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RESEARCH & CONSULTANCY REPORT No. 3

Deep-ocean environment of the Chile Margin and Chile Triple Junction

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ABSTRACT

Science cases for a multidisciplinary study of Earth-Ocean interactions in the SE Pacific have recently been proposed. The primary focus of the proposed science is biogeochemical cycling and ecosystem functioning across a range of chemosynthetic ecosystems (hydrothermal vents, cold seeps, whale falls, wood falls and an oxygen minimum zone) that occur close to the Chile Triple Junction. Here, the active subduction zone of the Chile Trench intersects the southern Chile Ridge, a medium-fast spreading mid-ocean ridge. The full scope of proposed investigations will expand across disciplines, ranging from Southern Ocean circulation to plate-tectonic processes.

In order to aid in the development of detailed science plans for such programmes, this DVD provides a comprehensive overview of all the key existing oceanographic and geologic data acquired by the international community in the SE Pacific study area. This area extends from 20 to 50°S and from 90 to 70°W and from 200m to full ocean depth. The background data represented here have been collected from a broad range of environmental settings along the Chile Continental Margin, the Chile Trench, the Chile Ridge and surrounding the Chile Triple Junction. Most of the papers and cruises are post 1986, with the exceptions of the 'Expedition Downwind' conducted in 1958 which covers a substantial area within the region and the 'Scorpio Expedition' of 1967.

KEYWORDS

Southeast Pacific, biogeochemistry, chemosynthetic, hydrothermal vents, cold seeps, whale falls, wood falls, oxygen minimum zone, Chile Margin, Chile Triple Junction, Chile Trench, Chile Ridge

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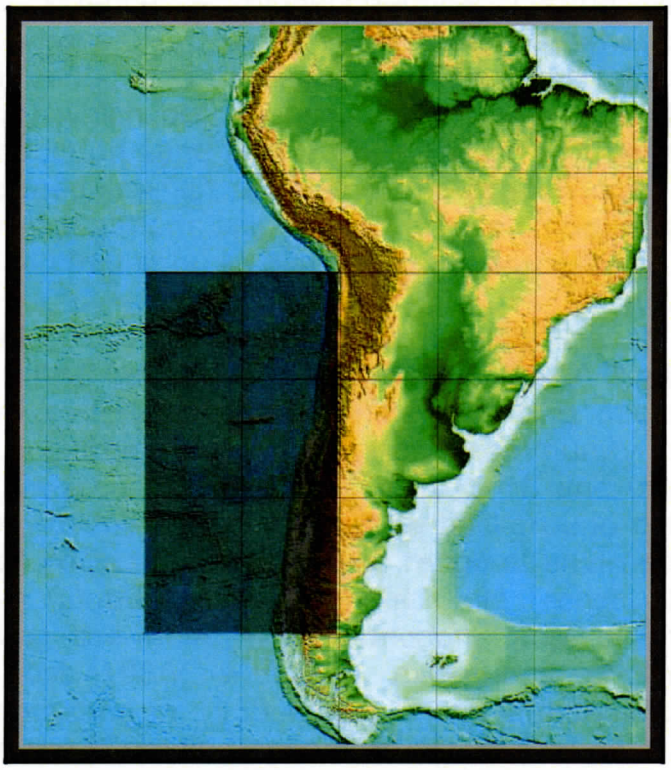
DEEP OCEAN ENVIRONMENT OF THE CHILE MARGIN AND CHILE TRIPLE JUNCTION



Introduction

Science cases for a multidisciplinary study of Earth-Ocean interactions in the SE Pacific have recently been proposed. The primary focus of the proposed science is biogeochemical cycling and ecosystem functioning across a range of chemosynthetic ecosystems (hydrothermal vents, cold seeps, whale falls, wood falls and an oxygen minimum zone) which occur close to the Chile Triple Junction. Here, the active subduction zone of the Chile Trench intersects the southern Chile Ridge, a medium-fast spreading mid-ocean ridge. The full scope of proposed investigations will expand across disciplines, ranging from Southern Ocean circulation to plate-tectonic processes.

In order to aid in the development of detailed science plans for such programmes, NERC have funded this project - a DVD which provides a comprehensive overview of all the key existing oceanographic and geologic data acquired by the international community in the SE Pacific study area. This area extends from 20 to 50°S and from 90 to 70°W and from 200m to full ocean depth. The background data represented here have been collected from a broad range of environmental settings along the Chile Continental Margin, the Chile Trench, the Chile Ridge and surrounding the Chile Triple Junction. Most of the papers and cruises are post 1986, with the exceptions of the "Expedition Downwind" conducted in 1958 which covers a substantial area within the region and the "Scorpio Expedition" of 1967.

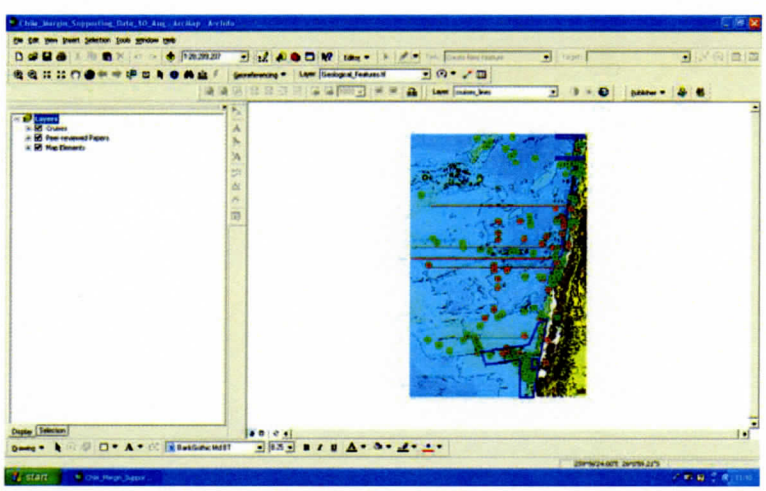
Background Data Availability

I. Georeferenced Map & Database

Using ArcGIS, a georeferenced database has been constructed to show the following:

- ❖ Relevant peer-reviewed papers from the study area (citations only). Papers are represented on the map by a point (centroid) which relates the centre of the area studied. Map 'tips' will inform the user of the paper title. The extent of the study area may also be viewed. Using ArcReader or ArcMap, use the ⓘ button to identify the author of a particular paper by clicking on the centroid on the map. Select Edit, Find (or use the binoculars tool) and type in the authors name in the find box. Select the Papers & Polygons Joint Table layer in the layer box. Click on the authors name in the value box and the polygon relating to the extent of area studied will flash up on the map.
- ❖ Sample stations from cruises in the form of a dot-density map. Map 'tips' will enable the user to see cruise references. Sample sites may be viewed in their entirety or by selecting one or more cruises at a time. Information regarding the sample type (e.g. core, trawl, CTD etc.) is also given. In some instances, sample sites consisted of lines or areas and these are also marked on the map.

This information is presented on a map constructed using ArcInfo, ArcMap (ArcGIS Version 9). A screen shot of the Map and Table of Contents (legend) is shown below.



This information may be viewed using either ArcMap or ArcReader http://www.esri.com/software/arcgis/arcreader/index.html (available as a free download).

II. Bibliography

A bibliography of source materials for peer-reviewed papers is available in electronic format (Endnote Library). This bibliography is also available as a Word document. Printed copies of these papers are available in a dedicated box file (Location LD1216) held in the National Oceanographic Library at the National Oceanography Centre, Southampton. A selection of key papers pre 1986 is also included in this file. This is a reference only collection.

III. Map "Views"

A selection of map "views" is also provided.

IV. Cruise Summary

A list of key cruises to the region (as featured on the map) is provided. This list features information (where available) regarding PI's and the nature of the cruise.

Appendices

Table below links to available file formats.

	PDF	Word	Endnote	JPG	Excel
Bibliography Post 1986		✓	✓		✓
Bibliography Pre 1986		✓	✓		✓
Map View – Cruise Sample Stations				✓	
Map View – Papers				✓	
Map View – Geological Features				✓	
Cruise Summary					✓
Proposal – NOAA O&E	✓				
Proposal – INSPIRE	✓	✓			

APPENDICES

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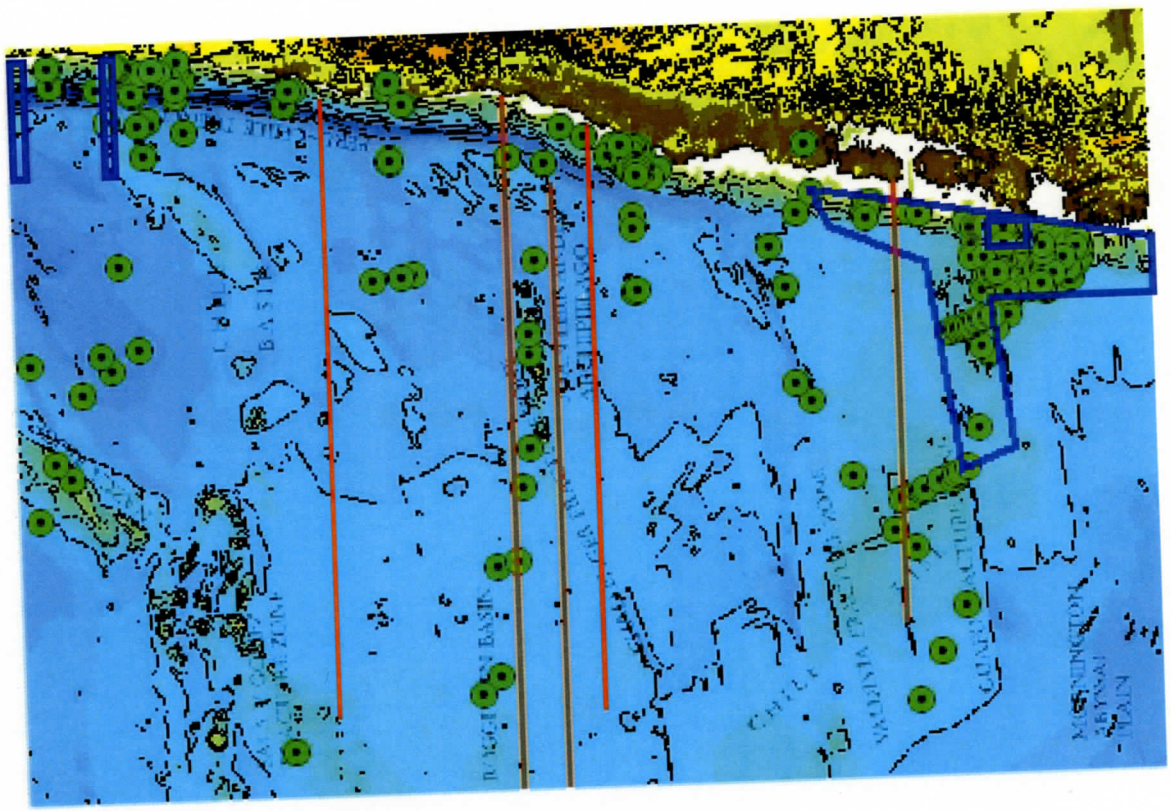

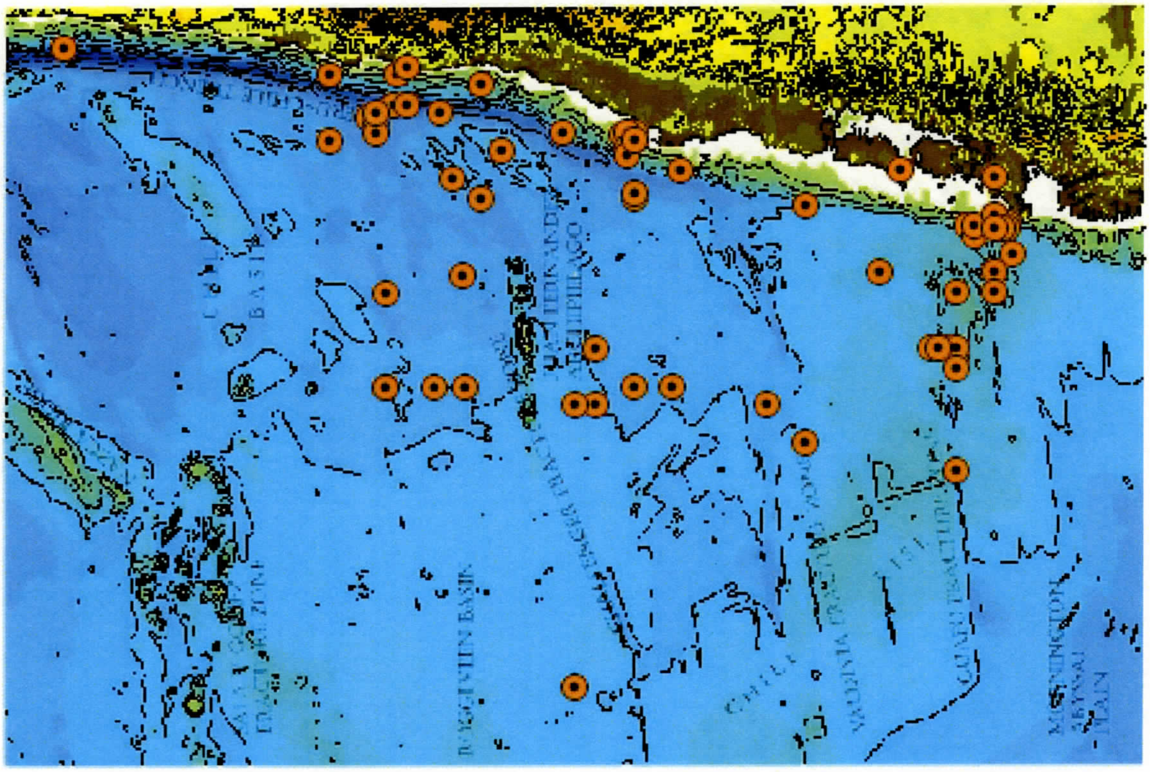

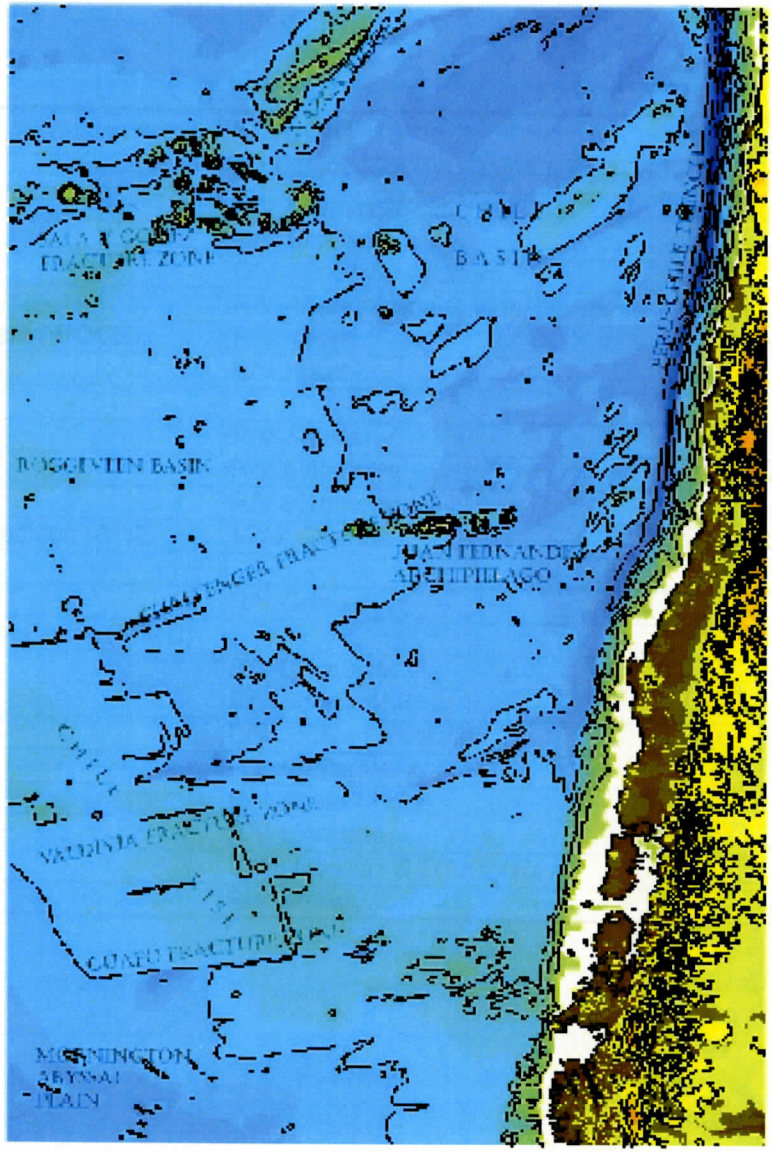
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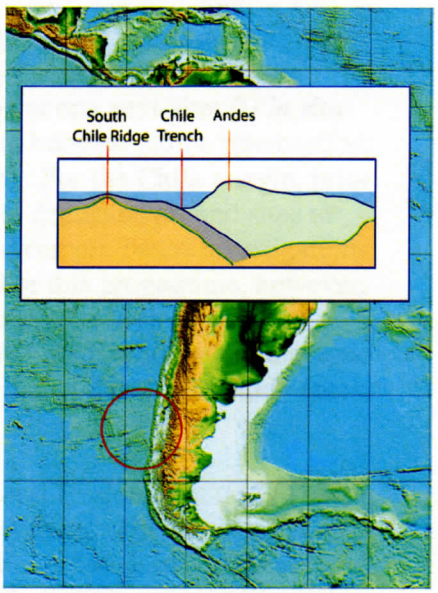
Date	Cruise Ref	Vessel	Chief Scientist
1958	Expedition Downwind	R/V *Spencer F. Baird & R/V Horizon*	H.W. Menard & R.L. Fisher
1967	Scorpio Expedition	R/V *Eltamin 28&29*	J.L. Reid, H.M. Stommel, E.D. Stroup, B.A. Warren
1988	CD 36	R/V *Charles Darwin*	G. Westbrook
1991-1992	ODP 141	D/V *Joides Resolution*	S.D. Lewis & H.D. Behrmann
1991-2001	Various Cruises	R/V *Abate Molina & Vidal Gormaz*	Various inc. P.I. Sehlstedt
1993	World Ocean Circulation Experiment (WOCE)	R/V *Knorr*	H. Bryden
1993	Southern Cross Expedition	R/V *Knorr*	
1993-1997	Off coast Coquimbo		
1995	Sonne 102	R/V *Sonne*	
1997	PUGU	R/V *L'Atalante*	B. Pontoise
1997	CTJ	R/V *L'Atalante*	J. Bourgois
1997	Atacama Trench International Expedition (ATIE)	*Vidal Gormaz*	N.D. Croce
1997-2000	Various Cruises		
1988	C2901	R/V *Conrad*	
1998	Multidisciplinary Intensive Research Cruise (MIRC)		
1999	Coquimbo - Iquique	R/V *L'Atalante*	
2001	PUCK Expedition	R/V *Sonne* 156	D. Hebbeln
2002	ODP 202	D/V *Joides Resolution*	A.C. Mix
2002	Dormido	R/V *Purihaalar*	
2003	Chups	R/V *Abate Molina*	
2004	BIOSOPE	R/V *L'Atalante*	H. Claustre & A. Sciandra
2004	Sellenes Paper	*Vidal Gormaz & LC Kay Kay*	
2004-2005	Sonne 181	R/V *Sonne*	I. Grevemeyer

Chief Scientist Institution(s)	Discipline	Other Info
Scripps Institution of Oceanography	Multidisciplinary	
Scripps, Massachusettes Inst. Tech., Univeristy of Hawaii, WHOI	Physics & Chemistry	Cruise reports and papers in Stommel et al.(1973), DSR 20(1-7)
University of Birmingham	Geophysics	Chile Ridge Geophys Survey (GLORIA)
USGS & Universität Giessen	Geophysics	Chile Triple Junction
University of Copenhagen	Physical processes	Current Mooring Arrays (shallow and deep water)
Southampton Oceanography Centre, UK	Physical processes	Ocean Circulation
University of Copenhagen	Paeleoproductivity	Ocean Circulation & Carbon Cycling
Universite Pierre-et-Marie-Currie, Paris	Geosciences	
CNRS, Paris	Geosciences	
Instituto de Sciencze Ambientali Marine, Universita di Genova	Biology/sedimentology	
Lamont-Doherty Earth Obs. Of Columbia University	Geophysics	Chile Ridge/Trench Site Survey for ODP
	Biology	Phytoplankton
	Biology	Phytoplankton
Universitat Bremen	Biology	See Palma et al. 2005 paper
Oregon State University	Paeleoceanography	South East Pacific
	Chemistry	
	Chemistry	See Castro & Farias 2004 paper
Laboratorie d'Oceanographie de Villefranche	Biology/Physics/Chemistry	Biogeochemistry & optics South Pacific Experiment
	Biology	Discovery of chemosynthetic communitites
Geomar, Germany	Geophysics	No details of sampling or cruise track

International South-East Pacific Investigation of Reducing Environments (INSPIRE)

Chris German, Dana Yoerger & Tim Shank (WHOI), Lisa Levin & Kevin Brown (SIO),
Marv Lilley (UW), Chuck Fisher (PSU), Ed Baker & John Lupton (NOAA-PMEL),
Paul Tyler, Doug Masson & Lindsay Parson (NOCS, Southampton, UK),
Juan Diaz-Naveas (PUCV, Valparaiso, Chile), Javier Sellanes (UCN, Coquimbo, Chile)

This proposal aims to conduct first exploration for and discovery of hydrothermal vents and cold seeps located close to one another at the intersection of the South Chile Ridge and Margin. The Chile Triple Junction (CTJ) is the only place on Earth where an active ridge is currently being subducted beneath a continental margin but such geologic processes have recurred throughout the 200Ma history of the Pacific Ocean basin, represent a direct precursor to the modern tectonic setting of earthquake-prone southern California and, at the CTJ, are associated with the largest single earthquake ever recorded. In this one-year programme, we will conduct state-of-the-art exploration combining TOBI sidescan sonar, CTD and nested ABE deployments to map and image the triple-junction and to locate and photograph new hydrothermal vents, cold seeps and novel "hybrid" chemosynthetic ecosystems at the triple-junction itself.



Although what we present here represents a self-contained proposal for fundamental ocean exploration, this collaborative international project would also mark the first important step toward a broader initiative to investigate the overlap of organisms between all the different known forms of chemosynthetic ecosystem which, uniquely, can co-exist in the Chile Triple-Junction area: hydrothermal vents, cold seeps, oxygen minimum zones and whale, kelp and wood-falls. Accordingly, this project is now highest priority for the Census of Marine Life field-program Chemosynthetic Ecosystems (ChEss).

Proposed Work:

Our programme requires 34 days of shiptime on-station to complete multibeam mapping (2.5 days), TOBI sidescan sonar (12 days), CTD tow-yo operations (6 days) and ABE investigations and seafloor sampling (13.5 days). The active margin of the Chile Triple Junction was mapped in Dec.2004 (I.Grevmeyer, Leibniz Institute, Germany) and we will extend that coverage for 200km along the adjacent South Chile Ridge (2.5 days) prior to TOBI deployment. Our TOBI/MAPR survey along this same 200km of ridge-crest will require 6 days shiptime which, along this medium-fast ridge should yield 3-4 plume-targets. A further 6 days' TOBI survey will be conducted across the triple-junction searching for cold seeps (readily identified by the high-backscatter from cementation/ precipitation of methane-derived carbonates) and novel "hybrid" fluid-flow sites resulting from close juxtaposition of hot vents and gas hydrates at the Triple Junction itself.

C.R.German - Chile

In detail, we aim to locate and investigate three sites of active fluid flow: (i) a "hybrid" site close to the Triple Junction, (ii) a high-temperature vent-site, nearby along the ridge-crest and (iii) a "normal" cold-seep along the adjacent margin. Each site will require a series of up to 6 CTD profiles and/or tow-yo sections prior to ABE deployment. Allowing ≤8 hours for each, this might require as much as 6 days' further shiptime, total. [NB: previously, no more than ~24 hours of CTD operations were required prior to ABE deployment to find new vent-sites in the Lau Basin and Sth Atlantic where we have previously pioneered and established this technique (German et al., 2004, 2005)]. ABE exploration and vent/seep ecosystem characterization will require a nested approach of 2-3 dives (total = 4.5 days per site) to locate, map, and photograph the completely novel ecosystems we will find in this (as yet unexplored) biogeographic province. On the South Chile Rise we will conduct all 3 phases of exploration at one vent-site: (I) *in situ* plume-mapping; (II) high-resolution (SM2000) mapping and buoyant plume interception; (III) photo-mosaicing of vent-habitats/ecosystems (4.5 days). For the Chile margin, prior work has shown that TOBI detection of authigenic carbonate deposited around sites of CH_4-rich active flow is sufficient to progress immediately to camera-based investigations of novel chemosynthetic ecosystems (e.g. Sahling, 2004). For this programme, however, we request 4.5 days for each of two more sites to conduct extensive high-resolution mapping and ecosystem characterisation (9 days). A virtue of ABE work is that the same time can also be used to conduct preliminary seafloor sampling at these three study areas.

Fit to NOAA-OE Mission Priorities:
This proposal fits well to all four of OE's priorities for General Exploration: (i) We will characterise novel vent, seep and "hybrid" habitats and ecosystems. (ii) Our work is of fundamental importance to CoML's major field program ChEss, focussed on chemo-synthetic ecosystems: www.noc.soton.ac.uk/chess/field.html. (iii) Our work will involve mapping at increasing resolution (multibeam, deep-tow 30kHz sidescan, SM2000, photo-mosaicing) of a quite unique geologic setting as well as completely new vent, seep and "hybrid" chemosynthetic habitats & ecosystems. (iv) Our research will provide insights into thermal destabilization of gas hydrates at ocean margins and reveal completely new species in what we will likely prove to be a completely new biogeographic province.

Proposed Budget & Explanation of Cost-Sharing:

German et al (WHOI) : ABE operations, TDMn analyses, cruise participation	$330,000
Lilley (U.Washington): CTD operations, CH_4 analyses	$170,000
Levin & Brown (SIO): Cruise participation, sidescan/biological interpretation	$60,000
Fisher (PSU): Cruise participation, biological interpretation	$30,000
Baker & Lupton (NOAA/PMEL): cruise participation, MAPRs, He-3/4 analysis	$60,000

We request full costs for ABE and CTD field operations plus partial science support to include analyses of water-column samples for TDMn and CH_4 and cruise participation for US co-PIs critical to future CoML/ChEss research in this area (Levin, Brown, Fisher, Shank). If this bid is successful, co-funding will be provided from NOC (UK) for TOBI field operations and senior NOC science staff (Co-PIs Masson, Parson & Tyler). NERC will support 2 students involved in chemical sensor/sample analyses and sidescan (TOBI & SM2000) data interpretation. ChEss (CoML) will provide salary support for lead PI German, outreach activities, database entry (ChEssBase/OBIS) and UK scientists' travel.

C.R.German - Chile

Exploring Chemically-Fuelled Ecosystems in the S.E.Pacific: Interactions Between the Solid Earth, Oceans and Life.

A WUN "Grand Challenge"

Prof.C.R.German (Southampton Oceanography Centre, UK)
Prof.L.A.Levin (Scripps Institution of Oceanography, USA)
Prof. P.A.Tyler (Southampton Oceanography Centre, UK)
Prof. C.R.Fisher (Pennsylvania State University, USA)

Executive Summary

We propose a novel, interdisciplinary investigation of interacting Earth-, Ocean- and Life-Science processes in the SE Pacific off Chile. This international programme, which will involve more than 20 internationally-recognised scientists from 7 different *WUN* Universities, will take full advantage of key UK capabilities - notably the deep-diving (6500m) remotely-operated vehicle (ROV) *Isis* and state-of-the-art expertise using the deep-tow sidescan vehicle TOBI to image the seafloor. SOC's co-ordinating role in this programme will be complemented by our lead partner in the USA, the Scripps Institution of Oceanography. In addition to their wealth of expertise in the S. Pacific, a particularly important contribution from SIO will be access to their major ocean-going research ships that operate regularly in the area.

The site for our proposed study, the intersecting ridge and margin off Chile, is critical on two counts. From an Earth-Science perspective, it offers a unique opportunity to examine the full spectrum of plate-tectonic processes, from mid-ocean ridge spreading centre to subducted oceanic plate, all at one location. Indeed, the Chile Triple Junction is one of only two modern sites on our planet where an active ridge crest is being swallowed by a subduction zone. This tectonic configuration is the direct precursor to modern (earthquake-prone) coastal California and our general study area will also include the site of the largest Earthquake yet recorded: the great Chile Earthquake of 1960 (Mw9.5). For the Life-Sciences, the SE Pacific is unique: it is perhaps the *only* location, worldwide, where one can investigate a full spectrum of deep-sea chemosynthetic ecosystems in close proximity: hydrothermal vents, cold seeps, whale carcasses, wood-falls, oxygen minimum zones (OMZs) and gas hydrates. The chemical fluxes from these systems are significant to both ocean chemistry and, hence, climate while the chemosynthetic communities that they host, many of which function largely independently of direct energy from the sun (hence the term *chemosynthesis,* cf *photosynthesis*) are increasingly linked to the origins of life on Earth and strategies for astrobiological exploration.

We envisage a three-year programme (2005-2008) with two major field seasons in Jan-Mar 2006 and Jan-Mar 2007. Research in year 1 will include location of vents and seeps from surface-ship operations while activities in year 2 will be dominated by detailed investigations at the deep seafloor using the 6500m-rated ROV *Isis*. Our proposal will include a strong outreach component, as well as training. It is to this end, that we are already in discussion with the BBC Natural History Unit, Bristol.

1. Programme Objectives & Outline

Our broad objectives for this project are three-fold:

A: To investigate the unique interaction of plate-tectonic processes currently observed at the Chile Triple Junction, 46°S, as the South Chile Ridge (a mid-ocean ridge) is subducted beneath the South American continent.

B: To locate and characterise new sites of chemically enriched fluid flow from the seafloor associated with the range of tectonic setting encountered and to investigate the chemosynthetic ecosystems – including species likely to be completely new to science - that they host.

C: To determine the interactions between *a)* chemosynthetic ecosystems driven by Solid-Earth processes (vents, seeps), *b)* chemosynthetic ecosystems fuelled by degradation of photosynthetic primary production (whale-falls, wood-falls, oxygen minimum zone) and *c)* adjacent, non-reducing, deep-sea ecosystems.

Year 1 (2005-06):	First field programme, surface ship operations.
Year 2 (2006-07):	Second field programme, ROV dives.
Year 3 (2007-08):	Work-up and synthesis of results, dissemination.

2. Background: Plate Tectonics and Chemosynthetic Ecosystems.

To explain the rationale of our approach it is important, first, to recap briefly on plate tectonic theory, chemosynthetic ecosystems, and their likely interactions.

a). Plate Tectonics.

More than half the Earth's surface is covered by deep-oceans more than 3,500m deep. But because less than 1% of the deep seafloor has been investigated, we currently know less about the Earth's surface than that of the Moon, Venus or Mars!
One key discovery arising from deep-ocean research in the last century was that of *plate tectonics*. This revolutionised our understanding of the workings of our planet. Heat is released from the Earth's interior at volcanic boundaries which, typically, are found deep beneath the seafloor: *mid-ocean ridges* (Fig.1). As these ridges spread, the ocean crust cools and subsides to form the flat seafloor of our deep-ocean basins; this becomes progressively covered by a rain of (detrital and biogenic) sediment.

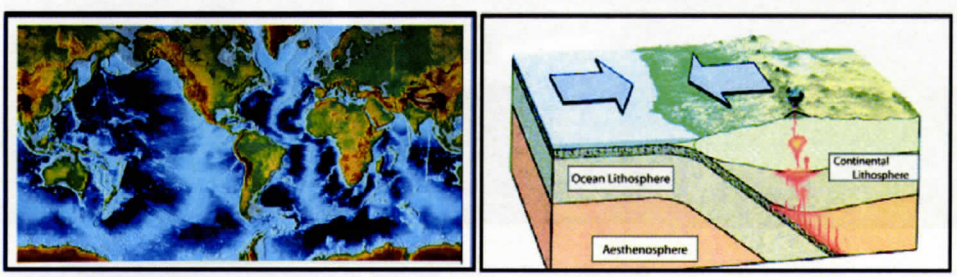


Fig.1 Left: NASA satellite image showing the shape of the deep ocean floor. Young Mid-Ocean Ridges, which are shallow, are shaded pale blue. Right: cross-section of a subduction zone.

Eventually, cooled slabs of ocean *lithosphere* become so dense that they subside back beneath the Earth's surface into the underlying, *asthenosphere*. These down-welling

plate boundaries - *subduction zones* – give rise to the very deepest parts of the Earth's seafloor: *ocean trenches* (Fig.1). In the SE Pacific Ocean, quite uniquely, we can study all of these processes in close association (see later).

b) Chemosynthetic Ecosystems.

It is now well recognised that there is significant fluid flow and release of chemical energy from the seafloor associated with plate tectonic boundaries. One spectacular manifestation is the formation of high-temperature vents on mid-ocean ridges. Chemically-enriched cold seeps are also known to be abundant along subduction zones that have been investigated to-date and increased attention is now being paid to the formation of gas hydrate deposits at ocean margins (Fig.2). What is common to all these settings is the exciting discovery that they are colonised by a wealth of completely new species, previously unknown to science, which tend to utilise energy from this chemical release, rather than sunlight - hence the term "*chemo*synthesis".

To date, most hydrothermal vent and cold seep discoveries have been restricted to the Northern Hemisphere. Even so, virtually every newly explored vent-field and cold-seep has yielded species new to science. In the SE Pacific we expect to find vent, seep and hydrate-fuelled ecosystems in close proximity. Our hypothesis is that these systems will represent an entirely new biogeographic province, different from chemosynthetic ecosystems explored previously. Of course, not all chemosynthetic ecosystems in the deep-sea are fuelled by plate tectonic processes. Large organic falls (e.g. whale carcasses or wood) or high phytoplankton inputs beneath high-productivity upwelling areas can also create chemosynthetic ecosystems. In the SE Pacific we can study these systems as well: whale migration, an oxygen minimum zone and wood-falls are all well established in the area.

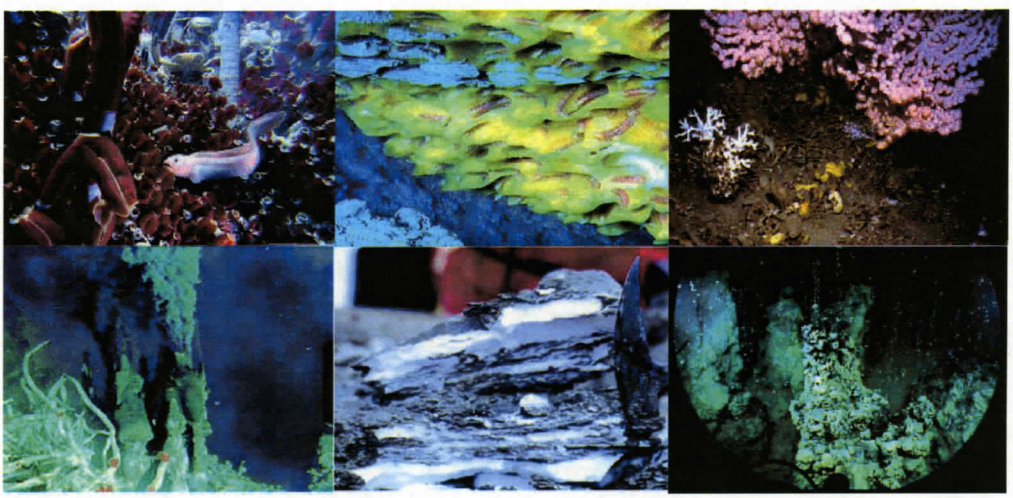


Fig.2 Chemosynthetic ecosystems in various forms (hydrothermal vents, gas hydrates, cold-seeps) can host a range of specialised, exotic fauna. The SE Pacific may represent a new biogeographic province.

3. Methodology and Approach

The SE Pacific Ocean represents a unique natural laboratory for our proposed programme. Here, we can study a full spectrum of the interactions between plate tectonics and chemosynthetic ecosystems (both tectonically driven and otherwise) in a single location. The setting, close to the Chile Triple Junction where the south Chile Ridge is being subducted beneath the Andes at the Chile Trench, also provides the modern analogue for the development of the San Andreas Fault (California) and associated seismic risk. Our study will include the site of the largest earthquake ever recorded (the M_w 9.5 great Chile earthquake, 1960) which made the Earth ring like a bell, ruptured the Chile margin for >950km and caused tsunami-fatalities on the opposite side of the Pacific, in the Philippines and Japan.

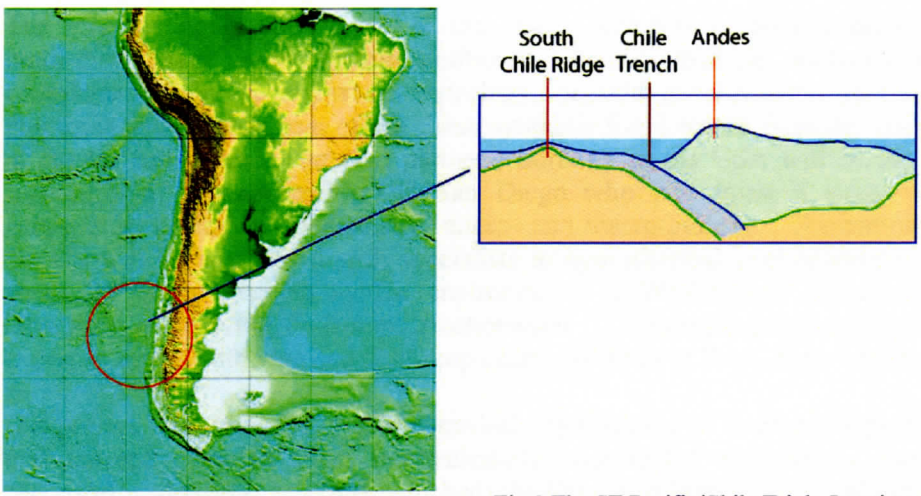


Fig.3 The SE Pacific/Chile Triple Junction Area.

Our objectives (see Appendix) can be subdivided into Solid Earth Sciences, Marine Geochemistry and Biological Oceanography. However, the true strength of our programme rests in the interdisciplinary interactions that lie at the core of our developed, integrated, strategy.

In Austral Summer 2005/06 we will conduct our preliminary field programme using state-of-the-art deep-tow sonar equipment coupled with *in situ* chemical sensing, water sampling and seafloor photography to investigate both the South Chile Ridge (42-46°S) and the adjacent Chile margin at sites between 38°S and 47°S. This work will identify new sites of hydrothermal activity, cold seep flow and, potentially, completely novel systems where the volcanic ridge is over-ridden by the hydrate-bearing margin. Seafloor imaging and water-column sampling will be complemented by sampling of fresh lavas at the ridge-axis, crucial to achieving new insights into the "plumbing" of subduction zones. We will also deploy long-term experiments in Year 1 including, wood-fall deployments, fluid-flow measurements and (where available) beached whale-carcass sinkings. In 2006/07 we will return with the 6500m-rated ROV (remotely operated vehicle) *Isis* to study the full suite of known chemosynthetic ecosystems: hydrothermal vents, cold-seeps, wood-falls, whale-carcasses (sunk in Yr1 ± historic), hydrates, and the oxygen minimum zone. All *Isis* investigations will involve overlapping and integrated geological, geochemical and marine (macro- and micro-) biological components.

4. The WUN Partnership

Our project will involve 25-30 principal investigators from seven laboratories. As well as establishing novel collaborations among the laboratories involved (no PI has worked previously with the majority of their co-PI's in this venture) we will also provide essential training for a new generation of interdisciplinary scientists. Sub-projects range from the contamination of the mantle at subduction zones to studies of gene-flow between ridges and margins via stepping stones (e.g. whale carcasses), from whether fluid flow is associated with major earthquake faults to an investigation of iron isotopic fractionation: is it a reliable tracer of biotic or abiotic processes?

The coordinating laboratory will be the SOC, University of Southampton where a multi-disciplinary team (geophysics/ocean chemistry/benthic biology) will be complemented by specialists in petrology, organic geochemistry, mineralization processes and development of the chemosynthetic fossil record from the Universities of Bristol and Leeds. Our lead partner laboratory in the USA will be the Scripps Institution of Oceanography, UC San Diego who also boast a strong team in geophysics, geology, geochemistry, micro- and macro-biology. The partnership in the US will be augmented with specialists in hydrothermal vent chemistry and the chemistry of low-oxygen marine environments (U.Washington) the world's lead laboratory in studying Fe-isotope fractionation (U.Wisconsin-Madison) and further expertise across both vent and cold-seep chemosynthesis at Penn. State University.

Our project, as formulated, would contribute significantly to three major programmes that currently benefit from internationally coordinated attention – InterRidge, Margins/EuroMargins and (just launched) the Census of Marine Life. While any one of those programmes might be particularly interested in some subset of our proposed study, only our programme would employ the full breadth of expertise required to investigate this fascinating system of Earth-Ocean-Life interactions as a whole.

Potential benefits to society will include a greater appreciation of the science involved – readily communicated via both the Web (live?) & BBC/Discovery using ROV and shipboard footage. Possible commercial benefits include: insurance risk; resource extraction (hydrates; hydrocarbon extraction *vs.* fragile ecosystems); pharmaceuticals.

5. Estimated Budget (2005-2008)

Our estimated budget for the full programme is ~£7.5M. Of this, ca. £2.5M is estimated for shiptime (2 mths each, Yrs.1 & 2) and the ROV "Isis" (Yr.2 only). Indirect costs vary, UK *vs* US. Here we use a rate of 50% of total direct costs.

Table 1: Direct costs

Scientist Salaries:	£1,610k
Student Training:	£380k
Consumables:	£580k
Equipment:	£320k
Travel:	£265k
Outreach:	£165k
Total Direct Costs:	£3,315k

Table 2: Overall Budget Totals

Direct Costs Total:	£3,315k
Indirect @ 50%:	£1,660k
Shiptime/ROV:	£2,450k
Grand Total:	**£7,452k**