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Werner, R.; Ackermand, D.; Worthington, T.;
and Shipboard Scientific Party

Cruise Report SONNE 144-3
PAGANINI 3

Panamá Basin and Galápagos "Plume" -
New Investigations of Intraplate Magmatism

Panamá Becken und Galápagos „Plume" -
Neue Untersuchungen zum Intraplatten Magmatismus

Puerto Caldera, Costa Rica – Balboa, Panamá
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Schriftleitung: Dr. Kyaw Winn

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ZUSAMMENFASSUNG

Gesteinsbeprobung

Hauptziel der Ausfahrt SO 144-3 war die systematische Beprobung vulkanischer Gesteine im Gebiet zwischen den Galápagosinseln und Mittel- bzw. Südamerika. Der Schwerpunkt lag auf den aseismischen Cocos-, Carnegie-, Coiba-, Malpelorücken sowie den damit assozierten Seamounts, die von den meisten Autoren als Hotspotspuren des Galápagos Hotspot angesehen werden. Die Beprobung erfolgte hauptsächich entlang von Profilen längs und/oder quer zu den Rückenachsen bzw. Seamountketten mittels Dregden und einem TV-Greifer. Es wurden insgesamt 96 Dredgezüge und 15 TV-Greifereinsätze durchgeführt, wobei kein Gerät verloren ging. An 87 Stationen wurden dabei 1225 Gesteinsproben gewonnen, die u.a. ein breites Spektrum an Laven (z.B. verschiedene Basalte, Trachyte), subvulkanische und plutonische Gesteine (z.B. Gabbros, Peridotite), vulkaniklastische Gesteine (z.B. Hyaloklastite, Schlacken, Bimse) und Sedimente (z.B. Ton-, Silt- und Kalksteine, Konglomerate, Turbidite) umfassen.

Während im Süden des Carnegierückens olivinreiche Laven dominieren, herrschen an seinem Nordrand plagioklasreiche Laven vor. Am Cocosrücken und den damit assozierten Seamounts treten dagegen im Nordwesten vorwiegend olivin- und pyroxenreiche und im Südosten plagioklasreiche Laven auf. Weiterhin existiert entlang des Südostrandes des Cocosrückens ein ca. 100 km breiter Bereich, in dem Gabbros häufig vorkommen. Im Gebiet des Malpelorücken wurden vorwiegend feldspatführende Gesteine gedredged und am Coibarücken ein weites Spektrum sehr unterschiedlicher Lithologien. An den meisten Stationen variierte der Alterationsgrad der Proben von frisch bis stark alteriert.

An den auf SO 144-3 gewonnenen Gesteinsproben werden vulkanologische, geochemische und geochronologische Untersuchungen im Rahmen des interdisziplinären Projektes „PAGANINI“ durchgeführt, daß zu einem besseren Verständnis geodynamischer Prozesse im Bereich der vom Galápagos Hotspot beeinflußten Ozeankruste im Ostpazifik beitragen soll. Hauptziele der Untersuchungen an den SO 144-3 -Proben sind (1) anhand der Rekonstruktion der zeitlich-räumlichen und magmatischen Entwicklung des Galápagos Plumesystems einen Beitrag zum besseren Verständnis von Mantelplumes und „Large Igneous Provinces“ zu leisten und (2) anhand der Charakterisierung der komplexen plattentektonischen Prozesse im Bereich des Panamábeckens Informationen über die Zeit-Raum-Evolution des „Galápagos Vulkanischen System“ während des Känozoikums zu gewinnen.

Geophysik

Während der gesamten Fahrt wurden kontinuierlich hydroakustische Daten aufgezeichnet und verarbeitet. Größtenteils handelt es sich dabei um erstmals überdeckte Gebiete. Nahe der costaricanischen Küste wurden die Transitprofile so gewählt, daß bislang nicht vermessene Gebiete erstmals überdeckt wurden. Diese Daten sind zur Ergänzung und Erweiterung der Basis früherer FS *Sonne*-Fahrten (SO 76, SO 81, SO 107, SO 144-1 und -2) für die tektonischen Untersuchungen des Areals von großer Bedeutung. Magnetische Messungen wurden ebenfalls kontinuierlich durchgeführt, ein spezielles magnetisches Profil wurde in Nord-Süd Richtung nördlich des Carnegierückens aufgenommen. Die gesammelten Daten waren im allgemeinen von sehr guter Qualität.

Auf SO 144-3b wurden außerdem Ozeanbodenseismometer (OBS) und Fluxmeter des Scripps Institutes vor der costaricanischen Osahalbinsel aufgenommen und nach Sicherstellung der Daten und Wartung der Geräte vor der Nicoyahalbinsel wieder ausgesetzt.

Biologie

Die Proben von den 87 Stationen erbrachten Material aus fast allen marinen Tiergruppen quer durch das Tierreich und zeigten die Vielfalt der Organismen auf verschiedenen untermeerischen Rücken und Seamounts. In 261 Probengefäße wurden etwa 1300 Individuen für die weitere wissenschaftliche Bearbeitung fixiert; zusätzlich wurden über 240 Individuen mikroskopisch kleiner Tiere direkt nach der Probennahme aus dem Sediment extrahiert. In weiteren 72 Gefäßen wurden vorwiegend schlickige Sedimente mithilfe der Rühr- & Dekantier-Methode konzentriert und konserviert. Aus diesen Proben lassen sich mittels anderer Extraktionsmethoden, z.B. der Dichte-Gradientenzentrifugation, weitere mikroskopisch kleine Organismen gewinnen.

Videoaufnahmen an 15 Stationen waren besonders aufschlußreich, denn sie zeigten (1) wie sehr sich der Meeresboden an verschiedenen Stellen in seiner Struktur unterschied und (2) wie heterogen die benthische Fauna an den einzelnen Stationen zusammengesetzt war. Die Videobander machten außerdem deutlich, daß (3) unsere Proben nur einen begrenzten Anteil der existierenden Fauna erfaßten. Arten, die auf den Videos zu erkennen waren, konnten zum Teil später gefangen und identifiziert werden.

SUMMARY

Hard Rock Sampling

The major objective of the SO 144-3 cruise was the systematic sampling of volcanic rocks in the area between the Galápagos Islands and Central –South America. This work focussed on the aseismic Cocos, Carnegie, Coiba and Malpelo Ridges, together with associated seamounts. These ridges are generally considered to mark the trail of the Galápagos hotspot. Most rock sampling took place on profiles that extended both along and across the ridge axes and seamount chains, and both a dredge and TV-grab were used. Altogether 96 dredge tracks and 15 TV-grabs were completed without any loss of equipment. A total of 1225 rock samples from 87 stations were recovered, consisting of lava (e.g., basalt, trachybasalt), subvolcanic and plutonic rocks (e.g., gabbro, peridotite), volcaniclastic rocks (e.g., hyaloclastite, scoria, pumice) and sedimentary rocks (e.g., clay-, silt- and limestone, conglomerate, turbidite).

Petrographically, a general progression was observed at Carnegie Ridge from olivine-bearing lavas on the southern margin to feldspar-bearing lavas along the northern margin, and across Cocos Ridge from olivine- and pyroxene-bearing lavas along the NW margin to plagioclase-bearing lavas along the SE margin. Also, gabbro frequently occurs in a 100 km-wide band along the SE margin of Cocos Ridge. Feldspar-bearing rocks are prevalent along the NW margin of Malpelo Ridge, whereas a broad spectrum of basaltic lavas were dredged from Coiba Ridge. Samples varied from fresh to deeply weathered at most stations.

Planned volcanological, geochemical and geochronological studies on the rocks recovered during SO 144-3 are part of the interdisciplinary "PAGANINI" project. This aims to provide a better understanding of the geodynamic processes where the East Pacific oceanic crust is influenced by the Galápagos hotspot. The major objectives of these studies are: (1) the reconstruction of the temporal, spatial and magmatic evolution of the Galápagos plume system in order to obtain a better understanding of mantle plumes, hotspot magmatism, and "Large Igneous Provinces", and (2) to gain information about the temporal and spatial evolution of the Galápagos Volcanic System during the Cenozoic by characterizing the complex plate tectonic processes in the Panamá Basin.

Geophysics

Hydroacoustic data were continuously recorded and processed during the cruise. The main part of the survey area was measured for the first time. However, previous cruises have acquired data for much of the coastline near Costa Rica, and transits on this cruise

were used to fill in the few remaining gaps. The new dataset extends the existing database, mostly obtained during RV *Sonne* cruises SO 76, SO 81, SO 107, SO 144-1 and -2. Magnetic profiles were also continuously recorded, as well as one special north-south magnetic profile. The data quality was generally excellent.

A series of ocean-bottom seismometers (OBS) and fluxmeters from the Scripps Institution of Oceanography were recovered off the Osa Peninsula of Costa Rica. After servicing and downloading of the data, these were re-deployed off the Nicoya Peninsula.

Biology

Samples from the 87 stations contained species from almost all marine groups of the animal kingdom, and demonstrated the diversity of animal life on submarine ridges and seamounts. The samples include 261 vials containing approximately 1300 specimens for further scientific analysis, and about 240 specimens of meiofauna which were isolated immediately after collection. In addition, the stir and decant method was used to extract meiofauna from 72 samples of soft muddy sediment recovered during dredging, and these were then preserved. Additional specimens of microscopic animals may be extracted from these samples by further processing (e.g., density gradient centrifugation).

Video tapes recorded at the 15 TV-grab stations were especially valuable, because they demonstrate: (1) how much the ocean floor differs in structure between different locations, and (2) how heterogeneous the benthic fauna were at different sites. The tapes also indicate that our samples contain only a limited spectrum of the often rich epibenthic fauna. The identity of some species seen on the videos was confirmed when specimens were obtained from dredging at later stations.

ACKNOWLEDGEMENTS

We would like to express our deepest gratitude to Captain Hartmut Andresen and all crew members of the RV *Sonne* for their expert help, advice, and professionalism. No dredges were lost thanks to their diligent and expert control of both the RV *Sonne* and the dredging winch. Minor hydraulic problems with the TV-grab were quickly repaired and it was always available for the next station. These are significant achievements considering the difficulties of handling a research ship, winches, and other equipment while dredging old MnOx-encrusted seamounts in variable sea conditions and under considerable time pressure.

We also thank the Governments of Columbia, Costa Rica, Ecuador, and Panamá for granting permission to work within their territorial waters. The Government of Costa Rica also granted permission for landing on Cocos Island, which allowed us to obtain important samples for comparative purposes.

The PAGANINI 3 project is funded by Bundesministerium für Bildung und Forschung (BMBF) project awards to Prof. Peter Stoffers and Prof. Kaj Hoernle. Their advice and contribution have been essential to the success of PAGANINI 3.

Ship's Crew:

Andresen, Hartmut	Captain		
Mallon, Lutz	1st Officer	Neumann, Peter	Chief Engin.
Priebe, Roland	1st Officer	Beyer, Helge	2nd Engineer
Sturm, Wolfgang	Radio Officer	Rex, Andreas	2nd Engineer
Vöhrs, Helmut	Electronic Engineer	Konrath, Rolf	Electrician
Hoffman, Hilmar	Chief Electr. Engineer	Blohm, Volker	Motorman
Grigel, Jens	Systems Manager	Szych, Uwe	Motorman
Gebhardt, Volkmar	Systems Manager	Sosnowski, Werner	Motorman
Walther, Anke	Doctor	Zeitz, Holger	Motorman
Wieden, Wilhelm	Chief Cook	Rosemeyer, Rainer	Fitter
Braatz, Willy	2nd Cook	Slotta, Werner	Chief Steward
Jahns, Winfried	Boatsman	Hasler, Justine	2nd Stewardess
Hoffmann, Werner	A.B.	Prechtl, Hans-Jürgen	2nd Steward
Bosselmann, Norbert	A.B. (144-3a)	Mucke, Hans-Peter	A.B.
Kreft, Norbert	A.B.	Hödl, Werner	A.B.
Kähler, Erhard	A.B.	Tamm, Stefan	A.B. (144-3b)

PARTICIPANTS

PAGANINI 3 is a multidisciplinary joint IfG-Kiel – GEOMAR project. It involves five German research groups; the Institut für Geowissenschaften - Universität Kiel, the GEOMAR, the Alfred-Wegener-Institut, the Freie Universität Berlin, and the Museum für Naturkunde Berlin. International scientists came from Columbia (the National University, Bogota), Ecuador (Oceanographic Institute of the Ecuadorian Navy), Panamá (Direccion General de Recursos Minerales), Costa Rica (Instituto Costarricensede Electricidad, Universidad de Costa Rica), the U.S.A. (Scripps Institution of Oceanography and Colgate University), and New Zealand (Institute of Geological and Nuclear Sciences).

Principal Investigators for PAGANINI 3 (not onboard):

Stoffers, Peter	IfG-Kiel
Hoernle, Kaj	GEOMAR

Shipboard Scientific Party:

144-3a	Ackermand, Dietrich (Chief Scientist)	IfG-Kiel	Petrology
	Caita Silva, Carlos	UNB	Petrology
	de Dios Villa Mata, Juan	DGR	Petrology
	Fretzdorff, Susanne	IfG-Kiel	Petrology/Geochemistry
	Götz, Peter	FUB	Biology
	Guerrero, Rafael	UNB	Petrology
	Lichowski, Frances	IfG-Kiel	Marine Geology
	Lissinna, Britta	GEOMAR	Petrology/Geochemistry
	Ludwig, Sandra	IfG-Kiel	Marine Geology
	Müller, Matthias	GEOMAR	Geophysics
	Neuhaus, Birger	MNB	Biology
	O'Connor, John	AWI	Geochron./Geochemistry
	Ripperger, Johannes	GEOMAR	Geophysics
	Santana, Essy	INOCAR	Marine Geology
	Schaffer, Irmgard	GEOMAR	Geophysics
	Schmidt, Angelika	GEOMAR	Petrology/Geochemistry
	Wenskowski, Beate	GEOMAR	Petrology/Geochemistry
	Werner, Reinhard	GEOMAR	Volcanology/Geochem.
	Worthington, Tim	GNS/IfG-Kiel	Petrology/Geochemistry
144-3b	Alvarado Induni, Guillermo	ICE/UCR	Volcanology/Petrology
	Caita Silva, Carlos	UNB	Petrology
	de Dios Villa Mata, Juan	DGR	Petrology
	Dorman, LeRoy	Scripps	Geophysics
	Duggen, Svend	GEOMAR	Petrology/Geochemistry
	Escher, Sharon	Scripps	Geophysics

Götz, Peter	FUB	Biology
Guerrero, Rafael	UNB	Petrology
Harpp, Karen	Colgate	Petrology/Geochemistry
Johnson, Russell	Scripps	Geophysics
Krüger, Ove	IfG-Kiel	Marine Geology
Lichowski, Frances	IfG-Kiel	Marine Geology
Lissinna, Britta	GEOMAR	Petrology/Geochemistry
Ludwig, Sandra	IfG-Kiel	Marine Geology
Mayhew, Lisa	Colgate	Petrology/Geochemistry
Müller, Matthias	GEOMAR	Geophysics
Neuhaus, Birger	MNB	Biology
Sassen, Bettina	San Jose	German Embassy
Sauter, Alan	Scripps	Geophysics
Schaffer, Irmgard	GEOMAR	Geophysics
Tryon, Mike	Scripps	Geophysics
Wanless, Dorsey	Colgate	Petrology/Geochemistry
Wenskowski, Beate	GEOMAR	Petrology/Geochemistry
Werner, Reinhard (Chief Scientist)	GEOMAR	Volcanology/Geochem.
Worthington, Tim	GNS/IfG-Kiel	Petrology/Geochemistry

Institutions:

IfG-Kiel	Institut für Geowissenschaften, Christian-Albrechts-Universität, Olshausenstr. 40, D-24118 Kiel, Germany (http://www.gpi.uni-kiel.de).
GEOMAR	Research Centre for Marine Geosciences, Christian-Albrechts-Universität, Wischhofstr. 1–3, D-24148 Kiel, Germany (http://www.geomar.de).
AWI	Alfred-Wegener-Institut für Polar und Meeresforschung, Columbus Str., D-27568 Bremerhaven, Germany (http://www.awi-bremerhaven.de).
GNS	The Institute of Geological and Nuclear Sciences, PO Box 31-312, Lower Hutt, New Zealand (http://www.gns.cri.nz).
Scripps	Scripps Institution of Oceanography, La Jolla CA, U.S.A. (http://www.sio.ucsd.edu).
Colgate	Department of Geology, Colgate University, Hamilton NY, U.S.A. (http://www.departments.colgate.edu/geology/).
FUB	Zoologisches Institut, Freie Universität Berlin, Germany (http://www.biologie.fu-berlin.de).
MNB	Institut für Systematische Biologie, Museum für Naturkunde Berlin, Germany (http://www.museum.hu-berlin.de).
ICE	Instituto Costarricensede Electricidad, San José, Costa Rica (http://www.newton.dgct.ice.go.cr).
UCR	Universidad de Costa Rica, San José, Costa Rica (http://www.ucr.ac.cr).
INOCAR	Oceanographic Institute of the Ecuadorian Navy, Guayaquil, Ecuador.
DGR	Department of Geology, Direccion General de Recursos Minerales, Ministerio de Comercio e Industrias, Panamá.
UNB	National University, Bogota, Columbia (http://www.usc.unal.edu.co).

1. OBJECTIVES

The main objective of cruise SO 144-3 was systematic rock sampling of the aseismic ridges and other volcanic structures belonging to the "Galápagos Volcanic System" (GVS). These include the Cocos, Carnegie, Coiba and Malpelo Ridges, some smaller ridges (e.g., Fisher Ridge), the seamount domain NW of Cocos Ridge (von Huene et al., 1995), and other seamounts adjacent to the ridges (Figs 1.1, 1.2). Additional objectives were to preserve and evaluate any biological material recovered with or growing on the rock samples, and to obtain multibeam bathymetric, PARASOUND, and magnetic profiles over the survey area during station transits.

The SO 144-3 cruise and follow-up sample studies and data interpretation are part of the interdisciplinary "PAGANINI" project (**PA**namá Basin and **GA**lápagos Plume – **N**ew **IN**vestigations of **I**ntraplate Magmatism). The main goal of PAGANINI is to achieve a better understanding of the geodynamic processes of the GVS, where the East Pacific oceanic crust is influenced by the Galápagos hotspot, and the adjacent active continental margins of Central and South America. The project emphasizes the temporal and spatial as well as magmatic evolution of the aseismic ridges in the area, and their interaction with the continental margins. It has developed from various earlier projects, including PACOMAR (SO 76, 81, 107), Hotline (SO 80), Foundat (SO 100), Condor (SO 101, 103), TICOSECT (**T**rans **I**sthmus **CO**sta Rica **S**cientific **E**xploration of a **C**rustal **T**ransect) and several DSDP Legs.

The volcanological, geochemical and geochronological studies will help to achieve the major objectives of PAGANINI:

1) To contribute to a better understanding of mantle plumes, hotspot magmatism, and "Large Igneous Provinces" through reconstruction of the temporal, spatial and magmatic evolution of the Galápagos plume system.
2) To gain information about the temporal and spatial evolution of the GVS during the Cenozoic by characterizing the complex plate tectonic processes in the Panamá Basin.
3) To characterize the relationship between the subduction of normal and anomalously thick crustal segments of the GVS and the seismic and volcanic activity along the continental margin via reconstruction of the long-term tectonic-magmatic evolution of the Central American/Columbian subduction zone. This will greatly assist in evaluating the earthquake and volcanic hazards of this region.

The Galápagos hotspot is one of the best studied hotspots, and some consider it generated a large igneous province (LIP), namely the Caribbean Plate (e.g., Duncan and

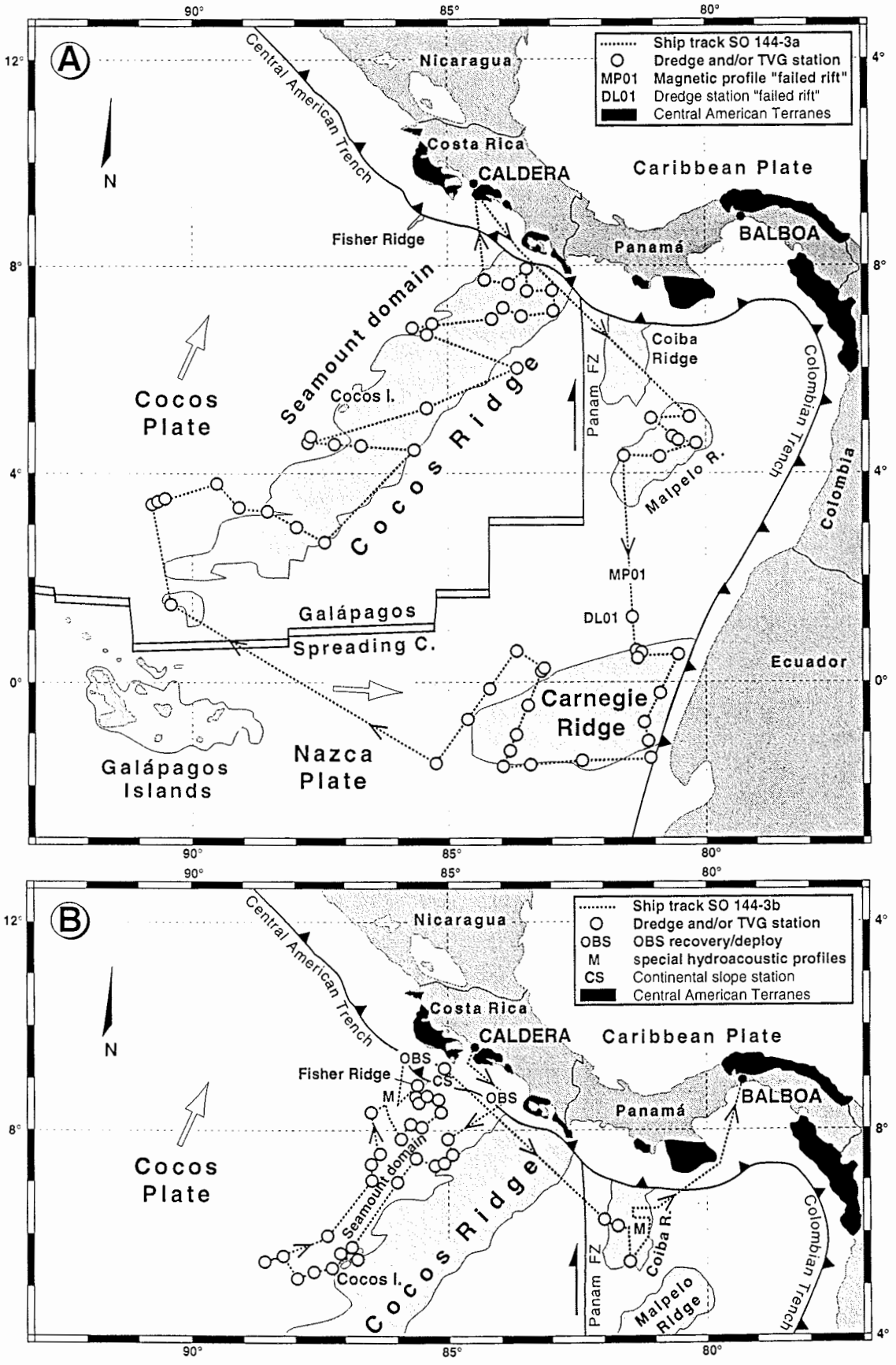

Fig. 1.1: Ship track and stations for SO 144-3a (A) and -3b (B)

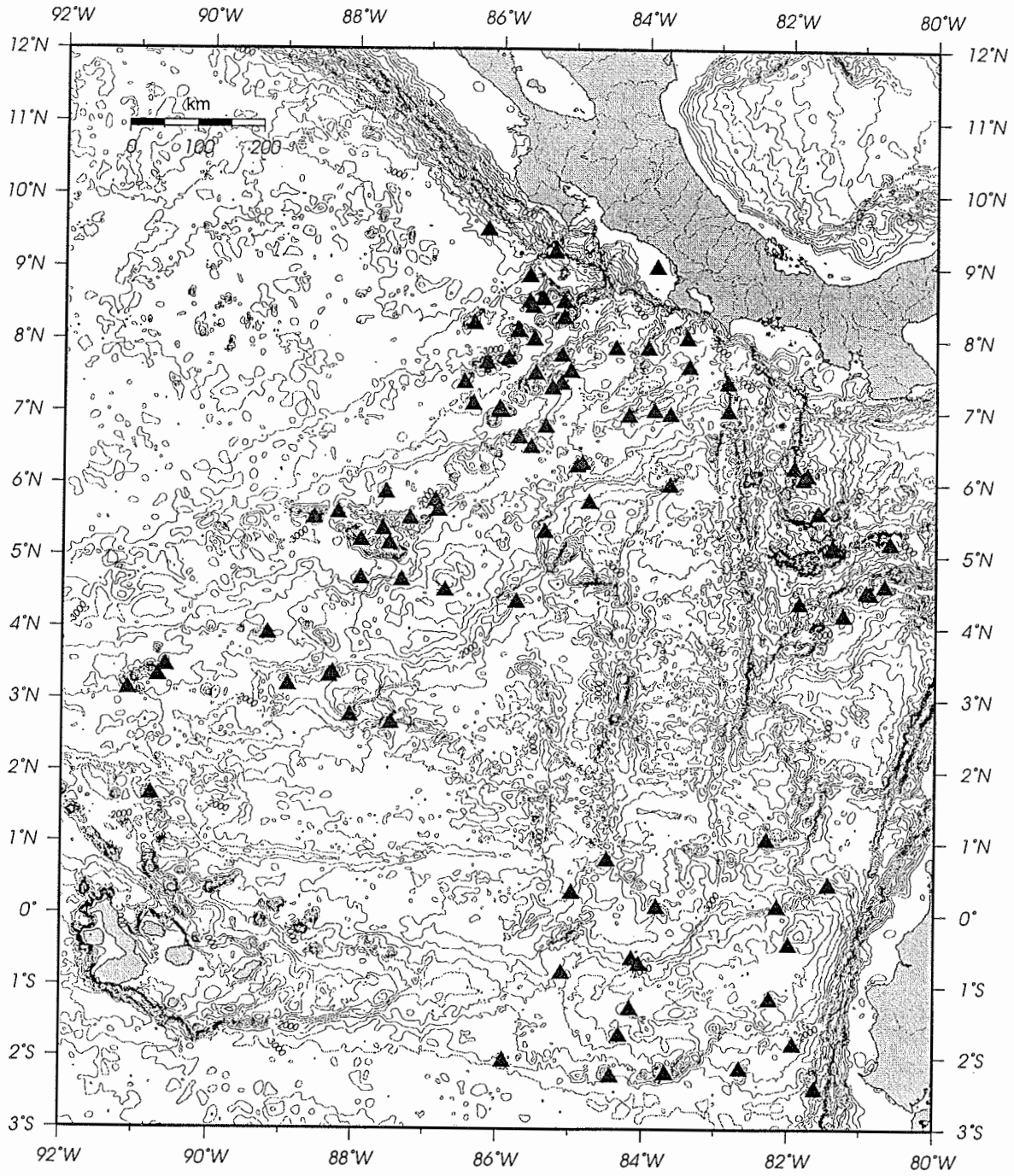

Fig. 1.2: Bathymetry of the Galápagos to Central-South America region (triangles are the SO 144-3a and -3b stations)

Hargraves, 1984; Richards et al., 1989; Alvarado et al., 1997; Sinton et al., 1997; Hauff et al., 1997; 2000). The relationship between hotspots and LIPs is controversial. LIPs are oceanic flood-basalt provinces, often >2000 km in diameter, that formed during relatively short intervals of intense volcanism (emplaced magma volumes >1,000,000 km^3). Although these events have occurred sporadically throughout history, they have had a major impact on the development of the Earth's mantle, crust, hydrosphere, atmosphere and biosphere.

An extensive high-quality geochemical data set exists for the recent Galápagos Archipelago (e.g., White et al., 1993; Graham et al., 1993). This has revealed a distinct chemical zonation across the archipelago (e.g., White and Hofmann, 1978; Geist et al., 1988; White et al., 1993; Graham et al., 1993), which cannot be explained by the classical plume models proposed for Hawaii (e.g., Chen and Frey, 1985; Clague, 1987; Clague and Dalrymple, 1987) or Iceland (e.g., Schilling, 1973). The Cocos and Carnegie Ridges, on the Cocos and Nazca Plates respectively, are considered by most authors to be the trail of the Galápagos hotspot or mantle plume, and to have formed by the interplay of the hotspot with the Galápagos spreading center (Fig. 1.1) during the Neogene (e.g., Hey, 1977; Lonsdale and Klitgord, 1978; Wilson and Hey, 1995).

The recent PACOMAR project (SO 107) has demonstrated that the morphology and unique geochemical signature of the Galápagos Archipelago is reflected in the oldest part of the Cocos Ridge and the associated seamounts off the coast of Costa Rica. For example, the composition and $^{40}Ar/^{39}Ar$ ages of this part of the Cocos Ridge and the seamounts are consistent with their formation above the Galápagos hotspot at 13.0–14.5 Ma (Werner et al., 1999; Hoernle et al., 2000). Therefore, our investigation of the aseismic ridges and seamounts between the Galápagos Archipelago and Central–South America is the missing link required to reconstruct the temporal, compositional and spatial evolution of the Galápagos hotspot and plume over the last 14.5 m.y.

The ***major volcanological and geochemical objectives*** of the PAGANINI project are to:

* Reconstruct the geochemical evolution of the Galápagos hotspot

  Geochemical methods (major and trace element analyses, determination of radiogenic isotope ratios) will be used to establish whether magma sources and petrogenetic processes have changed in the time interval between the formation of the various aseismic ridges and seamounts and the Galápagos Archipelago. Detailed studies of the temporal-geochemical evolution and the spatial arrangement of volcanoes (see below) formed above a hotspot are fundamental requirements for testing plume models (e.g., Hoernle et al., 2000).

* Reconstruct the volcanological-geological evolution of the Galápagos Archipelago

Volcanological and morphological methods, as well as the degree of degassing of the lavas (indicated by the volatile content [e.g., SO_2] of volcanic glass), will be used to characterize the spatial arrangement and paleoenvironment (deep water, shallow water or subaerial) of the volcanoes along the aseismic ridges. Combined with the geochemical, geophysical and radiometric age results, this should allow us to reconstruct whether and how the morphology of the volcanic structures built by the Galápagos hotspot has changed since the mid-Miocene, and also if the Paleo-Galápagos Archipelago (e.g., Christie et al., 1992; Werner et al., 1999) has been a permanent feature since 14.5 Ma. Reconstructing the spatial evolution of the Galápagos Archipelago also has important implications for plume models, since the formation of volcanic islands over the Galápagos hotspot is dependent on the magma supply.

* Establish the origin of the aseismic ridges and associated seamounts

  Trace element and isotope analyses of lavas from the aseismic ridges and seamounts will be used to characterize their sources (e.g., are they ocean island basalt [OIB], mid-ocean ridge basalt [MORB], or do they result from plume–ridge interaction) and to reconstruct the origin of these structures (e.g., Galápagos hotspot, Galápagos spreading center). This information is crucial in order to: (1) reach the objectives mentioned above, (2) reconstruct plate tectonic processes, and (3) evaluate the extent to which plume–ridge interaction influences the petrogenetic evolution of volcanic structures along the ridges. Several authors (e.g., Morgan, 1978; Geist et al., 1988; White et al., 1993; Ito and Lin, 1995) have proposed that plume–ridge interaction is an important process in the petrogenesis of Galápagos lavas.

* Establish the mass balance of the Central America subduction system

  An attempt will be made to quantify the amount of material subducting beneath Central and South America using geochemical methods (major-, trace element-, volatile- and isotope analyses).

* Verify a new model for the origin of Cocos Ridge (Meschede et al., 1997; 1998)

  An additional question concerns the origin of the Cocos Ridge. Is it part of the Galápagos hotspot trail (Morgan, 1971; Holden and Dietz, 1972; Heath and von Andel, 1973; Hey, 1977; Hey et al., 1977; Lonsdale and Klitgord, 1978)? Or was it formed by a separate "Cocos Island plume", as recently proposed (Meschede et al., 1997; 1998)?

The ***major geochronological objectives*** of the PAGANINI project are to:

* Reconstruct the absolute motion of the Nazca and Cocos Plates during the last 25

m.y. by measuring the age of volcanism along the Carnegie and Cocos Ridges (respectively).

* Determine the age of Coiba and Malpelo Ridges, and thus whether they were generated by the Galápagos hotspot.
* Reconstruct the changing spatial relationship between the Galápagos hotspot and the Galápagos spreading center. In combination with the geophysical and geochemical studies, this will improve the understanding of plume–ridge interaction on the style, distribution and composition of hotspot volcanism.
* Measure the rate at which the Carnegie and Cocos Ridges were generated, and thus to estimate the magma flux of the Galápagos plume for the last 25 m.y.
* Combine the migration rates of volcanism along the Carnegie and Cocos Ridges with those already determined for the Foundation (SO 100), Easter (SO 80) and Juan Fernandez (SO 101) volcanic chains, in order to develop a high-resolution integrated reconstruction of Nazca, Cocos and Pacific Plate absolute motions for the last 25 m.y.
* Test whether changes in the subduction rate of Galápagos plume-influenced lithosphere correlate with variations in earthquake and/or volcanic activity on the continental margin of Central–South America during the last 25 m.y.

2. CRUISE NARRATIVE

The SO 144-3a Shipboard Scientific Party embarked upon the RV *Sonne* at noon on 8 November. A press conference organised by the German Ambassador in San José and Gerhard Bohrmann was held onboard the RV *Sonne* in Puerto Caldera at 3:00 pm local time. All scientists participating in SO 144-3a were present, and answered questions from approximately 80 journalists. There was extensive coverage of the PAGANINI project by the press, radio and television news throughout Costa Rica. The RV *Sonne* moved to anchorage at 8:30 am on 9 November, and departed Puerto Caldera at 4:00 pm. The collection of HYDROSWEEP, PARASOUND and magnetic data began as soon as the ship left the 12 mile territorial limit of Costa Rica. Geological and biological seminars[1] were presented and the laboratories prepared for sample processing during the 2 day transit to the first target area (Malpelo Ridge).

During 11–12 November, dredge and TV-grab sampling was undertaken on an EW-trending profile across Malpelo Ridge and on two neighbouring seamounts (Figs 1.1, 2.1). Thereafter, a 200 mile-long NS-trending magnetic profile was recorded on transit from Malpelo to Carnegie Ridge. The aim of this magnetic survey was to identify a possible failed rift structure to the north of Carnegie Ridge. In addition, a successful dredge attempt was completed at the location of the rift.

The RV *Sonne* arrived at Carnegie Ridge on 14 November. The following 6.5 days were mainly devoted to dredge and TV-grab sampling combined with mapping on one EW- and three NS-trending profiles across Carnegie Ridge (Figs 1.1, 2.2). In contrast to other areas sampled during SO 144-3, both dredge and TV-grab sampling of Carnegie Ridge proved particularly difficult (see Chapter 4.3). Nevertheless, the EW- and two of the NS-trending profiles were successfully completed.

On 20 November RV *Sonne* left Carnegie Ridge and headed for the SW-end of Cocos Ridge, where the vessel arrived on 21 November at noon. The following 10 days were devoted to intensive dredge and TV-grab operations, mostly along several NW-trending profiles across Cocos Ridge (Figs 1.1, 2.3, 2.4). In addition, one station was dredged to the south of Cocos Ridge to obtain reference samples from the ocean crust.

The last station of SO 144-3a was completed near the NE-end of Cocos Ridge on 1 December. Sufficient time remained for two hydroacoustic profiles, which filled-in some small gaps in the bathymetric coverage by the RV *Sonne* of the Pacific coast of Costa Rica. These profiles were finished by late evening, after which the RV *Sonne*

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[1] John O'Connor: Overview of PAGANINI 3 Cruise Objectives
Birger Neuhaus: Deep Sea Biota I
Peter Götz: Deep Sea Biota II
Irmgard Schaffer: Bathymetric Maps Based on the TOPEX Data Set

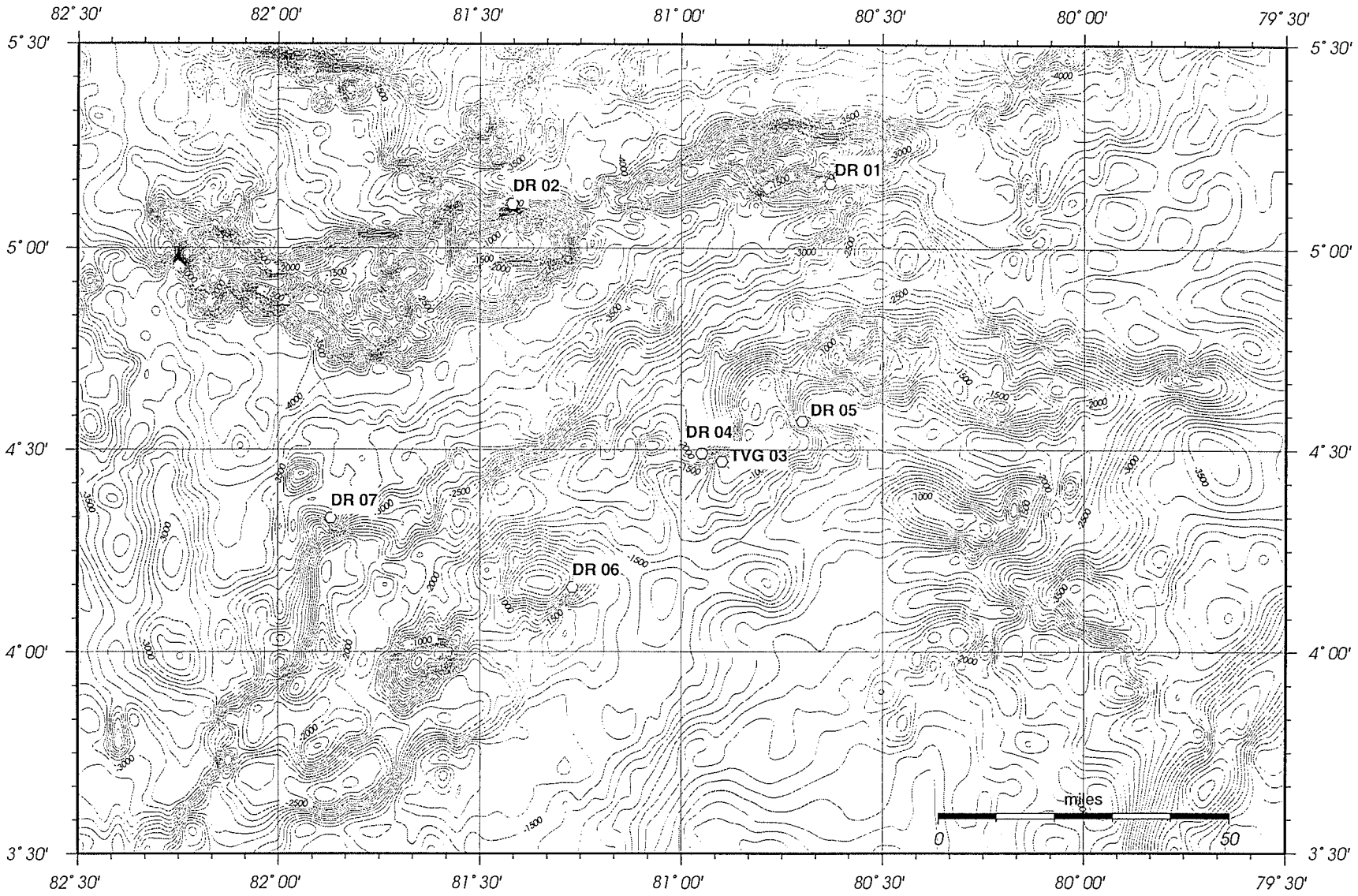


Fig. 2.1: Stations on Malpelo Ridge and nearby seamounts

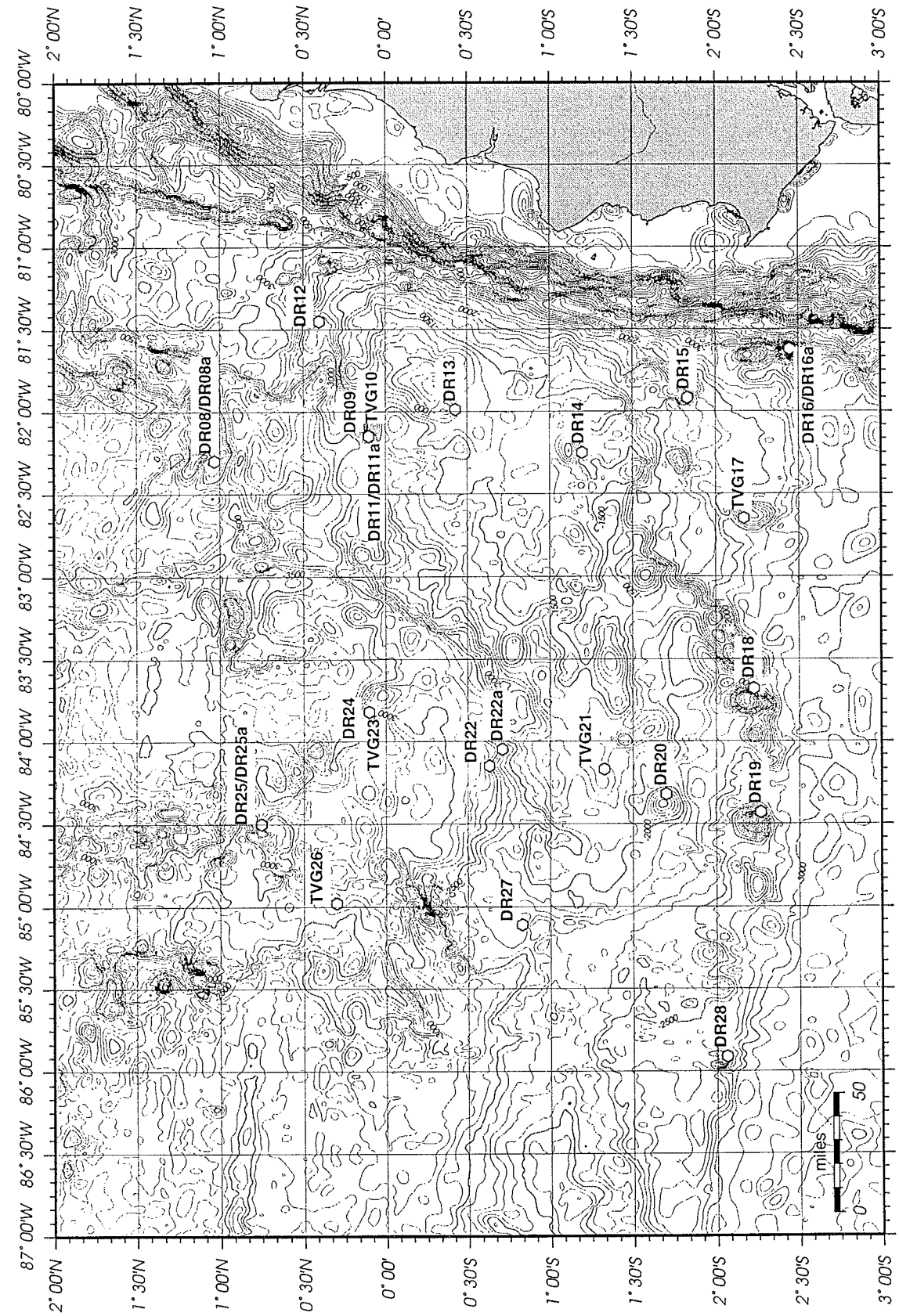


Fig. 2.2: Stations on Carnegie Ridge and nearby seamounts

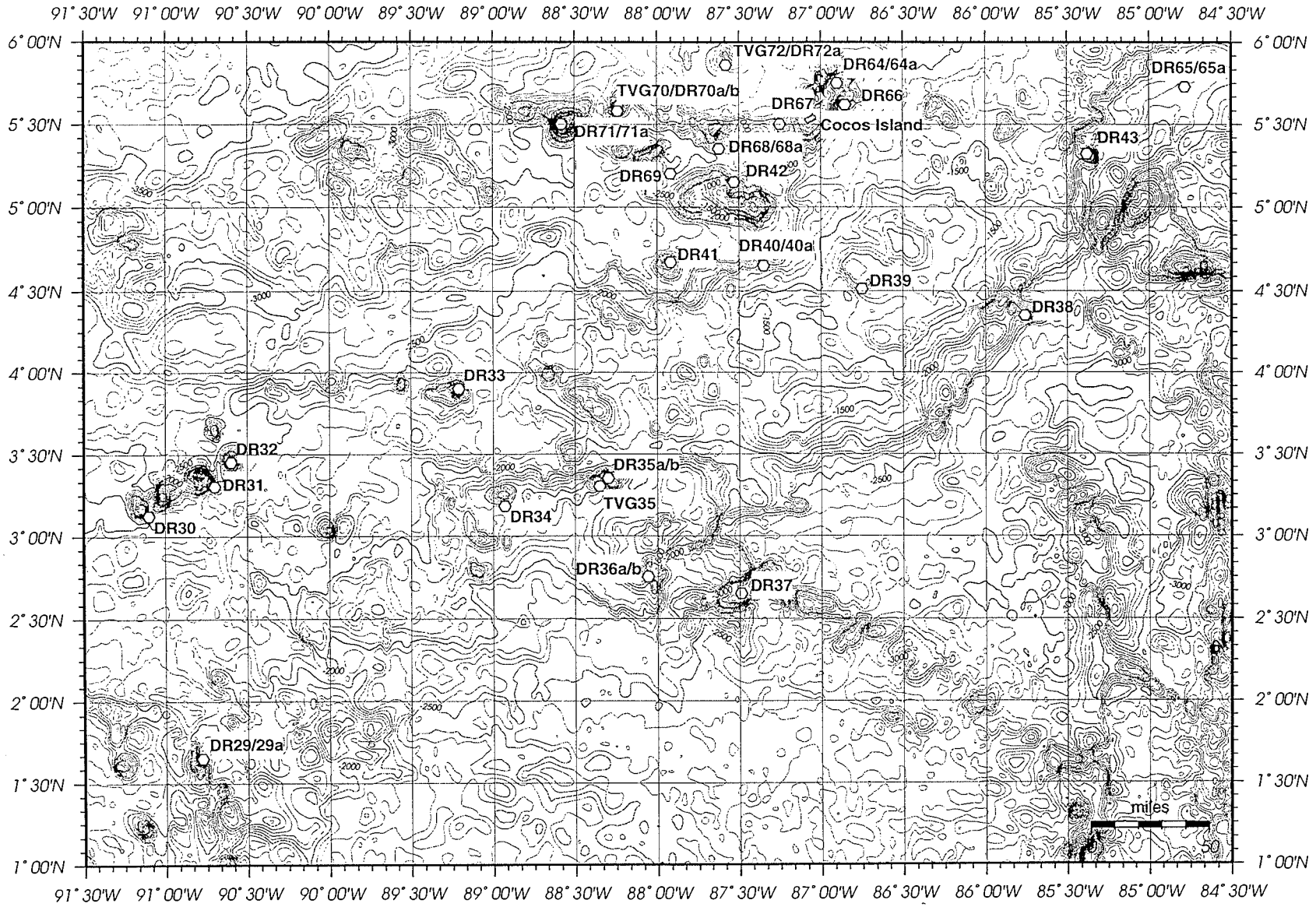


Fig. 2.3: Stations on southern Cocos Ridge and nearby seamounts

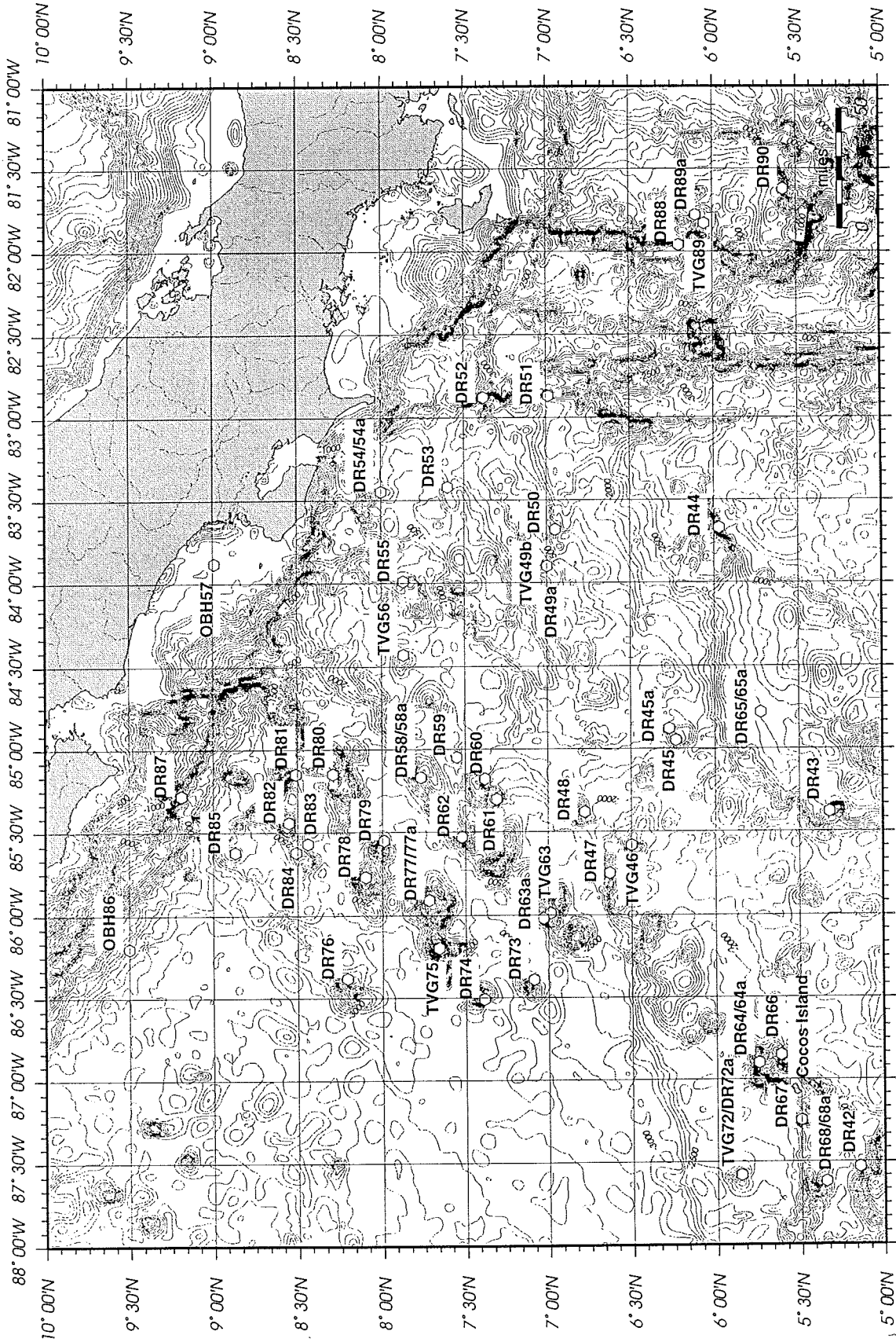


Fig. 2.4: Stations on northern Cocos Ridge and nearby seamounts

headed for Puerto Caldera and docked there on the morning of 2 December.

A TV-team and two newspaper journalists again boarded the vessel in Puerto Caldera on 2 December to obtain information about the cruise progress, in response to the widespread interest arising from the earlier press conference of 8 November. Six scientists left the ship and 13 scientists were welcomed aboard (5 of them geophysicists from the Scripps Institution of Oceanography). The RV *Sonne* left Puerta Caldera at 8:00 am on 3 December and headed NW to an area offshore from the Osa Peninsula. After a short transit, the 14 OBS and 7 fluxmeters were recovered by the geophysicists from Scripps. Intensive dredge and TV-grab sampling and mapping then resumed at a seamount chain on the northwest flank of Cocos Ridge on 5 December (Figs 1.1, 2.4).

The RV *Sonne* arrived at Cocos Island on 7 December. It was possible for the crew and scientists to spend a brief time ashore (4 hours). A group of 3 scientists remained on the island for 30 hours and, with the support of the local National Park Rangers, were able to collect samples from several different stratigraphic units. A representative from the German Embassy in San José (Costa Rica) also remained on the island for 30 hours, and investigated the construction of a small solar-powered electricity station financed by German foreign aid. During this time, the ship proceeded to dredge and map the submarine platform surrounding Cocos Island (Figs 1.1, 2.3).

The RV *Sonne* departed from Cocos Island at mid-afternoon on 8 December. Dredge and TV-grab sampling and mapping continued at a group of seamounts west of Cocos Island until 10 December (Figs 1.1, 2.3). After a half-day transit, further dredge and TV-grab sampling and mapping continued at a seamount chain immediately NW of Cocos Ridge, and also at the NE-end of Fisher Ridge (Figs 1.1, 2.4). An attempt to sample the SW part of Fisher Ridge failed because this structure, shown as a bathymetric high on available topographic maps, does not actually exist. An extensive HYDROSWEEP survey did not find any evidence of ridge structures or seamounts along the trend of Fisher Ridge in that area. Evidently, the ridge terminates as a bathymetric high immediately to the SW of the area where it is known to exist from previous HYDROSWEEP mapping by the RV *Sonne*.

While dredging and mapping operations continued, the geophysicists from Scripps downloaded the data stored on the OBS units, and serviced and prepared them for re-deployment. Furthermore, the crew of the RV *Sonne* were able to help repair equipment on a fishing boat from Costa Rica without any disruption to dredging operations on 12 December.

Dredging of the seamounts NW of Cocos Ridge was finished on 14 December. Afterwards, the 14 OBS units were re-deployed off the Nicoya Peninsula of Costa Rica. The vessel spent most of 15 December on a 26 hour transit to Coiba Ridge. Some small

gaps in bathymetric coverage by the RV *Sonne* of the Pacific coast of Costa Rica were filled-in during this transit, and one dredge station on the continental slope was sucessfully completed at a site where earlier seismic and bathymetric surveys had suggested outcropping basement rocks.

Coiba Ridge was reached on 16 December, and the RV *Sonne* investigated 5 different seamounts shown on available maps as major bathymetric highs rising from the ridge. HYDROSWEEP surveys demonstrate that none of these structures actually exist. Instead, the morphology of Coiba Ridge is very different to that of the other ridge structures in the survey area of SO 144-3. Nevertheless, dredge and TV-grab sampling was successful at 3 stations on the flanks of Coiba Ridge (Figs 1.1, 2.4).

The scientific work of SO 144-3 was completed by noon 17 December, and the RV *Sonne* then departed from Coiba Ridge for Balboa (Panamá). The vessel reached the "Explosives Anchorage" in front of Balboa at 8:00 am on 18 December, where bunkering activities commenced. A pilot was taken onboard the following morning, and the vessel proceeded into the Port of Balboa and berthed at 8:30 am local time.

In summary, 90 stations were visited during SO 144-3 (three did not involve dredging or TV-grabs). A total of 96 dredges and 15 TV-grabs were completed, 1225 rock samples were recovered, and numerous biological samples were collected in addition to the bathymetric, magnetic, and OBS work. No equipment was lost.

3. GEOPHYSICS

Irmgard Schaffer and Matthias Müller

3.1 HYDROSWEEP

Data Acquisition

The RV *Sonne* is equipped with the HYDROSWEEP multibeam system from STN ATLAS–ELEKTRONIK for continuous profiling. This system uses a frequency of 15.5 kHz and sends out 59 beams in a swath covering 90°. Thus, it can map the seafloor with a scanline width up to twice the water depth. The range of the central beam is up to 10 m with an error of 1 % and the range of the outer beams is up to 7 m with a precision of ~1 %, if the roll of the vessel is less than 10° and the pitch less than 5°. Corrections for roll, pitch and heave are applied automatically. Due to the fixed angle between the beams, the resolution is dependent upon the water depth and is about 170–200 m at depths of 5000–6000 m.

Data Processing

HYDROSWEEP data were recorded on magnetic tape and processed onboard with the academic software MB-system developed by Caress and Chayes (1996) at the Lamont–Doherty Earth Observatory. Calculating depths from echo time delay requires knowledge of the sound velocity in the different water layers of the ocean. Therefore, HYDROSWEEP uses a second set of transducers and a calibration scheme with soundings along track (Schreiber and Schencke, 1990). However, in certain areas (e.g., slope areas) this algorithm fails and direct measurement of the sound velocity using a CTD is preferred. During SO 144-3a, a watersound velocity profile from earlier cruises off Costa Rica was used. Post-processing of the sweeps (including all 59 beams) consists of merging the navigational data, calculation of the depths and positions of the beams, removal of artefacts, and editing of individual beams to eliminate erratic data points. A pre-cleaning program was used to tidy up the raw HYDROSWEEP data files and remove lines with lengths of less than, or equal to, 12 data points. Edited sweeps were then assembled, gridded and contoured with GMT software (Wessel and Smith, 1995). No filters were applied to smooth the data, and thus small tectonic features (but also more noise) are clearly visible on the maps.

First results

Multibeam bathymetry was recorded continuously during SO 144-3 whenever the vessel was outside the 12 mile territorial zone of Costa Rica (Figs 3.1.1, 3.1.2). A total

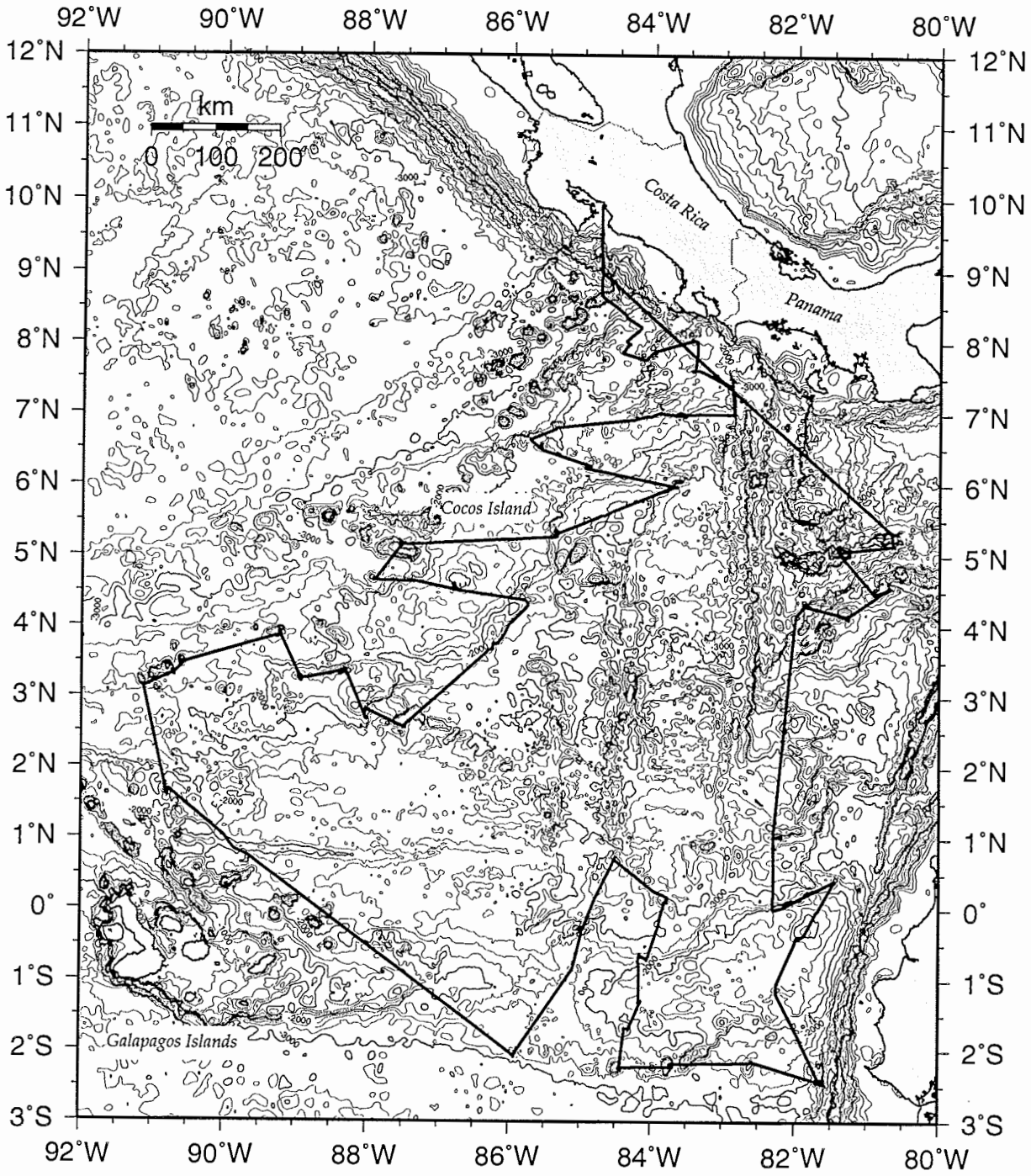


Fig. 3.1.1: HYDROSWEEP tracks of SO 144-3a

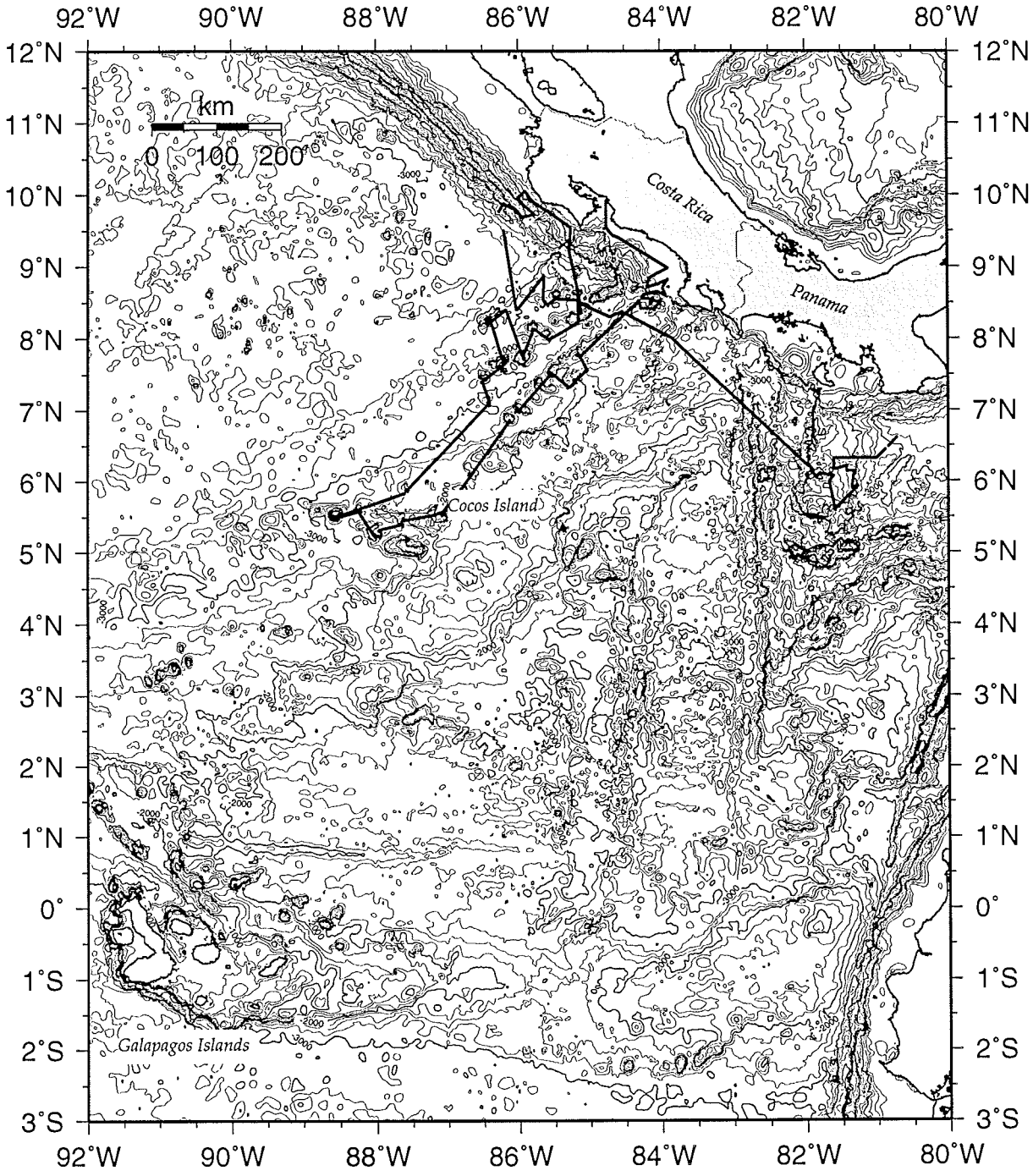


Fig. 3.1.2: HYDROSWEEP tracks of SO 144-3b

of 16,720 line-km was recorded during 75 profiles, and a list of all profiles with start and end points is given in Appendix 1. HYDROSWEEP mapping was used onboard to obtain the correct depth for dredging purposes and for the correlation of magnetic anomalies with depth.

HYDROSWEEP is normally used for detailed mapping of potential dredge stations before final site selection. However, this was not possible on SO 144-3 because of the number of stations and limited time. Instead, dredge sites were selected from the TOPEX bathymetry published by Smith and Sandwell (1997) and confirmed by a short HYDROSWEEP survey. The TOPEX data set was originally calculated from satellite altimetry and improved in some places with echo-sounding data. The basic resolution is 2 min or 2 nautical miles (3700 m) at the equator, and increases to 1 min or 1 nautical mile at a latitude of 70°. Figures 3.1.3–3.1.5 provide a comparison of the processed HYDROSWEEP bathymetry (upper) with the "predicted" bathymetry after Smith and Sandwell (lower). In Figure 3.1.4, the upper picture diplays a single HYDROSWEEP track and the TOPEX data are also plotted in the same clipped window; a difference in depth of >1000 m occurred in this case. However, the TOPEX maps generally correlate closely with the HYDROSWEEP maps for Carnegie, Malpelo, and parts of Cocos Ridge. Unfortunately, this was not always the case. Time-consuming efforts were necessary on Coiba Ridge to locate features, and sometimes even to find major ridges (e.g., the predicted extension of Fisher Ridge to the SW at 8°30'N and 86°W; Fig. 3.1.5).

Most of the area from the edge of the Costa Rica continental shelf to the Central America Trench and outwards to a distance of 50–90 km across the subducting oceanic plate was mapped during earlier cruises (SO 76, 81, 107, 144-1 and -2). However, a few special HYDROSWEEP profiles were recorded to fill gaps in the existing database and complete the map.

3.2 PARASOUND

Data Acquisition

The RV *Sonne* can also image shallow sediment structures up to 100 m thick using the PARASOUND system from ATLAS ELEKTRONIK (PARAmetric sediment survey echoSOUNDer). This system uses a parametric signal generated by the superposition of two slightly-offset high frequencies. In consequence, deeper penetration and higher resolution can be achieved relative to that of ordinary echo sounders. One signal is generated with a fixed frequency of 18 kHz whereas the other

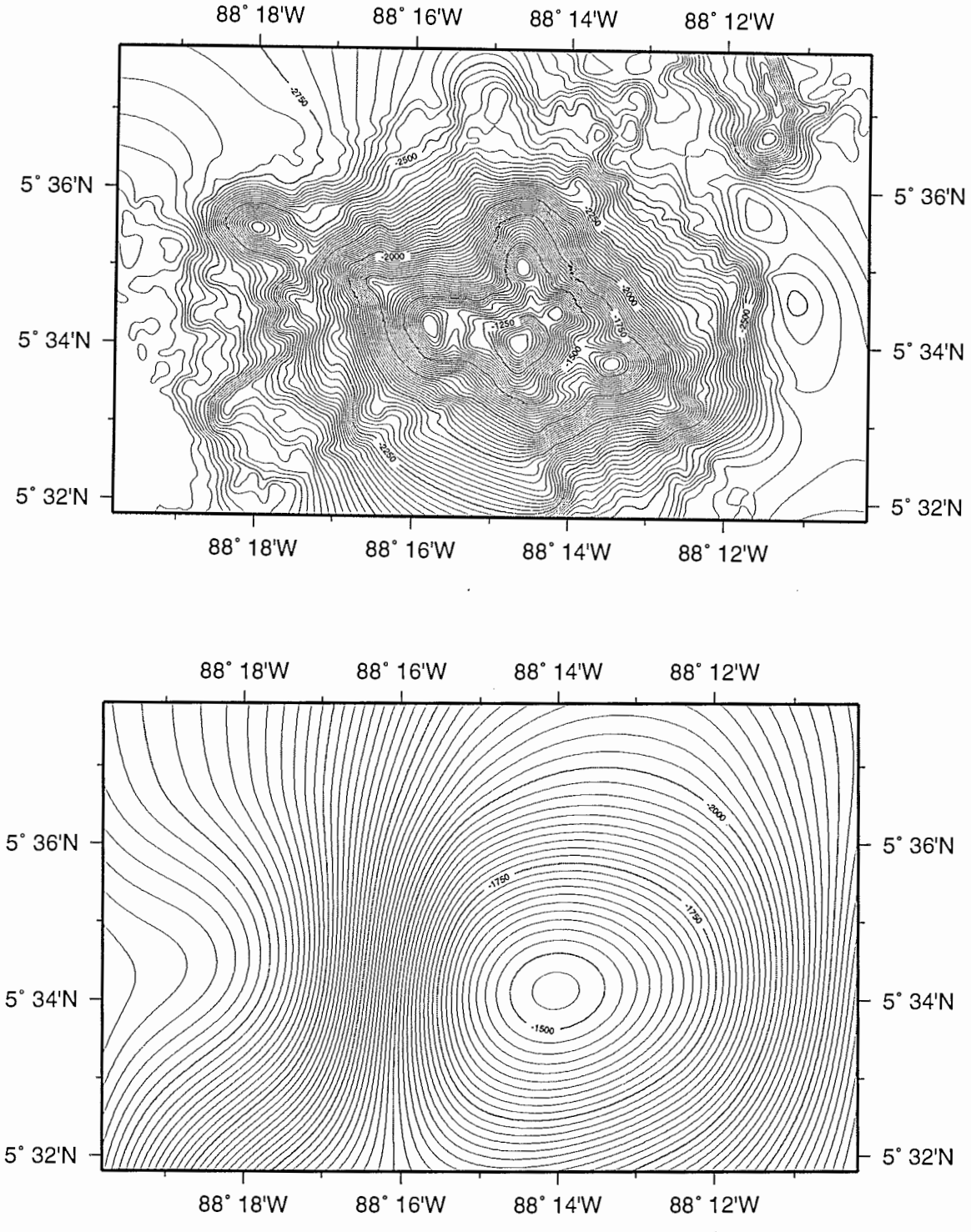


Fig. 3.1.3: Comparison of HYDROSWEEP (upper image) and TOPEX (lower image) data- similarity

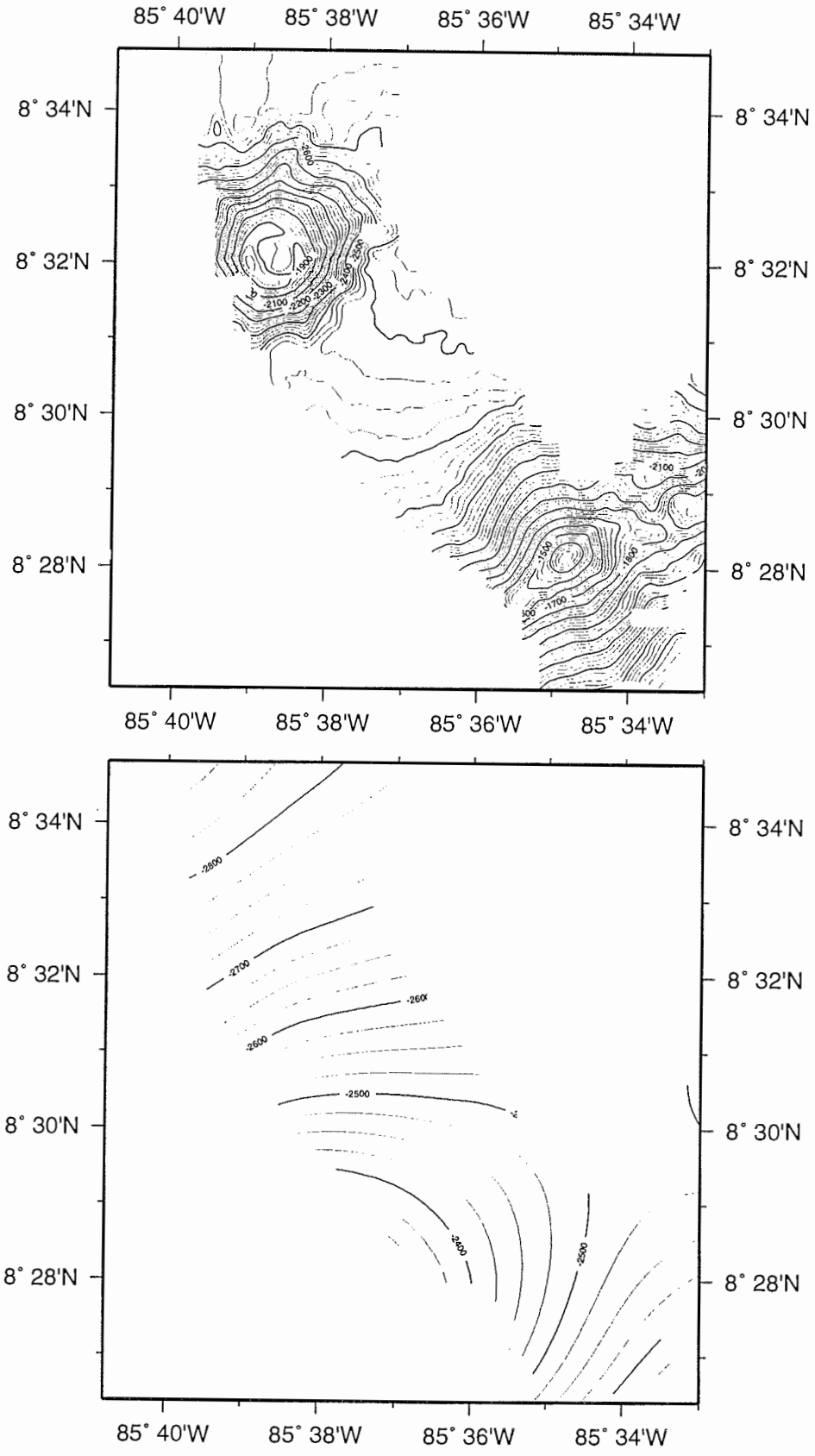


Fig. 3.1.4: Comparison of HYDROSWEEP (upper image) and TOPEX (lower image) data- disagreement (note height difference of 1000 m)

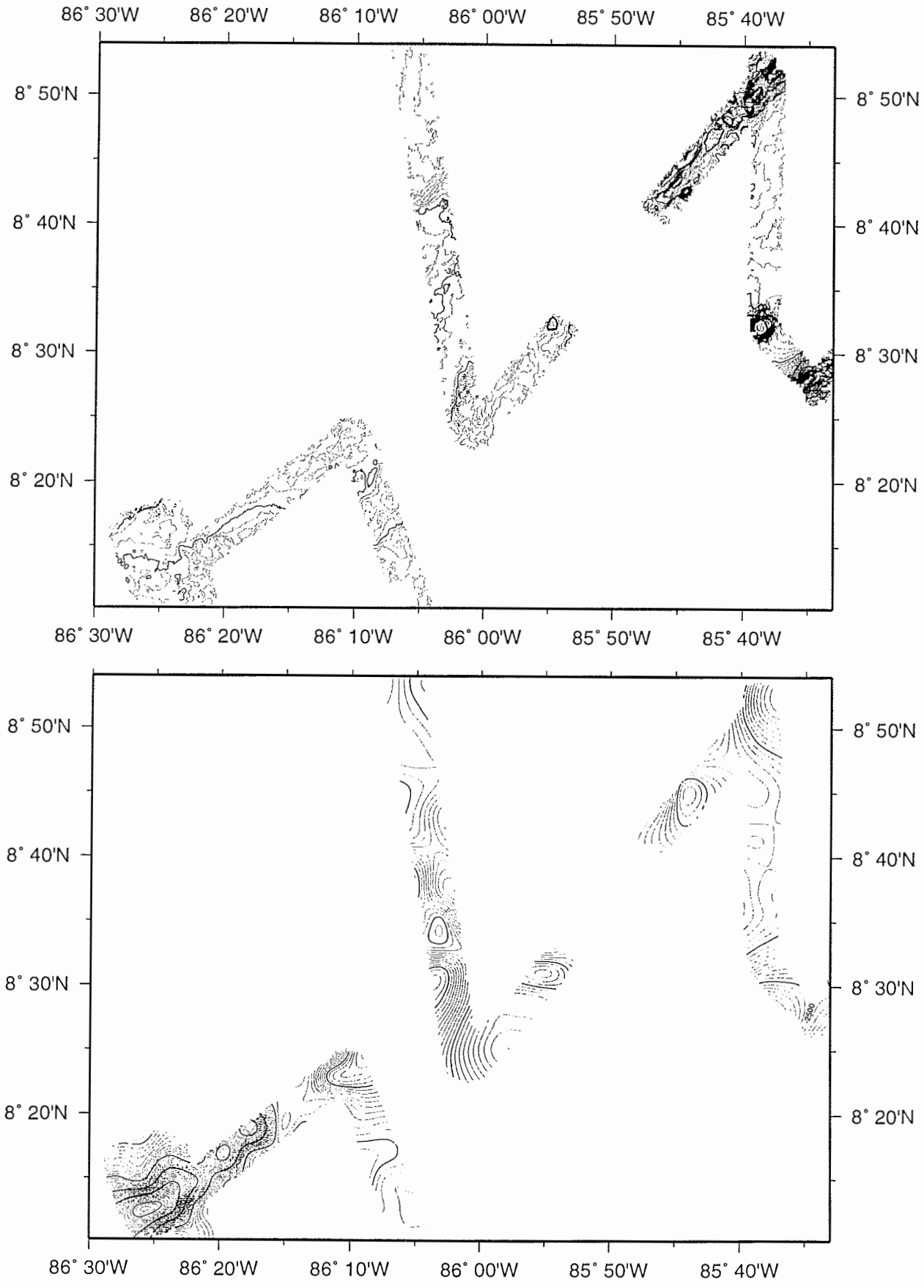


Fig. 3.1.5: HYDROSWEEP (upper image) and TOPEX (lower image) data for SW Fisher Ridge

can be set to values between 20.5–23.5 kHz, thus yielding a parametric signal of 2.5–5.5 kHz. The beam angle is ~4°, which gives a swath width nearly 7 % of the water depth. The data quality depends to a large extent on the morphology of the seafloor because of the narrow beam width. No echoes will be received if the seafloor slopes at >2°, and so the application of PARASOUND is restricted to relatively flat areas.

Data Processing

Raw analogue data was printed in color as it was collected. The PARADIGMA program (Spieß, 1993) stores the data digitally on hard disk in a special SEG-Y format for further processing at the University of Bremen (similar processing to seismic data).

First Results

PARASOUND data was collected during nearly all HYDROSWEEP and magnetic profiles, and a list of all profiles is provided in Appendix 1. A penetration of up to 100 m into the uppermost sedimentary layers was achieved in flat areas. The recorded profiles display a wide variety of different reflectors, ranging from weak reflections in the accretionary prism sediments to strong reflections from the oceanic crust. PARASOUND data was used as online help for estimating the sediment thickness and selecting dredge positions, but no further interpretation was attempted onboard.

3.3 MAGNETICS

Data Acquisition

A GeoMetrics G801/3 Marine Proton Magnetometer was used for magnetic data acquisition during SO 144-3. It consists of a gasoline-filled sensor with a 200 m-long marine cable, and a control unit. The sensor was towed to the port side of the vessel, ~150 m behind the ship. The total intensity magnetic field was measured every 3 seconds, and was stored together with UTC time in ASCII tables. In total, 7750 line-km of magnetic data were obtained from 72 continuous profiles. These profiles were generally collected while the ship was in transit between dredge stations; thus, most start and end on the upper flanks of dredged seamounts. Measurements were completed on every transit lasting more than 1.5 hours (ship velocity ~11 knots) in order to model the long wavelength variation of the magnetic anomalies in the area (5 to 20 km). One special magnetic north-south profile (profiles 6, 7) was also recorded. A list of all profiles with starting and end points is given in Appendix 1. Figure 3.3.1 shows all ship tracks on which magnetic data were recorded during SO 144-3.

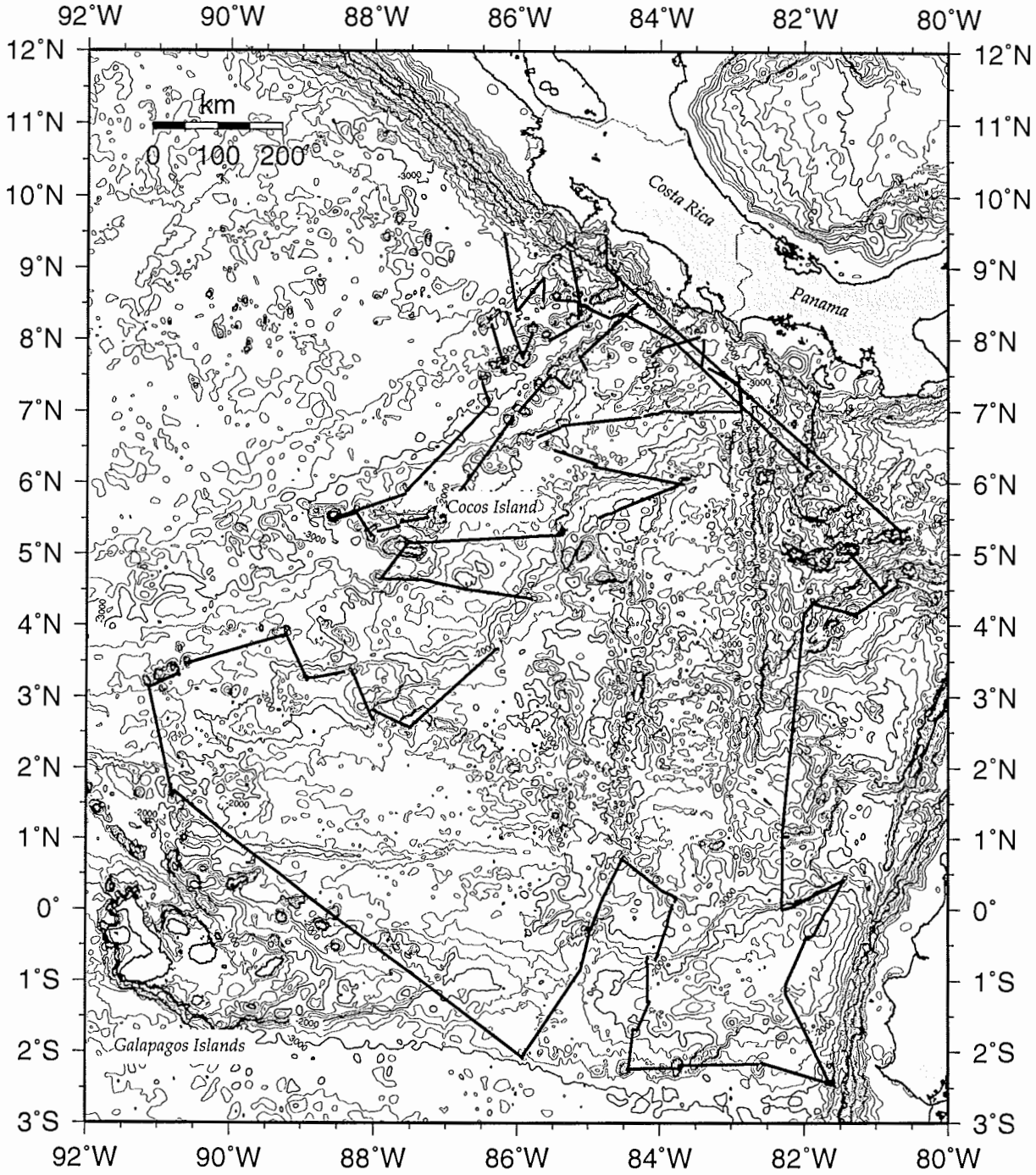


Fig. 3.3.1: Magnetic profiles of SO 144-3

Data Processing

Quality control, preliminary data processing and presentation were done onboard. After data backup, the raw ASCII files were transfered to a SUN workstation and the data merged with the ship's differential GPS navigation (on the basis of recording time). Processing consisted of filtering, re-sampling on a 10 second interval, and smoothing (achieved using a median filter of 120 samples). The data were also corrected by subtraction of the Earth's magnetic field (the International Geomagnetic Reference Field: IGRF). However, the data are still to be corrected for diurnal variations. For this, a magnetic observatory in southern Costa Rica will provide the land-based correction values. Data were displayed using GMT plot routines (Wessel and Smith, 1995).

First Results

The data quality is generally excellent. There is very little high frequency noise, and it is far less than the magnetic signal from the surveyed structures. The total magnetic intensity field ranges from 29,000–35,000 nT and increases to the north. Seamount magnetic anomalies of up to 400 nT stand out clearly against this background. Nevertheless, the data may still contain longer wavelength disturbances due to the interaction between the Earth's inner magnetic field and ionospheric fields.

A few profiles are displayed in Figures 3.3.2–3.3.5. These plots show: (a) the measured filtered data, (b) the calculated IGRF, (c) the anomalies obtained after subtraction of the IGRF, (d) the HYDROSWEEP water depth along the tracks, and (e) the track of each profile overlain with the "predicted bathymetry" dataset from Smith and Sandwell (1997). Profile 6 is part of a special magnetic survey intended to clarify uncertainty about the evolution of the Cocos–Nazca spreading centre. Anomalies that can be attributed to seafloor spreading are seen on this profile (e.g., between 1°30'N and 2°30'N. Figure 3.3.3 is a typical profile measured between dredge stations on Malpelo Ridge. There, the anomalies correlate with seafloor topography and reflect the geometry and composition of the seamounts. Profile 27 (Fig. 3.3.4) and Profile 37 (Fig. 3.3.5) were obtained on East–West traverses across Cocos Ridge, and show changes in polarisation that seem to arise from the specific remnant magnetisation of the oceanic crust. Thus, after further processing it should be possible to identify specific anomalies and to compare the data with the synthetic line calculated for the geomagnetic polarity time scale (Cande and Kent, 1995).

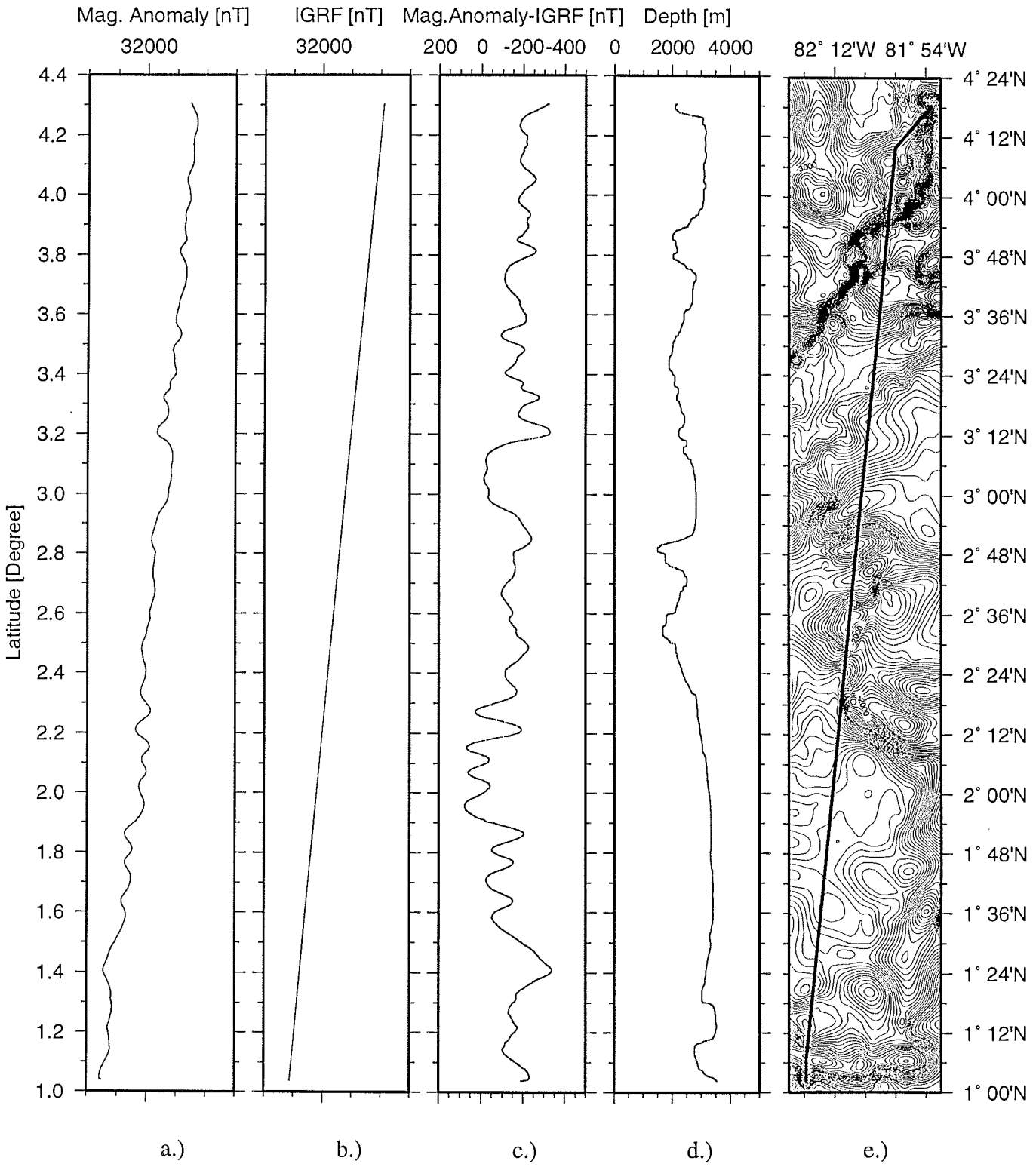


Fig. 3.3.2: Magnetic profile 6

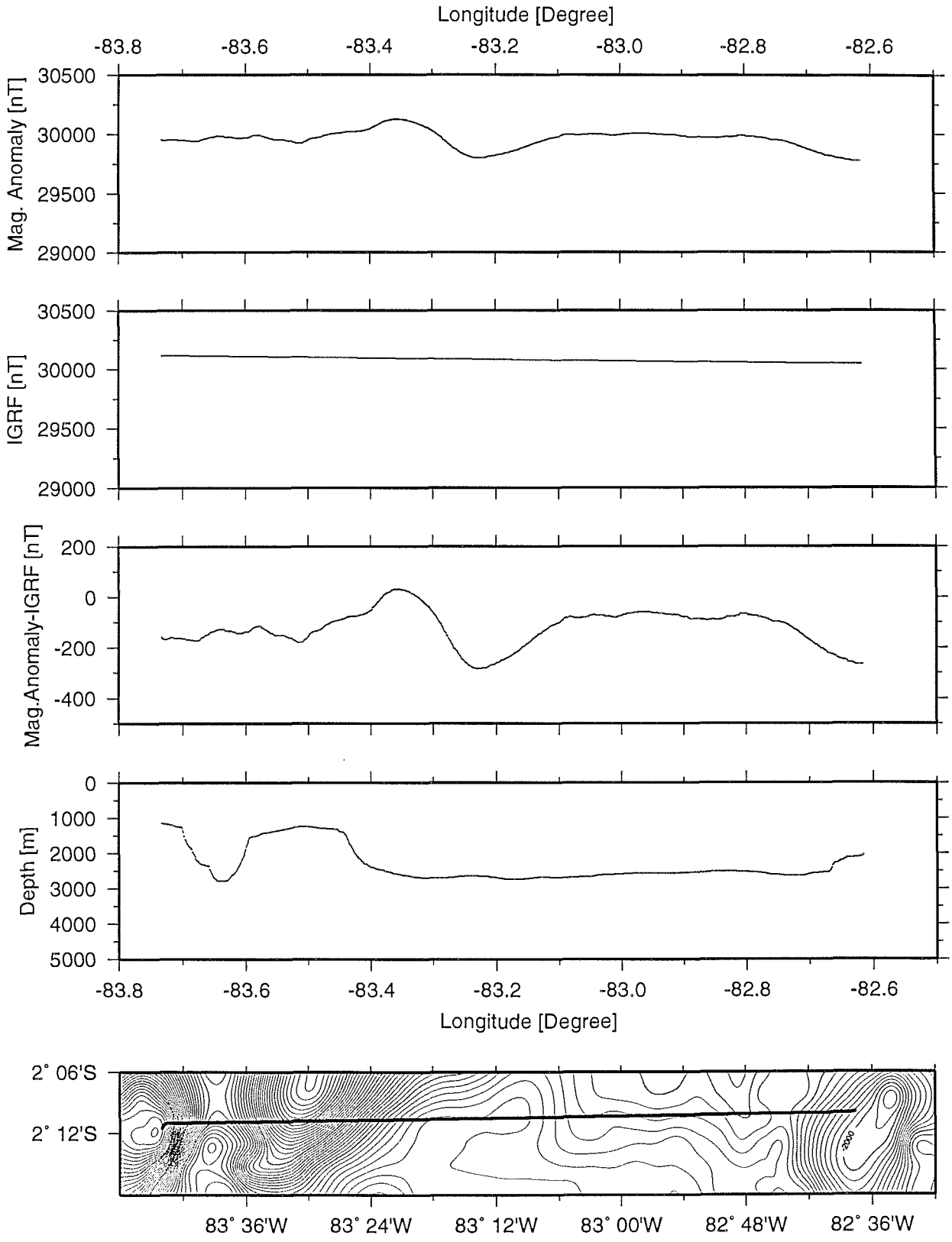


Fig. 3.3.3: Magnetic profile 14

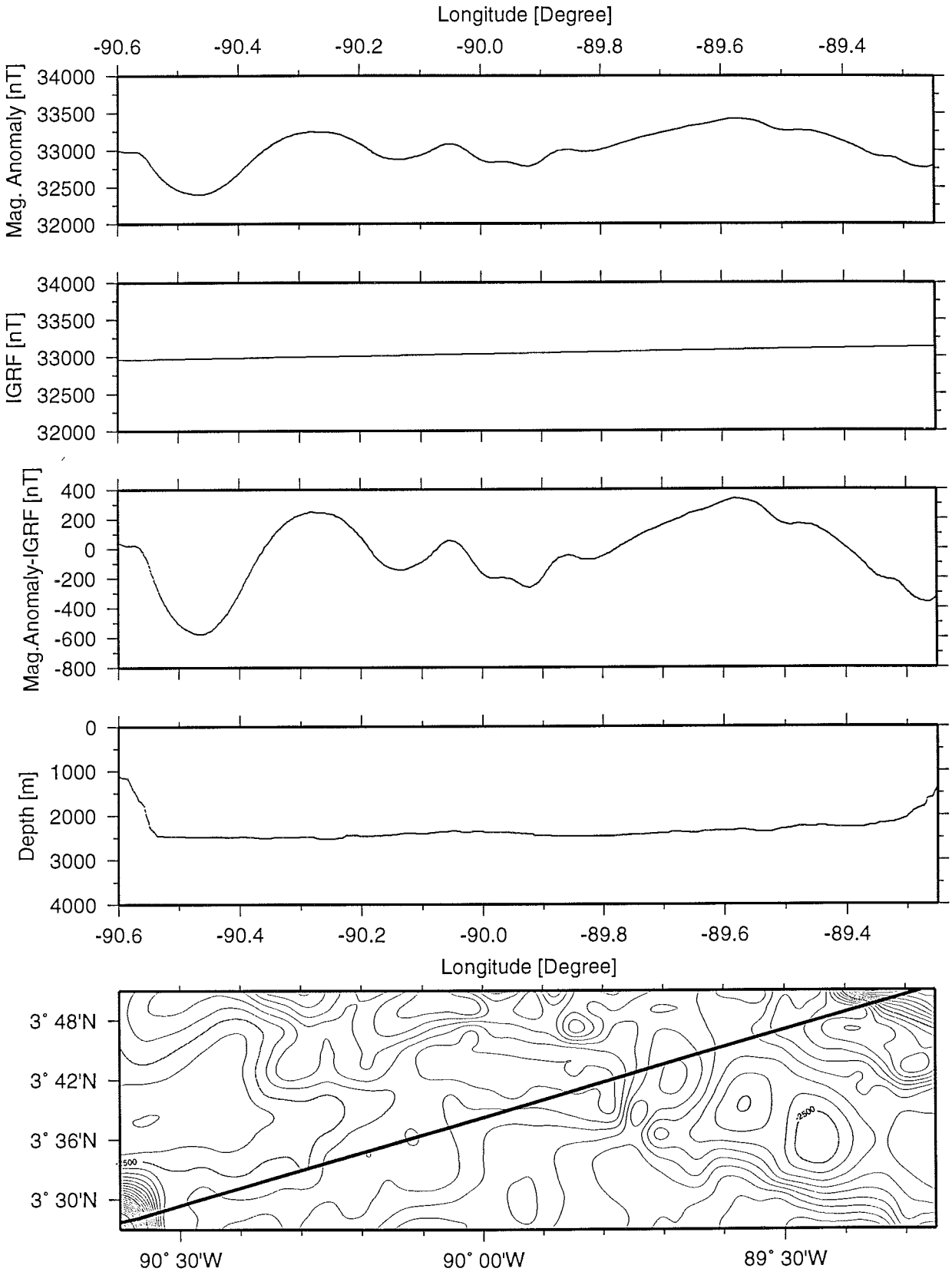


Fig. 3.3.4: Magnetic profile 27

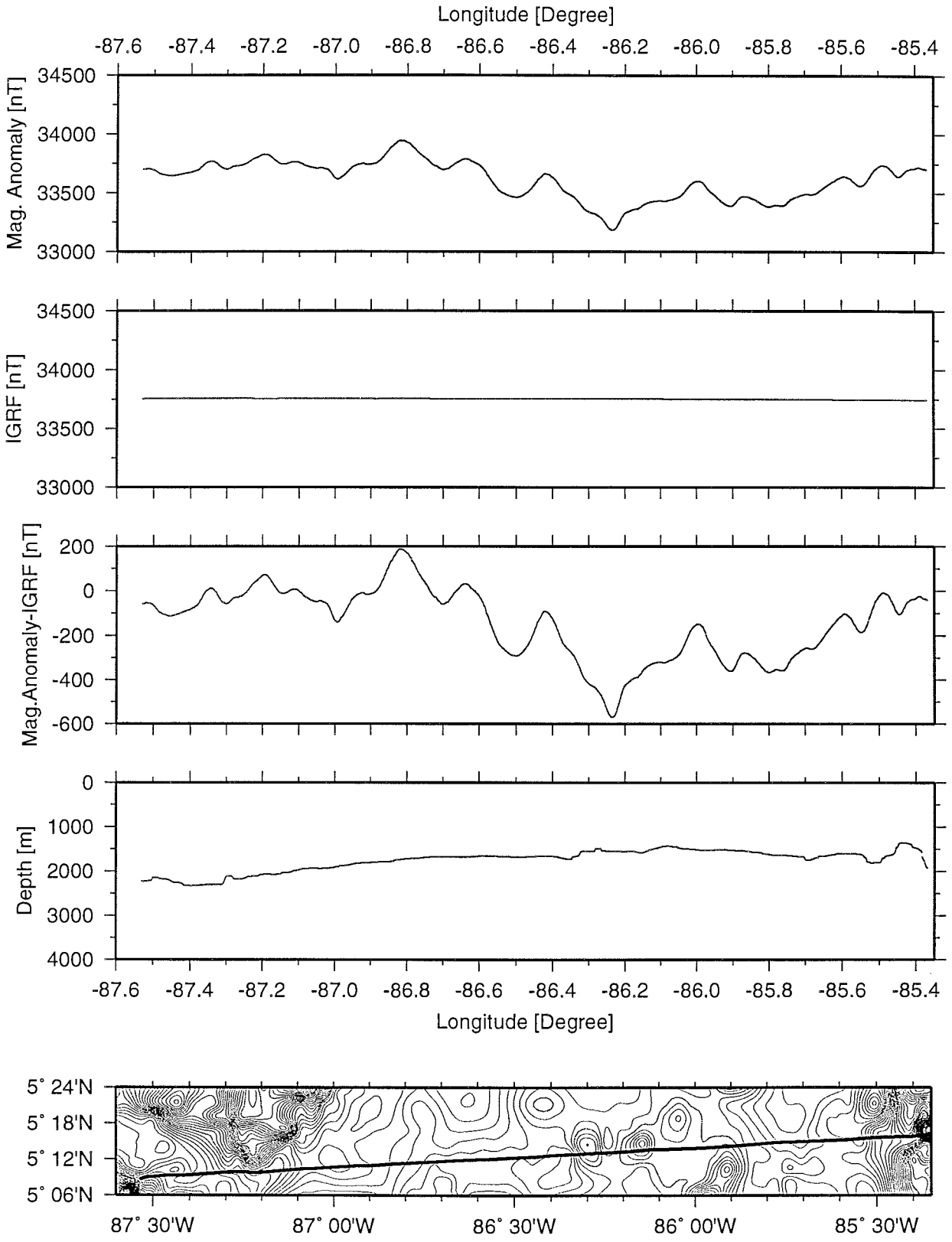


Fig. 3.3.5: Magnetic profile 37

4. ROCK SAMPLING AND THE COCOS ISLAND LANDING

Tim Worthington, Karen Harpp, Guillermo Alvarado, Reinhard Werner, Jens Grigel

4.1 INTRODUCTION

Selection of Dredge and TV-Grab Sites

Systematic rock sampling of the ridges and seamounts was completed on profiles across and along the axis of the ridges and seamount chains wherever possible (Fig. 1.1). Profile and station selection was mostly based on the TOPEX database (see Chapter 3). In general, the TOPEX maps generated by the GEOMAR geophysicists accurately displayed the bathymetry, and were crucial for the rapid selection of dredge and TV-grab stations. However, problems were encountered with the TOPEX database over some parts of Cocos Ridge, and especially Coiba and Fisher Ridges (Chapters 2 and 3.1). Final positioning of the ship over the dredge or TV-grab station was done using HYDROSWEEP data and allowing for weather and drift conditions.

Dredge tracks were usually located on the steep slopes of ridge flanks (Fig. 4.1.1) or on the slopes of seamounts (Fig. 4.1.2–4.1.4). This was to avoid areas of thick sediment cover. It was found that the most promising dredge sites were frequently located on the upper part of the slope, where the dredge could be dragged over the edge of a plateau or the top of a seamount (e.g., Figs 4.1.1, 4.1.2, 4.1.4). TV-grab stations were located on flat-topped seamounts or plateaux (Figs 4.1.4, 4.1.5), which were frequently covered with *in situ* (pillow) lavas and lava fragments. At some sites of particular importance, the TV-grab was also used to do a site survey before dredging.

Shipboard Procedure

A total of 1225 rock samples from 87 dredge/TV-grab stations and Cocos Island were recovered during SO 144-3 (Table 4.1, Appendices 2 and 3). Once onboard, most rocks were cleaned in water and cut using a rock saw. They were then examined with a hand lens, and grouped according to their mineral content and degree of marine weathering. The immediate aim was to determine whether material suitable for geochemistry and $^{40}Ar/^{39}Ar$ radiometric dating had been recovered. Suitable samples have an unweathered and unaltered groundmass, empty vesicles, glassy rims (ideally), and any phenocrysts are fresh. If suitable samples were present, the ship moved to the next station. If they were not, then the importance of obtaining samples from the station was weighed against the available time. A second dredge nearby and on the same station was often possible.

Fresh blocks of representative samples were then cut for thin section and microprobe

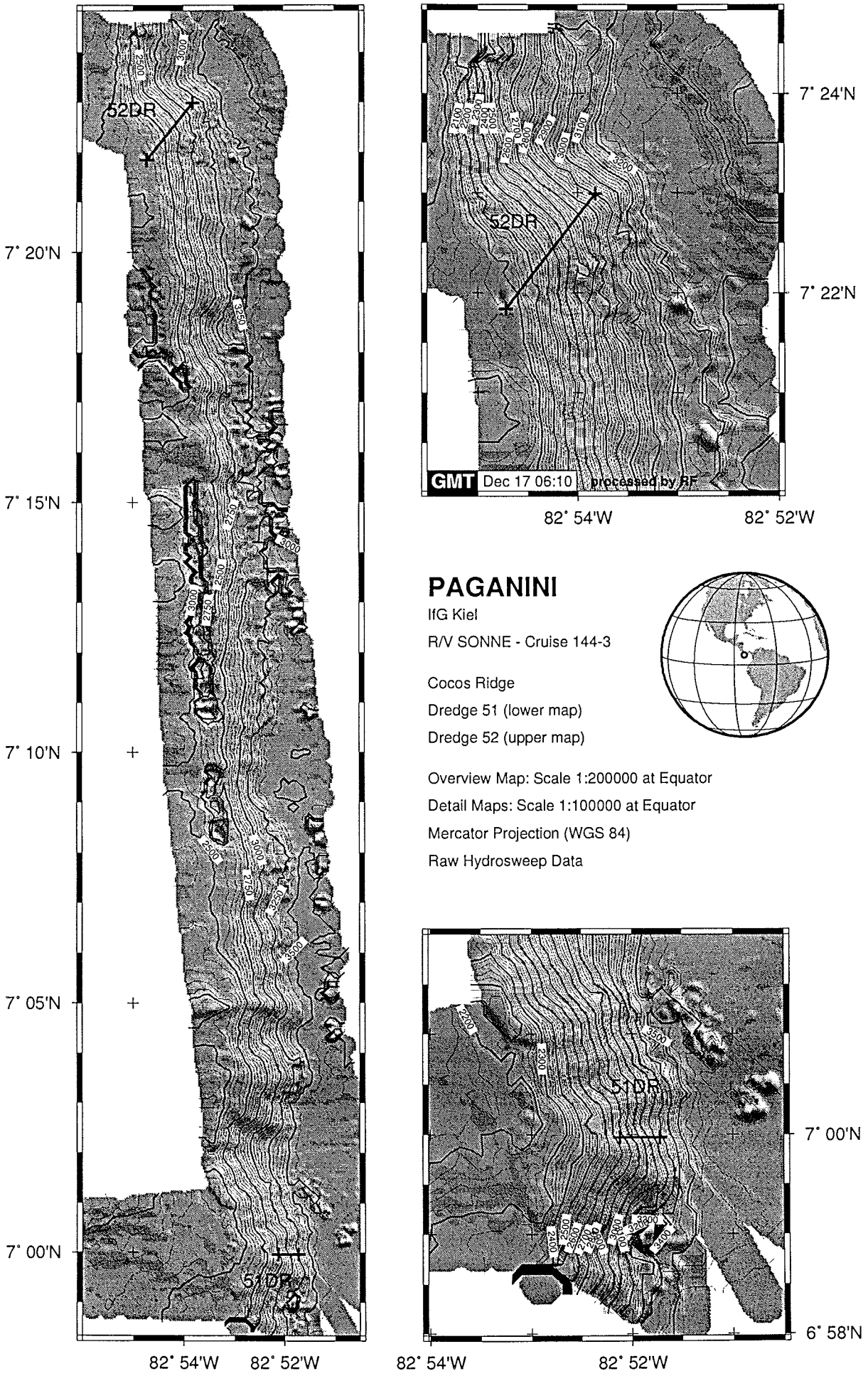
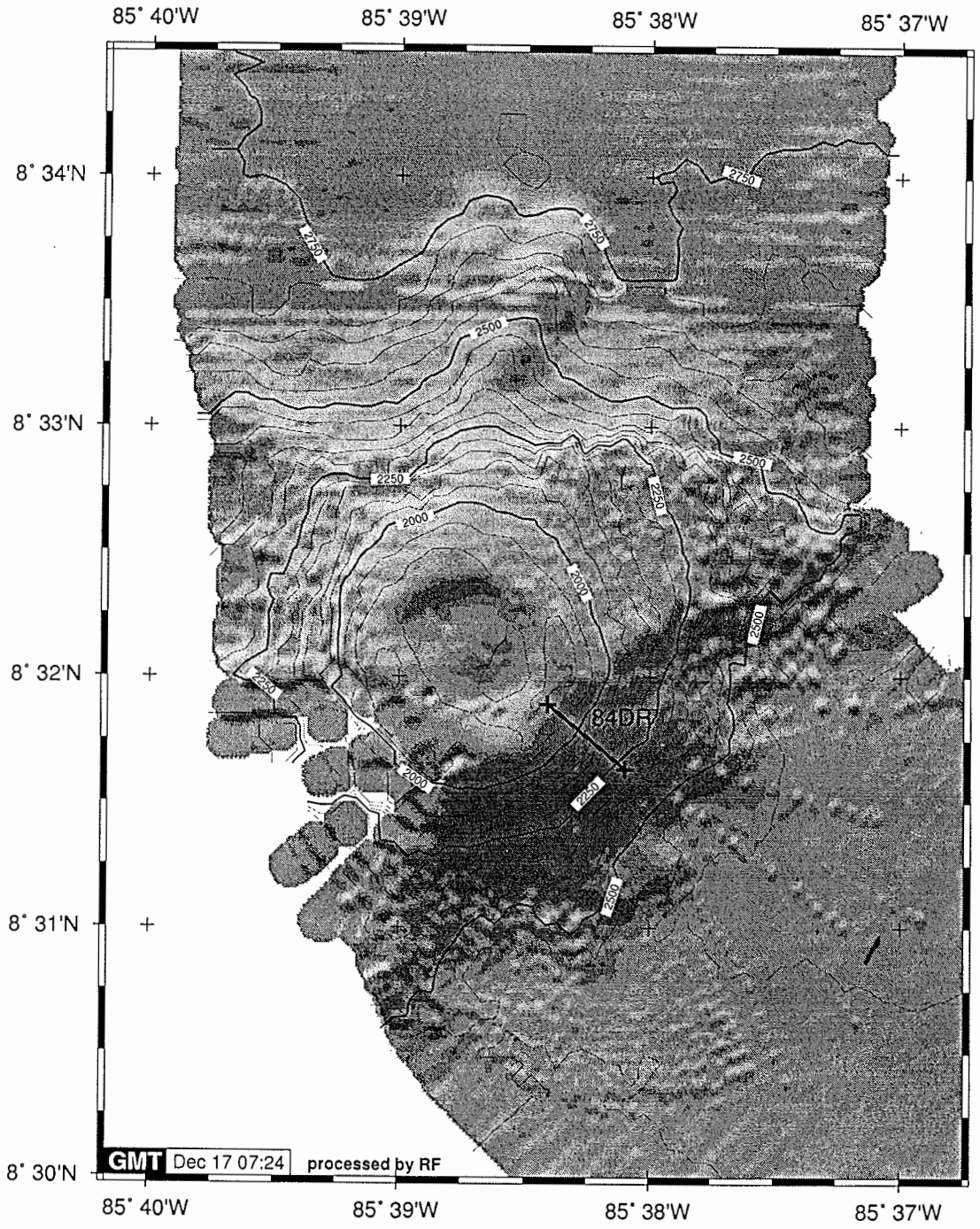


Fig. 4.1.1: Stations 51 and 52, near the Panamá Fracture Zone, SE Cocos Ridge



PAGANINI

IfG Kiel

R/V SONNE - Cruise 144-3

Cocos Ridge

Dredge 84

Scale 1:50000 at Equator

Mercator Projection (WGS 84)

Raw Hydrosweep Data

Fig. 4.1.2a: Station 84, seamount province NW of Cocos Ridge- A: Bathymetric map.

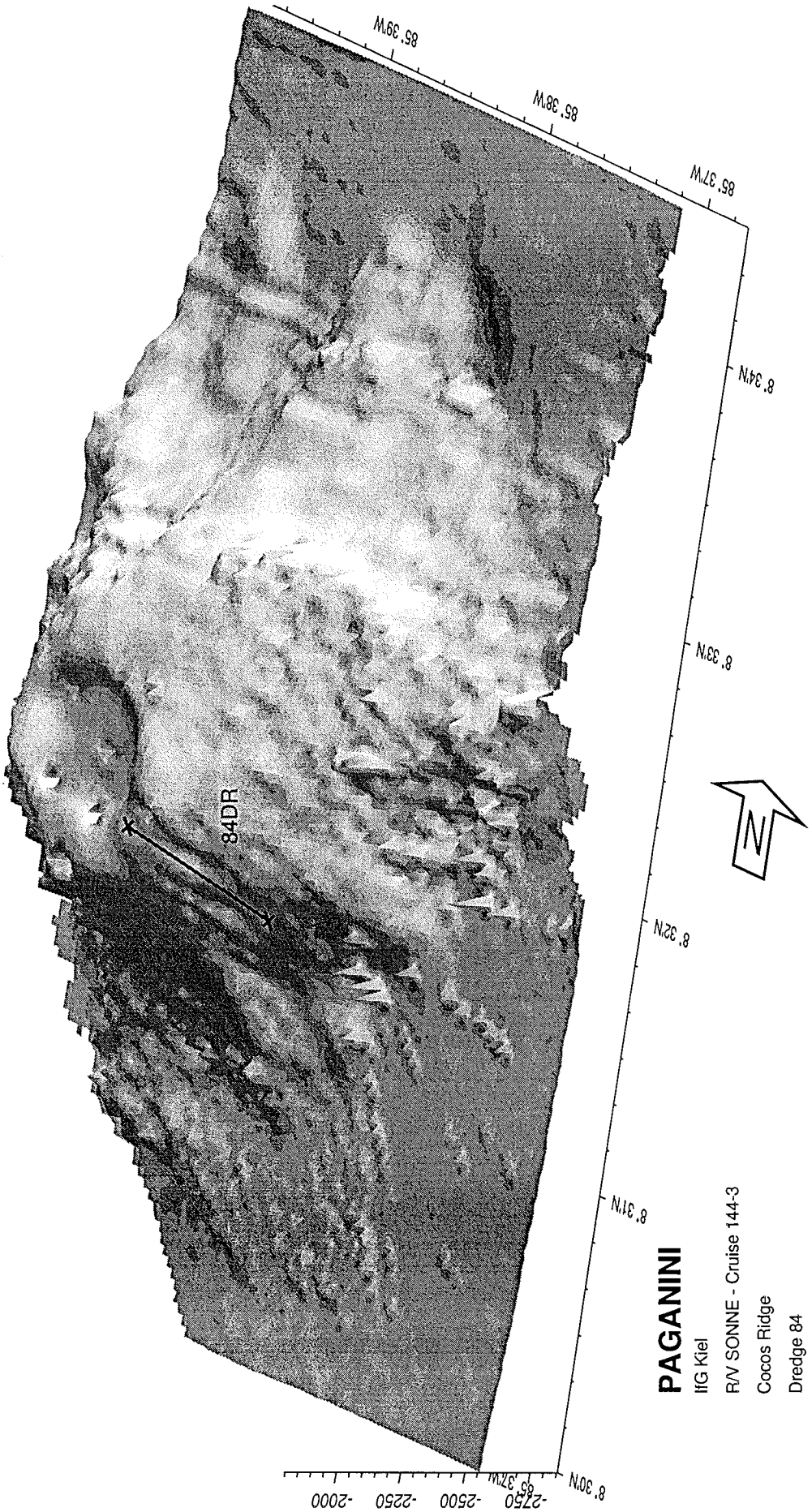


Fig. 4.1.2b: Station 84, seamount province NW of Cocos Ridge- B: 3D-projection.

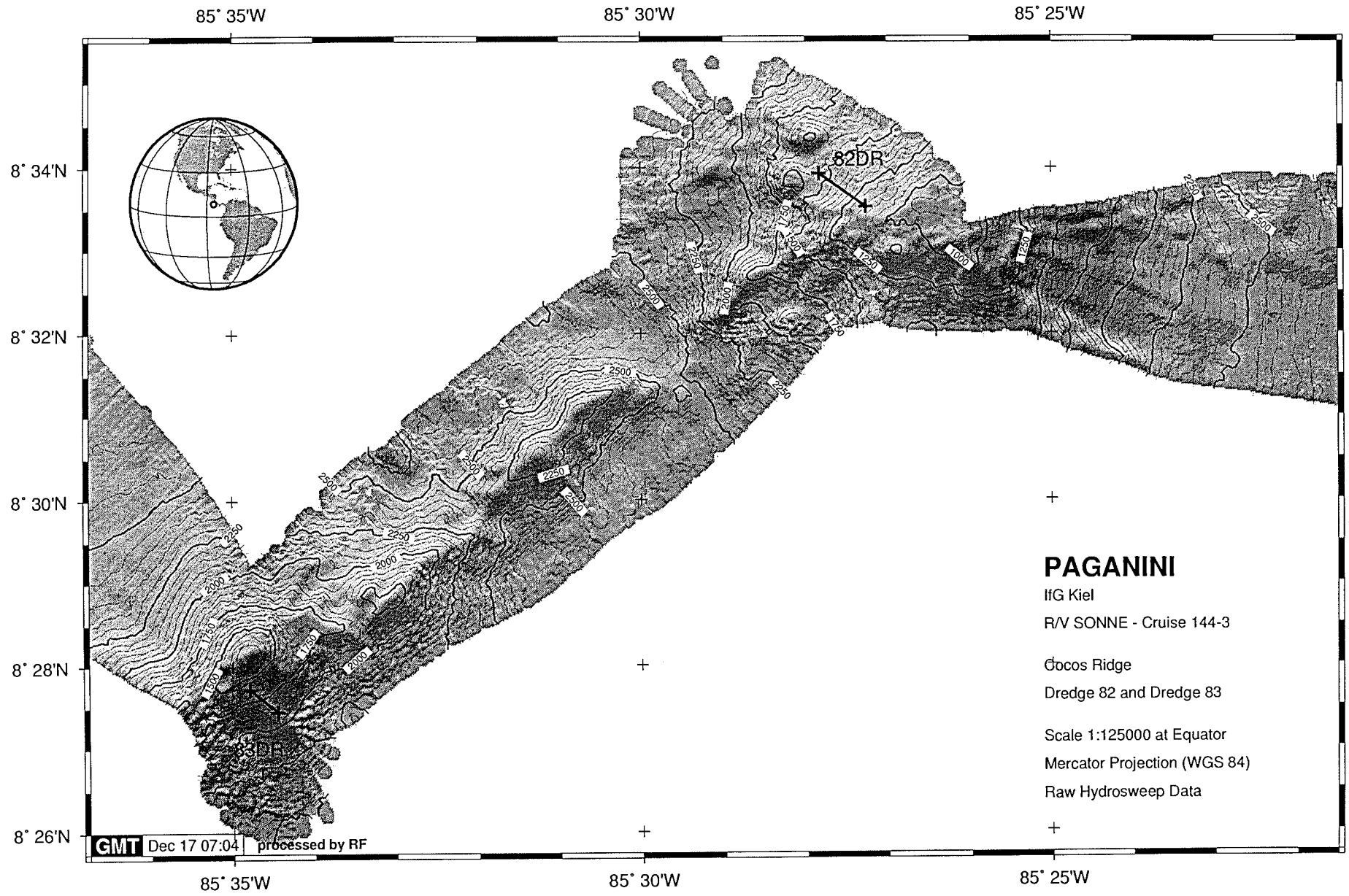


Fig. 4.1.3a: Stations 82 and 83, seamount and ridge NW of Cocos Ridge- A: Bathymetric map.

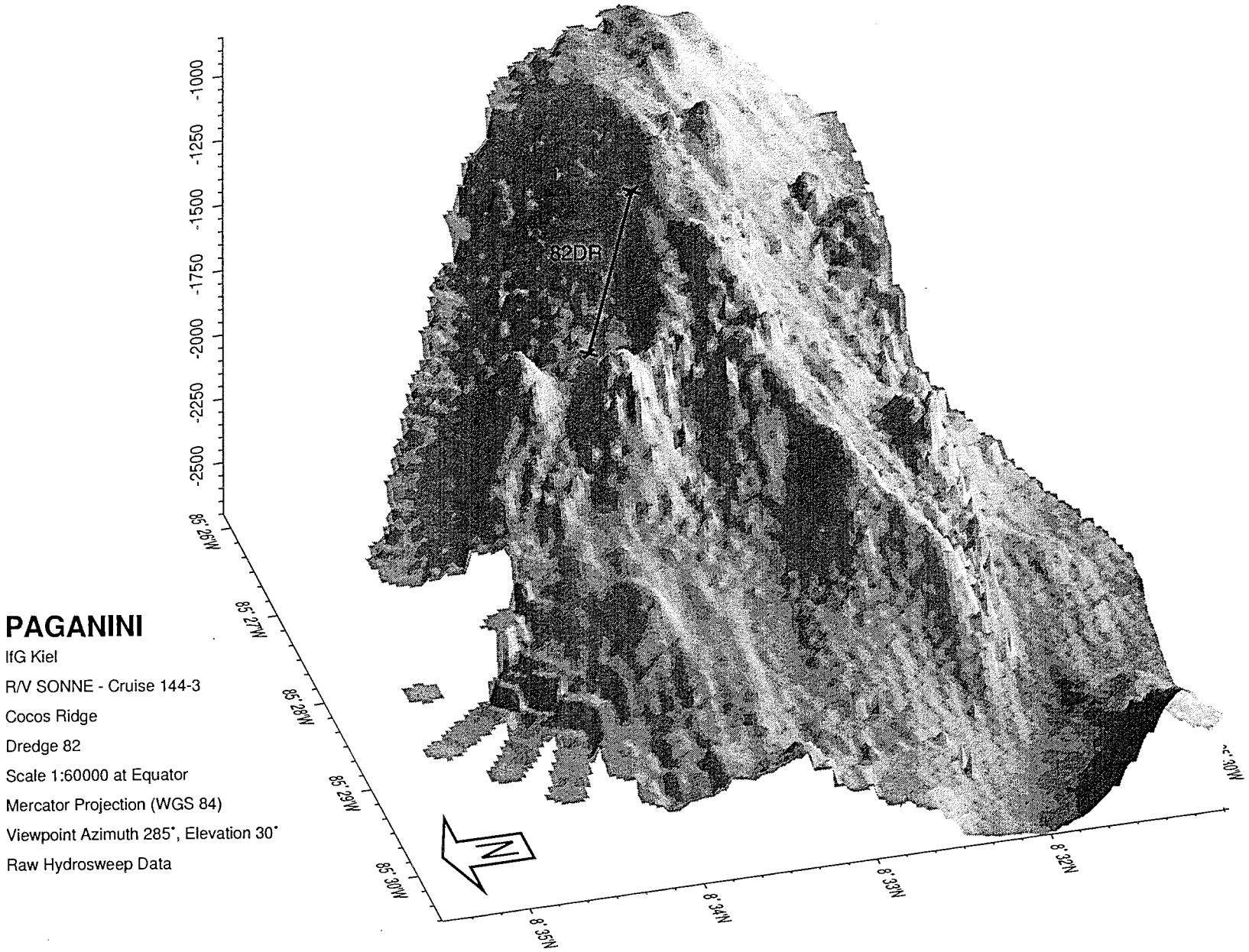


Fig. 4.1.3b: Stations 82 and 83, seamount and ridge NW of Cocos Ridge- B: 3D-projection of Station 82.

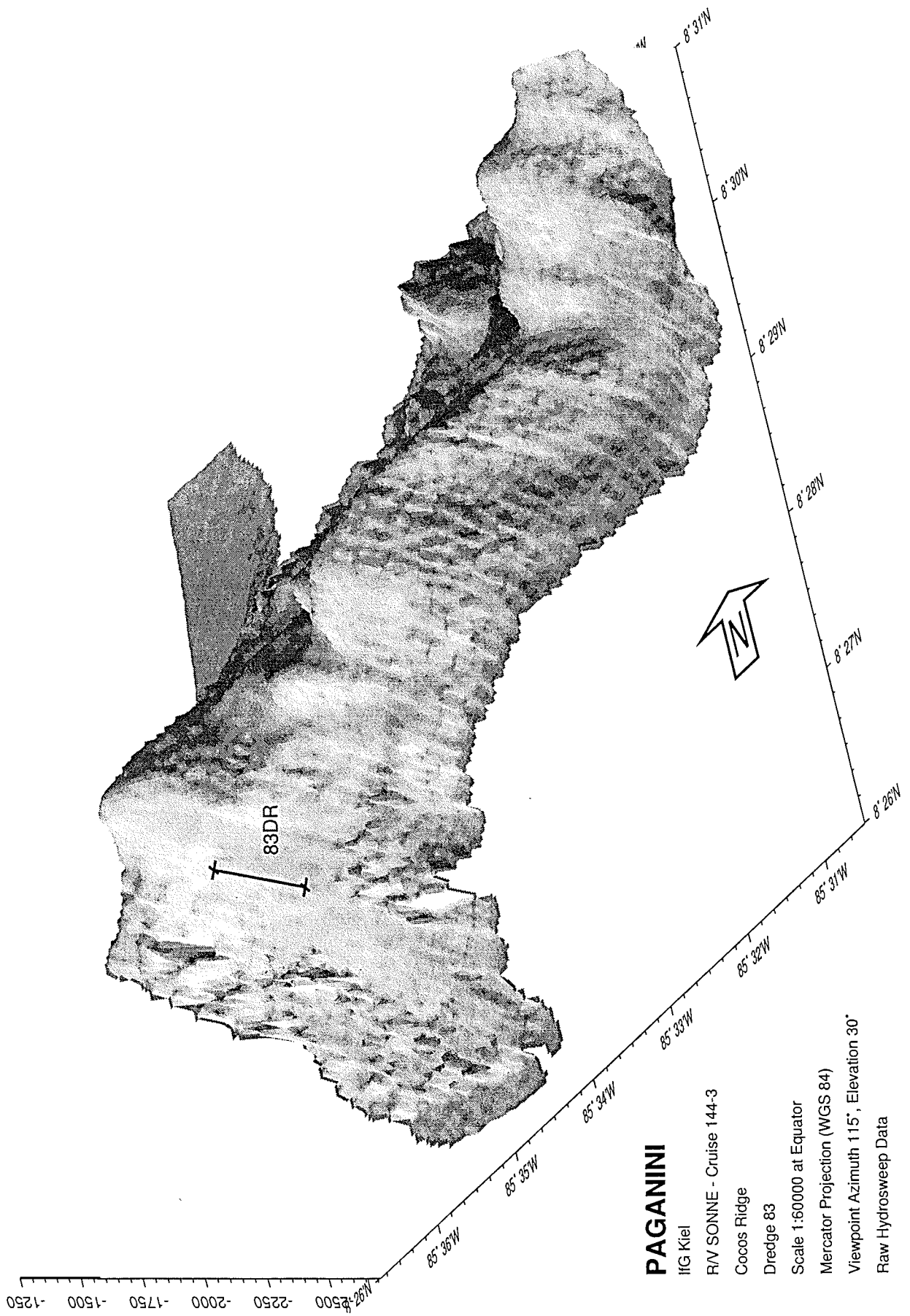


Fig. 4.1.3c: Stations 82 and 83, seamount and ridge NW of Cocos Ridge- C: 3D-projection of Station 83.

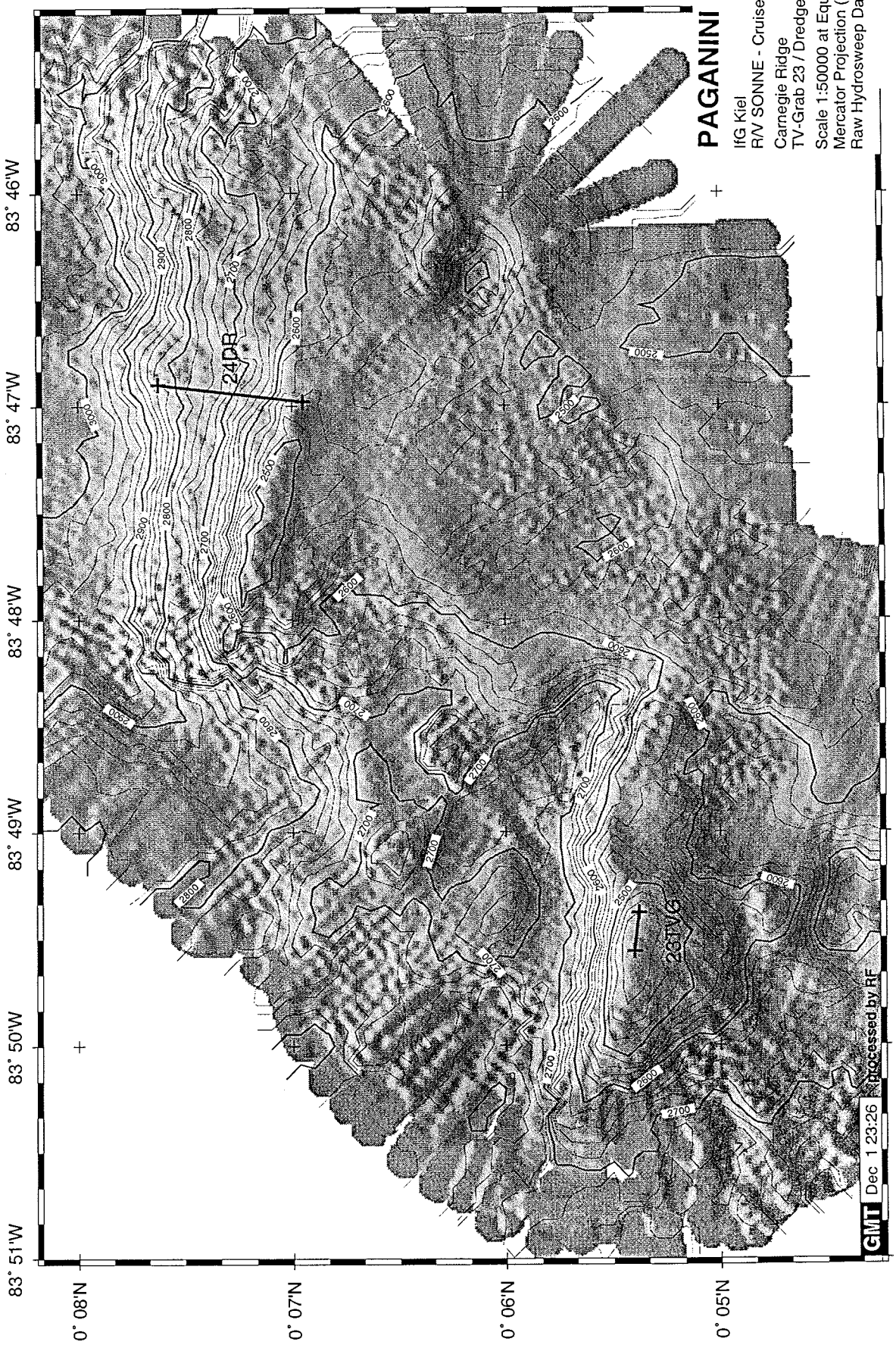


Fig. 4.1.4a: Stations 23 and 24, north flank of Carnegie Ridge (the ridge is sediment covered)- A: Bathymetric map.

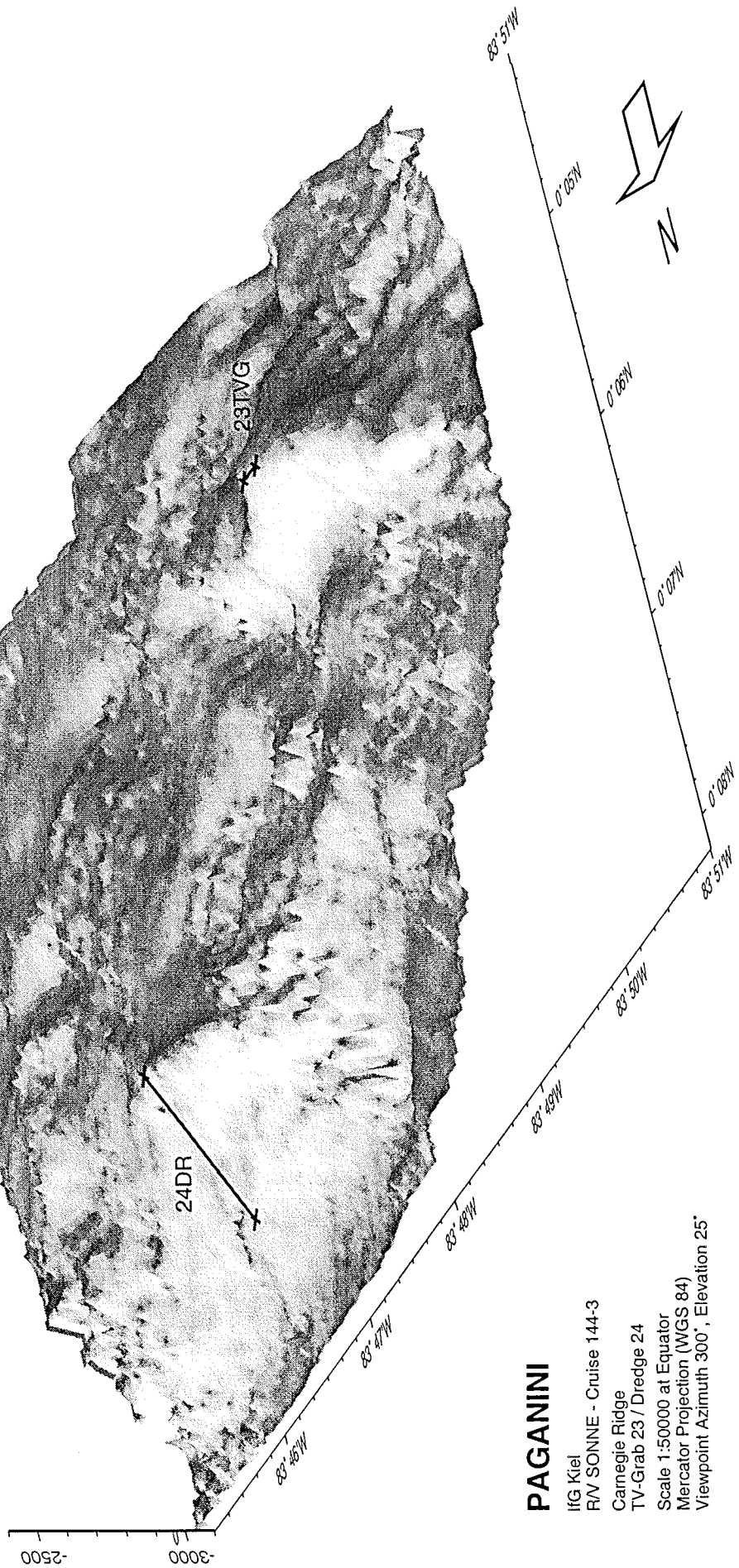


Fig. 4.1.4b: Stations 23 and 24, north flank of Carnegie Ridge (the ridge is sediment covered)- B: 3D-projection.

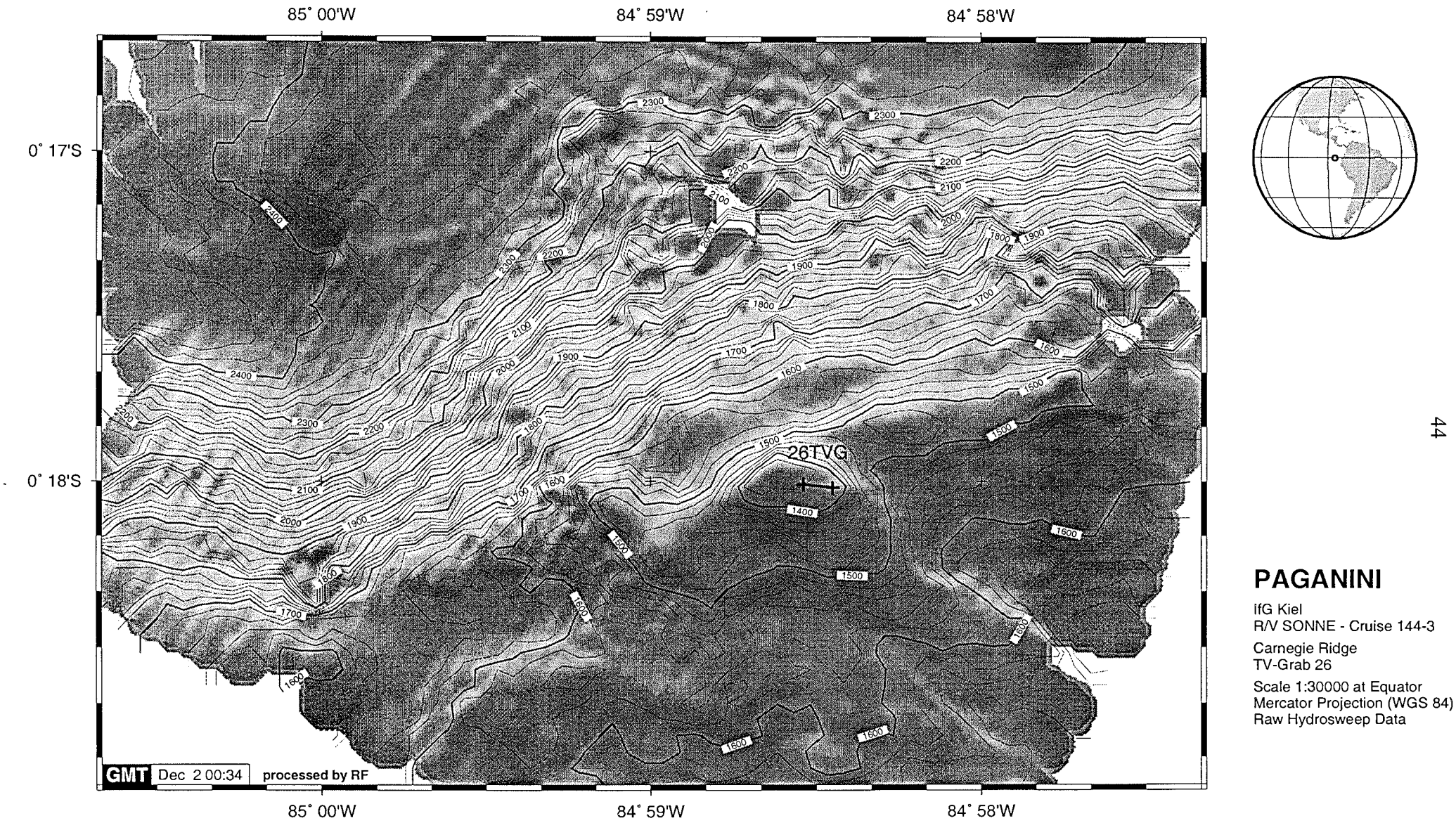


Fig. 4.1.5a: Station 26, small seamount on the northern flank of Carnegie Ridge- A: Bathymetric map.

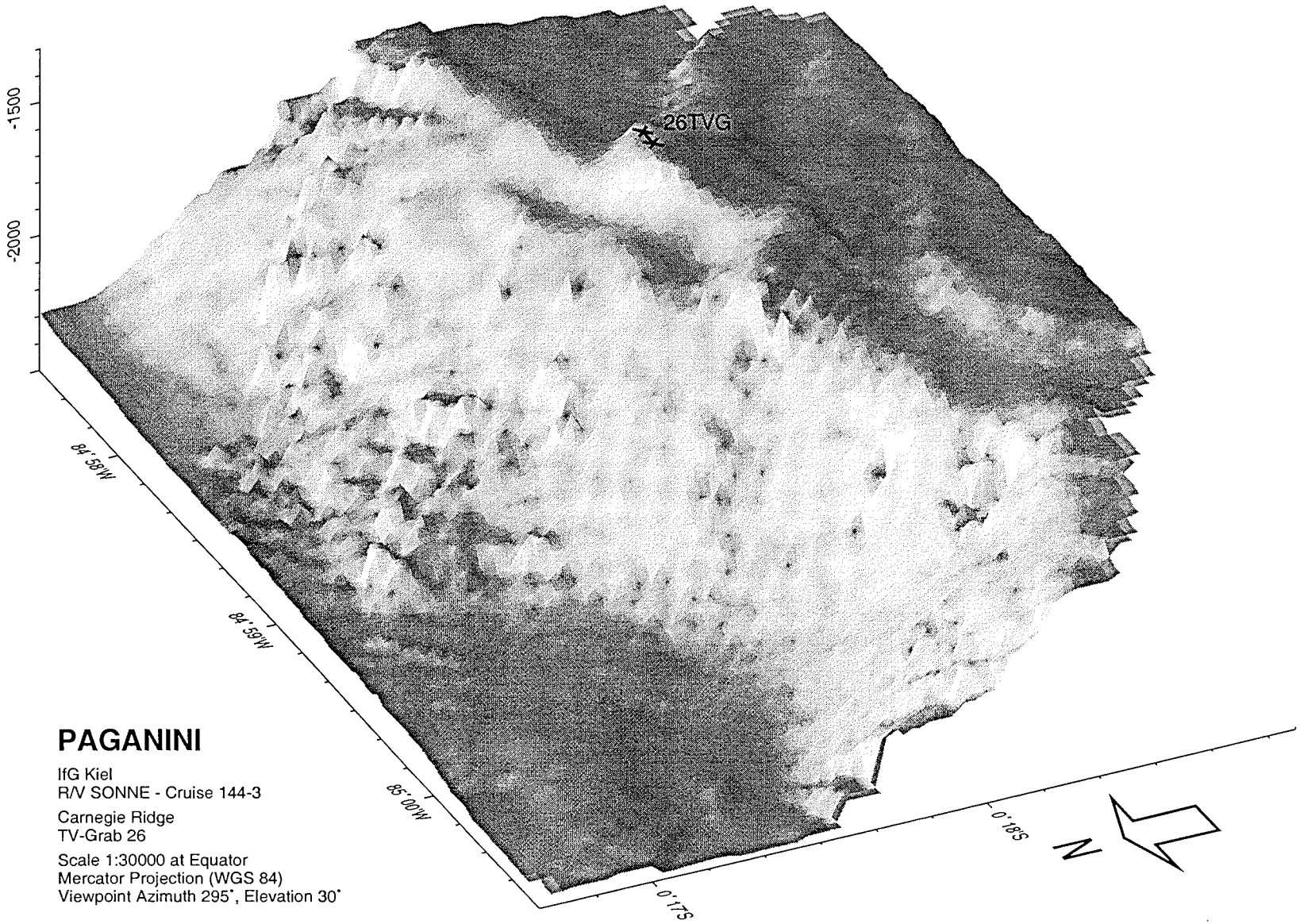


Fig. 4.1.5b: Station 26, small seamount on the northern flank of Carnegie Ridge- B: 3D-projection.

Table 4.1: Summary of dredge/TV-grab locations and lithologies (SO 144-3)

Ridge	*STN*	*DR*	*TVG*	*Samples*	*Glass*	*Aphyr. basalt*	*Ol bas <15%*	*Ol bas 15-30%*	*Ol-Px basalt*	*Px basalt*	*Px-Pl basalt*	*Ol-Pl basalt*	*Pl bas <15%*	*Pl bas 15-30%*	*Trach.*	*Hyal.*	*Plut.*	*Sed.*	*Oth.*
Malpelo	*1*	1		24		X						X			X				
	2	1		8	X	X	X												
	3		1	7									X						
	4	1		0															
	5	1		35		X						X	X	X				LST	
	6	1		23		X								X				ZST	
	7	1		24		X							X		X				
Carnegie	*8*	2		5											X				
	9	1		0															
	10		1	0															
	11	2		23		X								X					
	12	1		11										X		X			
	13	1		14		X										X			
	14	1		14												X		Turb	
	15	1		0															
	16	2		0															
	17		1	19					X	X						X			
	18	1		16	X		X												
	19	1		11	X		X												
	20	1		0															
	21		1	0															
	22	2		0															
	23		1	0															
	24	1		0															
	25	2		0															
	26		1	1										X					
	27	1		1															
	28	1		12		X										X			

Ridge	STN	DR	TVG	Samples	Glass	Aphyr. basalt	Ol bas <15%	Ol bas 15-30%	Ol-Px basalt	Px basalt	Px-Pl basalt	Ol-Pl basalt	Pl bas <15%	Pl bas 15-30%	Trach.	Hyal.	Plut.	Sed.	Oth.
Cocos	29	2		15	X	X							X	X					
(144-3a)	30	1		8	X			X											
	31	1		0															
	32	1		14			X									X			
	33	1		1			X												
	34	1		9												X			
	35	2	1	19	X			X								X			
	36	2		0															
	37	1		22													X		
	38	1		13	X		X												
	39	1		24		X						X	X			X	X		
	40	2		14	X								X						
	41	1		32		X						X		X		X			
	42	1		13		X													
	43	1		14	X	X							X			X			
	44	1		20		X	X									X	X		Pum
	45	2		22									X			X			
	46		1	10	X								X			X			
	47	1		12	X	X										X			
	48	1		9		X				X				X		X	X		
	49	1	1	17		X										X	X		
	50	1		15	X	X													
	51	1		34	X	X							X				X	Con	
	52	1		20	X	X										X	X		
	53	1		24		X							X	X					
	54	2		14		X							X			X	X		
	55	1		38	X	X							X	X		X	X		
	56		1	17			X									X			

Ridge	*STN*	*DR*	*TVG*	*Samples*	*Glass*	*Aphyr. basalt*	*Ol bas <15%*	*Ol bas 15-30%*	*Ol-Px basalt*	*Px basalt*	*Px-Pl basalt*	*Ol-Pl basalt*	*Pl bas <15%*	*Pl bas 15-30%*	*Trach.*	*Hyal.*	*Plut.*	*Sed.*	*Oth.*
Cocos	*58*	2		**14**		X										X			
(144-3b)	*59*	1		**0**															
	60	1		**18**	X		X		X	X			X		X	X			
	61	1		**2**												X			
	62	1		**12**		X				X						X			
	63	1	1	**15**	X	X				X						X			
	64	2		**22**		X	X									X			
	65	2		**30**	X	X	X					X						Clay	
	66	1		**7**	X		X	X											
	67	1		**12**			X												
	68	2		**5**												X			
	69	1		**14**	X		X									X			
	70	2	1	**16**					X							X			
	71	2		**28**			X					X				X			
	72	1	1	**23**	X							X				X			
	73	1		**11**	X		X												
	74	1		**12**		X										X		Turb	
	75		1	**10**					X										
	77	2		**31**		X	X		X	X						X			
	78	1		**11**					X							X			
	79	1		**17**		X			X	X						X			
	80	1		**20**			X		X							X			
	81	1		**17**	X	X			X							X			
	82	1		**9**		X										X			
	83	1		**14**	X		X									X			
	84	1		**7**		X													
Cocos Is.				**41**		2	3		2	12	8	9	3						2
Fisher	*85*	1		**28**	X	X										X	X		

Ridge	*STN*	*DR*	*TVG*	*Samples*	*Glass*	*Aphyr. basalt*	*Ol bas <15%*	*Ol bas 15-30%*	*Ol-Px basalt*	*Px basalt*	*Px-Pl basalt*	*Ol-Pl basalt*	*Pl bas <15%*	*Pl bas 15-30%*	*Trach.*	*Hyal.*	*Plut.*	*Sed.*	*Oth.*
Cont. Sl.	*87*	1		**20**														ZST	Arg
Coiba	*88*	1		**22**		X													
	89	1	1	**3**						X									
	90	1		**36**									X	X		X		ZST	
Malpelo	*7*	6	1	**121**	1	5	1	-	-	-	-	2	3	2	2	-	-	2	-
Carnegie	*21*	21	5	**127**	2	3	2	-	1	1	-	-	-	3	1	5	-	1	-
Cocos 3a	*28*	32	4	**450**	12	15	5	2	-	1	-	2	10	5	-	16	9	1	1
Cocos 3b	*26*	32	4	**377**	9	11	11	1	8	5	-	3	1	-	1	19	-	2	-
Cocos Is.	*-*	-	-	**41**	-	2	3	-	2	12	8	9	3	-	-	-	-	-	2
Fisher	*1*	1	-	**28**	1	1	-	-	-	-	-	-	-	-	-	1	1	-	-
Cont. Sl.	*1*	1	-	**20**	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Coiba	*3*	3	1	**61**	-	1	-	-	-	1	-	-	1	1	-	1	-	1	-
144-3a	*56*	59	10	**698**	15	23	8	2	1	2	-	4	13	10	3	21	9	4	1
144-3b	*31*	37	5	**527**	10	15	14	1	10	18	8	12	5	1	1	21	1	4	3
SO 144-3	*87*	96	15	**1225**	25	38	22	3	11	20	8	16	18	11	4	42	10	8	4

Notes:
- Abbreviations: STN = Station no., DR = no. of dredges, TVG = no. of TV-grabs, Aphyr. = aphyric, Ol = olivine, Px = pyroxene, Pl = plagioclase, bas = basalt, Trach. = trachytic lava, Hyal. = hyaloclastite, Plut. = plutonic rock (peridotite, gabbro), Sed. = sedimentary rock (LST = limestone, ZST = siltstone, Turb = turbidite, Con = conglomerate, Clay = claystone), Oth. = other lithologies (Pum = pumice, Arg = argillite).
- Glass refers to patches of glass or dark to black glassy areas found at the quenched rims of pillows, often immediately below a thin MnOx crust.
- Olivine (phenocrysts and groundmass) is often pseudomorphed by iddingsite, whereas pyroxene and plagioclase are unaltered.
- Totals for each ridge or location, each leg of the cruise, and the grand total are given at the base of the table (this page).

preparation, geochemistry, $^{40}Ar/^{39}Ar$ dating, and further processed to extract glass (if applicable). Each of these sub-samples, together with any remaining bulk sample, was sealed in either plastic bags or bubble wrap for transportation to Christian-Albrechts-University of Kiel and the GEOMAR. There, further studies will involve petrographic examination of thin sections, analyses of phenocryst and groundmass phases using the electron microprobe, determination of major and trace element geochemistry by X-ray fluorescence spectrometry and inductively coupled plasma mass spectrometry, analyses of radiogenic isotope ratios by thermal ionisation mass spectrometry, and radiometric dating of suitable samples by the $^{40}Ar/^{39}Ar$ technique.

A brief summary of the main shipboard findings for each ridge is provided below. An overview of the stations, number of samples, and principal lithologies can also be obtained from Table 4.1. More detailed descriptions of the dredge and TV-grab samples are listed in Appendix 2, and of the Cocos Island samples in Appendix 3.

4.2 MALPELO RIDGE

Malpelo Ridge is a high-standing broad NE–SW trending ridge approximately 300 km long by 100 km wide. It is located to the SE of Cocos Ridge and the NE of Carnegie Ridge. Several different models have been proposed for the origin of Malpelo Ridge (e.g., Hey, 1977; Lonsdale and Klitgord, 1978; Pennington, 1981; Hardy, 1991; Gardner et al., 1992); it may have rifted from Cocos Ridge, from Carnegie Ridge, or it may be an unrelated structure. Satellite altimetry-derived topographic maps proved remarkably accurate over the ridge, and little difficulty was experienced in locating either scarps or seamounts.

A total of 121 samples were recovered from 7 stations on or near the ridge (6 dredges and 1 TV-grab; Fig. 2.1). The recovered lithologies varied with station location:

- NW margin of Malpelo Ridge (Stations [hereafter STN] 1, 7). These samples consisted of dense aphyric basalt, olivine-plagioclase basalt, plagioclase basalt, and a series of lavas with abundant large (3–4 mm long) feldspar phenocrysts. The large feldspar phenocrysts have only simple twins, suggesting they are alkali feldspar and the lavas are trachybasalts. Samples of each lithology ranged from fresh to deeply weathered.
- NW margin to the central axis of Malpelo Ridge (STN 3–6). Multiple lithologies were recovered from most stations within this band. These samples consisted of both dense and vesicular varieties of aphyric basalt, olivine-plagioclase basalt, and

plagioclase basalt. Each lithology ranged from fresh to deeply weathered. Furthermore, well-rounded boulders that may represent paleo-beach cobbles were recovered from STN 5 and STN 6, a bivalve-gastropod limestone was recovered from STN 5, and a soft siltstone was recovered from STN 6.

- Southern scarp of the Malpelo Rift (STN 2). Samples from this scarp, approximately 40 km north of Malpelo Ridge, consisted of relatively fresh dense aphyric basalt and olivine basalt.

Trachytic lavas have previously been reported from Cocos Island on Cocos Ridge. Elsewhere, more evolved lavas are usually erupted from large volcanic edifices directly above the centre of a mantle plume. In addition, shallow-water indicators such as paleo-beach cobbles and mollusc-bearing limestone indicate the area between the NW margin and central axis of Malpelo Ridge was previously high-standing, and may have been emergent. Both results are consistent with Malpelo Ridge being part of a hotspot track. They may support models in which Malpelo Ridge rifted from Cocos Ridge, but pose difficulties for rival hypotheses invoking rifting only from Carnegie Ridge. Lavas from the southern scarp of Malpelo Rift are fresher than lavas from Malpelo Ridge, supporting the expected result that the rift is significantly younger than Malpelo Ridge.

4.3 CARNEGIE RIDGE

Carnegie Ridge is a high-standing broad east-west trending ridge approximately 1100 km long and up to 300 km wide. The ridge is considered to be a Galápagos hotspot trail (e.g., Hey, 1977; Lonsdale and Klitgord, 1978; Pennington, 1981; Gardner et al., 1992), and the volcanically active Galápagos Islands are located at the western end of the ridge. A major aim of SO 144-3 was to obtain samples from three north-south traverses across the eastern 450 km long by 300 km wide part of Carnegie Ridge, which is adjacent to the Columbian Trench off the coast of Ecuador. Satellite altimetry-derived topographic maps were found to be reliable over this part of the ridge, and seamounts were located near their predicted positions.

A total of 127 samples were recovered from 21 stations (21 dredges and 5 TV-grabs) on or near the ridge (Fig. 2.2). However, many stations (10) were unsuccessful and recovered only soft sediment (foram ooze). In particular, this was a major problem on the central north-south traverse. Many of the seamounts rising from Carnegie Ridge are evidently covered in soft sediment, and their slopes are not steep enough to cause sediment slumping and exposure of the underlying igneous rocks. At the successful

stations, the recovered lithologies show a progressive change in petrography across the ridge:

- Northern peripheral structures (STN 8, 23–26). Samples from seamounts and scarps to the north of Carnegie Ridge consisted of feldspar-bearing pillow basalt. Those from a scarp on the rift zone separating Carnegie and Malpelo Ridges appear to be trachybasalt (STN 8), whereas those from a seamount between this rift zone and Carnegie Ridge are plagioclase basalt (STN 26).
- Northern margin of Carnegie Ridge (STN 9–12, 22). Rock samples were only recovered from two stations on the eastern traverse (STN 11–12). The lithologies were more varied. Both stations reported vesicular plagioclase basalt, with dense and vesicular aphyric pillow basalt also present at STN 11 and weathered hyaloclastite recovered from STN 12.
- Central axis of Carnegie Ridge (STN 13–15, 20–21, 27). Few samples were recovered from seamounts in this area, with most dredge attempts returning sediment from the covering sequence (foram ooze or sand-silt turbidite-bedded material). Samples of weathered hyaloclastite were obtained from STN 13 and STN 14, and a vesicular aphyric basalt clast occurred in one hyaloclastite from STN 13.
- Southern margin of Carnegie Ridge (STN 16–19, 28). Dredging in this area was more successful. Vesicular olivine basalt with fresh olivine phenocrysts was recovered from STN 18 and STN 19, olivine-clinopyroxene basalt, clinopyroxene basalt, and hyaloclastite were found at STN 17, and aphyric basalt and hyaloclastite were obtained from STN 28.

There is an apparent change in predominant lithology across Carnegie Ridge from feldspar-bearing lavas in the north to olivine-bearing lavas in the south. Recovered lithologies at most stations ranged from fresh to deeply weathered, and it was not possible to infer any change in age along the ridge.

4.4 COCOS RIDGE

4.4.1 Cocos Ridge and Associated Seamounts

Cocos Ridge is a high-standing broad NE–SW trending ridge approximately 1200 km long and up to 300 km wide. The ridge is considered by most authors as a Galápagos hotspot trail (e.g., Hey, 1977; Lonsdale and Klitgord, 1978; Pennington, 1981; Gardner et al., 1992; Werner et al., 1999; Hoernle et al., 2000), and the volcanically active Galápagos Islands are located to the south of the SW end of the

ridge. Satellite altimetry-derived topographic maps were found to be reliable over most of the ridge, and seamounts were located near their predicted positions.

A total of 827 samples were recovered from 54 stations (64 dredges and 8 TV-grabs) on the ridge (Figs 2.3, 2.4). In marked contrast to the problems encountered at Carnegie Ridge, only three stations failed to return rock samples. This may indicate that seamounts rising from Cocos Ridge have a thinner sediment cover, that their slopes are steeper, or a combination of both factors. Seven traverses of Cocos Ridge were completed, with the bulk of the stations located on the NE part of the ridge. The recovered lithologies show a general relationship with location across the ridge, and it is convenient to subdivide the ridge into three 100 km-wide bands together with the region around Cocos Island:

- NW margin of Cocos Ridge (STN 30–33, 69–75, 77–84). Samples recovered from seamounts within 100 km of the NW margin of the ridge were predominantly dense to vesicular olivine pillow basalt (STN 30, 32, 33, 69, 71, 73, 77, 80, 83). Those from STN 32 and STN 69 were scoriaceous. Black glassy pillow rims were often present, and olivine phenocrysts ranged from fresh in some samples to completely pseudomorphed by iddingsite in others. There was no obvious correlation between degree of olivine replacement and distance from the Galápagos Islands. Subordinate lithologies recovered were olivine-pyroxene basalt (STN 70, 75, 77, 78, 79, 80, 81), aphyric basalt (STN 74, 77, 79, 81, 82, 84), pyroxene basalt (STN 77, 79), and plagioclase-olivine basalt (STN 71, 72). Weathered hyaloclastite was also recovered from 12 of the 18 stations. Some samples from STN 71 were altered and silicified, with the development of clay minerals. A breccia (hyaloclastite?) from STN 77 contained several well-rounded boulders that may be paleo-beach cobbles, and numerous shell fragments were present in the sandy matrix.
- Base of Cocos Island. Samples were recovered from three stations immediately east of Cocos Island (STN 64–66) and two stations immediately SW of the island (STN 67–68). The recovered lithologies were predominantly dense to vesicular olivine pillow basalt (STN 64, 65, 66, 67), often with black glassy pillow rims. The olivine phenocrysts ranged from fresh in some samples to completely pseudomorphed by iddingsite in others. Subordinate lithologies were aphyric basalt (STN 64, 65) and olivine-plagioclase basalt (STN 65). Weathered hyaloclastite was found at STN 64 and STN 68, and claystone was recovered from STN 64 and STN 65. Overall, the lithologies recovered from this area were the same as those from the NW margin of Cocos Ridge (the Cocos Island platform lies within this 100 km-wide band).
- Central axis of Cocos Ridge (STN 29, 34–35, 40–42, 46–47, 56, 58–63). Multiple and varied lithologies were recovered from many of these seamounts in the central

100 km-wide band of the ridge. The predominant types were aphyric basalt (STN 29, 34, 41, 42, 47, 58, 62, 63) and plagioclase basalt (STN 29, 40, 41, 46, 60). Subordinate lithologies were olivine basalt (STN 35, 56, 60), pyroxene basalt (STN 60, 62, 63), olivine-plagioclase basalt (STN 41), olivine-pyroxene basalt (STN 60), and trachybasalt (STN 60). Most of the lavas were vesicular, but dense varieties and pillows with glassy rims were also common. The olivine phenocrysts in most olivine-bearing samples were pseudomorphed by iddingsite, but some were fresh. Weathered hyaloclastite was also found at 11 of the 15 stations. Some rocks from STN 60 were silicified, and some from STN 41 contain disseminated pyrite.

- SE margin of Cocos Ridge (STN 36–39, 43–45, 48–55). Multiple lithologies were recovered from most seamounts within 100 km of the SE margin of the ridge. The main types were aphyric basalt (STN 39, 43, 44, 48, 49, 50, 51, 52, 53, 54, 55), plagioclase basalt (STN 39, 43, 45, 48, 51, 53, 54, 55), and a sequence of gabbroic rocks (STN 37, 39, 44, 48, 49, 51, 52, 54, 55). Subordinate lithologies found at a few stations were olivine basalt (STN 38, 44), olivine-plagioclase basalt (STN 39), and pyroxene basalt (STN 48). Most of the lavas were vesicular, but dense varieties and pillows with glassy rims were occasionally obtained. Weathered hyaloclastite was also found at 9 of the 15 stations. Hydrothermal alteration involving silicification, development of clay minerals, and occasional development of pyrite +/- pyrrhotite had affected some rocks at STN 37, 44, 45, 51, and 54; in particular, this was a feature of many gabbroic rocks. Well-rounded boulders that may represent possible paleo-beach cobbles were recovered from STN 44, 50, 51, 52, and 53; again, a high-degree of rounding was a feature of many gabbroic rocks.

There is an apparent gradation across Cocos Ridge from olivine- and pyroxene-bearing lavas in the NW to feldspar-bearing lavas in the SE. This change is a mirror image of that recognized across Carnegie Ridge. The widespread occurrence of gabbroic rocks near the SE margin of Cocos Ridge may suggest that cross-sections through the crust have been exposed by rifting. The occurrence of paleo-beach cobbles at several stations along the SE margin of the ridge may indicate that uplift, possibly in response to an increase in heat flow, preceeded the rifting event. The petrographic evidence supports models in which Cocos Ridge represents part of the Galápagos plume trail. Recovered lithologies at most stations ranged from fresh to deeply weathered, and it was not possible to infer any change in age along the ridge.

It has been suggested that Cocos Island is anomalously young (1.9–2.4 Ma; Bellon et al., 1983), and that it may represent a second mantle plume (Meschede et al., 1997; 1998). The petrography of samples from the platform around Cocos Island does not

differ significantly from that of other lavas recovered from the NW margin of Cocos Ridge. This suggests that if a second mantle plume exists, then the magma flux from that plume is small.

4.4.2 Cocos Island

A field group consisting of Tim Worthington, Karen Harpp and Guillermo Alvarado landed on Cocos Island. Although weather conditions were difficult (continual rain with low cloud and limited visibility), part of the island was mapped and 41 samples were collected. A brief description of the mapped areas is given below, and further details of the samples are provided in Appendix 3.

West Wafer Bay

The western coast of Wafer Bay was mapped, with extensive sampling of a volcaniclastic and pyroclastic sequence immediately west of the river mouth. The following stratigraphic sequence was established:

- >4 m thick debris flow (top of unit obscured by vegetation)- sub-angular to subrounded clasts up to 2 m in diameter of vesicular lava, dense flow banded aphyric lava, and some more weathered vesicular feldspar-bearing lavas. Crude reverse grading is apparent at the base of the unit, but the remainder is massive. The unit dips at 15° towards 270°. Samples collected from this unit were predominantly of pyroxene basalt, with subordinate olivine basalt (fresh olivine) and pyroxene-plagioclase basalt (Cocos 2, 5, 6, 8, 9, 10, 39).
- 1.2 m thick pyroclastic flow- fine-grained pumiceous unit containing several small lenses of basaltic clasts. The basaltic clasts in these lenses are up to 15 cm in diameter, angular, and exhibit normal-grading.
- 1.2 m thick pyroclastic surge- fine-grained pumiceous unit with well-developed cross-bedding.
- 1.5 m thick pyroclastic unit, possibly airfall or tuff- fine-grained massive pumiceous unit with accretionary lapilli and occasional 0.5-20 cm in diameter lava fragments. One sample of this material was collected (Cocos 40).
- 0.7 m thick pyroclastic unit, possibly a tuff- fine-grained massive pumiceous unit. One sample of this material was collected (Cocos 3).
- >4 m thick debris flow (base of unit continues below sea-level)- sub-angular to subrounded clasts of various lava lithologies up to 1 m in diameter. Massive. A sample of pyroxene basalt was collected from this unit (Cocos 41).

A sedimentary dyke cross-cuts the lowermost two units at this locality. In addition, a

series of well-rounded beach cobbles were also collected; these consisted of pyroxene basalt, vesicular olivine basalt, and an olivine-plagioclase basalt (Cocos 1, 4, 7, 14). All are thought to have come from the lower debris flow.

East Wafer Bay

The eastern coast of Wafer Bay was also visited. A series of three lava flows separated by two autobreccia units was mapped and sampled. In addition, two dykes intrude the lower lava flow. Evidence of previous sampling for paleomagnetism (drill holes) was observed in the lower flow and both dykes.

- upper lava: consists of plagioclase-olivine basalt (Cocos 38).
- autobreccia
- middle lava: consists of olivine-plagioclase basalt (Cocos 37).
- autobreccia
- lower lava: consists of pyroxene-olivine basalt (Cocos 33).
- western dyke: this intrudes the lower flow and is the thicker of the two sampled dykes. It consists of olivine-plagioclase basalt, and was sampled at both the vesicular core of the dyke (Cocos 34) and the laminate at the contact to the lava flow (Cocos 35).
- eastern dyke: the smaller of the two dykes intruding the lower flow, which also consists of olivine-plagioclase basalt (Cocos 36).

Cascade Waterfall – Cerro Iglesias Track

The main track beside the Rio Genio was followed from Wafer Bay to a small waterfall on a tributary stream opposite and just past the junction of the Cascade Waterfall and Cerro Iglesias tracks. At that site, a >4 m thick lava flow on the southern bank of the Rio Genio was sampled. This lava flow is overlain by an inaccessible volcaniclastic unit (debris flow), and float from that unit was collected approximately 50 m downstream. The track to Cerro Iglesias was then followed until the elevation was approximately 50 m above Rio Genio, where another sample of float was collected. No outcrop occurs for a considerable distance beyond and above this site (>500 m), and the track there is carved into clay. These observations fit the following stratigraphic model:

- clay unit: clay, probably representing deeply weathered pyroclastic material. This unit may be correlative with the pyroclastic sequence at West Wafer Bay.
- debris flow: underlies the clay, overlies the lava flow, and is ~50 m thick. Float from this unit includes pyroxene basalt (Cocos 13) at an elevation of 50 m above the Rio Genio, and pyroxene-olivine basalt (Cocos 12) near the Rio Genio. Probably

correlative with the lower debris flow at West Wafer Bay.

- lava flow: >4 m thick, strongly jointed with jointing parallel to the flow base. Consists of pyroxene basalt (Cocos 11).

Wafer Bay – Chatham Bay Track

The main track between Wafer Bay and Chatham Bay was followed. A sample of pyroxene-plagioclase basalt was collected from a lava flow at the top of the scarp overlooking Wafer Bay (Cocos 28), and two float samples of pyroxene-plagioclase basalt (Cocos 29, 30) were collected from further along the track overlooking Chatham Bay.

West Chatham Bay

A series of three relatively thin lava flows separated by thin autobreccia units outcrop at the first point to the east of the river at Chatham Bay, and these were also sampled. Based on observations made while travelling around the coast of Cocos Island by boat, these thinner lava flows are believed to be valley-filling and to represent the younger Cocos Island suite:

- upper lava: >1 m thick (top of section obscured by vegetation), olivine-plagioclase basalt (Cocos 25).
- breccia: 1 m thick autobreccia or the eroded brecciated top of the middle lava.
- middle lava: 1 m thick more vesicular flow, olivine-plagioclase basalt (Cocos 26).
- clay/soil: 0.3 m thick paleosol.
- breccia: 1.5 m thick autobreccia or the eroded brecciated top of the lower lava.
- lower lava: >1.5 m thick massive flow (base of section is at sea-level), olivine-plagioclase basalt (Cocos 27).

East Chatham Bay

The eastern coast of Chatham Bay was examined at low tide, and three thick lava flows were sampled. They are described in sequence from east to west:

- flow 2: >7 m thick flow, pyroxene-plagioclase basalt, upper part is columnar jointed, lower part is massive with large pull-apart structures, dips at 5° to the east. Outcrops at the eastern end of Chatham Bay at the last accessible point during low tide, where a sample was taken from the middle part of the flow at the base of the columnar jointing (Cocos 15; GPS = 05°32'58.5" N, 087°02'19.2" W). The upper part of this flow was also sampled at a smaller outcrop 50 m further west and 7 m higher (Cocos 16; GPS = 05°32'57.9" N, 087°02'22.1" W).

- flow 1: >8 m thick flow, pyroxene basalt, upper and central part is columnar jointed, lower part is strongly sheared, dips at 10–15° to the east. Outcrops along much of the eastern coast of Chatham Bay to the west of flow 2, and underlies flow 2 (contact obscured by slip and vegetation). Samples were taken from the eastern side of the outcrop in the fractured basal region (Cocos 17, 31; GPS = 05°32'57.5" N, 087°02'23.4" W), and from the western side of the outcrop in the columnar jointed region (Cocos 18; GPS = 05°32'59.0" N, 087°02'26.6" W).
- falls lava: thick flow with obscured upper and lower contacts, pyroxene-plagioclase basalt. Outcrops at a prominent waterfall 12 m above the beach at the eastern end of Chatham beach. Sampled *in situ* at the base of the waterfall (Cocos 24) and from a float boulder downstream of the falls (Cocos 32). This lava flow is probably correlative with flow 2.

In addition, a series of well-rounded beach cobbles were collected from the coast at the flow 1 outcrop. Sampled lithologies were dense aphyric basalt and plagioclase basalt (Cocos 19-23).

Iglesias Bay

An attempt to land and sample rocks around Iglesias Bay on the southwest coast of Cocos Island was defeated by sea swells of >2 m breaking onto a steep (>40°) rocky beach slope, in combination with heavy rain and minimal visibility.

Summary of Cocos Island

Previous reconnaissance mapping of Cocos Island has identified three major units; an Upper Volcanic Series of hawaiite and alkali olivine basalt flows, a middle sequence consisting of trachytic rocks and associated pyroclastic flows, and a Lower Volcanic Series dominated by alkali olivine basalt (e.g., Castillo et al., 1988). Most samples collected during the SO 144-3 landing are thought to represent the Lower Volcanic Series. Exceptions are the two pyroclastic sequence samples from West Wafer Bay. Also, the samples from the Wafer Bay – Chatham Bay Track and West Chatham Bay may represent the Upper Volcanic Series.

4.5 FISHER RIDGE

Fisher Ridge is depicted on bathymetric maps derived from satellite altimetry as a narrow NE–SW trending ridge approximately 150 km long. It is located to the north of,

and trends subparallel to, Cocos Ridge. Previous cruises (SO 81, SO 107) have sampled that part of Fisher Ridge closest to the Central America Trench, but the rest of the ridge was unsurveyed and had not been dredged. Age data (19 and 30 Ma) from the Fisher Ridge show that this structure is older than Cocos Ridge and its associated seamounts (Werner et al., 1999). Whereas the 19 Ma age agrees well with the interpretation of the available magnetic data, the 30 Ma age remains enigmatic. Volcanological data and the MORB-like geochemistry of the SO 81 and SO 107 samples are consistent with Fisher Ridge being oceanic crust (Werner et al., 1999). In order to test this hypothesis, one of the aims of SO 144-3 was to recover samples from the SW and NE parts of Fisher Ridge.

Attempts to locate the topographic highs shown on the satellite altimetry-derived maps in the SW area of Fisher Ridge failed, and a 10 hour HYDROSWEEP survey confirmed that Fisher Ridge has minimal topographic expression in this region (see Chapter 2). A total of 28 samples were recovered from one dredge station (STN 85) near the NE end of Fisher Ridge. The predominant lithology was a black aphyric basalt that grades into a hyaloclastite consisting of aphyric basalt, black glassy aphyric basalt, and palagonitic clay. A few plutonic rocks were also recovered (gabbro and dolerite). These had thicker weathering rinds, suggesting a longer time at the seafloor, and some occurred as clasts within a breccia of palagonitic clay. The presence of plutonic rocks further suggests that a section through the oceanic crust may be exposed along the scarps of Fisher Ridge. This combination of lithologies supports the opinion that Fisher Ridge is unrelated to the nearby Cocos Ridge, and instead represents an uplifted piece of oceanic crust.

4.6 CONTINENTAL SLOPE OFF COSTA RICA

Seismic and bathymetric data suggest that igneous rocks on the continental slope west of Costa Rica may be exposed at a scarp on a half-subducted seamount near 09°12'N and 85°16'W (Roland von Huene, pers. comm. 1999). A total of 20 samples were recovered from one dredge station (STN 87) at this site to test this hypothesis. The recovered rocks form two distinct units:

- A younger sequence of soft siltstone and claystone with evidence of bioturbation.
- An older sequence of argillite (metamorphosed siltstone) and tectonically brecciated argillite with calcite veining.

These rock units are typical of the turbidite-deposited sedimentary sequences found

in other accretionary prisms. The younger sequence may represent sediment recently deposited in this region, whereas the older sequence probably represents a similar siltstone-claystone sequence that has been buried to a depth of several km, weakly metamorphosed, and then uplifted and exposed along a thrust fault. The dredged scarp on the seamount is probably the surface expression of this postulated thrust fault. No igneous rocks were recovered from the seamount.

4.7 COIBA RIDGE

Coiba Ridge is a high-standing broad north-south trending ridge approximately 150 km long by 100 km wide. It is located to the east of Cocos Ridge and to the north of Malpelo Ridge, and may be a rifted part of Cocos Ridge or unrelated to either of those structures (e.g., Hey, 1977). Satellite altimetry-derived topographic maps proved inaccurate over much of ridge. In particular, large seamounts shown rising from the central, SE and eastern parts of the ridge do not exist, and the topography in those areas has minimal relief. Instead, Coiba Ridge appears to be a large plateau with steep western and southern flanks up to 1500 m high and a gently dipping eastern slope.

A total of 61 samples were recovered from 3 stations at scarps around the western, central, and southern margins of Coiba Ridge (3 dredges and 1 TV-grab). The lithologies encountered at each station were different:

- Samples from the western scarp (STN 88) were dense to vesicular aphyric basalt. A few were pervasively altered, with clay developed along pull-apart structures and associated with traces of pyrrhotite.
- At the central scarp (STN 89), samples consisted of pervasively altered pyroxene basalt. Clay was developed along the joints, and again associated with traces of pyrrhotite.
- Samples recovered from the southern scarp (STN 90) represent a complex series of plagioclase-phyric lavas, ranging from vesicular to dense, 5 % plagioclase phenocrysts up to 1.5 mm long to 25 % plagioclase phenocrysts up to 3 mm long, weakly weathered to deeply weathered, and with vesicles partly filled by calcite, chlorite, serpentinite, or ferruginous clays. At this station, hyaloclastite and a covering sequence of gritty sedimentary rocks (sandy claystone, sandy siltstone) were also recovered. Two blocks of massive serpentinite without relic textures were also recovered from the southern scarp, and may represent altered dunite or peridotite.

Overall, the rocks recovered from Coiba Ridge and the new bathymetric data suggest the ridge is more likely to represent an uplifted block of oceanic crust than a part of Cocos Ridge. The uplift may have been associated with an increase in heat flow that allowed hydrothermal cells to develop, leading to the widespread pervasive alteration and pyrrhotite mineralisation.

4.8 SUMMARY AND PRELIMINARY RESULTS

Rock sampling during SO 144-3 yielded a wide spectrum of volcanic rocks from all designated working areas. The results are summarised in Table 4.2. A series of observations and some provisional conclusions can be drawn from the petrography of the dredge and TV-grab samples:

- There is a general progression across Carnegie Ridge from olivine-bearing lavas outcropping on the southern margin to feldspar-bearing lavas outcropping along the northern margin.
- There is a general progression across Cocos Ridge from olivine- and pyroxene-bearing lavas outcropping along the NW margin to plagioclase-bearing lavas outcropping along the SE margin. This is a mirror image of the changes observed across Carnegie Ridge.
- Outcrops of gabbro occur in a 100 km wide-band along the SE margin of Cocos Ridge, and may be interpreted as crustal sections exposed by faulting. Thus, crustal extension and rifting across the original plume-generated ridge may have occurred in a wide deformation zone and was not localised along a single structure.

Table 4.2: Station and sampling statistics

Area	No. Stations	No. Successful	No. Rock Samples
Malpelo Ridge	7	6	121
Failed Rift	1	1	5
Carnegie Ridge	20	10	122
Cocos Ridge	54	51	827
Cocos Island			41
Fisher Ridge	1	1	28
Continental slope	1	1	20
Coiba Ridge	3	3	61
Total	87	73	1225

- Although lavas from Cocos Island are known to be anomalously young, samples recovered from the vicinity of Cocos Island do not differ from those found elsewhere along the NW 100 km-wide margin of Cocos Ridge. If a second mantle plume is currently located in this area, its effects appear to be minor.
- Feldspar-bearing rocks are prevalent along the NW margin of Malpelo Ridge, and there is evidence that much of the NW half of the ridge was high-standing or emergent. These results are consistent with rifting from Cocos Ridge, but difficult to reconcile with rifting from Carnegie Ridge.
- Pervasively altered lavas outcrop on Coiba Ridge. Coiba Ridge may be an uplifted area of oceanic crust, and is possibly unrelated to any other ridges in the region. The uplift may reflect an underplating event or passage over a thermal anomaly.
- Lavas and gabbroic rocks outcrop on Fisher Ridge, suggesting that the ridge is probably unrelated to any other ridges in the region and supporting models in which Fisher Ridge is formed by uplift of oceanic crust.
- Samples recovered from most stations varied from fresh to deeply weathered, and olivine in olivine-bearing lavas at any station ranged from fresh to completely pseudomorphed by iddingsite. Thus, petrographic observations yield no evidence of age variation along any of the ridges.

5. BIOLOGY

Peter Götz and Birger Neuhaus

5.1 INTRODUCTION

Biologists have described 1.6–1.8 million species on Earth, including some 160,000 marine species (Gage, 1997). Although marine environments have been studied intensely for more than 150 years, knowledge of deep-sea organisms, their evolution, and their ecology is still poor. About half the number of species recovered from any deep-sea site are new to science (Grassle, 1989; Grassle and Maciolek, 1992). Only 500 m^2 of the 270 million km^2 ocean floor has been sampled quantitatively for macrofauna, and less than 1 m^2 has been investigated quantitatively for microscopic animals (= meiofauna) (Gage, 1997).

The deep-sea represents one of the oldest environments on Earth. It might be expected that those species which are "original" in an evolutionary sense will be found predominantly in the deep-sea. However, few "original" species have been recorded from deep-sea environments because of climatic changes, such as the cooling of the oceans in the early Oligocene and migration of "modern" species from shallow waters into the deep-sea. This process has lead to an exchange of the species composition in the deep-sea. The steep thermocline has probably been responsible for an increased isolation of species. Phylogenetic studies of the Isopoda (Crustacea) support these hypotheses; for example, the deep-sea Janiroidea constitute an "original" group with many species and very specialized biology, whereas the Arcturidae, Serolidae, and Anthuridae are phylogenetically younger, have less specialized biology, and are represented by few species in the deep-sea (Wägele, 1994). Regional differences in the biodiversity of the deep-sea may be influenced, at least in part, by the geological history of the area. A phylogenetic analysis of the organisms recovered from the deep-sea may clarify whether their closest related species live in the deep-sea or on the continental shelf. This phylogenetic data may also be correlated with geological data.

For many species of most marine groups, biogeographic data is missing or incomplete at best. This statement is valid both for macrofaunal organisms (Rex et al., 1997) and for microscopic animals such as the Kinorhyncha (Higgins, 1983; Higgins and Kristensen, 1988). Even if the group is mentioned in ecological articles on deep-sea benthos, specimens have rarely been identified to species level (Dinet, 1979; Meadows et al., 1994; Thistle et al., 1985; Vincx et al., 1994; Vanhove et al., 1995). Rex and co-workers (Rex et al., 1997: p.94) summarize the dilemma most marine biologists find themselves in: "A complete understanding of diversity must incorporate the influence

of historical, biogeographic and oceanographic processes that are imposed at much larger scales".

Two biologists were invited to participate in SO 144-3 in order to qualitatively sample both meiofaunal and macrofaunal organisms and survey the animal life on several submarine ridges between the coasts of Costa Rica, Panamá, and Ecuador, and the Galápagos Islands. In an interdisciplinary approach with the geologists, the aim was to shed light on the evolution of the Pacific Central America area. Follow-up studies should compare the faunal composition of the ridges with that of neighbouring abyssal basins, isolated islands, and the continental shelf.

5.2 METHODS

Biological specimens were obtained in several ways:

1) Sediment sampled by two tubes (length: 21 cm, diameter: 4 cm) inside the chain-sack dredge was emptied into a bucket with water. In order to check for cuticle-covered microscopic animals, organisms were extracted by the bubble and blot technique and viewed under a stereo microscope. Specimens of Tanaidacea, Amphipoda, Copepoda (all crustaceans), Gastrotricha, Kinorhyncha, Halacarida, Bryozoa, and other groups were isolated in Eppendorf cups and preserved. Further samples of meiofauna were extracted from 72 sediment probes by the stir and decant method, generally followed by anaethetization of the samples with a solution of 6 % $MgCl_2$.
2) Rocks recovered with the chain-sack dredge, as well as the dredge itself, were inspected carefully for macroscopic animals immediately after retrieval. Specimens were removed using a scalpel and forceps, or excavated from crevices with a hammer and chisel. Individual animals and the distribution of organisms on the rocks were photographically documented with a macro lens (if applicable). Specimens were identified to group, and sometimes to species, level using a stereo microscope or a compound microscope. In addition, organisms were documented by video sequences and by video prints. These prints were arranged as a photographic atlas giving detailed collection data.
3) Occasionally, a meiofauna dredge (after Higgins) was attached to the chain-sack dredge in order to sample a larger amount of sediment. This combination worked adequately after some modifications to the meiofauna dredge and the sampling sack.
4) The ocean floor and seamount plateaux were inspected by the TV-grab on 15 transects ranging from 100–500 m in length. The TV images were recorded on video

tape. The tapes were analyzed later for the structure of the ocean floor, the structure of the benthic animal community, and the density of inhabitation of the organisms. A 17-minute summary video film was produced from the original video material (which is of 22 hours duration). The TV images repeatedly revealed rocks with epifauna, sediment, or both. Recovered material was treated as described in (1) and (2).

5) Additional organisms were sampled during the recovery of the 14 OBS units by scientists from the Scripps Institution of Oceanography. Some OBS that had been deployed in shallow water (<500 m) were covered by epifauna, and contained mud (including microscopic animals) and macroscopic animals in the crevices and cavities of the hydrophones (Appendix 4).

All specimens were preserved for later studies by immediate immersion in 4 % formaldehyde buffered at pH = 7 by buffer tablets used for haematology (Merck).

5.3 INITIAL RESULTS AND DISCUSSION

The samples from the dredge and TV-grab stations revealed species from almost all marine groups of the animal kingdom, and demonstrated the diversity of animal life on several submarine ridges and seamounts between the coasts of Costa Rica, Panamá, and Ecuador, and the Galápagos Islands. The 261 vials (Appendix 4) contain approximately 1300 specimens for further scientific analysis. About 240 specimens of the meiofauna were isolated immediately after collection. Further samples of meiofauna were extracted from 72 muddy sediment probes by the stir and decant method and preserved. From these samples, additional specimens of microscopic animals may be extracted by other techniques (e.g., density gradient centrifuging).

The video tapes recorded at the 15 TV-grab stations were especially valuable, because they demonstrate: (1) how much the ocean floor differs in structure between stations, (2) how heterogeneous the benthic fauna was at the different sites, and (3) that only a limited spectrum of the often rich epibenthic fauna was sampled. Occasionally, extensive pillow lava fields were seen to be densely inhabited by surface fauna, but these were difficult to probe. Material from large sediment covered areas yielded few macroscopic and microscopic species, or individuals, but was much easier to obtain with the TV-grab. Considerably fewer microscopic animals were found on Carnegie Ridge in comparison to Malpelo Ridge, but Carnegie Ridge samples did contain a much broader spectrum of larger animals. Species seen on the videos of the 15 TV-grab

stations were later identified when specimens of them were recovered at other stations.

Due to the limited number of specimens collected from any single animal group, biogeographical and evolutionary questions can only be answered for the Porifera, Bryozoa, and Brachiopoda. The occurrence of Kinorhyncha on both the continental shelf and at 9 sites on various submarine ridges may allow us to investigate whether species from the deep-sea are endemic to the deep-sea, and whether shallow water Kinorhynchs are identical to deep-sea Kinorhynchs. Specimens of Nematoda, Copepoda, and other groups will be forwarded to specialists of these groups for proper identification. It is possible that the Nematoda will also be a good candidate for analyzing biogeographical and evolutionary questions.

During the expedition it was often extremely difficult to recover enough organisms in undamaged condition for meaningful scientific analysis. Macrofaunal specimens of all sizes often suffered from severe abrasion in the chain-sack dredge. Such specimens may be impossible to identify. Smaller macrofauna simply passed through the holes in the chain-sack of the dredge. The TV-grab proved far more successful for collecting macrofauna from essentially untouched rocks or in sediment.

Generally, low numbers of meiofauna were collected by the two tubes inside the chain-sack dredge. Once the chain-sack dredge hit the ocean floor, it probably sank into the sediment with immediate filling of the tubes by the substrate. Since only the upper few millimeters of deep-sea sediment are inhabited by meiofauna, only a small amount of this meiofauna-rich material could be captured by the tubes. Sediment layers sampled by the TV-grab were considerably distorted while the grab closed. Subsequently, a varying amount of the top substrate layer was washed out during the grab's passage through the water column. The built-in TV camera allowed us to observe these processes. A box corer would do a much better job of recovering the sediment layers, including meiofauna, in an undisturbed condition.

It would be very useful for biologists if extensive use of the TV-grab and a box corer were made on submarine ridges during future interdisciplinary collaborative expeditions involving biologists and geologists. Depending on the goals of such expeditions, it may be very useful to include biological sampling both in abyssal basins and on the continental shelf or islands neighbouring the submarine ridges. For that purpose, it is suggested that biological sampling be accomplished with a (TV-)box corer and with a specific (meiofauna) dredge.

In summary, the participation of biologists on SO 144-3 is considered very worthwhile. As a result, precious biological material recovered during the normal course of geological sampling was collected and preserved for further scientific analysis. The material is open to interested scientists worldwide on request and, in

addition, sub-samples will be given to highly respected experts known by Peter Götz and Birger Neuhaus. Type samples for new species will be deposited in the Museum für Naturkunde (Berlin) according to the 4th edition of the rules of the International Commission on Zoological Nomenclature. However, a conclusive statement about the real biological value of the SO 144-3 samples can only be made after the specimens have been thoroughly studied by different taxonomists.

6. OCEAN BOTTOM SEISMOMETERS AND FLUXMETERS

LeRoy Dorman, Sharon Escher, Russell Johnson, Alan Sauter and Mike Tryon

The geophysicists from the Scripps Institution of Oceanography completed three tasks during SO 144-3b: (1) recovery of 14 Ocean Bottom Seismometers (OBS) set down to the NW of the Osa Peninsula during the earlier SO 144-1a cruise in September 1999, (2) recovery of the 7 seafloor fluid fluxmeters set down at the same time and in the same area as the OBS units, and (3) refurbishment and re-deployment of the 14 OBS units off the Nicoya Peninsula (Table 6.1; Fig. 6.1). The OBS units will be recovered during June 2000 on a cruise of the RV *Melville*.

The instrument recovery was uneventful, and all OBS units and fluxmeters were recovered over two days. Most instruments returned data of excellent quality. Figure 6.2 shows several representative seismograms from the Oaxaca (Mexico City) earthquake of 30 September 1999. The top traces are data from OBS units using conventional 1 Hz Mark Products geophones, and the lower traces are from instruments equipped with broadband electrolytic sensors from Precision Measurement Devices. The broadband instruments have a low-frequency corner frequency of 0.03 Hz compared to 1 Hz for the Mark Products sensors. This additional bandwidth at the low-frequency end of the spectrum makes these instruments better for earthquake moment determinations, which require extrapolation of the source spectrum to zero frequency.

An airgun shooting program was carried out by BGR for the first deployment (SO 144-1a), so the instruments with Mark Products sensors were programmed to sample at 128 Hz. For the Nicoya deployment, all OBS units were set to sample at 64 Hz, which should almost fill the 9 Gb storage capacity of the OBS units during the planned 6 month recording period.

Table 6.1: OBS positions and water depths

Site	Frame	Latitude (N)	Longitude (W)	Depth (meters)
s1	f14	9°30.018'	86°11.996'	3699
s2	f4	9°34.530'	86°02.393'	3416
s3	f3	9°41.964'	86°09.557'	3762
s4	f15	9°42.004'	86°17.907'	4135
s5	f8	9°52.522'	86°11.991'	3103
s6	f5	9°47.022'	86°01.500'	2375
s7	f10	9°41.016'	85°56.539'	2299
s8	f1	9°43.197'	85°45.689'	1276
s9	f6	9°50.418'	85°54.002'	1465
s10	f12	9°56.998'	85°59.975'	1305
s11	f11	10°03.018'	85°54.022'	420
s12	f2	9°55.219'	85°48.004'	229
s13	f9	9°49.802'	85°40.804'	102
s14	f7	9°45.007'	85°32.996'	108

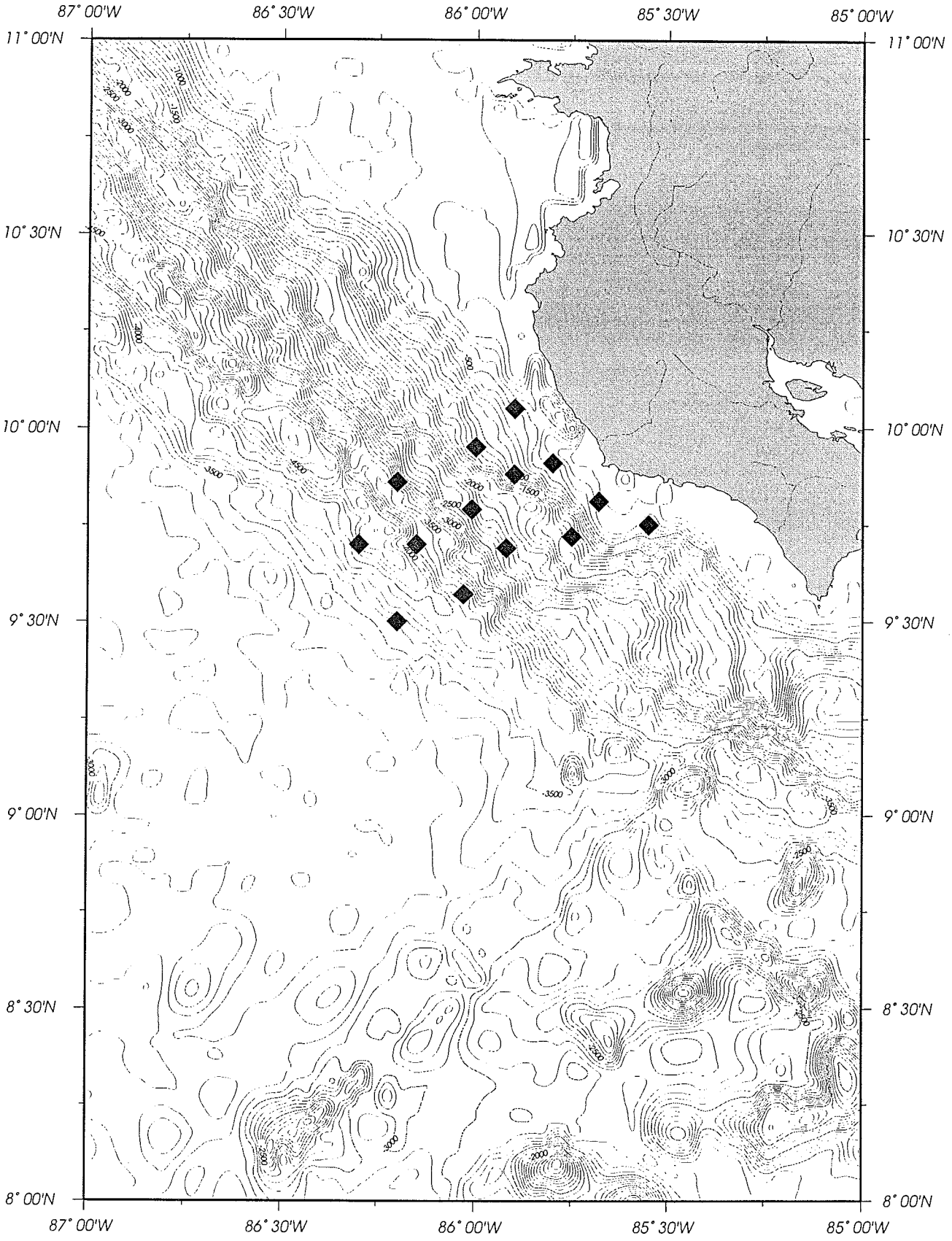


Fig. 6.1: OBS drop positions off the Nicoya Peninsula, Costa Rica

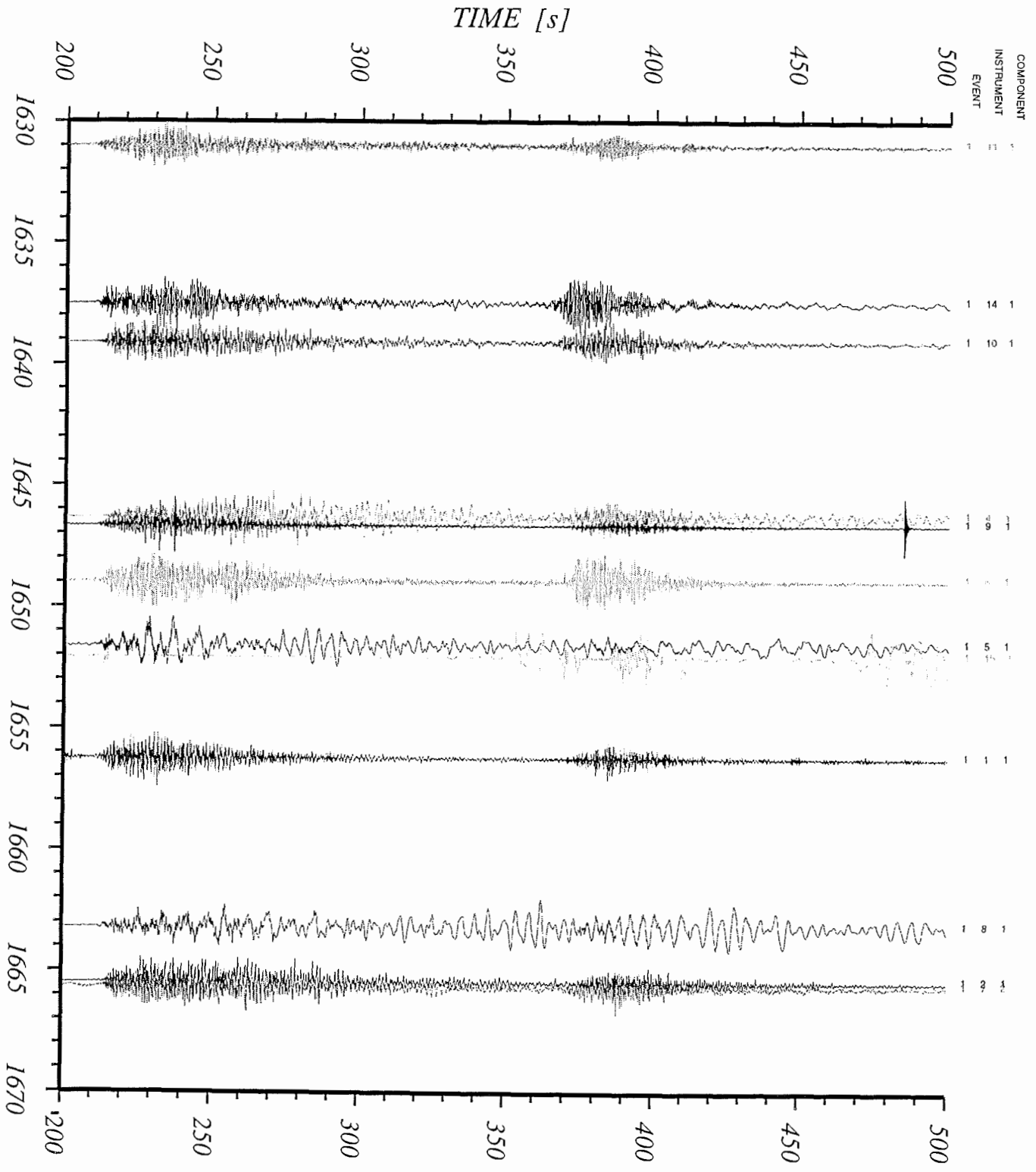


Fig. 6.2: OBS record of the Oaxaca earthquake of 30 September 1999. Two OBS did not initialize properly (no data), and the OBS at site 15 had a malfunction in its fast gain-ranging circuit (recovering true amplitudes will require hand editing of the data). Compressional arrivals occur at ~210 secs and shears at ~370 secs. OBS at sites 4, 5, 8, 10, 14 and 15 had broadband sensors.

REFERENCES

Alvarado, G., Denyer, P. and Sinton, C., 1997. The 89 Ma Tortugal komatiitic suite, Costa Rica: implications for a common geological origin of the Caribbean and Eastern Pacific region from a mantle plume. Geology 25: 439–442.

Bellon, H., Saenz, R. and Tournon, J., 1983. K-Ar radiometric ages of lavas from Cocos Island (eastern Pacific). Mar. Geol. 54: 17–23.

Cande, S.C. and Kent, D.V., 1995. Revised calibration of the geomagnetic polarity time scale for the Late Cretaceous and Cenozoic. J. Geophys. Res. 100: 6093–6096.

Caress, D.W. and Chayes, D.N., 1996. Improved processing of HYDROSWEEP DS multi-beam data on the R/V *Maurice Ewing*. Mar. Geophys. Res. 18: 631–650.

Castillo, P., Batiza, R., Vanko, D., Malavassi, E., Barquero, J. and Fernandez, E., 1988. Anomalously young volcanoes on old hot-spot traces: I. Geology and Petrology. Geol. Soc. Am. Bull. 100: 1400–1414.

Chen, C.Y. and Frey, F.A., 1985. Trace element and isotopic geochemistry of lavas from Haleakala volcano, East Maui, Hawaii: implications for the origin of Hawaiian basalts. J. Geophys. Res. 90: 8743–8768.

Christie, D.M., Duncan, R.A., McBirney, A.R., Richards, M.A., White, W.M., Harpp, K.S. and Fox, C.G., 1992. Drowned islands downstream from the Galápagos hotspot imply extended speciation times. Nature 355: 246–248.

Clague, D.A., 1987. Hawaiian alkaline volcanism. In: Fitton, J.G. and Upton, B.G.J. (eds), Alkaline Igneous Rocks. Geol. Soc. Spec. Pub. 30: 227–252.

Clague, D.A. and Dalrymple, G.B., 1987. The geology of the Hawaiian–Emperor volcanic chain. U.S. Geol. Surv. Prof. Paper 1350: 5–49.

Dinet, A., 1979. A quantitative survey of meiobenthos in the deep Norwegian sea. Ambios Spec. Rept. 6: 75–77.

Duncan, R. and Hargraves, R., 1984. Plate-tectonic evolution of the Caribbean region in the mantle reference frame. In: Bonini, W., Hargraves, R. and Shangani, R. (eds), The Caribbean: South American Plate Boundary and Regional Tectonics. Geol. Soc. Am. Mem. 162: 81–93.

Gage, J.D., 1997. High benthic species diversity in deep-sea sediments: the importance of hydrodynamics. In: Ormond, R.F.G., Gage, J.D. and Angel, M.V. (eds), Marine Biodiversity. Patterns and Processes. Cambridge University Press, Cambridge: 148–177.

Gardner, T.W., Verdonck, D., Pinter, N.M., Slingerland, R., Furlong, K.P., Bullard, T.F. and Wells, S.G., 1992. Quaternary uplift astride the aseismic Cocos Ridge, Pacific coast, Costa Rica. Geol. Soc. Am. Bull. 104: 219–232.

Geist, D.J., White, W.M. and M^{c}Birney, A.R., 1988. Plume-asthenosphere mixing beneath the Galápagos Archipelago. Nature 333: 657–660.

Graham, D.W., Christie, D.M., Harpp, K.S. and Lupton, J.E., 1993. Mantle plume helium in submarine basalts from the Galápagos platform. Science 262: 2023–2026.

Grassle, J.F., 1989. Species diversity in deep-sea communities. Tree 4: 12–15.

Grassle, J.F. and Maciolek, N.J., 1992. Deep-sea species richness: regional and local diversity estimates from quantitative bottom samples. Am. Naturalist 139: 313–341.

Hardy, N.C., 1991. Tectonic evolution of the easternmost Panamá Basin: some new data and interferences. J. Am. Earth Sci. 4: 291–296.

Hauff, F., Hoernle, K., Schmincke, H.-U. and Werner, R., 1997. A mid-Cretaceous origin for the Galápagos hotspot: volcanological, petrological, and geochemical evidence from Costa Rican oceanic crustal segments. Geol. Rdsch. 86: 141–155.

Hauff, F., Hoernle, K., Tilton, G., Graham, D. and Kerr, A.C., 2000. Large volume recycling of oceanic lithosphere: geochemical evidence from the Caribbean Large Igneous Province. Earth Planet. Sci. Lett. 174: 247–263.

Heath, G.R. and van Andel, T.H., 1973. Tectonics and sedimentation in the Panamá basin: geologic results of Leg 16, DSDP. Washington D.C., U.S. Govt. Print. Off.: 899–913.

Hey, R., 1977. Tectonic evolution of the Cocos–Nazca spreading center. Geol. Soc. Am. Bull. 88: 1404–1420.

Hey, R., Johnson, G.L. and Lowrie, A., 1977. Recent plate motions in the Galápagos area. Geol. Soc. Am. Bull. 88: 1385–1403.

Higgins, R.P., 1983. The Atlantic barrier reef ecosytem at Carrie Bow Cay, Belize, II: Kinorhyncha. Smithson. Contrib. Mar. Sci. 18: 1–131.

Higgins, R.P. and Kristensen, R.M., 1988. Kinorhyncha from Disko Island, West Greenland. Smithson. Contrib. Zool. 458: 1–56.

Hoernle, K., Werner, R., Morgan, J., Garbe-Schönberg, D. and Bryce, J., 2000. Existence of complex spatial zonation in the Galápagos plume for at least 14 m.y. Geology in press.

Holden, J.C. and Dietz, R.S., 1972. Galápagos Gore, NazCoPac Triple Junction and Carnegie/Cocos Ridges. Nature 235: 266–269.

Ito, G.T. and Lin, J., 1995. Mantle temperature anomalies along the present and paleoaxes of the Galápagos spreading center as inferred from gravity analyses. J. Geophys. Res. 100: 3733–3745.

Lonsdale, P. and Klitgord, K.D., 1978. Structure and tectonic history of the eastern

Panamá Basin. Geol. Soc. Am. Bull. 89: 981–999.

Meadows, P.S., Reichelt, A.C., Meadows, A. and Waterworth, J.S., 1994. Microbial and meiofaunal abundance, redox potential, pH and shear strength profiles in deep sea Pacific sediments. J. Geol. Soc. 151: 377–390.

Meschede, M., Barckhausen, U. and Worm, H.-U., 1997. The abandoned spreading system of the Cocos and Malpelo Ridges in the Eastern Pacific. EOS Trans. AGU Fall Meeting, Suppl. V78, N46:F721.

Meschede, M., Barckhausen, U. and Worm, H.-U., 1998. Extinct spreading on the Cocos Ridge. Terra Nova 10: 211–216.

Morgan, W.J., 1971. Convection plumes in the lower mantle. Nature 230: 42–43.

Morgan, W.J., 1978. A second type of hotspot island. J. Geophys. Res. 83: 5355–5360.

Pennington, W.D., 1981. Subduction of the eastern Panamá Basin and seismotectonics of northwestern South America. J. Geophys. Res. 86: 10753–10770.

Rex, M.A., Etter, R.J. and Stuart, C.T., 1997. Large-scale patterns of species diversity in the deep-sea benthos. In: Ormond, R.F.G., Gage, J.D. and Angel, M.V. (eds), Marine Biodiversity. Patterns and Processes. Cambridge University Press, Cambridge: 94–121.

Richards, M., Duncan, R. and Courtillot, V., 1989. Flood basalts and hotspot tracks: plume heads and tails. Science 246: 103–107.

Schilling, J.-G., 1973. Iceland mantle plume. Nature 246: 141–143.

Schreiber, R. and Schencke, H.W., 1990. Efficient hydrographic surveying of EEZ with new multibeam echosounder technology for shallow and deep water. Ocean Resources 1: 73–87.

Sinton, C.W., Duncan, R.A. and Denyer, P., 1997. Nicoya Peninsula, Costa Rica; a single suite of Caribbean oceanic plateau magmas. J. Geophys. Res. 102: 15507–15520.

Smith, W.H.F. and Sandwell, D.T., 1997. Global seafloor topography from satellite altimetry and ship depth soundings. Science 277: 1956–1962.

Spieβ, V., 1993. PARASOUND Digitalisierungs- und Mehrkanal Auswertesystem. Uni. Bremen, 199 pp.

Thistle, D., Yingst, J.Y. and Fauchald, K., 1985. A deep-sea community exposed to strong near-bottom currents on the Scotian Rise (Western Atlantic). Mar. Geol. 66: 91–112.

Vanhove, S., Wittoeck, J., Desmet, G., Berghe, B.vd., Herman, R.L., Bak, R.P.M., Nieuwland, G., Vosjan, J.H., Boldrin, A., Rabitti, S. and Vincx, M., 1995. Deep-sea meiofauna communities in Antarctica: structural analysis and relation with the environment. Mar. Ecol. Progr. Ser. 127: 65–76.

Vincx, M., Bett, B.J., Dinet, A., Ferrero, T., Gooday, A.J., Lambshead, P.J.D., Pfannkuche, O., Soltwedel, T. and Vanreusel, A., 1994. Meiobenthos of the deep northeast Atlantic. Adv. Mar. Biol. 30: 1–88.

von Huene, R., Bialas, E., Flüh, E.R., Cropp, B., Csernok, T., Fabel, E., Hoffmann, J., Emeis, K., Holler, P., Jeschke, G., Leandro, C., Peréz Fernandéz, I., Chavarria, S., Florez, A., Escobedo, Z., León, R. and Barrios, O., 1995. Morphotectonics of the Pacific convergent margin of Costa Rica. In: Mann, P. (ed), Geologic and Tectonic Development of the Caribbean Plate Boundary in Southern Central America. Geol. Soc. Am., Spec. Pap. 295: 291–307.

Wägele, J.-W., 1994. Notes on Antarctic and South American Serolidae. Zool. Jb. Syst. 121: 3–69.

Werner, R., Hoernle, K., Bogaard, P.vd., Ranero, C., Huene, R.v. and Korich, D., 1999. Drowned 14-m.y.-old Galápagos Archipelago off the coast of Costa Rica: implications for tectonic and evolutionary models. Geology 27: 499–502.

Wessel, P. and Smith, W.H.F., 1995. The Generic Mapping Tools (GMT) version 3.0. Technical Reference Cookbook, SOEST/NOAA.

White, W.M. and Hofmann, A.W., 1978. Geochemistry of the Galápagos Islands: Implications for Mantle Dynamics and Evolution. Carnegie Inst. Washington, pp. 596–606.

White, W.M., M°Birney, A.R. and Duncan, R.A., 1993. Petrology and geochemistry of the Galápagos Islands: portrait of a pathological mantle plume. J. Geophys. Res. 98: 19533–19563.

Wilson, D.S. and Hey, R.N., 1995. History of rift propagation and magnetization intensity for the Cocos–Nazca spreading center. J. Geophys. Res. 100: 10041–10056.

Appendices

Title		Date (UTC)	Time (UTC)	Longitude [ ]	Latitude [˚]	Depth	Profile	Magnetik			Hydrosweep		
Profile 1	Start	10.11.1999	1:17	-84.74990 W	9.41875 N	317m	HS/PS/Mag	-84.7499	9.41875	256.35	-84.7499	9.41875	256.35
	End	10.11.1999	14:20	-83.25530 W	7.66140 N	1621m		-83.2553	7.6614		-83.2553	7.6614	
Profile 2	Start	10.11.1999	15:14	-83.24073 W	7.64838 N	1676m	HS/PS/Mag	-83.24073	7.64838	400.93	-83.24073	7.64838	400.93
	End	11.11.1999	10:45	-80.63458 W	5.15310 N	2560m		-80.63458	5.1531		-80.63458	5.1531	
Profile 2b	Start	11.11.1999	15:02	-80.65206 W	5.16140 N	2039m	HS/PS	-80.65206	5.1614		-80.65206	5.1614	81.49
	End	11.11.1999	19:49	-81.38371 W	5.11171 N	3511m		-81.38371	5.11171		-81.38371	5.11171	
Profile 3	Start	11.11.1999	23:40	-81.40564 W	5.05380 N	1908m	HS/PS/Mag	-81.40564	5.0538	85.77	-81.40564	5.0538	85.77
	End	12.11.1999	3:36	-80.90450 W	4.46670 N	901m		-80.9045	4.4667		-80.9045	4.4667	
Profile 4	Start	12.11.1999	13:43	-80.71090 W	4.55883 N	914m	HS/PS/Mag	-80.7109	4.55883	78.89	-80.7109	4.55883	78.89
	End	12.11.1999	17:50	-81.26775 W	4.11841 N	1744m		-81.26775	4.11841		-81.26775	4.11841	
Profile 5	Start	12.11.1999	20:41	-81.29544 W	4.16097 N	991m	HS/PS/Mag	-81.29544	4.16097	67.03	-81.29544	4.16097	67.03
	End	13.11.1999	0:15	-81.87172 W	4.33916 N	3188m		-81.87172	4.33916		-81.87172	4.33916	
Profile 6	Start	13.11.1999	4:54	-81.88074 W	4.30446 N	2220m	HS/PS/Mag	-81.88074	4.30446	365.77	-81.88074	4.30446	365.77
	End	13.11.1999	21:34	-82.29326 W	1.03870 N	3527m		-82.29326	1.0387		-82.29326	1.0387	
Profile 7	Start	14.11.1999	5:54	-82.21088 W	1.03152 N	3131m	HS/PS/Mag	-82.21088	1.03152	105.34	-82.21088	1.03152	105.34
	End	14.11.1999	12:42	-82.14460 W	0.08590 N	2368m		-82.1446	0.0859		-82.1446	0.0859	
Profile 8	Start	15.11.1999	0:10	-82.11854 W	0.06890 N	1376m	HS/PS/Mag	-82.11854	0.0689	82.62	-82.11854	0.0689	82.62
	End	15.11.1999	4:08	-81.44944 W	0.39315 N	2422m		-81.44944	0.39315		-81.44944	0.39315	
Profile 9	Start	15.11.1999	7:55	-81.46244 W	0.39579 N	2275m	HS/PS/Mag	-81.46244	0.39579	109.92	-81.46244	0.39579	109.92
	End	15.11.1999	13:10	-81.99144 W	-0.44007 S	1289m		-81.99144	-0.44007		-81.99144	-0.44007	
Profile 10	Start	15.11.1999	16:06	-81.99341 W	-0.42857 S	1234m	HS/PS/Mag	-81.99341	-0.42857	88.92	-81.99341	-0.42857	88.92
	End	15.11.1999	20:16	-82.24995 W	-1.18659 S	1500m		-82.24995	-1.18659		-82.24995	-1.18659	
Profile 11	Start	15.11.1999	23:27	-82.25044 W	-1.18050 S	1386m	HS/PS/Mag	-82.25044	-1.1805	84.74	-82.25044	-1.1805	84.74
	End	16.11.1999	3:21	-81.91289 W	-1.86432 S	2068m		-81.91289	-1.86432		-81.91289	-1.86432	
Profile 12	Start	16.11.1999	6:42	-81.92544 W	-1.84980 S	1923m	HS/PS/Mag	-81.92544	-1.498	109.16	-81.92544	-1.498	109.16
	End	16.11.1999	9:55	-81.62834 W	-2.43439 S	1975m		-81.62834	-2.43439		-81.62834	-2.43439	
Profile 13	Start	16.11.1999	17:02	-81.62347 W	-2.43987 S	2389m	HS/PS/Mag	-81.62347	-2.43987	111.54	-81.62347	-2.43987	111.54
	End	16.11.1999	22:11	-82.58447 W	-2.14980 S	2487m		-82.58447	-2.1498		-82.58447	-2.1498	
Profile 14	Start	17.11.1999	1:12	-82.62630 W	-2.16543 S	2117m	HS/PS/Mag	-82.6263	-2.16543	117.65	-82.6263	-2.16543	117.65
	End	17.11.1999	7:08	-83.68344 W	-2.22376 S	2397m		-83.68344	-2.22376		-83.68344	-2.22376	
Profile 15	Start	17.11.1999	9:46	-83.70059 W	-2.22518 S	2062m	HS/PS/Mag	-83.70059	-2.22518	80.87	-83.70059	-2.22518	80.87
	End	17.11.1999	13:50	-84.42722 W	-2.26571 S	2424m		-84.42722	-2.26571		-84.42722	-2.26571	
Profile 16	Start	17.11.1999	17:05	-84.43577 W	-2.24680 S	1750m	HS/PS/Mag	-84.43577	-2.2468	63.2	-84.43577	-2.2468	63.2
	End	17.11.1999	20:07	-84.30765 W	-1.69269 S	1893m		-84.30765	-1.69269		-84.30765	-1.69269	
Profile 17	Start	17.11.1999	22:27	-84.30687 W	-1.67719 S	1913m	HS/PS/Mag	-84.30687	-1.67719	46.58	-84.30687	-1.67719	46.58

Title		Date (UTC)	Time (UTC)	Longitude [ ]	Latitude [°]	Depth	Profile	Magnetik			Hydrosweep		
	End	18.11.1999	0:33	-84.14827 W	-1.28917 S	1778m		-84.14827	-1.28917		-84.14827	-1.28917	
Profile 18	Start	18.11.1999	3:44	-84.16802 W	-1.29802 S	1621m	HS/PS/Mag	-84.16802	-1.29802	71.14	-84.16802	-1.29802	71.14
	End	18.11.1999	6:50	-84.16656 W	-0.65777 S	2573m		-84.16656	-0.65777		-84.16656	-0.65777	
Profile 19	Start	18.11.1999	13:54	-84.05525 W	-0.70603 S	2402m	HS/PS/Mag	-84.05525	-0.70603	90.5	-84.05525	-0.70603	90.5
	End	18.11.1999	18:02	-83.81727 W	0.07283 N	2673m		-83.81727	0.07283		-83.81727	0.07283	
Profile 20	Start	19.11.1999	2:40	-83.78313 W	0.11829 N	2583m	HS/PS/Mag	-83.78313	0.11829	106.56	-83.78313	0.11829	106.56
	End	19.11.1999	7:32	-84.51667 W	0.73599 N	3315m		-84.51667	0.73599		-84.51667	0.73599	
Profile 21	Start	19.11.1999	13:59	-84.52324 W	0.71069 N	3011m	HS/PS/Mag	-84.52324	0.71069	122.15	-84.52324	0.71069	122.15
	End	19.11.1999	19:39	-84.96939 W	-0.29395 S	1617m		-84.96939	-0.29395		-84.96939	-0.29395	
Profile 22	Start	19.11.1999	23:15	-84.97783 W	-0.31486 S	1623m	HS/PS/Mag	-84.97783	-0.31486	60.33	-84.97783	-0.31486	60.33
	End	20.11.1999	20:15	-85.10687 W	-0.84223 S	2560m		-85.10687	-0.84223		-85.10687	-0.84223	
Profile 23	Start	20.11.1999	4:47	-85.11562 W	-0.86271 S	2189m	HS/PS/Mag	-85.11562	-0.86271	162.02	-85.11562	-0.86271	162.02
	End	20.11.1999	12:25	-85.91722 W	-2.08060 S	2755m		-85.91722	-2.0806		-85.91722	-2.0806	
Profile 24	Start	20.11.1999	17:23	-85.93017 W	-2.06179 S	2188m	HS/PS/Mag	-85.93017	-2.06179	679.52	-85.93017	-2.06179	679.52
	End	21.11.1999	2:27	-90.78986 W	1.65025 N	2308m		-90.78986	1.65025		-90.78986	1.65025	
Profile 25	Start	22.11.1999	3:53	-90.79486 W	1.59215 N	2707m	HS/PS/Mag	-90.79486	1.59215	176.11	-90.79486	1.59215	176.11
	End	22.11.1999	11:39	-91.11244 W	3.14485 N	2228m		-91.11244	3.14485		-91.11244	3.14485	
Profile 26	Start	22.11.1999	15:15	-91.10255 W	3.14259 N	2438m	HS/PS/Mag	-91.10255	3.14259	47.1	-91.10255	3.14259	47.1
	End	22.11.1999	17:39	-90.70531 W	3.29038 N	2192m		-90.70531	3.29038		-90.70531	3.29038	
Profile 27	Start	22.11.1999	23:43	-90.59900 W	3.46209 N	1196m	HS/PS/Mag	-90.599	3.46209	159.71	-90.599	3.46209	159.71
	End	23.11.1999	7:00	-89.22627 W	3.88806 N	1401m		-89.22627	3.88806		-89.22627	3.88806	
Profile 28	Start	23.11.1999	9:02	-89.22204 W	3.87894 N	1111m	HS/PS/Mag	-89.22204	3.87894	79.65	-89.22204	3.87894	79.65
	End	23.11.1999	12:56	-88.92296 W	3.22755 N	840m		-88.92296	3.22755		-88.92296	3.22755	
Profile 29	Start	23.11.1999	16:00	-88.92298 W	3.26854 N	1137m	HS/PS/Mag	-88.92298	3.26854	57.83	-88.92298	3.26854	57.83
	End	23.11.1999	18:46	-88.40832 W	3.34594 N	1976m		-88.40832	3.34594		-88.40832	3.34594	
Profile 30	Start	24.11.1999	4:42	-88.30308 W	3.36554 N	1090m	HS/PS/Mag	-88.30308	3.36554	81.36	-88.30308	3.36554	81.36
	End	24.11.1999	8:45	-88.00721 W	2.69581 N	2324m		-88.00721	2.69581		-88.00721	2.69581	
Profile 31	Start	24.11.1999	16:13	-88.02490 W	2.81938 N	1904m	HS/PS/Mag	-88.0249	2.81938	65.83	-88.0249	2.81938	65.83
	End	24.11.1999	19:29	-87.49108 W	2.56246 N	2501m		-87.49108	2.56246		-87.49108	2.56246	
Profile 32	Start	24.11.1999	23:43	-87.47394 W	2.59331 N	3298m	HS/PS/Mag	-87.47394	2.59331	179.31	-87.47394	2.59331	179.31
	End	25.11.1999	7:58	-86.27305 W	3.67117 N	2722m		-86.27305	3.67117		-86.27305	3.67117	
Profile 32b	Start	25.11.1999	8:03	-86.25998 W	3.67328 N	2747m	HS/PS	-86.25998	3.67328		-86.25998	3.67328	92.82
	End	25.11.1999	12:55	-85.78400 W	4.35966 N	2433m		-85.784	4.35966		-85.784	4.35966	
Profile 33	Start	25.11.1999	15:46	-85.79463 W	4.36998 N	2430m	HS/PS/Mag	-85.79463	4.36998	112.7	-85.79463	4.36998	112.7
	End	25.11.1999	21:35	-86.79851 W	4.51414 N	1252m		-86.79851	4.51414		-86.79851	4.51414	
Profile 34	Start	26.11.1999	1:21	-86.77520 W	4.51343 N	1167m	HS/PS/Mag	-86.7752	4.51343	66.21	-86.7752	4.51343	66.21

Title		Date (UTC)	Time (UTC)	Longitude [°]	Latitude [°]	Depth	Profile	Magnetik			Hydrosweep		
	End	26.11.1999	4:50	-87.35751 W	4.63972 N	1965m		-87.35751	4.63972		-87.35751	4.63972	
Profile 35	Start	26.11.1999	10:44	-87.37322 W	4.63200 N	1829m	HS/PS/Mag	-87.37322	4.632	61.68	-87.37322	4.632	61.68
	End	26.11.1999	13:50	-87.92801 W	4.64933 N	1320m		-87.92801	4.64933		-87.92801	4.64933	
Profile 36	Start	26.11.1999	17:21	-87.89578 W	4.66827 N	2217m	HS/PS/Mag	-87.89578	4.66827	65.65	-87.89578	4.66827	65.65
	End	26.11.1999	20:19	-87.54210 W	5.14154 N	1918m		-87.5421	5.14154		-87.5421	5.14154	
Profile 37	Start	26.11.1999	23:14	-87.53104 W	5.14475 N	2145m	HS/PS/Mag	-87.53104	5.14475	240.55	-87.53104	5.14475	240.55
	End	27.11.1999	9:54	-85.36971 W	5.26655 N	1913m		-85.36971	5.26655		-85.36971	5.26655	
Profile 37b	Start	27.11.1999	13:17	-85.37800 W	5.29866 N	1770m	HS/PS	-85.378	5.29866		-85.378	5.29866	58.74
	End	27.11.1999	15:55	-84.88866 W	5.49866 N	2986m		-84.88866	5.49866		-84.88866	5.49866	
Profile 38	Start	27.11.1999	17:41	-84.85240 W	5.51364 N	2965m	HS/PS/Mag	-84.8524	5.51364	131.05	-84.8524	5.51364	131.05
	End	27.11.1999	23:25	-83.75924 W	5.95620 N	2094m		-83.75924	5.9562		-83.75924	5.9562	
Profile 39	Start	28.11.1999	3:46	-83.67391 W	5.97528 N	2344m	HS/PS/Mag	-83.67391	5.97528	141.88	-83.67391	5.97528	141 88
	End	28.11.1999	10:21	-84.92570 W	6.22678 N	1308m		-84.9257	6.22678		-84.9257	6.22678	
Profile 40	Start	28.11.1999	18:49	-84.88792 W	6.26204 N	1517m	HS/PS/Mag	-84.88792	6.26204	69.55	-84.88792	6.26204	69.55
	End	28.11.1999	22:18	-85.48308 W	6.45578 N	1693m		-85.48308	6.45578		-85.48308	6.45578	
Profile 40b	Start	29.11.1999	0:47	-85.64666 W	6.54733 N	1944m	HS/PS	-85.64666	6.54733		-85.64666	6.54733	10.6
	End	29.11.1999	1:17	-85.72033 W	6.60800 N	1932m		-85.72033	6.608		-85.72033	6.608	
Profile 41	Start	29.11.1999	4:46	-85.72533 W	6.63627 N	1930m	HS/PS/Mag	-85.72533	6.63627	38.29	-85.72533	6.63627	38.29
	End	29.11.1999	6:28	-85.40764 W	6.76973 N	1555m		-85.40764	6.76973		-85.40764	6.76973	
Profile 42	Start	29.11.1999	9:16	-85.37395 W	6.79369 N	1426m	HS/PS/Mag	-85.37395	6.79369	122.71	-85.37395	6.79369	122.71
	End	29.11.1999	14:53	-84.27646 W	6.91597 N	1233m		-84.27646	6.91597		-84.27646	6.91597	
Profile 43	Start	29.11.1999	19:01	-84.21756 W	6.93444 N	1045m	HS/PS/Mag	-84.21756	6.93444	33.19	-84.21756	6.93444	33.19
	End	29.11.1999	20:36	-83.92777 W	7.00694 N	1077m		-83.92777	7.00694		-83.92777	7.00694	
Profile 44	Start	29.11.1999	22:44	-83.89867 W	7.00531 N	1049m	HS/PS/Mag	-83.89867	7.00531	37.01	-83.89867	7.00531	37.01
	End	30.11.1999	0:26	-83.56766 W	6.96865 N	1962m		-83.56766	6.96865		-83.56766	6.96865	
Profile 45	Start	30.11.1999	4:32	-83.65065 W	6.98821 N	1739m	HS/PS/Mag	-83.65065	6.98821	84.67	-83.65065	6.98821	84.67
	End	30.11.1999	8:17	-82.88875 W	7.00002 N	2201m		-82.88875	7.00002		-82.88875	7.00002	
Profile 46	Start	30.11.1999	12:16	-82.86913 W	7.01028 N	2971m	HS/PS/Mag	-82.86913	7.01028	40.76	-82.86913	7.01028	40.76
	End	30.11.1999	14:10	-82.89941 W	7.37581 N	2676m		-82.89941	7.37581		-82.89941	7.37581	
Profile 47	Start	30.11.1999	18:47	-82.91743 W	7.38657 N	2253m	HS/PS/Mag	-82.91743	7.38657	49.45	-82.91743	7.38657	49.45
	End	30.11.1999	21:12	-83.31070 W	7.59490 N	1719m		-83.3107	7.5949		-83.3107	7.5949	
Profile 48	Start	01.12.1999	0:56	-83.42099 W	7.61345 N	1227m	HS/PS/Mag	-83.42099	7.61345	42.75	-83.42099	7.61345	42.75
	End	01.12.1999	2:56	-83.39407 W	7.99721 N	1629m		-83.39407	7.99721		-83.39407	7.99721	

Title		Date (UTC)	Time (UTC)	Longitude [°]	Latitude [°]	Depth	Profile	Magnetik			Hydrosweep		
Profile 49	Start	01.12.1999	9:33	-83.45016 W	8.03377 N	1212m	HS/PS/Mag	-83.45016	8.03377	60.86	-83.45016	8.03377	60.86
	End	01.12.1999	12:33	-83.97633 W	7.88175 N	1482m		-83.97633	7.88175		-83.97633	7.88175	
Profile 50	Start	01.12.1999	16:21	-84.00077 W	7.87743 N	705m	HS/PS/Mag	-84.00077	7.87743	18.35	-84.00077	7.87743	18.35
	End	01.12.1999	17:16	-84.11948 W	7.76265 N	1165m		-84.11948	7.76265		-84.11948	7.76265	
Profile 50b	Start	01.12.1999	22:25	-84.39490 W	7.92993 N	1690m	HS/PS	-84.3949	7.92993		-84.3949	7.92993	24.41
	End	02.12.1999	0:29	-84.28520 W	8.12021 N	1762m		-84.2852	8.12021		-84.2852	8.12021	
Profile 51	Start	05.12.1999	5:31	-84.31415 W	8.50072 N	2485m	HS/PS/Mag	-84.31415	8.50072	120.37	-84.31415	8.50072	120.37
	End	05.12.1999	11:07	-85.10698 W	7.76265 N	1175m		-85.10698	7.76265		-85.10698	7.76265	
Profile 52	Start	05.12.1999	19:26	-85.14289 W	7.77141 N	1301m	HS/PS/Mag	-85.14289	7.77141	24.19	-85.14289	7.77141	24.19
	End	05.12.1999	20:37	-85.03498 W	7.58239 N	1814m		-85.03498	7.58239		-85.03498	7.58239	
Profile 52b	Start	06.12.1999	0:31	-85.15690 W	7.40846 N	1355m	HS/PS	-85.1569	7.40846		-85.1569	7.40846	3.59
	End	06.12.1999	0:51	-85.18833 W	7.40088 N	1256m		-85.18833	7.400883		-85.18833	7.400883	
Profile 52c	Start	06.12.1999	4:07	-85.19543 W	7.39688 N	1228m	HS/PS	-85.19543	7.39688		-85.19543	7.39688	14.31
	End	06.12.1999	5:07	-85.30428 W	7.32801 N	1781m		-85.30428	7.32801		-85.30428	7.32801	
Profile 53	Start	06.12.1999	8:03	-85.30978 W	7.33388 N	1575m	HS/PS/Mag	-85.30978	7.33388	25.13	-85.30978	7.33388	25.13
	End	06.12.1999	9:17	-85.48281 W	7.47954 N	1401m		-85.48281	7.47954		-85.48281	7.47954	
Profile 54	Start	06.12.1999	14:05	-85.53476 W	7.50436 N	1575m	HS/PS/Mag	-85.53476	7.50436	73.67	-85.53476	7.50436	73.67
	End	06.12.1999	17:47	-85.97529 W	7.00890 N	1931m		-85.97529	7.0089		-85.97529	7.0089	
Profile 55	Start	07.12.1999	3:40	-86.06792 W	6.92631 N	2528m	HS/PS/Mag	-86.06792	6.92631	174.42	-86.06792	6.92631	174.42
	End	07.12.1999	13:05	-86.97662 W	5.64645 N	264m		-86.97662	5.64645		-86.97662	5.64645	
Profile 56	Start	09.12.1999	0:03	-87.25997 W	5.50956 N	1647m	HS/PS/Mag	-87.25997	5.50956	42.1	-87.25997	5.50956	42.1
	End	09.12.1999	1:25	-87.63263 W	5.44136 N	1290m		-87.63263	5.44136		-87.63263	5.44136	
Profile 56b	Start	09.12.1999	1:26	-87.63263 W	5.44136 N	1290m	HS/PS	-87.63263	5.44136		-87.63263	5.44136	0.45
	End	09.12.1999	2:22	-87.62870 W	5.44226 N	1350m		-87.6287	5.44226		-87.6287	5.44226	
Profile 57	Start	09.12.1999	9:51	-87.65485 W	5.38365 N	1378m	HS/PS/Mag	-87.65485	5.38365	34.28	-87.65485	5.38365	34.28
	End	09.12.1999	11:48	-87.95503 W	5.31249 N	2606m		-87.95503	5.31249		-87.95503	5.31249	
Profile 58	Start	09.12.1999	16:52	-88.04000 W	5.25435 N	2543m	HS/PS/Mag	-88.04	5.25435	38.87	-88.04	5.25435	38.87
	End	09.12.1999	18:50	-88.22825 W	5.54919 N	2090m		-88.22825	5.54919		-88.22825	5.54919	
Profile 59	Start	10.12.1999	4:12	-88.23506 W	5.57287 N	1265m	HS/PS/Mag	-88.23506	5.57287	34.12	-88.23506	5.57287	34.12
	End	10.12.1999	6:08	-88.53040 W	5.48883 N	463m		-88.5304	5.48883		-88.5304	5.48883	
Profile 60	Start	10.12.1999	11:38	-88.59096 W	5.48275 N	790m	HS/PS/Mag	-88.59096	5.48275	119.92	-88.59096	5.48275	119.92
	End	10.12.1999	16:48	-87.57241 W	5.83952 N	1920m		-87.57241	5.83952		-87.57241	5.83952	
Profile 61	Start	10.12.1999	21:26	-87.56764 W	5.87181 N	1253m	HS/PS/Mag	-87.56764	5.87181	185.44	-87.56764	5.87181	185.44
	End	11.12.1999	5:24	-86.41879 W	7.08221 N	1611m		-86.41879	7.08221		-86.41879	7.08221	
Profile 62	Start	11.12.1999	9:42	-86.40080 W	7.09702 N	1832m	HS/PS/Mag	-86.4008	7.09702	32.47	-86.4008	7.09702	32.47
	End	11.12.1999	11:20	-86.48911 W	7.37558 N	2030m		-86.48911	7.37558		-86.48911	7.37558	

Title		Date (UTC)	Time (UTC)	Longitude [ ]	Latitude [ ]	Depth	Profile	Magnetik			Hydrosweep		
Profile 63	Start	11.12.1999	16:38	-86.50468 W	7.39575 N	1568m	HS/PS/Mag	-86.50468	7.39575	29.02	-86.50468	7.39575	29.02
	End	11.12.1999	17:56	-86.29798 W	7.55535 N	2866m		-86.29798	7.55535		-86.29798	7.55535	
Profile 64	Start	11.12.1999	22:04	-86.20626 W	7.65731 N	1048m	HS/PS/Mag	-86.20626	7.65731	64.01	-86.20626	7.65731	64.01
	End	12.12.1999	1:11	-86.37292 W	8.20868 N	3077m		-86.37292	8.20868		-86.37292	8.20868	
Profile 65	Start	12.12.1999	4:19	-86.16414 W	8.38380 N	2979m	HS/PS/Mag	-86.16414	8.3838	76.57	-86.16414	8.3838	76.57
	End	12.12.1999	7:56	-85.93093 W	7.73542 N	713m		-85.93093	7.73542		-85.93093	7.73542	
Profile 66	Start	12.12.1999	14:01	-85.92347 W	7.77318 N	1964m	HS/PS/Mag	-85.92347	7.77318	36.75	-85.92347	7.77318	36.75
	End	12.12.1999	15:51	-85.79751 W	8.07896 N	717m		-85.79751	8.07896		-85.79751	8.07896	
Profile 66b	Start	12.12.1999	20:24	-85.76060 W	8.12075 N	1779m	HS/PS				-84.7499	9.41875	256.35
	End	12.12.1999	21:18	-85.68275 W	8.49166 N	2035m					-83.2553	7.6614	
Profile 67	Start	13.12.1999	0:47	-85.55664 W	7.98298 N	1480m	HS/PS/Mag	-85.55664	7.98298	49.94	-85.55664	7.98298	49.94
	End	13.12.1999	3:11	-85.16687 W	8.20666 N	1294m		-85.16687	8.20666		-85.16687	8.20666	
Profile 68	Start	13.12.1999	7:28	-85.15047 W	8.29199 N	2172m	HS/PS/Mag	-85.15047	8.29199	23.43	-85.15047	8.29199	23.43
	End	13.12.1999	8:40	-85.15140 W	8.50284 N	2141m		-85.1514	8.50284		-85.1514	8.50284	
Profile 69	Start	13.12.1999	13:33	-85.15965 W	8.53037 N	1645m	HS/PS/Mag	-85.15965	8.53037	35.21	-85.15965	8.53037	35.21
	End	13.12.1999	15:20	-85.47590 W	8.54944 N	1865m		-85.4759	8.54944		-85.4759	8.54944	
Profile 70	Start	14.12.1999	2:27	-85.64120 W	8.53928 N	1918m	HS/PS/Mag	-85.6412	8.53928	34.12	-85.6412	8.53928	34.12
	End	14.12.1999	4:06	-85.63376 W	8.84628 N	2457m		-85.63376	8.84628		-85.63376	8.84628	
Profile 71	Start	14.12.1999	7:42	-85.64189 W	8.85600 N	2330m	HS/PS/Mag	-85.64189	8.856	65.91	-85.64189	8.856	65.91
	Wayp.	14.12.1999	10:53	-86.01348 W	8.39367 N	2885m		-86.01348	8.39367	122.39	-86.01348	8.39367	73.91
	End	14.12.1999	16:25	-86.19671 W	9.47973 N	3640m		-86.19671	9.47973		-86.19671	9.47973	
Profile 71b	Start	14.12.1999	18:07	-86.86183 W	9.62263 N	3500m	HS/PS				-86.86183	9.47973	342.87
	End	14.12.1999	4:06	-85.27100 W	9.19618 N	2605m					-82.21088	9.62263	
Profile 72	Start	15.12.1999	14:58	-85.26874 W	9.20975 N	2222m	HS/PS/Mag	-85.26874	9.20975	496.56	-85.26874	9.20975	56.54
	End	16.12.1999	15:02	-81.95827 W	6.20809 N	2253m		-81.95827	6.20809		-81.95827	6.20809	
Profile 73	Start	16.12.1999	17:54	-81.93168 W	6.20448 N	1144m	HS/PS			7750.6	-81.44944	6.20448	113.98
	End	16.12.1999	18:27	-81.88565 W	6.10883 N	1519m					-81.46244	6.10883	
Profile 74	Start	16.12.1999	23:55	-81.68686 W	6.98766 N	922m	HS/PS				-81.99144	6.98766	29.06
	End	17.12.1999	3:35	-81.58641 W	5.60196 N	1000m					-81.99341	5.60196	
Profile 75	Start	17.12.1999	6:44	-81.53600 W	5.65291 N	1074m	HS/PS				-82.24995	5.65291	9166.8
	End	17.12.1999	17:14	-80.97371 W	6.34360 N	2812m					-82.25044	6.3436	
													16719

Appendix 2: Station Locations and Rock Sample Descriptions

Abbreviations:

DR -	Kettensackdredge	Chain-bag dredge
TVG -	TV-Greifer	TV-Grab
OBS -		Ocean bottom seismometers
HYD -		Hydrosweep survey area

Station no., type, place	**Date** **Time (UTC)** **Depth** **Coordinates** on bottom: off bottom:	**Description**
01 DR Malpelo	11.11.1999 on bottom: 11:44 h 2395 m 05°09.41' N 080°38.39' W off bottom: 14:07 h 1812 m 05°10.07' N 080°38.72' W	-1: 30 cm in diameter fine grained dense basalt. Microphenocrysts of pyroxene or olivine (10%) set in a groundmass containing plagioclase and pyroxene (olivine?). Outer weathered zone is <5 mm wide. A pillow fragment. **Unit A.** -2: 11 x 5 cm **Unit A**, as for 1. -3: 9 x 4 cm **Unit A.** -4: 10 x 3 cm **Unit A.** A well-formed fragment from a pillow, with a 6 mm wide darker surface area (glass?). -5: 8 x 4 cm **Unit A.** Outer 3-10 mm is darker. -6: 9 x 4 cm **Unit A.** Outer 5-15 mm is darker. A pillow fragment. -7: 7 x 4 cm **Unit A.** Outer 5-25 mm is darker. A pillow fragment. -8: 10 x 4 cm **Unit A.** Outer 3-15 mm is darker, and olivine is pseudomorphed by iddingsite there. A pillow fragment. -9: 16 x 7 cm **Unit A.** Outer 5-40 mm is darker, and all olivine is partly pseudomorphed by iddingsite. A pillow fragment. -10: 8 x 4 cm **Unit A.** Outer 5-10 mm is lighter, with olivine pseudomorphed by iddingsite. -11: 15 x 6 cm **Unit A**, as for 10. -12: 9 x 5 cm **Unit A.** A core 3 cm in diameter is fresh, but elsewhere all olivine is pseudomorphed by iddingsite. Pronounced iron migration sphere. -13: 22 cm in diameter dense basalt. Microphenocrysts of pyroxene or olivine (10%) and much skeletal olivine in the coarser groundmass (relative to Unit A). **Unit B.** -14: 10 cm in diameter **Unit B**, with 1 cm wide weathering rind.

		-15: 9 cm in diameter **Unit B**. All of rock except a 1.5 cm core region is weathered with iron mobilisation bands. -16: 9 x 5 cm olivine basalt. Small olivine phenocrysts (10%) are pseudomorphed by white serpentinite at the rock's core and iddingsite at its rim. **Unit C**. -17: 10 x 5 cm **Unit C**, but olivine is fresh near the rim. -18: 24 x 6 cm olivine-plagioclase basalt. Plagioclase phenocrysts (10%) and small olivine phenocrysts (5%). Vesicles partly filled by serpentinite. A pillow fragment. **Unit D**. -19: 9 cm in diameter **Unit D**. Outer 5-15 mm is lighter coloured (weathered). -20: 9 x 4 cm **Unit D**. Some olivine pseudomorphed by iddingsite. -21: 13 x 4 cm **Unit D**. Olivine pseudomorphed by iddingsite in the outer 5 mm wide rind. -22: 9 x 4 cm **Unit D**, but with slightly fewer plagioclase phenocrysts. -23: 10 cm in diameter trachyte? Large feldspar phenocrysts (20%) up to 3 mm across in an olivine-bearing groundmass. Some olivine pseudomorphed by iddingsite. **Unit E**. -24: 20 cm in diameter **Unit D**. A pillow fragment, with an outer dark 5 mm glassy zone and a chloritic crust.
02 DR **Malpelo**	11.11.1999 on bottom: 20:56 h 3354 m 05°06.33' N 081°25.02' W off bottom: 22:42 h 2767 m 05°05.50' N 081°25.07' W	-1: 11 x 6 cm fine grained basalt. Small olivine or pyroxene microphenocrysts (10%) set in a fine grained groundmass. **Unit A**. -2: 11 x 6 cm **Unit A**. Weakly weathered in outer 5-20 mm where olivine is partly pseudomorphed by iddingsite. A pillow fragment. -3: 7 x 4 cm **Unit A**. Outer 10 mm much more weathered and olivine there is pseudomorphed by iddingsite. A pillow fragment. -4: 6 cm in diameter **Unit A**, as for 3. -5: 9 x 4 cm dense olivine basalt. Olivine phenocrysts (10%) are fresh and larger than in Unit A. Outer 7 mm is black and glassy. **Unit B**. -6: 10 x 4 cm **Unit B**. More weathered in outer 5 mm, where olivine is partly pseudomorphed by iddingsite. -7: 7 x 4 cm **Unit B**. -8: 7 x 2 cm **Unit B**, as for 6.
03 TVG **Malpelo**	11.11.1999 on bottom: 04:18 h 916 m 04°28.02' N 080°54.34' W off bottom: 05:57 h 908 m 04°28.00' N 080°54.30' W	-1: 40 cm in diameter vesicular fine grained plagioclase basalt. Small plagioclase phenocrysts (10%) in a reddish grey groundmass. Small black specks mark incipient pull-aparts. Vesicles are lined with chlorite and filled with soft orange clay. MnOx crust up to 5 mm wide. **Unit A**. -2: 30 cm in diameter **Unit A**. Vesicles are up to 10 mm long, and there are well-developed pull-apart structures.

		-3: 22 x 9 cm **Unit A**. Various biota (annelids and bryozoa) on surface. -4: 20 x 9 cm **Unit A**, as for 3. Biology sample. -5: 12 x 4 cm **Unit A**. More weathered with iron-staining. -6: 10 x 5 cm **Unit A**. -7: 7 x 4 cm **Unit A**.
04 DR Malpelo	12.11.1999 on bottom: 08:04 h 2061 m 04°29.06' N 080°55.53' W off bottom: 09:13 h 1845 m 04°28.70' N 080°55.07' W	No rock samples.
05 DR Malpelo	12.11.1999 on bottom: 11:37 h 1639 m 04°33.94' N 080°41.98' W off bottom: 13:00 h 1530 m 04°33.67' N 080°42.15' W	-1: 27 x 13 cm dense blue-grey aphyric basalt. Flow banded, with each band about 1 mm wide (lighter/darker). Some bands are iron-stained. Rare vesicles are up to 2 cm long and filled with soft clay. **Unit A**. -2: 13 cm in diameter **Unit A**. -3: 25 x 12 cm **Unit A**. Edge of the rock is serrated at 5 cm intervals reflecting the flow banding. -4: 17 x 8 cm **Unit A**. -5: 10 x 5 cm **Unit A**. -6: 21 x 7 cm **Unit A**. More weathered, with iron-staining on the flow bands. -7: 14 x 3 cm **Unit A**, as for 6. -8: 9 x 5 cm **Unit A**, but somewhat more vesicular (10%). Vesicles are filled with soft orange clay. -9: 17 x 5 cm blue-grey fine grained aphyric basalt. Unlike Unit A, the groundmass is cryptocrystalline. The rock surface is a thin dark green chlorite layer (<1 mm thick). A pillow fragment. **Unit B**. -10: 10 x 6 cm **Unit B**. Also has a few small vesicles lined by chlorite and filled by soft pale clay. -11: 11 x 6 cm **Unit B**. -12: 6 x 3 cm **Unit B**. -13: 14 x 6 cm **Unit B**. Outer 5-30 mm is more weathered and weakly iron-stained. -14: 18 x 9 cm **Unit B**, as for 13. -15: 15 x 8 cm **Unit B**, as for 13. -16: 16 x 6 cm **Unit B**. Strongly weathered, with iron-staining and pale yellow clay near the rim. -17: 15 x 7 cm. Lithology very similar to Unit B, but contains small vesicles (10%) filled with dark chlorite. Disseminated 1-2 cm wide dappled patches of dark chlorite also occur throughout the rock. **Unit C**.

		-18: 15 x 4 cm **Unit C**. Outer 10 mm is more weathered. -19: 14 x 6 cm **Unit C**. Has flow banding, with bands 5-10 mm thick. -20: 7 x 3 cm **Unit C**, as for 19. -21: 28 cm in diameter. Lithology similar to Unit C, but 30% of the groundmass is dark grey in colour (chlorite?). **Unit D**. -22: 15 x 6 cm **Unit D**. -23: 13 x 5 cm dark blue-grey plagioclase basalt. Plagioclase phenocrysts (10%). Outer 10 mm is more weathered. **Unit E**. -24: 8 x 3 cm fine grained olivine-plagioclase basalt. Olivine phenocrysts (5%) are pseudomorphed by iddingsite, plagioclase phenocrysts (10%). Rather weathered. **Unit F**. -25: 13 x 5 cm dark grey vesicular plagioclase basalt. Plagioclase phenocrysts (20%). Vesicles are filled by either clay or zeolite. **Unit G**. -26: 27 x 11 cm fine grained plagioclase basalt. Plagioclase phenocrysts (10%) and trace pyroxene. **Unit H**. -27: 21 x 10 cm **Unit H**. -28: 12 x 6 cm vesicular reddish grey aphyric basalt. Vesicles (15%) are up to 1 cm and filled by green chlorite. **Unit I**. -29: 20 x 12 cm vesicular plagioclase basalt. Plagioclase phenocrysts (10%). Vesicles (20%) filled by green chlorite. **Unit J**. -30: 22 x 10 cm **Unit J**. -31: 17 cm in diameter **Unit J**. -32: 22 x 12 cm **Unit J**. -33: 12 x 4 cm pink limestone. Cross-sections of bivalves and gastropods are recognisable. **Unit K**. -34: Bulk sample of 4 small pieces (up to 9 x 4 cm) of MnOx crust. -35: Bulk sample containing numerous small (6 cm diameter) rounded boulders. These may represent a possible paleo-beach deposit.
06 DR Malpelo	12.11.1999 on bottom: 19:18 h 1564 m 04°09.32' N 081°16.51' W off bottom: 20:01 h 1398 m 04°09.42' N 081°16.69' W	-1: 16 x 8 cm green-grey dense fine grained basalt. Groundmass olivine slightly discoloured, plagioclase fresh. A few thin veinlets of zeolite, and a 1 mm thick chloritic rind to the rock. **Unit A**. -2: 11 x 7 cm fine grained plagioclase basalt. Plagioclase phenocrysts (20%). Groundmass olivine appears partly chloritised. The few vesicles are filled with zeolite. **Unit B**. -3: 30 x 8 cm vesicular fine grained basalt. Groundmass olivine appears partly altered. Vesicles (20%) are filled by soft dark green chlorite. Joints are iron-stained, and the rock is quite weathered. **Unit C**.

		-4: 14 x 5 cm **Unit C**. More weathered, with zeolite in many vesicles. -5: 35 x 10 cm **Unit C**, but more weathered. -6: 17 x 5 cm **Unit C**, as for 5. -7: 11 x 6 cm **Unit C**, as for 5. -8: 17 x 7 cm fine grained basalt. Very similar lithology to Unit C, but with vesicles aligned like flow bands every 1-5 mm. Quite weathered, with much iron staining. A pillow fragment with a 5 mm thick MnOx crust. **Unit D**. -9: 23 x 5 cm **Unit D**. -10: 17 x 4 cm **Unit D**. -11: 16 x 7 cm **Unit D**. -12: 23 x 3 cm **Unit D**. -13: 10 x 4 cm **Unit D**, but no iron-staining. -14: 13 x 5 cm **Unit C**, but much more weathered and soft. Abundant chlorite and soft yellow clay in vesicles. -15: 17 x 5 cm **Unit B**, but with reddish grey groundmass. -16: 12 x 4 cm **Unit C**. More weathered, with soft white clay coring chlorite-lined vesicles. -17: 17 x 6 cm reddish grey vesicular fine grained basalt. Outer vesicles filled with zeolite, inner vesicles by chlorite. Probably a very weathered **Unit C**. -18: 17 x 9 cm uncut sample, probably **Unit D**. Has a 1 cm thick MnOx crust underlain by goethite. -19: 15 x 6 cm uncut sample, probably **Unit C**. Has green chloritic surface rind. -20: Bulk sample of 11 MnOx encrusted boulders. Each is probably **Unit D**. -21: Bulk sample of 10 boulders with chloritic surface rinds. Each is probably **Unit C**. -22: Bulk sample of several rounded boulders that might represent a paleo-beach deposit. -23: A small piece of soft sediment.
07 DR Malpelo	12.11.1999 on bottom: 01:27 h 3000 m 04°19.92' N 081°52.48' W off bottom: 03:53 h 2450 m 04°18.80' N 081°52.29' W	-1: 19 x 3 cm green-grey dense fine grained aphyric basalt. Groundmass olivine appears fresh. **Unit A**. -2: 9 x 3 cm **Unit A**. Outer 5 mm is weakly weathered, and olivine there is partly pseudomorphed by iddingsite. -3: 10 x 4 cm **Unit A**, as for 2. -4: 8 x 4 cm **Unit A**. As for 2, but outer 10 mm is weathered. -5: 8 x 3 cm **Unit A**. Much more weathered, with outer 20 mm iron-stained. -6: 17 x 10 cm grey dense basalt. Very similar lithology to Unit A, but coarser grained. Quite weathered, with only 2 cm around core fresh. **Unit B**. -7: 15 x 8 cm **Unit B**. -8: 24 x 8 cm grey dense trachyte. Alkali feldspar

		phencrysts (25%) are up to 4 mm long and have only simple twins. Groundmass is fine grained. Rare vesicles are filled with zeolite. **Unit C**. -9: 15 x 5 cm **Unit C**. -10: 40 x 7 cm **Unit C**. Outer 2-3 cm is weakly weathered. -11: 26 x 5 cm **Unit C**, as for 10. -12: 17 x 6 cm **Unit C**, as for 10. -13: 22 x 6 cm **Unit C**, as for 10. -14: 15 x 5 cm **Unit C**, as for 10. -15: 14 x 5 cm **Unit C**, as for 10. -16: 16 x 4 cm. Similar to Unit C, but only 5% alkali feldspar phenocrysts. **Unit D**. -17: 23 x 9 cm vesicular fine grained basalt. Vesicles (5%) are filled by dark chlorite and serpentinite. **Unit E**. -18: 22 x 10 cm vesicular plagioclase basalt. Plagioclase phenocrysts (10%). Vesicles are flow aligned and filled by chlorite. **Unit F**. -19: 10 x 5 cm **Unit F**. -20: 22 x 5 cm **Unit F**. Outer 5 mm is weakly weathered. -21: 20 x 6 cm **Unit F**, as for 20. -22: 9 x 3 cm **Unit F**. Weakly weathered throughout, with iron-staining. -23: 6 cm in diameter **Unit F**. Rather more vesicular, and weathered throughout with iron-staining. -24: Bulk sample of MnOx crust filling two sample bags.
08 DR Carnegie	13.11.1999 on bottom: 22:45 h 3571 m 01°02.01' N 082°17.55' W off bottom: 00:02 h 3374 m 01°02.44' N 082°17.13' W	No rock samples.
08a DR Carnegie	13.11.1999 on bottom: 03:25 h 3375 m 01°01.56' N 082°11.40' W off bottom: 04:42 h 3124 m 01°02.01' N 082°11.32' W	-1: 20 x 8 cm vesicular grey trachybasalt. Large feldspar phenocrysts (20%) whose lack of multiple twins suggests alkali feldspar. Vesicles (15%) are filled with either soft dark green serpentinite or talc. A pillow fragment. **Unit A**. Annelids growing on surface. -2: 18 x 9 cm **Unit A**. Outer 5 mm is deeply weathered, and it has more internal fractures where the rock is weathered to clay. -3: 10 x 4 cm **Unit A**. Outermost 5-10 mm is strongly weathered. -4: 8 x 2 cm **Unit A**. -5: 15 x 10 cm **Unit A**. Good wedge-shape to pillow. MnOx crust 10 mm thick.

09 DR Carnegie	14.11.1999 on bottom: 13:45 h 2432 m 00°05.23' N 082°08.76' W off bottom: 16:13 h 1531 m 00°04.37' N 082°08.35' W	No rock samples.
10 TVG Carnegie	14.11.1999 on bottom: 17:32 h 1409 m 00°04.07' N 082°07.50' W off bottom: 19:22 h 1406 m 00°04.04' N 082°02.49' W	No rock samples.
11 DR Carnegie	14.11.1999 on bottom: 20:50 h 1447 m 00°04.21' N 082°07.57' W off bottom: 21:42 h 1432 m 00°03.91' N 082°07.44' W	No rock samples.
11a DR Carnegie	14.11.1999 on bottom: 22:32 h 1446 m 00°03.33' N 082°07.34' W off bottom: 23:40 h 1456 m 00°04.25' N 082°07.70' W	-1: 20 x 7 cm blue-grey dense basalt. Microphenocrysts of olivine (30%) partly pseudomorphed by iddingsite, and plagioclase (20%). Outer 2 cm is more weathered, and has a 2 mm MnOx crust. **Unit A**. -2: 22 x 5 cm **Unit A**. The MnOx crust is very platy and pigments skin. -3: 30 cm diameter **Unit A**. Probably a pillow fragment. -4: 18 x 5 cm **Unit A**, with a 5 mm thick MnOx crust. -5: 15 x 7 cm **Unit A**. -6: 22 x 6 cm **Unit A**. A pillow fragment. -7: 11 x 4 cm **Unit A**. More weathered, with iron-stained fractures. -8: 8 x 4 cm **Unit A**, as for 7. -9: 17 x 6 cm **Unit A**. A pillow fragment. -10: 33 x 9 cm **Unit A**. A pillow fragment. -11: 15 x 5 cm **Unit A**. Sub-sample from a boulder >0.5 cm in diameter. -12: 20 x 5 cm **Unit A**. Sub-sample from a boulder >0.5 cm in diameter. -13: 12 x 7 cm **Unit A**. Sub-sample from a boulder >0.5 cm in diameter. -14: 10 x 3 cm **Unit A**. Sub-sample from a boulder >0.5 cm in diameter.

		-15: 11 x 7 cm **Unit A**. Sub-sample from a boulder >0.5 cm in diameter. -16: 16 x 6 cm vesicular blue-grey basalt. Similar lithology to Unit A, but is somewhat vesicular (5%) with chlorite and soft clay filling the vesicles, and the olivine microphenocrysts are very fine grained (<0.1 mm). Sub-sample from a boulder >0.5 cm in diameter. **Unit B**. -17: 16 x 9 cm **Unit B**. -18: 12 x 3 cm **Unit B**. -19: 32 x 7 cm pale blue-grey vesicular basalt. Microphenocrysts of olivine (30%) up to 0.1 mm across, mostly pseudomorphed by iddingsite, in a cryptocrystalline groundmass. Vesicles are usually empty. A pillow fragment. **Unit C**. -20: 9 x 5 cm **Unit C**, with more weathered outer 1 cm. -21: 11 x 5 cm pale blue-grey vesicular plagioclase basalt. Plagioclase phenocrysts (5%) are up to 0.5 mm long. Olivine microphenocrysts (20%) are partly pseudomorphed by iddingsite. **Unit D**. -22: 6 x 4 cm **Unit D**. -23: 30 cm in diameter pillow fragment waiting to be cut with the large saw.
12 DR Carnegie	15.11.1999 on bottom: 05:09 h 2364 m 00°23.89' N 081°27.18' W off bottom: 07:15 h 1984 m 00°24.39' N 081°27.44' W	-1: 8 x 4 cm grey plagioclase basalt. Small plagioclase phenocrysts (10%) are set in a fine grained olivine-plagioclase groundmass. Small vesicles (5%) are sometimes filled with soft clay. Outer 1 cm is more weathered. Appears to be a well-rounded boulder from a conglomerate. **Unit A**. -2: 12 x 3 cm conglomerate. All clasts are deeply weathered to orange clays, with a maximum clast size of 1 cm but most being <0.5 cm. Probably a hyaloclastite. **Unit B**. -3: 16 x 6 cm **Unit B**. Clasts are less weathered than for 2, and some are vesicular. Matrix is orange clay, and the rock is friable. MnOx crust is 2 mm thick on one side. -4: 15 x 3 cm **Unit B**, as for 3. -5: 10 x 2 cm **Unit B**, as for 3. -6: 10 x 3 cm **Unit B**, as for 3. -7: 10 x 3 cm **Unit B**, as for 3. -8: 9 x 2 cm **Unit B**, as for 3. -9: 12 x 3 cm **Unit B**, as for 3. -10: 10 x 2 cm **Unit B**, as for 3. -11: 11 x 2 cm **Unit B**, as for 3.
13 DR Carnegie	15.11.1999 on bottom: 13:50 h 1250 m 00°26.20' S 081°59.51' W	-1: 12 cm in diameter brown-grey highly vesicular fine grained basalt. Groundmass consists of plagioclase and olivine pseudomorphed by iddingsite. Vesicles (20-30%) are banded and range in size from very small to 5 mm; they are empty in the rock interior but

	off bottom: 15:25 h 1184 m 00°25.49' S 081°59.59' W	filled with soft pale clay near the rim. Weathered hyaloclastite fragments adhere to the surface. **Unit A**. -2: 20 cm in diameter **Unit A**, with a 5 mm thick MnOx crust. -3: 17 x 12 cm **Unit A**. Most vesicles are filled by soft clay. MnOx crust is 5 mm thick. -4: 15 x 7 cm **Unit A**, as for 3. -5: 13 x 7 cm **Unit A**, as for 3. Particularly well-developed hyaloclastite and palagonite on surface of this boulder. -6: 13 x 7 cm **Unit A**, as for 3. -7: 10 x 4 cm **Unit A**, as for 3. -8: 7 x 4 cm **Unit A**, as for 3. -9: 7 x 4 cm **Unit A**, as for 3. -10: 8 x 5 cm **Unit A**, as for 3. -11: 11 x 3 cm **Unit A**. All vesicles are filled with soft yellow clay. -12: 14 x 6 cm conglomerate of **Unit A** clasts (hyaloclastite). Largest clasts are 6 cm long. Pale grey clay separates the clasts. -13: 9 x 4 cm **Unit A**. Vesicles in outer part of boulder are filled by soft green clay. -14: Bulk sample of small MnOx crust boulders.
14 DR **Carnegie**	15.11.1999 on bottom: 20:50 h 1408 m 01°10.92' S 082°15.00' W off bottom: 22:55 h 1333 m 01°10.46' S 082°15.00' W	-1: 14 x 4 cm turbidite, consisting of alternating sand and silt beds up to 5 mm thick. The sand is composed of feldspar and deeply weathered rock fragments. A few larger pebbles up to 10 mm across occur in the clay beds, and these are an extremely vesicular pumice. **Unit A**. -2: 13 x 6 cm hyaloclastite. Mostly yellow palagonitic clay, but there are a few highly vesicular rock fragments up to 2 mm across. The MnOx crust is 2 mm thick. **Unit B**. -3: 10 x 4 cm **Unit B**. -4: 24 x 4 cm **Unit B**. Finely bedded on a scale of a few mm and with flame structures. There are a few extremely vesicular pumiceous feldspar-phyric clasts up to 10 mm across, but all the vesicles are clay-filled. -5: 6 x 4 cm **Unit B**, as for 4. -6: 9 x 3 cm **Unit B**, as for 4. -7: 12 x 4 cm **Unit B**. -8: 10 x 3 cm **Unit B**. -9: 9 x 4 cm **Unit B**. -10: 12 x 4 cm **Unit B**. -11: 9 x 3 cm **Unit B**. -12: 6 x 3 cm **Unit B**. -13: 5 x 3 cm **Unit B**. -14: 7 x 2 cm **Unit B**.
15 DR	16.11.1999	No rock samples.

Carnegie	on bottom: 04:30 h 1681 m 01°50.20' S 081°55.83' W off bottom: 06:08 h 1689 m 01°50.17' S 081°55.80' W	
16 DR Carnegie	16.11.1999 on bottom: 10:53 h 2422 m 02°26.62' S 081°37.36' W off bottom: 13:02 h 2276 m 02°26.62' S 081°37.51' W	No rock samples.
16a DR Carnegie	16.11.1999 on bottom: 14:47 h 2307 m 02°26.69' S 081°37.50' W off bottom: 16:08 h 2393 m 02°26.74' S 081°37.41' W	No rock samples.
17 TVG Carnegie	16.11.1999 on bottom: 23:09 h 1899 m 02°09.83' S 082°36.64' W off bottom: 23:49 h 1932 m 02°09.91' S 082°36.77' W	-1: 20 x 11 cm olivine-clinopyroxene basalt. Dark green clinopyroxene phenocrysts (30%) are up to 5 mm long, whereas small olivine phenocrysts (5%) are all pseudomorphed by iddingsite. Fragments of hyaloclastite (same lithology) adhere to the surface of the boulder. **Unit A**. -2: 13 x 4 cm **Unit A**, but with 10% large vesicles filled by either soft clay or by zeolite. -3: 15 x 3 cm **Unit A**, but finer grained with maximum clinopyroxene length 3 mm. Also 5% empty vesicles. -4: 15 x 9 cm **Unit A**. As for 3, but more weathered with orange clay in vesicles. -5: 12 x 6 cm **Unit A**, as for 3. -6: 12 x 6 cm vesicular clinopyroxene basalt. Clinopyroxene phenocrysts (15%) are up to 3 mm across, and the rock lacks olivine phenocrysts. Vesicles (20%) are up to 1 cm long and empty. **Unit B**. -7: 13 x 9 cm **Unit A**. As for 3, but more vesicular (20%) and the outermost 5 cm is disaggregating to form hyaloclastite fragments in a palagonitic matrix. -8: 8 x 4 cm **Unit A**. -9: 9 x 5 cm **Unit A**, but 15% vesicles which are filled by zeolite.

		-10: 5 x 3 cm **Unit A**, but 20% vesicles and more weathered. -11: 5 x 3 cm **Unit A**, but 20% small empty vesicles. -12: 5 x 3 cm **Unit A**, with vesicles filled by soft clay and zeolite. -13: 6 x 3 cm **Unit A**, as for 11. -14: 5 x 3 cm **Unit A**. As for 11 but more weathered. -15: 9 x 3 cm **Unit B**, with vesicles filled by chalcedony. -16: 10 x 3 cm **Unit B**, occurring as a deeply weathered breccia. -17: 30 x 9 cm hyaloclastite with 5 mm MnOx crust. Average clast size is 2 mm, and clasts are set in palagonitic clay. **Unit C**. -18: Bulk sample of 3 boulders, each 12 x 8 cm, of MnOx crust. -19: 12 x 7 cm **Unit B**, as for 16 and with a 1 cm MnOx crust.
18 DR Carnegie	17.11.1999 on bottom: 07:54 h 2449 m 02°13.55' S 083°40.94' W off bottom: 08:58 h 2200 m 02°13.27' S 083°41.51' W	-1: 17 x 6 cm vesicular olivine basalt. Olivine phenocrysts (10%) are up to 2 mm across, often clustered, and many contain or are surrounded by an opaque mineral. They are still green, but slightly discoloured. The groundmass contains fine grained pyroxene. Small vesicles (15%) are often filled by green clay or zeolite. The boulder is a pillow fragment, and its outer 15 mm is more weathered than the interior. **Unit A**. -2: 13 x 7 cm **Unit A**. -3: 12 x 5 cm **Unit A**. -4: 7 x 4 cm **Unit A**. -5: 17 x 5 cm **Unit A**, but almost all vesicles are filled by either green clay or cream zeolite. -6: 13 x 6 cm **Unit A**. The interior is more weathered than normal, but the outermost 3-4 mm is dark and glassy. -7: 9 x 6 cm **Unit A**, as for 6. -8: 14 x 6 cm **Unit A**, as for 6. -9: 12 x 6 cm **Unit A**, as for 6. -10: 19 x 6 cm **Unit A**, as for 6. -11: 13 x 5 cm **Unit A**, but more weathered with all olivine discoloured to yellow. Most vesicles are filled with either green clay or cream zeolite. -12: 15 x 5 cm **Unit A**, as for 11. -13: 7 x 5 cm **Unit A**, as for 11. -14: 8 x 4 cm **Unit A**, as for 11. -15: 9 x 3 cm **Unit A**, as for 11. -16: Bulk sample of 15 boulders representing the largest of the remaining samples and those with glassy rims. Left uncut. All are **Unit A**.
19 DR Carnegie	17.11.1999 on bottom: 14:47 h	-1: 16 x 7 cm vesicular fine grained olivine basalt. Small olivine phenocrysts (5%), green but slightly

	2381 m 02°15.94' S 084°25.65' W off bottom: 16:16 h 2009 m 02°15.30' S 084°26.18' W	discoloured at core of the rock, partly pseudomorphed by iddingsite near rock rim. Small vesicles (15%) often filled by soft white clay or harder zeolite. Intermittently developed black glassy zone 2 mm wide at rock rim. Interpreted as a pillow fragment. MnOx crust usually <2 mm wide. **Unit A**. -2: 9 x 6 cm **Unit A**. Well-developed 5 mm wide glassy rim. -3: 10 x 5 cm **Unit A**. -4: 13 x 10 cm **Unit A**. Relatively fresh core with fresh olivine. Glassy rim zone 5 mm wide. -5: 15 x 10 cm **Unit A**. Outermost 1 cm is more weathered than interior, and vesicles in the interior are zeolite-filled. -6: 12 x 9 cm **Unit A**. -7: Three fragments of a large pillow about 30 x 20 cm, **Unit A**. Intermittent glassy rim, and MnOx crust up to 1 cm wide. -8: Two fragments of a large pillow about 40 x 20 cm, **Unit A**. Large empty vesicle cavities up to 9 x 4 cm in interior of rock. Otherwise as for 7. -9: Three fragments of a large pillow about 30 x 15 cm, **Unit A**. As for 7. -10: Bulk sample of 6 boulders of **Unit A** up to 9 cm in diameter each, all with intermittently developed glassy rims. -11: Bulk sample of 7 small pieces of MnOx crust.
20 DR Carnegie	17.11.1999 on bottom: 20:48 h 1869 m 01°42.09' S 084°18.55' W off bottom: 21:45 h 1770 m 01°41.84' S 084°18.92' W	No rock samples. Foram ooze on sides of dredge.
21 TVG Carnegie	18.11.1999 on bottom: 01:54 h 1674 m 01°18.61' S 084°10.22' W off bottom: 02:50 h 1690 m 01°18.79' S 084°10.24' W	Full load of foram ooze, comprising 70% forams, 30% pale cream clay, and some biota.
22 DR Carnegie	18.11.1999 on bottom: 07:55 h 2650 m 00°38.16' S 084°09.02' W	No rock samples.

	off bottom: 09:20 h 2593 m 00°38.86' S 084°08.94' W	
22a DR Carnegie	18.11.1999 on bottom: 11:22 h 2491 m 00°41.96' S 084°03.29' W off bottom: 13:11 h 2366 m 00°42.72' S 084°03.47' W	No rock samples. Foram ooze on sides of dredge.
23 TVG Carnegie	18.11.1999 on bottom: 19:48 h 2439 m 00°05.40' N 083°49.56' W off bottom: 21:12 h 2453 m 00°05.38' N 083°49.38' W	Full load of foram ooze, comprising 70% forams, 30% pale cream clay, and some biota. Uppermost 5 mm of ooze is stained light brown (bacteria?).
24 DR Carnegie	18.11.1999 on bottom: 23:44 h 2830 m 00°07.62' N 083°46.90' W off bottom: 01:39 h 2538 m 00°06.95' N 083°46.98' W	No rock samples. Foram ooze over sides of dredge.
25 DR Carnegie	19.11.1999 on bottom: 08:39 h 3394 m 00°44.49' N 084°31.01' W off bottom: 10:03 h 3174 m 00°43.87' N 084°31.04' W	No rock samples.
25a DR Carnegie	19.11.1999 on bottom: 11:56 h 3189 m 00°43.86' N 084°31.04' W off bottom: 12:55 h 3016 m 00°43.49' N 084°31.09' W	No rock samples. Foram ooze over sides of dredge.
26 TVG	19.11.1999	-1: 30 x 17 cm vesicular plagioclase basalt. Large

Carnegie	on bottom: 20:50 h 1388 m 00°18.01' N 084°58.54' W off bottom: 22:26 h 1402 m 00°18.02' N 084°58.45' W		plagioclase phenocrysts (20%) up to 5 mm across in a fine grained plagioclase-pyroxene groundmass. A few dark green clinopyroxene phenocrysts (<5%). Vesicles (10%) are mostly empty, but some are filled with soft green clay. Fractures and outer 1 cm of rock are weathered, but rock interior is fresh. MnOx crust is 2 mm thick. A pillow fragment. **Unit A**. Abundant biota were attached to the surface and sampled by the biologists, including large hydrozoa, corals, polychaetes, and bryozoa.
27 DR Carnegie	19.11.1999 on bottom: 03:10 h 2466 m 00°50.80' S 085°06.56' W off bottom: 03:55 h 2119 m 00°51.15' S 085°06.58' W	-1:	Bulk sample of about 15 small 5-10 cm in diameter MnOx nodules. Two cut rocks have finely laminated interiors with alternating 1-5 mm thick dark black MnOx and MnOx + yellow clay. Sample split with one bag for CAU and one for GEOMAR.
28 DR Carnegie	20.11.1999 on bottom: 13:30 h 2495 m 02°04.26' S 085°55.00' W off bottom: 16:34 h 2106 m 02°03.67' S 085°55.04' W	-1: -2: -3: -4: -5: -6: -7: -8: -9: -10: -11:	22 x 11 cm blue-grey vesicular aphyric fine grained basalt. Small vesicles (20%) are empty. Groundmass is cryptocrystalline. Outer 5 mm is more weathered. A pillow fragment. **Unit A**. 14 x 9 cm **Unit A**. Slightly more weathered along fractures than 1. 23 x 9 cm **Unit A**. Interior is pervasively weathered to greenish yellow chlorite (?), which occurs as dappled 1 mm patches. Vesicles are partly filled with this material. Outer 1-2 cm is more weathered and darker, with a sharp contact to 15 mm thick MnOx crust. 18 x 9 cm **Unit A**. As for 3, but dappled patches are elongate and much larger (1-2 cm). 17 x 6 cm **Unit A**. All but core (2 cm diameter) is weathered to yellow clay minerals. Associated opaque minerals imply much original olivine in the groundmass. 11 x 5 cm **Unit A**. As for 5, but all of rock is weathered. 15 x 10 cm **Unit A**. Uncut boulder broken along iron-stained fractures. A pillow fragment, with a 15 mm thick MnOx crust. 16 x 7 cm **Unit A**. As for 7, but MnOx crust is up to 4 cm thick. 19 x 10 cm **Unit A**, as for 7. 38 x 16 cm hyaloclastite. Clasts of deeply weathered **Unit A** up to 1 cm long are set in a yellow-orange clay matrix. Overlying MnOx crust is botryoidal and up to 3 cm thick. Outer part of a pillow fragment. Bulk sample of 5 rocks up to 12 cm long (each). All

		are **Unit A**. -12: Bulk sample of 27 rocks up to 12 cm long (each). All are pieces of MnOx crust.
29 DR **Cocos**	21.11.1999 on bottom: 21:49 h 2483 m 01°39.37' N 090°47.65' W off bottom: 23:18 h 1845 m 01°39.42' N 090°47.12' W	-1: 7 x 5 cm dark grey fine grained vesicular basalt. Trace amounts of plagioclase and olivine phenocrysts (<5%). Groundmass is very fine grained. Vesicles (20%) are empty in interior of rock, but partly filled by soft orange clay in the more weathered outer 1 cm. Outermost 3 mm is darker but not glassy. A pillow fragment. **Unit A**.
29a DR **Cocos**	21.11.1999 on bottom: 01:28 h 2428 m 01°35.20' N 090°47.31' W off bottom: 02:53 h 2183 m 01°35.21' N 090°47.09' W	-1: 13 x 7 cm dark grey dense plagioclase basalt. Plagioclase phenocrysts (10%) are fine grained (<1 mm). Groundmass is crystalline but phases unclear. Rare small vesicles occur in patches. Outermost 3 mm is more weathered. A black glassy crust up to 2 mm thick is present at the pillow surface. **Unit A**. -2: 10 x 5 cm **Unit A**. Plagioclase phenocrysts are slightly larger (up to 1 mm) and the rock is somewhat vesicular (vesicles are empty). -3: 17 x 7 cm **Unit A**. Outermost 5 cm below glassy crust is weakly weathered, and the groundmass is finer grained. -4: 10 x 4 cm **Unit A**. Plagioclase is very small and almost microphenocrysts. The groundmass is very fine grained and cryptocrystalline. -5: 13 x 9 cm dark grey vesicular plagioclase basalt. Plagioclase phenocrysts (25%) are up to 5 mm long. A few fresh olivine phenocrysts (<1 %) are also present. Vesicles (10%) are empty. A 2 mm thick glassy rim is well developed. A pillow fragment. **Unit B**. -6: 13 x 6 cm **Unit B**. -7: 9 x 6 cm **Unit B**, more weathered. -8: 23 x 19 cm **Unit A/B**. Glassy outer 1 cm has 25% large plagioclase phenocrysts (Unit B), but the uncut interior of the rock appears to be Unit A. This is evidence Unit B is related to Unit A by hydraulic sorting of plagioclase, and is the same flow. -9: Bulk sample of 6 boulders from the core of **Unit A** pillows (no glass). -10: Bulk sample of 5 boulders from the glassy pillow rims of **Unit A**. -11: 40 x 20 cm **Unit B**, as for 8. Large pillow fragment. -12: 40 x 16 cm **Unit B**, as for 8. Large pillow fragment. -13: 60 x 30 cm **Unit B**, as for 8. Large pillow fragment. -14: 65 x 35 cm **Unit B**, as for 8. Particularly large pillow fragment.
30 DR	22.11.1999	-1: 14 x 6 cm dark grey vesicular olivine basalt. Olivine

Cocos	on bottom: 12:43 h 2436 m 03°08.51' N 091°06.00' W off bottom: 14:24 h 2322 m 03°08.62' N 091°06.61' W	phenocrysts (20%) are fresh in rock core, discoloured and pseudomorphed by iddingsite in the outermost 2-3 cm. Vesicles (10%) are empty. Black glass is intermittently developed at the rim and up to 2 mm thick. MnOx crust is up to 5 mm thick. A pillow fragment. **Unit A**. -2: 17 x 9 cm **Unit A**. From pillow interior, and so has no glass or MnOx. -3: 12 x 9 cm **Unit A**. More weathered, with most olivine discoloured or partly pseudomorphed by iddingsite. -4: 12 x 6 cm **Unit A**, as for 3. -5: 7 x 6 cm **Unit A**. More weathered, with all olivine pseudomorphed by iddingsite. -6: 14 x 11 cm **Unit A**. A well-formed pillow left uncut for display purposes. -7: Bulk sample of 8 boulders of **Unit A**. These are large (25 x 20 cm) pillow fragments with intermittent 2 mm glassy rinds and 5 mm thick MnOx crusts. -8: 35 x 24 cm **Unit A**. A large well-formed pillow with MnOx crust up to 5 mm thick.
31 DR **Cocos**	22.11.1999 on bottom: 18:39 h 2167 m 03°18.79' N 090°41.98' W off bottom: 19:42 h 1974 m 03°18.77' N 090°42.45' W	No rock samples.
32 DR **Cocos**	22.11.1999 on bottom: 22:16 h 1458 m 03°27.60' N 090°37.00' W off bottom: 23:10 h 1224 m 03°27.56' N 090°36.63' W	-1: 10 x 7 cm dark grey extremely vesicular olivine basalt. Olivine phenocrysts (10%) are large (up to 6 mm long) and generally colourless and partly altered. Trace amounts of large plagioclase phenocrysts. Vesicles (50%) are up to 3 mm long and empty. Outermost 2 cm of rock is more weathered. **Unit A**. -2: 17 x 9 cm **Unit A**. More weathered, with a weakly weathered core but orange clays developed towards the rim. MnOx crust is 5 mm thick. -3: 10 x 3 cm **Unit A**. Strongly weathered, with only the core area weakly iron-stained. MnOx crust is 5 mm thick. -4: 19 x 8 cm **Unit A**. As for 3, but consists of two such pillows cemented together by hyaloclastite (sand-sized clasts). -5: 12 x 4 cm **Unit A**. Strongly weathered to soft orange clays. -6: 15 x 7 cm **Unit A**, as for 5. -7: 10 x 6 cm **Unit A**. Completely weathered to a yellow-orange clay ball with a few relic plagioclase phenocrysts.

		-8: Bulk sample of 21 **Unit A** rocks. Selected because they are scoriaceous and have less weathered blue-grey zones near their rims. -9: Bulk sample of 7 **Unit A** rocks. Selected because they are pumiceous or coarsely scoriaceous, with vesicles up to 15 mm in diameter. -10: Bulk sample of 2 large 20 x 15 cm hyaloclastite boulders. Clasts are **Unit A** pebbles up to 6 cm long, set in an orange clay matrix. -11: 18 x 3 cm hyaloclastite with finer grain size (sand). Possibly bedded. -12: 15 x 5 cm hyaloclastite, as for 11. -13: 26 x 7 cm **Unit A**. Represents the strongly weathered surface of a pillow and is good for textural displays. -14: 12 x 4 cm hyaloclastite, as for 10.
33 DR **Cocos**	23.11.1999 on bottom: 07:43 h 1694 m 03°53.88' N 089°13.62' W off bottom: 08:30 h 1492 m 03°53.44' N 089°13.64' W	-1: 21 x 11 cm dark grey dense fine grained olivine basalt. Olivine phenocrysts (5%) are small (<0.2 mm across) and partly pseudomorphed by iddingsite or discoloured to yellow. Traces of pyroxene phenocrysts (<2%). The groundmass is fresh, and the few small vesicles are empty. More weathered in the outermost 5 mm of the rock below a thin (<1 mm) MnOx crust. Hard white clay with altered rock fragments and forams fills some fracture surfaces, and was sampled for Prof. P. Schaeffer (Tertiary forams?). **Unit A**.
34 DR **Cocos**	23.11.1999 on bottom: 14:19 h 1228 m 03°16.68' N 088°55.81' W off bottom: 15:23 h 1117 m 03°16.24' N 088°55.79' W	-1: 31 x 16 cm volcaniclastic rock composed of 2-3 mm long pebbles of black vesicular (scoriaceous) lava. These appear fresh and aphyric. Clast-supported, with a little yellow-orange clay as matrix. MnOx crust is 10-15 mm thick. Interpreted as a palagonite-poor hyaloclastite. **Unit A**. -2: 25 x 12 cm **Unit A**. -3: 18 x 9 cm **Unit A**. -4: 14 x 10 cm **Unit A**. -5: 18 x 7 cm **Unit A**. Mostly MnOx crust. -6: 12 x 5 cm **Unit A**. -7: 9 x 5 cm **Unit A**. -8: 125 x 40 cm **Unit A**. Left on deck as display. -9: 45 x 18 cm **Unit A**. Also left on deck as display.
35 TVG **Cocos**	23.11.1999 on bottom: 20:17 h 1107 m 03°19.44' N 088°21.17' W off bottom: 20:57 h 1128 m 03°19.42' N 088°21.30' W	Jaws didn't close- no sample return. Views of MnOx-encrusted hyaloclastite with large areas of foram ooze.
35a DR	23.11.1999	-1: 28 x 11 cm volcaniclastic rock consisting of 2-5 mm

Cocos	on bottom: 22:40 h 1778 m 03°21.79' N 088°21.69' W off bottom: 00:50 h 1550 m 03°20.97' N 088°21.56' W	long greenish yellow weathered rock fragments. Clast-supported with a little yellow-orange clay in the matrix. Interpreted as a palagonite-poor hyaloclastite. MnOx crust is 2-2.5 cm thick. **Unit A**. -2: 23 x 11 cm **Unit A**. -3: 12 x 11 cm **Unit A**. -4: 21 x 10 cm **Unit A**. -5: 16 x 6 cm **Unit A**. Cut through the MnOx crust reveals some fine-scale banding (<<1 mm) concentric to the rock surface. -6: 12 x 8 cm **Unit A**, as for 5.
35b DR **Cocos**	24.11.1999 on bottom: 02:50 h 1710 m 03°22.65' N 088°18.37' W off bottom: 04:09 h 1377 m 03°22.23' N 088°18.31' W	-1: 15 x 6 cm dark grey fine grained vesicular olivine basalt. Olivine phenocrysts (20%) are up to 1 mm long and fresh, except at the rim of the rock. Vesicles (30%) are small and empty. Glass is developed at the pillow rims and is up to 5 mm thick. **Unit A**. -2: 13 x 5 cm **Unit A**. More weathered in the outermost 2 cm, where soft yellow-green clay fills the vesicles. -3: 8 x 5 cm **Unit A**. As for 2, but all vesicles are partly or totally filled by soft green clay. -4: 15 x 6 cm **Unit A**, as for 2. -5: 11 x 4 cm **Unit A**, as for 3. -6: 12 x 6 cm **Unit A**. As for 2, but with a glassy rim 5 mm wide. -7: 13 x 6 cm **Unit A**, as for 6. -8: 25 x 7 cm **Unit A**. As for 6, but with an MnOx crust 5 mm wide outside the glassy rim. -9: 30 x 19 cm **Unit A**. Long cylindrical pillow with 15 mm thick MnOx crust. Very good for display purposes. -10: 13 x 2 cm yellow palagonitic clay containing a few weathered rock fragments 1-2 mm long. -11: Bulk sample of 15 small pieces of hyaloclastite. Similar to 10, but yellowish grey in colour. -12: Bulk sample of 9 rocks, representing pillow fragments and cores of **Unit A**. Good for further fresh material. -13: Bulk sample of 8 rocks. MnOx-encrusted **Unit A**, with the crust up to 5 mm thick.
36 DR **Cocos**	24.11.1999 on bottom: 09:42 h 2158 m 02°41.60' N 088°01.01' W off bottom: 11:56 h 1739 m 02°41.62' N 088°02.28' W	No rock samples.
36a DR **Cocos**	24.11.1999 on bottom: 13:47 h	No rock samples.

	2111 m 02°49.12' N 088°00.72' W off bottom: 15:23 h 1872 m 02°49.32' N 088°01.50' W	
37 DR **Cocos**	24.11.1999 on bottom: 20:51 h 3328 m 02°35.32' N 087°28.92' W off bottom: 22:45 h 2858 m 02°34.88' N 087°28.57' W	-1: 16 x 9 cm greyish blue peridotite. Dense, very heavy, holocrystalline rock consisting of interlocking soft serpentinite pseudomorphing olivine. Original grain size about 1 mm across, and no sign of layering. Black soft chlorite patches (10%) also occur. More weathered in outer 1 cm with dark green rind. Interpreted as originally dunite. **Unit A**. -2: 12 x 6 cm **Unit A**. -3: 11 x 6 cm **Unit A**, but dark blue with no black chlorite. Less weathered than 1? -4: 14 x 3 cm **Unit A**, as for 3. -5: 13 x 4 cm **Unit A**. -6: 12 x 7 cm **Unit A**, but with 20% dark green chlorite patches. -7: 18 x 5 cm **Unit A**, as for 6. -8: 19 x 5 cm **Unit A**, as for 6. -9: 12 x 6 cm **Unit A**. As for 6, but more weathered with minor iron staining. -10: 7 x 4 cm **Unit A**, as for 6. -11: 11 x 7 cm **Unit A**. As for 9, but with a 3 mm wide MnOx crust. -12: 14 x 5 cm **Unit A**, but more weathered with yellow clays in interior. -13: 9 x 4 cm **Unit A**. Altered and partly silicified (harder, reddish grey, but texture preserved). -14: 15 x 6 cm **Unit A**. Cut by 1-2 mm wide quartz veins containing pyrite, pyrrhotite(?, reddish brown) and opaques. -15: 9 x 3 cm **Unit A**. Cut by 1 mm wide quartz vein with opaques developed along the vein margins. -16: 19 x 6 cm breccia of Unit A. Clasts are 2-3 mm across up to 5 cm across, and strongly weathered to soft light green-yellow serpentinite. Opaque minerals are developed along clast margins. Tectonic breccia? **Unit B**. -17: 15 x 6 cm **Unit B**. -18: 13 x 5 cm **Unit B**, but clasts are altered to soft apple green chlorite instead. -19: 6 x 3 cm possible hyaloclastite. More probably the weathered surface of **Unit A** boulder. -20: Bulk sample of 10 small MnOx crust pieces. -21: 30 x 22 cm **Unit A** large boulder for cutting on the large saw.

		-22: Bulk sample of 8 large **Unit A** boulders up to 20 x 15 cm each.
38 DR Cocos	25.11.1999 on bottom: 13:49 h 2419 m 04°21.59' N 085°47.05' W off bottom: 14:50 h 2197 m 04°21.92' N 085°47.39' W	-1: 13 x 5 cm black vesicular olivine basalt. Olivine phenocrysts (10%) are fresh and up to 1 mm across. Groundmass is fine grained and also olivine-bearing (fresh). Vesicles (30 %) are mostly empty and banded with large (up to 5 mm across) vesicles at pillow cores and small numerous vesicles (<1 mm) at pillow rims. Black glassy rim zone is 5 mm wide. A pillow fragment. **Unit A**. -2: 9 x 5 cm **Unit A**. -3: 11 x 6 cm **Unit A**. The most olivine-rich sample (15%) and with the coarsest groundmass. Soft pale cream clay fills the outer vesicles. -4: 12 x 4 cm **Unit A**. A complete small pillow with a 4 cm long vesicle at its core. Good glassy rim. -5: 11 x 6 cm **Unit A**. -6: 14 x 8 cm **Unit A**. -7: 11 x 4 cm **Unit A**. As for 4, but no central vesicle. -8: 14 x 4 cm **Unit A**. Rather more weathered with weak iron-staining, and covered in soft clay. -9: 13 x 7 cm **Unit A**. -10: 14 x 9 cm **Unit A**, as for 7. -11: 13 x 4 cm **Unit A**, as for 7. -12: 15 x 9 cm **Unit A**. Has the thickest glassy rim of all samples (10 mm). -13: Bulk sample of 7 large boulders of **Unit A**, each up to 20 x 15 cm across.
39 DR Cocos	25.11.1999 on bottom: 23:24 h 1164 m 04°30.84' N 086°46.23' W off bottom: 00:40 h 1087 m 04°30.73' N 086°45.94' W	-1: 14 x 5 cm vesicular blue-grey aphyric basalt. Vesicles (30%) up to 3 mm long and partly filled with orange clay. Weathered and iron-stained, especially in the outermost 1 cm. **Unit A**. -2: 12 x 5 cm vesicular blue-grey plagioclase basalt. Plagioclase phenocrysts (5%) are small but up to 2 mm long. Trace olivine phenocrysts usually replaced by iddingsite. Vesicles (20-30%) stained or partly filled by soft orange clay. Weathered rock with some iron-staining. **Unit B**. -3: 20 x 10 cm **Unit B**, with a 1 mm thick MnOx crust. -4: 9 x 5 cm **Unit B**. -5: 12 x 6 cm **Unit B**. Deeply weathered with a 3 mm thick MnOx crust. -6: 11 x 7 cm vesicular blue-grey plagioclase-olivine basalt. Olivine phenocrysts (20%) are mostly pseudomorphed by iddingsite. Plagioclase phenocrysts (5%) are smaller. Vesicles (20-30%) often iron-stained and partly filled by soft orange clay. Weathered, with some iron-staining throughout the rock. **Unit C**. -7: 10 x 5 cm **Unit C**.

		-8: 12 x 6 cm **Unit C**. More weathered, with much iron-staining. -9: 9 x 6 cm **Unit C**, as for 8. -10: 10 x 5 cm **Unit C**, as for 8. -11: 9 x 6 cm **Unit C**, as for 8. -12: 9 x 5 cm **Unit C**. Deeply weathered. -13: 12 x 4 cm **Unit C**, as for 12. -14: 15 x 11 cm green-grey holocrystalline rock. Olivine (10%) is occasionally fresh and set in a matrix of plagioclase whose grain size is 2 mm. Some large cavities up to 1 cm long occur. Weathered, with minor iron-staining. Olivine gabbro. **Unit D**. -15: 16 x 7 cm **Unit D**, deeply weathered. -16: 17 x 11 cm **Unit D**. Extremely weathered to yellow clays and black iron-MnOx. The MnOx crust is 3 cm thick and contains hyaloclastite fragments. -17: 13 x 5 cm **Unit D**(?). Extremely weathered to dark green, yellow and orange clays. -18: 13 x 6 cm **Unit D**(?). As for 17. -19: 12 x 7 cm **Unit D**(?). As for 17. -20: 11 x 6 cm **Unit D**(?). As for 17. -21: 12 x 5 cm hyaloclastite. Clasts of deeply weathered lava up to 1 cm across in a yellow-orange clay matrix. MnOx crust up to 1 mm thick. **Unit E**. -22: Bulk sample of 4 hyaloclastite pieces (uncut), up to 10 x 5 cm each. **Unit E**. -23: Bulk sample of 5 large MnOx encrusted **Unit E** boulders, for display purposes. -24: Bulk sample of 2 MnOx pieces for Prof. Stoffers.
40 DR Cocos	26.11.1999 on bottom: 06:07 h 2005 m 04°37.98' N 087°21.31' W off bottom: 07:13 h 1755 m 04°37.96' N 087°21.84' W	No rock samples.
40a DR Cocos	26.11.1999 on bottom: 08:35 h 2019 m 04°38.62' N 087°21.95' W off bottom: 10:06 h 1635 m 04°37.87' N 087°22.05' W	-1: 15 x 6 cm black highly vesicular plagioclase basalt. Plagioclase phenocrysts (5%) are small (<1 mm across). Trace olivine phenocrysts are also small and fresh pale green. Vesicles (20-50%) are largest at pillow cores and bases (2 mm) and smaller but more numerous at pillow rims. Most vesicles are empty, but a few are slightly iron-stained. Glassy rim up to 5 mm thick to boulders. Extremely fresh rock in appearance, with minimal MnOx or surface weathering. **Unit A**. -2: 26 x 10 cm **Unit A**. -3: 21 x 8 cm **Unit A**.

		-4: 22 x 9 cm **Unit A**. -5: 13 x 7 cm **Unit A**. Includes a 5 mm long olivine-bearing xenolith. -6: 23 x 17 cm **Unit A**. -7: 19 x 12 cm **Unit A**. -8: 15 x 14 cm **Unit A**. Good glass rind. -9: 25 x 15 cm **Unit A**. More weathered surface than the others, but still very fresh in appearance. -10: 15 x 13 cm **Unit A**. Vesicles are larger (up to 4 mm) and plagioclase phenocrysts in the denser vesicle-free groundmass areas are more numerous (10%). -11: 13 x 5 cm **Unit A**, as for 10. -12: 10 x 4 cm **Unit A**. Contains a large vesicle 2.5 cm long at the core of this small pillow. -13: 15 x 5 cm **Unit A**. As for 10, but few vesicles, denser, and with 10-15% plagioclase phenocrysts. -14: Bulk sample of 3 large pillow boulders of **Unit A**. Largest is 30 cm pillow with glassy top and smooth base where it has flowed over the underlying rock.
41 DR **Cocos**	26.11.1999 on bottom: 15:21 h 2285 m 04°40.46' N 087°54.59' W off bottom: 16:25 h 2035 m 04°40.07' N 087°54.15' W	-1: 15 x 6 cm dark grey olivine-plagioclase basalt. Olivine phenocrysts (5%) are up to 4 mm across and most are pseudomorphed by iddingsite. Plagioclase phenocrysts (10%) are much smaller (seldom 2 mm long) and fresh. Vesicles (5%) are small. Some pull-apart structures in the lava. A pillow fragment. Weathered and iron-stained surface, but no MnOx crust (<1 mm thick). **Unit A**. -2: 8 x 8 cm **Unit A**. -3: 11 x 6 cm **Unit A**. -4: 13 x 8 cm **Unit A**. -5: 18 x 10 cm **Unit A**. -6: 15 x 7 cm **Unit A**. Some big internal cavities 2 cm long. -7: 15 x 8 cm **Unit A**. A 1 cm thick band of yellow sandstone (hyaloclastite?) adheres to the rim. -8: 12 x 5 cm **Unit A**. -9: 10 x 6 cm **Unit A**. -10: 17 x 6 cm **Unit A**. -11: 14 x 4 cm **Unit A**. More weathered and iron-stained. -12: 10 x 3 cm **Unit A**. -13: 8 x 3 cm **Unit A**. -14: 6 x 3 cm **Unit A**. -15: 9 x 5 cm **Unit A**. -16: 11 x 6 cm **Unit A**. -17: 7 x 5 cm **Unit A**. -18: 8 x 4 cm **Unit A**. -19: 12 x 8 cm dark grey plagioclase basalt. Plagioclase phenocrysts (15%) are typically 2 mm across and fresh. Vesicles (10%) are usually empty. Traces of disseminated fine grained pyrite, especially along a

		<0.1 mm wide veinlet. Darker within 1 cm of rim, but no MnOx crust or glass. **Unit B**. -20: 11 x 4 cm **Unit B**. Much disseminated pyrite, especially around a 1 cm long vesicle. -21: 12 x 5 cm **Unit B**. Traces of disseminated pyrite. -22: 14 x 5 cm **Unit B**, as for 21. -23: 9 x 3 cm **Unit B**, as for 21. -24: 10 x 4 cm **Unit B**, as for 21. -25: 8 x 6 cm black vesicular fine grained basalt. Traces of olivine phenocrysts (<5%), partly pseudomorphed by iddingsite. Vesicles (30-50%) mostly empty, but filled with soft pale clay near the rim. **Unit C**. -26: 10 x 4 cm **Unit C**. -27: 7 x 4 cm **Unit C**. Deeply weathered with much iron-staining. -28: 8 x 4 cm **Unit C**, as for 27. -29: 9 x 3 cm **Unit C**. Deeply weathered to orange clays. -30: 10 x 3 cm sandstone. Deeply weathered but appears layered. Hyaloclastite? (same material as on 7). -31: Bulk sample of 5 boulders up to 25 x 15 cm each. Iron-stained rinds with yellow clays. Probably all **Unit A**. Pillow fragments. -32: Large 45 x 26 cm pillow fragment, uncut and left on deck for display. Probably **Unit A**.
42 DR **Cocos**	26.11.1999 on bottom: 21:16 h 2050 m 05°08.68' N 087°32.60' W off bottom: 22:32 h 1820 m 05°08.26' N 087°32.58' W	-1: 11 x 5 cm grey fine grained aphyric basalt. Groundmass contains small fresh olivine crystals. Vesicles (20%) are very small (<0.1 mm) and empty. Rock surface is weakly weathered with no MnOx. **Unit A**. -2: 13 x 4 cm **Unit A**. -3: 24 x 8 cm **Unit A**. Also contains some large spherical vesicles (5%) up to 3 mm across. -4: 20 x 7 cm **Unit A**. Contains 15% large vesicles up to 3 mm across. -5: 20 x 8 cm **Unit A**, as for 4. -6: 17 x 6 cm **Unit A**. Contains 15% large vesicles up to 5 mm across. -7: 14 x 4 cm **Unit A**. Pale grey in colour and with elongate small vesicles that develop into pull-apart structures. No other changes. -8: 14 x 6 cm **Unit A**, as for 7. -9: 27 x 7 cm **Unit A**. As for 7, but a lighter shade of grey and more weathered along pull-aparts. -10: 15 x 8 cm **Unit A**, as for 9. -11: 14 x 6 cm **Unit A**, as for 9. -12: 17 x 6 cm **Unit A**, as for 9. -13: Bulk sample of 6 **Unit A** boulders up to 30 x 15 cm each. Three are of the large vesicle sub-type, and three of the pull-apart sub-type.
43 DR	27.11.1999	-1: 16 x 9 cm grey fine grained plagioclase basalt.

Cocos	on bottom: 11:13 h 2066 m 05°18.60' N 085°22.67' W off bottom: 12:31 h 1715 m 05°17.82' N 085°22.71' W	Plagioclase phenocrysts (5%) are up to 2 mm across. Groundmass contains olivine and plagioclase and is fresh. Vesicles are up to 10% at the rim, and range from small to 1.5 cm long. Most are empty, but some near the rim are iron-stained and filled by soft pale yellow clay. Darker within 5 mm of the rim. **Unit A**. -2: 13 x 8 cm **Unit A**. More vesicular (20%) and more weathered. -3: 12 x 6 cm grey vesicular aphyric basalt. Groundmass is crystalline but very fine grained and fresh. Vesicles (30%) range from a few 3 mm across to numerous very small, and are empty except at the rim where some are filled by soft yellow clay. **Unit B**. -4: 13 x 7 cm **Unit B**. Glassy zone at rim is 5 mm wide. -5: 12 x 6 cm **Unit B**, as for 4. -6: 29 x 8 cm **Unit B**. A few large vesicles (5%) up to 3 mm across and many very small vesicles. -7: 14 x 8 cm **Unit B**. Many (20%) large vesicles 3 mm across. -8: 14 x 7 cm **Unit B**. As for 7, and with intermittent glassy rim up to 5 mm wide. -9: 9 x 5 cm **Unit B**. Many small vesicles. -10: 15 x 9 cm hyaloclastite consisting of clasts of **Unit B**. One clast is 7 cm long (as for 3), others are smaller (2-3 mm) and in a yellow-orange clay matrix. MnOx crust is 2 cm thick. -11: 17 x 7 cm hyaloclastite. Mostly yellow-green palagonitic clay with a few deeply weathered rock fragments. MnOx crust is 2 cm thick. -12: Bulk sample of 3 pieces of 2 cm thick MnOx crust on hyaloclastite. -13: Bulk sample of 3 boulders up to 30 x 15 cm each of **Unit B**. Intermittent glass development at their rims. -14: 15 x 12 cm large hyaloclastite boulder. Clasts up to 10 cm long, but most about 1 cm long.
44 DR **Cocos**	27.11.1999 on bottom: 01:18 h 2961 m 05°58.10' N 083°40.03' W off bottom: 02:19 h 2698 m 05°58.33' N 083°40.18' W	-1: 22 x 6 cm reddish grey aphyric basalt. Groundmass is very fine grained but appears to be pervasively altered. Vugs (5%) are filled by hard silica. Darker at 5 mm wide rim zone. Dark green chloritic rind <5 mm thick. **Unit A**. -2: 14 x 8 cm **Unit A**. Rather more vesicular (5%) with pale cream or yellow clays in vesicles. -3: 17 x 6 cm **Unit A**, but with soft zeolite in vugs and vesicles. Well-formed pillow surface. -4: 16 x 8 cm brown-grey olivine basalt. Olivine phenocrysts (5%) are small (<0.5 mm) and pseudomorphed by iddingsite. Vesicles (10%) are filled by soft white zeolite. **Unit B**. -5: 13 x 4 cm **Unit B**. -6: 15 x 8 cm **Unit B**. More weathered.

		-7: 14 x 8 cm pale grey vesicular aphyric basalt. Vesicles (10%) are small and empty. Some large (1 cm) vugs filled by banded pale blue hard silica. Darker in outer 5 mm. **Unit C**. -8: 13 x 5 cm **Unit C**. -9: 18 x 5 cm **Unit C**. -10: 12 x 5 cm **Unit C**. No large silica vugs, but weathered or altered interior. -11: 18 x 8 cm **Unit C**, as for 10. -12: 14 x 5 cm **Unit C**, as for 10. -13: 7 x 4 cm dark green dolerite. Holocrystalline rock with 40% fine grained olivine partly pseudomorphed by iddingsite and black opaques and/or pyroxene. Well-rounded; a beach cobble? **Unit D**. -14: 14 x 5 cm greenish blue gabbro. Holocrystalline matrix of plagioclase and black pyroxene 1 mm across. Fresh interior, but more weathered in outer 2 cm. **Unit E**. -15: 14 x 7 cm **Unit D**. -16: 15 x 5 cm **Unit D**. -17: 16 x 7 cm hyaloclastite. Clasts of Unit A up to 5 mm long, but most are 3-4 mm in a black and yellow clay matrix. **Unit F**. -18: 11 x 7 cm **Unit F**. As for 17, but clasts are larger with most >5 mm and little matrix. MnOx crust is up to 5 mm thick. -19: Bulk sample of four big boulders up to 20 x 15 cm each. Uncut. Probably **Units D and E**. -20: Bulk sample of 7 rounded pebbles ranging from 4-9 cm in diameter. Possibly beach cobbles. Uncut.
45 DR **Cocos**	28.11.1999 on bottom: 11:30 h 1679 m 06°14.33' N 084°57.65' W off bottom: 14:11 h 1359 m 06°13.70' N 084°56.94' W	-1: 20 x 9 cm hyaloclastite. Deeply weathered ferruginous clasts of extremely vesicular (60%) lava in a yellow-orange-green palagonitic clay marix. Most clasts about 5 mm across. MnOx crust up to 2 mm thick. **Unit A**. -2: 13 x 7 cm **Unit A**. -3: 11 x 6 cm **Unit A**. -4: 13 x 7 cm **Unit A**. -5: 10 cm in diameter **Unit A**. -6: 16 x 7 cm **Unit A**. -7: 16 x 5 cm **Unit A**. Very deeply weathered with 5 mm thick MnOx crust. -8: 9 x 4 cm **Unit A**, as for 7. -9: 19 x 6 cm **Unit A**, but most of the rock is MnOx crust 5 cm thick with fine scale concentric banding. -10: 16 x 8 cm **Unit A**, as for 9. -11: 7 x 5 cm MnOx crust with small (0.1 mm) orange clay specks. **Unit B**. -12: 19 x 5 cm **Unit B**, but just MnOx crust. -13: 17 x 4 cm **Unit B**, but just MnOx crust.

		-14: 11 x 5 cm **Unit B**. Just MnOx crust, with well-developed concentric banding. -15: 15 x 4 cm cream coloured palagonitic clay with deeply weathered rock fragments up to 5 mm across. **Unit A**. -16: 20 x 15 cm pumice. Cream white interior with fresh glass(?). Vesicles (40%) are empty and elongated. MnOx staining in outer 2 cm. **Unit C**.
45a DR Cocos	28.11.1999 on bottom: 16:17 h 1644 m 06°16.00' N 085°53.25' W off bottom: 18:12 h 1459 m 06°15.65' N 084°53.36' W	-1: 4 cm in diameter hyaloclastite. Largest clast (3 cm) is brown-grey vesicular plagioclase (5%) basalt. Vesicles (40%) are either empty or filled by dark grey very hard silica. **Unit A**. -2: 15 x 10 cm **Unit A**. Clasts up to 5 cm, partly replaced by dark grey silica. Most of clay matrix is also replaced. MnOx crust up to 3 cm thick. -3: 8 x 6 cm **Unit A**. -4: 13 x 6 cm MnOx crust with well-developed concentric banding. -5: Bulk sample of 4 small pieces of MnOx crust. -6: Bulk sample of thick (7 cm) banded MnOx crust from rim of 2.
46 TVG Cocos	28.11.1999 on bottom: 23:22 h 634 m 06°29.43' N 085°34.25' W off bottom: 23:39 h 634 m 06°29.43' N 085°34.78' W	-1: 13 x 8 cm drak grey vesicular plagioclase basalt. Small plagioclase phenocrysts (5%) and traces of olivine (fresh). Vesicles (40%) are small (<0.1 mm), numerous and empty. Fresh rock with little staining of surface. Almost certainly a clast within grabbed hyaloclastite. **Unit A**. -2: 8 x 7 cm **Unit A**. Glassy dark rim 5 mm wide. Much larger vesicles, though fewer, and rock is scoriaceous. -3: 11 x 8 cm **Unit A**, as for 2. -4: 10 x 5 cm **Unit A**. As for 2, but with glassy rim zone up to 2 cm wide. -5: 10 x 5 cm **Unit A**. -6: 14 x 7 cm **Unit A**. -7: Bulk sample of about 20 small cut pieces of **Unit A**. -8: Bulk sample of about 5 small weathered **Unit A** clasts. Four grade into hyaloclastite at their margins. -9: Bulk sample of about 40 small uncut **Unit A** pebbles. Most are strongly weathered. -10: 25 x 16 cm large boulder of **Unit A** hyaloclastite. Clast supported with little matrix. Strongly weathered clasts. MnOx crust up to 3 mm thick.
47 DR Cocos	29.11.1999 on bottom: 02:26 h 2015 m 06°38.44' N 085°44.77' W off bottom: 03:59 h 1600 m 06°37.98' N	-1: 25 x 15 cm black vesicular basalt. Trace fresh olivine and plagioclase phenocrysts (<1% each). Vesicles (30%) up to 3 mm across. Dark glassy 3 mm rind. Very fresh. **Unit A**. -2: 15 x 7 cm **Unit A**, but outer 5 mm is glassy and with smaller vesicles. -3: 13 x 8 cm **Unit A**, as for 2. -4: 15 x 9 cm **Unit A**, as for 2.

	085°44.29' W	-5: 14 x 7 cm **Unit A**, as for 2. -6: 9 x 6 cm **Unit A**. Denser, with 20% vesicles and no glassy rim. -7: 9 x 7 cm **Unit A**. As for 2, but more weathered. -8: 9 x 4 cm **Unit A**. Much more weathered. -9: 9 x 5 cm **Unit A**. Vesicles (20%) are filled with soft cream clay. -10: Two pebbles of hyaloclastite. Clasts to 1 cm across, and little matrix material. **Unit B**. -11: Bulk sample of glass from pillow rind of a **Unit A** rock. -12: Bulk sample of 14 uncut pebbles of **Unit A**.
48 DR Cocos	29.11.1999 on bottom: 07:26 h 1517 m 06°47.74' N 085°22.88' W off bottom: 08:39 h 1252 m 06°47.20' N 085°22.97' W	-1: 8 x 4 cm brownish grey plagioclase basalt. Plagioclase phenocrysts (20%) are up to 4 mm across and partly altered. Trace olivine phenocrysts pseudomorphed by iddingsite. Vesicles (10%) are up to 4 mm long and partly filled by soft clay. Quite weathered. **Unit A**. -2: 5 x 2 cm reddish grey vesicular pyroxene basalt. Pyroxene phenocrysts (5%) are set in a weathered groundmass. Vesicles (20%) are partly clay-filled. Hyaloclastite forms the rim of the pebble. **Unit B**. -3: 6 x 3 cm dark grey aphyric vesicular basalt. Vesicles (20%) are small and partly fille by soft clay. Weathered at the rim. **Unit C**. -4: 8 x 2 cm deeply weathered rock consisting of soft green clays (after olivine?) and black material. Gabbro? **Unit D**. -5: 12 x 5 cm hyaloclastite. Deeply weathered vesicular rock fragments up to 5 mm long set in yellow-orange palagonitic clay. **Unit E**. -6: 13 x 3 cm **Unit E**. -7: 19 x 4 cm **Unit E**, but mostly a 2 cm thick MnOx crust. -8: Bulk sample of 3 small **Unit E** pebbles, each with maximum clast sizes of about 2 mm. -9: Bulk sample of 10 small **Unit E** pebbles consisting of yellow palagonitic clay and some small (<2 mm) deeply weathered rock fragments.
49a DR Cocos	29.11.1999 on bottom: 16:17 h 1615 m 06°56.39' N 084°14.95' W off bottom: 18:23 h 1203 m 06°55.77' N 084°14.84' W	-1: 13 x 11 cm dark blue vesicular aphyric basalt. Heavy. Olivine is present in the groundmass and is partly pseudomorphed by iddingsite. Vesicles (30%) are small and partly filled by orange clay. Some iron-staining. **Unit A**. -2: 11 x 6 cm **Unit A**. Rounded boulder. More weathered and coarser grained. -3: 13 x 5 cm **Unit A**. Vesicles (10%) occur as large pull-aparts up to 1 cm long. Iron-stained around and in vesicles. -4: 14 x 5 cm **Unit A**. As for 3, but outer 2 mm is darker

		(MnOx?). -5: 19 x 7 cm **Unit A**, as for 4. -6: 13 x 9 cm **Unit A**, as for 4. -7: 7 x 6 cm dark green fine grained olivine gabbro. Olivine (30%) often fresh, some pseudomorphed by iddingsite. Black pyroxene is the same size (0.1 mm). **Unit B**. -8: 13 x 8 cm **Unit B**. Coarser grained (0.2 mm) and more weathered. -9: 12 x 6 cm hyaloclastite with a large Unit A fragment 5 cm long. MnOx crust is 5 mm thick. -10: 9 cm in diameter hyaloclastite. Deeply weathered vesicular rock fragments to 5 mm long in sand-sized yellow clay/silt matrix. **Unit C**. -11: 10 x 5 cm **Unit C**. -12: 17 x 7 cm **Unit C**, but finer grained (0.1 mm). -13: 9 x 7 cm **Unit C**, as for 12. -14: 17 x 8 cm **Unit C**. As for 12, but palagonised to yellow clay. -15: Bulk sample of 2 big uncut **Unit A** boulders (up to 30 x 10 cm). Chloritic weathering rind. -16: Small pieces of MnOx crust from a hyaloclastite Unit C boulder. -17: Large 30 x 20 cm boulder of hyaloclastite left on deck (**Unit C**).
49b TVG Cocos	29.11.1999 on bottom: 21:42 h 1048 m 07°00.28' N 083°54.14' W off bottom: 21:56 h 1048 m 07°00.29' N 083°54.17' W	No rock samples. Grab full of cream grey foram ooze consisting of 70% forams, 20% pale cream clay, and 10% black iron-stained deeply weathered rock fragments <0.1 mm across.
50 DR Cocos	30.11.1999 on bottom: 02:27 h 1738 m 06°58.59' N 083°41.39' W off bottom: 03:41 h 1488 m 06°59.06' N 083°41.58' W	-1: 11 x 5 cm vesicular aphyric basalt. Vesicles (40%) are empty. Heavy. Minor iron-staining. **Unit A**. -2: 23 x 6 cm **Unit A**. Somewhat coarser grained and more weathered. -3: 9 x 5 cm **Unit A**. -4: 10 x 6 cm **Unit A**. -5: 12 x 7 cm **Unit A**. Dark glassy rim 5 mm thick. Some pull-apart structures up to 2 cm long. -6: 11 x 6 cm **Unit A**, as for 5. -7: 11 x 5 cm **Unit A**. Soft clay fills vesicles (5%) up to 3 mm across. -8: 14 x 6 cm **Unit A**, as for 5. -9: 9 x 5 cm **Unit A**. More weathered, with dark glassy zone 1.5 cm thick and overlain by MnOx crust 3 mm thick. -10: 15 x 7 cm **Unit A**. MnOx crust up to 5 mm thick.

		-11: 15 x 7 cm **Unit A**. More weathered, with well developed mottled texture. -12: 15 x 4 cm **Unit A**. Deeply weathered with 3 mm thick central clay vein. -13: Bulk sample of 3 **Unit A** boulders with chloritic rinds. -14: Bulk sample of 7 well rounded cobbles of **Unit A**. -15: Bulk sample of 13 small MnOx pieces for Peter Stoffers.
51 DR **Cocos**	30.11.1999 on bottom: 09:34 h 3289 m 06°59.97' N 082°51.72' W off bottom: 11:20 h 2753 m 06°59.97' N 082°52.12' W	-1: 11 x 7 cm blue-grey aphyric basalt. Trace black pyroxene phenocrysts. Groundmass has much plagioclase (30%). A few small empty vesicles. Outer 1 cm is weathered. **Unit A**. -2: 15 x 8 cm dark grey aphyric basalt. Fine grained groundmass plagioclase and olivine, with the latter partly pseudomorphed by iddingsite. Many very small vesicles, which are empty except near the pillow rim. Dark glassy rim 3 mm wide. **Unit B**. -3: 13 x 7 cm **Unit B**. Some large vuggy vesicles up to 5 mm across with orange clay filling some of them. -4: 12 x 8 cm **Unit B**, as for 3. -5: 10 x 5 cm **Unit B**. As for 3, but more vuggy vesicles. -6: 13 x 6 cm black aphyric basalt. Flow banded on the scale of a few mm with white devitrified specks in a black cryptocrystalline groundmass. **Unit C**. -7: 10 x 6 cm **Unit C**. Outer 1 cm much more weathered. -8: 14 x 6 cm blue-grey plagioclase basalt. Plagioclase phenocrysts (5%) form large (5 mm) clusters. Groundmass is fine grained and fresh. Small vesicles (10%) are empty. Yellow and orange clays developed along fractures. **Unit D**. -9: 10 x 6 cm dolerite. Large (2 mm) plagioclase crystals in a holocrystalline olivine-pyroxene-plagioclase matrix. Olivine partly pseudomorphed by iddingsite. Well rounded and weathered boulder. **Unit E**. -10: 16 x 6 cm blue gabbro. Dark and dense holocrystalline plagioclase-two pyroxene gabbro with a grain size of 1-2 mm. Fine grained disseminated pyrite. **Unit F**. -11: 11 x 6 cm **Unit F**. Outer 2 mm is more weathered. -12: 17 x 7 cm **Unit F**. Outer 1-2 cm is more weathered. -13: 11 x 7 cm **Unit F**. As for 12, but traces of pseudomorphed olivine. -14: 14 x 7 cm **Unit B**, as for 2. -15: 23 x 6 cm **Unit F**. Coarser grained (3 mm) with a few quartz veinlets. -16: 20 x 8 cm green gabbro. Holocrystalline rock consisting of olivine partly pseudomorphed by iddingsite, pyroxene and plagioclase. Some plagioclase is coarser (2 mm) than the rest of the rock

		(1 mm). Many small vesicles are partly filled by yellow clay. Well rounded and weathered boulders. **Unit G.** -17: 11 x 6 cm **Unit G.** -18: 7 x 5 cm **Unit G.** Particularly well rounded. -19: 13 x 7 cm **Unit G.** Deeply weathered. -20: 20 x 5 cm **Unit G.** Extremely weathered (clay) with a 5 mm bluish MnOx crust. -21: 13 x 6 cm blue conglomerate. Rock fragments are deeply weathered and up to 1.5 cm long, set in a hard silty matrix. Outer 1 cm is blue (chloritised?), whereas the core is green. **Unit H.** -22: 13 x 4 cm **Unit H,** but all blue. -23: 16 x 9 cm **Unit H,** but reddish grey and very hard (silicified?). -24: 16 x 6 cm yellowish grey conglomerate. Deeply weathered rock fragments up to 1 cm long are sometimes vesicular or silicified, and set in a sandy clay matrix. Hard. Innermost 2 cm of boulder is blue (chloritised?). **Unit I.** -25: 18 x 7 cm **Unit I.** -26: 12 x 7 cm **Unit I,** but no blue core. -27: 14 x 10 cm **Unit I,** as for 26. -28: 18 x 7 cm **Unit I,** as for 26. -29: 18 x 8 cm **Unit I.** As for 26, but more weathered. -30: 14 x 6 cm **Unit I.** As for 26, but more weathered and matrix is red (hematite?) in places. -31: 12 x 7 cm yellow green altered vesicular aphyric basalt. Vesicles (20%) are partly filled with chloritic clay. Pervasive chlorite alteration. Clay veins 2-3 mm wide have opaque margins and silicified patches with fine grained pyrite. **Unit J.** -32: 16 x 7 cm **Unit J.** -33: 8 x 4 cm **Unit J.** No veins. -34: Bulk sample of 4 boulders up to 12 x 10 cm each. All are probably **Unit F.**
52 DR **Cocos**	30.11.1999 on bottom: 15:22 h 2912 m 07°22.99' N 082°53.82' W off bottom: 17:51 h 2441 m 07°23.04' N 082°54.72' W	-1: 22 x 7 cm dark grey aphyric basalt. Groundmass is relatively coarse (0.1 mm), includes plagioclase and is fresh. Small vesicles (10%) are empty. Thin darker glassy rim zone 2 mm thick. Very fresh rock. **Unit A.** -2: 9 x 7 cm **Unit A.** More weathered outer 5 mm. -3: 15 x 12 cm **Unit A.** -4: 11 x 10 cm **Unit A.** More vesicular (20%) with larger vuggy vesicles up to 2 mm across which are often filled by black chlorite. -5: 10 x 6 cm **Unit A,** as for 4. -6: 10 x 8 cm **Unit A,** as for 4. -7: 7 x 5 cm **Unit A.** As for 4, but more weathered and softer. -8: 9 x 5 cm **Unit A.** More vesicular (15%) and coarser

		grained. -9: 13 x 6 cm dark grey vesicular aphyric basalt. Equivalent to Unit A, but coarser grained groundmass (0.5 mm) and 30% vesicles to 6 mm across which are lined by dark green chlorite. **Unit B**. -10: 6 x 5 cm **Unit B**. Well rounded. -11: 15 x 8 cm **Unit B**. Vesicles often filled by pale blue silica. -12: 10 x 6 cm **Unit B**. Deeply weathered. -13: 13 x 10 cm grey gabbro. Holocrystalline rock consisting of plagioclase and two pyroxenes. Grain size 1 mm. Weathering rind 1 mm thick, but very fresh. **Unit C**. -14: 11 x 8 cm **Unit C**. Somewhat coarser grained (2 mm), and more weathered with weathering rind 5 mm thick. -15: 15 x 9 cm **Unit C**, as for 14. -16: 15 x 6 cm **Unit C**. Coarser grained (3 mm), with opaques surrounding dark green clinopyroxene. -17: 10 x 5 cm **Unit C**. Moderately weathered and iron-stained. -18: Bulk sample of 3 big chloritic boulders up to 20 x 15 cm each. One is a **Unit A/B** pillow, the other two are **Unit C**. -19: Bulk sample of 4 small pieces of hyaloclastite. -20: Bulk sample of 5 rounded rocks representing a possible paleo-beach deposit.
53 DR **Cocos**	30.11.1999 on bottom: 23:00 h 1530 m 07°36.24' N 083°25.21' W off bottom: 00:21 h 1365 m 07°36.46' N 083°25.21' W	-1: 11 x 10 cm reddish grey vesicular plagioclase basalt. Plagioclase phenocrysts (25%) up to 5 mm long. Vesicles (20 %) are empty. Scoriaceous and fresh. **Unit A**. -2: 11 x 4 cm **Unit A**. Vesicles are larger but fewer. -3: 12 x 6 cm reddish grey vesicular aphyric basalt. Groundmass very fine grained. Vesicles (30%) up to 3 mm across, empty at core but pale red clays fill those near the rim. **Unit B**. -4: 12 x 5 cm **Unit B**. Soft green mud in some vesicles. -5: 8 x 5 cm **Unit B**, as for 4. -6: 11 x 5 cm **Unit B**. More weathered with yellow clay in some vesicles. -7: 10 x 5 cm **Unit B**. As for 6, with much yellow-orange clay in vesicles. -8: 9 x 5 cm **Unit B**. More weathered and darker in colour. Yellow and green clays in vesicles. -9: 11 x 7 cm **Unit B**. More weathered, and with trace plagioclase phenocrysts. Darker in colour. -10: 20 x 8 cm red aphyric basalt. Flow banded on few mm scale. Fine grained groundmass. **Unit C**. -11: 11 x 7 cm **Unit C**. -12: 16 x 6 cm **Unit C**. Darker in colour, more vesicular,

		and with trace plagioclase phenocrysts. -13: 11 x 4 cm black vesicular plagioclase basalt. Plagioclase phenocrysts (5%) in cryptocrystalline groundmass. Vesicles (30%) are empty. **Unit D**. -14: 19 x 9 cm **Unit D**. Larger vesicles filled by soft green clays. -15: 14 x 6 cm greenish grey aphyric basalt. Cryptocrystalline groundmass is partly altered with orange-stained domains and opaque mineral development. Fractures coated in dark green chlorite. Few large vesicles are filled with brown clay. **Unit E**. -16: 13 x 6 cm **Unit E**. -17: 9 x 6 cm **Unit E**. More weathered. -18: 22 x 5 cm **Unit E**. More vesicles (10%) to 3 mm across, and more weathered. -19: 20 x 7 cm **Unit E**, as for 18. -20: 10 x 5 cm **Unit E**, with trace plagioclase phenocrysts. -21: 8 x 7 cm **Unit E**, as for 20. Particularly well rounded. -22: 12 x 6 cm **Unit E**. As for 20, but a few large iron-stained vesicles. -23: Bulk sample of several rounded cobbles. Possible paleo-beach deposit. -24: Bulk sample of 2 large 30 x 15 cm boulders. One is vesicular lava (**Unit B**?), and the other is non-vesicular (**Unit E**?).
54 DR Cocos	31.11.1999 on bottom: 04:25 h 1433 m 08°01.34' N 083°27.62' W off bottom: 06:27 h 1223 m 08°01.81' N 083°27.68' W	Dredge safety cable broke. No rock samples.
54a DR Cocos	01.12.1999 on bottom: 07:48 h 1477 m 08°01.89' N 083°26.13' W off bottom: 08:58 h 1142 m 08°02.28' N 083°26.35' W	-1: 15 x 5 cm dark grey vesicular basalt. Fine grained groundmass with 5% olivine pseudomorphed by iddingsite. Vesicles (20%) are up to 1 cm long and partly filled by orange clay. **Unit A**. -2: 16 x 9 cm grey plagioclase basalt. Plagioclase phenocrysts (5%) up to 2 mm long in dense cryptocrystalline groundmass. Small vesicles (5%) mostly empty, but some filled by white clay. **Unit B**. -3: 15 x 7 cm grey gabbro. Holocrystalline rock consisting of plagioclase, black and dark green pyroxene. Grainsize 1 mm. Quite fresh except for 5 mm weathering rind. Rounded boulder. **Unit C**. -4: 13 x 5 cm **Unit C**. More weathered in outer 1 cm and angular. -5: 10 x 7 cm **Unit C**. More weathered in outer 1 cm. Rounded boulder.

		-6: 15 x 6 cm **Unit C**. Many dark green clinopyroxenes replaced by yellow-brown actinolite(?). -7: 20 x 11 cm olivine gabbro. Holocrystalline rock consisting of green or brown pseudomorphed olivine, plagioclase and pyroxene. Grain size 1 mm. Only outer 5 mm is much weathered. **Unit D**. -8: 13 x 7 cm gabbro. Similar to Unit C, but coarser grained (2 mm) and dark bluish green pyroxenes are much larger. **Unit E**. -9: 17 x 10 cm black breccia. Angular fragments of vesicular black lava up to 1 cm across (but most 2 mm) set in red clay. Clast-supported. Most clasts (30%) are pervasively silicified to black silica. Extremely hard and dense. Silicified hyaloclastite. **Unit F**. -10: 12 x 6 cm **Unit F**. -11: 10 x 5 cm **Unit F**. -12: 10 x 4 cm **Unit F**. But only weakly silicified and with much yellow-orange clay. -13: 12 x 5 cm pale brown clay with 1 cm thick deeply weathered ferruginised crust on one side. -14: 7 x 3 cm dark green laminated silicified serpentinite. Probably originally a clay-rich hyaloclastite.
55 DR Cocos	01.12.1999 on bottom: 13:28 h 1366 m 07°52.68' N 083°59.25' W off bottom: 15:53 h 735 m 07°52.66' N 083°59.98' W	-1: 20 x 11 cm dark blue-grey fine grained aphyric basalt. Vesicles (10%) very small, and some lined with dark chlorite or filled with white clay. Weathering rind 5 mm thick. **Unit A**. -2: 12 x 6 cm **Unit A**. -3: 11 x 5 cm **Unit A**. Larger vesicles near rim on one side (2 mm). -4: 15 x 7 cm **Unit A**. More weathered, with 1 cm weathering rind and many vesicles filled by white clay. A pillow fragment. -5: 12 x 8 cm blue-grey plagioclase basalt. Plagioclase phenocrysts (5%) up to 2 mm across. Weathering rind 1 cm wide. Vesicles (10%) lined with chlorite. Iron-stained near surface. **Unit B**. -6: 15 x 8 cm **Unit B**. Concentric weathering below 1 cm weathering rind. -7: 7 x 4 cm **Unit B**. A few large (3 mm) vesicles iron-stained. -8: 14 x 5 cm **Unit B**. -9: 16 x 7 cm **Unit B**. A pillow fragment. -10: 11 x 5 cm **Unit B**. -11: 10 x 5 cm **Unit B**, but with more plagioclase phenocrysts (10%). -12: 15 x 9 cm **Unit B**. Much chlorite lining the vesicles. -13: 9 x 6 cm **Unit B**. More weathered, with yellow clay in vesicles. -14: 9 x 7 cm grey plagioclase basalt. Plagioclase

		phenocrysts (5%) up to 2 mm across. Groundmass is coarser grained than for Unit B, and contains olivine pseudomorphed by iddingsite. Vesicles (10%) are filled by yellow clay. Concentric weathering rind 1 cm thick. **Unit C.** -15: 9 x 6 cm **Unit C**. But with more plagioclase phenocrysts (10%). -16: 14 x 6 cm **Unit C**. -17: 7 x 6 cm grey vesicular basalt. Groundmass is relatively coarse grained and plagioclase-bearing (0.05 mm). Vesicles (20%) up to 2 mm across, most empty but some iron-stained. **Unit D.** -18: 8 x 5 cm **Unit D**, with 5 mm wide dark glassy rim. -19: 12 x 6 cm grey vesicular plagioclase basalt. Similar to Unit D, but with plagioclase phenocrysts (5%). **Unit E.** -20: 9 x 7 cm dark grey plagioclase basalt. Plagioclase phenocrysts (10%) up to 3 mm long. Groundmass contains large plagioclase laths (0.1 mm). Only weakly weathered. **Unit F.** -21: 9 x 6 cm brown-grey plagioclase basalt. Plagioclase phenocrysts (20%) up to 3 mm long in a plagioclase-bearing groundmass. Outer 5 cm is weathered, only the core is fresh. A few empty vesicles. **Unit G.** -22: 11 x 5 cm **Unit G**. -23: 13 x 6 cm **Unit G**. But deeply weathered and iron-stained vuggy vesicles. -24: 16 x 6 cm weathered vesicular aphyric basalt. Vesicles (30%) are small (0.1 mm) and filled with yellow-orange clay. Iron-stained. **Unit H.** -25: 10 x 7 cm **Unit H**. Fresher, with most vesicles empty. -26: 15 x 7 cm grey vesicular basalt. Trace plagioclase phenocrysts. Groundmass contains plagioclase. Vesicles (30%) concentrated near the rim, most empty but some are iron-stained. Iron-stained and clays developed along fractures. Dark 1 cm thick glassy rim. **Unit I.** -27: 11 x 5 cm **Unit I**. Vesicles developing into 1.5 cm long iron-stained pull-aparts with orange clay. -28: 10 x 5 cm **Unit I**. More weathered, with glassy rim palagonised and all vesicles filled by soft black chloritic clay. -29: 12 x 5 cm **Unit I**, as for 28. -30: 9 x 6 cm **Unit I**, as for 28. -31: 19 x 10 cm **Unit I**. As for 28, but more weathered with black chloritic clay also along joints. Groundmass is diffuse (altered). -32: 10 x 7 cm **Unit I**, as for 31. -33: 15 x 5 cm **Unit I**, as for 31. -34: 12 x 7 cm olivine gabbro. Holocrystalline rock

		consisting of olivine partly pseudomorphed by iddingsite, black pyroxene and plagioclase. Grain size 0.1 mm. More weathered in outer 1 cm, with concentric weathering inside that. **Unit J.** -35: 10 x 3 cm **Unit J.** -36: 14 x 5 cm gabbro. Holocrystalline rock consisting of plagioclase (0.3 mm), green and black pyroxene (0.2 mm). Some iron-staining. **Unit K.** -37: 10 x 6 cm deeply weathered brown lava. Probably an aphyric vesicular basalt with groundmass olivine. Most vesicles filled by orange clay. **Unit L.** -38: 4 x 3 cm hyaloclastite. Vesicular aphyric angular rock fragments to 5 mm long in orange-black clay matrix. **Unit M.**
56 TVG Cocos	01.12.1999 on bottom: 20:00 h 978 m 07°52.18' N 084°26.38' W off bottom: 20:49 h 980 m 07°52.11' N 084°26.40' W	-1: 10 x 5 cm Dark grey olivine basalt. Olivine phenocrysts (10%) fresh at core pseudomorphed by iddingsite near the rim. Vesicles (5%) have some orange clay in them. Outer 1 cm is weathered. **Unit A.** -2: 15 x 7 cm **Unit A.** All olivine pseudomorphed by iddingsite. More vesicles (10%) which are empty. -3: 15 x 11 cm **Unit A,** as for 2. -4: 18 x 7 cm **Unit A,** as for 2. -5: 10 x 4 cm **Unit A,** as for 2. -6: 16 x 5 cm **Unit A,** as for 2. Possibility of getting fresh olivines from the core. -7: 19 x 11 cm **Unit A.** Larger vesicles (2 mm) and more weathered. MnOx crust is 3 cm thick. -8: 19 x 4 cm **Unit A,** as for 7. -9: 13 x 6 cm hyaloclastite. Small deeply weathered fragments of **Unit A**(?) in an orange clay matrix. MnOx crust is 2 cm thick. **Unit B.** -10: 17 x 8 cm **Unit B.** -11: 12 x 6 cm **Unit B.** More weathered. -12: 10 x 4 cm **Unit B.** All except a 2 cm core zone is MnOx crust. -13: 12 x 10 cm MnOx crust. A core 1 cm in diameter of **Unit B.** -14: 13 x 5 cm MnOx crust, as for 13. -15: 28 x 8 cm red-orange hyaloclastite. Deeply weathered rock fragments 1-2 mm across in orange clay. -16: MnOx crust from a large **Unit B** boulder for Peter Stoffers. -17: Bulk sample of 3 boulders 20 x 10 cm each of **Unit A.**
57 OBS Recovery		Recovery of ocean bottom seismometers from offshore of the Osa Peninsula, Costa Rica.
58 DR Cocos	05.12.1999 on bottom: 12:26 h 1790 m	No rock samples.

	07°45.65' N 085°10.04' W off bottom: 14:57 h 1384 m 07°45.13' N 085°09.20' W	
58a DR **Cocos**	05.11.1999 on bottom: 16:46 h 1593 m 07°46.49' N 085°09.16' W off bottom: 18:49 h 1443 m 07°46.41' N 085°08.94' W	-1: 17 x 14 cm rounded boulder. Contains a 6 x 4 cm clast of highly vesicular aphyric basalt = **Unit A**. Pale clay fills some vesicles, iron and Mn staining along fractures. Several other small weathered clasts of the same. MnOx crust up to 3 cm thick. -2: 20 x 11 cm rounded boulder, **Unit A**. More weathered than 1. -3: 12 x 6 cm **Unit A**. Clasts fresh at core, deeply weathered at their outer rims. -4: 10 x 6 cm **Unit A**, more weathered than 1. -5: 11 x 6 cm **Unit A**, very weathered. -6: 14 x 6 cm **Unit A**. Clasts extremely weathered. -7: 14 x 5 cm **Unit A**. Many small clasts up to 3 mm long. Extremely weathered. -8: Bulk sample of MnOx crust with mm scale concentric banding. Some clay at centre. -9: Bulk sample of MnOx crust with concentric banding. No clay. -10: 11 x 5 cm ferruginous breccia (hyaloclastite). **Unit B**. -11: 14 x 6 cm **Unit B**. Pebbles up to 3 cm long. -12: 30 x 40 cm **Unit B**. Clasts up to 5 mm long set in a pale clay matrix. Approximately 5% of clasts are moderately fresh. -13: 24 x 15 cm **Unit B**. Relatively clay-rich and more weathered than 12. MnOx crust to 5 cm thick. -14: Bulk sample several small pieces of MnOx crust.
59 DR **Cocos**	05.12.1999 on bottom: 21:57 h 1700 m 07°32.80' N 085°02.91' W off bottom: 23:14 h 1342 m 07°32.58' N 085°02.38' W	No rock samples.
60 DR **Cocos**	05.12.1999 on bottom: 01:49 h 1723 m 07°23.20' N 085°11.18' W off bottom: 23:26 h 1298 m 07°23.21' N 085°11.39' W	-1: 12 x 8 cm **Unit A**. Dark grey pyroxene basalt. Tabular pyroxene phenocrysts (5%) up to 5 mm long. A few small empty vesicles. Fresh apart from 2 mm weathering rind. -2: 18 x 6 cm **Unit A**. -3: 13 x 8 cm **Unit B**. Pillow fragment. Grey pyroxene-olivine basalt, with 10% olivine phenocrysts mostly pseudomorphed by iddingsite and 10% pyroxene phenocrysts.

		-4: 11 x 5 cm **Unit B**. -5: 7 x 4 **Unit B**. Olivine mostly fresh. -6: 21 x 10 cm **Unit B**. Olivine fresh in the rock centre. Outer 2 cm very iron-stained. -7: 15 x 7 cm vesicular olivine basalt. **Unit C**. 10% olivine phenocrysts totally pseudomorphed by iddingsite. 30% vesicles which are mostly empty. -8: 19 x 10 cm **Unit D**. Trachybasalt(?) with 30% small feldspar phenocrysts. Strong flow banding. Outer 2 cm is iron-stained. -9: 18 x 6 cm deeply weathered **Unit D**. MnOx crust 1 cm thick. -10: 13 x 5 cm **Unit D**. -11: 20 x 8 cm dark grey plagioclase basalt, a pillow fragment. **Unit E**. 5% plagioclase phenocrysts. Groundmass silicified. Outer 2.5 cm is iron-stained. -12: 7 x 4 cm. Large clast of **Unit B** plus hyaloclastite. -13: 12 x 8 cm **Unit F**. Breccia of silicified rock fragments. Original rock is a highly vesicular aphyric basalt. MnOx crust is 2 mm thick. Clasts are usually 5 mm in length. -14: 12 x 7 cm **Unit F**. Large areas of soft yellow clay. Some glass on surface? Quite porous. -15: 11 x 15 cm **Unit F**. -16: 11 x 5 cm **Unit F**. -17: 21 x 6 cm **Unit F**. Glassy areas 3 cm long plus clay. Glass is pumiceous with conchoidal fracture, and with a strongly laminated texture. -18: 3 bulk samples left uncut. All are 20 x 15 cm boulders.
61 DR Cocos	06.12.1999 on bottom: 06:03 h 2090 m 07°19.19' N 085°18.22' W off bottom: 07:28 h 1751 m 07°19.73' N 085°18.19' W	-1: 8 x 4 cm green clay. Forams on surface. 1 mm MnOx crust. **Unit A**. Hyaloclastite? -2: 7 x 4 cm **Unit A** with small rock fragments up to 2 mm long.
62 DR Cocos	06.12.1999 on bottom: 10:35 h 2090 m 07°31.21' N 085°32.60' W off bottom: 13:22 h 1550 m 07°30.61' N 085°31.66' W	-1: 15 x 10 cm dark grey fine-grained basalt. Trace pyroxene phenocrysts and olivine phenocrysts pseudomorphed by iddingsite. **Unit A.** Angular clast in a breccia with 10% small vesicles, mostly empty. MnOx crust is 2 mm thick. The breccia is Unit C hyaloclastite. -2: 9 x 4 cm dark grey pyroxene basalt. **Unit B**. Large pyroxene phenocrysts (~15%) up to 1 cm long. Traces of olivine pseudomorphed by iddingsite. 10% small vesicles which are mostly empty. 2 mm wide MnOx crust.

		-3: 15 x 9 cm brownish grey deeply weathered **Unit B**. Fresh pyroxene to 5 mm long. -4: 5 x 3 cm **Unit C** breccia with deeply weathered rock fragments up to 5 mm long and fresh pyroxene crystals to 5 mm long set in deeply weathered clay matrix. -5: 25 x 9 cm deeply weathered breccia. **Unit D**. Rock fragments to 1 cm long in orange clay matrix. MnOx crust up to 15 mm thick. -6: 14 x 8 cm **Unit D**. -7: 10 x 7 cm **Unit D** including 1 cm long fresh pyroxene crystal. Possibly same as **Unit C** only more weathered. -8: 15 x 6 cm **Unit D**. Deeply weathered rock clasts to 2 cm. -9: 20 x 7 cm **Unit D**. All but the central 2 cm is MnOx crust. -10: 12 x 6 cm soft pale green clay. -11: Bulk sample of 4 MnOx pieces with concentric mm-scale banding. -12: Bulk sample of **Unit C** breccia, 5 pieces. Many fresh pyroxene crystals (mineral separation?).
63 TVG Cocos	06.12.1999 on bottom: 19:13 h 1257 m 06°58.77' N 085°58.54' W off bottom: 19:53 h 1251 m 06°58.77' N 085°58.61' W	No rock samples, but a full load of foram ooze consisting of 70% forams, 20% pale soft clays, and 10% very small ferruginous rock fragments.
63a DR Cocos	06.12.1999 on bottom: 22:11 h 2419 m 07°01.80' N 086°01.07' W off bottom: 02:21 h 2084 m 07°00.91' N 086°00.48' W	-1: 35 x 18 cm **Unit A.** Dark grey fine grained basalt. Trace pyroxene phenocrysts. 10% empty vesicles. -2: 32 x 7 cm **Unit A** -3: 25 x 10 cm **Unit B**. Dark grey pyroxene basalt with 5% pyroxene phenocrysts up to 3 mm long. 10% vesicles mostly empty. Darker (glassy) zone 1 cm wide near rim. A pillow fragment. -4: 17 x 8 cm **Unit B**. Very well developed 1 cm thick glass at rim. Pillow fragment. -5: 9 x 4 cm **Unit B**. Vesicles partly filled with light blue clay. -6: 7 x 5 cm **Unit B**. As for 5. -7: 9 x 3 cm **Unit B**. As for 5. -8: 9 x 5 cm **Unit B**. No glass, no blue clay. -9: 35 x 12 cm black pyroxene basalt. **Unit C**. 10% pyroxene phenocrysts to 3 mm long. 20% vesicles ranging from small to vuggy. Concentric fracturing. 8 mm wide dark glassy rim. Pillow fragment. -10: 13 x 5 cm **Unit D**, a bedded hyaloclastite. Small

		deeply weathered rock fragments up to 2 mm in diameter, but mostly clay. 2 mm wide MnOx crust. -11: Bulk sample of clay with MnOx staining. Hyaloclastite. **Unit D**. -12: Bulk sample of soft yellow-green clay with MnOx staining. MnOx crust up to 5 mm thick. **Unit D.** -13: Bulk sample of hyaloclastite. Weathered rock fragments to 1 cm across in yellow-orange clay. MnOx crust to 2 cm wide. **Unit D**. -14: Bulk sample of MnOx crust with concentric banding on mm scale. -15: Bulk sample of 2 boulders up to 35 x 20 cm each. **Unit B**.
64 DR Cocos	07.12.1999 on bottom: 01:37 h 1802 m 05°45.66' N 086°54.08' W off bottom: 03:03 h 1443 m 05°45.02' N 086°54.04' W	-1: 18 x 7 cm vesicular aphyric basalt. **Unit A**. Pillow fragment but no glass. Fine-grained groundmass. Vesicles up to 4 mm in diameter, mostly lined with chlorite. -2: 23 x 7 cm vesicular olivine basalt. **Unit B**. 10% olivine phenocrysts are fresh and up to 1 mm across. Vesicles (20%) are up to 1 cm in diameter, often vuggy, some filled with pale soft clay. Pillow fragment but no glass. Deeply weathered rock fragments (hyaloclastite) attached to one side. -3: 16 x 7 cm **Unit B**. -4: 26 x 8 cm **Unit B**, but dense with few vesicles (<1%). Pillow fragment. -5: 9 x 4 cm **Unit B**. Olivine remains fresh, but rock is weathered and somewhat iron-stained except the central 1 cm. A rounded pebble. -6: 9 x 5 cm **Unit B**. -7: 16 x 9 cm **Unit B**. Somewhat denser (10% vesicles) with many linear pull-apart structures. Olivine partly pseudomorphed to iddingsite near rim. -8: 14 x 4 cm **Unit B**, as for 7. -9: 10 x 5 cm **Unit B**. Approximately 50% of olivine is pseudomorphed by iddingsite. -10: 10 x 6 cm **Unit B**. As for 9. Vesicles are banded on 5 mm scale. -11: 15 x 7 cm **Unit B**. As for 9, but with vesicles up to 1 cm across. -12: 13 x 6 cm **Unit B**, as for 10. -13: 20 x 7 cm **Unit B**. All olivine is pseudomorphed by iddingsite. Large vuggy vesicles to 2 cm across. -14: 19 x 5 cm **Unit B**. All olivine is pseudomorphed by iddingsite. -15: 10 x 7 cm **Unit B**. Dense with 5% small vesicles. Olivine mostly fresh, but iron-staining along joints. -16: 10 x 5 cm breccia. **Unit C**. Variably weathered clasts of Unit B up to 2.5 cm long, most <5 mm long, in an altered clay matrix. Well cemented.

		-17: 26 x 12 cm hyaloclastite. **Unit D**. Rock fragments up to 2 cm long but most ~3 mm across. Mostly Unit B clasts, some extremely vesicular and appear aphyric. Clasts in pale yellow clay (palagonite) matrix. Two layers are separated by 5 cm palagonitic clay layer with relatively few rock fragments. -18: 15 x 10 cm **Unit E**. Deeply weathered and finer grained than 17. -19: Two pieces of claystone.**Unit F**.
64a DR Cocos	08.12.1999 on bottom: 05:30 h 1215 m 05°43.73' N 086°55.00' W off bottom: 07:00 h 1036 m 05°43.38' N 086°54.97' W	-1: 16 x 7 cm olivine basalt. **Unit A**. 10% olivine phenocrysts are relatively fresh (with slight discoloration), and up to 0.7 mm long. 5% small vesicles are mostly empty. Some plagioclase in groundmass <0.5 mm long? This is a large clast in a hyaloclastite, with other deeply weathered rock fragments up to 1 cm long and an orange clay matrix. -2: 12 x 8 cm **Unit A**. -3: 10 x 5 cm **Unit A**. Much more weathered than the other two samples.
65 DR Cocos	08.12.1999 on bottom: 09:10 h 1556 m 05°44.23' N 086°47.68' W off bottom: 10:40 h 1194 m 05°44.21' N 086°48.14' W	-1: 21 x 11 cm black vesicular basalt. **Unit A**. Trace olivine phenocrysts (2%) which are small, fresh and up to 1 mm across. 30% vesicles up to 5 mm across, empty except near rim. 1 cm thick dark glassy rind. -2: 12 x 7 cm **Unit A**. Vesicles are smaller than 1 mm and partly filled with pale clay. -3: 12 x 6 cm **Unit A**, as for 2. -4: 10 x 9 cm **Unit A**. As for 2, but more clay in the vesicles. -5: 15 x 8 cm **Unit A**. Slightly more weathered than 1. -6: 12 x 6 cm **Unit A**. -7: 11 x 5 cm **Unit A**. -8: 12 x 8 cm **Unit A**. As for 2. -9: 15 x 7 cm **Unit A**. As for 2. -10: 16 x 8 cm **Unit A**. Weathered to pale grey and no glass. -11: 9 x 5 cm **Unit A**, as for 2. -12: 17 x 11 cm dark grey olivine basalt. **Unit B**. Olivine phenocrysts (10%) are small, up to 1 mm long, and fresh. 30% vesicles to 5 mm in diameter are mostly empty. Black patches in groundmass up to 1 cm in diameter (weathering feature?). -13: 9 x 6 cm **Unit B**. -14: 29 x 17 cm **Unit B**, for olivine separation. -15: 19 x 15 cm **Unit A**, for olivine separation. -16: 17 x 6 cm pale grey claystone.
65a DR Cocos	08.12.1999 on bottom: 11:55 h 1241 m 05°44.18' N 086°48.15' W	-1: 17 x 10 cm vesicular dark grey olivine plagioclase basalt. **Unit A**. Olivine phenocrysts (10%) up to 3 mm across are fresh. Plagioclase phenocrysts (5%) are smaller than the olivine. Outer 1 cm is a black glassy rim, the outer 2 mm of which is deeply

	off bottom: 13:24 h 1069 m 05°44.04' N 086°48.67' W	weathered. 30% vesicles up to 5 mm in diameter, with the outer ones partly filled by soft orange clay. MnOx crust 1 mm thick. -2: 16 x 6 cm **Unit A**. No glassy rim, and vesicles smaller than in 1. -3: 27 x 15 cm **Unit A**. As for 2, but with plagioclase phenocrysts up to 4 mm long. Fewer vesicles, and they are larger. Pillow fragment. -4: 17 x 10 cm **Unit A**. As for 3, but vesicles in outer 1 cm are filled with soft orange clay. -5: 16 x 10 cm **Unit A**. As for 2, but in the outer 1 cm vesicles are filled with soft orange clay. -6: 14 x 7 cm **Unit A**, as for 5. -7: 29 x 20 cm **Unit A**. As for 5, but with a 2 mm MnOx crust. -8: 15 x 12 cm dark grey olivine plagioclase basalt. **Unit B**. Similar to Unit A, but with 2% olivine and 2% plagioclase phenocrysts. 5 mm thick dark glassy rim. 20% vesicles. Vesicles in outer 2 cm and joints are filled with soft pale clay. -9: 20 x 14 cm **Unit A**. As for 4, but with vesicle banding. A pillow fragment. -10: 10 x 8 cm **Unit A**. As for 1, but with more clay (50% of the vesicles are filled with soft orange clay). -11: 15 x 13 cm **Unit A**, as for 4. -12: 15 x 7 cm **Unit A**. As for 1, but much more weathered with iron-staining in outer 1.5 cm. -13: 17 x 8 cm **Unit B**. Larger vesicles than 8, which are up to 7 mm in diameter. Vesicles are partly filled with pale cream clay, and partly with harder zeolite. -14: 29 x 20 cm **Unit A**. Outer surface and joints have lots of clay and iron-staining. For mineral separation.
66 DR **Cocos**	08.12.1999 on bottom: 15:54 h 1204 m 05°37.36' N 086°51.63' W off bottom: 17:06 h 1018 m 05°37.18' N 086°52.00' W	-1: 17 x 10 cm olivine basalt. **Unit A**. 5% small olivine phenocrysts are pseudomorphed by iddingsite, but are fresh and pale green at the rock core and up to 0.6 mm in diameter. -2: 11 x 7 cm **Unit A**. Outer 1 cm is black and glassy. Pillow fragment. -3: 8 x 4 cm **Unit A**. -4: 5 x 4 cm **Unit A**. Coarser grained groundmass and contains a 7 mm long feldspar xenocryst. -5: 35 x 10 cm olivine basalt. **Unit B**. Olivine phenocrysts (15%) up to 2 mm long, pseudomorphed by iddingsite in outer 2 cm of rock. Black glassy rim up to 8 mm wide. Pillow fragment. Fresher than Unit A. -6: 19 x 7 cm **Unit B**. -7: 7 x 4 cm **Unit B**.
67 DR **Cocos**	08.12.1999 on bottom: 22:19 h	-1: 11 x 8 cm black vesicular olivine basalt. **Unit A**. Olivine phenocrysts (5%) are fresh and up to 3 mm

	1800 m 05°30.24' N 087°15.44' W off bottom: 23:24 h 1512 m 05°30.66' N 087°15.35' W	long. There is a second set (5%) of olivine microphenocrysts also. Trace plagioclase phenocrysts also present. 30% small vesicles are empty, and up to 2 mm across. Possibly trace small pyroxene phenocrysts. -2: 12 x 8 cm **Unit A**. Vesicles are smaller than 1. -3: 15 x 7 cm **Unit A**. Clay fills vesicles in the outer 1 cm. -4: 10 x 6 cm **Unit A**. Large vesicles up to 5 mm in diameter. Soft pale clay in some vesicles. -5: 17 x 8 cm **Unit A**. Yellow clay in many vesicles. Some olivine is partly pseudomorphed by iddingsite. -6: 17 x 8 cm **Unit A**. Vesicles are banded. Some olivine is pseudomorphed by iddingsite, but most is fresh. -7: 11 x 5 cm **Unit A**. Deeply weathered in outer 1 cm. Pillow fragment. -8: 19 x 9 cm **Unit A**. Some olivine is pseudomorphed by iddingsite. -9: 16 x 8 cm **Unit A**, with soft pale clays in outer vesicles. -10: 11 x 6 cm **Unit A**. More weathered with orange clay in many vesicles. Darker in outer 1 cm, with a 2 mm MnOx crust. -11: 19 x 9 cm **Unit A**. Many small vesicles and several large vugs up to 2.5 cm in length (vugs are more weathered). Pillow fragment. -12: Bulk sample of 2 large **Unit A** boulders up to 25 x 15 cm.
68 DR Cocos	09.12.1999 on bottom: 03:58 h 2129 m 05°21.57' N 087°37.69' W off bottom: 05:40 h 1913 m 05°22.22' N 087°37.88' W	No rock samples.
68a DR Cocos	09.12.1999 on bottom: 07:30 h 1483 m 05°23.12' N 087°37.66' W off bottom: 09:04 h 1256 m 05°23.41' N 087°37.59' W	-1: 20 x 7 cm breccia of deeply weathered rock fragments up to 1 cm long, but most 3 mm long, set in a pale orange matrix. **Unit A**. MnOx crust 1 cm thick. Hyaloclastite. -2: 14 x 5 cm **Unit A**. More weathered than 1. MnOx crust up to 2 cm thick. -3: 14 x 4 cm **Unit A**, mostly MnOx crust. -4: 11 x 4 cm **Unit A**, mostly MnOx crust. -5: 4 small pieces of **Unit A**, deeply weathered.
69 DR Cocos	09.12.1999 on bottom: 13:52 h 2077 m 05°12.52' N	-1: 14 x 7 cm black vesicular olivine basalt. **Unit A**. Olivine phenocrysts (10%) are pale green, but slightly discolored, and up to 1 mm across. Vesicles (30%) are up to 8 mm long and empty. Glassy rim 6 mm

	087°56.77' W off bottom: 15:24 h 1905 m 05°11.90' N 087°56.89' W	thick. -2: 9 x 5 cm **Unit A**. -3: 9 x 4 cm **Unit A**. -4: 7 x 4 cm **Unit A**. -5: 7 x 5 cm **Unit A**. -6: 12 x 6 cm **Unit A**, with 30% of vesicles filled with pale orange clay. -7: 9 x 6 cm **Unit A**, as for 6. -8: 10 x 6 cm **Unit A**, as for 6. -9: 8 x 5 cm **Unit A**, as for 6. -10: 8 x 5 cm **Unit A**. As for 6, but 40% vesicles and rather scoriaceous. -11: 10 x 7 cm **Unit A**, as for 10. -12: 5 x 5 **Unit A**. As for 6, but more weathered. -13: 9 x 4 cm **Unit A**, as for 12. -14: 9 x 6 cm clasts of **Unit A** in hyaloclastite. Largest clast is 7 cm across, most are 3 mm across, and they are set in soft yellow-orange clay.
70 TVG Cocos	09.12.1999 on bottom: 20:17 h 1056 m 05°33.97' N 088°14.69' W off bottom: 21:16 h 1058 m 05°33.97' N 088°14.69' W	-1: 30 x 10 cm breccia of deeply weathered rock fragments up to 2 cm long, most 3 mm long, set in pale cream silty clay matrix. **Unit A**. Rock has bedding, with rock fragment-rich and sandy-rich layers. Hyaloclastite.
70a DR Cocos	09.12.1999 on bottom: 23:13 h 1980 m 05°34.55' N 088°13.19' W off bottom: 00:28 h 1631 m 05°34.40' N 088°13.57' W	-1: Recovery of two 20 cm diameter deeply weathered claystones after hyaloclastite. Not sampled.
70b DR Cocos	09.12.1999 on bottom: 01:55 h 1631 m 05°34.48' N 088°13.61' W off bottom: 03:24 h 1455 m 05°34.44' N 088°13.87' W	-1: 17 x 7 cm dark grey olivine pyroxene basalt. **Unit A**. Pyroxene phenocrysts (10%) up to 2 mm across. Olivine phenocrysts (5%) up to 3 mm across but most are smaller than pyroxene, fresh and pale green. 5 mm thick weathering rind. Vesicles (2%) are small. -2: 18 x 9 cm **Unit A** for mineral separation. -3: 9 x 7 cm **Unit A**. -4: 13 x 5 cm **Unit A**. Olivine is discoloured. -5: 18 x 9 cm **Unit A**, as for 4. -6: 10 x 6 cm **Unit A**, as for 4. -7: 15 x 5 cm **Unit A**. As for 4, but with internal fractures. -8: 14 x 7 cm **Unit A**, as for 7. -9: 11 x 6 cm **Unit A**. All olivine is discoloured or partly

		pseudomorphed by iddingsite. -10: 14 x 10 cm **Unit A**, as for 9. -11: 11 x 7 cm **Unit A**, as for 9. -12: 14 x 8 cm breccia of Unit A clasts up to 10 cm across in a soft cream coloured clay matrix. **Unit B**. -13: Bulk sample of 3 boulders up to 30 x 20 cm each of **Unit A**. For mineral separation. -14: 35 x 13 cm **Unit B**.
71 DR Cocos	10.12.1999 on bottom: 07:16 h 1251 m 05°30.96' N 088°34.79' W off bottom: 08:44 h 967 m 05°30.46' N 088°34.90' W	-1: 10 x 6 cm dark grey vesicular olivine basalt. **Unit A**. Olivine phenocrysts (10%) up to 4 mm long are pale green and fresh. Trace plagioclase phenocrysts. Vesicles (10%) are small (<1 mm) and empty. More weathered in outer 2 mm. -2: 10 x 9 cm dark grey vesicular plagioclase olivine basalt. **Unit B**. Olivine phenocrysts (10%) are pale green, fresh, and up to 4 mm long. Plagioclase phenocrysts (5%) are up to 4 mm long. 10% small vesicles are up to 2 mm long and empty. Rock is a clast from a breccia (hyaloclastite). -3: 6 x 3 cm breccia consisting of silicified rock clasts up to 2 mm across in yellow-green clay. Possibly a xenolith within a basalt. **Unit C**. -4: 12 x 5 cm breccia consisting of deeply ferruginised rock fragments set in soft dark clay. Rock fragments are 2-3 mm across. Deeply weathered hyaloclastite. **Unit D**. -5: 23 x 7 cm **Unit D**. -6: 22 x 5 cm **Unit D**. -7: 11 x 3 cm **Unit D**, with deeply weathered rock fragments up to 2.5 cm long. -8: 11 x 3 cm **Unit D**. -9: 16 x 8 cm **Unit D**. -10: 21 x 7 cm **Unit D**, but very deeply weathered to clay. -11: 14 x 5 cm **Unit D**, but clast-supported and friable. -12: 17 x 13 cm pale yellow breccia. **Unit E**. Main mineral is serpentinite, with opaque minerals along joints and possibly rock fragment margins. 5 mm of Unit D surrounds the main sample, and it may be a clast within Unit D. Sub-sample taken for Dietrich Ackermand. -13: Bulk sample of breccia of somewhat weathered rock fragments, each up to 5 mm across. Clast-supported. **Unit F**.
71a DR Cocos	10.12.1999 on bottom: 10:02 h 1631 m 05°28.47' N 088°36.64' W off bottom: 11:03 h 1294 m	-1: 22 x 10 cm dark grey vesicular plagioclase olivine basalt. **Unit A**. Olivine phenocrysts (15%) are pale green to pale brown, and up to 4 mm long. Plagioclase phenocrysts (5%) are up to 3 mm long. 30% vesicles up to 3 mm across and empty. -2: 10 x 7 cm **Unit A**. All olivine is pale brown. -3: 10 x 7 cm **Unit A**, as for 2.

	05°28.59' N 088°36.17' W	-4: 12 x 8 cm **Unit A**. As for 2, but vesicles are smaller and up to 1 mm in diameter. -5: 15 x 11 cm **Unit A**. As for 4, but some olivine pseudomorphed by iddingsite. Pillow fragment. -6: 18 x 14 cm **Unit A**, as for 2. -7: 24 x 13 cm **Unit A**. As for 2, but vesicles are banded with some infilled by pale yellow-white clay. -8: 12 x 11 cm **Unit A**, as for 5. -9: 16 x 15 cm **Unit A**. As for 5, but vesicles are larger and up to 2 mm in diameter. -10: 18 x 10 cm **Unit A**. As for 2, but most vesicles are filled with soft pale yellow to green clay. One large plagioclase phenocryst is 5 mm x 1 cm across. -11: 11 x 7 cm **Unit A**. As for 4, but half of the vesicles are filled with pale yellow clay. -12: 23 x 17 cm breccia of small rock fragments of Unit A and some orange clay. Fragments are up to 2 mm in length. Clast-supported. **Unit B**. -13: Bulk sample of 2 **Unit A** rocks up to 12 x 6 cm. Large olivine phenocrysts up to 4 cm x 5 mm on surface. Also large plagioclase phenocrysts up to 1 cm x 5 mm across. -14: Bulk sample of 2 small pieces of predominantly MnOx crust up to 1 cm thick. -15: Bulk sample of 3 rocks up to 26 x 17 cm. **Unit A**. For mineral separation.
72 TVG Cocos	10.12.1999 on bottom: 18:08 h 730 m 05°51.89' N 087°34.40' W off bottom: 18:49 h 741 m 05°51.90' N 087°34.38' W	No rock samples.
72a DR Cocos	10.12.1999 on bottom: 19:53 h 968 m 05°52.11' N 087°34.36' W off bottom: 20:55 h 760 m 05°51.82' N 087°34.41' W	-1: 16 x 8 cm dark grey plagioclase olivine basalt. **Unit A**. 10% olivine phenocrysts, half are fresh, half are discoloured to pale brown, up to 3 mm across. Plagioclase phenocrysts (5%) are smaller and up to 1 mm across. Vesicles (5%) to 2 mm across and occur as 3 mm wide bands interspersed with dense lava. -2: 21 x 10 cm **Unit A**, but 20% vesicles again in bands. -3: 17 x 10 cm **Unit A**. Vesicles coarser and up to 4 mm across, with iron-staining along joints. -4: 15 x 8 cm **Unit A**, as for 2. -5: 13 x 7 cm **Unit A**. As for 2, but with soft white clay in 50% of the vesicles. -6: 10 x 8 cm **Unit A**, as for 5. -7: 17 x 13 cm black vesicular plagioclase olivine basalt. **Unit B**. Similar lithology to Unit A, but with 40%

		vesicles. Vesicles are up to 4 mm in diameter but smaller along the rim. Dark glassy rim 1 cm wide. Fresh. -8: 16 x 9 cm **Unit B**. -9: 16 x 8 cm **Unit B**, with a well developed glassy rim partly stained orange. -10: 17 x 8 cm **Unit B**, as for 9. -11: 16 x 5 cm **Unit B**. Poorly developed pillow surface. -12: 21 x 6 cm **Unit B**, as for 11. -13: Bulk sample of 4 dense **Unit A** rocks, each up to 20 x 15 cm, for mineral separation. -14: Bulk sample of 2 **Unit B** pillow fragments each up to 17 x 15 cm with well developed glassy rims. -15: Bulk sample of 2 rocks up to 20 x 10 cm each, consisting of a breccia of angular Unit A clasts up to 4 cm long, but most 5 mm long, set in a pale green clay matrix (palagonitic clay). Hyaloclastite. **Unit C**. -16: Glass concentrate from big **Unit B** boulder. -17: Glass concentrate from big **Unit B** boulder. -18: Glass concentrate from big **Unit B** boulder. -19: Glass concentrate from big **Unit B** boulder. -20: Glass concentrate from big **Unit B** boulder. -21: Glass concentrate from big **Unit B** boulder. -22: Glass concentrate from big **Unit B** boulder. -23: Glass concentrate from big **Unit B** boulder.
73 DR **Cocos**	10.12.1999 on bottom: 06:50 h 1843 m 07°05.39' N 086°23.85' W off bottom: 08:59 h 1766 m 07°05.37' N 086°23.97' W	-1: 10 x 6 cm grey vesicular olivine basalt. **Unit A**. Olivine phenocrysts (<5%) up to 0.6 mm across. Possible second generation of olivine just above groundmass size. All olivine is partly discoloured to pale brown or pseudomorphed to iddingsite. Vesicles (10%) are vuggy, up to 1.5 cm long, and mostly empty. Glassy rim up to 5 mm wide. MnOx crust up to 5 mm wide. -2: 19 x 5 cm **Unit A**. Pillow fragment. -3: 10 x 6 cm grey vesicular olivine basalt similar to Unit A, but only the larger olivine is present. **Unit B**. Glassy rim up to 1 cm wide. Pillow fragment. -4: 13 x 5 cm **Unit B**. -5: 13 x 9 cm **Unit B**. Pale cream clay fills largest vesicles. -6: 28 x 10 cm **Unit B**. As for 5, but with well developed 5 mm black glass at rim. MnOx crust up to 1.5 cm thick. -7: 9 x 8 cm **Unit B**. Most of the rock is MnOx crust. -8: 23 x 6 cm MnOx crust. Concentric banding on mm-scale. -9: 14 x 5 cm, as for 8. -10: 13 x 4 cm, as for 8. -11: Bulk sample of several small MnOx pieces for P. Stoffers.

74 DR **Cocos**	11.12.1999 on bottom: 12:34 h 2210 m 07°23.02' N 086°31.29' W off bottom: 15:59 h 1792 m 07°23.46' N 086°30.62' W	-1: 23 x 8 cm dark grey aphyric basalt. **Unit A**. 5% vesicles, mostly small but some up to 5 mm long and empty. Almost fresh rock. -2: 6 x 4 cm **Unit A**, but weathered with pale yellow clay in 50% of vesicles. -3: 7 x 4 cm **Unit A**, deeply weathered and brown. -4: 25 x 6 cm bedded siltstone-conglomerate consisting of deeply weathered vesicular orange rock fragments up to 1.5 cm across. Turbidite? Fine-grained sand to silt layers show normal grading. Matrix in conglomerate is soft pale grey clay. MnOx crust up to 7 mm thick. **Unit B**. -5: 15 x 8 cm **Unit B**, but massive. -6: 13 x 8 cm ball of clay. Pale soft yellow-green clay and MnOx, with 1 cm wide MnOx crust. **Unit C**. -7: 18 x 6 cm **Unit C**, but mostly MnOx. -8: 12 x 5 cm **Unit C**, as for 7. -9: 13 x 3 cm **Unit B**, same as the conglomerate part of 4. -10: 12 x 3 cm **Unit B**, as for 9. -11: 7 x 4 cm MnOx crust with concentric banding on mm-scale. -12: Bulk sample of small MnOx pieces for Peter Stoffers.
75 TVG **Cocos**	11.12.1999 on bottom: 20:26 h 918 m 07°38.64' N 086°12.04' W off bottom: 21:25 h 913 m 07°38.67' N 086°12.08' W	-1: 25 x 10 cm brown olivine pyroxene basalt. **Unit A**. Olivine phenocrysts (15%) totally pseudomorphed to iddingsite and up to 5 mm in length. Black pyroxene phenocrysts (10%) are also up to 5 mm in length and fresh. Groundmass is soft, brown, and moderately weathered. MnOx crust up to 1 cm thick. -2: 20 x 9 cm **Unit A**. -3: 17 x 11 cm **Unit A**. -4: 6 x 4 cm **Unit A**. -5: 19 x 6 cm **Unit A**. -6: 10 x 5 cm **Unit A**. -7: 8 x 5 cm **Unit A**. -8: 8 x 4 cm **Unit A**. -9: 22 x 7 cm **Unit A**. MnOx crust up to 2 cm wide, and more weathered. -10: Bulk sample of several small MnOx pieces for Peter Stoffers.
76 HYD **Fisher**		Hydrosweep survey over the area shown on satellite bathymetry maps as southwestern Fisher Ridge.
77 DR **Cocos**	12.12.1999 on bottom: 08:51 h 741 m 07°44.11' N 085°55.33' W off bottom: 09:49 h 600 m 07°43.96' N	-1: 10 x 7 cm dark grey vesicular olivine basalt. **Unit A**. Olivine phenocrysts (10%) are up to 2 mm across, pale green and fresh at the core but discoloured in outer 1 cm. Vesicles (15%) are up to 3 mm across and empty. A clast within a breccia, part of which is preserved on the outer rim. -2: 18 x 9 cm **Unit A**. Olivine is fresh at core, but pseudomorphed by iddingsite in the outer 2 cm. More

	085°55.66' W	vesicular than 1, with vesicles up to 6 mm across. -3: 11 x 7 cm **Unit A**, as for 2. -4: 12 x 7 cm **Unit A**. All olivine is pseudomorphed by iddingsite. Groundmass is more weathered than previous samples. -5: 32 x 9 cm **Unit A**, as for 4. -6: 8 x 4 cm **Unit A**, as for 4. -7: 11 x 2 cm **Unit A**. As for 4 but with much pale green clay in vesicles. -8: 30 x 12 cm breccia of angular Unit A rock fragments up to 7 cm across, but most are 5 mm across, in a matrix of pale cream coloured soft clay. Clast-supported in some places. Hyaloclastite. **Unit B**. -9: 15 x 6 cm **Unit B**. Deeply weathered, iron-stained, and clast-supported. -10: 27 x 10 cm **Unit B**, as for 9. -11: 18 x 6 cm **Unit B**, as for 9. -12: 20 cm in diameter **Unit B** boulder, as for 8.
77a DR Cocos	12.12.1999 on bottom: 11:23 h 1591 m 07°45.87' N 085°55.49' W off bottom: 13:25 h 1622 m 07°45.92' N 085°55.51' W	-1: 17 x 8 cm black aphyric basalt. **Unit A**. Vesicles (5%), some iron-stained. Iron-staining along joints. Groundmass is mostly fresh, hard and dense. Trace pyroxene phenocrysts. -2: 13 x 6 cm **Unit A**. -3: 25 x 15 cm **Unit A** with 5% large vesicles up to 5 mm in length. Includes gypsum/calcite(?) crystals on an internal surface. A large boulder from hyaloclastite. -4: 11 x 9 cm **Unit A**, but with more vesicles up to 12 mm across. Approximately half the vesicles contain white crystals (zeolite/calcite? Probably the same mineral as in 3). -5: 11 x 6 cm **Unit A**. As for 4, but with smaller vesicles. -6: 8 x 5 cm **Unit A**, as for 4. -7: 12 x 8 cm **Unit A**. More weathered, and with smaller vesicles <5 mm across. -8: 25 x 10 cm dark grey dense olivine pyroxene basalt. **Unit B**. Olivine phenocrysts (5%) up to 3 mm long pseudomorphed by iddingsite. Pyroxene phenocrysts (5%) up to 5 mm long and fresh. Groundmass is discoloured to brown and weathered along joints. It is a large clast from a hyaloclastite. -9: 13 x 6 cm dark grey vesicular pyroxene basalt. **Unit C**. Pyroxene phenocrysts (5%) are large and up to 5 mm across. Vesicles (5%) are small, empty and <1 mm across. Groundmass is partly discoloured to brown, and is weathered. -10: 10 x 8 cm **Unit C**. -11: 18 x 8 cm **Unit C**. More vesicular with 20% vesicles up to 5 mm across, approximately 50% are filled by soft yellow clay.

		-12: 12 x 6 cm breccia of Unit A rock fragments up to 6.5 cm long, but most approximately 5 mm long, in a sandy matrix of deeply weathered rock fragments and clay. **Unit D.** -13: 16 x 10 cm **Unit D**. Contains shell fragments in the matrix. -14: 23 x 6 cm **Unit D**, but relatively well sorted with the largest clasts 2 cm across and less clay. -15: 25 x 8 cm **Unit D**, as for 14. -16: 18 x 7 cm **Unit D**, as for 14. -17: 24 x 9 cm breccia of deeply weathered rock fragments up to 3 mm across in pale yellow clay. **Unit E.** -18: Bulk sample of well rounded beach cobbles(?) extracted from a large **Unit D** breccia sample. Cobbles up to 15 cm in diameter. -19: Bulk sample of **Unit D** breccia, predominantly matrix material for fossil and foram hunting.
78 DR **Cocos**	12.12.1999 on bottom: 17:05 h 1465 m 08°06.88' N 085°47.50' W off bottom: 18:44 h 1374 m 08°06.83' N 085°47.59' W	-1: 25 x 8 cm dark bluish grey dense olivine pyroxene basalt. **Unit A.** Olivine phenocrysts (5%) up to 1 mm across, pseudomorphed by iddingsite in outer 1 cm; fresh in interior. Pyroxene phenocrysts (10%) up to 3 mm across. A few small empty vesicles. -2: 20 x 9 cm **Unit A.** -3: 13 x 7 cm **Unit A**. All olivine pseudomorphed by iddingsite. Pillow fragment. Outermost 5 mm is darker. -4: 21 x 10 cm **Unit A.** -5: 12 x 6 cm **Unit A**. All olivine pseudomorphed by iddingsite. -6: 15 x 8 cm **Unit A**. As for 5, but more weathered. -7: 21 x 12 cm reddish grey vesicular olivine pyroxene basalt. Similar to Unit A, but with 30% vesicles up to 1 cm long and empty. Outer 2 cm is a breccia of Unit A fragments in clay. **Unit B.** -8: 22 x 10 cm **Unit B.** -9: 23 x 13 cm breccia of Unit A rock fragments and deeply weathered other rock fragments up to 1.5 cm long, but usually 2 mm long, in a red/orange silty clay matrix. Some rock fragments appear glassy. **Unit C.** -10: 14 x 6 cm **Unit C**, deeply weathered. -11: Bulk sample of two 30 x 20 cm boulders, one is Unit A and the other is Unit B.
79 DR **Cocos**	12.12.1999 on bottom: 22:29 h 1625 m 07°58.34' N 085°33.49' W off bottom: 00:10 h 1190 m	-1: 28 x 15 cm black aphyric basalt. **Unit A.** Fresh, dense, and no vesicles. -2: 17 x 8 cm **Unit A**, with 5 mm lighter coloured weathering rind. -3: 9 x 5 cm **Unit A** with trace of partly weathered olivine microphenocrysts and phenocrysts of pyroxene up to 2 mm long.

	07°58.67' N 085°33.92' W	-4: 9 x 6 cm **Unit A**, but with 5% small vesicles and 2% pyroxene phenocrysts. 1 cm thick weathering rind at one end. Pillow fragment? -5: 12 x 10 cm grey vesicular basalt with 2 large pyroxene phenocrysts up to 3 mm long. 30% vesicles up to 3 mm in diameter, with a few outer vesicles filled with soft white clay but almost all empty. Probably still **Unit A**. -6: 11 x 6 cm **Unit A** with 5% vesicles. Moderate iron-staining throughout the rock, but vesicles are mostly empty. MnOx crust is up to 1 cm thick, and the rock has a 1 cm wide weathering rind. -7: 20 x 12 cm grey olivine pyroxene basalt. **Unit B**. Pyroxene phenocrysts (30%) up to 4 mm long and fresh. Olivine phenocrysts (2%) up to 1 mm long and mostly fresh. Iron staining across joints and a discoloured groundmass. MnOx crust is up to 3 mm thick. Small vesicles (10%) are mostly empty. -8: 13 x 5 cm **Unit B**. -9: 12 x 6 cm **Unit B**, but with more weathered olivine. -10: 11 x 4 cm **Unit B**, with slightly larger vesicles. -11: 7 x 7 cm grey vesicular pyroxene basalt. **Unit C**. Pyroxene phenocrysts (5%) up to 1 cm long. Vesicles (15%) up to 5 mm wide. Outer rim has vesicles filled with pale yellow-orange soft clay, others are empty. -12: 17 x 6 cm grey pyroxene basalt. **Unit D**. Pyroxene phenocrysts (15%) up to 5 mm long. Vesicles (5%) are mostly partly filled with pale yellow soft clay. 1 cm weathering rind. -13: 18 x 10 cm **Unit D**. Vesicles are larger, up to 2 mm, and more abundant (20%), and those on the rim are filled with pale orange clay. -14: 18 x 8 cm weathered breccia with basalt clasts up to 0.5 cm long. Most clasts are highly vesicular pyroxene-bearing basalt. MnOx crust is up to 3 cm thick with concentric banding on mm scale. **Unit E**. -15: 19 x 3 cm **Unit E**, deeply weathered with rock clasts of Unit B up to 3 cm long. -16: 20 x 6 cm MnOx crust with concentric banding on mm scale. -17: Bulk sample of 3 small pieces of greenish yellow banded sandy clay. MnOx crust. Probably matrix to Unit E.
80 DR **Cocos**	13.12.1999 on bottom: 04:43 h 1751 m 08°17.07' N 085°08.99' W off bottom: 06:45 h 1592 m	-1: 17 x 7 cm dark grey vesicular olivine pyroxene basalt. **Unit A**. Olivine phenocrysts (10%) up to 4 mm across, half are pale green, half are pseudomorphed by iddingsite. Pyroxene phenocrysts (10%) are up to 4 mm across. Vesicles (10%) are empty and up to 2 mm across. Some big voids to 3.5 cm long are filled with bedded hyaloclastite.

	08°16.93' N 085°08.83' W	-2: 14 x 5 cm **Unit A**, with a 2 mm wide MnOx crust. -3: 12 x 10 cm **Unit A**. All olivine is pseudomorphed by iddingsite. -4: 12 x 8 cm **Unit A**, as for 3. -5: 14 x 7 cm **Unit A**, as for 3. -6: 18 x 8 cm **Unit A**. As for 3, but soft white clay in some vesicles and hyaloclastite in some large voids. -7: 21 x 10 cm dark grey olivine pyroxene basalt. **Unit B**. Pyroxene phenocrysts (5%) up to 2 mm across. Olivine phenocrysts (2%) to 3 mm across, but most much smaller and pseudomorphed by iddingsite. Groundmass is weathered with brown patches and pale yellow clay developed along joints. -8: 12 x 8 cm **Unit B**. -9: 10 x 4 cm olivine pyroxene basalt. Very similar to Unit B, but with 10% pyroxene phenocrysts up to 3 mm across. **Unit C**. -10: 20 x 6 cm dark grey vesicular olivine basalt. **Unit D**. Olivine phenocrysts (5%) up to 0.5 mm across and pseudomorphed by iddingsite. Groundmass contains fine-grained pyroxene. Vesicles (15%) are up to 5 mm long, most are empty but a few are filled with pale blue clay. -11: 15 x 6 cm **Unit D**. Vesicles in outer 2 cm are filled with soft orange clay. -12: 15 x 11 cm olivine basalt. Very similar to Unit D, but non-vesicular and dense. **Unit E**. -13: 18 x 7 cm **Unit E**, with a 5 mm MnOx crust. -14: 18 x 9 cm **Unit E**. -15: 13 x 5 cm **Unit E**, somewhat more weathered. -16: 8 x 4 cm **Unit E**, as for 15. -17: 17 x 7 cm **Unit E**, with 5% small vesicles mostly filled with soft white clay. -18: 11 x 5 cm breccia of Unit A clasts up to 4 cm across, but most are 3 mm in length, set in an orange clay matrix. **Unit F**. -19: Bulk sample of MnOx pieces for Peter Stoffers. -20: Bulk sample of three 25 x 15 cm boulders, two of Unit A and one of Unit E.
81 DR **Cocos**	13.12.1999 on bottom: 09:57 h 1726 m 08°31.39' N 085°09.09' W off bottom: 12:55 h 1376 m 08°31.80' N 085°08.96' W	-1: 20 x 10 cm dark grey vesicular olivine pyroxene basalt. **Unit A**. Olivine phenocrysts (10%) up to 6 mm long, discoloured to pale brown. Pyroxene phenocrysts (5%) up to 2 mm long. Vesicles (20%) up to 5 mm across, mostly empty, those in the outer 1 cm are filled with soft white clay. MnOx crust 2 mm thick. -2: 14 x 7 cm **Unit A**. -3: 13 x 11 cm **Unit A**. -4: 15 x 12 cm **Unit A**, with banding of vesicles on 1 cm scale.

		-5: 19 x 15 cm **Unit A**. More weathered, with some vesicles throughout filled with soft white clay and some white zeolite. -6: 13 x 7 cm **Unit A**. As for 5, but with all olivine pseudomorphed by iddingsite and 50% of vesicles filled by zeolite or clay. -7: 8 x 6 cm **Unit A**, as for 6. -8: 14 x 8 cm **Unit A**. As for 7, but with MnOx crust up to 3.5 cm thick. -9: 8 x 5 cm **Unit A**. As for 8, but olivine rich (20%). -10: 32 x 13 cm blue grey vesicular aphyric basalt. **Unit B**. Vesicles (10%) up to 1 mm across and some larger vugs. Groundmass is discoloured to brown over small areas <7 mm across. MnOx crust up to 2 mm wide. -11: 14 x 5 cm **Unit B**. Slightly more weathered, with clay developed along some fractures. -12: 5 x 4 cm **Unit B**. Rounded, and more weathered. -13: 25 x 8 cm aphyric basalt. Very similar to Unit B, but with trace pyroxene phenocrysts up to 1 mm long. **Unit C**. Many pull-apart structures which are filled with cream coloured clay. Dark glassy rim up to 8 mm wide. -14: 14 x 6 cm breccia of deeply weathered Unit A clasts up to 7 cm long, but most are 1 cm long. Clast-supported, with a small amount of soft yellow clay. MnOx crust up to 1 cm thick. **Unit D**. -15: 15 x 7 cm **Unit D**, but more weathered. MnOx crust up to 2 cm wide. -16: 20 x 6 cm **Unit D**, but matrix-supported and with more pale yellow clay. Clasts of Unit A and Unit C, and pyroxene crystals up to 3 mm long are also present. -17: Bulk sample of several small pieces of MnOx crust. Concentric banding on mm-scale.
82 DR **Cocos**	13.12.1999 on bottom: 16:49 h 1546 m 08°33.93' N 085°27.83' W off bottom: 18:39 h 1148 m 08°33.53' N 085°27.26' W	-1: 14 x 9 cm black vesicular aphyric basalt. **Unit A**. Vesicles (25%) are mostly 1 mm across, some up to 1 cm across, and are almost all empty. Weathered to brown along fractures, with a 2 mm MnOx crust. -2: 10 x 7 cm **Unit A**, with soft pale white clay along joints. -3: 22 x 11 cm **Unit A**. As for 2, but with large areas weathered to brown. -4: 8 x 4 cm **Unit A**, as for 2. -5: 7 x 4 cm **Unit A**, as for 2. -6: 22 x 10 cm **Unit A**, as for 3. -7: 13 x 6 cm breccia consisting of deeply weathered rock fragments up to 4 mm long in an orange clay matrix. MnOx crust up to 1.5 cm wide. **Unit B**. -8: 12 x 4 cm **Unit B**. -9: 6 x 4 cm **Unit B**.

83 DR **Cocos**	13.12.1999 on bottom: 20:58 h 1899 m 08°27.45' N 085°34.45' W off bottom: 22:07 h 1678 m 08°27.72' N 085°34.79' W	-1: 14 x 6 cm dark grey vesicular olivine basalt. **Unit A**. Olivine phenocrysts (10%) are pale green to pale brown. Vesicles (25%) are empty, some up to 5 mm across but most are 1 mm across. Darker, glassy rim zone 1 cm wide. Pillow fragment. -2: 20 x 10 cm **Unit A**. As for 1, but with soft white clay in some vesicles. -3: 19 x 11 cm **Unit A**. As for 2, but with MnOx crust up to 1 cm thick. -4: 13 x 6 cm **Unit A**. -5: 17 x 12 cm **Unit A**, as for 2. -6: 15 x 7 cm **Unit A**, as for 2. -7: 18 x 8 cm **Unit A**. Soft white clay fills vesicles in outer 1 cm. -8: 15 x 5 cm **Unit A**. Vesicles up to 1 cm across, half are filled by soft white clay. -9: 18 x 7 cm **Unit A**, as for 8. -10: 18 x 8 cm breccia. Clasts of pyroxene basalt, aphyric basalt, and Unit A up to 7 cm across set in a pale yellow clay matrix. Some clasts have a thin orange palagonitic rim. **Unit B**. -11: 24 x 6 cm **Unit B**, but much better sorted with most clasts 1 cm across. -12: 27 x 7 cm **Unit B**. As for 11, but left uncut. -13: Bulk sample of three 25 x 15 cm pillow fragments of **Unit A** for mineral separation. -14: 12 x 6 cm MnOx crust for Peter Stoffers.
84 DR **Cocos**	13.12.1999 on bottom: 00:31 h 2297 m 08°31.63' N 085°38.10' W off bottom: 01:44 h 1906 m 08°31.89' N 085°38.41' W	-1: 8 x 5 cm dark grey aphyric basalt. **Unit A**. Groundmass is fine grained and fresh. 5% very small vesicles, plus a few vugs up to 5 mm across. All are empty. Pillow fragment. -2: 10 x 5 cm **Unit A**. Few brown specks in groundmass. -3: 14 x 3 cm **Unit A**. Rough concave surface on one side, whereas the other is darker. A lava drip. -4: 9 x 5 cm **Unit A**. Some clay in vugs. -5: 24 x 10 cm **Unit A**. Zeolites and pale yellow clay in vugs. MnOx crust up to 3 cm wide. -6: 5 x 5 cm **Unit A**. More weathered, with yellow clay in vesicles. Darker 5 mm rim zone. A small pillow. -7: Several small pieces of MnOx crust for Peter Stoffers.
85 DR **Fisher**	14.12.1999 on bottom: 05:23 h 2537 m 08°52.25' N 085°38.49' W off bottom: 06:37 h 2165 m 08°51.94' N 085°38.14' W	-1: 11 x 8 cm black aphyric basalt. **Unit A**. Outer 1 cm is rounded and slightly weathered. 5% small empty vesicles. -2: 15 x 7 cm **Unit A**. -3: 13 x 9 cm **Unit A**. -4: 13 x 8 cm **Unit A**. -5: 16 x 7 cm **Unit A**. Pale blue clay in some vesicles. -6: 14 x 7 cm **Unit A**. -7: 13 x 7 cm **Unit A**.

		-8: 15 x 8 cm **Unit A**. -9: 11 x 6 cm **Unit A**, as for 5. -10: 10 x 5 cm **Unit A**. -11: 11 x 6 cm **Unit A**, as for 5. -12: 13 x 8 cm **Unit A**, as for 5. -13: 12 x 5 cm **Unit A**. As for 5, but more weathered with yellow clay on joints and hyaloclastite along the rim. -14: 12 x 6 cm **Unit A**, as for 5. -15: 14 x 4 cm **Unit A**, as for 5. A pillow fragment. Dark glassy rim 5 mm wide. -16: 9 x 4 cm **Unit A**, but more weathered with dark clay on joints and a weathering rind 1 cm thick. -17: 18 x 6 cm **Unit A**, as for 16. -18: 10 x 5 cm aphyric basalt. Very similar to Unit A, but with 10% more vesicles which are often iron-stained and a 5 mm thick black glassy rim. **Unit B**. -19: 20 x 6 cm **Unit B**, as for 18. Soft white clay fills most of the vesicles. This is a large clast from a hyaloclastite with glassy fragments. -20: 11 x 6 cm **Unit B**. -21: 21 x 11 cm **Unit B**. Coarser grained groundmass with vesicles up to 3 mm across. Weathering rind 1.5 cm wide. -22: 8 x 4 cm fine-grained holocrystalline rock consisting of plagioclase and pyroxene. Dolerite. Weathering rind 3 mm thick. **Unit C**. -23: 10 x 6 cm holocrystalline rock consisting of plagioclase, pyroxene, and opaque minerals. Grain size is 1-2 mm across. Gabbro. Weathering rind 5 mm thick. This is a clast within a hyaloclastite. **Unit D**. -24: 10 x 7 cm breccia of angular Unit A rock fragments. Dense and often glassy, the fragments are up to 3 cm across (though most are 2 mm across) and set in a pale green to pale yellow clay matrix. **Unit E**. -25: 12 x 7 cm **Unit E**. -26: Bulk sample of 2 large boulders up to 20 x 10 cm each. Unit A? -27: Bulk sample of 9 pieces of Unit E breccia with glass fragments and MnOx up to 1 cm thick. -28: Bulk sample of several small MnOx crust pieces for Peter Stoffers.
86 OBS Deploy		Deployment of the ocean bottom seismometers off the Nicoya Peninsula of Costa Rica.
87 DR Continent. Slope	15.12.1999 on bottom: 12:19 h 2462 m 09°11.37' N 085°16.38' W off bottom: 14:05 h	-1: 13 x 6 cm dark blue grey argillite with numerous small calcite veins and blobs. **Unit A**. Iron-staining along some joints. Soft, but dense. -2: 17 x 6 cm **Unit A**. -3: 10 x 7 cm **Unit A**. -4: 8 x 7 cm **Unit A**.

	2165 m 09°12.66' N 085°16.44' W	-5: 8 x 5 cm **Unit A**, brecciated in part. -6: 8 x 4 cm **Unit A**. -7: 10 x 4 cm **Unit A**. -8: 10 x 3 cm **Unit A**. -9: 10 x 5 cm **Unit A**, with sand lenses. -10: 8 x 5 cm **Unit A**, as for 9. -11: Bulk sample of 12 small **Unit A** pieces. -12: 17 x 7 cm greenish yellow breccia of Unit A clasts, with calcite and much yellow-green clay. Tectonised argillite. **Unit B**. -13: 18 x 6 cm **Unit B**. -14: 13 x 3 cm **Unit B**. -15: Bulk sample of 5 small **Unit B** pieces. -16: 8 x 4 cm dark grey silty claystone. **Unit C**. Soft and well-rounded. -17: 6 x 4 cm **Unit C**, with sandy lenses filling bioturbation patches left by annelids or other foraging creatures. -18: Bulk sample of 5 small **Unit C** pieces. -19: 18 x 7 cm pale green clayey siltstone, massive. **Unit D**. -20: 23 x 11 cm **Unit D**.
88 DR **Coiba**	16.12.1999 on bottom: 15:57 h 1848 m 06°12.27' N 081°56.93' W off bottom: 17:18 h 1219 m 06°12.34' N 081°56.06' W	-1: 14 x 9 cm dark grey dense aphyric basalt. **Unit A**. Outer 1 cm has some chlorite development in the groundmass along incipient pull-apart structures. -2: 25 x 7 cm **Unit A**. Chlorite developed along pull-apart structures which are flow-banded and 5 mm apart. Vesicles (5%) are up to 4 mm across and half are filled with soft white clay. -3: 20 x 7 cm **Unit A**, with 5% small vesicles. -4: 17 x 6 cm **Unit A**. -5: 6 x 4 cm **Unit A**, but more weathered. -6: 12 x 7 cm **Unit A**, but more vesicular with 10% empty vesicles that are up to 1 mm across. Groundmass is cryptocrystalline. -7: 20 x 6 cm **Unit A**, but with 10% vesicles up to 5 mm across. Minor iron-staining. -8: 19 x 5 cm **Unit A**. Black chlorite fills most of the vesicles. More weathered in outer 5 mm. -9: 10 x 5 cm **Unit A**. As for 7, but the groundmass is reddish grey in colour. -10: 10 x 6 cm **Unit A**. As for 9, but the vesicles are elongated and some are filled with soft clay. -11: 8 x 7 cm **Unit A**. As for 9, but with 20% vesicles. -12: 7 x 4 cm **Unit A**. As for 11, but vesicles are filled by soft blue clay. -13: 8 x 5 cm **Unit A**, as for 12. -14: 11 x 4 cm **Unit A**. As for 12, but the vesicles are filled by vermiform blue and black chloritic clays. -15: 9 x 4 cm **Unit A**. Consists of black lava fragments up

		to 2 mm across and red scoriaceous material, apparently in the process of fragmenting. -16: 14 x 7 cm **Unit A**. As for 15, but with 5% vesicles and more weathered. -17: 7 x 4 cm **Unit A**. As for 7, but with yellow-orange clay in vesicles. -18: 15 x 7 cm **Unit A**. Altered, with yellow clay along incipient pull-apart structures and traces of a shiny copper-like sulphide mineral (pyrrhotite?). -19: 17 x 8 cm **Unit A**. As for 18, but with more and larger disseminated sulphide (pyrrhotite?). -20: 15 x 7 cm **Unit A**. Chloritised, and with yellow clay. -21: Bulk sample of small MnOx crust pieces for Peter Stoffers. -22: Bulk sample of 3 boulders up to 30 x 20 cm each of **Unit A**.
89 TVG Coiba	16.12.1999 on bottom: 20:04 h 679 m 06°03.39' N 081°50.43' W off bottom: 20:40 h 678 m 06°03.38' N 081°50.36' W	Full load of sand consisting of 98% foraminifera and 2% brown clay.
89a DR Coiba	16.12.1999 on bottom: 22:18 h 1041 m 06°06.03' N 081°47.47' W off bottom: 23:29 h 845 m 06°05.90' N 081°47.60' W	-1: 12 x 8 cm dense brownish grey pyroxene basalt. **Unit A**. Pyroxene phenocrysts (5%) up to 1 mm long. Groundmass appears crystalline, but consists of pale grey and greenish grey patches which is probably a weathering effect. Moderately weathered, with dark clays along joints and traces of a bright copper-coloured sulphide mineral (pyrrhotite?). -2: 7 x 5 cm **Unit A**, but more weathered. -3: 12 x 5 cm **Unit A**. Deeply weathered, with orange clay in the interior.
90 DR Coiba	16.12.1999 on bottom: 04:28 h 1517 m 05°35.55' N 081°35.07' W off bottom: 05:40 h 1029 m 05°35.98' N 081°35.25' W	-1: 10 x 7 cm reddish grey vesicular plagioclase basalt. **Unit A.** Plagioclase phenocrysts (5%) up to 1.5 mm long in a relatively coarse-grained groundmass containing plagioclase and pyroxene. Vesicles (15%) are usually elongate and vuggy, and up to 1.5 cm long. Soft green clay in some vesicles. -2: 10 x 6 cm **Unit A**. -3: 12 x 9 cm **Unit A**, but more weathered and vesicles are partly filled with yellow-brown clay. -4: 13 x 7 cm **Unit A**. Weathered to brown, and with calcite in some vesicles. -5: 14 x 8 cm **Unit A**, as for 4. -6: 12 x 6 cm **Unit A**. Groundmass is brownish grey and yellow-orange clay fills the vesicles. -7: 9 x 5 cm **Unit A**, as for 6.

		-8: 18 x 6 cm blue grey dense plagioclase basalt. **Unit B**. Plagioclase phenocrysts (5%) up to 5 mm long. Vesicles (5%) are filled by black chloritic clay. 2 mm wide weathering rind. Boulder is sub-rounded. -9: 18 x 6 cm **Unit B**. -10: 11 x 7 cm **Unit B**, with soft blue clay in some vesicles (serpentine?). -11: 10 x 6 cm **Unit B**. Groundmass is more weathered, with white and black patches. -12: 10 x 6 cm **Unit B**, as for 11. -13: 13 x 6 cm **Unit B**. Weathering rind is 5 mm thick. Yellow-orange clay developed along joints. -14: 11 x 4 cm **Unit B**, as for 13. -15: 17 x 4 cm **Unit B**. As for 13, but more weathered. -16: 13 x 7 cm **Unit B**. Black to dark green clay fills all vesicles (10%), and the groundmass is coarser grained. -17: 16 x 6 cm **Unit B**, as for 16. -18: 12 x 6 cm **Unit B**, as for 11. -19: 10 x 5 cm dark grey plagioclase basalt. **Unit C**. Plagioclase phenocrysts (10%) up to 3 mm long. Vesicles (5%) filled with black clay. Iron-staining along joints. 5 mm wide weathering rind. -20: 11 x 6 cm **Unit C**. More vesicles (10%), and moderately weathered with iron-staining. -21: 14 x 6 cm reddish grey vesicular plagioclase basalt. **Unit D**. Plagioclase phenocrysts (15%) up to 3 mm long. Groundmass is relatively coarse and contains plagioclase and pyroxene. Vesicles (5%) are mostly empty. -22: 16 x 8 cm **Unit D**. All vesicles are filled with black chloritic clay. -23: 13 x 5 cm **Unit D**. -24: 12 x 6 cm brownish grey plagioclase basalt. **Unit E**. Plagioclase phenocrysts (20%) up to 3 mm long. Dense. Groundmass is weathered to brownish grey in colour. Weathering rind is 1 cm thick. -25: 14 x 6 cm **Unit E**, but with less plagioclase phenocrysts and these are smaller. -26: 10 x 5 cm **Unit D**, but core is stained brown and the rock is more weathered. -27: 11 x 4 cm brown plagioclase basalt. **Unit F**. Plagioclase phenocrysts (15%). Groundmass plagioclase is lath-like up to 1 mm long. Trace pyroxene. Weathered, with the groundmass stained brown. Possibly a fine grained dolerite.

		-28: 7 x 4 cm black plagioclase basalt. **Unit G**. Plagioclase phenocrysts (25%) up to 2 mm long. Few vesicles, which are up to 4 mm long. A 5 mm wide weathering rind. -29: 10 x 7 cm **Unit G**, but plagioclase phenocrysts are up to 3 mm long and the rock is more weathered. -30: 16 x 3 cm sandy claystone. **Unit H**. Rock fragments are up to 1 mm across and set in a laminated clay-rich matrix. -31: 18 x 8 cm sandy siltstone. **Unit I**. Sandy lenses with irregular margins set in a predominantly silty matrix. -32: 20 x 6 cm greenish yellow serpentinite. **Unit J**. Protolith is unknown (?dunite). -33: 15 x 5 cm **Unit J**. -34: 15 x 9 cm breccia. **Unit K**. Deeply weathered rock clasts up to 2 cm long, but most 3 mm long, in an orange to black clay matrix. Clasts are angular, some are very vesicular, whereas others appear dense. Hyaloclastite. -35: 14 x 7 cm **Unit K**. -36: 16 x 6 cm **Unit K**.

Appendix 3: Cocos Island Rock Sample Descriptions

Sample	Location	Description
Cocos 1	Wafer Bay. West side of river, a beach cobble at the first point along the coast.	10 x 5 cm dark grey pyroxene basalt. Pyroxene phenocrysts (5%) up to 1 mm long. Groundmass banded between black and brown (weathering). Well-rounded.
Cocos 2	Wafer Bay. West side of river, boulder in upper debris flow at first point along the coast.	9 x 6 cm dark grey pyroxene basalt. Pyroxene phenocrysts (10%) up to 2 mm long. Groundmass alternating black and dark brown patches (weathering). Well-rounded.
Cocos 3	Wafer Bay. West side of river, bulk sample from lower massive pyroclastic beds at first point along the coast.	Cream coloured pyroclastic material from massive lower pyroclastic bed beneath a pyroclastic surge layer.
Cocos 4	Wafer Bay. West side of river, a beach cobble at the first point along the coast.	11 x 6 cm dark vesicular blue-grey olivine plagioclase basalt. Plagioclase phenocrysts (30%) up to 7 mm in length. Olivine phenocrysts (5%) pseudomorphed by iddingsite and up to 1 mm across. Trace pyroxene phenocrysts up to 1 mm across. Vesicles (10 %) are empty. Rounded.
Cocos 5	Wafer Bay. West side of river, boulder in upper debris flow at first point along the coast.	12 x 6 cm black pyroxene basalt. Pyroxene phenocrysts (10%) up to 2 mm across. Vesicles (5%) empty in core, filled with soft white clay in outer 5 mm. 5 mm wide weathering rind. Sub-angular.
Cocos 6	Wafer Bay. West side of river, boulder in upper debris flow at first point along the coast.	15 x 5 cm dense black pyroxene basalt. Pyroxene phenocrysts (5%) up to 2 mm long. Numerous sub-parallel joints cut the rock, are spaced approximately 3 mm, and represent shears in the lava. Slight yellow clay development along joints.
Cocos 7	Wafer Bay. West side of river, beach boulder at first point along the coast.	13 x 6 cm reddish grey vesicular olivine basalt. Olivine phenocrysts (5%) up to 0.5 mm across, most pseudomorphed by iddingsite but some are pale green. Trace amounts of pyroxene up to 5 mm across. Vesicles (15%) are small and elongated, up to 3 mm across, and often lined by orange clay. Relatively weathered lava.
Cocos 8	Wafer Bay. West side of river, boulder in upper debris flow at first point along the coast.	13 x 8 cm blue grey vesicular olivine basalt. Olivine phenocrysts (5%) up to 1 mm across, almost all pale green and fresh. Trace amounts of pyroxene up to 5 mm across. Vesicles (15%) are elongated, up to 1 cm long, and some are iron-stained.
Cocos 9	Wafer Bay. West side of river, boulder in	17 x 4 cm dense dark grey pyroxene plagioclase basalt. Plagioclase phenocrysts (10%) up to 5 mm long. Pyroxene

	upper debris flow at first point alog the coast.	phenocrysts (5%) up to 5 mm across.
Cocos 10	Wafer Bay. West side of river, boulder in upper debris flow at first point along the coast.	10 x 7 cm blue grey vesicular olivine basalt. Olivine phenocrysts (5%) up to 1 mm long, discoloured to pale brown in outer 1 cm weathering rind, fresh in interior. Trace pyroxene phenocrysts up to 5 mm long. Vesicles (5%) up to 1.5 mm across, empty in core but filled with soft white clay in outer 1 cm zone.
Cocos 11	Wafer Valley. Lava flow outcropping on the west side of river about 1 km from the Ranger Station.	9 x 6 cm dark grey pyroxene basalt. Pyroxene phenocrysts (5%) up to 4 mm long. A few joints with minor iron-staining on them, and minor iron-staining on 1 mm-wide surface rind.
Cocos 12	Wafer Valley. Small boulders from a debris flow overlying the Cocos 11 flow, west side of the river about 0.95 km from the Ranger Station.	Several pieces of dark grey pyroxene olivine basalt, the largest of which is 18 x 5 cm. Olivine phenocrysts (10%) are up to 1 mm across, pale green, and form diffuse bands. Pyroxene phenocrysts (5%) are up to 1 mm long. Sub-angular fragments.
Cocos 13	Wafer Valley. Float from track on western side of river leading to Cerro Iglesias, about 1 km from the Ranger Station.	18 x 6 cm dark grey pyroxene basalt. Pyroxene phenocrysts (15%) up to 3 mm long. Some discolouration of the groundmass to brownish-green patches. Weathering rind 2 mm wide. Sub-rounded.
Cocos 14	Wafer Bay. West side of river, beach boulder just before the first point along the coast.	15 x 7 cm dark grey pyroxene basalt. Pyroxene phenocrysts (5%) up to 1 mm long. Groundmass pale brown in places and dark elsewhere (weathering). Strongly weathered 5 mm rim zone. Some small vesicles (2%). Well-rounded.
Cocos 15	Chatham Bay. East side of river, eastern lava flow along the coast.	16 x 8 cm reddish grey vesicular pyroxene plagioclase basalt. Plagioclase phenocrysts (10%) up to 3 mm long and chalky. Pyroxene phenocrysts (5%) up to 1 mm long. Groundmass is oxidised to reddish grey and has patches of opaque minerals. 5 mm darker rim zone. A few vesicles (5%) which are empty.
Cocos 16	Chatham Bay. East side of river, lava outcrop between the eastern and central flow.	19 x 3 cm blue grey pyroxene plagioclase basalt. Plagioclase phenocrysts (10%) up to 2 mm long. Pyroxene phenocrysts (5%) up to 4 mm long. A 1 cm wide weathering rind.
Cocos 17	Chatham Bay. East side of river along the coast, central lava flow from its basal shear zone.	11 x 7 cm dark green-grey dense pyroxene basalt. Pyroxene phenocrysts (10%) up to 5 mm long. Groundmass is relatively coarse grained. Outer 5 mm is deeply weathered to pale grey and is concentric about the core of the boulder. Linear fabric in the groundmass.
Cocos 18	Chatham Bay. East side of river along the	12 x 6 cm dark green-grey dense pyroxene basalt. Pyroxene phenocrysts (10%) up to 5 mm long. Groundmass is

	coast, central lava flow (Cocos 17) from the base of its columnar jointed zone.	relatively coarse grained. Outer 5 mm is deeply weathered to pale grey and is concentric about the core of the boulder. Linear fabric in the groundmass.
Cocos 19	Chatham Bay. East side of river, a beach boulder along the coast.	14 x 6 cm grey dense aphyric basalt. Groundmass weathered slightly yellow in small patches. Well-rounded.
Cocos 20	Chatham Bay. East side of river, a beach boulder along the coast.	15 x 7 cm dark grey plagioclase basalt. Plagioclase phenocrysts (5%) up to 5 mm. Trace pyroxene phenocrysts up to 2 mm long. Trace very small olivine phenocrysts. Elongated empty vesicles up to 3 cm long, and shear structures throughout the rock. Groundmass discoloured to brown along some of shear structures. Well-rounded.
Cocos 21	Chatham Bay. East side of river, a beach boulder along the coast.	17 x 8 cm black dense aphyric basalt. Trace plagioclase and pyroxene phenocrysts. Very fresh and hard. Some elongated vesicles up to 1.5 cm long. Lots of sub-parallel shear structures throughout the rock. Well-rounded.
Cocos 22	Chatham Bay. East side of river, a beach boulder along the coast.	19 x 6 cm reddish grey vesicular plagioclase basalt. Plagioclase phenocrysts (5%) up to 2 mm across. Vesicles (20%) elongated along flow structures and up to 1 cm long. Some yellow clay in the vesicles.
Cocos 23	Chatham Bay. East side of river, a beach boulder along the coast.	17 x 2 cm grey vesicular plagioclase basalt. Plagioclase phenocrysts (5%) up to 2 mm across. Vesicles (20%) elongated along flow structures and up to 1 cm long. Some yellow clay in the vesicles.
Cocos 24	Chatham Bay. East side of river, lava flow at the waterfall behind the beach.	21 x 8 cm reddish grey vesicular pyroxene plagioclase basalt. Plagioclase phenocrysts (10%) up to 3 mm long and chalky. Pyroxene phenocrysts (5%) up to 1 mm long. Groundmass is oxidized to reddish grey and has patches of opaque minerals. A 5 mm darker rim zone. A few vesicles (5%) which are empty.
Cocos 25	Chatham Bay. West side of river, uppermost lava flow of 3 at first point along the coast.	16 x 8 cm dark grey olivine plagioclase basalt. Plagioclase phenocrysts (20%) up to 4 mm long. Olivine phenocrysts (5%) pseudomorphed by iddingsite and also up to 4 mm long. A few small vesicles (5%) which are empty.
Cocos 26	Chatham Bay. West side of river, central lava flow of 3 at first point along the coast.	15 x 11 cm dark grey pyroxene olivine plagioclase basalt. Plagioclase phenocrysts (10%) up to 4 mm long. Olivine phenocrysts (10%) pseudomorphed by iddingsite and also up to 4 mm long. Pyroxene phenocrysts (5%) up to 2 mm. A few small vesicles (5%) which are empty.
Cocos 27	Chatham Bay. West side of river, lowermost lava flow of 3 at first point along the coast.	21 x 5 cm dark grey vesicular olivine plagioclase basalt. Plagioclase phenocrysts (20%) up to 4 mm long. Olivine phenocrysts (5%) pseudomorphed by iddingsite and also up to 4 mm long. Small vesicles (15%) are elongated and grade into vuggy pull-aparts up to 1.5 cm long. Outer 5 mm is more weathered.
Cocos 28	Lava flow outcrop at	Pale reddish grey pyroxene plagioclase basalt. Plagioclase

	the top of the scarp on the track from Wafer Bay to Chatham Bay.	phenocrysts (10%) up to 3 mm long and chalky. Pyroxene phenocrysts (5%) up to 1 mm long. Groundmass is oxidised to reddish grey, and has patches of opaque minerals. Darker rim zone 5 mm wide. Vesicles (5%) which are empty.
Cocos 29	Overlooking Chatham Bay on the track from Wafer Bay to Chatham Bay.	13 x 5 cm Pale reddish grey pyroxene plagioclase basalt. Plagioclase phenocrysts (10%) up to 3 mm long and chalky. Pyroxene phenocrysts (5%) up to 1 mm long. Groundmass is oxidised to reddish grey, and has patches of opaque minerals. Darker rim zone 5 mm wide. Vesicles (5%) which are empty.
Cocos 30	Overlooking Chatham Bay on the track from Wafer Bay to Chatham Bay.	14 x 5 cm Pale reddish grey pyroxene plagioclase basalt. Plagioclase phenocrysts (10%) up to 3 mm long and chalky. Pyroxene phenocrysts (5%) up to 1 mm long. Groundmass is oxidised to reddish grey, and has patches of opaque minerals. Darker rim zone 5 mm wide. Vesicles (5%) which are empty.
Cocos 31	Chatham Bay. East side of river along the coast, central lava flow (Cocos 17).	(archived before description)
Cocos 32	Chatham Bay. East side of river, lava flow at the waterfall behind the beach (Cocos 24).	(archived before description)
Cocos 33	Wafer Bay. East side of river, lowest lava flow of 3 along the coast.	Black olivine pyroxene basalt. Olivine phenocrysts (15%) pseudomorphed by iddingsite and up to 4 mm across. Pyroxene phenocrysts (5%) up to 3 mm across.
Cocos 34	Wafer Bay. East side of river, centre of dyke cutting across the lowest lava flow (Cocos 33) along the coast.	15 x 7 cm dark grey vesicular olivine plagioclase basalt. Plagioclase phenocrysts (20%) up to 4 mm long. Olivine phenocrysts (5%) pseudomorphed by iddingsite and also up to 4 mm long. Many small vesicles (15%) which are elongated and grade into vuggy pull-aparts up to 1.5 cm long. Outer 5 mm is more weathered.
Cocos 35	Wafer Bay. East side of river, western margin of dyke (Cocos 34) cutting across the lowest lava flow (Cocos 33) along the coast.	Dark grey olivine plagioclase basalt. Plagioclase phenocrysts (20%) up to 4 mm long. Olivine phenocrysts (5%) pseudomorphed by iddingsite and also up to 4 mm long.
Cocos 36	Wafer Bay. East side of river, centre of second smaller dyke cutting across the lowest lava flow (Cocos 33) along the coast.	10 x 2 cm dark grey olivine plagioclase basalt. Plagioclase phenocrysts (20%) up to 4 mm long. Olivine phenocrysts (5%) are up to 4 mm long, with half pale green and half pseudomorphed by iddingsite. Vesicles (10%) are empty.
Cocos 37	Wafer Bay. East side	12 x 3 cm dark grey olivine plagioclase basalt. Plagioclase

	of river, middle lava flow of 3 along the coast.	phenocrysts (20%) up to 4 mm long. Olivine phenocrysts (5%) pseudomorphed by iddingsite and up to 4 mm long. Trace pyroxene. Some vesicles (10 %) which are empty.
Cocos 38	Wafer Bay. East side of river, uppermost lava flow of 3 along the coast.	12 x 6 cm dark grey plagioclase olivine basalt. Plagioclase phenocrysts (10%) up to 3 mm long. Olivine phenocrysts (20%) up to 3 mm across and pseudomorphed by iddingsite.
Cocos 39	Wafer Bay. West side of river, boulder in upper debris flow at first point along the coast.	10 x 5 cm black pyroxene basalt. Pyroxene phenocrysts (15%) up to 3 mm long. Angular.
Cocos 40	Wafer Bay. West side of river, pyroclastic sequence at first point along the coast.	Pyroclastic material with accretionary lapilli.
Cocos 41	Wafer Bay. West side of river, boulder in lower debris flow at first point along the coast.	13 x 5 cm black pyroxene basalt. Pyroxene phenocrysts (15%) up to 3 mm long. Weathered to yellow clays along joints, and with a 2 mm weathering rind. Angular.

Appendix 4: Probe Stations and Biological Sample Descriptions

Abbreviations:

DR -	Kettensackdredge (Chain sack dredge)
TVG-	TV-Bodengreifer (TV-grab)
SR-	Sediment sampler, two tubes mounted inside and at front of the chain sack dredge
RR-	Glass-tube
Epi-	Eppendorf-tube
K 100-	Kautex-bottle 100 ml
VP-	Videoprint no.
Sediment probe +	Concentrated probe from sediment preserved in 4-8% formalin

Station no., type, place	**Date Time (UTC) Depth Coordinates** on bottom off bottom	**Character-ization of the probe**	**Samples with preserved specimens**	**Video Print** no.	**Video Seq.**
01 DR Malpelo	11.11.1999 on bottom: 11:44 h 2395 m 05°09.41' N 080°38.39' W off bottom: 14:07 h 1812 m 05°10.07' N 080°38.72' W	Rocks with sharp edges, clay sediment.	(1) RR: - Dwelling tube, ceratoid, first adjacent, than upright, >VP 01. - Dwelling tubes on piece of rock, >VP 02. (2) RR: - Dwelling tubes covered with sediment, >VP 03. (3) RR: - Porifera (?).	VP 01 VP 02 VP 03	00.01.13 00.00.28 00.01.50
02 DR Malpelo	11.11.1999 on bottom: 20:56 h 3354 m 05°06.33' N 081°25.02' W off bottom: 22:42 h 2767 m 05°05.50' N 081°25.07' W	Few rocks SR* = Sediment.	(1) RR: - Porifera, >VP 04. ***Sediment***: Tanaidacea.	VP 04	00.03:45
03 TVG Malpelo	11.11.1999 on bottom: 04:18 h 916 m 04°28.02' N 080°54.34' W off bottom: 05:57 h 908 m 04°28.00' N 080°54.30' W		Only the 03-TVG material has been fixed and preserved in 70% ethanol, all other probes were treated with formalin (4-8%). (1) RR: - 2 *Galathea*, found free in the dredge, >VP 07. (2) Epi: - Amphipoda, from numerous dwelling tubes on the rocks. (3) Epi: - Further Amphipoda as (2). (4) Epi: - Ditto, >VP 08. (5) Epi: - Bryozoa, >VP 06. (6) Epi: - Hydrozoa. (7) RR: - Porifera, >VP 05. (8) Epi: - Porifera: cf. *Sycon*. (9) RR: - Diversa (Porifera, Polychaeta with dwelling tubes, Tunicata,	 VP 07 VP 08 VP 06 VP 05	See video 03-TVG 00.05.43 00.06.45 00.09.52 00.08.26

			Crinoidoidea?). (10) RR: - Squeezed Bivalvia, found free in the TV grab.		
	Video observation: nearly exclusively sediment floor, some fishes, little dwelling tubes, feeding or creeping traces. Very few epibenthic organisms on the rocks. Rocks partly covered with sediment; possibly unstable living conditions for epifauna, danger of sedimentation.				
04 DR Malpelo	12.11.1999 on bottom: 08:04 h 2061 m 04°29.06' N 080°55.53' W off bottom: 09:13 h 1845 m 04°28.70' N 080°55.07' W	No rock samples, only sediment in SR.	*Sediment*: Copepoda 4, Amphipoda 1, Nematoda 7.		
05 DR Malpelo	12.11.1999 on bottom: 11:37 h 1639 m 04°33.94' N 080°41.98 W off bottom: 13:00 h 1530 m 04°33.67' N 080°42.15' W	Many rocks.	(1) RR: - Porifera. (2) Epi: - Bryozoa from rock, >VP 09. (3) Epi: - Ceratoid dwelling tube type,VP 01. (4) RR: - Slimy dwelling tubes. (5) RR: - Ditto. (6) Epi: - Brachiopoda, >VP 11. (7) >VP 12. *Sediment*: Copepoda 4, Ostracoda 1, Nematoda 14, Kinorhyncha 9.	VP 09 VP 11 VP 12	00.12.40 00.10.30
06 DR Malpelo	12.11.1999 on bottom: 19:18 h 1564 m 04°09.32' N 081°16.51' W off bottom: 20:01 h 1398 m 04°09.42' N 081°16.69' W	Many rocks, little epifauna.	(1) Tunicata from rocks, >VP 10.	VP 10	00.11.59
07 DR Malpelo	12.11.1999 on bottom: 01:27 h 3000 m 04°19.92' N 081°52.48' W off bottom: 03:53 h 2450 m 04°18.80' N 081°52.29' W		No material found.		
08 DR Carneg.	13.11.1999 on bottom: 22:45 h 3571 m 01°02.01' N 082°17.55' W off bottom: 00:02 h 3374 m 01°02.44' N 082°17.13' W	No rock samples.	*Sediment*: Copepoda 8, Ostracoda 1.		
08a DR Carneg.	13.11.1999 on bottom: 03:25 h		(1) RR: - Dwelling tubes from rocks, empty, with shiny interior layer,		

	3375 m 01°01.56' N 082°11.40' W off bottom: 04:42 h 3124 m 01°02.01' N 082°11.32' W		covered with Foraminifera. (2) RR: - Mollusca, *Patella*-like (but with byssus-like threads), 10mm, >VP 13. (3) RR : - Polychaeta : Maldanidae (= Bamboo worms), 6-8 cm. (4) RR: - Diversa. ***Sediment***: - Copepoda 9.	VP 13	00.13.05
09 DR Carneg.	14.11.1999 on bottom: 13:45 h 2432 m 00°05.23' N 082°08.76' W off bottom: 16:13 h 1531 m 00°04.37' N 082°08.35' W	No rocks.	(1) K* 500: - Crustacea cf. Palaemonidae (from chain sack dredge); see Hayworth p. 409; >VP 14. ***Sediment***: Copepoda 6, Tanaidacea 1, Nematoda 5, Kinorhyncha 1.	VP 14	00.14.35
10 TVG Carneg.	14.11.1999 on bottom: 17:32 h 1409 m 00°04.07' N 082°07.50' W off bottom: 19:22 h 1406 m 00°04.04' N 082°02.49' W	Only sediment (SR).			
	Video observation: mainly sediment floor, occasional fishes and shrimps. Unclear structures burrowed in sediment with openings suggesting a bundle of upright tubes (see video sequence 14.11.99 / 18:09). Rich epifauna on the few rocks encountered, where crinoids dominate. In summary: much richer animal life than that of 10-TVG, although probing site 500 m deeper.				
11 DR Carneg.	14.11.1999 on bottom: 20:50 h 1447 m 00°04.21' N 082°07.57' W off bottom: 21:42 h 1432 m 00°03.91' N 082°07.44' W	No rock samples.			
11a DR Carneg.	14.11.1999 on bottom: 22:32 h 1446 m 00°03.33' N 082°07.34' W off bottom: 23:40 h 1456 m 00°04.25' N 082°07.70' W	Many rocks, epibenthic organisms partly collected with chisel from the rocks.	(1) Epi: - Porifera. (2) Epi: - Polychaeta (Maldanidae, ...), >VP 15, >VP 15a, >VP 29. (3) ** - Brachiopoda, >VP 50. (1) Epi: - Porifera (?). (2) Epi: - Bryozoa. (3) Epi: - Porifera on rock piece. (4) K26: - Crinoidoidea (ca. 6 cm), >VP 49. (5) K200: - Porifera fungoid (8mm) and Ophiuroidea, >VP 27. (9) K200: - Porifera on rock piece. ***Sediment***: Copepoda 2, Nematoda 18, Polychaeta 1, Gastrotricha 1.	VP 15 VP 15a VP 29 VP 50 VP 49 VP 27	00.15.30 00.16.30 00.28.25 00.47.50 00.47.25 00.27.26

12 DR Carneg.	15.11.1999 on bottom: 05:09 h 2364 m 00°23.89' N 081°27.18' W off bottom: 07:15 h 1984 m 00°24.39' N 081°27.44' W		***Sediment***: Sediment probe +.		
13 DR Carneg.	15.11.1999 on bottom: 13:50 h 1250 m 00°26.20' S 081°59.51' W off bottom: 15:25 h 1184 m 00°25.49' S 081°59.59' W	Rocks with mangan oxide crust (manganite).	(1) K500: - Coral (?) or Porifera; manganite-oxide incrusted. - Piece of manganite oxide crust. (2) RR: - Various Porifera , >VP 19. - calcareous tube, >VP 20. (3) Epi: - Brachiopoda (inferior surface coalesced with rock), >VP 18. ***Sediment***: Copepoda 2, Tanaidacea 2, Nematoda 17, Kinorhyncha 2. Sediment probe +.	VP 19 VP 20 VP 18	00.20.50 00.22.10
14 DR Carneg.	15.11.1999 on bottom: 20:50 h 1408 m 01°10.92' S 082°15.00' W off bottom: 22:55 h 1333 m 01°10.46' S 082°15.00' W		(1) K26: - Porifera (plastic foil-like, adjacent to rock surface), >VP 21a-c. (2) Bryozoa (stolon adjacent, zooids upright), >VP 25, >VP 28. ***Sediment***: Kinorhyncha 6. Sediment probe +.	VP 21ac VP 25 VP 28	00.22.45 00.26.00 00.28.05
15 DR Carneg.	16.11.1999 on bottom: 04:30 h 1681 m 01°50.20' S 081°55.83' W off bottom: 06:08 h 1689 m 01°50.17' S 081°55.80' W	No rocks.	***Sediment***: Kinorhyncha 2. Sediment probe +.		
16 DR Carneg.	16.11.1999 on bottom: 10:53 h 2422 m 02°26.62' S 081°37.36' W off bottom: 13:02 h 2276 m 02°26.62' S 081°37.51' W	No rocks.	***Sediment***: Sediment probe +.		
16a DR Carneg.	16.11.1999 on bottom: 14:47 h 2307 m 02°26.69' S 081°37.50' W off bottom: 16:08 h 2393 m 02°26.74' S 081°37.41' W	No rocks.			

17 TVG Carneg.	16.11.1999 on bottom: 23:09 h 1899 m 02°09.83' S 082°36.64' W off bottom: 23:49 h 1932 m 02°09.91' S 082°36.77' W	Rocks plus 0,1 cbm sediment (exclusively Foraminifera-ooze).	(1) RR: - Porifera sclerites, >VP 50 - parrot beak of a Cephalopoda, >VP 52. (2) RR: - Foraminifera (Auswahl). (3) RR: - Sediment probe, fixed, >VP 51. (4) RR: - Ophiuroidea (one arm only). (5) RR: - Skeleton structures, >VP 22. (6) RR: - Gastropoda (*Patella*-like), >VP 53. (7) RR: - Various dwelling tubes from rock surface, >VP 54. (8) RR: - Polychaeta (some heavily damaged), >VP 55. (9) RR: - Dwelling tubes from rock surface. (10) K 500: - Ophiuroidea, Sipuncula?). - Long sclerites from glass Porifera. ***Sediment***: Sediment probe +.	VP 50 VP 52 ua VP51 VP 22 VP 53 VP 54 VP 55	00.47.00 00.49.10 00.48.20 00.24.00 01.01.40 01.02.40 01.03.00
	Video observation 17-TVG: mainly sediment, rather solid, numerous dark circles of about 10 cm in diameter, surrounded by a whitish halo of further 10 cm width which can be interpreted as feeding area of tube dwelling animals. Seen from above, a number of openings can be discovered. During exposure (1h, 21 min) fishes, shrimps, ophiurida. For specimens in the grab see above.				
18 DR Carneg.	17.11.1999 on bottom: 07:54 h 2449 m 02°13.55' S 083°40.94' W off bottom: 08:58 h 2200 m 02°13.27' S 083°41.51' W	Many rocks, < 1% with epifauna: dwelling tubes, base plates from lost organisms, no Porifera or Bryozoa.	(1) K26: - 2 Brachiopoda (partly damaged). ***Sediment***: Sediment probe +.		
19 DR Carneg.	17.11.1999 on bottom: 14:47 h 2381 m 02°15.94' S 084°25.65' W off bottom: 16:16 h 2009 m 02°15.30' S 084°26.18' W	Large rocks, most with manganite; dwelling tubes along concave edges and in holes. Intact Polychaeta nearly impossible to recover.	(1) K500: - Actinia (ca. 10 cm high, 3-4 cm thick). - Parts of a glass Porifera. - Polychaeta-dwelling tube 4 mm thick. - Sipuncula (?; greenish, 1x4 cm), cf. *Aspidosiphon.* - "Vermes" brown, 6x18mm, from deepenings of the rocks. - Broken pieces of calcareous dwelling tubes. (2) K26: - Ceratoid tube type VP 01. - Parts of Porifera. - Unknown organism from rock hole, 4x15mm, brown. (3) - Epi: - Dwelling tubes (some with damaged Polychaeta). (4) RR: - Grey sediment recovered from rocks (Radiolaria, Foraminifera, Diatomea). ***Sediment***: Sediment probe +.		

20 DR Carneg.	17.11.1999 on bottom: 20:48 h 1869 m 01°42.09' S 084°18.55' W off bottom: 21:45 h 1770 m 01°41.84' S 084°18.92' W	No rocks, sediment only in SR.	*Sediment*: Sediment probe +.		
21 TVG Carneg.	18.11.1999 on bottom: 01:54 h 1674 m 01°18.61' S 084°10.22' W off bottom: 02:50 h 1690 m 01°18.79' S 084°10.24' W	0,3 cbm Foraminifera ooze, no rocks.	(1) - Ophiuroidea. - Polychaeta, partly in tubes. - Sipuncula (?, 1,5x25 cm, covered with ooze, of soft consistency). (2) K26: - Sediment probe, sieved (ca. 1mm mesh width). (3) hohes Epi: - Polychaeta, Maldanidae: cf. *Maldone* sp. (det. after Fauchald 1977) (4) hohes Epi: - Polychaet.a, Maldanidae, cf. *Praxillura* sp. (after Fauchald 1977). *Sediment*: Sediment probe +.		
	Video observation 21-TVG: only sediment (foraminifera ooze), no rocks. Sediment seems pretty solid, since the sensor weight of the TV grab penetrates only a little. A thin layer of loose material lies above the true sediment and is moved as a dusty cloud, when the weight touches the ground. Again, dark circles surrounded by fair halos (see also 17-TVG) and creeping traces, the larger ones presumably by holothurians. Direct observation of holothurians, echinoids, and fishes.				
22 DR Carneg.	18.11.1999 on bottom: 07:55 h 2650 m 00°38.16' S 084°09.02' W off bottom: 09:20 h 2593 m 00°38.86' S 084°08.94' W	Dredge empty.	*Sediment*: Sediment probe +.		
22a DR Carneg.	18.11.1999 on bottom: 11:22 h 2491 m 00°41.96' S 084°03.29' W off bottom: 13:11 h 2366 m 00°42.72' S 084°03.47' W	Dredge empty; Foraminifera ooze on sides of dredge.	*Sediment*: Sediment probe +.		
23 TVG Carneg.	18.11.1999 on bottom: 19:48 h 2439 m 00°05.40' N 083°49.56' W off bottom: 21:12 h 2453 m 00°05.38' N 083°49.38' W	No rocks, sediment only (SR).	*Sediment*: Amphipoda 1.		See Video to 23-TVG.

	Video observation 23-TVG: Underground predominantly sediment. Numerous dark circles with fair coronas (as in 10-TVG and 17-TVG). Long creeping-traces (up to more than 1 m in length, curved). Two types of holothurians, black ones and metallic shining ones with "little feet", asteroids and fishes (front part also shiny as seen from above).				
24 DR Carneg.	18.11.1999 on bottom: 23:44 h 2830 m 00°07.62' N 083°46.90' W off bottom: 01:39 h 2538 m 00°06.95' N 083°46.98' W	Sediment only in SR; 1 Holo-thuroidea, 25 cm long, in chain sack of the dredge.	(1) Holothurioidea: - Elasipodidae (deep-sea Holothurioidea (Westheide/Rieger); fixation by injection of formalin, sclerite preparation > VP 26.	VP 26	00.26.40
25 DR Carneg.	19.11.1999 on bottom: 08:39 h 3394 m 00°44.49' N 084°31.01' W off bottom: 10:03 h 3174 m 00°43.87' N 084°31.04' W	Dredge empty, SR with sediment.			
25a DR Carneg.	19.11.1999 on bottom: 11:56 h 3189 m 00°43.86' N 084°31.04' W off bottom: 12:55 h 3016 m 00°43.49' N 084°31.09' W	Dredge empty, sediment in SR and along sides of the dredge.	*Sediment*: Sediment probe +.		
26 TVG Carneg.	19.11.1999 on bottom: 20:50 h 1388 m 00°18.01' N 084°58.54' W off bottom: 22:26 h 1402 m 00°18.02' N 084°58.45' W	One single rock between "teeth" of the grab, with rich epifauna.	(1) K500: - Porifera (2x6 cm). - Gorgonacea (fan 2x6 cm, with polyps), >VP 56. - Gorgonacea (white, 1,5x2 cm). - Hydroid polyp (athecat, 3x3 cm), >VP 57. - Further colonies of Hydrozoa, some with epifauna (Porifera, Bryozoa), >VP 58. - Hydrozoa, colony stout, 1-2 mm, thick, 5 cm long, yellowish, with 2 polyps, stolon with whitish longitudinal stripes, >VP 59. - 6 Anthozoa (*Actinia*-like), >VP 60. (2) K200: - Porifera, many disk-like, type VP 125). (3) RR: - Small colonies from Hydrozoa or Bryozoa. (4) -RR: - Brachiopoda (shell only). - Bryozoa. - Diversa. - Coral, type VP 61. (11) -Gerda-Box: - Large Gorgonacea.	VP 56 VP 57 VP 58 VP 59 VP 60 VP 61	01.03.30 01.03.42 01.03.55 01.04.11 01.04.36 01.05.31

	Video observation 26-TVG: stones mixed with sediment. In spite of considerable depth (1.400m), very rich epifauna, especially on the rocks. Most often several organisms per single rock visible, up to 20 organisms per sight area (ca. 2.4 qm). Most numerous "white sponges" in large dimensions (approximately 30x50 cm ((19.11.99 / 21:29). In addition: glass sponges, Cnidaria (cf. *Actinia*-like, Pennularia-like, Gorgoniacea and other corals) and some fishes and shrimp-like crustaceans were observed. On the ground we can see creeping and feeding traces.				
27 DR Carneg.	19.11.1999 on bottom: 03:10 h 2466 m 00°50.80' S 085°06.56' W off bottom: 03:55 h 2119 m 00°51.15' S 085°06.58' W				
28 DR Carneg.	20.11.1999 on bottom: 13:30 h 2495 m 02°04.26' S 085°55.00' W off bottom: 16:34 h 2106 m 02°03.67' S 085°55.04' W		(1) RR: - Porifera. - Basal plates of lost corals (?; white, hollow, 2-3 mm thick). - Bryozoa (Typ VP 25). - Thin arborescent specimens on rock piece. (2) RR: - Fine ooze, adhering to rocks, not composed of Foraminifera).		
29 DR Cocos	21.11.1999 on bottom: 21:49 h 2483 m 01°39.37' N 090°47.65' W off bottom: 23:18 h 1845 m 01°39.42' N 090°47.12' W		*Sediment*: Sediment probe +.		
29a DR Cocos	21.11.1999 on bottom: 01:28 h 2428 m 01°35.20' N 090°47.31' W off bottom: 02:53 h 2183 m 01°35.21' N 090°47.09' W				
30 DR Cocos	22.11.1999 on bottom: 12:43 h 2436 m 03°08.51' N 091°06.00' W off bottom: 14:24 h 2322 m 03°08.62' N 091°06.61' W		(1) RR: - Brachiopoda, >VP 62. - Bryozoa (colony), >VP 63. - Unidentified: colony on rock piece, >VP 64. (2) K26: - Porifera (on rock). – Further pieces with epifauna.	VP 62 VP 63 VP 64	01.06.08 01.06.44 01.09.22
31 DR Cocos	22.11.1999 on bottom: 18:39 h 2167 m	Dredge empty.			

	03°18.79' N 090°41.98' W off bottom: 19:42 h 1974 m 03°18.77' N 090°42.45' W		***Sediment***: Sediment probe +.		
32 DR Cocos	22.11.1999 on bottom: 22:16 h 1458 m 03°27.60' N 090°37.00' W off bottom: 23:10 h 1224 m 03°27.56' N 090°36.63' W	ca. 50 kg Steine, alle porös und brüchig, unterschiedlich veil Bewuchs.	(1) RR: – Porifera. - Anthozoa. (2) RR: - Bryozoa, u.a. VP 63. (3) RR: - Polychaeta (dwelling tubes). (4) K26: Porifera from rock, incl. >VP 66. (5) RR: Unidentified, white balls (eggs?) in shell (?), >VP 65. (6) - Foraminifera probe from sediment, >VP 47.	VP 66 VP 65 VP 47	01.10.10 00.46.23
33 DR Cocos	23.11.1999 on bottom: 07:43 h 1694 m 03°53.88' N 089°13.62' W off bottom: 08:30 h 1492 m 03°53.44' N 089°13.64' W				
34 DR Cocos	23.11.1999 on bottom: 14:19 h 1228 m 03°16.68' N 088°55.81' W off bottom: 15:23 h 1117 m 03°16.24' N 088°55.79' W		(1) RR: Porifera (incl. >VP67). (2) RR: Bryozoa (incl. >VP 68). (3) RR: - Porifera (slimy). (4) RR: - Crustacea: exuvia of cf. *Galathea*. (5) RR: - Brachiopoda (damaged). (6) RR: - Polychaeta. (7) K26: - Ophiuroidea. – Bryozoa, >VP 69. (8) K100: - Porifera (various types). (9) K500: - Porifera (2 large specimens). – Empty shell of Brachiopoda.	VP 67 VP 68 VP 69	01.11.21 01.12.52 01.13.10
35 TVG Cocos	23.11.1999 on bottom: 20:17 h 1107 m 03°19.44' N 088°21.17' W off bottom: 20:57 h 1128 m 03°19.42' N 088°21.30' W		(1) Porifera (1 *Sycon*-like, 1 with a cubic sclerite system).		
	Video observation 35-TVG: sediment with some manganite encrusted rocks in between. Only a forty minute observation period; lacking electrical power the grab could not be closed, and no material was brought on board. Sponges, gorgonas and fishes (the black type) were seen.				
35a DR Cocos	23.11.1999 on bottom: 22:40 h 1778 m 03°21.79' N		(1) K26: - 2 Porifera.		

	088°21.69' W off bottom: 00:50 h 1550 m 03°20.97' N 088°21.56' W				
35b DR Cocos	24.11.1999 on bottom: 02:50 h 1710 m 03°22.65' N 088°18.37' W off bottom: 04:09 h 1377 m 03°22.23' N 088°18.31' W	Dredge empty.			
36 DR Cocos	24.11.1999 on bottom: 09:42 h 2158 m 02°41.60' N 088°01.01' W off bottom: 11:56 h 1739 m 02°41.62' N 088°02.28' W	No rocks; 1 seastar caught in the chain sack of the dredge.	(1) K1000: - Echinodermata: Asteroidea (ca. 10 cm). ***Sediment***: Tanaidacea, Copepoda, Nematoda. Sediment probe +.	Macro-photo-graphs.	
36a DR Cocos	24.11.1999 on bottom: 13:47 h 2111 m 02°49.12' N 088°00.72' W off bottom: 15:23 h 1872 m 02°49.32' N 088°01.50' W	No rocks; 1 sea cucumber in the chain sack of the dredge.	(1) K500: - Echinodermata: Holothuroidea (ca. 10 cm). ***Sediment***: Tanaidacea. Sediment probe +.	Macro-photo-graphs.	
37 DR Cocos	24.11.1999 on bottom: 20:51 h 3328 m 02°35.32' N 087°28.92' W off bottom: 22:45 h 2858 m 02°34.88' N 087°28.57' W	4 fish boxes of rocks; very little epifauna.	(1) K26: – Brachiopoda. - Porifera. - Some dwelling tubes. ***Sediment***: Ostracoda, Nematoda. Sediment probe +.		
38 DR Cocos	25.11.1999 on bottom: 13:49 h 2419 m 04°21.59' N 085°47.05' W off bottom: 14:50 h 2197 m 04°21.92' N 085°47.39' W	Many rocks, little epifauna ("Aufwuchs")	(1) RR: - 2 Brachiopoda, >VP 77. - 1 *Spirorbis*-like tube, >VP 79. - 1 club-like structure of unknown origin, >VP 78. - 2 Ceratoid tubes (type VP 01). ***Sediment***: Tanaidacea, Copepoda, Nematoda. Sediment probe +.	VP 77 VP 79 VP 78	01.22.58 01.22.46 01.22.50
39 DR Cocos	25.11.1999 on bottom: 23:24 h 1164 m 04°30.84' N 086°46.23' W	Many rocks, with manganite crust, rich epifauna.	(1) K26: - Various Porifera, including "Swiss cheese Porifera" (>VP 83) and "slimy Porifera" (not preserved). (2) RR: - Bryozoa (including a "blue	VP 83	01.26.03

	off bottom: 00:40 h 1087 m 04°30.73' N 086°45.94' W		bryozoan" >VP 82). (3) RR: - Olive-coloured gelatinous balls from rocks. (4) RR: - Polychaeta with white calcarous brittle tube, >VP 84. (5) RR: - Basal plate of coral. - Polyplacophoa (cf. *Chiton*). - Ophiuroidea. - Diversa. ***Sediment***: Nematoda, Tanaidacea, Copepoda. Sediment probe +.	VP 82 VP 84	01.25.41 01.26.41
40 DR Cocos	26.11.1999 on bottom: 06:07 h 2005 m 04°37.98' N 087°21.31' W off bottom: 07:13 h 1755 m 04°37.96' N 087°21.84' W	No rocks.	***Sediment***: Tanaidacea, Amphipoda. Sediment probe +.		
40a DR Cocos	26.11.1999 on bottom: 08:35 h 2019 m 04°38.62' N 087°21.95' W off bottom: 10:06 h 1635 m 04°37.87' N 087°22.05' W	Enormous amount of rocks with much biological material. In addition, fouling from the under the ship was also brought on board.	(1) RR: - Porifera, ca. 2 dozen specimens of various growth forms, most sphaeric, others flat-leatherlike, some flat covered with Foraminifera or plastic foil-like with elevated oscula. (2) RR: - Bryozoa. - Brachiopoda. - 1 Ophiuroidea. - 2 rather sphaeric Brachiopoda. (3) K 26: - 2 Crinoidoidea. (4) Epi: - 2 "Ladder"-like Porifera, >VP 80.	VP 80	01.24.20
41 DR Cocos	26.11.1999 on bottom: 15:21 h 2285 m 04°40.46' N 087°54.59' W off bottom: 16:25 h 2035 m 04°40.07' N 087°54.15' W	Many rocks, even very large ones; however almost without any epifauna.	(1) RR: - Part of a dwelling tube covered with Foraminifera. ***Sediment***: Sediment probe +.		
42 DR Cocos	26.11.1999 on bottom: 21:16 h 2050 m 05°08.68' N 087°32.60' W off bottom: 22:32 h 1820 m 05°08.26' N 087°32.58' W	Rocks with little epifauna.	(1) Epi: - Brachiopoda.		
43 DR Cocos	27.11.1999 on bottom: 11:13 h 2066 m	Many large rocks, 5 very large rocks,	(1) High Epi (in K 200): - 7 Porifera. - 2 Bryozoa (upright stems). - 2 Bivalvia (white, type VP 17).		

	05°18.60' N 085°22.67' W off bottom: 12:31 h 1715 m 05°17.82' N 085°22.71' W	partly with manganite. 1 injured jellyfish caught by the dredge on its way to the sea surface.	- Dwelling tubes with Foraminifera. - Semisphaeric Porifera (?), 2mm, with white cupole, inside amorphous mass with few if any sclerites ; >VP 85. - Calcareous disks, 2-3mm, type VP 125. - Brown, thin stem, 2 cm. - Brown hollow balls, from sheltered positions on the rocks, very fragile, inside empty: cf. *Gromia*, ca. 4 mm, >VP 86. - Various dwelling tubes. - Flat crust of Porifera, partly covered by Foraminifera. ***Sediment***: Tanaidacea. Sediment probe +.	VP 85 VP 87	01.27.00 01.28.28
44 DR Cocos	27.11.1999 on bottom: 01:18 h 2961 m 05°58.10' N 083°40.03' W off bottom: 02:19 h 2698 m 05°58.33' N 083°40.18' W	Many rocks, some with manganite crust, mainly these have epifauna.	(1) High RR: - ca. 15 Porifera. (2) Epi: - Smaller Porifera (e.g.: glass Porifera, cylindric, 2-3mm, >VP 89). - Brown hollow balls as VP 87. - 2 Brachiopoda, membraneous form. - 1 *Spirorbis*-like tube as VP 81 and VP 108. - Several pieces from skeletons and/or dwelling tubes.	VP 89	01.28.52
45 DR Cocos	28.11.1999 on bottom: 11:30 h 1679 m 06°14.33' N 084°57.65' W off bottom: 14:11 h 1359 m 06°13.70' N 084°56.94' W		(1) K26: - Ca. 15 different Porifera, e.g. blue crusty Porifera. - Brown hollow balls (cf. *Gromia*) as VP 87. - Bryozoa colony as VP 25. - 1 Crinoidoidea (part of). - 4 club-like structures, 0,3x1cm, erect, brownish, with brownish stolons, >VP 91. (2) Epi: - Brachiopoda. - Bryozoa. - Porifera with prolonged osculum. - Porifera covered with Forminiferea. - White, thin, tree-like, >VP 90. (3) K100: - Several pieces of broken sea-feather (Pennatularia), each ca. 1 cm long, >VP 92. - 1 large villose Porifera 10x10 cm, with stalk. - 1 tube-shaped Porifera. - 1 branched Porifera, covered with polyps in groups of 1-3. ***Sediment***: Tanaidacea, Copepoda, Ostracoda, Amphipoda, Nematoda, Kinorhyncha. Sediment probe +.	VP 91 VP 90 VP 92	01.31.33 01.30.34 01.32.33

45a DR Cocos	28.11.1999 on bottom: 16:17 h 1644 m 06°16.00' N 085°53.25' W off bottom: 18:12 h 1459 m 06°15.65' N 084°53.36' W		(1) High Epi: - Porifera. - Polyp colony (with Porifera). - Brachiopoda. - Bivalvia. - Fouling from under the ship: Cirripedia (barnacles), Hydrozoa Plathelminthes.		
46 TVG Cocos	28.11.1999 on bottom: 23:22 h 634 m 06°29.43' N 085°34.25' W off bottom: 23:39 h 634 m 06°29.43' N 085°34.78' W		(1) High Epi: - Larger Porifera. (2) RR: - Smaller Porifera. (3) RR: - Slimy Porifera. (4) RR: - Anthozoa (several intact sea anemones, Gorgonacea; see macro photos). (5) RR: - Bryozoa (crusty and treelike ones). (6) RR: - Brachiopoda, including >VP 107. (7) RR: - Polychaeta, including >VP 103, >VP 106. (8) K26: - *Galathea*-like crab. - Several Isopoda. - Ophiuroidea. - Polychaeta. (9) K200: - Arborescent epifauna. .- further Porifera. (10) K200: - Gorgonacea (1x4 cm). - Anthozoa. (11) Round K1000: Rock with epifauna. (12) K200: - Rock with epifauna. (13) K200: - Rock with epifauna. (14) K100: -Rock with epifauna. (15) K1000: - Pieces of white Gorgonacea. (16) 1ml Epi: - Small pieces. ***Sediment***: Nematoda, Kinorhyncha, Ostracoda, mites (*Scaptognatha*?). Sediment probe +.	VP 107 VP 103 VP 106	01.49.07 01.45.39 01.48.32
	Video observation 46-TVG: solid rocky underground, little sediment in grooves and depressions. 17 minutes observation time. Spongi, Gorgonacea, Pennatularia, and eel-like fish could be discerned.				
47 DR Cocos	29.11.1999 on bottom: 02:26 h 2015 m 06°38.44' N 085°44.77' W off bottom: 03:59 h 1600 m 06°37.98' N 085°44.29' W		(1) K26: - Porifera, 2x4 cm, both Porifera-like. - Ceratoid tube (type VP 01). - Transparent tube (0,6x15 cm). - Calcareous tubes (0,4xcm 1 and 0,4x2 cm respectively). ***Sediment***: Nematoda, Kinorhyncha, Ostracoda. Sediment probe +.		
48 DR Cocos	29.11.1999 on bottom: 07:26 h 1517 m 06°47.74' N		(1) RR: - Felt-like Porifera, 1x2 cm, >VP 97. - Smaller Porifera. - Porifera (half dome with radiating	VP 97	01.37.35

	085°22.88' W off bottom: 08:39 h 1252 m 06°47.20' N 085°22.97' W		needles, >VP 96. - Brachiopoda shell, covered with Porifera. - Tree-like Bryozoa, type VP 68*. - Brittle star (Ophiuroidea), >VP 95. ***Sediment***: Sediment probe +.	VP 96 VP 95	01.37.50 01.37.46
49a DR Cocos	29.11.1999 on bottom: 16:17 h 1615 m 06°56.39' N 084°14.95' W off bottom: 18:23 h 1203 m 06°55.77' N 084°14.84' W		***Sediment***: Nematoda, Ostracoda. Sediment probe +.		
49b TVG Cocos	29.11.1999 on bottom: 21:42 h 1048 m 07°00.28' N 083°54.14' W off bottom: 21:56 h 1048 m 07°00.29' N 083°54.17' W		(1) High RR: - Polychaeta: Maldanidae, cf. *Microclymene* sp. (2) High Epi: - Polychaeta: Cirratulidae. (3) Anthozoa: - Pennatulida, ca. 10 cm long, basis thickened. (4) ** Polychaeta: 0,8x4 cm, paired bristle pockets visible. - Various dwelling tubes. - White needle (surface covered with fine spines, internal structure detectable), >VP 99. - Polychaet, some in tubes >VP 98. ***Sediment***: Nematoda, Tanaidacea, Kinorhyncha. Sediment probe +.	 VP 99 VP 98	 01.40.05 01.38.00
	Video observation 49b-TVG: no rocks, pure sediment. Some current indicated by the drift of material after the weight had touched the ground. Visible epifauna consisting of glass sponges, Cnidaria, Holothurioidea (black type), Asteroidea (red coloured), Ophiurioidea and an unidentified black fish. During the closing of the grab dwelling tubes can be observed within the sediment mass.				
50 DR Cocos	30.11.1999 on bottom: 02:27 h 1738 m 06°58.59' N 083°41.39' W off bottom: 03:41 h 1488 m 06°59.06' N 083°41.58' W		(1) RR: 4 Porifera. - cf. *Gromia* (Type VP 87). - White calcareous balls, VP 132. - 8 Brachiopoda. - 2 gelatinous balls with white spheres (type VP 65). - Arborescent Bryozoa, type VP 68. ***Sediment***: Nematoda, Ostracoda, Kinorhyncha. Sediment probe +.		
51 DR Cocos	30.11.1999 on bottom: 09:34 h 3289 m 06°59.97' N 082°51.72' W off bottom: 11:20 h 2753 m 06°59.97' N	Many rocks, no organisms.			

	082°52.12' W				
52 DR Cocos	30.11.1999 on bottom: 15:22 h 2912 m 07°22.99' N 082°53.82' W off bottom: 17:51 h 2441 m 07°23.04' N 082°54.72' W		Fouling material from under the ship: 2 Asteroidea. (1) High RR: 15 rock pieces with boring Porifera, >VP 100c. - Unidentified structures from rocks, >VP 101; many white balls. - Calcareous tube, >VP 101. - Polychaeta: Maldanidae (type VP 29). - cf. *Spirorbis,* type VP 108. - 2 Brachiopoda. 0 2 "Plastic foil" Porifera, 1x3cm each. (2) "Gerda" box: - Echinodermata: Asteroidea.	VP 100c VP 101	01.44.07 01.44.30
53 DR Cocos	30.11.1999 on bottom: 23:00 h 1530 m 07°36.24' N 083°25.21' W off bottom: 00:21 h 1365 m 07°36.46' N 083°25.21' W		(1) RR: - *Spirorbis,* >VP 108. - White basal plates, >VP 109. - Small Porifera	VP 108 VP 109	01.49.25 01.49.40
54 DR Cocos	31.11.1999 on bottom: 04:25 h 1433 m 08°01.34' N 083°27.62' W off bottom: 06:27 h 1223 m 08°01.81' N 083°27.68' W	No rocks.	***Sediment***: Nematoda, Tanaidacea. Sediment probe +.		
54a DR Cocos	01.12.1999 on bottom: 07:48 h 1477 m 08°01.89' N 083°26.13' W off bottom: 08:58 h 1142 m 08°02.28' N 083°26.35' W		(1) RR: ca. 30 ceratoid tubes, type VP 01. - ca. 20 cf. *Gromia,* type VP 87. - Porifera. - 1 spheric Porifera, ca. 10 mm, with corona, *Sycon*-like as VP 05. - 1 Polychaeta: Maldanidae, type VP 29. - Membranaceous Bryozoa, type VP 82. - Branched Bryozoa, type VP 69. - White basal plate, type VP 109.		
55 DR Cocos	01.12.1999 on bottom: 13:28 h 1366 m 07°52.68' N 083°59.25' W off bottom: 15:53 h 735 m 07°52.66' N 083°59.98' W		(1) High RR: - 1 large Brachiopoda, 2x3cm, with loose lophophor. - Ophiuroidea, >VP 110. - 1 *Fissurella*-like snail (possible from under the ship). - Some Porifera (slimy Porifera are no more preserved). ***Sediment***: Nematoda. Sediment probe +.	VP 110	01.50.05

56 TVG Cocos	01.12.1999 on bottom: 20:00 h 978 m 07°52.18' N 084°26.38' W off bottom: 20:49 h 980 m 07°52.11' N 084°26.40' W		(1) K500: - Large Porifera. (2) K26: - Various skeletons. - Basal plates (from Anthozoa?). - Shark tooth, >VP 111. - *Galathea*-like crab. (3) Epi: Small Porifera. - cf. *Spirorbis*, type VP 108 *. - Small corals. (4) Epi: - Bryozoa (membraneous, arborescent and creeping forms, the latter with avicularia and with "rhizoids" to the substrate). (5) Epi: - Brachiopoda, e.g. >VP 114 (?). (6) RR: - Polychaeta and their tubes. (7) High RR: - Bryozoa (tree-form, >VP 112. - Porifera crust above membranaceous Bryozoa. - Glas Porifera, tree >VP 113, VP 117. (8) Epi: - Exuvia from Crustacea. (9) Epi: - "Vermes", >VP 116. (10) K500: - 3 Alcyonidae. - 1 white sponge. - 1 Brachiopoda. - 2 Porifera. - 1 Polychaeta dwelling tube. (11) Gerda Box: - White Gorgonacea. ***Sediment***: Nematoda, Tanaidacea, Copepoda, Ostracoda. Sediment probe +.	VP 111 VP 114 VP 112 VP 113 VP 117 VP 116	01.50.17 01.51.58 01.5026 01.51.22 01.53.25 01.53.11
	Video observation 56-TVG: ocean bottom is rocky, uneven, considerable differences in height, little sediment in crevices. Red alcyonids (?) dominant, 6-8 per rock, 20-30 per viewing area possible. In addition (sorted by abundance), white Gorgonacea, white Porifera, white corals, blue encrusting Porifera: red shrimps occasionally on rocks but often on sediment. A few rare sea-stars, urchins and sea cucumbers.				
57 OBS	OBS-1, OBS-5 and OBS-6		***Sediment***: Nematoda, Polychaeta, Gastrotricha, Kinorhyncha. Sediment probe +.		
OBS-1	03.12.99 08°58.60' N 083°53.57' W 85 m	OBS covered with hydro-zoa.	(1) K500: Hydrozoa (cf. *Tubularia* and others). - 12 Crustacea (Crabs). - 2 Gastropoda.	VP 120, 121,122 124	01.55.17 01.58.20
OBS-2	03.12.99 08°54.20' N 084°01.64' W 78 m	OBS covered with hydro-zoa.	(1) K500: Hydrozoa (cf. *Tubularia*). - 4 Crustacea (sea spider; legs autotomized upon fixation). - 1 Cephalopoda (cf. *Sepia*).		
OBS-3	03.12.99 08°50.00' N 084°09.19' W 108 m		(1) RR: - Hydrozoa (cf. *Tubularia*). - 1 Crustacea (sea spider; legs autotomized upon fixation).		
OBS-4	03.12.99 08°42.61' N 084°10.71' W		No animals detected.		

	745 m				
OBS-5	03.12.99 08°45.49' N 084°00.51' W 98m		(1) 1 Crustacea (sea spider, legs autotomized upon fixation). - Crustacea (crab, 3x7 cm). - 4 Gastropoda.		
OBS-6	03.12.99 08°48.80' N 083°53.59' W 67 m		(1) K500: 1 Anthozoa. - 11 Crustacea (6 small and 2 large sea spiders, some with epifauna, 3 shrimps). - 2 Gastropoda.		
OBS-7	04.12.99 08°36.60' N 083°55.48' W 74 m		(1) High Epi: - 1 Crustacea: Isopoda.		
OBS-8	04.12.99 08°38.70' N 084°03.20' W 203 m		No animals detected.		
OBS-9	04.12.99 08°36.30' N 084°13.00' W 1692 m		- 1 Crustacea cf. *Galathea* (caught within parts of the OBS, - since pale and rather benthic it may come from the depth).		
OBS-10	04.12.99 08°31.28' N 084°07.89' W 1587 m		No animals detected on the OBS; a ball of fish eggs pierced by the antenna should have been collected during uprising of the instrument.		
OBS-11	04.12.99 08°30.61' N 083°59.50' W 782 m		No animals detected.		
OBS-12	04.12.99 08°24.51' N 084°05.20' W 2263 m		No animals detected.		
OBS-13	04.12.99 08°25.01' N 084°15.99' W 2120 m		(1) Epi: - 4 Anthozoa (?) with stalks.		
OBS-14	04.12.99 08°31.10' N 084°17.58' W 2580 m		No animals detected.		
FLOW-METER 1-7	08° N 084° W depth 849-2264 m	Smaller instruments, different material.	No animals detected.		
58 DR Cocos	05.12.1999 on bottom: 12:26 h 1790 m 07°45.65' N 085°10.04' W off bottom: 14:57 h 1384 m 07°45.13' N 085°09.20' W	No rocks, no material.	***Sediment***: Nematoda, Tanaidacea, Kinorhyncha.		

58a DR Cocos	05.11.1999 on bottom: 16:46 h 1593 m 07°46.49' N 085°09.16' W off bottom: 18:49 h 1443 m 07°46.41' N 085°08.94' W	Many rocks, most with Mangan-oxide crust, few little organisms on the rocks, mainly Porifera and cf.. *Gromia.*	(1) RR: - White calcareous disks (2-3 mm), type >VP 125. - Porifera (various pieces). - Bryozoa (membranaceous). - Bryozoa (twig-like). - cf. *Gromia* (type VP 87). - Dwelling tubes (pieces only).	VP 125	01.58.30
59 DR Cocos	05.12.1999 on bottom: 21:57 h 1700 m 07°32.80' N 085°02.91' W off bottom: 23:14 h 1342 m 07°32.58' N 085°02.38' W	No rock samples.	***Sediment***: Tanaidacea. Sediment probe +.		
60 DR Cocos	05.12.1999 on bottom: 01:49 h 1723 m 07°23.20' N 085°11.18' W off bottom: 23:26 h 1298 m 07°23.21' N 085°11.39' W	Many rocks, with Mn-crust, and conglom-erate; boring Porifera, crustose Porifera and cf. *Gromia.*	**Material:** (1) Epi: - Porifera (small specimens). - Calcareous dwelling tubes. - Bivalvia (small specimen). - Bryozoa (membraneous). - Polyplacophora, >VP 127. - 2 unidentified objects (banana-formed), >VP 128. (2) RR: - Slimy Porifera. - Anthozoa (brownish, corrugated, ca 0.8 cm), >VP 126. (3) RR: - Porifera (boring Porifera), dissected, > VP 131.	VP 127 VP 128 VP 126 VP 131	01.59.00 01.59.30 01.58.50 02.00.50
61 DR Cocos	06.12.1999 on bottom: 06:03 h 2090 m 07°19.19' N 085°18.22' W off bottom: 07:28 h 1751 m 07°19.73' N 085°18.19' W		***Sediment***: Sediment probe +.		
62 DR Cocos	06.12.1999 on bottom: 10:35 h 2090 m 07°31.21' N 085°32.60' W off bottom: 13:22 h 1550 m 07°30.61' N 085°31.66' W	Huge pile of rocks, most with Mn-crust, partly with epifauna.	(1) RR: - Bryozoa (tree-like type) (>VP 129). (2) RR: White balls, type VP 64. - 4 Brachiopoda. - Several calcareous disks, type VP 125. - 2 Ophiuroidea (>VP 130). - *Gromia*-like balls (both fair-brown (type 87) and reddish brown ones). (3) 2 ml Epi: - Various well preserved Porifera (*Sycon*-like, crustose, tree and antleriform). (4) RR: - Porifera, (>VP 131).	VP 129 VP 130 VP 131	01.59.22 01.59.55 02.00.50
63 TVG	06.12.1999		Description of probe site and video		

Cocos	on bottom: 19:13 h 1257 m 06°58.77' N 085°58.54' W off bottom: 19:53 h 1251 m 06°58.77' N 085°58.61' W		observations see list **. Material preserved: (1) K200: - Dwelling tubes covered with mud, with and without - Polychaeta. - Scaphopoda, >VP 134. - Pennatularia. - Unidentified specimen: dichotom-like, branched, rooted structure (colony ?) with two brachiopod- or *Lepas*-like individuals, >VP133. ***Sediment***: Nematoda. Sediment probe +.	VP 134 VP 133	02.03.20 02.01.50
63a DR Cocos	06.12.1999 on bottom: 22:11 h 2419 m 07°01.80' N 086°01.07' W off bottom: 02:21 h 2084 m 07°00.91' N 086°00.48' W		(1) RR: - Polychaeta (Errantia), large specimen, ca. 8 cm. - 1 Brachiopoda. - Dwelling tubes (Polychaeta: Maldanidae?). - Unidentified specimen, pink, 0.4x1.4 cm, irregularly shaped. - Dwelling tube, ceratoid, type VP 01. ***Sediment***: Nematoda. Sediment probe +.		
64 DR Cocos	07.12.1999 on bottom: 01:37 h 1802 m 05°45.66' N 086°54.08' W off bottom: 03:03 h 1443 m 05°45.02' N 086°54.04' W		(1) 1 ml Epi: - Red ball with yellow-whitish interior, 3 mm. ***Sediment***: Nematoda. Sediment probe +.		
64a DR Cocos	08.12.1999 on bottom: 05:30 h 1215 m 05°43.73' N 086°55.00' W off bottom: 07:00 h 1036 m 05°43.38' N 086°54.97' W				
65 DR Cocos	08.12.1999 on bottom: 09:10 h 1556 m 05°44.23' N 086°47.68' W off bottom: 10:40 h 1194 m 05°44.21' N 086°48.14' W		(1) 2ml Epi: - 1 Ophiuroidea. - 1 white basis of lost specimen (coral?). - 1 Brachiopoda. - 1 calcareous disk. - 1 white ball (>VP 132). - Various Bryozoa. (2) RR: - Porifera (various types). ***Sediment***: Nematoda. Sediment probe +.	VP 132	02.01.20
65a DR Cocos	08.12.1999 on bottom: 11:55 h 1241 m		(1) K26: - Porifera. - 1 Ophiuroidea. (2) 2ml Epi: - 1 Brachiopoda.		

	05°44.18' N 086°48.15' W off bottom: 13:24 h 1069 m 05°44.04' N 086°48.67' W		- Bryozoa (various types).		
66 DR Cocos	08.12.1999 on bottom: 15:54 h 1204 m 05°37.36' N 086°51.63' W off bottom: 17:06 h 1018 m 05°37.18' N 086°52.00' W		(1) 2ml Epi: - Porifera. - 1 Ophiuroidea. - 1 Bryozoa (twig-like). - 1 calcareous disk (type 125). ***Sediment***: Nematoda, Copepoda. Sediment probe +.		
67 DR Cocos	08.12.1999 on bottom: 22:19 h 1800 m 05°30.24' N 087°15.44' W off bottom: 23:24 h 1512 m 05°30.66' N 087°15.35' W		(1) 2ml Epi: - Crustacea: Paguridae-like, from hole in rock surface. - Porifera (variuos types). - 1 Ophiuroidea. - Dwelling tubes. - Calcareous disks, 1 mm (type VP 125).		
68 DR Cocos	09.12.1999 on bottom: 03:58 h 2129 m 05°21.57' N 087°37.69' W off bottom: 05:40 h 1913 m 05°22.22' N 087°37.88' W	No rock samples.	***Sediment***: Nematoda, Tanaidacea. Sediment probe +.		
68a DR Cocos	09.12.1999 on bottom: 07:30 h 1483 m 05°23.12' N 087°37.66' W off bottom: 09:04 h 1256 m 05°23.41' N 087°37.59' W		***Sediment***: Nematoda, Tanaidacea, mites. Sediment probe +.		
69 DR Cocos	09.12.1999 on bottom: 13:52 h 2077 m 05°12.52' N 087°56.77' W off bottom: 15:24 h 1905 m 05°11.90' N 087°56.89' W		(1) RR: - 2 unidentified specimens, leather-like, brownish, stout, 0.6 cm, >VP 135.	VP 135	
70 TVG Cocos	09.12.1999 on bottom: 20:17 h 1056 m 05°33.97' N		Description of probe site and video obeservations see list**. In grab, only one plate (10x30 cm) of weathered rock, on which no epifauna		

	088°14.69' W off bottom: 21:16 h 1058 m 05°33.97' N 088°14.69' W		could be discovered.		
70a DR Cocos	09.12.1999 on bottom: 23:13 h 1980 m 05°34.55' N 088°13.19' W off bottom: 00:28 h 1631 m 05°34.38' N 088°13.57' W	Considerable number of rocks, partly with Mn-oxide crust.	(1) 1ml Epi: Crustacea (from hole-like deepening in one of the rocks (VP 136). (2) 1ml Epi: Crustacea (from same hole as (1), VP 137. (3) **- unidentified: actinomorphic stolons of several cm length with central protrusions, similar to type VP 138. (4) Porifera (without the also present slimy Porifera). - Dwelling tube with Polychaeta. - 1 Brachiopoda. - Bryozoa (membranaceous and hedgehog-like). - Reddish *Gromia*-like specimen. - Calcareous tubes. - White ball (type VP 132). - 1 calcareous basis. ***Sediment***: Tanaidacea, Ostracoda. Sediment probe +.	VP 136 VP 137	02.03.50 02.03 55
70b DR Cocos	10.12.1999 on bottom: 01:55 h 1631 m 05°34.48' N 088°13.61' W off bottom: 03:24 h 1455 m 05°34.44' N 088°13.87' W		No animals.		
71 DR Cocos	10.12.1999 on bottom: 07:16 h 1251 m 05°30.96' N 088°34.79' W off bottom: 08:44 h 967 m 05°30.46' N 088°34.90' W		No animals found.		
71a DR Cocos	10.12.1999 on bottom: 10:02 h 1631 m 05°28.47' N 088°36.64' W off bottom: 11:03 h 1294 m 05°28.59' N 088°36.17' W	Little material.	No animals found.		
72 TVG Cocos	10.12.1999 on bottom: 18:08 h	No material.	TV grab regularly fell aside because of uneven terrain, and could not be closed.		

	730 m 05°51.89' N 087°34.40' W off bottom: 18:49 h 741 m 05°51.90' N 087°34.38' W				
72a DR Cocos	10.12.1999 on bottom: 19:53 h 968 m 05°52.11' N 087°34.36' W off bottom: 20:55 h 760 m 05°51.82' N 087°34.41' W		Very rich epifauna, mainly Anthozoa. (1) K500 - Porifera (?): 10 cm "tree", with thin spiny branches (see macro photo). (2) K500: - Porifera (various larger specimens). (3) 3ml Epi: Porifera (various small specimens). (4) RR: - Anthozoa (8 red and 2 white ones). - 1 Polyplacophora. - 1 calcareous basis. (5) 2ml Epi: - Brachiopoda. (6) 2ml Epi: Bryozoa. (7) 1.5ml Epi: Polychaeta, dwelling tubes and damaged worms, also tentacles of Polychaeta and elytra (?). (8) Unidentified specimens, >VP 138-143). (9) 2 Ophiuroidea.	VP 138-143	02.06.10
73 DR Cocos	10.12.1999 on bottom: 06:50 h 1843 m 07°05.39' N 086°23.85' W off bottom: 08:59 h 1766 m 07°05.37' N 086°23.97' W		*Sediment*: Nematoda. Sediment probe +.		
74 DR Cocos	11.12.1999 on bottom: 12:34 h 2210 m 07°23.02' N 086°31.29' W off bottom: 15:59 h 1792 m 07°23.46' N 086°30.62' W		*Sediment*: Nematoda. Sediment probe +.		
75 TVG Cocos	11.12.1999 on bottom: 20:26 h 918 m 07°38.64' N 086°12.04' W off bottom: 21:25 h 913 m 07°38.67' N 086°12.08' W		(1) White tube. (2) K500: - Porifera. (3) RR: - Small Porifera. (4) 2ml Epi: - Bryozoa. (5) RR: - Brachiopoda. - Ophiuroidea. (6) RR: - Dwelling tubes + Polychaeta. *Sediment*: Nematoda, Copepoda, Gastrotricha?		

			Sediment probe +.		
76 HYD Fisher			Hydrosweep survey. No seamounts or ridge found, no dredges or grabs.		
77 DR Cocos	12.12.1999 on bottom: 08:51 h 741 m 07°44.11' N 085°55.33' W off bottom: 09:49 h 600 m 07°43.96' N 085°55.66' W		(1) K100: - Porifera. (2) 2ml Epi: - cf. *Gromia* (many). (3) - Porifera. (4) 2ml Epi: - Bryozoa. (5) K26: - 6 Brachiopoda. - 10 Ophiuroidea. (6) - Dwelling tubes, Polychaeta and 2 type VP 01. (7) - Crustacea. (8) - Diversa. (9) - Thin bunchlike Porifera.		
77a DR Cocos	12.12.1999 on bottom: 11:23 h 1591 m 07°45.87' N 085°55.49' W off bottom: 13:25 h 1622 m 07°45.92' N 085°55.51' W		(1) (1) RR: Porifera. (2) 1ml Epi: - Small Porifera. (3) 1ml Epi: - Bryozoa. (4) 2ml Epi: - 6 Brachiopoda (inclusive 1 oval specimen, type VP 114). (5) 2ml Epi: - Polychaeta dwelling tubes + cf. *Gromia*. ***Sediment***: Nematoda. Sediment probe +.		
78 DR Cocos	12.12.1999 on bottom: 17:05 h 1465 m 08°06.88' N 085°47.50' W off bottom: 18:44 h 1374 m 08°06.83' N 085°47.59' W		(1) 2ml Epi. - 20 Porifera, calcareous, type VP 125. (2) 1ml Epi: - 2 Brachiopoda. - 2 Bryozoa. (3) 1ml Epi: - Small Porifera. - 1 calcareous ball, type VP 132. - 1 tube, type VP 01. - Unidentified structures. Slimy Porifera, not preserved.		
79 DR Cocos	12.12.1999 on bottom: 22:29 h 1625 m 07°58.34' N 085°33.49' W off bottom: 00:10 h 1190 m 07°58.67' N 085°33.92' W		(1) K1000: - Echinoidea (squeezed). - White Porifera. - Several pieces of "white sponge" with epifauna (anthozoan-like, >VP 145). – "Black sponge" with epifauna. - Dwelling tubes, hydrozoan colonies, etc. (2) RR: - Porifera (>VP 147A et al.). - Ophiuroidea. - 2 Tubes, type VP 01. - Calcareous disks, type VP 125. - cf. *Gromia*, type VP 87. (3) 2ml Epi: - Unidentified, >VP 144. – Bryozoa (>VP 148, VP 149). (4) 2ml Epi: - Crustacea cf. *Caprella*. ***Sediment***: Nematoda. Sediment probe +.	VP 145 VP 147 VP 144 VP 148 VP 149	02.08.20 02.10.12 02.08.10 02.10.33 02.10.42
80 DR Cocos	13.12.1999 on bottom: 04:43 h 1751 m 08°17.07' N 085°08.99' W		(1) RR: - Slimy Porifera. (2) 2ml Epi: - 4 Brachiopoda. - 1 tube, type VP 01. - 1 gelatinous ball, ca. 2mm. - 2 calcareous disks, type VP 125.		

	off bottom: 06:45 h 1592 m 08°16.93' N 085°08.83' W				
81 DR Cocos	13.12.1999 on bottom: 09:57 h 1726 m 08°31.39' N 085°09.09' W off bottom: 12:55 h 1376 m 08°31.80' N 085°08.96' W		(1) 10l container: - 4 large (up to 6x40 cm) pieces of solid Porifera with rest of its epifauna. (2) RR: - Porifera. (3) RR - Porifera (?) bunches. (4): K26: - Porifera, other bunch-type, two-dimensional. (5) K26: - Hydrozoa colonies, type VP 155. (6) 2ml Epi: - Anthozoa or not? (*Actinia*-like buds, but masses of sclerites when dissected (VP 153). (6a) 2ml Epi:- Additional material, as (6). (7) 1ml Epi: - Bryozoa. (8) 1ml Epi: - 4 Brachiopoda. (9) RR: - Polychaeta dwelling tubes. (10) RR: - Crustaceans: Balanidae, .>VP 151. (11) 2ml Epi: - Additional Balanidae. - 1 *Scalpellum,* >VP 149a. (12) 1ml Epi: - "Black Porifera" - Calcareous ball, type VP 132. - cf. *Gromia.* - 5 tubes, type VP 01. - Ophiuroidea. - Calcareous dwelling tube (broken pieces).	VP 153 VP 151 VP 149a	02.13.15 02.12.00 01.12.52
82 DR Cocos	13.12.1999 on bottom: 16:49 h 1546 m 08°33.93' N 085°27.83' W off bottom: 18:39 h 1148 m 08°33.53' N 085°27.26' W		(1) Round K100 bottle: - Some pieces of something which may have been a jellyfish, found in the chain sack, could have come from higher area in the water and not necessarily from the bottom. (2) 2ml Epi: - Porifera. - cf. *Gromia.* ***Sediment***: Tanaidacea.		
83 DR Cocos	13.12.1999 on bottom: 20:58 h 1899 m 08°27.45' N 085°34.45' W off bottom: 22:07 h 1678 m 08°27.72' N 085°34.79' W		(1) 2ml Epi: Porifera type VP 30. ***Sediment***: Nematoda, Copepoda, Tanaidacea, Ostracoda. Sediment probe +.		
84 DR Cocos	13.12.1999 on bottom: 00:31 h 2297 m 08°31.63' N 085°38.10' W		(1) 1ml Epi: - 1 Polychaeta, cf. *Spirorbis.* - 1 dwelling tube, without Polychaeta.		

	off bottom: 01:44 h 1906 m 08°31.89' N 085°38.41' W		*Sediment*: Nematoda, Tanaidacea, Ostracoda. Sediment probe +.		
85 DR Fisher	14.12.1999 on bottom: 05:23 h 2537 m 08°52.25' N 085°38.49' W off bottom: 06:37 h 2165 m 08°51.94' N 085°38.14' W	Rocks without animals.	*Sediment*: Nematoda, Tanaidacea, Ostracoda, Copepoda. Sediment probe +.		
86 OBS deploy.			*Sediment*: Nematoda, Tanaidacea.		
87 DR Contin. Slope	15.12.1999 on bottom: 12:19 h 2462 m 09°11.37' N 085°16.38' W off bottom: 14:05 h 2165 m 09°12.66' N 085°16.44' W	Few rocks, one with interesting animals.	(1) 2ml Epi: Polychaeta, VP 155a. – Polychaeta, cf. *Spirorbis* (including damaged Polychaeta), >VP 156a. – Polychaeta (?) tentacle crown (?), >VP 157a. – Sipuncula (?), >VP 158. *Sediment*: Nematoda. Sediment probe +.	VP 155a VP 156a VP 157a VP 158	02.15.08 02.16.27 02.16.42 02.17.11
88 DR Coiba	16.12.1999 on bottom: 15:57 h 1848 m 06°12.27' N 081°56.93' W off bottom: 17:18 h 1219 m 06°12.34' N 081°56.06' W	Many rocks, some with Mn-oxide crust.	(1) 1ml Epi: - Disk like Porifera (slimy Porifera omitted). (2) 1ml Epi: - Bryozoa. (3) 2ml Epi: - Intact Polychaeta. (4) 2ml Epi: - Various dwelling tubes. (5) 2ml Epi: - Ophiuroidea. (6) 1 ml Epi: - Polychaeta. - Structure >VP 159. *Sediment*: Nematoda, Tanaidacea, Copepoda, Kinorhyncha, Ostracoda. Sediment probe +.	VP 159	02.18.01
89 TVG Coiba	16.12.1999 on bottom: 20:04 h 679 m 06°03.39' N 081°50.43' W off bottom: 20:40 h 678 m 06°03.38' N 081°50.36' W		(1) K 500: - Pieces of rotten wood, >VP 164. (2) K200: - Bivalvia shells, >VP 163. (3) K26: - Bivalvia shells. (4) K26: - Bivalvia shells. (5) K26: - Polychaeta (in pieces). (6) RR: - Foraminifera ooze. (7) 2ml Epi: - Brachiopoda, >VP 160. (8)1ml Epi: - Polychaeta, >VP 161. (9) 2ml Epi: - Polychaeta, >VP 162. (10) RR: "Vermes" + Scaphopoda. (11) RR: "Vermes" thick, white. *Sediment*: Nematoda. Sediment probe +.	VP 164 VP 163 VP 160 VP 161 VP 162	02.22.14 02.20.40
	Video observation 89-TVG: sea floor of pure sediment. Many shrimp-like Crustacea, some fishes, rare Holothurioidea. Sediment probe in the grab contained several Polychaeta, masses of shells from one type of a taxodont Bivalvia (different shell sizes).				
89a DR Coiba	16.12.1999 on bottom: 22:18 h	Huge pile of rocks, only a	(1) RR: - Veil-like sheath with yellow bodies, see Video documentation.		

	1041 m 06°06.03' N 081°47.47' W off bottom: 23:29 h 845 m 06°05.90' N 081°47.60' W	few with some Epifauna.	(2) K26: - Porifera. (3) 1ml Epi: - Disk-like Porifera, type VP 125. (4) Epi: - Porifera, >VP 167. (5) Epi: - >VP 166 (same as VP 114). (6) Epi: Bryozoa. (7) Epi: - 1 Brachiopoda. (8) Epi: - Polychaeta, >VP 168. (9) Epi: - Polychatea. (10) Epi: Diversa (incl.cf. *Spirorbis*). ***Sediment***: Nematoda, Kinorhyncha. Sediment probe +.	VP 167 VP 166 VP 168	02.24.30 02.23.20 02.25.14
90 DR Coiba	16.12.1999 on bottom: 04:28 h 1517 m 05°35.55' N 081°35.07' W off bottom: 05:40 h 1029 m 05°35.98' N 081°35.25' W		No material. ***Sediment***: Tanaidacea.		

Appendix 5: Cruise Participants (contact information)

Dr. Dietrich Ackermand
Chief Scientist, SO 144-3a
Institut für Geowissenschaften
Christian-Albrechts-Universität
Olshausenstraβe 40
D-24118 Kiel, Germany
fax: +49-431-8804457
email: da@min.uni-kiel.de

Dr. Guillermo Alvarado Induni
Dept. Geología
Instituto Costarricensede Electricidad
Apdo. 10032-1000, San José, Costa Rica
fax: +506-2208212
email: gainduni@cariari.ucr.ac.cr

Carlos Caita Silva
Universidad National de Colombia
Facultad de Ciencias
Sede Santafe de Bogota
Ciudad Universitaria, Colombia
fax: +571-3165165
email:egresa@ciencias.ciencias.unal.edu.co

Dr. Juan de Dios Villa Mata
Jefe del Departamento de Geologia y Seccion Ambiental
Direccion General de Recursos Minerales
P.O. Box: Apartado 8515, Zona 5, Panamá
fax: +507-2362868
email: dgrm@sinfo.net

Prof. LeRoy Dorman
Scripps Institution of Oceanography
Marine Physical Laboratory-0205
8602 La Jolla Shores
La Jolla, CA 92037-0205, U.S.A.
fax: +1-858-5346849
email: ldorman@ucsd.edu

Svend Duggen
Dept. Volcanology and Petrology
GEOMAR
Wischhofstraβe 1-3
D-24148 Kiel, Germany
fax: +49-431-6002922
email: sduggen@geomar.de

Dr. Sharon Escher
Scripps Institution of Oceanography
Marine Physical Laboratory-0205
8602 La Jolla Shores
La Jolla, CA 92037-0205, U.S.A.
fax: +1-858-5346849
email: sescher@ucsd.edu

Dr. Susanne Fretzdorff
Institut für Geowissenschaften
Christian-Albrechts-Universität
Olshausenstraβe 40
D-24118 Kiel, Germany
fax: +49-431-8804376
email: sf@gpi.uni-kiel.de

Prof. Peter Götz
Institut für Allgemeine Zoologie
Freie Universität Berlin
Konigin-Luise-Straβe 1-3
D-14195 Berlin, Germany
fax: +49-030-8383916
email: goetzp@zedat.fu-berlin.de

Rafael Guerrero Oyaga
Universidad National de Colombia
Facultad de Ciencias
Sede Santafe de Bogota
Ciudad Universitaria, Colombia
fax: +571-3165165
email: egresa@ciencias.ciencias.unal.edu.co

Prof. Karen Harpp
Department of Geology
Colgate University
13 Oak Drive
Hamilton, NY 13346, U.S.A.
fax: +1-315-2287187
email: kharpp@mail.colgate.edu

Prof. Kaj Hoernle (not onboard)
Principal Investigator, SO 144-3
Dept. Volcanology and Petrology
GEOMAR
Wischhofstraβe 1-3
D-24148 Kiel, Germany
fax: +49-431-6002922
email: khoernle@geomar.de

Dr. Russell Johnson
Scripps Institution of Oceanography
Marine Physical Laboratory-0205
8602 La Jolla Shores
La Jolla, CA 92037-0205, U.S.A.
fax: +1-858-5346849
email: gjohnso2@san.rr.com

J. Ove Krüger
Institut für Geowissenschaften
Christian-Albrechts-Universität
Olshausenstraße 40
D-24118 Kiel, Germany
fax: +49-431-8804376
email: ok@gpi.uni-kiel.de

Frances Lichowski
Institut für Geowissenschaften
Christian-Albrechts-Universität
Olshausenstraße 40
D-24118 Kiel, Germany
fax: + 49-431-8804376
email: frances.l@gmx.de

Britta Lissinna
Dept. Volcanology and Petrology
GEOMAR
Wischhofstraße 1-3
D-24148 Kiel, Germany
fax: +49-431-6002922
email: blissinna@geomar.de

Sandra Ludwig
Institut für Geowissenschaften
Christian-Albrechts-Universität
Olshausenstraße 40
D-24118 Kiel, Germany
fax: +49-431-8804376
email: batman-1@gmx.de

Lisa Mayhew
Department of Geology
Colgate University
13 Oak Drive
Hamilton, NY 13346, U.S.A.
fax: +1-315-2287187
email: lmayhew@mail.colgate.edu

Matthias Müller
Dept. of Marine Geodynamics
GEOMAR
Wischhofstraße 1-3
D-24148 Kiel, Germany
fax: +49-431-6002922
email: hmueller

Dr. Birger Neuhaus
Institut für Systematische Zoologie
Museum für Naturkunde
Humbolt Universität Berlin
Invalidenstraße 43
D-10115 Berlin, Germany
fax: +49-(0)30-20938528
email: birger.neuhaus@rz.hu-berlin.de

Dr. John O'Connor
Alfred-Wegener-Institut für Polar und
Meeresforschung
Columbustraße
D-2850 Bremerhaven, Germany
fax: +49-431-8804376
email: joconnor@awi-bremerhaven.de

Johannes Ripperger
Institut für Allgemeine und Angewandte
Geophysik (IAAG)
Ludwi-Maximilians Universität
Theresienstraße 41
D-80333 München, Germany
fax: +49-89-23944226
email: johannes.ripperger@stud.uni-muenchen.de

Essy Santana
Instituto Oceanografico de la Armada
Base Naval Sur, Av. 25 Julio, Via Maritimo
Guayaquil, Ecuador
fax: 593-4-485166
email: cdm06@inocar.mil.ec

Bettina Sassen
Deutsche Botschaft San José
Postfach 1500, Bonn
fax: (506)-2896492
email: sassenjo@sol.hacsa.co.ck

Dr. Allan Sauter
Scripps Institution of Oceanography
Marine Physical Laboratory-0205
8602 La Jolla Shores
La Jolla, CA 92037-0205, U.S.A.
fax: +1-858-5346849
email: asauter@ucsd.edu

Irmgard Schaffer
Dept. of Marine Geodynamics
GEOMAR
Wischhofstraße 1-3
D-24148 Kiel, Germany
fax: +49-431-6002922
email: ischaffer@geomar.de

Angelika Schmidt
Dept. Volcanology and Petrology
GEOMAR
Wischhofstraβe 1-3
D-24148 Kiel, Germany
fax: +49-431-6002922
email: aschmidt@geomar.de

Prof. Peter Stoffers (not onboard)
Principal Investigator, SO 144-3
Institut für Geowissenschaften
Christian-Albrechts-Universität
Olshausenstraβe 40
D-24118 Kiel, Germany
fax: +49-431-8804376
email: pstoffers@gpi.uni-kiel.de

Dr. Michael Tryon
University of California, San Diego
9500 Gilman Drive,
Mail Code 0244
La Jolla, CA 92037-0205, U.S.A
fax: +1-858-8223310
email: mtryon@ucsd.edu

V. Dorsey Wanless
Department of Geology
Colgate University
13 Oak Drive
Hamilton, NY 13346, U.S.A.
fax: +1-315-2287187
email: vwanless@mail.colgate.edu

Beate Wenskowski
Dept. Volcanology and Petrology
GEOMAR
Wischhofstraβe 1-3
D-24148 Kiel, Germany
fax: +49-431-6002922
email: bwenskowski@geomar.de

Dr. Reinhard Werner
Chief Scientist, SO 144-3b
Dept. Volcanology and Petrology
GEOMAR
Wischhofstraβe 1-3
D-24148 Kiel, Germany
fax: +49-431-6002922
email: rwerner@geomar.de

Dr. Tim Worthington
Institut für Geowissenschaften
Christian-Albrechts-Universität
Olshausenstraβe 40
D-24118 Kiel, Germany
fax: + 49-431-8804376
email: tw@gpi.uni-kiel.de