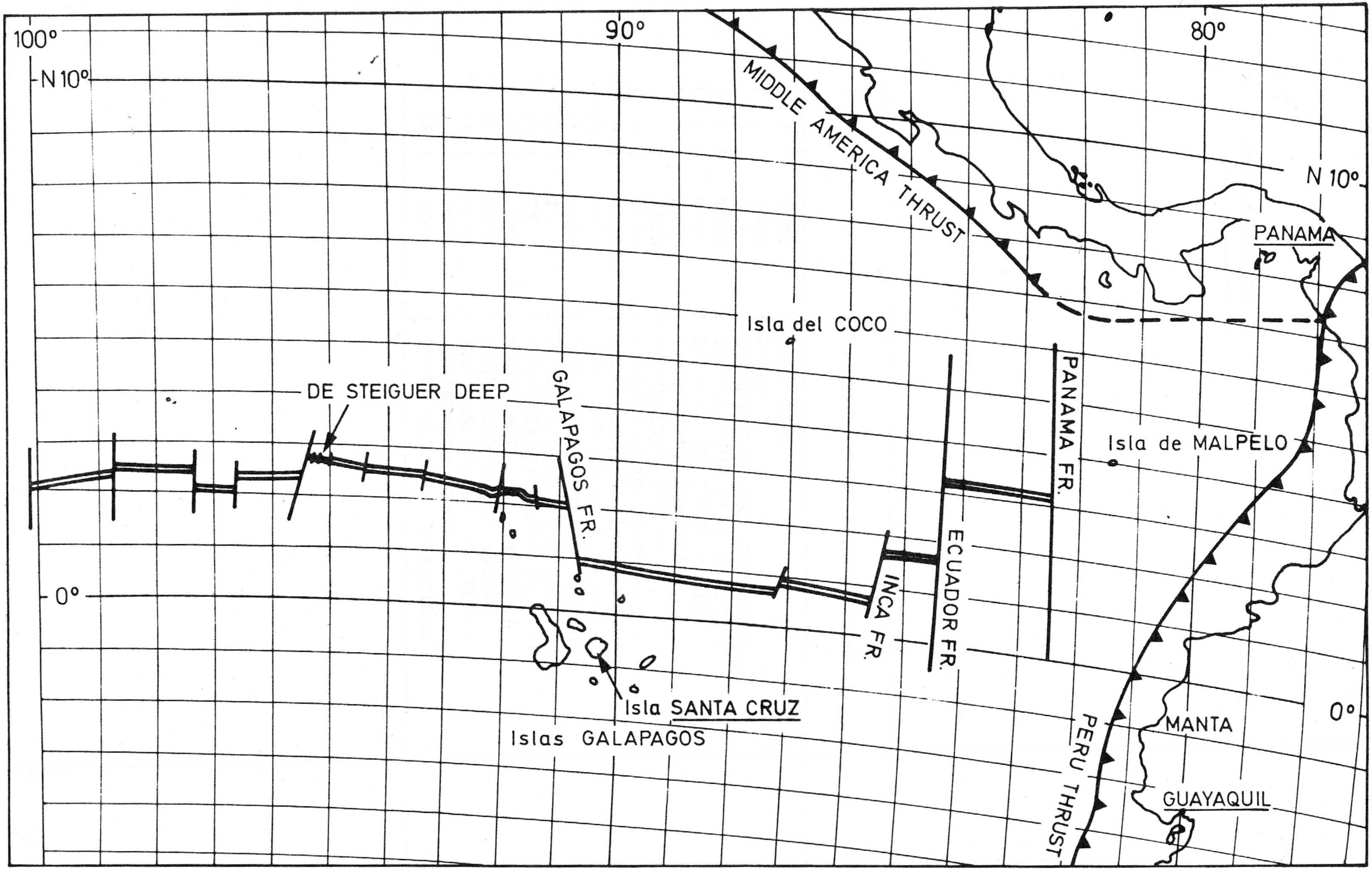

FIG. 1.1

THE EASTERN PART OF THE GALAPAGOS RIFT
WORKING AREA OF CRUISE GARIMAS 1
PORTS OF CALL ARE UNDERLINED

2. CRUISE STATISTICS

EXPLANATION OF ABBREVIATION

1	PORT	PORT TIME
2	TRAN	TRANSIT
3	SEE	STEAMING TO AND FROM PORT
4	TRAV	TRAVEL TIME BETW.STATIONS
5	NAV	NAVIGATION (INCL.BUOYS)
6	BATS	BATHYMETRY (SEABEAM)
7	BATN	BATHYMETRY (NBES)
8	CURR	CURRENT MEASUREMENTS(CS)
9	HYDR	HYDRO.STATION (MS,H,MS+H)
10	SEDI	SED. CORING (P,K,GK,GR)
11	SAMP	ROCK/SULF.SAMPL.(DC,DT,D)
12	TV	TV-MAP./SAMPL.(GTV,STV,TTP)
13	FS	PHOTOGRAPHIC MAPPING (FS)
14	FSMS	PHOTO.MAP./MS (FS+MS)
15	DTOW	SIDE-SCAN-SONAR (DTOW)
16	REP	REP. AND RECOV. OF EQUIP.
17	TEST	INSTRUMENT TESTS
18	OOP	OTHER OUTBORD OPERATIONS

METHODS	NO.	TOTAL TIME MIN.	(%)	MEAN	MINIMUM	MAXIMUM
PORT	5	6645	6.29	1329.00	698	1962
TRAN	5	16814	15.91	3362.80	45	11197
SEE	6	3819	3.61	636.50	93	2280
TRAV	78	4066	3.85	52.13	13	229
NAV	77	5809	5.50	75.44	6	565
BATS	90	23473	22.22	260.81	6	1381
BATN	7	9082	8.60	1297.43	404	2698
CURR	1	4	0.00	4.00	4	4
HYDR	14	1139	1.08	81.36	10	170
SEDI	15	1608	1.52	107.20	81	173
SAMP	51	7249	6.86	142.14	112	191
TV	32	6608	6.25	206.50	120	368
FS	66	15540	14.71	235.45	55	642
FSMS	1	248	0.23	248.00	248	248
DTOW	5	1116	1.06	223.20	87	342
REP	12	786	0.74	65.50	18	168
TEST	19	1491	1.41	78.47	18	233
OOP	1	163	0.15	163.00	163	163

METHODS	NO.	TOTAL TIME HOURS	(%)	MEAN	MINIMUM	MAXIMUM
PORT	5	110.00	6.29	22.15	11.00	32.00
TRAN	5	280.00	15.91	56.05	0.0	*****
SEE	6	63.00	3.61	10.61	1.00	38.00
TRAV	78	67.00	3.85	0.87	0.0	3.00
NAV	77	96.00	5.50	1.26	0.0	9.00
BATS	90	391.00	22.22	4.35	0.0	23.00
BATN	7	151.00	8.60	21.62	6.00	44.00
CURR	1	0.0	0.00	0.07	0.0	0.0
HYDR	14	18.00	1.08	1.36	0.0	2.00
SEDI	15	26.00	1.52	1.79	1.00	2.00
SAMP	51	120.00	6.86	2.37	1.00	3.00
TV	32	110.00	6.25	3.44	2.00	6.00
FS	66	259.00	14.71	3.92	0.0	10.00
FSMS	1	4.00	0.23	4.13	4.00	4.00
DTOW	5	18.00	1.06	3.72	1.00	5.00
REP	12	13.00	0.74	1.09	0.0	2.00
TEST	19	24.00	1.41	1.31	0.0	3.00
OOP	1	2.00	0.15	2.72	2.00	2.00

METHODS	NO.	TOTAL TIME DAYS	(%)	MEAN	MINIMUM	MAXIMUM
PORT	5	4.58	6.29	0.92	0.46	1.33
TRAN	5	11.67	15.91	2.34	0.0	7.75
SEE	6	2.63	3.61	0.44	0.04	1.58
TRAV	78	2.79	3.85	0.04	0.0	0.13
NAV	77	4.00	5.50	0.05	0.0	0.38
BATS	90	16.29	22.22	0.18	0.0	0.96
BATN	7	6.29	8.60	0.90	0.25	1.83
CURR	1	0.0	0.00	0.00	0.0	0.0
HYDR	14	0.75	1.08	0.06	0.0	0.08
SEDI	15	1.08	1.52	0.07	0.04	0.08
SAMP	51	5.00	6.86	0.10	0.04	0.13
TV	32	4.58	6.25	0.14	0.08	0.25
FS	66	10.79	14.71	0.16	0.0	0.42
FSMS	1	0.17	0.23	0.17	0.17	0.17
DTOW	5	0.75	1.06	0.15	0.04	0.21
REP	12	0.54	0.74	0.05	0.0	0.08
TEST	19	1.00	1.41	0.05	0.0	0.13
OOP	1	0.08	0.15	0.11	0.08	0.08

METHODS	APRIL SA 28	SU 29	MO 30	MAY TU 01	WE 02	TH 03	FR 04	SA 05	SU 06	MO 07	TU 08	WE 09	TH 10
PORT TIME													
TRANSIT													
STEAMING TO AND FROM PO													
TRAVEL TIME BETW.STATIO													
NAVIGATION (INCL.BUOYS)													
BATHYMETRY (SEABEAM)													
BATHYMETRY (NBES)													
CURRENT MEASUREMENTS(CS													
HYDRO.STATION (MS.H.MS+													
SED. CORING (P.K.GK.GR)													
ROCK/SULF.SAMPL.(DC.DT.													
TV-MAP./SAMPL.(GTV.STV.													
PHOTOGRAPHIC MAPPING (F													
PHOTO.MAP./MS (FS+MS)													
SIDE-SCAN-SONAR (DTOW)													
REP. AND RECOV. OF EQUI													
INSTRUMENT TESTS													
OTHER OUTBORD OPERATION													

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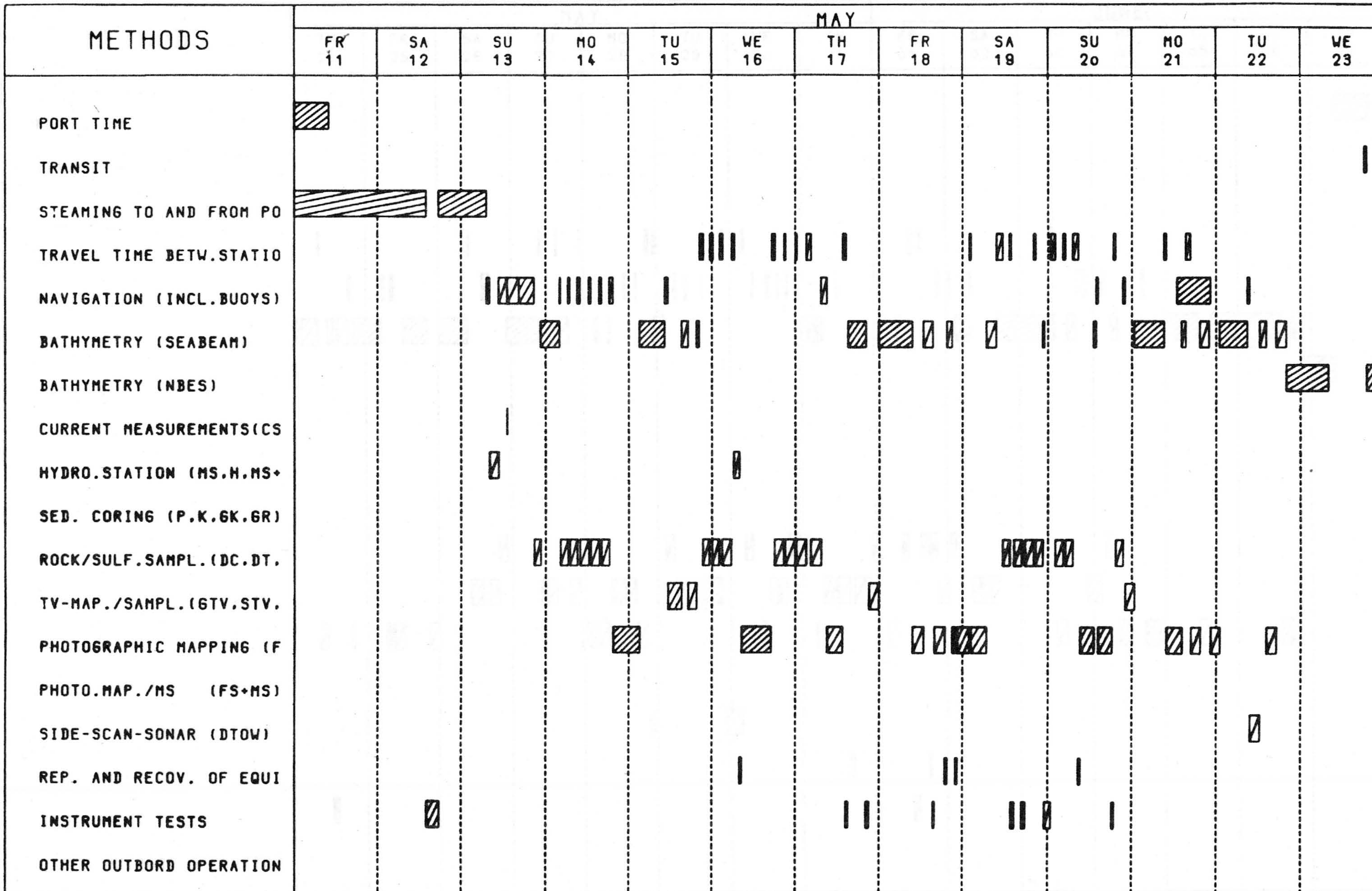
MARINE TECHNOLOGY

SO 32
GARIMAS 1



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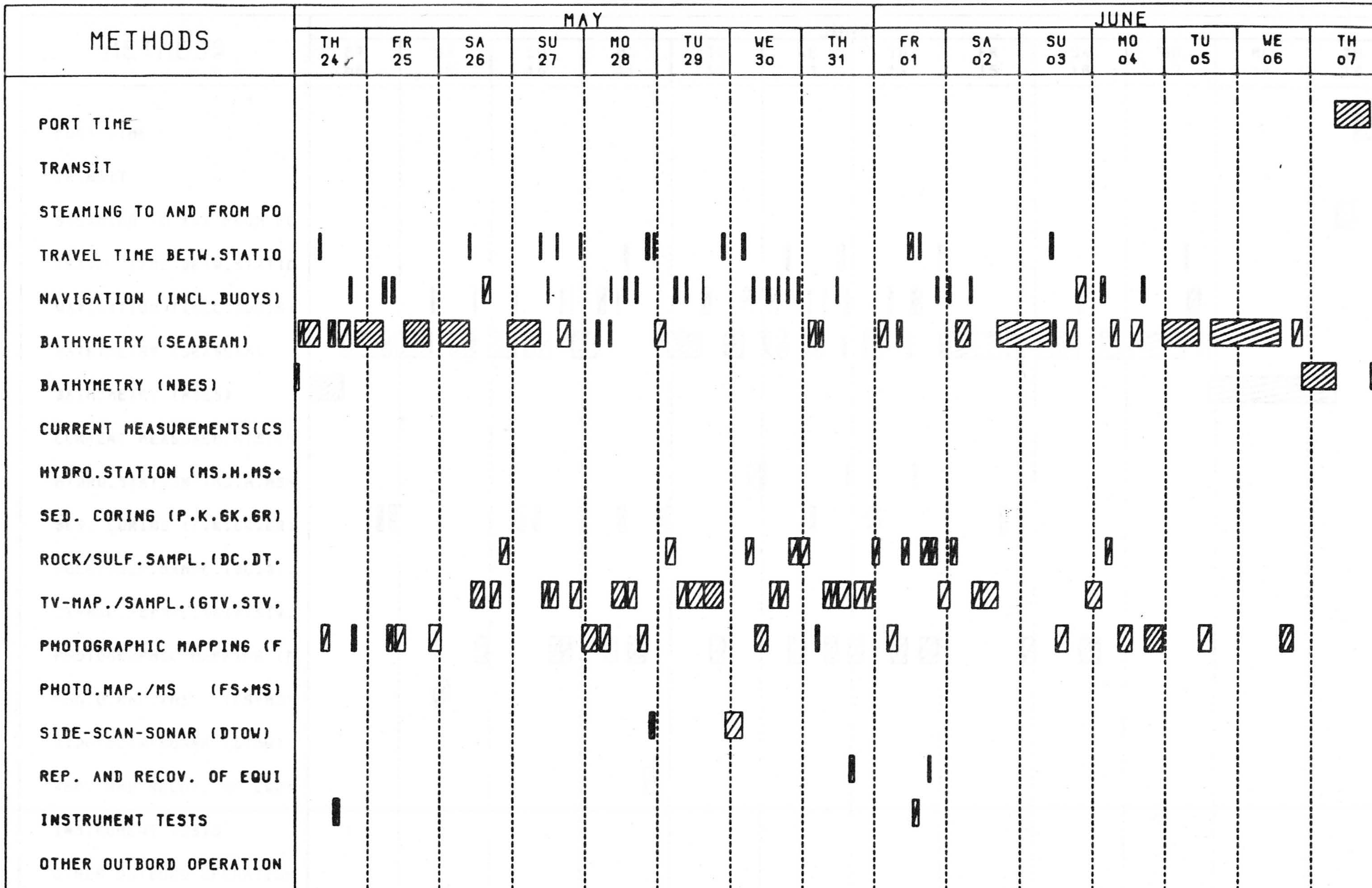
MARINE TECHNOLOGY

SO 32

GARIMAS 1



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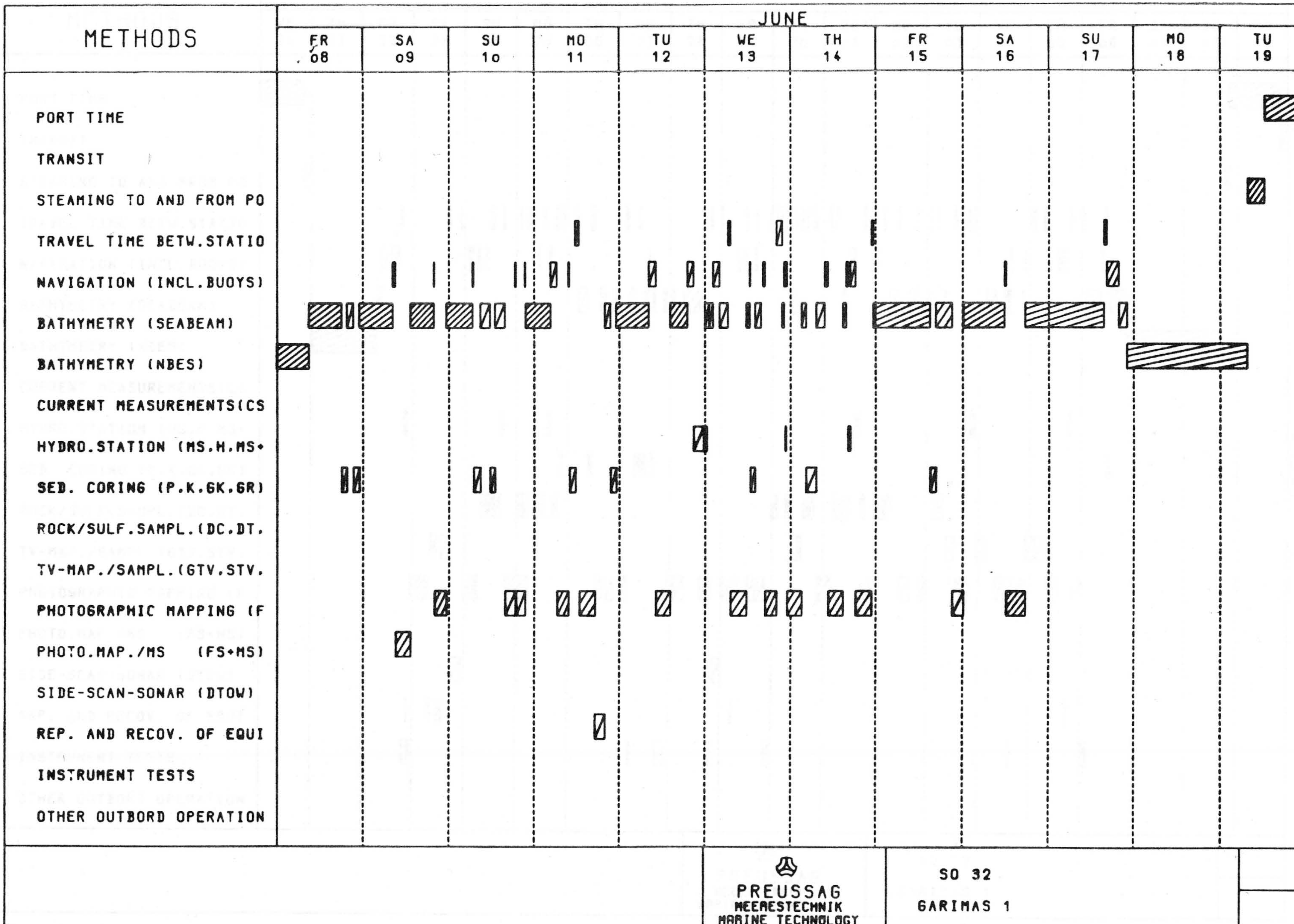
GARIMAS 1


METHODS
JUNE
FR 08
SA 09
SU 10
MO 11
TU 12
WE 13
TH 14
FR 15
SA 16
SU 17
MO 18
TU 19
PORT TIME
TRANSIT
STEAMING TO AND FROM PO
TRAVEL TIME BETW.STATIO
NAVIGATION (INCL.BUOYS)
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PREUSSAG
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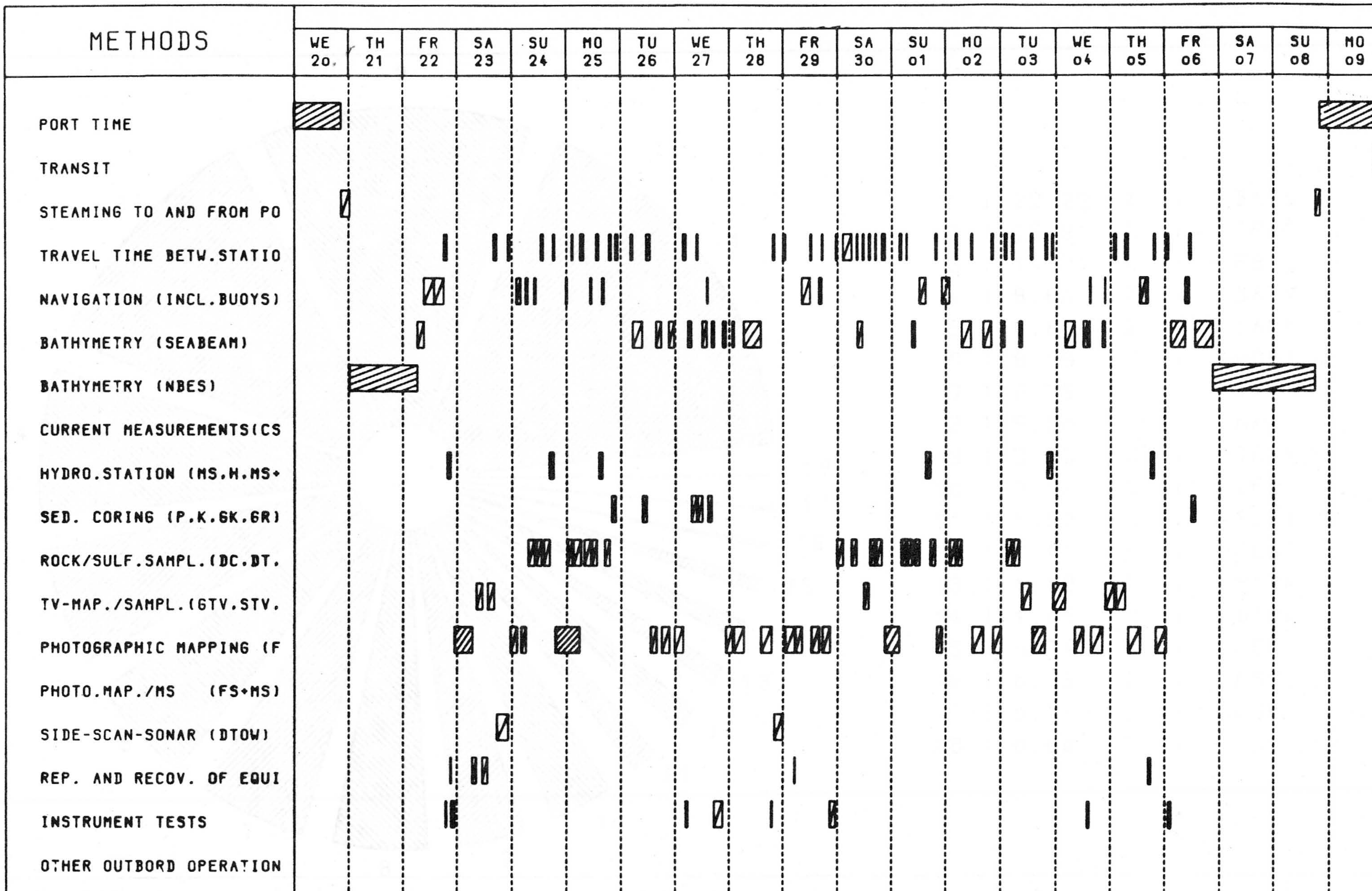
MARINE TECHNOLOGY
SO 32
GARIMAS 1



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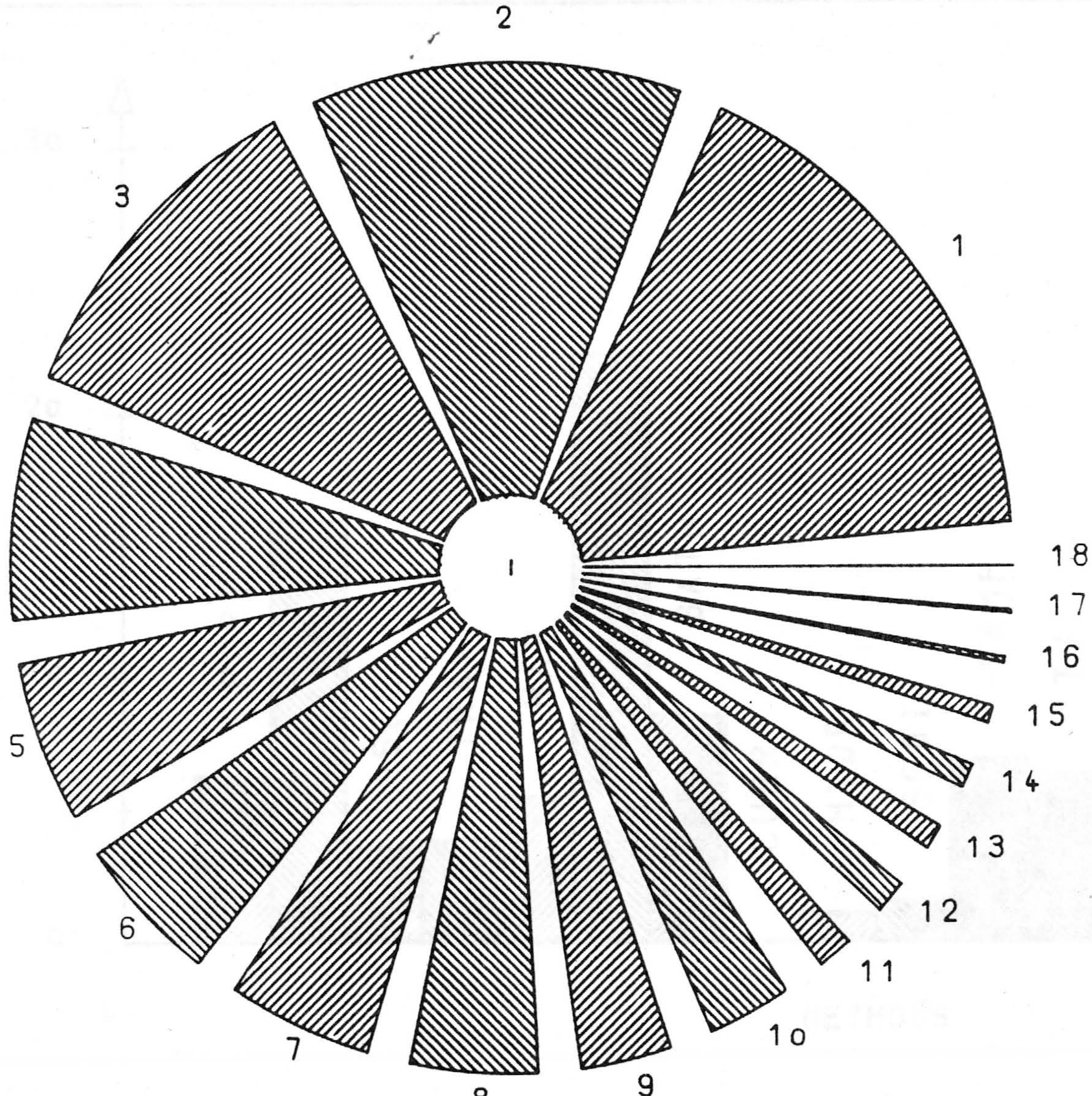
SO 32

GARIMAS 1



1)	22.22	%	:	BATS
2)	15.91	%	:	TRAN
3)	14.71	%	:	FS
4)	8.6o	%	:	BATN
5)	6.86	%	:	SAMP
6)	6.29	%	:	PORT
7)	6.25	%	:	TV
8)	5.5o	%	:	NAV
9)	3.85	%	:	TRAV
1o)	3.61	%	:	SEE
11)	1.52	%	:	SEDI
12)	1.41	%	:	TEST
13)	1.o8	%	:	HYDR
14)	1.o6	%	:	DTOW
15)	o.74	%	:	REP
16)	o.23	%	:	FSMS
17)	o.15	%	:	OOP
18)	o.oo	%	:	CURR

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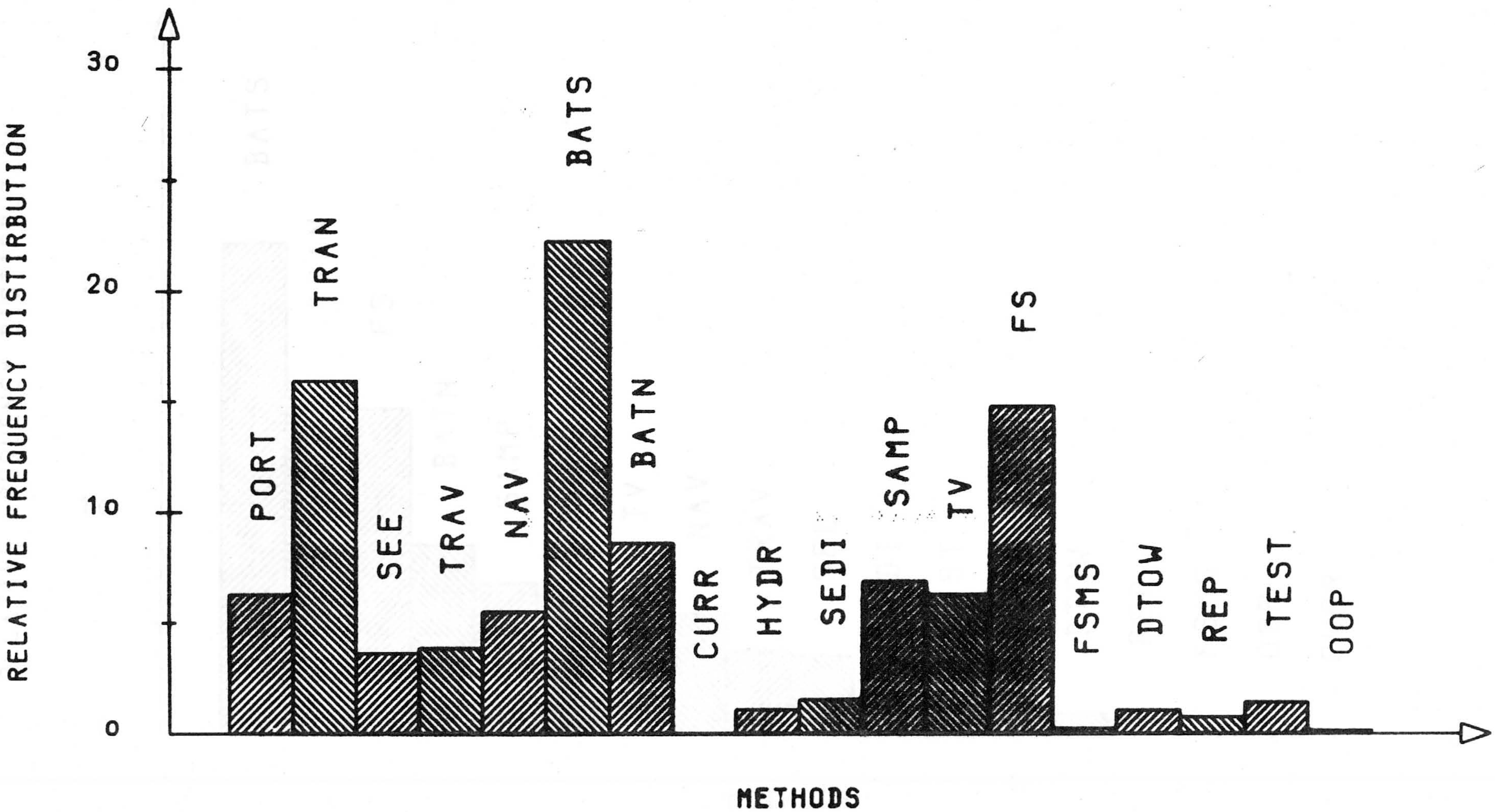

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GARIMAS 1

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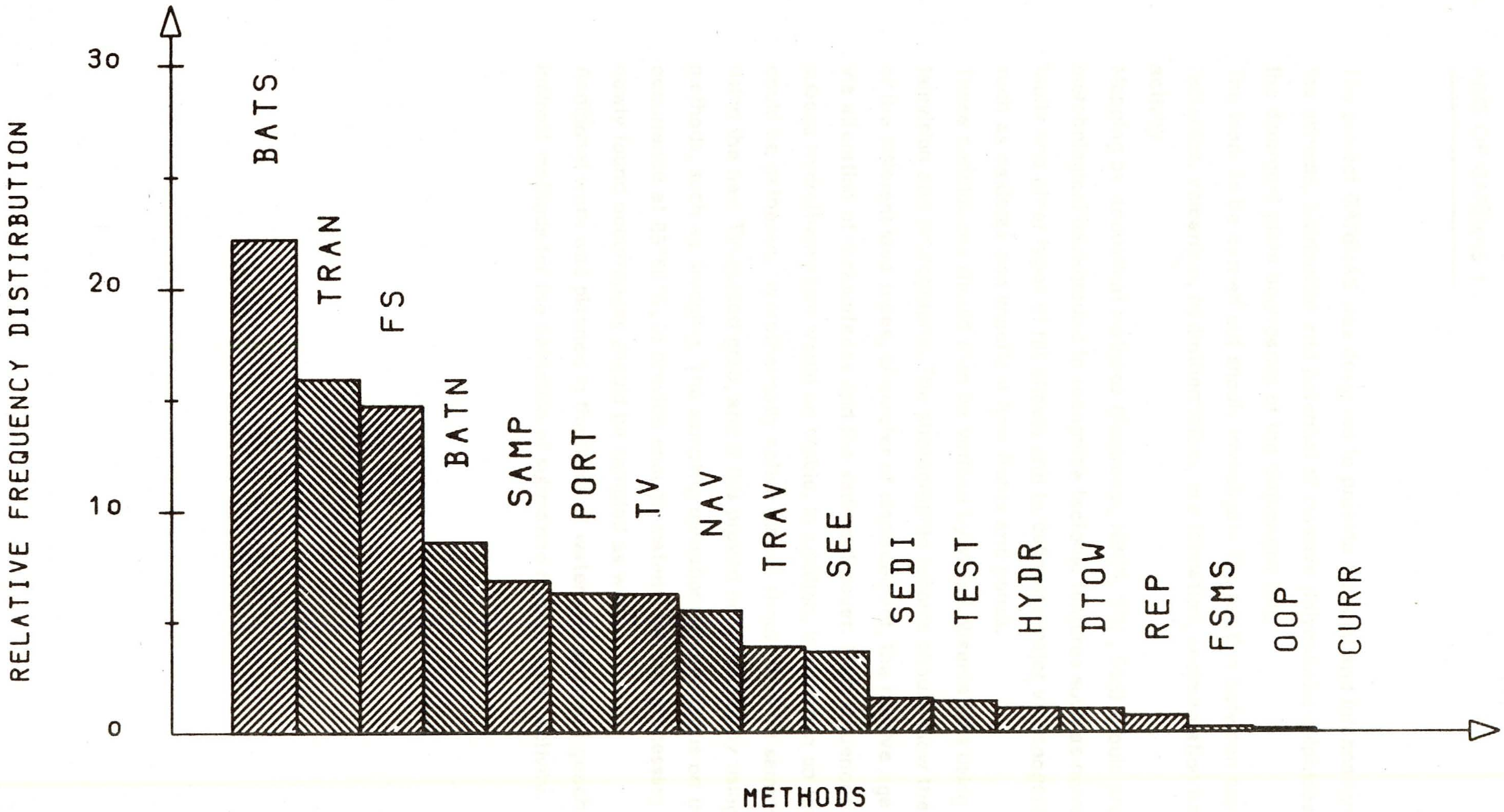

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MARINE TECHNOLOGY

SO 32
GARIMAS 1

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3. AIMS OF GARIMAS 1

The project GARIMAS was designed to provide material and information concerning the genesis, distribution and potential of massive polymetallic sulphides occurring along the divergent plate boundaries of the Galapagos Rift.
The work to be carried out should investigate the relation between sea floor spreading, tectonics, volcanism, hydrothermalism, ore formation, sedimentation and biological activity.
Mapping by acoustical methods (Seabeam, NBES, SBP, SSS) should provide the necessary morphological background to recognize tectonic features such as normal faults, transform faults and other types of rift offsets and to delineate major volcanogenic features, such as calderas and important flow fronts and ponds.
These conclusions should then be verified by visual observations using deepwater television and photography. The photographic records should allow the determination of the different lava types, character of displacement, the relative age of the seafloor via alteration of rocksurfaces and the sediment cover. Most influences caused by subsea hydrothermalism would be visible. In addition, information on faunal abundances could be gathered. Hydrothermally active places should then be sampled, preferentially using the new TV-guided grab, and if this proved not possible, by using more simple methods, such as dredging. The sampling operations should focus on the known sulphide occurrence at 85°50'W, to provide enough material for first processing tests. However, newly found occurrences should be sampled as well.
Additional work was planned in the fields of water and sediment geochemistry to develop indirect methods for the detection of submarine hydrothermal activity.

4. PARTICIPANTS

The participants of cruise GARIMAS 1 are subdivided into a group of 26 persons responsible for the ship and ship performance ("nautical crew") and a group of 18 to 20 persons responsible for the execution of the research programme.
The first group, headed by the captain (G. Müller until June 19, followed by H. Papenhagen) was provided by the ship's owner RF.
Most scientific and technical staff members belonged to Preussag.
Due to the innovative character of most of the technical operations emphasis was laid on a good technical representation, especially in the field of electronics. There was some exchange during the cruise, the first on June 7 being caused by a minor accident. The first leg was attended by two electronic engineers only to terminate the modification on some research equipment introduced during previous cruises.
There were representatives of the Instituto Oceanografico de la Armada (INOCAR) in Guayaquil and of the Dirección General de Geologia y Minas in Quito. One scientist of Hamburg University worked in the field of sediment and water geochemistry, one mineralogist of Heidelberg university carried out the shipboard chemical and mineralogical analyses.

PERSONNEL NAUTICAL CREW		
FUNCTION	1984	
	10.5.-19.6.	19.6.-
Master	Müller	Papenhagen
Ch. Mate	Oellerich	Müller
2nd Mate	Buse	Staak
R.O.	Stratmann	
Ch. Eng.	Sack	
2nd Eng.	Thaysen	
3rd Eng.	Kroehning	von Wieding
4th Eng.	Ruelke	
Electr.	Rademacher	
Electr.	Heygen	
Mot. man	Irion	
Mot. man	Rosemeyer	Leinemann
Mot. man	Priebe	
Mot. man	Jaeger	
1st Cook	Woch	Helwig
2nd Cook	Gruen	
1st Stew.	Ahlrichs	
2nd Stew.	Richter	
2nd Stew.	Tiedemann	
Boats w.	Gruendinger	
A.B.	Krummel	Jahns
A.B.	Peschkes	Olemann
A.B.	Zilinski	
A.B.	Hoedt	
A.B.	Lude	
A.B.	Seidel	

PERSONNEL SCIENTIFIC-TECHNICAL CREW

NAME	FUNCTION	INSTITUTION	1ST LEG 28.04.–09.05.	2ND LEG 10.05.–23.05.	3RD LEG 23.05.–07.06.	4TH LEG 07.06.–19.06.	5TH LEG 19.06.–09.07.
Bäcker, H.	Operation management	PREUSSAG		x	x	x	x
Lange, J.	Geology	PREUSSAG		x	x	x	x
Probst, U.	Geology	PREUSSAG		x	x	x	x
Post, J.	Oceanography	PREUSSAG		x	x	x	–
Lettau, J.	Geophysics	PREUSSAG		x	x	x	x
Wanninger, A.	Geophysics	PREUSSAG		x	x	x	x
Eilmes, K.D.	Mineralogy/Chemistry	UNI HEIDELBERG		x	x	x	–
Weber, G.	Photo-Geology	PREUSSAG		x	x	x	x
Meyer, W.	Electronics	PREUSSAG		x	x	x	–
Krueger, H.	Mechanics	PREUSSAG		x	x	x	x
Spoetter, M.	Mechanics	PREUSSAG		x	–	–	–
Bayer, F.	Geophysics	PREUSSAG		x	x	x	x
Voehrs, H.	Electronics	PREUSSAG		x	x	x	x
Keipke, D.	Electronics	PREUSSAG	x	x	x	x	–
Ziranek, P.	Electronics	PREUSSAG	x	x	x	x	x
Ergunalp, D.	Sample evaluation	PREUSSAG		x	x	–	–
Greger, B.	Mechanics	PREUSSAG		x	x	x	–
Heidbüchel, E.	Ship's Doctor	PREUSSAG CONTR.		x	x	x	x
von Minden, H.	Navigation	RF		x	x	x	x
Vossmer, O.	Electronics	PREUSSAG CONTR.			x	x	x
Tse, P.H.	Chemistry	UNI HAMBURG				x	x
Valencia, M.	Guest Ecuador	INOCAR				x	–
Stammer, K.	Electronics	PREUSSAG					x
Evers, G.	Mechanics	PREUSSAG					x
Leon, O.G.	Guest Ecuador	DGGM					x
Mazon, R.E.	Guest Ecuador	INOCAR					x

5. NARRATIVE

Since the first cruise of FS Sonne 1977 the ship was only once back in Germany to receive some additional modification. The passage of the ship, in March 1984, through the Mediterranean Sea was therefore used to receive new supply and to perform a number of tests of equipment to be used during GARIMAS 1 (VAX computer, TV grab, corer, deeptow, photo-TV sledge). During a storm, the deeptow was damaged, and two electronic engineers were therefore sent already to Punta Delgada, Azores, to start the repair work during transit to Panama. This passage took 11 days, from April 27 to May 9, when the ship arrived at 6 hrs in San Cristobal. The scientific-technical staff had already arrived during the night in Panama City, was brought by cars to San Cristobal and taken on board at noon. The following night R/V Sonne passed through the Panama Canal, and next day 480 tons of fuel were taken over in Balboa. This gave part of the crew the opportunity to have a look at the old town of Panama. At night, Sonne headed for the Galapagos Rift. On the way equipment and laboratories were prepared for the following operations. This concerned mainly the anchoring systems of the Atnav navigation, photo TV sledge, multisonde, water samplers, TV grab and the development machine. On May 12 multisonde and float packages for the Atnav transponders were tested.

On arrival in the working area near 86° on the Galapagos Rift a multisonde station for the calibration of the seabeam system was carried out. Subsequently 6 Atnav transponders were anchored and the system calibrated. One float package was furnished with an Anderaa current meter (results see figs. 11.6 and 11.7).

After a number of dredge stations (3 D to 8 D) the first TV-photo profile was carried out along the eastern part of the rift valley, yielding 726 photos most of them of good quality. The valley was found to be covered by pillow lavas with abundant protuberances and by bulbous sheet lava. On one photo an oxidated sulphide chimney was seen.

On May 5, on station SO 32 - 10 GTV, in presence of a crowd of curious scientists and technicians, the new TV-guided grab touched the floor of the Pacific Ocean for the first time. Closing of the grab functioned properly and 80 kg talus was recovered from the place where "Alvin" in 1980 had first located sulphides. This place was tabelled "Location A" or "Alvin site". Station 10 yielded only hydrothermally altered basalt and some weathered hydrothermal products with sulphide remains.

During the following stations, however, the "Alvin" find could be confirmed. The sulphides, at this place, align along two fault scarps which follow the southern slope of what appeared to be a central high between two rift valleys. Investigations of the southern valley showed, however, that this depression is not active any more. Unfortunately, during the next GTV station water penetrated through a damaged plug into the telemetric box of the grab which required long repair efforts. On station 21 (17.5.) location A was photographed in detail. Sulphides were found at the foot of an 60 m high escarpment. They were weathered, more or less displaced and mostly covered by sediments and talus.

Bottom operation in this environment appeared difficult because any tough stirred up the sediments and produced clouds.

To use the time necessary for the repair of the grab exploration on May 17 was extended towards the west for two days, making seabeam bathymetry and 2 photo - profiles.

On May 19 work at location A continued by positioning a dredge by use of an Atnav subtransponder into the sulfide field.

30 kg of sulphides could thus be recovered. The RFA analysis made on board by a student of the university of Heidelberg showed high iron (37%) and copper (15%) contents, but less than 0,3% of zinc. This seemed to confirm the published opinion that the Galapagos sulphides are copper-rich and poor in zinc. Later on, however, high-grade zinc ores could be recovered as well. The same day, another dredge yielded 60 kg of sulphides containing 44% Fe, but little base metals.

The work at location A continued until May 21 when an eye trouble of M. Spötter, one of the technicians, made an extra port call necessary. On the way to the island of Sta. Cruz additional profiles were made along the Galapagos Rift axis from 86 to 88°W. On May 23, at Academy Bay, the technician disembarked and was replaced by O. Vossmer.

Seabeam and photo-surveying of the Galapagos Rift continued from May 23 to May 26 when "Sonne" was back at Location A. Station 46 GTV on May 26 yielded the first 150 kg of sulphides sampled with the TV-grab after visual inspection.

The sample analysis revealed 0,2 - 2,5% Cu and 31 - 41% Fe, but low zinc contents. During the work at location A it turned out that certain morphological details could better be dissolved by the old narrow-beam echo sounder "Schelfrandlot" than by the modern Seabeam system. This is specially true for steep slopes and vertical displacements and the top of narrow mountain chains. Therefore an additional detail map was produced which covers the area of location A (profiles 66 and 67).

The work at and around location A continued until June 5, using the TV grab, the TV-photo sledge and the chain dredge as main tools. Some excursions to the west were made to supplement the existing bathymetric data. This charting work continued with profile 110 ff. on the second voyage to Sta. Cruz. In addition to the profiles in strike direction a number of cross-sections were produced which demonstrate the

zero-age zone of the Galapagos Rift north of the islands as an uplifted faulted block.
On June 7 Sonne was back in Academy Bay to collect boxes with spare parts. Three new scientists boarded, among them Dr. M. Valencia, the representative of INOCAR. Visits on Sonne were made by the harbour master and by the director of the Darwin Station, Dr. G. Reck and his colleagues.
From Sta. Cruz Sonne headed for the central portion of the Galapagos Rift at 91,5°W and then followed the spreading axis towards the west to the De Steiguer Deep. The axis, at 92°W was found at very shallow depth, around 1,700 m.
In addition to the programs carried out during legs one and two, a new geochemical program was introduced which involved Multisonde measurements in conjunction with water sampling and surface sediment sampling using a Reineck box corer.
Surprisingly, the new multiple water sampler attached to the multisonde worked immediately well. Towards the De Steiguer Deep the positive horst structure of the axial zone of the GR turns into a graben. On the way stations 91 to 98 were carried out, three of them photo profiles. The De Steiguer Deep, a deeply submerged basin near a spreading center offset which is regarded as a place for rift propagation into older seafloor, had already been mapped during the GEOMETEP cruises. Some indications pointed to metallogenesis, possibly in relation to the implacement of acidic differentiation rocks. The inspection of the apparent rift axis showed much talus, locally covered with hydrothermal products. There was also some benthos with hydrothermal affiliation. Further north from the axis in older terrain rock outcrops were photographed which seem to belong to the acidic volcanics.
Some profiles (172 - 177) were run at the southwestern margin of De Steiguer Deep to better recognize the continuation of the rift towards the triple junction.
On June 12 Sonne left the De Steiguer Deep to continue the exploration of the rift between 95,5° and 82°W. At 95° 2'W an axial volcano was found, the caldera of which is in 2,512 m water depth. A photo profile (no. 107) showed hydrothermal products on faults probably related to the construction of the volcanic cone.
An important site with hydrothermal activity was found on June 13, south of a manganese anomaly in seawater detected during cruise Geometep 3. The fresh rock outcrops on an axial volcano at 94°55' are covered with abundant yellowish hydrothermal products, and elements of the known hydrothermal fauna can be seen on many photos. Hydrothermal activity was also noted 5 miles further east.
To allow for a later systematic investigation a special Seabeam map was produced before leaving the place.
Subsequently the rift bathymetry (profiles 190 to 201) continued until an axial caldera volcano was found at 91°22'W. This feature showed an unusual rich benthos population, mainly composed of sponges, Gorgonarian and Pennacularian, but no sign of hydrothermalism was seen.

Passing the location A area on June 17 an additional transponder was launched to improve the Atnav navigation. On the same day Sonne headed for Guayaquil for the scheduled port call to exchange personnel and receive provisions and spares (19. to 20.6.). Two engineers, J. Stammer and G. Evers, introduced a second version of the TV grab.

INOCAR sent R.E. Mazon as their representative for the next cruise, the Direccion General de Geologia y Minas O. G. Leon Carrera. Sonne was back at location A on June 22.

Two transponders had to be exchanged because of two week signals. Consequently the system was re-calibrated. The same day, the multiple water sampler was damaged during recovery after the oceanographic station 121. There was lot of work for the technician, at the same time on Atnav, water sampler, 2 TV grabs, deeptow and photo sledge.

In addition to the continuing work at location A during leg 4 a new location further west was investigated. Here sulphide outcrops were photographed which belong to a number of more or less extinct hydrothermal fields. The new findings were called location B or Sonne site. The presence of certain elements of the known hydrothermal fauna suggests that there are still places with active hydrothermalism, contrarily to what was known from previous cruises. This was later confirmed when open fissures (gjas) were found the walls of which are covered with organisms which profit from the inflowing warm wate. Nearby large field of clams were found (Station 186). The first sulphides from location B were recovered when occupying station 139 on June 25. They showed the typical external chimney structures produced by the vent worm Alvinella.

Work at the locations A and B continued during the whole leg. Positioning of the ship and the towed instruments became more difficult when the Atnav navigation computer broke down and could not be repaired permanently.

The arriving Atnav ranges had to be hand-plotted into a chart constructed for the purpose. To improve the security a buoy was anchored west of location B on June 29, which carried a miniranger radio beacon. The buoy behaved well even in rough seas. On July 30 the ship was anchored by dredge no. 112, which could not be freed. Wire with dredge and pingers had to be cut off.

On July 4 the telemetric box of the TV grab was found flooded again. Additional troubles during the last days were caused by disturbances of the TV-signals in the winch.

So everybody was happy that the field work could be terminated on July 6 with the successful recovery of Atnav transponders and buoy.

Sonne reached Balboa on July 8 in the night and left next day for Honolulu. The two containers with equipment and samples were alreaoy packed during transit.

6. WORKING AREAS

The working areas of GARIMAS 2 are placed along the Galapagos Rift axis between the Inca Fracture Zone at 85°20' W and the De Steiguer Deep Fracture Zone at 95°35'W. The ship's track and bathymetric results are displayed in a number of single maps the extensions of which are indicated in figs. 6.1 and 6.2. Dependent on the variable extension of previous work the amount and character of the investigations carried out during cruise SO 32 was quite different in the different sections of the Galapagos Rift. All activities, however, were restricted to the neo-volcanic zone of the Rift up to about 15 miles from the axis, the exact position of which was determined during the cruise.

6.1 De Steiguer Deep Area

The De Steiguer Deep area (fig. 6.3) was visited during leg 4, June 10 to 13. The Deep which is believed to represent a propagating rift, has been charted already during the GEOMETEP program, and a bathymetric map 1:50.000 was available. The rift axis, in this area, follows the floor of a deep rifted valley (profile 179, fig. 6.4).
Main aims of the short excursion were the visual verfication by photo sledge stations of the exact position, nature and age of the rift axis and the inspection of an area north of the axis, where unusual rocks and indications of metallogenesis were found during previous cruises.
Some additional profiles (172-177) should locate the southwestern continuation of the rift.

6.2 Galapagos Rift 95°02' - 94°46' W

The Galapgos Rift east of the De Steiguer Deep (fig. 6.5) was visited twice during leg 4 (June 10 and June 12-15. The discovery, during GEOMETEP 3, of a manganese anomaly in seawater had induced a more detailed study of the area around 94°55'W which resulted in the production of a special map 1:20.000 and the discovery of hydrothermal products. Oceanographic, sediment sampling and photographic stations were carried out.
At 95°01' a circular seapeak was found within the axis (fig. 6.6, profiles 181 and 182).

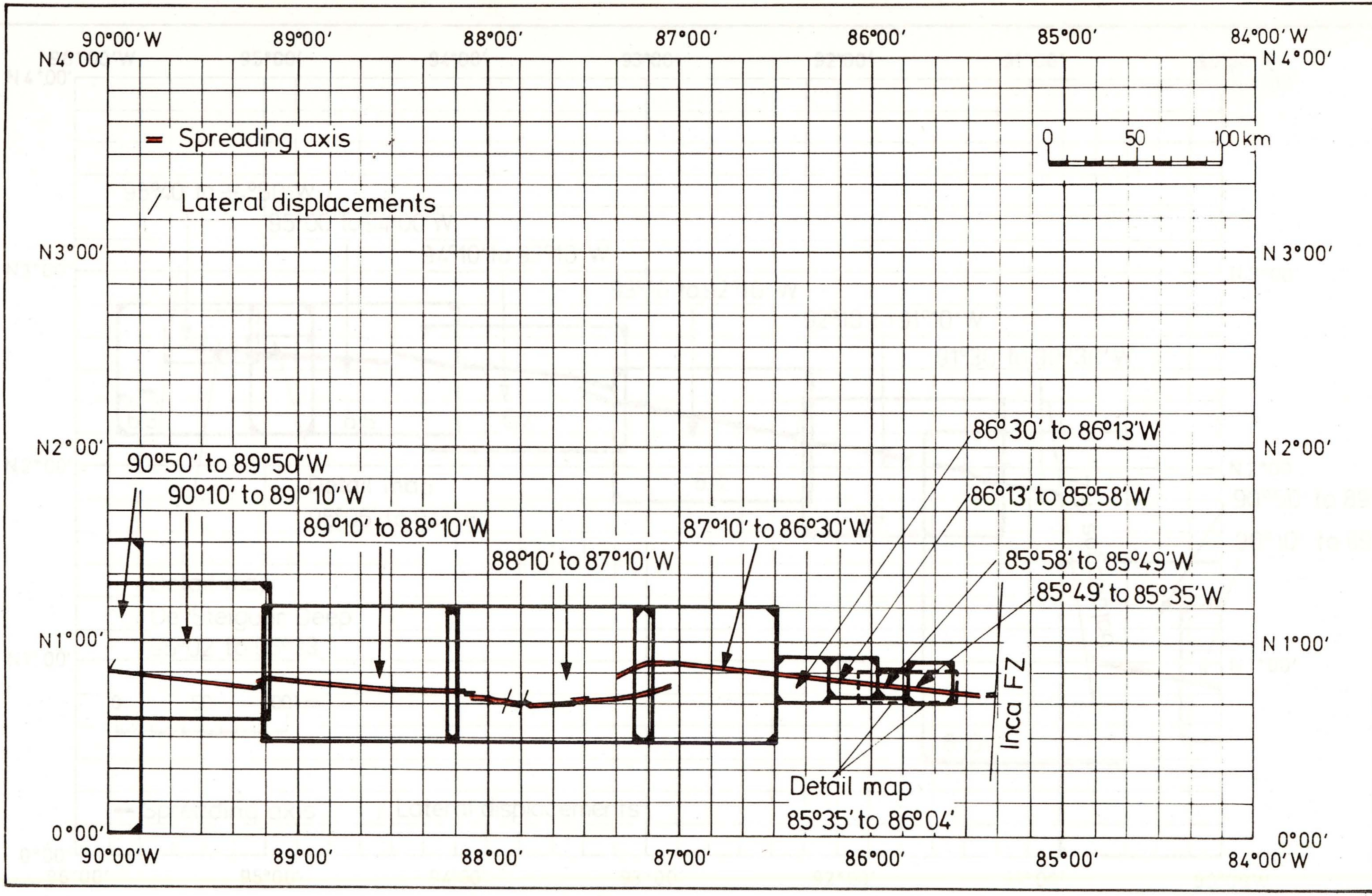


Fig. 6.1.

GARIMAS 1, Working areas Galapagos Rift 85 - 90° W
Boxes with solid lines overlook trackcharts, boxes with dashed lines detail bathymetric maps.

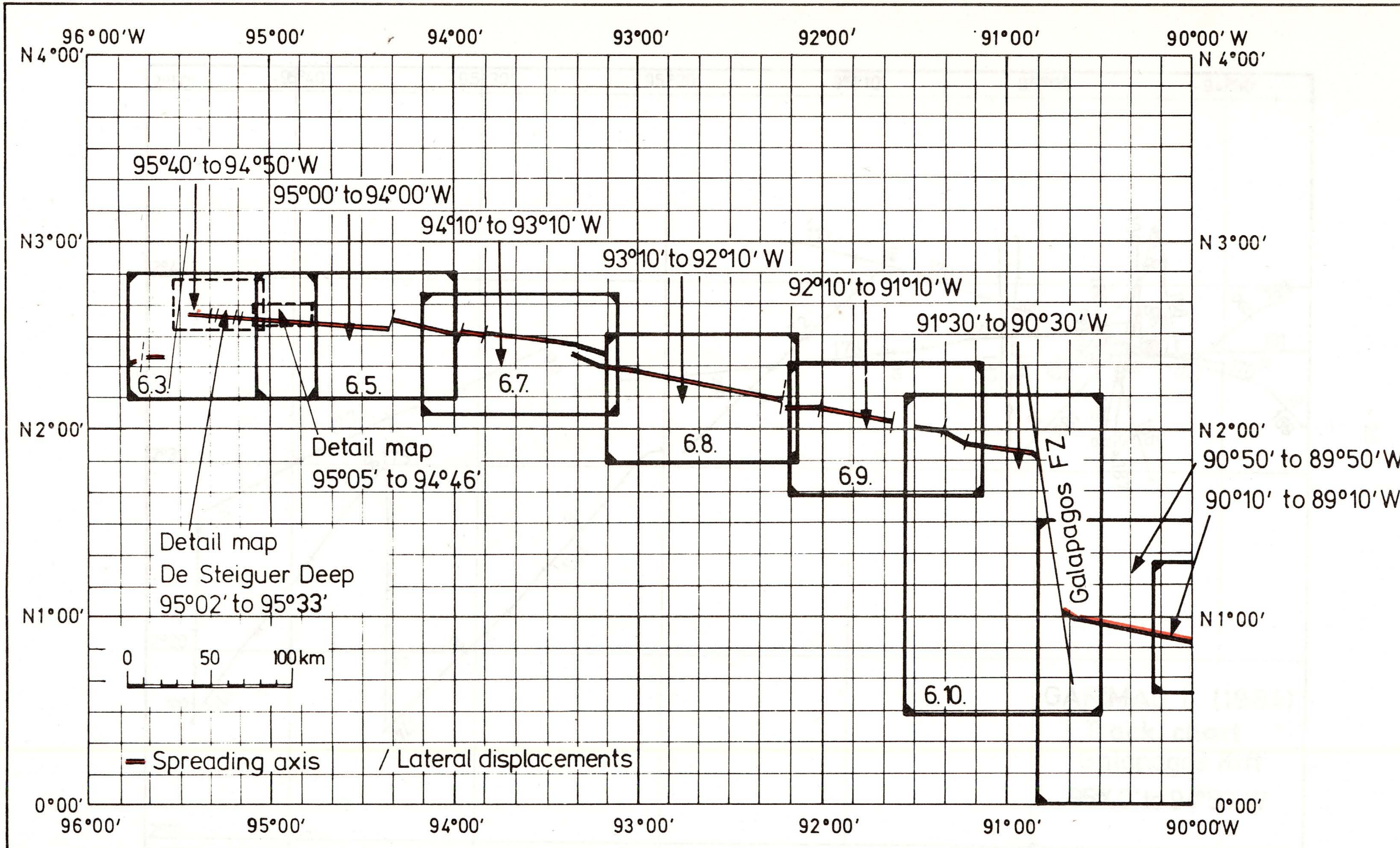


Fig. 6.2.

GARIMAS 1, Working areas Galapagos Rift 90 - 96° W.
Boxes with solid lines overlook trackcharts, boxes with dashed lines bathymetric maps.

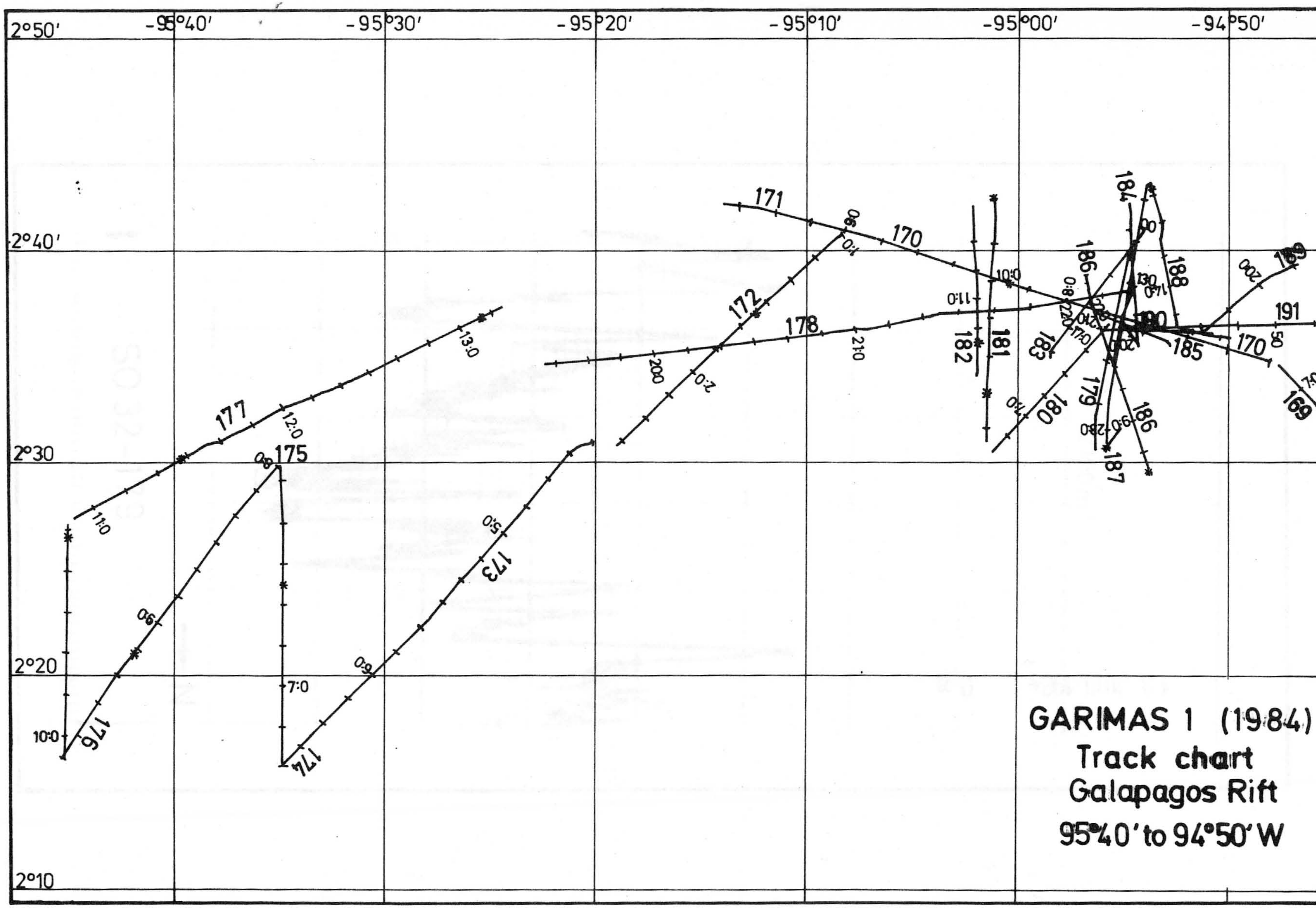

2°50'
-95°40'
-95°30'
-95°20'
-95°10'
-95°00'
-94°50'
2°40'
2°30
2°20
2°10
171
170
172
178
177
175
176
173
174
182
181
183
184
186
188
189
190
191
185
180
179
187
169
GARIMAS 1 (1984)
Track chart
Galapagos Rift
95°40' to 94°50' W

Fig. 6.3.

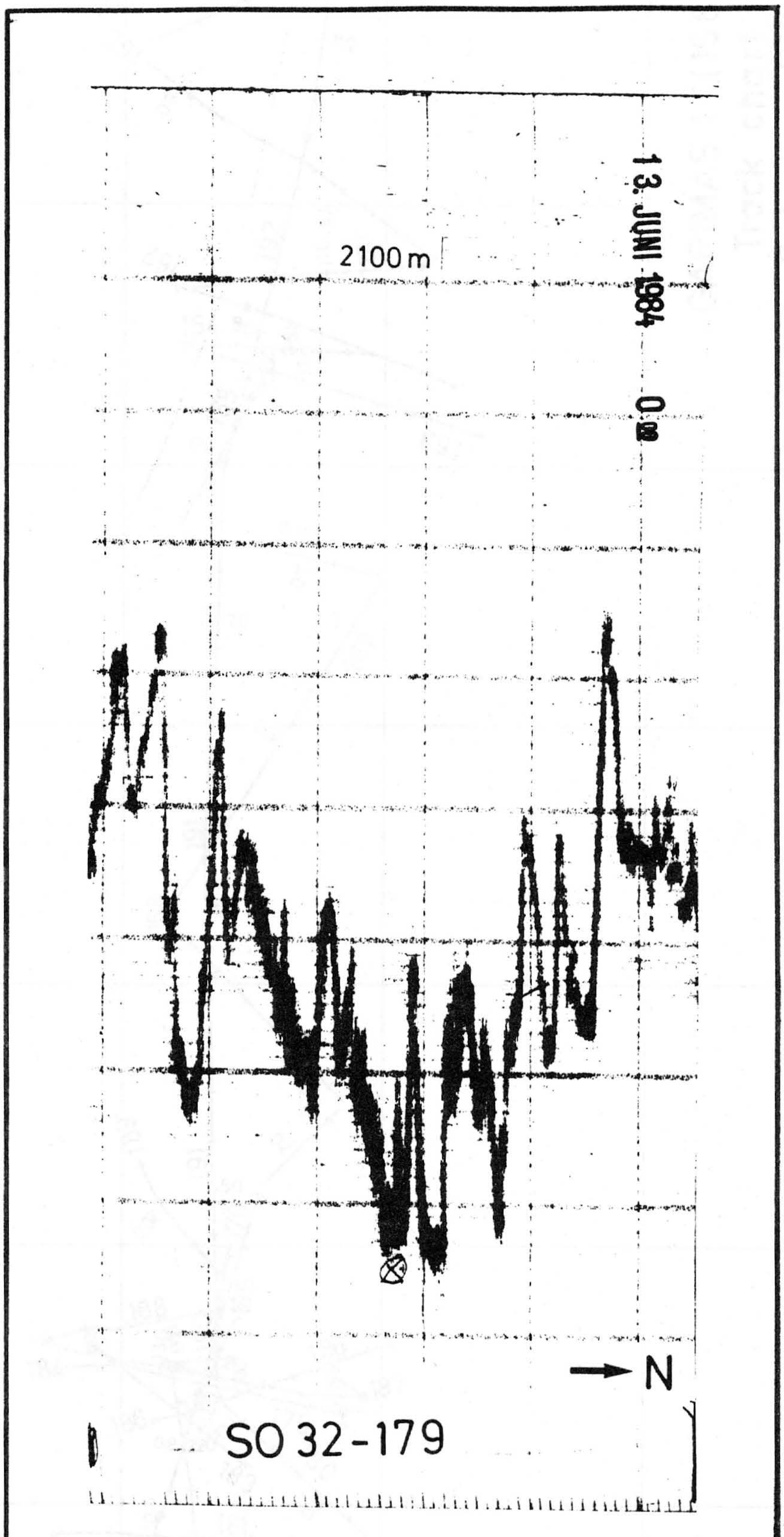


Fig. 6.4.

Bathymetric section across the rift axis in the De Steiguer Deep, at 94°55' W
NBES (Schelfrandlot) 20 khz

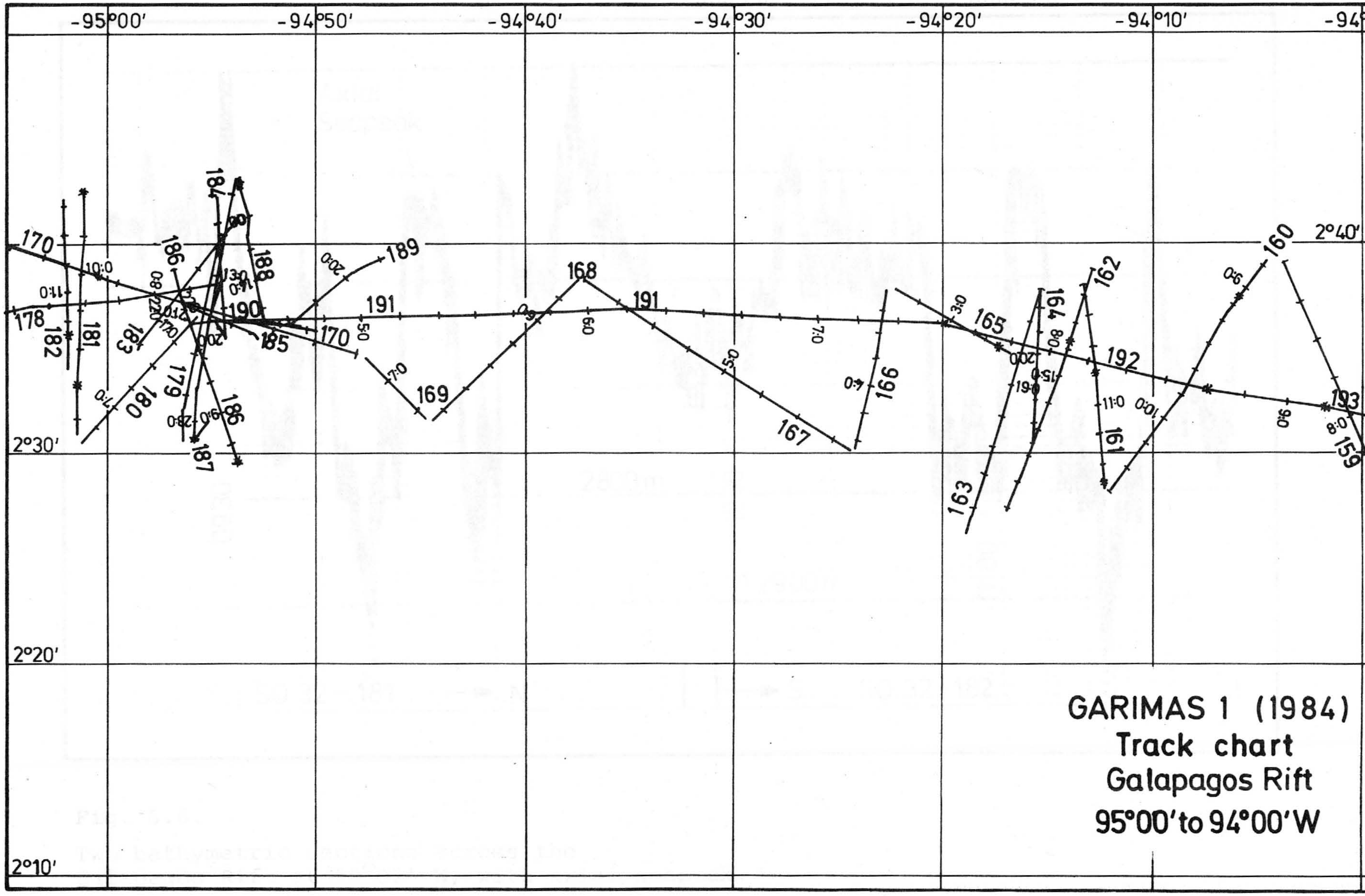

-95°00'
-94°50'
-94°40'
-94°30'
-94°20'
-94°10'
-94°0
2°40'
2°30'
2°20'
2°10'
GARIMAS 1 (1984)
Track chart
Galapagos Rift
95°00' to 94°00'W

Fig. 6.5.

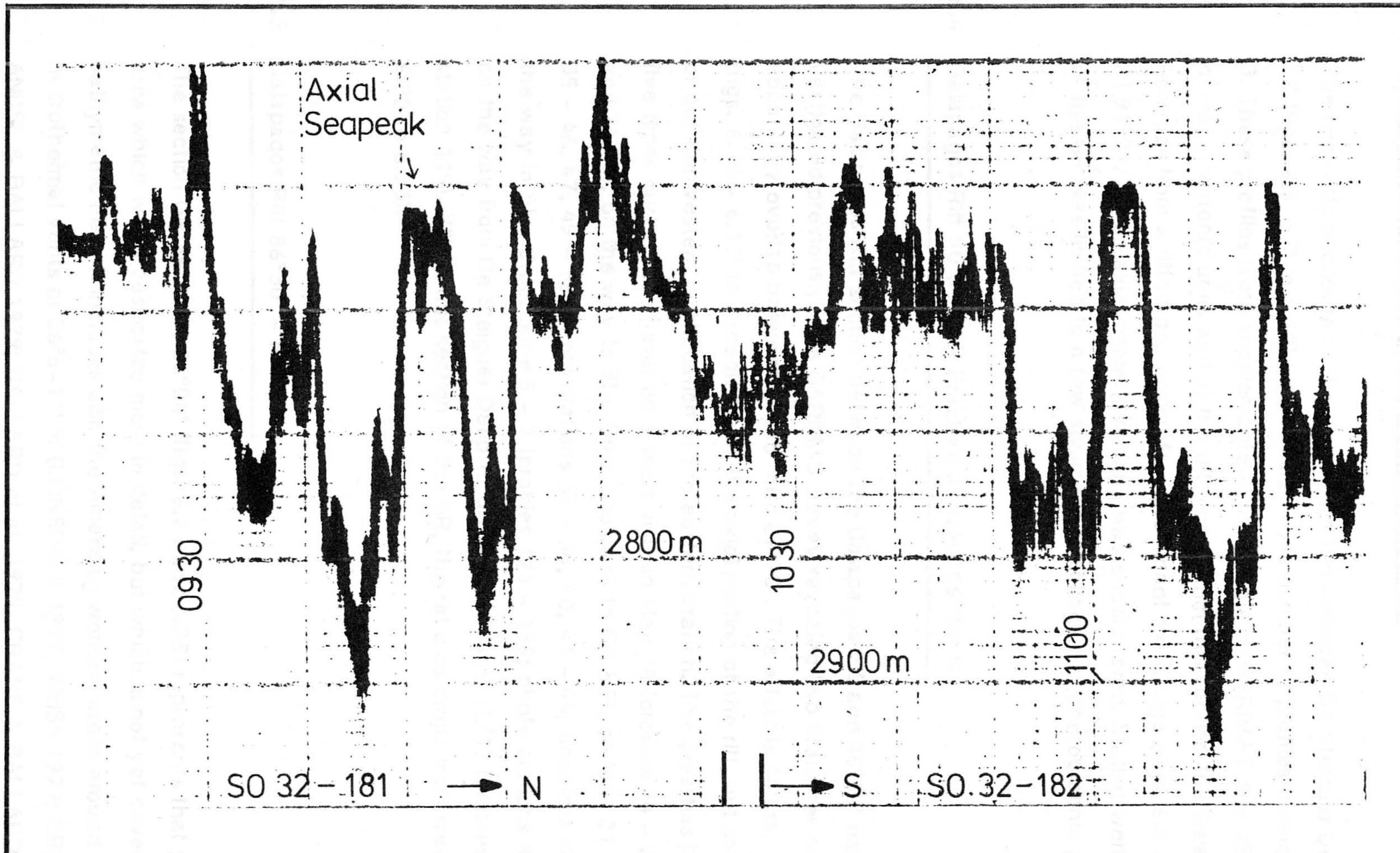


Fig. 6.6.

Two bathymetric sections across the Galapagos Rift at 95°02' W, with axial seapeak.

6.3 Galapagos Rift 94°46' - 90°50' W (Galapagos FZ)

The neo-volcanic zone of the Galapagos Rift between De Steiguer Deep and the Galapagos FZ (figs. 6.5, 6.7 to 6.10) was covered by a number of profiles during cruise GEOMETEP 3. These profiles were supplemented during leg 4 of GARIMAS 1 to allow the recognition of major tectonic units and of the rift axis. Within this section the Galapagos Rift axis emerges from a rifted depression to a prominant axial ridge (figs. 6.4 and 6.11 to 6.14). At 91°21/22' an axial caldera volcano was encountered. Station work along this section of the GR was limited to a few sediment samplings and photographic profiles.

6.4 Galapagos Rift 90°50' (GR Fracture Zone) - 86°30' W

The Galapagos Rift section between the Galapagos FZ and 86°30' had not been investigated previously. The GARIMAS survey revealed two branches of the rift which apparently overlap between 87°05' and 87°20'. The offset is 14 km. The survey lines (figs. 6.15 - 6.19) in general cover the axial portion of the rift, but some profiles follow or cut the western continuation of the eastern branch. The area has been touched five times during the cruise: on a short visit on May 18 (profiles 24 - 28; stations 23 and 24 FS), on the way to Sta. Cruz and back to GR 86°, on May 21 - 25 (profiles 35 - 46, 47, 49 - 58; photo stations 36 - 38, 40, 41 - 44; deeptow station 39), on the way to Sta. Cruz, June 5 - 7 (profiles 121 - 139; photo stations 89 and 90) and on the way from De Steiguer Deep to GR 86°, on June 16/17 (profiles 205 - 210, photo station 119). Within this section of the GR, the rift axis drops from west to east (figs. 6.20 to 6.23).

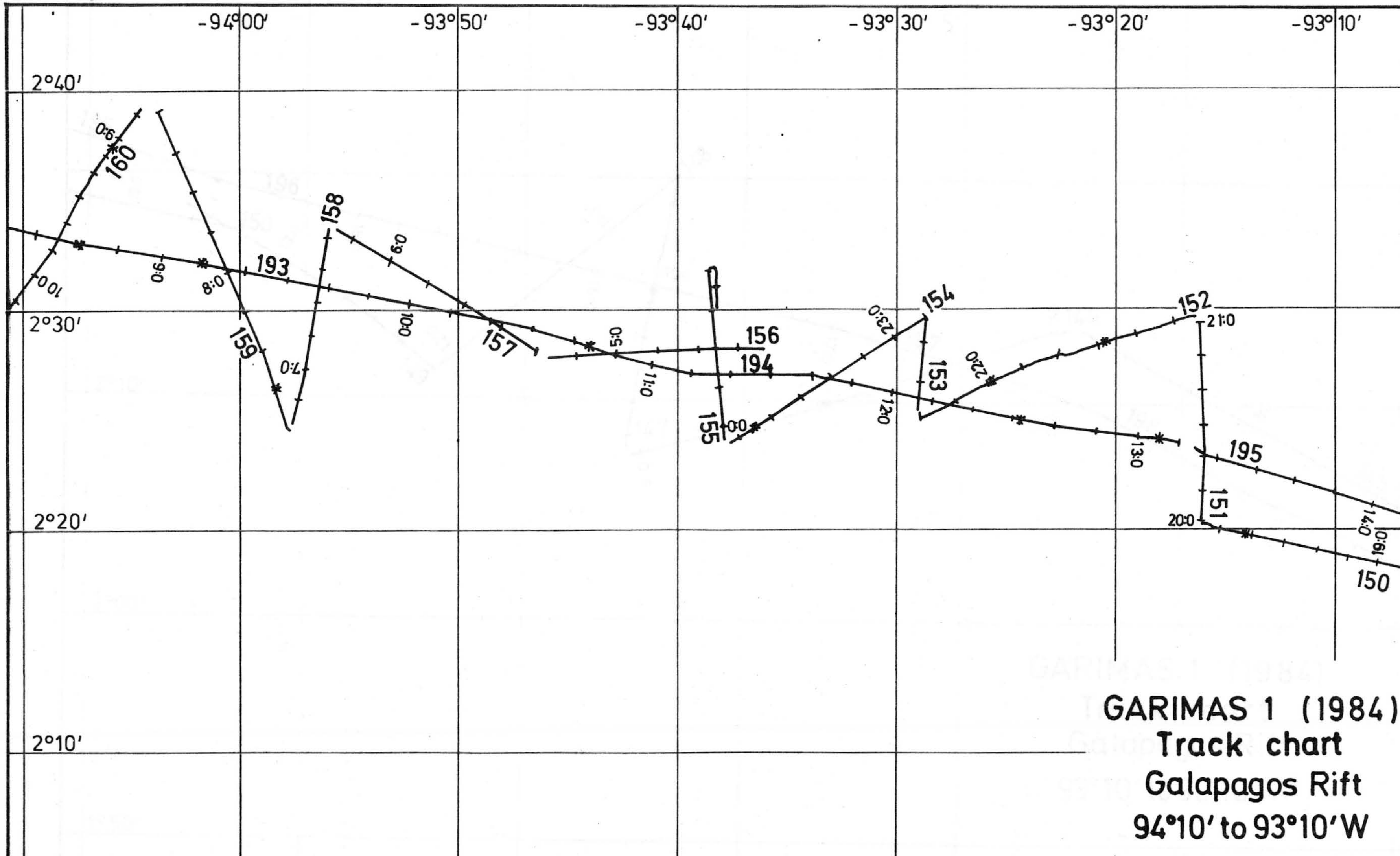
6.5 Galapagos Rift 86°30' - 86°04'W

The section GR 86°30' - 86°04' (figs. 6.24 and 6.25) represents that part of the survey area which was investigated more in detail, but which is not yet covered by a complete bathymetric map. It includes also the American working areas around the low temperature hydrothermal vents at 86°5-11' W (LONSDALE 1977; WEISS 1977; CRANE 1978; VAN ANDEL & BALLARD 1979; BALLARD et al. 1979; CRANE & BALLARD 1980 and many others). Within this section the Galapagos Spreading centre is represented by an uplifted horst with a variable rifted axial zone (figs. 6.26 to 6.33). The mean height of the

gently drops from west to east (fig. 6.34).
The work carried out during GARIMAS 1 in this region focused on Seabeam mapping and bottom photography.

6.6 Galapagos Rift 86°04' - 85°40' W

The eastern portion of the Galapagos Rift east of 86°W (figs. 6.25, 6.35, 6.36) was already surveyed during the previous GEOMETEP cruises. It contains also the Alvin 1001 site where the first Galapagos Rift sulphides were found (MALAHOFF et al. 1983). As a result of the GEOMETEP cruises detailed bathymetric maps were available for the GR section 85°35' - 86°04'W.
Most work carried out during cruise SO 32 again focused on this area. The work was supported by the installation of an Atnav transponder system. To ensure a perfect Seabeam and NBES coverage within the Atnav array, a new very detailed morphological survey was run in a special 4 square miles box centred at 85°51' W 0°45' N (figs. 6.35; 6.37-6.39).
This area was mapped at 1:10.000 with 5 m contour intervals. The work carried out east of 86° focused on rock sampling (dredges and TV-grabs) and photo profiling. In addition, sediments were recovered using a Reineck corer along a section across the rift (fig . 6.40). Some oceanographic stations were occupied as well.



GARIMAS 1 (1984)
Track chart
Galapagos Rift
94°10' to 93°10'W

Fig. 6.7

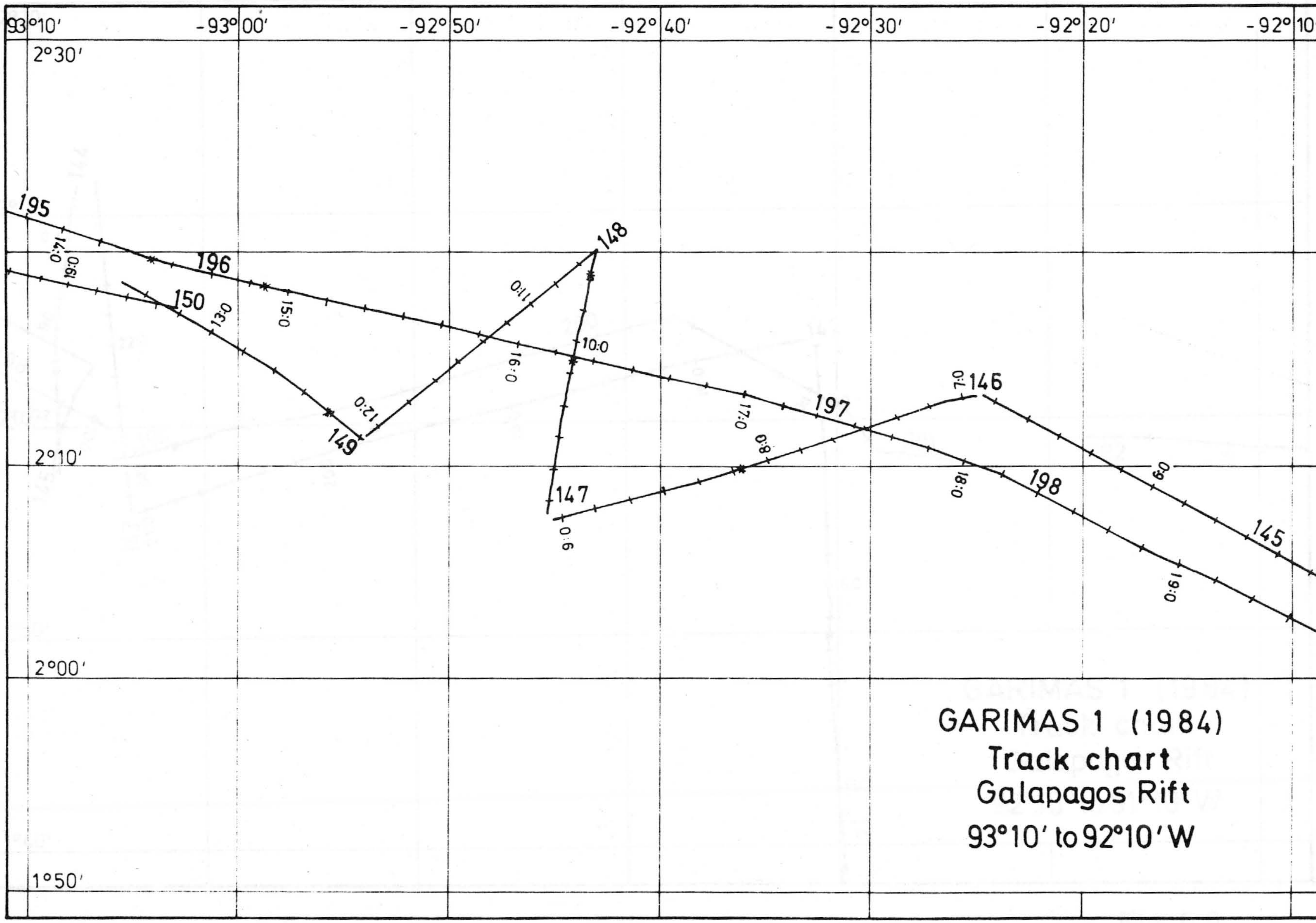
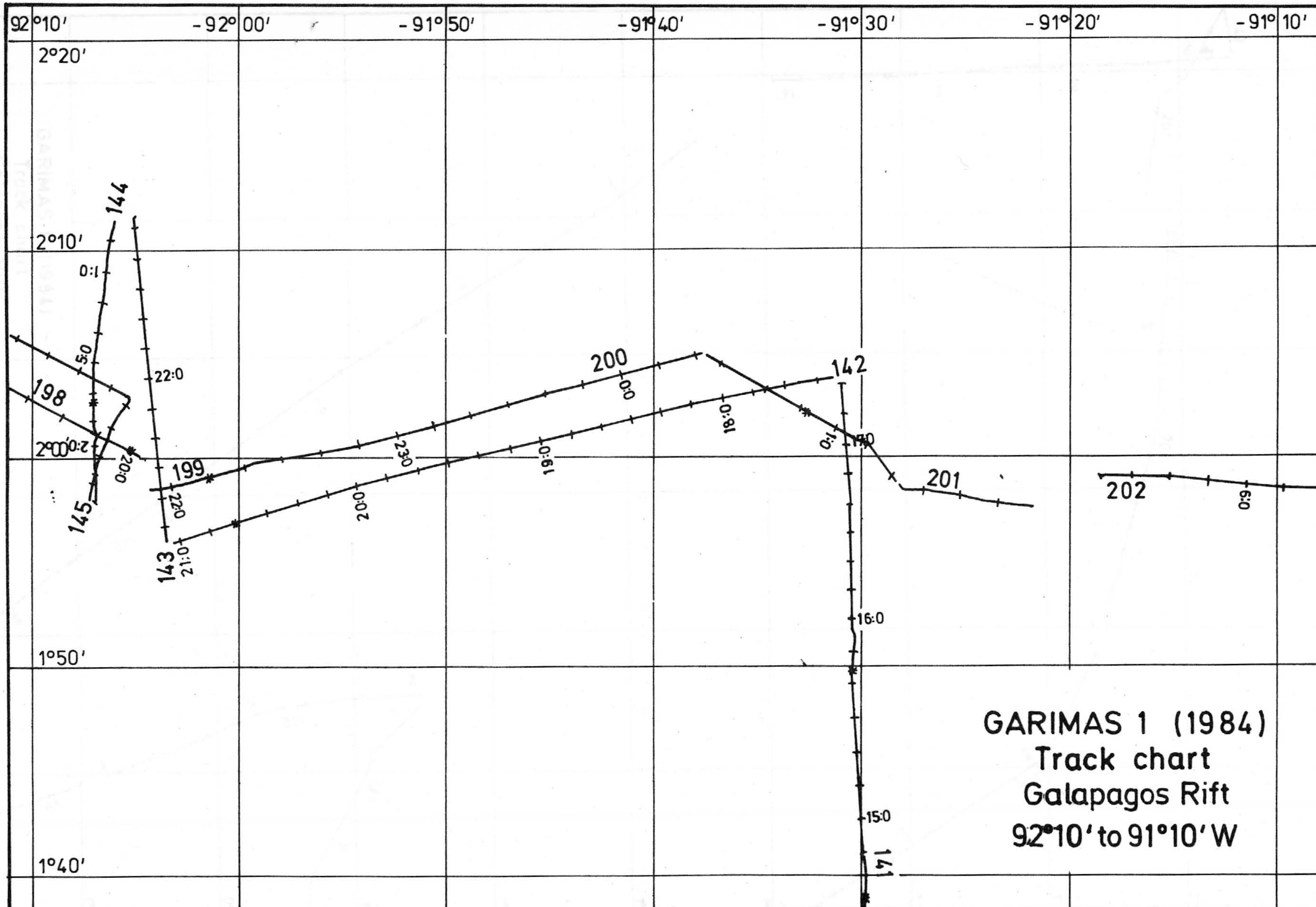

93°10'
-93° 00'
-92° 50'
-92° 40'
-92° 30'
-92° 20'
-92° 10'
2°30'
2°10'
2°00'
1°50'
195
196
197
198
150
149
148
147
146
145
GARIMAS 1 (1984)
Track chart
Galapagos Rift
93°10' to 92°10' W

FIG. 6.8



92°10'
-92°00'
-91°50'
-91°40'
-91°30'
-91°20'
-91°10'
2°20'
2°10'
2°00'
1°50'
1°40'
144
145
198
199
200
142
143
141
201
202
0:1
5:0
0:2
20:0
22:0
21:0
23:0
19:0
18:0
0:0
17:0
16:0
15:0
6:0
GARIMAS 1 (1984)
Track chart
Galapagos Rift
92°10' to 91°10' W

Fig. 6.9.

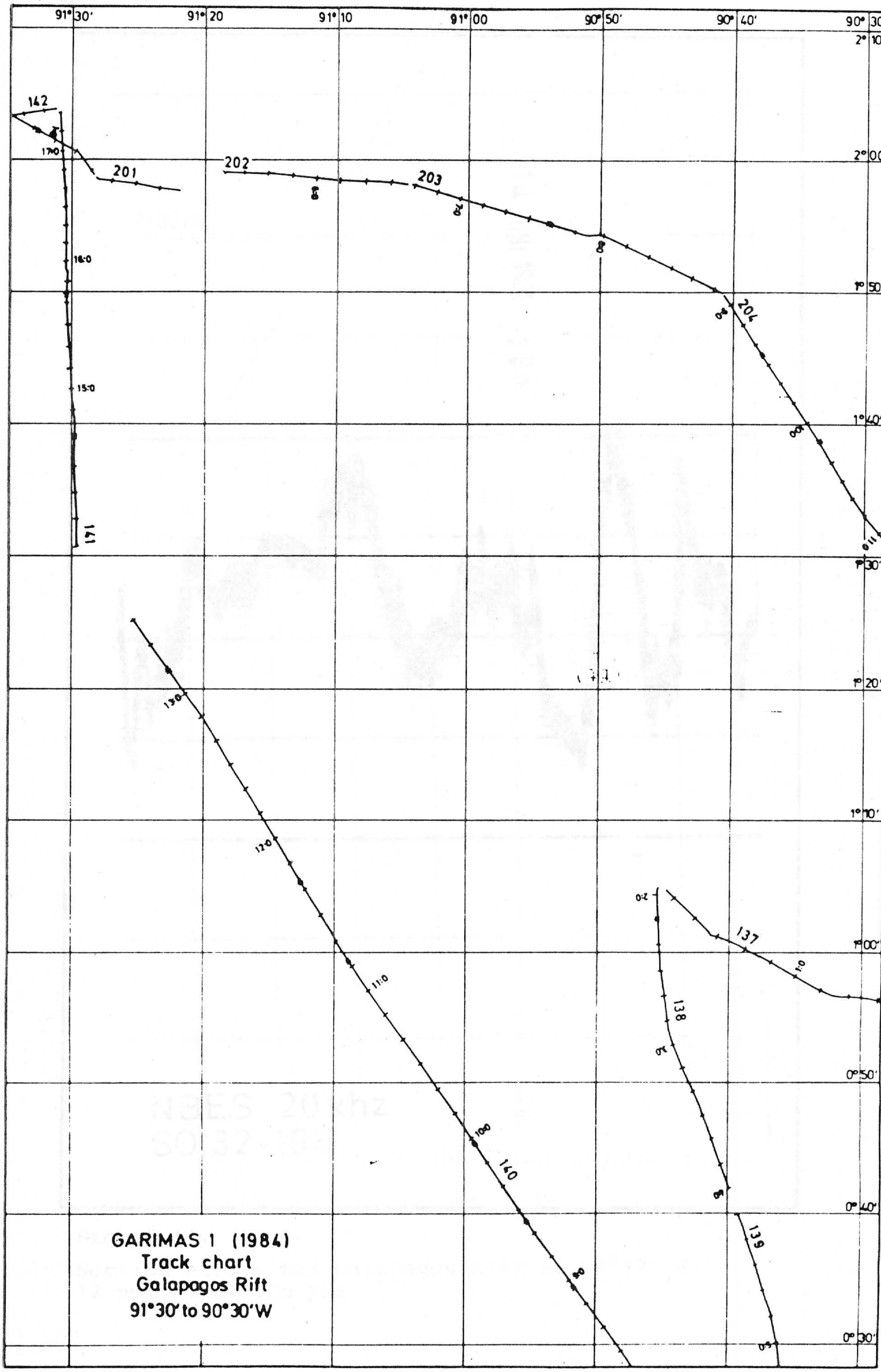

91° 30'
91° 20
91° 10
91° 00
90° 50'
90° 40'
90° 30
2° 10'
2° 00'
1° 50'
1° 40'
1° 30'
1° 20'
1° 10'
1° 00'
0° 50'
0° 40'
0° 30'
142
141
201
202
203
204
140
137
138
139
GARIMAS 1 (1984)
Track chart
Galapagos Rift
91°30' to 90°30'W

Fig. 6.10.

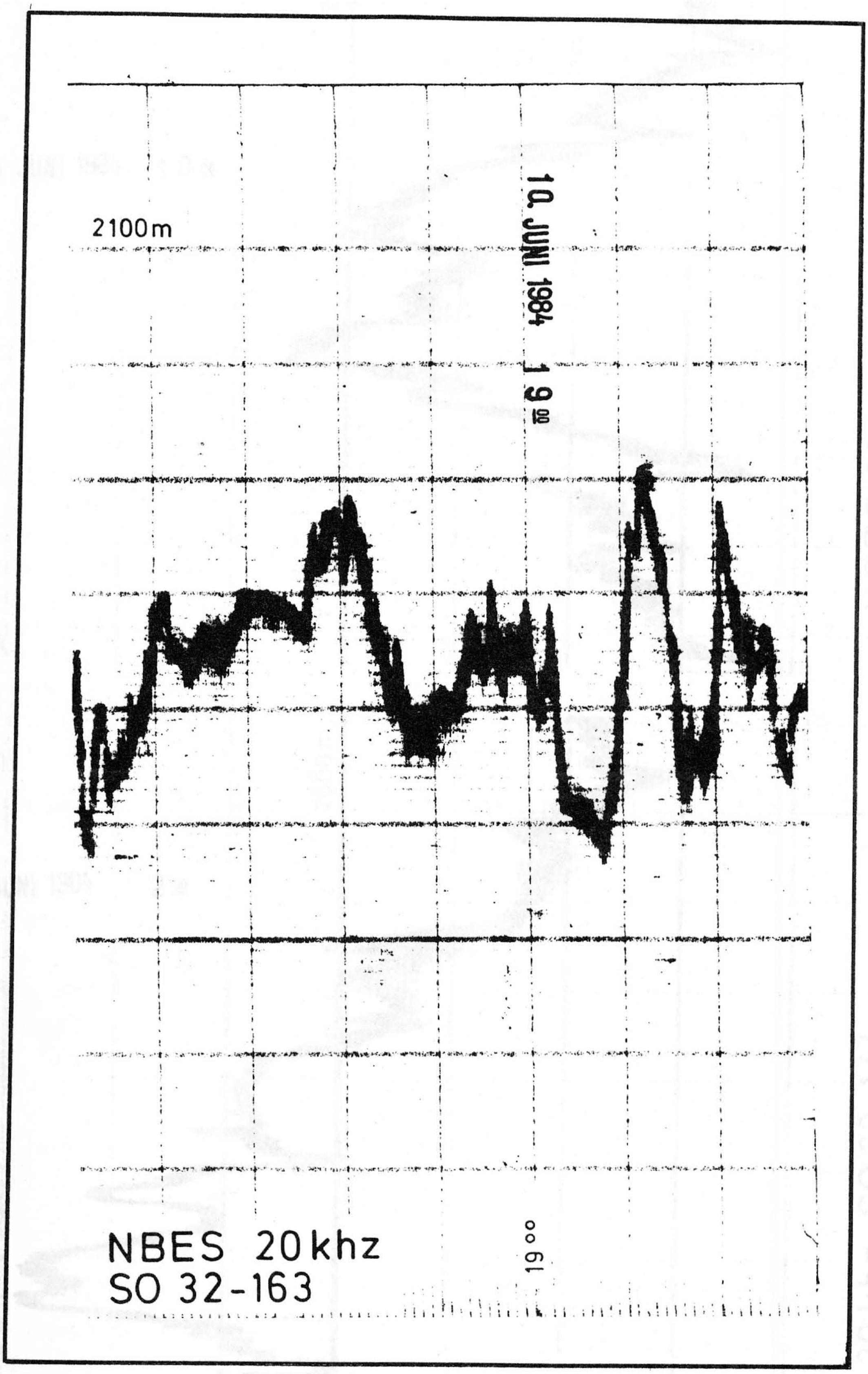


Fig. 6.11.

Section across the Galapagos Rift at 94°17' W.
12 nm, direction NNE

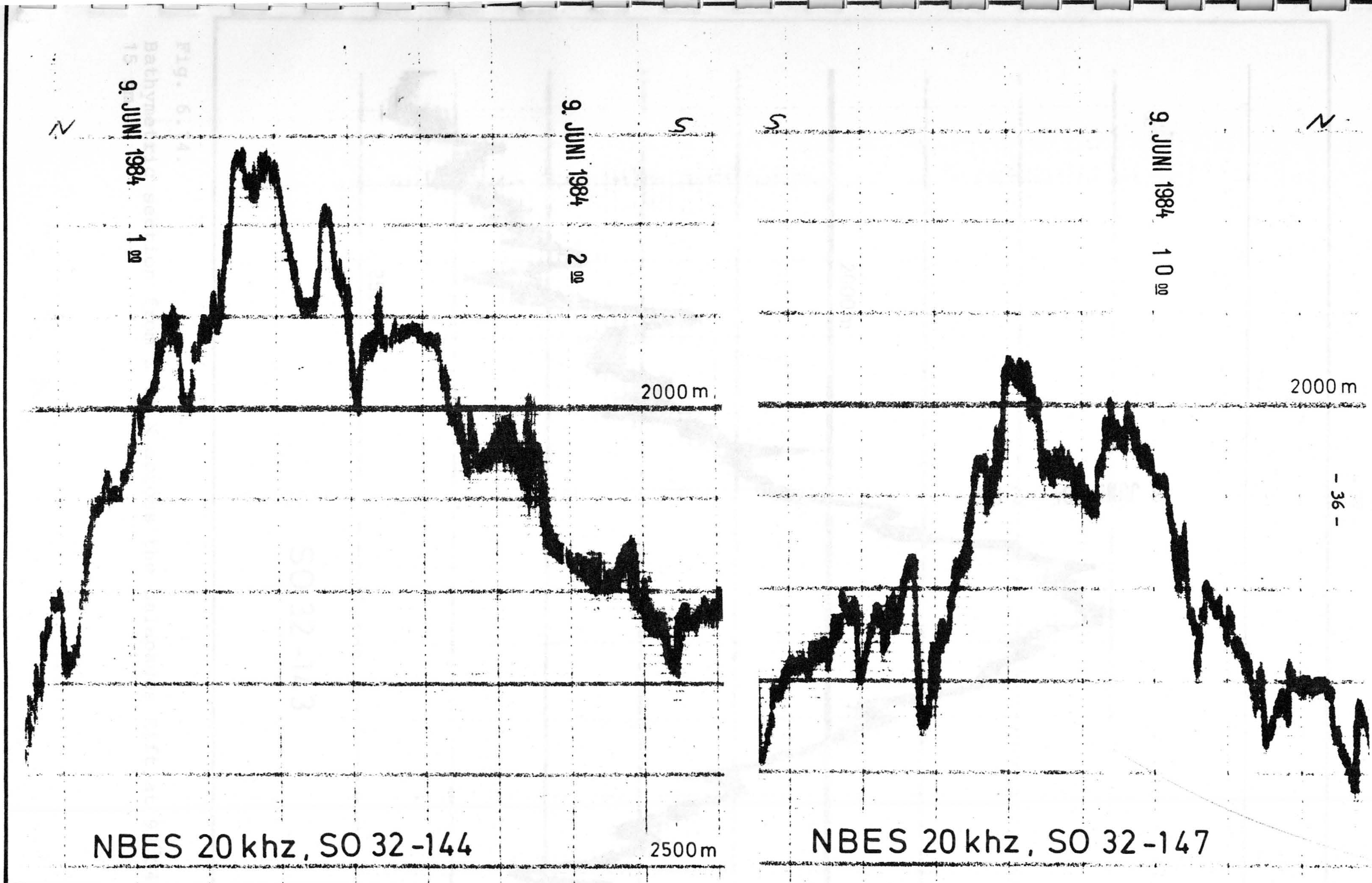


Fig. 6.12/6.13

Both sections 13 nm

Bathymetric sections across the Galapagos Rift at 92°07' W (144) and 92°44' W (147).

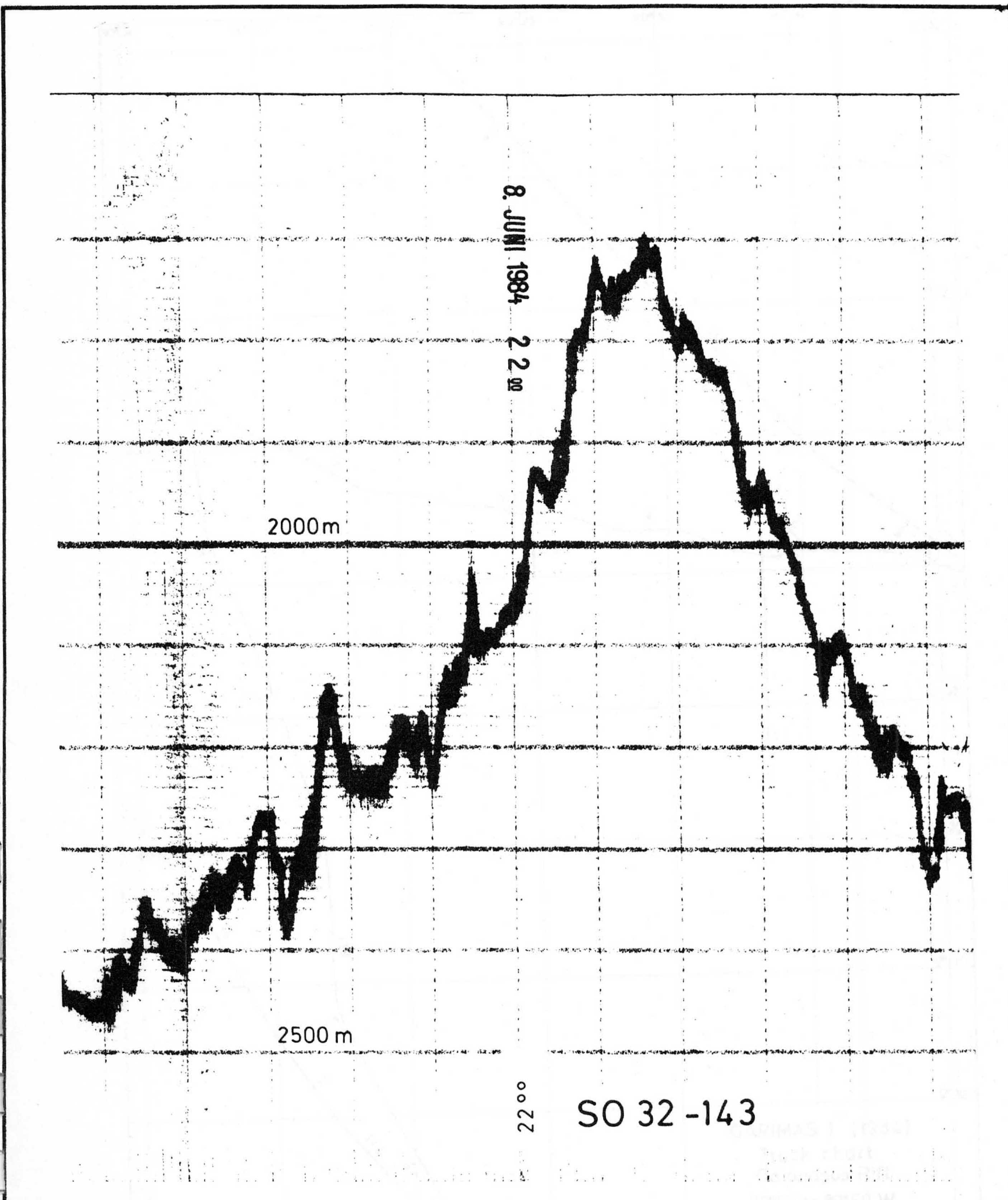


Fig. 6.14.

Bathymetric section from S to N across the Galapagos Rift at 92°04' W.
15 nm

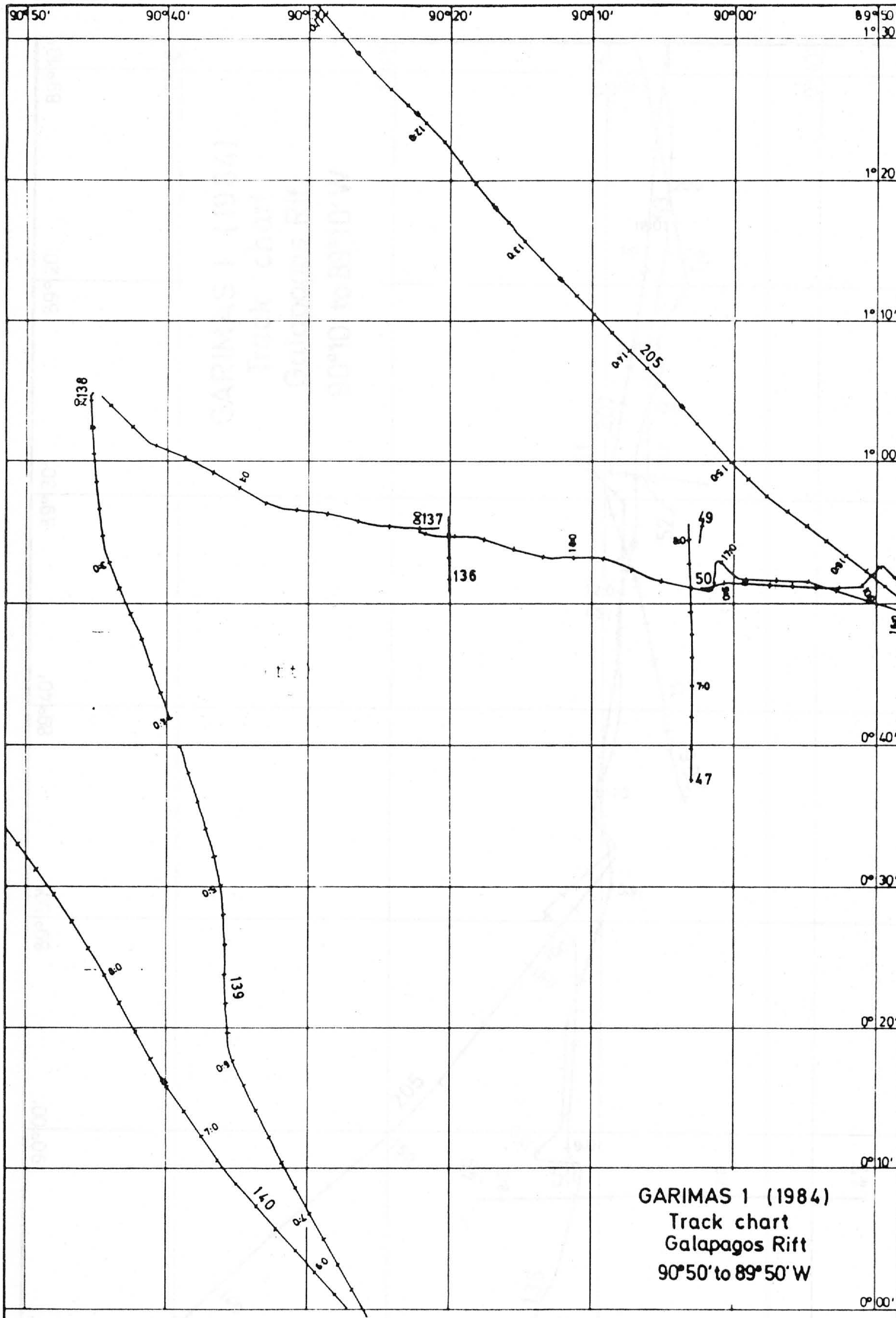

90°50'
90°40'
90°30'
90°20'
90°10'
90°00'
89°50'
1°30'
1°20'
1°10'
1°00'
0°40'
0°30'
0°20'
0°10'
0°00'
205
138
137
136
49
50
47
139
140
GARIMAS 1 (1984)
Track chart
Galapagos Rift
90°50' to 89°50' W

Fig. 6.15.

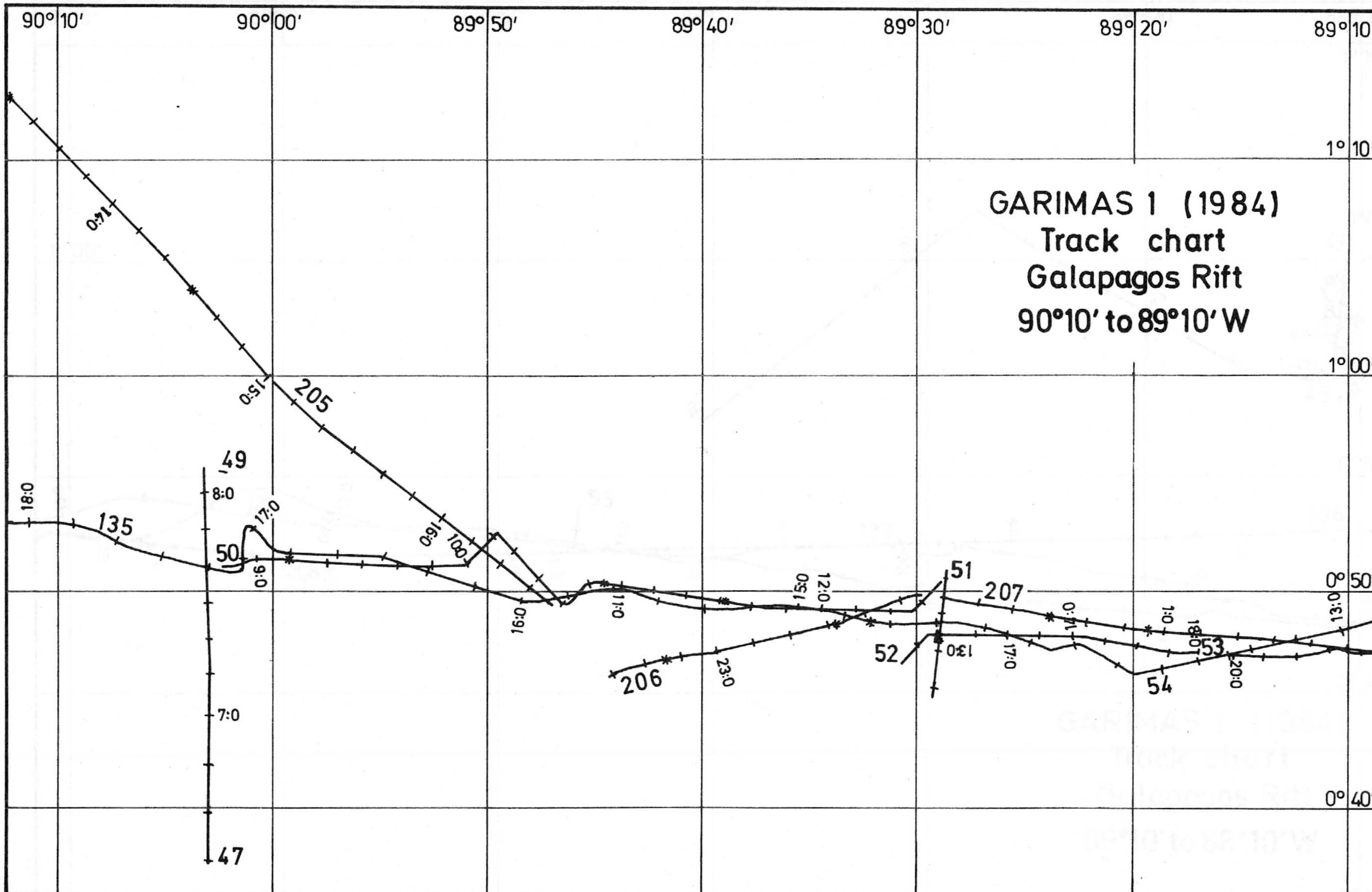

90° 10'
90° 00'
89° 50'
89° 40'
89° 30'
89° 20'
89° 10'
1° 10'
1° 00'
0° 50'
0° 40'
GARIMAS 1 (1984)
Track chart
Galapagos Rift
90°10' to 89°10' W
205
135
49
50
47
51
52
53
54
206
207

Fig. 6. 16.

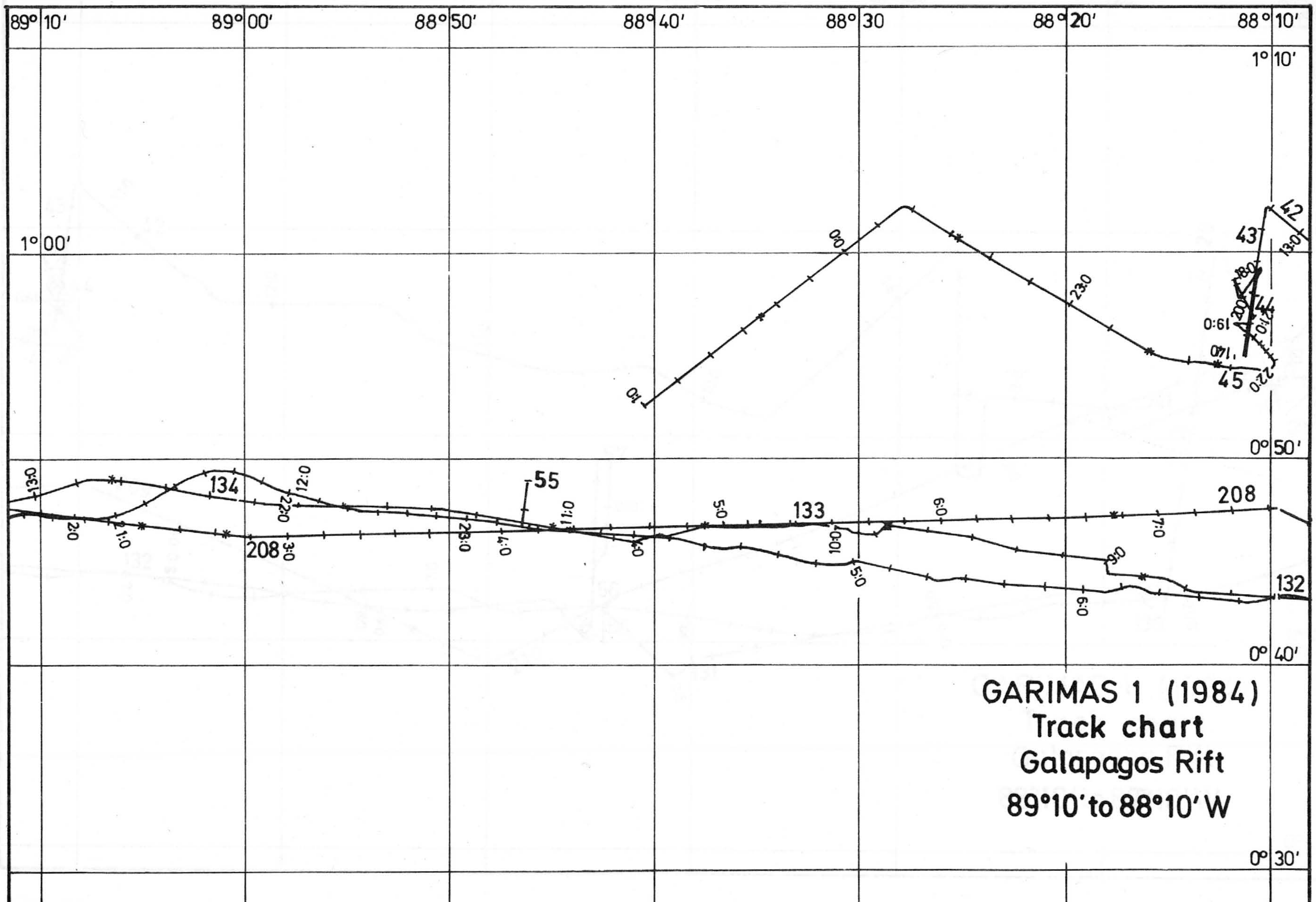

89° 10'
89° 00'
88° 50'
88° 40'
88° 30
88° 20'
88° 10'
1° 10'
1° 00'
0° 50'
0° 40'
0° 30'
42
43
44
45
55
134
133
208
132
GARIMAS 1 (1984)
Track chart
Galapagos Rift
89°10' to 88°10' W

Fig. 6.17.

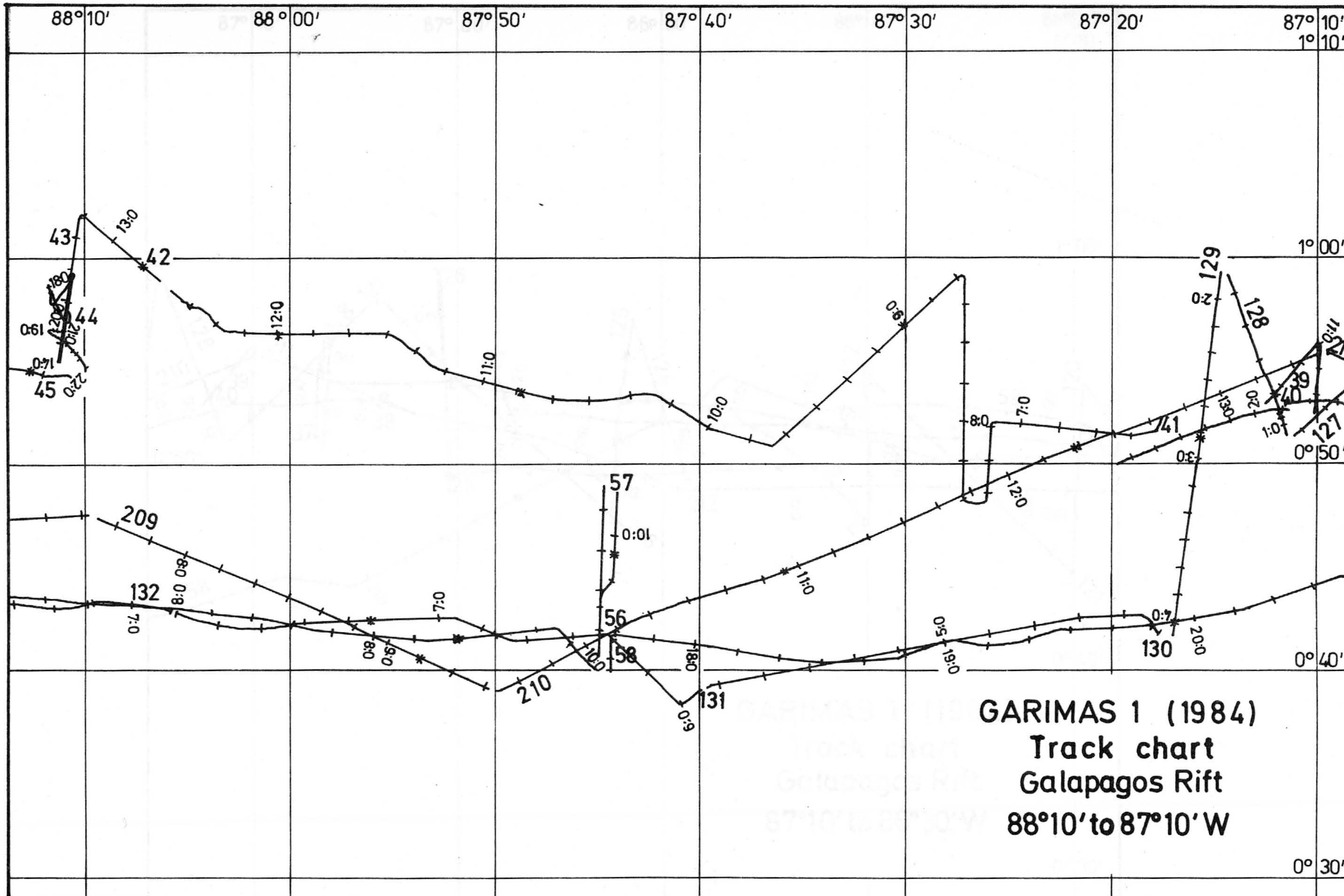

GARIMAS 1 (1984)
Track chart
Galapagos Rift
88°10' to 87°10' W
88° 10'
88° 00'
87° 50'
87° 40'
87° 30'
87° 20'
87° 10'
1° 10'
1° 00'
0° 50'
0° 40'
0° 30'
42
43
44
45
56
57
58
127
128
129
130
131
132
209
210

Fig. 6.18.

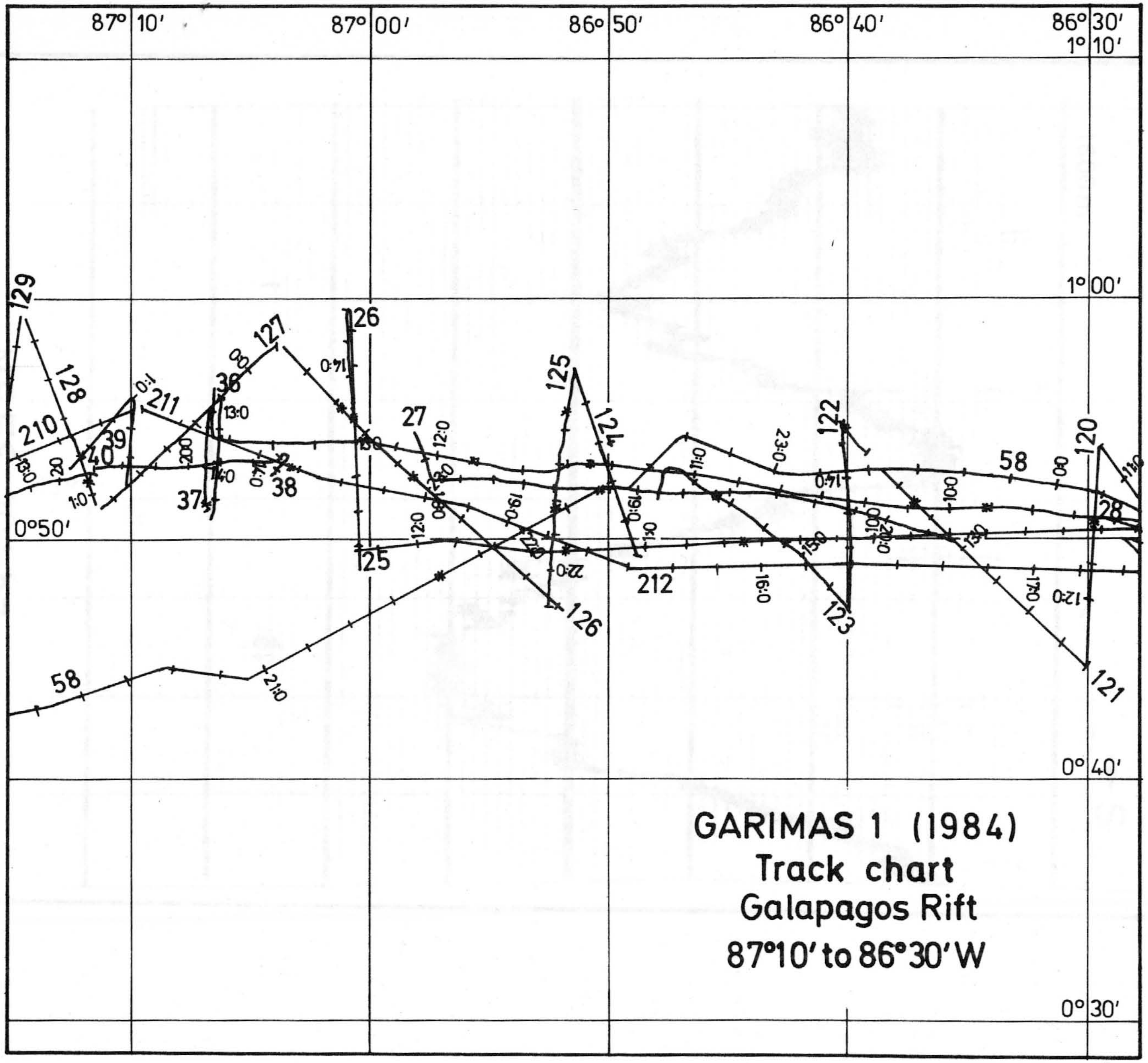

87° 10′
87° 00′
86° 50′
86° 40′
86° 30′
1° 10′
1° 00′
0°50′
0° 40′
0° 30′
GARIMAS 1 (1984)
Track chart
Galapagos Rift
87°10′ to 86°30′W

Fig. 6.19.

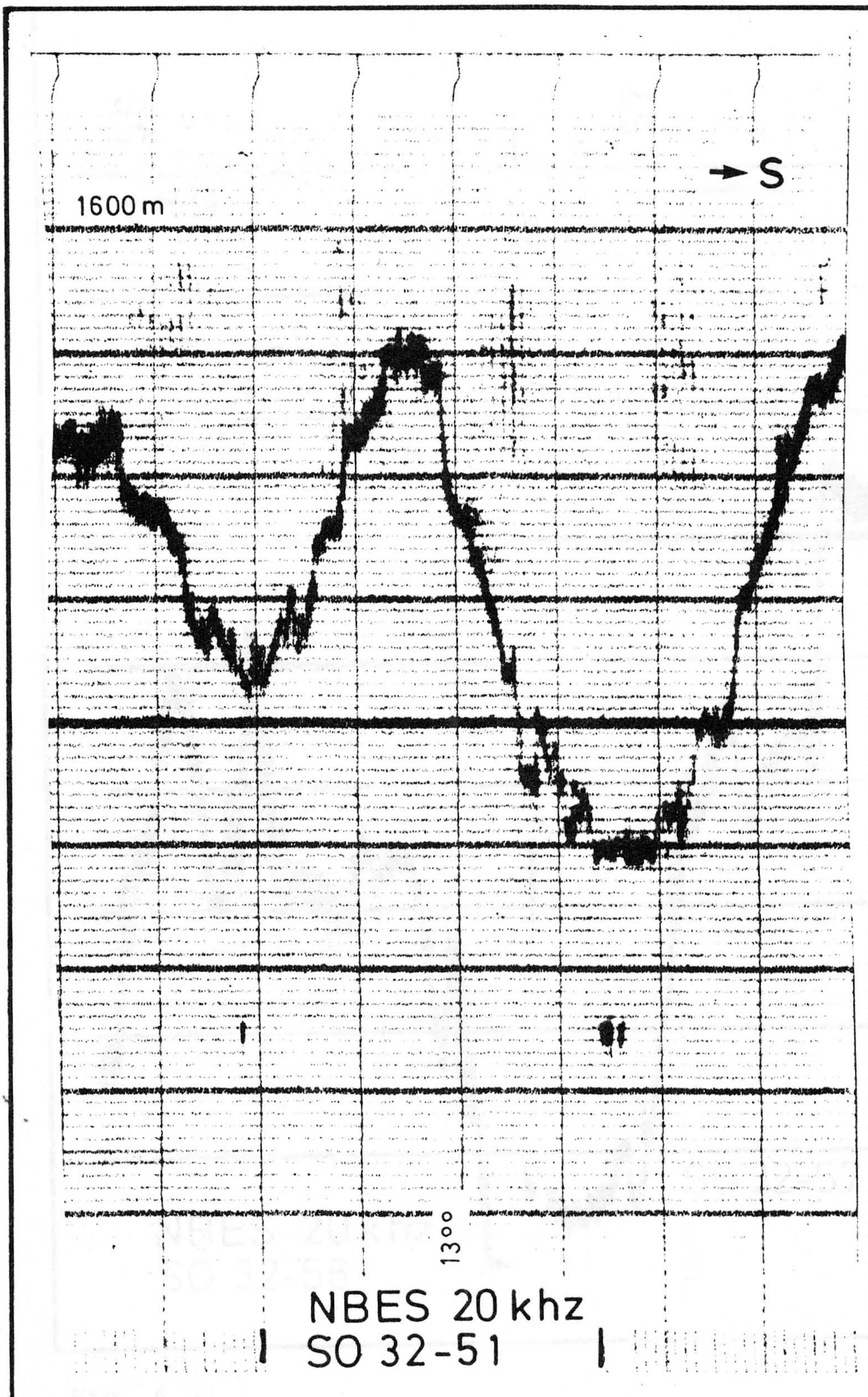


Fig. 6.20.

Bathymetric section across the Galapagos Rift axis at 89°29' W. (central peak)

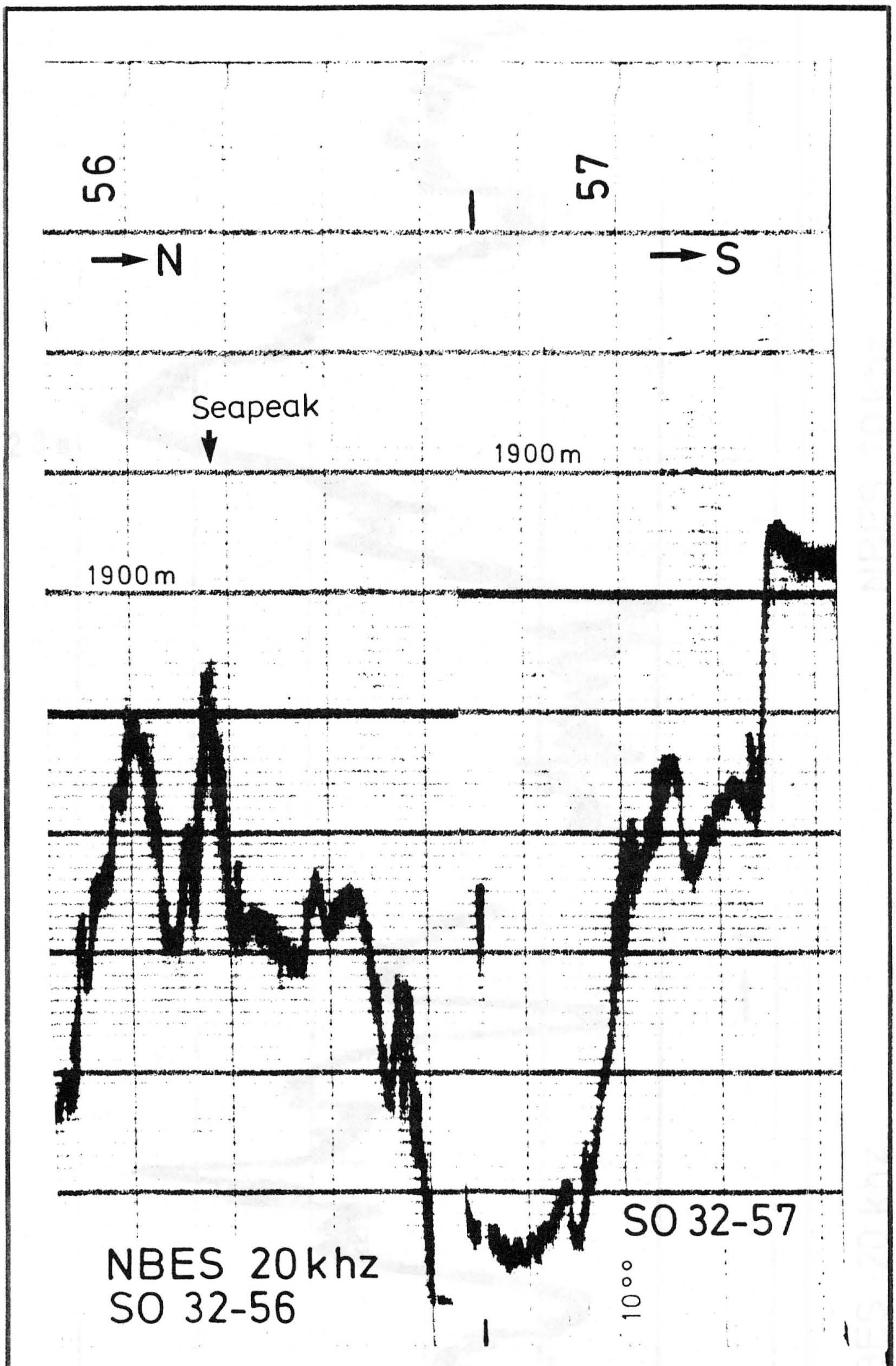


Fig. 6.21.

Bathymetric profiles GR $84^{o}44'$ W.
showing the rift axis and the development of a seapeak.

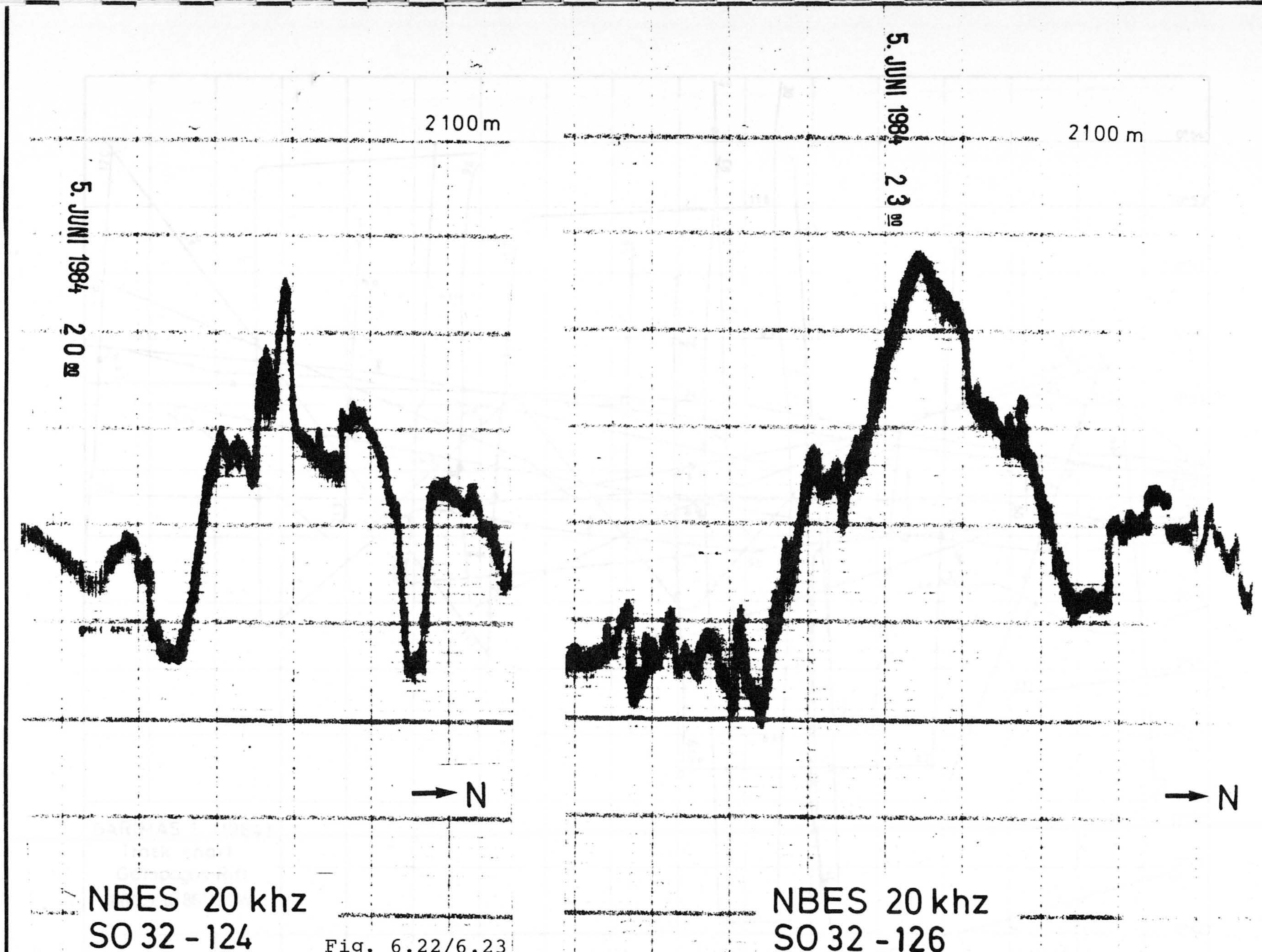


Fig. 6.22/6.23

Bathymetric sections across the
Galapagos Rift at 86°50' and 86°58' W.
124 = 9 nm, 126 = 17 nm

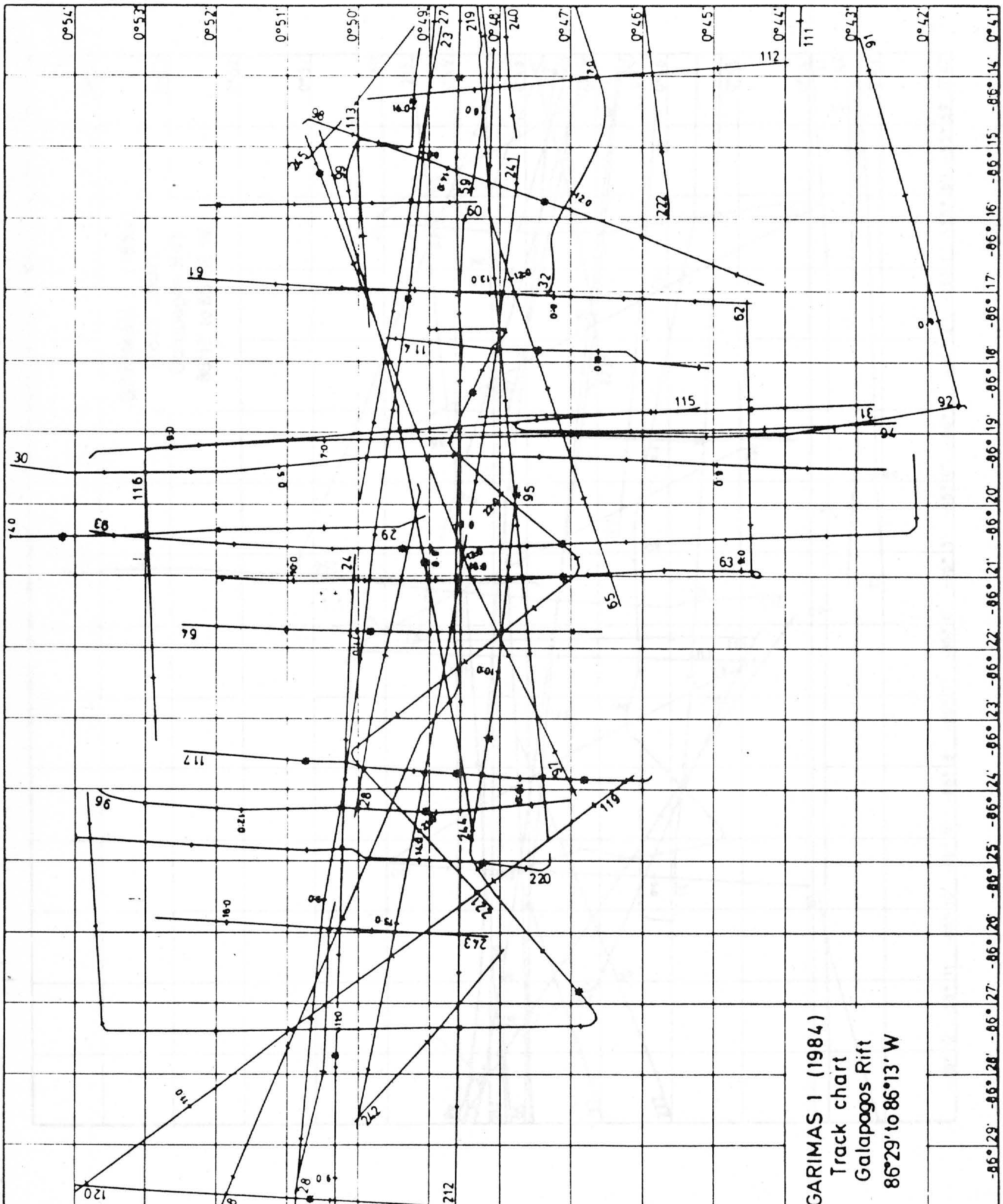


Fig. 6. 24.

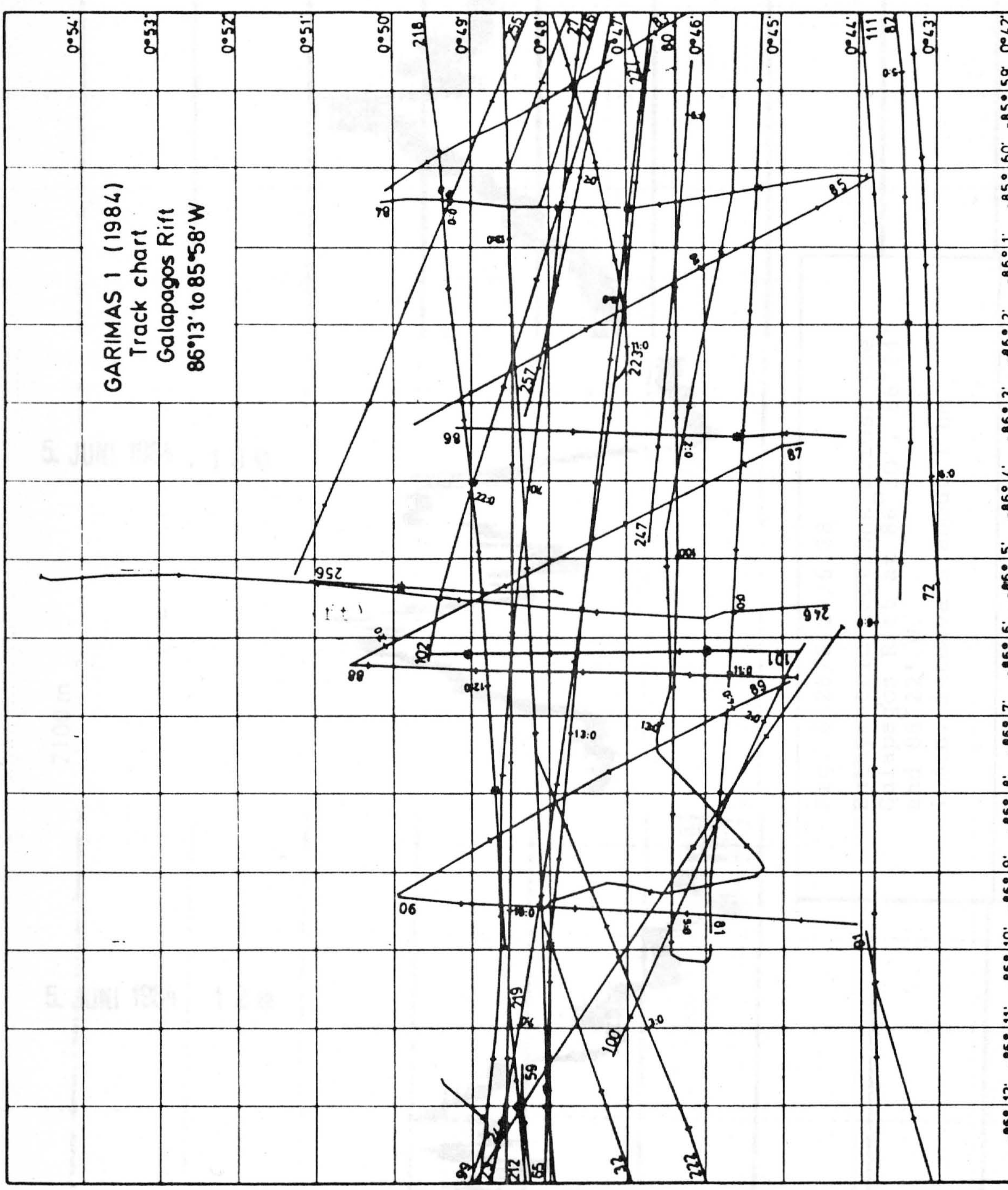


Fig. 6.25.

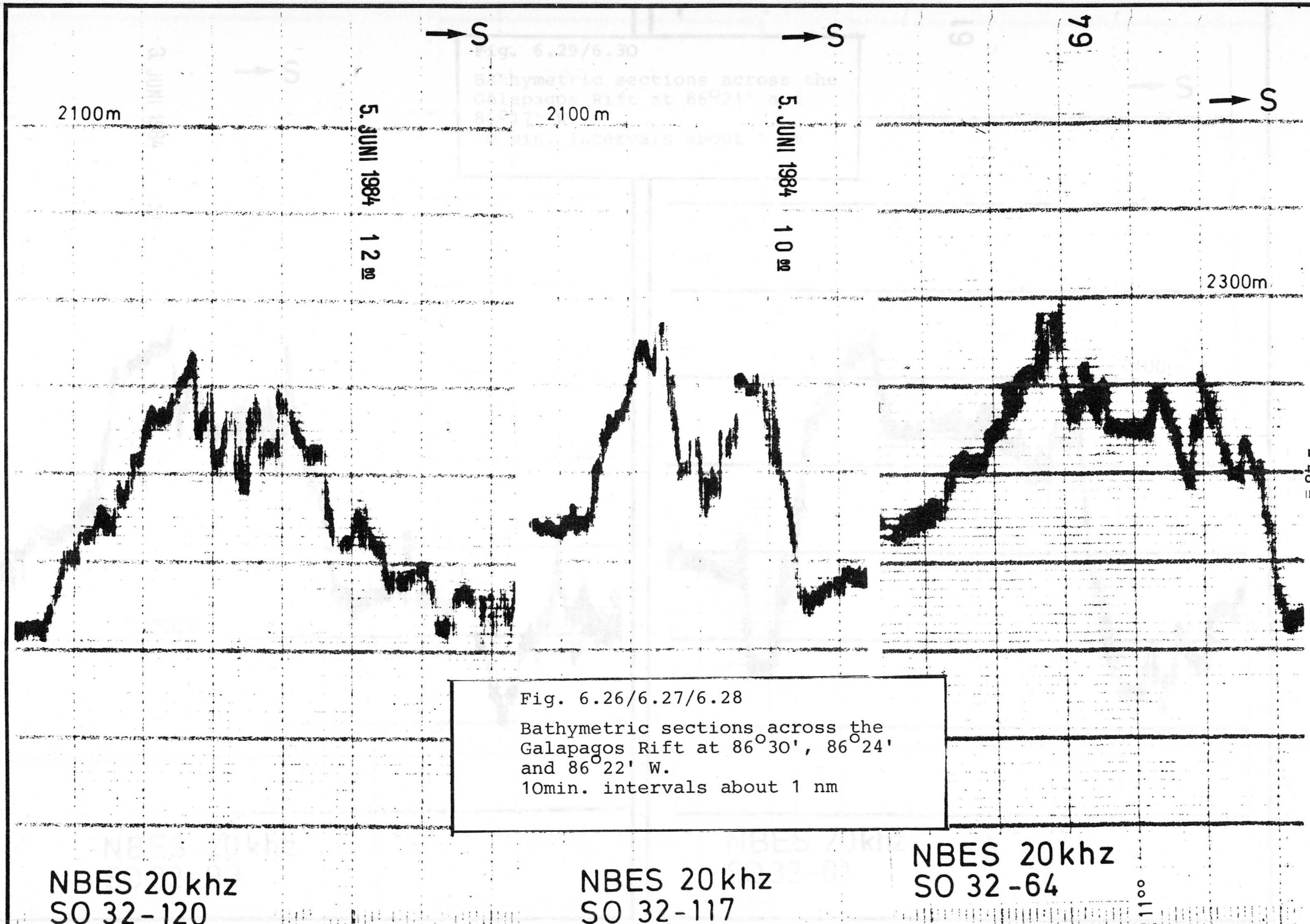
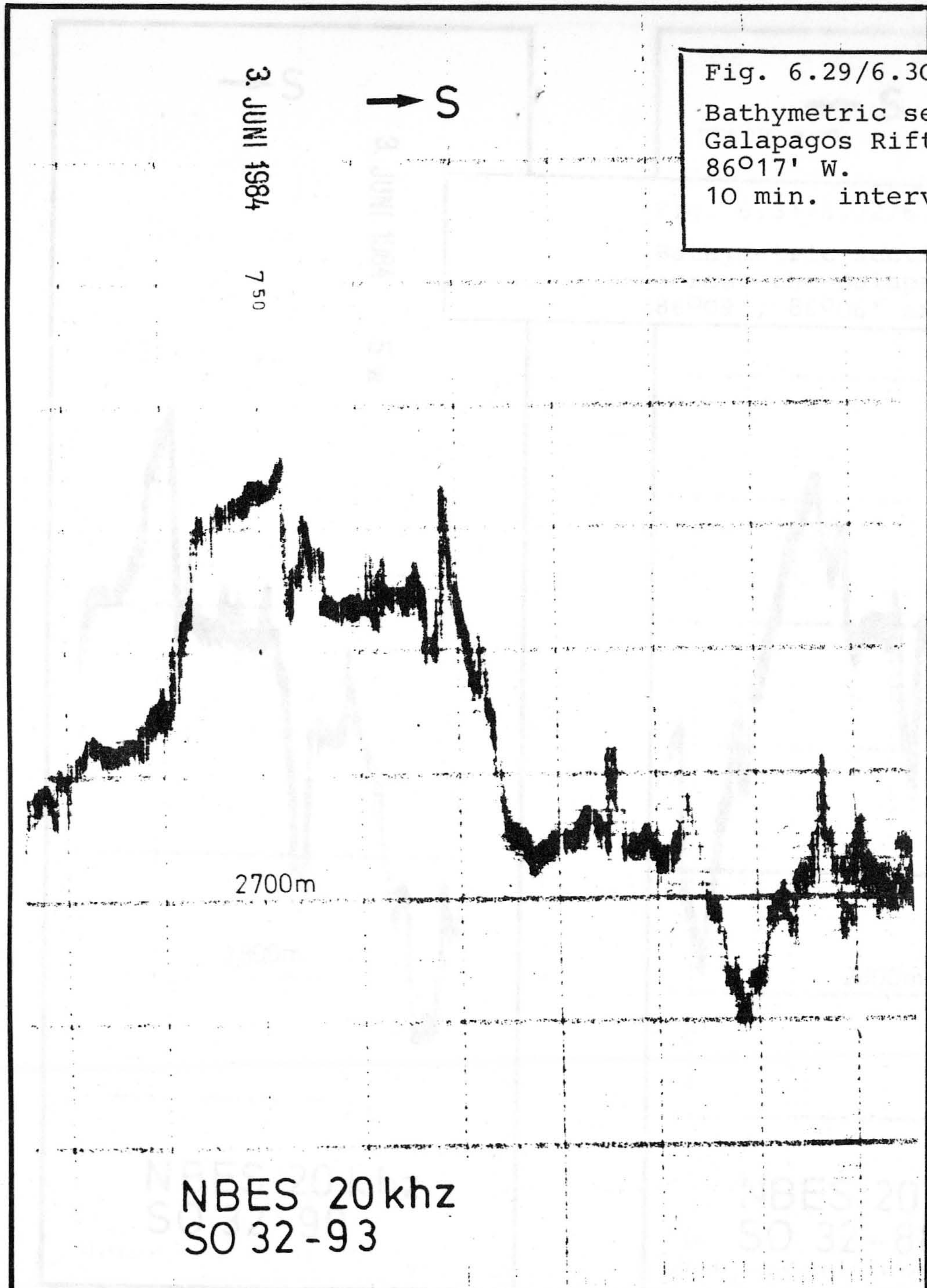


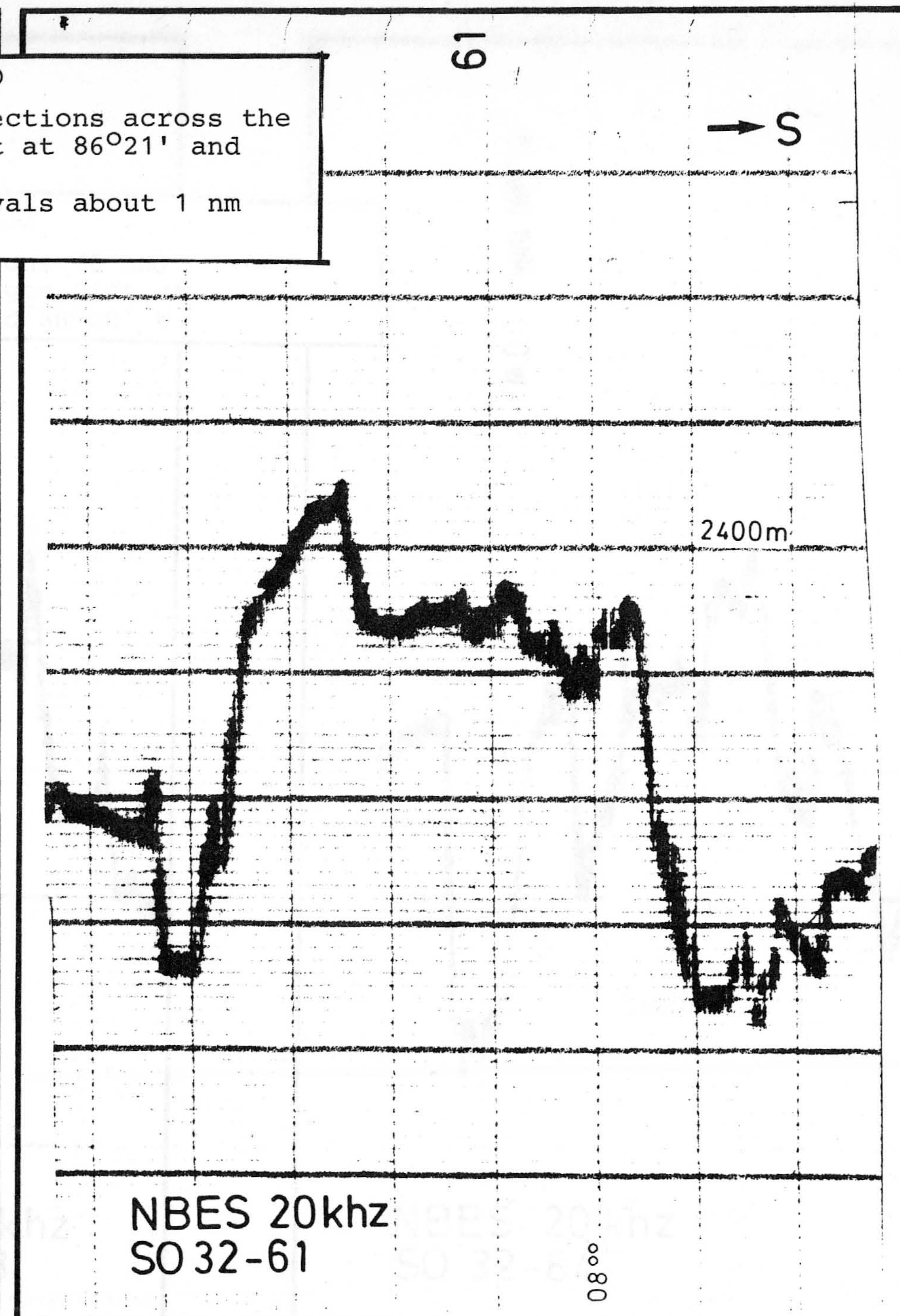
Fig. 6.26/6.27/6.28

Bathymetric sections across the Galapagos Rift at 86°30', 86°24' and 86°22' W.
10min. intervals about 1 nm

Fig. 6.29/6.30

Bathymetric sections across the Galapagos Rift at 86°21' and 86°17' W.
10 min. intervals about 1 nm





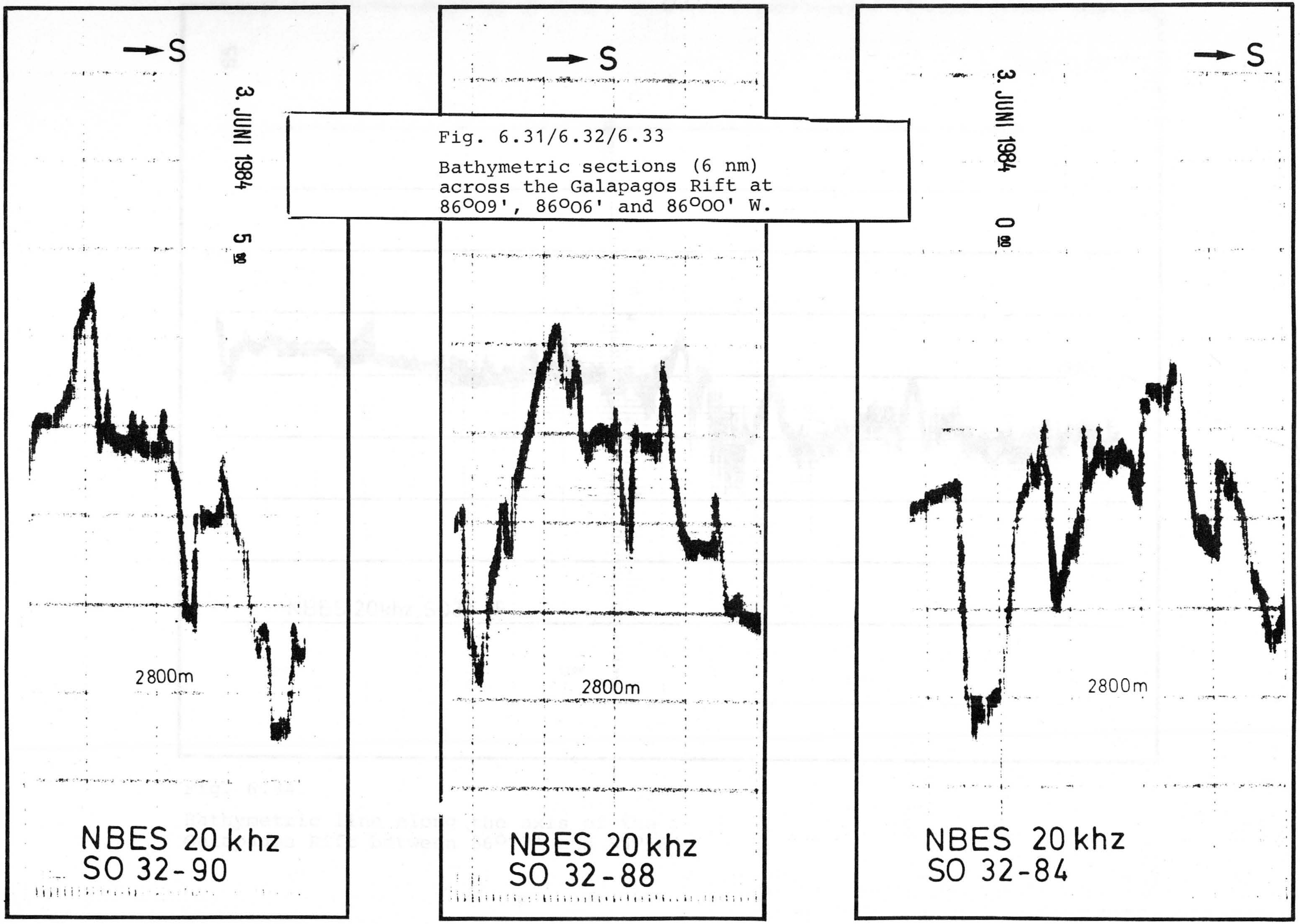


Fig. 6.31/6.32/6.33

Bathymetric sections (6 nm) across the Galapagos Rift at 86°09', 86°06' and 86°00' W.

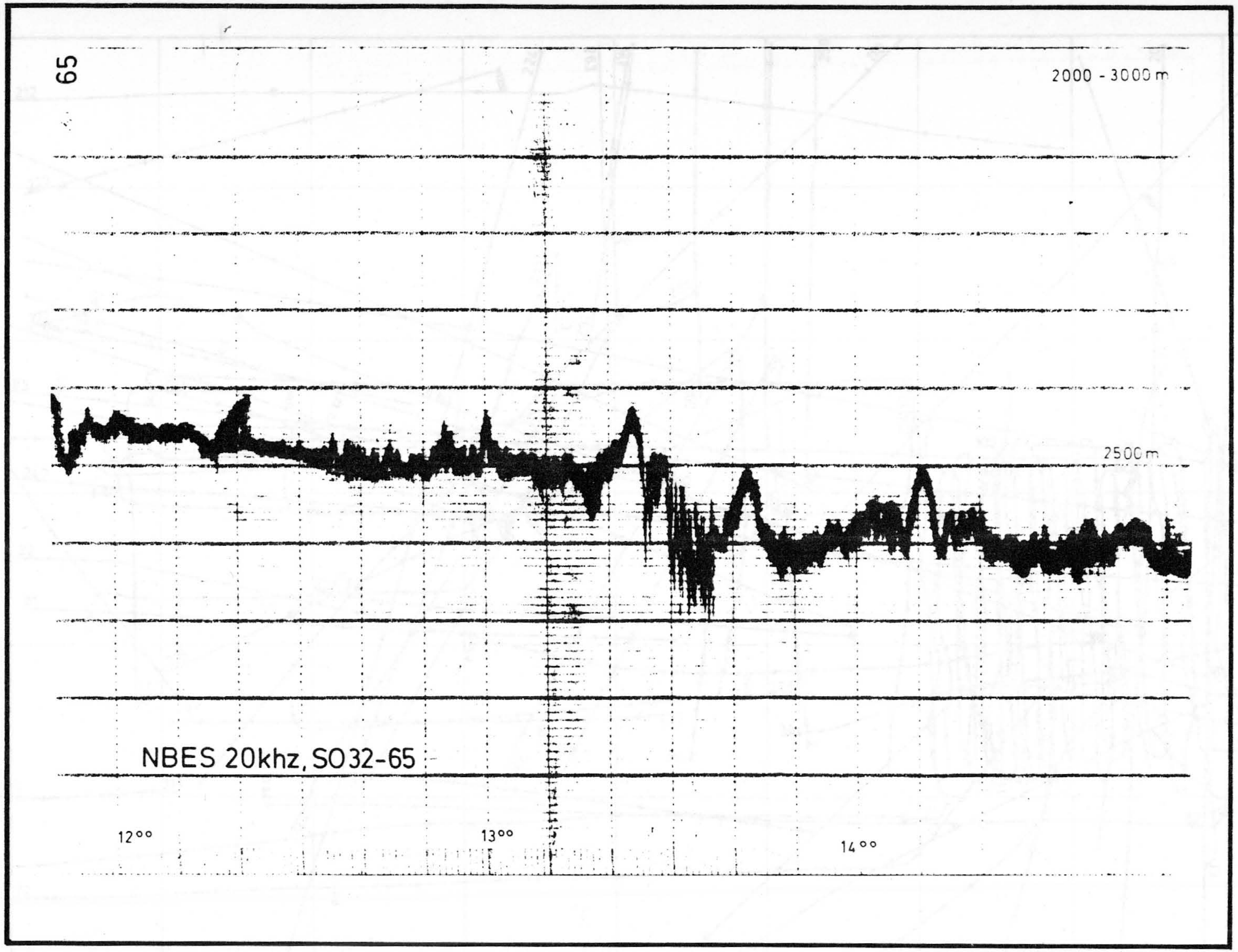


Fig. 6.34.

Bathymetric line along the axis of the Galapagos Rift between 86°17' and 85°58'

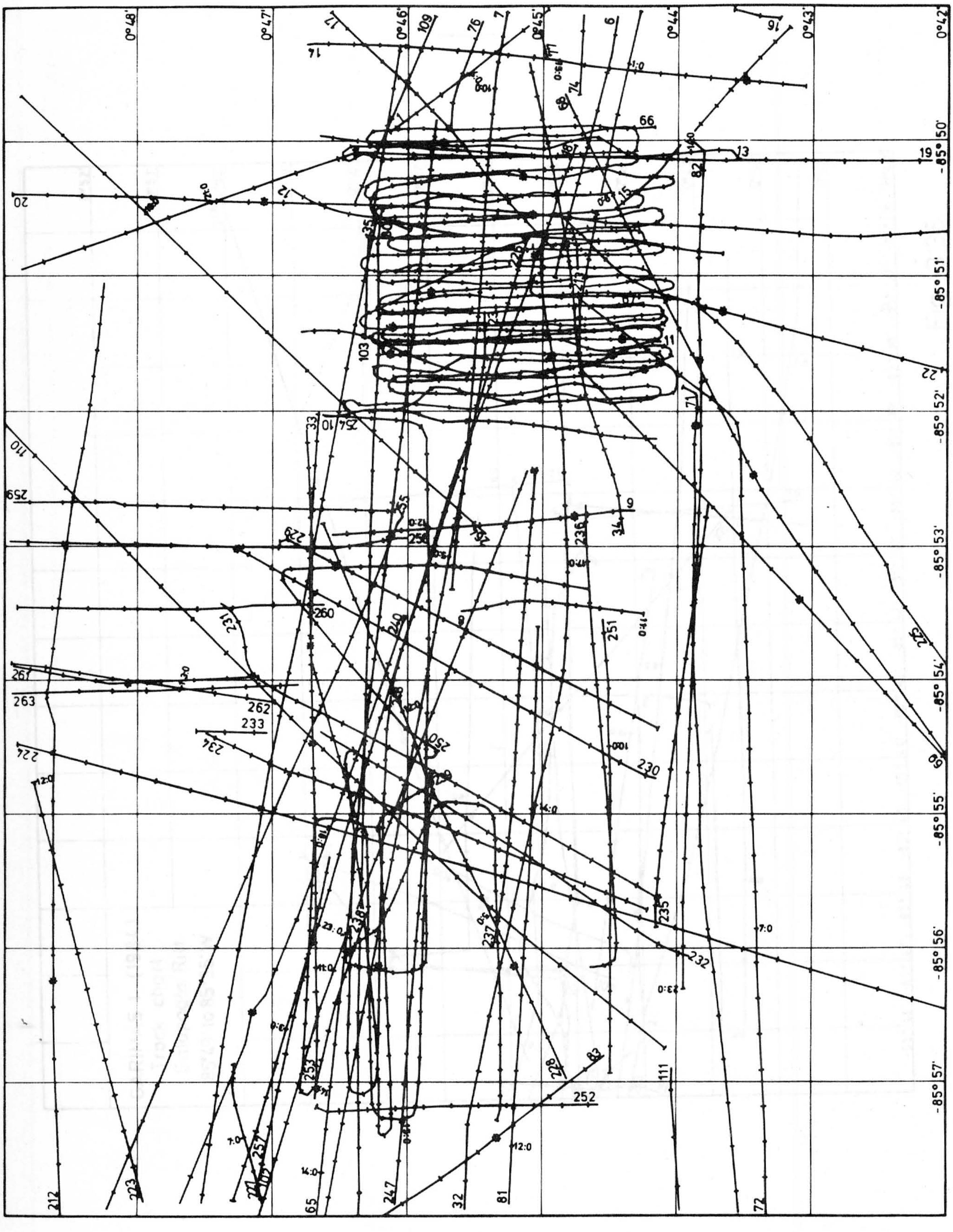

0°48'
0°47'
0°46'
0°45'
0°44'
0°43'
0°42'
-85°50'
-85°51'
-85°52'
-85°53'
-85°54'
-85°55'
-85°56'
-85°57'

Fig. 6.35.

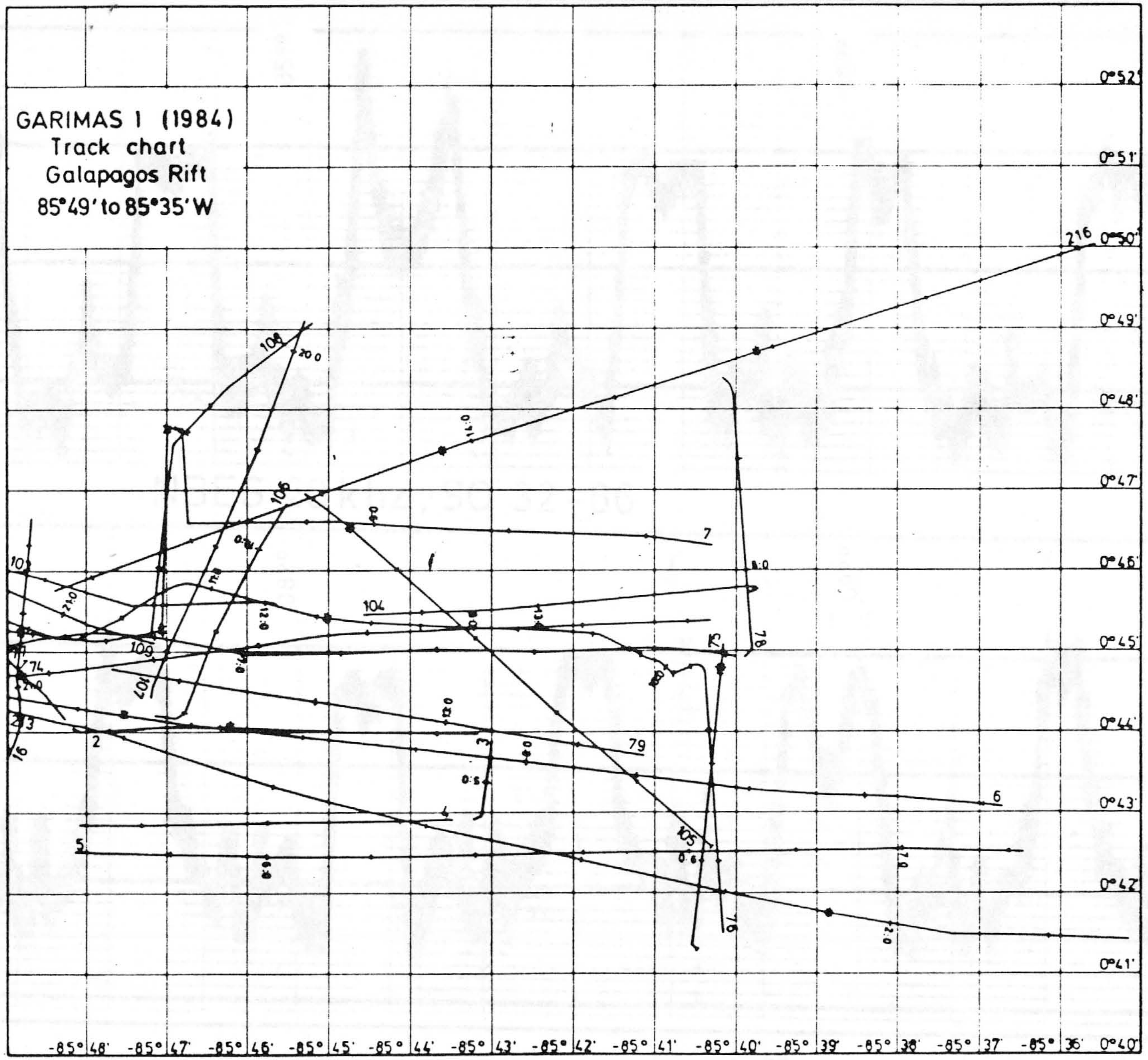


Fig. 3.36.

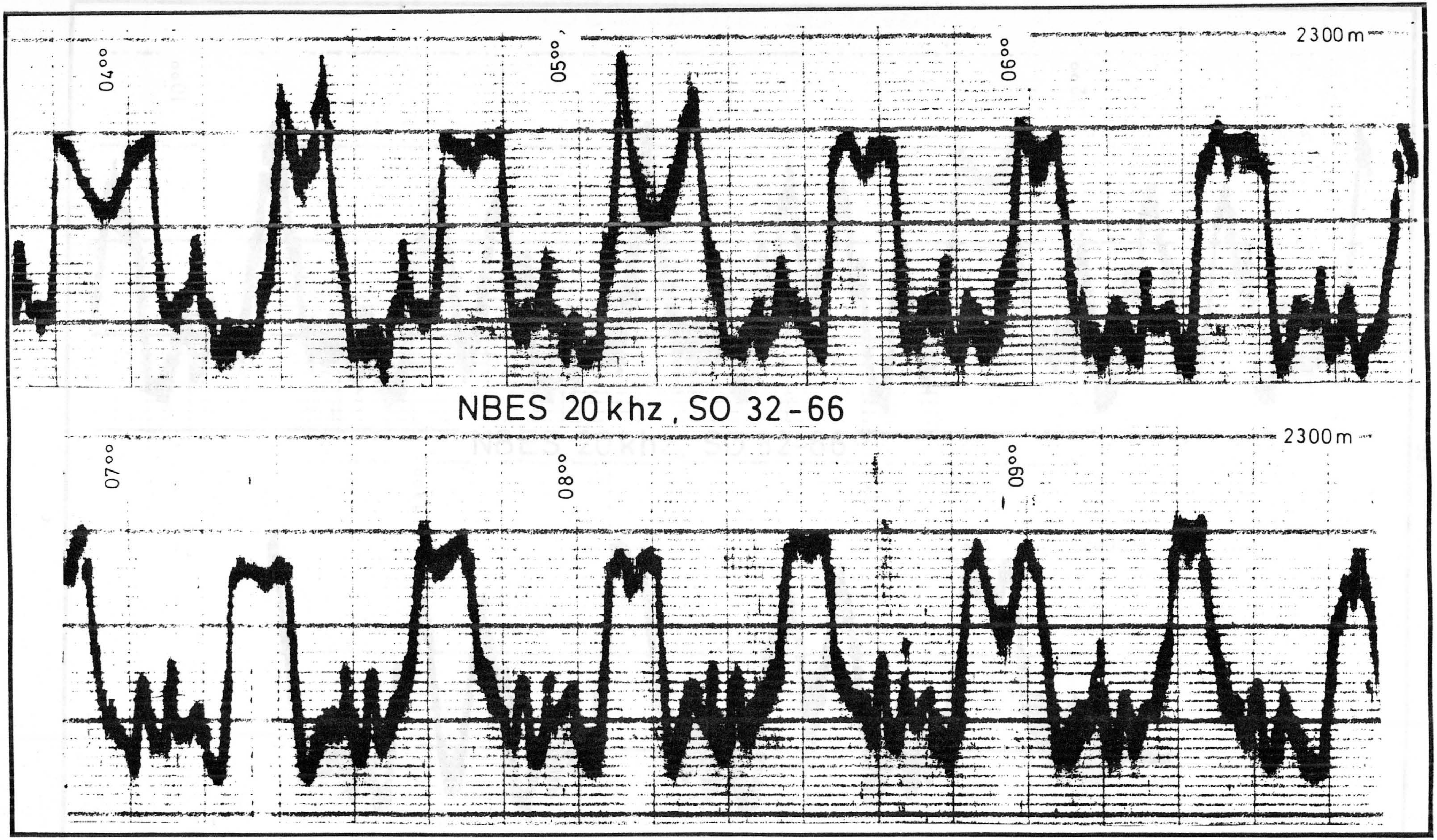


Fig. 6.37.

Series of bathymetric cross-sections at 85°51' W.

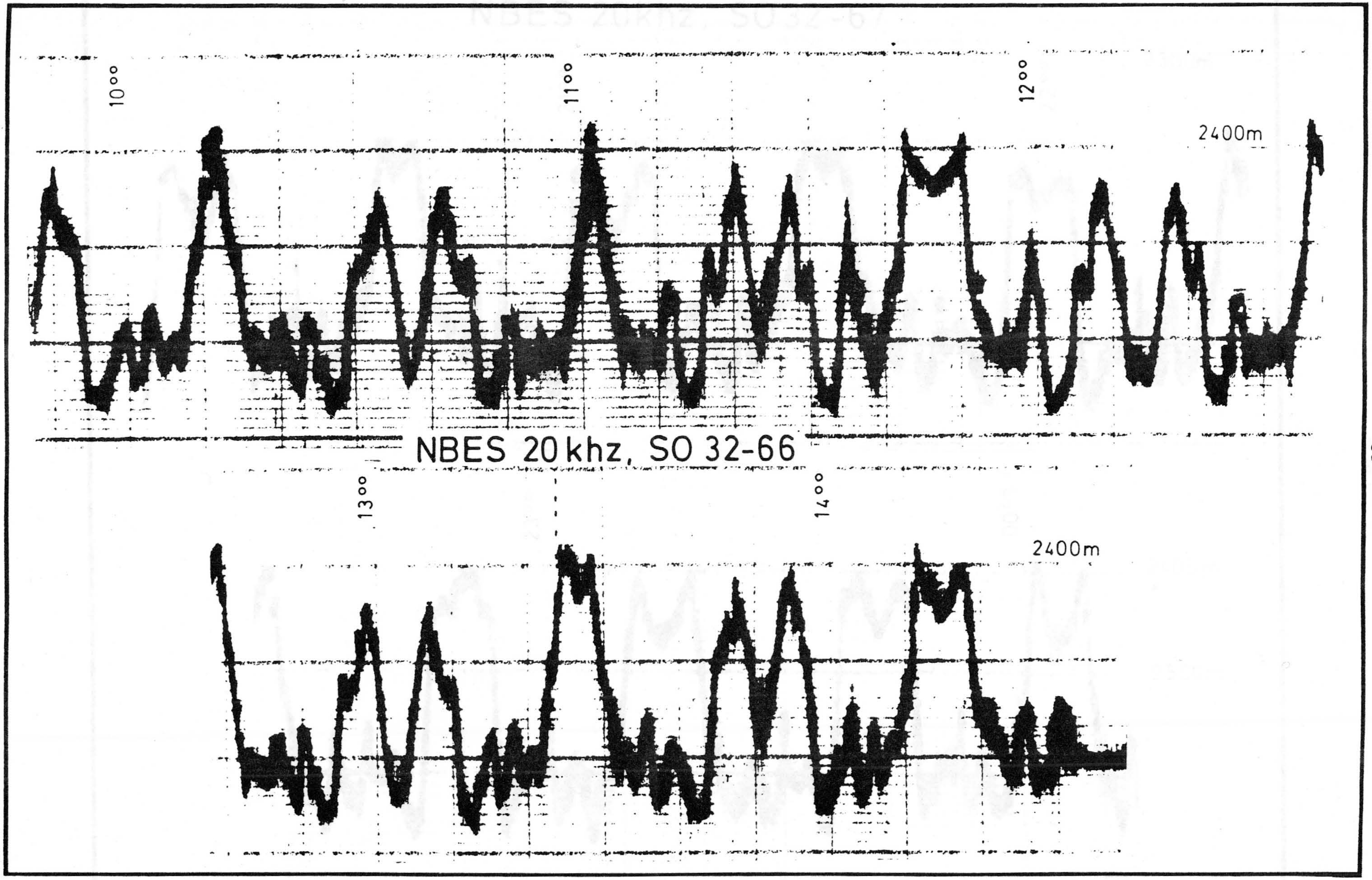


Fig. 6.38.
Series of bathymetric cross sections at $85^{o}51'$ W.

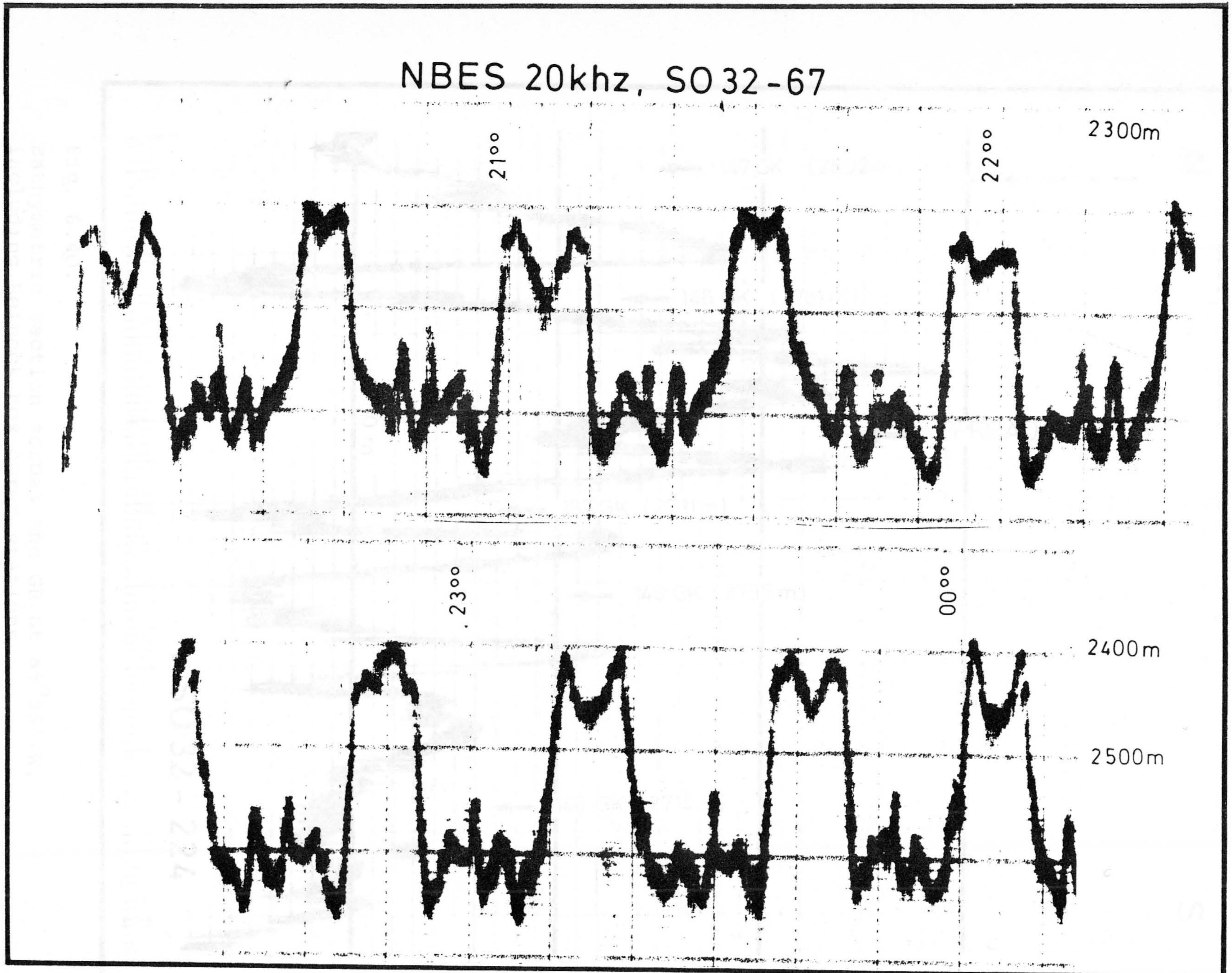


Fig. 6.39.

Series of bathymetric cross-sections at 85o51' W.

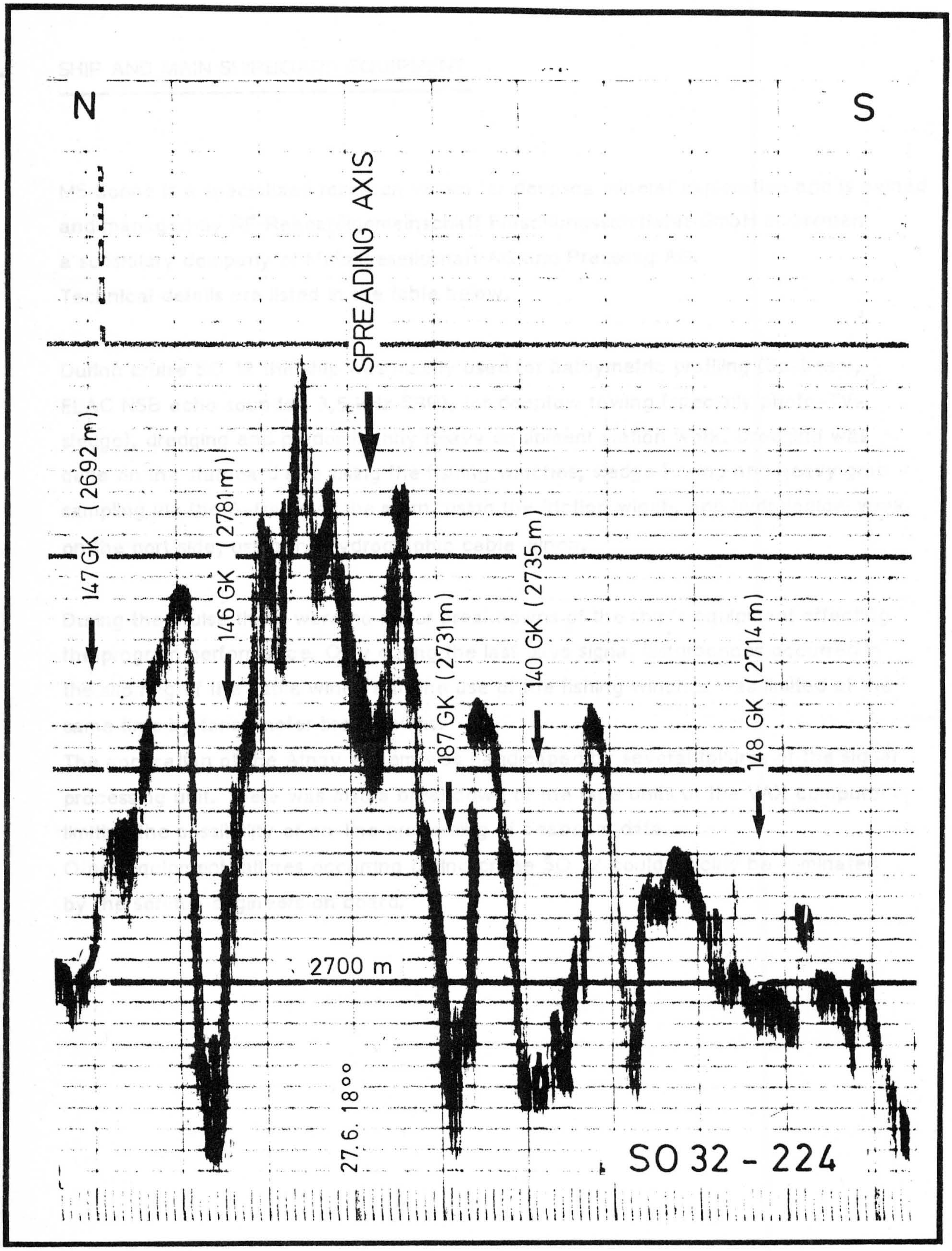


Fig. 6.40.

Bathymetric section across the GR at 85°55' W, including Reineck box corer stations.

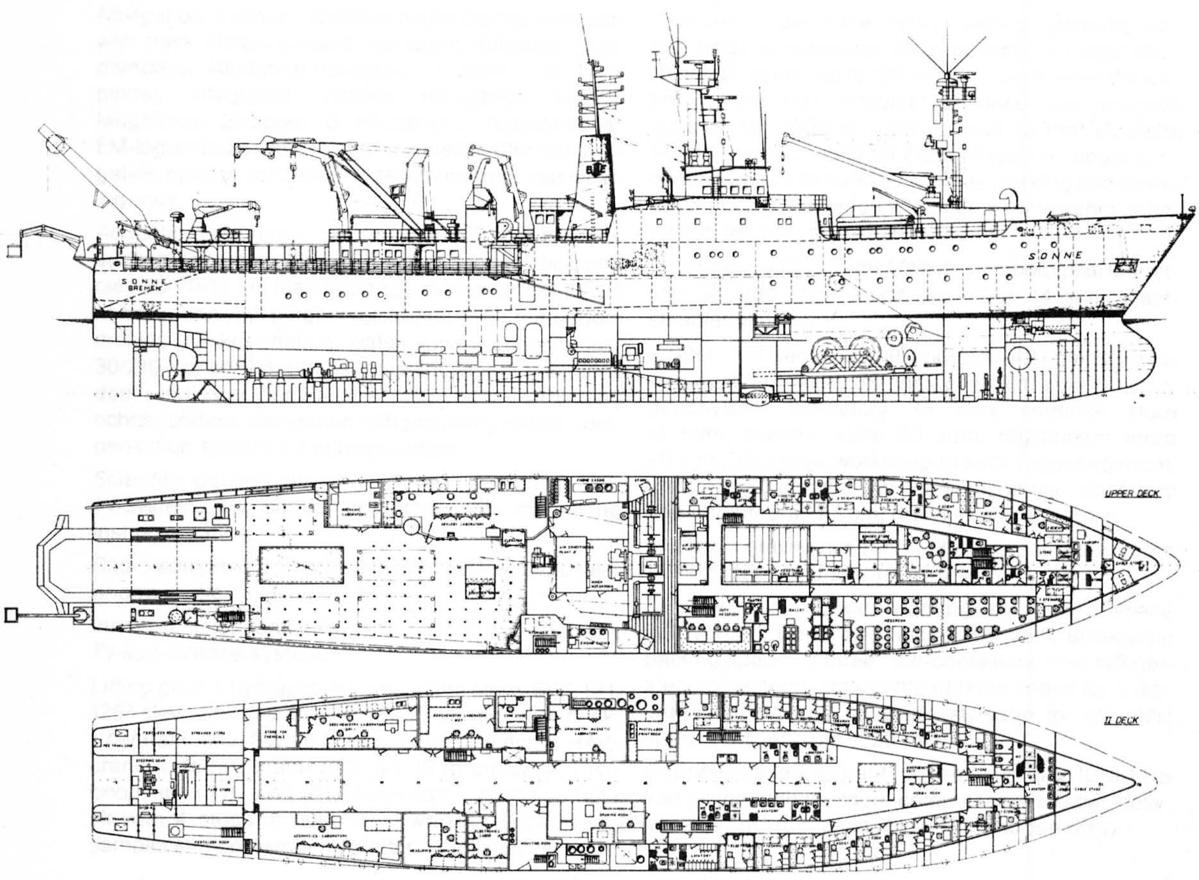
7. SHIP AND MAIN SHIPBOARD EQUIPMENT

MS Sonne is a specialized research vessel for deepsea mineral exploration and is owned and managed by RF Reedereigemeinschaft Forschungsschiffahrt GmbH in Bremen, a subsidiary company of Metallgesellschaft AG and Preussag AG.
Technical details are listed in the table below.

During cruise SO 32 the ship was mainly used for bathymetric profiling (Seabeam, ELAC NSB echo sounder, 3,5 kHz SBP), for deeptow towing (specially photo-TV-sledge), dredging and predominantly heavy equipment station work. Dredging was done on the starboard side using the fishing winches, sledge towing and heavy grab sampling via the A-frame at the stern, using the friction winch, and hydrological work on the port side, using the hydrographic cable winch.

During the cruise there were no major breakdowns of the ship's equipment effecting the program performance. Only during the last days signal disturbances occurred in the slip ring of the cable winch and the use of the fishing winches was limited at the same time by tensiometer breakdowns.
The application of the Atnav system was handicaped by several failures of the signal processing unit. There was also a breakdown of the tape units of the VAX computer limiting the possibility of on-line processing of Seabeam data.
Other equipment failures occurring during cruise SO 32 could quickly be eliminated by the service engineers on board.

RV SONNE, technical details



Flag: Federal Republic of Germany.

Port of registration: Bremen.

Call sign: DFCG.

Classification: GL + 100 A4 EF + MC.

Owners: Partenreederei MS SONNE.

Managing owners: RF Reedereigemeinschaft Forschungsschiffahrt GmbH, August-Bebel-Allee 1, D-2800 Bremen 41, Tel.: (421) 232059, Telefax: (421) 239462, Telex: 246062 rfor d.

Built: 1969, as stern-fishing trawler at Rickmers Werft, Bremerhaven, converted 1977 at Schichau Unterweser AG, Bremerhaven and 1978 at Rickmers Werft, Bremerhaven.

Basic dimensions: GRT: 2607, NRT: 1263, Displacement: 3834 t, Length o.a.: 86.81 m, Length p.p.: 76.20 m, Beam 14.2 m, Draught: max. 6.50 m, Depth main deck: 9.30 m, Service speed: 13 kn.

Personnel: Crew: 26, Scientists: 23.

Main engine: 4 x MaK 8 M 281 AK = 4x735 kW.

Propulsion: 2 x BBC-propulsion motors. 2 x 1100 kW.

Manoeuvring propulsion devices: Escher Wyss variable pitch propeller, bowthruster 588 kW, 10 t thrust. Special rudder with flap.

Generators: 4 x BBC, 4 x 810 kVA, 380 V, 50 c.

Ship's network: 380 V, 50 c; 220 V, 50 c by transformator.

Stabilized network: 380/220 V, 50 c, voltage stab. ±1%, frequency: stab. ±0.5%, dynamic ±1.2%, 40 kVA total.

All living rooms and laboratories are fully air conditioned.

Bunker capacity: 920 t gasoil, 50 t fresh water, fresh water production 30 t/day.

Consumption: 10 t gas oil/day at service speed.

Maximum service duration: 90 days.

Sewage treatment, oil seperator.

Navigation: 3 radars, direction finder, Decca navigator with track plotter, Loran-C-navigator, autopilot, gyrocompass, Nautomat-navigation system with track plotter, integrated satellite navigation system Magnavox, 2xLoran C micrologic, doppler-sonar, EM-log, monitors and teletypes, satellite/Omega navigation system, additional master's control near working area.

Acoustic equipment: bathymetric multi-beam-sonar system Sea-Beam, Elac NSB echo sounder 3 frequencies 30/20/12 kc, Elac deep sea-echosounder (ENIF) combination with pinger registration 12 kc, subbottom profiler, 3.5 kc, shallow water survey echosounder 30/210 kc, acoustic transponder navigation system, depth indicator, horizontal echosounder, fish finding echosounders, navigation echosounder, heave compensation system for echosounders.

Scientific equipment: x-ray spectrometer, deep sea-TV-system, XBT-sonde, comprehensive measuring instrumentation.

Radio equipment: Short wave SSB 1.6 kW, radio telephony, wireless teletype, VHF.

Intercom: telephone, talk-back-system, walky-talkies, TV-surveillance system.

Lifting gear: 1 hydraulic A-frame at the stern, SWL 12 t, 125° slewable, 2 cranes AK 6000 on the work deck, 1 central crane, SWL 8 t, max. 14 m outreach, 1 HAP-crane, 1 derrick crane SWL 5 t, 12 m outreach, 1 jib-boom up to 3 m, SWL 10 t, 1 corer frame, 24 m, 1 sample lift with 4 stops in hold, labs, working deck, water sampler station, 1 working platform (dolly) at the stern.

Winches: 1 Deep tow winch, electro-hydraulic with 2 storage winches for 8000 m rope or cable each 18 mm Ø, speed up to 120 m/min, "slack-line-take-up" and "wave compensator", 2 deep sea winches (spares) for 7000 m rope, 12 and 18 mm Ø, each, 1 hydrographic winch for 6000 m rope or single conductor cable, 4 to 8 mm Ø, various working and auxiliary winches, 3 measuring systems for winches (controlling tension, speed and length).

Laboratories (379 sqm) Main deck: geological laboratory 58 sqm, mechanical workshop 14 sqm, water sampler station.

II. Deck: wet geochemical laboratory 42 sqm, dry geochemical laboratory 38 sqm, chemical store 10 sqm, geophysical laboratory 35 sqm, streamer store 15 sqm, seismic store 30 sqm, registration room 20 sqm, electronic workshop 13 sqm, mounting room, gravimetry/magnetic lab 30 sqm, photo laboratory and copy room 17 sqm, drawing office 22 sqm.

III. Deck: gravimeter room 13 sqm, computer room 14 sqm, echo sounder room 8 sqm.

Handling/work space: working deck, free space 220 sqm, II. Deck: free space 200 sqm, accessible parking space for three 20 ft-containers (also refrigerated containers), accessible parking space for 5 laboratory containers on deck, stowage for scientific equipment 145 sqm (320 m^3).

Geophysical equipment: (for seismic) 6 x JUNKERS free piston high pressure compressors 150 bar, delivery 2.05 m^3/min each, slipway for airgun array.

RF Reedereigemeinschaft
Forschungsschiffahrt GmbH · Bremen
August-Bebel-Allee 1 · D-2800 Bremen 41
Phone (421) 232059 · Telex 246062 · Telefax (421) 239462

8. NAVIGATION

The positioning of the ship was based mainly on satellite navigation (Satnav). During stationary work the satellite navigation has been supported by acoustic transponder navigation (Atnav) and the bathymetry mapping system Seabeam.

8.1 Satellite Navigation

The US satellite navigation system TRANSIT consists of five to six satellites in polar orbit. Each satellite continually transmits on the two frequencies 400 and 150 MHz and on each carrier the orbital information of that particular satellite is impressed. While measuring the Doppler shifts of the two frequencies of the moving satellite during the visible time of 15 to 20 minutes, the integrated computer of the Magnavox Satellite Navigation System calculates the position of the ship by means of the dead reckoned ship's position. This position has been determined continually between the two satellite fixes by recording the ship's speed by Doppler Sonar and the ship's heading by gyro.

The precision of a satellite fix depends much on the accuracy of the ship's position during the pass. During stationary work the ship's speed values have the largest inaccuracy and the absolute position of the ship will be worst. A measure of the position accuracy is the offset between a satellite fix and its dead reckoning position. For the Galapagos Rift Area W 86° the following results have been calculated:

time interval:	June 23rd 1984 0:02 - June 30th 1984 23:57
number of accepted fixes:	100
fix rate:	1 fix/115 min
mean offsets	latitude 0.242
	longitude 0.333 km

The fix rate and the offset are better than values observed during earlier cruises in the southeast Pacific.

8.2 Atnav Navigation

Another navigation system used in the Galapagos Rift area was the Acoustic Transponder Navigation System ATNAV II manufactured by AMF SeaLink/EG+G. Here the positioning is performed with reference to an array of bottom-moored acoustic transponders. The system operates on the principle of measuring the ranges of the ship to three transponders. To determine the slant range an interrogation pulse is transmitted from the ship and the elapsed time until receiving the reply pulse by the trnasponder is measured. Then with reference to the precisely known positions of the transponders the position of the ship within the array can be calculated. Additionally the position of a deeptowed vehicle can be monitored by using a so-called sub-transponder which is attached to the vehicle.

Within the W 86°-area totally nine transponders had been moored at the top of the graben flanks. The length of the array was about 5 nautical miles and the width about 2 nm, the distances between the transponders were about 2 nm (Fig. 8.1). The positioning precision inside the calibrated array met the standard (rms 1.4 m). Because of several malfunctions of the calculator, which was not repairable using the ship's facilities, it was not possible to calculate the ship's position by the Atnav system during the whole cruise. Instead ranges of the transponders were hand-plotted on range maps produced for the purpose.

Position of the transponder

No. - XPNDR	Frequ. (kHz)	Latitude (N)	Longitude (W)
0	7.5	0°45.5'	85°50.3'
1	8.0	0°45.9'	85°51.8'
2	8.5	0°44.7'	85°51.6'
4	9.5	0°46.9'	85°54.2'
6	10.5	0°45.7'	85°53.2'
7	11.0	0°45.5'	85°49.0'
8	11.5	0°44.7'	85°50.1'
10	12.5	0°45.0'	85°51.4'
11	13.0	0°45.7'	85°53.2'

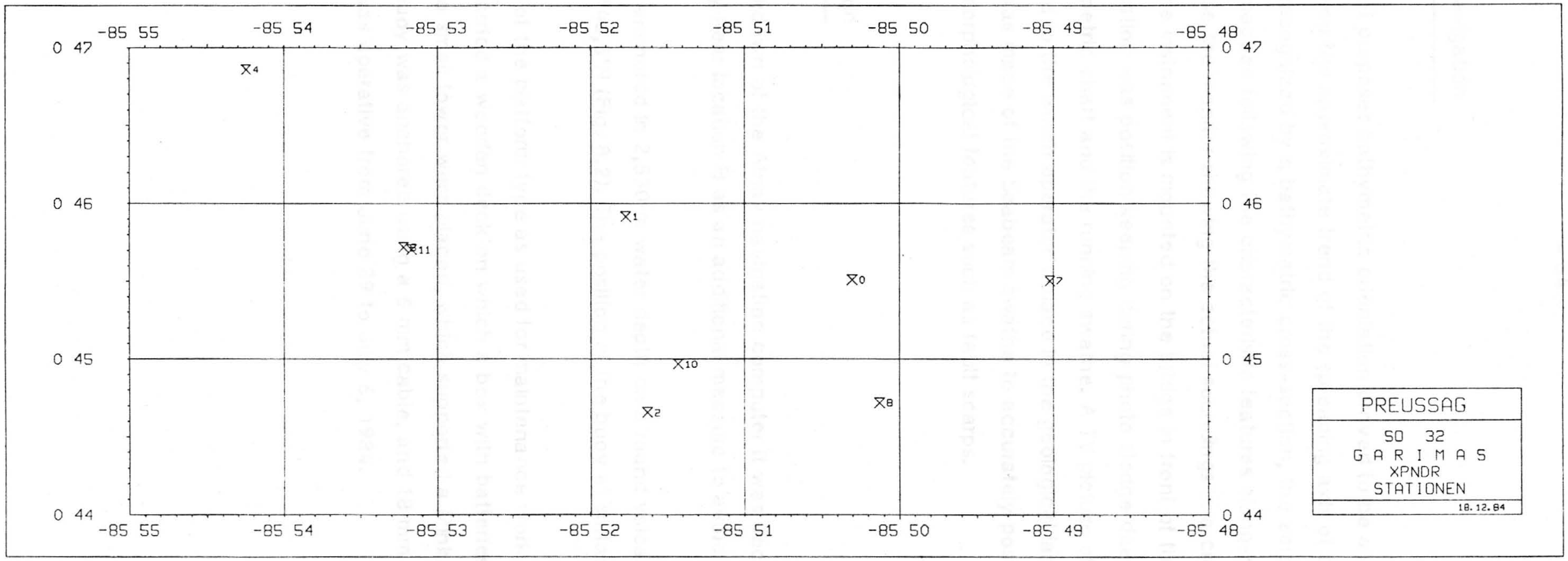


FIG. 8.1 ATNAV–TRANSPONDER STATIONS DURING SONNE CRUISE 32 (1984)

8.3 Bathymetric Navigation

For a number of purposes bathymetric orientation proved to be a good navigation aid. E.g. knowing the approximate trend of the spreading axis of the Galapagos Rift, and having it recognized by a bathymetric cross-section, the zero-age zone was subsequently mapped following the characteristic features along-strike.
For that purpose the monitor showing the actual soundings in a cross-section, was very useful. The instrument is mounted on the bridge in front of the helmsman.
Another application was position keeping during photo sledge deeptow profiling, using a bathymetric chart and the running swathe. A TV picture of the latter was also transferred to the winch operator's place in the geological lab.
A similar use was made of the Seabeam swathe to accurately position the TV grab in relation to morphological features such as fault scarps.

8.4 Buoy Navigation

After the breakdown of the Atnav navigation computer it was decided to place an anchored buoy near location B as an additional measure to avoid drifting during sampling.
The buoy was anchored in 2,530 m water depth on a round volcanic edifice near 85°56W and 0°46,5'N (Fig. 8.2). The position of the buoy at surface proved to be rather stable.
The buoy was of the platform type as used for maintenance work around the ship. Steel barrels carried a wooden deck on which a box with batteries (those used for the grab) and a small tower were placed, which supported a Miniranger navigation beacon. The buoy was anchored using a 6 mm cable, and 18 mm cable near bottom. The platform was operative from June 29 to July 6, 1984.

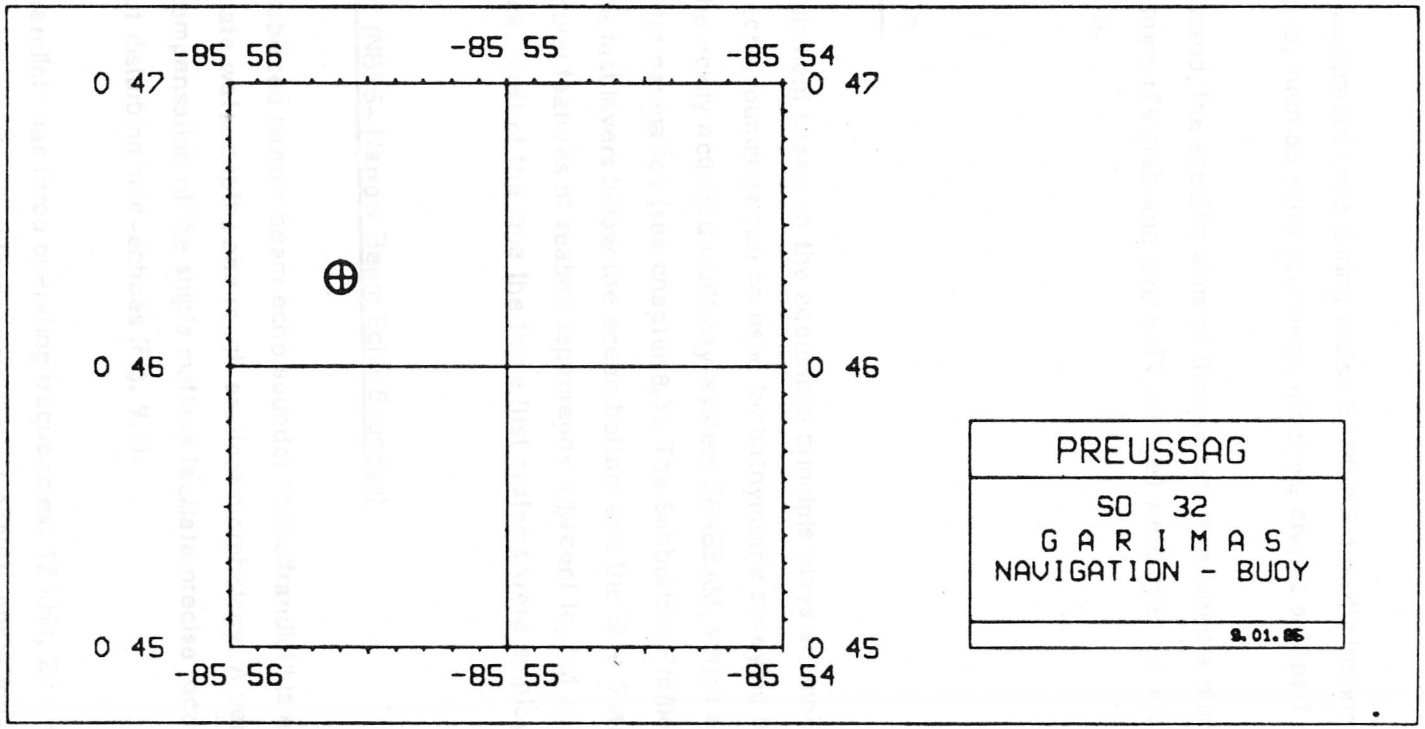


FIG. 8.2 POSITION OF THE NAVIGATION BUOY, 29.6. – 6.7.1984

9. RESEARCH EQUIPMENT

The research equipment used during cruise GARIMAS 1 partly belongs to the normal outfit of the ship, such as echo sounders, winches, cranes and part of the navigation systems.
On the other hand, the specific aims of the operation required a number of special tools, two of them (TV grab and photo-TV-sledge) were used for the first time in a research cruise.

9.1 Echo Sounders

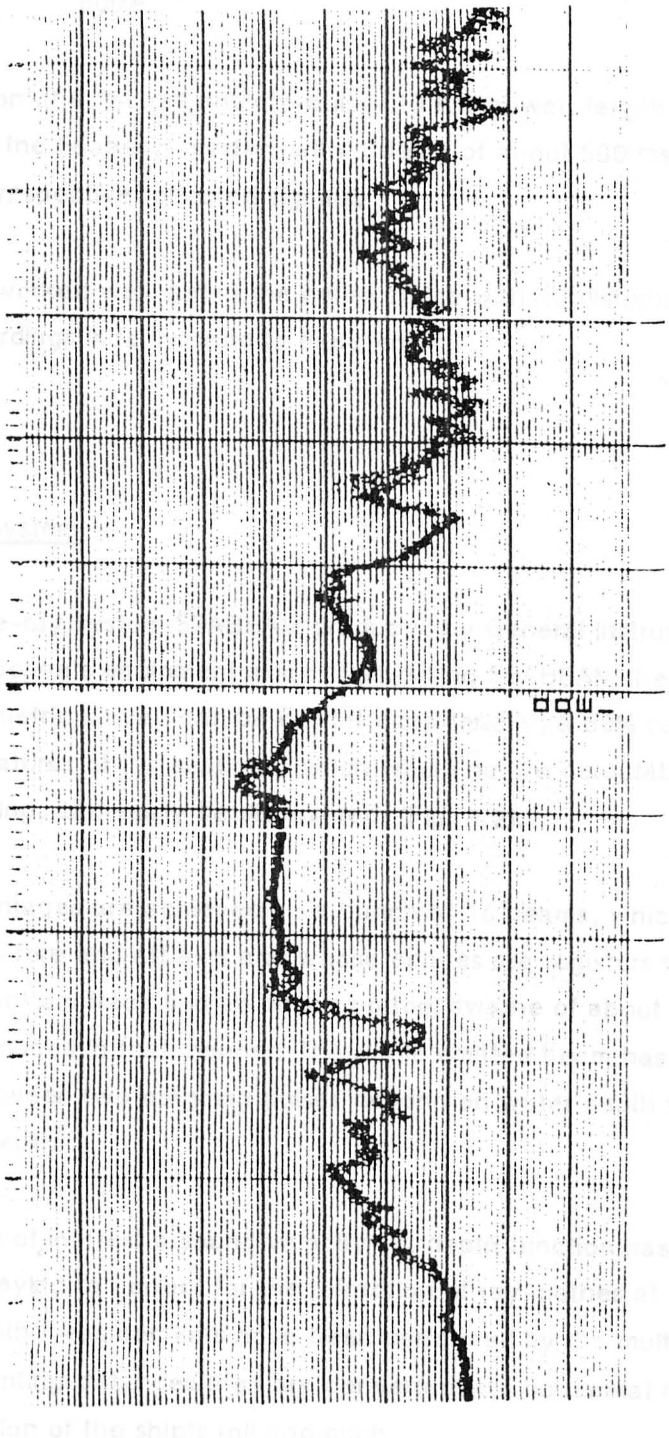
Research equipment based on the acoustical principle plays an important role in marine geophysics. Echo soundings can be used for bathymetric suveying by either "Schelf-randlot" or the newly acquired multi-ray-system SEABEAM, which also serves as an practical aid for navigation (see chapter 8.3). The Subbottom Profiler reveals the stratification of the first layers below the ocean bottom and the Side Scan Sonar is a mean to detect natural features of seabed topography adjacent to, but not directly beneath the tools track. Most of the time the three first systems were employed simultaneously.

9.1.1 Schelfrandlot (NBES- Narrow Beam Echo Sounder)

The ELAC stabilized narrow beam echo sounder "Schelfrandlot" is especially designed for intermediate water depths and rough seafloor morphology. A very small beam angle (1,4°) and compensation of the ship's motions faciliate precise recording of the bottom track without disturbing side-echoes (Fig. 9.1).

The "Schelfrandlot" has three operating frequencies: 12 kHz, 20 kHz and 30 kHz.
20 kHz was used as standard frequency. During ATNAV-operations (chapter 8.2) and detailed surveying over the locations of interest frequency has been switched to 30 kHz for two reasons:

FIG. 9.1 RECORD OF THE ELAC NARROW BEAM ECHO SOUNDER "SCHELFRANDLOT". 100 M-INTERVALS STARTING WITH 1,300 M. MASTER RECORDER. FOR DETAIL WORK, SLAVE RECORDERS WERE SET TO 500 OR 100 M TOTAL RECORD INTERVAL



- to avoid disturbance of the acoustic transponder navigation system (working within a range of 7.5 kHz to 15 kHz)
- to achieve a better resolution of steeply inclined structures by a sharp pulse.

The emission of a "Schelfrandlot"-pulse (10 KW power, length 10 ms) is triggered externally by the Seabeam-system with a delay of about 500 ms to enable proper identification of respective reflected signals.

The NBES worked well during the entire curise with no disturbances and the quality of the recordings is fairly good to excellent.

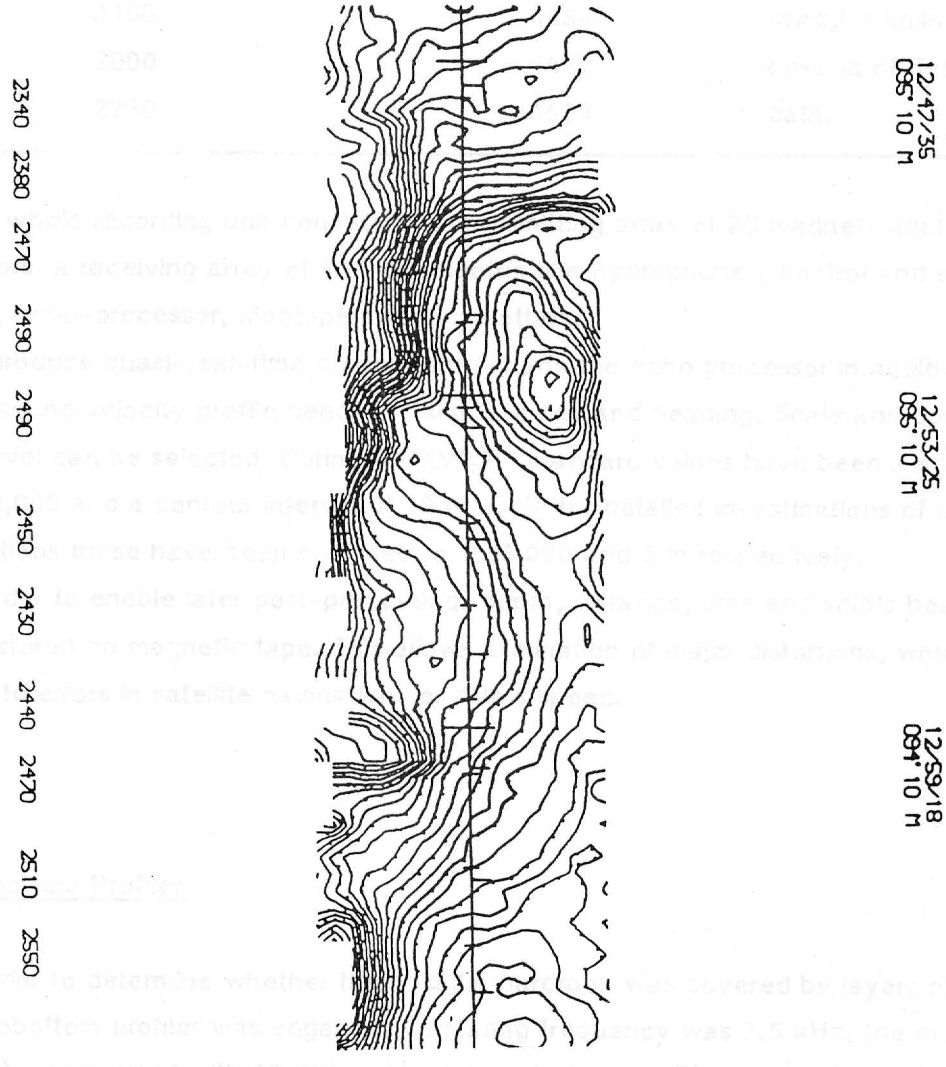
9.1.2 Seabeam-System

The multiple-ray system SEABEAM produced by General Instrument Corp. has been part of RV Sonne's equipment since 1981. Using SEABEAM the amount of time necessary for a bathymetric survey can be cut off considerably, a 50% reduction is possible at least. Features of the seafloor, which would not be detectable by conventional echo sounding, can easily be discovered (Fig. 9.2).

These advantages are achieved by a bunch of 16 beams, which fan out perpendicularly to the ship's fore and aft axis and whose echoes are registered simultaneously. Instead of a single bottom track line an ocean bottom swathe of about 0.8 times the water depth is produced in that manner. The single emitted beam has a solid angle of 2 2/3°, intervals between two outgoing pulses depend on water depth (rate decreases with increasing depth).

In the region of interest a sound velocity vs. depth function has to be determined prior to surveying to correct for the refraction of ray-pathes at layer boundaries. Velocity-depth measurements have been performed by the multisonde (see chapter 9.2). The slanting distances then are converted into horizontal distances and depths after correction of the ship's roll and pitch.

FIG. 9.2 EXAMPLE OF SEABEAM RECORDING DURING GARIMAS 1. THE SWATHE WIDTH IS ABOUT 1.5 KM. LEFT SIDE CONTOUR LINE DEPTH (IN M) AT THE SMALL MARKERS CROSSING THE AXIAL LINE. RIGHT SIDE TIME, HEADING AND CONTOUR LINE INTERVALS.



Depth (m)	Velocity of sound ($\frac{m}{s}$)	
0	1535	
100	1507	
300	1500	
500	1490	
900	1485	Sound velocity profile
1160	1484	used for online pro-
2000	1492	cessing of Seabeam
2730	1503	data.

The whole recording unit consists of a transmitting array of 20 magnetostrictive projectors, a receiving array of 40 piezoelectric line hydrophones, control and steering unit, echo-processor, magtape and two plotters.

To produce quasi-real-time contour strip charts the echo processor in addition to the sound velocity profile needs the ship's speed and heading. Scale and contour interval can be selected. During GARIMAS 1 standard values have been a scale of 1:20,000 and a contour interval of 10 m. Only for detailed investigations of certain locations those have been switched to 1:10,000 and 5 m respectively.

In order to enable later post-processing, depth, distance, time and ship's heading are stored on magnetic tape. This allows elimination of major distortions, which are due to errors in satellite navigations or ship's speed.

9.1.3 Subbottom Profiler

In order to determine whether the basaltic hardrock was covered by layers of sediment a subbottom profiler was engaged. Operating frequency was 3.5 kHz, the pulse (length 1 ms) was emitted with 10 KW and an interval of 1 sec. Because of the relatively low working frequency echoes from below the seabed can be recorded.

The complete unit consits of a 10 KW transceiver and control unit (O.R.E.), an array of 16 transducers and an EPC Graphic Recorder.

Quality of records was not at an optimum due to the very rough topography of the spreading centre and its vicinity. Particularly a great number of side-echoes disturbed the recordings, yet it was possible almost every time to determine the presence of sediments covering the fresh lava.

9.1.4 Deep-Towed Side Scan Sonar

The AMR-Deeptow system consists of a deep-towed carrier and its shipboard units for deep ocean research of the ocean bottom micromorphology. The vehicle is equipped beside some control sensors with a side scan sonar and a subbottom profiler.

The side scan sonar operates on a frequency of 100 kHz and an acoustic source level of 117 dB at 1.2 KW power output. The bottom reflected signals are transmitted digitally via an 18 mm coax cable to the surface and then recorded on a graphic recorder. Digitally side scan signals can be displayed slant range corrected with the fish depth as input. The swathe width of the observed ocean bottom was two times 200 m.

Within the Galapagos area W 86° the subbottom profiler was used as an altimeter in order to keep the fish exactly at 50 m altitude above ground.

On 3 profiles in the 86°W Galapagos Rift area the Deeptow-fish has been engaged. Initial problems with the signal recording became worse during the last two deeptow deployments. As a reaction to this malfunction the application of the tool has been abandoned for the rest of the cruise.

9.2 Oceanographic Equipment

9.2.1 Multisonde

The Multisonde of ME Meerestechnik-Elektronik, Trappenkamp, is a high-precision multi-sensing STD-probe, which provides the opportunity to gather fast and simultaneous information about the vertical and horizontal distribution of a great number of different hydrophysical and -chemical parameters (see Tab. 9.1). Beside the parameters listed in Tab. 9.1 the salinity is on-line calculated from the pressure, temperature and conductivity readings applying the recently developed so-called "UNESCO-Formula". The Multisonde is a versatile measuring instrument capable to monitor up to 32 different parameters.
The system consists of two parts - the underwater measuring unit and the board unit. The underwater unit is equipped with six different probes and is tested for a water depth down to 6,000 m. The unit is designed to measure preferably continuous vertical profiles, but, mounted in a deep towed vehicle, it is also capable to measure horizontal profiles. The underwater unit is connected to the board unit via a hydrographic winch

and a 8 mm diameter coaxial cable. The board unit displays all parameters and provides three analogue outputs for on-line graphic recording. The digital output is recorded on magnetic tape and additionally quasi on-line plotted on a computer graphic screen. Last not least the Multisonde provides the possibility to trigger twelve release mechanisms mounted in a rosette water sampler.

9.2.2 Water Samplers

Water sampling during the Garimas cruise was carried out with the rosette water sampler triggered via the Multisonde. The electric-mechanical release mechanisms mounted in the rosette sampler were tested for water depths down to 6,000 m. The rosette sampler was equipped with ten plastic water samplers of the Niskin type, each capable to recover 5 liters of sea water. The Niskin water sampler features all plastic construction with a free flushing design by large inlets. The sampling tube is completely metal-free. Four of the mounted samplers were supplied with a triple thermometer tube for three thermometers. Each of the thermometer tubes was equipped with 2 reversal thermometers.

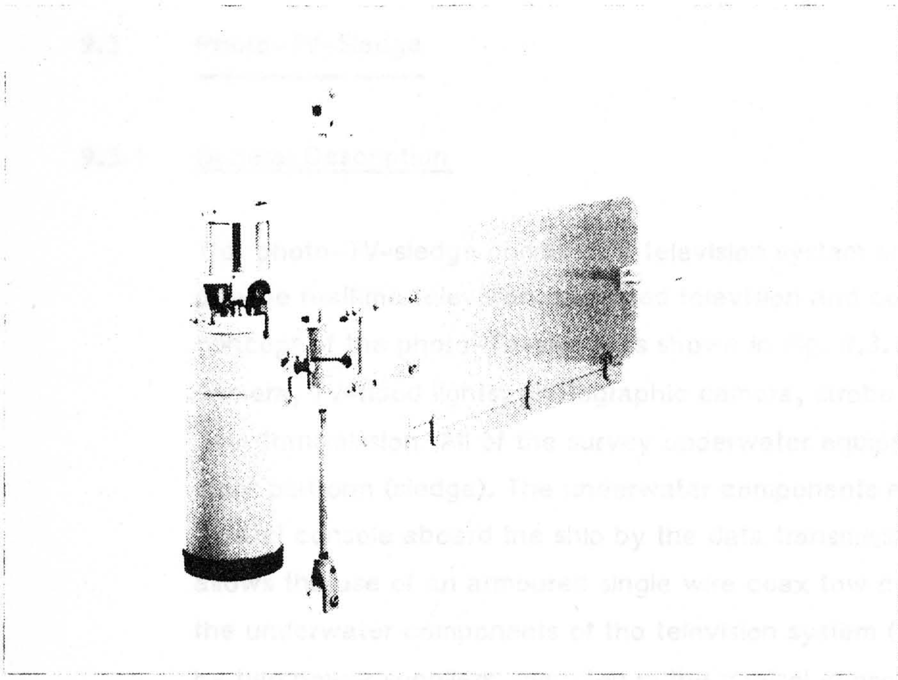
9.2.3 Current Meter

Current measurements above the sea floor were carried out with an "Aanderaa RCM 5", which is a cycle counting "Savonius" rotor type current meter. The RCM 5 is a self-recording instrument. It is pressure-proved to a water depth of 6,000 m. Depending on the measuring interval the recording and battery capacity reaches up to 2 years. More technical data are presented in Tab. 9.2.

TAB. 9.1 TECHNICAL DATA OF MULTISONDE PROBES

	Pressure	Temperature	Conductivity	Diss.Oxygen	Light Attenuation	Sound Velocity
Physical unit	d bar	°C	mmho/cm	% O_2	a/m	m/sec
Principle of measurement	piezo re-sistive	platinum re-sistance	symmetric elec-trode cell	membran covered multi microcathode	light at-tenuation	wave oscillator with constant wave length
Meas. range	0-6000 dbar	-2 - +32°C	0-60 mmho/cm	0-150% O_2	0-94%/m	1400-1600 m/sec
Resolution	0.1 dbar	0.001°C	0.001 mmho/cm	0.1% O_2	0.01 %/m	0.015/m/sec
Accuracy	± 2.5 %o	± 0.005°C	± 0.01 mmho/cm	1% O_2	± 0.1 %/m	± 0.04 m/sec
Time constant of probe	-	60 msec.	50 msec.	60 sec.	50 msec.	10 msec
Duration of one single measurement	2 msec	2 msec	2 msec	-	2 msec	2 msec
Max. working depth	6000 m	6000 m	6000 m	6000 m	6000 m	6000 m
Remarks	3 different measuring ranges are available	2 different types are available	2 different ranges are available	output is also in mg/l avai-lable	the length of light path is selectable	the measuring range is selectable

TAB. 9.2



SPECIFICATIONS

MEASURING SYSTEM:
Self balancing bridge with sequential measuring of six channels and recording on magnetic tape. A ten bit binary word is used for each channel.
Measuring Speed: 4 seconds each channel.
The channels are:

1. REFERENCE:
This is a fixed reading that acts as a control on the performance of the *RCM*, and also as an identification of individual instruments.

2. TEMPERATURE:
Sensor Type: Thermistor (Fenwal GB32JM19)
Ranges:
Low Range: – 2.46°C to 21.40°C (standard).
High Range: 10.08°C to 36.00°C.
Wide Range: – 0.34°C to 32.17°C.
Accuracy: ± 0.05°C.
Resolution: 0.1% of range selected.
63% Responce Time: 12 seconds.

3. CONDUCTIVITY: (optional)
Sensor Type: Inductive cell.
Ranges: 0 – 77 mmho/cm., (standard).
25 – 72 mmho/cm
25 – 38 mmho/cm
Resolution: 0.1% of range.
Calibration Accuracy: ± 0,025 mmho/cm

4. PRESSURE: (optional)
Sensor Type: Bourdon tube driving a potentiometer.
Ranges: 0-100 PSI, 0-200 PSI, 0-500 PSI, 0-1000 PSI, 0-3000 PSI, and 0-9000 PSI. 0-3000 PSI is standard.
0-9000 PSI is available for *RCM5* only
Accuracy: ± 1% of range.
Resolution: 0.1% of range.

5. CURRENT DIRECTION:
Sensor Type: Magnetic compass with needle clamped on to potentiometer ring.
Resolution: 0.35°.
Accuracy: ± 7,5°C for current speed within 2,5 to 5 cm/sec., or 100 to 200 cm/sec.
± 5° for speed within 5 to 100 cm/sec.
Maximum Compass Tilt: 12° from horizontal.

6. CURRENT SPEED:
Principle: Rotor with magnetic coupling through instrument case. The number of rotations during the period between 2 samplings are counted by an electronic counter. This counter has a pre-circuit with a choice between ten dividing factors, suited for sampling intervals from 0,5 to 180 minutes.
Standard is 4 rev/count.
Range: 2.5 to 250 cm/sec.
Accuracy: ± 1 cm/sec., or ± 2% of the actual speed, whichever is greater.
Starting Velocity: 2.0 cm/sec.

CLOCK:
Type: Quartz crystal
Accuracy: Better than ± 2 sec/day within 0°C to 20°C.
Sampling Intervals: 0.5, 1, 2, 5, 10, 15, 20, 30, 60 and 180 minutes, selected by interval selecting switch.
External Triggering: For calibration purposes, a six volts positive pulse to terminal on top end plate will activate the instrument.

RECORDING SYSTEM:
Type: Reel to reel 1/4 inch magnetic tape.
Coding: 10 bit binary words (short and long pulses) in serial form
Storage Capacity: 10.000 samplings using 600 feet of magnetic tape on 3 inch reels.

TELEMETRY:
Acoustically:
By switching on and off carrier from acoustic transducer.
Frequency: 16,384 KHz ± 5 Hz.
Detection Range: Typically 800 meters with *Hydrophone Receiver 2247*.
By Cable:
5 volts negative, short and long pulses from terminal on top endplate. May be used for real time readings and for calibration purposes by use of *Printer* 2860.

POWER:
Battery: 9 volts, non-magnetic. Leclanche 821
Size: 63 x 50 x 80 mm.
Capacity: sufficient for 10,000 samplings.

MOORING:
Spindle designed for 15 mm. maximum diameter rope. Gimbal mounting permits 27° deviation between spindle and instrument

EXTERNAL MATERIALS:
Pressure Case: Cu Ni Si alloy (OSNISIL) and stainless acid proof steel. Epoxy coated.
Vane: 8 mm PVC plastic.
Other plastic parts: Polyamid & Polystyrene.
Other metal parts: Stainless acid proof steel and nickel plated bronze. Epoxy coated.

		RCM4	RCM5
DEPTH CAPABILITY:		2000m	6000m
NET WEIGHT:			
Recording Unit,	in air	13.7kg	15.8kg
	in water	9.2kg	11.0kg
Vane Assembly,	in air	12.9kg	13.4kg
	in water	8.1kg	8.5kg
DIMENSIONS:			
Recording Unit:	height	510mm	535mm
	diameter	128mm	
Overall length		1370mm	
Overall height		750mm	
Vane size		370 x 1000mm	
GROSS WEIGHT:			
Recording Unit		19.1 kg	21.0 kg
Vane Assembly		20.6 kg	21.1 kg

PACKING: (RCM4 & RCM5)
Recording Unit:
Plywood Case 190x230x610mm
Vane Assembly:
Plywood Case 155x400x1020 mm

SPARES:
A set of recommended spares is delivered with each instrument. (rotor, bearings, o-rings etc.)

WARRANTY:
One year aganist faulty materials and workmanship.

9.3 Photo-TV-Sledge

9.3.1 General Description

This photo-TV-sledge combines a television system and a photographic system to provide realtime television, recorded television and colour photography. The overall concept of the photo-TV-sledge is shown in Fig. 9.3. The system includes the TV-camera, TV-flood lights, photographic camera, strobe lights, batteries and control data transmission. All of the survey underwater equipment is mounted on an instrument platform (sledge). The underwater components are connected with a system control console aboard the ship by the data transmission system (telemetry) which allows the use of an armoured single wire coax tow cable. The required poser for the underwater components of the television system (incl. flood lights) is supplied by two power suppliers, mounted in the control console. They provide up to 640 VDC at 1.6 amperes.

9.3.2 Television System

The television system consists of a low light level camera, two flood lights mounted in the sledge and a shipboard monitor and video recorder. The underwater camera includes a motorized lens assembly and a silicon intensifier target (SIT) camera tube. The lens is a f/1.3 mini element design which has a focal length of 15 mm. The lens has a diagonal field of view of 55° in air and 40° in water. The two flood lights supply 2 x 250 watt of incandescent light power for illumination. With the use of the realtime television on the monitor it is possible to make decisions affecting the exploration work of the sledge (e.g. actuating of the photographic camera).

9.3.3 Photographic System

The photographic system is a general purpose instrument proven for use in a variety of deep ocean applications. The used photographic camera takes approx. 3200 exposures of 35 mm standard film per loading, and approx. 6400 exposures using thin-base film. A digital data chamber with light emitting diodes displays time, date and altitude (distance to the ocean floor). The altitude is measured with a short-range acoustic sounding device. Each time the camera takes a photo, it records the distance in meters to help to interpret the resulting photographs.

The camera is used with three strobe lights and companion power tracks. The strobe lights are fast recycling, high energy light sources, to provide an output of approx. 600 Ws, where the flash duration is so short that under most conditions photographs are sharp even if the camera or subject is in motion.

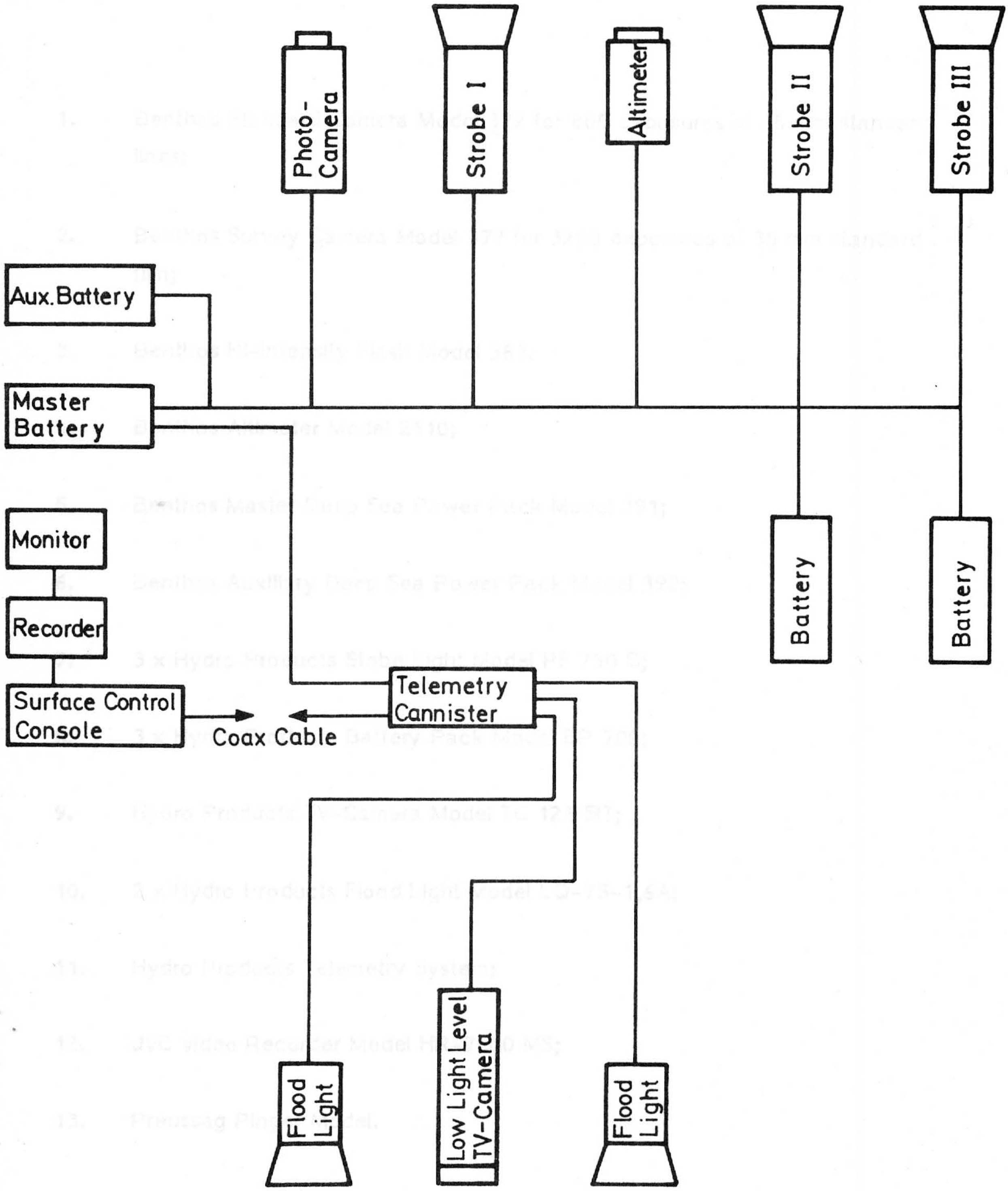
The whole system is powered by four battery packs which supply 28 VDC from rechargeable nickel cadmium batteries. A master battery pack controls triggering of the strobes, as well as actuation of the camera shutter and film drive. Three auxiliary battery packs are provided to assure continuous power for the strobes during a deep ocean mission. There are three possibilities to actuate the system

- actuation by a programmed interval
- actuation by a bottom switch
- actuation by a remote signal.

The photo and TV equipment used is listed in Table 9.3.

9.3.4 Telemetry System

The telemetry system consists of a system control console aboard the ship and a telemetry canister mounted in the sledge. The system control console includes power supply and all circuit boards involved in coding-transmitting and receiving-decoding of the telemetry signals. A front panel with control switches allows the user to control the underwater TV-system and actuate the photographic system. The telemetry canister includes some circuit modules identical to those in the control console. It provides operating power for the television camera, couples the TV video signal to the coaxial cable, and separates the light and television camera DC loads from the video signals.



PREUSSAG
Meerestechnik
Marine Technology

Photo - TV Sledge
overall concept

FIG. 9.3

TAB. 9.3 PHOTO AND TV EQUIPMENT USED DURING CRUISE SO 32

1. Benthos Standard Camera Model 372 for 800 exposures of 35 mm standard lines;

2. Benthos Survey Camera Model 377 for 3200 exposures of 35 mm standard film;

3. Benthos Hi-Intensity Flash Model 383;

4. Benthos Altimeter Model 2110;

5. Benthos Master Deep Sea Power Pack Model 391;

6. Benthos Auxiliary Deep Sea Power Pack Model 392;

7. 3 x Hydro Products Stobe Light Model PF 730 B;

8. 3 x Hydro Products Battery Pack Model BP 708;

9. Hydro Products TV-Camera Model TC 125 SIT;

10. 2 x Hydro Products Flood Light Model LQ-7S-1,6A;

11. Hydro Products Telemetry System;

12. JVC Video Recorder Model HR-7600 MS;

13. Preussag Pinger Model.

9.4 Electro-hydraulic TV Grab

During numerous cruises for deep seafloor exploration common sampling technologies often had turned out to be almost inefficient, when hard, consolidated sediments or rocks had to be recovered. This was mainly due to

- low penetration into the soil or low cutting forces, which yielded minimal or even no recovery;
- geologically bad or worthless samples because of blind sampling;
- loss of equipment because of getting entangled with the rocky seafloor.

Since 1982 Preussag Offshore Technology department has therefore designed and constructed a TV-equipped deep sea grab in order to overcome these disadvantages. Consequently the instrument is the prototype of a new generation of tools developed for controlled sampling of sediments and rocks in the deep sea.

After various pretests of components and shallow water trials, the final clamshell grab was then successfully tested at 950 - 1,760 m in the Red Sea and at 2,680 m in the Mediterranean Sea (Febr. and March 1984). Thus, GARIMAS 1 was the grab's first mission for non-testing purposes and its first one in rocky, hostile seafloor environment. The grab successfully accomplished its task and recovered for the first time rocks from the deep ocean floor.

9.4.1 Description of the Grab System

Basically its mechanical lay-out is similar to common clamshell dredges. However, its closing mechanism to achieve high cutting forces, the shape of jaws to realize a neutral grabline (for not disturbing any sediment samples) as well as its driving are the main components that have been newly designed.

All components of the steel construction - each one zinc-plated to minimize corrosion - are bolted and may easily be demounted by means of few tools available on board in order to facilitate maintenance or repair work.

The two jaws are operated by two hydraulical differential cylinders made out of stainless steel. A proceeding version of the grab was equipped with a pneumatic closing system. However, this principle is not suited for deep sea applications, but reasonably used down to a depth of some 500 m only. An electrohydraulic driving unit has therefore been developed. The unit is pressure-compensated and centrically placed right above the jaws, protected against any damage by 10 mm steel plates.

The direct current electrical motor inside the oilhydraulic equipment is capsulated under kerosene for reducing frictional losses and for isolating reasons.

The power supply is realized by two zinc-lead-batteries specially revised to withstand submerged service at great depths.

The TV-monitoring system basically consists of

- a black and white low light level video camera;
- two flood lights and one spot light;
- a serial working bidirectional telemetry transmission
- and a control center with one monitor on board.

The wide angle camera with an automatic focus is symmetrically placed between the jaws and covers an observation area of some 25 m^2 when moving over the sea-floor at a 2.5 m distance. High resolution (500 lines) as well as its high sensitivity guarantees good visual inspection of geological formations. Once the jaws are closed after sampling, the camera visualizes the grab's content, thus provides the information before returning on board whether sampling has been successful or not. This way, expensive down-time of the vessel may be avoided.

Control facilities provide two different modes of working. The first one being the normal one, when commands for jaw operation (closing or opening) as well as for lightning are submitted from the control center on board the vessel. Once the data link breaks down the system automatically switches to an automatic or emergency mode: One flood light is turned on and the jaws close or open respectively after a soil contact of more than 20 seconds.

9.4.2 Operation of the Deep Sea Grab

The grab is handled over the ship's stern ramp by means of the A-frame and then released in opened condition at a speed of some 80 m/min. After having reached the seafloor (1,700 - 2,900 m in the inspected area) lightning is turned on and seafloor observation may start by slowly moving above the ground at 1 m/sec according to the ship's heading. Depending on the distance between the sea bottom and the grab, which is roughly measured by a chain hanging freely vertical below the grab the track to be inspected ranges between 2 and 8 m.

Once a target has been detected sampling is only possible if the target is right below the grab as any steering is absolutely impossible. After soil contact cable has to be released until the grab is closed because the ship keeps drifting. During this critical phase of almost 30 sec it may happen (and it actually occurred twice) that the grab overturns, entangles the rope and damages the cable.

If sampling has not been successful, jaws may be reopened on command and sampling may be repeated. Depending on the number of closing and reopening actions, there is enough energy available for missions of 4 to 8 hours.

Heaving the grab is performed at less than 50 m/min limited due to chemical degasification of the batteries.

9.4.3 Maintenance

After each mission various components always have to be checked

- state of charge of batteries

  Voltage and current are measured during opening of jaws. If those values fall short of certain limits, both batteries, each one having a weight of some 70 kg, have to be replaced by a new set and recharged for about 12 hrs. Due to easy handling facilities, battery exchange lasts merely some minutes.
  On the average, depending on time and number of samplings, some three missions could be performed with one set of batteries.

- density and quantity of battery acid

  During decompression of batteries while surfacing, gas removes from the acid and escapes through special valves. However, it may happen that also acid is entrained or even seawater penetrates and dilutes battery cells. Usually the density is checked by means of an aerometer and leaving acid is replaced.

- diaphragm for oil and kerosene pressure compensation

  Because of cooling down from roughly 30°C (on board) to 1°C (near the bottom) as well as because of the environmental hydrostatic pressure of some 300 bar, the volume of oil and kerosene within the hydraulic unit is diminished which is compensated by 6 diaphragms. This reduction of volume turned out to be in the order of magnitude of 2 - 3 l. In order to avoid any entrainment of sea water the diaphragms had always carefully to be inspected because they could be damaged by small, sharp chips of hard basaltic rocks.

9.4.4 Results and Conclusions

Generally the grab worked almost satisfactorily. In spite of some failures the device performed 29 emissions with a total time of submergence of more than 100 hrs and recovered about 5 tons of rocks and sediments, including one ton of massive sulphides.

Mechanically, the grab worked perfectly, though one experienced that still a few components might be improved:

- diaphragms turned out not to be resistant against UV-light;
- some parts of the pressure compensating system on top of the batteries were oxidized by battery acid;
- the encapsulation of battery poles needed to be improved as some sealings leaked and caused creeping currents. Additionally, leaking oil formed bubbles, floated around the camera and sometimes deteriorated the view on the sea floor;
- leakage of battery acid due to degasification must be avoided as it represents a permanent danger to operating and scientific staff;
- handling of heavy batteries may be further facilitated by ergonomic improvements.

Electrically, failure of the telemetry caused some trouble and downtime. New types of plugs, different sealing of the telemetry box and avoiding creeping currents by a modified insulation of battery cells may be the most striking improvements that are necessary to increase the efficiency of the grab.

Concerning the performance of sampling and geological observations the grab operated well. Nevertheless on a long term range one should aim at finding reasonable technical solutions for:

- heave compensation, as vertical oscillations induced by the movement of the vessel renders observations difficult under bad weather conditions;
- detecting steep slopes just in front of the grab in order to avoid crushing;
- avoiding the cable to get entangled with the grab.

Extensive and expensive modifications would therefore be necessary, however.

9.4.5 Technical Data

dimensions	open	closed
width	2,1 m	1,95 m
height	3,05 m	2,40 m
depth	1,30 m	1,30 m
weight in air	2,9 t	

driving

electrical motor	34 W at 24V dc
hydraulic working pressure	220 bar

power supply

zinc-lead batteries	2, 4 stand by
capacity	230 Ah

operation

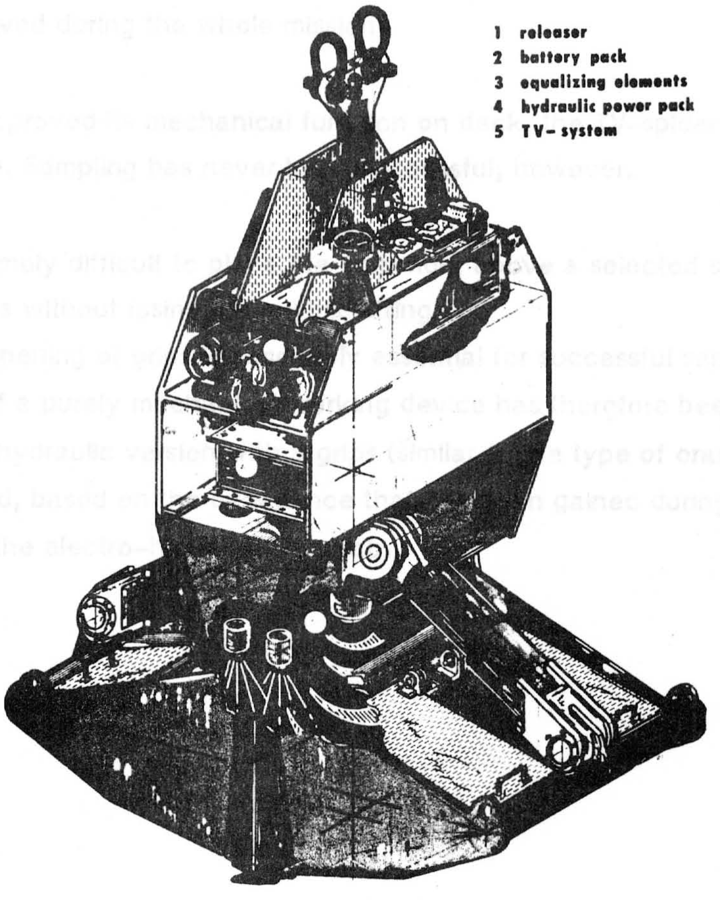
max. depth	10.000 m
cutting force	35 KN ≙ 3,5 t (independent of depth)
penetration	max. 0.7 m
closing time	20 sec
content	0.8 m^3
sampling area	1.05 x 2.0 m

ELECTRO–HYDRAULIC GRAB SYSTEM with TV monitoring

Fig.: 9.4.

Electro-hydraulic Grab System with TV Monitoring

The grab system is specially designed for exploration and taking of samples in hard rock sediments. This requires an extremely powerful drive force to crush rocks caught between the jaws in order to ensure a fully closed grab after sample taking. The jaws are provided with teeth to break and collect the sediment. Four large flaps allow analysis and photography of the sediments prior to opening the grab for sample taking. The grab is driven by an electrohydraulic power pack having a battery power supply which can be changed without the use of tools in less than a minute.
A black and white TV-system allows the observation of the sea floor and assists the operator in deciding where to take a sample and whether the taken sample is good. Sould it be necessary, the grab can be reopened on the sea floor in preparation to take a new sample. This saves a lot of expensive ship's time and makes sampling more efficient.



Technical Data:

Capacity	0,8 m^3
Penetration up to	0,7 m
Cutting Force	3,5 t
Operating Depth	unlimited
Weight in air	2,9 t
Battery Power supply	12 V

9.5 TV Spider Grab

As a second TV grab (for redundancy reasons) was not yet available (though under construction) a simple mechanically working grab for rock sampling has been constructed by Preussag Offshore Engineering. It should actually be tested and applied only in case of loss of the TV-grab or if long down time of the grab should delay the preset program.

The design based on a steel frame which had previously been used as rig for soil mechanical instruments. Below this frame, 3 grips have been hinged bolted and biased in horizontal position. Once mechanical released by soil contact, these grips should be able to seize large blocks on the seafloor. Due to lack of any hydraulic driving reopening of grips was impossible.
By means of a TV-system the grips, the releasing mechanism as well as the soil sample could be observed during the whole mission.

After having approved its mechanical function on deck, the TV-spider grab has been launched twice. Sampling has never been successful, however.

It proved extremely difficult to place the grab right above a selected sample and to seize big blocks without losing them while lifting.
This is why reopening of grips is absolutely essential for successful sampling. The further development of a purely mechanical working device has therefore been given up.
Instead a new hydraulic version with 6 grips (similar to the type of orange peel buckets) will be designed, based on the experience that has been gained during the development and testing of the electro-hydraulic TV-grab.

9.6 Dredge

During 53 stations a rock dredge to recover hard rocks, including massive sulfides, was used.
The dredge consists of a 100 x 40 cm rectangular mouth, a thill and a 130 cm long chain bag (40 mm mesh), with a 10 mm mesh net inserted. The total weight is 275 kg. The dredge is preceded by a swivel which in turn is connected with the end of the bag by a 4 tons safty wire.
The dredge was mostly operated at the starboard side, using the 18 mm wire of the fishing winch. A pinger was mounted 200 m above the dredge.
In general, the drege was lowered to the seafloor with the wire in vertical position. After arrival at the sea floor, the ship moved apart until the wire was in a 30°position. Subsequently the movement of the dredge was controlled by the winch operator.
In some cases the installed Atnav transponder array was used for the position determination of the dredge, using a sub-transponder fixed to the wire 190 m above the dredge, and 10 m below the pinger. Several times, the dredge was fixed to rocks in the extremely rough zero-age volcanic terrain, but could be freed by adequate ship operations. However, two dredges went lost.

9.7 Reineck Box Corer

In order to recover undisturbed surface sediments for geochemical investigations, a conventional box corer of the Reineck type was used. The dimensions of the - stainless steel frame are 2,80 x 1,77 x 2,30 m (height), its weight is 160 kg. 10 lead weights totalling 500 kg were available. The boxes used have a cross section of 40 x 20 cm and a length of 60 cm.
The Reineck corer was handled at the starboard side, using the fishing winches. A pinger mounted 30 m above the corer controlled the bottom approach.
Most coring stations yielded full core boxes.

9.8 Analytical Equipment

The main instruments of the analysis center used during GARIMAS 1 was the Philips PW 1410 x-ray fluorescence spectrometer for quantitative work, and the Philips PW 1965/60 proportional detector used to identify minerals by x-ray diffraction. Complementary Philips equipment are:

Generator PW 1120/90
Automatic interface PW 1425
Channel control PW 1390
Programmer PW 1395
Motor control PW 1394
Single pen recorder PM 8203
Goniometer supply PW 1373
Hewlett-Packard 9815 A desk top calculator is used to operate the analytical equipment in automatic measurement mode.

Supplementary equipment are:

Stereoscopic microscope for sample examination
Disc mill for sample grinding
Mortar and pestle for sample preparation
Hand held balance for sample weighing
Hydraulic Press for sample pelletizing.

9.9 Computers

During cruise SO 32 several computer systems have been used. Some of them belong to specific exploration systems, such as the satellite navigation, Atnav navigation, Deeptow and Seabeam. They are not described here. The following two systems were used for data reduction and presentation.

9.9.1 VAX-11/750

The newly installed main research computer-system consists of the following main components (fig. 9.5):

- VAX-11/750 central processor unit (CPU) with 3 MB memory
- dual disc-drive 2 x 70 MB
- 2 tape drives 800/1600 bpi selectable
- 3 CRT-terminals with graphic option
- printer terminal with graphic option
- line printer
- 3-pen calcomp plotter
- data acquisition system: interfaces for parallel and serial data transfer
- scientific and graphic software library.

The main purpose of this system was to collect and interpret navigation and bathymetric data, and to support the cruise management.

9.9.2 PDP-LSI-11/23-System

The Microcomputer PDP-LSI-11/23 with its peripherical devices is designed as a multi-purpose computer for flexible applications on different cruises and ships. The computer system consists of

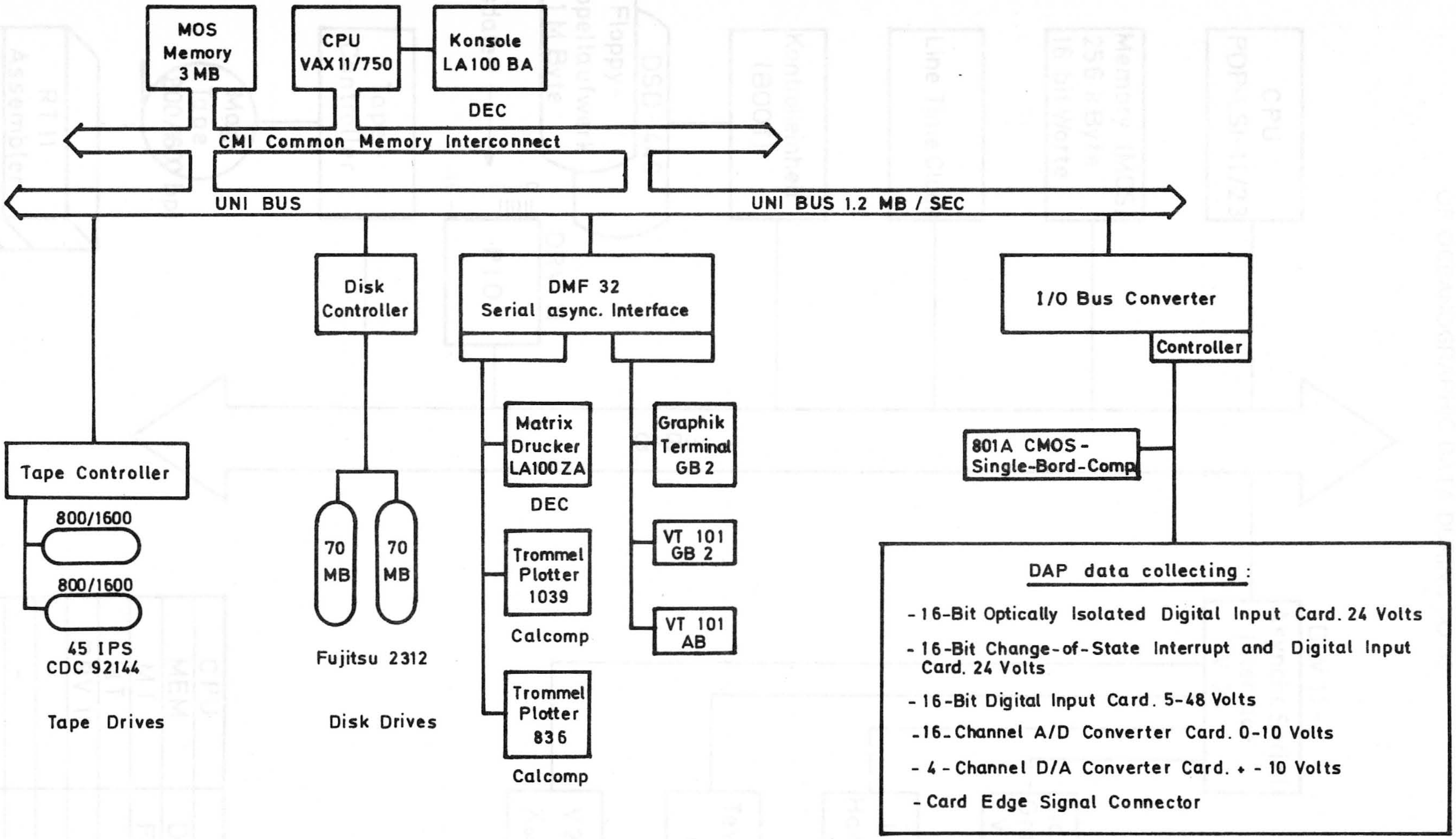
- the central processor unit (CPU) with memory-handler, 256 Kbyte memory, 4 serial interfaces and line-time clock,
- one double floppy disc unit (external memory, 1 Mbyte),
- one line-printer with hard-copy facility,
- one 1/2 inch magnetic tape unit with selectable 800 or 1600 bpi recording density (spool diameter 8 inch),
- one plotter (paper size A3) providing 8 different colour or pen size possibilities,
- one video-terminal with graphic screen.

The computer works with Fortran 77 and Calcomp plot routines. Fig. 9.6 shows the configuation of the system.

During the Garimas cruise the system was used for

- data storage on 1/2" magnetic tapes,
- online plots during measurement,
- data pre-processing and reduction.

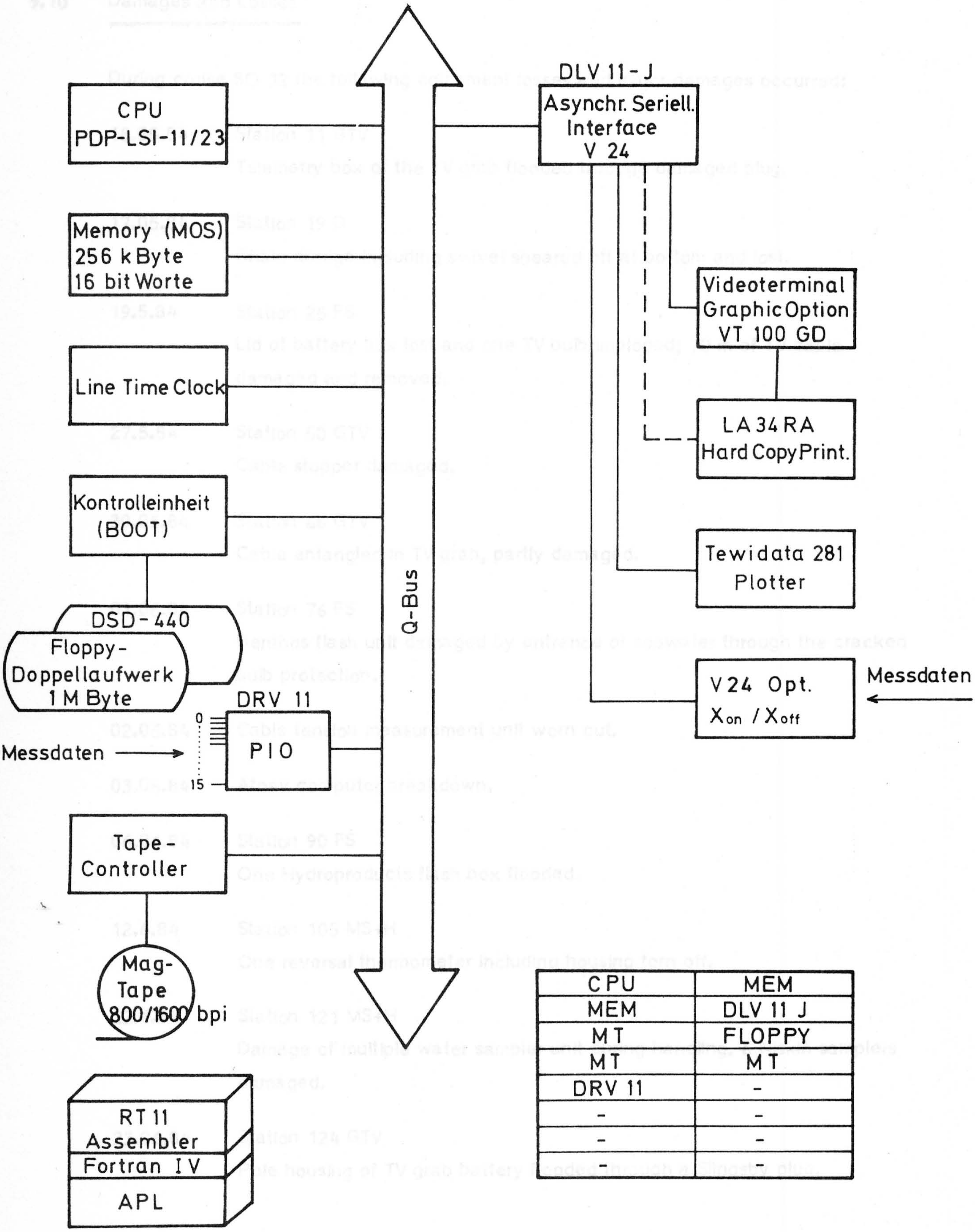
The system was applied for the data handling of Multisonde-, current meter- and Deeptow measurements.



Software producer : VAX / VMS V 3.5 11/780
FORTRAN V 3.1
DAP (Driver für VMS)
Calcomp (H CBS)
TDV Minigraph

Fig. 9.5. The main research computer system of FS Sonne

FIG. 9.6 COMPUTER SYSTEM USED FOR THE REGISTRATION AND PROCESSING OF OCEANOGRAPHIC DATA DURING SO 32



9.10 Damages and Losses

During cruise SO 32 the following equipment losses and major damages occurred:

15.05.84 Station 11 GTV
Telemetry box of the TV grab flooded through damaged plug.

17.05.84 Station 19 D
Chain dredge including swivel sheared off at bottom and lost.

19.5.84 Station 25 FS
Lid of battery box lost and one TV bulb imploded; 70 m of TV cable damaged and removed.

27.5.84 Station 50 GTV
Cable stopper damaged.

30.05.84 Station 66 GTV
Cable entangled in TV grab, partly damaged.

01.06.84 Station 76 FS
Benthos flash unit damaged by entrance of seawater through the cracked bulb protection.

02.06.84 Cable tension measurement unit worn out.

03.06.84 Atnav computer breakdown.

06.06.84 Station 90 FS
One Hydroproducts flash box flooded.

12.6.84 Station 105 MS+H
One reversal thermometer including housing torn off.

22.6.84 Station 121 MS+H
Damage of multiple water sampler unit during handling. 6 Niskin samplers damaged.

23.06.84 Station 124 GTV
Pole housing of TV grab battery flooded through a Slingsby plug.

30.06.84 Station 162 D

Dredge fixed at bottom. 2550 m cable, swivel, Pinger and chain dredge lost.

04.07.84 Station 182 GTV

Telemetry box of TV grab flooded.

Part of the damaged equipment could already be reapired on board.

10. LOGISTICS, TRANSPORT, SUPPLY AND COMMUNICATIONS

The opportunity of the passage of MS Sonne through the Mediterranean Basin was used to load most equipment and material destinated for cruise GARIMAS 1 already in Athens and Malta. Food supply was taken over in Cadiz prior to the Atlantis passage. Last air freight was received on May 9th in San Cristobal, Panama. Next day, following the passage through the Canal 480 tons of fuel were taken over in Balboa.
The next short port call was in Academy Bay, Sta. Cruz, Galapagos, on May 23, due to a minor accident, to replace one technician. The official call at the same place was on June 6. Air freight containing spare parts was received and personnel exchanged.
The main port call, however, was on June 19/20 in Guayaquil. One container had arrived from Hamburg which included material for a new TV grab and 4 boxes air freight with spare parts from Germany and the USA. Some people were exchanged and a void container taken over for the transport back from Panama.
The final port was Balboa which was reached on July 8th and left for Honolulu next day. The GARIMAS personnel disembarked. One box left Panama per air freight; the remaining equipment and material was shipped in two 20 ft. containers to Hannover, where they arrived on August 31st, 1984.
During the cruise there was a good communication by telex and phone with the company bases in Hannover and Berkhöpen, with equipment suppliers in Europe and USA, and with the agents in Panama and Guayaquil.
Most communications went via San Francisco Radio.
The agent in Panama was:

Wilford & McKay S.A.
Edificio Portuario
Apartado 782
Balboa/Panama
Telex RCA 8811; phone no. 62-4956

The agent in Guayaquil was:

Transoceanica CIA Ltd.
P.O.Box 1067
Malecon 1401
Guayaquil/Ecuador
Telex 3371, 3641; phone no. 511360.

11. PROGRAM PERFORMANCE

11.1 Morphological and Structural Mapping

The scattered occurrences of hydrothermal activity and metal formation along mid-ocean ridges requires detailed mapping efforts before starting with time consuming and expensive station work. Due to little sediment cover in the neo-volcanic zone the seafloor morphology fairly well reflects the forces presently active in the area. Constructural features like volcanic cones can be recognized by circular to lobated outlines of morphological highs, while young faults are indicated by steep, linear escarpments which usually trend in the direction of the rift. The records of the stabilized narrow-beam echo sounder ("Schelfrandlot") even allows to recognize the direction of dipping of the faults which in turn statistically indicates the direction towards the rift axis.

The early recognition of the axis is of paramount importance, since most easily accessible hydrothermal products are found within the zero-age zone.

The most efficient mapping tool available on R/V SONNE is the Seabeam system which produces on-line bathymetric maps at a swathe width which corresponds to about 0,8 times the water depth. These maps are supplemented by the records of the stabilized narrow-beam echo sounder running at 20 or 30 kHz, which present a more precise picture of steep slopes, high peaks and narrow holes.

The third instrument usually running during mapping is the 3,5 kHz subbottom profiler. Normally designed to measure the thickness and layering of the uppermost 30 - 100 metres of sediments, within the neo-volcanic zone ist is used to indicate trends in sediment cover which result in a changing reflectibility.

Within the survey area, morphological maps (1:20.000 and 1:50.000) were available only from the De Steiguer Deep and the axial zone between 85°35'W and 86°/4'W which were produced during Sonne cruise 22 (GEOMETEP 2) and 26 (GEOMETEP 3).

A number of isolated profiles followed the Galapagos Rift axis from De Steiguer Deep to the Galapagos Fracture Zone. During cruise GARIMAS 1 additional profiles were run along and across this section of the GR allowing for a rather precise position of the spreading axis. A detailed map was produced of a small area at 95°W which showed abundant indications of ongoing hydrothermal activity.

The GR between the Galapagos FZ and the detail study area at 86°W was surveyed for the first time during GARIMAS 1. At most places the rift axis could be located as well as major disturbances. Some additional profiles and ground checks will be required. In the 86° detail survey area a number of supplementary profiles were run to extend and improve the existing map. To get the best out of both "Seabeam" and "Schelfrandlot" systems in the locations A and B areas a new 1:10.000 map with 5 m contour intervals was produced from new closely spaced profiles based on the Atnav navigation system.

11.2 Water Sampling and Physical Measurements

11.2.1 Water Sampling

The geochemical properties of seawater and its suspended matters are important indicators for hydrothermal activities at the floor of the ocean. For this reason a water sampling program was carried out on selected positions along the Galapagos Rift to determine characteristical hydrothermally originated constituents in sea water and suspended matter.

21 water samples were recovered from 10, 500, 1000, 2000 meters water depth and above the bottom using the rosette water sampler equipped with 10 Niskin bottles each with 5 l sampling capacity. In general 40 l were recovered from every sampling depth. The samples were taken at 13 different stations. On each station a vertical Multisonde profile was recorded.

The sampling positions were selected using the information derived from structural mapping and from bottom observations which were carried out with the photo sledge.

A compilation of water sampling station data is presented in Table 11.1.

The water samples were filtered on board applying for one portion a 0.45 µ membrane-filter and for the other portion a glass fibre-filter (GF/c Whatman). Analyses on filter and filtrate will be done at Hamburg University.

11.2.2 Multisonde Measurements

The detection and discovery of hydrothermal anomalies along the Galapagos Rift was one of the main tasks of the Garimas 1 cruise. Beside geothermal, geochemical, hydrochemical and photographical methods the measurement of hydrophysical parameters is one of the most effective techniques to detect such hydrothermal anomalies. For this purpose the Multisonde was applied for vertical and horizontal profiling within the deeper water portions above the Galapagos Rift. Additionally, the Multisonde measurements provided essential information about the whole water column (e.g. sound velocity data to calibrate the Seabeam measurements).

Mounted into the photo sledge, the Multisonde was used for horizontal profiling and to trigger the photographic devices. Additionally to the 13 stations listed within Tab. 11.1 three other Multisonde profiles were carried out during the first leg of Garimas I (see Tab. 11.1).

The Multisonde used during Garimas I provided the possibility to measure 7 different hydrophysical parameters. Out of these the temperature and the light attenuation

are of special interest, when searching for hydrothermal anomalies.
The temperature probe failed during the first four measurements. It was replaced by a very similar probe from the Bathysonde. The relative accuracy of this probe was as good as that of the original probe. Its absolut accuracy was about ± 0.02°C. This was tested by making parallel measurements with reversal thermometers.
Due to an unrepairable failure the dissolved oxygen probe did not furnish any measurements. Unfortunately, also the light attenuation showed misfunctions during the first 5 measurements. The probe could be repaired. From station No. 120 MS+H until the end of the cruise the sound velocity probe failed to work.
A short pre-evaluation of the on board processed measuring data did not reveal any anomaly of measurements, but further evaluation will be done using the more comprehensive facilities available in the home laboratories.

11.2.3 Current Measurements

Exploring hydrothermal anomalies at the ocean floor, the knowledge about the deep ocean currents is of major importance. Especially the transport of hydrothermal effluences is of great interest. A current meter was moored together with a transponder of the underwater navigation array. It was suspended over a period of 39 days. The whole set of station data is presented within the station record (Tab. 11.2).
A short pre-processing of the recorded data showed that the instrument worked without failures.
Some first selected data gathered from the Multisonde and current meter measurements are presented within Chapter 11.8 of this report.

TAB. 11.1

OCEANOGRAPHIC STATIONS

STAT. NO. SO-32	DATE	POSITION	WATER DEPTH	RECOVERY DEPTH	MAX.MEAS.DEPTH	REMARKS
1 MS	13.05.84	1 19.600 85 27.300	2820 m		2820 m	Temp., O_2,L.A. defect
15 MS	16.05.84	0 44.926 85 55.028	2786 m		2580 m	Temp., L.A. defect
93 FS+MS	09.06.84	2 17.87 93 05.41	2161 m		2158 m	O_2, Temp., L.A. defect
104 MS+H	12.06.84	2 30.723 95 19.309	2637 m	2630,2620,2610,2600, 2590,2580,2570,2560, 2550 m		O_2, L.A. defect. 45 l recovery
105 MS+H	13.06.84	2 36.558 94 55.285	2623 m	2000 m		Temp., O_2,L.A. defect. 40 l recovery
109 MS+H	13.06.84	2 36.732 94 56.025	2662 m	500 m		O_2, L.A. defect. 40 l recovery
111 MS+H	14.06.84	2 38.100 94 56.600	2623 m	10 m		O_2, L.A. defect. 40 l recovery
115 MS+H	14.06.84	2 35.700 94 50.000	2587 m	1000 m		O_2, L.A. defect. 40 l recovery
120 H	22.06.84	0 45.934 85 53.887	2580 m	10 m		45 l recovery
121 MS+H	22.06.84	0 45.832 85 54.035	2540 m	500 m		O_2, SV defect. 35 l recovery
131 MS+H	24.06.84	0 45.856 85 54.913	2488 m	1000 m		O_2, SV defect. 35 l recovery
132 MS+H	24.06.84	0 45.754 85 54.671	2562 m	500 m		O_2, SV defect. 35 l recovery
138 MS+H	25.06.84	0 45.799 85 54.726	2497 m	2000 m		O_2, SV defect. 40 l recovery
167 MS+H	01.07.84	0 46.008 85 54.896	2580 m	2525 m		O_2, SV defect. 45 l recovery
178 MS+H	03.07.84	0 45.810 85 54.656	2592 m	2589,2554,2041,1532, 1021,509,105,53,13 m		O_2, SV defect. 5 l recovery per sampling depth
185 MS+H	05.07.84	0 46.077 85 55.169	2580 m	1500, 1000, 150, 20 m		O_2, SV defect. 5 l recovery per sampling depth

TAB. 11.2

RECORD CURRENT MEASUREMENTS

RESEARCH VESSEL : SONNE	STATION No.: SO – 32 – 002 CS
CRUISE : SO – 32, Garimas 1	
SEA AREA: Galapagos Rift 85° Area	
PROTOCOL: J. Post	

CURRENT METER MOORING	+
CURRENT METER PROFILER	–
SURFACE DRIFT BUOY	–
UNDERWATER DRIFT FLOAT	–

		SUSPENDING	RECOVERING	1. POSITION CHECK	2. POSITION CHECK
DATE:		13.05.84			
START OF OPERATION		12.50			
REACHING OP. DEPTH		13.40			
END OF OPERATION		13.09			
POSITION	LAT. N	00° 45.71'	° '	° '	° '
	LONG. W	85° 53.17'	° '	° '	° '
WATER DEPTH		(m)	(m)	(m)	(m)
ECHO SOUNDER (UNCORR.)		–			
MATTHEWS CORRECTED		2320			
BRINE CORRECTED		–			
WIND SPEED	kn	11			
WIND DIRECTION	°	210			
SEA STATE	m	1.0			
SWELL	m	1.5			
CLOUDINESS	x/8	6			

CURRENT METER		1	2	3	4	5	6	7	8
INSTRUMENT No.		6742							
REC. START	DATE	13.05.84							
	TIME	13.05							
REC. END	DATE	22.06.84							
	TIME	11.15							
OPERATION DEPTH		2210							

REMARKS: **The selected recording interval was 5 minutes.**

Time is recorded in local time.

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11.3 Visual Seafloor Investigations

Visual instruments to inspect the seafloor available during cruise SO 32 were television cameras mounted in the photo sledge, in a tripod and the TV-grab, and photo cameras for 24 x 36 mm films. These methods proved to be very useful to identify the nature of morphological features, to estimate the relative age of the oceanic crust through its sediment cover, to find places with hydrothermal activity and products and to recognize faunal elements and distribution patterns.

Usually locations for visual observations were chosen on the basis of bathymetric maps or at least a Seabeam swathe. In prospecting areas only the photo sledge was used for the purpose. Generally the combination of TV and photography was applied. Only once the TV was replaced by the multisonde, and the camera was released by bottom tough of a messenger weight, to be able to react immediately when heat anomalies would be registered by the multisonde. Normally, however, the seafloor was observed continuously by TV, and the camera released manually. Thus overlapping photos could be shot at important sites, and recording rates could be reduced in uniform environments. Good pictures were obtained at bottom distances between 3 and 10 metres.

Off bottom the position of the sledge was controlled by pinger signals which determined the distance to the ocean floor. Typical photo profiles were about one nautical mile long. After termination of the station or after completing one 30 m film, the latter was developed immediately on board. With the exception of 2 negative films, all photos produced during GARIMAS 1 are slides.

A total of about 22,000 usable bottom photos were made. While the interpretation of the black and white TV records is difficult and ambiguous, the photos clearly show the nature of the seafloor. In a data field on each photo the following information is presented: first row: hours, minutes; second row: seconds, days; third row: bottom distance in metres up to 9,9 m maximum. The results of photographic stations occupied during cruise SO 32 are summarized in Table 11.3.

Outside the photo stations, TV observation was mainly used to select sample points. For this purpose the TV grab was slowly moved over prospective areas. Outside the neo-volcanic zone of the rift this operation was rendered difficult by sediment turbidity in the water caused by the up and down movement of the instrument. In the main working area objects to recover are partly buried by unconsolidated sediments. Discrimination between sulfides, breccias and certain types of ponded lava requires much experience.

The total number of TV profiles obtained during GARIMAS 1 is 96, 64 of which were combined with photographing.

TABLE 11.3

GARIMAS 1 (SO 32)

LIST OF BOTTOM PHOTOGRAPHIES

STATION NO.	RECORDING TIME		NO. OF PHOTOS		REMARKS
09	15.05.	02.05 - 04.46	726	F	T: 04.05 - 06.34
16	16.05.	14.48 - 21.14	708	F	
21	17.05.	15.01 - 16.17	726	F	± statistical
23	18.05.	15.34 - 16.45	124	F	
24	18.05.	21.47 - 23.07	126	F	
25	19.05.	08.24 - 10.54	675		about 50% of track photographies
32	20.05.	14.55 - 17.07	711	C	T: 28.5., 17.49 - 19.28
33	20.05.	20.27 - 22.31	728	F	T: 28.5., 23.22 - 00.41
36	21.05.	15.41 - 17.45	714	F	T: 29.5., 18.36 - 20.41
37	21.05.	22.48 - 23.41	144	F	T: 30.05., 01.44 - 02.37
38	22.05.	04.14 - 04.57	179	F	T: 30.05., 07.10 - 07.51
40	22.05.	20.20 - 21.07	190	F	T: 30.05., 23.16 - 00.03
41	24.05.	14.23 - 15.36	244	C	
42	25.05.	00.46 - 02.21	484	C	
43	25.05.	07.14 - 07.32	105	C	T: 12.11 - 12.26
44	25.05.	15.23 - 16.26	284	C	
45	26.05.	02.33 - 04.18	341	C	
52	27.05.	05.04 - 07.59	749	C	
53	28.05.	11.19 - 11.57	221	C	
56	28.05.	23.40 - 00.41	474	C	from 23.47 no data field
64	30.05.	14.10 - 16.24	319	F	
(69)			005		at 500 m break down of telemetry
76	01.06.	10.14 - 11.36	285		flash failure, underexposed
84	03.06.	17.45 - 19.21	385		poor quality
87	04.06.	14.25 - 16.51	456		"
88	04.06.	23.25 - 03.03	401		"
89	05.06.	17.12 - 19.00	261	F	
90	08.06.	20.01 - 21.57	217		poor quality
93	09.06.	15.36 - 16.29	128	C	
94	10.06.	01.56 - 03.14	202	F	
97	10.06.	21.37 - 22.15	120	C	
98	11.06.	00.45 - 01.28	074	C	
99	11.06.	12.23 - 12.52	056	C	
101	11.06.	18.46 - 21.54	444	C	
103	12.06.	16.18 - 18.08	202	C	
107	13.06.	12.57 - 15.41	314	C	
110	13.06.	22.47 - 23.23	045	C	
112	14.06.	04.57 - 06.57	135	C	
114	14.06.	16.37 - 18.42	388	C	
116	15.06.	00.19 - 02.40	335	C	
118	16.06.	02.48 - 04.27	339	C	
119	16.06.	17.39 - 21.33	410	C	
122	23.06.	05.33 - 10.57	722	C	
126	24.06.	05.23 - 07.08	415	C	

TABLE 11.3 continued GARIMAS 1 (SO 32)

LIST OF BOTTOM PHOTOGRAPHIES

STATION NO.	RECORDING TIME		NO. OF PHOTOS		REMARKS
127	24.06.	09.37 - 10.31	336	C	
133	25.06.	01.07 - 04.12	746	C	
141	26.06.	06.41 - 08.37	241		partly poor quality
143	26.06.	19.05 - 19.55	106	C	
144	27.06.	00.30 - 01.17	118	C	
155	27.06.	00.10 - 01.16	118	C	
145	27.06.	04.46 - 07.24	235	C	
149	28.06.	04.35 - 05.35	075	C	
150	28.06.	08.13 - 10.02	162	C	
151	28.06.	20.08 - 23.05	744	C	
153	29.06.	06.59 - 09.04	310	C	
154	29.06.	11.17 - 12.16	406	C	
155	29.06.	18.19 - 19.59	533	C	
156	29.06.	23.19 - 00.45	216	C	
163	01.07.	02.48 - 07.22	601		negative film
169	02.07.	01.52 - 02.22	060	C	T: 01.02 - 01.16
172	02.07.	17.38 - 20.42	454	C	
173	03.07.	02.27 - 03.53	143	F	
177	03.07.	19.34 - 22.54	747	C	
180	04.07.	14.03 - 15.57	295	C	
181	04.07.	21.05 - 00.27	456	C	
184	05.07.	14.06 - 22.30	743		negative film
186	06.07.	01.56 - 04.12	748	C	

C = working copies, original un-cut
F = original framed
T = time on photos not corresponding to ship's time

11.4 Sediment Sampling

During GARIMAS 1 only 16 stations were devoted to sediment sampling. This sub-program started already in 1980 with Sonne cruise 12 (GEOMETEP 1), with the aim of recognizing hydrothermally active sections of the spreading centre through metal dispersion halos. To compare identical strata, the Reineck box corer was used for sampling the uppermost 40 cm of the sediment column without disturbances (Table 11.4). 14 coring attempts yielded sediment samples. The station locations were placed in pairs north and south of the spreading axis to account for the effects of the residual current transport. The usual sediments encountered along the eastern portion of the Galapagos Rift are foraminiferal nanno oozes (FNO) with detrital and volcanogenic components. The surface layer, in some cases representing the whole recovered core, is oxigenated and brown coloured. The manganese content is increased by diagenetic transport from below. Deeper stratas are grey to olive coloured and represent a reducing environment.

11.5 Rock Sampling

Rocks were sampled for two reasons: first volcanic rocks could be investigated to detect alterations and precipitates originating from hydrothermal activity, and, secondly, metal sulphides were recovered from known places.
The main instruments used for rock sampling were dredges andTV grabs described in Chapters 9.4 and 9.6.
Usually the sample places were chosen on the basis of a tectonic interpretation of morphological data using bathymetric maps or Seabeam swathes. Within the Atnav navigation field, stations were also occupied as a result of the position determination of discoveries made on single photos.
In reconnaissance areas dredges were operated up slope after the instrument had reached the bottom and the ship had advanced about one mile. To dredge sulfides from a known field, the dredge was thoroughly positioned within the field and subsequently torn only a short distance across the seafloor. Usually the position of the dredge was controlled by a pinger mounted 200 m above the dredge. Within the Atnav array a subtransponder was also attached. The TV grab was only lowered at known sulphide places. After reaching the seafloor the ship slowly moved across the prospective zone. The navigation was done using both Atnav ranges and Seabeam bathymetry.

STATION NO.	N	W	WATER DEPTH (M)	RECOVERY (CM)	DISTANCE FROM AXIS	(KM)	REMARKS
SO 32-91 GK	02°11.50'	92°5,64'	2240	36	N	9,3	FNO
SO 32-92 GK	01°58,20'	92°7,12'	2215	–	S	13,9	some basalt chips
SO 32-95 GK	02°39,66'	94°14,03'	2782	16	N	11,1	FNO, oxidized
SO 32-96 GK	02°25,77'	94°18,54'	2497	37	S	11,1	FNO, base reducing
SO 32-100 GK	02°44,16'	95°13,09'	3097	39	N	13,0	FNO, base reducing
SO 32-102 GK	02°30,73'	95°19,53'	2314	21	S	0,4	FNO, oxidized
SO 32-106 GK	02°30,30'	95°1,28'	2699	–			Sediment lost
SO 32-108 GK	02°41,23'	94°54,56'	2549	38	N	10,7	FNO, oxidized up to 38 cm
SO 32-113 GK	02°30,35'	94°55,12'	2652	40	S	1,9	FNO, oxidized
SO 32-117 GK	01°59,72'	92°4,51'	2306	38	S	11,1	FNO, top oxidized
SO 32-140 GK	00°43,74'	85°56,08'	2735	200 g	S	5,2	FNO, top oxidized
SO 32-142 GK	00°53,27'	85°24,83'	2549	200 g	N	6,5	FNO; 3 attempts
SO 32-146 GK	00°48,53'	85°54,81'	2781	40	N	3,7	FNO; top and base oxidized
SO 32-147 GK	00°50,70'	85°54,59'	2692	40	N	8,3	FNO; base reducing
SO 32-148 GK	00°40,45'	85°56,50'	2714	40	S	11,1	FNO; top oxidized (0-11 cm)
SO 32-187 GK	00°45,07'	85°53,20'	2731	200 g	S	1,9	FNO, oxidized, + basalt glass chips

TAB. 11.4 GARIMAS 1 (SO 32): SEDIMENT STATIONS

Since all investigated sulphide occurrences were inactive and partly covered by sediments, recognition was not very easy.
Therefore, following sampling a rock outcrop, the contents of the grab were inspected a few hundred metres above bottom after the sediments accompanying the rocks were washed off. In case the rocks proved to be of volcanic nature, the grab was reopened and the operation repeated.
During GARIMAS 1, a total of about 5 tons of rocks were hoisted to the surface, one ton being massive sulphides. 29 TV grab stations were occupied, and dredges were employed 53 times.

11.6 Technical Tests

Due to the innovative character of some of the technical systems employed during GARIMAS 1 some ship time had to be devoted to test operations. Usually, however, testing was combined with station work presenting part of the research program.
In this case, components of a new system were tested separately and exchanged from time to time. The TV-photo sledge, e.g., was fitted out with between 1 and 4 strobe lights in varying arrangements. Also different cameras and release mechanisms were used.
The main instruments tested during SO 32 were TV-photo sledge, deeptow, two TV-grabs and the spider grab.

11.7 Sample Preparation and Analyses

Water, sediment and rock samples obtained during cruise GARIMAS 1 were described and subdivided into various series already on board immediately after recovery. Sediment samples were stored in plastic tubes and bags, rock samples in plastic bags. Only a small portion of the analysis work was carried out during the cruise, those mineralogical and chemical determinations which were necessary to guide the sampling strategies.

11.7.1 Seawater and Suspended Matter

Water was collected at 13 stations. After taking a 50 ml sample for phytoplankton determinations. The water (30 - 50 l at one station) was subdivided into two portions, one passing a membrane filter. The solids, after cleaning with destilled water were used for microscopy and determination of inorganic components (main constituents, metals). The acidified filtrate was stored for chemical analysis as well.
The second half of the collected water was passed through a GF/C Whatman glass fibre filter. The solids were destinated for the determination of particulate organic substances, the filtrate, after adding 0,3% mercury chloride, for the analysis of dissolved organic carbon, nutriants and organic substances.

11.7.2 Sediments

From the 40 cm long square box core subsamples of equal lengths were produced by punching it with circular plastic liners after execution of pH and Eh measurements. No chemical analyses were made on board.

11.7.3 Rocks

Rock samples (basalt, breccias, fresh and altered sulphides and other hydrothermal products) were examined and described on board after recovery and subsequently sub-sampled for various determinations and tests. For chemical analysis, the Philips PW 1410 x-ray fluorescence system combined with the HP 9815 was used.

11.7.3.1 Sample preparation

Each sample was ground in the disc mill for 3 min. to ensure a consistent grain size from sample to sample. Ground samples were mixed with binding agents and further ground in the porcelain mortar and pestle to have a uniformly sized mixture. The type and quantity of binders differed; Boric acid (1.5 g) was used for sulfide samples (3.5 g), and a commercial brand, Somar Blend (1 g) was preferred with basalt samples (4 g). The somewhat large amount of 5 g was to make sure that there was always sufficient depth for x-ray penetration. Pellets had salt back. Pressing was done at 15 t.

11.7.3.2 Calibration

The instrument had not been used for massive sulfide analysis prior to SO 32, and its calibration and programming occupied the first week.
A qualitative elemental scan identified what elements can be measured without interference and which analytical line can be used for each element. The peak positions for the selected lines were then determined exactly to avoid inaccuracies that may have arisen from slight shifts from standard positions. Other operating variables like voltage, current, analysing crystal, counting time have also been established in the course of this preparatory work. These were then coded and stored in the programmer as the set of instructions that enabled the instrument operate automatically.
Calibrations were done by HP-9815 A. A simple linear relationship was used; $y = ax + b$. The coefficients were determined by regression analysis on measurement results from a relatively large number of Geometep III samples that had been very accurately analyzed by wet chemistry. Finally, HP-9815 A was programmed to operate the XRF spectrometer automatically.

11.7.3.3 Measurements

Of the chemically analyzed elements in the Geometep III sulfide samples, only As, Zn, Cu, Co, Fe were found free of interference in the x-ray scan, and hence, were calibrated for. Some of the Garimas samples with high Cu content (e.g. 15%), or low zinc content (e.g. 0.5% and lower) fell outside the calibration ranges. Due to lack of assayed basaltic samples the instrument could not be calibrated for basalt. XRF analyses on basalt samples recovered during the campaign were therefore semi-quantitative. The Philips PW 1965/60 detector for x-ray diffraction mineral determinations was only partially operational during the cruise.

TABLE 11.5: SAMPLE SERIES

SEDIMENTS

D	Documentation, PREUSSAG
CP	Sediments for chemical analysis
HH	Sediments University Hamburg, Geological Institute (Tse)
BGR	Sediments for geochemical work at BGR (Marchig)
BS	Sediments University Braunschweig, Geological Institute
ECS	Sediment samples University of Guayaquil (Valencia)

VOLCANIC ROCKS

DR	Documentation, PREUSSAG: representative sample
KS	University Karlsruhe, Petrographic-Geochemical Institute: representative sample
GKS	Same (Laschek): samples of fresh glass
CB	PREUSSAG: mineralized rock samples, for chemical analysis
CC	PREUSSAG: ferro-manganoan coatings and crusts from rock surfaces
HD	University Heidelberg, Institute for Sediment Research: altered basalts, secondary products
SP	Samples for special determinations
EC	Rock samples for the Ecuadorian representatives

SULPHIDES AND OTHER HYDROTHERMAL PRODUCTS

DS	Documentation, PREUSSAG
GT	Geotechnical investigations
DH	Oxidized sulphides, sulphide impregnated basalt, basalt with other hydrothermal products (PREUSSAG)
HDS	Same (University Heidelberg)
CLS	Same (University Clausthal)
CXS	Sulphides and mineralized breccias, IFREMER/COB
MBS	Sulphides, University Marburg
ECS	Sulphides for the Ecuadorian representatives
SPS	Sulphide samples for special determinations
CS	Sulphides for chemical analysis
CO	Oxidized material from sulphide sites, for chemical analysis
MS	Sulphides for mineralogical analysis
MO	Oxidic products for mineralogical analysis

MB	Sulphidic basalts for mineralogical analysis
XS	Sulphides, oxides, silicates and altered basalts for mineralogical investigations (ore microscopy), University Marburg (Tufar)
YS	Sulphide samples from Loc. A (1-11) and B (12-13) for microanalytical and mineralogical analysis, University Clausthal (Halbach)
MS GA	∅ sample sulphides location A, mineralogy
MS GB	∅ sample sulphides location B, mineralogy
MO GA	∅ sample oxides location A, mineralogy
MO GB	∅ sample oxides location B, mineralogy
MB GA	∅ sample sulphidic basalts location A, mineralogy
CSIB	∅ sample silicate mud location B, chemistry
MSIB	∅ sample silicate mud location B, mineralogy
CSGA	∅ sample sulphides from 16 station samples CS (loc. A)
CSGB	∅ sample sulphides from 3 station samples CS (loc. B)
COGA	∅ sample oxides from 15 station samples CO (loc. A)
COGB	∅ sample oxides from 6 station samples CO (loc. B)
CBGA	∅ sample sulphidic basalt from 11 station samples CB (loc. A)
MT	Sulphides for processing tests

ORGANIC Material

Bio	Faunal samples obtained from dredge hauls, Univ. Hamburg/ Senckenberg Institute Frankfurt.

The complete lable of a sample is:

SO 32 - 147 GK 25-30 D 48 = Sonne cruise 32, station no. 147, Reineck corer, 25-30 cm from top core, sample series D, sample no. 48 of that series (of the whole cruise).

11.8 Data Collection, Reduction and Processing

11.8.1 Multisonde

The board unit of the Multisonde provides three different possibilities to control and record the measuring data.

i. During the measurement all parameters are displayed on-line on the front panel of the unit to control the measurement.

ii. Three analogue outputs are available, which can be connected with an analogue multi-channel graphic recorder. This facility provides the possibility to have a quick-look control of measuring data and occurrences of anomalies.

iii. The most effective technique to control the measuring data on-line was newly developed applying the transportable PDP/LSI-11/23 computer system. The measuring data are recorded on a 1/2 inch magnetic tape and on-line plotted on the graphic screen of the computer. Additionally, the computer system provides a hard-copy facility to take a copy of graphic plotted on the screen.

After the measurement a preprocessing of the Multisonde data including calibration, correction and reduction of data is carried out on board. Examples of a hard-copy and preprocessed plots are given in Figures 11.1 to 11.4.

11.8.2 Current Measurements

The Aanderaa RCM 5 is a self-recording current meter. The current data are recorded on a 1/4 inch tape. After recovery of the instrument the tape is read with a special tape reader (Aanderaa Type 2650) and restored via a 24 V interface on the 1/2 inch magnetic tape of the computer system. Similar to the Multisonde data reduction procedure the current data were preprocessed on board including

- convertion of the original readings into physical units;
- calibration, correction and reduction of the converted data;
- preparation of data listings;
- preparation of scatter plots and time series (Figs. 11.5 - 11.7).

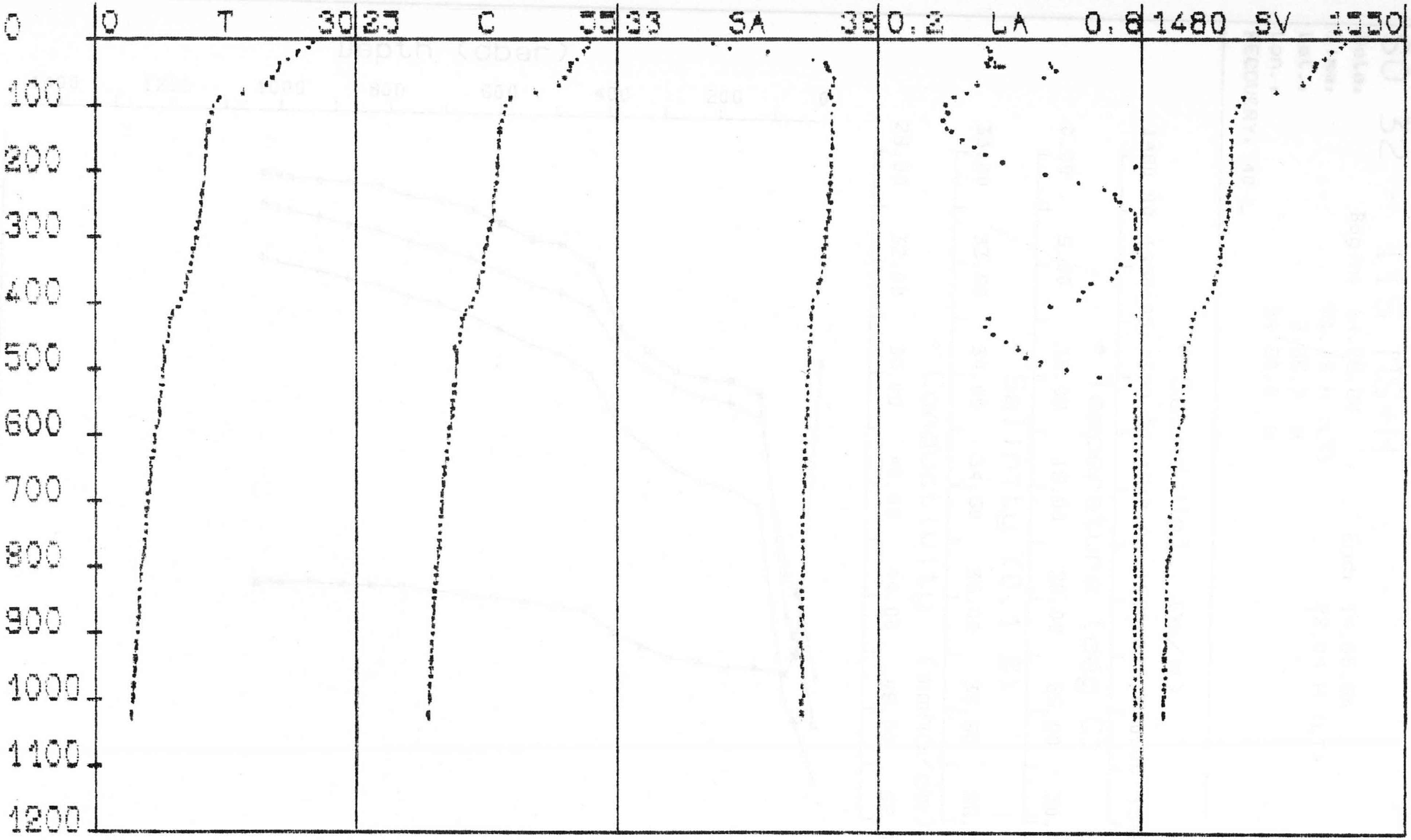
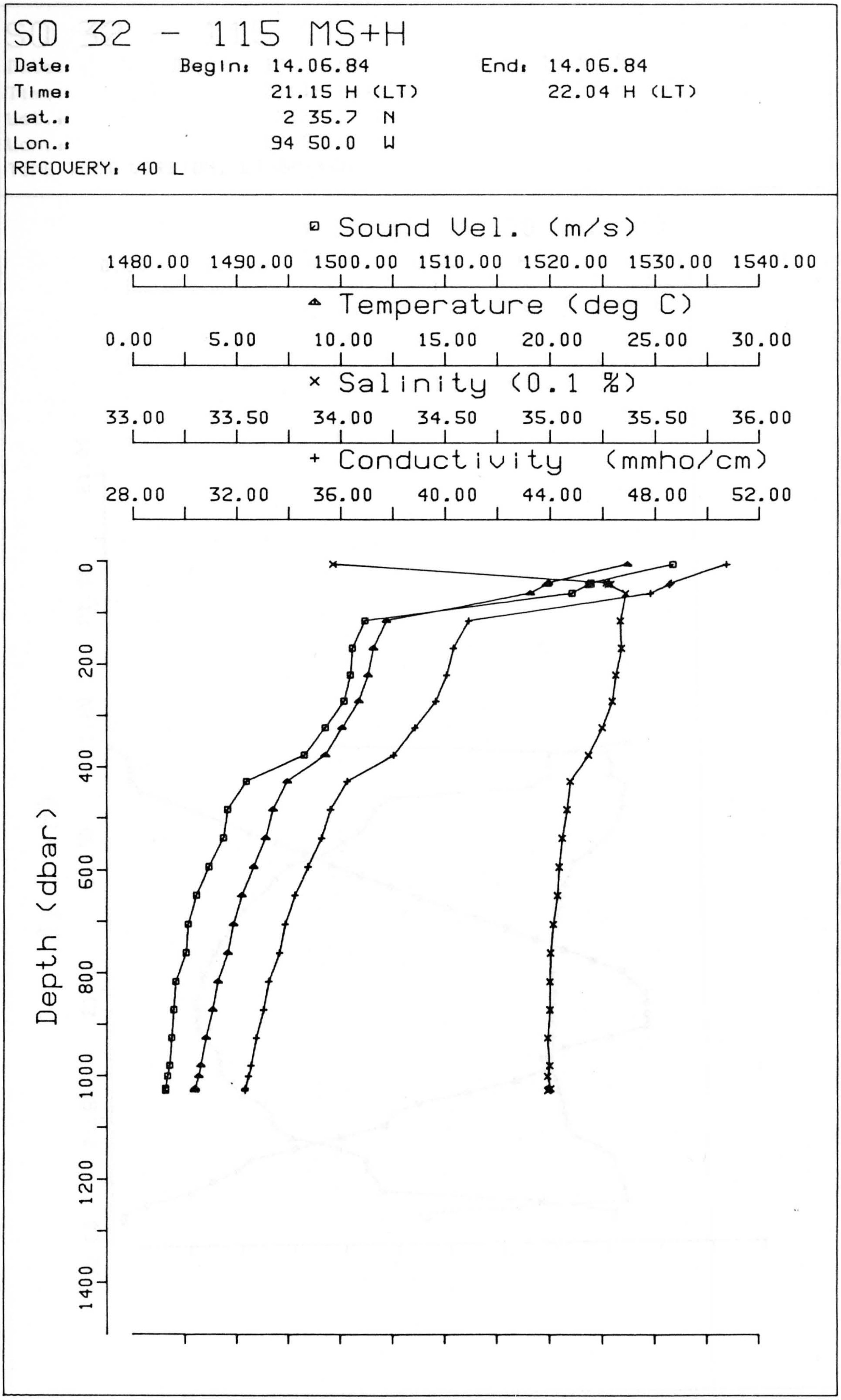


FIG. 11.1 Station No. SO 32 - 115 MS+H

Hard copy of the on-line graphic screen plot of multisonde registrations

FIG. 11.2 MS MEASUREMENTS AGAINST DEPTH



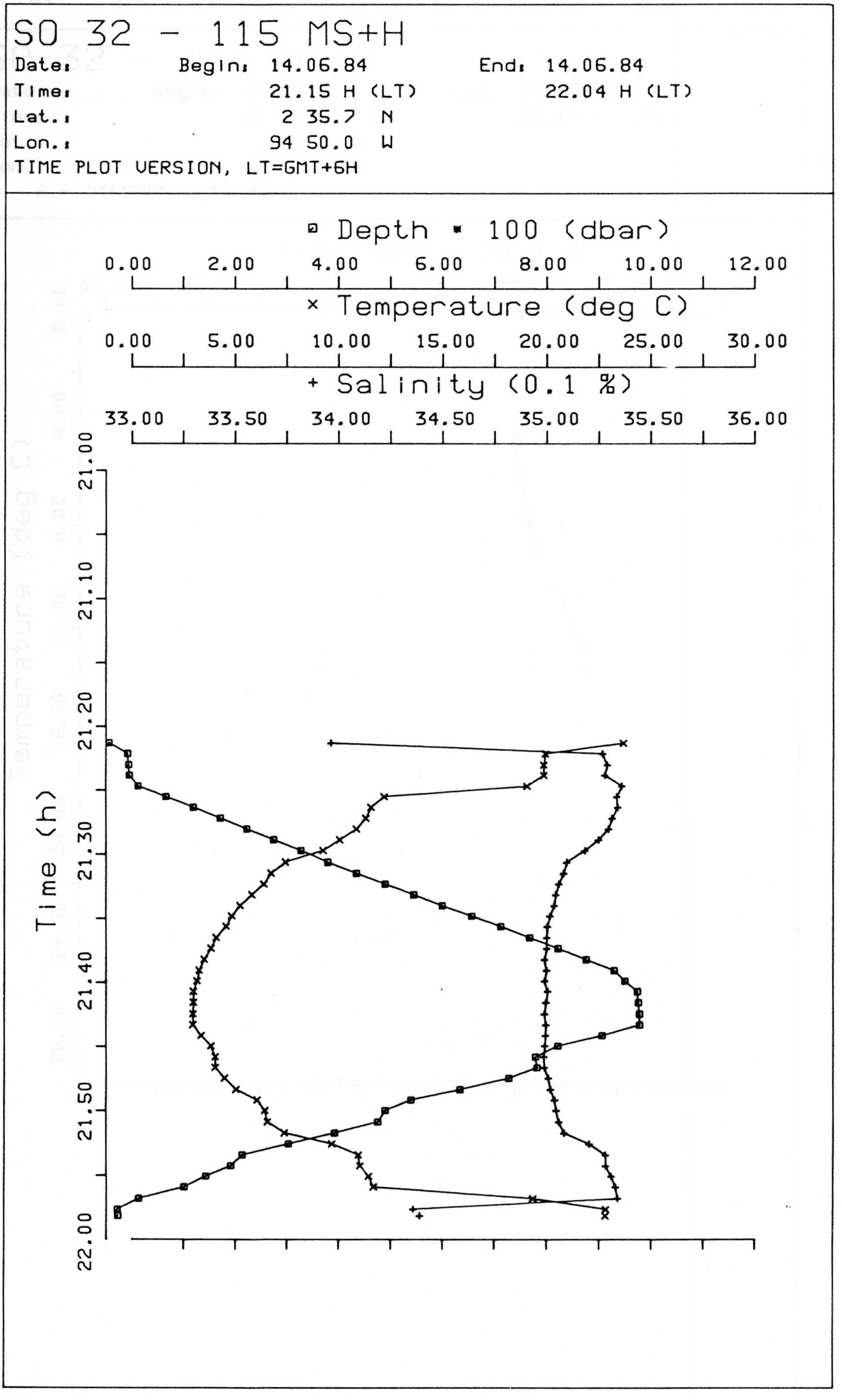

SO 32 - 115 MS+H
Date: Begin: 14.06.84 End: 14.06.84
Time: 21.15 H (LT) 22.04 H (LT)
Lat.: 2 35.7 N
Lon.: 94 50.0 W
TIME PLOT VERSION, LT=GMT+6H
□ Depth * 100 (dbar)
0.00 2.00 4.00 6.00 8.00 10.00 12.00
× Temperature (deg C)
0.00 5.00 10.00 15.00 20.00 25.00 30.00
+ Salinity (0.1 %)
33.00 33.50 34.00 34.50 35.00 35.50 36.00
Time (h)
21.00 21.10 21.20 21.30 21.40 21.50 22.00

FIG. 11.4 T-S DIAGRAM

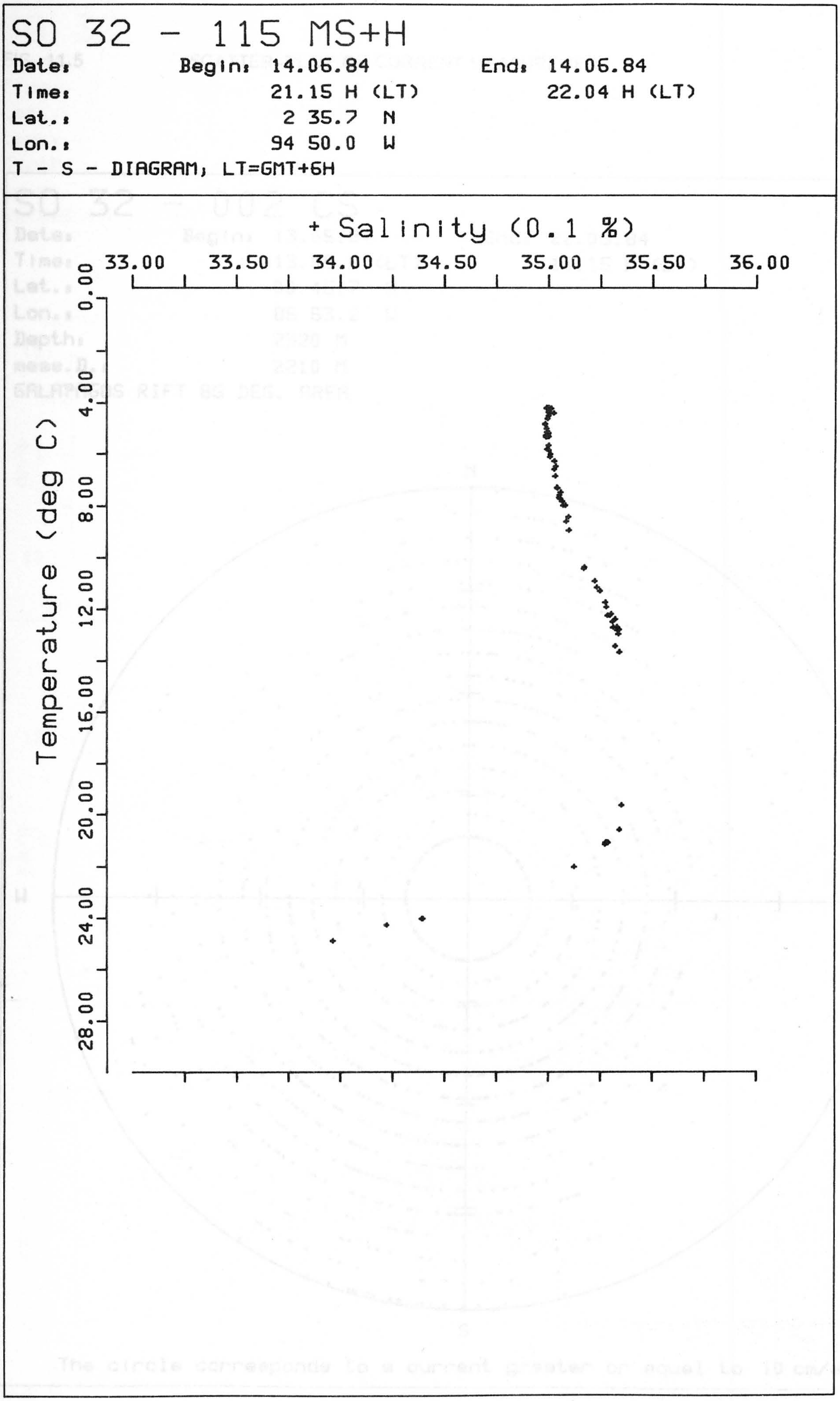
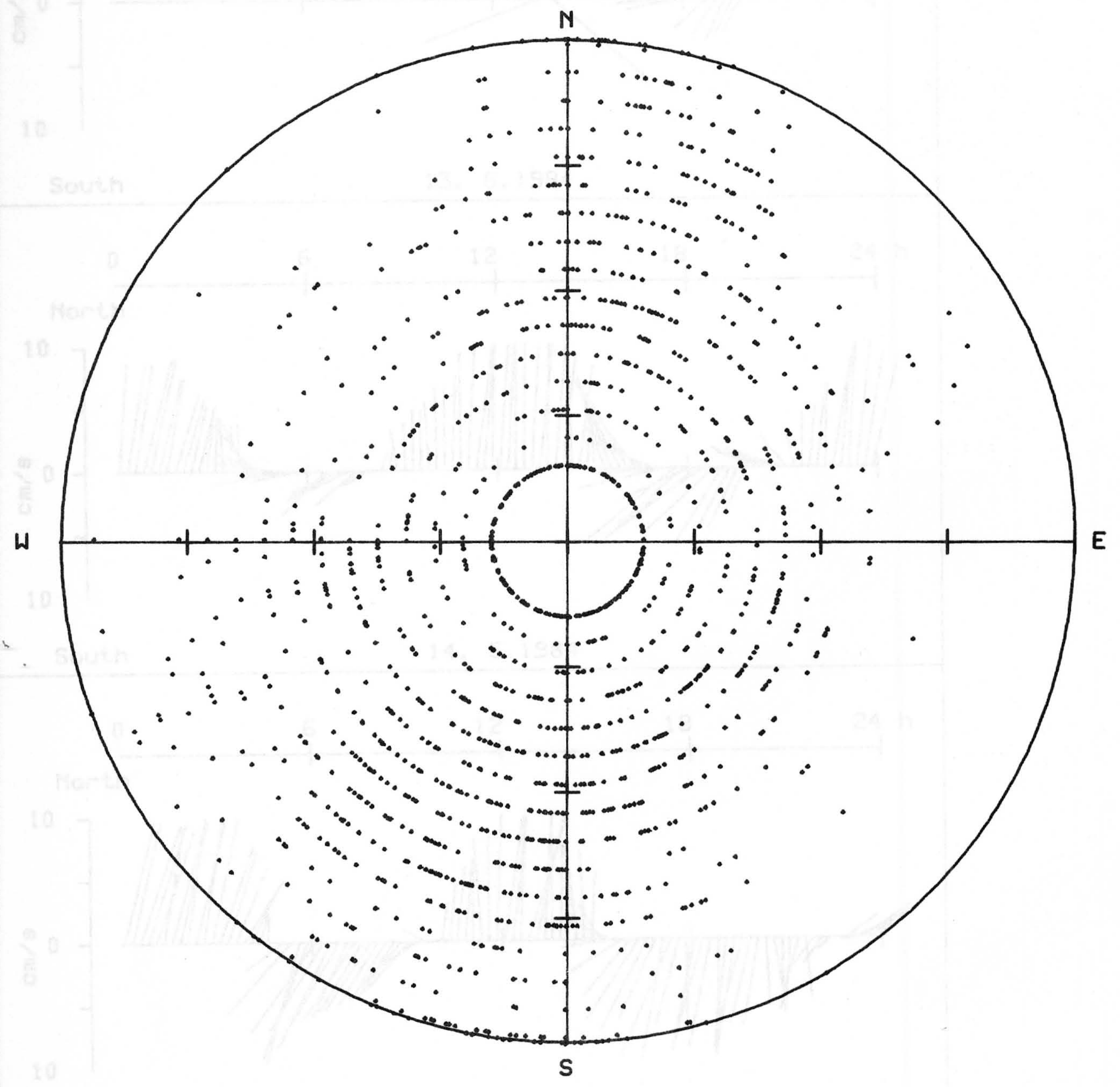


FIG. 11.5 SCATTER-PLOT OF CURRENT MEASUREMENT

SO 32 - 002 CS

Date:	Begin:	13.05.84	End:	22.06.84
Time:		13.05 H (LT)		11.15 H (LT)
Lat.:		00 45.7 N		
Lon.:		85 53.2 W		
Depth:		2320 M		
meas.D.:		2210 M		

GALAPAGOS RIFT 85 DEG. AREA

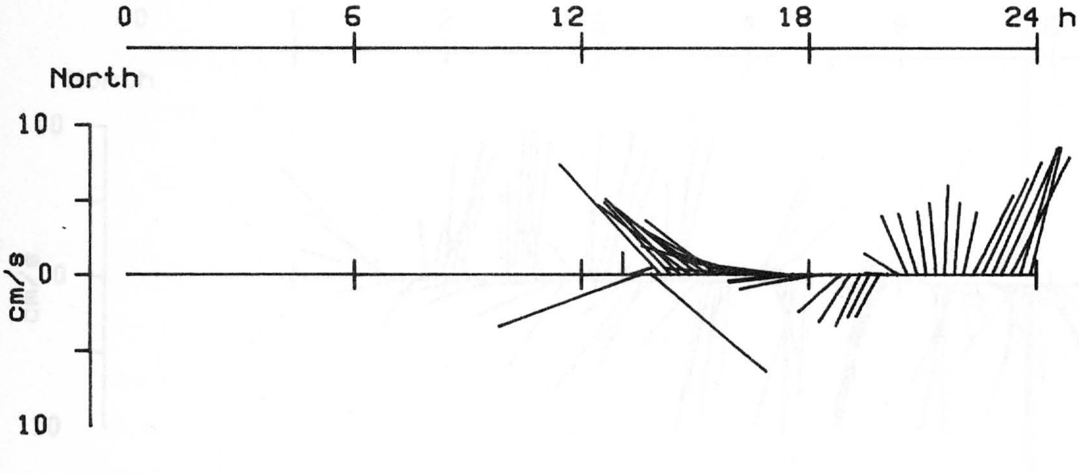


The circle corresponds to a current greater or equal to 10 cm/s

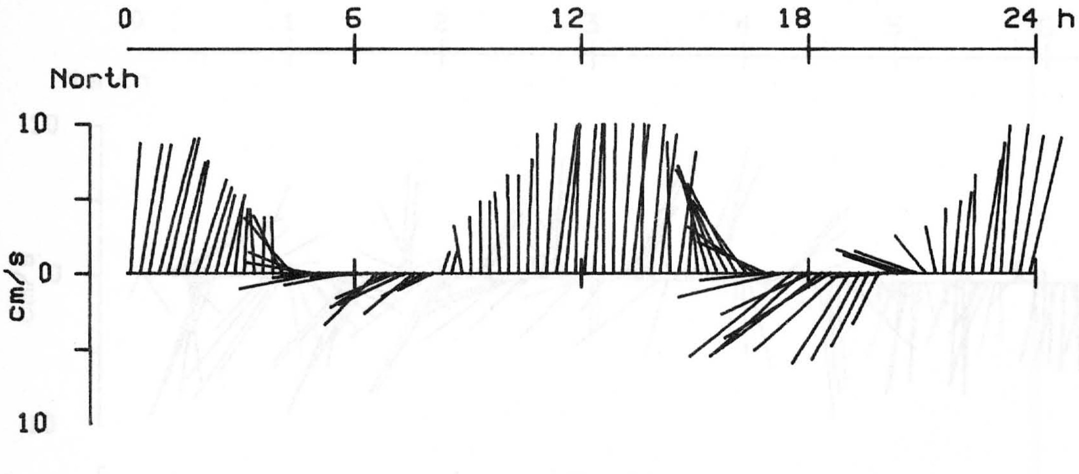
SO 32 - 002 CS

Date:	Begin:	13.05.84	End:	22.06.84
Time:		13.05 H (LT)		11.15 H (LT)
Lat.:		00 45.7 N		
Lon.:		85 53.2 W		
Depth:		2320 M		
meas.D.:		2210 M		

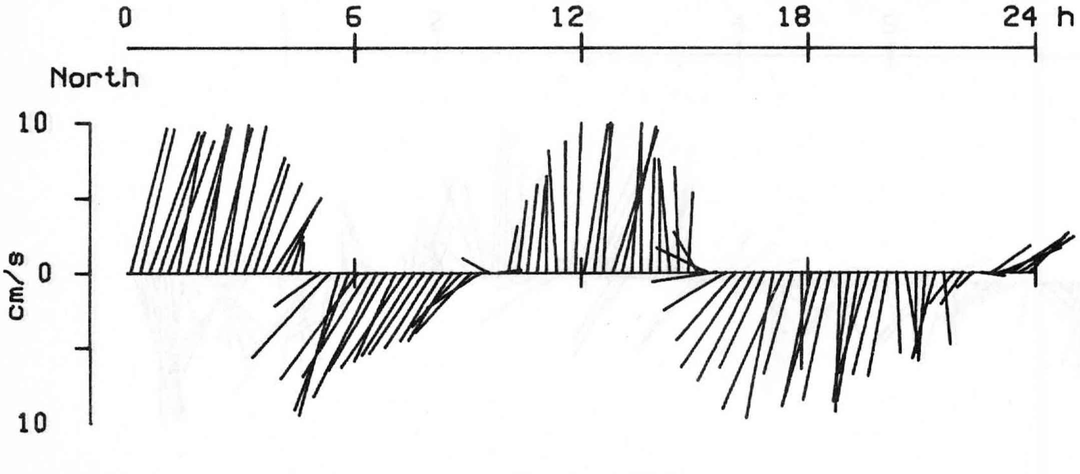
RECORDING INTERVAL IS 5 MIN, LT=GMT+6H, DAY-PLOT



13. 5.1984



14. 5.1984

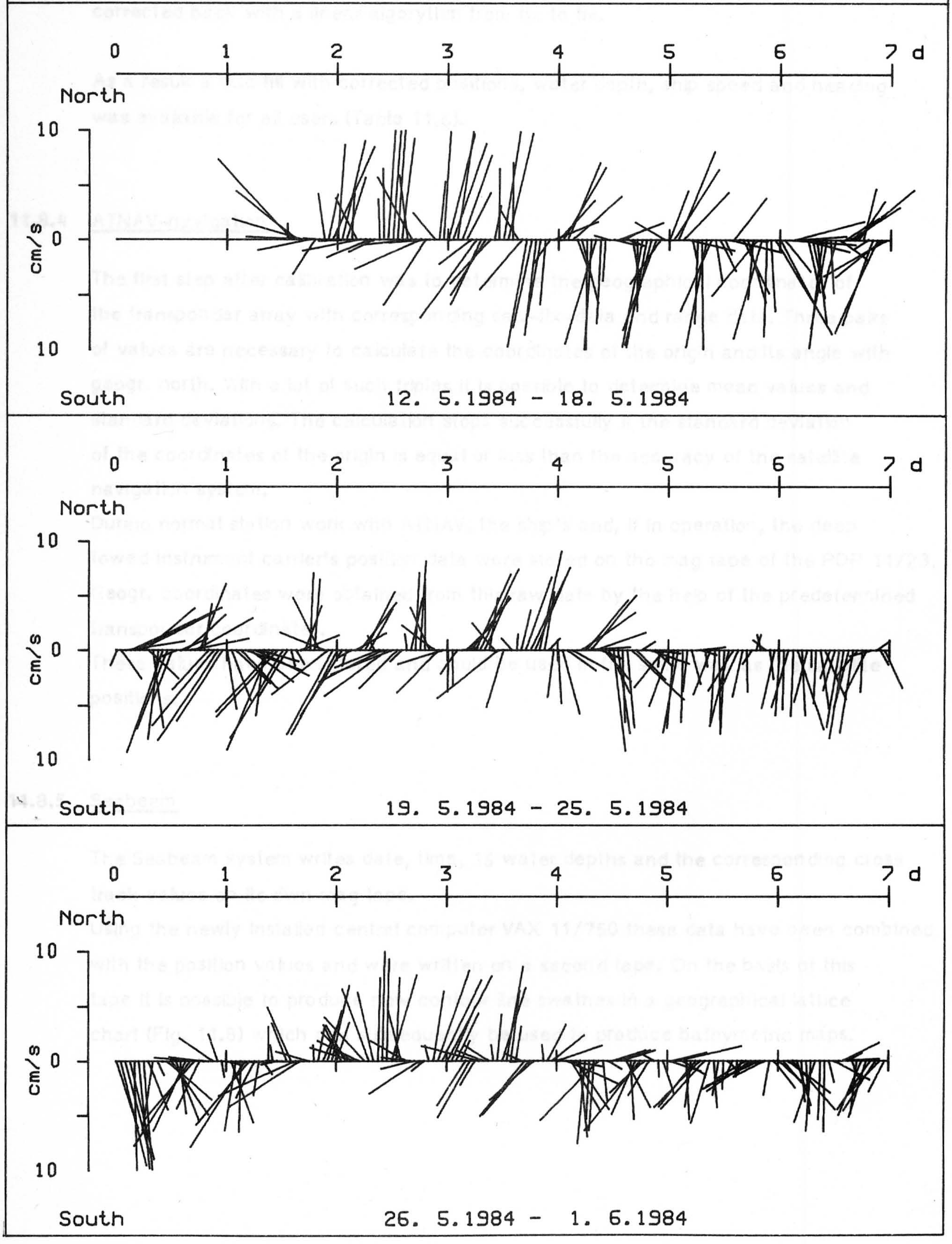


15. 5.1984

SO 32 - 0002 CS

Date:	Begin:	13.05.84	End:	22.06.84
Time:		13.05 H (LT)		11.15 H (LT)
Lat.:		00 45.7 N		
Lon.:		85 53.2 W		
Depth:		2320 M		
meas.D.:		2210 M		

RECORDING INTERVAL IS 5 MIN.



11.8.3 Satellite Navigation

The position raw data (satellite fix positions, dead reckoning positions) and information from narrow beam echo sounder, doppler sonar and gyro were recorded on tape every minute. From this tape the significant data were extracted and the positions corrected back with a linear algorythm from fix to fix.

As a result a disc fill with corrected positions, water depth, ship speed and heading was available for all users (Table 11.6).

11.8.4 ATNAV-navigation

The first step after calibration was to determine the geographical coordinates of the transponder array with corresponding sat.-fix-data and range data. Three pairs of values are necessary to calculate the coordinates of the origin and its angle with geogr. north. With a lot of such triples it is possible to determine mean values and standard deviations. The calculation stops successfully if the standard deviation of the coordinates of the origin is equal or less than the accuracy of the satellite navigation system.

During normal station work with ATNAV, the ship's and, if in operation, the deep towed instrument carrier's position data were stored on the mag tape of the PDP 11/23. Geogr. coordinates were obtained from this raw data by the help of the predetermined transponder coordinates.

These values have been stored and could be used in the same way as the satellite positions.

11.8.5 Seabeam

The Seabeam system writes date, time, 16 water depths and the corresponding cross track values on its own mag tape.

Using the newly installed central computer VAX 11/750 these data have been combined with the position values and were written on a second tape. On the basis of this tape it is possible to produce new contour line swathes in a geographical lattice chart (Fig. 11.8) which can subsequently be used to produce bathymetric maps.

DAY	MON	DAY	HOUR	MIN	SEC	LATITUDE	LONGITUDE	DEPTH	SPEED	HEADING
166	6	14	16	23	0	2 35.7773	-94 50.0633	2600	0.8	107.33
166	6	14	16	24	0	2 35.7741	-94 50.0578	2604	0.4	106.67
166	6	14	16	25	0	2 35.7713	-94 50.0546	2603	0.4	107.00
166	6	14	16	26	0	2 35.7698	-94 50.0510	2602	0.2	107.17
166	6	14	16	27	0	2 35.7675	-94 50.0505	2602	0.8	107.17
166	6	14	16	28	0	2 35.7670	-94 50.0459	2599	0.3	106.83
166	6	14	16	29	0	2 35.7663	-94 50.0446	2590	0.2	107.00
166	6	14	16	30	0	2 35.7662	-94 50.0427	2602	0.2	107.17
166	6	14	16	31	0	2 35.7639	-94 50.0409	2609	0.2	107.17
166	6	14	16	32	0	2 35.7622	-94 50.0386	2609	0.4	107.00
166	6	14	16	33	0	2 35.7600	-94 50.0354	2602	0.5	107.50
166	6	14	16	34	0	2 35.7583	-94 50.0349	2602	0.2	107.00
166	6	14	16	35	0	2 35.7567	-94 50.0317	2599	0.3	106.83
166	6	14	16	36	0	2 35.7559	-94 50.0290	2602	0.4	106.83
166	6	14	16	37	0	2 35.7523	-94 50.0267	2593	0.4	107.00
166	6	14	16	38	0	2 35.7503	-94 50.0262	2599	0.3	107.33
166	6	14	16	39	0	2 35.7500	-94 50.0198	2608	0.2	106.50

TAB. 11.6 EXAMPLE OF A SATELLITE NAVIGATION DATA PLOT

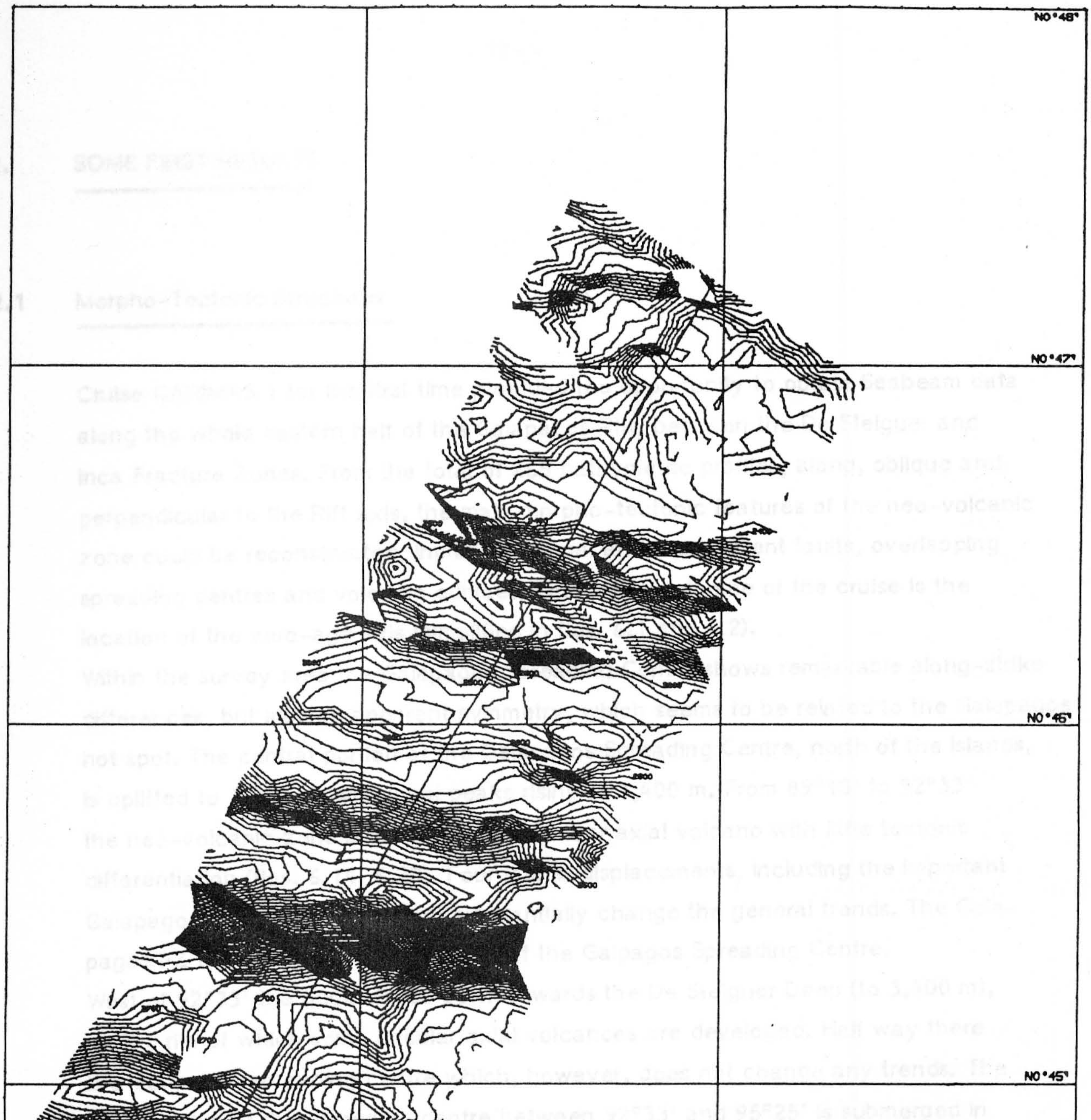


FIG. 11.8 EXAMPLE OF A SEABEAM SWATHE REPLAYED WITHIN A GEOGRAPHIC COORDINATE MAP AFTER MERGING OF SATELLITE NAVIGATION AND ECHO SOUNDING DATA.

12. SOME FIRST RESULTS

12.1 Morpho-Tectonic Structures

Cruise GARIMAS 1 for the first time provided the opportunity to obtain Seabeam data along the whole eastern half of the Galapagos Rift, between the De Steiguer and Inca Fracture Zones. From the total of 265 bathymetric profiles, along, oblique and perpendicular to the Rift axis, the main morpho-tectonic features of the neo-volcanic zone could be reconstructed, including normal and transcurrent faults, overlapping spreading centres and volcanic edifices. One major outcome of the cruise is the location of the zero-age axis (simplified in figs. 6.1 and 6.2).

Within the survey area the Galapagos Spreading Centre shows remarkable along-strike differences, but also an apparent symmetry, which seems to be related to the Galapagos hot spot. The central portion of the Galapagos Spreading Centre, north of the islands, is uplifted to 1,700 m, with local peaks rising to 1,400 m. From 89°10' to 92°33' the neo-volcanic zone is developed as a linear axial volcano with little tectonic differentiation (figs. 6.14, 6.20). Four lateral displacements, including the important Galapagos fracture zone, do not substantially change the general trends. The Galapagos FZ occupies the summit region of the Galpagos Spreading Centre.

West of 92°33' the ridge slopes down towards the De Steiguer Deep (to 3,400 m), on the rim of which some circular axial volcanoes are developed. Half way there is a conjugate spreading centre which, however, does not change any trends. The axial portion of the spreading centre between 92°33' and 95°25' is submerged in respect to the marginal high (figs. 6.4, 6.6, 6.11), and the amount of submergence increases towards the De Steiguer Deep.

On the opposite side, east of 89°10' a similar trend can be noticed, but the submergence of the axial portion of the rise is less pronounced or not developed to a major displacement at 87°10' W which is not yet sufficiently covered by geophysical profiles to classify it as a propagating rift or conjugate (overlapping) spreading centre. East of this lateral displacement of the rift axis the spreading centre is developed as an uplifted rise with a complicated rifted axial zone (figs. 6.26 to 6.33). Towards the Inca Fracture Zone the axis slopes down to more than 2,600 m.

The general morpho-tectonic information derived from the bathymetric data could locally be supplemented by visual data. TV and photo profiles clearly display the tectonic style present in the different sections of the GR and in relation to the age of the crust.

While the presently active volcanic belt is mostly devoid of tectonic features, swarms of gjas (open, up to a few m wide fissures) and small normal faults cut the seafloor within the neo-volcanic zone along-strike, generally arranged in an "en echelon" pattern. On slightly older terrain some faults develop to major displacements, which according to strong brecciation, seem to be deeply rooted.
Normally, several sub-parallel, closely spaced faults form a graded escarpment, several tenths to about 200 m high. Important masses of well sorted talus pile up at the foot of the escarpments.
Outside the neo-volcanic zone, fault escarpments are the only morphological feature to be recognized in visual profiles, except for the upper parts of major basalt pillows. Most of these faults seem to be inactive or dormant.

12.2 Volcanism

Constructional features produced by volcanic events are generally superimposed by tectonic displacements. Only locally round and lobated morphological structures can be classified as volcanic edifices already on the morphological Seabeam maps. There are a few small, up to 300 m high caldera volcanoes along the Galapagos Rift axis and on the marginal highs.
More clearly the different volcanic formations can be recognized on side scan sonograms obtained with the deeptow fish. The best information on the volcanism along the Galapagos Rift, however, were obtained from the photographic records.
Several different lava types could be distinguished (see chapter 13).
Freshest flows are nearly sediment-free, and the glassy surfaces are still glimmering. With age and distance from the axis the lava surfaces are increasingly covered by sediments giving easily rise to misinterpretations. Usually, at about 2 km from the rift axis only the upper parts of pillows are visible, while all other lava types become undiscernable. The lava production appears to be discontinuous, and mostly located in the deeper parts of the inner rift. Most flows originate in longitudinal fissures and extend as subhorizontal covers rather than walls or piles. The type of lava produced depends mainly on quantity and slope angle. No significant chemical differences could be detected so far. The typical pillow lavas are mainly formed from small eruptions and at the front of major flows, while the various types of ponded lavas belong to major volcanic events and preferably fill the deeper portions of the rift. The rugged lava lake topography is favoured by a combination of ponded lava flows and fissure swarms produced by extensional forces.

12.3 Hydrothermal Activity and Products

Hydrothermal activity has locally developed along the Galapagos Spreading Centre and a number of distinct products indicate present or past activity.
The discovery of such indications requires considerable exploration effort. Ongoing hydrothermal activity can be detected by physical and geochemical anomalies in the surrounding seawater, but also by the presence of certain faunal elements related to the sources. Near metal-rich hydrothermal vents also the sediments are enriched in certain metals, like manganese, iron and zinc.
On seafloor photos black manganese stains on sediment and rock surfaces indicate hydrothermal sources nearby. The most conspicuous hydrothermal products are sulphides of iron, zinc and copper, which, together with silicates and sulfates, form near high-temperature vents. The occurrences, when already extinct, are usually more or less oxidized and exhibit various colours.
At the beginning of cruise GARIMAS 1, the sulphide occurrences found during Alvin cruise 1001, were relocated and subsequently photographed and sampled. Though the presence of elements of the hydrothermal vent community indicates some ongoing activity, most sulphides photographed or sampled are heavily oxidized and partly covered by sediments. The occurrences are found outside the actual rift valley along the southern slope of a 60 m high horst structure. Most material is more or less displaced. The base metal contents of the samples analyzed on board (Table 12.1) are very variable. At the Alvin site ("location A") about one ton of sulphides was recovered during GARIMAS 1.
A second important group of hydrothermal sites, subsequently called location B or "Sonne site" were discovered during the cruise around 85°55'W and 0°46'N. A preliminary evaluation of the visual profiles indicate at least 7 single sulphide sites, some of them showing fresher appearance than the Alvin site. Nearby, also low temperature thermal water was observed in gjas, the walls of which were covered by sessile benthos. There were also large clam fields.
The hydrothermal products at location B are very variable. There are even zinc-rich sulfides and silicate mounds.
Besides the two main locations with sulphide formation, a number of places along the Galapagos Rift showed interesting indications of hydrothermal activity during cruise SO 32, but could not yet been sampled (Table 12.2).

Station	Sample	Fe %	Cu %	Zn %	Co ppm	As ppm	Facies	Pyrite	Marcasite	Chalcopyrite	Sphalerite
26 D	1	45.45	0.42	0.20	696	65	MS	XX	XX		
26 D	2	37.79	15.54	0.27	1167	49	MS	XX	X	XX	
28 D	1	43.99	0.07	0.22	145	37	MS	XXX	X		
28 D	2	44.30	0.05	0.26	263	61	MS	X	XX		
28 D	3	37.20	0.43	0.22	21	101	O.S.	a	m o	r p h	
46 GTV	1	44.35	0.14	0.35	351	66	MS	(X)			
46 GTV	3	42.43	2.58	0.21	1853	35	MS	(X)	(X)	(X ?)	
46 GTV	4	(77.28)	1.24	0.30	737	144	O.S.				
49 GTV	ϕ	30.95	14.02	3.57	49	57	MS	(X)	(X)	(X)	(X)
60 GTV	DS 11	u.d.	7.98	6.71	u.d.	18	Sp.				
60 GTV	DS 13	36.47	13.63	0.27	1117	46	Sp. (MS)				
60 GTV		(82.33)	1.22	0.41	609	(510)	O.S.				
60 GTV	ϕ	34.92	2.43	0.36	1312	89	MS	(X)	(X)		
61 GTV	ϕ	43.82	3.85	0.30	409	44	MS	(X)	(X)	(X ?)	
61 GTV		36.12	(27.58)	0.19	365	8	Sp (MS)			(X)	
65 GTV	ϕ	32.43	12.60	0.61	260	45	MS	(X)	(X)	(X)	
67 D	ϕ	20.24	0.20	0.20	5	u.d.	a.B.	(X)			
68 D	ϕ	36.40	9.19	0.63	519	77	MS	(X)	(X)	(X)	
72 GTV	ϕ	25.88	1.66	6.81	20	89	MS	(X)	(X)	(X ?)	(X)
73 GTV	ϕ	18.12	0.08	0.66	17	4	a.B.	(X)			
80 GTV	ϕ	38.24	7.99	0.38	425	51	MS	(X)	(X)	(X)	

MS = massive sulfides
OS = oxid sulfides
Sp = special sample
aB = altered basalt
(X) = macroscopy

TAB. 12.1

METAL CONTENTS OF SULPHIDES FROM LOCATION A (ALVIN SITE)

(Det. K.P. Eilmes)

TAB. 12.2 HYDROTHERMAL SITES FOUND DURING CRUISE SO 32 (GARIMAS 1)

85°39' (87 FS, 15.43): HB, S in sediments

85°43' (09 FS, 16.00): ox. S-chimney ?

85°51' Alvin site ("location A"): S, HP, HB

85°55' Sonne site ("location B"): S, HP, Si, HB

86°05' (173 FS, 4.15): HB

86°06' (181 FS, 22.00, 22.57 - 0.22): HP, HB

86°12' (45 FS, 4.12): HB (clams)

86°26' (143 FS, 19.49; 172 FS, 19.27 - 19.39), HP, ox. S

93°39' (94 FS, 2.35): S-chimney ?

94°50' (114 FS, 18.10): HP

94°55' (112 FS, 4.57 - 5.49): HP, HB; (116 FS, 0.22 - 1.09; 1.38): HP, HB

95°02' (107 FS, 14.42 - 15.11): HP

95°16' (101 FS, 19.25): HP, HB

S = Sulphide
HB = Hydrothermal vent benthos
HP = Hydrothermal products
ox = oxidized
Si = Silicates

13. ABBREVIATIONS

The following abbreviations are used in this cruise report and other reports of cruise GARIMAS 1.

A) EQUIPMENT

FS	Forschungsschiff, research vessel
SB	Seabeam System
NBES	Narrow-beam echo sounder. Stabilized echo sounder "Schelfrandlot" of ELAC, 20 and 30 kHz
SBP	Subbottom profiler, sediment echograph, 3,5 kHz
TB	Bottom pinger, 16 kHz
TT	Transponder of the Atnav navigation system
MS	Multisonde of ME Meerestechnik-Elektronik
K	Kasten corer 15 cm
GK	Reineck box corer
GR	Gravity corer
P	Piston corer
G	Grab
GTV	TV-guided electro-hydraulic grab
STV	Spider grab
D	Dredge, DC chain dredge
FS	Photo TV-sledge
FSMS	Photo-multisonde-sledge
CS	Eulerian current measurement
H	Water sampling station
DFow	Deeptow vehicle, furnished with SSS=Side Scan Sonars and 2,5/3,5 kHz SBP=Subbottom profiler

B) SEAFLOOR FORMATIONS

GR	Galapagos Rift
FNO	Foraminiferal nanno ooze
Sed.	Sediment
KS	Collapse structures
Pi	Pillow
PL	Pillow lava, hummocky pillow flows

PP	Protuberance pillow lava
S	Sheet lava, ponded lava
SL	Lobated sheet lava
SP	Platy sheet lava
SC	Curtain fold/ropy sheet lava
SS	Scrambled sheet lava
SPL	Sheet lava with single pillow protrusions
T	Talus
TP	Displaced pillow fragments
TS	Displaced sheet lava fragments
H	Hydrothermal indications
HF	Hydrothermal fauna
HK	Iron-manganese crusts
HH	Sulphides
HM	Sediment discoloration
HP	Hydrothermal products (on cracks and rock surfaces)
HA	Hydrothermal rock alterations
HO	Turbid waters
FB	Vagrant and sessile benthos
FE	Endo-benthos.

14. STATION LISTS

The following station lists contain the coordinates and water depth of stations occupied during cruise SO 32. They are based on corrected satellite navigation (SATNAV) outside the 86°W area (location A and B) and on Atnav navigation inside that area. In GTV stations the coordinates are those of the last sampling operation, if several took place. D station locations are approximate and correspond to the estimated sampling point.

The second list contains the approximate position of the photo profiles, which partly are more than one mile long, according to SATNAV readings.

Not listed stations are tests.

GARIMAS 1

STATION LOCATIONS AND WATER DEPTH

(EXCEPT FOR PHOTO PROFILES)

1	MS	1 19.600	-85 27.300	2820
2	CS	0 45.703	-85 53.168	2537
3	D	0 45.217	-85 50.293	2515
4	D	0 44.755	-85 51.137	2624
5	D	0 44.662	-85 51.181	2625
6	D	0 44.716	-85 50.509	2620
7	D	0 44.890	-85 50.496	2640
8	D	0 45.387	-85 50.181	2627
10	GTV	0 45.183	-85 50.544	2625
11	GTV	0 44.933	-85 50.671	2602
12	D	0 45.155	-85 54.720	2755
13	D	0 45.012	-85 50.508	2605
14	D	0 44.785	-85 51.053	2655
15	MS	0 44.926	-85 55.028	2786
17	D	0 45.382	-85 52.134	2623
18	D	0 45.273	-85 51.344	2623
20	D	0 45.036	-85 51.071	2522
22	GTV	0 44.922	-85 50.610	2605
26	D	0 45.005	-85 50.566	2608
27	D	0 44.874	-85 50.510	2577
28	D	0 45.035	-85 50.490	2605
29	D	0 44.981	-85 50.476	2555
30	D	0 44.952	-85 50.547	2610
31	D	0 45.005	-85 50.462	2584
34	D	0 44.875	-85 50.575	2587
35	GTV	0 44.970	-85 50.703	2603
46	GTV	0 44.944	-85 50.602	2608
47	STV	0 45.001	-85 50.711	2602
48	D	0 44.940	-85 50.848	2610
49	GTV	0 44.813	-85 50.888	2608
50	GTV	0 45.061	-85 50.701	2550
51	GTV	0 44.887	-85 50.657	2606
54	GTV	0 44.999	-85 50.858	2602
55	GTV	0 44.974	-85 50.748	2610
58	D	0 44.928	-85 50.925	2639
59	GTV	0 45.041	-85 50.708	2612
60	GTV	0 44.948	-85 50.630	2613
61	GTV	0 44.976	-85 50.662	2615
63	D	0 44.977	-85 50.696	2613
65.	GTV	0 45.039	-85 50.700	2616
67	D	0 45.026	-85 50.857	2613
68	D	0 45.015	-85 50.675	2620
70	GTV	0 45.161	-85 50.683	2653
71	GTV	0 44.870	-85 50.665	2605
72	GTV	0 45.017	-85 50.701	2610
73	GTV	0 45.097	-85 50.778	2613
74	GTV	0 45.014	-85 50.724	2603
75	D	0 45.064	-85 50.723	2649
77	GTV	0 45.064	-85 50.822	2652
78	D	0 45.054	-85 50.771	2605
79	D	0 45.010	-85 50.815	2613
80	GTV	0 44.853	-85 50.604	2613
81	D	0 45.014	-85 50.754	2616
82	GTV	0 45.058	-85 50.724	2603
83	GTV	0 44.931	-85 50.730	2610
85	GTV	0 44.977	-85 50.540	2613

86	D	0 45.321	-85 50.519	2652
91	GK	2 11.502	-92 5.643	2240
92	GK	1 58.199	-92 7.116	2215
95	GK	2 39.664	-94 14.032	2782
96	GK	2 25.769	-94 18.539	2497
100	GK	2 44.158	-95 13.092	3097
102	GK	2 30.726	-95 19.526	2314
104	MS+H	2 30.723	-95 19.309	2637
105	MS+H	2 36.558	-94 55.285	2623
106	GK	2 30.300	-95 1.280	2699
108	GK	2 41.225	-94 54.562	2549
109	MS+H	2 36.732	-94 56.025	2662
111	MS+H	2 38.100	-94 56.600	2623
113	GK	2 30.349	-94 55.116	2652
115	MS+H	2 35.700	-94 50.000	2587
117	GK	1 59.715	-92 4.511	2306
120	H	0 45.934	-85 53.887	2580
121	MS+H	0 45.832	-85 54.035	2540
123	GTV	0 44.860	-85 50.502	2602
128	D	0 45.005	-85 50.552	2608
129	D	0 44.901	-85 50.238	2598
130	D	0 45.911	-85 54.275	2520
131	MS+H	0 45.856	-85 54.913	2488
132	MS+H	0 45.754	-85 54.671	2562
134	D	0 45.831	-85 54.521	2555
135	D	0 45.965	-85 54.182	2592
136	D	0 44.762	-85 50.806	2566
137	D	0 44.675	-85 50.453	2590
138	MS+H	0 45.799	-85 54.726	2497
139	D	0 46.020	-85 54.840	2576
140	GK	0 43.743	-85 56.078	2735
142	GK	0 53.273	-86 24.825	2565
146	GK	0 48.534	-85 54.812	2783
147	GK	0 50.702	-85 54.586	2692
148	GK	0 40.446	-85 56.500	2714
157	D	0 46.043	-85 54.952	2540
158	D	0 45.931	-85 54.885	2485
159	D	0 45.874	-85 54.549	2510
161	D	0 45.769	-85 54.922	2480
162	D	0 45.766	-85 54.773	2566
164	D	0 45.941	-85 54.343	2567
165	D	0 46.076	-85 54.891	2586
166	D	0 46.109	-85 54.749	2569
167	MS+H	0 46.008	-85 54.896	2580
168	D	0 46.065	-85 53.747	2600
170	D	0 45.906	-85 54.863	2572
171	D	0 45.970	-85 54.686	2562
174	D	0 45.902	-85 54.396	2576
175	D	0 46.051	-85 54.218	2610
176	STV	0 46.050	-85 54.248	2605
178	MS+H	0 45.810	-85 54.656	2511
179	GTV	0 46.105	-85 54.906	2580
182	GTV	0 46.159	-85 54.766	2583
183	STV	0 45.767	-85 55.173	2523
185	MS+H	0 46.077	-85 55.169	2580
187	GK	0 45.069	-85 53.204	2711

GARIMAS 1

APPROXIMATE LOCATION OF PHOTO PROFILES

STATION NO.	DEGR.	MIN. N	DEGR.	MIN. W
09 FS	0	45	85	42/41
16 FS	0	44/43	85	55/51
21 FS	0	45	85	50/51
23 FS	0	52/54	86	59
24 FS	0	49/51	86	34/33
25 FS	0	48/47	86	19/18
32 FS	0	46	85	54
33 FS	0	45		50/51
36 FS	0	55/54	87	06/04
37 FS	0	52/53	87	11/12
38 FS	0	50/51	87	19/18
40 FS	0	56/55	88	10/11
41 FS	0	48/47	89	29/31
42 FS	0	47/48	88	49/46
43 FS	0	42	87	45
44 FS	0	44/40	87	45
45 FS	0	48	86	15/12
52 FS	0	45	85	53/51
53 FS	0	41/40	85	55/56
56 FS	0	45	85	51
64 FS	0	45/46	85	51
76 FS	0	45	85	40
84 FS	0	49/48	86	11/12
87 FS	0	45/44	85	40
88 FS	0	46/45	85	50/51
89 FS	0	52/50	86	49/48
90 FS	0	56/52	90	22/21
93 FS	2	18	93	05
94 FS	2	37/30	94	06/10
97 FS	2	31/33	94	17
98 FS	2	33/35	94	18/17
99 FS	2	42/43	95	15/14

STATION NO.	DEGR.	MIN. N	DEGR.	MIN. W
101 FS	2	39/36	95	16/14
103 FS	2	37/35	95	25/24
107 FS	2	38/36	95	02/00
110 FS	2	38/39	94	56/55
112 FS	2	39/40	94	55/56
114 FS	2	36	94	50/48
116 FS	2	37/33	94	55/54
118 FS	1	57/59	91	22/20
119 FS	0	50/47	89	47/45
122 FS	0	46/45	85	55/50
126 FS	0	45	85	51/50
127 FS	0	45	85	51/50
133 FS	0	46/47	85	56/52
141 FS	0	47/46	85	59
143 FS	0	49/48	86	26
144 FS	0	48/47	86	18/17
145 FS	0	48	86	07/05
149 FS	0	48/47	86	00
150 FS	0	47/45	85	57
151 FS	0	46	85	54/53
153 FS	0	46	85	56/55
154 FS	0	46	85	55/54
155 FS	0	46/47	85	56/54
156 FS	0	46/45	85	55/54
163 FS	0	47/44	85	55/54
169 FS	0	46	85	54
172 FS	0	48/50	86	27/26
173 FS	0	48/47	86	06/05
177 FS	0	46/45	85	55/53
180 FS	0	46	85	54/53
181 FS	0	48/49	86	06/04
184 FS	0	45/46	85	51
186 FS	0	46/47	85	56/55

PHOTO TABLE 1

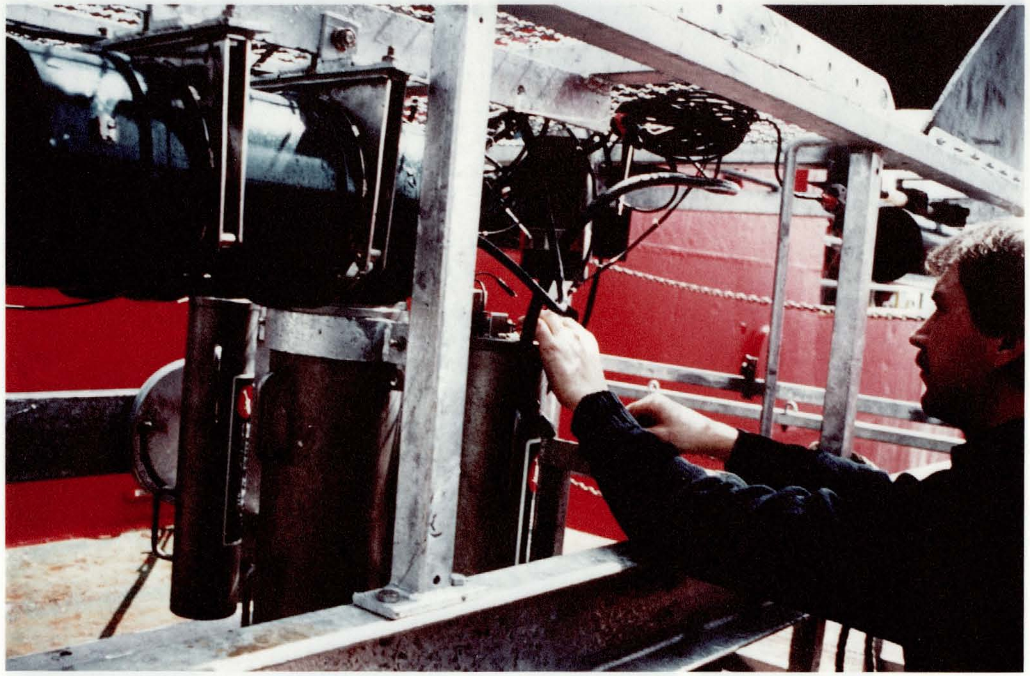
a) Photo-TV sledge: instrument package for visual sea-floor investigations

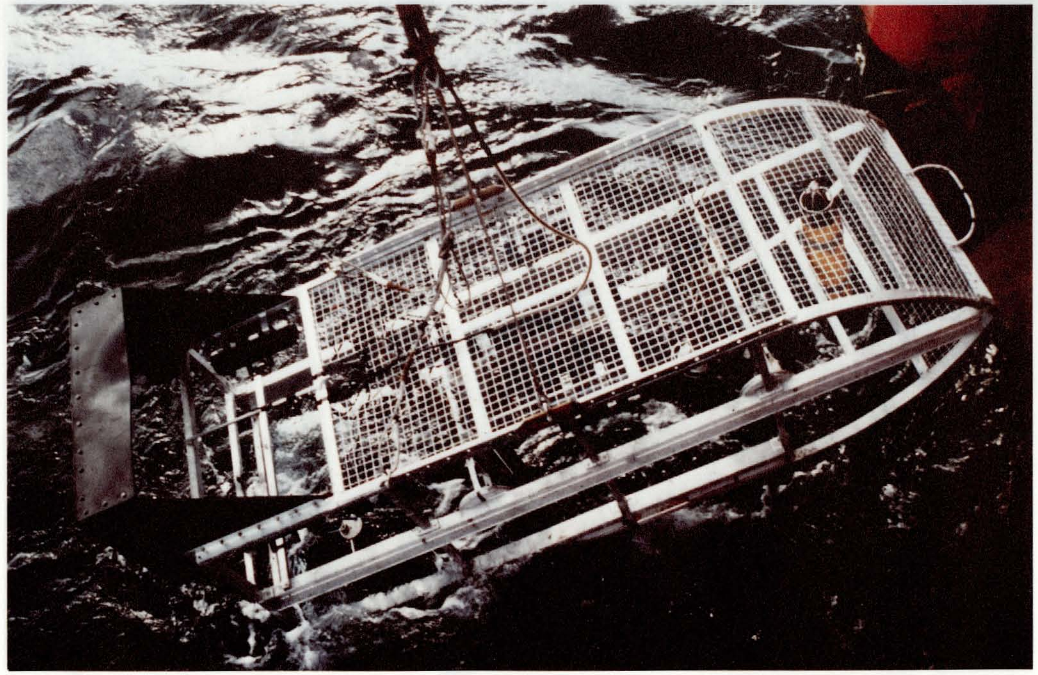
b) Same, details of instruments

c) Sea-floor observations in the geological laboratory

d) Launching of the photo-TV sledge

e) Development of diapositive films.





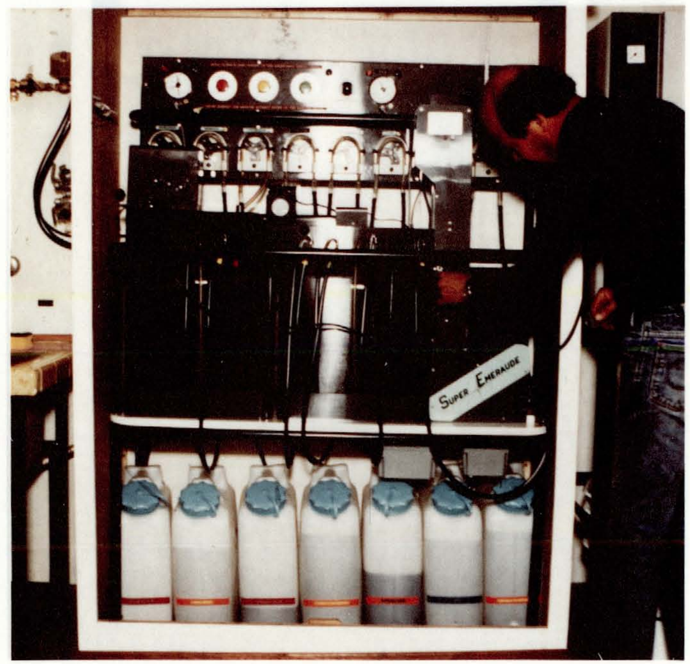

SUPER EMERAUDE

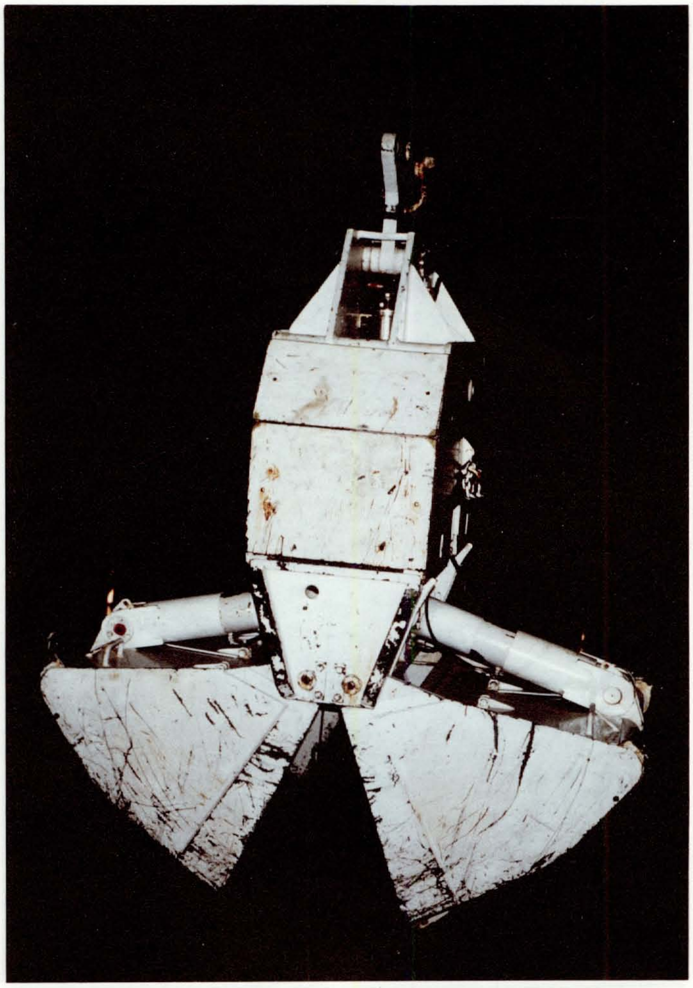
PHOTO TABLE 2

a) Basalt fragment. Folded surface of a glassy ponded lava flow

b),c) Electro-hydraulic TV-grab

d) Specimen of hydrothermally altered and mineralized basalt breccia produced at one of the major marginal faults of the Galapagos Rift valley at 85°50'W

e) Fragment of a black smoker sulphide chimney from the same location.

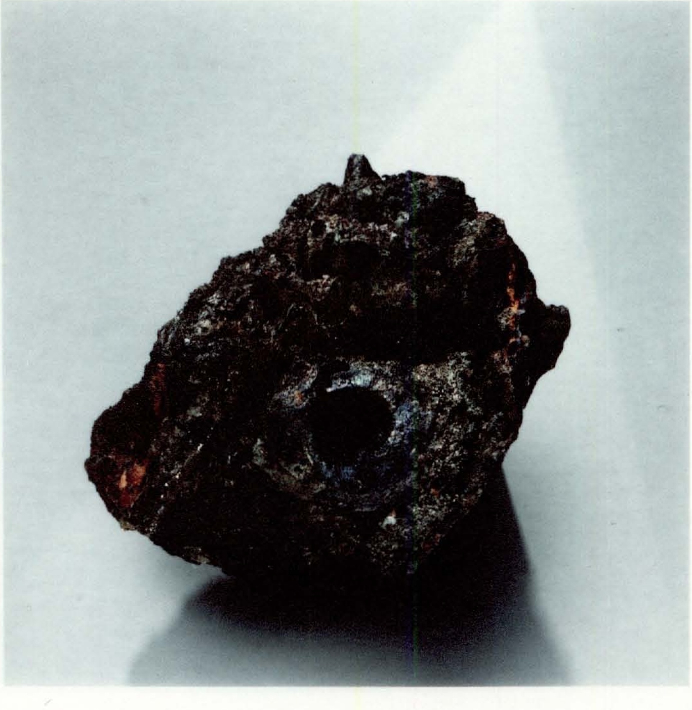



PHOTO TABLE 3

a) A geochemist and a processing engineer examining the load of rocks collected by the TV grab

b) Fresh massive sulphides from the Galapagos Rift at 86°50'W

c) Strongly oxidized sulphides from the Galapagos Rift at 85°50'W.


28

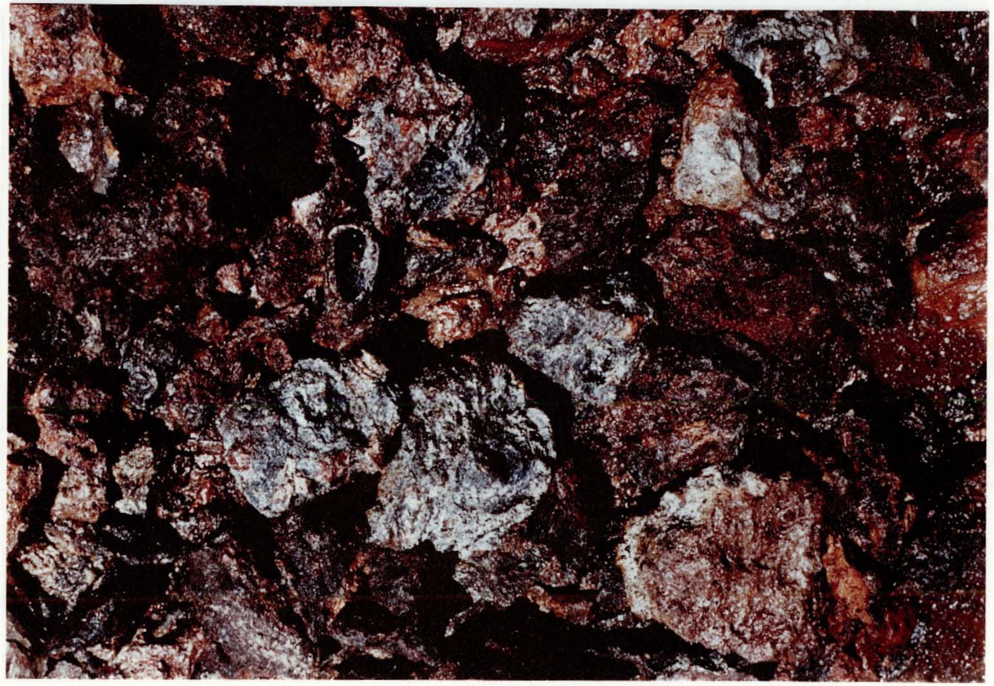
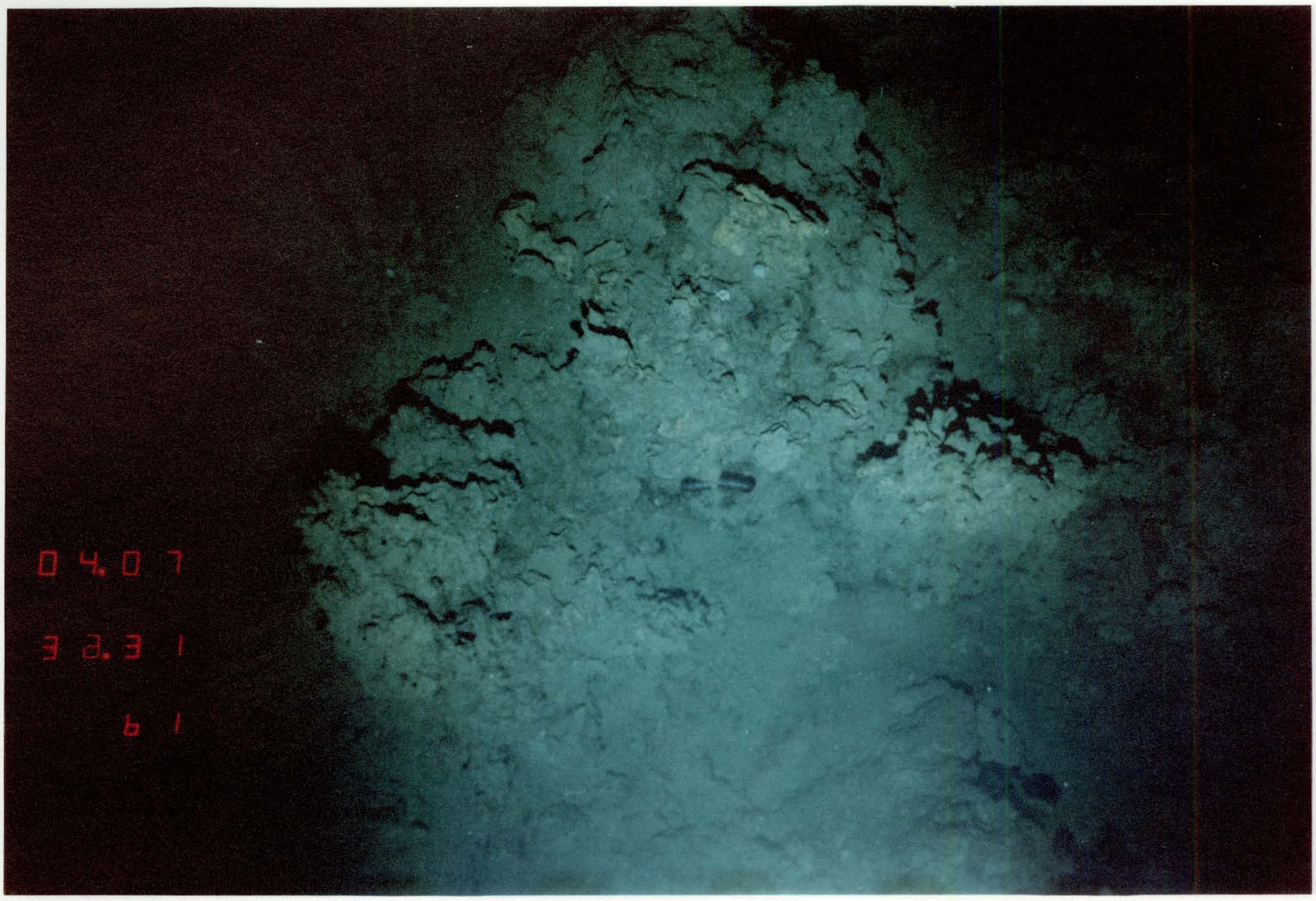


PHOTO TABLE 4

Bottom photos of partly oxidized massive sulphides in the Galapagos Rift at 85°50'W. Primary and secondary hydrothermal products. Surface area 17 m^2.


04.07
32.31
61


4.07
3.31
58